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TECHNICAL NOTE TN-33

Why Did Geonics Limited Build the EM61-MK2?
Comparison Between EM61-MK2 and EM61

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I. INTRODUCTION

This Technical Note provides, first of all, a short description of Geonics EM61 Time Domain Metal Detector, and its new version EM61-MK2, followed by a discussion on a concept and application of the apparent time-constant. In the second part of this paper several case histories are given over known targets, and comparison is made between the EM61-MK2 and the original EM61. Use and benefit of compressed amplitude scale is also discussed.

A Short Description of EM61

The EM61 is a high power time domain metal detector used for detection of ferrous and non-ferrous metallic targets for environmental, UXO and engineering applications. It comprises of a transmitter coil of dimensions 1 x 1 m that is energized by the pulses of current. The magnetic field caused by the transmitter current induces eddy currents in the target, which in turn produces a secondary magnetic field, that generates a signal in the receiving coil. The coil is coincident with the transmitter coil, and it is of the same size. The second receiver coil, parallel to the transmitter coil, is mounted 40 cm above the main receiver coil. The coil array is normally mounted on a set of wheels so that the bottom of the coil array is 43 cm above the ground level.

The main receiver coil is used for detection of targets by sampling the response decay at one time gate after termination of transmitter current pulse. The second receiver coil that has the sampling time gate at the same position as the main coil has the following functions: a) to reduce response from near surface unwanted targets, b) allows for calculation of depth to the target and c) can be used to reduce noise from external electromagnetic interference, like power and telephone lines. Data is normally recorded digitally on a small handheld data logger.

A short description of the EM61-MK2

The EM61-MK2 is an enhanced version of the EM61. The following are comments on the more important characteristics of the EM61-MK2 in comparison with the EM61.

1. Four Time Gates

The EM61-MK2 can provide output from the four time gates geometrically spaced in time in the

For the exponential time-decay the following can be written:

$$V(t) = k\, e^{-t/\tau}$$

where: $V(t)$ = output signal as function of time in mV at time t in μs

τ = characteristic time-constant in μs

k = constant

From four outputs measured with the EM61-MK2 at four time gates, six different time-constants can be derived in the following way:

$$\tau_{m-n} = \frac{t_n - t_m}{\ln(V_m/V_n)}$$

where: τ_{m-n} is time-constant between channels m and n

m and n are gate numbers 1 to 4 ($n > m$)

V_m and V_n are gate output at time t_m and t_n

For illustration Figure 1 shows the time-decay response of a 105 mm projectile in horizontal position in time range from 10 μs to 100 ms. Figure 2 shows a section of decay with indication of EM61-MK2 gate position.

In this example (Figure 2) calculation of apparent time-constant can be performed:

$$\tau_{1-3} = \frac{t_3 - t_1}{\ln\frac{V_1}{V_3}} = \frac{660-216}{\ln\frac{110}{48}} = 535\mu s$$

If the target response is thoroughly exponential all six time-constants will be the same. For the non-exponential response time-constants will be different, or partially different, depending on the decay curve departure from the exponential. From the same target at the different depth, and, therefore, different response magnitude, corresponding time-constant will be similar.

In practice it is a good idea to calculate, process automatically performed in the EM61 program DAT61W, apparent time-constants with two different time sets, let's say τ_{1-3} and τ_{2-4} and then compare results. If the two calculated time-constant for the different targets are the same, it maximum coupling between the long axes of target and the coil array that happens just slightly before and after the array crosses the target center, magnetic induction is a predominant effect at the peak response points, producing larger response than eddy current effect that is maximum over the target center.

2. Various Ferrous and Non-ferrous Balls

A set of six balls are equally spaced at five meters on the ground's surface. The targets 1 to 3 are iron balls, while targets 4 to 6 are aluminum. The following comments on the results of the test can be made:

a) Response from iron (ferrous) balls is considerably larger than response from the equivalent size aluminum ball. The reason for this is that the response, in case of iron ball, comes from two effects: eddy current and magnetic induction (permeability) effect, while in the case of aluminum ball only eddy currents effect contributes to the response.

b) The ratio between gates 1 and 3, EM61 equivalent gate, for aluminum ball is about two, while in the case of the 12.5 cm diameter steel ball ratio is about four.

3. Miscellaneous Metallic Objects

Figure 8 shows the response from various small metallic objects lying on the surface of the ground, spaced five meters apart.

The following comments can be made:

a) Response signature from ferrous material is spatially wider due to the combination of eddy current and magnetic induction effect.

b) It is interesting to observe that aluminum plate, target 3, gives larger response than equivalent size steel plate, target 2. A simple explanation for this is that unlike in case of balls, magnetic induction effect is not sufficiently large to compensate for the difference in the electrical conductivity, related to the eddy current effect, between aluminum and steel.

c) The ratio between channels 1 and 3 is between two to three for iron plates and somewhat less than two for aluminum targets.

4. Columbia Test Site - University of Waterloo

Figure 9 shows the survey site with location and description of different metallic targets buried at the site.

Figure 10 shows the seven profiles over targets to demonstrate a huge dynamic range in amplitude

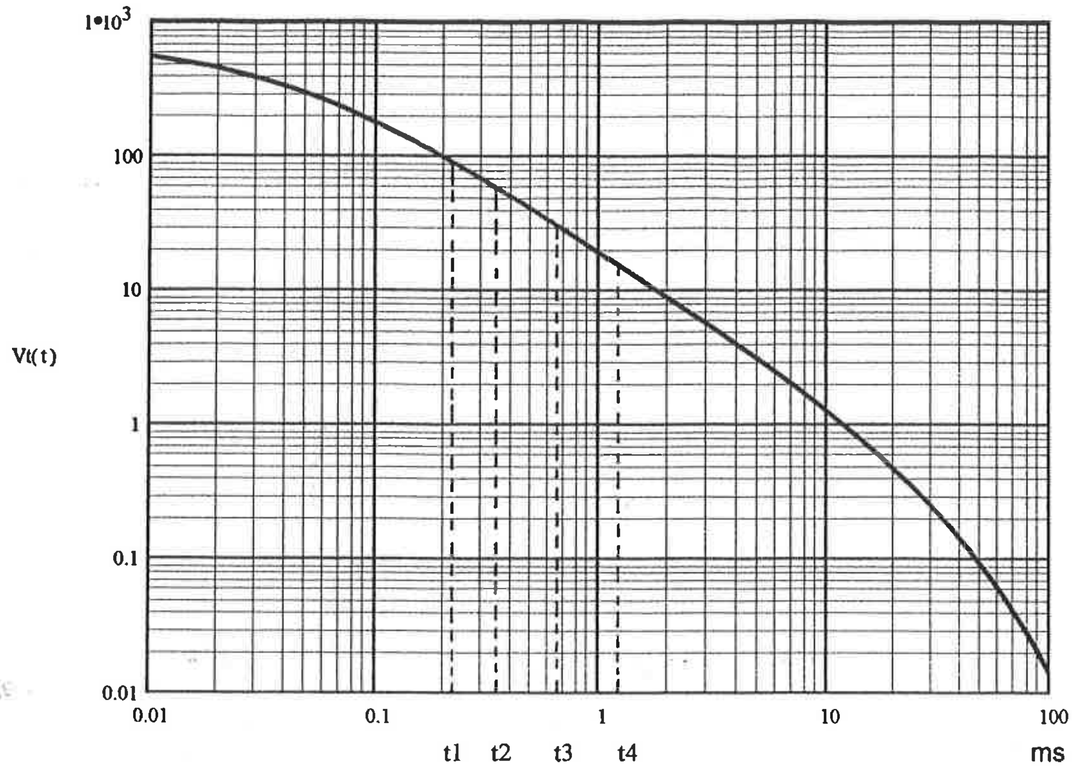


Figure 1

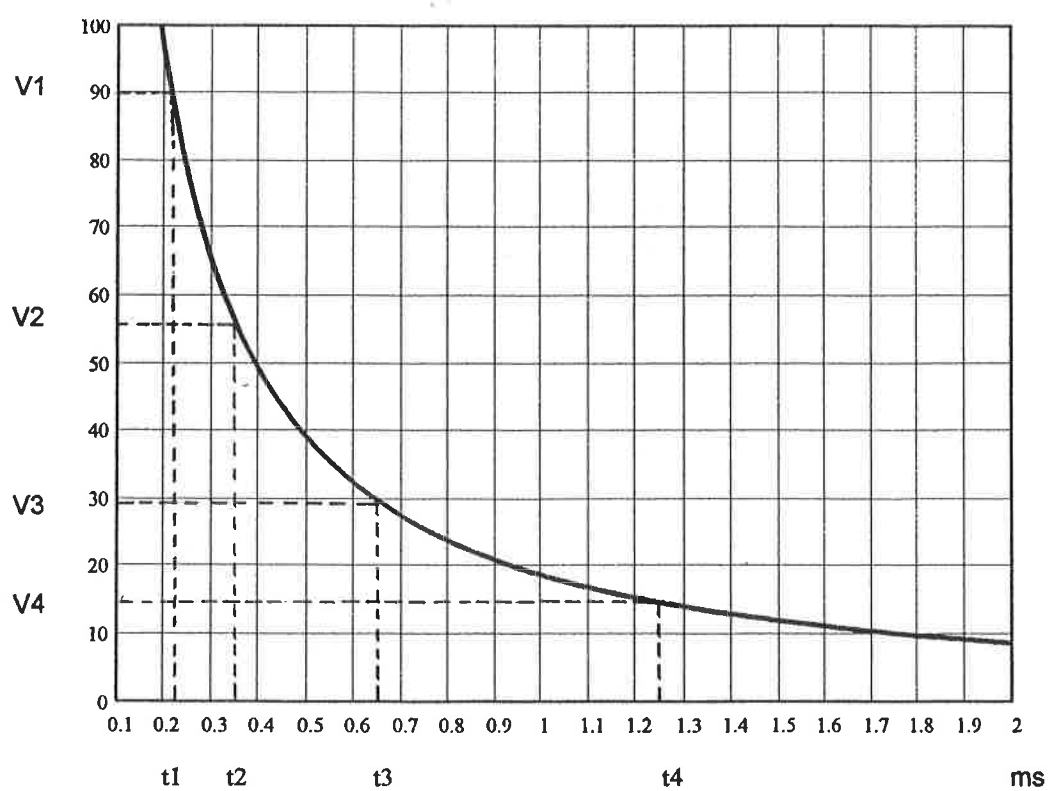


Figure 2

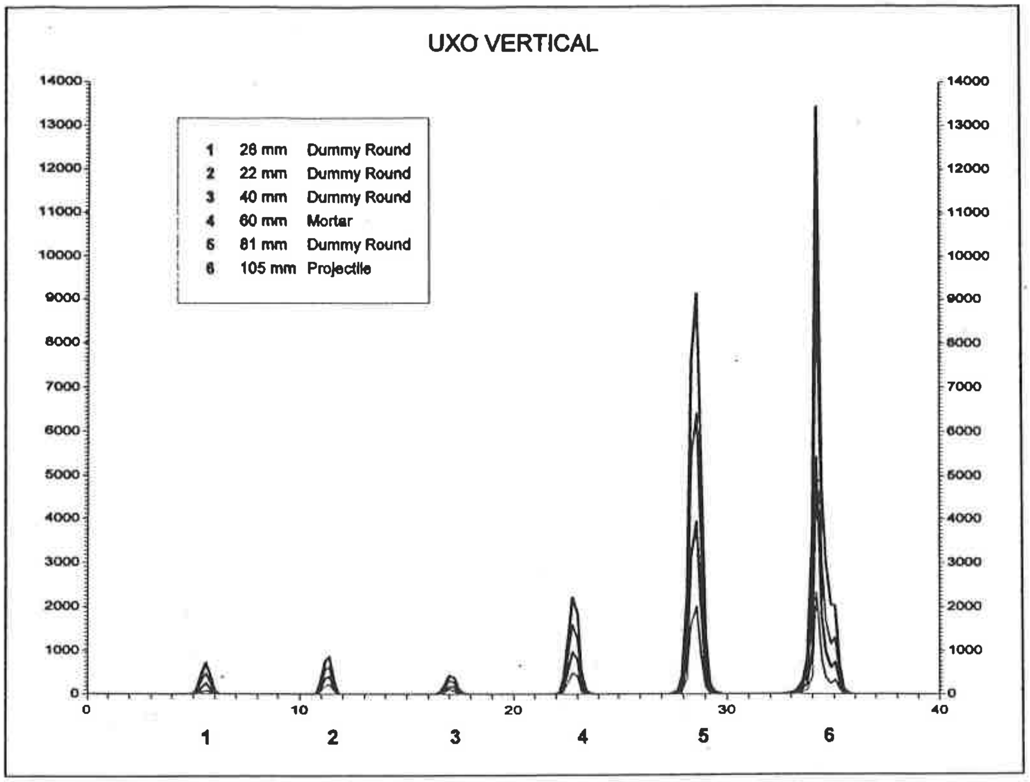


Figure 5

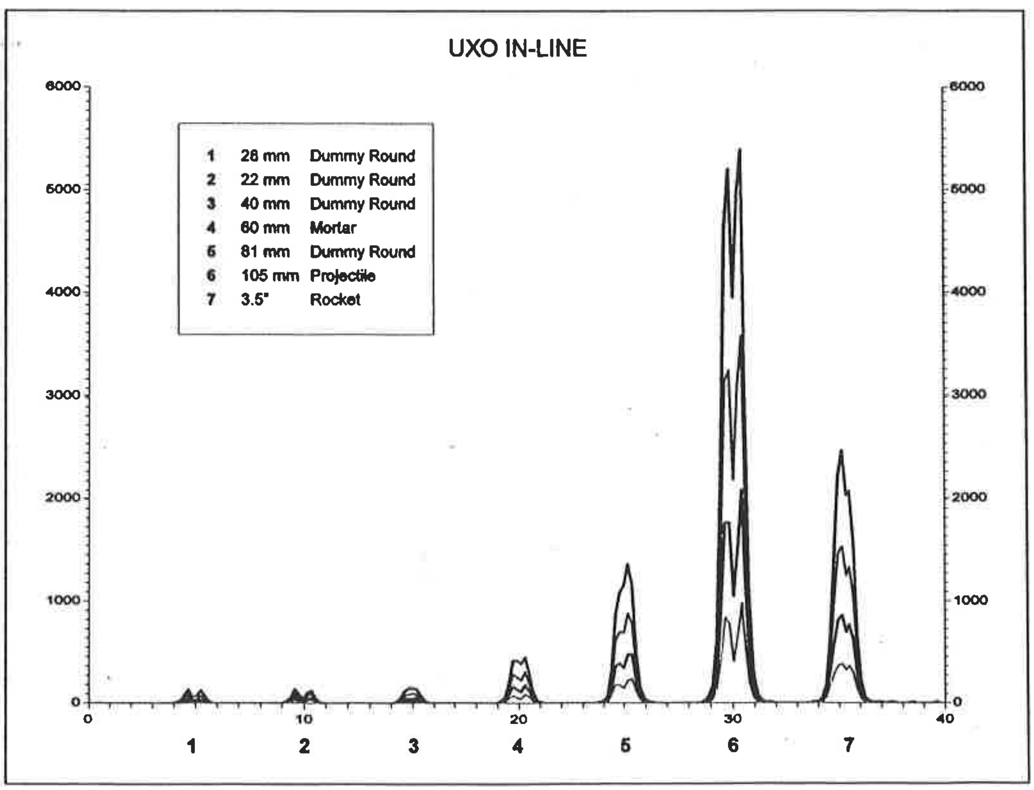
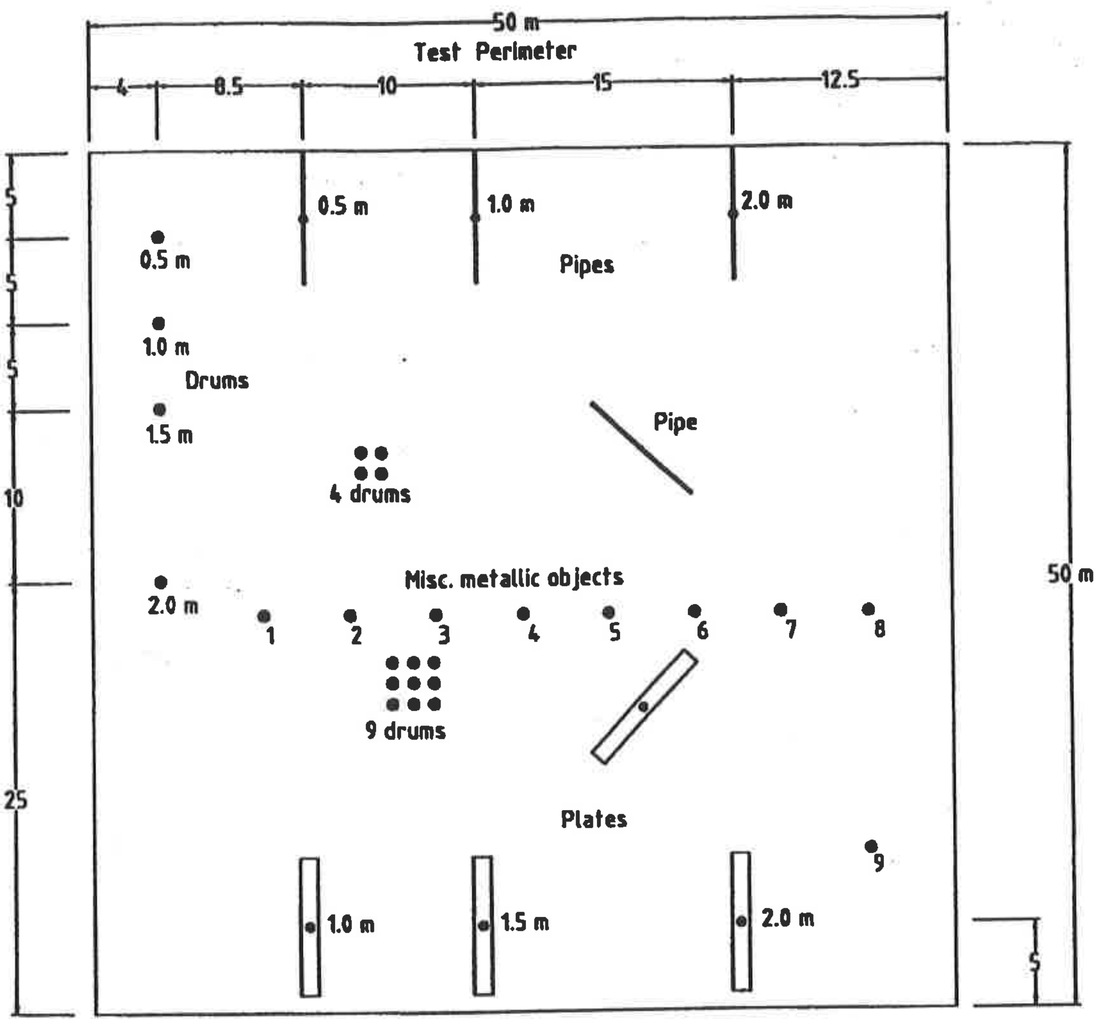


Figure 6



COLUMBIA GOLF COURSE TEST SITE

vertical barrel .6 by .9 m

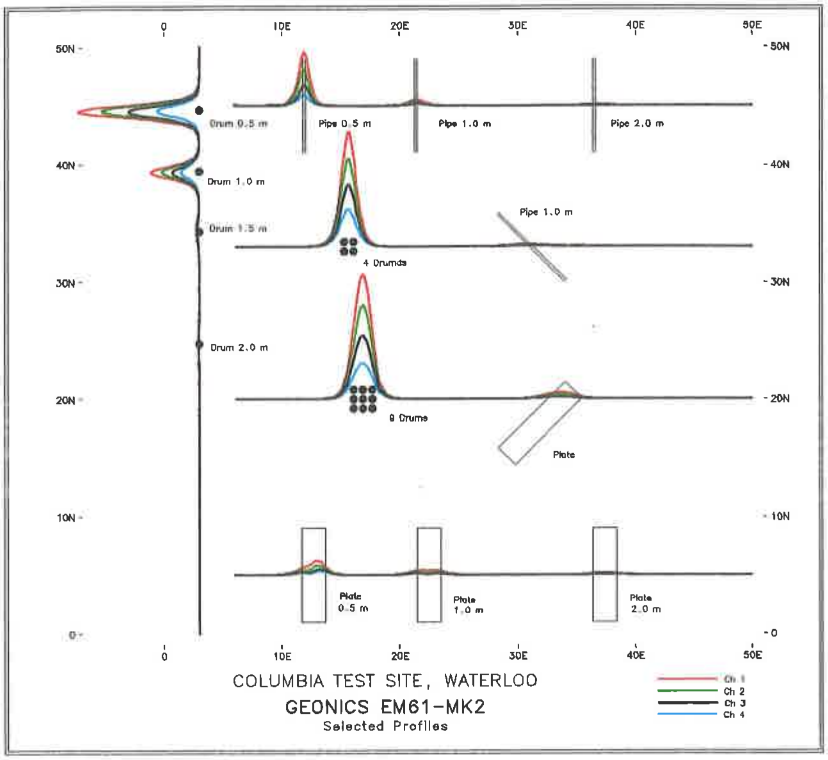
pipeline .10 by 8 m

sheet metal 1 by 8 m

target markers with depth

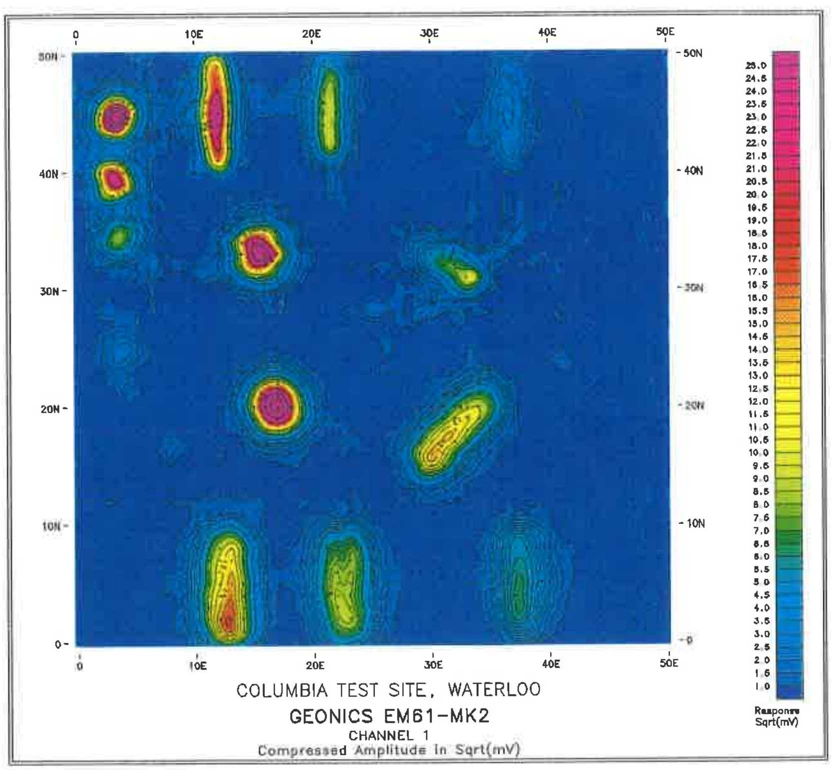
Survey direction

Figure 9



Drum 0.5 m
Pipe 0.5 m
Pipe 1.0 m
Pipe 2.0 m
Drum 1.0 m
Drum 1.5 m
Pipe 1.0 m
4 Drums
Drum 2.0 m
9 Drums
Plate
Plate 0.5 m
Plate 1.0 m
Plate 2.0 m
COLUMBIA TEST SITE, WATERLOO
GEONICS EM61-MK2
Selected Profiles
Ch 1
Ch 2
Ch 3
Ch 4

Figure 10



COLUMBIA TEST SITE, WATERLOO
GEONICS EM61-MK2
CHANNEL 1
Compressed Amplitude in Sqrt(mV)
Response Sqrt(mV)

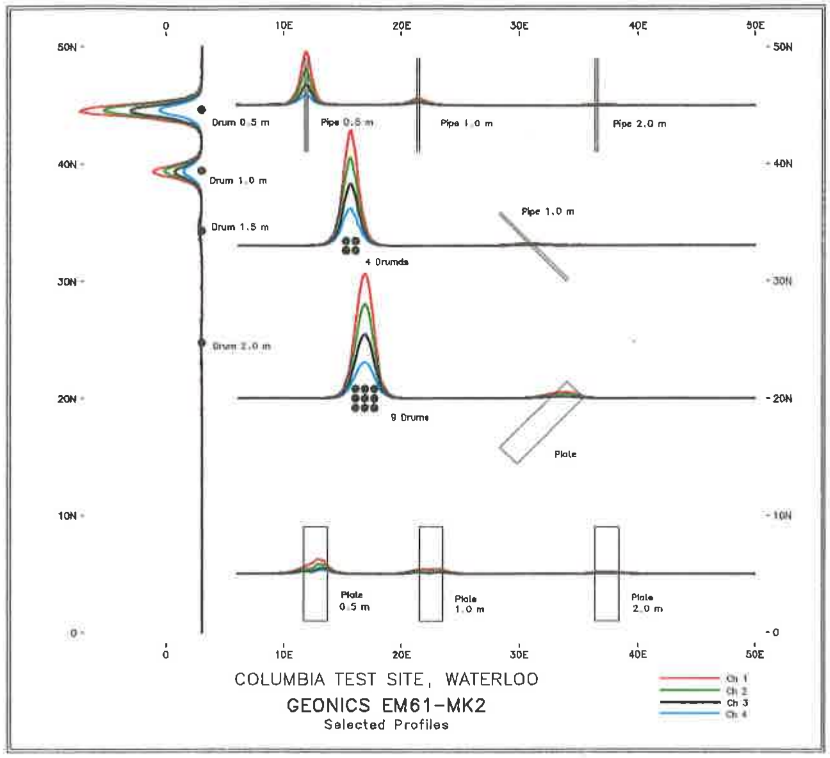


Figure 12

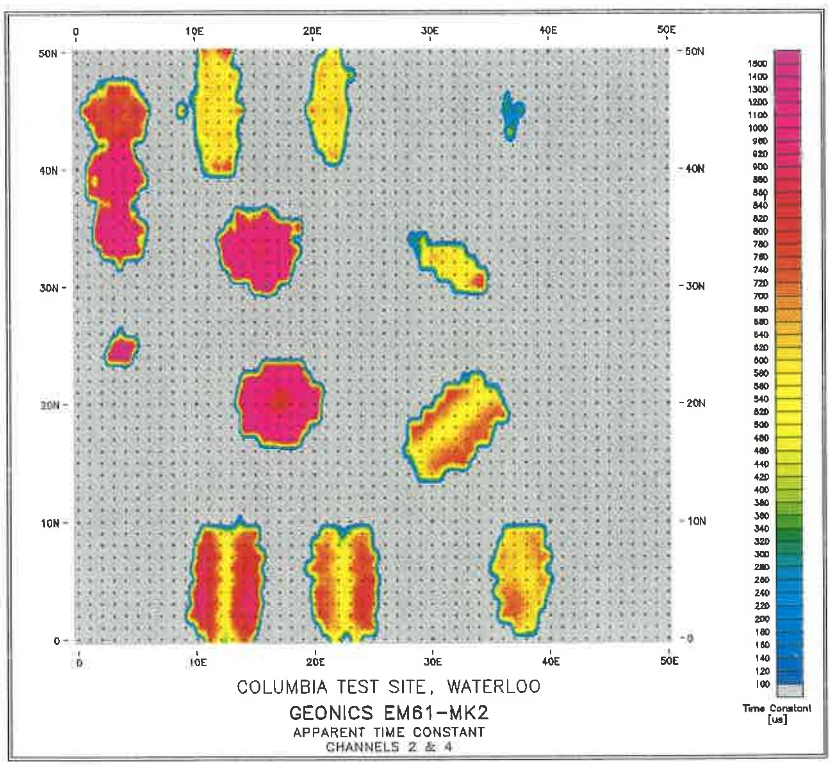


Figure 13