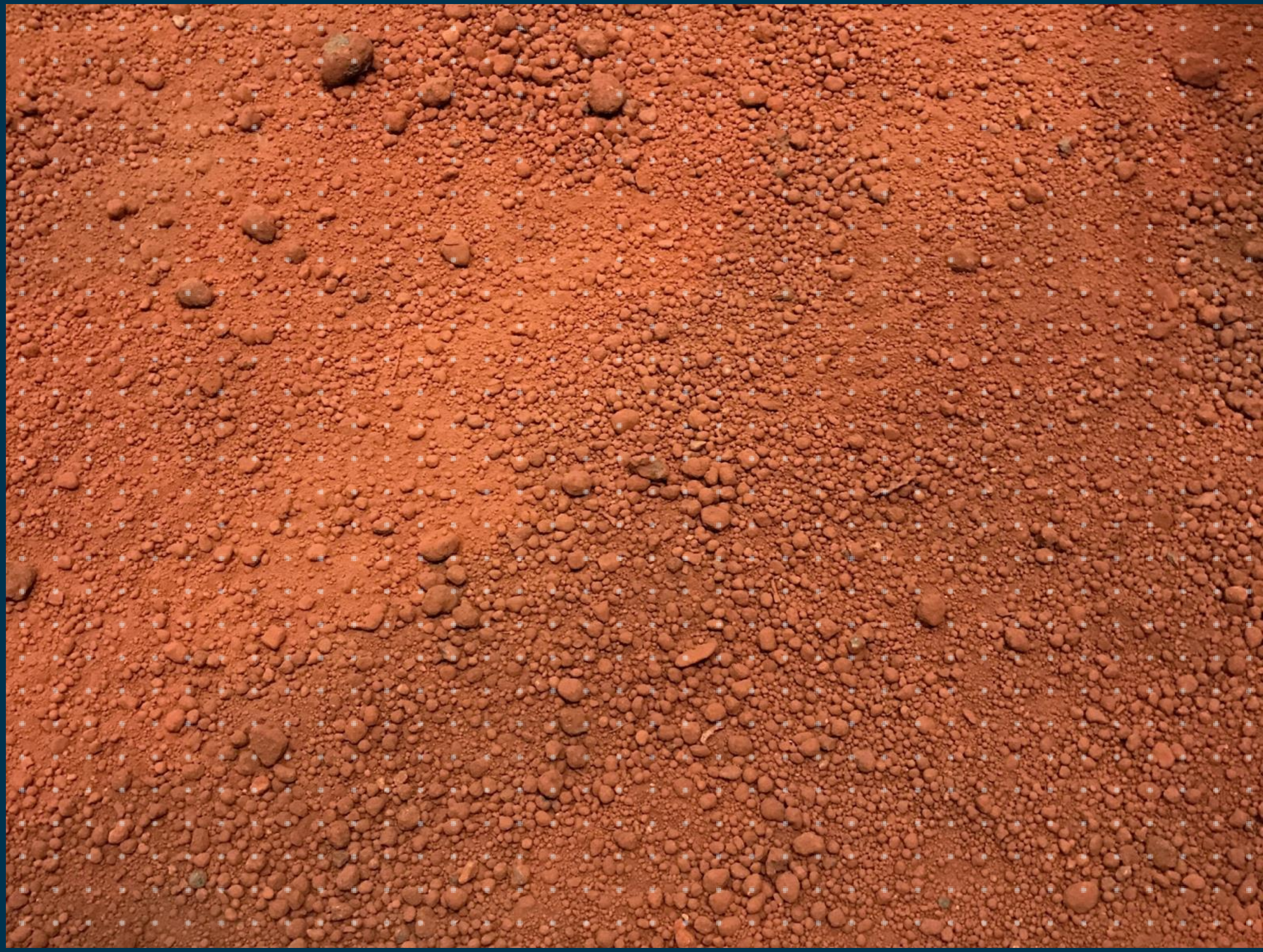
Environment Protection Authority

Contaminated Land Advice and Audit Team Update



Jo Graham

19 May 2023

Welcome

Automatic Mutual Recognition (AMR)

- Exemption from AMR finishes on 1 July 2023
- Victoria and Western Australia have commenced AMR for auditors
- Queensland not adopting AMR Scheme
- NSW accredited auditors able to audit in Victoria and WA – need to check eligibility/notification requirements with the interstate regulatory authority
- Minor amendments to the Guidelines for the NSW Site Auditor Scheme
- Information on AMR to be included on Auditor webpages
- General information on AMR already on EPA website

Automatic Mutual Recognition (AMR)

- Definition of **home state** on NSW Government webpage on AMR:
  - "Your home state is where your primary place of residence or work is located.
  - If you change your home state or territory to NSW, and you mainly work in NSW, you must apply through the existing mutual recognition arrangements for a new substantive registration or licence in NSW and pay any applicable fees."

Minor Amendments to Auditor Guidelines

- AMR information
- Contaminated Land Management Regulation 2022 amendments
- Outdated links / email addresses (e.g. waste notification email address)
- EPA guideline updates

Direct Accreditation Round 2022

- Sixteen applications
- Nine invited to take the exam
- Seven invited to interview
- Six successful to be accredited as new auditors
- Improvements following last accreditation round
- Feedback

Updates / reminders / admin

- Reminder to terminate audits where no involvement/activity for some time – termination notices (EPA / consent authority)
- SAN / SAS forms – correct logo
- Include a survey plan with SAS clearly depicting the audit area for partial lots
- Auditor meetings

Environment Protection Authority

LAND AND RESOURCES POLICY

UPDATE

Joanne Stuart & Mark Hanemann

May 2023

CONTENTS

1. Independent review of asbestos in recovered materials
2. EPA Position Statement on Management of Asbestos Contaminated Sites

Independent review of asbestos in recovered materials

Engagement of the Office of the Chief Scientist and Engineer

Review of asbestos management in recovered materials

- Office of the Chief Scientist and Engineer (OCSE) asked to provide advice on management of asbestos in recovered materials, including recovered fines
- Terms of Reference developed in consultation with NSW Asbestos Coordination Committee (NACC)
- Will also address recommendation 20 from the independent review of the Resource Recovery Framework
- Terms of Reference have been published on the OCSE website at https://www.chiefscientist.nsw.gov.au/independent-reports/asbestos-management

Terms of Reference – in brief

- Review of national and international jurisdictions standards/guidelines
- Can a tolerable threshold level be set for asbestos in recovered materials – should this be different from threshold levels for legacy asbestos-contaminated soils?
- Are thresholds best approach or are there better risk-based approaches?
- What is the most appropriate sampling and analytical approach?
- Scientific and risk assessment principles for setting threshold levels

Status and next steps

- Currently undertaking preliminary literature review and gap analysis
- Formal work will commence in August 2023
- OCSE looking to consult with various stakeholders:
  - CLM consultants/auditors
  - C&D industry
- Potentially looking to visit remediation sites where asbestos is a CoC
- OCSE will produce a report setting out their advice and recommendations – Minister may release report publicly
- Government will consider response to all recommendations

Updated Position Statement

Position statement – Management of asbestos-contaminated sites

- EPA received many comments on the Position statement on WA asbestos guidelines
- We've listened to your concerns – document has been renamed and updated to better reflect current industry best practice
- Clearer separation between waste and CLM frameworks - legacy asbestos contamination is generally managed differently to dumped asbestos waste
- On-site remediation to <HSLs permitted, in certain circumstances
- On-site reuse of soil <HSLs permitted, with caveats
- Remains consistent with NSW legislation

Next steps

- EPA currently seeking comments on draft revised document
- Final position statement will be published mid-late 2023 – will replace current document
- You will be notified when it's published
- Position statement will be further informed by outcomes of review by Office of the Chief Scientist and Engineer (OCSE)

Legal Case Study

EPA v Zoya Investments Pty Ltd

Failure to Comply with Management Order

(under CLM Act 1997)

Brigitte Elvy, Legal Services Branch
Donna Phelan, Regulatory Operations Branch

19 May 2023

Photo source: Google images (2017)

The Site

Photo source: Google Streetview (2010)

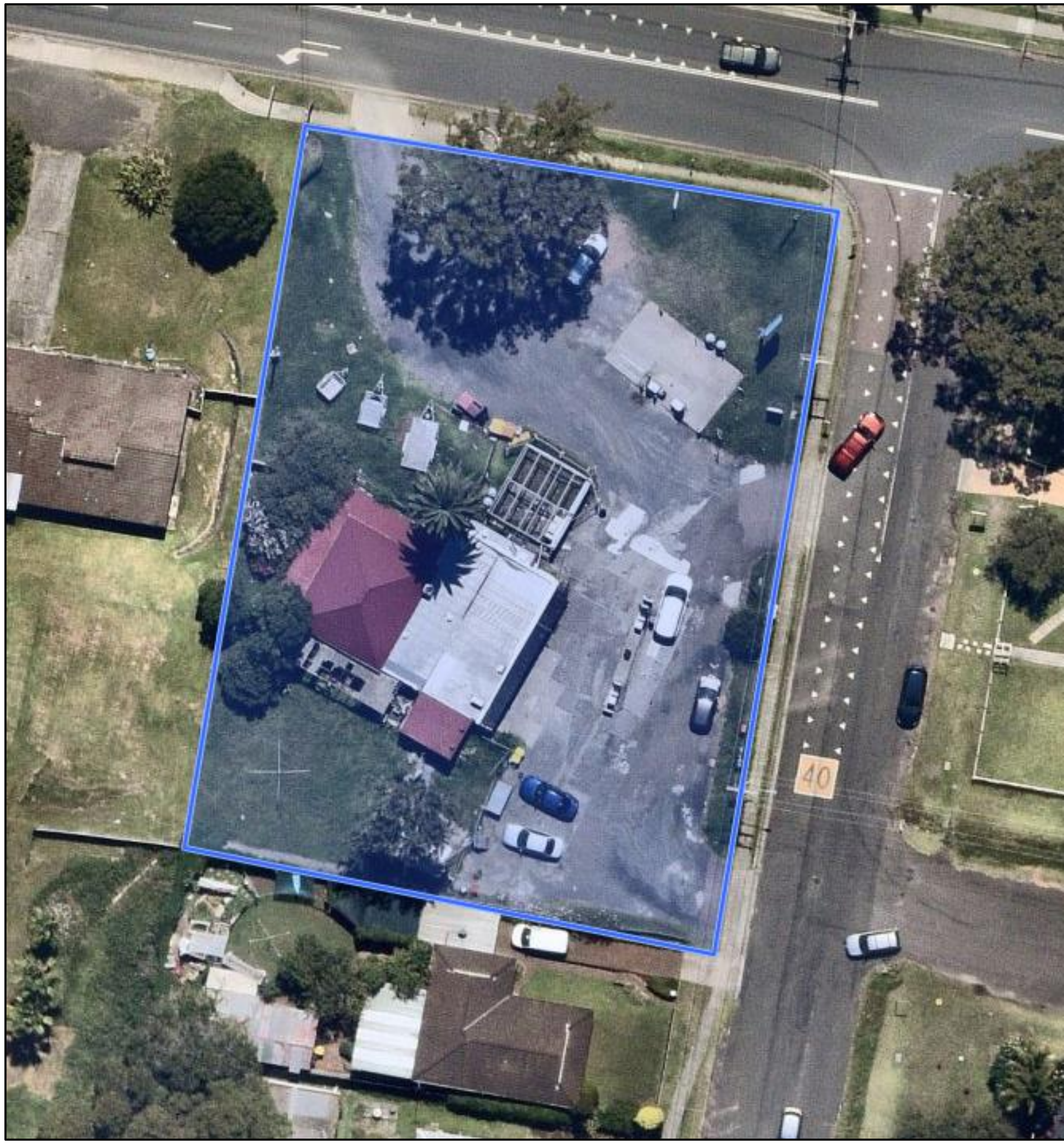


Photo source: Nearmaps (2023)

Regulation

- Declared the land to be significantly contaminated in Dec 2018
- Two different statutory instruments
- Management Order
  - issued to Zoya Investments in Feb 2020
  - focused on investigation stage
  - all actions completed with exception of Action D(ii)

Photo source: Nearmap (2023)

Management Order - Action D(i) and (ii)

- Action D(i) of MO
  - equipment integrity testing (EIT) and submit report
- Action D(ii) of MO
  - rectify operational issues identified and submit report

- EIT report found
  - pin hole leak in anaconda
  - 3 USTs failed tank integrity test
- EIT report recommended
  - replacing the anaconda / retest
  - retesting the 3 USTs in isolation

Photo source: Neo Consulting, Kanwal EIT Report (2020)

Management Order Non-Compliance

- Zoya Investments failed to comply with Action D(ii) of MO

- EPA Regulatory Policy and Prosecution Guidelines

- EPA used a range of regulatory tools under CLM Act 1997 and POEO Act 1997:
  - show cause letters
  - statutory notices
  - directed interviews

- Received sporadic responses from Zoya Investments
  - outstanding works did not get done
  - non-compliance with MO and risk of contamination continued

14 Management orders

(1) The EPA may, by order in writing served on a person who is an appropriate person or a public authority, direct the person to do one or both of the following in relation to significantly contaminated land, within such reasonable time as is specified in the order—

(a) carry out any action in relation to the management of the land that may be specified in the order in accordance with this Division,

(b) submit for the EPA's approval a plan of management of the land (a **plan of management**).

…

Offence provision – CLM Act

14 Management orders

…

(6) **A person** (other than a public authority that is not an interested person with respect to the relevant land) **served with a management order must not, without reasonable excuse, fail to comply** with any direction or other requirement specified by the order within the time specified by the order.

Maximum penalty—

(a) in the case of a corporation**—$1,000,000 (if responsible for the contamination)** or **$137,500 (in any other case)** and, in the case of a continuing offence, a further penalty of **$120,000 for each day the offence continues**, or

(b) in the case of an individual—$250,000 (if responsible for the contamination) or $66,000 (in any other case) and, in the case of a continuing offence, a further penalty of $60,000 for each day the offence continues.

EPA v Zoya Investments Pty Ltd [2022] NSWLEC 149

Land and Environment Court proceedings

- EPA commenced 1 x failure to comply with a Management Order without reasonable excuse (contrary to s14(6) of CLM Act)
- Charged Zoya for the **352 day period** during which it continued not to comply with the requirement of the Management Order
- Zoya pleaded guilty to charge (after 9 months)
- EPA also issued clean up notice to occupier of site requiring carrying out of Action D(ii) works, given ongoing risk of harm
- The outstanding Action D(ii) works were carried out by Zoya

EPA v Zoya Investments Pty Ltd [2022] NSWLEC 149 – Sentencing

On sentence, Justice Moore of the Land and Environment Court found:

- Zoya was "**responsible**" for the contamination at the site, even though previous owners may have also contributed
  - A person is responsible for contamination of land if the person carried on activities on the land that generate or consume the same substances as those that caused the contamination, unless able to prove otherwise (see s6(1)(d)(i))
- Whilst actual harm could not be proven, the **risk of harm** caused by a failure to investigate for 352 days was significant
  - Court may consider the "degree of risk that harm will be caused by the commission of the offence" (see s97(1)(b)).
- Not trivial and undermined the integrity of the regulatory regime for preventing, controlling and rectifying contamination

EPA v Zoya Investments Pty Ltd [2022] NSWLEC 149 – Penalty

The Court ordered that Zoya Investments:

- be **convicted** of one offence against s14(6) of the CLM Act for failing to comply with a Management Order without reasonable excuse,
- pay a fine of **$180,000 plus $140,000** in daily penalties (**$320,000 in total**),
- pay 50% of the fine to the EPA as a moiety,
- within 14 days, **publish a notice** detailing the offence in:

  (i) ACAPMAg, the online publication of the Australasian Convenience and Petroleum Marketers Association (**ACAPMA**), and

  (ii) the online weekly newsletter to subscribers of ACAPMA, and

- pay the **EPA's legal costs** as agreed or assessed

Key Takeaways

- Non-compliances are taken seriously by the Land and Environment Court
- Risk of harm may be increase Court penalty, even if no actual harm evident
- Reminder to conduct due diligence – a person in breach of a management order may be considered “responsible” under the CLM Act for contamination also contributed to by others (s 6 CLM Act)
- Multiple regulatory options available and penalties for non-compliance with EPA investigation
- Procedural fairness
- Consultant/Auditor involvement

Links

- Judgment in *EPA v Zoya Investments Pty Ltd* [2022] NSWLEC 149:

https://www.caselaw.nsw.gov.au/decision/185089824b3f347692992b08

- Published notice ordered by Court:

https://acapmag.com.au/2023/02/contaminated-site-declaration/

How Many Samples are Enough?

Maximum Probable Error (MPE) Method

Presentation to EPA – Auditor Meeting

May 2023

Marc Salmon
Principal Environmental Scientist

Easterly Point Environmental

How many samples? Why do we care?

Jim Chalmers, in his recent Monthly article *Capitalism after the crises*, observed that "What we measure directs our actions. If our measurements are flawed or incomplete, it follows that what we do will be too". In contaminated land, flawed actions translate to:

- Type I errors, i.e. we left a potential risk (health, environment, financial, and/or reputational);
- Type II errors, i.e. we "cleaned-up" something that didn't warrant cleaning-up (poor allocation of resources; unnecessary stress).

Conceptually, we use the data quality objectives (DQOs) process as a framework, and statistical analysis to control and communicate these error types.

How many samples? What are we trying to achieve?

Primarily, we are trying to determine the *population mean*.

While the true mean of a population often cannot be known, we can estimate the *population mean* using sampling data.

How many samples are required to ensure that, with some quantifiable certainty, the *sample mean* provides a reasonable estimate of the *population mean?*

Methods included in the EPA's 2022 guideline *Sampling Design*:

- combined risk value (CRV) method; and
- maximum probable error (MPE) method.

This **CRV method** determines the number of samples needed if the objective of the sampling is to show that the average concentration of a contaminant is below an acceptable limit.

The method can be applied to sampling an area or to sampling a stockpile(s) of soil.

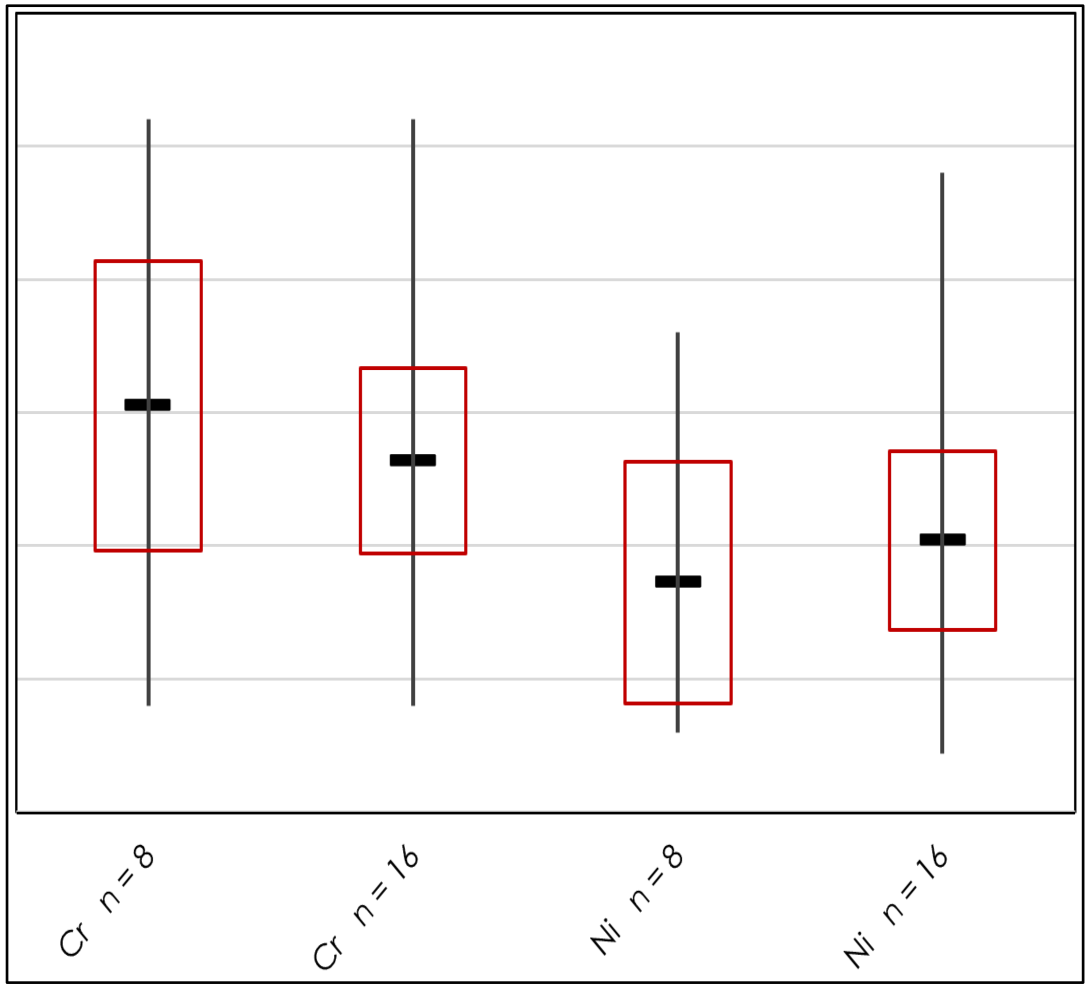
The method requires that the probable average concentration and standard deviation of the contaminant are known. This method is most applicable for validation sampling, where the average concentration and the standard deviation can be estimated from the previous sampling results.

From EPA (1995) *Contaminated Sites: Sampling Design Guidelines.*

When estimating the population mean at a specified confidence level, the **MPE method** can be used to determine n.

This method uses the margin of error (MoE), the sample standard deviation (s), and the t critical value, usually at a 95% confidence level.

"The use of confidence intervals is one way to state the required precision" (Provost 1984);



… remembering that precision simply refers to how close measurements of the same thing are to each other.

MPE method using ProUCL

Both the CRV and the MPE methods can be determined using the USEPA's freeware statistical software ProUCL.

USEPA's Office of Research and Development (ORD) funded and managed the research described in the ProUCL technical guide and the methods incorporated into the ProUCL software.

Its development began in 1999 for internal USEPA use, and grew into a publicly released software package.

It has been peer reviewed by the USEPA and approved for publication.

MPE method using ProUCL

ProUCL version 5.2.00 (5.2) is the latest update. For details and software, see:

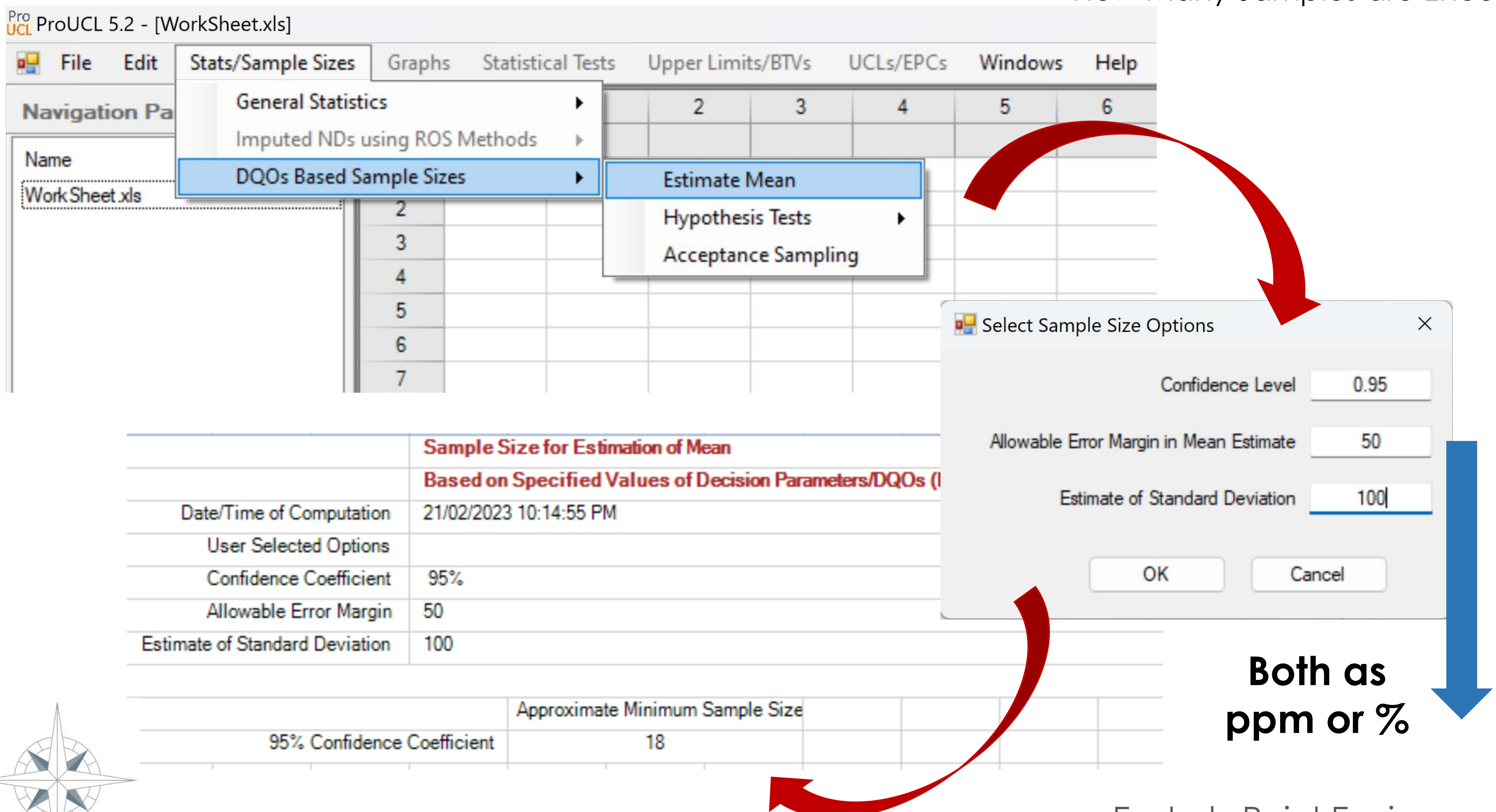
https://www.epa.gov/land-research/proucl-software

Supported by technical guidance, including:

- USEPA (2022) *ProUCL Version 5.2.0 User Guide; Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations*, (183 pages); and

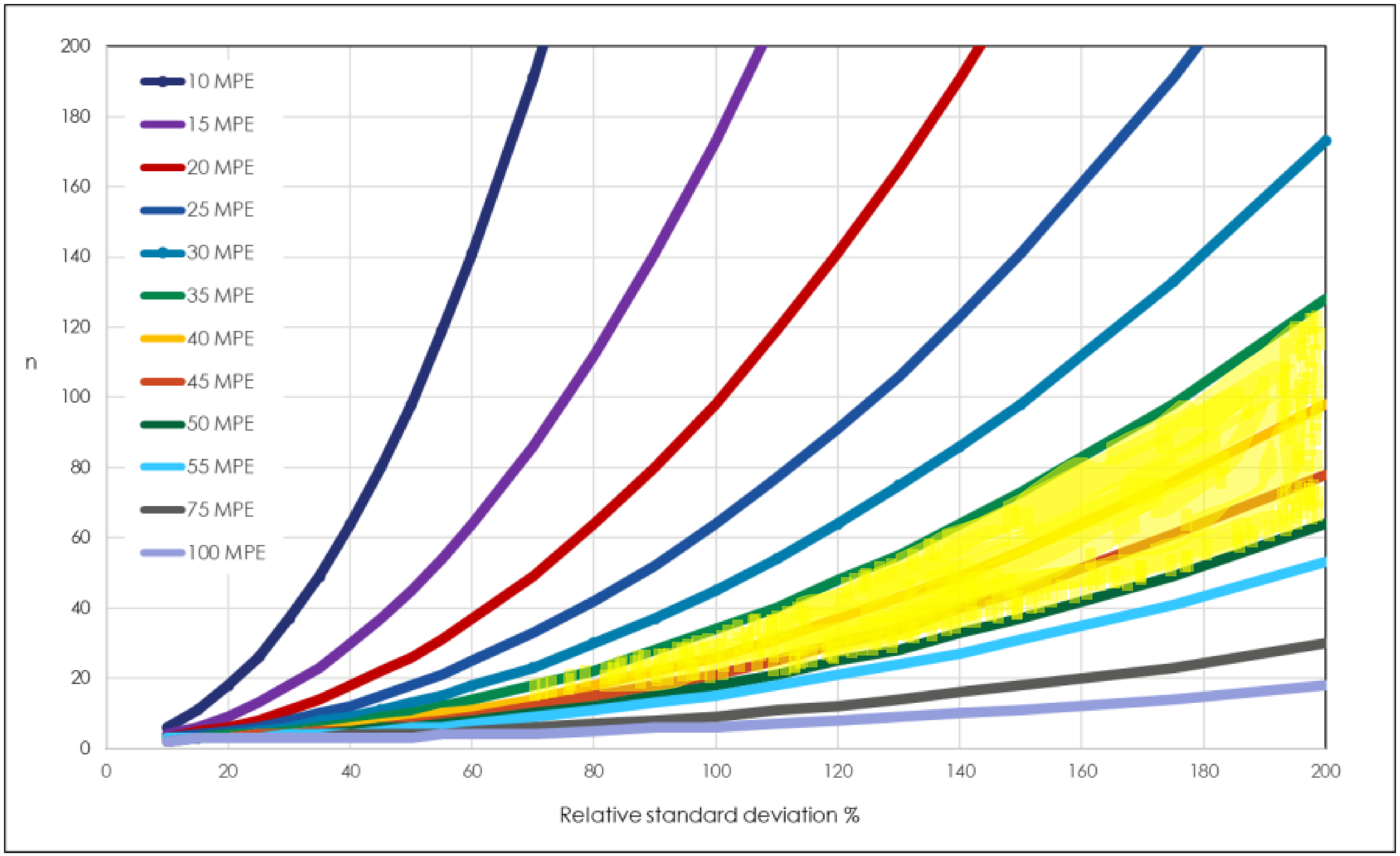
- USEPA (2022) *ProUCL Version 5.2.0 Technical Guide; Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations*, (350 pages)

How Many Samples are Enough?



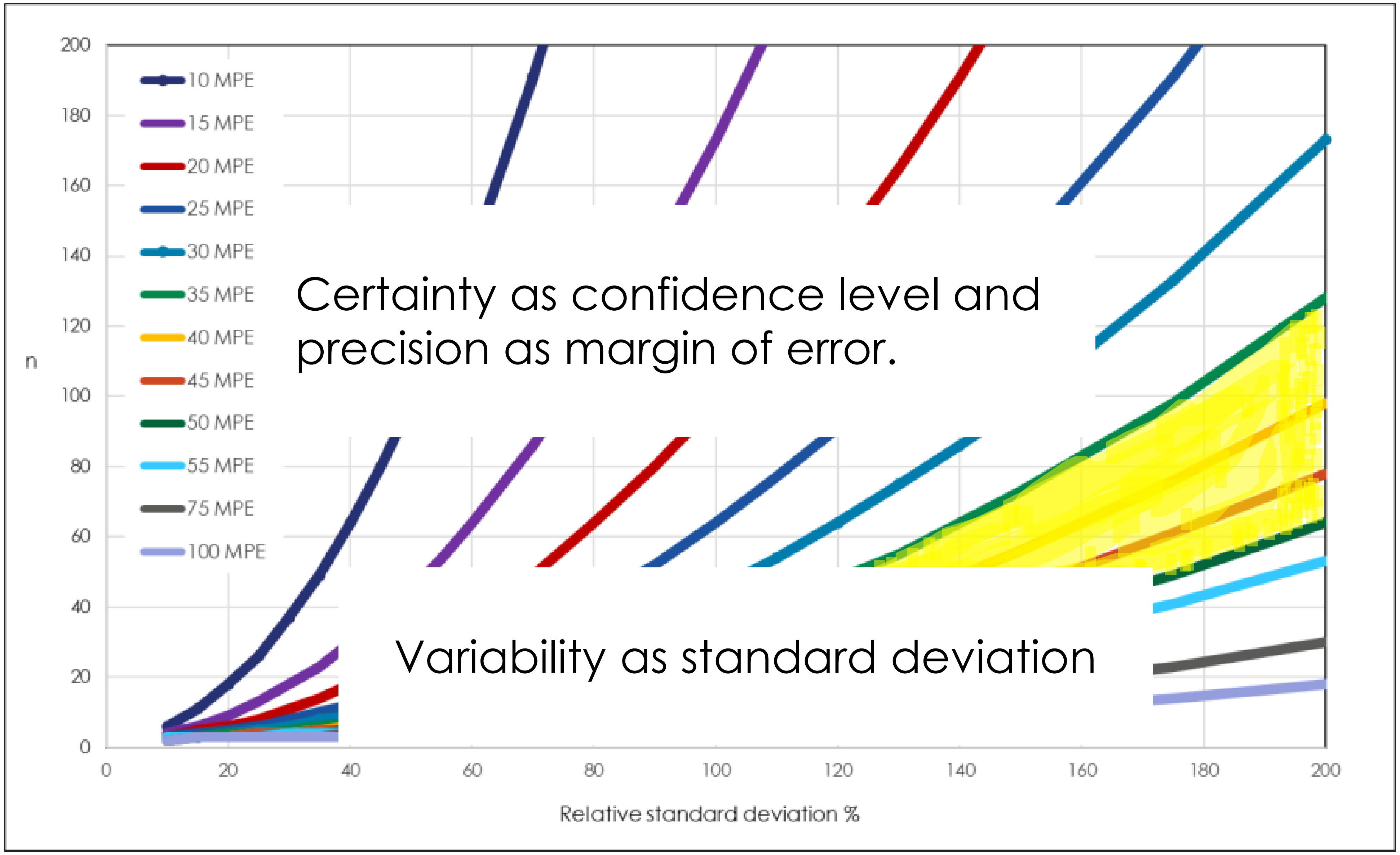
Both as ppm or %

Figure 11 Number of samples (n) required to estimate mean, based on the MPE method



Source: Easterly Point Environmental Pty Ltd

Figure 11 **Number of samples (n) required to estimate mean, based on the MPE method**



Source: Easterly Point Environmental Pty Ltd

How Many Samples are Enough?

Number of samples (n) required to estimate the arithmetic mean based on the MPE method

RSD %	Maximum probable error % at 95% confidence level											
	10	15	20	25	30	35	40	45	50	55	75	100
10	6	4	3	3	3	3	3	3	3	3	2	2
15	11	6	5	4	3	3	3	3	3	3	3	3
20	18	9	6	5	4	4	3	3	3	3	3	3
25	26	13	8	6	5	4	4	4	3	3	3	3
30	37	18	11	8	6	5	4	4	4	4	3	3
35	49	23	14	10	8	6	5	5	4	4	3	3
40	64	30	18	12	9	7	6	5	5	4	4	3
45	80	37	22	15	11	9	7	6	6	5	4	3
50	98	45	26	18	13	10	8	7	6	6	4	3
55	119	54	31	21	15	12	10	8	7	6	4	4
60	141	64	37	25	18	14	11	9	8	7	5	4
70	191	86	49	33	23	18	14	12	10	9	6	4
80	248	112	64	42	30	22	18	15	12	11	7	5
90	314	141	80	52	37	28	22	18	15	13	8	6
100	387	173	98	64	45	34	26	21	18	15	9	6
110	467	209	119	77	54	40	31	25	21	18	11	7
120	556	248	141	91	64	48	37	30	25	21	12	8
130	652	291	165	106	75	55	43	34	28	24	14	9
140	755	337	191	123	86	64	49	40	33	27	16	10
150	867	387	219	141	98	73	56	45	37	31	18	11
175	1,179	525	297	191	133	98	76	61	49	41	23	14
200	1,539	685	387	248	173	128	98	78	64	53	30	18

Why not use ProUCL to write guidelines?

An EPA – Auditor meeting post meeting agreed that the most efficient approach to updating the 1995 *Sampling Design Guidelines* would be to write it around ProUCL, including the use of screenshots and reliance on associated resources.

Elvin Wong, David Wai, Christina Lowe, Ross McFarland, Peter Beck, myself, and … ?? Other meetings over the years, including Phil Mulvey, James Davis, Julie Evans …?

Wasn't involved in all, but point is, many contributions over the years.

USEPA's ProUCL example; DNR Wisconsin 2015 *

This guidance identifies a few key tools within the USEPA's ProUCL statistical software package for averaging soil data. For data analysis, DNR recommends using EPA's ProUCL statistical software.

For the purpose of determining compliance with a numerical soil standard, compliance averaging for a particular contaminant will involve determining the 95% upper confidence limit for the mean (UCL) of the contaminant concentrations in soil samples.

A good understanding of statistics is necessary to complete the requisite data analysis for compliance averaging.

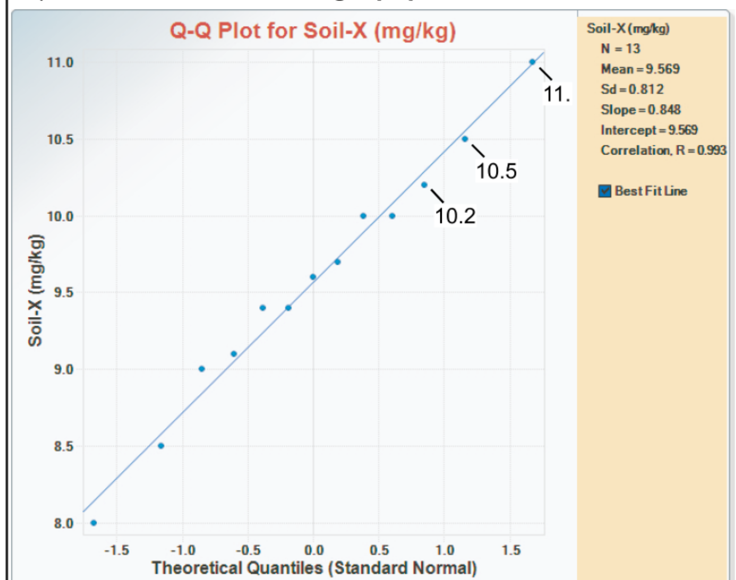
* *Compliance Averaging of Soil Contaminant Concentration Data* (DNR-RR-991); also see State of Connecticut (2014) *Guidance for Calculating the 95%* (860-424-3705).

Example 4 - Straightforward RCL-UCL Comparison

Data for Contaminant X
(RCL for X is **10** mg/kg.)
Red font indicates RCL exceedance.

Sample#	Soil-**X** (mg/kg)
1	8.5
2	9.7
3	10.
4	9.
5	8.
6	10.
7	9.1
8	10.5
9	11.
10	10.2
11	9.4
12	9.6
13	9.4

*1.) Q-Q Plot indicates a **single population**.*



*2.) Outlier test results in **no outlier**.*

Dixon's Outlier Test for Soil-X (mg/ kg)
Number of Observations = 13
10% critical value: 0.467
5% critical value: 0.521
1% critical value: 0.615
1. Observation Value 11 is a Potential Outlier (Upper Tail)?
Test Statistic: 0.316
For 10% significance level, 11 is not an outlier.
For 5% significance level, 11 is not an outlier.
For 1% significance level, 11 is not an outlier.
2. Observation Value 8 is a Potential Outlier (Lower Tail)?
Test Statistic: 0.400
For 10% significance level, 8 is not an outlier.
For 5% significance level, 8 is not an outlier.
For 1% significance level, 8 is not an outlier.

*3.) UCL (9.97) is **not greater** than RCL (10).*

General Statistics			
Total Number of Observations	13	Number of Distinct Observations	11
		Number of Missing Observations	0
Minimum	8	Mean	9.569
Maximum	11	Median	9.6
SD	0.812	Std. Error of Mean	0.225
Coefficient of Variation	0.0848	Skewness	-0.227
Normal GOF Test			
Shapiro Wilk Test Statistic	0.99	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.866	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.11	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.246	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	9.971	95% Adjusted-CLT UCL (Chen-1995)	9.924
		95% Modified-t UCL (Johnson-1978)	9.968
Suggested UCL to Use			
95% Student's-t UCL	9.971		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Some post-remediation confirmation samples showed soil-X contaminant still exceeding the RCL: 3 largest concentrations > RCL of 10 mg/kg.

Statistical analysis demonstrates the following:
1.) A single population (Q-Q plot has correlation coefficient R > 0.99.)
2.) No outliers (Dixon's test shows neither of the extreme value is an outlier.)
3.) UCL < RCL.

ProUCL will calculate several UCL estimates based on several different distributions ProUCL assumes for a given set of data. Then it will provide a suggested UCL near the bottom of the output. For soil-X, a normal distribution sufficiently explains the data set; hence, its normal-distribution UCL can be used to compare to the RCL.

Conclusion: Even though there were individual samples that exceeded the RCL, the UCL for the data set was less. Hence, the statistical analysis indicates that they can remain at the site.

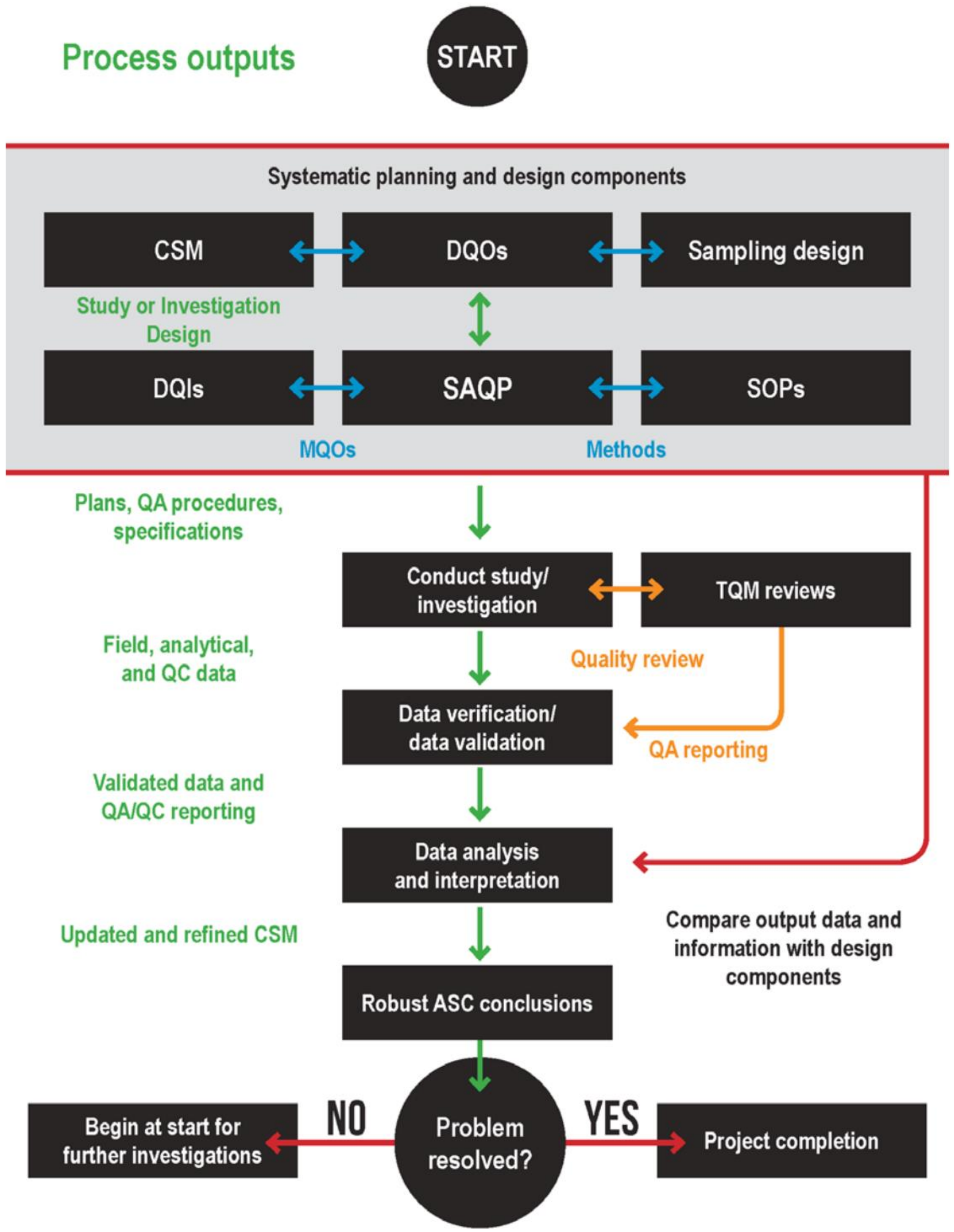
Sampling design guidelines sans ProUCL …

Why text book aspects?

Couldn't use the ProUCL theoretical framework (technical guide, user guide, etc.).

Needed to provide some theoretical background. It would have been easier to write the guidance around ProUCL screenshots and references.

Be that as it may … either a good review; or turgid and overblown …



Number of samples

There is spatial coverage, i.e. targeted sampling around features, and sampling density in plan across a site or areas that have been stratified; *decision areas*. Table A (EPA 1995); now Table 2 (Part 1, EPA 2022).

But are there sufficiently representative samples from the target population?

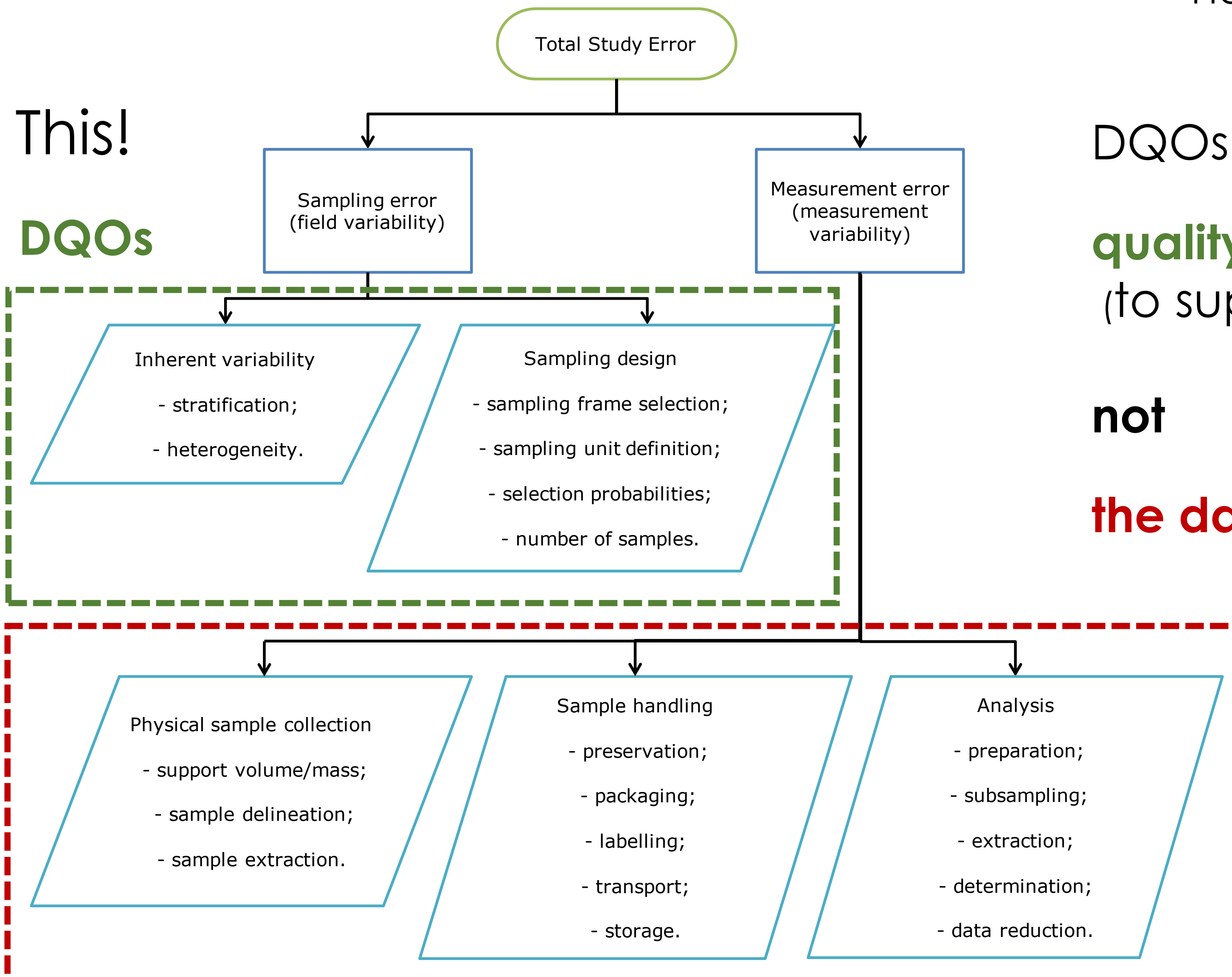
When can we stop sampling?

Representative sampling

In analytical sense, assessed as part of field and laboratory quality control (measurement variability); but in this case, how representatively sampled was the target population? How well do the samples represent the population (field variability)?

USEPA (2015) in discussing hypotheses testing approaches, highlights that “good quality data” relates to representative data.

If the samples cannot be shown to be representative of the condition of the site or decision area, in the context of the decision to be made, evaluation of the measurement quality in isolation cannot demonstrate if the data are of a suitable quality to support the required decision (Crumbling 2001).



DQOs are about the

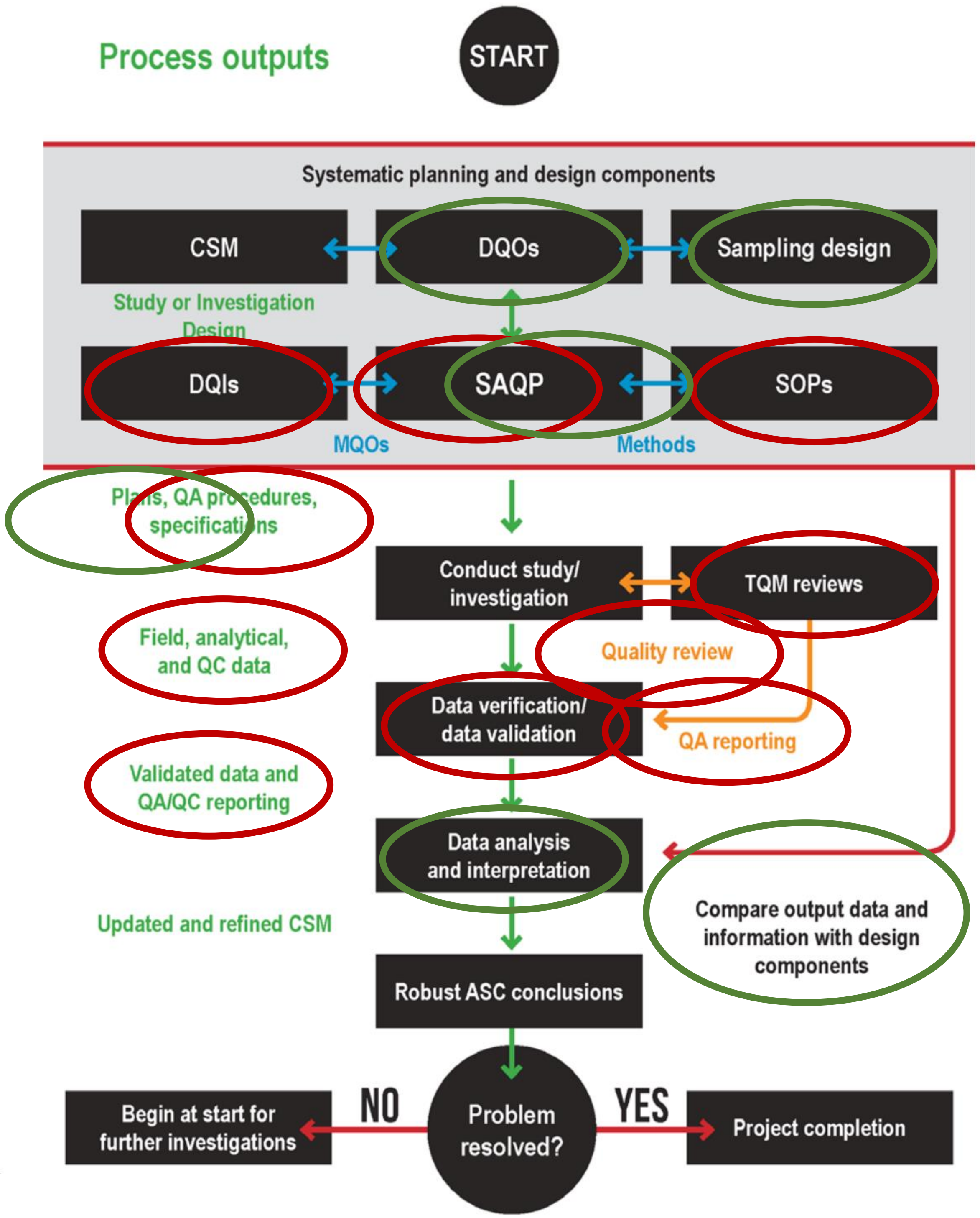
quality of the data
(to support the decision)

not

the data quality!

Not this!

DQIs
MQOs
SOPs



Not saying measurement error is not important to control; just not as part of DQOs or sampling design. At least until Step 7.

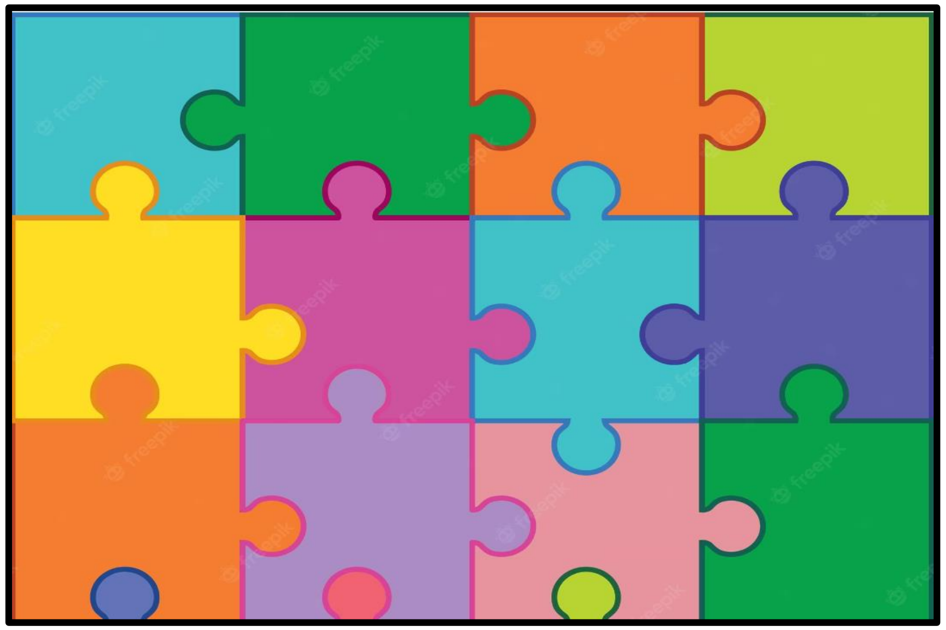
Plenty of places in EDLC process for data quality to be addressed!

Quality of the data

Data quality

How Many Samples are Enough?

Representative sampling



How many samples are required to represent the different soil types???

Representative sampling

Representative sampling assures that inferences and conclusions can reasonably extend from the sample to the population as a whole.

Not uncommon to read "because we used the sampling density from Table 2 or AS4482.1, representative sampling was achieved". Complete non-sequitur. Rhubarb, rhubarb, rhubarb.

So, how do we demonstrate that we have sufficient samples to make our decision? Or, simply put, when can we stop sampling?

Back where we started … *DQOs as a framework and statistical analysis to control and communicate these error types*.

DQOs (USEPA 2006, G-4)

The methodology of "classical" Neyman-Pearson statistical hypothesis testing provides a framework for:

- setting up a statistical hypothesis;
- designing a data collection program that will test that hypothesis;
- evaluating the resulting data;
- drawing a conclusion about whether the evidence is sufficiently strong to reject or (by default) accept the hypothesis;
- while assessing uncertainties in the data and the assumptions underlying the methodology.

The DQO Process has been designed to support a statistical hypothesis testing approach to decision making.

Null hypothesis significance testing (NHST)

The **null hypothesis H_0** is the assertion that is initially assumed to be true.

The **alternate hypothesis H_A** is the claim that is contradictory to H_0.

H_0 will be rejected in favour of H_A, only if sample evidence suggests that H_0 is false. If the sample does not strongly contradict H_0, we will continue to believe in the truth of H_0.

The two possible conclusions from a hypothesis-testing analysis are then *reject H_0* or *fail to reject H_0*.

Null hypothesis significance testing (NHST)

H_0 in the ASC?

That the site (or decision area) *is contaminated*.

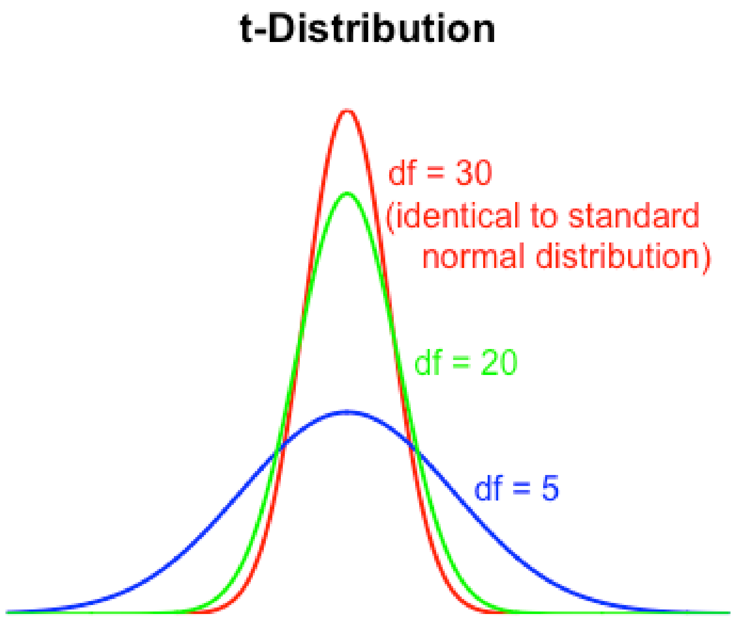
The snake *is venomous*!

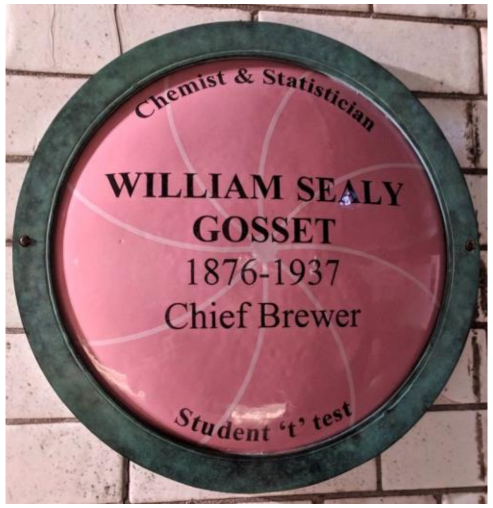
Decision made	Actual condition – state of nature	
	H_O is true	H_O is false (H_A is true)
Accept H_O	Correct decision 1-α = Significance	Decision error Type II error Beta (β)
Reject H_O	Decision error Type I error Alpha (α)	Correct decision 1-β = power of test

T-distribution

T-tests, based on Student's distribution. Developed by William Sealy Gosset, who worked for the Guinness Brewery in Dublin, and was interested in the problems of small samples.

Pseudonym used as Guinness preferred their staff to use pen names when publishing scientific papers, ergo Student. Or, Guinness did not want their competitors to know that they were using the t-test to determine the quality of raw material.





Hypothesis testing vs. UCL $\bar{x}$

T-tests and **confidence intervals** are different sides of the same coin.

$$t_0 = \frac{\bar{x} - \mu}{s/\sqrt{n}} \qquad \mu \approx \bar{x} \pm t_{\alpha/2,n-1}\left(\frac{s}{\sqrt{n}}\right)$$

If a value is accepted using hypothesis testing, the result would also fall within the confidence interval; ergo same outcome.

That is, a confidence interval is a form of hypothesis test.

Note: For standard error of the mean (SE$\bar{x}$), as n increases, SE$\bar{x}$ goes down.

Derivation of combined risk value (CRV) equation

The Z-test hypothesis testing formula for a normal distribution is:

$$Z = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}}$$

As:

$$\frac{\bar{x} - \mu}{\sigma / \sqrt{n}} = (\bar{x} - \mu) \sqrt{n} / \sigma$$

Can be written as:

$$Z = \frac{(\bar{x} - \mu) \sqrt{n}}{\sigma}$$

As a sample, with unknown μ and σ, and comparing to an action level (AL), the Z-test becomes:

$$Z = \frac{(\bar{x} - AL)\sqrt{n}}{s}$$

Which can be rearranged to:

$$\frac{Z * s}{(\bar{x} - \mathrm{AL})} = \sqrt{n}$$

Which can be rearranged to:

$$\frac{Z^2 * s^2}{(\bar{x} - \mathrm{AL})^2} = n$$

For CRV method, the expression $Z_{1\text{-}\alpha} + Z_{1\text{-}\beta}$ replaces Z, which gives:

$$n = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 * s^2}{(AL - \bar{x})^2}$$

At alpha = 0.05 and beta = 0.2, this becomes:

$$n = \frac{6.2 * s^2}{(AL - \bar{x})^2}$$

As $Z_{1-\alpha}$ = 1.645 and $Z_{1-\beta}$ = 0.842 (USEPA 1989).

Example of use of CRV method from USEPA (2006)*

Box 3-1: Directions for the One-Sample *t*-Test

COMPUTATIONS: Compute the mean, $\overline{X}$, and standard deviation, s, of the data set.

STEP 1. Null Hypothesis: $H_0: \mu = C$

STEP 2. Alternative Hypothesis:
i) $H_A: \mu > C$ (upper-tail test)
ii) $H_A: \mu < C$ (lower-tail test)
iii) $H_A: \mu \neq C$ (two-tail test)

STEP 3. Test Statistic: $t_0 = \dfrac{\overline{X} - C}{s/\sqrt{n}}$

STEP 6. If the null hypothesis was not rejected, there is only one false acceptance error rate (β at μ_1), and if

$$n \geq \frac{s^2\left(z_{1-\alpha'} + z_{1-\beta}\right)^2}{(\mu_1 - C)^2} + \frac{z_{1-\alpha'}^2}{2}$$

, then the sample size was probably large enough to achieve the DQOs.
The value of α' is α for a one-sided test and $\alpha/2$ for a two-sided test.

$$n = \frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2 * s^2}{(AL - \bar{x})^2}$$

* USEPA (2006) *Data Quality Assessment: Statistical Methods for Practitioners, EPA QA/G-9S*

Box 3-3: A One-Sample *t*-Test Example

Consider the following 9 random data values (in ppm):

82.39, 103.46, 104.93, 105.52, 98.37, 113.23, 86.62, 91.72, 108.21.

This data will be used to test: H_0: $\mu \leq 95$ ppm vs. H_A: $\mu > 95$ ppm. The decision maker has specified a 5% false rejection error rate (α) at 95 ppm (C), and a 20% false acceptance error rate (β) at 105 ppm (μ_1).

COMPUTATIONS: The mean is $\overline{X} = 99.38$ ppm and the standard deviation is $s = 10.41$ ppm.

STEP 1. Null Hypothesis: H_0: $\mu \leq 95$

STEP 2. Alternative Hypothesis: H_A: $\mu > 95$ (upper-tail test)

STEP 3. Test Statistic: $t_0 = \dfrac{\overline{X} - C}{s/\sqrt{n}} = \dfrac{99.38 - 95}{10.41/\sqrt{9}} = 1.26$

STEP 4. a) Critical Value: Using Table A-2, $t_{n-1,1-\alpha} = t_{8,0.95} = 1.86$

STEP 4. b) p-value Using Table A-2, 0.10 < p-value < 0.15. Using statistical software, $\text{p-value} = P(t_{n-1} > t_0) = P(t_8 > 1.26) = 0.1216$.

STEP 5. a) Conclusion: Since 1.26 < 1.86, we fail to reject the null hypothesis that the true population mean is at most 95 ppm.

STEP 5. b) Conclusion: Since p-value = 0.1216 > 0.05 = significance level, we fail to reject the null hypothesis that the true population mean is at most 95 ppm.

STEP 6. Since the null hypothesis was not rejected and there is only one false acceptance error rate, it is possible to use the sample size formula to determine if the error rate has been satisfied. Since,

$$n \geq \frac{s^2\left(z_{1-\alpha'} + z_{1-\beta}\right)^2}{\left(\mu_1 - C\right)^2} + \frac{z_{1-\alpha'}^2}{2} = \frac{10.41^2(1.645 + 0.842)^2}{(95 - 105)^2} + \frac{1.645^2}{2} = 8.049,$$

the false acceptance error rate has probably been satisfied.

Arsenic example from Appendix E, SD Part 1

	HIL-A	HIL-B	HIL-C	HIL-D
Health investigation level (HIL)	100	500	300	3,000
s = sample standard deviation	88.3	88.3	88.3	88.3
$\bar{x}$ = sample mean	66.3	66.3	66.3	66.3
$n = 6.2 * s^2 / (Cs - \bar{x})^2$	42.6	0.26	0.89	0.006
n based on CRV	43	1	1	1
Delta (Δ) of Cs - $\bar{x}$	34	434	234	2,934

Why not just use ProUCL for MPE?

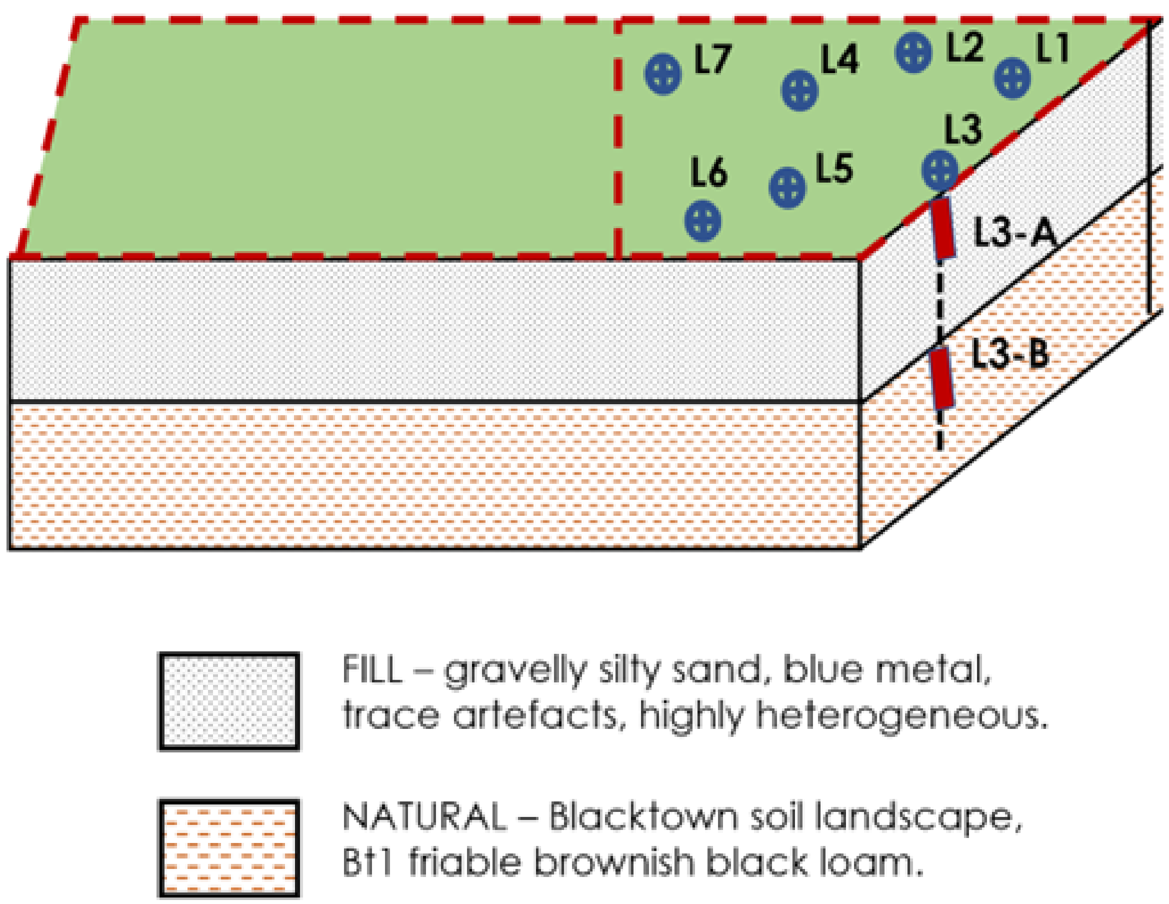
Formula cancels out to give n = n, such that you can't use it to confirm sufficient number of samples were analysed; just tells you what you did.

$$\text{Margin of error (MOE)} = t_{\alpha/2,n-1} * \frac{s}{\sqrt{n}}$$

$$\text{Number of samples (n)} = \left(\frac{t_{\alpha/2,n-1} * s}{\text{MOE}}\right)^2$$

$$n = \left(\frac{\cancel{t_{\alpha/2,n-1}} * \cancel{s}}{\cancel{t_{\alpha/2,n-1}} * \frac{\cancel{s}}{\cancel{\sqrt{}}n}}\right)^{\cancel{2}}$$

How Many Samples are Enough?



	Surficial fill	Natural soil
Statistics		
Number of samples	7	7
Number of detects	7	7
Percentage non detects	0%	0%
Maximum	**343**	**42**
95% UCL $\bar{x}$	**294.8**	**28.5**
Arithmetic average ($\bar{x}$)	185.0	20.9
95% LCL $\bar{x}$	30.5	16.5
Minimum	19	8
Standard deviation	**149.5**	**10.5**
Coefficient of variation	0.8	0.5
Relative standard deviation	**81%**	**50%**
Margin of error	138.3	9.7
Maximum probable error	**75%**	**46%**
Acceptance criteria		
Maximum ≤ 250% HIL-A	**750**	**750**
95% UCL$\bar{x}$ ≤ HIL-A	**300**	**300**
Standard deviation ≤ 50% HIL-A	**150**	**150**

Easterly Point Environmental

Number of samples (n) required to estimate the arithmetic mean based on the MPE method

RSD %	Maximum probable error % at 95% confidence level											
	10	15	20	25	30	**35**	**40**	**45**	**50**	55	**75**	100
10	6	4	3	3	3	3	3	3	3	3	2	2
15	11	6	5	4	3	3	3	3	3	3	3	3
20	18	9	6	5	4	4	3	3	3	3	3	3
25	26	13	8	6	5	4	4	4	3	3	3	3
30	37	18	11	8	6	5	4	4	4	4	3	3
35	49	23	14	10	8	6	5	5	4	4	3	3
40	64	30	18	12	9	7	6	5	5	4	4	3
45	80	37	22	15	11	9	7	6	6	5	4	3
50	98	45	26	18	13	10	8	**7**	6	6	4	3
55	119	54	31	21	15	12	10	8	7	6	4	4
60	141	64	37	25	18	14	11	9	8	7	5	4
70	191	86	49	33	23	18	14	12	10	9	6	4
80	248	112	64	42	30	22	18	15	12	11	**7**	5
90	314	141	80	52	37	28	22	18	15	13	8	6
100	387	173	98	64	45	34	26	21	18	15	9	6
110	467	209	119	77	54	40	31	25	21	18	11	7
120	556	248	141	91	64	48	37	30	25	21	12	8
130	652	291	165	106	75	55	43	34	28	24	14	9
140	755	337	191	123	86	64	49	40	33	27	16	10
150	867	387	219	141	98	73	56	45	37	31	18	11
175	1,179	525	297	191	133	98	76	61	49	41	23	14
200	1,539	685	387	248	173	128	98	78	64	53	30	18

How Many Samples are Enough?

Number of samples (n) required to estimate the arithmetic mean based on the MPE method

RSD %	Maximum probable error % at 95% confidence level											
	10	15	20	25	30	**35**	**40**	**45**	**50**	55	75	100
10	6	4	3	3	3	3	3	3	3	3	2	2
15	11	6	5	4	3	3	3	3	3	3	3	3
20	18	9	6	5	4	4	3	3	3	3	3	3
25	26	13	8	6	5	4	4	4	3	3	3	3
30	37	18	11	8	6	5	4	4	4	4	3	3
35	49	23	14	10	8	6	5	5	4	4	3	3
40	64	30	18	12	9	7	6	5	5	4	4	3
45	80	37	22	15	11	9	7	6	6	5	4	3
50	98	45	26	18	13	10	8	**7**	6	6	4	3
55	119	54	31	21	15	12	10	8	7	6	4	4
60	141	64	37	25	18	14	11	9	8	7	5	4
70	191	86	49	33	23	18	14	12	10	9	6	4
80	248	112	64	42	30	22	18	**15**	12	11	7	5
90	314	141	80	52	37	28	22	18	15	13	8	6
100	387	173	98	64	45	34	26	21	18	15	9	6
110	467	209	119	77	54	40	31	25	21	18	11	7
120	556	248	141	91	64	48	37	30	25	21	12	8
130	652	291	165	106	75	55	43	34	28	24	14	9
140	755	337	191	123	86	64	49	40	33	27	16	10
150	867	387	219	141	98	73	56	45	37	31	18	11
175	1,179	525	297	191	133	98	76	61	49	41	23	14
200	1,539	685	387	248	173	128	98	78	64	53	30	18

Workshop bit

1. Examples of MPE tables. Prizes!!!
2. Wording of MPE?
3. Sliding scale, or fixed, e.g. banana lands 16 per ha?
4. Flow charts = should we add check number of samples using MPE and/or other methods?
5. Any other feedback on Guidelines? Suggestions, complaints, problems, etc.?

Number of samples (n) required to estimate the arithmetic mean based on the MPE method

RSD %	Maximum probable error % at 95% confidence level											
	10	15	20	25	30	35	40	45	50	55	75	100
10	6	4	3	3	3	3	3	3	3	3	2	2
15	11	6	5	4	3	3	3	3	3	3	3	3
20	18	9	6	5	4	4	3	3	3	3	3	3
25	26	13	8	6	5	4	4	4	3	3	3	3
30	37	18	11	8	6	5	4	4	4	4	3	3
35	49	23	14	10	8	6	5	5	4	4	3	3
40	64	30	18	12	9	7	6	5	5	4	4	3
45	80	37	22	15	11	9	7	6	6	5	4	3
50	98	45	26	18	13	10	8	7	6	6	4	3
55	119	54	31	21	15	12	10	8	7	6	4	4
60	141	64	37	25	18	14	11	9	8	7	5	4
70	191	86	49	33	23	18	14	12	10	9	6	4
80	248	112	64	42	30	22	18	15	12	11	7	5
90	314	141	80	52	37	28	22	18	15	13	8	6
100	387	173	98	64	45	34	26	21	18	15	9	6
110	467	209	119	77	54	40	31	25	21	18	11	7
120	556	248	141	91	64	48	37	30	25	21	12	8
130	652	291	165	106	75	55	43	34	28	24	14	9
140	755	337	191	123	86	64	49	40	33	27	16	10
150	867	387	219	141	98	73	56	45	37	31	18	11
175	1,179	525	297	191	133	98	76	61	49	41	23	14
200	1,539	685	387	248	173	128	98	78	64	53	30	18

Is the wording for MPE method too confusing?

Does this need to be clearer?

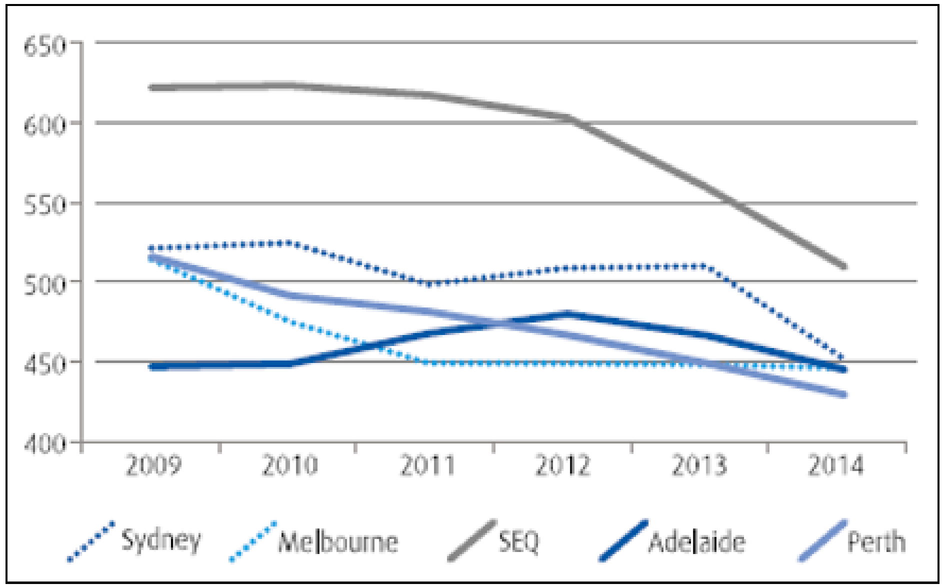
When the objective of the sampling includes the estimation of the population arithmetic mean at a specified confidence level, the MPE method as described in Provost 1984 and Gilbert 1987 can be used. This method uses the margin of error (MoE), the standard deviation(s), and the t critical value, at a 95% confidence level or higher.

As MPE is based on parametric methods, it assumes nearly-normal distribution and independent and unbiased sampling data. The MPE equation ultimately reduces to n = n, that is, all other parameters cancel out. MPE cannot retrospectively demonstrate sufficient sampling, but provides a guide to an appropriate number of samples based on the variability of the data (standard deviation, s), and the required precision of the data (MoE). Once the standard deviation of the sample dataset is known, the desired MPE can be selected, and the number of samples required to achieve that MPE can be determined.

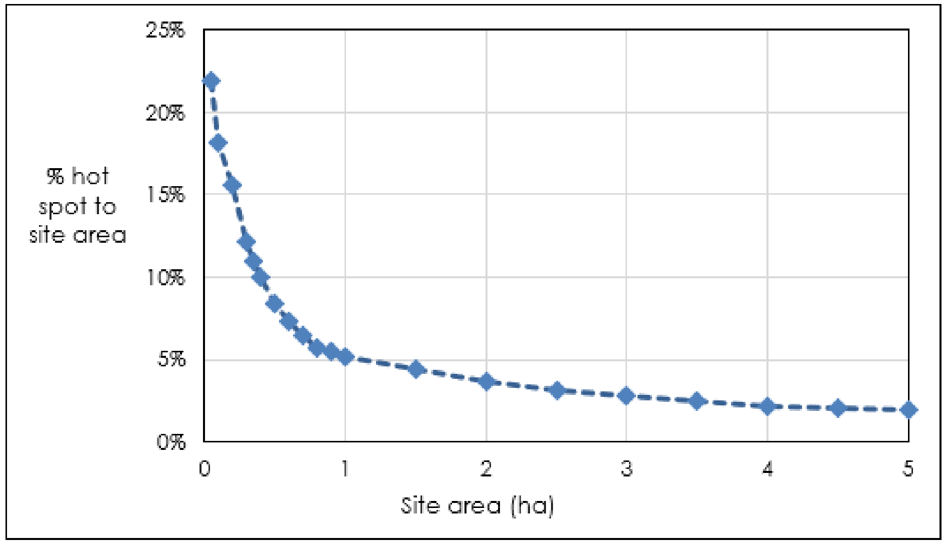
How Many Samples are Enough?

Table 2 Minimum number of sampling points for a square grid, based on site area

Size of site (ha)	Minimum number of sampling locations	Grid size (m)	Diameter of the hotspot that can be detected with 95% confidence (m)
0.05	8	8	9.3
0.1	8	11	13.2
0.2	8	16	18.7
0.3	9	18	21.5
0.4	11	19	22.5
0.5	13	20	23.1
0.6	15	20	23.6
0.7	17	20	23.9
0.8	19	21	24.2
0.9	20	21	25.0
1.0	21	22	25.7
1.5	25	24	28.9
2.0	30	26	30.5
2.5	35	27	31.5
3.0	40	27	32.3
3.5	45	28	32.9
4.0	50	28	33.4
4.5	52	29	34.7
5.0	55	30	35.6



Median greenfield growth area lot size (UDIA/NLSP 2015)



Size of hot spot that can be detected relative to site area

Easterly Point Environmental

Workshop bit

1. ~~Examples of MPE tables. Prizes!!!~~
2. ~~Wording of MPE?~~
3. ~~Sliding scale, or fixed, e.g. banana lands 16 per ha?~~
4. Flow charts = should we add check number of samples using MPE and/or other methods?
5. Any other feedback on Guidelines? Suggestions, complaints, problems, etc.?

Statistical resources:

- **Open UCL** is a free online tool, developed to provide a concise statistical summary of analytical data sets for ASC projects: https://openstatsonline.shinyapps.io/Open_UCL_V503/

- How Many Samples is Enough, Part 1 and Part 2, and more: https://13.239.74.255/

- USEPA **ProUCL** is a freeware statistical package: https://www.epa.gov/land-research/proucl-software

- USEPA Quality: https://www.epa.gov/quality/agency-wide-quality-program-documents

Open UCL - a statistical tool for contaminated sites

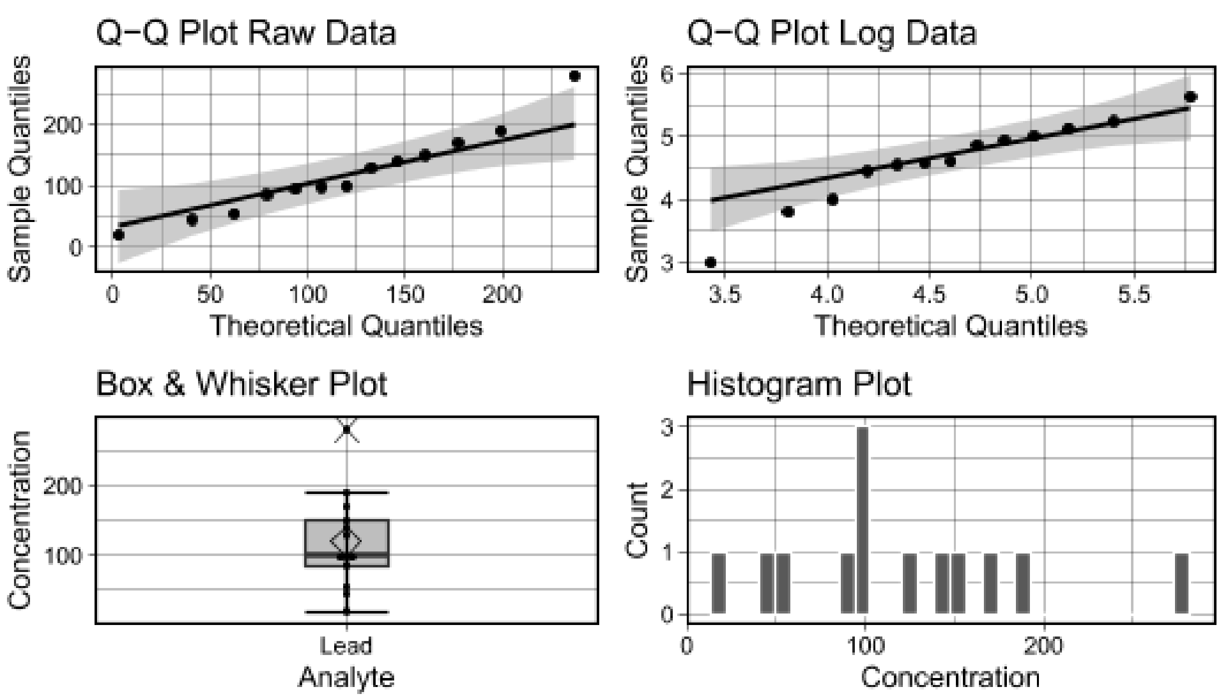
Open UCL is a free online tool developed to provide a concise statistical summary of analytical data sets for contaminated land assessment and remediation projects.

Open UCL is an open-source project. The code is available on a Github repository.

Developers and contributors are Tim Chambers, Alex Mikov, Marc Salmon, and Alan Bull.

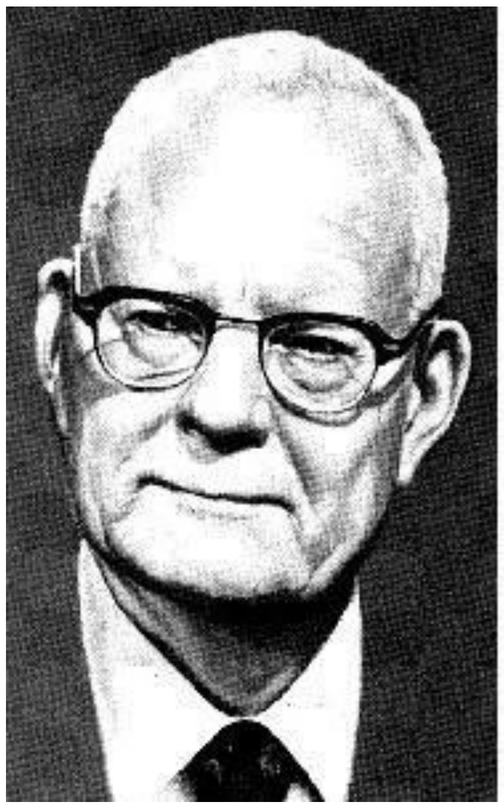
Currently a Beta version, so some things may not work perfectly or may change without much notice as we make improvements.

Open UCL outputs



Lead

Descriptive Stats		Students t 95% UCL	153.97
n	13	Upper Conf Limits	
min	20	Lands 95% HUCL	202.53
max	280	Zou 95% UCL	196.79
range	260	Chebychev 95% UCL	203.17
mean	119.92	Other Results	
gm	99.83	CV High	FALSE
median	100	Normality Raw Data	TRUE
standard deviation (sd)	68.87	Normality Log Data	TRUE
standard error of mean (sem)	19.1	Critical t (95%) 2 Sided	2.18
coeficient of variation (cv)	0.57	MOE	41.64
skewness	0.86	Z	233.2
Log Transformed		MPE(%)	34.72
Log min	3	%RSD	57.43
Log max	5.63		
Log mean	4.6		
Log sd	0.69		
Normality Tests			
Shapiro-Wilks Value (raw)	0.95		
Shapiro-Wilks p (raw)	0.64		
Shapiro-Wilks Value (log)	0.94		
Shapiro-Wilks p (log)	0.47		



"Without data you're just another person with an opinion"

- W. Edwards Deming