United States Department of Agriculture | **Natural Resources Conservation Service** | **11 Campus Boulevard, Suite 200 Newtown Square, PA 19073**

Subject: Soil - Geophysical Assistance **Date:** 23 May 2008

To: Serapio Flores Jr.
State Conservationist
USDA-NRCS,
220 East Rosser Avenue
P.O. Box 1458
Bismarck, ND 58502-1458

Purpose:
Electromagnetic induction (EMI) is being used to as a validation tool and to help select sampling sites for the salinity appraisal of MLRA 56, the Red River Valley of the North. This portion of the field investigation process involved the completion of high-intensity EMI surveys of nineteen fields that represent different MODIS-determined classes. As part of this process, detailed plots showing the locations of six optimal sampling sites were developed using the ESAP (version 2.35) software developed by USDA-ARS, US Salinity Laboratory in Riverside, California. Soil samples were collected for laboratory analysis at 108 optimal sampling sites by a team of soil scientists and technicians.

Participants:
Keith Anderson, MLRA Soil Survey Leader, USDA-NRCS, Fargo, ND
Steve Ashpole, Soil Conservation Technician, USDA-NRCS, Park River, ND
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Lance Duey, Soil Scientist, USDA-NRCS, Devils Lake, ND
Harry Forester, Technician, USDA-ARS, Salinity Lab., Riverside, CA
Alan Lepp, Soil Scientist, USDA-NRCS, Bismarck, ND
Brandon Schwab, Soil Scientist, USDA-NRCS, Devils Lake, ND
Rita Sveen, Soil Conservationist, USDA-NRCS, Park River, ND
Kyle Thomson, Soil Scientist, USDA-NRCS, Devils Lake, ND
Mike Ulmer, Senior Soil Scientists, MO7, USDA-NRCS, Bismarck, ND

Activities:
All field activities were completed during the period of 7 to 16 May 2008.

Summary:
1. This trip report provides documentation of the data collected with the EM38DD meter for each of the MODIS (moderate-resolution imaging spectroradiometer) generated class index values and site locations. In addition, a summary of the basic EC_a statistics and the locations of the optimal sampling sites within each of the sites are provided. Plots of EC_a data and the locations of sample sites are also enclosed in this summary report.

2. Moderately strong correlations were obtained between averaged EC_a and the *classes* (determined by principal component analysis) for the sampled field (r = -0.752 and -0.708 for measurements obtained in the vertical and horizontal dipole orientations, respectively). These findings are encouraging considering the wide range of parent materials, soil types (with textural classes ranging from sandy to clayey), soil drainage classes (ranging from very poorly drained to well drained), and soil temperatures (ranging from 34 ^{o} to 44 ^{o} F).

3. To avoid confusion, it is imperative that the sample pedon numbers are quickly associated with each site and the ESAP generated observation numbers.

It was my pleasure to work in North Dakota and with members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
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Equipment:
The EM38DD meter, manufactured by Geonics limited (Mississauga, Ontario) was used in this investigation.[1] This meter requires no ground contact and only one person to operate. The meter has a 1-m intercoil spacing and operates at a frequency of 14,600 Hz. The EM38DD meter consists of two, coupled EM38 meters. This instrument weighs about 2.8 kg (6.2 lbs). Operating procedures for the EM38DD meter are described by Geonics Limited (2000). When placed on the soil surface, these meters provide theoretical penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively. The EM38DD meter measures the apparent conductivity (EC_a) of earthen materials, which is expressed in milliSiemens/meter (mS/m).

To complete an EMI survey of a site, the EM38DD was placed in a plastic sled and towed behind a Polaris Ranger. An Allegro CX field computer (Juniper Systems, North Logan, UT) was used to record and store both EC_a and position data. The coordinates of each EC_a measurement were recorded with a Trimble AgGPS114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA).[1] The Trackmaker38DD software program developed by Geomar Software Inc. (Mississauga, Ontario) was used to record, store, and process EC_a and GPS data.[1]

To help summarize the results, the SURFER for Windows (version 8.0) software, developed by Golden Software, Inc., was used to construct the two-dimensional simulations shown in this report.[1] Grids were created using kriging methods with an octant search.

Selection of Study Sites (Scott Lesch):
Drs. Dennis Corwin, Scott Lesch, and David Lobell provided a list of sites within Walsh County based on MODIS (Moderate-resolution imaging spectroradiometer) data. The following is Scott Lesch's description of the procedures he used to select these sites:

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

"MEVI (mean enhanced vegetation index) values from MODIS imagery collected at multiple time frames above [Walsh County] were subjected to a principal components analysis. The first principal component (EVIPC1) was then extracted from this analysis and used as a stratification variable across the county. These spatial EVIPC1 readings were separated into 20 distinct classes, and 5 potential sampling locations were randomly chosen from within each class. The salinity sampling plan called for selecting a field corresponding to one of these five locations within each class, surveying these fields using EMI techniques, and acquiring a limited set of calibration soil samples based on the observed spatial EMI pattern.

In summary, this project employed a two-stage sampling approach. Stage 1 was set up as a stratified random sampling plan (where the EVIPC1 data were used as the stratification variable). Stage 2 was set up as a model-based (sensor directed) sampling plan, where soil samples within each field were chosen to represent the observed range and spatial variation in the EMI pattern observed within each field.

The fundamental goal of this project is to test if the mean estimated salinity levels across the 20 surveyed fields are correlated with the corresponding EVIPC1 values (associated with these fields). If a strong correlation can be established, then it should be possible to use the EVIPC1 data (derived from the MODIS imagery) to predict the spatial salinization potential across [Walsh] County (and hopefully the larger Red River Valley)."

These procedures provided 2 to 5 potential site locations in each of the 20 generated *classes*. From this list Rita Sveen and Steve Ashpole selected 1 site from each of the 20 classes for EMI surveying and soil sampling, and contacted the landowners for permission to access their fields. The identification and locations of each EVIPC1 (class and point #) of each of the selected field sites are listed in Table 1. This table also includes the symbols of the included soil map units and the measured soil temperature at a depth of 50 cm. Table 2 lists the soil map unit names and symbols for the delineations mapped in the selected sites. The taxonomic classifications of these soils are listed in Table 3.

Survey Procedures:
A mobile (using a Polaris Ranger) EMI survey was completed at each of the field sites in Walsh County. A mobile EMI survey provides more comprehensive site coverage, in a shorter period of time, and with less effort than the pedestrian surveys. In this survey, an EM38DD meter was towed behind a Polaris Ranger in a plastic sled at speeds of 2 to 4 m/sec. The EMI survey was completed by driving the Polaris Ranger at a uniform pace in a back and forth manner across each field. Using the NAV38DD program, both GPS and EC_a data were simultaneously recorded on an Allegro CX field computer.

All data were entered into an Excel spreadsheet. The EC_a data recorded on the Excel spreadsheet were processed thru the ESAP Software Suite. For each field, based on one measurement, EC_a data were temperature corrected to a standard temperature. Apparent conductivity increases with soil temperature. As the soil temperature rises, the soil water become less viscous and dissolved ions become more mobile. This results in higher EC_a values (McNeill, 1980). As it is impractical to account for variations at each point and at different soil depths, the correction factor is often based on a single measurement. Based on a single temperature measurement made in each field at a depth of 50 cm, all EC_a data shown in this report have been corrected to a standard temperature of 24^o C (75^o F) using equation [1] from Handbook 60 (U.S. Salinity Laboratory Staff, 1954):

$$EC_{25} = f_t EC_t \qquad [1]$$

Where, f_t is a temperature conversion factor. Temperatures varied from 34 to 44 ^{o} F. Soil scientists tasked with obtaining the soil samples often encountered relatively thick layers of frozen soil materials between depths of 60 and 100 cm.

Although high levels of soil salinity (areas with EC_a greater than 400 mS/m) existed in some fields, a natural log transformation was not applied to the data. For each site, plots of EC_a data, which were collected with the EM38DD meter in both the horizontal and vertical dipole orientations, were prepared using the ESAP Software Suite. One of the statistical programs available in ESAP is the Response Surface Sampling Design (RSSD). This program generates an optimal sampling design based on the EC_a data. Based on the response surface sampling design, six optimal sampling locations were selected within the surveyed portions of each field. In each field, survey grids were established at a distance from road and field boundaries where artificially induced levels of soil salinity are more likely to occur.

Table 1. Summary of Pertinent Field Site Data.

Site #	Point	Location	Soil Map Units	Temperature (F)
1	5	SE 1/4 SEC 4 158-52	GiA, BnA	36
2	9	NE 1/4 SEC 33 156-51	HmA	37
3	12	SW 1/4 SEC 36 157 51	HmA	40
4	17	NW 1/4 SEC 18 155-51	BnA	37
5	21	SE 1/4sec 5 158-52	GiA	36
6	29	NW 1/4 SEC 30 156-52	BnA, HmA, Gr	37
8	39	SW 1/4 SEC 27 156-52	HmA, BnA	37
9	43	NW 1/4 SEC 7 156-53	BnA	34
10	50	NW 1/4 SEC 10 155-53	OiA, OIC	41
11	52	SE 1/4 SEC 35 158-52	BnA	42
12	57	NE 1/4 SEC 23 156-54	BnA	42
13	62	NE 1/4 SEC 2 155-53	Ow, OiB	37
14	69	SE 1/4 SEC 14 155-54	GiA	43
15	72	SE 1/4 SEC 30 158-30	HiA	42
16	78	SW 1/4 SEC 5 157-54	Bm, BnA	36
17	82	NW 1/4 SEC 27 158-53	FfA, BnA	42
18	87	SW 1/4 SEC 29 158-55	HiA, HiB	42
19	91	NW 1/4 SEC 20 158-54	GiA	34
20	57	NW 1/4 SEC 11 158-55	BnA, Bo	44

Table 2. Summary of sampled soil map unit names and symbols.

Symbol	Soil Map Unit
Bm	Bearden silt loam
BnA	Bearden silty clay loam, level
Bo	Bearden silty clay loam, fan
FfA	Fargo silty clay, level
GiA	Glyndon silt loam, level
Gr	Grano silty clay, very wet
HiA	Hecla loamy sand, nearly level
HiB	Hecla loamy sand, gently undulating
HmA	Hegne-Fargo silty clays, nearly level
OiA	Overly silty clay loam, nearly level
OiB	Overly silty clay loam, gently sloping
OiC	Overly silty clay loam, sloping
Ow	Overly silty clay, fans

Table 3. Taxonomic Classification of Soils.

Soil Series	Taxonomic Classification
Bearden	Fine-silty, mixed, superactive, frigid Aeric Calciaquolls
Fargo	Fine, smectitic, frigid Typic Epiaquerts
Glyndon	Coarse-silty, mixed, superactive, frigid Aeric Calciaquolls
Grano	Fine, smectitic, frigid Typic Endoaquerts
Hecla	Sandy, mixed, frigid Oxyaquic Hapludolls

Hegne	Fine, smectitic, frigid Typic Calciaquerts
Overly	Fine-silty, mixed, superactive, frigid Pachic Hapludolls

Plots of EC_a data showing the locations of the six optimal sampling points within each site were compiled and copies used by soil scientists involved in soil sampling. The collected soil samples will be tested for EC from saturated paste extract, saturation percent, and field moisture content. In addition, chloride will be determined on the upper and lower layers.

Results:
Table 4 provides the basic statistics for the EMI surveys that were completed at the nineteen sites in Walsh County. In general, EC_a decreased with increasing *Class* numbers. Based on interpretations of the MODIS imagery and principal component analysis, sites with lower *Class* numbers were hopefully anticipated to be associated with high levels of soil salinity. At the surveyed sites, an inverse relationship exists between *Class* number and EC_a. Moderately strong correlations were obtained between averaged EC_a and *class* number for the sampled fields ($r = -0.752$ and -0.708 for measurements obtained in the vertical and horizontal dipole orientations, respectively). These findings are encouraging considering the wide range of parent materials, soil types (with textural classes ranging from sandy to clayey), soil drainage classes (ranging from very poorly drained to well drained), and soil temperatures ($34\ ^{o}$ to $44\ ^{o}$ F) experienced in the Walsh County EMI survey.

Table 5 summarizes the locations of the sample sites within the selected fields (determined by *class* inclusion). These data are presented as documentation that is designed to avoid confusion during subsequent analyses by different group members.

Spatial Patterns of EC_a:
Spatial EC_a patterns within each of the nineteen sites are shown in the accompanying plots. Sites have been arranged according to ascending "*class*" numbers. EC_a was variable both within and between sites. For display purposes, the same color scale and intervals were used in each plot. In each of the accompanying figures, separate plots show the spatial distribution of EC_a in both the shallower-sensing (0 to 75 cm) horizontal or deeper-sensing (0 to 150 cm) vertical dipole orientations. The locations of the soil sampling sites and their identifier (observation #) are shown in these plots.

References:
Geonics Limited, 2000. EM38DD ground conductivity meter: Dual dipole version operating manual. Geonics Ltd., Mississauga, Ontario.

McNeill, J. D., 1980. Electrical conductivity of soils and rock; Technical Note TN-5: Geonics Limited, Mississauga, Ontario, Canada,

U.S. Salinity Laboratory Staff, 1954. Diagnosis and improvement of saline and alkali soils, USDA Handbook 60. U.S. Government Printing Office, Washington, DC, USA.

Table 4. Basic statistics for the twenty sampled fields.
With the exception of *Number*, all values are measures of EC_a expressed in mS/m

Site	*Dipole*	*Number*	*Mean*	*Std. Dev*	*Minimum*	*25%tile*	*75%tile*	*Maximum*
Site 1	VDO	4356	253.6	87.8	66.8	188.4	310.7	600.4
Site 1	HDO	4356	163.9	70.6	42.4	110.5	205.4	550.1
Site 2	VDO	2096	163.9	36.3	93.1	140.1	188.4	283.3
Site 2	HDO	2096	106.7	27.9	56,6	84.8	124.3	206.6
Site 3	VDO	3258	197.3	48.4	102.9	157.7	234.5	368.7
Site 3	HDO	3258	142.8	37.5	71.2	112.0	168.7	318.7
Site 4	VDO	4014	205.0	94.7	71.8	127.3	269.2	526.4
Site 4	HDO	4014	130.0	67.4	29.9	75.2	171.3	386.9
Site 5	VDO	3899	271.5	101.4	89.3	93.4	329.8	623.8
Site 5	HDO	3899	157.7	72.4	26.8	101.5	195.3	424.6
Site 6	VDO	4461	174.4	52.7	81.8	138.0	199.1	370.4
Site 6	HDO	4461	128.6	41.3	61.1	99.5	145.3	314.0
Site 8	VDO	4416	200.8	38.2	92.7	171.3	226.0	384.1
Site 8	HDO	4416	131.5	29.9	71.6	110.4	147.4	340.5
Site 9	VDO	4471	92.4	27.6	50.9	73.5	104.9	206.6
Site 9	HDO	4471	51.5	20.6	20.8	36.7	60.8	131.8
Site 10	VDO	3155	102.8	15.3	72.4	91.3	112.3	154.4
Site 10	HDO	3155	58.8	12.4	33.7	49.8	65.7	106.5
Site 11	VDO	3511	113.4	37.6	56.9	84.5	133.4	336.5
Site 11	HDO	3511	71.3	26.1	29.2	52.8	83.4	248.5
Site 12	VDO	5825	137.6	48.5	65.5	102.2	162.6	355.0
Site 12	HDO	5825	96.4	37.7	44.3	70.0	110.8	290.3
Site 13	VDO	3151	108.4	19.2	61.3	95.9	121.3	186.1
Site 13	HDO	3151	74.8	13.3	44.7	65.8	83.1	144.8
Site 14	VDO	4105	62.4	24.0	32.4	44.3	75.9	148.7
Site 14	HDO	4105	40.5	18.4	15.3	27.3	50.4	111.0
Site 15	VDO	3809	32.7	4.2	20.4	29.4	35.9	47.7
Site 15	HDO	3809	18.9	3.5	11.4	16.1	21.4	34.9
Site 16	VDO	5495	83.1	17.7	44.3	69.6	93.4	127.6
Site 16	HDO	5495	49.8	13.0	22.1	40.5	58.7	137.0
Site 17	VDO	2253	142.1	38.5	73.0	115.1	158.1	264.8
Site 17	HDO	2253	113.3	24.9	58.6	94.9	129.4	202.0
Site 18	VDO	3135	35.1	5.2	23.5	31.4	38.4	54.3
Site 18	HDO	3135	20.6	5.1	12.6	16.7	23.7	56.9
Site 19	VDO	4121	85.5	19.8	51.4	71.7	94.7	164.0
Site 19	HDO	4121	56.3	14.9	29.7	45.9	62.8	119.2
Site 20	VDO	2186	136.2	29.52	67.8	115.8	158.9	203.8
Site 20	HDO	2186	94.8	22.6	41.8	78.9	108.7	174.0

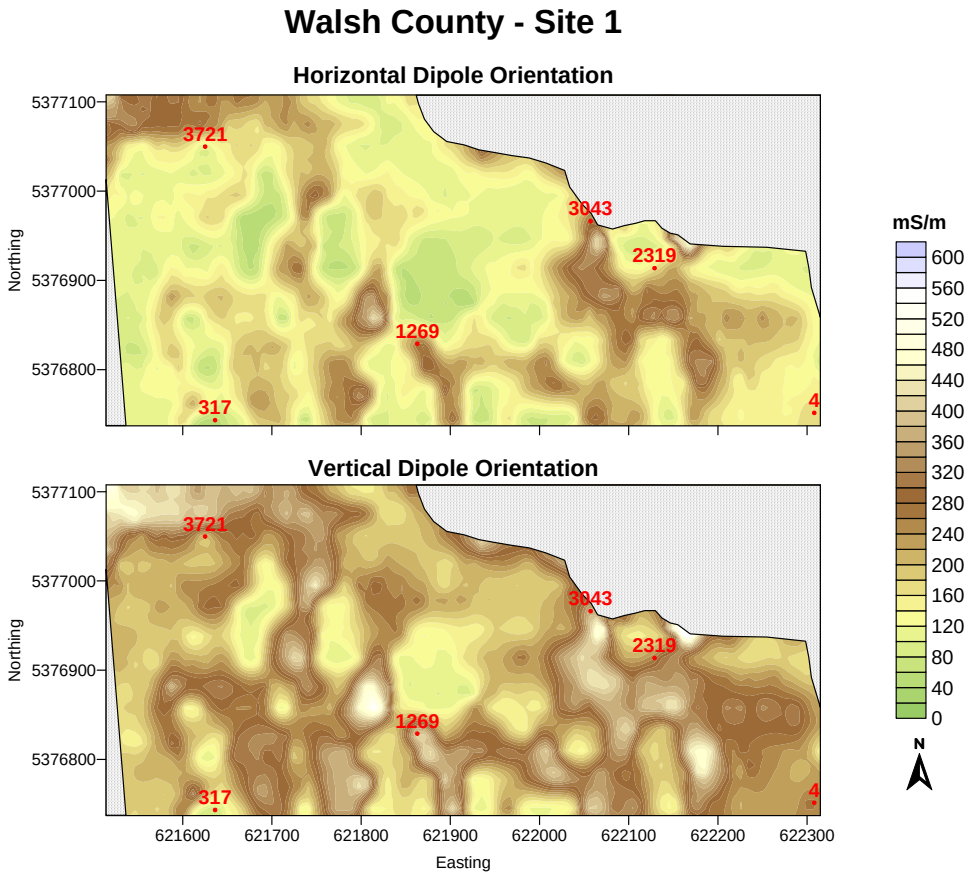
Table 5 Sampling Point Data.

Site (Class)	OBS	Longitude	Latitude	Easting	Northing	EM38DD VDO	EM38DD HDO
Site 1							
SE 1/4 4 158-52							
	4	-97.34325	48.53194	622308.000	5376751.516	272.6	176.9
	317	-97.35235	48.53200	621636.243	5376743.356	83.5	51.6
	1269	-97.34926	48.53273	621863.001	5376828.964	422.9	269.2
	2319	-97.34563	48.53344	622128.968	5376913.632	255.9	165.5
	3043	-97.34659	48.53392	622057.224	5376966.192	377.3	286.1
	3721	-97.35241	48.53476	621625.112	5377049.813	194.6	91.4
Site 2							
NE1/4 Sec 33 156-51							
	155	-97.19246	48.29261	634067.736	5350402.444	163.9	107.0
	360	-97.19277	48.29369	634041.949	5350522.349	95.1	67.1
	692	-97.19372	48.29267	633973.999	5350406.592	209.8	154.9
	1341	-97.19499	48.29371	633877.114	5350519.993	231.4	145.5
	1436	-97.19499	48.29260	633880.144	5350397.252	120.5	65.6
	2081	-97.19629	48.29416	633779.575	5350568.321	157.5	101.3
Site 3							
NW 1/4 10 155-53							
	38	-97.16481	48.37262	635905.711	5359343.393	129.3	83.4
	356	-97.16527	48.36927	635879.996	5358971.130	279.9	193.2
	822	-97.16545	48.37154	635860.968	5359223.214	186.3	133.6
	1778	-97.16645	48.36954	635792.316	5358998.593	117.2	95.3
	2118	-97.16683	48.37245	635756.430	5359320.890	193.8	139.7
	2259	-97.16683	48.37089	635760.799	5359147.705	267.3	211.5
Site 4							
NW1/4 Sec 18 155-51							
	365	-97.25367	48.24735	629641.970	5345266.501	203.4	128.6
	737	-97.25328	48.24989	629664.794	5345550.016	96.6	67.7
	1758	-97.25225	48.25121	629737.978	5345698.357	347.6	250.8
	2228	-97.25160	48.24671	629797.548	5345199.245	389.0	241.2
	2807	-97.25115	48.25004	629822.303	5345570.442	182.7	112.6
	3819	-97.25030	48.24877	629888.771	5345429.925	101.3	44.9
Site 5							
SE 1/4 5 158-52							
	152	-97.36985	48.53508	620337.062	5377058.091	452.5	308.3
	349	-97.37576	48.53510	619900.799	5377050.527	295.1	172.6
	1008	-97.37319	48.53463	620091.859	5377002.691	190.1	82.9
	1425	-97.36674	48.53435	620568.591	5376982.204	274.5	159.3
	2029	-97.37105	48.53423	620250.795	5376962.033	109.9	63.8
	2103	-97.36870	48.53417	620424.482	5376958.333	450.1	261.9
Site 6							
NE1/4 Sec 30 156-52							
	315	-97.38251	48.30743	619937.033	5351734.551	152.8	96.8
	1632	-97.38115	48.30567	620042.396	5351541.464	280.7	194.4
	2683	-97.38026	48.30388	620111.896	5351343.727	247.4	200.0
	3717	-97.37904	48.30515	620199.369	5351486.675	177.7	130.3
	3852	-97.37905	48.30677	620194.924	5351667.066	172.8	126.7
	3979	-97.37906	48.30832	620190.730	5351839.733	90.6	79.3

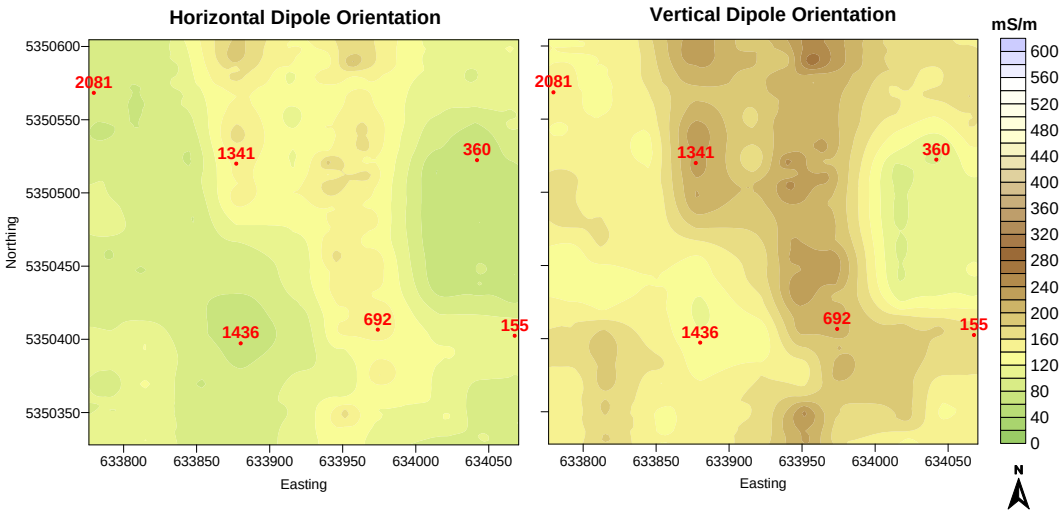
Site (Class)	OBS	Longitude	Latitude	Easting	Northing	EM38DD VDO	EM38DD HDO
Site 8 SW1/4 Sec 27 156-52							
	347	-97.312601	48.29667	625146.983	5350651.246	278.8	177.5
	471	-97.314751	48.29670	624987.462	5350650.240	254.9	182.2
	1448	-97.318553	48.29759	624703.270	5350743.750	156.6	86.7
	2013	-97.316298	48.29777	624870.069	5350767.429	200.8	131.2
	4084	-97.31368	48.29915	625060.891	5350924.355	129.5	88.4
	4360	-97.318038	48.29920	624737.552	5350923.459	193.8	125.2
Site 9 NW 1/4 7 156-53							
	172	-97.51097	48.35373	610312.007	5356688.266	132.3	90.9
	955	-97.50949	48.35331	610422.793	5356643.935	92.7	51.8
	2007	-97.51052	48.35269	610347.710	5356572.853	54.0	26.5
	2175	-97.51300	48.35270	610164.007	5356570.607	86.6	47.9
	2620	-97.50847	48.35230	610500.360	5356533.463	143.2	79.6
	4319	-97.51093	48.35145	610319.685	5356434.443	71.9	30.0
Site 10 SW 1/4 36 157-51							
	117	-97.49123	48.25089	611999.033	5345285.999	133.7	76.0
	623	-97.48776	48.24877	612261.192	5345056.372	74.0	43.8
	835	-97.49088	48.24889	612029.837	5345064.602	101.6	57.7
	1973	-97.48973	48.25046	612111.505	5345241.138	86.7	38.9
	2147	-97.48771	48.25064	612260.817	5345264.232	122.4	81.7
	2981	-97.48897	48.25160	612165.698	5345368.582	100.0	55.6
Site 11 SE 1/4 35 158-52							
	843	-97.30808	48.45658	625089.556	5368431.365	215.2	134.0
	1076	-97.30485	48.45673	625328.397	5368453.602	168.5	117.1
	1775	-97.30106	48.45721	625606.927	5368512.928	111.4	69.8
	2268	-97.30378	48.45770	625404.931	5368563.715	62.0	42.2
	3228	-97.31022	48.45845	624926.741	5368636.510	104.5	65.7
	3334	-97.30655	48.45840	625198.092	5368636.641	60.0	30.2
Site 12 NE 1/4 23 156-54							
	125	-97.53790	48.32168	608384.737	5353088.053	92.6	51.4
	327	-97.54134	48.32169	608130.054	5353084.097	215.3	139.1
	899	-97.53662	48.32188	608479.279	5353111.199	134.1	93.2
	3397	-97.54301	48.32321	608002.956	5353250.475	203.0	155.5
	3952	-97.53772	48.32348	608394.658	5353287.492	71.0	57.5
	4562	-97.54044	48.32373	608192.690	5353312.058	125.3	85.5
Site 13 NE1/4 Sec 2 155-53							
	474	-97.41460	48.27894	617623.043	5348519.065	79.7	50.8
	799	-97.41105	48.27872	617886.867	5348499.439	74.8	56
	1506	-97.41390	48.27773	617677.921	5348384.884	103.4	71.8
	1826	-97.41175	48.27746	617837.878	5348358.194	107.0	73.7
	2127	-97.41551	48.27677	617560.327	5348275.863	145.9	96.4
	2943	-97.41180	48.27582	617838.067	5348176.418	137.4	98.1

Site (Class)	OBS	Longitude	Latitude	Easting	Northing	EM38DD VDO	EM38DD HDO
Site 14 SE1/4 Sec 30 155-54							
	425	-97.54071	48.23891	608351.565	5343883.673	103.8	77.7
	1274	-97.53756	48.23946	608584.341	5343949.185	35.1	23.5
	2774	-97.53638	48.24083	608669.070	5344103.889	57.7	37.3
	3005	-97.54042	48.24085	608369.323	5344099.611	108.9	70.6
	3796	-97.54170	48.24172	608272.309	5344194.968	62.8	40.6
	4005	-97.53800	48.24171	608547.067	5344199.351	35.7	15.9
Site 15 Center Sec 30 158-55							
	47	-97.78467	48.47164	589827.817	5369436.099	23.3	15.5
	394	-97.78469	48.47475	589821.230	5369781.985	36.9	26.9
	1605	-97.78523	48.47359	589783.224	5369653.057	32.8	19.0
	2471	-97.78558	48.47427	589756.300	5369728.079	32.6	18.8
	2975	-97.78568	48.47250	589751.475	5369530.850	29.2	12.4
	3294	-97.78572	48.47523	589743.854	5369834.301	41.2	21.4
Site 16 SW 1/4 5 157-54							
	176	-97.64132	48.44923	600467.349	5367123.635	106.6	72.4
	401	-97.63755	48.44920	600746.151	5367125.135	85.0	50.8
	906	-97.64377	48.44882	600287.247	5367075.363	49.2	33.8
	3122	-97.63875	48.44804	600659.493	5366994.420	83.3	49.5
	4517	-97.64304	48.44754	600343.663	5366933.867	58.7	25.3
	5203	-97.63965	48.44722	600594.548	5366902.442	119.1	66.0
Site 17 NW 1/4 27 158-53							
	234	-97.46620	48.48168	613344.095	5370975.341	103.6	98.1
	784	-97.46412	48.48229	613496.237	5371046.400	217.7	145.5
	988	-97.46839	48.48274	613179.516	5371089.831	143.2	114.0
	1504	-97.46581	48.48335	613368.676	5371161.350	88.1	64.3
	1949	-97.46863	48.48404	613159.059	5371233.640	132.2	108.5
	2150	-97.46584	48.48430	613364.563	5371267.266	179.1	155.1
Site 18 SW 1/4 Sec 29 158-55							
	46	-97.77210	48.47644	590748.753	5369985.002	41.0	29.6
	658	-97.77241	48.47468	590728.902	5369788.948	33.9	19.6
	1347	-97.77249	48.47693	590718.938	5370038.328	46.3	26.3
	1475	-97.77316	48.47639	590670.118	5369978.434	24.7	15.7
	2134	-97.77410	48.47610	590601.503	5369944.311	31.8	13.5
	2284	-97.77491	48.47516	590542.985	5369839.464	34.7	20.2
Site 19 NW 1/4 20 158-54							
	321	-97.63966	48.49229	600505.187	5371911.698	53.3	37.4
	667	-97.64377	48.49207	600201.907	5371882.354	81.6	53.1
	1225	-97.64158	48.49177	600364.138	5371851.660	85.3	56.0
	2799	-97.64400	48.49107	600186.656	5371771.200	112.4	80.7
	3390	-97.64289	48.49069	600269.153	5371730.382	120.9	77.8
	3743	-97.64021	48.49050	600468.171	5371712.611	63.2	35.2

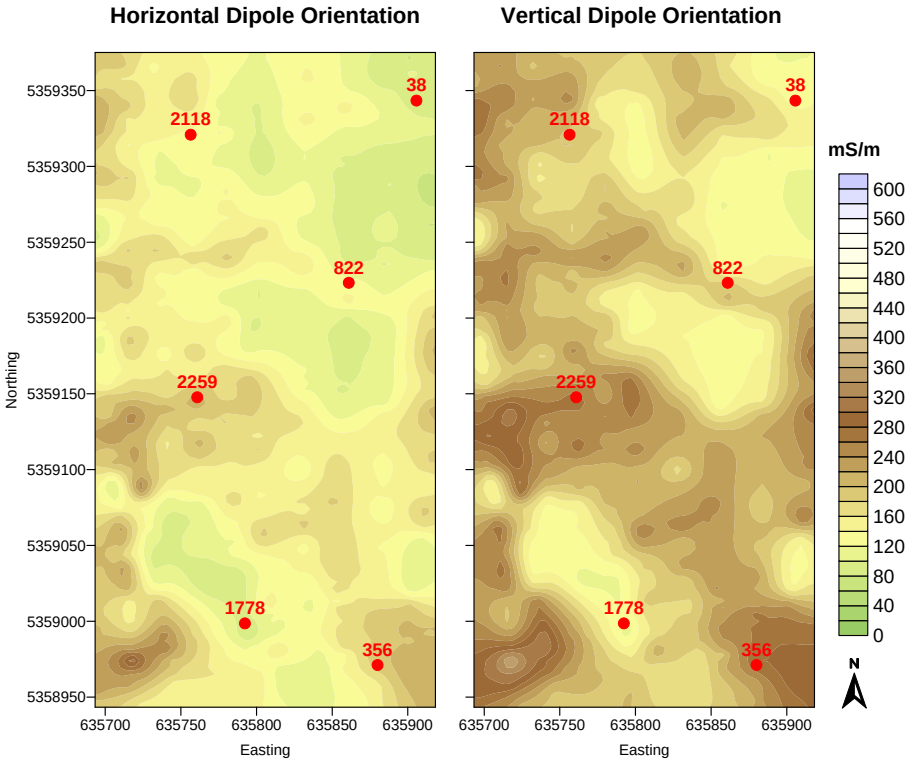
Site (Class)	OBS	Longitude	Latitude	Easting	Northing	EM38DD VDO	EM38DD HDO
Site 20 NW 1/4 11 158-55							
	12	-97.69923	48.52797	596036.265	5375801.002	176.5	142.1
	187	-97.69924	48.52403	596042.833	5375363.571	78.3	63.8
	301	-97.69954	48.52672	596015.757	5375662.677	196.2	128.4
	848	-97.70050	48.52531	595947.530	5375504.247	135.4	96.6
	1770	-97.70237	48.52731	595806.044	5375724.007	103.1	56.2
	2036	-97.70298	48.52482	595765.792	5375446.474	134.7	94.0

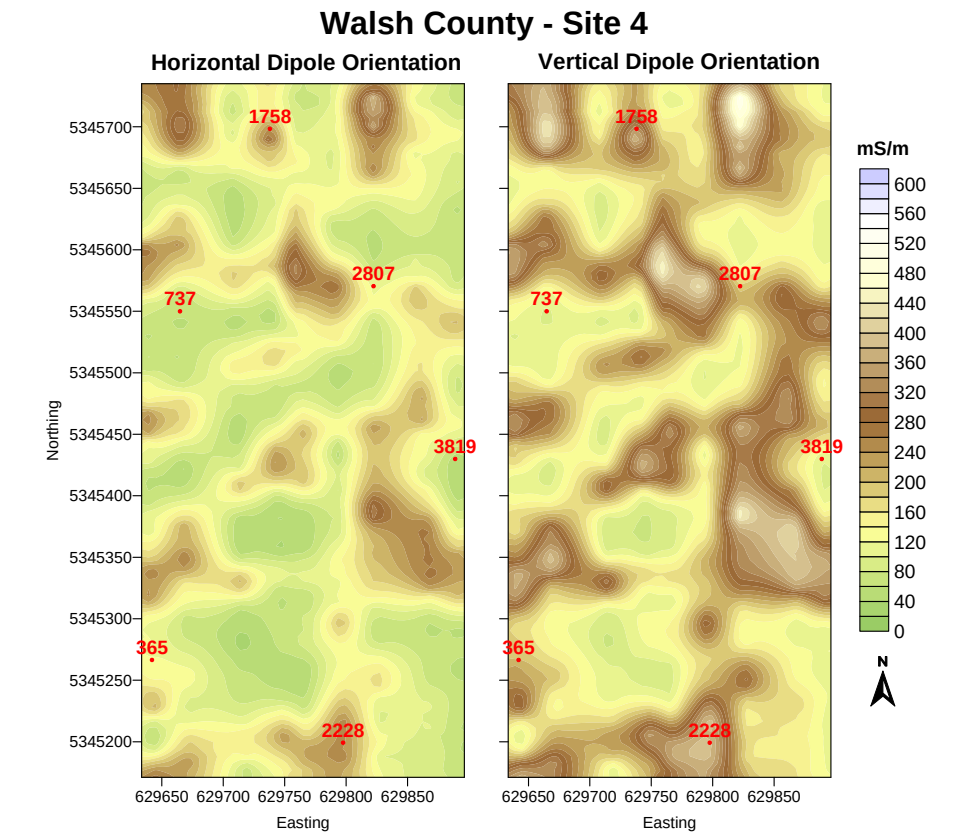


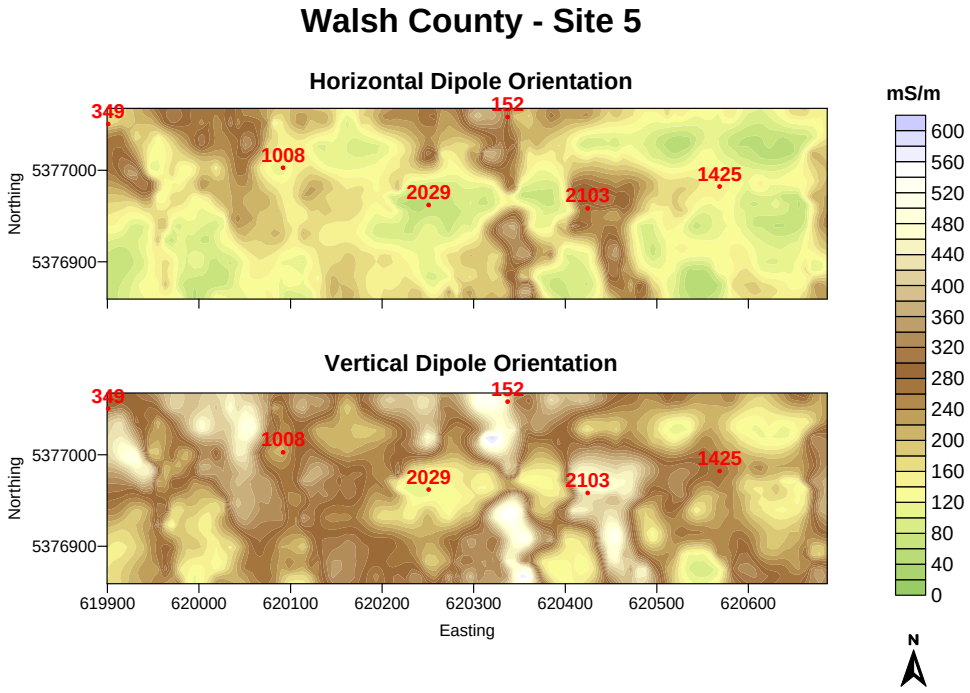
Walsh County - Site 2



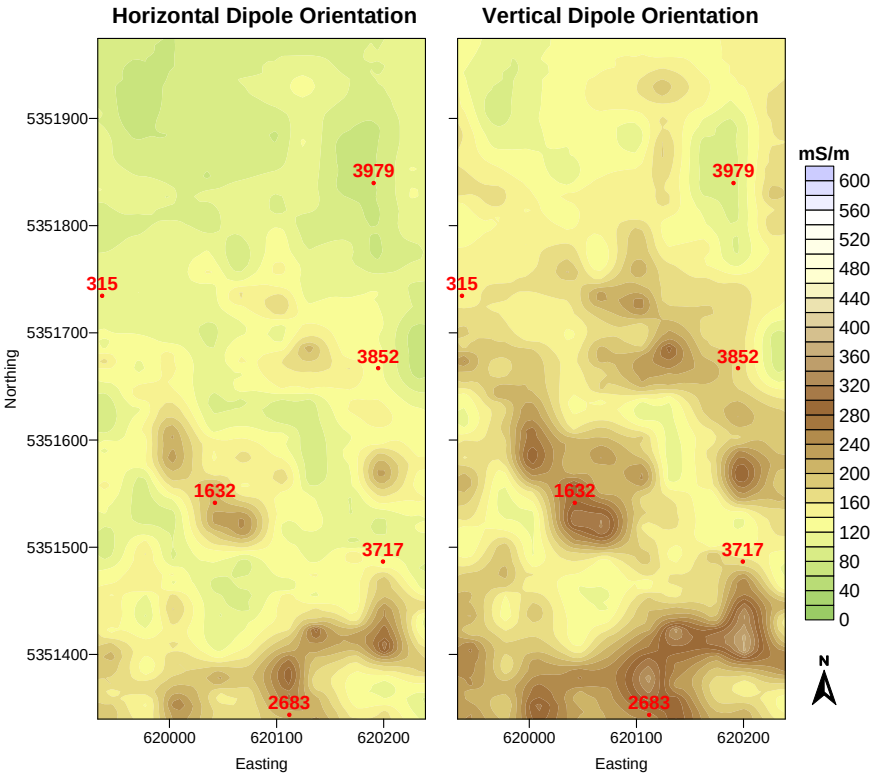
Walsh County - Site 3



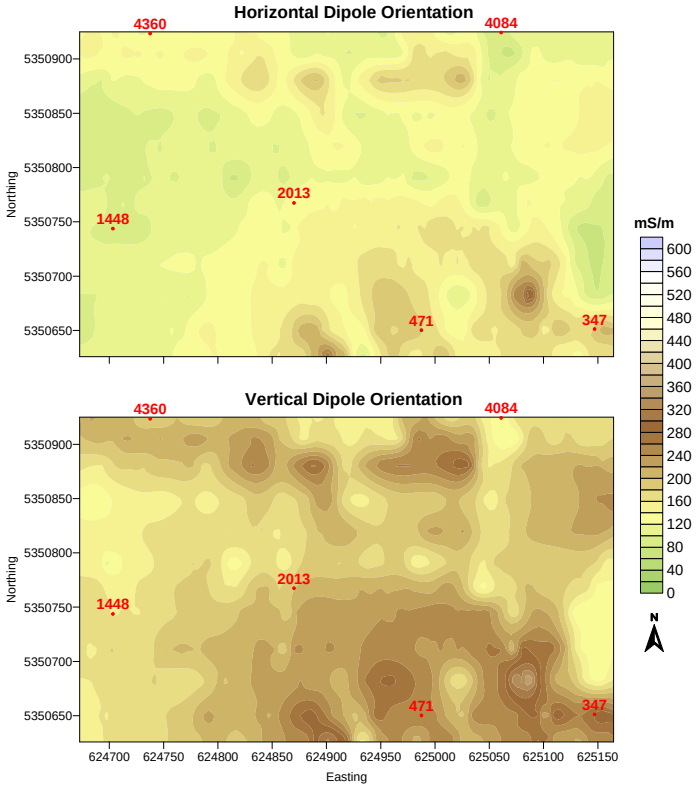

Walsh County - Site 4
Horizontal Dipole Orientation
Vertical Dipole Orientation
1758
2807
737
3819
365
2228
Northing
5345700
5345650
5345600
5345550
5345500
5345450
5345400
5345350
5345300
5345250
5345200
629650 629700 629750 629800 629850
Easting
mS/m
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
N


Walsh County - Site 5
Horizontal Dipole Orientation
Vertical Dipole Orientation
349
152
1008
2029
2103
1425
Northing
5377000
5376900
619900 620000 620100 620200 620300 620400 620500 620600
Easting
mS/m
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
N

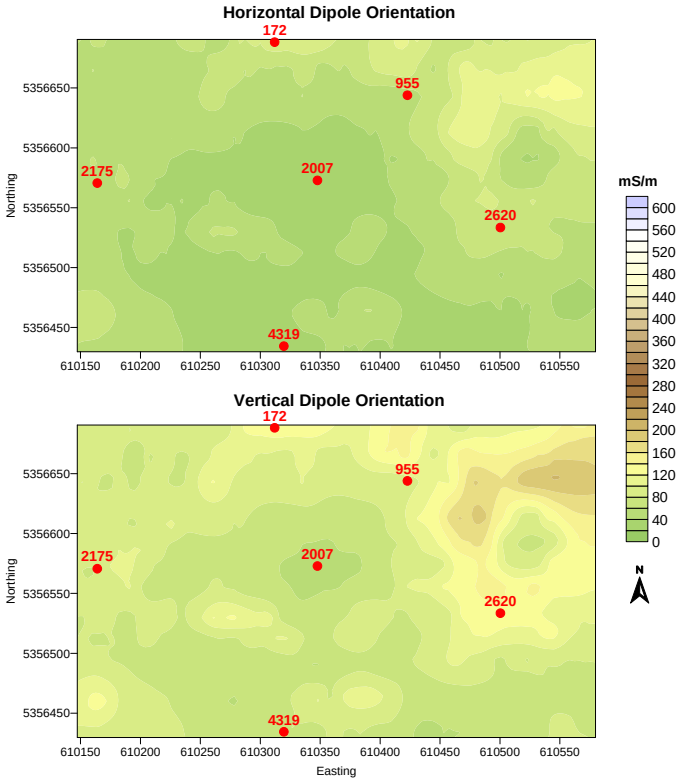
Walsh County - Site 6



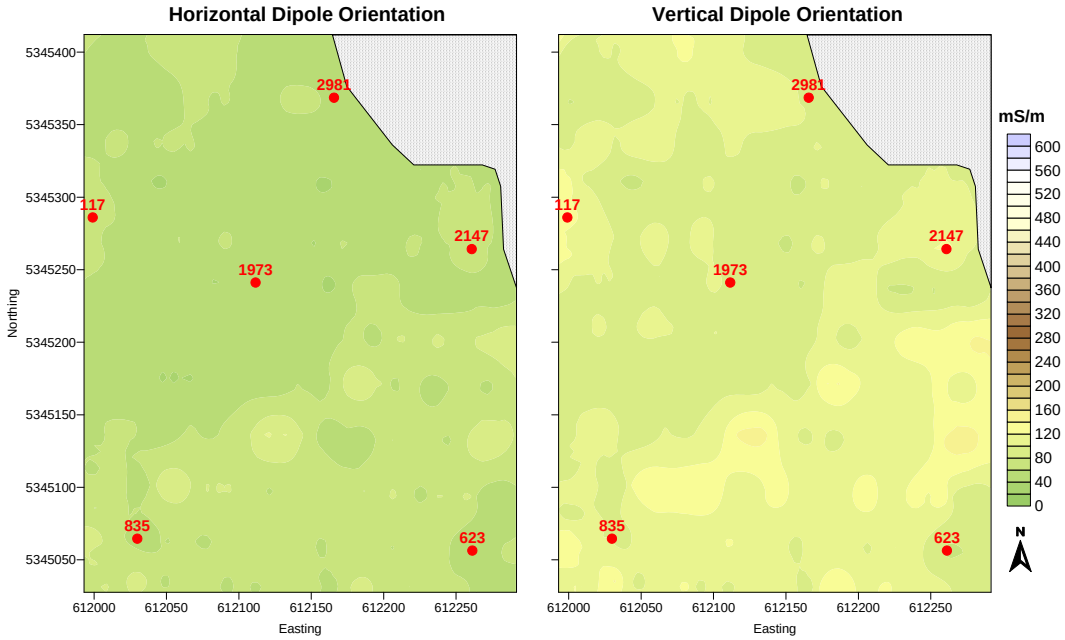
Walsh County - Site 8



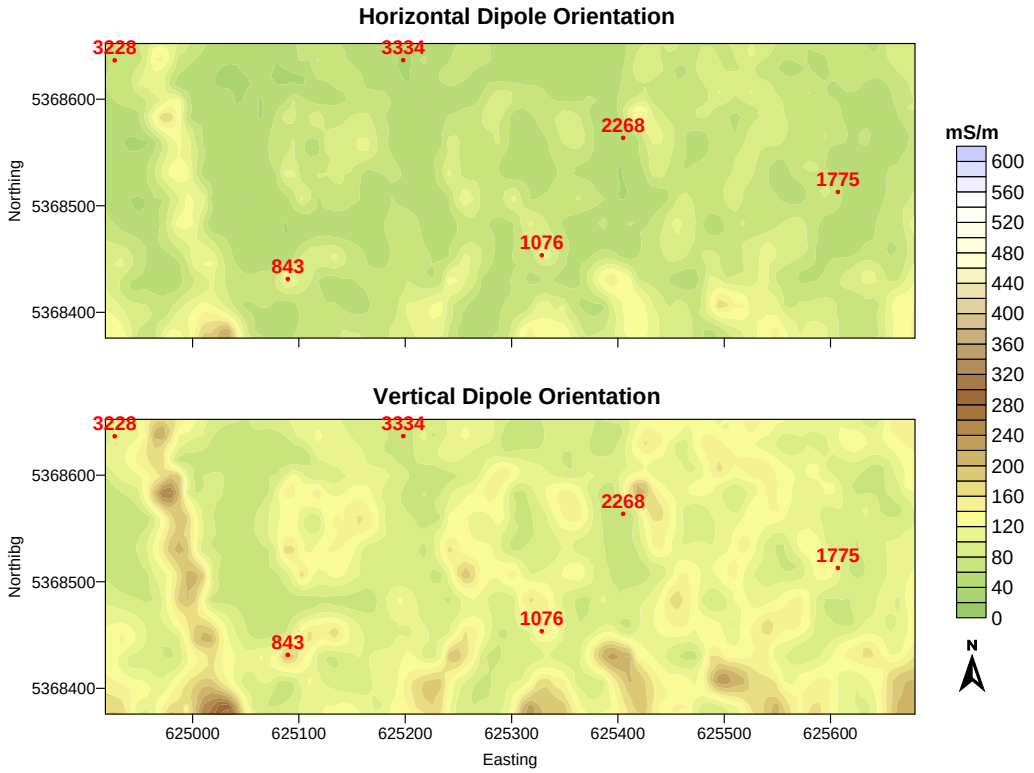
Walsh County - Site 9



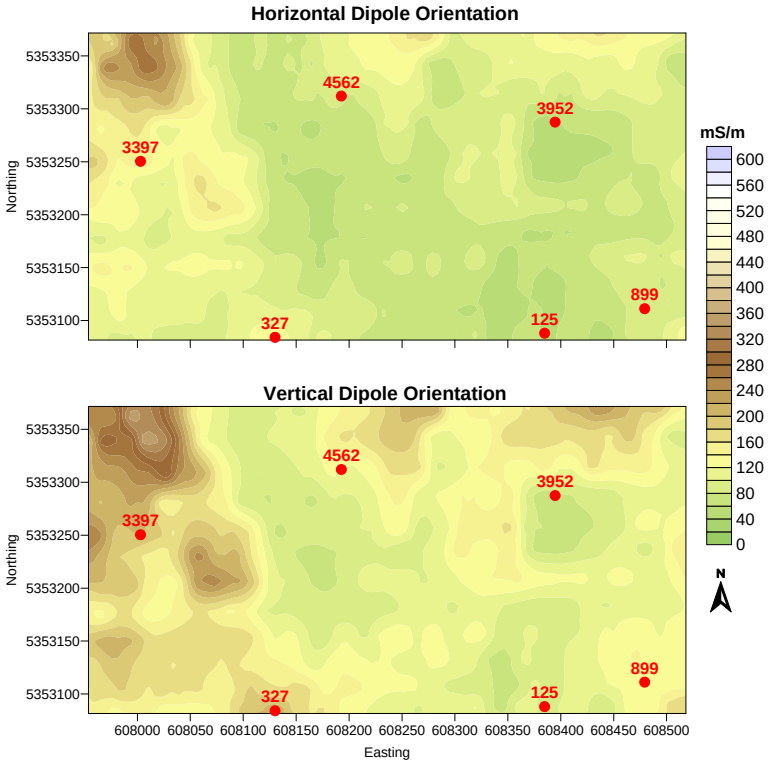
Walsh County - Site 10



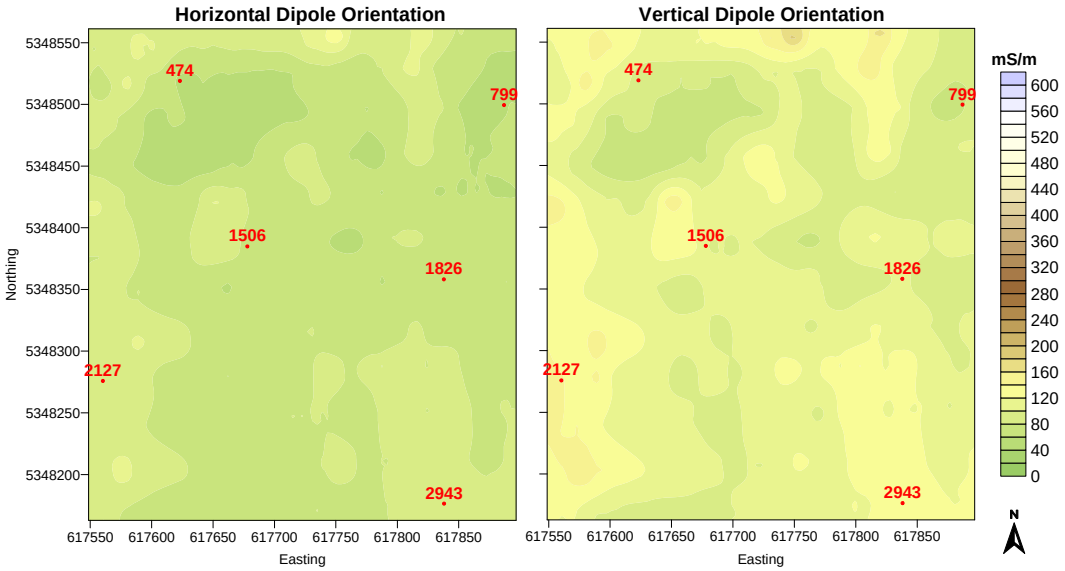
Walsh County - Site 11



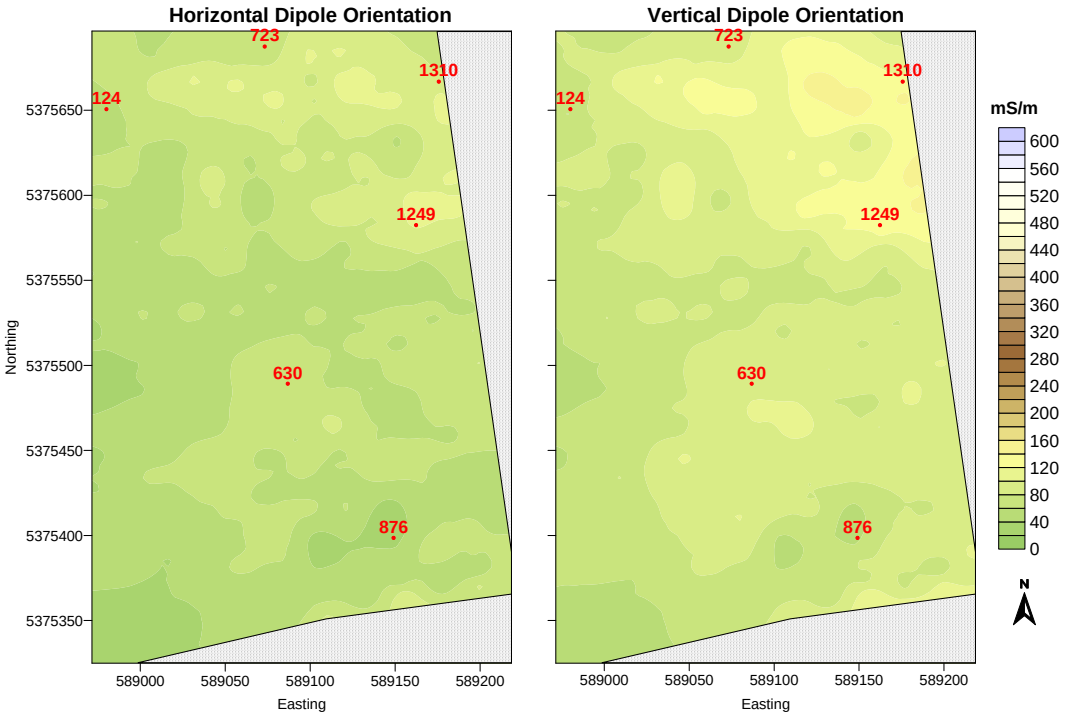
Walsh County - Site 12



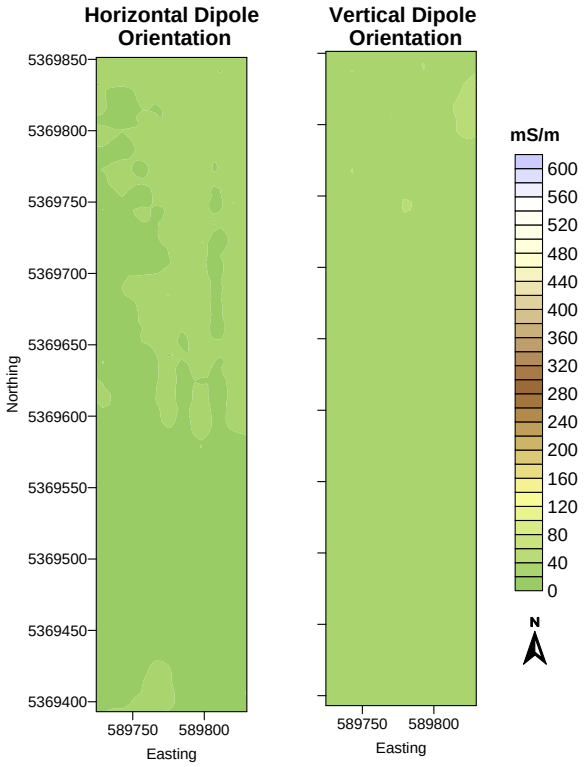
Walsh County - Site 13



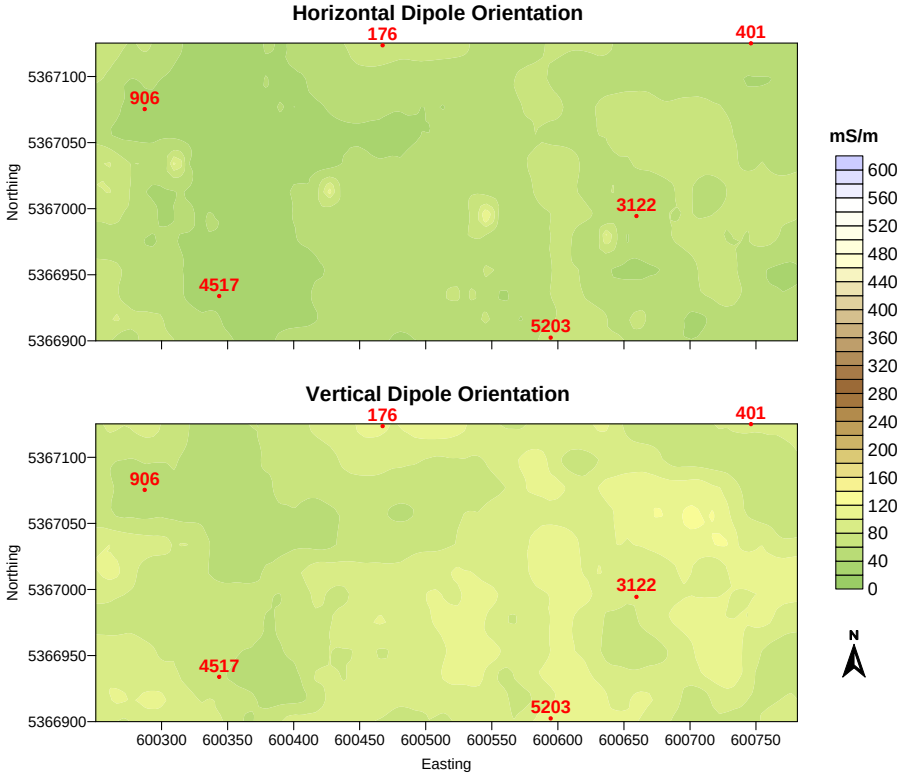
Walsh County - Site 14

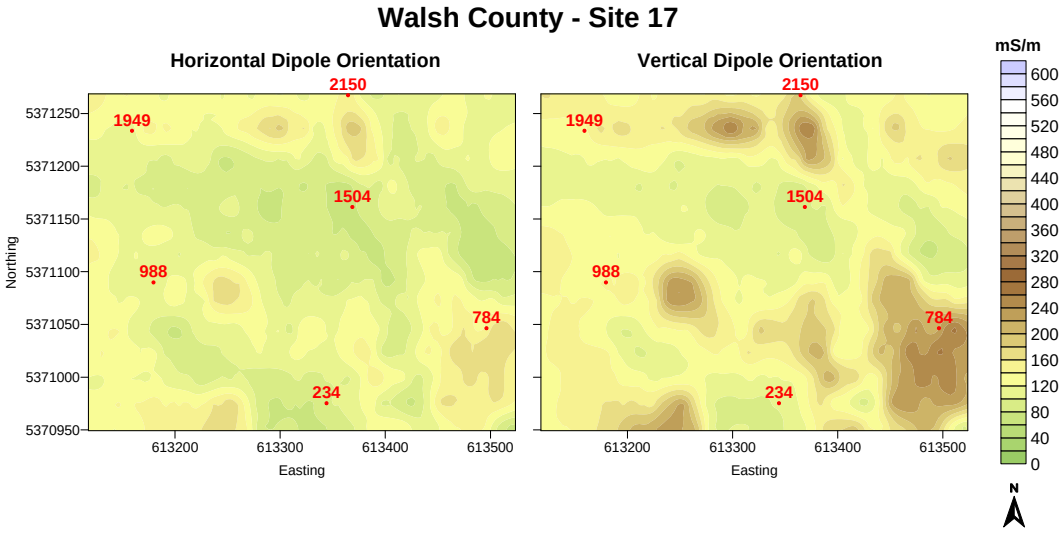


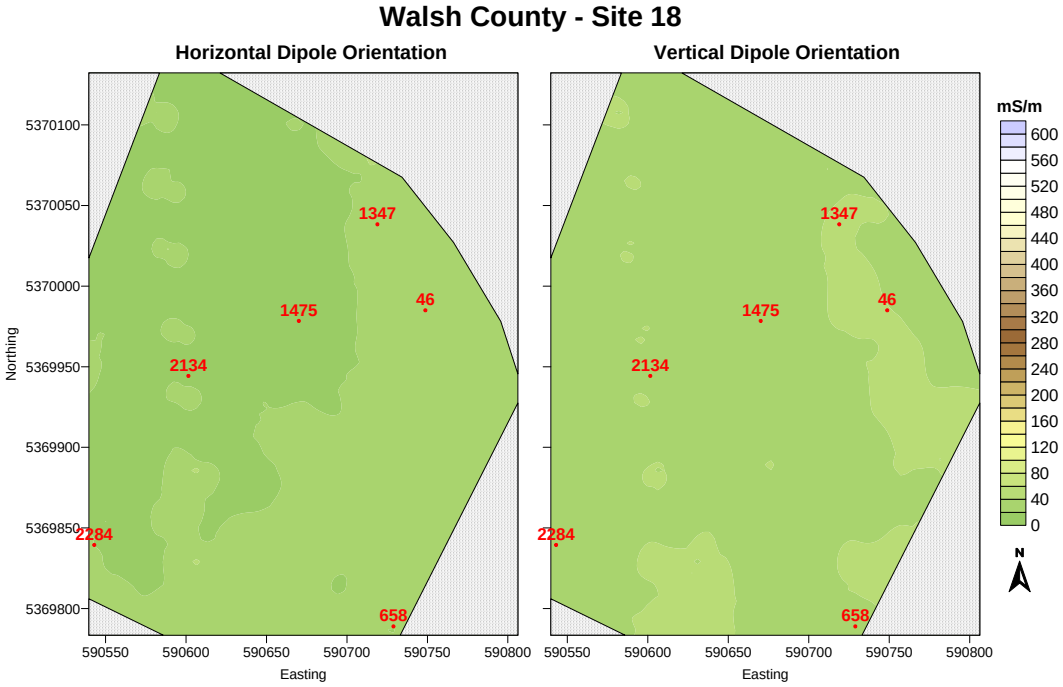
Walsh County - Site 15



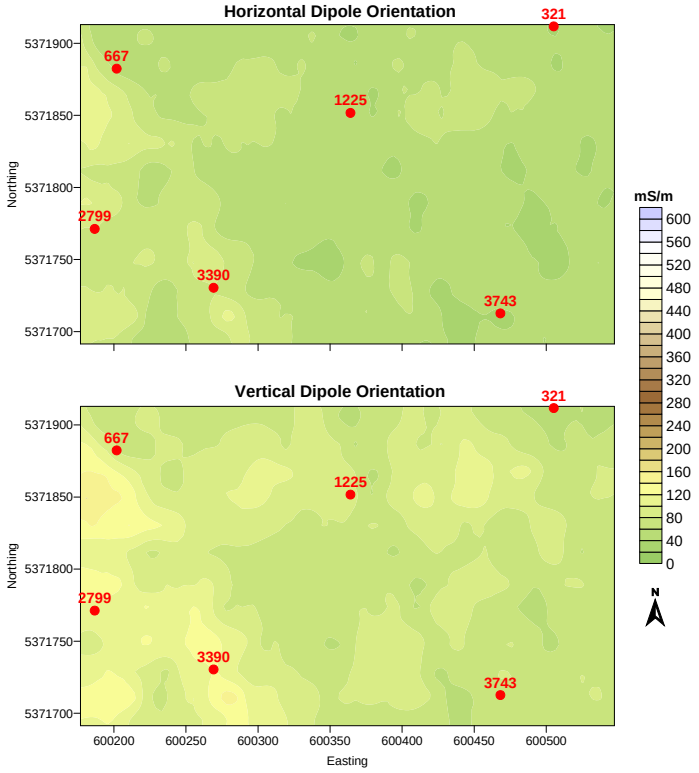
Walsh County - Site 16




Walsh County - Site 17
Horizontal Dipole Orientation
Vertical Dipole Orientation
2150
1949
1504
988
784
234
Northing
5371250
5371200
5371150
5371100
5371050
5371000
5370950
613200
613300
613400
613500
Easting
mS/m
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
N


Walsh County - Site 18
Horizontal Dipole Orientation
Vertical Dipole Orientation
1347
1475
46
2134
2284
658
Northing
5370100
5370050
5370000
5369950
5369900
5369850
5369800
590550
590600
590650
590700
590750
590800
Easting
mS/m
600
560
520
480
440
400
360
320
280
240
200
160
120
80
40
0
N

Walsh County - Site 19



Walsh County - Site 20