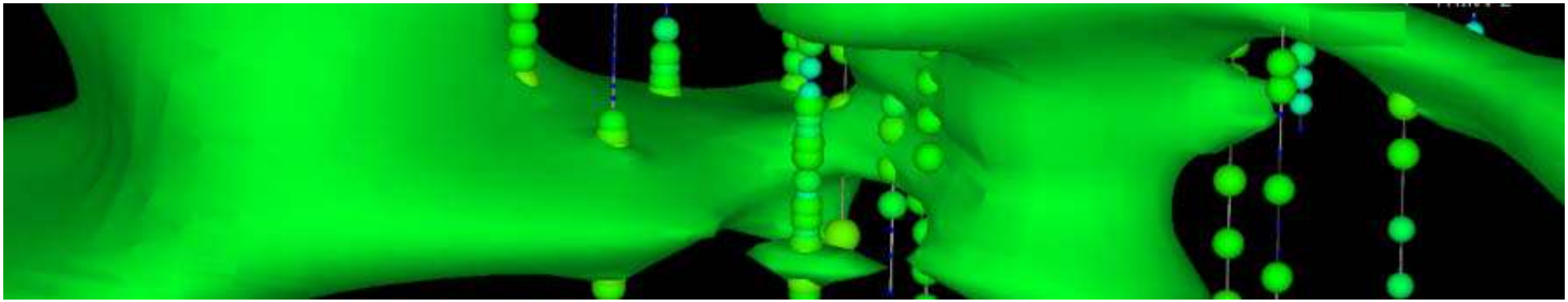


3D MODELLING OF CONTAMINATED SITES

MIDWEST AIR AND WASTE MANAGEMENT CONFERENCE

FEBRUARY 24, 2016

RAMBOLL

3D MODELLING FOR CONTAMINATED SITES
KERRY STONESTREET

Ramboll Environ will present concepts to consider during subsurface characterization and remediation of contaminated sites with an emphasis on 3D (spatial) and 4D (spatiotemporal) data visualizations. Once considered only for big budget projects (e.g., litigation), sophisticated data visualizations have become more accessible, cost effective and integral to efficient site remediation. Key topics presented will include data management, High Resolution Site Characterization (HRSC) and Conceptual Site Models (CSM).

- Data
- Characterization and Remediation Concepts
- Decision Support Tools
- Case Studies and Workflows
- Conclusion

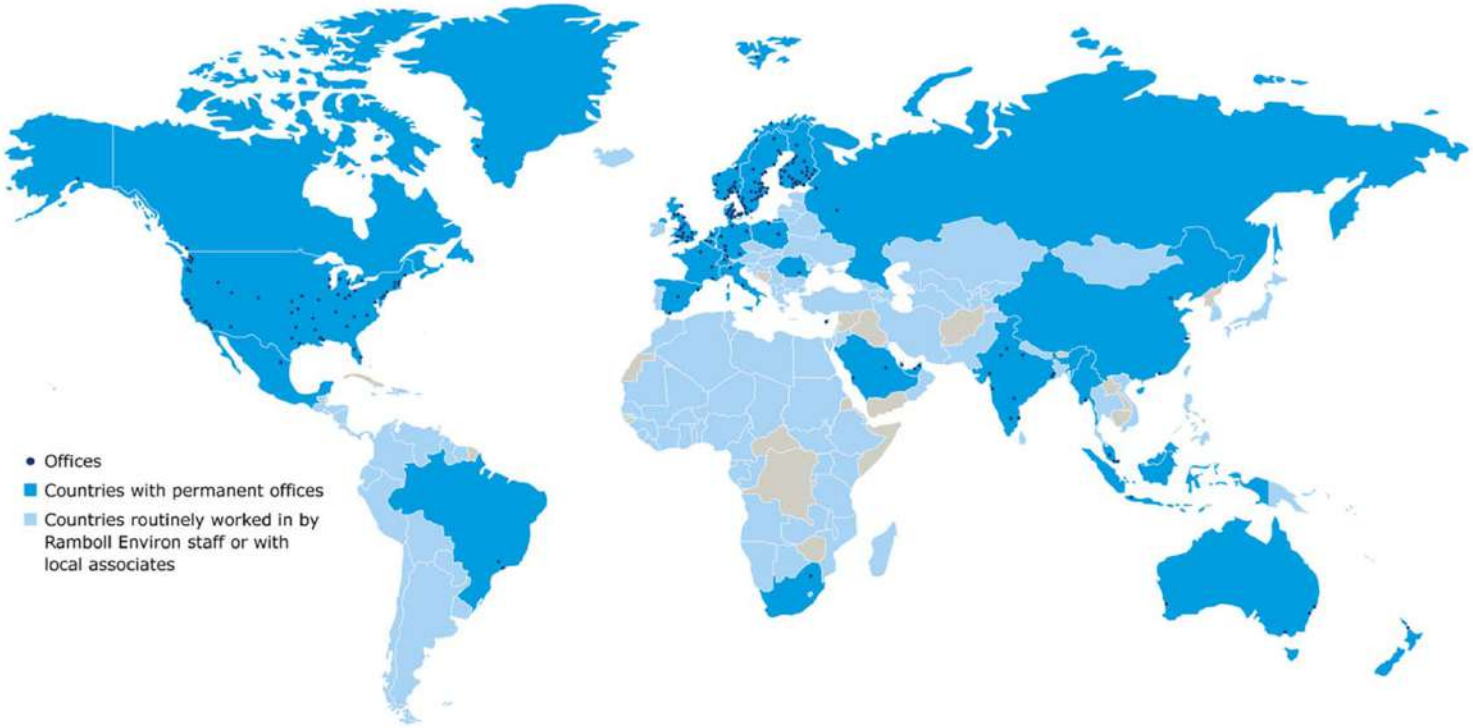
RAMBOLL

SCIENCE-FIRST CONSULTING

A premier global consultancy, Ramboll Environ is trusted by clients to manage their most challenging environmental, health and social issues.

We have earned a reputation for technical and scientific excellence, innovation and client service. Our independent science-first approach ensures that our strategic advice is objective and defensible. We apply integrated multidisciplinary services and tailor each solution to our client's specific needs and challenges.

GLOBAL PRESENCE AND EXPERIENCE



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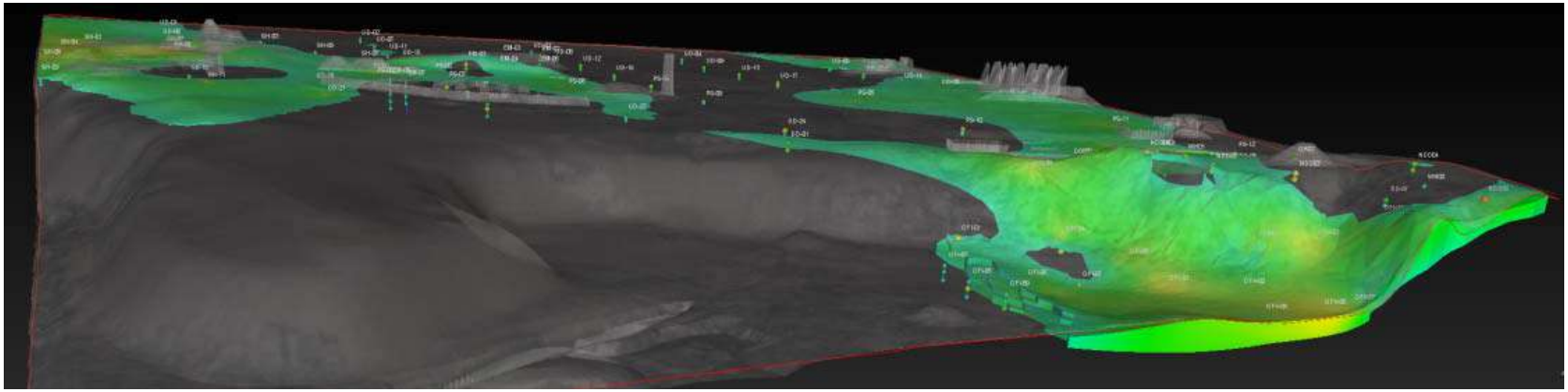
INTRODUCTION

What are three-dimensional data-based models?
What are four-dimensional data-based models?
Why are they useful?
When should they be used?
What is required?



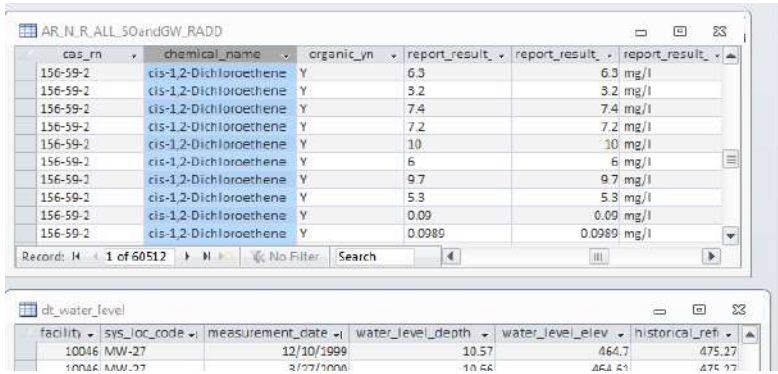
Data

Characterization and Remediation Concepts

Decision Support Tools

Case Studies and Workflows

Conclusion



AR_N_R_ALL_SOandGW_RADD

cas_rn	chemical_name	organic_yn	report_result_	report_result_	report_result_
156-59-2	cis-1,2-Dichloroethene	Y	6.3	6.3	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	3.2	3.2	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	7.4	7.4	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	7.2	7.2	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	10	10	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	6	6	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	9.7	9.7	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	5.3	5.3	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	0.09	0.09	mg/l
156-59-2	cis-1,2-Dichloroethene	Y	0.0989	0.0989	mg/l

Record: 1 of 60512 No Filter Search

dt_water_level

facility	sys_loc_code	measurement_date	water_level_depth	water_level_elev	historical_ref
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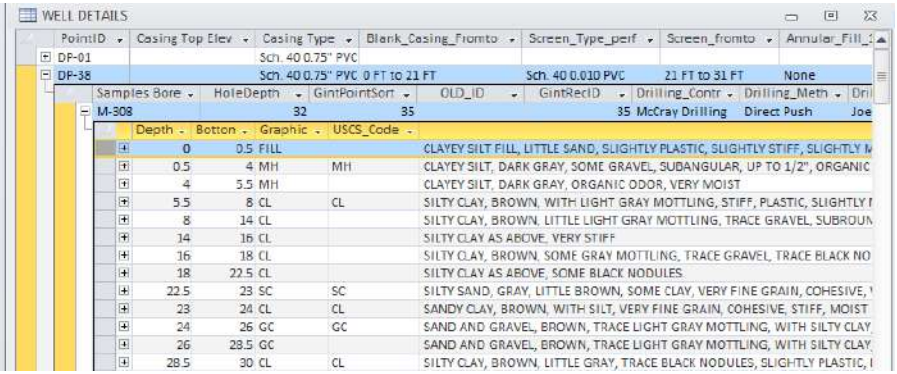
10046	MW-27	3/27/2000	10.66	464.51	475.27



WELL DETAILS

PointID	Casing Top Elev	Casing Type	Blank_Casing_Fromto	Screen_Type_perf	Screen_fromto	Annular_Fill_1
DP-01		Sch. 40 0.75" PVC				
DP-38		Sch. 40 0.75" PVC	0 FT to 21 FT	Sch. 40 0.010 PVC	21 FT to 31 FT	None

Samples Bore	HoleDepth	GintPointSort	OLD_ID	GintRecID	Drilling_Contr	Drilling_Meth	Dri
M-308	32	35		35	McCray Drilling	Direct Push	Joe

Depth	Botton	Graphic	USCS_Code	
0	0.5	FILL		CLAYEY SILT FILL, LITTLE SAND, SLIGHTLY PLASTIC, SLIGHTLY STIFF, SLIGHTLY M
0.5	4	MH	MH	CLAYEY SILT, DARK GRAY, SOME GRAVEL, SUBANGULAR, UP TO 1/2", ORGANIC
4	5.5	MH		CLAYEY SILT, DARK GRAY, ORGANIC ODOR, VERY MOIST
5.5	8	CL	CL	SILTY CLAY, BROWN, WITH LIGHT GRAY MOTTLING, STIFF, PLASTIC, SLIGHTLY I
8	14	CL		SILTY CLAY, BROWN, LITTLE LIGHT GRAY MOTTLING, TRACE GRAVEL, SUBROUN
14	16	CL		SILTY CLAY AS ABOVE, VERY STIFF
16	18	CL		SILTY CLAY, BROWN, SOME GRAY MOTTLING, TRACE GRAVEL, TRACE BLACK NO
18	22.5	CL		SILTY CLAY AS ABOVE, SOME BLACK NODULES
22.5	23	SC	SC	SILTY SAND, GRAY, LITTLE BROWN, SOME CLAY, VERY FINE GRAIN, COHESIVE,
23	24	CL	CL	SANDY CLAY, BROWN, WITH SILT, VERY FINE GRAIN, COHESIVE, STIFF, MOIST
24	26	GC	GC	SAND AND GRAVEL, BROWN, TRACE LIGHT GRAY MOTTLING, WITH SILTY CLAY,
26	28.5	GC		SAND AND GRAVEL, BROWN, TRACE LIGHT GRAY MOTTLING, WITH SILTY CLAY,
28.5	30	CL	CL	SILTY CLAY, BROWN, LITTLE GRAY, TRACE BLACK NODULES, SLIGHTLY PLASTIC, I

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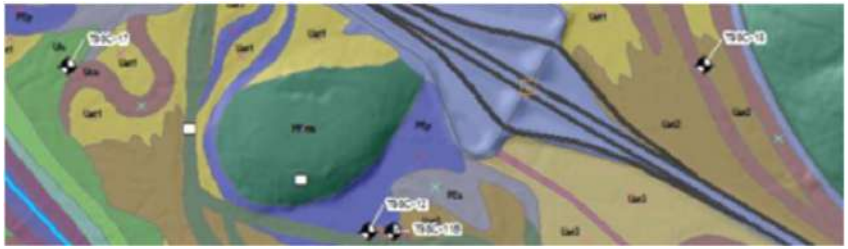
Data – Federal Sources



USGS EarthExplorer | EPA | US Army Corps of Engineers | USDA | USGS science for a changing world | FEMA

Data – State & Local Sources

DASC STATE OF KANSAS GIS DATA ACCESS & SUPPORT CENTER
Your resource for geospatial data from the State of Kansas

Missouri Spatial Data Information Service
Committed to the wise sharing & use of digital spatial information and tabular data sets.
MSDIS Making Missouri Available Digitally

MISSOURI DEPARTMENT OF NATURAL RESOURCES

DEQ OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Kansas Department of Health and Environment

OKLAHOMA GEOLOGICAL SURVEY 1908

KU KANSAS GEOLOGICAL SURVEY The University of Kansas

Missouri Geological Survey

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Data - Historical Sources

Previous Site Reports

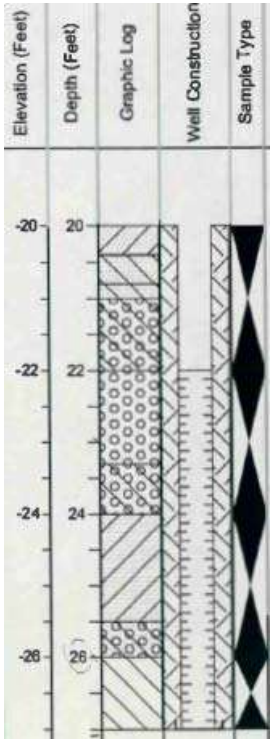
Figures

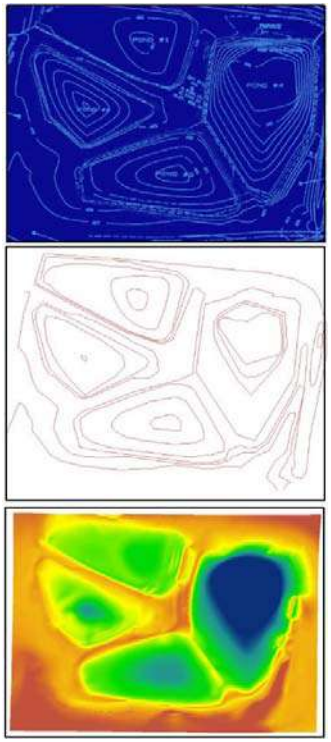
Tables

Boring Logs

TABLE 1
GROUNDWATER DEPTHS AND ELEVATIONS
OCTOBER 18, 1989

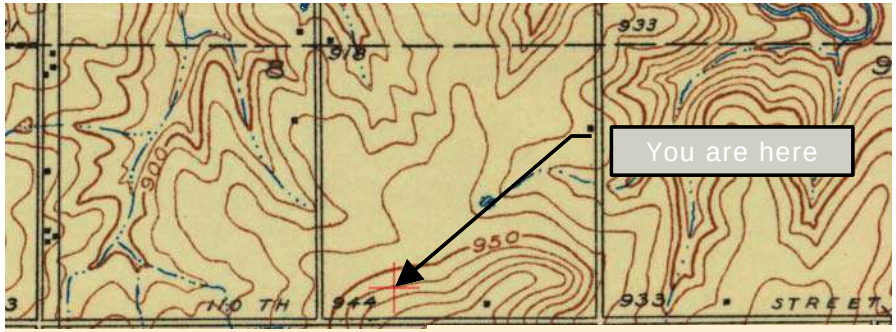
LOC	CASING ELEVATION	WATER DEPTH	WATER ELEVATION	TIME
MW-1	12.04	2.71	6.33	1007
MW-2	12.30	2.75	6.55	1011



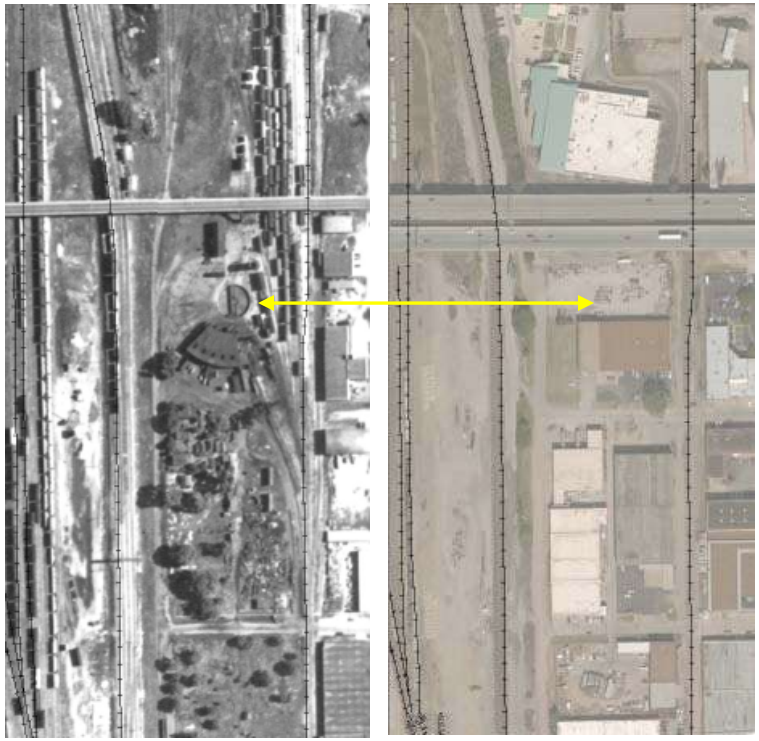


Data - Historical Sources

Historic Aerial Photography,
USGS Historical Topographic,
Sanborn, BLM, RR Valuation Maps



1935 USGS 24k Lenexa Quadrangle http://historicalmaps.arcgis.com/usgs/



1950 2010

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Data – Site Contemporary

Contractors: Laboratory (EDDs), Surveyor, Geophysical, MIP
Field Collected: DGPS, Boring Logs, real-time sensors

AR_N_R_ALL_SOandGW_RADD

cas_rn	chemical_name	organic_yn	report_result_
156-59-2	cis-1,2-Dichloroethene	Y	6.3
156-59-2	cis-1,2-Dichloroethene	Y	3.2
156-59-2	cis-1,2-Dichloroethene	Y	7.4
156-59-2	cis-1,2-Dichloroethene	Y	7.2
156-59-2	cis-1,2-Dichloroethene	Y	10
156-59-2	cis-1,2-Dichloroethene	Y	6
156-59-2	cis-1,2-Dichloroethene	Y	9.7
156-59-2	cis-1,2-Dichloroethene	Y	5.3
156-59-2	cis-1,2-Dichloroethene	Y	0.09
156-59-2	cis-1,2-Dichloroethene	Y	0.0989

Record: 1 of 60512 No Filter Search

dt_water_level

facility	sys_loc_code	measurement_date	water_level_depth
10046	MW-27	12/10/1999	10.57
10046	MW-27	3/27/2000	10.66
10046	MW-27	9/18/2000	10.25
10046	MW-27	3/26/2001	10.89
10046	MW-27	9/10/2001	10.56
10046	MW-27	2/18/2002	11.28

Record: 5 of 1084 No Filter Search

dt_coordinate

sys_loc_code	coord_t	observation_date	identifier	x_coord
MW-172	NAD83SP_	10/28/2014	PRIMARY	590858.18
MW-173	NAD83SP_	1/23/2015	PRIMARY	591972.97
MW-174	NAD83SP_	1/23/2015	PRIMARY	591975.59
MW-175	NAD83SP_	1/23/2015	PRIMARY	591602.58
MW-176	NAD83SP_	1/23/2015	PRIMARY	591473.47
MW-177	NAD83SP_	1/23/2015	PRIMARY	591147.72
MW-178	NAD83SP_	1/23/2015	PRIMARY	590972.63

Record: 391 of 516 Unfiltered Search

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Data Requirements

Spatial PLUS Temporal Attributes

Spatiotemporal Coordinates = XYZ + Time

Metadata

Data Quality

Data Objectives

dt_water_level

facility	sys_loc_code	measurement_date	water_level_depth	water_level_elev	historical_ref
10046	MW-27	12/10/1999	10.57	464.7	475.27
10046	MW-27	3/27/2000	10.66	464.61	475.27
10046	MW-27	9/18/2000	10.25	465.02	475.27
10046	MW-27	3/26/2001	10.89	464.38	475.27
10046	MW-27	9/10/2001	10.56	464.71	475.27
10046	MW-27	2/18/2002	11.28	463.99	475.27

Record: 5 of 1084 No Filter Search

dt_coordinate

sys_loc_code	coord_t	observation_date	identifier	x_coord	y_coord	ele	elev_unit	elev_datum	horz_c
MW-172	NAD83SP_	10/28/2014	PRIMARY	590858.18	369001.88	472.94	ft amsl	NAVD88	G3
MW-173	NAD83SP_	1/23/2015	PRIMARY	591972.978	369622.996	463.56	ft amsl	NAVD88	G3
MW-174	NAD83SP_	1/23/2015	PRIMARY	591975.593	369643.789	463.45	ft amsl	NAVD88	G3
MW-175	NAD83SP_	1/23/2015	PRIMARY	591602.587	369654.939	464.16	ft amsl	NAVD88	G3
MW-176	NAD83SP_	1/23/2015	PRIMARY	591473.471	369675.04	465.24	ft amsl	NAVD88	G3
MW-177	NAD83SP_	1/23/2015	PRIMARY	591147.725	369697.948	471.49	ft amsl	NAVD88	G3
MW-178	NAD83SP_	1/23/2015	PRIMARY	590972.637	369231.682	475.40	ft amsl	NAVD88	G3

Record: 391 of 516 Unfiltered Search

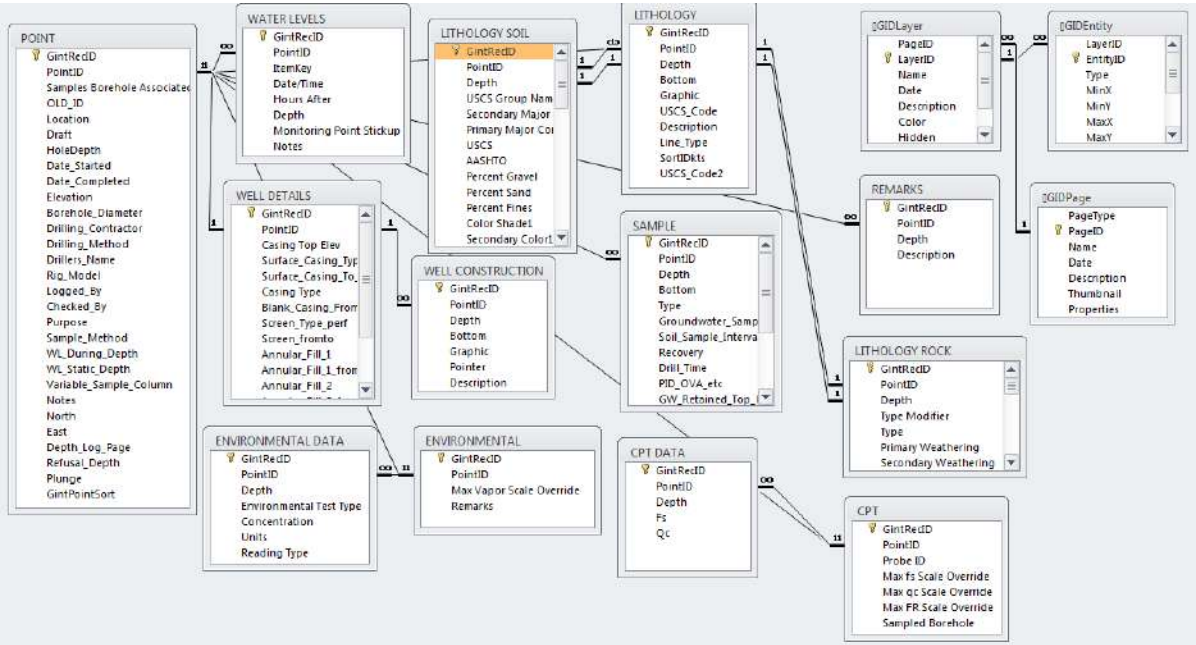
Data Management - RDBMS – Relational Database Management System

Environmental geology and analytical chemistry data management system.

Relational database that use reference tables (i.e., lookup tables) and data inputs.

Analytical data
Field data (e.g., sample depths, coordinates, soil descriptions)
Third party data (e.g., regulatory criteria)

DATA INTEGRITY



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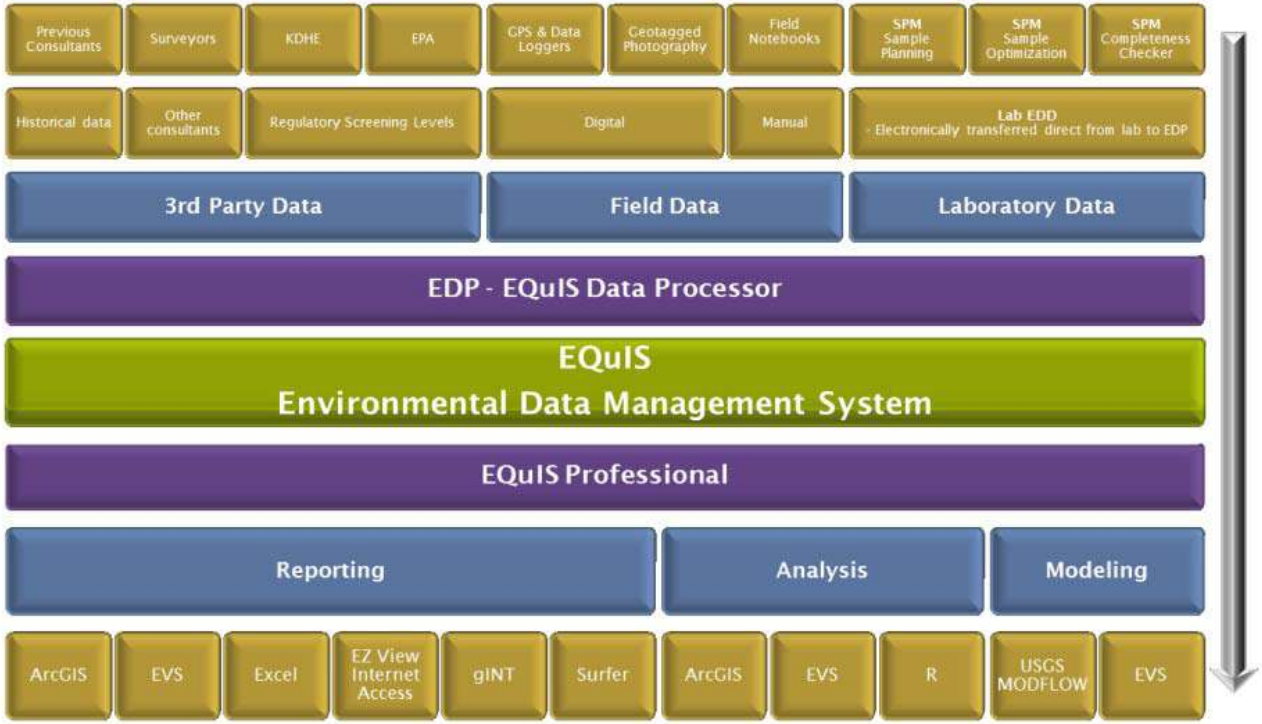
Data Management

Data Flow Diagram



Data Summary

Sources and Types

- Geospatial and Tabular
- Regional, State and Local Scale

Historical and Contemporary

- Quantity and Quality
- Level of Effort

Data Management

- Attribution and Documentation
- Data Integrity

Data

Characterization and Remediation Concepts

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CSM – Conceptual Site Model

"The Conceptual Site Model (CSM) is an iterative, 'living representation' of a site that summarizes and helps project teams visualize and understand available information."
EPA 2011 - Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model

Six Stages of the Project Life Cycle CSM

Development

Preliminary – Synthesis of existing/historic data.
Baseline – Identify data gaps and uncertainties.

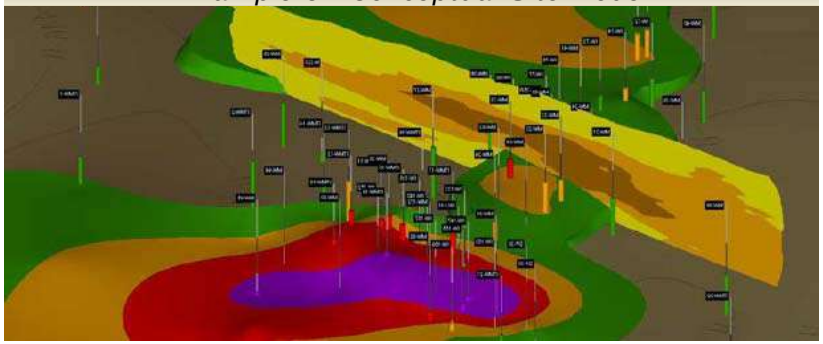
Evolution and Refinement

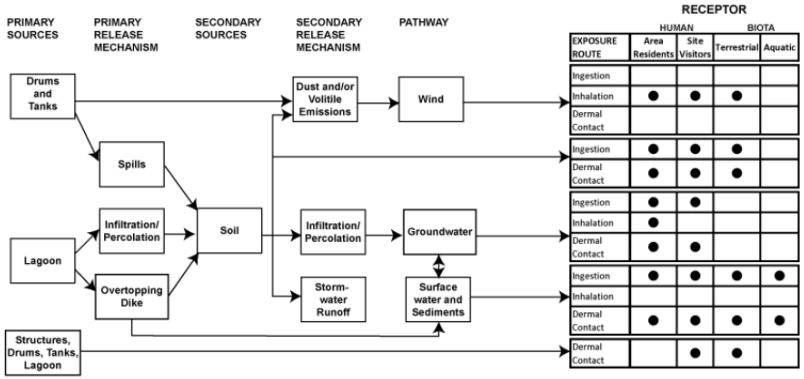
Characterization – Incorporate new data. Reduce spatial uncertainty and close data gaps.
Design –Technology and remedy decision making.
Remediation / Mitigation – Supports remedy implementation and optimization efforts.
Post Remedy – Mature CSM supports reuse planning; documents institutional controls.

Components of a CSM

- Maximize use of available site data.
- May incorporate 2D/3D visualizations and network diagrams.
- Identification of source areas, contaminant pathways, fate and transport.
- Evaluation of ecological and human health risks and exposure pathways.
- Project planning and management tool
- Communication tool
- Iterative, becomes increasingly quantitative and decreasingly conceptual.

Example 3D Conceptual Site Model





Example Pathway Receptor Network Diagram

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HRSC – High Resolution Site Characterization

EPA's Definition:

High-resolution site characterization (HRSC) strategies and techniques use scale-appropriate measurement and sample density to define contaminant distributions, and the physical context in which they reside, with greater certainty, supporting faster and more effective site cleanup.

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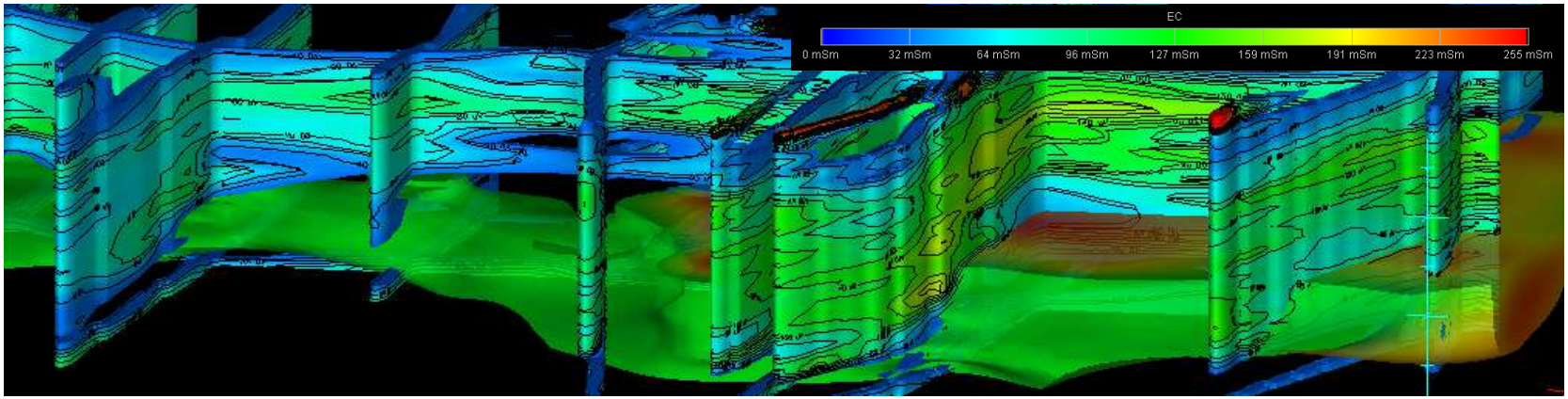
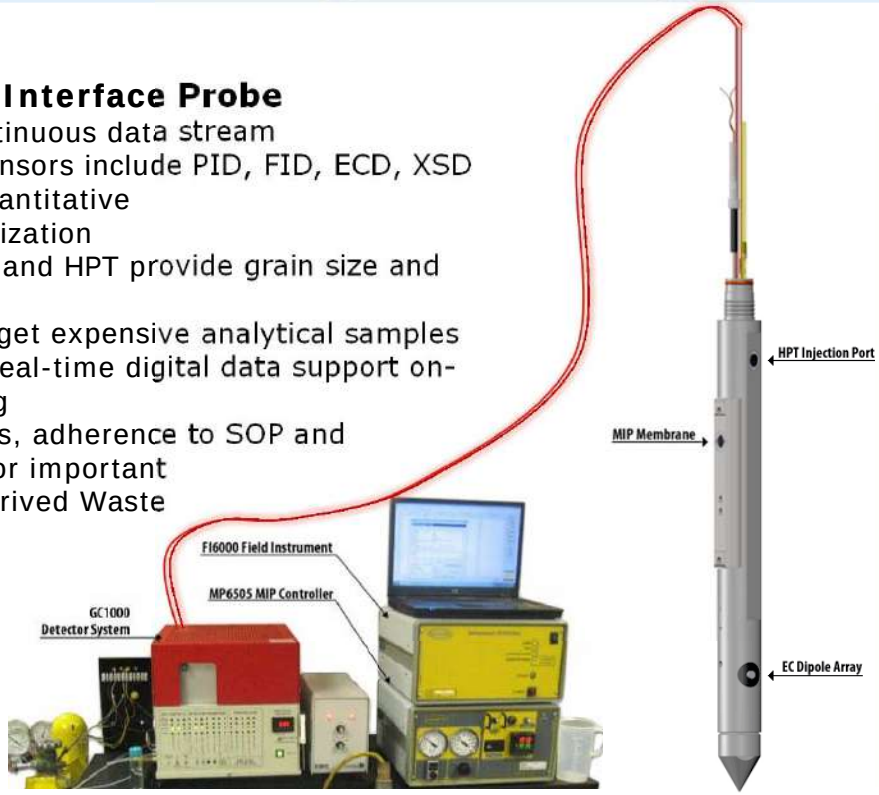
Components of HRSC

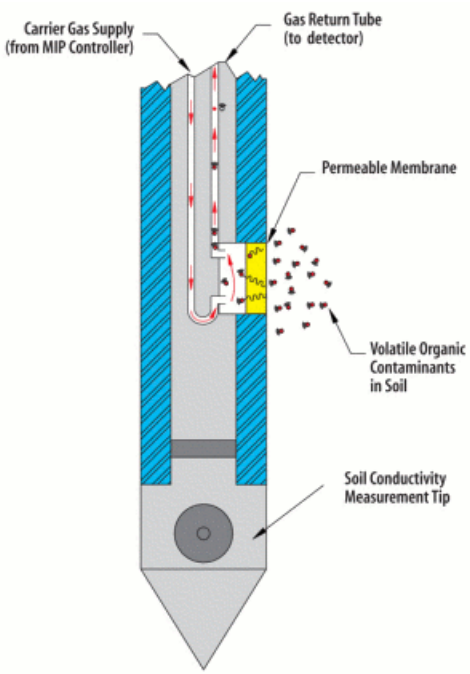
- High-density data at scale appropriate for site-specific heterogeneity
- Collaborative datasets
- Supports life cycle CSM
- Best Management Principal (BMP)



MIP – Membrane Interface Probe

- Direct Sensing, continuous data stream
- Primarily VOCs - Sensors include PID, FID, ECD, XSD
- Qualitative/semi-quantitative
- Rapid site characterization
- Simultaneously, EC and HPT provide grain size and hydrogeologic data
- Use response to target expensive analytical samples
- High data density, real-time digital data support on-site decision-making
- In use for 15+ years, adherence to SOP and experienced operator important
- No Investigation Derived Waste





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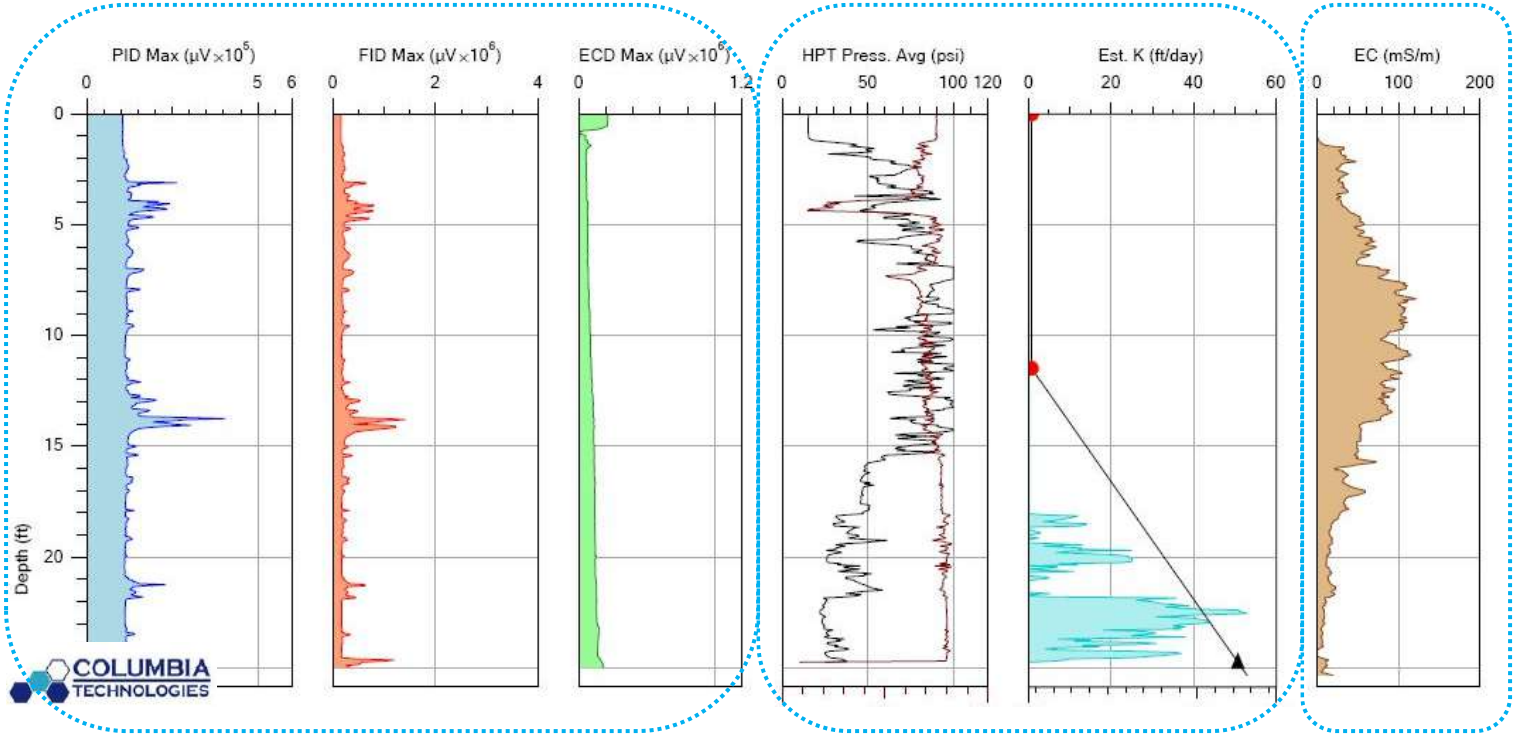
MIP + HPT – Vendor-Supplied **MiHpt** Log – Membrane interface Hydraulic Profiling Tool



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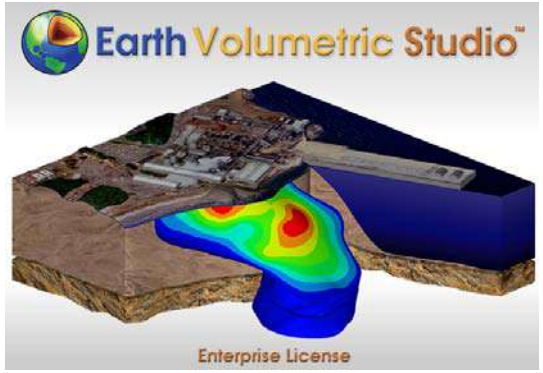

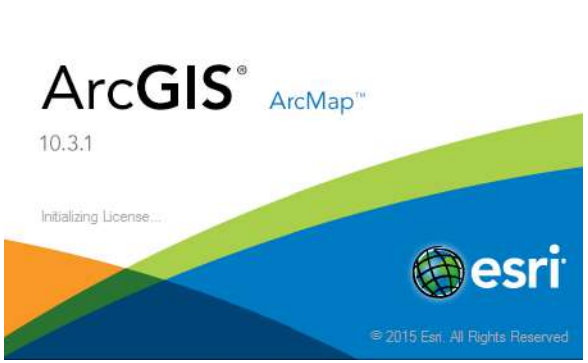

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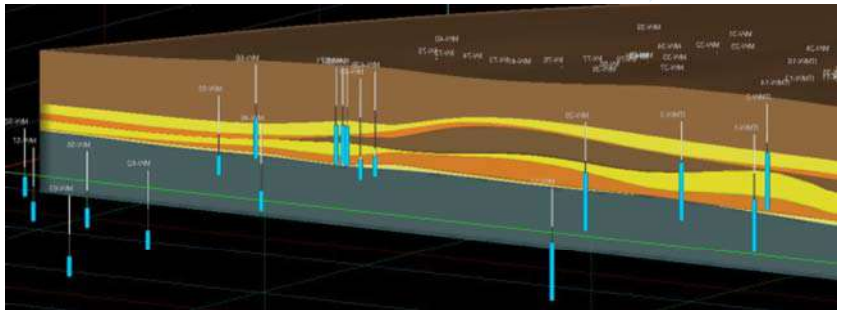
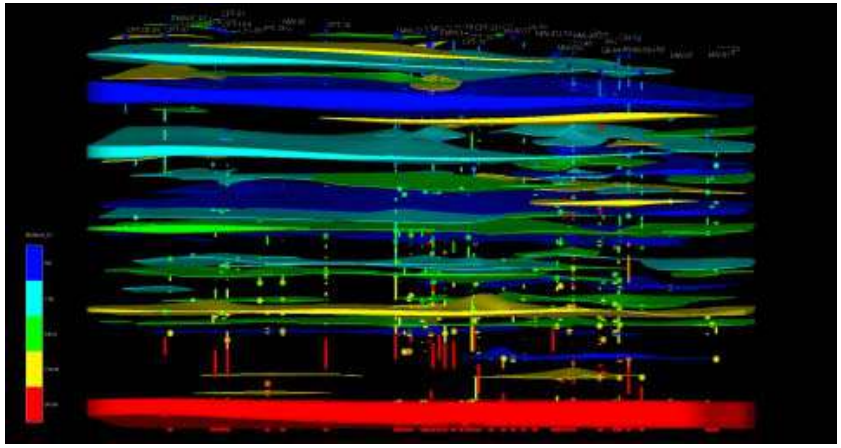
ArcGIS
ESRI
Earth Volumetric Studio
AUTODESK
SGeMS
YSI
HORIBA
earthsoft
EQuIS
gINT V8i
Google Earth Pro
Trimble
leapfrog

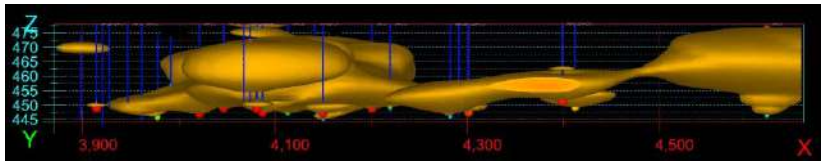
EVS / MVS

Environmental/Mining Visualization System

- True 3D volumetric models
- Mature technology, 25 years
- 3D and 4D kriging – animate through time
- Geostatistics
- DrillGuide™ and Well Decommission™ tools.
- Distribute interactive models as 3DPDF/4DIMs
- EVS/MVS, EnterVol (ArcGIS) and Earth Volumetric Studio (2016)







gINT Boring Log Software

- gINT RDBMS system
- Data captured in the field (e.g., tablet PCs)
- Boring logs generated directly from the database (e.g., same day logs)
- Customize to include additional data (e.g., CPT, MIP)
- Database connection to EQuIS, ArcGIS, EVS

<u>Analytical plus Geology defines the impact</u>

Main Group | CPT | Site Map | Fence Drapes

Project | Borehole | Lithology | Soil Components | Rock Components | Sample | Water Levels | Environmental | Well | Remarks | Membrane Interface Probe | Soil Liscs Group Name

Borehole ID	Samples Borehole Associated with MIP	Draft	Total Depth (ft)	Date Started	Date Completed	Surface Elevation (ft)	Borehole Diameter	Drilling Contractor	Drilling Method	Drillers Name	Rig Model	Logged By	Checked By	Purpose	Sample Method
DP-61	M-335	☐	41	8/26/2014	8/26/2014	488.00	2.25	McCray Drilling	Direct Push	Joe Fleegar		N. Zurweller	K. Stonestreet	Soil Boring	Continuous Sampler
DP-62	M-348	☐	28	8/26/2014	8/26/2014	471.19	2.25	McCray Drilling	Direct Push	Joe Fleegar		N. Zurweller	K. Stonestreet	Soil Boring	Continuous Sampler
DP-63		☐	15.5	12/17/2014	12/17/2014		3	Walker-Hill	Sonic			N. Zurweller	K. Stonestreet	Soil Boring	Sonic
DP-64		☐	15	12/17/2014	12/17/2014		3	Walker-Hill	Sonic			N. Zurweller	K. Stonestreet	Soil Boring	Sonic

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Former Lead Smelter

- 60 acre former lead smelter
- Former operations area on an upland plateau
- Smelter operated from 1900s to 1950s
- Operations generated 1.5 million tons of slag
- Metals-impacted soils, building debris, and former smoke stack debris
- RI completed 2012, remedial activities began in 2013

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- Operations generated 1.5 million tons of slag
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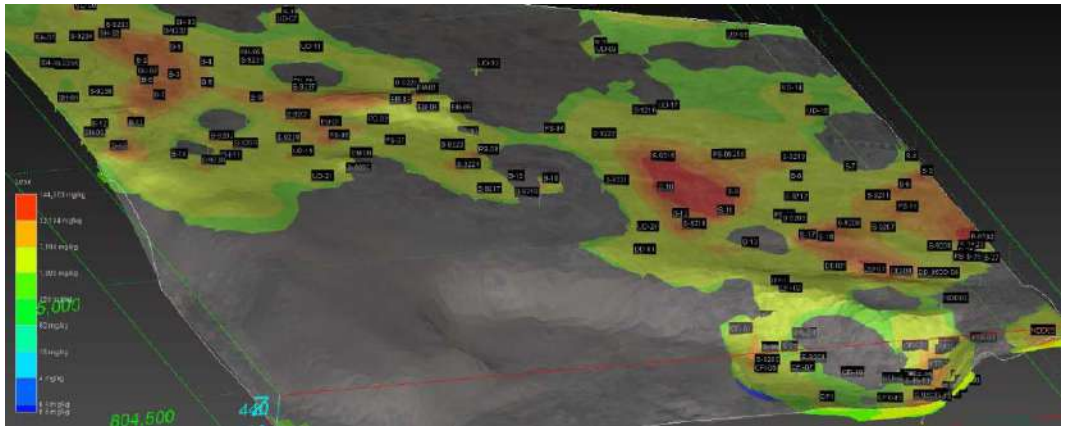
- RI completed 2012, remedial activities began in 2013

Excavation Summary (cu yd = cubic yards)

- 12,000 cu yd excavated from the lowland
- 108,000 cu yd excavated from the upland

EVS was used to calculate volume of soils in exceedance of multiple regulatory limits, design site excavations, and monitor volumes of excavated and placed material.

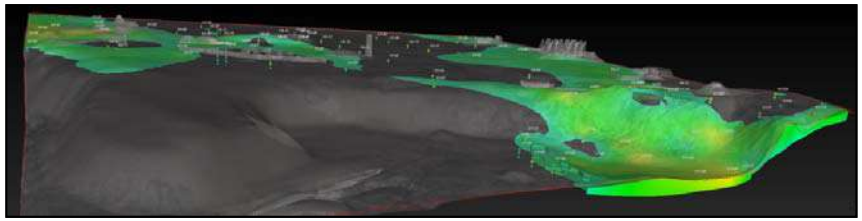


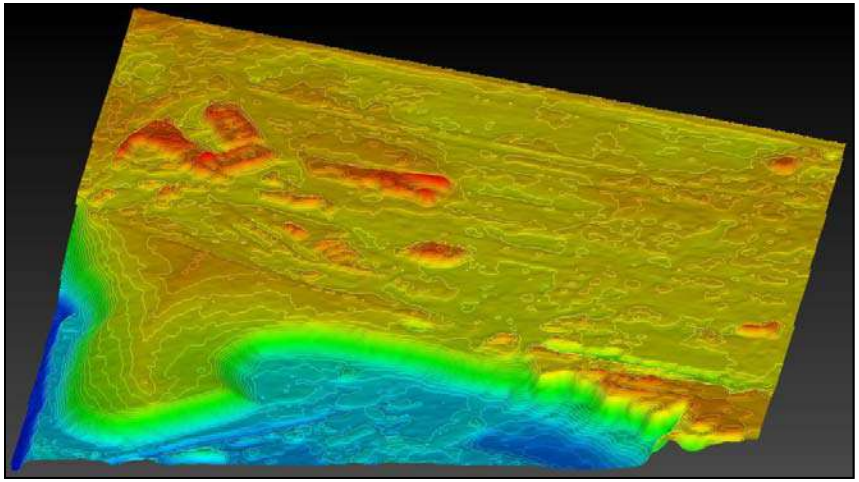
Former Lead Smelter

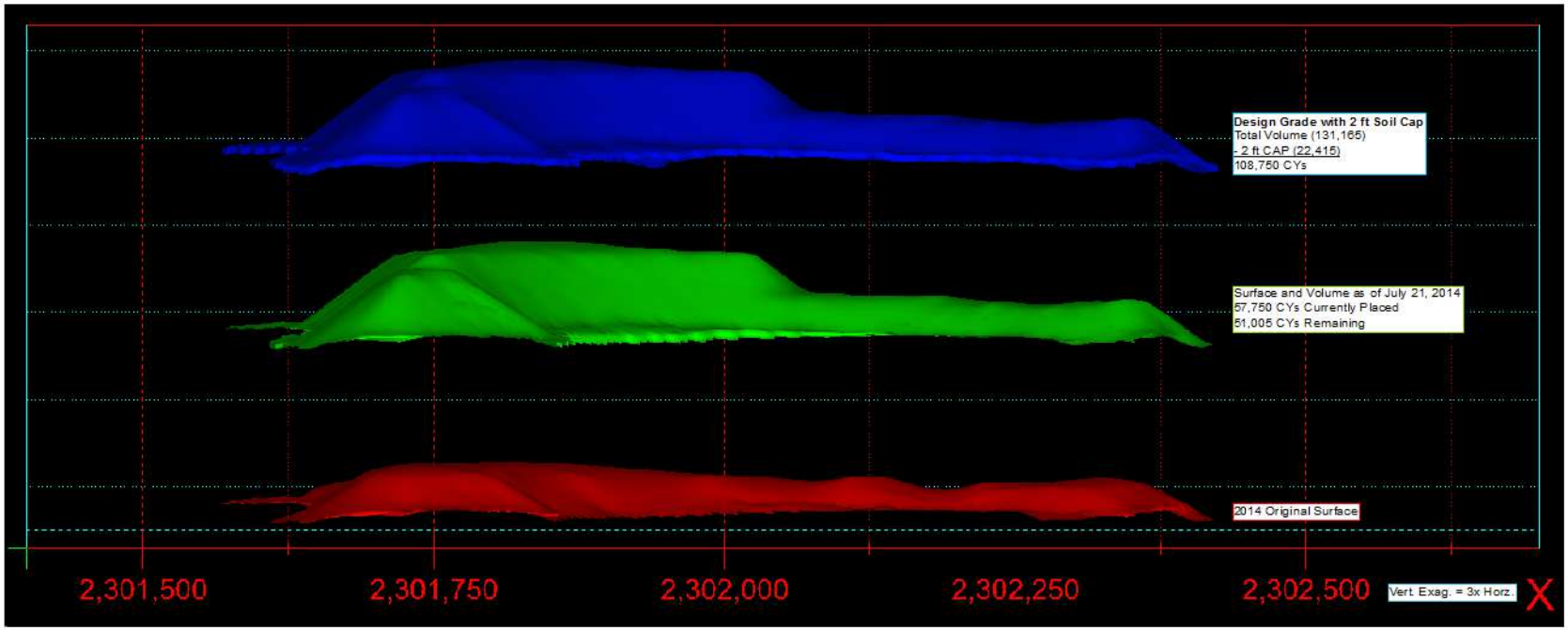
- The 2012 Remedial Investigation (RI) provided subsurface characterization data for EVS/MVS
- RI data supplemented with historical data

- Lead, Cadmium and Mercury risk-based drivers
- EVS' 3D Kriging used to estimate volume of soil exceeding Lead OR Cadmium OR Mercury

- 2012 EVS estimate was 120,000 cu yd
- 2015 completion estimate 108,000 cu yd






Design Grade with 2 ft Soil Cap
Total Volume (131,165)
- 2 ft CAP (22,415)
108,750 CYs
Surface and Volume as of July 21, 2014
57,750 CYs Currently Placed
51,005 CYs Remaining
2014 Original Surface
2,301,500
2,301,750
2,302,000
2,302,250
2,302,500
Vert. Exag. = 3x Horz.
X

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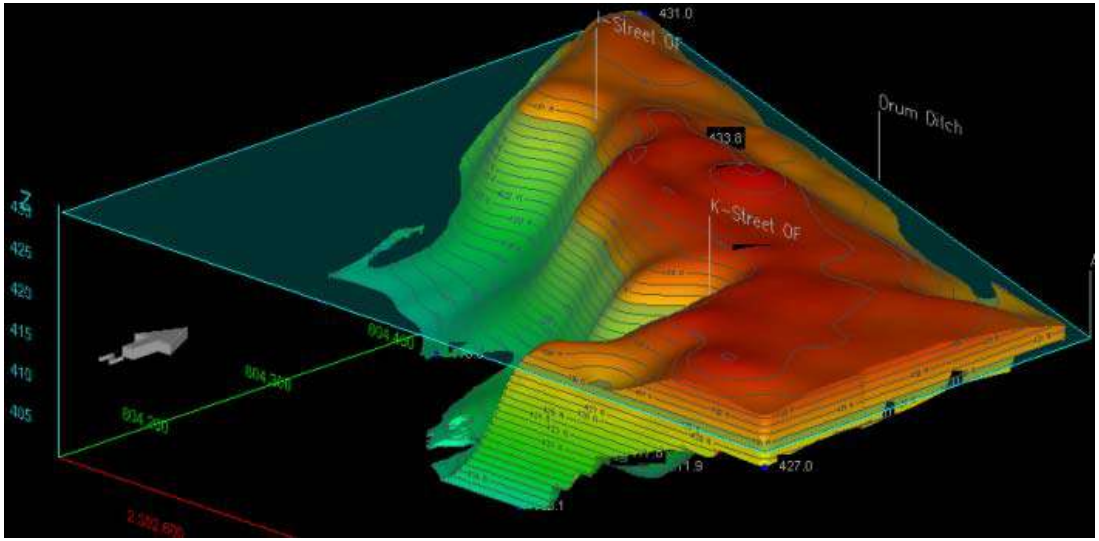
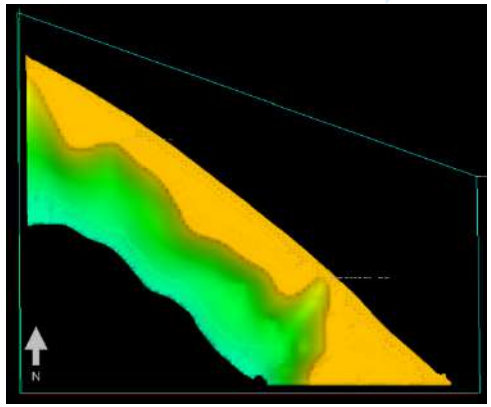
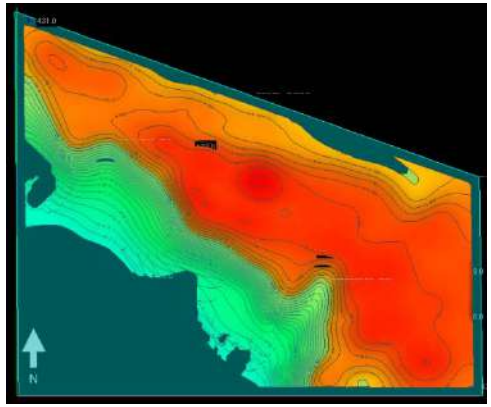
Additional 3D Task Completed

Volume estimates along a complex 3D slope (river bluff)

- Original alignment modified by material dumped from upland
- Identified native alignment with historical USGS Topos
- Supplemented with test pit excavations to native soil
- Input into EVS to calculate volume of non-native material, 8,500 cu yd







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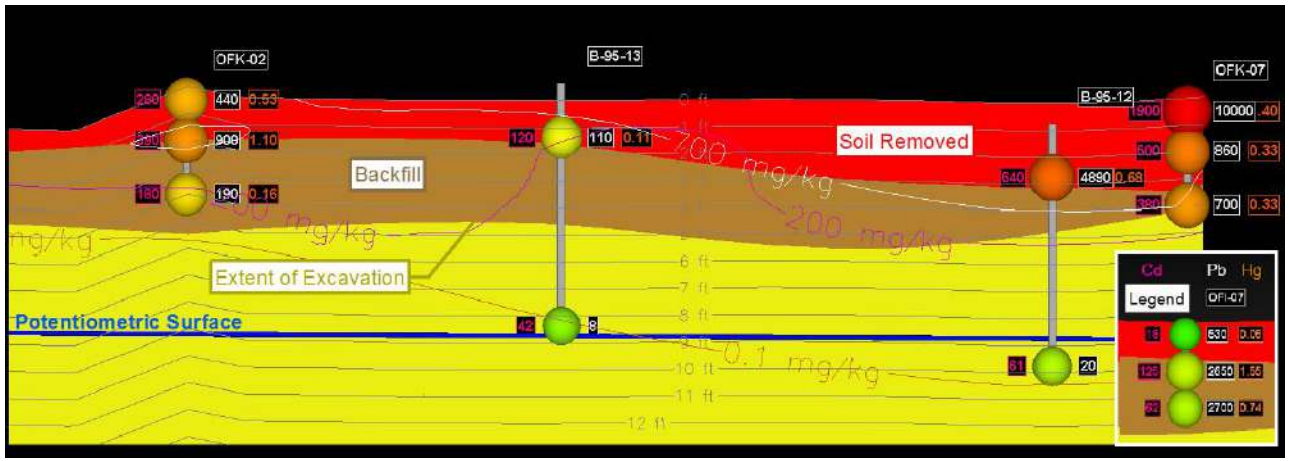
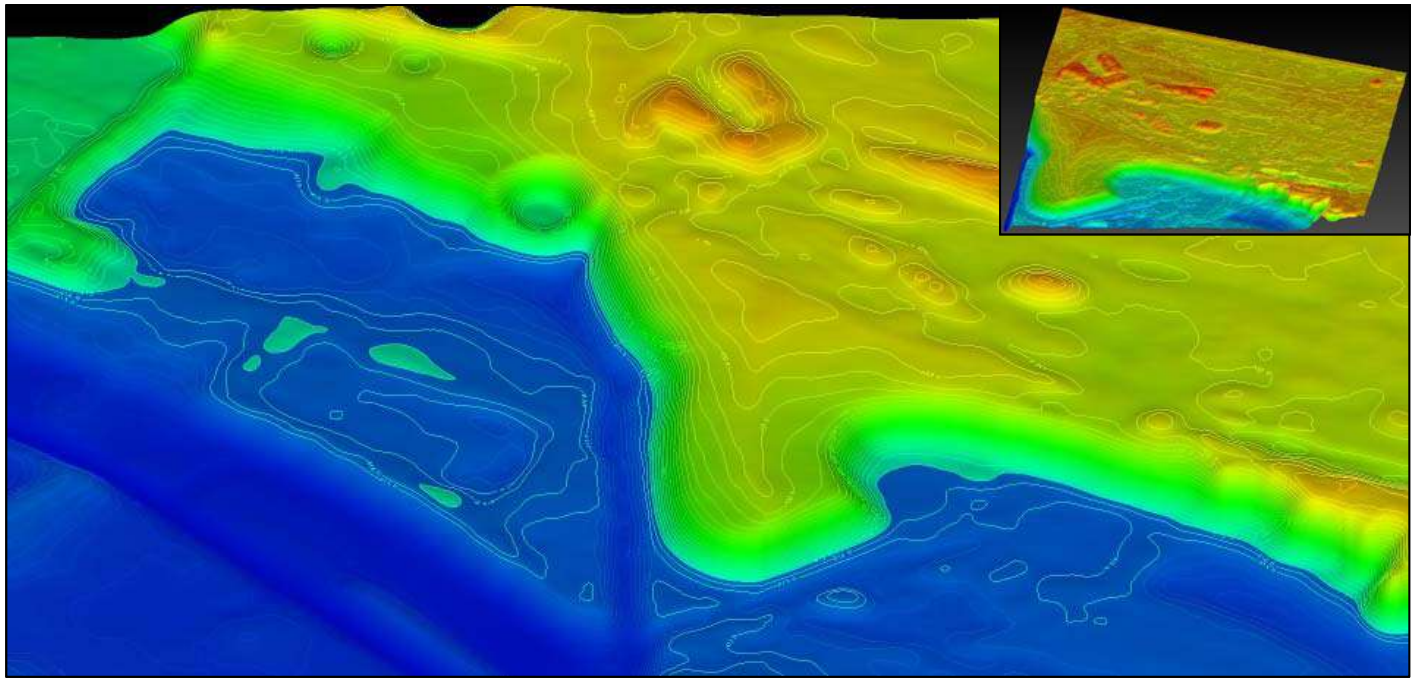
Additional 3D Task Completed

Excavation and backfill design, soil volume updates in near real time



Additional 3D Task Completed

Evaluation of USACE flood elevation surface



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Chlorinated Solvent Site – Applied HRSC and MIP Example

- 150 MIP + 35 collocated Direct Push confirmation soil borings
- Kriging results each day while deployed on-site. (i.e., Triad-based)
- Generates very large datasets - 96,000 records
- Data table for a 30ft bgs boring, 600+ records →
- Data supplied as text files (CSV)
- Database and data loading script created

NAME	Depth	EC_mSm	ECD_	PID_	FID_	XSD_
M-205	24.2	26.04	2888272	61037	247200	24186
M-205	24.25	23.94	3100680	57070	236824	24644
M-205	24.3	21.52	3203223	55849	241401	23728
M-205	24.35	15.55	3182470	53713	217902	23041
M-205	24.4	12.3	2885830	49745	189825	22965
M-205	24.45	14.21	2685629	44862	150761	22889
M-205	24.5	12.44	2269356	39979	124821	25330
M-205	24.55	11.69	1859188	39674	124516	28306
M-205	24.6	10.08	1839656	42421	162664	28916
M-205	24.65	12.71	3554796	56459	278024	29374
M-205	24.7	12.98	2656331	45473	165410	25254
M-205	24.75	13.81	2486648	47304	173040	26170
M-205	24.8	15.45	2428053	42726	129093	28611
M-205	24.85	11.79	2047182	37233	79348	30671
M-205	24.9	10.88	1626026	34791	64394	30671

Record: 486 of 632 Filtered Search

Boring_	Depth_ft	EC_mS_m	ECD_MAX	FID_MAX	PID_MAX	XSD_MAX	HPT_Press_Max_psi	HPT_Flow_Max_mL_min	ROP_ft_min	Temp_Min_deg_C	Temp_Max_deg_C	Elev_Z	x_coord	y_coord	elev
M-306	11.45	132.76	1,032,289	211341	152,593		75.733	154.9	1.41	123.2	124.4	464.05	590613.99	368762.07	475.5
M-306	11.5	131.71	1,030,763	211341	151,067		73.515	154.6	1.33	118.5	123.1	464	590613.99	368762.07	475.5
M-306	11.55	130.41	1,028,474	211341	151,830		68.434	151.9	1.52	115.3	118.3	463.95	590613.99	368762.07	475.5
M-306	11.6	131.91	1,030,000	209815	151,830		67.768	152.3	1.93	113	115.2	463.9	590613.99	368762.07	475.5
M-306	11.65	132.45	1,030,763	210578	151,067		74.972	152.4	1.76	110.9	113	463.85	590613.99	368762.07	475.5
M-306	11.7	138.17	1,031,526	211341	151,830		75.034	149.6	1.86	110.2	110.9	463.8	590613.99	368762.07	475.5
M-306	11.75	138.57	1,033,814	211341	152,593		76.587	150.6	1.9	109.2	110.2	463.75	590613.99	368762.07	475.5
M-306	11.8	138.38	1,033,052	211341	152,593		75.224	158.8	1.92	108.9	109.1	463.7	590613.99	368762.07	475.5
M-306	11.85	136.86	1,031,526	210578	150,304		61.327	154.1	1.95	108.4	108.8	463.65	590613.99	368762.07	475.5
M-306	11.9	136.01	1,031,526	210578	150,304		66.356	151	2	108.5	108.6	463.6	590613.99	368762.07	475.5
M-306	11.95	136.08	1,033,814	211341	151,067		74.501	152.7	2.03	108.6	108.9	463.55	590613.99	368762.07	475.5
M-306	12	132.2	1,036,103	212104	150,304		82.915	151.1	1.39	109	110.1	463.5	590613.99	368762.07	475.5
M-306	12.05	131.59	1,046,022	213630	151,067		83.843	153	0.08	110.2	124.1	463.45	590613.99	368762.07	475.5
M-306	12.1	133.67	1,042,207	213630	148,015		76.871	152.5	1.21	116.8	120.4	463.4	590613.99	368762.07	475.5
M-306	12.15	133.77	1,041,444	212867	148,778		73.312	154.8	1.5	116.8	118.6	463.35	590613.99	368762.07	475.5
M-306	12.2	137.62	1,041,444	212104	149,541		70.222	154.3	1.48	119	123.2	463.3	590613.99	368762.07	475.5
M-306	12.25	138.37	1,040,681	212867	148,778		60.214	155.8	1.62	123.3	125.5	463.25	590613.99	368762.07	475.5
M-306	12.3	138.56	1,040,681	212867	147,252		71.67	153.5	1.35	125.6	125.9	463.2	590613.99	368762.07	475.5
M-306	12.35	144.08	1,042,207	211341	149,541		68.286	155.1	1.4	125.7	126	463.15	590613.99	368762.07	475.5

Record: 45951 of 96031 Unfiltered Search

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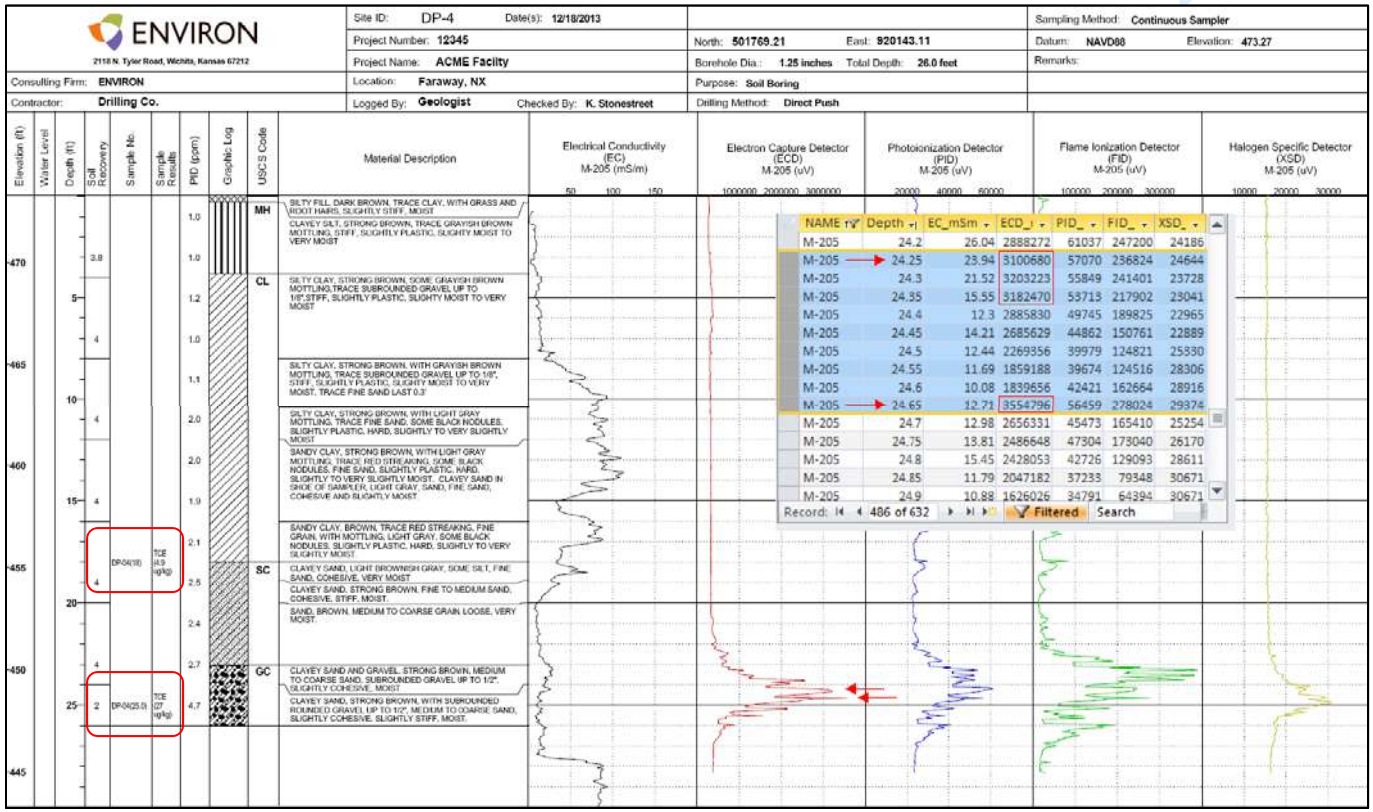
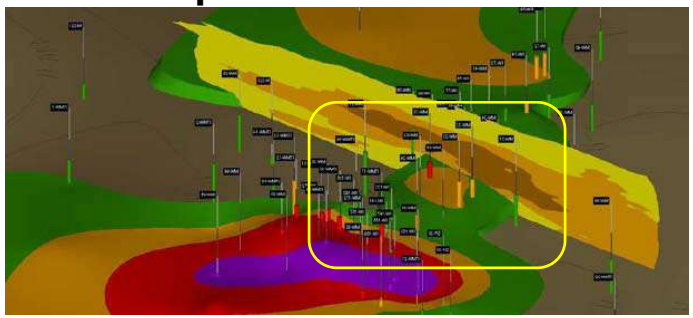
Combined Boring Log Using gINT and the MIP database

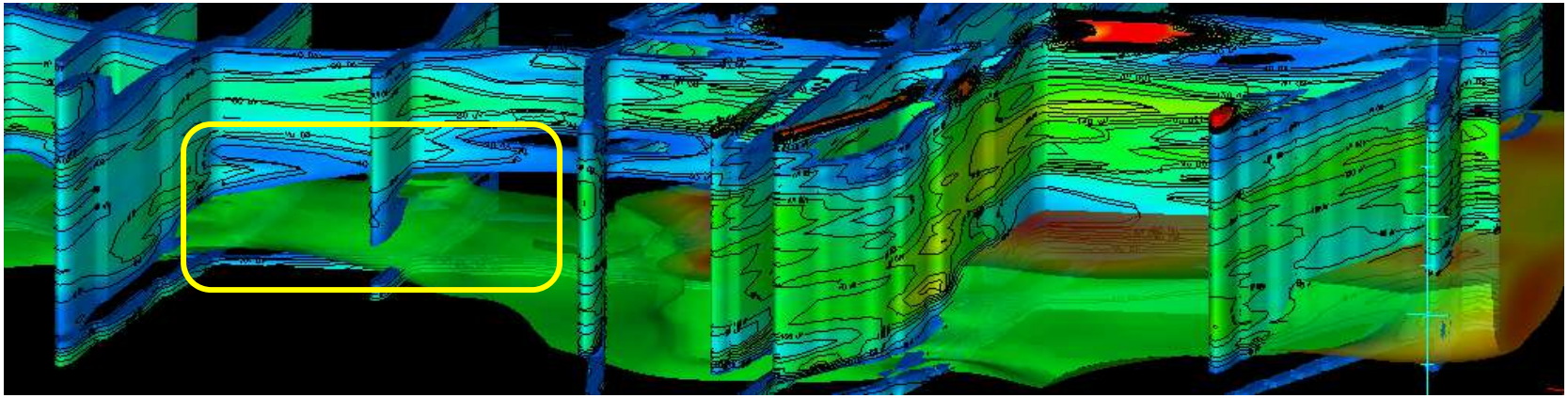
At approximately 20% of MIP locations a collocated direct push (DP) soil boring was completed. Confirmation soil and groundwater samples collected based on MIP response.



Chlorinated Solvent Site – Applied HRSC and MIP Example

- Identified a narrow 'neck' of contamination pathway
- Estimates using a treatment volume delineated using only monitoring well results resulted in an treatment volume an order of magnitude greater
- High density data provided a more accurate representation of the plume and significant savings on the ISCO remedy
- Value of a quality model used to make smart decisions





Data

Characterization and Remediation Concepts

Decision Support Tools

Case Studies and Workflows

Conclusion

What are data-based 3D/4D models and why are they useful?

To clear the grey fog of subsurface uncertainty. The ability to visualize and critically evaluate complex 3-dimensional datasets improves clarity and decision confidence.

When should they be used?

Throughout the project lifecycle.

What is required?

Data of known quality.

QUESTIONS?

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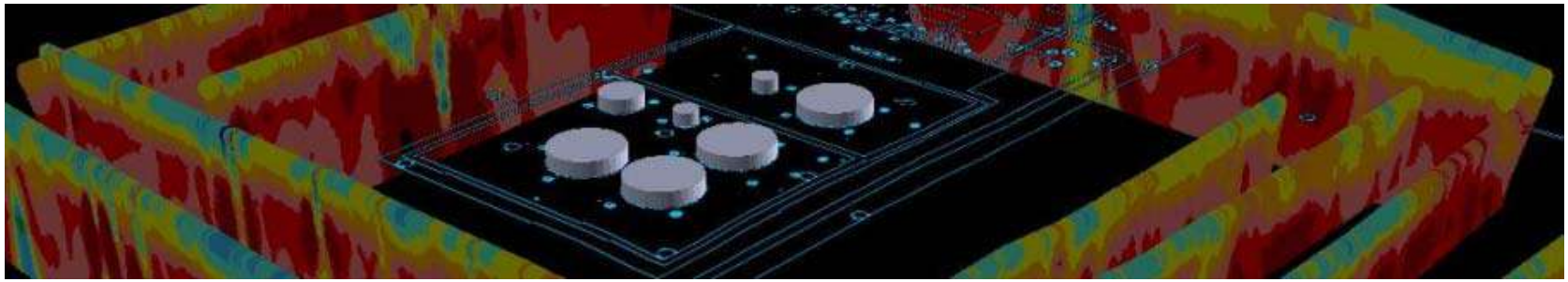

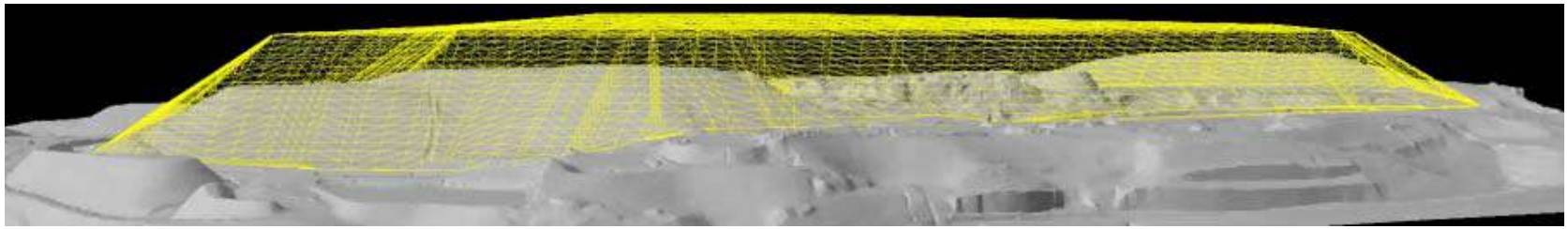

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QUESTIONS?

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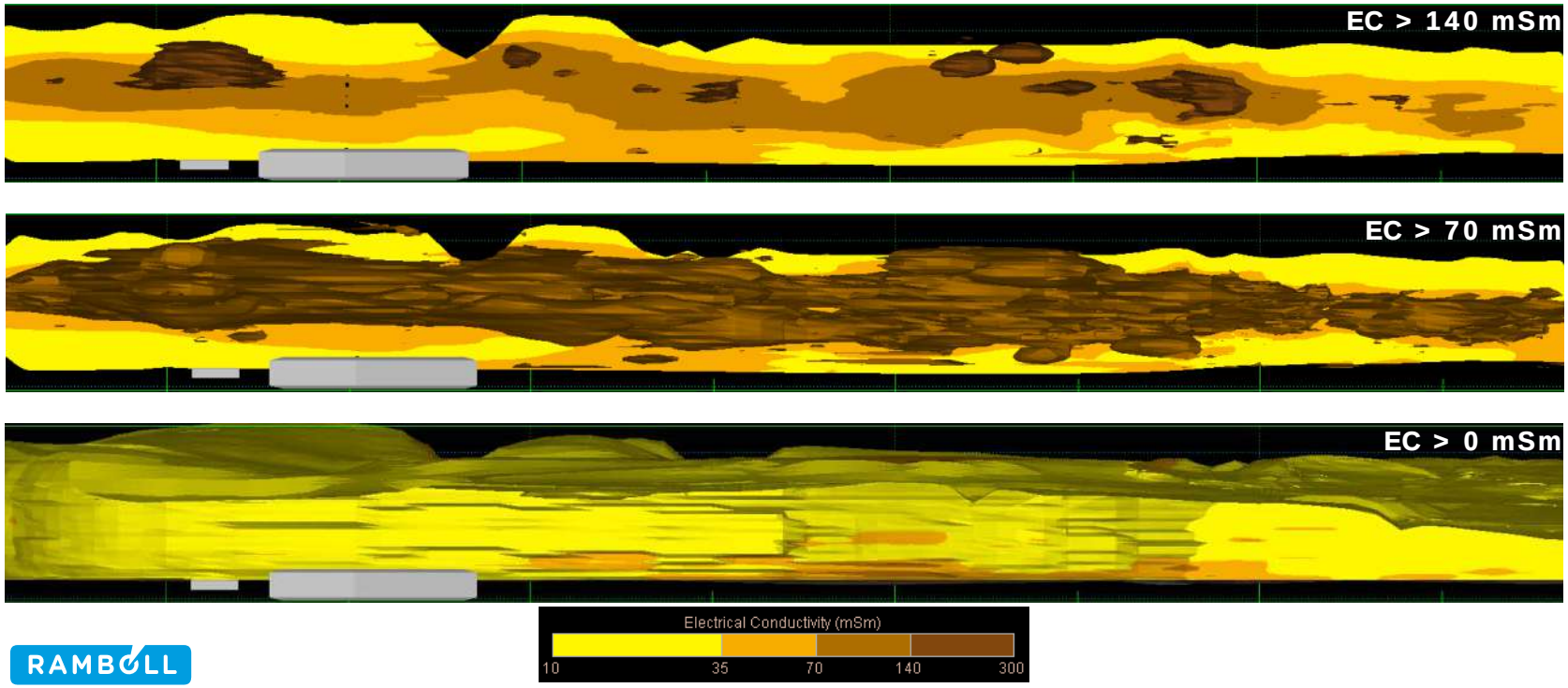
Chlorinated Solvent Site – MIP - Electrical Conductivity Model



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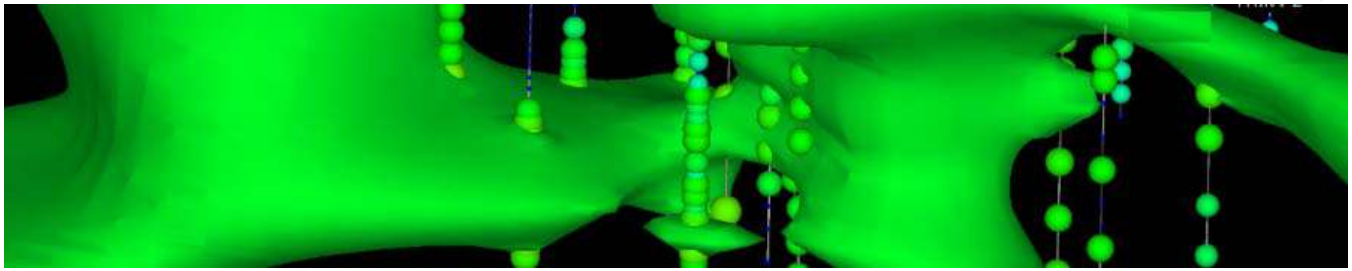

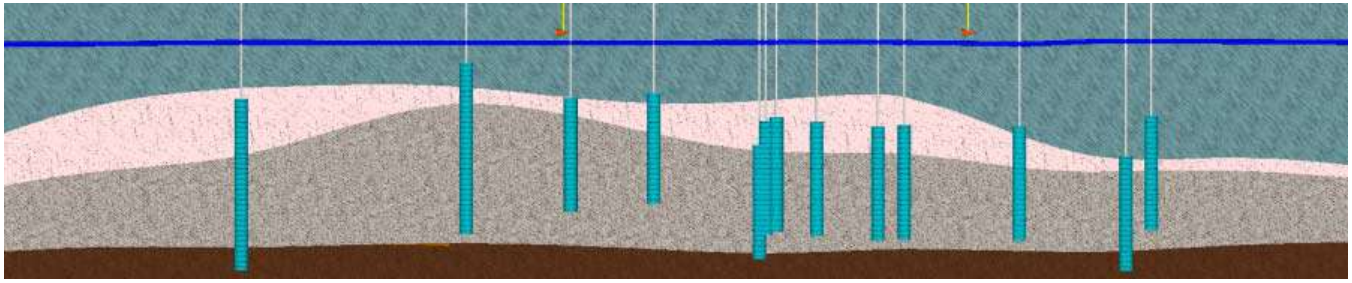

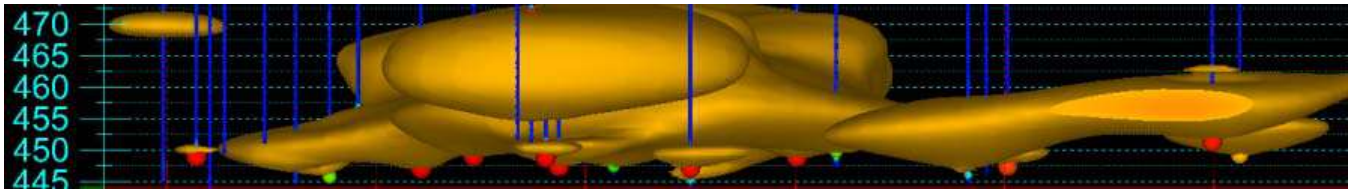

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