[redacted]

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WELLS G & H SITE

CENTRAL AREA

REMEDIAL INVESTIGATION

PHASE IA REPORT

VOLUME 1

Prepared for: **February 14, 1994**

Beatrice Corporation
UniFirst Corporation
W.R. Grace & Co. - Conn.

63 Great Road
Maynard
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ENVIRONMENTAL
PROJECT CONTROL

February 18, 1994

David Lederer
US EPA – Region I
Waste Management Division
JFK Federal Building (HRS–CAN2)
Boston, MA 02203

RE: Central Area RI/FS
Wells G&H Site, Woburn, Massachusetts
EPC Reference No.: 03.01/JTL.0797

Dear Dave,

Enclosed are the requested copies of the draft Phase 1A Report—Initial Site Characterization. I submit this report on behalf of Beatrice Company, UniFirst Corporation and W.R. Grace & Co.—Conn. The companies request that their representatives meet with the EPA and DEP at the agencies' earliest convenience to discuss this report. The companies recommend that we meet before the EPA finalizes its formal comments on the document.

Should you have any questions regarding this document, please call me.

Sincerely,

Jeffrey T. Lawson, P.G.
President

enclosure

ENVIRONMENTAL
PROJECT CONTROL

cc: Anna Mayor, DEP
Boyd Allen, Ensearch
Gretchen Latowsky, FACE
Jay Stewart, Lowenstein, Sandler et al.
Rob Block, RETEC
Jack Guswa, GeoTrans
John Cherry, Waterloo
Gary Augustyn, UniFirst
Deirdre Menoyo, Goodwin, Procter & Hoar
Maryellen Johns, Grace
Mark Stoler, Grace

File: 03.01/54.12.00

WELLS G & H SITE
CENTRAL AREA
REMEDIAL INVESTIGATION
PHASE IA REPORT

VOLUME I

Prepared for:

Beatrice Corporation
UniFirst Corporation
and
W.R. Grace & Co. - Conn.

Prepared by:

GeoTrans, Inc.
and
RETEC

February 14, 1994

GeoTrans, inc.

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EXECUTIVE SUMMARY

This report provides a detailed description and discussion regarding the Central Area of the Wells G & H Site (Site) which is located within the Aberjona River watershed (Record of Decision (ROD), EPA, 1989). The Aberjona River watershed is located north of Boston, Massachusetts. About 7 square miles of the watershed are located upstream of the southern boundary of the Wells G & H Site. In the early 1800s, with the construction of the Middlesex Canal, industrialization of the watershed began. After almost two centuries of industrialization and urbanization, the watershed has evolved into a densely developed suburb of Boston. The report describes a conceptual model of this highly industrialized urban watershed including a description of:

- the hydrogeologic conditions which affect ground-water flow and chemical transport within the Central Area,
- the interaction of the Aberjona River and the Central Area Aquifer, and
- the nature and extent of contamination in the Central Area including past, present, and likely future sources of contamination.

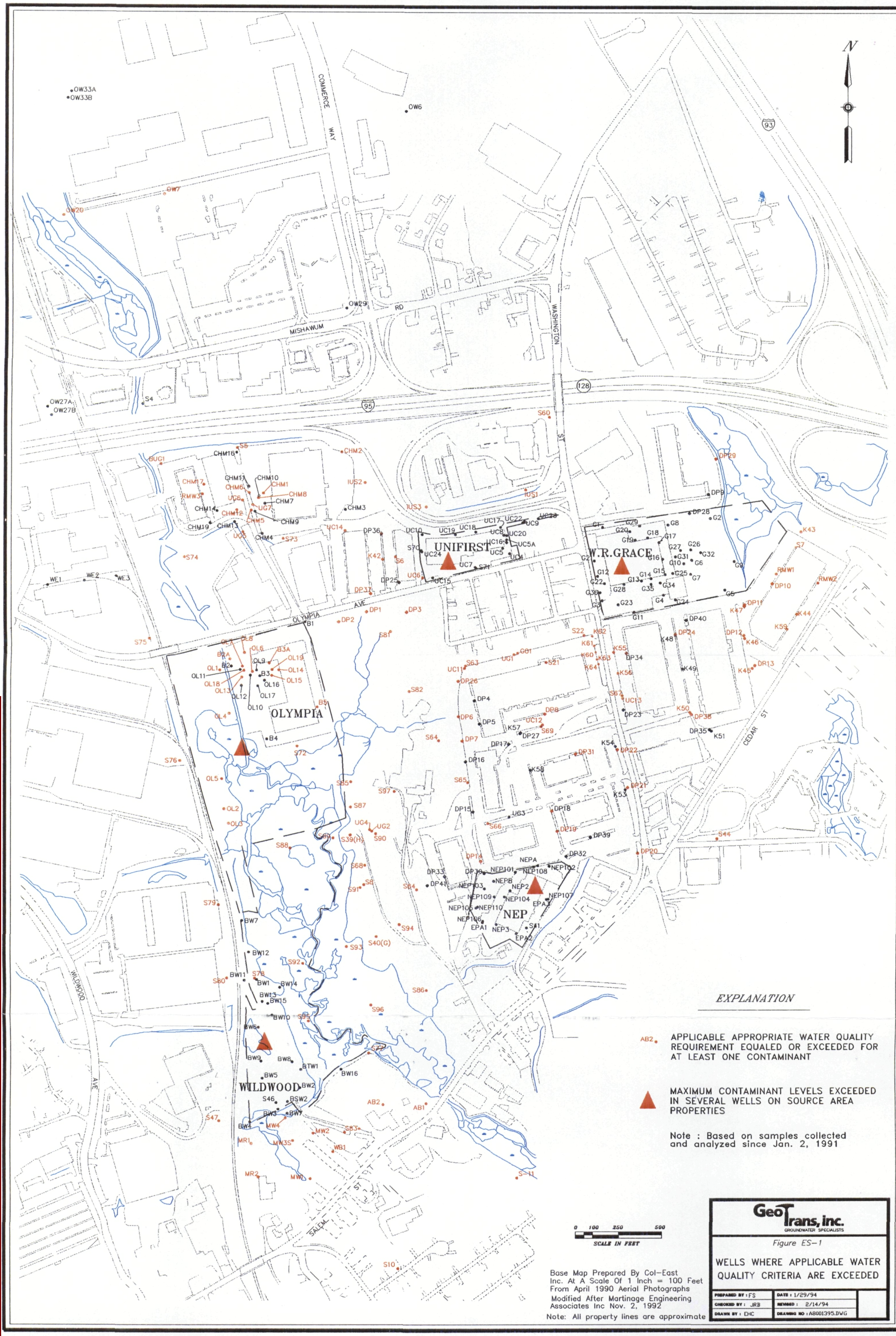
The interpretations and conclusions contained within this report are based on a substantial information base developed over years of site investigations and studies including data collected as part of this investigation. This investigation was undertaken by Beatrice Company (Beatrice), UniFirst Corporation (UniFirst), and W. R. Grace & Co. - Conn. (Grace) pursuant to the Consent Decree (Decree) between Beatrice, UniFirst, Grace, New England Plastics (NEP), U.S. Environmental Protection Agency (EPA), Massachusetts Department of Environmental Protection (DEP), and other parties. Since January 1992, Beatrice, UniFirst, and Grace have continued the RD/RA activities at their respective properties. In addition, they have initiated independent as well as

coordinated data collection activities on both sides of the Aberjona River. As part of the Central Area Phase 1A investigations, 188 monitoring wells were installed, 728 ground-water and surface water samples were collected, and 492 ground-water level measurements were made. There have also been concurrent studies of the Aberjona River watershed by researchers at MIT. The level of investigation done and amount of information available regarding the Central Area of the Wells G & H Site make it one of the most, if not the most, extensively studied Superfund Sites in the United States.

The Phase 1A studies have confirmed the conceptual model which had been described in earlier studies. The Wells G & H Site is a portion of a large, intensely urbanized watershed which is inhabited by more than 50,000 people and has been industrialized for almost two centuries. The Central Area Aquifer comprises a smaller portion of this dynamic regional hydrologic system. It exists under unconfined water table conditions, is hydraulically connected to the Aberjona River, and thus is vulnerable to the wide variety of contaminants and contaminant sources within the Aberjona River watershed. All runoff from the approximately seven square mile Aberjona River drainage basin north of the Salem Street bridge, including the Industri-Plex Superfund Site and the industries, former dumps, and landfills located adjacent to the East Drainage Ditch (Ecology and Environment [E&E], 1982), flows through the Central Area. In addition, ground water which originates within the watershed north of the Salem Street bridge flows toward and through the Central Area Aquifer. Consequently, there is a continuous flow of surface water and ground water from the seven square mile portion of the urbanized Aberjona River watershed through the Central Area.

The hydraulic connection between the Central Area Aquifer and the Aberjona River has previously resulted in the induced infiltration of contaminated Aberjona River surface water into the underlying Central Area Aquifer in response to pumping. Under current hydraulic conditions, with no ground-water pumping from within the Central Area Aquifer, there is a natural ground-water discharge from the Central Area Aquifer to the Aberjona River and associated wetlands. This discharge, which has been determined during one three month period to be about 450 gallons per minute, effectively results in a natural extraction, or natural flushing, of contaminated ground water from the Central Area Aquifer.

Ground-water analyses in the Central Area show exceedances of drinking water standards and guidelines for a variety of chemicals and compounds including inorganic and organic compounds such as arsenic, beryllium, chromium, cadmium, lead, nitrate, benzene, toluene, tetrachloroethene, trichloroethene, and vinyl chloride. These exceedances are pervasive both areally and vertically within the Central Area ground water. The many studies that have been performed have identified multiple sources that contribute contamination to the Central Area. These sources include releases from waste disposal facilities and leaky underground fuel tanks and more widely dispersed releases, such as highway runoff, fertilizer, pesticide and de-icing salt application, and leaky sewers as well as sudden localized releases resulting from leaks or spills and midnight dumping. The numerous contamination sources and historic changes in hydrologic conditions within the Central Area have resulted in widespread distribution of the many types of contaminants, such that it is not possible to define or map individual contaminant plumes for any significant distance. Figure ES-1 illustrates the monitoring well locations where maximum contaminant levels (MCLs) or Massachusetts Secondary MCLs (SMCLs), or Massachusetts Office of Research and Standards Guidelines (ORSGs) have been equaled or exceeded for one or more contaminants. In addition, almost every investigation which has been undertaken to date has shown indications of the presence of previously undetected additional contamination sources. Even if all existing contamination sources within the Central Area could be located and controlled, current land-use activities within the Aberjona River watershed and Wells G & H Site almost guarantee that there will be new additional contamination releases in the future.


N
93
128
95
COMMERCE WAY
MISHAWUM RD
WASHINGTON ST
OLYMPIA AVE
CEDAR ST
WILDWOOD AVE
SALEM ST
UNIFIRST
W.R.GRACE
OLYMPIA
NEP
WILDWOOD
EXPLANATION
AB2
APPLICABLE APPROPRIATE WATER QUALITY REQUIREMENT EQUALED OR EXCEEDED FOR AT LEAST ONE CONTAMINANT
MAXIMUM CONTAMINANT LEVELS EXCEEDED IN SEVERAL WELLS ON SOURCE AREA PROPERTIES
Note : Based on samples collected and analyzed since Jan. 2, 1991
0 100 250 500
SCALE IN FEET
Base Map Prepared By Col-East Inc. At A Scale Of 1 Inch = 100 Feet From April 1990 Aerial Photographs
Modified After Martinage Engineering Associates Inc Nov. 2, 1992
Note: All property lines are approximate
GeoTrans, inc.
GROUNDWATER SPECIALISTS
Figure ES-1
WELLS WHERE APPLICABLE WATER QUALITY CRITERIA ARE EXCEEDED
PREPARED BY : FS
DATE : 1/29/94
CHECKED BY : JRB
REVISED : 2/14/94
DRAWN BY : EHC
DRAWING NO : A8001395.DWG

The Central Area information base is sufficient to conclude that the ROD objective to restore the Central Area Aquifer to drinking water quality (EPA, 1989, p. 35) is technically impracticable and that additional investigations and evaluations directed toward that objective are not warranted.

1 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF REPORT

The Wells G & H Site Central Area Remedial Investigation Phase 1A Report presents a comprehensive evaluation of information relevant to understanding the hydrologic and chemical characteristics of the Central Area. The information which has been evaluated includes hydrogeologic data relevant to understanding the physical framework which controls ground-water flow and chemical transport toward and within the Central Area, and which would permit evaluation of the potential usefulness of remedial action; ground-water quality data which provide information regarding the nature, extent, mobility, persistence, and sources of ground-water contamination; and topical reports and evaluations which describe past, present, and likely future sources of ground-water contamination to the Central Area.

The Phase 1A report considers data and information which were available prior to February 1994. These data and information were obtained through file searches and data reviews; specific field investigation programs which included drilling and well installation, water level measurements, and water quality sampling; and, for information derived from study of the NEP site, review of progress reports regarding RD/RA activities there.

This report is organized as follows. A summary of relevant investigatory history and Source Area (Remedial Design/Remedial Action) RD/RA activities is contained in Chapter 1. Chapter 2 describes the specific information and data collection activities done since January 1992 as part of this Phase 1A investigation as well as other related investigations. Attachment 1 provides a detailed description of the Remedial Investigation (RI) activities which have been done on the Southwest Properties. Chapter 3 presents a conceptual model of the Central Area. The conceptual model includes a discussion of the hydrogeologic setting, contaminant distribution, and known and suspected past, present, and likely future sources of contamination. Chapter 4 provides the conclusions drawn from this study and summarizes the technical basis for those conclusions.

1.2 DESCRIPTION OF THE CENTRAL AREA AND GEOGRAPHIC SUBDIVISIONS

The Central Area Remedial Investigation/Feasibility Study (RI/FS) is directed to Operable Unit Two (OU2) of three Operable Units planned for the Wells G & H Superfund Site. It provides a link between the Operable Unit One (OU1) investigations, which address the five ROD-named Source Area Properties, and the Operable Unit Three (OU3) investigation, the so-called "River Study", which should focus on the Aberjona River and its sediments, tributaries, and wetlands (Decree). Altogether, the three Operable Units were originally designed to provide, if possible, a comprehensive and coordinated evaluation of the Wells G & H Site leading to an effective remedial strategy for the entire Site.

The boundaries of the Central Area have changed since they were first defined in the Wells G & H Site Record of Decision (ROD). In the negotiations which led to entry of the Consent Decree, EPA agreed to perform a study of the Aberjona River and its tributaries and their sediments as well as the associated wetlands to the east of the Aberjona River. This River Study was intended to be coordinated with the Central Area investigations (Decree). Figure 1-1 illustrates the current boundaries of the Central Area and shows the boundaries of the Source Area Properties and the River Study area. The Central Area includes the entire Wells G & H Site with the exception of the five ROD-named Source Area properties and the Aberjona River, its tributaries, and their sediments and associated wetlands on the east side of the Aberjona River. The boundaries between the Central Area and the portions of the Wells G & H Site addressed by OU1 are the individual Source Area Property boundaries. The theoretical division between the Central Area and the Aberjona River system (OU3) has been defined to be the depth of modern sediments below the Aberjona River, its tributaries, and associated wetlands to the east (Decree).

Figure 1-2 illustrates the geographic subdivision which has been adopted for use in describing selected portions of the Central Area. The four geographic areas are the Central Area Aquifer, the Eastern Uplands, the Northeast Quadrant, and the Southwest Properties. The Central Area Aquifer generally refers to the portion of the Central Area which is underlain by permeable outwash deposits. The Eastern Uplands generally refers to the portion of the Central Area located east of the Aberjona River and the Central Area Aquifer. The Eastern Uplands are generally underlain by less permeable till and bedrock. The Northeast Quadrant refers to the portion of the Eastern Uplands which is the focus of the coordinated UniFirst/Grace ground-water remedy. The Southwest Properties refer specifically to three properties located on the western side of the Aberjona River in the southwestern portion of the Central Area. These properties are referred to as the Aberjona Auto Parts, Whitney Barrel, and Murphy Waste Oil properties.

Source Area Property (OU1) investigations and remediation are in progress at four of the five ROD-named Source Area Properties including the New England Plastics, Wildwood, UniFirst, and Grace properties. No RD/RA investigations have been done at the fifth ROD-named Source Area Property, the Olympia Nominee Trust property. The OU1 investigations are relevant to the Central Area investigations because portions of the Central Area will be within the combined capture zones of the long-term remedial action pumping of ground water at the various Source Areas Properties.

Ground-water extraction and treatment systems have operated at the Grace and UniFirst properties for more than 15 months. The individual recovery systems have been designed to provide a coordinated remedy for ground-water contamination at the two individual properties as well as what has been referred to as the Northeast Quadrant of the Wells G & H Site (see Figure 1-2). Performance monitoring data indicate that the coordinated remedial action is effectively dealing with contaminated ground water in the unconsolidated deposits and bedrock beneath the Grace property and in the bedrock beneath the UniFirst property. Evaluations are being made to determine the effectiveness of the UniFirst recovery system on contaminated ground water within the unconsolidated deposits on the UniFirst property. The combined recovery systems have also established a large capture zone which is effectively capturing contaminated ground water from off-property areas. In addition to providing information relevant to evaluating the effectiveness of the individual recovery systems, the extensive monitoring program for these RD/RA activities has also provided information relevant to the Central Area investigations. This information includes water level data which are used to describe the extent of hydraulic capture of the combined systems within the Central Area and ground-water quality data which are used to describe the nature and extent of contamination within portions of the Central Area.

Remedial design and remedial action investigations are currently in progress at the New England Plastics and Wildwood Conservation Trust properties. These investigations will ultimately lead to effective remedies for soil and ground-water contamination at each of these two Source Area Properties. As mentioned previously, there are no known RD/RA investigations or evaluations in progress regarding the Olympia Nominee Trust Source Area Property.

The EPA River Study (OU3) is integral to the Central Area investigations. The overall objectives of the River Study are to determine the nature and extent of surface water, sediment, biota, and wetland contamination and to gather enough data to determine the necessity for, and the extent of, any remedial actions (Ebasco, 1991). Researchers from MIT are currently studying the fate, transport and environmental effects of chemicals within the Aberjona River watershed. Some of the MIT Aberjona River watershed research is currently being done within the boundaries of OU3.

1.3 SUMMARY OF THE HISTORY OF THE ABERJONA RIVER WATERSHED AND RELEVANT INVESTIGATIONS

The Wells G & H Site and areas of the Aberjona River basin that contribute surface water and ground water to the Site have been studied extensively since the late 1950s. Table 1-1 includes the title or description of many of these investigations or studies. The majority of these studies were directed to understanding and characterizing the effects of industrialization and urbanization on surface water and ground-water quality within the Aberjona River watershed. These studies provide information that is relevant to understanding past sources of contamination to the Central Area as well the general vulnerability of the Central Area Aquifer to future contamination.

The many studies have established that the industrialization of the Aberjona River watershed has significantly affected the quality of surface water and ground water. The following discussion first presents an overview of the industrial history of the watershed and then summarizes the well-documented history of contamination within the watershed. This summary of the industrial development of the Aberjona River watershed is derived from a report prepared by Dr. Joel Tarr, a professor of industrial history at the University of Pittsburgh. His original report was included as Appendix B of a 1987 GeoTrans report submitted to EPA on behalf of Grace. In addition, a summary of his report was also contained in a 1989 report submitted to EPA on behalf of UniFirst (Cherry et al., 1989).

1.3.1 Industrial Development History of the Aberjona River Watershed

The numerous studies of the Aberjona River watershed area have documented a long history of industrialization and associated impacts on the watershed region. The watershed upgradient of Salem Street is heavily urbanized and industrialized. It is one of the most industrialized portions of the Upper Mystic Lake watershed. It contains the Industri-Plex Superfund site and has historically been a source of industrial and land use

Table 1-1. Summary of previous reports and investigations

Date	Title or Description	Comments
1958	Report on Improvements to Water Supply of the City of Woburn; Whitman and Howard, Inc.	Recommended not developing public water supplies in Aberjona River Valley because of the presence of industrial pollution
1963	Letter report regarding water supply exploration in East Woburn; Whitman and Howard, Inc.	Pre-installation of test wells for G & H, includes water quality data. Nitrate detected at 6.4 mg/L.
1964	Letter report regarding pumping tests for well in East Woburn; Whitman and Howard, Inc.	Pumping test at site of Well G
1967	CDM Report to Aberjona River Watershed Committee	Identified new pollutants, including wastewater overflows, chloride from street wash and salt stockpiles, and piggery wastes.
1970	Aberjona River Sanitary Survey at Wilmington, Woburn; Winchester, and Stoneham	Investigation of drinking water quality in Aberjona River and its tributaries. Identified additional pollutant sources to the Aberjona River including the Woburn dump, two barrel reclamation facilities and other industrial discharges.

Table 1-1 (continued)

Date	Title or Description	Comments
1978	Report on East Side Water Problems; Dufresne - Henry, Inc.	Investigation of drinking water quality problems
1980	Hydrology and Water Resources of the Coastal Drainage Basins of Northeastern Massachusetts from Castle Neck River, Ipswich, to Mystic River, Boston; Delaney & Gay USGS HA 589	Compilation of water resource information (includes Aberjona River watershed)
1980	Preliminary Site Assessment of Aberjona Auto Parts, 270 Salem St., Woburn, MA; Ecology and Environment, Inc.	Identified the use of chlorinated solvents for degreasing auto parts. Solvent was reportedly disposed of in the MDC sewer.
1980	Preliminary Site Assessment of Whitney Barrel Co., 256 Salem Street, Woburn, Mass; Ecology and Environment, Inc.	Found drums labeled for chlorinated solvents, pesticides, and acids.
1981	Mystic River Comprehensive Hydrologic Study	Discussed impacts of Aberjona River watershed urbanization.
1982	Preliminary Investigation of Surface Water Contamination at the East Drainage Ditch, Wilmington and Woburn; Ecology and Environment, Inc.	Identified VOC contamination of surface water in the railroad drainage ditch and several possible sources of contamination north of the Site. Identified East Drainage Ditch as a likely source of contamination to the Aberjona River.

Table 1-1 (continued)

Date	Title or Description	Comments
1982	Chlorinated Solvent Contamination of the Ground Water, East Central Woburn; Ecology and Environment, Inc.	Identified widespread ground-water contamination in the Aberjona River Valley with a variety of contaminants.
1982	Evaluation of the Hydrogeology and Ground-water Quality of East and North Woburn, Mass; Ecology and Environment, Inc.	Compendium of hydrogeologic information in the Aberjona River Valley.
1983	Environmental Assessment, Woburn Industri-Plex 128 Site; Stauffer Chemical Company	Report of site investigations regarding hazardous waste deposits.
1984	Remedial Investigation, Woburn Industri-Plex 128 Site; Stauffer Chemical Company	Report of site investigations to identify hazardous waste sources and evaluate recommended remedial actions.
1986	ROD Industri-Plex 128 NPL Superfund Site	Soil and ground-water remedies selected; multiple source ground-water response plan (MSGWRP) to investigate other contaminant sources proposed.
1986	Wells G & H Site Remedial Investigation Report, Part 1, Woburn, MA; NUS	Investigation of ground-water contamination in the Wells G & H Site.
1986	Wells G & H Site Remedial Investigation Report, Part II, Woburn, MA; Alliance Technology Corp.	Summarizes soil contamination at Source Areas identified in Part 1 of the RI.

Table 1-1 (continued)

Date	Title or Description	Comments
1986	Wells G & H Wetlands Assessment, Final Report; Alliance Technology Corp.	Mapped and characterized wetlands on the Wells G & H Site.
1987	Review of EPA Report Titled Wells G & H Site Remedial Investigation Report Part 1 Woburn, MA; GeoTrans, Inc.	Identifies limited scope of RI. Summarizes available information regarding sources of pollution within the Aberjona watershed upgradient of the Wells G & H Site.
1987	Area of Influence and Zone of Contribution to Superfund - Site Wells G & H, Woburn, MA; USGS WRI 87-4100	Describes 30-day pumping test of Wells G and H. Evaluates zones of influence and capture of wells G and H.
1988	Supplemental Remedial Investigation for Feasibility Study of Wells G & H Site, Woburn, MA; Ebasco Services, Inc.	Additional investigations of ground-water and soil contamination. Identified significant river contamination.
1988	Site Assessment Report of the former Whitney Barrel Co. site, 256 Salem St., Woburn; GHR Engineering Associates	Investigation of ground-water and soil contamination at former Whitney Barrel site.
1989	Draft Final Feasibility Study Report, Wells G & H Site, Woburn, Massachusetts; Ebasco Services, Inc.	Evaluation of remedial action alternatives for Site.

Table 1-1 (continued)

Date	Title or Description	Comments
1989	Review Comment regarding the US EPA January 1989 Draft Final Feasibility Study Report, Wells G & H Site, Woburn, Massachusetts; GeoTrans, Inc.	W.R. Grace Co. review comments regarding the Final Supplemental RI/FS.
1989	Technical report on the Woburn, Massachusetts Wells G & H Site, Cherry, J.A., Johnson, J.L., Jaeger, R., ENSR, Johnson Company, and Environmental Medicine.	UniFirst comments regarding the Final Supplemental RI/FS.
1989	Comments of Beatrice Food Company concerning USEPA studies and preferred remedy relating to the Wells G & H Superfund Site.	Beatrice Company comments regarding the Final Supplemental RI/FS.
1990	Results of laboratory analyses of soil and ground-water samples from the Murphy Waste Oil Property; Clean Harbors	Identifies contamination of soil and ground water with petroleum hydrocarbons.
1990	The History of Leather Industrial Waste Contamination in the Aberjona watershed: A Mass Balance Approach; Durant et al.	Concludes that a significant portion of metals discharged by the leather industry is still present in the Aberjona watershed.
1990	Pre-Design Investigation, Task GW-1, Phase 1 Interim Report, Industri-Plex Site; Golder Associates	Interim report of investigations.

Table 1-1 (continued)

Date	Title or Description	Comments
1991	Ground-Water/Surface Water Investigation Plan, Phase 1 RI - Final Report, Industri-Plex 128 Site; Roux Associates	Summary of RI results and information to develop remedial alternatives for evaluation.
1991	Remedial Design Investigation Report and Final Design, N.E. Quadrant of the Wells G & H Site, EPC, ENSR, and GeoTrans, Inc.	Investigations in support of the Remedial Design for the N.E. Quadrant. Includes synoptic water quality sampling and water level measurements of most wells in the N.E. Quadrant.
1991	Technical Memorandum, Water Quality Data from Selected Central Area Wells Sampled in August 1991, GeoTrans, Inc.	Synoptic water quality sampling of Central Area wells located on the East side of the Aberjona River.
1991	Technical memorandum, multi-level well installation elevations, Wells G & H Site, Woburn, MA, GeoTrans, Inc.	Evaluation of alternative multi-level well installation techniques.
1992	Full-scale operation of on-site ground-water extraction and treatment systems at UniFirst and Grace	Monthly reports by UniFirst and Grace describing system operation, hydraulic response to pumping, and water quality monitoring
1992	RD/RA Planning at Wildwood, RETEC	Monthly progress reports describing various activities including data collection
1992	RD/RA Planning at New England Plastics, CEI, Inc.	Monthly progress reports describing various activities including data collection

Table 1-1 (continued)

Date	Title or Description	Comments
1992 - 1993	Drive Point and K Well Installation and Sampling	Provided ground-water quality and elevation data for the Eastern Uplands.
Ongoing	MIT Aberjona River watershed studies	Documents extensive migration of arsenic and chromium within the surface water and ground water of the Aberjona River basin
1992 - 1993	Central Area Phase 1A Remedial Investigation, GeoTrans and RETEC	Installation of monitoring wells; sampling and analysis of ground-water samples and surface water samples

pollution to the Aberjona River (Tarr, in GeoTrans, 1987, p. B-33). Historically documented pollution sources include industrial discharge to the Aberjona River or its tributaries such as the East Drainage Ditch, three City of Woburn dumps located adjacent to the Aberjona River, and underground fuel storage tanks. In essence, there are a variety of point and non-point sources of pollution within the watershed which have affected, and will continue to affect, the quality of water in the Central Area Aquifer.

Industrial development within the then predominantly agricultural Aberjona River valley began primarily as a result of the construction of the Middlesex Canal in 1803 (Tarr, in GeoTrans, 1987, p. B-1). From approximately 1814 to the 1850s, the region was dominated by leather processing and related industries. The industries were tanning factories, shoe and boot factories, and machine shops that manufactured equipment for these industries. By the middle 1800s, there were approximately 26 shoe and boot factories and 21 tanning factories.

The introduction of the chemical industry to the region occurred prior to the Civil War. Woburn Chemical Works started operation in 1853 producing chemicals for tanning processes and dyes. By 1899, Woburn Chemical Works had been bought out by Merrimack Chemical Corporation and had become the leading national producer of arsenic pesticides. Industrial wastes were disposed of on-site, and many by-products were stored in slag piles for possible future use. Merrimack Chemical was producing many organic chemicals, including phenol, benzene, toluene, and pyric acid by 1915. During World War I, Merrimack Chemical was involved in coal tar distillation, paint grinding, and the production of trinitrophenol and trinitrotoluene (TNT). After 1929, the factory was rapidly expanded to one of the largest chemical plants in the United States, 415 acres covered by 980 buildings (Cherry et al., 1989).

Concurrent with the development and expansion of the chemical industry during the 1850s to the 1930s was a growth in the tanning and machine shop industries. The advent of chromium tanning processes at the turn of the century enabled these industries to increase production levels tremendously. Again, the industrial wastes were disposed of on site. For the Industri-Plex Site alone, reference is made to an "approximately 80-acre burial ground" which attests to the magnitude of operations of the tanning industry and does not include other factories in the watershed (Cherry et al., 1989).

Starting in approximately 1940, the Woburn area, including the Aberjona River watershed, experienced a diversification of its industrial base to include light industry and manufacturing. The number of tanning operations had decreased to five and there were 14 foundries and machine shops. In 1947, there were five chemical factories producing glue, tallow, fertilizer, and other products.

By 1989, the region contained more than 135 manufacturing firms. Of these firms, 66 to 81 percent were operating within the Aberjona River watershed upgradient of the Salem Street bridge. Table 1-2 contains a partial list of products manufactured by the firms within the watershed. The processes used in production of these products involve the use of a wide variety of chemicals which constitute potential sources for contaminants.

Industrialization of the watershed was accompanied by infrastructure developments, which, as would be expected, affected both surface water and ground-water quality in the water shed. According to the Woburn Department of Public Works, there are approximately 147 miles of road in the City of Woburn, most of which are two lanes wide. Based on areal unitization of the amount of watershed within the City of Woburn, this translates into approximately 240 acres of roadway including 5 miles of Interstate Routes 95 and 93. This is a conservative estimate, given that Reading, Stoneham, and Burlington have not been included in this estimate of acreage of pavement within the watershed (Cherry et al., 1989). Contributions of contaminants from vehicles on these roads as well as road maintenance include salt, petroleum products, PAHs, and lead as well as direct spills from transporting vehicles.

Table 1-2. List of products produced by manufacturers in the Aberjona River watershed

Chemical Factory	Generators	Motor Oil Waste
Electronics	Adhesives	Products
- Microwave	Textile Goods	Petroleum Waste
- Heat Exchanger	Packing Machinery	Products
- Generators	Machine Shops	Lead Fabrication
- Computers	Commercial Printing	Paint
Cosmetics	Wood Laminates	Stone Cuttings
Solvents	Formica	Lighting Fixtures
Perfume	Processed Meats	Manufacturing
Drugs	X-ray Equipment	Wood Preservatives
Graphic Arts	Silk Screening	Anhydrous Ammonia
Leather Manufacturing	Electro-plating	Glass Works
Sheet Metal	Abrasives	Printing
Photographic	Greenhouse Pesticides	Brass Works
Grease	Ceramic Coating	Metals Foundry
Oil	Tires	and Castings
Insulating Material	Metalized Film	Cryogenic Materials
Plastics and Resins	Pest Control Equipment	Rope
Hydraulic Equipment	Tallow	Cleaning Materials
Carpet and Upholstery	Grinding Fluids	Rubber
Cleaners	Chemical Cuttings	Vinyl
Dry Cleaning	Industrial Laminates	
Metal Grinding	Metal Treating	
Infrared Materials		

The occurrence of surface water and ground-water contamination within the Wells G & H Site by sewer surcharging has been documented (GeoTrans, 1987, p. 83; Tarr, in GeoTrans, 1987, p. B-35) and recognized by EBASCO (1988). Of particular concern are the trunk sewer lines that run through the Site just east of the Boston and Maine railroad tracks. Although it is not entirely clear, it appears that the first sewer line was constructed in the 1920s (Tarr, in GeoTrans, 1987, p. B-36). By the late 1920s into the mid-1930s, surcharging caused by the inadequate system and lack of maintenance triggered legal action by the Commonwealth of Massachusetts (Tarr, in GeoTrans, 1987, B-37). In 1947, the Attorney General brought an action against Woburn to prevent it from polluting the Aberjona River with human and industrial wastes (GeoTrans, 1987, p. B-37). The Wilmington extension sewer was built by the Metropolitan District Commission (MDC) in 1961 to relieve the city sewer and provide additional capacity to serve the increasing industrial and residential sewer demands in the north Woburn/ Wilmington area. Given the age of the sewer system and its maintenance history, exfiltration from the sewer should be considered as a past and likely future source of ground-water contamination to the Central Area Aquifer. This conclusion is based on (1) sewer surcharging and historical records indicating that the sewer is, on occasion, pressurized and (2) the age of the sewer casting doubt on the integrity of the system.

1.3.2 History of Observed Contamination of the Aberjona River Watershed

Degradation of water quality within the Aberjona River basin occurred contemporaneously with industrial development in the region. As early as the 1870s, material spent by the tanneries rendered the river useless for domestic purposes. Direct and indirect discharges from the tanneries appear to have been commonplace. Specific citations of pre-1900 pollution include the discharge of ammonia and tar products by the Woburn Gas Company to Russell Brook, which is a tributary to the Aberjona River; discharge of refuse from a glue factory causing serious pollution to the Aberjona River; as well as spent bark liquor (tanning process waste) from the tanneries being discharged to gravel infiltration pits (Tarr, in GeoTrans, 1987, p. B-35, B-37).

At the turn of the century, protest over this pollution resulted in pollution control legislation. The Massachusetts State Board of Health described the Aberjona River and its tributaries north of Upper Mystic Lake in 1906 as "the most seriously polluted stream in the watershed of the Mystic River above Upper Mystic Lake" (Tarr, in GeoTrans, 1987, p. B-9).

From approximately 1920 to World War II, the advent of a sewer system partially mitigated on-site discharges by the tanning and chemical industries. However, chromium wastes generated by the tanning industry were not allowed to be disposed of in the sewers. Consequently, tannery treatment sludge as well as animal by-products were disposed of in private and public dumps. Thus, "throughout the late 1920s, the Aberjona remained extremely polluted from tannery waste" (Tarr in GeoTrans, 1987, p. B-36). In 1924, the Massachusetts State Department of Health (MSDH) prosecuted five tanneries for industrial pollution (GeoTrans, 1987, p. B-36).

Throughout the 1930s, the MSDH focused on pollution from chemical factories and frequent sewage overflows from the municipal sewer system. "Partially spent chemicals" and seepage from pyrite slag deposits were identified by the MSHD as polluting the river (GeoTrans, 1987, p. B-37). The partially spent chemicals came from a chemical plant that produced arsenic-based insecticides, acids, ammonia, sodium salts, and other chemicals. By the last half of the 1930s, the Massachusetts State Department of Health was again concerned with the problems caused by sewage overflow. Conditions were so bad in 1937 that it was necessary to treat the river and part of the Upper Mystic Lake with chlorine. In addition, oil was sprayed on the river surface to prevent the emergence of insects because of the pollution (GeoTrans, 1987, p. B-37).

From the mid-1950s to 1980, numerous investigations and studies performed on the Aberjona watershed identified sources of pollution. These investigations and studies are listed in Table 1-1. During the late 1960s and 1970s, there were numerous complaints regarding the water quality of the Aberjona River. In his analysis of the history of pollution in Woburn, Professor Joel Tarr (Tarr, 1987; see GeoTrans, 1987, Appendix B) indicated that many of the complaints were received from the Town of Winchester which is located downstream of the Wells G & H Site. The complaints resulted in several studies of the Aberjona River watershed. Some of the principal studies were:

- Camp, Dresser and McKee, 1967. Winchester, Massachusetts Aberjona River Watershed Committee, Report on Aberjona River.

- Cady, Robert M., 1970. Aberjona River Sanitary Survey at Wilmington, Woburn, Stoneham, and Winchester, Massachusetts DEQE Report.

- Defeo, Fred L., (date unknown, approximately 1972). The Establishment and Operation of the Aberjona River Commission.

- Warrington, R.A., 1973. Hydraulic Survey of the Aberjona River and Operation of the Aberjona River Commission.

- Massachusetts Water Resources Commission, 1975. Mystic River 1973 Water Quality Analysis.

- Metropolitan Area Planning Council, 1977. Mystic River Basin Preliminary Report.

These studies and other observations identified numerous sources of contamination in the Aberjona River watershed. Sources identified included direct discharge of industrial wastes to the Aberjona River and its tributaries; indirect discharges of leachate from the Woburn dump and landfill and other waste disposal sites into the ground water and surface water of the Aberjona River basin; wastewater overflows containing formaldehyde, acid, and oils from the National PolyChemical plant, a salt stock pile leaching to surface waters, leachate from buried and surface deposits of piggery manure at four sites, sulfate leachate from stock piles on the Stauffer Chemical property, use of pesticides in the watershed, as well as surface water contamination and transport of contaminated sediments as a result of flooding of the Aberjona River and its tributaries and the active excavation and channelization of the Aberjona River drainage system associated with construction of the Industri-Plex 128 area.

From the late 1970s to the present, the major investigations within the Aberjona River watershed have centered around two federal superfund sites, the Industri-Plex Site and the Wells G & H Site with work being done by several investigators and a basin wide watershed chemical fate and transport study being done by researchers at MIT. Studies from both sites have generated data on ground-water and soil chemistry. These data indicate contamination by a wide range of volatile organic, semi-volatile organic, and inorganic compounds including metals. Many of these compounds are listed in the EPA priority pollutants list.

As previously noted, Table 1-1 lists many of the previous investigations conducted within the Wells G & H Site and areas hydraulically upgradient. The table provides general comments regarding the specific investigations or reports. The conceptual model of the Central Area, which is described in Chapter 3, was developed, in part, using information provided by these numerous investigations.

1.4 STATUS OF SOURCE AREA RD/RA ACTIVITIES

1.4.1 Olympia Nominee Trust Property

There have been no RD/RA related activities at this ROD-named Source Area Property.

1.4.2 UniFirst Property

A deep bedrock extraction well (UC22) and an on-site treatment system have been operational since September 1992. The system appears to have been successful in managing migration of contaminated ground water from the bedrock under, and in the vicinity of, the UniFirst and Grace Source Area Properties to the Central Area. UniFirst is evaluating whether ground-water contamination in the unconsolidated deposits on the UniFirst property is being captured by UC22. Monthly reports describing the operation of the UniFirst extraction and treatment system have been submitted to EPA and DEP since system start up. A November 1993 report provides a summary of the first year of system operation (ENSR, 1993).

1.4.3 W.R. Grace Property

A ground-water extraction and treatment system has been operating on the Grace property since September 1992. The system has been successful in managing migration of contaminated ground water from the Grace property in the unconsolidated deposits and shallow bedrock. Reports describing the operation of the on-site system have been submitted to EPA and DEP on a monthly basis since the system became operational. An interpretive report which describes and summarizes the first year of system operation (GeoTrans, 1993) was prepared and submitted to EPA and DEP in November 1993.

1.4.4 New England Plastics Property

The status of RD/RA activities on this Source Area property is documented in monthly reports prepared by Comprehensive Environmental, Inc. (CEI) on behalf of New England Plastics. As of September 30, 1993, the data collection and analysis activities at this property have been directed toward source area soil boring and sampling programs and consideration of soil contamination remedial alternatives. As of December 31, 1993, RD/RA activities were estimated to be 15 percent complete.

1.4.5 Wildwood Property

The status of RD/RA activities at the Wildwood property is documented in monthly progress reports prepared by Remediation Technologies, Inc. (RETEC, 1993a) on behalf of Beatrice. A predesign investigation report describing predesign activities completed at the site was submitted to EPA and DEP in March 1993 (RETEC, 1993b). Debris and the majority of debris soils at the site have been removed. Drums and drum carcasses have been removed from the property. The draft final design of the mixed contaminated soils remedy has been submitted to EPA for approval. Currently, an in situ volatilization pilot study is being conducted along with the remedial design studies for ground-water contamination.

2 CENTRAL AREA RI AND RELATED INVESTIGATIONS

As described in the Draft Work Plan (GeoTrans et al., 1992), several types of investigations were undertaken for this Phase 1A report to fill in data gaps in the previously existing database. These investigations have been ongoing since the completion of the fieldwork for the Northeast Quadrant RD/RA investigations. The investigations, which are described in this section of the report, included:

- review of files of the Massachusetts Department of Environmental Protection (DEP), U.S. Environmental Protection Agency (EPA) and the City of Woburn,

- installation of 188 new monitoring wells at 114 locations,

- evaluation of three alternative monitoring well installation techniques,

- investigations of the Southwest Properties (see Attachment 1),

- ground-water level and stream measurements at 492 wells and four stream locations,

- collection of 728 ground-water and surface water quality samples,

- review of the USGS ground-water flow model, and

- interraction/communication with the MIT Aberjona River watershed research team.

The following section describes the specific tasks which were done and provides some general conclusions and observations regarding those tasks. The results of the investigations were analysed and their significance is described in more detail in Section 3.

2.1 REVIEW OF GOVERNMENTAL AGENCY FILES

Publicly available files of the DEP, EPA and the City of Woburn have been reviewed to evaluate the presence of other sources of contamination to the Central Area. Our review has resulted in identification of more than 47 disposal sites, or contamination sources other than the five ROD-named Source Area Properties, within the portions of the Aberjona River Watershed that contribute surface water and ground water to the Central Area.

The August 1993 DEP List of Confirmed Disposal Sites and Locations to be Investigated (DEP, 1993) was reviewed for sites located in the Aberjona River watershed upstream of Salem Street and in the small Snyder Creek tributary watershed within the Wells G & H Site. Forty seven sites were identified, the locations of which are shown on Figure 2-1. Table 2-1 lists the sites, their current status, and the contaminants identified on the sites. Of the 47 sites, one site is listed by DEP as having implemented remedial response actions. Nine of the sites have implemented either a short-term measure or interim remedial actions. Eight of these sites, including sites with extensive contamination and the presence of gasoline related compounds as non-aqueous phase liquids (NAPL), have been granted "waivers" of DEP approvals under the Massachusetts hazardous waste site cleanup program. By granting these waivers, DEP has made a determination that the aquifer affected by these sites is not a potential drinking water supply aquifer. See former 310 C.M.R. 40.544(2)(c) and subsequent discussion in Section 3.3 of this report.

The DEP Emergency Response Spills and Releases database was also reviewed. The database identifies 190 reported spills and releases of hazardous materials which occurred in the Aberjona River Watershed upstream of Salem Street between 1977 and 1992. Appendix A contains a summary of the reported spills including their location, hazardous material spilled, and quantity spilled. Materials spilled and released include petroleum fuels and oils, solvents, waste oils, paints, transformer oils, metal wastes, pesticides, acids, caustics, and cyanides in quantities from less than a gallon to 5,000 gallons.

2.2 MONITORING WELL INSTALLATION

To evaluate further the nature and extent of contamination in the Central Area, to investigate additional sources of contamination to the Central Area, and to provide additional information regarding geologic conditions and ground-water flow conditions, 188 new monitoring wells and twelve recovery wells have been installed at 114 locations since June 1991. Table 2-2 lists the wells and their installation data. The locations of the monitoring wells are included on Plate 2-1. Appendix B contains a summary of well construction information for all wells used in this investigation, including the new monitoring and recovery wells. Several well construction techniques were used for installation of the new wells to evaluate various multi-level well installation procedures. These new investigations and evaluations have provided sufficient hydrogeologic and water quality data to complete the characterization of the Central Area of the Wells G & H Site.

2.2.1 Multi-Level Well Installation Evaluation

For purposes of evaluating the cost effectiveness of alternative well construction techniques, two well clusters were installed near existing well cluster S90 which is located near former Woburn public supply well H (S39) (see Plate 2-1). One cluster, UG2, was installed by the drive point method and the second cluster, UG4, by the bundle piezometer method. A detailed discussion of the installation of these drive point and bundle peizometers is presented in a technical memorandum, "Multi-Level Well

Installation Evaluation, Wells G & H Site, Woburn, Massachusetts" (GeoTrans, 1991) which was previously submitted to EPA.

Well cluster, UG2, was installed by driving small diameter well points to different depths with a handheld vibratory hammer. The well point was constructed of stainless steel and attached to a steel drive pipe. A polyethylene tube led from the drive point through the steel pipe to the ground surface. Water samples and water level measurements were taken inside the polyethylene tube. Well cluster UG4 was installed by drilling a bore hole with a hollow stem auger to the desired depth of the deepest piezometer. The bundle piezometer was fabricated at land surface prior to installation. The UG4 bundle piezometer was constucted with a central core of a 1-inch threaded PVC pipe and a 2-foot long 0.010 slot screen. Attached to the 1-inch PVC pipe were four 3/8-inch diameter polyethylene tubes with 1-foot perforated sections. The perforated sections of the polyethylene tubes were located at different positions along the PVC pipe. After the entire bundle was assembled, it was installed inside the hollow stem auger and the auger flights were removed allowing for natural collapse of the unconsolidated deposits around the bundle. Variations of both well construction techniques have been used in continuing investigations of the Central Area. Drive point type wells have been installed to identify and investigate additional sources of contamination within the Central Area. A bundle type well, BUG1, was installed of the Wells G & H Site to characterize the vertical hydraulic gradients and to provide screening data regarding the quality of ground water flowing into the Wells G & H Site from the north.

2.2.2 Charrette Property Well Installation

Wells were installed downgradient of the Charrette property to evaluate the nature and extent of ground-water contamination flowing off the Charrette property. The location of the Charrette property within the Central Area is shown as Site 37 on Figure 2-1.

Ground-water contamination by gasoline related compounds and soil contamination by tetrachloroethene had been discovered previously at the Charrette property. This previous investigation is described in the report titled "Phase I Limited Site Investigation, 31 Olympia Avenue, Woburn, Massachusetts" (GZA, 1990). Charrette applied for, and obtained, a waiver of approvals under the Massachusetts Contingency Plan (MCP). In order to grant such a waiver, as explained more fully in Scetion 3.3 below, DEP must have first determined that the Central Area Aquifer, which exists beneath the Charrette property, was not a potential public drinking water supply source. In a subsequent investigation done by GZA, gasoline was found floating on the water table as a NAPL. A leaking pipe associated with an on-site gasoline storage tank was identified as a source of the gasoline release. Six recovery wells were installed and free-phase gasoline collection and removal from one of the recovery wells began in 1990. This investigation is described in the report "Phase II Comprehensive Site Assessment, Charrette Corporation, 31 Olympia Avenue, Woburn, Massachusetts" (GZA, 1992).

To evaluate the concentrations of VOCs in ground water flowing from the Charrette property, four wells were installed by UniFirst and Grace at three off-site locations adjacent to the downgradient Charrette property boundary. The locations of the four wells, and the previously installed wells, are shown on Figure 2-2 and Plate 2-1. The four wells, designated UG5, UG6, UG7S, and UG7D, were installed using the hollow stem auger technique. Continuous samples of the unconsolidated deposits were taken by the Standard Penetration Test as described in ASTM D1586-84. Each of the wells was constructed of 2-inch threaded PVC pipe with a 9-foot long 0.010 slot well screen. At each of the three locations, one well was installed so that the screened interval crossed the water table. A deeper well, UG7D, was also installed. Geologic logs for the UG5, UG6, and UG7 borings are included in Appendix C and well construction diagrams are included in Appendix D.

The samples of the unconsolidated deposits were analyzed for selected VOCs by the headspace technique using a portable gas chromatograph. Results of the soil sample analyses indicate high concentrations of BTEX compounds in soil samples from wells UG6 and UG7. An elevated tetrachloroethene concentration was also detected in a soil sample from the 0 to 2-foot depth in well UG5.

2.2.3 Drive Point Wells

To provide additional information regarding the areal distribution of ground-water contamination, to evaluate the presence of additional contaminant source areas within the Eastern Uplands on the east side of the Aberjona River, and to provide additional water level data to refine interpretations of ground-water flow, 44 drive point type monitoring wells were installed at 38 locations on or near the Cummings properties within the Central Area of the Wells G & H Site. These drive point wells were designated with the prefix DP and are listed in Table 2-2. The construction method of the drive point type wells is described in Section 2.2.1. The dense compact nature of the till in the Eastern Uplands limited the depth of drive point installation. Most of the drive points were only able to be installed to the depth of the water table and, at several locations, the drive points had to be terminated above the water table. Locations of the drive point installations are included on Figure 2-3 and Plate 2-1. Well construction diagrams are included in Appendix D. Because the drive point type wells were installed without drilling a borehole, geologic samples were not collected. Consequently, there are no geologic logs for the drive point well installations.

2.2.4 K Wells

To further evaluate the distribution and sources of contaminants within the Eastern Uplands located on the east side of the Aberjona River and to provide additional water level data to refine interpretations of ground-water flow, 48 monitoring wells were installed at 23 locations during the summer of 1993. These wells were designated with the prefix K (see Table 2-2) and their locations are included on Figure 2-3 and Plate 2-1.

The K wells were constructed by drilling with a hollow stem auger to 2 feet above the desired well depth, then driving the well point to the desired depth. After the well point was driven to the desired depth, the annulus between the casing and borehole wall was backfilled with fine sand to about two feet above the top of the well screen. The annulus was then grouted to the surface with a cement/bentonite grout. The wells were constructed of 1¼-inch diameter stainless steel casing with a 1-foot long stainless steel drive point and screen. Geologic logs of the borings for the K wells are included in Appendix C. Well construction diagrams for the K wells are included in Appendix D.

2.2.5 Northern Boundary Well (BUG1)

To provide additional information regarding the vertical hydraulic gradients at the northern boundary of the Site and to provide screening data regarding the quality of ground water flowing into the Central Area from north of Route 128, a multi-level well (BUG1) was installed on the east bank of the Aberjona River south of Route 128. The location of BUG1 is included on Plate 2-1. BUG1 was installed by drilling a 12-inch diameter hole from the ground surface to refusal, presumably the bedrock surface, by the cable tool method. The depth of the drilled hole was 84 feet. Continuous split spoon samples of the unconsolidated deposits were collected. Eleven individual wells were installed in the 12-inch borehole. The deepest well, BUG1-1, was constructed of 2-inch threaded PVC with a 2-foot well screen. Wells BUG1-2 through BUG1-11 were constructed of ¾-inch threaded PVC with 1-foot long 0.010 slot well screens. Within the sections of the borehole that penetrated fine grained cohesive deposits, sand packs were placed around the screens and bentonite seals were placed between the sand packs. Most of the borehole penetrated well sorted, fine grained sand. Within these sections, the borehole was allowed to collapse naturally around the wells and no bentonite seals were used. The geologic log for BUG1 is included in Appendix C and the well construction diagram is included in Appendix D.

2.2.6 Installation of New Monitoring Wells on Southwest Properties

Ten new ground-water monitoring wells were installed and two previously existing wells were replaced on the three Southwest Properties. Plate 2-1 shows the location of these wells. The overall objective of these wells was to provide data regarding the vertical and horizontal flow of ground water, to identify the vertical and horizontal distribution of contamination within the aquifer, and to provide additional details of the water-table surface and distribution of contamination in the aquifer beneath the Southwest Properties. Three of these wells were installed at locations of existing wells to form well clusters. The remaining seven wells were installed as clusters or as single wells in new locations.

The boreholes for the shallower wells in the unconsolidated deposits (MR-2SS, WB-1SS, S-83SS, MR-1SS, MW-4SS, AB-2SS) were drilled using a 6⅞-inch O.D. hollow-stem auger rig operated by Soil Exploration Corporation of Leominster, Massachusetts. Soil Exploration advanced boreholes for the deeper wells by driving steel casing and washing the borehole (drive-and-wash). The casing diameter was reduced from 6 inches to 5 inches, and finally to 4 inches diameter as necessary with increasing borehole depth. Bedrock was cored using a wire line coring tool inserted through the steel casing.

Monitoring wells were constructed with nominal 2-inch diameter PVC riser and 0.010-inch slotted PVC well screen. Ten-foot long well screens were used to maintain consistency with the existing wells in the area of the Southwest Properties. For mid-aquifer and bedrock wells, the annulus between the borehole and the well screens was backfilled with a filter pack of clean well-rounded silica sand extending 2 feet above the screen. The holes were sealed with a minimum 2-foot bentonite plug. For water-table wells, 6 inches of sand and a minimum 1-foot bentonite plug was placed above the well screen. The remainder of the annulus was filled with a 2 percent bentonite-cement grout mix. A 4-inch diameter, 5-foot steel protective casing with locking cap was set in a cement surface seal. The shallow bedrock wells were constructed using the same procedure except a temporary steel drive casing was seated in the bedrock surface prior to coring the bedrock and installing the well screen. Bentonite was placed in the cored hole from the top of the sand pack to the bedrock surface to isolate the bedrock screened interval from the overlying unconsolidated deposits.

To prevent introduction of contaminants, water added into the boreholes during drilling was obtained from the public water supply. All of the cuttings generated during the well installation process were placed into 55-gallon drums and left on site adjacent to the monitoring well. All downhole equipment was decontaminated by steam cleaning between each location. All water used during the drilling process was collected and placed in 55-gallon drums, and subsequently treated in the on-site water treatment system.

Well logs were maintained during the installation of each well. The soil was classified and any stratigraphic changes were identified. The blow counts required to advance the split spoon in 6-inch increments were recorded. Boring logs and well completion details are included in Attachment 1.

2.3 MASSACHUSETTS INSTITUTE OF TECHNOLOGY STUDIES

Faculty and graduate students at the Massachusetts Institute of Technology (MIT) are conducting a watershed-wide study of the fate and transport of chemicals in the Aberjona River basin. The study is funded by an NIEHS Superfund Basic Research Program grant. A significant study of the distribution and movement of metals, such as arsenic and chromium in the surface water, ground water, and sediments within the basin has been completed. Arsenic and chromium have been found in the water and sediments of the the main stem of the Aberjona River and the sediments of Upper Mystic Lake. The MIT studies have found that the source of the arsenic and chromium is the Industri-Plex Site located north of Route 128.

Analysis of the arsenic mass flux in the river indicates that the arsenic enters the river in contaminated ground water which discharges into the Halls Brook storage area. The mass flux of arsenic in the river where it enters the Wells G & H Site is approximately the same as the flux entering the river from the Industri-Plex Site and is also approximately the same as the flux entering Upper Mystic Lake. Analysis of the wetland sediments adjacent to well H has shown extremely high concentrations of arsenic, greater than 7,000 milligrams per kilogram (mg/kg), within the upper 2 meters of the sediments. Both ground water and surface water have been found to be important transport pathways for the arsenic (Hemond, 1993).

2.4 WATER LEVEL ELEVATION MEASUREMENT

To provide a synoptic view of ground-water elevations and a determination of hydraulic gradients, water level measurements were made at 492 wells and four stream gauges over the entire Wells G & H Site between September 7 and 15, 1993. The measurements were taken by GeoTrans, RETEC, and ENSR staff. A list of the wells, depth-to-water measurements, and resulting water level elevations are presented in Appendix E. These measurement locations are shown on Plate 2-1.

In addition to the September 1993 synoptic water level measurements, periodic water level measurements were made on the Grace, UniFirst, and Wildwood properties in support of the Northeast Quadrant Remedial Action and Wildwood Remedial Design. Water level measurements are also made quarterly in 51 non-Source Area Property wells in the Northeast Quadrant. Water levels in three non-Source Area Property wells, four wells on the UniFirst property, thirteen wells on the Grace property and four wells on the Wildwood property are recorded at 15-minute intervals using pressure transducers and data loggers. Hydrographs for the period September 30, 1992, through September 1993 for all wells measured in support of the Northeast Quadrant Remedial Action have been included in annual reports submitted to EPA in November 1993 by Grace (GeoTrans, 1993) and UniFirst (ENSR, 1993; the Johnson Company, 1993). Monthly and quarterly water level measurements are made manually with electric water level tapes. Periodic manual measurements are made in wells equipped with pressure transducers and data loggers to monitor the performance of the instruments. Both the manual and electronic measurements are made to assess the performance of the pumping systems on the Grace and UniFirst properties.

2.5 WATER QUALITY SAMPLING AND ANALYSIS

There is a long history of ground-water sampling within the Wells G & H Site. Sampling associated with public water supply wells G and H began in 1963 during the exploration for, and development of, well G. Wells G and H were sampled periodically between 1964 and 1979 while they were in use for public water supply. Samples collected during that time were analyzed for selected inorganic compounds, selected metals, and coliform bacteria. The first samples for extractable organic compound analysis were collected in 1977 during explorations in the Central Area Aquifer for a third public water supply well. The first samples for volatile organic compound (VOC) analysis were collected from the Central Aquifer in 1979 when wells G and H were sampled in response to the discovery that barrels containing hazardous waste had been dumped along the banks of the Aberjona River just north of Route 128.

Since 1979, when VOCs were detected in wells G and H, numerous ground-water sampling events have been undertaken within the Wells G & H Site. Most of the sampling that has been conducted since 1979 has been for VOC analysis. Selected samples have been analyzed for semi-volatile organic compounds (SVOCs), metals, and other inorganic compounds.

Groundwater samples collected specifically for the Central Area investigations have been used in conjunction with samples collected for the Source Area RD/RA to evaluate and to characterize the nature and current extent of ground-water contamination. The current extent of contamination, therefore, is based on samples collected since

1991. Data from the entire period of sampling and analysis, however have been used to evaluate trends in contaminant concentrations at selected wells.

As part of this Central Area investigation, several ground-water sampling events have been undertaken to evaluate the nature and extent of ground-water contamination in the Central Area and to evaluate specific sources of contamination to the Central Area. Table 2-3 summarizes the various sampling rounds undertaken at the Site since January 1991. These sampling rounds were done in support of this RI/FS and Source Area RD/RA activities. The results of the long history of ground-water sampling from the Central Area Aquifer indicate that the aquifer has been contaminated with coliform bacteria and inorganic chemicals such as nitrate, sulfate, chloride, and sodium at least as early as the installation of public water supply wells G and H. Sampling and analysis for VOCs indicate that VOC contamination is widespread within and adjacent to the Central Area Aquifer and that there are multiple sources of VOC contamination to the Central Area. SVOC analyses indicate that polynuclear aromatic hydrocarbons (PAHs) are flowing into the Site from the north, east, and west and that there are multiple sources of PAHs within the Site. Surface water, ground-water, and sediment sampling performed by MIT researchers indicate that there is widespread metals contamination of the Aberjona River basin, including the Wells G & H Site, which originates at the Industri-Plex Site north of Route 128. The sampling events conducted for this study are discussed below. The results of the sampling and analysis are discussed in detail in Section 3.2.2 and temporal trends in contamination at selected wells are discussed in Section 3.2.2.6.

2.5.1 August 1991 Sampling

In preparing the Central Area RI/FS Work Plan and as part of the Multi-Level Well Installation Evaluation, ground-water samples were collected from 41 wells at 15 locations on the east side of the Aberjona River in August 1991. Table 2-4 lists the wells sampled in the August 1991 sampling round. The wells sampled are included on

Plate 2-1. This group of wells was selected because the wells either had never been sampled or had not been sampled since 1985. The collected samples were analyzed for VOCs and selected metals and inorganics. Table 2-5 is a list of the analytes for the August 1991 sampling. The results of the analyses are summarized in Appendix F.

In general, the results of the August 1991 sampling indicated that there is widespread ground-water contamination on the eastern side of the Central Area Aquifer. Contaminants included VOCs as well as inorganic compounds and metals.

2.5.2 1992 Drive Point Sampling

To determine the distribution of ground-water contamination in the upper portion of the saturated unconsolidated deposits on the Cummings properties, ground-water samples were collected from 26 drive point type monitoring wells between December 1991 and September 1992. Due to the shallow nature of the drive points, they generally are a screening tool to detect the presence of contamination. Table 2-6 lists the wells sampled and the locations of the wells are included on Plate 2-1 and Figure 2-3. The samples were analysed by CLP methods for VOCs, SVOCs, pesticides, PCBs, triethyl phosphate (TEP), selected metals, and inorganics. The results of the drive point sampling indicate that there are other sources of contamination, in addition to the UniFirst, Grace, and NEP properties, located within the Eastern Upland of the Wells G & H Site. Table 2-7 lists the analytes for the 1992 drive point sampling. The results of the analyses are summarized in Appendix F.

2.5.3 Charrette Well Sampling

After the installation of wells UG5, UG6, UG7S, and UG7D along the down-gradient boundary of the Charrette property, ground-water samples were collected. The samples were analyzed for VOCs by EPA Method 8240. The samples from wells UG6 and UG7S contained high concentrations of gasoline related compounds. The results indicate that ground water containing high concentrations of benzene, toluene, ethylbenzene, and xylenes, and trichloroethene concentrations above its MCL, is found in the Central Area Aquifer beneath and downgradient of the Charrette property. This contamination has resulted from on-site releases to the Charrette property. The results of the analyses are discussed in more detail in Section 3.2.2.1. Appendix F contains a summary of all analytical results.

2.5.4 BUG1 Sampling

Water samples were collected from the Aberjona River and each well in the BUG1 cluster to evaluate the vertical distribution of water quality in the central portion of the Central Area Aquifer and to provide screening data regarding contaminants flowing into the Wells G & H Site from north of Route 128. All samples were analyzed for VOCs by EPA Method 524.2, selected metals and inorganics by CLP methods, and tritium. The samples from BUG1-1 and an Aberjona River water sample were also analyzed for SVOCs, pesticides, PCBs, and total metals. Prior to sampling, the wells were purged with a peristaltic pump. The following water quality parameters were measured in the field: pH, eH, specific conductance, temperature, dissolved oxygen, and turbidity (Table 2-8). The wells were pumped at low pumping rates and samples were collected after each of the field parameters stabilized. Except for turbidity, all water quality sensors were located in flow-through cells through which the water was pumped. The flow-through cells prevented alteration of water chemistry which would have resulted from atmospheric exposure. The results of the analyses of samples from well cluster BUG1 indicate that ground water flowing into the Wells G & H Site from the north is contaminated with several VOCs and naphthalene, and has elevated concentrations of several inorganic compounds.

The sampling results are discussed in more detail in Section 3.2. The analytical results are summarized in Appendix F and copies of the laboratory data reports are included in Appendix G.

2.5.5 Spring 1993 Eastern Uplands Sampling

To evaluate the distribution of contamination in the Eastern Uplands during high water table conditions, ground-water samples were collected from 22 drive points and 21 wells between March 29 and April 28, 1993. Table 2-9 lists the wells sampled. Samples were analyzed for VOCs, SVOCs, nitrate, chloride, and sulfate. The results of these analyses are summarized in Appendix F. Analyses of the samples collected during this sampling round confirmed the assessment of the 1992 drive point sampling that there were other sources of contamination located in the Eastern Uplands in addition to the UniFirst, Grace, and NEP properties. The results from the spring 1993 sampling were used to assist in selection of locations for subsequent installation of the K wells.

2.5.6 1993 Central Area Sampling

Between August 16 and September 3, 1993, ground-water samples were collected from 118 wells at 66 locations in the Wells G & H Site. The wells which were sampled are listed in Table 2-10 and the locations of the wells are included on Plate 2-1. The samples were analyzed for VOCs, SVOCs, metals, total purgeable organic carbon (TPOC), and selected inorganic compounds. A complete list of analytes is presented in Table 2-11. Samples were collected in accordance with procedures described in the Field Sampling Plan (FSP) of the Draft RI/FS Project Operations Plan (POP) so that the data quality objectives as described in the Quality Assurance Project Plan (QAPP) (GeoTrans et al., 1992) could be met. Depending on the type of well construction, monitoring wells were purged as appropriate by inertial pump, peristaltic pump, centrifugal pump, or the specialized sampling equipment for the Solinst multi-level devices. Wells were purged until the field water quality parameters stabilized. The following water quality parameters were measured in the field: pH, eH, specific conductance, temperature, dissolved oxygen, and turbidity (Table 2-8).

The water samples were analyzed by Aquatec Laboratories using the US EPA Contract Laboratory Procedures (CLP) methodology detailed in the QAPP. The TCL organic and TAL inorganic constituents for which these samples were analyzed are included in Table 2-12. A list of non-CLP analytes is included in Table 2-13. The results of the 1993 Central Area sampling indicate that there continues to be widespread contamination of the Central Area with VOCs, inorganic compounds, metals, and SVOCs. The results are discussed in more detail in Section 3.2.2. The analytical results are summarized in Appendix F.

2.5.7 Northeast Quadrant Remedial Action Sampling

To monitor the effectiveness of the ongoing combined UniFirst/W.R. Grace Northeast Quadrant ground-water remediation, 55 monitoring wells have been sampled quarterly for VOC analysis since September 30, 1992. The wells which have been sampled are listed in Table 2-14 and the locations are shown on Figure 2-4. The analytes for the remedial action sampling are listed in Table 2-15. The results of the quarterly sampling are summarized in Appendix F.

2.5.8 Drive Point Profiler Sampling

Between October 3 and 8, 1993, a drive point ground-water sampling device, which was developed at the University of Waterloo and is known as the Ingleton Profiler, was tested (Pitkin, 1993). The profiler allows for collection of ground-water samples at closely spaced depth intervals. The profiler consists of a stainless steel drive point with six radially arranged 5/32-inch diameter ports fitted with stainless steel screens. All six ports empty into a common reservoir in the profiler tip. Stainless steel tubing is coupled to fittings threaded into the reservoir. The stainless steel tubing connects the drive point to the ground surface.

During installation, a hole was first augered manually to a depth of 3 to 6 feet. Target water quality sampling depths were marked on the drill rod. The profiler was then placed in the hole and advanced using an air hammer. Work crews used scaffolding to assist in advancement of the profiler tool. De-ionized water was pumped down the tubing during profiler advancement. As the profiler approached the depth to be sampled, the pump was reversed to begin pumping water to the surface. This procedure was employed to minimize introduction of foreign water into the zone to be sampled and also to minimize cross-contamination with other zones to be sampled. Once the profiler hole was completed to the desired depth, the profiler was withdrawn using a winch and the hole was backfilled by natural collapse.

Three profile holes were completed in October 1993 at locations near existing monitoring well clusters BUG1, S90, and S81. The corresponding profiler identifications are GH1, GH2, and GH3 respectively. Locations of the profiler holes are included on Plate 2-1. Profiler GH1 was advanced only to 79 feet because there was not enough drill rod available and, therefore, it could not be driven to match the 84-foot depth of well BUG1. Profilers GH2 and GH3 were driven to refusal at 41 feet and 33 feet respectively. Difficult driving conditions prevented them from being advanced through the full depth of the unconsolidated deposits. At these locations, the profiler encountered refusal at the depth below ground surface that cobbles and boulders were reported in logs for the nearby monitoring wells.

When the profiler reached a desired sampling depth, a ground-water sample was extracted using a peristaltic pump. Prior to collecting a sample, the ports were developed by purging the profiler. Depending on the flow rate from the profiler, the development was accomplished either by pumping water from the profiler until the water appeared sediment free or surging the profiler by alternately running the pump in forward and reverse to mobilize the sediment around the screen. Because of the very small volume of the profiler, little purging was required. For samples collected from depths less than 46 feet, a minimum of 100 ml was purged. For samples collected from depths greater than 46 feet, a minimum of 150 ml was purged. The ground-water volume required for the analyses was collected in separate sample bottles which were manifolded together. The samples were analyzed for the following parameters:

- VOCs (University of Waterloo - GC)
- VOCs (Commercial Laboratory - EPA Method 624)
- Total non-purgeable organic carbon (University of Waterloo)
- Chloride and nitrate (University of Waterloo)

Thirty samples were collected from profiler location GH1 which is located near well cluster BUG1. Samples were collected at 1.64-foot (0.5-meter) intervals from a depth of 9.8 feet (3 meters) to 49.2 feet (15 meters). Between 49.2 feet (15 meters) and 78.7 feet (24 meters), samples were collected at 3.3-foot (1-meter) intervals. Analysis of the samples indicated that chloride and nitrate were present at concentrations in excess of Massachusetts drinking water standards in some samples.

Twenty two samples were collected from profiler GH2 which is located near well cluster S90, drive point cluster UG2, and bundle piezometer UG4. Samples were collected at 1.64-foot (0.5-meter) intervals between 4.9 feet (1.5 meters) and 41 feet (12.5 meters). Analysis of the samples indicated tetrachloroethene, trichloroethene and nitrate concentrations in excess of Massachusetts MCLs in some samples.

Nineteen samples were collected from profiler location GH3 which is located near well cluster S81. Samples were collected at 1.64-foot (0.5-meter) intervals from a depth of 3.3 feet to 32.7 feet where the profiler reached refusal. Analysis of the samples indicated tetrachloroethene, trichloroethene and chloride concentrations in excess of Massachusetts drinking water standards in some samples.

The field trial of the drive point profiler demonstrated that this technique for sample collection can be useful for detailed one-time analysis of vertical and areal distribution of contamination. The results of sample analyses compared well with the results of sample analyses from adjacent conventional monitoring wells. The profiler allows more detailed vertical sampling than a conventional well. As was the case at locations GH2 and GH3, depth of penetration may be limited by a geologic setting. This technique of ground-water sampling would be useful for either preliminary screening for selection of monitoring wells or for providing detailed water quality information to fill data gaps at sites where there are existing monitoring wells.

2.5.9 Surface Water Sampling

In May and September 1993, samples were collected from the Aberjona River south of Route 128 near monitoring well BUG1. Samples were analyzed for the following parameters:

- VOCs
- SVOCs
- Metals
- Nitrate, nitrite, sulfate, and chloride

The results of the analyses are similar to the results of analyses of samples collected previously by NUS and EBASCO for the Remedial Investigation (NUS, 1986) and Supplemental Remedial Investigation (Ebasco, 1988) and indicate that the Aberjona River, where it enters the Site, is still contaminated with metals and VOCs originating north of Route 128. The results of the analyses are discussed in more detail in Section 3.2. Appendix F contains a summary of the analytical results.

2.6 REVIEW OF USGS MODEL

In accordance with the scope of work in the Central Area RI/FS work plan, we have made a preliminary review of the USGS ground-water flow model (de Lima and

Olimpio, 1989) to determine the applicability of, and utility for, its use as a management tool within the Central Area. The USGS model of the Wells G & H Site is a three-dimensional model which simulates ground-water flow within the unconsolidated deposits. The model was developed using the USGS modular, three-dimensional, finite-difference flow simulator developed by McDonald and Harbaugh (1988).

As applied to the Wells G & H Site, the modeled area is about 0.8 square miles. The unconsolidated deposits are discretized using a variably spaced horizontal grid and three model layers (Figure 2-5). The grid block dimensions in the horizontal direction range from 20 feet to 200 feet. The model bottom is specified to be a no-flow boundary representing the contact between the unconsolidated deposits and the underlying bedrock. The east and west boundaries, specified to coincide with the till/stratified drift or bedrock/stratified drift interface, are defined to be no-flow boundaries. The north and south model boundaries, which cross the aquifer, are also treated as no-flow boundaries. The Aberjona River is treated as a head-dependent flux boundary. The hydrologic conditions defined for the model are based on data collected during the 1985/1986 30-day USGS pumping test of wells G and H and from samples collected during the installation of monitoring wells. The model was calibrated, under steady-state and transient conditions, to water level measurements made prior to and during the 30-day USGS pumping test.

In concept, a model such as the USGS model of the Wells G and H Site could be useful as a management tool to evaluate the hydraulic response expected to result from certain remedial actions, particularly the combined effects of ground-water extraction from the Source Area properties. In actuality, the utility of model analyses is highly dependent upon the representativeness of model approximations to actual conditions. For applications related to the Wells G & H Site, the existing USGS model is not expected to be directly applicable or useful because certain boundary condition approximations of the existing model are inconsistent with known hydraulic conditions. In particular, the existing model does not consider ground-water flow within the bedrock, nor does it consider lateral flow into the Wells G and H Site from the north or lateral flow out of the Site to the south. Prior to application to the Wells G & H Site, the USGS model would, at a minimum need to be revised to incorporate these hydrologic conditions and subsequently recalibrated. Notwithstanding the potential utility of the USGS model to evaluate the combined effects of ground-water extraction from the Source Area Properties, the well-understood hydraulic connection between the Aberjona River and the Central Area Aquifer and the equally well-understood nature and extent of contamination within the Central Area Aquifer obviate the need for model analyses to evaluate remediation of the Central Area Aquifer.

Table 2-1. DEP identified waste disposal sites within the Aberjona River Watershed upstream of Salem Street

Map* Site No.	Site Name	DEP No.	Site Status	Primary Contaminant
1	Ritter Trucking	3-0009	Phase 5	VOC
2	3-M	3-1786	Remedial	PEST
3	Acme Printing Co.	3-3797	Waiver	VOC
4	AGFA Corp.	3-3688	Phase 1	VOC/ PEST
5	Raffi & Swanson	3-0470	Waiver	VOC
6	H.B. Fuller Co.	3-0498	Phase 1	VOC
7	Commercial Property	3-3684	P.A.	VOC/SVOC
8	United Tool & Die	3-4168	P.A.	VOC
9	Olin Chemical	3-0471	Waiver	VOC/SVOC/I
10	Commercial Prop/Ind	3-4336	P.A.	I/PET/PEST
11	Michienzi Const.	3-0488	Phase 1	VOC
12	McLean Trucking	3-1715	Waiver	VOC
13	No. Woburn Ind. Park	3-0150	Phase 2	VOC
14	Property	3-2079	Waiver	VOC
15	Property	3-2147	Phase 1	I
16	MBTA Property	3-1735	Remedial	I
17	Weyerhauser	3-0595	Phase 2	VOC/SVOC
18	Digital Equip. Corp.	3-4105	P.A.	VOC/PET
19	Getty Service Station	3-4067	P.A.	VOC/I/PET
20	Motors, Elec. & Contr.	3-3961	Phase 1	VOC
21	Woburn Mall	3-3794	Waiver	I/VOC
22	Winn Trucking	3-0480	Phase 2	VOC/I

Table 2-1 (continued).

Map* Site No.	Site Name	DEP No.	Site Status	Primary Contaminant
23	Industrial Property	3-1890	Phase 1	I/PET
24	Industrial Building	3-0507	Phase 1	VOC
25	Industrial Property	3-1966	Phase 1	VOC/I
26	Destefano Studios	3-2642	P.A.	VOC/I
27	Continental Chem.	3-0478	Phase 4	VOC
28	Chomerics	3-0121	Phase 1	VOC
29	Hilltop Const.	3-0854	Phase 1	VOC
30	Former Ace Disposal	3-1861	Waiver	VOC
31	Globe Ticket Company	3-0671	Phase 1	I
32	Gorchev Photo	3-0151	Phase 1	VOC
33	Property	3-4015	P.A.	PET
34	Ames	3-3218	P.A.	PET
35	Industrial Property	3-0507	P.A.	VOC
36	Aberjona Auto Parts	3-1146	P.A.	VOC
37	Charrette	3-3377	Waiver	PET/VOC
38	Whitney Barrel	3-0534	Phase 2	VOC/PEST
39	DOWD Enterprise	3-1063	P.A.	File missing from DEP
40	Industri-Plex	3-1731	Phase 4	I/VOC
41	Murphy Waste Oil	3-2198	P.A.	VOC/PET
42	Property	3-1736	P.A.	File missing from DEP
43	Romicon, 20 Normac Road	3-4186	P.A.	VOC, SVDC, I

Table 2-1 (continued).

Map* Site No.	Site Name	DEP No.	Site Status	Primary Contaminant
44	Romicon, 100 Cummings Park	3-4185	P.A.	VOC, SVDC, I
45	Woburn Steel Drum	3-1738	P.A.	File missing from DEP
46	Dundee Park	3-0474	Phase 1	I
47	Carolina Trucking	3-3272	Waiver	PET/VOC

*Site locations are shown on Plate 2-1.

PA	Preliminary assessment
Phase 1	Initial site assessment
Phase 2	Comprehensive site assessment
Phase 4	Remedial response implementation plan
Phase 5	Remediation
VOC	Volatile organic compounds
SVOC	Semi-volatile organic compound
PEST	Pesticides and PCBs
PET	Petroleum
I	Metals and other inorganics
Remedial	Remediation in progress

Table 2-2. Monitoring wells installed within the Wells G & H Site since January 1992

Well Name	Installation Date	Company Installed For
AB2M	12 August 1993	Beatrice
AB2R	10 August 1993	Beatrice
AB2SS	3 August 1993	Beatrice
BDW6	14 April 1993	Beatrice
BMW17	9 April 1993	Beatrice
BOW15	2 September 1992	Beatrice
BOW16	25 August 1992	Beatrice
BSSW15	10 September 1992	Beatrice
BSSW16	25 August 1992	Beatrice
BSSW17	9 April 1993	Beatrice
BSSW5	16 September 1992	Beatrice
BUG1-1	23 April 1993	Beatrice, UniFirst & Grace
BUG1-2	23 April 1993	Beatrice, UniFirst & Grace
BUG1-3	23 April 1993	Beatrice, UniFirst & Grace
BUG1-4	23 April 1993	Beatrice, UniFirst & Grace
BUG1-5	23 April 1993	Beatrice, UniFirst & Grace
BUG1-6	23 April 1993	Beatrice, UniFirst & Grace
BUG1-7	23 April 1993	Beatrice, UniFirst & Grace
BUG1-8	23 April 1993	Beatrice, UniFirst & Grace
BUG1-9	23 April 1993	Beatrice, UniFirst & Grace
BUG1-10	23 April 1993	Beatrice, UniFirst & Grace
BUG1-11	23 April 1993	Beatrice, UniFirst & Grace

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
BW2R	9 September 1992	Beatrice
BW5R	16 September 1992	Beatrice
BW6R	21 September 1992	Beatrice
BW15R	8 September 1992	Beatrice
BW16R	24 August 1992	Beatrice
BW17R	7 April 1993	Beatrice
CHM9	3 October 1992	Charrette
CHM10	24 April 1992	Charrette
CHM11	24 April 1992	Charrette
CHM12	24 April 1992	Charrette
CHM13	27 April 1992	Charrette
CHM14	27 April 1992	Charrette
DP1D	December 1991	UniFirst
DP1S	December 1991	UniFirst
DP2D	December 1991	UniFirst
DP2M	December 1991	UniFirst
DP2S	December 1991	UniFirst
DP3	December 1991	UniFirst
DP4	9 January 1992	UniFirst
DP5	9 January 1992	UniFirst
DP6D	9 January 1992	UniFirst
DP6S	10 January 1992	UniFirst
DP7	10 January 1992	UniFirst

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
DP8	13 January 1992	UniFirst
DP9D	16 January 1992	UniFirst
DP9S	16 January 1992	UniFirst
DP10	17 January 1992	UniFirst
DP11	20 January 1992	UniFirst
DP12	21 January 1992	UniFirst
DP13	21 January 1992	UniFirst
DP14	22 January 1992	UniFirst
DP15	23 January 1992	UniFirst
DP16	24 January 1992	UniFirst
DP17	27 January 1992	UniFirst
DP18D	29 January 1992	UniFirst
DP18S	28 January 1992	UniFirst
DP19	30 January 1992	UniFirst
DP20	30 January 1992	UniFirst
DP21D	3 February 1992	UniFirst
DP21S	3 February 1992	UniFirst
DP22	5 February 1992	UniFirst
DP23	6 February 1992	UniFirst
DP24D	7 February 1992	UniFirst
DP24S	7 February 1992	UniFirst
DP25	10 February 1992	UniFirst
DP26	13 February 1992	UniFirst

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
DP27	14 February 1992	UniFirst
DP28	15 February 1992	UniFirst
DP29	15 February 1992	UniFirst
DP30	15 February 1992	UniFirst
DP31	17 February 1992	UniFirst
DP32	18 February 1992	UniFirst
DP33	18 February 1992	UniFirst
DP34	19 February 1992	UniFirst
DP35	19 February 1992	UniFirst
DP36	20 February 1992	UniFirst
DP37D	20 February 1992	UniFirst
DP37S	20 February 1992	UniFirst
DP38	21 February 1992	UniFirst
DP39	25 February 1992	UniFirst
DP40	27 February 1992	UniFirst
DP41	29 February 1992	UniFirst
G2DB	8 January 1992	Grace
G2DB2	23 December 1991	Grace
K42D	20 July 1993	UniFirst
K42M	21 July 1993	UniFirst
K42S	16 July 1993	UniFirst
K43D	1 July 1993	UniFirst
K43S	1 July 1993	UniFirst

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
K44D	30 June 1993	UniFirst
K44S	30 June 1993	UniFirst
K45	19 July 1993	UniFirst
K46	1 July 1993	UniFirst
K47	1 July 1993	UniFirst
K48	7 July 1993	UniFirst
K49D	6 July 1993	UniFirst
K49M	6 July 1993	UniFirst
K49S	6 July 1993	UniFirst
K50	7 July 1993	UniFirst
K51D	2 July 1993	UniFirst
K51M	6 July 1993	UniFirst
K53D	13 July 1993	UniFirst
K53M	14 July 1993	UniFirst
K54D	13 July 1993	UniFirst
K54M	14 July 1993	UniFirst
K55D	8 July 1993	UniFirst
K55M	12 July 1993	UniFirst
K55S	12 July 1993	UniFirst
K56D	8 July 1993	UniFirst
K56M	12 July 1993	UniFirst
K56S	17 July 1993	UniFirst
K57D	15 July 1993	UniFirst

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
K57M	15 July 1993	UniFirst
K57S	16 July 1993	UniFirst
K58D	16 July 1993	UniFirst
K58S	15 July 1993	UniFirst
K59D	27 August 1993	UniFirst
K59S	27 August 1993	UniFirst
K60D	5 October 1993	UniFirst
K60M	6 October 1993	UniFirst
K60S	6 October 1993	UniFirst
K61D	7 October 1993	UniFirst
K61M	8 October 1993	UniFirst
K61S	11 October 1993	UniFirst
K62D	14 October 1993	UniFirst
K62M	15 October 1993	UniFirst
K62S	16 October 1993	UniFirst
K63D	12 October 1993	UniFirst
K63M	12 October 1993	UniFirst
K63S	13 October 1993	UniFirst
K64D	16 October 1993	UniFirst
MR1SS	16 August 1993	Beatrice
MR2SS	13 August 1993	Beatrice
MW4D	24 August 1993	Beatrice
MW4M	24 August 1993	Beatrice

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
MW4SS	20 August 1993	Beatrice
RMW1	6 December 1991	Romicon
RMW2	6 December 1991	Romicon
RMW3	6 December 1991	Romicon
RW11	11 June 1992	Grace
RW12	12 June 1992	Grace
RW13	12 June 1992	Grace
RW14	16 June 1992	Grace
RW15	17 June 1992	Grace
RW16	18 June 1992	Grace
RW17	18 June 1992	Grace
RW18	19 June 1992	Grace
RW19	22 June 1992	Grace
RW20	23 June 1992	Grace
RW21	23 June 1992	Grace
RW22	26 June 1992	Grace
S83SS	2 August 1993	Beatrice
S83M	17 August 1993	Beatrice
UC6S	23 September 1992	UniFirst
UC10D	23 September 1992	UniFirst
UC10M	24 September 1992	UniFirst
UC10S	24 September 1992	UniFirst
UC19M	22 September 1992	UniFirst

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
UC19S	21 September 1992	UniFirst
UC24D	22 September 1992	UniFirst
UC24S	21 September 1992	UniFirst
UC25	23 September 1992	UniFirst
UC26D	2 December 1993	UniFirst
UC26S	7 December 1993	UniFirst
UC29D	7 December 1993	UniFirst
UC29S	8 December 1993	UniFirst
UC30	9 December 1993	UniFirst
UC31D	13 December 1993	UniFirst
UC31M	10 December 1993	UniFirst
UC31S	14 December 1993	UniFirst
UG2-1	8 June 1991	UniFirst & Grace
UG2-2	8 June 1991	UniFirst & Grace
UG2-3	8 June 1991	UniFirst & Grace
UG2-4	8 June 1991	UniFirst & Grace
UG3-1	8 June 1991	UniFirst & Grace
UG4-1	13 June 1991	UniFirst & Grace
UG4-2	13 June 1991	UniFirst & Grace
UG4-3	13 June 1991	UniFirst & Grace
UG4-4	13 June 1991	UniFirst & Grace
UG4-5	13 June 1991	UniFirst & Grace
UG5	1 February 1993	UniFirst & Grace

Table 2-2 (continued).

Well Name	Installation Date	Company Installed For
UG6	1 February 1993	UniFirst & Grace
UG7D	2 February 1993	UniFirst & Grace
UG7S	1 February 1993	UniFirst & Grace
WB1M	20 August 1993	Beatrice
WB1SS	19 August 1993	Beatrice

Table 2-3. Summary of Central Area ground-water sample collection

Sampling Round	# Wells Sampled	Analytes
August 1991	41	VOCs, Selected Metals & Inorganics
1992 Drive Points	26	VOCs, SVOCs, Pesticides, PCBs, Selected Metals & Inorganics
1992 Wildwood RD/RA Sampling	60	TCL Organics and TAL Inorganics
1993 Charrette Well Sampling	4	VOCs
1993 BUG 1	11 and Aberjona River	VOCs, SVOCs, Selected Metals, Inorganics, and Tritium
1993 Central Area Sampling	118 and Ajerjona River	VOCs, SVOCs, Pesticides, PCBs, Selected Metals & Inorganics
Spring 1993 Eastern Uplands Sampling	39	VOCs and selected inorganics

Table 2-4. Wells sampled in August 1991

S39	S84D	S87D	S90M	S93S	UG2-4
S40	S84M	S87M	S90S	S94D	UG4-1
S68D	S84S	S87S	S91D	S94M	UG4-2
S68S	S85M	S89D	S91M	S94S	UG4-3
S72D	S85S	S89M	S91S	UG2-1	UG4-4
S72M	S86D	S89S	S93D	UG2-2	UG4-5
S72S	S86S	S90D	S93M	UG2-3	

The locations of these wells are included on Plate 2-1.

Table 2-5. Analytes and compounds analyzed for in August, 1991, pre-Work Plan sampling

Inorganic and Other Analytes	VOAs 624 w/25-ml Purge (low level detection)
Arsenic (dissolved and total) Chloride Chromium (dissolved and total) Lead (dissolved and total) Nitrate Nitrite Phosphate Sodium (dissolved and total) Sulfate Total dissolved solids Total organic carbon	Chloromethane Bromomethane Vinyl chloride Chloroethane Methylene chloride Acetone Carbon disulfide 1,1-Dichloroethene 1,1-Dichloroethane 1,2-Dichloroethene (total) Chloroform 1,2-Dichloroethane 2-Butanone 1,1,1-Trichloroethane Carbon Tetrachloride Vinyl acetate Bromodichloromethane 1,2-Dichloropropane cis-1,3-Dichloropropene Trichloroethene Dibromochloromethane 1,1,2-Trichloroethane Benzene Trans-1,3-dichloropropene Bromoform 4-Methyl-2-pentanone 2-Hexanone Tetrachloroethene 1,1,2,2-Tetrachloroethane Toluene Chlorobenzene Ethylbenzene Styrene Xylenes (total)

Table 2-6. Wells sampled, December 1991 - June 1992

DP1	DP13	DP31
DP2	DP14	DP32
DP3	DP18S	DP36
DP6S	DP19	DP37S
DP7	DP20	DP38
DP8	DP21S	DP39
DP9S	DP22	DP40
DP10	DP24S	DP41
DP11	DP26	
DP12	DP29	

See Figure 2-2 and Plate 2-1 for well locations.

Table 2-7. December 1991 - June 1992 sampling analyte list

Acetone	Benzo(b)fluoranthene	PCB-1260
Benzene	Benzo(g,h,i)perylene	Aldrin
Bromoform	Benzo(k)fluoranthene	Alpha-BCH
Bromomethane	bis-(2-Chloroethoxy)methane	Beta-BCH
2-Butanone	bis-(2-Chloroethyl)ether	Delta-BCH
Carbon disulfide	bis(2-Chloroisopropyl)ether	Gamma-BCH
Carbon tetrachloride	bis(2-Ethylhexyl)phthalate	4,4'-DDD
Chlorobenzene	4-Bromophenyl phenyl ether	4,4'-DDE
Dibromochloromethane	Butyl benyl phthalate	4,4'-DDT
Chloroethane	4-Chloroaniline	Dieldrin
Chloroform	2-Chloronaphthalene	Endosulfan I
Chloromethane	4-Chlorophenyl phenyl ether	Endosulfan II
Bromodichloromethane	Chrysene	Endosulfan sulfate
Dichlorodifluoromethane	Dibenz(a,h)anthracene	Endrin
1,1-Dichloroethane	Dibenzofuran	Endrin ketone
1,2-Dichloroethane	1,2-Dichlorobenzene	Haptachlor
1,1-Dichloroethylene	1,3-Dichlorobenzene	Heptachlor epoxide
Cis-1,2-dichloroethylene	1,4-Dichlorobenzene	Methoxychlor
Trans-1,2-dichloroethylene	3,3'-Dichlorobenzidine	Toxaphene
1,2-Dichloropropane	Diethyl phthalate	alpha-Chlordane
Cis-1,3-dichloropropylene	Dimethyl phthalate	gamma-Chlordane
Trans-1,3-dichloropropylene	Di-n-butyl phthalate	Aldicarb sulfoxide
Ethylbenzene	2,4-Dinitrotoluene	Aldicarb sulfone

Table 2-7 (continued).

2-Hexanone	2,6-Dinitrotoluene	Oxymyl
Methylene chloride	Di-n-octyl phthalate	Methomyl
4-Methyl-2-pentanone	Fluoranthene	3-Hydroxycarbofuran
Styrene	Fluorene	Aldicarb
1,1,2,2-Tetrachloroethane	Hexachlorobenzene	Baygon
Tetrachloroethylene	Hexachlorobutadiene	Carbofuran
Toluene	Hexachlorocyclopentadiene	Carbaryl
1,1,1-Trichloroethane	Hexachloroethane	Methiocarb
1,1,2-Trichloroethane	Indeno(1,2,3-c,d)pyrene	Azinphos methyl
Trichloroethylene	Isophorone	Bolstar
Trichlorofluoromethane	2-Methylnaphthalene	Chlorpyrifos
Vinyl chloride	Naphthalene	Coumaphos
Xylene (total)	2-Nitroaniline	Demeton, o and s
1,2-Dibromoethane	3-Nitroaniline	Diazinon
1,1,1,2-Tetrachloromethane	4-Nitroaniline	Dichlorvos
1,2-Dichloroethylene (total)	Nitrobenzene	Dimethoate
Methanol	n-Nitrosodi-n-propylamine	Disulfoton
Isopropylbenzene	n-Nitrosodiphenylamine	EPN
Bromobenzene	Phenanthrene	Ethoprop
1,2,3-Trichloropropane	Pyrene	Fensulfothion
n-Propylbenzene	1,2,4-Trichlorobenzene	Fenthion
2-Chlorotoluene	Carbazole	Malathion
4-Chlorotoluene	p-Chloro-m-cresol	Merphos
1,3,5-Trimethylbenzene	2-Chlorophenol	Mevinphos
Tert-butylbenzene	2,4-Dichlorophenol	Nalad
1,2,4-Trimethylbenzene	2,4-Dimethylphenol	Parathion-ethyl

Table 2-7 (continued).

Sec-butylbenzene	4,6-Dinitro-2-methylphenol	Parathion-methyl
4-Isopropyltoluene	2,4-Dinitrophenol	Phorate
n-Butylbenzene	2-Methylphenol	Ronnel
1,2-Dibromo-3-chloropropane	4-Methylphenol	Sulfotep
1,2,3-Trichlorobenzene	2-Nitrophenol	Stirophos
2,2-Dichloropropane	4-Nitrophenol	Tokuthion
Bromochloromethane	Pentachlorophenol	Trichloronate
1,1-Dichloropropene	Phenol	TEP
Dibromomethane	2,4,5-Trichlorophenol	Arsenic, total
1,3-Dichloropropane	2,4,6-Trichlorophenol	Beryllium, total
Ethyl alcohol	PCB-1016	Cadmium, total
Acenaphthene	PCB-1221	Chromium, total
Acenaphthylene	PCB-1232	Lead, total
Anthracene	PCB-1242	Chloride
Benzo(a)anthracene	PCB-1248	Nitrate
Benzo(a)pyrene	PCB-1254	Sulfate

Table 2-8. BUG1 and 1993 Central Area sampling, water quality parameters measured in the field

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
Aberjona River	5/11/93	21.6	7.1	-37	616	6.0	
Aberjona River	9/30/93	12.8	6.0	156	1794	5.2	82.3
BUG1-1	8/31/93	13.1	6.8	-101	1104	1.3	
BUG1-1	5/11/93	15.1	7.0	-81	1120	0.2	>200
BUG1-2	5/10/93	12.8	6.9	-110	220	0.2	35.9
BUG1-3	5/10/93	11.7	7.0	-94	650	0.1	42.1
BUG1-4	5/10/93	11.6	7.4	-128	396	0.2	39.5
BUG1-4	8/31/93	15.0	7.1	-111	839	1.4	
BUG1-5	5/10/93	11.6	7.1	-122	362	0.2	41.5
BUG1-6	5/11/93	12.5	6.7	-93	227	0.2	48.6
BUG1-7	5/11/93	14.5	6.6	-100	551	0.2	44.4
BUG1-7	8/31/93	16.0	6.2	-44	609	2.7	2.7
BUG1-8	5/11/93	13.7	6.7	-113	380	0.1	49
BUG1-8	8/31/93	16.4	6.3	-63	754	4.0	
BUG1-9	5/11/93	13.2	6.3	-76	440	0.1	51.3
BUG1-10	5/11/93	11.5	6.3	-35	409	0.5	44
BUG1-11	5/11/93	12.9	7.0	-134	575	0.5	39.8
DP1D	8/5/93	19.9	6.86		913		
DP1S	8/5/93	22.9	6.48		1095		
DP2D	8/11/93	18.4	6.85		113		
DP2M	8/11/93	18.8	7.05		109		
DP2S	8/11/93	19.4	6.85		108		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
DP3	8/11/93	21.1	7.78		32		
DP6D	8/9/93	22.8	6.53		491		
DP6S	8/9/93	21.4	5.75		602		
DP7	8/9/93	24.5	6.28		484		
DP10	8/3/93	25.7	6.61		1441		
DP11	7/30/93	28.1	5.40		1800		
DP12	7/30/93	23.2	6.20		2530		
DP18D	8/2/93	21.3	6.88		695		
DP18S	8/2/93	30.6	5.12		882		
DP19	8/3/93	24.6	6.05		487		
DP20	8/2/93	33.7	6.55		953		
DP21D	8/2/93	27.0	6.20		1160		
DP21S	7/29/93	25.9	6.00		1529		
DP22	8/2/93	28.4	6.62		1595		
DP26	8/6/93	26.2	5.19		388		
DP31	8/3/93	30.2	6.11		668		
DP32	8/2/93	23.9	6.75		334		
DP35	7/30/93	25.3	6.20		1460		
DP36	8/5/93	33.0	6.74		1217		
DP37D	8/5/93	21.1	6.60		1115		
DP37S	8/5/93	21.8	6.47		1147		
DP38	8/2/93	24.8	6.16		2560		
DP39	8/3/93	29.6	6.20		920		
DP40	7/30/93	32.6	5.40		267		
DP41	8/3/93	27.2	5.70		236		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
DP42D	8/6/93	26.9	6.75		417		
GO1D	8/10/93	13.8	6.57				
GO1DB	8/10/93	14.5	7.04				
K42M	7/27/93	18.1	6.29		386		
K42S	7/27/93	18.7	6.07		918		
K43D	7/22/93	15.9	6.95		1524		
K43D	9/2/93	16.2	6.40		1282		
K43S	7/22/93	23.1	6.78		1392		
K43S	9/7/93	18.3	5.76		2690		
K44D	7/26/93	18.1	6.73		1670		
K44D	8/10/93	24.3	7.03		182		
K44S	8/10/93	24.2	7.32		167		
K45	7/22/93	25.5	6.11		1463		
K45	9/8/93	18.3	6.09		1485		
K46	7/27/93	28.1	5.96		1039		
K46	9/10/93	21.2	6.07		1702		
K47	7/22/93	20.9	5.72		1191		
K47	9/7/93	20.4	6.50		1194		
K48	7/27/93	34.2	6.33		507		
K48	9/9/93	19.1	6.35		424		
K49D	7/23/93	19.7	6.39		1375		
K49D	9/8/93	17.3	7.00		1027		
K49M	7/23/93	21.0	6.90		1178		
K49M	9/8/93	18.3	7.17		1008		
K49S	9/8/93	20.9	8.60		680		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
K50	7/23/93	18.5	6.90		1583		
K50	9/9/93	17.8	6.49		1157		
K51D	7/27/93	27.0	6.57		665		
K51D	7/30/93	23.9	7.40		1870		
K51D	9/2/93	18.3	5.10		507		
K51	9/7/93	16.8	6.30		732		
K51M	7/23/93	17.5	6.66		807		
K51M	9/8/93	17.2	5.71		526		
K53D	7/23/93	22.5	7.01		298		
K53D	9/16/93	16.7	6.82		383		
K53M	7/23/93	23.3	6.83		496		
K53M	9/9/93	16.4			630		
K54D	7/23/93	26.1	6.30		320		
K54D	9/7/93	17.0	6.54		270		
K54M	7/27/93	19.2	5.50		368		
K54M	9/7/93	19.6	5.62		374		
K55D	7/26/93	16.9	7.25		470		
K55D	9/2/93	17.8	6.93		460		
K55M	7/30/93		11.40				
K55M	9/9/93	20.0	11.75		3340		
K56D	7/26/93	21.7	6.05		399		
K56D	9/10/93	17.7	8.89		5497		
K56M	7/26/93	20.2	6.56		564		
K56M	9/10/93	18.4	8.34		475		
K57D	7/27/93	17.3	5.80		272		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
K57D	9/10/93	17.3	7.57		447		
K58D	7/28/93	20.8	7.97		661		
K58D	9/8/93	16.1	7.52		712		
K58S	7/28/93	28.6	9.15		384		
K59D	9/9/93	22.1	7.55		1625		
K59S	9/9/93	25.1	6.59		1515		
RMW-1	7/30/93	24.7	6.00		1341		
RMW-1	9/8/93	19.1	6.31		1288		
RMW-2	7/30/93	27.8	6.01		1253		
RMW-2	9/8/93	20.3	5.77		1620		
S6	8/10/93	18.4	6.50		781		
S7	7/30/93	17.9	6.33		1557		
S21	8/10/93	22.1	6.52		426		
S22	8/9/93	16.2	6.34		595		
S40	8/21/91	11.6	7.0	-60	467		
S63D	8/10/93	13.2	6.34				
S63S	8/10/93	17.2	6.4				
S64D	8/11/93	15.9	6.75		703		
S64M	8/11/93	14.7	6.81		505		
S64S	8/11/93	14.2	7.19		439		
S65DR	8/11/93	19.1	7.31		103		
S65M	8/6/93	18.8	6.62		412		
S66D	5/16/93	18.3	6.09		570		
S66D	8/11/93	17.9	7.72		344		
S66D	8/30/93	17.8	7.01		570		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
S66D	9/20/93	18.6	7.05		580		
S67D	8/6/93	21.1	7.27		298		
S67M	8/6/93	18.3	6.79		436		
S67S	8/6/93	17.1	6.68		369		
S68D	8/21/91	11.1	6.5	18	279		
S68S	8/21/91	11.5	6.0	37	502		
S69	8/4/94	20.5	6.76		578		
S70S	8/5/93	20.7	5.59		2060		
S71D	8/12/93	17.3	6.75		800		
S71S	8/11/93	22.1	11.03		171		
S72D	8/21/91	16.8	7.2	-41	379		
S72D	8/30/93	12.7	7.8		538	1.2	
S72M	8/21/91	12.3	6.5	20	799		
S72M	8/30/93	13.3	6.7		741	0.6	
S72S	8/21/91	12.7	6.5	-3	240		
S74D	9/2/93	14.2	7.3	89	728	3.8	
S74S	8/31/93	12.4	6.3	127	1929	1.5	
S81D	8/11/93	10.9	6.46				
S81M	8/11/93	11.6	7.59				
S81S	8/11/93	11.4	5.57				
S84D	8/20/91	15.5	6.5	98	634		
S84M	8/20/91	12.5	5.8	133	553		
S84S	8/20/91	12.3	5.8	169	422		
S85M	8/23/91	13.6	6.9	15	402		
S85M	9/2/93	11.6	6.4	87	773	2.8	67.4

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
S85S	8/23/91	13.3	6.1	29	500		
S85S	9/2/93	11.1	6.0	60	421	2.9	
S86D	8/26/91	13.7	6.5	10	623		
S86S	8/26/91	13.5	6.6	13	618		
S87D	8/23/91	12.1	7.1	30	750		
S87M	8/23/91	14.9	6.9	38	374		
S87S	8/23/91	14.9	6.4	30	557		
S89D	8/26/93	11.4	6.4	64	405		
S89D	9/2/93	11.4	6.4	99	746	0.8	47.1
S89M	8/26/91	19.5	6.1	77	645		
S89S	8/26/91	14.9	6.5	43	659		
S90D	8/2291	11.8	6.9	79	485		
S90M	8/22/91	12.1	6.8	95	415		
S90S	8/22/91	15.9	6.1	82	39		
S91D	8/21/91	11.7	6.6	45	557		
S91D	9/1/93	12.8	6.4	77	577	8.6	40.8
S91M	8/22/91	13.5	6.4	91	545		
S91M	9/1/93	11.5	6.0	103	534	4.3	
S91S	8/21/91	15.5	5.6	79	464		
S91S	9/1/93	15.6	5.4	127	468	2.6	
S93D	8/27/91	12.2	6.2	20	604		
S93D	9/1/93	12.1	6.0	49	607	1.0	25.7
S93M	8/27/91	12.9	6.5	17	510		
S93S	8/27/91	16.9	5.9	-2	602		
S94D	8/20/91	11.2	5.9	255	433		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
S94M	8/20/91	12.2	5.5	250	362		
S94S	8/20/91	12.5	5.8	128	240		
S97D	9/2/93	14.6	7.0	67	702	4.6	
UC4	8/10/93	20.4	9.25		262		
UC5	8/10/93	20.2	5.97		264		
UC6	8/9/93	19.3	9.53		168		
UC6S	8/9/93	20.2	6.24		1301		
UC7-1	8/19/93	18.6	7.03		552		
UC7-2	8/19/93	18.5	6.30		554		
UC7-3	8/19/93	18.6	7.04		827		
UC7-4	8/19/93	19.4	7.22		445		
UC8	8/12/93	17.4	7.90		520		
UC9-1	8/17/93	19.4	7.29		361		
UC9-2	8/17/93	18.7	7.51		397		
UC9-3	8/17/93	21.4	5.05		471		
UC9-4	8/17/93	16.8	7.78		421		
UC10-1	8/9/93	18.4	6.20				
UC10-2	8/9/93	16.9	6.87				
UC10-3	8/9/93	16.4	7.20				
UC10-4	8/9/93	16.5	7.42				
UC10-5	8/9/93	17.1	7.28				
UC10-6	8/9/93	16.7	7.54				
UC10D	8/4/93	21.8	6.92		900		
UC10M	8/4/93	22.2	6.03		2270		
UC10S	8/4/93	21.2	5.89		2470		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
UC11-2	8/13/93	19.9	6.88				
UC11-4	8/19/93	21.6	6.39		2370		
UC12-4	8/19/93	19.1	7.03		420		
UC13-1	8/17/93	19.1	7.86		535		
UC13-2	8/17/93	18.3	7.89		539		
UC13-3	8/17/93	18.4	7.85		376		
UC13-4	8/17/93	18.2	7.64		528		
UC14-1	8/18/93	17.5	7.32		471		
UC14-2	8/18/93	17.6	7.51		517		
UC14-3	8/18/93	19.5	7.73		476		
UC14-4	8/18/93	19.5	6.77		376		
UC14-5	8/18/93	17.5	7.71		288		
UC15D	8/12/93	23.9	11.87		1690		
UC15S	8/12/93	21.7	12.10		5450		
UC16	8/10/93	21.3	6.96		21		
UC17	8/11/93	20.9	6.15		54		
UC19	8/4/93	27.6	6.02		875		
UC19M	8/4/93	24.4	7.07		1069		
UC19S	8/4/93	21.1	5.58		2150		
UC20	8/6/93	16.9	6.55		220		
UC22	8/10/93	17.2	8.10		740		
UC23-1	8/16/93	23.6	5.61		1550		
UC23-4	8/19/93	23.7	6.83		2800		
UC24D	8/6/93	20.9	6.47		238		
UC24S	8/5/93	18.1	5.87		1055		

Table 2-8 (continued).

Well No.	Date	Temp (°C)	pH	eH (mu)	Spec. Cond. (μS/cm)	DO (mg/L)	Turbidity (NTU)
UC25	8/10/93	31.6	6.18		46		
UG1-2	8/10/93	20.8	6.44				
UG1-3	8/10/93	18.4	6.66				
UG1-4	8/11/93	21.9	6.42				
UG1-5	8/11/93	21.7	6.32				
UG1-6	8/10/93	15.9	6.07				
UG1-7	8/13/93	23.2	6.6				
UG2-1	8/10/93	20.8	6.44				
UG2-3	8/26/91	19.7	6.7	75	538		
UG2-4	8/26/91	14.4	6.6	45	55		
UG4-1	8/23/91	13.9	7.8	-23	496		
UG4-2	8/22/91	13.9	7.4	8	562		
UG4-3	8/22/91	15.6	7.2	-40	415		
UG4-4	8/22/91	16.3	6.7	-32	342		
UG4-5	8/23/91	15.9	6.9	-7	382		

Table 2-9. Eastern Uplands drive points and wells sampled between March 29 and April 28, 1993

DP2S	DP24S	S64S
DP2M	DP24D	S64M
DP2D	DP26	S64D
DP4	DP28	S65S
DP5	DP35	S65M
DP6D	DP36	S65DR
DP7	DP37D	S66D
DP9D	DP38	UG1-2
DP11	DP40	UG1-3
DP12	RMW1	UG1-4
DP18D	RMW2	UG1-5
DP21D	S63S	UG1-6
DP22	S63D	UG1-7

Table 2-10. Wells sampled in the Summer 1993 Central Area sampling event

AB1	DP31	K49D	K62M	S67S	S95D
AB2M	DP32	K49M	K62S	S69D	S95S
AB2R	DP35	K49S	K63D	S7	S97D
AB2SS	DP36	K50	K63M	S70D	UC11-2
BUG1-1	DP37D	K51D	K63S	S70M	UC11-4
BUG1-4	DP37S	K51M	K64D	S70S	UC12-4
BUG1-7	DP38	K53D	MR1SS	S71D	UC13-2
BUG1-8	DP39	K53M	MR2SS	S71S	UC13-3
DP10	DP40	K54D	MW4D	S72D	UC13-1
DP11	DP41	K54M	MW4M	S72M	UC13-4
DP12	DP6D	K55D	MW4SS	S74D	UC14-1
DP18D	DP6S	K55M	RMW1	S74S	UC14-5
DP18S	DP7	K56D	RMW2	S77D	UC14-2
DP19	GO1D	K56M	S21	S77SS	UC14-4
DP1D	GO1DB	K57D	S22	S81D	UC14-3
DP1S	K42D	K57M	S6	S81M	UG1-6
DP20	K42M	K58D	S63D	S81S	UG1-5
DP21D	K42S	K58S	S63S	S83M	UG1-7
DP21S	K43D	K59D	S64D	S83SS	UG1-3
DP22	K43S	K59S	S64M	S85M	UG1-4
DP24D	K44D	K60D	S64S	S85S	UG1-2
DP26	K44S	K60M	S65DR	S89D	WB1M
DP2D	K45	K60S	S65M	S91D	WB1SS
DP2M	K46	K61D	S66D	S91M	
DP2S	K47	K61M	S67D	S91S	
DP3	K48	K62D	S67M	S93D	

Table 2-11. CLP compound/analyte list for waters and soils

VOLATILE ORGANIC COMPOUNDS
Chloromethane
Bromomethane
Vinyl chloride
Chloroethane
Methylene chloride
Acetone
Carbon disulfide
1,1-Dichloroethene
1,1-Dichloroethane
1,2-Dichloroethene (total)
Chloroform
1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon Tetrachloride
Bromodichloromethane
1,2-Dichloropropane
cis-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
Trans-1,3-dichloropropene
Bromoform
4-Methyl-2-pentanone
2-Hexanone
Tetrachloroethene
Toluene
1,1,2,2,-Tetrachloroethane
Chlorobenzene
Ethyl benzene
Styrene
Xylenes (total)

Table 2-11. (continued)

SEMIVOLATILE ORGANIC COMPOUNDS

ACID COMPOUNDS	BASE/NEUTRAL COMPOUNDS	
Phenol	N-nitrosodiphenylamine	2-Methylnaphthalene
2-Chlorophenol	4-Bromophenyl-phenylether	Hexachlorocyclopentadiene
2-Methylphenol	Hexachlorobenzene	Dibenzofuran
4-Methylphenol	1,3-Dichlorobenzene	2,4-Dinitrotoluene
2-Nitrophenol	1,4-Dichlorobenzene	Diethylphthalate
2,4-Dimethyphenol	1,2-Dichlorobenzene	4-Chlorophenyl-phenyl ether
2,4-Dichlorophenol	2,2'-Oxybis(1-chloropropane)*	Fluorene
4-Dimethylphenol	2-Chloronaphthalene	4-Nitroaniline
4-Chloro-3-methylphenol	2-Nitroaniline	Hexachlorobutadiene
2,4,6-Trichlorophenol	Dimethylphthalate	Benzo(g,h,i)perylene
2,4,5-Trichlorophenol	Acenaphthylene	Bis(2-chloroisopropyl)ether
2,4-Dinitrophenol	2,6-Dinitrotoluene	
4-Nitrophenol	3-Nitroaniline	
4,6-Dinitro-2-methylphenol	Acenaphthene	
Pentachlorophenol	Phenanthrene	
	Anthracene	
	Carbazole	
	Di-n-butylphthalate	
	Fluoranthene	
	N-Nitroso-di-n-dipropylamine	
	Hexachlorethane	
	Nitrobenzene	
	Isophorone	
	Pyrene	
	Butylbenzylphthalate	
	3,3'-Dichlorobenzidine	
	Benzo(a)anthracene	
	Chrysene	
	Bis(2-ethylhexyl)phthalate	
	Bis(2-chloroethoxy)methane	
	Di-n-octylphthalate	
	Benzo(b)fluoranthene	
	1,2,4-Trichlorobenzene	
	Benzo(k)fluoranthene	
	Benzo(a)pyrene	
	Indeno(1,2,3-cd)pyrene	
	Dibenz(a,h)anthracene	
	Naphthalene	
	4-Chloroaniline	

* Previously known by the name bis(2-chloroisopropyl)ether

Table 2-11. (continued)

PESTICIDES/PCBs	INORGANIC ANALYTES
alpha-BHC	Aluminum
beta-BHC	Antimony
delta-BHC	Arsenic
gamma-BHC (Lindane)	Barium
Heptachlor	Beryllium
Aldrin	Cadmium
Heptachlor epoxide	Calcium
Endosulfan I	Chromium
Dieldrin	Cobalt
4,4'-DDE	Copper
Endrin	Iron
Endosulfan II	Lead
4,4'-DDD	Magnesium
Endosulfan sulfate	Manganese
4,4'-DDT	Mercury
Methoxychlor	Nickel
Endrin ketone	Potassium
Endrin aldehyde	Selenium
alpha-Chlordane	Silver
gamma-Chlordane	Sodium
Toxaphene	Thallium
Aroclor-1016	Vanadium
Aroclor-1221	Zinc
Aroclor-1232	Cyanide
Aroclor-1242	
Aroclor-1248	
Aroclor-1254	
Aroclor-1260	

Table 2-11. (continued)

NON-CLP LABORATORY MEASUREMENTS

MEASUREMENT	MATRIX
Nitrate/nitrite	Water
Total organic carbon	Soil
Grain-size distribution	Soil

Table 2-12. TCL organic and TAL inorganic constituents

Dichlorodifluoromethane	Phenol	beta-BCH
Chloromethane	bis(2-Chloroethyl)ether	delta-BCH
Vinyl chloride	2-Chlorophenol	gamma-BHC (Lindane)
Bromomethane	1,3-Dichlorobenzene	Heptachlor
Chloroethane	1,4-Dichlorobenzene	Aldrin
Trichlorofluoromethane	1,2-Dichlorobenzene	Heptachlor epoxide
1,1-dichloroethene	2-Methylphenol	Endosulfan I
Acetone	2,2'-oxybis (1-Chloropropane)	Dieldrin
Carbon disulfide	4-Methylphenol	4,4'-DDE
Methylene chloride	n-Nitroso-di-n-propylmine	Endrin
Trans-1,2-dichloroethene	Hexachloroethane	Endosulfan II
1,1-Dichloroethane	Nitrobenzene	4,4'-DDD
2,2-Dichloropropane	Isophorone	Endosulfan sulfate
Cis-1,2-dichloroethene	2-Nitrophenol	4,4'-DDT
2-Butanone	2,4-Dimethylphenol	Methoxychlor
Bromochloromethane	Bis(2-chloroethoxy) methane	Endrin ketone
Chloroform	2,4-Dichlorophenol	Endrin aldehyde
1,1,1-Trichloroethane	1,2,4-Trichlorobenzene	alpha-Chlordane
Carbon tetrachloride	Naphthalene	gamma-Chlordane
1,1-Dichloropropene	4-Chloroaniline	Toxaphene
Benzene	Hexachlorobutadiene	Aroclor-1016
1,2-Dichloroethane	4-Chloro-3-methylphenol	Aroclor-1221
Trichloroethene	2-Methylnaphthalene	Aroclor-1232
1,2-Dichloropropane	Hexachlorocyclopentadiene	Aroclor-1242

Table 2-12 (continued).

Dibromomethane	2,4,6-Trichlorophenol	Aroclor-1248
Bromodichloromethane	2,4,5-Trichlorophenol	Aroclor-1254
Cis-1,3-dichloropropene	2-Chloronaphthalene	Aroclor-1260
4-Methyl-2-pentanone	2-Nitroaniline	Aluminum
Toluene	Dimethylphthalate	Antimony
Trans-1,3-dichloropropene	Acenaphthylene	Arsenic
1,1,2-Trichloroethane	2,6-Dinitrotoluene	Barium
Tetrachloroethene	3-Nitroaniline	Beryllium
1,3-Dichloropropane	Acenaphthene	Cadmium
2-Hexanone	2,4-Dinitrophenol	Calcium
Dibromochloromethane	4-Nitrophenol	Chromium
1,2-Dibromoethane	Dibenzofuran	Cobalt
Chlorobenzene	2,4-Dinitrotoluene	Copper
1,1,1,2-Tetrachloroethane	Diethylphthalate	Iron
Ethylbenzene	4-Chlorophenyl-phenylether	Lead
m- & p-Xylene	Fluorene	Magnesium
o-Xylene	4-Nitroaniline	Manganese
Styrene	4,6-Dinitro-2-methylphenol	Mercury
Bromoform	n-Nitrosodiphenylamine (1)	Nickel
Isopropylbenzene	4-Bromophenyl-phenyl-ether	Potassium
Bromobenzene	Hexachlorobenzene	Selenium
1,1,2,2-Tetrachloroethane	Pentachlorophenol	Silver
1,2,3-Trichloropropane	Phenanthrene	Sodium
n-Propylbenzene	Anthracene	Thallium
2-Chlorotoluene	Carbazole	Vanadium

Table 2-12 (continued).

4-Chlorotoluene	Di-n-butylphthalate	Zinc
1.3.5-Trimethylbenzene	Fluoranthene	Cyanide
Tert-butylbenzene	Pyrene	
1,2,4-Trimethylbenzene	Butylbenzylphthalate	
sec-Butylbenzene	3,3'-Dichlorobenzidine	
1,3-Dichlorobenzene	Benzo(a)anthracene	
1,4-Dichlorobenzene	Chrysene	
p-Isopropyltoluene	Bis-(2-ethylhexyl)phthalate	
1,2-Dichlorobenzene	Di-n-octyl phthalate	
n-Butylbenzene	Benzo(b)fluoranthene	
1,2-Dibromo-3-chloropropane	Benzo(k)fluoranthene	
1,2,4-Trichlorobenzene	Benzo(a)pyrene	
Hexachlorobutadiene	Indeno(1,2,3-cd)pyrene	
Naphthalene	Dibenz(a,h)anthracene	
1,2,3-Trichlorobenzene	Benzo(g,h,i)perylene	
Xylene (total)	alpha-BHC	

Table 2-13. Non-CLP analytes

Chloride
Nitrate as N
Organic carbon, total
Conductivity (μmhos/cm)
Alkalinity (as $CaCO_3$)
Total dissolved solids
Acidity (μequiv/l)
Sulfate
BOD5
Phosphate, total as P
Ammonia-nitrogen
Chemical oxygen demand
Nitrite nitrogen
Tritium

Table 2-14. Wells sampled quarterly as part of the Northeast Quadrant ground-water remediation monitoring

G11S	RW10	S70D
G11D	RW11	S81S
G12S	RW12	S81D
G12D	RW13	UC10-1
G23S	RW14	UC10-2
G23D	RW15	UC10-3
G36S	RW16	UC10-4
G36D	RW17	UC10-5
G36DB	RW18	UC10-6
G36DB2	RW19	UC11-2
RW1	RW20	UC18
RW2	RW21	UG1-2
RW3	RW22	UG1-3
RW4	G01S	UG1-4
RW5	G01DB	UG1-5
RW6	S7	UG1-6
RW7	S63S	UG1-7
RW8	S63D	
RW9	S70M	

Table 2-15. Analytes sampled for in the Northeast Quadrant ground-water remediation monitoring

Chloromethane	Bromodichloromethane
Vinyl chloride	4-Methyl-2-pentanone
Bromomethane	Cis-1,3-dichloropropene
Chloroethane	Toluene
Acetone	Trans-1,3-dichloropropene
1,1-Dichloroethene	1,1,2-Trichloroethane
Carbon disulfide	2-Hexanone
Methylene chloride	Tetrachloroethene
1,2-Dichloroethene (total)	Dibromochloromethane
1,1-Dichloroethane	Chlorobenzene
Vinyl acetate	Ethylbenzene
2-Butanone	Xylenes (total)
Chloroform	Styrene
1,1,1-Trichloroethane	Bromoform
Carbon tetrachloride	1,1,2,2-Tetrachloroethane
Benzene	1,3-Dichlorobenzene
1,2-Dichloroethane	1,4-Dichlorobenzene
Trichloroethene	1,2-Dichlorobenzene
1,2-Dichloropropane	

3 CENTRAL AREA CONCEPTUAL MODEL

This section of the report provides a detailed description of the conceptual model of the Central Area. The conceptual model is based on information collected specifically as part of this investigation along with the extensive previously existing environmental and land use data regarding the Aberjona River watershed north of the southern boundary of the Wells G & H Site. The text has been organized to provide discussion of the geologic and hydrologic information regarding the Central Area and the Aberjona River watershed, to describe contaminant sources and releases within the Aberjona River watershed that affect the nature and extent of contamination within the Central Area, as well as to discuss the distribution of contamination within the Central Area. A brief summary of the conceptual model is provided as part of this introduction. Subsequent portions of this section provide more detailed information regarding the various components of the conceptual model.

The Central Area of the Wells G & H Site is a subset of the highly industrialized and urbanized Aberjona River watershed. The Aberjona River originates in the Town of Reading about 10 miles north of Boston and flows through the City of Woburn on its way southward to the Mystic Lakes. From its headwaters in Reading to the Salem Street bridge at the southern boundary of the Wells G & H Site the river flows through an area of substantial industrialization and urbanization. There is a long history of contamination of the Aberjona River from a variety of sources including industrial discharges, waste disposal adjacent to the river, and highway runoff.

The Aberjona River basin is a typical New England glaciated river valley that has been significantly affected by almost two centuries of industrialization. The edges of the river valley are underlain by low permeability till and bedrock. The central portion of the river valley contains a through-flowing river which overlies coarse-grained glacial outwash which was deposited in a trough shaped depression in the bedrock. The coarse-grained material found in the center of the valley forms a small but permeable valley-fill aquifer.

> "These valley aquifers have a relatively small volume and storage capacity, however, they are very productive because of induced infiltration from streams.
>
> Most public water supply wells are sited close to these streams to take advantage of this situation" (Roy, 1987).

Under natural or non-pumping conditions within the Central Area, ground water generally flows from the sides of the valley toward the Aberjona River in the center of the valley. In closer proximity to the Aberjona River, ground water flowing from the sides of the valley converges with ground water flowing from the northern upstream reaches of the watershed. As a result, the ground-water flow direction becomes more southerly and generally parallel with the course of the Aberjona River. There is some ground-water discharge into the Aberjona River, its tributaries and associated wetlands. The central portions of the Aberjona River valley essentially serve to collect and transmit the surface water runoff and ground-water flow within the watershed. Under pumping conditions within the Central Area Aquifer, the Aberjona River is a source of water to the underlying aquifer as a result of induced infiltration in response to pumping.

Tritium analyses of ground water samples were done to determine the relative age of ground water within the Central Area. The analyses indicate a relatively dynamic localized groundwater flow system with relatively young water found almost five hundred feet below land surface.

During the last two centuries, there has been intensive industrialization within the Aberjona River watershed, and the Aberjona River has played an important role in that urbanization.

> "The various Woburn industries, especially the tanning industry and different branches of the chemical industry, have made use of the Aberjona (River) for both process water and for pollution discharge" (Tarr, in GeoTrans, 1987, p. B-33).

As a result of this industrialization, there is a long history of complaints and concerns regarding the quality of both surface water and ground water within the watershed. These complaints and concerns reflect a common dilemma regarding conflicting demands for land use.

> "We often find that the most productive aquifer areas in communities are zoned industrial or they have already been developed with industrial, commercial, or waste disposal activities that may threaten the quality of ground and surface water. Frequently in Massachusetts, one can determine where the public water supply wells are by locating the landfills first. Since most of the older municipal landfills were placed in worked out sand and gravel areas, it is only natural that nearby you will find public water supply wells using the same resource" (Roy, 1987).

In addition to the siting of tanery industry and chemical industry facilities in proximity to the Aberjona River, the City of Woburn has operated three dumps or landfills along the western edge of the Aberjona River north of Route 128. Two barrel reclamation facilities and other industries were also located adjacent to the East Drainage Ditch, a tributary to the Aberjona River (GeoTrans, 1987 p. 97).

As a result of the almost two centuries of industrialization and urbanization within the Aberjona River watershed, it is not surprising that there is widespread distribution of a variety of contaminants within the Central Area. It was known prior to the installation of the City of Woburn public water supply wells G and H that the Central

Area Aquifer was contaminated with industrial pollution (Whitman and Howard, 1958). In fact, Whitman and Howard advised the City of Woburn that

> "The Aberjona River valley still has a potential for groundwater supply for certain industrial used (sic), but the ground waters of this valley are, in general, too polluted to be used for public water supply." (Whitman and Howard, 1958, p. 34).

The consequence of the industrialization and urbanization of the watershed has been to render the ground-water system within the Central Area, and the Central Area Aquifer in particular, vulnerable to contamination from a wide variety of contaminant sources. These sources exist both within the Central Area and in the upstream reaches of the Aberjona River watershed.

The current distribution of contamination within the Central Area reflects the presence of numerous contributing sources. There is widespread ground-water contamination by inorganic as well as organic compounds. Many of the contaminants are indicative of the anthropogenic activity within the watershed. In addition to the chlorinated solvent contamination, which was the focus of the original RI/FS investigations of the Wells G & H Site, there is evidence of long-standing contamination of the Central Area Aquifer by coliform bacteria and inorganic compounds such as nitrate, sodium, chloride, and sulfate. There is also evidence that there has been a long history of metals transport, such as arsenic and chromium, from the upstream reaches of the Aberjona River watershed into, as well as through, the Central Area. Recent data collected by MIT Aberjona River watershed researchers indicate that a considerable amount of these metals still persist within the river sediments and wetland deposits in the Central Area and are being transported by both surface water and ground water in the watershed (Hemond, 1993).

Several contamainant releases can be related to the infrastructure within the Central Area, such as leaky or surcharging sewer lines, as well as the intentional diversion of surface runoff from parking lots and other paved areas to the central portions of the Aberjona River valley. In addition, there have been releases from underground fuel tanks directly to the Central Area Aquifer. A recent article in the Boston Globe highlights the consequences of urbanization on ground-water quality. The article was directed to the widespread contamination of ground water within the Commonwealth caused by highway salting but an anecdotal reference to the Town of Reading illustrates the larger-scale consequence of urbanization to ground-water quality.

> "Reading closed down Well No. 9 in the early 1980s because of contamination caused by runoff from a nearby state road salt storage area but reopened it last summer when its other wells were contaminated by a major gasoline spill caused by an accident on Interstate 93. 'We only use (Well No. 9) when we need it during peak demand times with the understanding the salty water is being diluted by other water sources,' said town manager Peter Hechenbleikner. 'But short of building a fullscale desalination plant, there is no way to treat the water once a well is contaminated with salt.'" (Boston Globe, NorthWest Weekly, February 13, 1994, p. 4).

Figure 3-1 is a schematic illustration of the conceptual model of the Central Area of the Wells G & H Site. It reflects the hydrogeologic setting of the Central Area as well as the general variety of contaminant sources that have contributed to the existing contamination and/or would likely contribute to future releases. The hydrogeologic setting of the Central Area is typical of a New England glaciated river valley with ground water and surface water flow essentially directed toward the center of the valley and then following the main course of the Aberjona River southward toward the Mystic Lakes. As a result of almost two centuries of industrialization and urbanization, the past and current land use practices have created numerous sources of contamination within the

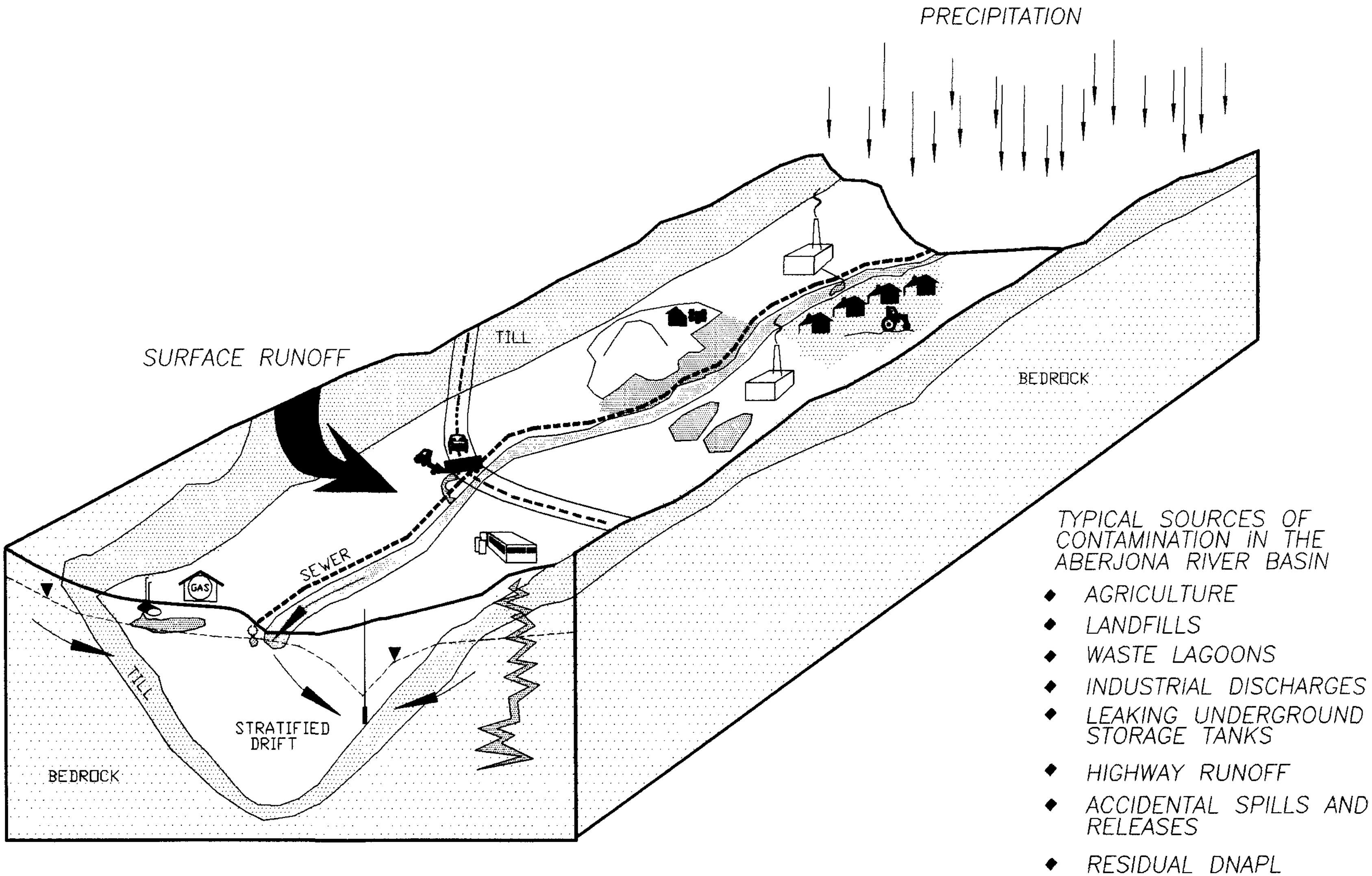


Figure 3-1 Central Area conceptual model

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watershed. These contamination sources have created a widespread distribution of a variety of contaminants within the Aberjona River watershed and the Central Area of the Wells G & H Site. The persistent nature of some of the existing contaminant sources, and the continued urbanization of the watershed, effectively guarantee the continued presence of contamination within the Central Area.

3.1 HYDROGEOLOGIC SETTING

The Central Area of the Wells G & H Site is part of the Aberjona River watershed within the Mystic Lakes drainage basin. The geologic framework which controls the occurrence and movement of surface water and ground water within the drainage basin can be characterized as Pleistocene glacial deposits and modern alluvial deposits which overlie crystalline bedrock. The Aberjona River is the principal surface water drainage within the drainage basin, and Hall's Brook and the East Drainage Ditch are major tributaries in the upstream reaches. Snyder Creek is a smaller tributary to the Aberjona River. Part of Snyder Creek is located within the eastern portion of the Wells G & H Site and it joins the Aberjona River south of the Site.

The Aberjona River has been described as a leaky river because of the hydraulic connection between surface water and ground water within the river basin. Ground-water withdrawals for industrial and municipal uses have caused the river to experience losses of flow (Massachusetts Water Resources Commission, 1973). From a quantity perspective, this "leaky" condition was considered favorable for siting ground-water supplies. In the 1930s, Consolidated Chemical Industries, Inc., subsequently known as Stauffer Chemical Company, installed five production wells along the western shore of the former Mishawum Lake. A sixth well was added in 1952 (USGS, 1980). The total system capacity was determined to be in excess of 3500 gallons per minute (gpm). Woburn public water supply wells G and H are also known to have induced a substantial amount of leakage from the Aberjona River into the underlying aquifer as a result of their pumping (Myette, et al., 1987; GeoTrans, 1987; Cherry, et al., 1989).

Within the Aberjona River drainage basin, the amount and availability of ground water is determined largely by variations in the type and thickness of unconsolidated deposits overlying bedrock. In most of the study area, bedrock is at or near land surface; in some places it is overlain by a mantle of till. The bedrock is generally capable of supplying only a few gallons per minute to wells. The most productive aquifers, capable of sustaining well yields of several hundred gallons per minute, are composed of sand and gravel deposited during the Pleistocene glaciation in the Aberjona River Valley (Delaney and Gay, 1980).

The following sections describe the geologic and hydrologic framework of the Central Area.

3.1.1 Geologic Framework of the Central Area

The Central Area is underlain by unconsolidated glacial deposits which unconformably overlie crystalline bedrock. The following describes the physical properties and stratigraphy of the geologic material which is found within the Central Area. A surficial geology map (Figure 3-2) and twelve geologic sections (Figures 3-3 to 3-14) have been included to illustrate the three dimensional variability of the geologic framework within the Wells G & H Site and the Central Area.

3.1.1.1 Unconsolidated Deposits

The unconsolidated deposits at the edges of the Aberjona River Valley are primarily ground moraine deposits which directly overlie the bedrock and outwash deposits which overlie the ground moraine (Figure 3-2). Within the Eastern Uplands, two varieties of till have been identified, a lodgment till and an ablation till. The lodgment till, which lies directly on the bedrock surface, consists of a heterogeneous mixture of sand, silt, clay, gravel, cobbles, and boulders. This till, which was deposited at the base of the glacial ice, is very densely packed, generally has low permeability, and does not easily yield water to wells. Overlying the lodgment till is a thin layer of ablation till. The ablation till, released from the glacial ice as it melted and receded, has a more sandy texture and is less densely packed than the lodgment till. In the Eastern Uplands the ablation till generally exists above the water table.

The low lying western portion of the Central Area is underlain by stratifed outwash deposits, which comprise the Central Area Aquifer, as well as swamp deposits. The outwash deposits, laid down by meltwater streams flowing from a receding glacier, consist of interbedded sand, gravel, cobbles, and silt. Geologic logs of wells and borings indicate that within the buried bedrock valley, the outwash deposits generally overlie the bedrock surface directly. In some areas, there is a thin layer of lodgment till between the outwash deposits and bedrock surface (deLima and Olimpio, 1989, p. 4). In the area between the eastern edge of the buried bedrock valley and Washington Street, outwash deposits overlie till deposits and the thickness of the outwash deposits decreases from the center of the valley to the edges.

The swamp deposits consist of varyingly decayed vegetal matter, silt, sand, and possibly clay. These deposits generally lie at the surface, except where covered by artificial fill, and are found within the wetlands that border the Aberjona River and its tributaries.

Figure 3-2 is a surficial geology map of the Site area that shows the surficial distribution of the unconsolidated deposits and bedrock outcrops within the Wells G & H Site. Figures 3-3 to 3-14 are geologic sections that show the stratigraphy of the unconsolidated deposits beneath the Central Area and adjacent portions of the Wells G & H Site. Also included on the sections are the September 1993 water level data. The locations of the geologic sections are shown on Figure 3-15.

3.1.1.1.1 Lodgment Till

The lodgment till, which underlies the Eastern Uplands of the Central Area and lies unconformably on the bedrock surface, was deposited beneath glacial ice during the last glacial advance. As a result of being deposited under great pressure, it is very dense and is composed of a poorly sorted heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders. The lodgment till is generally grey to olive grey in color and is up to 30 feet thick.

The hydraulic conductivity of the lodgment till, based on the results of hydraulic testing conducted in 23 wells screened in the lodgment till, ranges from 0.01 to 0.6 feet per day (see Table 3-1). No water supply wells have been installed in the lodgement till within the Wells G & H Site.

3.1.1.1.2 Ablation Till

The ablation till, which overlies the lodgment till on the Eastern Uplands of the Site, was deposited directly from ice during the wasting of the last ice sheet. Because of the difference in the mode of deposition, the ablation till is less compact than the lodgment till and generally contains more sand and less silt and clay. The ablation till is generally tan to brown in color and consists of poorly sorted fine to coarse sand, gravel, cobbles, boulders, and minor amounts of silt and clay. As a result of the lower percentage of silt and clay and the degree of compaction, the hydraulic conductivity of the ablation till is higher than the hydraulic conductivity of the lodgment till. Based on hydraulic testing performed in 14 wells screened in the ablation till, the hydraulic conductivity ranges from 1.1 to 10.3 feet per day (see Table 3-1). No water supply wells have been installed in the ablation till within the Wells G & H site.

3.1.1.1.3 Stratified Drift Deposits

The stratified drift deposits, which were laid down as outwash by melt-water streams flowing away from the wasting ice sheet, fill the Aberjona River Valley and make up the Central Area Aquifer. The stratified drift, which lies unconformably on the bedrock surface and conformably on the till, is up to 130 feet thick and consists of well sorted sand, gravel, cobbles, and silt. Figure 3-16 is an isopach map showing the thickness and areal extent of the stratified drift within the Wells G & H Site. Because the stratified drift deposits are well sorted, the hydraulic conductivity of the stratified drift deposits is much higher than the hydraulic conductivity of the till. City of Woburn public water supply wells G and H and the J.J. Riley supply wells were constructed in the stratified drift because the high hydraulic conductivity of these deposits and proximity to the Aberjona River allowed large well yields. Consolidated Chemical Industries, Inc. and Stouffer Chemical Company also operated several industrial supply wells within the stratified drift deposits north of the Wells G & H Site (Delaney and Gay, 1980).

The hydraulic conductivity of the stratified drift deposits, based on hydraulic testing in 31 individual wells and 43 grain size analysis estimates, ranges from 0.1 feet per day in the finer grained deposits to 350 feet per day in the gravelly layers. The transmissivity of the Central Area Aquifer, based on analysis of the 1985 pumping tests of wells G and H conducted by the USGS, was determined to be between 17,000 and 30,000 feet squared per day (Myette, et. al., 1987). The results of all hydraulic testing performed in wells within the Wells G & H Site are summarized in Table 3-1. The table lists wells in which hydraulic testing has been performed and the hydrostratigraphic unit in which the wells are screened.

3.1.1.1.4 Swamp Deposits

The swamp deposits, which have accumulated since the glaciers receded, are located in the wetlands adjacent to the Aberjona River and in isolated upland wetlands such as the eastern portion of the Grace property. In the area adjacent to the Aberjona River, the swamp deposits overlie the stratified drift. In the upland wetlands, the swamp deposits probably directly overlie till. The swamp deposits are composed of decaying vegetal matter, peat, and interbedded fine sand, silt, and clay. Based on geologic logs from wells drilled through the swamp deposits, the thickness, which varies considerably and is probably a result of the surface topography of the outwash deposits, is generally less than 5 feet. The deposits are thickest in areas where there are depressions in the outwash surface on the flood plain of the Aberjona River. The thickest deposits, measured at well S89, are approximately 25 feet thick. No measurements of hydraulic conductivity have been made. Researchers at MIT are conducting detailed investigations of the swamp deposits near well H and will be making measurements of the hydraulic properties of these deposits in the near future (personal communication 1993, Peter Zeeb). No water supply wells have been installed in the swamp deposits within the Wells G & H Site.

3.1.1.2 Bedrock Geology

The bedrock underlying the Site has been mapped as Salem Granodiorite, Dedham Granite, and undifferentiated metavolcanics (Barosh et al., 1977). Figure 3-17 shows the bedrock topography based on data from wells, borings, and seismic refraction surveys. The underlying bedrock surface rises steeply from an elevation less than -100 feet National Geodetic Vertical Datum (NGVD) along the buried valley axis to an elevation greater than 100 feet NGVD near the intersection of Washington Street and Route 128. The buried bedrock valley, which is located in the western portion of the Central Area and approximately coincident with the course of the Aberjona River, is shown as a northerly trending depression in the bedrock surface. Borehole geophysical logging, such as caliper logging and acoustic televiewer logging, down-hole camera logging, packer testing of bedrock holes and rock coring was previously done on selected wells to evaluate the degree of bedrock fracturing. Analysis of the acoustic televiewer logging of wells UC11, UC12, UC13, UG1, and NEP3 was done by Colog (1993). Stereo net plots prepared by Colog indicated that there was no systematic or preferred orientation to the fractures detected in the boreholes. In general all of these evaluations indicate the bedrock is generally competent; contains an interconnected fracture network; is not extensively fractured, but contains localized fracture zones capable of yielding water to wells.

The hydraulic conductivity of the bedrock beneath the Grace and Wildwood properties has been estimated in several bedrock wells and borings from 66 packer and slug tests. The range of the estimated hydraulic conductivity for the bedrock beneath these properties is from 1.3 x 10^{-4} to 102 feet/day. Ninety five percent of the calculated hydraulic conductivities are less than or equal to one foot per day. The hydraulic conductivity of the bedrock is generally low and, in general, potential well yields would be low. Localized areas within the site, however, have been discovered where water yields have been sufficient for well installation.

Four bedrock wells are known to have been installed at the Site for water supply purposes. One of these was a 364-foot deep well at the former Johnson Brothers greenhouses near existing wells GO1 and UG1 (see Plate 2-1). The water was reportedly used for irrigation and as a potable supply in the greenhouses. The Johnson Brothers well had a reported average pumping rate of 5.2 gpm (GeoTrans, 1987, p. 162). There is no reported information regarding the drawdown which occurred during pumping of this well.

New England Plastics also operated three bedrock water supply wells. They are no longer in use for water supply. Well S41 is 358 feet deep, well NEP2 is 500 feet deep, and well NEP3 is 940 feet deep. Pumping tests conducted by HMM for New England Plastics indicated that the yields of the NEP wells were generally low. A 72-hour pumping test of well NEP2 indicated that drawdown in well NEP2 was greater than 200 feet at a pumping rate of 16 gpm (HMM, 1990).

In addition to the four bedrock water supply wells, one deep bedrock well and 22 shallow bedrock wells have been installed as part of Source Area property remedial actions. UC22 is a 190-foot deep bedrock well installed on the UniFirst property. It currently is pumped at a rate of about 45 gallons per minute with a drawdown of about 50 feet (Johnson Company, 1993). Twenty recovery wells screened in the lodgment till and shallow bedrock and two recovery wells screened in the lodgment till were installed at the Grace property. The total yield from all 22 recovery wells is about 5 gpm, with an average drawdown of more than 10 feet.

The most extensive evaluation of the hydraulic response to pumping from bedrock wells occurred during the UniFirst/Grace pilot study (EPC, 1991). During that study numerous water level measurements were made throughout the Northeast Quadrant of the Wells G & H site for the purpose of evaluating the spatial and temporal hydraulic response to pumping. The results of the evaluation indicate that a relatively large zone of influence and zone of capture developed in the bedrock as a result of pumping from UC22. Evaluation of the drawdown which occurred in response to pumping indicates that an interconnected fracture network exists in the bedrock beneath the Eastern Uplands of the Site with zones of relatively slow response to pumping connected to zones of more rapid response to pumping. No systematic pattern to the zone of drawdown, and therefore to the fracture orientation, was determined to exist.

3.1.2 Hydrologic Framework of the Central Area

3.1.2.1 Surface Water

The Wells G & H Site lies within the Aberjona River Basin. The Aberjona River flows in a generally north-south direction through the western portion of the Site. The drainage basin area of the Aberjona river upstream of the Salem Street bridge, which marks the downstream end of the Wells G & H Site, is approximately seven square miles. Surface water runoff within the drainage basin flows toward the Aberjona River through natural, as well as constructed, drainage ways.

The U.S. Geological Survey maintains a surface water gauging station at Winchester which is about four miles downstream of the Salem Street bridge. The average river discharge, as measured at the Winchester gauging station, for the period of record is 28.7 cubic feet per second (cfs). Extreme flows at Winchester during the period of record range from 0.25 cfs on October 10, 1950, to 1330 cfs on January 25, 1979 (USGS, 1991). Figure 3-18 is a hydrograph of average daily discharge measured at the Winchester gauging station between April 1939 and September 1993. In addition to reflecting the magnitude of the extreme flow events, the hydrograph indicates that since the early 1940s, there has been a general increase in both the frequency and magnitude of high flow events. The increase in frequency and magnitude of the high flow events likely reflects increased surface runoff as a result of increases in the areal extent of paving and urbanization within the drainage basin. This change in streamflow patterns is characteristic of urbanized watersheds (Kibler, 1982).

Aberjona River discharge data for areas upstream of the Winchester gauging station are generally limited. A low streamflow gauging station with a short period of record was located at Montvale Avenue, approximately 1 mile south of the Salem Street bridge. Low flow data collected at this station indicated an annual 7-day low flow discharge of 8.97 cfs, and 7-day low flow rates of 0.97 and 0.57 cfs with two-year and ten-year recurrence intervals, respectively (Delaney and Gay, 1980).

The most extensive river discharge measurements made within the Wells G & H Site boundaries are data collected as part of the 1985/1986 USGS 30-day pumping test of wells G and H. During the three-month period preceding the pumping test, river discharge at the Salem Street bridge, which is at the downstream end of the Site, ranged from about 3 to about 27 cfs. During the pumping test, the river discharge at the bridge ranged from about 4 to about 12 cfs. River discharge measurements were also made at several other locations within the Wells G and H Site during the pumping test. These data were used to calculate a net river gain and/or loss during the pumping test. A net river gain when the wells were not pumping and a net river loss when they were pumping was documented. The results of that evaluation are discussed in more detail in Section 3.1.2.2 of this report.

As part of their water resources evaluation, the USGS also did time-of-travel studies for certain segments of the Aberjona River (Delaney and Gay, 1980). One segment included the area between Mishawum Road and Salem Street. Data collected during October 1973 and March 1974 indicated that pollutants dissolved in the Aberjona River could flow from the area of Mishawum Road to Salem Street, a distance of about 4,500 feet, in three to five hours. Water quality data collected by the USGS from the Aberjona River at Salem Street and analyzed for inorganic compounds showed that the river water had concentrations of chloride, sulfate, and nitrogen species that were interpreted as reflecting run-off from the highly industrialized headwaters of the Aberjona River (Delaney and Gay, 1980).

September 1993 sampling of Aberjona River water near Route 128 indicated the presence of VOCs and arsenic and concentrations of other inorganic compounds, such as sodium and lead above drinking water quality standards.

3.1.2.2 Ground Water

Under non-pumping conditions, ground water within the boundaries of the Wells G & H site generally flows laterally in the unconsolidated deposits and bedrock from the edges of the valley toward the center of the valley. In proximity to the center of the valley and the Aberjona River, ground water which originated in the upland areas converges with ground water flowing from north of Route 128 and generally assumes a more southerly flow direction approximately parallel to the course of the Aberjona River. This general flow pattern is illustrated in Figures 3-19 and 3-20. Figure 3-19 is an estimated non-pumping water table elevation map based on measurements made on December 4, 1985. The water level data included on the map were modified slightly to remove the effects of the pumping of the Riley wells which were pumping in the southwestern portion of the Site at that time. Figure 3-20 reflects bedrock potentiometric levels measured on September 30, 1992. Comparison of Figures 3-19 and 3-20 indicates a general similarity in the pattern of ground-water elevations in the unconsolidated deposits and bedrock in the Eastern Uplands under non-pumping conditions.

From the Eastern Uplands of the Aberjona River Valley, ground water flows generally west-southwesterly toward the Aberjona River and the center of the valley. In the more easterly portion of the Eastern Uplands, ground water flow also has a generally downward component from the till into the underlying bedrock. In closer proximity to the center of the valley, ground-water flow has a generally upward component. Figure 3-21 schematically illustrates the vertical pattern of ground-water flow from the Eastern Uplands to the Central Area Aquifer under non-pumping conditions. Figure 3-22 illustrates actual non-pumping potentiometric elevations and the vertical head differences along an east-west section from the Grace property to the center of the valley. The potentiometric contours illustrate the downward flow component in the more easterly portions of the uplands and an upward flow component in the central portion of the valley. Intermediate between the uplands and the center of the valley is a transition zone where vertical flow components are insignificant.

In the absence of pumping in the Central Area Aquifer, the Aberjona River serves as a region of flow convergence and ground-water discharge for both the eastern and western sides of the river valley. During the three month period prior to the 1985/1986 30-day pumping test, river discharge measurements indicated an average streamflow gain of about 450 gallons per minute between Olympia Avenue and Salem Street (Myette, et al., 1987). This stream flow gain represents natural ground-water discharge to the Aberjona River within the boundaries of the Wells G and H Site, and is, in effect, a natural extraction of ground water from the Central Area Aquifer.

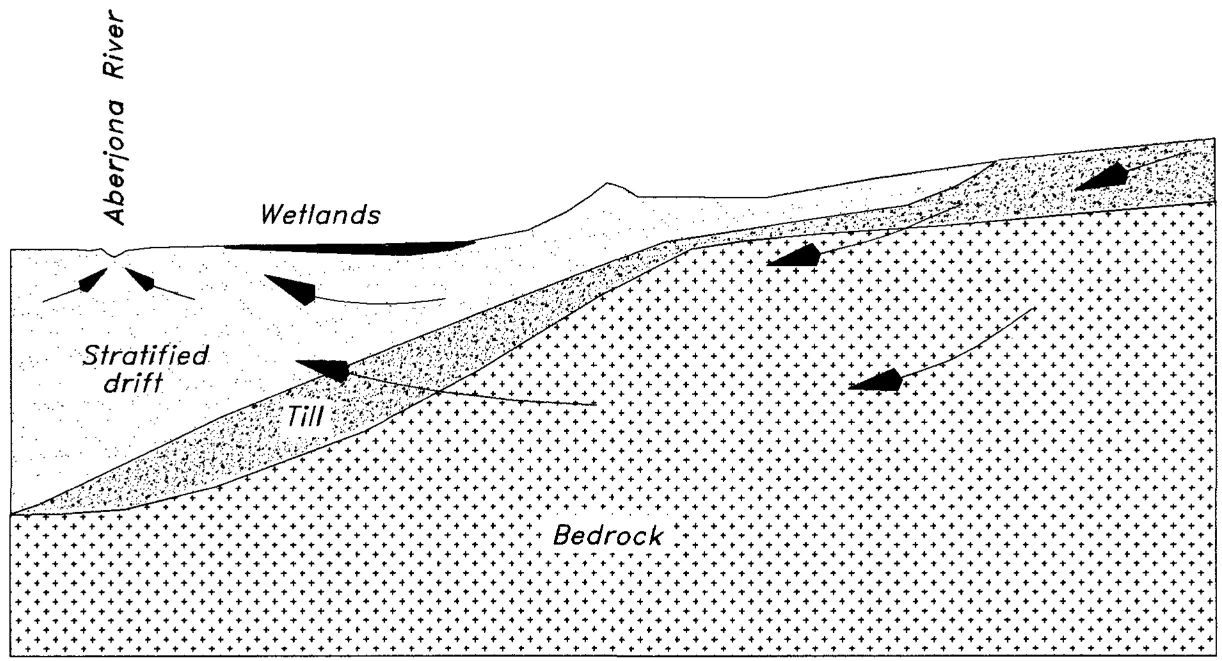

Figure 3-21 Schematic of ground-water flow from Eastern Uplands to the Central Area Aquifer

Under non-pumping conditions, the sources of ground water to the Central Area Aquifer are lateral inflow of ground water from the till and bedrock of the Eastern Uplands and from west of the Aberjona River; southerly ground-water flow across the northern boundary of the Central Area; and local infiltration of precipitation within portions of the center of the Aberjona River Valley. Ground water leaves the Central Area Aquifer as discharge to the Aberjona River and southerly ground-water flow across the southern boundary of the Central Area.

Past pumping of ground water from within the Central Area Aquifer has had a significant effect on ground-water flow directions within the Central Area Aquifer as well as on the water balance. The effects of previous pumping from within the Central Area Aquifer are illustrated in Figure 3-23. The figure is based on water level measurements made during the 1985/1986 30-day USGS pumping test. Wells G and H were pumped at a combined rate of 1,100 gallons per minute (gpm). The pumping rate approximated their peak pumping rate during the time they were used for water supply. As the wells began pumping, they drew water from all directions which resulted in a lowering of water levels around the well. Instead of a circular cone of depression around the wells, however, an elliptical cone of depression developed. The elliptical shape resulted from a combination of two factors. One was the alignment of the wells parallel to the river valley and the second was the limited amount of ground water available from the till and bedrock of the Eastern Uplands. The cone of depression which resulted from pumping expanded in the directions from which water was more readily available which, in the case of the Central Area Aquifer, was the sand and gravel outwash aligned parallel to the Aberjona River Valley. Consequently, an elongate cone of depression aligned approximately parallel to the Aberjona River developed in response to the pumping.

In addition, lowering of water levels due to pumping resulted in a localized reversal of the vertical hydraulic gradient from upward to downward, thereby causing induced infiltration of water from the Aberjona River and associated wetlands into the underlying aquifer. Figure 3-24 schematically illustrates the pattern of ground-water

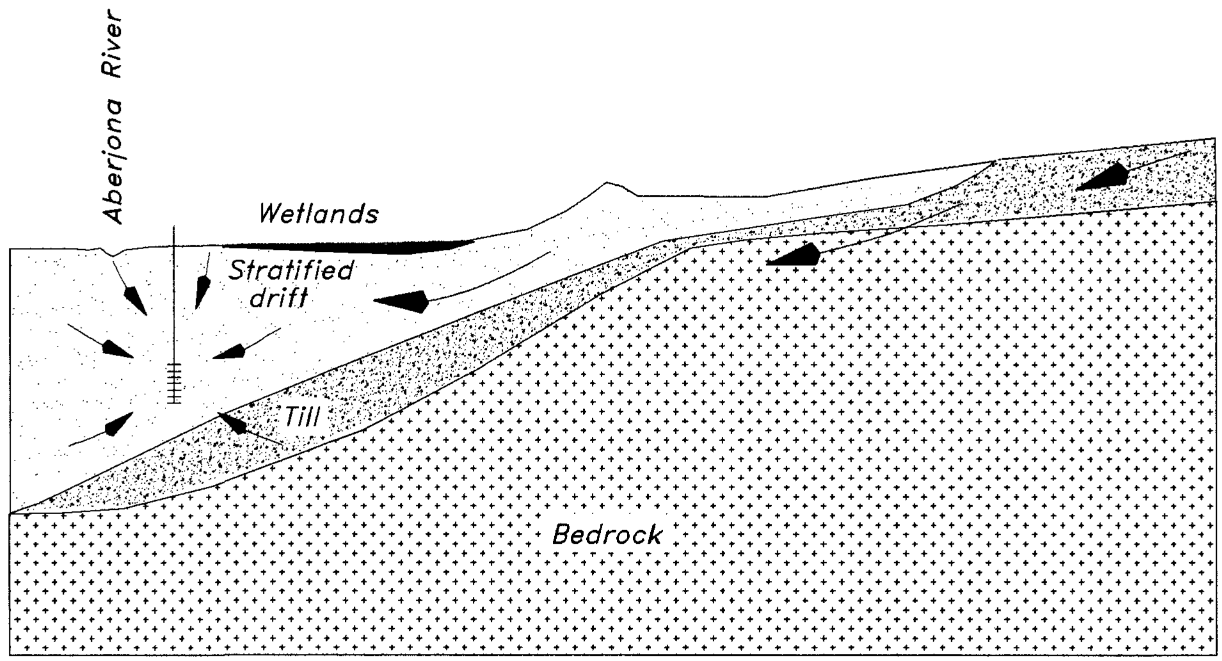

Figure 3-24 Schematic of induced infiltration from Aberjona River and wetlands into underlying aquifer

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flow that existed when wells G and H were pumping. In particular, the figure illustrates the reversal of flow direction in the vicinity of the Aberjona River. Instead of ground water discharging upward into the Aberjona River and asociated wetlands, surface water from the river and wetlands was induced to flow into the underlying aquifer and toward the pumping wells. Water which would have naturally discharged to the river and wetlands was also diverted to the wells. At the end of the 1985/1986 30-day USGS pumping test, river discharge measurements indicated that pumping had resulted in about 600 gpm of induced infiltration of Aberjona River water into the Central Area Aquifer. The amount of infiltration was about 50 percent of the combined pumping rate of the two wells. That is, for every two gallons of ground water extracted from wells G and H, one gallon of Aberjona River water was induced to infiltrate into the underlying aquifer.

Ground-water extraction from the UniFirst and Grace properties within the Eastern Uplands has also had a demonstrable effect on ground-water flow and the water balance within the Central Area. Since September 1992, coordinated ground-water extraction and treatment remedies have operated on the UniFirst and Grace properties. The UniFirst extraction system consists of a 190-foot deep bedrock well, UC22, which is extracting ground water at a rate of about 45 gpm (Johnson Company, 1993). The Grace recovery system consists of 22 shallow extraction wells which extract ground water from the unconsolidated deposits and shallow bedrock at a total rate of about 5 gpm. The data obtained from one full year of operation of the combined UniFirst and Grace extraction systems provide the most detailed characterization of the bedrock flow system within the Central Area under pumping conditions. A regional monitoring network encompassing much of the Eastern Uplands of the Central Area has been used for this characterization. Monitoring on a regional scale demonstrates the interconnectedness of the fracture system in the bedrock. Monitoring of water level changes in response to pumping UC22 (EPC, 1991; ENSR, 1993) has documented a zone of influence which is more than 400 feet deep and extends more than 1,500 feet from UC22. More detailed information regarding the hydraulic effects of the UniFirst and

Grace coordinated RD/RA activites is presented in EPC, 1991; ENSR, 1993; Johnson Company, 1993; and GeoTrans, 1993.

Figures 3-25 and 3-26 illustrate water table elevations and bedrock potentiometric elevations as measured in September 1993. The figures illustrate the hydraulic effects of the coordinated remediation. It is clear from Figure 3-25 that the Grace system has created an effective capture zone at the Grace property boundary and Figure 3-26 indicates that a fairly extensive capture zone has developed in the bedrock in response to pumping from UC22. The hydraulic consequence of the combined capture zones is that some of the ground water which under non-pumping conditions would have flowed from the Eastern Uplands toward the Central Area Aquifer is now diverted toward the UniFirst property or the Grace property and is captured by the recovery wells. Consequently, there has been a reduction in the rate of ground-water flow from the Eastern Uplands to the Central Area Aquifer. Figure 3-27 schematically illustrates the pattern of ground-water flow that results from pumping from the bedrock in the Eastern Uplands.

A second consequence of pumping from UC22 and the Grace wells is that local vertical gradients have been reversed. Certain Eastern Upland areas within the zone of influence of the UniFirst and Grace pumping wells which formerly had downward hydraulic gradients now have upward hydraulic gradients. Figure 3-4 illustrates September 1993 potentiometric levels in a vertical section extending from east of the Grace property to the western edge of the Eastern Uplands. Figures 3-4 and 3-22 can be used to compare the change in potentiometric levels and, consequently, ground-water flow directions as a result of pumping from the UniFirst and Grace properties.

For purposes of evaluating the relative age of groundwater within the Central Area, two separate ground-water sampling events for tritium analyses were completed within the Central Area. Tritium is frequently used for determining the relative age of ground water because of greatly contrasting tritium concentrations in pre-1953 precipita-

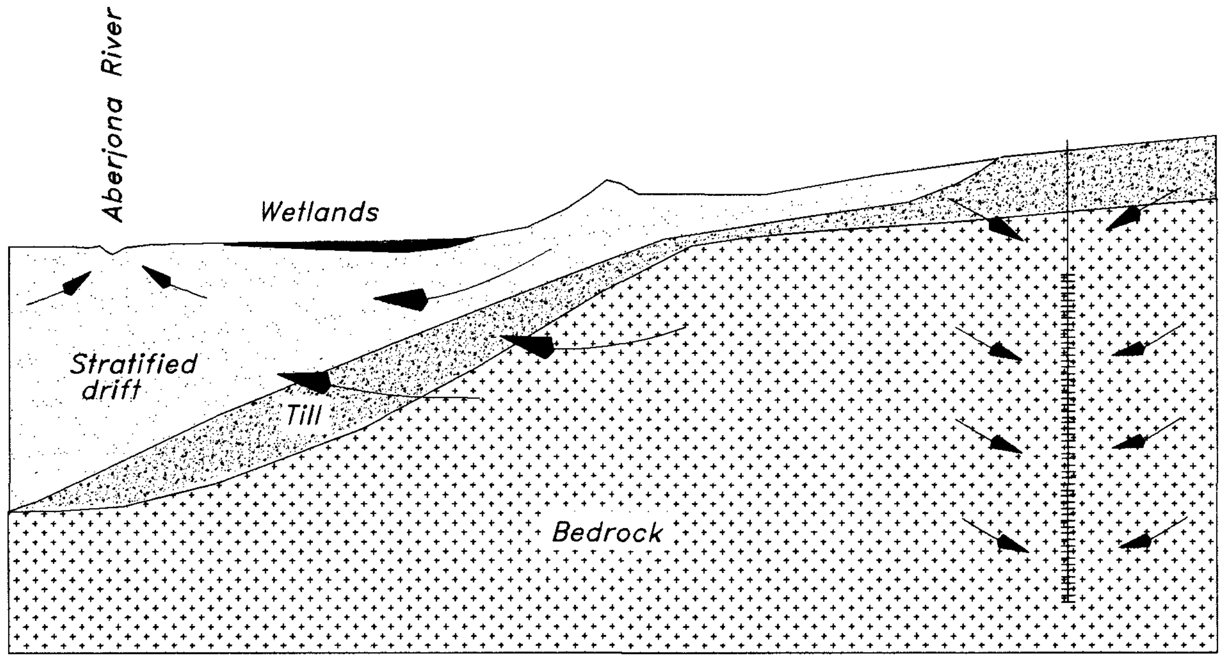

Figure 3-27 Schematic of ground-water flow in response to pumping from bedrock

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tion compared to post-1953 precipitation and because of a distinct peak in atmospheric tritium concentrations that occurred during 1962-1965 (Robertson and Cherry, 1989). The presence of detectable tritium in a sample implies that the water contains some component of post-1952 water (Fontes, 1980). Ground-water samples for tritium analysis were collected from the GO1/UG1 monitoring well clusters in March 1993 and from the BUG1 well cluster in May 1993. Analyses were done by the University of Miami Tritium Laboratory. The results of the analyses are summarized in Table 3-2.

The data indicate that ground water at each of these two locations is tritiated at all levels monitored. The BUG1 analyses detected tritiated water at the bottom of the Central Area Aquifer near the northern Site boundary, and the GO1/UG1 analyses detected tritiated water as deep as 480 feet below ground surface. Consequently, one can conclude that the ground water within the Central Area is relatively young and is likely recharged from within the Aberjona River basin.

3.2 CONTAMINANT DISTRIBUTION IN GROUND WATER

The following discussion summarizes the nature and extent of contamination within the Central Area and discusses some examples of the various sources contributing to that contamination. In an industrialized urban watershed, such as the Aberjona River watershed, one should expect to find numerous sources of contamination. As the following section will demonstrate, numerous sources have been found within the Aberjona River watershed. Discussions of conditions specific to the Source Area Properties (OU1) are not provided in this report because they are not part of this investigation.

3.2.1 Known and Suspected Sources of Contamination

Within the Wells G & H Site, there are several known sources that contribute to contamination of the Central Area. These include the five ROD-named Source Area Properties as well as several other sources. The five Source Area Properties are:

1. the Olympia property,
2. the UniFirst property,
3. the W.R. Grace property,
4. the New England Plastics property, and
5. the Wildwood property.

In addition to the five Source Area properties, there are numerous other known, suspected, or potential sources of contamination in the Central Area itself. Much of the Central Area was developed as industrial parks in the 1970s through the mid-1980s. These developments include Cummings Park, West Cummings Park, 21 Olympia Avenue, and 25 Olympia Avenue. The tenants of the industrial parks are typical industrial and commercial operations including, among others, light manufacturing, printing facilities, and chemical laboratories for research and development. Many of the tenants use hazardous substances on site. In addition, since at least 1980, Cummings Properties Management, Inc. has operated a service garage and storage facility at 74 Cummings Park where it has used degreasing agents containing tetrachloroethene and 1,1,1-trichloroethane.

Ten spills within the Central Area have been recorded in the DEP spill database. The spills are listed in Appendix IIA. On September 19, 1986, DEP responded to a release of an unknown quantity of material containing methanol and acetone at the MedChem facility at 236 West Cummings Park. On April 22, 1988, DEP also received a report that Romicon, Inc. had disposed of solvents in drains on the Cummings properties. These incidents are illustrative of the potential for spills and releases of chemicals throughout the Central Area. Individual known sources of contamination, including several gas stations, are discussed more completely below.

Forty seven disposal sites have been identified by DEP within the Aberjona River and Snyder Creek watersheds. These sites are in different phases of investigation and remediation under the MCP. Plate 2-1 shows the locations of the 47 DEP sites and Table 2-1 lists each site, its current status with regard to the MCP process, and primary contaminants identified at the site.

Of the 47 DEP sites within the Aberjona drainage basin, 16 sites are located within or adjacent to the Wells G & H Site. Their locations are shown on Figure 3-28. The following presents a summary of data and information available for these 16 sites.

3.2.1.1 Aberjona Auto Parts Property

3.2.1.1.1 Studies prior to the Central Area RI

The Field Inspection Team (FIT) Ecology & Environment Inc. (E&E) found no evidence of soil, ground-water, or surface water contamination during a previous examination of the Aberjona Auto Parts property (E&E 1980). However, it was noted that a degreasing solvent was used to clean engine parts on the property and that the spent solvent was discharged to the municipal sewer system. Samples collected from a drum at the site and from a sewer manhole indicated the presence of VOCs.

A limited amount of soil analytical data was previously collected on the Aberjona Auto Parts property (Ebasco, 1988). Four samples were collected from depths ranging from zero to 11 feet below grade during installation of monitoring well AB-1. These samples were analyzed for VOCs and SVOCs. Five VOCs were detected in soil at concentrations ranging from 0.006 to 4.0 mg/kg and SVOCs were not detected. PCBs were not analyzed in these samples. Well AB-1, however, is located close to the property boundary in an area not utilized during the typical operations of the salvage yard and may not be representative of the environmental conditions of the property.

Ground-water samples were collected and analyzed from two monitoring wells during the EPA RI of the Site. Ground water from monitoring well S-83, located adjacent to the City of Woburn and MWRA sewer line, showed detectable concentrations of four VOCs including trichloroethene (1,400 $\mu g/L$ in April 1985), trans-1,2-dichloroethene (10 $\mu g/L$), 1,2-dichloroethene (7 $\mu g/L$), and tetrachloroethene (15 $\mu g/L$). Monitoring well AB-1 showed detectable concentrations of xylene, (6 $\mu g/L$) in December 1987. Two SVOCs were also detected at low concentrations. The analytical results from the previous investigations are summarized in Figure 2-1 of Attachment 1.

3.2.1.1.2 Central Area RI Studies

The field investigation for the RI for the Southwest Properties presented in detail in Attachment 1 entailed collection of soil samples from nine locations on the Aberjona Auto Parts property. Samples were collected from the ground surface and from the ground-water table interface. Soils were analyzed for VOCs, SVOCs, PCBs, pesticides, metals, and cyanide.

The Aberjona Auto Parts property is characterized by limited VOCs present in the surface and subsurface soils. The only chlorinated compound detected was 1,2-dichloroethene, which was detected in seven of the nine surface samples and in all of the subsurface samples. Concentrations were reported as estimated values, detected below the practical quantification limit (PQL). Total BTEX was identified at low concentrations in both surface and subsurface soils.

The distribution of SVOCs in soils on the Aberjona Auto Parts property is concentrated in AB-SS5 and to a lesser extent in AB-SS6. Shallow soil sample AB-SS5 had the highest concentration of PAHs and CPAH constituents of the nine samples collected on the Aberjona Auto Parts property. The concentration of total PAHs in soil ranged from below detection limit to 14.1 mg/kg. Total CPAH concentrations ranged from PQL to 8.014 mg/kg.

Pesticides were identified in shallow and deep soil samples with the highest concentrations detected in shallow soils. The principal pesticides detected on this property were 4,4-DDD, 4,4-DDT, and chlordane.

PCBs were detected in both shallow and deep soil samples at low concentrations. Typically, shallow soils had higher concentration of PCBs. Soil sample DUP1AB and the AB-SS9 duplicate sample had the highest PCB concentration reported at 0.763 mg/kg.

The metals of concern, arsenic, chromium, and lead, were typically detected at higher concentrations in deep soils with the exception of lead which was reported at the highest concentration in shallow soil sample AB-SS3 at 45,824 mg/kg. Arsenic was identified in all soil samples at concentrations ranging from 2.4 to 27 mg/kg. Chromium was identified in all soil samples at concentrations ranging from 6.3 to 44.4 mg/kg.

The drilling program on the Aberjona Auto Parts property entailed installation of four new wells and replacement of one existing well. Well S-83SS was installed adjacent to the former location of well S-83, which was badly damaged and replaced with well S-83M. The new well, S-83SS, was screened across the water table to evaluate ground water at the top of the aquifer at this location. A cluster of three wells was installed near the center of the Aberjona Auto Parts property where no ground-water data had been collected previously. The screened intervals of these wells were: AB-2SS, 3 to 13 feet; AB-2M, 58 to 68 feet; and AB-2R, 122 to 132 feet (15 feet into bedrock).

The contaminants of primary concern, VOCs, were analyzed in each well for the full TCL list. The chlorinated compounds identified on the Aberjona Auto Parts property included 1,2-dichloroethene, trichloroethene, and tetrachloroethene. 1,2-Dichloroethene was identified in wells AB-1 and S-83M at 4.0 and 1.3 μg/L respectively. Trichloroethene was reported in three wells, S-83M, AB-2M, and AB-2R, with a concentration range of 4.4 to 363 μg/L. The highest concentration was reported in AB-2M. Trichloroethene was identified in the bedrock well AB-2R at 144 μg/L. This bedrock well is screened 10 feet into competent bedrock. Tetrachloroethene was also reported in these three wells at a concentration range of 0.09 to 21.2 μg/L. The distribution of tetrachloroethene was the same as reported for trichloroethene. The highest concentration was reported in AB-2M, with 20.7 μg/L in the bedrock well AB-2R.

BTEX concentrations were not reported above the PQL in any of the ground-water samples collected on the Aberjona Auto Parts property. However, the detection limits in AB-2M and AB-2R were reported as 50 and 20 μg/L respectively.

Ground-water samples collected for SVOC, pesticide, and PCB analysis did not detect any constituents above the PQL. Manganese was the only metal detected above the Massachusetts secondary MCL (SMCL) of 50 μg/L. Samples from all monitoring wells on the property exceeded the SMCL.

3.2.1.2 Whitney Barrel Property

3.2.1.2.1 Studies Prior to Central Area RI

The first investigation conducted on the Whitney Barrel property was an FIT Inspection performed by E&E (1980) under the direction of EPA. The FIT inspection of the Whitney Barrel property noted a large number of empty tanks and drums on site. Some of the empty drums displayed labels for pesticides and solvents. A number of empty steel drums and one full cardboard drum bore caustic material labels. In addition to the drums and tanks, the property was reported to be covered with scrap metal, debris, and trailers.

During the Wells G & H RI Part I well installation activities in 1985, soil contamination was identified on the Whitney Barrel property. As a result, DEP ordered the property owner to conduct an assessment to determine the nature and extent of soil and ground-water contamination on the property. This investigation was carried out by GHR Engineering Associates (GHR) in 1988 and described in a site assessment report (GHR, 1988). The investigation included a geophysical survey; installation and chemical screening of soil vapor probes; and excavation and sampling of 18 test pits. The drilling program included installation and sampling of twelve unconsolidated deposit soil borings and installation of four ground-water monitoring wells and four piezometers in the unconsolidated deposits. The sampling program entailed sampling all new ground-water monitoring wells and floor drain sediments. Test pits were excavated to depths of between 5 and 8 feet below ground surface (bgs) and soil borings were advanced from 10 to 15 feet bgs. All unconsolidated deposit samples from test pits and soil borings were composited across the total depth of the excavation.

The unconsolidated deposit sample results from the 1988 site assessment of the Whitney Barrel property are summarized in Figure 2-3 of Attachment 1. Contaminants detected in the unconsolidated deposits included VOCs, SVOCs, pesticides, and PCBs, as well as relatively low levels of inorganic substances detected generally within background range. VOCs were detected in 14 of 25 samples analyzed, with a maximum total VOCs concentration of 711 mg/kg at location TP-12. Specific compounds detected included trichloroethene, tetrachloroethene, xylene, toluene, and ethylbenzene. SVOCs were detected in all soil samples with a maximum concentration of 24.1 mg/kg at location TP-17. SVOCs detected included PAHs and phthalates. The pesticide chlordane was detected in 16 unconsolidated sediment samples at a concentration as high as 26.8 mg/kg (TP-11) and PCBs were detected in 21 samples with a maximum concentration of 94.8 mg/kg (TP-12D).

VOCs, SVOCs and PCBs were also detected in ground-water samples at the Whitney Barrel Property (Attachment 1, Figure 2-3). Total VOCs were detected in all four samples at a maximum concentration of 1,020 μg/L in MW-4S. VOCs detected included 1,1-dichloroethane, 1,1,1-trichloroethane, vinyl chloride, benzene, xylene, and toluene. Concentrations as high as 10 μg/L of PCBs in ground water were detected in two wells, MW-2S and MW-3S.

Conclusions about unconsolidated deposit and ground-water contamination on the Whitney Barrel property as stated in the GHR (1988) report included the following:

- Soil VOC contamination in the vicinity of TP-12 is probably the result of spills or leaks of solvents or degreasers and gasoline on the property in the area near the test pit.

- It is likely that unconsolidated deposit and ground-water contamination by SVOCs, pesticides, and PCBs is the result of activities on the property and events including fires, leaks of petroleum products from vehicles, vehicle exhaust, tank cleaning, and pesticide application.

Historical soil analytical data available for the Whitney Barrel property are the most extensive and complete of the three Southwest Properties. A large number of samples were collected throughout the property and were analyzed for a broad set of compounds. These results show a limited area of unconsolidated deposits in the vicinity of TP-12 which contain VOCs, surrounded by an area with lesser concentrations of VOCs. The results for SVOCs show a more extensive distribution of constituents. The highest concentrations are found in three areas, in the vicinity of B-3, TP-17, and B-7. The distribution and varied concentrations of the detected contamination are consistent with the history of releases known to have occurred on the Whitney Barrel property. This history includes leaks and spills from past property uses including vehicle storage and tank and drum cleaning. Unconsolidated deposit PCB contamination is greatest in the area behind the existing building on the property. The highest concentrations were detected in locations TP-6, TP-7, TP-11, TP-12, B-5, and MW-3S.

3.2.1.2.2 Central Area RI Studies

The site characterization activities performed on the Whitney Barrel property entailed unconsolidated deposit soil sample collection at four locations, installation of four new monitoring wells, and replacement of one well. The unconsolidated deposit sampling program was designed to augment data collected during the previous GHR investigation of the property (GHR, 1988).

VOCs identified in soil samples collected from the Whitney Barrel property are limited to 1,1-dichloroethene, tetrachloroethene and BTEX. Both chlorinated compounds were reported as estimated values below the detection limit. The highest concentration of BTEX was reported in WB-SS2D at 4.18 mg/kg and was composed predominantly of xylene (3.33 mg/kg).

The principal SVOCs identified on the Whitney Barrel property were PAHs. Seven PAHs were identified in the shallow and deep samples with the highest concentration reported in shallow soil sample WB-SS2 at 4.086 mg/kg and in the deep soil sample WB-SS2 at 7.46 mg/kg.

Pesticides were detected in every soil sample collected on the Whitney Barrel property. The principal pesticides identified on the property were 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, and chlordane. Chlordane was reported at the highest concentration in surface sample WB-SS3 at 1.3 mg/kg.

PCBs were detected in all of the surface soil samples collected on the Whitney Barrel property and in two of the subsurface soil samples. Concentrations ranged from 0.09 to 2.89 mg/kg total PCBs with the highest concentration reported in WB-SS2D.

The metals of concern, arsenic, chromium, and lead, were typically detected in both the shallow and deep soil samples, however, the shallow soil typically identified higher concentrations. Lead was reported above the soil cleanup criterion of 649 mg/kg established for the Wildwood property in two of the four samples analyzed

The drilling program on the Whitney Barrel property consisted of installing four new monitoring wells and installing MW-4SS, a replacement well for monitoring well MW-4S which could not be located. Monitoring wells were installed as couplets screened in discrete zones of the aquifer. Ground-water analytical data identified the following chlorinated compounds on the Whitney Barrel property: 1,2-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene. Monitoring well MW-4SS, a shallow monitoring well installed along the northern property boundary, contained the greatest number of chlorinated compounds. However bedrock well MW-4D, located adjacent to this well, reported the highest trichloroethene concentration at 3.6 μg/L. BTEX constituents were all reported below the PQL.

SVOC data for Whitney Barrel did not identify any CPAH or PAH constituents. The only pesticide detected on the property in ground water was chlordane at 0.093 μg/L in MW-4SS. All other analytical results were below the PQL. All PCB analyses reported concentrations below the PQL.

Manganese was the only metal detected on the Whitney Barrel property above the SMCL. Manganese was detected in monitoring wells WB-1SS, WB -1M, MW-4SS, and MW-4M at concentrations ranging from 85 to 480 μg/L.

3.2.1.3 Murphy Waste Oil Property

3.2.1.3.1 Studies Prior to Central Area RI

In 1988, EPA and its Technical Assistance Team (TAT) contractor, Roy F. Weston, Inc. (Weston), collected a single surface soil sample from the northern part of the Murphy Waste Oil property. The sample was collected in an area where the surface was identified as "oil stained". Sample A-1 was analyzed for PCBs and SVOCs. Laboratory results from the sample identified PCBs at concentrations of 0.01 mg/kg, fluoranthene at 0.96 mg/kg, and pyrene at 2.4 mg/kg (Weston, 1988). The sample location and analytical summary are shown on Figure 2-4.

In 1989 and 1990, Clean Harbors Environmental Services performed a limited site investigation and remedial action on the Murphy Waste Oil property. This work, carried out with DEP approval, was intended to allow construction of a new waste oil handling facility on the property to be constructed and operated by Clean Harbors. The DEP findings with respect to the site are summarized in a letter on March 16, 1989, from John J. Fitzgerald, P.E., Chief, Site Assessment and Cleanup Section, and Richard J. Chalpin, Deputy Regional Environmental Engineer to the Northeast Region, Massachusetts DEP, to William St. Hillaire, Vice President, Clean Harbors Environmental Engineering Corporation. They state that "Preliminary data indicate the presence of low to high concentrations of petroleum hydrocarbons in the vicinity of the proposed new construction. VOCs, phenols and PCBs do not appear to be a problem." The location chosen for the facility was in an area where subsurface deposits were contaminated with petroleum products. Wells were installed in eight borings on the property and unconsolidated deposit and ground-water samples were collected. Unconsolidated deposit samples were analyzed for TPHs, PCBs, and VOCs. Ground water was analyzed for TPHs. These results are summarized in Figure 2-4 of Attachment 1.

The results of these investigations show that both ground water and the unconsolidated deposits on the Murphy Waste Oil property contain petroleum product residues. Samples of unconsolidated deposits also show some evidence of VOCs and PCBs at low concentrations. Clean Harbors excavated those deposits determined to be contaminated during the investigation and transported them to an off-property disposal facility. The excavations were backfilled and a new waste oil facility was constructed.

3.2.1.3.2 Central Area RI Studies

The site characterization activities conducted on the Murphy Waste Oil property during the current RI entailed shallow and deep soil sampling, sediment sampling from the adjacent wetland, and installation of two ground-water monitoring wells. Three surface and four subsurface soil samples were taken on the Murphy Waste Oil property. Two of the soil samples were taking from the borings of monitoring wells MR-1SS and MR-2SS. One sample was taken in the former building foundation and the last sample was taken from the driveway area to the east of the main building.

Chlorinated VOCs on the Murphy Waste Oil property were characterized by 1,1-dichloroethene and trichloroethene with the highest concentrations detected in the subsurface sample MR-SS2D. BTEX constituents were identified in soil samples at concentrations ranging from 0.0079 to 15.3 mg/kg. The highest concentrations were detected in subsurface soil sample MR-SS2D. Xylene was the principal constituent in this sample at a concentration of 10.6 mg/kg.

The principal SVOCs identified on the Murphy Waste Oil property were polynuclear aromatic hydrocarbons (PAHs). MR-SS2 identified the highest concentration of total PAHs at 4.877 mg/kg. Deep sample MR-SS2D reported all SVOC constituents below elevated PQL.

Chlordane represented the principal pesticide detected on the Murphy property. Two soil samples, MR-SS1 and MR-SS2, had concentrations of 0.0477 mg/kg and 0.0266 mg/kg respectively in the shallow soils and lower concentration in the subsurface soils. Other pesticides identified included Heptachlor, Epoxide, and Endrin. PCBs were detected in shallow sample MR-SS3 at 0.073 mg/kg. All other samples reported PCBs below the PQL.

The three wetland samples collected on the Murphy Waste Oil property, MR-SS5, MR-SS6, and MR-SS7, all contained pesticides. Chlordane was reported in each sample with the highest concentration reported in MR-SS6 at 2.861 mg/kg, the highest concentration identified in any sample at the Southwest Properties. PCBs were detected in all three samples with a concentration range of 1.096 to 13.33 mg/kg. The highest concentration was reported in MR-SS6, again the highest concentration recorded on the three Southwest Properties. Lead was detected in two wetland samples at concentrations above the cleanup criterion established for the Wildwood property.

The drilling program on the Murphy Waste Oil property entailed installation of two ground-water monitoring wells, MR-1SS and MR-2SS, screened vertically across the water table. Chlorinated compounds detected in ground water on the Murphy Waste Oil property included 1,1-dichloroethene, 1,1-dichloroethane, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene. 1,2-Dichloroethene was reported at the highest concentration of 461.0 μg/L in monitoring well MR-2SS. Trichloroethene was identified in this well at 22 μg/L. All other chlorinated compounds were reported below 5 μg/L. BTEX was reported at a concentration range of 4 to 355.5 μg/L. The highest concentration again was reported in MR-2SS. Total xylene was identified at 324 μg/L and benzene was reported as an estimated value. SVOCs were detected at low concentrations with three PAHs identified at a total concentration of 43 μg/L. No PCBs or pesticides were detected in samples collected from the site and no metals were detected above the MCL.

3.2.1.4 Charrette Property

3.2.1.4.1 Studies Prior to Central Area RI

The Charrette property is located at the northern end of the Wells G & H Site and directly overlies the Central Area Aquifer. A Phase I Limited Site Investigation was conducted at the Charrette property between July and November 1990 (GZA, 1990). This study indicated the presence of gasoline related VOCs in ground water adjacent to, and downgradient from, a 5,000-gallon underground fuel storage tank. The source of the gasoline was thought to be from spillage during tank filling, leakage from pipe joints, and possible leakage from the gasoline pump. Repairs were made to the piping, the system was upgraded, and the surrounding soil was excavated and removed in September 1990. Tetrachloroethene was detected at a concentration of 2,800 μg/kg in one of the soil samples taken during the excavation. Floating (separate phase) gasoline was observed in the monitoring well CHM1 which is located southwest of the tank. Recovery of free-phase gasoline was begun by Charrette using bailers in a passive recovery system. The passive recovery system, which was installed in December 1990, consisted of six recovery wells downgradient from the tank.

A Phase II Comprehensive Site Assessment of the Charrette property was conducted between April and October 1992 (GZA, 1992). Results of analyses of groundwater samples collected during the Phase II study indicated that the plume of dissolved gasoline constituents extended beyond the property line between Charrette and the adjacent property on Normac Road. The range of concentrations for the VOCs detected in groundwater is shown in Table 3-3. BTEX concentrations exceed their MCLs. Trichloroethene and tetrachloroethene were detected at concentrations below method quantitation limits.

Surface water samples from the drainage ditch along Normac Road contained the compounds shown in Table 3-4. In addition to the gasoline related compounds, chlorinated volatile organic compounds, tetrachloroethene and vinyl chloride, were detected. Benzene, tetrachloroethene, and vinyl chloride exceed their MCLs. Trichloroethene and 1,2-dichloroethene (total) were also detected but at concentrations below method quantitation limits.

No additional remedial action other than continued collection of floating product from the tank area, maintenance of the tank and piping system in accordance with state requirements, and ongoing monitoring of VOC concentrations in ground water downgradient of the gasoline storage tank was recommended by GZA.

3.2.1.4.2 Central Area RI Studies

Additional investigations of the Charrette property contamination were undertaken in March 1993 by UniFirst and Grace. These investigations were done to evaluate the contribution of VOCs to the Central Area Aquifer from the Charrette property. Four wells were installed at three locations along the downgradient Charrette property boundary. Continuous split-spoon samples of the unconsolidated deposits were collected during drilling. The samples were analyzed with a portable gas chromatograph for benzene, toluene, ethylbenzene, xylene, and tetrachloroethene using the headspace technique. BTEX compounds were consistently detected in samples from borings UG6, UG7S, and UG7D. The gas chromatograph results are summarized in Table 3-5.

Ground-water samples were collected on March 3, 1993, and analyzed for VOCs by Method 8240. The results of the ground-water analyses are summarized in Table 3-6. The results confirmed that ground water contaminated with gasoline related VOCs as well as trichloroethene was migrating off the Charrette property. The distribution of gasoline related VOCs downgradient from the Charrette underground tank is shown on Figure 3-29.

Concentrations of benzene, trichloroethene, and toluene leaving the Charrette property are greater than MCLs for these compounds. In addition, surface water samples collected from the drainage ditch along Normac Road downgradient from the Charrette property contained benzene, vinyl chloride, and tetrachloroethene at concentrations greater than MCLs.

3.2.1.5 McLean Trucking Property

The McLean Trucking property is located on Cedar Street near Route 93 at the eastern edge of the Site (Figure 3-28). Prior to May 1986, one 20,000-gallon and two 10,000-gallon underground storage tanks were removed from the McLean property. During the tank removal, it was discovered that one of the 10,000-gallon tanks had leaked. Also prior to May 1986, Geotechnical Consultants of Massachusetts (1986) performed a site assessment in conjunction with the sale of the property. Seven test borings were drilled and water samples were collected and analyzed for VOCs. Gasoline related compounds were detected at concentrations as high as 34,500 and 66,100 μg/L (ERM, 1986). GZA performed additional assessment work and further documented soil and ground-water contamination by petroleum products (ERM, 1986).

Beginning July 1986, ERM (1986) performed a remedial action investigation to supplement the previous investigations. One of their stated objectives was to locate the downgradient boundary of the contaminant plume to aid design of a remedial action plan. Their investigation indicated the presence of non-aqueous phase gasoline and ground-water contamination associated with the release from the old underground storage tanks. The contaminant plume was migrating west from the former location of the tanks. Ground-water analyses indicated BTEX concentrations ranging from ND to 66,000 μg/L. The higher concentrations were detected closer to and downgradient from the former tank area. It was determined by ERM that the significant levels of non-aqueous phase gasoline and contaminated ground water would necessitate remedial action including ground-water pumping, treatment, and petroleum recovery.

A ground-water recovery and carbon absorption treatment system has been operating since April 2, 1990. The results of the first influent analysis are included in Table 3-7. The benzene and toluene concentrations exceed MCLs for those compounds.

No records of any ground-water sampling following the start of treatment system operation were found at DEP.

3.2.1.6 Getty Service Station Property

A field investigation was conducted and a Preliminary Assessment Report was produced by Groundwater Techology, Inc. (GTI) in May 1992 (GTI, 1992) regarding subsurface conditions at the Getty Service Station located at 325 Washington Street, Woburn, Massachusetts. GTI also provided Getty Petroleum Corporation with data that would be useful in evaluating procedures for replacing the underground gasoline storage tanks at the property after a 5,000-gallon tank failed to pass a tightness test in July 1991. To assess the subsurface soil and ground-water conditions at the property, five soil borings were drilled and completed as monitoring wells. Reported detectable concentrations in March 1992 ground-water samples are summarized in Table 3-8. The reported benzene and toluene concentrations exceed MCLs for those compounds.

In May 1992, one 1,000 gallon fuel oil tank, one 1,000 gallon waste oil tank and three 5,000 gallon gasoline tanks were removed. In June 1992, soil was excavated from the tank area and analyzed prior to disposal. Total petroleum hydrocarbon concentration of the soil was 140 mg/Kg

Ground-water samples were also collected in December 1992 and the results of the analyses with concentrations greater than the detection limit are summarized in Table 3-9. Benzene concentrations were still greater than the MCL for benzene. Non-aqueous phase petroleum was not detected in any of the monitoring wells.

Drive point DP20, located on the west side of Washington Street and about 100 feet from the Getty Service Station, was sampled in June 1992 and August 1993 as part of this RI investigation. Benzene was detected at 0.4 μg/L and 18 μg/L respectively in the samples. These data indicate that benzene contaminated ground water is flowing off the Getty Service Station property at concentrations greater than MCLs.

3.2.1.7 Industrial Property at 225 Wildwood Avenue

In 1988, an assessment of subsurface conditions at the property located at 225 Wildwood Avenue was made by Gordon Associates (Gordon Associates, 1988). The property is located west of the Wildwood Conservation Trust property on the west side of the railroad tracks. The purpose of their work was to assess whether hazardous materials or oils were present in the soil or ground water. Eleven test borings were drilled, twenty eight test pits excavated and two monitoring wells installed. Six of these explorations reportedly encountered materials that were discolored (black and grey) and had an unpleasant odor in two different areas of the property. Some soil discoloration was also reported. Ground-water samples were collected from the two wells and analyzed. Reported detectable concentrations are summarized in Table 3-10. The results of analyses of soil samples taken during the same time period are summarized in Table 3-11. Chromium, lead, arsenic, and barium were detected at high concentrations in both soil and ground-water samples. Chromium and lead exceed MCLs. In addition, several VOCs were detected in both ground-water and soil samples.

It was determined by Gordon Associates that the discolored soils appeared to be tannery wastes and that the presence of metals in soil and ground water was the principal environmental concern. The soil and black/grey materials have been covered by fill or pavement. Gordon Associates recommended that if future development of the property is considered, the discolored soils and materials should be excavated. It was also recommended that water samples be collected periodically and tested for VOCs and trace metals to determine if additional soil cover is warranted. No record of additional sampling was found in the DEP files.

3.2.1.8 Weyerhauser Company Property

The Weyerhauser site first attracted attention when contamination was found by EPA in wells installed as part of the Wells G & H Superfund Site Remedial Investigation in January 1985. Three additional borings with ground-water monitoring wells were installed in February 1987 as part of a ground-water study performed by the Massachusetts FIT contractor under contract to DEQE (Wehran, 1987). Their results indicated that "ground-water quality varies across the Weyerhauser site, from trace concentrations of a few contaminants at the northern site boundary to quantifiable concentrations of a large number of contaminants at the downgradient southeastern corner" (Wehran, 1987). Table 3-12 lists the reported ground-water concentrations that were greater than the detection limit. Benzene concentrations exceed MCLs and several PAHs exceeded Massachusetts DEP guidance levels.

In March 1989, Cortell Associates (Cortell, 1989) installed nine additional monitoring wells and sampled all wells in April 1989. Table 3-13 lists the reported concentrations that were greater than the detection limit. Benxene, trichloroethene and methylene chloride concentrations exceed MCLs for those compounds. TPH was found in wells in the southeastern corner of the site with concentrations of 2,300 - 2,500 μg/L at a depth of 0.5 feet to 11.5 feet.

Cortell determined that there was a source of methylene chloride and trichloroethene contamination located off site and north of the Weyerhauser property. This determination was based on the detection of these contaminants in wells located along the northern and western boundaries. An on-site source of coal tar was discovered in the southeastern corner of the property and Cortell recommended that it be removed. They also recommended that more test borings be made to determine the extent of contamination by all petroleum hydrocarbons.

Cortell recommended the removal of an underground 10,000-gallon diesel fuel storage tank and the tank was removed in April 1990. Inspection of the tank and surrounding soil indicated no holes or breaches, petroleum product odors, or stains. Based on the results of the soil sampling program and visual inspection of the excavated tank, no additional action was recommended.

The Weyerhauser property is a source of VOCs and PAHs to the Central Area at concentrations greater than MCLs or applicable guidance levels. These contaminants are migrating into the Central Area.

3.2.1.9 Motors, Electronics, and Controls Corporation Property

Inland Environmental Services (IES) conducted a Preliminary Site Assessment of the property at 73 Olympia Avenue in Woburn, Massachusetts, in the spring of 1991 (IES, 1991). Two monitoring wells were installed and soil samples taken from the borings. The wells were sampled three days later. The results from the ground-water and soil analyses are summarized in Table 3-14. The benzene concentration in ground water exceed the MCL.

Inland Environmental Services recommended additional analyses be performed on some of the soil samples in order to possibly "fingerprint" the nature of the contaminant. It was their opinion that the contaminant levels found were very low. It was also their opinion that the potential for environmental enforcement action with respect to possible human and environmental receptors and potable water supplies was low due to the location of the site. No additional information regarding additional investigations or remedial action were found in the DEP files.

3.2.1.10 Property at 5 Wheeling Avenue

In October 1988, two underground storage tanks were removed from the northern portion of the property at 5 Wheeling Avenue, Woburn, Massachusetts. Following the removal of these tanks, fuel was observed in ground water at the bottom of the tank excavation. M&E/Zecco (1990) performed a subsurface evaluation beginning in December 1988 when it was determined that a release of gasoline had occurred. The subsurface evaluation was followed by a Phase I-Limited Site Investigation from November 1989 through July 1990 to determine the relative degree and extent of gasoline contamination caused by the fuel release. Reported detectable concentrations in January and June 1990 ground-water samples are summarized in Table 3-15. Benzene, toluene, and ethylbenzene concentrations exceed MCLs for these compounds. These results indicate the presence of petroleum related VOCs at locations downgradient (south) of the former 4,000-gallon gasoline tank and the 10,000-gallon diesel fuel tank. It was determined by M&E/Zecco that further site investigations and ultimately remedial actions were warranted. The status of additional investigations and remediation is not known.

3.2.1.11 Romicon, Normac Road Property

In December 1991, an initial environmental site assessment was performed by CH_2M Hill (1991) at the Romicon Inc. facility at Normac Road, Woburn, Massachusetts. Soil borings and one monitoring well were installed at the site and samples of soil and ground water were taken. Reported detectable concentrations for the soil and ground-water samples are summarized in Tables 3-16 and 3-17. Ground-water concentrations of tetrachloroethene and nickel exceed MCLs and sodium and chloride concentrations exceed the Massachusetts ORSG and SMCL respectively.

It was recommended by CH_2M Hill that additional investigations be done to determine sources for the contaminants detected during their investigation and to evaluate whether remediation would be required under Massachusetts law. No additional reports were found in the DEP files.

3.2.1.12 Romicon, Cummings Park Property

3.2.1.12.1 Studies Prior to Central Area RI

An initial site assessment was performed by CH_2M Hill (1991) at the Romicon Inc. facility at 100 Cummings Park, Woburn, Massachusetts. Soil borings and two monitoring well were installed at that time. In December 1991, soil samples were taken from these borings and ground-water samples were taken from the two monitoring wells and one existing on-site well for analysis. Reported detectable concentrations for the ground-water and soil samples are summarized in Tables 3-18 and 3-19.

It was recommended by CH_2M Hill that further investigations be conducted to determine sources for the contaminants detected during their investigation and to evaluate whether remediation would be required under Massachusetts law. There is no information in the DEP files that the recommended investigations have been done.

3.2.1.12.2 Central Area RI Studies

As part of the Central Area RI, there have been additional reviews of DEP files and installation of wells on the Cummings property downgradient of the former Romicon facility. It has been determined that about 500 feet of the sanitary sewer line which serviced the Romicon facility were replaced in 1987 due to complete corrosion of the bottom of the sewer pipe. A variety of chemicals were used and handled at the Romicon facility including cleaning agents containing tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. These chemicals have been detected in ground water downgradient of the Romicon facility.

3.2.1.13 Continental Metal Products Property

A site assessment was conducted at Continental Metal Products, Woburn, Massachusetts by The Geotechnical Group, Inc. (TGG, 1986). The assessment was done to evaluate the presence of oil or other hazardous materials at the site or in the environment of the site. Low levels of chlorinated hydrocarbons were detected in ground water obtained from two wells. As the facility has not used significant quantities of VOCs and because upgradient wells had higher concentrations than downgradient wells, it was determined that the contamination was probably related to an off-site source. When sampled again in April 1987, there was no detection of VOCs in the wells and it was determined that the VOC contamination was "not present in the environment at this time" (TGG, 1986).

In December 1988, after a 5,000-gallon #2 fuel oil underground storage tank had been removed, a layer of fuel oil was observed floating on ground water in the excavation. Approximately 10 cubic yards of contaminated soil were removed during excavations around the tank. Subsequent quantitative analyses revealed that soils at the limits of the excavation met DEQE standards for total petroleum hydrocarbons and the excavation was backfilled and the excavated soil properly removed.

The wells were sampled again in March 1989 when 1,2-dichloroethane was found in the two upgradient wells at levels of 12 and 5.5 μg/L. Based on this and results of previous studies, it was again determined that the contamination was from an off-site source (TGG, 1989).

3.2.1.14 Carolina Freight Carrier Corporation Property

The Carolina Freight Carrier Corporation terminal was previously located at 95 Cedar Street in Stoneham at the eastern edge of the Site. The site is identified as Site No. 47 on Figures 2-1 and 3-28. Three underground storage tanks have been removed from the former Carolina terminal. A 10,000-gallon gasoline tank was removed on October 12, 1986, a 550-gallon waste oil tank was removed on November 17, 1989, and a 10,000-gallon diesel tank was removed on January 8, 1990.

Subsequent to the removal of the diesel tank, a Phase 1 site investigation was performed by Webb Engineering Associates, Inc. (Webb, 1990). Four test borings were drilled and monitoring wells installed near the former tank locations. Samples of the unconsolidated deposits collected during drilling were screened with a photoionization detector for the presence of VOCs. Results of the screening indicated that VOCs were present in samples from all four borings with the highest concentrations detected in samples from well MW-3. Groundwater samples were collected from the wells on February 7, 1990, and analyzed for VOCs and TPHs. Results of the analyses indicated that the sample from well MW-3, located downgradient from the location of the former tanks, contained BTEX compounds at concentrations greater than MCLs (Webb, 1990). The actual VOC concentrations could not be determined because the analytical results were missing from the DEP files.

In June 1990, the Phase 1 report (Webb, 1990), the Preliminary Assessment report (Webb, 1990), the Interim Site Classification form, and the Application for Waiver of Approvals were submitted to DEP. DEP granted the Waiver of Approvals on September 24, 1990. There was no information in the DEP files regarding implementation of a remedy at the site. The Carolina Trucking terminal is another likely source of petroleum related VOCs to the Wells G & H Site.

3.2.2 Nature and Extent of Contamination within the Central Area

Given the multiplicity of sources that have been identified, it is not surprising that there is a widespread distribution of a variety of contaminants in the Central Area. The specific chemical contaminants discussed in this section include inorganic compounds such as major ions and metals, volatile organic compounds, and semi-volatile organic compounds. The chemicals discussed comprise both anthropogenic and naturally-occurring compounds which are viewed as contaminants when they exceed acceptable levels. A consideration of the distribution of these chemicals provides insight into the current extent of aquifer contamination, possible origins of this contamination, as well as an indication of the continuing vulnerability of the aquifer to both point-source releases and more areally widespread non-point-source releases.

With respect to VOCs, discussion is provided for both those chemicals defined as contaminants of concern in the ROD as well as other VOCs which are relevant to understanding generic and specific sources of contamination. Discussion of SVOCs includes PAH compounds as well as other SVOCs. Metals which are presented include arsenic, chromium, and lead. The major ions which are discussed include sodium, chloride, nitrate, and sulfate. This group of chemicals was selected because they either are VOC chemicals of concern as defined in the ROD for the Wells G & H Site, had been identified as chemicals of concern prior to investigations related to VOCs (GeoTrans, 1987, Chapter 2), or are indicators of anthropogenic influences within the Aberjona River watershed.

The current distribution of ground-water contamination within the Central Area is illustrated on maps showing the most recent sampling result for each location. With a few exceptions, all samples have been collected since February 1991. A more complete summary of analytical results for all ground-water samples collected from within the Wells G & H Site is included as Appendix F. Ground-water quality data have been presented in areal plots for both the unconsolidated deposits and bedrock. In addition, ground-water quality data have also been presented on selected cross sections. The areal plots and the cross sections provide a three-dimensional representation of the distribution of contamination within the Central Area. The specific chemicals which have been included on the areal maps and sections are nitrate, sodium, chloride, sulfate, arsenic, chromium, lead, benzene, tetrachloroethene, trichloroethene, 1,2-dichloroethene, and 1,1,1-trichloroethane.

In the following sections, an overview of the contaminant distribution is provided first. This is followed by a more detailed treatment of specific contaminants. A discussion of contaminant trends and their significance with respect to interpreting site conditions is also provided.

3.2.2.1 Overview of Current Distribution of Contamination in Surface Water

Water quality in the Aberjona River and its tributaries has been impacted by both point source and non-point sources of contamination. While point sources such as industrial discharges to the river have likely been stopped, non-point sources of contamination continue. Non-point sources of contamination to the river include the following:

- Runoff from roads and highways
- Leachate from landfills and dumps
- Contaminated ground water from many known sources
- Accidental spills and releases

Surface water samples were collected from the Aberjona River approximately 20 feet south of the Route 128 bridge to evaluate water quality of the Aberjona River where it enters the Site (see Plate 2-1). The results of the analyses indicate that the Aberjona River contains VOCs, SVOCs and inorganic chemicals. The VOCs detected are listed in Table 3-20. Concentrations of VOCs were lower in samples collected in September than in May. Conversely, the inorganic constituents were generally detected at higher concentrations in the September samples. Arsenic and lead were detected in both sampling events. Lead concentrations in the September sample were 24.4 μg/L which is greater than the Massachusetts MCL of 15 μg/l. The source of lead may be from Industri-plex, other sources north of Route 128, or runoff from roads and highways. Based on investigations by MIT, the likely source of arsenic is Industri-Plex. Sodium was detected at 48.7 mg/L and 225 mg/L in May and August respectively. These concentrations exceed the DEP Office of Research and Standards Guideline (ORSG) of 28 mg/L.

Other metals which were detected include aluminum, barium, calcium, copper, iron, manganese, magnesium, and zinc. Except for bis(2-ethylehexel)phthalate, which was reported at 3.5J μg/L in the September sample, SVOCs were not detected in surface water samples collected in 1993.

In 1989, the Johnson Company conducted sampling to evaluate the contribution of PAHs to the Aberjona River by runoff from Route 128 (Cherry et al., 1989). Samples were collected from the drainage ditch on the south side of the highway and east of the Aberjona River. Samples were also collected from the Aberjona River downstream of the Route 128 bridge and upstream of the Salem Street bridge. Both field filtered and non-filtered samples were collected to evaluate the transport of PAHs in both suspended and dissolved states. The Route 128 drainage ditch samples contained higher concentrations of PAHs than the samples from the Aberjona River, indicating the importance of highway runoff as a source of PAHs to the Aberjona River. All the unfiltered samples contained higher PAH concentrations than the filtered samples. The filtered samples also contained significant concentrations of PAHs, indicating that both aqueous and suspended transport mechanisms are important (Cherry et al., 1989).

A comparison of the analytical results from the river samples indicated that the non-filtered sample from the Route 128 bridge contained higher concentrations of 17 out of the 18 compounds than the non-filtered Salem Street bridge sample. This indicates that deposition of the suspended PAHs is occuring in the slow moving reach of the Aberjona River between Route 128 and the Salem Street bridge. The concentrations of the dissolved PAHs, however, changes very little between the two sampling locations (Cherry et al, 1989).

The deposition of sediment and other particulate material in the river sediments and wetlands has created a contaminant repository and a potential source of contamination to the Central Area Aquifer. Both solute and colloidal transport of contaminants are potentially significant transport mechanism that would result from induced infiltration of surface water into the underlying aquifer in response to pumping.

The results of the surface water analyses for 1985 to 1993 are summarized in Appendix G.

3.2.2.2 Overview of Current Distribution of Contamination in Ground Water

The water quality data which have been collected within the Wells G & H Site document widespread ground-water contamination by inorganic and organic chemicals. Ground-water contamination at levels exceeding those proposed for use as a drinking-water source are found almost ubiquitously throughout the Central Area in both the unconsolidated deposits and bedrock. To illustrate this point, Figure ES-1 identifies monitoring well locations within the Central Area from which the most recent ground-water sample shows an exceedance of recommended or promulgated drinking-water limits for at least one contaminant. Although the contamination is widespread, the distribution for any particular chemical does not form readily identifiable plumes. The overlapping influence of multiple sources for the same contaminant, and the mixing which has occurred in the central portions of the valley due to the convergence of flow, preclude identifying all contamination with discrete sources.

The following text is organized to discuss the current distribution of contamination as well as temporal changes in concentration at specific locations within the Central Area Aquifer and Eastern Uplands. For purposes of this report, data collected since February

1991 have generally been used to define the current distribution of contamination. If more than one sample has been collected since 1991, the most recent analysis was used. In some instances, where the only sampling occurred prior to 1991, the most recent sampling data were used.

The current distribution of the various chemicals is illustrated on several areal plots and sections. Individual maps of the areal distribution of tetrachloroethene (Figures 3-30 and 3-31), trichloroethene (Figures 3-32 and 3-33), 1,2-dichloroethene (Figures 3-37 and 3-35), 1,1,1-trichloroethane (Figures 3-36 and 3-37), nitrate (Figures 3-38 and 3-39), sodium (Figures 3-40 and 3-41), chloride (Figures 3-42 and 3-43), and sulfate (Figures 3-44 and 3-45) within the unconsolidated deposits and bedrock are included. In addition, the current areal distributions of arsenic, chromium, and lead (Figure 3-46) and benzene (Figure 3-47) and napthalene (Figure 3-48) are shown. Several sections which illustrate the vertical distribution of many of these chemicals have also been prepared. The vertical distribution of selected organic chemicals is shown on Figures 3-49 through 3-59. The vertical distribution of selected inorganic chemicals is shown on Figures 3-60 through 3-70.

At some locations, water quality data have been collected over an extended period which allows for an evaluation of temporal changes in water quality. Concentration versus time plots have been prepared for selected chemicals at several wells to illustrate the temporal changes in concentration.

3.2.2.3 Inorganic Compounds

3.2.2.3.1 Nitrate

Historically, nitrate has been a chemical of concern with respect to the Central Area Aquifer. During the operational life of the Woburn public water supply wells G and H, local water supply and state health officials expressed concern regarding the elevated levels of nitrate detected in the supply wells. The concerns were raised primarily because of known discharges of nitrogen compounds to the Aberjona River by industries north of Route 128 (GeoTrans, 1987, p. 30-40).

Common sources of nitrate contamination are leaky sewers, fertilizer application, manure disposal, leachate from waste disposal in dumps or landfills, and use of on-site sanitary waste disposal systems. Each of these sources or activities is known to have occurred within the Central Area.

Figures 3-38 and 3-39 illustrate the current distribution of nitrate within the Central Area. The East Cummings Park area is an area of elevated nitrate concentrations which appears to extend into the center of the Aberjona River Valley although the elevated levels in the center of the valley may reflect different nitrate sources. The Cummings property northeast of the Grace property, an area to the west of the UniFirst property, and south of the Dewey Avenue neighborhood also indicate nitrate concentrations in excess of 2 mg/L. At GO1D and DP7 and drive point profiler locations GH1 (near BUG1) and GH2 (near S90), the detected concentrations exceed the drinking water standard of 10 mg/L. The reported concentrations elsewhere, however, are sufficiently elevated above naturally occurring nitrate concentrations to indicate contamination.

3.2.2.3.2 Sodium

Figures 3-40 and 3-41 indicate widespread distribution of sodium concentrations in excess of the Massachusetts drinking water health advisory of 28 mg/L. Local water suppliers and state health officials have been concerned about elevated sodium levels in public water supply wells G and H since at least 1973 (GeoTrans, 1987, p. 26). Their concerns were primarily related to elevated sodium discharges to surface water north of Route 128 and the subsequent induced infiltration into the aquifer as a result of pumping from wells G and H.

Common sources of sodium concentration include application of de-icing chemicals to roads (Boston Globe February 13, 1994) and parking lots, landfill leachate, runoff from salt storage facilities, leaky sewers, and on-site sanitary waste disposal systems. Each of these sources or activities is known to have occurred within the Central Area.

The distribution of sodium within the Central Area clearly indicates the presence of sources of sodium contamination other than the Aberjona River. Areas of significantly elevated sodium concentrations include the northeastern portion of East Cummings Park and an area between Olympia Avenue and Route 128. Water quality analyses from BUG1 indicate that sodium contaminated ground water is entering the Wells G & H site from north of Route 128 and that the highest concentrations are found in the deeper portions of the Central Aquifer.

Almost all ground-water analyses from within the Central Area, regardless of depth, have sodium concentrations in excess of the Massachusetts drinking water guideline (ORSG) of 28 mg/L.

3.2.2.3.3 Chloride

Figures 3-42 and 3-43 indicate that chloride concentrations are elevated throughout the Central Area, although not all ground water exceeds the drinking water quality standard of 250 mg/L. There is an area of significantly elevated chloride concentrations extending from the northeastern portion of East Cummings Park toward and beneath West Cumming Park. Chloride concentrations within this region are about 200 mg/L to more than 700 mg/L. There is a region of similarly elevated chloride concentrations in the area between Olympia Avenue and Route 128. Bedrock wells located north of the UniFirst property have significantly elevated chloride concentrations. BUG1 water quality analyses indicate that chloride contaminated ground water is flowing into the

Wells G & H Site from north of Route 128 with the highest concentrations detected in the deeper portions of the aquifer.

3.2.2.3.4 Sulfate

Sulfate concentrations in the unconsolidated deposits and shallow bedrock within the Central Area are below the Massachusetts drinking water standard of 250 mg/L (Figures 3-44 and 3-45). With one exception, the concentrations are within the 0 to 119 mg/L range of sulfate concentrations previously reported for ground water within coastal drainage basins of northeastern Massachusetts (Delaney and Gay, 1980). Most values, however, exceed the previously reported median sulfate concentration of 22 mg/L. Water quality analyses from BUG1 indicate that sulfate contaminated ground water is flowing into the Wells G & H Site from north of Route 128 with one analysis having a reported value of 176 mg/L. Sulfate is one of the inorganic chemicals whose presence in wells G and H was of concern to local water supply and public health officials prior to the discovery of the presence of VOCs in the wells (GeoTrans, 1987, p.27. A 1957 analysis of a water sample from a test well installed by Consolidated Chemical Industries near the former Mishawum Lake north of Route 128 detected a sulfate concentration in excess of 3000 milligrams per liter.

3.2.2.3.5 Arsenic, Chromium, and Lead

Figure 3-46 illustrates the areal distribution of arsenic, chromium, and lead within the Central Area. The values plotted represent the maximum concentrations detected at a well cluster, regardless of depth, in the most recent sampling and analysis since 1991. While these compounds can be naturally occurring as well as derived from contamination sources, the distribution within the watershed and the industrial history indicate that the arsenic and chromium are derived from industrial sources. Most notably, as discussed below, arsenic pervades much of the Aberjona River watershed. Figure 3-46, which combines both the unconsolidated deposits and bedrock, illustrates that these chemicals are present throughout the Central Area but there are no clear patterns to their distribution. Some general observations, however, can be made. Their ubiquitous presence conforms to expectations for an unprotected urban watershed. BUG1 analyses indicate that each of these chemicals is present in ground water which flows into the Wells G & H Site from north of Route 128.

Researchers at MIT have been investigating the fate and transport of various metals, including arsenic and chromium, and other chemicals within the Aberjona River watershed (Hemond, 1993; Durant, 1991; Aurilio, 1992; Durant et al., 1990; Knox, 1991). Some of their observations have been presented in public meetings with citizens of Woburn. They have indicated that their investigations show that arsenic and chromium have been transported in surface water and ground water within the Aberjona River Basin from the area north of Route 128 south to the Mystic Lakes. They have also detected the presence of significantly elevated arsenic and chromium concentrations within the river sediment and wetlands deposits in the Central Area. In one vertical profile of arsenic concentrations in the wetlands peat, two distinct well defined concentration peaks were observed. The upper peak was defined by a maximum arsenic concentration of 7,000 mg/kg (Hemond, 1993). Part of the ongoing MIT research is directed toward evaluating the mobility of these chemicals in ground water within the Central Valley of the Central Area.

Investigations to date have indicated that the "hydrology and concomitant redox, sorption, and alkylation processes determine the observed patterns of arsenic movement" (Hemond, 1993, p. 3). The geochemistry of arsenic in the environment is complex. It is known, however, that arsenic solubility and mobility are significantly affected by redox conditions, and that measured geochemical conditions, such as the negative oxidation potential (see Table 2-8) as well as the potential for colloidal transport within the Aberjona River Valley, are favorable for arsenic mobility. Consequently, pumping from the Central Area Aquifer has the potential to cause downward migration of arsenic from the overlying wetland deposits into the underlying aquifer.

3.2.2.4 Volatile Organic Compounds

3.2.2.4.1 Benzene

Benzene, along with other gasoline related compounds, has been detected in ground water at the Site at concentrations above MCLs. Figure 3-47 shows the location of known sources of gasoline releases as well as distribution of benzene in ground water within the unconsolidated deposits. The map is based on the most recent sampling since 1991.

Gasoline related VOCs have been detected at the following properties:

- Olympia Property
- Charrette Property
- McLean Trucking Property
- Getty Property
- Aberjona Auto Parts Property
- Weyerhauser Property
- Property at 225 Wildwood Avenue
- Motors, Electronics, and Controls Corporation Property
- Property at 5 Wheeling Avenue
- Carolina Freight Carrier Corp. Property

Free-phase gasoline has been reported to be present on two of the above-mentioned properties, Charrette and McLean Trucking. Properties on which known releases from on-site petroleum storage tanks have been documented are shown on Figure 3-47. Benzene has been detected in ground-water samples from 20 wells in the Central Area, eight of which had concentrations greater than the MCL of 5 μg/L.

3.2.2.4.2 Chlorinated Solvents

Among the main contaminants of concern at the Wells G & H Site are organic compounds belonging to the chemical grouping of chlorinated (halogenated) organic solvents. Chlorinated solvents are among the most commonly identified contaminants in ground water and commonly occur as dense non-aqueous phase liquids (DNAPLs). The chlorinated solvent chemicals discussed specifically in this section were identified as volatile organic chemicals of concern in the Record of Decision (ROD) for the Central Area, tetrachloroethene, trichloroethene, 1,2-dichloroethene, and 1,1,1-trichloroethane.

Historical land use in this area suggests the widespread use of chlorinated solvents for a variety of purposes and over a significant time period. This fact alone provides significant indication for the likelihood of multiple DNAPL releases over the Site (EPA, 1993b). The widespread nature of the chlorinated solvent contamination across the Central Area also provides strong evidence for the existence of numerous contaminant sources. Not only is ground water contamination by chlorinated solvents found in almost all parts of the Central Area, but also the total width of the zone in which dissolved contamination persists in the Eastern Uplands in the direction transverse to the main direction of ground-water flow (roughly north-south) requires multiple upgradient sources in addition to natural mixing processes to account for it.

Review of areal plots (Figures 3-30 and 3-31) indicates a generally widespread distribution of tetrachloroethene within the eastern and northern portions of the Central Area. In addition to some of the named Source Area properties, there are other sources of tetrachloroethene contamination within the Central Area. For example, within the East and West Cummings Park properties south of the Grace property, there is a previously undetected region of elevated tetrachloroethene concentrations in ground water. Analyses of recovery well and monitoring well water quality data for the Grace property extraction and treatment system indicate the presence of an off-site source of ground-water contamination to the south of the Grace property (GeoTrans, 1993).

Subsequent sampling and analysis of water samples from drive points and K wells installed on the Cummings property confirmed the presence of additional source(s) of tetrachloroethene and 1,1,1-trichloroethane contamination.

The areal and sectional plots also indicate a localized region of tetrachloroethene contamination in the vicinity of the Olympia property. The localized region is characterized by concentrations in the range of 10-40 μg/L with one well, OL6, having a reported concentration of 520 μg/L. BUG1 water quality data also indicate that ground water flowing into the Wells G & H Site from north of Route 128 contains tetrachloroethene at low concentrations.

Within the Central Area Aquifer and underlying bedrock, there is a region of tetrachloroethene concentrations greater than 100 μg/L (Figures 3-30 and 3-31). This zone appears to be the result of converging tetrachloroethene contamination from several source areas in the Eastern Uplands as well as within the Central Valley.

The pattern of trichloroethene contamination within the Central Area is somewhat similar to the tetrachloroethene contamination distribution with a few differences (see Figures 3-32 and 3-33). The notable differences are localized areas of trichloroethene contamination in the vicinity of the Charrette and Olympia properties and elevated trichloroethene concentrations in the southwestern portion of the Site. There also appears to be a localized source of trichloroethene contamination on the East Cummings property south of the Grace property. BUG1 water quality analyses also indicate that ground water entering the Wells G & H Site from north of Route 128 contains trichloroethene at low concentrations.

Excluding the Source Area properties, detectable trichloroethene concentrations in the unconsolidated deposits and shallow bedrock within the Eastern Uplands of the Central Area are about 20 to 40 μg/L. Within the Central Area Aquifer and underlying shallow bedrock, detectable concentrations range from about 10 to about 60 μg/L.

The distribution of 1,2-dichloroethene within the Central Area essentially parallels the trichloroethene distribution although, in general, 1,2-dichloroethene concentrations are lower (see Figures 3-34 and 3-35).

1,1,1-Trichloroethane is currently detected in localized or isolated regions of the Central Area (see Figures 3-36 and 3-37). Detectable concentrations range from about 1 to about 50 μg/L. Within the Central Area Aquifer, 1,1,1-trichloroethane concentrations are generally less than 20 μg/L. Within the upper 50 feet of bedrock, the detected concentrations of 1,1,1-trichloroethane are less than 5 μg/L. The 1,1,1-trichloroethane distribution is somewhat different from either tetrachloroethene, trichloroethene, or 1,2-dichloroethene and reflects a previously undetected source area(s) south of the Grace property.

1,1,1-Trichloroethane is a chemical which was essentially not present in ground water on the Grace property prior to the coordinated operation of the UniFirst and Grace on-site recovery systems. Subsequent to the combined operation of the UniFirst and Grace recovery systems, and the consequential change in ground-water flow directions south of the Grace property, 1,1,1-trichloroethane began to be detected in recovery and monitoring wells in the southwest portion of the Grace property (GeoTrans, 1993). Subsequent sampling and analysis of water samples from drive points and K wells installed on the Cummings property confirmed that additional source(s) of 1,1,1-trichloroethane contamination exist south of the Grace property.

3.2.2.5 Semi-Volatile organic Compounds (SVOCs)

3.2.2.5.1 Polynuclear Aromatic Hydrocarbons (PAHs)

Fifteen polynuclear aromatic hydrocarbons (PAHs) have been detected in ground-water samples from the Wells G & H Site. Table 3-21 lists the PAHs which have been detected within the Site. Naphthalene is the PAH which has been detected most often and with the most widespread distribution. Figure 3-48 shows the areal distribution of naphthalene in ground water. The results of naphthalene analyses indicate that naphthalene is entering the Wells G & H Site from north of Route 128, indicated by the results of analyses of samples from BUG1, and from the east, indicated by the results of analyses of samples from K43. Data from well cluster S75 indicate that naphthalene and other PAHs may be flowing into the Site from the Weyerhauser property where coal tar contamination was previously reported (Cortell, 1989). Coal tar is a mixture of PAHs, MAHs, and phenols. Table 3-22 lists the concentrations of the PAHs detected in well S75.

Based on samples collected in 1990 from wells located on the Olympia Nominee Trust property, there appears to also be a source of naphthalene and other PAHs on the Olympia Nominee Trust property. Results of the 1990 ground-water sampling at the Olympia Nominee Trust property indicate the presence of the PAHs, 2-methylnaphthalene, acenaphthene, acenaphthylene, naphthalene, and phenanthrene.

Based on the distribution of the compounds and our understanding of ground-water flow directions, it appears that there are at least two sources of the PAHs detected in the vicinity of the Olympia Nominee Trust property.

1. On the west side of the Aberjona River, samples from three wells, OL1, OL2, and OL4, contained four different PAHs. Table 3-23 summarizes the results of PAH analyses from wells on the west side of the Aberjona River.

2. On the east side of the Aberjona River, near the trucking terminal, samples from five wells contained no PAHs other than naphthalene. Reported concentrations, however, ranged from 0.6 μg/L in well OL9 to 4,370 μg/L in well OL6.

Sources of PAHs found on the west side of the Aberjona River are possibly from the coal tar located on the Weyerhauser property or a source located on or upgradient from the Olympia Nominee Trust property on the west side of the Aberjona River. The naphthalene detected in wells near the trucking terminal on the east side of the river appear to originate near well OL6.

3.2.2.5.2 Other Semi-volatile Organic Compounds

In addition to the PAHs discussed in the previous section, semi-volatile organic compound (SVOC) analyses of ground-water samples indicate that ground water from the Central Area contained several other SVOCs at low concentrations. Table 3-24 lists the SVOCs detected in ground-water samples collected from the Site since January 1, 1991. The SVOC most frequently detected was bis(2-ethylhexyl)phthalate. The phthalate compounds, di-n-butylphthalate, di-n-octylphthalate, and diethylphthalate, were also detected. These phthalate compounds are used as plasticizers in the production of PVC and other plastics. They have also been a common laboratory contaminant. The concentrations of phthalates were either very low, inconsistent from one sampling event to another, or inconsistent between duplicate samples. Due to the inconsistency in analytical results and because the wells from which samples were collected were all constructed with PVC casing and/or contain plastic tubing, it is likely that the phthalates are the result of laboratory contamination or an artifact of well construction and not an indicator of phthalate contamination in ground water. The results of the SVOC analyses are summarized in Appendix F.

3.2.2.6 Temporal Changes in Concentration

For many wells within the Central Area there is a relatively long sampling and analysis history. Data from many of the wells indicate trends which can be evaluated in the context of the hydrogeologic conditions within the Central Area. These data reflect both decreasing, as well as increasing, trends in concentration of specific compounds within certain portions of the Central Area. The trends, in general, do not support any unique interpretation of the data due to the following circumstances:

- The presence of numerous contaminant sources.

- The presence of unidentified sources of contamination to the Central Area.

- The high degree of variability in the lateral and vertical extent of contamination zones and concentration gradients.

- The presence of DNAPL.

- The variability in ground-water flow over the course of the various investigations due to start up and shutdown of various pumping systems.

Recognizing the possible complicating factors, the trends in concentrations at selected wells are discussed in the context of known hydrogeologic conditions. Four wells or well clusters were selected to illustrate temporal trends in concentration within the Central Area. The selected wells or well clusters are the S63 well cluster, the GO1 well cluster, and former Woburn public water supply wells H (S39) and G (S40). The S63 and GO1 well clusters were selected because they are located in the Eastern Uplands and are within the zone of capture of UC22. The concentration trends at these two well clusters provide insight regarding the effectiveness of the coordinated UniFirst/Grace ground-water remediation. Wells S39 and S40 were selected because they have a long history of sampling and analysis, and their concentration trends provide insight regarding concentrations in the Central Area Aquifer.

3.2.2.6.1 Well Cluster S63

Well cluster S63 is located near the western edge of the Eastern Uplands approximately 300 feet south of the UniFirst property and 400 feet west of the Grace property. It is a two-well cluster with one well screened in the unconsolidated deposits and one well screened in the bedrock. Water samples have been collected for VOC analyses periodically since April 1985. Figure 3-71 illustrates the variation in tetrachloroethene concentration since 1985. The graph generally shows that between April 1985 and September 1992, tetrachloroethene concentrations in both the unconsolidated deposits and shallow bedrock were on the order of 100s of μg/L, with bedrock ground-water concentrations generally higher than unconsolidated deposit ground-water concentrations. Subsequent to September 1992, the tetrachloroethene concentrations have declined substantially. Figure 3-72 shows a similar pattern for trichloroethene concentrations. While the trichloroethene concentrations were generally lower than the tetrachloroethene concentrations, the same substantial decrease in concentration after September 1992 is demonstrated. The reduction in concentration of tetrachloroethane and trichloroethene most likely reflects the effects of the operation of the coordinated UniFirst and Grace ground-water extraction systems and, in particular, pumping from UC22. The coordinated ground-water extraction systems began operating on September 30, 1992.

3.2.2.6.2 Well Cluster GO1

The GO1 well cluster is located on the West Cummings Park property approximately 100 feet east of well cluster S63. It is a three-well cluster with one unconsolidated deposit well (GO1S) and two bedrock wells (GO1D and GO1DB). Figures 3-73 and 3-74 illustrate the temporal trends of tetrachloroethene and trichloroethene concentrations respectively. Both figures show a similar pattern for the three wells. From about 1985 to September 1992, the reported concentrations showed variability but were essentially unchanged. Subsequent to September 1992, when the combined Uni-

First/Grace ground-water extraction systems began pumping, there was a significant decrease in PCE and TCE concentrations in both the unconsolidated deposit and shallow bedrock (GO1D) monitoring wells. However, for GO1DB, the reported concentrations are essentially unchanged with perhaps a slight decrease in tetrachloroethene concentrations. It appears that the concentration decreases in GO1S and GO1D are related to pumping from UC22, but that UC22 pumping has had little or no effect on concentrations in GO1DB. The reason for this disparity in concentration trends between the two shallower wells, GO1S and GO1DB, and the deeper well well, GO1DB, is not known. It may reflect local hydrogeologic variability or perhaps the proximity of a DNAPL contaminant source that affects GO1DB but not the other two wells.

3.2.2.6.3 Well S39 (Woburn Supply Well H)

Well S39 is the former Woburn public water supply well H. It was installed in 1967 and had a pumping capacity of about 400 gpm. The well is screened at a depth of about 70 to 80 feet within the permeable sand and gravel deposits of the Central Area Aquifer. As it was a public water supply well, it has a long history of sampling and analysis. Concentration trends of inorganic and organic chemicals demonstrate the general trends in contamination of the Central Area Aquifer.

Figure 3-75 illustrates the trend in chloride concentrations between 1964 and 1993. The 1964 sample is from a test well installed prior to the installation of the supply well at the same location as well H. The graph illustrates that since 1967, when the well became operational, and about three years after well G was put into service, the chloride concentrations have been elevated to levels which have previously been characterized as being indicative of the industrial pollution in the headwaters of the Aberjona River (Delaney and Gay, 1980). The most recent analysis is at the low end of the range of concentrations observed during the operational period of the well and may reflect a gradual reduction in concentration resulting from cessation of pumping within the Central Area Aquifer and the consequent cessation of induced surface water infiltration and a corresponding return to a condition of natural flushing of the aquifer by ground-water discharge to the river.

Figure 3-76 illustrates the trend in sodium concentrations in well H between 1964 and 1992. All reported concentrations are greater than the current Massachusetts drinking water health advisory of 28 mg/L. These data also indicate a fairly consistent concentration level during the period of operation of the well and a slight reduction since the well has stopped pumping. Similar to chloride, the trend may reflect a gradual reduction in concentration due to the cessation of pumping and consequent cessation of surface water infiltration as well as a return to a condition of natural flushing of the aquifer by ground-water discharge to the river.

Nitrate concentrations are illustrated on Figure 3-77. These data show that during the mid-1960s through at least 1974, the nitrate concentrations were close to and, at least on one occasion, exceeded the drinking water standard of 10 mg/L. The data also show that during the mid-1970s, nitrate concentrations had reduced but were still at levels which are generally indicative of pollution.

Figure 3-78 illustrates sulfate concentrations detected in well H. The data for the period 1974 through 1979 represent some of the highest sulfate concentrations observed in ground water within the northeastern Massachusetts coastal drainage basins (Delaney and Gay, 1980). The August 1991 reported sulfate concentration is considerably reduced from concentrations observed during the operational period of the well but may be slightly anomalous. 1993 sulfate concentrations from nearby monitoring well cluster S89 were about 20 to 30 mg/L. The recent sulfate concentrations from well cluster S89 are still reduced from the concentrations observed in well H during its operation but not as dramatically reduced as is indicated by the 1991 sample from well H.

Tetrachloroethene concentrations in well H are illustrated in Figure 3-79. The time frame for sampling and analysis for tetrachloroethene and other VOCs is different from that for inorganic chemicals. The first sampling occurred in 1979. In 1985, as part of the EPA/USGS pumping test, there was an intensive sampling and analysis effort. The most recent sample was collected in August 1991 as part of pre-RI/FS activities. The tetrachloroethene concentration data indicate that concentrations observed in 1985 exceeded values reported for the 1979 to 1981 time frame and that more recent concentrations are significantly reduced. Similar to the sulfate analysis, however, the magnitude of reduction may not be as great as indicated in the graph. More recent concentrations from well cluster S89 are reduced from the 1985 levels observed in well H but are higher than was observed in well H in 1991.

Figure 3-80 illustrates trichloroethene concentrations in well H from the period 1979 to 1991. The sampling history is generally the same as for tetrachloroethene. Concentrations have generally decreased since the early samplings of the well. The August 1991 trichloroethene concentration is considerably less than was observed between 1979 and 1985 and about one-half the values reported for nearby well cluster S89.

In general, the reduction in concentration of the various chemicals in Well H since the cessation of pumping in 1979 is interpreted to reflect the natural flushing of the aquifer as a result of ground-water discharge to the Aberjona River.

3.2.2.6.4 Well S40 (Woburn Supply Well G)

Well G was installed in 1964 as a public supply well for the City of Woburn. The well is screened at a depth of about 70 to 80 feet within the permeable Central Valley outwash deposits. During its operation, well G was pumped at a rate of 700 gpm and was the primary pumping well in this area. The trends in concentrations of the inorganic and organic chemicals described for well H are similar for well G.

Figure 3-81 illustrates the trend in chloride concentration for well G. Chloride concentrations began to increase almost immediately when pumping began. The increasing trend likely reflects the induced infiltration of Aberjona River water into the aquifer as a result of pumping. Peak concentrations were measured during the late 1960s and early 1970s. Subsequent to cessation of pumping in 1979, there has been only one analysis for chloride concentration. This 1991 analysis is at the low end of the range observed during the mid to late 1970s.

Sodium concentrations for well G are illustrated in Figure 3-82. The first analysis for sodium did not occur until about two years after the well began pumping. With one exception, the sodium concentrations are above the Massachusetts drinking water health advisory of 28 mg/L and reflect the widespread occurrence of elevated sodium concentrations within the Central Area.

Figure 3-83 illustrates nitrate concentrations which have been reported for well G. Similar to the observations for well H, there is a long-standing history of elevated nitrate concentrations. It appears that the highest concentrations were reported during the 1960s and early 1970s with a general decrease to a concentration of 1 or 2 mg/L by the late 1970s.

Sulfate concentrations in well G were almost identical to those observed in well H including the dramatic reduction in concentration by 1991. Figure 3-84 illustrates the variation in concentration between 1966 and 1991.

Figure 3-85 illustrates tetrachloroethene concentrations in well G for the time period 1979 to 1991. The sampling and analysis history for VOCs in well G is identical to the history for well H. Between 1979 and 1985, there was a general increase in tetrachloroethene concentrations. Subsequent to the 1985/1986 sampling, there appears to have been a reduction in tetrachloroethene concentration to levels more representative of the 1979 time period.

Similar to the pattern observed in well H, trichloroethene concentrations show a continual decline from the 1979/1981 analyses to the 1991 analyses. Figure 3-86 indicates that there appears to have been about an order of magnitude decrease in trichloroethene concentrations in well G since pumping stopped.

3.3 APPLICABLE, RELEVANT, AND APPROPRIATE REQUIREMENTS (ARARS)

A comparison of concentrations in ground-water samples collected after January 1991 with federal and state MCLs and federal AWQCs was made to determine chemical-specific ARARs. The ARARs and TBCs for the Central Area are listed in Table 3-25 The compounds detected and corresponding chemical specific ARARs are listed in Table 3-26.

The conceptual model which places the Wells G & H Site and the Central Area in the context of a large unprotected, industrialized, urban watershed draws attention to certain ARARS and TBCs which deserve discussion. The policies underlying the wide array of regulatory schemes that are applicable or relevant and appropriate to the Central Area Aquifer militate against potential use of the aquifer as a public drinking water supply source. More significantly, state officials have already concluded that the Aberjona River watershed in general, and the Central Area Aquifer in particular, are not in fact even potential drinking water supply sources.

That DEP has already determined that the Central Area Aquifer is neither a current nor a potential drinking water supply source is evidenced by DEP's grant of as many as eight waivers of approvals for investigations and remediation within the Central Area itself. A waiver granted under the 1988 Massachusetts Contingency Plan (the 1988 MCP) allows a responsible party to clean up a contaminated site without DEP's involvement in, and approval of, each step in the process. DEP could not have granted such waivers to sites within the Central Area unless the state had first concluded that the underlying aquifers are not now, and will not become, sources of public drinking water supplies. Waivers could only have been granted to sites classified as "non-priority" (see former 310 C.M.R. 40.537). If the Wells G & H Site included "areas of planned or potential water supplies", sites within those areas would have to have been classified as "priority" under the 1988 MCP unless DEP had made a further determination that contamination had not affected, and would not affect, the potential water supply. Absent that further finding, a site would have necessarily been classified as "priority" if:

> "there is evidence of groundwater contamination with oil or hazardous materials at or from the disposal site at levels exceeding state or federal drinking water standards or guidelines...and the evidence of groundwater contamination is...within a Zone II [recharge zone] or in areas of planned or potential water supplies" [see former 310 C.M.R. 40.544(2)(c)].

("Zone II is defined as the area of an aquifer which contributes to a well under the most severe pumping and recharge conditions that can be realistically anticipated" [310 C.M.R. 22.20]). If a site met the foregoing criterion, DEP nevertheless could have classified it as "non-priority" if DEP had concluded that contamination had not migrated, or would not migrate, to the public or private water supply well(s):

> A disposal site which meets any of the above criteria shall be considered a priority disposal site unless the Department is persuaded that one or more of the following circumstances exists: There is no hydrogeological connection between the ground water containing oil or hazardous materials and the water supply; the concentrations of oil or hazardous material for which there are no drinking water standards or guidelines will not be harmful to those drinking the water; or the oil and hazardous materials have not and will not migrate to the public or private water supply well(s) [see former 310 C.M.R. 40.544(2)(c)].

It has been known for some time that oil and hazardous materials are both widely and deeply distributed throughout the Central Area Aquifer in concentrations exceeding drinking water standards (see Figure ES-1). Consequently, when DEP granted waivers within the Central Area, DEP effectively determined that this aquifer would not be used for public or private drinking water supplies in the future.

DEP's determination that the Central area Aquifer is not a potential drinking water source is consistent with other ARARs and TBCs for the Central Area. Several key state regulatory schemes converge to limit land uses allowed in areas that might affect drinking water quality. For example, the presence of abandoned landfills that could affect the water quality of the Central Area Aquifer militates against such use of these waters. According to DEP's solid waste facility siting regulations set forth at 310 C.M.R. 16.40(3), new landfills may not be sited within the boundaries of Zone II or Interim Wellhead Protection Areas (IWPA) and most existing facilities within such zones must be closed before July 1, 1995.

Consistent with this prohibition, under the Massachusetts drinking water regulations, DEP's approval of a public water supply system requires wellhead protection zoning or non-zoning controls to prohibit certain land use activities within the Zone II, or recharge area, for any given well. Land uses that cannot be sited with a Zone II include, among others: landfills and open dumps; certain sewage disposal systems; and, with some exceptions, facilities that generate, treat, store, or dispose of hazardous materials or wastes that are subject to G.L. c. 21C and 301 C.M.R. 30.000 and hazardous materials subject to G.L. c. 21E and 310 C.M.R. 40.000 [see 310 C.M.R. 22.21(2)(a)]. Furthermore, certain land uses are prohibited within a Zone II unless they are designed in accordance with specified performance standards. These include land uses involving the storage of sludge and septage, de-icing chemicals, commercial fertilizers, animal manures, liquid hazardous materials, and most liquid petroleum products as well as land uses that render impervious more than 15 percent or 2,500 square feet of any lot, whichever is greater [see 310 C.M.R 22.21(2)(b)]. While DEP cannot impose zoning requirements on a locality, it can refuse to permit a public drinking water supply where a locality has not made an attempt to enact protective zoning. In some circumstances, wells may be approved without meeting DEP's wellhead protection requirements. If the proponent of a new public water supply source can demonstrate that it used its best efforts to have those cities and towns in which the Zone II of the proposed public supply well is located to establish such zoning or non-zoning controls and they refused, DEP can grant a variance from the requirement for implementation of the above listed land use controls [see 310 C.M.R. 22.21(5)]. In Woburn, however, no proponents seek to use the Central Area Aquifer as a public drinking water supply so the DEP would have no occasion to grant such a variance. It should be noted that no wellhead protection zoning or non-zoning controls have implemented in Woburn and, in fact, the Aberjona River watershed and the Central Area have been geared for industrial uses since the early 1800s. While some restrictions were imposed in the 1980s, uses with potential to pollute are still permitted in the Central Area and in the Aberjona River watershed.

Guidance documents issued by the state articulate the policy against allowing incompatible land uses to pollute drinking water supply aquifers. DEP's June 1989 Massachusetts Wellhead Protection Program Report (WPPR) and the April, 1993 Wellhead Protection Manual set forth a matrix table showing land uses which have the potential to pollute public supply wells (see WPPR after 37, Figure 4-20). A number of land uses known to have occurred in the Aberjona River watershed and the Central Area Aquifer are identified as high overall threats that may render groundwater at a public-supply well undrinkable in accordance with federal and state maximum contaminant levels. These include: clandestine dumping, industrial lagoons and pits, landfills, municipal waste water/sewer lines, railroad tracks and yards, animal husbandry and manure piles, and underground storage tanks.

Given the presence of contamination related to unrestricted past land uses and the manifest inability to protect the watershed, the ground waters in the Aberjona River watershed should be classified as Class III ground waters under the Massachusetts ground-water classification scheme set forth in 310 C.M.R. 6.00. Ground waters in Class III "are designated for uses other than as a source of potable water supply" for which the "most sensitive use" should be "as a source of non-potable water which may come in contact with, but is not ingested by humans" [310 C.M.R. 6.03(3)]. This ground-water classification should be made on the basis of a determination that "the ground water is contaminated or degraded to the point that recovery of water for drinking water purposes is economically or technologically infeasible".

EPA's ground-water protection strategy calls for the classification of ground water on a site-by-site basis to determine the highest beneficial use of the particular ground-water resource and the appropriate level of protection or remediation. Although the wells G & H Record of Decision ("ROD") states that the Aberjona River Aquifer is classified as Class IIB, a potential source of drinking water (EPA, 1989, p. 8-9), this classification appears inconsistent with the EPA guidance document entitled "Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy" ("Guidelines"). If the Central Area Aquifer were to be used as a public water-supply system, it would require treatment that is not "reasonably employed in a public water supply system". Consequently, according to the guidelines, ground water in the Central Area Aquifer should be classified Class III; that is, it is ground water that is "so contaminated by naturally occurring conditions or by effects of broad-scale human activities (i.e., unrelated to a specific activity) that it cannot be cleaned up using treatment methods reasonably employed in public water-supply systems" (Guidelines, p. 22).

The Aberjona River and Mystic Lake are currently classified as Class B waters under the Massachusetts surface water classification system set forth in 314 C.M.R. 4.00. Class B waters are designated for primary and secondary contact recreation and as a habitat for fish, other aquatic life, and wildlife. Class B waters are meant to be suitable as a source of public water supply with appropriate treatment. They should also be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. They should also have consistently good aesthetic value. Given some of the findings of the MIT Aberjona river watershed studies [Hemond, 1993], the waters of the Aberjona River watershed fit more appropriately into Class C because they do not have the potential to be used as a source of public water supply, they should not be used for primary recreational contact (swimming), and their aesthetic quality is not likely to be "consistently" good. They could be used for such uses as industrial cooling and processing.

It should also be noted that the Central Area Aquifer underlies the flood plain of a 100-year flood. As such, it should not be used as a source of public water supply facility because it could be subject to a breakdown [see 310 C.M.R. 22.04(2)].

Taken together, these regulatory programs and guidance documents, among others, dictate a coherent regulatory strategy to prevent use of a degraded, unprotected, and unprotectable aquifer, such as the Central Area Aquifer, as a public drinking water supply source.

A key guidance document "To Be Considered" ("TBC") with regard to the Central Area is the OSWER Directive No. 9234.2-25 entitled "<u>Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration</u>" ("TI Guidance") (EPA, 1993b). Many of the circumstances which, according to that guidance, would cast doubt on the practicability of ground-water restoration at an isolated site are magnified when they converge in a complex urban aquifer with multiple sources of contamination.

The EPA memorandum transmitting the guidance states that the guidance promotes the use of a phased approach to site remediation "particularly where a moderate to high level of uncertainty exists regarding the potential outcome of restoration efforts". As a part of this approach, early actions to control migration and remove sources are encouraged. These actions are encouraged to reduce risks and to provide information for evaluating restoration potential (EPA, 1993a, p.3; EPA, 1993b, p. 2-4). Such a strategy has been adopted at the Wells G & H Site. Specifically, the source areas at the Site that have been identified in the ROD are in various stages of source control and management of migration activity. In Grace's and UniFirst's case, ground water is already being contained and much useful information has been obtained regarding the effects of ground-water extraction in the Eastern Uplands.

The T-I Guidance focuses on engineering feasibility and reliability limitations on aquifer restoration, in particular, interrelated constraints resulting from the hydrogeological setting and from the characteristics of the contaminants at the site (EPA, 1993b, p.1-2). The technological constraints may be engineering constraints on the removal and/or containment of sources and the ground-water plumes they generate (EPA, 1993b, p 9 and 20). To the extent that some combination of site constraints and technical constraints renders source removal and containment infeasible and unreliable, restoration is to be deemed technologically impracticable.

The TI Guidance states that, where detailed site characterization and data analysis supports evaluation of critical limitations to ground-water restoration, a technical impracticability decision can be made at the "front-end", that is, before remedy selection (EPA, 1993b, p. 10-11). According to the TI Guidance, technical impracticability demonstrations can be made when date have been obtained regarding the operation of remediation systems at a site and when sufficient data have been obtained to develop a detailed conceptual model of the site with a high level of confidence (EPA, 1993b, p. 13-19). For the Wells G & H Site, numerous studies have resulted in perhaps the most extensive data set on an urbanized watershed ever developed, including extensive data from the USGS pumping test in the valley, from the UniFirst pumping in the bedrock underlying the Eastern Uplands, and from the Grace pumping in the till in the uplands as well as several phases of investigation and evaluation, further including remediation of some of the other known sources within the Wells G & H Site.

These data and the conceptual model they support have revealed a number of disabling site constraints based on the interaction of two major factors: the hydrogeologic setting and the nature of contamination.

Consistent with the guidance the conceptual model which is presented in this report is based on several phases of investigation and evaluation, including remediation of some of the known sources within the Wells G & H Site. The investigations which can be relied upon for factual information regarding the Site began more than 30 years ago, and provide the necessary and sufficient information to develop a reliable detailed conceptual model of the Site. Each of the numerous investigations has provided information relevant to understanding the complex interaction between hydrogeologic conditions, contaminant characteristics and technical constraints of the Site. The data and the conceptual model they support have revealed a number of site constraints which preclude groundwater restoration.

The hydrogeologic setting presents a number of disabling constraints. The low permeability till which is found throughout the Eastern Uplands is too impermeable to permit effective groundwater extraction except where the contamination source is localized and has been identified. The generally low permeability of the bedrock and the localized nature of fracturing, which is sufficient to yield water to wells, renders a priori determination of effective areas for ground-water extraction from bedrock generally unreliable. Within the center of the Aberjona River Valley, the stratified drift and swamp deposits contain sufficient heterogeneity that they serve as contaminant sinks. The wetlands deposits in particular are known to be a repository of significant concentrations of arsenic which has been transported to the Central Area from north of the Site. The hydraulic connection between the Aberjona River and its wetlands with the underlying Central Area Aquifer preclude ground-water restoration by pumping. Pumping from wells within the Central Area Aquifer results in the induced infiltration of contamination into the underlying aquifer, thereby further contaminating the aquifer.

The characteristics of the contamination at the Site is also a disabling site constraint. Contaminants include chlorinated solvents which are found as DNAPLs, and are found within the fractured bedrock; petroleum related LNAPLs which have been released directly to the Central Area Aquifer; metals, such as arsenic and chromium with their complex sorption/desorption characteristics and potential for colloidal transport, which are residing in the sediments and wetlands deposits of the Aberjona River; PAHs found within the surface water and river sediments; and the pervasive distribution of major ions, such as sodium, chloride, nitrate, and sulfate which demonstrate widespread areal and vertical distribution throughout the Site.

The urbanized setting of the site creates a disabling constraint. The Site is part of a large, industrialized urban watershed, with all of the associated problems such as roadway runoff, leaking underground storage tanks and sewers, old dumps and landfills, and chlorinated solvent and petroleum spills. Many of the contaminant sources within the watershed cannot be exactly located, and/or remove or contained and the distribution of contaminants necessarily implies that there must be more such sources. Much of the contamination is already in the bedrock, but its fractured nature and the potential presence of chlorinated solvent DNAPLs make source location there impracticable and risky. Finally the general hydrology of the watershed and its irrevocable commitment to commercial and industrial land use render the Central Area Aquifer unprotectable from future releases of contamination.

In summary, these factors combine to make restoration of Central Area ground water infeasible and unreliable. Sources cannot be found and/or removed or contained. There is a multiplicity of sources in the watershed both within and outside of the site. Contaminants present at the site include DNAPLs in fractured rock and arsenic with its complicated sorption/desorption mechanics. The valley aquifer is hydrologically resistant to attempts to augment natural flushing, the upland till is generally impermeable, and the hydrogeologic characteristics of the bedrock make predictions of the effectiveness of extraction and treatment unreliable without extensive investigations and testing. Finally, the hydrological and land use characteristics of the watershed make the aquifer impossible to protect with either engineering or institutional controls.

Table 3-1. Summary of hydraulic testing results

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
S64	SD	4.0	9-11	HTL
	SD	3.8	9-11	HVH
	SD	2.8	19-21	HTL
	SD	0.25	19-21	HVH
	SD	3.9	31.5-33.5	HTL
	SD	3.7	31.5-33.5	HVH
S74	SD	127.6	39-41	HTL
	SD	56.7	39-41	HVH
	SD	170.1	54-56	HTL
	SD	283.5	54-56	HVH
S74	SD	0.5	66-68	HTL
	SD	0.4	66-68	HVH
S76	SD	0.1	20-22	HTL
	SD	0.1	20-22	HVH
	SD	0.1	60-62	HTL
	SD	0.1	60-62	HVH
	SD	0.1	126-128	HTL
	SD	0.1	126-128	HVH
S77	SD	0.1	30-32	HTL
	SD	0.1	30-32	HVH
	SD	0.2	73-75	HTL
	SD	0.4	73-75	HVH

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
S84	SD	0.1	16-18	HVT
	SD	0.1	16-18	HVH
	SD	0.3	78-80	HTL
	SD	0.3	78-80	HVH
S85	SD	1.5	15-17	HTL
	SD	1.5	15-17	HTL
	SD	0.4	35-37	HTL
	SD	0.6	35-37	HVH
S86	SD	0.4	50-52	HTL
	SD	0.4	50-52	HVH
S64M	SD	2.3×10^{-1}	9	GS
	SD	1.8×10^{-1}	32	GS
S66D	SD	1.4×10^{-3}	10	GS
S67	SD	0.1	40	GS
S71	SD	0.1	0	GS
	SD	0.2	2	GS
	SD	0.2	4	GS
	SD	2.6×10^{-2}	6	GS
	SD	1.5×10^{-2}	8	GS
	SD	0.1	10	GS
	SD	0.1	12	GS
	SD	1.5	14	GS
S72D	SD	6.4×10^{-3}.	35	GS
	SD	4.8×10^{-3}	55	GS
	SD	0.6	80	GS

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
S74M	SD	0.1	39	GS
	SD	6.4×10^{-3}.	34	GS
S75D	SD	1.1	10	GS
	SD	0.1	40	GS
	SD	0.01	65	GS
S76	SD	9.1×10^{-3}	21	GS
S76M	SD	0.1	60	GS
S77	SD	0.6	20	GS
S77D	SD	1.4	70	GS
	SD	2.9×10^{-4}	120	GS
S78	SD	0.2	17	GS
	SD	3.5×10^{-4}	63	GS
S79	SD	0.8	14	GS
	SD	0.1	69	GS
S80	SD	6.4×10^{-3}	8	GS
	SD	0.1	-	GS
S82	SD	0.1	10	GS
	SD	0.2	20	GS
S83	SD	0.8	40	GS
	SD	1.8	60	GS
	SD	2.6×10^{-2}	80	GS
S84	SD	1.8	10	GS
	SD	0.6	40	GS
	SD	0.3	65	GS
S85	SD	2.2	34	GS
	SD	1.4×10^{-2}	59	GS

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
S86D	SD	1.1	25	GS
	SD	1.5	50	GS
BSSW5	SD	3.7	3-13	B&R Falling
	SD	1.6	3-13	B&R Rising
	SD	17.9	3-13	HVH Rising
BSSW6	SD	18.1	12-16	B&R Falling
BSSW6	SD	20.4	12-16	B&R Rising
	SD	85	12-16	HVH Falling
	SD	34	12-16	HVH Rising
BOW9	SD	34	4-14	B&R Falling
	SD	130.4	4-14	B&R Rising
	SD	204.1	4-14	HVH Falling
	SD	136.1	4-14	HVH Rising
BOW13	SD	23.2	4-14	B&R Falling
	SD	17.6	4-14	B&R Rising
	SD	51.0	4-14	HVH Falling
	SD	102.0	4-14	HVH Rising
BSSW15	SD	28.3	3-13	B&R Falling
	SD	39.7	3-13	B&R Rising
	SD	87.9	3-13	HVH Falling
	SD	87.9	3-13	HVH Rising
BSSW16	SD	13.6	3-13	B&R Falling
	SD	17.0	3-13	B&R Rising
	SD	87.9	3-13	HVH Falling
	SD	59.5	3-13	HVH Rising

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
BSW1	SD	76.5	25-35	B&R Falling
	SD	59.5	25-35	B&R RISING
	SD	68.0	25-35	HVH Falling
	SD	93.5	25-35	HVH Rising
BSW6	SD	17.0	20-25	B&R Falling
	SD	17.3	20-25	B&R Rising
BSW6	SD	56.7	20-25	HVH Falling
	SD	22.7	20-25	HVH Rising
BSW9	SD	16.7	20-25	B&R Falling
	SD	16.7	20-25	B&R Rising
	SD	34.0	20-25	HVH Falling
	SD	17.0	20-25	HVH Rising
BOW15	SD	19.3	20-30	VK Falling
	SD	48.2	20-30	VK Rising
BW1	SD	13.3	33-43	VK Falling
	SD	16.4	33-43	VK Rising
BW5	SD	19.0	30-40	B&R Falling
	SD	20.4	30-40	B&R Rising
	SD	39.7	30-40	HVH Falling
	SD	25.5	30-40	HVH Rising
BOW16	SD	17.3	35-45	B&R Falling
	SD	5.1	35-45	B&R Rising
	SD	6.0	35-45	HVH Falling
	SD	8.8	35-45	HVH Rising
S39 (H)	SD	130-215	78-88	PT
S40 (G)	SD	125-350	69-79	PT

Table 3-1 (continued):

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
G2M	LT	.1	23-28	HVH
G3S	LT	.1	22-37	HVH
G4S	LT	.1	16-26	HVH
G8S	LT	.1	34-44	HVH
G10S	LT	0.6	15-25	HVH
G13S	LT	.04	17-27	HVH
G14S	LT	.04	12-22	HVH
G15S	LT	.6	14-24	HVH
G17S	LT	.05	37-47	HVH
G16S	LT	.01	20-30	HVH
G18S	LT	.07	22-32	HVH
G19M	LT	.2	35-45	HVH
G20S	LT	.3	25-35	HVH
G20M	LT	NC	48-58	HVH
G21S	LT	.06	19-29	HVH
G23S	LT	.5	16-26	HVH
G24S	LT	.1	16-26	HVH
G25S	LT	.1	20-30	HVH
G26S	LT	.2	11-21	HVH
G27S	LT	.1	11-21	HVH
G28S	LT	.3	15-25	HVH
G31D	LT	.04	33-48	HVH
G32S	LT	.05	15-25	HVH
G19S	4' AT 6' LT	.3	10-20	HVH
G22S	6' AT 9' LT	.07	17-32	HVH

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
G1S	AT	5.2	27-37	HVH
G2S	AT	.4	9-19	HVH
G5S	AT	2.3	11-21	HVH
G7S	AT	.6	6-21	HVH
G9S	AT	1.3	13-18	HVH
G11S	AT	1.1	16-21	HVH
G12S	AT	2.6	15-25	HVH
GO1S	AT	1.5	8-18	HVH
S63	AT	0.6	13	GS
S67	AT	2×10^{-3}	15	GS
S70	AT	0.1	15	GS
S70D	AT	0.1	35	GS
	AT	0.6	55	GS
S82	AT	0.01	35	GS
BCW13	AT	8.8	45-50	B&R Falling
	AT	7.4	45-50	B&R Rising
	AT	17	45-50	HVH Falling
	AT	14.2	45-50	HVH Rising
G34S	AT	.67	12-22	B&R Falling
G31S	LT/B	.02	18-28	HVH
BW5R	5' AT 5'B	5.7	48-58	B&R Falling
	5' AT 5'B	5.7	48-58	B&R Rising
	5' AT 5'B	25.8	48-58	HVH Falling
	5' AT 5'B	51.0	48-58	HVH Rising

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
G35DB	B	2.2×10^{-2}	47-56.8	Packer
	B	.17	56.2-66	Packer
G36DB3	B	.1	38-47.8	Packer
	B	.02	47.5-57.3	Packer
	B	.05	57.05-66.85	Packer
	B	.51	66.45-76.25	Packer
	B	.3	74.75-109.7	Packer
	B	.01	109.5-119.3	Packer
	B	0	119-128.8	Packer
	B	1.3×10^{-4}	127.5-137.3	Packer
	B	2×10^{-3}	137.5-147.3	Packer
	B	5.8×10^{-4}	147-156.8	Packer
	B	.02	165-174.8	Packer
	B	.03	174-183.8	Packer
	B	1.9×10^{-3}	189-199	Packer
	B	1.3×10^{-3}	197-207	Packer
	B	.48	205-215	Packer
	B	.3	213-223	Packer
	B	2×10^{-3}	221-231	Packer
	B	3×10^{-3}	226-236	Packer
G2DB	B	2.23	208.5-219	Packer
G2DB2	B	.38	338.5-349	Packer
	B	.38	158.5-169	Packer
	B	.51	148.5-159	Packer
	B	.29	31.5-42	Packer
G1D	B	5.4	42-52	HVH

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
G2D	B	.7	35-50	HVH
G3D	B	.1	46-61	HVH
G3DB	B	.03	81-96	HVH
GD4	B	.1	30-45	HVH
G5D	B	.2	26-41	HVH
G7D	B	.6	36-51	HVH
G10D	B	.2	30-45	HVH
G10DB	B	.1	55-70	HVH
G11D	B	0.1	29-44	HVH
G12D	B	.5	36-46	HVH
G13D	B	.02	37-52	HVH
G14D	B	.07	28-43	HVH
G15D	B	.07	32-47	HVH
G16D	B	.02	44-59	HVH
G17D	B	NC	57-72	HVH
G18D	B	.07	37-52	HVH
G19D	B	.09	59-74	HVH
G20D	B	NC	70-85	HVH
G21D	B	.07	33-48	HVH
G22D	B	.1	38-53	HVH
G23D	B	.4	33-48	HVH
G24D	B	.07	32-47	HVH
G25D	B	.2	33-48	HVH
G26D	B	.1	25-40	HVH
G27D	B	.09	26-41	HVH
G28D	B	.1	30-45	HVH

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
GO1D	B	.1	24-39	HVH
G01DB	B	.5	55-70	HVH
BW9	B	7.4	34-44	B&R Falling
	B	6.8	34-44	B&R Rising
	B	39.7	34-44	HVH Falling
	B	102.0	34-44	HVH Rising
BW13	B	7.1	62-67	B&R Falling
	B	3.1	62-67	B&R Rising
	B	21.3	62-67	HVH Falling
BW13	B	22.7	62-67	HVH Rising
BW2R	B	6.0	85-95	B&R Falling
	B	2.4	85-95	B&R Rising
	B	42.5	85-95	HVH Falling
	B	6.8	85-95	HVH Rising
BW6R	B	0.4	38-48	B&R Falling
	B	0.4	38-48	B&R Rising
	B	2.2	38-48	HVH Falling
	B	0.9	38-48	HVH Rising
BW15R	B	4.3	54-64	B&R Falling
	B	6.0	54-64	B&R Rising
	B	12.2	54-64	HVH Falling
	B	9.4	54-64	HVH Rising
BW16R	B	0.2	123-133	B&R Falling
BW16R	B	1.2	123-133	HVH Falling

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
G34D	B	3.8×10^{-2}	27-37	B&R Falling
	B	5.3×10^{-2}	27-37	CB&P Falling
	B	8×10^{-2}	27-37	B&R Rising
	B	3.6×10^{-3}	27-37	CB&P Rising
G35D	B	9.1×10^{-3}	29-39	B&R Falling
	B	1.4×10^{-2}	29-39	CB&P Falling
	B	1.6×10^{-2}	29-39	B&R Rising
	B	4.9×10^{-3}	29-39	CB&P Rising
G35DB	B	1.4	56-66	CB&P Falling
	B	.35	56-66	B&R Rising
	B	1.1	56-66	CB&P Rising
G36D	B	5×10^{-2}	41-51	B&R Falling
	B	.12	41-51	CB&P Falling
	B	1.5	41-51	B&R Rising
G36D	B	6.4×10^{-2}	41-51	CB&P Rising
G36DB	B	2.9	73-83	B&R Falling
	B	7.6	73-83	CB&P Falling
	B	.94	73-83	B&R Rising
	B	8.6	73-83	CB&P Rising
G36DB2	B	2.3	207-217	B&R Falling
	B	1.7	207-217	CB&P Falling
	B	.42	207-217	B&R Rising
	B	1.7	207-217	CB&P Rising

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
RW1	9' LT 11'B	.53	12-32	B&R Falling
	9' LT 11'B	.8	12-32	CB&P Falling
	9' LT 11'B	.7	12-32	B&R Falling
	9' LT 11'B	.63	12-32	CB&P Rising
RW3	9' LT 11'B	.29	12-32	B&R Falling
	9' LT 11'B	.48	12-32	CB&P Falling
	9' LT 11'B	.34	12-32	B&R Rising
	9' LT 11'B	.55	12-32	CB&P Rising
RW7	2' LT 18' B	1.4	28-48	B&R Falling
	2' LT 18' B	4.2	28-48	CB&P Falling
	2' LT 18' B	1.34	28-48	B&R Rising
	2' LT 18' B	3	28-48	CB&P Rising
RW9	3' LT 17' B	7.6×10^{-2}	25-45	B&R Falling
	3' LT 17' B	5.2	25-45	CB&P Falling
RW9	3' LT 17' B	76	25-45	B&R Rising
	3' LT 17' B	6	25-45	CB&P Rising

Table 3-1 (continued).

Well	Hydrostratigraphic Unit	K (ft/day)	Depth (ft)	Method
RW10	3' LT 17' B	2.2	25-45	B&R Falling
	3' LT 17' B	5.8	25-45	CB&P Falling
	3' LT 17' B	1.3	25-45	B&R Rising
	3' LT 17' B	6.3	25-45	CB&P Rising

Notes:

SD = Stratified drift
AT = Ablation till
LT = Lodgment till
B = Bedrock
CB&P = Cooper, Bredehoeft, and Papadopolous
B&R = Bouwer and Rice
Rising = Rising head
Falling = Falling head

VK = Van der Kamp
GS = Estimated from grain size
HVH = Hvorslev variable head
HTL = Hvorslev time lag
PT = Pumping test Boulton
NC = Not calculated

Sources:

NUS, 1986
Myette, Olimpio, and Johnson, 1987
RETEC, 1993

Table 3-2. Tritium concentrations in ground-water samples, March and May 1993

Well ID	Depth of Screen (feet bgs)	Tritium Concentration (tritium units)
GO1S	8-18	10.8
GO1D	24-35	8.93
GO1DB	55-70	7.96
UG1-7	121.0	13.1
UG1-6	158.5	13.8
UG1-5	172.0	12.4
UG1-4	226.5	8.56
UG1-3	390.0	12.3
UG1-2	480.5	3.79
BUG1-5	52.1-54.1	11.2
BUG1-3	68.7-70.7	21.6
BUG1-1	81.60-83.2	16.5

Table 3-3. Range of detected VOC concentrations in ground-water samples from the Charrette property

COMPOUND	MCL, $\mu g/L$	CONCENTRATION, $\mu g/L$
Benzene	5	20 - 2,500
Toluene	1,000	5 - 27,000
Ethylbenzene	700	6.5 - 2,500
Xylenes	10,000	5.5 - 11,000

Table 3-4. Range of detected VOC concentrations in surface water samples from the Charrette property

COMPOUND	**MCL, (μg/L)**	**CONCENTRATION, μg/L**
MTBE	-	77 - 1400
Benzene	5	93 - 570
Toluene	1,000	Trace - 140
Ethylbenzene	700	Trace - 67
Xylenes	-	Trace - 210
Vinyl Chloride	2	120
Tetrachloroethene	5	5.4

Table 3-5. Field screening results of unconsolidated deposits from wells UG5, UG6, UG7S, and UG7D, Charrette property (μl/L, ppm by volume)

Well	Sample Depth (feet)	Benzene	Ethyl benzene	Toluene	Total Xylenes	PCE	TCE (mVS)
UG-5	0 to 2	0.02				0.06	
	5 to 7						*
	7 to 9						*
	9 to 11						*
UG-6	0 to 2	0.01					
	5 to 7	6.18	0.95	17.37	3.34		
	7 to 9	15.12	2.83	42.64	9.81		
	9 to 11	90.96	16.55	102.24	50.75		*
UG-7S	0 to 2						
	5 to 7	3.93		0.25	0.06		*
	7 to 9	24.66	1.37		0.32		
	9 to 11	133.72	15.34	128.56	42.46		*
UG-7D	12 to 14	279.40	23.26	294.44	46.93		
	14 to 16	215.40	30.20	247.00	92.70		*
	16 to 18	44.57	4.13	46.37	12.21		
	18 to 20	0.27	0.02	0.35	0.11		
	20 to 22	0.11		0.12	0.02		*
	22 to 24	0.84	0.09	0.88	0.40		*
	24 to 26	0.10		0.13			*
	26 to 28	0.06		0.07			*
	28 to 30	0.06		0.06			
	30 to 32	1.43	0.20	1.50	0.57		
	32 to 34			0.02			
	34 to 36	0.03		0.03			

* Indicates TCE tentatively identified

PCE = tetrachloroethene
TCE = trichloroethene

Table 3-6. Summary of VOC results for ground-water samples collected from wells UG5, UG6, and UG7, March 3, 1993, Charrette property (concentrations in μg/L)

Well	1,1 DCA	1,1 DCE	TCE	Vinyl Chloride	1,2 DCE	Benzene	Ethyl-benzene	Toluene	Xylene	MTBE
MCL	-	7	5	2	cis 70 trans 100	5	700	1,000	10,000	-
UG5	15	4J	41	1J	24	5U	5U	5U	5U	
UG6	26U	26U	26U	53U	26U	380	160	1,100	710	
UG7S	110U	110U	110U	220U	110U	3,300	560	2,900	2,500	180
UG7D	1U	1U	1U	2	1U	1U	1U	1U	1U	.6J

U = not detected above indicated concentration

J = approximate concentration

1,1-DCA = 1,1-dichloroethane

1,1-DCE = 1,2-dichloroethene

TCE = trichloroethene

1,2-DCE = 1,2-dichloroethene

Table 3-7. BTEX compounds detected in McLean Trucking recovery system influent

COMPOUND	MCL, μg/L	CONCENTRATION, μg/L
Benzene	5	1,300
Toluene	1,000	2,600
Ethylbenzene	700	340
Total xylenes	10,000	3,300

Table 3-8. Range of VOC concentrations in ground-water samples from Getty Service Station, March 1992

COMPOUND	MCL, $\mu g/L$	CONCENTRATION, $\mu g/L$
Benzene	5	13 - 570
Toluene	1,000	2,700
Ethylbenzene	700	
Xylenes	10,000	4,700
MTBE	-	1.3 - 170

Table 3-9. Range of VOC concentrations in ground-water samples from Getty Service Station, December 1992

COMPOUND	MCL, μg/L	CONCENTRATION, μg/L
Benzene	5	4.2 - 470
Toluene	1,000	740
Ethylbenzene	700	210
Xylenes	10,000	1,300
Total BTEX	-	4.2 - 2,700
MTBE	-	94 - 120

Table 3-10. Summary of ground-water analysis results, 225 Wildwood Avenue, March 1988

COMPOUND	MCL, $\mu g/L$	CONCENTRATION, $\mu g/L$
Toluene	1,000	11
Chlorobenzene	100	Trace
1,2-Dichlorobenzene	600	2
Arsenic	50	12
Barium	2,000	150 - 1260
Chromium	100	59 - 344
Lead	15	204

Table 3-11. Summary of soil analysis results, 225 Wildwood Avenue, March 1988

COMPOUND	CONCENTRATION, mg/kg
Acetone	5.4
Methylene Chloride	Trace - 2.3
2-Butanone	4.0
Chloroform	Trace
Toluene	.4 - .7
Chlorobenzene	.2
1,4-Dichlorobenzene	Trace - .4
1,2-Dichlorobenzene	1.9 - 3.2
Arsenic	12.9 - 47
Barium	31.5 - 32
Chromium	1,980 - 3,600
Lead	62.1 - 101
Mercury	.37

Table 3-12. Summary of ground-water analysis results, Weyerhauser Company, February 1987

COMPOUND	MCL, μg/L	CONCENTRATION, μg/L
Methylene Chloride	5	7 - 12
Chloroform		11
Benzene	5	180
Toluene	1,000	6 - 23
Ethylbenzene	700	120
Total Xylenes	10,000	6 - 290
Bis(2-ethylhexyl)phthalate	-	4 - 8
Naphthalene	-	580
Acenaphthene	-	10
Acenaphthylene	-	44
Phenanthrene	-	42
Pyrene	-	2
2-Methylnaphthalene	-	47
Total Base/Neutrals	-	729
Total PAH	-	725

Table 3-13. Summary of ground-water analysis results, Weyerhauser Company, April 1989

COMPOUND	MCL, µg/L	CONCENTRATION, µg/L
Methylene Chloride	5	11
Trichloroethene	5	11-44
Benzene	5	140
Toluene	1,000	10
Chlorobenzene	-	41
Total Xylenes	10,000	180

Table 3-14. Summary of ground-water and soil results,
Motors, Electronics, and Controls Corporation, 1991

COMPOUND	**MCL, μg/l**	**GROUND-WATER CONCENTRATION, μg/L**
Benzene	5	7.6
1,1,1-Trichloroethane	200	5.5 - 6.5
		SOIL CONCENTRATION, mg/kg
TPH		6.3 - 391.6

Table 3-15. Summary of ground-water analysis results,
5 Wheeling Avenue, January and June 1990

COMPOUND	**MCL, μg/L**	**CONCENTRATION, μg/L**
Benzene	5	130 - 7,000
Toluene	1,000	92 - 7,200
Ethylbenzene	700	60 - 1,400
Xylene	10,000	880 - 7,600

Table 3-16. Summary of ground-water analysis results, Romicon, Normac Road, December 1991

COMPOUND	MCL, μg/L	CONCENTRATION, μg/L
Carbon Disulfide	-	2J
Tetrachloroethene	5	15
Triethylene Glycol (ACN)	-	23J
Silver	-	34
Aluminum	-	3,700
Barium	2,000	1,100
Calcium	-	45,600
Chloride	-	536,000
Cobalt	-	260
Copper	1,300	720
Iron	-	610
Potassium	-	9,300
Magnesium	-	5,300
Manganese	-	8,500
Sodium	-	170,000
Nickel	100	180
Sulfate	-	9,4000
Zinc	-	380

Table 3-17. Summary of soil analysis results,
Romicon, Normac Road, December 1991

COMPOUND	**CONCENTRATION, $\mu g/kg$**
Carbon Disulfide	5J
Toluene	2J
Ethylbenzene	1J
Xylenes (total)	8
Di-n-butylphthalate	65J
Fluoranthene	46J
Pyrene	56J
Bis(2-ethylhexyl)phthalate	41J
Sulfur, Mol. (S8)	230J
Hexane,2,3,5-Trimethyl	240J
Ethanone,1-(3-Ethyloxiranyl)	540J
3-Heptanone, 2,4-Dimethyl	710J
Benzeneacetic Acid	360J
Aluminum	9,600
Calcium	1,600
Cyanide, distilled	57.6
Chromium	16
Copper	9.5
Iron	8,300

Table 3-17 (continued).

COMPOUND	**CONCENTRATION, μg/kg**
Lithium	11
Magnesium	2,900
Manganese	80
Lead	4.5
Sulfate	23.1
Titanium	680
Vanadium	17
Zinc	12

Table 3-18. Summary of ground-water analysis results,
Romicon, Cummings Park, December 1991

COMPOUND	MCL, μg/L	CONCENTRATION, μg/L
Phosphoric Acid, Diethyl Ester		130J
Aluminum		1,500
Calcium		55,000 - 68,000
Chloride		421,000 - 500,000
Iron		170 - 2,800
Potassium		5,100 - 10,100
Magnesium		9,900 - 19,800
Manganese		560 - 3,600
Sodium		170,000 - 220,000
Sulfate		19,800 - 43,000

Table 3-19. Summary of soil analysis results,
Romicon, Cummings Park, December 1991

COMPOUND	CONCENTRATION, $\mu g/kg$
Carbon Disulfide	3J
Xylenes (total)	2J
Naphthalene	48J
2-Methylnaphthalene	75J
Acenaphthene	250J
Phenanthrene	330J
Anthracene	130J
Di-n-butylphthalate	100J
Fluoranthene	2,500
Pyrene	1,700
Benzo(a)anthracene	1,700
Chrysene	2,000
Bis(2-ethylhexyl)phthalate	89J
Benzo(b)fluoranthene	2,200
Benzo(k)fluoranthene	1,200
Benzo(a)pyrene	1,500
Indeno(1,2,3-cd)pyrene	920
Dibenz(a,h)anthracene	510
Benzo(g,h,i)perylene	780
Heptane, 2,3-Dimethyl	290J
Disphosphoric Acid, Tetraethyl Ester	800J
Sulfur, Mo. (S8)	2,300J
11H-Benzo(a)fluorene	950J

Table 3-19 (continued).

COMPOUND	CONCENTRATION, μg/kg
Benzo(c)phenanthrene	400J
Chrysene, 3-Methyl	890J
Octadecane	2,400J
Pentatria contane	2,700J
Benzo(j)fluoranthene	680J
Aluminum	11,000 - 12,000
Arsenic	6.2
Calcium	2,300 - 3,200
Chloride	62.7 - 72.7
Chromium	15 - 22
Copper	11 - 30
Iron	15,000 - 22,000
Mercury	.49
Lithium	21 - 23
Magnesium	3,700 - 4,300
Manganese	180 - 240
Nickel	9.8 - 14
Lead	4.1 - 115
Sulfide	10.6
Sulfate	20.4 - 20.8
Titanium	560 - 590
Vanadium	27 - 38
Zinc	33 - 160

Table 3-20. Volatile organic compounds detected in Aberjona River water samples May and September, 1993 (concentrations in μg/L)

DETECTED VOCs	MCL, μg/L	5/10/93	9/30/93
Chloromethane	-	.73	ND
1,2-dichloroethane	5	.73	ND
Cis-1,2-dichloroethene	70	.68	.25J
Trichloroethene	5	.80	.16J
1,1,1-Trichloroethane	200	ND	.06J

Table 3-21. Detected polynuclear aromatic hydrocarbons

2-methylnaphthalene	Chrysene
Acenaphthene	Floranthene
Acenaphthylene	Fluorene
Benzo(a)pyrene	Indeno(1,2,3-C)pyrene
Benzo(b)fluoranthene	Naphthalene
Benzo(ghi)perylene	Phenanthrene
	Pyrene

Table 3-22. Concentrations of PAH compounds detected at well cluster S75

Compound	Concentration $\mu g/L$
2-MethylNaphthalene	192J
Acenaphthene	11J
Acenaphthylene	74J
Fluorene	19J
Naphthalene	1,244J
Phenanthrene	8J

Table 3-23. PAH concentrations in ground-water samples from wells on the west side of the Aberjona River, $\mu g/L$

Compound	Well OL1	Well OL2	Well OL4
2-Methylnaphthalene	3		
Acenaphthene			13
Acenaphthylene			7
Naphthalene		1	120

Table 3-24. Semi-volatile organic compounds detected in samples collected since January 1, 1991

1,2-dichlorobenzene	Bis(2-ethylhexyl)phthalate
2-methylphenol	Di-n-butylphthalate
2-nitrophenol	Di-m-octylphthalate
4-methylphenol	Isophorone
Benzoic acid	Diethylphthalate
Benzyl alcohol	Phenol

Table 3-25. Chemical specific, location specific, and action specific ARARs and TBCs
Wells G & H Site

REQUIREMENT	REQUIREMENT SYNOPSIS
CHEMICAL-SPECIFIC ARARs	
SDWA - Maximum Contaminant Levels (MCLs) (40 CFR 141.11-141.16)	MCLs have been promulgated for a number of common organic and inorganic contaminants. These levels regulate the concentration of contaminants in public drinking water supplies but may also be considered relevant and appropriate for ground-water aquifers potentially used for drinking water.
DEP - Massachusetts Drinking Water Regulations Maximum Contaminant Levels (MCLs) (310 CMR 22.00)	Massachusetts MCLs establish levels of contaminants allowable in public water supplies. They are essentially equivalent to SDWA MCLs.
DEP - Massachusetts Ground Water Quality Standards (314 CMR 6.00)	These standards consist of ground-water classifications which designate and assign the uses of Commonwealth ground waters and water quality criteria necessary to sustain these uses. There is a presumption that all ground waters are Class 1.

Table 3-25 (continued).

REQUIREMENT	REQUIREMENT SYNOPSIS
CHEMICAL-SPECIFIC TBCs	
IRIS Risk Reference Doses (RfDs)	RfDs are dose levels developed by EPA for non-carcinogenic effects.
IRIS Carcinogen Potency Factors	Potency Factors are developed by the Integrated Risk Information System (IRIS)
RCRA Proposed Rule for Corrective Action 55 FR 30798 (July 27, 1990). Appendix A.	Sets forth examples of concentrations meeting criteria for action levels for substances for which no MCLs have been established.
"Evaluation of Groundwater Extraction Remedies" EPA No. 540.2-89 (October 1989)	Analyzes the effectiveness of ground-water pump and treat systems in achieving significant reductions of ground-water contamination.
"Guidance for Disposal Site Risk Characterization and Related Phase II Activities in Support of the MCP" (May 17, 1988)	Explains how health assessments are to be used under MCP to establish ground-water action levels.
DEP Addendum to Massachusetts Drinking Water Standards and Guidelines, Spring 1991	Incorporates amendments to federal drinking water regulations including Maximum Contaminant Level Goals and National Primary Drinking Water Regulations.
DEP Policy #DEP-91-001 Policy for Discharges to Groundwater in Support of Remedial Actions Conducted in Accordance with M.G.L. c. 21E	Contains interim guidance to assist in evaluating the feasibility of achieving remedial action goals.
Basics of Pump and Treat Groundwater Remediation Technology EPA 600/8-90/003, March 1990	Provides basic guidance on how to use available hydrogeologic and chemical data to determine when, where, and how pump and treat technology can be used successfully to contain and/or remediate contaminant plumes.
Estimating Potential for Occurrence of DNAPL at Superfund Sites OSWER Publication No. 9355.4-07F6	Provides guidance on evaluation of Superfund Sites where DNAPL is found.
Massachusetts Contingency Plan, 1993 310 CMR 40	Provides guidance regarding reported quantities and concentrations for specific contaminants.

Table 3-25 (continued).

REQUIREMENT	REQUIREMENT SYNOPSIS
LOCATION-SPECIFIC ARARs	
CWA - Section 404 Dredge and Fill Requirements (Guidelines at 40 CFR 230)	The placement for fill following excavation of contaminated soil pursuant to remediation activities in the Aberjona River wetlands triggers Section 404 jurisdiction. The governing regulations favor practicable alternatives that have less impact on wetlands. If no mitigated practicable alternative exists, impacts must be mitigated.
Massachusetts Wetlands Protection Requirements (310 CMR 10.00)	These requirements control regulated activities in freshwater wetlands, 100-year floodplains, and 100-foot buffer zones beyond these areas. Regulated activities include virtually any construction or excavation activity. Performance standards are provided for evaluation of the acceptability of various activities.
Wetlands Executive Order (EO 11990)	Under this Executive Order, federal agencies are required to select alternatives that minimize the destruction, loss, or degradation of wetlands, and preserve and enhance natural and beneficial values of wetlands.
Floodplains Executive Order (EO 11888)	Federal agencies are required to reduce the risk of flood loss, to minimize impact of floods, and to restore and preserve the natural and beneficial value of floodplains. In addition, practicable alternatives must be selected that have less impact on wetlands.
Massachusetts Drinking Water Standards: Wellhead Protection Regulations at 310 CMR 22.21	These regulations develop procedures for the protection of public water supply wells within the Commonwealth.
Massachusetts Water Resource Management Program at (310 CMR 36.00)	These regulations develop procedures for the management of surface water and ground water resources within the Commonwealth.
LOCATION-SPECIFIC TBCs	
EPA Groundwater Protection Strategy	EPA classifies ground water into three categories depending on current, past, or potential use. This serves as a guide for protection of the resource.
EPA Memorandum: OSWER Directive 9234.2-25 Guidance for Evaluating the Technical Impracticalities of Ground-Water Restoration	Provides guidance on evaluating the technical impracticality of restoring ground-water quality.

Table 3-25 (continued).

REQUIREMENT	REQUIREMENT SYNOPSIS
ACTION-SPECIFIC ARARs	
OSHA - General Industry Standards (29 CFR 1910)	This regulation specifies the 8-hour, time-weighted average concentration for various organic compounds and two PCB compounds; site control procedures; training; and protective clothing requirements for worker protection at site remediations.
OSHA - Safety and Health Standards (29 CFR 1926)	This regulation specifies the type of safety equipment and procedures to be followed during construction and excavation activities.
OSHA - Recordkeeping, Reporting, and Related Regulations (29 CFR 1904)	The regulation outlines the recordkeeping and reporting requirements for an employer under OSHA.

Table 3-26. Frequency of exceedance of chemical-specific ARARs for the Wells G & H Central Area (all concentrations in μg/L)

COMPOUND	# of Wells in Which Detected	MCL	# of Wells Exceeding	SMCL	# of Wells Exceeding	ORSG	# of Wells Exceeding	Fresh Water Chronic Standard	# of Wells Exceeding	MCP GW-1	# of Wells Exceeding
1,1,1-Trichloroethane	118	200	4					2400	0	200	4
1,1,2,2-Tetrachloroethane	2									2	2
1,1,2-Trichloroethane	2	5	1					9400	0	5	1
1,1,2-trichlorotrifluoroethane	4					210000	0				
1,1-Dichloroethane	82	7	20			70	0			70	0
1,1-Dichloroethene	55	7	8							1	36
1,2,4-Trichlorobenzene	1	70	1					50	1	70	1
1,2,4-Trimethylbenzene	5									100	0
1,2-Dibromo-3-chloropropane	1	0.2	0							100	0
1,2-Dibromoethane	1									0.02	1
1,2-Dichlorobenzene	2	600	0					763	0	600	0
1,2-Dichloroethane	2	5	1					20000	0	5	1
1,2-Dichloroethene (total)	164	70(100)	16							100	12
1,2-Dichloropropane	1	5	1					5700	0	5	1
1,2-Dichloropropylene	6							244	0	0.5	6
1,3,5-Trimethylbenzene	3									100	1

Table 3-26 (continued).

COMPOUND	# of Wells in Which Detected	MCL	# of Wells Exceeding	SMCL	# of Wells Exceeding	ORSG	# of Wells Exceeding	Fresh Water Chronic Standard	# of Wells Exceeding	MCP GW-1	# of Wells Exceeding
Butanone	34					350	5			400	5
2-Chlorotoluene	2									5000	0
2-Hexanone	3									400	0
4-Methyl-2-Pentanone	2					350	0			400	0
Acenaphthene	3							520	0	20	0
Acenaphthylene	3									300	0
Acetone	87	70	24			3000	8			3000	8
Aldicarb	1	3	1							100	0
Alkalinity, total (as CaCO3)	61							20000	60		
Aluminum	84			50	79						
Ammonia (as N)	12									1000	6
Antimony	11	6	3					1600	0	6	3
Arsenic	75	50	11							50	11
Barium	91	2000	0								
Benzene	51	5	17							5	17
Benzoic Acid	2									10000	0
Beryllium	41	4	24					5.3	19	4	24

Table 3-26 (continued).

COMPOUND	# of Wells in Which Detected	MCL	# of Wells Exceeding	SMCL	# of Wells Exceeding	ORSG	# of Wells Exceeding	Fresh Water Chronic Standard	# of Wells Exceeding	MCP GW-1	# of Wells Exceeding
Bis(2-Ethylhexyl)phthalate	42	6	25							6	25
Bromomethane	1					10	1			2	1
Butyl benzyl phthalate	1									1000	0
Cadmium, total	36	5	18					1.1	29	5	18
Carbon disulfide	47									1000	0
Carbon tetrachloride	3	5	3							5	3
Chlordane	1	2	0					0.0043	1	2	0
Chloride	183			250000	43						
Chlorobenzene	7	100	1					50	1	100	1
Chloroethane	4									1000	0
Chloroform	72					5	15	1240	0	5	15
Chloromethane	9									1000	0
Chromium, total	85	100	18							100	18
Cis-1,2-dichloroethene	95	70	4							70	4
Cobalt	45									100	6
Copper	79	1300	1					12	68	10000	0
Cyanide, total	4	200	0	1000	0			5.2	2	10	0

Table 3-26 (continued).

COMPOUND	# of Wells in Which Detected	MCL	# of Wells Exceeding	SMCL	# of Wells Exceeding	ORSG	# of Wells Exceeding	Fresh Water Chronic Standard	# of Wells Exceeding	MCP GW-1	# of Wells Exceeding
Di-n-butyl phthalate	10									500	0
Di-n-octyl phthalate	3									10000	0
Dibromochloromethane	2									5	1
Ethylbenzene	26	700	4							700	4
Fluorene	1									300	0
Fluoride, soluble	20	4000	0	2000	1						
Iron	109			300	96			1000	79		
Isopropylbenzene	4									10000	0
Lead	90	15	40					3.2	74	20	32
Manganese	117			50	109			0.012	117		
Mercury	17	2	1							1	3
Meta- & Para-Xylenes	26									6000	1
Methanol	1									10000	0
Methyl-t-butyl ether	7					700	3			700	3
Methylene chloride	94	5	45							5	45
N-Nitrosodiphenylamine	2									1000	0
Naphthalene	13							620	2	20	6

Table 3-26 (continued).

COMPOUND	# of Wells in Which Detected	MCL	# of Wells Exceeding	SMCL	# of Wells Exceeding	ORSG	# of Wells Exceeding	Fresh Water Chronic Standard	# of Wells Exceeding	MCP GW-1	# of Wells Exceeding
Nickel	53	100	13					96	13	80	16
Nitrate	87	10000	4								
Nitrate + Nitrite (as N)	75	10000	2								
Nitrite Nitrogen	22	1000	0								
Ortho-Xylene	21									6000	1
PCB-1221	1									0.3	1
Phenanthrene	2									50	0
Phenol	9							2560	0	4000	0
Pyrene	1									80	0
Selenium	6	50	0					35	0	50	0
Silver	14			100	0			0.12	14	7	10
Sodium	149					28000	109				
Styrene	3	100	1							100	1
Sulfate	127			250000	3						
Tetrachloroethene	187	5	133					840	18	5	133
Thallium	5	2	3					40	0	2	3
Toluene	103	1000	6							1000	6

Table 3-26 (continued).

COMPOUND	# of Wells in Which Detected	MCL	# of Wells Exceeding	SMCL	# of Wells Exceeding	ORSG	# of Wells Exceeding	Fresh Water Chronic Standard	# of Wells Exceeding	MCP GW-1	# of Wells Exceeding
Total Dissolved Solids	92			500000	22						
Trans-1,2-dichloroethene	23	100	0							100	0
Trichloroethene	217	5	149					21900	1	5	149
Trichlorofluoromethane	6									10000	0
Vinyl chloride	15	2	7							2	7
Xylene (total)	56	10000	3							6000	4
Zinc, total	85			5000	0			47	60	900	5
alpha-Clordane	1							0.0043	1	2	0
gamma-Chlordane	1							0.0043	1	2	0
n-Propylbenzene	2									1000	0
pH	5			6.5-8.5	5			6.5-9	5		

Notes:

MCL = Maximum contaminant level
SMCL = Secondary maximum contaminant level
ORSG = Office of Research and Standards guidelines
MCP GW-1 = Massachusetts Contingency Plan - Ground water - Region 1

4 CONCLUSIONS

The Central Area Aquifer is a shallow unconfined, or water-table, aquifer which is vulnerable to contamination by a wide variety of chemicals from numerous sources in a highly developed and industrialized area. Ground-water analyses in the Central Area show exceedances of drinking water standards for a great variety of chemicals and compounds, and these exceedances are pervasive both areally and vertically. The numerous studies which have been done have identified multiple sources that contribute contamination to the Central Area. The myriad of sources and historic changes in hydrologic conditions within the Central Area have resulted in widespread distribution of the many types of contaminants. Contaminants which have been detected in ground water within the Central Area include inorganic compounds such as arsenic, chromium, lead, sodium, chloride, nitrate, and sulfate; organic compounds such as chlorinated solvents, benzene, semi-volatile organic compounds; and PAH compounds. In addition, almost every investigation which has been undertaken to date has shown the presence of previously undetected additional sources of contamination.

Numerous investigations which have been done since the late 1950s have provided the information base which is sufficient to describe the technical impracticability of restoring ground water in the Central Area Aquifer to drinking water quality. These investigations include the studies of the Aberjona River and watershed north of the Central Area which were done to identify the numerous sources of contamination to the Aberjona River and the Central Area Aquifer. They also include the phased investigations of the Wells G & H Site, which include the RI (NUS, 1986), the 30-day pumping test of wells G and H (Myette, et al., 1987) the Supplemental RI (Ebasco, 1988), the coordinated UniFirst/Grace RD/RA (EPC, 1991), and the on-going RD/RA investigations of the NEP and Wildwood properties. The studies also include the numerous property investigations which have been done within the watershed in accordance with MGL c. 21E. As a result there is an extensive information base which identifies hydrogeologic factors and contaminant-related factors that preclude ground-water restoration for the Central Area Aquifer (EPA, 1993b).

The hydrogeologic factors which make aquifer restoration impracticable include the hydraulic connection between the Central Area Aquifer and the Aberjona River, the nature of the Aberjona River watershed drainage area which contributes both surface water and ground-water flow to the Central Area. Contaminant related factors which make aquifer restoration impracticable include the numerous past, present, and likely future sources of contamination to the Central Area Aquifer which result from the conflicting land uses within the Aberjona River watershed, the persistent nature of some of several of the contaminants, such as DNAPL in the fractured bedrock, the continual replenishment of contamination by highway and parking lot runoff to the Aberjona River and the Central Area Aquifer, the presence of arsenic and chromium in the Aberjona River sediments and associated wetlands within the Central Area.

For the following reasons restoration of the Central Area Aquifer to drinking water standards is technically impractical and not warranted:

- The Central area is part of a large unprotected, unprotectable, urban watershed system that has been industrialized for almost two centuries.

- In 1958 Whitman and Howard determined that ground water within the Central Area Aquifer was not suitable for use as a public drinking water supply due to the presence of industrial contamination. Much of this contamination is directly attributable to contamination releases in upstream reaches of the Aberjona River watershed which are outside the boundaries of the Central Area. Contamination continues to flow toward the Central Area from the upstream reaches of the Aberjona River.

- There is widespread contamination within the Central Area. This contamination is derived from numerous known and unknown sources of a wide variety of chemicals. The history and nature of the known releases indicate that it is unreasonable to expect that future releases of contamination with the Central Area and Aberjona River watershed can be prevented from occurring. Anthropogenic compounds are widely and deeply distributed throughout the area. Because of the numerous sources and hydrologic setting it is difficult to identify specific sources of all the contamination found.

- In the absence of pumping within the Central Area Aquifer, there is natural ground-water discharge from the aquifer to the river. This discharge which has been determined during one three month period to be about 450 gpm is, in effect, a natural ground-water extraction system which is currently flushing contamination from the Central Area Aquifer.

- Pumping from the Central Area Aquifer would not be an effective remedial alternative. The hydraulic connection between the Central Area Aquifer and the Aberjona River has been well described and understood (MWRA, 1973; Myette, et al., 1987; GeoTrans, 1987; Cherry et al., 1989). In the event of pumping from the Central Area Aquifer, there will be induced infiltration of surface water from the Aberjona River and associated wetlands into the underlying Central Area Aquifer. The river and its wetlands have been, and continue to be, contaminated with a variety of contaminants. The effect of pumping from the Central Area Aquifer will be to induce contamination from the Aberjona River and associated wetlands into the aquifer, thereby contaminating the Central Area Aquifer.

- The river sediment and wetlands associated with the Aberjona River are currently a repository for arsenic and chromium which have been and continue to be transported to the Wells G & H Site from the northern reaches of the Aberjona River watershed. If pumping from within the Central Area Aquifer were to occur, it is likely that these metals would be induced to penetrate deeper into the Central Area Aquifer.

- Based on the contamination conditions observed in the Central Area and knowledge of its history, the Central Area conforms with a Category I (confirmed or high potential) DNAPL site as suggested by the US EPA (1992) . That is, both the site characterization data and chemical use data indicate the presence of DNAPL.

- Within recent years, there have been several releases of benzene directly to ground water within the Central Area Aquifer. These releases were from underground storage tanks which are not regulated by CERCLA. DEP has assigned non-priority status and granted waivers from DEP approvals to the sites where the releases occurred. For DEP to have granted a waiver of approvals it made a determination that the releases did not pose a threat to an actual or potential drinking water supply. As some of the releases were directly to the Central Area Aquifer, DEP has determined that the Central Area Aquifer is not a potential drinking water supply.

The ROD objective to restore the Wells G & H Site Central Area Aquifer to drinking water quality (EPA, 1989, p. 35) is technically impracticable and no additional investigations and evaluations are warranted. This conclusion is based on an extensive Site characterization which provided a detailed understanding of the hydrogeologic conditions or factors which affect ground water flow and chemical transport within the Site, the interaction between the Aberjona River and the Central Area Aquifer, and the nature and extent of contamination within the Site. The numerous studies and investigations within the Site and within the Aberjona River watershed have provided more than enough information to develop a conceptual model of the Site which clearly demonstrates the infeasibility of restoration of the Central Area Aquifer to drinking water quality standards.

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