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Memorandum

To: Steve Teel, Washington State Department of Ecology

Copies: Dave Zabrowski, Avenue 55; Scott Hooton, Port of Tacoma

From: Tom Colligan and Kristin Anderson, Floyd|Snider

Date: August 10, 2018

Project No: Ave 55-Taylor Way

Re: **Sampling Plan Addendum for Vapor Intrusion Assessment**
1544 Taylor Way, Tacoma, Washington

This sampling plan is an addendum to Appendix B of the Interim Action Work Plan (IAWP; Floyd|Snider 2017) for the Taylor Way property, which is part of the larger Taylor Way and Alexander Avenue Fill Area Site. Appendix B of the IAWP presented procedures for a methane survey and preliminary vapor intrusion (VI) assessment at the Taylor Way property. This addendum presents procedures for supplemental VI assessment based on the results from the preliminary VI assessment that was performed as described below.

BACKGROUND

The methane survey and preliminary VI assessments were performed before and during the preloading phase of construction of two above-grade warehouse buildings (Building A and Building B) at the property, between December 2016 and May 2018. Soil gas samples were collected from above the shallow groundwater table at several locations within each building footprint and along the future drive aisle between the two buildings. The vapor samples were field analyzed for methane using a landfill gas detector. At a subset of the locations, soil gas samples were collected for laboratory analysis of volatile organic compounds (VOCs). The locations of the methane and VOC samples are shown on Figure 1. The results of the methane survey and preliminary VI assessment were summarized in a memorandum (Floyd|Snider 2018). The memorandum also described the plans for the installation of a vapor mitigation system, which was installed under the future offices of each warehouse.

Methane was not detected in soil gas at either building at concentrations that necessitated further action per the IAWP. The maximum detected soil methane concentration was 1.4 percent by volume.

On the western portion of Building A, however, VOC analysis detected chloroform at a concentration exceeding the Model Toxics Control Act (MTCA) screening level for industrial worker exposure. Benzene was also detected at a concentration less than its industrial screening level but greater than the residential screening level. A number of additional VOCs were detected but at concentrations less than residential MTCA screening levels.

At Building B, VOC sampling conducted during construction was complicated by excessive moisture and perched wet lenses in the soil and pad backfill. Multiple attempts were made to acquire samples free of moisture, but were abandoned due to water in the sampling point. In the sample that was able to be collected, the laboratory reported excessive water vapor as well as excessive residual vacuum in the Summa canister that was used for sample collection. Chloroform, benzene, and other VOCs exceeded their MTCA industrial screening levels at this location; however, these data are not considered be completely reliable due to the bias caused by the presence of water vapor.

Based on the results of the preliminary assessment, which indicated a potential excessive VI risk under the future buildings, a passive vapor mitigation system was installed under each of the two office "node" locations in both buildings. The office nodes are shown on Figure 1. As described in Floyd|Snider's 2018 memorandum, the passive mitigation system includes perforated PVC piping laid in trenches under the subgrade of the office areas. The piping is connected to an above-ground riser vent. After the piping was installed, it was overlain with a PVC membrane and the concrete floor slab was subsequently poured over the membrane. The passive system allows ventilation driven by atmospheric pressure differentials (i.e., soil vapor at pressure exceeding atmospheric pressure vents via the riser so vapor pressure cannot build up below the floor slab). The vertical riser allows for the installation of an inline blower. The addition of a blower would convert the system from passive ventilation to an active system that would maintain a negative pressure under the floor slab, if needed.

PROPOSED SUPPLEMENTAL VAPOR INTRUSION ASSESSMENT

Additional VI assessment is necessary to better quantify the VI risk at the two warehouse buildings to determine if any additional mitigation actions are needed. The additional VI assessment will include the following scope of work:

- Sub-slab soil vapor sampling
- Passive ventilation system evaluation
- Data evaluation and indoor air sampling

Sampling will be conducted in accordance with VI protocols already described in the IAWP, which presents standard VI field sampling standard procedures, laboratory analytical methods, quantitation limits, and data quality objectives.

Sub-Slab Soil Vapor Sampling

Sub-slab soil vapor samples will be collected from representative locations at Building A and Building B, including in the vicinity of the prior VOC detections in soil gas and at locations immediately adjacent to the office nodes. A total of 10 permanent vapor monitoring points will be installed as shown on Figures 2 and 3. Permanent sub-slab vapor sample points will extend 6 inches below the concrete floor slab in order to collect soil vapors directly in contact with the slab; sub-slab monitoring point installation details are presented in Figure 4. Field procedures for vapor point installation and sampling that were presented in the IAWP are provided as Attachment 1 to this sampling plan addendum.

The sub-slab monitoring points will initially be sampled twice. The first event will be completed 48 hours after the monitoring points are installed. The second event will be completed after the roof has been installed and the building ventilation systems have been commissioned, which is anticipated to occur by November 2018. Samples will be analyzed by USEPA Method TO-15/TO-15 SIM for the analytes specified in IAWP.

Passive Ventilation System Evaluation

The passive mitigation system includes sub-slab perforated PVC piping designed to vent soil vapor, combined with a PVC membrane to seal the system below the concrete floor slab. Performance monitoring will be performed to assess the efficacy of the passive ventilation driven by atmospheric differentials and the PVC membrane seal.

The passive vapor mitigation systems installed under the two office “node” locations in both buildings will be evaluated by:

1. Collecting sub-slab vapor samples at the perimeter of the lining system at each office node and monitoring initial differential pressure prior to sample collection
2. Collecting a vapor sample from one vent riser at each office node
3. Collecting indoor air samples as discussed below

Passive vapor mitigation system evaluation will be performed during the second sub-slab soil vapor sampling event. During sub-slab sample collection at the locations along the perimeter of the lining system (i.e., adjacent to the office nodes), the differential pressure below the slab will be measured by connecting a handheld manometer to the sample port prior to sample collection. If sub-slab differential pressures greater than 500 Pascals (approximately 2 inches of water column pressure) are detected below the membrane, a photoionization detector (PID) will be used to perform a detailed inspection of office node areas including slab penetrations, floor drains, and any visible expansion or contraction joints or cracks in the concrete to determine if the membrane is functioning as an effective barrier.

Vent riser sampling will be performed to assess whether vapors are being vented through the risers. Samples will be collected from the sample port attached to each vent riser after purging the equivalent air volume of the riser pipe. Samples will be collected using an evacuated Summa canister and analyzed by USEPA Method TO-15/TO-15 SIM for targeted analytes that were detected in sub-slab soil vapor during the first monitoring event.

If office node indoor air sampling concentrations exceeding MTCA industrial screening levels are detected or supplemental PID inspections indicate a breach in the membrane barrier, corrective actions will be performed.

Data Evaluation and Indoor Air Sampling

Indoor air samples will be collected during the second sub-slab monitoring event described above. Indoor air samples will be collected following Washington State Department of Ecology (Ecology) VI assessment guidance (Ecology 2018) and the field procedures are presented in the IAWP. Samples collected during the second monitoring event will be analyzed by USEPA Method TO-15/TO-15 SIM for the targeted list of analytes detected in soil vapor during the first round of sub-slab sampling. Within each building, one air sample will be collected from within each office node and from within each warehouse space. A survey of materials stored and chemicals used in each building will be conducted concurrent with indoor air sample collection. An ambient air background sample will also be collected in the drive aisle between the buildings. The samples will be collected when the HVAC is not operational and all doors are closed to obtain worst-case sample results.

REPORTING

The results of additional VI assessment will be presented to Ecology in a summary memorandum, which will include the results of analytical data and concentrations predicted by modeling, compared to the applicable MTCA industrial screening levels and cleanup levels. Recommendations for additional mitigation, if determined to be necessary by the VI assessment, will also be presented in the summary memorandum.

REFERENCES

Floyd|Snider. 2017. *Interim Action Work Plan, 1514 Taylor Way Development*. Prepared for Avenue 55, LLC. June.

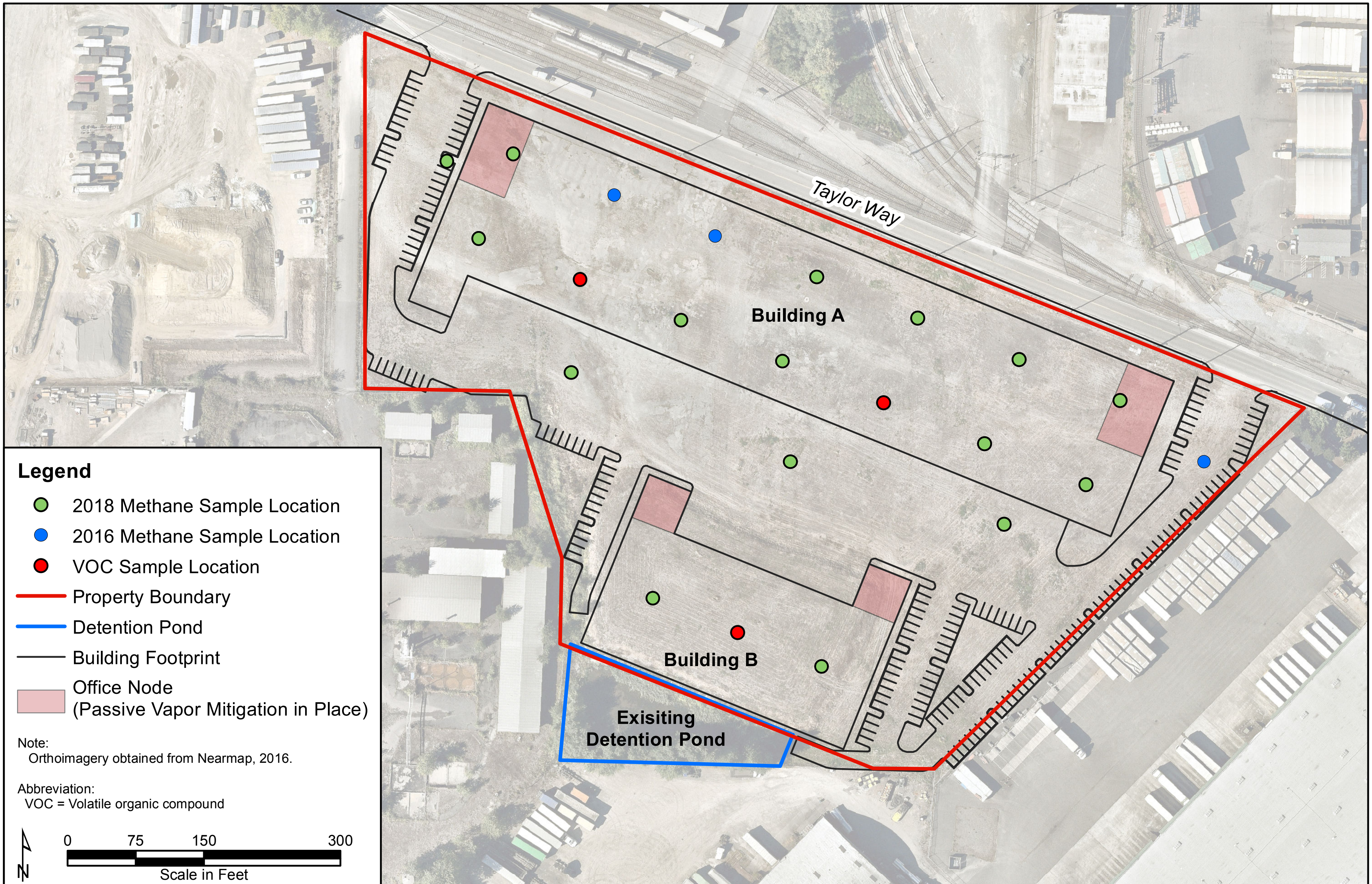
_____. 2018. *Summary of Soil Vapor Survey Data and Vapor Mitigation Plan for the 1514 Taylor Way Site*. Memorandum from Tom Colligan and Kristin Anderson, Floyd|Snider, to Steve Teel, Washington State Department of Ecology. 8 June.

Washington State Department of Ecology (Ecology). 2018. *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action*. April.

ATTACHMENTS

Figure 1	Property Features and Previous Soil Gas Sample Locations
Figure 2	Taylor Way Methane Mitigation, Pad A
Figure 3	Taylor Way Methane Mitigation, Pad B
Figure 4	Taylor Way Methane Mitigation, Installation Detail
Attachment 1	Vapor Intrusion Field Sampling Standard Guideline

Figures



FLOYD | SNIDER
strategy ▪ science ▪ engineering

Sampling Plan Addendum
for Vapor Intrusion Assessment
1514 Taylor Way Development
Tacoma, Washington

Figure 1
Property Features and
Previous Soil Gas Sample Locations

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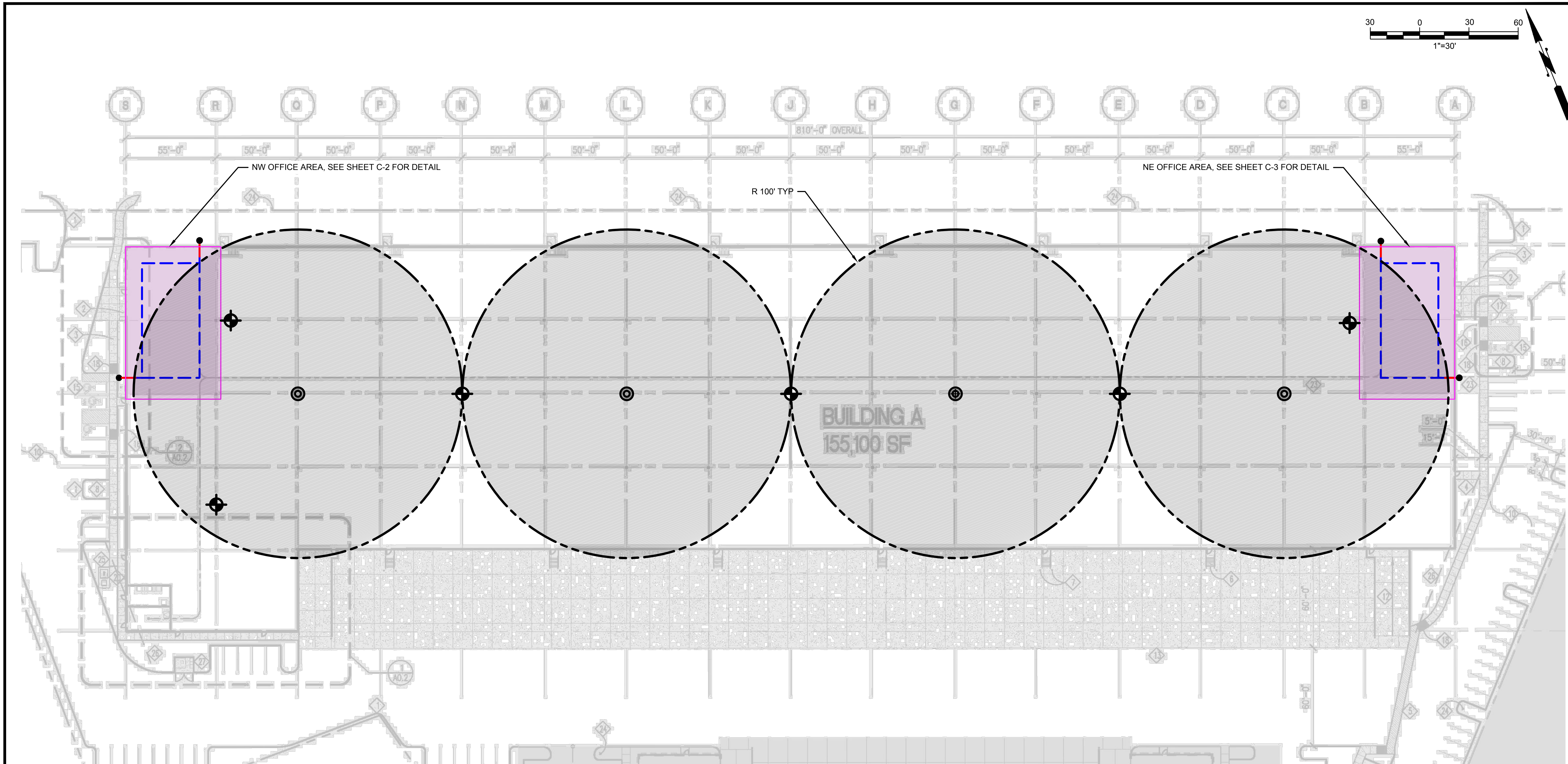
8/10/2018



NOTES:

1. 30mil GEOMEMBRANE SHALL BE A CONTINUOUS SHEET UNDER BUILDING SLAB AND SHALL EXTEND TO EXTERIOR EDGE OF PERIMETER FOOTING OR BE SEALED TO FOOTINGS BY BATTEN STRIP.
2. ALL PENETRATIONS THROUGH MEMBRANE SHALL BE BOOTED AND SEALED. SEE DETAILS 1 AND 2/C-8.
3. ALL INTERIOR VENT PIPING MUST BE PRESSURE TESTED USING HYDRO STATIC OR PNEUMATIC METHOD.
4. GRANULAR MATERIAL UNDER SLAB IN PIPE TRENCH SIZED LARGER THAN PERFORATIONS IN PIPE OR ADD GEOTEXTILE WRAP AROUND PERFORATED PIPE.
5. ALL SLAB PENETRATIONS SHALL BE SEALED WITH ELASTOMERIC POLYURETHANE SEALANT.

LEGEND:

- 4" RISER VENT
- RISER VENT WITH BLOWER
- MONITORING LOCATION
- 2" DIA SCH 40 PERFORATED PVC COLLECTION PIPE
- 4" DIA SCH 80 OR GALVANIZED SOLID WALL PIPE
- VAPOR MONITORING ZONE
- 30mil PVC MEMBRANE EXTENTS

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WORK PLAN MEMO

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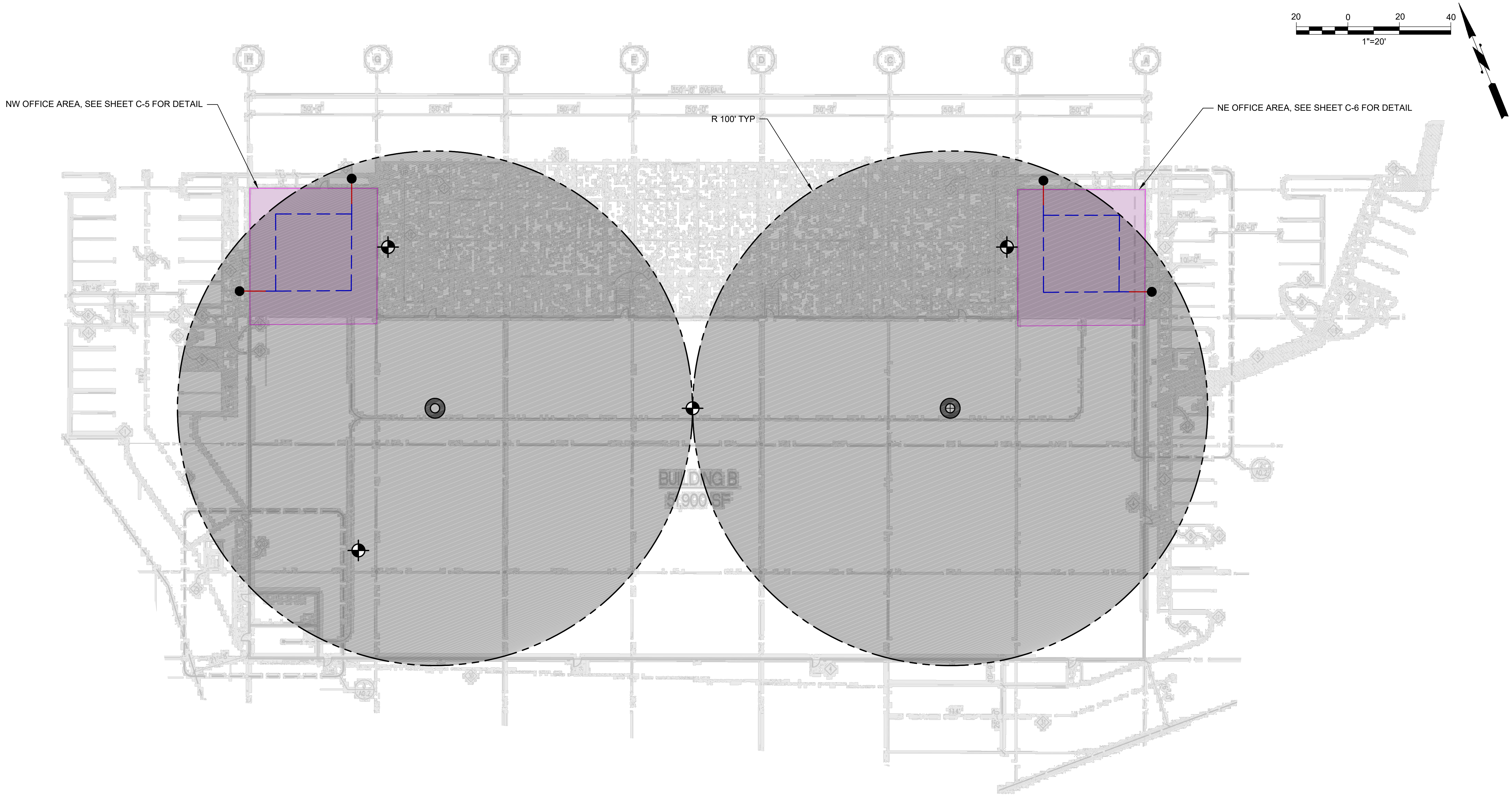
HERRERA

DESIGNED: K. JOHNSON	DRAWN: T. PRESCOTT
DESIGNED: M. SPILLANE	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: M. SPILLANE

AVE 55
TAYLOR WAY METHANE MITIGATION

PAD A

DATE: AUGUST 2018
PROJECT NO: 16-06475-000
DRAWING NO: Figure 2
SHEET NO: 2 OF 4



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LEGEND:

●	4" RISER VENT
◎	RISER VENT WITH BLOWER
⌖	MONITORING LOCATION
blue dashed line	2" DIA SCH 40 PERFORATED PVC COLLECTION PIPE
red line	4" DIA SCH 80 OR GALVANIZED SOLID WALL PIPE
grey box, dashed outline	VAPOR MONITORING ZONE
pink box	30mil PVC MEMBRANE EXTENTS

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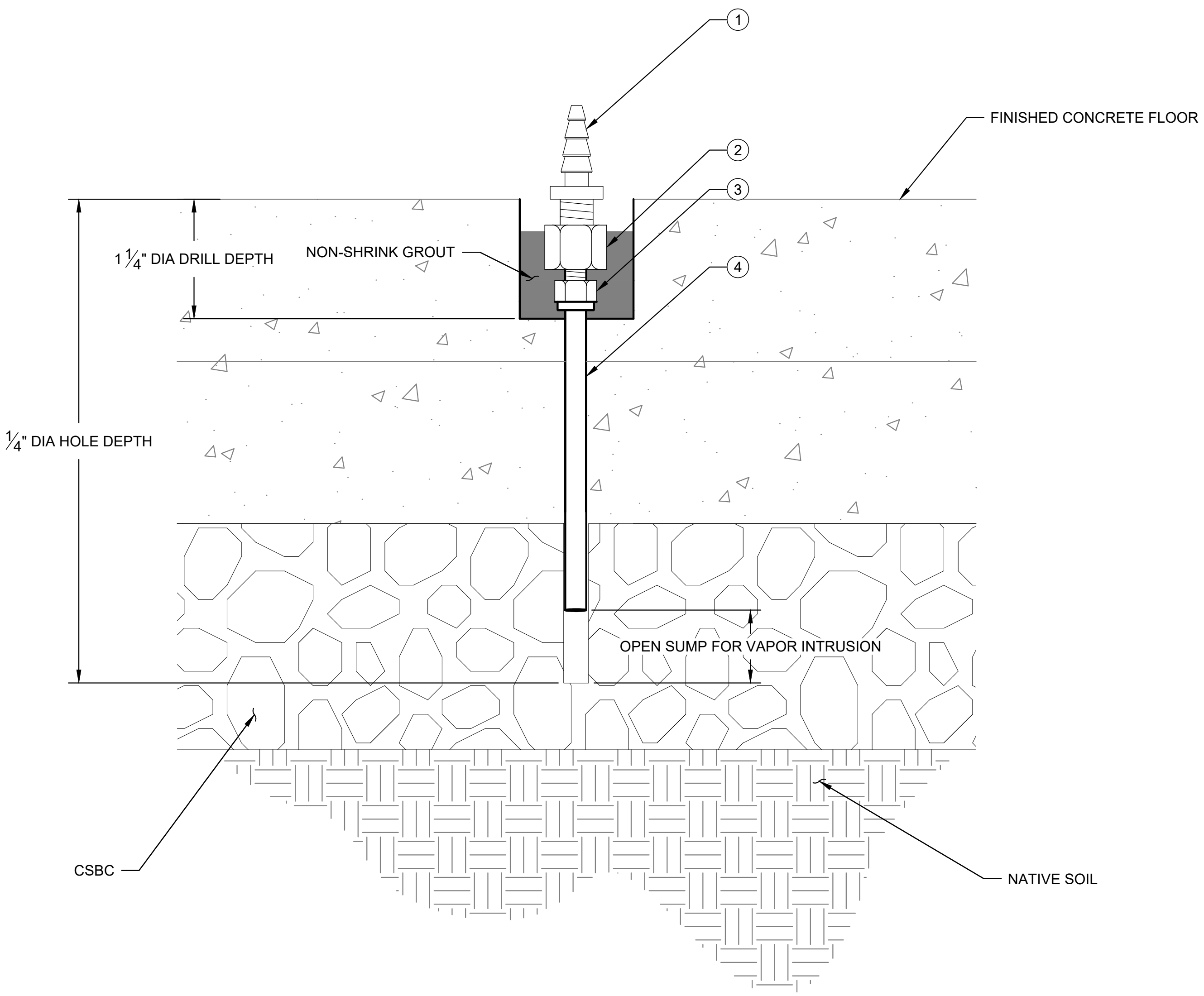
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: M. SPILLANE

AVE 55
TAYLOR WAY METHANE MITIGATION

PAD B

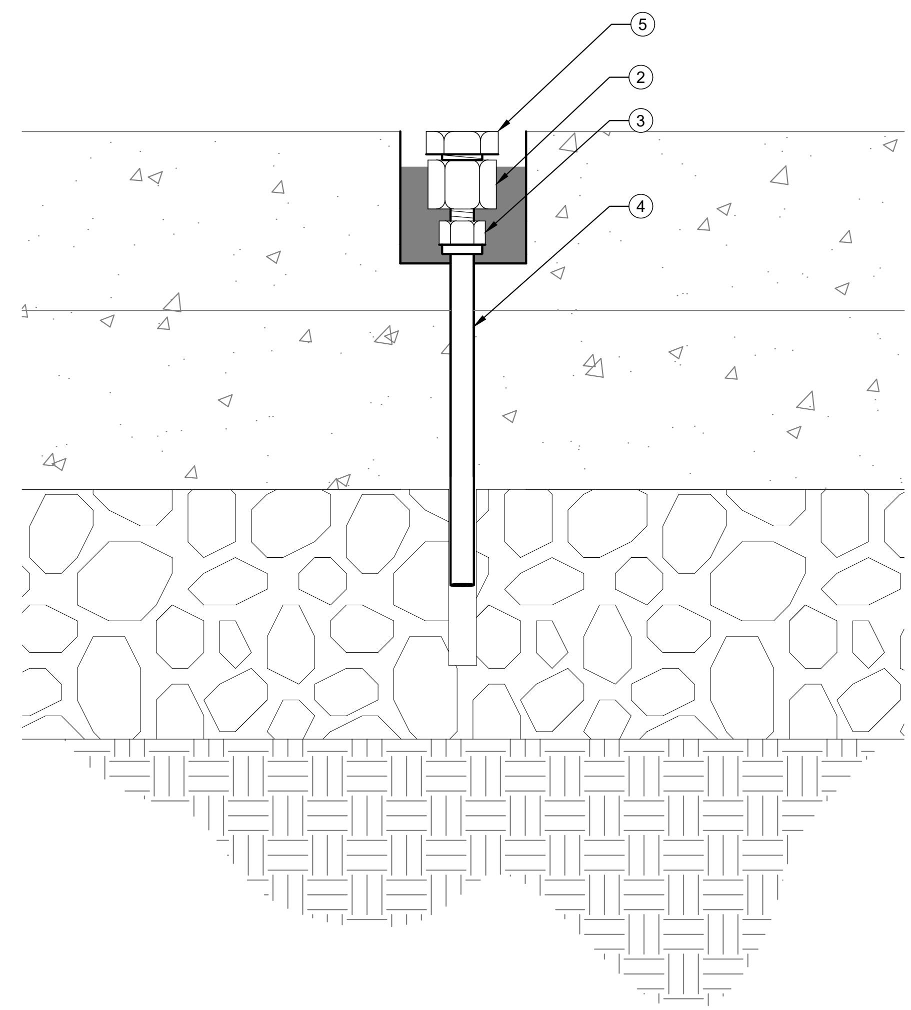
DATE: AUGUST 2018
PROJECT NO: 16-06475-000
DRAWING NO: Figure 3
SHEET NO: 3 OF 4



DETAIL - SUB-SLAB VAPOR PROBE DURING MONITORING

SCALE: NTS

1 / C-1



DETAIL - SUB-SLAB VAPOR PROBE CAPPED

SCALE: NTS

2 / -

ITEMIZED NOTES:

(1) STAINLESS STEEL HOSE BARB ADAPTER

(2) SWAGELOK® MODEL # 400-7-4 STAINLESS STEEL, FEMALE CONNECTOR (TAPERED THREAD) 1/4" TUBE x 1/4" NPT

(3) SWAGELOK® MODEL # 401-PC STAINLESS STEEL, 1/4" TUBE FITTING PORT CONNECTOR.

(4) 1/4" INERT VAPOR TUBING

(5) McMASTER-CARR MODEL # 4534K12 FLUSH MOUNT-HIGH PRESSURE STEEL HEX SOCKET PLUG, 1/4" PIPE, PTFE COATED, 1/4" HEX, 13/32" LENGTH

INSTALLATION NOTES:

1. SELECT LOCATION FOR THE PERMANENT SUB-SLAB PROBE BASED ON THE OBJECTIVES OF THE PHASE OF WORK, PRESENCE OR POTENTIAL PRESENCE OF OBSTRUCTIONS AND INPUT FROM THE BUILDING OWNER.
2. USING A HAMMER OR CHISEL, CHIP AN "X" IN THE CONCRETE AS A STARTING POINT FOR DRILLING TO PREVENT THE BIT FROM WANDERING OFF THE DESIRED TARGET LOCATION.
3. DETERMINE THE DEPTH OF THE PROBE BODY AND MARK THIS LENGTH ON THE 1-1/4" MASONRY BIT WRAPPED WITH DUCT TAPED FLAP. THE FLAP WILL ACT AS A DEPTH GAUGE. WHEN THE DUCT TAPE FLAP HITS THE SLAB, THE BIT IS AT THE APPROPRIATE DEPTH. THE DESIRED DEPTH OF THE HOLE WILL BE DEPENDANT IF THE PROBE IS TO BE FLUSH WITH THE FLOOR OR SLIGHTLY COUNTERSUNK TO THE FLOOR.
4. USE THE ROTARY HAMMER DRILL WITH THE 1-1/4" BIT TO ADVANCE THE OUTER HOLE TO THE PROPER DEPTH AND VACUUM OUT THE CUTTINGS.
5. USING THE HAMMER DRILL WITH A 1/4" BIT, PLACE THE BIT IN THE CENTER OF THE 1-1/4" HOLE AND DRILL THROUGH THE SLAB INTO THE CSBC SUBSURFACE MATERIAL BY 3" to 6". A SIGNIFICANT INCREASE IN THE RATE OF PENETRATION BY THE DRILL WILL INDICATE THE BOTTOM OF SLAB HAS BEEN PASSED THROUGH.
6. VACUUM OUT THE DRILL CUTTINGS FROM IN AND AROUND THE HOLE. TEST FIT THE PROBE IN THE HOLE SO IT IS AT THE DESIRED LOCATION. ALTER THE HOLE DEPTH IF REQUIRED.
7. DAMPEN A PAPER TOWEL WITH DISTILLED WATER AND WIPE AWAY THE DUST FROM 1-1/4" HOLE AND WET THE SIDEWALLS. DO NOT ALLOW EXCESS WATER ON THE TOWEL GO INTO THE SUBSURFACE.
8. MIX A SMALL AMOUNT NON-SHRINK GROUT OR QUICK DRYING CEMENT AND POUR INTO THE ANNULAR SPACE AROUND THE PROBE. ALLOW THE CEMENT TO CURE FOR THE RECOMMENDED TIME FOR CURING BY THE MANUFACTURER OF THE CEMENT OR GROUT.
9. DETAIL 1 IS A TYPICAL CROSS SECTION OF THE PERMANENT SUB-SLAB PROBE DURING THE MONITORING PROCESS.
10. DETAIL 2 IS A TYPICAL CROSS SECTION OF THE PERMANENT SUB-SLAB PROBE CAPPED FLUSH WITH THE FINISH GRADE.

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AVE 55

TAYLOR WAY METHANE MITIGATION

INSTALLATION DETAIL

DATE: AUGUST 2018

PROJECT NO: 16-06475-000

DRAWING NO: Figure 4

SHEET NO: 4 OF 4

Attachment 1
Vapor Intrusion Field Sampling Standard Guideline

Two Union Square
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Seattle, WA 98101
tel: 206.292.2078 fax: 206.682.7867

F|S STANDARD GUIDELINE

Vapor Intrusion

DATE/LAST UPDATE: December 2016

These procedures should be considered standard guidelines and are intended to provide useful guidance when in the field, but are not intended to be step-by-step procedures, as some steps may not be applicable to all projects.

All field staff should be sufficiently trained in the standard guidelines for the sampling method they intend to use and should review and understand these procedures prior to going into the field. It is the responsibility of the field staff to review the standard guidelines with the field manager or project manager and identify any deviations from these guidelines prior to field work. When possible, the project-specific Sampling and Analysis Plan should contain any expected deviations and should be referenced in conjunction with these standard guidelines.

1.0 Scope and Purpose

This standard guideline provides details necessary to complete vapor intrusion monitoring, which may include soil vapor point and sub-slab installation, soil vapor point monitoring and/or sampling, indoor air sampling, and remediation system compliance monitoring. Field screening for volatile organic compounds (VOCs) is most often conducted with a photoionization detector (PID) and confirmed via analytical sample collection. The most common sampling methods are included herein. These guidelines are designed to meet or exceed guidelines set forth by the Draft Washington State Department of Ecology's (Ecology's), *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action* (Ecology 2015 and 2016a). In addition, refer to Ecology's *Updated Process for Initially Assessing the Potential for Petroleum Vapor Intrusion: Implementation Memorandum No. 14* (Ecology 2016b) and the U.S. Environmental Protection Agency's (USEPA's) *Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites* (USEPA 2015). Defining the lateral and vertical inclusion zones will determine if soil vapor sampling is required. The Interstate Technology and Regulatory Council (ITRC) online guidance for soil vapor intrusion (ITRC 2014) is another good source of information.

2.0 Equipment and Supplies

The following is a list of typical equipment and supplies necessary to complete vapor intrusion monitoring. It is important to note that this list is for a typical project; site-specific conditions may warrant additional or different equipment for completion of the work.

Sub-Slab and Soil Vapor Point Installation:

- Rotary hammer drill
- Drill bit
- Vapor point (AMS or similar)
- Stainless steel (SST) dummy tip (optional)
- Teflon™, nylon, or stainless steel tubing
- Sand pack
- Bentonite chips
- Protective cover for permanent point
- Swagelok® on/off valve (optional)
- Caps or compression fittings
- Quick set (concrete) or hydraulic cement
- Paper towels
- Nylon ferrules
- Shop vac

Soil Vapor Point or Remediation System Screening and/or Sampling:

- PID
- Connector
- Teflon™ or nylon tubing
- SKC air sampling pump or peristaltic pump
- Tedlar® bag or SUMMA® canisters
- Two adjustable wrenches (to tighten SUMMA® canister connections)
- Duplicate sampling (as necessary if duplicate sample collection is required)
- Soil gas manifolds
- Ferrules/fittings
- Helium (or other detection gas if leak detection is necessary)

- Helium detector (if leak detection is necessary with helium)
- Soil vapor sampling sheet (enclosed)

Indoor Air Sampling:

- PID
- Regulator
- SUMMA® canisters (6-liter, lab certified)
- Sampling cane (optional)
- At least two adjustable wrenches
- Indoor air building survey form (enclosed)

3.0 Standard Procedures

Soil vapor samples and/or indoor air samples should be collected from a sufficient number of locations to assess the presence of VOCs and potential exposure to workers or occupants of potentially impacted buildings or future building locations.

3.1 PRE-SCREENING ASSESSMENT

When completing a vapor intrusion survey or indoor air sampling, it is important to complete a pre-sampling survey to document potential activities or storage items that may cause interference with sample results. Some important things to note (list is not comprehensive):

- If smoking has occurred in the building
- Storage of potential contaminants (cleaners, fuels, paints, or paint thinners, etc.)
- HVAC system operation (on or off)
- Temperature and weather (wind direction, barometric pressure, etc.)
- Vehicle maintenance or industrial activities on the property or in the immediate vicinity (especially upwind)
- If new carpet or furniture is present

A pre-sampling soil vapor building survey form can be found at the end of this document. Be mindful of your surroundings and make a comprehensive list of potential factors that may influence sample results.

3.2 SOIL VAPOR POINT INSTALLATION

Soil vapor points can be installed along the outside perimeter of a building or in the lowest level of a building directly through the slab (or beneath the floor into the subsurface if there is not a slab). It is important to evaluate the presence of utilities prior to drilling into the subsurface or through a concrete slab.

If the sampling point is for one time use, tubing inserted into a hole drilled in the slab is sufficient. However, if the sampling is to be part of a long-term monitoring program, a more robust sampler, such as a Geoprobe or AMS probe for permanent soil gas point is recommended. Four different methods for installing soil vapor installation points are described here.

1. For temporary sub-slab points:
    a. Drill a hole into the subsurface. Using a rotary hammer drill and a 3/8-inch drill bit (typical diameter size but not necessary), drill a hole through the concrete floor slab of the building and into the sub-slab material to some depth (e.g., 7 to 8 centimeters [cm] or 3 inches). Drilling into the sub-slab material will create an open cavity, which will prevent obstruction of the tubing intake by small pieces of gravel. Once the thickness of the slab is known, the tubing will be cut to ensure that the probe tubing does not reach the bottom of the hole in order to avoid obstruction with sub-slab material. Sample tubing can be placed directly into the sub-slab. Evaluate and note the sub-slab conditions.
    b. Care should be taken to reduce cross-contaminating sub-slab vapor and indoor air vapor. This may be done by sealing the sample point with VOC-free hydraulic cement, hydrated bentonite, or with VOC-free putty to the top of the slab. Once sealed, wait 15 to 30 minutes before sampling.
2. Suggested installation guidelines for temporary outdoor soil gas points using a rotary hammer and drill bit:
    a. Manufacturers, such as Geoprobe or AMS, make soil gas implant systems designed for use with their equipment. Stainless steel or polyvinyl chloride (PVC) screen can also be used to construct an appropriate soil gas point. The probe screen will be fitted with a Swagelok® or similar fitting and connected to a length of 0.25-inch outer diameter, rigid wall nylon or Teflon™ tubing that will be above grade. Refer to the manufacturer or driller's instructions for specific details regarding assembly and deployment.
    b. To seal the point, the implant should be surrounded with a clean sand pack. Concrete (VOC-free hydraulic cement preferred) should be used above the seal to the top of the slab. Placement of some sort of cap or protective device is recommended if the sampling point will remain in place for some time after the soil gas sample is collected. Once sealed, wait 15 to 30 minutes before sampling.
3. Suggested installation guidelines for outside permanent points installed with a Geoprobe rig or hand auger:
    a. Advance the boring using a geoprobe or hand auger to the required maximum depth. Install a 6-inch long by 0.75-inch diameter stainless steel screen that is capped on the bottom end and fitted with a Swagelok® fitting connected on the

other end (or similar approved screen or soil vapor point). Attach a length of 0.25-inch outer diameter rigid wall nylon or Teflon™ tubing to the probe screen that will be above grade. The above grade end of the probe should be fitted with a stainless steel Swagelok® on/off control valve or similar valve (optional), which is used to prevent short-circuiting of ambient air into the probes and to conduct closed-valve tests. Teflon™ tape should be used on threaded joints to ensure a good seal. Depending on the work plan, it might be necessary to collect an air equipment blank sample through the vapor probe components prior to installation.

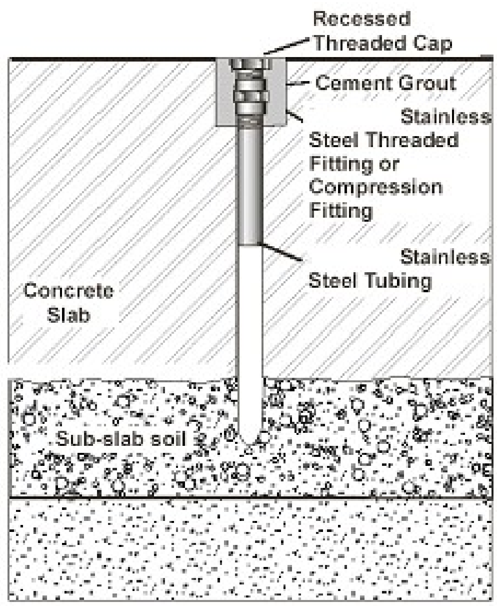
b. The 6-inch screen tip should be vertically centered in a 1-foot long interval containing standard sand pack, resulting in 3 inches of sand above and below the screen. The sand pack will be covered with a 1-foot interval of dry granular bentonite, which should be covered with at least 2 feet of pre-hydrated granular bentonite. The dry granular bentonite is emplaced immediately above the sand pack to ensure that pre-hydrated granular bentonite slurry does not flow down to the probe screen and seal it. The remainder of the borehole will be filled with pre-hydrated granular bentonite slurry (mixed at the surface and poured in) to approximately 12 inches below ground surface (bgs). The top portion should be completed with a 1-foot thick cement cap. A flush-mounted well box or other suitable protective cover should be installed to protect the nylon/Teflon™ tubing and on/off control valve.

4. The following contains suggested equipment and installation guidelines for permanent sub-slab vapor points within a building; however, site-specific conditions may warrant additional or different equipment for completion of the work:

   a. To install the sub-slab vapor probes, a rotary hammer drill will be used to create a “shallow” hole (e.g., ¼-inch deep) that partially penetrates the slab (do not completely penetrate the slab). A portable vacuum can be used to remove the drill cuttings from the hole without compromising the soil vapor samples. Next, a smaller diameter “inner” hole (e.g., 0.8 cm or 5/16 inch diameter) will be drilled through the remainder of the slab and into the sub-slab material to some depth (e.g., 7 to 8 cm or 3 inches). Drilling into the sub-slab material will create an open cavity which will prevent obstruction of the probes by small pieces of gravel. Once the thickness of the slab is known, the tubing will be cut to ensure that the probe tubing does not reach the bottom of the hole and in order to avoid obstruction with sub-slab material.

   b. Each sub-slab vapor point should consist of vacuum-rated Nylon, Teflon™, or stainless steel tubing with ¼-inch outer diameter by 0.15-inch inner diameter, and stainless-steel compression to thread fittings (e.g., ¼-inch outer diameter Swagelok® (SS-400-7-4) NPT female thread connectors or similar equipment). This will be capped with sub-slab tamper resistant cap or other similar protective caps that will be inset into the floor to avoid trip hazards. When time to sample, the sub-slab tamper resistant cap will be removed and Nylon tubing will be attached to the sub-slab vapor point with a ¼-inch out diameter (SS-400-1-4) male NPT. Prior to the installation of one of the sub-slab vapor probes, an air equipment blank sample will be collected if required by the work plan (See Section 3.4.3).

c. Teflon™ tape should be used with all stainless steel treads. All fittings should be attached prior to installing the probe in the sub-slab. A sub-slab tamper resistant cap will be used to ensure that the top of the probe is flush with the surface so as not to interfere with day-to-day use of the building. Portland cement can be used as a surface seal and allowed to cure for at least 24 hours prior to sampling. Hydraulic cement may also be used if free of VOCs, and requires less cure time (typically less than one hour) prior to sample collection. A typical soil gas probe schematic is provided here for reference.



Sub-slab soil gas probe schematic (Source: Ecology 2016a)

3.3 SOIL VAPOR POINT SAMPLING USING TEDLAR® BAGS

The objective of the vapor sampling procedures is to collect representative samples of the targeted media and analyze the gas for the presence of VOCs. Typically, a low volume air pump is used to pull a sample through the sampling train.

1. Connect proper tubing to your sampling point and to your low volume air pump.
2. Purge for 3 to 5 minutes to ensure that you are collecting a representative sample.
3. After purging, connect your Tedlar® bag to your air pump and collect your sample (Note: Tedlar® bags should be filled at a rate of approximately 5 liters per minute).
4. A PID is typically used in conjunction with sample collection in a Tedlar® bag.
   a. Connect the PID probe to the sample container using a section of tubing
   b. Use the PID to read the organic vapor level present in the sample.

Soil Vapor samples are typically collected into 1-liter Tedlar® bags and have a short (typically less than 72-hours) holding time. Samples collected into Tedlar® bags should be transported to the laboratory immediately under chain-of-custody protocol and stored in a dark container at ambient temperature during transport out of direct UV-light. Do not ship Tedlar® bags to the laboratory using an air transportation method as the pressure could compromise the sample or the bag. If air transport is necessary, do not completely fill the Tedlar® to avoid bursting. Soil vapor grab samples can also be collected into 1-liter SUMMA® canisters to provide additional holding time, lower laboratory method detection limits for some analytes, or sample delivery alternatives.

3.4 SOIL VAPOR AND SUB-SLAB SAMPLING WITH SUMMA® CANISTERS

Prior to soil vapor sampling, check all soil vapor sampling supplies to ensure the right sampling equipment arrived from the lab including duplicate Tees, if duplicate sample collection is necessary, and purging canisters. Conduct the following:

- Confirm that all SUMMA® canisters have at least 27 to 30 inches of mercury (in. Hg) prior to going out in the field to sample.
- Check and record all manifold and SUMMA® canister tags and numbers.
- Make sure all connections on the SUMMA® canisters and manifolds are tight.
- Order Helium (or other tracer gas) if needed and rent a helium detector.

Once the sub-slab or soil vapor probes are installed and the concrete well seal at each vapor point has fully cured, vapor sampling activities may commence (ideally a minimum of 2 hours is necessary for probe equilibration, depending on surface seal cure time). Alternatively, existing monitoring wells that are appropriately screened for a vapor intrusion assessment may be used. If indoor air samples will be collected, they may be collected simultaneously during the sub-slab sampling activities (details found in Section 3.6) if required by the work plan. If feasible, vapor sampling should not be conducted during or immediately after a significant rain event (i.e., greater than an inch of rainfall) due to the reduced effective diffusion coefficient and decrease in relative vapor saturation in the unsaturated zone. For sub-slab or soil vapor probe sampling, 1-liter lab certified SUMMA® canisters should be used in order to minimize the volume of soil vapor collected.

A closed-valve test should be conducted prior to soil vapor sample collection to check for leaks in the sampling train. A closed-valve test is conducted by capping the ends with proper Swagelok caps and/or closing any valves at the sampling point and purge canister. Once all ends are closed tight, turn the sampling canister valve on for 5 minutes. If the sampling train maintains its original vacuum for 5 minutes, the equipment will be assumed to be functional and there are no leaks. If the vacuum reading starts to drop, turn off the valves right away, check all connections, tighten if necessary, and re-test. If this passes, the only location that a leak can occur is from the soil ground seal around the vapor probe, which will be tested using helium or another tracer gas during sampling (See Section 3.4.1).

After the close-valve test, a minimum of three tubing volumes should be purged. Purging can be completed using a non-certified 6-Liter SUMMA® canister or a vacuum pump. The maximum flow rate during purging will not exceed the flow rate limit used for subsequent sampling and care will be taken not to over purge. An excel spreadsheet to help calculate tubing volume and purging time can be found at the end of this document.

After the sampling train has been purged, sub-slab soil vapor samples will be collected over a 10 minute period at a flow rate of less than 167 milliliters per minute (ml/min). The flow rate will be controlled by a flow regulator, which is set by the lab. Sub-slab soil vapor samples will be collected in laboratory-certified and pre-evacuated 1-liter SUMMA® canisters. Each SUMMA® canister will be supplied with an analytical test report certifying that the canister is "clean" to concentrations less than the respective method detection limits (MDLs). Each canister will be equipped with a pre-calibrated flow controller sampling train to allow collection of the desired sample. Prior to collecting the samples, the SUMMA® canister ID numbers will be recorded in the field notebook along with the initial canister vacuums, prior to sampling.

Soil vapor samples will be collected per the following steps:

1. Opening the valve on the top of the SUMMA® canister and recording the time in the log book;
2. Observing the vacuum gauge on the sampling train to ensure that the vacuum in the canister is decreasing over time;
3. Shutting off the valve once the vacuum gage reads between 4.0 and 5.0 inches of mercury (in. Hg).

3.4.1 Leak Testing

In addition to soil gas sampling activities, leak testing may be required at sampling locations and should be conducted using the following soil gas sampling set-up procedures:

- Place a large plastic bag (or other acceptable shroud) around the SUMMA® canister, sampling apparatus, and vapor probe.
- Cut a small hole in the bag to allow tubing to be inserted to introduce tracer gas, such as helium, and to subsequently fill the plastic bag.
- Keep the tracer gas (i.e., helium) concentration in the bag at 10 percent by volume or higher.

Detections of the tracer gas in the soil gas samples would indicate that the canister, valves, or ground surface seal to the sample probe have potentially leaked ambient air into the sample. Small amounts of sample train leakage is permissible, however, the leak percentage should not exceed 10 percent of the soil gas results. If the leak percentage exceeds 10 percent, the sampling point may have to be resampled. The integrity of the soil vapor samples can be assessed by estimating the percent leakage as shown here in micrograms per square meter ($\mu g/m^3$):

$$\% \text{ leakage} = 100 \times \frac{\text{helium concentration in soil vapor sample } [\mu g/m^3]}{\text{average helium concentration measured inside the shroud } [\mu g/m^3]}$$

Tracer gas leaks should not occur if the sampling train passes a properly performed closed-valve test and given the low flow rate of 167 ml/min.

3.4.2 Final Readings

Once the sampling is completed and the final vacuum is recorded, the sampling train will be removed from the canister and a Swagelok® cap will be tightly fitted to the inlet port of the canister. A PID can be used to record vapor readings from the manifold connection and logged in the notebook and/or soil vapor sampling sheet (enclosed). In addition, the initial canister vacuums, vacuum testing times, purging times, purged volumes, helium readings, sampling starts and times, final vacuum readings, and PID readings should be recorded on a vapor sampling sheet. Some of this information will also be required on the chain-of-custody.

3.4.3 Equipment Blank

Occasionally, the work plan requires an equipment blank to be collected. An equipment blank can be conducted by collecting a sample of clean air or nitrogen through the probe materials before installation in the ground. Analysis of the equipment blank can provide information on the cleanliness of new materials. Clean stainless steel, Nylon or Teflon® tubing and a certified regulator should be used. Lab-certified canisters (the sample canister and the source canister/cylinder, if applicable) or Tedlar® bags can be used to collect an equipment blank.

3.5 USE OF MONITORING WELLS FOR SOIL GAS SAMPLING

While dedicated soil gas probes are typically used to collect soil gas samples, existing monitoring wells that are appropriately located and screened can also be used for this purpose, with limitations. This is an advantage when evaluating the risk of vapor intrusion solely from contaminated aquifers (as compared to contaminated vadose zone soil) as the soil gas that will be sampled can reflect a soil gas sample that lies close to the zone of saturation and represents a worse case condition for equilibrium partitioning of contamination in groundwater to the gas phase. Also, monitoring wells are typically constructed at a deeper depth than soil vapor probes and are less influenced by changes in barometric pressure. They are also inherently constructed to be well sealed against breakthrough from atmospheric air (while purging and sampling). For an existing well to be used for soil gas sampling, it must have at least 2 to 3 feet of open screen above the water table during sample collection.

The main disadvantage of using existing monitoring wells is that the required purge volume would be much greater because of the significantly larger diameter of the well screen as compared to probes. This requires the use of a larger air pump or small blower instead of the SKC hand pump or peristaltic pump. While purging, care must be taken to minimize the vacuum in the well casing which may be large enough to raise the water column high enough to cover the exposed well screen and invalidate the use of the well for sampling soil gas. Appropriate temporary fittings will need to be installed to allow the reduction of the well casing sufficient to allow connection to the collection tubing.

3.6 INDOOR AIR SAMPLE COLLECTION

Indoor air samples are typically collected into 6-liter SUMMA® canisters, and can either be a grab (not often recommended) or time weighted samples. For time weighted samples, the laboratory will provide preprogrammed flow controllers for the samples for your desired sample duration. An 8-hour flow controller is the most common to assess typical working conditions or to provide a time-weighted average (TWA) to assess residential risk (a 24-hour flow controller may also be used for residential assessments). SUMMA® canisters should be placed in an area that is close to the breathing zone (i.e., 3 to 4 feet above the floor level), a sampling cane can be connected to the SUMMA® canister to sample indoor air at breathing zone height. As a basic guideline and starting point, indoor air samples should at a minimum be collected from the basement (if applicable), first floor living or work area, and from outdoors (ambient/upwind). Other site-specific factors will influence the specific placement location of the SUMMA® canisters, such as proximity to subsurface source area(s) or penetrations through the slab or foundation.

3.6.1 Connection Guidelines

Refer to specific guidelines provided by the laboratory, as equipment can be slightly different from lab to lab. It is important to note the initial vacuum reading on the gauge as well as the post-sampling vacuum. For reference, initial vacuum should be between 27 and 30 inches of mercury, while post-sample vacuum should be between 4 and 5 inches of mercury. Sample collection start and finish times should also be recorded. After sample collection, the SUMMA® canister valve should be shut and the flow controllers should be disconnected from the SUMMA® canisters. Both the controller and the canister ID (unique laboratory tracking ID) should be recorded on the chain-of-custody and the samples should be packed appropriately for delivery to the laboratory following chain-of-custody protocol.

3.7 REMEDIATION SYSTEM VAPOR SAMPLE COLLECTION

Remediation systems that have a soil vapor extraction (SVE) component often require compliance monitoring to evaluate mass removal and effluent discharge limits. Both screening (with a PID) and sampling are routinely conducted during active operation. Tedlar® bags are often used to simplify SVE system screening. Fill a bag following the procedures described in this section and use a PID to measure the VOCs in the sample. Record the maximum observed concentration. Vapor samples for laboratory analysis are most often collected in 1-liter Tedlar® bags, but SUMMA® canisters can also be used. It is a good idea to fill out the label on the Tedlar® bag prior to sample collection.

If the sample port is under vacuum (i.e., SVE manifold or wellhead), it is often necessary to reduce the flow somewhat and to use a hand or mechanical pump to extract the vapor from the line. If the sample port is under a high vacuum, it may be necessary to step down the flow (i.e., close the flow valve) in order to collect a sample. Follow steps in Section 3.3 for sample collection and delivery.

If the sample port is under pressure (i.e., SVE system discharge), the sample can be collected without the use of a pump. Simply attach a clean piece of tubing securely to the sample port, connect the Tedlar® bag to the tubing, open the Tedlar® bag, slowly open the sample port valve, and be careful not to overfill the bag. Remove the Tedlar® bag when full, close the Tedlar® bag (do not over-tighten), and close the sample port valve. Follow steps in Section 3.3 for sample delivery.

4.0 Field Documentation

Soil vapor probe and monitoring point installation field activities should be documented in field notebooks and completion diagrams or boring logs should be completed to document construction. Information recorded will include personnel present, total depth, type and length of implant or screen, screen and filter pack intervals, bentonite seal intervals and surface completion details. Photographs of construction activities should be taken. After probe and monitoring point installation is complete, location coordinates should be recorded with a global positioning system (GPS). If GPS cannot be used (i.e., location within a building), it is important to document the location by recording representative measurements to fixed points.

All sampling activities must be documented in a field notebook and/or on field forms appropriate for the sampling activity. Information recorded will include at a minimum personnel present, weather conditions, date, and time of sample collection, length of sample purge time, and any deviations from the project's work plan or sampling and analysis plan.

5.0 References

Interstate Technology Regulatory Council (ITRC). 2014. Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management. <http://www.itrcweb.org/PetroleumVI-Guidance/>. October.

Washington State Department of Ecology (Ecology). 2015. Vapor Intrusion Table Update. (Replaces Table B-1 of Ecology's Guidance for Evaluating Soil Vapor Intrusion in Washington State). <http://www.ecy.wa.gov/programs/tcp/policies/VaporIntrusion/Vapor%20Intrusion%20Table%20update%20April%206%202015.xlsx>. 6 April.

_____. 2016a. *Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action*. Review Draft. Prepared by the Toxics Cleanup Program. Publication No. 09-09-047. Originally published October 2009; revised February.

_____. 2016b. *Updated Process for Initially Assessing the Potential for Petroleum Vapor Intrusion: Implementation Memorandum No. 14*. Publication No. 16-09-046. 31 March.

U.S. Environmental Protection Agency (USEPA). 2015. *Technical Guidance for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites*. Prepared by the Office of Underground Storage Tanks. EPA 510-R-15-001. June.

Enclosures: Indoor Air Building Survey Form
Purge Volume Calculations during Soil Vapor Sampling
Soil Vapor Sampling Sheet

INDOOR AIR BUILDING SURVEY FORM

Date:

Site Name:

Title:

Building Use:

Occupants: ______________________________

Building Address: ______________________________

Property Owner: ______________________________

Contact's Phone: ______________________________

Number of Occupants: ______________________________

Business or Residential: ______________________________

Building Characteristics

Building Type: ☐ Residential ☐ Multifamily ☐ Office

☐ Commercial ☐ Industrial ☐ Mall

Describe Building:____
____

Number of Floors Below Grade: ____________ ☐ Basement ☐ Slab-On-Grade ☐ Crawl Space

Bldg Dimensions: Width:______ Length: ________ Height: _________

Basement Floor: Dirt / Concrete / Painted? Foundation Walls: Concrete / Cinder Blocks / Stone

VENTILATION SYSTEM

☐ Central Air Conditioning ☐ Mechanical Fans ☐ Bathroom Vans

☐ Conditioning Units ☐ Kitchen Range Hood ☐ Outside Air Intake

Other:_________________________

HEATING SYSTEM

☐ Hot Air Circulation ☐ Hot Air Radiation ☐ Wood ☐ Steam Radiation

☐ Heat Pump ☐ Hot Water Radiation ☐ Kerosene Heater ☐ Electric Baseboard

Other:_____________

Outside Contaminant Sources

Nearby surrounding property sources: Gas Stations / Emission Stacks

Soil Contamination: Petroleum Hydrocarbons / Solvents

Heavy Vehicle Traffic: Yes / No

Indoor Contaminant Sources

Identify all potential sources found in the building (including attached garages), the location of the source (floor and room), and whether the item was removed from the building 48 hrs prior to indoor sampling event. Any ventilation implemented after removal of the items should be completed at least 24 hours prior to the commencement of the indoor air sampling event.

Potential Sources	Location(s)	Removed (Yes / No / NA)
Gasoline storage cans		
Gas powered equipment		
Kerosene storage cans		
Paints / Thinners / Strippers		
Cleaning solvents / Dry cleaners		
Oven cleaners		
Carpet / upholstery cleaners		

Other house cleaning products		
Moth Balls		
Potential Sources	**Location(s)**	**Removed (Yes / No / NA)**
Polishes / waxes		
Insecticides		
Furniture / floor polish		
Nail polish / polish remover		
Hairspray		
Cologne / perfume		
Air fresheners		
Fuel tank (inside building)		
Wood stove or fireplace		
New furniture		
New carpeting / New flooring		
Hobbies – glues, paints		
Other: __________________		
Other: __________________		
Other: __________________		

SAMPLING INFORMATION

Sampler(s) ____

☐ Indoor Air / Outdoor Air ☐ Sub-slab ☐ Soil Vapor Point ☐ Exterior Soil Gas

☐ Tedlar® Bag ☐ Sorbent ☐ SUMMA® ☐ Other _________

Analytical Method: TO-15 / TO-17 / Other: _________________

WEATHER CONDITIONS

Was there a significant rain event in the last 24 hours? Yes / No

Temperature: _________ Atmospheric Pressure: _______________ Pressure: Rising or Falling?

Describe the general weather conditions: ____

Wind Speed and Direction: ____

PURGE VOLUME CALCULATIONS DURING SOIL VAPOR SAMPLING

Sample Tubing Purge												
Tubing Length (feet)	Pi	Casing Radius (inches)	Area of Casing Radius (Pi(R²)) (inches)	Length of casing (feet)	Conversion of feet to inches	Number of Casing Volumes to Purge	Conversion of cubic inches to ml	Purge Volume (ml)	Purge Volume (l)	Purge rate (ml/min)	Purge Time (min)	
5	3.141593	0.125	0.049087	5	60	1	16.387064	48.263888	0.048264	167	0.29	
5	3.141593	0.125	0.049087	5	60	3	16.387064	144.79166	0.144792	167	0.87	
5	3.141593	0.125	0.049087	5	60	7	16.387064	337.84721	0.337847	167	2.02	

Annular Space Purge												
Annular Space Length (inches)	Pi	Boring Radius (inches)	Area of Boring Radius (radius²)	Volume of Annular Space (inches)	Assumed Porosity of Sand Pack*	Air Filled Volume of Annular Space (cubic inches)	Number of Casing Volumes to Purge	Conversion of cubic inches to ml	Purge Volume (ml)	Purge Volume (l)	Purge rate (ml/min)	Purge Time (min)
12	3.141593	2	12.56637	150.7964	0.3	45.23893	1	16.387064	741.3333	0.741333	167	4.44
12	3.141593	2	12.56637	150.7964	0.3	45.23893	3	16.387064	2224	2.224	167	13.32
12	3.141593	2	12.56637	150.7964	0.3	45.23893	7	16.387064	5189.333	5.189333	167	31.07

Summary of Purge Durations	
One Purge Volume	4.73
Three Purge Volumes	14.18
Seven Volumes	33.10

SOIL VAPOR SAMPLING SHEET

Site Reference: ____________________________________ Date: ____________________________________

Address: ____________________________________ Personnel: ____________________________________

	Vacuum Test		Purging				Helium		Sampling				PID		
Soil Vapor Sampling Point ID	Time Start Vacuum Testing	Time Stop Vacuum Testing	Time Start Purging	Time Stop Purging	Purging Rate (ml/min)	Total Volume Purged (ml)	Time of Helium Reading	Helium Reading (%)	Time Start Sampling	Time Stop Sampling	Canister Vacuum Before Sampling (in Hg)	Canister Vacuum After Sampling (in Hg)	Time of PID Reading	PID Reading	Notes
					167										
					167										

Notes:

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