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United States Nuclear Regulatory Commission
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RIL 2021-12

PROCEEDINGS OF THE SUBSURFACE SOIL SURVEYS PUBLIC WORKSHOP

July 14–15, 2021

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U.S. Nuclear Regulatory Commission
Rockville, MD 20852

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Research Information Letter
Office of Nuclear Regulatory Research

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ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) is developing the technical basis for guidance on conducting and evaluating surveys of residual radioactivity in the subsurface soils of licensee sites. The NRC began to address this technical issue in NUREG/CR 7021, “A Subsurface Decision Model for Supporting Environmental Compliance,” issued January 2012. As part of this research effort, the agency held a public workshop in July 2021 to present current research results and solicit feedback from stakeholders and interested members of the public.

These workshop proceedings transmit the agenda and presentation materials for the Subsurface Soil Surveys Public Workshop held virtually July 14–15, 2021, using Web conference software. Attendees included members of the public; NRC technical staff, management, and contractors; staff from other Federal agencies; and members of academia. The workshop began with an introductory session that included perspectives and research program highlights from NRC staff members, NRC contractors, and industry representatives. Invited Federal and public speakers gave technical presentations and participated in various styles of panel discussion during the 2-day workshop. The workshop included four main topic areas for discussion:

(1) geospatial and statistical methods

(2) subsurface derived concentration guideline levels or cleanup levels

(3) subsurface hot spots

(4) surveys of subsurface materials (including surveys of excavations, backfill materials, suspect areas, and hard-to-access areas)

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1 INTRODUCTION

This research information letter (RIL) details the proceedings of the Subsurface Soil Surveys Public Workshop held virtually July 14–15, 2021. It provides the agenda, speaker information, and presentation materials. Attendees included members of the public; U.S. Nuclear Regulatory Commission (NRC) technical staff, management, and contractors; staff from other Federal agencies; and members of academia.

The workshop began with an introduction from Trish Holahan, Director, Division of Decommissioning, Uranium Recovery, and Waste Programs in the Office of Nuclear Material Safety and Safeguards (NMSS). Following these opening remarks, staff members from the Office of Nuclear Regulatory Research (RES) and an NRC contractor (SC&A, Inc.) provided an overview of the results of current research. Additionally, Bruce Montgomery from the Nuclear Energy Institute (NEI) gave industry perspectives during this introductory session.

Technical sessions followed the introduction session. Most sessions included several technical presentations and concluded with a panel of all speakers, who discussed the session topic in general. At the end of each day, participants provided feedback and asked generic questions related to that day's discussion topics.

1.1 Background

Dose modeling is used to determine cleanup levels or derived concentration guideline levels (DCGLs) that meet regulatory criteria for license termination. After remediation has been completed, final status surveys are conducted to confirm that residual radioactivity remaining at the site meets license termination rule (LTR) radiological criteria. The NRC has issued guidance for characterization and final status surveys of residual radioactive material in surface soils and structures in NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," and NUREG-1757, "Consolidated Decommissioning Guidance." MARSSIM includes procedures for these surveys and the statistical approaches used for their analysis for surficial contamination. However, this guidance applies only to contaminants in surficial materials (i.e., the top 15 centimeters of soils) and is not appropriate for use on subsurface soils (i.e., below 15 centimeters).

The NRC and industry expect an increasing number of complex decommissioning sites to become active soon. Many of these are reactor sites that can be expected to contain areas of residual radioactivity in subsurface soils. Moreover, instead of entering long-term storage before decommissioning (SAFSTOR), some reactor sites are now being decommissioned soon after shutdown. These facilities will need to be surveyed and have a determination made on the need for subsurface remediation. Statistical methods are needed to determine acceptable numbers and distributions of soil samples (or other subsurface media) taken at depth, to maintain appropriate coverage while keeping costs of sampling and analysis reasonable. Therefore, the NRC needs guidance on characterization and final status survey procedures for subsurface contamination.

Compliance assessments for surface and subsurface residual radioactivity have similar objectives, in that both focus on demonstrating that LTR radiological criteria are met. These criteria consider residual radioactivity (1) averaged over the entire site or survey unit and (2) potentially elevated concentrations in smaller areas of the site or survey unit. However, the subsurface presents substantial challenges that add to the complexity of these surveys. First, access to subsurface soils is limited, and surveying subsurface soils is much more expensive compared to surface soils. Continuous scanning techniques, which are commonly used to provide fast and detailed surveys of the surface, cannot be conducted for subsurface soils unless the soils are exposed. Second, subsurface soils can be expected to be heterogeneous in ways that may not be evident. Third, the development of DCGLs for subsurface soils is more complex and often involves consideration of various intrusion events to bring subsurface residual radioactivity to the surface, where a receptor could be exposed. In this regard, ground water exposure pathways also appear to be more important for subsurface contaminants than for contaminants found at the surface. At complex sites that operated over an extended period, mobile radionuclides may have been transported deep in the vadose zone and into ground water or fractured rock, further adding to the difficulty of characterizing subsurface residual radioactivity. For these reasons, guidance is needed for the design and implementation of radiological surveys of the subsurface that includes statistical methods to determine acceptable sample distributions in three dimensions. The NRC hopes that licensees will be able to use this guidance to demonstrate the adequacy of site characterization and final status surveys by providing reasonable assurance of compliance with radiological criteria while limiting overly conservative approaches.

The NRC has sponsored some previous work on this topic, as described in NUREG/CR-7021, "A Subsurface Decision Model for Supporting Environmental Compliance," issued January 2012. While NUREG/CR-7021 outlines an approach that overcomes obstacles to detailed subsurface surveys, it does not detail methods and statistical tests for use in the subsurface. Limitations of access to and sampling of the subsurface require an approach that, as stated in NUREG/CR-7021, "maximizes the available information, technologies, and expertise; addresses and mitigates sources of uncertainty; and is meaningful within a compliance setting." Guidance is needed to provide licensees with acceptable approaches to subsurface surveys. Ultimately, this guidance may become associated with a modeling tool that can be used to process data, visualize contaminant distributions, interpolate and extrapolate data to areas where no data exist, consider subsurface structures (natural and anthropogenic) that may influence contaminant flow and transport, and help assess the radiological status of the site for comparison against the criteria for license termination.

1.2 Workshop Objectives

The Subsurface Soil Surveys Public Workshop had two main objectives: (1) to inform and solicit feedback from internal NRC stakeholders, partner Federal agencies, industry, and the public about research in this topic area, and (2) to provide a forum for the presentation and discussion of notable U.S. activities in this area.

1.3 Workshop Scope

The workshop included four main topic areas for discussion:

(1) geospatial and statistical methods

(2) subsurface derived concentration guideline levels or cleanup levels

(3) subsurface hot spots

(4) surveys of subsurface materials (including surveys of excavations, backfill materials, suspect areas, and hard-to-access areas)

Within these main topics, the scope of the workshop presentations and discussions generally included the following:

- subsurface radiological surveys, ranging from historical site assessments, scoping, characterization, remedial action, and confirmatory and final status surveys
- DCGLs for contaminants in the subsurface and the use of multiple DCGLs for surface and subsurface layers
- evaluation of elevated areas or hot spots ($DCGL_{EMC}$) for potential doses to receptors, including the inadvertent intruder
- evaluation of sites with geospatial and statistical methods
  - statistical methods and geospatial modeling tools and software to analyze contaminant distributions and optimize sampling and scanning of the subsurface
  - methods to determine the sample density, spatial distributions, depths, and volume to achieve a level of confidence and limit decision errors
  - applicability of MARSSIM statistical tests and other alternative methods
  - treatment of uncertainty and data sufficiency
  - applicability of "composite sampling" or surrogate ratios
- applicability of Scenario B for subsurface residual radioactivity and demonstrating indistinguishability from background
- methods to survey large subsurface soil excavations and survey of soils for reuse in large excavations, including the use of conveyor belts and other methods

1.4 Organization of Workshop Proceedings

Section 2 of this RIL includes the agenda for this workshop. The agenda is also available in the Agencywide Documents Access and Management System (ADAMS) at Accession No. ML21208A212.

Section 3 presents the proceedings for the workshop, including speaker information and presentation materials. The complete workshop presentation package is available at ADAMS Package Accession No. ML21208A206.

Section 4 lists the workshop registrants, and Section 5 summarizes the workshop.

1.5 Reference Material

The following three references provide helpful background on this topic:

- Executive Summary, "Guidance on Surveys for Subsurface Radiological Contaminants," Draft Technical Letter Report," SC&A, Inc., issued April 2021 (ADAMS Accession No. ML21123A229).[1]

- NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," Revision 1, issued August 2000 (ADAMS Accession Nos. ML003761445 and ML003761454).[2]

- NUREG/CR-7021, "A Subsurface Decision Model for Supporting Environmental Compliance," issued January 2012 (ADAMS Accession No. ML12026A022)

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1 The Executive Summary report was prepared by the same contractor that supported this public workshop.

2 MARSSIM Revision 2 has been issued for public comment and is available at https://www.epa.gov/radiation/multi-agency-radiation-survey-and-site-investigation-manual-marssim-proposed-revision-2.

2 WORKSHOP AGENDA

The workshop agenda is also available at ADAMS Accession No. ML21208A212.

DAY 1 AGENDA: WEDNESDAY, JULY 14, 2021

Time	Topic	Speaker
10:00–10:05	Welcome, Webinar Logistics	Ken Hamburger, Trish Holahan, NRC
10:05–10:20	NRC Overview Presentation	Tom Aird, NRC
10:20–11:20	Overview of Guidance on Surveys for Subsurface Radiological Contaminants + Q&A	Carl Gogolak, SC&A, Inc.
11:20–12:00	NEI Presentation + Q&A	Bruce Montgomery, Nuclear Energy Institute (NEI)
12:00–13:00	***1-hour Break***	
	Workshop Topic: Geospatial and Statistical Methods	
13:00–13:30	EPRI Presentation: Experiences with Geospatial and Statistical Based Surveys of Subsurface Soil	Richard Reid, Electric Power Research Institute (EPRI)
13:30–14:00	VSP Geospatial Statistical Methods to Support Decommissioning	Debbie Fagan, Pacific Northwest National Laboratory (PNNL)
14:00–14:10	***10-minute Break***	
14:10–15:50	Open discussion on the evaluation of sites with geospatial and statistical methods: – applicability of MARSSIM statistical tests and other methods – treatment of uncertainty and data sufficiency. – methods to determine the sample density, spatial distributions, depths, and volume to achieve a level of confidence and limit decision errors	
15:50–16:00	Daily Wrap-up	

DAY 2 AGENDA: THURSDAY, JULY 15, 2021

Time	Topic	Speaker
10:00	Day 2 Welcome	NRC Staff
10:00–10:30	**Presentation:** MARSSIM Subsurface Background	Kathryn Snead, EPA
	Presentation: A Graded Approach to Subsurface Characterization and Remediation and Related Tools and Methods	Matt Darois, RSCS
10:30–11:15	**Discussion Topic: Subsurface DCGLs**	
	Short Presentations:	
	Development of Derived Concentration Guideline Levels (DCGLs or clean-up levels) for Subsurface Residual Radioactivity	Cynthia Barr, NRC/NMSS
	Subsurface DCGL: Effects of Thickness, Area, and Cover	Charley Yu, Argonne National Laboratory
	--specific discussion on this topic--	
11:15–12:30	**Discussion Topic: Subsurface Hot Spots**	
	Short Presentations:	
	Elevated Areas or “Hot Spots” in the Subsurface	Cynthia Barr, NRC/NMSS
	Subsurface Hot Spots	Carl Gogolak, SC&A
	--specific discussion on this topic--	
12:30–13:30	***1-hour Break***	
13:30–15:00	**Discussion Topic: Surveys of subsurface, including surveys of excavations, backfill materials, suspect areas, and hard-to-access areas**	
	Short Presentations:	
	Survey Issues with Excavations from Recent Decommissionings	Bruce Watson, NRC/NMSS
	Low Level Radioactive Objects at a Former Department of Defense Facility	Matthew Wright, California Department of Public Health
	Surveys of Survey Units with Low-Levels of Radioactivity	Claude Wiblin, SC&A
	--specific discussion on this topic--	
15:00–15:15	***15-minute Break***	
15:15–16:00	**Discussion Topic: Surveys of subsurface, including surveys of excavations, backfill materials, suspect areas, and hard-to-access areas**	

Specific discussion on subsurface survey topics, including but not limited to:

- dose calculations for backfill materials
- applicability of Scenario B for subsurface residual radioactivity
- methods to survey large subsurface soil excavations

16:00	Workshop Wrap-up	NRC Staff

3 PROCEEDINGS

3.1 Day 1: Introductory Presentations

3.1.1 NRC Overview Presentation (ADAMS Accession No. ML21208A213)

Speaker: Thomas Aird, NRC Office of Nuclear Regulatory Research

3.1.1.1 Presentation Materials

Workshop Objective

We want your ideas, perspectives, and experience with <u>characterizing and surveying</u> subsurface contamination

Is this "Subsurface MARSSIM"? → No

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Today's Agenda, July 14

10:05 - 10:20	**NRC Introduction**	**Tom Aird, NRC**
10:20 - 11:20	Overview of Guidance on Surveys for Subsurface Radiological Contaminants + Q&A	Carl Gogolak, SC&A, Inc.
11:20 - 12:00	NEI Presentation + Q&A	Bruce Montgomery, Nuclear Energy Institute (NEI)
12:00 - 13:00	***1-hour break***	
	Discussion Topic: Geospatial and Statistical Methods	
13:00 - 13:30	EPRI presentation: **Experiences with Geospatial and Statistical Based Surveys of Subsurface Soil**	Richard Reid, Electric Power Research Institute (EPRI)
13:30 - 14:00	PNNL Presentation	Pacific Northwest National Laboratory (PNNL)
14:00 - 14:10	***10-minute break***	
14:10 - 15:50	Open Discussion on the evaluation of sites with geospatial and statistical methods: -Applicability of MARSSIM statistical tests and other methods -Treatment of uncertainty and data sufficiency. -Methods to determine the sample density, spatial distributions, depths, and volume to achieve a level of confidence and limit decision errors	
15:50 - 16:00	Daily Wrap-up	

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Tomorrow's Agenda, July 15

Time	Agenda
10:00 - 10:30	**EPA Presentation: MARSSIM Subsurface Background** **Industry Presentation:** A Graded Approach to Subsurface Characterization and Remediation and Related Tools and Methods
10:30 – 11:15	**Discussion Topic: Subsurface DCGLs** Presentation(s): **Cynthia Barr, NRC/NMSS** **Charlie Yu, Argonne National Lab** Open Discussion
11:15 – 12:30	**Discussion Topic: Subsurface Hot Spots** Presentation(s): **Cynthia Barr, NRC/NMSS** **Carl Gogolak, SC&A** Open Discussion
12:30 - 13:30	***1-hour break***
13:30 - 15:00	**Discussion Topic: Surveys of subsurface, including surveys of excavations, backfill materials, suspect areas, and hard-to-access areas** Presentation(s): **Bruce Watson, NRC/NMSS** **Matthew Wright, California DPH** **Claude Wiblin, SC&A** (10-minute talk) Open Discussion
15:00 - 15:15	***15-minute break***
15:15 – 16:00	Open Discussion on subsurface survey topics including but not limited to: -Dose calculations for backfill materials; DCGLs for contaminants in the subsurface -Applicability of Scenario B for subsurface residual radioactivity -Methods to survey large subsurface soil excavations

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Attendance Snapshot

Federal agencies registered:

Also:

125+ total registrants

20+ registrants from commercial companies

4+ DOE National Laboratories

3+ international registrants

Oak Ridge National Laboratory

Argonne National Laboratory

Pacific Northwest National Laboratory

Los Alamos National Laboratory

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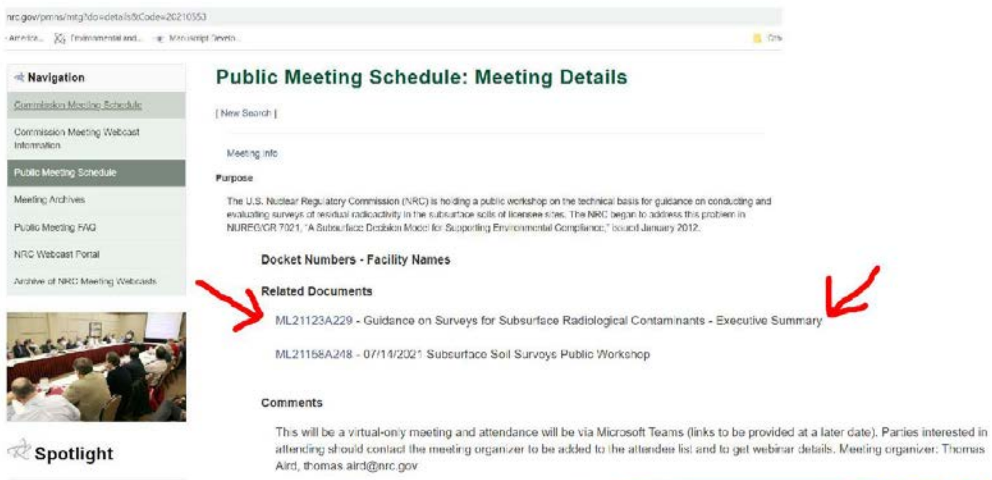
Helpful Background Info

Public meeting website:

https://www.nrc.gov/pmns/mtg?do=details&Code=20210553



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Workshop Motivation

Workshop Objective: we want your ideas, perspectives, and experience with characterizing and surveying subsurface contamination

Workshop Motivation?

- More sites are being rapidly decommissioned instead of entering SAFSTOR
- These sites are complex and expected to contain areas of residual radioactivity in subsurface soils
- These facilities will need to be surveyed and a determination made as to the need for subsurface remediation.

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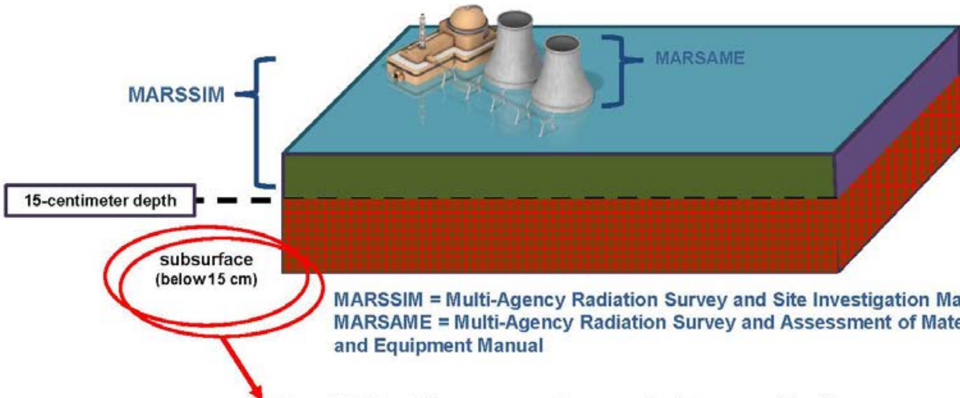
A simple illustration of the issue…



MARSSIM = Multi-Agency Radiation Survey and Site Investigation Manual
MARSAME = Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual

New NRC guidance may be needed to provide licensees with acceptable approaches to subsurface surveys…

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This is not a new issue

- NRC Office of Nuclear Material Safety and Safeguards (NMSS) has already reviewed and approved many decommissioning licensee applications
- Some of these applications had subsurface contamination
- What we propose did not exist then, so what did licensees and NMSS do instead?
  - Employed a case-by-case approach → very fact specific

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Prior NRC guidance

- NUREG/CR-7021 (January 2012)
  - A Subsurface Decision Model for Supporting Environmental Compliance
- NUREG-1757, Volume 2, Revision 1
  - Consolidated Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria
  - Volume 2, Revision 2 has been issued as a draft report for comment
- NUREG-1575, Revision 1
  - Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)

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RESEARCH PROCESS

Guidance on Subsurface Contamination Surveys

WE ARE HERE

1. **NRC Licensing Office Requests Assistance**
   Guidance is needed to provide licensees with acceptable approaches to subsurface surveys
2. **Research project proposed and awarded**
   Statement of work drafted by NRC staff for subsurface surveys research proposal
3. **NRC and Contractor develops technical basis**
   NRC and SC&A Inc. develops technical basis document(s) with NRC staff **and public input**
4. **NRC staff drafts guidance**
   RES and NMSS staff write NUREGs, Regulatory Guides, or other guidance documents to support licensee subsurface surveys

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Thanks again for attending!
NRC Subsurface Surveys Workshop
July 14 – DAY 1
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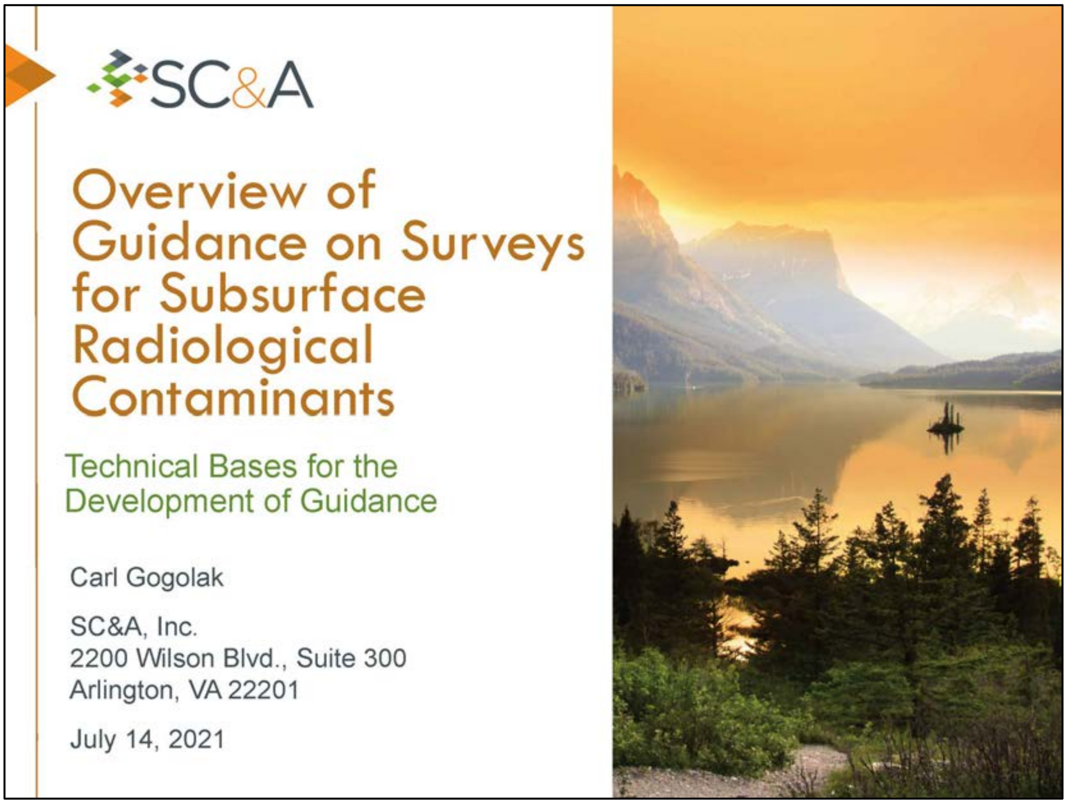
3.1.2 Overview of Guidance on Surveys for Subsurface Radiological Contaminants (ADAMS Accession No. ML21208A214)

Speaker: Carl Gogolak, SC&A, Inc.

3.1.2.1 Presentation Materials



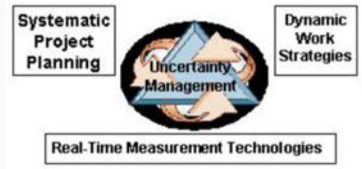
Some Technical Issues To Be Addressed

1. Introduction
2. Survey Approaches for Different Types of Licensees
3. Derived Concentration Guideline Levels
4. Implications of NUREG-1757, Volume 2
5. Stages of the Subsurface Decision Framework
6. Geospatial Modeling Tools
7. Statistical Methods and Tests
8. Geospatial and Statistical Methods
9. Assessing Background and Scenario B
10. Evaluations of Large Soil Excavations and Equipment
11. Treatment of Uncertainty and Data Sufficiency
12. Elevated Areas and Hot Spots

Key References

- EN ISO 18557:2020, "Characterization Principles for Soils, Buildings and Infrastructures Contaminated by Radionuclides for Remediation Purposes"
- ANSI/ANS-2.17-2010, "Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Plants"
- NUREG/CR-7021, "A Subsurface Decision Model for Supporting Environmental Compliance"

Survey Approaches



Triad Approach

- ISO and ANSI standards summarize approaches needed for different types of NRC-licensed sites (e.g., reactors vs. materials sites)
- Data Quality Objectives (DQO) Process EPA QA/G-4
- Triad: Conceptual site model (CSM)
- A CSM uses all available historical and current information to manage decision uncertainty
- MARSSIM connects to the Triad approach through the DQO process

Triad, DQOs, and MARSSIM

- The DQO process focuses primarily on data collection, while the Triad approach emphasizes decision-making and other site-related activities deemed to be within the scope of "systematic project planning"
- In Triad, an accurately maintained and updated CSM can be employed to decide how classical statistics and geostatistics will be used for evaluating data
- MARSSIM focuses on demonstrating compliance during the final status survey, which follows historical assessment scoping, characterization, and any necessary remedial actions

Conceptual Site Model (CSM)

- Triad activities are based on the management of *decision uncertainty*
  - Systematic project planning
  - Dynamic work strategies
  - Real-time measurement technologies (to support real time decision-making)
- Misconceptions that Triad:
  - Is nothing new
  - Increase regulatory workload
  - Always less costly
  - Has inadequate quality assurance/quality control
  - Is the same as the DQO process
  - May need the guidance of an experienced Triad practitioner

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Conceptual Site Model

- A CSM delineates and summarizes:
  - How contamination occurred
  - What is happening to it
  - Who might be exposed to it
  - What might be done to mitigate that exposure
- An accurate CSM is the basis for confident decisions about risk and remediation
- The CSM is used as a primary tool in NUREG/CR-7021

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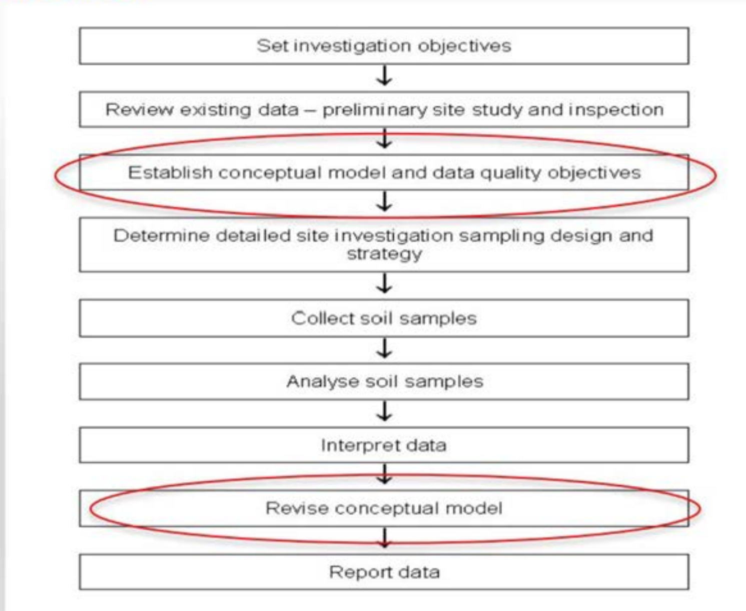
CSMs Are Similar to DQOs But with Broader Application



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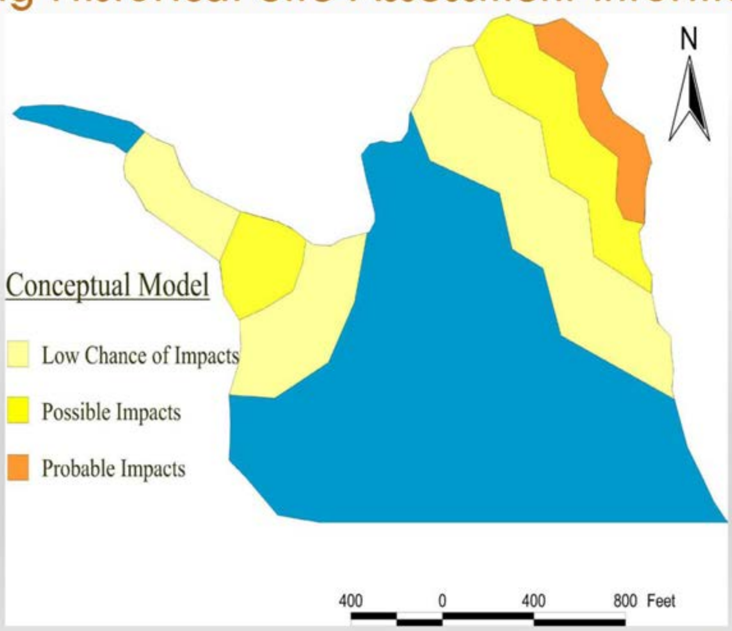
Potential Impacted Areas on a CSM Map Using Historical Site Assessment Information



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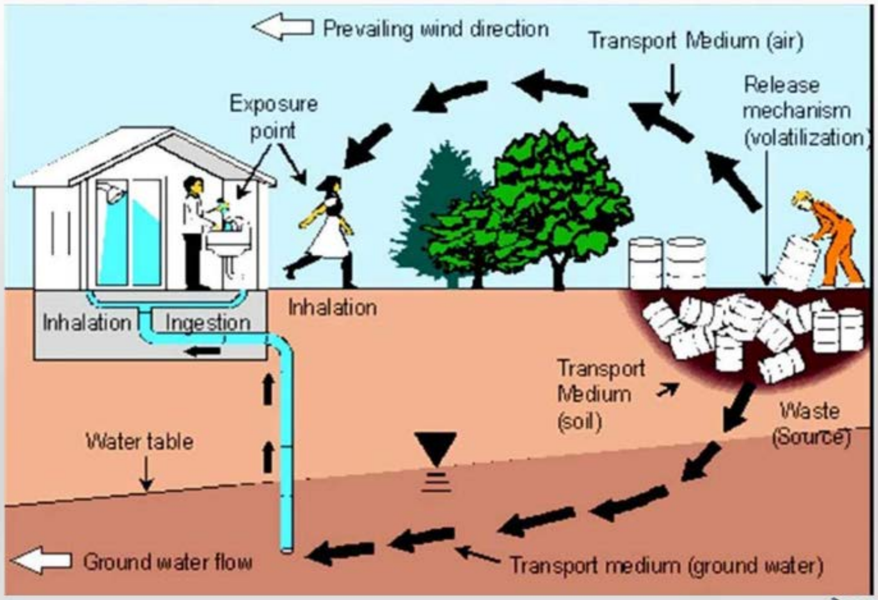
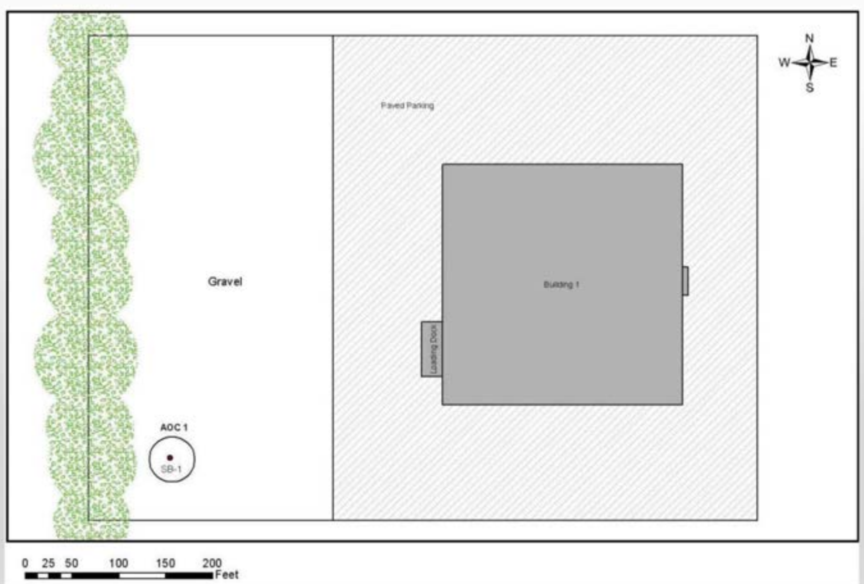
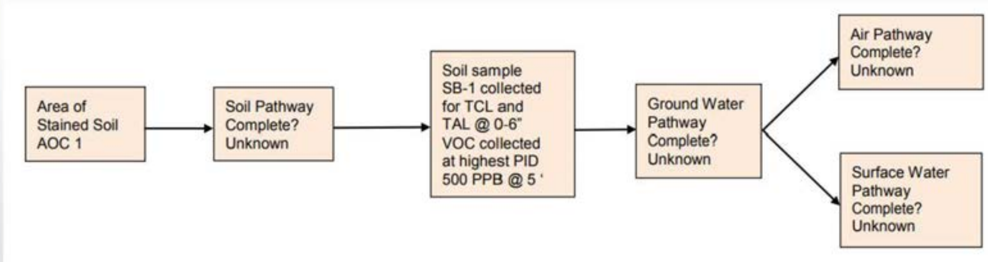
CSM for Exposure: USACE EM1-12 (2012)



CSM: Single Area of Concern Near a Building



Conceptual Site Model

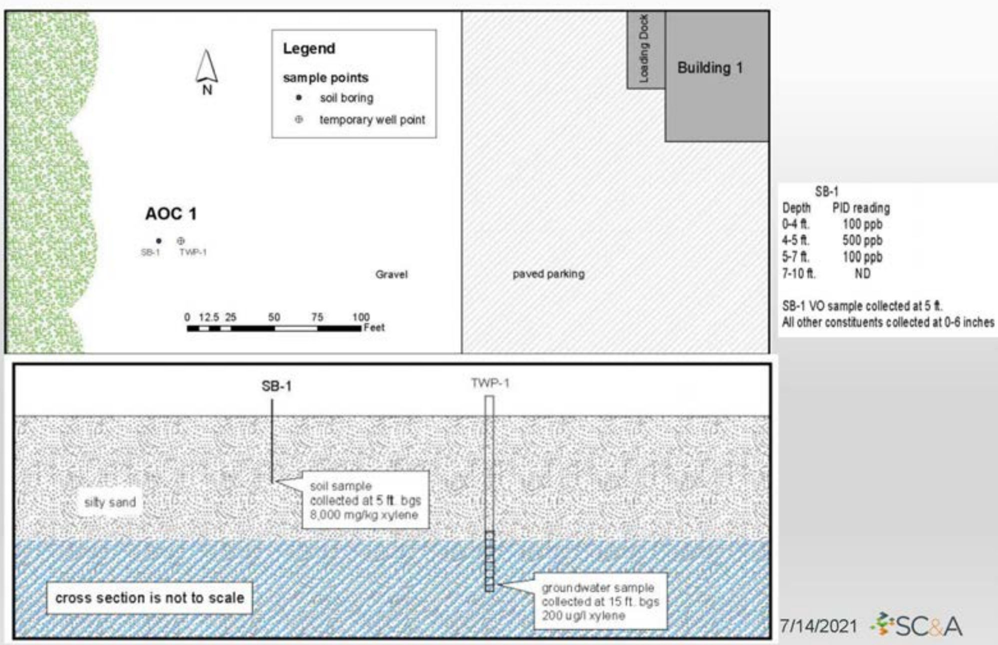


Area of Concern (AOC) 1 is an area of stained soil/gravel less than 25 square feet. AOC 1 is the only AOC on site. Review of aerial photographs, Sanborn maps, and staff interviews indicate no other potential discharges. Surrounding properties are zoned commercial/industrial.

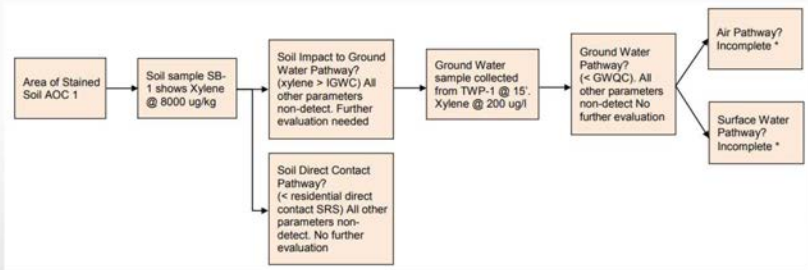
Actions Taken: Soil samples collected for target compound list plus tentatively identified compounds (TICs)/Target Analyte List (TCL + TICs/TAL). Volatile organic compounds (VOCs) sample collected at 5 feet based on the highest photoionization detector reading. All other parameters collected at 0–6 inches.

Impacted Media: Based on staining, soil is expected to be impacted. Groundwater has a potential impact, while air (>200 feet to structure) and surface water (>200 feet to closest feature) are unlikely to be impacted.

CSM: Sampling Conducted



CSM Flowchart



AOC 1 is an area of stained soil/gravel less than 25 square feet. AOC 1 is the only AOC on site. Review of aerial photographs, Sanborn maps, and staff interviews indicate no other potential discharges. Surrounding properties are zoned commercial/industrial.

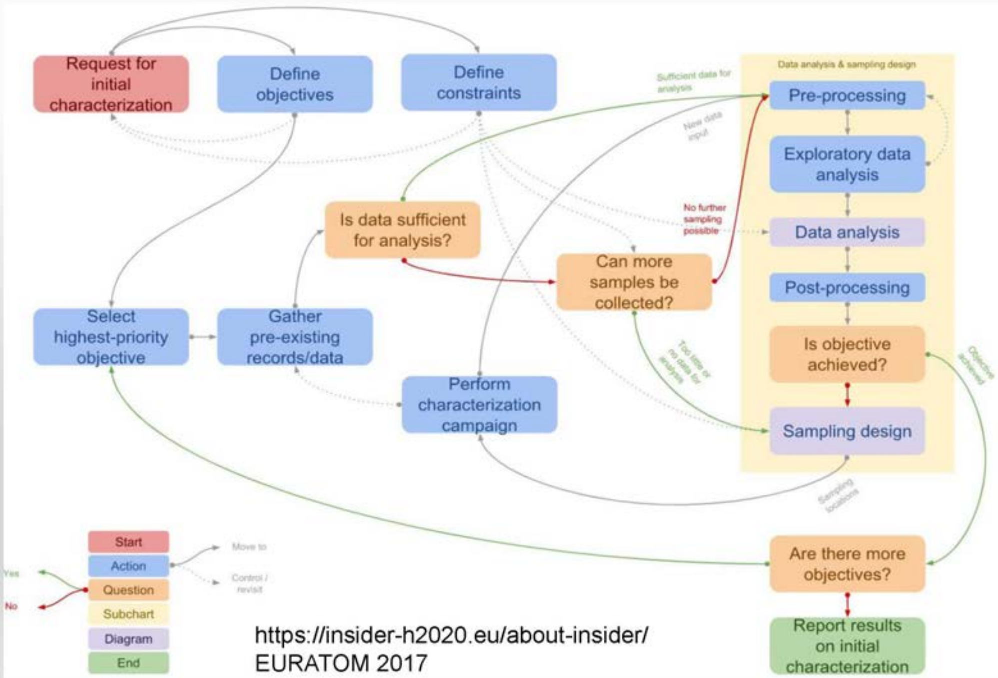
Actions Taken: Soil samples SB-1 collected at 5 feet for VOCs showed 8,000 ug/kg of xylene. All other parameters are non-detect. Groundwater sample collected at 15 feet for VOCs. Sample contained 200 ug/l of xylene.

Impacted Media/Pathway:
Soil Direct Contact: All parameters below direct contact criteria.
Soil Impact to Groundwater: Xylene above default soil IGWC; therefore, groundwater investigated.
Groundwater: Xylene detected below GWQC.
Air: Pathway incomplete.
Surface water: Pathway incomplete.

INSIDER

https://insider-h2020.eu/about-insider/
EURATOM 2017

INSIDER Strategy



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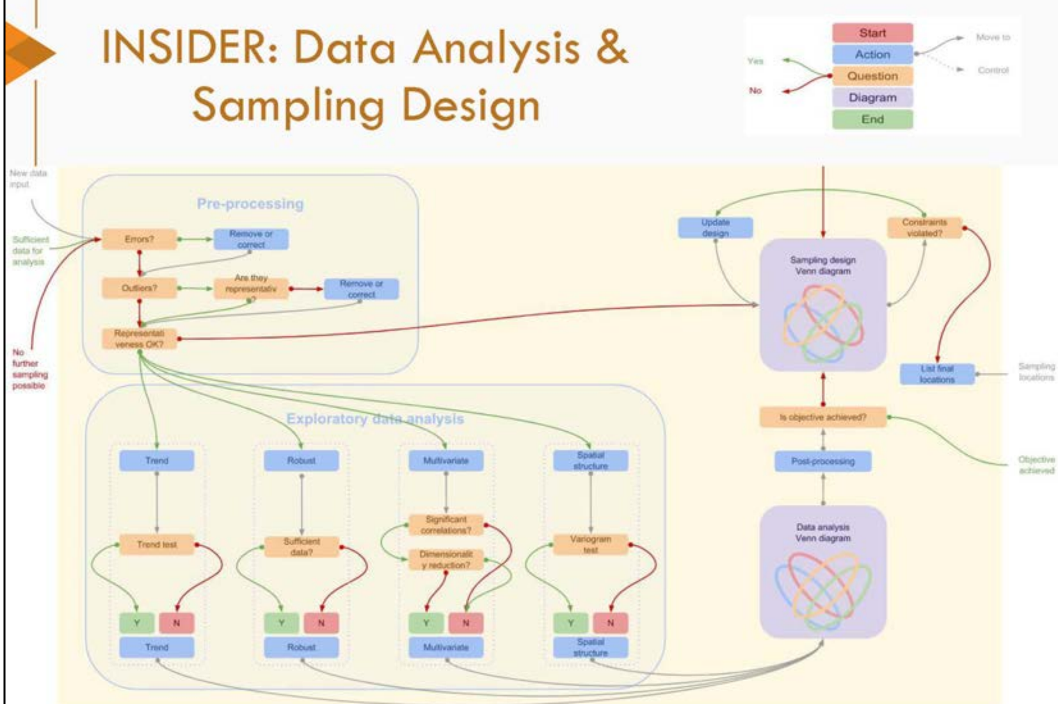
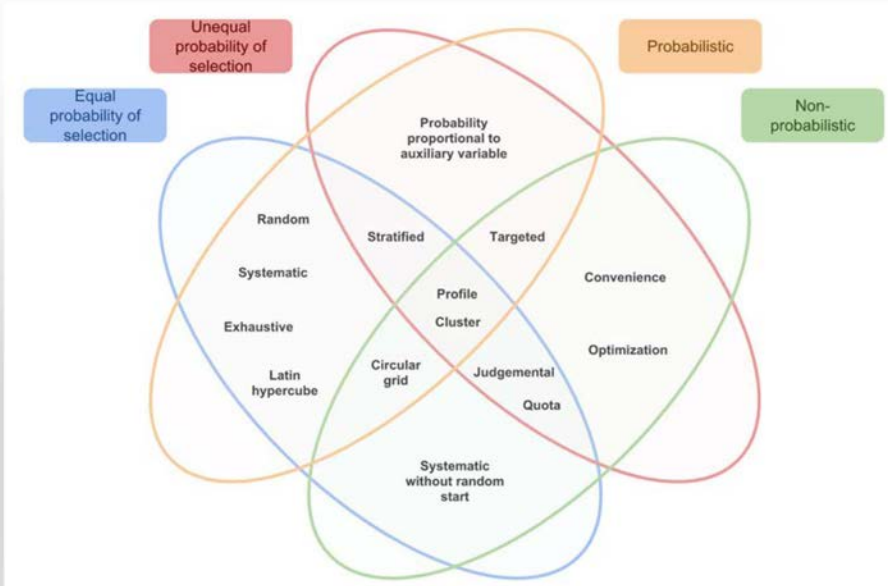
EURATOM 2017

INSIDER: Data Analysis & Sampling Design



INSIDER Sampling Design



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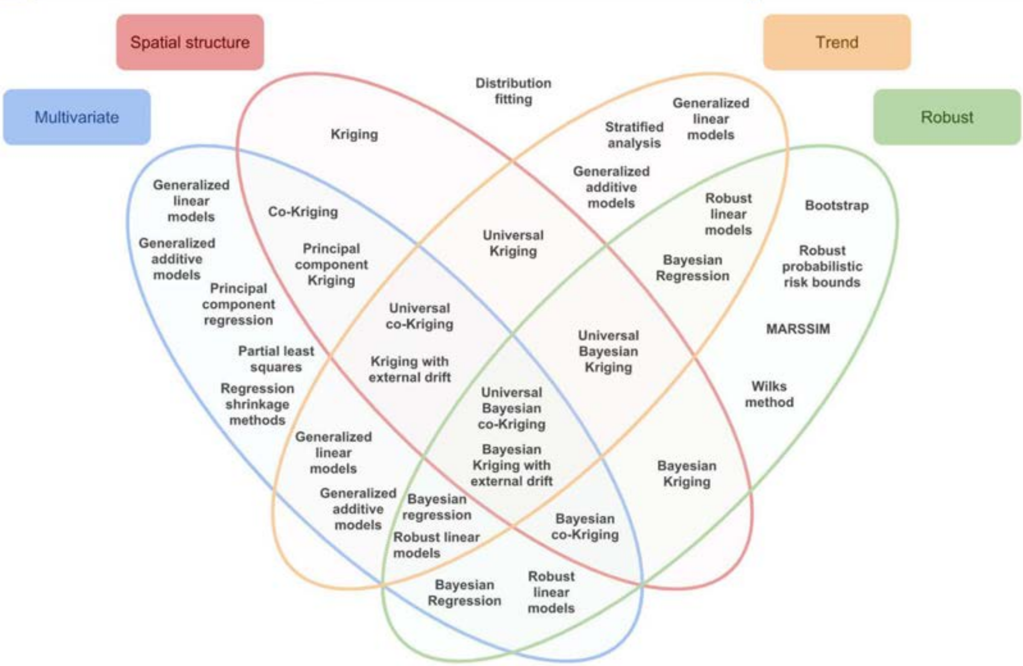
INSIDER: Data Analysis



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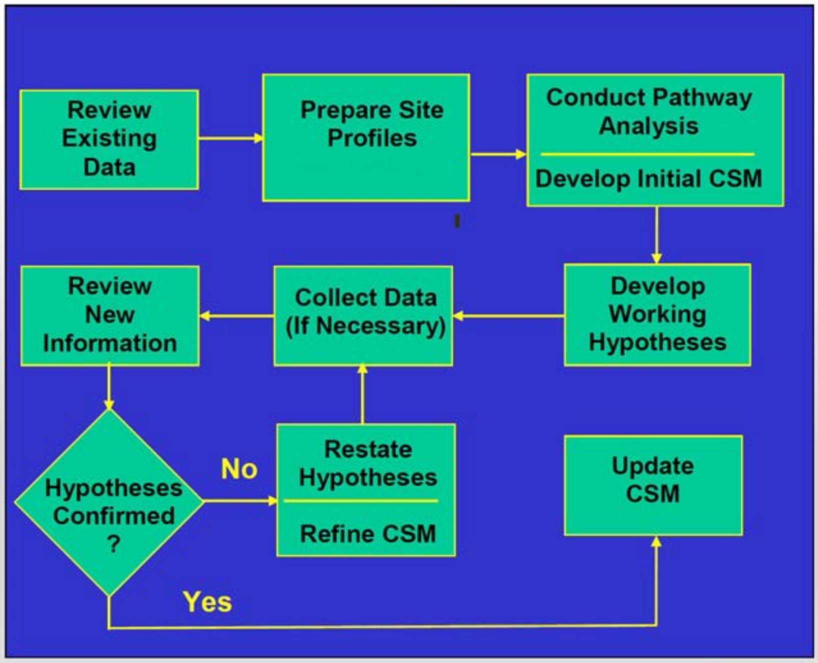
CSM Iterative Development Process



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1- State the Problem

- CCM is a mapping of the site with continuous estimates of activity levels and the uncertainty of those values
- At each stage in the survey process (Scoping → FFS), an updated Contamination Concern Map (CCM) is constructed
- The CCM is not a schematic or diagram but a spatially explicit, numerical model that may require the use of geographical mapping tools (e.g., GIS) and other spatial modeling software to implement

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1- State the Problem (cont.)

- Information intensive sampling (hard data) that sampling would provide is replaced and/or augmented with all auxiliary forms of available and useable data. Hard data is based on measurable quantities from reliable sources and methodologies.
- Interpolation tools (such as kriging) can be used to produce a continuous CCM. The relationship between measurements at nearby hard data locations is exploited to extract more information from the data set.

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1- State the Problem (cont.)

- "Soft data" is based on qualitative observations such as rankings, expert judgment, and employee interviews. Such information may be considered "surrogate" values. Such may not be as accurate and precise as hard data but are generally less costly to obtain.
- Hard and soft data may be combined mathematically (e.g., co-kriging) to produce a model of the probability of exceeding an established decision across a site or survey unit. Modeled values can also direct the placement of secondary samples and update the CSM.

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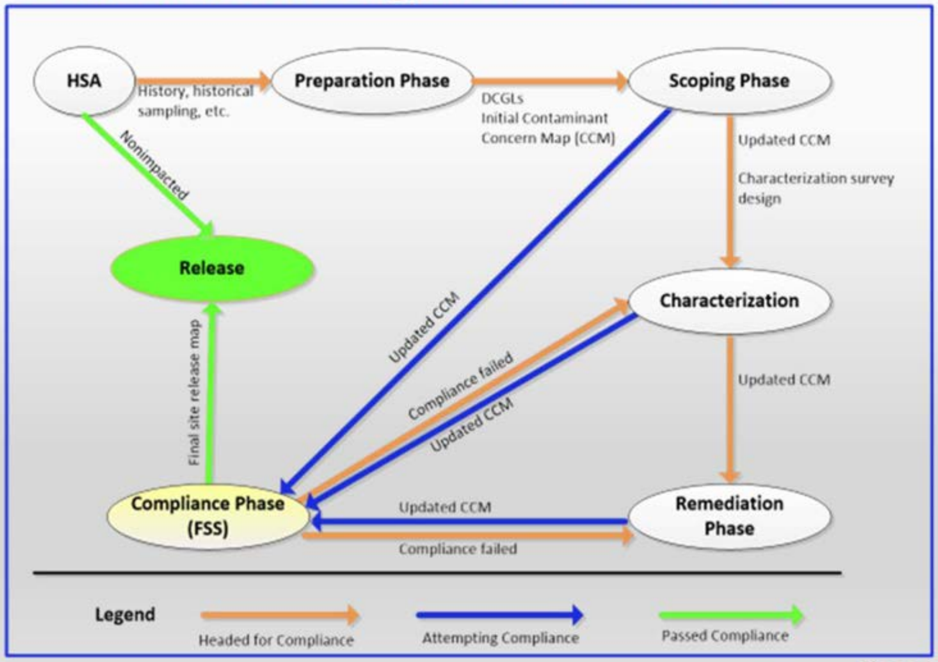
Radiation Investigation Flow Chart



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Complexities of Subsurface Sampling

- In the subsurface, all radionuclides essentially become hard to detect
- Soil types may vary more than surface soils
- Sampling at depth requires special sampling tools
- Samples are taken from a core for testing at an analytical laboratory
- Samples are taken at several different depth intervals to define the vertical extent of the residual radioactivity in the vadose zone and into ground water or fractured rock

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2 - IDENTIFY THE GOAL OF THE STUDY

- Historical Site Assessment
  - Preliminary: the initial CCM and preliminary CSM
- Scoping
  - Estimate a reasonable number and location for scoping samples
- Characterization
  - Estimate both the extent and volume of the contaminated media, construct an AOC map
- Remedial Action
  - Use the AOC map to aid the remedial action design
- Final Status Survey
  - Latest CCM is used as the basis for developing a compliance survey

Complexities of Subsurface Sampling

- Number and location of soil core samples
  - For each location, the number and depth of subsamples within each soil core must also be specified
  - Cross contamination among vertical layers must be avoided
  - In case of boring tool refusal, an alternative should be specified

3 - IDENTIFY INFORMATION INPUTS

- Exposure scenarios needed for decision-making
  - Dose modeling is used to determine action levels/DCGLs
  - Select appropriate sampling and analysis methods to match the assumptions and parameters of the model
- Additional pathways need to be considered
  - Intruder scenarios
  - Construction of buildings
  - Groundwater
- NRC-accepted computer codes for developing DCGLs
- NUREG-1757, Volume 2, contains primary references for the definition of RESRAD parameters

Derived Concentration Guideline Levels

- What should a release criterion be?
  - The average concentration in a volume? …in a survey unit?
  - The maximum concentration in a volume? …in a survey unit?
  - The probability of exceeding the DCGL?
  - A percentile of the concentration distribution at a location?
  - The release criterion should be consistent with the quantity calculated by the dose model.

Derived Concentration Guideline Levels (cont.)

- NUREG-1757, Volume 2, Revision 2, exposure scenarios for buried materials:
  - Basement excavation (residual radioactivity within 3 meters of the subsurface considering erosion) and other scenarios if residual radioactivity is found deeper in the subsurface (e.g., well drilling)
  - Large backfilled subgrade structures (e.g., containment basements at a reactor site)
- NUREG/CR-7268, "User's Manual for RESRAD-OFFSITE Code Version 4," Volume 1, considers three possible subsurface soil configurations:
  - Contaminants above the water table
  - A portion of the primary contamination in the water table
  - All of the primary contamination within the water table
  - However, RESRAD ONSITE and OFFSITE do not address existing groundwater contamination outside of the source area

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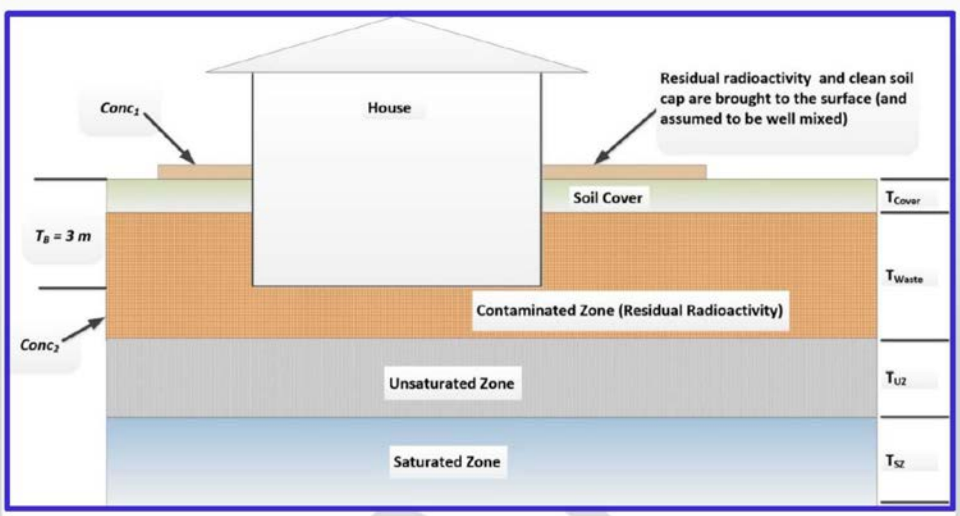
Subsurface exposure scenarios



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Derived Concentration Guideline Levels

- What is an elevated volume?
- Can a layered approach be used for excavations?
- Multiple subsurface layers or strata considered individually and then the cumulative risk from the multiple layers or strata is assessed

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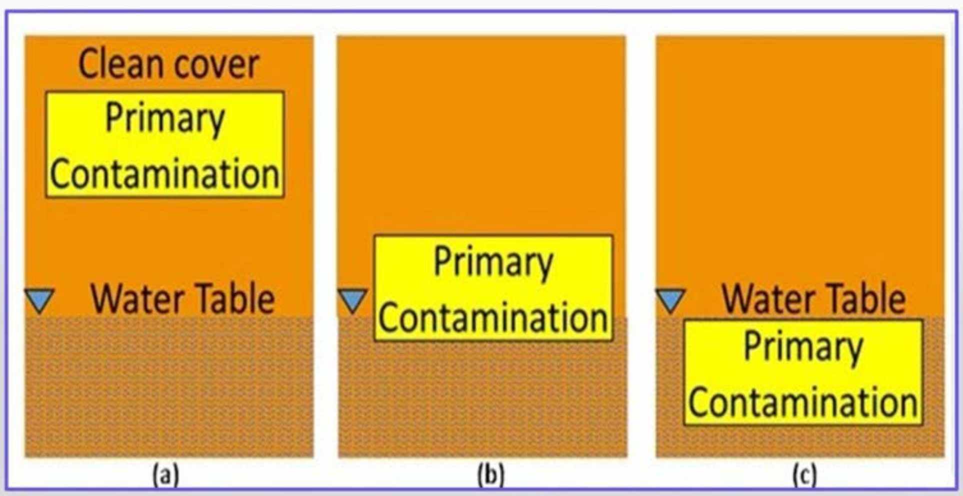
RESRAD: Three Possible Subsurface Soil Configurations



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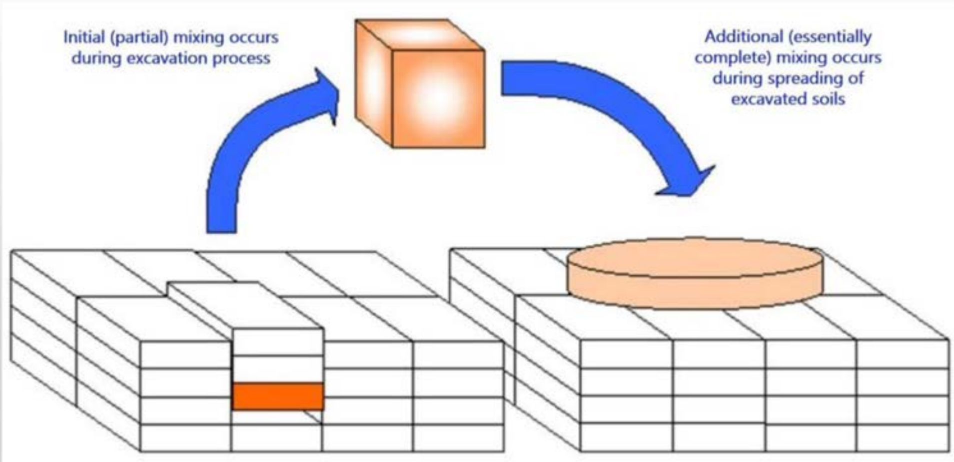
DCGLs for Buried Waste



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Derived Concentration Guideline Levels

- Guidance that distinguishes between surface a DCGLw (wide area) and a subsurface DCGLv (volumetric) may be needed
  - Different classes of survey units may apply to the surface of the excavation vs. the walls of the excavation or surface soils
- Multiple DCGLs may be needed depending upon the radionuclides present, applicable exposure scenarios, and actual site conditions
  - May be beneficial to develop separate DCGLs for cases such as deep subsurface residual radioactivity because of the importance of the groundwater pathway
  - Using multiple DCGLs may be more straightforward where different sources are present (e.g., residual radioactivity at the surface vs. residual radioactivity associated with buried material or from deep subsurface spills or leaks that may contain mixtures of radionuclides)

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4 – DEFINE THE BOUNDARIES OF THE STUDY

- MARSSIM survey units may not directly apply to the subsurface
  - Define a survey unit
  - Define the size of a subsurface survey unit
  - Define survey unit classifications
    (non-impacted, impacted Class 1, 2, 3)
  - Must a subsurface survey unit align with the surface survey unit it is beneath?
  - What, if any, are the requirements for a reference area?
- MARSAME is an example of applying MARSSIM concepts to very different kinds of survey units

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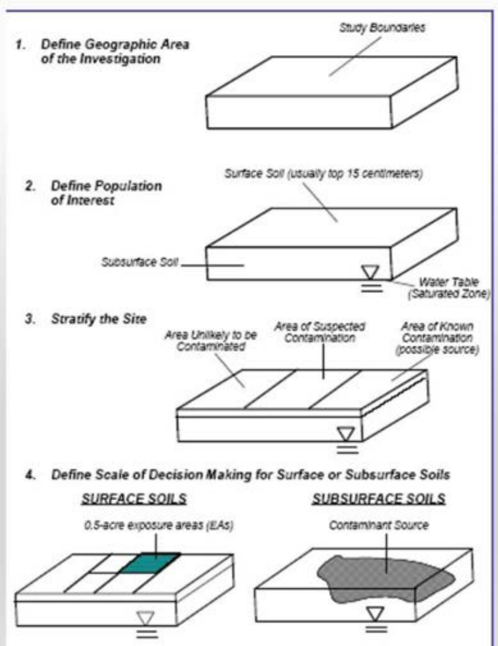
Subsurface Survey Unit: Example



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Large Soil Excavations and Equipment

- Evaluate methods to survey large subsurface soil excavations
  - Excavation experiences across the industry are inconsistent in handling layers and volumes just above the DCGL
  - Lessons learned include topics for dose modeling, characterization, and remediation
- Survey soils for reuse in large excavations
- Use of conveyor belts and other soil sorters; what DCGL is appropriate? $DCGL_W$? $DCGL_V$? Other?
- Can surface $DCGL_W$s be applied to excavation sides and layers? When material is brought to the surface?
- Can licensees correctly identify the class of all survey units, impacted or not impacted? Areas that need remediation?

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5 - DEVELOP THE ANALYTIC APPROACH Geospatial Modeling Tools – Key References

- Electric Power Research Institute (EPRI) (2016) "Guidance for Using Geostatistics to Develop Site Final Status Survey Program for Plant Decommissioning"
- Stewart, R., C. Welsh, T. Purucker, P. Goovaerts, C. Gogolak, D. Stewart (2009) An Introduction to Spatial Analysis and Decision Assistance (SADA) User's Guide for Version 5, University of Tennessee
- Matzke, B.D., J.E. Wilson, L.L. Newburn, S.T. Dowson, J.E. Hathaway, L.H. Segol, M. Bramer, and B.A. Pulsipher (2014) Visual Sample Plan (VSP) Version 7.0 User's Guide Pacific Northwest National Laboratory Report PNNL-23211, Richland, Washington

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Geospatial Modeling Tools
EPRI Review

- Evaluated 17 two- and three-dimensional geospatial modeling tools
- SADA and VSP were chosen for further study
- Both have a suite of geostatistical tools
- Are concerned with both sampling design and analysis
- Specifically support MARSSIM data analysis
- SADA is not currently supported, while VSP is
- SADA is three dimensional, while VSP is two dimensional
- NUREG/CR-7021 makes much use of SADA for examples
- Both are “freeware” but have a steep learning curve

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SADA and VSP

- Whatever the tool, the use of geostatistics will need software, support, training and/or a subject matter expert
- There is a balance to be struck between the depth of analysis and ease of use
- Variogram fitting is part of the kriging procedure and is probably the most difficult, but the variogram may not need to be very accurate
- The variogram specifies the weights to be given values measured nearby a given location; the nearer measurements contribute more to the weighted average than further locations
- VSP supports more classical statistical methods compared to SADA, although it also contains geostatistical methods outside of the MARSSIM module
- SADA supports more geostatistical methods compared to VSP

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6 - SPECIFY PERFORMANCE OR ACCEPTANCE CRITERIA (DECISION RULES, HYPOTHESIS TESTS)

- How should a decision rule be formulated?
  - Assume the survey unit meets release criteria unless proved otherwise (MARSSIM Scenario B) or
  - Assume the survey unit does not meet release criteria unless proved otherwise (MARSSIM Scenario A)
  - If there is a wide variability in reference areas, should there be an indistinguishable from background test?
- Appendix G to NUREG-1757, Volume 2, contains examples of Scenario B for three-dimensional data

SPECIFY PERFORMANCE OR ACCEPTANCE CRITERIA FOR ELEVATED MEASUREMENT COMPARISON (EMC)

- Should there be an EMC for the subsurface?
- Since scanning is not possible, every radionuclide in the subsurface is “hard-to-detect”
- MARSSIM does not directly address the issue of “hard-to-detect” radionuclides
  - MARSSIM considers that elevated areas the size of the space between discrete sampling locations will be found with essentially 100% probability as calculated using ELLIPGRID
  - An elevated area that is smaller will have some risk of being missed by the sampling grid. Again, the probability of detection can be calculated by ELLIPGRID. In the DQO process will determine the risk that is deemed acceptable

SPECIFY PERFORMANCE OR ACCEPTANCE CRITERIA FOR EMC (cont.)

- Geostatistics and other interpolation methods cannot find locations that exceed the largest value of the measurand unless there is some soft data that can drive higher concentrations (e.g., dry deposition data can extrapolate higher wet concentrations where the rainfall rate is higher)
- If indicator kriging is used to develop a probability distribution for the residual radioactivity, then a high percentile (e.g., 95%) may also extrapolate the data to higher concentrations; of course, this will require that the release criterion is expressed as an action level for that percentile

SPECIFY PERFORMANCE OR ACCEPTANCE CRITERIA FOR DATA UNCERTAINTY

- Statistically rigorous quantitative application of measurement quality objectives in MARSAME and MARLAP apply equally well to field measurements of radiation and radioactivity, although MARSSIM Revision 1 did not include such objectives explicitly
- Essential guidance for measurement uncertainties in the ISO GUM (ISO IEC Guide 98-3 2008(E), "Uncertainty of Measurement," Part 3, "Guide to the Expression of Uncertainty in Measurement")
  - De facto standard for estimating the uncertainty associated with measurements of any type
  - GUM methodology essential for the assessment of measurement uncertainty but not previously treated in MARSSIM

SPECIFY PERFORMANCE OR ACCEPTANCE CRITERIA FOR DATA UNCERTAINTY (cont.)

- MARLAP Volume III, Chapter 19, gives applications and examples for radiological analytical chemistry measurements
  - Recommends that all radioanalytical laboratories adopt the terminology and methods of the GUM for evaluating and reporting measurement uncertainty
  - This recommendation could be extended to apply to the determination of uncertainty of subsurface sample measurements, whether laboratory or field instrument measurements
- Software programs to perform the calculations to determine the combined standard uncertainty of a measurement:
  - GUMCalc
    - Report provides an example uncertainty calculation using GUMCalc in contrast with a more labor-intensive hand calculation approach
  - NIST Uncertainty Machine
  - GUM Workbench version 1.4 (commercial)

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7 - DEVELOP THE PLAN FOR OBTAINING DATA

- As usual, the key issue for sample planning is "how many samples are enough?"
- To answer this question, there must be some measurable benefit for each addition sample taken
- In MARSSIM Scenario A, a minimum number of samples will be needed to achieve the desired Type I and Type II error rates α and β
- Once this number is reached, each additional sample results in the benefit of higher power ($1-\beta$)
- For the subsurface, a measure analogous to the power of the hypothesis test vs. sample size is desired

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DEVELOP THE PLAN FOR OBTAINING DATA: A BAYESIAN APPROACH

- SADA uses a survey design called “check and cover” using a parameter called a “p-median,” but it has not been tested and is not currently implemented
- An alternative method for an initial survey design, also using SADA, is the Bayesian ELLIPGRID formulation
- Using information from the Historical Site Assessment, a map of the site indicating the likelihood of an elevated area existing in various parts of the site

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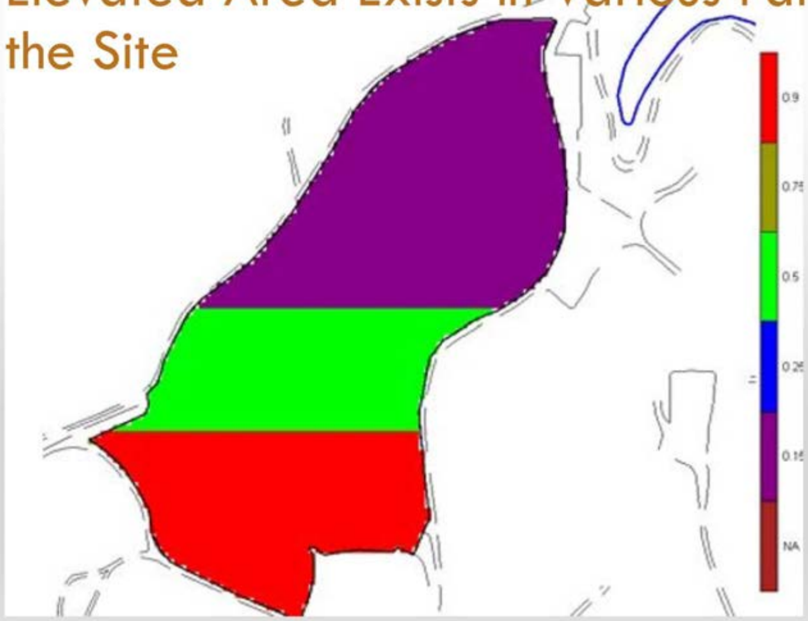
Bayesian ELLIPGRID: Likelihood of an Elevated Area Exists in Various Parts of the Site



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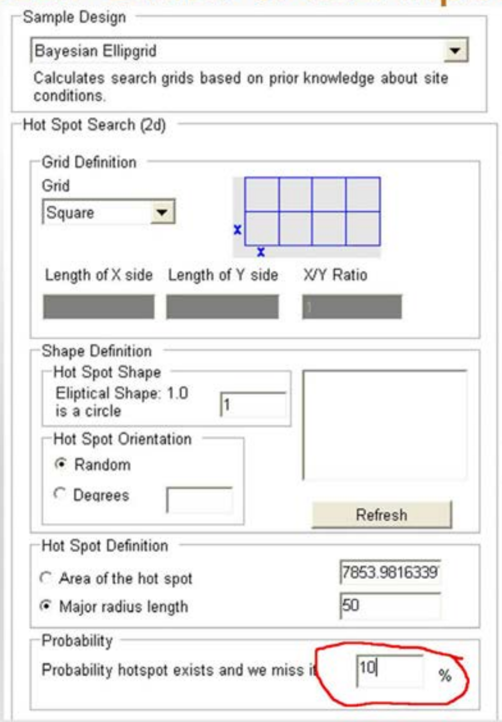
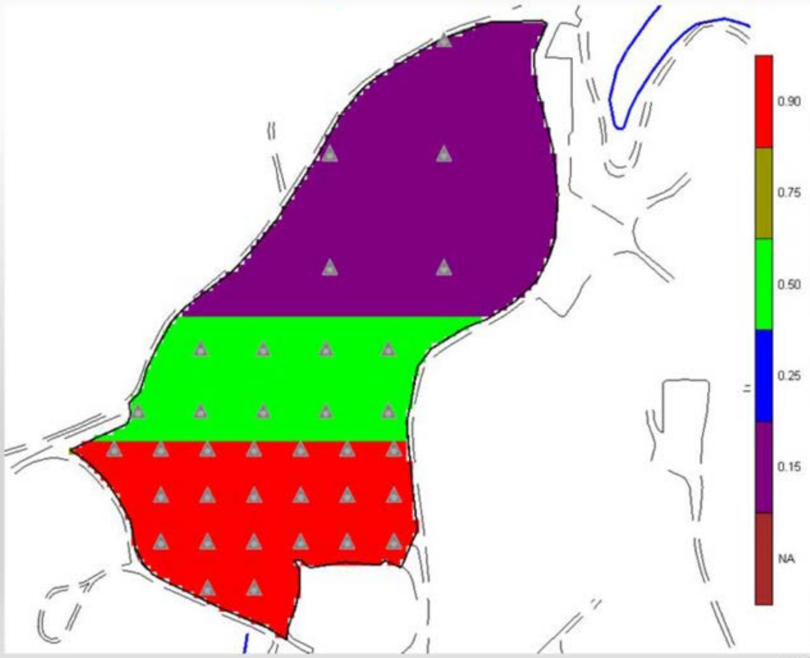
Bayesian ELLIPGRID: SADA Input



Initial Survey Design: 37 Samples



Bayesian ELLIPGRID

- The 37 measurements "kick-start" the process
- In SADA, the Bayesian prior probabilities can be "painted" on the site map
- Using the results from these 37 sample measurements, a secondary sampling design can be planned

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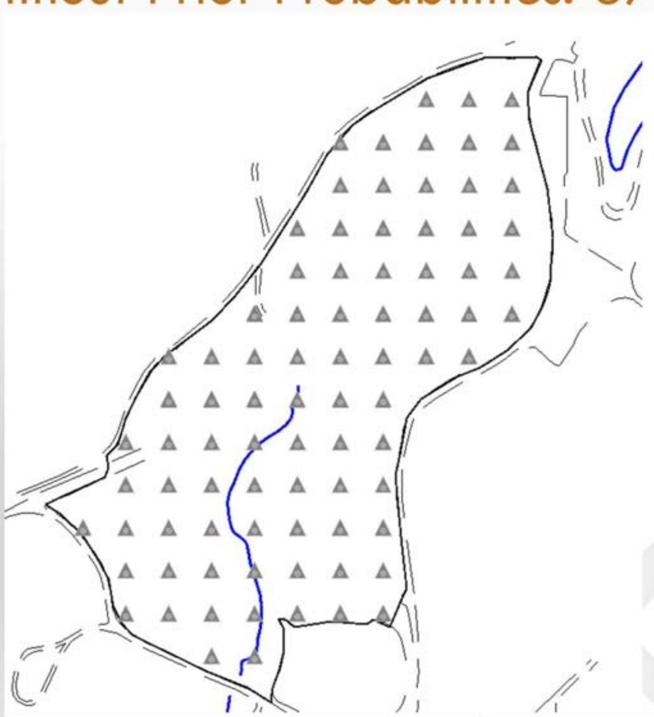
Without Prior Probabilities: 87 Samples



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Markov Bayes and Cokriging

- Cokriging allows other data types that are correlated with the contaminant of concern to support a geospatial model
  - Rather than ordinary cokriging, an indicator cokriging approach is used, whereby hard data are first converted to 0s or 1s depending on whether they exceed a specified criterion. The cokriging method is then applied to these 0s and 1s along with the user-defined prior-probability map. This results in an updated probability map that contains the influences of both the hard and soft data.
  - In SADA, a prior probability map must first be created
    - This is done by creating a user-defined map and then choosing the interview "Update My Probability Map."
  - Suppose the soft prior probability map data (see user-defined maps) is represented by Y. Let I represent the indicator transformed hard sample data being interpolated.
    - Indicator Transform: Hard data transforms to 0 if the measured value is less than or equal to the decision criteria, and 1 otherwise
  - In the correlation modeling step, a correlation model is developed for the indicator transformed data set.

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3.1.3 Nuclear Energy Institute Presentation

Speaker: Bruce Montgomery, NEI

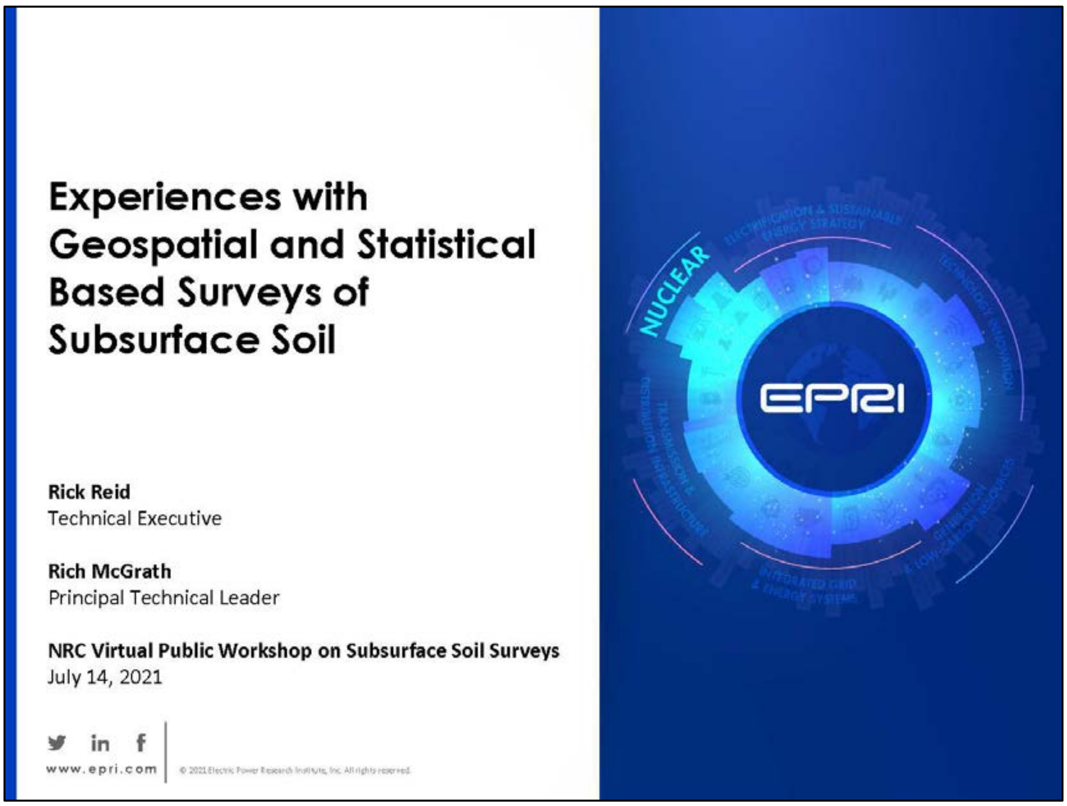
No presentation materials (e.g., Microsoft PowerPoint slides) exist for this presentation

3.2 Day 1: Geospatial and Statistical Methods

3.2.1 EPRI Presentation: Experiences with Geospatial and Statistical Based Surveys of Subsurface Soil (ADAMS Accession No. ML21208A215)

Speakers: Rick Reid and Rich McGrath, EPRI

3.2.1.1 Presentation Materials



Overview

- Most sites undergoing decommissioning have not experienced substantial issues with residual radioactivity in the environment
  - Some common areas of isolated contamination
- Monitoring and record keeping during operations are key to identification of potential areas of concern
  - NEI 07-07 groundwater protection initiative
  - 50.75(g) documentation process
- With the exception of well-known but isolated cases, groundwater monitoring in the current fleet has not identified substantive issues
  - Remediation has been implemented, as warranted
    - For example, in most cases, pump-and-release and monitored natural attenuation techniques have been practiced

Scoping and Characterization Surveys
Land Areas

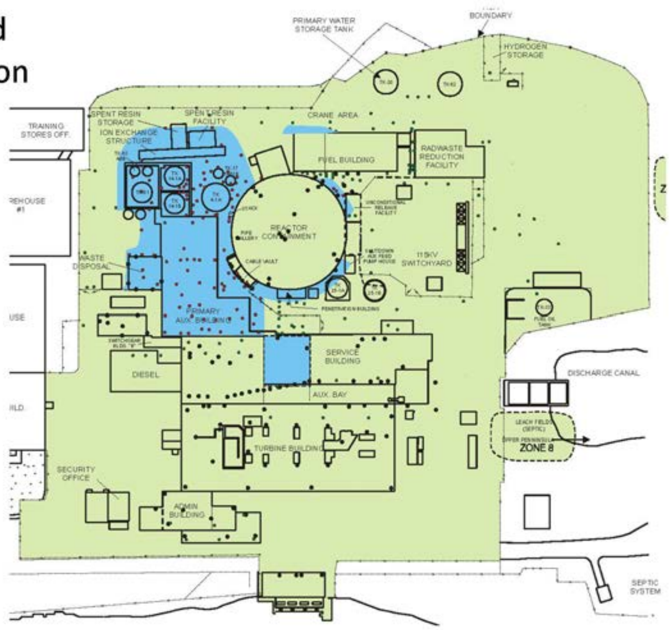
- To support decommissioning, the extent of radiological contamination in site areas needs to be determined
  - Surveys biased based on Historical Site Assessment
  - Information collected during other work included (i.e. soil samples collected during Groundwater Monitoring well installation)
  - Systematic sampling done when no events have occurred in an area
  - Additional sampling to bound contamination horizontally and vertically, if detected
    - Determines limits of the required remediation
  - Need to evaluate for Hard To Detect Nuclides (HTDN, i.e., Alpha, Pure Beta nuclides) early in the process
- Information used to inform remediation and Final Status Survey (FSS) design

Case Study: Soil and Groundwater Contamination at Connecticut Yankee (Reference: EPRI Report #1013511, *Connecticut Yankee Decommissioning Experience Report, 2006)*

Subsurface Soil Sample Locations – Characterization

- Areas in blue required subsurface remediation


Direct Push Sampler



Sampling and Remediation Locations

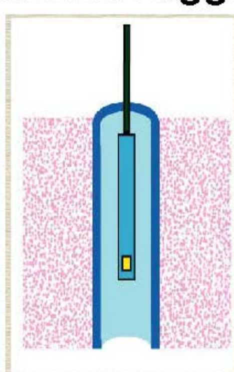
Techniques used to Assess Contamination in Bedrock

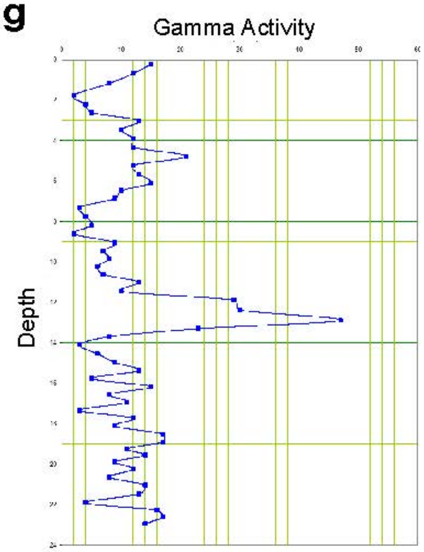

Coring


Surveys of Cores


Sampling using Rock Drill

Alternate Technique: Assessing Bedrock/Soil Using Down-Hole Gamma Logging

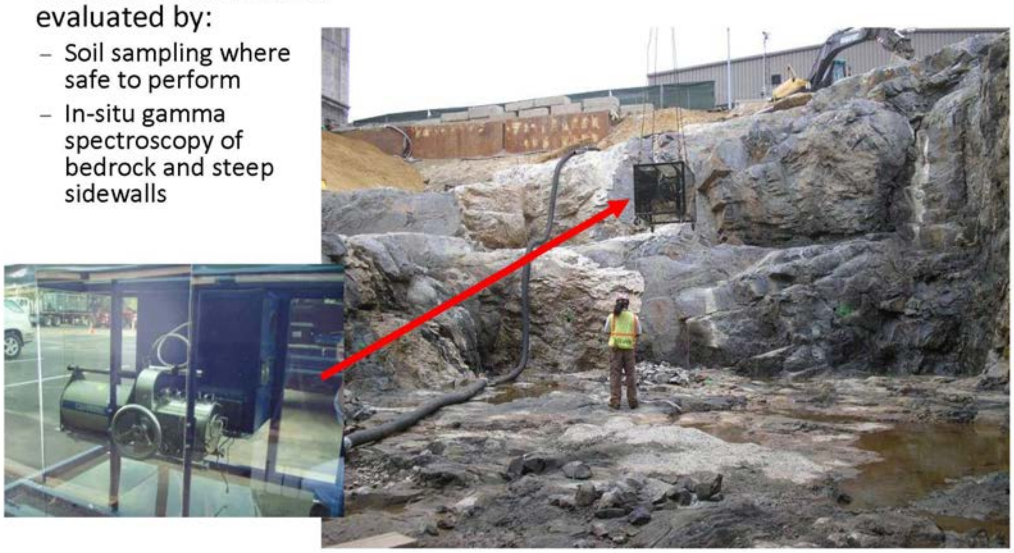




Sensitivities as low as 1 pCi/g for Fission Products with High Resolution Spectra Gamma Logging

Assessment of Excavations at CY

- Surfaces of excavation evaluated by:
  - Soil sampling where safe to perform
  - In-situ gamma spectroscopy of bedrock and steep sidewalls



FSS Approaches used for Subsurface

- Most plants have surveyed soil excavations as if they were surface land areas
- CY needed a more comprehensive FSS approach as there was concern that all subsurface contamination had not been identified during site characterization
- NRC approved a graded subsurface survey protocol summarized below:
  - Table shows the required # of direct push sample locations for various survey areas
  - Gridded plus biased sample locations in Class A areas
  - Random samples were obtained in Class B and Class C areas:
    - In addition, biased samples were obtained based upon characterization data and professional judgment.
  - Samples were obtained to a depth of 3 meters or bedrock
    - These samples were homogenized over the entire depth of the sample obtained and evaluated using MARSSIM based statistical methods.

Classification of Survey Area	Number Sample Locations Required for Each Type of Survey Area (Total for Each Type)
Class A (Highest Potential)	31 Samples (1 sample per 500 m^2)
Class B (Medium Potential)	25 Samples
Class C (Lowest Potential)	15 Samples

Use of Geostatistics to Evaluate Subsurface Contamination (Reference: EPRI Report #3002007554, *Guidance for Using Geostatistics in Developing a Site Final Status Survey Program for Plant Decommissioning*, 2016)

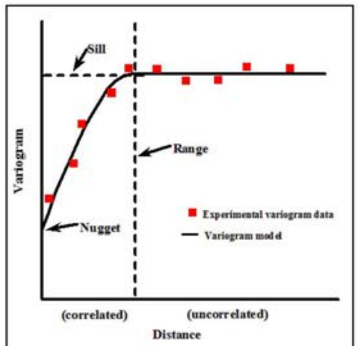
Background

- To date, site characterization and final status survey guidance has focused on surface contamination
  - For example, US approach described in MARSSIM (NUREG-1575)
  - When performed, subsurface characterization has been addressed using non-standard, site-specific approaches
- Although not currently required, regulators desire a standardized approach to subsurface characterization
  - Improves technical basis for site release
  - Allows cost-effective decommissioning planning for utilities
- Goal of this 2016 EPRI project was to educate the industry about the precedents for and potential benefits of geostatistics

Introduction to Geostatistics

Overview

- Geostatistics is a class of methods to:
  1. Infer patterns from spatially structured data:
     - Sparse or large data sets
     - Structured or unstructured grids
     - Multidimensional spaces
  2. Make predictions at an arbitrary point (or manifold) in space, crediting spatial correlation
     - Many such predictions can be made to attain a virtually continuous representation of the spatial variable



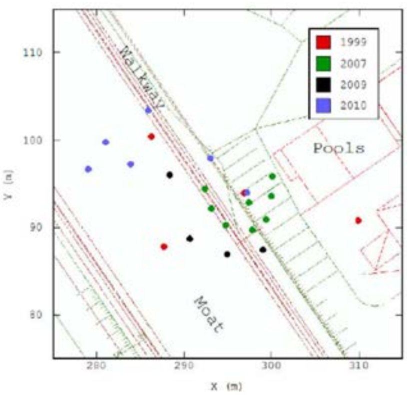
Example of variogram describing spatial correlation [PNNL]

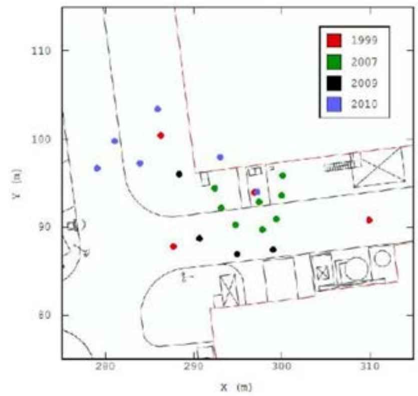
  3. Associate uncertainty with each prediction
     - Large uncertainty in areas of considerable spatial variation or at large distances from measured data points
     - Low uncertainty near measured data points
- Prevalent use in many fields, including mining, oil and gas, hydrogeology, environmental monitoring, climate science, and epidemiology

Case Study in the Use of Geostatistics

Subsurface Characterization at Fontenay-aux-Roses (1/4)

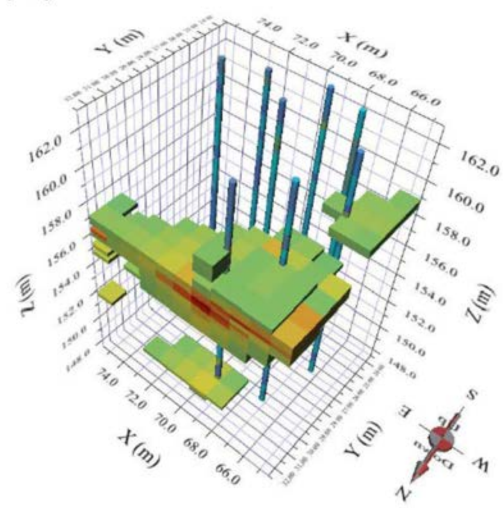
- Fontenay-aux-Roses is a CEA research facility in France
- A series of drill hole campaigns were conducted to characterize Cs-137 concentration in the soil where buildings and structures were previously located at the facility.





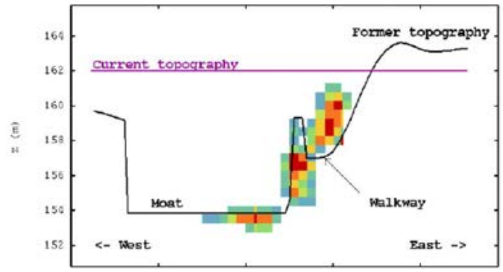
Subsurface Characterization at Fontenay-aux-Roses (2/4)

- 3D kriging map was developed using measurements from the 2007 campaign
- This kriging map informed the placement of the 2009 and 2010 sampling campaign locations



Subsurface Characterization at Fontenay-aux-Roses (3/4)

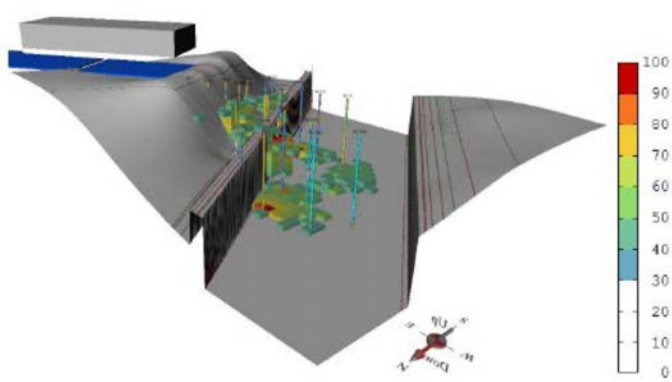
- Analysis of the 2007 and 2009 campaigns revealed a thin contaminated layer along a vertical gradient
- The gradient was consistent with topology of the first generation site configuration, lying along the bank of a former moat



- Agreement between the contamination pattern and the former topology led the investigators to conjecture that the source of the contamination was an accidental spillage from the storage pools or contaminated media used to fill the moat

Subsurface Characterization at Fontenay-aux-Roses (4/4)

- Enabled by geostatistical maps, the area was successfully remediated in 2013 producing 2,000 m^3 of very low level waste and 2,000 m^3 of conventional waste



Software Review (1/2)

- A large set of geostatistical software products was reviewed as part of the EPRI project
- Factors considered when appraising geostatistical software products included:
  - Cost
  - User interface
  - Flexibility
  - Algorithm availability
  - Visualization capabilities
- The review extended to contemporary standalone software, contemporary libraries deployed by common programming languages, and software with historical precedent

Software Review (2/2)

Software (Developer)	Cost	Dimensionality	Directed Workflow?	Exploratory Data Analysis	Sample Design / Optimization	Structural Analysis	Anisotropic Variograms	Point Kriging	Block Kriging	Universal Kriging	Co-Kriging	Indicator Kriging	Spatial-Temporal Krgiing	Discontinuities / Complex Geometries	Conditional Simulation	Cross-Validation	Fate and Transport Modeling	Dose Assessment	Geographical Information System	Highlights
ASCEM (U.S. DOE)	Proprietary	3D	n	n	n	n	n	n	n	n	n	n	n	n	n	y	y	n	n	model assimilation with flow and transport predictions
Earth Volumetric Studio (C Tech)	High	3D	n	y	y	y	y	y	n	n	n	y	n	n	n	n	n	n	y	block diagram interface, treatment of geological lithofication, borehole optimization
geoR and RGeostats (R Software)	Free	3D	n	y	n	y	y	y	y	y	y	y	n	y	y	y	n	n	n	exemplary combination of breadth and depth
Geostatistical Analyst (ESRI)	High	2D	y	y	n	y	y	y	n	y	y	y	n	n	y	y	n	n	y	high degree of user control, user-friendliness
GS+ (Gamma Design Software)	Low	2D	n	y	n	y	y	y	y	y	y	y	n	y	y	y	n	n	n	abundance of autocorrelation measures
GsTL (C++)	Free	3D	n	n	n	n	n	y	n	y	y	y	n	n	y	n	n	n	n	generic programming paradigm
HPGL (Python)	Free	3D	n	n	n	y	y	y	n	y	y	y	n	n	y	n	n	n	n	efficient and parallelized algorithms
HydroGeoAnalyst (Schlumberger)	High	3D	n	n	n	n	n	y	y	y	n	n	n	n	n	n	n	n	y	integrated data management utilities
Isatis (Geovariances)	High	3D	y	y	n	y	y	y	y	y	y	y	n	y	y	y	n	n	y	journal file, principal component analysis, abundance of variogram model forms, block kriging in complex subregions, suppored by active R&D
Kartotrak (Geovariances)	High	3D	y	y	y	y	n	y	n	n	y	n	n	n	n	n	n	n	y	real-time data streaming, highly structured workflow, MARSSIM and ISO 8550 sampling protocols
mGstat (MATLAB)	Free	3D	n	n	n	y	y	y	n	y	n	n	y	n	y	n	n	n	n	interfaces for gstat and SGeMS
Native command set (SAS)	Free	2D	n	y	n	y	y	y	n	y	n	n	n	n	y	n	n	n	n	automated exploration of many variograms
SADA (University of Tennessee)	Free	3D	y	y	y	y	y	y	n	n	y	y	n	n	y	y	n	y	y	area of concern maps, map arithmetic, sampling optimization, remediation cost-benefit analysis
SGeMS (Stanford)	Free	3D	n	y	n	y	y	y	y	y	y	y	n	n	y	n	n	n	n	optional command line interface, downscaling predictions, multiple-point geostatistics
Surfer (Golden Software)	Low	2D	n	y	n	y	y	y	y	y	n	n	n	y	n	y	n	n	y	native scripting language
T-Progs (Lawrence Livermore)	Free	3D	n	n	n	y	y	n	n	n	n	y	n	y	y	n	n	n	n	transition probability / Markov chain geostatistics
VSP (Pacific Northwest NL)	Free	2D	y	y	y	y	n	y	y	n	n	y	y	n	n	n	n	n	n	Walsh's outlier test, data quality objective (DQO) based sampling planning, economic analysis

Challenges for Demonstrating Subsurface Compliance (1/2)

- Surface compliance frameworks often rely on surface scanning technologies to characterize the spatial variation of contamination. There is no analogous option viable for the subsurface
  - Places emphasis on other methods for spatial characterization
- The extension from the surface to the subsurface increases the number of dimensions, resulting in generally sparser data sets
  - A framework is required that may make compliance possible in spite of spatial uncertainty
- The subsurface environment can present heterogeneity and complex processes
  - Places new emphasis on integrating data-driven analysis with a conceptual or physical understanding of the environment
  - Compounds the risk of hot spots in the subsurface environment

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Challenges for Demonstrating Subsurface Compliance (2/2)

- The subsurface sample design requires vertical characterization in addition to lateral characterization of contamination
  - Compliance framework may need to accommodate different subsurface measurements, including from core boring, laboratory samples collected at well locations, or borehole gamma logging
  - Differences in the spatial variation in lateral directions versus the vertical direction need to be accounted for
  - Sample costs increase, which places a premium on the empirical science used to derive information from samples
- The exposure pathways for subsurface contamination are distinct from the surface, including groundwater migration and excavation scenarios

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Roadmap for Applying Geostatistics
General

- EPRI report provides a roadmap identifying:
  - Major phases of geostatistical analysis
  - Steps within each phase
  - Key questions associated with each step

Roadmap Phase	Steps Associated with Phase
Preliminary Steps	■ Perform conventional site characterization steps ■ Educate site characterization team on geospatial data characteristics ■ Select software to support geostatistical analysis ■ Develop expertise with selected software
Exploratory Data Analysis	■ Define and format data for geostatistical analysis ■ Visualize and consolidate data ■ Perform statistical analysis ■ Assess data for violations of the constraints of geostatistical methods ■ Assess inter-variable correlation ■ Perform data manipulation
Structural Analysis	■ Study spatial structure empirically ■ Fit the analytical variogram ■ Assess anisotropy ■ Perform structural analysis for multiple regionalized variables
Geostatistical Interpolation	■ Design the prediction grid ■ Select a geostatistical interpolation method ■ Design the search neighborhood ■ Execute geostatistical interpolation
Post-Processing Steps	■ Perform inverse transformation ■ Perform cross-validation ■ Perform sensitivity testing ■ Apply geostatistical interpolation results ■ Apply results to demonstrate compliance of subsurface contamination ■ Report the geostatistical analysis

Roadmap for Applying Geostatistics
Example Compliance Framework

- An exposure unit is defined as the shape, size, and location of the area/volume in which compliance is sought
- DCGL is derived for exposure unit
- Geostatistics is used to calculate average concentration within exposure unit (and its associated uncertainty)
  - Allows for the calculation of probability of exceedance
- Compliance is demonstrated across a range of exposure units

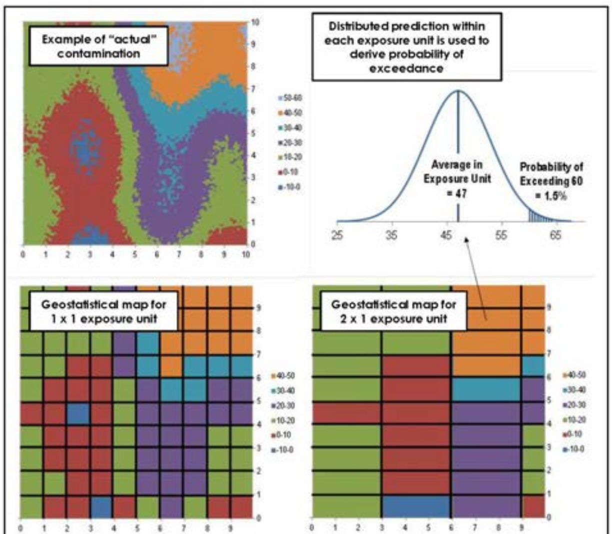
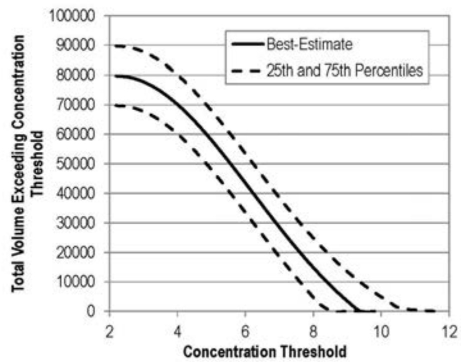


Illustration of Compliance Framework for Two Different Exposure Unit Sizes

Other Application Capabilities

- *Identifying hot spots*
  - Statistical methods—without spatial awareness—cannot be used to identify hot spots
  - Less sophisticated interpolation methods can be used, but can be more susceptible to bias for sparse data sets
  - Geostatistical interpolation also allows the analyst to assess contamination maps at different levels of conservatism
- *Estimating likelihood of exceeding some concentration threshold*
- *Visualizing/estimating volume of environment exceeding some concentration threshold*
  - Helps investigators identify areas of concern, e.g., requiring remediation
  - Can calculate remediation area as a function of threshold (see right) or as a function of confidence



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Key Findings of EPRI Report

- The use of geostatistics addresses numerous challenges associated with subsurface compliance demonstration and provides additional insight to augment existing procedures for surface characterization
- Various nuclear regulators have acknowledged the use of geostatistics as a valid response to challenges associated with subsurface characterization
  - In 2012, the U.S. NRC published NUREG-7021, which endorses the use of geostatistics for decommissioning applications
  - In 2016, the CEA published an ISO standard articulating a set of principles, including geostatistical analysis, for sampling strategy and characterization of soils, buildings, and infrastructures
- Geostatistics has been deployed for decommissioning nuclear plants, laboratories and research facilities in France, Spain, and Belgium, among other countries, leading to tangible cost savings.
  - At the Brennilis and Chooz A NPP decommissioning sites, for instance, geostatistics has been used to optimize remediation and excavation activities

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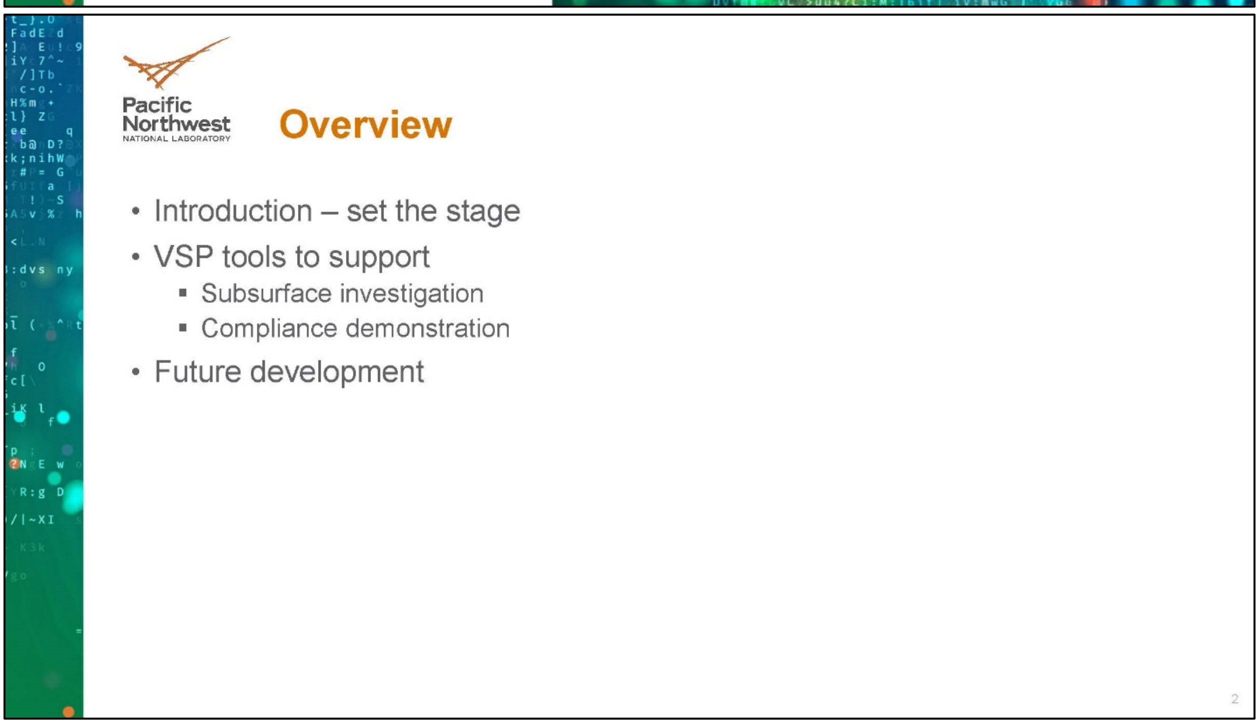
EPRI

3.2.2 VSP Geospatial Statistical Methods to Support Decommissioning (ADAMS Accession No. ML21208A216)

Speaker: Debbie Fagan, PNNL

3.2.2.1 Presentation Materials



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Subsurface can be complex

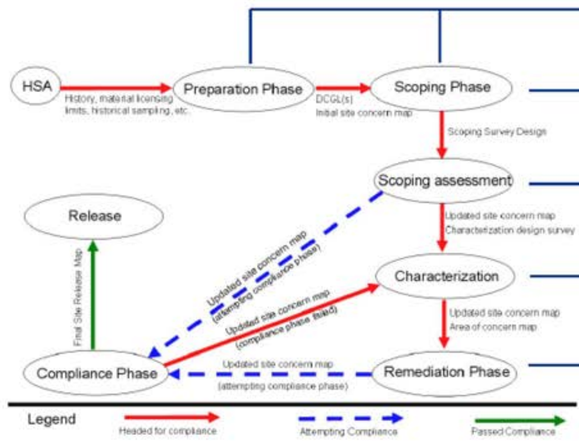
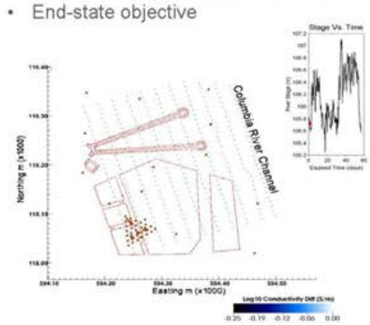


Figure 3.3 from NUREG/CR-7021

Dynamic Conceptual Site Model
- Co-mingled COPCs
- 4D spatio-temporal dynamics
- Groundwater/surface water interactions
- Vadose zone/groundwater interactions
- End-state objective



Johnson, et al, 2015

3

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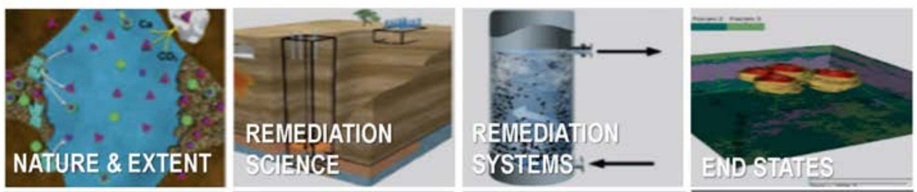
PNNL state-of-the-science for subsurface characterization, remediation, monitoring, closeout



NATURE & EXTENT	REMEDIATION SCIENCE	REMEDIATION SYSTEMS	END STATES
114 Staff; >1300 Pubs DOE-EM, DOE-SC, DOE-FE, NRC, EPA	**34 Staff; >400 Pubs** DOE-EM, EPA, DoD	**74 Staff; >900 Pubs** DOE-EM, EPA, DoD	**96 Staff; >600 Pubs** DOE-EM, EPA, NRC
• Subsurface biogeochemistry & hydrology • Contaminant behavior • Subsurface heterogeneity • Characterization of controlling processes • Metal and radionuclide speciation • Computational and numerical modeling	• Quantification of attenuation mechanisms • Quantification of contaminant flux • Fate of inorganic and radionuclide contaminants • Moisture and contaminant flux control • Materials development	• Systems-based engineering • Biogeochemical stabilization • Hydrogeological flux mitigation • Multi-phase flow & transport • Process scaling • Numerical and computational modeling • Predictive analytics	• Risk analysis and decision science • Advanced imaging • Systems-based monitoring • Systems-assessment and performance simulation
Environmental Molecular Science Laboratory (EMSL), VSP	Environmental Systems Laboratory Institutional Computing – STORM, STOMP, eSTOMP	Vadose Zone Field Test Beds Environmental Systems Laboratory Subsurface Flow and Transport Laboratory	E4D Institutional Computing – Data Analytics and Risk Assessment Software (e.g., GENII, PHOENIX, VSP)

4

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Subsurface MARSSIM – Compliance phase

What information is needed to show that end-state is achieved?

- Surface & subsurface matrix samples show that
  - Fate & transport of COPCs on-/off-site are understood
  - COPC spatio-temporal concentrations meet release criteria
    - fixed laboratory, real-time measurement technologies

What tools are needed to show compliance?

- Visualization
- Data collection planning
- Data analysis

How does VSP fit in?

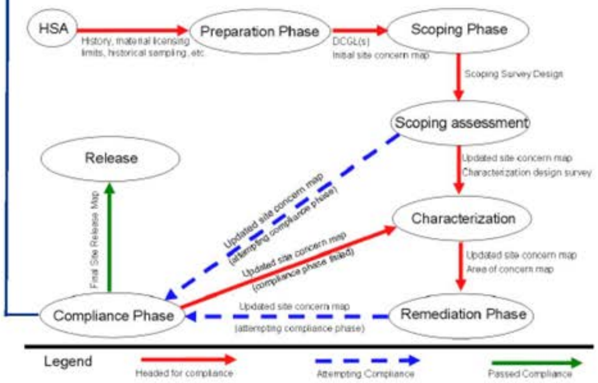

Figure 3.3 from NUREG/CR-7021

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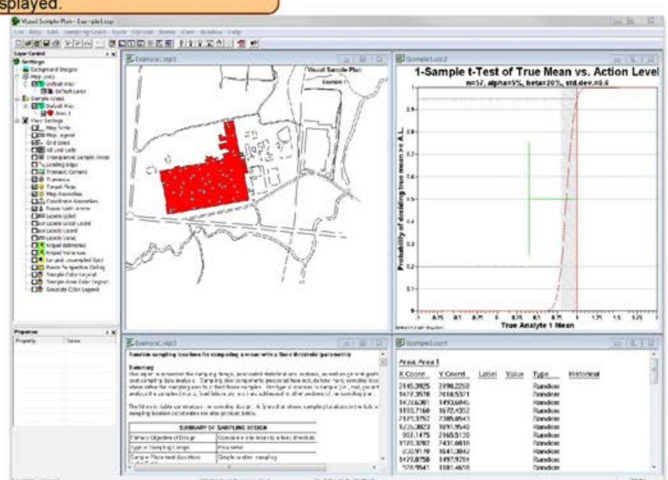
Introduction – Visual Sample Plan (VSP)

- Sampling Strategy Design
  - Number and location of samples
  - Decision-driven and statistically defensible
- Statistical Analysis for Decisions
  - Simple data import
  - Statistical tests, summary statistics and graphs
- Mapping and 3D Modeling
  - Map design
  - Road and aerial imagery download
  - Import from AutoCAD / ArcGIS
  - Immersive room development with furniture and surface types
- Use Made Easy
  - Designed for the non-statistician
  - Report generator documents analysis steps and assumptions
  - Expert Mentor

Maps can be imported/exported with sample areas defined and samples displayed.



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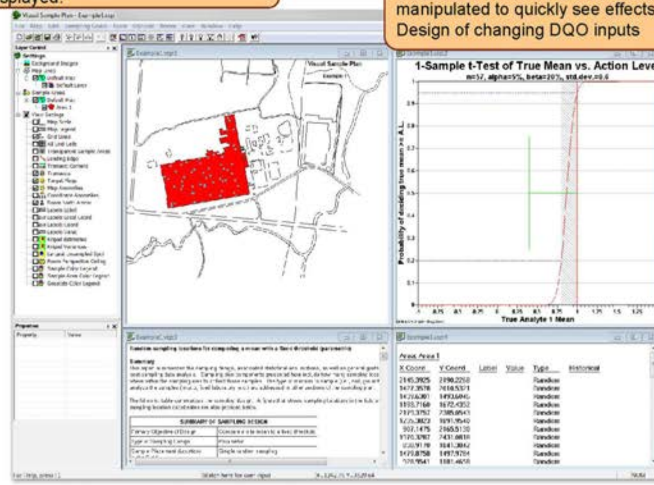
Diagnostic interactive graphics can be manipulated to quickly see effects on Design of changing DQO inputs



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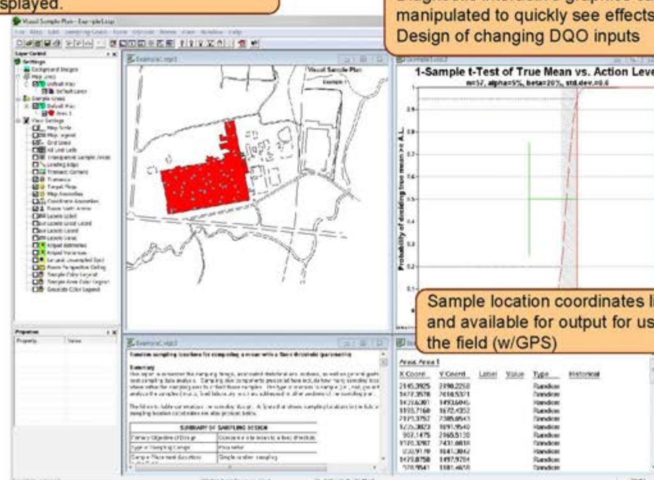

Sample location coordinates listed and available for output for use in the field (w/GPS)

8

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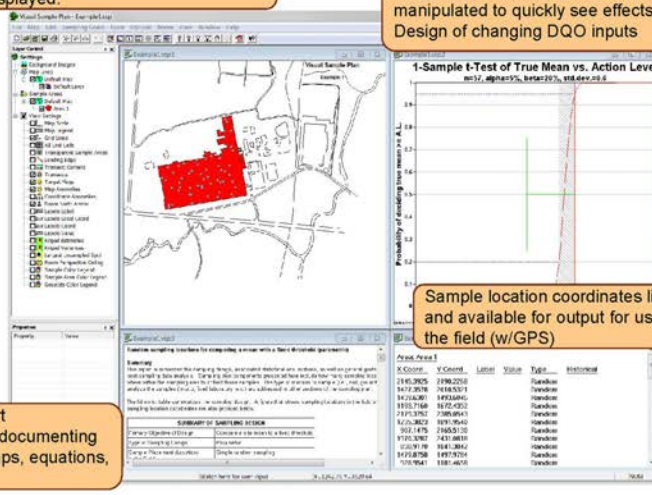
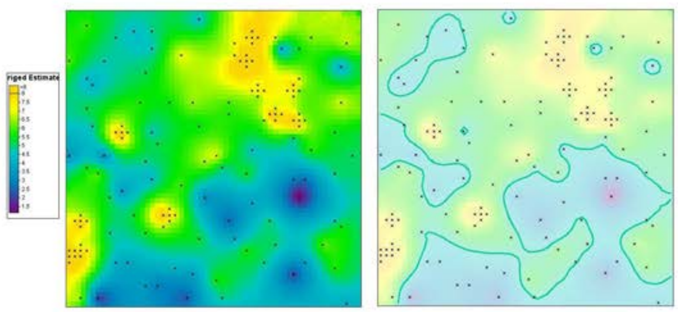
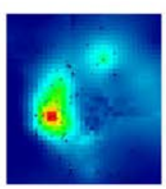
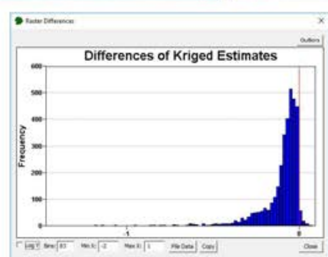


Subsurface Tools – Visual Sample Plan (VSP)

- Spatial Interpolation Methods
  - Nearest Neighbor
  - Inverse Distance Weighting
  - Geostatistical Analysis
- Interpolated Estimate Rasters
  - Custom color scales
  - Contour definition and export
  - Histogram of differences
  - Import / export to .ASC

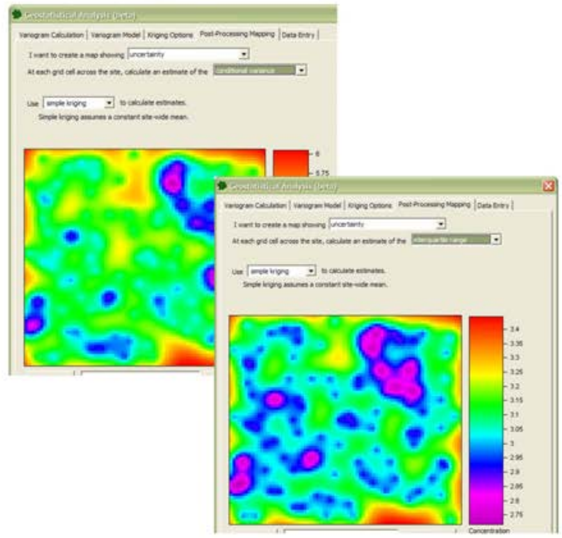






Subsurface Tools – Visual Sample Plan (VSP)

- Probability and Uncertainty Maps
  - Conditional variance
  - Interquartile Range (IQR)
  - Reference Uncertainty Index (RUI)
    - ✓ Uncertainty with reference to a particular threshold
  - Probability of Exceeding a Threshold
    - ✓ Can be used to delineate areas with high likelihood of elevated values



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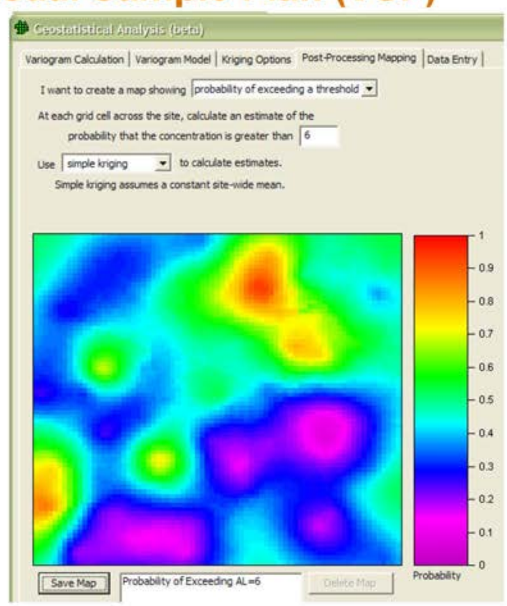


Spatial Analysis: Uncertainty Boundaries

Analysis Goal:

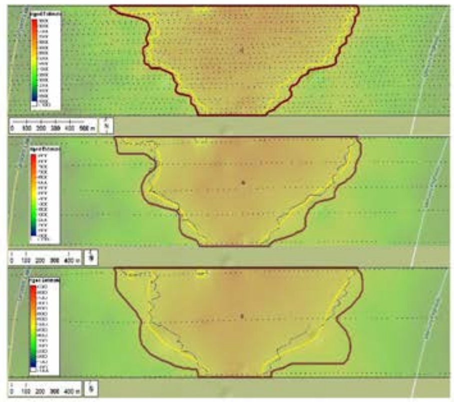
- Delineate boundaries based on interpolated spatial maps that account for uncertainty

Method Used:

- Delineate areas based on probability of exceeding a threshold
- Can also create contours based on the UCL of the kriged estimates

Example Statements:

- For a given location outside the boundary, there is 95% confidence that radiation levels do not exceed a specified threshold



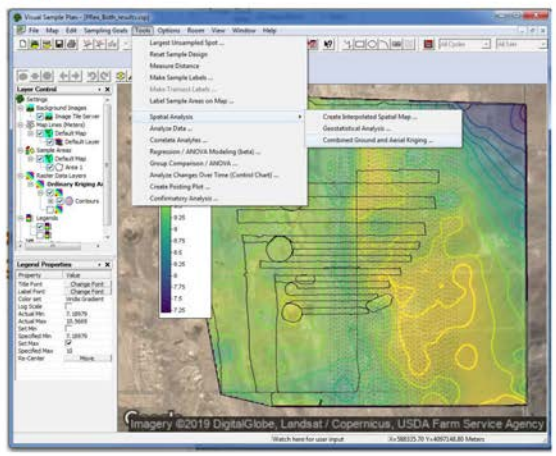
VSP Future development

Sample bookkeeping:

- GW well, borehole sampling
- GPS survey parameters

Geospatial analysis

- Anisotropic variogram estimation
- 3-D kriging
- Bayesian kriging
- Fixed rank kriging



From Fortin, et al, 2019

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References

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Johnson, Tim, et al (2015). "Four-dimensional electrical conductivity monitoring of stage-driven river water intrusion: Accounting for water table effects using a transient mesh boundary and conditional conversion constraints". *Water Resources Research*. 10.1002/2014WR016129.

"A Subsurface Decision Model for Supporting Environmental Compliance." NUREG/CR-7021.

"Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)." NUREG-1575, Rev. 1.

Visual Sample Plan (VSP), Version 7.16. Pacific Northwest National Laboratory, Richland, WA

"Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup – Brownfields Technology Primer Series." Brownfields Technology Support Center, US EPA Office of Solid Waste and Emergency Response. Washington, DC, June, 2003.

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Thank you

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3.3 Day 2: Opening Presentations

3.3.1 MARSSIM Subsurface Background

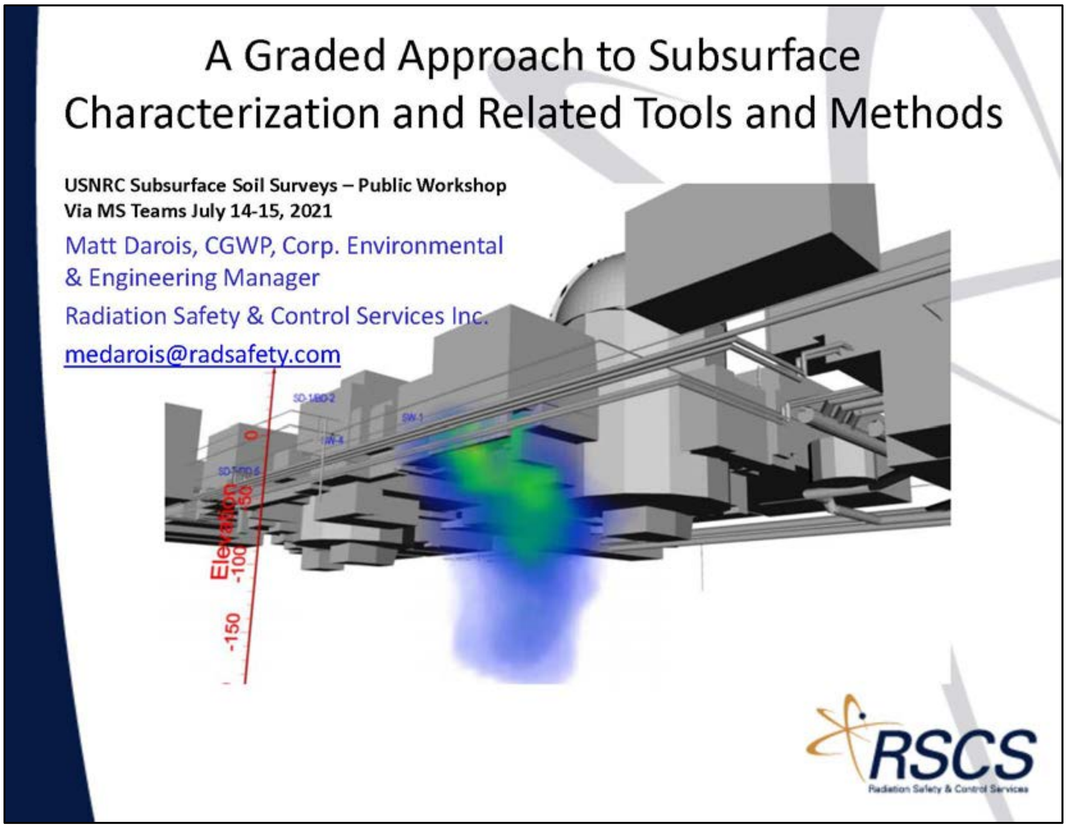
Speaker: Kathryn Snead, U.S. Environmental Protection Agency (EPA)

No presentation materials (e.g., Microsoft PowerPoint slides) exist for this presentation

3.3.2 A Graded Approach to Subsurface Characterization and Remediation and Related Tools and Methods (ADAMS Accession No. ML21208A217)

Speaker: Matt Darois, Radiation Safety and Control Services Inc. (RSCS)

3.3.2.1 Presentation Materials



Outline

- History of Characterization and Remediation
  - Historical Approaches
  - Legacy Sites (pre CERCLA/RCRA) vs Contemporary Sites (1980's-Present)
- Triad and Graded Approach at Nuclear Sites
- Advances in Tech Supporting Graded Approach
  - Improved synergy between geologic/hydrogeologic data and facility design, operations/work practices and system arrangement
- Applied Examples
  - Characterization, CSM/CDE use
  - Non-Destructive Evaluation (NDE) Characterization Integration

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History of Subsurface Characterization and Remediation

- Historical Approaches
  - "Iterative Investigations": "Mobilize, dig, sample, demobilize, lab test, assess data, remobilize, remediate, lab test, assess data, repeat until clean"
  - Historical Land Use Pre ~1980's more uncertain
- 1980's/90's
  - Expedited Site Characterization (ESC)
    - Objective: Reduce overall characterization and remediation costs
    - Field Measurement and decision-making during assessment and remediation tasks
- 2003 International Tech and Reg Council (ITRC):
  - Developed Systematic Triad Approach based on ESC https://itrcweb.org/home
  - Funded by DOE and USEPA
- Mid 2000's: wide adoption of Triad concepts (USEPA)

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Triad Approach

- Systematic Planning:
  - Land use Survey / Historical Site Assessment
  - Develop a dynamic Conceptual Site Model (CSM)
    - CSM drives characterization plan and methods
- Dynamic Work Strategies:
  - DQO's
  - The characterization plan's tech basis is the CSM
  - Characterization data driven decision making in the field
    - Characterization and Remediation
  - Characterization methods selected to meet DQO's with rapid deployment capabilities/tech
- Real-Time Measurements:
  - Mobile labs, and instrumentation
  - Remote sensing, GIS/GPS data integration with digital twins

https://triadcentral.clu-in.org/

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Benefits

- Front-loads cost into CSM and Site Investigation:
  - Reduces multiple field mobilizations
  - Reduce overall characterization/remediation duration
  - Iterative and dynamic technically defensible characterization remediation approach
  - Limits remediation to targeted areas above action levels
- Invest in characterization to reduce remediation and waste disposal costs:
  - Characterization, targeted remediation Costs <<<< Rad Waste Shipping & Disposal Cost
- Well suited to address radiological contamination
  - Practical Remediation Options: Removal, Mitigation, MNA/decay

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Technology and Strategy Advancements

Conceptual Site Model (CSM)

- No longer just a "document with figures in it"
- Geographic Information Systems:
  - SSC risk ranking (buried pipe and GW, NEI 09-14 and 07-07)
  - HSA integration
  - ODCM/land use data integration
  - GW/Hydrogeologic data
  - Site boundaries/areas/use
  - Realtime integration with GPS platforms
  - LiDAR and Digital Survey Integration
- Building Information Models (BIM)
  - Architectural, Mechanical (system) and Structural facility data-embedded in 3D digital twin
    - Facility Layout, Construction, System design and Orientation Relative to CSM Areas of Interest
  - Integration with GPS and Plant structural and Mechanical Drawings
  - LIDAR and Digital Survey Integration
- Common Data Environment (CDE):
  - GIS + BIM (digital twin)= CDE (Spatial model w/database)
  - The CDE becomes the data display and analysis tool for the CSM

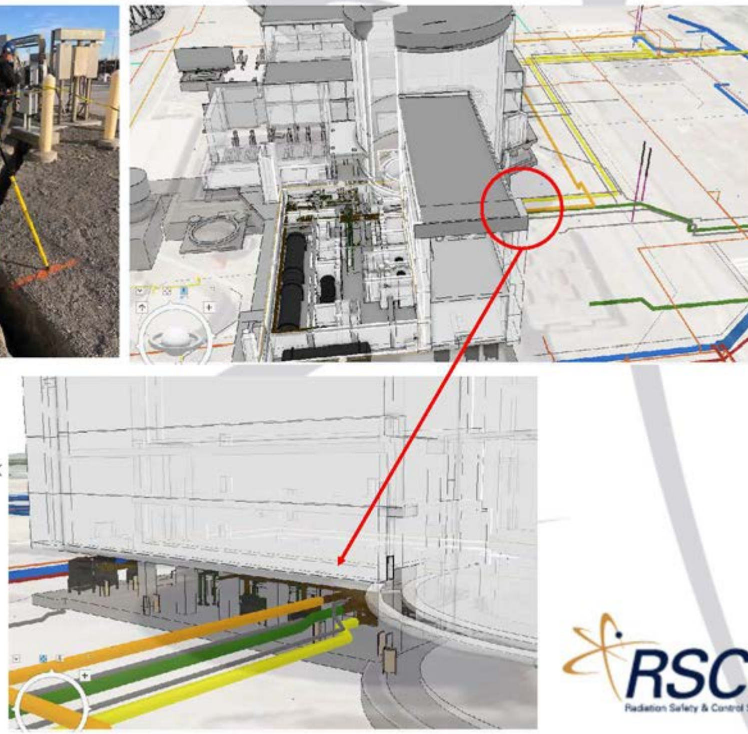
RSCS Radiation Safety & Control Services

The Use of a CDE is Well Suited At Nuclear Facilities Due to Design Controls and Extensive Documentation

- Design Specs: MEP, Architectural, Structural, Civil
- FSAR/UFSAR
- Engineering changes
- Plant modifications
- Procedures and QA/QC
- Operations Logs
- Corrective actions records
- Environmental monitoring (REMP, NEI 07-07)
- Aging Asset Management (NEI 09-14, Maintenance record keeping)

RSCS Radiation Safety & Control Services

Common Data Environments



Software Ecosystem: ArcPro, Revit, Trimble TerraFlex

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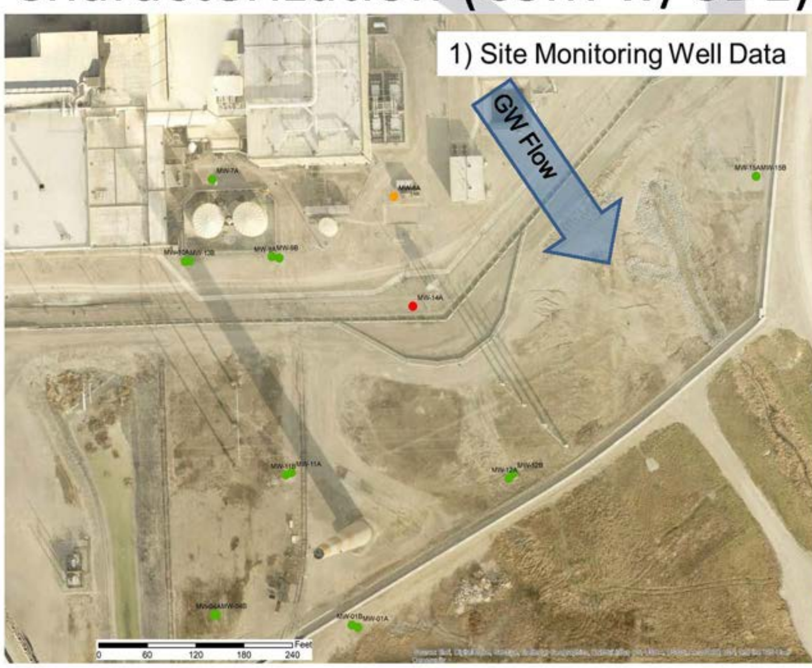
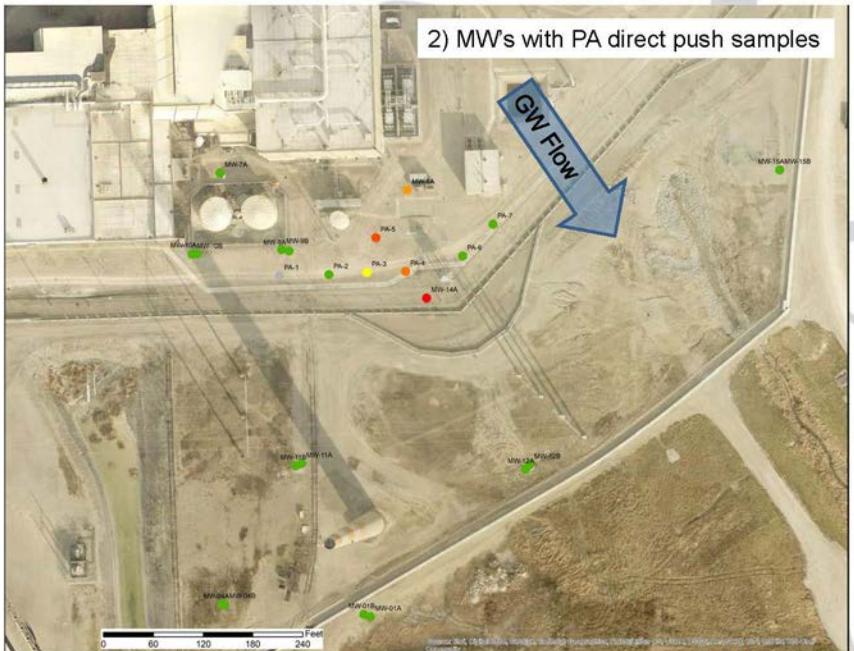
Graded Approach to GW Characterization (CSM w/CDE)





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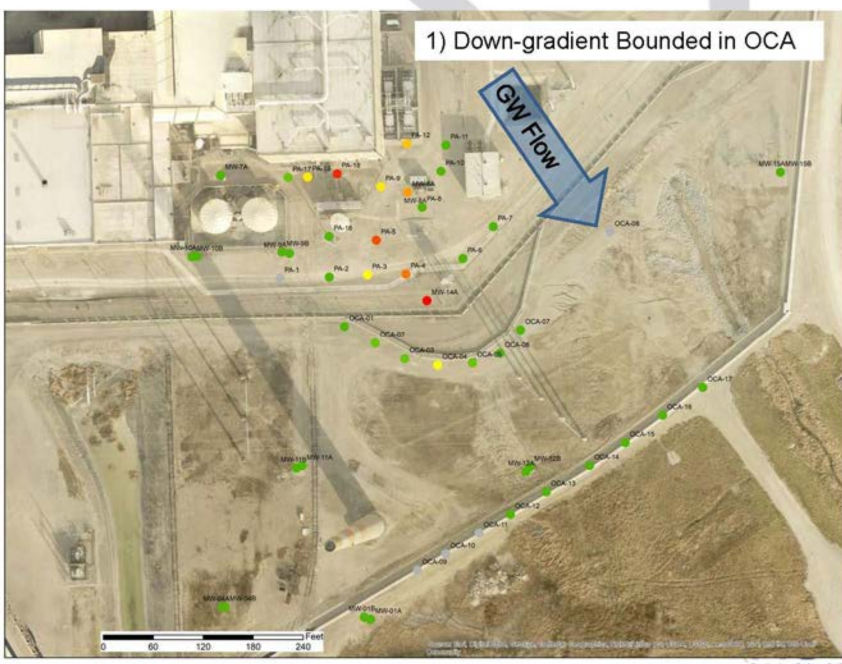
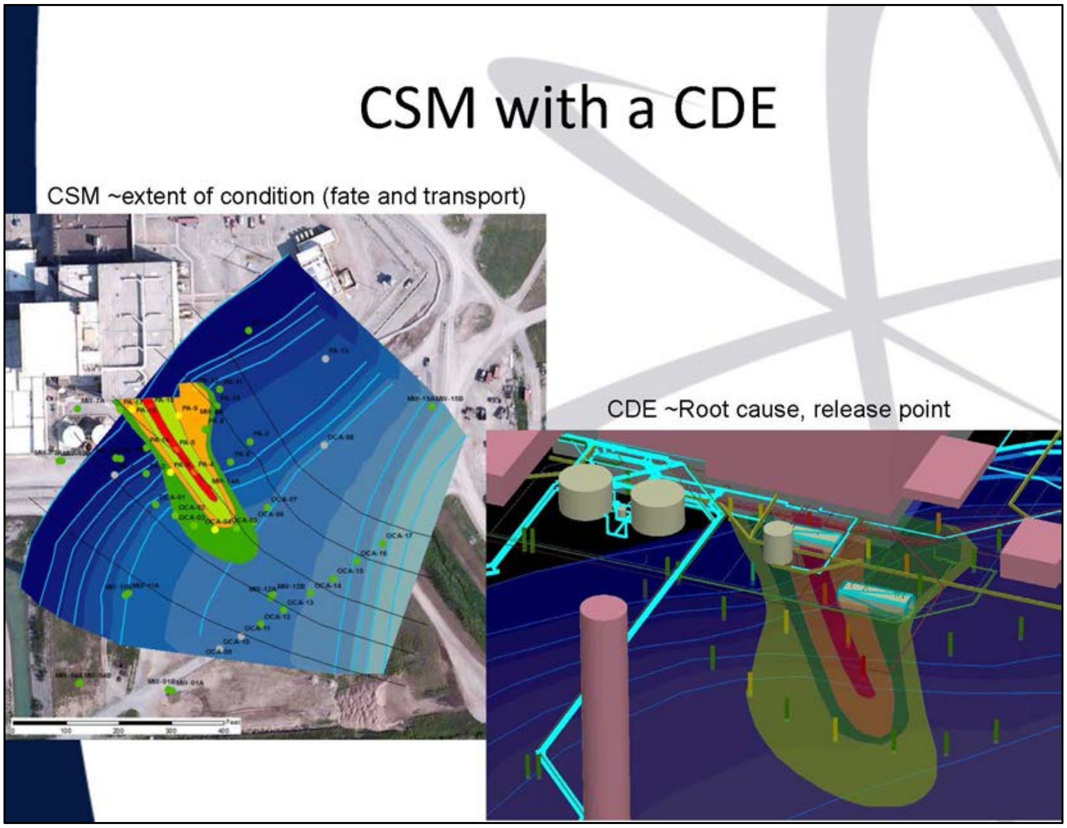
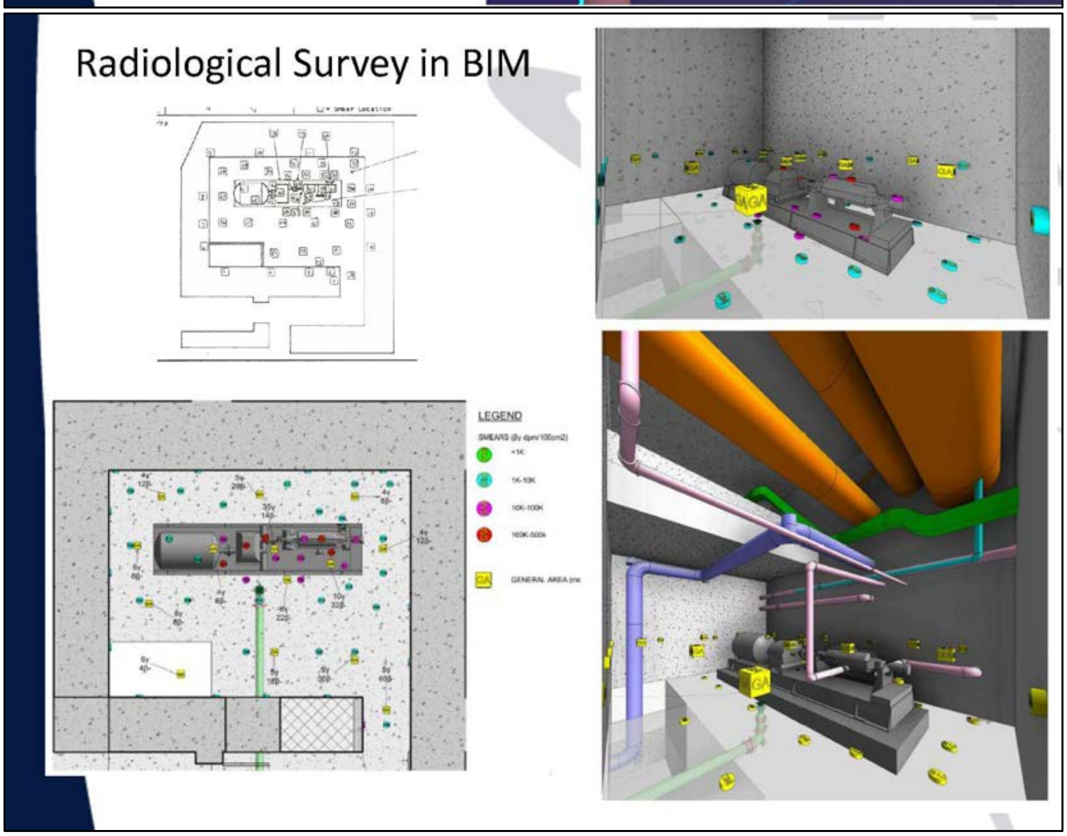
Characterization Complete Foundation Walls

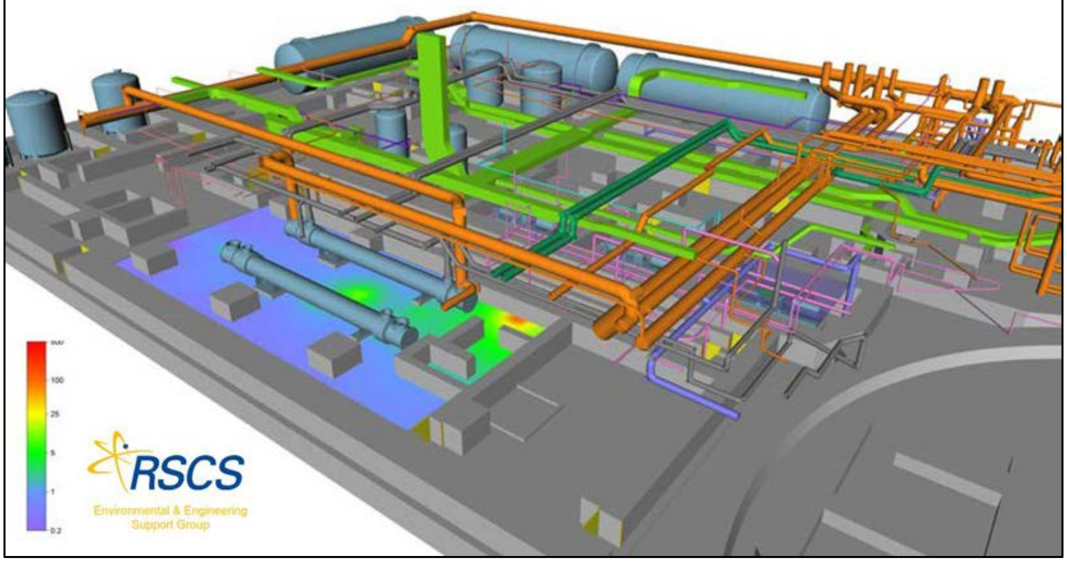


Radiation Safety & Control Services

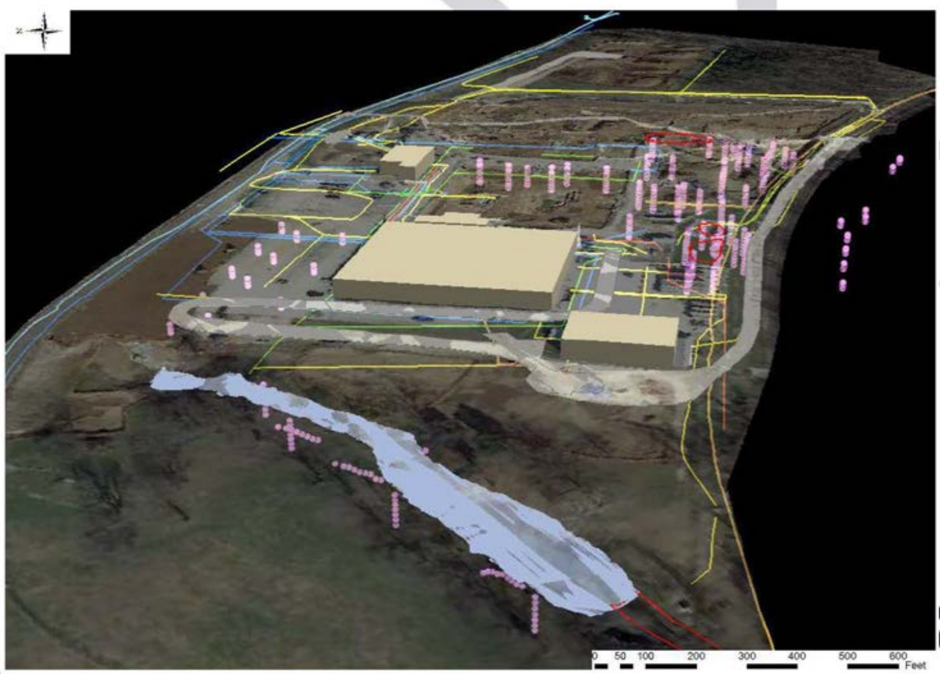

CSM with a CDE
CSM ~extent of condition (fate and transport)
CDE ~Root cause, release point


Radiological Survey in BIM
LEGEND

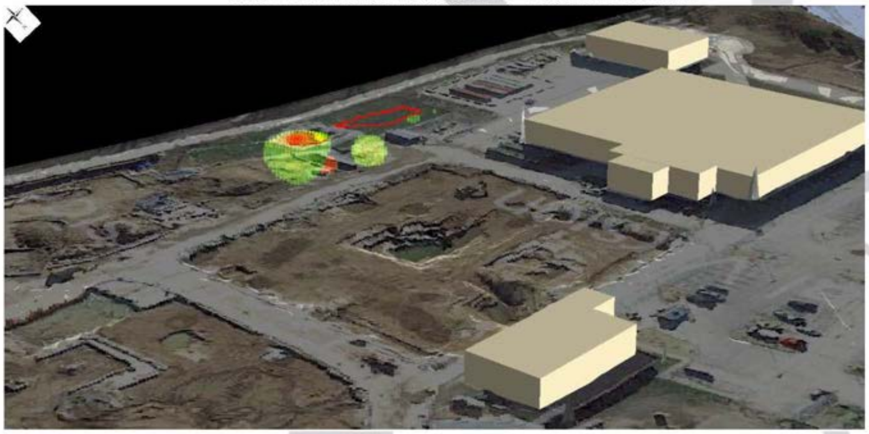
Modeled Contamination in BIM Ecosystem (CDE)

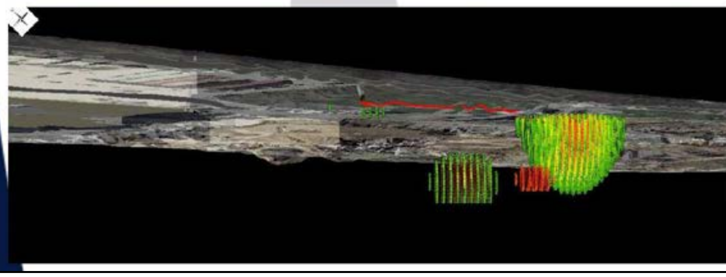


Contamination Extent, Volumes, and Ex-situ Concentration Estimates



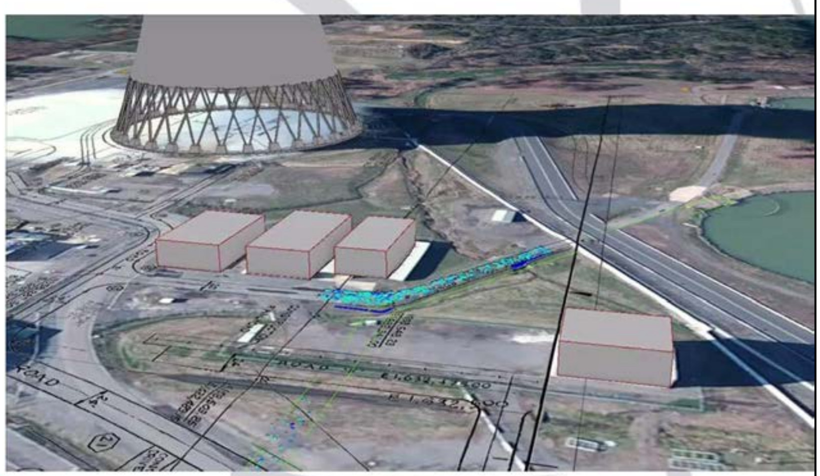
Contamination Extent, Volumes, and Ex-situ Concentration Estimates

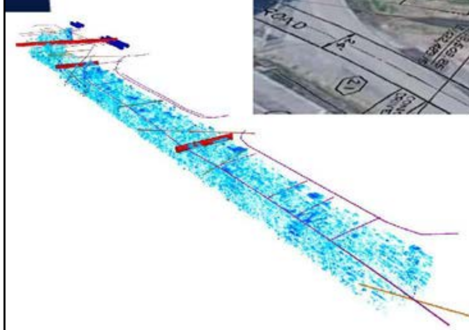




RSCS
Radiation Safety & Control Services

NDE to Support Characterization





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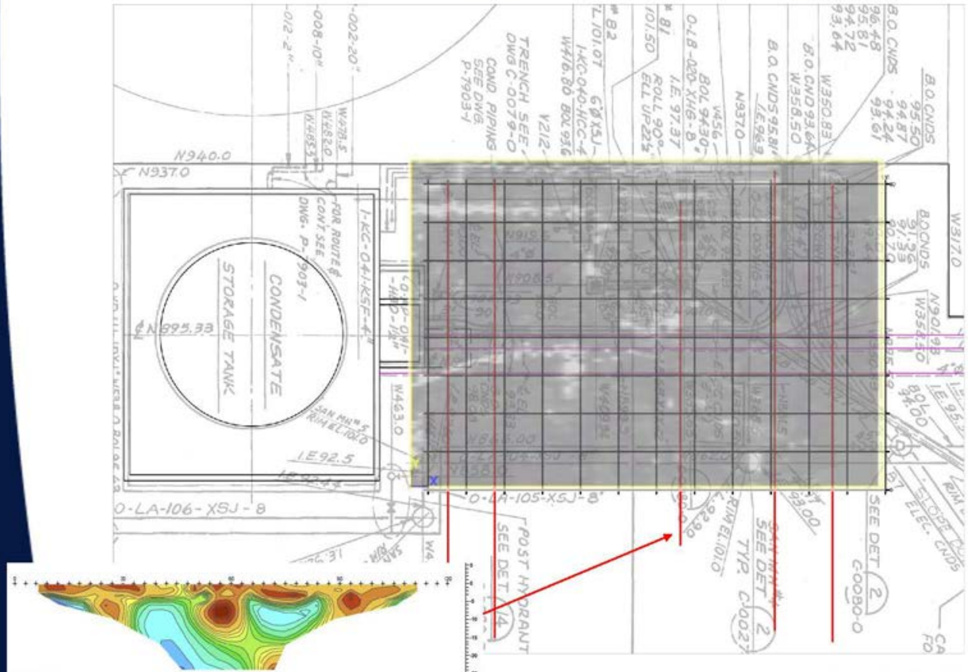
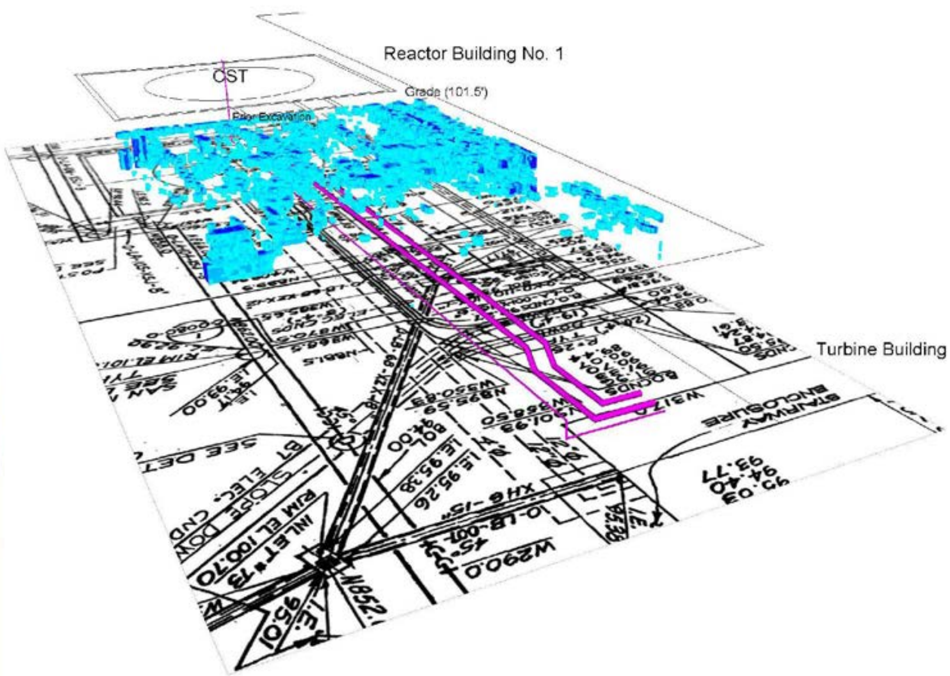
Integrating NDE data to Support Characterization

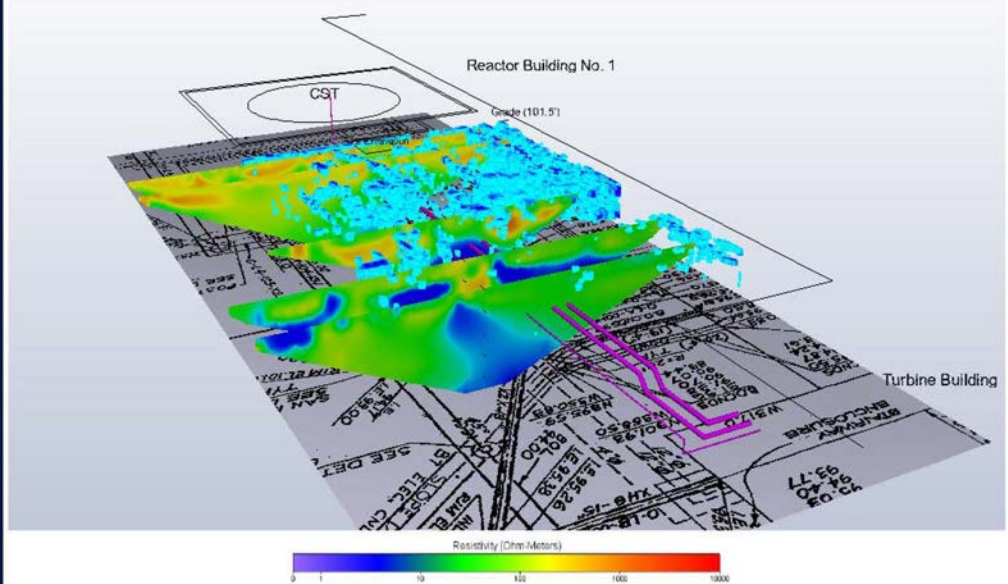


Radiation Safety & Control Services

Integrated 3D GPR with CDE Showing Only Hard Returns (0.0-8.5ft b.g.s)



3D Integrated NDE Data in CDE



Modeled Earth Resistivity and Ground Penetrating Radar Survey to Support Buried Pipe Encasement Evaluation - DRAFT

Comments, Questions

Matt Darois, CGWP, Corp. Environmental & Engineering Manager

Radiation Safety & Control Services Inc.

medarois@radsafety.com

3.4 Day 2: Workshop Topic on Subsurface DCGLs

3.4.1 Development of Derived Concentration Guideline Levels (DCGLs or clean-up levels) for Subsurface Residual Radioactivity (ADAMS Accession No. ML21208A218)

Speaker: Cynthia Barr, NRC/NMSS

3.4.1.1 Presentation Materials

Development of Derived Concentration Guideline Levels (DCGLs or clean-up levels) for Subsurface Residual Radioactivity

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Surface versus Subsurface DCGLs

- What is surface soil?
  - Typically top 6 inches, but
  - Dependent on what can be scanned and
  - Dose modeling assumptions
- Typically, different radionuclides and pathways will dominate dose for surface versus subsurface soils
  - it is important to understand the importance of source parameters such as area, thickness and depth of residual radioactivity to dose through sensitivity analysis

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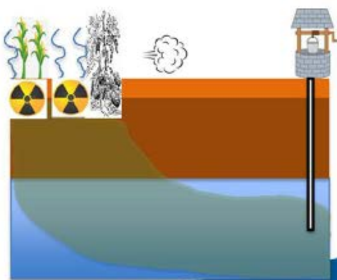
Surface versus Subsurface DCGLs

- Soil Depth (Important Pathways)
  - Surface (external radiation, incidental ingestion, inhalation)
  - Intermediate (plant)
  - Deep subsurface (groundwater dependent pathways)



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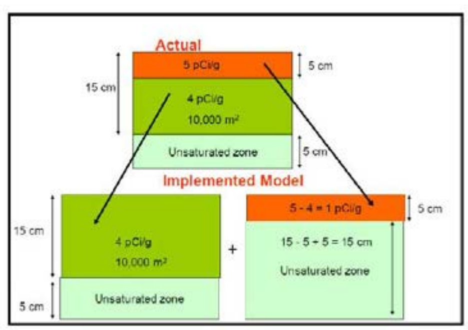
Multiple DCGLs

- Potential need for multiple DCGLs
  - Vertical heterogeneity and sensitivity of dose results to depth and thickness (i.e., significantly different DCGLs for surface versus subsurface residual radioactivity)
  - Various contaminated media (buildings; surface and subsurface soils; groundwater or surface water; and streambed sediments)



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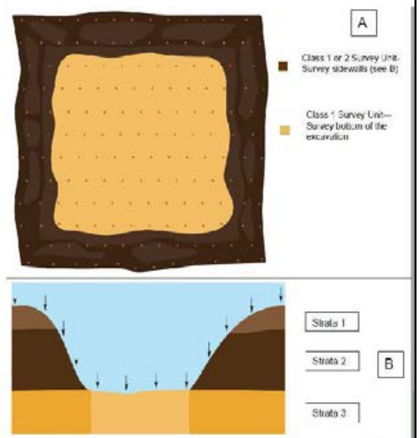
Multiple DCGL Considerations

- Challenges associated with applying multiple DCGLs
  - Survey of soils for reuse in an open excavation (when and how to survey)
  - Soil layers are in close contact with each other making accounting of residual radioactivity difficult
- Lack of guidance on conduct of MARSSIM statistical tests for multiple soil layers.
- Potential scenarios that could re-distribute residual radioactivity to the surface should be considered.



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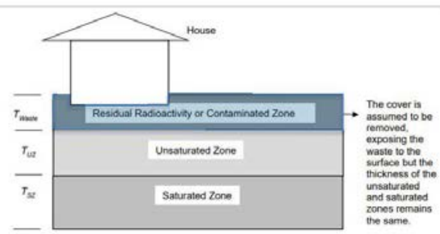
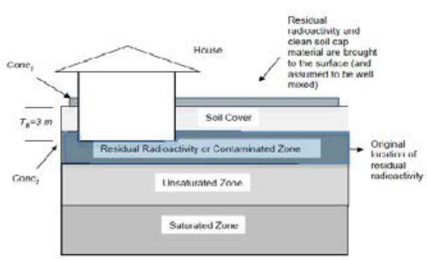
Scenarios for Buried Radioactivity

- Two conceptual models can be considered
  - No soil cover
  - Soil cover





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Groundwater Considerations

- In some cases, enough time has elapsed that existing groundwater contamination is present
- The contribution to dose associated with the existing groundwater contamination should be considered
- Biosphere or dose modeling can be used to determine the dose per unit groundwater concentration to determine the contribution of existing groundwater contamination to dose

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Thank you!

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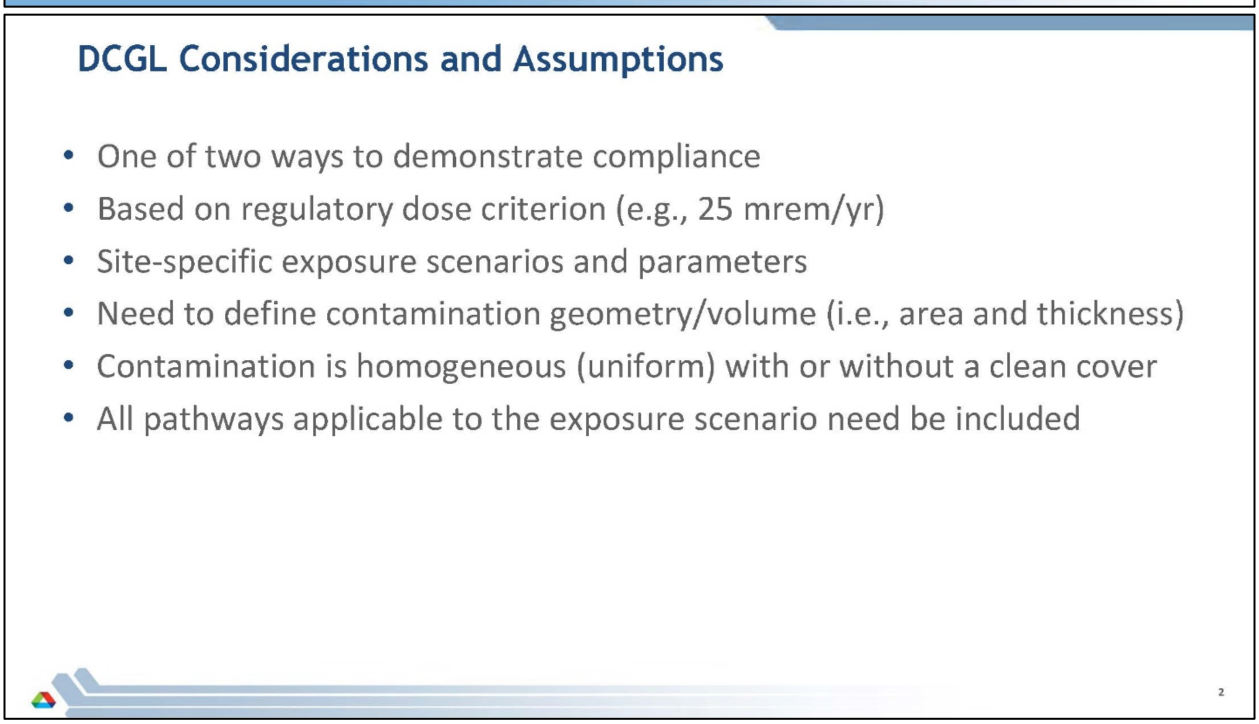
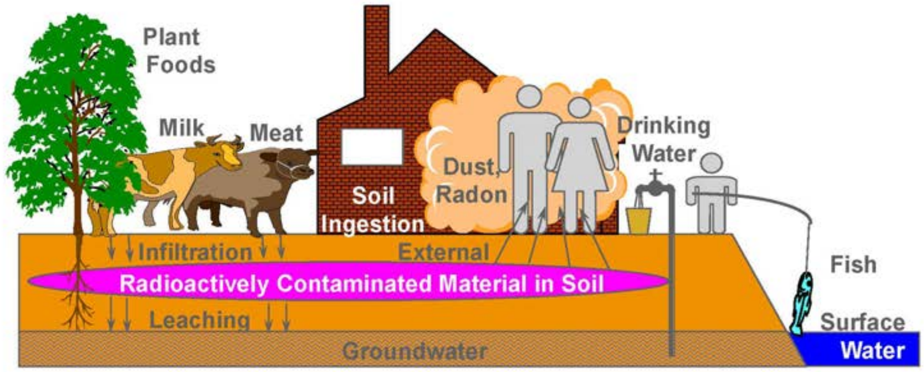
3.4.2 Subsurface DCGL: Effects of Thickness, Area, and Cover (ADAMS Accession No. ML21208A219)

Speaker: Charley Yu, Argonne National Laboratory

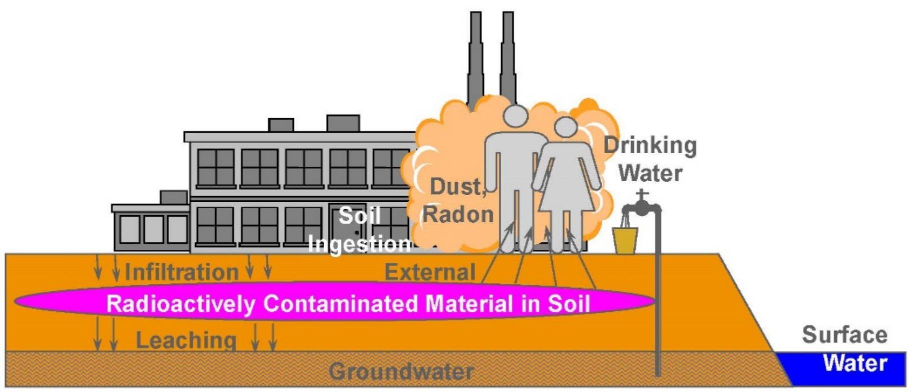
3.4.2.1 Presentation Materials



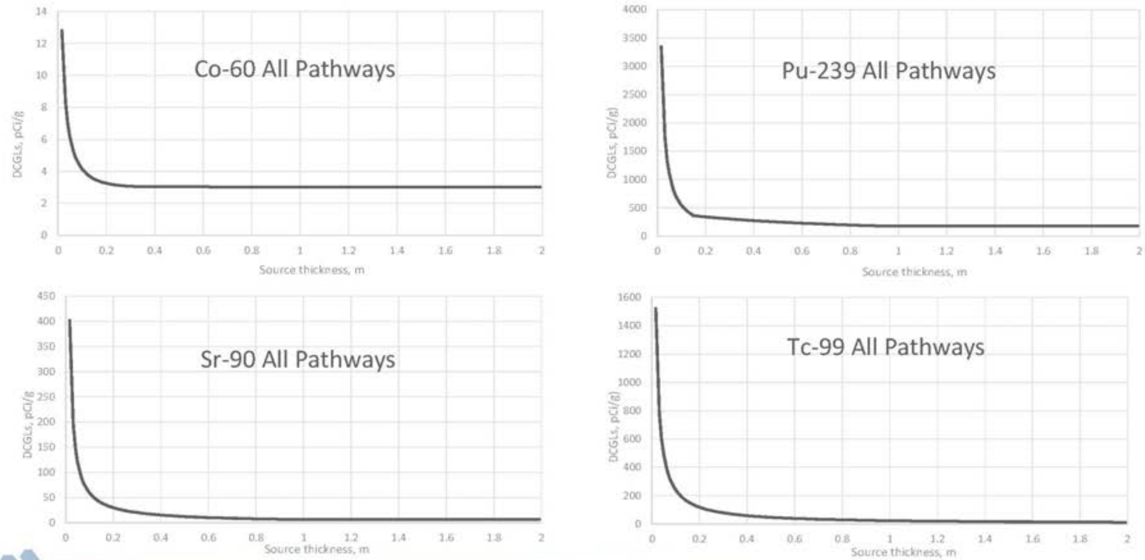
Resident Farmer Scenario



Industrial Use Scenario



Effect of Source Thickness on DCGLs (Linear-Linear Scale, based on 25 mrem/yr, 10000 m², no cover)



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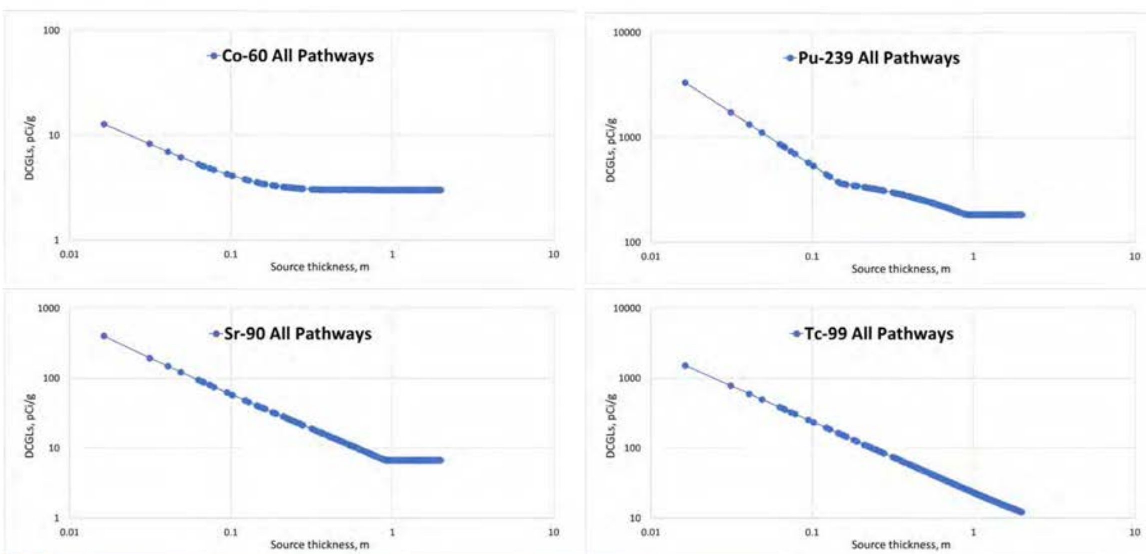
Effect of Source Thickness on DCGLs (Log-Log Scale, based on 25 mrem/yr, 10000 m², no cover)



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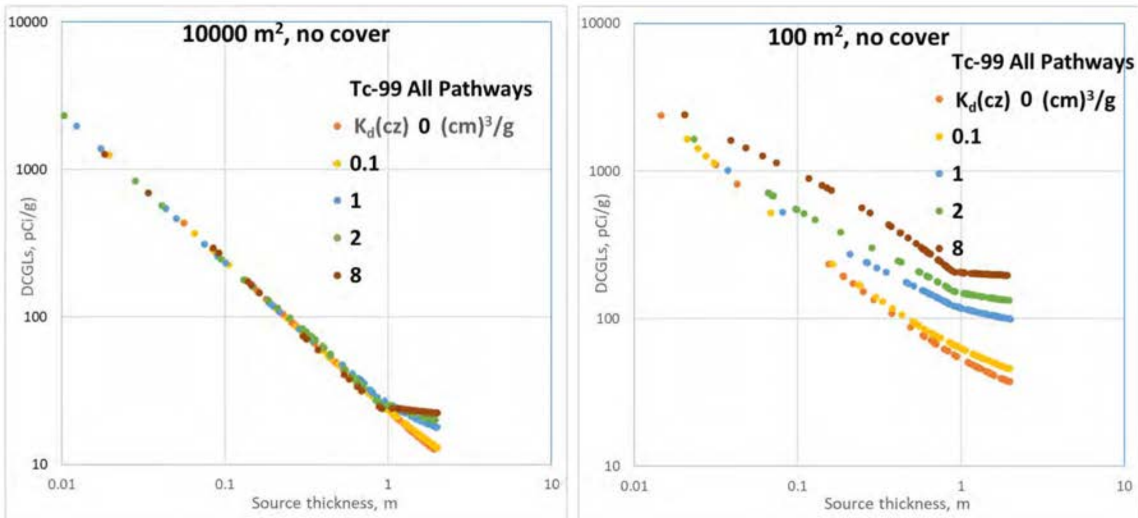
Effect of Distribution Coefficient on DCGLs (based on 25 mrem/yr)



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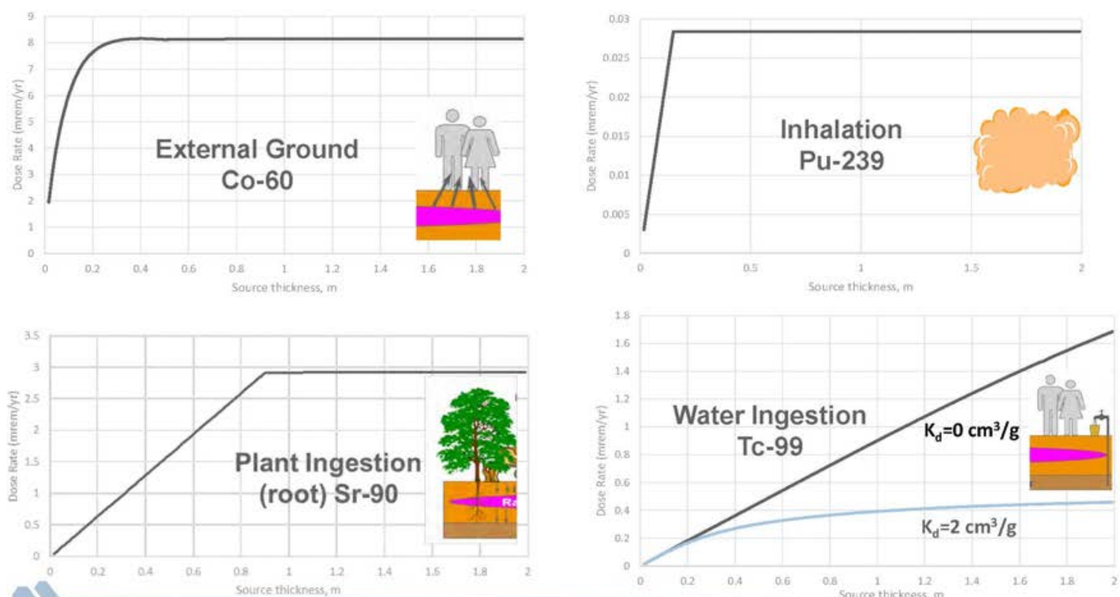
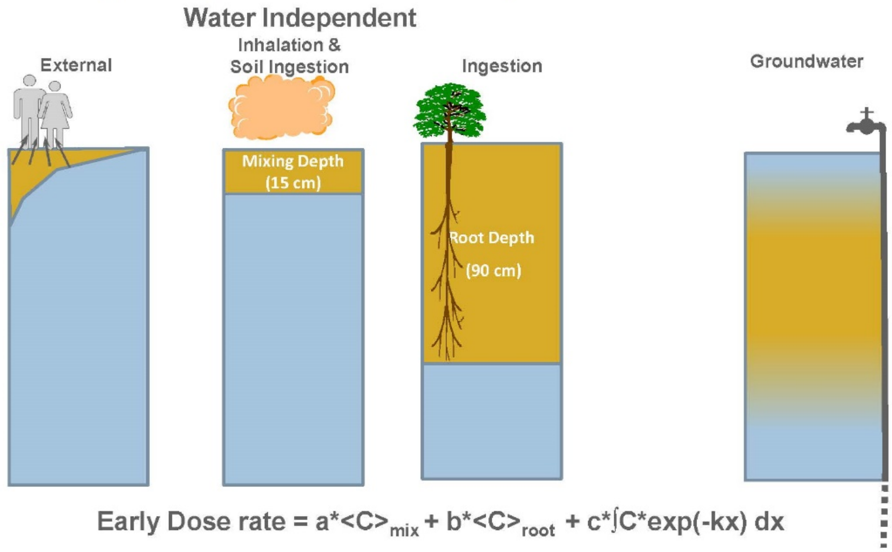
Effect of Source Thickness on Pathway Doses



(with uniform concentration, 10000 m2, no cover)

8

Simplified Depth Dependence of Pathways



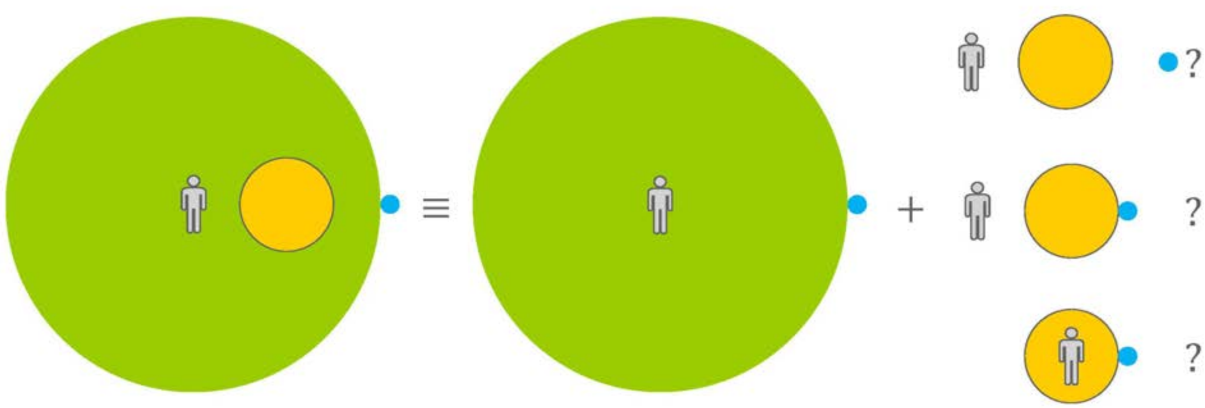
Early Dose rate = $a^*\langle C\rangle_{mix} + b^*\langle C\rangle_{root} + c^*\int C^*\exp(-kx)\,dx$

Later Dose rate = d^*Q

(Also need to consider: decay and ingrowth, cover)

9

Spatial Characterization – Area Factor Consideration



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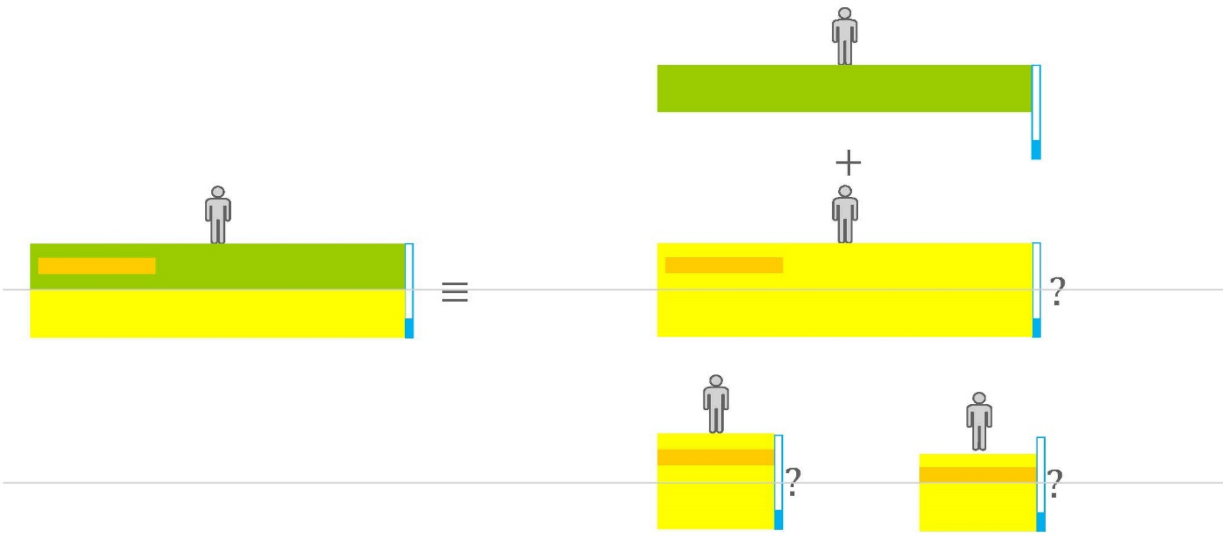
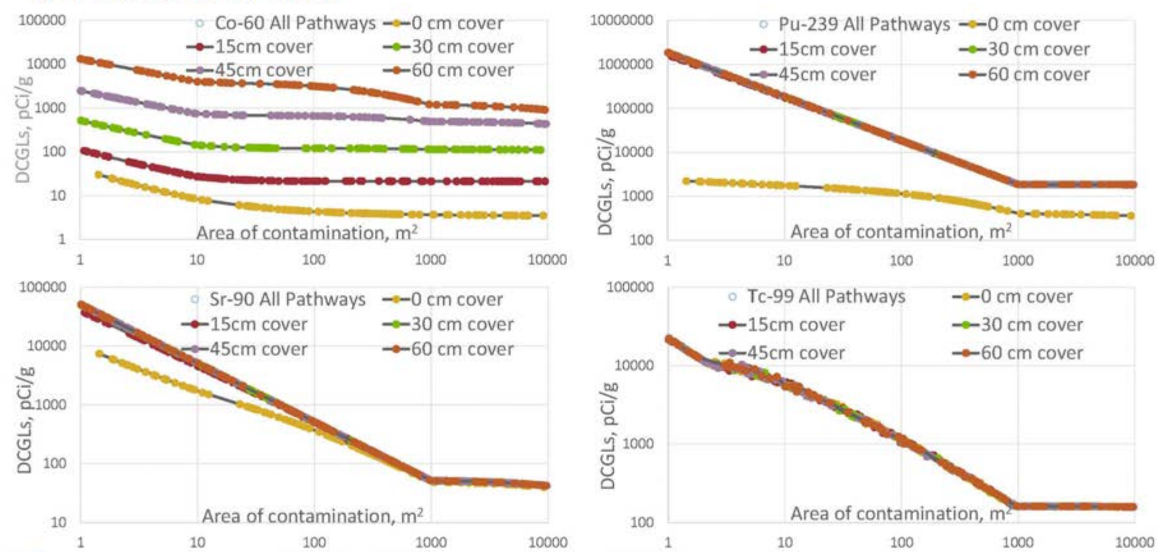
Spatial Characterization – Depth Factor Consideration



DCGLs with15 cm Contamination at Different Depths (Cover) as Function of Area



3.5 Day 2: Workshop Topic on Subsurface Hot Spots

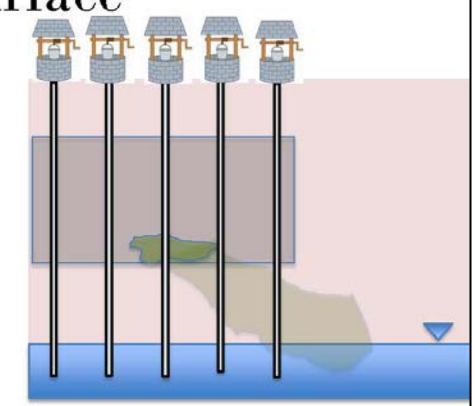
3.5.1 Elevated Areas or "Hot Spots" in the Subsurface (ADAMS Accession No. ML21208A220)

Speaker: Cynthia Barr, NRC/NMSS

3.5.1.1 Presentation Materials

Elevated Areas or "Hot Spots" in the Subsurface

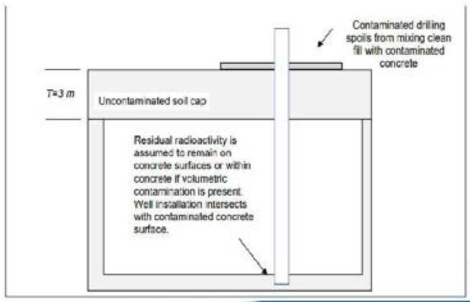
Consideration of Elevated Areas in the Subsurface



- Elevated areas in subsurface soils may be less important than on the surface (the total inventory may drive the dose from the groundwater pathway)
- Elevated areas may be a more important consideration for intrusion scenarios

Alternative DCGL Approaches for Elevated Areas

- In the case that open excavation surfaces are available for scan survey, DCGLemcs could be based on the intrusion scenarios, or
- The DCGLw could be developed based on the most limiting scenario



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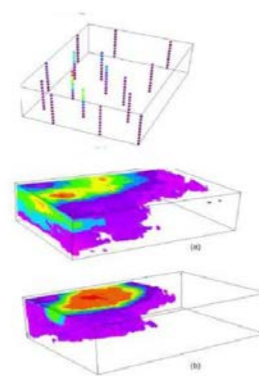
Considerations for Elevated Areas in the Subsurface

- On the surface, scan surveys are typically used to detect elevated areas between sample locations.
- What should the rigor of the survey be to detect elevated areas where there are no exposed surfaces to scan in the subsurface?
- Could the survey be designed to detect elevated areas of a certain size based on dose modeling?
- The sample size could be based on the probability of detecting an elevated area of a certain size.



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3.5.2 Subsurface Hot Spots (ADAMS Accession No. ML21208A221)

Speaker: Carl Gogolak, SC&A, Inc.

3.5.2.1 Presentation Materials

What Is a Subsurface "Hot Spot"?

- Should there be an elevated measurement comparison for the subsurface?
- Since scanning is not possible, every radionuclide in the subsurface is "hard-to-detect"
- How many and at what depths should subsurface subsamples be analyzed?
- Can the core be scanned?

Complexities of Subsurface Sampling

- Number and location of soil core samples
  - For each location, the number and depth of soil subsamples within each soil core must also be specified
  - Cross contamination among vertical layers must be avoided
  - In case of boring tool refusal, an alternative should be specified

MARSSIM Elevated Areas

- MARSSIM does not directly address the issue of "hard-to-detect" radionuclides
  - MARSSIM considers that elevated areas the size of the space between discrete sampling locations will be found with essentially 100% probability as calculated using ELLIPGRID
  - An elevated area that is smaller will have a higher risk of being missed by the sampling grid. Again, the probability of detection can be calculated by ELLIPGRID. The data quality objectives process will determine the risk that is deemed acceptable

Derived Concentration Guideline Levels (DCGLs)

- Guidance will be needed that distinguishes between a surface DCGLw (wide area) and a subsurface DCGLv (volumetric)
  - Different classes of survey units may apply to the surface of the excavation vs. that of the subsurface survey units

Pathways for Subsurface Residual Radioactivity

- Is the dose due to an intruder scenario or building foundation limiting?
- Is the groundwater pathway limiting?
- Is the DCGLv primarily dependent on inventory across a site? ...across a survey unit?

Derived Concentration Guideline Levels

- Multiple DCGLs may be needed depending upon the radionuclides present, applicable exposure scenarios, and actual site conditions
  - It may be beneficial to develop separate DCGLs for cases such as deep subsurface residual radioactivity because of the importance of the groundwater pathway
  - Using multiple DCGLs may be more straightforward where different sources are present (e.g., residual radioactivity at the surface vs. residual radioactivity associated with buried material or from deep subsurface spills or leaks that may contain mixtures of radionuclides)

Derived Concentration Guideline Levels

- NUREG-1757, Volume 2, Revision 2, Appendix G, notes that the class of the side walls may be different (Class 1, 2, or 3) depending on slope
- Typically, DCGLs are developed for layers (depth below ground surface and thickness) and apply to the final configuration/distribution after soil is placed back in the hole, or can apply to "as-is" residual radioactivity below excavation (or to the side of the excavation)

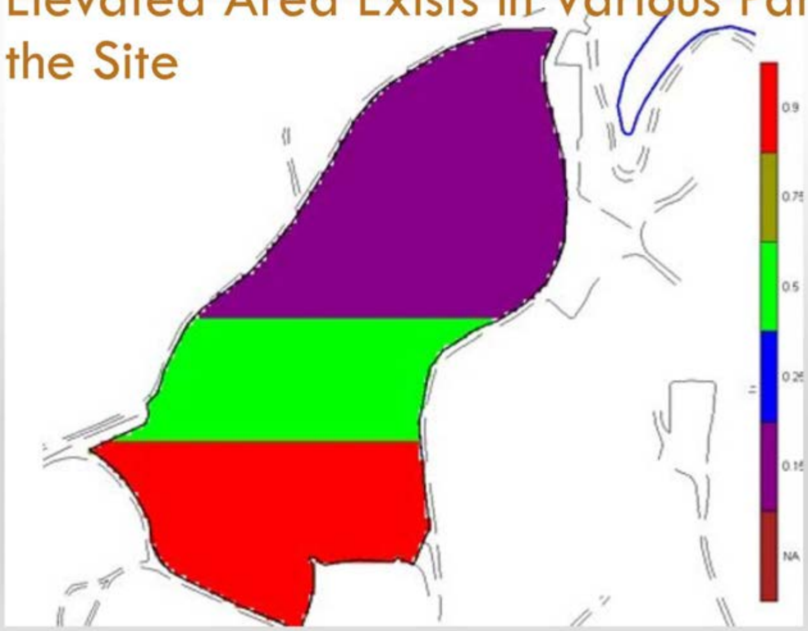
Locating Subsurface "Hot Spots"

- What is an elevated volume (size)?
- Can a layered approach be used for excavations?
- Can multiple subsurface layers or strata be considered individually and then the cumulative risk from the multiple layers or strata be assessed?

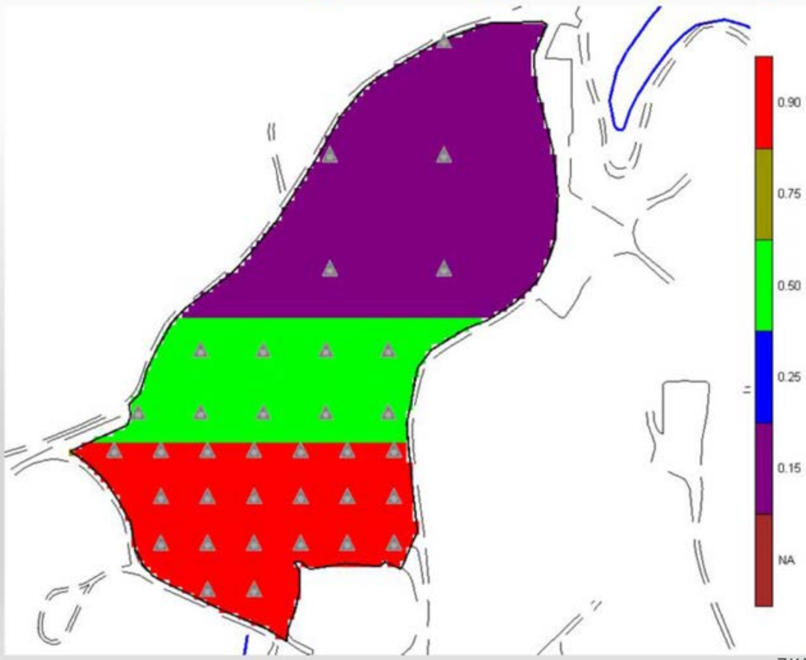
How Many Samples Are Enough?

- How much does adding sampling locations lower the decision uncertainty?
- To answer this question, there must be some measurable benefit for each additional sample taken
- In MARSSIM Scenario A, a minimum number of samples will be needed to achieve the desired Type I and Type II error rates α and β
- Once this number is reached, each additional sample results in the benefit of higher power (1-β)
- For the subsurface, a measure analogous to the power of the hypothesis test vs. sample size is desired

Bayesian ELLIPGRID: Likelihood of an Elevated Area Exists in Various Parts of the Site



Initial Survey Design: 37 Samples



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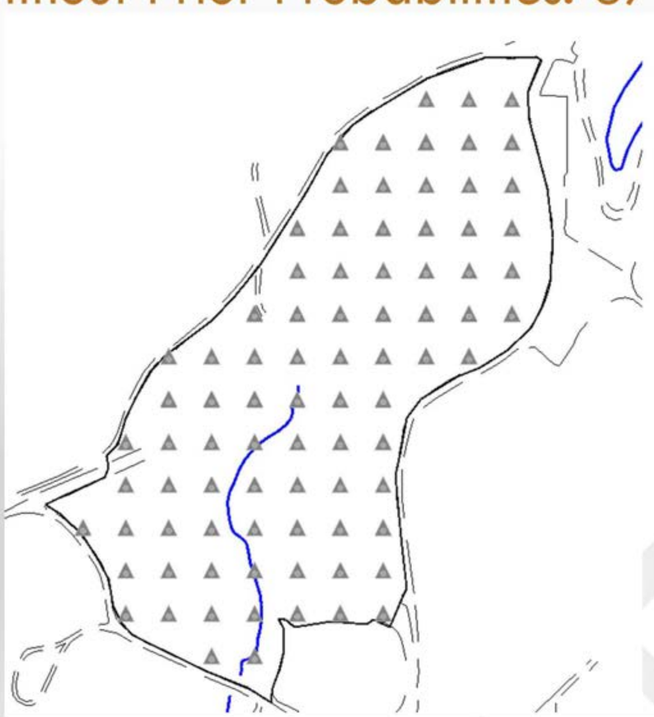
Without Prior Probabilities: 87 Samples



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Hypothesis Tests

How should a decision rule be formulated?

- Assume the survey unit does not meet release criteria unless proved otherwise (MARSSIM Scenario A) or
- Assume the survey unit meets release criteria unless proved otherwise (MARSSIM Scenario B)
  - Appendix G to NUREG-1757, Volume 2, contains examples of Scenario B for three-dimensional data
- What are the criteria for choosing between scenarios?
- If there is a wide variability in reference areas, should there be an indistinguishable-from-background test?

Other Sampling and Analysis Tools

- Are geophysical tools such as ground penetrating radar, electrical resistivity, and metal detectors useful aids in locating subsurface residual radioactivity?
- Can transect scanning (as in the UXO module in VSP) be used with such data?
- Redundant data: VSP can rank well locations by the value it contributes to the whole and eliminate those that are least useful; might this be done in reverse?

Update Existing Tools: VSP &SADA

- Geostatistics and other interpolation methods cannot find locations that exceed the largest value of the measurand unless there is some soft data that can drive higher concentrations (e.g., dry deposition data can extrapolate higher wet concentrations where the rainfall rate is higher)
- If indicator kriging is used to develop a probability distribution for the residual radioactivity, then a high percentile (e.g., 95%) may also extrapolate the data to higher concentrations; of course, this will require that the release criterion is expressed as an action level for that percentile

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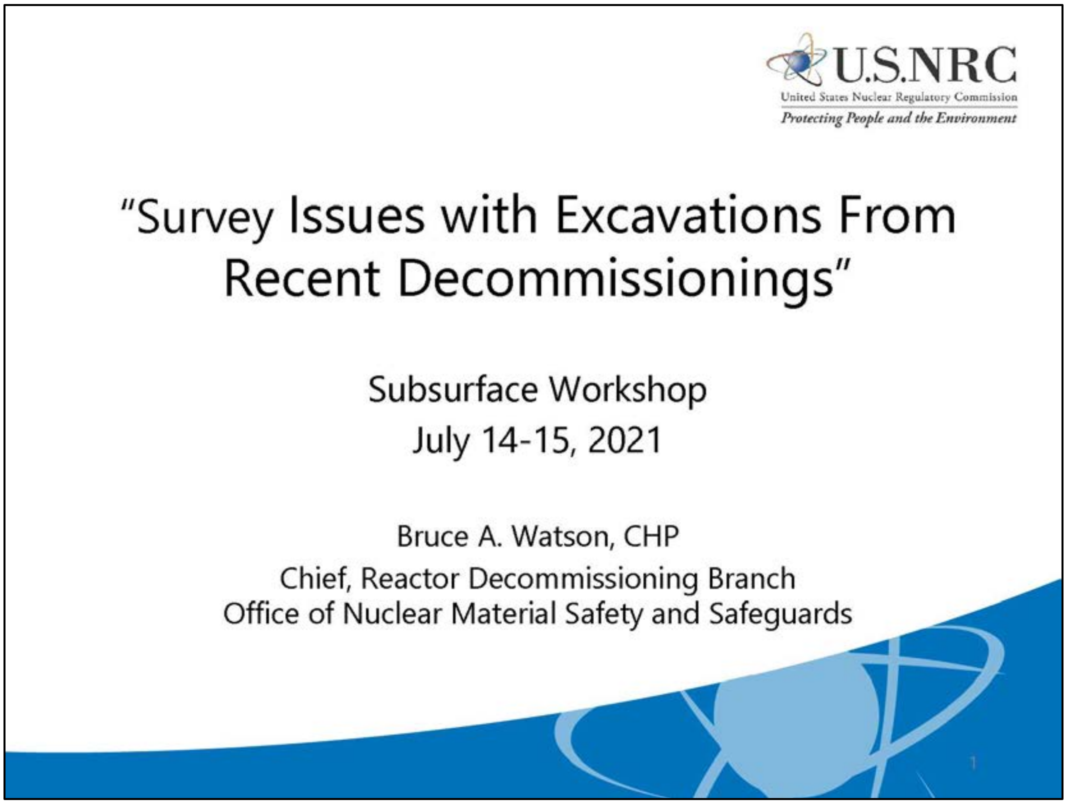
3.6 Day 2: Workshop Topic on Surveys of Subsurface, Including Surveys of Excavations, Backfill Materials, Suspect Areas, and Hard-to-Access Areas

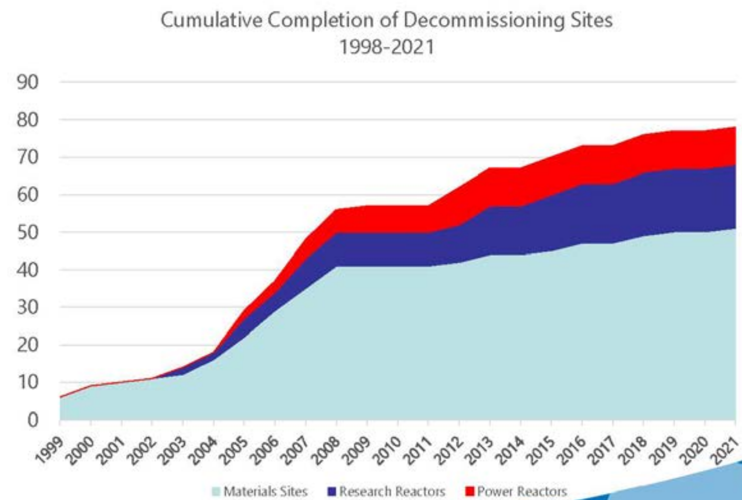
3.6.1 Survey Issues with Excavations from Recent Decommissionings (ADAMS Accession No. ML21208A222)

Speaker: Bruce Watson, NRC/NMSS

3.6.1.1 Presentation Materials



NRC Decommissioning Experience



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To Excavate or Not?

3

Excavation Required

4

Seasonal Flooding Issues?

5

Weather Impacts?

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6

Shallow Ground Water?

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7

Background Issues?

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Excavation Depth?

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9

Contaminant Layering and Stratification

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Excavation Safety

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11

Surveys of Backfill Materials

- Generally, State Regulators have concerns over backfill material constituents and dose
- Backfill plans must be addressed in the Decommissioning Plan (LTP)
  - Include a Survey Plan for determining the residual radioactivity to support dose modeling
  - Need to address residual radioactivity and dose contribution (ALARA)
  - Need to address origin and constituents of the backfill (soil, concrete debris)
- Survey Plans:
  - Radionuclides from Characterization and excavation surveys
  - Based on MARSSIM
  - Scan Surveys of soil, typically 6-inch (15 cm)
  - Sampling for lab analysis
  - Direct Measurement Sampling
  - As left surveys and sampling after backfilling with 6-inch lifts.
- Backfill compression to prevent depression

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Survey and Sampling Concerns

- Excavation sidewall issues
  - Survey unit area (bottom and sides)
  - Sampling of sidewalls
  - Scanning of sidewalls
- Composite Sampling and averaging
- Inaccessible areas (?)
  - Standing or running water
  - Excavation sidewalls
  - Gas pipeline and other safety concerns
  - Mud, ice and snow
  - Rocky substrate

Survey Concerns

- Under building subsurface activity is always a concern and the licensee needs to address in the site characterization report.
- High background count rates generally indicates that of the residual radioactivity has not been remediated.
- Based on the radionuclides present, soil lifts need to be limited to 6" (15 cm) for surveys to be effective. Reminder: MARSSIM is based on 6" inch (15 cm) depth.
- Need to verify that the survey unit has been remediated to the proper depth to remove the residual radioactivity
- Class 1 surveys require 100 % SCAN surveys, if not already in the approved Decommissioning Plan, seek Regulator input for unusual situations.
- Class 2 and 3 areas require minimal Scan Coverage, chose the most where residual activity is likely to be present.

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Subsurface Issues?

In developing guidance for subsurface surveys/sampling, many of the issues with excavation surveys, sampling and safety may be applicable.

Thank you for the opportunity to speak today!

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3.6.2 Low Level Radioactive Objects at a Former Department of Defense Facility (ADAMS Accession No. ML212108A223)

Speaker: Matthew Wright, California Department of Public Health

3.6.2.1 Presentation Materials

Radionuclide of Concern: Ra-226

Conceptual Site Model: **Low Level Radioactive Objects (LLROs)**

Origins of LLROs: **buried as trash in disposal pits in 1950s**

- ❖ Radium foils thought to be used for calibration of survey instruments
  - ❑ 1 REM contact (average) 12 to 15 mRem at 30 cm, milli curie range
  - ❑ 75 recovered
- ❖ Deck markers, metal fragments, disintegrated objects, microCurie range
  - ❑ 1200 + recovered

In 1960s and 1970s soil from disposal pits containing LLROs was then scraped up and transported throughout the facility to be used as land fill for base housing. Former base housing now used as low-income housing.

Unique Challenges

Facility has two areas of concern:

Former Disposal Pits

- ❖ Facility adjacent to large body of water:
  Excavations 16 to 18 feet Below Ground Surface, flooded with water: LLROs still being found: is there a point where you cease further excavations? Does anyone have experience in anything similar they can share?

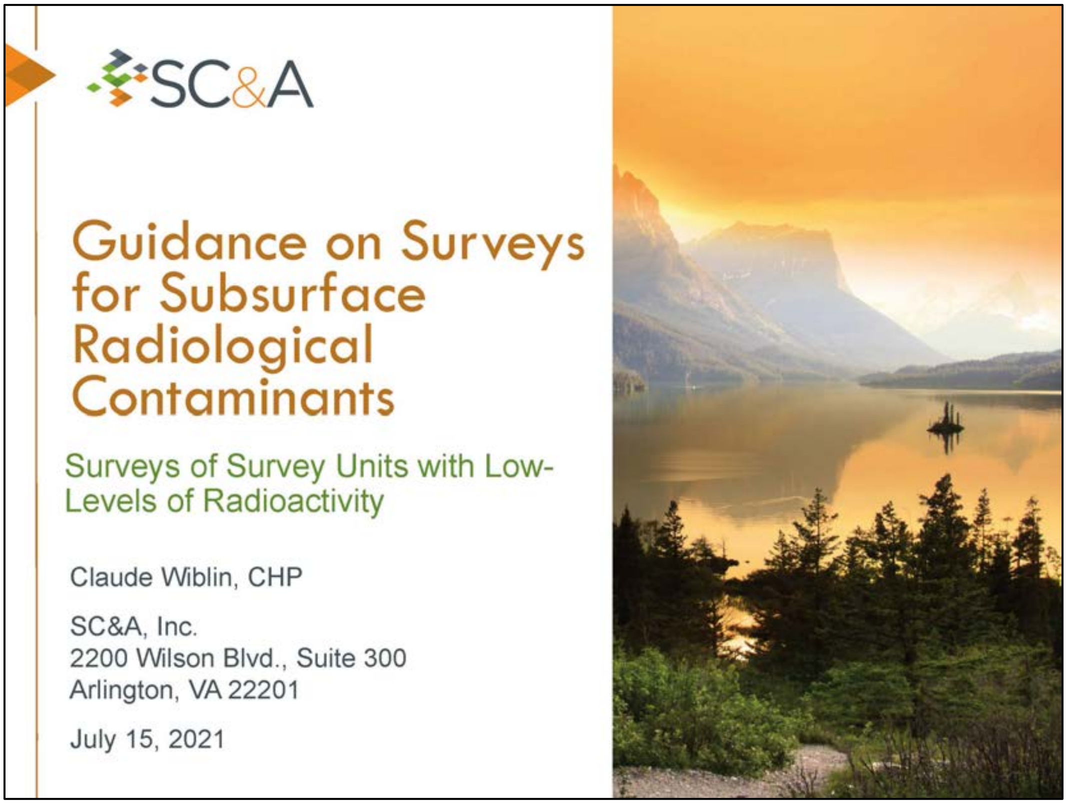
Housing Areas

- ❖ Soil containing LLROs was used as land fill:
  What radiological instrumentation is appropriate to detect 1 microCurie sources at least 1 foot below ground surface ?
  Are there any technical papers which discuss capabilities of the RSI (RS-700) system?

3.6.3 Surveys of Survey Units with Low-Levels of Radioactivity (ADAMS Accession No. ML21208A224)

Speaker: Claude Wiblin, SC&A, Inc.

3.6.3.1 Presentation Materials



Introduction

- Describe key issues concerning contaminants in subsurface soils that might be described as a now "undefined" Class 3 subsurface soil, Materials and Equipment (M&E).
- Suggest approaches to address survey design (including NUREG-1757, Vol. 2, Rev. 2) and statistical methods for evaluating contaminants in the subsurface.

Class 3 Subsurface Survey Design per MARSSIM

- MARSSIM provides statistical testing techniques that can be universally applied to the subsurface:
  - Wilcoxon Rank Sum (WRS) Test
    - Quantile Test follows if WRS is passed
  - Sign Test
  - Retrospective Power Test (especially Scenario B)

Scenario A or Scenario B?

- Scenario A uses a null hypothesis that assumes the concentration of radioactive material in the survey unit exceeds the derived concentration guideline level (DCGL); it is "presumed not to comply" or "presumed not clean".
- Scenario B uses a null hypothesis that assumes the concentration of radioactive material in the survey unit is less than or equal to the action level or lower bound of the gray region; it is "indistinguishable from background" or "presumed clean".

Low-Level Concentrations of Radionuclides

- Per MARSSIM, a *Class 3* Area is any impacted area that is not expected to contain any residual radioactive material or is expected to contain levels of residual radioactive material at a small fraction of the DCGL.
- Per MARSAME, NUREG-1575, Supp. 1, Class 3 M&E have, or had, (1) little, or no, potential for radionuclide concentration(s) or radioactivity above background and (2) insufficient evidence to support categorization as nonimpacted. Radionuclide concentration(s) and radioactivity above a specified small fraction of the DCGL are not expected in Class 3 M&E. The specified fraction should be developed by the planning team using a graded approach and approved by the regulatory authority.

NUREG-1757, Vol. 2, Rev. 2 Guidance

- The number of cores to be taken is initially the number (*N*) required for the WRS or Sign test, as appropriate from MARSSIM.
- Random locations for coring (Class 3).
- Core samples are homogenized over a soil thickness that is consistent with assumptions made in the dose assessment, typically not exceeding 1 meter in depth. Do not average radionuclide concentrations over an arbitrary soil thickness.
- Develop a contaminant concern map per NUREG/CR-7021, “A Subsurface Decision Model for Supporting Environmental Compliance.”

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Core Scan and Sample Size

- Standard practice is to sample (~500 grams) at location of highest radiation level. Usually scan survey both core and downhole.
- Sample size (length) should be consistent with DCGL development.

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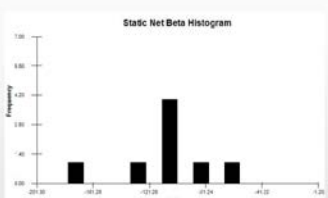
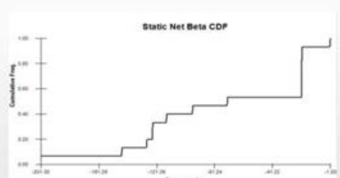
Spatial Analysis and Decision Assistance (SADA) Statistical Package

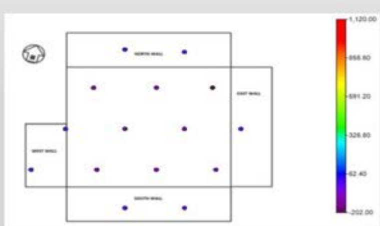
Univariate Statistics

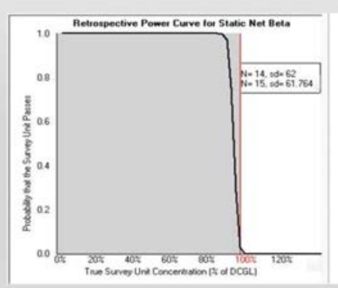
- [x] Detects
- [x] N
- [x] Mean
- [x] Median
- [x] Variance
- [x] Standard Deviation
- [x] Geometric Mean
- [x] Coefficient of Variance
- [x] Range
- [x] Interquartile Range
- [x] UCL95 (Normal- Student's t)
- [x] UCL95 (Lognormal- Land's H)
- [x] Skewness
- [x] Kurtosis
- [x] Mean Absolute Deviation
- [x] Mode

SADA Ready-to-Use Figures









Data Gaps

- Surface areas for subsurface volumes are not sized and defined for subsurface soil classes.
- Statistical software is under development.
- Scenario B is based on either:
  - NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey for Instruments for Various Contaminants and Field Conditions," for multiple background reference units, or
  - draft MARSSIM Rev. 2.
- DCGL development: volumetric, multiple layers, or intrusion scenarios.

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4 WORKSHOP PARTICIPANTS

Approximately 195 people registered to attend the July 2021 Subsurface Soil Surveys Public Workshop, with approximately 67 individuals from State agencies, 48 from industry and commercial companies, 36 from non-NRC federal organizations, 33 NRC staff members, 8 from the general public, and 3 from international organizations. The workshop had approximately 160 virtual workshop participants during each day.

External registrants came from the following organizations:

American Nuclear Insurers
Argonne National Laboratory
Barrick
Bechtel
Bestica, Inc.
BHP
CDI Oyster Creek
Curtiss-Wright Nuclear
Duane Arnold Energy Center
ENERCON
EnergySolutions
EPRI
Exelon
Geosyntec Consultants
H3 Environmental, LLC
Homestake Mining Company of California
Iberdrola Nuclear Generation (Spain)
Los Alamos National Laboratory
National Nuclear Security Administration Savannah River Site
NEI
NEIS.com
Oak Ridge Associated Universities
Omaha Public Power District
PNNL
RSCS
San Onofre Decommissioning Solutions
SC&A, Inc.
Southern California Edison
Southern Nuclear
State Scientific and Technical Center for Nuclear and Radiation Safety (Ukraine)
Tennessee Valley Authority
Tidewater, Inc.
Town of Duxbury, MA, Nuclear Advisory Committee
U.S. Air Force
U.S. Army Corps of Engineers (USACE), Buffalo District
U.S. Army Public Health Center
U.S. Department of Energy (DOE), Office of Public Radiation Protection
U.S. Department of Energy, Office of Environmental Management
U.S. Department of Energy, Office of the Chief of Nuclear Safety
U.S. Department of Energy, West Valley Demonstration Project

U.S. EPA National Center for Radiological Field Operations
U.S. EPA Office of Radiation and Indoor Air
U.S. EPA Region 2
U.S. Navy
Wood PLC.

State agencies (e.g., Department of Public Health, Environment) from the following:

- State of Alabama
- State of Arkansas
- State of California
- State of Colorado
- State of Connecticut
- State of Mississippi
- State of Nevada
- State of New Jersey
- State of New York
- State of North Carolina
- State of Tennessee
- State of Texas
- State of Utah
- State of Vermont
- State of Washington

5 SUMMARY AND CONCLUSIONS

5.1 Summary

This report includes the agenda and presentations for the Subsurface Soil Surveys Public Workshop held in July 2021. Attendees of the virtual workshop included members of the public; NRC technical staff, management, and contractors; staff from other Federal agencies; and members of academia. Public attendees over the course of the workshop included industry groups, industry members, consultants, independent laboratories, and research institutions.

5.2 Conclusions

As reflected in these proceedings, subsurface characterization of licensee sites undergoing decommissioning is a very active area of research for the NRC and other Federal agencies, industry, and academia. Readers of this report will have been exposed to current technical issues, research efforts, and accomplishments in this area within the NRC and the wider research community.

These proceedings represent the main efforts in the first phase (technical basis phase) of this research effort. As part of this technical basis phase, the NRC has initiated research into case studies that synthesize various technical basis results and lessons learned to demonstrate the development of realistic modeling and characterization of subsurface contaminants. The final phase (development of selected guidance documents) is an area of active discussion between RES and NRC licensing offices. The NRC staff looks forward to further public engagement in this area.

6 ACKNOWLEDGEMENTS

An organizing committee in the RES Division of Risk Analysis, Fire and External Hazards Analysis Branch, planned and executed this workshop with the assistance of NMSS staff and contractors from SC&A, Inc.

Organizing Committee Members: Mark Fuhrmann, Tom Aird, Sarah Tabatabai, Cynthia Barr, Carl Gogolak, Claude Wiblin, and Deborah Schneider

Workshop NRC Facilitator: Kenneth Hamburger

Several NRC offices contributed to this workshop and the resulting proceedings. The organizing committee would like to highlight the efforts of the RES administrative staff, as well as agency publishing staff. The organizers appreciated managerial direction and support from MarkHenry Salley, Mark Thaggard, Christian Araguas, and Trish Holahan.

Members of the NRC Subsurface Soil Surveys Research Group:

Tom Aird (RES), Mark Fuhrmann (RES), Sarah Tabatabai (RES), and Cynthia Barr (NMSS)