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Use of Ground Penetrating Radar for Locating Contraband Aboard Ocean Going Vessels: Feasibility Study

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Final report
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Prepared for U.S. Coast Guard Research and Development Center
1082 Shennecossett Road
Groton, CT 06340
Appendix G: Crushed Pumice GPR Records – Buried Contraband Simulant Test
Appendix H: Bauxite GPR Records – Buried Contraband Simulant Test
Appendix I: Coal GPR Records – Buried Contraband Simulant Test
SF 298
Preface

Personnel of the U.S. Army Engineer Research and Development Center (ERDC) conducted a series of ground penetrating radar (GPR) surveys at the Alabama State Docks, Mobile, Alabama, during the period 20-22 September 2000. The work was funded by the U.S. Coast Guard Research and Development Center (R&DC), Groton, CT, under MIPR DTCG39-00-X-R00012, dated 13 April 2000.

The GPR surveys were conducted by Mr. José L. Llopis and Dr. Janet E. Simms, Engineering Geology and Geophysics Branch (EGGB), Geosciences and Structures Division (GSD), Geotechnical and Structures Laboratory (GSL), ERDC. Dr. Chih-Wu Su, U.S Coast Guard R&DC, and Mr. Steve Rigdon, Anteon Corporation, Groton, CT, were project managers.

The work was performed under the direct supervision of Dr. Lillian D. Wakeley, Chief, EGGB, and under the general supervision of Drs. Robert L. Hall, Chief, GSD, and Michael J. O’Connor, Director, GSL.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.
Executive Summary

In January 2000 personnel of the U.S. Coast Guard Research and Development Center (R&DC), Groton, CT, and the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, met to discuss possible methods to non-intrusively locate contraband aboard ocean going vessels. R&DC personnel were particularly interested in using current or developing technologies that could be used for this purpose. R&DC personnel stipulated that the equipment had to be compact, man-portable, be able to be used in confined areas of ships, be user-friendly, and the results easy to interpret. One of the methods that was agreed to show promise in locating contraband in the holds of ships was ground penetrating radar (GPR).

GPR surveys were conducted over various stockpiled materials at the Alabama State Docks located in Mobile, AL, to determine whether GPR is a viable method for rapidly detecting contraband materials buried in the cargo holds of ocean going vessels. The surveys were conducted by burying various objects including a contraband simulant (a bundle of four 10-lb bags of sugar duct-taped together) in stockpiled materials available at the site. The stockpiled materials tested were crystal gypsum, powdered gypsum, crushed pumice, coarse coal, fine coal, and bauxite.

Two GPR systems, the pulseEKKO 1000 and the Noggin Plus systems, manufactured by Sensors & Software, Inc., were used to conduct the surveys. Antenna frequencies ranged between 225 and 900 MHz. GPR surveys were run over the stockpiled materials using a suite of antenna frequencies to determine the effects of material type on depth of penetration and target resolution.

All of the antennas tested were successful in detecting the location of the contraband simulant in at least one of the stockpiled materials. The 225 and 250 MHz antennas had the highest percentage of detecting the simulant in the stockpiled materials (60 and 90 percent, respectively) whereas the 900 MHz antenna had the lowest (30 percent). All of the antennas tested have penetration depths of greater than 1.5 m.

The GPR surveys run on the different stockpiled materials at the Alabama State Docks demonstrate that GPR is a feasible means of locating contraband buried to depths of at least 1 to 2 m (limit of testing). However, the probability of success of locating contraband with GPR on board ships depends on the size and
depth of the target as well as the magnetic and electrical properties of target and the material in which it is hidden.
Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

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<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
</tr>
</thead>
<tbody>
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<td>meters</td>
</tr>
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<td>inches</td>
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<td>ohm-feet</td>
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<td>pounds (force)</td>
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1 Introduction

Background

A series of ground penetrating radar (GPR) surveys were conducted in Mobile, AL, during the period 20-22 September 2000 in support of the U.S. Coast Guard Research and Development Center’s (R&DC), Vessel Search Project. Personnel of the Geotechnical and Structures Laboratory (GSL), Engineer Research and Development Center (ERDC), Vicksburg, MS, conducted the GPR surveys. The purpose of the surveys was to determine the effectiveness of GPR in locating contraband buried in various types of bulk cargo materials.

Ground Penetrating Radar Principles and Equipment

Traditionally, GPR has been used as a geophysical technique for subsurface exploration. GPR involves transmitting high-frequency electromagnetic (EM) pulses into a material. The GPR system consists of a transmitting and receiving antenna. When the transmitted EM signal impinges upon the boundaries of materials with contrasting electrical properties some of the EM signal is reflected back to the surface where it is detected by the receiving antenna. The time the signal takes to travel from the transmitting antenna, reflect off a boundary, and be detected by the receiving antenna are amplified, processed, and recorded to provide a “continuous” profile of the subsurface, as illustrated in Figure 1. The lack of coincidence between zero time and zero depth is due to the separation of the transmitter and receiver antenna. The first arrival at the receiver is the direct wave traveling from the transmitter to the receiver, not the reflection from the ground surface. The time span between zero time and zero depth is the one-way travel time of the direct wave between the transmitter and the receiver. The depth scale, in particular at very shallow depths, is nonlinear. The depth scale is based on the velocity of the transmitted EM pulse through the propagating media. Because the transmitter and receiver antenna are separated by a finite distance and the transmitted pulse has a lobe-shaped radiation pattern, the ray of the transmitted pulse that arrives at the receiver does not strike the subsurface interface at normal incidence, but at an acute angle. The depth scale is corrected for non-normal incidence of the transmitted ray path.
The transmitted EM signals respond to changes in materials with sufficiently different electrical properties such as those caused by mineral content, salinity, water content, density, voids, etc. The depth of penetration and amount of definition that can be expected is determined by the electrical properties of the host material being tested as well as the power and frequency of the transmitting antenna. In general, the higher the conductivity of the host material is, the less the GPR depth of penetration. The primary disadvantage of GPR is its extremely site specific applicability. It is difficult to predict whether GPR will be successful in accomplishing its goal without prior knowledge of the electrical properties of the host materials.

Two Sensors and Software, Inc. GPR systems were used for these tests: a pulseEKKO (pE) 1000 and a Noggin Plus. Antenna frequencies of 225, 450, and 900 MHz were used with the pE 1000 while a 250 MHz antenna was used with the Noggin Plus system. The reflection profiling survey mode was used for these surveys. In this mode, the receiving and transmitting antennas are kept a fixed distance apart as the antenna pair is pulled along a survey line. Antenna separations of 0.5, 0.25, and 0.170 m were used with the 225, 450, and 900 MHz antennas, respectively. Although the pE 1000 system allows the flexibility to vary...
As previously mentioned two different GPR systems were used, the pE 1000 and the Noggin Plus. Fundamentally, the two systems are alike however there are several operational differences. The pE 1000 system is a very flexible instrument in that it allows different antenna separations and orientations, modes of operations, and system parameters to be used. System parameters are input and controlled from a laptop computer. As the data is being collected a profile of the subsurface is displayed on the laptop's screen. Because of its flexibility it takes an experienced operator to use the system effectively. Figure 2 shows the pE 1000 system with the 225 MHz antennas. On the other hand, the cart mounted Noggin Plus is a more user-friendly and straightforward system to operate. The system consists of an antenna and a digital video logger (DVL) all mounted on a cart (Figure 3). Once the unit is unfolded and powered-up, a GPR survey can begin in less than a minute. The DVL is used to input system parameters, collect, display, and store data.
Figure 3. Sensors and Software Noggin Plus Smart Cart system with 250 MHz antenna
GPR Field Tests

The GPR surveys were conducted over several different stockpiled materials at the Alabama State Docks, Mobile, AL, and that are typical of cargo carried in the holds of ocean going vessels. Stockpiled materials available at the time of testing were gypsum (crystal form), finely powdered gypsum, crushed pumice, coal, and bauxite.

Initial Investigations

The objective of the first phase of testing day was to determine the penetrating capabilities of the different antennas in selected stockpiled materials. This was accomplished by burying an object that would reflect EM signals back to the ground surface, in this case a steel pipe 5.1 cm in diameter and 30.5 cm long, in the stockpiles of crystal and powdered gypsum, pumice, and coal. The depths at which the pipe was buried varied between approximately 15 and 32 cm. The surveys were typically conducted by dragging a given radar antenna set on the ground surface along profile lines that were perpendicular to the long axis of the steel pipe. The profile lines were extended beyond the pipe by one or more meters to allow the collection of undisturbed (background) information. Survey lines were run directly over and in some cases off to one or both sides of the pipe. The steel pipe is identifiable in the record as vertically alternating dark and light bands in the shape of a hyperbola as shown in Figure 4.

Crystal gypsum pile

Figure 5 shows the crystal gypsum pile being prepared for a GPR survey. The material is coarse-grained and has little or no fine-grained material as shown in Figure 6. The steel pipe was laid on the ground surface oriented in a north-south orientation and covered to a depth of approximately 15 cm with gypsum crystals. A sketch of the test layout showing the orientation of the four survey lines relative to the steel pipe is presented in Figure 7. The GPR records of the surveys conducted over the crystal gypsum pile are presented in Appendix A. Table 1 presents the GPR results for the pE1000 and Noggin systems. The pipe was detected with the pE 225 and 450 MHz antennas and with the Noggin system. The depth of penetration in this material is approximately 1 to 1.5 m and is based on the strength of the GPR signal returns seen on the records.
Hyperbolas indicating the position of a buried 5.1 cm diameter steel pipe

Figure 4. Hyperbolic signature of a 5.1 cm diameter steel pipe buried approximately 15 cm in stockpiled crystal gypsum

Figure 5. Crystal gypsum pile being prepared for GPR surveying

**Powdered gypsum pile**

An area near the toe of the powdered gypsum pile was prepared for testing as shown in Figure 8. The material was very fine-grained with the consistency of flour but with some cohesion (Figure 9). A sketch of the test layout is shown in Figure 10. The pipe and a 30 cm long piece of 5.1 cm by 10.2 cm lumber were buried at depths of approximately 20 and 15 cm, respectively. The GPR survey records for the powdered gypsum pile are presented in Appendix B. The
Figure 6. Example of crystal gypsum material showing grain size

Plan View

South Edge of Pile
South Edge of Pipe
Over Pipe
North Edge of Pipe
North Edge of Pile

f1 f2 f3 f4 f5

Note: Sketch not to scale

Fiducial Markers: f1 = start, f2 = beginning of pipe, f3 = pipe location, f4 = end of pile, f5 = end
Pipe Depth = Approximately 15 cm

Figure 7. GPR survey line layout, crystal gypsum pile, initial investigation
### Table 1
GPR Results, Crystal Gypsum, Initial Investigation

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
<th>Comments</th>
<th>Pipe Detected?</th>
</tr>
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<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225GP1</td>
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<tr>
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<td>CG225GP2</td>
<td>Over pipe</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225GP3</td>
<td>South edge of pipe</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225GP4</td>
<td>South edge of pile off of pipe</td>
<td>No</td>
</tr>
<tr>
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<td>pE1000</td>
<td>CG450GP5</td>
<td>North edge of pile off of pipe</td>
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<td>pE1000</td>
<td>CG450GP6</td>
<td>Over pipe</td>
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<td>pE1000</td>
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<td>pE1000</td>
<td>CG900GP1</td>
<td>North edge of pile off of pipe</td>
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</tr>
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<td>900</td>
<td>pE1000</td>
<td>CG900GP2</td>
<td>Over pipe</td>
<td>No</td>
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<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900GP3</td>
<td>South edge of pipe</td>
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<td>CG900GP4</td>
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<td>Noggin</td>
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<td>North edge of pile off of pipe</td>
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<td>250</td>
<td>Noggin</td>
<td>CG250GP1</td>
<td>Over pipe</td>
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<td>250</td>
<td>Noggin</td>
<td>CG250GP3</td>
<td>South edge of pipe</td>
<td>Yes</td>
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<td>250</td>
<td>Noggin</td>
<td>CG250GP5</td>
<td>South edge of pile off of pipe</td>
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</table>

Figure 8. The powdered pumice pile being prepared for GPR surveying
Figure 9. Image showing the fine-grained pumice with apparent cohesion

Figure 10. GPR survey layout, powdered gypsum pile, initial investigation
results of the GPR surveys are summarized in Table 2. Based on the strength of the signal returns, both GPR systems have at least a 1 m depth of investigation.

<table>
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<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
<th>Comments</th>
<th>Pipe Detected?</th>
<th>Wood Block Detected?</th>
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</thead>
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<td>225</td>
<td>PE1000</td>
<td>CG225PP1</td>
<td>West edge of pile</td>
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<td>No</td>
</tr>
<tr>
<td>225</td>
<td>PE1000</td>
<td>CG225PP2</td>
<td>Over pipe</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
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<td>PE1000</td>
<td>CG225PP3</td>
<td>Over pipe</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
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<td>PE1000</td>
<td>CG450PP1</td>
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<tr>
<td>450</td>
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<td>No</td>
</tr>
<tr>
<td>450</td>
<td>PE1000</td>
<td>CG450PP3</td>
<td>Over pipe</td>
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<td>No</td>
</tr>
<tr>
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<td>PE1000</td>
<td>CG900PP1</td>
<td>West edge of pile</td>
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<td>Over pipe</td>
<td>No</td>
<td>No</td>
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<td>No</td>
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<td>Noggin</td>
<td>CG250PP3</td>
<td>Over pipe</td>
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<td>No</td>
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</table>

Crushed pumice pile

The survey lines for the crushed pumice were located at the toe of the pile as shown in Figure 11. The material consists of moderately sorted vesicular fine- to medium-grained pebble gravel in a fine- to medium-grained sand matrix (Figure 12). A sketch of the test layout is shown in Figure 13. The pipe and a 30 cm long piece of 5.1 cm by 10.2 cm lumber were buried at respective depths of approximately 24 and 30 cm. The GPR records for the surveys conducted on the crushed pumice pile are presented in Appendix C. The results of the GPR surveys are summarized in Table 3. The depth of investigation in this material is greater than 3 m.
Figure 12. Image illustrating crushed pumice grain size

Figure 13. GPR survey layout, crushed pumice pile, initial investigation
Table 3
GPR Results, Crushed Pumice, Initial Investigation

<table>
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<th>Antenna frequency, MHz</th>
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<th>File name</th>
<th>Comments</th>
<th>Pipe detected?</th>
<th>Wood block detected?</th>
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<td>No</td>
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<td>No</td>
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</table>

Coarse coal pile

The survey lines for the coarse coal pile were located at the toe of the pile as shown in Figure 14. A sketch of the GPR survey layout is presented in Figure 15. The GPR records for the surveys conducted over the coal pile are presented in Appendix D. The results of the GPR surveys are summarized in Table 4. The pipe was difficult to distinguish with the Noggin and not detected with any of the pE antennas. The depth of investigation in this material is at least 1 m.

Figure 14. GPR survey being conducted at the toe of the coarse coal pile with the pE1000 system
Buried Contraband Simulant Tests

The second phase of testing consisted of burying contraband simulants in stockpiled materials and determining the ability of GPR in detecting them. The simulant consisted of four 10-lb bags of sugar duct-taped together to form a 40-lb bundle as shown in Figure 16. The sugar bundles were buried in different stockpiled materials at a depth of about 40 cm and GPR profile lines run over the bundles in an attempt to detect the sugar or any evidence of disturbance caused.
Figure 16. Two contraband simulants each consisting of four 10-lb bags of sugar duct-taped together by digging and burying activities. The same GPR systems and antennas used in the first phase of testing were used in the second phase.

**Crystal gypsum pile**

The site was prepared by placing several lifts of crystal gypsum on the ground surface with a front-end loader to construct an area large enough on which to conduct the GPR surveys (Figure 17). The prepared area measured approximately 10 m long by 5 m wide and varied from about 0.3 to 1 m in height (Figure 18). A 40-lb bundle of sugar was buried near the middle of the prepared area to a depth of approximately 0.4 m and backfilled with crystal gypsum. A sketch of the test area showing the location of the GPR profile lines is presented Figure 19. The GPR records for the surveys conducted over the crystal gypsum are presented in Appendix E. The results of the GPR surveys are summarized in Table 5. The sugar bundle is visible using the Noggin system but is not readily detectable using the pE system.

**Powdered gypsum pile**

The site was prepared by placing, with a front-end loader, several lifts of powdered gypsum on the ground surface to construct an area large enough on which to conduct the GPR surveys. The prepared area measured approximately 8 m long by 4 m wide by 0.6 m high. Figure 20 shows the prepared tests site.
Figure 17. Contraband simulant being covered with crystal gypsum

Figure 18. GPR survey being conducted over prepared crystal gypsum site
Figure 19. GPR survey line layout, crystal gypsum pile, buried contraband simulant tests

Table 5
GPR Results, Crystal Gypsum, Buried Contraband Simulant Tests

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
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<th>Simulant Detected?</th>
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<td>CG225GS</td>
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</tr>
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<td>pE1000</td>
<td>CG225GS2</td>
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</tr>
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<td>pE1000</td>
<td>CG225GS3</td>
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</tr>
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<td>225</td>
<td>pE1000</td>
<td>CG225GS4</td>
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<td>225</td>
<td>pE1000</td>
<td>CG225GS5</td>
<td>South of sugar</td>
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</tr>
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<td>450</td>
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<td>CG450GS2</td>
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</tr>
<tr>
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<td>pE1000</td>
<td>CG450GS3</td>
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<td>900</td>
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<td>CG900GS2</td>
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<td>Over sugar</td>
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</tr>
<tr>
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<td>Noggin</td>
<td>CG250GS2</td>
<td>Over sugar</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250GS3</td>
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</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250GS4</td>
<td>Over sugar (N-S line orientation)</td>
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</tr>
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</table>
The bundle of sugar was buried near the middle of the prepared area to a depth of approximately 0.4 m and backfilled with powdered gypsum. The steel pipe was buried to a depth of approximately 25 cm near the sugar bundle as shown in Figure 21. The GPR records for the surveys conducted over the powdered gypsum are presented in Appendix F. The results of the GPR surveys are summarized in Table 6. The pE 225 MHz antenna and the Noggin system are able to locate the sugar bundle. The pipe was buried after the Noggin and prior to the pE systems being run over the site.

**Crushed pumice pile**

Testing was conducted on the same narrow ridge of pumice on the toe of the pumice pile as was used for locating the pipe in the initial investigations as shown in Figure 22. The 40-lb bundle of sugar was buried to a depth of 40 cm and backfilled with crushed pumice. All of the GPR profile lines were run over the buried sugar because of the limited testing area. A sketch of the test area showing the location of the GPR profile lines is presented Figure 23. The GPR records for the surveys conducted over the crushed pumice are presented in Appendix G. The results of the GPR surveys conducted over the crushed pumice are summarized in Table 7. The sugar bundle or soil disturbance can be detected using the Noggin and pE 225 and 450 MHz.
Figure 21. GPR survey line layout, powdered gypsum pile, buried contraband simulant test

Table 6
GPR Results, Powdered Gypsum, Buried Contraband Simulant Tests

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
<th>Comments</th>
<th>Simulant Detected?</th>
<th>Pipe Detected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225PS1</td>
<td>West of sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225PS2</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225PS3</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225PS4</td>
<td>East of sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450PS1</td>
<td>West of sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450PS2</td>
<td>Over sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450PS3</td>
<td>Over sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450PS4</td>
<td>East of sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900PS1</td>
<td>West of sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900PS2</td>
<td>Over sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900PS3</td>
<td>Over sugar</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250PS0</td>
<td>West of sugar</td>
<td>Yes</td>
<td>N/A¹</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250PS1</td>
<td>Over sugar</td>
<td>Yes</td>
<td>N/A¹</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250PS2</td>
<td>Over sugar</td>
<td>Yes</td>
<td>N/A¹</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250PS3</td>
<td>East edge of pile off of pipe</td>
<td>No</td>
<td>N/A¹</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250PS4</td>
<td>Over sugar (W-E line orientation)</td>
<td>Yes</td>
<td>N/A¹</td>
</tr>
</tbody>
</table>

¹Note: The pipe was not in-place during the Noggin system surveys.
Figure 22. pulseEKKO 1000 GPR survey over simulated contraband, crushed pumice

Figure 23. GPR survey line layout, crushed pumice pile, buried contraband simulant test
Table 7  
GPR Results, Crushed Pumice, Buried Contraband Simulant Tests

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
<th>Comments</th>
<th>Simulant Detected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225MS1</td>
<td>Over sugar</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225MS2</td>
<td>Over sugar</td>
<td>Yes</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450MS1</td>
<td>Over sugar</td>
<td>No</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450MS2</td>
<td>Over sugar</td>
<td>No</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900MS1</td>
<td>Over sugar</td>
<td>No</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900MS2</td>
<td>Over sugar</td>
<td>No</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250MS0</td>
<td>Over sugar</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250MS1</td>
<td>Over sugar</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Bauxite pile

GPR tests were conducted along a 6-m-long track on the slope of a large bauxite pile as shown in Figure 24. The bauxite pile was not initially tested using a buried pipe, as was the case with the gypsum and pumice piles because this was an area with heavy truck traffic and access to the pile was limited to after regular work hours. Two holes were dug into the bauxite pile. The holes, one located 2.5 m from the survey start, was used to bury a 40-lb bundle of sugar and the other hole, located 4.1 m from the start, a steel pipe that measured 5.1 cm in diameter and 30.5 cm long. A sketch of the test area showing the location of the GPR profile lines is presented Figure 25. The GPR records for the surveys conducted over the bauxite pile are presented in Appendix H. The results of the GPR surveys conducted over the crushed pumice are summarized in Table 8. The buried steel pipe appears as a hyperbola and is easy to discern in the records of all the frequencies. Without prior knowledge of the location of the sugar bundle it would be difficult to distinguish its location in the GPR records. The sugar bundle signature can be seen in all of the records and is most clearly seen in the 450 MHz records, especially record CG450BS2.

Coal pile

GPR testing was conducted along an area just above the toe of a large pile of crushed coal (Figure 26). This coal pile was different than the one used for the initial buried pipe test. The coal in this pile was finer grained and in a looser density state because it had been recently been offloaded whereas the coal pile used in the initial investigations was coarser grained and the pile appeared to have been in place for months if not years. Two holes were dug into the coal pile. The holes, one located 2.2 m from the survey start, was used to bury a 40-lb bundle of sugar and the other hole, located 3.9 m from the start, a steel pipe that measured 5.1 cm in diameter and 30.5 cm long. The bundle of sugar and the steel pipe were buried at a depth of 0.35 m. A sketch of the test area showing the location of the GPR profile lines is presented Figure 27. The GPR records for the surveys conducted over the coal pile are presented in Appendix I. The results of the GPR surveys conducted over the coal are summarized in Table 9. The pipe is detected with all of the antennas. The higher frequency antennas provide greater resolution. The bundle of sugar is only detectable with the 450 and 900 MHz antennas.
Figure 24. Noggin GPR survey over simulated contraband, bauxite pile
Figure 25. GPR survey line layout, bauxite pile, buried contraband simulant test

Table 8
GPR Results, Bauxite, Buried Contraband Simulant Tests

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
<th>Comments</th>
<th>Simulant Detected?</th>
<th>Pipe Detected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225BS1</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225BS2</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450BS1</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450BS2</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900BS1</td>
<td>Over sugar</td>
<td>Questionable</td>
<td>Yes</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900BS2</td>
<td>Over sugar</td>
<td>Questionable</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250BS0</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250BS1</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Figure 26. Noggin GPR survey over simulated contraband, coal pile

Plan View

Over Sugar and Pipe

Sugar Bundle

Pipe

f1 | f2 | f3 | f4

Note: Sketch not to scale
Fiducial Markers: f1=start, f2=sugar bundle location, f3=pipe location, f4=end
Sugar depth = Approximately 35 cm
Pipe depth = Approximately 35 cm

Indicates GPR Survey Line Position and Direction

Figure 27. GPR survey line layout, coal pile, buried contraband simulant test

Chapter 2  GPR Field Tests
<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>System</th>
<th>File Name</th>
<th>Comments</th>
<th>Simulant Detected?</th>
<th>Pipe Detected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225LS1</td>
<td>Over sugar</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>pE1000</td>
<td>CG225LS2</td>
<td>Over sugar</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450LS1</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>450</td>
<td>pE1000</td>
<td>CG450LS2</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900LS1</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>900</td>
<td>pE1000</td>
<td>CG900LS2</td>
<td>Over sugar</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250LS0</td>
<td>Over sugar</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Noggin</td>
<td>CG250LS1</td>
<td>Over sugar</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Terrain Conductivity Tests

In addition to the GPR surveys, conductivity surveys were also conducted over the various test materials. The conductivity measurements were collected to determine if there was a correlation of conductivity to GPR depth of penetration or detection capability. A Geonics Ltd. EM38 terrain conductivity meter was used to collect the conductivity measurements (Figure 28). The measurements for the crystal and powdered gypsum and pumice were collected along the GPR survey lines used for the buried sugar experiments. The EM surveys were conducted by placing the meter in direct contact with the material and taking measurements every 0.5 m along the survey line. During the surveys it was noticed that the EM values for these materials were quite high. It was suspected that the metal rebar in the reinforced concrete slabs upon which the crystal and powdered gypsum, crushed pumice, and coarse coal piles are placed were affecting the conductivity readings. Spot conductivity measurements were taken at different elevations on the piles to collect readings not influenced by the metal rebar. Table 10 summarizes the conductivity values in millisiemens per meter (mS/m) for all the piles tested with the exception of the fine coal pile. Because of truck loading operations taking place by the fine coal pile, conductivity measurements were not taken. It is noted that, with the exception of the bauxite pile, the conductivity values taken along the GPR lines are significantly higher than those taken near the top of respective piles.
Table 10
Conductivity Values for Different Test Pile Materials

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Range and Average Conductivity Values Along GPR Profile Line, mS/m</th>
<th>Conductivity Range on Pile, mS/m</th>
</tr>
</thead>
</table>
| Crystal gypsum | Range = 44-83  
Average = 70 | 5-20; top of pile |
| Powdered gypsum | Range = 65-91  
Average = 77 | 9-16; top of pile |
| Pumice | Range = 66-166  
Average = 105 | 29-40; ½ way up pile  
15; ¾ way up pile  
8; top of pile |
| Coal (coarse) | Range = 110-140  
Average = 125 | 85-128; ½ way up pile  
63-84; ¾ way up pile |
| Bauxite | Range = 17-45  
Average = 35 | 12-28; ½ way up pile |
3 Discussion of Results

Ground penetrating radar surveys were run over several stockpiled materials to determine the effectiveness of GPR in detecting buried contraband material. Several items types were buried in the stockpiled materials and GPR surveys run over them to determine which antennas were the most effective in detecting the items in specific materials. The buried items consisted of a pipe, a block of wood, and bundled together bags of sugar. Table 11 summarizes the ability of the tested GPR antennas in detecting the buried objects in the different stockpiled materials. Table 11 pertains to surveys conducted directly over the buried items.

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>Buried Item</th>
<th>Crystal Gypsum</th>
<th>Powdered Gypsum</th>
<th>Crushed Pumice</th>
<th>Coarse Coal</th>
<th>Bauxite</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>Steel Pipe</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>450</td>
<td>Steel Pipe</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>900</td>
<td>Steel Pipe</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Steel Pipe</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>225</td>
<td>Wood Block</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>450</td>
<td>Wood Block</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>900</td>
<td>Wood Block</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>250</td>
<td>Wood Block</td>
<td>?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>225</td>
<td>Sugar Bundle</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>450</td>
<td>Sugar Bundle</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>900</td>
<td>Sugar Bundle</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>250</td>
<td>Sugar Bundle</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 11 pertains to surveys conducted directly over the buried items. Referring to Table 11 it is seen that the GPR antennas perform differently in detecting the different buried objects in the various stockpiled materials. Table 12 shows the ability of the different antennas in detecting the steel pipe, wood block, and sugar bundle in the stockpiled materials.

Referring to Table 12 the steel pipe was the most readily detected object, as expected, and the wood block the most difficult. The 250 MHz antenna was the only antenna capable of detecting the wood block. In general, the 250 MHz antenna was the most effective antenna for detecting the buried items followed by, in the order of most effective in detecting the buried targets, the 225, 450,
Table 12

GPR Detection Capability for a Steel Pipe, Wood Block, and Sugar Bundle in Stockpiled Materials

<table>
<thead>
<tr>
<th>Antenna Frequency, MHz</th>
<th>Percent Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steel Pipe</td>
</tr>
<tr>
<td>225</td>
<td>83</td>
</tr>
<tr>
<td>450</td>
<td>67</td>
</tr>
<tr>
<td>900</td>
<td>33</td>
</tr>
<tr>
<td>250*</td>
<td>100</td>
</tr>
</tbody>
</table>

* Denotes Noggin Plus System.

and 900 MHz antennas. The wood block was detected in the coarse coal and it is questionable whether it was detected in the powdered gypsum with the 250 MHz antenna.

With the exception of the initial tests conducted on the coarse gypsum pile, the GPR surveys were run over test sites prepared by placing relatively thin layers (1-2 m) of stockpiled material on the ground surface. Because of the relative thinness of the prepared test site and since many of the tests were conducted on reinforced concrete pads, a very good EM energy reflector, it is difficult to determine the maximum depth of penetration of the GPR for the various stockpiled materials. The survey records indicate that the GPR was able to penetrate through the entire thickness of all the tested materials to the top of the reinforced concrete. In order to determine the maximum depth of penetration in each of the materials GPR surveys would have to be conducted over increasing amounts of material until the reflecting concrete surface was no longer visible in the records.
4 Summary and Conclusions

Ground penetrating radar (GPR) surveys were conducted over various stock-piled materials at the Alabama State Docks located in Mobile, AL. The surveys were conducted to determine whether GPR is a viable method for rapidly detecting contraband materials buried in the cargo holds of ocean going vessels. The surveys were conducted by burying a steel pipe, a wood block, and a contraband simulant (a bundle of four 10-lb bags of sugar duct-taped together) in stockpiled materials available on site. The different materials reflect different amounts of radar energy back to the surface. The steel pipe was used because metal objects reflect one hundred percent of the radar energy that strikes it and should provide the easiest target to locate whereas, the wood block and sugar bundle, which were used as a more realistic target, reflect only a fraction of the radar energy that strikes them and therefore should be a more difficult target to detect. The materials tested were; gypsum crystal, powdered gypsum, crushed pumice, coarse coal, fine coal, and bauxite.

Two GPR systems manufactured by Sensors & Software, Inc, were used to conduct the surveys. The first system, the pulseEKKO 1000 system, was used with 225, 450, and 900 MHz antennas. The Noggin Plus was the second system used and it employed a 250 MHz antenna. Different frequency antennas were used to obtain different penetration depths and target resolution. The lower the GPR's antenna frequency the deeper it can search but less able it is to resolve smaller targets. High frequency GPR antennas cannot search as deep as the low frequency antennas but provide better definition of small buried targets within their search range. Therefore there is a trade-off between the search depth and the ability to resolve a target.

All of the antennas tested were successful in detecting the location of the contraband simulant in at least one of the stockpiled materials. The 225 and 250 MHz antennas had the highest percent of detecting the simulant in the stockpiled materials (40 and 80 percent, respectively) whereas the 900 MHz antenna had the lowest (20 percent). All of the antennas tested have penetration depths of greater than 1.5 m. Because of the way the test sections were configured the maximum depth of penetration for the antennas was not obtained.

Terrain conductivity values were collected for all the materials except for the fine coal pile. The conductivity values were taken to determine the effect of conductivity on the GPR's depth of penetration. In general, the lower the conductivity the greater the GPR depth of penetration. Since the maximum depth of
penetration could not be determined from the GPR surveys no correlation between conductivity values and penetration depth could be made.

The GPR surveys run on the different stockpiled materials at the Alabama State Docks demonstrate that GPR is a feasible means of locating contraband buried to depths of at least 1 to 2 m on ocean going vessels. However, the success of GPR in locating contraband material depends on the size of the target and the material in which it is hidden. The performance of GPR in different materials is dependent on the material’s magnetic and electrical properties and therefore difficult to assess prior to deployment.

It is recommended that the U.S. Coast Guard consider using GPR for detecting contraband in the cargo holds of ships. It is also recommended that future GPR surveys be conducted using the Noggin system for the following reasons: (1) the Noggin system with the 250 MHz antenna performed better than the pE1000 system in detecting the sugar bundles, (2) it is easy to set-up, operate, and is fairly portable, (3) the antennas are shielded which means that the data would not be affected by reflections from overhead or nearby surfaces, (4) the antenna can be detached from the cart system to survey in tight areas, and (5) the system has a real-time display that is easy to read and interpret. An interchangeable 500 MHz antenna that may provide greater resolution is also available for the Noggin system.

Since it has been shown that GPR can be used in locating contraband simulants in various stockpiled materials under fairly ideal conditions the next step is to determine how it would perform under more realistic conditions such as those encountered aboard a ship. It is proposed that the Noggin system with the 250 and 500 MHz antennas be tested aboard a ship to assess its capabilities to detect buried simulants and also to assess any system deficiencies or problems, such as equipment portability, access issues, and potential sources of interference that may be affect the GPR.
Appendix A
Crystal Gypsum
GPR Records - Initial Investigation
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FILE</td>
<td>n:\Coast\205EPO\CG225GP2</td>
</tr>
<tr>
<td>JOB#</td>
<td></td>
</tr>
<tr>
<td>TITLE</td>
<td>Alabama Shipyard, Bulk Handling Area</td>
</tr>
<tr>
<td>TITLE</td>
<td>Crystal Gypsum File, 225 Mhz, Pipe - Profile Over Pipe</td>
</tr>
<tr>
<td>DATE</td>
<td>20/09/16</td>
</tr>
<tr>
<td>NUMBER OF TRACES</td>
<td>191</td>
</tr>
<tr>
<td>NUMBER OF PTS/TRC</td>
<td>200</td>
</tr>
<tr>
<td>TIME ZERO AT POINT</td>
<td>0.0</td>
</tr>
<tr>
<td>TOTAL TIME WINDOW</td>
<td>60</td>
</tr>
<tr>
<td>FINAL POSITION</td>
<td>190.000</td>
</tr>
<tr>
<td>STEP SIZE USED</td>
<td>1.000</td>
</tr>
<tr>
<td>POSITION UNITS</td>
<td>metres</td>
</tr>
<tr>
<td>NOMINAL FREQUENCY</td>
<td>225.00</td>
</tr>
<tr>
<td>ANTENNA SEPARATION</td>
<td>1.000</td>
</tr>
<tr>
<td>PUSHER VOLTAGE</td>
<td>20.00</td>
</tr>
<tr>
<td>NUMBER OF STACKS</td>
<td>16</td>
</tr>
<tr>
<td>SURVEY MODE</td>
<td>Reflection</td>
</tr>
<tr>
<td>COLLECTED BY PE1000</td>
<td>CON: 981119 RX: 981120</td>
</tr>
<tr>
<td>TX: 9811121 ANI: 971195/98</td>
<td></td>
</tr>
</tbody>
</table>

**Processing Selected**

- Trace Stacking: 2
- Point Stacking: 2
- Trace Differentiating: N
- Correction: Blank

**Selection Time:** -12 to 48

**Positions:** 0.000 to 190.000

**Gains:** Gain Type: Constant Multiplier: 100.000

**Plot Layout Parameters**

- Trace Spacing and Width: 0.0500 and 0.2500
- Trace Bottom and Top: -1.0000 and 9.0000
- Margin Left and Right: -0.5000 and 1.0000
- Page Width: 10.0000
- Border Size: 0.0000
- Printer Name: LAT300
- Scale Bar: None Grey Type: EA Expansion: 0.500 Contour: 0

---

**Diagram Description:**

- The diagram shows a profile with a pipe marked as 'Pipe'.
- The time axis is labeled from -10.00 to 10.00.
- The depth axis is labeled from 0.00 to 4.00.
- Trace numbers range from 100.00 to 190.00.
pulseEKKO HEADER PARAMETERS
FILE = s:\COASTG~1\20SEP0~1\CG450GP5
JOB# =
TITLE = Alambama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum Pile, 450 MHz, Pipe - North Edge of Pile
DATE = 20/09/10
NUMBER OF TRACES = 91
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 90
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 90.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -9 to 41
POSITIONS: 0.000 to 90.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0500 and 0.2500
TRACE BOTTOM AND TOP: 0.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE = s:\COASTG~1\20SEP0~1\CG450GP6
JOB# = 
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum Pile, 450 MHz, Pipe - Profile Over Pipe
DATE = 29/09/10
NUMBER OF TRACES = 80
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 89
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 79.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -8 to 42
POSITIONS: 0.000 to 79.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0700 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE = s:\COASTG\1\25SEP0-1\CG450GP8
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum Pile, 450 MHz, Pipe - South Edge of Pile
DATE = 20/09/10
NUMBER OF TRACES = 70
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 89
TOTAL TIME WINDOW = 50.2
STARTING POSITION = 0.000
FINAL POSITION = 69.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -8 to 42
POSITIONS: 0.000 to 69.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0700 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
PulseEKKO HEADER PARAMETERS
FILE = s:\COASTG\120SEP0\CG900GP2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum Pipe, 900 MHz, Pipe - Profile Over Pipe
DATE = 20/09/10
NUMBER OF TRACES = 47
NUMBER OF PTS/TRC = 1000
TIMEZERO AT POINT = 190
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 46.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -9 to 41
POSITIONS: 0.000 to 46.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
PulseEkko

HEADER PARAMETERS
FILE = c:\COASTG\M20SEP01\CG900GP3
JOB# = 1
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Coref Gypsum Pile, 900 MHz, Pipe - South Edge of Pipe
DATE = 20/09/10
NUMBER OF TRACES = 45
NUMBER OF PTS/TRC = 1000
TIMEZERO AT POINT = 192
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 44.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS:  TRACE STACKING: 2
         POINT STACKING: 2
         TRACE DIFFERENCING: N
         CORRECTION: DEWOW
SELECTION TIME: -9 to 41
POSITIONS: 0.000 to 44.000
GAINS:  GAIN TYPE: CONSTANT
       MULTIPLIER: 100.00

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: NAME: GREY Type: EA Expansion: 0.500 Contour: 0
Appendix B
Powdered Gypsum
GPR Records - Initial Investigation
pulseEKKO HEADER PARAMETERS
FILE = s:\COASTG-1\20SEPO-1\CG225PP1
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
        Powdered Gypsum Pile, 225 M-H, Pipe – West Edge of Pile
DATE = 20/09/10
NUMBER OF TRACES = 128
NUMBER OF PTS/TRC = 250
TIME ZERO AT POINT = 47
TOTAL TIME WINDOW = 75
STARTING POSITION = 0.000
FINAL POSITION = 125.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 225.00
ANTENNA SEPARATION = 0.500
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 – CON 981119 RX: 981120
TX: 981121 ANT: 971195/96

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
        POINT STACKING: 2
        TRACE DIFFERENCING: N
        CORRECTION: DEWOW
SELECTION TIME: -14 to 61
        POSITIONS: 0.000 to 125.000
GAINS: GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0500 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
pulseeKko HEADER PARAMETERS
FILE = s: \COAST~\120SEP0~\1\CG450PP2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Powdered Gypsum Pile, 450 MHz, Pipe – Profile Over Pipe
DATE = 20/09/10
NUMBER OF TRACES = 58
NUMBER OF PTS/TRC = 600
TIMEZERO AT POINT = 117
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 57.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 – CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -11 to 49
POSITIONS: 0.000 to 57.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulsEKKO HEADER PARAMETERS
FILE = s:\COASTG~1\20SEP0~1\CG900PP1
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Powdered Gypsum Pile, 900 MHz, Pipe - West Edge of Pile
DATE = 20/09/10
NUMBER OF TRACES = 43
NUMBER OF PTS/TRC = 1000
TIMEZERO AT POINT = 205
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 42.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -10 to 40
POSITIONS: 0.000 to 42.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: 0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
PULSEKO HEADER PARAMETERS
FILE = s:\COASTG\W20SEP0-1\CG900PP2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Powdered Gypsum Pile, 900 MHz, Pipe - Profile Over Pipe
DATE = 20/09/10
NUMBER OF TRACES = 42
NUMBER OF PTS/TRC = 1000
TIMEZERO AT POINT = 193
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 41.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -9 to 41
POSITIONS: 0.000 to 41.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS:
FILE = s:\COASTG\120SEP0\1\CG250PP3
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Powdered Gypsum Pile, 250 MHz, Pipe - Profile Over Pipe
DATE = 09/20/20
NUMBER OF TRACES = 158
NUMBER OF PTS/IRC = 111
TIMEZERO AT POINT = 11
TOTAL TIME WINDOW = 44
STARTING POSITION = 0.000
FINAL POSITION = 7.850
STEP SIZE USED = 0.050
POSITION UNITS = m
NOMINAL FREQUENCY = 250.00
ANTENNA SEPARATION = 0.305
PULSER VOLTAGE = 100
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED:
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION: TIME: -4 to 40
POSIIONS: 0.000 to 7.850
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS:
TRACE SPACING AND WIDTH: 0.0500 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
Appendix C
Crushed Pumice
GPR Records - Initial Investigation
**File Header Parameters**

- **FILE**: s1003se0-1203ep0-1100225mp1
- **JOB**: 0
- **TITLE**: Port of Mobile: Bulk Handling Area
- **TITLE**: Port of Mobile: Bulk Handling Area
- **DATE**: 10/10/98
- **NUMBER OF TRACES**: 112
- **NUMBER OF PICTURES**: 3
- **TOTAL TIME WINDOW**: 75
- **STARTING POSITION**: 0.000
- **FINAL POSITION**: 11.000
- **STEP SIZE USED**: 1.000
- **POSITION UNITS**: metres
- **ANTENNA SEPARATION**: 0.500
- **PULSER VOLTAGE**: 200
- **NUMBER OF STACKS**: 16
- **SURVEY MODE**: Reflection
- **COLLECTED BY**: PE1000
- **CORR**: 981119 RX 981120 TX 981121 ANT 971109/98

**Processing Selected**

- **FILTERS**: TRACE STACKING: 2
- **FILTER STACKING**: 2
- **TRACE DITHERING**: N
- **CORRECTION**: DEW

**Selection**

- **TIME**: 0.15 to 60
- **POSITION**: 0.000 to 11.000
- **GAINS**: ORAL TYPE: CONSTANT
- **MULTIPLIER**: 100.000

**Plot Layout Parameters**

- **TRACE SPACING AND WIDTH**: 0.1120 and 0.2900
- **TRACE BOTTOM AND TOP**: 1.0000 and 5.0000
- **MARGIN LEFT AND RIGHT**: 0.0000 and 1.0000
- **PAPER WIDTH**: 10.5000
- **BORDER SIZE**: 0.003
- **PRINTER NAME**: L5300
- **SCALE BAR**: Name: GREY Type: EA Expansion: 0.500 Contour: 0

![Image of the plot](image-url)
pulseEKKO HEADER PARAMETERS
FILE = s:\COASTG\1\20SEPO\1\CG900MP1
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Furnace Pile, 900 MHz, Pipe – West Edge of Pile
DATE = 20/09/10
NUMBER OF TRACES = 49
NUMBER OF PTS/TRC = 600
TIMEZERO AT POINT = 126
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 48.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
Tx: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS:  TRACE STACKING: 2
        POINT STACKING: 2
        TRACE DIFFERENCING: N
        CORRECTION: DEWOW
SELECTION TIME: -12 to 48
POSITIONS: 0.000 to 48.000
GAINS:  GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1100 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
PulseEKKO HEADER PARAMETERS
FILE = \COAST\200EPP0\1CO25EP0
JOIN =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Panama Pipe, 250 kHz, Pipe - West Edge of Pipe
DATE = 09/20/20
NUMBER OF TRACES = 157
TOTAL TIME WINDOW = 44
STARTING POSITION = 0.000
STEP SIZE USED = 0.050
POSITION UNITS = m
ANTENNA SEPARATION = 0.305
PULSER VOLTAGE = 100
NUMBER OF STACKS = 15
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
         TRACE DIFFERENCING: N
         CORRECTION: CDOW
SELECTION TIME: -4.0 to 4.0
POSITION: 0.000 to 7.800
GAINS: GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0250 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: 0.5000 and 0.5000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.2500
PRINTER NAME: LAS3100
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0

Distance, m
Depth (m): 0.0 to 2.0
Time (ms): 0.0 to 20.0

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
0.0 0.5 1.0 1.5 2.0
Appendix D
Coarse Coal
GPR Records - Initial Investigation
**pulseEKKO HEADER PARAMETERS**

- **FILE** = s:\COAST\1\20SEPO\1\CO225CP2
- **JOB** =
- **TITLE** = Alabama Shipyard, Bulk Handling Area
- **DATE** = 20/08/10
- **NUMBER OF TRACES** = 124
- **NUMER OF PTS/TRC** = 200
- **TOTAL TIME WINDOW** = 160
- **STARTING POSITION** = 0.000
- **FINAL POSITION** = 133.000
- **STEP SIZE USED** = 1.000
- **POSITION UNITS** = metres
- **NOMINAL FREQUENCY** = 225.00
- **ANTENNA SEPARATION** = 0.500
- **PULSER VOLTAGE** = 200
- **NUMBER OF STACKS** = 16
- **SURVEY MODE** = Reflection
- **COLLECTED BY** = PE1000
- **CON: 981119 RX: 981120 TX: 981121 ANT: 971195/96

**PROCESSING SELECTED**

- **FILTERS:**
  - TRACE STACKING: 2
  - POINT STACKING: 2
  - TRACE DIFFERENCING: N
  - CORRECTION: DENOW
- **SELECTION TIME:** -12 to 48
- **POSSITIONS:** 0.000 to 133.000
- **GAINS:**
  - GAIN TYPE: CONSTANT
  - MULTIPLIER: 100.000

**PLOT LAYOUT PARAMETERS**

- **TRACE SPACING AND WIDTH:** 0.0750 and 0.2500
- **TRACE BOTTOM AND TOP:** 1.0000 and 9.0000
- **MARGIN LEFT AND RIGHT:** -0.5000 and 1.0000
- **PAGE WIDTH:** 10.0000
- **BORDER SIZE:** 0.000
- **PRINTER NAME:** LAS300
- **SCALE BAR NAME:** GREY Type:EA Expansion:0.500 Contour:0

---

**Graph Description**

- **Graph Title:** Data from the Alabama Shipyard, Bulk Handling Area
- **Graph Type:** Profile over pipe
- **Graph Axes:**
  - **X-Axis:** Trace Number
  - **Y-Axis:** Depth (ft) at 0.500 m/s
- **Legend:**
  - **Depth Legend:**
    - 0.0: Red
    - 1.0: Green
    - 1.5: Blue

---

**Notes:**

- The data represents the pipe profile with depth measurements.
- The graph shows variations in depth over the pipe profile.
FILE = C:\COAST\~1\20SEP\~1\CG450CP1

TITLE = Coal (coarse) Pile, 450 MHz, Pipe – North Edge of Pile
DATE = 20/09/10
NUMBER OF TRACES = 50
NUMBER OF PTS/TRC = 600
TIME ZERO AT POINT = 126
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 49.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -12 to 48
POSITIONS: 0.000 to 49.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE  = s:\COASTG\v\20SEP0\\CG900CP2
JOB#  =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Cool (coarse) Pile, 900 MHz, Pipe - Profile Over Pipe
DATE  = 20/09/10
NUMBER OF TRACES = 55
NUMBER OF PTS/TRC = 600
TIMEZERO AT POINT = 123
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 54.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971259/59

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
         POINT STACKING: 2
         TRACE DIFFERENCING: N
         CORRECTION: DEWOW
SELECTION TIME: -12 to 48
POSITIONS: 0.000 to 54.000
GAINS: GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
**PulseEkko Header Parameters**

- **File**: s:\COASTG\1\020SEPO\1\CC250CP2
- **Job #:**
- **Title**: Alabama Shipyard, Bulk Handling Area
- **Title**: Coal (coarse) Pile, 250 MHz, Pipe - Profile Over Pipe
- **Date**: 09/20/20
- **Number of Traces**: 84
- **Number of pts/trc**: 111
- **Timezero at Point**: 11
- **Total Time Window**: 44
- **Starting Position**: 0.000
- **Final Position**: 4.150
- **Step Size Used**: 0.050
- **Position Units**: m
- **Nominal Frequency**: 250.00
- **Antenna Separation**: 0.305
- **Pulser Voltage**: 100
- **Number of Stacks**: 16
- **Survey Mode**: Reflection

**Processing Selected Filters:**
- **Trace Stacking**: 2
- **Point Stacking**: 2
- **Trace Differentencing**: N
- **Correction**: Dewow
- **Selection Time**: -4 to 40
- **Positions**: 0.000 to 4.150
- **Gains**: Gain Type: Constant
- **Multiplier**: 100.000

**Plot Layout Parameters**
- **Trace spacing and width**: 0.0600 and 0.2500
- **Trace bottom and top**: 1.0000 and 9.0000
- **Margin left and right**: -0.5000 and 1.0000
- **Page width**: 10.0000
- **Border size**: 0.000
- **Printer Name**: LAS300
- **Scale Bar**: Name:GREY Type:EA Expansion:0.500 Contour:0
Appendix E
Crystal Gypsum
GPR Records – Buried Contraband Simulant Test
PulseEKKO HEADER PARAMETERS

FILE: 5XCOAST16-121560-1VC25G552
JOB:  
TITLE: Alabama Shipyard, Bulk Handling Area
TITLE: Crystal Gypsum File, 225 Mic, Sugar - North Edge of File
DATE: 21/9/99

NUMBER OF TRACES = 151
NUMBER OF P/FS: 1/100
TRACE ZERO AT POINT = 4
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 150.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
MINIMAL FREQUENCY = 2.2000
ANTENNA SEPARATION = 0.500
FILTER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -13 to 47
POSIIONS: 0.000 to 150.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0800 and 0.2500
TRACE BOTTOM AND TOP: 10.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE = s:\COAST\~1\21SEP0\~1\CG450GS2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum File, 450 MHz, Sugar - Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 60
NUMBER OF PTS/TRC = 600
TIMEZERO AT POINT = 119
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 59.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 16
SURVEY MODE = Reflection
COLLECTED BY PE1000 - COI: 981119 RX: 981120
FX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
          POINT STACKING: 2
          TRACE DIFFERENCING: N
          CORRECTION: DEWOW
SELECTION TIME: ±11 to 49
POSITIONS: 0.000 to 59.000
GAINS: GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: ±0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE = s:\COASTG\1\21SEP0-1\CG450GS3
JOB  =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum Pile, 450 MHz, Sugar - South Edge of Pile
DATE  = 21/09/10
NUMBER OF TRACES  = 57
NUMBER OF PTS/TRC  = 600
TIMEZERO AT POINT  = 120
TOTAL TIME WINDOW  = 60
STARTING POSITION  = 0.000
FINAL POSITION    = 56.000
STEP SIZE USED    = 1.000
POSITION UNITS    = metres
ANTENNA FREQUENCY = 450.00
PULSER VOLTAGE    = 200
ANTENNA SEPARATION = 0.250
NUMBER OF STACKS  = 16
SURVEY MODE       = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
RT: 981120 ANT: 277121, 37

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DOWOW
SELECTION TIME: -12 to 48
POSITIONS: 0.000 to 56.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
PulseEKKO HEADER PARAMETERS
FILE: c:VCOASTG~1V7FSP~1VCOASTG1
UNIT: Alabama Shipyard, Hull Handling Area
HULL: Crystal gangway Pile, 500 MHz, Sugar - North Edge of Pile
DATE: 21/09/10
NUMBER OF TRACES = 79
NUMBER OF PTS/TRC = 400
TIME ZERO AT POINT = 95
TOTAL TIME WINDOW = 40
STARTING POSITION = 0.000
FINAL POSITION = 78.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 700
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 = CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: None
SELECTION TIME: 0 to 31
POSITIONS: 0.000 to 78.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
**PULSED EKO HEADER PARAMETERS:**

- **TITLE**: Alabama Shipyard, Bulk Handling Area
- **TITLE**: Crystal Gypsum Pile, 900 MHz, Sugar - Profile Over Sugar
- **DATE**: 21/08/10
- **NUMBER OF TRACES**: 81
- **NUMBER OF PTS/TRC**: 480
- **TIME ZERO AT POINT**: 81
- **STARTING POSITION**: 0.000
- **TOTAL WINDOW**: 40
- **FINAL POSITION**: 80.000
- **STEP SIZE USED**: 1.000
- **POSITION UNITS**: metres
- **NOMINAL FREQUENCY**: 900.00
- **ANTENNA SEPARATION**: 0.15
- **PULSER VOLTAGE**: 700
- **NUMBER OF STACKS**: 4
- **SURVEY MODE**: Reflection

**COLLECTED BY EKO**: 981119 RX: 981120
TX: 981121 ANI: 971258/59

**PROCESSING SELECTED FILTERS:**
- **TRACE STACKING**: 2
- **POINT STACKING**: 2
- **TRACE DIFFERENCING**: N
- **CORRECTION**: DEWOW

**SELECTION TIME**: –8 to 32

**POSITIONS**: 0.000 to 80.000

**GAINS**:
- **GAIN TYPE**: CONSTANT
- **MULTIPLIER**: 100.000

**PLOT LAYOUT PARAMETERS**
- **TRACE SPACING AND WIDTH**: 0.1000 and 0.2500
- **TRACE BOTTOM AND TOP**: 1.0000 and 9.0000
- **MARGIN LEFT AND RIGHT**: 0.5000 and 1.0000
- **PAGE WIDTH**: 10.0000
- **BORDER SIZE**: 0.000
- **PRINTER NAME**: LAS.300
- **SCALE BAR**: Name: GREY Type: EA Expansion: 0.500 Contour: 0

**Diagram Description**
- **Axes**: Time (ns) and Depth (m)
- **Legend**: Various annotations such as time and depth measurements.
### PulseEKKO Header Parameters

**FILE** = s:\COASTG-1\21SEP0-1\C0000053
**JOB** =
**TITLE** = Alabama Shipyard, Bulk Handling Area
**TITLE** = Crystal Gypsum Pile, 900 MHz, Sugar = South Edge of Pile
**DATE** = 21/09/10
**NUMBER OF TRACES** = 76
**NUMBER OF PTS/TRC** = 400
**TIMEZERO AT POINT** = 81
**TOTAL TIME WINDOW** = 40
**STARTING POSITION** = 0.000
**FINAL POSITION** = 75.000
**STEP SIZE USED** = 1.000
**POSITION UNITS** = metres
**NOMINAL FREQUENCY** = 900.00
**ANTENNA SEPARATION** = 0.170
**PULSER VOLTAGE** = 290
**NUMBER OF STACKS** = 4
**SURVEY MODE** = Reflection
**COLLECTED BY** = PET1000 - C/MI: 981119 RX: 981120
**TX: 981114 RX: 971258/59

### Processing Selected

**FILTERS:**
- TRACE STACKING: 2
- POINT STACKING: 2
- TRACE DIFFERENCING: N
- CORRECTION: DEWOW

**SELECTION:**
- TIME: -8 to 32
- POSITIONS: 0.000 to 75.000

**GAINS:**
- GAIN TYPE: CONSTANT
- MULTIPLIER: 100.000

### Plot Layout Parameters

- TRACE SPACING AND WIDTH: 0.1000 and 0.2500
- TRACE BOTTOM AND TOP: 1.0000 and 0.0000
- MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
- PAGE WIDTH: 10.0000
- BORDER SIZE: 0.000
- PRINTER NAME: LAS300
- SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
FILE = 'NODAS40-N21SEP08-00256050
JOB# =
TITLE = Alabama Shipyards, Bulk Handling Area
TITLE = Crystal Gypsum File, 250 MHz, Sugar - North Edge of File
DATE = 09/21/20
NUMBER OF TRACES = 143
NUMBER OF PTS/TRC = 111
TIME ZERO AT POINT = 11
TOTAL TIME WINDOW = 44
STARTING POSITION = 0.000
FINAL POSITION = 7.100
STEP SIZE USED = 0.050
POSITION UNITS = m
NOMINAL FREQUENCY = 250.00
ANTENNA SEPARATION = 0.305
PULSER VOLTAGE = 100
NUMBER OF STACKS = 18
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOR
SELECTION TIME: 4 to 40
POSITIONS: 0.000 to 7.100
GAINS: GAIN TYPE: CONSTANT
MULTIPLE: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: 0.0000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: L45300
SCALE BAR: None:GREY Type:EA Expansion:0.500 Contour:0
**PulseEcho Header Parameters**

- **File:** C:\DOGS\gim.nh.1P01.25\09.21\01\CG25FGS1
- **Title:** Alabama Shipyard, Bulk Handling Area
- **Title:** Crystal Gypsum Pale, 250 MHz, Sugar - Profile Over Sugar
- **Date:** 09/21/20
- **Number of Traces:** 150
- **Number of MZ/FIRs:** 111
- **Y-meters at Point:** 44
- **Total Time Window:** 0.000
- **Final Position:** 7.450
- **Step Size Used:** 0.050
- **Position Units:** m
- **Nominal Frequency:** 250.00
- **Antenna Separation:** 0.305
- **Pulsar Voltage:** 100
- **Number of Stacks:** 16
- **Survey Mode:** Reflection

**Processing Selected**
- **Filters:** Trace Stacking: 2
- **Point Stacking:** 2
- **Trace Differencing:** H
- **Correction:** Dewow
- **Selection:** Time: -4 to 40
- **Gains:** Gain Type: Constant
- **Multiplier:** 100,000

**Plot Layout Parameters**
- **Trace Spacing and Width:** 0.0750 and 0.2500
- **Trace Bottom and Top:** 1.0000 and 9.0000
- **Margin Left and Right:** 0.0000 and 9.0000
- **Bias Width:** 10.0000
- **Border Size:** 0.000
- **Printer Name:** L3500
- **Scale Bar:** Marine GREY Type EA Expansion: 0.500 Contour: 0

**Diagram Description:**
- The diagram shows a profile over the Crystal Gypsum Pale with a focus on Sugar.
- The X-axis represents Distance, m, ranging from 0.00 to 7.00.
- The Y-axis represents Depth, m, ranging from 0.00 to 2.00.
- Various features and layers are indicated with different shading and contour lines.
**pulsedPRANG**

**HEADER PARAMETERS**

- **FILE**: KVCQSTC~F1215/PO~KCC25052
- **TITLE**: Alabama Shipyard, Bulk Handling Area
- **DATE**: 09/11/00
- **NUMBER OF TRACES**: 154
- **TIMEZERO AT PONT**: 11
- **TOTAL TIME WINDOW**: 44
- **STARTING POSITION**: 0.000
- **FINAL POSITION**: 7.650
- **STEP SIZE USED**: 0.050
- **POSITION UNITS**: m
- **NORMAL FREQUENCY**: 250.00
- **ANTENNA SEPARATION**: 0.305
- **PULSER VOLTAGE**: 100
- **NUMBER OF STACKS**: 16
- **SURVEY MODE**: Reflection

**PROCESSING SELECTED**

- **FILTERS**: Trace Stacking: 2
- **TRACE DIFFERENCING**: 11
- **CORRECTIONS**: Dewow
- **SELECTION**: Time: -4 to 40
- **GAINS**: Gain Type: Constant
- **MULTIPLIER**: 100.000

**PLOT LAYOUT PARAMETERS**

- **TRACE SPACING AND WIDTH**: 0.0750 and 0.2500
- **TRACE BOTTOM AND TOP**: 1.0000 and 9.0000
- **MARGIN LEFT AND RIGHT**: 0.5000 and 1.0000
- **PAGE WIDTH**: 10.0000
- **BORDER SIZE**: 0.000
- **PRINTER NAME**: LASCO
- **SCALE BAR**: HOME.GREY Type: EA Expansion: 0.500 Contour: 0
PulseEXIG HEADER PARAMETERS

FILE = s:COAST\1\21SEP\1\G25COGS3
JOB = 
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Crystal Gypsum Pile, 250 MHz, Sugar - South Edge of Pile
DATE = 09/21/85
NUMBER OF TRACES = 138
NUMBER OF PTS/TRC = 111
TIMEZERO AT POINT = 11
TOTAL TIME WINDOW = 44
STARTING POSITION = 0.000
FINAL POSITION = 6.850
STEP SIZE USED = 0.050
POSITION UNITS = 
NOMINAL FREQUENCY = 250.00
ANTENNA SEPARATION = 0.005
PULSER VOLTAGE = 100
NUMBER OF STACKS = 18
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWAV
SELECTION TIME: -4 to 40
PICKOUTS: 0.000 to 6.850
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: -1.0000 and 1.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
Appendix F
Powdered Gypsum
GPR Records – Buried Contraband Simulant Test
pulseEKKO HEADER PARAMETERS
FILE = z:\COASTG\\21SEP0\\C0225PS3
JOB =
TITLE = Alabama Shipyards, Bulk Handling Area
TITLE = Power Gen Gypsum Pip, 225 MHz, Sugar - Profile Over Sugar
DATE = 21/09/10
NUMER OF TRACES = 141
NUMBER OF PTS/TRC = 200
TIMEZERO AT POINT = 37
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 140.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 225.00
ANTENNA SEPARATION = 0.500
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971195/96

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2 POINT STACKING: 2 TRACE DIFFERENCING: N CORRECTION: DEWOW
SELECTION TIME: -11 to 49 POSITIONS: 0.00 to 140.000
GAINS: GAIN TYPE: CONSTANT MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0000 and 0.2500 TRACE BOTTOM AND TOP: 1.0000 and 9.0000 MARGIN LEFT AND RIGHT: -0.0000 and 1.0000 PACE WIDTH: 0.0000 BORDER SIZE: 0.000 PRINTER NAME: L85300 SCALE BAR: Name=GREY Type=EA Expansion:0.500 Contour:0
**pulseEKKO HEADER PARAMETERS**

FILE = s:\\COASTG~1\21SEP0~1\CG450PS1  
JOB# =  
TITLE = Alabama Shipyard, Bulk Handling Area  
TITLE = Powered Gypsum Pile, 450 MHz, Sugar - West Edge of Pile  
DATE = 21/09/10  
NUMBER OF TRACES = 63  
NUMBER OF PTS/TRC = 500  
TIME ZERO AT POINT = 99  
TOTAL TIME WINDOW = 50  
STARTING POSITION = 0.000  
FINAL POSITION = 62.000  
STEP SIZE USED = metres  
POSITION UNITS = metres  
Nominal Frequency = 450.00  
ANTENNA SEPARATION = 0.250  
PULSER VOLTAGE = 200  
NUMBER OF STACKS = 4  
SURVEY MODE = Reflection  
COLLECTED BY PE1000 - CON: 981119 RX: 981120  
TX: 981121 ANT: 971181/82

**PROCESSING SELECTED**

FILTERS: TRACE STACKING: 2  
POINT STACKING: 2  
TRACE DIFFERENCING: N  
CORRECTION: DEWOW  
SELECTION TIME = -9 to 41  
POSITIONS: 0.000 to 62.000  
GAINS: GAIN TYPE: CONSTANT  
MULTIPLIER: 100.000

**PLOT LAYOUT PARAMETERS**

TRACE SPACING AND WIDTH: 0.0750 and 0.2500  
TRACE BOTTOM AND TOP: 1.0000 and 9.0000  
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000  
PAGE WIDTH: 10.0000  
BORDER SIZE: 0.000  
printer NAME: LPS300  
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulsEKKO HEADER PARAMETERS
FILE = s:\COASTG\21SEP0\CG450PS2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Powered Gypsum Pile, 450 MHz, Sugar' - Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 65
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 115
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 64.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 = CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -11 to 39
POSITIONS: 0.000 to 64.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pul sequential file
FILE = s:\COAST\~\21SEP0\~\CG450PS3
DATE = 21/09/10
NUMER OF TRACES = 66
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 110
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 65.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACF STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -11 to 39
POSITIONS: 0.000 to 65.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS5300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
**PulseEKKO HEADER PARAMETERS**

- **FILE** = s:\COASTG\1\Z1SEP0-1\CG450PS4
- **JOB#** = 1124
- **TITLE** = Alabama Shipyard, Bulk Handling Area  
  Powered Gypsum Pile, 450 MHz, Sugar East Edge of Pile
- **DATE** = 21/09/10
- **NUMBER OF TRACES** = 51
- **NUMBER OF PTS/TRC** = 500
- **TIMEZERO AT POINT** = 105
- **TOTAL TIME WINDOW** = 50
- **STARTING POSITION** = 0.000
- **FINAL POSITION** = 50.000
- **STEP SIZE USED** = 1.000
- **POSITION UNITS** = metres
- **NOMINAL FREQUENCY** = 450.00
- **ANTENNA SEPARATION** = 0.250
- **PULSER VOLTAGE** = 200
- **NUMBER OF STACKS** = 4
- **SURVEY MODE** = Reflection
  COLLECTED BY PE1000 - CON: 981119 RX: 981120  
  TX: 981121 ANT: 971181/82

**PROCESSING SELECTED**
- **FILTERS:**  
  - TRACE STACKING: 2
  - POINT STACKING: 2
  - TRACE DIFFERENCING: N
  - CORRECTION: DEWOW
- **SELECTION TIME:** -10 to 40
- **POSITIONS:** 0.000 to 50.000
- **GAINS:**  
  - GAIN TYPE: CONSTANT
  - MULTIPLIER: 100.000

**PLOT LAYOUT PARAMETERS**
- **TRACE SPACING AND WIDTH:** 0.0750 and 0.2500
- **TRACE BOTTOM AND TOP:** 1.0000 and 9.0000
- **MARGIN LEFT AND RIGHT:** -0.5000 and 1.0000
- **PAGE WIDTH:** 10.0000
- **BORDER SIZE:** 0.000
- **PRINTER NAME:** LAS300
- **SCALE BAR:** Name:GREY Type:EA Expansion:0.500 Contour:0
**PulseEVO HEADER PARAMETERS**

**FILE** = \#\V04SG-\V215EPO-\V0250PS0

**CORE** =

**TITLE** = Alabama Shipyards Bulk Handling Area

**TITLE** = Powdered Gypsum Pile, 250 MHz, Sugar - West Edge of Pile

**DATE** = 09/22/20

**NUMBER OF TRACES** = 148

**NUMBER OF PTS/TRC** = 111

**TIME ZERO AT POINT** = 11

**TOTAL TIME WINDOW** = 44

**STARTING POSITION** = 0.000

**FINAL POSITION** = 7.350

**STEP SIZE USED** = 0.050

**POSITION UNITS** = m

**NOMINAL FREQUENCY** = 250.00

**ANTENNA SEPARATION** = 2.035

**PULSER VOLTAGE** = 100

**NUMBER OF STACKS** = 16

**SURVEY MODE** = Reflection

**PROCESSING SELECTED**

**FILTERS:**

- TRACE STACKING: 2
- POINT STACKING: 2
- TRACE DIFFERENTIATION: N
- CORRECTION: DENO

**SELECTION:**

- TIME: -4 to 40
- POSITIONS: 0.000 to 7.350

**GAINS:**

- GAIN TYPE: CONSTANT
- MULTIPLIER: 100.000

**PLOT LAYOUT PARAMETERS**

- TRACE SPACING AND WIDTH: 0.0750 and 0.2500
- TRACE BOTTOM AND TOP: 1.0000 and 9.0000
- MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
- PAGE WIDTH: 10.0000
- BORDER SIZE: 0.0000
- PRINTER NAME: L330S
- SCALE BAR: None; GREY Type: EA, Expansion: 0.500 Contour: 0
**PulseEcho HEADER PARAMETERS**

FILE:  
JOB:  
TITLE:  
DATE:  
NUMBER OF TRACES = 149
NUMBER OF PFS/TRC = 111
TIMEZERO AT POINT = 11
TOTAL TIME WINDOW = 41
STARTING POSITION = 0.000
FINAL POSITION = 7.400
STEP SIZE USED = 0.000
POSITION UNITS = m
NOMINAL FREQUENCY = 250.00
ANTENNA SEPARATION = 0.303
PULSER VOLTAGE = 100
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

**PROCESSING SELECTED**
FILTERS:  
TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DENOW
SELECTION TIME: -4 to 40
POSITIONS: 0.000 to 7.400
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

**PLOT LAYOUT PARAMETERS**
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
PAPER SIZE: 0.0000
PRINTER NAME: LSI300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0

**Diagram Description**
- The diagram shows a seismic profile with depth measurements along the vertical axis (7.0 m) and distance measurements along the horizontal axis (Distance, m).
- The depth range is from 0.0 to 1.5 m.
- The time axis is labeled with Time (ns).
- The depth axis is labeled with Depth (m).
pulses: EKKO HEADER PARAMETERS
FILE = s:\COASTG\~\21SEP0~1\CG250PS4
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Powdered Gypsum Pile, 250 MHz, Sugar -E/W Profile Over Sugar
DATE = 09/21/20
NUMBER OF TRACES = 64
NUMBER OF PTS/TRC = 111
TIMEZERO AT POINT = 11
TOTAL TIME WINDOW = 44
STARTING POSITION = 0.000
FINAL POSITION = 3.150
STEP SIZE USED = 0.050
POSITION UNITS = m
NOMINAL FREQUENCY = 250.00
ANTENNA SEPARATION = 0.305
PULSER VOLTAGE = 100
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -4 to 40
POSITIONS: 0.000 to 3.150
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
Appendix G
Crushed Pumice
GPR Records – Buried Contraband Simulant Test
pulseEKKO HEADER PARAMETERS

FILE = s:\COASTG\21SEPO\CG225MS1
JOS# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Pumice Pile, 225 MHz, Sugar - Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 91
NUMBER OF PTS/TRC = 200
TIME ZERO AT POINT = 40
TOTAL TIME WINDOW = 60
STARTING POSITION = 0.000
FINAL POSITION = 30.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 225.00
ANTENNA SEPARATION = 0.500
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971195/96

PROCESSING SELECTED
FILTERS:  TRACE STACKING: 2
        POINT STACKING: 2
        TRACE DIFFERENCING: N
        CORRECTION: DEWOW
SELECTION  TIME: -12 to 48
            POSITIONS: 0.000 to 90.000
GAINS:  GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE = s:COASTG~1\21SEP0~1\CG450MS1
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Pumice File, 450 MHz, Sugar - Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 43
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 92
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 42.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY P1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS:  TRACE STACKING: 2
          POINT STACKING: 2
          TRACE DIFFERENCING: N
          CORRECTION: DEWOW
SELECTION  TIME: -9 to 41
            POSITIONS: 0.000 to 42.000
GAINS:      GAIN TYPE: CONSTANT
            MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP:  1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:GREY Type:EA Expansion:0.500 Contour:0
pulseEKKO HEADER PARAMETERS
FILE = e:\COASTG\121SEP\1 \CG450MS2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Pumice Pile, 450 MHz, Sugar = Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 42
NUMBER OF PTS/TRC = 500
TIMEZERO AT POINT = 92
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 41.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 450.00
ANTENNA SEPARATION = 0.250
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971181/82

PROCESSING SELECTED
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -9 to 41
POSITIONS: 0.000 to 41.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
pulseEKKO HEADER PARAMETERS

FILE = s:\COASTG\1\21SEP0\1\CG900MS1
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Pumice Pile, 900 MHz, Sugar - Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 40
NUMBER OF PTS/TRC = 500
TIME ZERO AT POINT = 91
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 39.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

PROCESSING SELECTED
FILTERS: trace stacking: 2
POINT STACKING: 2
trace differencing: N
CORRECTION: DEWOW
SELECTION
TIME: -9 to 41
POSITIONS: 0.000 to 39.000
GAINS: GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
PulseEkko Header Parameters

FILE = E:\COASTG-1\721SEP0-1\CG900MS2
JOB# =
TITLE = Alabama Shipyard, Bulk Handling Area
TITLE = Pumice File, 900 MHz, Sugar - Profile Over Sugar
DATE = 21/09/10
NUMBER OF TRACES = 42
NUMBER OF PTS/TRC = 500
TIME ZERO AT POINT = 106
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 41.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
NOMINAL FREQUENCY = 900.00
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 = CON: 981119 RX: 981120
TX: 981121 ANT: 971258/59

Processing Selected
FILTERS: TRACE STACKING: 2
POINT STACKING: 2
TRACE DIFFERENCING: N
CORRECTION: DEWOW
SELECTION TIME: -10 to 40
POSITIONS: 0.000 to 41.000
GAINS: GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

Plot Layout Parameters
TRACE SPACING AND WIDTH: 0.1000 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARION LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
**PulseEKKO HEADER PARAMETERS**

**FILE** = s:\COASTG\1\21SEP0\1\CG250MS0

**JOB** =

**TITLE** = Alabama Shipyard, Bulk Handling Area

**DATE** = 09/21/20

**NUMBER OF TRACES** = 95

**NUMBER OF PTS/TRC** = 111

**TIMEZERO AT POINT** = 11

**TOTAL TIME WINDOW** = 44

**STARTING POSITION** = 0.000

**FINAL POSITION** = 4.700

**STEP SIZE USED** = 0.050

**POSITION UNITS** = m

**NOMINAL FREQUENCY** = 250.00

**ANTENNA SEPARATION** = 0.305

**PULSER VOLTAGE** = 100

**NUMBER OF STACKS** = 16

**SURVEY MODE** = Reflection

**PROCESSING SELECTED**

**FILTERS:**

- **TRACE STACKING:** 2
- **POINT STACKING:** 2
- **TRACE DIFFERENCING:** N

**SELECTION**

- **TIME:** -4 to 40
- **POSITIONS:** 0.000 to 4.700

**GAINS:**

- **GAIN TYPE:** CONSTANT
- **MULTIPLIER:** 100.000

**PLOT LAYOUT PARAMETERS**

- **TRACE SPACING AND WIDTH:** 0.0750 and 0.2500
- **TRACE BOTTOM AND TOP:** 1.0000 and 9.0000
- **MARGIN LEFT AND RIGHT:** -0.5000 and 1.0000
- **PAGE WIDTH:** 10.0000
- **BORDER SIZE:** 0.000
- **PRINTER NAME:** LAS300
- **SCALE BAR:** Name:GREY Type:EA Expansion:0.500 Contour:0

**Diagram:**

- **SUGAR**
  - Time (ms)
  - Depth (m) at 0.100 m/ns
  - Distance, m
Appendix H
Bauxite
GPR Records – Buried Contraband
Simulant Test
**PulseEcho Header Parameters**

- **FILE**: /Users/DOASO-T/FZ15SEP/01C022585Z
- **JOB**: Alabama Shipyards, Bulk Handling Area
- **TITLE**: Sugar Pile, 225 A.M.T., Sugar – Profile Over Sugar and Pipe
- **DATE**: 23/03/90
- **NUMBER OF TRACES**: 447
- **NUMBER OF PTG/PR**: 250
- **TIMEZERO AT POINT**: 51
- **TOTAL TIME WINDOW**: 75
- **STARTING POSITION**: 0,000
- **FINAL POSITION**: 448,000
- **STEP SIZE USED**: 1,000
- **POSITION UNITS**: m
- **NOMINAL FREQUENCY**: 225,000
- **ANTENNA SEPARATION**: 0,500
- **PULSER VOLTAGE**: 2,000
- **NUMBER OF STACKS**: 4
- **SURVEY MODE**: Reflection
- **COLLECTED BY**: PE1000 - CON: 981119 RH: 981120
  - **TX**: 981121 AN: 971120/00

**Processing Selected Filters**

- **TRACE STACKING**: 2
- **POINT STACKING**: 2
- **TRACE DIFFERENCING**: N
- **CORRECTION**: PW
- **SELECTION**: T= 15 to 60
- **GAINS**: GAIN TYPES:
  - CONSTANT
  - MONOMETER: 100,000

**Plot Layout Parameters**

- **TRACE SPACING AND WIDTH**: 0,0250 and 0,2500
- **TRACE BOTTOM AND TOP**: 1,0000 and 9,0000
- **MARGIN LEFT AND RIGHT**: -0,0000 and 1,0000
- **PAGE WIDTH**: 10,0000
- **REPORT SIZE**: 6,000
- **PRINTER NAME**: LAS300
- **SCALE BAR**: Name: SHEY Type: EA Expansion: 0,500 Contour: 0
Appendix I
Coal
GPR Records – Buried Contraband Simulant Test
### PulseEXPO Header Parameters

- **File:** excoast121sep01c0900ls1
- **Job:** U.S. Coast Guard
- **Title:** Coal Pile (second), 900 MHz, Sugar
- **Date:** 21/09/10
- **Number of Traces:** 210
- **Number of Pts/Trc:** 500
- **Time Zero At Point:** 97
- **Total Time Window:** 0.0
- **Final Position:** 290.000
- **Step Size Used:** 1.000
- **Position Units:** metres
- **Nominal Frequency:** 400.00
- **Antenna Separation:** 0.170
- **Pulser Voltage:** 200
- **Number of Stacks:** 20
- **Survey Mode:** Reflection
- **Collected By:** PE1000
- **CON:** 9B1119 R/P: 9B1130
- **TX:** 981121 ANT: 971250/59

### Processing Selected

- **Filters:**
  - Trace Stacking: 1
  - Point Stacking: 5
  - Trace Differencing: N
  - Correction: Denow
- **Selection:**
  - Time: 9 to 41
  - Positions: 0.000 to 209.000
- **Gains:**
  - Gain Type: Constant
  - Multiplier: 100.000

### Plot Layout Parameters

- **Trace Spacing and Width:** 0.0500 and 0.2500
- **Trace Bottom and Top:** 1.0000 and 9.0000
- **Margin Left and Right:** 0.5000 and 1.0000
- **Page Width:** 10.0000
- **Border Size:** 0.000
- **Printer Name:** LAS500
- **Scale Bar:** Name: GREY Type: EA Expansion: 0.500 Contour: 0
PulseEcho HEADER PARAMETERS
FILE = k\COAST\1\121\P02\\1\CO900\LS2
JOB =
TITLE = U.S. Coast Guard
TITLE = Cool Fie (second), 900 kHz, Sugar
DATE = 21/09/16
NUMBER OF TRACES = 207
NUMBER OF PTS/TRC = 500
TOTAL TIME WINDOW = 50
STARTING POSITION = 0.000
FINAL POSITION = 206.000
STEP SIZE USED = 1.000
POSITION UNITS = metres
ANTENNA SEPARATION = 0.170
PULSER VOLTAGE = 200
NUMBER OF STACKS = 4
SURVEY MODE = Reflection
COLLECTED BY PE1000 - CON: 981110 RX: 981120
TX: 981111 ANT: 971259/09

PROCESSING SELECTED
FILTERS:
TRACE STACKING: 1
POINT STACKING: 5
TRACE DIFFERENCING: N
CORRECTION: GAIN
SELECTION TIME = 9 to 41
POSITION: 0.000 to 206.000
GAINS:
GAIN TYPE: CONSTANT
MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0500 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAC300
SCALE BAR: Name:GREY Type:EA Expansion:0 Contour:0

Sugar
Pipe
FILE = s:\COASTG~1\21SEP0~1\CG250LS1
JOB# = 1234
TITLE = Data Collected with Noggin Plus
DATE = 09/21/20
NUMBER OF TRACES = 94
NUMBER OF PTS/TRC = 111
TIME ZERO AT POINT = 11
TOTAL TIME WINDOW = 44
STARTING POSITION = 0.000
FINAL POSITION = 4.650
STEP SIZE USED = 0.050
POSITION UNITS = m
NOMINAL FREQUENCY = 250.00
ANTENNA SEPARATION = 0.305
PULSER VOLTAGE = 100
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 1
        POINT STACKING: 5
        TRACE DIFFERENCING: N
        CORRECTION: DEWOW
SELECTION TIME: -4 to 40
        POSITIONS: 0.000 to 4.650
GAINS: GAIN TYPE: CONSTANT
        MULTIPLIER: 100.000

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0600 and 0.2500
TRACE BOTTOM AND TOP: 1.0000 and 9.0000
MARGIN LEFT AND RIGHT: -0.5000 and 1.0000
PAGE WIDTH: 10.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name: GREY Type: EA Expansion: 0.500 Contour: 0
Use of Ground Penetrating Radar for Locating Contraband Aboard Ocean Going Vessels: Feasibility Study

Ground Penetrating Radar (GPR) surveys were conducted over various stockpiled materials at the Alabama State Docks located in Mobile, AL, to determine whether GPR is a viable method for rapidly detecting contraband materials buried in the cargo holds of ocean going vessels. The surveys were conducted by burying various objects including a contraband simulant (a bundle of four 10-lb bags of sugar duct-taped together) in stockpiled materials available at the site. The stockpiled materials tested were crystal gypsum, powdered gypsum, crushed pumice, coarse coal, fine coal, and bauxite.

Two GPR systems, the pulseEKKO 1000 and the Noggin Plus systems, manufactured by Sensors & Software, Inc., were used to conduct the surveys. GPR surveys were run over the stockpiled materials using a suite of antenna frequencies ranging between 225 and 900 MHz to determine the effects of material type on depth of penetration and target resolution.

All of the antennas tested were successful in detecting the location of the contraband simulant in at least one of the stockpiled materials. The 225 and 250 MHz antennas had the highest percentage of detecting the simulant in the stockpiled materials (60 and 90 percent, respectively) whereas the 900 MHz antenna had the lowest (30 percent). All antennas tested have penetration depths of greater than 1.5 m.

The GPR surveys run on the different stockpiled materials at the Alabama State Docks demonstrate that GPR is a feasible means of locating contraband buried to depths of at least 1 to 2 m (limit of testing). However, the probability of success of locating contraband with GPR on board ships depends on the size and depth of the target as well as the magnetic and electrical properties of the target and the material in which it is hidden.

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