RESULTS OF GEOPHYSICAL SURVEY FOR BEDROCK EVALUATION AT PICATINNY ARSENAL, DOVER, NEW JERSEY

February 6, 2003

Prepared For

Shaw Environmental & Infrastructure
111 Howard Blvd, Suite 110
Mt. Arlington, NJ 07856

Prepared By

Shaw Environmental & Infrastructure
1326 North Market Boulevard
Sacramento, California 95834

RESULTS OF GEOPHYSICAL SURVEY FOR BEDROCK EVALUATION AT PICATINNY ARSENAL, DOVER, NEW JERSEY

February 6, 2003

Prepared For

Shaw Environmental & Infrastructure
111 Howard Blvd, Suite 110
Mt. Arlington, NJ 07856

Prepared By

Shaw Environmental & Infrastructure
1326 North Market Boulevard
Sacramento, California 95834

Martin J. Miele, RGP, RG
IT Corporation
Senior Geophysicist

Table of Contents

List of Figures

1.0 Introduction

This report presents the results of a geophysical investigation conducted by Shaw Environmental & Infrastructure, Inc. (Shaw) at Picatinny Arsenal, New Jersey. The geophysical fieldwork was conducted January 6 through January 8, 2003.

1.1 Objectives

The objective of the geophysical investigation was to obtain seismic refraction data on 4 profiles that vary from approximately 500 to 800 feet in length to determine bedrock variation as well as a possible bedrock channel that may exist in the area. Geophysical data was collected and analyzed to: 1) interpret whether there exists a bedrock channel or faults that may influence groundwater flow, acting as groundwater conduits or barriers; 2) characterize bedrock conditions including depth, configuration and density as determined by seismic velocity; and to 3) detect and map the geologic structure or any faults that may exist.

2.0 Technology and Approach

This section presents the theoretical background and rationale for using seismic refraction for this investigation.

2.1 Seismic Refraction

The seismic refraction method determines the seismic velocity of subsurface seismic materials as well as their thickness and configuration. Seismic velocity is affected by composition, degree of hardness, degree of consolidation, degree of weathering and fracturing, and other physical characteristics of the subsurface materials. Igneous rocks and highly lithified sedimentary rocks (limestone, for example) typically have very high seismic velocities. Unconsolidated and unlithified sediments, colluvium, highly weathered and fractured rock, have lower seismic velocities.

In the seismic refraction method, data is collected along geophone spreads. Each spread is a collinear array of geophones (sensors) distributed at predetermined intervals. Seismic energy is generated at several points along the spread (shotpoints). The time that it takes for a compressional wave (P-wave) to travel from a shotpoint to each geophone (arrival times) is recorded with a seismograph for each shotpoint. The data are stored electronically and field hard copies of the data can be generated.

The arrival times versus distance between each shotpoint and geophone are plotted on time-distance (T-D) graphs. Straight-line segments are fit through the arrival times whereby various seismic layers are identified and their apparent velocities are determined. These parameters and the actual arrival times serve as input to computer modeling programs to invert the data. The output consists of seismic velocity cross-sections showing the seismic velocity of subsurface layers and the depth to each seismic velocity interface below every shotpoint and geophone. The cross-sections are used for geologic interpretation.

Several assumptions and limiting factors should be considered when interpreting and/or applying seismic refraction information. These assumptions are inherent to the technique and are common to all interpretation routines. They are as follows:

- The seismic velocity must increase with depth. The velocity of each layer must be greater than the layers overlying it. This is usually the case in the real world. However, in some cases where velocity inversions occur, the low velocity layer is not detected and the computed depth to all layers underlying it will be erroneous.

- Specific lithologic layers will not be individually resolved unless they are of considerable thickness and their velocity contrasts with that of adjacent layers. Conversely, variation in the elastic properties of a given lithologic unit may result in two or more seismic layers.

- Unless otherwise designated, seismic layers are assumed to have a constant velocity (average velocity) along the entire length of the profile.

- Steeply dipping seismic velocity layers may cause inaccurate depth estimates.

- The computed depth to a seismic interface may not be directly below the profile. There may be a slight difference if a shallow interface dips in a direction transverse to the profile.

- The velocity of a seismic layer can vary with direction depending upon the orientation of the sedimentary structure, bedding planes, fracture patterns, etc. relative to the seismic profile. This can result in a slight discrepancy in the computed velocity and depth of seismic layers between crossing profiles.

2.2 Navigational Technology

Differential Global Positioning System (GPS) technologies provide the shot point and geophone locations at approximately one-half foot, real-time accuracy. For this project, Shaw utilized the single frequency, Trimble Pathfinder Pro XR. The Pro XR GPS system was used for accurate locations of the sensors, associated geophysical equipment, and station locations in the survey. Real-time differential solutions acquired from the local New Jersey area beacons (base-station) provided differential corrections.

The availability of sufficient satellite coverage dictates the appropriate use of GPS. Two factors dictate sufficiency of satellite coverage: the view of the sky from the survey site, and the number and height of GPS satellites above the survey site. Tree coverage and proximity to buildings and topographic features such as cliffs and steep hills affect access to a clear view of the sky. The orbits of the GPS satellites can be readily viewed through use of GPS planning software such as Trimble's Quick Plan software. By reviewing the satellite availability on a daily basis, optimal survey periods can be defined, and periods of poor satellite visibility coordinated with rest times, preventative maintenance, data downloading, and travel. The site conditions at Picatinny Arsenal were favorable for the use of GPS at all four sites. Most areas were open with minimal tree cover above the area of interest.

3.0 Field Procedures and Data Reduction

This section describes the geophysical field procedures used during this investigation and general data reduction and processing steps.

3.1 Field Survey

Four separate profiles were assessed individually depending on the local site and surface conditions. These profiles were designated Profile 1, 2, 3, and 4 with Profile 1 the easternmost profile and Profile 4 the westernmost profile as depicted in Figure 1. All profiles were collected from the westernmost point to the easternmost point.

All four profiles included two or three seismic arrays (known as spreads) per profile. Unless otherwise noted, each spread included five shot points. These shot points were collected at the beginning, center, and end of each spread. Shot points were also located at either end of the spread that was offset a given distance calculated from the initial data collected.

For each profile, a measuring tape was laid out along the side of the road and pin flags were placed every 10 to 15 feet across the length of the survey. Seismic cable was placed next to the pin flags and geophones were placed in the ground at each pin flag location and attached to the seismic cable. The seismic cable was attached to a Geometrics, Inc. StrataView R24, 24 channel engineering seismograph.

Energy sources for each shot point for this survey included either a 12 lb. sledgehammer or acoustic wave generator (AWG). For each source, a one-inch thick aluminum plate was placed on the ground and was struck with either the sledgehammer or a hammer dropped by the AWG. The AWG consists of a 90 lb. cylindrical hammer that mounts to the hitch of a truck. It uses a hydraulic motor to lift the hammer against a large elastic band. When the hammer reaches the top of its stroke, it disengages and the weight of the hammer is dropped, accelerated by the tension created from the elastic band.

The aluminum plate was placed in-line with the seismic line when used with the sledgehammer, and due to the fact that the AWG was mounted on a two-wheel drive truck, it could not be maneuvered close to the seismic line in the snow, so the shot points were collected in the middle of the roads that were approximately 10-15 feet from the seismic lines.

For each shot point collected, the aluminum plate was struck many times. This practice is called stacking. Stacking of seismic data is a method to amplify the actual data and cancel the noise under the premise that every time a seismic shot is recorded the seismic signal due to the underlying geology will not change, but the randomness of the associated noise will cancel itself. The number of times each shot point was stacked was determined by real-time assessment of field data, but generally ranged from 3 to 10 times per shot point.

Local conditions at all profiles included soil with intermittent rocks and boulders and some brush and trees. Conditions at the time of the survey included approximately six inches of snow on the ground.

3.1.1 Profile 1

Profile 1 is the easternmost seismic refraction profile. This consists of a 470-foot profile that trends approximately 30 degrees with two spreads that include 24 receivers each placed 10-feet apart in a linear trend. The first geophone was positioned at the southwestern most end of the line that was on the southeastern side of a paved road, approximately 6 feet from an above ground pipeline that paralleled the road.

Five shot points were collected with the AWG at each spread totaling 10 shot points for the entire profile. The shot points were collected at the center of the road, approximately 12 feet northwest of the seismic line. For each spread, there were shot points collected at the beginning, center, and end of each spread along with a shot point 100 feet away from each endpoint in line with the spread.

3.1.2 Profile 2

Profile 2 is a 470-foot profile that trends approximately 150 degrees with two spreads that each include 24 receivers placed 10-feet apart in a linear trend. The first geophone was positioned at the northwestern most side of the line on the southwestern side of a road.

Five shot points were collected with the sledgehammer at each spread totaling 10 shot points for the entire profile. The shot points were collected in-line with the seismic line, except where the shot points occurred near a geophone station, in which case it was moved one foot away from the geophone towards the road. For each spread, there were shot points collected at the beginning, center, and end of each spread along with a shot point 50 feet away from each endpoint in line with the spread.

3.1.3 Profile 3

Profile 3 is a 710-foot profile that trends approximately 150 degrees with three spreads that each include 24 receivers placed 10-feet apart in a linear trend. The first geophone was positioned at the northwestern most side of the line on the southwestern side of a road.

Five shot points were collected with the sledgehammer at the first spread, five shot points were collected with the AWG at the second spread and four shot points were collected with the AWG at the third spread, totaling 14 shot points for the entire profile. The shot points collected with the sledgehammer were collected in-line with the seismic line, except where the shot points occurred near a geophone station, in which case it was moved one foot away from the geophone towards the road. The shot points collected with the AWG were collected in the center of the road, approximately 15 feet to the east of the seismic line. For each spread there were shot points collected at the beginning, center, and end of each spread along with a shot point 80 feet away from each endpoint in line with the spread. There was no off-end shot point collected at the end of profile 3 due to the end of the seismic line continuing into a ditch and then into a dense forest. This also led to the end shot being collected 20 north of the end of the line at station 70 rather than station 72.

3.1.4 Profile 4

Profile 4 is an 825-foot profile that was collected on the side of a road in an area between the road and a metal fence. The first spread trends approximately 50 degrees with 24 receivers that were placed 15-feet apart in a linear trend. A bend in the road and fence necessitated collecting the next two spreads at a trend of approximately 30 degrees that each include 24 receivers placed 10-feet apart in a linear trend. The first geophone was positioned at the southwestern most side of the line on the southeastern side of a road.

Five shot points were collected with the AWG at each spread totaling 15 shot points for the entire profile. The shot points were just off to the east of the road, approximately 15 feet northwest of the seismic line. For each spread, shot points were collected at the beginning, center, and end of each spread along with a shot point 100 feet away from each endpoint in line with the spread.

3.2 Data Processing

For each site raw field data for seismic and GPS data were downloaded to a laptop computer and evaluated for potential errors.

GPS data were downloaded to a laptop computer and evaluated within Trimble's Pathfinder Office software version 2.9. These data from all four sites were then differentially corrected from a base station in Trenton, New Jersey maintained by the New Jersey Department of Environmental Protection, approximately 82 kilometers away.

Seismic data were evaluated in real-time on the seismograph display and then downloaded and entered into SIP, a seismic refraction inversion software program. Within this program, data can be filtered and the first arrivals are picked and then inverted to create a layered subsurface cross-section. Elevation data for each shot point is also integrated into the inversion process to better constrain subsurface layer interface locations. Both two-layer and three-layer models were tested for validity.

4.0 Results

The results from the geophysical surveys from each of the four profiles at Picatinny Arsenal are presented below. All seismic refraction profiles are depicted as three layer models. Both two and three layer models were tested, however the three-layer model provided more reasonable layer velocities and structure models. Descriptions of the layers are presented below.

<u>Layer 1:</u> 1884 to 3542 feet per second (fps). These velocities are typical of unconsolidated to semi-consolidated sediments and may represent highly weathered rock in places. Layer 1 is a surface layer and varies from approximately 724 feet to 852 feet deep.

<u>Layer 2:</u> 6181 to 7068 feet per second (fps). These velocities are typical of saturated sediments and may represent moderately weathered/fractured rock in places. Layer 2 is a central layer that varies from 6 feet to 102 feet in thickness.

<u>Layer 3:</u> 11,595 to 15,303 feet per second (fps). These velocities are typical of slightly weathered to un-weathered bedrock. Layer 3 is the bottom layer surveyed and varies from 660 feet to 842 feet in depth.

4.1.1 Profile 1

Results from seismic refraction profile 1, as depicted in Figure 2, include layers with velocities of 3542, 6181 and 13,396 feet per second for layers one, two, and three, respectively.

This profile was collected from southwest to northeast and encompasses approximately 30 feet of variation in bedrock elevation across the 470-foot length of the profile. The lowest elevation of bedrock at 786 feet occurs at approximately 80-feet along the profile, corresponding with geophone station 9. The highest elevation of bedrock at 820 feet occurs on the northeast side of the profile at 460-feet, corresponding with geophone 47. In the southwestern portion of the profile, an area of low elevation occurs in the bedrock that does not correlate with the surface expression of a stream that crosses the profile; although this area does appear to be a possible channel in the bedrock.

4.1.2 Profile 2

Results from seismic refraction profile 2, as depicted in Figure 3, include layers with velocities of 1884, 7068 and 15,303 feet per second for layers one, two, and three, respectively.

This profile was collected from northwest to southeast and encompasses approximately 64 feet of variation in bedrock elevation across the 470-foot length of the profile. The lowest elevation of bedrock at 778 feet occurs at approximately 400-feet along the profile, corresponding with geophone station 41. The highest elevation of bedrock at 842 feet occurs on the northwest side of the profile at 20-feet, corresponding with geophone 3. The general trend of decreasing elevation of bedrock from northwest to southeast corresponds with the location of the stream running through the area and may represent a bedrock channel.

4.1.3 Profile 3

Results from seismic refraction profile 3, as depicted in Figure 4, include layers with velocities of 3334, 7040 and 11,595 feet per second for layers one, two, and three, respectively.

This profile was collected from northwest to southeast and encompasses approximately 72 feet of variation in bedrock elevation across the 710-foot length of the profile. The lowest elevation of bedrock at 702-feet occurs at approximately 525-feet along the profile, corresponding with geophone stations 53 and 54. The highest elevation of bedrock at 774 feet occurs on the northeast side of the profile at 225-feet, corresponding with geophones 23 and 24. Although bedrock elevation in this profile appears somewhat hummocky, a low occurs at approximately the same location as a stream crosses the surface of the profile and this may represent a bedrock channel. A general decrease in bedrock elevation to the southeast also corresponds to a stream that roughly parallels the southeast half of the profile.

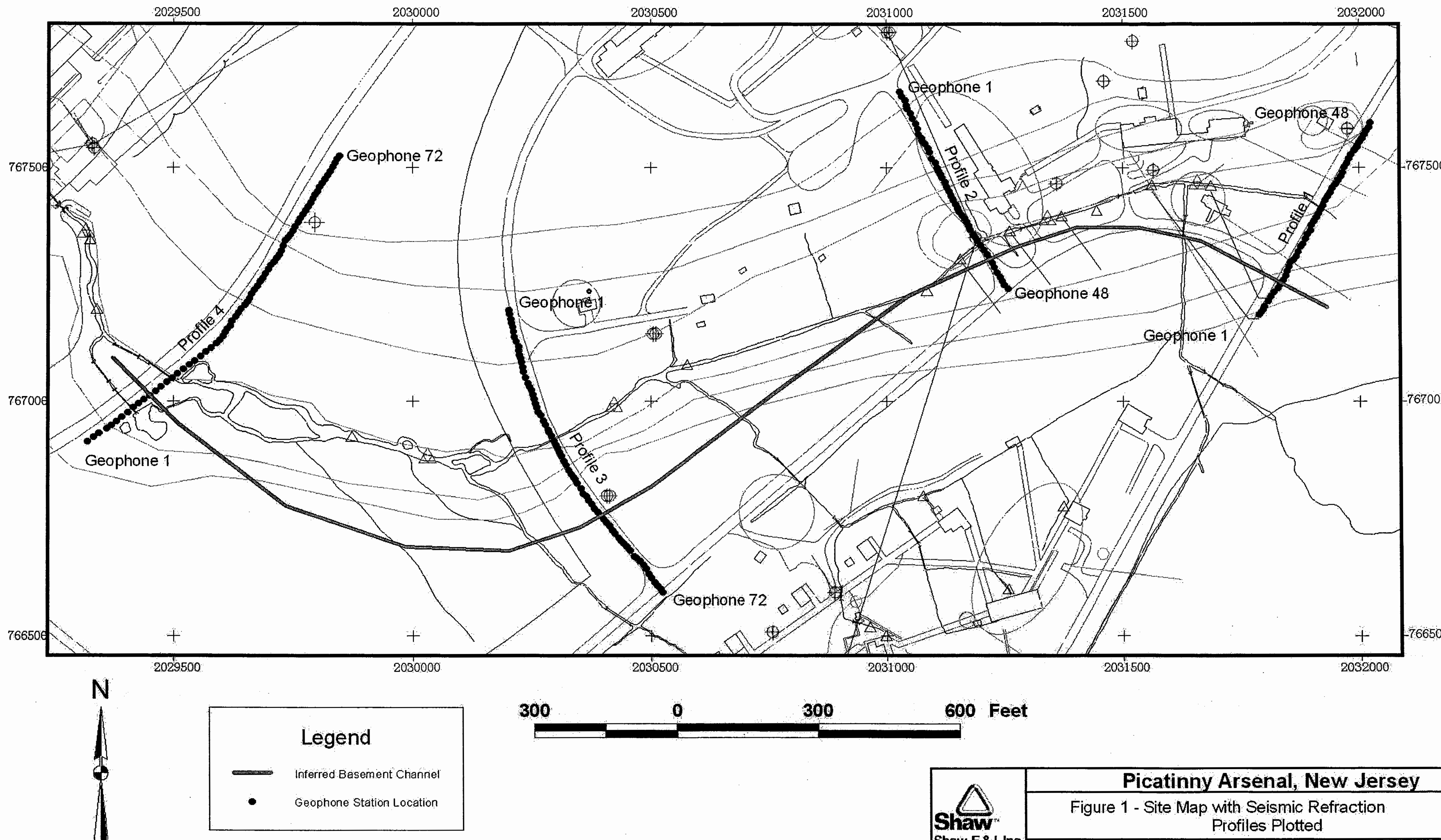
4.1.4 Profile 4

Results from seismic refraction profile 4, as depicted in Figure 5, include layers with velocities of 2374, 6828 and 15,129 feet per second for layers one, two, and three, respectively.

This profile was collected from southwest to northeast and encompasses approximately 24 feet of variation in bedrock elevation across the 825-foot length of the profile. The lowest elevation of bedrock at 658 feet occurs at approximately 110-feet along the profile, corresponding with geophone station 12. The highest elevation of bedrock at 722 feet occurs on the northeast side of the profile at 625-feet, corresponding with geophones 63 and 64. The surface expression of the stream that passes across this profile splits into a braided stream at this lower surface elevation, and corresponds to the lower elevation of the bedrock on the southwest side of the profile that appears to correspond with a bedrock channel. The drop off in elevation on the southwest side of this profile may also be due to a normal fault that trends approximately perpendicular to the profile.

5.0 Discussion

The data collected at Picatinny Arsenal reflect a possible channel in the bedrock that roughly corresponds to a stream currently mapped as a surface feature in the area. This channel is displayed on Figure 1 and Figure 6 and is not distinctive as one specific low, but rather a low area that may represent multiple channels in the bedrock or just minor variations in elevation across the channel. This channel is approximately 50 feet wide at higher surface elevations to the east and widens to approximately 300 feet at the lower surface elevations to the west and varies from approximately 20 to 40 feet in depth.

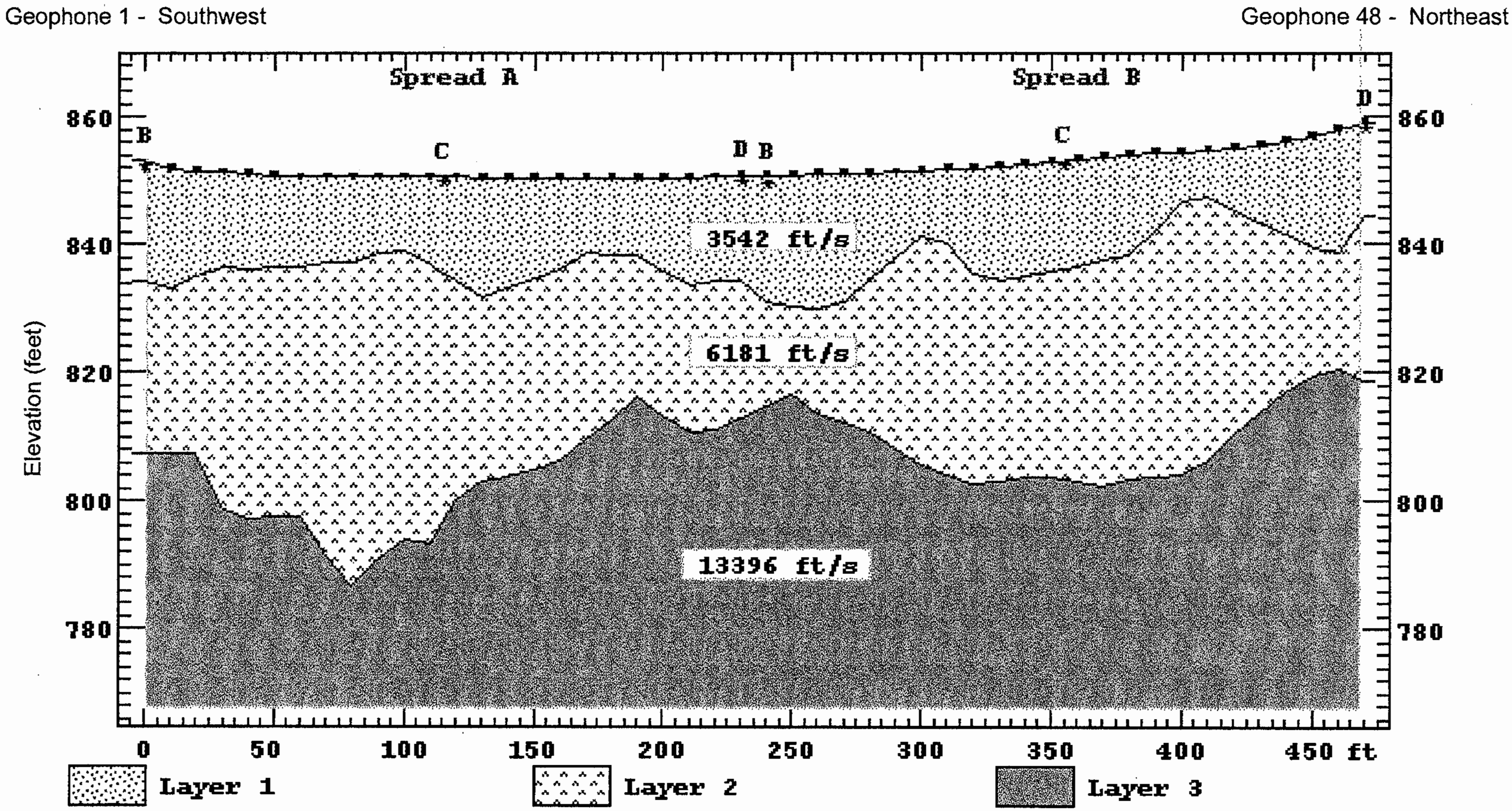


Shaw
Shaw E & I, Inc.

Picatinny Arsenal, New Jersey

Figure 1 - Site Map with Seismic Refraction Profiles Plotted

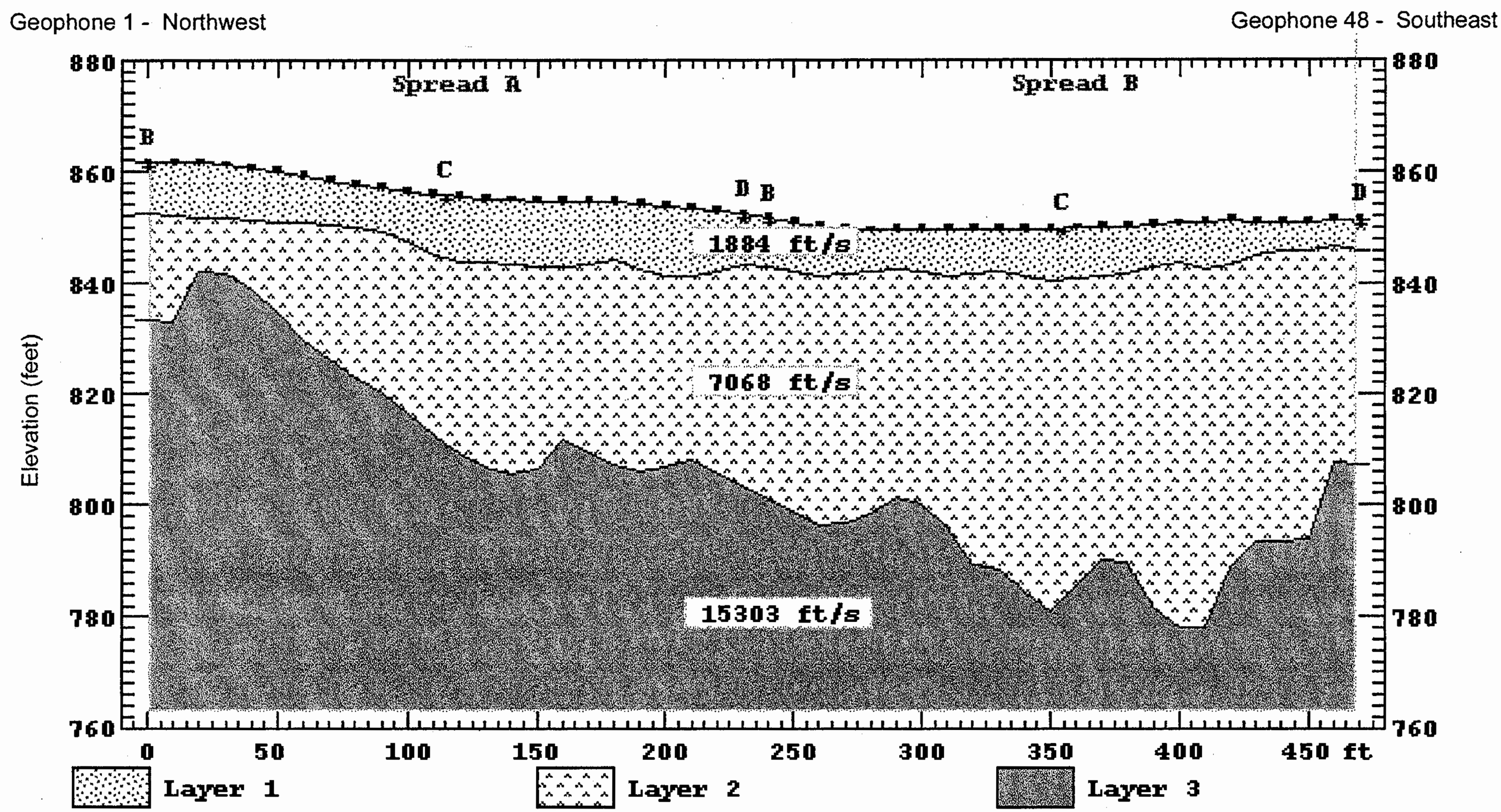
New Jersey State Plane, NAD 27, feet



Shaw E & I, Inc.

Picatinny Arsenal, New Jersey

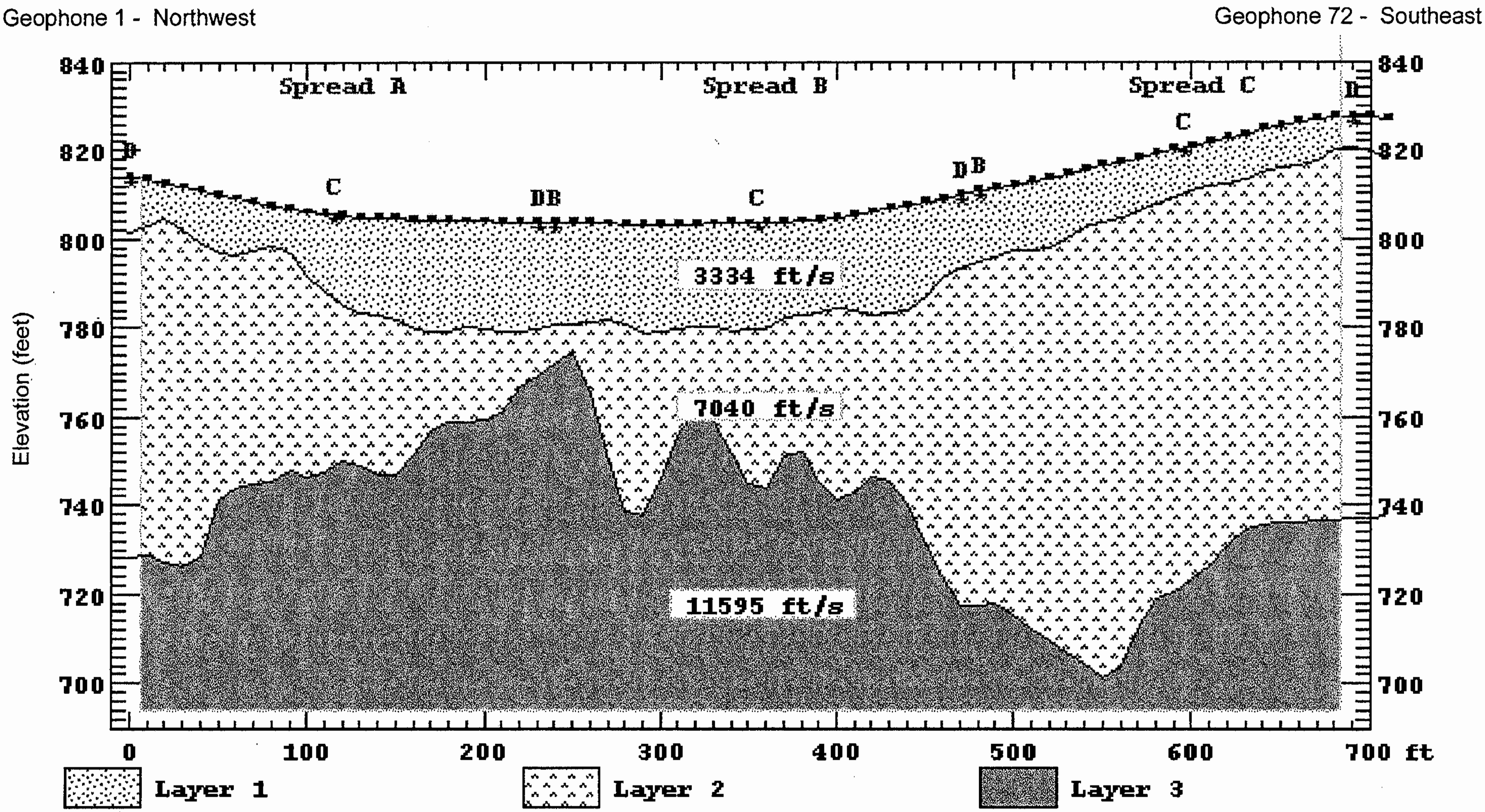
Figure 2 - Seismic Refraction Profile 1



Shaw Shaw E & I, Inc.

Picatinny Arsenal, New Jersey

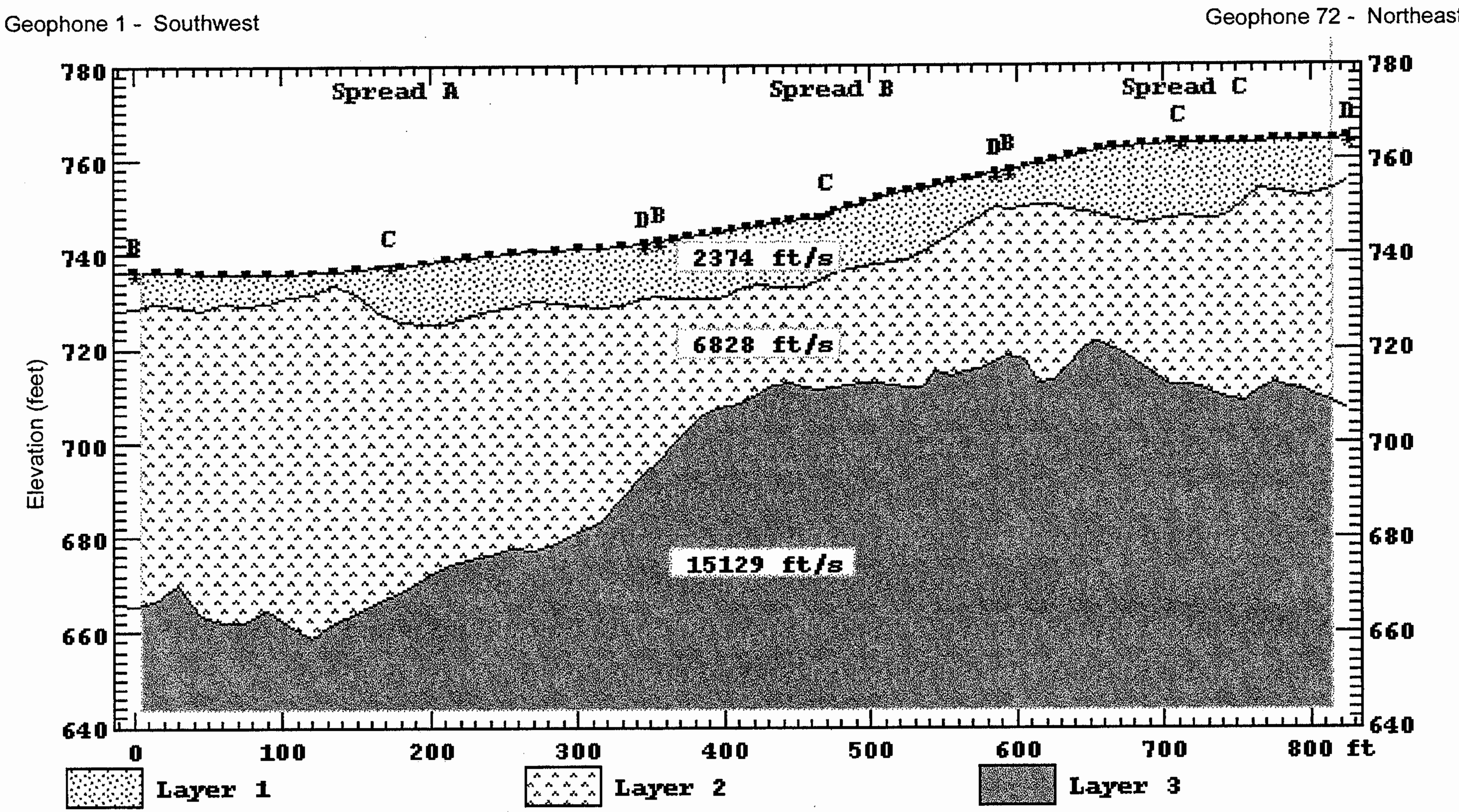
Figure 3 - Seismic Refraction Profile 2



Shaw E & I, Inc.

Picatinny Arsenal, New Jersey

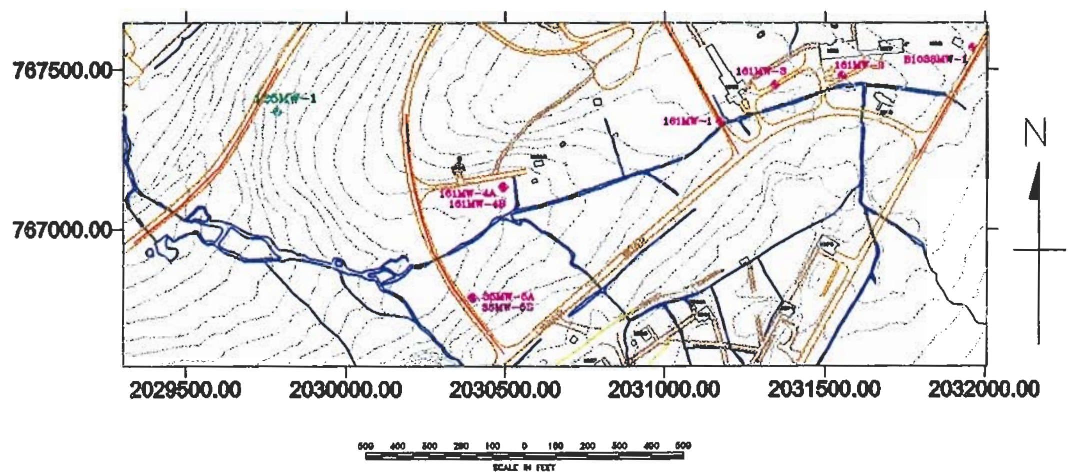
Figure 4 - Seismic Refraction Profile 3

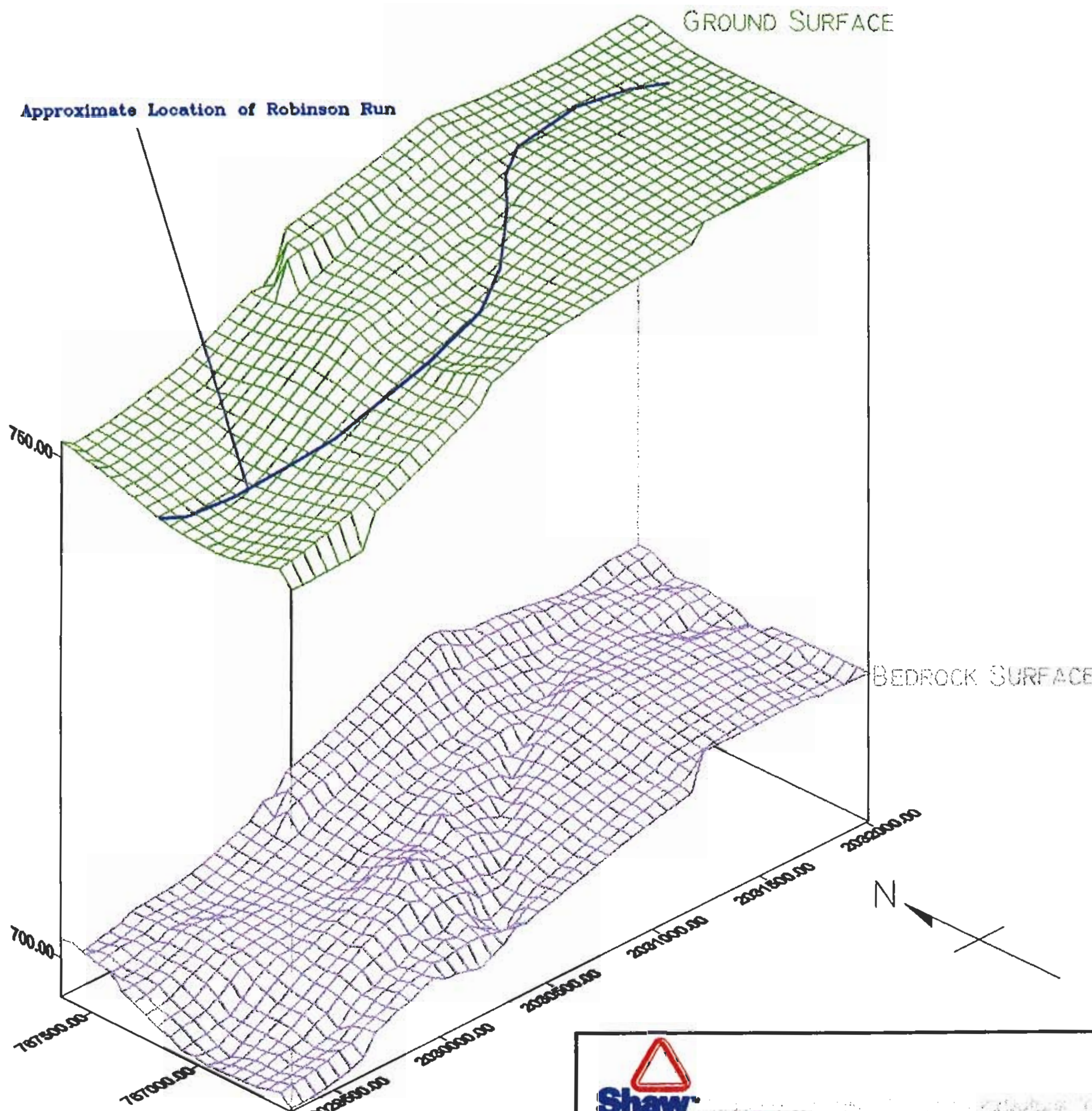


Shaw E & I, Inc.

Picatinny Arsenal, New Jersey

Figure 5 - Seismic Refraction Profile 4





DRAFT

DRAWN BY	CHECKED BY	APPROVED BY	DRAWING NUMBER
A. Smith	--	--	seismicprofile.dwg

Shaw

Picatinny Arsenal Installation Restoration Program

U.S. Army Corps of Engineers

FIGURE 6

3-DIMENSIONAL REPRESENTATION OF SEISMIC PROFILE OF BEDROCK

MID-VALLEY GROUNDWATER INVESTIGATION

PICATINNY ARSENAL, DOVER, NJ