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LANSING

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January 31, 2005

TO: Qualified Underground Storage Tank Consultants, Certified Underground Storage Tank Professionals and Interested Parties

FROM: Mohammad Yusaf, P.E.

SUBJECT: Addendum to Storage Tank Division (STD) Operational Memorandum 9 "Groundwater and Soil Closure Verification Guidance"

The STD Operational Memorandum 9 (attached) is amended as follows:

The Guidance Document for Verification of Soil Remediation (VSR), dated 1994, should no longer be used unless specifically mandated by a historic settlement document. The Sampling Strategies and Statistics Training Materials for Part 201 Evaluations (S3TM), dated 2002, should be referred to for recommendations related to verification of soil remediation. Portions of the VSR have been updated and incorporated into the S3TM. Refer to tabbed section 4.0 of the S3TM for recommendations on soil verification sampling and to tabbed section 7.0 for statistical analysis of verification data. The URL for the S3TM is: http://www.deq.state.mi.us/documents/deq-erd-stats-s3tm.pdf

Attachment: STD Operational Memorandum 9

SUBJECT: Groundwater and Soil Closure Verification Guidance	DATE: 11/6/96	Operational Memorandum No. 9 Page No. 1 of 16

This operational memorandum is intended to provide guidance for verification sampling of the groundwater and soil to achieve an unrestricted closure at Leaking Underground Storage Tank Sites. These same guidelines may be utilized to evaluate groundwater and soil Site Specific Target Levels (SSTLs) where the appropriate institutional controls are proposed. This operational memorandum replaces the existing draft procedure dated August 11, 1995 as Attachment No. 26, in your Guidance Document for Risk-Based Corrective Action at Leaking Underground Storage Tanks.

GROUNDWATER CLOSURE VERIFICATION GUIDANCE

Groundwater Remedial Systems

Verification of groundwater remediation via a groundwater injection/extraction, air sparge, biosparge system or similar technology to achieve an unrestricted closure may be documented using the following:

1. When the purge well(s) meet the Risk-Based Screening Levels (RBSLs) for six (6) consecutive monthly samples and all performance monitoring wells meet the RBSLs for two(2) consecutive quarterly samples for all the contaminants of concern the system may be turned off.

2. Once the system is turned off, it is necessary to evaluate the potential seasonal variations in the hydrogeology and groundwater quality as affected by the smear zone in the capillary fringe, soil desorption and other factors. Therefore after the system has been turned off, the purge well(s) and all performance monitoring wells shall be sampled quarterly, at a minimum, for one year for the appropriate contaminants of concern. Sample results from all wells must be at or below the RBSLs to verify that the closure guidelines have been met. This same criteria may be applicable for SSTLs, where institutional controls are planned.

3. If the contaminant concentrations in any of the monitoring wells or purge well(s) exceed the RBSLs or SSTLs during this verification process, the Underground Storage Tank Division (USTD) project manager should be immediately notified. The Qualified Consultant (QC) shall resample the well(s) in question to validate the previous sample result(s) and determine, based on the sample validation and risk posed by the exceedance, whether the remediation system needs to be restarted. This determination along with all supporting documentation shall be provided in writing to the USTD project manager 45 days prior to the next quarterly sampling. The QC should also provide in writing, justification whether the verification process should be repeated, extended, remain the same or whether alternate remedial options are appropriate (i.e., amend Corrective Action Plan). If documentation is not provided consistent with these provisions, the remediation system shall be restarted and the verification process repeated as stated in item 2 above.

Groundwater In-situ Bioremediation and Natural Attenuation
Verification of groundwater remediation via bioremediation or natural attenuation to achieve closure can be documented using the following:

1. The extent of contamination has been defined and characterized for the site both vertically and horizontally.

2. Sufficient data has been gathered to document that the plume has stabilized and is not advancing.

3. Historical site data should demonstrate diminishing contaminant concentrations with minimal seasonal variation in the groundwater concentrations, taking into account that there may be diminished bioactivity during the winter.

4. When the concentration of contaminants in all the site monitoring wells are below the RBSLs, four (4) consecutive quarterly samples from all monitoring wells within the plume must be collected to verify that the contaminants of concern are below the RBSLs. Based upon site conditions, the amount of historical data, and site specific factors, the USTD project manager can approve a minimum of two (2) consecutive quarterly samples at or below the RBSLs to verify site closure. The QC must provide, to the USTD project manager, appropriate justification for a reduced verification period.

Groundwater Verification Where No Planned Remediation of the Groundwater Has Taken Place
Situations may arise at sites where as part of the hydrogeological investigation, contaminants are detected in the groundwater at one or more locations that exceed the Tier 1 RBSLs. A subsequent sampling event may indicate that contaminant concentrations at the previous monitoring location(s) are now below the Tier 1 RBSLs. In order to achieve closure, the complete vertical and horizontal extent of groundwater impact must be defined, and a minimum of two (2) consecutive monthly sampling events at or below the Tier 1 RBSLs must be documented for those well(s) that previously exceeded the Tier 1 RBSLs.

SOIL CLOSURE VERIFICATION GUIDANCE

See January 31, 2005 Addendum to Op Memo 9

In-situ Verification Soil Sampling for Small and Medium Sized Sites

Guidance for verification of soil remediation is found in the GUIDANCE DOCUMENT FOR VERIFICATION OF SOIL REMEDIATION" April 1994, Revision 1. In addition, the Underground Storage Tank Division has developed supplemental guidance for in-situ verification soil sampling for small and medium sized sites.

Introduction
This guidance is intended to serve as a supplement to the Guidance Document Verification of Soil Remediation April 1994, Revision 1 (VSR) to provide additional guidance concerning the collection of in-situ verification soil samples. This document only pertains to the collection of in-situ verification soil samples at small (<0.25 acres or 10,890 sq. ft.) and medium (0.25-3 acres

or 10,890-130,680 sq. ft.) sized sites. Any alternate in-situ verification soil sampling strategies should be discussed with the USTD project manager prior to implementation.

In-situ verification soil sampling is required to evaluate the effectiveness of the remedy or to propose closure upon completion of an in-situ soil corrective action (e.g., soil vapor extraction, bioventing, in-situ bioremediation, natural attenuation). In addition, in-situ verification soil sampling must be conducted whenever contaminated soils are identified but not remediated, including when contaminated soil is returned to an excavation after the removal of an underground storage tank (UST).

The purpose of the in-situ verification soil sampling is to demonstrate that the entire volume of contaminated soil is below the appropriate soil cleanup standards (e.g., the Tier 1 risk-based screening levels for leaching to groundwater). Because the in-situ verification soil sampling is characterizing a volume of soil, additional samples will be required beyond the number of sidewall and floor samples that the VSR requires from an excavation.

<u>Method</u>

The sampling grid interval equations, found on page 28 in the VSR , should be used to determine the sampling grid interval for the entire area of concern or the remediation area. In addition, known or suspected contamination source areas should be subgridded (e.g., UST vaults and pump islands) in the same manner. The area(s) covered by the contamination source(s) should be determined and a tighter sampling grid interval(s) calculated using the equations on page 28 in the VSR. For the purpose of this document, the user will assume that an adequate site investigation has determined that the UST vaults and the pump islands were the contamination source areas. Figures 1 and 2 show examples of small and medium size site sampling grids and subgrids applied to known or suspected contamination source areas at these sites.

A sampling cell is defined as the area within one grid interval. The area of a sampling cell should be calculated by squaring the grid interval. The total area covered by the sampling grid should be divided by the area of a sampling cell to determine the total number of sampling locations. Attachment 2 of the VSR recommends installing soil borings at 25% of the total number of sampling locations or installing a minimum of 12 borings, whichever is greater, to allow statistical analyses to be performed. This procedure should be followed for the total area covered by the larger sampling grid. Installing 12 soil borings in a typical UST area or the subgrid source area may be inappropriate because of the amount of soil boring in such a small area. Therefore, the number of soil borings that should be installed in the subgridded source area(s) is 25% of the total number of sampling locations for the subgridded area. Attachment A shows the calculations for determining the number of verification soil borings for the example sites. These calculations would normally predict the number of soil verification borings as indicated in the table below for small and medium site sizes.

Site Acreage	**Square Feet**	**Remediation Area # Verification Soil Borings**	**Source Area # Verification Soil Borings**
up to 0.25 (small)	up to 10,890	12	3
0.25-3.00 (medium)	10,890-130,680	13	3

<u>Locating the Verification Soil Borings</u>:

In order to perform a statistical analysis of the verification sample data, a random sampling strategy must be used to locate the verification soil borings. Pages 24-27 in the VSR discuss several random sampling strategies and how to use the random numbers table or a random number generator to select which sampling locations will be the boring locations. Random sampling strategies should be applied to both the larger grid area and any subgridded area(s). Examples using random sampling strategies for the example sites are found in Attachment B.

Statistical analysis of the verification soil sample data (see pages 29-31 in the VSR) may indicate that additional samples are necessary to demonstrate that the upper confidence limits for the soil sample data are below the appropriate cleanup standards. Collecting extra samples during the initial verification soil sampling may eliminate the need to remobilize to collect the additional samples. The extra samples must be extracted and analyzed within the original sample holding times.

Determining the Number of Vertical Sampling Intervals:
For the purpose of this document, it is assumed that the extent of soil contamination has been adequately characterized. A biased sampling strategy should be used to select the vertical sampling intervals that are the most likely to still contain contaminant concentrations above the appropriate cleanup standards. The following areas should be considered for vertical sampling intervals: areas of probable high contaminant concentrations (based on previous sample results and/or the field screening instrumentation) and areas where the flow of air and/or nutrients will be impeded (e.g., low permeability lenses and the capillary fringe zone). If air flow modeling indicates the possible presence of stagnation zones, these areas should be sampled.

At least one sample should be collected from each five feet of the verification sample boring, with the exception of borings that are advanced through uncontaminated backfill. If there is no basis for selecting a biased sample from a five foot interval, then the QC may subdivide the five foot interval into six inch intervals and randomly select one or more intervals for sampling.

The verification soil borings must extend at least as far as the known depth of the soil contamination. If a lower confining layer is encountered, the consultant should have already determined (during the hydrogeological study) whether the contamination extended into or through the confining layer. If not, at least one soil sample should be submitted from the top of the lower confining layer.

Partial dewatering of an aquifer can allow SVE and/or bioventing systems to remediate the residual soil contamination below the water table. If the groundwater potentiometric surface is being lowered during the corrective actions, then the verification soil samples should be collected while the soils in question are still dewatered. The groundwater dewatering system should then be discontinued and verification groundwater samples collected.

Collecting additional samples during the initial sampling may eliminate the need to remobilize if the statistical analysis indicates that additional samples are needed. The extra samples must be extracted and analyzed within the original sample holding times.

Examples of biased sampling strategies for vertical sampling are found in Attachment C.

Evaluating the Verification Sample Data:
The VSR (beginning on page 29) outlines statistical calculations for determining the upper confidence limits (UCL) for the contaminants of concern. The Lambda relationship (see page 30 in the VSR) is used to determine if the sample population is sufficient to demonstrate at the appropriate confidence level (usually 95%) that the UCLs are below the clean up standards. The table on page 36 of the VSR can be used to determine how many additional samples are needed at the designated confidence interval. In general, the sample data from the subgrid area(s) can be combined with the sample data from the larger grid area for the statistical calculations. There may be site specific reasons, however, why the sample data from the subgrid area(s) should not be combined with the sample data from the larger grid area. For example, elevated PNA compound concentrations may have only been found near the diesel fuel UST excavation and not over the whole area of contaminated soil at the site.

The Closure Report should contain site maps and cross-sections, drawn to scale, which depict the area and volume of contaminated soil; any remediation area(s); the locations of any air/fluid injection and/or extraction wells with their estimated radius of influence (ROI); the sampling grids; and the verification soil boring locations and vertical sampling intervals. The Closure Report should include the calculations for determining the sampling grid intervals, a statement documenting the random sampling strategy utilized for selection of the sampling locations, the number of verification soil borings and any statistical calculations used to evaluate the sample data.

Questions concerning this operational memorandum should be addressed to the appropriate USTD project manager or District Supervisor at the district office responsible for the area where the site is located.

Periodic review and revisions to this operational memorandum are the responsibility of the Chief of the Field Operations Section.

Authorization:	Date:

Distribution: DEQ Division/Office Chiefs
USTD Supervisors

Attachments

References:

Engineering-Science, 1993, Air Sparging/Soil Vapor Extraction Remediation Demonstration Project-Data Evaluation Report, BP Oil Site No. 04216, West 65th Street & Denison Avenue, Cleveland, Ohio, Draft internal report submitted to BP Exploration & Oil, Inc.

Michigan Department of Natural Resources, Environmental Response and Waste Management Divisions, Guidance Document Verification of Soil Remediation, April, 1994, Revision 1.

U.S. Environmental Protection Agency, Office of Research & Development, Assessing UST Corrective action Technologies: Lessons Learned About In Situ Air Sparging at the Denison Avenue Site Cleveland, Ohio, December, 1994, EPA/600/R-95/040.

University of Wisconsin, College of Engineering, Department of Engineering Professional Development, Designing Air-Based In Situ Soil and Groundwater Remediation Systems, Short course notebook, February 20-22, 1995, Madison, Wisconsin.

Wisconsin Department of Natural Resources, Emergency and Remedial Response Section, Guidance for Design, Installation and Operation of Soil Venting Systems, July, 1993, PUBL-SW185-93.

Example 1 - Small Site

Remediation Area: RA = 44 ft. x 129 ft. = 5,676 sq. ft.

Grid interval, $GI_{RA} = \frac{\sqrt{RA / \pi}}{2} = 21.25$ ft. ≈ 21 ft.

Sampling cell area, $GI_{RA}^2 = 451.56$ sq. ft.

$RA \div GI_{RA}^2 = 12.57$ sampling locations

25% of 12.57 = 3.14 3.14 < 12 ∴ install 12 verification soil borings.

Potential Source Area #1 (Suspected Former Tank Location):

PSA 1 = 20 ft. x 8.33 ft. = 166.67 sq. ft.

Grid interval, $GI_{PSA1} = \frac{\sqrt{PSA\ 1 / \pi}}{2} = 3.64$ ft.

Sampling cell area, $GI_{PSA1}^2 = 13.25$ sq. ft.

$PSA1 \div GI_{PSA1}^2 = 12.58$ sampling locations

25% of 12.58 = 3.14 ≈ 3 verification soil borings

Potential Source Area #2 (Former Diesel Tank Pit):

PSA2 = 16.67 ft. x 10 ft. = 166.67 sq. ft.

Grid interval, $GI_{PSA2} = \frac{\sqrt{PSA\ 2 / \pi}}{2} = 3.64$ ft.

Sampling cell area, $GI_{PSA2}^2 = 13.25$ sq. ft.

$PSA2 \div GI_{PSA2}^2 = 12.58$ sampling locations

25% of 12.58 = 3.14 ≈ 3 verification soil borings

Example 2 - Medium Site

Remediation Area: RA = (210 ft. x 80 ft.) + [(210 ft.)^2 ÷ 2] = 38,850 sq. ft.

Grid interval, $GI_{RA} = \frac{\sqrt{RA / \pi}}{4} = 27.80$ ft. ≈ 28 ft.

Sampling cell area, $GI_{RA}^2 = 772.84$ sq. ft.

$RA \div GI_{RA}^2 = 50.27$ sampling locations

25% of 50.27 = 12.57 ≈ 13 verification soil borings

Tank Pit: TP = (35 ft.)^2 = 1,225 sq. ft.

Grid interval, $GI_{TP} = \frac{\sqrt{TP / \pi}}{2} = 9.87$ ft. ≈ 10 ft.

Sampling cell area, $GI_{TP}^2 = 97.48$ sq. ft.

$TP \div GI_{TP}^2 = 12.57$ sampling locations

25% of 12.57 = 3.14 ≈ 3 verification soil borings

Former Diesel Fuel UST:

DF = 43 ft. x 12 ft. = 516 sq. ft.

Grid interval, $GI_{DF} = \frac{\sqrt{DF / \pi}}{2} = 6.41$ ft.

Sampling cell area, $GI_{DF}^2 = 41.06$ sq. ft.

$DF \div GI_{DF}^2 = 12.57$ sampling locations

25% of 12.57 = 3.14 ≈ 3 verification soil borings

North Pump Islands: NPI = 30 ft. x 36 ft. = 1,080 sq. ft.

Grid interval, $GI_{NPI} = \frac{\sqrt{NPI / \pi}}{2} = 9.27$ ft. ≈ 9.25 ft.

Sampling cell area, $GI_{NPI}^2 = 85.93$ sq. ft.

$NPI \div GI_{NPI}^2 = 12.57$ sampling locations

25% of 12.57 = 3.14 ≈ 3 verification soil borings

South Pump Islands: Same as the North Pump Islands.

Example 1

Figure 3 is an enlargement of the sampling grids for the small site example. The cells have been numbered in increasing order from left to right and from the bottom to the top of the figure. The large grid has 21 cells. The subgrid covering the suspected former UST location has 18 subcells. The subgrid covering the former diesel fuel UST pit has 15 subcells.

The random number chart in the VSR (pages 25-27) will be used to randomly select the locations of the verification soil borings. The grid node at the southwest (bottom left) corner of a cell will be where the boring is installed. It is equally valid to select any grid node, the center of each cell or to subdivide each cell into nine subcells and then randomly locate the boring in one of the subcells. The boring locations should be chosen randomly in a consistent and systematic manner.

Remediation Area:

Since there are 21 cells, only the first two digits of each number in the random number chart will be used. The starting point in the random number chart is line nine (9), column ten (10). Cell number 12 is the first boring location. Moving down column 10, the next cell chosen is cell 17. The remaining borings (continuing down column 10) are located in cells 20, 8, 6, 14, 2, 15, 19, 3, 18 and 5.

Suspected Former UST Location:

Since there are 18 subcells, only the first two digits of each number in the chart will be used. The starting point in the chart is line 14, column three (3). Moving down column 3, subcell 5 is the first boring location. Subcell 4 is the next boring location. Subcell 18 is the final boring location.

Former Diesel Fuel UST Pit:

Since there are 15 subcells, only the first two digits of each number in the chart will be used. The starting point in the chart is line seven (7), column five (5). Moving down column 5, the first boring is located in subcell 9. The next boring is located in subcell 13. The final boring is located in subcell 4.

Example 2

Remediation Area:

Figure 4 is an enlargement of the sampling grids for the medium size site example. The sampling grid covering the entire site has 60 cells, numbered from left to right and front to back along the grid. Only the first two digits of the numbers in the random numbers chart will be used. The starting point is in line 45, column 5. The first boring is located in cell 58. Moving down column 5, the next boring is in cell 14. The remaining borings are in cells 10, 4, 45, 15, 32, 5, 44, 47, 20, 29 and 17.

Tank Pit:

The subgrid has 16 subcells, numbered from left to right and from front to back (the origin points of the subgrids are in the northwestern corners). Only the first two digits of the numbers in the chart will be used. The starting point is in line 9, column 11. Moving down column 11, the first boring is located in subcell 16. The remaining borings are located in subcells 1 and 12.

Former Diesel Fuel Tank Pit:

The subgrid has 14 subcells, numbered from left to right and from front to back. Again, only the first two digits of the numbers will be used. The starting point is line 34, column 8. Moving down column 8, the first boring is in subcell 14. The remaining borings are in subcells 6 and 5.

North Pump Islands:

The subgrid has 12 subcells, numbered from left to right and from front to back. Only the first two digits of each number will be used. The starting point is in line 87, column 8. Moving down column 8, the first boring is in subcell 9. The remaining borings are in subcells 12 and 2.

South Pump Islands:

The subgrid has 12 subcells, numbered from left to right and from front to back. Only the first two digits of the numbers will be used. The starting point is in line 44, column 11. The first boring is located in subcell 11. Moving down column 11, the remaining borings are in subcells 12 and 2.

Figure A on page C-2 shows a biased vertical sampling strategy for isotropic conditions. The vertical sampling intervals are located at the stagnation zone, the capillary fringe zone and randomly chosen depth intervals between the ground surface and the stagnation zone or the capillary fringe zone.

Figure B on page C-2 shows a biased vertical sampling strategy for isotropic conditions with a perfect surface seal. The vertical sampling intervals are located in the stagnation zones, the capillary fringe zone and in randomly chosen depth intervals between the ground surface and the capillary fringe zone or stagnation zones.

Figure C on page C-2 shows a biased vertical sampling strategy for isotropic conditions with a gravel subgrade beneath a surface seal. The vertical sampling intervals are located at the stagnation zones, the capillary fringe zone, where the native soils are bypassed by the preferential air flow through the gravel subgrade and at randomly chosen depth intervals between the near surface soils and the capillary fringe zone and the stagnation zones.

Figure D on page C-2 shows a biased vertical sampling strategy for heterogeneous conditions. The vertical sampling intervals are located at the capillary fringe zone, the stagnation zone, the low permeability lenses and randomly chosen depth intervals between the surface and the water table.