Volume I of II

Report, Tables and Figures

Volume II of II

Sheets and Appendices

SUPPLEMENTAL INVESTIGATION WORK PLAN NON-PUBLIC PROPERTIES STUDY AREA HAMDEN, CONNECTICUT

Prepared for:

Olin

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ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

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DOCUMENT CERTIFICATION

I have personally examined and am familiar with the information submitted in this document and all attachments thereto, and I certify, based on reasonable investigation, including my inquiry of those individuals responsible for obtaining the information, that the submitted information is true, accurate and complete to the best of my knowledge and belief. I understand that any false statement made in the submitted information is punishable as a criminal offense under §53a-157b of the Connecticut General Statutes and any other applicable law.

____
Chief Executive Officer (or duly authorized representative)
Olin Corporation

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____

Malcolm Pirnie, Inc.
Responsible for document preparation

1.0 INTRODUCTION

1.1 REGULATORY STATUS

On July 10, 2001, the Connecticut Department of Environmental Protection (CTDEP) issued unilateral Order No. SRD-128 to Olin Corporation and three other potentially responsible parties. This order was subsequently appealed by all parties and resulted in Consent Order No. SRD-128 (the original unilateral order number was retained) being entered on April 16, 2003 as the final decision of the hearing officer (see Appendix A). It separates the Hamden Middle School and adjacent area, located in Hamden, Connecticut (see Figure 1-1), into Public Properties and Non-Public Properties (NPP) study areas, which together make up the "site".

The Consent Order directs Olin to prepare a work plan to determine the extent and degree of soil, surface water, and ground water pollution resulting from the disposal of waste on the NPP study area as encompassed within the areas outlined on Figure 1-1 and Sheet 1. The Public Properties, which are also shown on the figure and sheets, are adjacent to the NPP, are the responsibility of others under the Consent Order, and are not subject to the scope of work described in this Work plan.

As shown on Figure 1-1 and Sheet 1, the 100-acre site is located in the southern portion of Hamden, Connecticut, east of Dixwell Avenue and just north of the border with New Haven. The 36-acrePublic Properties study area consists of:

- Hamden Middle School, 550-560 Newhall Street (formerly the Michael J. Whalen Junior High School).
- Hamden Community Center, 496 Newhall Street (formerly the Newhall Street School).
- Rochford Field.
- Mill Rock Park (a.k.a. Rochford Field Annex).
- Two Hamden Housing Authority properties, 249-251 and 253-255 Morse Street.
- The sewage pump station, 1099 Winchester Avenue.

The approximately 64-acre NPP study area has two portions, a smaller approximately

5.6-acre portion lying north of, and a larger approximately 58.4-acre portion lying south of, the intervening Public Properties study area. Based on the base plan from the Town of Hamden assessors map (revised April 2000), 302 properties were identified in the NPP study area (some adjacent properties with common ownership, if known, are counted as one).

In accordance with the Consent Order, this Supplemental Investigation Work plan includes the following required elements:

- Proposed sampling and analytical program, including the parameters to be tested, the sampling and analytical methods, and quality assurance/quality control procedures.
- Proposed locations and depths of groundwater monitoring wells and soil and surface water samples.
- Proposed schedule for conducting the investigation, including deliverable reports and dates of report submissions to the CTDEP.

1.2 PREVIOUS STUDIES

Several investigators and environmental regulatory agencies have conducted studies and/or limited interim remedies within the NPP study area. After sampling soil or fill at 76 properties during April 2001, USEPA conducted limited removal of surficial materials at 11 properties within the NPP study area between October 1, 2001 and May 1, 2002. Between December 2000 and November 2002, the CTDEP conducted investigations (soil/fill and groundwater) within the NPP study area. During this period, the Town of Hamden compiled background information on the site as part of a Phase I environmental site assessment. During September and October 2002, HRP Associates, Inc. completed environmental assessment reports on the properties at 425 and 449 Newhall Street. In the summer of 2002, Olin conducted a voluntary Initial Investigation on portions of the NPP study area. The results of Olin's Initial Investigation are summarized in the "Initial Investigation Findings Report, Newhall Street Residential Area, Hamden Connecticut", dated December 2002.

The Initial Investigation identified and described five geographically separate areas of fill within the NPP study area: Southwest Satellite Area, Morse Street Area, Newhall Street

Area, Bryden Terrace Area, and Augur Street Area (approximately delineated on Sheet 1). The Morse Street, Newhall Street, and Bryden Terrace Areas are contiguous to fill underlying the Public Properties to the north, which are the subject of investigations by others. The extent of filling on the site correlates with historical and anecdotal descriptions and photographs of filling in the record. Detailed descriptions of the history, extent, composition, chemistry, and current use of the fill areas are included in the Conceptual Site Model. Similar information on the filling of the Public Properties is included in this Work plan only to the extent that the filling, due to its proximity, has a bearing on the Conceptual Site Model and affects the scope of work for the NPP study area.

1.3 DEFINITIONS

The following terms are strictly used in this work plan as defined below. Any other term appearing in the CTDEP Remediation Standard Regulations (RSRs) (RCSA 22a-133k-1(a)) and not otherwise defined below is used in accordance with its RSR definition.

Soil

Unconsolidated, solid, subsurface material that was naturally placed (native) and is composed of geologic mineral and rock grains and/or natural organic matter. It does not include sediment as defined in the RSRs. Soil typically displays natural textural features such as varying grain size and/or composition sorted into laminations (<1/2-inch-thick) and layers (>1/2-inch-thick). Three types of soil occur in the site as defined by composition, texture, and mode of deposition: Fines, Sand, and Glacial Till.

Fines – Soil composed primarily of clay and silt sized mineral grains, with some very fine-grained sand and commonly including organic matter. Is typically dark colored (gray, brown, or black) and generally less permeable to groundwater than other soils. Deposited by slow-moving surface water in a restricted basin.

Sand - Soil composed primarily of sand sized mineral grains, with some gravel. Is typically pink or light red-brown colored and laminated or layered and generally more permeable to groundwater than other soil. Deposited by fast-flowing surface water in river channels.

Glacial Till - Soil composed of all grain sizes, including abundant cobbles and boulders, and completely non-sorted, typically red-brown colored, and exhibits no laminations or layers and with widely varying permeability to groundwater. Deposited by glacial ice.

Fill

Unconsolidated, solid, subsurface material that was artificially placed and/or disturbed. It is divided into three general types based on a bulk visual assessment of differing texture and composition: Disturbed Soil Fill, Refuse Fill, and Waste Fill.

Disturbed Soil Fill - Fill composed primarily of reworked natural soil. It may have been reworked locally or brought in from another location. It may contain minor or trace commingled proportions of brick, ceramics, concrete, asphalt paving fragments, and miscellaneous refuse such as wood debris, metal, or glass. This description is based on texture and the absence of other fill indicators, and does not imply that substance concentrations meet the RSR in all cases.

Refuse Fill - Fill composed primarily of commingled articles such as wood (e.g. construction and demolition debris), metals, glass, ceramics, papers and cardboard, dishware, leather goods, bottles, cinders, paint chips, roof shingles, margarine containers and newspapers. Also may contain white to gray ash from the combustion of these articles and minor commingled proportions of reworked soil and rock, and ash, slag, and cinders. The key distinction is that it contains differing discarded and/or incinerated manufactured items but implies no specific source(s) for the items observed such as residential versus industrial/commercial. This type of fill is similar to municipal solid waste.

Waste Fill - Fill composed primarily of typically black ash, slag, cinders, coal and/or coke, or a discrete, identifiable waste product item in quantity (such as wood chips or batteries). It may contain a significant refuse fraction and/or minor commingled proportions of soil and rock. The key distinction is that it consists of materials disposed in quantity, indicative of a waste byproduct from a single source or source(s) that contributed loads, of discrete materials.

<u>Bedrock</u>
Consolidated or cemented, subsurface, solid material that was naturally placed and is composed of naturally produced mineral and rock grains. Bedrock contiguously underlies all soil and fill deposits and may outcrop at the ground surface such as at Mill Rock Ridge.

<u>Kettle</u>
A kettle is a natural, topographic basin formed where a block of glacial ice was buried by soil and then later melted. The melting of the ice causes the overlying and surrounding soil to collapse, leaving a depression with angle-of-repose side slopes and circular outlines. Larger ones are complexly segmented and typically contain surface water bodies.

<u>Logging</u>
The collection and description of small, representative portions of fill, soil, or bedrock for the purpose of visually identifying and describing these materials.

<u>Sampling</u>
The collection of representative portions of fill, soil, groundwater, or surface water for the purposes of field or laboratory analyses of the material and/or of substances within the material.

<u>Surficial</u>
That portion of fill or soil that is within 0.5 feet beneath the ground surface.

<u>Underlying</u>
That portion of fill or soil that is deeper than 0.5 feet beneath the ground surface.

2.0 CONCEPTUAL SITE MODEL

2.1 STATEMENT OF THE PROBLEM

Environmental investigations, beginning in 1989 at the Hamden Middle School and expanding into the adjacent NPP, identified areas where wetlands formerly existed and/or where waste materials were historically placed. The investigations revealed that fill including, but not limited to, ash, slag, and coal waste, as well as other industrial and household waste are buried throughout the area in varying proportions and at various locations. Soil and fill are potentially polluted with metals, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and total petroleum hydrocarbons (TPH).

In accordance with the Consent Order, Olin shall perform all investigations that the CTDEP Commissioner deems necessary to determine the extent and degree of pollution of the NPP and perform the remediation of the NPP, in accordance with the Regulations of Connecticut State Agencies (RCSA), Sections 22a-133k-1 to k-3 ("Remediation Standard Regulations"). Because the Commissioner determined that Olin's Initial Investigation Report is incomplete, Olin must submit for the Commissioner's review and written approval a scope of study for a supplemental investigation on the portion of the site encompassed by the NPP to:

- Define the three-dimensional extent and the physical and chemical nature of fill materials.
- Determine the extent and degree of soil, surface water, and groundwater pollution resulting from such fill.

This requires the development of a conceptual site model (CSM) describing and evaluating the information, whether generated by Olin, CTDEP, or other responsible parties, on the site's physical condition and history, particularly the:

- Location, extent, thickness, and types of fill.
- Chemical and physical characteristics of the fill and how they vary.
- Origin of the fill.
- Effect filling has on the quality of soil, groundwater, and surface water.

The evaluation also identifies the gaps in Olin's understanding of the extent and degree of pollution and provides a basis for the scope of work needed to collect the data necessary to fully characterize the pollution on the NPP.

2.2 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are qualitative and quantitative criteria used to determine when there are enough representative data of sufficient precision and accuracy to address the data gaps in the CSM (see Section 2.3). The DQOs determine when, where, and how many samples to collect and analyze and the desired level of confidence needed to make a decision. Like the CSM, the development of DQOs is an iterative process. Existing data and data gaps in the CSM are evaluated relative to the DQOs to determine what data gaps are significant. Then the sampling and analysis plan is developed or modified accordingly to address the significant data gaps.

Closing data gaps and verifying the CSM requires additional characterization, which includes determining where and how many samples to collect (described in detail in Section 3.2). Once the sample locations are selected, other DQOs address the analyses to perform, and the sampling procedures, analytical methods, and required accuracy of the analyses. The work plan has been developed to ensure that the uncertainties in data accuracy are minimal, the database is of sufficient size, and the results are appropriate for comparison to RSR criteria. These procedures are discussed in the Quality Assurance Project Plan.

For the study area the primary DQOs are identifying and delineating actual and potential release areas (contiguous and isolated fill areas) and associated substances of concern (SOCs). In this case the data quality objective is spatial. The areas of contiguous fill are understood well enough to predict which parcels lie completely within them even if not previously investigated, but presumed fill thicknesses need to be verified. These DQOs were addressed through research into site history, interviews with knowledgeable individuals, historic maps, photographs, correspondence, reports, and field work. Only the edge of fill must be mapped on a parcel-specific scale so that the degree of contiguous fill at any given parcel can be predicted and remedial decisions can be made for each separately owned parcel of the study area. The same parcel-specific DQO is needed for finding and characterizing isolated fill areas because of the general absence of detailed historical documentation and their presumed small extent. This information is summarized in the following sections and is evaluated to determine if there is enough information of sufficient detail or quality to meet the objectives.

For evaluating SOCs, the DQOs require that the individual analyses have detection limits that are below remedial criteria and that the samples are representative of the materials potentially requiring remediation. The materials themselves are visually distinctive such that laboratory analyses are not needed to distinguish fill material from soil. Because the nature of the release was the placement of fill into low-lying areas, with the SOCs intrinsic to the fill when placed, the occurrence of SOCs is presumed to be coincident with the occurrence of fill and mobility within environmental media. The DQO is determining the range of SOC concentrations in fill and the occurrence and range of SOC concentrations in surrounding soil and groundwater. The ultimate goal is to obtain the ability to predict the presence or absence of SOC concentrations relative to remedial criteria. Samples can be collected anywhere from within or around/outside the fill areas to meet this objective and determine remedial needs. However, given the scale of the features, a sizable database is needed to make reliable comparisons between the range of SOCs in fill and in the soil and to assess if and how the SOCs may have migrated out of the fill.

For groundwater characterization, the DQOs are both spatial and temporal. Permanent sampling locations at representative points throughout the study area are needed to determine how groundwater flow and SOC concentrations vary in both space and time.

The CSM will be considered complete when all of the data from various sources are in agreement, it can successfully predict the presumed conditions, the DQOs resolve the data gaps such that the problems can be logically explained to the stakeholders, and a remedial action plan can be developed.

2.3 SITE DESCRIPTION

2.3.1 Physical Setting

Olin evaluated available data from multiple sources in formulating a CSM for the NPP study area. Sheet 1 summarizes most of the physical and historical information and contains a list of documents and aerial photographs that provided the best historic information regarding thickness and chronology of contiguous fill at the site. Cross-sections are shown on Sheet 2. In addition to Olin's 2002 Initial Investigation, the results from other investigations of the site (see Section 1.2), especially maps, boring and test pit logs, well completion logs, field notes, cross-sections, groundwater level measurements, and other field observations provided additional physical and analytical information supporting the CSM.

To facilitate the evaluation and interpretation of the stratigraphic and analytical information from the various studies, these data were compiled into electronic databases and combined with digital maps using geographic information software (GIS) to display the information in 3-D space. Laboratory analytical data pertaining to the NPP study area that were made available electronically to Olin by December 15, 2003 have been included in an Access software database file. Paper copies of analytical data that were unavailable electronically were reviewed but were not be included in the GIS maps or data summary tables. These include:

- USEPA Final Investigation Report (2001).
- CTDEP Surface Soil Screening Reports.
- HRP Phase II Subsurface Investigation for the Christian Tabernacle Baptist Church at 425 and 449 Newhall Street.

<u>Geography</u>

As shown on Figure 1-1 and Sheet 1, the approximately 100-acre site, located in the southern portion of Hamden, Connecticut, east of Dixwell Avenue and just north of the border with New Haven, consists of two study areas. The 36-acre Public Properties study area consists of:

- Hamden Middle School, 550-560 Newhall Street (formerly the Michael J. Whalen Junior High School).
- Hamden Community Center, 496 Newhall Street (formerly the Newhall Street School).

- Rochford Field.
- Mill Rock Park (a.k.a. Rochford Field Annex).
- Two Hamden Housing Authority properties, 249-251 and 253-255 Morse Street.
- The sewage pump station, 1099 Winchester Avenue.

The NPP study area consists of 18 city blocks occupied by residential, light commercial/industrial, and religious institutional development. Based on the base plan from the Town of Hamden assessors map revised April 2000, 302 properties were identified in the NPP (some adjacent properties with common ownership, if known, are counted as one).

The approximately 64-acre NPP has two portions, a smaller approximately 5.6-acre portion lying north of, and a larger approximately 58.4-acre portion lying south of, the intervening Public Properties study area.

The smaller portion of the NPP study area encompasses 32 properties between Newhall Street and New Haven Water Company land on the east and west, and between 698 Newhall Street and Mill Rock Road Extension on the north and south. The southern boundary of this portion of the NPP study area is a portion of the northern boundary of the Public Properties study area. This portion of the NPP study area includes all properties along Remington Street (f.k.a. Central Lane) and Harris Street.

The larger portion of the NPP study area encompasses the remaining 270 non-public properties. It is bordered on the south by the section of Goodrich Street between St. Mary Street on the west and Prospect Lane on the east. St. Mary Street forms the western boundary. The eastern boundary consists of most of Wadsworth Street, the eastern property lines of 96 Morse Street and 44 Prospect Lane, and most of Prospect Lane. The northern boundary of the NPP study area is also the southern boundary of the Public Properties study area and consists of:

- A section of Morse Street between St. Mary Street and 319-21 Morse Street.
- The western property line of 319-21 Morse Street.
- The northern property lines of 319-21 to 259 Morse Street (odd numbers only).
- The eastern property line of 259 Morse Street.
- The section of Morse Street between 259 Morse Street and

Newhall Street.

- The section of Newhall Street between Morse Street and Newbury Street.
- Newbury Street.
- The section of Winchester Avenue parallel to the western property lines of 1061, 1067, and 1071 Winchester Avenue.
- The northern property lines of 1071 Winchester Avenue, 99 to 131 Bryden Terrace (odd numbers only), and 60 Wadsworth Street.

Where the study area is bounded by streets, the actual boundary lies in the center of these streets.

For ease of geographic reference, the city blocks or large properties within the site, are given the letters shown on Sheets 1 through 5. The NPP includes blocks A, C, E, F, H, J, K, L, M, N, P, Q, R, S, and T. Block T collectively refers to the four small blocks in the Augur-Remington-Harris northern portion. The public properties include blocks B, D, and G. The Letters I and O are not used to avoid confusion with the numbers 1 and 0.

Current Topography and Drainage

The site lies within the Central Lowland geographic province of Connecticut, a north-northeast-oriented series of wide, flat valleys and narrow ridges that is 20 miles wide at the Massachusetts border but only 4 miles wide at New Haven Harbor. As shown on Figure 1-1, the site area lies in the western part of the lowlands within a flat valley extending south-southeast into western New Haven. The area has a generally flat topography with typical elevations between about 50 to 65 feet above mean sea level (MSL). To the immediate east is the northwestern flank of Prospect Hill, a 1.6-mile-long, 0.5-mile wide NNE-SSW trending hill with a summit over elevation 200 feet MSL. Forming a “T” at the northern toe of Prospect Hill is Mill Rock Ridge, a 0.8-mile-long, east-west trending ridge that rises abruptly to about elevation 150 feet MSL immediately northeast of the site.

Because of the regional valley’s generally flat topography and the presence of local highlands to the northeast, east and southeast, surface water drainage from the site is to the north via a small stream and associated wetland. This unnamed stream lies in a small north-tending, 1,500-foot long, 200-foot-wide, flat-bottomed valley with an elevation of about 38 feet above high sea level (HSL). [All elevations that follow and are shown on the sheets are referenced to HSL.] This stream drains into the series of kettle ponds at Pine Swamp, which in turn drains into Lake Whitney. This reservoir has an outlet on the east end of Mill Rock Ridge on the eastern side of Prospect Hill from the site. There are no ponds of streams within the site; all of the site's surface water runoff is conveyed northward to the unnamed stream via catch basins and underground drain pipes. The only other permanent, natural surface water bodies in the area are the ponds at Beaver Ponds Park, located about 0.5 miles to the southwest.

Locally, there are some subdued but noteworthy topographic variations within the site.

The athletic fields west of the school in block G occupy a large, flat area at elevation 48 to 53 feet, with 4 to 9-foot-high scarps along the northern, western, and southern boundaries. The school itself lies on slightly higher ground than the fields, but drops down to about elevation 44 feet along Newhall Street. The Hamden Community Center is situated on a triangular terrace at elevation 60.5 feet.

The parks east of Newhall (blocks B and D) have elevations of 45 to 49 feet (increasing eastward) and the elevation of the developed areas south of Mill Rock Park within blocks C and F are also about 48 to 50 feet, with a local low of 47.5 feet along Bryden Terrace.

This low topography continues south of block F into blocks R and S, with a closed, triangular depression in the center of block S below elevation 48 feet. A 1 to 2-foot-high escarpment sloping up to properties east of blocks C, D, and F parallels the eastern edge of Wadsworth Street. The western to northwestern slopes of Prospect Hill lie east of blocks C, D, F, and S.

The south-central part of the site is a typically higher elevation than those blocks just described, with elevations of around 58 to 60 feet. In particular, a north-trending local high up to elevation 60 feet lies along Winchester Avenue, terminating to the north at some retaining walls at its southwestern corner at Newbury Street. The flanks of this local high occupy the very southwestern corner of block F, the western edge of block R, and the eastern parts of blocks E, P, and Q.

The western parts of these latter three blocks have variable, but lower elevations than the eastern parts. From the highest ground in the western center of block P at elevation 57 feet, western block E slopes gradually down to Rochford Field at elevation 47 feet, and to the south, in southwestern block Q, is a local depression, which is partly occupied by the parking lot of Christian Tabernacle Baptist Church. This parking lot, at elevation 52 to 53 feet, is bordered to the north by an approximately 7-foot-high escarpment sloping up to elevation 60 feet within properties along Marlboro Street and a 3-foot high escarpment sloping down to elevation 50.5 feet within properties to the east. To the west it slopes gradually up to the 60-foot-high elevation of Newhall Street.

The highest terrain in the southern portion of the NPP study area includes block A and the area southwest of the intersection of Newhall and Morse, typically around elevation 63 to over 64 feet. As Newhall Street descends northward from Marlboro Street, there is a escarpment along its western side that is only about two feet high along the western edge of block K, but which increases to over 10 feet high at the southeastern corner of block G. However, there are local depressions down to:

- Elevation 58.7 feet in the center of block H.
- Elevation 61.2 feet in the center of block J.
- Elevation 59.6 feet in the center of block L.
- Elevation 56.6 feet at the east end of block K.

Block T, the portion of the NPP study area north of the Public Properties, is a terrace sloping mostly westward with elevations 69 to 60 feet. It is sandwiched on the east and west by the very steep scarps leading up to Mill Rock Ridge and down to the flat-floored wetland, respectively. A local, southwest-draining swale lies along its northern edge, and the southern part of the block slopes gradually down to Mill Rock Road Extension at about elevation 45 to 50 feet.

<u>Water Quality Classifications</u>

Groundwater quality beneath most of the site and the area to the north encompassing Pine Swamp and Lake Whitney is classified by the CTDEP as “GAA impaired.” This classification indicates that the area may not be currently meeting the GAA standards for use or potential use as a public drinking water supply. The extreme southwestern corner of the site (St. Mary and Goodrich Streets) lies in the abutting GB classification. The GB classification indicates that the groundwater is known or presumed to be unsuitable for direct human consumption without treatment. The site area is served by public water supplies.

The local surface water bodies have different classifications. The unnamed stream leading north to Pine Swamp is class A, as are the Beaver Ponds to the southwest of the site. CTDEP designates Class A water as habitat, potential drinking water supply, recreation, and navigation. Pine Swamp is class AA and Lake Whitney is class B/AA. CTDEP designates Class AA water as existing or proposed drinking water supply, as well as habitat, recreation, and navigation. The B/AA designation for Lake Whitney indicates that the water quality is not meeting the class AA water quality goals.

2.4 AREAS OF KNOWN CONTIGUOUS FILLING

General Site-Wide History of Filling

According to historical records, the study area was part of the "Highwood" district developed in the late 1800s to early 1900s. A large hog farm was reported in the area in 1899. In 1909, the New Haven Water Co. planned to extend a water main to Highwood in order to encourage development in the area. The earliest available records indicate that wet, low-lying parts of the site were being filled in the early 20th century, mainly to eliminate public health threats and later to provide more dry land for development. A typhoid epidemic (22 cases) reported in Highwood in 1912 was blamed on poor sanitary conditions. Public dumping in the streets and control of malarial mosquitoes were perennial issues in the area. Historically, and continuing well into the mid to late 1900s, it was a well accepted and customary practice throughout the state to eliminate wetlands and low-lying areas that were considered to be mosquito breeding areas in order to protect the public from mosquito borne diseases (e.g., malaria and yellow fever).

To that end, in 1913 the Town of Hamden health officer reported, "Steps are being taken toward the abolishing of mosquito breeding places" and the Town permitted and regulated the filling of wetlands in the Highwood Area for the common public good. (This was in addition to the use of other mosquito controls, such as spraying of oil and lead arsenate pesticides (Conn. Agricultural Experiment Station Bulletin, 1926).) As early as 1915, Hamden public officials encouraged homeowners and local industries to dump their waste in these areas to fill the swamps. In some instances the town would operate public dumps on these properties. When filled and the public health concerns eliminated, the properties would be developed by their owners. Historic records show that the Town of Hamden established at least three public dumps within or near the site. It was permissible to dump "rubbish", e.g. bottles, cans, and paper, but not "garbage, carcasses of dead animals, and decaying vegetables." Furnace ash, from household and industrial coal and/or coke-fired furnaces, was also discarded in these dumps. Manufacturers in the area disposed of large quantities of ash and other manufacturing wastes over several decades.

As swamplands were filled, they were developed for other uses, including homes, parks, and a school. With the mosquitoes under control, malaria was removed as a public health threat. It was not until environmental investigations in the area revealed that soils were polluted with metals, organic compounds, and other substances that public health concerns were raised about the materials used to fill the swamps.

Identification of Fill Areas

Olin identified and described five geographically separate areas of contiguous filling within the NPP study area as shown on Sheet 1. For convenience of reference, they have been given the following names:

- Morse Street Area.
- Southwest Satellite Area.
- Newhall Street Area.
- Bryden Terrace Area.
- Augur Street Area.

Appendix B contains a detailed interpretation of historic aerial photographs taken between 1934 and 1980, both as annotations on the photographs and text descriptions. These photographs, as well as historic topographic quadrangle maps dating back to the late 19th century, show that most of the public properties and at least two portions of the NPP study area consisted of contiguous, low-lying areas (kettles, many of them with standing water) that were gradually filled in until the late 1970s. Besides the filling and other topographic modifications to the Public Properties study area, aerial photographs document two fill areas within the NPP study area within the blocks on the north and south sides of Bryden Terrace (C and F) and on the east side of Newhall Street (E and Q). These fill areas are contiguous with fill underlying the public properties to the north, which are the subject of investigations by others.

Other sources of information, such as historic documents and local property maps, shed more light on the filling at the Bryden Terrace and Newhall Street Areas and described other changes to topography and potential filling. This lead to field work that identified at least three more large, contiguous fill areas in the NPP study area: the Southwest Satellite Area in blocks H, J, and L; the Morse Street Area in block A, and the Augur Street Area in block T. It also showed that the Newhall Street Area is contiguous across the western part of blocks E, P, and Q. These three areas, and block E, were already filled and almost completely developed by the 1934 aerial photographs and were not resolved by the 20-foot contour interval of the early topographic quadrangle maps.

The approximate edge of the fill areas are delineated by the 1-foot thickness contour line on Sheet 1, based on interpolation between boring logs and interpretation of aerial photographs, site topography, and other physical features. The detailed history of known filling activities, physical and analytical characteristics, and data gaps for each fill area in the NPP, and to a lesser degree the adjacent filling on the Public Properties, are provided in the following sections.

Laboratory analytical data from the complete Olin database for the NPP study area are summarized in tables for each fill area and for the whole study area. For each selected compound the tables identify the location of the sample by material and include: total number of analyses, total number of detections, total number of detections exceeding an RSR criterion, and the range of concentrations, including median values. Although it is not the purpose of this document to compare individual sample results to Connecticut regulatory criteria (known as RSRs), presenting comparisons with applicable criteria in summary format is helpful in evaluating whether there are sufficient data in the database to assess a particular material's compliance with the RSRs. In addition, 20 figures were prepared to show the distribution and concentration ranges of several SOCs in each soil matrix. These SOCs include total and SPLP arsenic, total and SPLP lead, ETPH, benzo(a)pyrene (as a representative PAH), PCBs, and 4,4-DDT (as a representative pesticide). Two additional, figures show locations where any pesticide was detected.

2.4.1 MORSE STREET AREA

2.4.1.1 History

Fill in the Morse Street Area underlies four properties (259, 263, 267 & 271) on the north side of Morse Street directly west of the Hamden Housing Authority property adjacent to the Hamden Community Center and bounded to the north by the Hamden Middle School playing fields. Assessor records show that these 4 homes, and the others within block A, were built in 1920 consistent with the development shown on the 1924 Sanborn map. The 1934 aerial photographs show level, landscaped backyards for the homes in block A, with the land to the north consisting of irregular, vegetated slopes descending into the low-lying wetland in a partially filled kettle complex to the north. The level, terraced backyards have stepped elevations relative to each other suggesting some grading/filling of these parcels before 1934. There was an apparent fill slope along the north sides of properties 279 to 311 descending into local depressions in the vegetated slopes that is best visible in the 1964 aerial photographs. This finding suggests the presence of additional filling under more properties in block A than is currently delineated. Filling in these lots predates and is physically unrelated to the filling of the municipal parcel to the north. By 1980, the wetland and wooded slopes were covered with fill and a denuded, six-foot-high escarpment (down to the athletic fields) was created along the northern boundary of these properties that may have caused some local commingling of the different fill episodes.

In April 2001, USEPA initiated characterization of surface material for arsenic, lead, mercury, and SVOCs at 76 residential properties in the vicinity of the Hamden Middle School. As a result of this investigation, USEPA identified 3 properties in the Morse Street Area for interim removal action. Between October and December 2001, the top 18 inches of soil exceeding USEPA's 1,200 mg/kg lead concentration action level were excavated and replaced with clean fill (see Sheet 1).

2.4.1.2 Physical Characteristics

The specific shape and thickness of the known fill area is based on borings as the filling predates aerial photographs and was apparently too small and thin to appear on the 1892 and 1914 topographic maps. The semi-circular, 1-foot fill thickness contour line was drawn by interpolating fill thickness between borings and encompasses the footprints of the previous USEPA removal actions as shown on Sheet 1. The fill lobe underlies at least the northern halves of the properties, but does not appear to extend as far south as Morse Street based on the previous CTDEP boring drilled in the right-of way north of Morse Street. However, the fill extends north (outside of the NPP study area) toward the Hamden Middle School property and east toward the Hamden Housing Authority property. The semi-circular shape and increasing fill thickness to the north indicate that the fill was placed in a northward deepening swale, much like the one formerly present under the Housing Authority property to the east (see Sheets 1 and 2). If present, fill under other properties in block A are expected to have similar geometry, based on the 1964 aerial photographs.

Olin drilled three borings in this area during the Initial Investigation. Two borings penetrated fill material up to 7.5 feet deep, which is comprised primarily of sand, ash, slag, cinders, and peat. CTDEP sampled up to 3 feet below the bottom of each USEPA excavation where they observed ash, glass, metal, brick and/or wood. As shown on Figure 2-1, fill in this area, which has an approximate volume of 3,600 cubic yards, is classified as about 48% refuse fill, 32% disturbed soil fill, and 20% waste fill.

Beneath and around the fill areas is light-brown to reddish-brown sand containing minimal silt and gravel typically covered by a surface layer approximately 0.25 to 1.5 foot thick of light brown to brown organic topsoil. The water table is inferred, based on data from wells to the north, to be within the sand and well below the base of the fill.

2.4.1.3 Analytical Characteristics

Soil data available electronically from samples analyzed from the Morse Street Area (block A in the Non-Public Properties) are summarized in Table 2-1. Figures 2-2 to 2-23 show the distribution and relative concentrations of several representative substances in different materials. Of the 23 metals analyzed, only selenium was not detected in any sample. Antimony, thallium, and PCBs were detected in less than 20% of samples analyzed. Median concentrations of barium and copper are greater in samples from underlying fill than in samples from surficial fill, surficial soil, or soil beneath the fill. However, significantly more samples were collected from the underlying fill than from the other matrices.

Figures 2-2 and 2-4 show that arsenic concentrations are less than 10 mg/kg in surficial sand, surficial fill, and underlying sand. Although the median concentration of arsenic in fill is less than 5 mg/kg (Table 2-1), concentrations ranging from 10 to 138 mg/kg were detected primarily in the area of fill near the border with the Public Properties (Figure 2-3).

Figures 2-5 to 2-6 show the distribution of lead concentrations in each material. Lead greater than 400 mg/kg was detected in one of the two surficial sand samples and 12 of the 36 fill samples.

A subset of samples was analyzed for SPLP metals. Figures 2-8 to 2-10 show that SPLP arsenic exceeds 10 µg/L in 3 samples from fill located near the Public Properties. Tables 2-11 to 2-13 show that SPLP lead exceeds 15 µg/L throughout the fill and surficial sand, but not in the underlying sand.

ETPH was detected in less than half the analyses. Figures 2-14 to 2-15 show that the greatest concentrations (up to 1,400 mg/kg) are in the fill. However, the median concentration in fill is only 37 mg/kg.

Very few semi-volatile organic compounds (SVOCs) were detected. Benzo(a)pyrene, a common PAH detected by SVOC analysis, was detected in about 25% of samples analyzed. Its distribution is shown in Figures 2-16 to 2-17. Concentrations in fill range from less than 100 to 25,000 µg/kg but concentrations in surficial soil samples are less than 1000 µg/kg.

No PCBs were detected in the surficial fill or surficial sand (Figure 2-18), but aroclor 1260 was detected in 2 of the 35 deeper fill samples (Figure 2-19). The pesticide 4,4-DDT was also detected in these same 2 samples. Low concentrations (less than 100 µg/kg) of 4,4-DDT were detected in 3 out of 18 samples analyzed (Figures 2-20, 2-21). These 3 samples were from the fill at 1.5 to 2 feet below ground surface. No other pesticides were detected.

No underlying sand samples were analyzed for ETPH, PAHs, PCBs, or pesticides.

Thirty-six fill samples were analyzed for VOCs. Trace concentrations of a few compounds were detected in most samples; however, most of the VOCs were below analytical detection.

2.4.1.4 Data Gaps

The extent and thickness of fill is uncertain in the properties from 259 to 321 Morse Street. Although borings were drilled on properties from 259 to 275 Morse Street in the Initial Investigation, delineation of the perimeter of fill within all of block A is needed. In addition, greater analytical characterization is needed of the surficial sand, surficial fill, and native soil beneath the fill for all SOCs. Site-specific data from the EPA characterization of properties west of 275 Morse Street are not available. Therefore, additional investigation of this area is warranted.

2.4.2 SOUTHWEST SATELLITE AREA

2.4.2.1 History

The Southwest Satellite Area lies principally within blocks H, J, and L. The name derives from the observation that it is not contiguous with the other fill areas found in the NPP or Public Properties. Various historic documents generally refer to filling in this area but its extent was determined through fieldwork as there are no aerial photographs or historic topographic maps depicting it.

The historic topographic maps included in Appendix B show that the streets transecting or bordering the Southwest Satellite Area (with the exception of Butler Street) were already in place by 1892, long before any filling described below occurred. A few structures are shown along the both sides of Edwards Street, with additional development along Edwards and St. Mary Streets by 1914. Note that these maps have a 20-foot contour interval and do not show any topographic depressions in the area, indicating that they were less than 20 feet deep.

Written documents post-dating the maps indicate that these three blocks were fill areas.

A long-time resident describes "marshy ground of perhaps four acres" present in 1914 at a location consistent with the Southwest Satellite Area, which was a mosquito breeding ground. In the 1916 Hamden Annual Report, Health Officer G. H. Joslin reported that, "The very large [mosquito] breeding place on the corner of St. Mary and Morse Streets is nearly filled in." Although the exact corner of those streets was not specified, independent historical research done in the 1970s noted that during World War One, the block bordered by Morse, Edward, Goodrich and St. Mary Streets, was raised 15 feet and a skating pond existed there until 1917. Town records also show that by 1917 a public dump was established in Highwood on Shelton Avenue between Goodrich and Morse streets. Residents were permitted to dump "rubbish, tin cans, etc.", but disposal of "garbage, carcasses of dead animals, decaying vegetables, etc." was prohibited. [1917 Hamden Annual Report, pg. 36]. A smaller third block (L), located between Shelton Avenue and Butler, Goodrich, and Marlboro Streets, is referred to as containing a "coke lot". The New Haven Water Co. reported in its December 1, 1917 Monthly Report that a surface water drain was installed at the corner of St. Mary and Goodrich Streets that discharged to the far corner of Newhall St. swamp (to the northeast). In 1919, St. Mary, Morse and Edwards Streets were raised and a surface water sewer was completed.

The depiction in the historic research paper and topographic maps of homes immediately adjacent to the streets indicates that the depressions must have been principally between the roads. Based on assessor records most homes in this area were built between 1900 and 1930. Based on home construction dates, filling here was most likely completed by 1920. Sanborn maps show development of these blocks to be virtually complete by 1924. In several places, assessor cards record construction dates later than shown on the 1924 Sanborn maps indicating that older homes were replaced with newer construction.

In all aerial photos from 1934 and afterward, the site topography and development appears essentially as it does today, so no evidence of filling is apparent from these sources. The "coke lot" within block L is unpaved in 1934 and appears flat or very slightly depressed, which it still is today, even after the construction of the factory in 1965.

2.4.2.2 Physical Characteristics

Thickness and extent

The actual thickness and extent of the filling in this area comes from fieldwork completed by Olin during the Initial Investigation and by other investigators. Olin drilled 35 borings in blocks H, J, K, L, and M as part of the Initial Investigation. CTDEP drilled four borings and collected surface samples (0 to 6 inches deep) along Morse Street bordering blocks H, J, and K. Two samples consisted of sand; two of fill. Surface soil screening was done by CTDEP at six properties within blocks H, J, and K, with fill only identified in the two properties in the center of the fill area (block J). CTDEP also dug test pits on both sides of Edwards Street (blocks H and J) and encountered fill up to 7.5 feet deep. In April 2001, USEPA collected several samples in the eastern portion of block K, but no information is available about physical or analytical characteristics of these samples.

The borings revealed three elliptical deposits of fill within former topographic depressions within blocks H, J, and L as shown on Sheet 1, with the deepest parts of the fill (18, 14, and 20 feet, respectively) underlying the center of the blocks. The edges were defined by interpolation between borings. The shape and orientation of the former depressions, and the alignment of Shelton and Edwards Streets between them indicates that the road network was established before filling, consistent with the historical record. The depths of the former depressions are just under 20 feet, which is also consistent with the 1889 topography, and their gentle regular slopes, rounded edges, and spatial clustering indicate their origin as kettles. Their generally level current surfaces, with slight topographic depression in their centers as discussed in Section 2.2.1 (perhaps related to fill consolidation), is also consistent with the historical record. Total volume of fill in the Southwest Satellite Area is about 115,000 cubic yards.

The base of fill in blocks H, J, and K is 8 to 15 feet above the approximate water table in the underlying sand as established by the direct push borings and the wells in the athletic field at Hamden Middle School (see Sheet 2). Historical descriptions of these depressions refer to surface water, however, fines were encountered beneath the fill in only one boring, located in the northwest section of the fill lobe in block H. The current depth to the water table suggests that this surface water was seasonal and/or ephemeral. Additional information is needed to investigate the spatial relationships of the fill, stratigraphy, and water table.

Composition

Most of the fill has the appearance of black, fine-grained sand. Mineralogical and chemical analysis determined that this material is waste fill composed of:

- >50 % glass grains (ash - primarily oxides of silica, aluminum, and iron).
- 25% anisotropic coke.
- 10% uncoked coal, including anthracite.
- lesser amounts of spinel, mullite, inertinite, and quartz.

Other materials found in the fill include cinders, slag, and brick. In other words, the black material is waste fill as defined in Section 1, primarily coal or coke-fired furnace ash.

A very different type of fill was found in the middle of block J. It consists of light gray ash with slag, glass, and wood. A CTDEP test pit, dug over 7 feet deep in the same area of gray ash, revealed numerous glass bottles and jars, broken ceramic dishes and pottery, newspaper fragments, three "D" size dry cell batteries, jar lids, a few pieces of slag, and part of a leather shoe. On one jar was a Hellmans label. Dates were written on the bottom of 2 jars: "PAT FEB 10 03" and "PATENTED JUN 9 03 JUNE 23, 03". The composition of the material found is indicative of refuse fill, as defined in Section 1.

Test pits dug in the middle of block H revealed a mix of both waste and refuse fill. A newspaper fragment contained text, "..h 8, 1879" and written on the side of one small round, clear glass bottle with a cork stopper, containing a small amount of orange liquid was, "DAVID'S Quality ESTABLISHED 1825". On the bottom of the same bottle was written, "Patent 1886". Other items found included saw dust, wood chips, bullets and bullet casings, broken pane and safety glass, bricks, oyster shells, leather shoes, numerous bottles (including a bottle with "BROMO SELTZER EMERSON DRUG CO BALTIMORE"), several pieces of wood, paper, and vacuum tubes.

These articles of refuse are also consistent with the historical references regarding the type and timing of filling in this area. Overall, the fill is classified as 66% waste fill, 18% disturbed soil fill, and 17% refuse fill.

2.4.2.3 Analytical Characteristics

Soil data from the Southwest Satellite Area are summarized in Table 2-2. All metals analyzed were detected in at least one sample. Thallium was detected in only one sample and antimony, beryllium, cadmium, and silver were detected in about half the samples analyzed. Hexavalent chromium was analyzed only in the few Olin samples where total chromium concentrations exceed the regulatory criterion (RDEC) for the hexavalent form of chromium. As Table 2-2 shows, the concentrations of hexavalent chromium are very low and well below the RDEC of 100 mg/kg. Median concentrations of antimony, arsenic, barium, cadmium, copper, lead, mercury, nickel, selenium, silver, zinc, ETPH, and benzo(a)pyrene are greater in samples from underlying fill than in samples from surficial fill, surficial soil, or soil beneath the fill. However, significantly more samples were collected from the underlying fill than from the other matrices.

Figures 2-2 to 2-17 show that most representative substances of concern (arsenic, lead, ETPH, and benzo(a)pyrene) appear to be distributed throughout the three lobes of underlying fill at much greater concentrations than in the surficial fill or native soil. Most total arsenic concentrations in fill are less than the median 15 mg/kg. Note that the maximum concentration of 303 mg/kg, from a sample in the middle of block L, is an outlier, exceeding the next highest arsenic concentration by nearly a factor of 7.

The distribution of total lead in fill is similar to that of arsenic (Figures 2-5 to 2-7). Most concentrations are between 400 and 10,000 mg/kg. One sample in block L has a lead concentration of 10,100 mg/kg.

Twelve other metals were detected in at least one sample from underlying fill, albeit at relatively low concentrations (Table 2-2). Compared to the other fill samples, elevated concentrations of antimony, copper, nickel, and zinc were found in only one sample 8 to 10 feet below ground surface in block H.

Figures 2-4 and 2-7 show little variation in the concentrations of metals in the native sand layer underlying and surrounding the fill. Arsenic concentrations are less than 10 mg/kg in all underlying sand samples in the Southwest Satellite Area. Lead concentrations are less than 10 mg/kg in most underlying sand samples. Samples with lead concentrations between 10 and 400 mg/kg are evenly distributed between those beneath and those outside the fill. Only one sample from sand underlying fill has a lead concentration greater than 400 mg/kg. These data indicate that there has been little migration of substances from fill into native material in this area.

Twenty-three fill samples were analyzed for SPLP metals as a conservative indicator of pollutant mobility. Results for arsenic and lead SPLP analyses are shown in Figures 2-8 to 2-13. The results mirror those for total concentrations discussed above, with much greater concentrations in the fill material than in surrounding soil. SPLP arsenic concentrations are similar throughout the fill, typically <50 µg/L. SPLP lead concentrations in fill are greatest in block L, and were detected at concentrations greater than 15 µg/L in blocks H and J also. SPLP beryllium, silver, and thallium were not detected in any of the 23 SPLP sample analyses. Of the remaining metals not yet discussed, SPLP antimony, barium, copper, and nickel were detected in 20% to 95% of the SPLP samples.

Several samples from sand underlying fill were analyzed for SPLP arsenic and lead in block J (Figures 2-10 and 2-13). Neither metal was detected in any sample, but the detection limit for SPLP arsenic in one sample was greater than 10 µg/L. Results from underlying soil outside the known fill area show that SPLP arsenic was detected in one sample and SPLP lead exceeds 15 µg/L in two samples. Although not enough samples were analyzed from sand underlying fill in blocks H and L, high concentrations of indicator metals do not appear to be leaching into underlying native soils.

ETPH was detected in all 31 samples analyzed. Concentrations in fill range from 21 to 11,000 mg/kg, but concentrations in surficial sand range from 24 to 72 mg/kg. The median concentration in fill is 340 mg/kg. ETPH concentrations are lower in fill in block J than in blocks H and L (Figure 2-15).

Benzo(a)pyrene, the most prevalent indicator of PAHs, was found throughout the fill in concentrations varying from less than 21 to 80,000 µg/kg. Concentrations in all fill samples from block L are less than 1,000 µg/kg; concentrations are greatest in block H (Figure 2-17). Benzo(a)pyrene was not detected in surficial fill samples, but was detected in sand samples from a boring in block K at concentrations less than 700 µg/kg.

Olin did not analyze for PCBs or chlorinated pesticides from samples in this area because filling was completed prior to the commercial availability of these substances. No PCBs were detected in any of the CTDEP right-of-way samples in this area (Figure 2-18), but low concentrations of pesticides were detected in two samples (Figure 2-22).

Twenty-seven fill samples were analyzed for VOCs. Trace amounts of a few compounds were detected in most samples, however, most of the VOCs were below analytical detection.

2.4.2.4 Data Gaps

Although the Initial Investigation identified three elliptical shaped areas of contiguous filling in blocks H, J, and L, verification of the maximum thickness and enhanced delineation of the perimeter of fill is needed. In addition, greater analytical characterization is needed of the surficial sand, surficial fill, and native soil beneath the fill for all SOCs, including SPLP metals. We assume that chlorinated pesticides and PCBs are not present in the contiguous fill areas in the Southwest Satellite Area because filling was completed prior to the commercial availability of these compounds. Analysis of a limited number of samples of the fill for pesticides and PCBs is necessary to verify this assumption.

2.4.3 NEWHALL STREET AREA

2.4.3.1 History

The Newhall Street Area lies within blocks E, P, and Q along the east side of Newhall Street. The 1892 topographic map shows blocks P and Q defined by existing streets and several buildings in block P. The 1892 and 1914 topographic maps show blocks E and B as one block, without Newbury Street. A closed, circular contour line, with vegetation indicated on the 1914 map, lies in the eastern part of block E, indicating the historic presence of the current high ground there, with a topographic low immediately to the west along Newhall Street. The historic presence of this depression, and another at the western end of block Q, suggests that the fill area was once a contiguous, northward-sloping swale, but not deep enough to be resolved by the 20-foot contour interval of these old topographic maps. The Newhall Street Area appears to be contiguous with the fill found in the Public Properties to the north (block B).

Included in the Town of Hamden Phase I ESA Report are anecdotal reports from an "old timer" who lived in the neighborhood in the 1920s and 1930s. He states that filling occurred in "the area from Marlboro Street to Mill Rock Road bordering on Winchester Ave. on the east side to Newhall Street on the west side." Exceptions were properties along the east (Winchester Ave.) side of these blocks. Videotaped interviews of other knowledgeable residents conducted by CTDEP suggest that this area may have once been a sand quarry.

Filling and subsequent development of this area apparently started in the western end of block P and northwestern-most part of block Q, with homes there dating from 1924. By the first aerial photographs in 1934 this block is already filled and developed; however, depressions still existed to the immediate north and south.

To the north, filling in the western part of block E began before 1934 and apparently ended by 1943. In 1934, the western part of the block is slightly lower than Newhall St. and slopes up from about the same elevation (45 feet) as the filling continued within the future Rochford Field to the north (block B) to almost the elevation of Morse Street to the south (57 feet). The gray tones and patterns are similar to this fill lobe suggesting that the western part of this block has also been filled, almost to the height of Newhall and Morse Streets. By 1943, the western part of this block has been filled and brought up to surrounding road level, and the ground is covered with shrubs. Development of this part of the fill area began in 1944 with the home at 499 Newhall Street and was completed by 1957.

The aerial photos show that the eastern part of block E has always been high ground (up to elevation 59), mostly vacant and heavily wooded until gradually developed during the 1930s to 1963. The high ground slopes down to the north from Morse St. In 1934 what is now Newbury Street is shown as an unpaved path cut into the toe of this slope. Aerial photos from 1943 onward show topography that is consistent with today's. A low retaining wall is present along the south side of the eastern part of Newbury and around the corner along Winchester where these roads were cut into the toe of the sloping hill.

The depression at about elevation 50 feet in the southwestern part of block Q was vacant in 1934, similar to the topography to the east of this parcel and sloping very steeply up to Newhall St. to the west. In 1941 the rectory at the Christian Tabernacle Baptist Church was constructed, with some local filling of the depression under and around the building. Additional filling of the depression apparently took place when the rest of the church was built in 1975, with about 3 to 5 feet of fill added up to the property line. A 2 to 3-foot-high escarpment remains along the southern and western property lines.

Throughout the period of aerial photographs, the topography and degree of development on the west side of Newhall Street is consistent with today's appearance. Therefore, if some filling took place on the west side of the street, then the historical record does not document it.

2.4.3.2 Physical Characteristics

Thickness and extent

The actual thickness and extent of the filling in this area comes from fieldwork completed by Olin during the Initial Investigation and by other investigators and from field observations of topographic features. Olin drilled 16 borings in blocks E, P, and Q as part of the Initial Investigation. CTDEP drilled 17 borings along Morse, Newhall, and Newbury Streets, Winchester Ave. and behind the Christian Tabernacle Baptist Church at 425-431 Newhall Street. CTDEP also installed a well at 499 Newhall St., collected soil samples at 465 and 473 Newhall St., conducted post-EPA removal action sampling at 33 Marlboro St., and dug test pits at 473 and 499 Newhall St. In August 2002, HRP drilled nine borings up to a depth of 27 feet around the Christian Tabernacle Baptist Church rectory at 449 Newhall St. In April 2001, USEPA collected scores of samples throughout blocks E and P and part of block Q, but no detailed information is available about physical characteristics of these samples.

These explorations reveal fill in the western sections of blocks E, P, and Q extending from the Christian Tabernacle Baptist Church parcel in the south into block B to the north, consistent with the historical record. Numerous small topographic depressions are found throughout this fill area. The thickest fill encountered, 13 feet, was near the northwest corner of the house at 499 Newhall St. (Sheets 1 and 2). Another filled depression at least 12 feet deep was discovered in a parcel at 34 Marlboro St. just north of the church. The base of the fill is approximately 3 to 12 feet above the water table. Note that the base of fill does not have a regular slope to the north, but is undulatory, which suggests that the original depression was not a former stream channel but was perhaps a series of small kettles, possibly modified by local sand quarrying. Only sand was found underlying the fill, there are no fines to suggest the potential presence of former wetlands in this depression.

While the northern edge merges with the filling under Rochford Field to the north, and escarpments along the northern boundary of the church property define the southern part, the western and eastern boundaries are less well constrained. Fill thickness decreases to the east and west, and the western boundary appears to be coincident with Newhall Street, which has a cut escarpment along its western edge that increases in height as the road drops in elevation to the north. However, no borings have been drilled west of the street. To the east, the boundary is interpolated between widely separated borings, however, historically high and heavily wooded ground underlies the eastern part of blocks E, P, and Q, where borings found only native sand at the surface and small topographic depressions are absent. Retaining walls are present along the northeastern corner of block E where Winchester Avenue and Newbury Street were cut into this high ground. Fill is present under Newbury Street, separating a small area where fill is absent at the southeastern corner of Rochford Field from the rest of the historic high ground south of Newbury. Total volume of fill in the Newhall Street Area, minus that present at the Christian Tabernacle Baptist Church property is estimated to be about 33,000 cubic yards. Another approximately 4,800 cubic yards underlies the church property.

<u>Composition</u>

Most of the fill has the appearance of black, fine-grained sand. This material is characteristic of waste fill and is composed mainly of ash (which consists primarily of glass) and coke with smaller amounts of coal, mullite, and other minerals. Sand, gravel, slag, cinders, and peat are also present in the fill, which overall consists of about 59% waste, 29% disturbed soil, and 12% refuse fill. However, the fill encountered at the Christian Tabernacle Baptist Church is different, consisting of disturbed soil fill composed of brown sand with traces of gravel, wood fragments, coal, concrete, and brick.

Test pits dug to a depth of approximately 7 feet in the western part of block E revealed several red and white bricks, chunks of black tar or asphalt, slag, wood chips, tools, and pieces of metal amidst the predominantly fine to medium-grained black ash material. Molded onto several of the red bricks was the word "STILES". Test pits dug about 6 feet deep in the western part of block P revealed some material similar to that found in the block E test pits. Other material is more representative of refuse fill, including large chunks of slag, a silvery slag material, pieces of broken pottery and safety glass, bottles, carbon battery cell rods, paper that appeared to be packing slips, cardboard fragments imprinted with the word "shells", and newspaper fragments with Italian writing. One fragment was dated 1920. Although the fill materials found in both blocks and in the northwestern part of block Q just north of the church, is typically waste fill, the variability in the type of waste found indicates more than one source. For example, fine-grained ash was likely produced in a furnace very different from that produced the coarse slag.

2.4.3.3 Analytical Characteristics

Soil data from the Newhall Street Area are summarized in Table 2-3. Of the 23 metals analyzed only thallium was not detected in at least one sample. Antimony, selenium, and silver were detected in about 15% to 25% of the samples analyzed. Median concentrations of arsenic, barium, copper, iron, lead, mercury, nickel, silver, sodium, and benzo(a)pyrene are greater in samples from fill than in samples from surficial fill, surficial soil, or soil beneath the fill. However, significantly more samples were collected from the underlying fill than from the native sand.

Figures 2-2 to 2-17 show that most representative substances of concern (arsenic, lead, ETPH, and benzo(a)pyrene) appear to be distributed throughout the underlying fill at much greater concentrations than in the surficial fill or native soil. Figure 2-2 shows that arsenic concentrations exceed 10 mg/kg in only one surficial fill sample and three surficial sand samples. The highest arsenic concentration (90 mg/kg) was found in a sample in block P. Arsenic concentrations are less than 10 mg/kg in all samples from the underlying sand (Figure 2-4). Figures 2-5 to 2-7 show similar results for lead. The lead concentration is less than 400 mg/kg in most samples from the surficial sand and surficial fill, and in all underlying sand samples. Lead concentrations in underlying fill ranged from 60 to 8,750 mg/kg with the highest values reported in blocks P and E.

HRP reported similar results from their investigation of the Christian Tabernacle Baptist Church property on Newhall St. (block Q). HRP analyzed 19 samples primarily for arsenic and lead, plus 6 for SPLP lead; 16 samples are disturbed soil fill and 3 are sand underlying fill. Arsenic concentrations in the fill range from below detection to 5.8 mg/kg and in the underlying sand they are below detection. Lead concentrations in the fill range from 4 to 24,000 mg/kg, with 8 samples exceeding 400 mg/kg, but in the sand the concentrations are only between 3.5 and 28 mg/kg. All 6 SPLP lead concentrations (0.061 to 0.78 mg/l) exceed 0.015 mg/l and are from fill sample analyses.

A subset of samples was analyzed for SPLP metals. Figures 2-8 to 2-13 show SPLP results for arsenic and lead. Higher values were reported for samples taken from surficial sand than from surficial fill. SPLP arsenic is greater than 10 µg/L in 3 of the 19 samples taken from fill and 1 of the 3 samples from the underlying sand. SPLP lead is greater than 15 µg/L in 12 of the 19 samples taken from the fill and 1 of the 3 samples from the underlying sand. SPLP analyses detected antimony, barium, chromium, copper, mercury, nickel, and zinc in at least one sample. Elevated concentrations of antimony and mercury were found in 1 and 3 samples in block P.

The biggest data gap is the scarcity of SPLP data from the underlying sand and from all layers in block Q. However, HRP analyzed 1 fill sample for SPLP arsenic and 6 fill samples for SPLP lead. SPLP arsenic was not detected and SPLP lead ranged from 61 to 780 µg/L.

ETPH was detected in 70% of the samples analyzed. ETPH concentrations exceed 500 mg/kg in only 3 of the 41 samples analyzed. Although the highest concentration was in a sample from the fill, the median concentration was higher in the surficial sand (147 mg/kg) than in the fill (110 mg/kg).

Benzo(a)pyrene was found in the surficial and underlying fill at concentrations ranging from non-detect to 17,000 µg/kg. It was not detected in any native sand samples.

PCBs were not detected in any of the 17 surficial soil samples and in only 3 of the 12 underlying fill samples, albeit at low levels (maximum 61 µg/kg). Low concentrations of pesticides (<600 µg/kg of 4,4-DDT) were detected in most surficial fill and surficial sand samples, which were mainly along roadways. Low concentrations of DDT were also detected in 3 samples from the underlying fill (Figure 2-21). Only one sample from the underlying sand was analyzed for ETPH, PAHs, PCBs, or pesticides.

Sixteen fill samples were analyzed for VOCs. Trace amounts of acetone were detected in about half the samples. Most of the other VOCs were below analytical detection.

2.4.3.4 Data Gaps

While the Initial Investigation identified a band of fill in the western part of blocks E, P, and Q contiguous with Rochford Field to the north, delineation of the perimeter of fill is needed to the east, south, and west across Newhall St. in blocks K and N. In addition, greater analytical characterization is needed of the surficial sand, surficial fill, and native soil beneath the fill for all SOCs, including SPLP metals.

2.4.4 BRYDEN TERRACE AREA

2.4.4.1 History

The Bryden Terrace underlies blocks C and F and is contiguous with fill underlying Rochford Field (block B) and Mill Rock Park (block D) in the Public Properties study area (Sheet 1). The 1892 and 1914 topographic maps show this area as a wooded depression.

Various historic documents refer to the filling activities east of Winchester Avenue. Long time area resident John J. Carbrey reported in the December 15, 2000 New Haven Register that the town dump was located on the east side of Winchester Avenue from Morse Street to Mill Rock Road and part way up towards Prospect Street. The area east of Winchester Ave. between Morse and Goodrich Streets (blocks R and S) was solid ground and had been a golf course. Because most of the filling took place after 1934, the most detailed historic information comes from aerial photographs.

The 1934 aerial photo shows this area as mostly wetland undergoing filling from the northwest, southwest, and south. No homes are present and Winchester is an unpaved path that does not extend north past what will be the western extension of Bryden

Terrace. A black area interpreted to be water occupies the central and northwestern part of the blocks and merges with a channel leading westward through what will be Rochford Field (block B). Based on relationships to the west and the western drainage pattern, the water is inferred to be at about elevation 38 feet.

Land just west of Wadsworth St. (an unpaved road) is mostly dark gray wetland vegetation with some ditching that grades into the central black area, and thus has elevations sloping up from 38 feet to less than about 45 feet. Wadsworth St. itself consists of a level path between a low escarpment on the east (cut into higher ground) and an embankment on the west (fill spoils deposited in the lower wetlands). It appears to be at the same elevation as it is today (50 to 54 feet).

Gray, sharp-edged lobes of fill occupy the southern and western sides of block F and terminate at Winchester Ave., Morse, and Wadsworth streets. These fill lobes are at or slightly above the adjacent road elevations and post-date the roads. Given that their upper surfaces appear to be at about the same elevation as today (48 to 51 feet), and assuming that the wetland under them sloped upward toward Morse to about elevation 48, then these fill lobes are about 0 to 11 feet thick.

No filling is apparent immediately west of Winchester Ave. (block E), east of Wadsworth St., or south of Morse (blocks R and S), where there are fields, homes, and wooded areas with the same topography as today. Another unpaved path extends northeastward from the intersection of Winchester and Morse into the water. This path and Winchester Ave. are shown on the 1892 and 1914 topographic maps as extending north to Mill Rock Road; however their northern portions were underwater on the early spring date of the 1934 aerials.

The 1939 oblique aerial photo shows the future residential parcels as vacant land, indicating that filling is largely complete. This aerial shows the Mill Rock Park parcel as very light-toned, suggesting filling and disturbance rather that wetland/swamps. The 1939 oblique taken from the top of Mill Rock shows an active fill area within the future Bryden Terrace Area, with a smoke plume from a fire at the southern edge of the fill area. The future Mill Rock Park (block D) area is obscured by trees, but both areas are seen in the 1943 vertical and 1946 oblique photographs as completely filled and graded to road level.

The 1949 topography of the land east and south of the fill area is consistent with today's and include a heavy, continuous cover of large trees and consistent gray-tone. These topographic relationships and other features suggest that filling contiguous with that on Rochford Field and Mill Rock Park covers most of these parcels, but does not appear to extend past Wadsworth to the east and Morse on the south. Assuming that the center of the former underlying wetland area was at or above elevation 38, the underlying fill in the vicinity of Bryden Terrace (elevation 48) is inferred to be up to about 10 feet thick. The highest ground within these blocks lies at the southwest corner (elev. 56), which is just across Winchester Ave. from the natural-appearing high ground on block E. The lowest ground is at the south-central border of block F along Morse St. (elev. 48), although this elevation is higher than on Morse St. (elev. 46). Ground to the east across Wadsworth St. is higher; in fact, the photos show Wadsworth St. under construction with escarpments cut into the higher ground all along the east side of this road.

Residential development occurred during the late 1940s to late 1950s. In the 1949 aerials, the western extension of Bryden Terrace between blocks C and F did not exist and the fill area was undeveloped except for 10 homes along the southern edge and corners (12 Wadsworth, 95-135 Morse, 1019-1027 Winchester). In 1951 blocks D and F appear similar to 1949, except that leafed out shrubs and small trees obscure the surface details. By 1957, Bryden Terrace extended westward through the fill area to Winchester Avenue, and by 1959 all of the homes present there today are visible in this and subsequent photos.

2.4.4.2 Physical Characteristics

<u>Thickness and extent</u>

While the extent of filling is clear from the aerial photographs, the actual thickness comes from fieldwork completed by Olin and other investigators. Olin drilled 21 borings in blocks C, F, R, and S as part of the Initial Investigation. In early 2001, CTDEP drilled 20 right-of-way borings to depths of 8 to 12 feet along Morse, North Sheffield, and Wadsworth Streets, Winchester Ave., and Bryden Terrace. Between October 2001 and

October 2002, CTDEP also drilled 8 borings and installed 3 wells, collected soil samples at 7 other properties, conducted post-EPA removal action characterization at 7 parcels, and dug test pits at 127 Morse St. and 118 Bryden Terrace. In April 2001, USEPA collected scores of samples throughout blocks C and F and part of block S, but no information is available about physical characteristics of these samples.

These field investigations revealed that the majority of blocks C and F are underlain by fill up to 11 feet thick (see Sheets 1 and 2). The thickest fill is present within a northwest-trending swath from the center of block F to the west end of block C, consistent with the black area of standing water seen in the 1934 aerial photographs and the presence of the water table within the fill. The fill pinches out along the higher ground at blocks E, R, and S to the southwest and south, where no fill was encountered. Total volume of fill in the Bryden Terrace Area is estimated to be about 130,000 cubic yards.

Most of the fill in Bryden Terrace Area is underlain by a layer of fines, including peat consistent with the former presence of wetlands. Sand mostly underlies the fines, although glacial till is present under the extreme eastern edge of the fill area and at the ground surface east of Wadsworth Street.

Composition

Most of the fill in this area is composed of brown to black sand with varying amounts of gravel, gray ash, coal, brick, glass, wood, cinders, ceramic, concrete, asphalt, and assorted refuse. In addition to the material described, the EPA removals and CTDEP test pits in this area uncovered glass bottles and jars, broken pottery, cardboard, seashells, leather shoes, a bicycle tire, a bed frame and a toilet bowl. These materials are consistent with refuse fill and the reported historical use of this area as a town dump. Filling under Wadsworth Street is different, consisting mostly of disturbed soil fill, consistent with its 1934 appearance as a pathway cut into natural high ground. Overall, the Bryden Terrace Area fill consists of about 57% refuse, 26% disturbed soil, and 17% waste.

2.4.4.3 Analytical Characteristics

Soil data from the Bryden Terrace Area are summarized in Table 2-4. Of the 23 metals analyzed only thallium was not detected in at least one sample. Antimony, selenium, and silver were detected in only 17, 5, and 51 percent, respectively, of all samples analyzed; all detections were in fill samples. Median concentrations of arsenic, barium, calcium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, silver, sodium, zinc, ETPH, and benzo(a)pyrene are greater in samples from fill than in samples from surficial fill, surficial soil, or soil beneath the fill. However, significantly more samples were collected from the underlying fill than from the native sand.

Figures 2-2 to 2-17 show that most representative substances of concern (arsenic, lead, ETPH, and benzo(a)pyrene) appear to be distributed throughout the underlying fill at much greater concentrations than in the surficial fill or native soil. Figure 2-2 shows that arsenic exceeds 10 mg/kg in only one surficial soil sample in the Bryden Terrace Area. However, in most of the underlying fill samples, arsenic was found at concentrations ranging from 10 to 400 mg/kg (Figure 2-3). The maximum arsenic concentration detected in any of the 21 samples from underlying sand or fines was 2.1 mg/kg. Figure 2-5 shows that total lead concentrations are greater than 400 mg/kg in 4 of the 40 surficial soil samples. All 4 samples are from the surficial fill. On the other hand, lead exceeds 400 mg/kg in most of the underlying fill samples (Figure 2-6). Lead concentrations are less than 10 mg/kg in most of the 21 samples from underlying sand or fines (Figure 2-7); the maximum lead concentration detected was 42 mg/kg.

The results for SPLP arsenic and lead mirror those of total arsenic and lead to some degree (Figures 2-8 to 2-13). In most, but not all cases, samples with highest total metal concentration had highest SPLP concentrations. Exceptions to this correlation are evident primarily in samples from surficial soils and underlying sand where SPLP results were higher relative to the total concentrations detected in the same samples. The highest SPLP concentrations were detected in underlying fill samples. SPLP analyses detected antimony, barium, beryllium, cadmium, chromium, copper, mercury, nickel, selenium, silver, and zinc in at least one sample. Concentrations of detected SPLP antimony (13 samples) ranged from 9 to 80 µg/L. SPLP chromium exceeds 50 µg/L in 4 samples; SPLP copper exceeds 1,300 µg/L in 2 samples; and SPLP mercury exceeds 2 µg/L in 6 samples.

ETPH was detected in over 80% of the samples analyzed, exceeding 500 mg/kg in 27 of the 131 samples analyzed. All but one of these 27 samples is from the fill. The other is a surficial sand sample in the right-of-way along Morse Street. The median ETPH concentration in the fill is 180 mg/kg.

PAHs were detected in at least one fill sample from this area. Benzo(a)pyrene is a good indicator of the presence of other PAHs. It was detected in only one surficial sand sample (370 µg/kg), but concentrations in surficial fill samples ranged from non-detect to 2,120 µg/kg. Benzo(a)pyrene is distributed throughout much of the underlying fill at concentrations ranging from less than 100 to 390,000 µg/kg.

PCBs were not detected in any of the 19 surficial soil samples. Of the 16 underlying fill samples where at least one PCB isomer was detected, only 3 samples had concentrations greater than 100 µg/kg. However, no PCBs were detected in duplicates of two of these samples, including the one with the highest value reported anywhere in the NPP study area (89,000 µg/kg).

Pesticides were analyzed in surficial soil samples from rights-of-way as well as in samples from the underlying fill. Low concentrations (<600 µg/kg) of 4,4-DDT and other pesticides were detected in nearly all samples from both surficial sand and surficial fill and in about half the samples from underlying fill (Figures 2-20 to 2-23).

VOCs were analyzed in 92 fill samples. Trace amounts of one to ten analytes were detected in 18 samples. All other results were below analytical detection.

All of the surficial fill and sand samples analyzed for ETPH, PAHs, PCBs, and pesticides were collected from rights-of-way. No underlying sand samples were analyzed for ETPH, PAHs, PCBs, or pesticides.

2.4.4.4 Data Gaps

While the Initial Investigation identified a rectangular mass of fill encompassing nearly all of blocks C and F and contiguous with filling in Mill Rock Park to the north, delineation of the perimeter of fill is needed, particularly to the south and west. Previous investigations found fill up to the western edge of blocks C and F. In addition, greater analytical characterization is needed of the surficial sand, surficial fill, and native soil beneath the fill for all SOCs, including SPLP metals, particularly in the interior portions of the blocks.

2.4.5 AUGUR STREET AREA

2.4.5.1 History

The Augur Street Area lies within block T. There is no direct historical information on filling within this area, just maps depicting gradual residential development. The 1892 topographic map does not show any development of roads or buildings in this area west of Newhall Street, but the 1914 map shows a westward extension of Augur Street and the presence of Harris Street as far west as the future Remington Street. The 1924 Sanborn map shows homes built on nearly every parcel in this area. From 1934 and afterward, the topography and level of development in this parcel is consistent with today's appearance. The 1934 aerial photos show disturbance from the installation of the sewer pipe located along the west side of the block, within and parallel to the slope to the wetland. A tornado in 1989 destroyed several homes and scattered debris throughout this area. Some debris reportedly was buried in place during clean up/reconstruction efforts after the storm.

Some filling took place at the southern boundary of the block with Hamden Middle School. Until 1963, a swale separated 20 Harris St. and 596 Newhall St. from fill in the adjacent school parcel to the south. By 1963, the swale was filled and an unpaved road (Mill Rock Road Extension) continued westward from Newhall St., which became a paved road leading to the rear of the school by 1964. Development of the building at 596 Newhall Street in the early 1970s may have mobilized some of this fill material. Parcels to the north are at a higher elevation (up to elevation 68 feet) than the filling at Mill Rock Road Extension and the school; thus do not appear to be contiguous with fill in the Public Properties.

2.4.5.2 Physical Characteristics

<u>Thickness and extent</u>

Because there is no specific information in the historical record or aerial photographs, the actual thickness and extent of the filling in this area comes from fieldwork completed by Olin and other investigators. Olin drilled 4 borings in block T as part of the Initial

Investigation. CTDEP drilled 8 borings to a depth of 8 feet along Augur, Harris, Remington, and Newhall Streets and Mill Rock Road Extension. CTDEP also collected soil samples at 3 properties in the area. In April 2001, USEPA collected scores of samples throughout block T, but no information is available about physical characteristics of these samples. LBG drilled 5 borings near the southern boundary of block T in November 2002.

The widely-separated borings roughly delineate a fill area west of Remington Street. The thickest fill, 8 feet, is near the western end of Augur St. (Sheet 1). There is also 6.2 to 6.5 feet of fill at 331 Augur Street and at the west end of 22 Remington Street, respectively. Only one other boring, within Harris Street, encountered fill (2 feet thick). The distribution of data suggests localized filling of west-trending swales, such as the one currently bounding the northern part of block T.

The extent of fill to the north, east and south has been estimated by interpolation between borings. The western fill boundary has not been determined by boring data, but is inferred to be generally consistent with the steep slope to the west where relief greatly exceeds the fill thickness encountered within block T. Neither the southern edge of the Augur St. fill area nor the northern edge of the Hamden Middle School fill area have been precisely delineated. The volume of fill is roughly estimated to be about 14,000 cubic yards.

Native sand underlies and surrounds fill in the Augur Street Area. The fill does not intersect the water table.

Composition

The fill encountered in block T consists primarily of sand and gravel with only trace amounts of wood, concrete, brick, glass, and ash. This is consistent with the definition of disturbed soil fill. Thin lenses of waste fill and asphalt material were found sandwiched between layers of sand in the borings along Mill Rock Road Extension, indicating commingling of waste fill with disturbed soil fill during the road construction.

2.4.5.3 Analytical Characteristics

Soil data from the Augur Street Area are summarized in Table 2-5. Of the 23 metals analyzed selenium and thallium were not detected in any sample, antimony was detected in one sample, silver in two samples, and the other metals were detected in nearly all samples analyzed. Median concentrations of copper, ETPH and benzo(a)pyrene are greater in samples from underlying fill than in samples from surficial fill, surficial soil, or soil beneath the fill. However, the data set for these parameters is very small and no significant differences are apparent in the concentrations of indicator metals.

Figures 2-2 to 2-7 show that arsenic concentrations are less than 10 mg/kg and lead concentrations were less than 400 mg/kg in all 16 samples analyzed from all soil types in the Augur Street Area. A subset of samples was analyzed for SPLP arsenic and lead. SPLP arsenic is less than 10 µg/L in all samples analyzed, while SPLP lead is between 15 and 50 µg/L in 2 surficial fill samples. No samples from the underlying fill were analyzed for SPLP metals. Aside from arsenic and lead, no other metals were analyzed by SPLP.

ETPH was detected in 6 of the 10 samples analyzed. Only one ETPH concentration exceeds 500 mg/kg. This concentration (950 mg/kg) is in the only sample characterized from the underlying fill.

PAHs were detected in several samples from this area. Benzo(a)pyrene was detected at concentrations greater than 1,000 µg/kg in one surficial sand sample and one underlying fill sample (Figures 2-16 to 2-17).

PCBs were detected in only one sample, from the fill, at a concentration of 46 µg/kg. Low concentrations of pesticides were detected in one sample each from surficial sand, surficial fill, and underlying fill (Figures 2-22 to 2-23).

2.4.5.4 Data Gaps

While the Initial Investigation identified an elliptical shaped area of filling in the western section of blocks T, delineation of the perimeter of fill is needed. In addition, delineation of the perimeter of fill extending north from the Public Properties into the southern portion of block T is needed. Greater analytical characterization is needed of the surficial sand, surficial fill, and native soil beneath the fill for all SOCs, including SPLP metals.

2.5 NPP STUDY AREA CSM SUMMARY

Fill and Soil

Details pertaining to each identified fill area are discussed above. A summary of the data from the NPP study area as a whole is presented here to help tie different elements of the CSM together. Figure 2-1 illustrates the composition of the five known fill areas in the NPP study area according to the three fill types defined in Section 1. Due to the difference in time of deposition and type of fill material, the fill at the Christian Tabernacle Baptist Church property on Newhall Street is broken out as a separate fill area. The pie charts show three distinct groups of similar fill composition in the six areas:

- Fill in the Southwest Satellite and Newhall Street Areas consists primarily of waste fill with about 25% disturbed soil and lesser amounts of refuse fill.
- Fill in the Morse Street and Bryden Terrace Areas is approximately half refuse fill, 30% disturbed soil and 20% waste fill.
- Fill in the Augur Street and Tabernacle Church Areas is predominately disturbed soil.

The analytical composition of five of the six areas is very similar. The Augur Street Area is analytically distinct from the other known fill areas. Figures 2-2 to 2-23 graphically illustrate the occurrence of primary SOCs in each soil layer throughout the NPP study area. Table 2-6 summarizes the data for all metals analyzed, ETPH, total PCBs, and benzo(a)pyrene. Table 2-7 summarizes the data for SPLP metals.

- Except for the Augur Street Area, the concentrations of most substances of concern (excluding pesticides) are significantly greater in the underlying fill than in any other soil matrix, including surficial fill. The same substances appear in all other fill areas and in all three fill types.
- Most SOCs occur at similar ranges of concentrations in both surficial fill and surficial sand, suggesting that their surficial distribution is at least partly unrelated to the placement of fill. CTDEP concluded in its June 14, 2001 memorandum summary of rights-of-way sampling that "Elevated concentrations of arsenic and some pesticides that were found in some surface soil samples are likely a result of homeowner pesticide application. The elevated ETPH and PAH concentrations detected are possibly a result of driveway paving materials. Only benzo(a)pyrene was detected at higher concentrations in surficial fill than in surficial sand.
- Although there are limited data for several SOCs from the soil underlying fill (previously identified as a data gap), the dataset is substantial for

arsenic and lead (79 samples). Arsenic and lead apparently have not migrated from the fill. Figures 2-4 and 2-7 show the following:

  - Arsenic concentrations are less than 10 mg/kg in all samples of soil underlying fill.
  - Lead concentrations are similar in both sand underlying the fill and sand underlying surficial sand.
  - Concentrations of arsenic and lead are significantly lower in underlying sand and fines than in the fill. Median arsenic concentration (mg/kg) is 1.6 and 1.0 in sand and fines vs. 9.8 in fill; median lead concentration is 5.0 and 6.3 in sand and fines vs. 557 mg/kg in fill.

- There is little difference in SPLP arsenic concentrations found throughout the study area. The median concentration is less than to 10 µg/L for all 5 matrices.
- SPLP lead concentrations are higher in the fill and surficial fill (median concentrations 84 and 55 µg/L, respectively) than in surficial sand or underlying sand/fines (median concentrations 18 and <3.4 µg/L, respectively).
- In most, but not all cases, samples with highest total metal concentration had highest SPLP concentrations. Lead in surficial fill, surficial fill, and underlying sand is the exception to this correlation. There is no apparent correlation between the total and SPLP concentrations in samples from these matrices. Thus total lead concentrations cannot be used to predict SPLP lead concentrations.

The level of general surficial characterization throughout the NPP study area coupled with the fact that it is currently subject to a primarily residential land use highlights the need for parcel-specific evaluation of the potential exposure pathway from surficial materials to receptors. Therefore, another data gap is the need for surficial characterization of readily discernable bare spots on all properties within the known fill areas where potential exposure to SOCs is greatest.

Groundwater

The dataset for groundwater quality within the NPP study area is limited to 1-time grab samples obtained from 25 borings during Olin's Initial Investigation and periodic samples from 4 wells installed by GZA for CTDEP. Only groundwater data from Olin were available electronically. Drought conditions existed at the time of sampling, which may have limited the number of borings where it was possible to collect groundwater samples. The effect, if any, of drought conditions on the quality of the samples collected is unknown. Those samples were analyzed for the CTDEP Appendix II Landfill Leachate Parameters. Samples for metals analysis were filtered in the field. The results indicate that groundwater quality throughout the study area is largely unaffected by the fill. A few metals, PAHs, and chloroform were detected in several samples at concentrations exceeding GWPC.

Not enough data are available to determine the effects, if any, of fill materials on groundwater quality. Although grab samples from temporary borings are useful as an initial screening tool, multiple samples from permanent monitoring wells are necessary to determine compliance with the RSRs and evaluate possible effects from filling activities.

2.6 AREAS OF POTENTIAL ISOLATED FILL

The Initial Investigation was the first widespread effort at investigating Non-Public Properties. Based on available information, the Initial Investigation study area was limited to where there was historic information (documents and aerial photographs) of systematic, large-scale, contiguous filling. The Consent Order expanded the NPP study area to include more properties outside the boundaries of the Initial Investigation study area, where potentially smaller, isolated areas of filling may be present.

These potential fill areas are undocumented in the record and either were too small to be seen on aerial photographs or may have been placed before the first aerials were taken in 1934. Small isolated fill is not likely to be the result of institutional filling by a municipality or industry, but due to localized property development or waste disposal activities. The Initial Investigation discovered remnants of burn furnaces, which were identified by homeowners as places where residents burned their household trash. The primary sources of information available for assessing the presence of other, isolated fill areas are:

- Descriptions of site conditions by owners/tenant.
- Borings drilled outside known contiguous fill areas by Olin during the Initial Investigation in the summer of 2002.
- Borings drilled in rights-of-way by CTDEP within the NPP study area.
- Surface material sampling and analyses conducted by CTDEP at 24 properties in the NPP study area between December 12, 2001 and July 31, 2002.

Sheet 1 presents the available information on studies done in the NPP study area.

Fill thickness measurements and contours are shown. Note that outside the contiguous fill areas no fill was found by Olin borings, and that only limited amounts were found in several CTDEP rights-of-way borings. Fill found under roads may be associated with road building/grading and utility installation rather than an extension of fill from the adjacent properties. On Sheet 4 the 24 properties investigated by CTDEP are highlighted and an assessment on the presence or absence of surficial fill is indicated. Fourteen of these 24 properties lie completely outside known areas of contiguous filling and CTDEP identified isolated fill (typically sand with traces of ash, slag, glass, and/or brick) at six of them (see Table 2-8). A "D" on various properties indicates that the owner or tenant reported the presence of debris or other indications of potential fill on a questionnaire included in the Town of Hamden's Phase I ESA report and/or in a communication directly to CTDEP. These data show that there is the potential for small, isolated fill not visible in aerial photographs and that more investigation is needed to identify and characterize them.

2.7 GEOLOGY

The geology of the area is dominated by the regionally extensive and thick glacial Lake Connecticut deltaic sand deposit that underlies the southern Hamden/western New Haven area from upper Lake Whitney to Long Island Sound (see cross-sections on Sheet 2). The regional sand deposit pinches out against Prospect Hill to the east and Mill Rock Ridge to the north but is reportedly up to 300 feet thick under and southwest of the Southwest Satellite Area (Surficial Materials Map of Connecticut, Stone et al, 1992 and Quaternary Geologic Map of Connecticut and Long Island Sound Basin, Stone et al, 1998). The sand is typically fine to coarse-grained, with local, subordinate amounts of silt and gravel. Although it is mostly composed of quartz and some feldspar grains, it typically has a pink to red color due to the incorporation of local brownstone bedrock fragments. Glacial meltwater delta sand deposits of this kind typically exhibit laminations and layers of differing grain size and composition that is lost if the soil is disturbed. This characteristic provides a simple visual method of differentiating native, undisturbed sand from disturbed soil fill, and along with the light color, from the typically much darker waste/refuse fill.

Kettles, which are natural depressions caused by the melting of isolated blocks of glacial ice, are common within the sand deposit. They are often in clusters and hold surface water, as at the Pine Swamp Area north of the site, and at Lake Whitney. The former wetland depressions within the Public Properties/Bryden Terrace Area and the Southwest Satellite Area were probably kettles.

Numerous borings within the site show that a layer of fines is present between the fill and the sand in the Bryden Terrace Area and the adjacent Public Properties where wetlands were prevalent before that part of the site was filled. The fines are composed primarily of clay and silt sized mineral grains, with some very fine-grained sand and commonly including organic matter. It is typically dark colored (gray, brown, or black), generally less permeable to groundwater than other soils, and indicates deposition by slow-moving surface water in a restricted basin. The presence of the fines in the Bryden Terrace Area and the adjacent Public Properties is consistent with the distribution of wetlands seen on historic aerial photographs. The absence of fines under fill in the Morse Street, Southwest Satellite, Newhall Street, and Augur Street fill areas suggests that the bottom of these former topographic depressions were not perennially wet, although the Southwest Satellite Area has been described as containing a marsh and ice skating pond.

The sand and fines pinch out against the flanks of Prospect Hill and Mill Rock Ridge, which were never submerged. They were, however, once under an ice cap, and so thin deposits of glacial till mantle the sedimentary New Haven Arkose and basaltic West Rock Diabase bedrock that underlie Prospect Hill and Mill Rock Ridge, respectively. Composed of all grain sizes, including abundant cobbles and boulders, completely non-sorted, and typically red-brown colored, glacial till exhibits no laminations or layers and has widely varying permeability to groundwater. Because the bedrock surface plunges westward under the fines and sand beneath the site, it was only encountered at the western boundary of the site. Glacial till may also lie between the bottom of the regional sand deposit and the top of the bedrock at depth below the site.

2.8 HYDROGEOLOGY

As discussed in Section 2.2.1, the topography and drainage pattern in the site area has a direct bearing on the groundwater flow direction (see Figure 1). Because of the surrounding valley's flat topography and the presence of local highlands (Mill Rock Ridge and Prospect Hill) to the northeast, east and southeast, surface water drainage from the site is to the north via a small stream and associated wetland west of the Augur Street Area. This unnamed stream lies in a north-tending, 1,500-foot long, 200-foot-wide, flat-bottomed valley with an elevation of about 38 feet above high sea level. This stream drains into the series of ponds at Pine Swamp, which in turn drains into Lake Whitney. This reservoir has an outlet on the east end of Mill Rock on the eastern side of Prospect Hill from the site. There are no ponds or streams within the site; all of the site's surface water runoff is conveyed northward to the unnamed stream via catch basins and underground drain pipes. The only other permanent, natural surface water bodies in the area are the ponds at Beaver Ponds Park, located about 0.5 miles to the southwest. Consequently, the general groundwater flow should be away from the highlands (west) and towards the surface water features (north around the west end of Mill Rock and southwest towards the Beaver Ponds).

Most of the subsurface information on hydrogeology comes from permanent monitoring wells located in the Public Properties, the Bryden Terrace Area, and the northern part of the Newhall Street Area. Table 2-9 is a summary of all water levels measured from permanent monitoring wells from September 6, 2002 (the first complete round after a period of equilibration) through October 27, 2003. The degree of water level variation during these climatically very dry and very wet years is typically on the order of less than two feet, showing that the hydrogeology is not greatly affected by seasonal changes. Three wells (LBG-MW-1, HA-B108-MW, and RF-HA123-MW) show greater variations, which are attributed to a single anomalous measurement in their periods of record. The five well clusters in the Hamden Middle School parcel show mostly consistent, downward groundwater flow, except for well cluster MW-4, which shows a horizontal or very slightly upward gradient.

Sheet 5 shows water table contours based on the first complete round of water level measurements obtained by other investigators on September 23, 2002 and contoured by Olin. It also includes approximate water table elevations obtained by Olin from direct push borings in the NPP during August and September 2002. These direct push water levels are not necessarily equilibrated with the water table and thus represent only a rough measure of the water table elevation, but they are in general agreement with the water table contouring and anticipated groundwater flow directions based on extrapolation of the contouring and topography.

Despite the apparently anomalous values at wells LBG-MW-1 and HA-B108-MW, this water table map provides a depiction of shallow groundwater flow that is consistent with the general understanding based on the topography and drainage discussed above. Shallow groundwater flow in the northeastern part of the site (blocks C, D, E, and F) is westerly, which is consistent with the westward downhill sloping topography caused by Prospect Hill to the east. Northerly flow in this part of the site is prevented by Mill Rock Ridge. A water table mound is present under the Hamden Middle School fields. This mound and a local water table high in the northwest corner of Rochford Field form a water table divide, with a saddle located under the school. The mound displays radial flow to the north, northeast (towards the north-flowing, unnamed stream), southeast, and southwest (toward the Beaver Ponds), with most of the flow diverted to the latter direction. The downward vertical hydraulic gradients documented by well clusters in this area of the site are consistent with the presence of a divide, which signifies a groundwater recharge area.

Although water level data is absent in most of the NPP study area, northward extrapolation of the water table contours across Mill Rock Road Extension would produce the westward shallow groundwater flow expected in block T. To the south of the school, in the area of the Hamden Community Center, the shallow groundwater flow appears to switch direction from westward to southwestward, as expected based on the regional topography and drainage.

Locally, the water table is situated in the lower part of the fill, especially in the Bryden Terrace Area, adjacent Rochford Field and Mill Rock Park, and in the western part of the

Hamden Middle School parcel, or in the fines underlying the fill in these areas. This is consistent with the presence of standing water (wetlands) there as seen in historical aerial photographs. The absence of fines under fill in the Morse Street, Southwest Satellite, Newhall Street, and Augur Street fill areas suggests that the bottom of these former topographic depressions were not wetlands. The approximate water levels obtained in these areas show that the water table is in the underlying sand, as shown in the cross-sections on Sheet 2.

2.9 SUBSTANCES OF CONCERN

The purpose of this section is to determine the substances of concern (SOCs) for the Supplemental Investigation. Laboratory analytical data from the complete Olin database for the NPP are summarized in Tables 2-6 to 2-7. These tables facilitate determining which compounds are most likely to be associated with fill. If, during the course of the investigation, materials are encountered that challenge the assumptions of the CSM, additional SOCs may be added to the list or the CSM may be changed.

<u>Metals</u>

The total number of analyses performed is sufficiently large to have confidence in the validity of the data presented. The breakdown by soil matrix shows that the fill and surficial layers have been sampled the most. However, the underlying sand and fines matrices have not been adequately characterized. This data gap will be addressed in the work plan in Section 3.

The surficial fill and fill layers have been adequately characterized. Thirteen metals have been identified as SOCs for fill in the study area. The primary basis for selection is any substance that exceeded a criterion in the RSRs. Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, thallium, zinc, ETPH, PAHs, and PCBs and pesticides exceeded either RDEC and/or GAPMC. Concentrations of most of these metals are also significantly greater in fill than in native sand and soil. Although the concentration of manganese is fairly uniform throughout the different matrices, because it was a major component of dry cell batteries, which are known to be a component of some fill, manganese will be included as an SOC. The other metals shown in the tables are either major components of the earth's crust or have been found at concentrations uniformly throughout different matrices and are therefore not considered indicative of fill.

Due to the fact that PCBs and chlorinated pesticides did not exist prior to ca. 1940, they are SOCs primarily in areas where filling was known to occur after 1940.

3.0 SUPPLEMENTAL SCOPE OF WORK

3.1 PURPOSE

Under the terms of the Consent Order, Olin has prepared and submitted this Supplemental Investigation Work plan of the Non-Public Properties (NPP) for CTDEP's review and approval. The purpose of this work plan is to build upon the findings of the Initial Investigation by addressing the data gaps in the Conceptual Site Model. Primarily the scope of work will define the three-dimensional extent and the physical and chemical nature of fill in the NPP study area and determine the extent and degree of soil, groundwater, and surface water pollution resulting from such filling. Specifically, the scope of work will describe:

- Additional delineation of the perimeters of the five known areas of contiguous filling with identification of the portions of the properties underlain by such fill.
- Surficial characterization of readily discernable bare spots within the known fill areas.
- Assessment of properties outside the five known fill areas, but within the NPP study area, to determine if isolated fill is present.
- Characterization of the hydrogeology and groundwater quality underlying the NPP study area and its potential effect on surface water quality.

3.2 APPROACH

As explained in the CSM, the placement of fill in the contiguous fill areas occurred before development of most of the NPP study area. The current (approximately 302) property boundaries are unrelated to the filling activities. However, Olin recognizes that the fill areas are now owned and occupied by non-respondents who control access to the fill areas and have an interest in the completion of and results from the Supplemental Investigation. Therefore, owner permitting, Olin will investigate every property in the NPP study area. The investigation will start with a visual inspection of each property, followed by, in many cases, drilling, logging, and/or sampling, depending on where the property lies relative to known, contiguous fill areas. The results of these initial activities may lead to their expansion to other properties within the NPP. The following specific sections describe the activities that will be conducted during each element of the Supplemental Investigation.

3.2.1 Contiguous Fill Assessment

Sheet 3 shows the study area (blue outline) and the approximate known or inferred extent of contiguous fill based on the results of the Initial Investigation. The approximate edge of fill is shown as a 1-foot thickness contour interval (green line) that was interpolated between borings, estimated from stereoscopic inspection of historic aerial photographs, or identified in the field from exposures of fill/native soils and other topographic evidence and relationships. The locations and general extent of fill correlates with all historical and anecdotal descriptions and photographs of large scale filling in the record. The CSM identified the need for a more precise delineation of the contiguous fill as well as more characterization of exposed surficial fill at bare spots within these fill areas.

3.2.1.1 Extent Delineation

To obtain a more precise delineation of the approximate edge of contiguous fill, investigations of every property along the edge (access permitting) will be conducted via iterative, shallow subsurface borings. Table 3-1 lists the 95 non-public properties intersected by the edge of contiguous fill. One or more transects, of typically three borings each, will be advanced across the inferred fill perimeter on these properties, as approximately shown on Sheet 3. Because these 115 planned transects may extend onto some adjacent properties presumably near but not along the edge, or are planned for properties on either side of where the edge underlies a road, Table 3-1 proposes a total of 107 properties for inclusion in the contiguous fill extent delineation. Exact placement of the transect borings in the field will follow these guidelines, which may modify the final number of properties actually investigated:

<u>Determination of Transect Location</u>

An initial visual reconnaissance inspection of the properties will be conducted for the purpose of identifying potential filling. The inspection will look for any indication of filling that will guide the initial boring locations, including the following:

- Debris/waste visible at the ground surface.
- Differences in relief, apparent terracing or filled areas, especially along property lines.
- Areas of ground surface depressions.

- Hummocky or uneven terrain.
- Bare spots and/or stressed vegetation.

Based on the inspection, the investigation will proceed from within the fill to the outside or from native soil to the inside, depending on the material intersected by the first boring. A minimum of three borings is envisioned as shown on the typical property sketch map on Sheet 3; more will be drilled if necessary. Ideally, the drilling program will result in:

- Transects that are roughly perpendicular to the inferred perimeter.
- Borings along the transect that are spaced approximately 20 feet apart.

Wherever possible, borings will be advanced using direct push drilling equipment, supplemented by hand-operated tools, if necessary, in sensitive or physically inaccessible areas. The direct-push method creates minimal disturbance to the ground surface, however, there may be some incidental damage caused by the vehicle itself. Any damage to lawns or pavement will be repaired. Direct-push borings will fully penetrate the fill materials and advance into native soil. The borings will be inspected and logged to confirm the absence and presence of fill or soil. The materials encountered will be evaluated for color, odor, and texture and field screened for concentrations of volatile organics using a photoionization device. Based on the materials observed, the transect will progress in the direction necessary to determine the edge of fill by identifying the surrounding, undisturbed native soil as shown in the cross-section on Sheet 3. The number of points and their depth, and the degree that each technique is employed at any property will depend on the physical circumstances such as access by the drilling rig, subsurface utilities, landscaping, paving or buildings.

Native soil samples from transects that lie approximately every 150 feet (about every third transect, for an approximate total of 38) along the inferred perimeter of the known, contiguous fill areas will be submitted for laboratory analysis. The sample will be collected from the boring that encounters only natural soil and from the depth equal to that of the fill found in the adjacent boring as shown in the cross-section on Sheet 3. The analyses will be used to document the concentrations of substances outside the fill. The procedure for these samples is as follows:

<u>Collection of Sample for Laboratory Analysis</u>

- Samples will be taken from transects selected in the field approximately every 150 feet along known fill perimeter.

- One sample will be collected from undisturbed native soil just outside the edge of fill.
- The soil sample shall be obtained from the same depth horizon where the fill pinched out in the adjacent point.

The proposed 38 soil samples will be analyzed by a laboratory for the following substances reasonably expected to be found in the contiguous fill:

- SOC metals and SPLP metals by methods 6010B/7470A and 1312
- ETPH by method CTETPH
- PAHs by method 8270C
- Pest/PCBs by method 8081 (only in areas where filling may have postdated the mid 1930s as described in the Conceptual Site Model)

If ETPH concentrations in samples from around fill pre-dating the mid-1930s are elevated, then these samples will also be analyzed for pesticides and PCBs.

The locations of the borings and the subsequent delineation of the edge of fill will be plotted on plans by measuring their distance from permanent landmarks. The overall delineation of the edge of fill compiled from the individual property investigations will be added to the site plan.

3.2.1.2 Bare Spot Characterization

A visual inspection of all 163 of the Non-Public Properties (access permitting) within, and on the edge of, the known contiguous fill areas will be performed to identify the presence of any bare spots. When and where appropriate, this inspection will coincide with, and in certain instances guide, the Extent Delineation portion of the Work plan (Section 3.2.1.1). The bare spots will be mapped on each property, including places where vegetation has been worn away or is stressed due to:

- Frequent animal or pedestrian activities.
- Proximity to outdoor structures such as swing sets and picnic tables.
- Absence of direct sunlight limiting the growth of vegetation.

Samples will be collected at each property exhibiting bare spots. One to four surface samples (depending on the size of the exposed area) will be collected at a depth of 0 to 6 inches and analyzed in the field with an x-ray fluorescence (XRF) device for the metals reasonably expected to be found in the fill. The sample with the highest XRF results from each bare area will be sent to a certified laboratory for the following analysis:

- SOC metals and SPLP metals by methods 6010B/7470A and 1312
- PAHs by method 8270C

The locations of any bare spots and any sampling points will be pin flagged, photographed, and plotted on site maps by measuring distances from permanent landmarks.

3.2.1.3 Additional Characterization

A data gap identified by the CSM in Section 2 is the need for additional characterization of the bulk of the fill material and of native soil underlying fill to expand the database for certain SOCs. This data gap will be addressed by utilizing the borings needed for the installation of proposed monitoring wells within the thickest parts of the fill areas to obtain additional samples for analyses. These borings will also confirm the thickness of fill in the Southwest Satellite Area where spatial data are sparse due to limited access.

One 2-foot split-spoon sample of fill and one sample of native soil underlying fill will be collected for laboratory analysis from each 5-foot fill thickness interval. The laboratory analyses will be SOC metals (total & SPLP), PAHs, ETPH, PCBs, and pesticides. These borings, numbers of samples, and the proposed analyses are detailed below:

Boring	Fill Thickness	No. of Samples	Boring	Fill Thickness	No. of Samples
Southwest Satellite Area:			Bryden Terrace Area:		
H2002S	15	4	C2001D	10	3
H2002D	15	4	F2001S	3	2
J2001S	10	3	F2001D	3	2
L2001S	15	4	F2002S	8	3
L2001D	15	4			
			Augur Street Area		
Newhall Street Area:			T2002S	5	2
E2002D	10	3	T2003S	2	2
P2002S	5	2			
P2002D	5	2	TOTAL:		40

3.2.2 Isolated Fill Assessment

The Initial Investigation was the first widespread effort at investigating Non-Public Properties. Based on available information, the Initial Investigation study area was limited to where there was historic information (documents and aerial photographs) of systematic, large-scale, contiguous filling. The Consent Order expanded the NPP study area to include more properties outside the boundaries of the Initial Investigation study area, where potentially smaller, isolated areas of filling may be present.

The Conceptual Site Model determined that these potential fill areas are undocumented in the record and either were too small to be seen on aerial photographs or may have been placed before the first aerials were taken in 1934. Therefore, the primary information guiding the approach for investigating these properties is:

- Descriptions of site conditions by owners/tenant.
- Borings drilled outside known contiguous fill areas by Olin during the Initial Investigation in the summer of 2002.
- Borings drilled in rights-of-way by CTDEP within the NPP study area.
- Surface material sampling and analyses conducted by CTDEP at 24 properties in the NPP study area between December 12, 2001 and July 31, 2002.

Sheet 1 presents the available information on studies done in the NPP study area. Fill thickness measurements and contours are shown. Note that outside the known, contiguous fill areas no fill was found by Olin borings, and that limited amounts were found in several CTDEP rights-of-way borings. The 24 properties investigated by CTDEP are highlighted, the analytical sample locations are shown, and an assessment on the presence or absence of surficial fill is indicated. Fourteen of these 24 properties lie completely outside known areas of contiguous filling and CTDEP identified isolated fill (typically sand with traces of ash, slag, glass, and/or brick) at six of them (see Table 1-1). A "D" on various properties indicates that the owner or tenant reported the presence of debris or other indications of potential fill on a questionnaire included in the Town of Hamden's Phase I ESA report and/or in a communication directly to CTDEP. This information is summarized on Table 3-1, which lists 139 properties located outside the contiguous fill.

Using this information as a baseline, the assessment for the presence of isolated fill deposits in the NPP study area consists of the following approach:

Task 1: An initial sampling program at 49 selected properties outside the currently inferred perimeter of contiguous filling based on the following criteria:

- Properties whose owners reported the presence of debris or potential indicators of fill and that have not been previously investigated.
- Properties adjacent to the 6 properties where CTDEP already identified isolated fill.
- Properties adjacent to fill found by CTDEP rights-of-way borings and that have not been previously investigated.
- Properties not otherwise selected, but which provide additional geographic coverage of the NPP study area.

Proposed boring locations for these 49 properties are shown on Sheet 4. All proposed boring locations are subject to access, physical constraints, and utility clearance. Actual locations will be established in the field and will be influenced by the findings of an initial inspection of these properties (as described by Task 2 below). Note that this assessment does not include properties that lie along the edge of the known, contiguous fill areas. Those properties will be investigated (as shown on Sheet 3) during the extent delineation described in Section 3.2.1.1.

Wherever possible, borings will be advanced using direct push drilling equipment, supplemented by hand-operated tools, if necessary, in sensitive or physically inaccessible areas. The direct-push method creates minimal disturbance to the ground surface, however, there may be some incidental damage caused by the vehicle itself. Any damage to lawns or pavement will be repaired. Direct-push borings will fully penetrate any fill materials and advance into native soil. The borings will be inspected and logged to confirm the absence and presence of fill or soil. The materials encountered will be evaluated for color, odor, and texture and field screened for concentrations of volatile organics using a photoionization device. Subsequent to the physical characterization of the materials, a determination will be made whether any fill encountered is of limited extent and potentially attributable to on-site residential activities or alternatively, potentially attributable to and contemporaneous with other filling within the area. The locations of any isolated fill and any sampling points will be plotted on site maps by measuring distances from permanent landmarks. The occurrence of any isolated fill will be added to the site plan.

If additional areas of fill are discovered, then supplemental analytical characterization will be performed that will include:

- Field analysis for fill SOC metals with an x-ray fluorescence (XRF) device.
- Laboratory analysis of fill samples for the SOCs indicative of the contiguous fill materials: metals, ETPH, PAHs, and, in certain areas where filling may have post-dated mid 1930s, pesticides/PCBs.

Task 2: Concurrent with the initial boring program, a visual reconnaissance inspection of all 139 properties (access permitting) outside the known contiguous fill portion of the NPP study area will be conducted (including those proposed for sampling described in Task 1 above) for the purpose of identifying potential filling. The inspection will look for any indication of filling, including the following:

- Debris/waste visible at the ground surface.
- Differences in relief, apparent terracing or filled areas, especially along property lines.
- Areas of ground surface depressions.
- Hummocky or uneven terrain.
- Bare spots and/or stressed vegetation (same as bare spot evaluation for the entire site).

The bare spots also will be mapped for each property, including places where vegetation has been worn away or is stressed due to:

- Frequent animal or pedestrian activities.
- Proximity to outdoor structures such as swing sets and picnic tables.
- Absence of direct sunlight limiting the growth of vegetation.

Upon completion of these two tasks and following an initial evaluation of the results, an interim report and proposal for supplemental investigation, if warranted, will be made to the CTDEP. If necessary based on the initial results, further investigation will include some or all of the following procedures to determine the extent and potential origin of isolated fill:

- Subsurface exploration and surficial sampling at properties not yet investigated.
- Deeper and more extensive subsurface characterization using direct-push sampling.

3.2.3 Groundwater Investigation

The Supplemental Investigation will build upon the Initial Investigation groundwater grab sample data, and other data obtained by CTDEP, by obtaining reproducible samples from permanent wells at more areas and from multiple sampling rounds. Because few wells exist in the NPP study area, the proposed well network is principally intended for reconnaissance level mapping of the horizontal and vertical groundwater gradient, inferred flow directions, and for reproducible groundwater quality sampling to compare with the Initial Investigation grab sampling data.

The proposed locations were chosen based upon the current understanding of the extent of the principal fill areas and the apparent or inferred groundwater flow directions. Sheet 5 shows water table contours within the Public Properties, the Bryden Terrace Area, and the northern part of the Newhall Street Area based on a September 2002 round of water level measurements obtained by other investigators. It also includes approximate water table elevations obtained by Olin from direct push borings in the NPP study area during August and September 2002. These water levels are not necessarily equilibrated with the water table and thus represent only a rough measure of the water table elevation, but they are in general agreement with the water table contouring and anticipated groundwater flow directions based on extrapolation of the contouring and topography. A detailed discussion of the groundwater flow based on these data is included in the Conceptual Site Model section.

In conjunction with the well networks on the adjacent Public Properties, the NPP study area well network is designed to provide representative sampling from upgradient, within, and downgradient of the known fill areas and surrounding uncharacterized portions of the NPP study area. The four shallow wells installed for CTDEP will be incorporated into the proposed monitoring system, which consists of 29 new wells (20 shallow water table wells, with deeper wells included at nine of these locations, as shown on Sheet 5) for a total of 34 wells at 24 locations within the NPP study area. In addition, data from five well locations within the Public Properties (see Table 3-2) will also be used to evaluate the groundwater flow directions and quality. The purpose of the deeper monitoring wells is to provide an initial reconnaissance characterization of vertical hydraulic and substance concentration gradients. The nine well cluster locations are distributed evenly throughout the shallow well network. Because no information is available to guide the selection of vertical screen separation, the deeper wells will be installed with a nominal 20 feet of separation between the shallow and the deep 10-foot-long well screens. This vertical separation will be measured from the bottom of the shallower well sandpack interval to the top of the deeper well sandpack. In some instances, this nominal separation may require revision based on local field conditions. The presence of local confining layers in the native materials or shallow drilling refusal may necessitate deviations from the plan, which will be documented in the field notes and final investigation report.

The rationale for the specific location of each proposed monitoring well is described below and summarized on Table 3-2. Some wells will serve more than one purpose.

Southwest Satellite Area

Proposed well locations H2001 and K2001 are intended to characterize groundwater quality upgradient of, and thus unaffected by, the release of substances at this fill area. Their positions were chosen based on the typically south-southwesterly flow of shallow groundwater indicated by water table wells in the Hamden Middle School property to their north. This flow is inferred to continue toward a presumed groundwater discharge area at Beaver Ponds one-half mile to the south-southwest. The upgradient groundwater quality may be degraded from the releases of substances at the school and NPP study area north of Morse Street.

Proposed well locations H2002, J2001, and L2001 are intended to characterize groundwater quality beneath the thickest portions of this fill area where potential degradation from the release of substances may be greatest.

Proposed well locations H2003 and L2002 are intended to characterize groundwater quality downgradient of this fill area as it exits the NPP study area. Their positions were chosen based on the typically south-southwesterly flow of shallow groundwater indicated by water table wells in the Hamden Middle School property to their north. Concentrations of substances at these wells, as well as at locations H2002, J2001, and

L2001, will be evaluated to determine the potential presence and migration direction of any groundwater plume(s) emanating from this fill area as compared to the upgradient groundwater quality.

Morse Street Area

Existing wells within the southern portion of the Hamden Middle School property will be used to monitor upgradient groundwater quality. Data from these wells is appropriate for this purpose based on the typically south-southwesterly flow of shallow groundwater indicated by water table wells in the Hamden Middle School. The upgradient groundwater quality may be degraded from the release of substances at the school.

Proposed well locations H2001 and K2002 are intended to characterize groundwater quality downgradient of this fill area. Their positions were chosen based on the typically south-southwesterly flow of shallow groundwater indicated by water table wells in the Hamden Middle School property to their north. Concentrations of any substances in these wells will be evaluated to determine the potential presence and direction of any groundwater plume(s) emanating from this fill area as compared to the upgradient groundwater quality emanating from the school.

Newhall Street Area

Proposed well locations E2001 and P2001 are intended to monitor groundwater quality upgradient of this fill area. Their positions were chosen based on the typically westerly flow of shallow groundwater indicated by water table wells in the Bryden Terrace Area, Mill Rock Park and Rochford Field to their north and northeast, which is consistent with the westward downhill sloping topography east of Wadsworth Street and Prospect Lane. The upgradient groundwater quality may be degraded from the releases at the Bryden Terrace Area and from any potential isolated fill in the North Sheffield Street Area.

Existing well NH-499-MW and proposed well locations E2002 and P2002 are intended to monitor groundwater quality beneath the thickest portions of this fill area where potential degradation from the release of substances may be greatest.

Existing wells HA-B108-MW and HA-B109-MW and proposed well locations K2001 and N2001 are intended to monitor groundwater quality downgradient of this fill area.

Their positions were chosen based on the presumed west to southwesterly flow of shallow groundwater indicated by water table wells in the Hamden Middle School property to their north, and the westerly flow of shallow groundwater indicated by water table wells in the Bryden Terrace Area, Mill Rock Park and Rochford Field to the north and northeast. Concentrations of substances in these wells will be evaluated to determine the potential presence and direction of any groundwater plume(s) emanating from this fill area as compared to the upgradient groundwater quality emanating from the Bryden Terrace and North Sheffield Street Areas.

Bryden Terrace Area

Existing well location MRP-HA107-MW and proposed well location F2001 are intended to monitor groundwater quality upgradient of this fill area. Their positions were chosen based on the typically westerly flow of shallow groundwater indicated by water table wells in the Bryden Terrace Area, Mill Rock Park and Rochford Field to their north and northwest, which is consistent with the westward downhill sloping topography east of Wadsworth Street and Prospect Lane.

Existing well locations BT-113-MW, WIN-1067-MW, and MS-109-MW and proposed well locations C2001 and F2002 are intended to monitor groundwater quality beneath the fill area.

Proposed well location E2001 is intended to monitor groundwater quality within the NPP study area downgradient of this fill area. Its position was chosen based on the typically westerly flow of shallow groundwater indicated by water table wells in the Bryden Terrace Area, Mill Rock Park and Rochford Field to the north and northeast, which is consistent with the westward downhill sloping topography east of Wadsworth Street and Prospect Lane. Concentrations of substances in this well will be evaluated to determine the potential presence and direction of any groundwater plume(s) emanating from this fill area as compared to the upgradient groundwater quality.

Augur Street Area

Proposed well location T2001 is intended to monitor groundwater quality upgradient of this fill area.

Proposed well locations T2002 and T2003 are intended to monitor groundwater quality downgradient of this fill area. Concentrations of substances in these wells will be evaluated to determine the potential presence and direction of any groundwater plume(s) emanating from this fill area as compared to the upgradient groundwater quality.

<u>Uncharacterized Portion of the Study Area</u>

Proposed well locations located between the known fill areas (E2001, K2001, N2001, P2001, Q2001, R2001, and S2001) are intended to monitor groundwater quality that is upgradient, within, and/or downgradient of any unknown, isolated fill areas that may exist within their respective portions of the presently uncharacterized portions of NPP study area.

To enhance the effectiveness of the network, water table elevation measurements will be obtained from wells installed at the beginning of the field work and used to validate the Conceptual Site Model and modify subsequent well locations, if necessary. Because the greatest uncertainty in the groundwater flow direction is in the southwestern part of the NPP study area, the three well locations within the Southwest Satellite Area (H2002, J2001, and L2001) will be installed first. Equilibrated water levels from these wells and from those along the southern edge of the Hamden Middle School athletic field to the north (LBG-MW-4, -5, and –16) will be obtained and the flow direction in that part of the NPP study area determined to adjust subsequent well locations. The well installation sequence will generally progress in an easterly direction, with the last wells installed in the Bryden Terrace Area where the groundwater flow direction is well understood.

A total of four quarterly rounds of groundwater monitoring will be performed. Four rounds of groundwater samples will be collected from the NPP study area wells in conjunction with groundwater sampling events performed by others at the Public Properties so that data are comprehensive and concurrent throughout the entire Site. The sampling events will be conducted three months apart.

The analytical program will consist of the CTDEP Appendix II Landfill Leachate Parameters (which include metals, semi-volatile and volatile organic compounds, ETPH, and leachate indicator parameters – see Appendix D). Because of the later dates of filling and development in the Bryden Terrace Area and southeastern portion of the study area, pesticides and herbicides will only be sampled at the well locations associated with those areas (wells WIN-1067-MW, BT-113-MW, MS-109-MW, C2001D, F2001D&S, F2002S, E2001D&S, P2001S, Q2001S, R2001S, and S2001S). These substances did not exist or were not commercially available during the period of filling the other areas within the NPP study area.

3.2.4 Surface Water Quality Assessment

The need for a surface water sampling assessment program will be determined as a phased approach after the ground water quality assessment is completed. The Conceptual Site Model includes two surface water bodies that may be affected by the discharge of groundwater plume(s); the unnamed, northward-flowing stream and wetland located immediately outside the NPP study area west of the Augur Street Area, and the Beaver Ponds located one-half mile southwest of the southern part of the NPP study area. If the groundwater quality assessment conducted in accordance with this work plan determines that groundwater polluted by the filling in the NPP study area migrates out of the study area, then further characterization of the groundwater plume and sampling of surface water may be conducted in a later phase.

3.3 PROCEDURES

This section presents the major field procedures necessary for drilling borings and installing groundwater monitoring wells. Detailed sampling, logging, equipment operation, reporting, analytical, and quality control/quality assurance procedures are detailed in the Quality Assurance Project Plan that will be prepared and submitted to CTDEP under separate cover.

3.3.1 Borings and Fill/Soil Sampling

Borings will be used for delineating the edge of fill areas, identifying any isolated fill areas, and installing groundwater monitoring wells. Shallow borings will be dug by hand auger; deeper borings will be advanced by a direct push method. Direct-push refers to tools and sensors that are "pushed" into the ground without the use of drilling to remove soil or to make a path for the tool. Percussion hammers and static vehicle weight combined with hydraulic cylinders push a hollow tube containing a sealed sampling tube (usually 4-feet long) into the ground to the desired depth. The sampling tubes provide a core of material for a specific depth. The boring advances step-wise, one tube length at a time until the desired boring depth is achieved. Direct-push techniques do not generate a large volume of potentially contaminated drill cuttings as conventional drilling methods do. This means that the field investigators and local residents are less likely to be exposed to any affected media that may be inadvertently brought to the surface.

Borings for installing the monitoring wells will be drilled in overburden using hollow-stem augers. No bedrock drilling is envisioned because of its substantial depth under the NPP study area. All drilling locations will be marked in the field for utility clearance. "Call Before You Dig" will be contacted prior to initiating drilling as required by law.

To log borings and obtain samples for laboratory analyses, split-spoon samples will be collected from discrete, 2-foot depth intervals at the depths specified by this scope of work. All samples will be screened with a photo-ionization detector (PID) with an 11.7 eV lamp immediately upon opening the split spoon. Elevated PID readings will be used to augment sample selection for laboratory analyses. Split-spoon samples for laboratory analyses will be collected from no more than one 2-foot depth interval.

Samples for VOC analyses will be collected using USEPA method 5035. This field preservation method for VOCs uses two sets of three 40 ml vials, each set for material presumed to contain low and medium concentrations of VOCs. The low concentration set of vials contains magnetic stir bars for use by the laboratory. The medium concentration set of vials contains five milliliters of methanol and is pre-weighed by the laboratory. Approximately five grams of soil, measured with a calibrated sampling plunger device, is placed into each set of vials.

Augers, split-spoons, and other drilling and sampling equipment will be decontaminated as necessary to prevent cross-contamination between samples. The augers will be pressure washed. Split-spoons and direct push drilling equipment will be washed with a soap solution and rinsed with tap water and deionized water between each use. Cuttings and decontamination wastewater will be containerized for proper off-site treatment/disposal.

3.3.2 Monitoring Well Installation and Groundwater Sampling

Each monitoring well will be constructed in accordance with the draft CTDEP Water Management Bureau February 1990 guidelines. Typical water table and deeper monitoring well details are shown in the Quality Assurance Project Plan. The 10-foot-long screens and attached riser pipes will consist of 2-inch inside-diameter, schedule 40 PVC placed to the bottom of the borehole. To aid in minimizing groundwater sample turbidity, the screens will have 0.010-inch-wide slots, the minimum slot size commercially available. A clean sand pack will be placed around and two feet above the top of the screen. About two feet of bentonite will be placed above the sand pack, and the remainder of the borehole will be filled with a bentonite/cement grout to grade.

Depending on their location, each well will be finished with either a locking, steel protector pipe cemented in place and sticking about two feet above grade, or with an 8-inch-diameter curb box mounted flush with grade. A locking expansion plug will be placed on each well riser pipe.

Following installation, each well will be developed to remove cuttings and drilling water from the well, sand pack, and surrounding formation until the groundwater is relatively sediment-free. Depending on well yield, development will be accomplished with pumps and/or bailers. After development, the wells will be left undisturbed for two weeks to allow hydraulic and chemical conditions around the well to equilibrate prior to sampling. Well development purge wastewater will be containerized for proper off-site treatment/disposal.

The top of each PVC riser pipe and the ground surface adjacent to each well will be surveyed to the nearest 0.01 foot relative to on-site benchmarks. In accordance with a February 14, 2002 communication with CTDEP, the wells will be located relative to the following standards:

- Horizontal location: CT State Plane coordinates, NAD 1983.
- Vertical elevation: WGS 1984 HAE.

Note that the existing wells installed by other investigators have been surveyed relative to the standard Town of Hamden vertical datum of high sea level, as is the topography depicted on the sheets.

Before sampling groundwater, water levels will be measured in all monitoring wells concurrent with measurements at the Public Properties by the other Respondents. The monitoring wells will be sampled in accordance with CTDEP standards using low-flow (<300 milliliters/minute) submersible pumps to minimize sample turbidity with the goal of achieving less than five NTUs and less than one-foot of water level drawdown. During well purging and sampling, the groundwater will be analyzed in the field for turbidity, pH, temperature, and specific conductance. Well sampling purge wastewater will be containerized for proper off-site treatment/disposal.

4.0 REPORT DELIVERABLES

4.1 DATA EVALUATION

All sampling locations will be added to the site map and used in conjunction with the analytical database. Malcolm Pirnie will examine the laboratory analytical reports to determine if the data are valid, see the QAPP for specific details on the data validation procedure. Validated soil analytical data will be compared to the RDEC and GAPMC.

Groundwater elevation data from the monitoring well network will be used to determine the groundwater table gradient and inferred flow directions. The validated groundwater analytical data will be compared to Public Property concentrations, the groundwater protection criteria (GWPC), surface water protections criteria where appropriate to the Augur Street Area, and the groundwater volatilization criteria (GWVC).

4.2 REPORTING

A Quality Assurance Project Plan (QAPP) will be submitted to CTDEP within 15 days after submittal of the Work plan.

The interim deliverable following the isolated fill assessment will be submitted to CTDEP per the approach described in Section 3.2.2 with recommendations for additional investigation at non-public properties.

An interim deliverable that includes a groundwater quality assessment based on the first two groundwater sampling rounds will be submitted before the third round. This deliverable will include any recommendations for characterization of surface water.

The Supplemental Investigation Report will include the following elements:

- Information on the investigation of the Non-Public Properties, including:
  - Description and results of the investigation activities, including the first three rounds of groundwater monitoring.
  - Figures and tables summarizing hydrogeologic information, sampling

locations, field and analytical data, and comparison to RSR numerical criteria.

- Maps and cross-sections showing the stratigraphy, extent of contiguous and isolated fill, fill thickness contours, groundwater piezometric surface elevations and vertical gradient contours, and groundwater flow directions.

- Evaluation of the alternatives for remedial actions to abate pollution in accordance with the RSRs, including but not limited to alternatives specified by CTDEP.
- Detailed statement of the most reasonable schedule for performing each alternative.
- List of all permits and approvals required for each alternative, including but not limited to any permits required under CGS sections 22a-32, 22a-42a, 22a-361, 22a-368, or 22a-430.
- A proposed preferred alternative with supporting justification.
- A proposed remedial action plan (RAP) and schedule for performing the preferred remedial actions.

Following completion of the Supplemental Investigation Report, one additional report for the fourth quarter of groundwater monitoring will be submitted to the CTDEP.

5.0 SCHEDULE

Completion of the supplemental investigation, through the first four rounds of groundwater sampling, is estimated to take one year following receipt of approval of the WP and a notice to proceed by CTDEP. Figure 5-1 provides the estimated schedule with Month 1 being the first month after the work plan and QAPP are approved by CTDEP. This schedule assumes access agreements with the Non-Public Property owners will be completed within one month. The schedule may be affected if sufficient access is not available. However, field work may begin as soon as sufficient number of access agreements and utility clearances are obtained, pending weather constraints.

Installation of monitoring wells will begin as soon as possible in order to facilitate collection of the first two quarterly groundwater samples within the desired time frame. The contiguous fill extent delineation and bare spot characterization will proceed concurrently with the well installation, followed by the isolated fill areas assessment. Data will be evaluated as they are received and an interim report on the isolated fill will be prepared at the completion of that task at the end of Month 6. Recommendations for surface water monitoring will be submitted after two rounds of groundwater characterization is complete and in time for incorporation into the third and fourth rounds of groundwater monitoring beginning in Month 9. To expedite the overall schedule, the supplemental investigation report, including the proposed remedial action plan (RAP), will be finalized by the end of Month 11, before the laboratory data from the fourth round of quarterly groundwater monitoring is received. A separate data report for the last event will be prepared within 45 days of receipt of the data. The date for submission of a long-term monitoring plan for the NPP study area is contingent upon CTDEP approval of the RAP.

Appendix A – Consent Order

Appendix B – Interpretation of Aerial Photographs

Appendix C - Public and Non-Public Properties Stratigraphic Database

Appendix D – CTDEP Appendix II Landfill Leachate Parameters