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GZA

FINAL REMEDIAL INVESTIGATION
& RISK ASSESSMENT REPORT
CENTRAL LANDFILL OPERABLE UNIT 2
JOHNSTON, RHODE ISLAND
VOLUME I OF V

PREPARED FOR:
Rhode Island Resource Recovery Corporation
Johnston, Rhode Island

PREPARED BY:
GZA GeoEnvironmental, Inc.
Providence, Rhode Island

August 2001
File No. 31866.2

GZA
GeoEnvironmental, Inc.

Engineers and Scientists

August 10, 2001
File No. 31866.20

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Re: Central Landfill, Operable Unit 2
Final Remedial Investigation Report
Johnston, Rhode Island

Dear Mr. Mah:

Attached is one copy of the Final Remedial Investigation Report for Operable Unit 2 at the Central Landfill in Johnston, Rhode Island. The work was conducted by GZA GeoEnvironmental, Inc. (GZA) on behalf of the Rhode Island Resource Recovery Corporation (RIRRC). The remedial investigation and resulting report address the requirements of the Administrative Order by Consent (April 1987) between the Environmental Protection Agency and RIRRC, and the written and oral review comments provided by EPA and RIDEM through August 8, 2001.

The report is contained in five volumes (I through V) and one roll of 24 30"x42" figures. Volume I contains the text of the report, Volumes II and III contain the tables and Volumes IV and V contain the appendices. Provided in the report are a Baseline Human Health Risk Assessment and an Ecological Risk Assessment. These studies were conducted under the direction of Lisa Campe and Timothy Briggs of GZA's Risk Management Group. For ease of review we have reprinted only those pages or sections (text and tables) which have changed since our March 2001 submittal. These may be differentiated by the page footer date, which is March 2001 on pages without revisions and August 2001 on pages with changes.

We have forwarded copies directly to the individuals listed below. If you need additional copies or have questions do not hesitate to call either Ed or Mike.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

for Stephen M. Kline, P.E.
Project Engineer

Michael A. Powers, P.E.
Senior Project Reviewer

Edward A. Summerly, P.G.
Associate Principal

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1.00 INTRODUCTION

This final report describes the Remedial Investigation (RI) and Risk Assessment (RA) conducted for the second operable unit (Operable Unit 2 - OU2) at the Central Landfill (CLF) in Johnston, Rhode Island (the Report). It has been revised to reflect review comments provided by the United States Environmental Protection Agency (EPA) and the Rhode Island Department of Environmental Management (RIDEM) through August, 2001. A Site Locus Plan is provided on the cover sheet of figures which are an integral part of this report. The Report was prepared by GZA GeoEnvironmental, Inc. (GZA) for the Rhode Island Resource Recovery Corporation (RIRRC - formerly the Rhode Island Solid Waste Management Corporation) under the direction of the EPA and the RIDEM. The work was conducted under the terms of an Environmental Engineering Services Contract between GZA and RIRRC, and is subject to the limitations described in Section 11. References are provided in Appendix A.

Note background information contained within this report was current as of September 1997, the date of its original publication. This report contains additional information that post-dates the original report. While data tables and some figures have been updated to reflect these findings, no attempt was made to update all the information (e.g., topographic plans, descriptions of site use, property ownership).

1.10 BACKGROUND

In the first half of 1992, during the course of the EPA's review of the RI Report for the CLF, it became clear that there were insufficient data to identify all the potential adverse effects that the landfill may have had on the environment. Consequently, the EPA requested that the RI, RA and Feasibility Study (FS) for the 154-acre licensed landfill (designated at that time as Operable Unit 1-OU1) be completed, and that ecologically-related issues and the effects of off-site contaminant migration be addressed in a second RI/FS (designated Operable Unit 2). The OU2 Study Area was then defined as the area surrounding the OU1 Site, and includes all properties within the 2,000-foot buffer zone, (as defined in RI general laws 23-19-34 and 23-19-95), the Upper Simmons Reservoir, the upper third of the Lower Simmons Reservoir, the Almy Reservoir, and wetlands between the landfill and these reservoirs. The OU2 Study Area covers an area of about 1,333 acres.

The RI for OU1 was conducted by GZA for RIRRC. The RI Report, entitled: Central Landfill Remedial Investigation Report, Operable Unit 1, (GZA, 1993a), was submitted to the EPA on March 9, 1993. The Risk Assessment for OU1 was conducted by CDM Federal Programs Corporation for the EPA. That RA report, entitled Baseline Risk Assessment (CDM, 1993), was submitted to the EPA on November 11, 1993. The Feasibility Study for OU1 was conducted by GZA for RIRRC. The FS report, entitled Final Feasibility Study, Operable Unit OU1, Central Landfill, (GZA, 1993c), was submitted to the EPA in December 1993. In May of 1993, GZA prepared a draft work plan for the OU2 RI. That document, dated May 19, 1993, was titled Draft Operable Unit

2 Remedial Investigation Work Plan, Central Landfill, Johnston, Rhode Island (GZA, 1993b). The Record of Decision (ROD) for OU1 was issued by the EPA on June 17, 1994.

In response to EPA's December 28, 1994 amendment to the April 1987 Administrative Order by Consent (EPA, 1987a), GZA prepared a revised Work Plan through response summaries, a November 6, 1995 Sampling and Analysis Plan (SAP) (GZA, 1995d), and a Quality Assurance Project Plan (QAPP) (GZA, 1995c) for the OU2 RI. Those documents were reviewed and approved by the EPA and the RIDEM. Except as noted in this report, the OU2 RI was conducted in accordance with the requirements and procedures outlined in: (1) the OU2 Work Plan (GZA, 1993b), as finalized in a February 17, 1995 Response Summary; (2) the SAP (GZA, 1995d) as amended through November 28, 1995; and (3) the QAPP (GZA, 1995c).

1.20 PURPOSE

The overall purpose of the OU2 RI is to provide data to: support a Baseline Human Health and Ecological Risk Assessment; evaluate the extent of off-site migration of site-related contaminants; and support an OU2 Feasibility Study. More specifically, the objectives of the OU2 RI are to:

- Evaluate the nature and extent of contamination which has migrated from the OU1 landfill to the OU2 Study Area;
- Better characterize potential routes of off-site migration of contaminants via groundwater migration, and surface water flow in the Quarry Stream and Cedar Swamp Brook;
- Organize data in a manner which facilitates the performance of a Risk Assessment and a Feasibility Study; and
- Inform the public of environmental conditions in the area of the Central Landfill.

1.30 OU1 HISTORY

Filling at the CLF began in 1955 and was ongoing as the OU2 RI was being prepared. The RIRRC purchased the site in 1980. In 1996 the site received approximately 3,100 tons of solid waste per day. The CLF is presently the largest sanitary landfill in Rhode Island and the majority of Rhode Island's communities rely on the landfill for their solid waste disposal needs.

CLF is a 154-acre licensed landfill consisting of three subareas designated Phase I, II and III. In June of 1993, the 121-acre Phase I area had been filled to design capacity. Filling of the 21-acre, double-lined Phase II landfill, which abuts and will ultimately overlap Phase I, commenced in April 1993. In the summer of 1997, RIRRC began filling the 12-acre, double-lined Phase III landfill cell, which will piggyback Phase II cell. Preparation of a 45-acre Phase IV landfill, which is not a part of the superfund site, area got underway in September of 1998 *and RIRRC began filling the Phase IV cell in September 2000.*

During its operational history, the CLF has received municipal solid wastes, industrial wastes and septage wastes. A review of historical information (see Section 2.40 of the OU1 RI Report [GZA, 1993a]) indicates that liquid industrial wastes were disposed of into trenches excavated down to, or into, bedrock. These excavations were located near the eastern-central edge of the landfill. This approximately half-acre area was located during the OU1 RI and was designated as Hazardous Waste Disposal Area 2 (HWDA2). (Note, it was the second suspected industrial waste disposal area to be investigated, and was the only hazardous waste disposal area identified at the Site). For the purposes of the OU1 FS, this area was designated the "Hot Spot."

Landfill gas (LFG) is collected at the site by a system of more than 100 wells at a rate of approximately 9,500 standard cubic feet per minute (scfm) (see Section 3.11 of the OU1 RI Report [GZA, 1993a]). The LFG is used to power nine turbine-generators used to produce up to 13,800 KW of electrical power. Stack emissions from that facility are regulated by a permit issued to Ridgewood Providence Power Partners by RIDEM. During the OU1 studies, three phases of air monitoring and computer dispersion modeling of emissions from the power generating facility were completed by GZA. Those studies indicated that, with the power plant operating, there was no significant adverse effect on local ambient air quality (see Section 8.30 of the OU1 RI Report [GZA, 1993a]).

OU1 RI groundwater studies included the collection of samples from 66 OU1 RI monitoring wells located throughout the landfill and OU2 Study Area. Each sample was analyzed for approximately 160 individual parameters consisting of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, herbicides, inorganics (total and dissolved), and Water Quality Parameter (WQPs).

Our evaluation of the OU1 RI data was further supplemented by our review of quarterly groundwater monitoring data collected to address part of the RIDEM's solid waste requirements. Quarterly groundwater monitoring at the Site has resulted in the collection of more than 58 rounds of analytical samples from June 1980 through May 1997. This monitoring has culminated in samples collected from 111 different groundwater and surface water sampling locations that were analyzed for 316 individual analytical parameters. A typical monitoring round collected samples from up to 70 groundwater and surface water locations that were tested for approximately 75 parameters.

That 17-year environmental monitoring program, in conjunction with the OU1 RI, demonstrated that the Hot Spot is a significant source of VOC contamination. Concentrations of total VOCs in groundwater samples collected from this area are typically between 50 and 100 parts per million (ppm). The primary contaminants contributing to this total are chlorobenzene, dichlorobenzenes, methyl ethyl ketone, toluene, and xylenes.

During the OU1/Round 2 RI studies, a boring designated MW91-ML7 drilled immediately downgradient of the Hot Spot encountered a dense non-aqueous phase liquid (DNAPL) at a total depth of approximately 90 feet below ground surface (60 feet below the bedrock surface). This DNAPL was composed of approximately 60% dichlorobenzene, 20% chlorobenzene and <1 % toluene. During removal activities conducted between 1991 and 1997 GZA, on RIRRC's behalf, recovered more than 20 gallons of this DNAPL for off-site disposal.

Studies have also shown that the 121-acre unlined Phase I landfill as a whole is a significant contaminant source of some metals, SVOCs and nutrients (e.g., ammonia, nitrate, etc.). This contaminant distribution pattern is consistent with historical accounts of waste disposal practices, which included disposal of septage sludge within the landfill and Hot Spot areas. The sources of these contaminants are discussed in Section 8.10 and the observed distribution of contaminants in groundwater is described in Section 8.20 of the OU1 RI Report (GZA, 1993a). Other major conclusions of the OU1 RI were summarized in Section 10 of the OU1 RI Report (GZA, 1993a). That section is presented as Appendix B of this report. The observed distribution of dissolved phase VOC contamination within the OU2 Study Area is generally consistent with the identified source areas and the inferred directions of groundwater flow described in the OU1 RI Report (GZA, 1993a). That is, the majority of the VOC contamination migrates from the Hot Spot, southeast toward Cedar Swamp Brook and the Upper Simmons Reservoir. The plume, therefore, is located primarily beneath the Phase I waste cell, and organic contaminant concentrations decrease rapidly with increasing distance from the landfill toe-of-slope. Note that, OU1 studies failed to identify a high concentration VOC plume migrating downgradient from the landfill toe-of-slope. This may be due to contaminant destruction/natural attenuation beneath the landfill causing significant reduction in contaminant concentrations in groundwater beyond the toe-of-slope.

OU1 RI studies also identified a minor component of groundwater flow from beneath the Phase I landfill northeast toward the Almy Reservoir. This inferred flow direction is supported by groundwater analytical results from monitoring wells located within the upper portion of the Almy watershed, adjacent to the landfill, which show sporadic low level VOC contamination.

The observed distribution of elevated nutrient concentrations and other water quality parameters is generally consistent with, and somewhat more extensive than, that observed for VOCs. Ammonia concentrations also support a minor component of groundwater flow toward the Almy Reservoir.

The observed distribution of metals in groundwater, however, does not conform to the identified distribution of organics and WQPs. Although, it appears that the OU1 Landfill is a significant incremental source of some inorganic contaminants in groundwater downgradient of the toe-of-slope, many inorganic contaminants that are observed as elevated with respect to background concentrations beneath the footprint of the landfill, do not appear to be elevated downgradient of the OU1 Landfill.

The Remedial Design/Remedial Action (RD/RA) for OU1 required that six source control measures be performed. These are:

1. Constructing a multi-layer RCRA C cap over the existing 121-acre Phase I landfill that incorporates the existing 32 acres of RIDEM-approved cap on the side slopes;

2. Hydraulic containment and treatment of groundwater in the Hot Spot area of the landfill and discharging the treated groundwater to either on-site surface water or the Cranston Waste Water Treatment Plant;

3. Implementing deed restrictions on groundwater use and land development within property owned by the RIRRC;

4. Initiating a long-term program of sampling and analysis of groundwater, surface water and air;

5. Conducting a detailed evaluation of the existing landfill gas collection and combustion system; and

6. Installing a chain link fence to prevent access.

These six source control measures are detailed in Section I of the OU1 RD/RA Statement of Work (EPA, 1995f). The design of the OU1 cap was finalized in the spring of 1997 by Louis Berger/CH_2M Hill (Berger). In August 1997, Foster Wheeler began the earthwork associated with capping the first 28 acres of the 121-acre Phase I area.

2.00 AREA CHARACTERIZATION

The Central Landfill is located at 65 Shun Pike in Johnston, Rhode Island (latitude N41°-48'; longitude W71°-31'). The OU1 Site consists of the 154-acre Phase I, II and III licensed landfills. The OU2 Study Area is the area surrounding the OU1 Site and includes all properties within the 2,000-foot landfill buffer zone, the Upper Simmons Reservoir, the upper third of Lower Simmons Reservoir, the Almy Reservoir, and the wetlands between the landfill and these reservoirs. The OU2 Study Area has an area of about 1,333 acres. These features are shown on Figure 2-1, Area Plan.

2.10 AREA DESCRIPTION

The 154-acre OU1 Site is located on a 630-acre parcel that is owned by the RIRRC. Additionally, RIRRC controls a 1,000-foot buffer zone around the landfill and Operations Area (see Section 3.12 of the OU1 RI [GZA, 1993a]). RIRRC owns all residentially zoned property within 1,000 feet of the OU1 Site and Operations Area, as well as all residentially zoned property located along Simmons Lake Drive. In addition, RIRRC owns a significant area of residentially zoned land located within 2,000 feet of the Site. This land, acquired in accordance with provisions of RI General Laws 23-19-34 and 23-19-35, cost on the order of $23 million, and is subject to restrictions established by these laws. Property ownership, zoning and general land uses are presented on Figure 2-2, Property Zoning and Ownership.

The area around the Site (within a radius of approximately 2,500 feet) is composed of undeveloped property, residential property and commercial/agricultural property. Businesses include a pig farm, a transfer station, a recycling facility, other refuse handling facilities, a screw machine products manufacturer, and various small businesses associated with vehicle repair and transportation concerns.

Until 1986, water in the area was supplied by individual private wells. Between 1986 and 1990, RIRRC, in conjunction with the Town of Johnston, made public water available to area residents and businesses. Of the six non-community public supply wells identified on Figure 2-1, none are within the OU2 Study Area. The closest public supply well (Camp Massasoit) is located 4,200 feet northwest of the OU2 Study Area boundary. A survey of residential wells was conducted as part of the OU2 studies (see Section 3.11 of this report). It found 85 residential supply wells in the OU2 Study Area, 79 of which were reportedly not in use as of April 1997. The area development, public water distribution system, and plats and lots are shown on Figure 2-3, Area Development Plan. The location of identified private and public wells are shown on Figure 2-1. Sanitary wastewater in the OU2 Study Area is disposed of by below-ground individual sewage disposal systems.

The natural topography is characterized by glacial till-covered, bedrock hills and valleys (see Section 6.00 of the OU1-RI [GZA, 1993a]). Recorded precipitation in the area has varied from 33 to 75 inches per year and the mean annual temperature is approximately 50° Fahrenheit. Because of these conditions, on a yearly basis, precipitation exceeds evapotranspiration and groundwater is found at relatively shallow depths.

The area in the vicinity of the Central Landfill supports, or has supported, a number of businesses or activities which may have contributed to area groundwater contamination. As reported in the OU1-RI, the RIDEM has recognized at least four areas of degraded groundwater quality within the OU2 Study Area. As shown on Figure 2-1, these areas include the L. and J. Vinagro Landfills, and Lot 66 to the south and southwest of the OU1 Landfill, respectively. Also, the Shun Pike Disposal Pits and the A. Macera Dump are located to the east of the OU1 Landfill. In addition, the Cece-Macera Landfill, the Macera Brothers Dump and the M. Earl Adams Co. are all located within close proximity to the OU1 Landfill and based on observed groundwater elevations, have the potential to affect groundwater quality in the OU2 Study Area. A description of these identified potential sources of contamination is provided in Section 3.11.

Groundwater overlay maps prepared by the RIDEM/Division of Groundwater and Fresh Water Wetlands identify groundwater resource classifications for all portions of Rhode Island. This classification system involves the following designations:

GAA: Groundwater classified GAA are those groundwater resources suitable for public drinking water use without treatment.

GA: Groundwater classified GA are those groundwater resources which RIDEM has reason to believe are suitable for public or private drinking water without treatment.

GB: Groundwater classified GB are those groundwater resources, which RIDEM has designated not suitable for public or private drinking water.

GC: Groundwater classified GC are those groundwater resources which RIDEM has reason to believe are suitable for certain waste disposal practices because of past or present land use or hydrogeologic conditions.

Non-attainment Areas: Non-attainment areas are those that have pollutant concentrations greater than the groundwater quality standards for the applicable classification. The RIDEM designates such "non-attainment" groundwater resources as follows: GAA Non-attainment (GAA-NA), GA Non-attainment (GA-NA), or GB Non-attainment (GB-NA).

As depicted on Figure 2-1, the overlay on which the CLF site is present (North Scituate, November 8, 1991) illustrates that, while this area of the state has generally been assigned the GA classification, specific portions of the RIRRC's property and several nearby locations have been assigned alternate classifications. The area of the property on which the licensed portion of the landfill is located has been designated GC. GZA was notified by the RIDEM/Division of Groundwater and ISDS on January 19, 1993, that a "GB Buffer" had been established around the licensed landfill. The limit of GB classification was set at 100 feet from the GC boundary in the upgradient direction. In the downgradient direction, the GB classification is defined by the closest of the following: the property boundary, surface water body or wetland, or 500 feet from the GC boundary. This GB buffer zone is also shown on Figure 2-1.

Surface water bodies in the form of ponds, man-made reservoirs, streams (brooks) and wetland areas are located in the vicinity of the CLF. Major surface water bodies are illustrated on Figure 2-1. Surface waters located within a 1-mile radius of the site which have been designated by the RIDEM as Class B waters are Oak Swamp Reservoir, Almy Reservoir, and the Upper and Lower Simmons(ville) Reservoirs. This surface water quality classification is given to waters which are: (1) suitable for bathing and other recreational purposes, agricultural uses, industrial processes and cooling; (2) excellent for fish and wildlife habitat; (3) have good aesthetic value; and (4) are suitable for public water supply with appropriate treatment. It is our understanding, based on activities observed during visits to the area and their respective classifications, that these water bodies are used for recreational purposes. The Upper and Lower Simmons Reservoirs were reportedly drawn down for industrial purposes (Guthrie, 1997). None are known to be used as drinking water sources.

Other surface water bodies are also located within a 1-mile radius of RIRRC property boundaries. Duck Pond, Madison Pond, Brandy Brook, Pine Swamp and numerous unnamed wetland areas are present to the west and northwest of the Site. Betty Pond is present to the southwest of the Site. These surface water bodies are located in the Scituate Reservoir watershed and therefore have been designated Class A water bodies (suitable for water supply). Dry Brook, Hughesdale Pond and Simmons Brook are located to the east and southeast of the Site. Unnamed wetland areas associated with the Almy Reservoir watershed are also located to the northeast of the Site. These water bodies and wetlands are located in the watersheds of the Almy Reservoir or the Upper and Lower Simmons Reservoirs, and therefore are designated Class B surface waters.

2.20 CONCEPTUAL SITE MODEL

The approximately 1,333-acre OU2 Study Area straddles a portion of the surface water divide which separates the watersheds of the Upper Simmons Reservoir and the Almy Reservoir. Approximately 867 acres (65%) of the OU2 Study Area is in the watershed of the Upper Simmons Reservoir and 267 acres (20%) is in the watershed of the Almy Reservoir. The remaining 200 acres (15%) discharges to the northeast in the watershed supplying Dry Brook, which outlets from the Almy Reservoir. The OU2 Study Area is typically underlain by glacial till, which in turn is underlain by fractured granitic bedrock. Because of these conditions, the groundwater table is, in general, a subdued image of regional topography.

Bedrock was identified as the major potential pathway for migration of groundwater from the OU1 landfill to the OU2 Study Area. On the scale of the OU2 Study Area, the bedrock acts as a porous media, with groundwater flow being generally perpendicular to groundwater contours. The depth of the groundwater flow field was not fully defined by field measurements. The observed distribution of piezometric pressures, in conjunction with the construction of conceptual flow nets, indicates that the regional groundwater flow field is on average about 200 feet deep.

Based on the above considerations and the observed distribution of site contaminants, the OU1 RI established that groundwater beneath the 154-acre landfill discharges to the Upper Simmons Reservoir, the Almy Reservoir, Cedar Swamp Brook, the Quarry Stream, and Sedimentation Ponds 2 and 3. Based on geohydrologic considerations, the size of the Upper Simmons Reservoir, and the estimated depth of the regional groundwater flow field, we believe that landfill-contaminated groundwater does not flow beneath the Upper Simmons Reservoir. That is, we believe groundwater contaminated by the CLF discharges to the Upper Simmons Reservoir and not to points further downgradient. A goal of the OU2 RI was to further investigate the potential for groundwater flow beneath the Upper Simmons Reservoir. See Section 3.00 of this report for a discussion of all the studies undertaken to resolve issues identified by the OU1 RI.

Based on this conceptual site model, GZA identified the following areas/media of concern to be investigated as part of the OU2 Multi-media sampling and analytical program:

- Groundwater to the south and northeast of the OU1 landfill, and any additional areas of site-related contamination within the Study Area which may be identified during the OU2 RI activities;

- Surface water and sediments in the four sedimentation/retention ponds, Cedar Swamp Brook, Quarry Stream, the Almy and Upper Simmons Reservoirs, and wetland areas within the OU2 Study Area; and

- Soils in the OU2 Study Area potentially impacted by fugitive dusts from OU1.

3.00 SUMMARY OF OPERABLE UNIT 2 REMEDIAL INVESTIGATION TASKS

To address comments prepared by the EPA and RIDEM on the Draft Work Plan (GZA, 1993b), GZA prepared a "Comment Response Summary" (February 17, 1995). That document identified the 10 tasks summarized on Table 3-1 of this report. Three of these tasks (Nos. 5, 6 and 7) were intended to address data gaps identified in the OU1 RI. The remaining seven tasks were completed to provide data to support the human health and ecological risk characterizations and the FS for the OU2 Study Area. The results of these tasks were documented in reports that were submitted previously to the RIRRC, EPA and RIDEM, and are referenced below.

The following subsections summarize the 10 OU2 RI tasks in the groups and order in which they were presented in the Draft Work Plan (GZA, 1993b). These summaries are intended to facilitate both an understanding of what was accomplished, and describe the observed Site conditions. For details on these tasks, the reader is referred to the referenced documents or sections.

3.10 OU1 DATA GAPS

The purpose of these three tasks (Nos. 5, 6 and 7) was to supplement existing OU1 data in order to: (1) support the design actions developed in the OU1 Feasibility Study; and (2) provide additional information on groundwater and contaminant migration to the OU2 Study Area.

3.11 Residential Well Identification Survey

The three objectives of the residential well identification survey were: (1) to evaluate human health risks posed by the use of potentially contaminated groundwater from area drinking water supply wells (if any); (2) to expand our understanding of geohydrologic conditions within the OU2 Study Area; and (3) to evaluate contaminant migration patterns from, and in the vicinity of, the OU1 landfill. The methodology and findings of this study were presented in GZA's July 2, 1997 Residential Well Identification Survey Report - OU2/Task 5 (GZA, 1997b).

The study was conducted in two stages. Stage 1 consisted of the performance of several field reconnaissances and mail surveys, and reviews of federal, state, municipal and RIRRC files of properties in the OU2 Study Area, with the intent of locating all wells which may be used as a supply of water and identifying other possible sources of contamination. In addition to the final July 1997 report, the results of Stage 1 were described in our July 26, 1995 interim report entitled Operable Unit 2/Task 5 Residential Well Survey Draft Data Report and Field Sampling Plan (GZA, 1995b).

Stage 2 included the sampling and analysis of water from selected water supply wells within the OU2 Study Area to help generate data on the quality of groundwater which is currently being used for potable purposes (if any). We generally limited our sampling activities to wells that were currently in use or extended our areal coverage within the OU2 Study Area. Our selection of sampling locations was further limited to locations where the owner's permission had been received and the wells were accessible. A second component of Stage 2 (identified as Task 5C in the work plan), the conversion of select former residential supply wells to groundwater monitoring wells, was omitted with EPA's approval [refer to Residential Well Survey Report (GZA, 1997b), Section 1.20]. Stage 2 also included a review of regulatory information on other sites of environmental concern within the OU2 Study Area.

A summary of our findings is provided on Table 3-2 and relevant features are depicted on the attached Figure 2-2. Our major conclusions were:

1. The OU2 Study Area is composed primarily of undeveloped property, residential development and small businesses. Scattered and clustered single-family dwellings are present along all sides of the OU1 Landfill. There are a total of 269 properties that are within, or crossed by, the OU2 Study Area boundary. According to Town of Johnston Tax Assessor's records, 109 of these properties have never been developed and 160 are (or have been) developed. Records indicate that, of the 95 parcels located within the OU2 Study Area that are not owned by RIRRC, eight are publicly owned (by the Town of Johnston) and 87 are privately owned. Sixty-four of these parcels are developed, and 31 parcels are not currently developed. Four occupied private residences remain on properties (plat 31/lot 002, 43/119, 43/121 and 43/126) crossed by the Eminent Domain Buffer boundary.

2. Information from "as-built" drawings provided by the Johnston Water Board show that by July 1990, public water was made available to the residents of the OU2 Study Area. GZA's file reviews and field reconnaissances identified 86 properties within the OU2 Study Area where water supply wells were installed. Sixty-four wells were identified on properties owned by RIRRC and 22 wells were identified on properties not owned by RIRRC. Five properties were confirmed as using groundwater as a potable water supply source (31/004, 31/012, 43/070, 43/167, and 43/275), and one (43/244) was identified as using water for irrigation. Thirty-one former water supply wells have been demolished by agents of RIRRC while creating the state-mandated Eminent Domain Buffer Zone. To our knowledge, none of the water supply wells identified on properties not owned by RIRRC have been permanently taken out of service and/or decommissioned.

3. GZA sampled nine water supply wells within the OU2 Study Area. Five wells were on properties owned by RIRRC (43/007, 43/014, 43/017, 43/036 and 43/244), and four wells were on properties not owned by RIRRC (31/002, 31/004, 43/070 and 43/167). At the time of the study, GZA did not receive permission to sample two (31/012 and 43/275) of the six residential wells being used for water supply. We

note that the new owners of the 43/275 property recently granted permission to sample their residential water supply well. These results have been included in this report.

4. Beginning in 1980, the RIDOH has sampled a total of 274 water supply wells within a 2-mile radius of the OU1 landfill. Forty-six of these wells fall within the OU2 Study Area. In July 1987, EPA conducted a residential well sampling round that included 30 water supply wells within a 2-mile radius of the OU1 Landfill. Seven of these wells fall within the OU2 Study Area.

5. Our evaluation of available historic and current residential well analytical results did not identify any organic contaminants that we believe are attributable to the OU1 Landfill. Note, the majority of residential well testing consisted of organic analyses only. Thus, our evaluation focused on the organic data. We did not evaluate the limited inorganic data set in sufficient detail to identify potential contaminant sources. Because metals are naturally occurring, such an evaluation would require a rigorous statistical evaluation that considers background levels as well as the numerous potential source areas already identified. We do not believe that the existing data set (i.e., historical residential well data collected by EPA and RIDOH) is suitable for this level of evaluation.

Our combined evaluation of groundwater analytical results, regional groundwater migration patterns, and potential sites of environmental concern has identified likely sources of the majority of the historic residential well contamination. Review of the state and federal regulatory records identified 38 sites of known or suspected environmental concern with the potential to affect environmental conditions within the OU2 Study Area (refer to Figure 2-1 and Table 3-3). However, a small subset of these sites (including six CERCLIS, one RCRA and two State List sites) appear to be responsible for significant additional contamination detected within the OU2 Study Area.

The following paragraphs provide brief descriptions and summaries of these sites. This information has been tabulated in Table 3-3. For a more detailed treatment of these sites of potential environmental concern refer to the Residential Well Survey Report (GZA, 1997b), Section 5.00.

A.Macera Dump

The A. Macera Dump is a 13-acre private landfill that had been used for the disposal of residential, commercial and industrial wastes since 1965. During its operational period, the landfill was cited for a number of deficiencies regarding the State of Rhode Island "Rules and Regulations for Solid Waste Management Facilities." Landfilling activities were "officially" discontinued in 1976, however, there have been several reports confirmed by RIDEM of dumping at the landfill subsequent to 1976. In 1977, a Notice of Violation (NOV) was issued because the "closed" landfill failed to meet the RIDEM final cover and termination requirements.

In 1986, RIDEM responded to citizen complaints of daily illegal dumping at the site. RIDEM inspectors found active landfilling of construction debris (with a bulldozer) and evidence of partially buried general refuse and white goods. As a result of this dumping, the owners signed a Consent Decree in 1987 which generally stipulated: owners and employees of A. Macera, Inc. were prohibited from disposing of any and all solid waste/refuse on the site; groundwater monitoring wells would be installed at the site; and a survey of the current extent and depth of fill would be performed and submitted to RIDEM.

A Preliminary Assessment (PA) was performed in 1989 which noted evidence of recent dumping at the site and two 55-gallon drums of waste oil. The site was recommended for a "medium" priority SI. In 1991, RIDEM responded to a fire at the landfill which originated in "an area where cover material had been recently applied." In 1992, a Site Investigation (SI) was performed and soil and surface water samples were collected from the site. As of the conclusion of the SI studies, there was still no evidence of engineered containment on the site, there was evidence of recent illegal dumping, and access to the site was unrestricted.

The samples collected during the SI were tested for VOCs, SVOCs, PCBs/pesticides and metals. Soils from the site contained SVOCs, PCBs and elevated levels of metals. The SVOCs were (PAHs, such as bis[2-ethylhexyl]phthalate, butyl benzyl phthalate and di-n-butyl phthalate) with a total concentration of approximately 280 ppm. A soil sample containing what was described as "autofluff" contained PCBs with a total concentration of 57 ppm. Site soils indicated levels of antimony, arsenic, chromium, copper, lead, mercury and zinc at levels greatly exceeding background concentrations. The one surface water sample indicated the presence of elevated metals only including: antimony, copper, lead and zinc. Files reviewed by GZA indicated that no groundwater analytical testing data was available from the site.

Based on the findings of the SI, RIDEM recommended a "lower" priority for further investigation under Superfund. However, in August 1994 RIDEM wrote to A. Macera, Inc. to inform them they were recommending further actions to investigate risks based on high metals in surface water and wetland samples and a private water supply well within 0.25 miles of the dump. Based on the direction of groundwater flow, GZA believes that groundwater degraded by A. Macera Dump, if present, could potentially impact the OU2 Study Area. The site also appears in RIDEM's Resource Conservation and Recovery Act (RCRA) generator and Underground Storage Tank (UST) files.

Cece-Macera Landfill

The Cece-Macera Landfill is located at 1277 Plainfield Pike, on property to the southwest of the OU2 Study Area (as shown on Figure 2-1). Unlicensed dumping of solid waste on the Cece-Macera property owned by John and Robert Cece was first discovered by RIDEM in 1976. The RIDEM has conducted inspections of the facility and has initiated administrative actions, as well as civil and criminal proceedings against Anthony Macera and the Cece brothers. The PA indicates that the RIDEM received an anonymous complaint concerning the possible disposal of chemicals at the site. Neither RIDEM inspections, nor the PA report confirm this allegation. The PA assigned a Priority Assessment rating of "Medium" to the Cece-Macera Landfill site based on the lack of waste disposal information and the presence of private water supply wells near the site at the time of the study. RIDEM inspections revealed that solid waste consisting of paper, cardboard, glass, brick, metal goods, demolition debris, shingles, and wood were disposed of in three areas on the property (i.e., south landfill, east landfill and west landfill areas). An undetermined amount of "autofluff" was disposed of in the south landfill area. Soil samples taken from this area contained PCBs (Aroclor-1242 detected at concentration of 3 ppm and Aroclor-1254 at 7 ppm). VOCs were not detected in any soil samples.

The SI sampling indicated several groundwater (from on-site monitoring wells) and sediment samples (from on-site and adjacent wetland areas) contained metals concentrations significantly greater than background sample concentrations. However, based on GZA's interpretation of regional groundwater flow patterns, only a portion of the western landfill is upgradient of the monitoring wells included in the analytical program. Therefore, groundwater emanating from the eastern and southern landfills has, in our opinion, not been evaluated. The SI mentions solid waste closure activities commencing in 1990; however, it is unclear from the text of the report if the PCB contamination was remediated during closure or if the closure process has been completed. The SI report recommended "lower" priority for further investigations needed under Superfund. This was based on the undocumented statement that there was no downgradient groundwater contamination or use of downgradient groundwater.

L. Vinagro and J. Vinagro Landfills

Separate PAs and SIs were performed on both Vinagro Landfill sites. However, because RIDEM files do not distinguish between the two facilities, and because the sites are located in close proximity, this information summary includes both sites.

The J. Vinagro Landfill (Liberty Disposal Company) and the L. Vinagro Landfill (American Disposal, Inc.) are located at the intersection of Shun Pike and Green Hill Road on portions of lots 32/014, 32/017, 32/021, 32/022 and 32/025. The properties comprise roughly 40 to 50 acres with a 6 to 8-acre landfill on the south-central portion of the site. The facilities began operations in the 1970s, and within the past 18 years both landfills have accepted and disposed of demolition debris, domestic refuse, and industrial materials without RIDEM permits. Records also indicate potential dumping of medical wastes (i.e., hypodermic syringes found in on-site test pits), sewage sludge and animal carcasses. RIDEM site inspections have resulted in the issuance of numerous administrative actions and court orders associated with refuse disposal, leachate drainage, site clean-up, open burning and odor violations. Through American Disposal and American Reclamation Companies, the L. Vinagro properties continue to receive wastes as of the date of this report.

Soil, groundwater and surface water samples have been collected at both properties on numerous occasions by both RIDEM and EPA. Soil samples collected at the L. Vinagro site by RIDEM investigators in December 1986 indicated the presence of PCBs at concentrations greater than 50 ppm. RIDEM clean-up orders were subsequently issued to both Vinagro brothers for the PCB contamination. Other soil samples collected by EPA contained up to eight VOCs (as shown in Table 3-3) at concentrations ranging from 20 to 5,700 ppb, numerous PAHs at concentrations ranging from 90 to 1,000,000 ppb, and three pesticides (beta-BHC, delta-BHC and gamma-chlordane) at concentrations ranging from 15 to 92,000 ppb.

Groundwater samples are collected for RIDEM quarterly from several on-site monitoring wells and have been collected by EPA on select occasions. Historical groundwater monitoring has indicated the presence of up to 20 individual chlorinated and aromatic VOCs (as shown on Table 3-3) in site samples at concentrations ranging from 0.22 to 406 ppb. The PA report indicates that vinyl chloride was "found in groundwater at concentrations from 1.6 to 3.7 mg/l" (1,600 to 3,700 ppb). Surface water runoff, possibly containing landfill leachate, from the L. Vinagro property reportedly discharged from the site onto Shun Pike and subsequently into the Upper Simmons Reservoir on a regular basis. Samples of this fluid were reported to contain elevated levels of vinyl chloride, chloroethane, trichlorofluoromethane, 1,1-DCA, toluene and fecal coliform bacteria.

The PA assigned a "High" priority rating to the J. Vinagro and L. Vinagro Landfill sites. The ratings were based on information that; (1) soil and groundwater samples indicated the presence of contaminants, (2) the lack of waste disposal information and clean-up confirmation, and (3) the presence of private supply wells at the time of the study and the Simmons Reservoir (a sensitive receptor) near the site. Additional investigations, in the form of a SI were recommended. The PA (J. Vinagro) notes that because of the proximity of the sites to one another, the SI should be conducted in conjunction with the L. Vinagro Landfill inspection. The SI for L. Vinagro, completed in 1990, recommended that a Listing Site Inspection be conducted at the site due to the detected on-site contamination and the high percentage of area residents who relied on private drinking water supply wells at that time.

M. Earl Adams Company

The M. Earl Adams Company is located on Peck Hill Road, directly across from the end of Byron Randall Road (as shown on Figure 2-1). This site is located west of the OU2 Study Area boundary, but has the potential to affect conditions in the OU2 Study Area due to surface water and groundwater contaminant transport. The company manufactured screw parts, and in the process uses both cutting oils and degreasing products.

In May 1983, RIDEM inspectors observed a large area (an approximately 1,300 sq. ft. ditch/lagoon) in the back of the facility being used for the disposal of solid waste (scrap metal filings, metal pieces, paint cans, and punch plate wastes). Oil contaminated soils were also observed. The associated disposal practice was subsequently halted and the soils in this area were cleaned to the satisfaction of RIDEM officials. However, no post-remedial sampling was conducted by RIDEM.

The RIDEM returned to the site in December 1985. During this investigation, a pipe leading several hundred feet behind the plant was discovered illegally discharging oily wastes to a ditch. Samples of the waste material collected by RIDEM indicated the presence of VOCs, SVOCs, and metals. As a result of administrative actions taken by RIDEM in January 1986, the waste discharge was halted, the pipe was sealed and the length of the ditch was excavated and backfilled.

During the final PA inspection of the M. Earl Adams, soil samples from the front area near Peck Hill Road were found to contain 22 micrograms/kilogram (ppb) of trichloroethylene (TCE). The PA assigned a "High" rating to the "Peck Hill Road area." The rating is based on the presence of private water supply wells and an unconfirmed source of observed groundwater contamination.

Water samples collected by the Rhode Island Department of Health (RIDOH) from the two M. Earl Adams on-site production wells were analyzed for VOCs in 1985, 1986 and 1987. The results indicate the presence of several chlorinated solvents, including 1,2-dichloroethene (1,2-DCE), TCE, tetrachloroethylene (PCE), benzene, toluene and xylenes. Additional soil sampling was conducted as part of the SI in February 1990. Although all eight soil samples showed no indication of VOC contamination, SVOCs, and elevated metals were detected. In addition, three septic systems are located on-site which are potential conduits for the introduction of wastes into the groundwater.

Analysis of groundwater from 18 residential wells sampled by RIDOH between 1985 and 1993 detected TCE, PCE, 1,2-DCE, methylene chloride (dichloromethane), and chloroform. According to the SI report, eight private wells in proximity to M. Earl Adams were contaminated with PCE at levels greater than the Maximum Contaminant Level (MCL), and a sample from one of these wells exceeded the MCL for TCE as well. The reported concentrations of 1,2-DCE were below the applicable MCL. GZA was unable to review any results of testing of samples from the on-site monitoring well; however, samples from the on-site production wells also contained PCE, TCE and 1,2-DCE. In September 1993, RIDEM recommended M. Earl Adams receive a "High" prioritization under Superfund based on groundwater samples from 18 wells contaminated with VOCs similar to those identified at the site. Eight at levels above their MCLs. The recommendation also noted that RIDEM is currently supplying seven private residences with bottled water.

The M. Earl Adams Company is located on a local topographic high. As such, groundwater has the potential to flow radially, outward from the site. GZA believes that (at least seasonally) groundwater, surface water runoff and eroded surficial soils have the potential to flow easterly from the site and impact the western edge of the OU2 Study Area by discharge/deposition in the wetlands and tributaries associated with Cedar Swamp Brook. RCRA and UST files for M. Earl Adams were also reviewed by GZA.

MacDonald & Watson Property

The MacDonald & Watson Waste Oil property is located at 26 Greenhill Road in Johnston, Rhode Island (See Figure 2-1). The MacDonald & Watson Waste Oil site file maintained at the RIDEM contained a March 1991 "Technical Assistance Contract - Task Assignment Document" which included a general task description to complete a "comprehensive site assessment...to characterize the nature and extent of contamination in soils and groundwater and the potential for off-site migration...". The site is identified as Plat 30, Lots 34, 36 and 115 and encompasses approximately 10 acres. The document notes that "Allegations have been made that large amounts of chemically contaminated soil have been used as fill at this site in the past." A "Discussion Record" dated May 7, 1992 noted that RIDEM believed that a portion of Plat 30/Lot 34 was filled with material from the Convention Center project in Providence which is "...known to contain low levels of PCBs...", and that the material "...may overlie a small portion of the hazardous material from Poe Street." It also noted that "...this area and the remaining portion of the site will be investigated under CERCLA."

In April of 1991, GZA performed a site assessment of the property in preparation for siting a medical waste incinerator (Environmet, Inc.) on the rear of the 30/034 property. Three groundwater monitoring wells were placed in positions downgradient of 2 on-site USTs, a 12,000-gallon diesel tank and a 5,000-gallon gasoline tank. In addition, 16 test pits were excavated in a recently filled area created for the planned Environmet building foundations. This area had sloped steeply to the east. Soil samples from six of the test pits proved contaminated with PCBs with a maximum total concentration of 13 ppm.

In June of 1991, RIDEM issued a NOV to Barbara D'Allesandro which directed her to: 1) immediately cease solid waste facility operations; and 2) dispose of solid wastes and soil contaminated with petroleum hydrocarbons and fill containing PCBs with concentrations greater than 1 ppm. In 1993, the owners of the MacDonald and Watson property countered with a plan to cap the area of PCB contamination with an engineered landfill cap with a perimeter drainage system. In April 1994, Barbara D'Allesandro signed a consent decree to cap the area and monitor the site groundwater from the existing site wells.

In June 1994, RIDEM performed a SI in which groundwater from the three groundwater monitoring wells, and surface water samples from two locations between the site and Upper Simmons Reservoir were tested for VOCs, SVOC, PCBs/pesticides and metals. No organic compounds (VOCs, SVOCs, or PCBs) were reported in any of the water samples. In October 1995, based on the findings of the SI, RIDEM recommended that the MacDonald and Watson property receive a "lower" priority under Superfund. However, further investigations were recommended to accurately evaluate the ecological risks and surface water pathways.

Based on the anticipated direction of groundwater flow, GZA believes that the existing on-site monitoring well network would not detect groundwater migrating from beneath the area of contaminated fill. It also appears that as of April 1997, MacDonald and Watson had not begun construction of the cap designed to keep precipitation from eroding or percolating through the stockpiles of contaminated fill. RIDEM files also contain one UST and two RCRA listings for this property.

Shun Pike Disposal Pits

The Shun Pike Disposal Pits site is located along the eastern property line of the Central Landfill operations area, and it is GZA's understanding that the three parcels which comprise the site were recently acquired by the RIRRC. In November 1987, representatives of RIDEM conducted a field inspection of the site and an adjacent area, and collected one "solid" sample for analytical testing. The test results found PCBs (1,110 ppm) and several VOCs at lower concentrations (1 to 8 ppm). On December 1, 1987, a NOV was issued by RIDEM requiring the owners (Messrs. Albert and Anthony Silvestri) of lot 43/112 to immediately being a remedial action at the site.

A PA was performed of the site in April 1989 by the RIDEM. That report identifies the site as Plat 43/Lots 112, 141, and 142. Based on the presence of liquid wastes at the site, its unrestricted access, and the possible presence of private drinking water wells in the area, the RIDEM assigned a "Medium" priority ranking to the site.

In November 1989 a Preliminary Investigation of the property was conducted for the RIRRC. As part of that study, an apparent lagoon and a "disturbed area" were observed at the site. A third area located on 43/141 appeared to be prepared for waste disposal. The lagoon reportedly measured approximately 43 by 25 feet, which straddled the property boundary of 43/141 and 43/142 and the disturbed area approximately 20 by

30 feet was located in an area on the adjacent 43/112 property. The lagoon featured high, earthen berms and standing liquids. Additionally, a thin layer of asphalt-like material was observed along the sides of the lagoon and around some trees outside the lagoon.

RIDEM issued a NOV and Order to the then landowner (Karraker) of the lots 141 and 142 on December 9, 1989. As described in the PA report, "The Order(s) basically required the responsible parties to identify and properly dispose of all contaminated materials onsite." RIRRC purchased lots 43/141 and 43/142 and remedial efforts were initiated to excavate, for off-site disposal, the contents of the lagoon area on 43/142 (Area 1) and the disturbed area on 43/141 (Area 3). In March of 1992 approximately 150,000 kilograms (165 tons) of "Bulk PCB Solids", 15 yards of "Bulk PCB Solids", and 1,150 gallons of "storm water" were transported to the EnviroSafe Services of Idaho facility for disposal.

In March 1992, three groundwater monitoring wells were installed on lot 43/142. These wells were sampled for VOCs (8240), PCBs (8080) and total petroleum hydrocarbons (TPH) (8100) and groundwater elevations were measured in April 1992. The sampling revealed that groundwater contained low levels of TPH (>10 ppb) and low levels (less than their MCLs) of xylenes and dichlorobenzenes, and no PCBs were detected. Samples from the monitoring well closest to the excavation area contained three other VOCs: toluene (3 ppb), ethylbenzene (630 ppb) and chlorobenzene (450 ppb). Of these concentrations, only chlorobenzene was detected at a level above its MCL. Water level elevations indicated a north/northeastern direction of groundwater flow away from the lagoon area.

In June 1992, RIDEM issued a letter stating that the terms of the NOV issued December 9, 1989 had been complied with to the satisfaction of RIDEM. In addition, RIDEM issues a "Release of Violation" letter to the Johnston Town Clerk to remove the NOV from the records of Plat 43/Lot 142.

At approximately the same time, similar remedial activities were conducted to remediate Area 2 on Lot 43/112. PCB contaminated soils were removed from the site, transported by MacDonald and Watson Waste Oil to CWM's Model City facility in New York. In January 1992, a "composite" soil sample from the base of the remediated area was tested and indicated less than 1 ppm PCBs in soil. In February 1992, three monitoring wells were installed to determine the impact of the past disposal practices on groundwater quality. Two rounds of analytical testing (February and March 1992) for PCBs and VOCs indicated no PCB contamination and low levels of volatile organics in wells to the east and northeast (less than 10 ppb of chlorobenzene, trichlorobenzene, and xylenes). Southwest of Area 2, groundwater testing results also indicated no PCBs; however, high levels of VOCs were detected during the sampling. Groundwater chlorobenzene concentrations from samples southwest of Area 2 were 4,300 ppb in February 1992 and 22,800 ppb in March 1992.

In June 1992, four test pits were excavated outside the disposal area to confirm the lateral extent of remediation and two additional monitoring wells were installed. The soil samples indicated no PCBs and low (11 to 39 ppb total VOC) concentrations of PCE, trimethylbenzene, chlorotoluene and dichloropropane. Concentrations of VOCs were greatest in groundwater samples collected at wells located within the Area 2 disposal area (23,000 ppb chlorobenzene, 11,500 ppb ethylbenzene and 32,600 ppb xylenes). Other groundwater samples contained a similar suite of contaminants with lower levels of VOCs (i.e., 5,160 ppb and 2,100 ppb of chlorobenzene).

In an August 17, 1992 letter to RIDEM, the owner's consultant describes their attempts to determine groundwater flow direction in the vicinity of Area 2. They concluded, "based upon the information obtained in our subsurface investigation, the contamination plume is most likely to migrate to the west - southwest of (Area 2) onto the (Central Landfill) property. At the present time, the plume (containing 2,100 ppb of chlorobenzene at the property line or 21 times the MCL) does not represent an imminent hazard, as there are no water supply wells located downgradient of the contamination source and area homes and businesses are served by municipal water. In addition, the depth of groundwater at the site precludes direct human contact with the contamination. The area of contamination is also within the 1,000-foot buffer zone surrounding the landfill, which may limit the future potential for human contact." However, GZA's review of the groundwater elevation data reported in the April 17, 1992 letter indicated a component of groundwater flow from Area 2 north-northeast onto lot 43/142 and towards residential homes with water supply wells.

On September 14, 1992, based upon a review of the groundwater sampling results, RIDEM requested a work plan to be submitted by October 23, 1992 to clean up the groundwater in the vicinity of Area 2, and to further define the extent of groundwater contamination.

After a meeting with the property owners in September 1992, RIDEM notified the owners that the terms of the original December 1, 1987 NOV regarding soil contamination at the site had been complied with to RIDEM's satisfaction. On August 23, 1993, RIDEM issued a Letter of Responsibility (LOR) to the owners of Plat 43/Lot 112 (Messrs. Albert and Anthony Silvestri). This LOR required the submission of a work plan to more accurately define the extent of groundwater contamination at the site by October 1, 1993 or face further enforcement actions by RIDEM.

A new consultant for the owners of 43/112 removed an additional 1,700 cubic yards of soil from Area 2. This soil was pre-characterized by soil sampling conducted in June 1992 and field screened during excavation. The excavated soil was taken to the lined Phase II cell at Central Landfill and used as daily cover. On April 6, 1995, groundwater samples were collected and analyzed by EPA Method 8260 and detected a similar suite VOCs at similar concentrations to historic groundwater sampling conducted from these wells (in 1992). Groundwater concentrations remain elevated (11,000 ppb and 3,000 ppb chlorobenzene, respectively) and are essentially unchanged three years after removing soils from the source area.

In November of 1995, RIRRC purchased Lot 43/112 from Messrs. Silvestri. In December 1995, RIDEM contacted the Town of Johnston Town Clerk to have the original December 1, 1987 NOV for Lot 43/112 removed from the Johnston land evidence records. Because of the observed groundwater contamination, and the disposal pits proximity to an apparent groundwater divide, GZA believes that this site has the potential to degrade groundwater quality in the OU2 Study Area.

Taraco Precision Testing, Inc.

Taraco's operations consist primarily of UST testing, maintenance and removal/installation. Taraco owns/operates four properties discussed in RIDEM's RCRA file. Three of these properties (38, 40 and 42 Shun Pike) are within the OU2 Study Area. After a tank exploded at 38 Shun Pike facility, RIDEM personnel conducted inspections of the facilities located at 42 Shun Pike and 38 Shun Pike (on May 4, 1992, March 26, 1993, August 30, 1993, July 25, 1994 and November 8, 1995). A RIDEM Notification of Regulated Waste Activity, dated May 12, 1992 for 42 Shun Pike, listed the site as a generator of less than 1,000 kg/month of waste oil. The facilities were found to be in violation of numerous regulations.

Four samples were taken from drummed materials during the inspection conducted on March 26, 1993. Two samples were hazardous with flash points of 110°F and 75°F (hazardous is less than 140°F), and two samples were non-hazardous. However, one non-hazardous sample did have a high TPH value (15,800 ppm). On July 20, 1993 a RIDEM Letter of Deficiency under the Hazardous Waste Management Act was issued in response to the facility inspection conducted on March 26, 1993.

An anonymous complaint of improper storage of hazardous waste at 42 Shun Pike was made. Allegations reported include: "...oil has been spilled or dumped on the property and flowed overland to stain soils on a vacant area between 40 and 42 Shun Pike, material is being burned in oil USTs that have been cut in half". On February 14, 1995 a RIDEM NOV and Order and Penalty was issued in response to the inspection conducted on July 25, 1994. On August 2, 1994 Ray Wilbur indicated to the RIDEM that all of the drums of hazardous waste observed during the inspection had been removed, the contaminated soil outside the building had been collected and contained, and a hazardous waste container storage area with secondary containment had been constructed inside the building.

On September 23, 1994 the EPA identification number for 38 and 40 Shun Pike was deactivated since operations at these locations are reportedly no longer active, since the company had reportedly filed for bankruptcy protection. However, RIDEM continued RCRA compliance inspections at the site. On November 8, 1995 samples were taken from stained soil under the filtration unit, from a nearby puddle of brown stained water, and from drums located in the building at 38 Shun Pike. The results showed elevated lead concentrations, elevated TPH, and flash points which ranged from 133°F to > 200°F. On April 9, 1996 a RIDEM NOV and Order and Penalty was issued to Taraco's Precision Testing, Inc. in response to the inspection conducted on November 8, 1995. The file also contained a RIDEM NOV and Order and Penalty dated May 31, 1996. However, this violation was in regards to Raymond Wilbur d/b/a Taraco's Precision Testing, Inc. The rationale for this violation and order was the same as that for the April 9, 1996 violation.

The file contained a RIDEM Spill Response Form, dated January 9, 1995, regarding a fire that destroyed the building at 40 (rear) Shun Pike (31/055). The material involved was waste oil, gasoline and other chemicals; however, the amount of material involved is unknown. Approximately fifty 55-gallon drums containing unknown quantities of various chemicals were stored in the garage, which was located less than 200 feet from the shore of Upper Simmons Reservoir. Reportedly the drums contents were from tank cleaning operations, and other drums of products such as lubrication oil, antifreeze, and hydraulic oil. Approximately 2,500 gallons of liquid waste and 3 to 5 cubic yards of solid waste were removed by United Waste Oil Co. and disposed off-site at the Amereck, Inc. facility in Worcester, Massachusetts. Taraco may continue to improperly store materials that could potentially impact the OU2 Study Area.

Lot 66

Lot 66 is an approximately 50-acre property currently owned by RIRRC, and it is located on the north side of Shun Pike along the Central Landfill's southwestern property line. The site is mostly comprised of undeveloped woodlands, wetlands and cleared areas. A small portion of the property was used as a residential home owned by Mr. Julius Landi. In 1969 the house burned down. The property was then purchased in 1972 by Robert and John Cece. Lot 66 was then purchased by Town Realty Company which owned the property between December 1974 and December 1986. Until the property was purchased by RIRRC in 1996, the property was jointly owned by Michael and Steven Macera, and Robert and John Cece.

Environmental site assessments were performed at the site in September 1988 and November 1989 by GZA. During September 1988, seven soil borings were conducted and five groundwater monitoring wells were installed on the site. The aerial photography reviewed during the first site assessment indicate the eastern portion of the site was stripped for gravel post-1972. Then some time after 1981 the same eastern portion was filled with various forms of organic and inorganic solid waste and debris.

During the November 1989 assessment, a series of 22 test pits and three more monitoring wells were installed in the eastern portion of the site. The November 1989 studies identified a "Soil Contamination Area" measuring 25 feet wide and 125 feet long which extended 12 to 20 feet deep.

The assessments resulted in the characterization of an area of surface and subsurface contamination. Analytical testing of soil samples from this suspect area identified a variety of VOCs (1,1,1-TCA, TCE, PCE, toluene, ethylbenzene, xylenes, etc.), present at concentrations in the range of 500 to 220,000 ppb. Groundwater testing provided a similar chemical profile to that of soil, with total volatile concentrations in the range of 15 to 26,000 ppb. The major constituent appeared to be TCE with a maximum TCE concentration of 24,000 ppb observed in samples from a monitoring well adjacent to the soil contamination area.

During August and September 1994, approximately 2,200 cubic yards of soil was excavated by the Cece brothers from the VOC "source area" and stockpiled around the perimeter of the excavation. During September and October 1994, field and laboratory testing of the stockpiled soils revealed low levels of VOCs (i.e., total VOC concentrations from 1 to <16 ppm; individual VOCs ranged from "Not Detected" to <10 ppb PCE and TCE; and TPH ranged from "Not Detected" to <140,000 ppb). After approval from the RIDEM and RIRRC, the soil stockpiles were transported to Central Landfill for use as daily cover material for the lined Phase II Landfill cell.

On October 27, 1994, RIDEM issued a Letter of Compliance which requested continued groundwater monitoring downgradient of the VOC source area. One year of quarterly chemical and piezometric groundwater monitoring was conducted in the four shallow overburden monitoring wells (GZ-1 through GZ-3 and B-2). Consistent with anticipated regional groundwater flow patterns, this monitoring showed a northeast direction of groundwater flow. Levels of toluene, xylenes and ethylbenzene appeared to be decreasing since the remediation of the VOC source area; however, levels of TCE, PCE, 1,1,1-TCA and 1,2-DCE remained consistent with time.

Based on observed data, we believe that Lot 66 continues to have a significant affect on water quality in the southwestern portion of the OU2 Study Area. During baseline testing performed in May 1993 (i.e., prior to soil remediation on Lot 66) as part of permitting the Phase IV cell of Central Landfill, two wells (a deep bedrock and shallow bedrock well) were installed approximately 900 feet downgradient from the Lot 66 VOC source area. The groundwater testing from these wells indicated 54,000 ppb of TCE in SWLF-3A and 4,600 ppb TCE in SWLF-3B. Since TCE has an MCL of 5 ppb, these wells had concentrations approximately 10,000 and 1,000 times the drinking water standard for TCE, respectively. In November 1996, during similar sampling conducted by GZA, groundwater samples from these wells had concentrations of 32,000 ppb TCE and 4,000 ppb PCE in deep bedrock, and groundwater samples contained 5,800 ppb TCE and 760 ppb PCE in shallow bedrock. To our knowledge, contaminant concentrations in bedrock groundwater have not been evaluated on Lot 66.

Macera Brothers Dump

The Macera Brothers dump is located off Scituate Avenue, northeast of the OU2 Study Area boundary. GZA was not able to review a RIDEM file for this site; however, RIDEM has designated the groundwater beneath the site as a GA-NA zone because it was identified as a historical dump. The Macera Brothers operated two other disposal areas within close proximity to the OU2 Study Area (see A. Macera Dump and Cece-Macera Dump descriptions above) during the late 1960's and early 1970's. These dumps accepted a variety of residential, commercial and industrial solid wastes, and were noted for indiscriminate and unregulated waste disposal practices. It is reasonable to assume that similar activities were conducted on this property. The inferred groundwater flow direction from this site is to the north towards Dry Brook. GZA believes it is unlikely that conditions at this site have affected water quality in the OU2 Study Area; however, it may have historically affected residential wells which abut OU2 along Old Pocasset Road, Appletree Circle and the portions of Central Avenue.

Based upon the work conducted as part of the residential well survey study, we believe that the evaluation of the likely extent of groundwater contamination emanating from the OU1 landfill may reasonably be estimated from piezometric data alone. However, substantial chemical testing of groundwater quality in the vicinity of the landfill will also be conducted for a period of 30 years, in accordance with the May 1997 Revised Environmental Monitoring Plan (GZA, 1997a), (prepared by GZA as part of the OU1 Remedial Actions and approved by EPA).

3.12 Hot Spot Pumping Test

The purpose of the pumping test was to evaluate relevant hydrogeologic properties in order to estimate the number of wells and pumping rates required to contain contaminated groundwater emanating from the Hot Spot, formerly designated Hazardous Waste Disposal Area 2 (HWDA 2). The scope of work included: developing two existing bedrock wells; performing short-duration, specific capacity tests on the two wells; redrilling an existing bedrock well; performing a 3-day pump test in one well followed by a 3-day recovery test; evaluating the pump test data; analyzing the pumped groundwater for water quality; and preparing a report presenting our findings and conclusions.

As discussed in our July 12, 1994 report entitled Hot Spot Pump Test-OU2-Task 3 (GZA, 1994b), the pump test was conducted between May 16 and May 21, 1994. The results of the pump test indicated that the bedrock transmissivity immediately downgradient of the Hot Spot is in the range of 20 to 90 feet squared per day (ft^2/day). As anticipated, the water level response due to pumping was somewhat irregular, consistent with a fractured medium aquifer (i.e., bedrock). Based on this testing, the ambient flow of groundwater beneath the Hot Spot is estimated to be in the range of 4 to 11 gallons per minute (gpm). These estimates are in reasonable agreement with our initial estimates used in completion of the OU1 FS. It also indicates that the safety factor of 5 used to estimate extraction rates for the FS may be overly conservative. That is, we currently believe extraction rates in the Hot Spot will be on the order of 12 gpm, not the 20 gpm used for conceptual design during the FS.

Based on the results of the pump test, GZA recommended the use of six groundwater recovery wells, spaced 40 feet on center, to contain contaminated groundwater in this area. The recommended pumping rate at each well is approximately 2 gpm, resulting in a combined flow rate of approximately 12 gpm. However, we recognize that the bedrock transmissivity is irregular and that all six recovery wells may not yield 2 gpm. Therefore, we also recommend that if the recovery well's yield is less than 2 gpm, it should be considered an effective recovery well if it results in a water level drawdown of at least 3 feet at a distance of 20 feet from the well. Conversely, the potential yield of one or more of the wells may allow pumping at a rate of more than 2 gpm to obtain the desired drawdowns in these areas. In this case, we still recommend limiting total flows to 12 gpm, and recommend the installation of monitoring wells midway between the recovery wells to monitor the drawdown response.

3.13 Hot Spot Test Pits

The purpose of the test pit exploration program was to identify the southern and eastern extent of chemical sludges in the Hot Spot (HWDA 2), and to determine whether or not the area of chemical sludges resulting from disposal in the Hot Spot was located entirely within the 154-acre licensed landfill. The study consisted of: observing and documenting the excavation of seven test pits to the south and east of the Hot Spot in the vicinity of well MW-J; analysis of selected soil samples for VOCs, SVOCs, pesticides/PCBs, metals and petroleum hydrocarbons; surveying the locations and elevations of all test pit explorations; and preparation of our March 5, 1996 report entitled OU2-Task 7-Hot Spot Test Pits (GZA, 1996e), which documents our field methods and findings.

As described in the report, the test pits were generally excavated to the bedrock surface, with numerous soil samples taken from each exploration. Figure 3-1, Exploration Location Plan, shows the locations of the seven test pits, which were designated TP95-1 through TP95-7. No chemical or septage sludges were encountered at these locations. Selected soil samples were submitted for laboratory analysis to quantitatively support our field observations. We believe the concentrations of VOCs, SVOCs, metals and petroleum hydrocarbons detected in soil samples reflect the disposal of municipal household and commercial solid wastes. Subsurface conditions observed during this exploration program support the disposal practices reported in the March 1993 OU1 RI (GZA, 1993a).

3.20 RISK EVALUATION AND CONTAMINANT MIGRATION STUDIES

The objectives of these seven tasks, which were the main focus of the OU2 RI, were to: (1) provide additional data to assess the potential effects of current site conditions on the area's ecology and human health; and (2) further evaluate potential routes of contaminant migration from the OU1 landfill to the OU2 Study Area.

3.21 Ecological Characterization

As discussed in the SAP (GZA, 1995d), the purpose of the ecological characterization, OU2 RI Task 2, was to: (1) identify possible environmental receptors within the OU2 Study Area; (2) identify potential exposure pathways by which these receptors may be exposed to contaminants; (3) provide a quantitative assessment of baseline levels of environmental contaminants to which receptors may be exposed; and (4) present the data to the EPA in a manner which will facilitate its use in the quantitative assessment of the risks posed by present site conditions to the identified ecological receptors. The study consisted of delineation of existing and historic wetlands, a Wetland Evaluation Technique, Version 2.0 (WET2) assessment of wetland functions and values, and a qualitative wildlife habitat characterization of the OU2 Study Area.

The results of these tasks were presented in the June 17, 1994 Ecological Characterization Report (GZA, 1994a). Wetland resources areas, along with buffer areas, as defined by the Rhode Island Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act, are depicted in Figure 3-2, Habitat Resource Map. The rationale for assignment of the buffer areas, including 50-foot perimeter wetlands and 100-foot river bank wetlands, is discussed in Section 2.30 of the Ecological Characterization Report (GZA, 1994a). The results of the WET2 assessment indicated that Cedar Swamp Brook, Upper Simmons Reservoir, and the Almy Reservoir have, in general, moderate to high probability of providing social value and of being effective at contributing to most functions considered, including wildlife diversity, wildlife breeding and migration, flood flow alteration, sediment/toxicant retention, sediment stabilization, and/or nutrient removal/transformation. Wildlife habitats identified during this study are also depicted on Figure 3-2, attached.

This data was formally presented to the EPA, RIDEM and RIRRC and was utilized in the completion of a preliminary risk screening (refer to Section 3.27) and the quantitative ecological assessment presented in Section 9.00 of this report.

3.22 Groundwater Monitoring Well Installations

The OU2 groundwater monitoring well installation program was completed in two phases designated OU2 Task 4 and OU2 Task 4A. The purpose of the OU2 Task 4 groundwater monitoring well installation program, was to allow for the collection of piezometric and chemical data necessary to conduct ecological and human health risk assessments, and to better assess the nature and extent of contaminant migration in the OU2 Study Area. The program consisted of the drilling of three overburden borings (designated MW95-47S through MW95-48S and MW95-53), six shallow bedrock borings (designated MW95-47 through MW95-52), one deep bedrock boring (designated MW95-ML9), and the installation of at least one monitoring well in each borehole (total of 12 wells). Boring logs of these OU2 monitoring well installations are attached in Appendix C-1. The boring locations are shown on Figure 3-1. In addition to the drilling, this task included a survey of the new well locations and a comprehensive round of groundwater level readings in the new and existing site wells.

GZA's October 30, 1995 report entitled Monitoring Well Installations - OU2/Task 4 Data Report (GZA, 1995a) presented the findings of this investigation. As described in that report, two shallow borehole/monitoring wells and one deep borehole/monitoring well were installed to provide a well cluster to the southeast of the landfill, in the vicinity of Sedimentation Pond 2, where 1990 and 1994 groundwater elevation data suggested groundwater flow from the Hot Spot is likely to be discharging. Based on the observed thickness and characteristics of the overburden in this area, three additional soil borings/monitoring wells were installed in this area. Two shallow boreholes/monitoring wells were located in each of the areas to the north and northeast of the landfill to provide additional information on the location of the northeastern groundwater divide and potential mounding below the refuse, and to fill gaps in the contaminant monitoring network.

Hydraulic conductivity testing and geophysical logging (MW95-ML9 and MW90-ML6 through -ML8, only) were performed prior to well installation to aid in the selection of screened intervals in the monitoring wells. A highly weathered and fractured bedrock zone encountered south of the landfill (in MW95-47) yielded a hydraulic conductivity higher than any area tested during the OU1-RI (see Table 4-3 and 4-4). The hydraulic conductivity of the rock 30 feet deeper in boreholes in the same location is an order of magnitude lower. The hydraulic conductivity and bedrock conditions observed in this boring, and in others in close proximity to it, suggest that it is a very favorable location for potential leachate migration. The high transmissivities, high specific conductance values of groundwater, and relatively high total VOC readings in the soils observed in the overburden to the south of the landfill also suggest the likelihood of leachate migration through this area.

The purpose of the OU2 Task 4A well installation program was to evaluate the potential for contaminants to flow under the Upper Simmons Reservoir and discharge further downgradient. The findings of this field program, designated Task 4A - Deep Well Installations, were transmitted in our September 1997 data report (GZA 1997d). The OU2/Task 4A field program commenced in January 1997 and the drilling, testing and well installations were substantially completed by April 1997. The program created a well cluster of a total of three monitoring wells installed in two borings: one shallow overburden boring designated MW97-54; and one deep bedrock borehole with two wells designated MW97-ML10A and -ML10B.

Figure 3-1 provides as-built locations for each of the three wells installed as part of Task 4A. Hydraulic conductivity testing and geophysical logging (deep borehole only) were performed prior to well installation to aid in the selection of screened intervals in the monitoring wells. These wells were utilized in the OU2 Multi-media Sampling and Analytical Program which formed the basis for our comprehensive human health and ecological risk assessments. Furthermore, this well cluster has been incorporated into the OU1 Annual Post-closure Groundwater Monitoring program to continue to monitor for inter-watershed flows and contaminant transport of constituents migrating from the OU1 landfill and the Hot Spot area, to locations beyond the compliance boundary, (i.e., boundary of licensed landfill).

The observed piezometric levels at the dam support our regional conceptual hydrogeologic model that indicates groundwater discharges to the Upper Simmons Reservoir, and does not pass beneath it. Based on our field observations and an evaluation of the data gathered during OU2/Task 4 and 4A, we believe the fifteen new monitoring well installations are appropriately positioned. Further discussion of these data is provided in Sections 4.00, 5.00, and 6.00 of this report.

3.23 Multi-media Sampling and Analysis

Task 1 of the OU2 RI is described in the Draft Work Plan (GZA, 1993b) as Multi-media Sampling and Analysis. The purpose of this work was to obtain additional data for environmental media from potentially affected habitats to gain a better understanding of exposure point concentrations and bioavailability. This task was subsequently (February 17, 1995 "OU2/RI Draft Work Plan Response Summary") divided into four subtasks to more closely reflect the actual progression of ongoing work. These were:

- Task 1A - Collect and analyze the first round (Round 1A) of groundwater samples from 18 OU2 monitoring wells;
- Task 1B - Collect and analyze the first round of surface water samples from 42 locations within OU2 Study Area water bodies;
- Task 1C - Collect and analyze one round of 39 sediment samples from OU2 Study Area water bodies; and
- Task 1D - Collect and analyze one round of 13 surface soils from vegetated areas surrounding the OU1 landfill.

The portion of Task 1C which addresses sediments within the Upper Simmons Reservoir was described in two reports prepared by GZA entitled Upper Simmons Reservoir Sediment Study Phase I Report/Phase II Work Plan (GZA, 1993d) and Upper Simmons Reservoir Sediment Study Phase II Report (GZA, 1993e), dated February 5, 1993 and July 28, 1993, respectively. We note that the Phase II Sediment Study data was not submitted for independent data validation. However, a portion of this unvalidated data was used in our human health and ecological risk assessments (refer to Sections 6.00, 8.00 and 9.00). A screening level risk assessment was subsequently conducted by GZA for the Upper Simmons Reservoir sediments and is documented in a report entitled Upper Simmons Reservoir Screening Level Risk Assessment for Sediments, Operable Unit 2 Remedial Investigation - Task 1 (GZA, 1995e), submitted to EPA and RIDEM on June 30, 1995. The remaining multi-media sampling and analytical tasks were described in GZA's June 24, 1996 Draft Multi-media Sampling and Analytical Program Report (GZA, 1996b). These Round 1A data were used in assessing potential risk to human health and the environment (refer to Sections 8 and 9 of this report).

3.24 Surface Water Hydrology

The objective of the surface water hydrology study was to obtain discharge measurements at various locations within the 1,320-acre OU2 Study Area to better estimate groundwater baseflow and the general hydrologic budget of the contributory watershed. The results of the study were presented in a report entitled Surface Water Flow Monitoring Program - Central Landfill (GZA, 1997c), dated June 10, 1997. The information was gathered to be used in the mass balance/contamination dilution computations in Section 7 of this report, and to assess water quality and ecological impacts to Cedar Swamp Brook and the Upper Simmons Reservoir in the OU1 RD/RA and the OU2 FS. A potential OU1 RD/RA issue was whether or not treated groundwater from the Hot Spot Hydrodynamic Containment System should be discharged on-Site or to the Cranston POTW. The data will also be used to evaluate potential effects of groundwater pumping on stream flow volume. Consequently, the study focused primarily on periods of low flow.

Work performed as part of this study included: establishing and maintaining three stream gauging stations, one at the Four Corners culverts, one at the Pond 2 weir, and the third at the Upper Simmons Reservoir weir; weekly monitoring of streamflow over the period from July 26, 1995 to November 4, 1996; and analysis of results. Refer to Figure 3-1 for the locations of gauging stations.

Based on the work performed for this study GZA, concluded the following:

- The mean base flow for the area ranges from 1.4 to 2.9 cubic feet per second (cfs) per square mile.
- The lowest flows recorded over the time period of measurements were 0.07, 0.03 and 0.1 cfs at Four Corners, Pond 2 and Upper Simmons Reservoir, respectively, on September 7, 1995, during a period of four weeks with no rainfall. Low flow conditions on August 23, 1996 were generally higher, at 0.42, 0.52 and 0.1 cfs at Four Corners, Pond 2 and Upper Simmons Reservoir, respectively.
- The calculated 7Q10 low flow for Pond 2 is 0.035 cfs, consistent with the lowest flows measured during the summer of 1995.
- High flows for the period of measurement occurred in April and May, 1995 and ranged from 8 to 16 cfs.

3.25 Data Validation

The majority of the OU2 RI analytical results were independently validated by Environmental Chemistry Consultants, Inc. (ECCI) of Windham, Maine. In accordance with Section 5.30 of the SAP (GZA, 1995d), a Tier III validation was conducted following EPA Region I's Laboratory Data Validation Functional Guidelines for Evaluating Organic

Analyses (EPA, 1988a), dated November 1988, and Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses (EPA, 1989c), dated November 1989.

The validated analytical results (exclusive of the Upper Simmons Reservoir toxicity testing data) were previously submitted to EPA and RIDEM in the Draft Multi-media Sampling and Analytical Program Report (GZA, 1996b), and Progress Report No. 25, dated March 21, 1997, for OU2 Round 1 and Round 2, respectively. The chemical data tables presented in Section 6 of this report include the data validation flags for all OU2 testing results including the Upper Simmons Reservoir toxicity testing data. All chemical data evaluation conducted as part of the OU2 RI relied upon validated analytical results when available. Note, in some instances quarterly groundwater monitoring results, that are not routinely validated, were used to augment the OU2 data set. Also, as noted above, the Phase II Sediment Study analytical results were not validated due to the time constraints on that task. The validated analytical results are discussed in Section 6.00 and are summarized on Tables 6-4 through 6-25 of this report.

3.26 Interim Data Evaluation and Technical Memoranda

The purpose of our interim data evaluation and the generation of technical memoranda was to facilitate the review and evaluation by RIRRC, EPA and RIDEM, of the OU2 Round 1 field and analytical results and other pertinent findings of the OU2 RI studies as work progressed. Four primary documents were generated as part of this task. They consist of the following:

- January 16, 1996 Delineation of Groundwater Contamination Emanating From the OU1-Area Technical Memorandum (GZA, 1996a). That document presented GZA's proposed method for using piezometric data from an extensive monitoring well network to identify the outer limits of potential groundwater contamination migration from the landfill to the OU2 Study Area.

- Draft Multi-media Sampling and Analytical Program Report (GZA, 1996b). That report presented the methods and findings of the OU2 Round 1 multi-media sampling and analytical program.

- July 24, 1996 Draft Risk Screening and Recommendation Report (GZA, 1996c). That report presented the results of GZA's preliminary human health and ecological risk screening based on the OU2 Round 1 testing results. This report also contained our recommendations for the scope of the OU2 Round 2 sampling and analytical program based on areas of potential risk and identified data gaps (refer to Section 3.27 for details).

- November 7, 1996 Recommendation for Drilling Location of MW96-ML10 Technical Memorandum (GZA, 1996f). That document provided a summary of the findings of the surficial geophysical studies that were employed to assist in the selection of an appropriate drilling location for borehole MW97-ML10. The memorandum included GZA's proposed drilling location on the dam between the Upper and Lower Simmons Reservoirs.

- January 24, 1998 Ecological Risk Assessment Technical Memorandum (GZA, 1998). That document discussed proposed revisions to the Ecological Risk Assessment and the scope of work for proposed additional ecological risk assessment studies in the Upper and Lower Simmons Reservoirs.

These interim submittals, and the meeting and review comments which ensued, allowed RIRRC, GZA, EPA and RIDEM to evaluate critical data and reach a consensus on numerous technical issues prior to undertaking additional field studies.

3.27 Preliminary Risk Evaluation

The purpose of the preliminary risk evaluation, presented in the Draft Risk Screening and Recommendation Report (GZA, 1996c), was to identify potential ecological and human receptors, identify contaminant pathways, assess concentrations and bioavailability of site-derived contaminants, and qualitatively evaluate risks to potential receptors. The screening level risk evaluation was based on the OU2/Round 1 analytical results and was used to develop recommendations for the OU2/Round 2 sampling and analytical program. A summary of our conclusions, which were based solely on the field sampling and chemical analytical data presented in the body of that report, is as follows:

(1) Identified COCs: Soil, groundwater, surface water and sediment contamination is present at levels above human health and ecological risk based screening criteria within the OU2 Study Area. Primary contaminants exceeding these criteria consist of: inorganics (14 metals, cyanide and nitrate); volatile organics (aromatic and halogenated); semi-volatile organics; pesticides; and PCBs. Inorganics appear to be the primary contaminants of concern in each media. Exceedances of risk-based screening criteria for VOCs were generally limited to groundwater samples, and the vast majority of the observed compounds were detected in samples from wells MW-J and WE87-4, at relatively high concentrations. SVOCs, primarily PAHs and phthalates, exceeding risk screening criteria were most prevalent in OU2 Study Area sediment samples and, to a lesser extent, soils and surface waters. Pesticides and PCBs were only reported at concentrations exceeding screening criteria in sediment samples.

(2) Groundwater Consumption: At the time of our preliminary risk screening, GZA had identified only one residential well (RW43070) in the OU2 Study Area which was still in use as a potable water source. This well is located to the northwest of the landfill in an upgradient position. Contaminants were not detected in the samples collected from this well at concentrations above MCLs. (Note: as discussed in Section 3.11, the Residential Well Survey [GZA, 1997b] subsequently identified four additional properties within the OU2 Study Area which use

groundwater as a potable water source, and one property which uses groundwater for irrigation purposes.)

A number of organic and inorganic compounds were detected at levels above their respective MCLs in monitoring wells and former residential supply wells. All but one of these wells (RW31002) are located on properties now owned by RIRRC and, with few exceptions, these exceedances were limited to Hot Spot area and downgradient monitoring wells located in close proximity to the landfill toe-of-slope. Well RW31002 is not operational and the property owners have indicated that they are connected to the public water supply system and currently do not intend to use the supply well. RIRRC does not permit the use of groundwater as a potable source on properties that it owns in the OU2 Study Area. (Note, as described in Section 6.28, a sample collected during Round 2 from a residential well located on plat 31/lot 004 contained one inorganic constituent at a concentration in excess of MCLs. This well is not currently in use; however, the house has not been connected to public water.) Therefore, based on the data presented above, human health risks associated with consumption of contaminated groundwater emanating from the OU1 landfill are not anticipated.

(3) Groundwater Contaminant Migration: A purpose of the OU2 well installation and sampling program was to expand the understanding of groundwater migration patterns from the OU1 landfill. Studies performed during OU1 had identified the landfill and the Hot Spot as significant sources of groundwater contamination; however, the existing landfill perimeter groundwater monitoring network had not provided evidence of a high concentration contaminant plume migrating from the Hot Spot into downgradient areas. As discussed in Section 3.22, GZA installed eight additional monitoring wells within overburden, shallow bedrock and deep bedrock adjacent to the downgradient toe-of-slope in an area believed to be the most likely location for a contaminant plume migrating from the Hot Spot based on available groundwater flow data and chemical screening results. Additionally, GZA installed three wells (two bedrock and one overburden) on the crest of the dam between the Upper and Lower Simmons Reservoirs to evaluate the potential for deep contaminant migration to the Lower Simmons Reservoir or beyond. These wells were subsequently sampled as part of this multi-media sampling and analytical program (refer to Section 3.23).

We believe that the hydrologic evaluation we undertook to position the fifteen new wells, their areal spacing relative to each other and existing monitoring wells, and their variety of depths greatly reduce the possibility that we have not intercepted a contaminant plume, if present. The trend testing GZA performed as part of the Pentennial Water Quality Evaluation Report (GZA, 1996d) indicate that the majority of VOCs with trends were downward (66% down versus 34% upward). Downward trends were specifically noted for chlorobenzene, dichlorobenzene and toluene in Hot Spot and landfill perimeter wells, indicating that contaminant concentrations are not increasing with time. We believe that our studies failed to identify a significant VOC plume at the downgradient toe-of-slope from the Hot Spot, because one does not exist at that distance from the Hot Spot. Note that our trend testing did indicate more upward than downward trends for inorganic contaminants, however, we do not believe that this is related to migration rates.

In summary, we believe it is highly unlikely that a contaminant plume approaching our modeled concentrations (see the OU1-RI Report, Section 9.6) is migrating, or will in the future, beyond the landfill perimeter given the existing conditions.

GZA

The following recommendations, which formed the basis for the Round 2 sampling and analytical program, were developed by GZA based on the results of our screening level risk evaluation (GZA, 1996c):

(1) Surface Soils - Based on the potential risks to human health posed by some metals in samples SS95-2 and SS95-9 we recommended resampling and reanalysis of these areas for inorganics to confirm the prior results. Additionally, we recommended collecting two additional samples from the vicinity of each area (e.g., within a 25 foot radius) to evaluate the lateral extent of the observed contamination which we believe is likely very limited.

(2) Groundwater - We recommended that the 12 new monitoring wells installed as part of the OU2/Task 4 program be resampled and reanalyzed for the same suite of parameters employed during Round 1A. These wells had only been sampled and tested on one occasion and some low levels of contamination were observed which we believed should be confirmed prior to utilizing the data in the risk assessment. We also recommended resampling the three background wells for total and dissolved metals and water quality parameters to assist in the evaluation of background levels of inorganic contaminants. GZA did not believe that contaminants observed in the inactive residential supply wells were related to the landfill, and thus did not recommend resampling these locations.

We subsequently recommended and obtained two rounds of analytical samples from wells MW97-ML10 (A and B) and MW97-54 installed on the crest of the Upper Simmons Reservoir dam as part of OU2/Task 4A.

We also recommend that select OU1 and quarterly groundwater quality and piezometric data be incorporated into the OU2 risk assessment and contaminant migration evaluation. We believed that our findings presented in the, Pentennial Water Quality Report, (GZA, 1996d) supported this approach. Our recommendations regarding the scope of the OU2/Round 2 groundwater sampling were predicated on using this prior data.

(3) Surface Water - The screening level evaluation demonstrated potential risks to both human health and ecological receptors based primarily on metals in surface waters. To provide an adequate database with which to fully evaluate these potential risks, we

recommended resampling and reanalysis of all background and target surface water locations for total and dissolved metals. We also recommended that a subset of these samples, concentrated in downgradient discharge areas, be resampled and analyzed for the full suite of CLP and water quality parameters employed during the Round 1 program. We suggested that sampling be conducted during the seasonal low water period from late-August to early-October to assess surface water conditions when the groundwater contribution to flow is likely at its highest. Sampling and analytical procedures for mercury also needed to be reevaluated to ensure that the collected data met the project DQOs. Based on our reevaluation of the Round 1 results, the laboratory was required to analyze and report mercury concentrations to lower detection limits (i.e., the instrument detection limit).

Additionally, we recommended collection of four more samples from the Almy Reservoir/tributary mixing zones to further evaluate potential risks posed by surface water discharging to the Almy. We also recommend sampling of two to three locations of runoff from stockpiled soils in the vicinity of the Quarry Stream. Our evaluation indicated that runoff from these soil piles may be having a detrimental impact on the water quality in the Quarry Stream. Each of these samples should be tested for total and dissolved metals as well as water quality parameters.

(3) Sediment - Some potential for risk to ecological receptors was identified based on a limited number of metals at select locations. However, sediment contaminant concentrations were not expected to change significantly with time (i.e., within the nine month period between sampling events), therefore, we did not believe that additional sampling and analysis of sediments was necessary. We did anticipate the need for an extensive literature search, during the baseline risk assessment, to identify more applicable toxicity information for manganese in freshwater bodies.

Our recommendations for the second round of multimedia sampling and analysis were approved by EPA and RIDEM with minor comments. The results of the round 1 and round 2 programs are discussed in greater detail on September 6, 8 and 9.

4.00 SITE AND AREA GEOLOGY

The March 1993 OU1 RI Report (GZA, 1993a – Section 6) provides a detailed description of the surficial and bedrock geology of the OU1 Site and surrounding area (covering the majority of the OU2 Study Area). The OU1 RI Report also provides a detailed description of the subsurface conditions within the OU1 landfill and particularly the Hot Spot. We believe the geologic information provided in that document adequately supports the needs of the OU2 RI and FS.

OU2 Tasks 4 and 4A consisted of the drilling of four overburden borings (designated MW95-47S through MW95-48S, MW95-53 and MW97-54), six shallow bedrock borings (designated MW95-47 through MW95-52), two deep bedrock borings (designated MW95-ML9 and MW97-ML10), and the installation of at least one monitoring well in each borehole (total of 15 wells). Boring logs of these OU2 monitoring well installations are attached in Appendix C-1. The boring locations are shown on Figure 3-1. Table 4-1 provides a summary of environmental borehole drilling and well installation details, Table 4-2 documents the current status of monitoring installations. Table 4-3 provides a summary of the bedrock Rock Quality Designation (RQD) and hydraulic conductivity testing data for explorations which penetrated the bedrock. Table 4-4 provides a summary of fracture frequency and hydraulic conductivity testing data for explorations which had down-hole geophysical testing. Although the OU2 geologic information was not specifically generated to further evaluate geologic conditions (exclusive of selecting drilling and well placement locations), these data were integrated with the OU1 geological data set and information from both studies is presented on the referenced summary tables.

GZA conducted a surficial geophysical study to site borehole MW97-ML10, and performed a suite of down-hole geophysical testing (as well as packer testing) in the five newer "deep bedrock" boreholes (i.e., MW91-ML6 through -ML8, MW95-ML9, and MW97-ML10) to aid in the selection of well screened intervals.

In addition to the information generated by the Superfund-mandated studies, RIRRC has completed more than 30 additional bedrock explorations (e.g., SWLF-Series boreholes) to various depths. This information, generated as part of the Phase IV landfill expansion hydrological study, is clustered primarily in the area to the southwest of the Phase I landfill. *These data have not been reviewed by GZA, but are readily available.*

4.10 SURFICIAL GEOPHYSICAL INVESTIGATION

During the OU1 field studies, a regional fracture trace investigation of the site was completed by Geotech Enterprises, Inc. (Geotech) of Peace Dale, Rhode Island. The primary purpose of the study was to evaluate the regional geologic setting of the landfill with regard to the presence of faults, fracture zones, and other structures that may act as preferential pathways for groundwater flow within the bedrock which underlies the landfill. Attached to the OU1 RI (GZA, 1993a), as Appendix C-2, is the Fracture Trace/Geophysical Investigation report, dated August 1987. The identified lineaments and locations of geophysical explorations completed during the Geotech study are depicted on Figure 4-1 of this report. A subsequent surficial geophysical investigation was undertaken by GZA in the vicinity of WE87-10 to further evaluate the potential western migration of contaminants from the Hot Spot along Lineament No. 2. This 1991 study is also described in the OU1 RI, and the exploration locations are presented on Figure 4-1, Fracture Trace and Surface Geophysical Studies and Exploration Location Plan.

A variety of additional surficial geophysical studies were completed during the OU2 RI within the southeastern portion of the OU2 Study Area between the landfill and the lower portion of the Lower Simmons Reservoir. The purpose of these surficial geophysical investigations was to identify a drilling location for a proposed multi-level well (designated MW97-ML10) that fulfilled the objective of the "Deep Monitoring Well Installation," (Task 4A) as stated in the OU2 SAP (GZA, 1995d). GZA originally proposed two surface geophysical methods to help locate the deep monitoring well: 1) geoelectric depth soundings with a Schlumberger electrode array; and 2) a seismic refraction survey. In conjunction, these two methods had the potential to identify areas of high hydraulic conductivity, and/or changes in the electrical conductivity of groundwater. Other methods were subsequently added to the program to supplement the geoelectrics and refraction studies.

Our November 7, 1996 Recommendation for Drilling Location of MW96-ML10 Technical Memorandum (GZA, 1996f) details the findings of the surficial geophysical investigations and provides recommendations for a drilling location for MW97-ML10. The geophysical investigations, and our rational for selecting this location and depth, are briefly discussed in the following paragraphs. Please refer to Appendix B of our September 1997 Task 4A - Deep Well Installations Data Report (GZA, 1997d) for copies of the final Hager-Richter Geoscience (HRG) report (dated October 1996), and the Geotech report (dated November 1996) which formed the basis for our recommendations. These studies are briefly summarized in the following paragraphs.

The Task 4A surficial geophysical studies began on July 27, 1996 with geoelectric depth soundings performed by Geotech personnel. As shown on Figure 4-1, 16 depth soundings (CLF 11 through CLF 26) were completed by Geotech personnel along four profiles. Geophysical studies were performed along the length of the dam (Profile 3), on the eastern (Profile 2) and western (Profile 4) flanks of the Upper and Lower Simmons Reservoirs in the vicinity of the dam, and on the landfill property along Brook Street in the vicinity of MW95-ML9 (Profile 1). Note, Geotech only performed one geoeletric depth sounding along Profile 3 (CLF 17) The purpose of Profile 1 was to "calibrate" the methods to Site specific conditions in an area with good subsurface control. Geotech completed their field work on September 7, 1996. In addition, HRG conducted seismic refraction, seismic reflection, and VLF studies along the same study profiles. HRG personnel conducted these geophysical surveys between September 3 and October 3, 1996.

Based on an integrated interpretation of the four geophysical methods completed by GZA, three potential drillings locations were considered. The final recommended location lies on the dam (Profile 3), 250 feet east of the spillway. Although, no distinct geoelectric anomaly was identified below the dam, the area had relatively high conductance (i.e., low resistivity) which may indicate fractured and/or weathered bedrock. HRG's seismic refraction results from along the dam show an irregular bedrock surface forming a shallow valley achieving a minimum elevation between station 1+00 and 1+50 feet east of the spillway (approximately coincident with our recommended drilling location). Seismic velocities below the dam are in the range of 13,100 to 14,500 feet per second (fps) which is consistent with velocities observed along Profile 1 adjacent to boring MW95-ML9 (i.e., 12,800 to 14,500 fps) where moderately to highly fractured bedrock was observed to a depth of approximately 200 feet. The seismic reflection results show a series of six undulating reflectors, which roughly mirror the bedrock surface contours, beginning at a depth of 110 feet and running down to a depth of approximately 285 feet. These reflectors may, or may not, represent variably dipping bedrock fractures. The bedrock low at station 1+50 appears to correspond with both the point of maximum inflection of the bedrock reflectors and a large positive VLF anomaly. It also appears, based on the depth of the observed bedrock reflectors, that the proposed drilling depth of 300 feet adequately penetrates all the identified potential bedrock fractures.

The regional groundwater flow patterns, as presented on Figure 5-5, support the recommended drilling location which lies on the approximate centerline of a flow path from the area of the Hot Spot and through the dam. That is, based on the observed shape of the water table, and if the bedrock is transmitting groundwater as a blocky porous media, the recommended location is an appropriate location to observe underflow of the Upper Simmons Reservoir. Furthermore, the selected location is supported by the possible presence of a bedrock fracture zone (mapped as Lineament No. 7 on Figure 4-1) which runs approximately 150 feet northeast of the Hot Spot area and continues southeast through the Upper Simmons Reservoir, the dam and the Lower Simmons Reservoir.

4.20 BOREHOLE GEOPHYSICAL INVESTIGATIONS

In conjunction with hydraulic conductivity and chemical testing results, borehole geophysical analysis was used to select well screen locations in the deep boreholes during the OU2 studies (MW95-ML9 and MW97-ML10). As part of Task 4, Hager Geosciences, Inc. (HGI) of Waltham, Massachusetts performed a suite of borehole geophysical testing in March 1995. The purpose of this study was to identify and characterize hydraulically active fractures within the bedrock where they intersect the boreholes under consideration. Temperature, fluid resistivity, and 3-arm caliper logging were performed in the deep borehole MW95-ML9 and the other three deep "Hot Spot" test borings (MW91-ML6, -ML7 and -ML8). Acoustic Borehole Televiewer (ATV) logging was also performed in all four test borings by Colog, Inc. (Colog) of Golden, Colorado under contract to HGI.

In January 1997, Colog returned to perform a similar suite of borehole geophysical testing, on the deep borehole, MW97-ML10 (Task 4A). The purpose of this study was to identify and characterize hydraulically active fractures within the bedrock where they intersect the boreholes. This geophysical testing also consisted of borehole temperature logging; 3-arm caliper logging; ATV logging; and fluid resistivity logging (i.e., the same as Task 4). In addition, Colog performed heat pulse flow meter logging in MW97-ML10. Based on a review of the preliminary field results, GZA selected 16 unique 10-foot zones to be further evaluated with packer testing. Table 4-4 summarizes and compares observed fracture frequency and hydraulic conductivity results. GZA personnel estimated fracture frequencies from the ATV borehole logs, which were first interpreted by HGI personnel.

4.30 OVERBURDEN

As part of the OU2 field exploration program, as described in Section 3.13 of this report, GZA excavated seven test pits proximate to the OU1 Hot Spot (GZA, 1996e). The purpose of the test pit program (Task 7) was to evaluate the southern and eastern extent of chemical sludge associated with the Hot Spot and determine if it extended beyond the 154-acre licensed waste cell. The test pits terminated in glacial till or on bedrock. Historical and prior observational evidence suggests that much of the disposal of chemical waste and septage waste was directly onto the bedrock surface. The presence of glacial till and the absence of visual evidence of chemical or septage sludges confirms that the southeastern extent of the Hot Spot was adequately delineated during the OU1 remedial investigations.

During each stage of the OU2 drilling program, overburden wells were installed to investigate highly transmissive overburden soils beneath the water table and above the bedrock surface. All the test borings completed during the OU2 studies were performed by D.L. Maher Company (Maher) of North Reading, Massachusetts with a Barber Dual-Rotary drill rig utilizing air percussion drilling techniques.

Historic operations in and around the landfill area have resulted in the deposition of waste material over a 154-acre area, and the removal of the majority of the glacial deposits from landfill operational and borrow areas. The remaining overburden was generally observed to be comprised of approximately 9 to 14 feet of sand and gravel fill, underlain by siltier glacial till, consistent with the OU1 studies. However, during the completion of Task 4, boreholes MW95-47 and MW95-48 encountered greater than 30 feet of overburden to the south and downgradient of the OU1 Landfill. The observed overburden thickness was approximately double what was anticipated, and as such, the water table was encountered well above the soil/bedrock interface. Some soils observed during the drilling of MW95-47 and -48 were relatively high transmissivity glacial outwash deposits. To further evaluate the aquifer properties and groundwater quality within this area, GZA installed three overburden wells: two borings were designated MW95-47S and -48S; and the third overburden boring was designated MW95-53. Monitoring wells were installed in these borings and screened intervals were chosen based on field observations of the water table and the location of higher transmissivity soils.

During Task 4A, borehole MW97-ML10 encountered approximately 40 feet of stratified sand and gravel outwash deposits beneath the dam between the Upper and Lower Simmons Reservoirs. GZA installed monitoring well MW97-54 in close proximity to MW97-ML10 to evaluate the hydraulic connection in the overburden between the Upper and Lower Simmons Reservoir.

4.40 BEDROCK

As part of the OU2 RI, eight additional boreholes were completed into bedrock. The primary purpose of the OU2 drilling program was to site monitoring well installations in order to further define groundwater migration patterns and contaminant concentrations. These boreholes were drilled using air-hammer techniques that do not generate rock core samples and soil sample collection was generally limited. Consequently, limited information on soil and bedrock types was produced.

Consistent with the observations from the OU1 studies, the bedrock penetrated at all exploration locations was observed to be moderately to severely weathered granite. At many exploration locations, GZA was required to case-off large sections of the upper portion of the bedrock because it was weathered and fractured to the extent that it was not self-supporting. GZA generally continued bedrock drilling until we obtained 30 feet of wetted open bedrock borehole for in-situ testing. Therefore, drilling generally advanced 30 feet below the 6-inch steel casing elevation.

Large weathered fracture zones where encountered in the shallow bedrock to depths of approximately 73 feet below ground surface just south of the OU1 Landfill. To allow continued advancement of MW95-ML9, the 10-inch steel casing was drilled to 57 feet below ground surface (26 feet into bedrock) and 6-inch steel casing was telescoped into more competent bedrock at 82.5 feet below ground surface. To protect the shallower borings in this cluster both the 10-inch and 6-inch casings were grouted in place. Then MW95-ML9 was drilled open borehole using a 6-inch air hammer to a final depth of approximately 310.5 feet below ground surface (0 feet Mean Sea Level [MSL]). During the drilling of MW95-ML9, an apparent hydraulic connection was observed between the large weathered seam and the shallow bedrock (MW95-47) and overburden (MW95-47S) borings at this cluster well. This weathered and fractured seam was also encountered in borehole MW95-47, and caused the bottom approximately 10 feet of the borehole to cave-in. Several attempts were made to redrill and/or ream out this borehole without success. GZA remobilized to MW95-50 and drilled an additional twenty-five feet of borehole because the water table intersected the borehole eighteen feet below the casing level.

Self-supporting bedrock at borehole MW97-ML10 was encountered at 55 feet below the crest of the dam and was covered by a 6-foot veneer of "rotten rock." Since the upper bedrock was weathered and not self-supporting, GZA instructed Maher to advance the 10-inch casing five feet into competent bedrock and telescope 6-inch casing to a depth of 69.4 feet below the crest of the dam. MW97-ML10 was advanced to the design depth of 300 feet below the crest of the dam (elevation - 5.6 ft. MSL). As detailed in the Task 4A

Report (GZA 1997d), weathered fracture zones where encountered occasionally in the bedrock to a depth of approximately 290 feet bgs. However, GZA personnel also noted several long reaches of hard, unfractured granite in MW97-ML10.

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5.00 HYDROGEOLOGIC SETTING

An evaluation of the landfill's hydrogeologic setting was required because the OU1 RI identified groundwater flow in bedrock and surface water flow in the Quarry Stream and Cedar Swamp Brook as the most significant contaminant migration pathways. Subsurface materials within the OU1 landfill (i.e., saturated and unsaturated refuse) and the OU1 Hot Spot (i.e., chemical and seepage sludge) are acting as ongoing sources of contamination. The hydrologic properties of the soil and bedrock in the OU2 Study Area will, to a large degree, govern the direction and rate of contaminant migration. The major purpose of this section is to better characterize these pathways.

5.10 CONCEPTUAL HYDROGEOLOGIC MODEL

As presented in the OU1 RI, the regional ground surface topography, the distribution and thickness of unconsolidated sediments, and by extension, patterns of groundwater flow and recharge in the vicinity of the Central Landfill are controlled by the relatively shallow occurrence of crystalline bedrock. The area has been glaciated with ice advancing locally from the north and northwest eroding pre-glacial soils, weathering bedrock and aiding in the development of a system of northwest to southeast trending uplands and intervening valleys.

This orientation of upland and lowland topography is evident throughout much of northwestern Rhode Island. Its origin is probably pre-glacial, and related to preferential weathering along rock fractures produced by tectonic movement of the Avalon Zone of southeastern New England. The OU1 Landfill is situated along the northerly flank of one such valley. The OU2 Study Area is characterized by glacial till covered, bedrock-controlled, hills and valleys straddling a portion of the surface water divide which separates the Upper Simmons and Almy Reservoirs. As a consequence of this geologic setting, a relatively wet New England climate (average rainfall is almost 50 inches/year) and areal recharge to glacial till (estimated to be 9 inches/year-Section 3.2, OU1-RI [GZA, 1993a]), groundwater is generally found at shallow depths and groundwater divides typically coincide with surface water divides. That is, groundwater contours are typically a subdued image of land surface contours. This was observed on an area-wide basis by comparing published water table data to local topography (see Drawing No. 4-1 of the OU1 RI [GZA, 1993a]) and is also illustrated by OU2 site-specific data (see Figures 5-1 through 5-5, Groundwater Contour Plans). In reviewing these figures, note, that were multi-level well clusters were present, the shallowest interval was generally used to construct the groundwater contours.

On a conceptual basis, groundwater flows are vertically downward near the top of a groundwater basin and upward near discharge points. Based on the size of the groundwater basins and the relative size of the Upper Simmons and Almy Reservoirs, groundwater will discharge to, and not pass beneath, these two surface water bodies, whereas there could be groundwater migrating beneath retention ponds and wetlands. Because Cedar Swamp

Brook corresponds to the location of a surface water divide, it is also a likely discharge point for area groundwater. Piezometric measurements support this model (see Figures 5-1 through 5-5).

The mining of soil and rock, filling with pervious materials, pumping of groundwater, and potentially the presence of significant bedrock fractures can cause groundwater to flow across surface water divides. The potential for inter-watershed groundwater flow was considered when we developed both the OU1 and OU2 Remedial Investigations. As discussed in this section, no major inter-watershed groundwater flow was identified.

5.11 Size of the Watersheds

The OU2 Study Area is 1,333 acres (2.1 square miles); approximately 866 acres (65%) are in the watershed of the Upper Simmons Reservoir, 267 acres (20%) are in the watershed of the Almy Reservoir, and 200 acres (15%) are in the watershed of Dry Brook, which drains the Almy Reservoir. These estimates are based on the limits shown on Figure 2-1.

Approximately 150 acres (97.5%) of the 154-acre licensed landfill area are in the watershed of the Upper Simmons Reservoir. The remaining area, on the order of 4 acres, is in the watershed of the Almy Reservoir. We believe this estimate of the area of the landfill that potentially contributes contamination to the Almy Watershed represents a reasonable worst-case condition. We also note that the size of that area varies somewhat as the groundwater divide shifts due to variations in precipitation and areal recharge, and that area is generally less than 4 acres. Examples of the variation in the inferred location of the groundwater divide between the Almy and Upper Simmons Reservoir watershed are presented on Figures 5-1 through 5-4.

Based on USGS topographic maps of the area, we estimate that Cedar Swamp Brook has a watershed of approximately 2.05 square miles above the Upper Simmons Reservoir. Using the same technique, we estimate the Upper Simmons Reservoir has a total watershed of approximately 2.53 square miles and that the Almy Reservoir has a watershed of 2.25 square miles (see Drawing No. 4-1 of the OU1-RI [GZA, 1993a]).

5.12 Groundwater Recharge/Withdrawals

With few exceptions, public water is readily available in the OU2 Study Area (the distribution system is shown on Figure 2-3) and public sewers are not available. Consequently, aquifer recharge is due to both precipitation and recharge from irrigation and individual septic systems. We estimate that the average annual recharge to glacial till is approximately 9 inches per year (see Section 3.24.1 of the OU1 RI [GZA, 1993a]). For the purposes of this study, we ignored the effects of the disposal of municipal waters to septic systems in the OU2 Study Area. This is conservative in that this volume of water was not used to estimate (in dilution calculations) contaminant concentrations at identified receptors, and is somewhat offset by the discharge of leachate, captured by the lined Phase II/III and IV landfills, to the Cranston sewage treatment facility.

5.20 GROUNDWATER TABLE MEASUREMENTS

As part of the OU2 RI, water table measurements were made bi-monthly between September 1995 and November 1996, and on an hourly basis during the performance of a three-day pumping test. The resulting data were used to construct groundwater contour plans and to evaluate the hydraulic properties of the soils and bedrock. These efforts are described below, elevation measurement data is provided in Table 5-1, and the resulting contour plans are shown on Figures 5-1 through 5-5.

5.21 Periodic Measurements

Between September 1995 and November 1996, the depth of the water table was measured in available wells on eight occasions. This was performed on essentially a bi-monthly basis. During each round, measurements were made in 85 to 90 wells. These measurements were made between the rim of the well and the water surface in the well using an electronic water level meter with an accuracy of ±0.01 feet. Elevations, relative to the National Geodetic Vertical Datum of 1929 (NGVD), of the rims of the wells were determined by a registered land surveyor using standard differential leveling techniques (vertical accuracy reported to ±0.01 feet). These data, in conjunction with the depth measurements, were used to establish piezometric levels (relative to NGVD).

Based on a review of these eight data sets, provided in Table 5-1, we selected September 1995 and September 1996 as being representative of low-water table conditions, and November 1995 and November 1996 as being representative of high-water table conditions in the OU2 Study Area. Figures 5-1 to 5-4 present groundwater contours developed from these data. In addition, the piezometric data collected during the August 1997 groundwater monitoring round for the Revised Environmental Monitoring Plan (GZA, 1997a) was included in Table 5-1 and on Figure 5-5 in order to incorporate piezometric data from the MW97-ML10 well cluster. In reviewing this information, note that the water table elevation varies with time, and that the contours were developed from relatively widely spaced (relative to the size of aquifer heterogeneities) monitoring wells. Consequently, the elevation of the water table at any location may be outside the ranges shown on these figures. We note, however, the groundwater flow patterns, as evidenced by the 26 rounds of piezometric data presented in the OU1 and OU2 RI reports, have remained remarkably consistent.

5.22 Pump Test Measurements

A pump test was performed in well MW91-ML7, which was located in the vicinity of the OU1 Hot Spot. Between May 16 and May 21, 1994, the depth of the water table was measured in 47 wells at time intervals varying from minutes to hours. Refer to Section 5.41.3 for additional information.

5.30 STREAMFLOW MEASUREMENTS

As described in Section 3.24, GZA performed weekly stream flow measurements at the three locations shown on Figure 3-1 over a 15-month period (July 1995 through October 1996). We incorporated these data in performing mass balance/contaminant dilution studies to assess the potential for water quality impacts at the Upper Simmons Reservoir. This information is used in the risk assessments presented in this report (see Sections 8 and 9) and if necessitated by site conditions, will be used to help evaluate groundwater disposal options for the OU1 Hot Spot hydrodynamic containment system. An interpretation of this information is provided below.

5.31 Existing Data (OU1 Studies)

During the performance of the OU1 RI field work, stream flows were measured at the weir separating the Upper and Lower Simmons Reservoirs on four occasions (see Section 3.24.1 of OU1 RI [GZA, 1993a]). Because of the scarcity of site-specific flow data, we used estimates of areal recharge to develop estimated flows in various water bodies and beneath the landfill. The results of those studies are presented in Table 7-7 of the OU1 RI (GZA, 1993a) and are summarized as follows:

LOCATION	FLOW (gpd)[1]	DILUTION RATIO
Flow beneath landfill towards Upper Simmons Reservoir	143,000	---
Flow beneath landfill towards Almy Reservoir	11,000	---
Total Flow to Upper Simmons Reservoir	1,230,000	8.6[2]
Total Flow to Almy Reservoir	1,094,000	99.5[3]

1. gpd = gallons per day.
2. Calculated as flow beneath landfill divided by flow to Upper Simmons Reservoir.
3. Calculated as flow beneath landfill divided by flow to Almy Reservoir.

5.32 Overview of OU2 Surface Water Flow Measurements

Flow measurements at the weir on the dam separating the Upper and Lower Simmons Reservoir (the weir) during the 15-month monitoring period varied from about 0.1 cubic feet per second (cfs) (64,800 gpd) to approximately 60 cfs (39 million gpd). During that period of time, the gauging stations at the Scituate Reservoir received precipitation at the rate of 58.8 inches per year. Annual precipitation over a 75-year period, for that watershed has varied between 33 inches and 75 inches, and averaged 49.8 inches.

We estimated that the seasonal low flow at the weir was 1.4 cfs per square mile or 3.54 cfs. Actual flows at the weir exceeded this value during more than 85 percent of the study period. The longest duration when flows dropped below this value was for six weeks in August and September 1995 (see Figures 3 and 4 of the Surface Water Flow Report [GZA, 1997c]).

In reviewing these data, note that the Upper Simmons Reservoir is approximately 50 acres and averages about six feet in depth, thus having a volume of 300 acre-feet (13.07 x 10^6 cubic feet). Consequently, at a flow of 3.54 cfs, the Upper Simmons Reservoir has an average residence time of approximately 43 days.

5.33 Calculated Dilution Ratios

We used the estimated flow at the weir of 3.54 cfs and estimated groundwater flow rates to develop a dilution ratio for the Upper Simmons Reservoir. Because of the availability of pumping test data, we used the hydraulic properties of the bedrock and Darcy's equation to estimate flows beneath the landfill. Since no flow measurements were made in the watershed in the Almy Reservoir, we retained the dilution ratio that was calculated during the OU1 RI for that waterbody. The results are summarized as follows:

LOCATION	FLOW (gpd)	DILUTION RATIO
Flow beneath landfill[1] towards Upper Simmons Reservoir	136,000	---
Flow beneath landfill towards Almy Reservoir	11,000	---
Total flow to Upper Simmons Reservoir	2,294,000	17.0
Total Flow to Almy Reservoir	1,094,000	99.5

1. Based on observed flow directions and gradients, and a transmissivity of 110 ft^2/day, (see Section 5.42 of this report).

5.40 HYDRAULIC PROPERTIES

The average hydraulic conductivity of the glacial till and the underlying fractured bedrock are, on average, similar, with the effective average hydraulic conductivity of the shallow bedrock being somewhat higher than that of the glacial till. Consequently, for the limited purposes of this study, we have assumed that these two materials form one hydraulic unit. As recorded in Table 5-1 and shown on Figure 5-6, the groundwater table in the Hot Spot is at or below the bedrock surface. Therefore, the OU2 remedial investigations focused mostly on the migration of groundwater in this bedrock/glacial till unit.

Groundwater and contaminant flow patterns do appear to be affected by the high transmissivity soils found south of the OU1 Landfill. That is, the significant thickness of saturated highly permeable soils act as a preferential pathway for leachate migration in groundwater to the south/southeast of the OU1 Landfill toe-of-slope. However, this shallow groundwater discharges to the Sedimentation Ponds, Cedar Swamp Brook and the Upper Simmons reservoir consistent with the regional groundwater flow pattern. Refer to Section 7.37.2 of the OU1 RI Report (GZA, 1993a) for more information on hydraulic properties of surficial soils.

5.41 Hydraulic Conductivity Investigations

The OU1 RI (GZA, 1993a) found that the bedrock acts as blocky porous media, and that regional fractures, as evidenced by lineaments, have little influence on groundwater migration (see Section 7.37.1 of the OU1 RI Report [GZA, 1993a]). That is, on the scale of tens of feet, the shallow bedrock (e.g., upper 10 to 30 feet of bedrock) is so fractured it is reasonable to estimate groundwater flow directions and rates by assuming the rock is a porous media. Section 6.43 of the OU1 RI (GZA, 1993a) provides a detailed statistical evaluation of the observed patterns of bedrock fracturing with depth and proximity to lineaments. As discussed in the following subsections, this shallow bedrock aquifer was shown to transmit the majority of the groundwater flow and contamination during the OU1 and OU2 studies. These data also suggests that the bedrock fracturing and hydraulic conductivity decrease substantially with increasing depth. In addition, it should be noted that the bedrock aquifer contains significant heterogeneities. That is, the transmissivity of the bedrock varies dramatically over small distances.

5.41.1 Short Duration Specific Capacity Tests

During OU2 Task 4 and Task 4A, specific capacity tests were performed in a number of bedrock boreholes/wells and overburden wells. Specific capacity tests were performed in lieu of packer tests at locations MW95-47 and MW95-52 due to the poor rock quality. At MW95-51 a specific capacity test was run to estimate hydraulic conductivities in the borehole which had demonstrated greater than expected vertical leakage around the packer assembly. GZA also performed specific capacity tests on bedrock wells MW95-ML9B, -ML9C, MW97-ML10A and -10B, and on overburden wells MW95-47S, -48S, -53, and MW97-54.

Specific capacity tests were run to estimate hydraulic conductivity in the formations penetrated by these borings and as a comparison to the packer testing results. Test results are presented on Table 5-2. As shown in Table 5-2, the transmissivities of the deep outwash deposits observed southeast of the toe-of-slope of the landfill were approximately an order of magnitude greater than the underlying glacial till and bedrock hydraulic unit. The testing was conducted by pumping water from the borehole or well at a constant rate, which resulted in measurable drawdown in the well within 10 minutes, or pumping at the capacity of the pump (less than 30 gpm). Flow rates were estimated by measuring the time required to fill a 5-gallon container. Drawdowns were measured using an electronic water level meter. These measurements were made at one to ten minute intervals throughout the pumping period, which was generally less than ninety minutes. Transmissivities were estimated from the observed hydraulic capacities using methods presented by Walton (1970), calculations are provided in the OU2 Task 4 (GZA, 1995a) and OU2 Task 4A (GZA, 1997d) reports.

GZA

5.41.2 Packer Testing

During the OU1 RI, a total of 200 packer tests were performed in 33 wells at the landfill. These test results ranged from less than 0.4 ft/year ($4x10^{-7}$ cm/sec) to 3,070 ft/year ($3x10^{-3}$ cm/sec), with the arithmetic average of the tests being 178 ft/year ($1.7x10^{-4}$ cm/sec).

Packer testing during the OU2 RI was performed in the same way that the testing was performed during the OU1 RI. A total of 106 packer tests were completed in 16 boreholes in the OU2 Study Area. The test results ranged from less than 0.4 ft/year ($4x10^{-7}$ cm/sec) to 6,205 ft/year ($6.0x10^{-3}$ cm/sec), with the arithmetic average of the 106 tests being 174 ft/year ($1.7x10^{-4}$ cm/sec). Because of the marked similarities in these data sets, we combined the two and used the resulting data set as being representative of the OU2 Study Area. The combined OU1 and OU2 packer data are summarized in Tables 4-3 and 4-4. This data set consists of 306 packer test results, performed in 49 boreholes. Hydraulic Conductivity values range from 0.4 ft/year ($4x10^{-7}$ cm/sec) to 6,205 ft/year ($6.0x10^{-3}$ cm/sec), with an average value of 177 ft/year ($1.7x10^{-4}$ cm/sec).

During the OU1 RI, we compared the results of packer tests performed in boreholes located on lineaments to tests performed in boreholes located off lineaments. We found no significant differences in these subsets of the OU1 RI packer test results. Consequently, we did not evaluate the OU2 data set in this manner. Rather, we reviewed the combined data set for variations in hydraulic conductivity with depth below the top of bedrock.

The average computed hydraulic conductivity for the top 10 feet of the bedrock is 570 ft/year ($6x10^{-4}$ cm/sec), approximately 3.2 times the average for the entire rock mass. Conversely, at depths greater than 223 feet below the top of bedrock, the highest observed test result was less than 17 ft/year ($2x10^{-5}$ cm/sec), which is approximately one-tenth the average of the data set. These data demonstrate that the average hydraulic conductivity of the bedrock aquifer decreases with depth and most of the groundwater flow is generally limited to the upper 200 to 300 feet of the rock.

5.41.3 Pumping Test

As discussed in Section 3.12, a pump test was completed between May 16 and May 21, 1994 at the CLF, downgradient of the identified OU1 Hot Spot. The purpose of the test was to evaluate the hydrogeologic properties of the bedrock in the vicinity of the Hot Spot. The studies were performed in accordance with a work plan dated September

28, 1993, as revised on March 18, 1994. The results of the testing were provided in the Hot Spot Pump Test Report (GZA, 1994b). An interpretation of the test results is provided in the following subsections.

Pumping Test Results

The test was performed in borehole MW91-ML7, an 8-inch diameter hole which is open to the bedrock to a depth of 55 feet below the water table. We note that during the test, the water table was completely within the bedrock. Test results were analyzed assuming the rock behaved as a porous medium.

A short-duration test indicated the borehole had a specific capacity of 0.1 gpm/ft (based on 20 feet of drawdown and an extraction rate of 2.0 gpm). The well was subsequently pumped at an average rate of approximately 2 gpm (1.7 to 2.2 gpm) for three days. Time-drawdown data generated by monitoring in three wells were analyzed using the Cooper-Jacob methods. The resulting transmissivities are in the range of 20 ft^2/day (150 gpd/ft) to 90 ft^2/day (675 gpd/ft). The test data also suggest the bedrock has a storage coefficient in the range of 0.06 to 0.008.

Based on well hydraulics for flow in a porous medium, we assumed that the well withdrew groundwater from the depth of the well to as much as 1.5 times its depth. Based on this assumption, we estimate that the hydraulic conductivity of bedrock in the vicinity of the Hot Spot is in the range of 90 ft/year (8.7×10^{-5} cm/sec) to 400 ft/year (3.8×10^{-4} cm/sec).

Packer testing (see Section 5.41.1) indicates that the average hydraulic conductivity of the rock is approximately 180 ft/year, and that the bedrock aquifer extends to a depth of approximately 220 feet. Note, this estimate of the depth of groundwater flow is in good agreement with estimates based on flow net analyses performed as part of the OU1-RI (see Section 7.41.2 of OU1 RI [GZA, 1993a]). These data indicate an average effective bedrock transmissivity of approximately 110 ft^2/day (820 gpd/ft), which is in good agreement with the results of the pumping test.

Influence of Pumping

Water level measurements were made in a total of 47 monitoring wells and piezometers, with the primary emphasis on the eight wells located within 110 feet of well MW91-ML7. The water level in five of the 14 wells located within 1,000 feet of the extraction well responded to the three days of pumping. The water level in well MW90-34B, located approximately 395 feet from the extraction well, was drawn down approximately 0.5 feet. While water levels in some wells beyond this distance varied during the pumping test, we attributed these fluctuations to factors other than pumping.

As suggested above, and in the Hot Spot Pump Test Report (refer to Figure 5 of that report [GZA, 1994b]), the radius of influence of the pumping test was irregular and difficult to define. However, the available data indicate that at steady state conditions, there would be significant drawdowns at all locations within the bedrock aquifer at distances of 20 to 50 feet from the pumping well.

5.42 Effective Porosity of the Bedrock

No measurements of the bedrock porosity were made during either the OU1 or OU2 RIs. Rather, we relied upon published data (USDI, 1981) and estimated a value of 0.01. We believe this porous media model value is appropriate to estimate groundwater transport rates, and is believed to be representative of the upper, more-fractured rock, where hydraulic conductivities are higher than the average.

5.50 GROUNDWATER VELOCITY/CONTAMINANT TRANSPORT RATES

For the purposes of the OU1 RI, we used procedures that tended to underestimate contaminant transport velocities. For the purposes of that report, this was conservative because if contaminants had reached receptors some time ago, concentrations would (due to improvements at the landfill) on average decrease, not increase, with time. For the purposes of the present investigation, we were interested in evaluating the possible extent of contaminant migration from the OU1 Landfill. Consequently, we used procedures that tended to provide a reasonable estimate of the upper end of groundwater migration rates. As discussed in the following subsections, the combined OU1 and OU2 RI data indicate that groundwater seepage velocities are in the range of 2.0 to 6.0 ft/day.

5.51 Groundwater Seepage Velocities

We estimated the groundwater seepage or tracer velocity using a form of Darcy's equation (Todd, 1980). This equation is based on the assumption that the aquifer is a uniform, homogeneous media and groundwater flow is laminar. Flow in the bedrock is, for the most part, laminar, however, the properties of rock vary considerably. Consequently, we selected parameters we believe are representative of conditions which reflect the average value of the higher seepage velocities.

We estimated seepage velocities using the following form of Darcy's equation.

$$V = \frac{k \cdot i}{n}$$

where: V = groundwater seepage rate (ft/year)
k = hydraulic conductivity (ft/year)
i = hydraulic gradient (ft/ft)
n = effective porosity

Hydraulic Conductivity: We used 570 ft/year, which is the average hydraulic conductivity as computed from packer test results, for the upper ten feet of the rock (see Section 5.41.2).

Hydraulic Gradient: We used 0.04 (4 feet in 100 feet), which is representative of the slope of the water table across much of the OU2 Study Area (see Figures 5-1 through 5-5).

Effective Porosity: We used 0.01, which is based on published values and is believed to be representative of the upper portion of the aquifer (i.e., the upper 10 to 30 feet of bedrock) where the hydraulic conductivity is higher.

Groundwater Seepage Velocity: The resulting value is about 2,300 ft/year, or approximately 6 ft/day. This value is believed to represent the seepage velocity in the upper portion of the aquifer and is not representative of flow in the lower portion of the bedrock where seepage velocities are believed to be less. This estimate is provided to help evaluate the probable extent of contamination in the aquifer.

The Hot Spot is approximately 2,400 feet north (and upgradient) of the Upper Simmons Reservoir, and the northern edge of the landfill is about this same distance (and upgradient) from the Almy Reservoir. Consequently, we estimate that it will require, a minimum of a little more than one year for a particle of groundwater to migrate from the Hot Spot to the Upper Simmons Reservoir, or from beneath the northern portion of the landfill to the Almy Reservoir.

5.52 Contaminant Transport Velocities

On average, non-reactive, dissolved phase contaminants migrate with the groundwater at the groundwater seepage velocity. (Note, not all contaminants are conserved as many decay with time.) Due to the effects of hydrodynamic dispersion, a portion of the contaminant migration occurs at a rate higher than the average contaminant transport velocity, and a portion of the contaminant migration occurs at a rate less than the average contaminant migration rate. Due to the effects of adsorption, and depending on the chemical properties of both the aquifer and the contaminants, some contaminant migration is retarded, occurring at rates, on average, which are less than the average seepage velocity. As part of the OU1-RI, we estimated retardation factors (seepage velocity divided by contaminant transport velocity) for sixteen organic compounds identified within the OU1 area (see Section 9.41 of the OU1-RI [GZA, 1993a]). These values ranged from 1.2 for methyl ethyl ketone to 100 for bis(2-ethylhexyl)phthalate (see Table 9-3 of the OU1-RI [GZA, 1993a]). Therefore, due to the adsorption of organic compounds to organic carbon in the bedrock fractures (if present), methyl ethyl ketone released in the Hot Spot would theoretically reach the Upper Simmons Reservoir in about 15 months and bis(2-ethylhexyl)phthalate could take as much as 110 years to reach the Upper Simmons.

5.60 GROUNDWATER FLOW BENEATH THE SIMMONS RESERVOIR DAM

As discussed in Section 3.22 and 3.26, one purpose of the OU2 RI was to evaluate whether there is regional groundwater flow beneath the Upper Simmons Reservoir. After an extensive surficial geophysical program (see Section 4.10) and long-term bi-monthly piezometric monitoring (see Section 5.22), GZA investigated regional flow by the installation of a well cluster on the crest of the dam that separates the Upper and Lower Simmons Reservoirs (the Simmons Reservoir Dam). The following provides an interpretation of the groundwater flow patterns evidenced by that investigation. A discussion of the associated groundwater quality data is provided in Sections 6.00 and 7.00.

5.61 Hydrogeologic Features

The well cluster, consisting of wells MW97-ML10 (A and B) and MW97-54, is located near the east end of the dam, approximately 4 feet north (upstream) of the centerline of that approximately 27-foot-wide earthen structure. This location was deemed to be most probably location at which to detect underflow of the Upper Simmons Reservoir based on the recommendations made in the November 7, 1996 Recommendation for Drilling Location of MW96-ML10 Technical Memorandum (GZA, 1996f). The crest of the dam is at an elevation of approximately 294 feet NGVD, and the pond elevation of the Upper and Lower Simmons Reservoirs vary, but were at about elevation 292 and 283 feet NGVD, respectively, when piezometric measurements were made.

Packer testing was performed in the borehole for well MW97-ML10. These data, provided in Table 4-4, indicate that the hydraulic conductivity of the bedrock, which was encountered at a depth of approximately 50 feet below the crest of the dam, decreases dramatically with depth. A diagram showing major hydrogeologic features and piezometric measurements is provided on Figure 5-6.

5.62 Conceptual Seepage Model

The Upper Simmons Reservoir is long (2,800 feet, see figure 5-6) in comparison to the thickness of the underlying aquifer (less than 300 feet, see Section 5.41.2). With these conditions, and no bottom sediments non-site specific flow net analysis demonstrate that groundwater flow would discharge to and from the edges of the reservoir, with no groundwater underflow beneath the reservoir. The major factor which could cause underflow would be the presence of a continuous layer of thick fined grained bottom sediments (a confining layer).

Based on testing associated with the required dredging of the reservoir, we believed the bottom sediments would cause seepage to occur further away from the edges than would occur if no sediments were present, but that there would still be no underflow.

To test our conceptual model we installed a cluster of wells on the dam which separates the Upper and Lower Simmons Reservoir (wells MW97-ML10A and MW97-54). This location was selected because 1) it gave a single point that would allow us to evaluate piezometric levels indicative of under flow (if such heads exist) and 2) provide a location that has a high probability of detecting landfill contaminants (if present).

If the bottom sediments were acting as a confining layer (allowing underflow) we would expect to measure strong upward vertical gradients as well cluster MW97-ML10. The observed piezometer data (see Table 5-3), in our opinion, do not support this potential (but unlikely) flow path, rather we believe the observed data are more indicative of shallow local seepage between the Upper and Lower Reservoirs. This conclusion is further supported by water quality data (discussed in Sections 6 and 7) which indicates that groundwater at this location is not affected by the OU1 Landfill.

Sections:
6.0 Nature and Extent of Observed Contamination
7.0 Contaminant Fate and Transport
(pages 67-111)
are available
in a separate file (size: 3 MB).

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Section:
8.0 Human Health Risk Assessment
(pages 112-163)
is available
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Sections:
9.0 Ecological Risk Assessment
10.0 Conclusions
11.0 Limitations
(pages 164-242)
are available
in a separate file (size: 4.5 MB).

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