Sub-Slab Depressurization – A Necessary Part of the Final Remedy

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Introduction

Soil vapor monitoring and abatement have become a hot topic in the environmental field during the past few years. As a result, Sub-Slab Depressurization or "SSD" systems are now playing a key role in site closure activities. This article presents two case histories where SSD systems were implemented as the Final Remedy. The first case history is a dry cleaner remediation site and the second is a former gas station redevelopment site – both located in Brooklyn, New York.

At the dry cleaner site, an Air Sparging / Soil Vapor Extraction (AS / SVE) system operated until its termination criteria were achieved. To address remnant, low-level Perchloroethene (a.k.a. PCE or "Perc") vapors, the SVE wells (located in the basement of the dry cleaner) were converted into SSD wells by employing the use of high-flow, low-vacuum fans. This process was formalized in a Site Management Plan for the property.

The former gas station property is being converted into a mixed use residential/commercial building. The new development will consist of: a subsurface parking garage; ground level commercial units; and nine floors of residential units. Due to the presence of petroleum vapors in the subsurface soil, an SSD system was

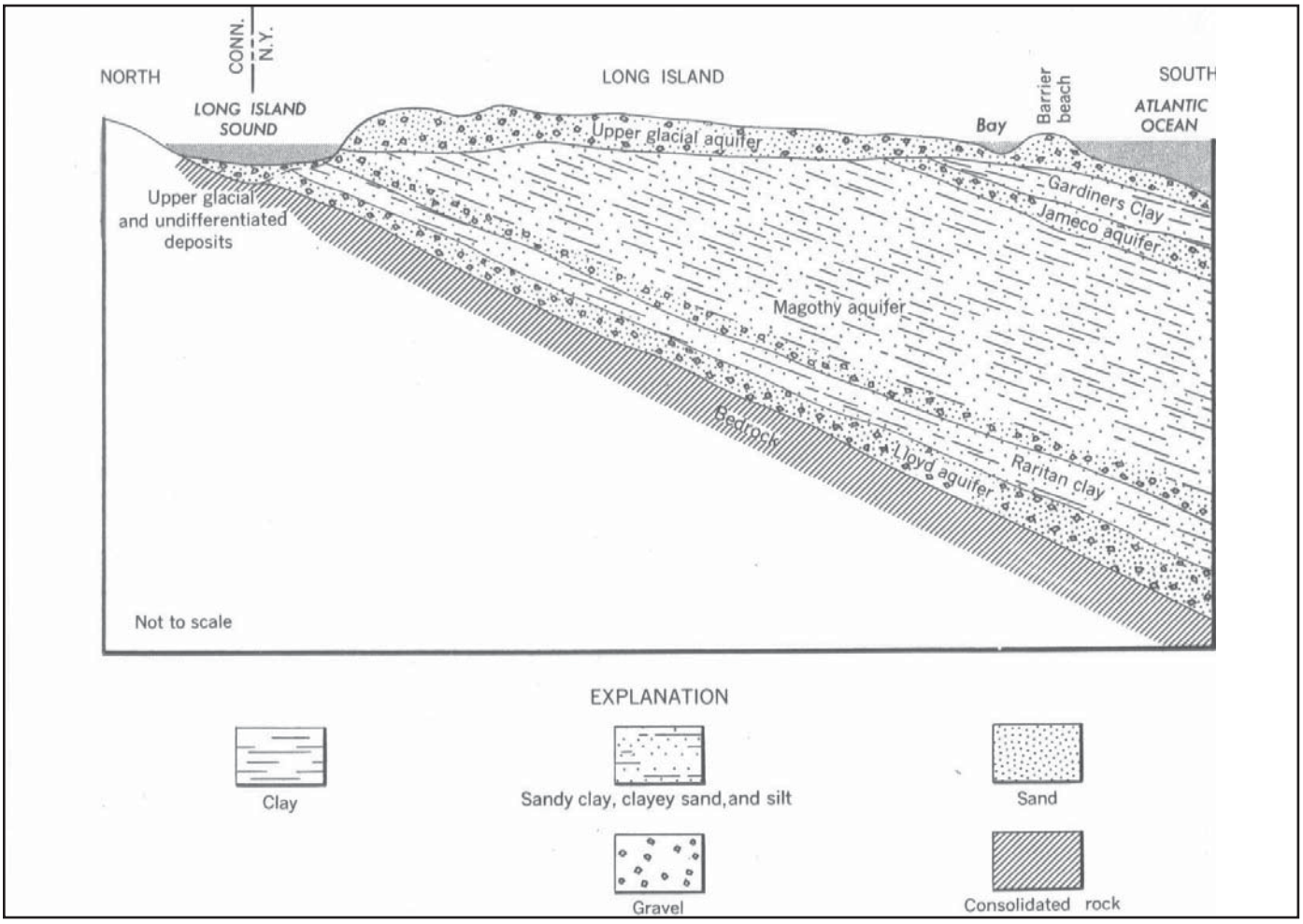

Figure 1. Generalized Geologic Cross-Section Of Long Island, New York. McClymonds and Franke, 1972.

incorporated into the design of the new structure's foundation.

Hydrogeology of Long Island

The Borough of Brooklyn comprises the western most portion of Long Island, the majority of which is covered by the highly permeable sands and gravels of the Pleistocene Age Upper Glacial Formation. This Formation varies in thickness, and is generally not used for water supply purposes (except for areas in eastern Suffolk County). A generalized geologic cross-section of Long Island, New York is included as Figure 1. The Upper Glacial Formation unconformably overlies the Cretaceous Magothy Formation, the principal water supply aquifer for the southeastern portion of the Borough of Queens, most of Nassau County, and Suffolk County, with many wells on the order of 400 to 600 feet in depth. The aquifers below the Borough of Brooklyn are no longer used as a source of potable water. The upper portion of the Magothy Formation is generally of low to moderate permeability and overlies highly permeable sands and gravels in the basal section of this geologic unit. The Magothy Formation is, in turn, underlain by the Cretaceous Raritan Formation. The Raritan Formation is composed of the upper Raritan Clay, a regional confining layer that overlies the more permeable Lloyd Sand. The Lloyd Sand was deposited directly upon Precambrian crystalline bedrock (McClymonds and Franke, 1972).

Case History Number One

The dry cleaning property is an active facility situated in a multi-use shopping center located in the Flatlands section of Brooklyn. The shopping center was the subject of a Phase I and Phase II Environmental Site Assessment for refinancing purposes during the summer of 2001. During the course of the Phase II subsurface investigation, a release of Perchloroethene was detected in the soils underlying the boiler room section of the basement.

Based on the results of the Phase II investigation, the owner of the shopping center entered into a Voluntary Cleanup Program (VCP) agreement with the New York State Department of Environmental Conservation (NYSDEC). A Site Investigation including soil, soil vapor and groundwater sampling was performed to define the nature and extent of contamination at the property. This was followed by the development and implementation of a Remediation Work Plan.

Case History One Remedial Action Plan

The approved cleanup program for the site included the installation and operation of:

- a 4-point Soil Vapor Extraction (SVE) system;
- a 3-point Air Sparging (AS) system; and,
- localized chemical oxidation treatments using permanganate.

The combined AS/SVE system was installed, and the system was placed into operation in March 2005. The AS portion of the system remained in operation for one year as the groundwater quality below the property improved. In addition to the AS system, localized "hot spots" of PCE in the groundwater (located outside the sparge radius of the AS system) were treated with permanganate injections applied using a Geoprobe™. The groundwater standard for PCE in New York State is 5 ug/L. While the AS portion of the system was turned off, the SVE system remained in operation to control the migration of the remnant, low-level PCE vapors.

While the operation of the AS system was terminated, the SVE system -- which included carbon units and the operation of an energy-consuming 4½ - horsepower blower -- was modified. A SSD pilot test was performed following the New York State Department of Health's (NYSDOH) October 2006 guidance document (NYSDOH, October 2006). A vacuum radius of approximately 50 feet was measured during the pilot test. Based on the results of the pilot test, the blower and carbon units were disconnected in the fall of 2006. The four existing vapor extraction wells were then equipped with individual energy-efficient vapor abatement fans. The fans selected create negative pressure below the basement floor and prevent sub-slab vapors from migrating into the building -- at a much lower operating expense than the initial SVE blower. This network of fans comprises the current SSD system and prevents remnant, low-level PCE vapors from entering the inhabited areas of the shopping center. A photograph of one of the fans is included as Figure 2.

Figure 2. Typical Sub-Slab Depressurization Fan and Vacuum Gauge, Case History Number 1.

A Site Management Plan or "SMP" was then prepared for the project. The SMP described the configuration of the SSD fan network and listed it as an engineering control for the property. To assure the proper operation of the fans in the future, the SMP requires annual indoor air testing in the basement and an annual inspection of the fans by a Professional Engineer or Qualified Environmental Professional.

The SSD fans must remain in operation until their termination criteria, as described in the SMP, are achieved. The termination criteria for the SSD fans comply with Indoor Air Matrix 2 of the NYSDOH's Guidance document. In summary, the following conditions must be demonstrated:

- The indoor air concentrations of PCE in the basement of the cleaners and the two adjoining units are less than 3 ug/m^3; and,
- The sub-slab soil vapor concentration of PCE below the cleaners is less than 100 ug/m^3.

This must be demonstrated during the winter heating season, to represent the worse case scenario, and after the SSD system has been turned off for a period of 30 days.

By converting the SVE system to an SSD system, the property owner was able to greatly reduce the long-term operating expense at the site. More importantly, the Site Management Plan also includes a mechanism to allow for the future termination or shut down of the SSD fans.

Case History Number Two

The gas station property is a 0.35-acre rectangular-shaped lot located in the Borough of Brooklyn, and is part of

the Atlantic Terminal Urban Renewal Area. The proposed new construction consists of a subsurface parking garage; ground level commercial units; and nine floors of residential units. A second-floor courtyard will provide 3,000 square feet of open space.

This site is currently vacant. However, historical records indicate that it was utilized for automotive fuel storage and dispensing purposes since as early as 1938. The historical presence of underground storage tanks (USTs) has lead to various environmental investigations. A total of seven former USTs were removed in 2001. The work performed to date indicated that subsurface soils in the vicinity of seven USTs contained elevated levels of Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs). Investigation and remediation of the remaining petroleum is being addressed under the review and regulatory oversight of the New York State Department of Environmental Conservation (NYSDEC) Region 2 Spills Group.

A site Investigation that included test pits, soil sampling, soil vapor sampling, monitoring well installation and groundwater sampling was performed during the fall and winter of 2006 with the following results. During that investigation, it was determined that the upper 20 feet of the site consisted of a mixture of native soils and imported fill materials. Soil in the tests pits was described as brown to gray medium sand containing domestic debris. In addition, six additional out-of-service tanks were identified and removed. The soil in the tank excavations exhibited a petroleum odor and elevated Photo Ionization Detector (PID) readings; this material is classified as a mixture of both "urban fill" and soil contaminated by petroleum from the operation of former gasoline filling stations.

The VOCs ethyl benzene and xylenes were detected in test pits along with varying levels of methyl benzene and cyclohexane compounds, all of which are related to petroleum. Four SVOCs -- benzo(a)anthracene, chrysene, benzo(b) fluroanthene, and benzo(a)pyrene -- were also detected above the State Cleanup Objectives in the soil samples

Soil vapor probes were installed in the test pit locations with a six-inch long screen set at 20 feet below grade. This depth was selected because it is just below the anticipated elevation of the proposed subsurface parking garage floor. Each of these points was sampled and the collected vapor was analyzed for VOCs. Concentrations of numerous petroleum compounds related to motor fuels including: propene (propylene); heptene; trimethylpentane; and hexane were detected in these soil vapor points.

Groundwater was encountered at the site at a depth of approximately 50 feet below grade flowing towards the southwest. The groundwater below the property has been contaminated by petroleum-related compounds, most likely from the site's historical use as a motor fuel filling station. Ethyl benzene, xylenes, and trimethylbenzenes, the same compounds detected in the test pits, were detected above State groundwater standards in all four of the site monitoring wells. The concentrations were higher in the on-site and downgradient wells than in the upgradient wells indicating that a historical release of petroleum occurred at this property.

Case History Two Remedial Action Plan

The following Remedial Action Plan (RAP) was developed for the redevelopment of this site. To date, the only elements of the RAP that have been completed are the UST removal and the soil excavation.

UST Removal – The six additional USTs uncovered during the excavation program were properly removed. The tanks were pumped dry; cut open and cleaned; and then disposed of as scrap metal. Any petroleum-contaminated soil encountered around the buried tanks was excavated and removed during the construction of the building foundation.

Excavation – As part of the construction of the basement and foundation of the new building, approximately 15 feet of soil was excavated from across the property using a track-mounted excavator. This soil was tested and then properly disposed of at a permitted facility in accordance with the results of the tests. The bulk of the contaminated soil at the site was removed by this process.

Design and Installation of a Vapor Barrier System - Based on the site's historical use as a gasoline filling station, installation of an engineered plastic vapor barrier will be included in the construction of the building's foundation. The purpose of the vapor barrier is to ensure that any petroleum vapors that remain below the ground cannot migrate into the structure. A membrane that meets or exceeds the American Society for Testing and Materials (ASTM) International standard as a vapor barrier was selected. The membrane will be installed by a knowledgeable contractor under the supervision of a New York State-licensed Professional Engineer in accordance with the manufacturer's installation procedures.

Design and Installation of a Sub-Slab Venting System - A sub-slab venting system will be incorporated into the building's foundation and structure with an intended purpose of venting any vapors trapped below the foundation to the atmosphere. The venting system will consist of four-inch diameter slotted pipe laid horizontal below the vapor barrier across the western, central and eastern portions of the foundation. The layout of the venting system is illustrated on Figure 3. These slotted pipes will be connected to a high-vacuum, high-flow mechanical blower. The blower will initially draw the hydrocarbon vapors out of the ground and through vapor-phase carbon filters to remove the hydrocarbons, and then pump the treated air through vertical pipes within the structure that vent above the roof line. As the levels of VOCs in the extracted soil vapor decrease, the sub-slab venting system will be modified by converting the initial blower to a high-flow, low-vacuum SSD blower. At this time, the VOC concentration should be low enough that carbon treatment of the exhaust will not be required. This will allow for a savings in both energy consumption and system maintenance. A site management plan will be prepared to ensure the proper long term maintenance and monitoring of the system as well as a procedure for terminating the system in the future.

Post Remedial Monitoring - After the construction of the building is completed, a separate Post-Remediation Monitoring Program will be implemented. This will include operation and maintenance of the venting system and semi-annual monitoring of the remaining groundwater monitoring wells for two years. At the conclusion of the two year groundwater monitoring portion of the program the data will be evaluated. If the levels of VOCs continue to decrease, a "No Further Action Letter" will be requested from NYSDEC for closure of the spill.

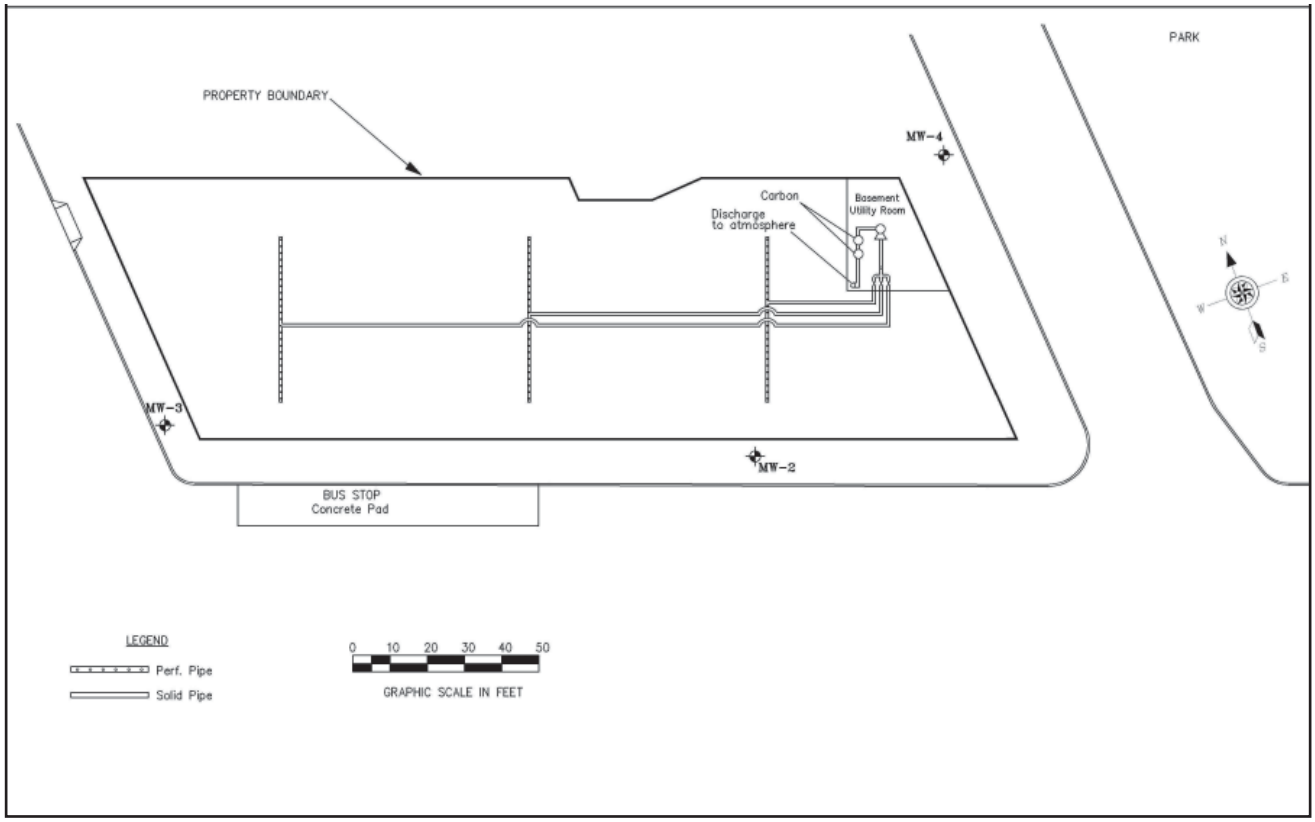

Figure 3. Layout of the Sub-Slab Venting System, Case History Number 2.

Summary

The two case histories presented in this paper include different contaminants of concern and different land uses. However, both include SSD systems as part of the Final Remedy. Soil vapor issues have become a significant factor in today's site investigations. Hand-in-hand with that, soil vapor abatement and remediation are common components of site clean ups.

Traditional methods of soil vapor remediation have typically included SVE systems that employ the use of regenerative blowers and carbon filtration. These systems consume large quantities of energy and have high operation and maintenance costs. By including SSDs as part of the Final Remedy, the energy consumption and operation & maintenance costs can be greatly reduced. At the same time, maintaining negative pressure below the building slab will ensure that subsurface vapors do not enter the structure. The SSD systems should be incorporated into a site management plan that provides for an annual check of the system and a methodology for terminating the system.

References

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