

MEASURED VERSUS MODEL-PREDICTED VAPOR INTRUSION ATTENUATION AT A SITE IN LITTLETON, COLORADO

A Site in Littleton, Colorado is a case where Johnson Ettinger (JE) model-predicted groundwater to indoor air attenuation closely matches that observed empirically. Shallow soil vapor to indoor air attenuation is approximately a factor of 100, similar to that observed at many other sites.

A shallow groundwater plume dominated by TCE and 1,1-DCE originates at a local topographic and water table high. Over time the plume has migrated to the fringe of an adjacent residential area causing the Colorado Dept. of Public Health and Environment and EPA to initiate vapor intrusion investigations at the site.

In the course of vapor intrusion investigations from 1999-2002, Johnson Ettinger modeling, soil vapor sampling and finally indoor air sampling were conducted for residential areas of the site. The JE modeling (using the 1991 JE Model with site-specific depth to groundwater of 33 feet and site-specific capillary fringe height of 50 cm) predicted no impact to the residential indoor air above an excess lifetime cancer risk of 1×10^{-6} for TCE.

Subsequent paired groundwater-shallow soil vapor-indoor air sampling demonstrated the lack of significant indoor air risk from vapor intrusion at the site. Measured groundwater to indoor air attenuation was approximately 100,000 (attenuation coefficient of 0.00001 (10^{-5})). This measured groundwater to indoor air attenuation is appropriate for the weathered clayey, silty, sandstone at the site and is consistent with the JE Model predictions. This measured attenuation is approximately an order of magnitude greater than the maximum tabulated in the 2002 OSWER Vapor Intrusion Guidance.

The measured shallow soil vapor to indoor air attenuation at the site is considerably greater (by an order of magnitude) than the 2002 OSWER Vapor Intrusion Guidance default screening value of 10 for shallow soil vapor.

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MULTIMEDIA PILOT STUDY

- ◆ A Pilot Study was designed to use contemporaneous sampling of co-spatial groundwater, soil vapor and indoor air.
- ◆ The Pilot Study was designed to use existing groundwater monitoring wells in combination with previously installed active soil vapor wells and residential indoor air sampling.
- ◆ Six single family residences were chosen proximal to existing groundwater monitoring wells.
- ◆ Four active soil vapor wells had been installed adjacent to groundwater monitoring wells. Three of these were adjacent to residences (MW-11, 12 and 13) and one was adjacent to the monitoring well with the highest VOC concentrations on the site (MW-10).
- ◆ Two active soil vapor wells were sampled from multiple depths (AV-12 and AV-13). The active vapor samples from AV-12 were collected from 9, 17 and 24-foot depths. The active vapor samples from AV-13 were collected from 8 and 19-foot depths.
- ◆ The other two active vapor wells were sampled from single depths (AV-10 at 16 feet and AV-11 at 9 feet).

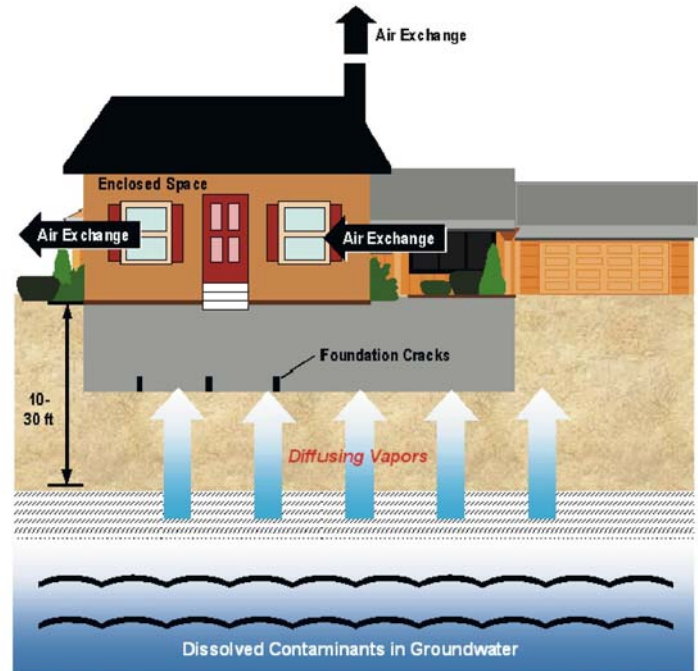
Pilot Study Sampling and Analysis Methods

- ◆ Groundwater samples were collected in 40ml VOA vials during August and January using a low-flow, Micropurge sampling systems with a stainless steel and teflon bladder pump connected to teflon lined tubing.
- ◆ Active soil vapor samples were collected in August and January from the single- or multi-depth vapor probes over approximately a 1-hour time frame into SUMMA canisters using stainless steel tubing and fittings.
- ◆ During soil vapor sampling, each well was evaluated for O₂ and CO₂ concentrations to ensure no short-circuiting from surface ambient air.
- ◆ Indoor air samples were collected from the lowest occupied living space within a residence in August and January over a 24-hour time period into “dedicated” SUMMA canisters.
- ◆ Active soil vapor and indoor air samples were analyzed for 8 VOCs by TO-15 SIM methods using reporting limits at the MDL for 1,1-DCE and TCE.

MULTIMEDIA PILOT STUDY

Data Interpretation Methods

- ◆ Data for each of the three media were evaluated for the type of population distribution and gross outliers prior to further analysis.
- ◆ For groundwater and active soil vapor the population distributions for all contaminants were determined to be approximately log normal.
- ◆ Paucity of VOC detections for all COCs except TCE in indoor air make it difficult to determine population distributions. By analogy with TCE, all COCs in indoor air are assumed to follow log normal distributions.
- ◆ The active soil vapor samples collected from multiple depths at the same location are generally consistent with the expectation of increasing concentrations of VOCs with increasing depth.



Intermedia Correlations

- ◆ Correlations between groundwater and active soil vapor for the combined results for both quarters were developed. These show good correlations between the principal VOCs in the two media significant at 80% to 95% Confidence Levels.
- ◆ Correlations between soil vapor and indoor air are very poor. This is partially the result of only three paired locations for these two media and due to the limited number of detections of most VOCs in indoor air (except TCE). Only one of the six pilot homes had detectable 1,1,1-TCA or 1,1-DCE.
- ◆ Correlations between groundwater and indoor air are also very poor. Again, the limited number of VOC detections in indoor air is the principal reason for this.

Site Specific Johnson Ettinger Model

- ◆ 1991 JE Model
- ◆ Site specific depth to groundwater of 33 feet
- ◆ Site specific capillary fringe height of 50cm based on soil type.
- ◆ Predicted no impact to residential area above 1×10^{-6} risk.
- ◆ Consistent with measured indoor air risk from TCE and 1,1-DCE vapor intrusion.

Attenuation Factors

- ◆ Using the maximum measured indoor air concentrations of TCE and 1,1-DCE from the pilot study homes results in groundwater to indoor air attenuation of approximately 100,000 (attenuation coefficient of 10⁻⁵).
- ◆ This measured attenuation is consistent with JE Model predictions for the site where the near surface geology is composed of weathered clayey, silty sandstone.
- ◆ The measured attenuation is an order of magnitude greater than the maximum tabulated in the 2002 OSWER Vapor Intrusion Guidance.
- ◆ Using the maximum measured indoor air concentrations of TCE and 1,1-DCE from the pilot study homes, compared to the measured shallow (8-9 foot deep) active soil vapor adjacent to these homes, results in soil vapor to indoor air attenuation of approximately 140 to greater than 200.
- ◆ This measured value is more than an order of magnitude greater than the default screening values for shallow soil vapor attenuation in the 2002 OSWER Vapor Intrusion Guidance.

Soil Vapor and Groundwater to Indoor Air Attenuation Factors

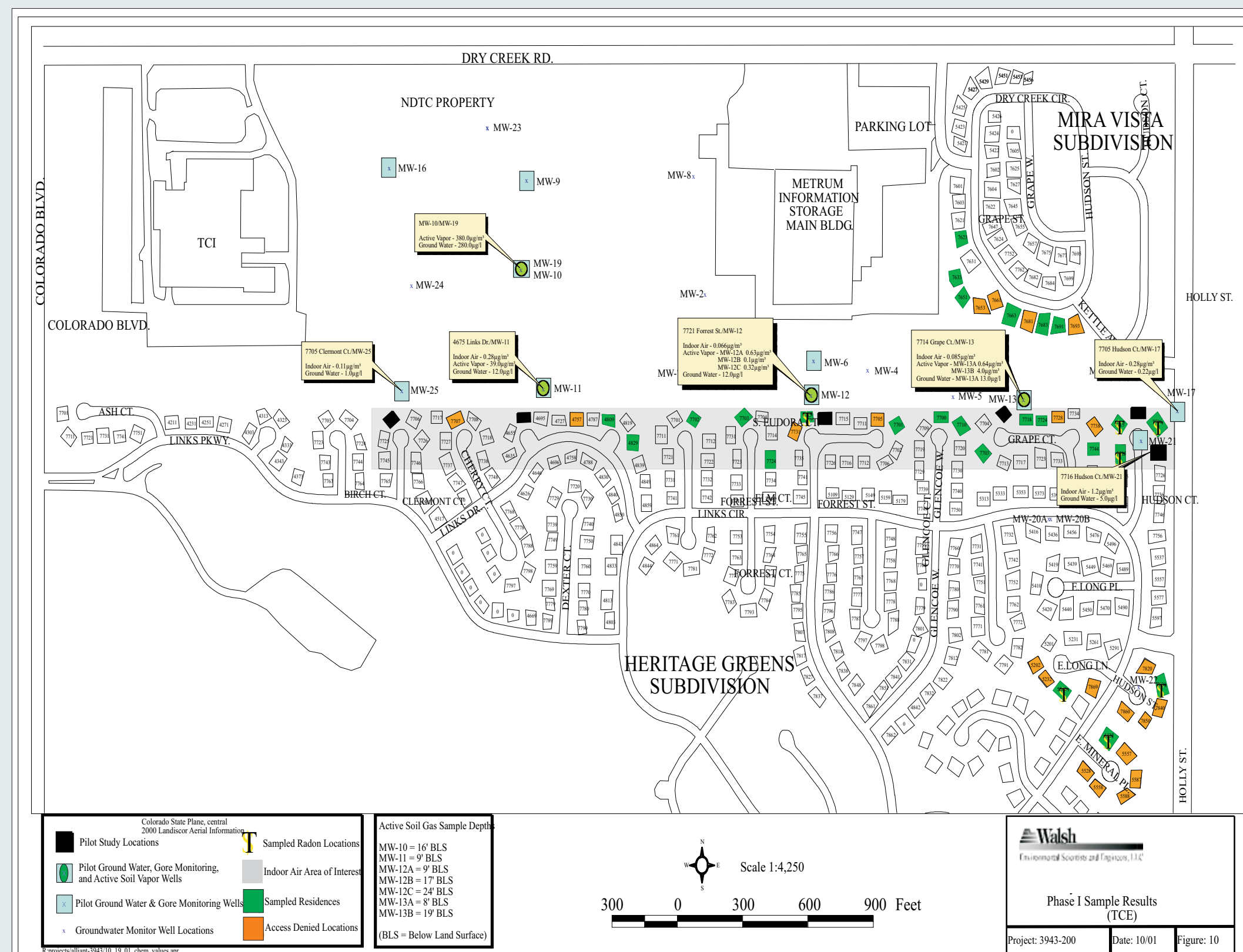
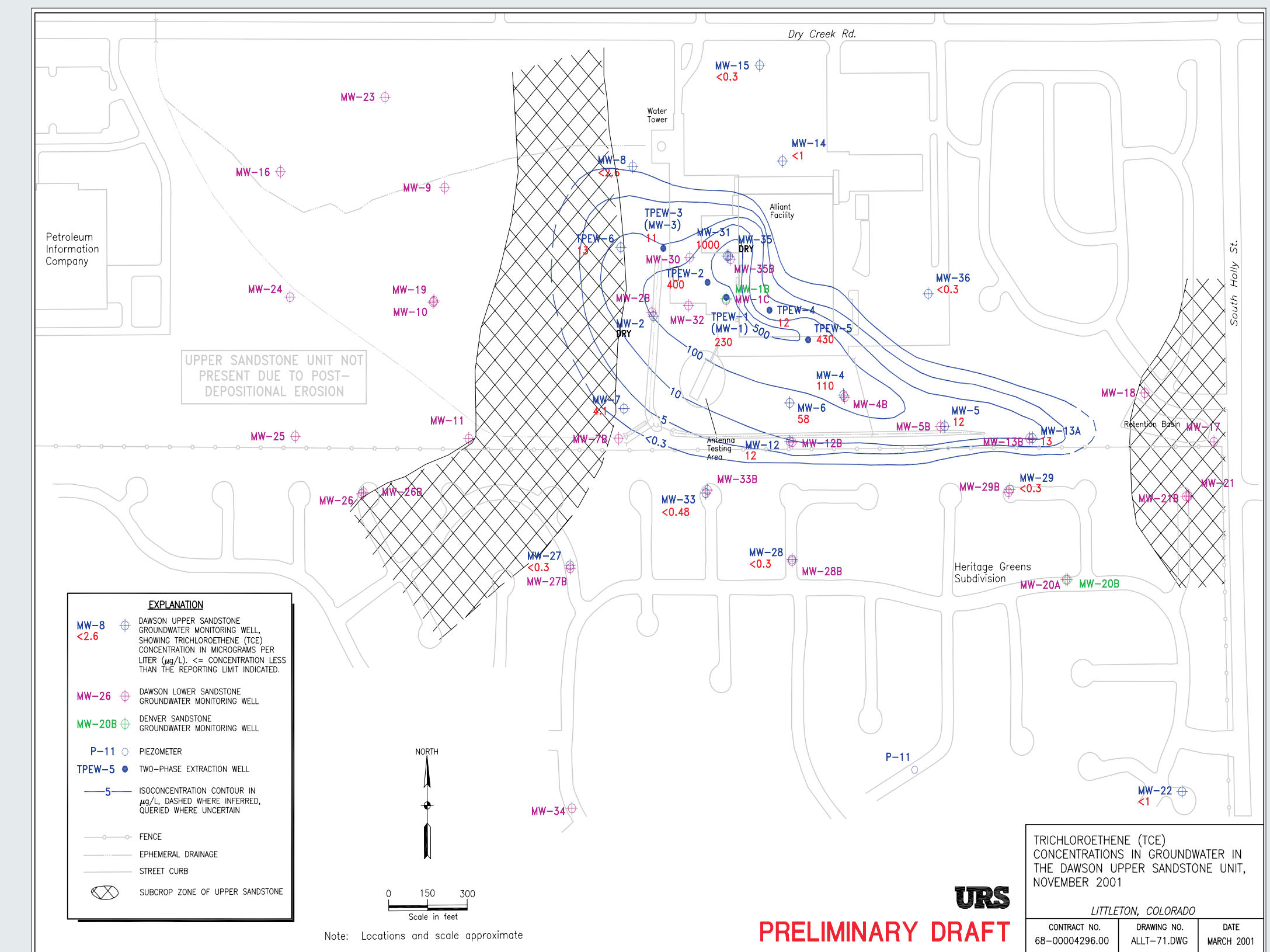
Building	DATE	IA 1,1-DCE ug/m3	IA TCE ug/m3	SV DCE ug/m3	SV TCE ug/m3	SVDEPTH feet	SVIA_ALPHA IA/SV DCE	SVIA_ALPHA IA/SV TCE	GW WELL	GW DCE ug/L	GW TCE ug/L	GWIA_ALPHA_DCE (IA/GW*HLC*1000)	GWIA_ALPHA_TCE (IA/GW*HLC*1000)	GW DEPTH feet	
4675LD	9/21/2000	<.011	0.22						MW-11						
4675LD	8/1/2001	<.011	0.28	2.1	39	9	<.0053	0.0072		6.6	12	2.40E-06	9.97E-05	18	
4675LD	1/16/2002	<.011	0.085	1.6	0.66	9	<.0069	0.1288#		4.5	11	3.52E-06	3.30E-05	18	
4675LD	1/16/2002	<.011	0.086							4.5	11	3.52E-06	3.34E-05	18	
7705CL	9/22/2000	0.011	0.1						MW-25						
7705CL	8/2/2001	<.011	.11(UFB.068)							<.07	<.09	NA	5.22E-03#	32	
7705CL	1/17/2002	<.011	0.056												
7705HC	9/15/2000	<.011	0.075						MW-17						
7705HC	7/31/2001	<.011	0.28							<.07	0.22	NA	5.44E-03#		
7705HC	2/7/2002	0.027	0.21												
7714GP	9/22/2000	<.011	0.047						MW-13A						
7714GP	8/2/2001	0.073	.085(UFB.068)	<.08	4	8	NA	<.0213#		2.9	13	3.62E-05	2.79E-05#	29	
7714GP	8/2/2001	0.023	.079(UFB.068)	<.08	4	8	NA	<.0198#		2.9	13	1.14E-05	2.60E-05#	29	
7714GP	1/24/2002	<.011	0.023	<.011	0.028	8	NA	0.8214#		2	12	7.91E-06	8.19E-06	29	
7714GP	1/24/2002	<.011	0.022							2	12	7.91E-06	7.83E-06	29	
7716HC	8/6/2001	<.011	1.2						MW-21	1.5	5	1.06E-05	1.026E-03#	16	
7716HC	1/23/2002	<.011	0.097												
7716HC	1/23/2002	<.011	0.096												
7721FS	8/9/2001	<.011	.068(UFB.032)	<.011	0.32	9	NA	<.02063#	MW-12	2.9	12	5.46E-06	2.35E-05#	28	
7721FS	1/17/2002	<.011	0.061	<.011	0.031	9	NA	1.9677#		1.9	8.8	8.33E-06	2.96E-05	28	
Footnote:	#	Alphas significantly impacted by indoor air background										MEDIAN	7.91E-06	3.30E-05	
		Henry's Law constants at 12.5C										AVERAGE	9.88E-06		
		1,1-DCE = 0.695													
		TCE = 0.234													

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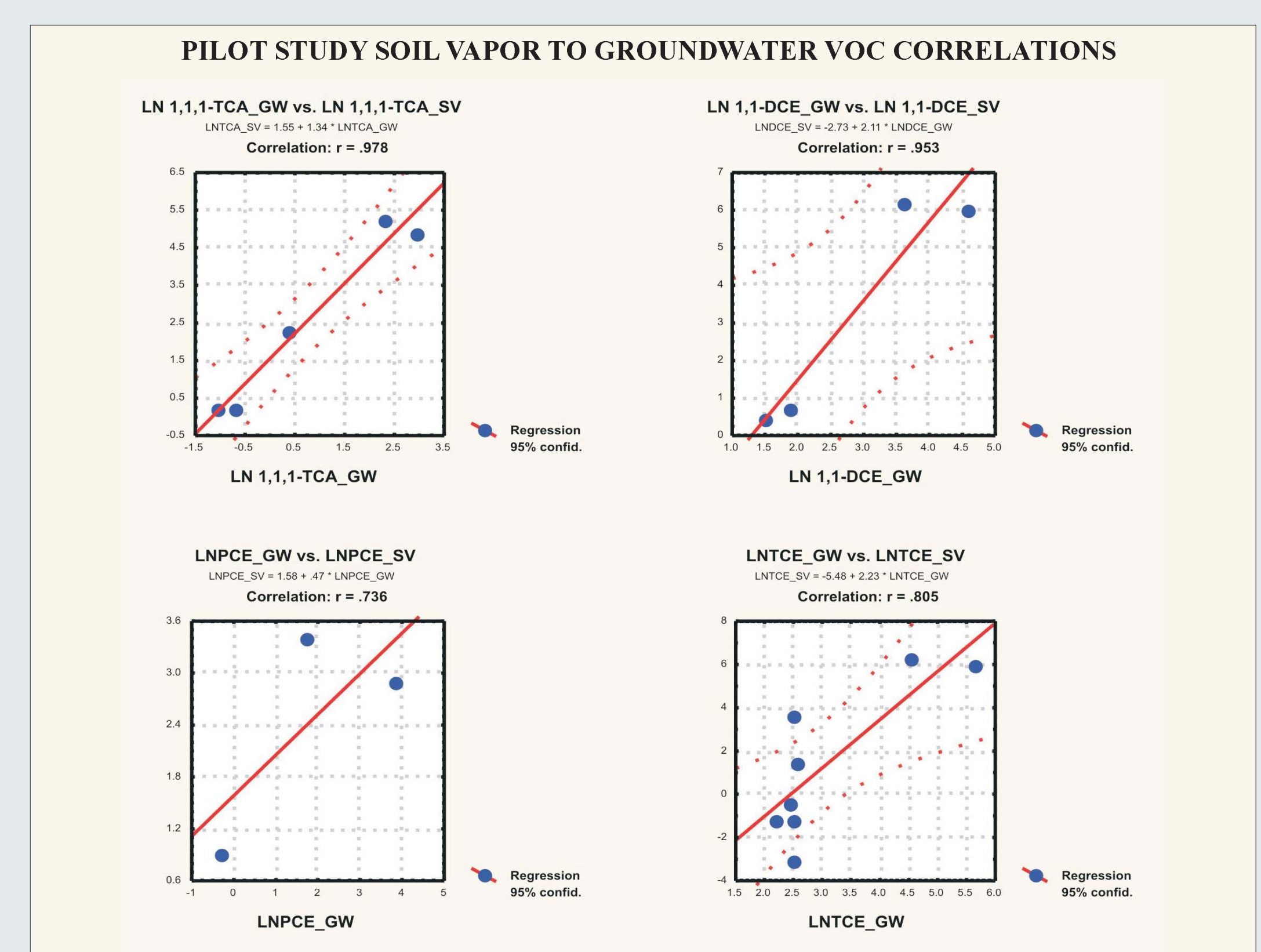
At a site in Colorado, the Johnson Ettinger (JE) model-predicted groundwater to indoor air attenuation closely matches that observed empirically; both are approximately a factor of 100,000. Shallow soil vapor to indoor air attenuation is approximately a factor of 100, similar to that observed at many other sites.

- A shallow groundwater plume dominated by TCE and 1,1-DCE originates at a local topographic and water table high. Over time the plume has migrated to the fringe of an adjacent residential area causing the Colorado Dept. of Public Health and Environment and EPA to initiate vapor intrusion investigations at the site.



- In the course of vapor intrusion investigations from 1999-2002, Johnson Ettinger modeling, groundwater, soil vapor and finally indoor air sampling were conducted for residential areas of the site.
- Seven locations were selected for contemporaneous sampling, which was conducted during two different seasons. Subsequent paired groundwater-shallow soil vapor-indoor air sampling demonstrated the lack of significant indoor air risk from vapor intrusion at the site.

- Correlations between groundwater and active soil vapor for the combined results for both quarters were developed. These show good correlations between the principal VOCs in the two media significant at 80% to 95% Confidence Levels.
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- The JE modeling (using the 1991 JE Model with site-specific depth to groundwater of 33 feet and site-specific capillary fringe height of 50 cm) predicted no impact to the residential indoor air above an excess lifetime cancer risk of 1×10^{-6} for TCE.

- Measured groundwater to indoor air attenuation was approximately 100,000 (attenuation coefficient of $0.00001 (10^{-5})$). This measured groundwater to indoor air attenuation is appropriate for the weathered clayey, silty, sandstone at the site and is consistent with the JE Model predictions. This measured attenuation is approximately an order of magnitude greater than the maximum tabulated in the 2002 OSWER Vapor Intrusion Guidance.

- The measured shallow soil vapor to indoor air attenuation at the site is considerably greater (by an order of magnitude) than the 2002 OSWER Vapor Intrusion Guidance default screening value of 10 for shallow soil vapor.

- Measured attenuation factors for groundwater-indoor air (approximately 100,000), and for shallow soil vapor-indoor air (approximately 100) at the Site were similar to factors determined at the more extensively sampled HQ CDOT Site in Denver, Colorado.

Attenuation Factor Table

Data Source	Approximate Attenuation Factor	
	Groundwater to Indoor Air	Soil Vapor to Indoor Air
Site, Littleton, CO	8×10^{-6} to 3×10^{-5}	0.007
HQCDOT Site, Denver, CO ¹	3×10^{-5}	0.006 ²
OSWER Guidance	10^{-2} to 10^{-4}	0.1 to 0.01

Note 1: Johnson, P.C. and others, 2001, API Tech. Bull.
 Note 2: Walsh, 1997, Evaluation of Subsurface Vapor Migration Via Utility Pathways
 CDOT MTL (Task 3, Table 12)

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