Understanding the Connections between Sampling Design, Exposure Points, and Exposure Point Concentrations

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LSP Association

assess.
advise.
restore.

Regulations Committee Workgroup on MCP Amendments for Sampling Design and EPCs

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Thank you!

MCP Amendments to Soil and Sediment Sampling Approach and Estimating Exposure Point Concentrations

- 310 CMR 40.0903(1)c **Scope of the Risk Characterization and Supporting Documentation**
- 310 CMR 40.0904(4) **Soil Sampling Approach for Risk Characterization**
- 310 CMR 40.0904(5) **Sediment Sampling Approach for Risk Characterization**

310 CMR 40.0924 Identification of Exposure Points

310 CMR 40.0924(7) Soil Exposure Points

310 CMR 40.0926 Identification of Exposure Point Concentrations

- 310 CMR 40.0926(8) **Soil Exposure Point Concentrations**

310 CMR 40.0926(12) Hot Spot Exposure Point Concentrations in Soil or Sediment

CSM↔Sampling → Exposure Points → Exposure Point Concentrations

MCP Amendments to Exposure Points for groundwater and coal tar waste deposits

- 310 CMR 40.0924(6) **Groundwater Exposure Points**
- 310 CMR 40.0924(8) Indoor Air Exposure Points
- 310 CMR 40.0924(9) Sediment Exposure Points
- 310 CMR 40.0924(10) Surface Water Exposure Points
- 310 CMR 40.0924(11) Hot Spots and **Visible Coal Tar Waste Deposits**

MCP Amendments to Estimating Exposure Point Concentrations for groundwater

310 CMR 40.0926	Identification of Exposure Point Concentrations
▶ 310 CMR 40.0926(7)	**Groundwater Exposure Point Concentrations**
310 CMR 40.0926(9)	Indoor Air Exposure Point Concentrations
310 CMR 40.0926(10)	Sediment Exposure Point Concentrations
310 CMR 40.0926(11)	Surface Water Exposure Point Concentrations
310 CMR 40.0926(12)	Hot Spot Exposure Point Concentrations in Soil or Sediment

310 CMR 40.0926(5) In estimating Exposure Point Concentrations, the objective shall be to identify a conservative estimate of the mean concentration contacted by a receptor at each Exposure Point over the relevant exposure period.

Judgmental or Systematic Sampling

- Data used to estimate EPCs for exposures to **soil or sediment** may be based on judgmental or systematic sampling.
- The choice of judgmental or systematic sampling shall consider the site history, the Conceptual Site Model, and the need to support a conservative estimate of exposure.
- Additional considerations for sediment include the type, size and depth of the water body in question, the hydrologic regime, the depositional patterns and the Receptors of Concern. Where systematic sampling is employed, these characteristics shall also be considered when determining whether systematic grid sampling or systematic transect sampling is appropriate. 310 CMR 40.0904(5)

Soil Sampling Approach for Risk Characterization
310 CMR 40.0904

Judgmental sampling approach for sites or portions of sites where:

- Contamination has originated from a known source or sources;
- There is evidence that the contamination is limited to a defined area
- The highest concentrations within the Exposure Point can be clearly identified; and
- No evidence that the soil has been significantly redistributed since the release.

Systematic sampling for sites or portions of sites where:

- Soil contamination has not been attributed to a known source;
- The contamination may not be limited to a defined area;
- Cannot identify the area with the highest concentrations within the Exposure Point; or
- Soil may have been significantly redistributed since the release.

food for thought

For many sites with known sources, can use judgmental sampling if no significant soil redistribution has occurred.

Systematic soil sampling required at a “fill” site where there is no clear pattern of contamination.

Possibly justify judgmental sampling if source of OHM unknown, if the soil exposure point is of limited extent and there are enough discrete soil samples collected to assert that the contaminant concentration distribution and variability have been captured.

Soil Exposure Points
310 CMR 40.0924(7)

- For Methods 1 and 2 Risk Characterization, the Exposure Point(s) shall be defined by the horizontal and vertical extent and distribution of the contamination in combination with the soil category(ies) determined to be applicable.
- Separate and distinct Exposure Points shall be represented by the soil in each category.
- The top 3 feet of surface soil shall also represent a separate Exposure Point for current use scenarios.

Soil Exposure Points
310 CMR 40.0924(7)

- For Method 3 Risk Characterization for current or potential soil exposures, the following depths shall be considered:
  - zero to three feet for exposures associated with surficial activity;
  - zero to six feet for exposures associated with utility installation and repair; and
  - zero to 15 feet for exposures associated with excavation scenarios and building construction.
- For Imminent Hazard Evaluations, the top foot of soil shall be the Exposure Point.

Soil Exposure Point Concentrations 310 CMR 40.0926(8)

If **Judgmental sampling** done:

EPC in soil can be estimated by the arithmetic mean provided

- 75% of the data points used in the averaging are equal to or less than the applicable standard or risk-based concentration limit, and
- no data point used in the averaging is ten times greater than the applicable standard or risk-based concentration limit.

Otherwise, soil EPCs can be set equal to:

- the maximum concentration; or
- the arithmetic mean supported by a technical justification that considers the size of the data set, density and potential biases of the sampling, and other relevant factors incorporated into the CSM.

Soil Exposure Point Concentrations 310 CMR 40.0926(8)

If **Systematic sampling** done:

EPC in soil can be estimated by the 90th percentile Chebyshev non-parametric upper confidence limit on the mean.

If the 90th percentile Chebyshev non-parametric upper confidence limit on the mean is determined not to provide a suitable estimate of the soil EPC, an alternative conservative estimate of the arithmetic mean may be used to determine the EPC supported by technical justification.

Need to document why the 90th percentile Chebyshev nonparametric upper confidence limit on the mean is not suitable, and the suitability of the alternative approach, considering the size of the data set, density and potential biases of the sampling, applicable statistical analyses of the data, and other relevant factors incorporated into the CSM.

Chebyshev Upper Confidence Limit on a Mean (UCL)

Chebyshev's theorem provides an upper bound on the probability of a random variable deviating from its mean by more than a certain amount.

The amount of that difference is related to the standard deviation of the data set (in the equation, k is the number of standard deviations)

This theorem is often used to derive a bound on the upper tail of data sets that do not fit other statistical distributions, which is often referred to as non-parametric statistics.

An UCL on a mean can be derived using a formula based on Chebyshev's inequality. The UCL is a statistical estimate of the upper limit of a distribution based on the sample mean, the sample standard deviation, the number of samples, and the level of confidence in the estimate.

Pafnuty Chebyshev (1821-1894), Russian mathematician

Chebyshev Theorem, published in 1870:

$$Pr(|X - \mu| \geq k \times \sigma) \leq \frac{1}{k^2}$$

Image sources: https://en.wikipedia.org/wiki/Pafnuty_Chebyshev and www.turing.com

Statistical Software ProUCL 5.2 for Environmental Applications for Data Sets with and without Nondetect Observations. EPA. 2022.
https://www.epa.gov/land-research/proucl-software

Summary of EPCs by Medium - Soil

Medium	Statistic at each Exposure Point
Soil	Where judgmental sampling done, arithmetic mean of the concentrations within the Exposure Point if meet 75/10 rule; if not, maximum concentration or justified mean
Soil	Where systematic sampling done, 90th percentile Chebyshev non-parametric upper confidence limit on the mean of the concentrations within the Exposure Point or alternative justified conservative estimate of the arithmetic mean
Soil Hot Spot	arithmetic mean concentration within the Hot Spot
Wildlife exposure to soil in Environmental Risk Characterization	arithmetic mean concentration

Groundwater Exposure Points
310 CMR 40.0924(6)

For Method 1 and 2 Risk Characterizations, the Exposure Point(s) for all groundwater categories (including GW-3) shall be the groundwater resource itself, as measured at each wellhead and/or nearest tap of a well screened within the horizontal and vertical distribution of the oil and/or hazardous material in the groundwater.

Existing water supply wells and monitoring wells shall be used to represent current or potential groundwater Exposure Points.

For Method 3 Risk Characterizations where GW-1 applies and comparison to Drinking Water Standards are done, the groundwater Exposure Points are the same as listed above.

For Method 3 Risk Characterizations, for comparisons to Applicable or Suitably Analogous Standards as described in 310 CMR 40.0993(3), the groundwater Exposure Point shall be identified in a manner consistent with the applicable regulations.

For Method 3 Risk Characterizations where the groundwater is categorized as GW-3 only, groundwater Exposure Points shall be determined based on site-specific conditions, and potential current and future exposures.

Summary of EPCs by Medium - Groundwater

Medium	Statistic at each Exposure Point
Groundwater (Method 1 and 2 Risk Characterizations)	A groundwater EPC shall be a conservative estimate of the temporal mean for the exposure period of concern and shall consider temporal trends.
Groundwater (Method 3 Risk Characterizations) – GW-1 area	When comparing to Drinking Water Standards (because GW-1 Standards are not used in Method 3 RC), same as above. See 310 CMR 40.0926(7) for EPC = zero for petroleum in some GW-1 areas.
Groundwater (Method 3 Risk Characterizations) – GW-3 only applicable category	Groundwater Exposure Points shall be determined based on site-specific conditions, and potential current and future exposures.

Summary of EPCs by Medium – Indoor Air

Medium	Statistic at each Exposure Point
Indoor Air	A conservative estimate of the OHM concentration contacted by a receptor over the exposure period of concern, based on concentrations **measured in indoor air**, shall be used for the EPC. When multiple rounds of data are available to characterize the spatial and temporal variability at the EP, a conservative estimate of the mean for the exposure period of concern that considers temporal trends may be used. In such cases, a valid justification must be provided that indicates that the sample mean is unlikely to underestimate the true mean. If not sufficient data to establish spatial and temporal variations, maximum concentration values shall be used as the EPC for each contaminant of concern.
Sub-slab Soil Vapor (SSV)	SSV can be used to estimate or aid in the estimation of EPCs if it is not possible to distinguish disposal site-related contamination at the EP from interior sources at ongoing commercial and/or industrial operations or interior building materials contaminated by past commercial or industrial operations; and where appropriate, to rule out an indoor air Exposure Pathway.
Fate and transport models	Fate and transport models **shall not be used** to estimate future indoor air EPCs in the indoor air of buildings that have not been constructed.

Summary of EPCs by Medium – Sediment and Surface Water

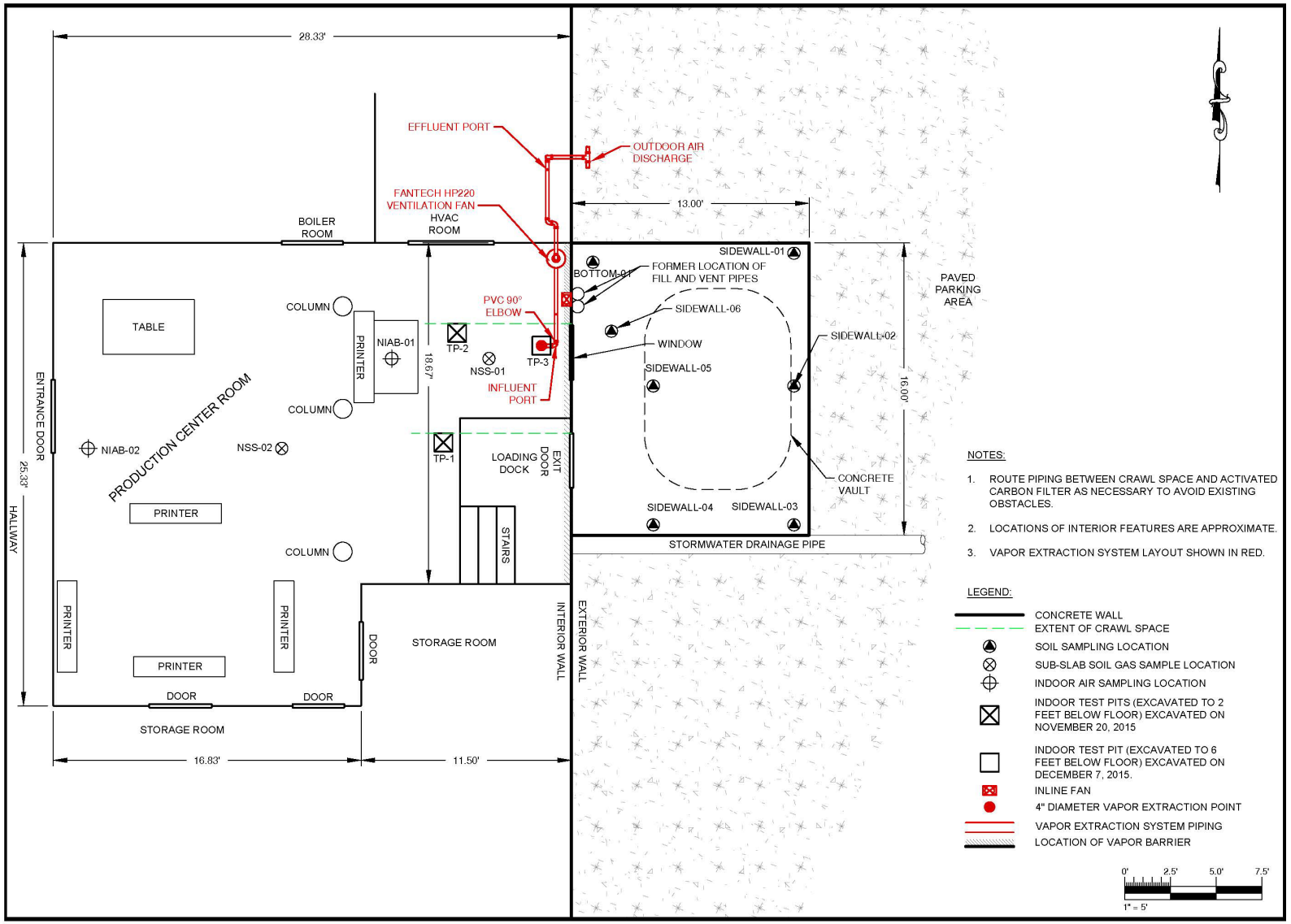
Medium	Statistic at each Exposure Point
Sediment	For assessing human direct contact exposure, the EPC shall be the arithmetic mean concentration within the Exposure Point.
Surface Water	For assessing human direct contact exposure, the EPC shall be the arithmetic mean concentration within the Exposure Point over the relevant time period.
Sediment Hot Spot	arithmetic mean concentration within the Hot Spot
Aquatic and semi-aquatic organisms' exposure to sediment and surface water	arithmetic mean concentration

little bites

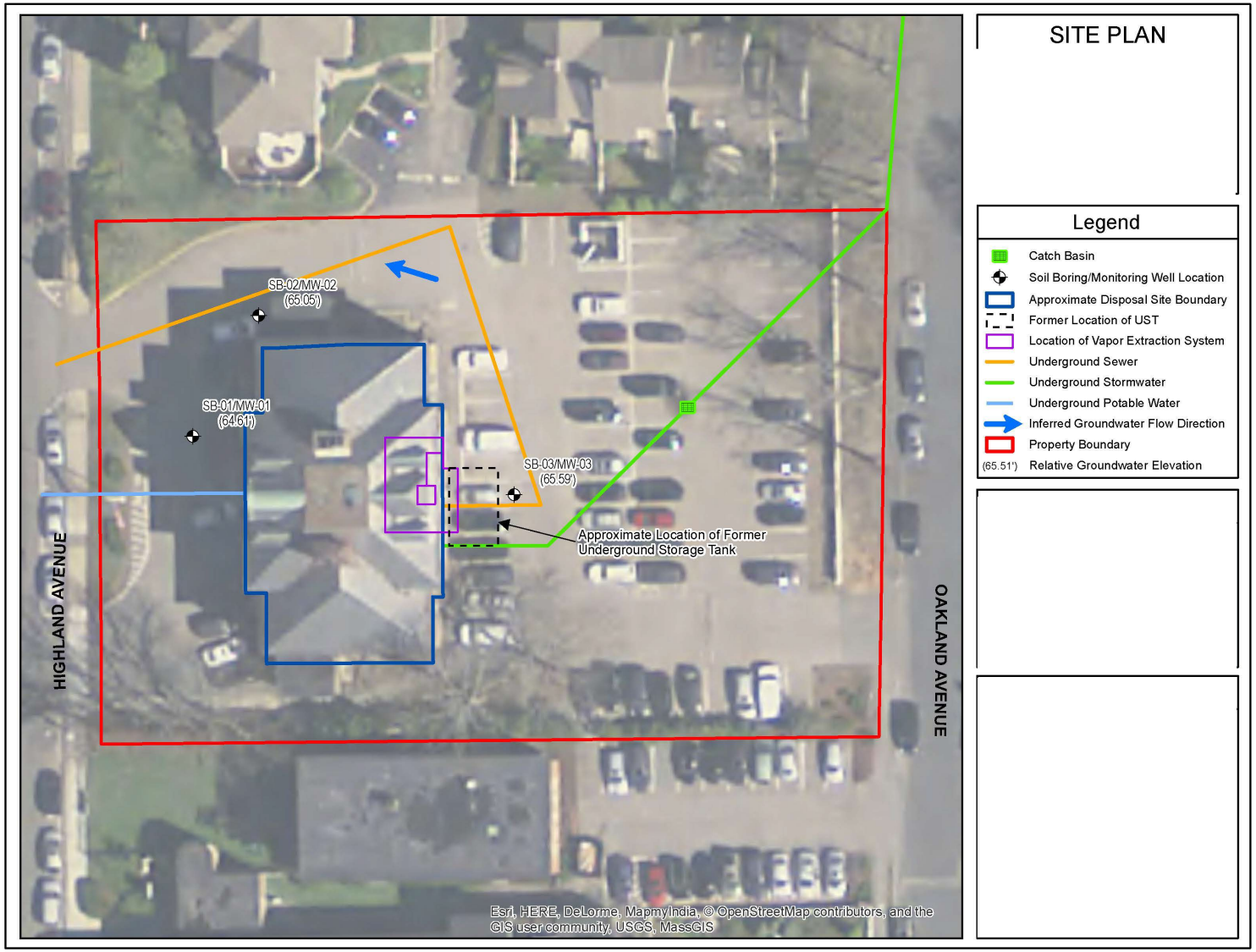
CSM	Integrate N&E sampling w/ exposure points
EPs	On- and off-property, now and future
EPCs	Conservative estimates of exposure
Stats	Know the variability in the data set

Examples of Sampling Design

Judgmental Sampling Design Example



Judgmental Sampling Design Example



Systematic Sampling Design Example