

# Appendix





# CRONE GEOPHYSICS & EXPLORATION LTD.

3607 WOLFEDALE ROAD, MISSISSAUGA, ONTARIO, CANADA, L5C 1V8  
Phone: (905) 270-0096 Fax: (905) 270-3472 www.cronegeophysics.com

## 3-D PULSE EM - SYSTEM DESCRIPTION

**Name of System:** Crone Pulse EM (PEM).

**Method Employed:** TDEM (Time-domain electromagnetics) or TEM (Transient EM).

**Survey Types:**

- **Surface** - DEEPEM, Large In-Loop, Moving Loop, Moving Coil - 3 components.
- **Borehole** - 3D Borehole PEM - 3 components are measured and oriented.
- **Underground** - 3D Borehole PEM - including flat or up-dipping holes.

**Measured Quantity:** Rate of change of magnetic field in nanoTesla/second (same as nV/m<sup>2</sup>).

**Receiver:** Fully digital (input is digitized before stacking) with 24 bit dynamic range.

**Channels (Gates):**

- Typically 20 logarithmic channels in off-time and 1 during ramp (PP).
- Operator can select from several built-in tables including:
  - 10, 20, or 30 channel system (single, double, triple density)
  - 45 channels 4.5 usec wide covering the end of ramp and start of off-time.
  - 42 channels and PP for 150 msec time base.
  - full sampling of ramp and off-time (8 on ramp and full off-time starting at 0 usec).
- Programmable channel positions in the field.

**Stacking:** 512 to 65536 stacks with spike rejection.

**Gain Control:** Automatic software control (no selection or correction required).

**Rx Operation:** Menu-driven software. Large 16x40 character LCD. Full alphanumeric keyboard.

**Display:** 256 x 128 pixel scrollable graphic LCD for decay curves and profiles in the field.

**Data Handling:** Solid state storage; multiple files; all files can be appended at any time. Plot, list, sort, delete data. RS232 transmission of all data or only certain files.

**Synchronization:** Radio, cable, or crystal clock

**Current Waveform:** Bipolar on-off square waveform with exponential turn-on and ramp off.

**Time Base:** Off-time plus ramp time.

- 8.33, 16.66, 50, 100 and 150 msec for 60 Hz noise rejection (equivalent base frequencies of 30, 15, 5, 2.5, 1.67 Hz.)
- 10.0, 20.0, 50.0, 100.0 and 150 msec for 50 Hz noise rejection (equivalent base frequencies of 25, 12.5, 5, 2.5, 1.67 Hz.)

**Ramp Time:** The time required for the current to turn off.

- 500, 1000, or 1500 usec selections for precisely controlled linear turn-off ramps.
- "fast ramp" option turns current off as quickly as possible for a given loop size and current (2 usec or less to a few hundred usec).

**Transmit Loop:**

- Single turn loop of any dimension (less than 100m x 100m to greater than 2km x 2km).
- Multi-turn 14m diameter loop for near-surface Moving Coil surveys.

**Tx Output Current:**

- 30 Amps maximum at 160 Volts for 4.8 kWatt system.
- 20 Amps maximum at 120 Volts for 2.4 kWatt system.

**Tx Output Voltage:**

- 48 to 240 Volts continuously adjustable for 4.8 kWatt system.
- 24 to 120 Volts continuously adjustable for 2.4 kWatt system.

**Tx Safety features:** Transmitter automatically shuts off when loop is opened. Also shuts off with high instrument temperature and overload. Fuse and circuit breaker overload protection.

**Borehole Probes:** 32 mm diameter.  
Pressure-tested for depths of 2500m or more.

**Operating Temperature:** -40°C to 50°C





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## 3-D PULSE EM - SPECIAL FEATURES

**High Power:** A new 4.8 kWatt transmitter allows very large loops to be used while maintaining a high current.

**Precise Current Ramps:** Precisely- controlled linear ramps of fixed duration allow for proper comparisons to be made between data from different loop sizes, and also allows for the step response transformation.

**Long Time Base (Low Frequency):** A new long time base of 150 msec (1.67 Hz) ensures that very long time constant conductors can be seen in complicated environments.

**Step Response:** A new step response transformation allows even longer time-constant conductors to be seen by reproducing the response that would be seen in a direct measurement of the step response. Our controlled linear ramps and our standard Primary Pulse (PP) measurement on the ramp are necessary for this calculation.

**Fast Ramp Option:** A new "fast ramp" option duplicates the response seen from other pulse-type systems, but this does not allow for the step response calculation. We do not recommend fast ramps because they are not as linear as our controlled ramps, they drift in duration as the loop warms up, and there is no advantage in terms of power put into the ground since the area under the dB/dt pulse produced by the ramp is the same.

**Calculation of Impulse Response:** The "fast ramp" response can be calculated (as well as the true impulse response) from our standard linear ramp data.

**True Digital Receiver:** The Crone receiver is a true digital receiver in that the input is immediately digitized before stacking and binning. This produces the following feature (programmable gate positions) .

**Programmable Gate Positions:** There is complete freedom of channel (or gate) positions and widths, which can be programmed in the field. There are also numerous built-in tables.

**Full Sampling:** The entire ramp and off-time can be sampled with contiguous channels if desired.

**Current Ramp always Sampled:** A Primary Pulse (PP) measurement is always made on the current ramp, which is of great help to ensure proper polarities, and also is crucial for the step response transformation.

**High Quality LCD Display:** The 256 x 128 pixel LCD on the receiver allows for accurate plots of decay curves and line or borehole profiles on the receiver, and is of great assistance to the operator to monitor noise and anomaly build-up.

**No Data Reduction:** There is no data reduction for surface surveys and Z-component borehole surveys, so that what is seen on the receiver is what will be seen in the final plots. For 3-D borehole surveys, there is only the correction applied to the direction of the X and Y components to aid interpretation. Gain controls are automatic, so that the output is always in nanoTeslas/sec (= nV/m<sup>2</sup>).

**Slim-line Probes:** A 32 mm probe diameter ensures that virtually all holes can be surveyed with 3-component measurements.

**Oriented X and Y Components:** X-Y orientation tools accurately orient the X and Y components. This helps tremendously with giving direction to off-hole conductors and to the centre of in-hole conductors.

**Reliable, Durable and Portable Equipment:** The PEM system has been in use since the early 1970's under temperature extremes of -40°C to +50°C, in desert, jungle, arctic, mountainous, and underground mining conditions.





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## 3-D PULSE EM - APPLICATIONS

- **Base metals**    ⇒ direct detection of:
  - ◊ volcanogenic massive sulphide (VMS) deposits
  - ◊ magmatic sulphide deposits
  - ◊ sedex massive sulphide deposits
  - ◊ higher grade ore within disseminated zones⇒ indirect detection of :
  - ◊ sphalerite and other non-conductors
  - ◊ galena and other poorly connected mineralsthrough detection of associated well-connected conductors.  
⇒ detection of conductive marker zones related to deposits
- **Gold**    ⇒ detection of associated conductors - e.g. pyrite/pyrrhotite  
⇒ detection of the host - e.g. banded iron formations
- **Uranium**    ⇒ detection of associated graphitic basement conductors  
⇒ detection of associated conductive alteration zones
- **Diamonds**    ⇒ detection and definition of clay-rich layer overlying kimberlites  
⇒ locating kimberlites under locally thinned conductive cover

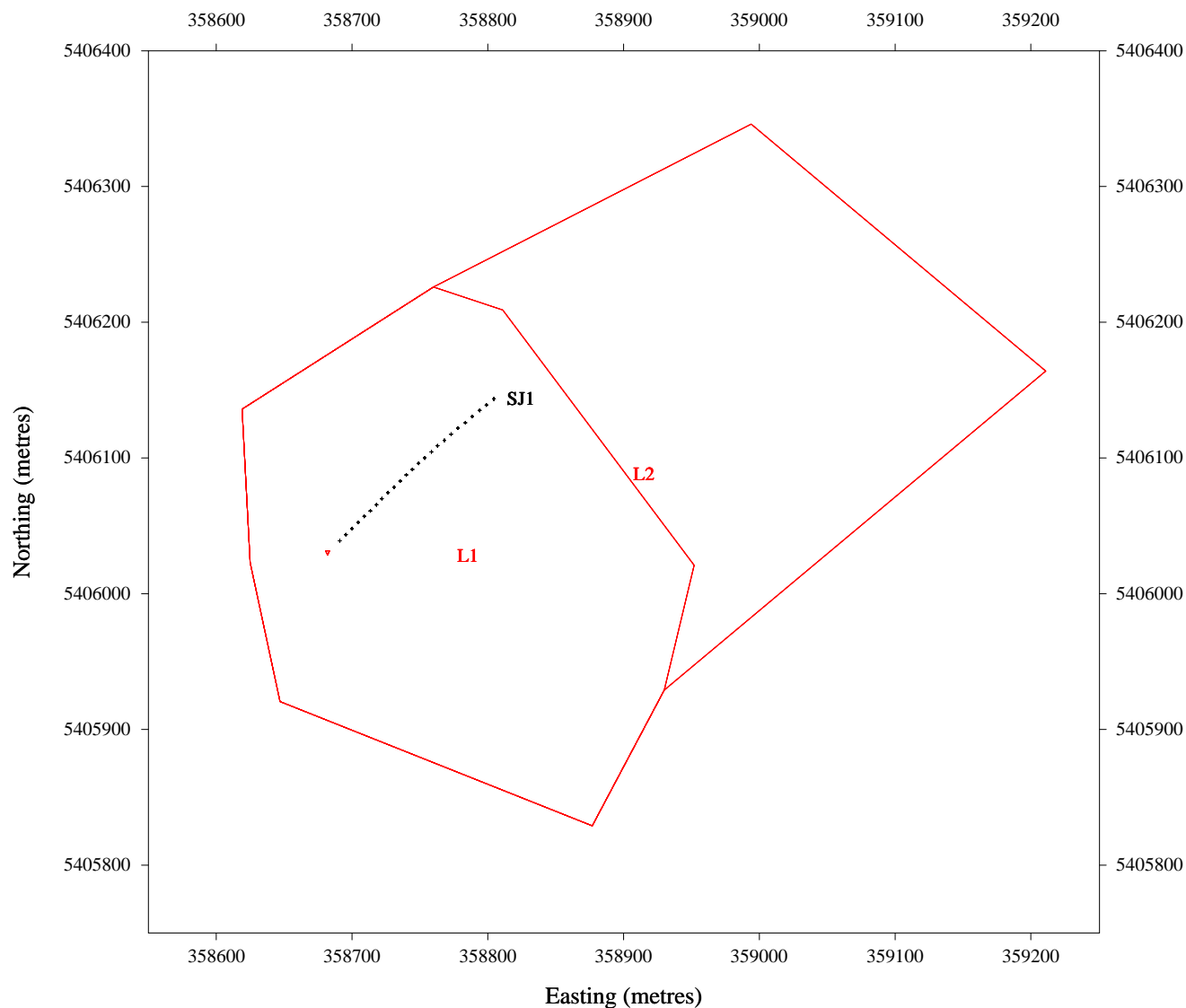
In the ore definition, delineation and production stages of a mining operation, Pulse EM can still be highly effective to:

- Define the boundaries of conductive ore
- Determine the size of intersected conductors and thereby determine whether they are connected to main ore zones.
- Reduce the number of necessary drillholes by exploring between holes.
- Survey underground drillholes - even flat or inclined holes.

Pulse EM can also be used for:

- General geological mapping of conductive structures
  - ⇒ shears, fractures, lineaments
  - ⇒ hydrothermal alteration
  - ⇒ graphite-rich rocks, including graphitic schist, shale, slate, and argillite
  - ⇒ clay alteration and zeolites
  - ⇒ differential and clay weathering
  - ⇒ conductive weathered layer at surface
- Groundwater exploration
- Mapping groundwater contamination plumes and freshwater-saltwater interface
- Geothermal exploration
- Mapping depth and thickness of horizontal strata
- Mapping permafrost thickness





### SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

### RECEIVER

Receiver : Crone  
Frequency : 5  
Component : A,U,V  
Rx Coil : Crone  
Rx Area : 8100m2, 3090m2 turn-m

### TRANSMITTER

Transmitter : Crone  
Loop : L1  
Tx Moment : 90000 turn-m  
Tx Current : 30 A  
Turn Off : 0.5 ms

### WINDOW TIMES (ms)

#### From the start of the Ramp

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.71
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
8 : 0.6680	18 : 1.632	28 : 8.014	
9 : 0.7040	19 : 1.868	29 : 9.578	
10 : 0.7460	20 : 2.154	30 : 11.47	



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**Downhole EM Survey**  
**Survey Location Plan**  
**Hole: SJ1**

Drawn : DJL

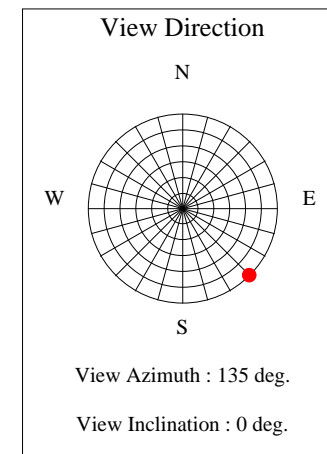
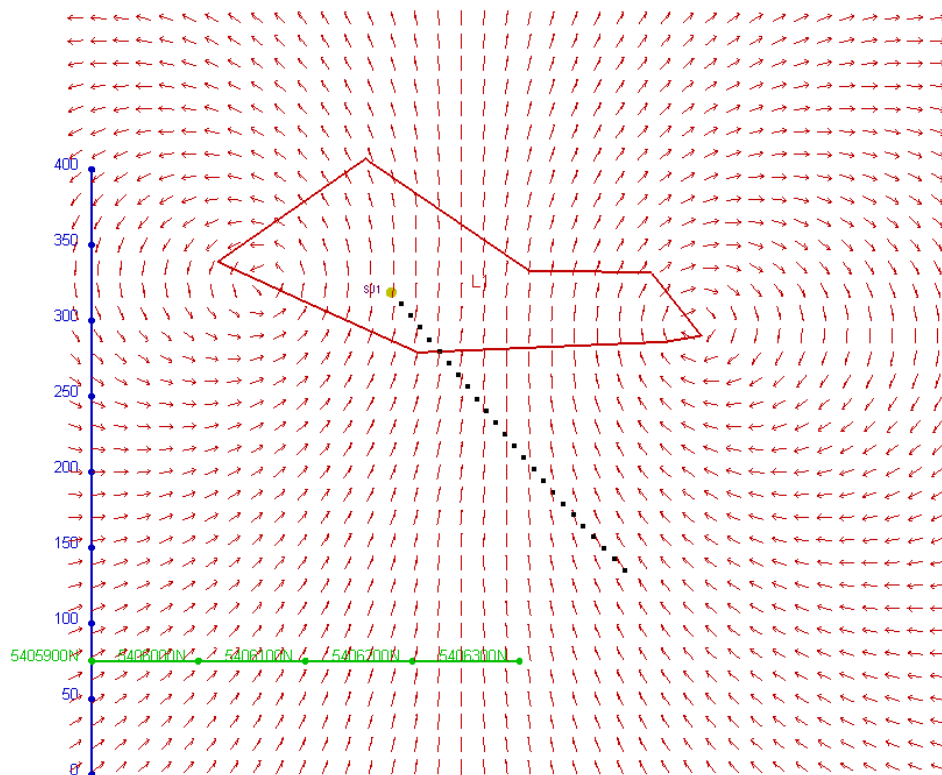
Job No.: JN 2799

Date: 07-05-2013

Fig No.:#1

Horizontal Scale 1:5000





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**Downhole EM Survey**  
Primary Field Plot  
**Hole: SJ1, Loop: L1**

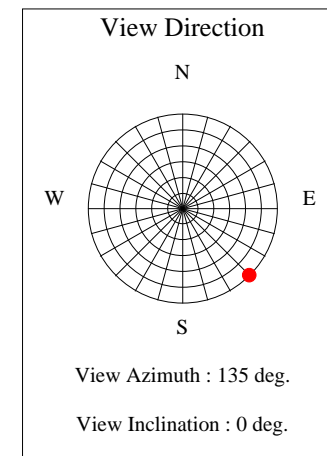
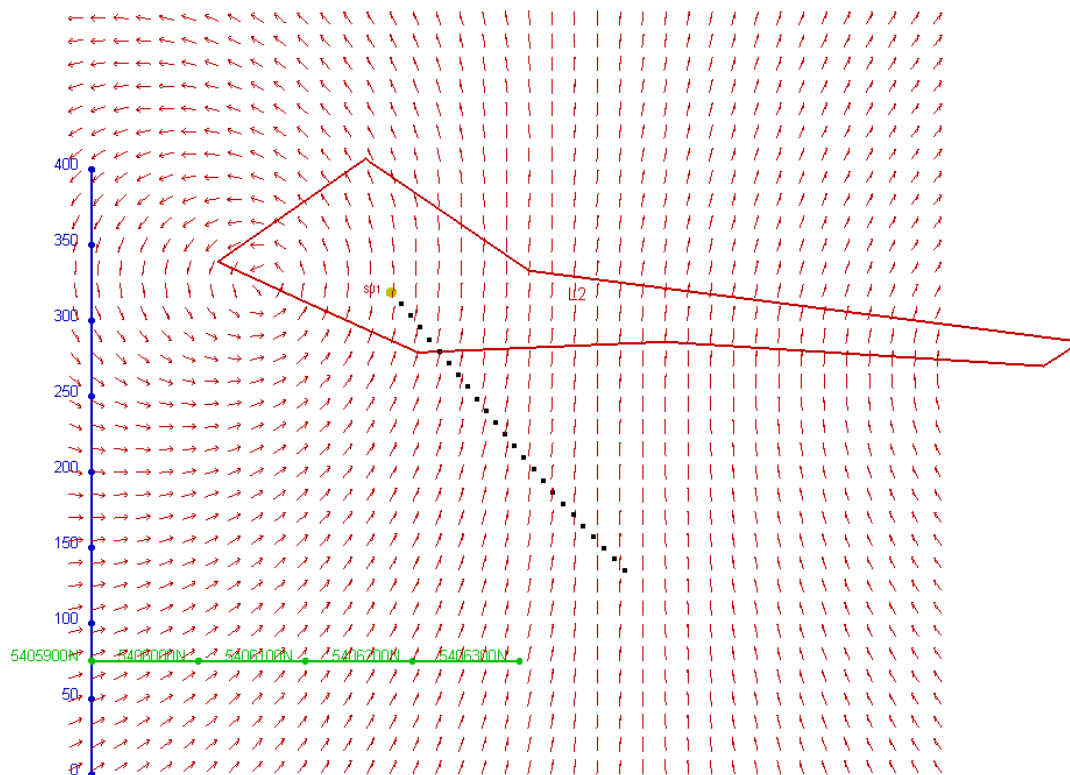
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Job No.: JN 2799

Date: 07-05-2013

Fig No.:#2





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**Downhole EM Survey**  
Primary Field Plot  
**Hole: SJ1, Loop: L2**

Drawn : DJL

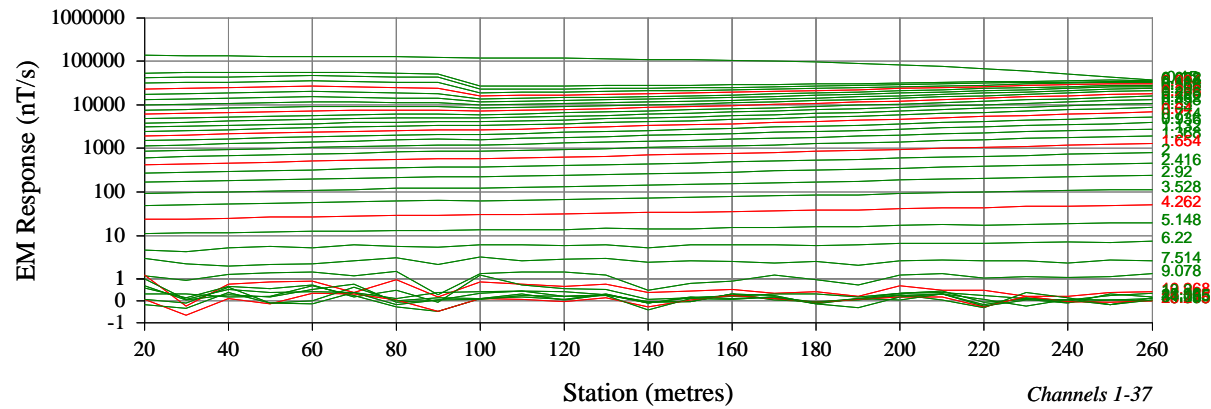
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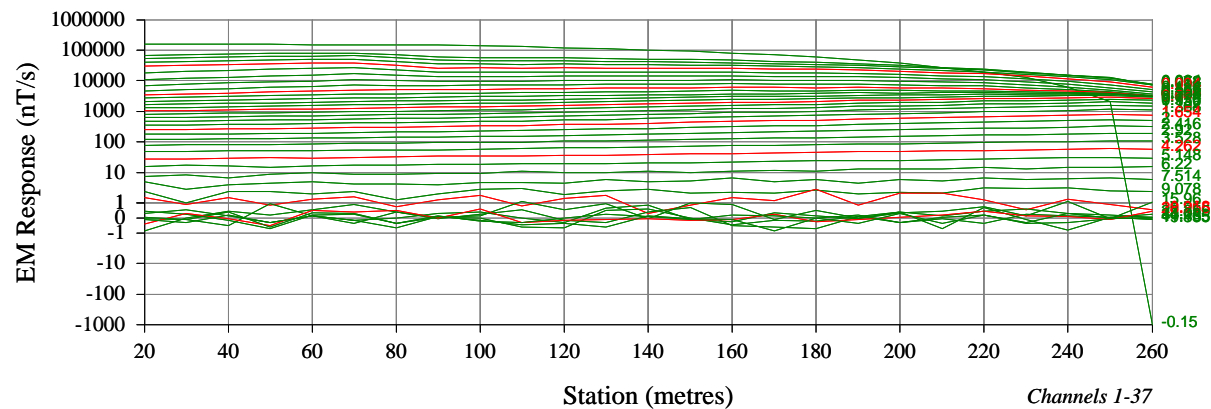
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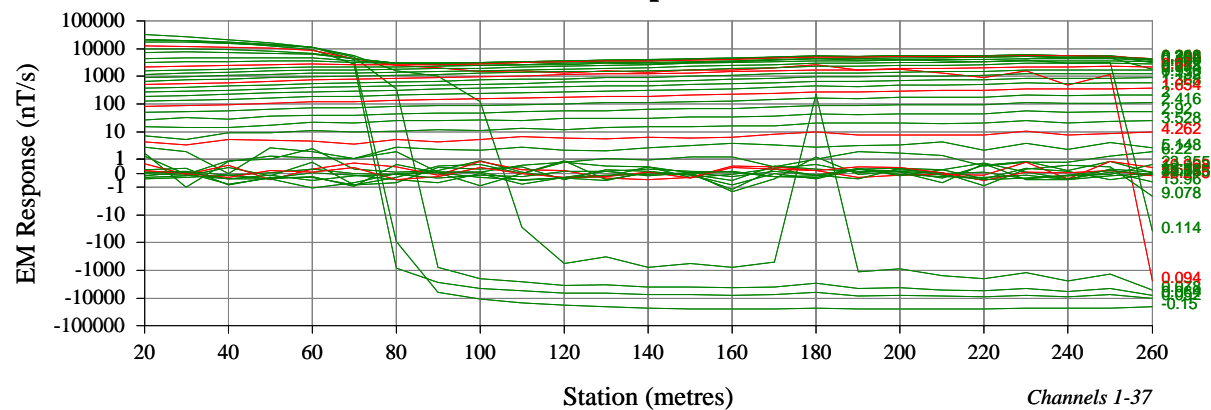
## A Component



## U Component



## V Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver	: Crone
Frequency	: 5
Component	: A,U,V
Rx Coil	: Crone
Rx Area	: 8100m2, 3090m2 turn-m

## TRANSMITTER

Transmitter	: Crone
Loop	: L1
Tx Moment	: 90000 turn-m
Tx Current	: 30 A
Turn Off	: 0.5 ms

**WINDOW TIMES (ms): Centre**  
**From the start of the Ramp**

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
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## Downhole EM Survey

### Log-Linear Profiles

#### Hole: SJ1, Loop: L1

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Drawn : DJL

Job No.: JN 2799

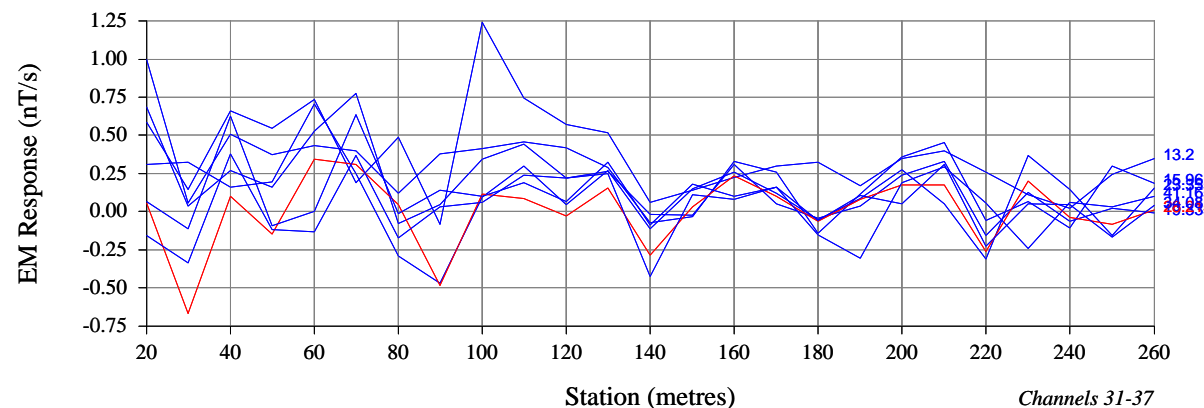
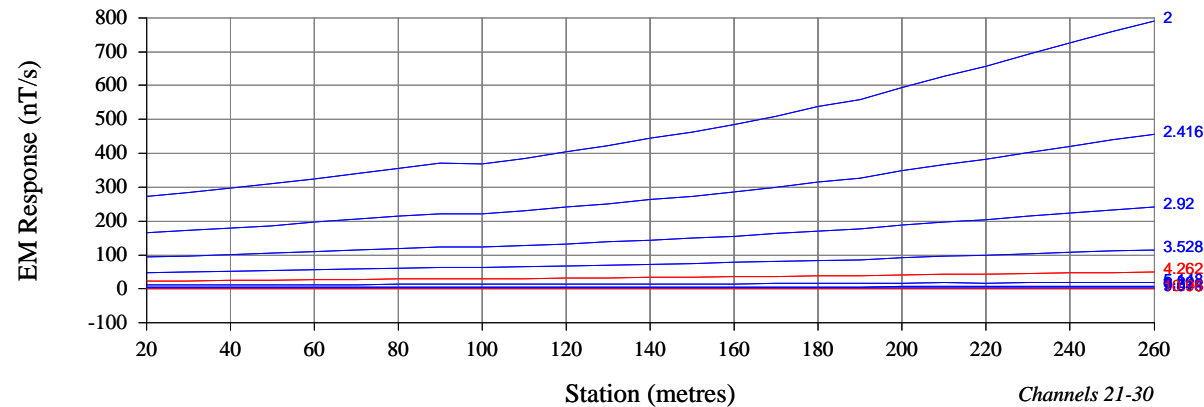
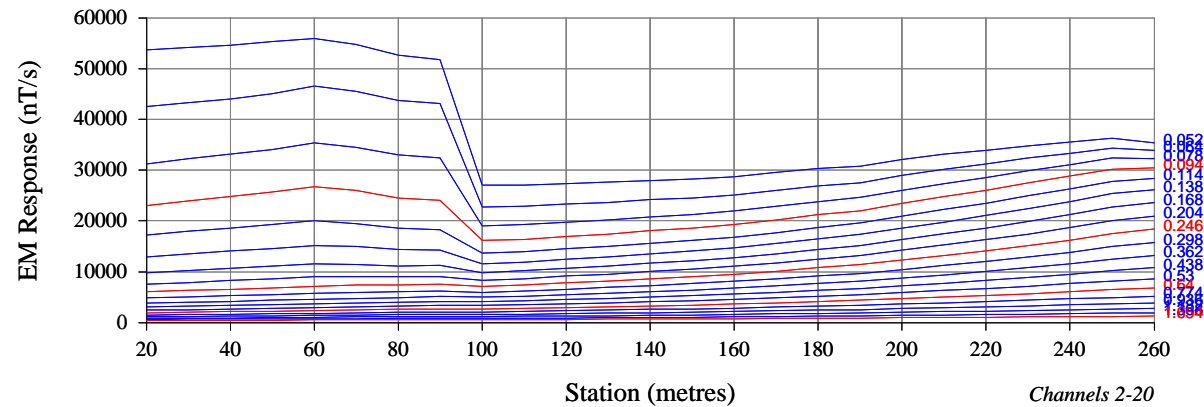
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Date: 06-05-2013

Fig No.:#4



## A Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver : Crone  
Frequency : 5  
Component : A  
Rx Coil : Crone  
Rx Area : 8100m2 turn-m

## TRANSMITTER

Transmitter : Crone  
Loop : L1  
Tx Moment : 90000 turn-m  
Tx Current : 30 A  
Turn Off : 0.5 ms

## WINDOW TIMES (ms): Centre From the start of the Ramp

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.72
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
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10 : 0.7460	20 : 2.154	30 : 11.47	



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Downhole EM Survey  
Linear Profiles - A Component  
Hole: SJ1, Loop: L1

Drawn : DJL

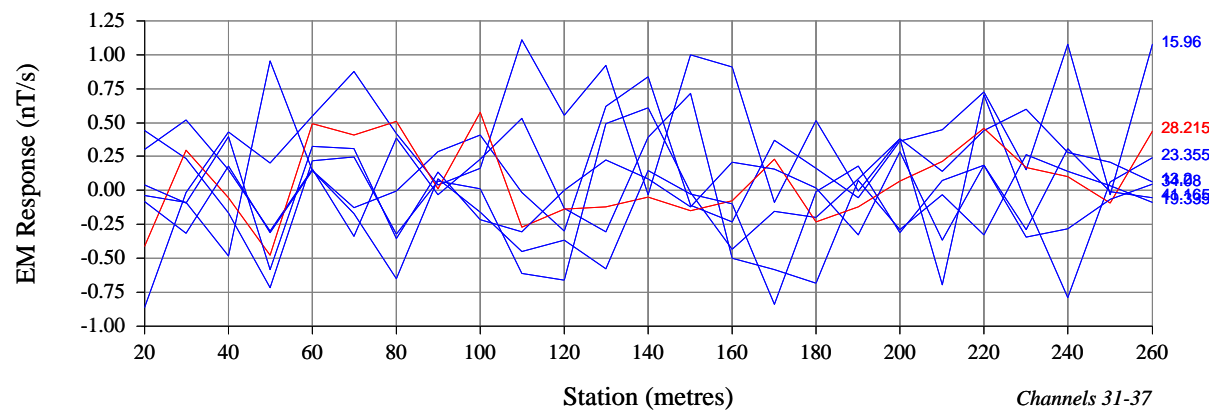
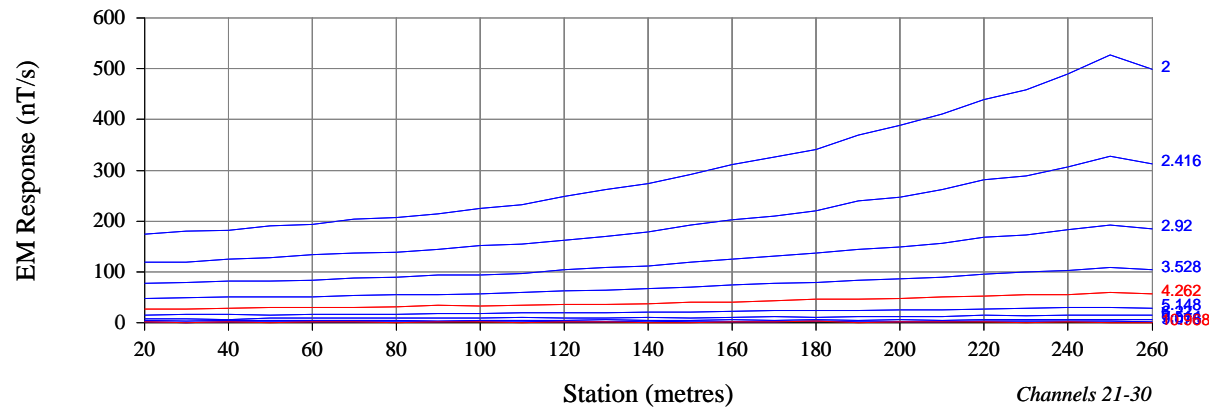
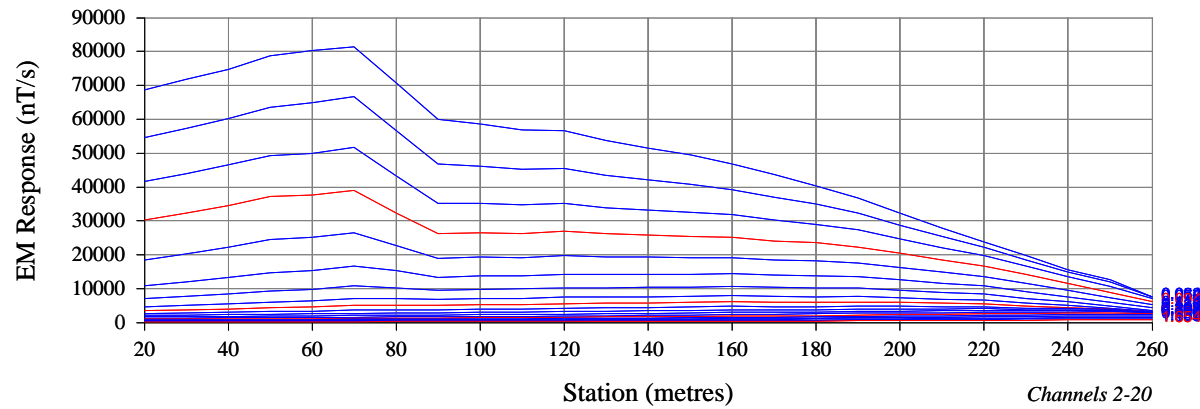
Job No.: JN 2799

Date: 06-05-2013

Fig No.:#5



## U Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver : Crone  
Frequency : 5  
Component : U  
Rx Coil : Crone  
Rx Area : 3090m<sup>2</sup> turn-m

## TRANSMITTER

Transmitter : Crone  
Loop : L1  
Tx Moment : 90000 turn-m  
Tx Current : 30 A  
Turn Off : 0.5 ms

## WINDOW TIMES (ms): Centre From the start of the Ramp

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.72
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
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**Downhole EM Survey**  
**Linear Profiles - U Component**  
**Hole: SJ1, Loop: L1**

Drawn : DJL

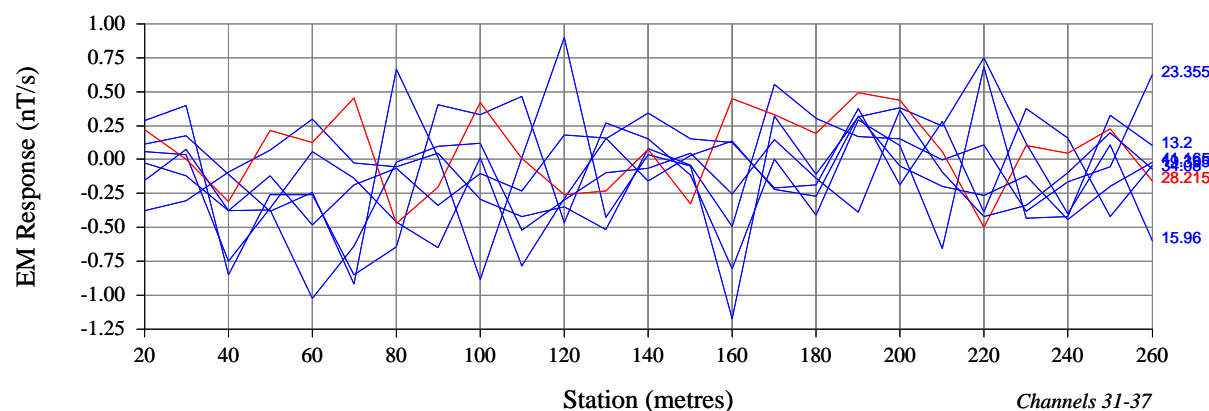
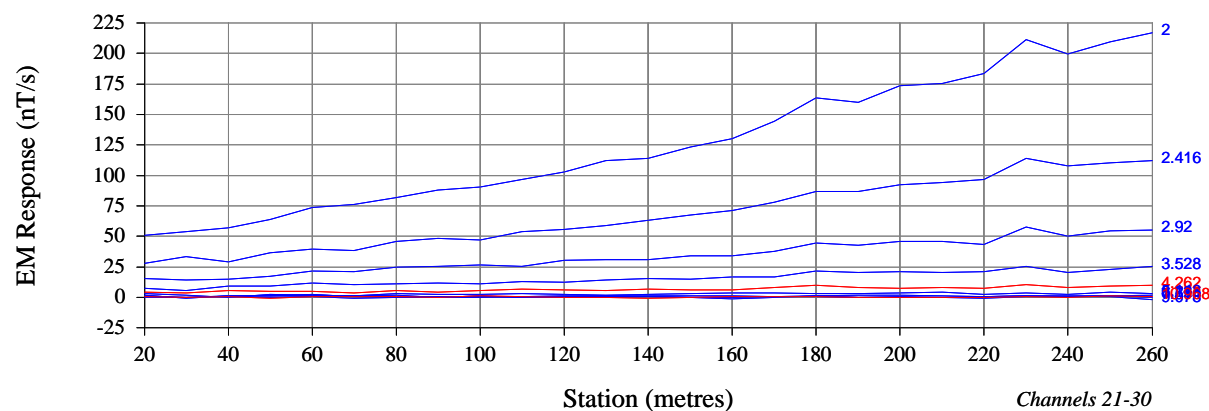
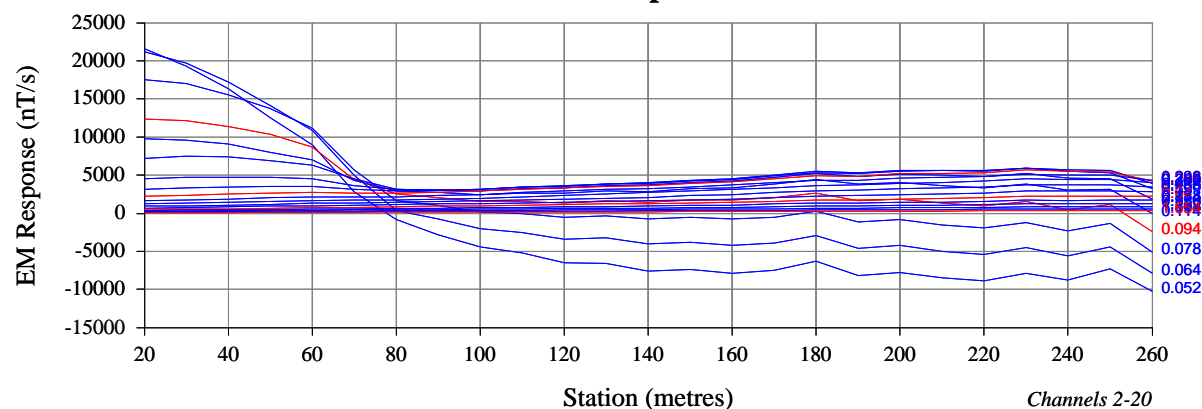
Job No.: JN 2799

Date: 06-05-2013

Fig No.:#6



## V Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver : Crone  
Frequency : 5  
Component : V  
Rx Coil : Crone  
Rx Area : 3090m2 turn-m

## TRANSMITTER

Transmitter : Crone  
Loop : L1  
Tx Moment : 90000 turn-m  
Tx Current : 30 A  
Turn Off : 0.5 ms

## WINDOW TIMES (ms): Centre From the start of the Ramp

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.72
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
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**Downhole EM Survey**  
**Linear Profiles - V Component**  
**Hole: SJ1, Loop: L1**

Drawn : DJL

Job No.: JN 2799

Date: 06-05-2013

Fig No.:#7



## SURVEY PARAMETERS

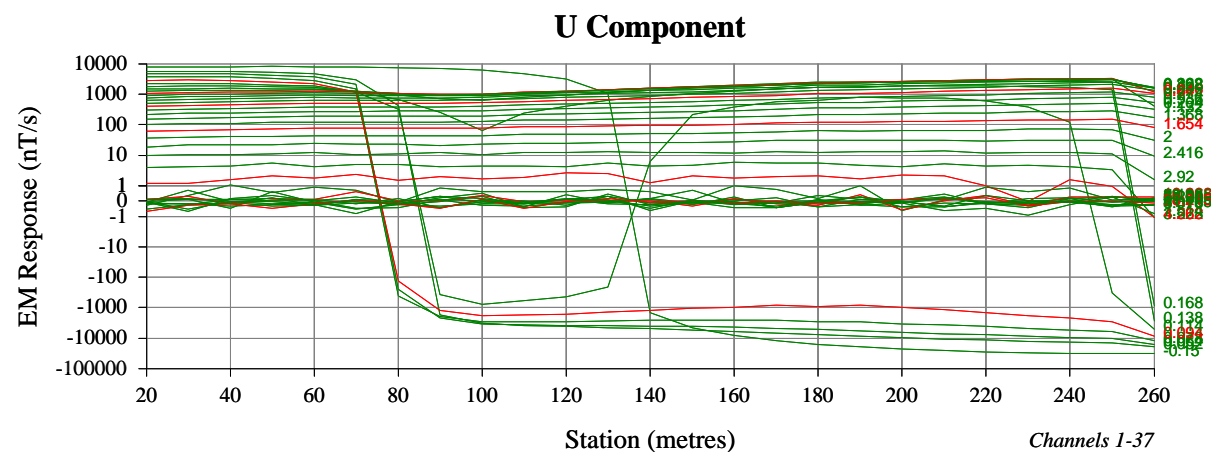
Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver	: Crone
Frequency	: 5
Component	: A,U,V
Rx Coil	: Crone
Rx Area	: 8100m2, 3090m2 turn-m

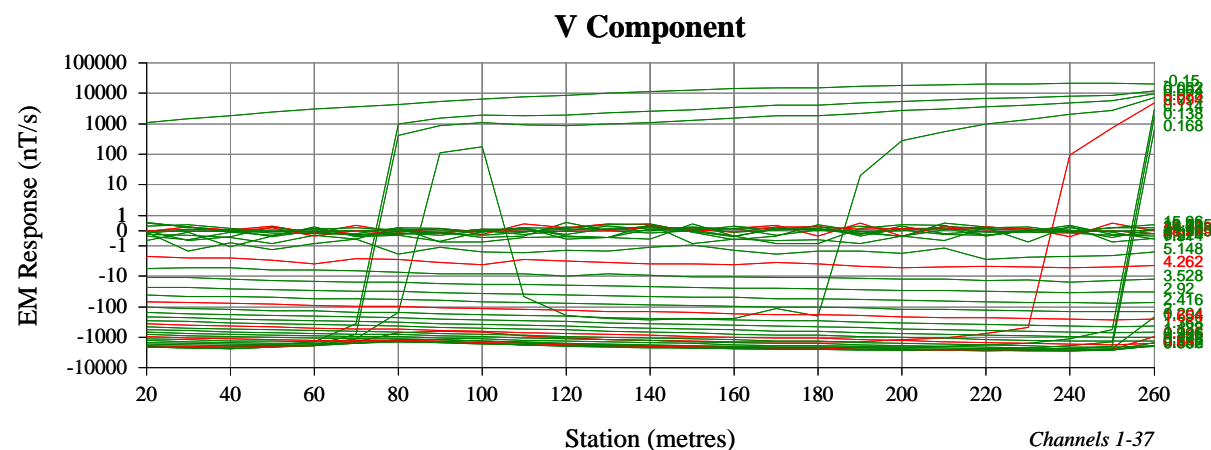
## TRANSMITTER

Transmitter	: Crone
Loop	: L2
Tx Moment	: 90000 turn-m
Tx Current	: 20 A
Turn Off	: 0.5 ms



**WINDOW TIMES (ms): Centre**  
**From the start of the Ramp**

1	: 0.3500	11	: 0.7980	21	: 2.500	31	: 13.70
2	: 0.5520	12	: 0.8620	22	: 2.916	32	: 16.46
3	: 0.5640	13	: 0.9380	23	: 3.420	33	: 19.83
4	: 0.5780	14	: 1.030	24	: 4.028	34	: 23.86
5	: 0.5940	15	: 1.140	25	: 4.762	35	: 28.72
6	: 0.6140	16	: 1.274	26	: 5.648	36	: 34.58
7	: 0.6380	17	: 1.436	27	: 6.720	37	: 41.66
8	: 0.6680	18	: 1.632	28	: 8.014		
9	: 0.7040	19	: 1.868	29	: 9.578		
10	: 0.7460	20	: 2.154	30	: 11.47		



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## Downhole EM Survey

### Log-Linear Profiles

#### Hole: SJ1, Loop: L2

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Drawn : DJL

Job No.: JN 2799

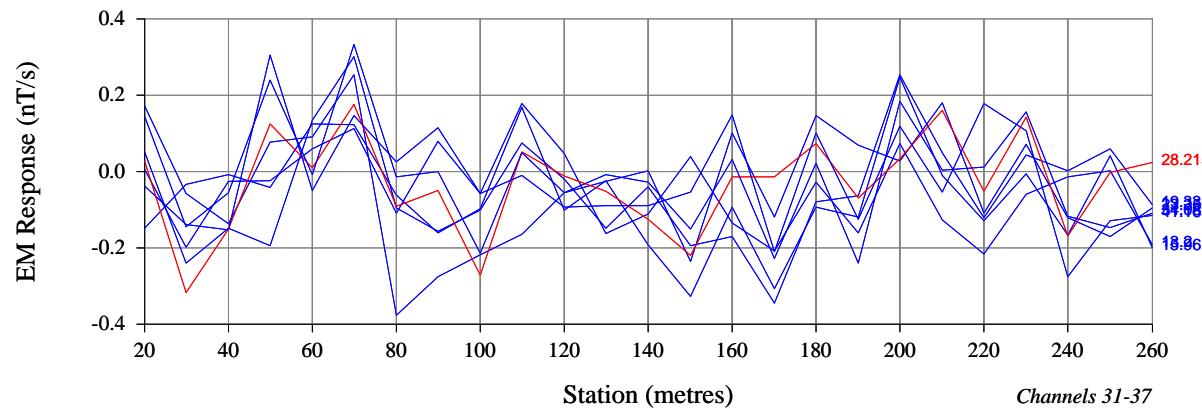
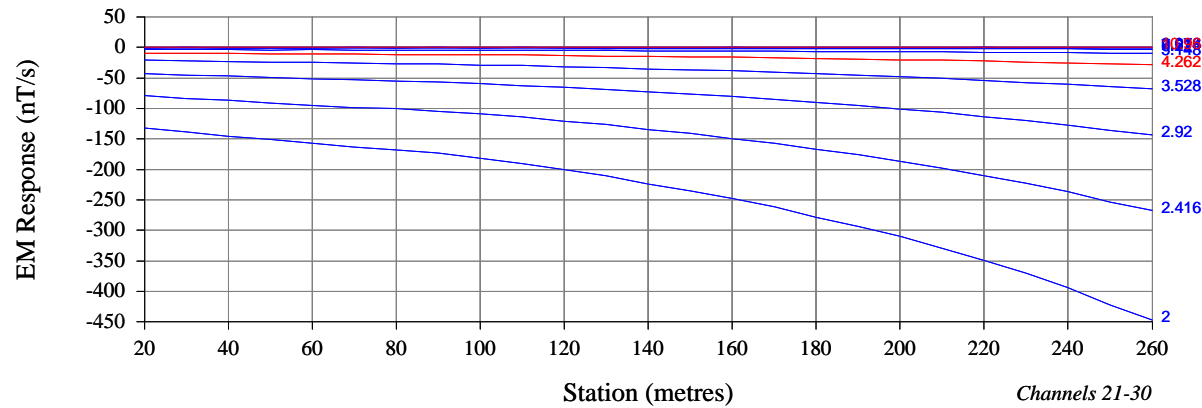
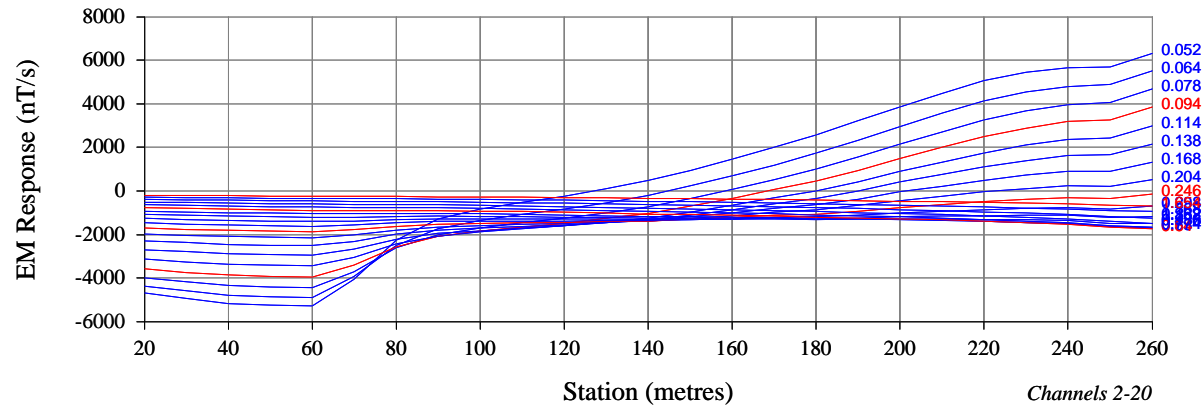
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Date: 06-05-2013

Fig No.:#8



## A Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVED

Receiver	: Crone
Frequency	: 5
Component	: A
Rx Coil	: Crone
Rx Area	: 8100m2 turn-m

## TRANSMITTER

Transmitter	: Crone
Loop	: L2
Tx Moment	: 90000 turn-m
Tx Current	: 20 A
Turn Off	: 0.5 ms

**WINDOW TIMES (ms): Centre**  
**From the start of the Ramp**

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.72
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
8 : 0.6680	18 : 1.632	28 : 8.014	
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10 : 0.7460	20 : 2.154	30 : 11.47	



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## Downhole EM Survey

### Linear Profiles - A Component

### Hole: SJ1, Loop: L2

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Drawn : DJL

Job No.: JN 2799

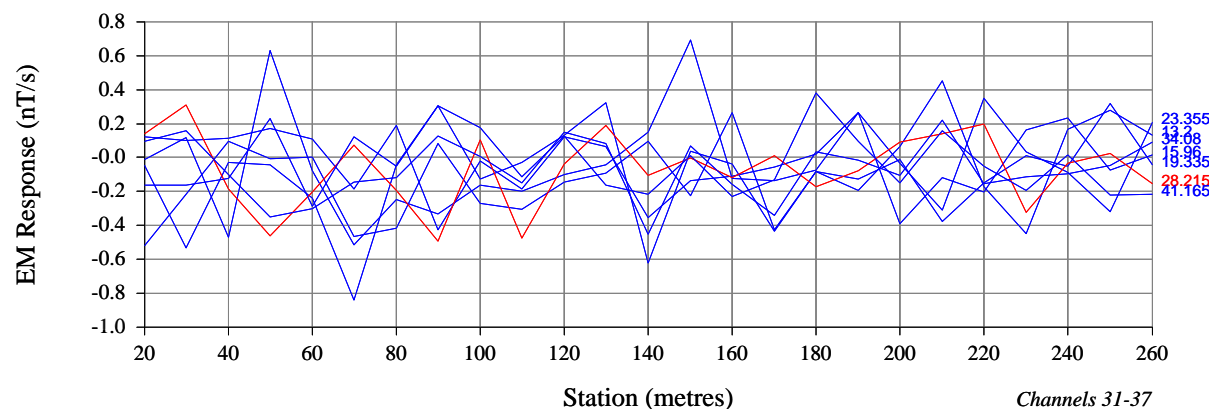
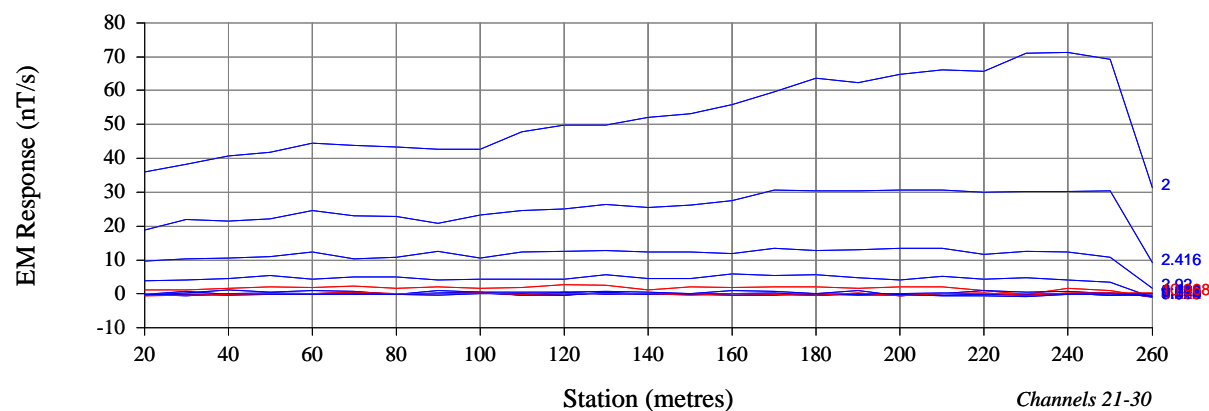
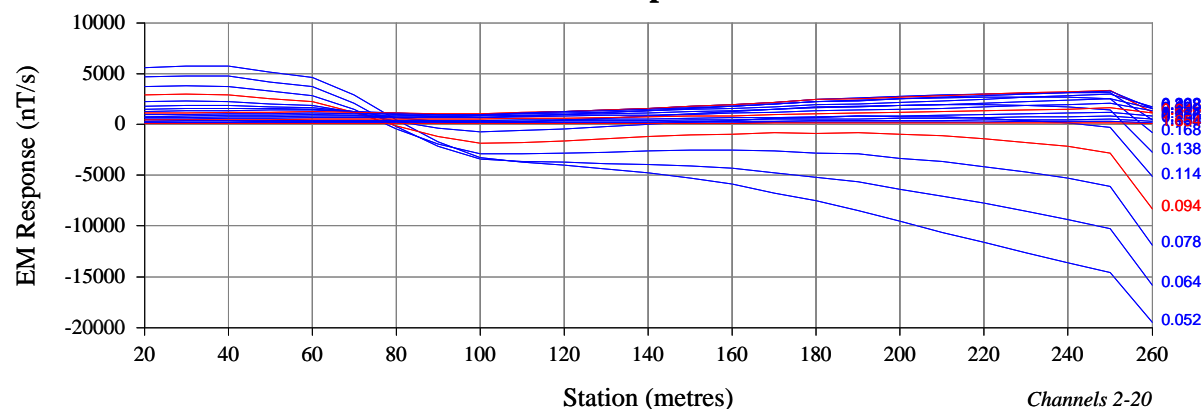
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Date: 06-05-2013

Fig No.:#9



## U Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver : Crone  
Frequency : 5  
Component : U  
Rx Coil : Crone  
Rx Area : 3090m2 turn-m

## TRANSMITTER

Transmitter : Crone  
Loop : L2  
Tx Moment : 90000 turn-m  
Tx Current : 20 A  
Turn Off : 0.5 ms

## WINDOW TIMES (ms): Centre From the start of the Ramp

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.72
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
8 : 0.6680	18 : 1.632	28 : 8.014	
9 : 0.7040	19 : 1.868	29 : 9.578	
10 : 0.7460	20 : 2.154	30 : 11.47	



Outer-Rim Exploration  
Services Pty Ltd

**Stellar Resources Ltd**  
Jasper

**Downhole EM Survey**  
**Linear Profiles - U Component**  
**Hole: SJ1, Loop: L2**

Drawn : DJL

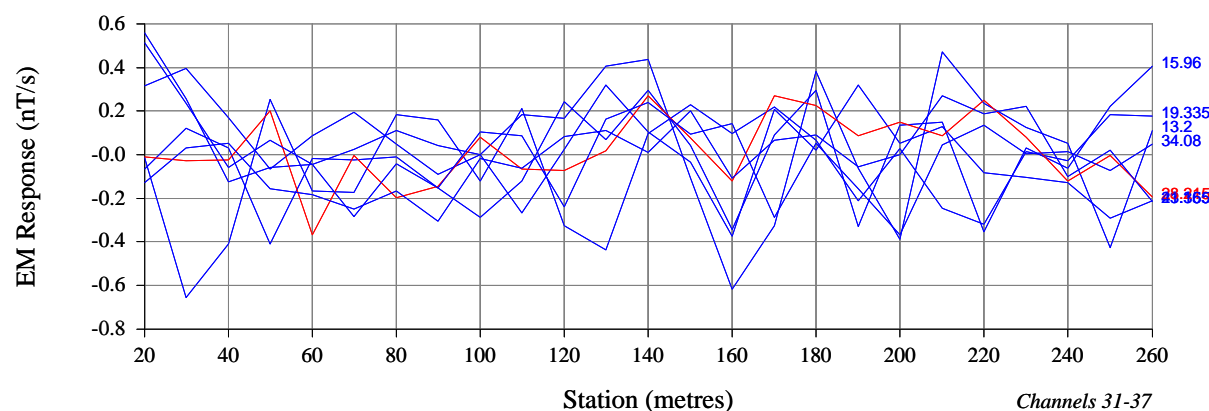
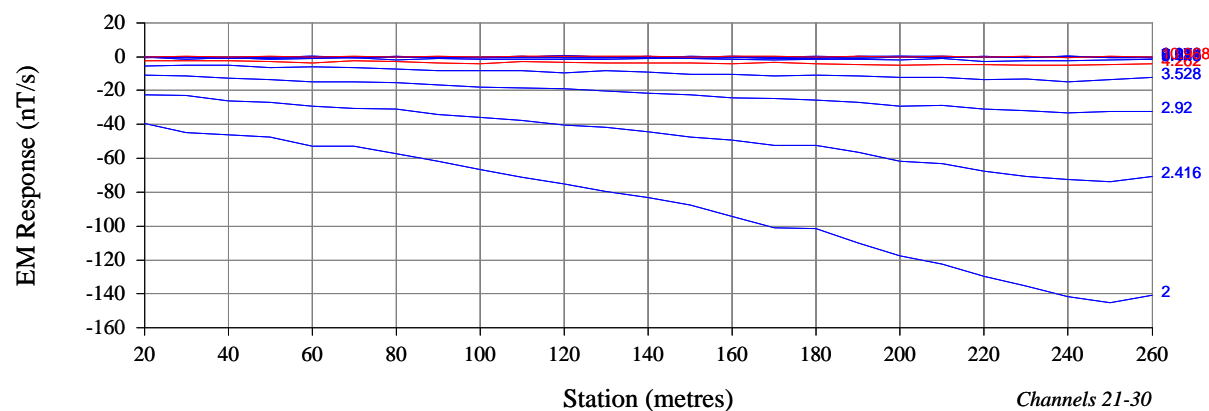
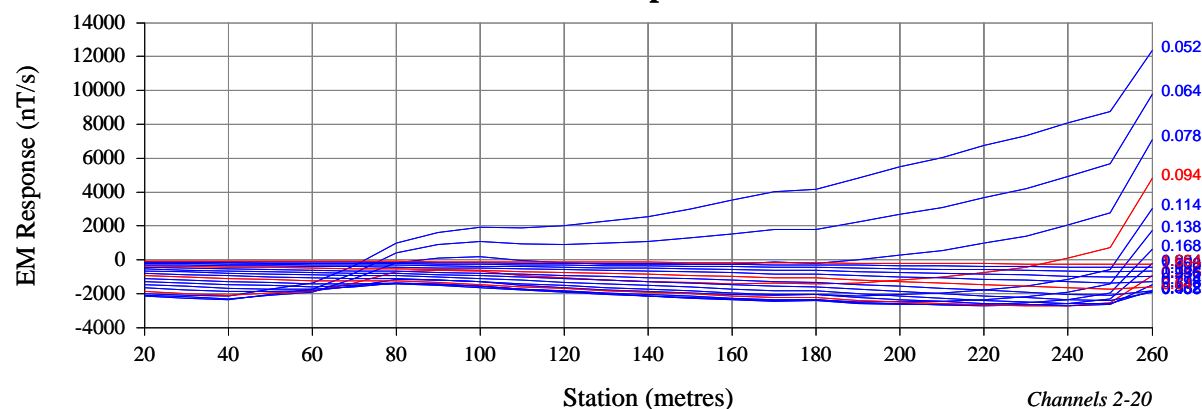
Job No.: JN 2799

Date: 06-05-2013

Fig No.:#10



## V Component



## SURVEY PARAMETERS

Configuration : Downhole  
Station Spacing : 10 m

## RECEIVER

Receiver : Crone  
Frequency : 5  
Component : V  
Rx Coil : Crone  
Rx Area : 3090m2 turn-m

## TRANSMITTER

Transmitter : Crone  
Loop : L2  
Tx Moment : 90000 turn-m  
Tx Current : 20 A  
Turn Off : 0.5 ms

## WINDOW TIMES (ms): Centre From the start of the Ramp

1 : 0.3500	11 : 0.7980	21 : 2.500	31 : 13.70
2 : 0.5520	12 : 0.8620	22 : 2.916	32 : 16.46
3 : 0.5640	13 : 0.9380	23 : 3.420	33 : 19.83
4 : 0.5780	14 : 1.030	24 : 4.028	34 : 23.86
5 : 0.5940	15 : 1.140	25 : 4.762	35 : 28.72
6 : 0.6140	16 : 1.274	26 : 5.648	36 : 34.58
7 : 0.6380	17 : 1.436	27 : 6.720	37 : 41.66
8 : 0.6680	18 : 1.632	28 : 8.014	
9 : 0.7040	19 : 1.868	29 : 9.578	
10 : 0.7460	20 : 2.154	30 : 11.47	



Outer-Rim Exploration  
Services Pty Ltd

**Stellar Resources Ltd**  
Jasper

**Downhole EM Survey**  
**Linear Profiles - V Component**  
**Hole: SJ1, Loop: L2**

Drawn : DJL

Job No.: JN 2799

Date: 06-05-2013

Fig No.:#11