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Organization Regulatory Affairs
Document Number PPPO-02-4381974-17A — Number of Pages 1728
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Document Title/Date Transmittal of Errata Pages and Complete Corrected Document for the C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at PGDP DOE/LX/07-2403&D2/R1

Author Tracey Duncan — Corporate Author DOE
Media (Check all that apply)
☒ Paper ☐ Photo ☐ Diskette ☐ Drawing ☐ Video ☐ CD ☐ Report/Letter ☐ Other
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Other/Comments

DC RH Watson — Date 9-11-17
TIO RH Watson — Date 9-11-17
Reviewing Official[2] RH Watson — Date 9-11-17
OPSEC RH Watson — Date 9-11-17

[1] Provide exemption number and category; contact the Classification Office prior to use of circumvention of statute.
[2] Signature of UCNI Reviewing Official is required for documents containing information in UCNI subject area.

SSTF-106 R3
07/18/16

Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
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AUG 30 2017

PPPO-02-4381974-17A

Mr. Brian Begley
Federal Facility Agreement Manager
Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Boulevard, 2nd Floor
Frankfort, Kentucky 40601

Ms. Julie Corkran
Federal Facility Agreement Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

ENV 1.A-01428

Dear Mr. Begley and Ms. Corkran:

TRANSMITTAL OF ERRATA PAGES AND COMPLETE CORRECTED DOCUMENT FOR THE C-400 VAPOR INTRUSION STUDY WORK PLAN TO SUPPORT THE ADDITIONAL ACTIONS FOR THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT FIVE-YEAR REVIEW AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-2403&D2/R1)

References:

1. Letter from A. Webb to T. Duncan, "Approval of the C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at the PGDP (DOE/LX/07-2403&D2/R1)," dated August 11, 2017
2. Letter from J. Corkran to T. Duncan, "C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the Comprehensive Environmental Response, Compensation, and Liability Act Five Year Review at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/LX/07-2403&D2/R1), Date Issued July 28, 2017, (PPPO-02-4331371-17B) EPA ID KY8890008982, McCracken County, KY," dated August 11, 2017
3. Letter from T. Duncan to B. Begley and J. Corkran, "Paducah Federal Facility Agreement–Signed Memorandum of Agreement for Resolution of Informal Dispute for the C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the Comprehensive Environmental Response, Compensation, and Liability Act Five Year Review at the Paducah Gaseous Diffusion Plant, Paducah , Kentucky (DOE/LX/07-2403&D2)," (PPPO-02-4310559-17), dated July 11, 2017

The U.S. Department of Energy (DOE) acknowledges receipt of the referenced approval letters for the *C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the*

CERCLA Five-Year Review at Paducah Gaseous Diffusion Plant, DOE/LX/07-2403&D2/R1 (Work Plan). Based on the approval date of August 11, 2017, the Vapor Intrusion Study is scheduled to start on September 10, 2017. Enclosed are the errata pages and complete corrected document (i.e., with errata pages included) that has been prepared to address observations received from the Kentucky Department for Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) in approval letters dated August 11, 2017. Specifically, KDEP noted in its approval letter that a column in Table 1 of the Work Plan was missing certain concentrations from the Vapor Intrusion Screening Level (VISL) tool. In response, DOE has revised Table 1 to include the missing VISL concentrations. With respect to KDEP's request to include field notes as an appendix to the C-400 Vapor Intrusion Study Report, DOE will summarize field notes and any deviations in the C-400 Vapor Intrusion Study Report, and copies of the field notes will be placed in the Administrative Record file for the project.

EPA provided eight observations with its approval letter. DOE has addressed observations 4 and 8, which identify DOE errors or omissions in the Work Plan. With respect to observation 5, DOE had provided a compact disc (CD) containing the Standard Operating Procedures (SOPs) that were referenced in the Work Plan. For EPA's and KDEP's convenience, a copy of the CD with the SOPs has been included as an enclosure to this transmittal. Incorporation of the remaining five observations, which are newly identified by EPA, will be considered in future documents.

In addition to the complete corrected document, an errata sheet that summarizes the changes in response to EPA's and KDEP's observations is enclosed.

If you have any questions or require additional information, please contact Cynthia Zvonar at (859) 219-4066.

Sincerely,

Tracey Duncan
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosures:

1. Errata sheet for C-400 VI SWP for CERCLA Five-Year Review, DOE/LX/07-2403&D2/R1
2. Errata pages for the C-400 VI SWP for CERCLA Five-Year Review, DOE/LX/07-2403&D2/R1—Redline
3. C-400 VI SWP for CERCLA Five-Year Review, DOE/LX/07-2403&D2/R1—Complete Corrected Document
4. Standard Operating Procedures—CD

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ERRATA SHEET

C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

July 28, 2017

DOE/LX/07-2403&D2/R1

The following four corrections have been incorporated into the document.

1. Cover Page: The cover was modified to indicate errata were issued for this work plan.
2. Title Page: The title page was modified to indicate errata were issued for this work plan on the date specified.
3. Section 5, page 5: Revised Table 1 to include missing Vapor Intrusion Screening Levels.
4. Appendix C, page 5: Updated the presentation to include revised problem statement.

DOE/LX/07-2403&D2/R1 Errata
Secondary Document

C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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DOE/LX/07-2403&D2/R1 Errata
Secondary Document

C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—July 2017

Errata Issued—August 2017

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FLUOR FEDERAL SERVICES, INC.,
Paducah Deactivation Project
managing the
Deactivation Project at the
Paducah Gaseous Diffusion Plant
under Task Order DE-DT0007774

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…Given the magnitude of high concentration volatile organic compounds (VOC) contamination, including TCE DNAPL present in surrounding subsurface soils and below the building, the potential for vapor intrusion is likely. Vapor intrusion into building C-400 is identified as an issue in the FYR with the recommendation that a vapor intrusion analysis be performed as part of any subsequent C-400 action.

DOE has reviewed and evaluated the available site information and concurs with EPA's determination that VOCs are present in high concentrations in the subsurface groundwater and soils surrounding and below C-400 at levels above the EPA VI Screening Levels (VISLs) (Table 1). The following subsections provide additional detail to support these conclusions: Section 5.1 presents a preliminary evaluation of the remaining subsurface sources with the potential to pose a VI concern and Section 5.2 presents a preliminary evaluation of the likelihood the VI pathway is complete at C-400.

Table 1. VISL for VOCs of Interest at the C-400 Cleaning Building, Commercial[1]

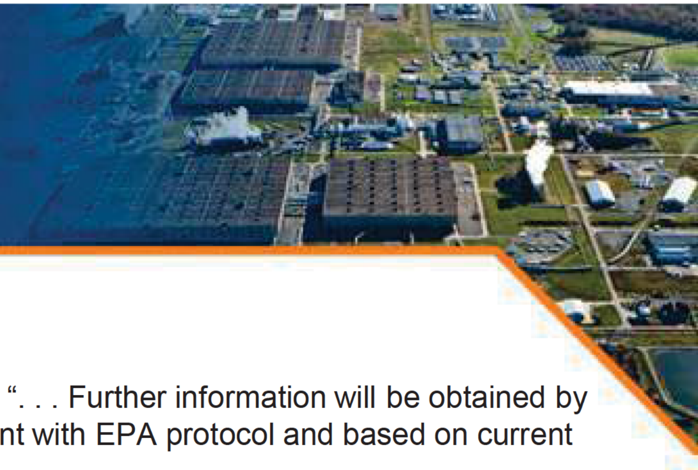
Chemical	Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk via Vapor Intrusion from Soil Source?	Is Chemical Sufficiently Volatile and Toxic to Pose inhalation Risk via Vapor Intrusion from Groundwater Sources?	Target Indoor Air Conc. (µg/m^3) @ TCR = 1E-06 or THQ = 1	Toxicity Basis	Target Sub-Slab and Exterior Soil Gas Conc. (µg/m^3) @ TCR = 1E-06 or THQ = 1	Target Groundwater Conc. (µg/L) @ TCR = 1E=06 or THQ = 1
	Cvp > Cia, target?	**Chc > Cia, target?**	**Min (Cia, c; Cia, nc)**	**C or NC**	**Csg**	**Csg**
1,1-Dichloroethane	Yes	Yes	7.7E+00	C	2.6E+02	3.3E+01
1,2-Dichloroethane	Yes	Yes	4.7E-01	C	1.6E+01	9.8E+00
1,1-Dichloroethene	Yes	Yes	8.8E+02	NC	2.9E+04	8.2E+02
cis-1,2-Dichloroethene	No Inhal. Tox. Info	No Inhal. Tox. Info	NVA*, 3,500	--, NC	--	--
trans-1,2-Dichloroethene	No Inhal. Tox. Info	No Inhal. Tox. Info	NVA*, 3,500	--, NC	--	--
Trichloroethene	Yes	Yes	3.0E+00	C	1.0E+02	7.4E+00
Vinyl Chloride	Yes	Yes	2.8E+00	C	9.3E+01	2.5E+00
1,1,1-Trichloroethane	Yes	Yes	2.2E+04	NC	7.3E+05	3.1E+04
1,1,2-Trichloroethane	Yes	Yes	7.7E-01	C	2.6E+01	2.3E+01
1,4-Dioxane	Yes	Yes	2.5E+00	C	8.2E+01	1.3E+04

C carcinogenic
Cia concentration, indoor air
Cia, target concentration, indoor air, target
Chc concentration, groundwater vapor
Csg concentration, sub-slab and exterior soil gas concentration
Cvp concentration, pure phase vapor
NVA* no VISL value available; provisional value provided by EPA as documented in Appendix E (E.9) of the Draft Risk Methods Document (DOE 2017). Value for *cis*-1,2-DCE uses *trans*-1,2-DCE value as surrogate
NC noncarcinogenic
TCR target risk for carcinogens
THQ target hazard quotient for noncarcinogens

[1] The VISL values are taken from the VISL calculator (May 2016 version 3.5.1, https://semspub.epa.gov/src/document/11/196702) derived for a commercial exposure scenario at a target excess cancer risk of 1.0 E-06 and a target hazard quotient of 1.0. Per the VISL calculator, the commercial exposure scenario has a 70 year averaging time for carcinogens, a 25-year averaging time for noncarcinogens, an exposure duration of 25 years, an exposure frequency of 250 days/year, and an exposure time of 8 hours/day.

Vapor Intrusion Evaluation

DQO Step 1. State the Problem



- **Problem Statement:**

  Determine if vapor intrusion is occurring.

  --Adapted from U.S. Environmental Protection Agency (EPA) letter, dated 9/30/2014: ". . . Further information will be obtained by taking the following actions: a vapor intrusion study will be conducted that is consistent with EPA protocol and based on current toxicity values and risk assessment methodology."

- **Problem Description:**

  Trichloroethene (TCE) and other VOCs are present in the Upper Continental Recharge System (UCRS) and the Regional Groundwater Aquifer (RGA) soils and groundwater (GW) around C-400. Due to the concentration of TCE/VOCs, vapor from the TCE/VOCs has the potential to migrate into the C-400 building and pose a possible risk to the workers.

- **Problem Approach:**
  - The planning team will review existing data; identify data gaps, if any; and, if necessary, determine what new data are needed to evaluate the potential for vapor intrusion into the C-400 building.
  - Planning Team: Federal Facility Agreement (FFA) Parties; Leader: U.S. Department of Energy (DOE)
  - Conceptual Model: Evaluate EPA VI Conceptual Site Model (CSM), adapt to PGDP conditions. Evaluate VI driving factors against PGDP CSM conditions.
  - Determine Resources:
    - Schedule: within 18 months of 9/30/2014
    - Budget: Based upon scope
    - Personnel: FPDP

1. State the Problem
- Give a concise description of the problem
- Identify leader and members of the planning team
- Develop a CSM of the environmental hazard to be investigated
- Determine resources—budget, personnel, and schedule

FLUOR

DOE/LX/07-2403&D2/R1 Errata
Secondary Document

C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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C-400 Vapor Intrusion Study Work Plan to Support the Additional Actions for the CERCLA Five-Year Review at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—July 2017

Errata Issued—August 2017

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FLUOR FEDERAL SERVICES, INC.,
Paducah Deactivation Project
managing the
Deactivation Project at the
Paducah Gaseous Diffusion Plant
under Task Order DE-DT0007774

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CONTENTS

TABLES

FIGURES

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ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	conceptual site model
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
FFA	Federal Facility Agreement
FYR	five-year review
IH	industrial hygiene
IRA	interim remedial action
PEM	preemptive mitigation
PGDP	Paducah Gaseous Diffusion Plant
QAPP	quality assurance project plan
RGA	Regional Gravel Aquifer
RI	remedial investigation
SAP	sampling and analysis plan
SWMU	solid waste management unit
UCRS	Upper Continental Recharge System
VI	vapor intrusion
VISL	vapor intrusion screening level
VOC	volatile organic compound
WAG	waste area grouping
WP	work plan

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1. INTRODUCTION

This Work Plan (WP) has been developed to document a site-specific vapor intrusion (VI) conceptual site model (CSM) for the C-400 Cleaning Building (C-400) at the U.S. Department of Energy (DOE) Paducah Gaseous Diffusion Plant (PGDP) and provide a sampling and analysis plan (SAP) to guide collection of vapor samples within and around C-400 to evaluate if the VI pathway presents an unacceptable risk to human health under current conditions. This historical data evaluation and additional investigation are being performed in response to a letter from the U.S. Environmental Protection Agency (EPA) dated September 30, 2014, (EPA 2014a) concerning the *Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FYR) (DOE 2014a). In the letter dated September 30, 2014, (EPA 2014a) EPA noted the following project-related uncertainty:

> …Given the magnitude of high concentration volatile organic compounds (VOC) contamination, including TCE DNAPL present in surrounding subsurface soils and below the building, the potential for vapor intrusion is likely. Vapor intrusion into building C-400 is identified as an issue in the FYR with the recommendation that a vapor intrusion analysis be performed as part of any subsequent C-400 action. The vapor intrusion study…should be conducted in the near term to determine whether this potential pathway presents an unacceptable risk to human health such as workers that work in and around the C-400 Cleaning Building. Until a vapor intrusion study is conducted that is consistent with EPA protocol and based on current toxicity values and risk assessment methodology, the protectiveness statement should be "deferred" until the protectiveness of the remedy can be determined.

The C-400 project-related uncertainty is one of three outlined in EPA's letter. The other two uncertainties (VI in the water policy area and demonstration of no groundwater usage over the contaminated plume) have been addressed by DOE and have been documented in an addendum to the 2013 FYR.

Meetings were held to scope VI investigations, both in the water policy area and at C-400, to address the concerns raised by EPA. As a result of a C-400 scoping meeting held September 29, 2015, DOE provided a path forward as summarized in two letters dated December 17, 2015, and January 15, 2016. The path forward includes a compilation and evaluation of the available historical data in the context of a VI CSM for C-400 and a SAP for the additional characterization to be conducted in C-400 to determine the impact of the potential VI pathway on the building's indoor air. This study is being conducted under the provisions of Section XXX, Five-Year Review, of the PGDP Federal Facility Agreement (FFA) (EPA 1998), as documented in the Record of Conversation letter dated August 1, 2014 (DOE 2014b).

DOE's compilation of available historical data identified existing information relevant to the assessment of VI at C-400. EPA's 2015 VI Technical Guide, *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (EPA 2015), distinguishes "two general levels of VI assessments," which are these: (1) a preliminary analysis that uses available information to develop an initial understanding of the potential for human health risks to be posed by VI; and (2) a detailed investigation, recommended when the preliminary VI analysis indicates that subsurface contamination with vapor-forming chemicals may be present underlying or near buildings. EPA VI guidance states, "the approach for assessing VI will vary from site to site" and the "Technical Guide, therefore, recommends a framework for planning and conducting VI investigations, rather than a prescriptive step-by-step approach to be applied at every site" (EPA 2015).

Consistent with EPA's 2015 VI Guide (EPA 2015), this WP presents background information on C-400 and its investigation history (Section 4); documents that a preliminary assessment of the VI pathway at

C-400 indicates additional evaluation of the VI pathway is warranted (Section 5); and presents a detailed evaluation of the existing site information and data in the context of a site-specific VI CSM (Section 6), including assessment of the completeness of the VI pathway and identification of data gaps. The existing data considered in the preliminary VI assessment and detailed VI pathway evaluation are compared to VI screening levels presented in Section 5. Based on the site-specific VI CSM, Section 7 provides the locations and rationale for the proposed sampling needed to determine the completeness of the VI pathway at C-400. Section 8 documents how the additional samples will be collected and analyzed. Section 9 summarizes how the sampling results will be evaluated. Section 10 provides decision rules for evaluating the newly collected sampling results. The information gathered as a result of this WP and evaluated in the context of the site-specific VI CSM will be used to determine whether measured VOC concentrations in indoor air [primarily trichloroethene (TCE)] present an unacceptable risk to human health due to VI in C-400.

2. PURPOSE

This WP has the following purposes:

1. Provide a compilation and summary of existing information and data relevant to the VI pathway at C-400;
2. Document the preliminary and detailed VI evaluations for C-400;
3. Summarize the site-specific VI-CSM, analyze the completeness of the VI pathway in the context of the VI CSM, and identify data gaps;
4. Present the rationale for additional sampling at C-400;
5. Recommend screening levels based on current toxicity values and risk assessment methodology;
6. Describe the sampling and analysis needed to determine whether VOCs (primarily TCE) concentrations present an unacceptable risk to human health due to VI in C-400; and
7. Provide decision rules for evaluating the data collected as part of this study.

3. INVESTIGATION BOUNDARIES

The vertical investigation boundaries of the VI evaluation and study include a lower boundary of the Upper Continental Recharge System (UCRS) or Regional Gravel Aquifer (RGA) matrix from the first available water below ground surface (bgs) in the C-400 area up through the vadose zone and an upper boundary in C-400. The lateral boundaries include the areas in the immediate vicinity of C-400 defined by 11th Street to the east, Tennessee Avenue to the south, 10th Street to the west, and Virginia Avenue to the north.

4. SITE BACKGROUND

4.1 FACILITY DESCRIPTION

The PGDP (EPA site identification number KY8890008982) is located in McCracken County in western Kentucky, about 3.5 miles south of the Ohio River and approximately 10 miles west of the city of Paducah. Most industrial activities at PGDP were sited in a 750-acre secured area and buffer zone that are restricted from access by the public. This secured area is located on 3,556 acres controlled by the DOE. The C-400 area is located inside the plant secured area, near the center of the industrial section of PGDP.

PGDP is an inactive gaseous diffusion plant that was used to produce enriched uranium beginning in 1952. The facility first was owned and managed by the Atomic Energy Commission and the Energy Research and Development Administration, DOE's predecessors; DOE then managed PGDP until 1993. On July 1, 1993, United States Enrichment Corporation assumed management and operation of the PGDP enrichment facility under a lease agreement with DOE that continued until October 2014 when the facility was returned to DOE. DOE retains ownership of the enrichment complex.

4.2 FACILITY INVESTIGATION HISTORY

In June 1986, a routine construction excavation along the 11th Street storm sewer revealed TCE soil contamination. The cause of the contamination was determined to be a leak in a drain line from C-400's basement sump to the storm sewer. The area of contamination became known as the C-400 TCE Leak Site and was given the designation of Solid Waste Management Unit (SWMU) 11. SWMU 11 and the C-400 area have been the subjects of several investigations and remediations since then.

After the discovery of the C-400 TCE Leak Site in June 1986, some of the soils were excavated in an attempt to reduce contamination in the area. Excavation was halted to prevent structural damage to the adjacent infrastructure (a fence, TCE storage tank, and road). Approximately 310 ft^3 of TCE-contaminated soil was removed and drummed for off-site disposal (CH2M HILL 1992). The excavation was backfilled with clean soil and the area was capped with a layer of clay.

The Phase I and Phase II Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Site Investigations (CH2M HILL 1991; CH2M HILL 1992) included installation of soil borings and groundwater wells in the area around C-400. These investigations confirmed that TCE contamination at the southeast corner of C-400 extended from near the surface to the base of the RGA at 92 ft bgs.

The *Northeast Plume Preliminary Characterization Summary Report* (DOE 1995) demonstrated that the area around C-400 was a major source for the Northwest Plume. Also in 1995, a review of C-400 process activities documented in the *C-400 Process and Structure Review*, KY/ERWM-38 (MMES 1995) confirmed that TCE historically was used at the building.

In 1997, the Waste Area Grouping (WAG) 6 remedial investigation (RI) focused on the area around C-400 and further delineated contamination at SWMU 11. The RI identified the TCE transfer system at the southeast corner of the building (later named SWMU 533) as a source of soil and groundwater contamination. An additional area of soil contamination comprised of TCE and other VOCs and associated with a storm sewer was identified near the southwest corner of the building.

DOE conducted an electrical resistance heating (ERH) treatability study in 2003 (DOE 2004) to assess the constructability and effectiveness of full-scale deployment of ERH to address VOCs in the UCRS and RGA. The ERH treatability study removed approximately 1,900 gal of VOCs from the subsurface in an approximate 43-ft diameter by an approximate 99-ft deep treatment area, extending through the RGA, near the southeast corner of C-400 (DOE 2004). Other treatability studies for the RGA at C-400 have assessed surfactant flushing (laboratory and field tests in 1994, followed by laboratory testing in 1998) and chemical oxidation (laboratory testing in 1998).

DOE completed a record of decision in 2005, *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* (DOE 2005) to address the Groundwater Operable Unit VOC (primarily TCE) source zones in the UCRS, upper RGA, and lower RGA east, southeast, and southwest of C-400. The interim remedial action (IRA) selected ERH as the primary treatment technology, based on the results of the 2003 ERH treatability study.

The IRA (as discussed further in Section 5) has been executed in two phases, Phase I and Phase II. The east and southwest areas of C-400 were selected for Phase I because they were the smallest of the source areas near the building and had contaminants primarily in the UCRS. Phase I ERH operations were initiated in 2009 and completed in December 2010.

Phase IIa followed Phase I to treat the UCRS and the upper RGA in the southeast area, which contained a larger amount of TCE contamination. Phase IIa ERH operations were completed in fall of 2014. A Phase IIb IRA will address remaining TCE contamination in the lower RGA of the southeast treatment area.

Section 5 describes the TCE contamination remaining that has the potential to serve as sources for the VI pathway and evaluates the likelihood the VI pathway is complete at C-400.

5. PRELIMINARY VI ANALYSIS FOR THE C-400 CLEANING BUILDING

EPA's 2015 VI Guide recommends a preliminary analysis of "available and readily ascertainable information to develop an initial understanding of the potential for human health risk that are or may be posed by VI." This involves (1) assembling, evaluating, and reviewing available information; (2) determining the presence of vapor-forming chemicals under buildings; (3) developing an initial VI CSM; and (4) evaluating preexisting and readily ascertainable sampling data.

EPA's 2015 VI Guide further recommends the preliminary analysis include evaluating the available site data to determine whether subsurface sources that remain have the potential to pose an unacceptable risk to human health due to VI and whether the VI pathway is likely to be "complete." Site-specific information for the C-400 area previously has been provided to EPA via various technical reports and presentations. The material presented in the September 29, 2015, scoping meeting has been included in Appendix C of this Work Plan. On the basis of this previously presented information, EPA has determined that there is a potential for VI because of the presence of historically high concentrations of TCE [including TCE dense nonaqueous-phase liquid (DNAPL)] in soil and groundwater under and adjacent to C-400 and because of the presence of workers in the building. Specifically, EPA in 2014 determined that:

…Given the magnitude of high concentration volatile organic compounds (VOC) contamination, including TCE DNAPL present in surrounding subsurface soils and below the building, the potential for vapor intrusion is likely. Vapor intrusion into building C-400 is identified as an issue in the FYR with the recommendation that a vapor intrusion analysis be performed as part of any subsequent C-400 action.

DOE has reviewed and evaluated the available site information and concurs with EPA's determination that VOCs are present in high concentrations in the subsurface groundwater and soils surrounding and below C-400 at levels above the EPA VI Screening Levels (VISLs) (Table 1). The following subsections provide additional detail to support these conclusions: Section 5.1 presents a preliminary evaluation of the remaining subsurface sources with the potential to pose a VI concern and Section 5.2 presents a preliminary evaluation of the likelihood the VI pathway is complete at C-400.

Table 1. VISL for VOCs of Interest at the C-400 Cleaning Building, Commercial[1]

Chemical	Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk via Vapor Intrusion from Soil Source?	Is Chemical Sufficiently Volatile and Toxic to Pose inhalation Risk via Vapor Intrusion from Groundwater Sources?	Target Indoor Air Conc. (μg/m^3) @ TCR = 1E-06 or THQ = 1	Toxicity Basis	Target Sub-Slab and Exterior Soil Gas Conc. (μg/m^3) @ TCR = 1E-06 or THQ = 1	Target Groundwater Conc. (μg/L) @ TCR = 1E=06 or THQ = 1
	Cvp > Cia, target?	Chc > Cia, target?	Min (Cia, c; Cia, nc)	C or NC	Csg	Csg
1,1-Dichloroethane	Yes	Yes	7.7E+00	C	2.6E+02	3.3E+01
1,2-Dichloroethane	Yes	Yes	4.7E-01	C	1.6E+01	9.8E+00
1,1-Dichloroethene	Yes	Yes	8.8E+02	NC	2.9E+04	8.2E+02
cis-1,2-Dichloroethene	No Inhal. Tox. Info	No Inhal. Tox. Info	NVA*, 3,500	--, NC	--	--
trans-1,2-Dichloroethene	No Inhal. Tox. Info	No Inhal. Tox. Info	NVA*, 3,500	--, NC	--	--
Trichloroethene	Yes	Yes	3.0E+00	C	1.0E+02	7.4E+00
Vinyl Chloride	Yes	Yes	2.8E+00	C	9.3E+01	2.5E+00
1,1,1-Trichloroethane	Yes	Yes	2.2E+04	NC	7.3E+05	3.1E+04
1,1,2-Trichloroethane	Yes	Yes	7.7E-01	C	2.6E+01	2.3E+01
1,4-Dioxane	Yes	Yes	2.5E+00	C	8.2E+01	1.3E+04

C carcinogenic
Cia concentration, indoor air
Cia, target concentration, indoor air, target
Chc concentration, groundwater vapor
Csg concentration, sub-slab and exterior soil gas concentration
Cvp concentration, pure phase vapor
NVA* no VISL value available; provisional value provided by EPA as documented in Appendix E (E.9) of the Draft Risk Methods Document (DOE 2017). Value for *cis*-1,2-DCE uses *trans*-1,2-DCE value as surrogate
NC noncarcinogenic
TCR target risk for carcinogens
THQ target hazard quotient for noncarcinogens

[1] The VISL values are taken from the VISL calculator (May 2016 version 3.5.1, https://semspub.epa.gov/src/document/11/196702) derived for a commercial exposure scenario at a target excess cancer risk of 1.0 E-06 and a target hazard quotient of 1.0. Per the VISL calculator, the commercial exposure scenario has a 70 year averaging time for carcinogens, a 25-year averaging time for noncarcinogens, an exposure duration of 25 years, an exposure frequency of 250 days/year, and an exposure time of 8 hours/day.

5.1 IDENTIFICATION OF POTENTIAL VI SOURCES

The historical evaluations conducted in and around C-400 have identified several sources that have the potential to yield VOC concentrations above EPA VISL concentrations in indoor air:

- RGA groundwater contaminated with TCE, including TCE in DNAPL form or as residual ganglia, in the vicinity of and underlying C-400;
- UCRS soils with historical DNAPL TCE contamination adjacent to and potentially extending under C-400; and
- UCRS soils with residual TCE contamination in remediated soils adjacent to C-400.

These identified sources have been and are being addressed by the 1986 soil removal, the 1993 closure of the degreasing operations, sump line rerouting, tank and line removal, the 2003 ERH treatability study, and the previous and ongoing IRAs. Nevertheless, subsurface contamination with the potential to pose a VI concern remains and is described in greater detail below.

Figure 1 presents a map of the TCE plume in the RGA at PGDP that demonstrates TCE continues to be present at concentrations indicative of the presence of DNAPL in the RGA in the area of C-400. The RGA Plume moves principally to the northwest (from the southeast) under/adjacent to C-400. This map shows that, as recently as 2014, high levels of TCE (10,000 to 100,000 µg/L) are present in RGA groundwater under the building. These levels exceed EPA's VISL of 7.4 µg/L for groundwater.

Figure 2 presents a contour map of maximum historical TCE concentrations detected in UCRS soil from the WAG 6 RI that shows that the highest TCE concentrations in the UCRS soils were present on the southwest, southeast, and east sides of C-400 and that high levels of TCE—representative of the historical presence of DNAPL—may extend under C-400. Although the exterior-to-C-400 UCRS areas have been remediated, post-remedial residual concentrations in the vicinity of C-400 still are high enough to pose a VI concern; and, based on interpretation of the extent of historical TCE contamination, high levels of TCE may continue to exist under the building.

Figure 3 presents a layout of the C-400 Building with callouts indicating the historical TCE use areas. Although the TCE use units were closed in 1993, there is the potential for the historical TCE use areas to contribute TCE to the indoor air of C-400 through off-gassing of residual TCE potentially absorbed/adsorbed in concrete under or around the former cleaning tanks or TCE remaining in piping or utility bedding areas under C-400.

Tabulation of historical data relevant to these sources and further analysis of data are presented in the site-specific VI CSM (Section 6).

5.2 PRELIMINARY EVALUATION OF THE VI PATHWAY COMPLETENESS

EPA's VI guidance states that a potential VI pathway should be considered complete when the following five key conditions are present:

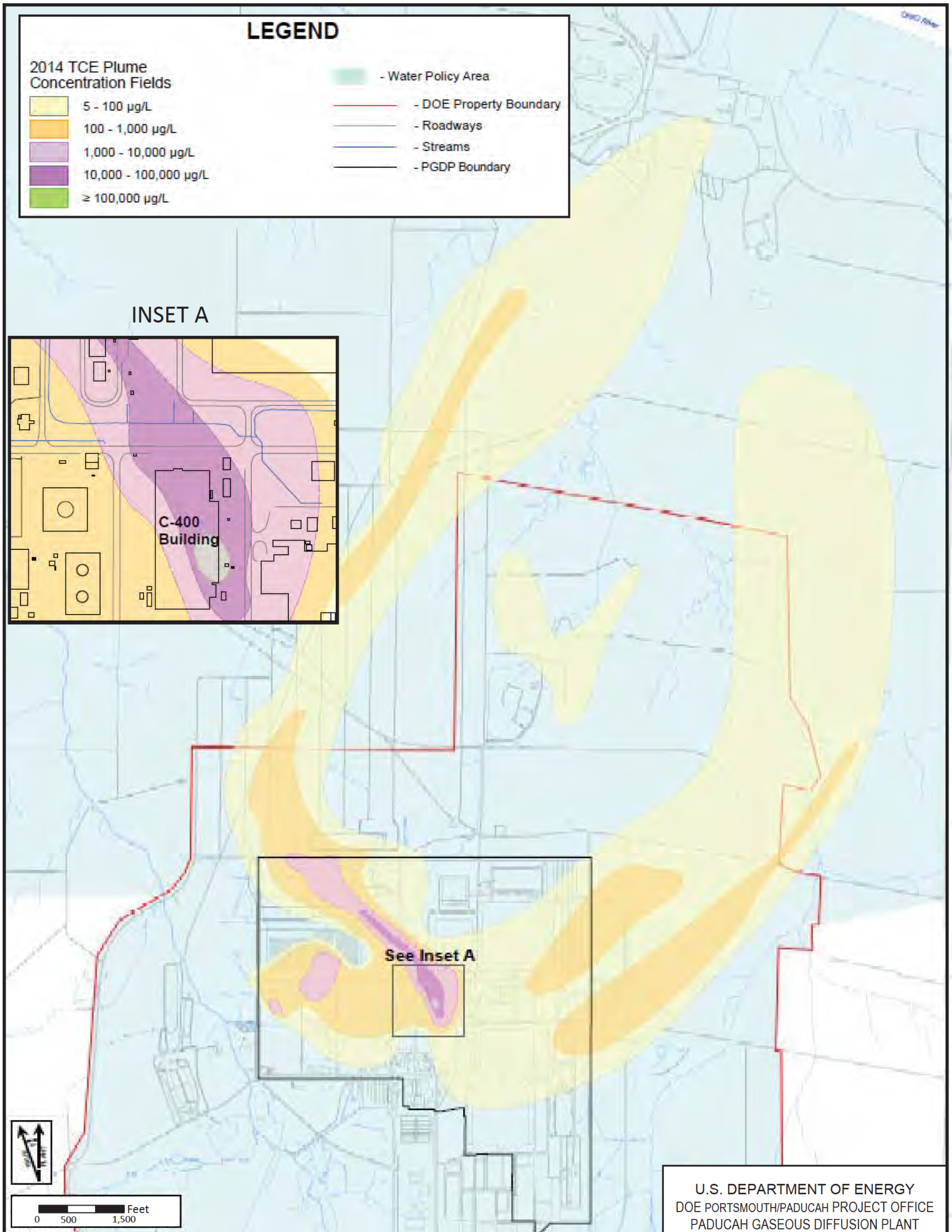

Figure 1. 2014 TCE Plume—Regional Gravel Aquifer

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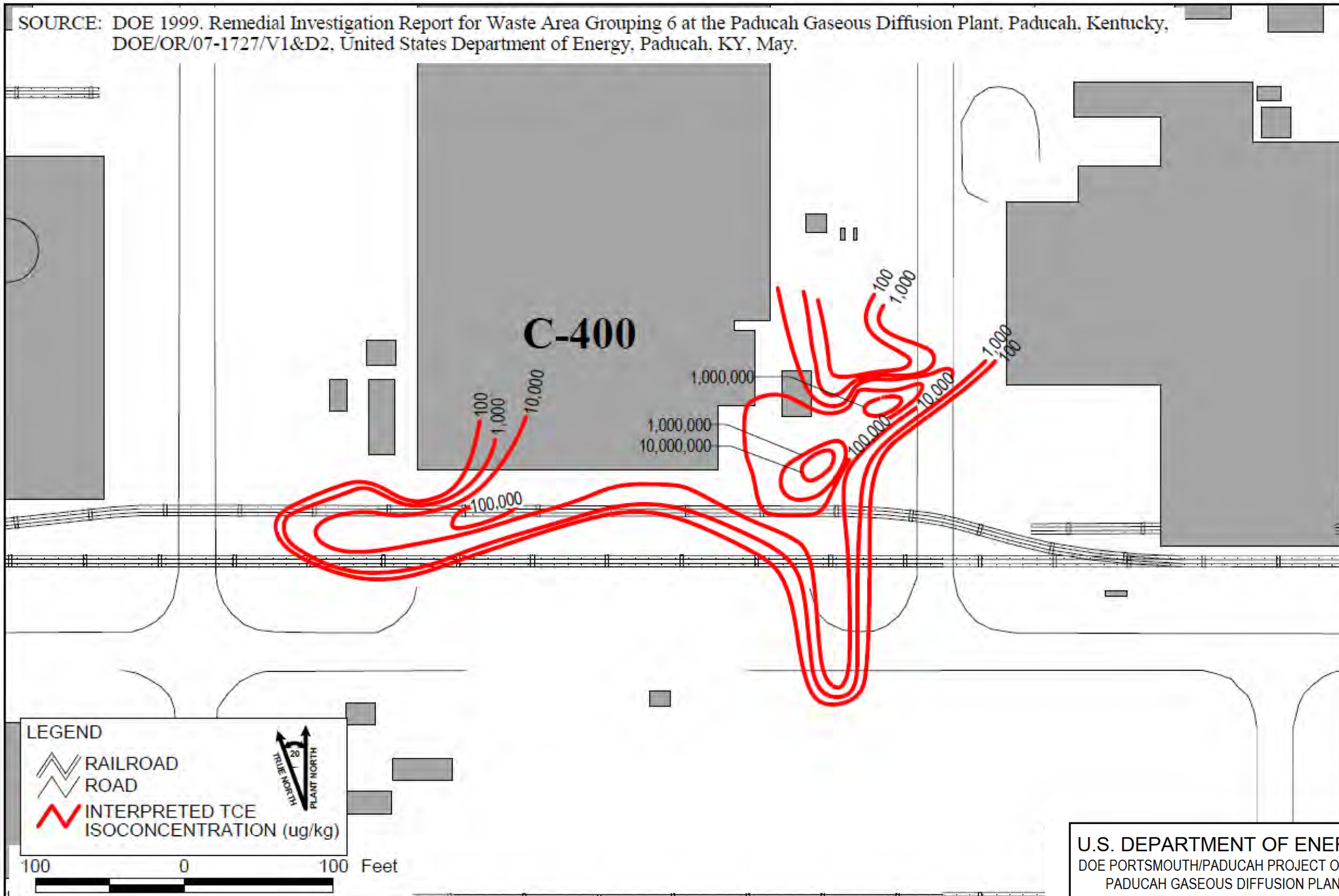

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Figure 2. 1999 Contour Map of Maximum Historical TCE Concentration Detected in UCRS Soil

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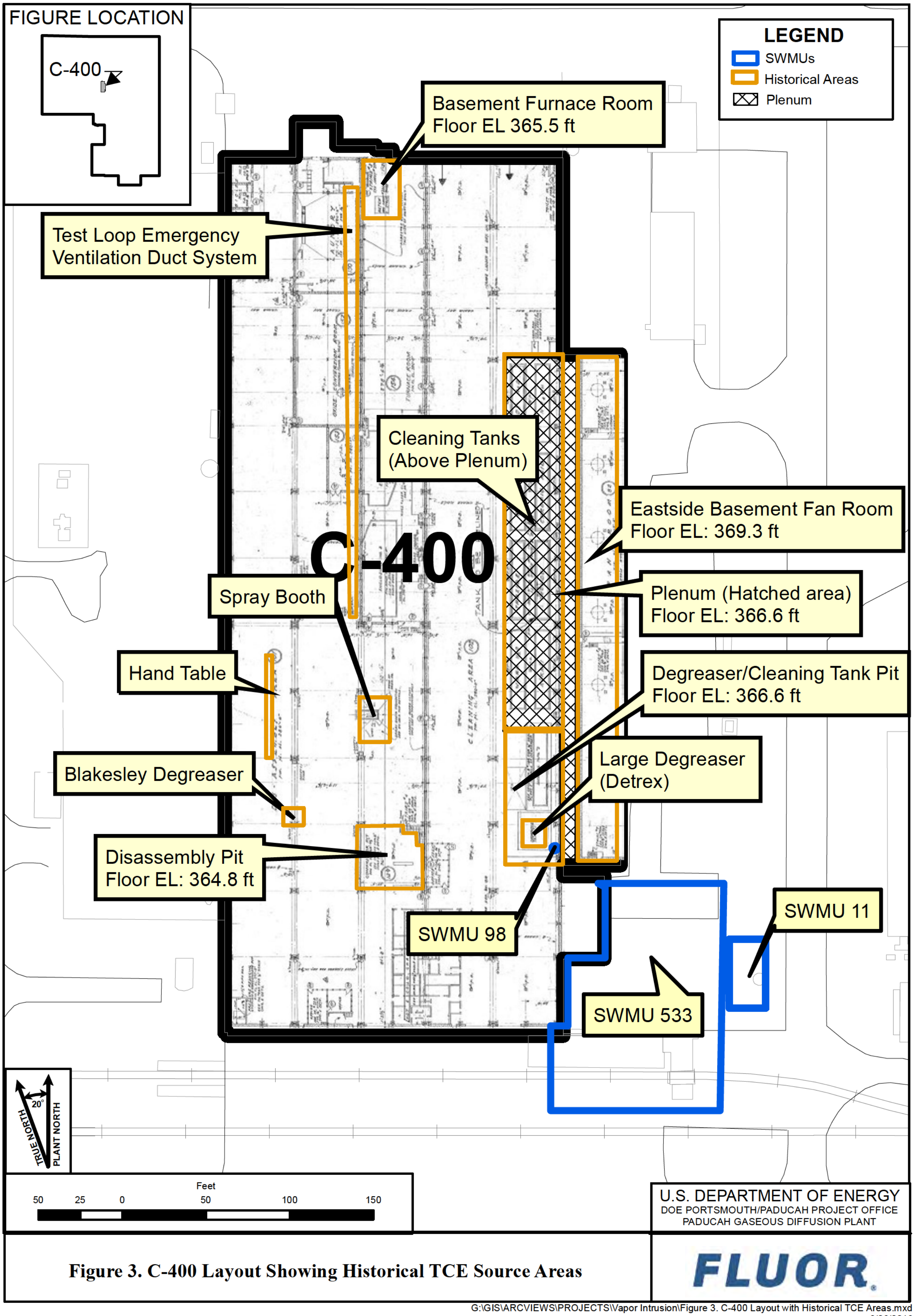

Figure 3. C-400 Layout Showing Historical TCE Source Areas

1. Subsurface sources of vapor-forming chemicals are present;
2. There is a route for the vapors to migrate;
3. The building is susceptible to VI;
4. Vapors are present in the indoor environment; and
5. People are in the indoor environment.

The following discussion presents a preliminary evaluation of the applicability of these conditions at C-400. Additional evaluation of the completeness of the VI pathway is presented in Section 6.

Subsurface sources of vapor-forming chemicals are present. As described above in Section 5.1, there are three primary (and potentially several more) residual sources of VOCs that may cause unacceptable vapor concentrations in the indoor air at C-400.

Routes for vapor migration likely are present. The documented presence of sand in a portion of the UCRS in the vicinity of C-400 and the presence of gravel immediately beneath the building (presented in Section 6) may allow vapor migration through the vadose zone. The large number of utilities present in the vicinity of the building also may serve as preferential pathways for vapor migration into C-400. Thus, it is reasonable to conclude subsurface routes for vapor migration likely are present.

Building is susceptible to VI. Deteriorated concrete has been identified in the building slab and other unidentified VI conduits in the building may exist, which could provide pathways for vapor migration into the building. Thus, it is reasonable to conclude C-400 potentially is susceptible to VI.

Vapors have been present and may continue to be present in the indoor air environment above VISL values. Previous industrial hygiene (IH) sampling of the indoor air in C-400 identified two indoor air samples collected in 2003 that had measured concentrations of TCE of 2,800 ppbv and 500 ppbv. These results were attributed to seep water in the sump located in the C-400 basement. Other IH sampling results have yielded no detectable VOCs; however, the detection limits were substantially greater than VISL values. Based on this information, it is reasonable to conclude that TCE may be present in the indoor air of C-400 at concentrations above VISL values.

People are in the indoor environment. C-400 is currently occupied by remediation workers. As a result, these workers have the potential to be exposed to TCE and other VOCs through the VI pathway.

Figure 4 presents a schematic CSM figure based on the conceptual model in the EPA VI Guide (EPA 2015), adapted to the C-400 facility. This figure provides a general illustration of the subsurface sources of contamination with the potential to pose a VI concern in the C-400 area.

EPA's VI Guide notes that, "when these conditions are not well established from existing information…EPA recommends that a detailed VI investigation be scoped and conducted to address these data gaps" (EPA 2015). The corollary is that, when conditions are well established from existing information, additional investigation should focus on the conditions that have not yet been well established.

Alternatively, EPA's VI Guide states that it may be appropriate to implement VI mitigation as an early action, though all pertinent lines of evidence have not been developed completely to characterize the potential VI pathway, when sufficient site-specific data indicate that VI may pose a health concern to building occupants (EPA 2015).

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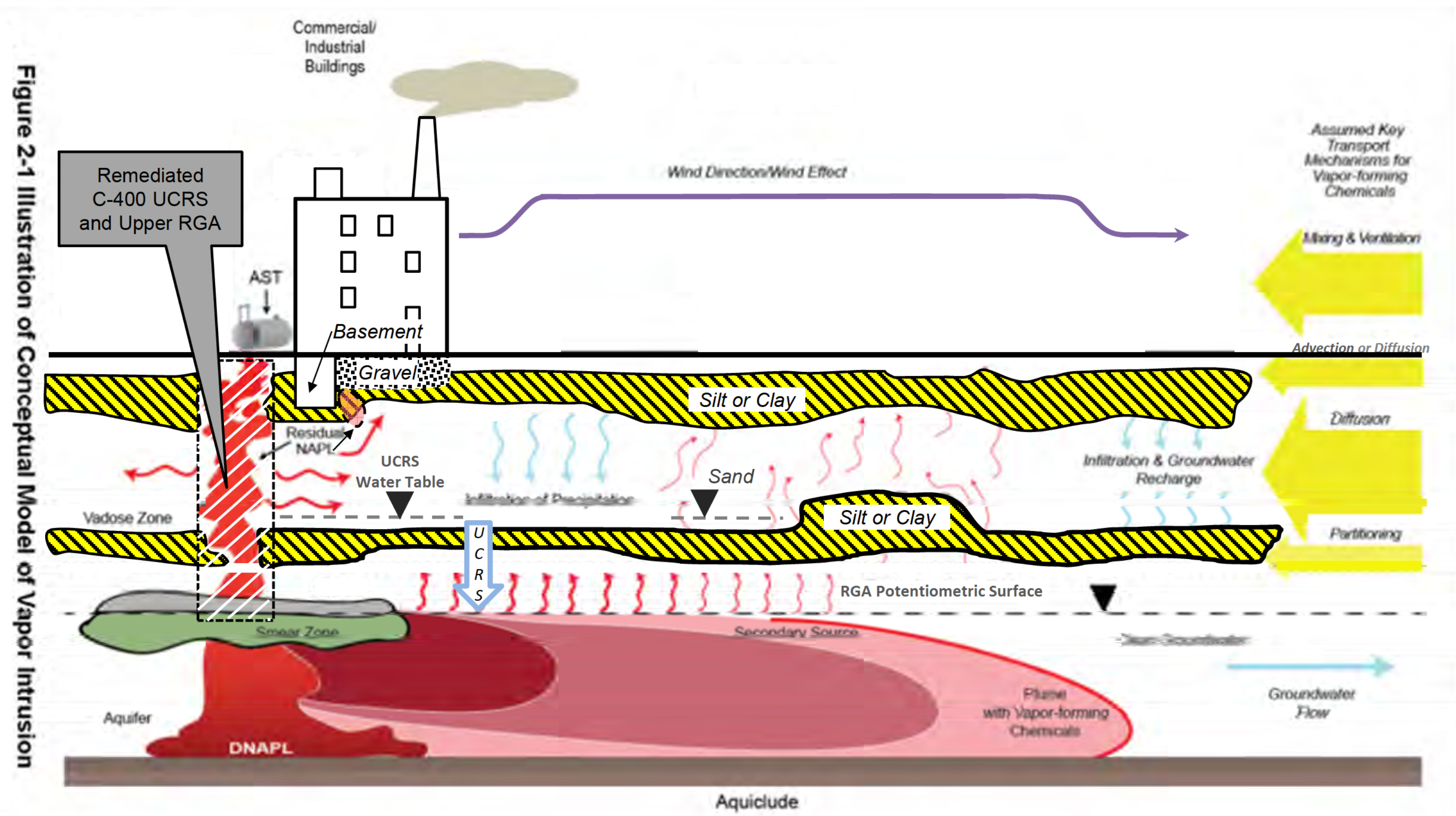

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Figure 4. C-400 Cleaning Building CSM (Approximate Perspective from Northeast Building Corner) Adapted from June 2015 EPA VI Guidance

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For C-400, four (1, 2, 3, and 5) of the five key conditions regarding completeness of the VI pathway are documented with site-specific data in Section 6. The remaining key condition (4) is considered potentially to exist at C-400, but represents a data gap that needs to be filled (e.g., by collection of indoor air samples) to determine if there are vapors present in the indoor environment at levels that pose an unacceptable risk. Section 6 further evaluates the existing data in the context of a site-specific VI CSM, determines the likelihood the VI pathway is complete, and identifies data gaps that need to be addressed with additional VI investigation.

6. SITE-SPECIFIC VAPOR INTRUSION CONCEPTUAL SITE MODEL

EPA's VI Guide (EPA 2015) recommends using available site data to develop a VI CSM that addresses, at a minimum, the nature, location, spatial extent of the vapor sources in the subsurface as well as location, use, occupancy, and construction of the existing buildings. EPA also recommends the CSM portray the current understanding of the hydrologic and geologic setting and its influence on vapor migration and attenuation in the vadose zone. To address these needs, a VI CSM generally includes descriptions of the following:

- Site operations and activities—the types of site operations and activities that occurred on or near the site that could have released VOCs to the subsurface;
- Chemicals of interest—the types of VOCs that may have been used or disposed at the site;
- Land and facility use—current and reasonably anticipated land and building use and occupancy;
- Building characteristics—such as layout; type and integrity of the building foundation, and heating, ventilating, and air conditioning operations;
- Potential residual subsurface sources—types, locations, and concentrations of vapor-forming sources under or near the building; and
- Potential vapor migration pathways—descriptions of vadose zone features conducive to vapor transport and potential vapor entry points into the building, including potential preferential pathways, such as subsurface utility corridors.

DOE's compilation of available historical data has identified considerable existing information relevant to the assessment of VI at C-400. The following sections present a compilation of the data relevant to the VI pathway and the use of that data to develop a site-specific VI CSM, evaluate the completeness of the VI pathway, and identify data gaps that need to be addressed.

In compiling the existing data, the following rules were used to determine the usability of historical data:

- Historical data that have been qualified as rejected by data validation or by data assessment were not included in the historical data evaluated for use.
- Historical data that contain units inconsistent with the sampled media or with the analysis were not included in the historical data evaluated for use (e.g., a soil sample with analytical units reported in mg/L would not be considered usable).

- Historical data with no reported result and no recorded detection limit were not included in the historical data evaluated for use.

- Data assessment qualifiers previously placed on the data were noted and applied as appropriate.

- A result was considered to be a nondetect if it was qualified by the reporting laboratory with a “U” qualifier or a “<” qualifier.

- A result was considered a nondetect if it has a “U” validation code or a “U” data assessment code.

- Historical data that are no longer representative of the current site conditions being evaluated were excluded (e.g., where site conditions were changed substantially as a result of remedial activities).

- Historical practical quantitation limits were compared to current screening levels to evaluate the usability of the data in the current context and the reliability of conclusions about presence or absence of contaminants.

- Historical analyses derived from an on-site laboratory were not included in historical data evaluated when analyses for duplicate samples were available from a fixed-base laboratory.

6.1 SITE OPERATIONS THAT COULD HAVE RELEASED VOCS

Operations at C-400 began in 1952. Cleaning metal parts and equipment with degreasing solvents (primarily TCE) was one of the principal operations performed in the building and resulted in releases of VOCs inside and outside the building.

6.1.1 TCE Releases Inside C-400

Historically, some of the primary activities associated with C-400 have included cleaning machinery parts. Degreasing solvents were used on metallic items that were contaminated with oil and grease. Due to the efficient cleaning abilities of TCE, it reportedly was used throughout C-400 and at a variety of locations across the plant (MMES 1995). Originally there were three vapor degreasers that used industrial grade TCE as the solvent. After degreasing was complete, the cleaned item was shifted to the side of the degreasing unit and excess solvents were allowed to drain into a collection basin connected to the degreaser. The item then was placed either on the floor next to the degreasers or into one of the cleaning tanks. Items placed on the floor may have been returned directly to service or cleaned in the spray booth (large items) or on the hand tables (small items). Floor drains were located throughout the building to direct spills and overflow into interior and exterior sumps or directly into storm sewer lines.

Each of the degreasers was equipped with a spray hose that could be used to direct a stream of TCE at difficult to clean areas on items within the degreaser or to fill containers (5-gal buckets) used in remote cleaning operations. The TCE tank loading facility was equipped with a hose that also could be used to fill small containers (drums).

Average usages of TCE in C-400 over the decades of plant operation are shown in Table 2.

Table 2. Average Rate of TCE Consumption in the C-400 Cleaning Building by Decade (CH2M HILL 1992)

Decade	TCE Use at the C-400 Cleaning Building
1960s	500 to 2,000 gal/month
1970s	> 15,000 gal/month
1980s	1,000 to 2,000 gal/month
1990s	600 to 700 gal/month

Areas of C-400 where historical TCE leaks and spills are known or suspected may include all areas of the building especially (1) degreaser and cleaning tank pits (see Figure 3); (2) drains and sewers (see Figure 6); (3) the east side basement (see Figure 3); (4) tanks and sumps outside the building (see Section 4.2), including underground piping running from tanks (see Figure 6); and (5) various first-floor processes (see Figure 3). These sources have resulted in the development of a source zone comprised of VOCs (primarily TCE and its breakdown products) at the C-400 area.

For an undetermined period of time, 1,1,1-trichloroethane (TCA) was used as a solvent for at least some of the degreasing activities. Commercial 1,1,1-TCA is stabilized with 1,4-dioxane and may have also contained impurities such as 1,1,2-TCA. Thus, there is a potential for 1,1,1-TCA, 1,1,2-TCA, 1,4-dioxane and TCA breakdown products to pose a VI threat. When discussing the historical releases of solvents from the C-400 Building, the statements concerning TCE should be considered as referring to 1,1,1-TCA also.

Vapor degreaser solvent use was discontinued at C-400 on July 1, 1993, and the identified TCE sources within C-400 were addressed. There is some potential for historically TCE-contaminated flooring (concrete) to be a current source of vapors; and other historical TCE releases from leaks in the floor drains and piping may remain under the floor slab where they have the potential to contribute to vapor sources in the interior of the building.

6.1.2 TCE Releases to the Vicinity of C-400

Historical operations released TCE DNAPL to the subsurface, which contaminated UCRS soils and RGA groundwater in the vicinity of C-400, as shown in Figures 1 and 2. To address TCE-contaminated soils located outside C-400, DOE performed a treatability study of ERH near the southeast corner of the building in 2003 to determine its applicability at PGDP as a remedial approach to remove TCE contamination from soil and groundwater. The treatability study results supported development of the record of decision (DOE 2005).

DOE implemented ERH between 2008 and 2010 to address TCE soil contamination east and near the southwest corner of C-400 in Phase I of the IRA and approximately 535 gal of VOCs (primarily TCE) were removed from the subsurface during Phase I. In Phase IIa, ERH was used to address TCE contamination in the UCRS and the upper RGA in the southeast area treatment area, which contained a larger amount of source contamination. Phase IIa operations were completed in fall of 2014 and approximately 1,137 gal of VOCs (primarily TCE) were removed from the subsurface. However, residual TCE remains in soil at concentrations ranging up to ~10,000 μg/kg in the vicinity of C-400 and has the potential to migrate as vapor into the building. The residual soil concentrations are discussed further in Section 6.5.1.2.

6.2 CHEMICALS OF INTEREST

As noted above, large volumes of TCE were used in historical operations at the site, and releases of TCE inside and outside of C-400 have contaminated site media. The VOCs of interest are TCE; its breakdown products (*cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, and vinyl chloride); and 1,1-dichloroethene. As part of the VISL calculator, EPA has not assigned inhalation toxicity values for *cis*-1,2-dichloroethene and *trans*-1,2-dichloroethene; thus, these chemicals do not have VISLs. EPA has provided provisional values to use on this project as listed in Table 1.

Degradation pathways for TCE are well understood [see Figure 5 (Figure 12.3.1 from Morrison et al. 2006), http://announce.exponent.com/practice/environmental/ef/morrison_murphy.pdf]. TCE degrades faster in a reducing environment to DCE isomers and then DCE degrades in a reducing environment to VC. However, as shown in the figure, once DCE or VC is present, it may degrade at significant rates via either a reductive or oxidative path. At PGDP, the Regional Gravel Aquifer is not a reducing environment; thus, TCE will tend to persist in the RGA, but DCE and VC typically will be degraded via the oxidizing environment present there.

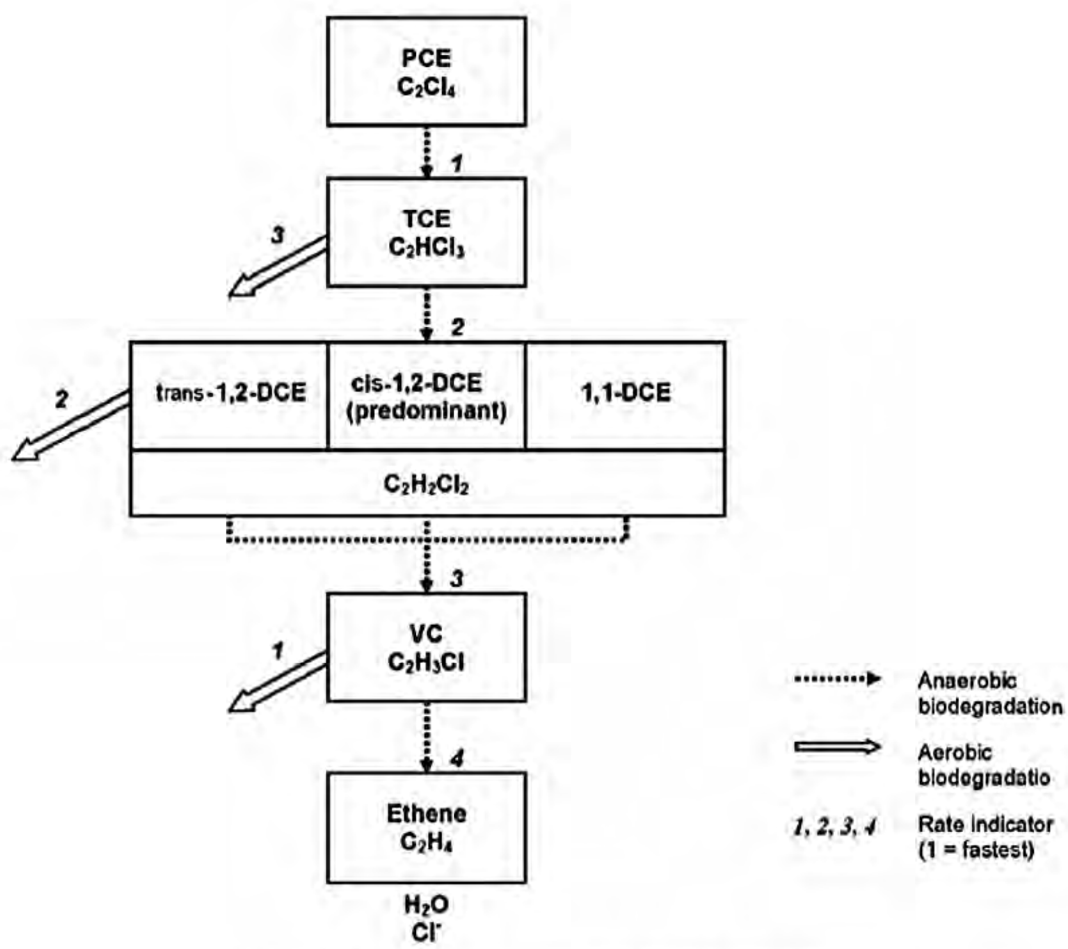


Figure 12.3.1 Degradation pathways for PCE and TCE.

(Morrison et al. 2006)

Figure 5. Degradation Pathways for TCE

There is evidence that 1,1,1-TCA was used in the building; thus, TCA and a common TCA-stabilizer, 1,4-dioxane, are included in the list of contaminants of interest. In addition, TCA degradation products and impurities not identified above are also included as chemicals of interest, including 1,1-dichloroethane and 1,2-dichloroethane. Please see Table 1 for the list of chemicals of interest and associated VISLs.

TCA degradation also is well understood [see Figure 6 (Figure 12.3.2 from Morrison et al. 2006), http://announce.exponent.com/practice/environmental/ef/morrison_murphy.pdf] and occurs much more rapidly in the environment than TCE degradation. TCA degradation products also degrade rapidly. Often, the only evidence of TCA migration to the environment is the detection of the presence of 1,4-dioxane. 1,4-dioxane is miscible with water and thus provides an essentially unattenuated plume front indicator of historical TCA contamination. However, its miscibility also allows effective transport downward and away from the source via a groundwater pathway.

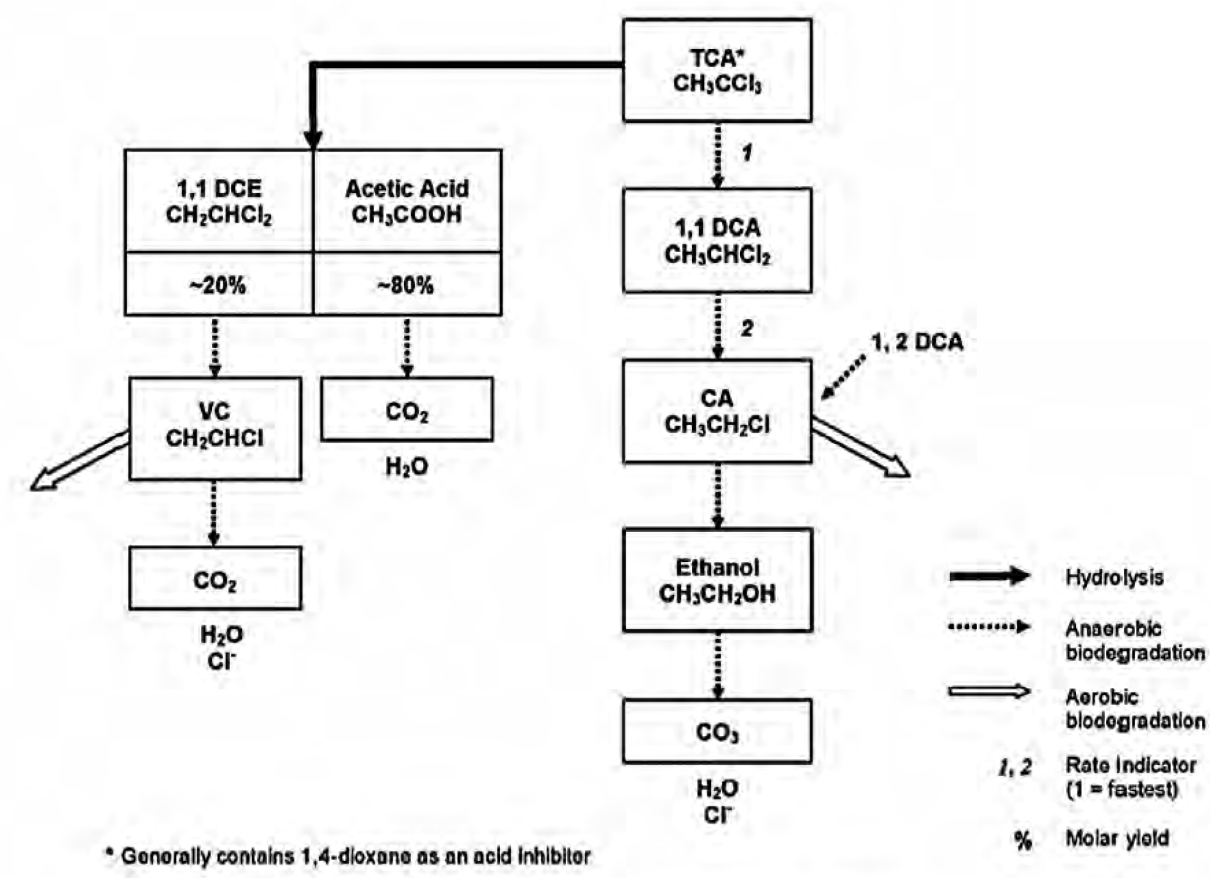


Figure 12.3.2 Degradation pathways for 1,1,1-TCA.

(Morrison et al. 2006)

Figure 6. Degradation Pathways for TCA

6.3 LAND AND FACILITY USE

Current and reasonably foreseeable future land uses at and adjacent to PGDP are industrial for areas located primarily inside the security fence, industrial or recreational for areas located outside the security fence, and residential for areas beyond the DOE property (DOE 2005). This land use determination was made after consideration of (1) existing lease agreements, (2) the nature of contamination currently present at the facility, and (3) stakeholder input. Data used to determine land uses were obtained through a land use survey performed in 1995 and future land use public workshops conducted in 1994 and 1995. Additionally, the subject has been discussed with a number of organizations, including city and county officials and the Citizens Advisory Board.

The Kentucky Research Consortium for Energy and Environment worked with federal, commonwealth, and local government representatives and community stakeholders to complete a risk-based end state vision for the site, *The PGDP Future Vision Project*, in 2011 (KRCEE 2011). The process included structured public involvement and technology integration. This end state vision informs DOE of current community preferences for future use of the PGDP site.

TCE and other VOCs in soil and groundwater originate in an area where current and expected future land use is industrial. There are no current exposures to on-site groundwater by nonremediation workers or the general public because of existing on-site restrictions and controls (e.g., the current excavation/penetration permit program). A Land Use Control Implementation Plan (DOE 2008) identifies specific controls and mechanisms to ensure four objectives:

1. Maintain the integrity of any current or future remedial or monitoring system;

2. Prohibit the development and use of the C-400 area for residential housing, elementary and secondary schools, child care facilities, and playgrounds;

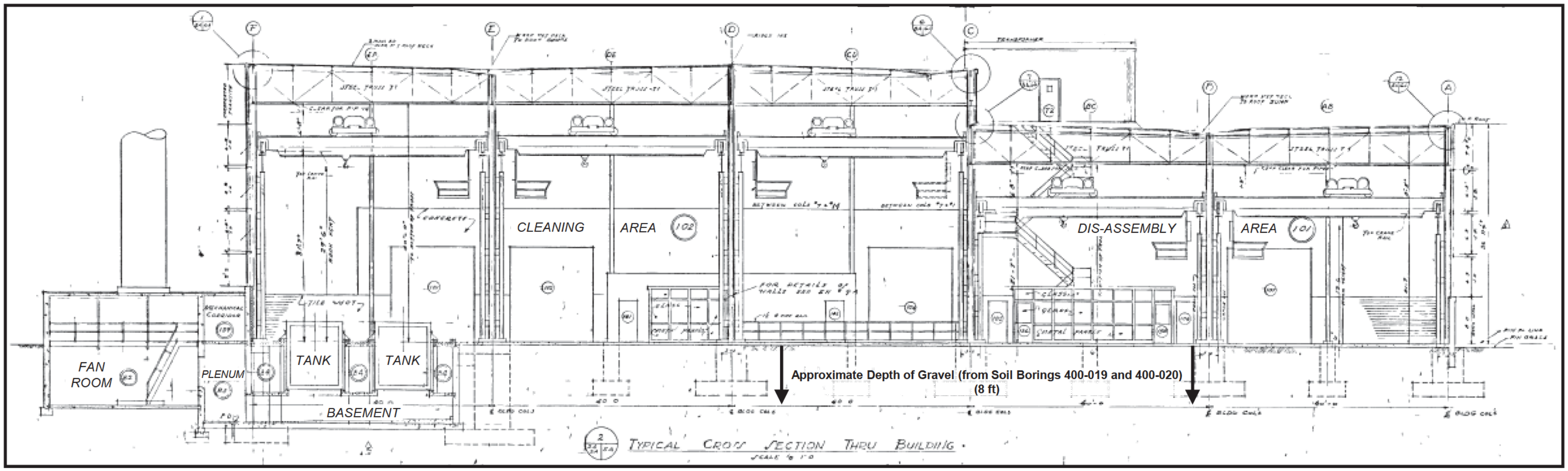
3. Prevent exposure of current and future on-site industrial workers to groundwater/soils and prevent use of the groundwater at the C-400 area through institutional controls (e.g., access controls, Excavation/Penetration Permits Program) and through deed restrictions; and

4. Provide notice in property records regarding contamination and response actions at the C-400 area.

There is a potential for TCE vapors from subsurface (and potentially indoor) sources to impact indoor air in C-400; therefore, both the remediation workers currently deactivating the building in anticipation of eventual demolition and nonremediation workers working in the building may come in contact with these vapors.

6.4 C-400 CLEANING BUILDING CHARACTERISTICS

Figure 3 presents the layout of the building with approximate locations of building features. C-400 rests on a 16-inch, on grade concrete slab in most areas, although there are four pits/sumps and an east-side basement area that are up to 15 to 20 ft below grade. Figure 7 shows a typical cross section through C-400. Construction photographs and soil boring logs suggest that the building floor overlies approximately 10 ft of gravel backfill. The east-side basement includes a plenum and fan room system to ventilate the building. Within the east-side fan room, two fans were connected to each of five stacks for a total of ten fans. All of the fans were of similar design and capacity. Currently, two of the ten fans are operational. At least one ventilation fan currently operates continuously to ventilate the building. The fans that are not in use have been removed and their stacks have been capped.



EAST

WEST

0 ft 50 ft 100 ft

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Figure 7. Cross Section through C-400 Building

Figure 8 shows many buried utilities service C-400, including sanitary water lines, return circulating water lines, storm sewers, sanitary sewers, and electrical lines and ducts. Floor drains found throughout the building have been sealed with epoxy (or equivalently closed) to prevent further releases from the building. These floor drains previously emptied into interior and exterior building sumps or directly into storm sewer lines. Sumps for wastewater treatment and disposal were located northeast (C-403 Neutralization Pit) and northwest (waste discard sump) of C-400.

Historical IH sampling and analysis of indoor air in C-400 (2003) is summarized in Table A.1 of Appendix A. The IH sampling has generally resulted in no detectable TCE or vinyl chloride, although two indoor air samples collected in 2003 in the C-400 basement as part of the ERH Treatability Study (DOE 2004) had TCE concentrations 900 and 5,000 times higher than the commercial TCE VISL screening level of 3 μg/m^3 (0.56 ppbv) [although the levels were below the American Conference of Governmental Industrial Hygienists (ACGIH) value of 50 ppm]. These samples were considered to have originated from seep water in a sump associated with an abandoned TCE storage tank located in the C-400 basement and not from other indoor sources. This sump (SWMU 98) remains and had been noted to contain water only once, and the source was unknown. The sump bottom is located approximately 7 ft to 12 ft above the water table. TCE concentrations in subsequent IH samples, including IH samples collected in 2015, were below detection (at a detection limit of ~500 ppbv). Because the IH detection limits for TCE are greater than EPA's commercial TCE VISL value of 3 μg/m^3 (0.56 ppbv), it is not known if indoor air concentrations in C-400 currently exceed the TCE VISL value.

Recent walkthroughs of C-400 indicate the integrity of the floor slab appears to be generally good, but did identify deteriorated concrete in the central west portion of the building that may serve as a conduit to subsurface vapors. Due to the size (approximately 144,000 ft^2) and complexity of C-400, identifying the specific locations of other potential VI conduits is not practicable. Instead, DOE assumes that both a subsurface source of TCE and preferential pathways for VI exist at C-400, and, for risk assessment and risk management purposes, assumes that any measured indoor air exceedances of the TCE VISL value are attributable to VI.

6.5 POTENTIAL SOURCES OF CHEMICALS OF INTEREST

The 1997 WAG 6 RI identified areas of soil and groundwater contaminated with VOCs, primarily TCE, outside of C-400. Similar levels of contamination, as discussed in the previous section, may be present beneath the building. Soil sampling conducted in 1997 at two locations beneath the building, 400-019 and 400-020, documented the presence of TCE in vadose zone soils at concentrations ranging up to 130 μg/kg.

6.5.1 Subsurface Sources

As described in Section 5, leaks and spills from past operations at PGDP have affected soil and groundwater at the site with TCE as both dissolved-phase contamination and DNAPL at locations through the UCRS and down to the base of the RGA. This section presents analytical data documenting the presence of TCE in subsurface media adjacent to and under C-400 with the potential to pose an unacceptable risk to human health via the VI pathway.

6.5.1.1 Groundwater

In the C-400 area, groundwater is encountered at approximately 30 to 35 ft bgs in the UCRS. The sands and gravels of the RGA are encountered at about 50 ft bgs. The sands and gravels of the RGA are highly permeable, and groundwater velocity is thought to be on the order of 0.1 to 0.3 ft per day around C-400.

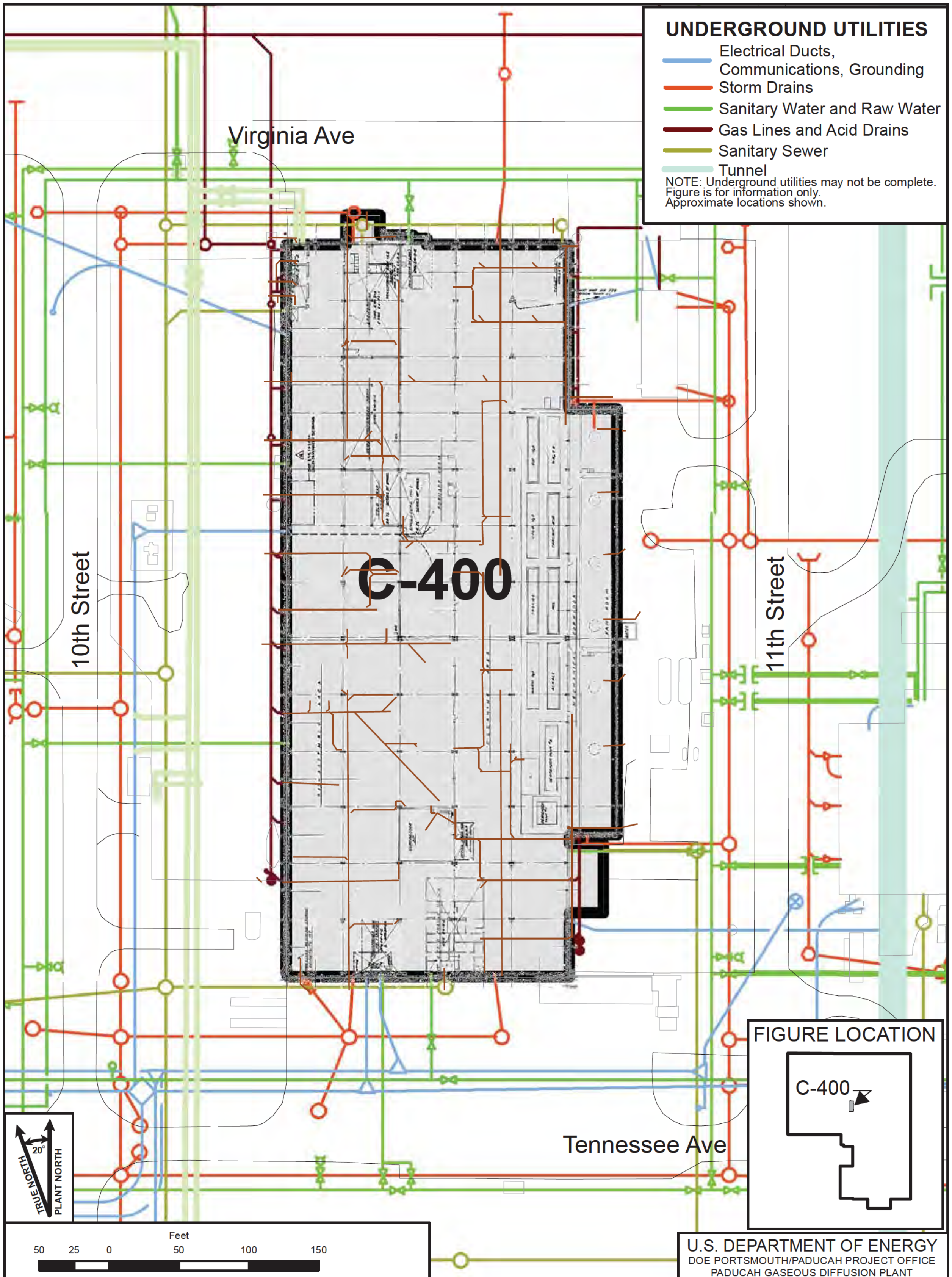

Figure 8. Underground Utilities near C-400

Groundwater flow in the RGA is generally to the north. Figure 9 illustrates the hydrogeology of the C-400 area.

The RGA TCE Plume concentrations are evaluated sitewide every two years and summarized as updates to the site plume maps. Dissolved TCE trends in the vicinity of C-400 continue to indicate the presence of DNAPL in the RGA below the building (i.e., dissolved concentrations in some wells are greater than 1% of TCE's aqueous solubility or approximately 13,000 µg/L.) The most recent plume map [calendar year 2014 (DOE 2015a)] is shown in Figure 10. Appendix A contains a compilation of the groundwater results collected over the past 10 years from wells located in the vicinity of C-400.

Upper and middle RGA wells nearest C-400 include MW156; MW178; and the upper sampled ports of wells MW406, MW407, MW408, MW421, MW422, MW423, MW424, and MW425. TCE concentrations for these wells from the latest round of sampling (2014) are tabulated in Appendix A. TCE Plume concentrations underlying the northwest corner of C-400 currently are higher than concentrations toward the southeast corner, but previously, the reverse was the case. All concentrations are substantially higher than the commercial groundwater TCE VISL of 7.4 µg/L. In the southeast area of C-400 (i.e., the upgradient end), TCE concentrations have been shown to be decreasing. For example, TCE concentrations in MW156 have decreased from previous levels of 56,500 µg/L to 925 µg/L in 2014. Similarly, concentrations in MW408-PRT5 and MW405-PRT5 have decreased from 2012 highs of 1,400,000 µg/L (MW408-PRT5) and 97,000 µg/L (MW405-PRT5) to values of 37.6 and 481 µg/L, respectively, in 2014. Concentrations in monitoring wells near the northwest corner of C-400 (i.e., the downgradient end) still exhibit high levels, generally above 10,000 µg/L. For example, the TCE concentration in MW421-PRT3 was 62,800 µg/L in 2014. These levels are several thousand times higher than the groundwater TCE VISL of 7.4 µg/L.

These data support the conclusion that TCE is present in groundwater surrounding and potentially below C-400 at aqueous concentrations with the potential to result in TCE soil vapor concentrations under C-400 that are likely to exceed EPA's soil gas TCE VISL of 100 $\mu g/m^3$.

6.5.1.2 Vadose zone

In the C-400 area, the vadose zone generally is comprised of fine-grained sediments (mostly silt and fine sand) of the UCRS, which overlies the RGA (Figure 9). Locally, however, at the south end of C-400, more intervals of sand and gravelly sand are noted (Figure 11). These sandy zones would be more amenable to vapor migration. The UCRS at C-400 is typically unsaturated for approximately the first 35 ft bgs.

Historical TCE contamination in unremediated UCRS soils adjacent to the southern end of C-400 initially exceeded 1,000,000 µg/kg and was interpreted to exceed 100,000 µg/kg under the southeast end of the building (Figure 2). These soil concentrations in the areas surrounding the building have been reduced by 95% to 99% through Phase I (DOE 2011) and Phase IIa of the ERH IRA (DOE 2015b), but residual TCE remains in the soil. Concentrations in the east and southwest remediated areas average 29 µg/kg and 15 µg/kg, respectively, with maximums of 315 µg/kg and 228 µg/kg, respectively. In the southeast remediated area, TCE soil concentrations average 225 µg/kg with a maximum of ~ 10,100 µg/kg. These levels exceed EPA's VISL of 7.4 µg/L for groundwater. The TCE concentrations remaining in soil after the Phase I and Phase IIa IRAs are summarized in Appendix A.

Historical sampling of sub-slab soil from two borings completed within the footprint of the building was conducted as part of the WAG 6 RI (DOE 1997). A total of 18 sub-slab soil samples was collected at regular depth intervals of 4 to 8 ft down to 48 ft. Analytical results from these samples are presented in Table 3. Of the 18 samples collected, 16 samples had detectable TCE concentrations, ranging from 1.6 to

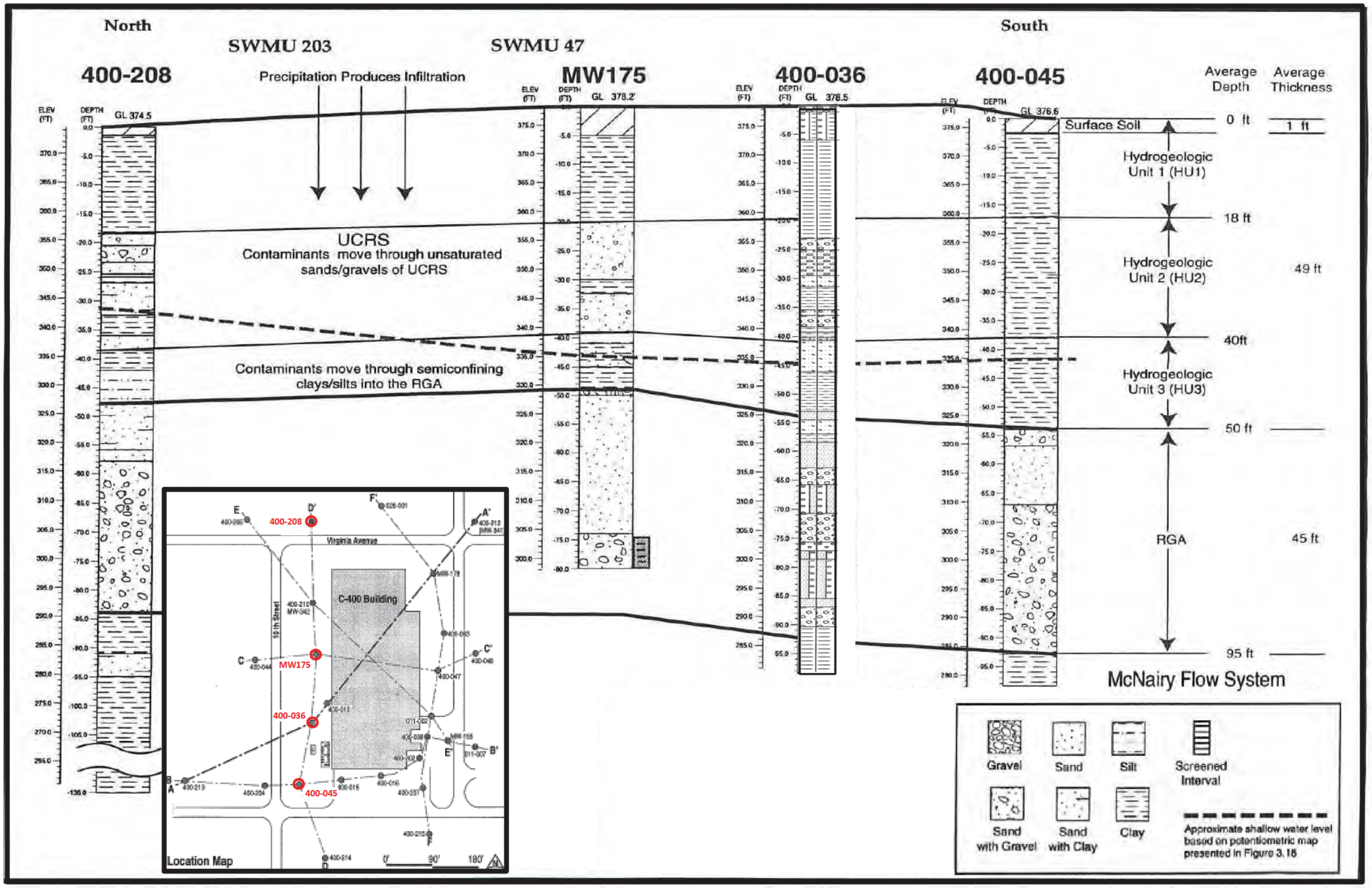

Figure 9. C-400 Area Hydrogeology (DOE 1999)

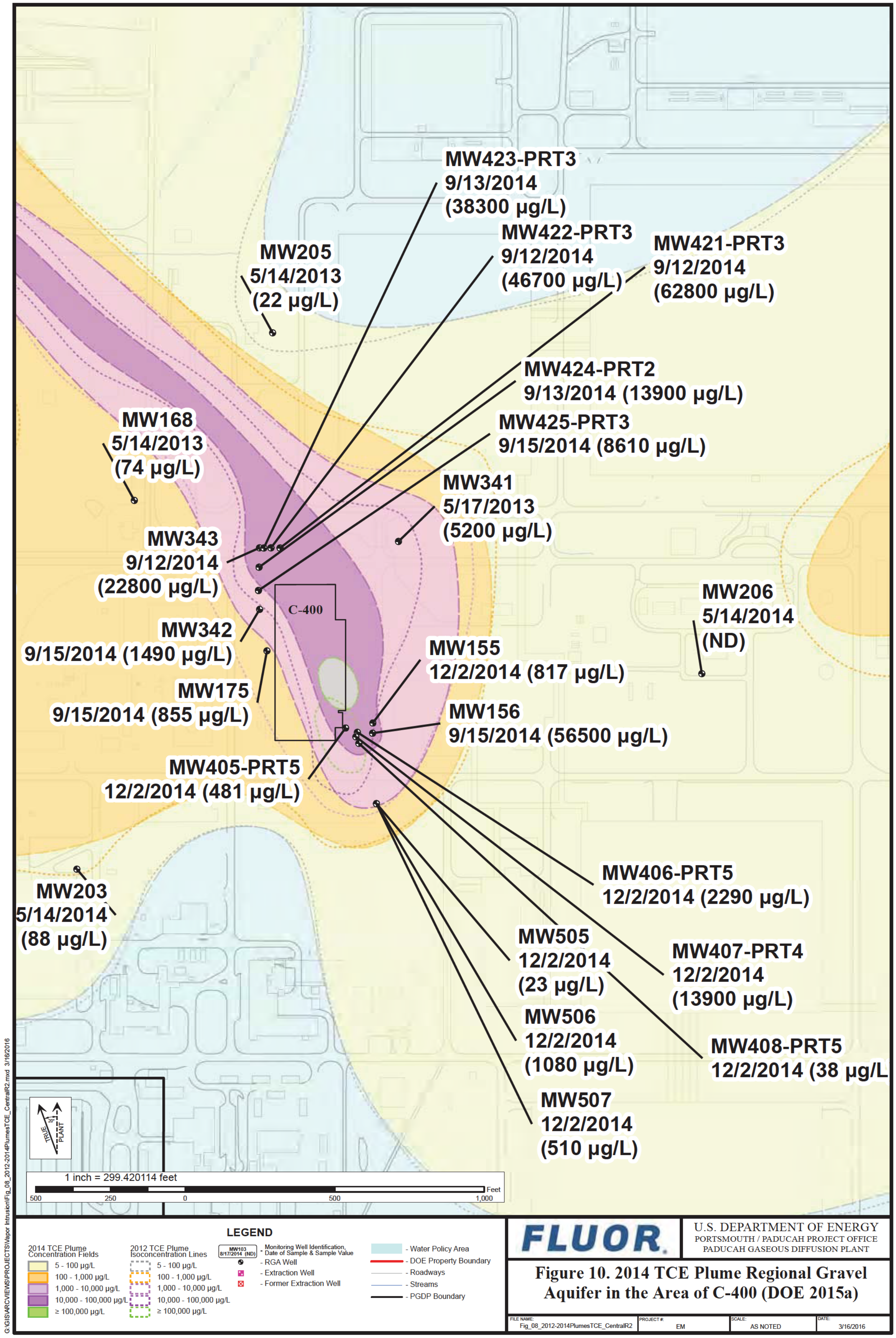

Figure 10. 2014 TCE Plume Regional Gravel Aquifer in the Area of C-400 (DOE 2015a)

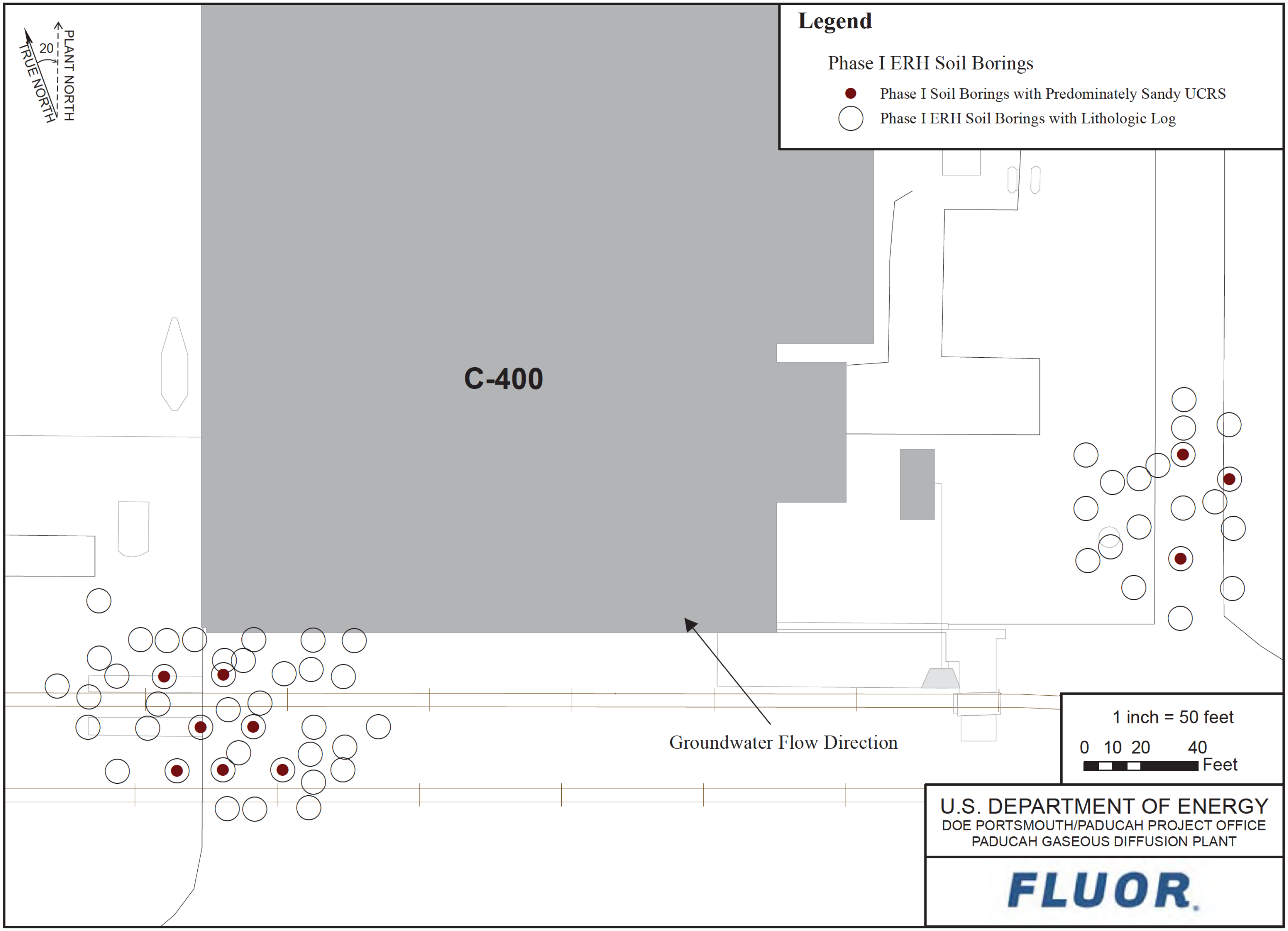

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Figure 11. Location of Phase I ERH Soil Borings with Predominately Sandy UCRS

Table 3. Waste Area Grouping 6 Remedial Investigation Volatile Organic Compound Analyses of Sub-Slab Soil Samples

STATION	Depth (ft)	TCE (µg/kg)	*cis*-1,2-DCE (µg/kg)	*trans*-1,2-DCE (µg/kg)	1,1-DCE (µg/kg)
400-019	0–4	1.6	< 6	< 6	< 6
400-019	8–12	11	< 6	< 6	< 6
400-019	16–20	6.3	< 5	< 5	< 5
400-019	24–28	13	< 6	< 6	< 6
400-019	28–32	< 5	< 5	< 5	< 5
400-019	32–36	7.1	< 6	< 6	< 6
400-019	36–40	< 5	< 5	< 5	< 5
400-019	40–44	< 6	< 6	< 6	< 6
400-020	0–4	< 6	< 6	< 6	< 6
400-020	8–12	17	< 6	< 6	< 6
400-020	16–20	130	< 6	< 6	< 6
400-020	16–20 (duplicate)	75	< 6	< 6	< 6
400-020	20–24	5.6	< 5	< 5	< 5
400-020	28–32	70	< 6	< 6	< 6
400-020	32–36	34	< 6	< 6	< 6
400-020	36–40	28	< 5	< 5	< 5
400-020	40–44	42	< 6	< 6	< 6
400-020	44–48	53	< 6	< 6	< 6

DCE = dichloroethene

130 µg/kg with a median of 22.5 µg/kg. These data are considerably older than the post-remediation data described above, but nevertheless provide insight as to the extent of contamination around and under C-400 (in the vadose zone) because the soils directly under the building have not been subjected to remedial activities.

The EPA VI Guide (EPA 2015) generally recommends against using soil concentrations for VI assessment, because of the likelihood of VOC losses during sampling and analysis, but notes that soil samples are useful for delineating soil source areas with the potential to pose a VI concern. EPA summarizes the challenges in soil sampling and analysis for VI screening of soil and discusses appropriate uses of soil data for VI assessment, which include using soil data to delineate sources (2014b). The report provides bulk soil concentrations corresponding to the target VISL levels for sub-slab soil gas. For TCE, the target soil level for residential settings is 0.02 µg/kg; the equivalent value for commercial settings is approximately 6 times higher or 0.12 µg/kg. The measured residual TCE concentrations in the remediated soil adjacent to C-400 (described above) are orders of magnitude higher than the target commercial TCE soil concentration (~ 0.1 µg/kg) corresponding to the commercial sub-slab VISL of 100 µg/m^3. Therefore, vapor concentrations associated with the residual TCE in the remediated soils as well as the TCE in soils under C-400 are likely to have been (and continue to be) many orders of magnitude higher than the commercial TCE sub-slab VISL of 100 µg/m^3. VOC losses upon soil sampling, the primary concern noted by EPA regarding the use of soil data for VI assessment, would simply mean the soil concentrations and associated soil vapor concentrations were actually higher.

These data support the conclusion that soil vapor concentrations adjacent to and directly under the C-400 floor slab are likely to be higher than the sub-slab TCE VISL value of 100 µg/m^3. The presence of approximately 10 ft of gravel fill under the slab is expected to allow the transport and accumulation of these vapors under the floor slab, under at least a portion of the footprint of the building. It should be noted that, while the 10-ft gravel layer thickness is based upon two vertical borings where the gravel thickness ranges from 8–12 ft, it is possible that the gravel thickness will vary and, as a result, there is some uncertainty associated with the variability of the gravel thickness.

The WAG 6 RI also included collection of exterior soil gas samples, but soil air permeabilities were so low that most soil samples reportedly were compromised by ambient air that leaked through joints in the aboveground drill pipe. Under these types of conditions, the primary route of vapor migration is likely to be along preferential conduits, such as utility lines. Of the 145 attempted samples, 10 (9 of which are on the south side of C-400) contained detectable TCE concentrations that were considered to represent some contribution from soil gas. The detected TCE soil gas concentrations from the south side of C-400 ranged from 1.5 to 1,678 μg/L (1,678,000 $\mu g/m^3$) with a median of 4.9 μg/L (4,900 $\mu g/m^3$). These values support the conclusion derived above, based on soil sampling, that vapor concentrations arising from TCE contamination under and adjacent to C-400 are orders of magnitude greater than the commercial TCE sub-slab VISL of 100 $\mu g/m^3$.

There are several lines of evidence that point to the likely continued presence of TCE in the soil under and adjacent to C-400 at levels that exceed VI screening values. Prior to remediation (by the ERH IRA), some of the UCRS soils were interpreted to contain DNAPL, with derived DNAPL saturations up to 4%. Additionally, membrane interface probe logs of historical area soil borings suggested that zones of DNAPL saturation were present. It is possible these zones extended under the building (and outside the remediated areas) as interpreted in Figure 2. The ERH IRA removed approximately 3,500 gal of VOCs from the UCRS and upper RGA soils exterior to the building and reduced soil concentrations, but residual soil concentrations still are higher than bulk soil concentrations corresponding to the target VISL levels for sub-slab soil gas (EPA 2014b). In addition, ERH was not implemented below the building.

Additionally, leaks from building drains and sewers are known to have contaminated utility trenches and adjacent soils in the vicinity of C-400, as directly evidenced by the SWMU 11 (TCE Leak Site). Other utilities lines and bedding material around the drain pipes leading from the floor drains or other utilities entering or leaving the building have not been investigated because of the presence of building equipment and infrastructure and uncertainties in utility locations (leading to operations and health risks). Given the lines of evidence described above, it is reasonable to conclude that TCE is present under C-400 in the UCRS soil, utility lines (and their bedding materials), and the gravel layer under the C-400 slab at concentrations sufficient to generate soil vapor concentrations higher than the commercial TCE sub-slab VISL of 100 $\mu g/m^3$.

6.5.2 Potential Indoor Sources

As described above, historical operations associated with C-400 resulted in TCE leaks and spills in areas such as the degreaser and cleaning tank pits, drains and sewers, and tanks and sumps outside the building, including underground piping running from tanks. Although the historical operations were terminated and the identified source areas were closed in 1993, potential indoor sources of TCE may remain in the building, such as TCE in concrete that may continue to off-gas. Additionally, there may have been other sources not identified at the time operations ceased. Nevertheless, DOE considers VI from subsurface sources of TCE under and adjacent to the building likely to be the primary source of any TCE detected in indoor air, because the subsurface sources have totaled thousands of gal of TCE and residual TCE contamination has been documented to be present, and the indoor source areas have been closed and have been subject to the ongoing building ventilation since 1993.

6.5.3 Summary of Potential Vapor Sources and Migration Pathways

The VI CSM uses site-specific information collected during characterization studies and IRAs to describe the nature, location, spatial extent of the vapor sources in the subsurface, as well as the uses (including those that could have the potential to serve as indoor vapor sources), occupancy, and construction of C-400. The VI CSM also portrays the hydrologic, hydrogeologic, and geologic setting and its influence on vapor migration and attenuation in the vadose zone.

As described above, TCE contaminated groundwater and soil adjacent to and under C-400 are considered potential sources of vapors that may impact C-400. Subsurface conditions in the C-400 area are considered to allow vapor transport toward the building. Although RGA concentrations in the vicinity of C-400 have decreased, groundwater concentrations still exceed EPA's groundwater VISLs. Similarly, remedial actions have achieved greater than 95% reduction in soil concentrations, but post remedial residual concentrations still exceed levels considered capable of generating soil gas concentrations above EPA's soil gas VISLs. Vapor concentrations associated with the remaining TCE contamination in groundwater and soil are expected to be many orders of magnitude higher than the commercial soil gas and sub-slab TCE VISL screening level of 100 $\mu g/m^3$ and, therefore, have the potential to pose an unacceptable health risk to workers in C-400.

Vapor migration from subsurface groundwater and soil sources through the vadose zone is promoted by the presence of sand in the UCRS in the vicinity of C-400, as well as the presence of gravel immediately beneath the building. The large number of utilities present in the vicinity of the building also may serve as preferential pathways for vapor migration. The presence of deteriorated concrete in the building slab and other potential, but unidentified VI conduits may provide potential pathways for vapor migration into the building.

The building includes an exhaust system (plenum with fans) constructed to induce intake of fresh air into the building and exhaust building air from C-400 to limit the potential for worker exposure to vapors. At least one fan continues to operate. The plenum is designed to enable air flow downward through the floor from the main portion of the building and exhaust it through the stack. The plenum also will induce flow of soil gas through conduits or other potential pathways and exhaust this induced flow. The work plan investigation is designed to determine whether the plenum exhaust system is sufficient to control VI in C-400, irrespective of which of the potential sources and conduits may be contributing vapors to the C-400 indoor air.

6.5.4 Evaluation of VI Pathway Completeness

As described earlier in Section 5, EPA's VI Guide states that a potential VI pathway should be considered complete when the following five key conditions are present:

1. A subsurface source of vapor-forming chemicals exists;
2. There is a route for the vapors to migrate;
3. The building is susceptible to VI;
4. Vapors are present in the indoor environment; and
5. People are in the indoor environment.

The VI CSM documents the presence of sources of TCE immediately under and adjacent to C-400 in the form of dissolved-phase groundwater contamination and residual or adsorbed TCE in soil. Additionally, leaks from building drains and sewers are known to have historically contaminated utility trenches and adjacent soils with TCE DNAPL. TCE concentrations in groundwater underlying C-400 exceed the groundwater screening levels for TCE in EPA's VISL calculator (EPA 2016). The post-remediation, residual TCE concentrations in soil adjacent to the building and those measured under the building are at levels sufficient to yield soil vapor concentrations exceeding the sub-slab VISLs. Where TCE DNAPL may be present (e.g., in abandoned drain lines and utility bedding material) under C-400 due to past practices, the associated vapor concentrations are expected to be greater (by orders of magnitude) than the sub-slab VISLs.

Known subsurface conditions, including the presence of sandy material in the vadose zone and gravel under the slab, favor vapor migration. There are no impediments (e.g., no laterally continuous clay layers) considered to inhibit vapor transport between the sources and the building sufficient to limit the intrusion to below VISL levels. The presence of deteriorated concrete flooring in the building and potentially unidentified VI conduits in the building may provide pathways for vapor migration into the building. DOE, therefore, considers that vapors may be migrating from the documented source materials under and adjacent to C-400 and through the sand and gravel into the building.

Openings exist in the building's foundation—openings such as perimeter cracks, stress relief seams, and perforations for utility conduits and structural supports—that could serve as a pathway for vapor entry into the building. Additionally, DOE has noted cracking in the basement area slabs, though the degree to which vapor migrates through cracks in the 16-inch slab is unknown.

These factors have led DOE to conclude that four of EPA's (2015) five conditions regarding completeness of the VI pathway are present and documented with site-specific data, which are (1) subsurface sources of vapor are present in soil and groundwater underneath or near C-400; (2) routes exist for vapor transport to the underside of C-400 and vapor sources are immediately adjacent to the building slab; (3) C-400 is susceptible to VI; and (4) the building had been occupied by nonremediation workers.

Indoor air sampling is needed to evaluate the remaining condition regarding completeness of the VI pathway (i.e., one or more of the chemicals in the sub-slab soil gas also are present in the indoor environment and, if present, pose an unacceptable health risk). DOE considers addressing this data gap to be the appropriate next step for a VI investigation. This approach is supported by EPA's 2015 VI Guide, which states that "if reliable pre-existing sampling data are available and an adequate CSM has been developed (i.e., sufficient subsurface characterization information exists to adequately characterize the locations, forms, and extent of site-specific vapor-forming chemicals and general subsurface conditions (e.g., hydrologic and geologic setting in and around the source(s) and the buildings)), then a risk-based screening may be useful to obtain some preliminary insights about the potential level of exposure and risk posed by vapor intrusion."

The following sections describe the types of samples to be collected and their locations and rationale (Section 7); the sampling methodology (Section 8); the approach for evaluating the sampling results (Section 9); and the Investigation Decision Rules (Section 10).

7. SAMPLING LOCATIONS AND RATIONALE

Historical sampling adjacent to and below C-400 indicates VOC contamination (primarily TCE) is present and vapor concentrations under the building likely exceed subsurface screening levels by orders of magnitude. Other major compounds of interest are 1,1,1-TCA, a solvent used in degreasing, and 1,4-dioxane, a stabilizing agent for 1,1,1-TCA.

A TCA impurity (1,1,2-TCA) and degradation products of TCE and 1,1,1-TCA potentially are present, including: 1,1-dichloroethene, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethane, and 1,1,2-TCA. Inspection of C-400 has identified the presence of deteriorated concrete flooring as well as cracking in basement areas that suggest there is the potential for vapor migration through the floors.

The goal of this SAP is to collect samples to determine whether the VI pathway is complete and presents unacceptable risks to humans in C-400. To that end, indoor air samples will be collected in areas believed to be susceptible to VI, along with sub-slab samples at some of the same locations and ambient air samples. The results will be used to determine if building occupants are exposed to contaminants of interest at levels of concern. Those levels will depend, in part, on the amount of time individuals spend in the building and are exposed to the vapors. Sub-slab vapor samples and outdoor air samples will be collected concurrently with indoor air samples to assist with interpreting the indoor air results, monitoring the difference between sub-slab vapors and indoor air vapors, evaluating the degree of vapor intrusion, and supporting other C-400 investigations.

This VI investigation will sample at eight indoor and four outdoor locations, as shown on Figure 12 and Figure 13, during each of three scenarios described below. Photos of the vicinity of the planned sample locations are provided in Appendix D, and photos will be taken of the sampling locations during the sampling events and included in the report. Seven of the eight indoor locations will have sub-slab vapor samples collected concurrently. SUMMA® canister samples will be collected as 10-hour composite samples during normal work hours to mirror the exposure duration of a typical worker.

The following three scenarios were selected based upon the possible working conditions now and in the expected future. Each scenario will be maintained for 24 hours prior to initiation of sampling. In no particular order, the three scenarios selected for sampling are as follows:

1. Exhaust fan on and large bay doors open
2. Exhaust fan on and large bay doors closed
3. Exhaust fan off and large bay doors closed

Locations 1–7, as shown on Figure 12, will have indoor air samples collected during each of the three scenarios and will have the temperature and differential pressure (relative to ambient outdoor air) measured in the vicinity of the SUMMA®, six times per each sampling event (i.e., start of the sampling event, end of sampling event, and every two hours during sampling).

Locations 1–7, as shown on Figure 12, will have sub-slab vapor samples collected at the same locations during each of the three scenarios and will have a pressure differential measured (split manometer) between the sub-slab and the indoor atmosphere six times per each sampling event (i.e., start of the sampling event, end of sampling event, and every two hours during sampling). The slab thickness will be measured and recorded at each sub-slab location.

The objective of the sub-slab vapor samples is to monitor the difference between sub-slab vapor concentrations and indoor air concentrations of the selected VOCs to support an estimation of degree of attenuation/vapor intrusion through the building floor. Collection of sub-slab samples was chosen, in part, because these data are expected to support other C-400 investigations.

Location 8, as shown on Figure 12, is the location of the operable fan exhaust sample. A port will be installed on the exhaust side of the operating fan and an air sample will be collected during each of the three scenarios and will have the differential pressure (relative to ambient outdoor air) and temperature measured six times per each sampling event (i.e., start of the sampling event, end of sampling event, and every two hours during sampling). Other differential pressure measurements (e.g., relative to indoor air at the intake of ductwork) may be collected.

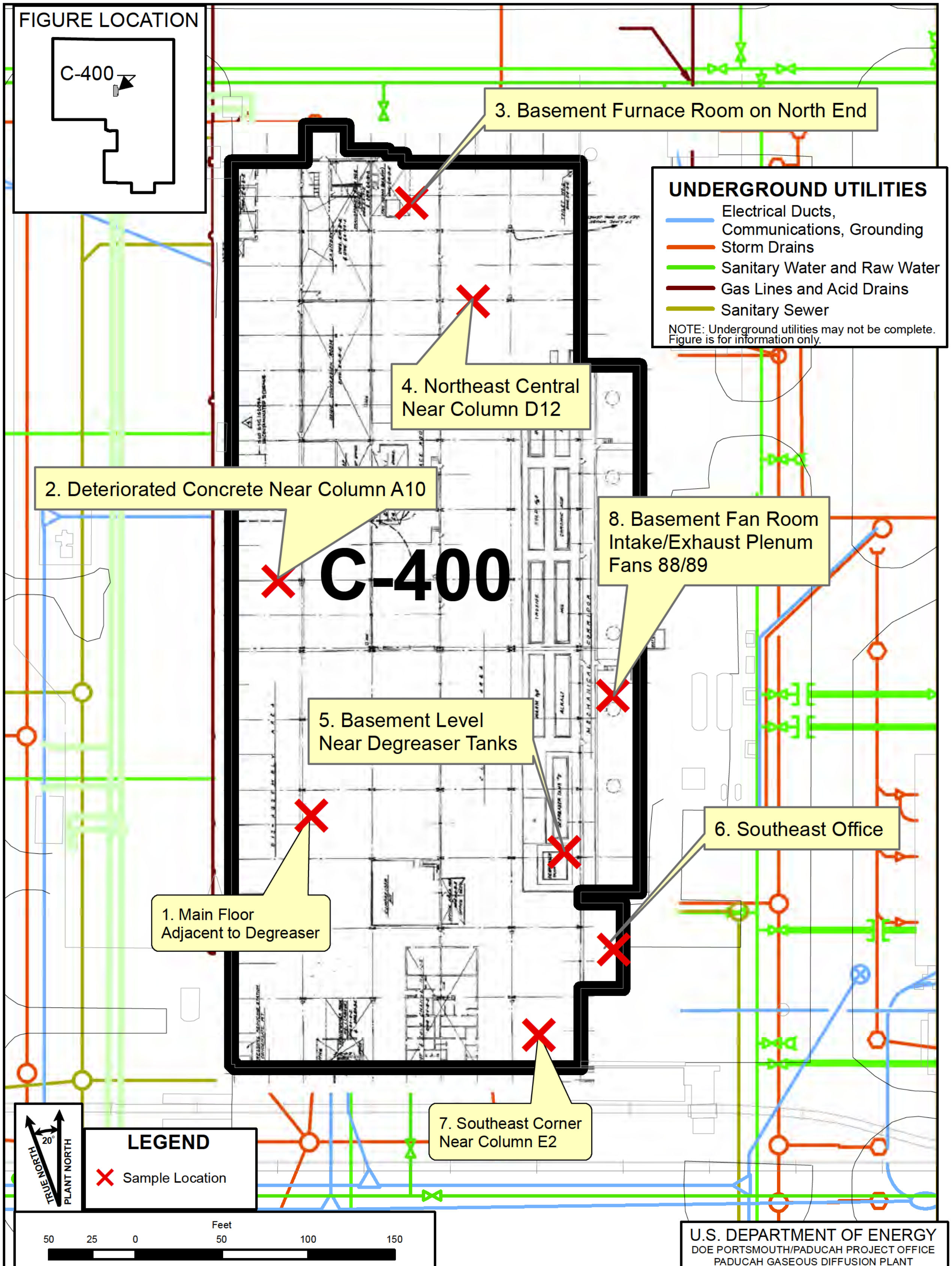

Figure 12. Indoor Sampling Locations for C-400 Building Vapor Intrusion Study

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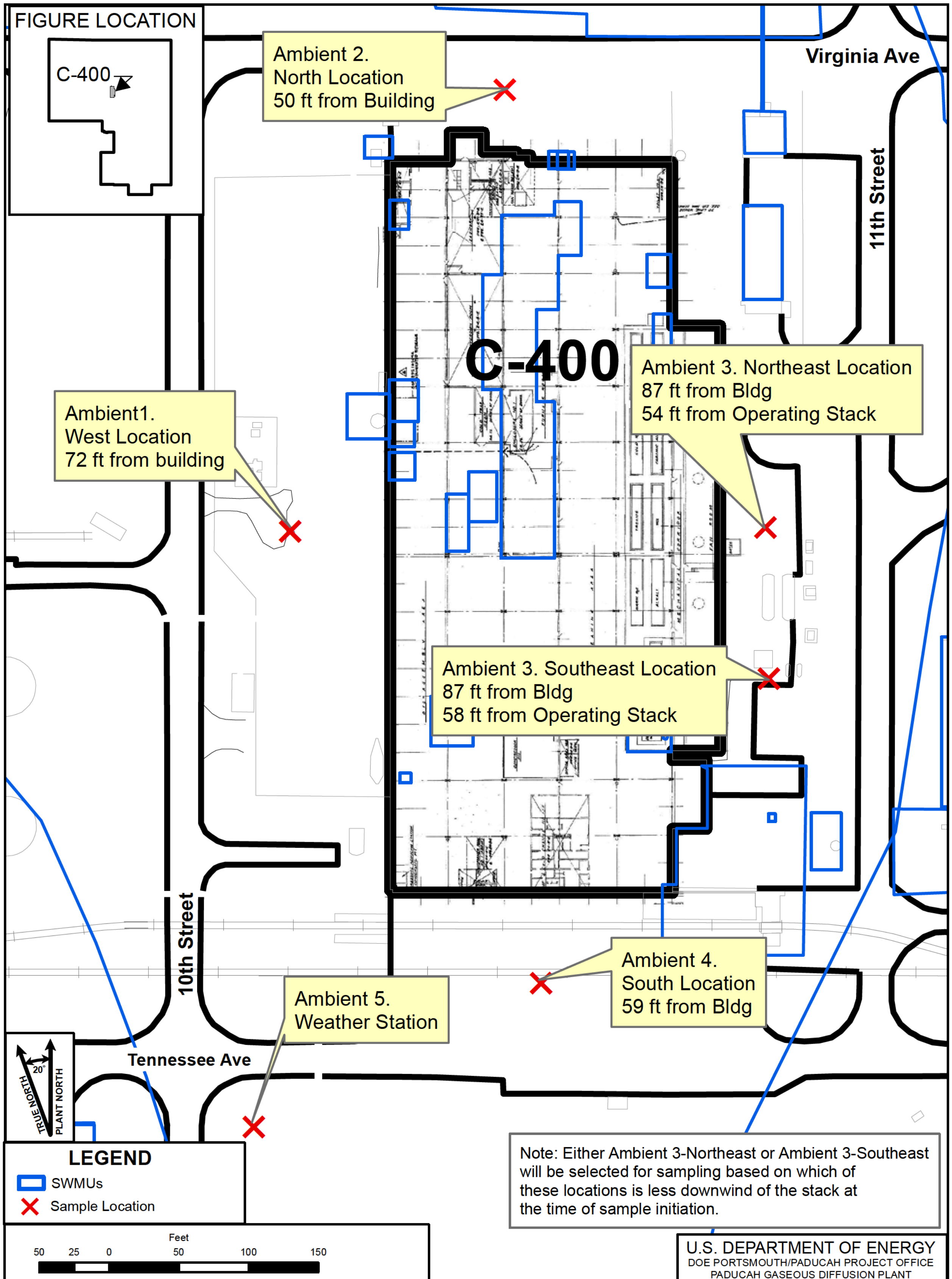

Figure 13. C-400 Map
(with Approximate Ambient Sampling Locations)

G:\GIS\ARCVIEWS\PROJECTS\Vapor Intrusion\MOA 400\Figure 13. C-400 Ambient Sampling Locations.mxd
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During each of the three scenarios, outdoor ambient air samples will be collected at four locations (Locations Ambient 1–Ambient 4 on Figure 13) which are located within 50 ft to 100 ft of the building. These samples will be used to differentiate outdoor air contributions to concentrations in indoor air. These locations were walked down on April 20, 2017, and selected to avoid external SWMUs, dumpsters, roads, construction, or other items that may influence the sampling results. One of the two locations on the east side will be selected depending on the wind direction on the day of sampling to minimize the potential for impacts on ambient concentrations due to the location of the operating fan stack. Therefore, either Ambient 3-Northeast or Ambient 3-Southeast will be selected for sampling based on which of these locations is less downwind of the stack at the time of sample initiation. The sampling team will document the rationale for the selected location on the day of each sampling event. Figure 14 provides locations of SWMUs located in and around C-400. Based on the wind rose (Figure 15) for Barkley Airport, Paducah, Kentucky, the prevailing winds come from the southwest.

A weather station, location Ambient 5 as shown on Figure 13, will be located outside of the C-400 Building to record the barometric pressure, wind direction and speed, relative humidity, along with temperature every two hours for a total of six readings during the sampling period of ten hours. (i.e., start of the sampling event, end of sampling event, and every two hours during sampling). Additionally, weather reporting data from the weather station located at the Paducah airport (i.e., official weather data) will also be included in the project's report with a focus on wind direction to supplement on-site wind direction determination.

Sampling and measurements, unless otherwise specified, will be conducted in the "breathing zone," which is assumed to be at 5–6 ft above ground surface.

The SUMMA® samplers will be protected in such a way as to ensure the safety/integrity of the device. SUMMA® samplers may have particulate filters and may be mounted inverted (at outdoor locations) so as to minimize the potential for rain to be collected. Sampling will not be attempted during inclement weather (e.g., when there is a sustained wind speed of 25 mph or greater, thunderstorms, lightning, or other weather conditions considered unsafe for personnel or may affect the integrity of the samples).

Table 4 summarizes the rationale and number of samples for each of the sampling locations.

The sample locations in the interior of C-400 (Figure 12) include locations that are near historical sources (basement area near the former large TCE degreaser/cleaning tanks and central main floor near the hand table) or areas of higher potential for VI (basement/plenum exhaust, basement near the former large TCE degreaser/cleaning tanks, and north basement furnace room).

C-400 currently is ventilated with one of two available fans (~ 41,000 cfm design) located in a basement room in which proposed indoor air samples are located. The fans draw air through a below grade concrete plenum that is a potential entry point for VI. Comparison of the concentrations obtained from the exhaust fan samples will be compared to the other concentrations to determine if the plenum or other areas serve as points of vapor entry.

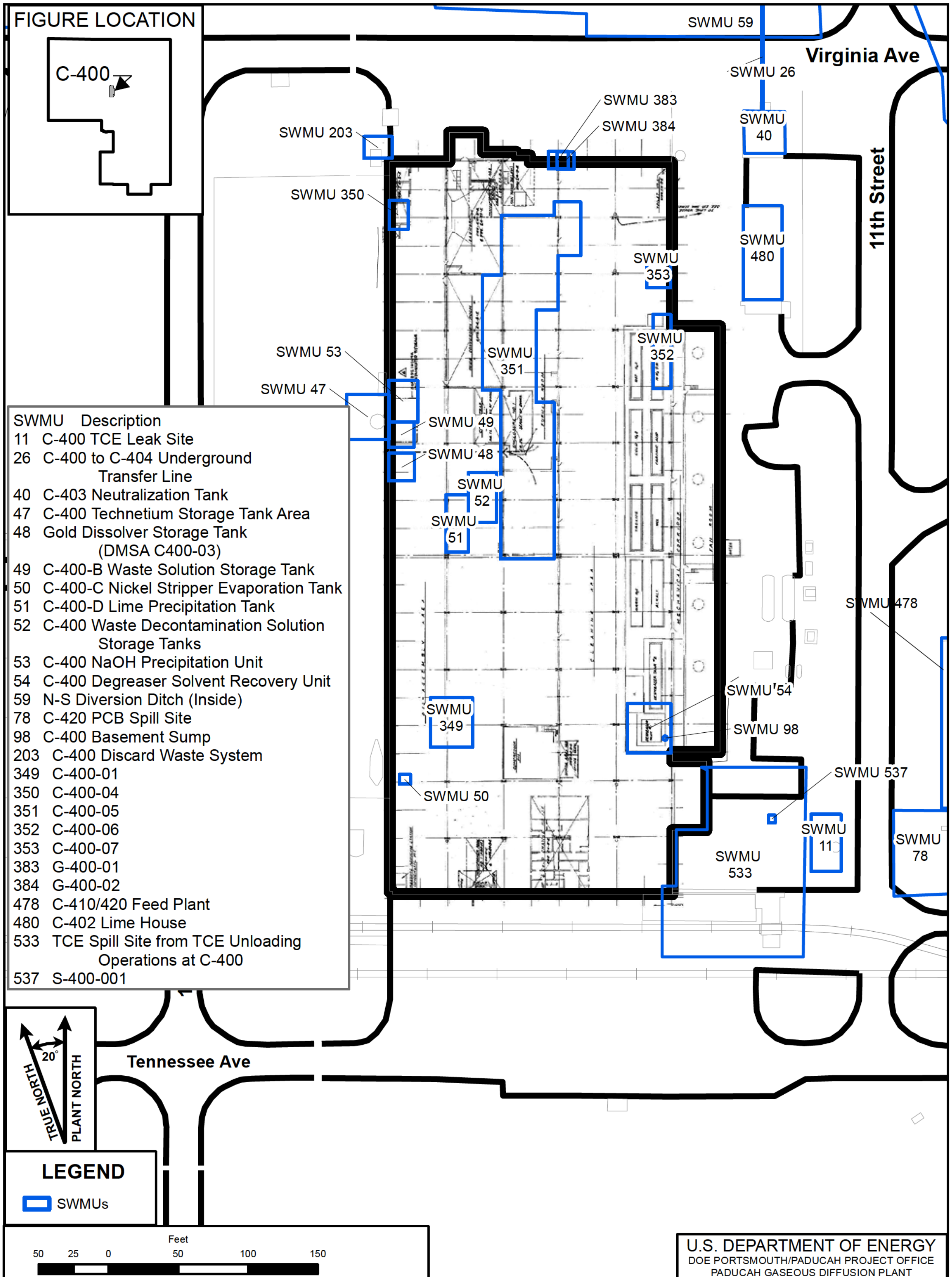

**Figure 14. C-400 Map
(with SWMU Locations in and around C-400)**

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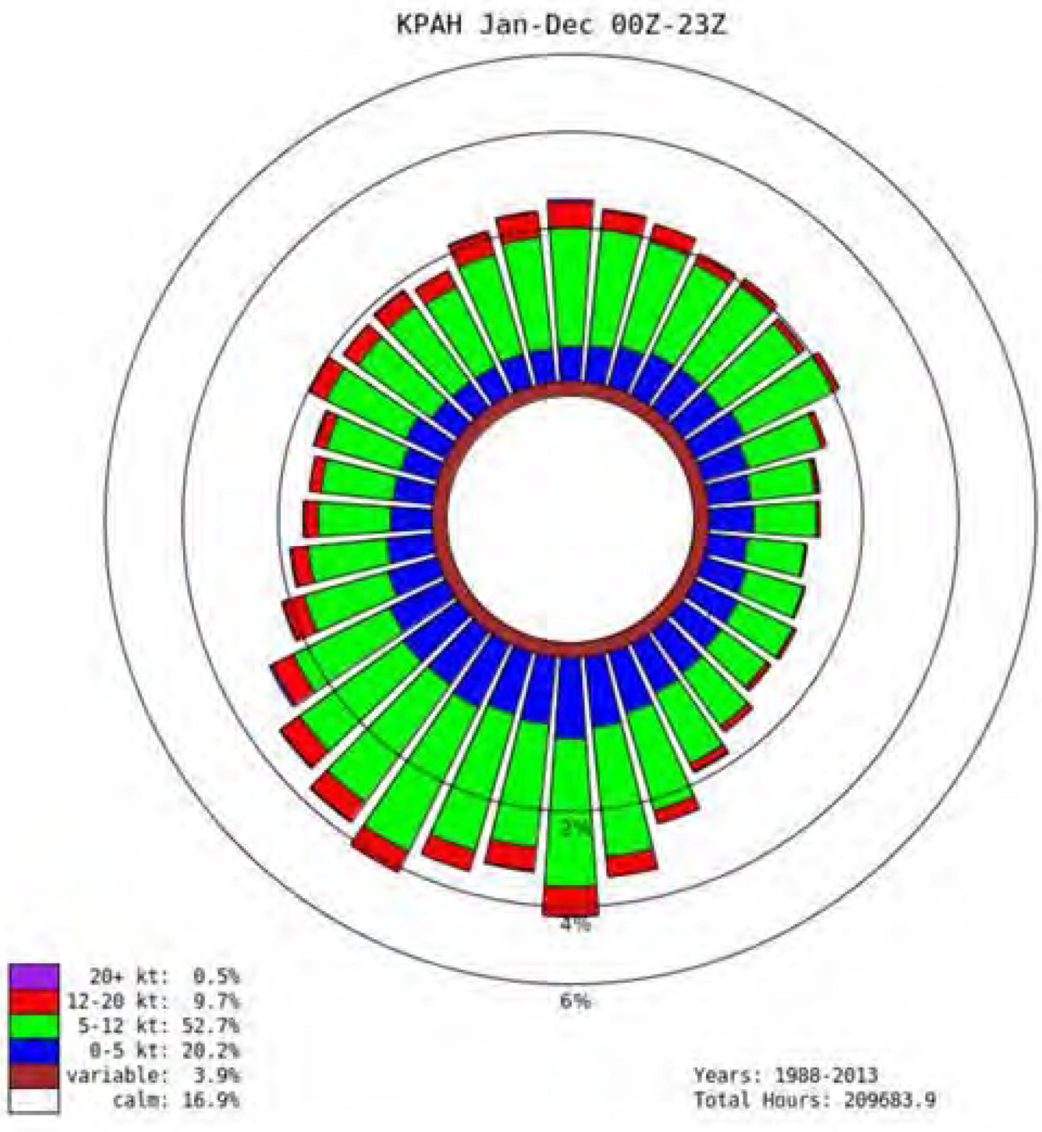

Figure 15. Wind Rose for the Barkley Airport, Paducah, Kentucky

Table 4. Proposed Locations and Rationale for VI Sampling

Sample Location Number	Number of Samples	Sample Location	Rationale
1	3 indoor air 3 sub-slab	Main Floor Adjacent to Degreaser	Located near former degreaser and hand tables, near Column B4.
2	3 indoor air 3 sub-slab	Deteriorated Concrete near Column A10	Deteriorated concrete flooring, Potential VI conduit. Samples will be collected 25–50 ft from the wall.
3	3 indoor air 3 sub-slab	Basement Furnace Room on North End	Located in a basement area with surface cracks in the concrete and an old sump.
4	3 indoor air 3 sub-slab	Northeast Central Near Column D12	General work area, which is open to mixture from all sources.
5	3 indoor air 3 sub-slab 3 replicates	Basement Level Near Degreaser Tanks	Located in vicinity of former large degreaser, water/solvent separator, cleanout operations, and cleaning tanks; potential indoor air source and/or VI entry point; lower elevations have potential to collect heavier-than-air vapors. Samples will be collected in the corridor next to the degreaser tank.
6	3 indoor air 3 sub-slab 3 replicates	Southeast Office	Previously occupied office area on main floor. This area currently is not utilized as office space.
7	3 indoor air 3 sub-slab	Southeast Corner Near Column E2	Located over the general area of suspected highest concentrations in groundwater and therefore greatest chance of vapor. Samples are to be collected within 10 ft of Column E2 to avoid influence from the exterior doors.
8	3 intake/exhaust air	Basement Fan Room Intake/Exhaust Plenum Fans 88/89	Fan intake air represents spatially averaged C-400 air. May be biased high by induced VI into the plenum. **No sub-slab sampling at this location.**
Ambient 1	3 outdoor ambient air	West Location, 72 ft west of building	Located in the west central area of the building and located outside of building influence.
Ambient 2	3 outdoor ambient air	North Location, 50 ft north of building	Located in the north central area of the building and located outside of building influence.
Ambient 3-North **OR** Ambient 3-South	3 outdoor ambient air	Ambient 3-Northeast Location, 87 ft east of building, 54 ft north of operating stack **OR** Ambient 3-Southeast Location, 87 ft east of building, 58 ft south of operating stack	Either Ambient 3-North **OR** Ambient 3-South will be selected for sampling based upon ambient air conditions of the day of sampling for each of the three scenarios.
Ambient 4	3 outdoor ambient air	South Location, 59 ft south of building	Located in the south central area of the building and located outside of building influence.
Ambient 5	N/A	Weather Station	Nominally upwind and away from influence of C-400.

8. SAMPLING AND ANALYSIS METHODS

This sampling was designed to understand the range of current indoor air concentrations and potential pathways of vapor intrusion into C-400. Sampling will be conducted in accordance with Fluor Federal Services, Inc., Paducah Deactivation Project procedure CP4-ER-1035, *Vapor Sampling*, as described therein.

- Individually certified-clean, evacuated 6 L SUMMA® canisters (or equivalent), equipped to collect time-integrated samples for 10 hours will be deployed at each sample location. These samples will be outfitted with particulate filters. Protection will be employed for SUMMA® canisters during sampling to ensure safety/integrity of the device.

- Samplers will be placed at the approximate breathing zone for area type samples, which is assumed to be at 5–6 ft above ground surface.

- Samplers will be placed to collect exhaust air of the operating fan to secure an integrated air sample expected to be representative of whole building air.

- Samplers will be connected to subsurface sample ports.

- The canister valves will be opened and initial sample time noted for each sampler.

- After 10 hours, the valve will be shut, the time and remaining vacuum noted, and the canister packaged for shipping to the laboratory under chain of custody.

- The laboratory will analyze the samples using EPA TO-15 methods with a practical quantitation limit, as identified in the quality assurance project plan (QAPP), preferably a value less than the commercial VISL screening levels.

- The VOCs of concern for this study are TCE, 1,1,1-TCA, and selected other compounds, including 1,1-dichloroethene, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,2-TCA, vinyl chloride, and 1,4-dioxane.

Prior to sampling, the sample locations will be confirmed; the operation of the fan will be confirmed; and the building ventilation conditions will be confirmed (i.e., each scenario will be maintained for 24 hours prior to initiation of sampling).

9. RESULTS EVALUATION

The VI pathway sampling to be conducted in C-400 (described in Section 7) includes indoor and outdoor air samples along with concurrent sub-slab vapor samples. These samples will be analyzed for TCE and other selected VOCs. The concentrations of VOCs in the indoor air samples will be compared against EPA's indoor air VISLs for default commercial scenarios (See Table 1). The outdoor air sample results will be used to evaluate potential outdoor air source contributions to indoor air, but the measured concentrations will not be subtracted from the indoor air results. EPA maintains a Web-based VISL calculator[2] (EPA 2016), which was last updated in 2016. The results of these comparisons will be

[2] https://semspub.epa.gov/src/document/11/196702

evaluated in the context of the site-specific VI-CSM to develop conclusions about VI impacts to C-400 using the decision rules described in Section 10.

The results will also be compared to other benchmarks if the VI pathway is determined to be complete. As described in a recent Strategic Environmental Research and Development Program-Environmental Security Technology Certification Program VI seminar (SERDP-ESTCP 2016), a number of commercial/industrial screening levels are available for TCE (Figure 16), including those intended for industrial hygiene applications such as Occupational Safety and Health Administration permissible exposure limits (PELs) of 537,000 $\mu g/m^3$ and the ACGIH threshold limit value of 54,000 $\mu g/m^3$. EPA's commercial indoor air VISL of 3.0 $\mu g/m^3$ is the same as EPA's commercial regional screening level of 3.0 $\mu g/m^3$. Both are based on default commercial worker exposure conditions and correspond to a 1×10^{-6} carcinogenic risk (for a 25-year exposure duration, 250 days per year exposure frequency, and 8 hour per day exposure time) which is less than the level corresponding to a hazard quotient of 1.0. Under differing site-specific conditions, where workers may be subject to different exposure durations, other target levels may be applicable. EPA's toxicity values and the CERCLA risk range will be used to make risk evaluation and risk management decisions using the data generated from this approved Work Plan.

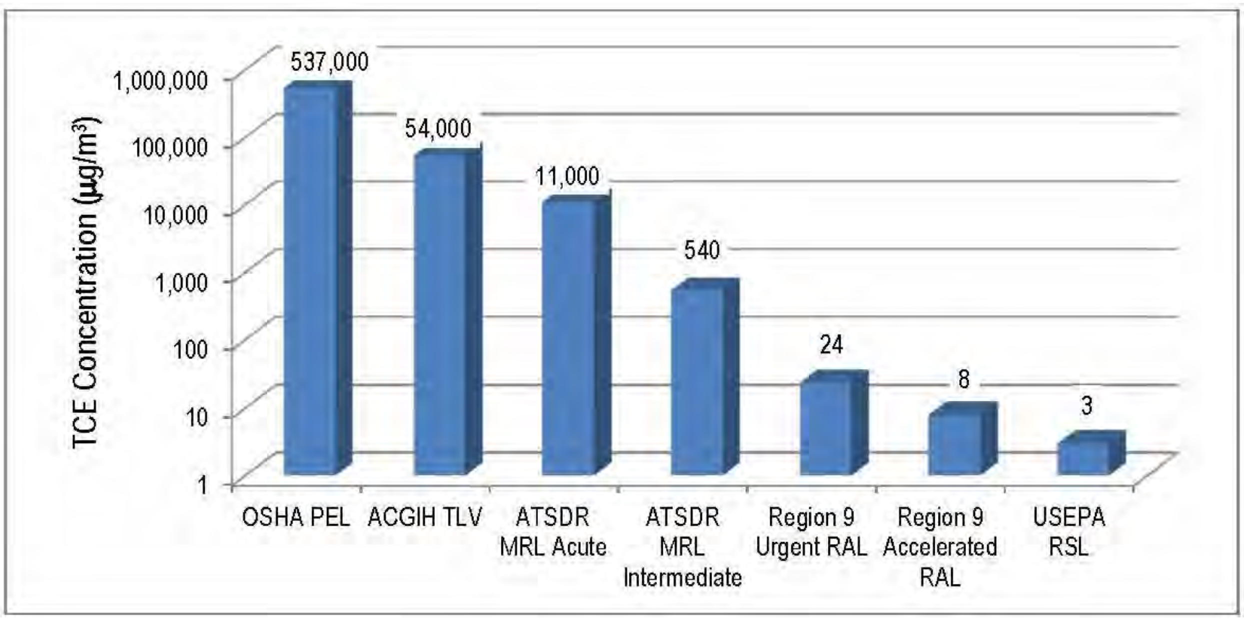

Figure 16. TCE Regulatory Levels for Commercial Industrial Scenarios (SERDP-ESTCP 2016) (Note: EPA RSL = EPA VISL for commercial settings)

10. INVESTIGATION DECISION RULES

The results of the indoor air monitoring will be evaluated to develop conclusions about the impact of VI on the indoor air of C-400. DOE will present the results and evaluations in a report, and subsequent actions will be negotiated among the FFA parties. The evaluation will include comparing results from individual locations against those from other locations, as well as comparing individual locations against the integrated fan exhaust results. The results will be compared to EPA's VISLs for default commercial exposure scenarios and site-specific benchmarks established for the types of workers present for the exposure durations that are representative of the types of workers. This evaluation will seek to understand the range of indoor air concentrations and, to the extent practicable from these data, the general location(s) of VI entry points.

Depending on results of the evaluation, DOE may implement additional actions that could include sampling, personnel monitoring, or other response actions needed to control worker exposure, including additional ventilation, building pressurization, and/or building evacuation. A second round of data collection is contingent upon evaluation and agreement by DOE, EPA, and KDEP of the initial round of data collection and current and expected building occupancy, if necessary, to manage uncertainties in support of evaluating remedy protectiveness. Any contingent sampling to address the conclusions of this study will be negotiated among the FFA parties and are not included in this Work Plan.

The following are the decision rules that will guide the evaluations and inform the conclusions.

- **IF** sub-slab vapor concentrations for selected VOCs are less than the VISL values or nondetect, **THEN** the pathway is considered to be incomplete.

- **IF** sub-slab vapor concentrations for selected VOCs are greater than the associated VISL values and the indoor air samples for the same selected VOCs are greater than the VISL values, **THEN** the pathway is considered complete and has the potential to result in unacceptable concentrations. Site-specific exposure scenarios will be evaluated to determine whether the VOC concentrations are protective for the types of workers present in the building as well as how much occupancy can be tolerated by nonremediation workers and/or remediation workers. These results will be used to determine whether response actions are needed to control worker exposure; these response actions could include additional ventilation, personal protective equipment, building pressurization, or building evacuation.

- **IF** sub-slab concentrations for selected VOCs are greater than the associated VISL values and the indoor air concentrations for same selected VOCs are less than the associated VISL values, **THEN** the pathway is considered to be incomplete and/or to not result in unacceptable concentrations under current conditions. DOE will evaluate the planned uses for the building and may choose to continue to maintain the building in its current occupied condition, which could include continued building ventilation and periodic monitoring.

- **IF** ambient concentrations are comparable to those in indoor air samples, the above conclusions will be reevaluated to determine the degree of certainty of the relative contributions of sub-slab, indoor, and outdoor sources.

11. TAKING ACTION WITH LIMITED DATA

Interim Actions. EPA has emphasized the importance of interim actions and site stabilization to control or abate "ongoing risks" to human health and the environment while site characterization is underway or before a final remedy is selected. Interim actions encompass a wide range of institutional and physical corrective action activities and can be implemented at any time during the corrective action process. EPA VI guidance states that interim actions, including preemptive mitigation, be employed as early in the corrective action process as possible, consistent with the human health and environmental protection objectives and priorities for the site (EPA 2015).

<u>Preemptive Mitigation (PEM):</u> The EPA VI guidance (EPA 2015) states that it may be appropriate to implement mitigation of the VI pathway as an early action, even though all pertinent lines of evidence have not been developed completely yet to characterize the VI pathway for the subject building(s), when sufficient site-specific data indicate that VI: (1) is occurring or may occur due to subsurface

contamination that is being addressed by federal statutes, regulations, or guidance for environmental protection; and (2) is posing or may pose a health concern to occupants of an existing building(s).

To consider PEM, the EPA VI guidance (EPA 2015) recommends obtaining reliable data supporting a preliminary and risk-based screening. In appropriate circumstances (e.g., where time is of the essence to ensure protection of human health), a formal human health risk assessment need not be conducted and documented before selecting PEM, but a preliminary evaluation of human health risk using individual building data or aggregated community data generally is recommended.

At C-400, there are concentrations of VOCs in media located in the vicinity of the building that are high enough to yield a potential risk. Historical screening has shown sporadic indoor air detections at levels much greater than VISLs. Recent indoor air samples have not had detectable VOCs; however, the detection limits of the method are well above VISL values. Thus, a preliminary evaluation of human health risk using building data indicates the potential for VI sufficient to consider PEM. DOE has relocated all office workers and laundry workers from the C-400 Building. Remediation workers (and/or deactivation workers) currently enter the building only to conduct deactivation activities and have a health and safety plan that covers their activities.

If there are insufficient data to perform a preliminary risk analysis, but subsurface vapor sources are known to be present near buildings (see Section 5.3), EPA guidance states that an appropriate VI investigation (see Section 6) be conducted to obtain sufficient data (EPA 2015). The planned investigation is considered an appropriate investigation to fill the data gaps concerning the potential for VI at C-400.

Note that "when these conditions are not well established from existing information…EPA recommends that a detailed VI investigation be scoped and conducted to address these data gaps" (EPA 2015). The corollary is that, when conditions are well established from existing information, additional investigation should focus on the conditions that have not yet been well established.

In summary, PEM, based on limited, but credible, subsurface and building data, can be an appropriate approach to begin to implement response actions quickly and ensure protectiveness of current building occupants. In such circumstances, resources can be used appropriately to focus first on mitigation of buildings and subsurface remediation, rather than site and building characterization efforts, which may be prolonged. Although PEM may be an effective tool to reduce the human exposure and human health risk, building mitigation generally is not intended to address the subsurface vapor source; as such, EPA VI guidance (EPA 2015) states that it typically be used in conjunction with remediation of the subsurface source of vapor-forming chemicals (e.g., source removal or treatment), which has been implemented, and further remediation is planned for the C-400 area.

12. QUALITY ASSURANCE

Appendix B provides the QAPP.

13. PROJECT DOCUMENTATION

The results of this investigation will be documented in an addendum to the *Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1289&D2/R1.

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