Geophysical Methods in Soil Surveys:

Past, Present, and Future

The two most widely used geophysical methods within the Soil Survey Division:

Electromagnetic Induction (EMI)

Ground-Penetrating Radar (GPR)

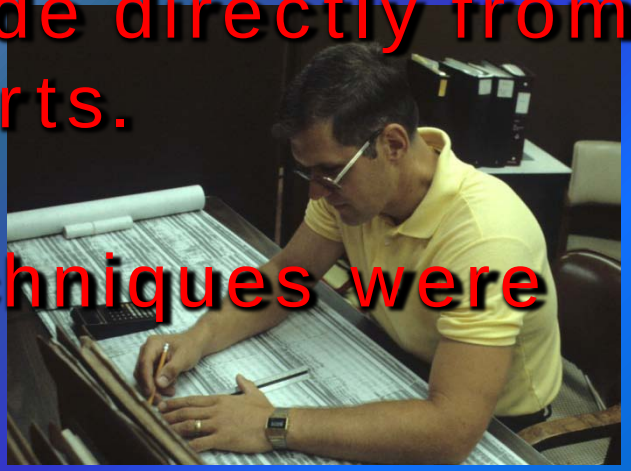
In soil surveys, geophysical tools (e.g., EMI & GPR) are principally used as quality control tool to:

- Determine the presence, depth, and lateral extent of diagnostic subsurface horizons, stratigraphic and lithologic layers.
- Improve interpretations by providing estimates of soil map unit composition.
- Characterize spatial and temporal variations in soil properties.

Early GPR Systems

- First GPR systems were bulky and cumbersome.

- Data were displayed on oscilloscopes and/or strip-chart recorders.
- Interpretations were made directly from raw data on strip charts.



- Available processing techniques were very primitive.

In the mid-1990s, we transitioned from analog to digital systems

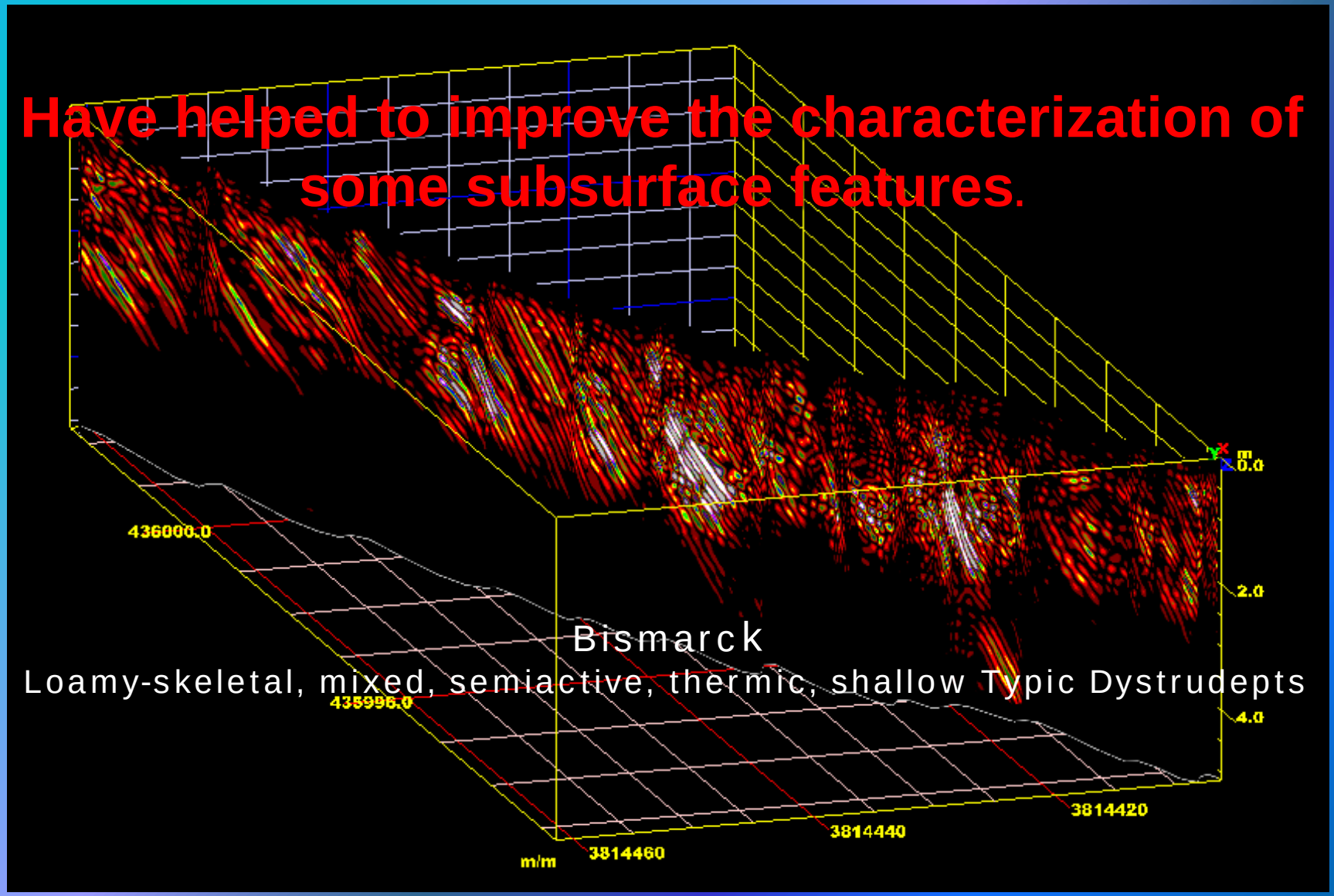
- Units were increasingly lighter weight and more compact.
- Less expensive.
- Greater capabilities.

In the late-1990s, processing was first effectively applied to soil data.

- Opened new windows of opportunity for GPR.
- Data processing is the “key” to modern GPR interpretations, but is seldom effectively used by NRCS’s GPR operators.

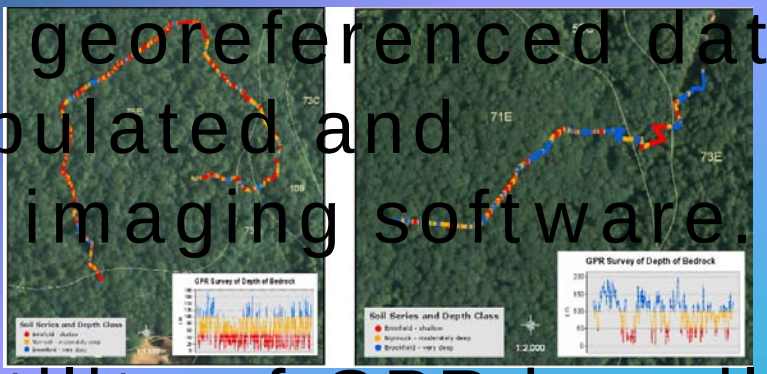
FINE, MIXED, SEMIACTIVE, MESIC TYPIC HAPLUDALFS

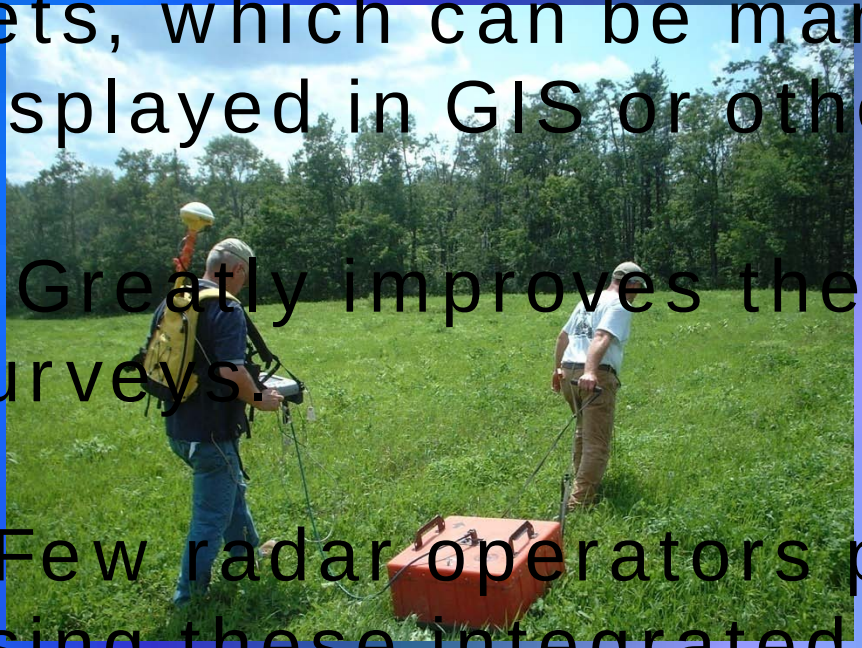
3D renditions of radar records



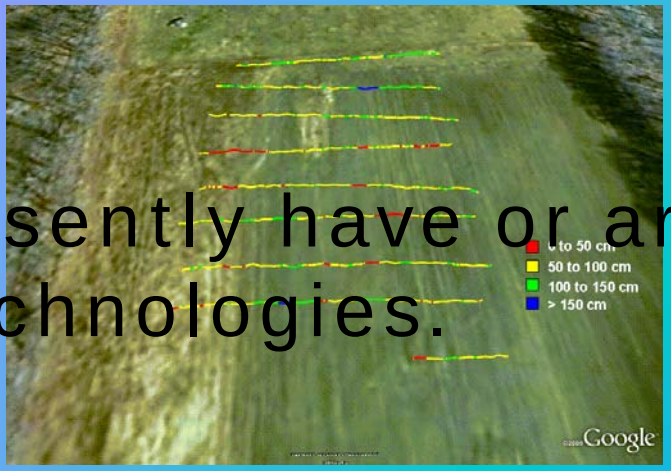
GPR, GPS, & GIS

- In 2008, the synergism of GPR and GPS permits the collection of georeferenced data sets, which can be manipulated and displayed in GIS or other imaging software.



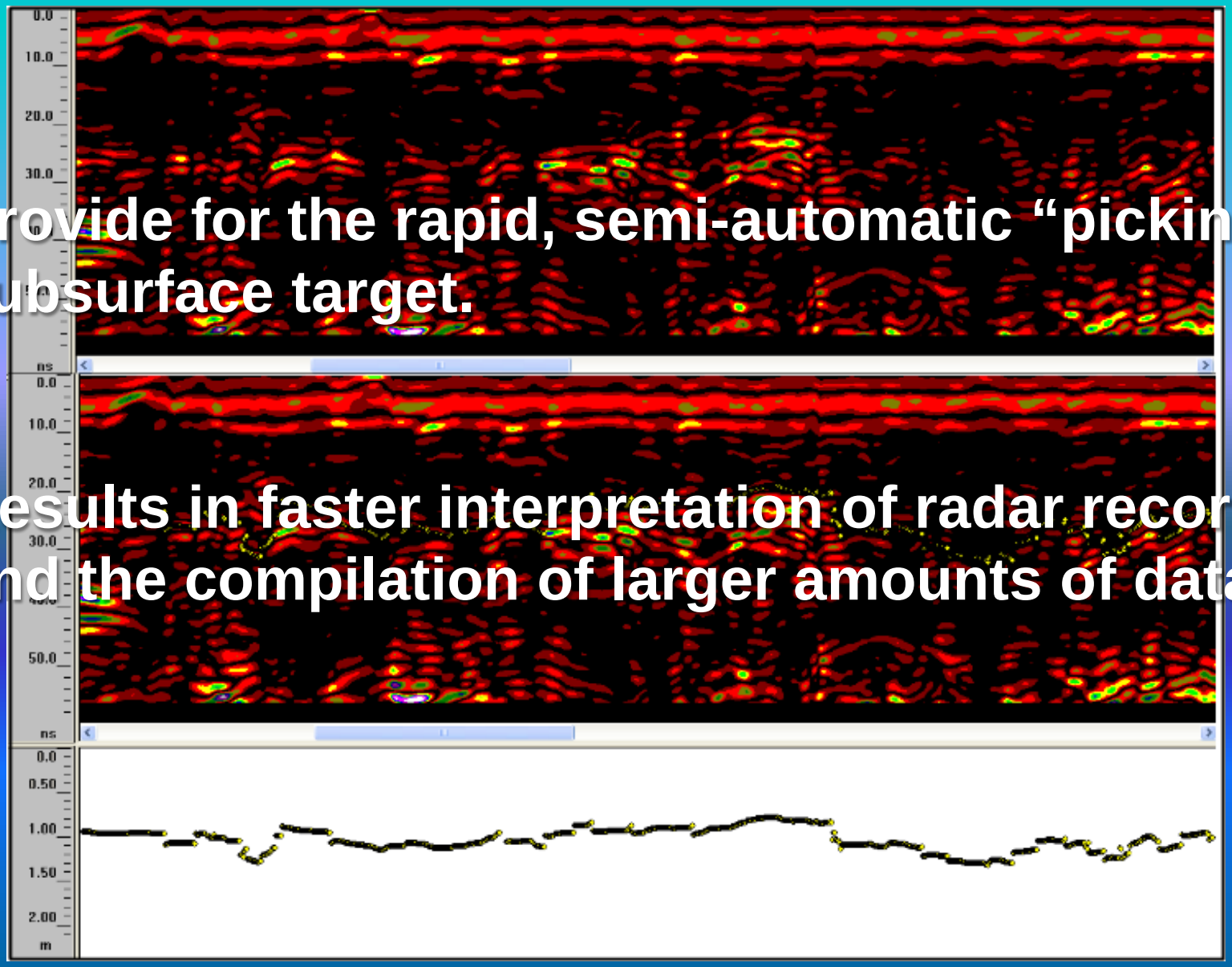


- Greatly improves the utility of GPR in soil surveys.



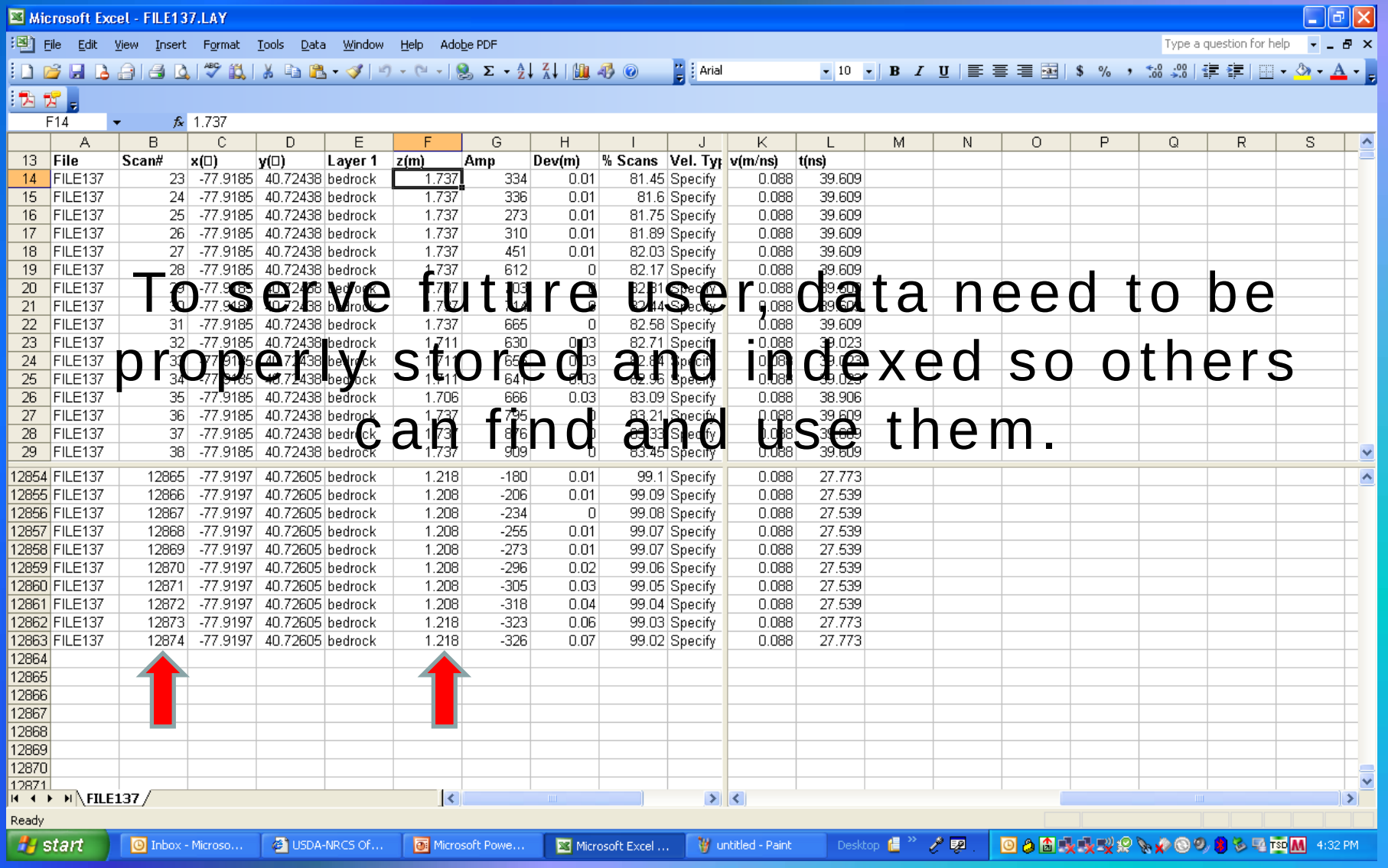
- Few radar operators presently have or are using these integrated technologies.

Interactive Interpretations



- **Provide for the rapid, semi-automatic “picking” of subsurface target.**
- **Results in faster interpretation of radar records and the compilation of larger amounts of data.**

Interactive modules allows “picked” GPR data to be exported to layer files.



	A	B	C	D	E	F	G	H	I	J	K	L
13	File	Scan#	x(□)	y(□)	Layer 1	z(m)	Amp	Dev(m)	% Scans	Vel. Typ	v(m/ns)	t(ns)
14	FILE137	23	-77.9185	40.72438	bedrock	1.737	334	0.01	81.45	Specify	0.088	39.609
15	FILE137	24	-77.9185	40.72438	bedrock	1.737	336	0.01	81.6	Specify	0.088	39.609
16	FILE137	25	-77.9185	40.72438	bedrock	1.737	273	0.01	81.75	Specify	0.088	39.609
17	FILE137	26	-77.9185	40.72438	bedrock	1.737	310	0.01	81.89	Specify	0.088	39.609
18	FILE137	27	-77.9185	40.72438	bedrock	1.737	451	0.01	82.03	Specify	0.088	39.609
19	FILE137	28	-77.9185	40.72438	bedrock	1.737	612	0	82.17	Specify	0.088	39.609
20	FILE137	29	-77.9185	40.72438	bedrock	1.737	703	0	82.31	Specify	0.088	39.609
21	FILE137	30	-77.9185	40.72438	bedrock	1.737	714	0	82.44	Specify	0.088	39.609
22	FILE137	31	-77.9185	40.72438	bedrock	1.737	665	0	82.58	Specify	0.088	39.609
23	FILE137	32	-77.9185	40.72438	bedrock	1.711	630	0.03	82.71	Specify	0.088	39.023
24	FILE137	33	-77.9185	40.72438	bedrock	1.711	650	0.03	82.85	Specify	0.088	39.023
25	FILE137	34	-77.9185	40.72438	bedrock	1.711	641	0.03	82.98	Specify	0.088	39.023
26	FILE137	35	-77.9185	40.72438	bedrock	1.706	666	0.03	83.09	Specify	0.088	38.906
27	FILE137	36	-77.9185	40.72438	bedrock	1.737	795	0	83.21	Specify	0.088	39.609
28	FILE137	37	-77.9185	40.72438	bedrock	1.737	876	0	83.33	Specify	0.088	39.609
29	FILE137	38	-77.9185	40.72438	bedrock	1.737	909	0	83.45	Specify	0.088	39.609
12854	FILE137	12865	-77.9197	40.72605	bedrock	1.218	-180	0.01	99.1	Specify	0.088	27.773
12855	FILE137	12866	-77.9197	40.72605	bedrock	1.208	-206	0.01	99.09	Specify	0.088	27.539
12856	FILE137	12867	-77.9197	40.72605	bedrock	1.208	-234	0	99.08	Specify	0.088	27.539
12857	FILE137	12868	-77.9197	40.72605	bedrock	1.208	-255	0.01	99.07	Specify	0.088	27.539
12858	FILE137	12869	-77.9197	40.72605	bedrock	1.208	-273	0.01	99.07	Specify	0.088	27.539
12859	FILE137	12870	-77.9197	40.72605	bedrock	1.208	-296	0.02	99.06	Specify	0.088	27.539
12860	FILE137	12871	-77.9197	40.72605	bedrock	1.208	-305	0.03	99.05	Specify	0.088	27.539
12861	FILE137	12872	-77.9197	40.72605	bedrock	1.208	-318	0.04	99.04	Specify	0.088	27.539
12862	FILE137	12873	-77.9197	40.72605	bedrock	1.218	-323	0.06	99.03	Specify	0.088	27.773
12863	FILE137	12874	-77.9197	40.72605	bedrock	1.218	-326	0.07	99.02	Specify	0.088	27.773
12864												
12865												
12866												
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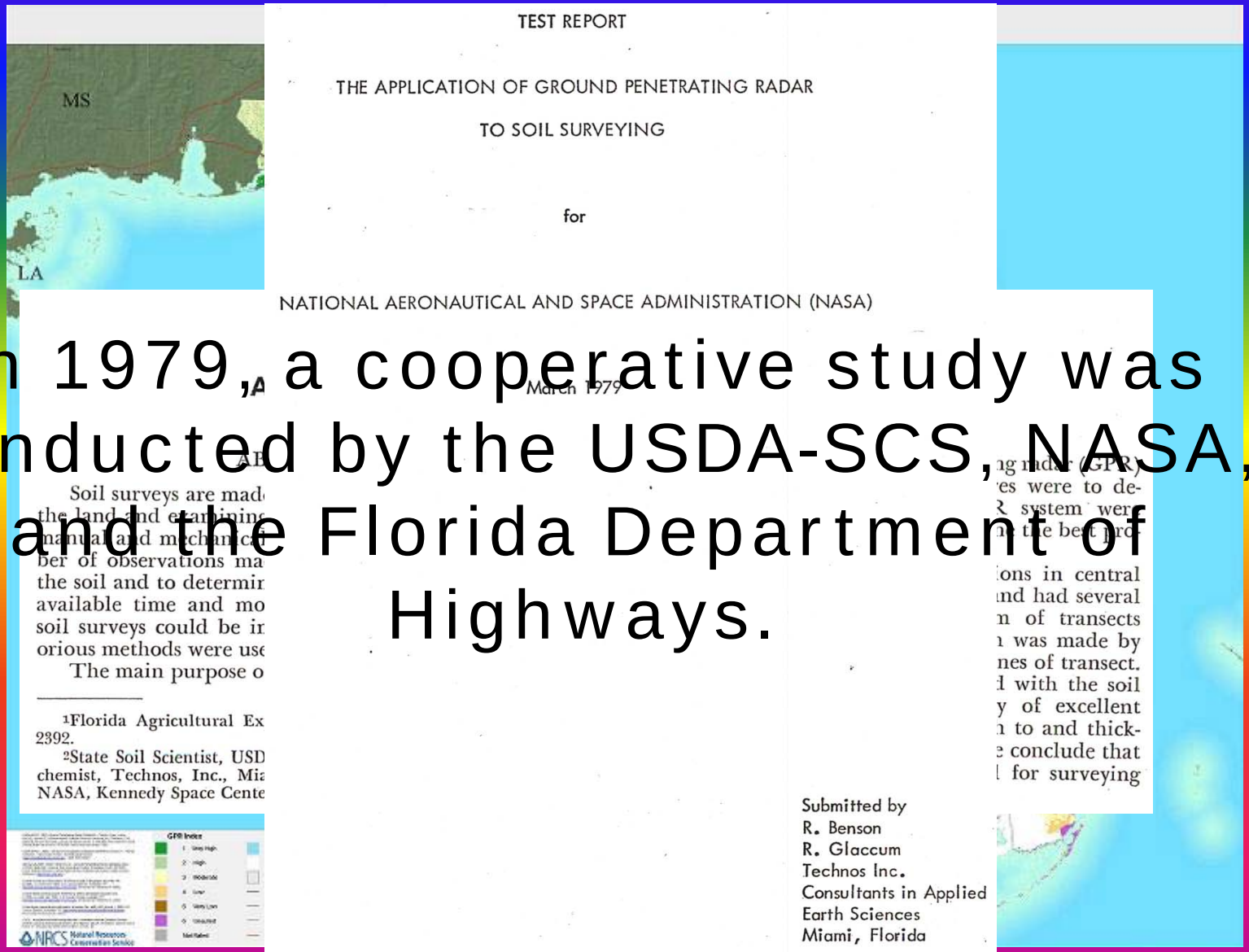
To serve future user, data need to be properly stored and indexed so others can find and use them.

Some uses of GPR:

- Quality control tool for soil surveys.
- Investigations of subaqueous soils.
- soil depth determinations.

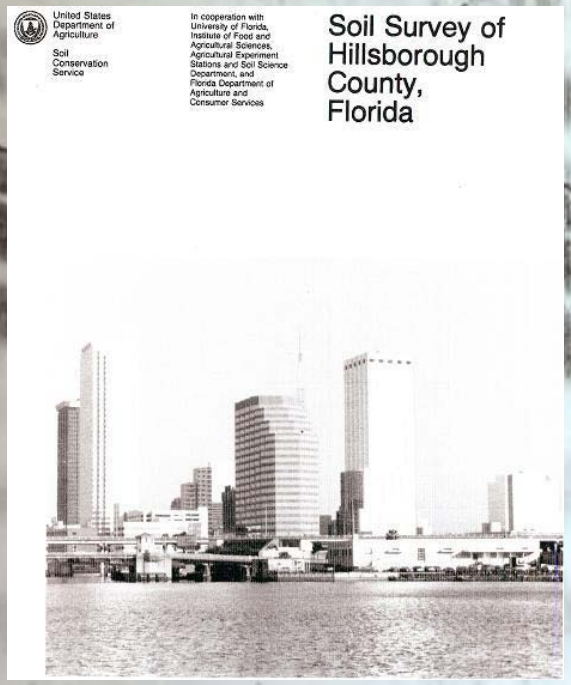
It all started in Florida.

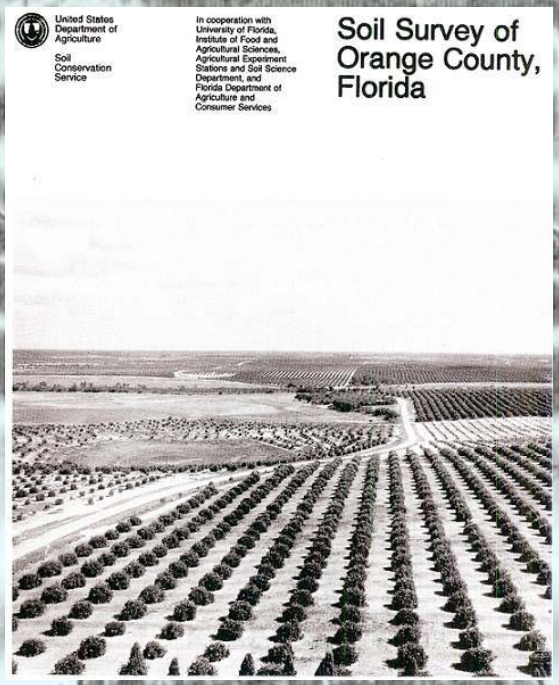


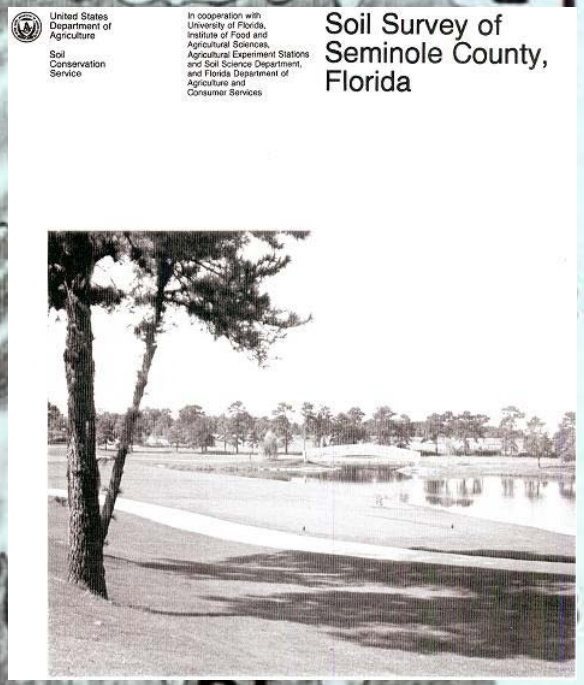
In 1979, a cooperative study was conducted by the USDA-SCS, NASA, and the Florida Department of Highways.

Updating Soil Surveys

water table





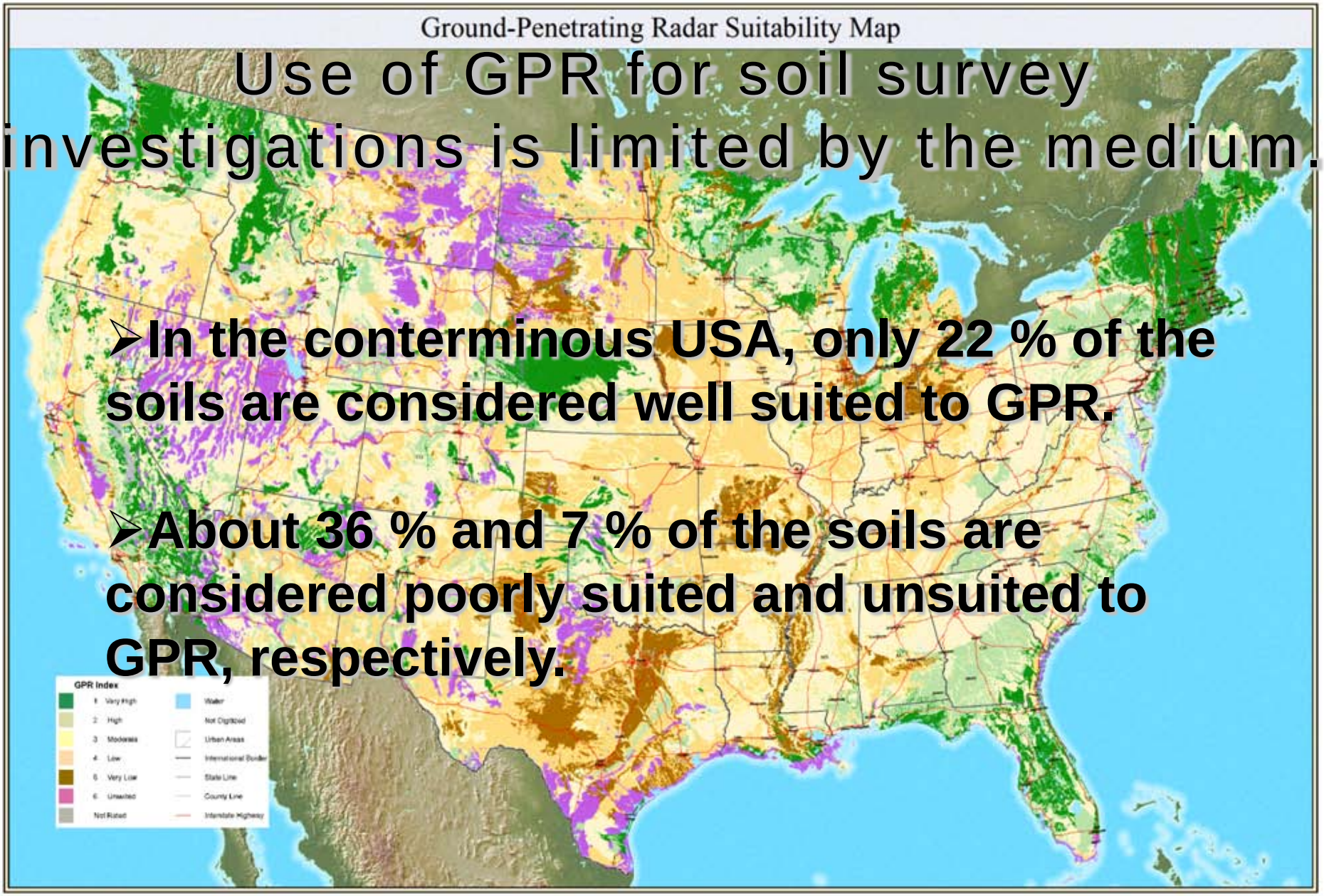


GPR PROFILE FROM AN AREA OF IMMOKALEE FINE SAND

GPR has been used in all fifty states as a quality control tool for soil surveys.

As a quality control tool, GPR must provide:

- Penetration depths of 2 m or to limiting lithologic or stratigraphic discontinuity.
- High resolution of soil horizons, layers, and/or features.
- Reasonable confidence in interpretations.



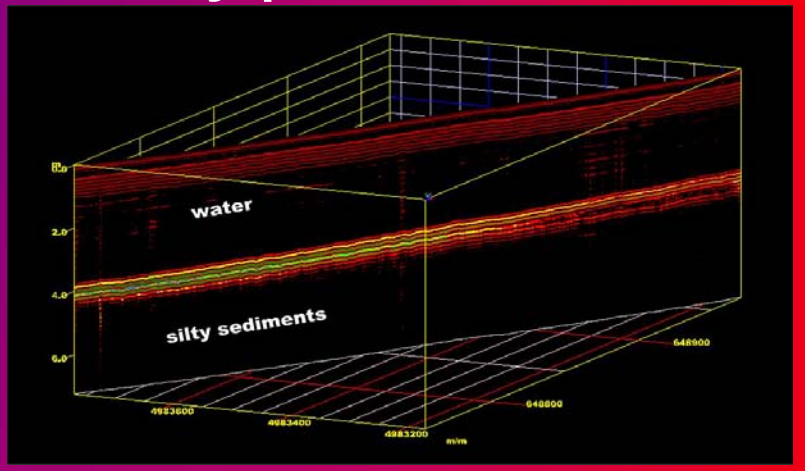
Use of GPR for soil survey investigations is limited by the medium.

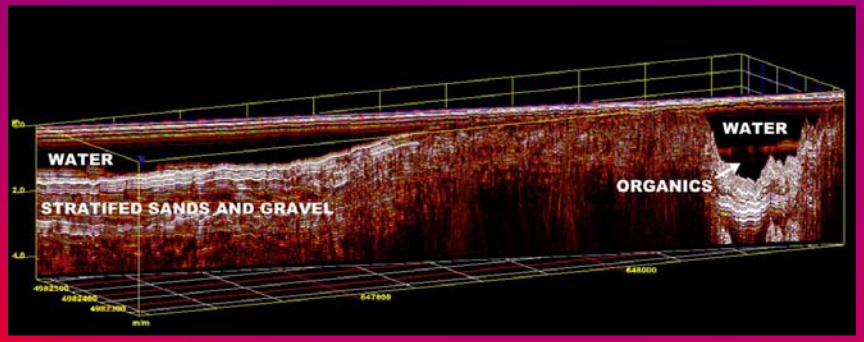
- **In the conterminous USA, only 22 % of the soils are considered well suited to GPR.**
- **About 36 % and 7 % of the soils are considered poorly suited and unsuited to GPR, respectively.**

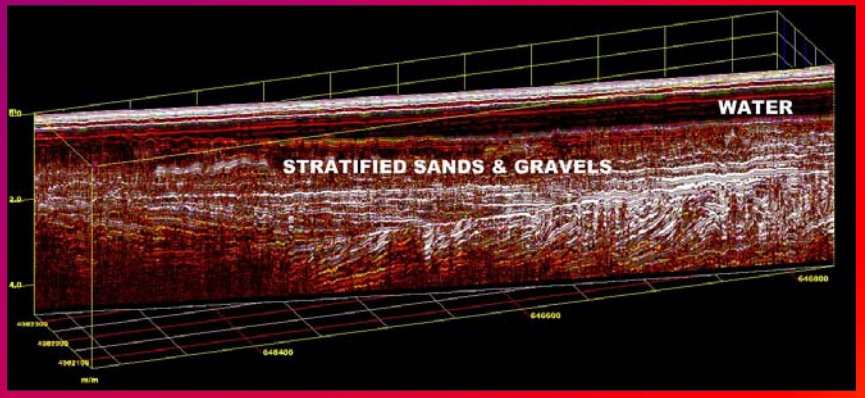
Subaqueous Soils

Different strokes for different folks:

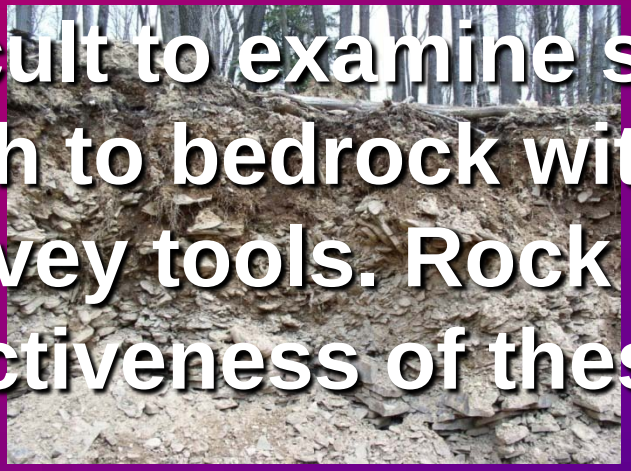
GPR can provide data on fresh water depths, subbottom topographies, and sediment types.



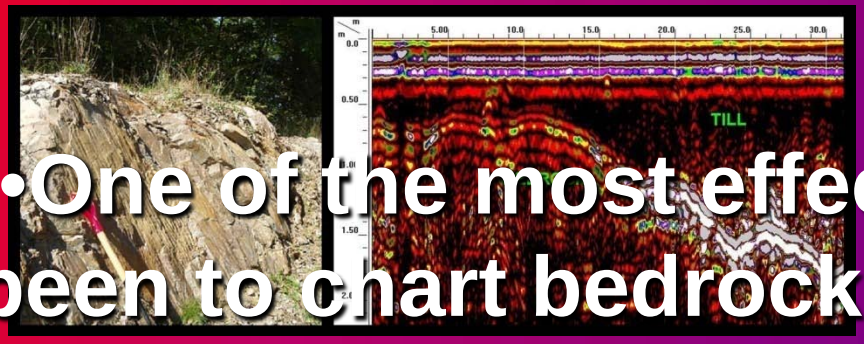


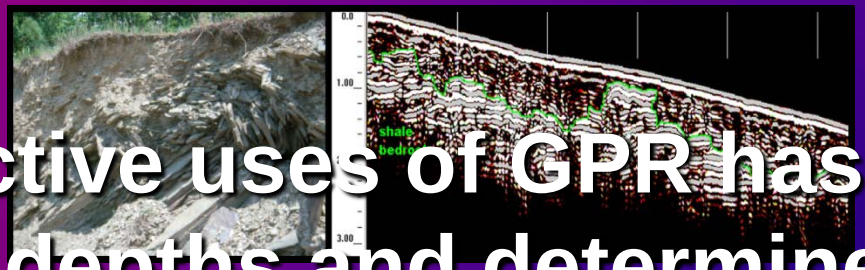


Soil Depth Determinations



- In upland areas it is difficult to examine soils and determine the depth to bedrock with conventional soil survey tools. Rock fragments limit the effectiveness of these tools.





- One of the most effective uses of GPR has been to chart bedrock depths and determine the taxonomic composition of soil map units based on soil-depth criteria.

EMI

Early EMI Methods

- Required the establishment of a survey grid.
- Time-consuming pedestrian surveys were conducted by an operator and a recorder moving from one grid point to the next.

Analog to Digital

In the early 1990's, soil scientists first used data loggers with EMI meters.

- Greatly reduced field time, but still required the setup of survey grids.
- Data were more accurately recorded and transferred to computers for processing and display.

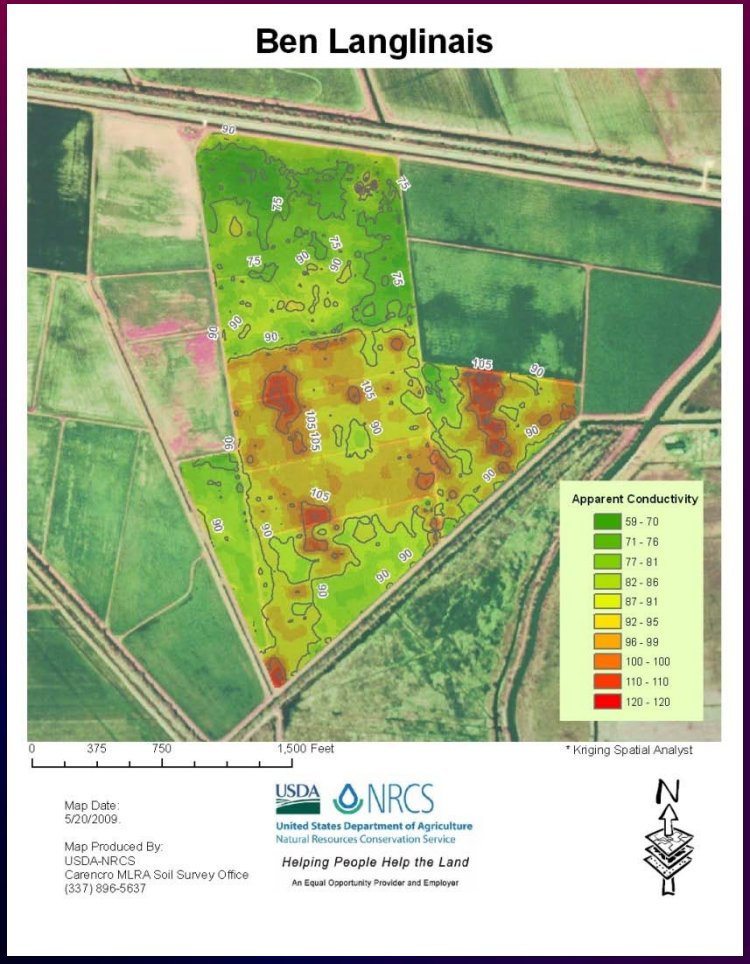
In the early 2000's, field computers and GPS receivers became integral components of EMI systems.

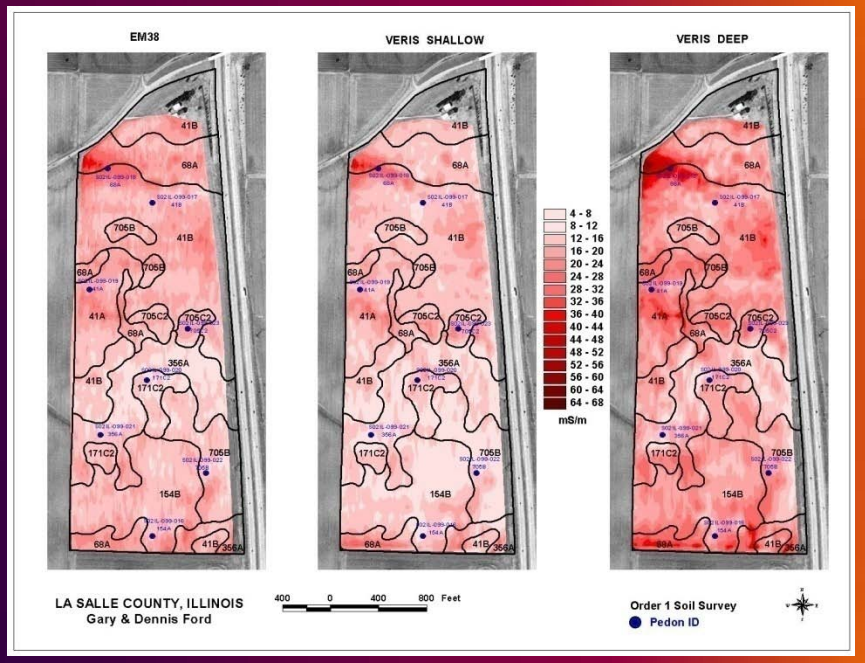
- EMI data now continuously recorded and georeferenced .
- Survey grids are no longer required.
- Allows mobile EMI surveys.
- Greatly reduces field time and labor.

In 2009, EMI meters, GPS receivers, and tablets are first used together by soil scientists.

- Used available technologies.
- Reduced expenditures.
- Method preferred by many soil scientists.

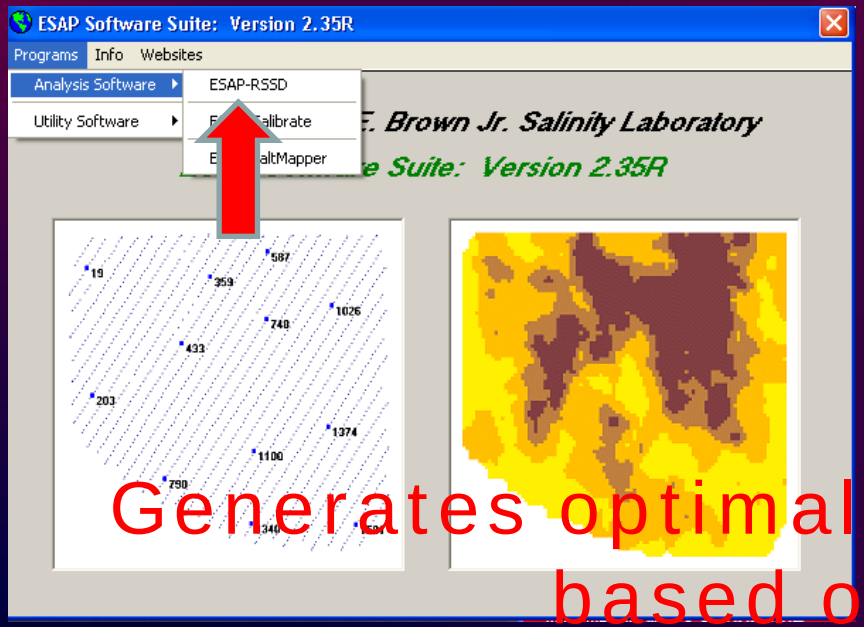
Some soil staffs have successfully integrated EMI with GIS.

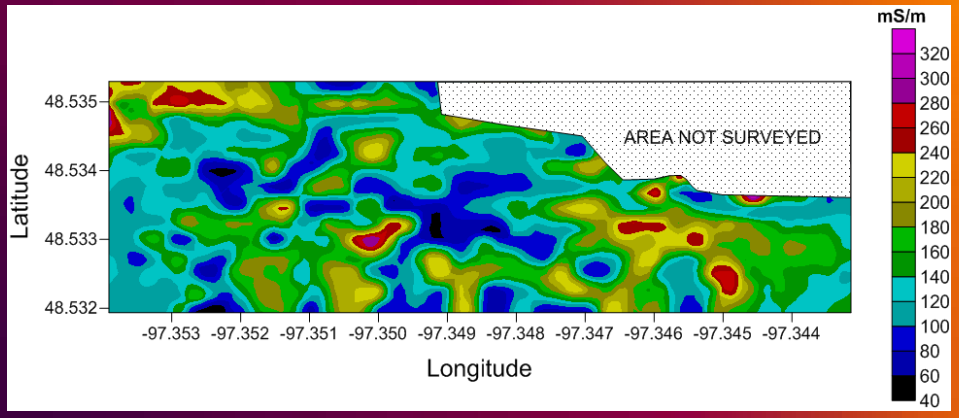


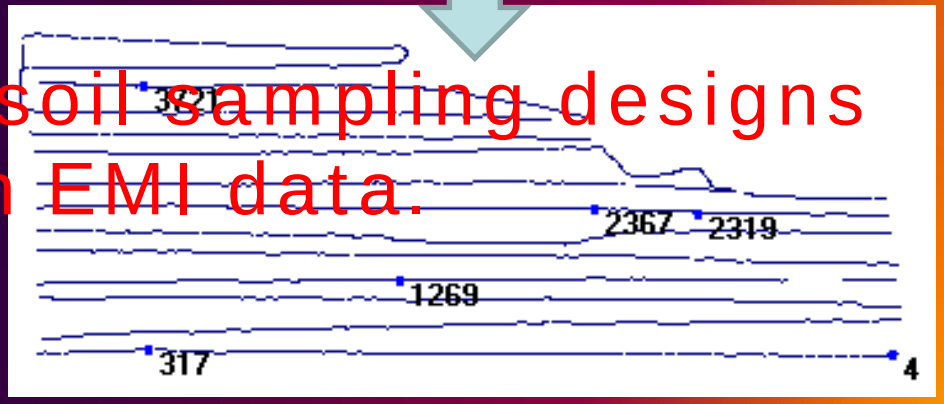


ESAP Software

RESPONSE SURFACE SAMPLING DESIGN

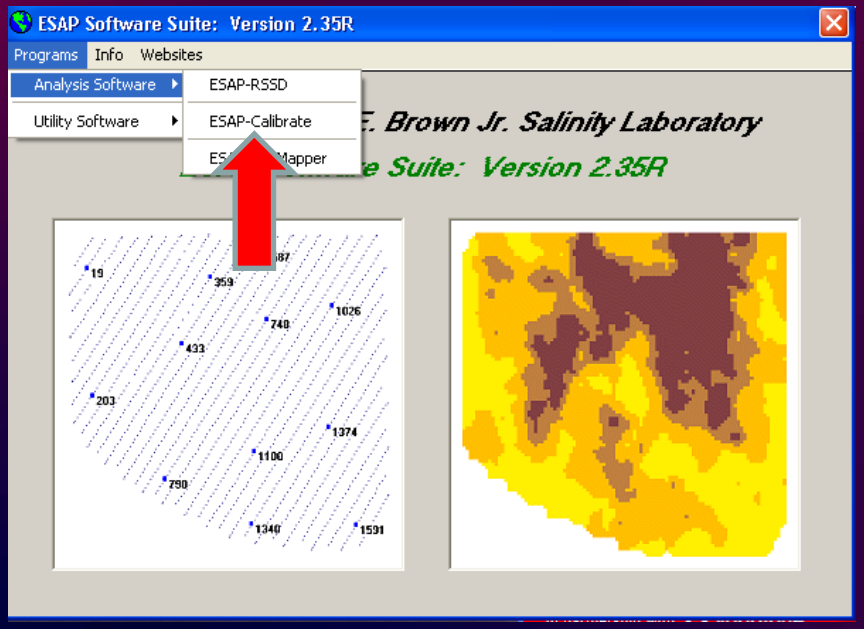


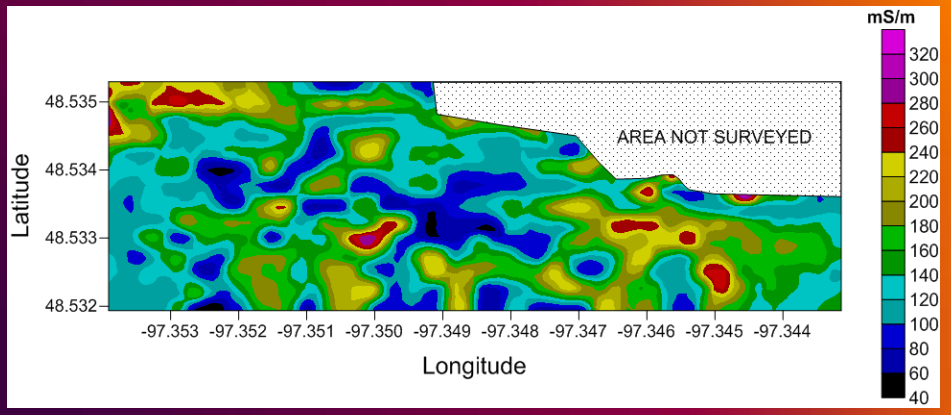


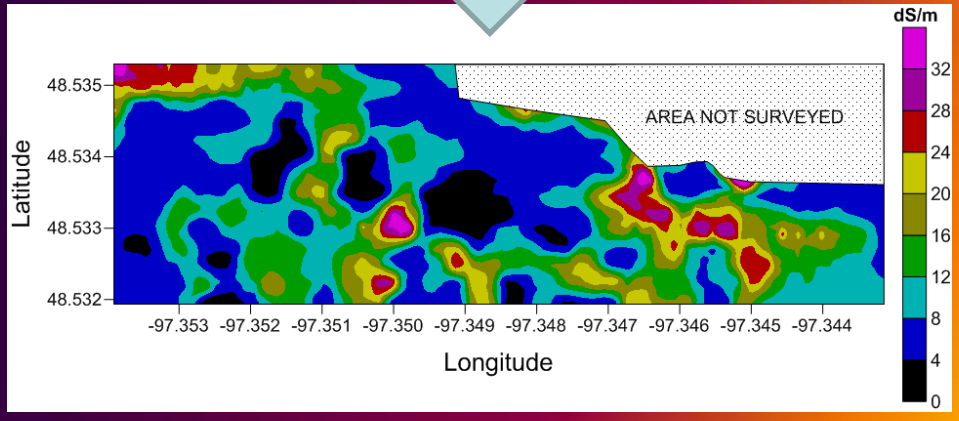


Generates optimal soil sampling designs based on EMI data.

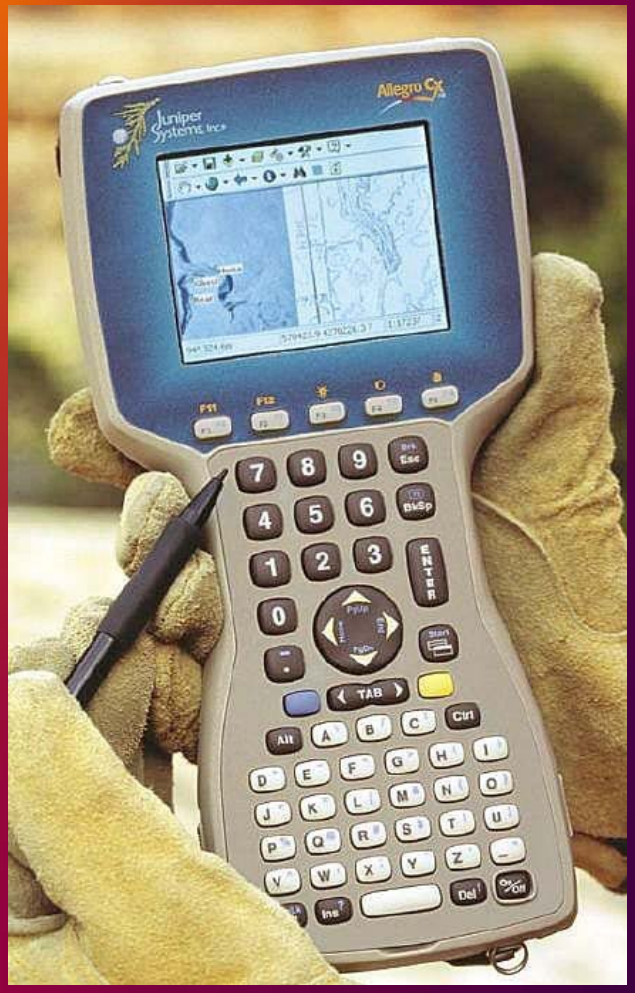
Stochastic and deterministic models are available to convert EC_a into EC_e







INTEGRATED ACCESSORIES ADD ADDITIONAL $$$



Field computer

GPS receiver

New software

PRICES OF EMI METERS HAVE RISEN.

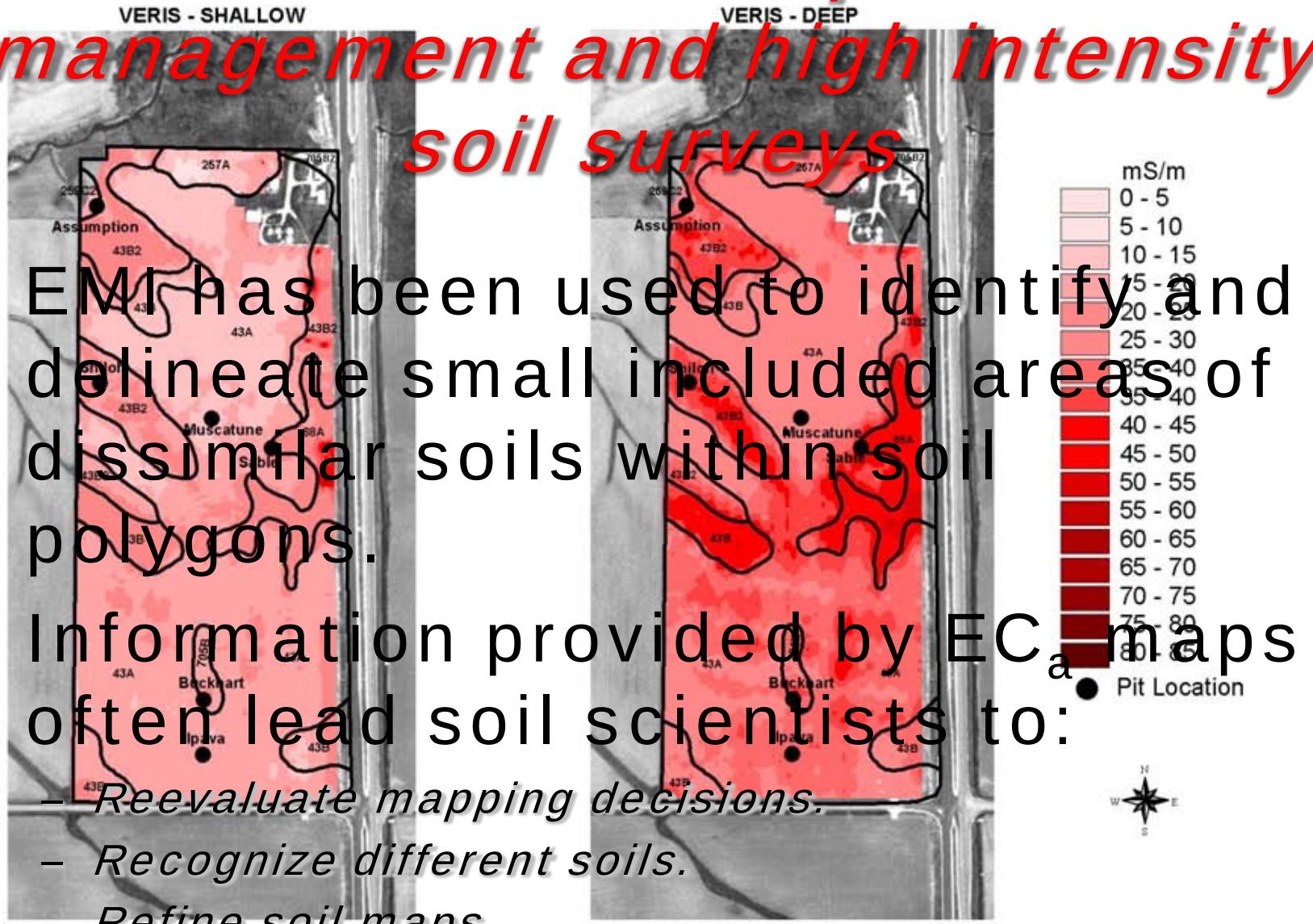
EM38MK2-2 meter 2009	$17,200
EM38DD meter 2002	$19,100
EM38 meter 2002	$7,965

Uses of EMI in Soil Surveys:

- High intensity soil surveys.
- Documenting within map unit variability.
- Mapping saline and sodium-affected soils.



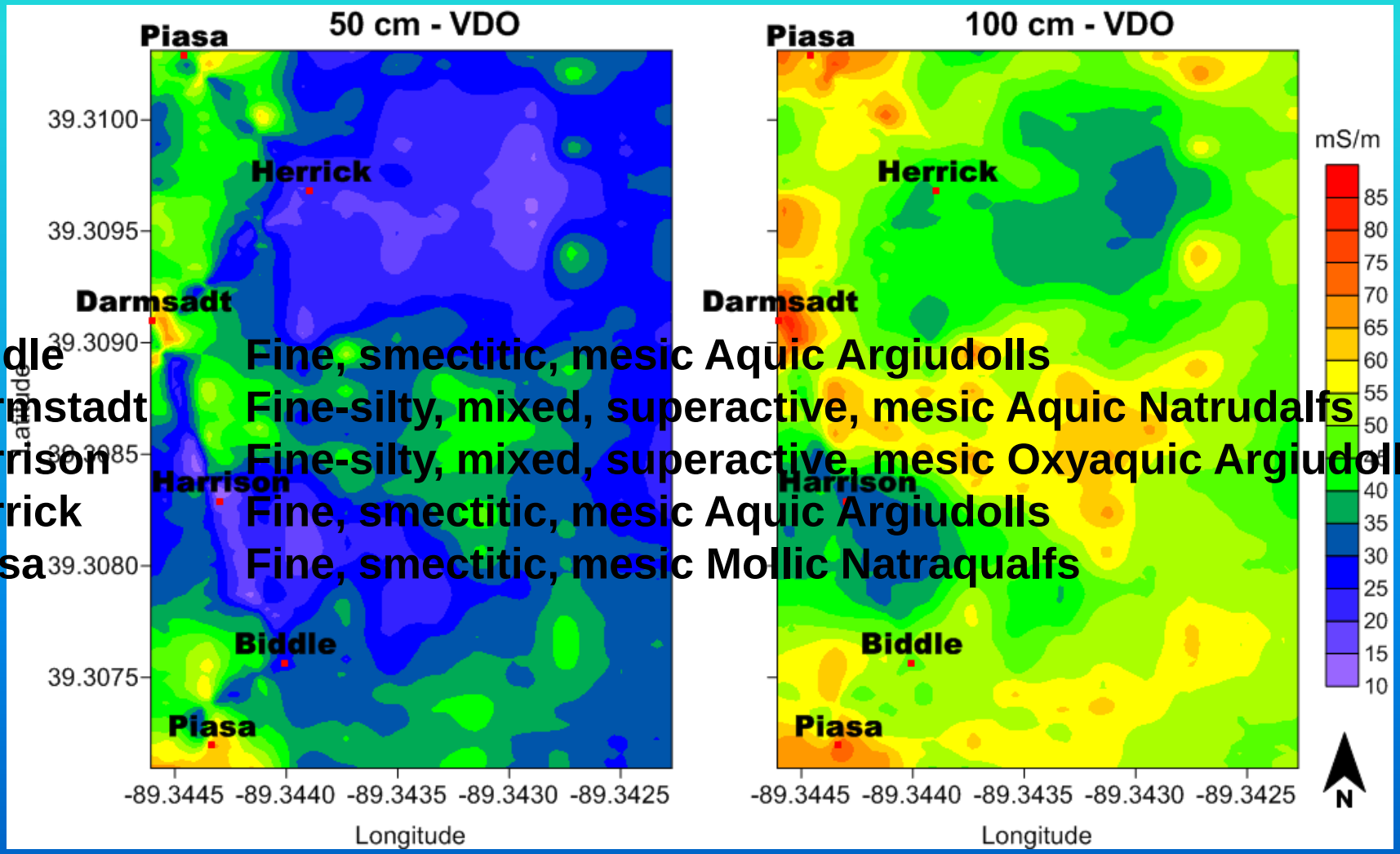

A tool for site-specific management and high intensity soil surveys



- EMI has been used to identify and delineate small included areas of dissimilar soils within soil polygons.
- Information provided by EC_a maps often lead soil scientists to:
  - *Reevaluate mapping decisions.*
  - *Recognize different soils.*
  - *Refine soil maps.*
  - *Have greater confidence in mapping decisions.*

Montgomery County, Illinois

Herrick-Biddle-Piasa silt loams, 0 to 2 % slopes



Biddle Fine, smectitic, mesic Aquic Argiudolls

Darmstadt Fine-silty, mixed, superactive, mesic Aquic Natrudalfs

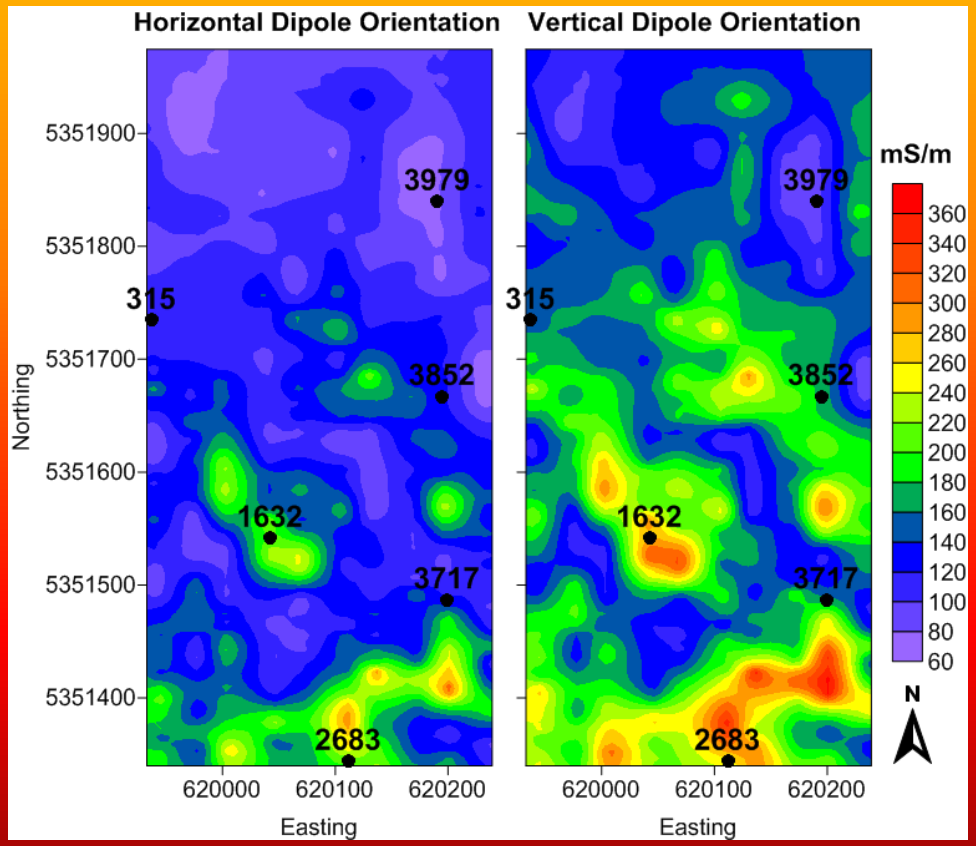
Harrison Fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls

Herrick Fine, smectitic, mesic Aquic Argiudolls

Piasa Fine, smectitic, mesic Mollic Natraqualfs

SOIL SALINITY

Salinity Appraisal
Walsh County, North Dakota



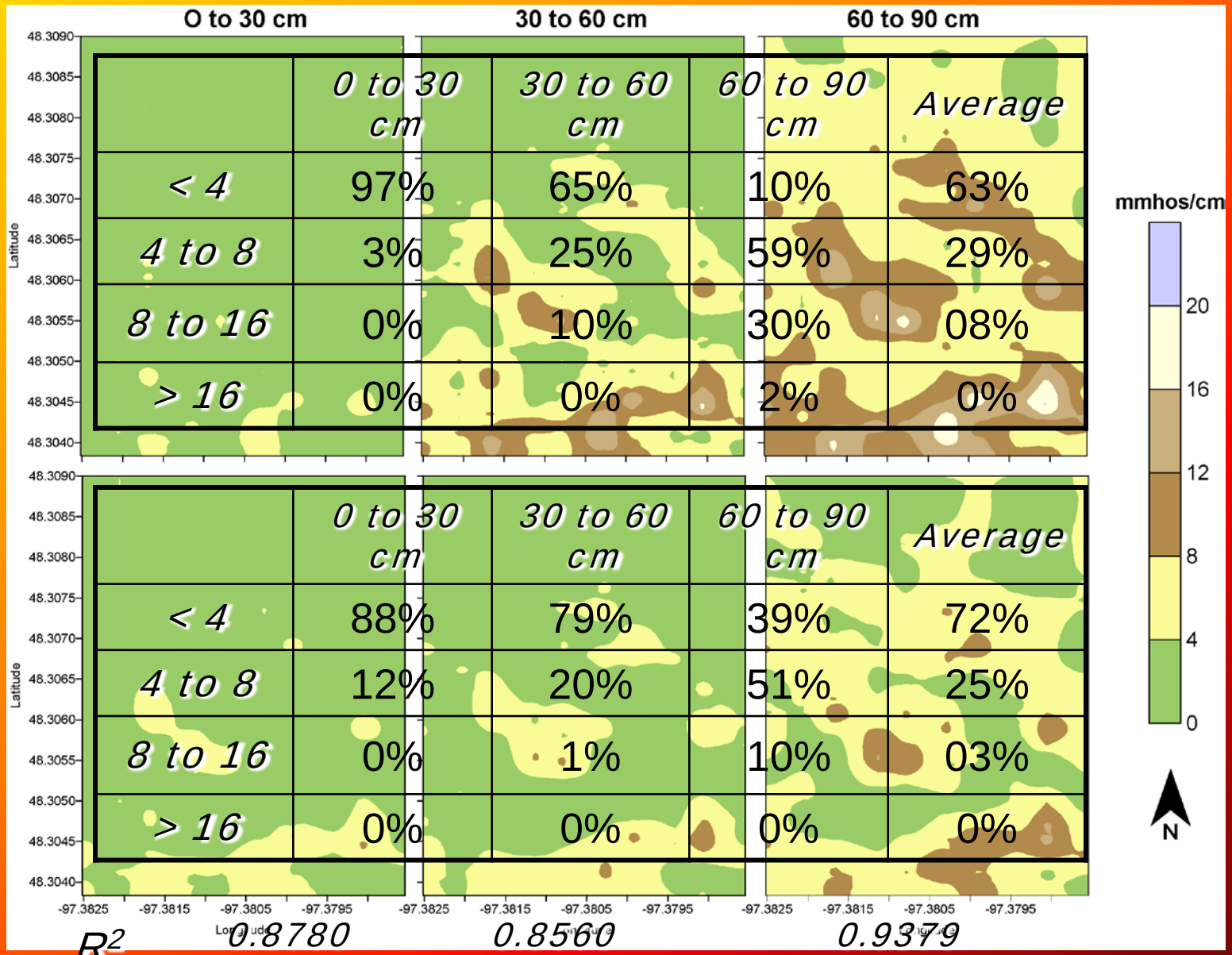
Plots of estimated soil salinity, Walsh County, ND

Deterministic

	0 to 30 cm	30 to 60 cm	60 to 90 cm	Average
< 4	97%	65%	10%	63%
4 to 8	3%	25%	59%	29%
8 to 16	0%	10%	30%	08%
> 16	0%	0%	2%	0%

Stochastic

	0 to 30 cm	30 to 60 cm	60 to 90 cm	Average
< 4	88%	79%	39%	72%
4 to 8	12%	20%	51%	25%
8 to 16	0%	1%	10%	03%
> 16	0%	0%	0%	0%

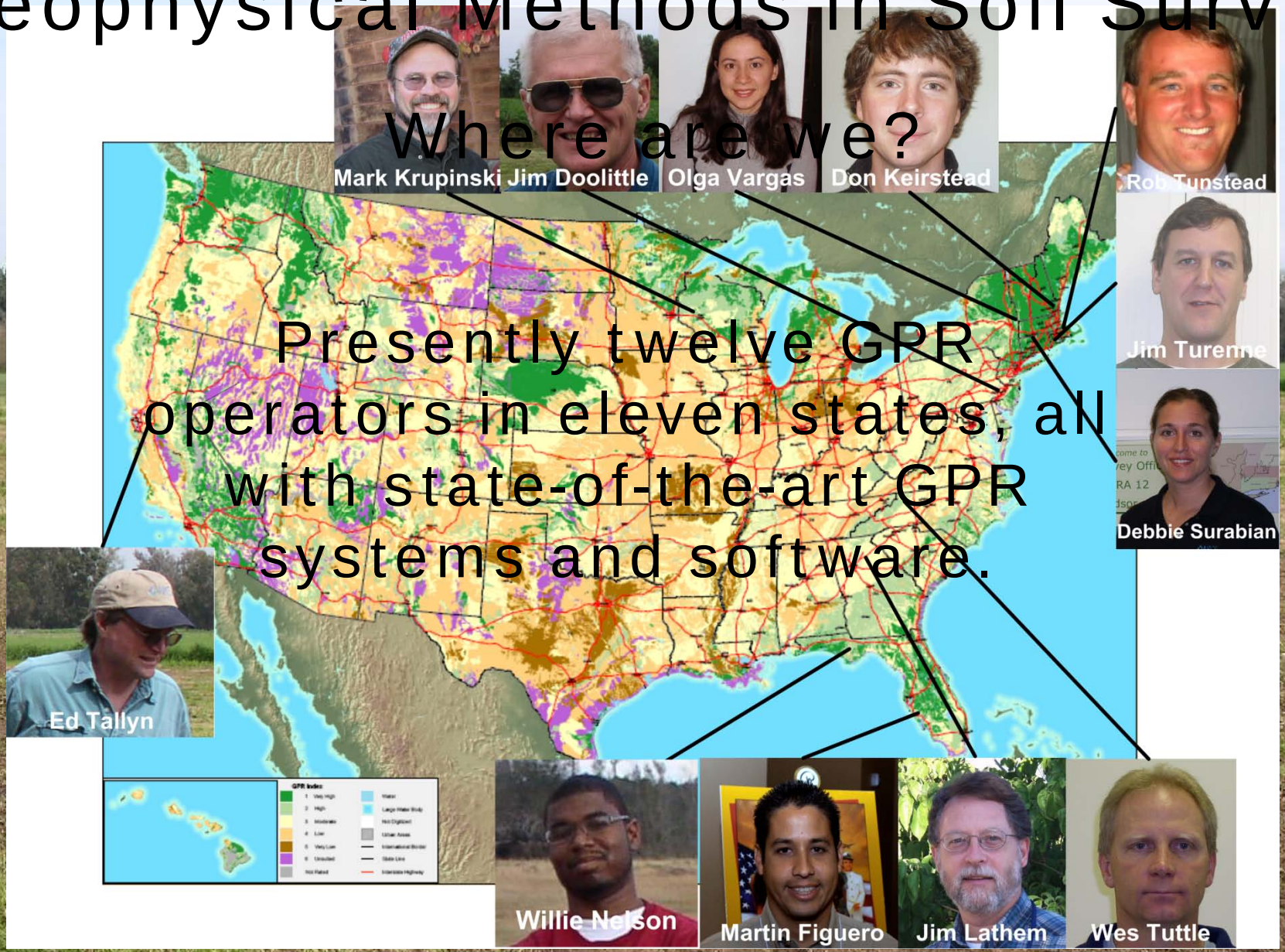


R^2 0.8780 0.8560 0.9379

The correlation values indicate the stochastic calibration model's ability to predict ECe from EMI data at different depths.

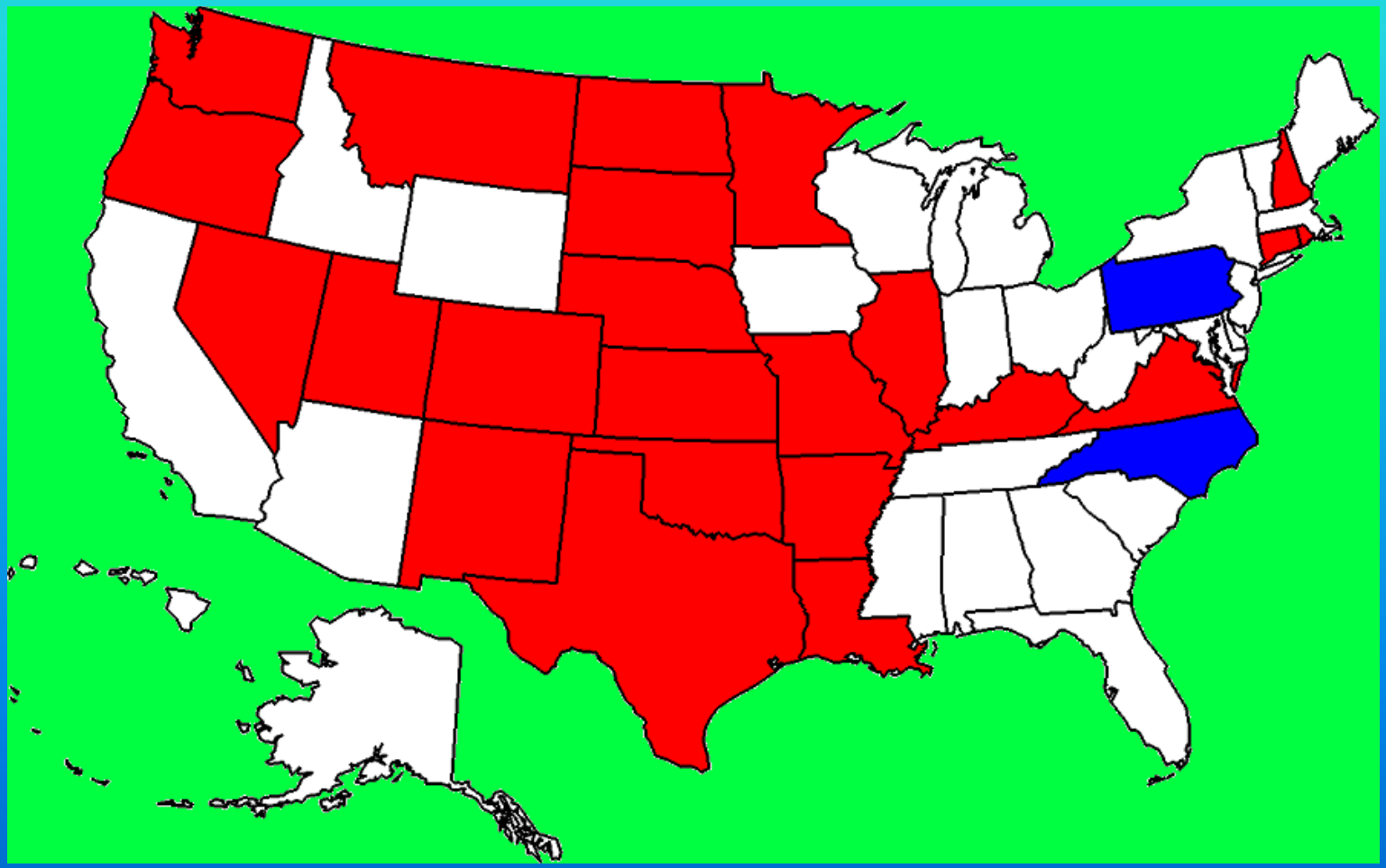
Geophysical Methods in Soil Survey

Where are we?



Presently twelve GPR operators in eleven states, all with state-of-the-art GPR systems and software.

of states with EMI meters has dramatically increased.



An inventory of EMI Tools


EMI Equipment												
State	EM38	EM38MK2	EM38DD	EM31	EM34-3	EM69	GEM300	Dualem 2/4	Dualem-1	Veris	Allegro field computer	Software
AR	1				1	1					1	DAT38W
CO	3	1	1				1	2				MAGMAP96, StarPal, DAT38 W, DAT38DDW
CT							1					MAGMAP96
IL	7			1						1	1	DAT31W, DAT38W,
KS	1										1	DAT38W
KY	1										1	DAT38W
LA									1		1	StarPal
MN	1										1	DAT38W
MO	1										1	DAT38W
MT	2										1	DAT38W
NE	1				1						1	DAT38W
NC	1			1				1			1	NSSC
NH		1									1	DAT38-MK1
ND	5											DAT38
NM									1			StarPal
NV	1										1	DAT38W
OK	1											DAT38
OR				1								StarPal
PA	1	1	1	1	1						2	NSSC
RI	1										1	DAT38W
SD				1								DAT31
TX	2							1				DAT38W
UT	3										3	DAT38W
VA	1			1							1	DAT38W, DAT31W
WA				1			1					DAT31W, MAGMAP96
Sum	34	3	2	7	3	1	3	4	2	1	19	


Approaching Storms

- CCE Certification:
  - Requirements for all software to be certified.
  - Some IT staffs have upset the purchase of geophysical equipment and software.
- Staying abreast of rapidly advancing and leapfrogging technologies.
- Rising costs of maintaining fully integrated and operational EMI and GPR systems.
- Operators lack of experience and field time.

Summary:

- Present GPR and EMI systems are well suited to soil survey investigations.
- We have come a long ways in thirty years. In many soils, the use of GPR and EMI to identify, characterize, and map soil features and properties offers advantages over traditional methods.

- Although there is a large number of GPR and EMI units within the Soil Survey Division:
  - Most are under-utilized.
  - Most operators lack sufficient experiences and confidence and therefore do not fully exploited existing technologies.

- Geophysical tools and integrated technologies are rapidly improving. Can we stay abreast and maintain our expertise?

- The effective use of geophysical methods is dependent on availability of processing software programs. These programs are not CCE certified. Use and development are being severely restricted.

- The effective use of geophysical methods within the Soil Survey Division may require a new order of organization and deployment.


THANK YOU