FINAL INVESTIGATION AND EVALUATION OF REMEDIAL ALTERNATIVES
FORMER NEW HAVEN WATER COMPANY PROPERTY
HAMDEN, CONNECTICUT

1.0 INTRODUCTION

This Final Investigation and Evaluation of Remedial Alternatives (FIERA) report was prepared by Leggette, Brashears & Graham, Inc. (LBG) on behalf of the South Central Connecticut Regional Water Authority (RWA). The FIERA report has been prepared to address data gaps identified in April 16, 2004 "Supplemental Scope of Study, Former Hew Haven Water Company Property, Middle School Site Hamden, Connecticut" which was issued pursuant to Consent Order No, SRD-128. The completion of the FIERA was required by the Connecticut Department of Environmental Protection (CTDEP) as part of the July 19, 2004 Conditional Approval Letter for the aforementioned Supplemental Scope of Study.

CTDEP issued Order No. SRD-128 on July 10, 2001 to Town of Hamden, RWA, Olin Corporation and the State Board of Education. The order required that respondents investigate and remediate sources of pollution on a "Site" situated in Hamden, Connecticut and known as the Hamden Middle School, Newhall Street School (aka Hamden Community Center), two Hamden Housing Authority Properties on Morse Street, Rochford Field, Mill Rock Park (aka Rochford Field Annex) and the sewage pump station, located at 1099 Winchester Avenue ("the Public Properties") and certain privately owned properties in the vicinity of the Public Properties, where wetlands formerly existed or where waste materials were historically placed. The order was appealed by all parties, which resulted in the consent order SRD-128 (same number as original order) being accepted as final decision on April 16, 2003.

As part of this order, the "site" was divided three separate areas. This FIERA focuses on areas identified as Hamden Middle School, athletic field, a portion of the Newhall Community Center and two residential properties (251-253 Morse Street and 253-255 Morse Street) which were formerly owned by the New Haven Water Company (NHWC). These areas are referenced as the "Middle School Site" and are shown on figures 1 and 2. Note that the aforementioned two residential properties are owned by the Hamden Housing Authority.

The following reports and transmittals are referenced in this FIERA and hereby should be considered part of this report.

- "Supplemental Scope of Study, Former New Haven Water Company Property, Hamden, Connecticut" dated April 16, 2004, prepared by LBG on behalf of RWA;
- "Response to March 8, 2004 CTDEP Comments on Phase III Environmental Site Investigation, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" dated April 16, 2004, prepared by LBG on behalf of RWA;
- CTDEP letter "Supplemental Scope of Study, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" (Conditional Approval) dated July 19, 2004
- "Quality Assurance Project Plan, Former New Haven Water Company Property, Hamden, Connecticut" dated July 2004, prepared by LBG on behalf of RWA;
- "Addendum and Modification to April 16, 2004 Supplemental Scope of Study, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" dated June 28, 2004, prepared by LBG on behalf of RWA;
- "Request for Modification to Sampling Plan, Former New Haven Water Company Property" dated August 5, 2004, prepared by LBG on behalf of RWA;
- CTDEP letter "Quality Assurance Project Plan, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" (Conditional Approval) dated August 9, 2004
- CTDEP letter "Modification to Supplemental Scope of Study, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" (Approval) dated October 6, 2004
- CTDEP letter "Sampling and Analysis Requirements for Dioxins and Furans, Newhall Street Neighborhood, Hamden, Connecticut, Consent Order No. SRD-128" dated December 1, 2004
- "Request for Modification to Sampling Plan and Addendum to April 16, 2004 "Supplemental Scope of Study, Former New Haven Water Company Property, Middle School Site, Hamden, Connecticut"" dated December 14, 2004, prepared by LBG on behalf of RWA;
- CTDEP letter "Request for Modification to Sampling Plan and Addendum Supplemental Scope of Study, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" (Conditional Approval) dated January 12, 2005
- "Clarification and Additional Information for Dioxin Sampling Modification identified in December 14, 2004 Request for Modification to Sampling Plan and Addendum to April 16, 2004 "Supplemental Scope of Study, Former New Haven Water Company Property, Middle School Site, Hamden, Connecticut" Consent Order No. SRD-128" dated January 18, 2005, prepared by LBG on behalf of RWA;

- CTDEP letter "Request for Modification to Sampling Plan and Addendum Supplemental Scope of Study, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" (Approval) dated February 2, 2005; and
- "Notice of Addendum to Final Investigation Report and Evaluation of Remedial Alternative Report, Former New Haven Water Company Property, Hamden, Connecticut, Consent Order No. SRD-128" dated March 3, 2005, prepared by LBG on behalf of RWA;

All reports and transmittals are on file with the CTDEP, available at local repositories set up in Hamden (Miller Library and Town Hall) and available on the Internet at the below web address: http://www.newhallinfo.org/. As identified in the March 3, 2005 LBG letter, all discussions concerning the investigation of dioxins and furans will be submitted as an addendum to this report. This addendum was necessitated by a recent CTDEP request which required field investigations beyond the scope identified in the conditionally approved April 2004 Supplemental Scope of Study.

This report and investigations were completed pursuant to the June 12, 2000 CTDEP "Draft Site Characterization Guidance Document". As such, this document includes all necessary components identified for a Phase III investigation.

2.0 REGULATORY ISSUES

The primary focus of this FIERA is to fully characterize the extent and degree of soil, surface water, and ground-water pollution at the Middle School Site and identify remedial alternatives to mitigate such pollution consistent with the CTDEP Remediation Standard Regulations (RSRs). In addition, the FIERA addresses halogenated volatile organic compound (VOC) impacted ground water that is flowing off of the Middle School Site. As part of determining the extent of pollution, the FIERA also evaluates the extent of contaminants in various media with respect to the CTDEP RSRs.

The current ground-water classification beneath the site is GAA-impaired. As requested by the CTDEP, all investigations incorporate the CTDEP's Proposed Revisions to Volatilization Criteria dated March 2003 and a Residential Direct Exposure Criterion for Lead of 400 parts per million (ppm). For GAA-impaired areas, the following criteria in the RSRs apply:

2.1 Soils

Direct Exposure Criteria (DEC): The residential DEC is applicable to the top 15 feet of material at the site.

Pollutant Mobility Criteria (PMC): The GA PMC apply to soils above the seasonal low water table, or above seasonal high water table if seasonal low is not technically practical or would not result in permanent elimination of source of pollution. For all parameters except metals, the listed criteria are based on total (mass) concentrations of the parameter in the soil. For metals and polychlorinated biphenyls (PCBs), the remediation criteria are based on the results of a leaching test, typically the synthetic precipitation leaching procedure (SPLP). For the other parameters, SPLP analyses can also be run and compared to GA ground-water protection criteria (GWPC); however, the total concentrations are usually determined first.

2.2 Ground Water

Ground-Water Protection Criteria: The GWPC apply to ground water beneath the site, and are generally consistent with drinking water standards.

Surface-Water Protection Criteria (SWPC): The SWPC apply to ground water prior to it discharging into a surface-water body.

Proposed Residential Volatilization Criteria (RVC): The RVC apply to VOC concentrations in ground water within 30 feet of the ground surface. Compliance of RVC can also be met with analysis of volatile organic compounds (VOCs) in soil-vapor beneath a building. Compliance with the RVC for soil vapor may also be met through interior air sampling.

2.3 Alternatives, Exemptions and Variances

For all of the criteria listed above, there are exemptions, alternatives and variances that can be applied. The following alternatives, exemptions and variances are discussed in this FIERA. The RSRs should be referred to for precise language of the alternative, variances and exemptions.

DEC Exemption

- Regulations of Connecticut State Agencies (RCSA) Section 22a-133k-2(b)(3);

In general, RCSA Section 22a-133k-2(b)(3) indicates the DEC does not apply to inaccessible soils at a release area provided an environmental land use restriction (ELUR) is in effect with respect to the subject parcel or portion of the parcel containing the release. If this exemption were implemented, inaccessible soils containing polychlorinated byphenols (PCBs) at the Middle School Site would need to be remediated to 10 ppm.

Inaccessible soils are defined by the RSRs as polluted soil which is:

A) more than 4 feet below grade; B) more than 2 feet below grade with a paved surface of a minimum of three inches of bituminous concrete or concrete (2 feet may include the sub-base for the pavement; and C) (i) beneath an existing building or (ii) beneath another existing permanent structure provided written notice that such structure will be used to prevent human contact with such soil has been provided to the Commissioner.

PMC Alternatives, Exemptions and Variances

- RCSA Section 22a-133k-2(c)(2)(A);
- RCSA Section 22a-133k-2(c)(2)(B)(i);
- RCSA Section 22a-133k-2(c)(2)(C);
- RCSA Section 22a-133k-2(c)(2)(D);
- RCSA Section 22a-133k-2(c)(4)(B);
- RCSA Section 22a-133k-2(d)(4);
- RCSA Section 22a-133k-2(d)(6); and
- RCSA Section 22a-133k-2(f)(1):

RCSA Section 22a-133k-2(c)(2)(A) is a self-implementing option. In general, this alternative indicates soils applicable to the GA PMC and polluted with a substance other than 1,2-dichlorobenzene, ethylbenzene, toluene or xylenes, may be remediated to concentrations at which the results of a SPLP analysis of such soil does not exceed the GWPC. Note that the RSRs state total petroleum hydrocarbons (TPH) are exempt from this option; however, the

CTDEP has issued a fact sheet since the enactment of the RSRs indicating Extractable TPH (ETPH) is applicable for this option.

RCSA Section 22a-133k-2(c)(2)(B)(i) is a self-implementing option. This alternative applies to soils polluted with volatile organic compounds (VOCs) other than 1,2-dichlorobenzene, ethylbenzene, toluene or xylenes. The mass analysis of these constituents may be compared 10 times the GA PMC, or SPLP analysis may be compared to 10 times the GWPC if the following conditions are met: 1) no non-aqueous phase liquids are present; 2) downward vertical flow velocity is not greater than the horizontal flow velocity; 3) the water table is at least 15 feet above the surface of the bedrock; 4) a public water supply distribution system is available within 200 feet of the subject parcel, and any parcel within the areal extent of the ground-water plume caused by the subject release area; 5) the ground water within the areal extent of such ground-water plume is not used for drinking water; 6) no public or private water supply wells exist within 500 feet of the subject release area; and 7) the ground water affected by the subject release area is not a potential public water supply resource. All of the aforementioned conditions are met for the applicable release area at the site and this option is self-implementing.

RCSA Section 22a-133k-2(c)(2)(C) is a self-implementing option. This alternative applies to soils contaminated with metals, semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs) and pesticides. The mass analysis of these constituents may be compared to 10 times the GA PMC, or SPLP analysis may be compared to 10 times the GWPC if the following conditions are met: 1) the release area is within 25 feet from the nearest legal boundary; 2) no non-aqueous phase liquids are present; and 3) the water table is at least 15 feet above the surface of the bedrock. All of the aforementioned conditions are met at the site and this option is self-implementing, except that this option as stated is not available to any contaminant identified in a 25-foot boundary along the downgradient property boundary.

RCSA Section 22a-133k-2(c)(2)(D) is a self-implementing option in GB ground-water classification areas. For this alternative to apply to the Middle School Site, the ground-water classification for site would need to be changed from GAA-impaired to GB. This alternative allows for polluted soils above the seasonal high water table to be compared 10 times the GWPC provided that no non-aqueous phase liquids are present. Note that the RSRs state total petroleum hydrocarbons (TPH) are exempt from this option; however, the CTDEP has issued a fact sheet since the enactment of the RSRs indicating ETPH is applicable for this option.

RCSA Section 22a-133k-2(c)(4)(B) indicates the PMC does not apply to environmentally isolated soils provided an ELUR is in effect with respect to the subject parcel or portion which the ELUR ensures that such soil will not be exposed to infiltration of soil water due to, among other things, demolition of the building. Environmentally isolated soils means soils that are 1) beneath a building or beneath another existing and permanent structure which the Commissioner has determined would prevent migration of pollutants; 2) not a continuing source; 3) not polluted with VOCs (if so, meet concentrations have been reduced to the maximum extent prudent); and above the seasonal low water-table.

RCSA Section 22a-133k-2(d)(4) identifies requirements for applying an alternative dilution or dilution attenuation factor for GA areas. This alternative soil criterion indicates the commissioner may approve an alternative dilution or dilution attenuation factor for GA areas, provided that it is demonstrated to the Commissioner’s satisfaction that application of the dilution factor will ensure the release will not degrade ground-water quality and thereby prevent the achievement of the applicable ground-water remediation standards.

RCSA Section 22a-133k-2(d)(6) identifies requirements for applying an alternative dilution or dilution attenuation factor for GB areas. This alternative soil criterion indicates the commissioner may approve an alternative dilution or dilution attenuation factor for GB areas, provided that it is demonstrated to the Commissioner’s satisfaction that application of the dilution factor will ensure that the soil water at such release area will not cause the ground water at the nearest downgradient property boundary to exceed the GWPC for such substance.

RCSA Section 22a-133k-2(f)(1) is a variance which would require a written request by the owner of the subject parcel and Commissioner approval. This variance is referred to as the widespread polluted fill variance. The variance indicates that the PMC does not apply if the following conditions are met: 1) geographically extensive polluted fill is present at and in the vicinity of the subject parcel; 2) the fill is not polluted with VOCs (this has been clarified by the CTDEP that VOCs can be separated, but must meet the PMC); 3) the fill is not affecting, and will not affect the quality of an existing or potential public water supply; 4) concentrations of fill meet applicable DEC; 5) the placement of fill was not prohibited by law at the time of filling; and 6) the person requesting the variance did not place the fill on the subject parcel. In addition, the Commissioner may consider in granting or denying the request the following: 1) the cost of compliance with the PMC; 2) how extensive the fill is and what relative proportion occurs on the subject parcel; 3) and whether the person requesting the variance is affiliated with any person responsible for placement of the fill through indirect or direct familial relationship, or an contractual, corporate or financial relationship other than that by which such person's interest in such parcel is to be conveyed or financed.

Engineered Control

- RCSA Section 22a-133k-2(f)(2)(A);

RCSA Section 22a-133k-2(f)(2)(A) is a variance for the DEC and/or PMC. The variance requires an engineered control of polluted soils be implemented pursuant to conditions identified in the RSRs. Three of the conditions which may apply to the site include:

1) It is not technically practical to remediate soil at the release area;
2) The Commissioner in consultation with the Commissioner of the CTDPH has determined that removal of substances or substances from such release area would create an unacceptable risk to human health; and
3) The Commissioner has determined, after appropriate public notice has been provided and opportunity for public hearing, that an engineered control is acceptable because a) the cost for remediation of polluted soils is significantly greater than implementing a engineered control and conducting ground-water monitoring pursuant to the RSRs; and b) the significantly greater cost for remediation outweighs the risk to the environmental and human health if the engineered control fails to prevent mobilization of a substance or human exposure to such substance.

In general, the engineered control potentially applicable for the Middle School Site would require a design to physically isolate polluted soils and minimize migration of liquids through soil. The control would need to include a drainage system to limit erosion or damage of the control. The system would potentially require a cap constructed to have a permeability less than 10^{-6} centimeters per second, *unless otherwise authorized by the Commissioner*. Nonetheless, the control would require maintenance, ground-water monitoring and implementation of an ELUR.

3.0 FIELD INVESTIGATIONS

3.1 Supplemental Investigation Objectives

Field investigations were completed between July 23, 2004 and February 25, 2005 to address data gaps identified in April 16, 2004 "Supplemental Scope of Study, Former New Haven Water Company Property, Middle School Site Hamden, Connecticut" which was issued pursuant to Consent Order No, SRD-128. Investigation objectives of the additional investigations identified in the Supplemental Scope of Study included the following:

1) Further definition of the extent of waste materials;
2) Determination if bulk material (i.e., drums) are present in the waste fill;
3) Additional characterization of fill (northern berm and beneath tennis and basketball courts)
4) Characterization of halogenated VOC source area and resulting ground-water and potential surface-water pollution;
5) Characterization of polychlorinated biphenyl (PCB) source area and potential impacts to ground water;
6) Surface-water quality;
7) Quality of surficial material at the athletic field not covered by the soil cap;
8) Further evaluation of ETPH in ground water;
9) Further refinement of ground-water flow direction:

In addition to the above objectives identified in the 2004 Supplemental Scope of Study, the following additional objectives were identified as a result of the field investigation completed in 2004 and 2005:

1) Quality of surficial material east of the school which was not addressed by CTDEP interim remedial measures.
2) Assessment of the ground-water quality which flows off of the Middle School Site to the northern wetland corridor.

All field activities described below were completed in accordance with the July 2004 LBG Quality Assurance Project Plan (QAPP), and conditions identified in the August 9, 2004 CTDEP conditional approval letter for the QAPP.

3.2 Contaminants of Concern

An extensive evaluation of all soil and ground-water results was described in the April 2004 Supplemental Scope of Study. One of the primary purposes of the evaluation was to identify constituents of concern (COCs) to be further evaluated during the subsequent investigations. A list was provided to the CTDEP, and after review and discussions, an agreed upon list of COCs were identified. The following were identified as COCs of the fill material:

- VOCs;
- SVOCs;
- ETPH;
- pesticides;
- PCBs;
- antimony, arsenic, barium, beryllium, cadmium, copper, cyanide, hexavalent chromium, total chromium, lead, mercury, nickel, selenium, silver, zinc;
- cyanide;
- asbestos (if suspect asbestos containing materials are identified);
- dioxins and furans

All samples detected with PCBs above 1 mg/kg (milligram per kilogram) were additionally analyzed for SPLP PCBs. All samples detected with cyanide were also analyzed for SPLP cyanide. Approximately 30 percent of the total metals analyzed were additionally analyzed by SPLP. The samples to be analyzed were chosen after a qualitative and quantitative review of the data. The protocol is described in the conceptual site model (CSM) and is similar to the protocol used in the previous investigations.

In addition to the listed COCs above, the CTDEP required as part of the July 19, 2004 conditional approval letter for the Supplemental Scope of Study that ground-water samples were to be analyzed for landfill leachate parameters.

All samples were analyzed by York Analytical Laboratory (York) of Stratford, Connecticut. York is a Connecticut Department of Public Health certified laboratory.

3.3 Field Activities and Protocols

Field investigations were completed between May 3, 2004 and February 25, 2005. The investigations included the following:

- Drilling 200 test borings with use of a direct push drill rig or hollow stem auger;
- Hand auguring 39 surficial test borings;
- Installation of 20 Monitor Wells;
- Collection and analysis of 143 water samples from 44 monitor wells over four quarters of ground-water sampling;
- Collection and analyses of 995 soil samples for various constituents of concern;
- Collection of one surface water sample;
- Completion of detailed site geophysical investigation; and
- Excavation of three test pits.

Plate 1 shows the locations of all samples locations collected during the 2002 through 2005 RWA investigations.

3.3.1 Drilling of Soil Borings

Soil borings were drilled utilizing the direct push method or hollow stem auger, depending on materials encountered, depth of boring and purpose of soil boring. All soil borings were backfilled with cuttings until 4 ft bg. The top 4 feet of all soil borings were filled with either top soil brought from offsite, sand or grout/bentonite. All soil borings completed as monitor wells were drilled with use of the hollow stem auger.

The depth of soil borings varied. The vast majority of the soil borings drilled were completed for the purposes of characterization. In these instances, unless the wetland organic layer was encountered or refusal, the soil borings were drilled to 15 ft bg or at least 3 feet below the base of the visibly identified fill, whichever was deeper. Seven soil borings drilled immediately north of the tennis and basketball courts were only drilled to 4 feet. These soil borings were drilled for the purposes of characterizing the shallow cover material in that area; therefore, there was no need to extend all of the soil borings in the area. In cases where the wetland organic layer was encountered, drilling ceased at that point unless the boring was to be completed as a monitor well, or in two instances during the investigation of the halogenated VOC area (see discussion below). The drilling procedures for monitor wells are outlined in Section 3.3.2.

At the request of the CTDEP, two soil borings were completed through the wetland organic layer for the purposes of vertical characterization of halogenated VOC impacted materials. The drilling was completed by drilling down to the top of the wetland organic layer. The wetland organic layer was identified through visual inspection of split-spoon samples (protocol discussed below). With the 4 ¼-inch inner diameter augers left in place as a seal in the wetland organic layer, an approximate 3 ½-inch outer diameter steel pipe was spun down inside the auger to the wetland organic layer. Split-spoon samples were then collected; thereafter, a smaller 2.5 inch roller bit was drilled down to the depth of the split spoon and materials were washed up through the casing; thereafter the casing was spun down. This process of driving the split spoon, auguring and then spinning of the casing was continued until the end of the soil boring. At the completion of the boring, the steel pipe was slowly removed, while the boring was backfilled with a grout and bentonite mixture. This backfill process continued to approximately 2 feet above the base of the augers. The remaining backfill procedures were as described above.

Soil samples were collected continuously at each soil-boring location until completion. At soil borings drilled by the direct push method, soil and fill samples were collected utilizing a 2-inch outer diameter, 4-foot long steel Macrocore sampler containing an acetate liner. At soil borings drilled with the hollow stem auger, soil and fill samples were collected utilizing a 3-inch or 2-inch outer diameter (dependant on availability), 2-foot long split spoon. Split spoons were decontaminated before and between each use. Decontamination procedures include brushing with an Alconox wash and rinsing with deionized water.

Soil samples collected from split spoons and macro cores were placed into dedicated, sealed plastic bags. The resultant headspace within each plastic bag was screened for the presence VOCs with use of a photoionization detector (PID) that was calibrated to an isobutylene standard. Any soil samples collected for analyses were placed in a properly labeled laboratory-supplied container, and stored in a chilled cooler until delivery to the laboratory. All split-spoon and Macrocore samples were photographed and geologically logged. Geologic logs were completed for each boring and soils were logged in accordance with ASTM D 2488 and

ASTM D 2487. Appendix I contains geologic logs completed by LBG. This appendix also contains construction diagrams for each monitor well and descriptions of test pits (discussed below). Appendix II includes all laboratory reports and chain-of-custody forms for all samples (soil, ground-water and surface water) collected during the 2004 and 2005 investigation. Table 1 provides summarizes analytical testing for all soil and fill sampling.

3.3.2 Monitor Well Design and Installation

With the exception of PZ-1, all monitor wells were installed with hollow-stem augers. The wells were constructed of 2-inch diameter SCH 40 PVC and 10-slot screen. Monitor well screen settings that cross the water table measured 10 feet in length. A 5-foot screen length was used for monitor wells completed below the water table. Each monitor well was installed with 0.010-inch slotted, flush-joint PVC screen set from the bottom of the borehole to above the water table observed in the field. Two-inch diameter PVC casing was installed from the top of the screen to grade. The annular space in the vicinity of the well screen was filled with FilterSil No. 1 gravel pack. A 2-foot thick bentonite seal was placed 2 feet above the screen setting. Grout was then used for backfill from the top of the bentonite seal to approximately 2 ft bg. The monitor wells were completed with steel-cased road boxes set in cement. All the monitor wells are covered with watertight locking well caps. At the request of Hamden's Park and Recreation Department, the surface of two of the monitor wells (MW-23A and MW-13B) were completed below grade, and covered with soil and grass.

Monitor well PZ-1 was installed north of the Middle School Site in the northern wetland corridor. This monitor well (piezometer) was installed to assess any ground-water flowing off of the Middle School Site to the north. Because of access restriction (thick wooded areas, steep slopes and shallow moist wetland soils), it was decided to install a drive point piezometer with use of a slam pipe. The monitor well consists of a 1 foot long, 1 ¼-inch inner diameter, 10-slot carbon steel screen. The casing consists of 1 ¼-inch inner diameter galvanized steel pipe. The top of screen was set approximately 7.6 ft bg. The well was set with a concrete set protective steel box.

After the wells were installed, the top of the PVC casing/pipe and grade at each monitor well was surveyed by a licensed surveyor. Monitor wells were developed within one week of installation. A minimum of three volumes of water were removed from each well and development was deemed complete when the water was clear and normal hydraulic conductivity with the aquifer was restored. Purge water was contained at the Middle School Site in 55-gallon drums prior to offsite disposal. Construction details for all the monitor wells are shown in Appendix I and summarized in table 2.

3.3.3 Ground-Water Sampling

All ground-water samples were collected using the low-stress purging and sampling technique. In general, the sampling procedure entails the removal of ground water through a bladder pump, centrifugal pump or peristaltic pump at extremely low flow rates (example, 0.1 to 0.4 l/min (liter per minute), even lower rates for low permeable materials). The sample is collected once stabilization for three consecutive readings is achieved for the following parameter and variance: turbidity (10 percent for values greater than 1 NTU), dissolved oxygen (10 percent), specific conductance (3 percent), temperature (3 percent), pH (0.1 units) and oxygen reduction potential (10 millivolts). The methodology for this technique is outlined in the July 30, 1996 USEPA Region I, “Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells.”

Between May 3, 2004 and February 25, 2005, four rounds of water-quality testing were completed. Table 3 summarizes analytical testing for all ground-water and surface water sampling. Field sampling sheets are located in Appendix III.

3.4 Extent and Content of Fill

3.4.1 Geophysics

To further characterize the extent of fill and identify bulk metallic objects (i.e. underground storage tanks and drums) potentially buried at the site, a detailed geophysical investigation was completed between July 23, 2004 and August 16, 2004. The geophysical investigation was completed by Hager-Richter Geoscience, Inc. of Salem, New Hampshire. The investigation consisted of a frequency domain electromagnetic induction terrain conductivity survey (utilizing an EM31) followed by a ground penetrating radar (GPR) survey, which were completed in accessible portions of the Middle School Site. The EM31 survey was completed over a 10-foot grid pattern; this allowed for overlapping coverage. The GPR survey was used to define anomalous areas identified during the EM31 survey. The investigation is detailed in the

September 2004 report entitled “Geophysical Survey Hamden Middle School 550 Newhall Street Hamden, Connecticut” by Hager-Richter Geoscience, Inc (Appendix IV).

Understanding the primary purpose of the investigation was to identify locations of large buried metallic objects, Hager-Richter Geoscience, Inc. personnel recommended three locations for further investigation; which were identified with significant anomalies. In addition to identifying areas of subsurface anomalies, the geophysical investigation results (specifically conductivity results from the EM31 survey) provided insightful data in assessing the extent of various fill materials at the site. These results are incorporated into the CSM.

3.4.2 Test Pits

After review of the geophysical survey data, three locations were for test pits to be completed to investigate anomalies. On August 27, 2004, the three test pits were excavated with a standard backhoe by Fleet Environmental of Bethel, Connecticut. The test pits are identified as LBG-TP-9, LBG-TP-10 and LBG-TP-11 on plate 1. Cover material and fill material was separated onto plastic sheets. Each test pit was logged and photographed. At the completion of the excavation, materials were placed back in the hole up to 4 ft bg. All excess fill material was stored in roll offs for offsite disposal. Thereafter, the test pits were filled with the excavated cap material and clean fill brought offsite from Mesa Excavation and Paving from Bethany, Connecticut. All fill brought onsite was tested for the following constituents:

- Volatile Organic Compounds (VOCs) by EPA Method 8260 plus MTBE;
- Semi-Volatile Organic Compound (SVOCs) by EPA Method 8270 plus carbazole;
- ETPH (plus oil identification when applicable);
- Priority Pollutant Metals plus barium and hexavalent chromium;
- Pesticides by EPA Method 8081
- PCBs by EPA Method 8082; and
- Cyanide

The fill was shown to be free of all contaminants. The laboratory report and chain-of-custody form are presented in Appendix II. Note that no large bulk metallic objects were identified during the test pit investigation. However, significant amounts of cobbles, brick, asphalt and concrete were identified in each test pit. Hager-Richter Geoscience, Inc personnel indicated that it is reasonable to conclude these objects were responsible for the geophysical survey anomalies. Results of the test pit investigation are incorporated into the CSM.

3.4.3 Soil Borings

3.4.3.1 Northern and Southern Extent of Fill

To further refine the extent of fill at the Middle School Site, soil borings were drilled along the northern and southern property boundaries. Transects and/or clusters of soil borings were drilled along the northern and southern boundaries of the Middle School Site to refine the extent of fill. These transects and/or clusters are shown below:

Soil boring transects and/or clusters drilled to refine southern extent of fill.

- LBG-TB-118, LBG-TB-121, LBG-TB-199 and LBG-TB-200;
- LBG-TB-122, LBG-TB-125 and LBG-TB-130;
- LBG-TB-202 and LBG-TB-201;
- LBG-TB-170 and LBG-TB-173;
- LBG-TB-167;
- LBG-TB-168;
- LBG-TB-175;
- LBG-TB-169, LBG-TB-171 and LBG-TB-176; and
- LBG-TB0-172;

Soil boring transects and/or clusters drilled to refine northern extent of fill.

- LBG-TB-148, LBG-TB-151, LBG-TB-152; LBG-TB-153, LBG-TB-154;
- LBG-TB-131, LBG-TB-132, LBG-TB-133, LBG-TB-146, LBG-TB-161, and LBG-TB-162;
- LBG-TB-71, LBG-TB-111, LBG-TB-144 and LBG-MW-145;
- LBG-MW-18B, LBG-TB-69 and LBG-TB-140; and
- LBG-TB-66 and LBG-TB-157.

In addition, two soil borings were drilled in the backyards of the Hamden Housing Authority Properties located at 253-255 Morse Street and 249-251 Morse Street properties (LBG-TB-164 and LBG-TB-165). The intent of the soil borings were to initially identify the visible extent of fill and then to verify the extent of fill through laboratory analysis. Two soil samples were collected from all soil borings in which fill was not identified and analyzed for the COCs identified in Section 3.2.

If constituents were detected, additional soil borings were drilled along the transects, and the sampling process was repeated. The investigation stopped when no contaminants were identified in all samples or at the Middle School Site boundary, except in the location of the

RWA owned northern wetland corridor. Fill was identified to extend onto this northern wetland corridor parcel and investigations to characterize the extent of fill are ongoing.

3.4.3.2 Tennis and Basketball Courts

Four soil borings were drilled inside the tennis and basketball court areas for the purposes of gathering additional information concerning fill in these areas. The soil borings are identified as LBG-TB-47, LBG-TB-48, LBG-TB-90 and LBG-TB-91 on plate 1. All soil borings were drilled with use of a direct push drill rig. Soil borings were drilled pursuant to protocols identified in Section 3.3.1. Soil samples were collected from the following intervals for laboratory analyses:

1) 0 to 2 ft bg;
2) 2 to 4 ft bg;
3) 4 ft bg to 10 ft bg (only fill: no sample collected if fill was not encountered);
4) 10 ft bg to end of fill (only fill: no sample collected if fill was not encountered); and
5) Unconsolidated material underlying fill material.

Samples analyzed within the zones of fill described above were chosen based on the highest VOC measured with the PID. If no VOCs were detected, the samples were chosen based on field observations (i.e., discoloration, odor and/or texture). Samples were analyzed for the COCs identified in Section 3.2, as well as for thallium. This additional analysis was completed because thallium was initially considered a COC by CTDEP; however CTDEP removed thallium as a COC after revaluation of the data. This is documented in the October 6, 2004 CTDEP approval letter.

All samples were placed in laboratory approved containers, properly labeled and placed in a chilled cooler until pick up that day by the laboratory courier.

3.5 Extent of Soil Cap Placed on the Athletic Field

Initially, seven surficial soil samples were collected for analyses of COCs (Section 3.2) from a depth of 0 to 6-inches below grade along the berm area located north of the tennis courts and basketball courts. The sample locations are identified as LBG-TB-66 through LBG-TB-72. In addition to the surficial samples collected in this area, deeper soil borings were drilled to assess the quality and extent of fill material in this area. The purpose of the surficial sampling was to determine if materials in this area contained contaminants above the Residential Direct Exposure Criteria (RDEC). All of the initial samples were collected with either a clean stainless steel trowel or direct push rig and analyzed for COCs identified in Section 3.2. After review of the initial results, an additional 15 soil samples were collected from the surficial and deeper soils located north of the tennis and basketball courts and the area located immediately south of the northern wetland corridor. These samples are identified as LBG-TB-134 through LBG-TB-143, LBG-TB-157, LBG-TB-181, LBG-TB-182, LBG-TB-186 and LBG-TB-187 shown on plate 1.

3.6 Quality of Surficial Material Located East of Middle School that were not Addressed by CTDEP Emergency Remedial Measures

To assess the quality of surficial material located on the eastern portion of the Middle School Site, which were not addressed through previous CTDEP Emergency Remedial Measures, three surficial soil samples (LBG-TB-211, LBG-TB-212 and LBG-TB-213 on plate 1) were collected for analyses of COCs (section 3.2) from a depth of 0 to 6-inches below grade. Results of the investigation identified concentrations of polynuclear aromatic hydrocarbons (PAHs) above RDEC in the surficial soils. The investigation was expanded in two phases to characterize the extent of the PAHs in the surficial soils. In total, an additional 31 surficial samples (LBG-TB-214 through LBG-TB-244 on plate 1) were collected and analyzed for PAHs. All samples collected contained PAHs; however, the soils are well vegetated which prevents causal contact with the soils.

The results of this investigation are further detailed in the CSM below.

3.7 Surface-Water Quality

To evaluate potential impacts to surface water in the northern wetland corridor as a result of ground-water potentially discharging to this area from the Middle School Site; a sample of surface water was collected on December 22, 2004. This wetland area was identified to be dry during the summer and early fall of 2004. The surface-water sample was collected with a clean stainless steel bailer for analyses for the following COCs:

- VOCs by EPA Method 524.2;
- SVOCs (plus carbazole) by EPA Method 8270;
- ETPH (plus oil identification);

- Priority pollutant metals (modified by replacement of thallium for barium);
- Cyanide;
- Pesticides by EPA Method 8081; and
- PCBs by EPA Method 8082

The samples were placed in laboratory approved containers, properly labeled and placed in a chilled cooler until delivery to the laboratory.

3.8 Ground-Water Flow Direction

Thirteen additional monitor wells were completed on the Middle School Site. The newly installed onsite wells are shown on table 2 and Plate 1. In general, the wells were installed along the north-central portion, central portion, and southwestern portions of the Middle School Site. As shown on table 2, most of the wells were installed as deep and shallow pairs. Installation of the monitor wells followed protocols outlined in Section 3.3.2. The Middle School Site currently has 36 monitor wells installed by RWA on the Middle School site. In addition, one monitor well was installed in the northern wetland corridor; a deep and shallow couplet were installed on the southern portion of the western abutting SNET property; and two shallow and deep pairs were installed in right-of-way areas located on Morse Street and St. Mary’s Street.

Grade and top of casing for all wells were surveyed into the existing network by Gesick and Associates P.C. of Clinton, Connecticut. Gesick and Associates P.C. is a licensed surveyor. In addition, monitor wells located on the western abutting SNET property were also surveyed into the existing network.

Depth to water-level data collected from the onsite and offsite regional wells, and the aforementioned survey data were utilized to develop ground-water flow maps for Middle School Site and surrounding area. The results of the ground-water flow refinement are presented in the CSM below.

3.9 ETPH in Ground Water

Ground-water samples collected from the expanded onsite monitor well network, and analyzed for ETPH, were used to further evaluate the source of ETPH in the site ground water.

All ground-water samples were collected using protocols identified in section 3.3.3. Results of the investigation are discussed in the CSM.

3.10 Characterization of Halogenated VOCs

An extensive drilling investigation was completed in the area of LBG-TB-4 (west of basketball courts) to characterize halogenated VOCs detected in the soil boring during the 2002 field investigations. This source area investigation included the drilling of 41 soil borings and collection and analyses of 430 soil and fill samples for analyses of halogenated VOCs by EPA Method 8021B. Sample locations are identified as LBG-TB-49 through LBG-TB-65, LBG-TB-92 through LBG-TB-106, LBG-TB-123 through LBG-TB-129, LBG-TB-156, LBG-TB-158, LBG-TB-159, LBG-TB-163 and LBG-TB-210 shown on Plate 1. All soil borings were drilling and sampling collected pursuant to protocols identified in Section 3.3.1.

In general, the investigation was completed in iterative steps. A sample grid was initially set up surrounding LBG-TB-4. Soil samples were collected continuously at 2-foot intervals (unless zero recovery) until the completion of each soil boring for analyses of halogenated VOCs. After review of the data, the grid was expanded as necessary to characterize the extent of the release area. This process was continued until the release area was fully characterized pursuant to the RSRs.

In addition to the source area investigation, the onsite monitor network was expanded to further characterize VOC impacts. All wells installed as part of the ground-water flow evaluation (Section 3.8) were utilized to further characterize the extent of VOCs in the site ground water. To assess the occurrence of halogenated VOC flowing off of the Middle School Site, a deep and shallow couplet were installed on the southern portion of the western abutting SNET property (MW-24A and B); and two shallow and deep pairs were installed in right-of-way areas located on Morse Street (MW-26A and B) and St. Mary’s Street (MW-27A and B). Ground-water samples were collected from this expanded on and offsite monitor well network pursuant to protocols outlined in Section 3.3.3. In addition to these offsite wells, ground-water samples were also collected from Monitor Well H2001S, which is located on Morse Street, and was installed as part of the Olin Corporation investigation. All samples were analyzed for VOCs by EPA Method 524.2.

3.10.1 Soil-Vapor Sampling

Vinyl chloride was detected at a concentration of 93 ug/l during the October 1, 2004 sampling event in the newly installed shallow monitor well (LBG-MW-24A) on the SNET property. Depth to ground water in LBG-MW-24A is approximately 27 feet below grade; the vinyl chloride concentration in ground water is above the proposed RVC of 1.6 ug/l. Therefore, in addition to the above ground-water and soil investigations, soil-vapor samples were collected from residential parcels (319-21, 330, 331 and 335 Morse Street) which are located approximately downgradient of this detection. The sampling was completed to determine if soil-vapor concentrations beneath the residential parcels exceed RVC. All proposed soil-vapor sampling activities were approved by the CTDEP and documented in their February 2, 2005 approval letter.

Between January 8 and January 15, 2005, soil-vapor samples were collected from each of the aforementioned residential parcels. The soil-vapor samples were collected from an approximate ½-inch diameter borehole that was drilled through the basement concrete floor slabs of the residential structures. A $^{3}/_{8}$-inch or ½-inch diameter hole was driven into the soil to a depth of 1 to 2 feet below the surface of the concrete floor using a slam bar. Thereafter, a ¼-inch outer diameter stainless-steel probe was inserted into the hole and sealed at grade with a silicon gel to reduce/eliminate dilution and short-circuiting. The aforementioned stainless-steel probe consists of an approximate six-inch long perforated section on the end which was installed beneath the concrete slab. Tygon tubing was then inserted into the top of the stainless-steel probe and the insertion point was sealed with silicon gel.

Purging was completed such that a minimum of one volume of ambient air within the sample tube and borehole were removed. The purging was completed by inserting the Tygon tubing into a peristaltic pump. Once the sample point as sufficiently purged, the soil-vapor sample was extracted by connecting the Tygon tubing to a regulator attached to a six-liter Summa canister. The regulator was set to 0.1 liter per minute and the sample was then extracted. Once the sampling was completed, the samples were sent to York for analyses of VOCs by EPA Method TO-14. Once the sample results were received, letters describing the sampling process and results, which were reviewed and approved by the CTDEP, were sent to each homeowner. No exceedances of the RVC were identified, and the results of the sampling showed any vapor detected beneath the homes were at concentrations which did not present a health concern.

Results of the above investigation are discussed in the below CSM.

3.11 Characterization of PCBs

During the 2002 field investigations, PCBs were detected in soils located on the southwestern, south central and eastern portions of the Middle School Site. During this investigation, PCBs were detected above the laboratory detection limit in 11 of 105 samples; therefore, they were not believed to be widely spread throughout the site. Therefore, soil boring locations were proposed in these areas to characterize the extent of the detections. Soil samples were collected continuously at 2-foot intervals (unless zero recovery) until the completion of each soil boring for analyses of PCBs by EPA Method 8082. All soil borings were drilled and sampled pursuant to protocols identified in Section 3.3.1.

After review of the data, it was clear that the presence of PCBs in the soil and fill materials at the Middle School Site was more widespread than the 2002 data indicated. Therefore, a site wide sampling plan was developed to evaluate PCBs. Utilizing a similar sampling and drilling protocol as discussed above, samples were collected for analyses of PCBs from all areas of the site. The results of this expanded sampling network identified a “hot spot” of PCBs concentrations immediately west of the basketball courts (near LBG-TB-111, which is approximately 100 feet due north of the halogenated VOC area). Therefore, additional soil borings were drilled in this area to characterize the extent of the PCB “hot spot.” Again, similar drilling and sampling techniques were implemented. At the completion of the PCB additional investigations (including extent of fill investigation), a total of 107 soil borings were drilled or dug, in which 532 fill and soil samples were analyzed for PCBs during the 2004 and 2005 field investigations. In addition to the mass PCB analyses, all samples identified with concentrations of PCBs above 1 mg/kg were additionally analyzed for SPLP PCBs by EPA Method 8082.

In addition to the aforementioned PCB “hot spot” investigation, a monitor well (MW-25) was installed downgradient of this release area. This water-table well was installed using protocols identified in Section 3.3.2. Ground-water samples were collected from the entire Middle School Site network and analyzed for PCBs by EPA Method 8082. Ground-water sampling was completed pursuant to Section 3.3.3.

Results of the PCB investigation are incorporated into the below CSM.

4.0 CONCEPTUAL SITE MODEL

4.1 Statement of the Problem

Environmental investigations completed at the Middle School Site document the historic filling of this former wetland area. The sources of fill have been documented to consist of industrial waste, general construction debris and municipal/domestic waste. The lateral and vertical extent and primary make up of the bulk fill has been substantially documented during Environmental Site Investigations (ESI) completed in 2002, 2004 and 2005. A surficial cap was placed over the fill in the athletic field during 1995 and 1996. In addition, several emergency remedial measures were completed by the CTDEP to cover identified exposed fill exceeding a Connecticut Department of Public Health (CTDPH) determined action criteria on the remainder of the site. In addition, RWA completed interim remedial measures to cover and restrict access to exposed impacted materials identified during the 2004 investigations (north central portion of Middle School Site).

According to CTDEP Consent Order SRD-128, RWA shall complete the investigation and remediation of the Middle School Site. Pursuant to the consent order, investigations shall "determine the extent and degree of soil, surface water and ground water pollution resulting from the disposal of waste materials at the Site" (paragraph B.3.b.(1) of Consent Order No. SRD-128). As referenced in the aforementioned statement, this investigation is not required to characterize any contaminant which are the result of potential releases related to the operation of the onsite fuel oil underground storage tank (UST), associated UST piping, storm-water drainage system, structural and/or operation of the school or the soil cap placed on the athletic field. Note that while the investigations of the sources potentially related to the operation of the school were not a focus of the FIERA, many of the features are characterized through the investigation of the waste disposed of onsite.

While extensive environmental investigation have been completed to characterize the waste materials at the Middle School Site and the resultant contamination to ground water, surface water and underlying soils, several data gaps remained after the completion of the 2002 Environmental Investigations. These general data gaps were identified in the conceptual site model presented in the 2004 Supplemental Scope of Study, and are discussed in Section 3.1. Note the final two data gaps listed were identified after the submittal of the Supplemental Scope of Study. The data gaps were addressed as part of the 2004 and 2005 field investigations. The conceptual site model (CSM) below incorporates the findings of the 2004 and 2005 field investigations.

4.2 Evaluation of Existing Data

4.2.1 Physical Description

The approximate 23.9 acre Middle School Site (figure 1 and 2) consists of the following parcels:

- Hamden Middle School which is located at 550- 560 Newhall Street in Hamden Connecticut;
- The northern and western portion of the Hamden Community Center. This property is located at located at 496 Newhall Street in Hamden, Connecticut; and
- Two residential properties located at 251-253 Morse Street and 253-255 Morse Street in Hamden, Connecticut.

The Hamden Middle School consists of four interconnected brick and steel buildings which were constructed in 1956. Note that the southern middle school building is partially located on the Hamden Community Center property. Asphalt pavement covers portions of the property located to the east, north and west of the building. Entrance to the site is obtained from one of access ways located on Newhall Street. Tennis and basketball courts and several soccer fields (referenced as the Athletic Field) are located on the western portion of the property. The property maintains one 10,000-gallon fuel UST which is located beneath a paved area on the west central portion of the property. As stated above, the investigation of the UST and associated piping are not part of this Supplemental Scope of Study. The topography of the property ranges from 42 to 61 feet high sea level. The topography east of the middle school building slopes moderately downward to the east and northeast. The topography on the athletic field and western paved parking area is generally flat. A relatively steep raise in grade elevation of approximately 3 to 6 feet occurs on the southern property line in which the athletic field abuts the Morse Street Parcels. This berm is shown along all southerly abutting residential parcels except 251-253 Morse Street and 253-255 Morse Street (Hamden Housing Authority owned properties). A berm is also shown on the north-central portion of the property, near the northern wetland corridor. As expected, the northern wetland corridor, which is located north of this property, is at a lower elevation than the northern edge of the property.

As shown on figure 1, the portion of the Hamden Community Center located on the Middle School Site consists of paved and grass areas and portion of the northern rectangular brick building. This structure was reportedly constructed in 1917 (ref. 3). This facility maintains a 6,000-gallon fuel oil UST; however, it is located to the south of the Middle School Site. Access to this parcel is obtained from a paved asphalt entrance along Morse Street. A moderate downward slope to the east and north is located on the eastern portion of this parcel. A moderate downward slope to the north and northwest is shown on the northern portion of this parcel, while the southwestern portion of the parcel (parking and entrance area) is generally flat.

The approximate 1.4 acre residential parcels are located at 251-253 Morse Street and 253-255 Morse Street. These parcels consists of two residential structures, asphalt paved areas and open grass areas. A steel chain link fence surrounds the parcels. Asphalt paved entrances lead onto the parcels from Morse Street while an asphalt paved area is located on the northern portion of the parcels. The topography slopes moderately downward from the south to the north.

4.3 Site History

The Middle School Site is located in an area formerly known as the Highwood District. As with much of the Highwood District, most of the Middle School Site was filled during the development of the area. The filling of the Highwood District, and specifically Middle School Site, occurred over a long period of time, and consisted of several different filling events.

From the 1970s through 1990s, several environmental investigations were completed by the United States Environmental Protection Agency (USEPA) and CTDEP at the Hamden Middle School property. Remedies to address environmental concerns identified by these agencies were implemented in 1995 and 1996 by the Town of Hamden. Preliminary environmental work completed for the expansion of the Middle School in 2000 created a renewed environmental awareness with the CTDEP of the historic waste present at the school.

Excluding the approximate 1.4-acre parcel consisting of 249-251 Morse Street and 253-255 Morse Street (Hamden Housing Authority owned properties) and a portion of the Newhall Community Center, NHWC acquired the Middle School Site in 1900. NHWC sold an approximate 1.4 acre rectangular parcel located on the southeast portion of the Middle School Site to the Town of Hamden in 1924, while NHWC acquired the approximate 1 acre rectangular parcel that included the Hamden Housing Authority owned residential properties (249-251 Morse Street and 253-255 Morse Street). In 1947, NHWC sold approximately 6.2 acres of land to the Town of Hamden. This parcel abuts the community center, Newhall Street and Mill Rock Extension. NHWC sold the remaining portion of the Middle School Site to the Town of Hamden in 1950.

A summary of the environmental investigations completed at the Middle School Site and the historic filling and development of the Middle School Site and surrounding area is presented below. The summary of the historic filling and growth of the Highwood District was developed through review of historical maps, aerial photographs, materials available at Hamden Town Hall (aerial photographs, Sanborn maps, annual reports, tax assessor cards, etc. (ref. 4)), maps and literature reviewed at the Miller Historic Room in Town of Hamden Library, historic NHWC documents, Town of Hamden Sanitation Inspector Reports and communications provided by the CTDEP. Note that a description of regional and Middle School Site filling/development is discussed below. The history of the regional filling is pertinent because it presents potential sources and content of fill at the Middle School Site.

4.3.1 Filling and Development Summary of Middle School Site and Surrounding Area

The Highwood District area was settled in at least 1850. The 1850 map, located in Appendix V, shows this area to be sparsely developed with a stream extending from the wetlands that currently end on the northern boundary of the Hamden Middle School property. Historical maps presented in Appendix V show the 1850 stream located on the northeast portion of the Hamden Middle School property, extending through future locations of Rochford Field and Mill Rock Park and ending near the westerly edge of Prospect Court (figure 11 of Appendix V).

Moderate development was shown in the Highwood District from the mid to late 1800s (figures 1 through 3 of Appendix V). During the turn of the century, the area was utilized for farming (ref. 5). The United States Geological Survey (USGS) 1892 New Haven, Connecticut Quadrangle Map (Appendix V) shows a greater density of roads present, which more closely mirror the present road system of the area.

Wetlands remained a prominent feature in the Highwood District and their presence represented a significant breeding ground for mosquitoes (ref. 6). The large populations of mosquitoes in the area were identified as a contributing factor to an 1891 epidemic of malaria in the Town (ref. 6). During this period and through the turn of the century, the Highwood District was a disposal area for trash brought in from New Haven (ref. 5 and 7). This garbage was reportedly fed to swine (ref. 7). The dumping created a significant nuisance in the area; the odor of the garbage was noted to create a stench a mile in every direction of the disposal area. In addition to the dumping areas, sewage in this farming community was utilized as fertilizer (ref. 5). The dumping in the area continued through 1909 (ref. 8). To alleviate the disposal problems, the Town of Hamden Health Officer, along with several others, informed the New Haven Board of Health that due to numerous complaints concerning the disposal of garbage in the Town, no licenses would be issued after June 1, 1909. The 1909 Hamden Annual Report indicates that only two collectors were known to be bringing garbage into the town and those cases were to be dealt with (ref. 8).

Development of the Highwood District continued at a rapid pace through the early 1900s (ref. 9). In 1913, a section of Newhall Street between Auger and Morse Streets was hardened, with a sidewalk constructed along the west side (ref. 10). A 1914 map (figures 5 and 6 of Appendix V) of the area shows an increased density of dwellings. The map also shows areas of vegetation present on the northern side of Morse Street, approximately between Shelton Avenue and Wadsworth Street (figure 11 of Appendix V).

A moderate epidemic of typhoid fever occurred in the Highwood District in 1912 (ref. 10). To avoid the epidemic in 1913, the health officer distributed notices to every home in the Highwood District notifying them how to control the disease. The notice indicated that flies spread the disease and that they should be controlled by cleaning out privy vaults before hot weather arrives and should be regularly spreading ashes, crude carbolic acid and chloride of lime on it. Mosquitoes were also a problem of the area; the Hamden Health Officer reported in the 1913 Hamden Annual Report that he would try to have swamps near Newhall Street, Auger Street and Putnam Avenue drained and opened to sunlight (ref. 10).

During 1915, the State of Connecticut took an active role in controlling the mosquito population in the state by passing Chapter 264 of Public Acts of 1915. The legislation placed the problem of mosquito extermination in the hands of the Directors of The Connecticut Agriculture

Experiment Station giving almost unlimited powers to carry on surveys and field work, ditching, etc.; however, the legislation failed to provide funds for the act (ref. 11). During this time, the mosquito population remained a concern of town officials for the area.

In 1915, when Town officials learned of Winchester Repeating Arms looking for dump sites for the "rejected industrial refuse and the thousands of tons of clean cinders from the furnaces in the factories", the Town gave permission for the company to fill in a marshy tract near Goodrich Street and Saint Mary Street. The area was reported to have been filled in a period of a few years (ref. 6).

The Town of Hamden Health Officer proposed in 1915 to establish Town public dumping areas under the control of Town officials and requested citizens to report infringements of the ordinance pertaining to the dumping (ref. 11). The 1916 Hamden Annual Report indicates that strides were made with respect to mosquito control by filling an area near the corner of Saint Mary and Morse Streets (figure 6 of Appendix V). Also in 1916, the NHWC and Winchester Repeating Arms were engaged in eliminating the largest single malaria swamp breeding grounds in the Town of Hamden by draining a large tract of land. The location of the tract of land was not identified in the annual report (ref. 12).

During 1917, the Town of Hamden maintained a dump in the Highwood District area (ref. 13) which was located on Shelton Avenue between Morse and Goodrich Streets (figure 11 of Appendix V). Also in 1917, the Town of Hamden installed a drain near Saint Mary and Goodrich Streets to alleviate surface water ponding; the drain discharged into the far corner of the Newhall Street swamp (ref. 14). Other notable events included the partial construction of the current Newhall Community Center in 1917. The block surrounded by Edwards Street, Saint Mary Street, Morse Street and Goodrich Street was reportedly filled in by Winchester Repeating Arms during World War I (1914 – 1918) (ref. 15). In 1919, Morse, Saint Mary and Edwards Streets were raised and sewer lines were installed, presumable when filling was completed in this area (ref. 16 and figure 7 of Appendix V)). Also in 1919, at the request of the Town Health Authorities, NHWC started clearing the approximate 30-acre Newhall Street Swamp. The clearing was requested because Town Health Authorities indicated the swamp was responsible for a great deal of malaria in the area. NHWC agreed to clear the brush and reopen the main drainage ditch to it (ref. 17).

By 1919, a significant amount of filling had already occurred in the Highwood District.

Areas of documented fill occurred throughout the entire region through the construction of roads, public and private dumping grounds and planned filling areas. The stream identified in the 1850 and 1852 maps is not shown on maps, but remained as a swampy area north of Morse Street. The filling in of the Highwood District continued; however, as shown by the 1924 Sanborn Maps (Appendix V), structural development of the area was primarily complete with the exception of the areas surrounding the former 1850 stream. While roads were constructed on land crossing the former streams, no structures are identified on this land. The headwater area of the 1850 stream was part of a golf course used by Yale students during the early 1900s (ref. 15). It is unclear if any filling occurred during this period to make the land more suitable for this purposes.

By 1924, the southwestern portion of the Highwood District contained a high-density of structures. Excluding 249 - 251 and 253 - 255 Morse Street (Hamden Housing Authority owned properties), information contained in tax cards at Hamden Town Hall indicate all housing on the northern side of Morse Street which abuts the Hamden Middle School athletic field were constructed. Another highly developed area is the western side of Newhall Street, just north of Mill Rock (ref. 18).

By 1925, the swamp area near Newhall Street was identified as the Newhall Street dump by Walter Conner of NHWC in a January 1925 report. The dump was referenced to be operated by Winchester Repeating Arms (ref. 19). This is the first reference to filling of the Middle School Site identified during this investigation. The Town of Hamden Health Officer promoted dumping in wetlands as noted by conclusions in the 1925 Hamden Annual Report (ref. 20) which stated "The establishment of so-called dumps for wastes of all kinds would be far more sanitary and economical, in that such dumps can be located on waste land, swamps, etc., thereby eliminating breeding places and creating play-grounds and public parks, much needed in this community."

By 1933, development of the Highwood District is nearly complete (figure 7 of Appendix V). The only significant region not completely developed is the area of the former 1850 stream. By 1933, the road system south of Mill Rock was nearly identical to the current road system, with the exception of a missing section of Bryden Terrace. As shown in the 1934 aerial photograph (figure 8 of Appendix V), filling appears to have occurred in Rochford Field and on the eastern portion of the Hamden Middle School property. The 1934 photograph shows evidence of the stream or wetland area crossing from the school property toward future Rochford Field. It is completely filled by 1939 (figure 9 of Appendix V). Rochford Field was completed by 1939. The 1939 aerial photograph also shows some filling had occurred in the Mill Rock Park area. This aerial photograph shows no remnants of the 1850 stream east of Newhall Street. The 1940 aerial photograph is similar to the 1939 photograph (figure 10 of Appendix V). During this time period (1936), the spreading of oil on wetlands was utilized for the control of mosquitoes (ref. 21). It is unclear how long this practice persisted in Hamden, who was responsible for the application of the oils and if this practice was a recommendation for mosquito control by Connecticut Health and Agricultural departments. In addition, no documentation was identified by LBG as to which locations in Hamden this type of mosquito control was utilized.

During the 1935 time frame, materials identified by a Hamden resident (ref. 22) to have been disposed of at the Middle School Site included: shotgun shells, globs of black material identified as grinding lubricants and metallic residue from the reaming process of the gun barrels, empty and full 50-gallon drums of liquid and domestic waste. Note that the resident indicated that fluids from some of the full drums would seep out of the containers as they fell on the ground. The resident also recall the materials dumped behind the Hamden Community Center primarily consisted of household waste disposed of by the local residents. The resident further stated that houses along the north side of Morse Street were existing at the time and were built on solid ground. The resident also recalls an approximate 100 foot deep buffer between the houses and the “dump.” The residence’s recollection of the filling on the southern portion of the site matches conclusions identified in the 2002 LBG ESI for this area and is also supported by data gathered during the 2004 and 2005 ESI.

Other than on the Hamden Middle School property, the 1949 and 1951 aerial photograph (figures 13 and 14 of Appendix V) shows no evidence of new filling occurring in Highwood District. As discussed above, NHWC sold its remaining portion of the Middle School Site to the Town of Hamden in 1950. Prior to the start of construction of the school in 1955, the Hamden Middle School property was filled with industrial material from Winchester Repeating Arms and illegal dumping of domestic waste (refs. 23 and 24). However, predominant filing material up to the early 1950s consisted of the industrial waste from Winchester Repeating Arms (ref. 24). The Michel J. Whalen Middle School was constructed in 1955 (ref. 25). After the construction of the school, the primary fill at the Middle School Site consisted of construction/building debris with sands and silt, incinerator ash and burn pit ash from the school and domestic waste (ref. 26 through 32). Ash from the school was generated from the interior incinerator operated in 1957 (ref. 26) and an exterior incinerator/burn pit operated from 1958 until at least 1965 (ref. 27, 28, 29 and 30). The construction/building debris may have been deposited by the Town of Hamden Department of Public Works (ref. 25). The department promised they would bulldoze the rear of the school property and cover it with adequate dirt in 1957 (ref. 26).

As shown in 1963 aerial photographs (figure 17 of Appendix V), all filling in the Highwood district is complete, with the exception of the Middle School Site. Areas of dense vegetation remain along the boundaries of the Athletic Field, and filling still appears to be occurring along the north-central boundary of the property.

In December of 1970 (ref. 31), the condition of the athletic field was identified as “tennis courts uplifted, basketball court of broken blocks of concrete, stagnant water breeding unhealthy bacteria, and a dumping ground for piles of concrete and asphalt rubble.” This excerpt was taken from a letter written to Dr. Frank Yulo, the Superintendent of Hamden Public Schools, from the Michael J. Whalen Jr. High P.T.A., in February 17, 1971. Dumping of refuse was reported behind the Hamden Middle School property to have occurred as late as July 1971 (ref. 32). Filling activities continued behind the school through the late 1970s (ref. 33). Reportedly large amounts of "acidic soils" were removed from behind the school and replaced with approximately 100,000 yards of “clean fill” from the West Woods school site.

The 1980 aerial photograph (figure 19 of Appendix V) shows the Middle School Athletic Field to be completely cleared. A pond is evident on the northwestern portion of the Middle School Site. It appears that the pond identified in the 1980 aerial photograph is filled by 1991 (figure 21 of Appendix V). A minimum of 18-inches of gravel cover material was placed on the Hamden Middle School athletic field sometime between March and May of 1995 as part of a lead encapsulation project (ref. 34). A March 24, 1995 Hamden Planning and Zoning Department interoffice memorandum (ref. 35) concerning the proposed placement of the soil cap on the athletic field also involved the excavation and removal of fill material.

Digital files provided to LBG by Barakos-Landino Design Group show the 1991 and 1995 topographic surveys of the athletic field. The 1995 topographic survey was taken after the installation of the 18-inch gravel layer. A comparison of surveyed maps show this layer was actually thicker than 18-inches in several areas of the athletic field. The review also showed that this initial cap was placed over all areas of identified fill in the athletic field (within property boundary) with the exception of a narrow area on the southeastern portion of the site, the raised undeveloped area north of the tennis and basketball courts and a narrow area east of the tennis and basketball courts (Appendix VI). Note that the area east of the tennis court was mitigated through emergency remedial measures by the CTDEP in 2002, while the southeastern area coincides with an area mitigated through 2002 CTDEP emergency remedial measures (ref. 3).

As part of the 2004 field investigations, surficial materials north of the tennis and basketball courts were investigated. A narrow strip of surficial materials were identified to contain polynuclear aromatic hydrocarbons (PAHs) and/or metals above the RDEC. Because thick vegetation was not present in the areas exceeding the RDEC, RWA immediately enacted interim remedial measures to eliminate potential exposure of the materials. In general, the mitigation included the placement of a geomembrane layer, followed by the placement of a minimum 6-inch layer of top soil and/or gravel mixture. The membrane and fill were placed on materials which exceeded the RDEC located south of an existing fence separating the northern wetland corridor and Hamden Middle School. Areas outside of the roadway immediately abutting the tennis and basketball courts were also seeded with grass. A small portion of the area located north of the fence is identified as part of the Middle School Site. This area is densely wooded. Surficial materials which exceeded the RDEC located immediately north of this fence were addressed through the installation of a second, 8-foot high galvanized steel fence. This second fence was installed to restrict access to these surficial materials.

The above area identified with the “18-inches” of gravel coincides well with an area described as “limits of earthwork” on an August 25, 1995 Barakos-Landino Design Group map entitled “Grading/Utility/Sec Plan.” The “limits of earthwork” extend to the western, southern and northwestern property boundaries. The eastern “earthwork” boundary coincides with the rear asphalt pavement of the school and the fence located on the southeastern portion of the athletic field. The northeastern limit of the “earthwork” coincides with the undeveloped raised area north of the tennis and basketball courts.

Approximately one year after the installation of the initial soil cap, a minimum 6-inches of top soil was placed throughout the athletic field in 1996 (refs. 36 and 37). Prior to the placement of top soil, additional gravel was placed on the athletic field to account for settling of the initial “18-inch” gravel cap (ref. 38). Note that no as-built drawing has been identified for the soil cap covering the athletic field.

4.3.2 Investigation History at Middle School Site

The list below presents a chronology of events and historic environmental investigations and actions for the Hamden Middle School property. This list was partially generated from information on file at the CTDEP and contained in the 2002 Phase I ESA (ref. 3). The results on these investigations identified the presence of metals, semi-volatile organic compounds (SVOCs), VOCs and total petroleum hydrocarbons in the subsurface material of the athletic field. Of these constituents, various metals, SVOCs and total petroleum hydrocarbons were identified above the CTDEP RSRs RDEC and GA PMC. The results of the available analytical data from environmental investigations are presented in Appendix VII and tables of this report.

1979 Local resident notifies Quinnipiac Health District of sunken areas on the playing field and history as disposal area.

1979 CTDEP collects two soil samples; locations and results were not identified for review.

1985 CTDEP completes Preliminary Assessment (PA) for Michael Whalen Jr. High School. Black material found on athletic field behind school. PA results identify metals in shallow soils.

1987 USEPA Site Discovery. Site added to CERCLIS List, No. CTD98254435.

1987 Site added to State Inventory of Hazardous Waste Disposal Sites.

1989 NUS corporation, on behalf of the USEPA conducts site investigation (SI) in which 11 shallow soil samples are collected between 0.5 and 1.5 ft bg (feet below grade) and analyzed for priority pollutant metals and VOCs. The results identified arsenic, lead and antimony above the CTDEP RDEC. Halogenated VOCs (1,1,1-trichloroethane (TCA), tetrachloroethylene (PCE) and 1,1,2,2-tetrachoroethane) are identified in the shallow soils on the central and northwest portion of the Athletic Field.

1991 Final USEPA SI completed. Report indicates that field area was used for community dumping for several years between 1940s and 1950. Local health department officials allege this was a disposal area of old batteries by the Winchester Repeating Arms.

1991 Roy F. Weston, on behalf of the USEPA conducts shallow soil investigation. Twenty (20) shallow soil samples were collected and analyzed for nickel, lead, chromium, mercury, SVOCs and VOCs. The results identify lead above the CTDEP RDEC (not promulgated at that time).

1992 Connecticut Department of Health Services (DOHS) letter to Quinnipiac Valley Health District states if athletic fields are kept grass-covered, they are safe for use. The DOHS used EPA lead exposure model assuming a concentration of 1,600 parts per million (ppm) and children would be exposed 4-hours a day.

1992 USEPA determines that Removal Action is not appropriate because *"the amount, quantity, or concentration released does not warrant Federal response."*

1993 CTDEP recommends the Town of Hamden to complete an environmental investigation at the school property. The Town retains HRP to conduct soil sampling for possible addition at school. Six samples were collected from 0 to 6 inches and four samples from 30 to 36 inches below grade. Lead detections ranged from 11.7 ppm to 5,680 ppm. Black ash-like material with traces of brick/wood pulp or cinders identified within the top 36 inches.

1993 HRP conducts shallow soil investigation in which 40 shallow soil samples were collected and analyzed for lead and/or leachable lead. The results identify lead above the CTDEP RDEC and GA PMC (not promulgated at that time).

1994 CTDEP receives anonymous complaint about landfill adjacent to Hamden Middle School. The complaint states that it is common knowledge that ammunition, radioactive waste, and other waste are buried in landfill behind school. Rochford Field identified with similar problem.

1994 USEPA Final Site Inspection Prioritization (SIP) completed. SIP states recent excavation to install an elevator at the school exposed domestic waste below the ground surface.

1995 CTDEP Water Bureau receives call from former athletic coach recalling that standing "black water with unnatural characteristics" was present in the ball field. Athletic coach sent letter to CTDEP showing location of standing black water at the northwest corner of the athletic field.

1995 Cap material placed on athletic field. Cap consisted of a minimum of 18-inches of gravel and was placed by United Excavating for Town of Hamden.

1996 Minimum of additional 6-inches of top-soil placed over athletic field by Furrey, Inc. for Town of Hamden.

2000 Phase I ESA completed by Town of Hamden Board of Education by Facility Support Services (FSS). The ESA noted the historical filling at the school.

2000 FSS conducts subsurface investigation in which 15 soil borings are drilled to depth ranging between 17 and 36.5 ft bg. Fill material was identified at depth starting at 2 and 3 ft bg, and extending to depths ranging from 7 to 26 ft bg. Forty-four (44) soil samples are collected and analyzed for total and TCLP metals, extractable total petroleum hydrocarbon, semi-VOCs (SVOCs) and VOCs. The results of the investigation identified concentrations of various metals, SVOCs and extractable total petroleum hydrocarbon (ETPH) above the RDEC and GA PMC.

2000 FSS conducts investigation in which 23 soil-vapor samples are collected from beneath the school foundation and analyzed for methane, hydrogen sulfide and/or VOCs. The results identified methane beneath the boiler room in two locations above the lower explosion limit. The Phase II and subsequent investigations included the collection of soil-vapor samples from beneath the floor of the school during October, November and December 2000. As a result of the soil-vapor investigations, the Town of Hamden installed methane monitoring and ventilation equipment to address this area of concern.

2000 CTDEP collects 10 soil-vapor samples from beneath the Middle School. The samples identify low level aromatic hydrocarbons and methane.

2000 Emergency remedial measures were completed, which included installation of geotextile and earthen caps at three areas surrounding the school. The areas consisted of approximately 120,000 square feet.

2001 CTDEP supervised the drilling of 26 soil borings to a depth of 4 ft bg throughout the school athletic field. Twenty-six (26) surficial samples were collected from these borings at a depth of 0 to 6 inches below grade. The samples were analyzed for priority pollutant metals (PPM), barium and SVOCs. The results showed no exceedances of criteria in the CTDEP RSRs. Fill material was identified at 7 of the 26 soil boring locations. The results of this investigation showed that the depth of the “cap” at the athletic field ranged from approximately 1.5 ft bg to at least 4 ft bg.

2001 CTDEP collects 39 shallow (0-3 inch bg) soil samples from the southeastern portion of the athletic field. The results of this shallow soil investigation identified concentrations of arsenic, lead and SVOCs above criteria in the CTDEP RSRs on the southeastern portion of the athletic field and around the tennis courts. Emergency remedial measures were initiated and included fencing the southeastern area and covering this area with wood chips.

2001 CTDEP issued an Administrative Order to the RWA, Olin Corporation, Town of Hamden and the State of Connecticut Board of Education on July 10, 2001, which requires the investigation and remediation of the Middle School Site, the town-owned Rochford Field and Annex, and several areas which have been developed for residential use.

2001 The Town of Hamden contracted Haley & Aldrich to complete a Phase I ESA of the Middle School Site, the town-owned recreational properties and residential properties in the Newhall area.

2002 Haley & Aldrich draft ESA issued January 2002. As part of the ESA, six test pits were completed in August 2001 at the Middle School Site under the supervision of Haley & Aldrich. Fill material was encountered in all of the test pits and the top of fill was observed at 2.5 ft bg to at least 7.3 ft bg. The fill material was observed to contain various industrial and domestic wastes.

2002 LBG completes extensive environmental site investigation of Middle School Site on behalf of RWA. Investigation is completed on a voluntary basis. Results of the investigation are documented in "Phase III Environmental Site (Consent Order was not signed) Investigation, Former New Haven Water Company Property, Hamden, Connecticut" Consent Order No, SRD-128", submitted in December 2002.

2003 Consent order is accepted as a final decision in Order No. SRD-128 pursuant to RCSA 22a-3a-6(1)(2) on April 16, 2003.

2003 Compliance monitoring was completed between April 2003 and February 2004 by LBG on behalf of RWA. Ground-water has continued on a quarterly basis through February 2005. Ground-water results show generally consistency in 2002 ground-water quality results, with exception of a decline in volatile organic compound (VOC) concentrations observed on the southwestern portion of the Middle School Site.

2003 Pursuant to Consent Order No. SRD-128, quarterly progress reports are submitted to the CTDEP by LBG on behalf of RWA. The reports were submitted on a quarterly basis between June 2003 and March 2004. In addition to the quarterly reports, maps depicting the regional potentiometric surfaces are submitted to the CTDEP. The maps show regional ground-water flow is generally flowing to the west/southwest.

2004 In January 2004, the CTDPH issues final public health assessment (ref. 39) for Hamden Middle School. The report states "It must be emphasized that existing surface soils which were added as part of capping of the field have been tested and are not contaminated[1/]. The athletic field at the Hamden Middle School was evaluated previously in a health consultation (ATSDR 2001) and was found to present no public health threat, as long as digging through the soil cap did not occur." 1/ *"The athletic field has a covering of clean soil which ranges in depth from approximately 2 feet to four feet."*

2004 LBG, on behalf of RWA, submits Supplemental Scope of Study to CTDEP. The Supplemental Scope of Study provides a detailed work plan to address data gaps identified in site CSM.

2004 CTDEP issues conditional approval of RWA Supplemental Scope of Study.

2004-2005 LBG, on behalf of RWA, completes extensive environmental investigations pursuant to the CTDEP conditionally approved Supplemental Scope of Study and subsequent approved/conditional approval addendum modifications. The investigation addresses all data gaps identified in the CSM.

4.4 Evaluation of Environmental Investigation Results

Little is known by LBG concerning quality assurance (QA) and quality control (QC) measures of the historic investigations completed by other firms. Therefore, LBG does not attest to the validity of the sample results discussed below.

4.4.1 Environmental Investigations Prior to Placement of Soil Cap in 1995 and 1996

Plate 2 shows the sampling locations for the following three environmental investigations that occurred prior to the placement of the soil cap in 1995 and 1996. Sample results are presented in Appendix VII.

- "Final Screening Site Inspection Report, Newhall Street Field, Hamden, Connecticut", dated July 23, 1991 and completed by NUS Corporation on Behalf of the USEPA;
- "Removal of Preliminary Assessment/Site Investigation (PA/SI) for the Newhall Street Field", dated August 1991 and completed by Roy F. Weston on behalf of USEPA; and
- "Evaluation of Newhall Street Screening Study and Recommendations for Subsequent Sample Collection/Analyses" dated May 1993 and completed by HRP Associated on behalf of the Town of Hamden.

4.4.1.1 1991 NUS Corporation Investigation

The eleven (11) soil samples collected as part of the 1991 NUS Corporation (ref. 40) environmental investigation were analyzed for priority pollutant metals (PPM) and VOCs. All samples were collected between 0.5 and 1.5 ft bg in November of 1989. The samples were collected from the central and northwest portion of the athletic field. Antimony, arsenic and/or lead were detected in four samples above the current RDEC. While arsenic was detected above the RDEC in three of the samples, the concentrations were generally low with a peak concentration of only 18.5 parts per million (ppm). The soil samples collected from the central portion of the athletic field (NU04 and NU12) generally contained the highest concentration of all inorganics analyzed, with elevated concentrations of zinc, copper, antimony, lead, manganese, nickel, barium and chromium detected in the samples. The samples collected from the northwest portion of the site generally consisted of low concentration of inorganics.

Chloroform was detected at 2 parts per billion (ppb) in three soil samples. The samples were collected from the central and northwest portion of the site.

TCA, TCE and/or 1,1,2,2-tetrachoroethane were detected at relatively low concentrations in NU8, NU10, NU11 and NU12. Concentrations of the total halogenated VOCs ranged from 5 ppb to 37 ppb. The detections, if accurate, would indicate halogenated VOCs were present in the shallow soils in the central and northwestern portions of the parcel. Note that the presence of the parent halogenated VOCs (TCA and TCE) and detection of no significant breakdown constituents would suggest this release was relatively recent to the time of the investigation. The detection of these halogenated VOCs at these general locations was not confirmed during the 2002 through 2005 environmental investigations completed by LBG. It is difficult to understand why these halogenated VOC detections, which were identified in nearly all regions sampled in the athletic field, would not be identified in any of the ground-water or soil samples collected from those locations during the 2002 ESI and subsequent 2004 and 2005 ESI. Therefore, these results are viewed with significant skepticism.

4.4.1.2 1991 Roy F. Weston Investigation

Twenty (20) shallow soil samples were collected and analyzed for nickel, lead, chromium, mercury, iron, SVOCs and VOCs during the 1991 Roy F. Weston (Weston) environmental investigation (ref. 41). Note that not all samples were analyzed for each of the aforementioned inorganics. The samples were all collected from 0 to 3 inches below grade. *No VOCs or SVOCs were detected above the laboratory detection limit.* These samples were collected throughout the athletic field. These results contradict the VOC results identified in the 1989 NUS Corporation investigation.

Lead was detected in 11 of the 19 samples analyzed (Appendix VII), ranging from 100 ppm to 1,600 ppm. Five of the aforementioned lead detections exceed the RDEC (not promulgated at that time). Generally higher concentrations of lead were detected in the samples collected from the southwestern, southeastern and northwestern portions of athletic field. Chromium and nickel were detected at 400 ppm and 200 ppm, respectively, from sample S006 which was collected from the northwest portion of the athletic field. Neither concentration exceeds the RDEC. No other notable detection was identified during the investigation.

4.4.1.3 1993 HRP Investigation

HRP completed two field investigations during 1993 at Hamden Middle School (ref. 42). The initial investigation occurred in April 1993 and included the collection and analyses of 40 shallow soil samples (this is pre-cap). The sampling event was primarily concentrated on the north-central and northeastern portion of the athletic field. The soil samples were analyzed for total lead, while three of the samples were analyzed for toxicity characteristic leaching procedure (TCLP) lead. The total lead results are shown on table 4 of Appendix VII. The locations of all forty samples are shown on plate 2. Of the samples reviewed, lead was sporadically detected throughout the athletic field. Eleven (11) of the 29 samples are above the RDEC (not yet promulgated). Of note, relatively high concentrations of lead (some above 500 mg/kg) were detected on the berm located on the north-central portion of the Middle School Site. This contradicts the analytical results identified for this area during the 2004 and 2005 ESI.

Samples HRP3, HRP5 and HRP38 were also analyzed by TCLP. The results identified for the TCLP lead in HRP3, HRP5 and HRP38 was of 13.2 mg/l, 0.06 mg/l and 8.08 mg/l, respectively. All of these results substantially exceed the current GA PMC of 0.015 mg/l. Note that these results do not correspond well with concentrations of SPLP lead analyses completed during the LBG 2002 ESI and subsequent 2004 and 2005 ESI. However, TCLP is known to be much more aggressive in leaching lead than SPLP.

The second field investigation occurred in October 1993 and included the collection of six soil samples from a depth of 0 to 6 inches and four soil samples from 30 to 36 inches below grade (ref. 3) (this is pre-cap). The samples were collected from the six sample locations located on the southern side of Hamden Middle School. Note that the precise location was not identified during the review; therefore, the samples are not identified in plate 2. Lead was detected in all samples and ranged from 11.7 ppm to 5,680 ppm. Black ash-like material with traces of brick/wood pulp or cinders identified within the top 36 inches.

4.4.2 Environmental Investigations Post Soil Cap and Prior to 2002 LBG Investigation

Plate 3 includes sample locations for the following environmental investigations that occurred after the placement of the soil cap in 1995 and 1996. Sample results are presented in Appendix VII.

- "Soil Vapor Survey of Hamden Middle School", dated November 2000 by Facility Support Services, LLC (FSS) on behalf of Town of Hamden;
- Environmental Soil Quality Assessment of Hamden Middle School", dated November 2000 by FSS on behalf of Town of Hamden; and
- CTDEP environmental investigation completed at Hamden Middle School in February 2001.

4.4.2.1 FSS Environmental Investigations

In July 2000, a Phase I Environmental Site Assessment (ESA) was completed at the Hamden Middle School property to address environmental concerns related to a proposed school expansion (ref. 43). The ESA was completed for the Town of Hamden Board of Education by Facility Support Services (FSS) of Hamden, Connecticut.

To address concerns identified in the ESA, a Phase II ESA (ref. 44) was completed by FSS in November 2000. The Phase II investigation included the drilling of 15 soil borings to depths ranging from 17 to 36.5 ft bg (B1 through B15 on plate 2). Fill material was identified at depth starting at 2 and 3 ft bg, and extending to depths ranging from 7 to 26 ft bg. Depth to water was reported to range from 10 to 19 ft bg.

Thirty-one soil samples were collected for analyses of SVOCs, VOCs, ETPH, and/or metals (20 metals, details shown in table 7 of Appendix VII). SVOCs (only polynuclear aromatic hydrocarbons (PAHs)) were detected in seven of the nine samples analyzed. The samples were collected from soil borings to the south, west and east of the school. No exceedances of the RDEC were identified in the analytical results for the shallow soil samples (0 to 2 feet below grade) collected from the athletic or other areas without pavement. Aromatic VOCs were detected at generally low concentrations in four of the 15 samples analyzed. All samples in which VOCs were detected appear to have been collected below the seasonal low water table.

Various metals were detected in all of the 31 samples analyzed. Of these samples, only antimony, arsenic and lead were identified above the RDEC. Barium was detected at concentrations greater than 100 ppm in 9 of the 31 samples. The elevated concentrations of metals were generally evenly distributed throughout the soil borings. Six of the soil samples were also analyzed for TCLP metals (same metal list as total analyses). Metals were detected above the GA PMC in all samples; the exceedances consisted of barium, cadmium, copper, nickel, lead, thallium and zinc.

The Phase II and subsequent investigations included the collection of soil-vapor samples from beneath the floor of the school during October, November and December 2000 (ref. 45). The results of the October and November samples identified concentrations of methane beneath the boiler room above the lower explosion level (LEL). The December 2000 soil-vapor results (ref. 41) showed that methane concentrations were well below the LEL. As a result of the soil-vapor investigations, the Town of Hamden installed methane monitoring and ventilation equipment to address this area of concern.

4.4.2.2 CTDEP Environmental Investigations

During February 2001, the CTDEP supervised the drilling of 26 soil borings to a depth of 4 ft bg throughout the school athletic field. Twenty-six (26) surficial samples were collected from these borings at a depth of 0 to 6 inches below grade. The samples were analyzed for priority pollutant metals (PPM), barium and SVOCs. The results of the LBG 2002 ESI and subsequent 2004 and 2005 ESI showed the most common constituents identified in the industrial waste material to exceed RSR criteria were PAHs, arsenic, antimony and lead. The results of the CTDEP investigation showed no exceedances of criteria in the CTDEP RSRs. Fill material was identified at 7 of the 26 soil boring locations. The results of this investigation showed that the thickness depth of the soil cap at the athletic field to range from approximately 1.5 ft bg to at least 4 ft bg. As shown on Plate 3, the CTDEP sample locations are generally evenly spaced throughout the athletic field.

A subsequent shallow soil investigation was completed by the CTDEP in response to an investigation completed by the USEPA at nearby residential properties. During this investigation, an additional thirty-nine (39) shallow (0-3 inch bg) soil samples were collected May 10, 2001. The samples were collected in the areas east of the tennis and basketball courts and on the southeastern portion of the athletic field. The results of this shallow soil investigation identified concentrations of arsenic, lead and SVOCs above criteria in the CTDEP RSRs on the southeastern portion of the athletic field and around the tennis courts. Emergency remedial measures were initiated and included fencing the southeastern area and covering this area with wood chips. The areas mitigated through emergency remedial measures coincide with areas identified by LBG that were not covered by the placement of the initial "18-inch" gravel cap. The only remaining area identified with fill in the athletic field which was identified through the review of the 1991 and 1995 survey not to have been covered by the "18-inch" soil cap is located on the northeast portion. This area is located north of the tennis and basketball courts. As discussed above, this area to the north of the tennis and basketball courts was investigated as part of the 2004 and 2005 ESI.

4.5 LBG 2002 through 2005 Environmental Site Investigations

Between July 15, 2002 and February 25, 2005, LBG has completed two extensive subsurface investigations and ten rounds of ground-water quality monitoring. The initial 2002 investigation was completed in accordance with the August 19, 2002, "Revised Work Plan Former New Haven Water Company Property Hamden, Connecticut", which was revised to incorporate comments of the CTDEP (ref. 46). The goal of the 2002 investigation was to evaluate environmental conditions and compare concentrations of regulated substances to the CTDEP RSRs. The investigation also responded, in part, to CTDEP Administrative Order No. SRD-128, which required the investigation and remediation of historical fill areas in the Newhall Street area of Hamden, Connecticut.

The 2004 and 2005 environmental investigations were completed in accordance with the April 16, 2004 LBG Supplemental Scope of Study, subsequent addendum modifications requests and CTDEP approval/conditional approvals identified in Section 1.0. The purpose of the investigations was to address data gaps identified in Section 3.1.

Field investigations completed between July 15, 2002 and February 25, 2005 included the following:

- Drilling 274 soil borings with us of a direct push drill rig or hollow stem auger;
- Hand auguring 39 surficial soil borings;
- Installation of 44 Monitor Wells;
- Collection and analysis of 273 water samples for various COCs from 47 monitor wells over ten quarters of ground-water sampling;
- Collection and analyses of 1,100 soil samples for various COCs;
- Collection of one surface water sample;

- Completion of detailed site geophysical investigation; and
- Excavation of 11 test pits.

Plate 1 shows the locations of all samples locations collected during the 2002 through 2005 RWA investigations. Tables 1 and 3 summarize laboratory testing for all soil and ground-water samples collected during the above referenced investigations.

Results of the above referenced investigations have been incorporated into the CSM.

4.5.1 Geology and Hydrogeology

4.5.1.1 Composition of Unconsolidated Materials

Site wide detailed geologic cross sections and cross section locations are shown in figure 3 through 7. Additional cross sections of select areas are shown on figures 8 through 11. The cross sections provide a good reference for viewing the complex mix of material deposited beneath the site. Additional detailed cross sections are shown in figures 3 through 13 of the 2002 ESI Report (ref. 47)

In general, the upper surficial material (primarily top 1 to 4 feet) consisted of a top soil and sand mixture. Much of this cover material was placed as part of remedial measures during 1995 and 1996. Immediately beneath the cover material is one of four primary materials. These materials are often found intermingled. The materials include:

1) Industrial Waste (IW): The primary materials of the industrial waste material (Identified as “black matrix fill” in prior report) are a black silt and/or slag. Numerous objects were encountered in this matrix; the most common were batteries, wood, ceramic and cardboard. Occasionally newspapers would be mixed in with this fill material. Newspapers were also identified as part of the domestic/municipal waste. Artifacts identified in this fill were often found with Winchester Repeating Arms labeling. The location and extent of this fill corresponds to areas known to be filled by Winchester Repeating Arms.

2) Construction debris (CD): Construction materials were generally found as part of a reddish-brown sand. Material most commonly associated with the construction/ building debris were stone blocks (generally rectangular, cobble size), bricks, wood, glass and plastics.

3) Domestic/municipal debris (DD): This is the most general category of fill at the site. Domestic/municipal waste was identified with silt to medium sand ranging in colors from gray to brown. Materials associated with the domestic/municipal waste included bottles, household products (such as margarine containers), shoes, cinders, electrical conduits, newspapers, etc. The materials used as identifiers were generally unique and not found in other areas or in quantity, thus potentially representing an individual's waste.

4) Visibly Observed Non-fill (VONF): Material primarily consists of reddish brown fine to medium grain sand with some silt. The nomenclature "visibly observed non-fill" includes materials such identified as the soil cap and underlying native materials, thus natural constituents, only. As referenced by the nomenclature, it was impossible to segregate the VONF in the field from the underlying native materials. This is because approximately 100,000 yards of "clean fill" (ref. 33) reportedly came from the West Woods school site. This fill is likely indistinguishable from native material. Nonetheless, the cross sections do include an approximate demarcation which separates the soil cap from underlying materials.

Fill was deposited on either a visibly observed non-fill layer (VONF) or a wetland organic layer. This wetland organic layer is identified as "organic silt and clay layer" on the cross sections in the 2002 LBG ESI report. The primary matrix of the organic wetland material is silt; however, it was also observed to contain some fine sand and/or clay. The organic materials observed were dense and primarily dark (generally grey to black) in color, with a musty wetland/organic type odor. Plate 4 shows the approximate extent and elevation of the wetland organic layer observed during the drilling investigations. The layer was identified to range in thickness from approximately 0.5 feet to 4 feet thick and was underlain by a fine to medium sand and silt material (also identified as VONF). Note that there is not a significant amount of data concerning the thickness of the wetland organic material; this is because the general drilling protocol was to cease drilling once the layer was encountered.

As shown, the wetland organic layer is present throughout much of the Middle School Site. The extent and orientation of the layer is consistent with the original stream and wetland system. In general, the elevation of the wetland materials is highest along the outer edges of the wetland organic layer, and lowest in the central and south-central portions of the site. On the east and central portion of the Middle School Site, the elevation of the top of this layer generally slopes downward to the southwest. The northwest edge of this layer appears to slope to the southeast, while the southwest portion of the layer appears to slope to the northeast. Note the northern portion of the wetland organic layer which abuts the northern wetland corridor is at a higher elevation than the central portion of the property.

Assuming the layer accurately depicts the top of the former wetlands, surface water would tend to accumulate in the central portion and south central portions of the Middle School Site. These central and south central portions of the site are at least 11 to 19.5 feet below the top of the wetland organic layer near the northern wetland corridor. This would indicate that surface water that entered the site from the east (location of historic stream), would drain to the south and southwest. Any surface water that would have flowed to the north would likely have been the result of spill over from ponding.

4.5.1.2 Cover Material

As discussed above, the Town of Hamden placed approximately two feet of cover material over the Hamden Middle School athletic field in 1995 and 1996 to address environmental concerns of the USEPA and CTDEP. As part of this investigation, soil samples were collected continuously in the shallow cover material throughout the Middle School Site to identify the thickness and extent of protective cover material. Plate 5 shows the extent and thickness of the protective cover material present at the Middle School Site above the fill identified during the field investigation. The thickness of the protective cover shown on this map represents the minimum depth to visibly identified fill materials potentially containing constituents above the RDEC. Note that the actual thickness of surficial materials that meet the RDEC would be at least as thick as the cover materials shown on this map.

In general, the athletic field has between 2 and 3 feet of this protective cover material. Locations beneath the tennis courts and the northwest portion of the athletic field were observed with a minimum of 1 foot of cover. The only locations on the athletic field observed with less than 1 foot of cover is an approximate 5,000 square foot area located on the northwestern portion of the Middle School Site.

Areas of interim remedial measures are also shown on plate 5. The areas completed under the direction of the CTDEP and the Town of Hamden consists of a geomembrane covered by minimum 6-inches of clean fill or wood chips.

During the 2004 and 2005 LBG investigations, surficial material north of tennis and basketball courts and an area located immediately south of the northern wetland corridor were identified with surficial materials that exceeded the RDEC for metals and/or SVOCs. Because thick vegetation was not present in much of this area exceeding the RDEC, RWA immediately enacted interim remedial measures to mitigate potential exposure risks. In general, the mitigation included the placement of a geomembrane layer, followed by the placement of a minimum 6-inch layer of top soil and/or gravel mixture. The membrane and fill were placed on materials which exceeded the RDEC located south of an existing fence separating the northern wetland corridor and Hamden Middle School. Areas outside of the roadway immediately abutting the tennis and basketball courts were also seeded with grass. A small portion of the area located north of the fence is identified as part of the Middle School Site. This area is densely wooded. Surficial materials which exceeded the RDEC located immediately north of this fence were addressed through the installation of a second, 8-foot high galvanized steel fence. This second fence was installed to restrict access to these surficial materials.

Plate 5 shows surficial materials located east of the school to contain constituents (PAHs) at grade above the RDEC; however the concentrations were below the CTDPH action level for interim remedial measures (ref. 2). Concentrations ranged from 1.1 to 7.6 times the RDEC for individual PAHs (Benzo(a)anthracene, Benzo(a)pyrene and Benzo[b]-fluoranthene). The action level is 10 times the RDEC.

The protective fill at the Newhall Community Center and Hamden Housing Authority is shown to range in thickness from approximately 0.5 feet to greater than 3 feet.

4.5.1.3 Extent and Thickness of Fill Materials

Plate 6 shows the approximate lateral extent of all types of fill observed at the site. In addition, the plate shows the lateral extent of all unconsolidated materials identified to contain COCs. As expected, all samples contain metals; therefore, the limits of fill containing COCs were evaluated comparing metal concentrations to the average concentration range of the elements found in uncontaminated soil in the Eastern United States (ref. 45)). As shown, a large portion of the Middle School Site is underlain with visibly identified fill; however, this fill is shown to be primarily contained on the site. However, unconsolidated materials which were identified to contain COCs extend to all of the Middle School Site boundaries with the exception 1) a narrow strip of land area located immediately north of 299 to 271 Morse Street; and 2) the southeastern portion of the Middle School Site.

The areas mapped as containing COCs on plate 6, which are outside the visually identified fill (industrial waste, construction debris and domestic debris) were generally identified to contain low concentrations of PAHs (all but two instances). The low level occurrence PAHs is not unusual, because PAHs are ubiquitous in soil (ref 1.). In fact, individual PAHs were detected in Artic soils above 150 ug/kg and total PAHs were detected in remote wooded areas of Wyoming at concentrations up to 210 ug/kg (ref. 1).

Visibly identified fill (industrial waste, construction debris and domestic debris) was identified to be as much as 22 feet thick. Plate 7 shows the thickest sections of fill are generally identified on the western portion of the property. Relatively thin sections of fill ranging from 0.6 feet to 8.8 feet were identified on the eastern portion of the property near Newhall Street.

The industrial waste fill is the predominant fill material located on the eastern and central portions of the property. Plate 8 shows the extent of the industrial waste overlaid on a 1951 aerial photograph. The 1951 photograph is utilized because the last parcel was sold by NHWC to the Town in 1950. The extent of this fill identified during the field investigation reasonably corresponds to locations shown to have been filled during this time period. Winchester Repeating Arms filling activities ceased by 1955, which corresponds to when the middle school was constructed. The spreading of the industrial waste fill may have occurred during future filling and grading activities. The 1951 aerial photograph clearly shows the extent of fill during that period on the Middle School Site; this extent of fill shown on the photograph corresponds closely to areas identified during the geophysical survey (Appendix IV) with higher conductive material. This correlation indicates the bulk of the industrial waste filling is represented by the extent of the mapped higher conductive material shown in Appendix IV. No areas of higher conductive materials were identified during the geophysical survey to extend beyond the industrial waste fill mapped on Plate 8. In addition, industrial waste fill was not identified to extend beyond the southern Middle School Site boundary. The only portion of the Hamden Housing Authority properties identified to contain industrial waste fill was a small section on the northern edge of 249-251 Morse Street. The only area in which the industrial waste fill appears to extend off of the site is to the northeast near Mill Rock extension and the northern wetland corridor. RWA has agreed to investigate the extent of fill in this northern wetland corridor. The investigation is ongoing.

Plate 9 shows construction debris was identified throughout the entire site. Note there are few soil borings in which construction debris was not identified; however, the soil borings were located in concentrated areas of drilling, and the construction debris was identified in several of the surrounding soil borings. While construction debris was widespread, it was the predominant fill encountered on the western portion of the Middle School Site. The materials on the western portion of the site may represent part of the approximate 100,000 yards of fill reportedly brought in from the West Wood school site. During excavation of test pit 3 (northwest portion of Middle School Site), an orange plastic caution tape (gas) was identified in the material along with wood and rectangular stone blocks. The condition and construction of the caution tape indicates a more recent filling event like that had reportedly occurred in the 1970s. Similar stone blocks were identified in Test Pits 1, 4 and 10.

Plate 10 shows scattered areas of domestic/municipal waste fill. These areas may be more extensive than shown because this fill was primarily identified during the excavation of test pits. Because of the nature of the materials associated with the fill (bottles, household products, shoes, cinders, electrical conduits, newspapers, etc.) it was difficult to identify in soil boring samples. Of note, all domestic debris fill areas are located on the edge of the Middle School Site; this make sense because it is more likely disposal of this type of waste would occur from easily assessable areas.

The largest area of the domestic/municipal waste fill is shown on the southeastern portion of the Middle School Site. Newspapers included in the waste and collected from test pit LBG-TP-5 identify the date as 1955. The newspapers were collected from 4 to 5.5 ft bg. 1955 corresponds with the approximate period that Winchester Repeating Arms ceased filling on the Middle School Site. This domestic waste in this area extends to the south and east as shown in test borings LBG-TB-42 through LBG-TB-45, LBG-TB-172, LBG-TB-174, LBG-TB-175 and test pit LBG-TP-9. This domestic/municipal waste fill in the area of LBG-Test Pit-5 and LBG-Test Pit-12 was deposited on top of the industrial waste fill. The filling in this area corresponds well with the resident that recalled the materials dumped behind the Hamden Community Center primarily consisted of household waste disposed of by the local residents (ref. 22).

Soil borings LBG-TB-42 through LBG-TB-46 were drilled on the top of a steep ridge along the southern property boundary (approximately 5 feet above the grade of the athletic field). As shown, a domestic/municipal waste was identified in the aforementioned borings; however, the soil matrix was not similar to that identified in LBG-Test Pit-5. Domestic/municipal waste has been shown to be located on several residential properties on the north side of Morse Street (ref. 47). Based on the aerial photographs shown in Appendix V, these houses and lots were fully developed before any filling occurred on the Middle School Site near their property lines. All of the houses located on the northern portion of Morse Street, which have a steep ridge at the rear edge of their properties, were developed in or before 1920.

It is likely that the filling that occurred on these residential properties spilled over onto the Middle School Site. The domestic fill material identified in test borings LBG-TB-42 through LBG-TB-46 along the ridge that straddles these residential properties is similar to that observed during the offsite investigation completed by the Olin Corporation on these properties. No domestic/municipal waste from that era (pre-1920) was identified in any other test borings or test pits completed on the Middle School Site. Waste such as industrial waste fill which was deposited in the mid to early-1920s to the early-1950s on the portion of the school site that is located in the vicinity of the homes was identified approximately 10 feet lower than the grade elevation of the these previously developed Morse Street residential properties. *Therefore, any filling activities that occurred on the Middle School Site could not have spilled over onto the Morse Street residential properties (259 through 279 Morse Street), as it would have had to spill uphill and on top of previously developed residential properties.* This conclusion matches the recollection of a former Hamden resident (ref. 22).

4.5.1.4 Composition of Bedrock

Bedrock beneath the Middle School Site is mapped as New Haven Arkose (ref. 48), which is characterized as reddish, poorly-sorted arkose. Arkose is a granular sedimentary rock consisting of quartz and feldspar or mica. Depth to bedrock is mapped to be approximately 40 feet on the eastern edge of the Middle School Site, and approximately 140 feet on the western edge (ref. 49). Bedrock was not encountered during the investigation.

4.5.2 Characteristics of Ground Water

4.5.2.1 Depth to Water Levels

Depth to ground-water levels were measured at the site from July 2001 through February 2005 (table 4). The depth to ground water at the site at the site during this period ranged between 3.74 and 21.25 feet below the top of the well casing (ft bc). Ground water is shallowest on the eastern edge of the Middle School Site where the topography is the lowest. Ground water is deepest on the southwestern portion of the athletic field.

Table 4 shows that ground-water levels were observed to be generally the lowest during the summer through fall, while the highest water levels are observed in spring. Depth to water levels remained relatively stable throughout the 3 ½-year recording period. Of the 24 wells which were installed during the 2002 ESI, the range of depth to water during the recording fluctuated from 0.79 feet (LBG-MW-10A) to 3.32 feet (LBG-MW-1). The maximum average change in seasonal water levels at the monitor wells located above the organic wetland material (LBG-MW-7A, LBG-MW-10A and LBG-MW-14A) was approximately 1 foot, whereas their deeper counterparts (LBG-MW-7B, LBG-MW-10B and LBG-MW-14B) changed a maximum average of approximately 2.6 feet. The seasonal fluctuation in the deeper wells more closely matched the average seasonal fluctuation (approximately 2.1 feet) of the monitor wells screened outside of the wetland organic layer.

4.5.2.2 Vertical Flow Direction and Magnitude

A downward flow direction has been shown consistently throughout the recording period in monitor well clusters LBG-MW-7, LBG-MW-10, LBG-MW-11, LBG-MW-14, LBG-MW-15, LBG-MW-18, LBG-MW-22 and LBG-MW-23. All of the screen setting on these shallow and deep monitor wells are separated by the wetland organic layer discussed above. In these seven clusters, the head difference, showing downward flow, ranged from 0.21 to 4.53 feet. The minimum downward flow gradient is shown in the MW-15 cluster, which is located close to the edge of the wetland organic layer. The magnitude of the downward flow gradient was shown to be greatest in the winter and spring period when the water levels were at their highest. While this is anticipated, the cause of the changes in seasonal head difference is not related to seasonal water-level fluctuations in the shallow well, but rather the seasonal water-level fluctuations in the deeper well. As discussed above, seasonal changes in water levels were more accentuated in the deeper wells than the shallow wells. This likely occurs because the wetland organic layer is not widespread and, therefore, the shallow ground water above the wetland organic layer is not as hydraulically connected to the regional aquifer.

LBG-MW-4 is located on the southeastern corner of the Middle School Site. A discontinuous portion of wetland organic layer is mapped in this area. This discontinuity of the layer in this area would explain why the head difference in the MW-4 cluster is minimal.

The head difference observed in well clusters outside of the organic wetland layer (LBG-MW-20, LBG-MW-21, LBG-MW-24, LBG-MW-26 and LBG-MW-27 cluster) were generally minimal throughout the recording period.

4.5.2.3 Potentiometric Surface

When creating the ground-water flow maps, water elevations from all wells screened in a similar depth interval were initially mapped (i.e. including monitor wells that were screened above the discontinuous wetland organic layer). The initial data collected during 2002 resulted in a radial flow pattern off of the athletic field region of the school site, as well as isolated areas of apparent mounds. The attempt at mapping of subsequent seasonal data also resulted in radial mounds; however, no consistency was shown in gradients and flow directions. Closer analysis showed that these mounds were, in fact, reflecting the higher heads supported by the localized fine-grained wetland organic layer. These higher heads (table 6) do not reflect the actual regional ground-water flow direction; chemical data from the wells show that there is no horizontal flow component from the regions where there are elevated heads above the wetland organic layer to adjacent locations where the layer does not exist.

A potentiometric map was then prepared utilizing the water elevations in the regional geologic material; the deeper wells of the clusters and the shallow wells where the fine-grained layer did not exist. This produced a uniform flow direction that was consistent with chemical patterns in the ground water. For the discussion below, LBG constructed two maps showing a detailed potentiometric surface for the immediate Middle School Site and a regional potentiometric surface. The detailed potentiometric surfaces maps (November 18, 2004 (plate 11) and October 1, 2004 (plate 12)) incorporate water elevations from a total of 24 onsite monitor wells and 12 offsite monitor wells. The offsite monitor wells incorporated into these maps are located on the western abutting SNET property and southwestern residential area. The regional potentiometric surface map (October 1, 2004 (plate 13)) also incorporates 24 onsite wells, and 24 offsite wells. The offsite wells include the aforementioned wells, in addition to wells located on Mill Rock Park, Rochford Field and in the eastern residential area.

While a more extensive regional ground-water database was collected in February 2005, the ground-water levels on the Middle School Site were significantly impacted by the wet conditions caused by snow melt. Therefore, the potentiometric maps were constructed using ground-water levels measured on October 1, 2004 and November 18, 2004. The table below summarizes local precipitation one week prior to collecting the water-levels.

Table 7
Precipitation Data from the Tweed New Haven Airport

Date	Precipitation (inches)	Date	Precipitation (inches)
9/24/04	0.00	11/11/04	0.00
9/25/04	0.00	11/12/04	0.69
9/26/04	0.00	11/13/04	0.19
9/27/04	0.01	11/15/04	0.00
9/28/04	2.32	11/16/04	0.00
9/29/04	0.70	11/17/04	0.00
9/30/04	0.03	11/18/04	0.00
10/1/04	0.01	11/19/04	0.00

The precipitation amounts identified above showed little impact on water-levels as they compare to historic measurements.

Plates 11 and 12 shows a detailed potentiometric surface for the Middle School Site on November 18 and October 1, 2004, respectively. As shown, ground-water flow at the Middle School Site is generally from the east to the west/southwest. A flow divide is present on the north-central portion of the site, in the immediate vicinity of the northern wetland corridor. It would appear a small portion of water entering the northeastern portion of the site would discharge to this corridor. The divide appears to occur within 60 feet of the northern site boundary. All ground water to the west of the northern wetland corridor, flows to the southwest.

The hydraulic gradients throughout the site on November 18 and October 1, 2004 are approximately 0.0013 ft/ft and 0.0016 ft/ft, respectively. The slightly steeper gradient shown on October 1, 2004 as compared to November 18, 2004 is likely attributed to the more notable precipitation the week prior to measuring the depth to water levels. Nonetheless, the overall site ground-water flow features are similar.

Plate 13 shows the regional potentiometric surface for October 1, 2004. The potentiometric contours shows that regional ground water generally flows from the east to the west/southwest. Near the Newhall Street community center, ground water is shown to flow to the northwest and then eventually discharging to the southwest. This is consistent with the topography and geology of the community center site. Note that the potentiometric contours on this map are presented at a greater interval than the detailed site map. This is because the hydraulic gradient off site is much larger than the hydraulic gradient on site. The hydraulic gradient east of the Middle School Site is 0.017 ft/ft, an order of magnitude larger than observed at the Middle School Site.

LBG has submitted maps of the regional potentiometric surface to the CTDEP for the various seasons of 2002 and 2003. A regional ground-water flow pattern similar to the October 1, 2004 pattern is shown on all these maps. Regional and the site ground-water flow were determined to flow from the east to the west/southwest.

4.5.3 Soil and Ground-Water Quality

As discussed, between 2002 and 2005, LBG completed extensive field investigations at the Middle School Site. Results from those investigations are discussed below.

4.5.3.1 Pesticides Overview

Low concentrations of pesticides were sporadically detected primarily in the shallow soils at the Middle School Site. None of the concentrations were identified above the RDEC, while one sample located next to the Middle School Site/northern wetland corridor boundary was identified above the applicable GA PMC. Pesticides detected in the site soils were shown not to be leaching at detectable concentrations to the site ground water. One pesticide, endrin aldehyde, was detected in one ground-water sample during compliance monitoring. Endrin aldehyde was not detected in the site soils. Review of the data suggests the detection in ground water was likely a false positive.

The source of low concentrations of pesticides in the site shallow soils is likely attributed to historic application. Pesticides have been sufficiently characterized and a further detailed investigation of pesticides is not warranted. Details of the investigation are discussed below.

4.5.3.1.1 Soil Quality

Table 8 and plate 14 present a summary of all detected pesticides. Low concentrations of pesticides were detected primarily in shallow soil samples collected from 19 of 81 soil borings/surficial sample locations. The detections consisted of 4,4'-DDD (DDD), 4,4'-DDT (DDT), 4,4'-DDE (DDE) and/or chlordane. The table below shows the pesticides were primarily detected in the industrial waste (IW) fill, construction debris (CD) fill and visibly observed non-fill (VONF). As shown, DDT is the most prevalent pesticide, occurring above laboratory detection limits in 21 detections out of 207 samples.

Table 9

Summary of Pesticide Occurrences

	Total Analyzed	Detections	Exceeds RDEC	Exceeds GA PMC and SPLP Pesticides Exceeds GWPC	Exceeds 10 Times GA PMC or SPLP Exceeds 10 Times GWPC	Exceeds GB PMC
4,4'-DDD	207	14	0	0	0	0
4,4'-DDE	207	12	0	0	0	0
4,4'-DDT	207	21	0	0	0	0
Chlordane	207	5	0	1	3	3
Total from VONF[1/]	115	16	0	1	3	3
Total from CD[2/]	16	5	0	0	0	0
Total from DD[3/]	4	0	0	0	0	0
Total from IW[4/]	48	5	0	0	0	0
Total from Combined Fill[5/]	69	10	0	0	0	0
Total	**207**	**26**	**0**	**1**	**3**	**3**

Note the 10 times the GA PMC does not apply to the pesticides detected from LBG-TB-182 because it is within 25 feet of the likely downgradient site boundary. SPLP was run on LBG-TB-182 and no constituents were identified; however, the analysis was performed after the holding time and the mass reanalysis showed no detections of pesticides; therefore, it is the only sample identified at the site above the applicable site PMC.

1/ Set consist of samples containing only VONF.
2/ Set consist of samples containing only CD fill or mix of CD and VONF.
3/ Set consist of samples containing only DD fill or mix of DD and VONF.
4/ Set consist of samples containing only IW fill or mix of IW and VONF.
5/ Set consist of samples containing any combination of visually identifiable fill (IW, CD and DD).

The vast majority of the pesticides detected were located within the athletic field and north of the athletic field near the northern wetland corridor. Pesticides were detected in only one location (LBG-TB-9) east of the school and none were detected south of the school (near the Hamden Housing Authority Property and Newhall Community Center).

Pesticides were primarily detected in the samples collected immediately below the soil cap and surficial soils located north of the tennis and basketball courts. The only deep detections of pesticides were identified at LBG-TB-23 at 18 to 20 ft bg (below seasonal low water-table) and LBG-TB-157 at 8 to 10 ft bg. The aforementioned saturated sample collected at LBG-TB-23 was identified with chlordane at a concentration of 511 ppb. Note that all pesticide detections were identified below the RDEC.

A GA PMC has not been established for DDD, DDT and DDE. While chlordane was detected in 4 of the 207 samples analyzed, it exceeded the GA PMC in three of the samples (LBG-TB-142, LBG-TB-157 and LBG-TB-182). All of the samples were re-analyzed for mass pesticides and additionally analyzed by SPLP pesticides. While the analyses were completed after the EPA Method identified hold times, the results of the mass analyses identified similar concentrations in LBG-TB-142 (183 ug/kg (first analysis) and 142 ug/kg (second analysis)) and LBG-TB-157 (77.7 ug/kg (first analysis) and 107 ug/kg (second analysis)). While the re-analysis was completed approximately four months after the sample was collected, the similar mass concentration results in LBG-TB-142 and LBG-TB-157 show no notable degradation or volatilization of the pesticide occurred. The SPLP pesticide analyses for LBG-TB-142 and LBG-TB-157 identified no pesticide concentrations above laboratory detection limits. It is reasonable to conclude that because the reanalyzed mass concentrations were similar to the initial analyses, and no pesticides were detected in the SPLP pesticide analyses, according to RCSA Special Circumstance 22a-133k-2(c)(2)(A), these samples are in compliance with the GA PMC.

The two mass reanalyses and SPLP analysis completed for sample LBG-TB-182 identified no concentrations of pesticides above the laboratory detection limit; therefore it is not technically appropriate to apply RCSA Section 22a-133k-2(c)(2)(A).

No other pesticides were identified in the soil. The source of the pesticides is unknown; however, these pesticides were commonly used historically for the control of insects. As identified in the historical summary, prior to the placement of the soil cap, standing water was typical in the athletic field, and therefore, would potentially be a good breeding ground for mosquitoes. The pesticides identified in the site soils tend to bind strongly to soils and slowly degrade. In addition, the pesticides detected in the site soils were commercially available and, therefore, may have been applied to control insects. This would explain why pesticides were primarily identified on the western portion of the Middle School Site.

4.5.3.1.2 Water Quality

The only pesticide detected in the 167 samples collected for analyses was endrin aldehyde (table 10). This constituent was detected in one sample collected on July 23, 2003 from LBG-MW-13 at a concentration of 0.015 ug/l. It was not detected in the previous samples collected in August 2002 or the subsequent five sampling events collected in October 2003 and February 2005. In addition, endrin aldehyde was not detected above laboratory detection limits during the soil investigation. Considering this was the only detection on the entire property for this constituent, it was not detected in any of the other sampling rounds and the extremely low detection limit for the analyses, it is reasonable to conclude this detection may be a false positive. A GWPC and SWPC have not been established for endrin aldehyde.

As discussed, none of the pesticides detected in the soils were detected in any of the ground-water samples collected for analysis. The absence of the pesticides detected in the site fill and soil (DDD, DDT, DDE and chlordane) in the site ground water would indicate these pesticides are not leaching to ground water at a detectable concentration.

4.5.3.2 Cyanide and Metals Overview

Thallium was not detected in the mass or SPLP soil analysis or in any of the ground water samples. Beryllium and selenium were sporadically detected at low concentration in the mass soil analyses, and were not detected during the SPLP or ground-water analyses. The aforementioned constituents have been shown not to be associated with the waste deposited at the Middle School Site, and should not be included in any subsequent sampling investigations.

While metals have been identified throughout all materials at the Middle School Site (metals naturally occur in soils), the source of elevated concentrations of metals is primarily associated with fill deposited at the site. Average mass concentrations of antimony, arsenic, lead, barium, copper, chromium, mercury, nickel and zinc in the visually identified fill materials (individual and combinations of IW, CD and DD) where detected at 5 to 31 times the average concentrations identified in the VONF. Lead, arsenic and antimony are the most prevalent metals identified above the RDEC.

Lead and antimony were the primary metals identified above the GA PMC. *Of these, only lead was detected in the site ground water above the GWPC and antimony was not identified above the laboratory detection limit.* The detections of lead in the site ground water above the GWPC were generally sporadic except at one location which was screened across saturated industrial waste fill located on the west-central portion of the site. This does indicate that for this site, the GA PMC does not correlate well with water-quality results.

While barium was only detected once above the GA PMC, it is clearly the primary inorganic constituent that has impacted ground water. The highest concentrations of barium in ground water are shown in locations of saturated industrial waste fill. Barium does appear to significantly sorb to the surrounding saturated materials, as evidence by the significantly lower concentrations shown in downgradient areas away from the industrial waste fill.

Metals and cyanide have been sufficiently characterized at the site and further investigations to solely characterize their presence are not warranted.

4.5.3.2.1 Total Cyanide and Total Metals Soil Quality

A total of 211 soil and fill samples were analyzed for PPM plus barium and hexavalent chromium, while 194 soil and fill samples were analyzed for cyanide. The aforementioned statistics exclude duplicate samples. Of the metals analyzed, only thallium was not detected. High occurrence of metals is anticipated because all naturally occur. Table 11 presents a summary of all detected total metals and cyanide.

As shown in table 12 below, no exceedances of the RDEC were identified for beryllium, cadmium, cyanide, hexavalent chromium, nickel, selenium, silver, thallium and zinc. Antimony, arsenic, barium, copper, lead and mercury were all detected at concentrations above the RDEC. Plate 15 summarizes the depth and locations of the detections and exceedances for these metals, and the types of material that were analyzed. Hexavalent chromium was detected in 6 of 211 samples, cyanide in detected in 18 of 194 samples and beryllium in just 22 of 211 samples.

Table 12

Summary of Mass Metal and Cyanide Occurrence and Regulatory Comparison

	Total Analyzed	Detections	Exceeds RDEC	Exceeds RDEC (0 to 4 ft bg)	Exceeds I/C DEC
Antimony	211	95	22	9	0
Arsenic	211	193	51	25	51
Barium	211	211	1	0	0
Beryllium	211	22	0	0	0
Cadmium	211	73	0	0	0
Copper	211	211	13	6	0
Cyanide	194	18	0	0	0
Hexavalent Chromium	211	6	0	0	0
Chromium	211	211	NA	NA	NA
Lead	211	211	57	30	39
Mercury	211	103	4	2	0
Nickel	211	211	0	0	0
Selenium	211	86	0	0	0
Silver	211	38	0	0	0
Thallium	211	0	0	0	0
Zinc	211	211	0	0	0
Total from VONF[1/]	120	120	17	15	12
Total from CD[2/]	15	15	7	5	6
Total from DD[3/]	4	4	3	3	3
Total from IW[4/]	47	47	25	9	22
Total from Combined Fill[5/]	91	91	54	23	48
Total	**211**	**211**	**71**	**38**	**60**

1/ Set consist of samples containing only VONF.
2/ Set consist of samples containing only CD fill or mix of CD and VONF.
3/ Set consist of samples containing only DD fill or mix of DD and VONF.
4/ Set consist of samples containing only IW fill or mix of IW and VONF.
5/ Set consist of samples containing any combination of visually identifiable fill (IW, CD and DD).

Barium was detected in all samples; however, only one of the samples exceeded the RDEC. Barium was identified at average concentrations in the industrial waste fill and construction debris fill at 244 mg/kg and 277 mg/kg, respectively. These are significantly higher average concentrations than identified in the visibly observed non-fill, which was 47 mg/kg.

Mercury was detected in 103 of 211 soil samples, while four of the samples exceeded the RDEC. All of the mercury soil samples that exceeded the RDEC were from samples that at least partially contained industrial waste. As shown in the table above, two of the four RDEC exceedances were identified within the top four feet of material. These shallow exceedances were located between 2 and 4 ft bg at LBG-TB-2 and LBG-TB-3, which are located approximately 60 feet east of the tennis courts and approximately 30 feet southwest of the basketball courts.

Copper was detected in all 211 soil and fill samples, while only 13 of the samples exceeded the RDEC. The copper RDEC exceedances were identified in all materials at the site. Average concentrations of copper identified in all fill materials (CD, DD and IW) was approximately an order magnitude higher than the average concentration identified in the VONF (1,691 mg/kg compared to 141 mg/kg, respectively).

Antimony was detected in 95 of 211 fill and soil samples, while 22 of the samples exceeded the RDEC. The antimony RDEC exceedances were identified in the VONF, IW and DD fills (i.e. no exceedances of RDEC in fill only containing CD). Average concentrations of antimony identified in all fill materials (individual and combinations of IW, CD and DD) was approximately 96 mg/kg, while average concentrations observed in the VONF was less than 4 mg/kg. It is reasonable to conclude that the presence of antimony above the RDEC at the Middle School Site is primarily attributed to fill containing industrial waste and domestic debris.

Arsenic was detected in 191 of 211 fill and soil samples, while 51 of the samples exceeded the RDEC. Nine of the 51 arsenic exceedances were identified in the VONF; however the average concentration in the VONF was approximately 3 mg/kg. The remaining 42 exceedances of the RDEC were generally evenly distributed in the visually identified fill materials (individual and combinations of IW, CD and DD). The average concentration of arsenic identified in all fill materials (individual and combinations of IW, CD and DD) was approximately 55 mg/kg. Arsenic is present throughout the site, in both shallow and deep unconsolidated materials. In general, overall lower concentrations of arsenic are present on the western portion of the Middle School Site.

Lead was detected in all soil samples, with 57 of the samples exceeding the RDEC for the site. The CTDEP has requested that 400 mg/kg be utilized for the RDEC to be consistent with the RCRA corrective action program. This is currently not a regulatory change and is being applied on a case by case basis. With few exceptions, when lead is identified above the RDEC, it is much higher than the criterion. Ten of the 57 lead exceedances were identified in the VONF; however, the average concentration in the VONF was 338 mg/kg. The remaining 47 exceedances of the RDEC were generally evenly distributed in the identified fill materials (individual and combinations of IW, CD and DD). The average concentration of lead identified in all fill materials (individual and combinations of IW, CD and DD) was 4,869 mg/kg. Lead was identified at an average concentration of 804 mg/kg in samples only containing CD fill. Lead was generally found at the highest concentrations in unconsolidated materials which either only contained IW or contained a mixture of IW and another unconsolidated material. Lead is present throughout the site, in both shallow and deep unconsolidated materials.

Average concentrations of antimony, arsenic, lead, barium, copper, chromium, mercury, nickel and zinc in the visually identified fill materials (individual and combinations of IW, CD and DD) were detected at 5 times to 31 times the average concentrations identified in the VONF.

4.5.3.2.2 SPLP Cyanide and SPLP Metals Soil Quality

During the 2002 ESI, the protocol for analyzing metals through SPLP was as follows: Target metals identified in soil samples from above the seasonal low water-table greater than 1.5 times the local background concentrations or average concentration of the element found in uncontaminated soil in the Eastern United States (ref. 45) (whichever is lower) were analyzed by SPLP for the target metal. Because of cost savings achieved by analyzing the entire set of PPMs plus barium rather than analyzing a few individual metals, most samples were analyzed for all the metals regardless of which metal triggered the need to perform the analyses. The aforementioned protocol was slightly modified during the 2004 and 2005 ESI; a qualitative aspect of selecting metals for SPLP analyses was added. If any of the elements in the sample were identified above the typical mass concentrations of that element detected at the site, then all detected metals in that sample were additionally analyzed by SPLP metals. A summary of the samples analyzed is shown on tables 1 and 13.

As show in the table 14 below, beryllium, cyanide, selenium and thallium were not detected in any of the samples analyzed. Depth and locations of all constituents which were identified to exceed the GA PMC, and the types of material they were detected in, are summarized on Plate 15.

Table 14

Summary of SPLP Metal and Cyanide Occurrence and Regulatory Comparison

	Total Analyzed	**Total Detected**	**Exceeds GA PMC**	**Exceeds 10X GWPC**	**Exceeds GB PMC**
Antimony	94	34	27	9	8
Arsenic	91	19	12	3	3
Barium	91	91	1	1	1
Beryllium	67	0	0	0	0
Cadmium	90	2	0	0	0
Chromium	91	14	1	0	0
Copper	97	88	0	0	0
Cyanide	15	0	0	0	0
Lead	97	69	54	15	15
Mercury	95	12	2	0	0
Nickel	92	43	9	1	1
Selenium	92	0	0	0	0
Silver	91	1	0	0	0
Thallium	57	0	0	0	0
Zinc	95	94	5	0	0
Total from VONF[1/]	31	27	14	5	5
Total from CD[2/]	8	7	4	1	1
Total from DD[3/]	1	1	1	1	1
Total from IW[4/]	28	28	20	4	4
Total from Combined Fill[5/]	74	72	49	14	14
Total	105	99	63	19	19

1/ Set consist of samples containing only VONF.
2/ Set consist of samples containing only CD fill or mix of CD and VONF.
3/ Set consist of samples containing only DD fill or mix of DD and VONF.
4/ Set consist of samples containing only IW fill or mix of IW and VONF.
5/ Set consist of samples containing any combination of visually identifiable fill (IW, CD and DD).

As shown above, cadmium was detected in 2 of 90, copper was detected in 88 of 97 and silver was detected of 1 of 91 samples analyzed. None of the aforementioned constituents were detected above the GA PMC.

Chromium, mercury and zinc were all detected above the numerical GA PMC; however, none of the aforementioned detections were identified above 10 times the GWPC; therefore, pursuant to RCSA Section 22a-133k-2(c)(2)(C), all of the aforementioned samples are in compliance with the GA PMC.

Barium was detected in all 91 samples analyzed. Only one sample exceeded the GA PMC. Barium was detected at a concentration of 26.7 mg/l in sample LBG-TB-48, which also exceeds the 10 times the GWPC and the GB PMC. This sample was collected from beneath the basketball courts. This is an unusually high concentration compared to the rest of the data set. The next highest barium SPLP concentration was 0.444 mg/l in sample LBG-TB-137 and the average barium detection (excluding LBG-TB-48 (6 to 8 ft bg)) was 0.262 mg/l. Also unusual is that no other metals detected in this sample were above 10 times the GWPC.

Antimony, arsenic, lead, mercury and nickel all were identified at concentrations above the GA PMC and 10 times the GWPC. Table 14 (shown above) summarizes the quantity of samples analyzed, those with detections, and quantity that exceeded the GA PMC, 10 times the GWPC and GB PMC. Plate 16 and table 13 show the detailed distribution and individual concentrations of all metals that exceeded the GA PMC at the Middle School Site.

Only a slightly greater percentage of samples were identified with one or more SPLP metal concentrations above the GA PMC in the combined fill material (66%) than were identified in the VONF (45%). In fact, a statistically equivalent number of samples exceeded 10 times the GWPC for combined fill versus VONF (16% versus 19%, respectively). The distribution of exceedances were generally scattered throughout the site. Note that a review of the inorganic data showed little correlation between the total and SPLP metal results. Nonetheless, it is clear that the bulk of the regulatory exceedances for total and SPLP metals are antimony and lead.

4.5.3.2.3 Cyanide and Metals Water Quality

Table 15 and plate 17 present a summary of all water-quality results for metals and cyanide. As shown, a long record of water-quality testing for metals has been completed at the site. Monitor wells installed as part of the 2002 ESI have been sampled a minimum of seven times (five wells were sampled eight times). During this period, antimony, beryllium, cyanide, thallium and tin were not detected above the laboratory detection limit. In addition chromium, cobalt, copper, cyanide, mercury, nickel, silver, vanadium and zinc were never detected above the GWPC or SWPC (SWPC most applicable at downgradient property line).

Plate 17 shows the distribution and concentration of all detected metals. Although some interior wells show an exceedance of SWPC, the furthest downgradient wells show compliance with the exception of LBG-MW-16. Selenium was detected at a concentration of 0.055 mg/l during the in the July 23, 2003 sampling event, which is above the SWPC and GWPC. Selenium was not identified above the laboratory detection limit in this well during the subsequent four quarters of sampling, and selenium has not been detected above the GWPC in any of the other site monitor wells. In addition, selenium was not detected in any of the 91 soil and fill samples analyzed by SPLP and none of the 211 soil and fill samples analyzed for mass selenium were identified above the RDEC. It is possible this detection is representative of a “slug” of dissolved selenium which may have been mobilized as part of the 2002 field investigations.

As shown on plate 17, ground water entering the site from the east (LBG-MW-8 and LBG-MW-9) meets the GWPC for all inorganics analyzed. Arsenic, barium, cadmium, lead, and selenium were all detected above the GWPC; however, with the exception of barium, the distributions of the detections are sporadically located throughout the site. In addition, the exceedances generally correspond to areas in which fill materials are saturated. The exceedances occur at a much higher frequency in the wells screened above the wetland organic layer.

Arsenic has been detected above the GWPC in MW-7A, MW-10A, MW-12, MW-14A, MW-15A and MW-23A above the GWPC. All of the aforementioned wells are located above the wetland organic layer and screened within saturated fill materials. Arsenic has never been identified above the laboratory detection limit in the wells located on the southwest downgradient property boundary. The absence of arsenic in these wells indicates migration of this dissolved metal is limited.

Cadmium was detected above the GWPC during one sampling event at LBG-MW-1, LBG-MW-12 and LBG-MW-13 (July 2003). Nickel was also detected during one sampling event at LBG-MW-23A (February 2003)

Lead has been detected sporadically above the GWPC in LBG-MW-1, LBG-MW-11, LBG-MW-12, LBG-MW-14B and LBG-MW-23A; however, it has been detected consistently above the GWPC in LBG-MW-14A.

As shown on plate 15, concentrations of barium in the ground water are generally consistent throughout the recording period. Higher concentrations of barium are shown in locations with saturated industrial waste material. The concentrations are substantially lower (1 to 2 orders of magnitude) in monitor wells that are located outside of the industrial waste material. It is clear that the presence of high concentrations of barium in the ground water is the result of saturated industrial waste material.

Fifty-four (54) exceedances of the GA PMC were identified for lead during the soil investigation (15 exceeded 10 times the GWPC). The distribution of the lead GA PMC exceedance does not indicate a single source location; however, with the exception of LBG-MW-14A, lead was only detected sporadically above the GWPC. The other most prevalent inorganic identified above the GA PMC, antimony, was not detected above the laboratory detection limit. This does indicate that for this site, the GA PMC does not correlate well with water-quality results.

While barium was only detected once above the GA PMC, it is clearly the primary inorganic constituent that has impacted ground water. The highest concentrations of barium in ground water are shown in locations of saturated industrial waste fill. Barium does appear to significantly sorb to the surrounding saturated materials, as evidence by the significantly lower concentrations shown in downgradient areas away from the industrial waste fill.

With the exception of selenium, none of the metals exceed the GWPC at the downgradient property line. Selenium has not been identified at the downgradient property boundary above the laboratory detection limit for the past four sampling events.

4.5.3.3 Petroleum Hydrocarbons Overview

Petroleum hydrocarbons were identified throughout the soils at the site. ETPH was identified at generally low concentrations at several locations in the underlying native materials. It is difficult to explain the widespread presence of ETPH throughout the site and presence in all fill material. Petroleum was clearly identified in some of the soil samples collected from the industrial waste fill. Anecdotal information indicated that grinding materials with lubricating oils were deposited as part of the fill by Winchester Arms. However, other constituents such as lead, arsenic, antimony and barium, seem to also be related to the industrial waste fill. These constituents were not identified in significant concentrations outside of this matrix. Therefore, one cannot presume ETPH was spread throughout the Middle School Site from grading activities. It is possible that ETPH was present in all fill material deposited at the Middle School Site; however, this seems to be unlikely considering all the different historic sources of fill. Another potential source may have been related to the historic application of oils to control insects, or possibly the presence of ETPH in the site soils is a combination of all the above.

While the source of the ETPH identified throughout the site soils is unclear, the distribution of the presence of ETPH in the site materials has been adequately characterized and further investigations to solely characterize their presence are not warranted.

The source of ETPH in ground water has also not been determined. It would be logical to assume that ETPH is present in ground water because of the numerous detections in soil; however, it has only been detected in the ground water west of the Middle School. Note that the Middle School fuel-oil UST is located on the western side of the school. In addition, ETPH detected in soil samples were primarily identified to contain motor oil; however, ETPH has only been identified in ground water as fuel oil. The source of the ETPH in water may be related to the operation of the middle school fuel-oil UST and associated piping, or a spill that may have occurred during filling of the UST.

Considering the site ground-water flow direction, ETPH identified in the ground water near a PCB "hot spot" area and northern corridor are likely not associated with a release associated with the operation of the UST. PCBs are typically associated with oils, while transmission fluid and creosote were uniquely identified in the area of the northern corridor. The ETPH ground-water occurrences in these areas are more likely associated with the unique oils associated with each of these areas.

4.5.3.3.1 Soil Quality

Table 16 and plate 18 show the detailed distribution and individual concentrations of all soil samples analyzed and compares the results to the RSRs. Of the 211 soil and fill samples analyzed (excluding duplicates), ETPH was detected in 139. As shown on plate 18 and table 16, ETPH was identified throughout the Middle School Site at all depths and materials. Of the 139 detections, 44 exceeded the RDEC, while 20 exceeded the Industrial/Commercial Direct Exposure Criteria (I/C DEC). The RDEC and I/C DEC are 500 mg/kg and 2,500 mg/kg, respectively.

Thirty eight (38) of the samples analyzed were identified above the GA PMC of 500, while 20 samples were identified the GB PMC of 2,500. Note that the PMC only applies to the soils above the seasonal low or seasonal high (criterion dependant) water-table. Recent CTDEP guidance allows compliance with the PMC to be evaluated through comparison of SPLP ETPH results with a concentration of 0.1 mg/l (for GA PMC) and 1 mg/l (for GB PMC). The table below shows soil samples which were collected from above the seasonal low water-table and analyzed for both mass ETPH and SPLP ETPH analyses. All samples identified above the GB PMC during the 2004 and 2005 investigation were analyzed for SPLP ETPH. In addition, an attempt was made to recollect all samples identified above the GB PMC during the 2002 ESI for SPLP ETPH analyses. Unfortunately, there was not a good correlation between the results of the 2002 analyses and the samples recollected and reanalyzed during the 2004 and 2005 investigations. In general, some mass samples from the reanalyzes were higher and some were lower. Nonetheless, the table below provides a wide range of mass ETPH concentrations collected from various media at the site; the range of mass ETPH concentrations in this set is similar to the complete data set for the site. Because of variabilities shown in the mass and corresponding SPLP results, a threshold mass ETPH concentration cannot be identified that would result in an SPLP analysis result which would meet the GA PMC. *However, the data set is sufficiently large enough to conclude that if all ETPH mass samples identified above the 2,500 mg/kg were analyzed for SPLP ETPH, the resultant concentration would be below 1 mg/l, and therefore meet the GB PMC.*

Table 17

Summary SPLP ETPH Results for Samples Collected above the Seasonal Low Water-Table

Sample Location	Sample Interval (ft bg)		Fill ID	Mass ETPH (mg/kg)	SPLP ETPH (mg/l)
LBG-TB-6A	13	14	VONF	12	ND<0.1
LBG-TB-2A	5	6	VONF & IW	96.7	ND<0.1
LBG-TB-181	0	0.5	VONF	**505**	ND<0.1
LBG-TB-16A	4.5	5	IW & CD	**550**	ND<0.1
LBG-MW-18B	2	4	VONF & IW & CD	**555**	ND<0.1
LBG-TB-24A	7.8	8	VONF	**574**	ND<0.1
LBG-TB-47	6	8	IW	**732**	ND<0.1
LBG-TB-22A	5.5	6	IW	**1,387**	ND<0.1
LBG-TB-16A	12	13	IW & CD	**1,390**	ND<0.1
LBG-TB-12A	5	6	IW & DD	**2,086**	ND<0.1
LBG-TB-5A	2	4	VONF & IW	**2,625**	ND<0.1
LBG-TB-51A	8	9	IW & CD	**2,480**	**0.17**
LBG-MW-11B	9	10	IW & DD	**2,610**	**0.17**
LBG-TB-25A	9.5	10	IW	**3,650**	**0.13**
LBG-TB-19A	8	10	IW	**5,128**	ND<0.1
LBG-TB-51A	10	11	IW & CD	**5,740**	ND<0.1
LBG-TB-1A	2	4	VONF & IW	**8,014**	ND<0.1
LBG-TB-16A	1	1.5	VONF & CD	**9,140**	ND<0.1
LBG-MW-18B	9	10	IW	**8,280**	**0.14**
LBG-TB-23A	7	8	IW & CD	**12,200**	ND<0.1

Sample Location	Sample Interval (ft bg)		Fill ID	Mass ETPH (mg/kg)	SPLP ETPH (mg/l)
LBG-TB-48	6	8	IW & CD	**16,000**	**0.35**
LBG-TB-25A	13.5	14	IW	**26,410**	**0.36**
CTDEP RDEC/GA PMC				500	0.1
CTDEP I/C DEC/GB PMC				2,500	1.0

LBG requested the laboratory to identify the petroleum hydrocarbon carbon range and, if possible, the type of hydrocarbon detected. The results are presented on plate 18 and table 16. A wide range of carbon chains were identified; however, the most common range was C-16 to C-36. Of the 139 soil samples detected with ETPH, the laboratory was able to identify sources of the petroleum hydrocarbons for 80 of the samples. Forty-seven (47) of the soil samples were identified to contain motor oil, 13 contained lubricating oil, 12 contained transmission fluid, 5 contained creosote, one soil sample each was identified to contain hydraulic oil, high boiling residual oil and diesel fuel. Hydraulic oil was identified in the shallow domestic debris/municipal waste located on the south central portion of the Middle School Site (LBG-TB-12 (2.2 to 3.1 ft bg)). Diesel fuel was identified in the relatively deeper construction debris located on the western portion of the site (LBG-TB-24 (13.5 to 14 ft bg)). The high boiling residual oil was identified in the shallow unconsolidated materials beneath the tennis courts. The transmission fluid and creosote were primarily identified in the fill located near the northern wetland corridor. The motor and lubricating oils were found throughout all fill materials.

4.5.3.3.2 Water Quality

ETPH has been detected at 11 wells at the site. Table 18 summarizes all detections and identifies the source compound of petroleum hydrocarbon for each of the samples collected during the second phase of the investigation. As shown on Table 18, all detections exceed the GWPC. Plate 19 shows the distribution and concentrations of ETPH detections and identifies the source compound of the oil when applicable.

As shown on plate 19, ETPH was detected in the eleven wells west of the middle school building. The detections ranged from 0.12 to 0.53 mg/l. Of the detections, the laboratory was only able to fingerprint the oil at two locations. The ETPH detections identified at LBG-MW-7A and LBG-MW-15A were identified to be fuel oil No. 2. No ETPH detections were identified on the upgradient of the Middle School building. With the exception of the ETPH detections in

MW-25 and MW-11A; the distribution of ground-water detections indicates the source is located behind the school and an intermittent plume of ETPH is flowing to the west/southwest.

The Town of Hamden completed an investigation of an onsite heating-oil UST during 2002 (ref. 51). ETPH was detected in the ground water near the UST, but the laboratory was unable to fingerprint the detections. The data did not suggest the presence of a non-aqueous phase liquid (NAPL) source.

ETPH detected in soils samples were primarily identified to contain motor oil; however, ETPH in ground water has only been identified to contain fuel oil. Therefore, it cannot be concluded that the source of ETPH in the ground water is related to the ETPH present in the site fill. In addition, the occurrence of ETPH in the site soil was widespread and occurred on the western and eastern side of the site building. ETPH is only identified in the site ground-water west of the middle school. Therefore, the source of the ETPH in water may be related to the operation of the middle school fuel-oil UST and associated piping.

ETPH detected in MW-25 and MW-11A are unlikely related to the fuel-oil UST. This is because MW-25 was installed to assess the potential impacts of a PCB "hot spot." PCBs are commonly associated with oils. Considering MW-25 was installed in the immediate downgradient vicinity of the PCB hot spot area, it is likely the ETPH detection in MW-25 is associated with this release. Until compliance monitoring in this area is complete, it is unknown if ETPH detections in MW-25 will persist in ground water or are a short term occurrence resulting from agitation of petroleum impacted soils during the drilling and installation process, and will eventually dissipate.

Transmission fluids and creosote were the primary oils identified in the soil and fill near MW-11. The oils identifications are notably different than those identified throughout the rest of the site. Detections of ETPH have sporadically been detected in MW-11. There is no northern ground-water flow component from the UST and MW-11, therefore the impacts in MW-11 cannot be related to the operation of the UST. This is further verified by the absence of ETPH in MW-19, which was intentionally installed between MW-11 and the UST to determine if there was a potential connection. Therefore the sporadic ETPH detections identified in MW-11A are likely the related to the oils deposited during filling on this portion of the Middle School Site.

With one exception, in one sampling round, ETPH has not been detected in monitor wells at the downgradient property line. For GB ground water, ETPH is not regulated.

4.5.3.4 Semi-Volatile Organic Compounds

Phenols have been sufficiently investigated and have been shown not to be related to the waste at the Middle School Site. The only phthalate identified in the site soils was bis(2-ethylhexyl)pthlate. The presence of bis(2-ethylhexyl)pthlate was generally sporadic. A localized occurrence of bis(2-ethylhexyl)pthlate was identified in the generally deeper unconsolidated materials on the southwest corner of the athletic field. The source of the bis(2-ethylhexyl)pthlate is not known; however, the release area is not laterally extensive.

PAHs were identified in all materials at the Middle School Site. PAHs were only sporadically detected along the athletic field property boundary. Peak concentrations of PAHs were detected in the industrial waste fill and are clearly associated with this material. The detection of PAHs outside the areas of IW may be related to the presence of asphalt or the presence of ETPH throughout the site materials. PAHs were not identified in the underlying native materials at notable concentrations.

Approximately one fifth the samples collected were identified with SVOCs which exceeded the RDEC. The RDEC exceedances were identified in both the shallow and deeper unconsolidated materials. With the exception of two samples collected from the area abutting the northern wetland corridor, all samples were shown to be in accordance with the GA PMC, based on SPLP testing.

PAHs (naphthalene and carbazole) were identified in a single shallow well (LBG-MW-7A) during initial 2002 investigation above the GWPC, and benzo(a)anthracene was detected sporadically during the October 2003 and February 2004 events above the GWPC. No other exceedances of the GWPC were identified for PAHs during compliance monitoring. It is believed that the concentrations of PAHs identified in 2002 may were the result of agitation to the unconsolidated materials during drilling. Nonetheless, while PAHs are prevalent in the site materials, they are not leaching to the ground water at significant concentrations.

Phenethrene was detected in MW-4A during the February 2004 sampling event at concentrations of 1.3 ug/l, which is above the SWPC; however, considering the distance to the nearest downgradient surface water body is approximately 0.5 mile to the southwest, it is very unlikely these contaminants would exceed the SWPC prior to discharge into Beaver Ponds.

SVOCs have been sufficiently investigated in the site soils and ground-water, and do not warrant additional investigations to solely identify their presence.

4.5.3.4.1 Soil Quality

Table 20 presents a summary of detected SVOCs and compares the results to regulatory criteria. Table 20 (shown below) presents a statistical summary of SVOC constituents detected and quantity that exceed regulatory criteria.

Table 20

Summary of Semi-Volatile Organic Compound Occurrence and Regulatory Comparison

	Total Analyzed	Detections	Exceed RDEC	Exceed RDEC (0 to 4 ft)	Exceed I/C DEC	Exceed GA PMC	Exceed Applicable GA PMC[1/]	Exceed GB PMC
Acenaphthene	241	42	0	0	0	1	0	1
Acenaphthylene	241	11	0	0	0	0	0	0
Anthracene	241	71	0	0	0	1	0	0
Benzo(k)-fluoranthene	241	120	6	2	2	48	2	46
Benzo(a)-anthracene	241	119	47	27	4	43	2	43
Benzo(a)-pyrene	241	110	36	22	36	32	2	32
Benzo(b)-fluoranthene	241	110	41	25	3	37	2	37
Benzo(g,h,i,)perylene	241	41	0	0	0	1	0	1
Bis(2-ethylhexyl)-phthalate	264	34	1	0	1	11	0[2/]	5
Chrysene	241	123	2	0	0	45	0	45
Dibenzofuran	218	12	0	0	0	1	0	0
Dibenz(a,h)anthracene	241	29	6	2	6	5	0	5
Fluoranthene	241	134	0	0	0	21	0	2
Fluorine	241	46	0	0	0	1	0	1
Indeno(1,2,3-cd)pyrene	241	50	7	3	1	5	0	5
Naphthalene	241	42	0	0	0	2	0	0
Phenanthrene	241	119	0	0	0	21	0	2
Pyrene	241	135	0	0	0	23	0	2
Total from VONF[3/]	172	84	23	23	0	26	1	25
Total from CD[4/]	19	9	3	2	0	3	0	3
Total from DD[5/]	4	1	0	0	0	1	0	1
Total from IW[6/]	66	45	14	7	3	20	0	17
Total from Combined Fill[7/]	116	80	34	12	36	42	1	36
Total	**288**	**165**	**58**	**36**	**4**	**68**	**2**	**61**

1/ Exceed 10 Times GA PMC, SPLP SVOC exceeds 10 times GWPC and SPLP SVOC exceeds GWPC (where applicable).

1/ Re-sampling at MW-25 area during the 2004 and 2005 investigations did not identify samples containing Bis (2-ethylhexyl)phthalate at similar concentrations as in 2002. However, the source was characterized through additional continuous sampling and all samples exceeding the GA PMC were analyzed by SPLP. No detections were identified and therefore it is concluded this impacted area is in compliance with the GA PMC.

3/ Set consist of samples containing only visually observed non-fill.

4/ Set consist of samples containing only CD fill or mix of CD and VONF.

5/ Set consist of samples containing only DD fill or mix of DD and VONF.

6/ Set consist of samples containing only IW fill or mix of IW and VONF.

7/ Set consist of samples containing any type visually identifiable fill.

The table above shows that the primary SVOCs detected at the site consists of polynuclear aromatic hydrocarbons (PAHs). Bis(2-ethylhexyl)phthalate is the only SVOC listed above which is not considered a PAH. With the exception of the southwestern corner of the site (near LBG-TB-25), bis(2-ethylhexyl)phthalate was sporadically detected throughout the site, and generally identified in a single sample from a test boring at moderately low concentrations. However, unconsolidated materials at and surrounding LBG-TB-25 were identified to bis(2-ethylhexyl)phthalate. At this location, bis(2-ethylhexyl)phthalate was characterized to be contained in a zone between 9 and 17 feet below grade. As shown on plate 19, the lateral extent of the contaminant was shown to be limited. All samples detected during the 2004 and 2005 investigations with bis(2-ethylhexyl)phthalate above the 10 times the GA PMC were also analyzed for SPLP bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl)phthalate was not detected in any of the samples, including all the samples collected during the continuous resampling of LBG-TB-25. While sample concentrations identified in 2004 from this boring were identified to be generally lower than detected in 2002; the distribution of the bis(2-ethylhexyl)phthalate was identified to be similar and the area was sufficiently characterized. Therefore, it is concluded this area is in accordance with the GA PMC based on the SPLP analysis

PAHs are compounds that contain more than one benzene ring. They are commonly found in petroleum fuels, coal products, and tar. PAHs are released in considerable quantities from the combustion of fossil fuels such as coal, oil, gas and the burning of wood. PAHs are ubiquitous in soil (ref 1.). Individual PAHs were detected in Artic soils above 150 ug/kg and total PAHs were detected in remote wooded areas of Wyoming at concentrations up to 210 ug/kg (ref. 1). They are also commonly associated with asphalt. Benzo(k)fluoranthene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, chrysene, fluoranthene, phenanthrene and pyrene were the most commonly detected SVOCs at the Middle School Site.

Plate 20 shows the detailed distribution and individual concentrations of the primary SVOCs that exceeded the RDEC at the Middle School Site. SVOCs were detected in VONF and all visually identified fill samples. As shown on plate 20, SVOCs are detected throughout the site, with only sporadic detections along the athletic field property boundary (with the exception of the area abutting the northern wetland corridor).

Asphalt was identified in test pits and soil borings outside of the industrial waste fill areas. The presence of SVOCs in these other areas may be related to asphalt. The SVOC detections may also be related the presence of ETPH throughout the site.

Approximately 20 percent of the samples collected were identified with SVOCs which exceed the RDEC. The RDEC exceedances were identified in both the shallow and deeper unconsolidated materials. All soil and fill samples which were identified above 10 time the GA PMC or GA PMC (if located within 25 feet of a downgradient boundary) were analyzed for SVOCs by SPLP. Based on SPLP results, with the exception of two samples collected from the area abutting the northern wetland corridor (LBG-TB-181 and LBG-TB-182), all samples were shown to be in compliance with the GA PMC.

4.5.3.4.2 Water Quality

As shown on table 21 and plate 21, during the August 2002 sampling event, bis(2-ethyl hexyl)phthalate was detected in monitor wells LBG-MW-6, LBG-MW-15B and LBG-MW-17 at concentrations ranging from 10 to 72 ug/l. Bis(2-ethyl hexyl)phthalate was detected again in LBG-MW-15B and LBG-MW-17 during the subsequent five sampling events, and was only detected one more time in LBG-MW-6. These detections of bis(2-ethyl hexyl)phthalate exceed the GPWC of 2 ppb; however, bis(2-ethyl hexyl)phthalate is a common laboratory artifact. In addition, bis(2-ethyl hexyl) phthalate is often identified in samples collected with latex gloves. LBG field personnel were wearing latex during the collection of the ground-water samples. While the sampling technique utilized nearly eliminates any potential contact with the water sample, there is the potential that the bis(2-ethyl hexyl)phthalate detections may be attributed to contamination caused during the ground-water sampling. The sporadic nature of the bis(2-ethyl hexyl)phthalate detections would suggest the detections were related to some type of field contamination.

During the May 2004 and February 2005 sampling event, bis (2-ethyl hexyl)phthalate was detected in monitor wells LBG-MW-2, LBG-MW-3, LBG-MW-5, LBG-MW-11, LBG-MW-11, LBG-MW-13, LBG-MW-15A, LBG-MW-16, LBG-MW-18B, LBG-MW-19 and LBG-MW-20 at concentrations between 2.2 ug/l and 8 ug/l. Considering that during the four prior sampling events bis(2-ethyl hexyl)phthalate was only detected in four separate occasions, it is highly unlikely that bis(2-ethyl hexyl)phthalate is now widespread at low level concentrations throughout the site. No subsurface investigations (i.e. drilling, test pits, etc.) occurred onsite after the 2002 investigations and prior to the May 2004 sampling event; therefore, the detections would not be related to agitation or disturbance of the subsurface fill and soil. It is much more likely the sudden presence of the bis(2-ethyl hexyl)phthalate is related to QA/QC at the laboratory. This conclusion is based on the fact that there has been consistency in the field sampling protocols. Past sample results suggest potential for only minor contamination from the sampling protocols. Note that none of the QA/QC duplicate sampling was completed at a well in which bis(2-ethyl hexyl)phthalate was detected.

Acenaphthene, anthracene, benzo(a)anthracene, naphthalene, chrysene, 2,4-dimethylphenol, dibenzofuran, fluorine, phenanthrene, 2-methylnaphthalene and carbazole were all detected in LBG-MW-7A. The detections of naphthalene and carbazole in the August 2002 sample were above the GWPC. The August 2002 exceedances of the GWPC were likely the result of agitation caused during the drilling of the monitor wells, or potentially dragging down of materials into the water-table.

Benzo(a)anthracene was detected above the GWPC at MW-7A and MW-14A during the October 2003 and February 2004 sampling events, while it was also detected above the GWPC at MW-4A during the February 2004 sampling event. Concentrations of benzo(a)anthracene ranged between 0.1 and 0.3 ug/l. No other detections of benzo(a)anthracene have been identified.

Phenathrene and benzo(a)anthracene were detected in MW-4A during the February 2004 sampling event at concentrations of 1.3 and 0.3 ug/l. The detection of phenanthrene exceeds the numeric SWPC of 0.3 ug/l. Considering the low level concentration detected, and the distance to the nearest downgradient surface water body (Beaver Ponds approximately 0.5 mile to the southwest, it is very unlikely the contaminant would exceed the SWPC prior to discharge into Beaver Ponds.

A large list of Tentatively Identified Compounds (TICs) were identified. All identified TICs are shown on table 21. Note that the previously discussed carbazole was a TIC, after the 2002 sampling event, it was added to the list of COCs. No other TICs exceeded established regulatory criteria.

The results of the compliance monitoring showed the only PAH above the GWPC was benzo(a)anthacene. It is clear that while PAHs are prevalent in the fill at the site, they are not leaching in any notable quantities from the unsaturated zone. Furthermore, with the exception of single detections of bis(2-ethylhexyl)phthalate and benzo(a)anthacene, all SVOC concentrations at the downgradient property line meet GWPC.

4.5.3.5 Volatile Organic Compounds Overview

An approximate 2,800 square foot source area of halogenated VOCs has been characterized in the fill material located west of the tennis and basketball courts. The source area is contained primarily in the saturated fill material located above the wetland organic layer. In general, a narrow plume extends from the halogenated VOC source area to the southwest corner of the Middle School Site. Thereafter, the plume extends in the shallow ground water to the southwest onto the abutting SNET property. Halogenated VOCs have not been detected beyond this point in any of the offsite monitor wells.

Concentrations of halogenated VOCs in the ground water at the source area have decreased dramatically over time. Understanding the halogenated VOC source area has likely remained for over 50 years, the trend in water-quality indicates the initial peak concentrations were likely the result of the disturbance of soil and fill in this area during the 2002 ESI and the more recent low level of detections of halogenated VOCs in this area are much more likely representative of steady state conditions. Water-quality results at the downgradient portions of the plume have also shown an overall decline in concentrations, and it is reasonable to conclude the trend will continue.

Offsite soil-vapor samples were collected from all residential parcels within close proximity of the downgradient portion of the halogenated VOC plume. The sampling was completed to determine if soil-vapor concentrations beneath the residential parcels exceed the proposed RVC. No exceedances of the proposed RVC were identified, and the results of the sampling showed any vapor detected beneath the homes were at concentrations which did not present a health concern.

Aromatic VOCs were detected at trace concentrations in the industrial waste, construction debris and VONF. Most of the detections were located in materials below the seasonal low water-table. It is speculated that the trace detections are associated with the presence of ETPH throughout the site. None of the detections exceed RSR criteria. Various trace aromatic VOCs have also been detected in the site ground water. Of these, only benzene and chloroform were detected above the GWPC. Benzene has been consistently detected at low concentrations at LBG-MW-7A, LBG-MW-15A and LBG-MW-22A. A single source has not been identified; however, the detections are likely related to the detections of ETPH.

The most common aromatic VOC detected at the site was chloroform. The source of the low chloroform detection is unclear; however, may be related to water leaching to the ground water from the school's athletic field irrigation system. This contaminant is not believed to be associated with the site fill materials because it easily volatilizes and is not a persistent contaminant in ground water.

VOCs have been sufficiently investigated in the site soils and ground-water and do not warrant additional investigations. Considering halogenated VOCs were not detected in the most downgradient offsite monitor wells and the dramatic decline in halogenated VOC concentrations at the source area; no additional offsite monitor wells are warranted. However, ground-water monitoring for VOCs should continue at least until a final remedy is in place or compliance with the GWPC is met. A sufficient amount of water-quality results has been obtained from the entire network; the additional monitoring should be collected only from select wells from the network.

4.5.3.5.1 Halogenated Volatile Organic Compounds Soil Quality

A release of halogenated VOCs was detected in the area immediately west of the basketball courts, near test boring LBG-TB-53. Unconsolidated materials were identified to contain concentrations of trichloroethylene (TCE), (cis) 1,2-dichloroethylene (cis)12DCE, (trans) 1,2-dichloroethylene (trans)12DCE, and vinyl chloride (VC). Table 22 shows the detailed distribution and individual concentrations of all halogenated VOCs detected, while plate 22 identifies the peak concentration of total halogenated VOCs identified at each sample point. Figures 8 and 9 show geologic cross sections through the source area, and clearly show the vertical distribution of the halogenated VOCs impacted materials.

In total, 629 samples were collected at the Middle School Site for analyses of halogenated VOCs. The source area is well characterized because samples were collected every two feet from each test boring for analyses, and the placement of the test borings was determined in an iterative logical manner. Halogenated VOCs were detected in 98 soil and/or fill samples. Peak concentrations for TCE, (cis)12DCE, (trans)12DCE and VC were 260,000 ug/kg, 54,000 ug/kg, 18 ug/kg and 19,000 ug/kg, respectively. None of the aforementioned concentrations indicate dense non-aqueous phase liquids (DNAPLs) are present at the site. DNAPL calculations pursuant to RCSA 22a-133k-2(c)(3) are presented in Appendix VIII.

As shown on the cross sections, halogenated VOCs were identified to be contained in the materials above the wetland organic layer. The peak concentrations of total halogenated VOCs were identified below the water-table and just above the wetland organic layer, which is generally encountered between 20 and 25 feet below grade in this area. The approximate lateral extent of the source area is shown on plate 22. This area is primarily located within the saturated industrial waste and is approximately 2,800 square feet. A much larger area of low concentrated VOCs was identified around the source area. This “halo” of VOCs is a common occurrence and the result of diffusion within the water-table and volatilization from the source VOCs impacting unsaturated soils.

Halogenated VOCs were detected above the RDEC in test borings LBG-TB-60, LBG-TB-106 and LBG-TB-210. Only LBG-TB-106 was identified with concentrations of VOCs above the I/C DEC. Pursuant to RCSA Section 22a-133k-2(c)(2)(B)(i), mass VOC concentrations may be compared to 10 times the GA PMC. Only one fill sample, LBG-TB-53 at 10 to 12 ft bg, was identified with halogenated VOCs above the 10 time the GA PMC (TCE at 1,900 ug/kg; 10 times GA PMC is 1,000 ug/kg). If soils are compared to the GA PMC numerical criteria without the multiplier, samples in LBG-TB-105, LBG-TB-61, LBG-TB-53, LBG-TB- 101, LBG-TB-60 and LBG-TB-49 exceed. Many of these test borings (LBG-TB-105 LBG-TB-61 and LBG-TB-101) are actually located outside of the source area; the aforementioned soil borings were impacted from the off gassing of the saturated source materials.

4.5.3.5.2 Halogenated VOC Water Quality

Plate 23 shows the distribution and concentrations of all halogenated VOCs detected in the ground water. As shown, trichloroethylene, (trans) 1,2-dichloroethylene, (cis) 1,2-dichloroethylene, vinyl chloride and chloroethane were all detected in the site ground water.

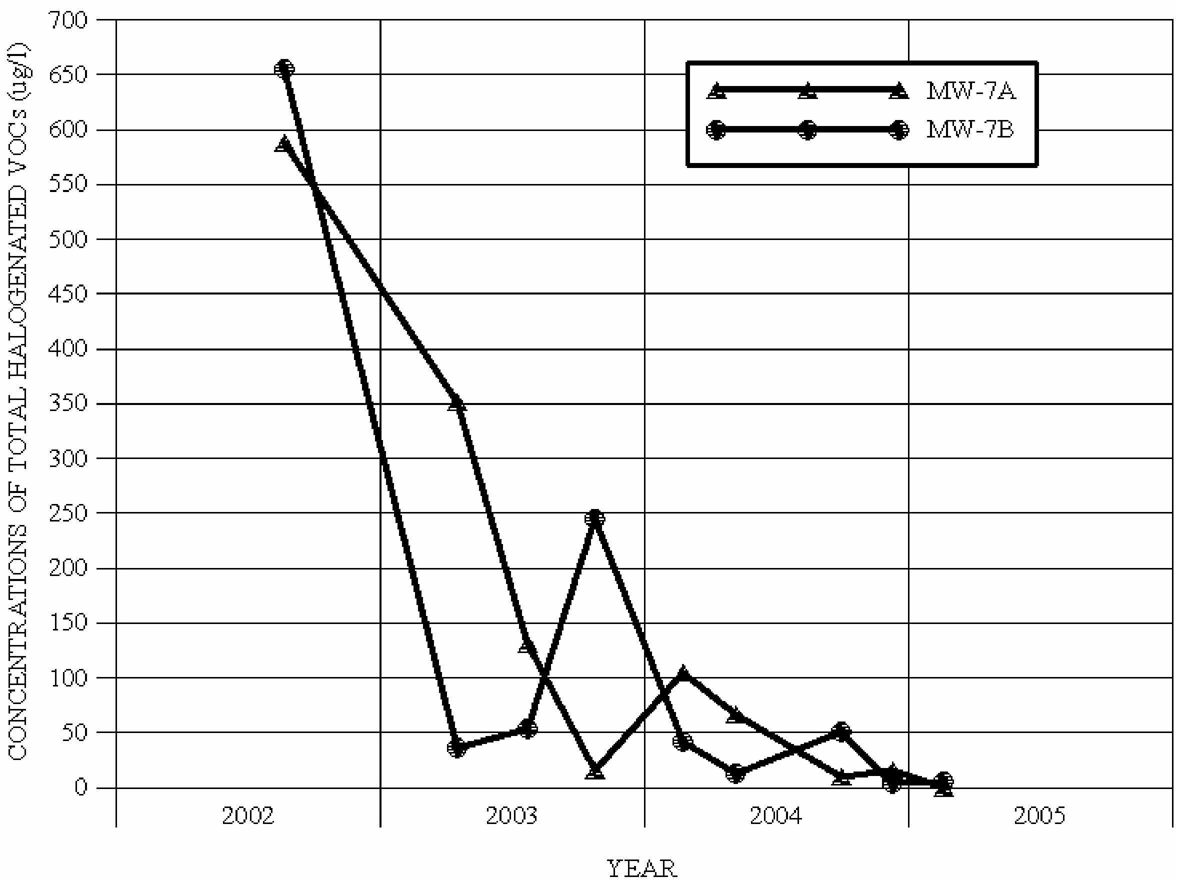
As shown on table 24, trichloroethylene, (trans) 1,2-dichloroethylene, (cis) 1,2-dichloroethylene and vinyl chloride were all detected in the ground water samples collected from the LBG-MW-7 cluster. Plate 22 shows the approximate extents of the total halogenated VOC impacts in ground-water. In general, a narrow plume extends from the halogenated VOC source areas to the southwest corner of the Middle School Site. Thereafter, the plume extends in the shallow ground water to MW-24, which is located on the southern portion of the SNET property. The plume has not been detected in any of the offsite wells beyond this point. As shown on plate 23, one monitor well cluster (LBG-MW-26) and a shallow monitor well

(H2001S, installed by Olin) located on Morse Street, and a monitor well cluster (LBG-MW-27) located on St. Mary's Street, were sampled. The migration pathway of the halogenated VOC plume further confirms that the ground water at the Middle School Site flows to the southwest.

As shown on plate 23 and below, concentrations of halogenated VOCs in the ground-water at the source area have decreased dramatically over time. Total halogenated VOCs detected at LBG-MW-7A and LBG-MW-7B during the initial August 2002 sampling event were 588 ug/l and 655 ug/l, respectively. Total halogenated VOCs detected during the most recent sampling event (February 2005) for LBG-MW-7A and LBG-MW-7B were no detection above laboratory limits and 4.9 ug/l, respectively.

Figure 12

Water-Quality Trend for Total Halogenated Volatile Organic Compounds at Source Area



Understanding the halogenated VOC source area has likely remained for over 50 years, the trend in water-quality indicates the initial peak concentrations were likely the result of the disturbance of soil and fill in this area during the 2002 environmental investigations. The more recent water-quality results in this area are much more likely representative of steady state conditions when the subsurface is not disturbed. Water-quality trends at the MW-4B pairs and MW-15A have also shown declines in halogenated VOC concentrations.

Vinyl chloride was detected at a concentration of 93 ug/l during the October 1, 2004 sampling event in the newly installed shallow monitor well (LBG-MW-24A) on the SNET property, which is above the proposed RSV of 1.6 ug/l. Therefore, in addition to the above ground-water and soil investigations, soil-vapor samples were collected from residential parcels (319-21, 330, 331 and 335 Morse Street) which are located approximately downgradient of this detection. The sampling was completed to determine if soil-vapor concentrations beneath the residential parcels exceed the proposed RVC. Once the sample results were received, letters describing the sampling process and results, which were reviewed and approved by the CTDEP, were sent to each homeowner. As shown on table 25, no exceedances of the proposed RVC were identified, and the results of the sampling showed any vapor detected beneath the homes were at concentrations which did not present a health concern. None of the trace VOC compounds detected in the soil-vapor samples have been detected the downgradient monitoring wells at the Middle School Site, and therefore, they are unrelated to the site.

4.5.3.5.3 Aromatic Volatile Organic Compounds Soil-Quality

As shown on table 22, low concentrations of aromatic VOCs were detected in 30 of 210 soil samples analyzed. Note that only 17 of the 30 detection were collected from soils above the seasonal low water-table. The aromatic VOC detected consisted of benzene, ethylbenzene, toluene, xylenes, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, n-butylbenzene, n-propylbenzene, sec-butylbenzene, tert-butylbenzene, isopropylbenzene and p-isopropyltoluene. These compounds were identified in the industrial waste fill, construction debris and VONF. None of the samples exceeded the RDEC or GA PMC.

With the exception of LBG-TB-10, no aromatic VOCs were detected in any borings completed along the Middle School Site boundary. 1,2,4-Trimethylbenzene was detected at 3 ug/kg at the 2 to 3 ft bg interval in LBG-TB-10.

Benzene was the only aromatic VOC identified in ground water above the GWPC. Benzene was detected in three soil samples at soil borings LBG-TB-2 (5 to 6 ft bg), LBG-TB-4

(16 to 18 ft bg) and LBG-TB-23 (27 to 29 ft bg) at concentration ranging from 5 to 8 ug/kg. Soil samples LBG-TB-4 (16 to 18 ft bg) and LBG-TB-23 (27 to 29 ft bg) were collected from below the water table and soil samples collected in the unsaturated zones at those borings showed no detections of benzene. A soil sample collected at LBG-TB-2 in between the top of the water-table and the screened portion of LBG-TB-2 (5 to 6 ft bg) showed no detections of benzene. While benzene was detected in the one unsaturated soil sample at extremely low concentrations, the low concentrations of benzene detected in the ground water do not appear to be related to this detection.

4.5.3.5.4 Aromatic Volatile Organic Compounds Water Quality

Plate 24 and table 24 shows the distribution and concentrations of all aromatic VOCs detected in the ground water. As shown, benzene, chlorobenzene, isopropylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, acetone, xylenes, toluene, chloroform and methyl tertiary-butyl ether (MTBE) were all detected in the Middle School Site ground water.

The most commonly detected aromatic VOC detected at the site was chloroform. Chloroform was detected in LBG-MW-6, LBG-MW-7, LBG-MW-9, LBG-MW-10B, LBG-MW-14A, LBG-MW-14B and HA-B111-OW. Chloroform was detected above the GWPC for three consecutive quarters above the GWPC at LBG-MW-6. Chloroform can be formed at low concentrations when chlorine is added to water, as is typical of public supplied water. Chloroform easily volatilizes and is not a common persistent contaminant in ground water. Therefore the presence of chloroform in the Middle School Site ground water likely is unrelated to the historic filling activities. The source is likely the Hamden Middle School athletic field's irrigation system. During the 2002 investigation, the athletic field irrigation system was observed to be leaking at two locations; RWA repaired the system because there were concerns the leakage from the system was artificially increasing ground water levels above the wetland organic layer.

Benzene has been consistently detected at low concentrations at LBG-MW-7A, LBG-MW-15A and LBG-MW-22A above the GWPC. Benzene has also been detected above the GWPC at LBG-MW-14A and LBG-MW-4C. Concentrations of benzene detected in the site ground water ranges from 0.6 to 4 ug/l. In general, trace concentrations of various other aromatic VOCs (toluene, xylenes, 1,2,4-trimethylbenzene and/or 1,3,5-trimethylbenzene) are detected along with benzene. These trace aromatic VOCs have sporadically been detected at the southwestern downgradient property line. *Only once during the monitoring period has an aromatic VOC been detected in this area above the GWPC (benzene in October 2003 at LBG-MW-4C).* No source of benzene or various other aromatic constituents were identified during the soil investigation. As discussed, the only petroleum hydrocarbon identified in the ground water was No. 2 fuel and it was identified at nearly all locations the trace aromatic VOCs have been detected. Therefore, it is reasonable to conclude the aromatic VOC detections are related to the presence of fuel oil in the ground water.

MTBE has been detected at trace concentrations at LBG-MW-16, LBGMW-7B, LBG-MW-22A and the upgradient well LBG-MW-9. The source of the detections is unknown; however considering MTBE has only been in widespread use since 1979, it is unlikely that the detection is ground-water are related to the historic filling activities at the Middle School Site.

4.5.3.6 Polychlorinated Biphenyls Overview

PCBs were detected throughout the site in both shallow and deeper materials. In addition, PCBs were detected in all unconsolidated materials, except those located near and on the Newhall Community Center and the two Hamden Housing Authority properties. In most occurrences, PCBs were detected at low concentrations, well below the RDEC. In five locations, PCBs were detected above the RDEC. All locations are located on the athletic field and at a depth greater than 4 feet below grade.

An isolated “hot spot” of PCBs was identified on the northwestern side of tennis and basketball courts. PCBs impacted materials above 10 mg/kg at this location are contained in an approximate 400 square feet area, and are located between 8 and 10 feet below grade.

PCBs have not been detected in the site ground water. PCBs are not miscible; therefore their absence in the ground water is not unexpected.

The source of the PCBs is not known; however it is theorized that the source of the PCBs may be attributed to the historic spraying of oils on wetlands to control the mosquito population. In this scenario, the oils would have needed to contain PCBs. The Middle School Site was a wetland and the presence of mosquitoes, and their ability to spread disease, was one of the primary reasons for their filling. It is also documented that spraying of oil to control mosquito populations did occur in Hamden (ref. 21). Note that PCBs were not detected in any fill materials at the Newhall Community Center; this area was historically at a generally higher elevation and was not filled because of wetlands, but because of residential and community dumping. In addition to PCBs being detected in all unconsolidated materials (fill and non fill) at the Middle School Site, PCBs have been detected in northern wetland corridor adjacent to the Middle School Site. These soils to the north were clearly not fill and representative of undisturbed soils (ref. 50). Therefore, it is reasonable to conclude the widespread presence of the generally low concentrations of PCBs is not related to the fill, but rather the treatment of mosquitoes through the application of oils.

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4.5.3.6.1 Soil-Quality

Table 26 shows the detailed distribution and individual concentrations of all PCBs detected, while plate 25 identifies the peak concentration of PCBs identified at each sample point. In total, 629 samples have been analyzed for PCBs from 133 sample locations. As shown in the table below, PCBs were detected in 101 of the 629 samples, with PCBs detected in 47 of 133 sample locations (approximately 35 percent).

Table 27

Summary of PCB Occurrence and Regulatory Comparison

	Total Analyzed	Detections	Exceed RDEC	Exceed RDEC (0 to 4 ft)	Exceed I/C DEC	Exceed GA PMC	Exceed 10 Times GA PMC or GB PMC
Total from VONF[1/]	330	41	6	0	0	0	0
Total from CD[2/]	58	8	1	0	0	0	0
Total from DD[3/]	4	2	0	0	0	0	0
Total from IW[4/]	158	37	9	0	2	2	0
Total from Combined Fill[5/]	299	60	11	0	2	0	0
Total	**629**	**101**	**17**	**0**	**2**	**2**	**0**

1/ Set consist of samples containing only VONF.
2/ Set consist of samples containing only CD fill or mix of CD and VONF.
3/ Set consist of samples containing only DD fill or mix of DD and VONF.
4/ Set consist of samples containing only IW fill or mix of IW and VONF.
5/ Set consist of samples containing any combination of visually identifiable fill (IW, CD and DD).

The distribution of PCB detections show their presence to be throughout the site in both shallow and deeper materials. In addition, PCBs were detected in all unconsolidated materials, except those located near and on the former Newhall Street Public School (Newhall Community

Center) and the 249 – 251 Morse Street and 253 -255 Morse Street (Hamden Housing Authority properties). As shown on table 26, concentrations of PCBs detected ranged from 0.02 mg/kg to 61.8 mg/kg. The distribution of the total PCB concentrations identified throughout the site does not indicate the presence of isolated spill areas with the exception of the area immediately surrounding LBG-TB-193 (northwestern side of tennis courts). This area has the characteristics of a spill area, which would typically be identified as a high concentration area surrounded by a decreasing chemical gradient.

Figures 10 and 11 show geologic cross sections through the single PCB source area, and clearly show the vertical distribution of the PCB impacted materials. Plate 25 shows that the PCBs impacted materials above 10 mg/kg are contained in an approximate 400 square feet area; however, PCBs impacted materials above 1 mg/kg in this area are spread out over an approximately 1,600 square feet. PCBs impacted materials above 10 mg/kg were identified at depths between 8 and 10 ft bg, while PCB impacted materials above 1 mg/kg were identified at depths between 4 and 15 ft bg.

The concentrations of PCBs detected outside of the aforementioned release area ranged from 0.02 mg/kg to 2.89 mg/kg. PCBs were detected above the RDEC (1 part per million or 1 mg/kg) at only four other locations (LBG-TB-25, LBG-TB-75, LBG-TB-147 and LBG-TB-162). As shown on plate 25, all of the locations are located on the western half of the athletic field. The detections above 1 mg/kg were identified at depths between 6 and 14 ft bg. Sampling completed in close proximity of each of these areas did not suggest a single point release area; rather they represented peaks in the widespread presence of PCBs throughout the Hamden Middle School Site.

No PCBs were detected above the RDEC in unconsolidated materials located between 0 and 4 ft bg.

4.5.3.6.1 Water Quality

No PCBs were detected above the laboratory detection limit in any of the ground-water samples analyzed. Note that Monitor Well LBG-MW-25 is located immediately downgradient of the PCB “hot spot” area located west of the tennis and basketball courts. PCBs are not miscible; therefore their absence in the ground water is not unexpected.

4.5.3.7 Herbicides

No herbicides were detected above the laboratory detection limit in any of the ground-water samples analyzed. Herbicides should not be considered a constituent of concern.

4.5.3.8 Surface Water and Ground-Water Quality in Northern Wetland Corridor

The northern wetland corridor is located hydraulically downgradient of an approximate 60-foot wide area extending from the northeastern corner of the Middle School Site to the western edge of the northern wetland corridor. Ground-water and surface water in this area would eventually discharge to a public water supply reservoir. Note that this corridor also receives large quantities of runoff from the school and surrounding area storm drainage system.

As shown on Plate 1, a surface water sample was collected from the northern wetland corridor. The sample was collected to assess the potential impact of surface water caused by the fill located on the Middle School Site. The sample was analyzed for the complete COC list. The only constituent detected was dieldrin at 0.005 ug/l, barium at 0.094 ug/l and zinc at 0.051ug/l. Dieldrin has not been detected in any fill, soil or ground-water samples collected at the Middle School Site and is therefore unrelated. While comparing this type of sample to an RSR criterion is not appropriate, the concentrations of barium and zinc are below the GWPC and SWPC.

In addition to the surface water sample, a ground-water sample was collected from Monitor Well PZ-1 during the February 2005 sampling event. Of the COCs, only barium and zinc were detected. These constituents were detected well below all the GWPC; however, zinc was detected above the SWPC. The concentration does not appear to be related to ground water at the Middle School Site. This conclusion is based on the fact that the concentrations of zinc identified in the MW-11 cluster are 118 to 247 times less than the concentration of zinc identified in LBG-PZ-1. The MW-11 cluster is located near the northern wetland corridor and is the furthest downgradient point on the Middle School Site to the northern wetland corridor. It is more likely the impacts at LBG-PZ-1 are related to the large quantities of runoff from the school and surrounding area that discharge to this area from the storm drainage system.

4.5.3.9 Landfill Leachate Indicators

Table 28 shows landfill leachate indicators for the water-quality results. The landfill leachate indicators tested include total alkalinity, ammonia, dissolved iron, dissolved manganese, nitrate, potassium, sodium, sulfate, sulfide, total dissolved solids, total suspended solids, 5-day Biological Oxygen Demand (B.O.D), pH, and oxidation-reduction potential (ORP - measurement of oxidized contaminants).

Two sampling events were completed at the site for the landfill leachate parameters, one during the week of August 21, 2002 and February 17, 2005. Total alkalinity is the only indicator which is identified with a consistently higher concentration in samples collected from monitor wells screened within the fill as compared to those screened upgradient/cross gradient of the fill and beneath the wetland organic layer. Concentrations of total alkalinity are less than half in wells screened beneath the wetland organic layer and monitor wells located on the hydraulically downgradient portions of the Middle School Site (northern wetland corridor and southwestern portion) than those screened within the fill material. A direct correlation cannot be made concerning the fate and transport of other contaminants using this data, because many parameters can affect solute transport. However, this data does favorably show that contaminants in the site ground water that are related to the fill would tend to be contained onsite.

5.0 REGULATORY COMPLIANCE DISCUSSION

5.1 Unconsolidated Materials

Without implementation of an ELUR or ground-water reclassification, unconsolidated materials must meet the RDEC and GA PMC. The sections below describe the extent of materials at the site which exceed the aforementioned criteria.

5.1.1 Direct Exposure Criteria

Currently, unconsolidated materials up to 15 feet below grade at the site must meet the RDEC. Plate 26 shows the lateral extent of all materials at the site Middle School Site which meet the RDEC. In addition, plate 26 also shows the minimum thickness of unconsolidated materials in compliance with the RDEC that overlay materials that exceed the RDEC.

Plate 26 was conservatively constructed through review of all analytical data and geologic logs. In constructing this plate, if an exceedance of the RDEC was identified in a fill material at depth and the upper fill material was not tested, the upper fill material was presumed to exceed the RDEC. The RDEC exceedance area mapped on the southern portion of 249-251 Morse Street was based heavily on the geologic log data, the concentration of the contaminant detected above the RDEC (lead at 408 mg/kg, proposed RDEC is 400 mg/kg), the location of fill mapped at the Middle School Site and areas investigated by other responsible parties, and analytical results identified in the materials on southern edge of the Newhall Community Parcel. The extent of this exceedance area would need to be refined prior to implementation of remediation. Other than the aforementioned area, because of the conservative nature utilized in constructing this map, it is likely the areas identified with exceedances above the RDEC are slightly smaller and deeper than shown. Dependant on the final remedy selected, additional sampling may be completed to refine these areas prior to the implementation of the final remedy.

As shown on plate 26, portions along the southeastern, southern, southwestern, western and northwestern boundaries meet the RDEC. A large portion of the athletic field contains unconsolidated materials from grade to a minimum of 4 feet below grade that meet the RDEC. Excluding the narrow strip of land immediately north of the tennis and basketball courts and on the southeastern corner, the remainder of the athletic field contains unconsolidated materials from grade to a minimum of 2 feet below grade that meet the RDEC. The remainder of the Middle School Site has materials either at grade or close to the surface (i.e. immediately below areas of interim remedial measures or approximately within 1 foot of grade) that exceed the RDEC.

Two locations at the Middle School Site contain unconsolidated materials which exceed the RDEC at grade. As shown, these areas are located on the eastern portion of the Middle School Site and in the wooded area immediately abutting the northern wetland corridor (access to the latter are restricted by an eight foot high fence).

The map does not show the extent of materials which exceed the I/C DEC because there is little change in the area which exceed the I/C DEC versus the RDEC. This is because two of the primary contaminants which exceed the RDEC (arsenic and benzo(a)pyrene) have the same numerical criteria for I/C DEC. The only locations shown on plate 26 which exceed the RDEC, that would meet the I/C DEC are: 1) the small area located in southern portion of 249-251 Morse Street; and 2) the approximate 7,000 square foot area located on the southwestern portion of the athletic field.

5.1.2 Pollutant Mobility Criteria

Plate 27 shows the lateral extent of all materials which meet the GA PMC and GB PMC. These areas of compliance were conservatively mapped. Areas shown that meet the GA PMC include self-implementing options in the RSRs that apply to this site. The following RSR self implementing options were utilized in constructing this map:

- RCSA Section 22a-133k-2(c)(2)(A);
- RCSA Section 22a-133k-2(c)(2)(B)(i);
- RCSA Section 22a-133k-2(c)(2)(C); and
- RCSA Section 22a-133k-2(c)(2)(D);

In mapping areas of GB PMC compliance, mass ETPH were compared to the numerical criterion, and SPLP ETPH results were compared to 1 mg/l.

Areas which meet the GA PMC are located on the eastern, southeastern, southwestern, northwestern edges of the site. In addition, a portion of the central and north central area of the site was also shown to be in compliance with the GA PMC. As shown, over half of the Middle School Site exceeds the GA PMC (approximately 14 acres).

If a ground water was reclassified at the site to GB, the area exceeding the PMC would be reduced by over half. In fact, if ground-water was reclassified, approximately 6 acres would exceed the GB PMC.

5.1.3 Ground Water

Considering the amount of fill at the site and the area of material identified to exceed the GA PMC, ground-water quality at the site is in generally good condition. No exceedances of the GWPC were identified for PCBs, herbicides and pesticides.

Arsenic, barium, cadmium, lead, and selenium were all detected above the GWPC; however, with the exception of barium, the distributions of the detections are sporadically located throughout the site. No metals were identified to be discharging off of the site above the GWPC or SWPC during the past four sampling events.

ETPH has been detected in the site ground water and is believed to be primarily caused by the school fuel oil UST or associated piping. ETPH has not been identified to be discharging off of the southwestern portion of the site above the GWPC during the past four sampling events. ETPH was detected twice over eight sampling events since August 2002 above the GWPC at the northern site boundary discharge point. However, ETPH has not been detected in the northern offsite monitor well PZ-1.

Trace concentrations of SVOCs have been detected throughout the site ground water. No SVOCs have been identified discharging off of the site to the north, while sporadic low concentrations of SVOCs have been detected at the southwestern discharge point of the site. Only bis(2-ethylhexyl)phthalate was identified above the GWPC on the southwestern portion of the site. However, this single detection is presumed to be a laboratory artifact. During the February 2004 sampling event, phenanthrene was detected on the southwestern downgradient portion of the site at concentrations slightly above the SWPC, and benzo(a)anthracene was detected above the GWPC. They subsequently have not been detected. Considering the distance to the nearest downgradient surface water body is approximately ½ mile to the southwest, it is very unlikely any contaminant would exceed the SWPC prior to discharge into Beaver Ponds.

Aromatic VOCs were identified in the site ground-water slightly above the GWPC; however, none were identified discharging from the site above the GWPC or SWPC for the past five quarters of sampling. Halogenated VOCs were also identified above the GWPC in the interior of the site; however, only vinyl chloride was identified to be discharging off the southwestern portion of the site above the GWPC. Ground-water quality trends over the past 2½ years show a substantial drop in concentrations at the source area which would potentially lead to compliance of the GWPC at the southwestern property boundary. Ground-water was shown to be in compliance with the proposed RVC off site through soil-vapor sampling. No exceedance of the SWPC were identified for halogenated VOCs.

If ground-water were reclassified to GB, only the SWPC and proposed RVC would apply for ground water. In summary, of the COCs, only vinyl chloride is consistently detected above RSR criteria leaving the Middle School Site, and soil-vapor sampling shows compliance with the RVC.

6.0 EVALUATION OF REMEDIAL ALTERNATIVES

In evaluating remedial options, one must consider the future use of the site. A new middle school is under construction in Hamden, and it is LBG's understanding that once constructed, the current Hamden Middle School will no longer be used as a public school. Future use is not known for the entire site. Several remedial scenarios were evaluated for site-wide remediation. Under all scenarios, it is presumed 249-251 and 253-255 Morse Street will remain as residential. In addition, under all scenarios, remediation of the PCB “hot spot” is required. Options for the entire site and specific circumstances are discussed below.

Note that while excavation of all impacted materials is a potential remedy, it is not included as part of the discussion below. This remedy is simply impractical; the cost of remediation through excavation and disposal would potentially be hundreds of millions of dollars.

6.1 PCBs Source Area

An isolated spill area of PCBs was identified on the northwestern side of tennis and basketball courts. PCBs impacted materials above 10 mg/kg at this location are contained in an approximate 400 square feet area, and are located between 8 and 10 feet below grade (approximately 30 yards of material). All PCBs above 10 mg/kg are subject to remediation and options are discussed below.

Unconsolidated materials impacted with PCBs above the RDEC and below 10 mg/kg would be mitigated through site wide remediation. Note that no PCB impacted materials were identified above 10 times the GA PMC, and, therefore, are in compliance with the GA PMC pursuant to self implementing option RCSA Section 22a-133k-2(c)(2)(C)

Note that PCBs have never been identified in the site ground-water.

6.1.1 PCB Impacted Soil Alternative 1

Remedial Alternative 1 for the PCB impacted soil consists of the excavation and offsite disposal of the soil based on the US EPA self-implementing option for PCB waste disposal and the CTDEP RSR criteria. Approximately 30 cubic yards or 45 tons (assuming 1 cubic yard = 1.5 tons) of impacted soil would be excavated from the property. The soil would be excavated to a depth of 10 feet below grade (ft bg). Excavated soil would be placed in a temporary storage unit designed according to the requirements outlined in Subpart D of 40 CFR 761.

Soil samples would be collected from the excavation to confirm removal of impacted soil according to Subpart R of 40 CFR 761. The excavation would be backfilled with a mix of clean fill and unconsolidated materials excavated to the top of the PCB release area (0 to 8 feet below grade).

As required by 40 CFR 761, the soil would be shipped offsite within 30 days and disposed at a RCRA Subtitle C Landfill accepting PCB impacted materials or an approved PCB disposal facility.

6.1.2 PCB Impacted Soil Alternative 2

Remedial alternative 2 for the PCB impacted soil consists of the in-situ treatment of the impacted soils using zero-valent iron (ZVI) particles. ZVI particles are extremely small iron particles with high surface area to volume ratios. These properties in combination with zero valency make ZVI extremely chemically reactive. When in contact with the ZVI particles, PCBs are reductively dechlorinated with resulting byproducts being biphenyls. Chemical reduction of PCBs in this manner does not produce the harmful dioxin precursors that are commonly produced by chemical oxidation processes.

The ZVI would be injected in a grid pattern across the impacted area at incremental depths. The ZVI particles would be injected into the soil using either a positive displacement pump or by compressed nitrogen. Permanent injection points would be installed in order to facilitate subsequent injections until destruction of the PCBs is complete. Because the ZVI needs to be wetted in order to complete the reduction process, temporary water sprinklers would be placed in the impacted soil to keep the soil wet. In bench scale tests completed by LBG using ZVI to treat PCB site impacted soils, up to a 70% reduction in the concentration of PCBs was observed within two weeks of treatment. In order to get further reduction in concentrations, additional ZVI injections may be completed during the remedial action.

Note that this treatment option would require an approved CTDEP discharge permit.

6.2 Halogenated VOCs

A release of halogenated VOCs was detected in the area immediately west of the tennis and basketball courts, near test boring LBG-TB-53. The source area is extremely well characterized and does not contain dense non-aqueous phase liquids (DNAPLs) pursuant to pursuant to RCSA 22a-133k-2(c)(3)).

The release area is primarily located within the saturated industrial waste fill and is approximately 2,800 square feet. A much larger area of low concentrated VOCs was identified around the source area. This "halo" of VOCs is a common occurrence and the result of volatilization from the source VOCs and chemical diffusion.

Halogenated VOCs were detected above the RDEC in test borings LBG-TB-60, LBG-TB-106 and LBG-TB-210. Only LBG-TB-106 was identified with concentrations of VOCs above the I/C DEC. Pursuant to RCSA Section 22a-133k-2(c)(2)(B)(i), mass VOC concentrations may be compared to 10 times the GA PMC. Only one fill sample, LBG-TB-53 at 10 to 12 ft bg, was identified with halogenated VOCs above the 10 times the GA PMC. The area that exceeds the GA PMC is estimated to 250 square feet and approximately contains 13 yards of impacted fill (volume calculated assuming 1.4 feet above seasonal water table).

If soils were compared to the GA PMC numerical criteria, samples in six test borings would exceed the criteria. Approximately half the test borings are actually located outside of the source area and the impacts are the result of off gassing of the saturated source materials.

Soils which exceed criteria the RDEC would be mitigated as part of the site wide remedy. Specific treatment options for the halogenated VOCs which exceed the 10 times the GA PMC are discussed below.

Concentrations of halogenated VOCs in the ground-water at the source area have decreased dramatically over time. Understanding the halogenated VOC source area has likely remained for over 50 years, the trend in water-quality indicates the initial peak concentrations were likely the result of the disturbance of soil and fill in this area during the 2002 environmental investigations and the more recent low level of detections of halogenated VOCs in this area are more likely representative of steady-state conditions. Water-quality results at the downgradient portions of the plume have also shown an overall decline in concentrations, and it is reasonable to conclude the trend will continue. Ground-water was shown to be in compliance with the proposed RVC off of the site through soil-vapor sampling.

6.2.1 Remedial Alternative 1

Remedial alternative 1 for the VOC impacted area is the treatment of the impacted soil through natural degradation processes. As discussed, ground water at the halogenated VOC source area has dramatically improved over the past 2 ½ years. In fact, during the most recent sampling event, there were no detections of halogenated VOCs identified in the shallow source area monitor well, and in the deep source area well only (cis) 1,2-dichloroethylene and vinyl chloride were detected at concentration of 2.7 ug/l and 2.2 ug/l, respectively. Declines have also been shown in the downgradient monitor wells. It is likely that if ground-water quality simply stabilizes in the source area, ground water at the downgradient southwestern site boundary will eventually meet the GWPC and proposed RVC. This conclusion presumes minimal, if any, dilution and retardation occurs to the dissolved halogenated VOCs as they migrate approximately 600 feet to the site boundary.

Because the soils that are above the GA PMC are generally above the water-table (even seasonal high), little attenuation of the TCE is anticipated through microbial degradations. The TCE would likely degrade through volatilization processes. TCE does have a relatively high vapor pressure; however at cool temperatures TCE is generally stable. This remedial process would be a long term solution; however implementation of this option would avoid subsurface disturbance of soils which could potentially release additional slugs of halogenated solvents to the ground water.

If a structure were to be built over this area as part of a future use, engineered controls should be made to mitigate vapors beneath the structure.

6.2.2 Remedial Alternative 2

Remedial alternative 2 for the halogenated VOC impacted area is the treatment of the impacted soil using ZVI or emulsified ZVI. It is well documented that ZVI coupled with a catalyst (such as palladium) reacts with chlorinated VOCs to de-chlorinate VOCs. The resultant abiotic chemical reaction produces iron, chloride and ethane (C_2H_6) or ethylene (C_2H_4). The effectiveness of this type of treatment is primarily based on the concentration of iron injected into the aquifer and ability to distribute the ZVI.

The material would be injected with a high-pressure pump to a pressure activated injection probe located at the tip of the probe inserted by direct-push technology. The ZVI is discharged through the tip of the injection probe assembly radially outward into the formation. The material would be injected at incremental depths throughout the impacted unsaturated zone. In order for the ZVI to degrade the VOCs in the unsaturated zone, the soil will need to be wetted using a temporary sprinkler system. Based on the concentrations of the impacted materials, additional injections may be required to degrade the VOCs.

Because the area to be treated is so small, a pilot test is not recommended because it would be similar scale of the full scale treatment. The benefit of this type of treatment is that the ZVI would also treat ground water and any saturated impacted materials it comes in contact with. A concern of this treatment would be that the injection of the ZVI may cause dissolution of TCE halogenated VOCs, resulting in a “slug” of halogenated VOCs migrating in the ground water.

6.2.3 Remedial Alternative 3

Remedial alternative 3 is the excavation and disposal of VOC impacted soil that exceeds the PMC. VOC impacted soil was identified at approximately 10 to 12 feet below grade. The material overlying the high concentration layer would be excavated and stored onsite for re-use as backfill. The high concentration layer would be excavated and transported offsite to an appropriate disposal facility. The excavation would be backfilled with the overburden soil and clean fill would be added if to backfill the excavation.

A concern of this treatment would be that impacted materials would be disturbed as part of the excavation and backfilling activities, potentially resulting in a “slug” of halogenated VOCs migrating in the ground water.

6.2.4 Remedial Alternative 4

Remedial Alternative 4 is a general category which includes mitigation through various technologies, such as injection of ozone, microbes, modified Fenton reagent, potassium permanganate, and various reducing agents. Any injections could follow a similar format as remedial alternative 2. The downside to these alternatives in that they have been proven to be either less effective than treatment through injection of ZVI or they create various unfavorable byproducts.

6.2.5 Remedial Alternative 5

Remedial Alternative 5 is a general category which includes mitigation through installation of systems such as soil-vapor extraction, air sparging and multi-phase extraction. All of these technologies would likely be effective in treating the unsaturated impacted materials, however, considering the small volume needed to be treated, these are not the most cost-effective treatment options. In addition, the installation and operation of an active system does not seem appropriate for setting.

6.3 Hamden Housing Authority

Soils have been identified on the northern and southern sides of the Hamden Housing Authority properties above the RDEC and GA PMC. Remedial alternative are discussed below.

6.3.1 Remedial Alternative 1

As part of the site wide remedy, the PMC may be mitigated through various alternative and exemptions in the RSRs. Assuming soils at the Hamden Housing Authority parcels would meet the PMC, excavate impacted materials to 4 ft bg for DEC compliance. Sidewall samples would be collected to confirm removal of impacted soil exceeding the RDEC. The excavations would be backfilled with clean fill and restored to pre-construction conditions, and an ELUR implemented.

6.3.2 Remedial Alternative 2

Impacted soil located on the northern side of 249-251 and 253-255 Morse Street would be excavated to a depth of 4 feet for DEC compliance. Sidewall samples would be collected to confirm removal of impacted soil exceeding the RSR criteria. The excavations would be backfilled with clean fill and restored to pre-construction conditions. If soils exceeding the PMC remain, an engineered control would be installed pursuant to RCSA Section 22a-133k-2(f)(2)(A). This remedy would require implementation of an ELUR and Commissioner approval. This remedy would also require implementation of a ground-water monitoring program to ensure any substance migrating from the area would be detected.

6.3.3 Remedial Alternative 3

An engineered control for PMC and DEC compliance would be constructed to physically isolate polluted soils and minimize migration of liquids through the soil pursuant to RCSA Section 22a-133k-2(f)(2)(A). This remedy would require implementation of an ELUR and Commissioner approval. This remedy would also require implementation of a ground-water monitoring program to ensure any substance migrating from the area would be detected.

6.4 Evaluation of Potential PMC Alternative and Variances

The site wide remedy must address both exceedance of the PMC and DEC. The discussion below explores potential alternatives and variances which may be applicable to achieve compliance with all or portions of the PMC.

6.4.1 Ground-Water Reclassification

Ground-water beneath the Middle School Site is classified as GAA-impaired. A ground-water flow divide is present on the north-central portion of the site, in the immediate vicinity of the northern wetland corridor. A small portion of water entering the northeastern portion of the site discharges to this corridor. The divide appears to occur within 60 feet of the northern property boundary. All other ground-water at the Middle School Site flows to the west/southwest. A GB ground-water classification area is located within close proximity of the site to the south and west.

Understanding that Regional Water Authority has no intentions of using ground water in the Consent Order area for public supply usage; a request would be made for a ground water classification change to GB for all areas of the Middle School Site that flow towards the west/southwest, towards an existing GB area. The request would include areas beyond the Middle School Site that also show that ground-water flows towards the GB classification area.

6.4.2 RCSA Section 22a-133k-2(d)(6)

Provided the application for the GB ground-water classification change is accepted, RCSA Section 22a-133k-2(d)(6) identifies requirements for applying an alternative dilution or dilution attenuation factor for GB areas. This alternative soil criterion indicates the Commissioner may approve an alternative dilution or dilution attenuation factor for GB areas, provided that it is demonstrated to the Commissioner's satisfaction that application of the dilution factor will ensure that the soil water at such release area will not cause the ground water at the nearest downgradient property boundary to exceed the ground-water protection criterion for such substance.

As discussed in Section 4.1.3, with the exception of VOCs (vinyl chloride) and bis(2-ethylhexyl)phthalate, ground water at the downgradient property boundary for the past year meets the GWPC. Bis(2-ethylhexyl)phthalate has been shown to meet the current GA PMC, while halogenated VOCs will be mitigated pursuant to section 5.2. Therefore, if a ground-water reclassification is approved, it is likely an alternative dilution or dilution attenuation factor pursuant to RCSA Section 22a-133k-2(d)(6) will be submitted for approval.

Site data clearly shows that natural dilution or dilution attenuation is resulting in few exceedances of ground-water criteria at the downgradient property line, despite the GB PMC exceedances. An alternative dilution or dilution attenuation factor should results in compliance with all GB PMC exceedances.

6.4.3 RCSA Section 22a-133k-2(d)(4)

As discussed in Section 2.0, RCSA Section 22a-133k-2(d)(4) identifies requirements for applying an alternative dilution or dilution attenuation factor for GA areas. This alternative soil criterion indicates the commissioner may approve an alternative dilution or dilution attenuation factor for GA areas, provided that it is demonstrated to the Commissioner's satisfaction that application of the dilution factor will ensure the release will not degrade ground-water quality and thereby prevent the achievement of the applicable ground-water remediation standards.

Dependant on the result of the proposed ground-water classification change, either all or a portion of the site would remain GAA-impacted. As shown in the CSM, a poor correlation has been shown in water-quality as compared to the identified PMC exceedances. For example, antimony was one of two primary metals shown to exceed the applicable PMC (10 times the GWPC); however, antimony has never been identified in the site ground water. A similar poor correlation is shown with ETPH; while numerous exceedances of the PMC have been identified unrelated to fuel oil, most ETPH ground-water impacts appear to be related to the Middle School fuel oil UST or associated piping. Therefore, a request for an alternative dilution or dilution attenuation pursuant to RCSA Section 22a-133k-2(d)(4) would result in a reduction of GA PMC exceedances.

6.4.4 RCSA Section 22a-133k-2(f)(1)

RCSA Section 22a-133k-2(f)(1) is a variance which would require a written request by the owner of the subject parcel and Commissioner approval. As discussed in Section 2.0, this variance is referred to as widespread polluted fill variance. The Middle School Site is part of much large area which has been historically filled. This is evident by the investigations of other responsible parties and the continued investigations of the CTDEP. The investigations of the CTDEP have identified fill areas well beyond the original Consent Order "Site."

The variance indicates that the PMC does not apply if the following conditions are met:

1) Geographically extensive polluted fill is present at and in the vicinity of the subject parcel. This condition is obviously met;

2) The fill is not polluted with VOCs. VOCs only need to meet RSR criteria and would be treated as discussed in Section 5.2;

3) The fill is not affecting, and will not affect the quality of an existing or potential public water supply. The fill areas identified at the Middle School Site and surrounding areas are located close to an existing large GB ground-water classification area. Ground water throughout most of the site has been clearly shown to flow to the southwest, towards the existing GB areas. Any request for the widespread polluted fill variance should only be made for the areas of the site in which ground-water flows to the southwest;

4) Concentrations of fill are consistent with RSR applicable to the DEC. This condition would be met as part of the final site wide remedy;

5) The placement of fill was not prohibited by law at the time of filling. It is presumed this condition has been met; however, it is outside the scope of this document to make this assessment; and

6) The person requesting the variance did not place the fill on the subject parcel. RWA has never been linked to the placement of fill. In addition, the Town of Hamden has never conclusively been identified as an active participant of disposal at the Middle School Site.

In addition, the Commissioner may consider in granting or denying the request the following: 1) the cost of compliance with the PMC; 2) how extensive the fill is and what relative proportion occurs on the subject parcel; 3) and whether the person requesting the variance is affiliated with any person responsible for placement of the fill through indirect or direct familial relationship, or an contractual, corporate or financial relationship other than that by which such person's interest in such parcel is to be conveyed or financed.

It seems reasonable that the consent order area and additional areas of fill continually being identified by the CTDEP would be candidates for this variance. However, because this variance requires a written request of the site owner, this variance would be difficult logistically to apply to the entire regional fill. However if a request were made by the Town of Hamden or future owner of the Middle School Site, it is a potential avenue which would address exceedances of the PMC.

6.5 Site Wide Remedy

The remedies discussed above address remediation of the PCBs “hot spot”, halogenated VOCs, the Hamden Housing Authority property and the PMC. Additional areas at the site which would require remediation include the top 4 feet of soil exceeding the DEC (assuming implementation of an ELUR), and areas exceeding the PMC if the ground-water reclassification and/or alternative dilution or dilution attenuation factor are not accepted, or various other PMC compliance efforts are not achieved. The discussion below addresses these remaining areas.

The remedies discussed below assume various future uses of the Middle School Site. In addition, the remedies also explore potential variance in the RSRs which may be applicable to the Middle School Site.

In all remedial scenarios, it is assumed that soils beneath current and future buildings would be part of the proposed remedy. With recording of an ELUR, these soils would be rendered “environmentally isolated” and “inaccessible.” Because the future use of the site is unknown, it is unclear as to what extent this option would be applicable.

Numerous active remedial measures were explored as part of this evaluation. Because the site has both inorganic and organic contaminants, and the remediation has to address both the mobility and exposure of the contaminants; treatment remedies were limited. The limiting factor in treatment remedies for fill and soil is the exposure and mobility of metals. Engineered controls are one solution to this problem; they can both render contaminants “inaccessible” and “environmentally isolated.” Soil removal for DEC compliance has been discussed. However a site wide remedy does not need to be addressed with a single solution and a multi-remedial solution may be favorable. For example, both organics and inorganics could be treated with use of phytoremediation, with a goal of reducing soil disposal needs. Phytoremediation is the use of plants and/or trees to remediate contaminants in soil and ground water. While phytoremediation is a potential option for the entire site, it could be a very effective remedy utilized on a portion of the site in which impacted materials have been stockpiled. A phytoremediation remedy on portions of the Middle School Site could also add beauty to the area if implemented in an appropriate fashion.

From the beginning of this process, RWA has taken a proactive approach of finding solutions for the community. Future land use of this parcel is unknown; therefore, solutions are explored which include extensive development options for the site. However, it is RWA's intent and hope that the final approved remedy provides a solution that the community will embrace. The remedial alternatives discussed below do not include all available options for the site; rather they present a framework on how various remedies may be implemented.

6.5.1 Remedial Alternative 1

The below is a conceptual remedial scenario on how multiple remedial strategies could be used to remediate the site and enhance the athletic field. This conceptual remedial alternative presumes that the site, with the exception of the 0.9 acres on the northeastern portion of the site, will be reclassified to GB. Under this scenario, approximately 6 acres of the site exceed the GB PMC (if an alternative dilution or dilution attenuation factor does not result in compliance). As shown on figure 26, a large portion of the athletic field has materials up to 4 ft bg that meet the RDEC. The areas that exceed are located in the northwest corner, south-central and southeastern. Areas of the athletic field that do not meet the GB PMC are located near and around the tennis and basketball courts and a portion on the western edged of the field. Note that all of the aforementioned areas that exceed the GB PMC have at least 2 feet of cover material that meets the RDEC.

All remediation described below would require implementation of an ELUR.

<u>Phytoremediation Treatment Areas</u>

1) Set up phytoremediation treatment areas along the Western Portion of the Athletic Field. This would include the northwestern area of the site which exceeds the GB PMC and RDEC. Clean soils which meet the GA PMC and RDEC from this area would be excavated and used as clean fill on other portions of the site. This type of mass balance could minimize the amount of soils needed to be brought onsite and also avoid significant stockpiling of soils in the phytoremediation area. This area would provide a visual buffer between the industrial parcel to the west and the athletic field. This area would be fenced off and a drainage system would be installed around it to mitigate run off.

2) A second phytoremediation treatment area would be established in the southern rear courtyard area of the Middle School. This second area is a logical place for the soils to be treated. Currently most materials in this area exceed the GB PMC, secondly this area is generally unused.

<u>Excavation Areas</u>

1) Materials which exceed the RDEC down to 4 ft bg on the southwestern portion of the field would be excavated and moved to one of the phytoremediation treatment areas. Clean soils from the western phytoremediation treatment area would be used to backfill this southwestern excavation area.
2) Soils/fill that exceeds the RDEC on the unpaved eastern portion of the site would be excavated to 4 ft bg and stockpiled in the phytoremediation treatment areas. Clean fill would be brought from offsite and from the western phytoremediation treatment area to fill this excavation area.

<u>Engineered Controls</u>

All engineered controls described include erosion and drainage controls. In addition, a ground-water monitoring program would be instituted to ensure the effectiveness of the controls.

1) Areas that exceed the GB PMC near the tennis and basketball courts would be addressed through implementation of an engineered control. These courts would be expanded such that they cover all GB PMC exceedance areas, with the exception of the central strip located on the east central portion of the site. This area would be completed as a paved parking area. The aforementioned would be completed such that soils exceeding the PMC would be rendered “environmentally isolated” by placing an engineering control over the impacted soil to physically isolate impacted soil and to minimize migration of liquids through soil.
2) The approximate 0.7 acres located on the eastern portion of the Middle School that exceeds the GB PMC would be excavated to 1 ft bg, and the soils would be stockpiled in one of the site phytoremediation treatment areas. A geosynthetic clay liner (GCL) would be placed over this area and backfilled to grade. Three inches of

bituminous asphalt would be placed over this area and the remaining portions of the eastern side of the school that exceed the RDEC (excluding the area backfilled with 4 feet of clean fill). The asphalt would be a proposed engineering control rendering the soil "inaccessible". Because this portion of the property will remain in a driveway and/or parking area, direct exposure with the impacted soil would be eliminated during normal recreational activities.

3) The approximate 0.9 acre area abutting the northern wetland corridor which exceeds the GA PMC and RDEC would be excavated to 4 ft bg, a GCL would be installed and the excavation would be backfilled with clean fill. Excavated areas would be placed in one of the two phytoremediation treatment areas on the site. An alternative to the installation of the GCL liner in this northern area would be administrative controls, such as a ground-water monitoring program. Ground-water in the wetland corridor has shown no impacts from the site ground water. A long-term monitoring program could be implemented, and if impacts are identified, then a remedial strategy to address the PMC in this area would be implemented.

6.5.2 Remedial Alternative 2

This remedial alternative assumes the site remains GA ground-water classification, which adds much of the athletic field to the areas needing remediation. The site use could remain the same with implementation of an engineered control. Nearly all of the athletic field area is already beneath 4 feet of material that meets the RDEC. The first objective of this alternative is to render impacted soil throughout the entire site exceeding the DEC as "inaccessible" as provided in the RSR. The second objective is to render impacted soil exceeding the PMC as "environmentally isolated" by placing an engineered control over the impacted soil to physically isolate impacted soil and to minimize migration of liquids through soil. An ELUR would be placed on the property as part of the remedial action to prohibit certain activities.

The remedial alternative would be completed in phases and would involve removing and stockpiling half of the clean fill placed on the athletic fields on the other half of the field (presumably down to four feet where applicable). The material would be re-used as clean fill during the remedial action. Following the removal of the clean fill from the athletic fields, impacted soils from half of the remainder of the site excavated down to 4 feet would be relocated to the half of the unearthed athletic field. The soil would be graded and sloped slightly away from the middle of the athletic fields to allow drainage of precipitation from the area. A GCL would be placed over areas that exceed the PMC (on the athletic field and excavated portions of the site). Then the clean stockpiled soil from the athletic field would be placed over the liner (and potentially additional clean fill from offsite) making a total of 4 feet of clean fill on half of the athletic field. Clean fill would be brought onsite to fill areas excavated to 4 feet. The process would be repeated for the remaining half of the site that had not been remediated.

An engineering control consisting of a GCL would allow impacted soils to be rendered "environmental isolated". The GCL consists of a layer of bentonite clay sandwiched between two layers of geosynthetic fabric to create a carpet like material that would be rolled out over the impacted area. The bentonite in the GCL is a clay mineral with expansive characteristics that when hydrated will swell up to 900% by volume. When the GCL is hydrated under confinement by overlying soil, the bentonite would swell and create a dense layer of clay with a permeability of less than 10^{-6} centimeters per second (cm/sec). Seams of the GCL will be overlapped and sealed with a bead granular bentonite according to the manufacturer's specifications to prevent migration of liquids through the GCL seams.

An ELUR prohibiting the disturbance of the soil at the property will be recorded on the municipal land records and a ground-water monitoring program would be put in place. Note that with commissioner approval, these activities could be completed without the GCL liner. If the site were determined to meet the GB PMC through ground-water classification change and acceptance of an alternative dilution or dilution attenuation factor, the impermeable barrier would not be a necessary component of this alternative.

6.5.3 Remedial Alternative 3

This remedial alternative assumes extensive future development (industrial park, convention center, retail establishments, community centers, etc.) on the Middle School Site. This would allow impacted materials to be moved beneath future Commissioner approved structures, and rendered "environmentally isolated" and "inaccessible" with the recording of an ELUR. Details of this type of site wide remediation would need to be developed with an understanding of the extent of any future proposed development. As shown on plate 26, a large portion of the site already has at least 4 feet of ground surface above that meets the DEC (i.e.

"inaccessible" with recording of an ELUR). If ground water were reclassified to GB, this option would be extremely favorable because the area of soils which exceed the PMC is significantly reduced. In addition, the areas which exceed the GB PMC could be further reduced through the acceptance of an alternative dilution or dilution attenuation factor.

6.5.4 Remedial Alternative 4

Remedial alternative 4 is a site wide phytoremediation program. The species of tree or grass to be planted may be varied based on the contaminants for each area. General species to be planted are hybrid poplars, white willows and various grasses.

As discussed above, phytoremediation is the use of plants and/or trees to remediate contaminants in soil and ground water. Remediation occurs through a variety of plant biological processes such as chemical and water uptake, metabolism within the plant, release of plant enzymes into the soil that leads to contaminant degradation, and the physical and biochemical impacts of plant roots to either degrade, accumulate, dissipate or immobilize contaminants in the plant or in the subsurface. Contaminated soil and ground water can be treated using the following phytoremediation processes: phytoextraction, phytostabilization, rhizodegradation, phytodegradation and phytovolatilization. Combinations of these processes will occur simultaneously or in sequence for a particular contaminant. Chlorinated solvents can be subject to biodegradation in the root zone and metabolism within the plant, with a loss of contaminant through volatilization from the plant. Some metals can be accumulated on or within the roots while other metals are simultaneously taken up into the above-ground portion of the plant.

6.5.5 Remedial Alternative 5

Remedial alternative 5 is a site wide engineered control. The objectives of remedial alternative 5 is to render the impacted soil exceeding the DEC "inaccessible" and soil exceeding the GA PMC "environmentally isolated." There are many ways in which this could accomplished, and several are discussed above. It may be an objective of the remediation to place an engineering control at or near grade. This type of engineered control, as with others, would require Commissioner approval, recording of an ELUR, and inclusion of a drainage system to limit erosion or damage of the control.

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"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."

____

South Central Connecticut Regional Water Authority
Thomas V. Chaplik
Vice President

____

Leggette, Brashears & Graham, Inc.
Jeffrey B. Lennox
Principal

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FINAL INVESTIGATION AND REMEDIAL EVALUATUION REPORT
FORMER NEW HAVEN WATER
COMPANY PROPERTY
HAMDEN, CONNECTICUT

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On Behalf Of:

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March 30, 2005

Prepared By:

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