An Update on EPA VI Activities

EPA Region 3 States RCRA CA Workshop

Bedford Springs, Bedford, PA

April 2, 2009

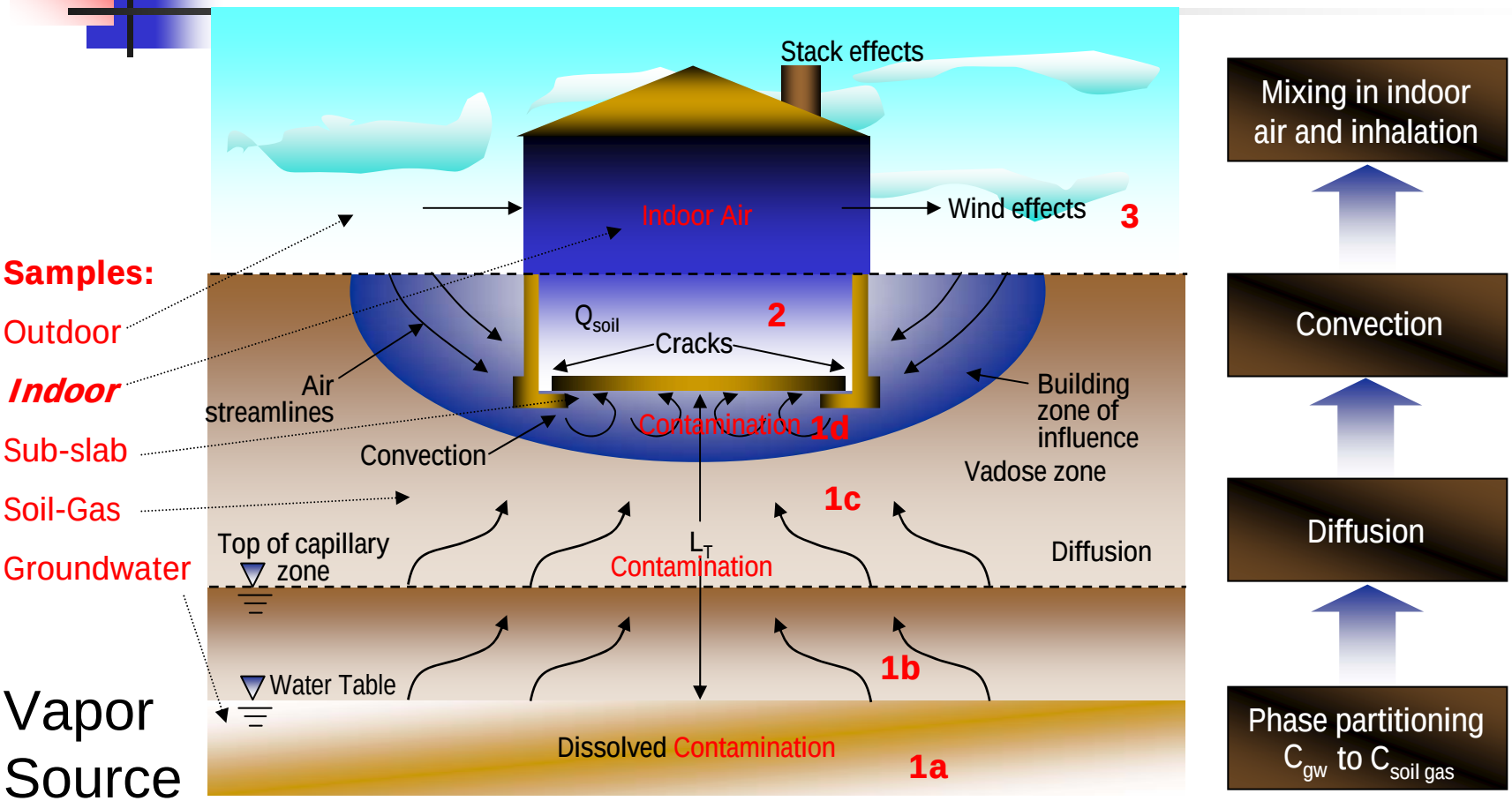
Presented by:

Henry Schuver, DrPH

USEPA – Office of Resource Conservation & Recovery (ORCR)

See: http://**iavi.rti.org** & www.envirogroup.com/vaporintrusion

Conceptual model of the vapor intrusion exposure pathway



Mod. from slide by M. Bolas, Ohio EPA, presented Jan. 2006

Overview of the VI Pathway

- *Chemicals* with evidence of toxicity, e.g.,
  - PCE, TCE, DCE, VC, ...
    - Carcinogenicity, neuro- & immuno- developmental ...
- Evidence of migration to receptors
- Exposure point conc. > ‘acceptable’
- Inhalation is relatively unavoidable
  - ‘Uninvited guest’
    - Many similarities to tap-water exposures

Exposure Factors
(Water Ingestion & Inhalation – per Day)

- Water - **2** liters/day of water (ingestion) *voluntary*
- Air - **20** m^3/day (20,000 liters/day) of air (inhalation)
  - Exposure factors **1:10** (in units of 2 l/d and 20 m^3/d)
  - **For equal Exposures per DAY:**
    - Inhalation conc. (in m^3/d) should be **1/10** of Ingestion (in l/d)
  - <u>Comparing similar exposure Conc.: Exposure Daily</u>
    - **MCL = 5 ug/l** (water) (x 2 l/d = 10 ug/d)
    - Similar exposure ~ 0.5 ug/m3 (air) (x 20 m^3/d = 10 ug/d)
      - Example indoor air concentrations:
      - **1** ug/m^3 ~ exposures from an **MCL** of **10** ug/l
      - **10** ug/m^3 ~ exposures from an **MCL** of **100** ug/l
      - **100** ug/m^3 ~ exposures from an **MCL** of **1,000** ug/l

Dominant Features of VI Pathway

- Uncertainty
  - Lack of knowledge
    - Reducible (in theory; e.g., intervening geology)
- Variability
  - Known to vary (range of *y*), but is unpredictable
    - Irreducible (e.g., pressure differences in subslab-indoor)
    - Need statistics (populations of data) to describe - historical
      - Temporal (variation across Time)
      - Spatial (variation across Space)
        - Commonly get both simultaneously

Introduction to ‘Road Map’

- Since the 2002 guidance was issued:
  - Number of sites where the vapor intrusion pathway has been evaluated

    and
  - Understanding of the vapor intrusion process
- have grown substantially

EPA's 2002 Guidance Remains Generally Protective

- While the approaches in the 2002 draft guidance remain generally protective:
- Since 2002 there have been improvements in:
  - Understanding of the *science* behind vapor intrusion
    - and
  - *Methods* to address it

Since 2002, the Agency has been working closely with the ITRC

- ITRC (2007) provides:
  - A wide variety of methods used by various states
  - Guidance for the mitigation of vapor intrusion
- The ITRC document illustrates:
  - Advantages and disadvantages of currently available investigation techniques
  - Benefits of using multiple lines of evidence when investigating vapor intrusion

In addition to working with the ITRC

- The Agency has been assembling and evaluating empirical data from vapor intrusion sites throughout the country
  - and
- Is producing additional policy and technical tools for use by VI investigators

Additional EPA Policy & Technical Tools

- National Vapor Intrusion Database
- Conceptual Model Scenarios of VI Processes
- Background Indoor Air Concentrations
- Brownfields VI Primer
- VI in Non-Residential Settings
- TCE & VI Memorandum
- Lessons from Radon Studies

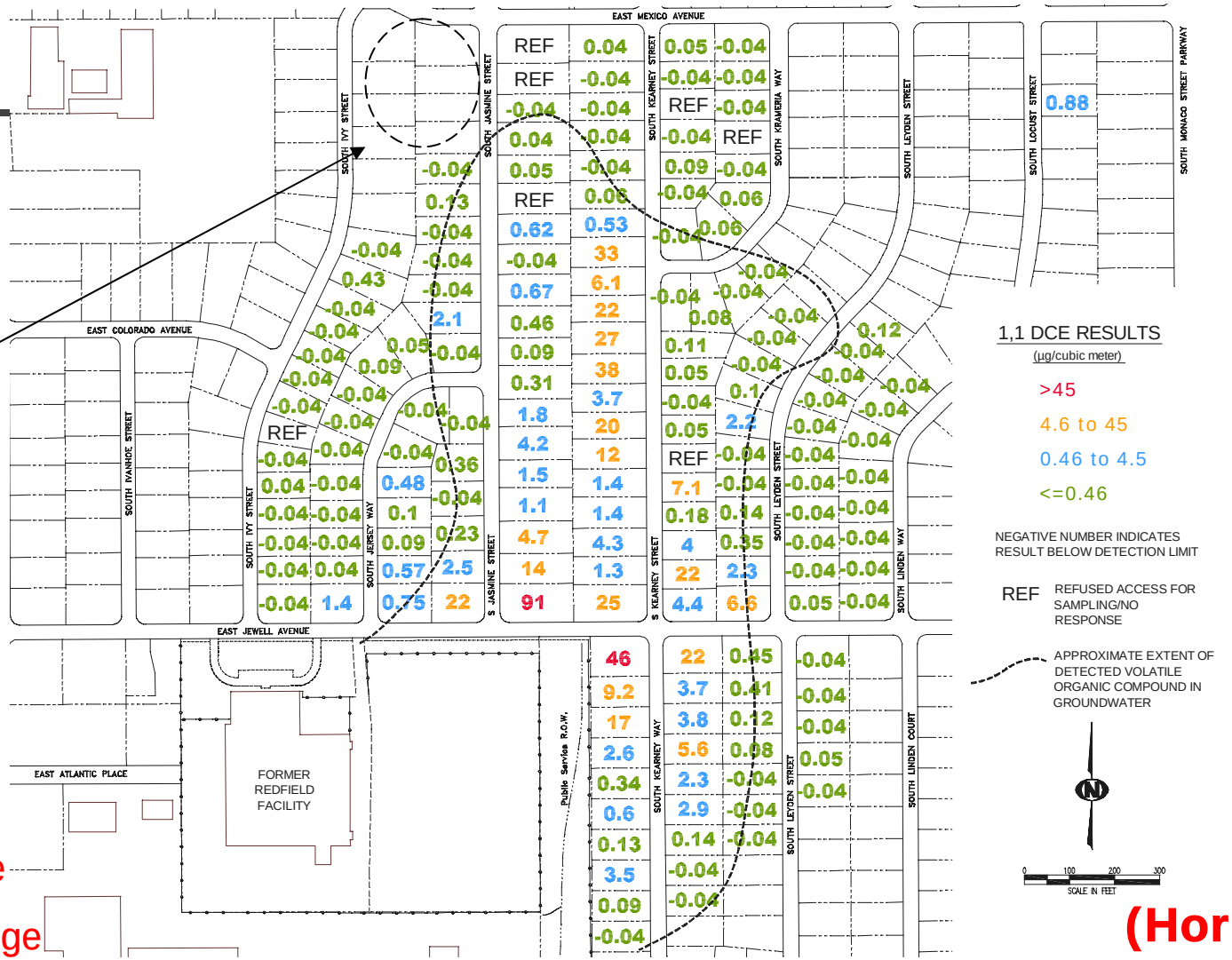
Summary of our VI Experience to-date

- Our investigations have found that **spatial** and **temporal** impacts on volatile organic chemical (VOC) concentrations are ***highly variable***
- Some is due to:
  - vertical and horizontal differences in **subsurface** conditions and the
  - differences in **building** structural conditions, such as foundation cracks, and ventilation rates from one building to another
  - **weather** conditions, such as rainfall and barometric pressure

1,1 DCE in Indoor Air

(Redfield Facility, Denver, Colo., Folkes, 2000)

Area did not meet 2-clean-house rule



"point" in time

- Temporality

- Mobile plume

10x Conc. range over time (Folkes 2009)

(Horizontal)

Vapor Source Area Characterization Needs

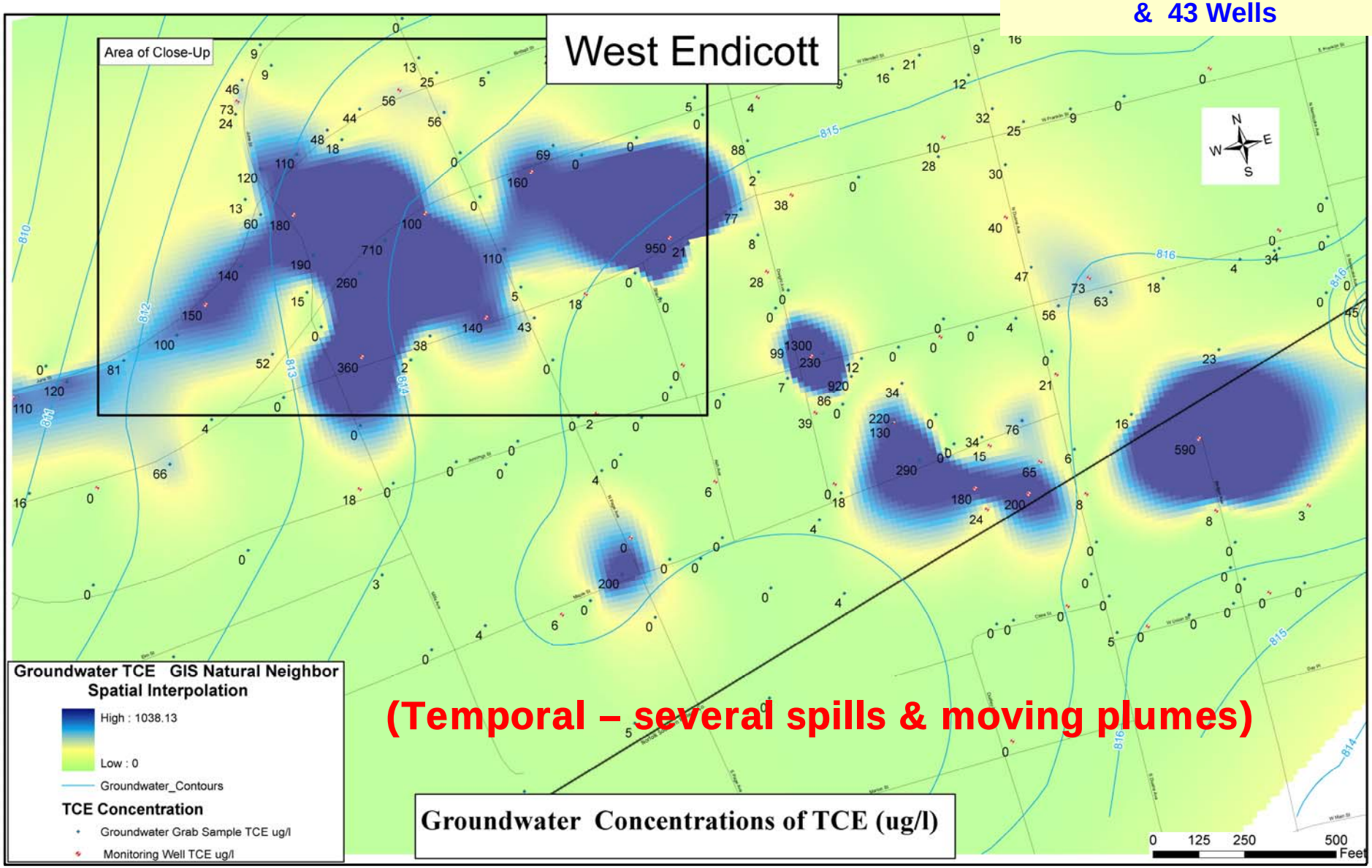
Identify the Nature and Extent of Contaminant Source

From Dr. Wertz, NYSDEC

Note

Groundwater Data Collected September 2007-December 2007

From 125 Water Table Grabs & 43 Wells



(Temporal – several spills & moving plumes)

Sub-Slab Concentrations at House B Raymark site, CT

Probe C is **Not** a sample of the "true" source of intruding vapors?

> 44 x

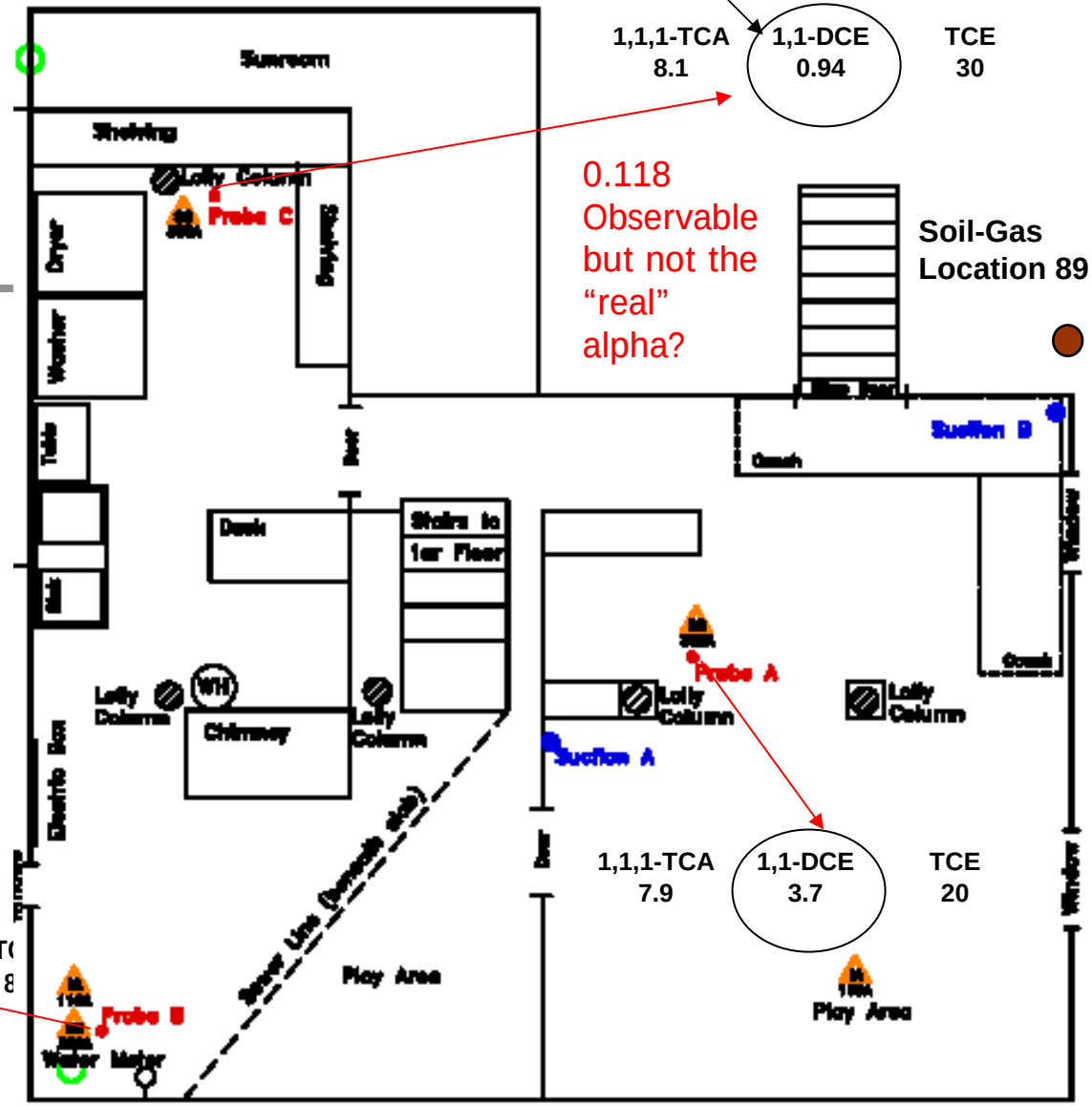
MW215 showed no VOCs

2008 - Now we ask, which sub-slab sample do we use for alpha?

Ranges!

Slide by **D. Digiulio** (EPA-ORD)

w/ mod. HJS

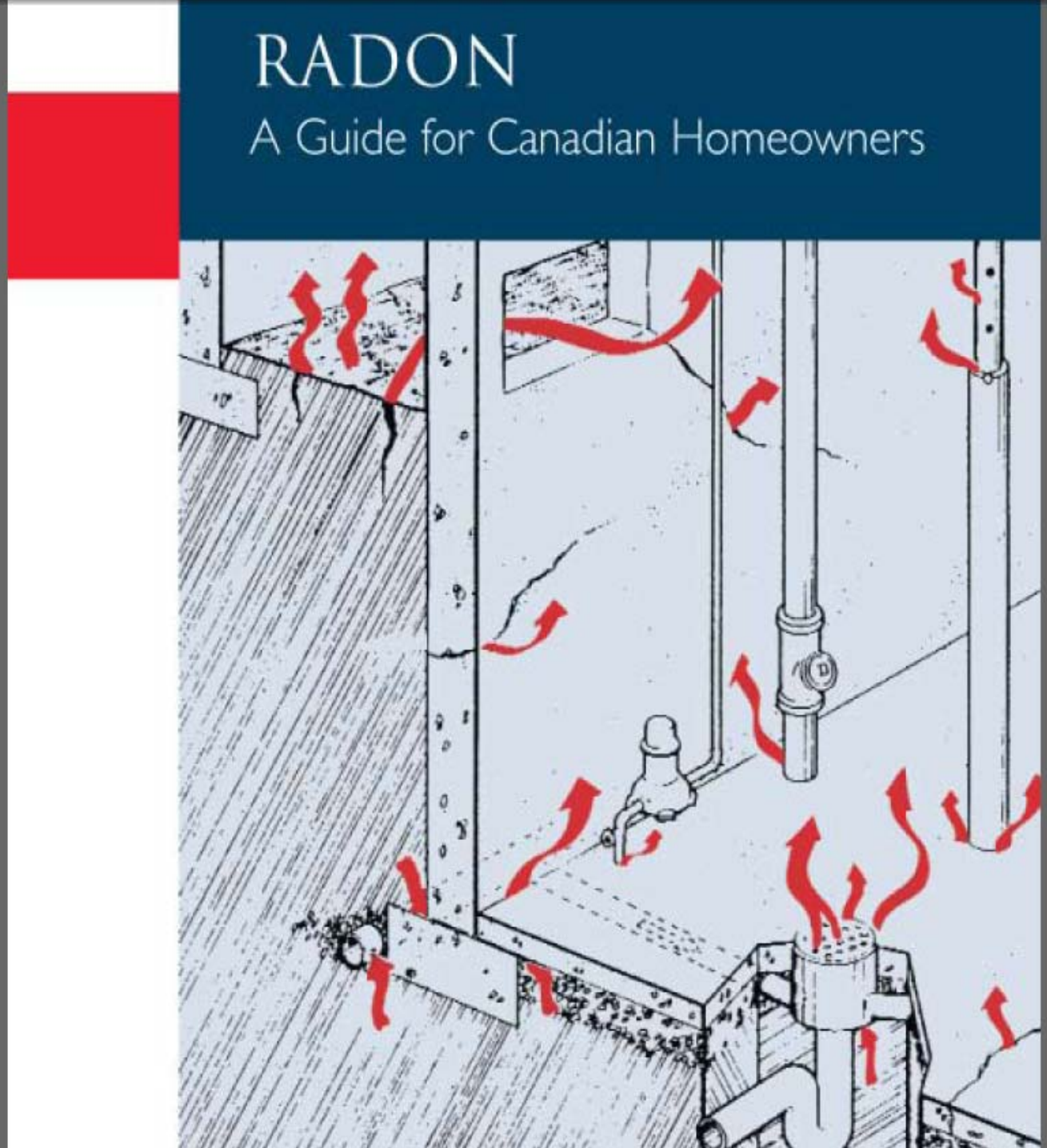


Using sub-slab *mean* – $Alpha_{ss}$ = 0.11/**16** = 0.0065

Using sub-slab point **C** – $Alpha_{ss}$ = 0.11/**0.94** = 0.118

Indoor Air 11DCE = 0.11 ug/m3

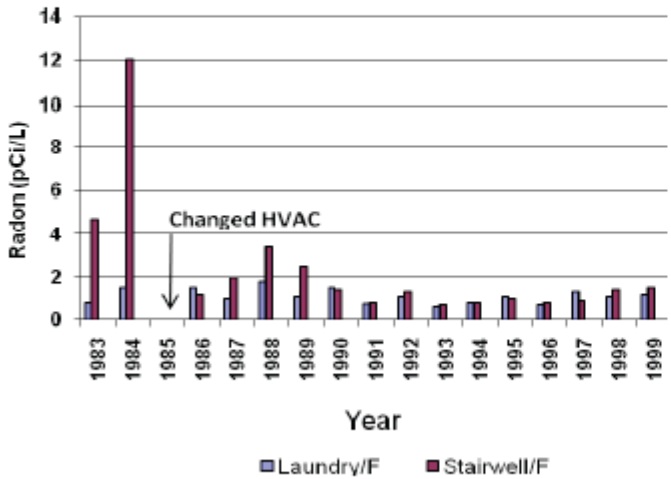
Radon workers are ahead of us



Steck 2007

Examples of (unpredictable) long-term changes – occupant influenced

American Association of Radon Scientists and Technologists 2007 Proceedings
Of the 2007 AARST International Symposium Jacksonville, FL, 2008©AARST



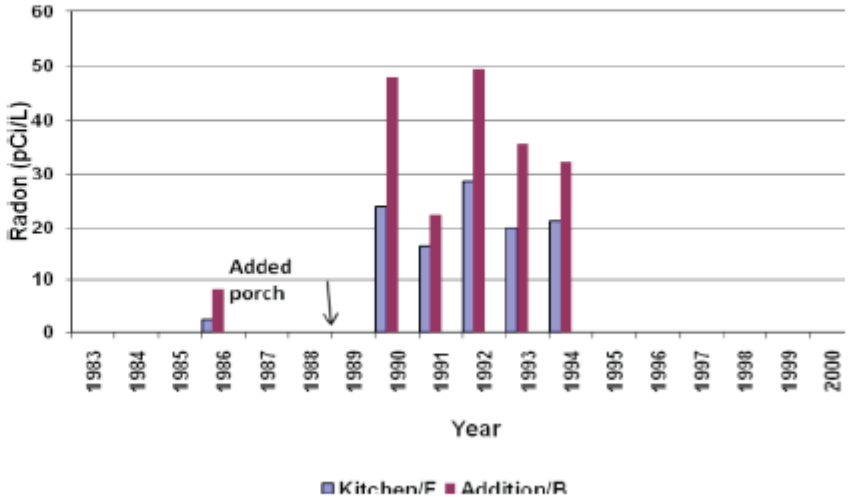


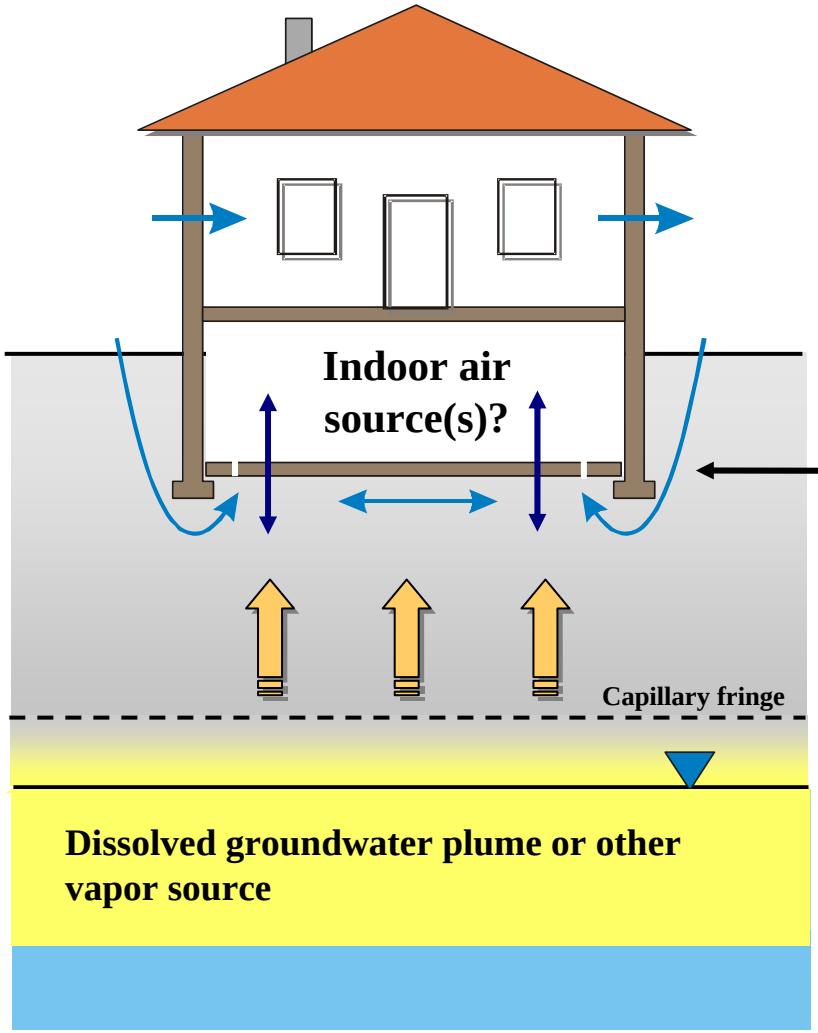
Figure 4 Examples of large radon changes created by house modifications

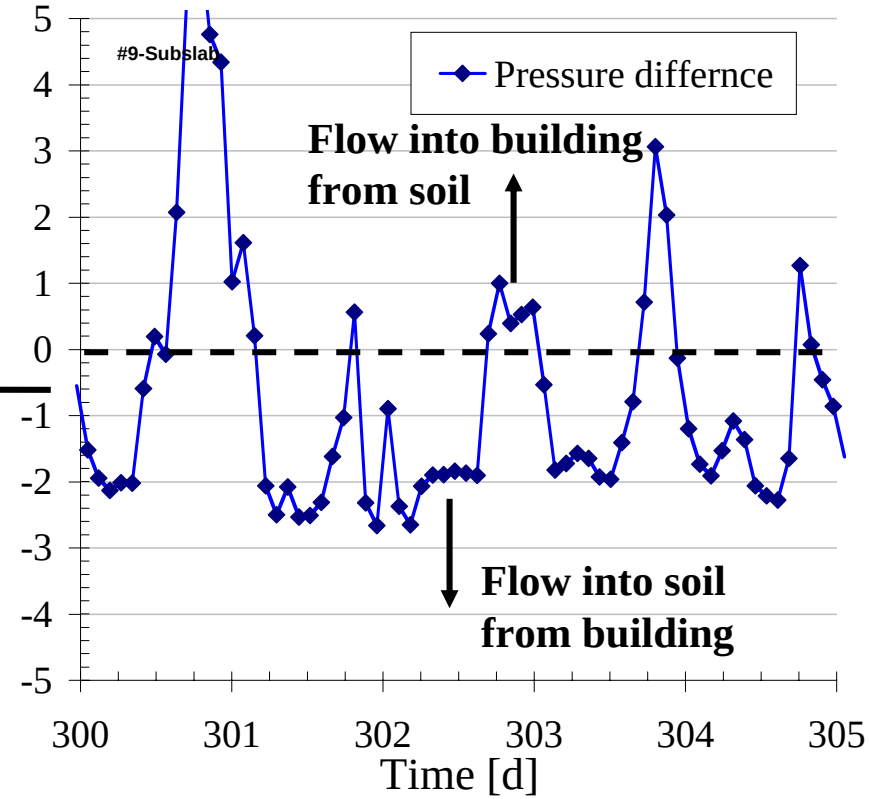
American Association of Radon Scientists and Technologists 2007 Proceedings
Of the 2007 AARST International Symposium Jacksonville, FL, 2008©AARST

http://www.aarst.org/proceedings/2007/8-SteckYTYRnvariation07.pdf

Challenges with the MLE Approach

[temporal variability in sub-slab and near-foundation data]





Temporal Variability
Building Breathing

Steck ≤ 2004*

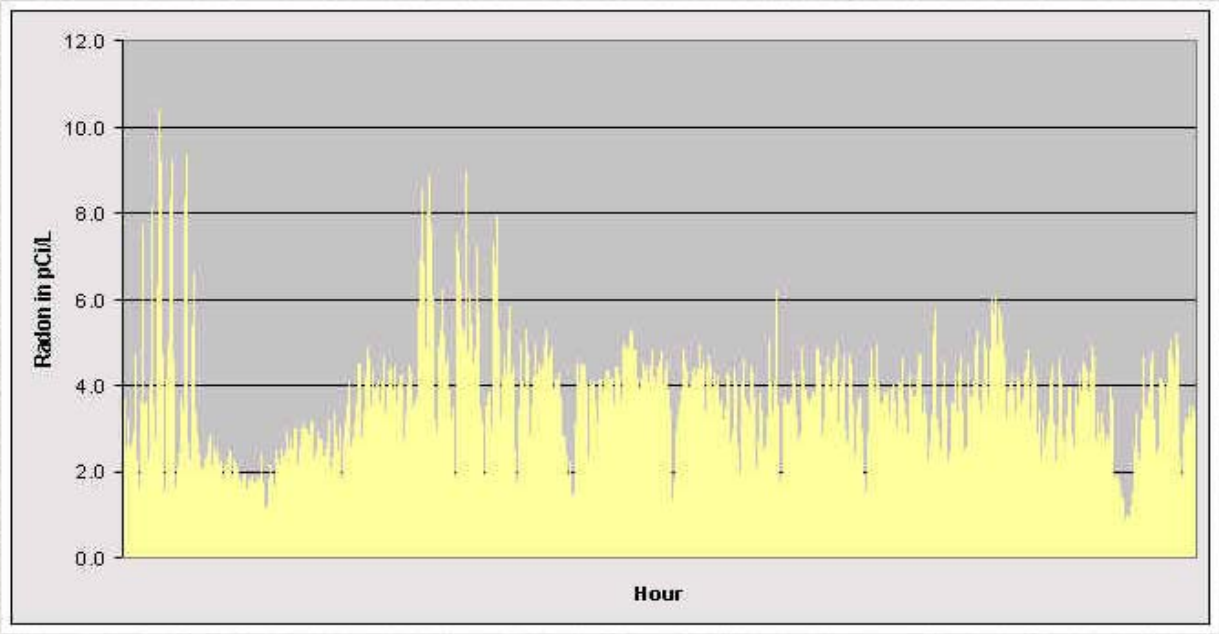
http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

Indoor radon variation with time and location

concentration in your home? That depends on which room you measure and what time that you measure. If you are interested in radon because of its health risk, you should m
e rooms that are frequently occupied by people.

Hour-to-hour

f the hourly average radon in a house from the beginning of January to the end of March 1995. Note that the average radon concentration ranged from a high of 10 pCi/L to less
verage over the period was 3.8 pCi/L. That's why a measurement that lasts only a few hours can give such a false reading of the long term average.



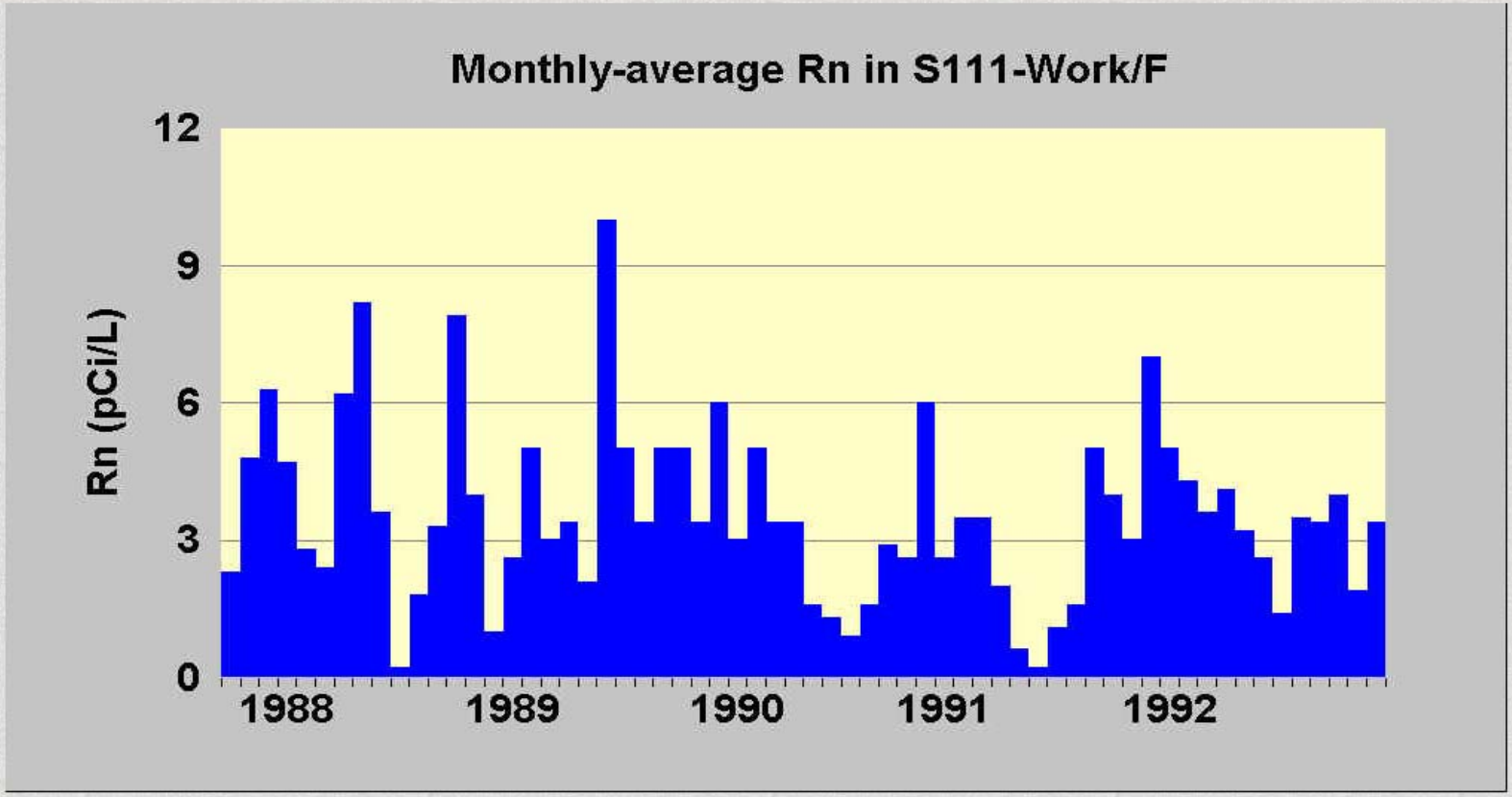
* Last update to website

Steck ≤ 2004

http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

Month-to-month

Here is a graph of the monthly average radon in a house for the period from the beginning of January 1988 to January 1993. Note that the average radon concentration ranged from a high of 10 pCi/L to ess than 1 pCi/L. The true average over the period was 3.5 pCi/L. Even a month-long measurement can be quite far from the long-term average.



f you analyze this graph for seasonal variation, you will find the highest readings in spring and fall, with summer being the lowest. Spring and fall are seasons of active weather at this site that often requires hat the house be closed and heated. heating

A draft-map for the road ahead

- A description of the current state of OSWER's guidance on the investigation and mitigation of vapor intrusion

- Ensure VI regulators will have a:
  - ***complete toolbox*** for addressing VI
  - with ***confidence*** *and* ***efficiency***

Two Key Assessment Guides:

- USEPA OSWER Draft Guidance for Evaluation the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (2002)
  - 1 - Generic (source) conc. screening values (Table 2) [e.g., MCLs]
  - 2 – Semi-generic (source) screening values (Fig. 3) [constrained model]
  - 3 – Indoor air (and sub-slab) screening values (i.e., interior samples)
  - http://www.epa.gov/epawaste/hazard/correctiveaction/eis/vapor/complete.pdf

- Interstate Technology & Regulatory Council (ITRC) Vapor Intrusion Pathway: A Practical Guideline (2007) (VI-1) *[not 1A]*
  - Additional methods and approaches for (more) investigations
  - 3 "primary decision-making tools" 1) Generic levels, 2) Models, 3) MLE
  - Refers to regulatory guidance & criteria for all regulatory decisions
  - http://www.itrcweb.org/Documents/VI-1.pdf

    - Inter-related and together form a state-of-the-art toolbox

EPA's 2002 Guidance Remains Generally Protective

- Framework & guidance for evaluating *individual lines* of evidence remain generally* protective:
  - However, increasing recognition of the variability & factors involved (esp. in exterior-based samples)
- No single media data set (gw, soil- or subslab-vapor, or indoor air) can be fully reliable for evaluating VI potential
  - i.e., single lines of evidence screen-outs are no longer appropriate (e.g., in Tier 2b)

    - * exception is deep soil-gas (w/ alpha of 1/100 (0.01))

Multiple Lines of Evidence (MLE) in the **EPA** Guidance

- EPA Guidance (2002) illustrated:
  - How relatively <u>few lines</u> of evidence can be used to responsibly screen sites ***in*** to concern for VI, and
  - Recommended that decisions to screen ***out*** sites (<u>after the first Tier</u>) "be based either upon <u>definitive measurement data</u> or upon multiple lines of converging information"
    - (e.g., Sec. V & Appendix A)

Multiple Lines of Evidence (MLE) in the **ITRC** Guide

- The ITRC Guide (2007) illustrates:
  - How multiple lines of evidence can be used to challenge sites screened ***in*** under the EPA guidance w/ 1 or 2 lines of evidence:
    - For example, the most in-depth discussion of MLE (Sec. 3.7.3) involves the MLE evaluation of indoor air data from a building that is currently screened in because it is:
      - 1) located above a subsurface vapor source, &
      - 2) has been found to have indoor air COC concentrations above screening levels

ITRC (2007) Sec. 3.7.3 suggests using Multiple Lines of Evidence, e.g.,

- *Expected* **attenuation factors**
- **J&E model *estimates***
- **Comparison to indoor background levels**
- **Comparison to outdoor (ambient) levels**
- **Chemicals of Concern**
- **Building construction and current condition [future?]**
- **Subslab data**
- **Constituent ratios (in soil gas and in groundwater)**
- **Marker chemicals**
- **Spatial correlations**
- **Concentration and pressure gradients**

- which are used to support a "professional judgment" as a part of a "successful exit strategy"
  - i.e., <u>to see if it can be</u> "***demonstrated*** through multiple lines of evidence that an indoor air concentration above a remediation goal is ***not*** derived **from a *subsurface source***"
- Or, alternatively, to "confirm" vapor intrusion

Indoor Air & Subslab as MLE

- While some parties my be interested in such extended MLE analyses:
  - One of the increasingly common, and apparently most successful, applications of MLE for determining if unacceptable VI is occurring is:
  - After consideration of the extent of the vapor source area, and the CSM;
- The comparison of individual building's *indoor air* and/or *sub-slab* concentrations
    - Complementary strengths & weaknesses (space & time)

Indoor Air & Subslab **Matrix**

- This often involves using a matrix of various combinations of sub-slab and indoor air results to help make:

- Evidence-based management decisions;
  - (more reliable than “professional judgment”)

  - Such as has been developed and used in New York, as well as EPA Regions 2, 3 & 5

In summary, OSWER believes:

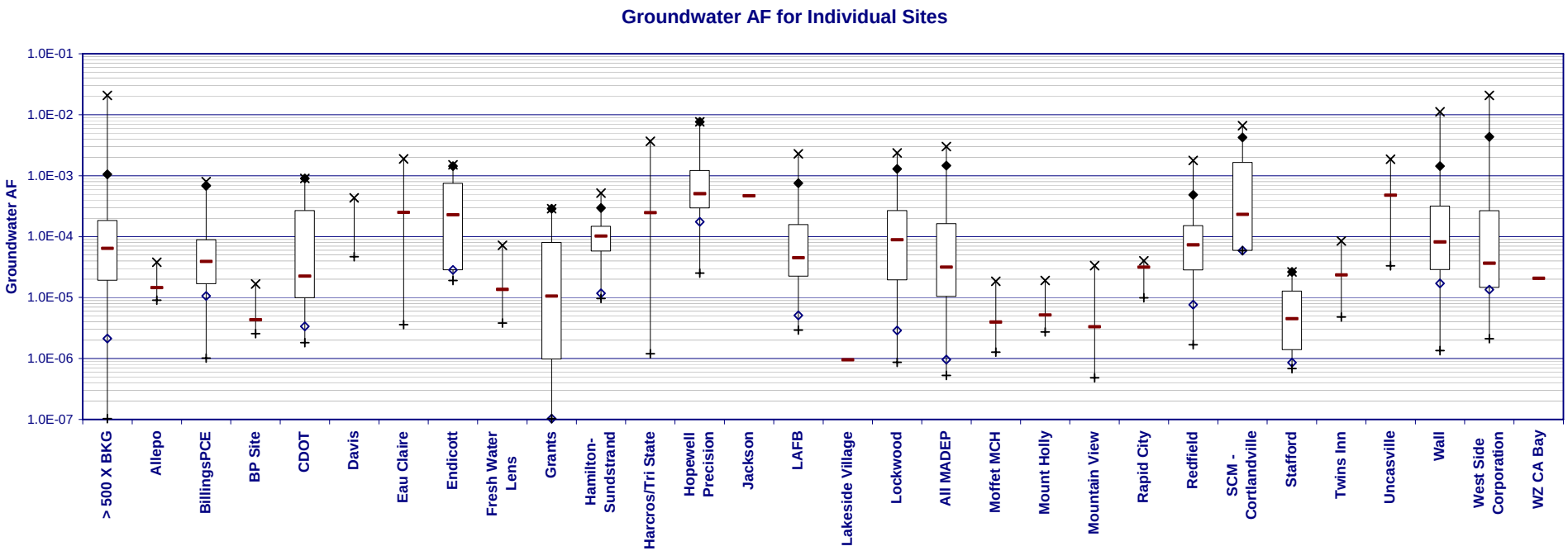
- It is often useful to collect sufficient data to evaluate two or more of these lines of evidence in parallel
  - For example, Regions should consider if it may be more *expeditious and cost-effective* to <u>sample indoor air</u> directly where there is existing ground water or sub-slab soil gas data that suggest the potential for a VI problem
    - e.g., As an alternative to external sampling & predictions

National Vapor Intrusion Database

- 2,200 paired samples
  - (external and indoor-air)
- 1,100 buildings
  - 44 sites
    - 13 states

- Draft version available 2008
- Public & Peer review 2009
- Final version 2010

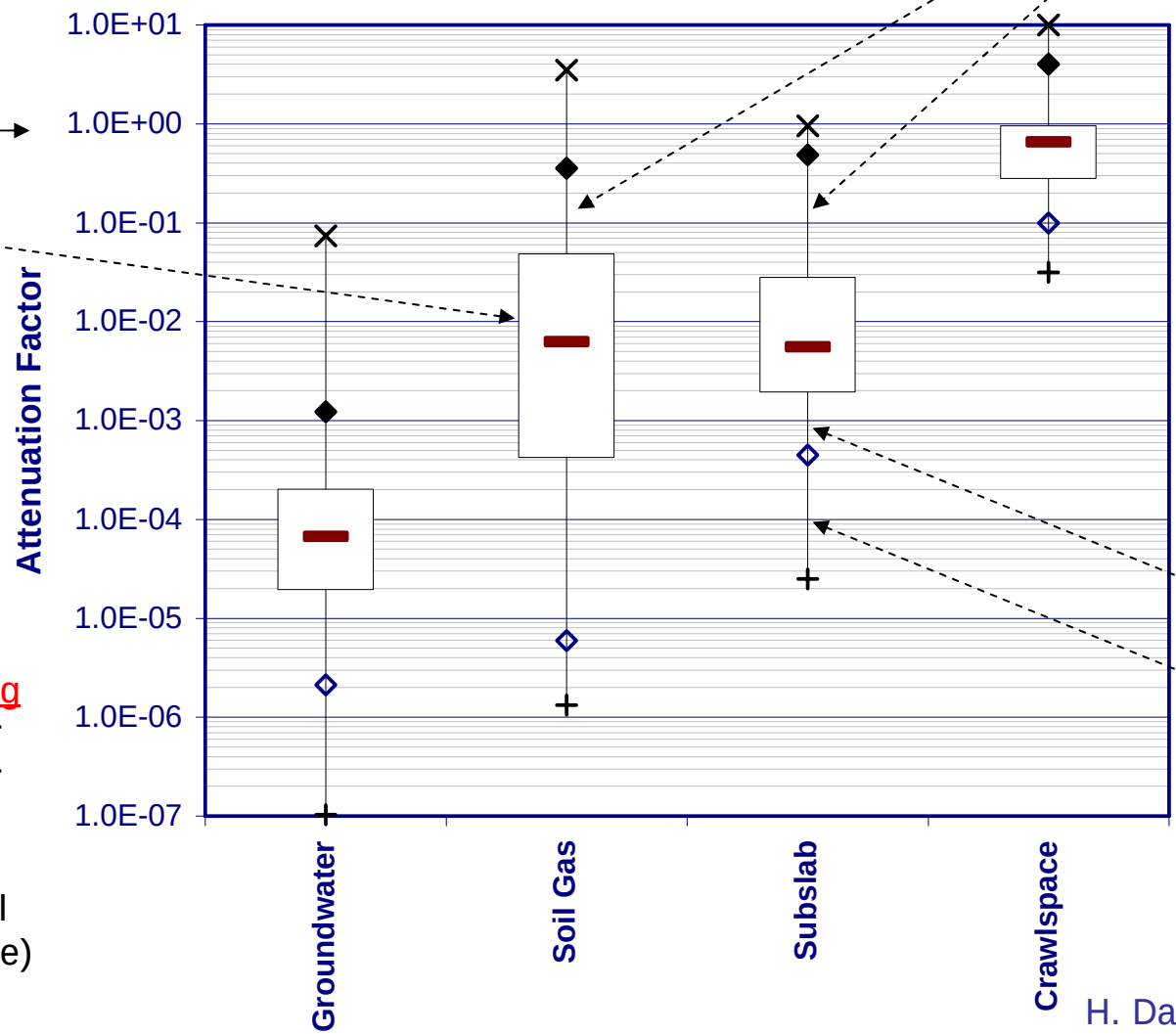
Groundwater-to-Indoor Air Attenuation
Individual Site Box Whisker Plots



Note, using the filtering criteria that are build into the database, one can look for sites in the database that have similar characteristics (geologic setting, depth to water, grain size etc.) to a new site of interest to get a sense of what the range of attenuation is that new site might be.

H. Dawson 8-12-2008

Vapor Intrusion Database Summary & Conclusions



2002 "deep" soil-gas default (0.01)

Currently available: http://iavi.rti.org (click on "Other Documents" for the document; and register for access to actual data in database) Final in 2009

H. Dawson 8-12-2008

Summary of the National Vapor Intrusion Database

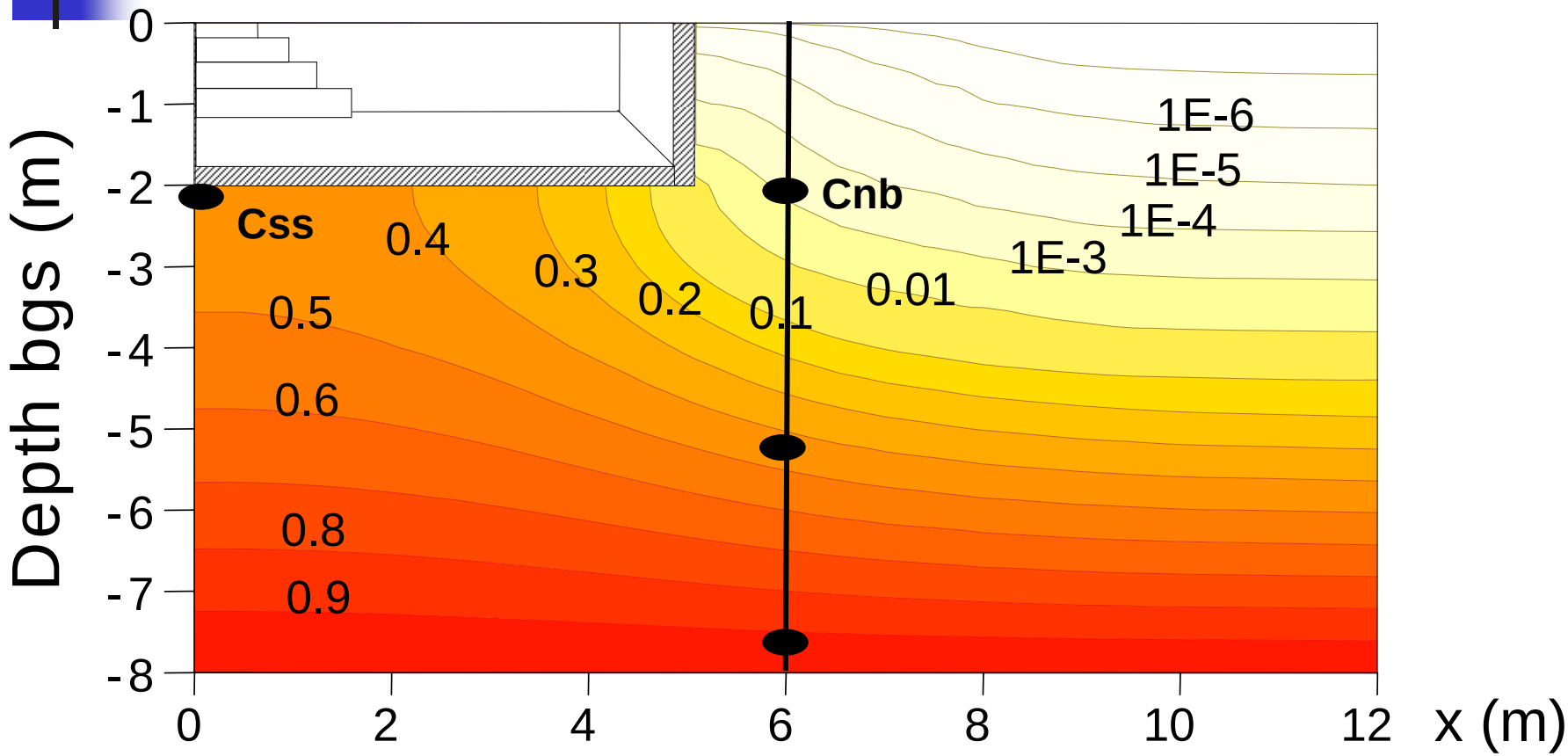
- This dataset is consistent with:
  - 1) the media-specific generic attenuation values presented in EPA 2002 (for groundwater, sub-slab and crawl-space samples,
    - but ***not*** *for external* (“deep”[0.01]) ***soil-gas***)
  - 2) the wide variability found in EPA’s detailed study of external Radon soil and soil-gas samples and their unsuccessful use in the quantitative prediction of indoor air Radon concentrations
  - 3) the EPA 2002 Tier 3 recommendations for using interior structure (indoor air and/or sub-slab) samples for the quantitative assessment of VI into individual buildings

Conceptual Model Scenarios (CMS) of VI Processes

- Provides theoretical overview of vapor intrusion processes and pathways under a number of various scenarios
- Assist visualization of processes and pathways
  - that can explain observed variability

- Draft version summer 2009
- Final version 2010

Representativeness of Soil Gas? Exterior Soil Gas vs. Subslab



Cnb: near building soil gas concentration
Css: subslab concentration

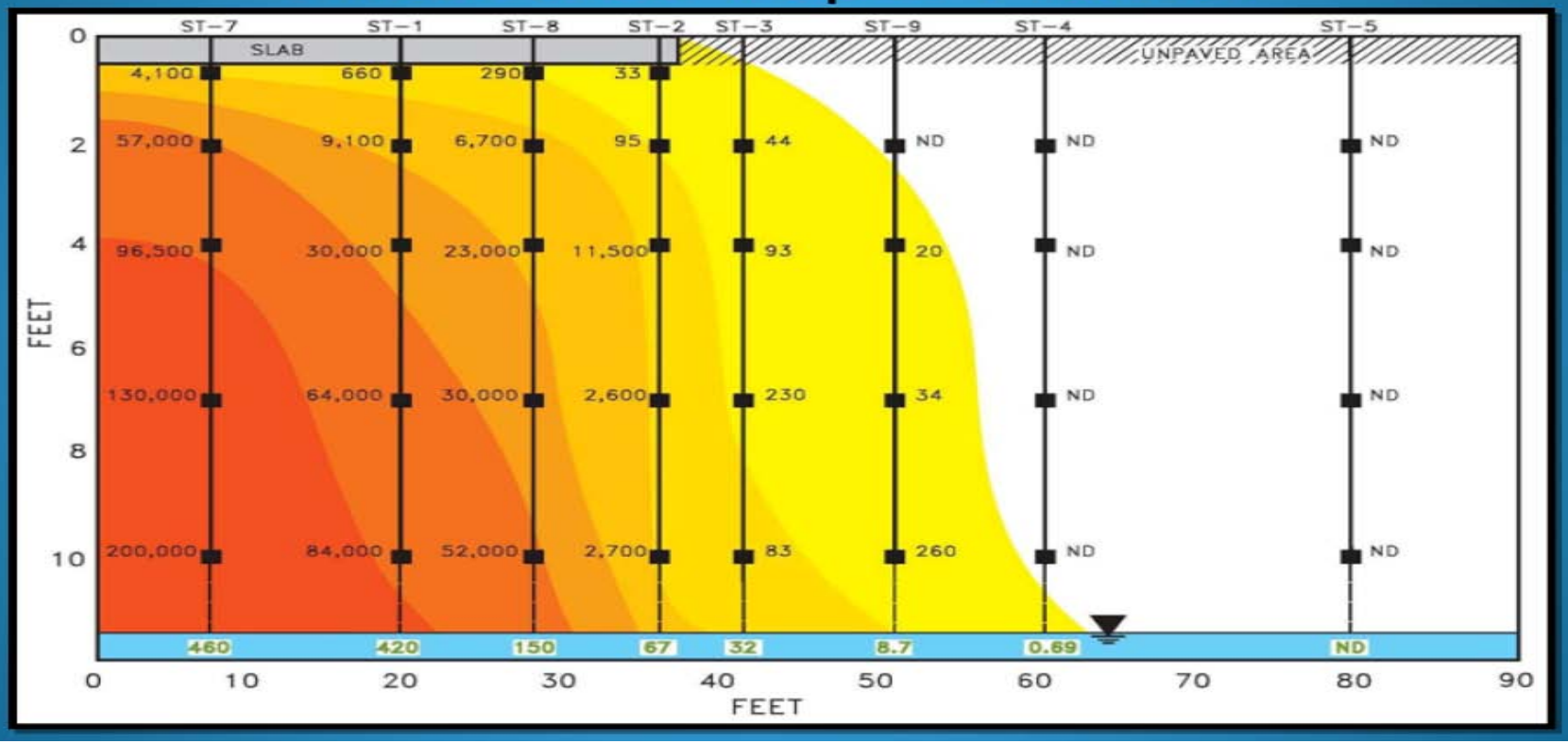
L. Abreu, 2006

Research by EPA-ORD (Brian Schumacher)
Presented by J. Elliot, Tetra-Tech VI Symposium, Feb. 24, 2009 [Lemoore NAS]

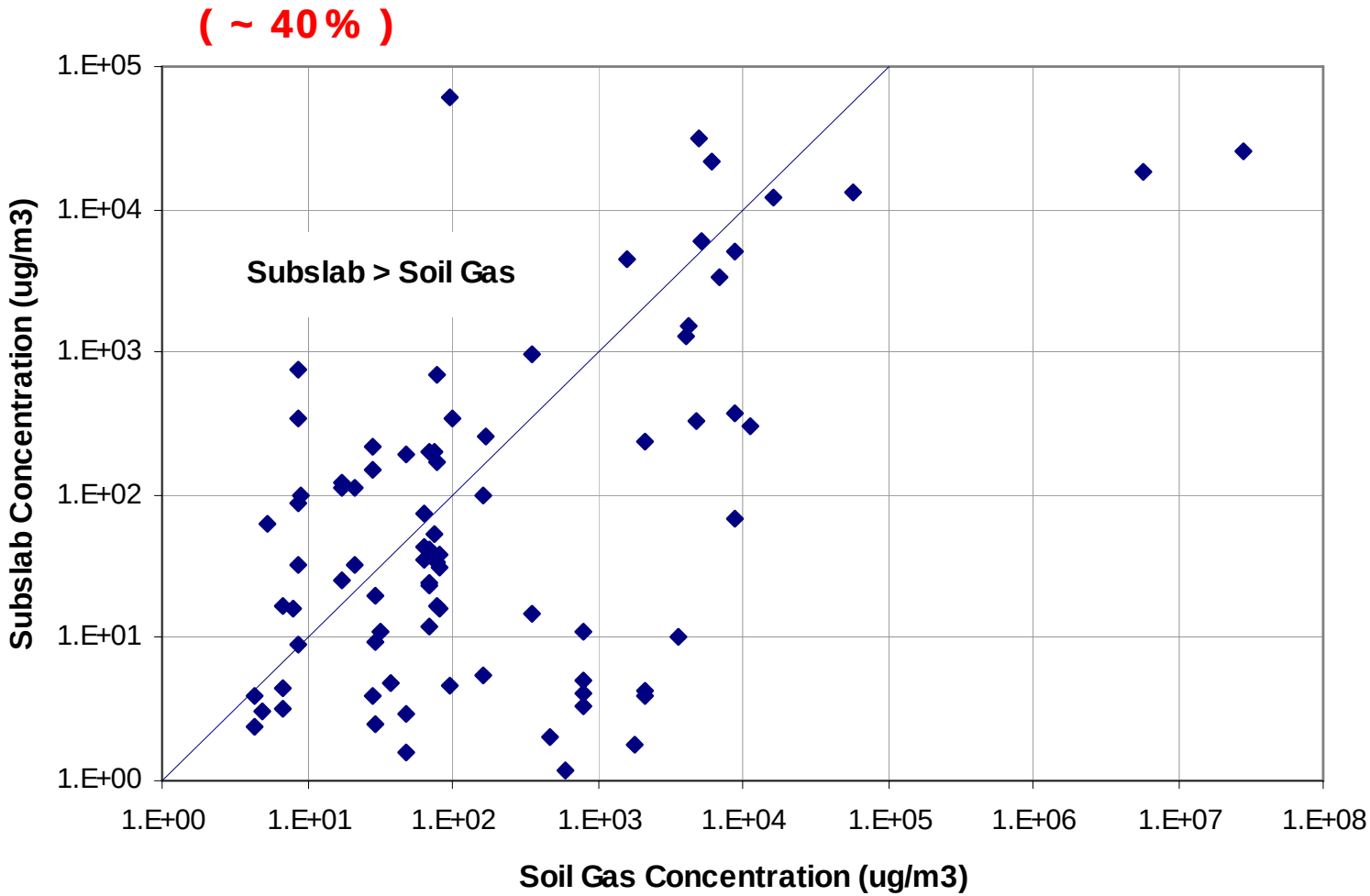
Spatial variability (w/ vertical)

TETRA TECH

Measured Vapor Profile



Vapor Intrusion Database example Exterior Soil Gas vs. Subslab



H. Dawson 8-12-2008

Summary of the Conceptual Model Scenarios of VI Processes

- The results of these simplified-hypothetical scenario model runs are consistent with:
  - 1) the wide variability found in EPA's detailed study of external Radon soil and soil-gas samples and their unsuccessful use in the quantitative prediction of indoor air Radon concentrations
  - 2) the EPA 2002 Tier 3 recommendations for using interior structure (indoor air and/or sub-slab) samples for the quantitative assessment of VI into individual buildings

Indoor Air Background Levels Document

- This most recent and comprehensive compilation of residential indoor air background levels will help regulators, facility owners, and the public recognize when indoor air concentrations are <u>likely</u>, or <u>unlikely</u>, to be *due to background sources*, as opposed to vapor intrusion

Some risk & conc. levels of interest

120 ug/m^3

Clearly Above Background

Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences: A Compilation and Implications for Vapor Intrusion

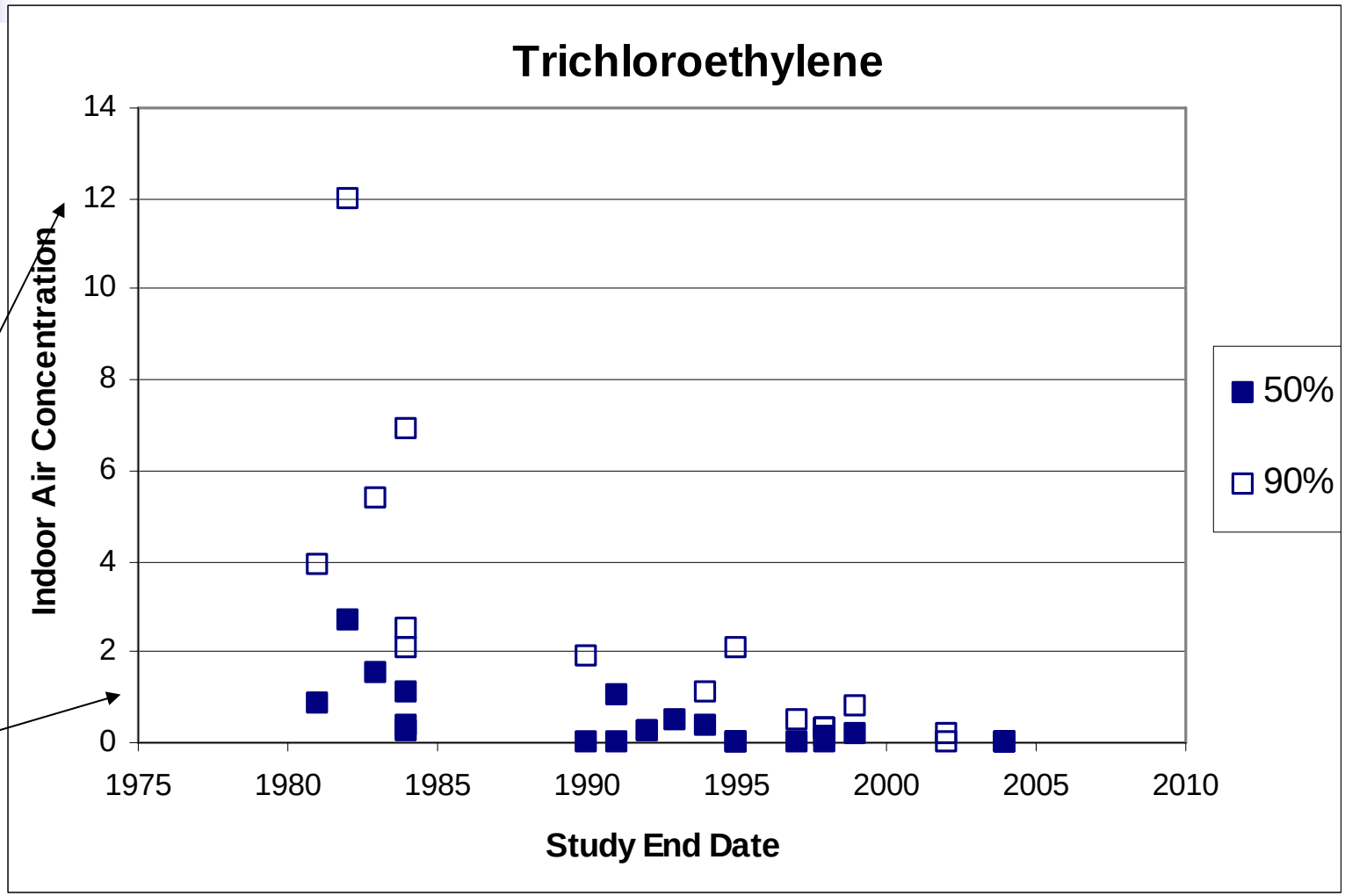
Graphic portion by H. Dawson see http//:iavi.rti.org

Draft 2009
Final 2010

"10^{-4}"

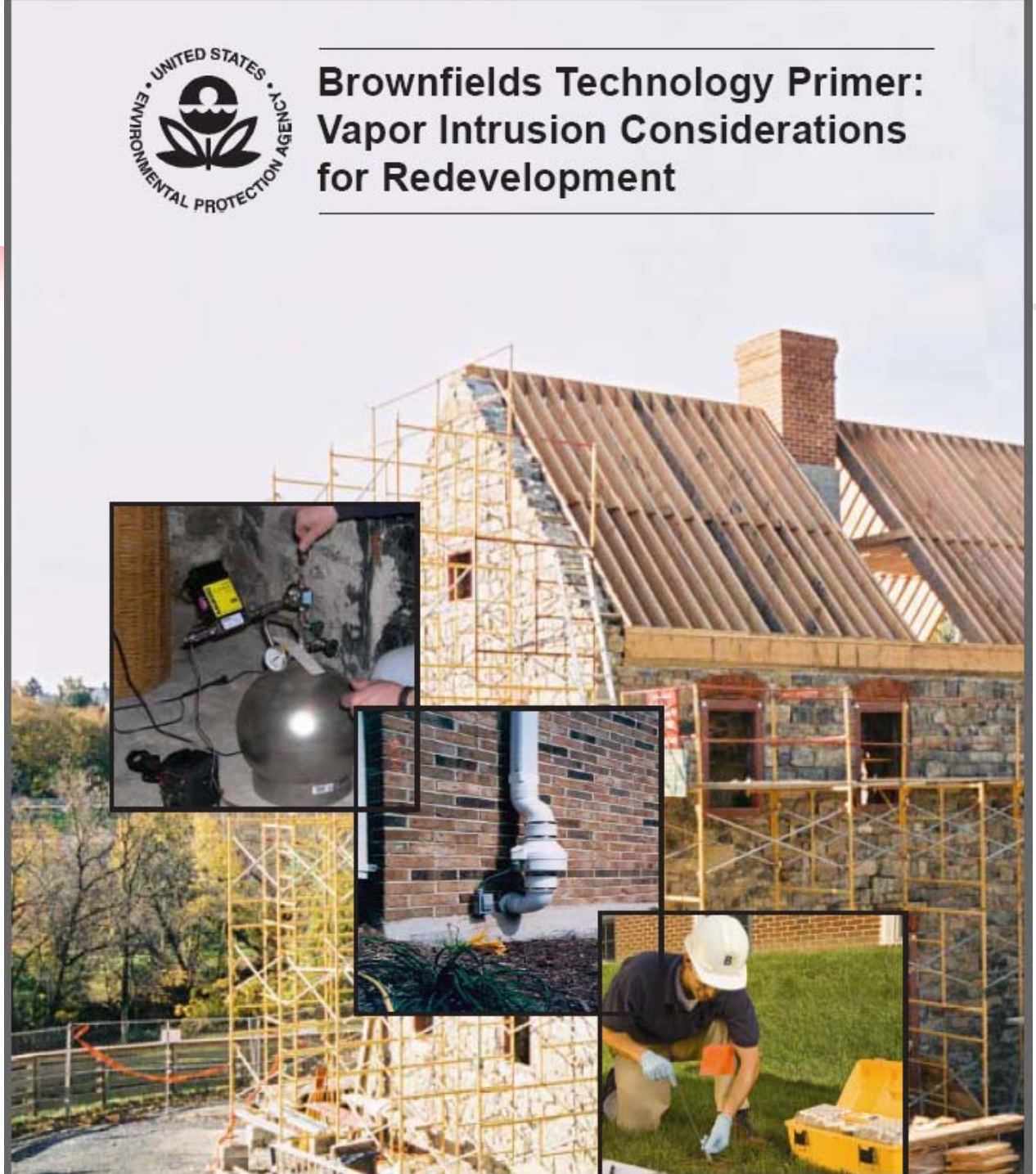
"10^{-5}"

"10^{-6}"



Summary of the Indoor Air Background Levels Document

- Presents the range of concentrations historically found in “background” indoor air
- Can be used to help with the interpretation of the source of observed indoor air levels,
  - Also, practicalities may dictate that the source of indoor air concentrations of a VOC that are less than or near the median background values may remain indeterminate
    - (i.e., w/o subsurface gas controls)



Great introduction to Vapor Intrusion

Major Points:

-**Early consideration of VI is always better**

-**Pre-construction cost savings**

- VI need not prevent re-development

http://www.brownfieldstsc.org
See New Publications

(EPA 542-R-08-001, 2008)

Brownfields VI Primer

- Builds on the scientific concepts developed in the CMS document:
  - where the building's presence can change the distribution of subsurface gases
  - where attempts to predict VI into future or to-be-modified buildings raises significant assessment and prediction challenges

Brownfields VI Primer cont.

- Brownfields redevelopers ***manage*** environmental **risk**,
  - including that due to *vapor intrusion*:
  - And should consider designing <u>engineering controls to mitigate</u> for the <u>potential</u> of VI before new buildings are constructed
    - Multiple Benefits:
      - Address the uncertainty in both site ***characterization*** and the ***toxicity*** of contaminants
      - Often ***more cost-effective*** to mitigate potential VI in advance of construction than to conduct the ***extensive sampling*** necessary (to fully assess future bldg risks)
      - Typically *more cost-effective* to incorporate VI mitigation measures during the design/build phase ***than to retrofit***

“Proactive” Controls Alternative (for Existing Buildings)

- **ITRC**’s 2007 guideline highlights the alternative of using “proactive” controls to mitigate possible vapor intrusion for sites not warranting further investigation
- **OSWER** also recognizes that some states and facilities have found it expeditious in some situations to implement mitigation rather than do extensive indoor air sampling for such sites
  - However, there are some issues with on-going obligations, &
  - *Even though* existing buildings can benefit from many of the factors discussed above for eng. controls in new buildings;
  - Little guidance has been provided on factors to be considered in the site-specific decisions to use vapor controls instead of, or as part of, detailed investigations of existing buildings

VI Database, CMS, & Background papers can help inform decisions:

- These documents can provide a:
  - Fuller recognition of:
    - *potential* site-specific complexities, and
    - the level of detailed characterization needed;
      - to have an appropriately *high level of confidence* regarding the *uncertainty* and (spatial and temporal) *variability;*
      - in both the *vapor source term* and vapor *migration/attenuation* at a bldg/site
  - Should help inform a “proactive” decision

Notes on the use of "Proactive" Controls (1)

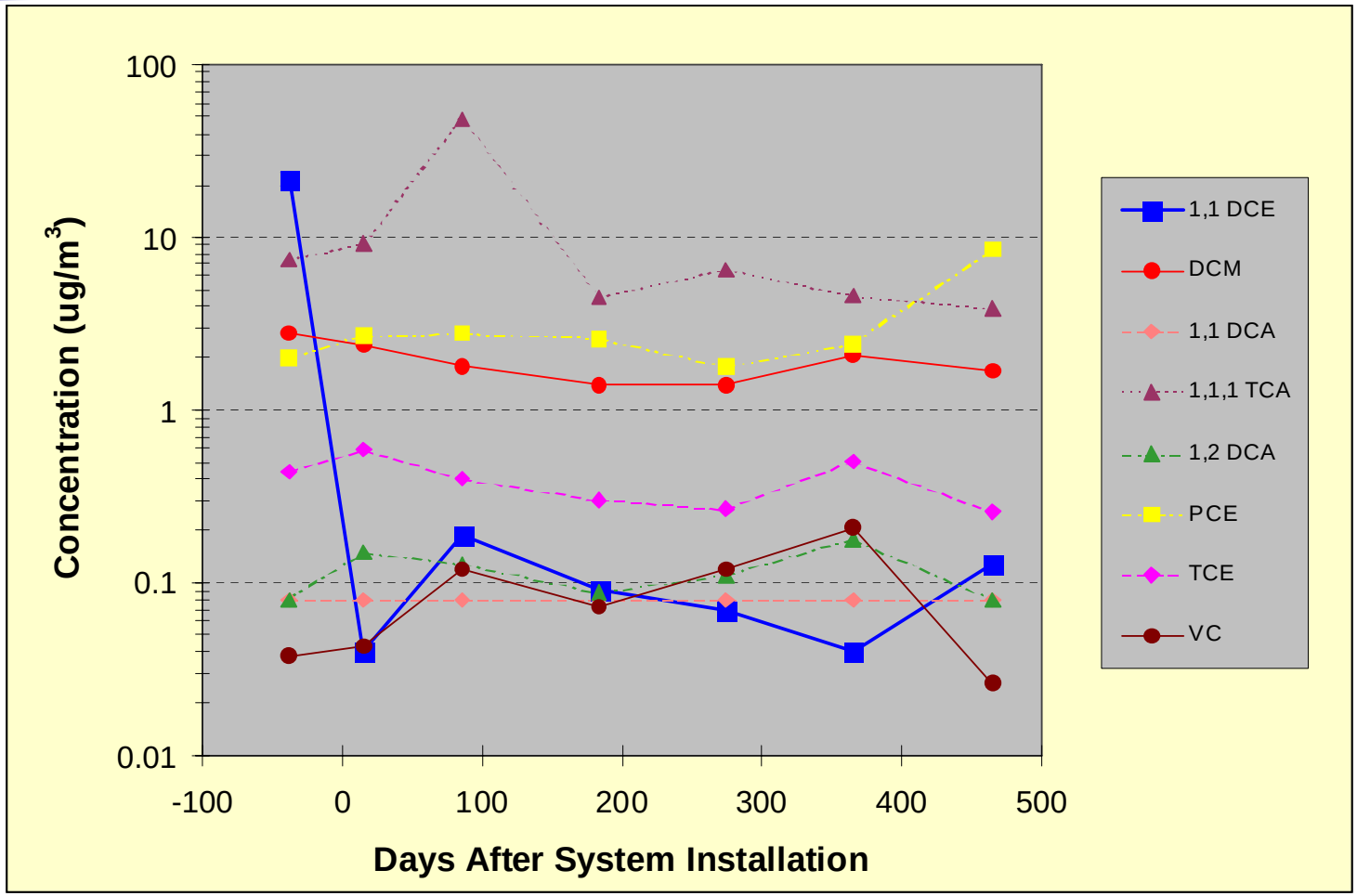
- When mitigation systems are used as a risk management alternative to more detailed characterization of the VI potential, (***and no further testing is conducted*** *to see if the system was needed or not*), it is typically *assumed* that these are needed for unacceptable chemical VI and the ***cost*** of oversight, monitoring, operations, and maintenance for these systems ***should be factored into the decision*** to "proactively" mitigate (without further testing)

- Also note however, that mitigation systems can also be used to *reduce exposures during extended investigations* (e.g., yrs) where VI has not yet been "confirmed", and these controls also provide useful VI assessment information:

  - For example, indoor air samples collected before and after the installation of an effective vapor control system can "confirm" if contaminants are from indoor sources (Folkes 2000).

SSDS confirming the source of contaminants in indoor air

Folkes, 2000

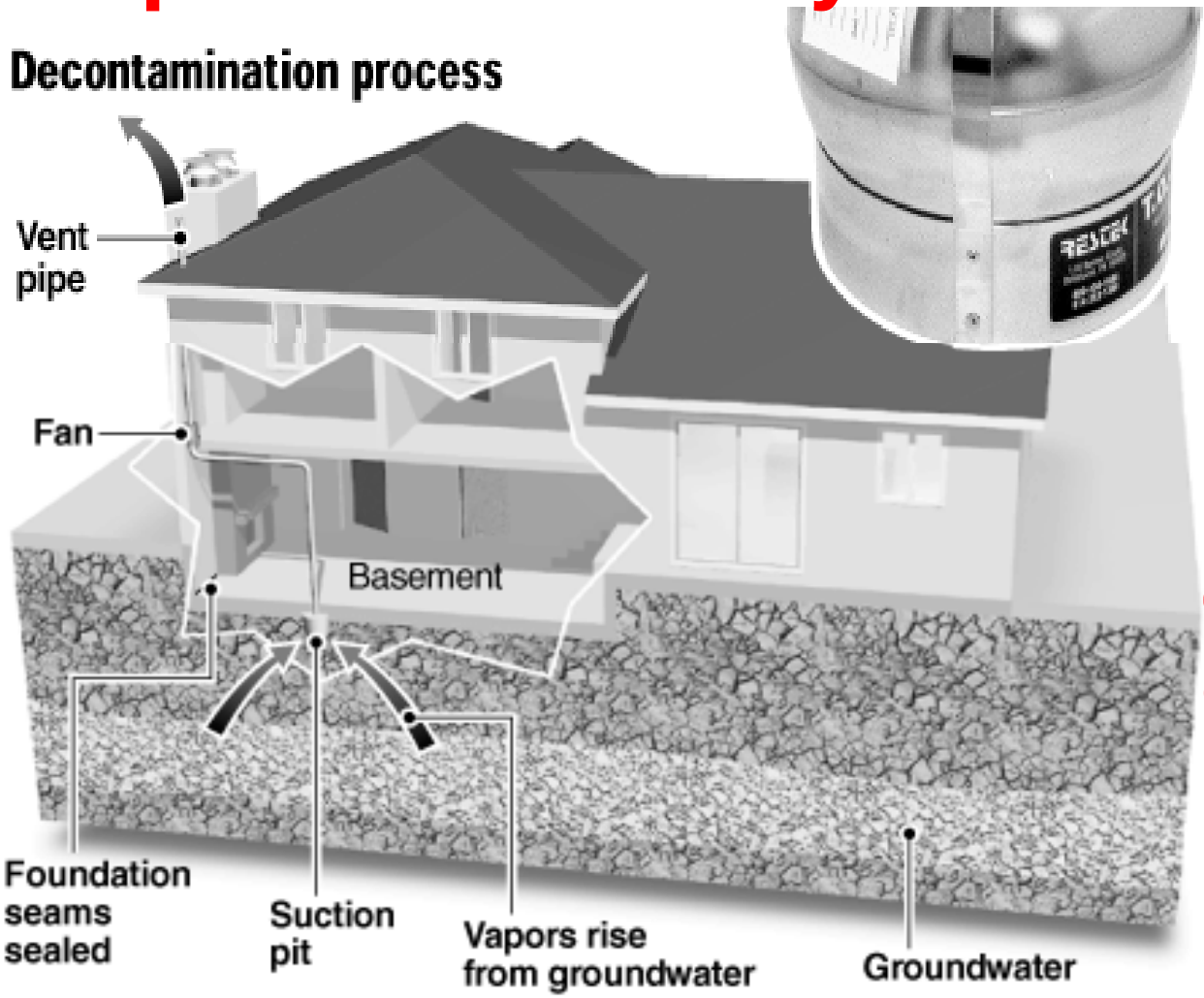


Notes on the use of "Proactive" Controls (2)

- Additionally, *if the cost* of oversight, monitoring, operations, and maintenance for "proactively" installed controls *becomes burdensome* it may be possible to then further assess *whether* such installed *controls were needed* or not (for unacceptable VI)
  - e.g., Using above (w/ & w/o controls) or related methods.
- Finally, note that subsurface vapor controls are LEED criteria and likely provide far more significant health benefits by reducing Radon in indoor air
  - (e.g., average population risks of 2.3% at the radon action level, Jalbert, 2004)
  - than the risks posed by the concentrations of VI chemicals typically encountered (however, w/ VI you get **both**)

Sub-Slab Depressurization System Controls

99.5% Reduction Possible



1 Seams and cracks in the foundation are sealed. If the house has a crawl space, a membrane is put down and sealed to the foundation walls.

2 A suction pit is dug beneath the foundation.

3 A ventilation system is installed to pull the vapors out from beneath the house.

Source: 2000 Conference on Hazardous Waste Research — The Denver Post

$1,000 - $2,500

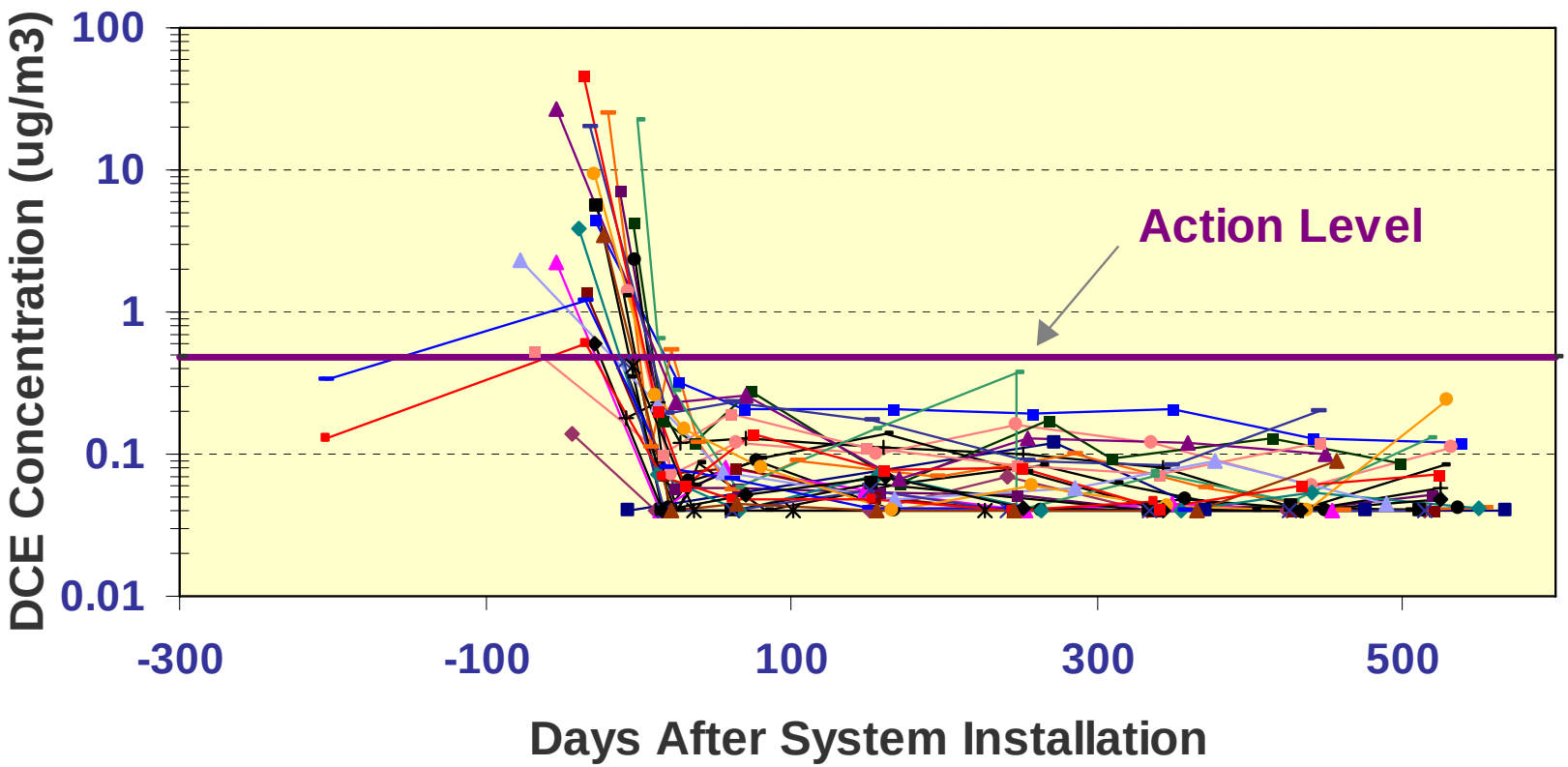
Cuts off the Path-way

SUB-SLAB SYSTEM PERFORMANCE

(typical system $ cost = 1-2 indoor air samples)

1,1-DCE only from subsurface sources

NO MODIFICATIONS REQUIRED



D. Folkes, 2000

EPA United States Environmental Protection Agency

Engineering Issue

Indoor Air Vapor Intrusion Mitigation Approaches

An Engineering Forum & ORD Collaboration

(Nov. 2008)

Table of Contents

1 PURPOSE 1

2 INTRODUCTION 1
- 2.1 Subject and Intended Audience 1
- 2.2 Overview of Contaminant Entry into Structures and Mitigation 3
- 2.3 Vapor Intrusion into Various Building Types 6
- 2.4 Quality Assurance Considerations 8

3 AVAILABLE ENGINEERED CONTROL MEASURES 8
- 3.1 Active and Passive Sub-slab Ventilation 10
- 3.2 Sealing of Penetrations and Entryways 19
- 3.3 Passive Barriers (including Membranes) 22
- 3.4 Natural Ventilation and HVAC Modification 23
- 3.5 Air Cleaning using Adsorbents, Scrubbers or Photocatalytic Oxidation 25
- 3.6 Combinations of Multiple Technologies 26

4 SELECTING A TECHNOLOGY 26
- 4.1 Concentration Limits for the Contaminant 27
- 4.2 Reliability 28
- 4.3 Effect of the Technology on Other Aspects of Indoor Air Quality 28
- 4.4 Structural and Occupancy Aspects for New and Existing Buildings 30
- 4.5 Cost Factors 33
- 4.6 Risk Communication and Stakeholder Involvement Considerations 34

1 PURPOSE

The U.S. Environmental Protection Agency (EPA) Engineering Issue in one of a new series of technology transfer documents that summarize the latest available information on selected treatment and site remediation technologies and related issues. The Engineering Issues are designed to help remedial project managers (RPMs), on-scene coordinators (OSCs), contractors, and other site managers understand the type of data and site characteristics needed to evaluate a technology for potential applicability to their specific sites. Each Engineering Issue document is developed in conjunction with a small group of scientists inside the EPA and with outside consultants and relies on peer-reviewed literature, EPA reports, Web sources, current research, and other pertinent information. The purpose of this document is to present the "state of the science" regarding management and treatment of vapor intrusion into building structures.

Wherever feasible, this information relies on independently reviewed mitigation performance information. In an effort to keep this Engineering Issue paper concise, important information is summarized, while references and Web links are provided for readers interested in additional information; **these Web links, verified as accurate at the time of publication, are subject to change.** Although we have endeavored to make these links fully functional with a mouse click, if they do not function on your system, you may need to copy them into your browser or reenter them. As science and technology associated with this route of exposure continues to develop, other mitiga-

Addresses approaches & technologies to mitigate VI problems for RPMs, OSCs, and other site managers

Includes QA & Performance Verification

Available at: **http://www.epa.gov/nrmrl/pubs/600r08115/600r08115.pdf**

EPA Policy Documents

- VI in Non-Residential Settings
  - Provides guidance to implementers in determining when to address potential vapor intrusion into non-residential settings.
  - Helps to focus current efforts to those non-residential buildings without on-going significant (e.g., occupational) indoor sources of VI COCs.
- TCE & VI Memorandum
  - Will provide improved consistency with an interim interpretation of the cancer and non-cancer toxicity for the common risk-driving contaminant, tricholoroethylene (TCE).

Lessons from Radon Studies

- There has been over *30 years of in-depth scientific study* of the intrusion of the analogous subsurface gas radon.
- Much of the early work in this field was *pioneered by EPA* and has been *continued by academic researchers across the globe*
- The scientific analysis of both high and low screening results have revealed the full nature of the now well-documented confidence intervals surrounding radon screening results (relative to year-long results).
  - [e.g., even using long-term (or seasonally repeated) indoor air samples 95% CI for screening results vary by **10x** (max-min)]
- Awareness of these radon study results can save years of VI workers re-learning these lessons and accelerate the appreciation of the full meaning of VI screening results.

Steck 2005

(Radon in indoor air, MN)

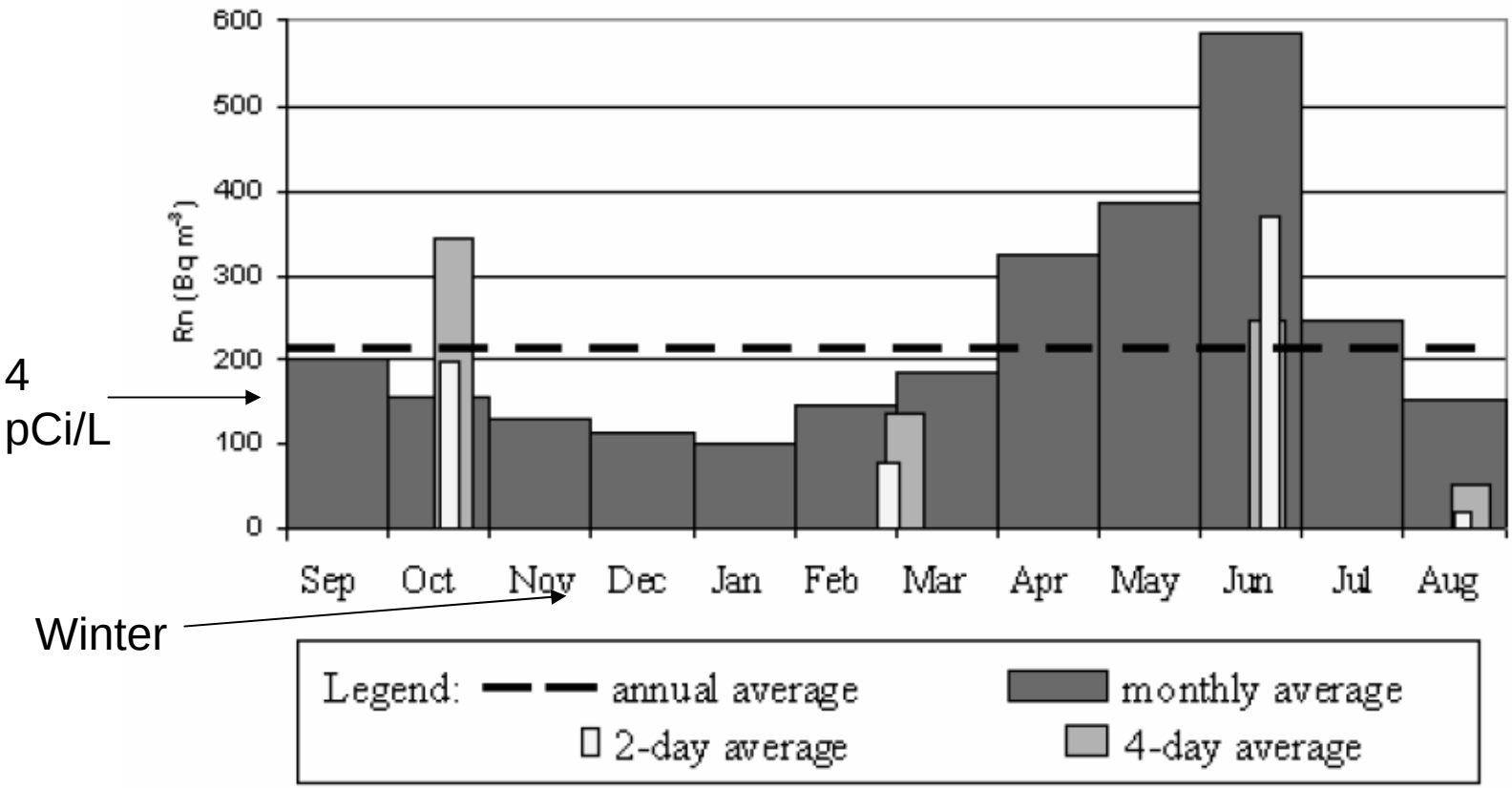


Figure 2. Sample Temporal survey results from measurement site SD3A0.

Radon in indoor air, by Steck 2005

STUDIES ON TEMPORAL VARIATIONS OF RADON IN SWEDISH SINGLE-FAMILY HOUSES

Lynn Marie Hubbard, Hans Mellander, and Gun Astri Swedjemark
Swedish Radiation Protection Institute, S-171 16 Stockholm, Sweden

Environment International, Vol. 22, Suppl. 1, pp. S715–S722, 1996

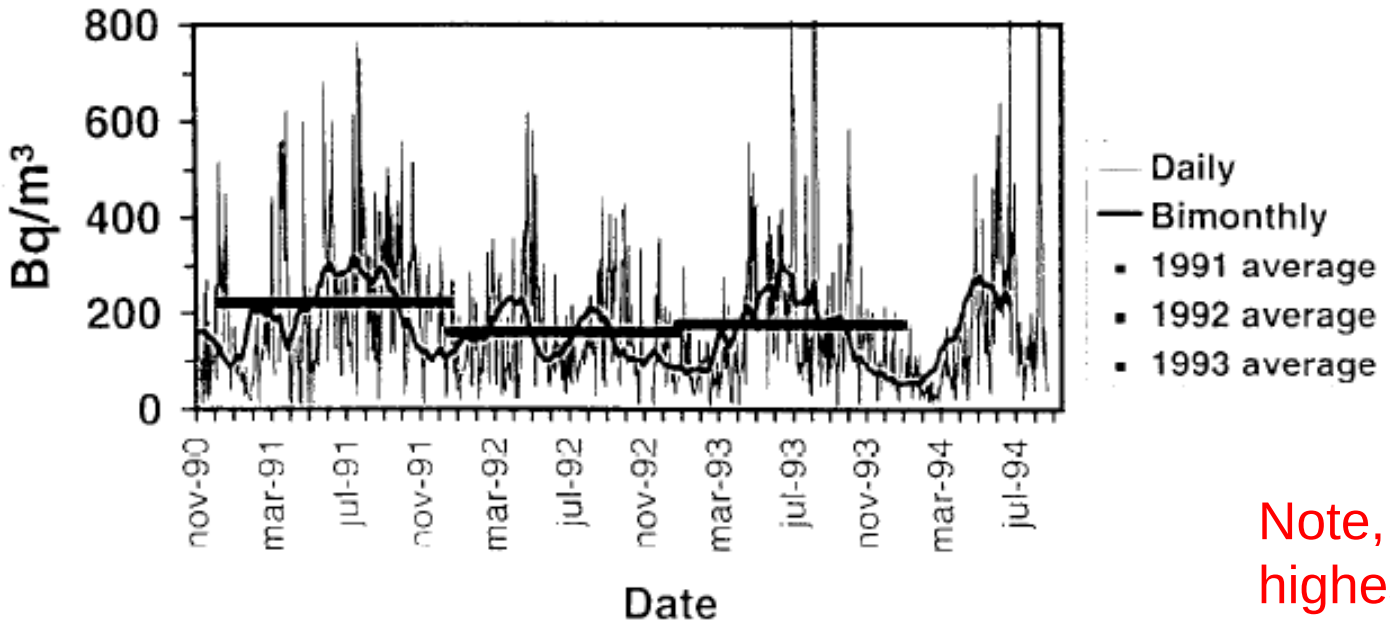


Fig. 1. Daily, bimonthly, and yearly averaged indoor radon concentration.

Note, highest in spring & fall

Rightslink Copyright Clearance License No. 2114510809616

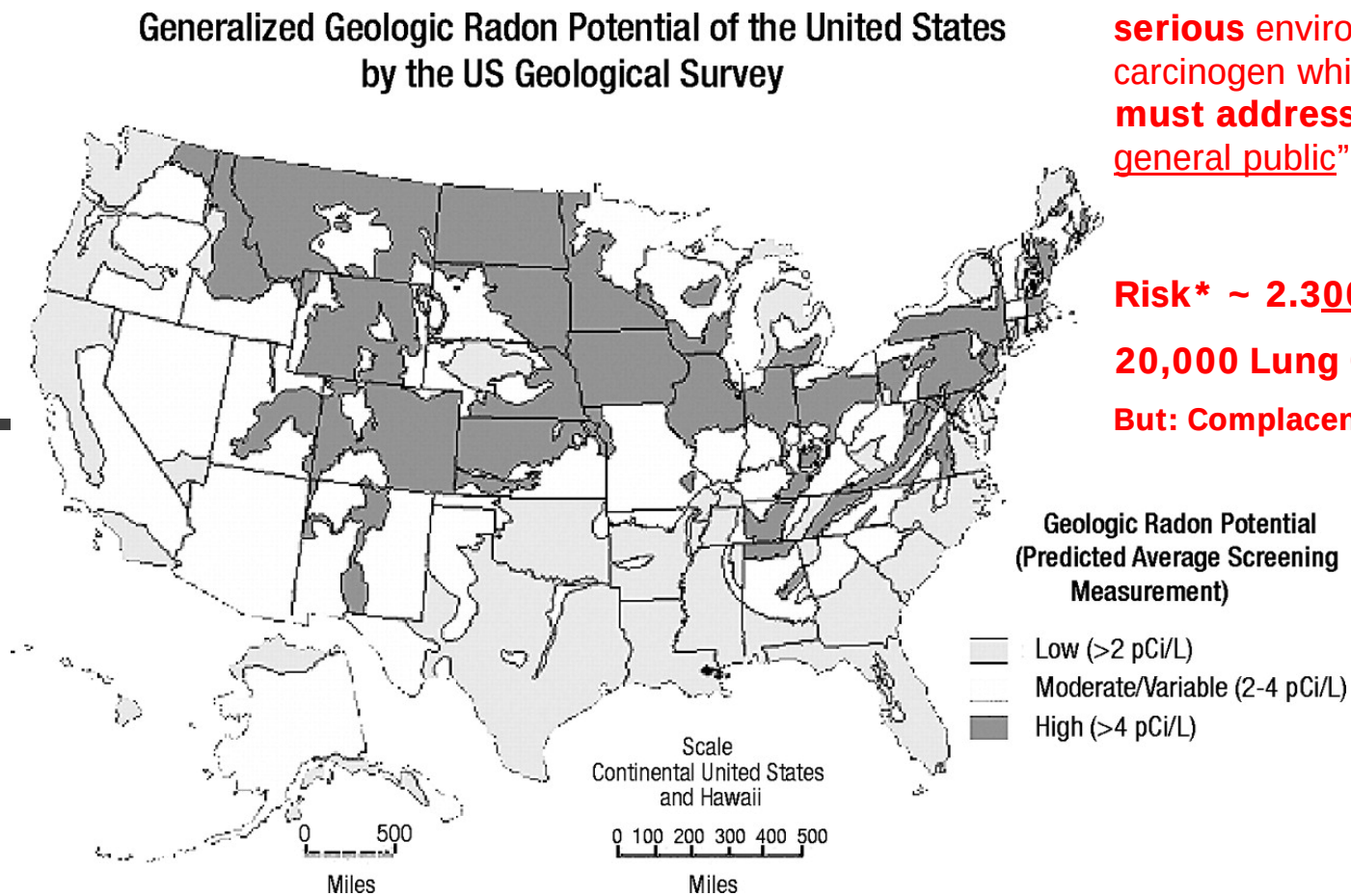
Summary of Radon Conc. (Bq/m^3) Hubbard et al. 1996 (Sweden)

Sample	Factor	Range	Avg.	Period
1-Day	80x	<10 to 800	yr.	4 yr. ’90-94
2-Week	4.3x	70 to 300	yr.	4 yr. ’90-94
Year	1.3x	180 to 230	-	4 yr. ’90-94

- ~ four year period Nov. 1990 – July 1994

RADON

FIGURE 1



From Frumkin, H. et al.
CA Cancer J Clin 2001;51:337-344.

EPA's Perspective on Risks from Residential Radon Exposure

"Indoor **radon** … **the most serious** environmental carcinogen which the **EPA must address** for the general public" Puskin 1989

Risk* ~ 2.3000 % (4pCi/L)

20,000 Lung Cancers/yr

But: Complacency & Costs

Jalbert, 2004

* adult cancer

The same VI pathway

Real 'background' for chemical VI

Chemically exposed get **both**

CA
A Cancer Journal for Clinicians

Copyright ©2001 American Cancer Society