



Spatial Analysis and Decision Assistance (SADA) Version 4.1

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PERFORMANCE BASED RADIOACTIVE MATERIALS CONTROL (MEASUREMENT)

Improve the process of determining the presence or absence of radioactive material for the requirements and conditions present.

- *Planning*
- *Instrumentation*
- *Sampling*
- *Analysis*

Instrumentation

- Selecting the proper instrument for surveys
- Advances and improvement
- Exploiting field analytical capabilities
 - Data logging
 - Live Time analysis
 - GPS
- Integration of instrumentation to analytical software

Analysis

- Parametric to non-parametric
- When is enough, enough?
- Iterative Methods - SADA
 - Infill
 - Adaptive Sampling and Analysis Program (ASAP)
 - Markov/Bayes
 - Co-Variance/Co-Kriging
 - Minimize Uncertainty of Exceedence
 - Minimize risk of misclassification



Research Objective Dealing with Subsurface Radionuclides

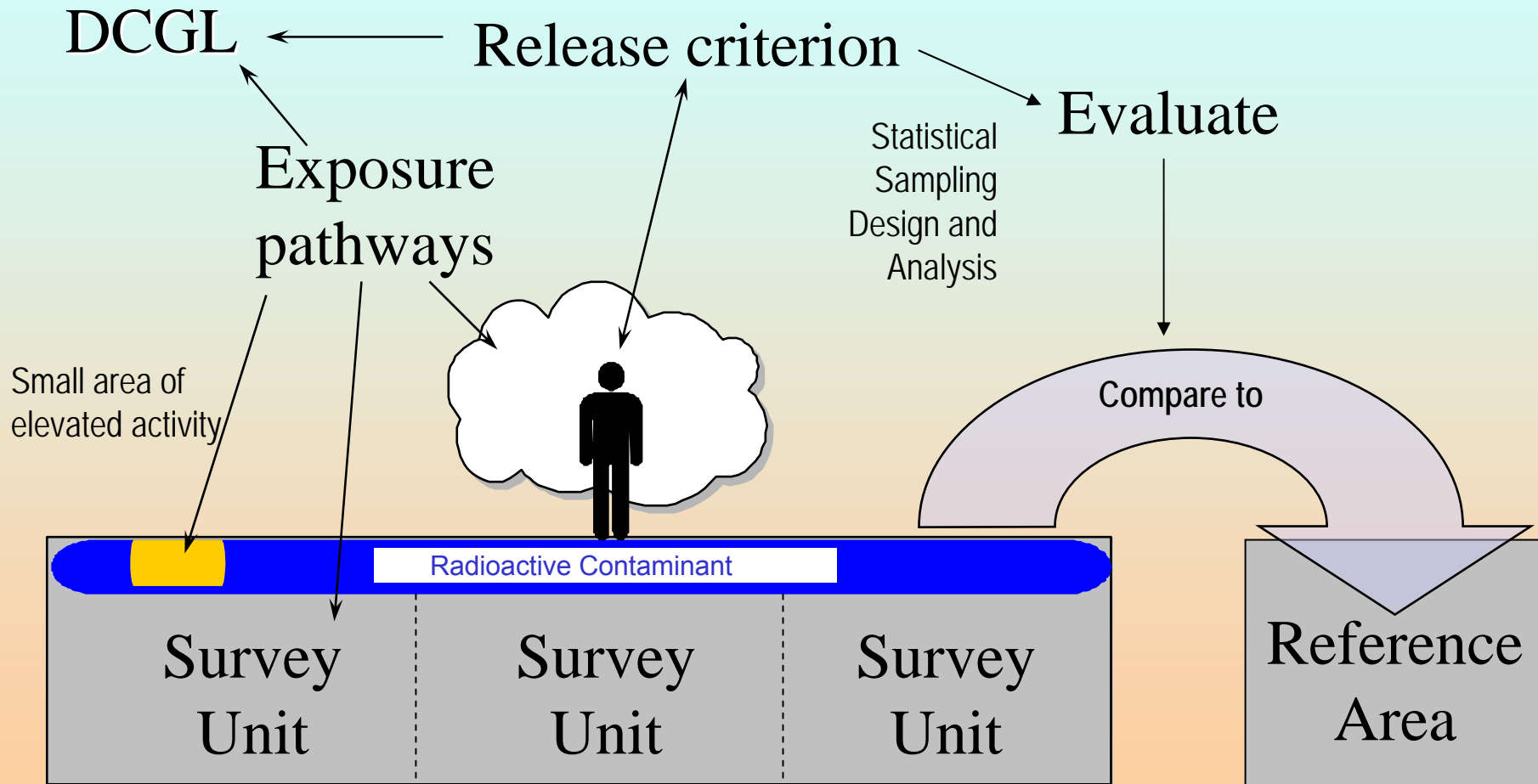
Pursue more **realistic** and **defensible estimates** of exposure of the public to radiation from radionuclides released from contaminated sites through **optimization** of **sampling** and **analysis**



Planning (Multi Agency)

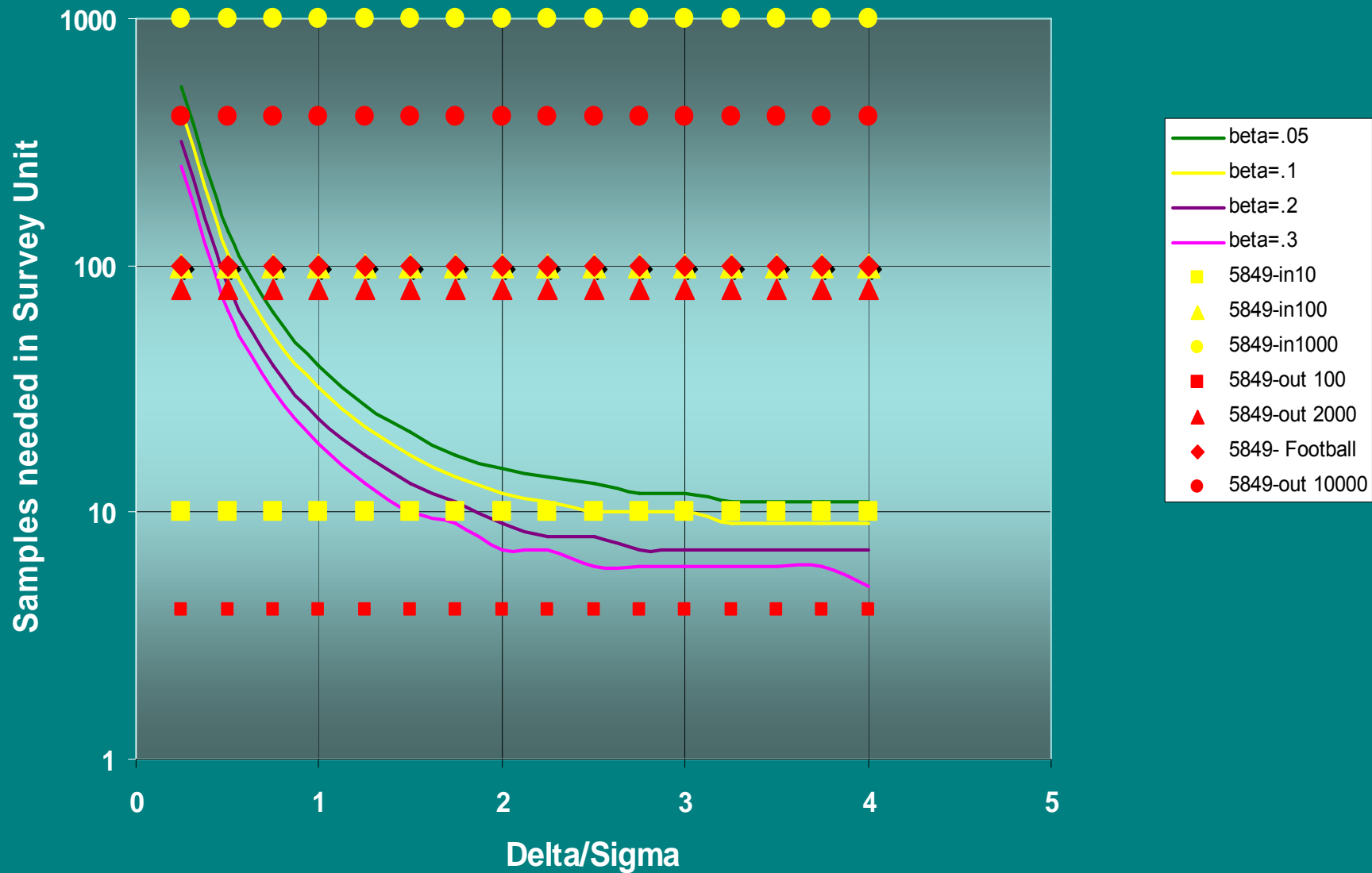
- Understand requirements of pending decisions
- Explicitly identify and manage uncertainties that could lead to decision errors
 - Sampling uncertainties - MARSSIM (Aug 2000)
 - Analytical uncertainties - MARLAP (Dec 2003)
 - Materials specific – MARSAME (Target 2007)
 - Subsurface specific – MARSSub (TBD)
- Implementing the intent of “performance based” (surface/subsurface sampling & analysis) – SADA

MARSSIM *DQO/DQA* Process



5849 vs MARSSIM

N vs Delta/Sigma



Sampling the Subsurface

- How is designing a sampling survey for subsurface materials different from designing a sampling survey for surface materials within the first 15 cm of soil?
- At issue is **how to design the survey more efficiently**, because the sampling effort is considerably higher for subsurface sampling than it is for surface soil sampling.
- The approach needs to be better than what we are doing now, with a justifiable technical basis and **no hidden assumptions**.

Design More Efficient Surveys

Reduce required number of samples by increasing the information available by other means than simply taking more direct measurements. This can be done in two ways:

- 1) **increase the information** available from professional knowledge of site processes, historical data, pollutant transport etc.
- 2) make **more efficient use of the hard data** that is already available by the use of more advanced statistical methods.

Develop further design efficiency

- Incorporate prior information quantitatively as “soft data” that can be combined with hard concentration data from samples- **Bayesian Statistics**
- Sampling design based on maximizing the information that will be added - **not all locations are equally informative**
- **Geostatistical** data analysis that incorporates known spatial relationships among data locations
- **Geophysical** data may be used for scanning - Bayesian extensions to estimate volume (volume factor)

SADA Overview

Windows--based freeware designed to integrate scientific models with decision and cost analysis frameworks in a seamless, easy to use environment.

- Visualization/GIS
- Statistical Analysis
- MARSSIM Module
- Geospatial Uncertainty Analysis
- Sampling Designs
- Custom Analysis
- Geospatial Interpolation
- Area of Concern Frameworks
- Human Health Risk Assessment
- Ecological Risk Assessment
- Cost Benefit Analysis
- Export to Arcview/Earthvision

SADA has been supported by both the DOE, EPA, and the NRC. SADA Version 3.0 had about 11000 downloads. Version 4.0/4.1 has had about 4000 since January, 2005.

Domestic and Foreign Collaboration/Interest

ClustrMaps for <http://www.tiem.utk.edu/~sada/>



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7896 visits since 11 Jan 2006, total visits 7890 since 11 Jan 2006, updated daily

⊞ distance in which individuals are clustered

Total number of visits depicted above = 7849

Dot sizes:

● = 1000 + ● = 100 - 999 ● = 10 - 99 ◆ = 1 - 9

The New SADA Look: Scaleable Interfacing

The image shows the SADA software interface with several components highlighted by callouts:

- Analysis Box**: Points to the top-left toolbar area.
- Data Type Box**: Points to the 'Soil' dropdown menu.
- Data Name Box**: Points to the 'Anthracene' dropdown menu.
- Labels Box**: Points to the '(None)' dropdown menu.
- Layers Box**: Points to the 'Z = 0' dropdown menu.
- Interviews**: Points to the 'Plot my data' button.
- Steps Window**: Points to the 'Steps' panel on the left, which contains a list of steps: 1. Choose your data, 2. Set vertical layers, 3. Set GIS layers, 4. Set polygons, 5. Show the results, 6. Import sampled data, 7. Format picture, 8. Auto-document, 9. Add to results gallery. It also has '<< Back' and 'Next >>' buttons, and a 'Show The Results' button.
- Parameters Window**: Points to the 'Data Query' panel, which includes options for 'Data Query' (All, Interval), 'Duplicate Data' (Use all values, Use only detected values, Use most recent value, Use most recent detected value), and 'Non Detects' (Use zero, Use half the detection limit, Use the full detection limit).
- Results Window**: Points to the 'Anthracene Sample Locations (Z = 0)' plot, which is a scatter plot showing sample locations with a color scale from 0.80 to 5.50.

The main window title is 'SADA (TempMy2dSADFile.sda)'. The menu bar includes File, Graphics, Setup, Reports, Statistics, Tools, and Help. The toolbar contains icons for file operations, plotting, and data management.

The New SADA Look

The image shows the SADA software interface with several components labeled:

- Analysis Box**: Points to the 'General' dropdown menu.
- Data Type Box**: Points to the 'Soil' dropdown menu.
- Data Name Box**: Points to the 'Anthracene' dropdown menu.
- Labels Box**: Points to the '(None)' dropdown menu.
- Layers Box**: Points to the 'Z = 0' dropdown menu.
- Interviews**: Points to the 'Plot my data' button.
- Steps Window**: A window on the left containing a list of steps: 1. Choose your data, 2. Set vertical layers, 3. Set GIS layers, 4. Set polygons, 5. Show the results, 6. Import sampled data, 7. Format picture, 8. Auto-document, 9. Add to results gallery. It includes '<< Back' and 'Next >>' buttons and a 'Show The Results' button.
- Parameters Window**: A central window titled 'Steps' containing the same list of steps as the Steps Window, but with a 'Show The Results' button at the bottom. It also includes '<< Back' and 'Next >>' buttons.
- Results Window**: A window on the right showing a scatter plot titled 'Sample Locations'. The x-axis is labeled 'Easting' with values 28,332.05, 28,767.40, and 29,202.7. The y-axis is a color scale ranging from 0.80 to 5.50.

Sample Laboratory Data

PROJECT NAME	PROJECT #	SAMPLE	SAMPLE ID	DATE COLL	DATE RECD	ANALYZED	TAI LAB #	ANALYTE	RESULT	PQL	UNITS	METHOD
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Aldrin	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	a-BHC	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	b-BHC	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	d-BHC	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	g-BHC, Lindane	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	4,4'-DDD	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	4,4'-DDE	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	4,4'-DDT	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Dieldrin	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endosulfan I	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endosulfan II	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endosulfan Sulfate	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endrin	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endrin Aldehyde	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Endrin Ketone	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Heptachlor	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Heptachlor Epoxide	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Methoxychlor	< 0.00010	0.0001	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	Toxaphene	< 0.00500	0.005	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	alpha-Chlordane	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/7/2002	02-A162603	gamma-Chlordane	< 0.00005	5E-05	mg/l	8081A
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1016	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1221	< 0.00100	0.001	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1232	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1242	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1248	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1254	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/6/2002	02-A162603	Aroclor 1260	< 0.00050	0.0005	mg/l	8082
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/5/2002	02-A162603	Arsenic	< 0.0050	0.005	mg/l	6010B
I-40/I-640 SINKHOLE	4969.013	BW/JO	HSSW1	10/1/2002	10/3/2002	10/5/2002	02-A162603	Barium	0.08	0.01	mg/l	6010B

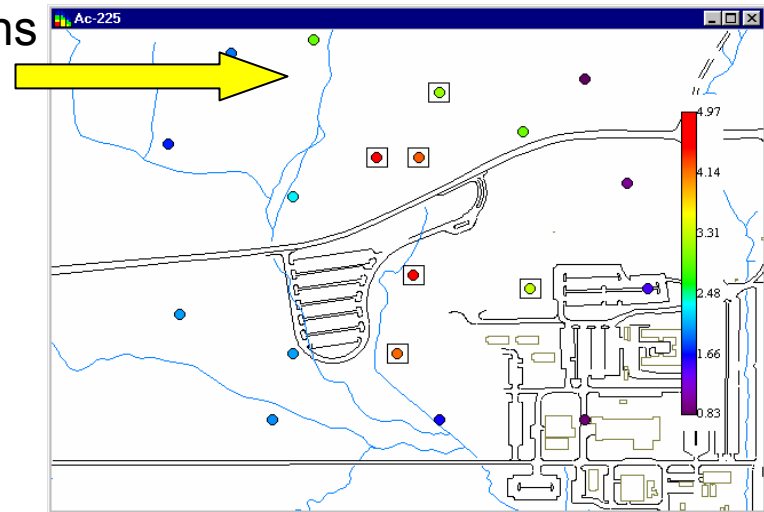
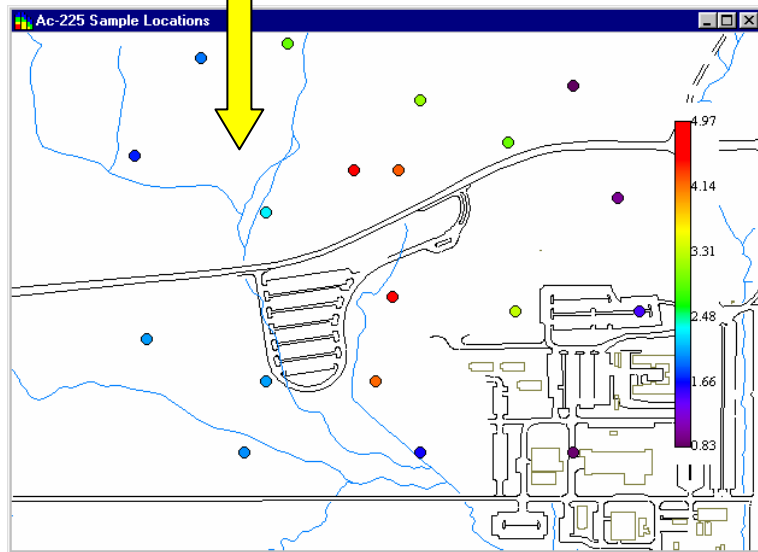
SADATM

Spatial Analysis and Decision Assistance

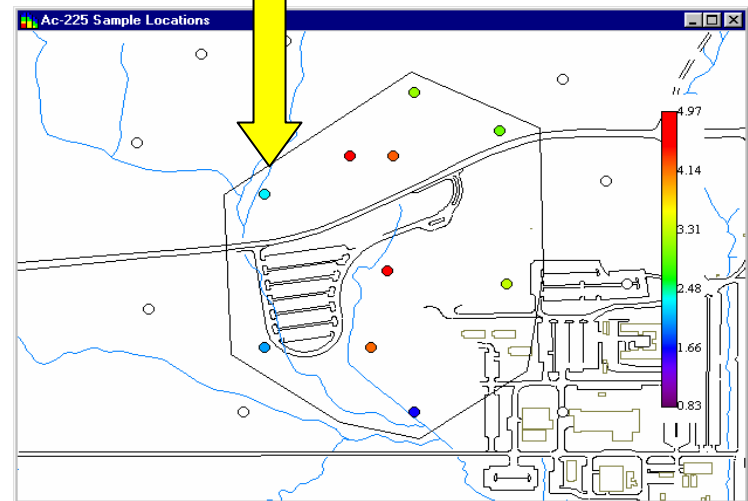
Data Exploration

Spatial Data Screens

Data Plot/GIS Overlays



Polygon Selection/Cutaways

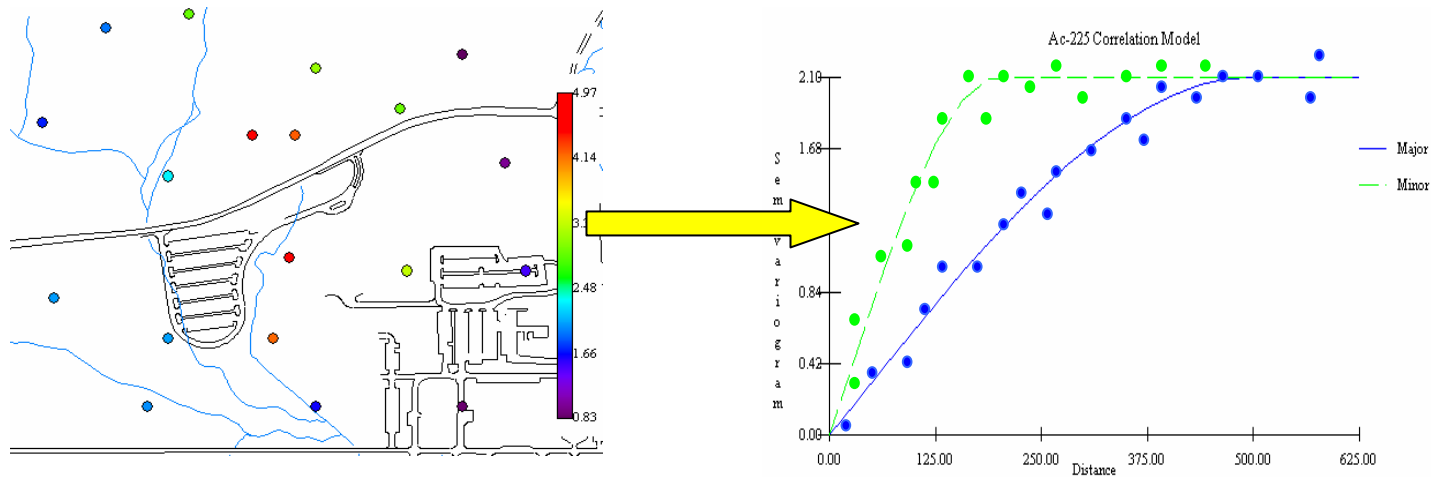


Statistics

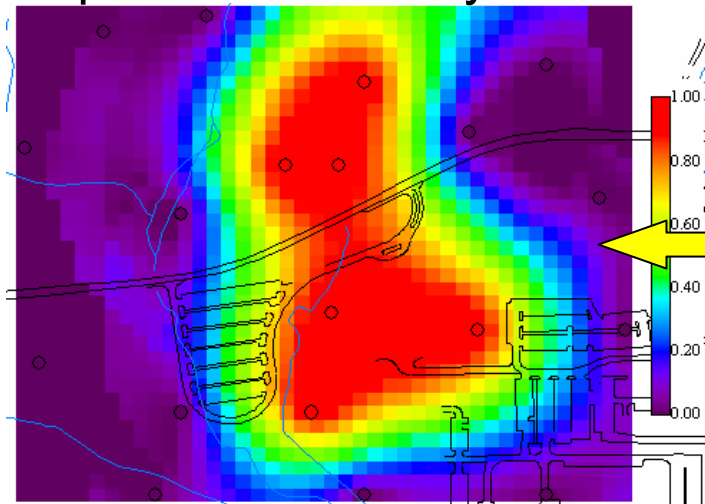
A window titled "Statistics" with a menu bar (Options, Format) and a toolbar. A yellow arrow points to the table below.

Name	CAS Number	Mean	Variance	Number of Data
Ac-225	14265851	3.4	1.3	10
Beryllium and compou	7440417	75.6	640.9	10
Arsenic, Inorganic	7440382	8.3	6.	10

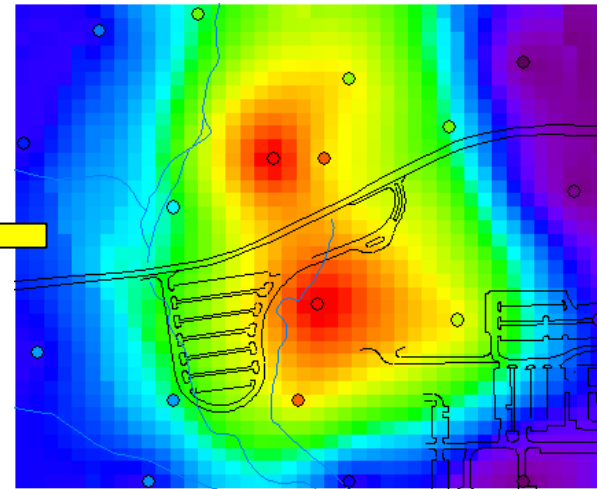
Spatial Analysis



Spatial Uncertainty



Spatial Estimation



Accounting for Local Uncertainty in Decision-making

Why do we model uncertainty?

Usually to make decisions such as:

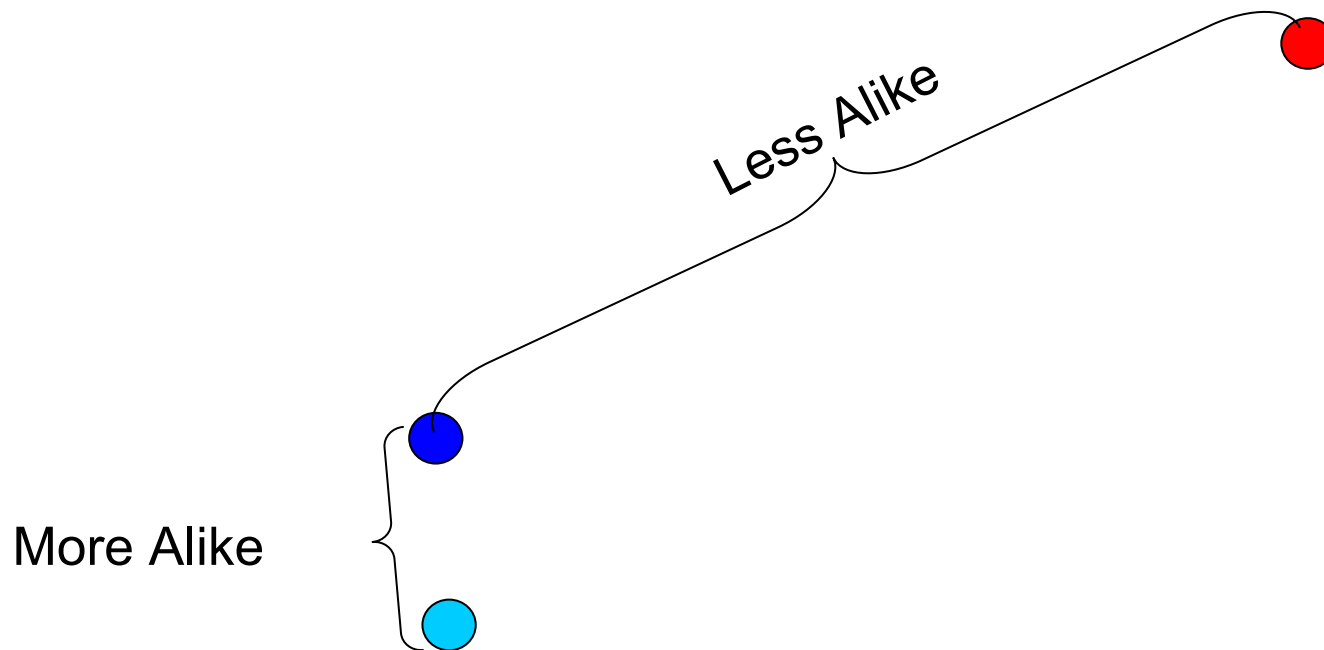
- Which remediation units should be cleaned
- Where should additional samples be collected

Criteria for cleaning of remediation units

1. Exceeding a probability threshold
2. Exceeding a physical threshold
3. Minimization of expected costs

Spatial Correlation

If data are spatially correlated, then on average, sample points that are close to each other are more alike than sample points further away. (More complex spatial correlations exist but this type is the most common).



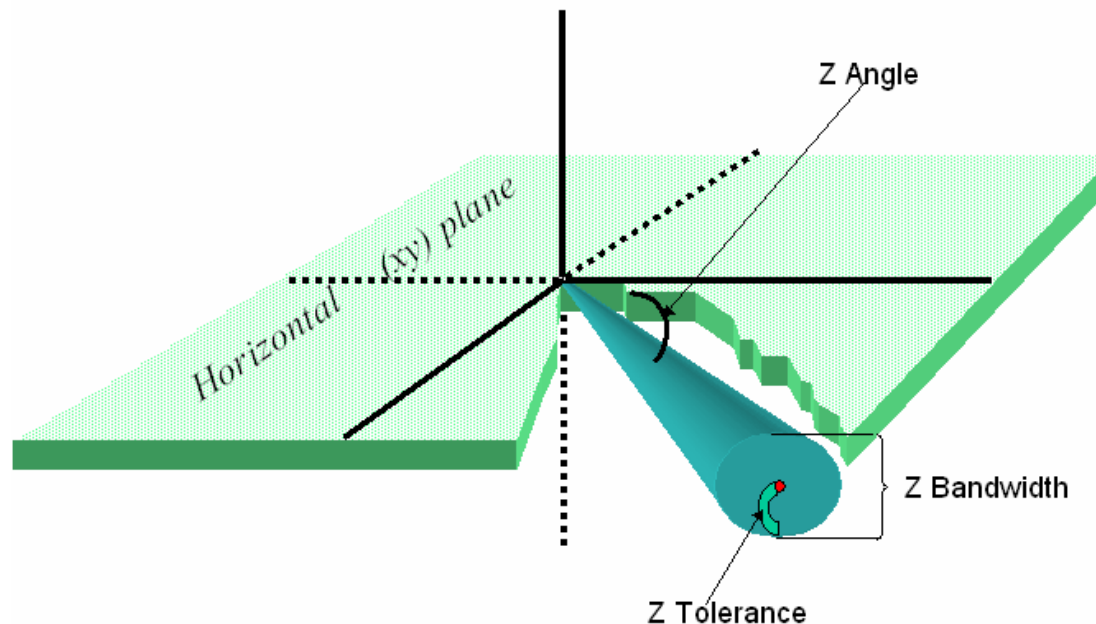
Three-Dimensional Variography

Three-dimensional semi-variogram calculation is the same approach as in the two-dimensional case. In addition to the previously defined parameters, a z angle (dip), z tolerance, and z bandwidth must be specified.

Z Angle (Dip) – The angle below the horizontal plane that the cone should dip.

Z Tolerance – The tolerance on this dip angle.

Z Bandwidth – The maximum distance the vertical component of the cone is permitted to go.

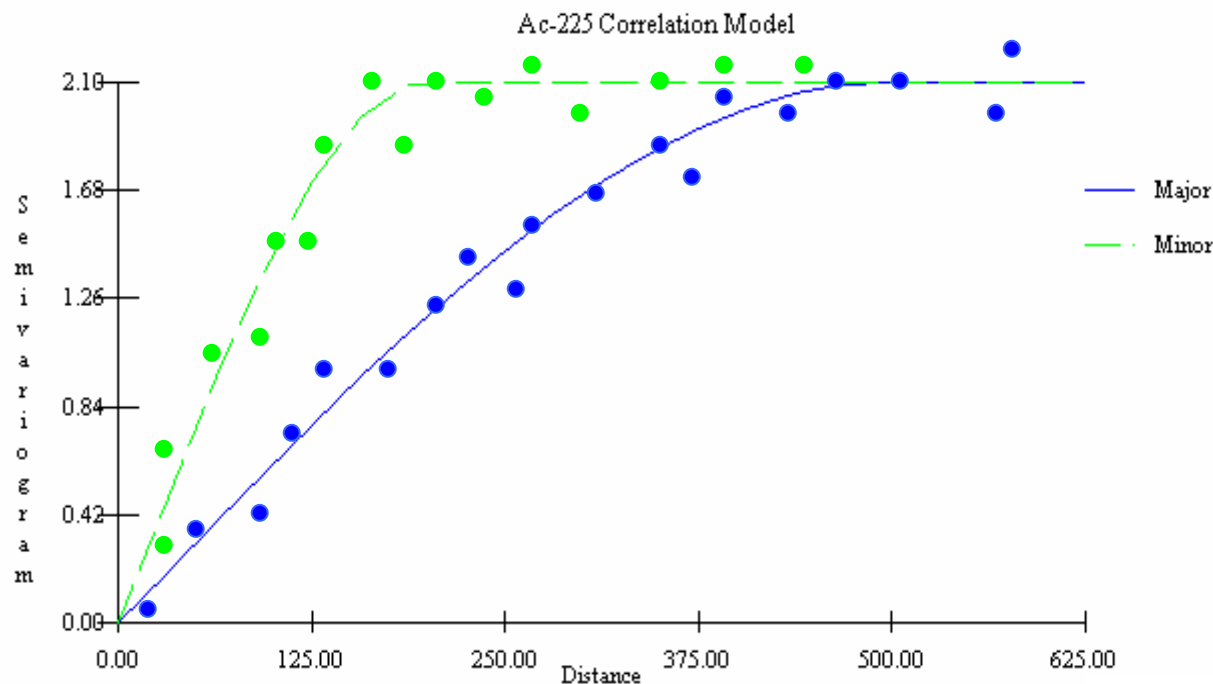


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Spatial Covariance

When the kriging models are used, they will require that the semi-variogram values are known for any distance h . At this point, we only have these values for a few discrete distances. Therefore, we need to fit a model to the data so that a semi-variogram value is available for every distance.

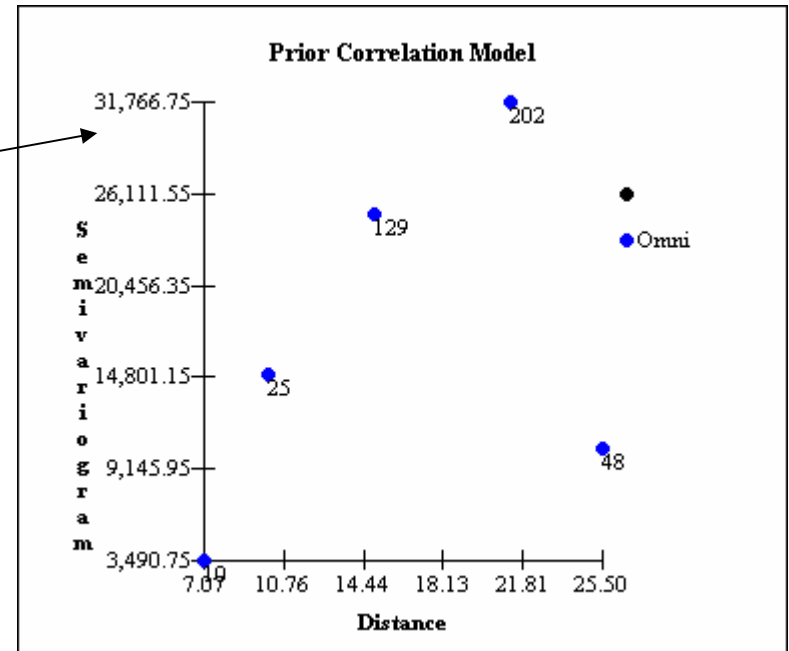
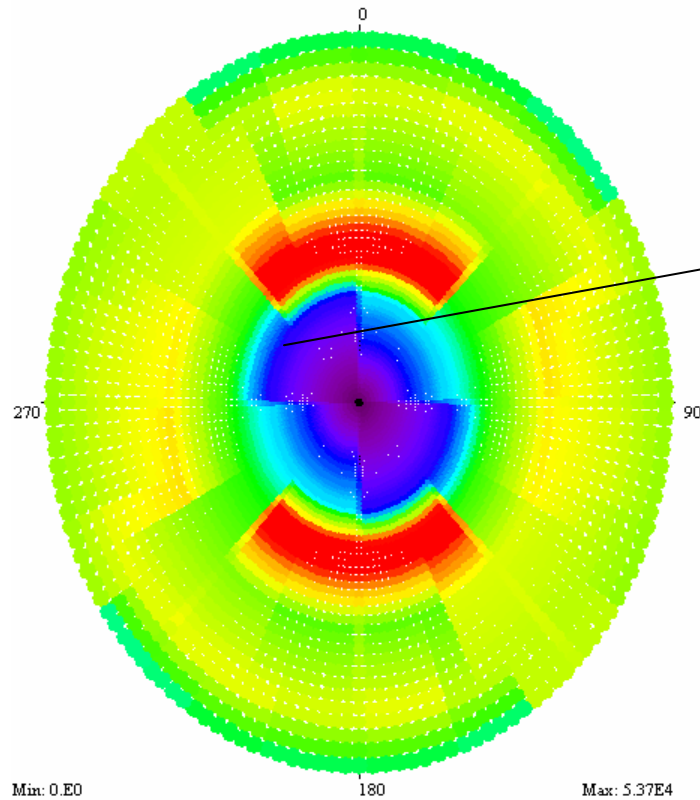


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Rose Diagrams

Rather than viewing only on angle at a time, users can view semivariogram values in all directions at once. They can then choose an angle of interest by clicking on the rose diagram map. SADA will show the semivariogram values for that direction.

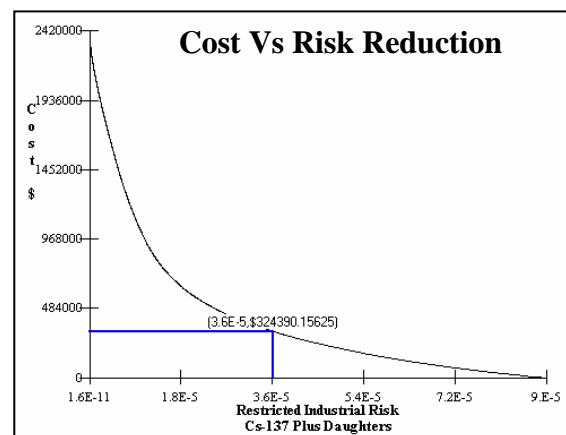
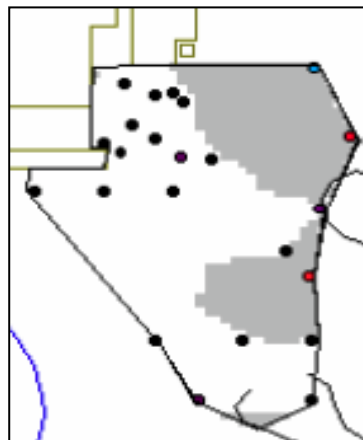
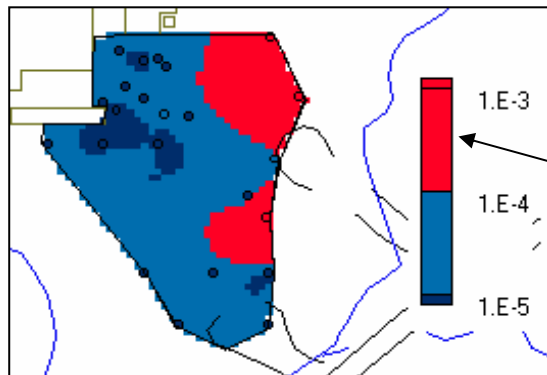
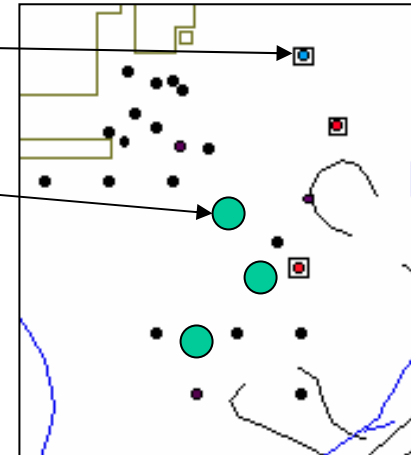


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Spatial Analysis and Decision Assistance

Decision Analysis

- Spatial Screens
- Sampling Strategies



- Spatial Risk
- Area of Concern
- Cost Benefit

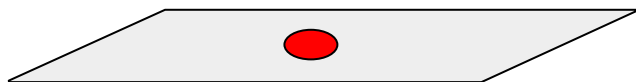
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Spatial Analysis and Decision Assistance

3 Types of Sample Designs: 2d, 3d, and 3d Core

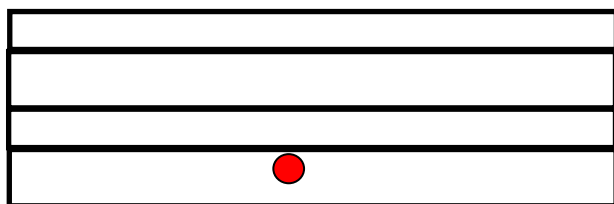
With all designs, SADA first identifies the location of the sample. Then, based on whether there are multiple layers and whether the user wishes to core, the following broad scenarios are possible for a single sample.

2d



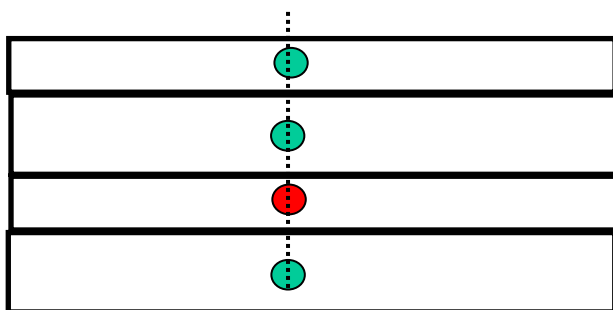
In a 2d application, the sample is placed on a single layer.

3d



In a 3d application, the sample is placed on a single layer at the depth required.

Core



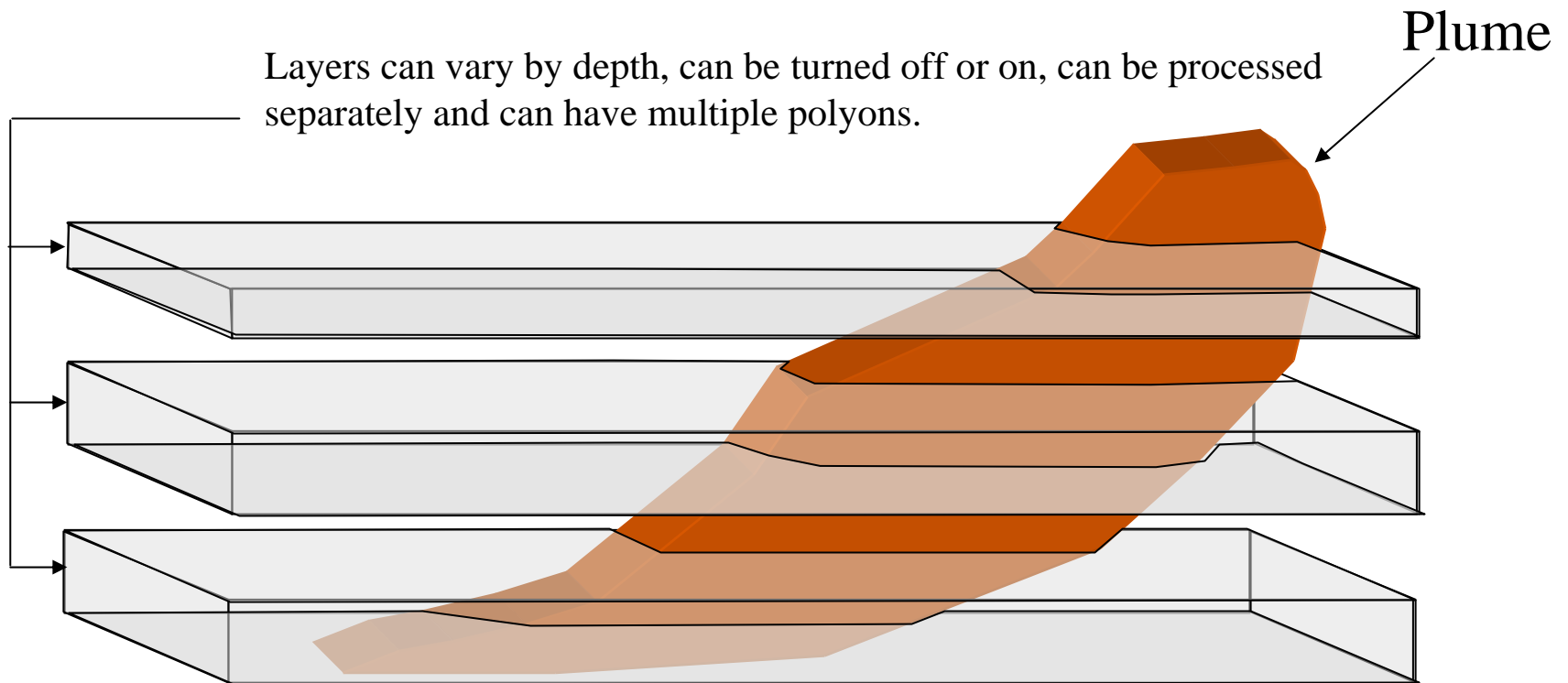
In a core application, the sample is placed on a single layer at the depth required. Then all layers above and below are also sampled subject to polygon definitions.

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3d Layering/Polygons

SADA is now equipped to draw multiple polygons, on multiple layers and invoke a cookie cutter approach vs layer by layer approach to establishing the subsurface design.

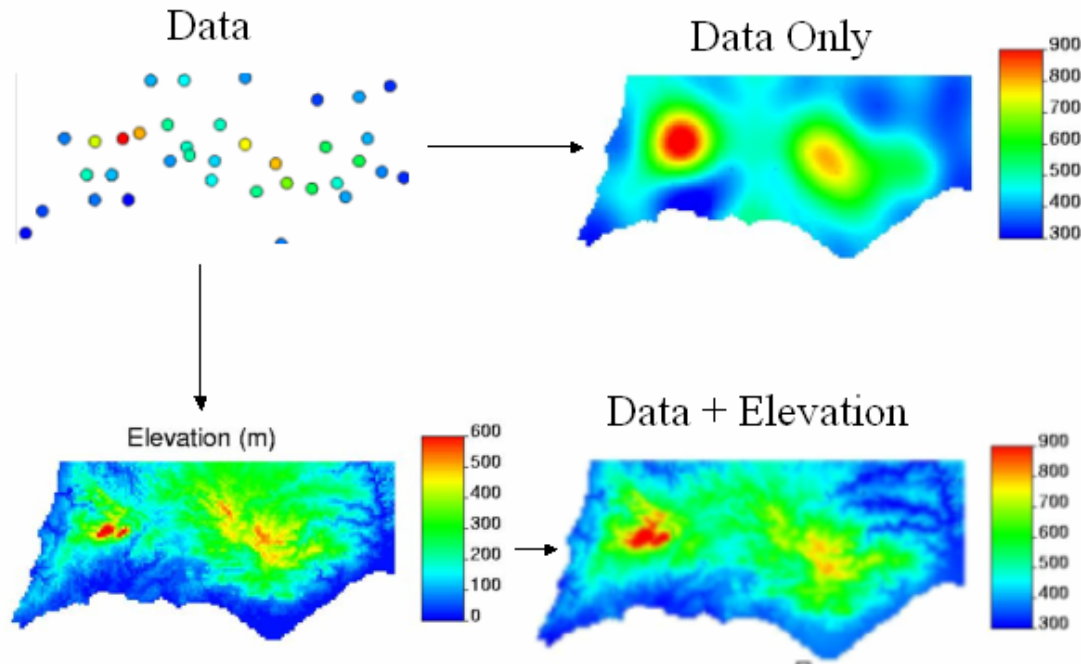


SADATM

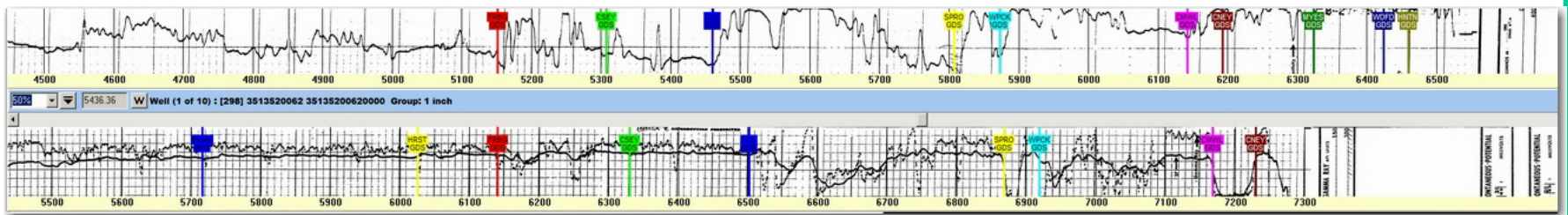
Spatial Analysis and Decision Assistance

Markov Bayes II

- Explicitly incorporates soft information such as core hole scans, ground penetrating radar, etc into the model
- Can produce more realistic heterogeneous results
- Can support investigations that have sparse data sets
- Source code is available for implementation in SADA



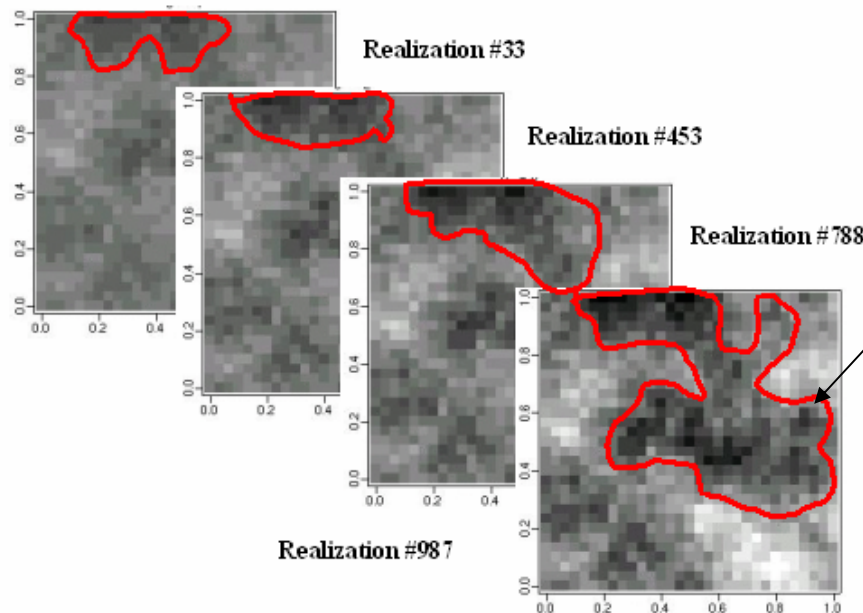
Well Logging Data





Geostatistical Simulation Cont

- Geostatistical simulation extends this idea by using the raw data values and spatial correlation structure to produce equiprobable realizations of what contamination could be given sample location and sample value.
- Simulations can then be used to predict probability of leaving behind a contiguous area of any shape or size
- One can perform a simple count of those realizations that have meet the conditions of elevated and contiguous zone and determine the probability of leaving such a zone behind.



Contiguous
contamination

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Spatial Analysis and Decision Assistance

Supporting tools: Incorporating Geophysical data

- In order to support such methods as bayesian ellipgrid and Markov Bayes, SADA needs to be able to import often dense forms of secondary information
- This information may come in the form of core hole scans, penetrating radar, stratigraphy, hydrostratigraphic units, hydraulic conductivity, porosity, seismic profiles.

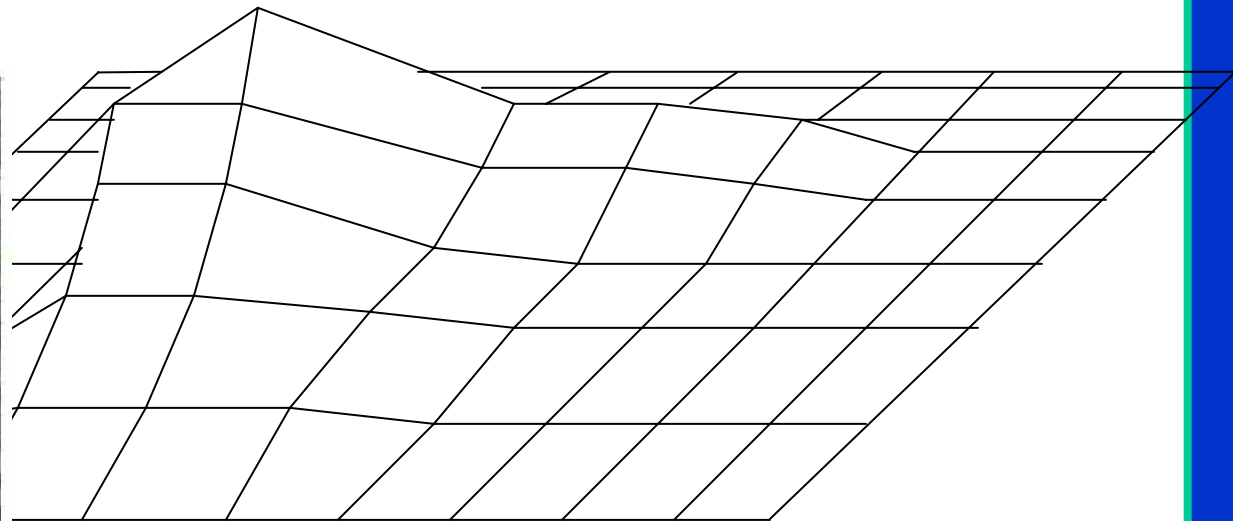
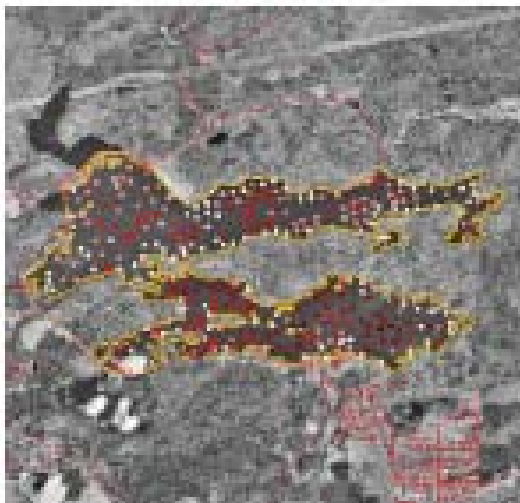


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Spatial Analysis and Decision Assistance

Elevation and Photo Draping

In the current version of SADA, elevation must be handled manually by users through a combination of layers and polygon tools. Since the release of 4.1, one method has been developed and is in an alpha state for incorporating elevation data directly into SADA and allowing SADA to shape layering systems according to elevation specifications. This work when finalized should solve the elevation problem.

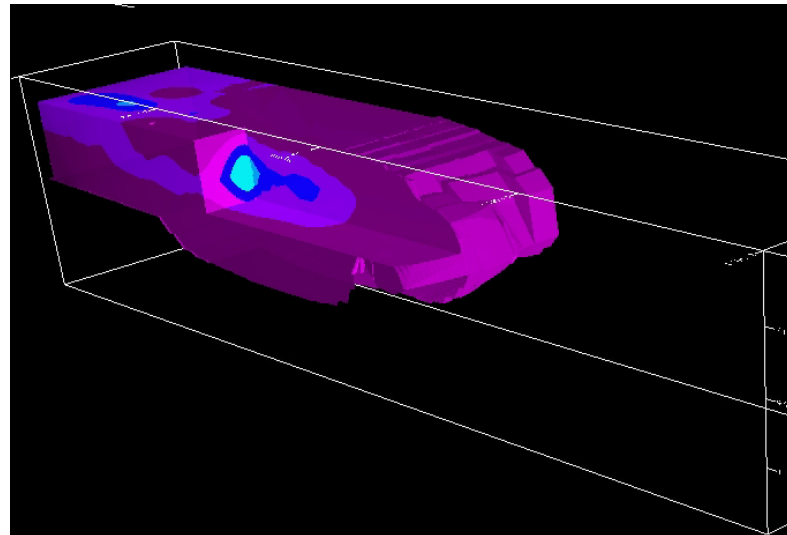
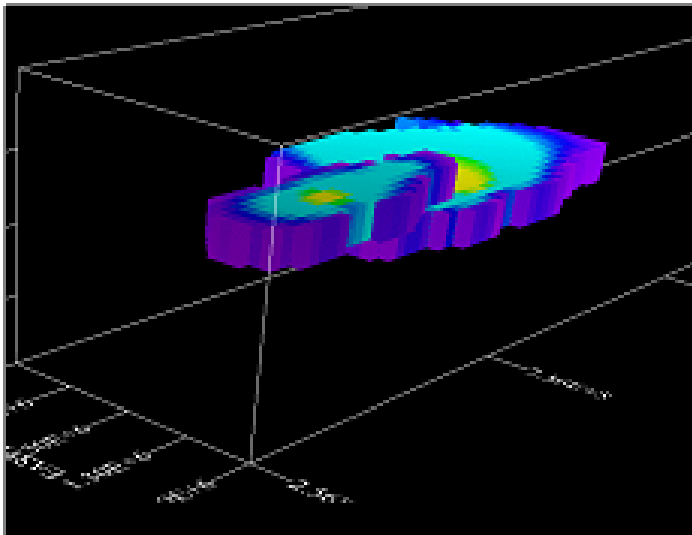
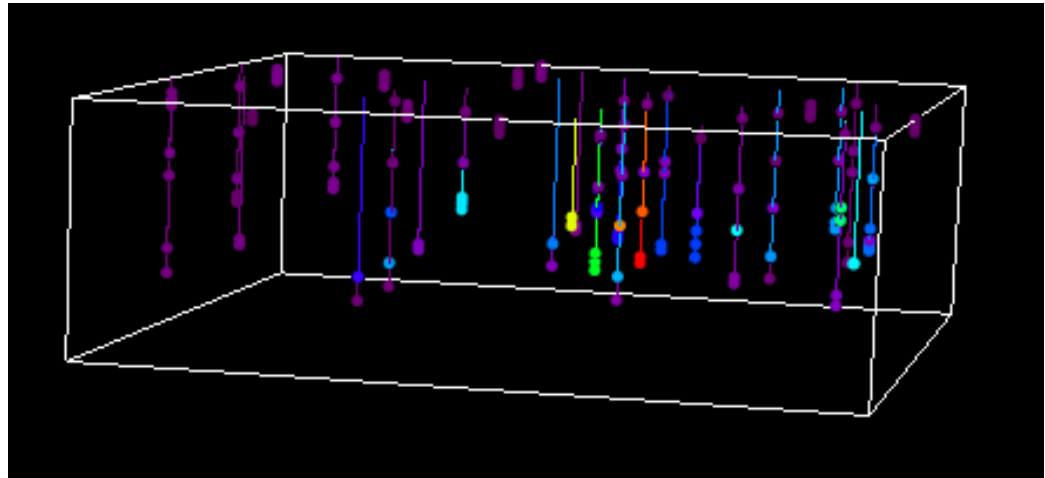


SADATM

Spatial Analysis and Decision Assistance

3D Visualization

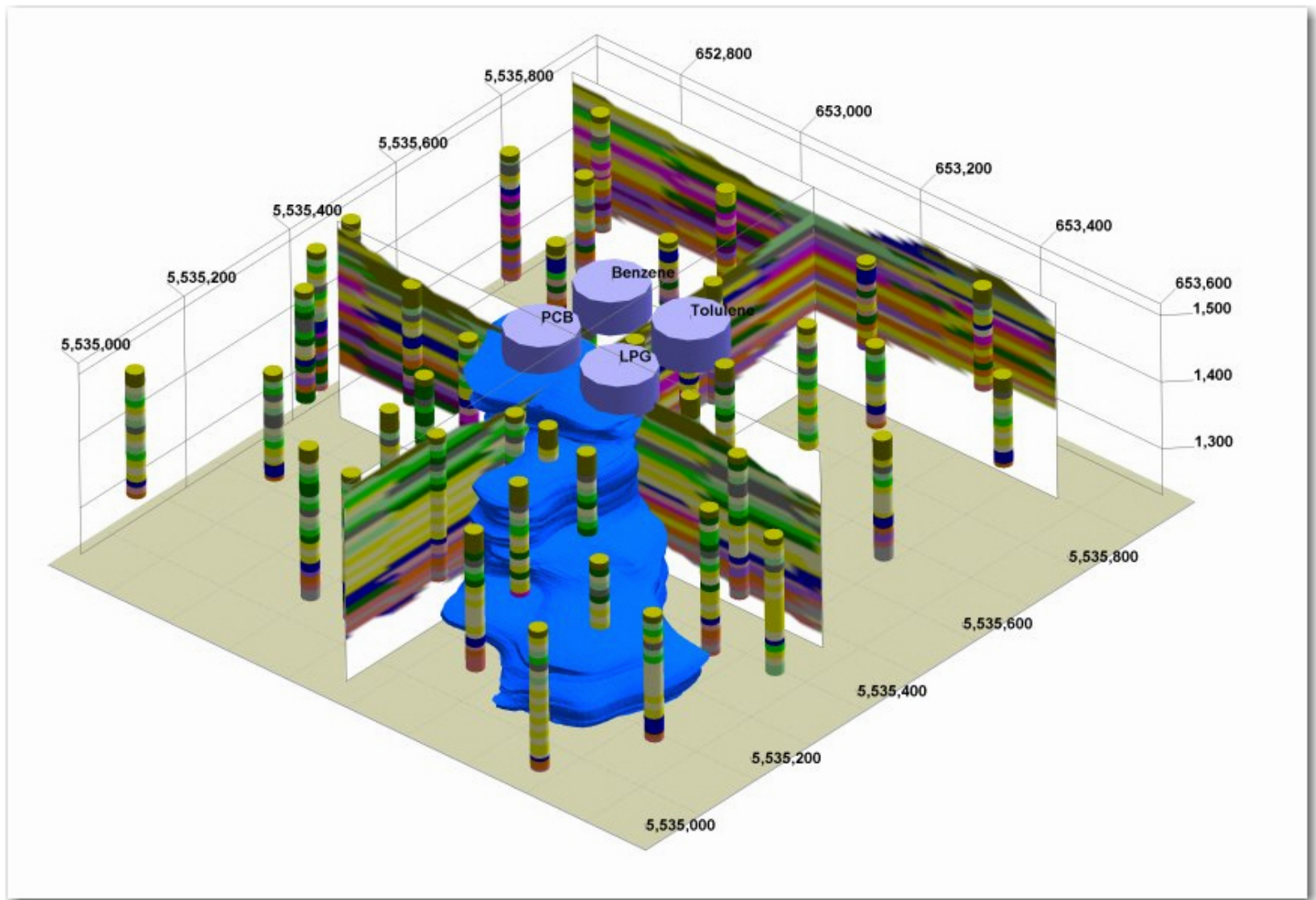
True 3d Views: Points,
Blocks, and Isosurfaces



SADATM

Spatial Analysis and Decision Assistance

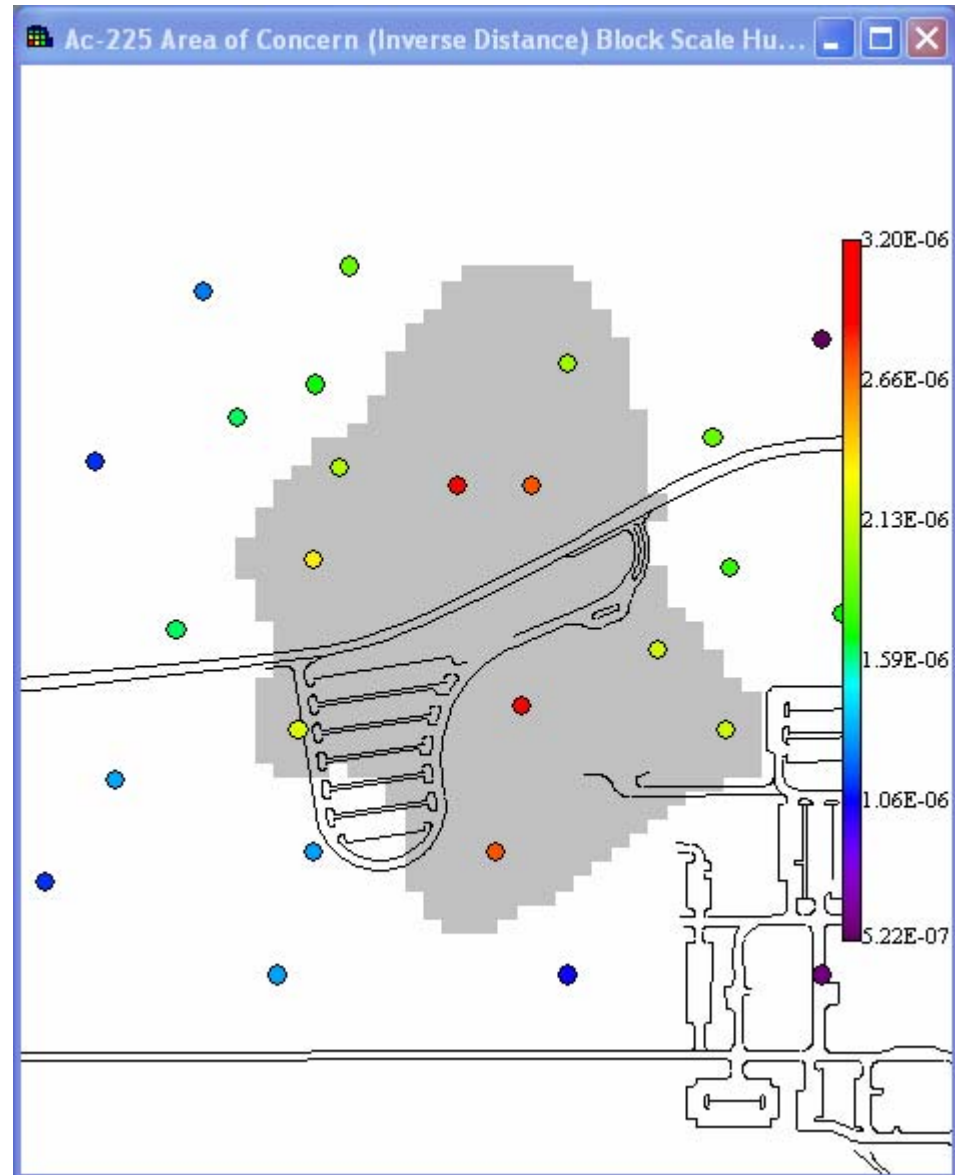
Radium Plume Display



* After ROCKWORKS

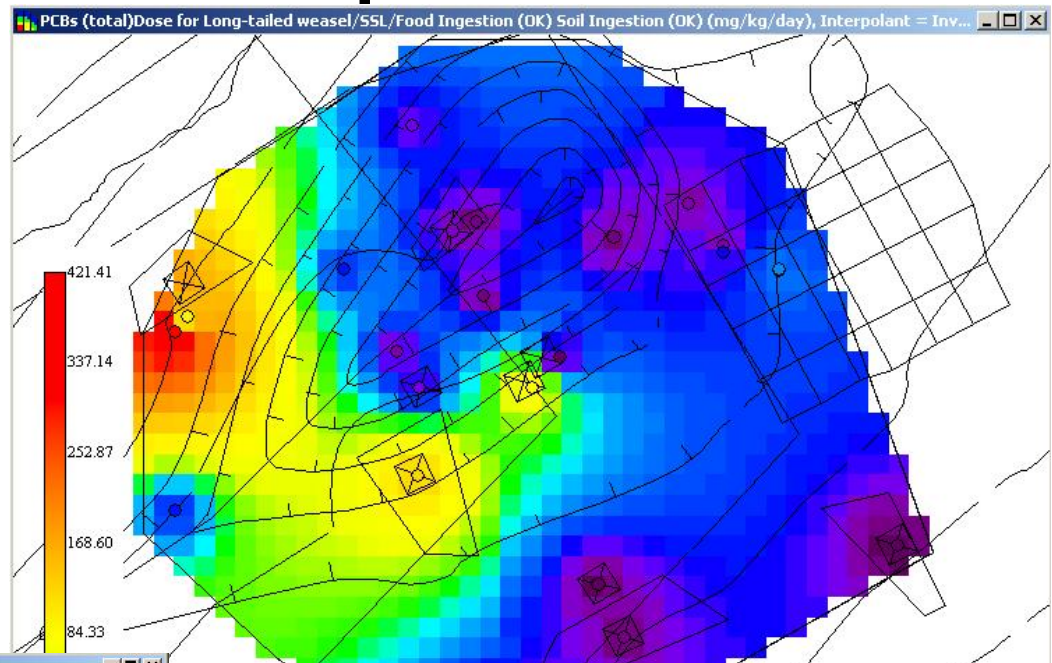
SADA Overview: Autodocumentation

- Area of concern map
- Based on HH Risk
- Utilized inverse distance as geospatial model
- Block based area of concern framework.



Ecological Dose Exposures


- SADA calculates dose (mg/kg BW d) from food ingestion, soil ingestion, dermal contact, and inhalation for terrestrial exposures
- SSL, Female, Male, or Juvenile
- Over 20 different species



Set Species-Specific Terrestrial Exposure Parameters

Select a species to view (and change if necessary) the default exposure parameters used in determining the daily contaminant dose received from exposure to soil.

Long-tailed weasel
Mustela frenata



Food Ingestion Parameters

Food ingestion rate: 0.1 kg dw / kg bw day

Fraction foliage: 0 0-1

Fraction seed: 0 0-1

Fraction invert: 0 0-1

Fraction mammal: 1 0-1

Mammalian Prey Diet

Fraction foliage: 0.485 0-1

Fraction seed: 0 0-1

Fraction invert: 0.485 0-1

Fraction soil: 0.029 0-1

Soil Ingestion Parameters

Soil ingestion: 0.039 fraction of food IR

Soil Inhalation Parameters

Inhalation Rate: 0.456 m³/day

Dermal Contact Parameters

Adherence Factor: 0.000001 kg/cm²

Surface area: 388 cm²

Physical Parameters

Body weight: 0.202 kg

Area usage factor: 1 fraction

Range:
Extending from just north of the United States-Canadian border through Central America to northern South America.

Save Changes Exit

Set Terrestrial Modeling Contaminant Parameters

PCBs (total)

Chemical Constants

Log Octanol/Water Partitioning Coefficient (Log Kow): 7.31 (mg/L)/(mg/L)

Inhalation

☒ Volatile ☐ Non-Volatile

Volatilization Factor (VF): m³/kg

Particulate Emission Factor (PEF): 1316239339 kg/m³

Soil -> Plant Concentration: Foliage

☐ Custom BAF (mg/kg)/(mg/kg)

☒ Kow-based BAF: 0.0313 (mg/kg)/(mg/kg)

☐ Tissue Regression

Log-linear slope

Log-linear intercept

Soil -> Plant Concentration: Seed

☐ Custom BAF (mg/kg)/(mg/kg)

☒ Kow-based BAF: 0.0313 (mg/kg)/(mg/kg)

☐ Tissue Regression

Log-linear slope

Log-linear intercept

Dermal Contact

Absorption Fraction: 0.06 mg/mg

Soil -> Invertebrate Concentration

☐ Custom BAF (mg/kg)/(mg/kg)

☒ Kow-based BAF: 33.4187 (mg/kg)/(mg/kg)

☐ Tissue Regression

Log-linear slope

Log-linear intercept

Soil -> Small Mammal Concentration

☐ Custom BAF (mg/kg)/(mg/kg)

☐ Tissue Regression

Log-linear slope

Log-linear intercept

Diet -> Small Mammal Concentration

☒ Custom BAF: 2.63 (mg/kg)/(mg/kg)

☐ Tissue Regression

Log-linear slope

Log-linear intercept

Save Changes Exit