Implementation of a Strategic Approach for Complex VI Assessment at a Large Military Facility

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ABSTRACT

Vapor intrusion (VI) assessments are often conducted on a building-by-building basis, with regulatory guidance-specified spacing for sampling of various media (soil gas, sub-slab gas and indoor air) and analytical methods (typically only volatile organic compounds [VOCs]). VI assessments at military installations may often include a large number of buildings and a broader range of contaminants of potential concern (COPCs), such as semi-VOCs, polychlorinated biphenyls (PCBs), pesticides, mercury, and/or chemical warfare agents, in which case, a sampling and analysis program based on a pre-determined sampling density for all COPCs at every building would be prohibitively expensive and logistically demanding. The VI pathway evaluation may be further complicated if screening levels and/or toxicity factors do not exist for some COPCs. These issues were addressed during the VI investigation at Canal Creek Study Area (CCSA), Aberdeen Proving Ground (APG), Maryland, which has more than 300 buildings and many uncommon COPCs. This paper describes a process of prioritization to improve the cost-effectiveness of the assessment, which can serve as a model for application more widely throughout APG as well as other military facilities.

Potential VI risks were prioritized based on historic soil and groundwater concentrations, geologic and hydrogeologic data, which were reviewed to develop a series of Conceptual Site Models (CSMs) of the VI pathway, depending predominantly on whether the source was in the vadose zone, unconfined aquifer or confined aquifer (decreasing potential for VI risks).

Site-specific screening levels were developed for as many of the COPCs as possible and historic concentrations measured in soil and groundwater were compared to the screening levels, from which a subset of 14 of the 317 buildings believed to pose the greatest risk for VI was selected for the first phase of investigation. Several innovative tools were employed, including Waterloo Membrane Samplers™ for sampling VOCs (Groenevelt et al., 2010), High Purge Volume (HPV) sampling (McAlary et al., 2010) for sub-slab sampling at large buildings, and customized active absorbent tubes for semi-VOCs, pesticides and chemical warfare agent degradation products in the subsurface and indoor air were utilized during the field investigation.

The first phase of investigation indicated that the potential for VI would not exceed acceptable risk levels at the vast majority of buildings. Further, uncommon COPCs were not detected in soil gas or indoor air, which allowed for the elimination of these compounds from further investigation. As a result, the scope of any additional VI investigation is expected to be reduced considerably from the default "comprehensive" scope of assessment (all COPCs at all buildings in all media) that would result from strictly following the regulatory guidance for vapor intrusion assessment (USEPA, 2002). This represents a significant savings in future investigation and mitigation costs.

INTRODUCTION

Aberdeen Proving Ground (APG), Maryland was established in 1917 with the Edgewood Area (APG-EA) serving as the center for research, development, testing, and manufacturing of military chemical agents and materials related to chemical warfare. As a result of environmental contamination resulting from historical operations at APG-EA, this area was placed on the National Priorities List in February 1990.

The Canal Creek Study Area (CCSA) is a 700-acre land parcel located within the northern portion of APG-EA bordered by the Bush River to the east and the Gunpowder River to the west (Figure 1). Within the CCSA, chemical manufacturing plants operated from approximately 1918 until the end of World War II (WWII). At the end of WWII, chemical manufacturing activities were scaled down and many of the plants were abandoned or converted to laboratory and pilot-scale chemical manufacturing facilities. Until the 1970s, most of the buildings in the central industrial area of the CCSA continued to discharge liquid wastes to the East and West Branches of Canal Creek through a vitrified clay tile sewer system. Chlorinated solvents were used as raw materials, decontamination agents, and cleaning agents in the chemical manufacturing plants. These disposal activities, along with improper surface disposals, have resulted in soil and groundwater impacts at CCSA. An assessment of VI within the CCSA had not been performed and the Army was tasked with investigating which buildings posed unacceptable risks to occupants.

The VI assessment at CCSA presented many challenges for the Army. One challenge was evaluating the large number of buildings on the Site in a reasonable and practical manner that also met regulatory and Army approval. With such a large number of buildings (317), some of which had very large footprints, thousands of samples would have been required to meet generic regulatory guidance-specified spacing for sampling of various media (e.g., soil gas, sub-slab gas and indoor air). The list of COPCs at CCSA included semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, mercury, and chemical warfare agent degradation products. A comprehensive sampling and analysis program to characterize all COPCs in all media at default sample spacing would have been prohibitively expensive. Furthermore, the site is large enough (700 acres) to encompass significant variations in hydrogeology, multiple known or suspected source areas, buildings of different design, construction, occupancy and ventilation, and a database of previous soil and groundwater investigation results. These factors were utilized for the development of a thorough Conceptual Site Model (CSM).

This paper describes a strategy for identifying the compounds and buildings most likely to pose an unacceptable risk, based on concentrations distributions, proximity to buildings, source depth and compound-specific toxicity using mathematical modeling and a geospatial relational database. This analysis was used to prioritize the investigation to focus on the compounds and buildings most likely to pose an unacceptable risk (a “worst-first” approach). Following regulatory review and approval of the logic and sequence of investigation, the initial phase of sampling and analysis was conducted at 14 occupied buildings at the Site, which provided results that inform subsequent phases of assessment. This paper also describes unique aspects of field sampling and analysis using passive diffusive samplers for indoor air monitoring and high purge volume sampling for sub-slab vapor assessment.

METHODOLOGY

Site Characteristics

The hydrogeology of the CCSA, characteristics of buildings contained within the Site boundary, and distribution of COPCs at concentrations above risk-based screening levels are critical aspects of the prioritization of potential VI risks. These Site characteristics are described in this section.

Hydrogeology

The hydrostratigraphic units in the CCSA, starting at the ground surface and heading deeper, consist of the surficial aquifer (SA), the upper confining unit (UCU), the Canal Creek Aquifer (CCA), the lower confining unit, and the lower confined aquifer (Figure 2). Chemicals in the three uppermost hydrologic units (SA, UCU, and CCA) are considered potentially relevant for the VI assessment.

The SA is an unconfined aquifer, and therefore poses a greater potential for VI risk than the UCU or CCA. In the vicinity of the East Branch Canal Creek (EBCC), the SA was deposited as a former estuarine channel (i.e., paleochannel) estimated to be up to 50 feet (ft) thick and in direct hydraulic connection with the underlying CCA. Elsewhere, the UCU underlies the SA and consists mostly of Potomac Group clays, which are stiff and plastic. The CCA is comprised mostly of coarse-grained quartz sand and gravel with small amounts of dark heavy mineral grains and small cobbles. Although the CCA is designated as a confined aquifer, it could potentially result in a complete VI pathway in discharge areas along the EBCC and West Branch Canal Creek (WBCC) where the UCU has been eroded.

Groundwater flow in the confined portions of the CCA underlying the Edgewood Area follows regional flow patterns. A north-south groundwater divide is present in the CCA between the EBCC and WBCC (*5*, *6*) (Figure 1). The SA receives recharge from infiltration of precipitation and discharge from leaky storm drains. In areas near the groundwater divide between the EBCC and WBCC, this recharge is expected to cause downward flow and potentially a fresh water lens or diving plume. These factors may reduce the risk of VI considerably. In the lowland areas, groundwater flow directions in the upper portion of the SA are tidally influenced. Horizontal hydraulic gradients in the CCA are moderate (0.03 ft/ft), and pump tests on the west CCA indicated mean hydraulic conductivity values of 28 ft/day (*5*). In general, the primary discharge area for the CCA is WBCC, where groundwater discharges to the wetland (*7*).

Site Contamination

Groundwater and soil contamination have previously been reported at CCSA, near and downgradient of several primary sources, including areas historically designated for chemical use, storage, and handling, former sumps, former sewer discharge locations and former landfill areas or waste disposal pits (*3, 5, 6*). Chemical warfare agent production occurred in many of the buildings and previous investigations have confirmed environmentally-impacted areas in close proximity to the buildings.

Downgradient of the primary source areas, there are multiple co-mingled contaminant plumes in the SA and CCA. Elevated contaminant concentrations within the plumes generally correlate to locations where waste-generating activities would have released wastes to ground surface or sewer discharge points (*2*). Major parent contaminants of interest in the CCSA groundwater plumes include trichloroethene (TCE), tetrachloroethene (PCE), tetrachloroethane (TeCA), carbon tetrachloride (CT), chloroform (CF), and their associated degradation products. Chemical use, storage, and handling operations have impacted surrounding shallow soils, as identified in previous investigations (*6*). In general, soil areas of the CCSA have been found to contain chlorinated VOCs, metals, polycyclic aromatic hydrocarbons (PAHs), PCBs, and mercury at levels above the USEPA Regional Screening Levels (RSLs) for industrial land use. Due to historical operations at the Site, some chemical warfare agents and their associated daughter products have also been detected on Site and were also evaluated as potential COPCs.

Site Buildings

There were 317 buildings (i.e., structures with numbers assigned) contained within the CCSA at the time of the VI assessment. All buildings within the boundary were considered as a possible receptor for VI. With such a large number of buildings, a strategic approach was required to prioritize buildings for investigation. Of the 317 buildings, a few had a footprint of less than 100 square feet (ft^2) and were verified to be unoccupied or were scheduled for demolition in 2008 or 2009 according to the APG Real Estate office. Due to their small size or scheduled demolition, these buildings were eliminated and 312 buildings were retained for further evaluation. Of these 312 buildings, 165 were known to be occupied, 101 buildings were known to be unoccupied, and the occupancy of 46 buildings could not be verified.

Foundation types varied with 202 buildings having slab foundations and 60 buildings known to have basements. Building use also varied within the CCSA. Dominant uses included administration, offices, laboratories, housing, maintenance and storage.

The initial scope of field work, described in this paper, evaluated VI potential in 14 occupied, non-demolished buildings and potentially elevated COPC levels surrounding the remaining slabs of 3 demolished buildings. Thirteen of the 14 non-demolished buildings investigated in the scope of work described in this paper were occupied, though at varying density. Of these 14 buildings, three had basements, one had a crawlspace, and 10 had slab-on-grade construction.

Conceptual Site Model Development

To prioritize VI risks at the site, the overall site-wide CSM for the CCSA was subdivided into five distinct conceptual model (CM) areas based on the likelihood of unacceptable VI risks as follows:

- CM1 – COPCs at concentrations above screening levels in vadose-zone soils (i.e., above the water table) within 100 feet (i.e., “near”) a building;
- CM2 – COPCs above screening levels in the SA near buildings
- CM3 – COPCs above screening levels in the UCU near buildings
- CM4 – COPCs above screening levels in the confined CCA near buildings; and
- CM5 – All other areas.

In areas where the CMs overlapped, the CM with the greatest potential for an unacceptable risk (i.e., lowest CM number) was assigned. A relational database and geographic information system (RD&GIS) was used to assign each building to the appropriate CM as shown on Figures 3 and 4. Of the 317 buildings considered, 47% were classified in CM1 or CM2 and 43% were classified in CM5. Therefore, approximately half of the buildings had relatively higher likelihood or a potentially complete VI pathway (CM1 and CM2), and approximately half of the buildings were in locations where a complete VI pathway was unlikely (CM5).

Identification of Contaminants of Potential Concern

During previous investigations of the CCSA, 90 compounds were detected in groundwater and 160 compounds were detected in soil. In order to identify COPCs relevant to VI, risk-based screening levels were calculated for each of the COPCs in soil and groundwater:

$$CSL_{GW} = \frac{RSL_{IA}}{1000H^{'}\alpha}$$

or

$$CSL_{soil} = \frac{RSL_{IA}}{1000\alpha}\left(\frac{\theta_{air}}{\rho_{soil}} + \frac{\theta_{water}}{\rho_{soil}}\frac{1}{H^{'}} + f_{oc}k_{oc}\frac{1}{H^{'}}\right)$$

where:

CSL_{GW} = Calculated risk-based groundwater screening level (μg/L);
CSL_{soil} = Calculated risk-based soil screening level (μg/kg);
RSL_{IA} = Ambient air risk-based screening level (μg/m^3); (from Oak Ridge National Laboratory Regional Screening Level table or calculated following similar approach);
θ_{air} = Soil air content = 0.321 cm^3/cm^3;
θ_{water} = Soil moisture content = 0.054 cm^3/cm^3;
ρ_{soil} = Soil bulk density = 1.66 g/cm^3;
f_{oc} = Soil fractional organic carbon content = 5E-05 (g/g);
k_{oc} = Organic carbon / water partition coefficient;
H' = Henry's law coefficient (cm^3/cm^3); and
α = Default empirical attenuation factor for soil gas = 0.01.

Compounds were retained as COPCs if they were detected at a frequency of greater than 1%, and at concentrations greater than the calculated risk-based screening level. Fourteen groundwater COPCs and 46 soil COPCs were identified from the analysis. Additionally, three COPCs where toxicity information was not available were retained for further evaluation. It is recognized that there is often poor correlation between the measured soil and soil gas concentrations and consequently, the soil data were used to identify COPCs, assign CM areas, and select locations for subsequent focused sampling, but not to calculate risks. The soil data were considered particularly useful for identifying vadose-zone source areas (i.e., assigning buildings to CM1). Within CM1, a further refinement was made to identify buildings within 100 feet of the highest soil concentrations (within an order of magnitude of maximum values), and this subset of buildings was assigned the highest priority for the initial phase of sub-slab and indoor air sampling.

Systematic Building Selection

The investigation strategy was based on a phased investigation approach, beginning with the buildings most likely to have unacceptable vapor intrusion, and using information gained in each phase to inform subsequent phases. Buildings to be investigated during the first stage of data collection were selected based on the criteria listed below:

- Historic use, storage and handling of COPCs were documented within the building, or immediately adjacent to the building in the RCRA Facility Assessment (RFA) report (*8*);

- Elevated concentrations of COPCs were identified in shallow soil samples in the Remedial Investigation (RI) Report (*9*);
- Soil samples with concentrations within an order of magnitude of the Site maximum soil concentration for each COPC were located within about 100 ft of the building; and
- Shallow groundwater samples with a cumulative risk greater than 10^{-6} were located within 100 ft of the building.

A total of 41 buildings met the criteria above. Of these buildings, a subset of 17 buildings were selected for the first round of sampling to avoid restricted entrance due to current building use and/or security concerns. A select few buildings from lower risk CMs (CM4, CM5) were also included in the first sampling event so that the subset of buildings selected were representative of the greater site. Subsequent rounds of sampling are planned following regulatory review and discussion of the results from the first subset of buildings.

Sampling and Analysis Plans

Sampling and analysis plans were developed and tailored for each of the 41 buildings in the initial scope of work, and included groundwater sampling, soil gas sampling, sub-slab sampling, indoor air sampling, and outdoor air sampling. Primary considerations when developing each individual sampling and analysis plan was historical building use and locations of chemical use, handling and potential disposal near the building. Sample locations were biased towards areas where there was evidence of a primary source of contamination (e.g., waste disposal pits behind buildings). Likewise, if soil and groundwater data indicated a spatial hotspot for COPCs, then sample locations were biased toward that particular hotspot. If historical documentation or data did not indicate a hotspot, then soil gas probes were evenly distributed around and within the building.

Building Inspections

For buildings selected for indoor air sampling, interior building inspections were completed to document general observations of the building conditions and potential interior sources of chemicals that could be detected in indoor air samples. In general, the building maintenance person provided a guided walkthrough of all areas of each building, including utility rooms, basements, crawl spaces, storage rooms, laboratories, office areas and roof tops. Building construction type, occupancy, building layout and floor slab condition were all noted during the inspections. Specific attention was given to HVAC equipment where observations were made on the amount of re-circulated air and/or fresh air make up and the type and number of units for each building.

An assessment of overall insulation, material, and potential leakiness with consideration of construction type and building condition was performed. Observations of HVAC equipment including type of system, outdoor air supply and exhaust fan flow rates, system operation (variable or constant duty cycle) were recorded. Measurement of the differential pressure across the building envelope was recorded over a period of about one minute using an Energy Conservatory model DG-2 digital pressure gauge at various locations to assess the potential for soil vapor advection into the building and the relative leakiness of the building. At buildings with multiple stories, measurements were made at windows on each floor and between the top floor and the roof, access permitting. Finally, measurement of the time weighted average carbon dioxide concentrations were conducted over a 20 to 40 minute period using a Telaire model 7001 CO_2 meter with datalogger in occupied areas of each building for qualitatively estimating building ventilation rates. Elevated CO_2 (from exhaled air) can indicate areas of low air exchange rates, but the observed values were all very low, so these data did not indicate the need to use more conservative attenuation factors. Observations were made of the number of occupants working in the area where concentrations were being recorded.

Focused Assessment of Uncommon COPCs

The Site has several COPCs in the subsurface that had sufficient volatility and toxicity to pose a potential risk via VI, but are not included in routine sampling and analytical procedures for VOCs (e.g., Summa canister sampling and analysis by EPA Method TO-15). These compounds ("uncommon COPCs") were separated into three groups: mercury; compounds not routinely analyzed by commercial laboratories; and, compounds with very low screening levels which require very large sample volumes when using sorbent tubes. Sampling for these uncommon COPCs was performed at building adjacent to maximum historical concentrations of these compounds in soil samples to assess the potential for VI risks in the probable worst-case locations. These data will inform future scoping decisions for subsequent phases of investigation.

Soil gas samples were collected below the slabs of demolished buildings where maximum historical concentrations had been observed for the analysis of:

- mercury,
- 2,4,6-tribromophenol,
- 4-chlorophenyl-phenylether,
- 4-bromophenyl-phenylether,
- hexachlorobenzene,
- dieldrin,
- heptachlor,
- heptachlor epoxide,
- alpha-BHC,
- beta-BHC,
- gamma-BHC (lindane),
- Aroclor-1260,
- Aroclor-1254,
- and Aroclor-1248.

Samples for analysis of 1,4-dithiane and 2-chloroethyl vinyl ether were collected from three sub-slab probes at an existing building.

Unique Aspects of Data Collection

Quantitative Passive Sampling of Indoor and Outdoor Air

Indoor and outdoor air samples for the analysis of VOCs were collected using Waterloo Membrane Samplers™ (*7*), which were deployed for a duration of 35 days. Waterloo Membrane Samplers™ incorporate a polydimethylsiloxane (PDMS) membrane across the face of a vial filled with a sorbent medium. VOC vapors partition into and permeate through the membrane. The sorbent then traps the vapors, and the mass of each compound is quantified on the sorbent after the deployment period is concluded. The uptake rate has been experimentally measured for over 40 VOCs, and can be estimated from the linear temperature programmed retention index for other compounds. Knowledge of the uptake rate permits the time-weighted average concentrations to be calculated from the measured mass of each compound in each sampler. Waterloo Membrane Samplers™ were employed instead of Summa cans in order to allow for a broader range of analytes, reduce shipping costs, analytical costs and to obtain time-weighted average COPC concentrations in indoor and outdoor air. Research on the evaluation of radon migration to indoor air has shown that time-weighted average samples provide data with less temporal variability than short-term or instantaneous samples.

High Purge Volume (HPV) Sub-Slab Testing

HPV testing (*8*) was conducted at five sub-slab probes installed in a large building to assess the concentrations and distribution of subsurface vapors between and beyond the probe locations. HPV tests were conducted after the collection of a routine sub-slab soil gas samples (as described in *9*). The HPV testing consisted of removing about 800 to 5,800 cubic feet (ft^3) of soil gas from beneath the floor slab at a consistent flow rate for a period of up to two hours. During the HPV testing, slip-stream samples of the extracted soil gas were collected and screened for total ionizable VOCs using a photoionization detector (PID). In addition, time-integrated samples for laboratory analysis were also collected for the duration of each HPV test using Waterloo Membrane Samplers™ deployed in a flow-through cell in the extraction line.

Modified Flux Chamber Sampling

One building included in the initial field investigation had a crawlspace with a dirt floor, so modified flux chamber samples were collected instead of sub-slab soil gas samples to assess vapor concentrations immediately beneath the building. The modified flux chamber samples consisted of suspending a Waterloo Membrane Sampler™ just above the dirt floor and covering the sampler with an aluminum container. The outer edges of the container were covered with sand to act as a partial seal to accommodate the uneven dirt surface. Samplers were deployed for approximately five hours.

Laboratory and Analytical Methods

Soil gas, sub-slab, indoor and outdoor air samples were analyzed by Air Toxics Ltd. (Folsom, California). Summa canister samples were analyzed by USEPA method TO-15 for a site-specific list of VOCs. Waterloo Membrane Samplers™ were analyzed for a site-specific list of VOCs, using carbon disulfide extraction and gas chromatography/mass spectrometry. Automatic thermal desorption tube samples were analyzed by USEPA Method TO-17 for SVOCs, including samples for uncommon COPCs with low reporting limits or that are not normally analyzed by laboratories. Polyurethane foam (PUF) (indoor air) or XAD (soil gas and sub-slab) adsorbent tubes were analyzed by USEPA Method TO-10A for pesticides, including samples for PCBs with low reporting limits. National Institute for Occupational Safety and Health (NIOSH) Method 6009 was used for mercury analysis. Groundwater samples were analyzed by GPL Laboratories of Frederick, Maryland, by USEPA Method 8260 for VOCs and USEPA Method 8270 for SVOCs.

RESULTS AND DISCUSSION

Air Handling Assessment and Building Inspection

Results from the air handling assessment and building inventory, in general, indicated the buildings had pressure or vacuum levels that were moderate to low, and within the range of normal fluctuations (+/- ~5 Pascal [Pa]). Default building underpressurization assumptions (underpressurized by 4 Pa) are therefore considered conservative. Furthermore the building ventilation rates estimated from the CO_2 measurements were generally in the range of 0.5 to 2 ACH, which is also within typical ranges for commercial/industrial buildings. Most of the buildings had typical penetrations through the floor (drains, expansion joints, and occasional cracks and utility penetrations), which were not noticeably different than typical commercial buildings.

Notable building characteristics observed during the air handling assessment and building inspection were as follows:

- One building had a crawlspace with a dirt floor, which may provide less resistance to VI than typical slab-on-grade construction, but there was a positive pressure of 15 Pa at the top floor, so it appeared to be operating with a significant net surplus of air to the building (i.e. air supply exceeds exhaust). Therefore, a net reduction in the VI attenuation factor is expected for this building.
- One building had numerous fume hoods in a laboratory, and if the make-up air is not sufficient to balance the exhaust, then negative pressure may result.
- One building was a maintenance facility with very large venting fans to manage indoor air quality issues, which produced a negative building pressure if operated

with doors and windows closed. However, the fans also increase the building ventilation rate, which will reduce the VI attenuation factor.

A screening-level attenuation factor of 0.01 was used in establishing screening levels for soil gas and sub-slab concentrations for the buildings examined in this study. The attenuation factor of 0.01 was considered reasonable or conservative for the commercial/industrial buildings at the Site.

During the inspections, several buildings had visible and olfactory evidence of potential interior ("background") sources within the building, which may be detected during indoor air monitoring and potentially complicate the interpretation of whether and to what extent vapors in indoor air are related to VI of COPCs from the subsurface. The activities of the buildings precluded removing these sources of COPC emissions without disrupting operations. Potential interior sources were accounted for while reviewing the indoor air data and determining the potential for VI in each building. Similar considerations were undertaken for ambient air quality, as indicated by outdoor air sampling.

Focused Assessment of Selected Buildings

Only 2 of 17 buildings in the initial phase of investigation exhibited evidence of a potentially complete VI pathway, meaning that vapor concentrations either approached or exceeded screening levels for a particular COPC in both subsurface and indoor air samples at co-located sampling positions within the building which did not appear to be attributable to ambient/interior sources. The potential for VI at the two buildings was observed for the following COPCs: carbon tetrachloride, chloroform, tetrachloroethene, trichloroethene, and hexachloroethane. At both of the two buildings with a potential VI pathway, only a subset of the sub-slab probes and indoor air samples exhibited COPC concentrations approaching and/or exceeding the screening levels, indicating only portions of the building may be subject to potential VI. Follow-up sampling at these two buildings during the heating season verified the results from earlier in the year and confirmed that certain COPCs approached and/or exceeded screening levels at certain locations within the buildings. Future monitoring will be discussed and negotiated by the stakeholders involved.

The majority (15 of 17 buildings) did not exhibit COPC concentrations approaching and/or exceeding screening levels in both subsurface and indoor air. Some buildings exhibited COPC concentrations that approached and/or exceeded screening levels in one sampling media (e.g., subsurface, indoor air), but not all media simultaneously. Thus, based on a multiple lines of evidence evaluation, a complete VI pathway was not indicated at these buildings. The screening levels are considered to be sufficiently protective that continued monitoring has not been recommended.

Focused Assessment of Selected COPCs

The results of focused sampling program to assess potential VI risks associated with mercury, compounds not routinely analyzed by laboratories, and compounds with very low screening levels demonstrated that at areas where historically high concentration of the compounds exist, subsurface and indoor air concentrations did not approach screening levels

Since the data indicate that uncommon COPCs, mercury, pesticides, and most SVOCs (except hexachloroethane) were not found to pose unacceptable exposures at locations of maximum historical concentrations, it has been recommended that they be removed from further analysis on the Site. Also, the results of the initial field investigation provide preliminary support that the number of buildings to be assessed for VI can be reduced from 317 to a more reasonable, practical number. This prospect of a reduction in buildings targeted for assessment, along with the reduced analytical suite required for analysis on Site, allows for a focused investigation effort and result in a significant reduction in investigation costs. The initial successes also document how a strategic, phased approach to VI at large sites can be developed and implemented for future VI investigations at APG as well as other federal installations.

SUMMARY

The Army was tasked with assessing VI at a large installation with greater than 300 buildings and significant groundwater/soil impacts. The large number of buildings and unique contaminants created a challenging scenario, and a comprehensive sampling approach (all chemicals in all buildings with multiple samples of multiple media) would have been prohibitively expensive and time-consuming. A phased approach to VI was developed and implemented that allowed for the creation of a site CSM and the subsequent prioritization of potential VI risks at each building. Historical documentation of site activities and groundwater and soil data were consulted to identify COPCs and primary sources of contamination. A number of sequenced screening steps allowed for the creation of a CSM and buildings were categorized based on priority level (e.g., CM1 through CM5). Following the CSM development, certain COPCs were eliminated from further consideration, and approximately half of the buildings on site were deemed to have low potential VI risk.

Initial field sampling to assess potential VI at 17 select buildings where VI was expected to more significant indicated that only 2 of the buildings have potential VI concerns. At these two buildings, subsurface and indoor air concentrations approached and/or exceeded screening levels for particular COPCs at co-located sampling points. COPC detections were not attributed to interior and/or ambient sources in these instances, however at several other buildings COPC detections in indoor air were due to interior and/or ambient sources. At several buildings, subsurface COPC concentrations approached screening levels, but indoor air COPC concentrations were below risk-based and/or background levels; continued monitoring of these buildings may not be necessary. Additionally, uncommon and analytically challenging COPCs may be eliminated from future investigations due to the lack of unacceptable risk at locations of historical maximum concentration. Results to date thus support limiting additional investigations in terms of number of buildings assessed and the analytical program required, both of which allows for a focused investigation effort that may result in a significant cost savings.

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KEY WORDS

Vapor intrusion, federal facility, conceptual site model, waterloo membrane sampler, modeling, high purge volume,

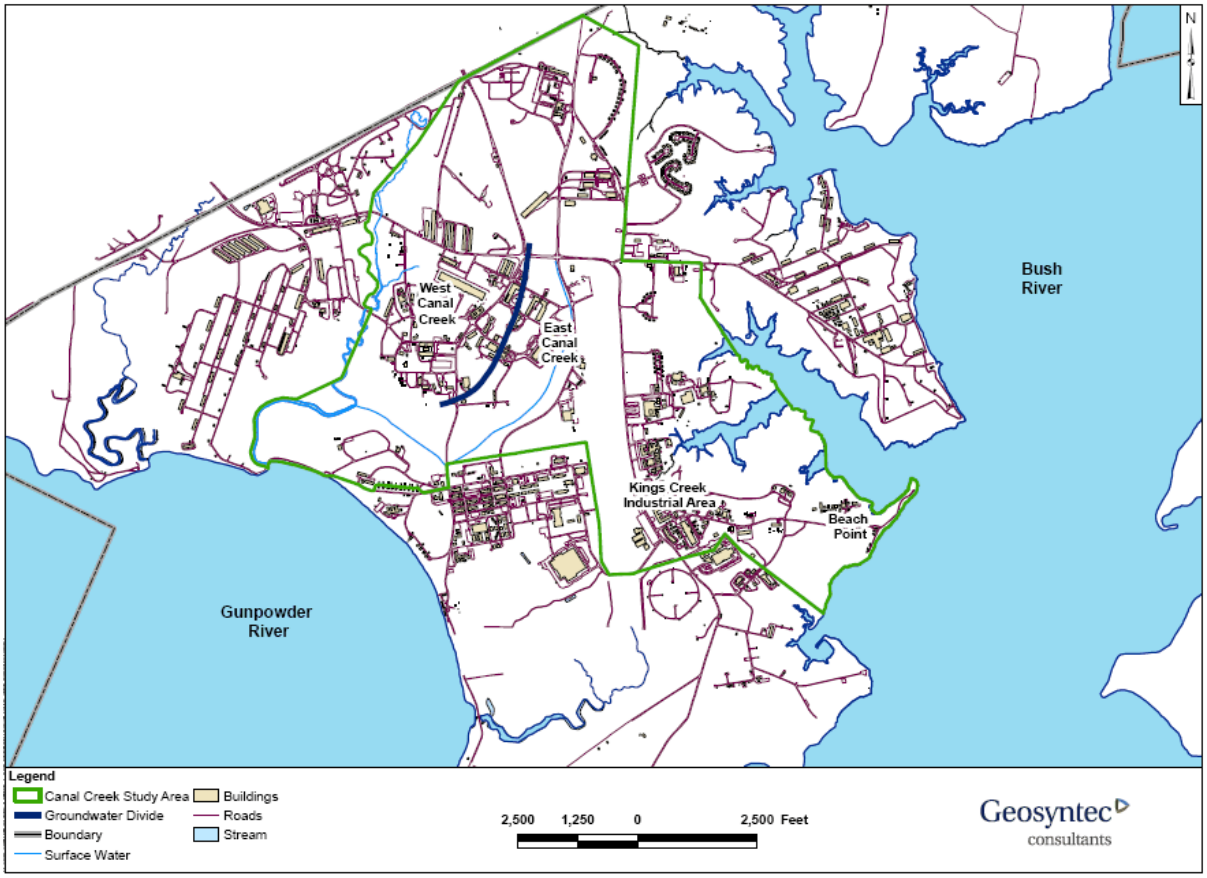

Figure 1: Site map and general location. The Canal Creek Study Area is delineated by the green border.

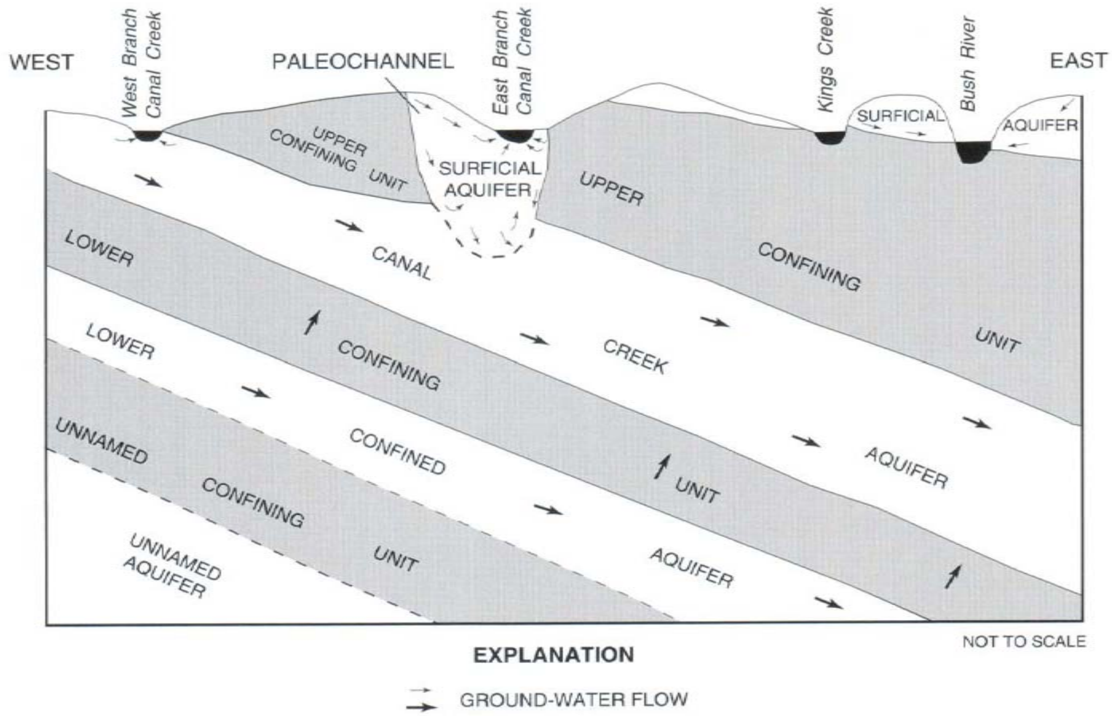

Figure 2: Generalized geological cross-section underlying the Canal Creek Study Area, Aberdeen Proving Ground. Adapted from (*3*).

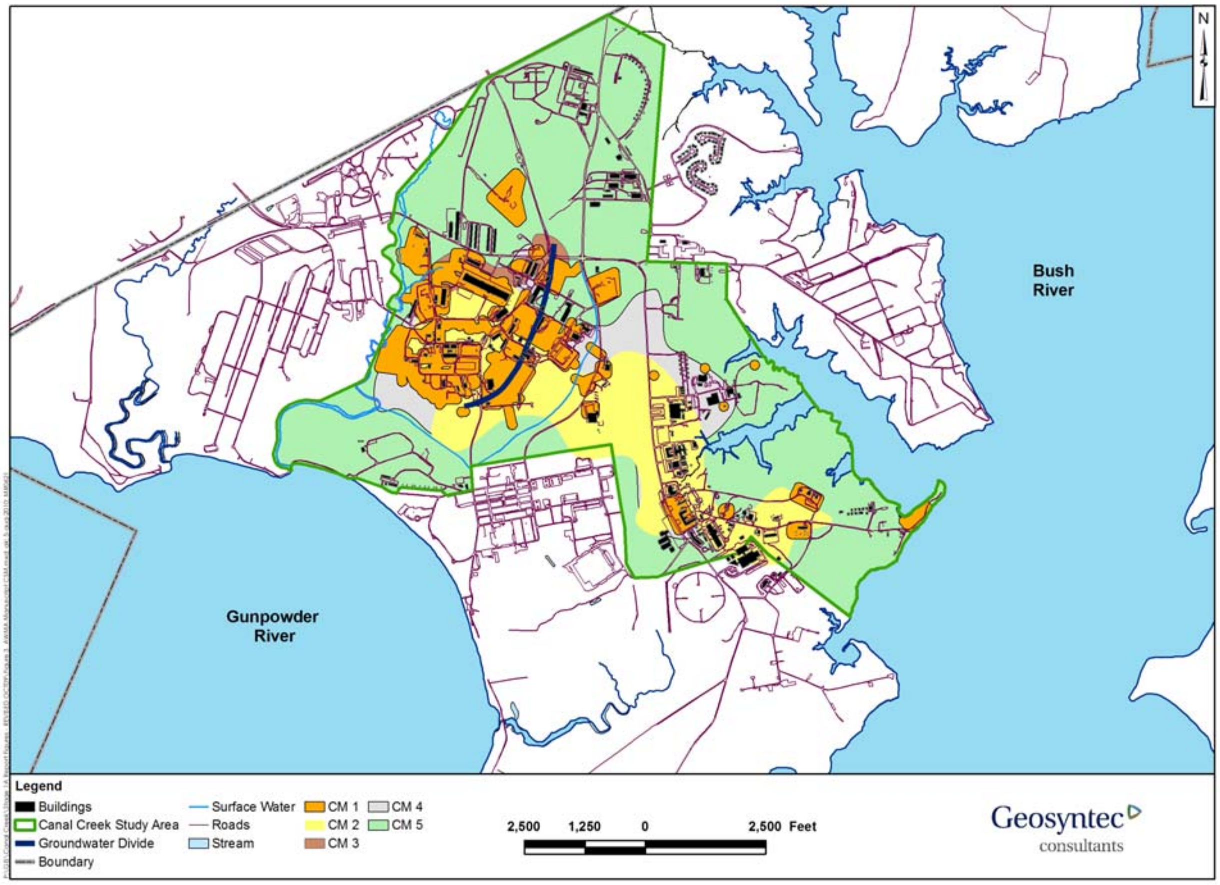

Figure 3: Conceptual Site Model delineation map showing different VI conceptual model units overlaid onto the Canal Creek Site. See Table 1 for definitions of each conceptual model classification.

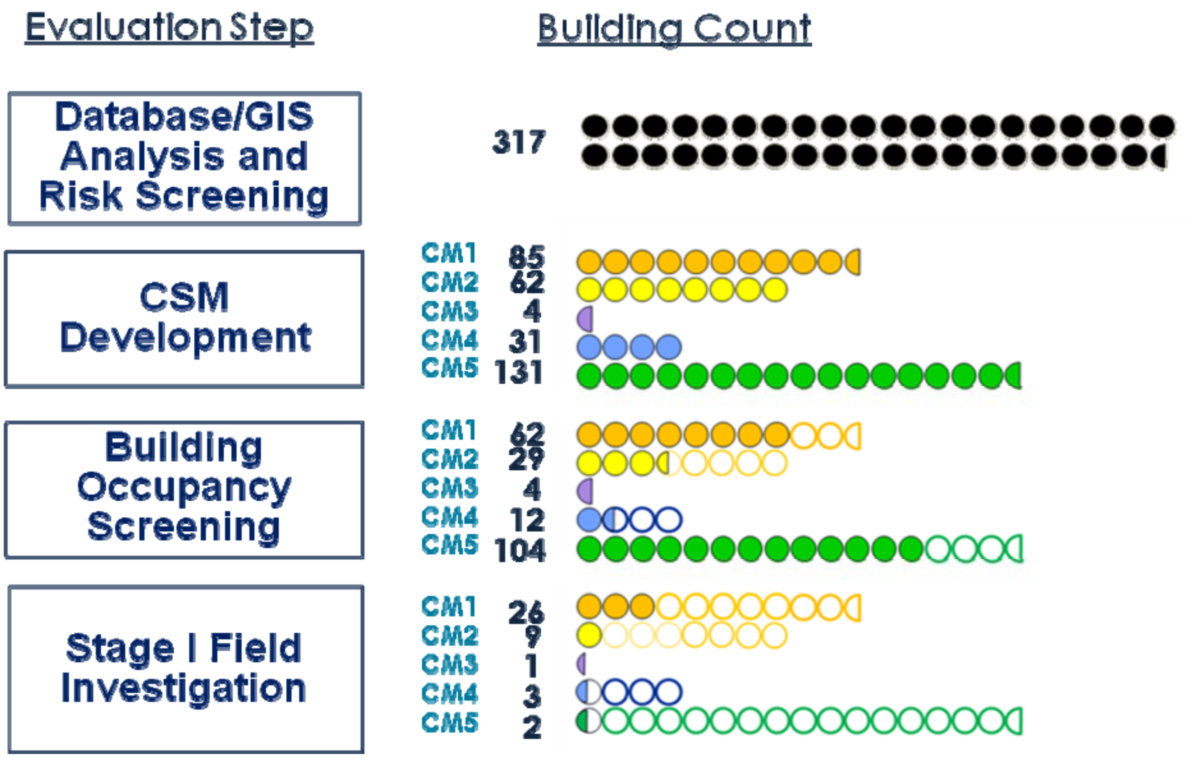

Figure 4: Use of CSM to prioritize buildings posing risk. Each full symbol represents 8 buildings.

Table 1: CSM development and categorization of buildings.

Conceptual Model ID	Description
Conceptual Model #1 – Primary Source Areas	Residual COPCs in the Vadose Zone near or beneath buildings
Conceptual Model #2 – Surficial Aquifer Source Areas	COPCs present in unconfined aquifer with no confining unit above the water table
Conceptual Model #3 – Upper Confining Unit (UCU) Source Areas	COPCs present in the UCU, and materials above the UCU are unsaturated
Conceptual Model #4 – Confined Canal Creek Aquifer (CCA) Source Areas	COPCs are present in the CCA, and the UCU is present above the CCA
Conceptual Model #5 – Areas with No Identified Source or No Existing Buildings	No sources identified

Notes:

CCA - Canal Creek Aquifer

CCSA - Canal Creek Study Area

COPCs - Contaminants of Potential Concern

UCU - Upper Confining Unit