# A Base-Wide Vapor Intrusion Evaluation at Marine Corps Base Camp Lejeune: Utilizing the Tri-Services Phased Approach to Prioritize Building Investigations

## Authors


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## Abstract


A base-wide vapor intrusion evaluation is being performed at Marine Corps Base Camp Lejeune in Jacksonville, North Carolina. This large-scale evaluation encompasses thousands of structures throughout the 236 square mile base, and approximately 150,000 potential receptors, including military personnel, dependants, retirees and civilians. The phased vapor intrusion evaluation approach was consistent with the Department of Defense (DoD) Tri-Services (2008), Interstate Technology Regulatory Council (2007) and USEPA (2002) Vapor Intrusion Guidance. Multiple volatile organic compound (VOC) subsurface releases, some of which are being actively remediated, have been documented at the Base. A geographic information system (GIS) was used to identify 168 buildings located within 100 feet of monitoring wells with VOC concentrations exceeding USEPA (2002) generic screening criteria or the North Carolina Groundwater Quality Standards (NCGWQS). Site-specific criteria generated with USEPA's (2004) version of the Johnson and Ettinger (1991) model were used to reduce the list of target buildings within each of the six investigation areas. Currently unoccupied or unenclosed structures were also eliminated, resulting in a list of 50 buildings for Phase 1 sampling. Phase 1 sampling was performed in June 2008 and included groundwater grab samples from the top of the water table, exterior near-slab soil gas sampling, and building surveys. The Phase 1 sampling approach was designed to account for several factors, including shallow groundwater (< 5 ft below-ground-surface), active air or biosparge remediation systems, select buildings with subslab depressurization systems, and the presence of non-aqueous phase liquid (NAPL) beneath or in the vicinity of select buildings. Phase 1 data were compared with the site-specific screening levels. Given the variability and uncertainties in modeled screening levels, co-located groundwater and exterior soil gas, along with subslab and indoor air data, were collected during Phase 1 in order to evaluate and, if necessary, adjust the modeled site-specific screening levels; the USEPA (2008) Regional Screening Levels for indoor air were also considered during this evaluation. Twenty-eight of the highest priority buildings were selected for further evaluation during Phase 2, including five with existing subslab depressurization systems. The Phase 2 field event performed in September and October 2008 included indoor/outdoor air and subslab sampling, detailed building surveys and pressure differential monitoring at select buildings. Conceptual site models incorporating the multiple lines of evidence (MLE) methods in the 2008 Tri-Services and 2007 Interstate Technology and Regulatory Council (ITRC) vapor intrusion guidance documents were developed for each of the 28 Phase 2 buildings in order to make conclusions regarding the vapor intrusion pathway at each building and determine potential further actions.


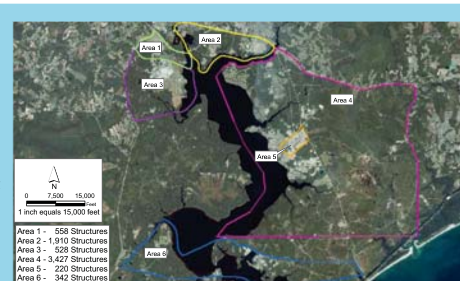

FIGURE 1 – Camp Lejeune Marine Corps Base Vapor Intrusion Investigation Areas

## Step 1 – Identified Buildings Near VOC-impacted Groundwater

- Used the database of shallow groundwater data from 2002 to 2007 from the Installation Restoration (IR), Resource Conservation and Recovery Act (RCRA), and Underground Storage Tank (UST) programs
- Identified site-specific constituents of potential concern (COPCs) for use as indicator compounds by searching database for compounds which exceed screening criteria by the greatest magnitude and frequency
  - Example of indicator COPCs identified for two investigation areas

| Area 4 | Area 5 |
|---|---|
| Chlorinated Solvents: PCE, TCE, cis-1,2-DCE, VC, 1,1,2,2-PCA, 1,1,2-TCA | Chlorinated Solvents: PCE, TCE, cis-1,2-DCE, VC, 1,1,2-TCA, 1,2-DCA |
| Petroleum Hydrocarbons: Benzene | Petroleum Hydrocarbons: Benzene, Ethylbenzene, Isopropylbenzene, Xylenes |

- COPC concentrations in groundwater were mapped using GIS and buildings located within 100 ft of groundwater concentrations exceeding the generic screening criteria were identified
  - 168 buildings of interest identified

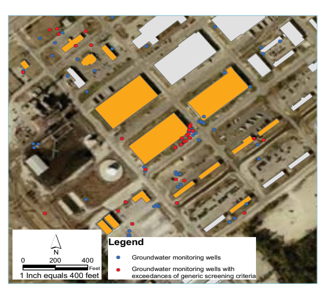

FIGURE 2 – Example Map (1 of 23 maps) Showing Buildings Located within 100 feet of Wells Exceeding Generic Screening Criteria

## Step 2 – Developed Site-Specific Screening Criteria for Each Investigation Area Using the Johnson and Ettinger (J&E) Model

- Used site-specific input parameters and two (small and large) building categories
  - Soil types and depth to groundwater for each area determined by reviewing existing site data
  - Building characteristics were selected for two general categories (small and large) of buildings

## Step 3 – Refined Building of Interest List

- Included buildings within 100 feet of NAPL or air or biosparge remediation systems
- Eliminated buildings which were unoccupied or not enclosed
- Re-screened the groundwater data with the site-specific screening criteria

| Investigation Area | Area 1 | Area 2 | Area 3 | Area 4 | Area 5 | Area 6 | Total |
|---|---|---|---|---|---|---|---|
| Buildings of Interest | 34 | 2 | 30 | 40 | 55 | 7 | 168 |
| Not Occupied | 10 | 2 | 15 | 4 | 6 | 3 | 40 |
| Not Enclosed | 5 | 0 | 1 | 6 | 5 | 0 | 17 |
| Demolished | 2 | 0 | 1 | 0 | 0 | 0 | 3 |
| Does not exceed site-specific criteria | 8 | 0 | 6 | 19 | 20 | 3 | 56 |
| Remaining Buildings of Interest for Phase I Sampling | 9 | 0 | 7 | 9 | 24 | 1 | 50 |

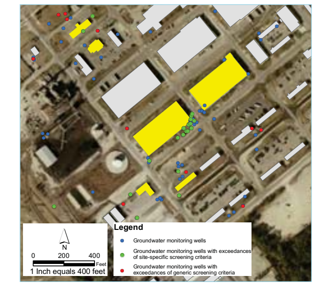

FIGURE 3 – Example Map (1 of 15 maps) Showing Buildings of Interest Located within 100 feet of Wells Exceeding Site-Specific Criteria

## Step 4 – Phase 1 Sampling Event

- Collected groundwater grab samples from the top of the water table and exterior soil gas samples
  - Subslab soil gas sampling at buildings within 100 feet of NAPL or air or biosparge systems or where groundwater is less than 5 feet below ground surface
  - Three outdoor air samples were collected in each investigation area where indoor air sampling was performed
  - One building had an elevated slab with open air underneath (on stilts) so two crawl space air samples were collected underneath the building.
- Total number of samples collected:
  - Groundwater – 54
  - Exterior soil gas – 40
  - Subslab soil gas – 21
  - Indoor air – 15

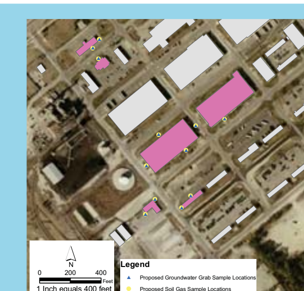

Figure 4 – Example Map (1 of 15 maps) Showing Phase 1 Proposed Groundwater and Soil Gas Sample Locations

## Step 5 – Evaluated the Phase 1 Sampling Data

- Evaluate the validity of the site-specific screening criteria by calculating empirical attenuation factors
  - Co-located groundwater and soil gas samples were used to calculate empirical groundwater-to-soil gas attenuation factors
    - The model both under and over-predicted soil gas concentrations. This may be due to vadose zone contamination, complexities in the subsurface that were oversimplified by the J&E model or preferential pathways.
  - Co-located subslab soil gas and indoor air samples were used to calculate empirical soil gas-to-indoor air attenuation factors.
    - Empirical attenuation factors were less than 1E-01; the majority ranged from 1E-03 to 1E-04
  - For the purpose of evaluating buildings for Phase 2 sampling decided to use default conservative screening criteria.
    - Generic screening criteria were calculated from the EPA Regional Screening Levels (RSLs) for air using conservative attenuation factors of 1E-01 for shallow soil gas, 1E-02 for deep soil gas and 1E-03 for groundwater.
  - Additional validation performed with Phase 2 sampling data
- Screened Phase 1 sample results against the RSL-based generic screening criteria and identified exceedances
- There were three buildings which had significant (4 to 5 orders of magnitude) exterior soil gas exceedances
  - Indoor air sampling was performed immediately at these buildings, with the subsequent risks less than the $10^{-4}$ risk criteria. Concurrent subslab and indoor air sampling was performed at these buildings during Phase 2.
- Buildings for additional data collection during Phase 2 field event selected
  - Greater weight was placed on soil gas data compared to groundwater data given the comparative uncertainties
  - Five buildings with existing active subslab depressurization (ASD) systems which had been excluded in Phase 1 were included in Phase 2

| Investigation Area | Area 1 | Area 2 | Area 3 | Area 4 | Area 5 | Area 6 | Total |
|---|---|---|---|---|---|---|---|
| Buildings of Interest for Phase I Sampling | 9 | 0 | 7 | 9 | 24 | 1 | 50 |
| Addition of buildings with active subslab depressurization systems | | | | | 5 | | |
| Buildings Retained for Phase II Sampling | 4 | 0 | 2 | 5 | 17 | 0 | 28 |

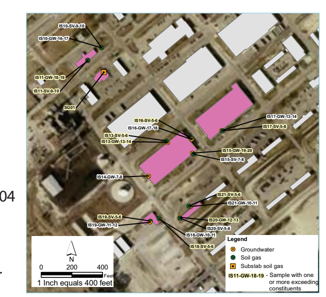

Figure 5 – Example Map (1 of 15) Showing Phase 1 Sample Locations and Screening Criteria Exceedances

## Step 6 – Phase 2 Field Event

- Collected subslab soil gas and concurrent indoor air samples at select buildings
  - Three outdoor air samples were collected in each investigation area where indoor air sampling was performed
  - Total number of samples collected:
    - Subslab soil gas – 67
    - Indoor air - 19
- Collected groundwater samples from shallow monitoring wells near the five ASD system buildings
- Performed detailed building surveys at each building to gather building characteristic data for the CSMs
- Performed pressure differential monitoring at the buildings with ASD systems to confirm that the systems had been turned off for enough time before sampling

FIGURE 6 – Example Map (1 of 8) Showing Phase 2 Proposed Subslab Soil Gas Sample Locations

## Step 7 – Evaluate the Phase 2 Sample Data

- Screened Phase 2 sample results against the RSL-based generic screening criteria and identified exceedances
- Developed vapor intrusion CSMs for each building
  - Information on building characteristics collected during building surveys
  - Focused on slab condition, indoor air volume and air flow in and out of the building
- Calculated empirical attenuation factors
  - Only used subslab soil gas results with greater than 100 times the indoor air results indicating high subslab soil gas source strengths.
  - Differentiated between indoor air results which were significantly (e.g. 5-times) greater than outdoor air concentrations and those which were similar.
    - Actual attenuation factors are likely less than empirical attenuation factors at locations with similar indoor and outdoor air concentrations. Actual attenuation factors in these cases no worse than empirical attenuation factors.
    - Empirical subslab-to-indoor air attenuation factors were generally between 1E-02 and 1E-04

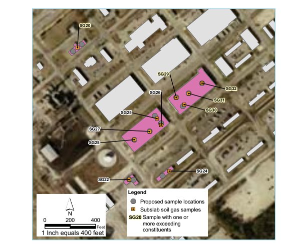

FIGURE 7 – Example Map (1 of 8) Showing Phase 2 Sample Locations and Screening Criteria Exceedances

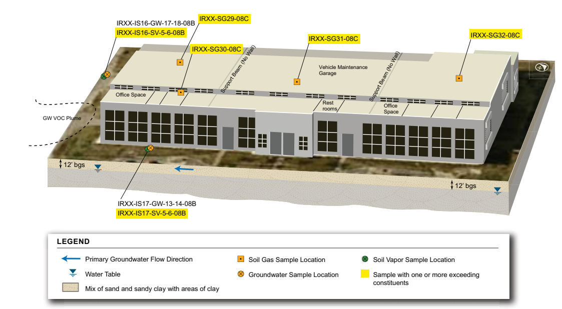

FIGURE 8 – Example Vapor Intrusion Conceptual Site Model

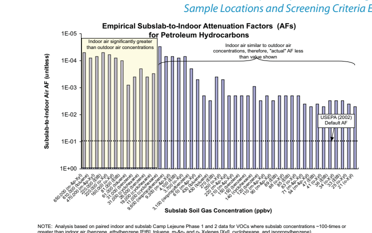

FIGURE 9 – Empirical Subslab-to-Indoor Air Attenuation Factors for Petroleum Hydrocarbons

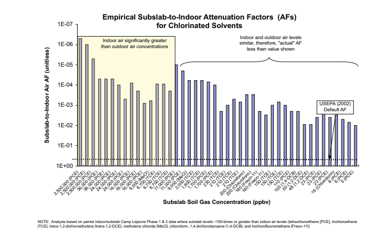

FIGURE 10 - Empirical Subslab-to-Indoor Air Attenuation Factors for Chlorinated Solvents

## Conclusions

- Although some significant VOC concentrations were observed in subslab soil gas, none of the measured indoor air concentrations were above indoor screening levels or significantly greater than outdoor air concentrations.
  - Likely due to intact slabs acting as pathway barriers as well as large indoor air volumes and significant outdoor air exchange
- Recommendations for possible further actions were made depending on sample results and CSMs
  - Continue to monitor subslab soil gas periodically
  - Re-check vapor intrusion pathway once remedial actions are complete
  - Inspect and repair buildings slabs
  - Remediate at locations with significant sub slab soil gas concentrations even though indoor air is currently not being impacted.
- Subslab-to-indoor air attenuation factor of 1E-03 should be used for future vapor intrusion evaluations at the base.

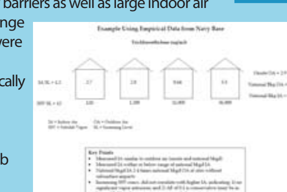
FIGURE 11 – Empirical Attenuation Factors at Four Example Buildings

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