FINAL

GEOPHYSICAL REPORT

Solar Evaporation Ponds
Operable Unit No. 4
Phase II RFI/RI

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

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ACRONYMS AND ABBREVIATIONS

BRA	baseline risk assessment
DMR	Document Modification Request
EM	electromagnetic
fps	feet per second
GAES	Geophysics Advisor Expert System
GPR	ground penetrating radar
HASP	health and safety plan
IAG	interagency agreement
IM/IRA	Interim Measure/Interim Remedial Action
ITS	interceptor trench system
LHSU	lower hydrostratigraphic unit
ms	milliseconds
OU4	Operable Unit 4
P-wave	compressional wave
PA	protected area
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
S-wave	shear wave
SEP	solar evaporation ponds
SOP	standard operating procedure
T-D	time-distance
TDS	total dissolved solids
UHSU	upper hydrostratigraphic unit
USGS	United States Geological Survey

GLOSSARY
OU4 PHASE II RFI/RI
GEOPHYSICAL REPORT

Alluvium All deposits resulting from the operations of modern rivers, including the sediments laid down in river beds, flood plains, deltas, fans at the foot of mountain slopes, and estuaries.

Apparent Velocity Velocity of seismic wave computed from slope of T-D graph which is uncorrected for dip or topography.

Colluvium A term applied to loose and incoherent deposits, usually at the foot of a slope or cleft and brought there chiefly by gravity.

Delay Time In refraction work, the additional time taken for a wave to follow a trajectory to and along a buried marker over that which would have been taken to follow the same marker considered hypothetically to be at the ground surface or at a reference level.

End Shot A shot point located at the end of a geophone spread.

Fluvial Of, or pertaining to, rivers; produced by river action, as a fluvial plain.

Geophone The instrument used to transform seismic energy into an electrical voltage.

Geophone Spread See Spread.

Interior Shot A shot point located within a spread of geophones.

Off-end Shot A shot point located on line but beyond the outer geophones of a spread.

Overburden Any material, natural or manmade, that overlies bedrock.

Parallelism The requisite parallel relationship between arrival times from the refractor which occurs between shots from the same direction.

Pediment Gently inclined planate erosion surfaces carved in bedrock and generally veneered with fluvial gravels.

Profile Seismic line made up of individual geophone spreads.

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Progradation A seaward advance of the shoreline resulting from the near shore deposition of sediments brought to the sea by rivers.

Ray Path A line everywhere perpendicular to wavefronts in isotropic media.

Ray Tracing Determining the arrival time at detector locations by following raypaths which obey Snell's law through a model for which the velocity distribution is known.

Reciprocal Time The travel time between common points on reversed refraction profiles. Surface-to-surface time from a shotpoint at A to a geophone at B must equal that from a shotpoint at B to a geophone at A.

Refractor A layer of higher velocity than overlying layers, through which a head wave (refraction wave) travels. In order to be useful for mapping, refractors must be sufficiently thick, extensive, and distinctive in velocity.

Refractor Coverage Portion of the deepest refractor which has generated overlapping arrival times on the T-D graph from reversed shotpoints.

Shotpoint The location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Also commonly used to refer to a hammer impact point when using a sledgehammer as an energy source.

Snell's Law When a wave crosses a boundary between two isotropic media, the wave changes direction such that the sine of the angle of incidence (angle between the wavefront and a tangent to the boundary) divided by the velocity in the first medium equals the size of the angle of refraction divided by the velocity of the second medium.

Spread The layout of geophone groups from which data from a series of shot points are recorded simultaneously. Generally, seismographs are set up to record multiples of 12 geophones at a time (i.e., 24 or 48 channels per record).

T-D Graph A plot of the arrival time against the shotpoint-to-geophone distance. The slopes of segments of the curve give the reciprocals of the apparent velocities for various refractor beds.

True Velocity Velocity of seismic wave computed from half-velocity plot (arrival time forward - arrival time reverse) which removes effects of dip and topography.

Unconformity A surface of erosion that separates younger strata from older rocks.

1.0 INTRODUCTION

The Operable Unit 4 (OU4) Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) at the Rocky Flats Environmental Technology Site (RFETS) was an integrated investigation undertaken to satisfy the requirements of the Interagency Agreement (IAG) of 1991. This investigation pertained to determining the nature and extent of contamination, describe contaminant fate and transport, and evaluate the impact of OU4 on surface water, ground water, air, the environment, and biota.

Historic sources of contaminants at OU4 have been liquids and sludges disposed of in the Solar Evaporation Ponds (SEPs) (see Figure 1.0-1). The liquids and sludges within the SEPs were characterized and described in the pre-IAG draft, *Solar Evaporation Ponds Closure Plan (DOE 1988)*, and *The Analysis of Solar Pond Sludge and Water* (Weston, 1991). According to these documents, the SEPs received wastes including low-level radioactive process wastes containing high nitrate concentrations, neutralized acidic wastes containing sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfates, hydrochloric and nitric acids, hexavalent chromium, and cyanide solutions.

This section presents an overall summary of the basis for conducting the geophysical survey portion of the Phase II RFI/RI, as well as a brief description of the investigative objectives and activities.

1.1 Purpose and Organization of the Geophysical Portion of the OU4 Phase II RFI/RI Report

This document presents the Geophysical report for the OU4 Phase II RFI/RI. The geophysical investigation is the initial study in the acquisition of data for the observational approach for the progressive OU4 Phase II RFI/RI. This approach is designed to be flexible and allow real-time analysis of data for subsequent field activities and to direct additional data acquisition.

The geophysical report focuses only on the seismic data gathered in this field investigation. Data acquisition was based on optimizing the subsequent field activities required for the evaluation of the nature, extent, fate and transport of contaminants, and effectiveness of the Interceptor Trench System (ITS).

The geophysical report is organized into six sections with appendices. Section 1, Introduction, provides a brief overview of the OU4 Phase II RFI/RI investigation, the geophysical survey, and the geology at RFETS. Section 2, Field Procedures, describes activities, methods, and equipment used to complete the geophysical portion of this task. Section 3, Processing, presents a discussion of the methods and computer program used to process and analyze the seismic data. Section 4, Results, presents the data results for each line. Section 5, Conclusions, presents a brief synopsis of the results. Section 6, Bibliography, contains a brief bibliography of pertinent references. Appendix A, Profile Data Forms, provides a description of features along the geophysical lines. Appendix B, Tj Method, provides a technical summary of this analytical technique.

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1.2 Overview

1.2.1 OU4 Phase II RFI/RI Overview

The goals defined for the Phase II RFI/RI investigation include characterization of the ground and surface waters, air, biota, and the environment as defined by the IAG. The objectives are listed below:

- Characterize the surface water, upper hydrostratigraphic unit (UHSU) and lower hydrostratigraphic unit (LHSU) hydrologic systems, and the hydraulic and chemical interactions between these systems;
- Characterize contamination in the OU4 surface water and ground water systems;
- Delineate the lateral and vertical extent of ground water contamination;
- Delineate the contribution of upgradient sources to ground water contamination at OU4 and assess the extent of chlorinated volatile organic compounds that were detected in wells just south of SEP 207-C;
- Evaluate contaminant fate and transport characteristics of OU4 media;
- Evaluate the ITS effectiveness;
- Evaluate the Building 774 Pond (Bowman's Pond) water system;
- Conduct a baseline risk assessment (BRA).

1.2.2 OU4 Phase II RFI/RI Geophysical Overview

The objectives of the geophysics program were to acquire seismic refraction geophysical data to identify preferential ground water flow paths by mapping the top of unweathered and weathered bedrock and the water table, major lithofacies variations in the alluvium, and barriers to the ground water flow.

Initially, frequency domain electromagnetic (EM) data and ground penetrating radar (GPR) surveys were identified in the Phase II RFI/RI Work Plan and planned to determine the location of high concentration total dissolved solids (TDS) plumes and to map the bedrock surface, respectively. Figure 1.2.2-1 shows the proposed Phase II geophysical line locations as presented in the Phase II RFI/RI Work Plan.

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Prior to implementing field work, an evaluation was performed of the seismic program in the Phase II RFI/RI Work Plan. Familiarity with the soil and geology at RFETS and their influence on the use of geophysical methods was essential for this evaluation. The soil at Rocky Flats contains significant amounts of mineralogical clay causing high attenuation of the GPR signal. GPR signal attenuation results in a depth penetration of less than 10 feet at most locations for GPR. Generally poor GPR results obtained for the OU4 Phase I Interim Measure/Interim Remedial Action (IM/IRA) Utility Verification Task confirmed this assumption.

Because GPR had been proven generally ineffective at the SEPs, all surface geophysical techniques were analyzed using the Geophysics Advisor Expert System (GAES), designed by the United States Geological Survey (USGS). Parameters entered into the GAES program were based on previous Phase I investigation findings and the Phase II RFI/RI objectives. The program evaluates each geophysical method and applies arbitrary weights to each method. The relative effectiveness of each geophysical method is ranked by the weighted values. The higher the value, the more likely that the method will be successful. Values less than or equal to zero mean that the chance of success with the method is negligible. The geophysical methods that were evaluated by the GAES for use at OU4 were weighted as follows:

Method	Weight
Seismic	10
Soil Gas	3
Resistivity	2
Radiometrics	2
Electromagnetics	0
GPR	-7

Seismic methods were strongly recommended by the program, and extremely low values resulted in the elimination of GPR and EM from the Phase II RFI/RI Program.

The Phase II RFI/RI Work Plan was modified to encompass suspected bedrock channels south and east of the SEP 207B South and north toward North Walnut Creek. The Work Plan was also modified to remove GPR and EM, and their objectives. SOP.18 was modified to include the methodology and documentation for the seismic refraction survey to be performed. Both compressional (P) and shear (S) wave data were collected. The P-wave data were used to delineate the top of weathered bedrock, the weathered zone, lithofacies identification, and the configuration of the UHSU water table. The S-wave data were used to delineate the top of unweathered bedrock. Borehole and well data were used to verify the geophysical data.

To achieve the objectives, compressional and shear wave profiles were acquired on 14 lines within OU4 as shown in Figure 1.2.2-2. The data were collected along each line according to priority. An order was established from the objectives for each line.

The original priority of the lines and their corresponding objectives were as follows:

<u>Line</u>	<u>Objective</u>
D	Testing of acquisition parameters, comparison with previously acquired seismic refraction data, identify preferential flowpaths in both the alluvium and the weathered bedrock in the vicinity of the ITS.
I, J	Define preferential flowpaths between the SEPs and the 700 industrial area, support initial geoprobe locations.
A, B, C, E	Identify preferential flowpaths into and beneath the ITS, identify preferential flowpaths to North Walnut Creek.
H, K	Identify preferential flowpaths from the SEPs to South Walnut Creek.
F, G, L	Identify preferential flowpaths and subsurface topography in the vicinity of possible future ground water remediation systems.
M	Identify preferential flowpaths to the south of the SEPs toward South Walnut Creek.
N	Tie line for Lines D and E.

Work was performed under Document Modification Request (DMR) 94-DMR-001997 (limited scope to OU4) to Standard Operating Procedure (SOP) 5-21000-OPS-GT.18, Rev. 2, *Surface Geophysical Surveys,* and DMR 95-DMR-ERM-0025 to RF/ER-94-00040, *Phase II Work Plan for OU4.* Additionally, comments and responses to the Phase II Work Plan for the Operable Unit 4 Phase II RFI/RI Requirements Post Closure Assessment Task Order were addressed and incorporated into the Work Plan DMR.

1.3 Geology and Site Overview

The geology of the region which encompasses the RFETS has been described by many geologists in recent years including Scott, 1960 and 1965; Spencer, 1961; Weimer, 1976; Machette, 1976; Van Horn, 1976; and various consultants and state and federal agencies. The following discussion is a synopsis of those studies and investigations.

The RFETS is situated on a broad, east-trending pediment surface that is located on the western edge of the Denver Basin. The top of the basin is underlain by more than 10,000 feet of Pennsylvanian and younger sedimentary rocks that have been locally folded and faulted. Within the foothills immediately west of the RFETS, sedimentary strata have easterly dips greater than 30 degrees and in some places beds are overturned. In the western buffer zone, Upper Cretaceous sandstone units of the Laramie Formation form a portion of the east dipping hogback that strikes north-northwest and extends from

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Wyoming to New Mexico. These steeply dipping sedimentary strata abruptly flatten to less than 2 degrees beneath and east of the RFETS. This thick sedimentary sequence (bedrock) is unconformably overlain by Quaternary alluvial materials, generally coarse-grained, that cap various pediment surfaces which encompass several distinct ages. The Upper Cretaceous bedrock units directly underlying the RFETS which are important to the understanding of plant site hydrogeology are, in descending stratigraphic order, the Arapahoe Formation, the Laramie Formation, and the Fox Hills Sandstone.

Depositional sedimentary environments in Colorado east of the Front Range during the late Cretaceous period were influenced by the Laramide Orogeny. This mountain building episode resulted in the uplift of the Front Range mountains. The uplift caused a west to east regression of the Cretaceous Sea which resulted in lateral progradation of Pierre (prodelta) shales and siltstones; Fox Hills (delta front) sandstones; Laramie (delta plain) sandstones, claystones, and coals; and Arapahoe (fluvial conglomerate) sandstones and claystones. These sedimentary formations are relatively distinct, reflecting increasingly higher gradients of deposition and higher energy facies. At the RFETS, the Arapahoe Formation is the upper bedrock unit encountered. The exception is in the western buffer zone where the Laramie Formation is the uppermost bedrock unit encountered. At OU4, the Arapahoe Formation is the upper bedrock unit encountered and this investigation is focused primarily on the materials which comprise the Arapahoe Formation. Based on the site-wide Phase II Geologic Characterization, there are two depositional environment interpretations for the uppermost Arapahoe sandstones. One interpretation assumes a single, meandering channel system, while the other interpretation assumes a fluvial system with multiple channels.

The Quaternary (unconsolidated) deposits at the RFETS have been characterized as three types of sediment cover and four types of valley fill. These alluvial units have been correlated along the Front Range based on their stratigraphic height above extant stream drainages. Colluvium occur on hill slopes northeast and southeast of the Solar Ponds descending to North and South Walnut Creeks.

The Solar Ponds are located on a Pre-Wisconsin age pediment remnant which is capped by the Rocky Flats Alluvium. This alluvial unit is poorly sorted and contains a wide range of clay, silt, sand, gravel, and occasional boulders. It can be weakly cemented. It is the only Quaternary deposit underlying the SEPs and its thickness ranges from 0 to 27 feet. The pediment erosional surface was cut from west to east. Later erosion may have been influenced by Pre-Wisconsin topography, possibly breaching the existing alluvial cover, exposing the Arapahoe Formation, and following earlier established drainage patterns.

As discussed earlier, the purpose of this investigation is to integrate the results of the seismic refraction program with the current understanding of OU4 geology and hydrogeology and use this information in identifying, in addition to the general flow of offsite ground water migration, any preferential pathways (paleochannels) for OU4 offsite contaminant migration.

2.0 DATA ACQUISITION

Field work for compressional and shear wave seismic refraction was performed in accordance to the RFETS procedures as a non-intrusive, investigative technique for delineation of weathered bedrock, unweathered bedrock, and ground water surface. Fifty-nine seismic refraction spreads were necessary to complete the geophysical task. Health and safety procedures were followed according to the OU4 site specific Health and Safety Plan (HASP) for the Phase I and Phase II RFI/RI (RFP/ERM-94-00037) and the DMR 94-DMR-ERM-0129.

2.1 Land Surveying and Seismic Line Locations

Fourteen thousand linear feet of seismic refraction data were acquired and interpreted. Line locations were staked and verified according to the approximate locations from the Phase II RFI/RI Work Plan. The spreads were measured from the map and then located on plantsite using a Brunton compass and fiberglass chain. Wooden stakes were placed on the ends of each seismic line and at locations where a gap in the line occurred. These gaps were because of roads, wetlands, and other inaccessible areas. Geophone marker flags were placed at every other geophone location and at the ends of each spread.

Field changes occurred at Lines H and N. Line H, Spreads 3 and 4 were combined into a single asymmetrical spread to avoid a large overlap. The new spread was labeled Spread 3 and consisted of a five foot geophone spacing for geophones 1 to 32, and a ten foot geophone spacing for geophones 32 through 48. Line N was added as a supplement for line ties to Lines D and E and the Phase I RFI/RI geophysical lines.

Land surveying was performed by RFETS surveyors on all seismic lines. The surveyors acquired data from the ends of each line and any breaks in slope. Linear interpolation was used to calculate the location and elevation of each geophone for seismic interpretation.

2.2 Equipment

The seismic refraction data were collected using a Geometrics Strataview® 48-channel signal enhancement seismograph. The seismograph displays the data in real time and also saves the data in SEG2[1] digital format on either the internal hard drive or diskette. The seismograph records the data in instantaneous floating-point format. Each seismic record contains a standard header which includes date, time, record number, line number, spread geometry, and shotpoint location information. Seismic energy was generated for the compressional wave data by impacting a slidehammer mounted vertically on a metal plate. Horizontally polarized energy for the shear wave data was generated by impacting a sledgehammer on a specially designed shear wave generator which was coupled to the ground by eight vertical spikes. The hammer operator generated horizontally polarized shear wave

1 SEG2 is the standard engineering format for seismic data recording established by the Society of Exploration Geophysicists.

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energy by hammering parallel to the ground surface on the two vertical plates of the shear wave generator while standing on the baseplate. The initial direction of the energy was reversed at each shotpoint and the seismograph recording polarity reversed for stacking to verify that energy reversal was observed. The compressional wave energy was recorded using 14-Hz vertical geophones and the shear wave energy was recorded using 28-Hz horizontal geophones oriented transverse to the seismic line.

2.3 Spread Geometry

Seismic spreads were laid out on a five foot geophone spacing using 48 geophones per spread. The five foot geophone spacing was necessary to obtain a lateral resolution of subsurface features 10 to 15 feet wide. The spread geometry and data acquisition sequence are shown in Figure 2.3-1. Spreads were labeled with a two number prefix in reference to the line. Each spread was 235 feet long with location labels from geophones 1 to 48 (e.g., A 02-141 is Line A, Spread 2, Geophone 41). In general, six records were taken on each spread, two off-end shots (approximately 60 feet from the end geophones) and four in-line shots (at 7.5, 82.5, 162.5, and 237.5 feet). The end shots (7.5 and 237.5 feet) were used to obtain a basic reversed refraction profile. The off-end shots were used to obtain full coverage on the refractor (deepest layer). The interior shot points (82.5 and 162.5 feet) were used to obtain additional depth and geometry information on the intermediate layers. Adjacent spreads were laid end-to-end with a minimum of a two geophone overlap between profiles to ensure adequate coverage and consistency.

Detailed information for each profile is listed in Appendix A, including spread overlap, line ties, and wells. For general location purposes, the lines will be briefly described below.

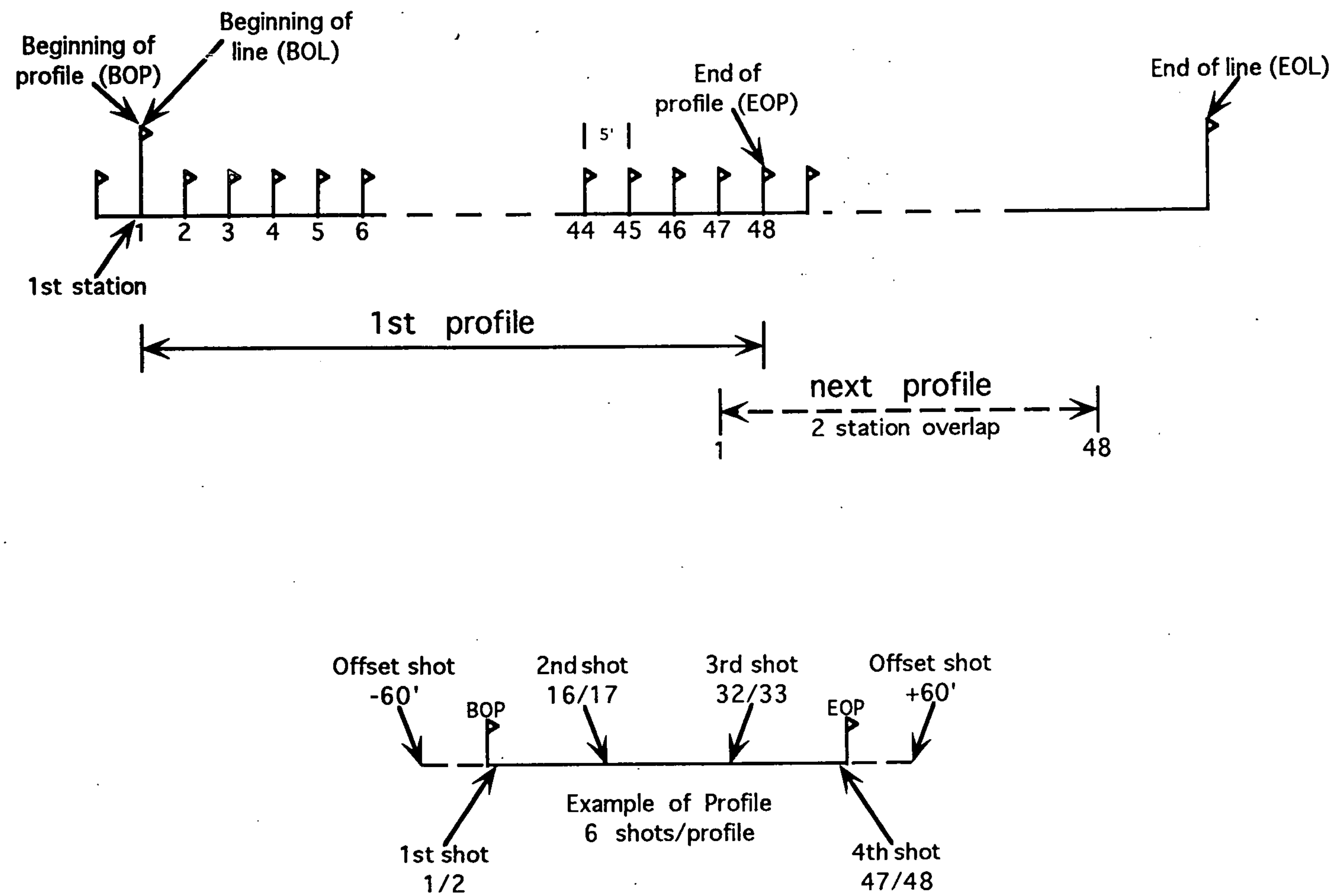
<u>Line A</u>
Line A is located east of Portal #3 and along the southern tributary to North Walnut Creek in the Buffer Zone. Line A was composed of five spreads and laid west-to-east with Spreads 1 through 3 to the west of the North Perimeter Access road, and Spreads 4 and 5 to the east. Spreads 4 and 5 have a 24 geophone overlap and a gap occurred between Spreads 3 and 4 because of the heavily trafficked asphalt road. Line A crosses C 01-107 at 03-115, D 02-117 at 04-126 and 05-102, and E 02-106 at 05-135.

<u>Line B</u>
Line B is parallel to Line A, north of the North Perimeter Access Road, east of the parking area for Portal #3, and is along North Walnut Creek in the Buffer Zone. Line B was composed of five spreads and laid west-to-east with a gap occurring between Spreads 2 and 3 because of wetlands. Line B crosses L 01-125 at 04-131 and has a near tie with D 01-101 at 02-105.

<u>Line C</u>

Line C is located south of the North Perimeter Access road, parallel to and north of the Protected Area (PA) fence, and parallel to Lines D, E, and L in the Buffer Zone. Line C was composed of seven spreads and laid northwest-to-southeast (approximate bearing of S62°E). Line C crosses A 03-115 at 01-107 and G 06-112 at 07-131.

Figure 2.3-1 - Data Acquisition Geometry



(diagram not to scale)

Line D

Line D is located north of the North Perimeter Access road and parallel to Lines C, E, and L in the Buffer Zone. Line D was composed of four spreads laid northwest-to-southeast, foreshortened near where the Phase I RFI/RI seismic lines were located. Spreads 3 and 4 have a 24 geophone overlap. Line D crosses A 04-126 and 05-102 at 02-117, N 01-135 at 04-146, and near B 02-105 at 01-101. Spreads 1, 2, and 4 were re-collected because of high wind noise on the first run.

Line E

Line E is located north of Line D, crossing over the edge of the hillside, and parallel to Lines C, D, and L in the Buffer Zone. Line E was composed of six spreads laid northwest-to-southeast and crosses A 05-135 at 02-106, N 01-117 at 03-129, and G 04-137 and 05-109 at 06-107.

Line F

Line F was laid northwest-to-southeast (S11°E), across the North Walnut Creek valley and across the Pond A1 dam in the Buffer Zone. Line F was composed of two spreads, did not cross any other line, and Spread 2 was re-collected because of high wind noise.

Line G

Line G is the longest line in the survey and is located east of the PA in the Buffer Zone. Line G was composed of ten spreads and laid approximately north-to-south. There is a gap from Spread 1 to 2 because of a wetland area and from 5 to 6 because of the North Perimeter Access road. There is an asphalt road that seismic was shot over at 06-143 to 06-148 and 07-101 to 07-110. Spreads 4 and 5 have an 18 geophone overlap, and Spread 2 was re-collected because of high wind noise. Line G crosses L 04-114 at 03-130, E 06-107 at 04-137 and 05-109, and C 07-131 at 06-112.

Line H

Line H begins in the "boneyard" area of the 964 pad and continues southward toward building 991 in the PA. Line H was composed of three spreads and laid north-to-south. There is a 21 geophone overlap between Spreads 1 and 2 and a gap from Spread 2 to 3 because of an asphalt road. Spread 3 was a combination of the old Spreads 3 and 4, and is asymmetrical because of the use of two geophone spacings. Spread 3 was re-collected because of high noise levels from a nearby sewage pump. Line H crosses M 04-138 at 02-148.

Line I

Line I is located west and south of SEP 207C in the PA and on the near side of the access road next to the SEP. Line I was composed of two spreads. Spread 1 was laid north-to-south, and Spread 2 was laid west-to-east. Line I did not cross any other line and was parallel to J, and on the near side of the access road next to the SEP.

Line J

Line J is located west and south of SEP 207C in the PA and on the far side of the access road next to the SEP. Line J was composed of two spreads. Spread 1 was laid north-to-south and Spread 2

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was laid west-to-east, on the other side of the access road from Line I. Line J did not cross any other line.

Line K
Line K begins in the "boneyard" area of the 964 pad and continues southward toward building 991 in the PA. Line K was composed of three spreads and laid north-to-south. Spread 1 was placed on the edge of the 964 pad. There was a gap between Spreads 1 and 2 because of an asphalt road and geophone 03-141 was not placed because of South Walnut Creek. Line K did not cross any other line and Spreads 2 and 3 were re-collected because of the high noise from the sewage plant pumps.

Line L
Line L is located north of Line E in the Buffer Zone. Line L was composed of five spreads and laid parallel with Lines C, D, and E. Line L began on the southern side of the wetlands and continued to the southeast. There was a gap between Spreads 4 and 5 because of a gravel road and Spreads 1, 2, and 5 were re-collected because of equipment malfunction and wind. Line L crosses B 04-131 at 01-125 and G 03-130 at 04-114.

Line M
Line M is located just south of SEP 207A and 207B South and extends east towards the edge of the 964 pad in the PA. Line M was composed of four spreads and was laid west-to-east. There was a gap between Spreads 1 and 2 because of driveways and cement blocks. Line M crosses H 02-148 at 04-138.

Line N
Line N is located north of the North Perimeter Access road and extends perpendicularly through Lines D and E, and near wells 44893 and 40593 in the Buffer Zone. Line N was composed of one spread and laid northeast-to-southwest (approximately S28°W). Line N crosses D 04-146 at 01-135 and E 03-129 at 01-117.

2.4 Acquisition Parameters

The seismic refraction data were recorded using similar parameters for both the P and S-wave data. After field testing, the sample rate was set at 0.5 milliseconds and the record length was set at 500 milliseconds. A high cut filter of 250 Hz was used to reduce wind noise on many records and to serve as an anti-aliasing filter. In some isolated cases, notch filters and bandpass filters were also used to eliminate cultural noise from pumps, traffic, and electrical lines, where the noise source could not be eliminated.

In general, stacking of 10 to 20 vertical blows of the hammer was sufficient to produce good P-wave records. For recording the shear wave data, 10 blows on the shear wave generator were recorded using a positive polarity in the seismograph and another set of 10 blows in the opposite direction were recorded using a negative polarity in the seismograph, resulting in a stack of 20 blows. More hammer blows were used where additional energy was needed.

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2.5 Field QA

Field operations were conducted in accordance with the applicable SOPs (5 -21000-OPS-FO.03, FO.04, FO.07, FO.11, FO.12, FO.15, FO.16). Technical work was performed in compliance with the requirements outlined in the Site-Wide Quality Assurance Project Plan (QAPjP), the OU4 Phase II Work Plan, the DMR 94-DMR-001997 to Standard Operating Procedure 5-21000-OPS-GT.18, Rev. 2 for surface geophysical surveys, and the Standard Operating Procedure 5-21000-OPS-GT.17, Rev. 2 for land surveying. All field activities associated with the seismic survey were documented in black waterproof ink in bound weatherproof field notebooks.

Weather, soil moisture, and wind conditions affected data quality. Other factors affecting data quality included ground vibration from vehicle traffic, airplanes, air monitors, ventilation fans, pumps, electrical lines, and other noise sources associated with an occupied industrial site. Hard copies of the seismic records were used in the field to check data quality. Where possible, spreads with unacceptable levels of noise were re-collected under more favorable conditions.

Seismic Refraction Survey Observer's Report forms (GT.18B - Rev. 2) were completed for all spreads, providing general information about the equipment and survey parameters. The form also identifies the line, spread number, operator name, the assigned record numbers (the computer filenames ****.DAT) for each shot location, and any quality related issues such as weather or malfunctioning geophones. All seismic records were retained in digital format on floppy disk and include survey information in the record header. Field hard copies of each record were printed and can be referenced to the observer's reports by the record number (****.DAT). These hard copies also contained hand-written documentation of any quality related issues. All field records were checked for completeness and legibility using a field form checklist. All errors, omissions, and inconsistencies were corrected and properly documented.

3.0 PROCESSING

3.1 SeisREFA©

The data were processed and analyzed using the SeisREFA© program developed by OYO Geospace. The program uses a combination of the conventional reciprocal method (Hagiwara's method) and the Tj method to develop a layered-earth model from the time-distance graphs. The conventional reciprocal method was used to compute the refractor depth and surface topography. The Tj method was used to compute upper layer boundaries in areas not fully covered by reversed arrivals from the end and interior shotpoints. After construction of a layered earth model, the program performs a ray-tracing calculation to construct a time-distance graph from the model which was compared to the field data. Adjustments can then be interactively made to the model to obtain the best fit between the model and observed field times. The Tj method is discussed in detail in Appendix B.

3.2 Data Processing

The first step of data processing involves picking the first arrival times of the seismic energy from the compressional wave records and picking the shear wave arrival times from the shear wave records. The arrival times for each shotpoint and the spread geometry (geophone distance and elevation data) were entered into a spreadsheet and checked for consistency . The arrival time data is then plotted versus distance for each geophone to create a time-distance (T-D) graph. The time-distance graph is reviewed for internal consistency using reciprocal time and parallelism tests. The refractor velocity is then computed from a least-squares fit of a line defined by the mathematical difference between the off-end shot arrival time data. The extent of refractor coverage, lateral changes in the refractor velocity and low velocity zones within the refractor, are also determined during this phase of processing.

After the refractor velocity has been determined, intermediate layers can be identified based on the character of the time-distance graph. After layer assignment, delay times for each layer are computed and a display of the calculated versus interpolated data points for each layer boundary are displayed. Ray tracing is then used to generate a time-distance graph from the model for comparison with the field time-distance data. Any of the steps outlined above can be edited, and interactive processing is necessary to obtain optimum results. Each spread was analyzed independently and then tied to adjacent spreads.

In general, an automatic solution was generated after careful inspection of the time-distance graph. In most cases, the automatic solution was unsatisfactory and the processing was repeated with careful editing at each step of the analysis procedure coupled with editing of the final solution.

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3.3 Data Quality

In general, compressional wave first arrival events were easily identifiable on the seismic records and picking of the arrival times was unambiguous. In most cases, the picking error was on the order of 0.5 milliseconds (ms) or the sample rate. Compressional (P) wave arrivals were very sharp and distinctive, being of much higher frequency than most of the background noise. Man-made machine noise and windy conditions on some spreads created some picking problems; however, the greatest source of interference on most spreads was from the air wave associated with the hammer source. This was a problem in areas where the surface layer had a P-wave velocity slightly less than the air wave velocity of 1,100 feet per second (fps). In this case, the air wave arrival comes in before the actual direct wave arrival yielding an incorrect first layer velocity. An incorrect velocity introduces error in the refractor depth. Where the P-wave velocity of the first layer was significantly less than the air wave, both arrivals could be distinguished.

Because the S-wave arrivals are later in the wavetrain and are typically of lower frequency, the onset of the shear energy is not as obvious as the compressional wave energy. The use of transverse horizontal geophones and a reversible, transverse horizontal energy source were used to eliminate most of the P-wave interference and to assist in S-wave verification. Records were also inspected for dispersion (change in frequency with distance). Picking error was typically on the order of 2 ms, and positive identification of the waveform as shear energy could not be confirmed. Most of the S-wave data were of good quality; however, many of the S-wave records yielded an unusual concave curvature in the arrivals from the intermediate layers. Records were re-examined and alternate time picks could not be located which would yield a more normal time-distance curve. The source of this phenomenon is unknown. This phenomenon yields unreliable velocities and can affect the calculated depth to the refractor, but will not significantly affect the refractor topography.

In the PA, S-waves were not observed. Initially, on Lines I and J, it was thought that shear was being observed on the close-in geophones and that the energy was abruptly attenuated at a relatively common distance along the spread. This same behavior was observed on all the other lines within the PA. However, the velocity for the observed energy was too fast to be a shear wave. It is believed that this phenomenon may be related to the early arrivals observed on some of the lines outside the PA as discussed above.

Both P and S-wave data sets exhibit a gradual change of velocity with depth as evidenced by the curved nature of the time-distance graphs generated from the arrival time data. This lack of distinct layering increases the chance for error in the interpretation of the seismic data because the layer velocities are determined from the slopes of the line segments defined by the time-distance graphs and depths are determined by the distances along the graph where the velocities change. Although the observed time-distance graphs were not actually curves, there were a number of spreads where the layer velocities were not well defined.

3.4 QA/QC

Accurate ground elevations and distances of the geophones and the shot points are necessary for accurate interpretations using the SeisREFA© program. Ground elevations for all geophones and shot points were determined using the land survey data and interpolating between land survey points assuming a linear slope. Geophone and shot point locations were determined using slope distances measured in feet from the beginning of the line. No corrections were made for differences between the slope distance and the actual horizontal distance. Therefore, some distance error may be present in lines with significant elevation changes. For example, there may be a distance error of up to 5 feet on Line G, Spread 1, which has the largest elevation change of any spread (a 50 foot change in elevation over 240 feet). However, these distance errors are corrected in the 3-D presentation which uses horizontal distance coordinates from the land survey.

The calculated distance and elevation data were then checked for accuracy. Calculation errors were flagged for the geophysicist to correct during the data interpretation stage. Smaller errors were found by checking first arrival time printouts from the SeisREFA© program for accuracy. All calculation and data entry errors were noted and corrected for geophone and shotpoint locations with distance and elevation errors greater than 1.0 foot. Locations of the off-end shots were not used in the interpretation calculations and were not corrected.

A checklist was used to check and document errors, omissions, and inconsistencies in the files. All data pertinent to the seismic interpretation, including plots of all interim and final interpretations and corresponding numerical printouts, can be found in the project files.

3.5 Data Correlation

Spreads were correlated using well logs. Well log correlation was limited to only the 1993 logs because earlier logs were logged incorrectly and were questionable. The 1993 well locations within 10 feet of a seismic line were correlated to those lines. The top of the third P-wave layer is the velocity break which would correspond to the top of weathered bedrock.

Correlation was made between the lines and wells listed below:

LINE			WELL	
Line/phone	**Distance along line (ft)**	**Bedrock Elevation**	**Well**	**Bedrock Elevation**
C4-133	860	5926.9	40393	5926.1
I 1-122	115	5969.5	41993	5971.1
I 1-136	185	5972.0	42383	5972.1
J 1-120	105	5970.8	41993	5971.1

LINE			WELL	
Line/phone	**Distance along line (ft)**	**Bedrock Elevation**	**Well**	**Bedrock Elevation**
J 1-134	175	5970.3	42393	5972.1
N 1-108.5	47.5	5890.4	40593	5888.5
N 1-141.5	217.5	5912.0	44893	5909.6

All line/1993 well correlations were accurate to within 2.4 feet in depth.

4.0 RESULTS

4.1 Overview

The interpreted seismic cross-sections for each line are presented on Figures 4.1.1-1 through 4.1.14-1. The cross-sections show the layer thicknesses and velocities derived from the P-wave data with the inferred geologic correlations overlaid in color. The deepest refractor interpreted from the S-wave data is also shown on the cross-sections as a heavy dashed line.

Trends in the bedrock surface were evaluated in terms of relative bedrock highs and bedrock lows (potential channels) which were correlated between seismic lines. In general, the surface of the second to lowest layer in P-wave appears to correlate with the weathered bedrock surface. The surface of the lowest P-wave layer appears to correspond to the weathered bedrock water table. The surface of the lowest S-wave layer appears to correlate to less weathered bedrock.

Correlating the interpretation to drill hole information, the first layer (Layer 1) is believed to consist of loose, surficial soils or fill and the second layer (Layer 2) is believed to consist of moderately dense, unsaturated alluvium, colluvium, or compacted fill. The third layer has velocities typical of both unsaturated, dense alluvium and weathered, unsaturated claystone bedrock. Based on available drill hole information, the third layer (Layer 3) is believed to be weathered claystone bedrock. Layer 4 is believed to represent either saturated claystone bedrock which may be similar in nature to the unsaturated material of Layer 3, or less weathered bedrock. In the shear wave data, Layer 4 represents a transition to less weathered bedrock.

The velocities in the overburden within the PA are generally higher than the velocities in the overburden on the lines outside the PA. It is not known if fill material was brought into this area and compacted or whether the natural materials on the surface of the pediment are denser than the materials downslope. In addition, the shear wave data within the PA (Lines I, J, M, and parts of H and K) all exhibited a wavetrain with a velocity around 1,100 fps which attenuated abruptly beyond 150 feet. This phenomenon may be related to fill, layer geometry, or localized geology.

4.1.1 Line A

Line A is located approximately 200 feet south of North Walnut Creek and runs approximately west to east. The line is composed of five spreads and covers approximately 1,135 feet. There is a gap between Spreads 3 and 4 of approximately 78 feet where the line crosses the road and an overlap of approximately 120 feet on Spreads 4 and 5. The P-wave and S-wave data consistently yielded a 4-layer case with the following velocity and thickness ranges:

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	390 - 620	0 - 5	100 - 300	0 - 4
2	1100 - 1400	1 - 16	330 - 450	0 - 14

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Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
3	2300 - 3100	10 - 30	700 - 820	20 - 43
4	5900 - 6500	-	1900 - 2200	-

The P-wave data generally show about 5 feet of overburden overlying about 15 feet of unsaturated weathered bedrock as shown on Figure 4.1.1-1. The top of the unsaturated bedrock shows a number of shallow lows and highs which may define small, broad channels. The top of this layer generally dips gently to the east from near elevation 5900 feet on the west end to about 5870 on the east end. The top of the presumed saturated bedrock also dips gently to the east from an elevation of about 5885 on the west end to about 5870 on the east end of the line. There appear to be some minor depressions as shown on the seismic cross-section.

The S-wave data show the same general trend as the P-wave data with the refractor surface dipping gently to the east from an elevation of about 5875 on the west end to about 5845 on the east end. There appears to be a minor depression in the surface of this layer at the end of Spread 5 between distances 1050 and 1135 feet.

4.1.2 Line B

Line B is located just south of North Walnut Creek and runs approximately west to east. The line is composed of five spreads and covers approximately 1,315 feet. There is a gap between Spreads 2 and 3 of 152 feet because of wetlands adjacent to the creek. Both the P-wave and S-wave data consistently yielded a 4-layer case with the following velocity and thickness ranges.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	370 - 720	0 - 5	180 - 400	0 - 5
2	1100 - 1400	1 - 16	510 - 700	5 - 14
3	2300 - 3200	10 - 30	880 - 1100	23 - 40
4	6200 - 6500	-	1400 - 2200	-

The P-wave data generally show 10 to 15 feet of overburden on Spreads 1, 2, and 5 overlying about 15 feet of unsaturated weathered bedrock as shown on Figure 4.1.2-1. The overburden thins

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to about 5 feet on Spread 3 and varies from 5 to 15 feet on Spread 4. The unsaturated bedrock thickens to nearly 30 feet at the beginning of the line. The top of the unsaturated bedrock dips to the east from an elevation of 5900 feet on the west end to about 5850 on the east end. The top of the presumed saturated bedrock also dips gently to the east from an elevation of about 5875 on the west end to about 5830 on the east end of Line B. There appears to be a minor depression in the saturated bedrock surface in the central portion of Spread 3 between distances of 650 and 825 feet.

The S-wave data show the same general trend as the P-wave data with the refractor surface dipping gently to the east from an elevation of about 5865 on the west end to about 5825 on the east end. There appears to be a minor depression in the surface of this layer across Spread 3 between distances of 625 and 850 feet.

4.1.3 Line C

Line C is located north of the perimeter fence around the PA and trends from northwest to southeast. The line is composed of 7 spreads and covers approximately 1,630 feet. The interpretation of the P-wave data consistently yielded a 4-layer case, while the S-wave data yielded a 3-layer case. The velocity and thickness ranges are summarized below:

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	400 - 620	0 - 4	230 - 400	0 - 7
2	1100 - 1600	2 - 15	640 - 780	17 - 43
3	2200 - 2800	8 - 23		
4	5800 - 6400	-	1300 - 1900	-

The P-wave data generally show about 10 feet of overburden overlying 10 to 20 feet of unsaturated weathered bedrock as shown on Figure 4.1.3-1. The top of the unsaturated bedrock shows a number of lows and highs which may define shallow channels. The top of this layer generally dips gently to the northwest from near elevation 5945 feet on the southeast end to about 5890 on the northwest end. The top of the presumed saturated bedrock also dips gently to the northwest from an elevation of about 5935 on the southeast end to about 5880 on the northwest end of the line. There appears to be a number of depressions in the saturated bedrock surface as shown on the seismic cross-section.

The S-wave data show the same general trend as the P-wave data with the refractor surface dipping gently to the northwest from an elevation of about 5915 on the southeast end to about 5875 on the northwest end. There appear to be minor depressions in the surface of this layer across Spread 1 (between distances 50 and 240 feet), Spread 2 (between distances 260 and 430 feet), Spread 3 (between distances 480 and 670 feet), Spread 4 (between distances 830 and 920 feet), and Spread

6/7 (between distances 1310 and 1410 feet). The high points on Spreads 1, 2 and 3 all seem to occur at the intersection of the spreads, suggesting that the apparent depressed areas of the bedrock surface may be related to velocity problems. The depressions observed on Spreads 4 and 6/7 are believed to be more reliable.

4.1.4 Line D

Line D consists of four spreads running from northwest to southeast starting near North Walnut Creek. Spread 1 starts just south of Line B, Spread 2 crosses Line A and Spread 4 crosses Line N as shown on the location map. Each spread is approximately 235 feet long. Spreads 3 and 4 overlap by about 100 feet, resulting in an overall line length of 820 feet. The interpretation of the P-wave and S-wave data both yielded a four layer case. The P- and S-wave velocity and thickness ranges are summarized in the table below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	370 - 530	1 - 4	160 - 260	1 - 3
2	1200 - 1500	10 - 21	460 - 600	3 - 16
3	2800 - 3100	13 - 28	720 - 950	23 - 56
4	6000 - 6200	-	1800 - 2100	-

The P-wave data generally show 15 to 20 feet of overburden overlying 15 to 20 feet of unsaturated weathered bedrock as shown on Figure 4.1.4-1. The top of the weathered bedrock tends to follow the ground surface with the exception of two small depressions, one between 280 and 350 feet on Spread 2 and one between 460 and 600 feet on Spread 3. The top of the saturated bedrock surface tends to follow the ground surface and slopes upward from elevation 5865 on the northwest end to an elevation of about 5885 on the southeast end. A depressed area is observed in the saturated bedrock surface from about 400 to 650 feet along the line.

The S-wave data interpretation yielded a four layer case as outlined in the summary table above. The S-wave data showed a fairly uniform refractor surface dipping gently to the northwest from elevation 5865 to about 5845. The refractor surface becomes irregular with a slight uphill trend on Spreads 3 and 4. The surface defines a depression between 450 and 570 feet on Spread 3 and a high between 570 and 700 feet on Spreads 3 and 4.

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4.1.5 Line E

Line E is oriented roughly northwest to southeast and crosses Lines A and G. The line is composed of 6 spreads and covers approximately 1,390 feet. The line starts near North Walnut Creek and traverses the hillside northeast of the solar ponds, crossing another small ephemeral drainage near the intersection of Spreads 5 and 6. The interpretation of the P-wave yielded a 4-layer case. A four-layer interpretation is also a good fit for the S-wave data. The velocity and thickness ranges are summarized in the table below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	370 - 520	1 - 5	190 - 280	0 - 7
2	920 - 1500	0 - 16	460 - 560	0 - 23
3	2100 - 3200	5 - 37	880 - 1000	13 - 34
4	6100 - 6700	-	1400 - 1600	-

The P-wave data generally showed 10 to 20 feet of overburden overlying 20 to 25 feet of unsaturated weathered bedrock as shown on Figure 4.1.5-1. The overburden is thinnest near North Walnut Creek (Spread 1) and on the highest sections of the line (Spreads 5 and 6). In general, the weathered bedrock surface follows the ground surface and there are no significant depressions in the weathered bedrock surface which might represent paleochannels. There are some depressions in the saturated bedrock surface which might indicate changes in permeability or porosity. The top of this surface is gently undulating and dips to the northwest from an elevation of about 5885 to about 5865.

The S-wave data showed the same general trend as the P-wave data with the interpreted S-wave refractor surface occurring both above and below the saturated bedrock surfaces on the P-wave sections. On the S-wave cross-section, the deepest portion of the bedrock is on Spreads 1 and 2 at an average elevation of about 5850. The elevation of the refractor rises to the southeast from Spread 3 from an elevation of about 5855 feet to an elevation of about 5885 on Spread 6.

4.1.6 Line F

Line F is oriented roughly north to south and crosses North Walnut Creek at a small earthen dam (Pond A1) located in the northeast corner of the study area. The line is composed of two spreads and covers approximately 470 feet. The interpretation of the P-wave data yielded a 4-layer case, while the interpretation of the S-wave data yielded a 3-layer case. The velocity and thickness ranges are summarized in the table below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	480 - 550	0 - 7	220 - 290	0 - 9
2	810 - 1100	1 - 10	620 - 850	9 - 21
3	2100 - 2600	4 - 13		
4	6500	-	1400 - 1800	-

The P-wave data generally show 5 to 10 feet of overburden overlying about 10 feet of unsaturated weathered bedrock as shown on Figure 4.1.6.-1. The weathered bedrock surface generally follows the ground surface, although the overburden appears to be thinner on the north side of the creek. There is no apparent difference between the slopewash/colluvium on the valley sides and the alluvium/dam embankment materials across the creek bottom. The small depression in the bedrock surface around stations 250 and 350 may represent the old creek bottom. The S-wave data showed the same general trend as the P-wave data with the interpreted refractor surface closely following the saturated bedrock surface on the P-wave sections. A four layer case could be fit to the S-wave data because of the curved nature of the time-distance graphs. Adding another intermediate layer would force the refractor surface deeper where it would be more consistent with other interpreted lines. However, a four layer model does not fit the field data as well as a three layer model. On the S-wave cross-section, the deepest portion of the bedrock in the valley is on the north side of the valley.

4.1.7 Line G

Line G trends from north to south starting on the north side of North Walnut Creek and extends to the south across Lines L, E and C. The line is composed of 10 spreads and covers approximately 2,415 feet. There are two gaps in the line, one between Spreads 1 and 2 where the line crosses North Walnut Creek, and one between Spreads 5 and 6 where the line crosses the access road. There is also an overlap between Spreads 4 and 5. The interpretation of both the P and S-wave data yielded 3 layer cases on some spreads and 4 layer cases on other spreads. The velocity and thickness ranges of all spreads are summarized below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	420 - 720	0 - 7	200 - 300	0 - 7
2	1000 - 1500	0 - 12	430 - 600	0 - 20
3	2000 - 3000	6 - 35	700 - 1100	1 - 52
4	6000 - 6500	-	1300 - 2900	-

The P-wave data generally showed about 15 feet of overburden overlying 10 to 30 feet of unsaturated weathered bedrock as shown on Figure 4.1.7-1. The overburden is the thinnest in the bottom of North Walnut Creek and on the top of the ridge. The top of the unsaturated bedrock generally follows the ground surface topography and seems to be somewhat deeper on the north-facing slopes. The top of the presumed saturated bedrock tends to follow the ground surface, but is more variable and shows a number of shallow lows and highs which may define shallow channels. Possible channel locations occur between distances 660 and 810, 840 and 940, 1400 and 1500, and 1960 and 2120 feet.

The S-wave data show the same general trend as the P-wave data with the refractor surface generally following the ground surface. The S-wave data were fairly reliable on Spreads 1 through 4, but are questionable on Spreads 5 through 10. There appear to be a number of small depressions in the surface of this layer across Spreads 3, 4 and 5 and a large, major depression on Spreads 8 and 9 between distances 1810 and 2280 feet. The pronounced refractor high on Spreads 6 and 7 may be genuine, but there is a high probability that this feature is related to the same phenomenon observed within the PA on Lines I, J, H, K and M. These lines all exhibit a pronounced wavetrain traveling at a velocity of about 1100 feet per second which is the first and only arrival, and which abruptly disappears after a distance of about 150 feet. This arrival, which has been interpreted on Spreads 6 and 7 as a very shallow shear wave refractor, may actually be some other type of seismic energy such as a surface wave.

4.1.8 Line H

Line H trends from north to south starting from east of SEP 207B series ponds and runs south along the edge of the industrial area. The line is composed of 3 spreads and covers approximately 755 feet. There is an overlap between Spreads 1 and 2 and a gap of about 70 feet across the paved road between Spreads 2 and 3. Spread 3 was composited from the original Spreads 3 and 4 by extending the geophone separation to 10 feet for about half the line. The interpretation of the P-wave data yielded a combination of a 3 and 4 layer model. The interpretation of the S-wave data yielded a three layer model. The velocity and thickness ranges are summarized below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	720 - 930	0 - 5	250 - 350	0 - 7
2	2000 - 2100	3 - 13	-	-
3	3600 - 4000	0 - 22	720 - 930	2 - 50
4	6000 - 6400	-	1400 - 1600	-

The P-wave data generally show about 5 to 20 feet of overburden overlying 0 to 20 feet of unsaturated weathered bedrock as shown on Figure 4.1.8-1. The overburden is the thinnest across the flat area at the top of the hill and thickest on the downhill slope. The top of the unsaturated

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bedrock generally follows the ground surface topography across the flat area and appears to be missing on the slope. The top of the presumed saturated bedrock tends to follow the ground surface, but is more variable and shows a broad low from distance 0 to 180 feet beneath the flat area and a narrow depression between 470 and 510 feet near the break in slope.

The S-wave data show the same general trend as the P-wave data with the refractor surface following the ground surface along the flat area and dropping off to a greater depth down the slope. There is one broad depression in the surface of Spread 3 between distances 470 and 670 feet. The interpreted model for the S-wave may be genuine, but there is a high probability that the interpreted structure is false and related to the same phenomenon observed within the PA on Lines I, J, K and M. These lines all exhibit a pronounced wavetrain traveling at a velocity of about 1100 feet per second which is the first and only arrival, and which abruptly disappears after a distance of about 150 feet.

4.1.9. Line I

Line I consists of two spreads oriented at right angles to one another. Spread 1 runs roughly north to south and ties with Spread 2 which runs roughly east to west. The line is situated west and south of SEP 207C as shown on the location map. Each spread is approximately 235 feet long. The interpretation of the P-wave data yielded a 4-layer case on both spreads. The S-wave data was not usable on either spread. The P-wave velocity and thickness ranges are summarized in the table below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)
1	800 - 1100	0 - 3
2	2200	3 - 9
3	3600 - 4000	8 - 11
4	5300 - 5900	-

The P-wave data generally showed about 10 feet of overburden overlying about 10 feet of unsaturated weathered bedrock as shown on Figure 4.1.9-1. The overburden is thinner on the south side of SEP 207C along Spread 2. The weathered bedrock surface and water table elevation appear to be relatively uniform and appear to mimic the ground surface along both spreads. The Layer 2 velocity (2200 fps) in this area is much higher than along lines elsewhere. This may be related to compacted fill.

The shear wave data along both spreads of Line I showed a strong event with a velocity of about 1,100 fps as a direct arrival which attenuated abruptly about midway through the spread. It is unclear if this event is a shear wave or some other type of wave, possibly a surface wave. Even if it is a shear wave, it is not a refracted wave and therefore cannot be interpreted in terms of a layered earth.

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4.1.10 Line J

Line J consists of two spreads oriented at right angles to one another. Spread 1 runs roughly north to south and ties with Spread 2 which runs roughly east to west. The line is situated west and south of Line I as shown on the location map. Each spread is approximately 235 feet long. The interpretation of the P-wave data yielded a 4-layer case on both spreads. The S-wave data was not usable on either spread. The P-wave velocity and thickness ranges are summarized in the table below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)
1	630 - 800	1 - 6
2	2200 - 2300	2 - 9
3	3600 - 3700	5 - 15
4	5800	-

The P-wave data generally show about 10 feet of overburden overlying 10 to 15 feet of unsaturated weathered bedrock as shown on Figure 4.1.10-1. The overburden is thinnest on the south side of SEP 207C along Spread 2. The weathered bedrock surface and water table elevation appear to be relatively uniform and appear to mimic the ground surface along both spreads. There is a small wedge of thicker surficial soil and a thickening of the weathered bedrock on the north end of Spread 1 where the line starts down the slope towards North Walnut Creek.

The shear wave data along both spreads of Line J showed a strong event with a velocity of about 1,100 fps as a direct arrival which attenuates abruptly about midway through the spread. It is unclear if this event is a shear wave or some other type of wave, possibly a surface wave. Even if it is a shear wave, it is not a refracted wave and therefore cannot be interpreted in terms of a layered earth.

4.1.11 Line K

Line K trends from north to south starting from east of SEP 207B series ponds and east and downslope of Line H. The line is composed of 3 spreads and covers approximately 830 feet. There is a gap of about 120 feet between Spreads 2 and 3 where the line crosses a road intersection . The interpretation of the P-wave data yielded a four layer model. The interpretation of the S-wave data

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yielded a three layer model. The velocity and thickness ranges are summarized below:

Layer	P-wave Velocity (Fps)	Thickness Range (Ft)	S-wave Velocity (Fps)	Thickness Range (FT)
1	500 - 640	0 - 4	220 - 250	0 - 3
2	1100 - 1900	2 - 8	580 - 610	20 - 40
3	2600 - 3400	7 - 33		
4	6000 - 6300	-	1300 - 1400	-

The P-wave data generally show about 5 feet of overburden overlying an average of 15 feet of unsaturated weathered bedrock as shown on Figure 4.1.11-1. The top of the unsaturated bedrock generally follows the ground surface topography, but has some minor depressions in the surface. The top of the presumed saturated bedrock tends to follow the ground surface, but is more variable and shows one broad low from distance 0 to 230 feet beneath the flat area and three minor depressions between 440 and 520, 620 and 700, and between 740 and 820 feet across the slope.

The S-wave data show the same trend as the P-wave data with the refractor surface generally dropping off to a greater depth down the slope. There is one obvious depression in the surface of the refractor across Spread 3 between distances 620 and 700 feet. The S-wave data for Spread 1 were not interpretable because of the phenomenon discussed under Lines G, H, I, J and M. The interpreted model for the S-wave data on Line H may be accurate, but there is a high probability that the interpreted structure is false and related to the same phenomenon observed within the PA on Lines I, J, H and M. These lines all exhibit a pronounced wavetrain traveling at a velocity of about 1100 feet per second which is the first and only arrival, and which abruptly disappears after a distance of about 150 feet.

4.1.12 Line L

Line L consists of five spreads running from northwest to southeast starting at North Walnut Creek. Spread 1 crosses Line B and Spread 3 crosses Line G as shown on the location map. Each spread is approximately 235 feet long. There is a gap in the line between Spreads 4 and 5 where the line crosses an access road. Line L is approximately 1,210 feet long. The interpretation of both the P and S-wave data yielded a 4-layer model. The P- and S-wave velocity and thickness ranges are summarized in the table below.

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Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	570 - 730	0 - 4	220 - 340	0 - 10
2	1200 - 1300	2 - 17	600 - 830	5 - 31
3	2600 - 2900	11 - 35	1000 - 1200	15 - 50
4	5700 - 6800	-	1800 - 2200	-

The P-wave data generally indicate about 15 feet of overburden overlying about 20 feet of unsaturated weathered bedrock as shown on Figure 4.1.12-1. The overburden is thinnest near North Walnut Creek. The weathered bedrock surface appears to follow the ground surface while the saturated bedrock surface appears to be relatively flat with a slight dip from elevation 5855 on the southeast end to about 5845 on the northwest end. A number of minor depressions were observed in the saturated bedrock surface from about 150 to 350, from 700 to 800, from 820 to 920, and from 1,040 to 1,120 feet along the line.

The S-wave data interpretation yielded a four layer case as outlined in the summary table above. The S-wave data show a fairly irregular refractor surface which follows the saturated bedrock layer from the P-wave data on Spreads 4 and 5, but which tends to be significantly deeper on the other spreads. On the S-wave cross-section, the deeper portions of the bedrock occur between 0 and 130 feet, 820 and 920 feet and between 1000 and 1180 feet.

4.1.13 Line M

Line M trends from west to east starting just south of the southwest corner of SEP 207A and extending to the east across Line H. The line is composed of 4 spreads and covers approximately 1,065 feet. There is a gap in the line between Spreads 1 and 2 of about 130 feet where the line crosses some concrete barriers and process lines. The line is situated in an area containing a wide variety of noise sources which could not be eliminated such as pumps and process lines. This resulted in data of poorer quality than most. The interpretation of the P-wave data yielded a composite of a 3 and 4 layer model. The S-wave data could not be interpreted. The P-wave velocity and thickness ranges are summarized below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)
1	750	0 - 3
2	1100 - 1400	2 - 7
3	3100 - 3300	6 - 18
4	5700 - 5900	-

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The P-wave data generally show about 5 feet of overburden overlying 10 to 20 feet of unsaturated weathered bedrock as shown on Figure 4.1.13-1. The top of the unsaturated bedrock generally follows the ground surface topography and is relatively featureless. The top of the saturated bedrock surface appears to follow the flat surface topography across Spreads 1, 2 and part of 3, at which point it continues to follow the surface topography at a greater depth. The top of the presumed saturated bedrock is more variable and shows two shallow depressions between distances 750 and 920 feet, and between 960 and 1040 feet.

The S-wave data could not be interpreted because of the same phenomenon observed on Lines H, I, J, and K. The pronounced wavetrain traveling at a velocity of about 1100 feet per second which is the first and only arrival, and which abruptly disappears after a distance of about 150 feet occurred on all four spreads of Line M. No interpreted S-wave model could be generated from the S-wave arrival data for Line M.

4.1.14 Line N

Line N consists of one spread oriented roughly from northeast to southwest, crossing Lines E and D. The line is approximately 235 feet long. The interpretation of both the P- and S-wave data yielded a 4-layer case. The velocity and thickness ranges for Line N are summarized in the table below.

Layer	P-wave Velocity (FPS)	Thickness Range (FT)	S-wave Velocity (FPS)	Thickness Range (FT)
1	750	0 - 4	210	0 - 5
2	1200	9 - 17	580	4 - 8
3	3200	11 - 30	900	14 - 43
4	6100	-	1800	-

The P-wave data generally show about 15 feet of overburden overlying 11 to 30 feet of unsaturated weathered bedrock as shown on Figure 4.1.14-1. The weathered bedrock surface appeared to be relatively uniform and followed the ground surface. The presumed saturated bedrock surface is more irregular, but still tends to follow the ground surface. Two minor depressions occur in the presumed saturated bedrock surface between 40 and 130 feet, and between 160 and 240 feet.

The S-wave data generally show a more complex configuration than the P-wave data. There was a variable layer 10 to 30 feet thick of surficial soil and colluvium overlying 15 to 40 feet of weathered bedrock. The shear wave refractor is located at an average depth of about 50 feet. The deepest refractor on the shear wave model is relatively level at an elevation of about 5865 with a broad depression from 60 to 180 feet along the line.

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5.0 CONCLUSIONS

The evaluation of the Phase II OU4 seismic refraction data appear to show that there are several erosional features and potentially one structural feature etched into the bedrock surface. These features are illustrated on Figures 5.0-1, 5.0-2, and 5.0-3. Figure 5.0-1 is a 3-D composite of all the P-wave seismic refraction depth data for the top of Layer 3 (the unsaturated weathered bedrock UHSU2). Figure 5.0-2 is a 3-D composite of all the P-wave seismic refraction depth data for the top of Layer 4 (the saturated weathered bedrock UHSU3). Figure 5.0-3 is a 3-D composite of all the S-wave seismic refraction data for Layer 4. In terms of shear wave layering, it is believed that Layer 4 represents a transition to less weathered bedrock. The erosional features are manifested as short, broad channels and in some areas appear as "pools" or depressions as opposed to a linear channel feature. The appearance of isolated depressions rather than linear features in the southern and southeastern portions of the study area is due primarily to the lower data density (fewer seismic lines) available for contouring.

Based on the thicker overburden on the south side of Walnut Creek generated from the seismic data, and a comparison to surface topography, we feel that the North Walnut creek drainage is currently north of where it was located in the past. If the ancient North Walnut Creek channel was previously located south of its present location, then it probably incised considerably into the hillside on the south side of North Walnut Creek. The features that are observed on the 3-D maps may then be short, steep channels and/or rotational slope failures which would leave a circular or semi-circular depression feature in the bedrock. These features may have then been exploited by flowing water to create some channelization upstream and downstream.

Most tributary channels developed on flat-lying sediments tend to form at angles less than 45 degrees to the main channel. Since the depressions and linear features tributary to North Walnut Creek are at angles greater than 45 degrees we believe they are controlled by something other than simple drainage patterns. The easternmost of these possible paleochannels, which is crossed by Lines G, L, and E, shows considerable surface expression at the site and exhibits intermittent surface flow depending on seasonal precipitation events. Possible paleochannels west of the above-described channel show little or no surface expression because of reworking of the ground surface adjacent to OU4 during the ITS installation. A possible linear structural feature was also seen as a broad channel-like feature in the seismic data. It appears to be structurally controlled because it enters North Walnut Creek at an angle almost normal to the drainage (approximately 80 to 90 degrees). This paleochannel approximately lines up with the suspected bedrock fault which underlies the SEP 207B Pond area.

The combination of this seismic data with future studies and extensive well correlation data will serve to enhance the interpretation of the bedrock surface beneath and adjacent to OU4.

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6.0 BIBLIOGRAPHY

American Geological Institute, 1976, "Dictionary of Geological Terms," Anchor Press, NY.

Bacelar, R.B., 1975, "Exploration for Buried Channels by Shallow Seismic Refraction and Resistivity and Determination of Elastic Properties at Rocky Flats, Jefferson County, Colorado." Colorado Schools of Mines Masters Thesis.

Dames and Moore, 1981, "Geologic and Seismologic Investigations for Rocky Flats Plant. " Contract DE-AC04-80A110890.

Dobrin, Milton B., 1952, Introduction to Geophysical Prospecting, McGraw-Hill, Inc.

EG&G, 1991i, "Draft Final Geologic Characterization Report for Rocky Flats Plant, Golden, Colorado." EG&G Rocky Flats, Inc., July.

EG&G, 1991a, "Phase II Geologic Characterization, Task 6 Surface Geologic Mapping Draft Report, Golden, Colorado." EG&G Rocky Flats, Inc.

EG&G, 1990e, "Draft Geologic Characterization Report, Golden, Colorado." EG&G Rocky Flats, Inc., January 3.

Hagedoorn, J.G., 1959, "The Plus-Minus Method of Interpreting Seismic Refraction Sections," *Geophysical Prospecting*, Vol. 7, No. 2, pp. 158-182.

Hagiwara, T., 1938, "An Analytical Method of the Travel-Time Curve for the Structure when the Inclination of Bed-Rock (sic) is Uneven" (in Japanese), Disin, Vol. 10, No. 11, pp 463-468.

Hawkins, L.V., 1961, "The Reciprocal Method of Routine Shallow Seismic Refraction Investigations," *Geophysics*, Vol. 26, No. 6, pp. 806-819.

Hydro-Search, Inc., 1985, "Hydrogeologic Characterization of the Rocky Flats Plant, Golden, Colorado." Project No. 1520, 55 pp.

Machette, M.N., Birkland, G. Markus, and M.J. Guccione, 1976, "Soil Development in Quaternary Deposits in the Golden-Boulder Portion of the Colorado Piedmont." *Studies in Colorado Field Geology*. Edited by Rudy C. Epis and Robert J. Weimer, No. 8, November.

Malde, H.E. 1955, "Surficial Geology of Louisville Quadrangle, Colorado." *U.S. Geological Survey Bulletin* 996-E, pp. 217-259.

Masuda, H. and A. Kitano, 1957, "On the Refraction Method for the Shallow Depth" (in Japanese), Butsuri-Tankō (Geophysical Exploration), Vol. 10, No. 2, pp. 56-66.

Olhoeft, Gary R., 1992, "Geophysics Advisor Expert System," U.S. Geological Survey Open File Report 92-526.

Oyo Geospace, 1991, "SeisREFA™ Refraction Analysis Program, Version 1.3," Houston, TX.

Robson, S.G., J.C. Romero, and S. Zawistowski, 1981a," Geologic Structure, Hydrology, and Water Quality of the Arapahoe Aquifer in the Denver Basin, Colorado." *U.S. Geological Survey Atlas*, HA-647.

Scott, G.R., 1965, "Nonglacial Quaternary Geology of the Southern and Middle Rocky Mountains." *The Quaternary of the United States*. Princeton University Press, pp. 243-254.

Scott, G.R., 1960, "Quaternary Sequence East of the Front Range Near Denver, Colorado" in *Guide to Geology of Colorado*. Weimer, R.J., and J.D. Haun, eds. Geological Society of America, Rocky Mountain Association of Geologists, Colorado Scientific Society, pp. 206-221.

Sheriff, R.E., 1973, "Encyclopedia Dictionary of Exploration Geophysics," Society of Exploration Geophysicists, Oklahoma.

Spencer, F.D., 1961, "Bedrock Geology of the Louisville Quadrangle, Colorado." *U.S. Geological Survey Geologic Quadrangle Map GQ-151.*

Van Horn, R., 1976, "Geology of the Golden Quadrangle, Colorado." *U.S. Geological Survey Professional Paper 872*, 116 pp.

Weimer, R.J., 1976, "Cretaceous Stratigraphy, Tectonics, and Energy Resources, Western Denver Basin." *Studies in Colorado Field Geology*. Edited by Rudy C. Epris and Robert Weimer. No. 8, November.

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Appendix A

Spread Data Forms

Line A (01-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	2/20/95 (a.m.)	X	2-101 w/1-147	none	60'	147.5 132.5 116.5 101.5	P S	none	Warm, calm (slight breeze). Beside creek. 38 & 39 dead.
Spread 2 (.02)	2/20/95 (a.m.)	X	2-147 w/3-101	none	60'	147.5 132.5 116.5 101.5	P S	none	Warm, calm. Beside creek and roadway. 38 & 39 dead.
Spread 3 (.03)	2/22/95 (a.m.)	X	none w/ 4 (road)	3-115 w/C-1-107	80'	147.5 132.5 116.5 101.5	P S	3-108 w/SEP 28-89 (-app. 10') (AKA P209989) 3-106 w/SEP 29-89 BR (AKA P210089)	Warm, calm. 48 dead. South side of road. Borrow ditch wet.
Spread 4 (.04)	2/21/95 (a.m.)	X	4-124 w/5-100	D-2-117 w/4-126	80'	147.5 132.5 116.5 101.5	P S	none	Warm, calm. 38 and 39 dead. North side of road.
Spread 5 (.05)	2/21/95 (p.m.)	X	5-125 w/4-149	5-135 w/E 2-106. 5-102 w/ D2-117.	60'	147.5 132.5 116.5 101.5	P S	none	Warm, calm. 48 dead.

Line B(02-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	2/14/95 (a.m.)	X	2-102 w/ 1-148	none	36' for P & S and 56' on east for S	101.5 116.5 132.5 147.5	no wind	none	Calm, sunny, snow surface app. 9". 38 & 39 dead. P-wave good. S-wave good. West end at parking lot for offset.
Spread 2 (.02)	2/10/95 (a.m.)	X	None between 2 and 3	near tiew/ B2-105 (app D 1-101) to south	86'	147.5 132.5 116.5 101.5	no wind	none	Cool, calm. P and S good. 38 & 39 dead.
Spread 3 (.03)	2/10/95 (a.m.)	X	Skip be-tween 2 and 3 app. 60 yds.	none	86' east 67' west	147.5 132.5 116.5 101.5	no wind	Well B 210389 @ app. 30' from 3-100 to South. B208689 @ 3-125. Pole @ 3-139.5	Cool, calm, w/light snow. Creek/wetlands area between 2 and 3. Culvert w/cobbles through #105.
Spread 4 (.04)	2/14/95 (p.m.)	X	3-148 w/4-102	4-131 w/ L 1-125	60'	147.5 132.5 116.5 101.5	P S	none	Slight wind, sunny and cool.
Spread 5 (.05)	2/14/95 (p.m.)	X	4-148 w/5-102	none	60'	147.5 132.5 116.5 101.5	P S	none	Calm, slight wind, sunny and cool.

Line C(03-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	2/22/95 (a.m.)	X	1-147 w/ 2-101	A 3-115 w/1-107	60'	147.5 132.5 116.5 101.5	P S	App 10' to P209989 w/1-100. 1-121 w/0671 app. 10' South.	Warm, soil moist, no wind, no snow. 48 good on S. 48 dead on P.
Spread 2 (.02)	2/22/95 (p.m.)	X	2-147 w/ 3-101	none	60'	147.5 132.5 116.5 101.5	P S	none	Cool, no wind.
Spread 3 (.03)	2/23/95 (a.m.)	X	3-149 w/ 4-103	none	60'	147.5 132.5 116.5 101.5	P S	none	Warm, no wind. Air monitor @ 3-112.
Spread 4 (.04)	2/23/95 (a.m./p.m.)	X	4-149 w/5-103	none	60'	147.5 132.5 116.5 101.5	P S	40393 w/4-133 (~30' to north)	Warm, no wind.
Spread 5 (.05)	2/23/95 (p.m.)	X	5-149 w/6-103	none	60'	147.5 132.5 116.5 101.5	P S	none	Warm, no wind.
Spread 6 (.06)	2/24/95 (a.m.)	X	6-103 w/5-149	none	60'	147.5 132.5 116.5 101.5	P S	none	Warm, slight wind. Culvert @ 6-132 thru 6-136.
Spread 7 (.07)	2/24/95 (a.m./p.m.)	X	6-149 w/7-101	7-131 w/G 6-112	60'	147.5 132.5 116.5 101.5	P S	none	Warm, slight wind. Power line at 7-132.

Line D(04-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	2/6/95	X	1-148 w/2-102	1-101 near tie w/B 2-105 app. 10' to north	80	100 101.5 116.5 132.5 147.5	yes	none	Cool and windy, sunny. Off-sets windy. Shear good. P-wave good. Elec pole @ 1-123.5.
Spread 2 (.02)	2/3/95	X	2-148 w/3-102	@2-117 w/Line A @ 5-102 & 4-126	80	101.5 116.5 132.5 147.5	yes	none	Warm, sunny. Good records. Overhead power line at 2-145.
Spread 3 (.03)	2/2/95	X	3-125 w/4-101	none	80	101.5 116.5 132.5 147.5	yes	none	Windy, warm, sunny. Windy on far offsets. Noisy. Shear good. P-wave good.
Spread 4 (.04)	2/2/95	X	3-149 w/4-125	4-146 w/ N 1-135	50	100 124.5 112.5 136.5 149	yes	5 piez off line by app. 36', 4-133 w/45393	Windy, cool.

Line D (4) redo	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	2/27/95 (p.m.)	X	1-147 w/2-101	near tie 1-101 w/B-2-105 app. 10' north	60'	147.5 132.5 116.5 101.5	P S	none	Cool, slight wind to windy, ground dry, sprinkles. Power pole at 1-124.
Spread 2 (.02)	2/27/95 (a.m./p.m.)	X	3-101w/ 2-147	2-117 w/ A-4-126 and A 5-102	60'	147.5 132.5 116.5 101.5	P S	none	Cool, calm, ground dry. Power line @ 2-145.
Spread 4 (.04)	2/27/95	X	3-149 w/4-125	4-146 w/ N-1-135	60'	147.5 132.5 116.5 101.5	P S	44893 w/4-147 45293 w/4-141 (app 36 feet)	Cool, slight wind, ground dry. Good data.

Line E(05-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	2/15/95 (a.m.)	X	2-101 w/1-147	none	60'	147.5 132.5 116.5 101.5	P S	none	Snow surface, cool and calm. 38 and 39 dead.
Spread 2 (.02)	2/15/95 (p.m.)	X	2-147 w/3-101	2/106 w/A 5-135	60'	147.5 132.5 116.5 101.5	P S	none	Snow surface, cool, slight wind. 38-39 dead. 48 sometimes dead.
Spread 3 (.03)	2/16/95 (p.m.)	X	3-147 w/4-101	3-129 w/ N 1-117	60'	147.5 132.5 116.5 101.5	P S	3-135 w/well 40593 (~39 ft north)	Snow surface, cool, slight wind. 38 & 39 dead.
Spread 4 (.04)	2/16/95 (p.m.)	X	4-147 w/5-101	none	60'	147.5 132.5 116.5 101.5	P S	none	Snow surface, cool, slight to gusty winds. 38-39 dead.
Spread 5 (.05)	2/17/95 (a.m.)	X	5-147 w/6 101	none	60'	147.5 132.5 116.5 101.5	P S	none	Windy w/snow surface, warm. 38-39 dead.
Spread 6 (.06)	2/17/95 (p.m.) 2/20/95 (a.m.)	X	5-147 w/ 6-101	6-107 w/G'5-109 and G 4-137	60'	147.5 132.5 116.5 101.5	P S	none	Windy w/snow surface, warm. Doing more shots because of wind. Ends redone 2/20/95 good P&S.

Line F(06-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/10/95	X	1-147w/ 2-101	none	60'	147.5 132.5 101.5 116.5	P S	none	Sunny, windy. 1-131 on tip of dam.
Spread 2 (.02)	3/13/95	X	1-147w/ 2-101	none	60'	147.5 132.5 101.5 116.5	P S	none	Sunny, slight breeze to breezy. Road 2-121 thru 2-126.

Line F(06-) redo	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 2 (.02)	3/17/95	X	1-147 w/ 2-101	none	60'	147.5 132.5 101.5 116.5	P S	none	Sunny, ground moist, slight breeze. (S-wave redo).

Line G (07-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/10/95	X	none	none	60' in No 20' on So.	147.5 132.5 116.5 101.5	P S	none	Sunny, ground dry, slight gusts to gusty. Slight wind on S-wave. Break in line from 1-2 due to wetlands.
Spread 2 (.02)	3/9/95 (a.m./p.m.)	X	2-147 w/3-101	none	60' on No. 20' on So.	147.5 132.5 116.5 101.5	P S	2-103 w/1386	Sunny, warm, snow melt, ground moist p.m., windy. Afternoon S-wave windy.
Spread 3 (.03)	3/9/95 (a.m.)	X	3-101 w/2-147	3-130 w/ L4-114	60'	147.5 132.5 116.5 101.5	P S	none	Sunny, warm, ground moist, snow melt.
Spread 4 (.04)	3/8/95(p.m.)	X	4-101w/ 3-147	4-137 and 5-109 w/E 6-107	60'	147.5 132.5 117 101.5	P S	none	Sunny, cool, ground moist, windy. Moved 116.5 because of bottom of creek with no elevation at shot location.
Spread 5 (.05)	3/8/95 (a.m.)	X	4-147 w/5-119 No (6) overlap	5-109 and 4-137 w/E 6-107	60' on So. 80' on No.	147.5 132.5 116.5 101.5	P S	none	Cool, slight wind. Break in line from 5-6 due to road. Air monitor at 5-140 notch in (60 Hz). S-wave 48 dead.

Line G (07-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 6 (.06)	3/7/95 (p.m.)	X	6-147 w/7-101	C7-131 w/6-112	60'	148.5 132.5 116.5 101.5	P S	none	Cool, slight wind. Asphalt between 143-148. Fence @ 6-137. Top of hill @ 6-125.
Spread 7 (.07)	3/7/95 (a.m.)	X	7-147 w/8-101	none	50'	147.5 132.5 116.5 101.5	P S	none	Cold, calm. 1-10 geophones on asphalt road.
Spread 8 (.08)	3/6/95	X	8-149 w/9-103	none	60'	147.5 132.5 116.5 101.5	P S	02691 w/8-130	Snowing, blowing. Ground moist/wet.
Spread 9 (.09)	3/6/95	X	9-149 w/10-103	none	60'	147.5 132.5 116.5 101.5	P S	none	Snow, slight winds. Culvert @ 9-135. Piping over head @ 9-113. Pump 60' to east of 9-135.
Spread 10 (.10)	3/13/95	X	9-149 w/10-103	none	60'	147.5 132.5 116.5 101.5	P S	well 02291 app. 100' E of 10-139	Warm, slight breeze. Overhead power line 10-120.

Line G (07-) redo	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 2 (.02)	3/17/95 (p.m.)	X	2-147 w/3-101	none	60' on So. 20' on No.	147.5 132.5 116.5 101.5	S	1386 @ 2-102.5	After light rain, calm, ground moist, cool. Shear data redone because of excessive noise on original.

Line H (08-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/3/95 (a.m.)	X	2-117 w/1-144	none	60'	101.5 116.5 132.5 148.5	P S	1-138 w/2986 app. 50' to east	Warm, slight wind to none, ground moist. In bone yard. Gravel surface.
Spread 2 (.02)	3/3/95 (a.m./p.m.)	X	1-140 w/2-113	M-4-138 w/2-148	60'	101.5 116.5 132.5 147.5	P S	2-111 w/2986 app. 50' to east	Warm, slight wind, ground moist. In bone yard. Gravel surface.
Spread 3 (.03)	3/2/95 (p.m.)	@ 5' 101-132 @ 10' 133-148	None-elev. for 32-48 on spread 4	none	60'	(3) 101.5 (3) 116.5 (3) 148 (4)-147	P S	none	Cold, snow melting, no wind. Break in line from 2-3 due to road. Noise due to facility machinery. Soil surface.
Spread 4 (.04)	3/2/95	see above							Cold, snow melting, no wind. Combined with Spread 3 Soil surface.

Line H (8-) redo	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 3 (.03)	3/16/95	1-32 @5' 33-48 @ 10'	none	none	60'	3-101.5 3-116.5 3-132.5 3-148.5 4-147.5	P S	none	Warm and breezy, ground dry. Asymmetrical shot/spread. See previous notations.

Line I (09-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01) No-So	2/7/95	X	1-147 w/ 2-102	none	22'	147.5 132.5 116.5 101.5	none	1-122 w/41993 1-136 w/42393	Misting, slight snow, cool, calmish. Some car noise, shear good and clear, offsets missing 1st breaks. 2nd refraction OK.
Spread 2 (.02) East-West	2/8/95	X	1-147w/ 2-102	none	22'	147.5 132.5 116.5 101.5	yes (no wind) for shot generated noise	(~10') 2-129 w/2286 (~20') 2-107 w/P209189	Clear, cool, slight wind. Slight wind on P wave, shear offsets w/ noise-possible shot generated.

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Line J (10-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01) No-So	2/7/95	X	1-148 w/ 2-101	none	22'	147.5 132.5 116.5 101.5	none	@ 1-134 w/42393 @ 1-120 w/41993	Warm, calm, no wind. Offset on shear missing upper refractor. P-good w/some car noise.
Spread 2 (.02) East-West	2/8/95	X	1-148 w/ 2-101	none	40'	147.5 132.5 116.5 101.5	Possible bldg. noise or w/ shot noise	@ 2-107 w/P209189 (app. 10') @ 2-127 w/P210189 well @ ~35 off end 42993	Cool and clear, no wind. P-good. Some shear wave problems.

Line K (11-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/1/95 (a.m.)	X	none	none	60'	147.5 132.5 116.5 101.5	P S	72892 w/147 (18') to east 72492 way off end to south	Snowing, no wind, cold, ground moist. Spread between roads. 60Hz noise. S-wave noisy.
Spread 2 (.02)	3/2/95 (a.m.)	X	2-149 w/3-103	none	60'	147.5 132.5 116.5 101.5	P S	none	Snowing, no wind, cold, ground moist. Break in line from 1-2 due to road. 991 Building Area (low area). Power pole @ 2-135, Pipe @ 2-135, noise.
Spread 3 (.03)	3/2/95	X	3-103 w/2-149	none	60'	147.5 132.5 116.5 101.5	P S	2187 w/3-144	Snow on ground, calm, cold, ground moist. Phone 41 dead because of creek; records noisy due to sewage plant operations.

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Line K (11-) redo	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 2 (.02)	3/22/95	X	2-149 w/3-103	none	60'	147.5 132.5 116.5 101.5	P S	none	Cool, windy. 991 Building Area (low area). Power pole @ 2-135, Pipe @ 2-135, noise.
Spread 3 (.03)	3/22/95	X	3-103 w/2-149	none	60'	147.5 132.5 116.5 101.5	P S	2187 w/3-144	Cool, windy. Phone 41 dead because of creek; records noisy due to sewage plant operations

Line L (12-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/14/95 also 3/23/95	X	2-103 w/ 1-149	1-125 w/B 4-131	60' on E 41' on W @ 15° angle	101.5 116.5 132.5 147.5	P S	1-143 w/ SEP 11-89 (AKA B208389) w/App. 15' to south of Line	Warm, sunny, slight breeze, ground dry.
Spread 2 (.02)	3-14-95 also 3/23/95	X	3-101 w/ 2-147	none	60'	101.5 116.5 132.5 147.5	P S	2-107 w/SEP 12-89 AKA B208489	Warm, sunny, slight breeze, ground dry.
Spread 3 (.03)	3/15/95 (a.m.)	X	3-146w/ 4-100	none	60'	101.5 116.5 132.5 147.5	P S	3-107 w/ 5874 @36' to South	Warm, sunny, calm, ground dry.
Spread 4 (.04)	3/15/95 (p.m.)	X	Road- no over lap with 5. 3-147w/ 4-102	4-114 w/G3-130	60'	101.5 116.5 132.5 147.5	P S	none	Warm, sunny, calm, ground dry
Spread 5 (.05)	3/16/95 (p.m.) also 3/23/95	X	none	none	60'	101.5 116.5 132.5 147.5	P S	none	Warm, ground dry, slight breeze.

23

Line L (12-) redo	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/23/95	X	2-103 w/ 1-149	1-125 w/B 4-131	60' on E 41' on W @ 15° angle	101.5 116.5 132.5 147.5	P S	1-143 w/ SEP 11-89 (AKA B208389) w/App. 15' to south of Line	P and S redos. Calm and dry.
Spread 2 (.02)	3/23/95	X	3-101 w/ 2-147	none	60'	101.5 116.5 132.5 147.5	P S	2-107 w/SEP 12-89 (AKA B208489)	P and S redos. Calm and dry.
Spread 5 (.05)	3/23/95	X	none	none	60'	101.5 116.5 132.5 147.5	P S	none	On and off ends for shear. Calm and dry.

54

Line M (13-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	3/21/95	X	none	none	63' on W 60' on E	147.5 132.5 116.5 101.5	P S	2686 w/1-138.5 north ~ 5' and P207589 south ~5'. 1-136 ~ 7' w/2586 north of line.	Windy, warm, ground dry. Gravel surface.
Spread 2 (.02)	3/21/95	X	2-147 w/ 3-101	none	60'	147.5 132.5 116.5 101.5	P S	2-117.5 w/ 3887' north of line.	Warm, windy, ground dry. Break in line from 1-2 due to driveway and cement blocks. 2-141 last phone on top of berm. 2-145 @ base of berm on the east. Staked location 3' to No. 101 through 117.
Spread 3 (.03)	3/20/95	X	3-147 w/4-101	none	60'	147.5 132.5 116.5 101.5	P S	3-121 w/ P207789 ~ 10' So 3-115 w/ P207689 ~ 3' So.	Warm and windy, ground dry. -Phones 8-11 on pavement. Shear wave-phones buried and lack signal.
Spread 4 (.04)	3/20/95	X	3-147 w/ 4-101	H 2-148 w/ 4-138	60' on W 29' on E	147.5 132.5 116.5 101.5	P S	4-136.5 w/ P219489	Traces 38 & 48 going bad.

95

Line N (14-)	Date	Phones @ 5' spacing	Spreads Overlap	Line Ties	Off-ends	Sources @	Noise Record	Wells @	Comments
Spread 1 (.01)	03/17/95	X	none	D-4-146 w/1-135 E-3-129 w/1-117	60'	101.5 116.5 132.5 147.5	P S	44893 @ 1-141.5 40593 @ 1-108.5	Cool, moist, sunny, slight breeze, ground damp.

Appendix B

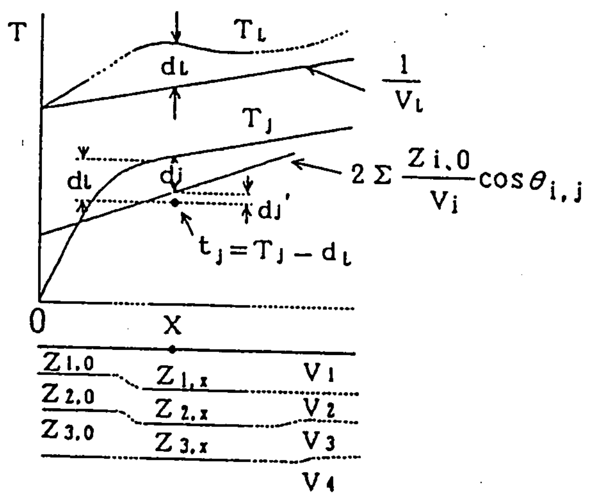
Tj Method

Tj METHOD

< An Extension of the Delay-Time Method >

In an "L" layer structure in which thickness changes, a reference point (0) and each layer thickness at a given receiving station (x) are assumed as follows:

$$Z_{1,o},\ Z_{2,o},\ \cdots\cdots,\ Z_{L-1,o}$$
$$Z_{1,x},\ Z_{2,x},\ \cdots\cdots,\ Z_{L-1,x}$$



Traveltime from the "j" layer Tj (j=2 to L) is expressed as follows, with Point 0 assumed as the origin:

$$T_j = \left(2\sum_{i=0}^{N} \frac{Z_{i,o}}{V_i}\cos\theta_{i,j} + \frac{X}{V_j}\right) + \sum_{i=0}^{j-1} \frac{Z_{i,x}-Z_{i,o}}{V_i}\cos\theta_{i,j} \qquad (1)$$

However, it is assumed that the layer slope does not change so much, and $\theta_{i,j}$ is an angle of incidence of the "j" layer refracted waves against the i layer. The complexity of the traveltime curve Tj is represented by the second member in Equation 1 and is denoted "dj".

$$d_j = \sum_{i=1}^{j-1} \frac{Z_{i,x}-Z_{i,o}}{V_i}\cos\theta_{i,j} \tag{2}$$

Using Hagiwara's Method, the delay-time relation to the "L" (or bottom) layer can be obtained easily by using a pair of traveltime curves that stand opposite each other and begin at a far distance. The method is expressed as:

$$\sum_{i=1}^{L-1} \frac{Z_{i,x}}{V_i}\cos\theta_{i,L} \tag{3}$$

The delay-time difference, d_L, between points 0 and x is expressed as follows:

$$d_L = \sum_{i=1}^{L-1} \frac{Z_{i,x}-Z_{i,o}}{V_i}\cos\theta_{i,L} \tag{4}$$

Assuming an imaginary traveltime curve Tj obtained by subtracting d_L from the traveltime curve of the "j" layer refracted waves, Tj is expressed as:

$$\begin{aligned} t_j &= T_j-d_L \\ &= 2\sum_{i=1}^{j-1} \frac{Z_{i,o}}{V_i}\cos\theta_{i,j}+\frac{x}{V_j} \\ &\quad+\sum_{i=1}^{j-1} \frac{Z_{i,x}-Z_{i,o}}{V_i}(\cos\theta_{i,j}-\cos\theta_{i,L}) \\ &\quad-\sum_{i=j}^{L-1} \frac{Z_{i,x}-Z_{i,o}}{V_i}\cos\theta_{i,L} \end{aligned} \tag{5}$$

The first member of Equation 5 represents a straight line, while the second and third members represent variations that disturb the straight line. If the second member is compared with dj in Equation 2, the result is:

Because in practical application the right part becomes about 1/10 of the left part, the second member of Equation 5 can be ignored. Thus, only the third member, dj', makes Equation 5 of the Tj curve complex. dj' is expressed as:

$$d_j' = \sum_{i=j}^{L-1} \frac{Z_{i,x} - Z_{i,o}}{V_i} \cos\theta_{i,L} \qquad (6)$$

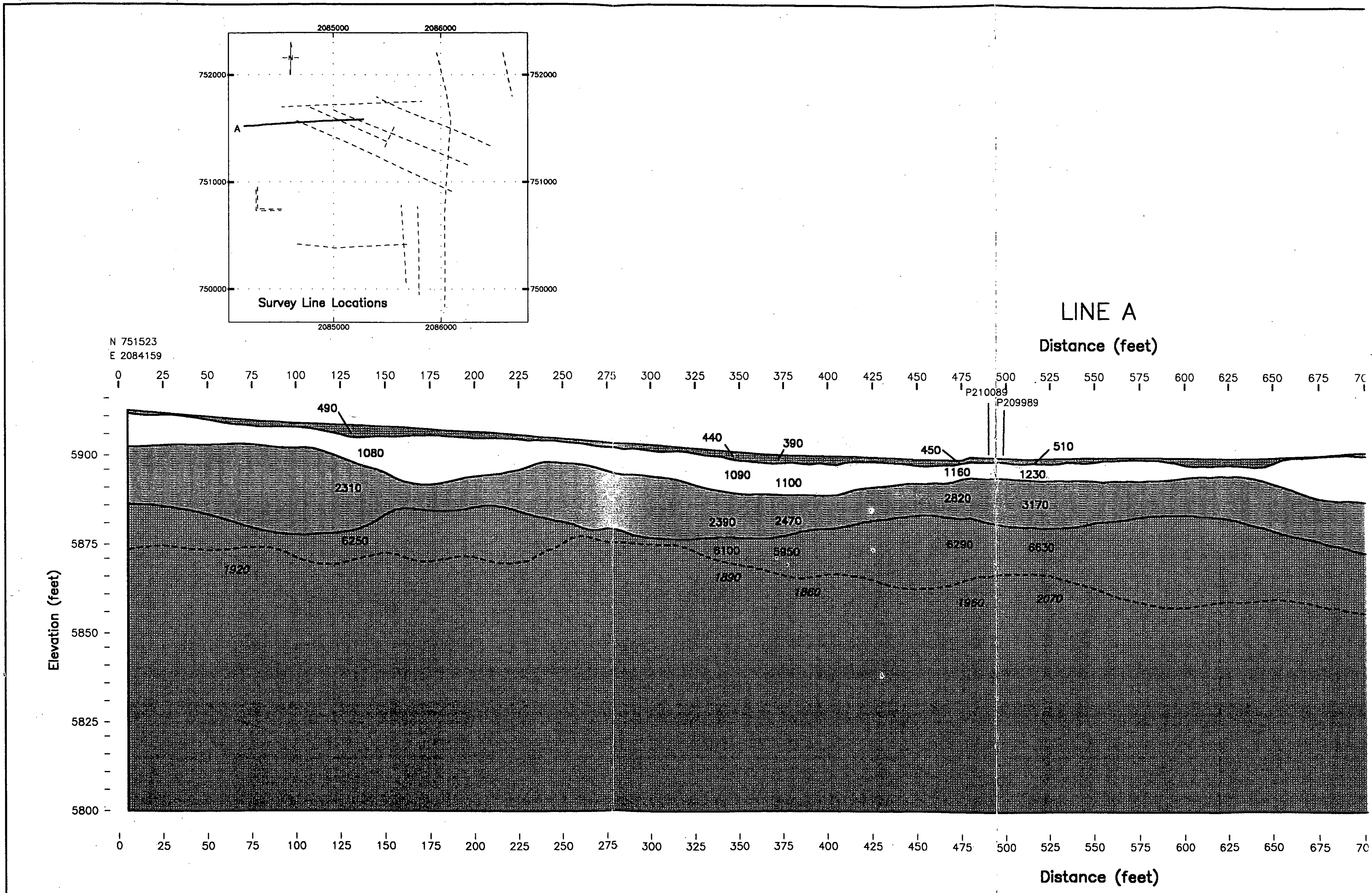
dj in Equation 2 is affected by the changes in the first to the (j-1) layers near surface, whereas dj' in Equation 6 is affected by the changes of the j to (L-1) layers in the deeper section. If the changes are near equal in thickness, the following equation is satisfied:

$$V_{1-(j-1)} < V_{j-(L-1)}$$

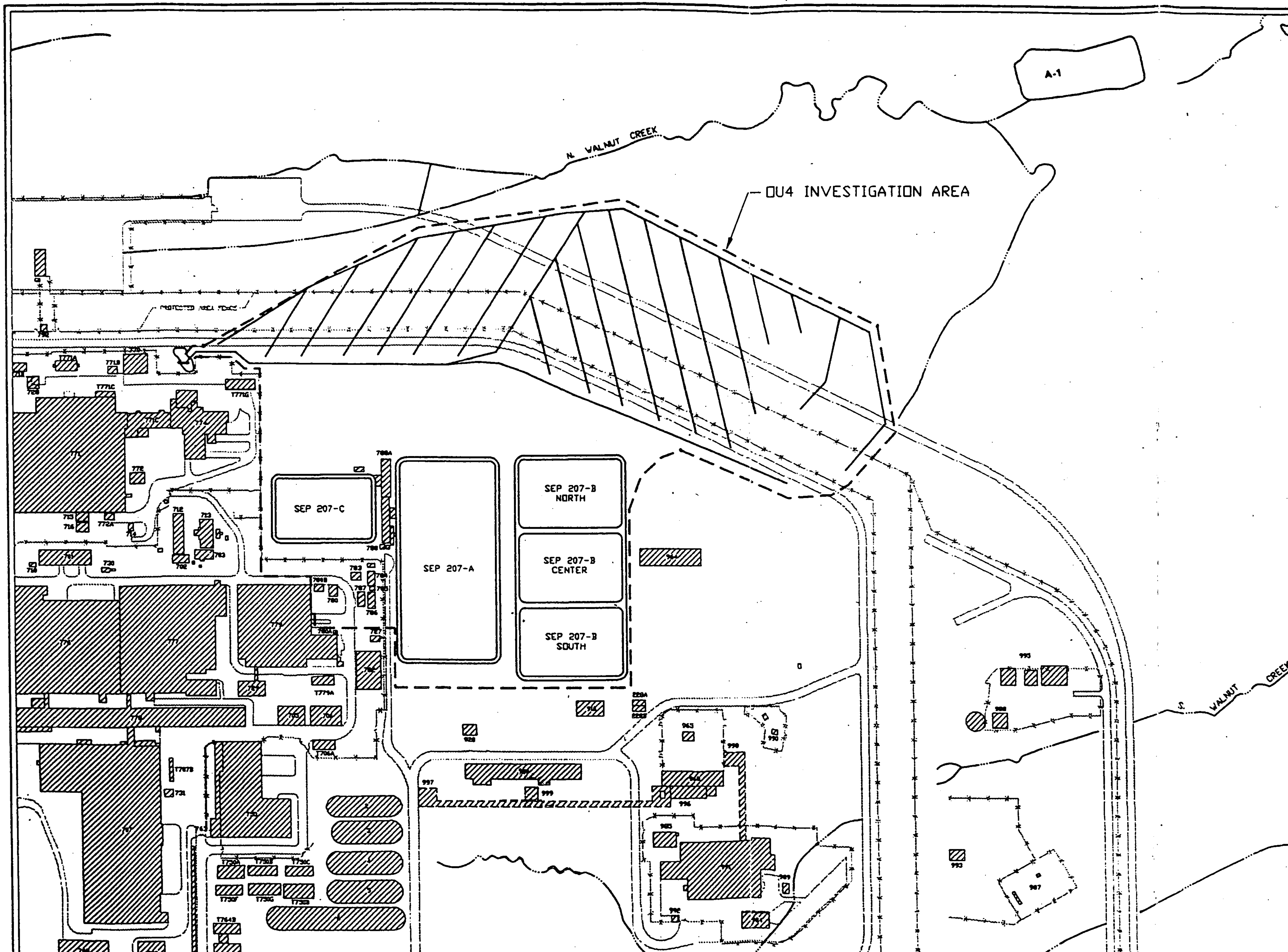
And the following general expression is sufficient:

$$|d_j| > |d_j'|$$

The Tj curve represented in Equation 5 becomes a polygonal line consisting of traveltime curve segments, and is straighter than Tj. In the Tj Method determination of the number of refracted layers, velocity, intercept time, T' lines, etc., is accomplished easily and objectively.



Survey Line Locations
2085000
2086000
752000
751000
750000
A
N
LINE A
Distance (feet)
N 751523
E 2084159
P210089
P209989
Elevation (feet)
5900
5875
5850
5825
5800
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650
675
490
440
390
450
510
1080
1090
1100
1160
1230
2310
2820
3170
2390
2470
6250
6100
5850
6290
6630
1920
1890
1860
1950
2070



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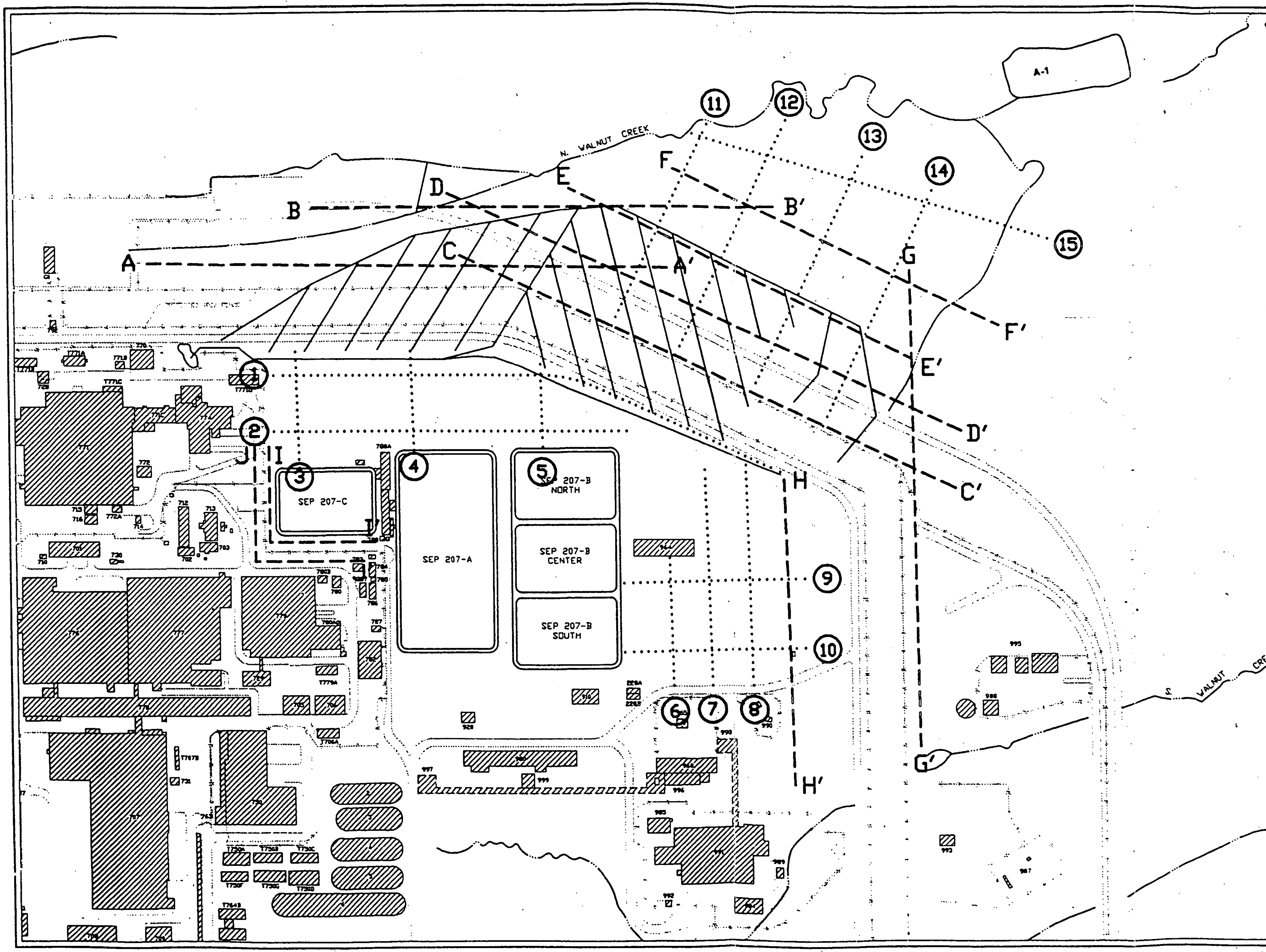
GOLDEN, COLORADO

Figure 1.0-1

Site Map of OU4

September 1, 1994 | Rev.: 0

8



LEGEND

- Streams
- Paved Roads
- Buildings
- Fence
- Interceptor Trench System
- Proposed Geophysical Line (GPR, EM, and Seismic)
- Proposed Geophysical Line (EM only)

100 0 100 200 300 FEET

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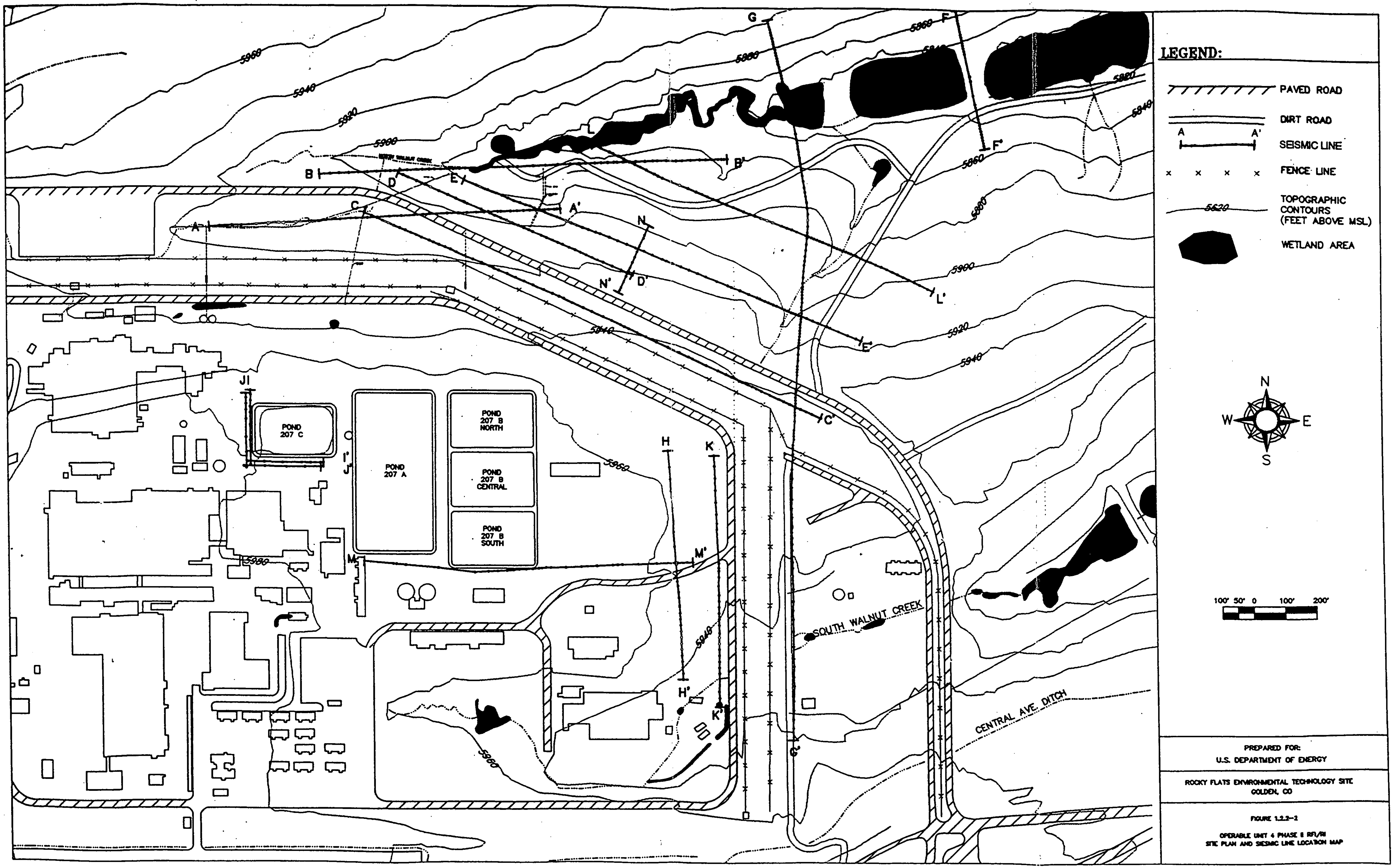
GOLDEN, COLORADO

Figure 1.2.2-1

OU4 Phase II Work Plan
Proposed Geophysical Line Locations

September 7, 1994 | Rev.: 0

10


LEGEND:
PAVED ROAD
DIRT ROAD
SEISMIC LINE
FENCE LINE
TOPOGRAPHIC CONTOURS (FEET ABOVE MSL)
WETLAND AREA
N
W
E
S
100' 50' 0 100' 200'
POND 207 C
POND 207 A
POND 207 B NORTH
POND 207 B CENTRAL
POND 207 B SOUTH
SOUTH WALNUT CREEK
CENTRAL AVE. DITCH
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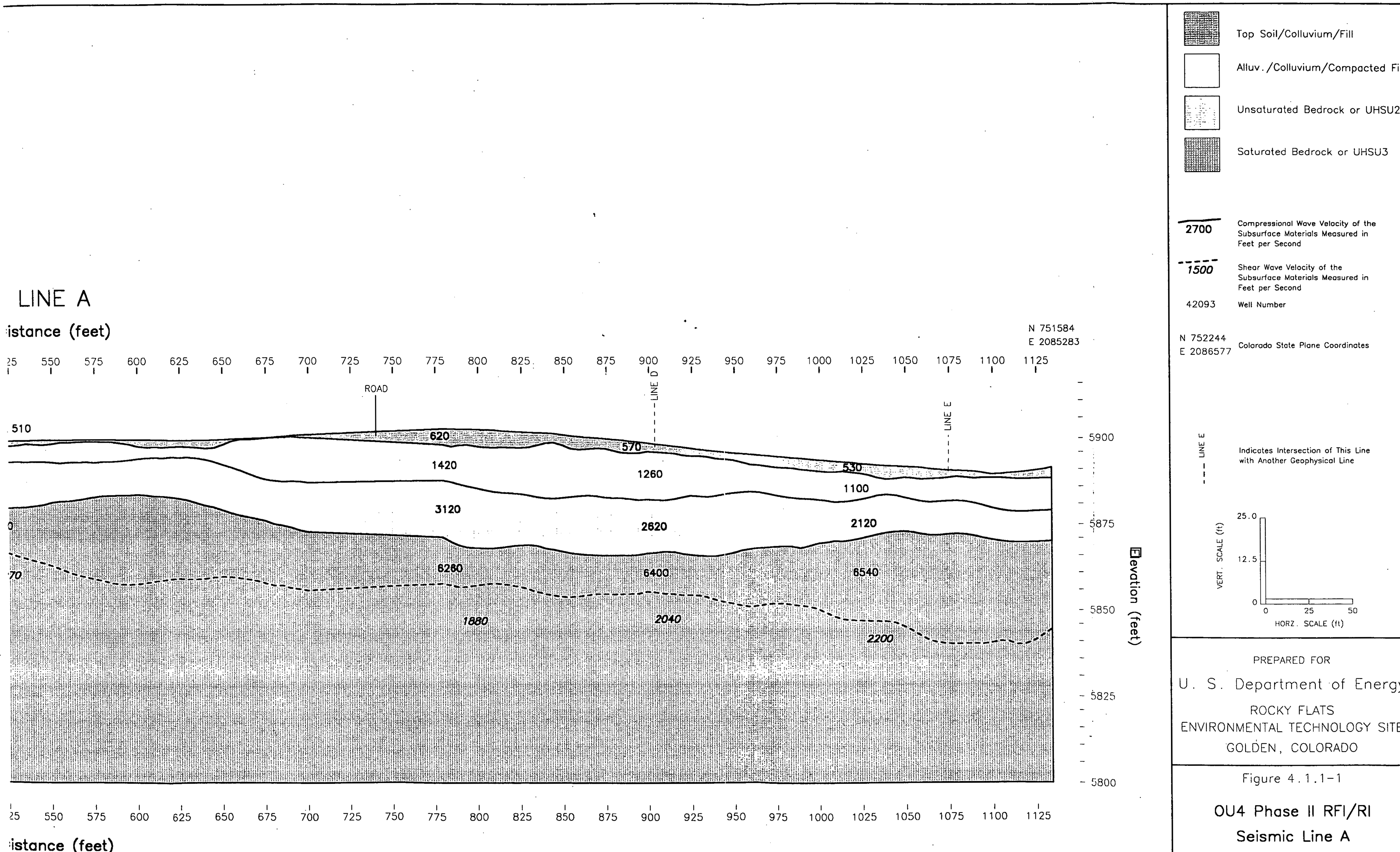
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, CO
FIGURE 1.2.2-2
OPERABLE UNIT 4 PHASE II RFI/RI
SITE PLAN AND SEISMIC LINE LOCATION MAP



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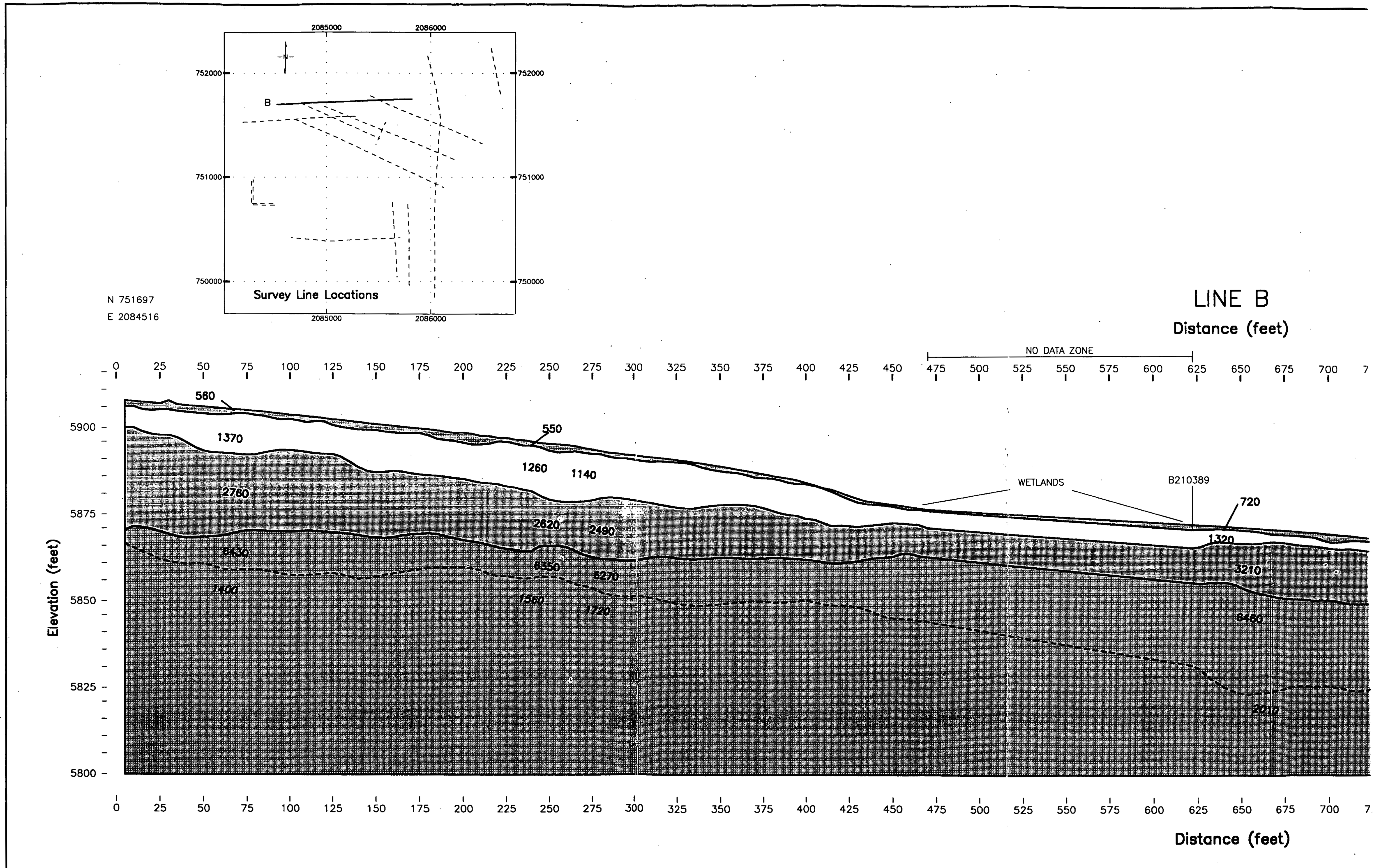
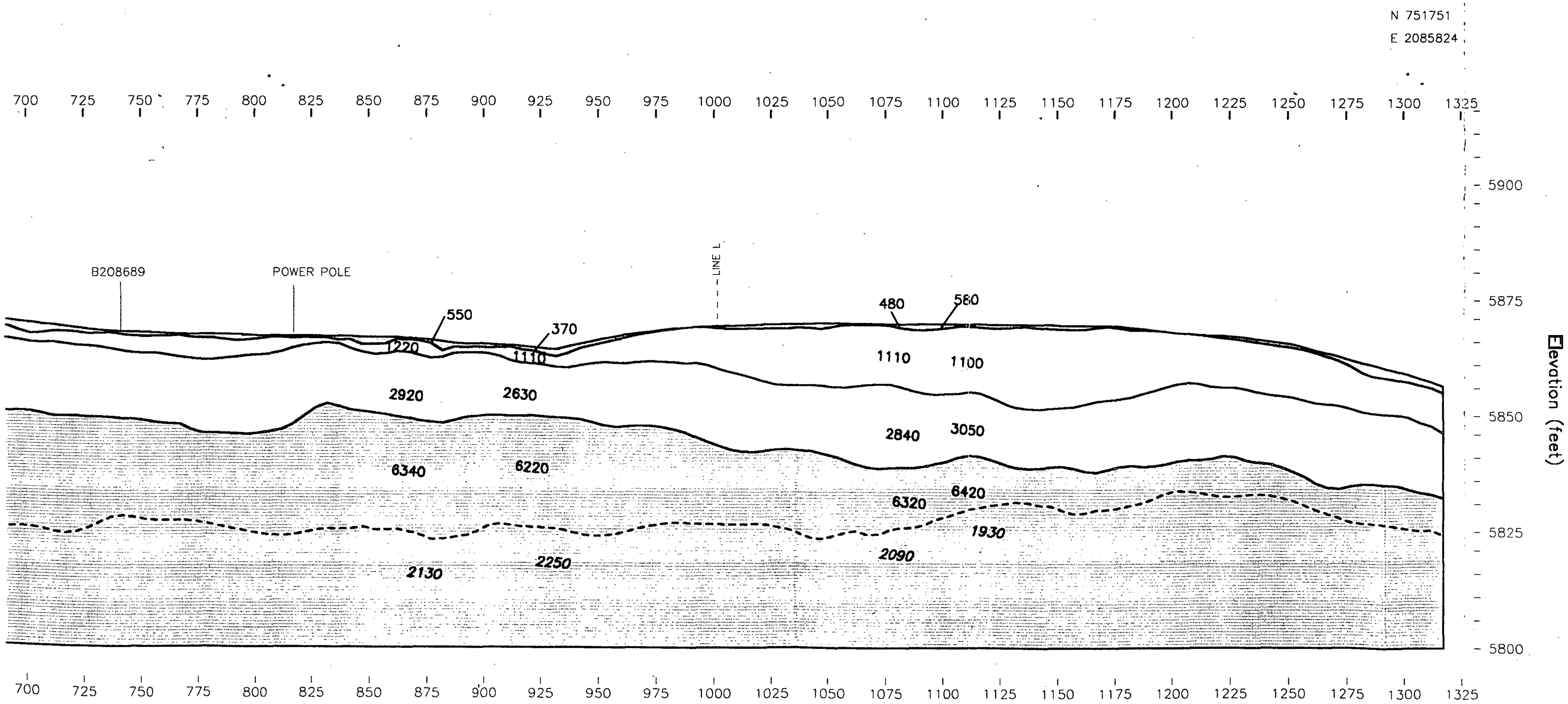
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.1-1

OU4 Phase II RFI/RI
Seismic Line A


Survey Line Locations
2085000
2086000
752000
751000
750000
B
N 751697
E 2084516
LINE B
Distance (feet)
NO DATA ZONE
WETLANDS
B210389
Elevation (feet)
5900
5875
5850
5825
5800
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650
675
700
560
550
1370
1260
1140
2760
2620
2490
720
1320
3210
6430
6350
6270
6460
1400
1560
1720
2010
Distance (feet)



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line

VERT. SCALE (ft): 0, 12.5, 25.0
HORZ. SCALE (ft): 0, 25, 50

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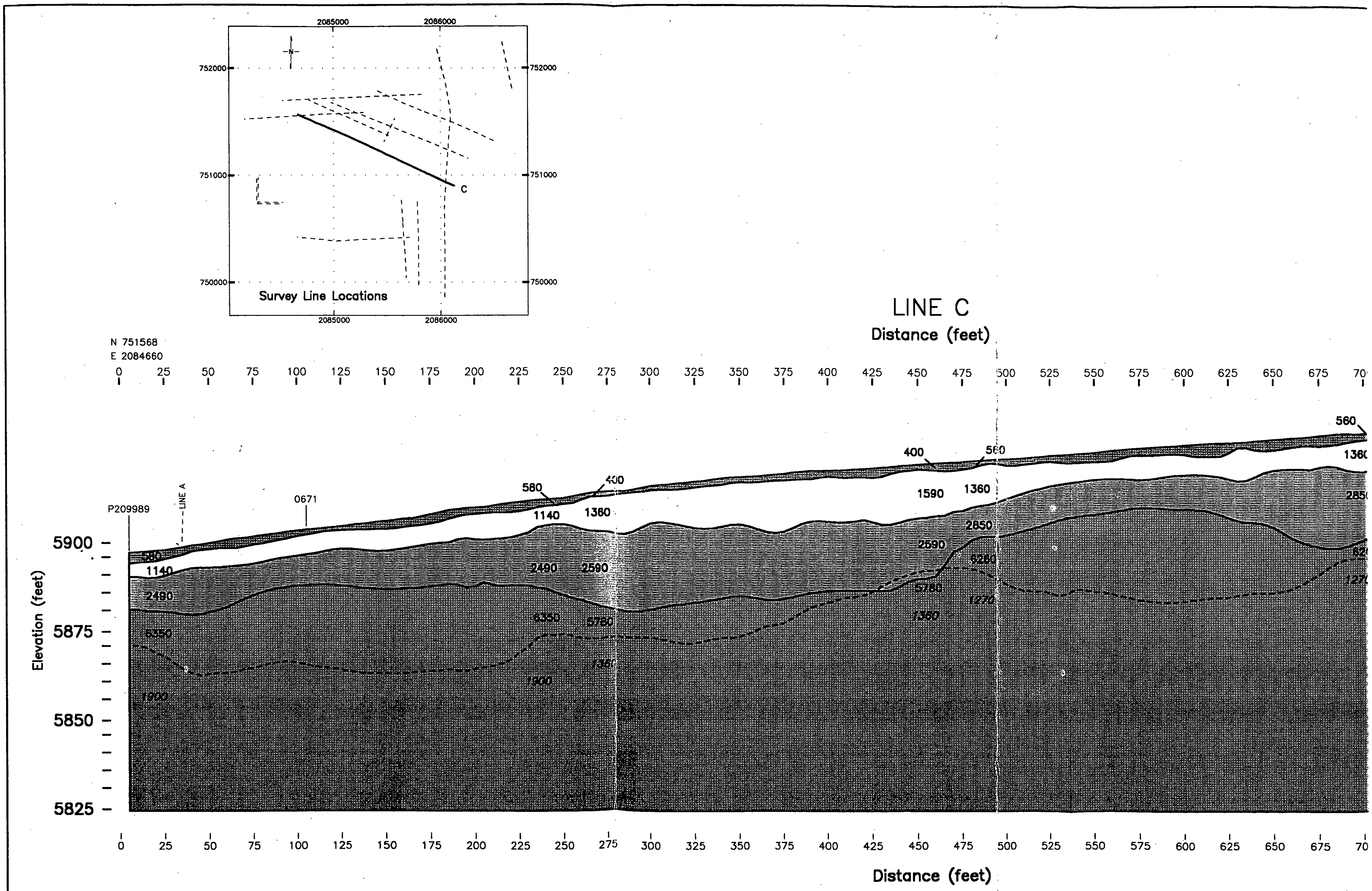
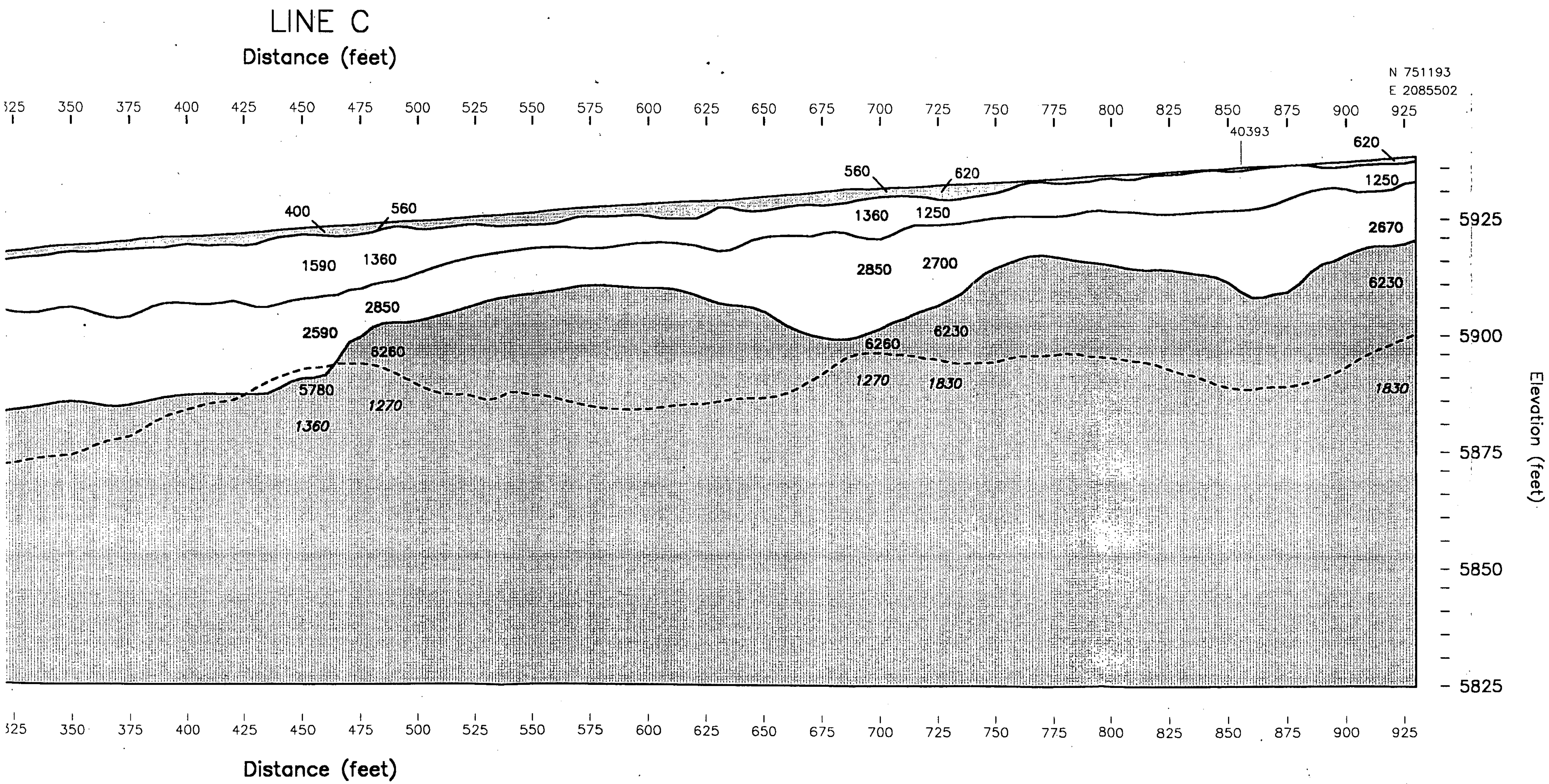
U. S. Department of Energy

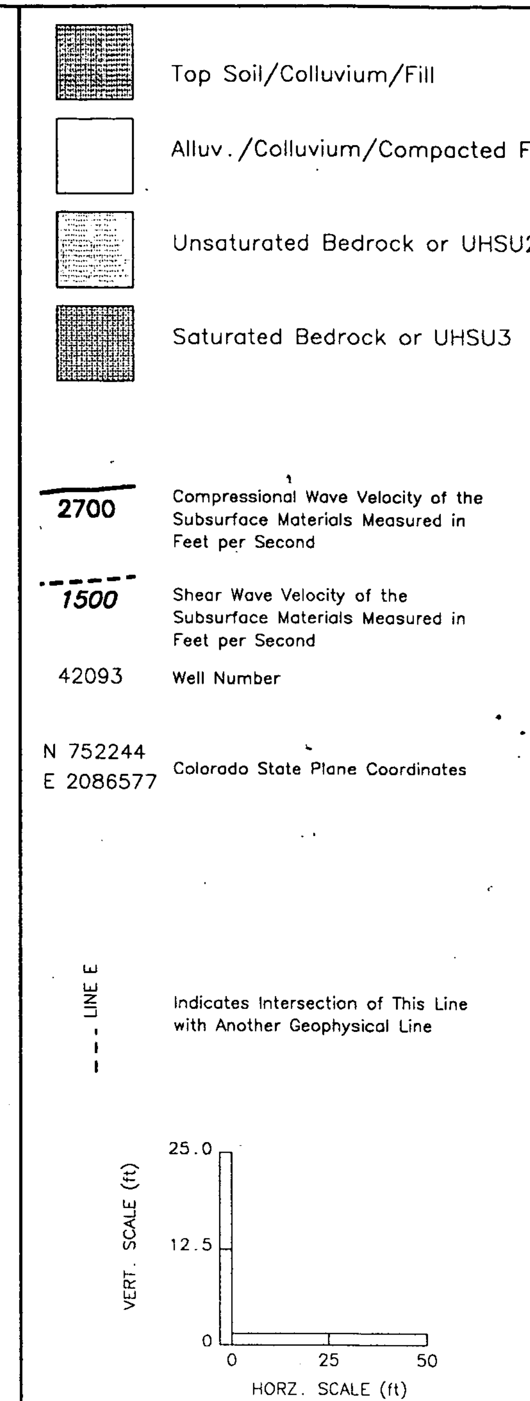
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.2-1

OU4 Phase II RFI/RI
Seismic Line B


Survey Line Locations
2085000
2086000
752000
751000
750000
C
LINE C
Distance (feet)
N 751568
E 2084660
P209989
LINE A
0671
Elevation (feet)
5900
5875
5850
5825
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625 650 675
580
1140
2490
6350
1900
400
1360
5780
1361
2590
1590
2850
6260
1270
560
Distance (feet)





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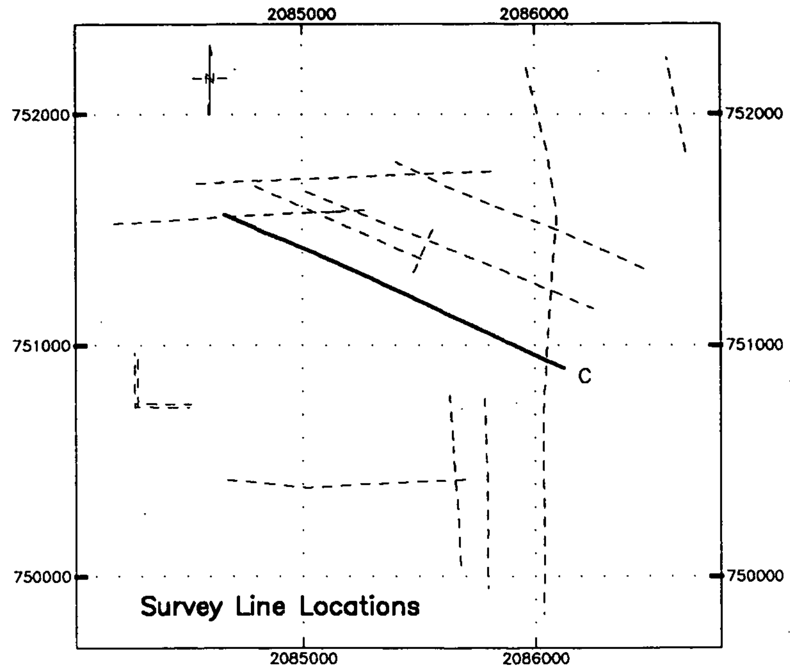
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

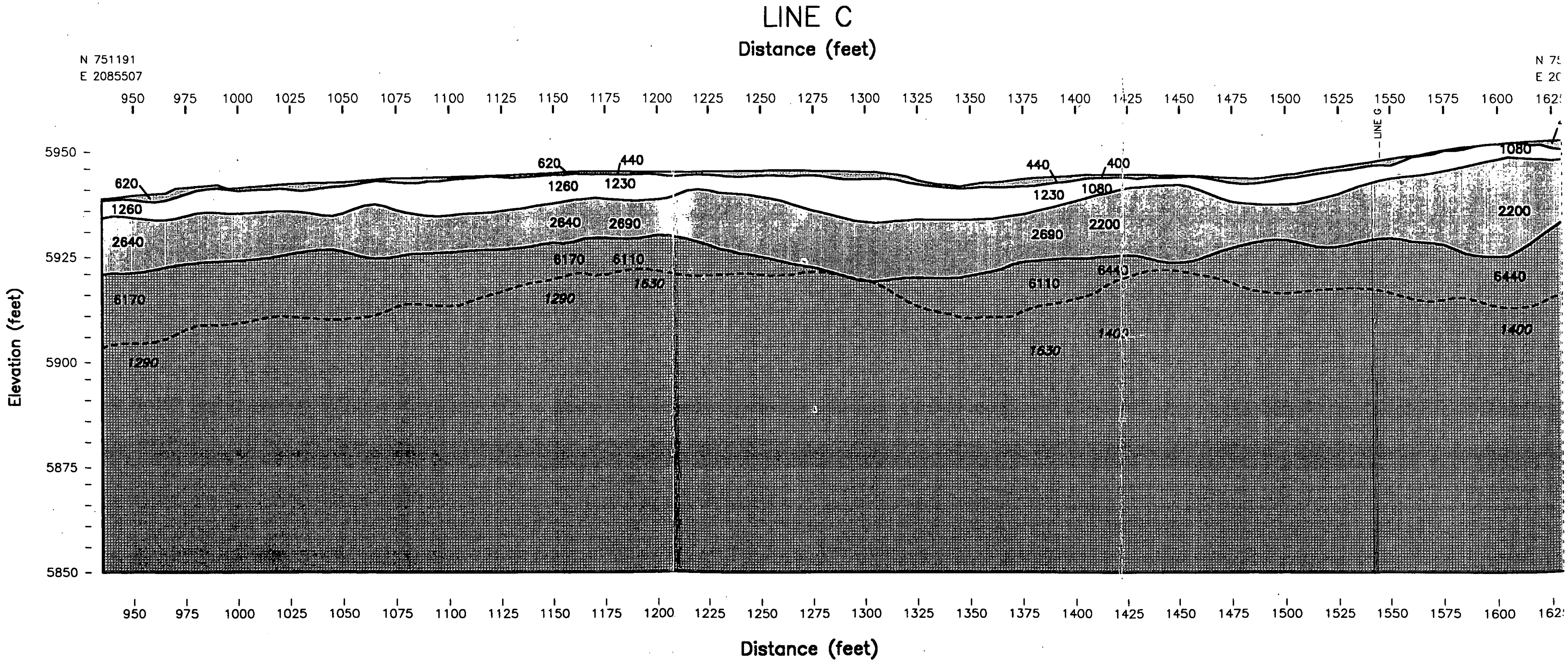
Figure 4.1.3-1A

OU4 Phase II RFI/RI
Seismic Line C

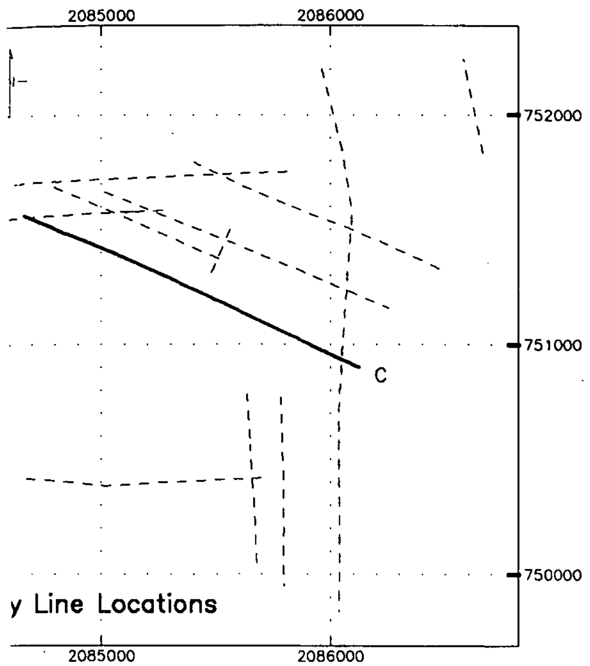
33


2085000
2086000
752000
751000
750000
C
Survey Line Locations

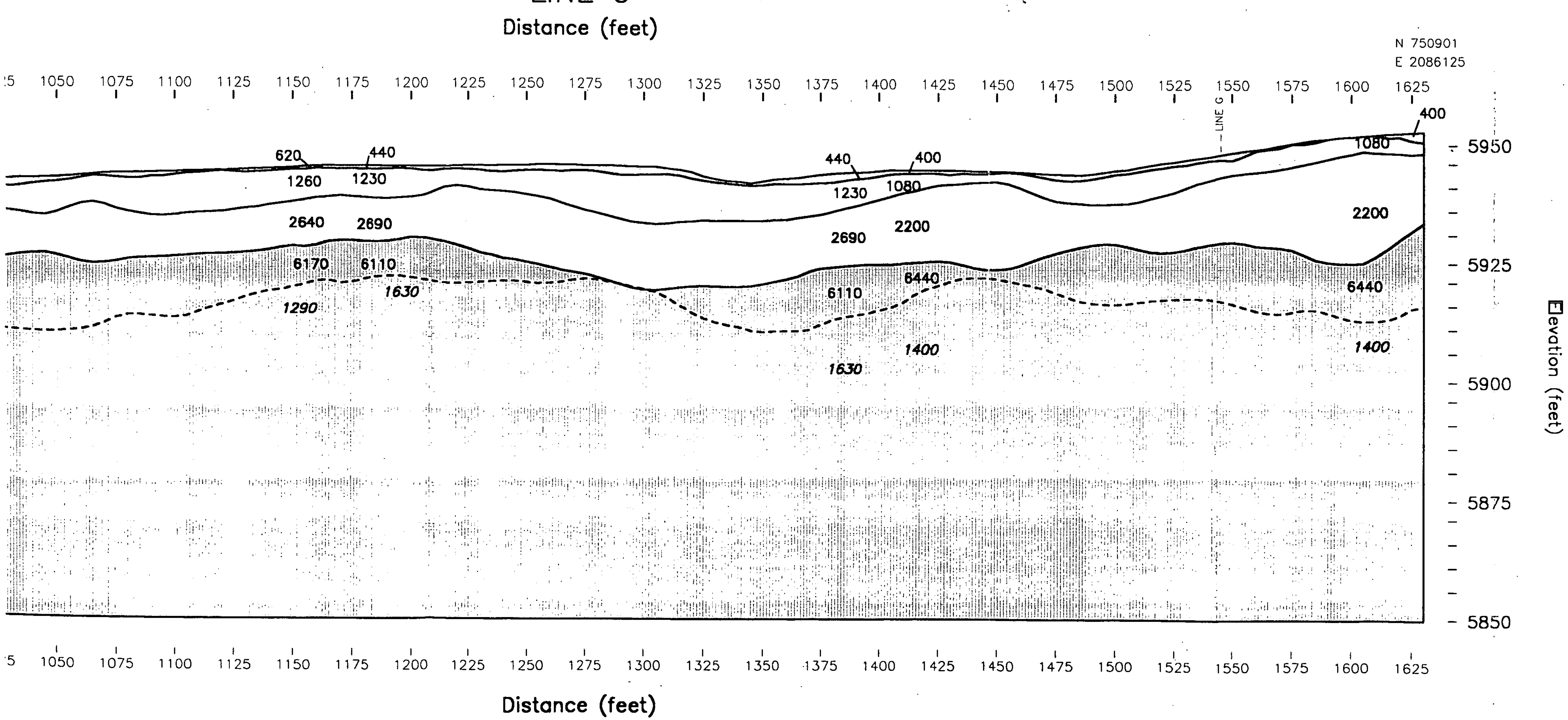
LINE C


Distance (feet)
N 751191
E 2085507
Elevation (feet)
LINE G
620
1260
2640
6170
1290
440
1230
2690
6110
1630
400
1080
2200
6440
1400
Distance (feet)

34



LINE C



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

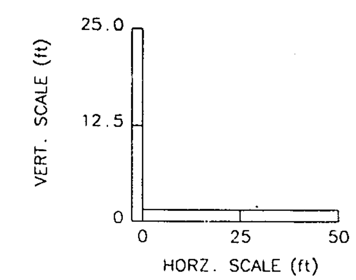
2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line



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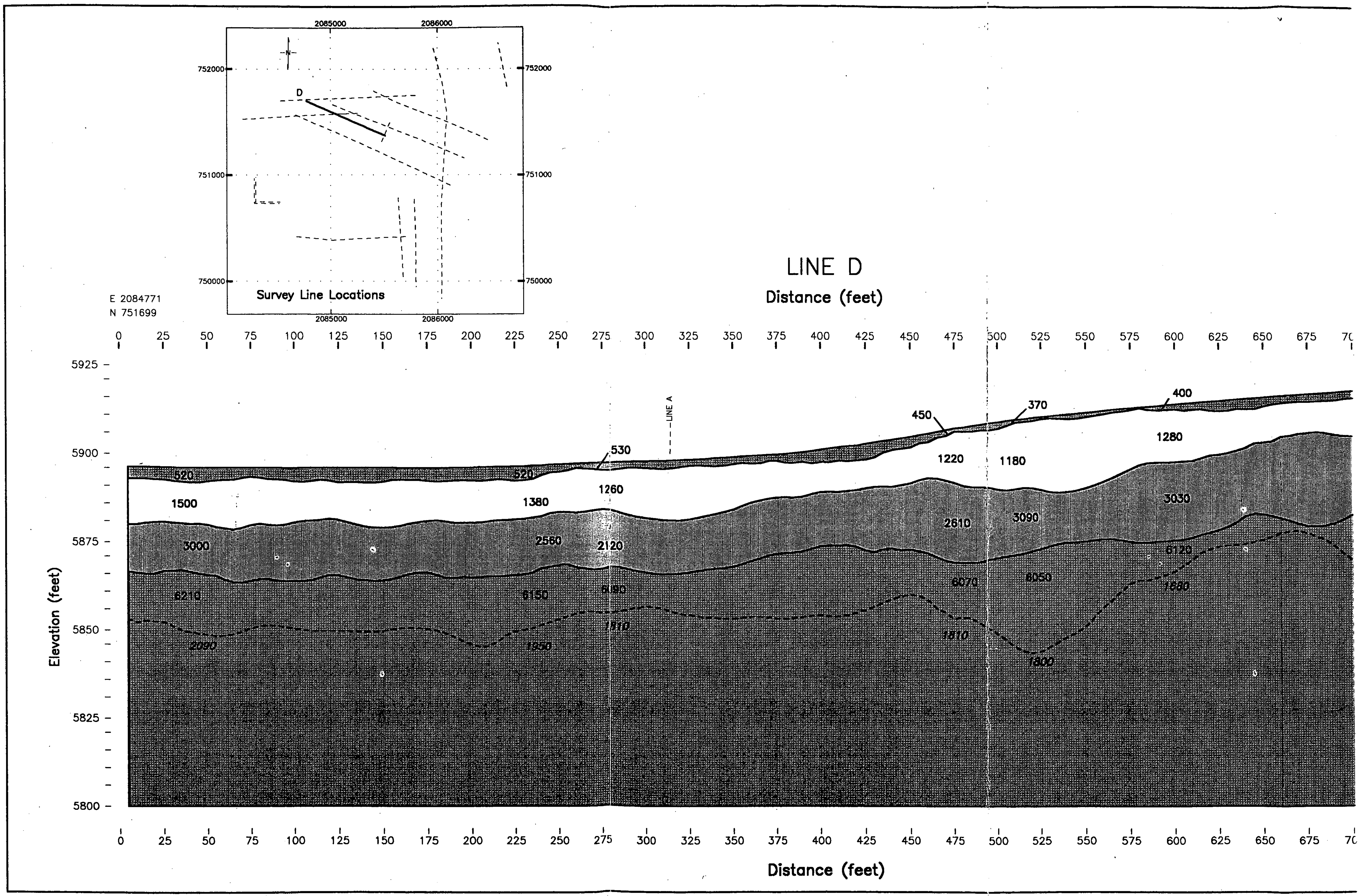
GOLDEN, COLORADO

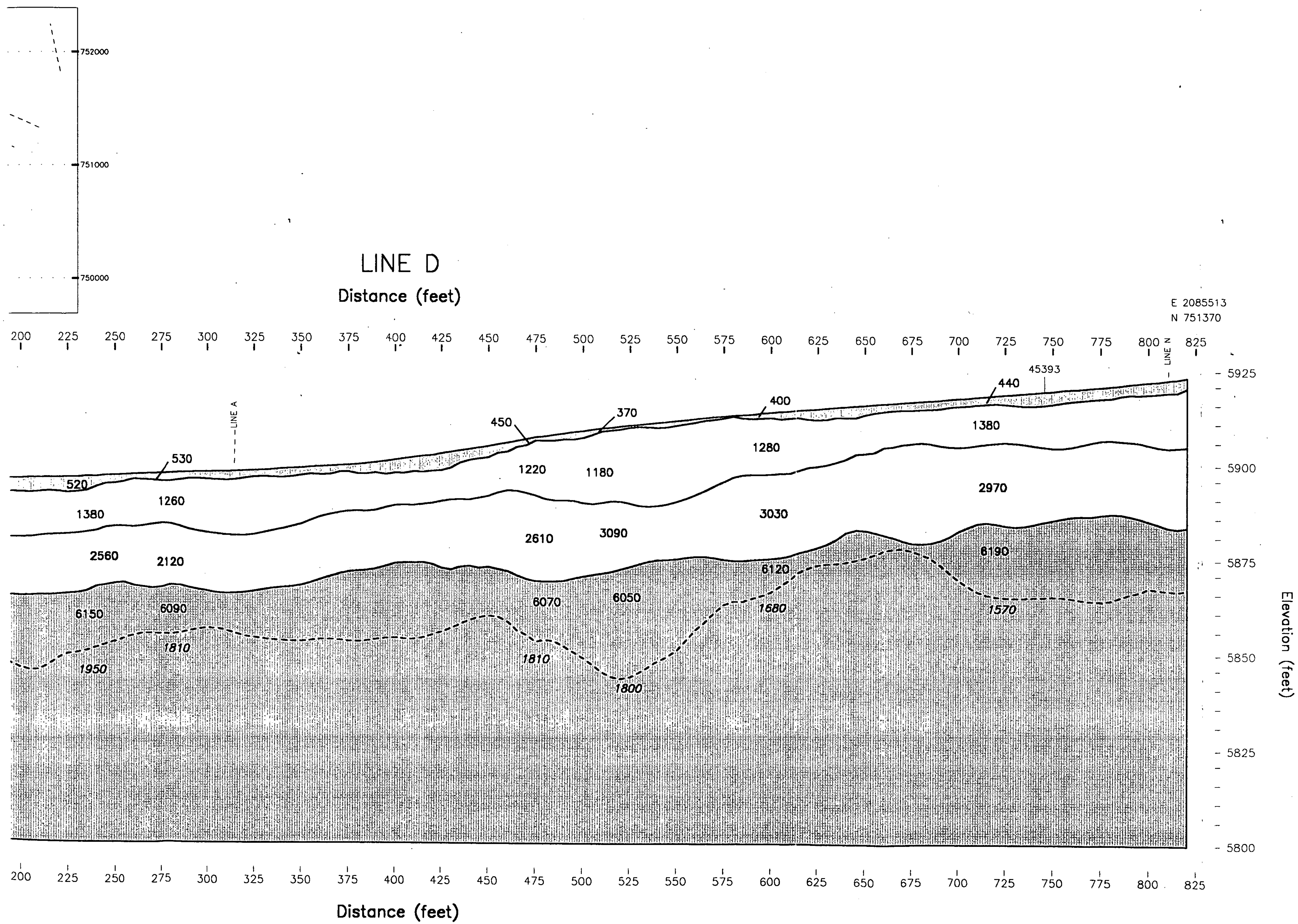
Figure 4.1.3-1B

OU4 Phase II RFI/RI
Seismic Line C



LINE D
Distance (feet)
Survey Line Locations
2085000
2086000
752000
751000
750000
D
LINE A
E 2084771
N 751699
Elevation (feet)
5925
5900
5875
5850
5825
5800
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650
675
520
530
450
370
400
1500
1380
1260
1220
1180
1280
3000
2560
2120
2610
3090
3030
6210
6150
6090
6070
6050
6120
2090
1950
1810
1810
1800
1680
Distance (feet)

37



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line

VERT. SCALE (ft): 0, 12.5, 25.0
HORZ. SCALE (ft): 0, 25, 50

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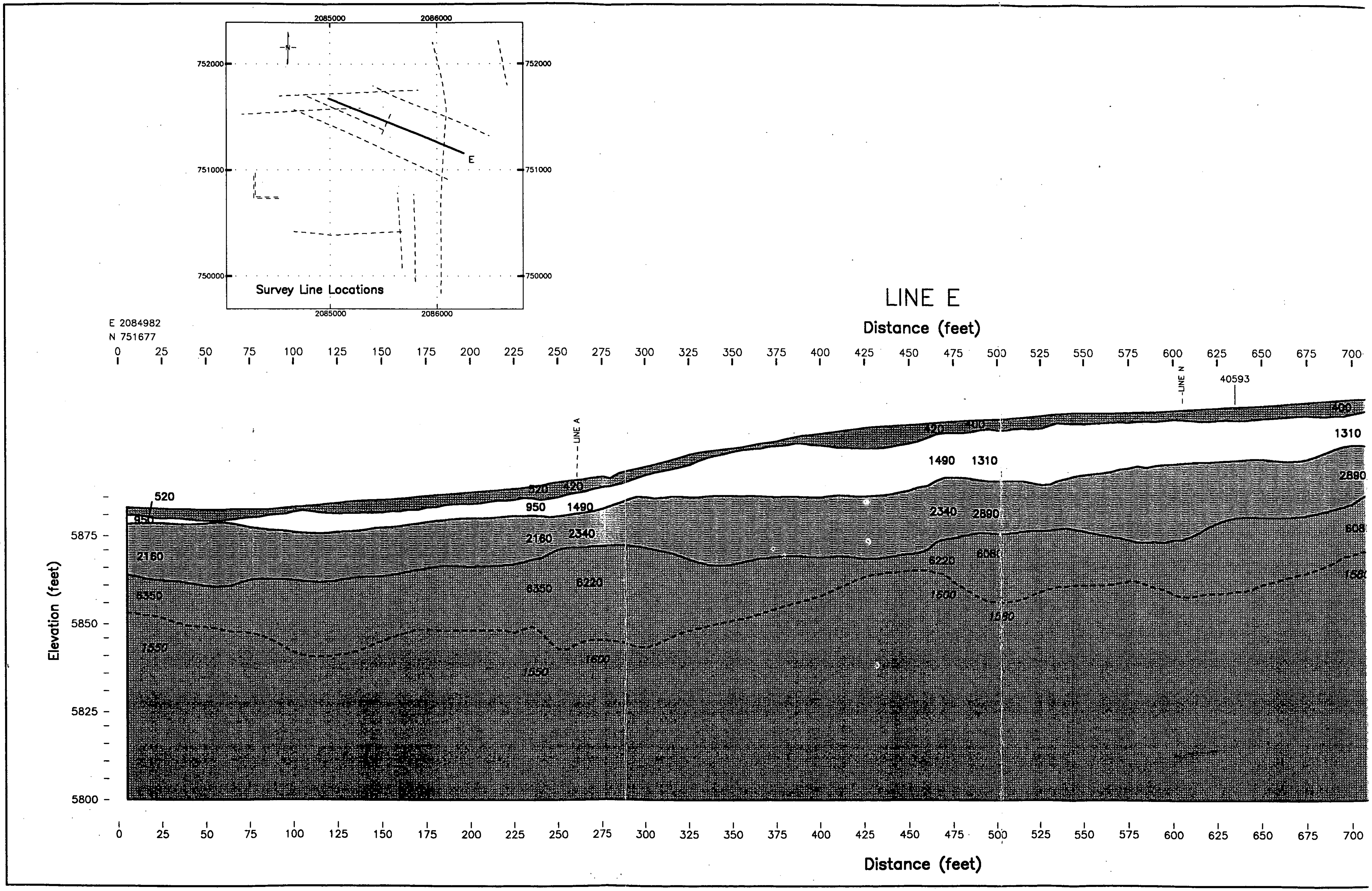
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.4-1

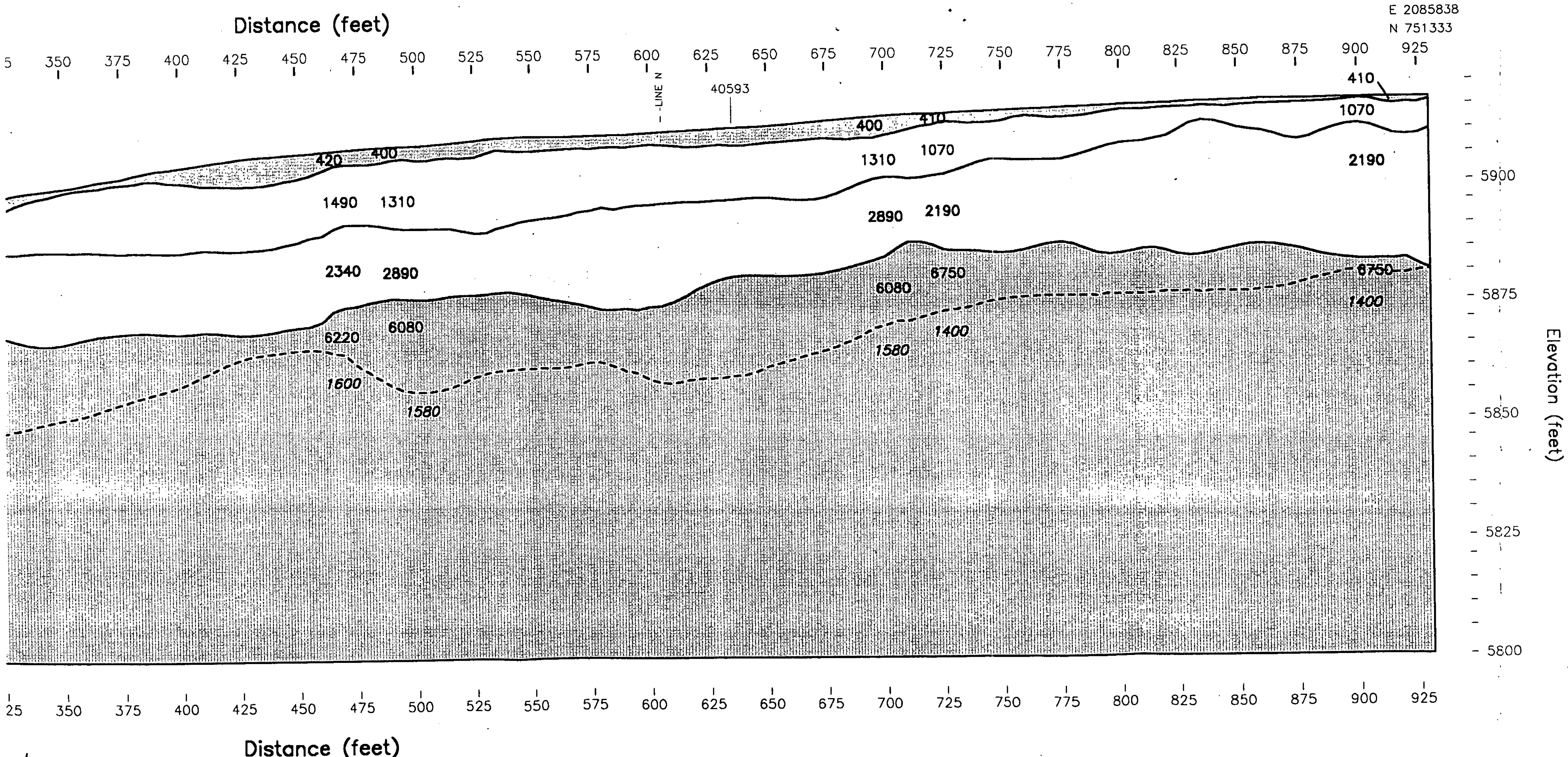
OU4 Phase II RFI/RI
Seismic Line D

38



LINE E
Survey Line Locations
2085000
2086000
752000
751000
750000
E 2084982
N 751677
Distance (feet)
Elevation (feet)
5875
5850
5825
5800
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625 650 675 700
LINE A
LINE N
40593
520
950
2160
6350
1550
420
1490
2340
6220
1600
1310
2890
6080
1580
400

LINE E



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

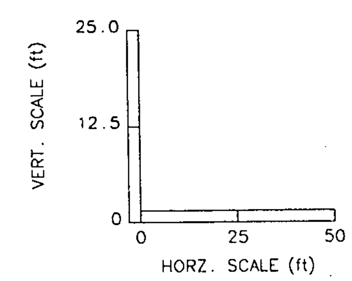
2700 Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 Well Number

N 752244
E 2086577 Colorado State Plane Coordinates

LINE E Indicates Intersection of This Line with Another Geophysical Line



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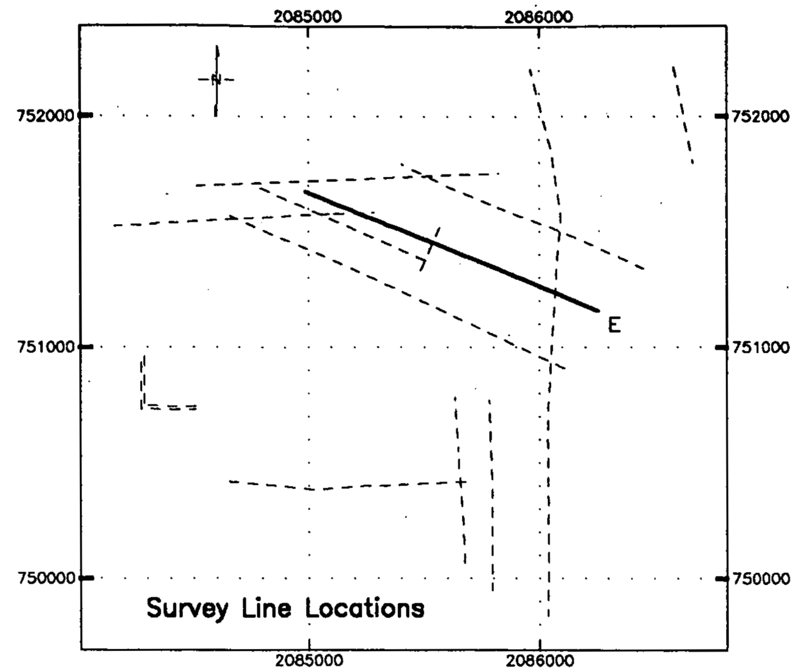
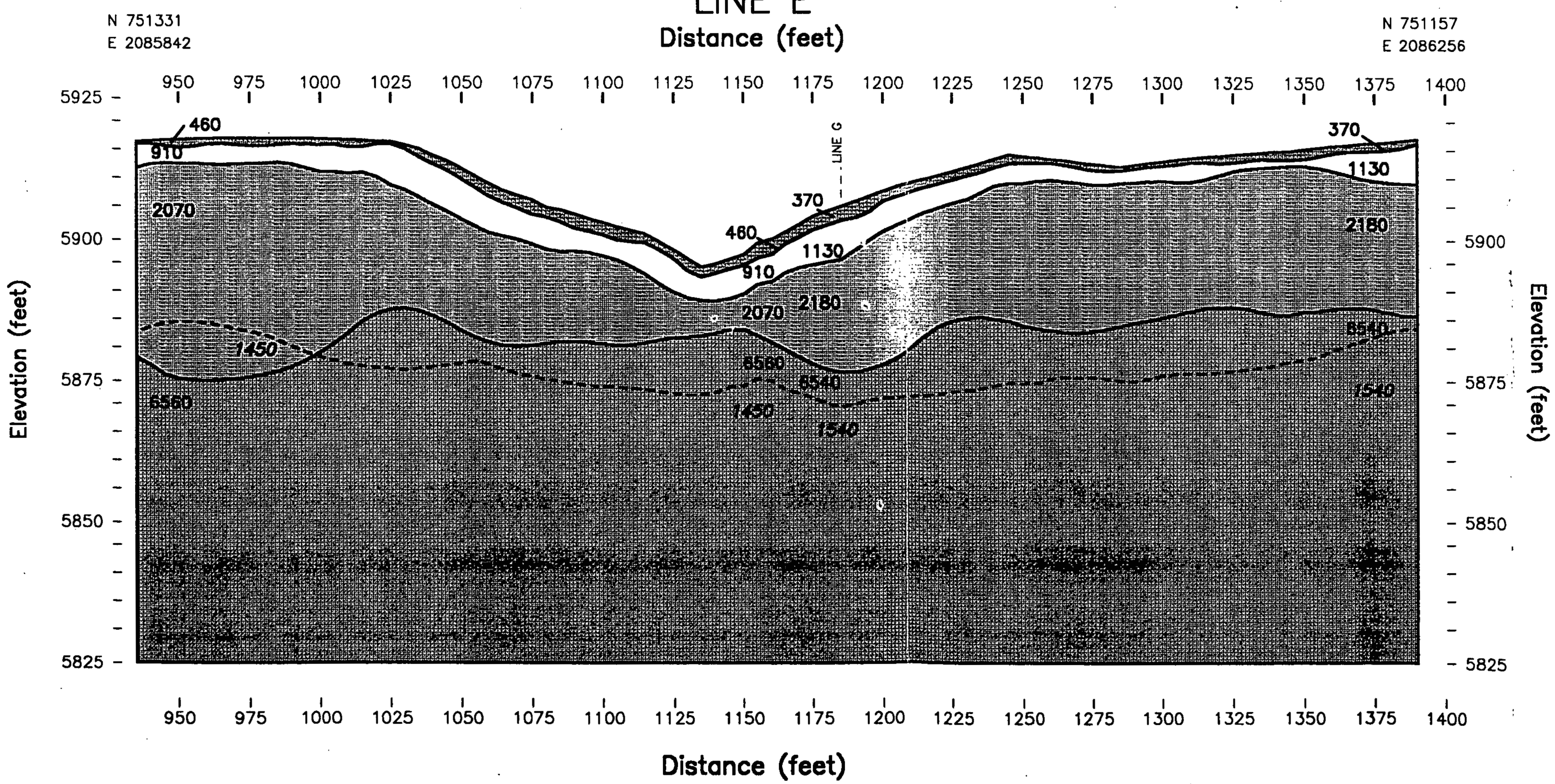
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.5-1A

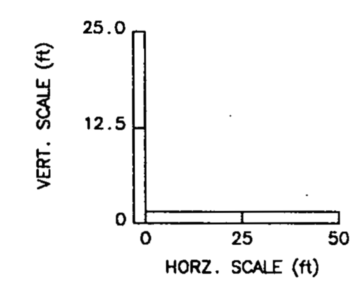
OU4 Phase II RFI/RI
Seismic Line E



LINE E



	Top Soil/Colluvium/Fill
	Alluv./Colluvium/Compacted Fill
	Unsaturated Bedrock or UHSU2
	Saturated Bedrock or UHSU3
2700	Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second
1500	Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second
42093	Well Number
N 752244 E 2086577	Colorado State Plane Coordinates
LINE E	Indicates Intersection of This Line with Another Geophysical Line



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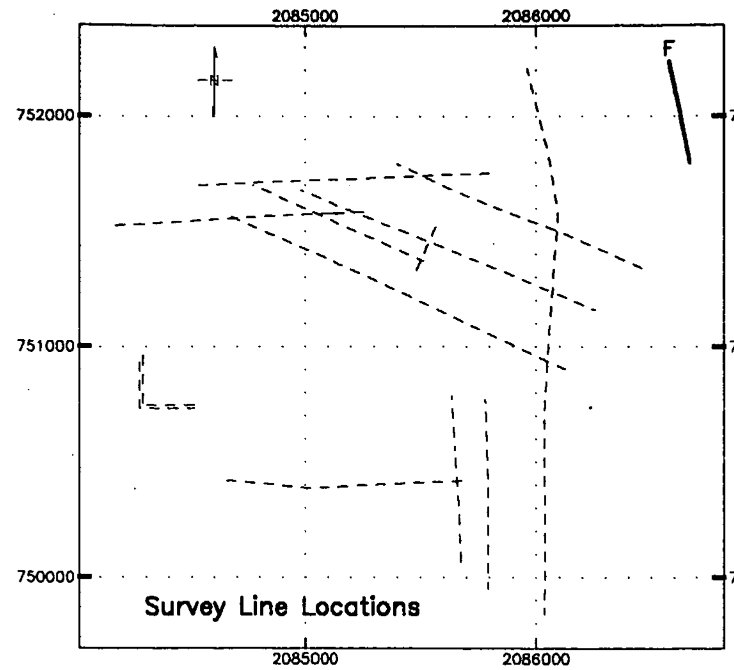
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

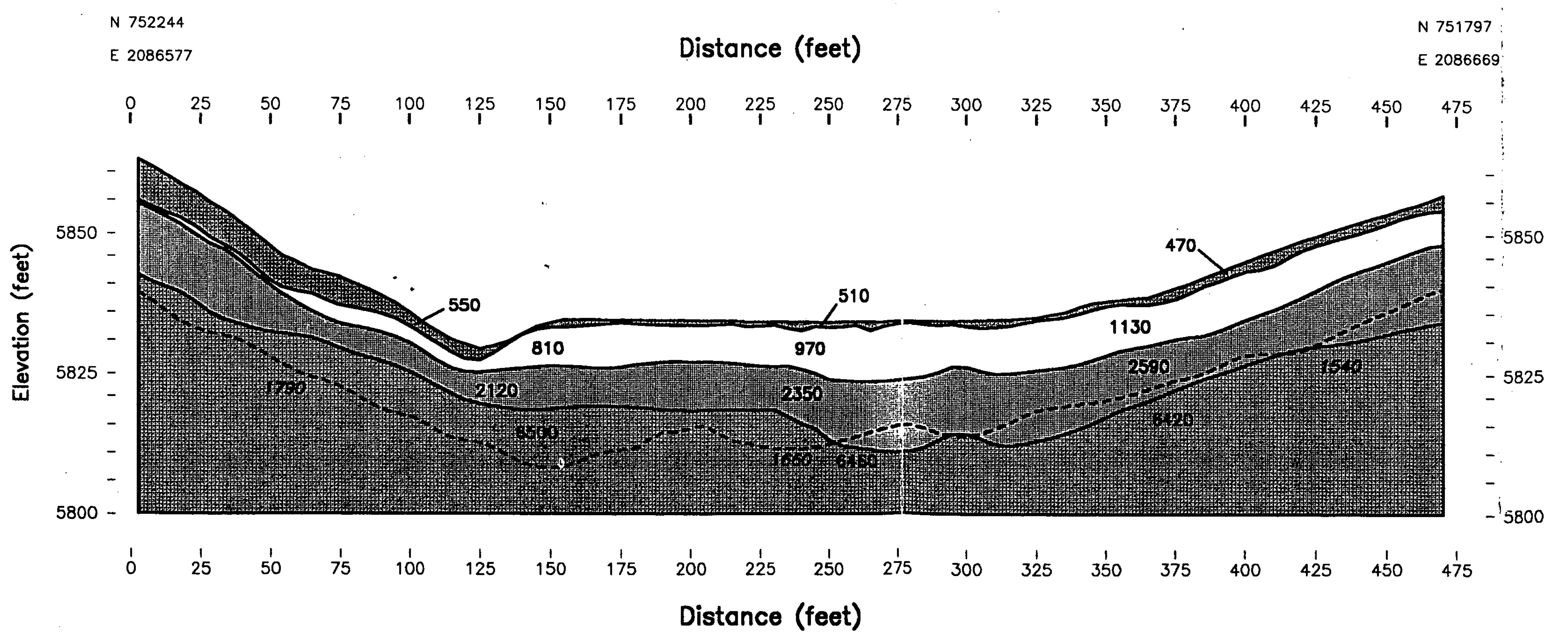
Figure 4.1.5-1B

OU4 Phase II RFI/RI
Seismic Line E

42



LINE F



- Top Soil/Colluvium/Fill
- Alluv./Colluvium/Compacted Fill
- Unsaturated Bedrock or UHSU2
- Saturated Bedrock or UHSU3

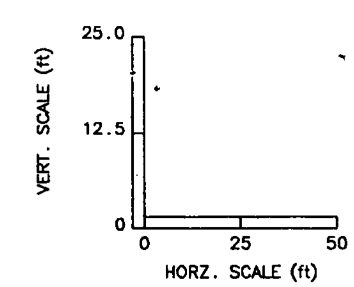
2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244 E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line



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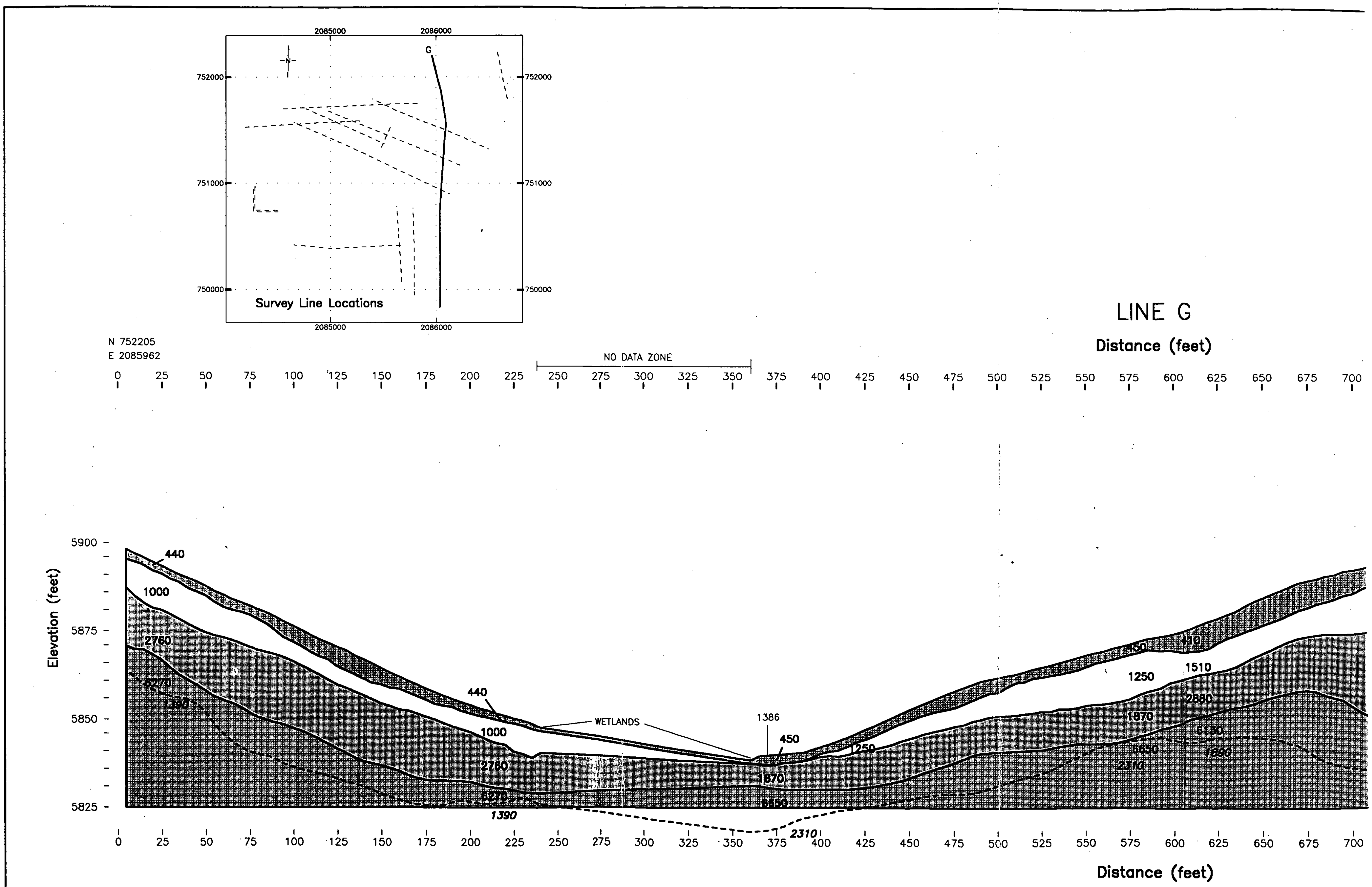
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE GOLDEN, COLORADO

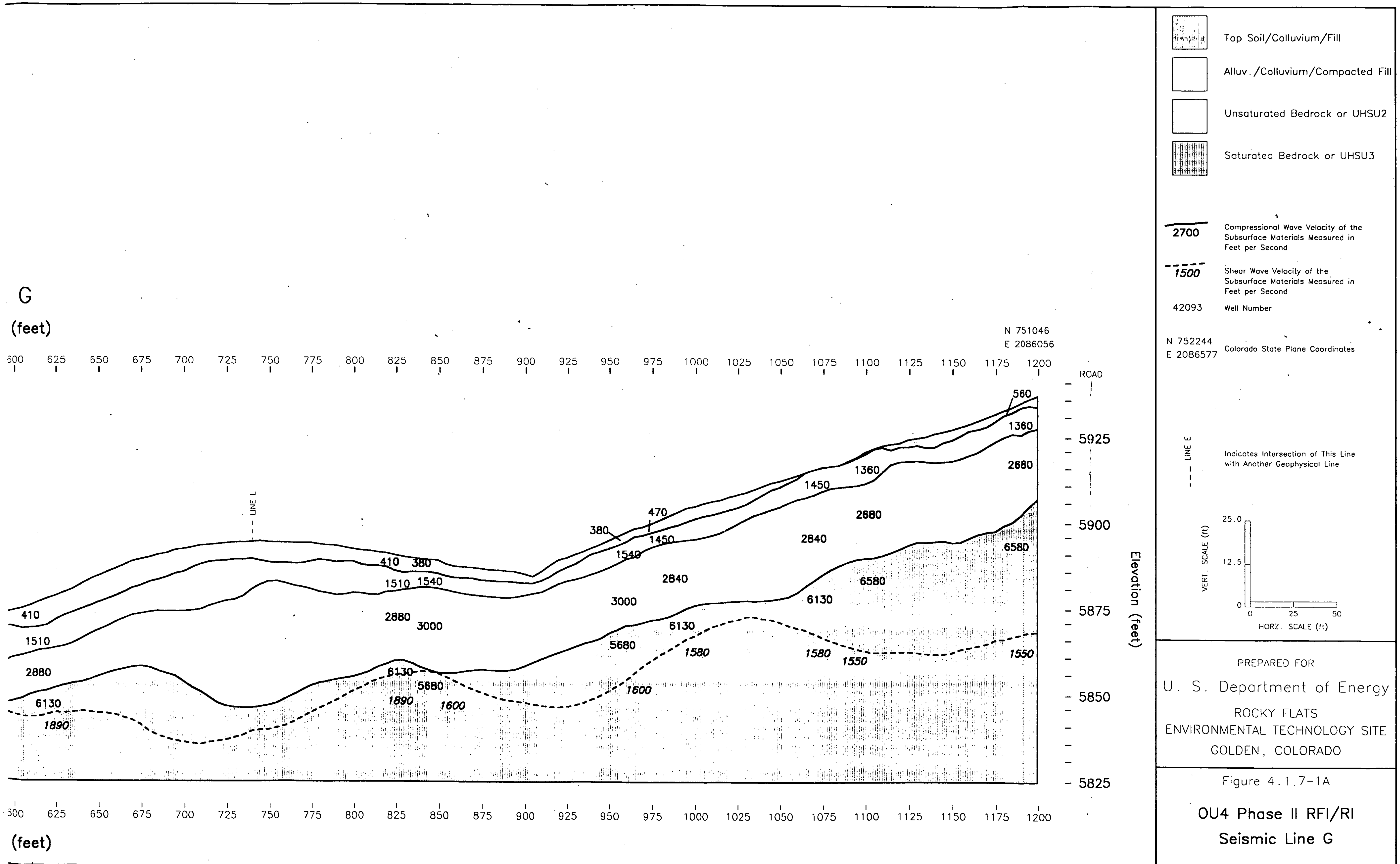
Figure 4.1.6-1

OU4 Phase II RFI/RI Seismic Line F

44


Survey Line Locations
2085000
2086000
752000
751000
750000
G
N 752205
E 2085962
LINE G
Distance (feet)
NO DATA ZONE
Elevation (feet)
WETLANDS
1386
440
1000
2760
6270
1390
1870
6850
2310
450
1250
1510
2880
6130
1890
410

46



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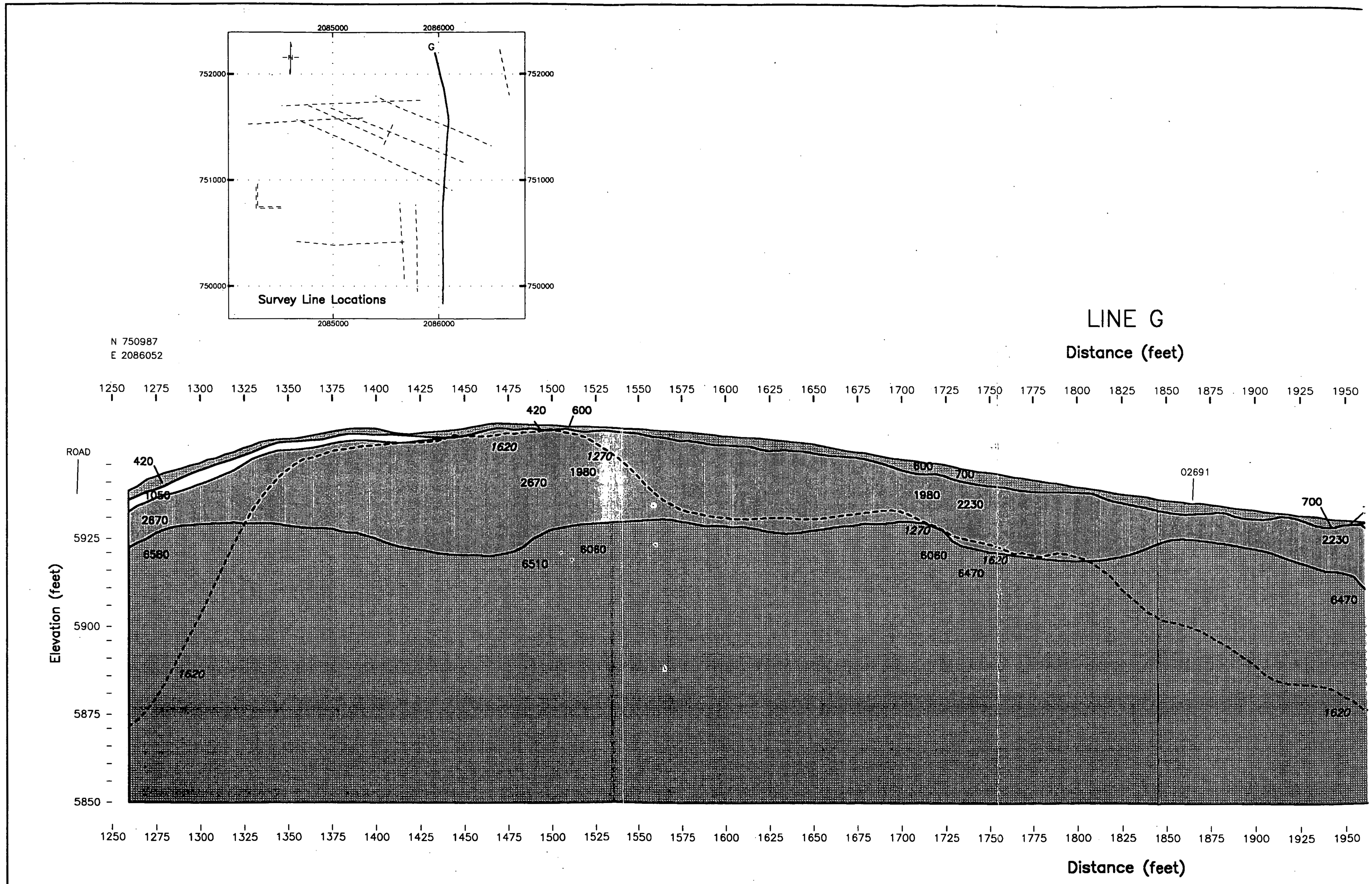
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.7-1A

OU4 Phase II RFI/RI
Seismic Line G

47

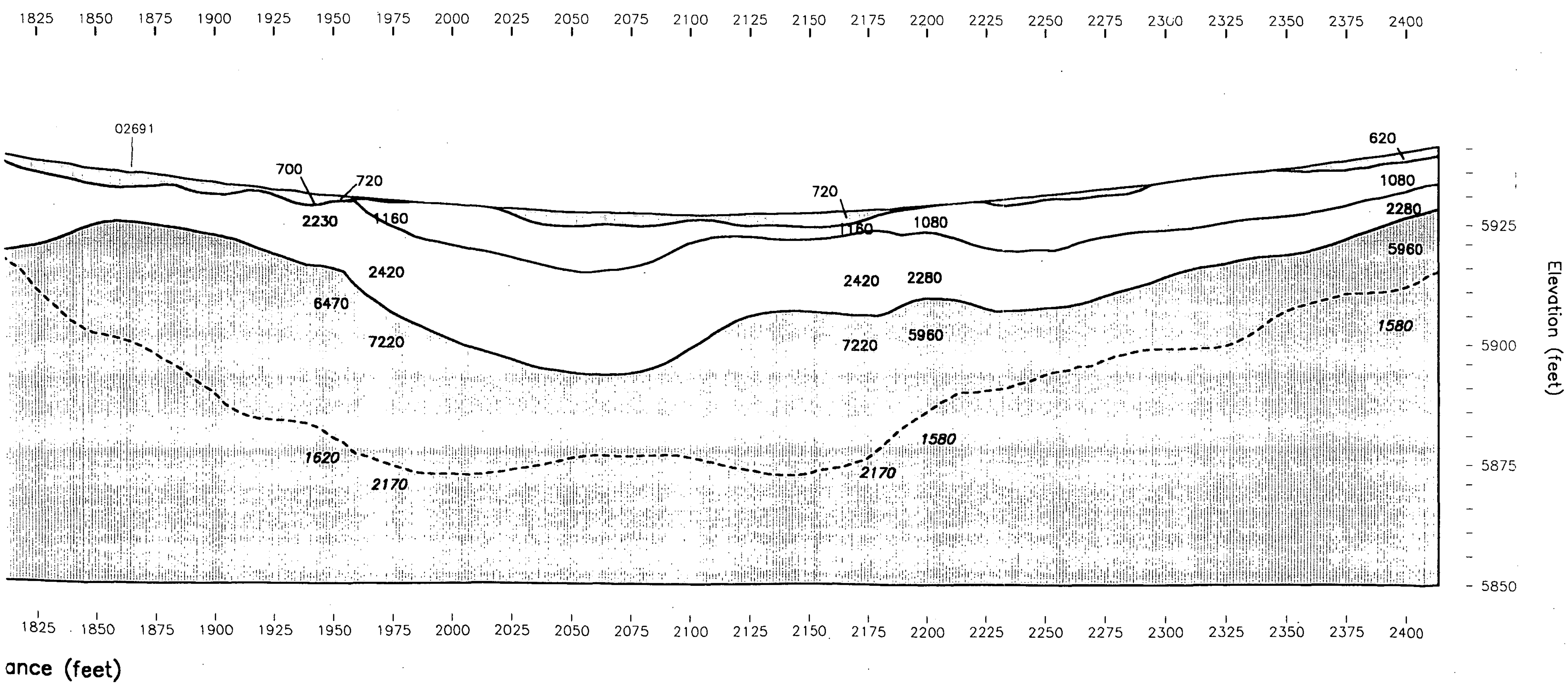


Survey Line Locations
2085000
2086000
752000
751000
750000
G
N
N 750987
E 2086052
LINE G
Distance (feet)
Elevation (feet)
ROAD
5925
5900
5875
5850
420
600
1050
2670
6580
1620
1270
1980
6510
6060
700
2230
6470
02691

.INE G

ance (feet)

N 749837
E 2086036



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line

VERT. SCALE (ft): 0, 12.5, 25.0
HORZ. SCALE (ft): 0, 25, 50

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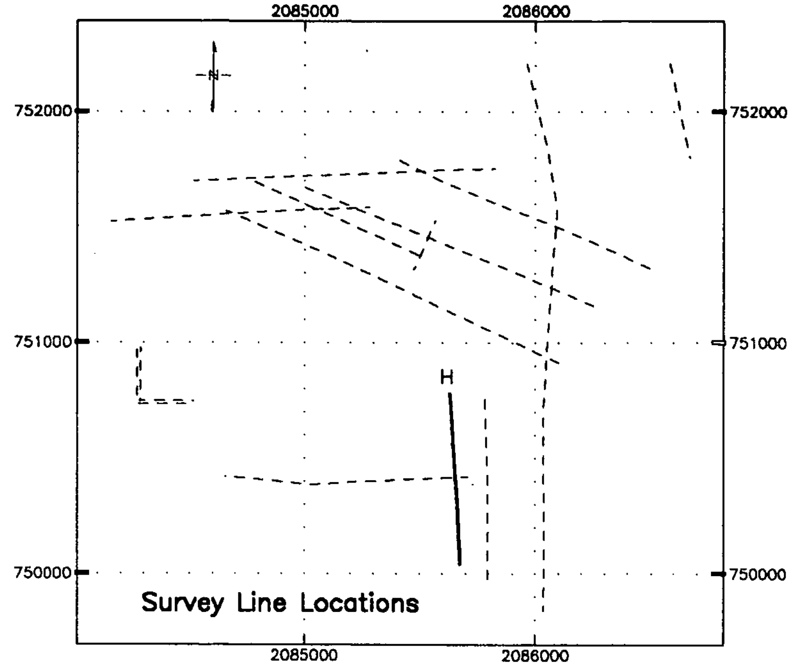
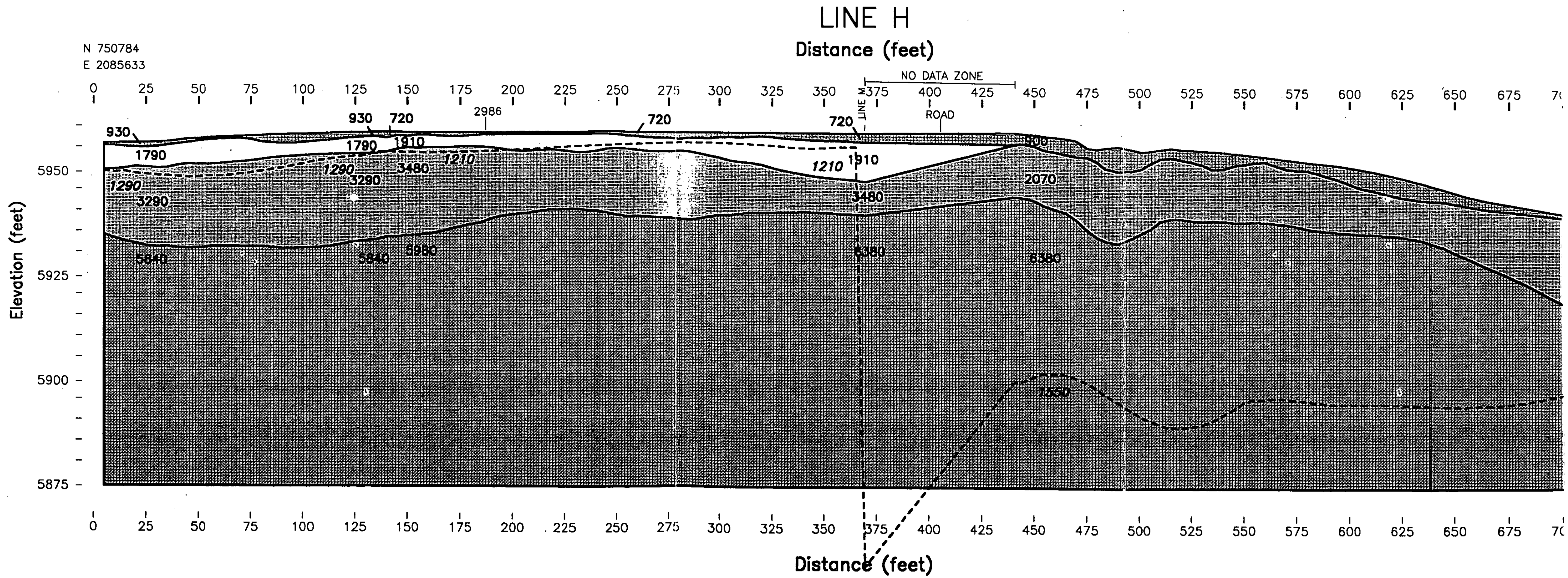
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.7-1B

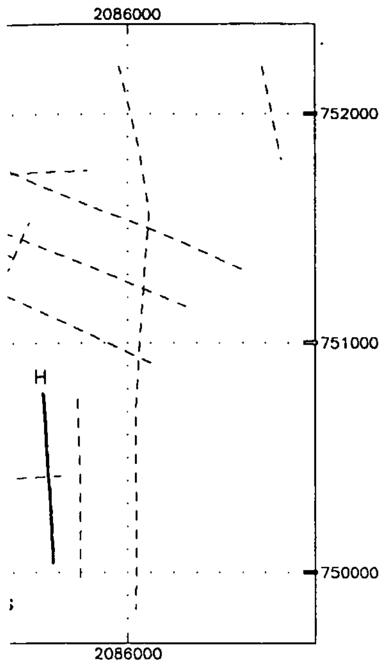
OU4 Phase II RFI/RI
Seismic Line G



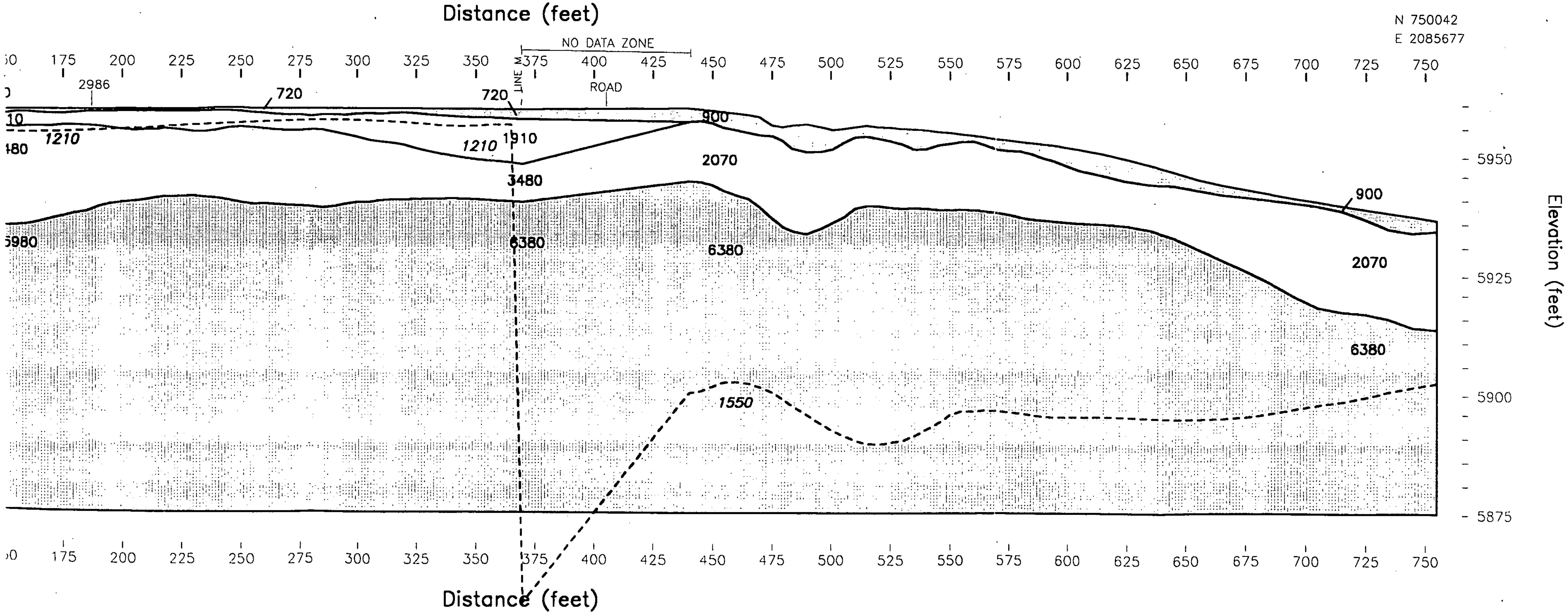
Survey Line Locations
2085000
2086000
752000
751000
750000
H



LINE H
Distance (feet)
N 750784
E 2085633
NO DATA ZONE
ROAD
LINE M
Elevation (feet)
5950
5925
5900
5875
930
720
2986
1790
1910
1290
3290
3480
1210
2070
5840
5980
6380
1550
Distance (feet)



LINE H



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

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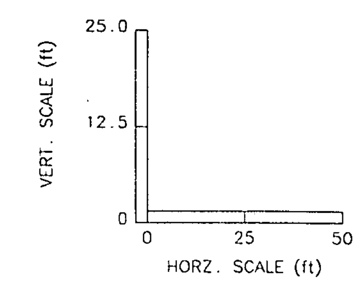
42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line



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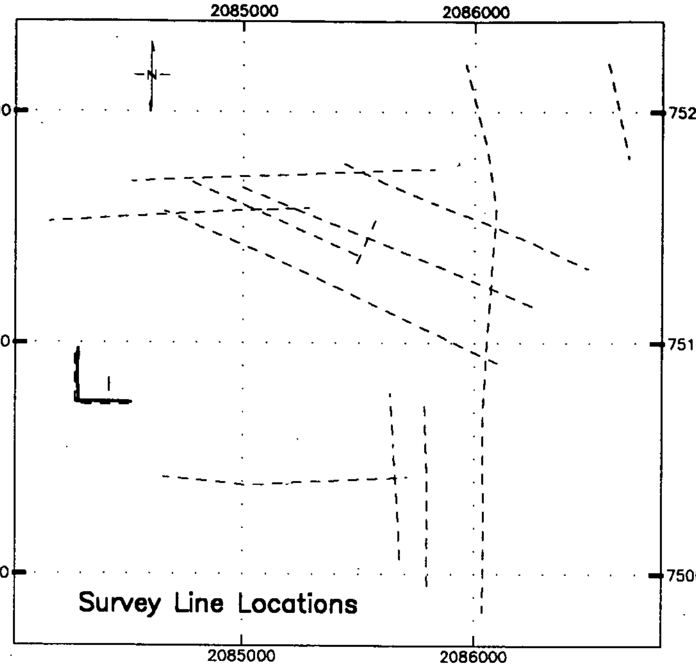
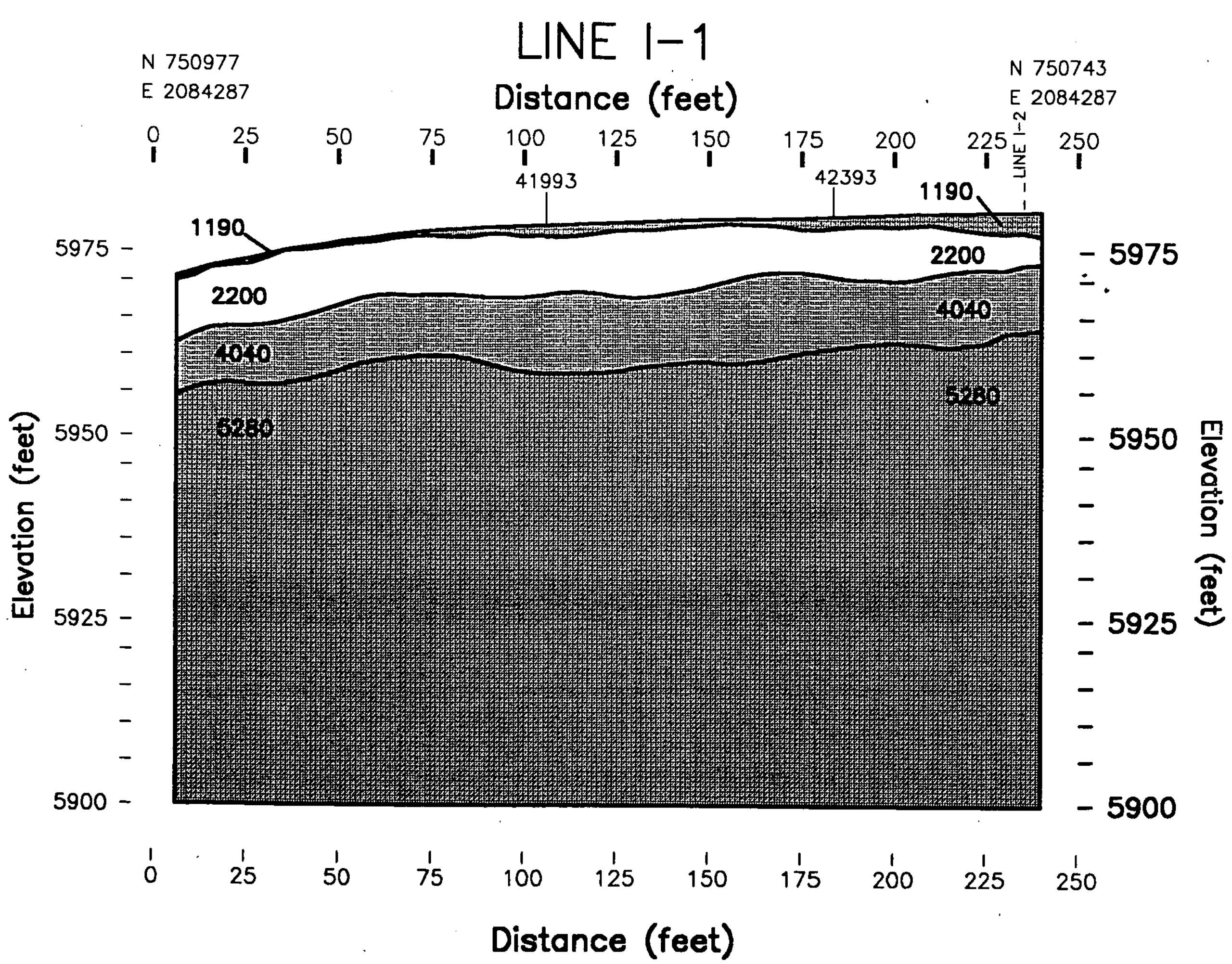
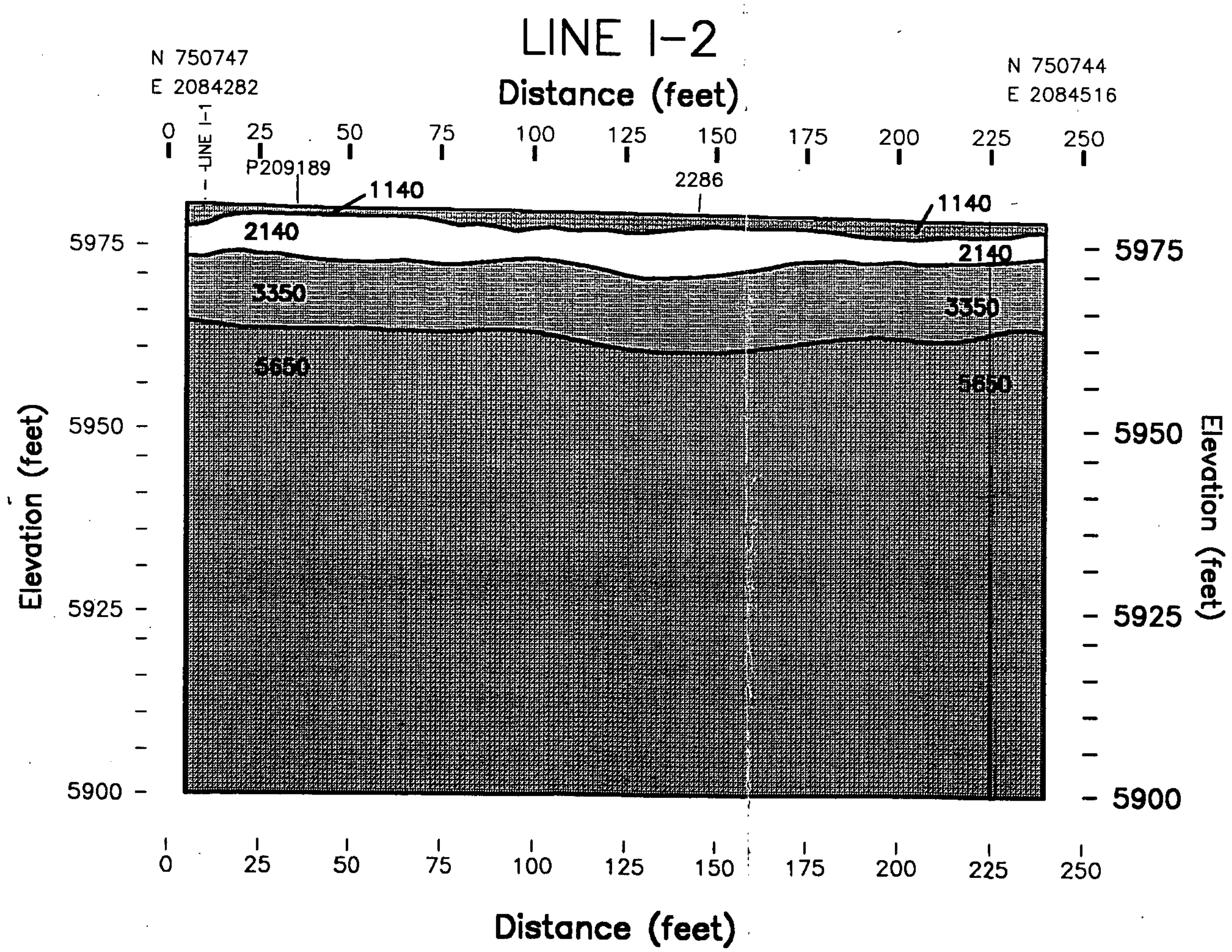
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.8-1

OU4 Phase II RFI/RI
Seismic Line H







2700

1500

42093

N 75224
E 20865

LINE E

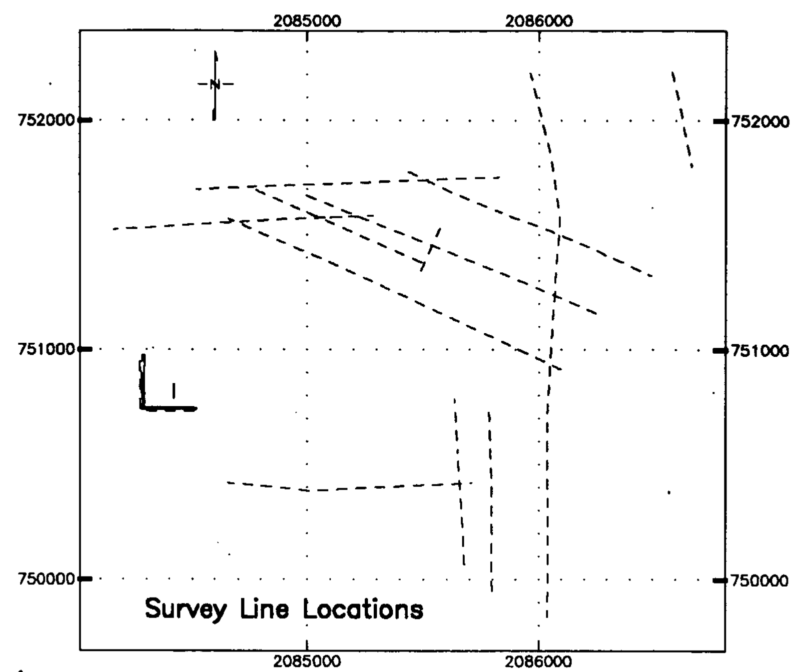
VERT. SCALE (ft)

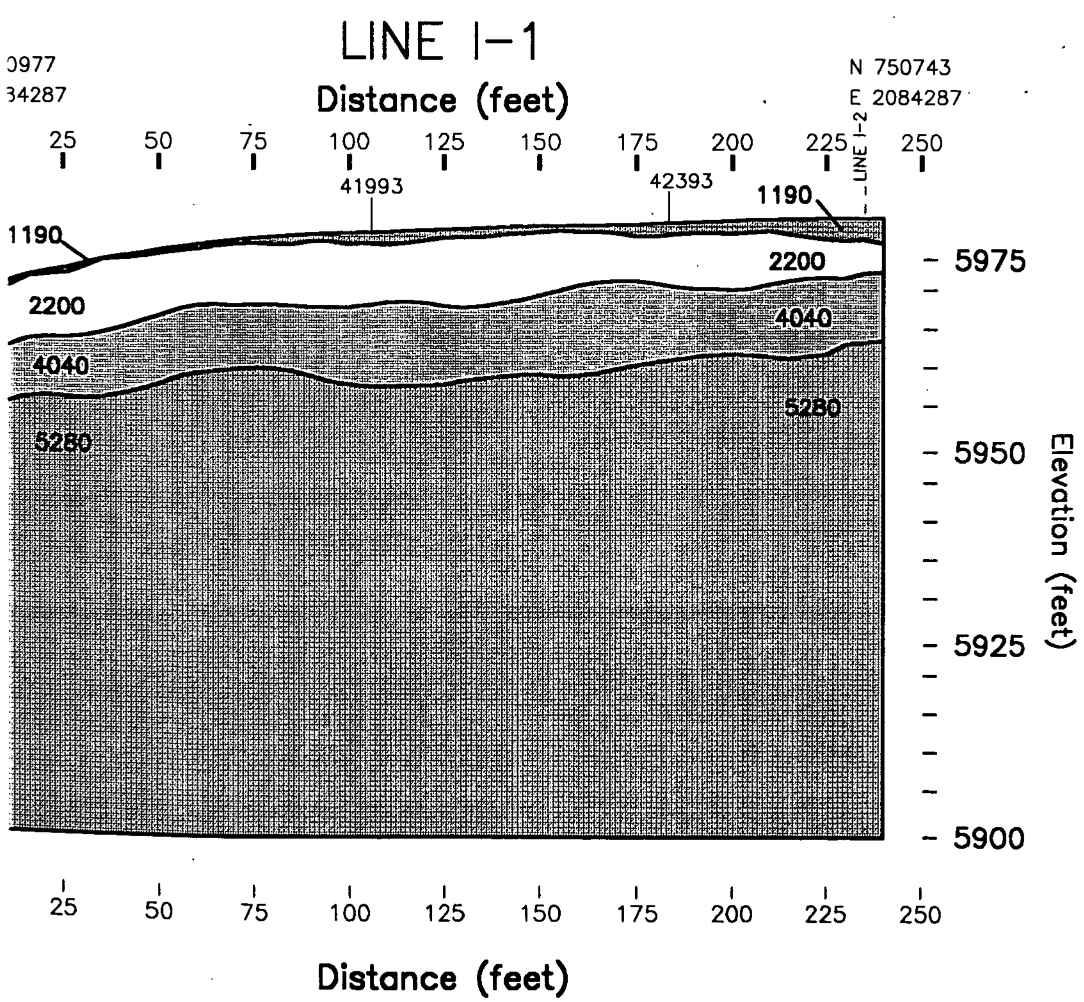
U. S.

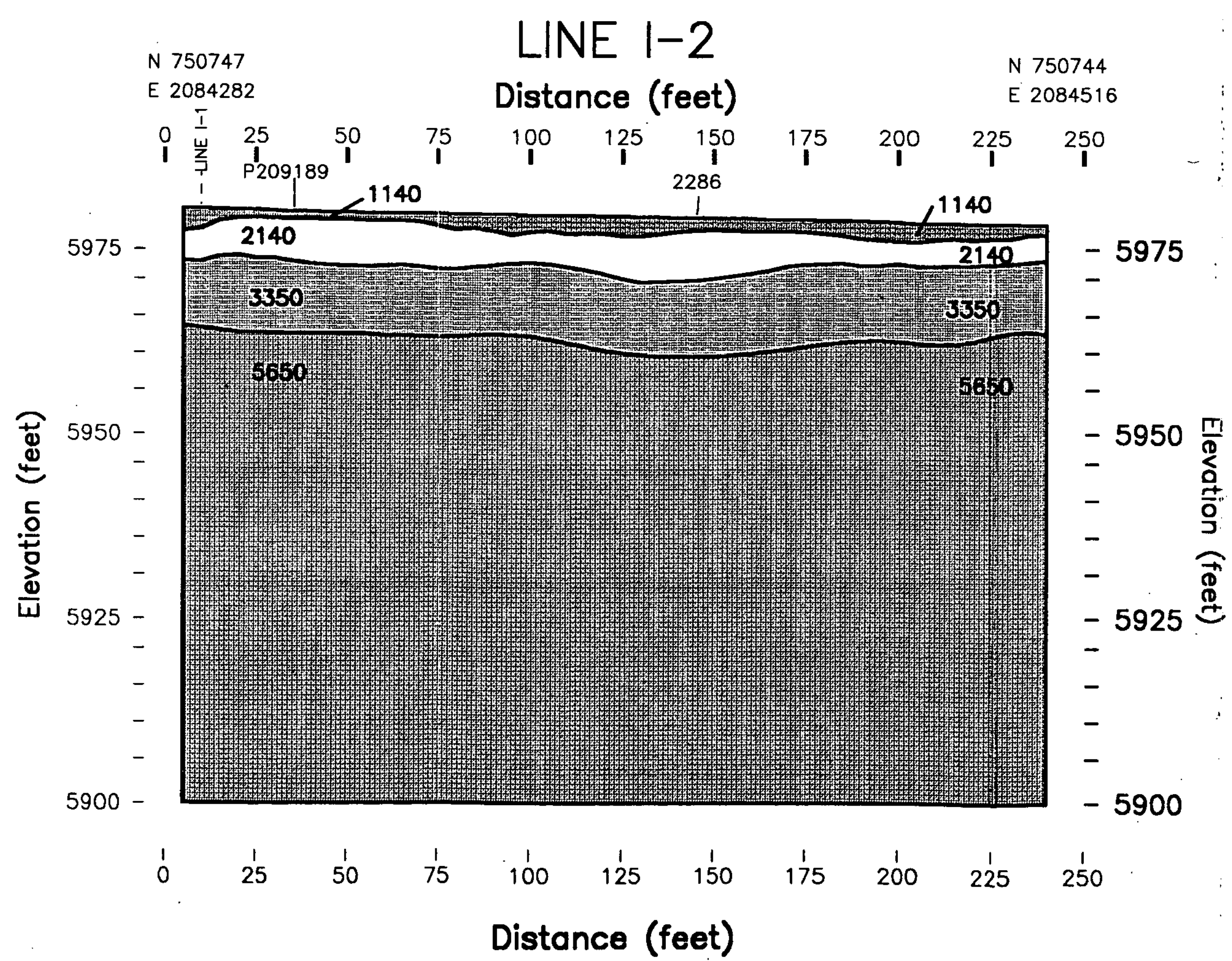
ENVIRO

OL

53







Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

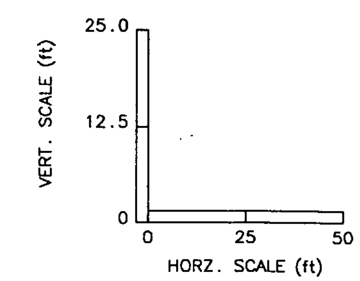
2700 Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 Well Number

N 752244
E 2086577 Colorado State Plane Coordinates

LINE E Indicates Intersection of This Line with Another Geophysical Line



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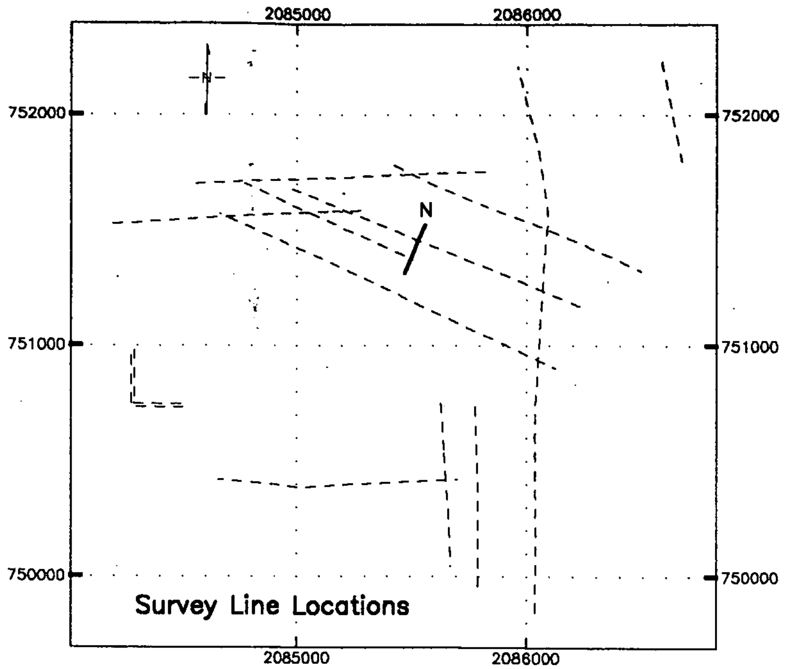
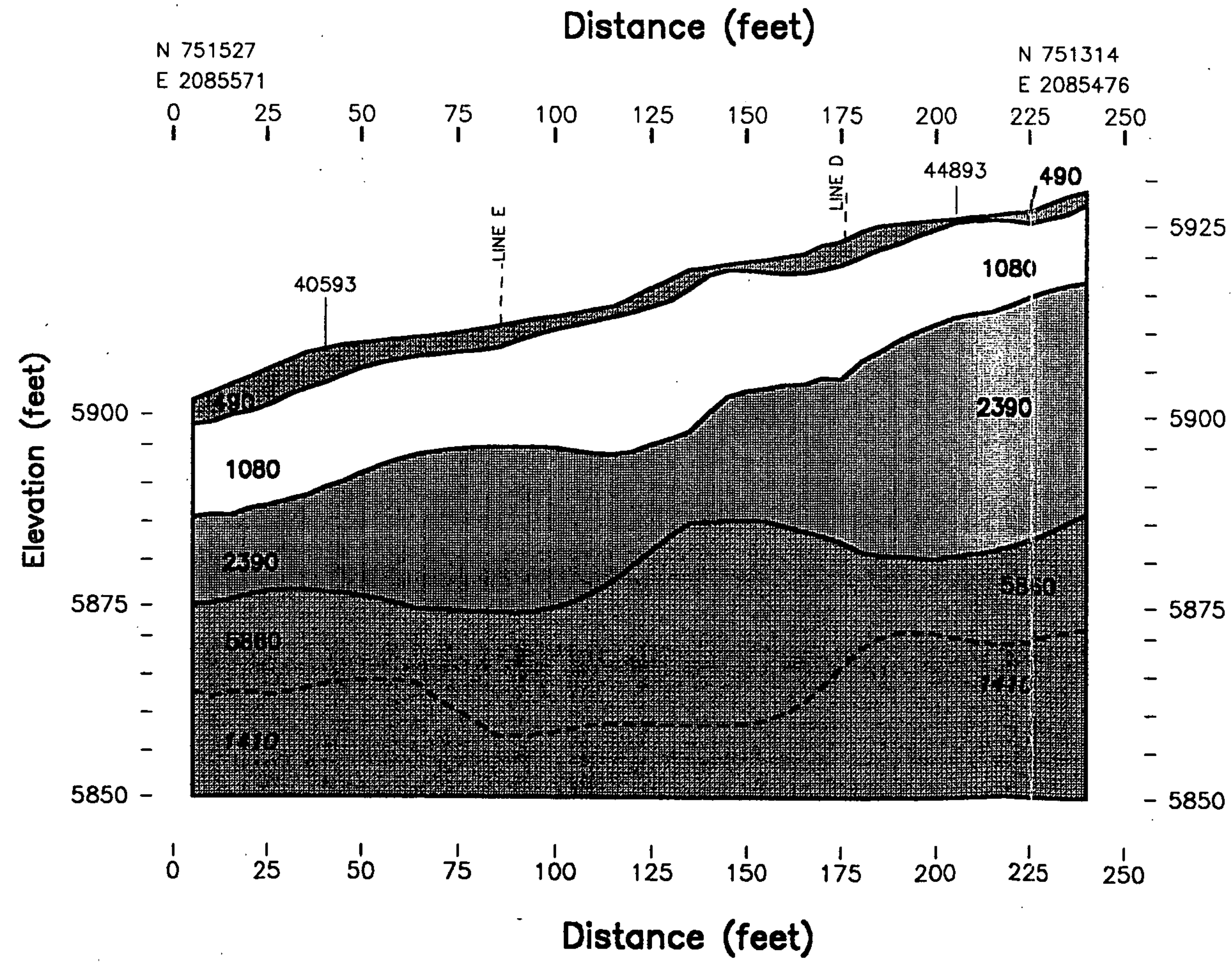
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.9-1

OU4 Phase II RFI/RI
Seismic Line I



LINE N



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

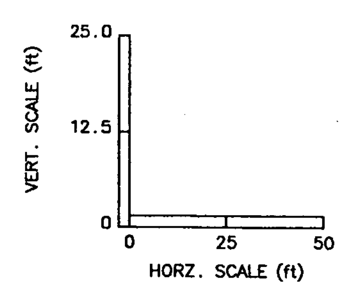
2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line



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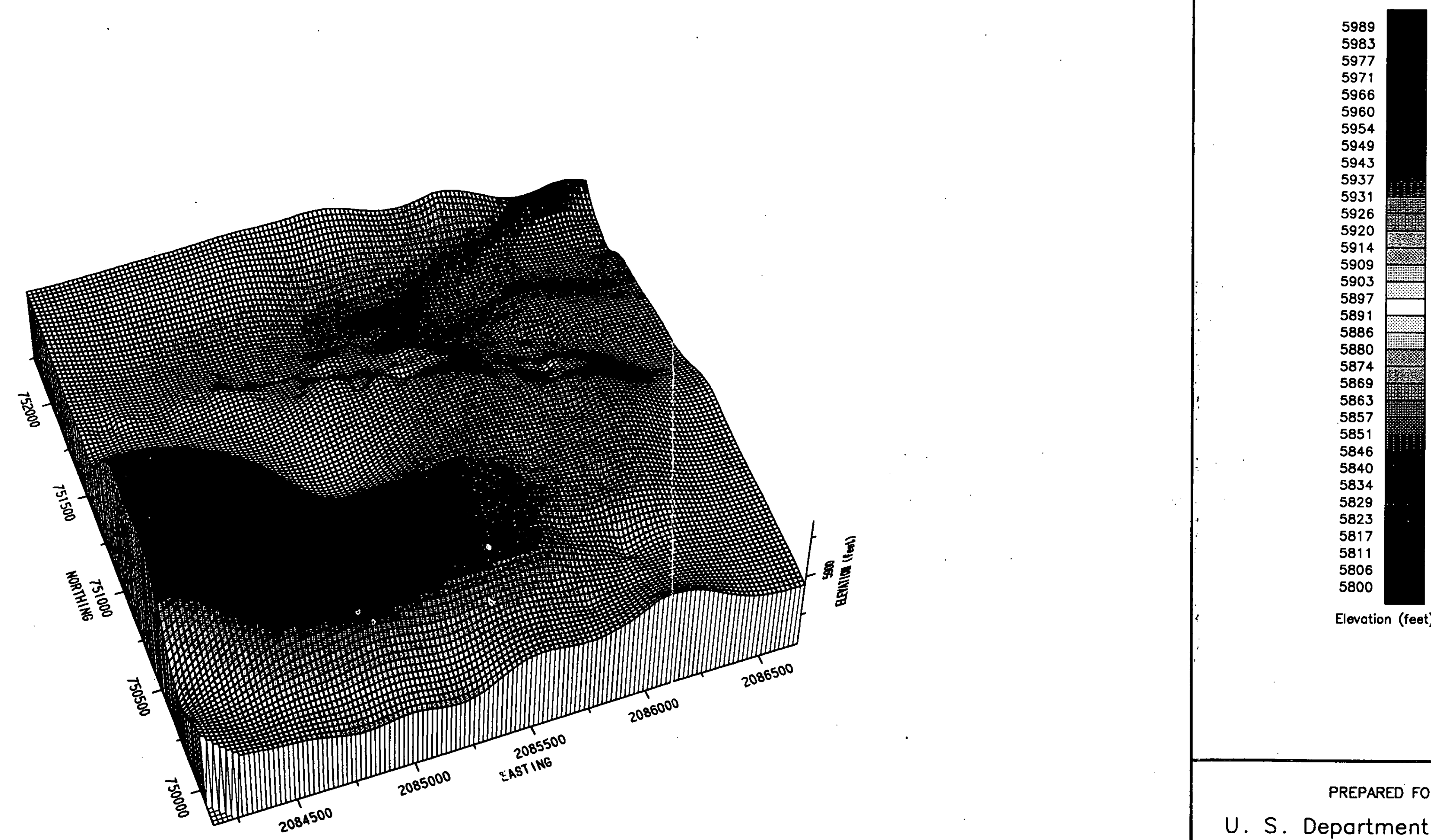
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.14-1

OU4 Phase II RFI/RI
Seismic Line N



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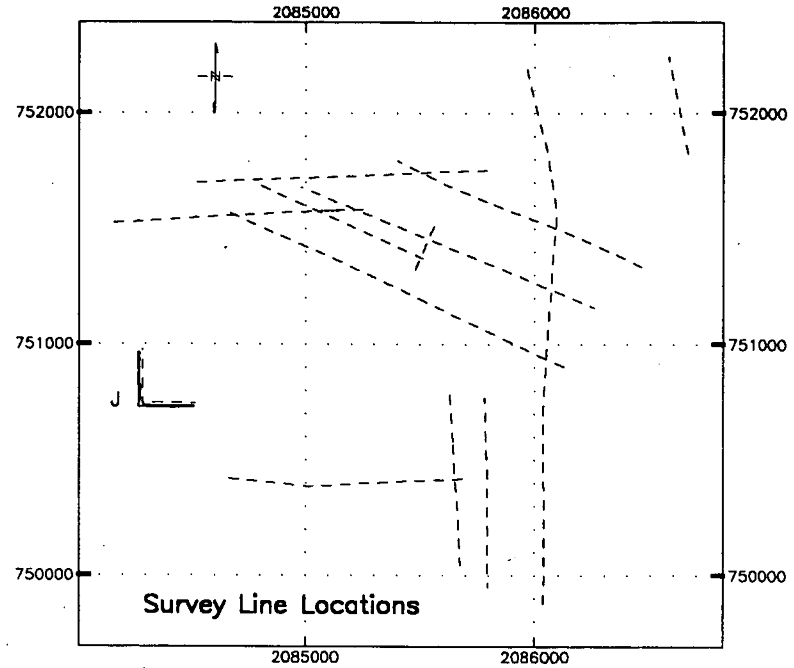
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

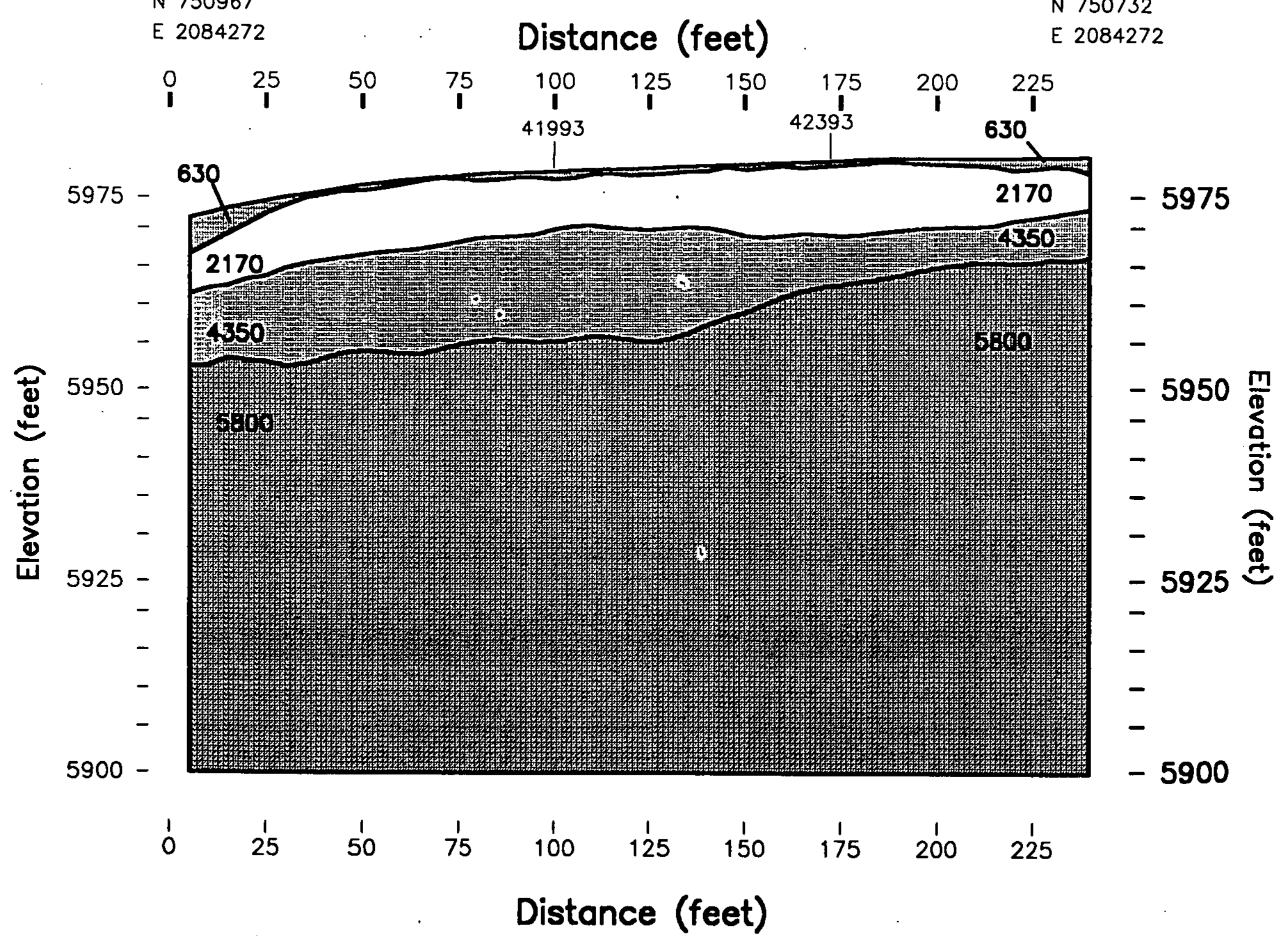
Figure 5.0-2

OU4 Phase II RFI/RI
Top of Saturated Bedrock
(Derived from P-Wave Data)

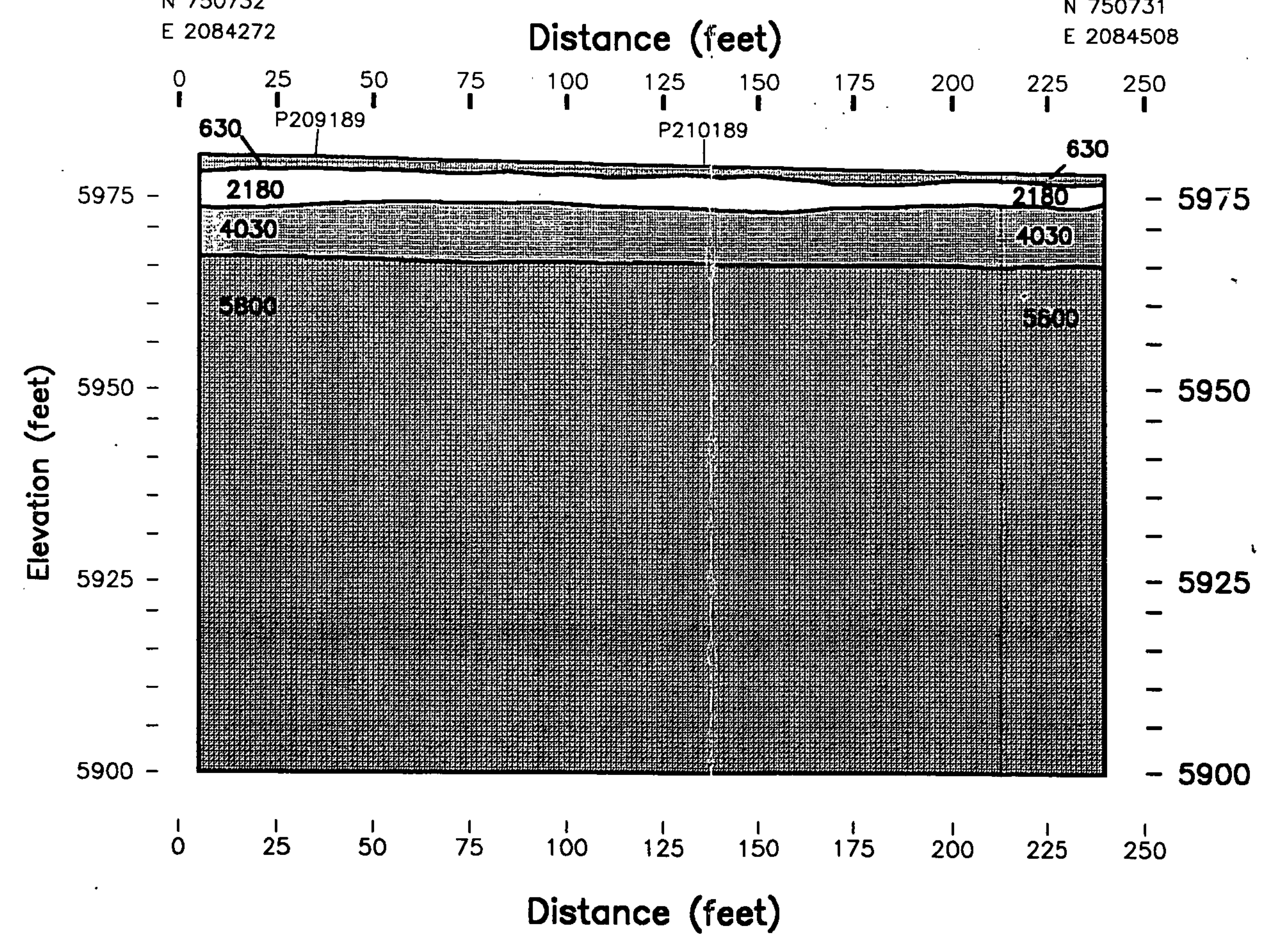
70

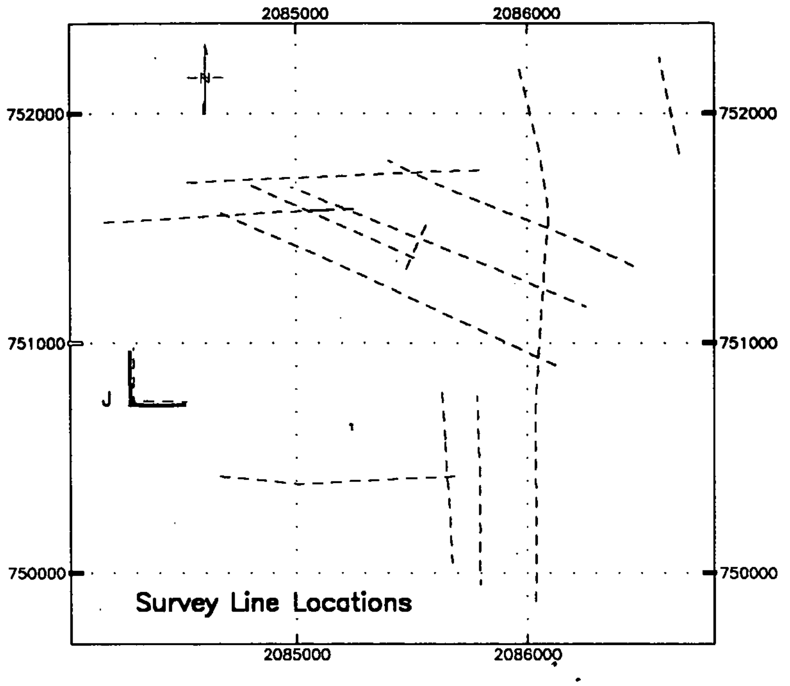


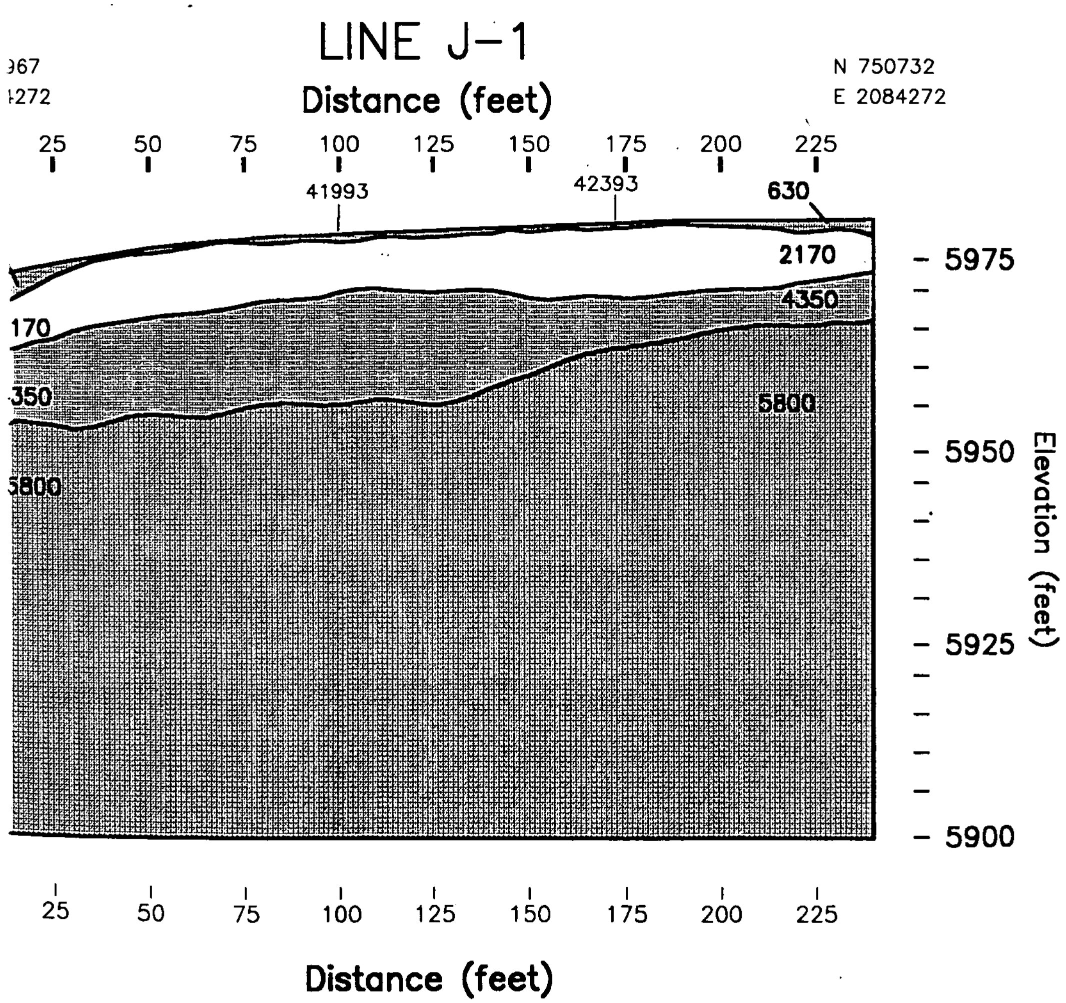
LINE J-1

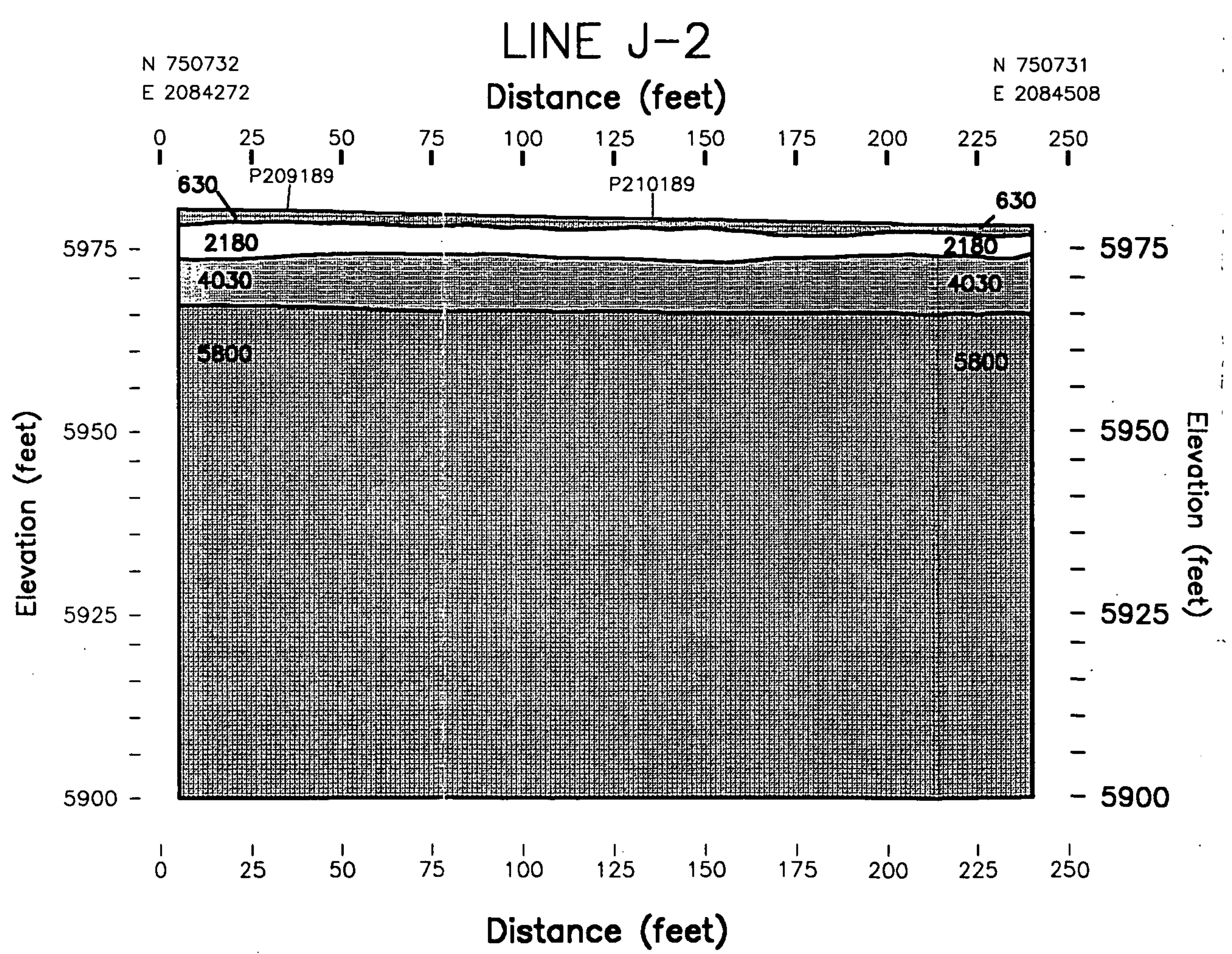


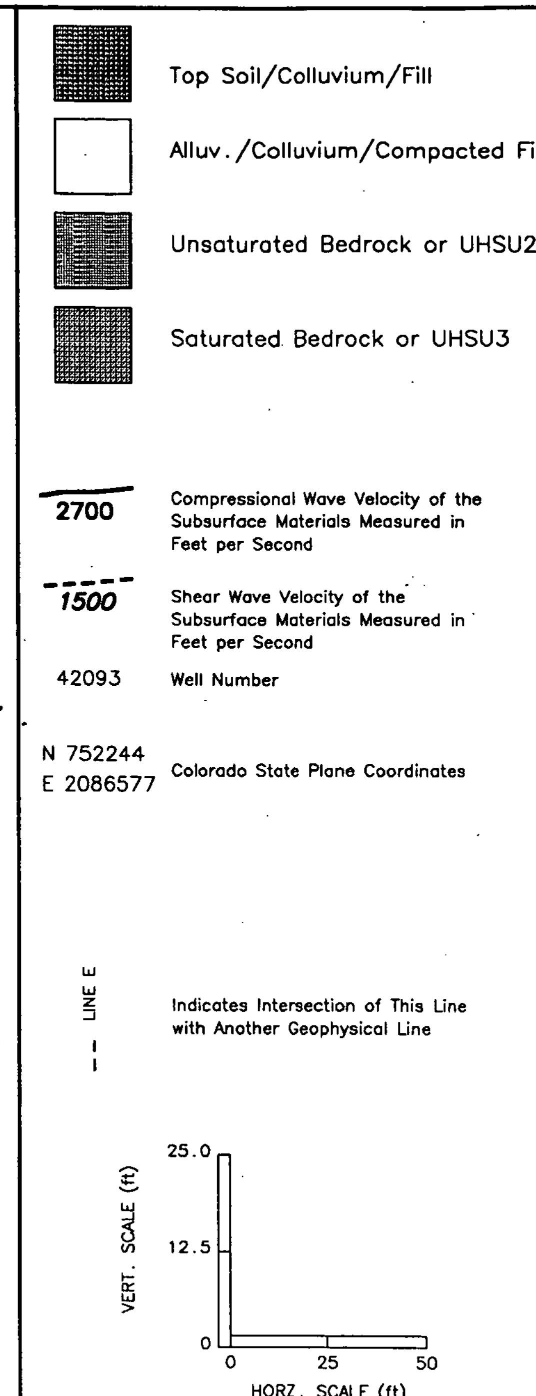
LINE J-2











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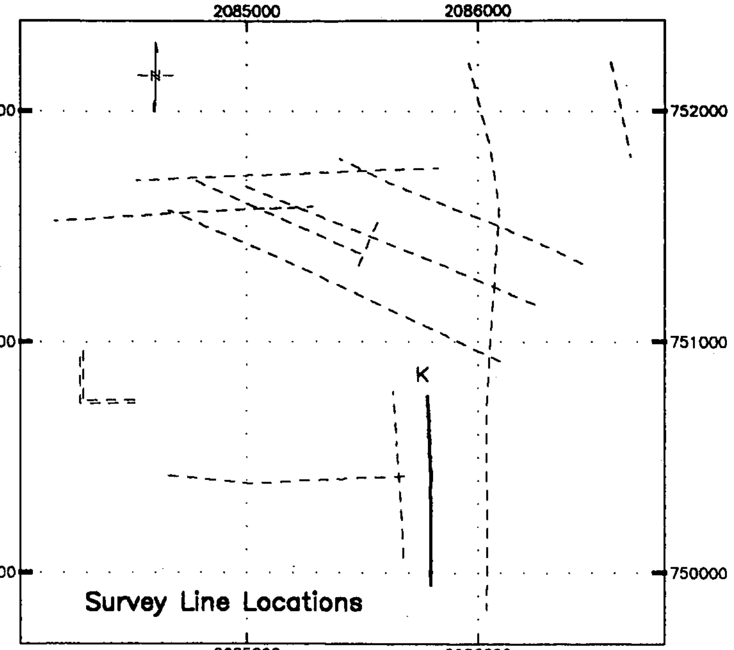
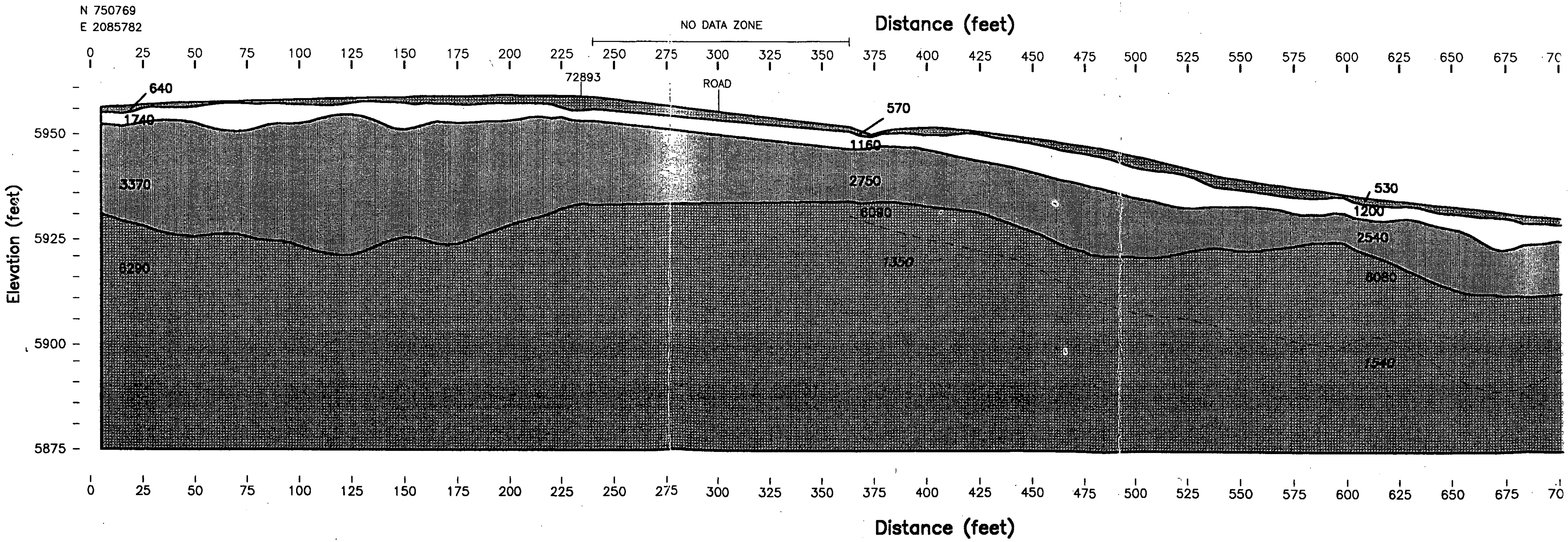
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

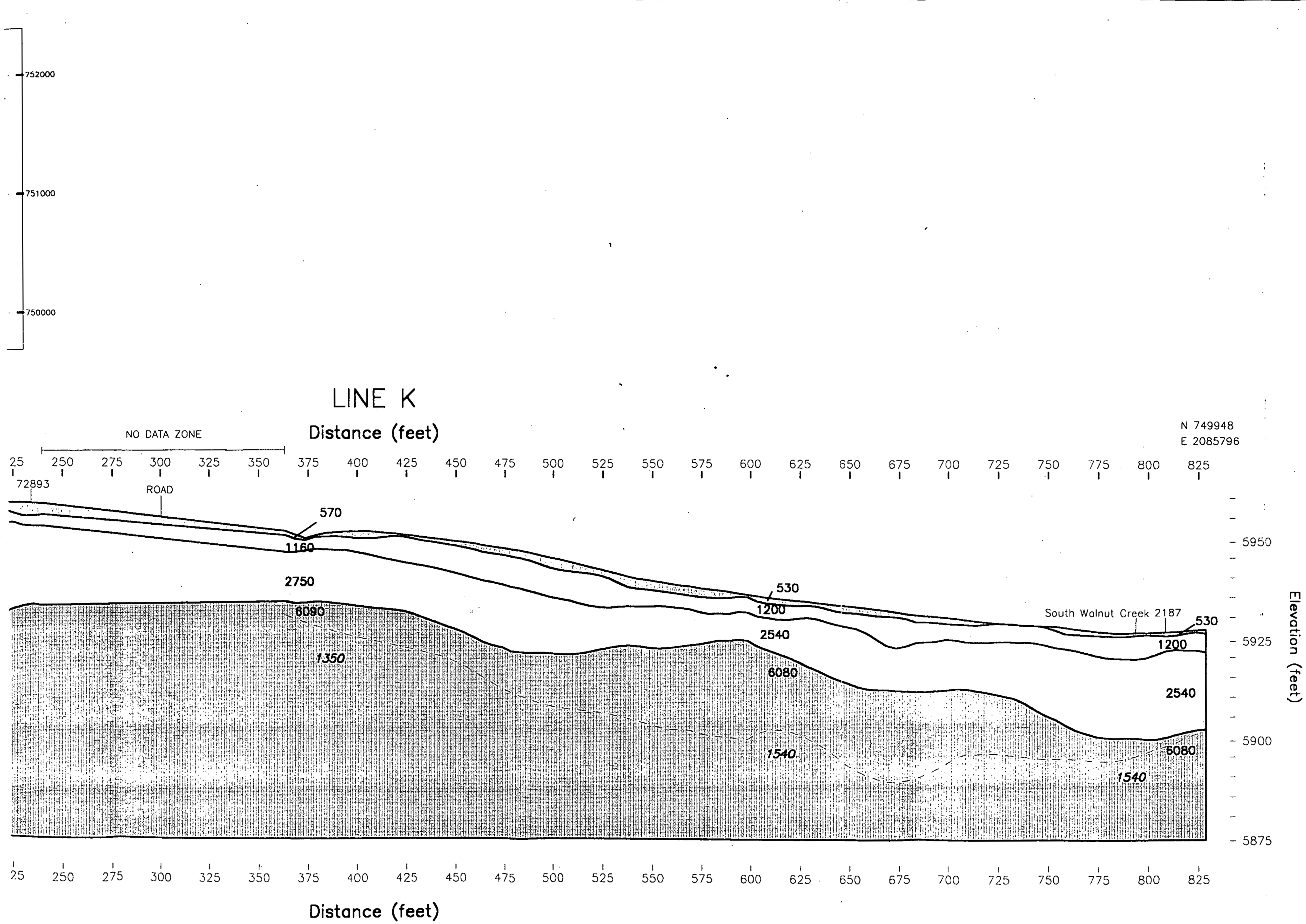
Figure 4.1.10-1

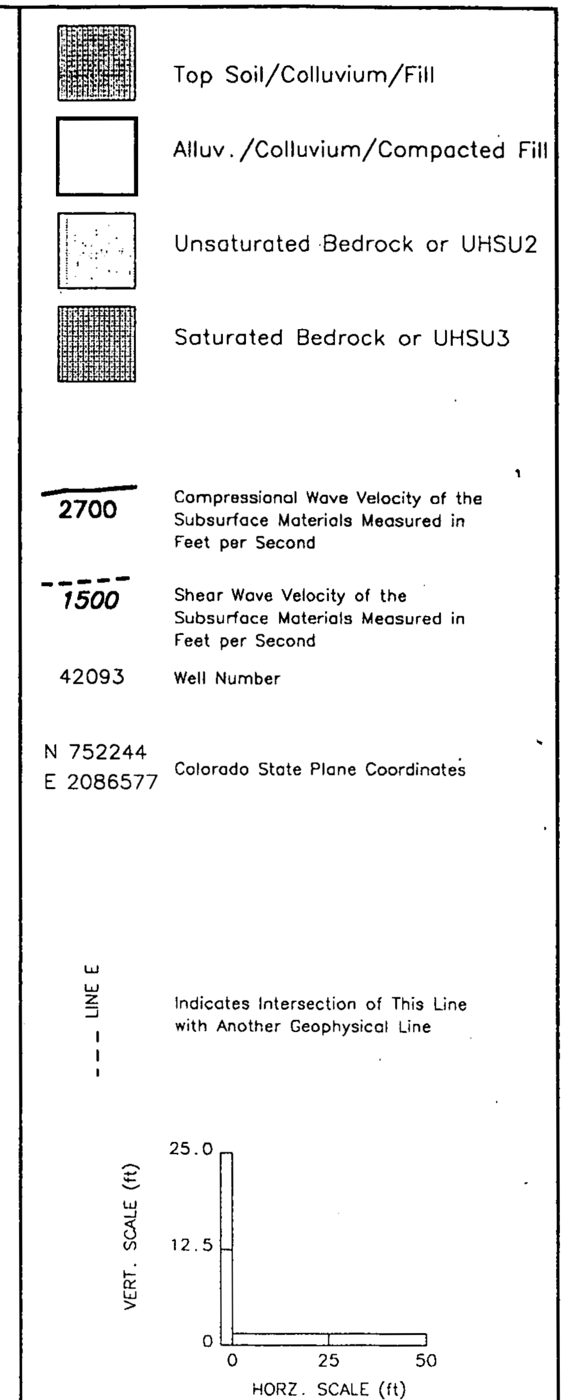
OU4 Phase II RFI/RI
Seismic Line J


2085000
2086000
752000
751000
750000
N
K
Survey Line Locations

LINE K


N 750769
E 2085782
NO DATA ZONE
Distance (feet)
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625 650 675 70
72893
ROAD
640
1740
3370
6290
570
1160
2750
6080
7350
530
1200
2540
6080
1540
Elevation (feet)
5950
5925
5900
5875





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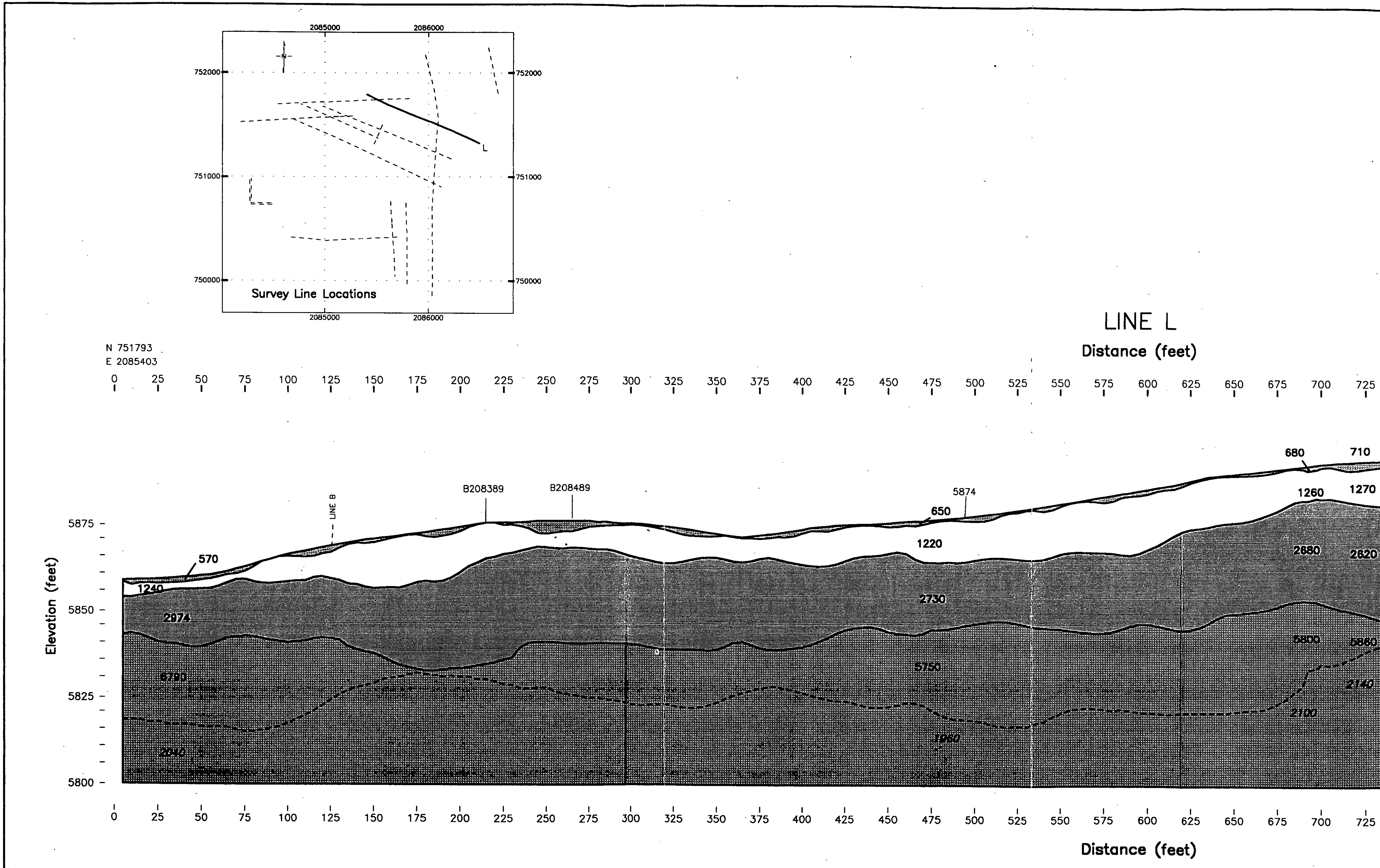
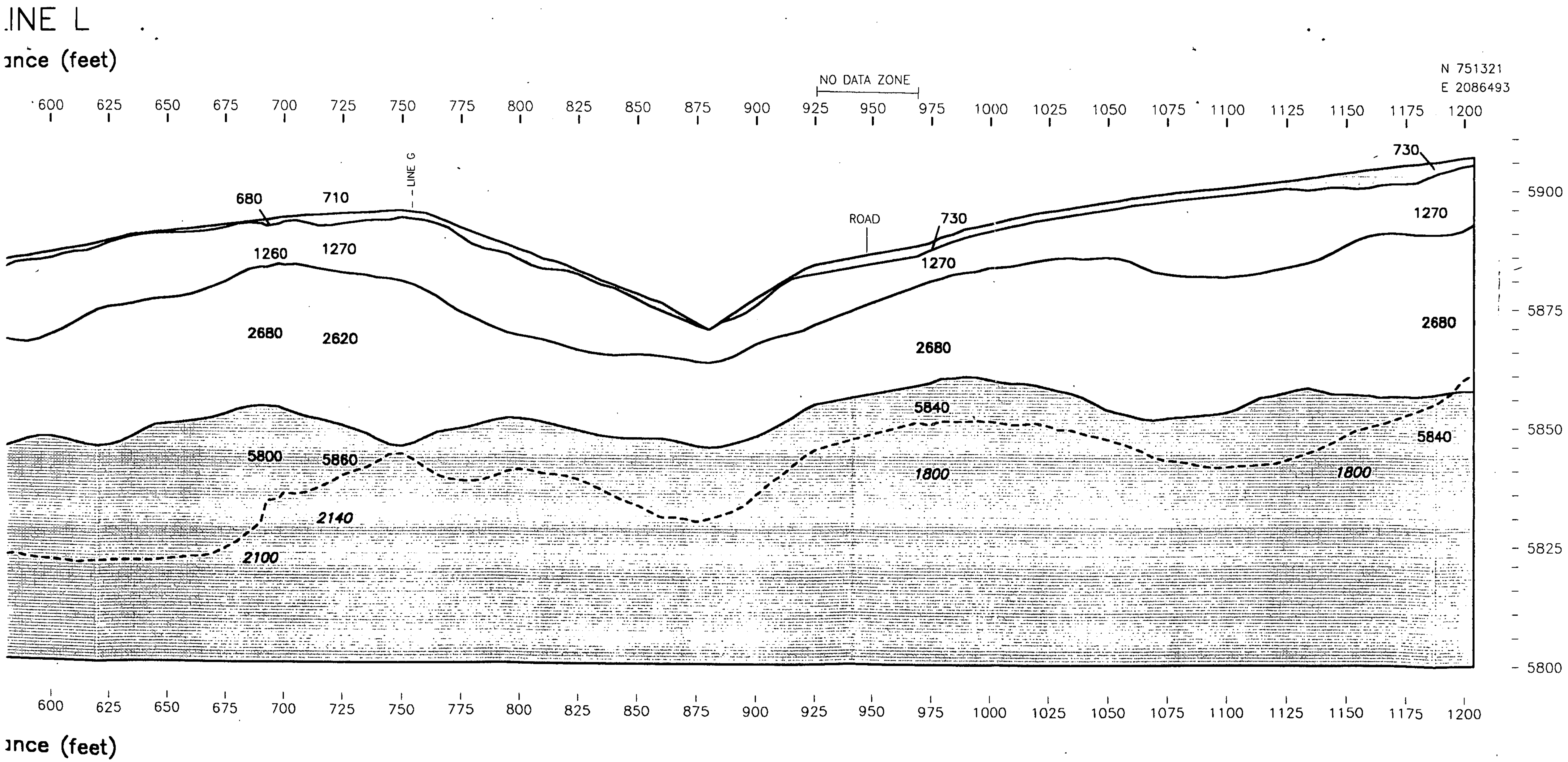
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.11-1

OU4 Phase II RFI/RI
Seismic Line K


Survey Line Locations
2085000
2086000
752000
751000
750000
N
L
LINE L
Distance (feet)
N 751793
E 2085403
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650
675
700
725
Elevation (feet)
5875
5850
5825
5800
LINE B
B208389
B208489
5874
570
1240
2974
5790
2040
650
1220
2730
5750
1960
680
710
1260
1270
2680
2620
5800
5860
2140
2100
Distance (feet)



Top Soil/Colluvium/Fill

Alluv./Colluvium/Compacted Fill

Unsaturated Bedrock or UHSU2

Saturated Bedrock or UHSU3

2700 — Compressional Wave Velocity of the Subsurface Materials Measured in Feet per Second

1500 — Shear Wave Velocity of the Subsurface Materials Measured in Feet per Second

42093 — Well Number

N 752244
E 2086577 — Colorado State Plane Coordinates

LINE E — Indicates Intersection of This Line with Another Geophysical Line

VERT. SCALE (ft): 0, 12.5, 25.0

HORZ. SCALE (ft): 0, 25, 50

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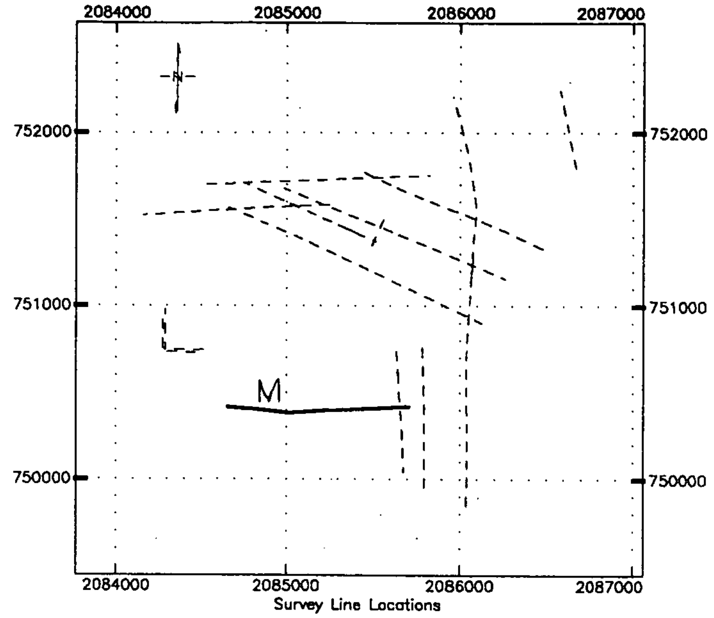
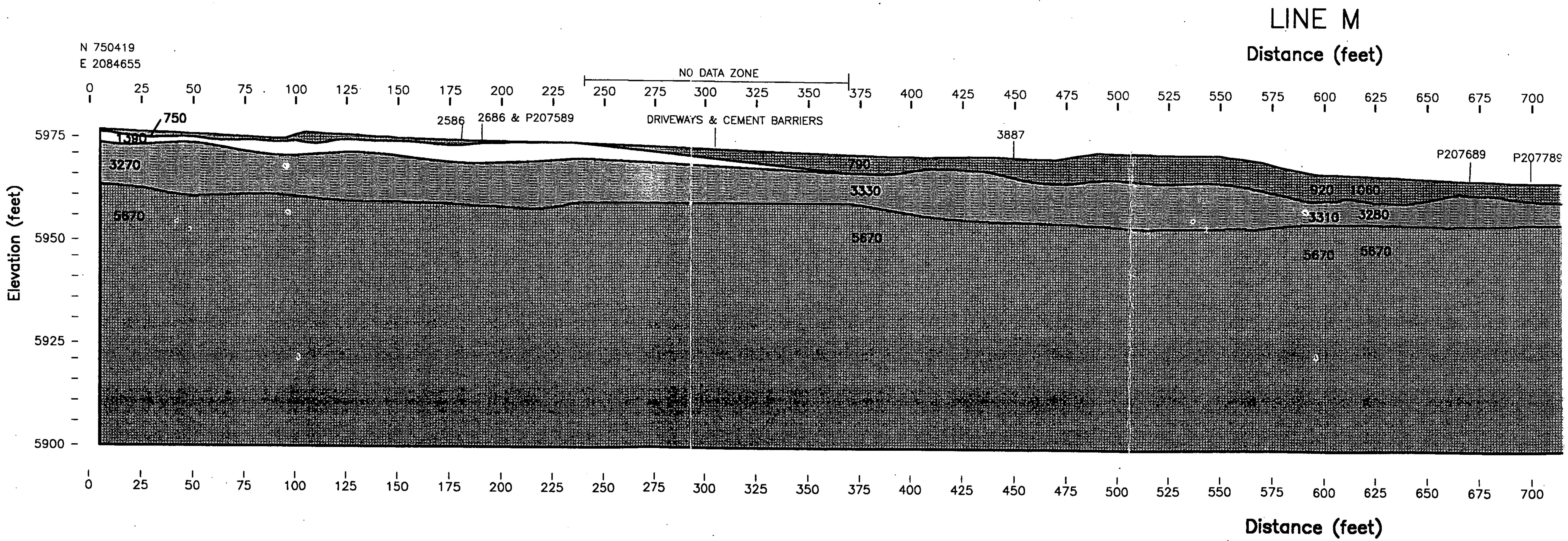
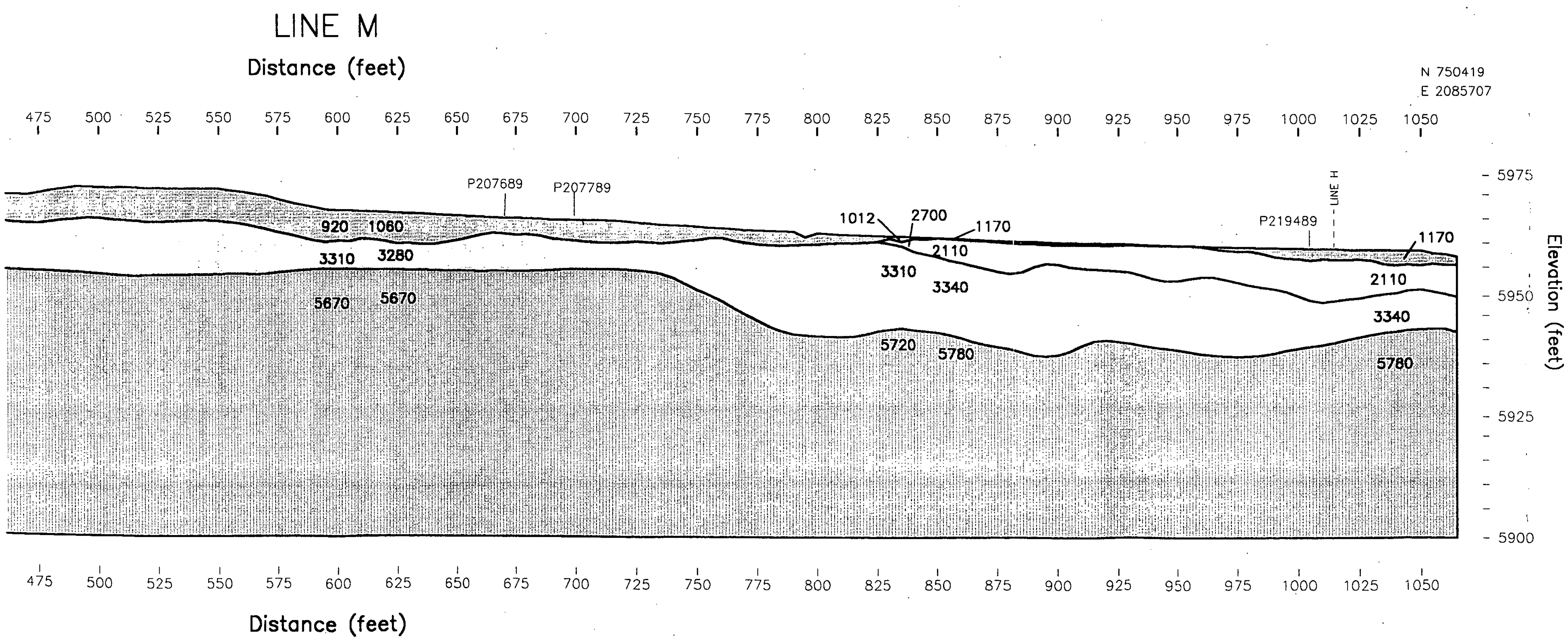
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

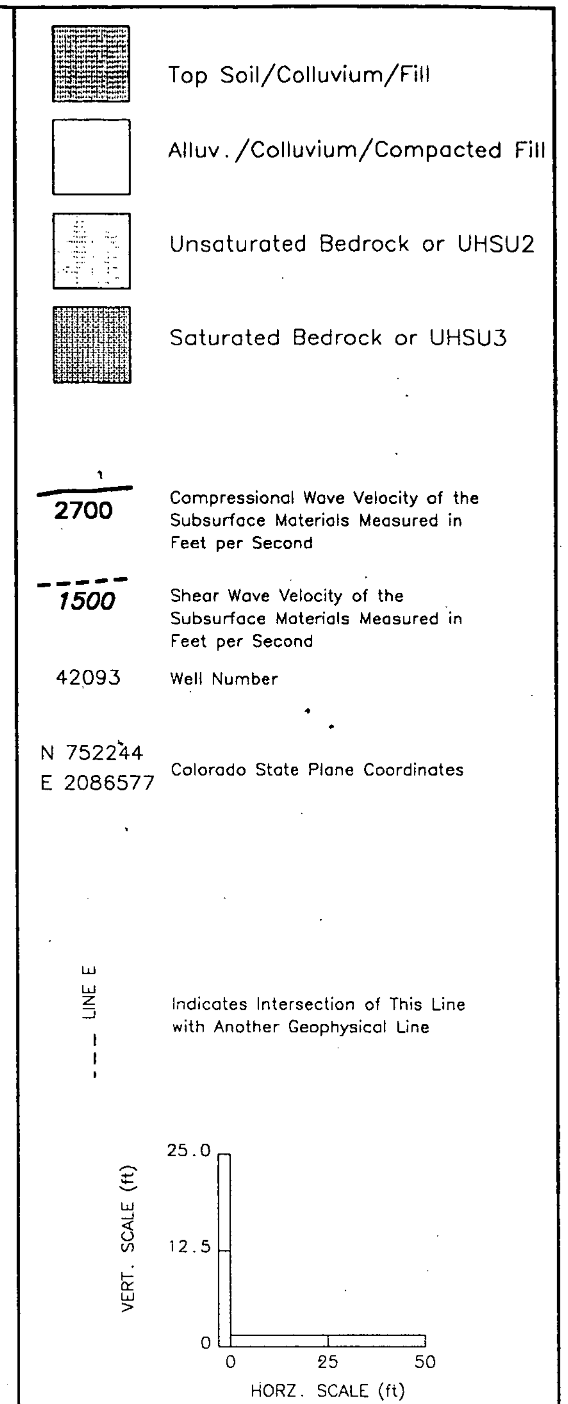
Figure 4.1.12-1

OU4 Phase II RFI/RI
Seismic Line L


2084000
2085000
2086000
2087000
752000
751000
750000
N
M
Survey Line Locations


LINE M
Distance (feet)
N 750419
E 2084655
NO DATA ZONE
DRIVEWAYS & CEMENT BARRIERS
0 25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625 650 675 700
750
1380
3270
5670
2586
2686 & P207589
3887
790
3330
5670
920
1060
3310
3280
5670
5670
P207689
P207789
5975
5950
5925
5900
Elevation (feet)
Distance (feet)





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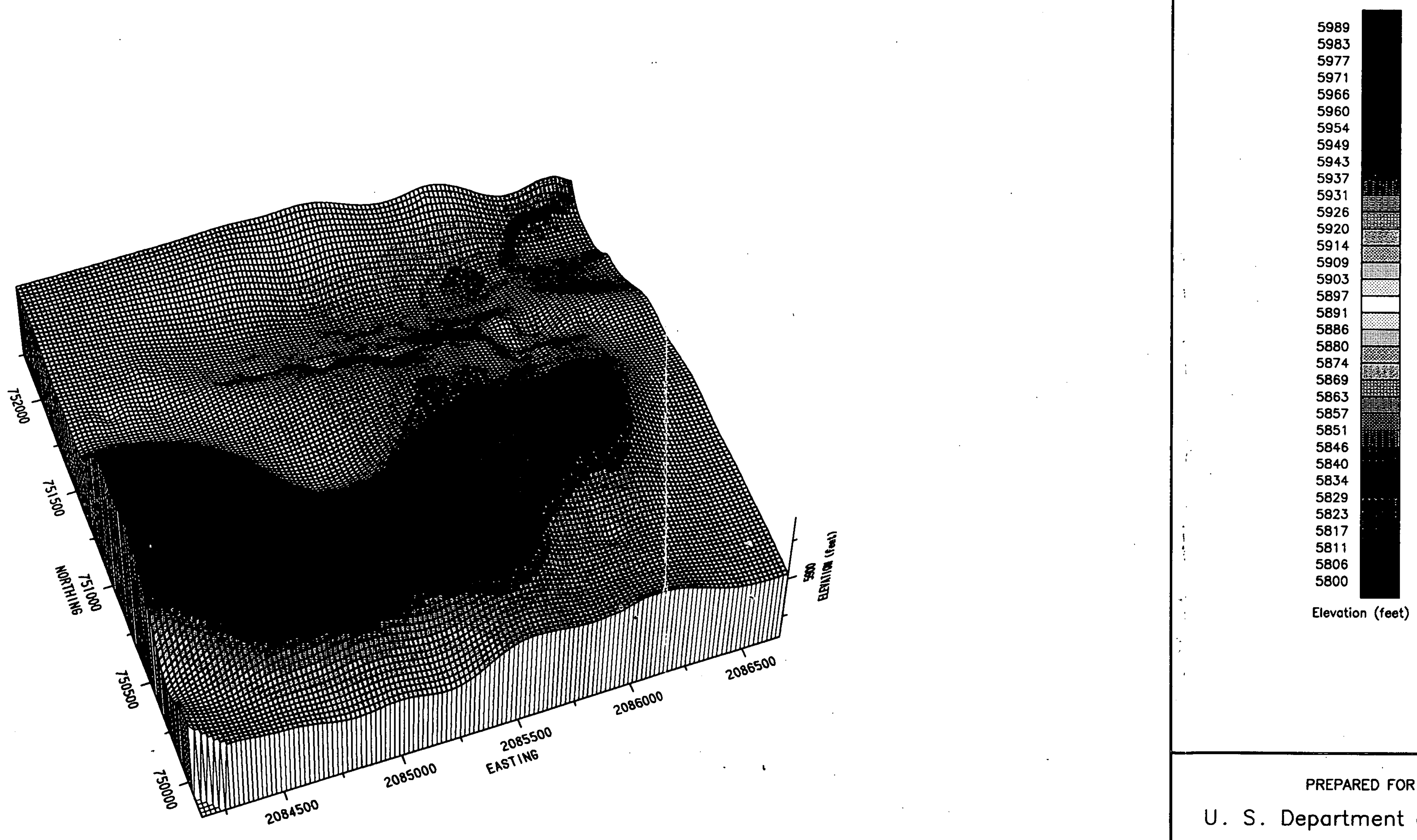
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 4.1.13-1

OU4 Phase II RFI/RI
Seismic Line M



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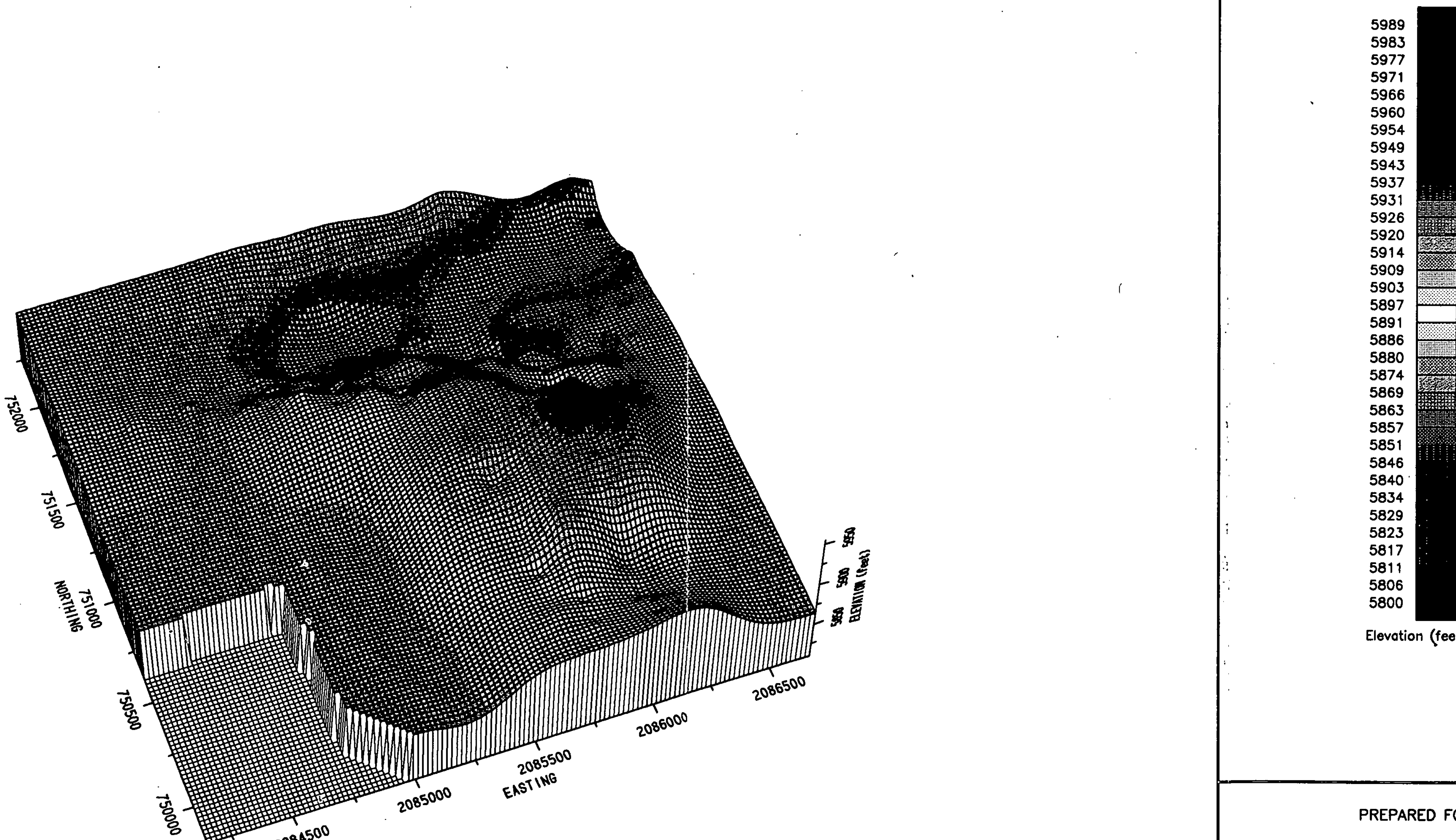
ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 5.0-1

OU4 Phase II RFI/RI
Top of Unsaturated Bedrock
(Derived from P-Wave Data)

69



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ROCKY FLATS
ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

Figure 5.0-3

OU4 Phase II RFI/RI
Top of Less-Weathered Bedrock
(Derived from S-Wave Data)