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Subject: Geophysical Instrument Verification Strip Report 2014  
Fort Wingate Depot Activity  
Gallup, New Mexico  
Contract No. W912QR-04-D-0025, Task Order 0001

The purpose of this report is to summarize the geophysical instrument verification strip (IVS) results for demonstrations performed at Fort Wingate Depot Activity (FWDA), on June 18, 2014. This IVS was conducted in support of production digital geophysical mapping (DGM) at the Site, and conforms to guidance specified in Engineering Manual (EM) 200-1-15 Interim Guidance Document (IGD) 14-01 (USACE, 2013).

## **INTRODUCTION**

Upon arriving at FWDA, URS began operations at the previously established IVS location. All geophysical and positioning instrumentation was inspected and tested to ensure that it was functioning within the parameters specified in the work plan. This report contains the results of those tests using a Geonics EM61-MK2 (EM61) time domain electromagnetic metal detector mounted on the standard 42 cm wheels paired with a real-time kinematic global positioning system (RTK GPS) for location.

## **OBJECTIVES**

The primary objectives of the IVS are the following:

- Demonstrate that the DGM instrument and positioning systems are functioning properly, and
- Verify conformance with specifications in the work plan (WP).

Secondary objectives of the IVS include:

- Determination of the root mean square (RMS) background noise at the site, and
- Quantification of expected errors in recorded response due to variations such as, seed item location, depth and orientation, and along-track offset.

## **INSTRUMENT VERIFICATION STRIP DESCRIPTION**

The IVS location was selected during a previous field effort on Monday, May 20, 2013 by the Unexploded Ordinance Quality Control Specialist (UXOQCS). The location was selected based

on its accessibility, proximity to the main area of DGM collection, and similarity in terrain and geology to the production environment. Three small Industry Standard Objects (ISOs) were placed in a line running east-west with nominal 15 foot spacing. Flags were used to mark the locations of the items and ends of the line at least 9 feet from the nearest item.

Table 1 shows the types, depths, orientations, and the locations of the ISO items used at the IVS location. The area was previously mapped in real-time with the EM61 prior to emplacing the ISO items and any anomalies were removed from the ground.

<b>Table 1 IVS Seed Geometry</b>					
<b>ID</b>	<b>X (ft)</b>	<b>Y (ft)</b>	<b>Depth (ft)</b>	<b>Orientation</b>	<b>Description</b>
IVS1-1 <sup>1</sup>	2489814.06	1623373.35	0.50	Across Line	Small ISO
IVS1-2	1623373.05	2489828.79	0.50	Along Line	Small ISO
IVS1-3	2489843.65	1623373.02	0.50	Vertical	Small ISO

<sup>1</sup> Position of this seed item resurveyed (corrected) July 14, 2014. These are the corrected coordinates.

A background lane was also marked 30 feet south of the IVS location. Both lines were marked with lathe, and the end points were recorded with RTK GPS in NAD 83, New Mexico State Plane Zone West, US Survey Feet.

Cable shake, personnel, static, IVS, and IVS background tests were run at the beginning and end of each day when geophysical mapping was performed. Additionally, a six-line test and offset tests were also conducted once in the IVS prior to collecting any production data.

**GEOPHYSICAL SURVEY EQUIPMENT**

EM61-MK2

The EM61 was configured using the standard wheels, nominally 42 centimeters (cm) above the ground surface. The survey was performed with the 1.0-meter (m) edge perpendicular to the direction of travel. Data was logged at a rate of 10 Hertz (Hz) and recorded from the four time gates of the lower coil. The top coil was not used.

Global Positioning System Equipment

A Trimble R8 RTK GPS was used to position the data during the IVS survey. Positional data and other GPS data were recorded in the National Marine Electronics Association (NMEA) time, position, and fix related data (GGA) and dilution of precision (DOP) and active satellites (GSA) formats at 1-second intervals (1 Hz) using a serial cable. The GPS antenna was placed on a tripod directly above the center of the coil for accurate location of data.

## **GEOPHYSICAL SURVEY PROCEDURES**

### **DATA ACQUISITION**

The EM61 data were collected by pulling the cart back and forth across the IVS. Data were collected for the Six-Line Test by walking up and down the IVS at a low rate of speed, normal rate of speed, and high rate of speed (respectively) to illustrate the effects of speed on peak response and assist in determining a maximum acceptable velocity. Additionally, data were collected offset by approximately 1 foot and 2 feet to each side of the IVS to ascertain the horizontal extent of detection.

Prior to the IVS demonstration, several tests were conducted to verify that the instruments were operating properly. Data were recorded from the EM61 while it was stationary and subjected to a cable shake, personnel test, and static test (Appendix A).

### **DATA PROCESSING**

Equipment operators monitored the quality of the data in real-time. Upon completion of the IVS survey, the raw data was downloaded from the Allegro data recorder. The geophysical and positional data collected over the IVS survey area were processed using the procedures listed below:

- Raw geophysical data were imported into DAT61 (a position/geophysical data-merging program).
- Correctly positioned data files were exported in \*.xyz format for use in Oasis montaj.
- Combined data were input into Oasis montaj.
- The cable shake/personnel and static test were evaluated for Quality Control (QC) compliance.
- The latency correction was estimated and applied to the IVS data. ISO location and amplitude data was determined.
- Geophysical sensor data were evaluated in profile format for spikes, gaps, and sensor failure.
- Background and IVS data were leveled to eliminate drift and/or improper nulling (i.e., the effect of inadvertently nulling near subsurface metal is mitigated).
- A latency correction calculated during the latency test was applied to the IVS offset and Six-Line Test datasets.
- The data sets were gridded using a grid cell size of 0.5 feet and a blanking distance of 2.5 feet.
- Both positional and sensor data quality were checked. If required, questionable GPS and EM data were removed and/or edited accordingly. Data were monitored for gaps or incomplete coverage to locate any possible sensor failure.

**RESULTS**

The IVS data are displayed below along with results for a variety of tests as specified in the work plan.

**DYNAMIC PEAK RESPONSE AND LOCATION OFFSETS**

The IVS lane centerline was surveyed twice each day and in two directions. The profile of the magnitude of the channels 1, 2, and 3 is plotted in Figure 1 (morning test). Depth/Response curves were generated to compare predicted Least Favorable Orientation/Most Favorable Orientation (LFO/MFO) responses to measured responses (Figure 2). The peak responses to each ISO are also presented in Table 2.

<b>Table 2 IVS Dynamic Peak Response Values (Channel 1)</b>						
<b>Date</b>	<b>Database</b>	<b>Line</b>	<b>Nominal Depth (cm)</b>	<b>IVS1-1 (LFO) (mV)</b>	<b>IVS1-2 (mV)</b>	<b>IVS1-3 (MFO) (mV)</b>
6/18/2014	Daily Tests_061814	ivs0618a (forward)	15.24	18.11	35.32	90.40
6/18/2014	Daily Tests_061814	ivs0618a (back)	15.24	17.20	34.27	86.74
6/18/2014	Daily Tests_061814	ivs0618p (forward)	15.24	16.58	36.48	99.20
6/18/2014	Daily Tests_061814	ivs0618p (back)	15.24	18.62	33.73	97.19
Mean Response				17.63	34.95	93.38
Expected ISO Response				14.70	NA	127.50
Mean Response vs. Expected Response (%)				120%	NA	73%
Maximum Deviation from Mean Response				6%	4%	7%

Table 3 contains the measured offsets between the surveyed seed location and the peak response (or midpoint between double peak responses) identified during the IVS surveys.

<b>Table 3 IVS Dynamic Peak Response Positional Offset Values</b>					
<b>Date</b>	<b>Database</b>	<b>Line</b>	<b>IVS1-1 Offset (cm)</b>	<b>IVS1-2 Offset (cm)</b>	<b>IVS1-3 Offset (cm)</b>
6/18/2014	Daily Tests_061814	ivs0618a (forward)	<b>25.5</b>	16.9	19.5
6/18/2014	Daily Tests_061814	ivs0618a (back)	13.7	13.9	16.9
6/18/2014	Daily Tests_061814	ivs0618p (forward)	<b>26.7</b>	16.4	19.9
6/18/2014	Daily Tests_061814	ivs0618p (back)	5.2	17.9	17.5

Note that the picked position for seed IVS1-1 exceeds 25cm by 0.5 and 1.7cm, respectively for the morning and evening forward IVS passes. Figure 3 presents the relative offset of IVS1-1 positional data collected between June 18<sup>th</sup> and June 28<sup>th</sup>, 2014 graphically and suggests a systematic error may exist (i.e. the surveyed position of this seed item may not be accurate). The location of IVS1-1 was resurveyed on July 14<sup>th</sup>, 2014. The results of the positional offset of IVS1-1 using the resurvey data are presented in Table 4, and Figure 4. The resurveyed position

aligns the seed item’s detected position to conform to standards prescribed by EM 200-1-15 and the WP.

Date	Database	Line	IVS1-1 Offset (cm)
6/18/2014	Daily Tests_061814	ivs0618a (forward)	15.2
6/18/2014	Daily Tests_061814	ivs0618a (back)	10.6
6/18/2014	Daily Tests_061814	ivs0618p (forward)	14.7
6/18/2014	Daily Tests_061814	ivs0618p (back)	9.7

**BACKGROUND NOISE LEVELS**

In addition to the seeded portion of each IVS, a background noise lane was surveyed. Table 5 shows the Background Noise Lane statistics (morning test), including the sum channel Sum1\_3 (Channel 1 plus Channel 2 plus Channel 3).

Channel Name	Minimum (mV)	Maximum (mV)	Mean (mV)	Standard Deviation (mV)	Signal to Noise (LFO)
lev1	-8.20	5.67	0.86	2.13	8.3
lev2	-5.29	4.00	0.59	1.41	7.8
lev3	-2.74	2.35	0.32	0.82	6.4
Sum1_3	-16.23	11.92	1.77	4.31	7.8

Background noise levels are substantially elevated from the previous IVS Report, but elevated noise levels do not appear to be an issue in the follow-on production data. Based on the results of the supplemental tests reported below, several factors contributed to the elevated noise including interactions between high winds and the numerous mud-cracks present at the background line. Table 6 presents the wind speed during the time of the background line tests for data collected between June 18<sup>th</sup> and June 28<sup>th</sup>, 2014.

Date	AM Background Standard Deviation (mV)	AM Wind Speed (mph)	AM Wind Gusts (mph)	PM Background Standard Deviation (mV)	PM Wind Speed (mph)	PM Wind Gusts (mph)
June 18	2.13	21	35	3.63	20	36
June 19	0.72	calm	none	1.01	4.6	none
June 21	0.72	13	none	0.98	12	30
June 28	0.69	3.5	none	0.57	12	none

<sup>1</sup> As recorded by the National Weather Service at Station Gallup Muni/Clarke (KGUP).

Figure 5 shows the results of a test from June 28 along the background line where forward motion of the EM61 was stopped at positions coinciding with obvious fractures in the soil. The EM61 response tends to decrease after stopping (black arrows), suggesting an apparent increase in subsurface electrical impedance. The source of the elevated noise also appears to be related to the wind and wind gusts and/or soil conditions along the background test line. Figure 6 shows the Ch1-3 and Sum1\_3 background line profiles from the June 18<sup>th</sup> AM test.

In order to access the effect of velocity with respect to background line data, a six-line test was conducted at the background line. The test results shown in Table 7 (Channel 1, turns removed) indicate that excessive velocity was not contributing to noise along the background test line.

<b>Table 7</b>		
<b>Background Six-Line Test Results</b>		
<b>Line</b>	<b>Average Velocity (mph)</b>	<b>Ch1 Standard Deviation (mV)</b>
Slow 1	2.09	2.23
Slow 2	1.90	1.67
Normal 1	2.50	2.08
Normal 2	2.33	2.14
Fast 1	2.99	2.00
Fast 2	3.14	1.83

**DETERMINATION OF OPTIMUM VELOCITY**

A six-line test consisting of two passes each over the seeded IVS at slow, medium, and fast pace was conducted to evaluate the influence of velocity on overall signal to noise levels. Table 8 shows the six-line test including a signal to noise composed of the peak response over IVS1-3 on Channel 1.

<b>Table 8 Six-Line Test Results</b>			
<b>Average Velocity (mph)</b>	<b>Average IVS1-3 Peak Channel 1 (mV)</b>	<b>Standard Deviation (mV)</b>	<b>Signal to Noise</b>
1.63	106.0	1.79	59.2
2.19	91.2	1.87	48.8
2.73	82.1	2.66	30.9

## QUALITY CONTROL

Quality control for the Fort Wingate IVS data was maintained by performing the tests described below and reviewing the tests for compliance. Quality control results are presented in Appendix A.

## EQUIPMENT WARMUP

The geophysical equipment was warmed up for a minimum of fifteen minutes prior to collecting data.

## VIBRATION TEST (CABLE SHAKE) AND PERSONNEL TEST

Prior to completing the morning static test the cables and connectors were shaken to verify that there were no loose connections or bad cables. The personnel involved in the data collection stepped towards and away from the instrument coil in order confirm that they do not have any metallic items that will influence the data results. No data spikes were observed in the field or when the test results were reviewed during data processing (Appendix A).

## RECORD SENSOR POSITIONS

The positioning accuracy of the data acquisition system was tested in conjunction with the IVS tests comparing peak responses to the known ISO item locations as presented in Table 1.

## STATIC BACKGROUND TEST

The static background test was performed by collecting data for 3 minutes in an area free of metallic items before and after data collection. All datasets exhibited levels of instrument noise within the normal range (Appendix A).

## CONCLUSIONS AND RECOMMENDATIONS

All of the ISO seed items buried in the IVS at Fort Wingate were detected and located accurately (<25cm) (Figure 7). The location of IVS1-1 was resurveyed on July 14<sup>th</sup>, 2014, and the resurveyed position aligns the seed item's detected position to conform to standards prescribed by EM 200-1-15 and the WP. Responses for IVS-1, IVS-2 and IVS-3 fell within the WP metrics for repeatability, and the amplitude for the responses to MFO and LFO are within expectations.

Overall, the IVS results demonstrate the capability and effectiveness of the equipment, personnel, and procedures to locate buried simulated MEC items under anticipated conditions at the site to the project depth detection requirements.

URS has determined that Channel 1, provides the best signal-to-noise ratio, followed by the Channel 2 and Sum1\_3 channel. Previous experience has shown that Channel 1 can be more susceptible to certain noise sources, including wet conditions, which are not typical of Fort Wingate. URS proposes to use Channel 1 to identify anomalies. URS will continue to calculate the Sum1\_3 channel in case site conditions change and result in increased noise levels for Channel 1, in which case the Sum1\_3 channel is expected to be used to identify anomalies.

Based on the six-line test results shown in Table 8, which shows good signal to noise even at relatively fast velocities, URS proposes for a maximum velocity tolerance that 98% of measured velocities are less than 3 miles per hour.

In order to maintain consistency with previous field efforts at Fort Wingate, URS proposes to continue using a 4mV (Ch1) target dig threshold. Experience at the site has demonstrated that no-finds were minimized during intrusive operations while observing the 4mV threshold. Elevated noise was observed in the background data on 18 June. Because the highest noise levels correspond to periods of relatively high sustained and gusting wind conditions, we will continue to monitor and note those periods when the wind speed is elevated. Due to local variations in terrain, wind conditions tend to vary across the site. Therefore, observations regarding wind speed should be noted when starting work in a new production area.

URS recommends proceeding with data acquisition with the geophysical system detailed in this IVS report.

## FIGURES

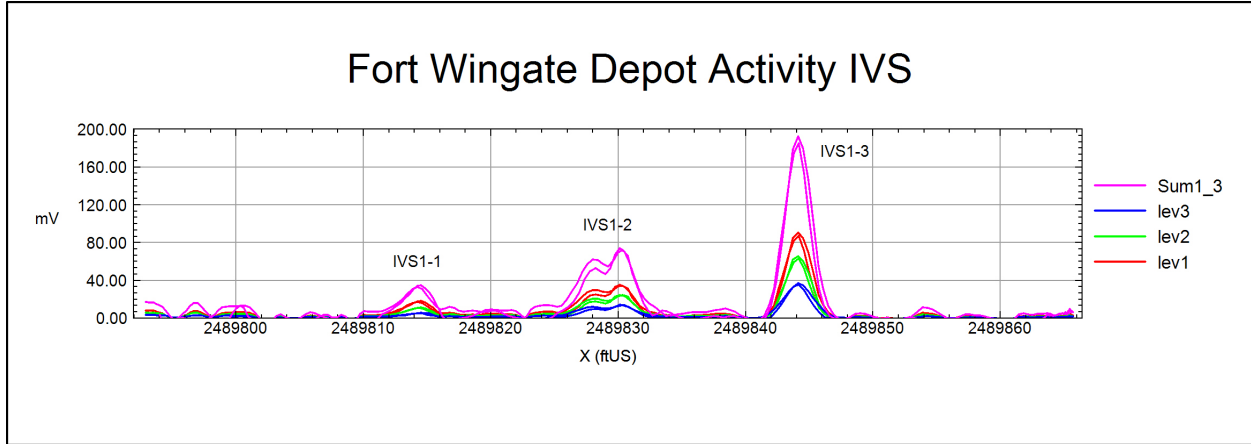
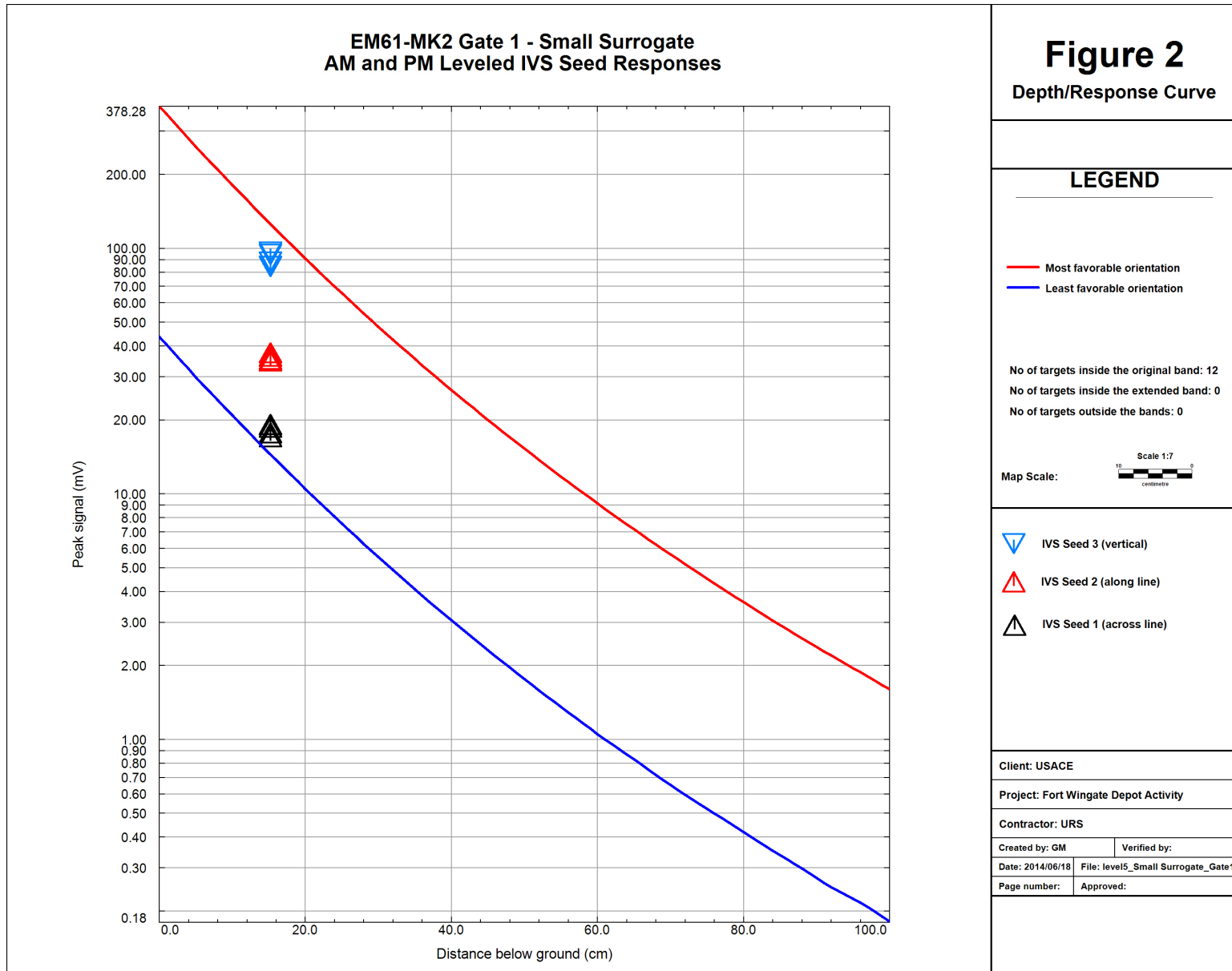


Figure 1 IVS Target Response Profile



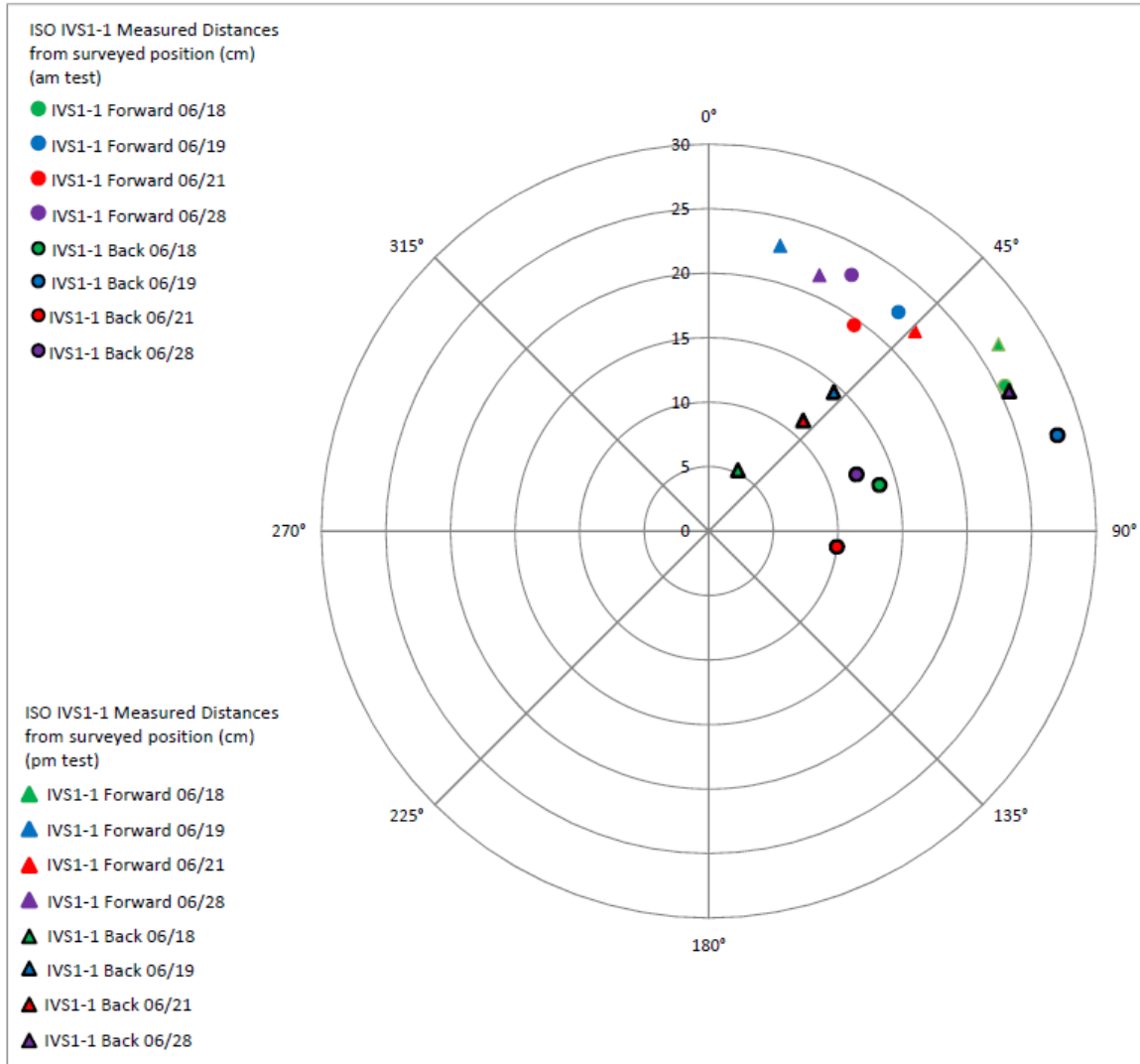


Figure 3 Relative offset (cm) in measured versus surveyed position of IVS1-1 prior to resurveying the seed position.

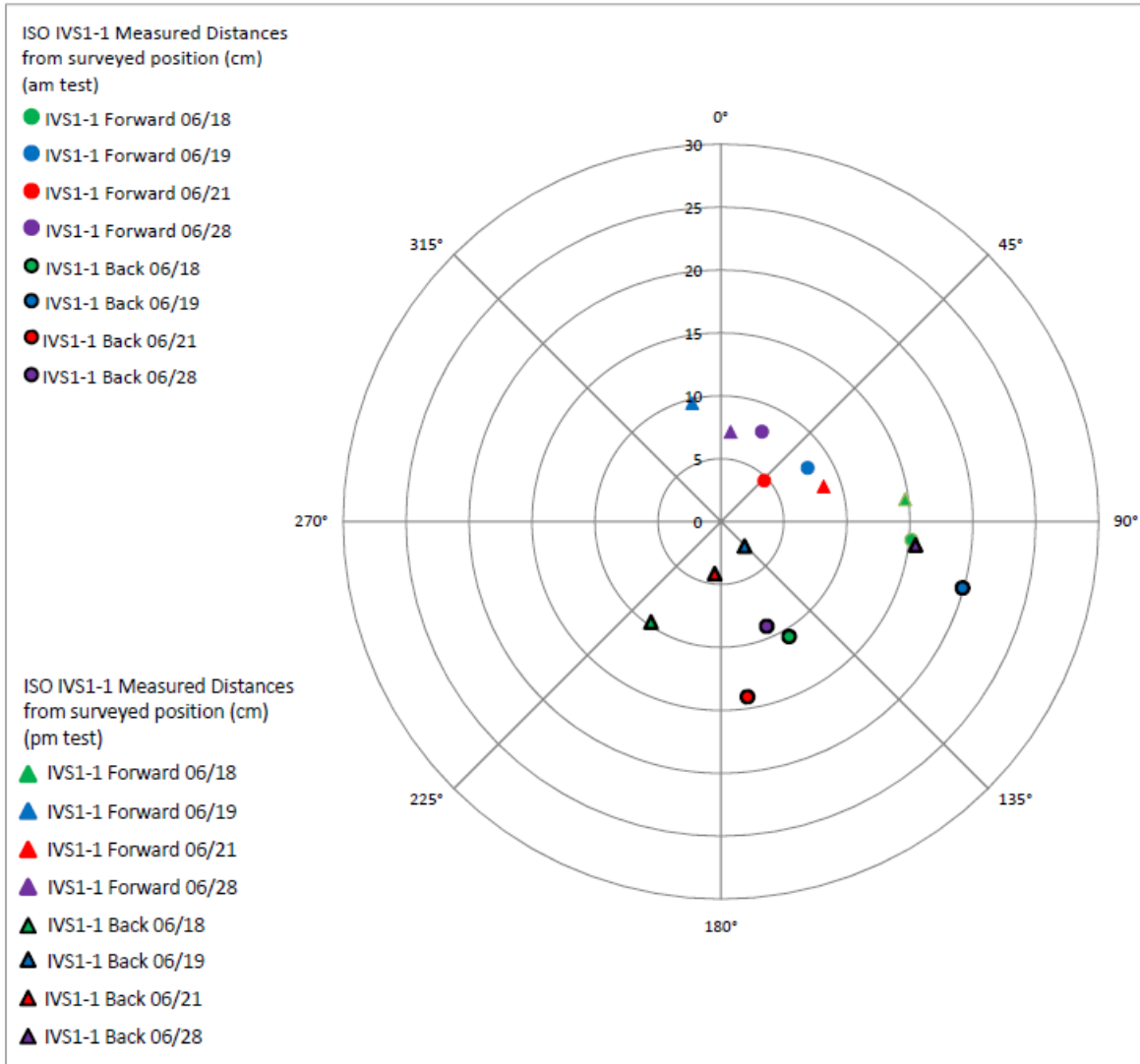


Figure 4 Relative offset (cm) in measured versus surveyed position of IVS1-1 after resurveying the seed position.

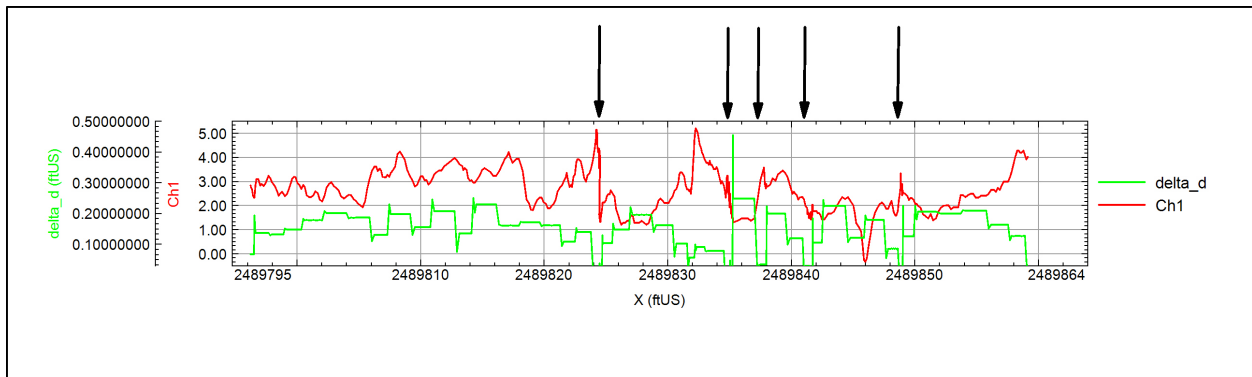


Figure 5 Background test line: Ch1 response and delta distance showing decrease in measured response when EM61 is stopped (black arrows).

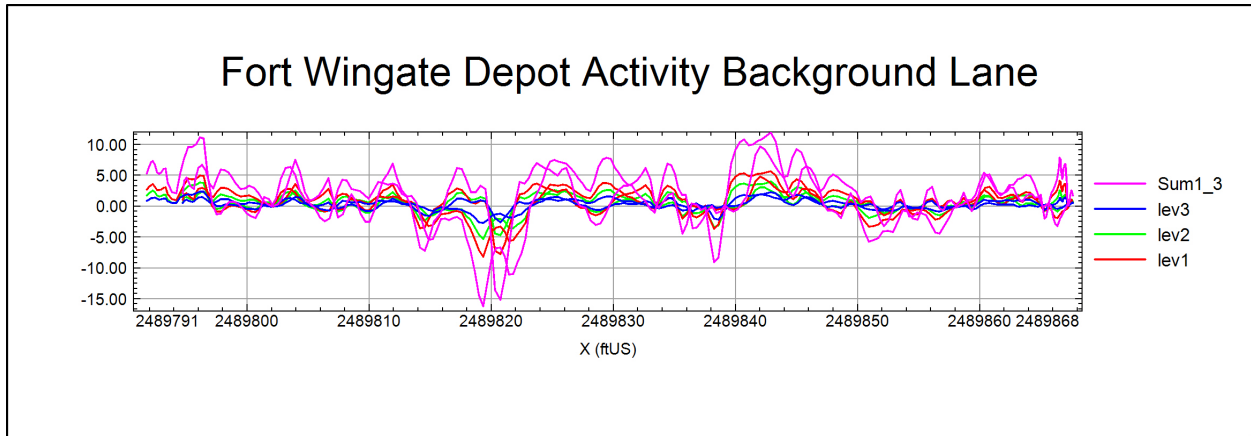


Figure 6 IVS Background Lane Plot

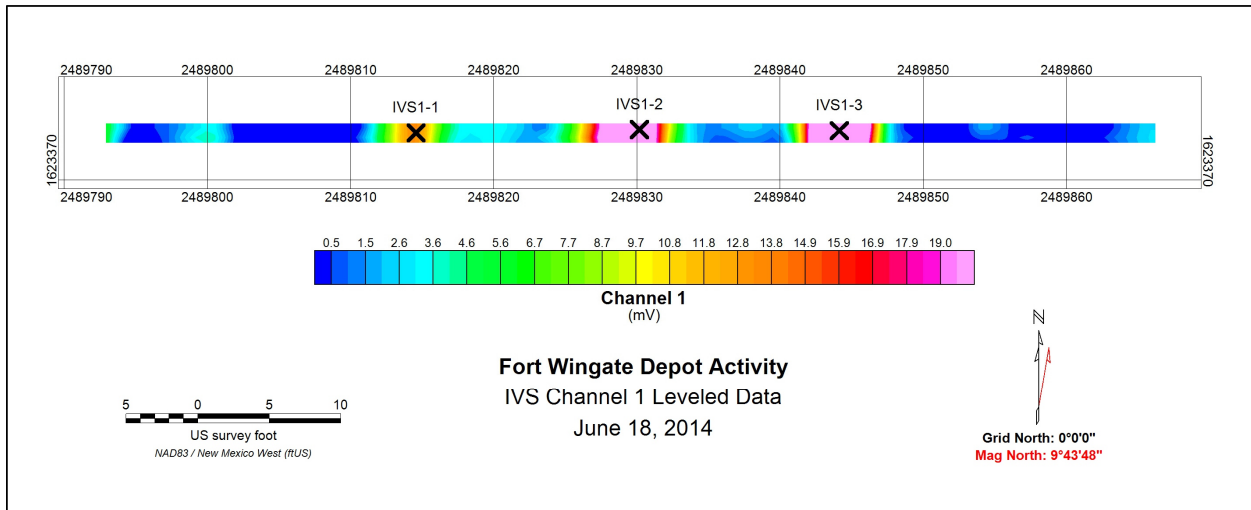


Figure 7 IVS Grid

## APPENDIX A

Quality Control Record 061814

File	Test	Latency	IVS_3_1 <sup>st</sup> pass	IVS_3_1st pass	IVS_3_1st pass	IVS_3_2 <sup>nd</sup> pass	IVS_3_2nd pass	IVS_3_2nd pass
			Ch1	loc E	loc N	Ch1	loc E	loc N
0618a	am	0.29	90.4	2489844.1	1623373.5	86.74	2489844.2	1623373.0
	pm	0.29	99.2	2489844.1	1623373.5	97.19	2489844.2	1623373.1

Test	Vert Seed	Vert Seed	IVS Resp	CSP Ch1	Stk Pre-Spike	Stk Spike	Stk Post-Spike	Mean Static Spike (MSS) minus	MSS- MSB
	Offset (cm)	Offset (cm)	EvsW path	+/- 2 mV	Ch1 Mean	Ch1 Mean	Ch1 Mean	Mean Static Background (MSB)	<10%
	1st pass	2nd pass	<20%	& no spikes					
am	19.5	16.9	4.0%	Yes	-1.77	7732.91	2.2	7732.7	Yes
pm	19.9	17.5	2.0%	Yes	-1.68	7708.67	-1.94	7710.5	0.3%

IVS Seed 3	2489843.651	1623373.021
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SIX LINE DATA	IVS-3 Response			IVS-3 Loc			
	1st pass Ch1	2nd pass Ch1	Ave Resp	1st Loc E	1st Loc N	2nd Loc E	2nd Loc N
Slow	106.73	105.32	106.03	2489844.152	1623373.406	2489844.082	1623372.998
Normal	92.79	89.67	91.23	2489844.025	1623373.409	2489844.121	1623373.064
Fast	81.83	82.4	82.12	2489844.193	1623373.572	2489844.056	1623373.092

OFFSET DATA	IVS-3 Response			IVS-3 Loc			
	1st pass Ch1	2nd pass Ch1	Ave Resp	1st Loc E	1st Loc N	2nd Loc E	2nd Loc N
Normal (from ivs0618a)	90.4	86.74	88.57	2489844.1196	1623373.4584	2489844.2034	1623372.9929
1 foot (0.79 to 1.18 actual)	49.35	70.83	60.09	2489844.036	1623372.227	2489844.149	1623374.199
2 foot (2.38 to 3.13 actual)	no peak	no peak	NA	NA	NA	NA	NA