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VOLUME ONE
SITE APPLICATION

SECTION II
HYDROGEOLOGIC REPORT AND GROUNDWATER MONITORING PLAN

MATERIAL RECOVERY, LLC BROWN-FIELD ROAD CONSTRUCTION AND DEMOLITION LANDFILL

WAKE COUNTY, NORTH CAROLINA

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1.0 INTRODUCTION AND OVERVIEW

In accordance with the NC Solid Waste Management Rules (NCSWMR) § .0504(1)(c and g), Material Recovery, LLC (MR) is submitting this portion of the Site Application for a construction and demolition debris (C&D) landfill, which includes the Hydrogeologic Report and Groundwater Monitoring Plan. The purpose of this portion of the Site Application is to demonstrate general hydrogeologic site suitability for the facility acreage. A Construction Plan Application for the proposed landfill is being submitted as volume two of this report.

The proposed C&D facility consists of approximately 210 acres in Wake County between the towns of Garner and Clayton, NC. There are two disposal areas within the facility footprint referred to as the northern area and the southern area, 45 and 24 acres in area, respectively. The details of the investigations conducted to characterize this facility are documented in this report. This report provides a detailed Hydrogeologic Report (Section 3.0) prepared in accordance with NCSWMR .0504(c), and a Groundwater Monitoring Plan (Section 4.0) prepared in accordance with NCSWMR .0504(g). For the reviewer's clarification, please note that the legend for the drawings referred to in the above documents is provided on Drawing No. 1. Use of the word "site" during the following discussions includes all acreage within the property boundaries of the proposed facility.

The results of this investigation show that this area meets all conditions for site suitability for a C&D Landfill. The geophysical data indicate that the diabase dike(s) on site do not inhibit the ability to effectively monitor and predict groundwater flow. The bedrock elevations and seasonal high water table can be reasonably determined based on the available data. The groundwater monitoring network will be effective in monitoring for a potential release from the C&D disposal area. There is no threat to current or potential groundwater users downgradient of the proposed facility. Further, the site provides an ideal setting for a landfill as much of the surrounding land is currently owned by the City of Raleigh and is non-residential.

2.0 SITE DESCRIPTION

This section describes the site location, its physical layout, and current land usage. Specific information regarding land usage in and around the site and geologic and hydrogeologic characteristics are discussed in subsequent sections of the report.

The proposed facility encompasses approximately 210 acres and is located in the southeast-central portion of Wake County, North Carolina, approximately 6 miles east of the town of Garner, along Brown-Field Road (Drawing No. 2). The site location, property boundaries, and surrounding topography are shown on Figure 1. The site is located in the Piedmont physiographic province on a group of knolls and valleys, the highest elevations of which rise approximately 100 feet above the floodplain of the Neuse River.

Three small northwest-trending drainages transect the site to intersect a north-trending unnamed stream that parallels the western facility property line. Two of the smaller drainages have 2- to 4-acre man-made ponds at their upstream limits. These streams and ponds are shown on Figure 1. The larger stream locally coincides with the location of a regional-scale diabase dike as discussed in detail in subsequent sections.

The northern portion of the site has previously been used for land application of wastewater treatment sludge by the City of Raleigh. The City disposed of sludge on this portion of the site for approximately eleven years and continues to dispose of sludge in the areas immediately north and east of the site (Figure 2). Fallow agricultural fields from these activities remains in the area that comprises much of the proposed northern cell. Trees and heavy brush occupy the northernmost, westernmost and northern ridgeline. Grass and scrub make up the vegetation in the remainder of the area in and around the proposed cells.

3.0 HYDROGEOLOGIC REPORT

3.1 Previous Investigations

Although there have been no apparent previous investigations for landfill suitability, there have been previous investigations on part of the proposed facility acreage related to research on the surrounding wastewater sludge fields. Eleven previously installed monitoring wells are located on the property and are discussed below. Investigations performed during the Hydrogeologic Report study are discussed in detail in subsequent sections.

3.1.1 Available Data from Monitoring Wells

Subsurface investigations were performed at the site prior to conducting the site investigation associated with this report. From 1990-1996, a study of three wastewater sludge fields was conducted on behalf of the City of Raleigh's Neuse River Wastewater Treatment Plant, located approximately one mile northeast of the proposed facility. This research is documented in the University of North Carolina's Water Resources Research Institute's Special Report Series No. 20 (*A Study of Nitrate Movement to Ground Water at the Neuse River Waste Water Treatment Plant*) authored by Charles W. Welby, which is included as Appendix 1.

The purpose of the above project was to examine nitrate concentrations in shallow groundwater in and around several sludge fields located near the Neuse River Waste Water Treatment Plant. The location of these fields is shown on Drawing No. 3 in Volume One – Section I of this report.

One of the three sludge fields discussed in the report is located on the site property. Nine monitoring wells from this study were located on the property and are shown on Drawing No. 2 and are referred to as "Wells" (Well 28, -28A, -28B, -28C, -38, -39, -40, -51 and -52). Another well, Well 26, was shown to be located on the site property according to the figures within the report. However, the location map and surveyed coordinates listed in the report shows the location of Well 26 to be north of the property boundary. Therefore, it was assumed that the location shown on the figure is incorrect. This well could not be located in or near either of these locations.

Two additional wells were installed by Law Engineering in the early 1990s according to well identification tags, and are referred to as the "Test Wells." One of these test wells (Test Well 40) had an identification tag. The other well is identified as Test Well 27 according to information provided by Mark Fender, the current manager of the Neuse River Waste Water Treatment Facility. All wells that were located are still functional, although it appears from inspection that they have not been monitored in recent years as they were covered with significant overgrowth.

The locations of each of the eleven wells discussed above are provided on Drawing No. 2. The surveyed locations were provided in the referenced report. The locations of Test Well 40 and Test Well 27 are approximate, and were determined from measurements from nearby piezometers that were installed and surveyed as part of our recent investigation.

The boring logs associated with the previous drilling programs were unavailable. Table 1 presents available well construction details for the wells discussed above. Water levels were taken during site visits as the wells were located and the elevations are summarized on Table 2. Although the raw data were not available, several hydrographs of water levels over a five-year period are included in the report in Appendix 1. These data are described in more detail in the discussion of seasonal high water level calculations in section 3.5.1.3.

3.1.2 Conclusions from Previous Investigations

Te study referenced above, which involved three sludge fields of varying ages, found that nitrate had reached shallow groundwater in the area beneath the sludge fields. However, the study also pointed out that the field that is contained within the site property also experienced attenuation of nitrate during a two-year period during which no sludge was applied. However, this is not considered to be an issue for the proposed site because nitrate is not a required sampling parameter for C&D landfills. Therefore, based on the data contained within this report, there is no reason to believe that the presence of sludge fields would adversely affect the siting of a landfill on this property.

3.2 Scope of Current Investigation

The field activities for this investigation were performed in August and September 2000, and July through November 2001. The fieldwork consisted of a magnetometer/gradiometer survey, the installation of twenty-six piezometers, the development of selected piezometers, a field survey of the new piezometers, the investigation of fifteen test pits, the investigation of fifteen borings, aquifer testing of piezometers, measurement of static groundwater elevations, and general site reconnaissance to locate outcrop and previously installed monitoring wells. The field activities are described in detail below. Interpretation of the data collected during these activities is provided during subsequent sections of the report.

3.2.1 Subsurface Investigations

3.2.1.1 Magnetometer Survey

The proposed site lies within an area that is characterized by the intrusion of both regional- and small-scale diabase dikes (refer to Section 3.3 for a detailed discussion). These dikes presented the potential for complications related to site characterization and groundwater monitoring network design due to the fracture zones that are commonly associated with them. Pyramid Environmental Inc. of Greensboro, NC was contracted to perform a geophysical survey of the study area in order to delineate the diabase dikes at the site. Their report is included as Appendix 2.

As described in the detailed report, the magnetic survey was performed with a Geometrics G-858G Cesium Magnetometer/Gradiometer. The survey was completed over a grid with a line spacing of 200 feet, oriented perpendicular to magnetic north in order to intercept the dikes, which characteristically have a strike of approximately north-south in this region. The data were then collected along the grid lines and logged in conjunction with location coordinates obtained using a portable Trimble AG-132 Real-time Differential Global Positioning System.

3.2.1.2 Drilling Program

Three preliminary investigation piezometers (P-1S, -1D and -2) were installed on August 30 and 31, 2000. These piezometers were drilled an installed by Bedford Well Drilling, Inc of Bedford, VA with an Ingersoll-Rand T3W air rotary drilling rig equipped with 6.25- and 8.25-inch OD air hammers. An experienced Joyce Engineering, Inc. (JEI) geologist was present to observe the drilling, log the boreholes and supervise the piezometer construction. The locations of these piezometers and those discussed below are provided on Drawing No. 2.

Twenty-three additional piezometers were installed in and around the proposed C&D footprints between August 13 and 29, 2001. Geologic Exploration of Statesville, North Carolina performed drilling and well installation activities. The drilling equipment consisted of a Mobil B-61 drilling rig equipped with 4.25-inch ID hollow-stem augers, a Diedrich D-120 drilling rig equipped with 4.25-inch ID hollow-stem augers, and a Drilltech Mission T25KW drilling rig equipped with 6.0-inch OD air hammer. An experienced JEI geologist was present to observe the drilling and rock coring, log the boreholes and supervise the piezometer construction. An experienced JEI technician developed selected piezometers. The drilling and well construction data are summarized in Table 1.

During this drilling program only a limited amount of bedrock was encountered in the upper fifty feet of drilling. As a result only two boreholes (P-10 and P-14) were initially chosen for rock coring based on availability of shallow bedrock. Approximately ten feet of rock core were obtained from each borehole. Coring was performed using a Mobil B-61 drilling rig equipped with an NQ wire-line rock coring device. For each borehole, a tricone roller bit was advanced approximately 0.5 foot beyond auger refusal in order to improve recovery during coring. The rock core data are summarized in Table 3.

Following a review of data from the initial drilling program it was determined that additional data for depths to bedrock were needed in two areas. Fifteen additional borings were completed in and around the proposed waste disposal footprints on October 1-2, 2001. The locations for B-1 through B-15 are approximate and were determined based on known surveyed locations of piezometers and structures as shown on Drawing No. 2. Drilling activities were performed by Superior Drilling, Inc. of Raleigh, North Carolina. A CME-550 ATV drilling rig equipped with 2.25-inch ID hollow-stem augers was used for the additional drilling in order to access areas that were not easily accessible by the other larger, truck-mounted rigs. An experienced JEI geologist was present to observe the drilling and log the boreholes. All borings were terminated at auger refusal above the water table or, in those that did not encounter bedrock, at a depth above the water table. After each boring was completed and logged, they were carefully back-filled with cuttings. The boring logs for the fifteen borings are included in Appendix 3. The estimated bedrock elevations for each of the borings are shown on Table 4.

Information gained during the above boring program confirmed a relatively irregular 'top of bedrock' configuration. Generally, it was unclear from the data obtained whether the rock that was encountered in the previous borings was vertically continuous or weathered as lenses of alternating rock and saprolite. Thus, additional rock coring locations were chosen to confirm the vertical continuity of rock in the areas of concern. Rock core was taken at five additional locations (C-1 through C-5) on November 20-23, 2001. Rock core was attempted in three other locations; however, the length of the core barrel prevented core from being taken due to very shallow bedrock (i.e. 5 feet or less). These additional three locations are referred to as borings B-16, -17 and -18, as they provided auger refusal depths.

The locations for C-1 through C-5 and B-16 through B-18 are approximate and were determined based on known surveyed locations of piezometers and structures as shown on Drawing No. 2. Graham and Currie Well Drilling Co., Inc. of West End, North Carolina, performed drilling activities. A CME-850 ATV track drilling rig equipped with 4.25-inch ID hollow-stem augers was used for the additional drilling in order to access areas that were not easily accessible by the other larger, truck-mounted rigs. An experienced JEI geologist was present to observe the drilling and log the boreholes and rock core. None of the locations encountered the water table. The three shallow borings were back-filled with cuttings after each boring was completed and logged. The five coring locations were abandoned by injecting grout through a tremie-pipe, filling the hole progressively from the bottom of the hole to ground surface. The boring logs for these borings and core locations are included in Appendix 3. The estimated bedrock elevations for each of the borings are shown on Table 4 and data for rock core are presented in Table 3. Diabase was encountered at core location C-4, near a relatively small magnetic anomaly identified near P-2. Significant core could not be obtained due to the intensely fractured nature of the rock.

Well/piezometer construction was performed in accordance with the standards described in the *RCRA Technical Enforcement Guidance Document* (1986) and the *Draft North Carolina Water Quality Monitoring Guidance Document for Solid Waste Facilities* (1995). Split-spoon samples were obtained at five-foot intervals and logged by the geologist for all of the boreholes.

Piezometers P-1S, -3 and -4 were installed in saprolite and range in depth from 15 to 49 feet with screens that range from 10 to 20 feet. Piezometers P-2, -9, -15, -16, 18, -19 and -24 were installed at the saprolite/partially weathered rock (PWR) transition zone and range in depth from 15 to 39 feet with screens that range from 5 to 30 feet. Piezometers P-5, -6, -8, 11, -12, -13, -17, -20, -21, -23 and -25 were installed in the PWR unit and range in depth from 20 to 50 feet with screened intervals that range from 10 to 30 feet in length. Piezometers P-1D, -7, -10 and -22 were installed in bedrock and range in depth from 40 to 100 feet with screened intervals that range from 15 to 20 feet in length. One piezometer, P-14, was installed in all three hydrogeologic units (saprolite, PWR and bedrock) with a 25 foot screen. why

Lockable expansion caps were installed into the top of each well casing. Piezometers P-1S, -1D, -2, -3, -4, -5, -15, -16 and -18 were covered by lockable steel standpipes installed into 4 x 4 x 0.5-foot concrete aprons to protect their integrity. All other piezometers that will be converted into permanent monitoring wells will have lockable steel standpipes and pads installed prior to the first sampling event. Piezometers were grouted to the surface and lockable expansion caps installed into the top of each casing. The well construction information and boring logs for the groundwater monitoring wells and piezometers are contained in Appendix 3.

Following construction, monitoring wells P-1S, -1D, -3, -6, -7, -8, -9, -14, -16, -18, -19, -20 and -25 were developed with an electric submersible pump and surge block to remove accumulated sediments resulting from the drilling and well construction process, and to hydraulically connect the wells with the surrounding soils. The surge block was used to loosen the disturbed sediments. Once the wells were thoroughly surged, the water-sediment mixture was removed with the pump, and the wells were allowed to recharge. This process was repeated until sediment-free water could be obtained from the wells. Approximately 6 to 60 gallons (or up to 7 casing volumes) of water, depending on recharge rates, were removed from each well during the development process. All other piezometers that will be converted into permanent monitoring wells will be developed using these procedures prior to the first sampling event.

The newly-installed piezometers were surveyed in September and October 2001 by Draper Aden Associates of Apex, North Carolina. Elevations and horizontal locations were referenced to the N.C. Grid Coordinate System. Two permanent site benchmarks were also installed at this time. The piezometer survey map prepared by Draper Aden Associates is provided as Appendix 4.

Static water level measurements were initially collected at the time of drilling, approximately 24-hours after construction for all but one piezometer. Stabilized water levels were collected after approximately seven days as noted on Table 5. The post-drilling water level for P-6 was obtained 72 hours after installation. Subsequent water levels were measured for all existing site monitoring wells and C&D investigation piezometers during nine additional site visits. The measurements were collected using a decontaminated electric water level meter. The surveyed point on the top of the well casing was used as reference, and the measurements were recorded to within 0.01 foot. The groundwater elevation data were used to construct a groundwater potentiometric surface map, and to infer groundwater flow directions in the area. A historic summary of the static groundwater elevations for all wells and piezometers is included in Table 5. Water levels measured on October 3, 2001 in new and existing wells were used to prepare a groundwater contour map for the site (Drawing No. 3). These measurements provided the earliest stabilized readings for the new wells.

Additional water level information was taken utilizing two pressure transducers in piezometers P-2 and P-15. These transducers were set to take continuous water level readings once an hour from August 30, 2001 through November 20, 2001 in P-2 and September 5, 2001 through November 20, 2001 in P-15. Two Model SSP-100 In-Situ Mini-Trolls™ with15 pounds per square inch (psi) pressure transducers and logging devices were used to take and record the water levels. These data provide fluctuations over a three-month period for the two major hydrogeologic units, the PWR and bedrock units. The raw water level data are provided on two compact discs and summary graphs for each piezometer are included as Appendix 5.

3.2.1.2 Test Pits

Fifteen test pits were dug utilizing a Caterpillar 315BL Track Excavator on August 28-30, 2001. The purpose of these test pits was to confirm or refute the presence of diabase as rock or saprolite as indicated during the magnetometer survey and to obtain further information about depth to groundwater and bedrock in areas where accessibility with a drilling rig was limited. The approximate locations of T-1 thorough T-15 as determined by measurements from surveyed piezometers are shown on Drawing No. 2. All test pits were inspected by an experienced JEI geologist to confirm the presence of diabase and/or weathered diabase saprolite, (granitic) PWR, (granitic) bedrock and groundwater, and log the data. The boring logs for the fifteen test pits are included in Appendix 3. A summary of estimated bedrock and groundwater elevations for each of these test pits is shown on Table 4.

3.2.2 Hydrogeologic Testing

Following rigorous well development, nine piezometers (P-1S, -1D, -3, -6, -7, -9, -14, -16, -20, and -25) were chosen for aquifer testing during the field investigation. The purpose of the testing was to assess the values of horizontal hydraulic conductivity at various locations within the water table and bedrock aquifers at the site. In situ rising- and falling-head tests (slug tests) were chosen for the assessment due to the relatively low well yields noted during well installation and development.

Rising- and falling-head tests were performed on piezometers P-1D and -6 on September 4-5, 2001. Only a rising head test was performed for the other piezometers because the water table intersected the well screen at the time of testing. Therefore, the results for a falling head test for these wells would not be considered to provide an accurate estimate of hydraulic conductivity. The slug tests for these piezometers were conducted on September 4-6, 2001 and November 9, 2001.

Prior to slug testing, the monitoring wells were opened and groundwater levels were allowed to equilibrate. Water level measurements were then collected using an electric water level probe referenced to a point on the top of casing. A 15 pounds per square inch (psi) pressure transducer was then lowered inside the well casing and placed approximately one foot from the bottom of the well. The pressure transducer was then attached to an In-Situ SE 1000C electronic data logger. A polyvinyl chloride (PVC) slug measuring five feet in length was then used to displace water inside the wells.

The first portion of the test was a falling head test that measured the rate water levels fell back to static after the injection of the PVC slug. The data logger recorded water level data from the transducer at logarithmic time intervals. Data from the transducer/data logger were verified with hand held water level readings. Falling head tests were terminated after water levels had recovered to within 95% of their pre-test level. A rising head test was performed on each well after the falling head test was completed or after the water level had equilibrated, for those piezometers that only had rising head tests performed. The rising head test was conducted by initiating a new logarithmic recording step on the data logger simultaneous with the removal of the PVC slug. The data were checked with hand held readings, and the test was terminated after water levels had recovered to within 95% of the pre-test level.

In situ rising- and falling-head tests provide a quantitative estimate of horizontal hydraulic conductivity (K) and a qualitative estimate of aquifer anisotropy in water-bearing units. The slug test data were analyzed using the Bouwer and Rice (1976 and 1989) equation, which is applicable to fully or partially penetrating wells in unconfined or confined aquifers. Aquifer thicknesses of 10-60 feet were assumed for all aquifers based upon information supplied on the boring logs. A packing porosity of 25% was assumed for the well filter pack. Computer software produced by Starpoint Software, Inc. was utilized to assist in the analysis and plotting of data. The individual data points and computer plots of time versus water level change are presented in Appendix 6. A summary of all aquifer testing performed at the site is included in Table 6.

In order to obtain a qualitative estimate of 'hydraulic conductivity' for a slowly recovering bedrock well, the water levels for piezometer P-10 were examined. The water level measurements were plotted and the corresponding hydraulic conductivity was calculated. These data span the time from twenty-four hours after well construction on August 29, 2001 through the time where the water level was assumed to have reached static conditions on October 3, 2001. The estimated hydraulic conductivity based on these data is 9.7×10^{-8} cm/sec. These plots are also included in Appendix 6.

3.3 Regional and Local Geology

This section of the report describes the geology of the site, with respect to the performance of engineered features upon the land surface in the proposed cell areas, and the groundwater flow regime, and the ability to effectively monitor water quality at the site.

3.3.1 Bedrock Geology

The study site is located within the southern portion of the Raleigh Belt, which is near the eastern edge of the Piedmont Terrane. The relevant geological features are shown on Figure 1, which shows features taken from the 1:250,000-scale *Geologic Map of Region J* (Wilson and others, 1975) overlain on the USGS regional topographic map. Geologic unit designations and descriptions used in this report are defined in *The Eastern Piedmont in North Carolina* (Stoddard and others, 1991).

The site is characterized by the granite of the Rolesville batholith, which is situated just west of the hinge zone of the north-northeast trending Wake-Warren Anticlinorium (Figure 3). The general regional geology is shown on Figure 1. The Rolesville batholith is comprised of three distinct phases of late Paleozoic granitoids and is one of the largest batholiths in the eastern United States. The rock types of this feature are predominantly medium- to coarse-grained biotite granite, hornblende-biotite granite, and biotite-muscovite granite (Stoddard and others, 1991). The rock seen in float and/or large outcrop, as well as rock core from this site was predominantly medium-grained biotite granite, and biotite-muscovite granite, with some garnets present (Photographs 1-4 in Appendix 7). Large K-feldspar megacrysts are also locally characteristic of these granites (Stoddard and others, 1991). These K-feldspar megacrysts were predominant at this site as seen both in bedrock and saprolite. These pegmatitic zones are commonly seen in the two-mica granite, with grain sizes up to an inch (refer to Photographs 5 and 6 in Appendix 7). Stoddard and others (1991) have reported a weak biotite foliation present locally within the plutons that comprise this batholith, although none was observed at this site. In fact, the site outcrops of granite were massive, with very little to no observed structure or foliation.

This region is also characterized by regional- and small-scale Mesozoic diabase dikes (Figure 4). Three major dikes in the area are also shown superimposed on the regional topographic map provide as Figure 1. Most of the dikes are near-vertical in dip and trend north-south to northwest-southeast and are characterized by plagioclase, augite and olivine (Ragland, 1991). The diabase found in boulders, rock core and the weathering profile was relatively weathered and fine-grained (Photographs 7-9 in Appendix 7). However we believe that it is generally consistent with the lithology described by Ragland (1991).

Bedrock elevation contours, based on auger refusal depths and additional information obtained from rock coring, are shown on Drawing No. 4. In general, auger refusal defines the top of bedrock for the site. However, as noted on the drawing, the top of bedrock was based on the assumed top of competent (i.e. non-rippable) bedrock in the two areas of concern noted above, as seen in data from rock cores from C-1 through C-5.

Not noted
Not acceptable

3.3.2 Joints and Fractures

A general conceptual model of fracture distribution at the site is useful for predicting preferred groundwater flow pathways. The model described below is based on the topography of the area surrounding the site, fracture orientations and densities in site outcrops (or lack thereof) and inferences from regional and site geology.

Topography of the area surrounding the site is shown in Figure 1. The orientation of many first and second order stream segments may have been determined by geomorphological development of slopes draining to the Neuse River, rather than by fracture control. Because of this, the utility of topographic fracture trace analyses is limited. However, from inspection of the topography, the drainage patterns along the western perimeter of the site and locally around the site appear to be controlled by the fracturing associated with the large-scale diabase dikes, and have a north-northwest or a northeast orientation. The other dominant orientation of drainages in and around the site is an approximate east-west trend. Several of these trends, based on topography, can be seen on Figure 1.

Of the rock exposures found in place, none contained significant fractures or fabrics that could be measured for the purposes of determining preferential fracture orientations. The locations of the outcrops of diabase and granite are noted on Drawing No. 2. The strike and dip of fractures found in rock core taken at the site could not be determined, as the core was not oriented, nor were there any pervasive fabric features that would allow for this determination. However, generally the fractures within the granite were few in number and randomly oriented. The only preferred orientation noted in 10 fractures was that half of them were subhorizontal to horizontal. (Figure 4).

Diabase dikes in this region typically create fracture zones in the country rock adjacent to their contacts. These fracture zones are limited in their horizontal/lateral extent, and are often characterized to be about 1/10 of the thickness of the dike, occurring on both sides of the feature. One strike and dip measurement was taken of a joint set in a stream exposure of granite at a diabase contact (Photograph 10 in Appendix 7). As shown on Drawing No. 2, the strike of this joint set was roughly north-south, parallel to the orientation of the large diabase dike, with a moderately steep northwest dip. However, it is likely that there are many random fracture orientations associated with the rock adjacent to the dikes. One rock core of diabase was highly-fractured. In a 4-foot section of core of the upper portion of weathered diabase, 13 fractures were noted and appear to be very random in nature, as would be expected for a weathering profile (Figure 5).

3.3.3 Definition and Properties of the Subsurface Hydrogeologic Units

Three subsurface hydrogeologic units for the site are defined in this section. Properties of the units described here will allow description of a general conceptual model of groundwater flow in the site area. Estimates of hydraulic conductivity, effective porosity, and preferred flow directions assigned to the units are made with reference to the laboratory test results presented in Table 7 and Appendix 8, to the slug tests summarized in Table 6, and to drilling information contained in Appendix 3. Because some of the groundwater flow in this site occurs in fractures, and because the subsurface is heterogeneous, utility of the numbers contained in those tables is limited, and properties are assigned, in large part, on the basis of geologic considerations described in the above sections.

3.3.3.1 Saprolite Hydrogeologic Unit

In nine of the piezometers, saprolite is the uppermost hydrogeologic unit, which occurs beneath the proposed disposal areas. This is consistent even in areas where bedrock is relatively shallow. All of the borings encountered this unit, although there were distinct and unpredictable differences in the thickness of this unit across the site. Split-spoon samples and auger cuttings of this material are described in boring logs as silty sands and sandy silts. Minor clayey silt to clayey sand was noted in only 10 out of 64 borings and test pits and appears to correlate with the areas of greatest saprolite thickness. These soils appear to be discontinuous in nature and its hydraulic characteristics are indistinguishable from the other saprolite. Thus, these soils were not considered as a separate unit.

Laboratory soils classifications of two split-spoon samples and one undisturbed (Shelby tube) sample were defined as silty sands (Table 7; Appendix 8). One other split spoon sample was classified as an elastic silt and a bulk sample was classified as a clayey sand. Although the laboratory-derived porosities determined from one undisturbed sample and one bulk sample were approximately 0.30 (Table 7), effective porosities are expected to be similar to those typically assigned to Piedmont saprolite, or about 0.20 (Harned and Daniel, 1989). Hydraulic conductivities are expected to be on the order of 10^{-4} to 10^{-5} cm/s, based on slug test data from two piezometers screened completely within saprolite and one piezometer screened across the saprolite/partially weathered rock transition zone (Table 6). The saprolite unit is considered to represent a significant hydrogeologic unit for the area around the proposed disposal areas.

3.3.3.2 Partially Weathered Rock Hydrogeologic Unit

For twelve of the piezometers, the uppermost hydrogeologic unit beneath and surrounding the proposed disposal areas is defined as "partially weathered rock" (PWR). The partially weathered rock is similar to the silty sands and sandy silts that overly it in composition. Laboratory soils classifications of one split-spoon sample and one undisturbed (Shelby tube) sample collected from this unit were defined as silty sands (Table 7; Appendix 8) and its hydraulic properties are very similar to those of the saprolite unit. Therefore, the PWR is indistinguishable from the saprolite unit based on its soil classification and hydraulic properties. However, it is visually distinct from the saprolite unit due to the prominent granitic fabric and fresh, often large feldspar and quartz grains as seen in split spoon samples (Photographs 6, 11 and 12 in Appendix 8).

The base of this unit is defined to coincide with auger refusal as noted in the boring logs. However, near the top of the highest knoll at the site in the southeastern corner of the proposed northern disposal area, information provided by additional rock core was used to define the top of competent bedrock. In this isolated area, rather than defining the top of bedrock as auger refusal, the RQDs and recoveries during rock coring were used to distinguish between weathered, rippable rock and competent bedrock. In this isolated area, the difference between auger refusal and the depth to competent rock as determined by rock core was approximately 13 feet. Therefore, in this area, the rock core data were used in favor of the auger refusal data, as indicated on the bedrock contour map shown on Drawing No. 4. The thickness of this unit is highly variable across the site and ranges from approximately 2 to 40 feet. As with the saprolite unit, the thickness of this unit is somewhat unpredictable.

Groundwater within the upper five to ten feet of the PWR unit in most parts of the expansion area is expected to be stored and transmitted in pore spaces, and the material can be reasonably described as hydraulically isotropic. Below this depth, groundwater will tend to be stored and transmitted in fractures. Hydraulic conductivities of the upper parts of the PWR unit are estimated to be similar to those estimated by slug tests in saprolite wells performed during the current investigation, and also reported for saprolite at typical Piedmont sites, or approximately 10^{-4} to 10^{-5} cm/sec.

The laboratory-derived porosity as determined from one undisturbed sample was approximately 0.35 (Table 7). Effective porosities of the upper parts of the PWR unit are expected to be similar to those often used for Piedmont saprolite, approximately 0.20 (Harned and Daniel, 1989). With depth through the weathering profile, effective porosities are expected to decrease to only a few percent (Harned and Daniel, 1989).

3.3.3.3 Fractured Bedrock Hydrogeologic Unit

The lowermost hydrogeologic unit defined for the site subsurface is the "fractured bedrock unit" (bedrock). In a limited area across the ridgeline that occurs along the southern portion of the proposed northern disposal area and an isolated portion in the eastern part of the proposed southern disposal area, this unit occurs beneath a very thin layer of saprolite with little to no transition into PWR, as seen in piezometers P-2, -7, -10 and -22 and on Drawing No. 4. The top of this unit is defined above.

Hydraulic conductivities estimated by slug tests in fractured bedrock wells as well as hydraulic conductivities reported for other Piedmont sites, are in the range of 10^{-4} to 10^{-8} cm/sec (Table 6). Hydraulic conductivities of the fractured bedrock unit are expected to fall within this range, and vary locally with fracture intensity. However as noted above in section 3.2.2 and in the RQDs shown on Table 3, the granite that underlies the site is highly competent with very few if any fractures beneath the upper 5-15 feet, depending on the degree of weathering. In general, the observed trend of fractures as seen in the granitic rock core at this site is that the RQD increases with depth (Figure 6). This was true in all but one sample from P-10; however only 10 feet of core were obtained and it is assumed that this trend would be seen over a larger core run. Therefore, groundwater movement through this unit is predicted to be very limited with increasing depth. Effective porosity of bedrock at the site is expected to be one percent or less (Heath, 1989). In areas where diabase dikes are in contact with the granite, the fracture intensity is predicted to be much greater as discussed above. p10 ?

3.3.4 Weathering Profile

The majority of the area beneath, surrounding, and hydraulically downgradient of the proposed cells is underlain by a relatively thick layer of saprolite and partially weathered rock. There are some localized zones that are characterized by bedrock that is relatively shallow, i.e., the topographic high in the central portion of the northern disposal area, and another area in the proposed footprint of the southern area between P-2 and P-23 and -24 (Drawing No. 2). It is inferred that these more resistant areas are characterized by the coarser-grained (i.e. pegmatitic) zones mentioned above, which did not weather as completely as the surrounding granite. The coring done during the third phase of drilling indicated that some of these more resistant zones would be 'rippable' during cell construction.

Within a portion of the site, completely weathered and severely weathered granite has resulted in sandy silts and silty sands that are generally thick, and range up to at least 50 feet in thickness. Other areas are characterized by a thicker zone of partially weathered rock with relatively fresh feldspar, quartz and muscovite crystals and a definitive granitic fabric (Photographs 6, 11 and 12 in Appendix 7). Many borings encountered saprolite interlayered with partially weathered rock.

The interface between partially weathered rock and unweathered bedrock is generally abrupt, and occurs over intervals of a few feet. Rock Quality Designations (RQDs), fracture counts and descriptions of rock core from site borings (Table 2; Appendix 3) confirm this. Standard penetration tests (SPT) and auger refusal information (Appendix 3) are highly variable over short intervals; the SPT blow counts were generally very low for the some of the borings.

3.4 Site Hydrogeology

The following section discusses the hydrogeological aspects of the site, with emphasis on the proposed C&D disposal areas. A significant amount of hydrogeologic investigation was performed on the site including a geophysical survey for diabase dikes, and the installation of 26 piezometers, 18 borings, 15 test pits, and 5 rock corings.

3.4.1 Hydrology and Discharge Features

As discussed in section 2.0, the site is located on a group of knolls and valleys, the highest elevations of which rise approximately 100 feet above the floodplain of the Neuse River (Figure 1). Regionally, surface water and groundwater both flow north and northwest to the Neuse River, which is located approximately 0.75 mile north of the site. In the vicinity of the proposed C&D cells, groundwater flow is generally to the west and northwest, and discharges to the surrounding tributaries that flow to the Neuse River. Ground water beneath the site flows in three vertically interconnected hydrogeologic units, a saprolite, a PWR and a fractured bedrock aquifer.

3.4.2 Site Groundwater Flow Regime

With minor exceptions in above-mentioned areas of shallow bedrock, the surficial aquifer beneath the site occurs within saprolite and PWR. Generally, these two units are very thick (up to 50 feet or greater) in the area in and around the proposed cells. The upper parts of saprolite and PWR are expected to behave as a relatively isotropic, porous medium, where groundwater flow directions conform to the potentiometric surface defined by water table wells. The potentiometric surface based on water level readings taken on October 3, 2001 is shown on Drawing No. 3.

With increasing depth through the partially weathered rock and upper portions of bedrock, groundwater flow is expected to be governed increasingly by fracture pathways. No preferred fracture orientations were noted for the PWR or bedrock unit as determined by several split spoon samples and seven rock cores.

The western boundary of the proposed C&D area is bordered by a roughly north-south trending unnamed tributary that discharges to the Neuse River at a short distance from the northern facility property boundary. The two proposed disposal areas are separated by another well-developed east-west trending drainage (Figure 1). Given the absence of preferred fracture orientations and the generally unfractured nature of the bedrock, groundwater in all three hydrogeologic units beneath the proposed disposal areas flows towards the unnamed tributary to the Neuse River.

3.4.2.1 Horizontal Gradient Calculations

Horizontal hydraulic gradients for the proposed C&D disposal areas were calculated using three groundwater elevation measurements in five pairs of wells located approximately parallel to the groundwater flow direction indicated by the potentiometric surface map (Drawing No. 3). These gradient pairs were selected to represent gradients within the uppermost aquifers.

Estimates of hydraulic conductivity obtained from slug tests on individual wells at this site are considered to be higher than actual conductivities for site-scale movement of groundwater. Curves generated by the slug test recovery data indicate that the data are dominated by near-field, or skin effects, and are reflective, in part, of the properties of the well screen filter pack. Also, some of the wells tested are screened in PWR. Therefore, the geometric mean of the hydraulic conductivities (Ks) as determined by aquifer testing, 1.2×10^{-4} cm/sec, was used for groundwater flow calculations for the site.

The average horizontal gradients for well pairs along with the geometric mean of available K values for slug-tested wells were used to estimate linear groundwater flow velocities. Average linear groundwater flow velocities for wells screened in saprolite were computed using the following modified Darcy equation:

$$V = Ki/n$$

where V = average linear velocity (feet per day), K = hydraulic conductivity (ft/day), i = horizontal hydraulic gradient, and n = effective porosity. An effective porosity of 0.20 was assumed for all units. This approach is based on assumptions of heterogeneity and of isotropic, porous media.

Data and calculations for the horizontal gradients are presented in Table 8. The calculated horizontal gradients from four well pairs in the vicinity of the proposed C&D areas range from 0.02 to 0.03 ft/ft. Calculated linear groundwater velocities ranged from approximately 12.4 to 18.6 ft/year.

The above equation makes the simplifying assumptions of a homogeneous, isotropic aquifer in a porous medium, which has been assumed for wells screened in regolith. An average linear groundwater flow velocity was not calculated for bedrock wells using this equation because the assumptions and equation mentioned above are not valid for groundwater flow in fractured media (Parker et al., 1994). However, although slug tests should not be used to determine a quantitative value for groundwater flow in bedrock fractures, slug test data can provide a qualitative idea of groundwater recovery in bedrock wells. Groundwater flow velocities within the fractured bedrock aquifer are likely to be highly variable, and, in some cases, less than those velocities calculated for the saprolite and PWR units.

3.4.2.2 Vertical Gradient Calculations

One nested piezometer pair (P-1S and -1D) was utilized for purposes of measuring vertical hydraulic gradients. This pair is located downgradient of the proposed southern disposal area near the main drainage feature at the site. Calculations were performed using water levels measured on three different dates. Vertical gradients were calculated using the vertical distance between the screen midpoints and/or surface water elevation of the pairs. Vertical gradients calculated for the well pair indicate a slight upward gradient and therefore suggest that groundwater discharge is taking place in this area. A summary of all available vertical gradient data is presented in Table 9. Several cross-sections are provided to illustrate the vertical component of groundwater flow (Drawing Nos. 5-7).

3.4.2.3 Diabase Dikes

The geophysical survey identified a major magnetic anomaly along the western edge of the property, which roughly coincides with the major drainage feature at this site (Drawing No. 2). This anomaly is consistent with a regional-scale diabase dike as identified on the NC State Geological Map (Brown, 1985) and on the 1:250,000-scale *Geologic Map of Region J* (Wilson and Carpenter, 1975) shown as Figure 1 overlain on the USGS regional topographic map. Several other smaller anomalies were identified east of this feature. From these data, the dikes were interpreted as shown in the report in Appendix 2 and on Drawing No. 2. The largest dike was interpreted in this report to be approximately 100 feet wide and the smaller ones on the order of 10-20 feet wide.

The presence of the largest dike was confirmed in outcrops along the stream west of the proposed northern area; the location of these outcrops is also shown on Drawing No. 2. In order to further investigate these dikes, ten test pits were excavated. These test pits were approximately 3 feet in width and ranged from 10 to 40 feet in length, with the longest axis oriented normal to the geophysical anomalies in order to maximize the chances of intersecting diabase if it was present. The length of the test pit was proportional to the correlating magnetic anomaly. Severely weathered diabase was only found in one of these test pits, T-10 (Photograph 9 in Appendix 8). Therefore, the excavations suggest that the geophysical features mapped in the central portions of the north and south areas are not related to the presence of diabase.

Diabase was encountered at rock core location C-4 during drilling activities conducted to characterize the site bedrock. This location is just east of one of the smaller magnetic anomalies near P-2 (Drawing No. 2). Diabase was not encountered in T-11, which is located along the same anomaly. It is possible that diabase is not present at T-11 but is present in C-4 because test pit locations were chosen based on the Pyramid Environmental, Inc.'s interpretation of the magnetic data, rather than the raw data. As seen in the raw magnetic data in Figure 3 of the report in Appendix 2, there is a large cluster of anomalies in the area near C-4, which does not exactly coincide with the interpreted anomaly as shown on Figure 5 of the same report. Further investigation of this feature may be warranted in this area prior to construction activities in the proposed southern area.

3.5 Site Suitability

The following paragraphs discuss the proposed site's suitability as a C&D waste management facility with special attention to the areas of proposed disposal.

3.5.1 Relationship Of Geology And Groundwater To Waste Disposal Units

Numerous borings, rock corings, piezometers and test pits have been drilled or excavated on site, and the area has been adequately explored. The geologic characteristics of the site are typical of the Piedmont and should pose no unusual monitoring requirements except for the diabase dikes, which are discussed in detail below.

3.5.1.1 Diabase Dikes

The diabase dikes described in section 3.4.2 have been explored thoroughly so that an effective groundwater monitoring network could be designed. The monitoring network described in detail in section 4.0 of this report was designed to intersect groundwater that could potentially have its flow direction influenced by these dikes. Specifically, monitoring wells were placed in the areas of concern where the dikes were confirmed such that if groundwater were to intercept the dike and flow laterally along it, rather than along its path towards the drainage, it would be adequately monitored. Thus, it is assumed that the dikes would not adversely impact the ability to effectively monitor groundwater in and around either of the two proposed waste disposal areas. In fact, the large diabase dike may serve as a barrier to groundwater movement toward the potential receptors described below.

3.5.1.2 Vertical Separation From Bedrock

The top of bedrock contours and top of bedrock elevations in all available site borings and rock corings are based on the determinations described in detail in section 3.3.3.2. The data are shown on Drawing No. 4. Proposed base grade contours are also shown on this drawing to allow comparison of the vertical separation from bedrock. As shown on the diagram, the proposed base grades are at least 4 feet above the top of competent bedrock. In the area beneath the proposed footprint, the occurrence of bedrock is generally below the water table except in the two areas noted in section 3.3.3.2, where bedrock is shallow. This is illustrated on the hydrogeologic cross-sections identified on Drawing No. 5 and shown in Drawing Nos. 6 and 7.

3.5.1.3 Vertical Separation From Seasonal High Water Table

At the time design base grades for the C&D area were finalized in December 2001, only limited seasonal groundwater data were available for the newly-installed site piezometers. Due to this fact, predictions of the seasonal range of water levels for the site were based on the recorded ranges of available measurements from existing site monitoring wells from previous studies (Welby, 2000), as well as other monitoring wells in Wake County. These data were supplemented with precipitation records for the area, as described below. The data referred to below is contained within Table 10, Figure 7 and Appendix 9 to this report, with a summary table of the comparisons included as Appendix 9 - Table 1.

The water levels from on site wells installed during previous investigations were obtained from the report prepared by Charles W. Welby of NC State University, included as Appendix 1. Hydrographs for eight wells that are located within the site (Wells -28A, -28B, -28C, -38, -39, -40, -51 and -52) are presented on pages 146-147 of Welby's report. These hydrographs span a range of up to approximately five years during 1990 through 1996. The average precipitation value for Wake County, North Carolina for this period of time is slightly above the average for a 52-year period as shown on Table 10. The recent water levels for these same wells fall within the ranges seen in the hydrographs. Therefore, it is reasonable to assume that the data from the Welby report provide a good estimate of the seasonal high water table.

actually below avg.

In order to supplement these data, water levels from monitoring wells at the nearby NC State Agricultural Research Farm (located approximately 2.3 miles south of the site as shown on Drawings No. 2 from Section I of this report), were used. The average precipitation value for the years 1988 through 1996, when the water levels were recorded was also above the long-term average. The water levels from this research facility were obtained from the Hydrogeologic Site Investigation Report for Shotwell Landfill, Inc. (G.N. Richardson and Associates, 1999). These water levels were used as part of the seasonal high justification for the Shotwell Facility, which is located approximately 3.75 miles from the proposed facility. In the Shotwell report, the seasonal adjustments were from + 3 to+ 5 feet based on these data. These adjustments were added to Shotwell site groundwater elevations from April and May 1999, during which the precipitation was slightly below average.

Finally, water levels from monitoring wells at three landfills in Wake County, NC (Feltonsville C&D Landfill and the North Wake Lined and Unlined Landfills) were used as part of the seasonal high calculations. These wells are screened both within saprolite and bedrock and provide water levels from a variety of topographic settings. Again, the average precipitation value for the time span that these water levels were taken (1994-2000) is above the overall average. The average range of water levels in these wells is also on the order of up to five feet, which is consistent with the range noted above.

The calculations and adjustments used to estimate the seasonal high water table surfaces are shown in Table 11. Each of the wells and piezometers in and around the proposed C&D areas were compared to other wells mentioned above, based on similar topographic settings and proximity to surface drainages. The seasonal high water elevations were calculated by adding from 3-5 feet to the October 3, 2001 elevation for a given well, depending on these factors mentioned above. Proposed base of liner elevations are at least four feet above the estimated seasonal high groundwater levels, as seen on the groundwater map (Drawing No. 8) and in cross-sections on Drawing Nos. 6 and 7.

3.5.2 Potential Groundwater Receptors

Two occupied houses exist on the proposed site, one on the west side of and adjacent to the southern pond and one approximately 700 feet west of the northern pond. Each house has an associated water well that is currently in use. The northern house will be demolished and the well will be abandoned, prior to construction in that particular phase of the proposal northern disposal area. The water well near the proposed southern disposal area will be abandoned prior to or during construction of the southern disposal area. Moreover, the existing structures and wells will be respectively removed and abandoned prior to violation of the buffers specified in Rule .0503(2)(f)(ii). Specific well abandonment activities are summarized in section 4.0 of this report.

A small subdivision consisting of 5 to 10 residential dwellings is located west of the proposed site. Each dwelling is served by an individual water well, rather than a community well system as confirmed with the Public Water Supply Section of DENR. None of the dwellings or their water wells is within 500 feet of the proposed waste disposal areas. MR has purchased the one of the two homes that adjoins the southern portion of the property. They also have an option to purchase the second adjoining home.

This residential area is separated from the site by a major discharge feature, the unnamed tributary to the Neuse River. The northwestern and southwestern perimeter areas of the site are undeveloped timberland, and as mentioned in section 2.0 of this report, the areas east and north of the property are currently owned by the City of Raleigh and are used for waste sludge disposal.

As shown in continuous water levels taken from two piezometers as described in Section 3.2.1.1, it is not likely that the aquifers within the site are affected by any significant local pumping, either from private potable wells or industrial pumping of groundwater. Water levels from the PWR piezometer, P-15, steadily decreased approximately 0.9 foot, while water levels from the bedrock piezometer, P-2, steadily decreased approximately two feet, over each of their respective time periods during September-November 2001. These water levels are consistent with the drought that the region suffered during these months, as seen in the precipitation data over this time span for Wake County (Table 10). If the uppermost aquifer at the site were being influenced by groundwater withdrawal activities, it is likely that some anomalous signature would be present in the pressure transducer data logs from these wells.

3.5.3 Ability to Effectively Monitor Groundwater

No known or potential significant sources of contamination have been identified within 2000 feet of the property boundary. The two C&D disposal areas will be monitored separately, as described in Section 4.0 below. Groundwater flowing west-northwest in the three interconnected hydrogeologic units from the proposed disposal areas will be monitored by the well networks described in the Groundwater Monitoring Plan.

There are no known conditions, physical or hydrogeologic, which will interfere with the effective monitoring of the proposed facility, and specifically the proposed C&D disposal areas. The discharge feature and the major diabase dike along the western facility boundary both serve as effective groundwater flow boundaries between the proposed cell and potential receptors. Residual nitrate concentrations may be present in the site's northern area (as discussed in Section 3.1); however, this is not considered a factor to C&D waste disposal activities and the effective environmental monitoring of these activities.

3.6 Conclusions

The purpose of the Hydrogeologic Report is to present the assessment of geologic and hydrogeologic characteristics of the proposed site, especially as they relate to proposed C&D construction. Furthermore, the report must present data in support (or non-support) of the site's use for C&D waste management activities. This report presents the current understanding of the groundwater flow regime and the relationship of the solid waste management units to groundwater receptors and groundwater discharge features. In addition, this section demonstrates that the proposed site can be monitored effectively for potential releases.

In summary, a review of the geologic and hydrogeologic data indicates that the site is located within typical Piedmont terrain. The uppermost aquifer at the site is generally contained within three interconnected hydrogeologic units, including saprolite and PWR, which are both generally thick where they occur, as well as the bedrock unit where shallow rock occurs in localized portions of the site. Depths to groundwater and bedrock are well defined in and around the site. Study of the regional and site structural setting indicates a potential for preferential flow paths. These regional preferential flow paths include the north-south/northwest-southeast trending set related to the regional-scale diabase dikes and an east-west set. Both of these are reflected in the site drainages. No other site-specific preferential fractures were noted in the rock core collected or outcrops observed during this study. In fact, the bedrock is only highly-fractured in the uppermost limits. Below that, the rock is very competent with few fractures. Because these orientations are well-defined, the design of an effective groundwater monitoring system for the facility is possible. The facility boundary extends beyond a groundwater discharge, an unnamed tributary to the Neuse River, and a minimum of a 500-foot buffer exists between the residential dwellings and their water wells, and the proposed C&D disposal areas.

4.0 GROUNDWATER MONITORING PLAN

4.1 Introduction and Purpose

This Groundwater Monitoring Plan was prepared to serve as a guidance document for collecting and analyzing groundwater samples, managing groundwater analytical results, and monitoring for any potential releases to the uppermost aquifer from the proposed C&D Landfill. The Plan is submitted in conjunction with the Hydrogeologic Report, in accordance with NCSWMR Subchapter 13B, .0504(1)(g)(iv) as part of the Site Application for the facility. This Plan also addresses the requirements for surface water monitoring specified in Rule .0602, and the specific issues addressed in the Solid Waste Section's January 1995 policy memorandum (*Re: Sampling and Analysis Requirements, Construction and Demolition Landfills and Closed Sanitary Landfills*). The necessary geologic and hydrogeologic characteristics of the proposed C&D area are summarized in this Plan and are supported by detailed descriptions provided in the Hydrogeologic Report, Section 3.0.

Given the waste capacity of this proposed facility, disposal activities in the southern area are not anticipated for approximately twenty years. Therefore, the compliance monitoring well network associated with the area, described below, is proposed for installation in the future prior to construction and waste disposal.

4.2 Groundwater Monitoring Network

The groundwater monitoring network is designed to monitor for potential releases to the uppermost aquifer at the proposed site. The boring log and well completion details for the existing monitoring network well are included in Appendix 10 of this report, along with the monitoring well schematics for the proposed wells. A summary of well construction specifications is included as Table 12.

4.2.1 Background and Compliance Monitoring Wells

Monitoring well MW-1 (referred to in Section 3.0 as P-4) is proposed as the upgradient background monitoring well for both the northern and southern areas. Four new wells (MW-2, -3, -4, and -5) are proposed as downgradient compliance monitoring wells designed to monitor the northern area. Monitoring wells MW-6 and -7 are proposed as downgradient monitoring wells designed to monitor the southern disposal area. The proposed monitoring well network is shown on Drawing No. 9 with the potentiometric surface contours and the geophysical data for reference.

Background monitoring well MW-1 is located upgradient from and approximately 625 feet southeast of the closest proposed northern waste boundary and approximately 400 feet northeast of the closest proposed southern waste boundary. This well is screened across the water table and has a 25-foot screen within saprolite. The relatively long screen section was necessary due to slow groundwater recovery in this area of the aquifer.

Each compliance well will be located approximately 125 feet from the waste unit boundary, at a point halfway between that point and the 250-foot compliance boundary. In the event that the proposed locations are shifted more than 25 feet in any direction, due to field conditions, the Solid Waste Section will be notified prior to drilling and well construction. Approval of the altered location will be obtained, or an alternate location will be agreed upon. Each well will be screened across the water table with a well screen 15 feet in length. Given average climatic conditions, approximately 10 to 12 feet of well screen will be placed below the water table.

With the absence of major structural lineaments traversing the disposal areas, many of the monitoring well locations were chosen based on localized topographic features. These features are generally a subdued representation of the water table and as such, are useful in predicting areas of groundwater flow convergence. These features provide four well-spaced downgradient monitoring points in the northern area. Wells MW-2 and MW-3 are proposed to be located north of the proposed northern disposal area. Each well is anticipated to be screened within saprolite and partially weathered rock. Monitoring wells MW-4 and MW-5 are proposed to be located downgradient from and west of the northern area. These wells are anticipated to be located within partially weathered rock and bedrock. Abundant diabase float was found in the drainage near MW-4. This well will be field located just east of the float that may be associated with a possible linear feature (i.e. a dike).

The proposed southern area well network consists of two downgradient wells, MW-6 and MW-7. Groundwater flow from the southern area is primarily westward until it intersects the major diabase dike that borders the downgradient edge of the cell. As demonstrated in numerous regional studies, the boundaries of this geologic feature are likely to serve as a localized 'conduit' for relatively accelerated groundwater flow. Well MW-6 provides an ideal monitoring point for this area, monitoring the collective flow at the base of the cell as it is diverted along the eastern side of the diabase dike.

The exact placement of MW-6 will be determined during construction of the southern areas initial waste cells. The area of concern will be locally excavated in order to determine the exact location, strike, and dip of the diabase dike. Based on this information, MW-6 will be constructed to intersect the water table in a location approximately 20 feet east of the feature. As discussed elsewhere in this Site Application, the exact placement of the westernmost cell boundary is also subject to revision based on pre-construction field activities to confirm the dike location.

Well MW-7 is proposed to monitor the potential diversion of groundwater flow associated with a relatively small diabase dike identified during the site characterization. As mentioned in the Hydrogeologic Report, core hole C-4 encountered diabase just west of the north-south trending geophysical anomalies. In the event that this feature has the capacity to divert the primary northwestern flow of groundwater under the cell, well MW-7 will serve as an excellent point to monitor water quality in the central portion of the cell. Well MW-7 will be field located and constructed to intersect the water table in a location approximately 20 feet east of the identified diabase feature.

4.2.2 Installation and Maintenance of Groundwater Monitoring Network

The background monitoring well MW-1 was installed by JEI in August 2001. The well was constructed according to specifications for monitoring wells codified in 15A NCAC Subchapter 2C, Section .0100, and according to draft guidance document *North Carolina Water Quality Monitoring Guidance Document for Solid Waste Facilities* (March 1995). Details of well drilling and construction are presented in Section 3.2.1.B. The additional proposed wells will also be constructed according to specifications for monitoring wells codified in 15A NCAC Subchapter 2C, Section .0100, and according to draft guidance document *North Carolina Water Quality Monitoring Guidance Document for Solid Waste Facilities* (March 1995). The proposed monitoring wells will be used and maintained in accordance with design specifications throughout the life of the monitoring program. Routine monitoring well maintenance will include inspection and correction/repair of, as necessary, identification labels, cement pad condition, locking caps and locks, and access to the wells. Should it be determined that the background or a compliance monitoring well no longer provides samples representative of the quality of groundwater passing the relevant point of compliance, the Solid Waste Section will be notified. The owner will reevaluate the monitoring network, and recommendations will be made for modifying, rehabilitating, abandoning, or installing replacement or additional monitoring wells, as appropriate.

4.3 Groundwater Monitoring

Groundwater samples will be collected and analyzed according to the methods and analyses outlined in the Solid Waste Section's January 1995 memorandum entitled *Sampling and Analysis Requirements for Construction and Demolition Landfills and Closed Sanitary Landfills*. The list of analytes provided in that memo includes the North Carolina Appendix I list of volatile organic constituents (VOCs) and the 8 RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver). Additional field parameters including pH, specific conductivity, and temperature will be collected during each event. The laboratory analytical results and field parameters will be submitted to the Solid Waste Section at least semiannually. Any exceedances of the NC 2L Drinking Water Standards will be identified in the semiannual submittals.

4.3.1 Establishment of Background Data

A minimum of one independent groundwater sample will be collected from the background and compliance wells prior to the start of disposal operations in the respective areas at the proposed C&D facility.

4.3.2 Groundwater Sampling Methodology

Groundwater samples will be collected in accordance with the Solid Waste Section's draft document titled *North Carolina Water Quality Monitoring Guidance Document for Solid Waste Facilities* (March 1995). Details of well purging, sample withdrawal, and decontamination methods as well as chain-of-custody procedures are outlined below.

Static water elevations and the total well depth will be measured to the nearest 0.01 of a foot in each well prior to the sampling of each well. An electronic depth meter will be used for the measurements. This device is lowered into the well and emits an audible tone when water is reached. The distance from the top of the well casing to the water surface and to the bottom of the well will be measured using the tape attached to the probe. Reference elevations of the proposed wells will be obtained from a North Carolina registered land surveyor.

The groundwater monitoring wells will be evacuated using disposable teflon bailers. A separate clean bailer will be used for each monitoring well during each sampling event.

A low-yield well (one that is incapable of yielding three casing volumes within a reasonable time) will be purged so that water is removed from the bottom of the screened interval. Low-yield wells will be evacuated to dryness once. As soon as the well recharges, or within 24 hours, the first sample will be field tested for pH, temperature, and specific conductance. Samples will then be collected and containerized in the order of the parameters' volatilization sensitivity (i.e., volatile organics then total metals).

A high-yield well (one that is capable of yielding more than three casing volumes during purging) will be purged so that water is drawn down from above the screen in the uppermost part of the water column to ensure that fresh water from the formation will move upward in the screen. At no time will a well be evacuated to dryness if the recharge rate causes the formation water to vigorously cascade down the sides of the screen and cause an accelerated loss of volatiles.

A minimum of three casing volumes will be evacuated from the well prior to sampling. A well volume is defined as the water contained within the well casing and pore spaces of the surrounding filter pack. The well volume will be calculated using the following formulas:

$$V_{well} = V_c + V_p$$

where:

V_{well} = total well volume
V_c = volume in the well casing
V_p = volume in the pore space of the filter pack

$$V_c = \left(\frac{d_c^2}{4}\right) \times h_w \times 7.48 \text{ gal/ft.}$$

$$V_c = 0.163\ h_w \text{ gals}$$

where:

d_c = casing diameter in feet ($d_c = 0.167$)
h_w = height of the water column (i.e., well depth minus depth to water)

$$V_p = \quad 4\ (d_f2 - d_c^2)\ x\ h_w^* \times 7.48 \times 0.3$$

$$V_p = 0.391\ h_w^* \text{ gals}$$

where:

d_f = filter pack diameter in feet ($d_f = 0.5$)
h_w* = height of the water column but must not exceed filter pack length

0.3 = assumed 30% porosity in the filter pack.

The purge volume will be a minimum of 3 times the calculated well volume.

Each well will be evacuated (purged) and sampled with a disposable Teflon® bailer. The bailer will be lowered gently into the well to minimize the possibility of causing degassing of the water. All equipment used for sampling will be handled in such a manner to ensure that the equipment remains 99.99% pure and decontaminated prior to use. Clean disposable gloves will be worn by sampling personnel.

The upgradient/background well will always be sampled first, followed by the downgradient wells. The order of sampling of the downgradient wells will be evaluated each sampling event to provide a sequence going from less contaminated to more contaminated based on the previous sampling event.

Field measurements of temperature, pH, and specific conductance will be made before and after sample collection as a check on the stability of the water sampled over time. The direct reading equipment used at each well will be calibrated according to the manufacturer's specifications prior to each sampling event. Groundwater samples will be collected and containerized in the order of the volatilization sensitivity, i.e., VOCs first, followed by the metals.

Pre-preserved sample containers will be supplied by the laboratory. The VOC vials will be filled in such a manner that no headspace remains after filling. Immediately upon collection, all samples will be placed in coolers on ice where they will be stored prior to/and during transit to the laboratory.

In between wells and following completion of the field sampling, the electronic depth meter will be decontaminated using the following procedure.

1) Phosphate-free soap and tap water wash;
2) Deionized or distilled water rinse;
3) Air dry.

Samples collected will be properly containerized, packed into pre-cooled coolers, and either hand-delivered or shipped via overnight courier to the laboratory for analysis. The chain-of-custody program will allow for tracing of possession and handling of samples from the time of field collection through laboratory analysis. The chain-of-custody program will include sample labels and seals, field logs, and chain-of-custody record.

Labels sufficiently durable to remain legible when wet will contain the following information:

- Job and sample identification number;
- Monitoring well number or other location;
- Date and time of collection;
- Name of collector;
- Parameter to be analyzed; and
- Preservative, if applicable.

The shipping container will be sealed to ensure that the samples have not been disturbed during transport to the laboratory. The tape is labeled with instructions to notify the shipper if the seal is broken prior to receipt at the laboratory. If the sample cannot be analyzed because of damage or disturbance, whenever possible, the damaged sample will be replaced during the same sampling quarter.

The field log will contain sheets documenting the following information:

- Identification of the well;
- Well depth;
- Static water level depth;
- Presence of immiscible layers;
- Purge volume (given in gallons or number of bailers);
- Time well was purged;
- Date and time of collection;
- Well sampling sequence;
- Field analysis data and methods;
- Field observations on sampling event;
- Name of collector(s); and

- Climatic conditions including air temperatures.

A copy of the log sheet will be maintained with the event files and provided to the Solid Waste Section upon request.

The chain-of-custody record is required to establish the documentation necessary to trace sample possession from time of collection to time of receipt at destination. A chain-of-custody record will accompany each individual shipment. The record will contain the following information:

- Sample destination and transporter;
- Sample identification numbers;
- Signature of collector;
- Date and time of collection;
- Sample type;
- Number of sample containers in shipping container;
- Parameters requested for analysis;
- Signature of person(s) involved in the chain of possession;
- Inclusive dates of possession; and
- Internal temperature of shipping container upon opening in laboratory (noted by the laboratory).

A copy of the completed chain-of-custody sheet will accompany the shipment and will be returned to the shipper with the analytical results. The chain of custody record will also be used as the analysis request sheet.

A field blank will be collected and analyzed during each sampling event to verify that the sample collection and handling processes have not affected the integrity of the field samples. The field blank will be prepared in the field from lab pure water (Type II reagent grade water) supplied by the laboratory. One field blank will be prepared for each sampling event. The field blank will be generated by exposing the lab pure water to the sampling environment and sampling equipment/media in the same manner as actual field samples being collected. The lab will provide appropriate sample containers for generation of the field blank(s). The field blank will be subjected to the same analysis(es) as the groundwater samples. As with all other samples, the time of the field blank collection will be recorded so that the sampling sequence is documented. The field blank monitors for contamination from the sampling equipment/media, or from cross-contamination that might occur between samples and sample containers as they are opened and exposed to the sampling environment.

Whenever groundwater samples are being collected for volatiles analysis, a trip blank will be generated by the laboratory prior to shipment of sampling containers and coolers to the field. The same lab pure water as above shall be used. The trip blank shall be transported with the empty sampling containers to the field, but will not be opened at any time prior to analysis at the laboratory. The trip blank will accompany the groundwater samples in the cooler(s) back to the laboratory and will be analyzed by the same volatile methods as the associated field samples. The trip blank monitors for potential cross-contamination that might occur between samples or that may be a result of the shipping environment.

Concentration levels of any contaminants found in the field blanks or trip blanks will not be used to correct the groundwater data, but will be noted accordingly. Contaminants present in trip blanks or field blanks at concentrations within an order of magnitude of those observed in the corresponding groundwater samples may be cause for resampling.

4.3.3 Sample Analysis Requirements

4.3.3.1 Analytical Requirements

Analysis of groundwater samples from the facility will be analyzed by a laboratory certified by the NCDENR. Analyses will be performed in accordance with U.S. EPA SW 846 methods. Method numbers and Practical Quantitation Limits (PQLs) to be used will be those listed in the January 1995 memorandum entitled *Sampling and Analysis Requirements for Construction and Demolition Landfills and Closed Sanitary Landfills*. This memorandum is included as Appendix 11.

4.3.3.2 Reporting and Record Keeping

The laboratory analytical results will be submitted to the DWM at least semiannually. The following measurements, analytical data, calculations, and other relevant groundwater monitoring records will be kept throughout the active life of the facility and the post-closure care period:

- Records of all groundwater quality data;
- Associated sample collection field logs and measurements, such as static water level measured in compliance wells at the time of sample collection; and
- Notices and reports of NC 2L exceedances, reporting or data error, missing data, etc.

4.3.3.3 Well Abandonment

All recently installed piezometers or pre-existing wells at the site that are not used for permanent monitoring will be properly abandoned in accordance with the procedures for permanent abandonment, as described in 15A NCAC 2C Rule .0113(a)(2). The piezometers and wells will be progressively abandoned as necessary to complete construction activities. The remaining piezometers will be used to supplement groundwater elevation data. The piezometers and wells that are within the proposed footprint will be overdrilled before they are grouted. Other wells that will potentially interfere with clearing and construction activities will be grouted in place without overdrilling. Two of the pre-existing wells that are proposed to be abandoned were constructed with steel casing. If possible, the casings will be removed prior to chlorination and grouting, in accordance with potable water well abandonment procedures. Refer to Table 13 for details of proposed abandonment procedures.

→ Don't abandon everything.

All borings (B-1 through B-18) were abandoned by back-filling cuttings into the boreholes immediately following drilling. All rock core locations (C-1 through C-5) were abandoned by injecting grout via a tremie-pipe to the bottom of the borehole. None of these borings or core locations encountered the water table. These activities are summarized on Table 14 and abandonment forms for all rock core locations are located in Appendix 12.

4.4 Surface Water Monitoring

Three surface water monitoring points are proposed for the facility as shown on Drawing No. 9. Each surface water sampling location will be marked with a metal fence post located on the stream bank normal to the sampling location.

Surface water point SW-1 is located to monitor water quality in the major tributary, as it crosses into the site. The sample location is at the property line, just upstream of the junction of the smaller tributary that originates on site, south of the southern area. Surface water monitoring point SW-2 will serve as a downstream monitoring point. Samples from this point will be collected at a location approximately 400 feet northwest of the northern disposal area near the northern property boundary. Surface water monitoring point SW-3 will monitor the smaller tributary just north of the northern disposal area, which flows into the aforementioned major tributary. This location will serve as an additional downstream monitoring point for the northern disposal area.

The surface water will be sampled for the constituents as outlined above that are required for C&D landfills and the locations will be monitored at least semiannually during the life of the facility. The results of the analysis of the surface water data will be submitted to the Solid Waste Section semiannually with the groundwater data.

4.5 Ability to Effectively Monitor Releases from Proposed C&D Areas

No known or potential sources of significant contamination have been identified within 2000 feet of the property boundary. Groundwater flow from this area is primarily to the northwest, with other components of flow to the west and north into minor drainages. There are no known conditions, physical or hydrogeologic, which will interfere with the effective monitoring of the proposed C&D cells.

Prior use of this land has generally been for agricultural purposes, although the City of Raleigh used a portion of the proposed northern disposal area for land application of sludge from the nearby Neuse River Waste Water Treatment Plant for approximately ten years, as discussed in Section 3.1 of this report. There is no reason to believe that the presence of sludge fields would adversely affect the siting of a landfill on this property. However, given the past history of land use on the northern portion of the property, several piezometers within the area that had been used for this purpose will be sampled for metals in order to establish background levels that may be elevated in this area.

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