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February 15, 2002

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Re: Hyde Park Remedial Program
Site Characterization Report

Dear Ms. Sosa and Mr. Jackson:

Enclosed you will find the "Site Characterization Report – Revised Geologic and Hydrologic Characterization" submitted as part of the Hyde Park remedial program. This report caps the tremendous effort made during 2001 to fully recharacterize the site and has identified the need for an ongoing hydrogeologic characterization (Section 5.0); this work will be carried out in the first half of 2002.

We appreciate the input EPA, DEC and their consultants have provided during the 2001 remedial program field work and evaluation. If, after reviewing this report, you would like to schedule a group meeting for presentation or discussion, we are available after March 4th. Please feel free to contact any member of the group, including SSPA, SEDA and CRA, should you have further questions.

Sincerely,

for George W. Luxbacher, P.E., Ph.D.

Encl.

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SITE CHARACTERIZATION REPORT - REVISED GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION

HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Prepared For:

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EXECUTIVE SUMMARY

The *Site Characterization Report – Revised Geologic and Hydrogeologic Characterization*, presents a refinement to the current characterization of hydrogeologic conditions at the Hyde Park Landfill Site. The report provides descriptions of a historical data review, an intensive field investigation completed in 2001, and the evaluation of these data.

The Hyde Park Landfill Site in the Town of Niagara, New York, is a former Hooker Chemical Corporation disposal facility that operated from 1953 to 1975. During the period of operation, the Landfill received approximately 80,000 tons of chemical waste, including non-aqueous phase liquids (NAPL). The chemical wastes were primarily chlorinated organic compounds and phenols.

The Landfill was closed by Occidental Chemical Corporation (OCC) in 1975 and in 1978 was covered with a clay cap. Several remedial systems have been installed to control the flow of groundwater. The first wells of the bedrock groundwater extraction system, collectively designated the NAPL Containment System, were installed in 1993 and 1994, to control the migration of NAPL and groundwater affected by NAPL. This system has been operational since 1994, and has been modified and augmented since that time. It has removed a significant mass of pure phase and dissolved chemicals, and reduced the loading to the Niagara River Gorge.

A hydraulic monitoring network was installed to evaluate the performance of the NAPL Containment System. Performance monitoring requirements were defined for the network in a *Stipulation on Requisite Remedial Technology Program* (RRT). To date, the NAPL Containment System has satisfied the remedial objectives of the RRT in all but the northwestern portion of the Site.

In response to difficulties in demonstrating hydraulic containment in the northwestern portion of the Site, Miller Springs Remediation Management, Inc. (MSRM) commissioned a modeling study of the bedrock aquifer, a review of historical data, and an assessment of the hydraulic monitoring network. These efforts were completed in 2000. The results suggested that the difficulties in satisfying the performance monitoring requirements might be related to the design of the monitoring network and the conceptual hydrogeologic model of the Site, and not necessarily a failure of the NAPL Containment System to achieve the performance objectives. Based on these findings, an extensive investigation effort was proposed for 2001. The objective of the 2001 investigations was to refine, and if necessary revise the Site geologic and hydrogeologic characterization. These investigations included:

- a borehole geophysical logging program;
- a borehole camera logging program;
- a borehole flowmeter profiling program;
- the lithologic and stratigraphic re-logging of existing drill core;
- mapping of outcrops; and
- the determination of the physical properties of selected intact drill core.

The results from these studies have been interpreted by the MSRM Technical Team and are presented in this report.

The geologic studies demonstrate that the geology of the Lockport Group at the Site is consistent with the regional geologic conditions described in publications of the United States Geological Survey and the New York State Geological Survey. The Site geologic characterization has been revised to conform to the current USGS geologic nomenclature presented in Brett et al. (1995). The Site geology is generally characterized as nearly flat-lying planar beds of dolomite with shaly intervals. The geologic strata are generally continuous over the Niagara region. Geologic bedding at the Site dips to the south-southeast at approximately 40 feet per mile, consistent with regional studies.

The revised hydrogeologic characterization presents a refined conceptual model of the groundwater system. The refined conceptualization is a framework to support evaluation and monitoring of the groundwater system. The revised hydrogeologic characterization integrates Site conditions with the regional conceptualizations developed by Johnston (1964) and Yager (1995). Johnston and Yager identified a combined total of eleven, bedding-parallel, flow zones in the region. The eleven regional flow zones have been identified at the Site. Horizontal groundwater flow occurs primarily within these flow zones. The flow zones are separated by aquitards. Groundwater flows vertically downwards through vertical fractures in the aquitards.

The revised hydraulic characterization described here represents a significant refinement of the existing Site characterization that conceived of Upper, Middle, and Lower bedrock monitoring intervals. The refined characterization demonstrates that the existing bedrock monitoring wells intercept multiple flow zones. This is particularly the case for the Upper bedrock monitoring wells; for many of these wells, the open intervals intersect different flow zones at different wells. The water levels in these wells provide weighted-averages of conditions in multiple flow zones, and are not reliable data for the demonstration of hydraulic containment as mandated in the RRT.

The refined hydrogeologic characterization highlights the limitations of the existing monitoring well network. However, further studies are required to complete the Site characterization. The hydrogeologic framework is defined in this report. Additional water level data from piezometers monitoring discrete flow zones are needed to fully assess groundwater flow. Additional detailed monitoring and hydraulic testing will be performed to complete the Site characterization. Using the new framework and the additional data collected, a groundwater flow model will be developed. The interpretations of the additional data and the model analyses will support the development of a performance-monitoring program for the NAPL Containment System that is capable of demonstrating the achievement of the remedial objectives for the Site.

1.0 INTRODUCTION

1.1 PURPOSE

Miller Springs Remediation Management, Inc. (MRSM) and Glenn Springs Holdings, Inc. (GSHI), have prepared the following Site Characterization Report (SCR) - Revised Geologic and Hydrogeologic Characterization for the Hyde Park Landfill Site. The report is a joint effort of a Technical Team comprising MSRM and GSHI, Conestoga-Rovers & Associates (CRA), Sayko Environmental Data Analysis (SEDA), and S. S. Papadopulos & Associates, Inc. (SSP&A). The report has been prepared to present the results of the additional Site geologic and hydrogeologic characterization activities undertaken since June 2001; and, to provide a revised hydrogeologic characterization. This additional work consisted of:

- drilling and geologic logging of 15 new monitoring wells and 5 new purge wells;
- geophysical logging of 117 monitoring wells and 17 purge wells;
- borehole camera logging of 24 monitoring wells;
- borehole flowmeter logging of 44 monitoring wells;
- local outcrop mapping; and
- petrophysical testing of samples of intact rock.

The findings of these recent investigations, and the revised hydrogeologic characterization, are consistent with the regional conceptualization of groundwater flow presented by others (e.g., Yager, 1996). The refined conceptual hydrogeologic characterization will guide the design of an appropriate water level monitoring network, the formulation of a new groundwater flow model, the development of a new NAPL Plume Containment System monitoring program, and, as necessary, modification of the bedrock NAPL Plume Containment System.

1.2 BACKGROUND

The Hyde Park Landfill Site (Site) is a former Hooker Chemical Corporation disposal facility that operated from 1953 to 1975. Occidental Chemical Corporation (OCC) closed the facility in 1975. The Site occupies approximately 25 acres in the northwest portion of the Town of Niagara, New York. Figure 1.1 presents the Site location and nearby major structures. Figure 1.2 presents a detailed Site plan, indicating the locations of the monitoring and purge wells.

During the period of operation the Landfill received approximately 80,000 tons of chemical waste, including non-aqueous phase liquids (NAPL) (Interagency Task Force on Hazardous Wastes, 1979). The chemical wastes consisted predominately of chlorinated organics including hexachloropentadiene, chlorinated acids, chlorinated toluenes, benzenes, and phenols. The Landfill was closed in 1975 and a clay cap was installed in 1978.

On April 30, 1982, the United States District Court (Court) approved a "Stipulation and Judgement Approving Settlement Agreement" (Settlement Agreement) between OCC and the United States Environmental Protection Agency (USEPA) and New York State Department of Environmental Conservation (NYSDEC). Subsurface investigations were performed at the Site under the Settlement Agreement. The geologic and hydrogeologic characteristics of the Site were originally evaluated in a series of investigations conducted by CRA between 1983 and 1986 (CRA, 1983a; 1984). The initial subsurface investigations also identified significant chemical migration through the overburden into the underlying bedrock, including the presence of NAPL.

The requirements for remediation at the Site were presented in the *Stipulation on Requisite Remedial Technology (RRT) Program* (RRT Stipulation), which was approved by the Court on August 11, 1986. The remedial systems specified in the RRT Stipulation included the bedrock NAPL Containment System. The purpose of the bedrock NAPL Containment System was to contain, to the extent practicable, the NAPL and impacted groundwater within the NAPL plume boundary. The performance of the bedrock NAPL containment system was based on the achievement of inward horizontal hydraulic head differentials across the NAPL plume boundary.

The bedrock NAPL containment system commenced operation in 1994. The system has undergone a number of improvements since that time, including the installation of additional bedrock purge wells and the recently completed upgrade of the groundwater treatment plant. However, demonstrating hydraulic containment in the northwestern portion of the Site with the inward horizontal head differential criterion has been problematic.

In 2000, MRSM and GSHI retained SSP&A to quantitatively analyze groundwater flow conditions at the Site. SSP&A reviewed Site data and developed a numerical groundwater model, documenting the results of their study in three reports (SSP&A, 2000; 2001a; 2001b). MSRM and GSHI also retained SEDA as a senior peer reviewer for the modeling, and to provide technical oversight of the field studies. SEDA

also evaluated the existing monitoring well network and water level database. SEDA (2001) identified wells that may provide water level data that are not representative of the bedrock units.

The USEPA and NYSDEC reviewed the groundwater modeling and non-representative well reports. They generally agreed that the groundwater flow model was reasonably consistent with available data and simulated general flow directions at the Site; however, they questioned the utility of the model to predict the capture zones of the purge wells. The concern was not based on the groundwater modeling efforts, but on the characterization of the Site. The Agencies believed that use of the Upper, Middle and Lower bedrock monitoring wells did not provide information on the discrete bedding-parallel flow zones that were identified in regional studies (i.e., Johnston, 1964; Miller and Kappel, 1987; Yager and Kappel, 1987; Yager, 1996). The work presented here is intended to address these concerns. MSRM and GSHI intend to develop a refined groundwater flow model based on this Site characterization as presented in this report.

1.3 REPORT ORGANIZATION

The SCR is organized as follows:

Section 1.0 Introduction - presents the purpose of the report and the background information that led to the development of the revised conceptual hydrogeologic characterization for the Site.

Section 2.0 Sources of Information - identifies the sources of data used to develop the revised conceptual hydrogeologic characterization.

Section 3.0 Geologic Characterization - presents a description of the regional and Site stratigraphy, lithology, and geologic structure.

Section 4.0 Hydrogeologic Characterization - presents a summary of the regional flow zones and the Site flow zones identified from the characterization data.

Section 5.0 Completion of the Hydrogeologic Characterization - presents the scope of work required to complete the characterization with respect to the direction of groundwater flow and physical properties of the bedrock flow zones.

Section 6.0 References.

Figures and Tables

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2.0 SOURCES OF INFORMATION

Numerous sources of information have been reviewed to develop the revised geologic and hydrogeologic characterization for the Site. These information sources are listed below:

- USGS and NYSGS Publications;
- graduate theses;
- communications from the USGS;
- consultant reports; and
- Site studies described here.

A complete list of references is provided in Section 6.0. This report and the appendices to this report provide details of the Site studies.

3.0 GEOLOGIC CHARACTERIZATION

3.1 INTRODUCTION

The geologic characterization presents a summary of published regional geologic studies, historical Site data, and the results of geophysical/Site investigations completed in 2001. Contour maps and cross-sections describing the stratigraphy in the vicinity of the Site are included, as well as an analysis of the vertical distribution of fractures.

The objectives of the geologic characterization are to document the current understanding of geologic conditions at the Site, and to make the Site geologic nomenclature consistent with the currently accepted USGS nomenclature.

3.2 REGIONAL GEOLOGY

Several regional geological and hydrogeological studies have been conducted in the Niagara region. These studies have focused on two major aspects: the geology - stratigraphy and depositional environments; and the hydrogeology - movement of groundwater in the bedrock.

The most current stratigraphic nomenclature and lithologic descriptions for the Niagara region are presented in a USGS publication (Brett et al., 1995). Brett et al. (1990) also described the depositional environments and erosional surfaces relative to sea levels for the Niagaran series of rocks.

The geology of the Niagara region consists of a generally thin blanket of unconsolidated Wisconsin-age glacial sediments overlying Silurian-age bedrock. The major water-bearing units in the Niagara region are in the bedrock above the Burleigh Hill member of the Rochester Shale. In the vicinity of the Site, this interval includes the rocks of the Lockport Group and the DeCew Formation of the Clinton Group. Figure 3.1 presents a stratigraphic column for these geologic units.

The bedrock sequence above the Rochester Shale consists of a series of stratigraphic units composed of dolomite, argillaceous dolomite, and dolomitic shale, forming a series of tabular units that dip generally southward at about 30 feet per mile.

3.2.1 STRATIGRAPHIC NOMENCLATURE AND LITHOLOGY

The bedrock exposed in the Niagara Falls area and the Niagara Gorge have been described by numerous authors, using several different nomenclature systems. The review of nomenclature presented here is confined to the more recent work conducted by the NYSGS and the USGS.

The most recent nomenclature systems are those presented by Zenger (1965), Rickard (1975), and Brett et al. (1995). Brett et al. (1995) significantly revised the nomenclature system for the Niagara region, building upon regional stratigraphic correlations and formalizing informal unit names. The nomenclature of Brett et al. (1995) has been officially recognized by the NYSGS, and has been adopted for use at the Site. The nomenclature used in previous Site reports is compared to the nomenclature of Brett et al. (1995) in Appendix B.

Lithologic descriptions of the stratigraphic units defined in Brett et al. (1995), are summarized on Table 3.1. Only those stratigraphic units relevant to the Site are presented. The descriptions presented on Table 3.1 are also representative of the bedrock in the vicinity of the Site.

The proper names of the stratigraphic units have been shortened in this report as follows:

Formal Name	***Short Name***
Eramosa Formation	Eramosa
Vinemount Member of the Goat Island Formation	Vinemount
Ancaster Member of the Goat Island Formation	Ancaster
Niagara Falls Member of the Goat Island Formation	Niagara Falls
Pekin Member of the Gasport Formation	Pekin
Gothic Hill Member of the Gasport Formation	Gothic Hill
DeCew Formation	DeCew
Burleigh Hill Member of the Rochester Shale	Rochester Shale

3.2.2 DEPOSITIONAL ENVIRONMENTS

Brett et al. (1990) described the depositional environments of the Niagaran Series (i.e., Medina, Clinton, and Lockport Groups) in western New York. The following summary, adapted from Brett et al. (1990), is provided to aid in understanding the local

stratigraphy. The reader is referred to Brett et al. (1990) for additional information.

The Niagaran Series of bedrock was deposited in the northwestern portion of the Appalachian Basin. The resulting lithology is reflective of changes in water depth. In general, fine-grained materials were deposited in deeper, quiet water settings. Coarse-grained materials were deposited in shallower water settings. The relationships between relative water depth and the regional bedrock stratigraphy and lithology, as defined by Brett et al. (1990), are presented on Figure 3.1.

Figure 3.1 indicates that most of the stratigraphic units were deposited in pelagic (deep water) settings. This resulted in a stratigraphic sequence consisting of uniform, regionally-extensive, horizontally continuous, and, for the most part, conformable strata. The sedimentary rocks are essential flat-lying, planar, and gently dipping (less than 1°).

3.2.3 REGIONAL FRACTURES

Several investigators have mapped regional fractures. Johnston (1964) noted that bedding-plane fractures were most significant with respect to groundwater flow, and in some cases were noted to be extensive. IJC (1974) noted open bedding fractures at several stratigraphic intervals along the face of the American Falls, in particular within the upper third of the Ancaster / Niagara Falls, near the Ancaster / Vinemount contact, and at the Vinemount / Eramosa contact.

The orientations of the vertical joints mapped in the various investigations are shown on Figure 3.2. The primary orientations of the regional vertical joints are:

- N.30°E. to N.50°E.;
- N.70°E. to N.90°E.; and
- N.20°W. to N.30°W.

Isachsen and McKendree (1977) reviewed published mapping of brittle geologic structures in the Niagara region. They did not identify any fault structures.

The regional vertical fracture orientations are approximately parallel and perpendicular to the current regional stress field indicated by Tepper et al. (1990). Sheeting joints, that is, vertical joints formed locally from the lateral stress relief (exfoliation), were noted in the Rochester near the American Falls. The sheeting joints in the Rochester Shale are

related to localized stress fields caused by erosion and rock falls at the American Falls, and the Rochester Shale is essentially intact away from the face of the American Falls (IJC, 1974).

Various investigators have noted that bedding-plane fractures and vertical joint sets are concentrated in the shallow portion of the bedrock, irrespective of the stratigraphic unit (Johnston, 1964; IJC, 1974; and Tepper et al., 1990). Generally, fractures or joints do not extend into or through the Rochester Shale (IJC, 1974).

3.3 SITE INVESTIGATIONS

3.3.1 PRE-2001 INVESTIGATIONS

Numerous investigations have been conducted at the Site since 1979.

The *Hyde Park-Bloody Run Aquifer Survey* (CRA, 1983a) presented information gathered from the core drilling and testing of 50 bedrock wells along eight vectors that radiate from the Site. These original vector wells were open across the full thickness of the Lockport to the top of the Rochester Shale. They have been abandoned, grouted, and replaced with the current Upper, Middle, and Lower bedrock vector monitoring wells.

The *Lockport Formation Investigation* (CRA, 1983b) presented the results of outcrop mapping of fracture and joint orientations along the NYPA access road west of the Site. The primary observations were that fractures were more frequent in the upper part of the bedrock, and that fractures were vertical or near-vertical.

Between 1983 and 1992, bedrock investigations and construction activities were focussed on meeting the requirements of the RRT Stipulation. These activities included the installation of a community early warning monitoring network, and the construction of a bedrock NAPL Plume Containment System and monitoring network. The results of these investigation and construction activities were reported in a sequence of reports and technical memoranda.

In 1993, the document Identification of Major Hydraulic Units of the Lockport Formation was submitted as Appendix B of the Drilling Summary Report, RRT Well Installations (CRA, 1993). The document, dated April 16, 1991, provided a conceptual hydrogeologic framework for the bedrock at the Site. The bedrock above the Rochester Shale was subdivided into three monitoring intervals, the Upper, Middle, and Lower

bedrock. The approximately 170 existing monitoring wells at the Site have been completed and named following that subdivision. The monitoring interval is indicated by the letter U, M, or L at the end of the well identifier, e.g., B1U, B1M, and B1L.

Between 1993 and 2001, additional bedrock investigations and construction activities focused primarily on augmenting the bedrock NAPL Plume Containment purge and monitoring well network, and the installation of the APL Plume Containment System. The construction activities were conducted in phases; the results of the activities were presented in a sequence of annual reports, quarterly monitoring reports, and technical memoranda.

3.3.2 SUMMARY OF 2001 INVESTIGATIONS

During 2001, MSRM completed several tasks to improve the geologic and hydrogeologic characterization of the Site. These tasks completed during 2001 included:

- a borehole geophysical logging program;
- a borehole camera logging program;
- a borehole flowmeter profiling program;
- the drilling and geologic logging of new monitoring and purge wells;
- the lithologic and stratigraphic relogging of existing drill core;
- mapping of outcrops; and
- the determination of physical properties of selected samples of drill core.

Each of these tasks is discussed briefly below.

Borehole Geophysical Logging Program

The principal objective of the borehole geophysical logging program was to locate water-bearing features in the bedrock at the Site. American and Canadian researchers with the USGS and National Water Research Institute (NWRI) previously used borehole geophysics in the Niagara region to aid in the identification of bedrock fractures (Kappel and Tepper, 1992; Novakowski and Lapcevic, 1988).

The 2001 Site borehole geophysical logging program consisted of:

- geophysical logging of 134 wells;
- geophysical relogging of eight wells with the nearby purge wells not operating; and
- geophysical logging of eight off-Site monitoring wells at a nearby site north of the forebay canal.

The wells north of the forebay canal were logged to aid in the assessment of the regional extent of fractures. However, since there was no drill core available to ascertain the stratigraphic contact elevations, the data were not used for fracture analysis.

MSRM retained Century Geophysical Corporation (Century) to complete the geophysical program. The geophysical logging conducted by Century included:

- caliper logging;
- natural gamma logging;
- spontaneous potential logging;
- fluid resistivity logging;
- 16-N and 64-N resistivity logging;
- lateral resistivity logging;
- single point resistivity logging;
- fluid temperature and delta temperature logging;
- P-wave sonic logging; and
- acoustic televiewer logging.

The acoustic televiewer used by Century was too narrow for logging in the purge wells (nominal diameter of 12 inches). Occidental Oil and Gas Company (OOGC) personnel suggested that Formation Micro Imager (FMI) logging could be performed on the larger diameter purge wells to provide similar data to the acoustic televiewer (Mike Metz, personal communication). MSRM retained Schlumberger Limited (Schlumberger) to complete the FMI logging. Due to the size of the FMI logging tool (approximately 40 feet long), only three purge wells had sufficient saturated intervals to complete logging (PW-1L, PW-2M, and PW-8M). A Section of the PW-2M FMI log with the interpretation of fractures is provided on Figure A.4 of Appendix A.

The complete details of the borehole geophysical logging program, and 2-page summary logs, are presented in Appendix A.

Borehole Camera Logging

MSRM is conducting ongoing logging of monitoring wells with a downhole camera. The camera is a GeoVision Micro M3 Color Camera, with video logged via a Sony Super 8 Video Camera Recorder at ground surface. Twenty-four (24) wells in ten clusters have currently been logged with the camera. The downhole camera provides a detailed visual impression of conditions along a borehole. The video records for 11 wells have been examined in detail to obtain visual confirmation of the fractures identified with the geophysical logs and flowmeter profiles.

Borehole Flowmeter Profiling

MSRM retained Quantum Engineering Corporation (Quantum) to complete an electromagnetic borehole flowmeter profiling program. The flowmeter data were used to locate water-bearing features. The borehole flowmeter measures vertical flow within the well bore. The measurements may be made under ambient conditions to identify where flow may enter the well, flow vertically (generally downward), and exit the well. Water can be added to the well during the profiling, to enhance the identification of location(s) where the injected water exits the well. The flowmeter has a lower limit of flow detection that precludes the detection of very low flows. Wells with very low permeability do not have detectable flow under ambient or injection conditions.

The borehole flowmeter was the only instrument that demonstrated directly the presence of a transmissive fracture in the wells. The geophysical testing described above provided only indirect evidence of water-bearing zones.

The borehole flowmeter program consisted of profiling 44 monitoring wells, under ambient and injection conditions. The Quantum report is presented in Appendix C. The borehole flowmeter data are included on the 2-page geophysical summary logs in Appendix A. Discussions of the results are included in Section 4.0.

Drilling and Logging of New Monitoring and Purge Wells

During 2001, additional drilling and logging was conducted at the Site. The work consisted of drilling of new monitoring wells for general monitoring, and drilling of new purge wells and related monitoring wells to enhance the bedrock containment system.

Monitoring well clusters J5 and AB1 were installed following the 2001 system shutdown for general water level monitoring. Their locations were selected to supplement the observation well network north of the Landfill. An Upper, Middle, and Lower bedrock monitoring well were installed at each location. The locations of these monitoring wells are shown on Figure 1.2. Well completion details are summarized on Table 3.2.

During 2001, 5 new purge wells were installed at the Site: four Upper bedrock wells PW-7U (retrofit of an existing NAPL recovery well), PW-8U, PW-9U, PW-10U; and one Middle bedrock well, PW-8M. Nine additional monitoring wells were installed close to the new purge wells as follow:

- MW1-2001 to MW7-2001 for monitoring drawdown response to pumping purge wells PW-8U, PW-9U, and PW-10U; and
- CD-5U and CD-6U for use as injection wells to complete a future tracer study with PW-7U.

The locations of these new monitoring and purge wells are shown on Figure 1.2.

The Stratigraphic and Instrumentation Logs for the new monitoring and purge wells are provided in Appendix D.

Lithologic Logging Program

The lithologic logging program consisted of the relogging of available drill core from 62 existing boreholes, as well as the new purge and monitoring well cores. The cores were relogged to update the Site geologic data to the stratigraphic nomenclature of Brett et al. (1995), and to check apparent outlier values for contact elevations in the original core logging data. The Site-specific lithologic descriptions are discussed in Section 3.4.1 and are presented in Appendix B.

Outcrop Mapping

In September 2001, personnel from the Technical Team performed a limited survey of outcrops along the NYPA access road and the Niagara Gorge (Figure 1.2). The mapping was undertaken to identify vertical fractures and joints where groundwater seepage was observed, or where it appeared that significant groundwater seepage might have occurred in the recent past. The results of the mapping are summarized in Appendix E.1, and discussed in Section 3.4.6.

Physical Properties Testing

At the suggestion of Occidental Oil and Gas Corporation (OOGC), selected representative samples of bedrock drill core from the J5 well cluster were tested to determine petrophysical properties, including:

- porosity;
- permeability;
- grain density;
- bulk density; and
- compressional and shear acoustic velocity.

3.4 SITE GEOLOGY

3.4.1 SITE LITHOLOGIC DESCRIPTIONS

Lithologic descriptions of the regional stratigraphic units are summarized on Table 3.1. Appendix B provides a detailed discussion of each stratigraphic unit of interest at the Site, the unit contacts, and photographs of local outcrops and selected drill core. The lithology observed at the Site is consistent with the regional descriptions. Table 3.3 presents a summary of published data on unit thicknesses for the Niagara region, and of the data collected at the Site. In general, the unit thicknesses observed at the Site are similar to regional observations. The thickness values presented on Table 3.3 should be considered with the recognition that there may be a relatively large uncertainty associated with the identification and measurement of unit contacts. The uncertainty is discussed in detail in Appendix G.

3.4.2 INTERPRETATION OF DATA

The interpretation of the data collected during the 2001 Site investigations for geologic characterization included:

- contouring of the lithologic contacts;
- comparing the gamma logs with the lithology; and
- evaluation of the distribution of fractures.

During the evaluation of the lithologic contact data, a number of outlier points were identified in the original data. Comparison of the original data with the results of the geophysical logs suggested that the vertical location of the contacts in a number of wells had either been picked or recorded incorrectly, had significant measurement error, or all three.

In response to the identification of outlier data, all available drill cores were lithologically relogged. Table 3.4 presents a list of the wells that were relogged and the elevations of the tops of the stratigraphic units. Only the data from relogged cores were used in the interpretation of the lithologic contacts presented here.

The identification of a lithologic contact has a subjective component. The subjective nature of the contact reflects the following:

- there are several potential criteria for picking a contact;
- many of the contacts are gradational in nature; and
- the stratigraphic units are lithologically similar.

There is also uncertainty in the measurement related to the survey of grade (the elevation datum). Based on an analysis presented in Appendix G, it was concluded that the accuracy of the contact picks appears to be about ±3 feet, and potentially as large as ±5 feet. As a result, some of the bends in the top of unit contours presented in the following Section may be related to unavoidable uncertainties in picking the contact elevation rather than a true variation in the contoured surface. In general, observations of stratigraphic units in the outcrops along the NYPA access road and the Niagara River Gorge suggest that the units are approximately flat-lying, planar, and uniformly thick.

3.4.3 CONTOURS OF THE LITHOLOGIC CONTACTS

Figures 3.3, 3.4, and 3.5 present the elevations of the top of the following:

- bedrock;
- Vinemount; and
- Ancaster.

Figure 3.3 presents the elevation of the bedrock surface. The uppermost bedrock units have been affected by glacial and pre-glacial erosion. Over most of the Site, the uppermost bedrock unit is the Eramosa. Along the northwestern side of the Site, the Eramosa is truncated and the Vinemount forms the uppermost bedrock unit. Near monitoring wells ABP-8 and APW-2, localized erosion has removed the Vinemount and most of the Ancaster / Niagara Falls. The bedrock low identified at ABP-8 and APW-2 is not apparent along the NYPA access road adjacent to these wells.

Figure 3.4 presents the elevation of the top of the Vinemount. Along the northwestern portion of the Site, the upper surface of the Vinemount is eroded, and the contours of the top of the unit are not presented.

Figure 3.5 presents the elevation of the top of the Ancaster. Along a small area near the Niagara Gorge, the upper surface of the Ancaster is also eroded, and the contours of the top of the unit are not presented.

Figures 3.6, 3.7, 3.8, and 3.9 present the elevations of the top of the following units:

- Pekin;
- Gothic Hill;
- DeCew; and
- Rochester Shale.

The full thicknesses of the Pekin, Gothic Hill, and DeCew appear to be present over the Site area. At the Site, it appears that these units have not been eroded since lithification. The top of the DeCew has been reported to represent a regional, erosional unconformity (Brett et al., 1995). However, no erosional features have been observed in the cores or outcrops, or are suggested from the contours presented on Figure 3.8.

The lithologic contacts at the Site may be characterized, within the margin of measurement error, as uniformly planar and parallel to the overlying and underlying units. Apparent deviations from an ideal plane surface are attributed to uncertainties in determining stratigraphic contact elevations (as discussed in Appendix G) and to depositional variations. The contact surfaces strike approximately N.70°E. and dip to the south-southeast at approximately 40 feet / mile.

3.4.4 GEOLOGIC CROSS-SECTIONS

A three-dimensional geologic model has been created for the Site using the Environmental Visualization System (EVS). The three-dimensional model is included on a compact disc (CD) enclosed with the report. The model is in a format that is compatible with the freeware 4-D Interactive Model Viewer, which is included on the CD. Using the 4-D Interactive Model Viewer, the model can be rotated in any direction, zoomed into or out of, and changed from orthographic to perspective view. Instructions on how to use the Interactive Viewer are also included on the CD.

EVS has been used to create two sections for the report, one along strike and one along dip. The cross-section locations are shown on Figure 3.10. Cross-section A-A', Figure 3.11, is along strike. This cross-section shows the limited extent of the Eramosa Formation. As well, the planar nature of the complete stratigraphic Section is apparent. Cross-section B-B', Figure 3.12, is along dip.

3.4.5 PROPERTIES OF THE INTACT ROCK

Petrophysical testing of drill core samples was conducted to determine the physical properties of the intact rock. These tests included porosity, permeability, grain density, bulk density, and compressional and shear acoustic velocity. Details of the tests and additional discussion of results are presented in Appendix F.

The porosity values determined for the intact bedrock ranged from 3.5 to 7.6 percent. These values are consistent with published values for limestone and dolomite (Table 2.4, Freeze and Cherry, 1979). The grain densities range from 2.83 to 2.85 g/cm^3, values consistent with the density for the mineral dolomite, 2.85 g/cm^3 (Deer et al., 1966). The bulk densities of the bedrock samples ranged from 2.71 to 2.73 g/cm^3, consistent with a total porosity of 4 to 5 percent.

The laboratory determined hydraulic conductivities ranged from 4.3×10^{-7} to 4.2×10^{-10} cm/sec. These values are consistent with values for intact dolomite (Table 2.2, Freeze and Cherry, 1979). They are several orders of magnitude lower than the slug test and packer test results for the Site (summarized in Appendix H and further discussed in Section 4.0). The difference is attributed to the presence of fractures in the rock mass tested *in situ*; these fractures are absent from the intact core sample analyzed in the laboratory.

The petrophysical testing results were sent to OOGC to aid in the determination of porosity from the P-wave sonic geophysical logs run on 74 boreholes. The laboratory determined acoustic velocity was used by OOGC to calibrate P-wave sonic (sonic) logs. OOGC used the following equation to determine porosity from the sonic logs:

$$\text{Porosity} = \frac{\Delta T - \Delta T_{MA}}{\Delta T_F - \Delta T_{MA}} \frac{1}{CP} \qquad (1)$$

Where:
- ΔT = Sonic log travel time;
- ΔT_{MA} = matrix travel time (μsec/ft);
- ΔT_F = Fluid travel time (μsec/ft); and
- CP = Compaction factor.

Typical values for ΔT_{MA} for dolomite and ΔT_F for water are 44 μsec/ft and 189 μsec/ft, respectively (Schlumberger, 1987). By calibrating observed and predicted porosities of core samples, OOGC determined that a value for CP of 1.45 was appropriate to calculate porosity from the sonic logs. The log processing software Powerlog was used to solve equation 1 with the above-noted parameter values. The calculated porosity values were similar to those determined in the laboratory.

The results of the petrophysical testing suggest that the hydraulic conductivity of the intact rock at the Site is very low. The hydraulic conductivities estimated from the laboratory measurements are much lower than those estimated from single-well response tests at the Site (summarized in Appendix H), suggesting that groundwater flow at the Site is controlled by the secondary porosity of the rock, in particular, bedding-plane fractures. The inference that groundwater flow occurs primarily in the secondary porosity of the rock, and in particular, discrete bedding-related features, is consistent with the conceptual hydrogeologic models formulated by Johnston (1964) and Yager (1996). Yager (1996) indicated that the rock matrix transmits negligible amounts of groundwater because of the low primary porosity. Based on the porosity results discussed in Section 3.4.6, the rock matrix porosity is in the range of 5 percent. Although Yager (1996) is correct that the rock matrix transmits negligible groundwater, the reason is more likely due to the low conductivity of the intact material rather than low porosity.

3.4.6 FRACTURES AND JOINTING

Based on inspection of local outcrops and review of the 2001 Site investigation data, three categories of fractures have been defined at the Site:

- near-horizontal;
- dipping fractures; and
- near-vertical fractures.

The near-horizontal fractures are bedding-related; for the purposes of this study they have been defined as fractures having a dip of less than 5°. The dipping fractures are defined here as having a dip between 5° and 75°. "Near-vertical" is taken here to mean having a dip greater than 75°.

All three categories of fractures have been observed in outcrops near the Site. At the outcrops, the orientation of the near-vertical fractures were measured and documented. In boreholes, all three categories were documented. The elevations of fractures observed in the boreholes have been tabulated, as well as the strike and dip of the dipping fractures. The orientations of the dipping fractures were determined from analysis of the acoustic televiewer images. This information is included on tables in Appendices A and B.

Yager (1996) reports that the upper 10 to 25 feet of bedrock is weathered, and that this weathered zone contains many closely spaced horizontal (bedding-plane) fractures that are interconnected by high-angle (near-vertical) fractures. Regionally, those observations may be correct. However, based on inspection of the cores collected at the Site, the weathering zone in the vicinity of the Site is limited to only the first 2 feet of the bedrock. Visual inspection of the geophysical logs suggests that the intensity of fracturing near the top of bedrock is commonly more intense than at depth. However, this appears to be related to the type of bedrock rather than the depth below top of bedrock.

The preceding observations are based on visual inspection of geophysical logs and rock core; therefore, they reflect a subjective rather than quantitative analysis. The following discussion presents quantitative analyses of the measurements collected in outcrops near the Site, and from the geophysical logs. These analyses provide fracture elevations and orientations. However, there is no assessment of the hydraulic properties, e.g., aperture, of the fractures.

3.4.6.1 FRACTURES DETECTED IN OUTCROP

Bedding-plane fractures were commonly observed in outcrops near the Site, along the NYPA access road and the Niagara River gorge. These are typically continuous along the outcrop, and are generally associated with shaly intervals. The shaly intervals are more susceptible to weathering than the dolomite, and differential weathering has accentuated the fractures within the shaly intervals. Dipping fractures were not commonly observed in outcrops near the Site, and those that were observed were typically not continuous along dip for a significant stratigraphic interval. Differential weathering has not accentuated these fractures.

In September 2001, members of the Technical Team mapped selected vertical fractures along the NYPA access road to the Robert Moses Power Plant, and along the face of the Niagara Gorge near the Site. Only those fractures that appeared to conduct water were mapped. The results of this mapping are reported in a memorandum presented in Appendix E.1. The general orientations (apparent strikes) of the mapped fractures were:

- N.90°E., or
- N.55°E.

Bedrock outcrops to the west of the Site along the NYPA access road were also previously mapped and reported in Appendix J of the report *Pump Well Installation and Pump Test Results*, CRA (1983). This appendix has been reproduced here as Appendix E.2. It should be noted that all large, accessible fractures, including blast-induced fractures from the construction of the NYPA access road, were mapped during this investigation. The major orientations of the mapped fractures were:

- N.30°E. to N.80°E.; and
- N.170°E. to N.180°E.

Other more randomly oriented fractures were also noted.

The orientations of the fractures mapped in outcrop near the Site are presented on Figure 3.13 along with the regional data previously presented on Figure 3.1. The vertical fracture and joint orientations are similar to the regional trends discussed in Section 3.2.4, with a predominant orientation approximately parallel to the regional stress orientation (northeast).

3.4.6.2 FRACTURES DETECTED IN BOREHOLES

Fractures were identified in boreholes through the geophysical logging program and the examination of rock core. The types of fractures identified included:

- near-horizontal fractures (bedding-parallel, with a dip of less than 5°);
- dipping fractures (i.e., dips between 5° and 75°); and
- near-vertical fractures (dips exceeding 75°).

Geophysical logs, primarily the caliper and acoustic televiewer logs, were used to identify the presence of near-horizontal, bedding-related fractures. Dipping fractures were identified from the acoustic televiewer and FMI logs. Both near-horizontal and dipping fractures were observed in drill core. However, the near-horizontal and dipping fractures observed in the drill core may be related to breakage during core handling and drying of the core, rather than to *in situ* fracture partings. Therefore, the core was not used for the identification of near-horizontal and dipping fractures.

Near-vertical fractures were not readily detected by borehole geophysical methods, and were determined through an examination of rock core or noted from a review of 11 borehole video logs. It is unlikely that many of the near-vertical fractures identified in drill core resulted from core handling or the desiccation of drill core because the primary planes of weakness, the shale partings and shale beds, are horizontal.

A total of 782 fractures were identified from Site borehole geophysical logs, examination of drill core, and inspection of the borehole video logs. The fractures were identified from 59 Upper wells, 32 Middle, and 35 Lower bedrock wells. Of the total number of fractures identified, 691 were near-horizontal bedding-plane fractures (Table A.2), 28 were dipping fractures (Table A.3), and 63 were near-vertical fractures (Table B.2).

The fracture data were analyzed to estimate fracture frequency. With respect to the hydrogeologic characterization, it is important to determine consistent patterns of bedrock fracturing. In particular, it is essential to determine whether the frequency of fracturing depends on depth or lithology. In conducting this evaluation, average fracture frequencies were determined for different depths and lithologies. The results are expressed as the number of fractures per 100 feet of log / core inspected.

Figure 3.14A presents a histogram of the distribution of caliper log footage versus depth below top of bedrock. The histogram "bins" represent 10-foot intervals starting at the top of bedrock. The results shown on Figure 3.14A show that there is a gradual decline in the footage of caliper logged with depth below top of rock. Figure 3.14B presents a histogram of the distribution of acoustic televiewer footage logged versus depth below bedrock. This Figure shows a similar pattern to the caliper logs.

Figure 3.14C presents a histogram of distribution of drill core by length versus depth below top of bedrock. The Figure shows that the footage of core is greatest for shallow depths, and declines with depth. This is consistent with the results shown on Figures 3.14A and 3.14B. This distribution was considered in the evaluation of the presence of near-vertical fractures determined from drill core.

Bedding-Plane Fractures

Approximately 90 percent (691 of 782) of the fractures identified are near-horizontal. Table A.2 provides a listing of the near-horizontal fractures, identified by inspection of the caliper, acoustic televiewer (saturated intervals only), and the FMI logs (PW-1L, PW-2M, and PW-8M; saturated intervals only).

Figure 3.15A presents a histogram of the frequency of bedding-plane fractures versus depth below the bedrock surface. The histogram "bins" represent 10-foot intervals beginning at the top of bedrock. The frequency is calculated by dividing the number of fractures observed in each 10-foot interval by the total number of feet of caliper log in that 10-foot interval. This provides an average value of fractures per foot value for each interval. The average value was converted to number of fractures per 100 feet of caliper logging for convenience.

Figure 3.15A shows that, relative to the top of bedrock, the frequency of fractures tends to decrease with depth. However, the decrease is relatively gradual, as opposed to a rapid drop in the fracture frequency at some fixed depth below the top of bedrock. This interpretation is important to the Site characterization, as the highly transmissive zone identified in the upper 15 feet of bedrock by Johnston (1964) and subsequent investigators, is not supported by the vertical distribution of bedding-related fractures at the Site. This analysis does not account for fracture apertures that influence fracture transmissivity.

Figure 3.15B presents a histogram of the bedding-plane fractures versus stratigraphic unit. These are the same data presented in Figure 3.15A, but the histogram "bins"

represent stratigraphic units rather than depth below top of bedrock. These results indicate that the frequency of near-horizontal fractures is greatest in the Eramosa, Vinemount, Ancaster / Niagara Falls, and Pekin (approximately 20 per 100 feet of caliper logging). This distribution is generally consistent with visual observations of local outcrops. The frequency of bedding-plane fractures is much lower in the Gothic Hill, DeCew and Rochester Shale (approximately 10 per 100 feet of caliper logging). The distribution of bedding-plane fractures is consistent with the lithology. For example, the Gothic Hill is a thick- to massive-bedded, coarse-grained dolomite. This unit has fewer open bedding-plane fractures than the more thinly-bedded units such as the Vinemount and the Pekin.

Dipping Fractures

Approximately 4 percent (28 of 782) of the fractures identified in the boreholes are dipping fractures, that is, the dips are between 5° and 75°. Dips of less than 5° could not distinguished from bedding-plane fractures, and the maximum dip observed was 31°. Dipping fractures were identified using the acoustic televiewer geophysical logging tool in the saturated portion of the open boreholes. Table A.3 provides a summary of the locations and orientations of identified dipping fractures, which range in dip from 6 to 31 degrees.

Figure 3.16A presents a histogram of the number of dipping fractures versus depth below the top of bedrock. The number of dipping fractures is limited compared to bedding-plane fractures; therefore, the histogram bins were increased to 30 feet. The number of fractures observed in the depth interval was divided by the total footage of acoustic televiewer logged in the depth interval. The results show very small fracture frequencies in all depth intervals (ranging from 0.5 to 3.5 fractures per 100 feet of logging). The greatest frequency was observed in the 120- to 140-foot interval below the bedrock surface. The apparently high fracture frequency is likely a statistical artifact associated with the limited length of geophysical logs over this interval.

Figure 3.16B presents a histogram of the frequency of dipping fractures versus stratigraphic unit. The Figure shows that there is no apparent pattern to the distribution of the dipping fractures other than the highest frequency (approximately 2.5 per 100 feet of acoustic televiewer logging) in the Eramosa, Pekin and DeCew.

Figure 3.17 presents a stereonet analysis of the orientation of dipping fractures. The dip of the fractures is between 6 and 31 degrees. Examination of this Figure shows that there is no significant clustering of fracture dip directions.

No spatial patterns in the distribution of dipping fractures were identified.

Near-Vertical Fractures

Approximately 8 percent (63 of 782) of the fractures identified are near-vertical (dips exceeding 75°). Near-vertical fractures have been logged in available drill core. In addition, three near-vertical fractures were noted on the 11 borehole video logs. The depths of near-vertical fractures are presented on Table B.2.

Figure 3.18A presents a histogram of the frequency of near-vertical fractures versus depth below bedrock. The results shown on Figure 3.18A indicate that there is a general decline in the occurrence of near-vertical fractures with depth.

Figure 3.18B presents a histogram of the distribution of near-vertical fractures versus stratigraphic unit. The greatest fracture frequency occurs in the Eramosa and then declines with depth to the DeCew. No near-vertical fractures were observed in the Rochester Shale, consistent with regional observations presented in Section 3.2.3.

No spatial patterns in the distribution of near-vertical fractures were identified.

3.5 SUMMARY

The following observations summarize the revised geologic characterization of the Site:

1. The Site stratigraphy is generally consistent in lithology, thickness, and orientation with published regional geologic information from USGS, NYSGS, and others.
2. The stratigraphic nomenclature of Brett et al. (1995) for the Lockport Group has been adopted for the Site, to be consistent with regional studies.
3. In the vicinity of the site, bedding strike is approximately N.70°E. and dips to the southeast at approximately 40 feet per mile.
4. Petrophysical testing of drill core samples indicates that the Site-specific bedrock properties are consistent with published values for dolomite bedrock. The low hydraulic conductivities of the intact samples suggest that groundwater flow occurs only in the connected fractures in the rock.

5. Fractures within the bedrock sequence have been identified through borehole geophysical logging, core logging, and outcrop mapping. The fractures consist of near-horizontal bedding-plane fractures, dipping fractures, and near-vertical fractures. The fracture identification was a simple true/false analysis and did not consider fracture aperture or hydraulic properties. In general, the average number of fractures per vertical foot of bedrock appears to decrease gradually with depth below top of bedrock. This observation appears to conflict with published reports that suggest that fracturing occurs primarily within the top 15 feet of bedrock.

6. Approximately 90 percent of the fractures identified have been classified as near-horizontal bedding-plane fractures. Bedding-plane fractures are evenly distributed within the Eramosa, Vinemount, Ancaster/Niagara Falls, and Pekin.

7. Approximately 4 percent of the fractures are detected with dipping fractures (6 to 31 degrees). There was no dominant orientation in dip direction. Dipping fractures were found most frequently in the Eramosa, Pekin, and DeCew.

8. Approximately 10 percent of the fractures identified are near-vertical fractures. These fractures were encountered most frequently in the Eramosa. Near-vertical fractures were not observed in the Rochester Shale, consistent with regional observations.

4.0 HYDROGEOLOGIC CHARACTERIZATION

4.1 INTRODUCTION

4.1.1 OBJECTIVE

The objective of the investigations performed by MSRM in 2001 has been to refine the understanding of the Site geology and hydrogeology. The hydrogeologic characterization is a conceptual model that represents a simplification of a complex groundwater system. This simplification is required to establish a tractable framework for evaluating and monitoring the groundwater system. The characterization developed in this Section will be used to refine the groundwater-monitoring network, develop a new groundwater flow model, and ultimately, to define an effective and practical monitoring program for the bedrock NAPL Plume Containment System.

The hydrogeologic characterization developed here is intended to refine the characterization presented initially in the Stipulation on the RRT (United States District Court for the Western District of New York, 1986). In the Stipulation on the RRT, groundwater was conceived as flowing in the Lockport Dolomite, and eventually discharging at the gorge of the Niagara River. The characterization presented here refines the understanding of the structure of the bedrock, and in particular identifies discrete flow zones at the Site. The higher resolution of bedrock flow processes will provide the basis for a new groundwater flow model for the Site.

This Section of the report presents a hydrogeologic framework, but no interpretations of groundwater flow. Although there is an extensive database of groundwater levels, the existing monitoring network does not monitor the hydrogeologic framework described here. To the extent practical, the existing water levels were reviewed with respect to the revised hydrogeologic framework. No reliable interpretation of groundwater flow could be developed.

4.1.2 REGIONAL HYDROGEOLOGIC CONCEPTUALIZATION

Johnston (1964) proposed that groundwater flow in the Lockport Group occurs primarily in discrete, bedding-parallel flow zones. The flow zones were separated by layers of typically more massive rock that acted as aquitards. Johnston's conceptual model of layered flow zones and aquitards was based largely on observations made during construction of the New York Power Authority (NYPA) Niagara Project conduits. Figure 4.1 shows the flow zones identified by Johnston (1964) along the

rock-cut created for construction of the conduits linking the upper Niagara River to the NYPA forebay. Johnston marked his flow zones with a relative estimate of the flow within them, with "**XXX**" indicating the greatest flow, and "**X**" indicating the least.

Geologists and hydrologists of the USGS conducted extensive research that supported Johnston's conceptualization of groundwater flow zones in the Niagara region. The USGS expanded on Johnston's work to include a greater vertical Section of the Lockport Group, and traced the flow zones laterally across the Niagara region. Progress on the conceptualization of flow zones was presented in Yager and Kappel (1987), Kappel and Tepper (1992), and Yager (1996). The work of the USGS demonstrated that the locations of the flow zones and aquitards within the stratigraphic sequence could be correlated regionally.

Yager (1996) presented the most recent USGS conceptual model of the regional hydrogeology. The USGS idealization of the bedrock hydrogeology was formulated to support the development of a numerical model of groundwater flow in the Niagara region. The USGS identified nine regionally extensive flow zones in the Lockport Group. Figure 4.2 presents a comparison of Johnston's 1964 mapping and the USGS interpretation. Johnston's stratigraphic column C reproduced on Figure 4.2 was developed from the conduit excavation located near the confluence of the NYPA conduits and the NYPA forebay. The USGS column is from well Lewiston-1 (LW-1) located along the south berm of the Lewiston Reservoir, about 3,800 feet east of Johnston's stratigraphic column. Johnston (1964) identified two lower flow zones that are not included in the Yager (1996) model. Yager (1996) identified five flow zones not included in Johnston's mapping, indicated as I-V on Figure 4.2. A synthesis of the flow zone mapping of Johnston (1964) and Yager (1996) therefore comprises 11 flow zones.

Figure 4.3 presents the USGS log of LW-1. The log presents the core breaks that indicate the locations of fractures or weakness in the rock. It can be seen that the core breaks do not always correlate with the flow zones, and some flow zones do not occur at core breaks. This suggests that the USGS recognized implicitly that only a subset of the bedrock fractures is significant for groundwater flow. The lack of core breaks at flow zones II, VI, and VIII, suggests that the USGS conceptualized flow zones as regional features that are not transmissive everywhere in the Niagara region.

4.1.3 SITE HYDROGEOLOGIC CONCEPTUALIZATION

As discussed in Section 3.4.5, the hydraulic conductivity of the intact rock at the Site is very low. Our review of Site data indicates that groundwater flow at the Site is controlled by bedding-plane fractures.

On the basis of the extensive geophysical and borehole flowmeter investigations conducted at the Site in 2001, the Technical Team has concluded that the combined total of 11 flow zones identified by Yager and Johnston are present at the Site. The eight deepest flow zones have been identified positively at the Site. The three shallow flow zones appear to be present; however, they are difficult to identify with certainty. The three uppermost flow zones occur in the Eramosa. As indicated on Figure 3.3, the Eramosa is eroded such that these flow zones subcrop beneath the Landfill.

Visual evidence of the existence of flow zones in the vicinity of the Site is presented on Figure 4.4. This Figure presents a photograph of the gorge of the Niagara River viewed from the Canadian side of the river, in November 2001. Groundwater seepage is visible discharging from a horizontal, bedding-parallel zone along the northwestern-facing wall of the gorge. This seep is located near the AFW-2 well cluster. The seep occurs just above the contact between the Vinemount and Ancaster; this location coincides with the USGS-designated flow zone VI.

The flow zones at the Site are idealized as essentially parallel, planar features. On the scale of the Site, the idealization of flow zones as parallel, planar features is consistent with the inferred nature of the geologic units presented in Section 3.5. The idealization is also consistent with observations from outcrops. Figure 4.5, a panoramic photograph taken from the Butterfly Conservatory in Canada, shows planar bedding along an approximately 1/2-mile Section of the Niagara River gorge. Site-related features are labeled for reference. No significant bedding parallel seeps directly downgradient from the Site are visible on Figure 4.5. The absence of local seeps is likely due to pumping by the bedrock purge wells.

4.2 BASIS FOR THE EXISTING SITE HYDROGEOLOGIC CHARACTERIZATION

The previous hydrogeologic conceptualization of the Site defined three bedrock monitoring intervals, the Upper (U), Middle (M), and Lower (L) bedrock. This characterization was presented in the *Drilling Summary Report, RRT Well Installations* (CRA, 1993). The basis for the characterization was packer testing described in

Identification of Major Hydraulic Units of the Lockport Formation, dated April 16, 1991. This technical note was included as Appendix B of the *Drilling Summary Report*.

The results of the packer testing were used to divide the bedrock above the Rochester Shale into the Upper, Middle, and Lower monitoring intervals. The criteria that defined these intervals are summarized below.

Upper wells

The open intervals for the Upper wells were specified according to two criteria:

- the "minimum depth of Upper well installation shall be 25 feet below top of bedrock"; and
- the "maximum depth shall be approximately halfway through the first non-water-bearing interval or the top of the Eramosa (approximate maximum depth is 70 feet below top of bedrock)." [According to the stratigraphic nomenclature of Brett et al. (1995), the Eramosa is now referred to as the Vinemount.]

Lower wells

The Lower wells were open "from approximately 1-foot below the top of Gasport Formation to the top of the Rochester Formation". According to the stratigraphic nomenclature of Brett et al. (1995), the specified open intervals for the Lower wells corresponded to the Gothic Hill of the Gasport Dolomite and the DeCew.

Middle wells

According to the *Identification of Major Hydraulic Units of the Lockport Formation*, the "delineation of the middle monitoring interval is left to whatever units are identified between the upper and lower intervals."

The existing bedrock monitoring wells were installed and are classified according to the Upper, Middle, and Lower classifications.

4.3 2001 INVESTIGATION ACTIVITIES FOR REFINEMENT OF THE HYDROGEOLOGIC CONCEPTUALIZATION

The data collected during the 2001 Site investigations that are the foundation of the revised hydrogeologic characterization are the geophysical and borehole flowmeter logs. The discrete vertical geophysical profiles were correlated across the Site, making use of the work of previous investigators. The important findings of the previous investigators are:

- groundwater flow zones are parallel to bedding;
- groundwater flow zones are regionally continuous; and
- there are eleven defined flow zones.

The evaluation presented here begins with the assumption that the previous investigators made reasonable interpretations of the data available to them.

4.3.1 FRAME OF REFERENCE FOR FLOW ZONES IDENTIFIED FROM THE GEOPHYSICAL AND BOREHOLE FLOWMETER INVESTIGATIONS

Our analysis of the results of the geophysical investigation has revealed that the gamma logs provide important insights into the structure of the groundwater system. In particular, the gamma logs provide a reliable and relatively precise basis for determining the orientation of bedding at the Site. The gamma logs provide an indirect measure of the clay content of the rock, and therefore can be used to identify distinct shaly intervals within the bedrock. Figure 4.6 presents the second page of the 2-page summary for well clusters F2 and H2. The gamma signature from the F2 cluster is typical of the Site. A comparison of the gamma signatures between wells and well clusters at the Site demonstrates a consistent signature from the bottom of the Eramosa down through the Pekin. Specific peaks in the gamma logs, indicative of shaly intervals, can be correlated across the Site.

The 2-page summary logs for all of the wells geophysically logged are included in Appendix A. Several clear overlays of the 2-page summary logs are also provided in Appendix A, to facilitate independent review of our correlations.

Figure 4.7 shows the gamma peaks visible in the logs for well F2U, F2M, F2L, H2U, H2M, and H2L. The peaks labeled on Figure 4.7, and others, can be traced across the

Site. Key gamma peaks have been identified in the logs for all wells that were logged. The gamma peaks have been labeled for two reasons:

- to provide a reference for tracking the bedding across the Site; and
- to provide a reference for locating flow zones.

The key peaks are special only in that they are more prominent, and can be identified clearly. There are no other criteria for their selection.

The USGS did not use gamma peaks as a reference, presumably because the peaks are more difficult to correlate on a regional scale. However, on the Site scale the gamma signatures are clear and unique. The distinctiveness of the gamma signatures makes the gamma peaks an excellent reference system for identifying the vertical locations of the flow zones. There is evidence that this distinctiveness extends beyond the immediate vicinity of the Site. Figure 4.8 presents a comparison of the gamma signature for USGS well LW-1, presented by Brett et al. (1995), and the gamma signatures from the AGW-2 cluster. Well LW-1 is located on the berm of the Lewiston Reservoir, approximately one mile northeast of the Site. The gamma signature for LW-1 is nearly identical to the gamma signatures from Site wells. Some peaks, particularly gamma peak E (GP-E), are clearly evident on a regional scale.

For the Site, gamma peaks rather than lithologic contacts are used to trace bedding, and ultimately flow zones. As discussed in Section 3.0 and Appendix G, the identification of lithologic or formation contacts is somewhat subjective. There may be several, potentially conflicting, criteria defined to identify a contact. As demonstrated in Appendix G, use of the criteria established by Brett et al. (1995) to pick the contacts has led the same geologist, inspecting the same core at two different times, to identify picks that differ by as much as 5 feet. The gamma peaks constitute a more precise set of markers for referencing the locations of bedding-parallel flow zones than do the lithologic contacts.

The purpose of identifying and labeling key gamma peaks has been to establish a common reference for the bedding. This purpose can be accomplished by identifying any of the obvious, traceable peaks. It is not necessary to either identify or follow every gamma peak across the Site to understand the bedding. Therefore, not every gamma peak has been labeled. The labels begin at "E", near the top of the Vinemount. Although there appear to be traceable peaks in the overlying Eramosa, there are fewer data in the Eramosa than in other units, as the thickness of the Eramosa over large portions of the Site has been reduced by erosion. Labels "A" to "D" are reserved for possible later use in

the Eramosa. There are also gamma peaks located between the labeled peaks that can be traced across the Site.

Table 4.1 presents a list of the elevations of the gamma peaks identified from the 2-page summary logs presented in Appendix A.1. The elevations of peaks are measured to the nearest foot. As discussed in Appendix G, the potential measurement error associated with the elevation of the gamma peaks is approximately ±2 feet.

4.3.2 INTERPRETATION OF GAMMA PEAKS AS PLANES

The locations of the gamma peaks presented on Table 4.1 have been plotted in three dimensions, and inspected to evaluate the nature of bedding beneath the Site. Figures 4.9A, B, and C present side views of these gamma peak picks. The gamma peaks have been color-coded, with a common color assigned to the same gamma peak identified in each log. As shown on Figure 4.9A, when viewed from an arbitrary angle, the locations of peaks appear to be essentially random. However, as the view is rotated, the gamma peak data begin to align. Figure 4.9B, which presents a view rotated 90° with respect to Figure 4.9A, shows a more systematic arrangement of the gamma peaks. An analysis of the spatial distribution of the gamma logs has determined that the direction of strike of the bedding is N.69°E. Figure 4.9C shows that the gamma peaks when viewed along bedding strike (strike is into and out of the page, dip is parallel to the page). The gamma peak data form essentially parallel lines (actually planes) striking N.69°E. and dipping N.159°E. at 39 feet per mile.

The surfaces containing each gamma peak on Figure 4.9C appear to be planar. Furthermore, these planes appear to be parallel. These observations suggest that bedding is planar and parallel at the Site. This characterization of the bedding is consistent with the regional mapping described in Section 3.0 and with visual observations from outcrops near the Site (cf. Figure 4.5).

A set of parallel planes has been fit to gamma peaks GP-E through GP-N. Figure 4.10 presents the three-dimensional plot of all of the gamma peak picks and the best-fit planes. The Figure presents the same side view as Figure 4.9C, that is, looking along strike. The bedding-parallel planes match closely all of the gamma peaks. Figure 4.11 presents cross-section B-B' showing the gamma logs for selected wells and the traces of the best-fit planes, along strike. The location of the cross Section is shown on Figure 3.10. The Section is similar to Figure 4.10, and shows the relation between the gamma signatures and the best-fit planes.

Figures 4.10 and 4.11 depict qualitatively the match between the gamma peaks and the mathematical best-fit planes. Figure 4.12 presents a probability plot of the differences between the best-fit planes and the gamma peaks listed on Table 4.1. The differences are referred to as residuals. The probability plot includes the residuals for all of data from GP-E through GP-N. Based on the discussion of measurement errors presented in Appendix G, the measurement error associated with any pick from the gamma logs is about ±2 feet. This measurement error is depicted on the probability plot.

Approximately 90 percent of the residuals are within the potential measurement error of ±2 feet. Of the residuals greater than ±2 feet, some appear to be related to survey/zero datum issues. For example, at well H2M, every residual is between -1.9 feet and -3.0 feet; i.e., every gamma peak, not just one or two, is 2 to 3 feet lower than predicted with the best-fit planes. Similarly, every one of the residuals from AGW-2M is between +2.0 feet and +2.8 feet. A geologic condition that causes a uniform offset of every gamma peak from the top of the Vinemount through the Pekin Member seems unlikely. It seems more likely that there is a survey error, or that the geophysical survey zero datum was incorrectly referenced. If the geophysical survey had been referenced to the top of the well casing at H2M instead of ground surface, the error would cause every gamma peak to appear approximately 2 feet low, i.e., the residuals would all be -2 feet. Regardless of the explanation for the residuals greater than ±2 feet, none are more than 1 foot greater than the potential measurement error.

The uncertainties in the elevations of the gamma peaks discussed above are not great enough to affect the interpretations in this report. The characterization is intended to identify Site-wide features, and is relatively insensitive to minor uncertainties smaller than 2 or 3 feet.

The conceptualization of bedding defined by parallel planes is a simplifying assumption that is mathematically and conceptually reasonable. The conceptualization is consistent with the depositional environment in which the beds were formed. This conceptualization is carried through the definition of flow zones.

4.3.3 INTERPRETATION OF WATER-BEARING FEATURES FROM GEOPHYSICAL DATA

The significance of the different borehole logging tools is discussed in Appendix A. Based on our review of the data, four of the geophysical tools provided information that

was useful for identifying fractures: three-arm caliper; temperature (and delta temperature); fluid resistivity; and acoustic televiewer. These tools provided indirect indications of inflows along the open intervals, or in the case of the acoustic televiewer, indications of changes in the properties at the surface of the borehole wall. As indicated previously, the natural gamma log also provided crucial information for this investigation. Review of the gamma signatures for the wells revealed that particular peaks in the gamma response could be used as a yardstick for vertical referencing.

Only one of the borehole tools, the borehole flowmeter, provides definitive evidence that a permeable zone exists. The borehole flowmeter measures vertical flow within a borehole, under either ambient or injection conditions. Water is added to enhance the vertical flow and potentially improve the detection of water-bearing features. The QEC report on the borehole flowmeter testing is included as Appendix C.

All other geophysical measurements provide indirect evidence of a water-bearing feature. In interpreting the geophysical data, water-bearing features have been identified where the results of the borehole flowmeter profiling demonstrate that a permeable feature is present, or where one or more of the geophysical measurements strongly indicates that a water-bearing feature is present. An example interpretation is provided on Figure 4.13. Figure 4.13 presents the geophysical log for the B2 well cluster. At approximately 554 feet above mean sea level (ft AMSL), the borehole flowmeter data ("fluid flow") demonstrates the presence of a water-bearing zone (the red line shows flow under injection conditions). At 549 ft AMSL, an offset in temperature and fluid resistivity indicates another water-bearing feature. Green lines on Figure 4.13 indicate the 549 and 554 ft AMSL levels.

The interpretation of water-bearing features discussed above seems simple and was initially undertaken on a quantitative level. However, the interpretation quickly became subjective. A subjective interpretation was necessary due to several factors. Three of these factors are discussed below.

- Except for the borehole flowmeter, the geophysical measurements are indirect indicators of a water-bearing feature;
- There is some uncertainty associated with the elevation of a selected water-bearing feature due to the potential offset between the actual location of the feature and its appearance on the geophysical signal. For example, a conductivity shift occurs where water of a different conductivity enters the borehole. Depending on the rate of flow into the well, the magnitude of vertical flow at that point of entry, and the

conductivity of the incoming water, the conductivity shift will be offset from the point where groundwater enters the borehole; and

- There is a balance between picking every feature that possibly indicates flow and picking only those that are unequivocal. Only the significant features need to be captured to define a conceptual model. Our experience demonstrated that identifying every detail confounds the identification of the flow zones. Studying minute detail also increases the number of incorrect picks, further confounding the characterization.

Several guidelines were developed during the review of the geophysical logs to assist in the identification of water-bearing features. These guidelines are described below.

1. Confidence in the pick should be high.
2. Data near the water surface, and at the bottom of the well casing, often appear to be unreliable. An example of noisy, unreliable data at the water surface may be seen in the log for well B1M at 527 ft AMSL. The data may be disturbed by vertical flow around the casing and / or the introduction of the tool into the water column.
3. Changes in the specific conductance (the inverse of fluid resistivity) in the Lower wells may not be indicative of groundwater flow. A layer of high conductance water is frequently observed in the Lower wells, including the Lower wells with essentially zero transmissivity and therefore, no groundwater flow. The high conductance layer is more likely related to diffusion of salt from the brine known to be present in the Rochester Shale, than to water-bearing features.
4. Some of the temperature changes are so small as to have questionable validity. Even if the changes are accurate, the flow is so small that the actual groundwater temperature is not offset, and the magnitude of the flow is likely insignificant. This general observation is tempered by the observation that the transmissivity in many Lower bedrock wells is so low that small temperature spikes may indeed be a significant indicator of groundwater flow.
5. The temperature and fluid resistivity data from re-logged wells may not be equally reliable. Pumping was stopped temporarily at some purge wells to allow for water levels in the Middle bedrock monitoring wells to recover. Under pumping conditions, the water level in many Middle wells is within the open interval. The acoustic televiewer does not work unless submerged, and in those wells with the water level in the open interval, the acoustic televiewer only recorded a portion of the open interval. Pumping was temporarily stopped at selected purge wells to allow water levels to recover, and eight Middle bedrock

monitoring wells were re-logged with the acoustic televiewer. The multi-parameter tool described in Appendix A was also run after recovery to provide quality control. However, because these wells had recently refilled, the temperature and fluid resistivity profiles may have shifted and not had sufficient time to equilibrate.

Occasionally, two different measurements indicating a water-bearing feature occur at slightly different elevations. The difference in elevation may be as much as 2 or 3 feet. If these measurements are judged to represent the same feature, the water-bearing feature may be picked at an average elevation; or possibly at either extreme, based on the reviewer's judgment. Figure 4.13 shows that at B2M, the caliper and acoustic televiewer logs indicate a feature at 520 ft AMSL. The borehole fluid flow measurement shows water entering the formation between 521 and 522 ft AMSL. In this case, the water-bearing feature is picked at the midpoint in the data, 521 ft AMSL. This level is indicated by a green line on Figure 4.13.

The uncertainties in the elevations of the water-bearing features discussed above are not great enough to affect the interpretations in this report. The characterization is intended to identify Site-wide flow zones, and is relatively insensitive to minor uncertainties smaller than 2 or 3 feet.

The water-bearing features identified by inspection of the 2-page summary logs are presented on Table 4.2. As noted above, only features considered significant are identified on the table. The picks represent an attempt to balance between too fine and too coarse an interpretation of the data.

The water-bearing features can also be observed in the borehole videos being collected by MSRM. The geophysical logs generally provide more quantitative evidence of flow than do the video logs. In contrast, the video logs provide a better "feel" for what the water-bearing features look like.

4.3.4 GROUPING OF WATER-BEARING FEATURES INTO FLOW ZONES

Not all of the water-bearing features identified on Table 4.2 are flow zones. They may be points within a flow zone. However, water-bearing features will exist between flow zones. Flow zones are identified by the consistent occurrence of water-bearing features aligned along bedding.

The water-bearing features are grouped into flow zones using the conceptualization that bedding is aligned with the parallel planes fit to the gamma peaks, that the flow zones are parallel to these planes, and that water-bearing features will be observed more frequently at flow zones than between flow zones. The evaluation of flow zones was initiated by defining the plane fit to gamma peak "E" (GP-E) as a datum. This peak has been used because it is the most prominent peak in the gamma signature, it can be seen in almost every well at the Site, and it is regionally identifiable.

All points in a flow zone parallel to the GP-E plane will be offset by the same vertical distance from the GP-E plane. The vertical distances between the GP-E plane and each water-bearing feature have been calculated and are listed on Table 4.2. These distances have been inspected for clustering.

Figure 4.14 presents the results of the clustering analysis. The distances between the water-bearing feature and GP-E are sorted from smallest to largest, and plotted with a uniform spacing along the x-axis. If the water-bearing features are all from one flow zone, the data points will fall along a single horizontal line, representing a particular vertical distance from GP-E. If the features are distributed randomly, the data will fall on a single sloping line. Multiple flow zones will appear as steps on the plot. Ideally, the data for a single flow zone lie at a common distance from the GP-E plane, followed by a vertical step to the position of the next flow zone. Measurement error and the failure of nature to conform to mathematically-perfect planes, results in some deviation from the ideal horizontal line at one elevation.

The clustering of water-bearing features around common positions is clearly evident on Figure 4.14. The flow zones are identified on Figure 4.15. The discussion of flow zones presented here follows the numbering system adopted by the USGS (Yager, 1996), with the modification of Roman numerals to conventional Arabic numerals. Flow zones 4 to 9 are the same as zones IV to IX identified by the USGS and presented in Yager (1996). Johnston (1964) identified the same flow zones as Yager, as well as two deeper flow zones, one at the Gothic Hill/DeCew contact, and one at the DeCew/Rochester Shale contact. These flow zones are present at the Site, and have been numbered 10 and 11.

Figure 4.16 presents gamma logs for well clusters F2 and H2. The gamma log is annotated with the gamma peak labels and the flow zones. Based on the analyses presented above and inspection of the geophysical data, the correlations between the flow zone locations and the gamma peaks or unit contacts are:

Flow Zone	*Gamma Peak or unit contact*
1	Estimated to be 47 feet above GP-E
2	Estimated to be 26 feet above GP-E
3	Estimated to be 17 feet above GP-E
4	10 to 14 feet above GP-E
5	0 to 5 feet above GP-E
6	From GP-G to GP-H
7	Around GP-K
8	Just above GP-L
9	Between GP-L and GP-M
10	Middle to lower Gothic Hill
11	Bottom of DeCew

Where gamma logs are available, identification of the gamma peaks allows determination of the positions of the flow zones. If gamma logs are not available, or are inconclusive, the elevation of the flow zones can be estimated from the following equation:

$$\text{Elevation of flow zone} = C_x \text{ Esp} + C_y \text{ Nsp} + \textit{Constant}$$

where:

C_x, C_y, and *Constant* are constants determined by the fitting of bedding-parallel planes through the center of the flow zones. Esp and Nsp are Easting and Northing coordinates in the NYS 1983 state-plane coordinate system, Western zone. In this equation, flow zone elevations are referenced with respect to the NAD83 datum.

The equations for each flow zone are tabulated below.

Flow Zone	C_x	C_y	*Constant (ft)*
1	-0.002660558	0.006826912	-4454.1
2	-0.002660558	0.006826912	-4475.1
3	-0.002660558	0.006826912	-4484.1
4	-0.002660558	0.006826912	-4490.1
5	-0.002660558	0.006826912	-4498.6
6	-0.002660558	0.006826912	-4515.1
7	-0.002660558	0.006826912	-4535.1

Flow Zone	C_x	C_y	*Constant (ft)*
8	-0.002660558	0.006826912	-4540.1
9	-0.002660558	0.006826912	-4544.1
10	-0.002660558	0.006826912	-4558.6
11	-0.002660558	0.006826912	-4573.1

It is important to retain all of the decimal places for C_x and C_y since they are used in conjunction with the state plane coordinates. The calculated elevations from these equations will generally be within 3 feet of the actual location for flow zones 4 to 11. Flow zones 1, 2, and 3 are estimates based on limited data and the accuracy of the mathematical planes for these zones cannot be reliably assessed at this time.

4.4 CHARACTERISTICS OF THE HYDROGEOLOGIC SYSTEM

The hydrogeologic characterization described in this Section summarizes our interpretation of the studies completed at the Site, both past and present, the published reports from the USGS and NYSGS, and the experience and expertise of the Technical Team. The characterization focuses on the spatial configuration of the flow zones. Quantitative assessment of the spatial hydraulic properties has been deliberately excluded. A discussion of the reason for not including more quantitative results is presented in Section 4.4.2.

The characterization developed here is sufficient to guide the evaluation and possible refinement of the current monitoring network to more accurately reflect hydrogeologic conditions at the Site.

4.4.1 GENERAL DESCRIPTION OF THE HYDROGEOLOGIC SYSTEM

The results of the regional and Site-specific groundwater investigations demonstrate that there are zones of enhanced permeability parallel to bedding. These zones are defined as flow zones and have been recognized in numerous publications. Horizontal groundwater flow is concentrated in the flow zones. The hydraulic properties of the flow zones are spatially variable, as indicated in the summary of results of past slug and packer testing presented in Appendix H.

The flow zones are separated by aquitards. Figure 4.15, the cluster analysis presented in Section 4.3.4, shows that there are water-bearing features within the aquitards.

However, the density of water-bearing features is low within the aquitards as compared to the adjacent flow zones. Like flow zones, the hydraulic properties of the aquitards are spatially variable. Between flow zones 9 and 10, there are very few water-bearing features, suggesting that the hydraulic conductivity of this aquitard is probably low compared to the aquitard between flow zones 5 and 6, where there are many water-bearing features.

Although flow zones are the focus of the evaluation presented here, the aquitards are equally important, as it is the layering and contrasting hydraulic properties that comprise the hydrogeologic system. The aquitards will be addressed with equal consideration in future groundwater modeling efforts.

Johnston (1964) suggested that most of the groundwater flow occurs within flow zones. This suggestion must be interpreted carefully. Groundwater flow occurs throughout the bedrock system. The groundwater system is recharged by the infiltration of precipitation. It is more reasonable to conceive of recharge flowing vertically downwards through the overburden and vertical fractures in the aquitards, to replenish the flow zones. Horizontal groundwater flow occurs primarily within the flow zones.

Johnston (1964) suggested that the recharge to the flow zones occurs in the outcrop area of the flow zones, north of the Site. Kappel and Tepper (1992) added the qualification that this applies "in areas undisturbed by natural or manmade structures." When the planes defining the flow zones at the Site are extended they are truncated by both natural and manmade structures: the NYPA forebay, NYPA conduits, and the gorge of the Niagara River.

Previous investigations have indicated that the Rochester Shale forms an impermeable bottom to the shallow bedrock groundwater system at the Site. Kappel and Tepper (1992) concluded that at the regional scale, "Ground water is prevented from flowing below the Lockport Group by the low permeability of the underlying Rochester Shale." Away from the Niagara River, groundwater flow across the Rochester Shale is further limited by overpressurization of the natural-gas reservoir within and below the Rochester Shale. The data from the Intermediate Formation Wells (IFWs) installed at the Site confirm that there is no hydraulic communication across the Rochester Shale to deeper formations.

4.4.2 DETAILS OF THE HYDROGEOLOGIC SYSTEM

The refinement of the hydrogeologic characterization presented in Section 4.0 has provided the location of flow zones. The elevations of the flow zones can be estimated using the equations presented in Section 4.3.4. As indicated previously, the frame of reference defined by the peaks of the gamma responses has been crucial in the synthesis of the results from the geophysical and borehole flowmeter investigations. To confirm that this frame of reference is reliable, the predicted elevations of the flow zones have been mapped back to the summaries of the geophysical logs, and in particular to the gamma logs. Two examples of this mapping, for well clusters F2 and H2, are shown on Figure 4.16. The results shown on Figure 4.16 illustrate the relations between the flow zones and the gamma peaks, and demonstrate the consistency of those relations across the Site.

The flow zones identified in this report have been numbered following the convention set by the USGS, as described in Yager (1996). Flow zone 7 in this report is equivalent to Yager's flow zone VII. Yager identified nine flow zones, the lowest located in the Pekin Member of the Gasport Formation. Johnston identified two flow zones below Yager's flow zone IX, one at the top of the DeCew, and one at the DeCew/Rochester Shale contact. These have been identified as flow zones 10 and 11.

Flow Zones 4 Through 11

Eight of the flow zones (4 through 11) have been clearly identified from the data collected during the 2001 Site investigations, as described in Section 4.4.4. Flow zones 4 through 9 correspond to six of the flow zones incorporated in the regional model of Yager (1996), flow zones IV to IX. Flow zones 10 and 11 correspond to the two lowest flow zones identified by Johnston (1964). The three flow zones that have not been clearly identified at the Site are Yager's uppermost flow zones I, II, and III. As indicated previously, these three flow zones are located in the Eramosa where the thickness may have been reduced by erosion. Identification of discrete flow zones at the top of the Eramosa may also be confounded by the relatively higher intensity of fracturing due to weathering.

Flow Zones 1, 2, and 3

The cluster analysis does not provide clear evidence of any flow zones above flow zone 4. Flow zones 1, 2, and 3 are likely present at the Site; however, the greater density of fractures in the Eramosa than the underlying units obscures their identification. Since

reliable identification of key water-bearing features above flow zone 4 is not possible from the cluster analysis, the flow zones above flow zone 4 were estimated by more subjective interpretation of the data on water-bearing features, and by estimating the probable vertical position from the USGS flow zone picks at well LW-1, shown on Figure 4.2. The borehole flowmeter data suggest that a transmissive zone has been observed in two wells, F3U and J1U, approximately 26 feet above GP-E. This position coincides with the elevation of Yager (1996) flow zone II.

The cluster analysis also shows an absence of water-bearing features between about 31 and 44 ft above GP-E. This is indicative of an aquitard. Four water-bearing features are identified between 45 and 49 ft above GP-E. There are few points here because this is approaching the highest elevation in the bedrock in the vicinity of the Site. Although the data are sparse, a critical feature implicit in the identification of a flow zone is the presence of an underlying aquitard. The water-bearing features between 45 and 49 feet above GP-E are assumed to represent a flow zone, coinciding approximately with Yager's flow zone I. A small cluster of data likely indicates flow zone 3, centered approximately 17 feet above GP-E.

Dominant Flow Zones

Based on the frequency of occurrence of water-bearing features, Johnston's "**XX**" flow classification, and results of the borehole flowmeter testing, flow zones 5, 6, and 9 appear to be the most transmissive. This observation is very preliminary.

No detailed investigation of the hydraulic properties of individual flow zones has been conducted. The results of the packer tests conducted at the Site in 1991 have been inspected to assess the transmissivity of individual flow zones. These data are inconclusive, as the 15-foot packer spacing for these tests precludes isolation of the individual flow zones. The performance data from the purge wells have also been examined to assess the transmissivity of the individual flow zones. However, no conclusions can be drawn from these data either, as the open intervals of the purge wells also intercept multiple flow zones.

Additional evaluation of the relative transmissivity of the flow zones will be important for future modeling as well as monitoring.

Comparison of the Flow Zones and Stratigraphic Units

Figure 4.17 presents the flow zones identified above, overlain on the cross-section B-B' that was presented on Figure 3.12. The flow zones are shown as black lines representing the parallel planes given by the equations in Section 4.3.4. Several concepts are presented in this figure.

- The geology discussed in Section 3.0 uses the best-estimate elevations of the stratigraphic contacts, determined by inspection of drill cores. This is standard practice in the industry. The flow zones are idealized plane surfaces. The goal of the hydrogeologic characterization has been to revise the description of the subsurface so that it is consistent with regional characterizations formulated in terms of flow zone concepts. Based on the discussion of data accuracy presented in Appendix C, both approaches are valid interpretations.
- The dips of the flow zone planes are parallel to the stratigraphic contacts and the gamma planes.
- The locations of the flow zones defined at the Site conform to the location of the flow zones defined regionally by Johnston (1964) and Yager (1996) and referenced to stratigraphy.
- Flow zones 1 through 6 are truncated on Site due to erosion of the bedrock prior to intersecting the Niagara Gorge.

Overburden and Upper 15 Feet of Bedrock

Two features of the hydrogeologic system that have not yet been addressed are the overburden sediments and the first 15 feet of bedrock. The overburden consists of lacustrine silts and clays overlying glacial till. The results of single-well response tests at the Site indicate that the silts and clays have limited transmissivity (CRA, 1983a; CRA, 1984). The results from the single-well response tests are consistent with the very low yields of the monitoring wells and extraction wells/trenches located in these materials. The basal till immediately overlying the bedrock was characterized as being connected directly to the top of rock (CRA, 1983a; CRA, 1984). Groundwater flow in the overburden is therefore most likely downwards, replenishing the bedrock aquifer.

The upper 15 feet of bedrock has been characterized by Johnston (1964), Kappel and Tepper (1992), and Yager (1996), as a "highly-fractured weathered zone…" that is very transmissive. We believe that Kappel and Tepper (1992) and Yager (1996) presented the 15-foot depth as a 'carry-over' from Johnston (1964). Although it is reasonable to expect

that fractures will be most open at the top of bedrock, and will tend to close deeper in the bedrock due to lithostatic pressure, the 15-foot depth described by Johnston (1964) does not appear to be an appropriate generalization for the Site.

As shown on the cross-sections (Figures 3.11 and 3.12), the upper 15 feet of bedrock generally includes the Eramosa and the Vinemount. Visual inspection of the geophysical logs for signs of fracturing (principally caliper logs, acoustic televiewer, and temperature) suggests that fracturing in the shallow bedrock is highly variable. At AGW-2, 30 feet of the Eramosa appears to be intensely fractured, while at AGW-3U, a similar Section of the Eramosa appears to be sparsely fractured. At wells B1U and B2U, where the Eramosa has been eroded and the Vinemount is the uppermost bedrock unit, there does not appear to be any intense fracturing of the shallow bedrock at these wells. In general, inspection of the geophysical data suggests that the depth and intensity of fracturing is highly variable across the Site.

Section 3.0 presents an evaluation of the frequency of fractures with respect to depth below top of bedrock, and by stratigraphic unit. The results of that analysis indicate that the number of fractures gradually decreases with depth below the top of bedrock, and that the frequency of fractures is dependent on the lithology. There is no indication of a rapid change in the frequency of fractures at a specific depth. Although the evaluation does not consider fracture apertures, the results suggest that an assumed 15-foot zone of weathering / more intense fracturing is not necessarily appropriate for the Site.

4.4.3 IMPLICATIONS OF THE REVISED HYDROGEOLOGIC CHARACTERIZATION

The revised hydrogeologic characterization described above satisfies the objective defined for this study; it provides a tractable framework for evaluating groundwater flow, and APL and NAPL migration. It also leads to a conclusion that the existing monitoring network may require revision for detailed groundwater flow analysis, and in particular, the evaluation of hydraulic containment.

Figure 4.18 presents a view along strike of the flow zones and open intervals of the existing bedrock monitoring wells. The view is similar to Figures 4.11 and 4.17. The flow zones are truncated at the top of bedrock and the Niagara River gorge. The Upper, Middle, and Lower bedrock wells are designated by color. The Figure shows that the open intervals of the monitoring wells intersect multiple flow zones. The water level in a well that spans multiple flow zones represents a weighted average of the water levels

in the individual flow zones. The average water level is a function of the hydraulic head in each flow zone intercepted, weighted by the local transmissivity of each flow zone. The transmissivity of the flow zones is spatially variable; two nearby wells that are open across the same flow zones may have water levels that represent averages with significantly different transmissivity weighting, resulting in different water levels in the wells.

Figure 4.19 is identical to Figure 4.18, with the exception that the open intervals of the monitoring wells have been replaced by the open intervals of the purge wells. This Figure shows that the existing purge wells also intercept multiple flow zones. This construction allows the purge wells to contain multiple flow zones. However, it complicates the analysis of pumping test data.

Figure 4.20 presents a plan view of the Site showing the subcrop of the aquitards separating the eleven flow zones identified. The color bands represent the subcrop of the bedrock aquitards (the intersection of the top of bedrock with the aquitard). The contacts between aquitards are the flow zone subcrops (assuming that flow zones are very thin planes). Figure 4.20 demonstrates an interesting result of the revised hydrogeologic characterization. Although eleven flow zones are identified, flow zones 1 through 5 subcrop before reaching the gorge face. The point of potential exposure is at the gorge face. Therefore, only flow zones 6 to 11 represent the potential exposure pathways. Flow zone 1 does not even reach the downgradient (northwest) portion of the Landfill. The truncation of flow zones has important implications for monitoring conditions at the Site, and these will be examined in detail as our understanding of the groundwater flow system evolves. Here, the Figure is presented as a conceptual / working tool.

Figures 4.18, 4.19, and 4.20 were created from a three-dimensional EVS model. The three-dimensional model is included on a compact disc (CD) enclosed with the report. The model is in a format that is compatible with the freeware 4-D Interactive Model Viewer included on the CD. Using the 4-D Interactive Model Viewer, the model can be rotated in any direction, zoomed into or out of, and changed from orthographic to perspective view. The CD includes instructions on viewing the EVS model.

4.5 SUMMARY

The following observations summarize the revised hydrogeologic characterization of the Site:

1. The previous hydrogeologic characterization of the Hyde Park Landfill Site defined three bedrock monitoring intervals: Upper, Middle, and Lower. The monitoring intervals were based on the criteria defined in the *Drilling Summary Report, RRT Well Installations* (CRA, 1993).
2. The revised hydrogeologic characterization developed here represents a refinement of the previous characterization.
3. The revised hydrogeologic characterization defines discrete flow zones that transmit groundwater in the horizontal direction. The primary characteristics of the flow zones are:
   - they are parallel to bedding; and
   - they are regionally continuous.
4. The combined total of 11 regional flow zones identified by previous investigators are present at the Site. The eight, deepest flow zones have been identified positively at the Site. The three shallow flow zones appear to be present, but are based on a very limited data set. The three uppermost flow zones occur in the Eramosa.
5. Northwest of the Landfill, in the downgradient direction of groundwater flow, flow zones 1 through 5 subcrop before reaching the gorge face. The point of potential exposure is at the gorge face. Therefore, only flow zones 6 to 11 represent the potential exposure pathways. The truncation of flow zones has important implications for monitoring conditions at the Site.
6. Based on the frequency of occurrence of water-bearing features, Johnston's "**XX**" flow classification, and results of the borehole flowmeter testing, flow zones 5, 6, and 9 appear to be the most transmissive. This observation is very preliminary.
7. Although flow zones are the focus of the evaluation presented here, the aquitards are equally important, as it is the layering and contrasting hydraulic properties that comprise the hydrogeologic system. The aquitards will be addressed with equal consideration in future groundwater modeling efforts.
8. No detailed investigation of the hydraulic properties of individual flow zones has been conducted. Additional evaluation of the relative transmissivity of the flow zones will be important for future modeling as well as monitoring.

9. The revised hydrogeologic characterization described above satisfies the objective defined for this study; it provides a tractable framework for evaluating groundwater flow, and APL and NAPL migration. It also leads to a conclusion that the existing monitoring network may require revision for detailed groundwater flow analysis, and in particular, the evaluation of hydraulic containment.

5.0 ONGOING HYDROGEOLOGIC CHARACTERIZATION

The existing numerical groundwater models of the region Yager (1996), and of the Site (SSP&A, 2001a) simulate the general groundwater flow directions, however, neither of these models simulate the 11 discrete flow zones. The existing monitoring wells provides water levels that are averages of the multiple flow zones intercepted. These water level data are useful for evaluating the general direction of groundwater flow. However, they are not useful for the calibration of a model simulating 11 discrete flow zones, or for the precise hydraulic monitoring required in the RRT.

While the characterization presented here provides a tractable hydrogeologic framework for the Site, an interpretation of the groundwater flow within individual flow zones cannot be determined. Thus, it is the opinion of the Technical Team that the hydrogeologic characterization is a continuing effort. Three steps remain to complete the characterization of the Site.

1. Installation of multi-level piezometers to monitor water levels in flow zones.
2. Monitoring the multi-level piezometers to assess both pumping and non-pumping conditions.
3. Mathematical modeling of groundwater flow.

Installation of Multi-level Piezometers

Monitoring groundwater levels in individual flow zones is necessary to complete and validate the revised hydrogeologic characterization. The objective of the multi-level monitoring will be to determine the groundwater flow conditions in each flow zone, and to assess the significance of individual flow zones. The data will also provide a calibration reference for the groundwater flow model.

Multi-level monitoring devices must be installed at select locations across the Site. The design of the multi-level monitoring network is currently being evaluated. The feasibility of retrofitting existing wells versus installing new borings for monitoring is also being reviewed. Potential multi-level piezometer designs include:

- conventional small-diameter, short-screen piezometers;
- multiple transducers in a single borehole; and
- commercial multi-level monitoring devices such as those available from Solinst Canada, Ltd., and Westbay Instruments, Inc.

Monitoring and Reporting

The multi-level piezometers will be distributed across the site to assess Site-wide groundwater flow conditions. A monitoring program will be developed for the new piezometers. It is anticipated that select piezometers will be monitored continuously with data loggers, and periodic monitoring of piezometers that are not instrumented will be performed. Both pumping and non-pumping conditions will need to be monitored, as well as the transient response when changing from pumping to non-pumping conditions. At least one pumping test at PW-2M will be performed.

The results of the multi-level piezometer monitoring will be compiled, evaluated, and presented in a report. The report will provide contour maps of the potentiometric surface for each of the significant flow zones that can be monitored independently, and estimates of the spatial properties of the flow zones. This report will represent the completion of the revised hydrogeologic characterization.

Groundwater Flow Modeling

The MSRM Technical Team will complete a model that is consistent with the revised conceptualization presented here, and that is capable of accurately simulating the groundwater flow and purge well containment system. The groundwater levels and spatial hydraulic properties of the flow zones developed during the installation and monitoring of the multi-level piezometers will be incorporated into the new Site groundwater flow model. The model will be used to evaluate the flow directions as well as the significance of individual flow zones (with respect to the proportion of groundwater flow carried). A report describing the modeling will be prepared.

Performance monitoring for the NAPL Plume Containment System

The revised site characterization described in this report has been undertaken to resolve the inability to satisfy all of the requirements for demonstration of containment of the NAPL plume mandated in the RRT. As discussed previously, the inability to satisfy the RRT requirements is not necessarily an indication of failure of the NAPL Plume Containment System. Rather, the existing monitoring network does not provide sufficient precision to demonstrate achievement of the RRT requirements.

An alternative performance monitoring program must be developed for the Site. The hydrogeologic characterization presented here represents a significant refinement of the

previous characterization. There are presently no groundwater level data available to evaluate the reliability of the revised hydrogeologic characterization. The results of additional monitoring, testing, and modeling described above must be completed and evaluated prior to developing a monitoring program that is capable of providing a reliable demonstration of the achievement of the remedial objectives of the RRT.

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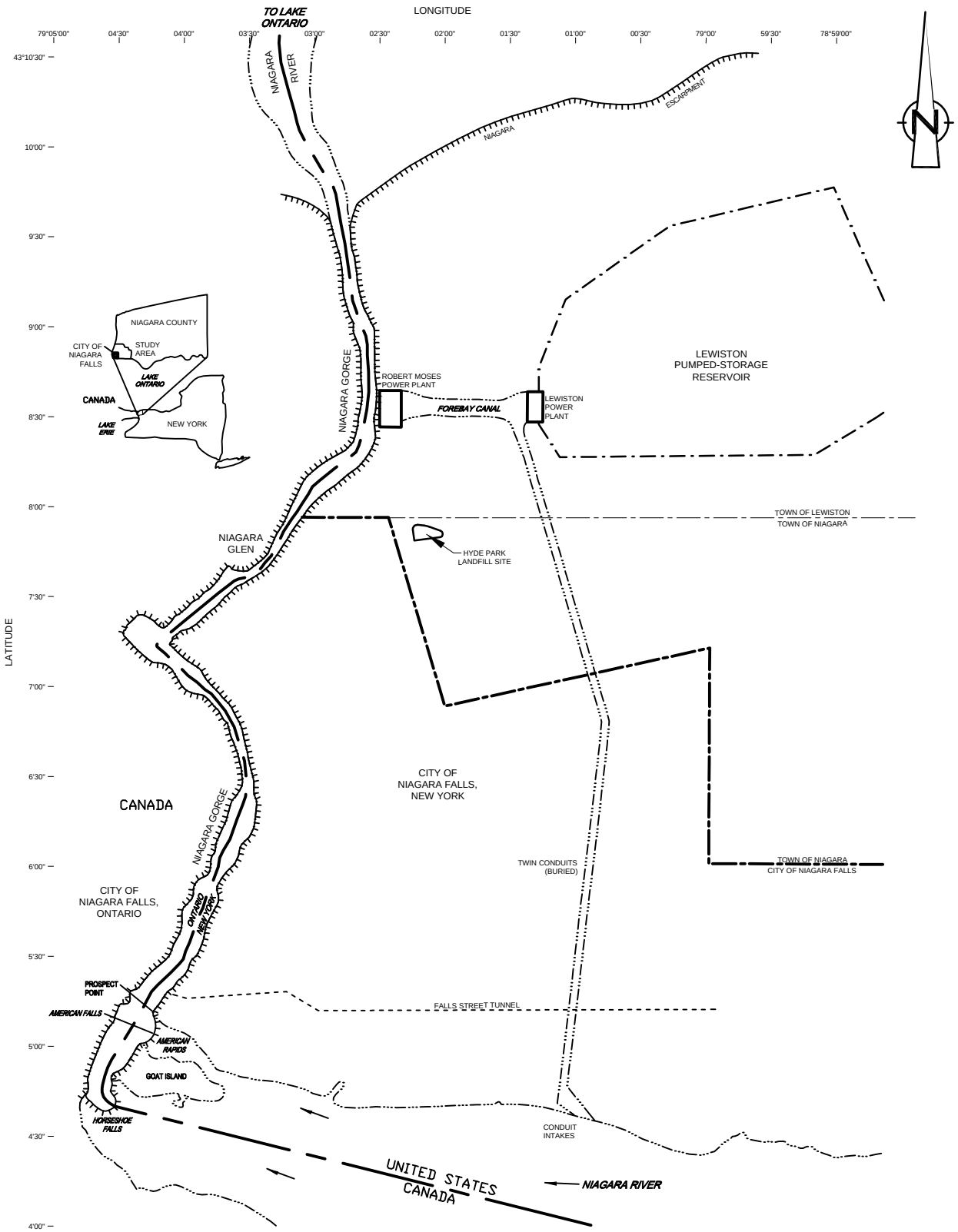
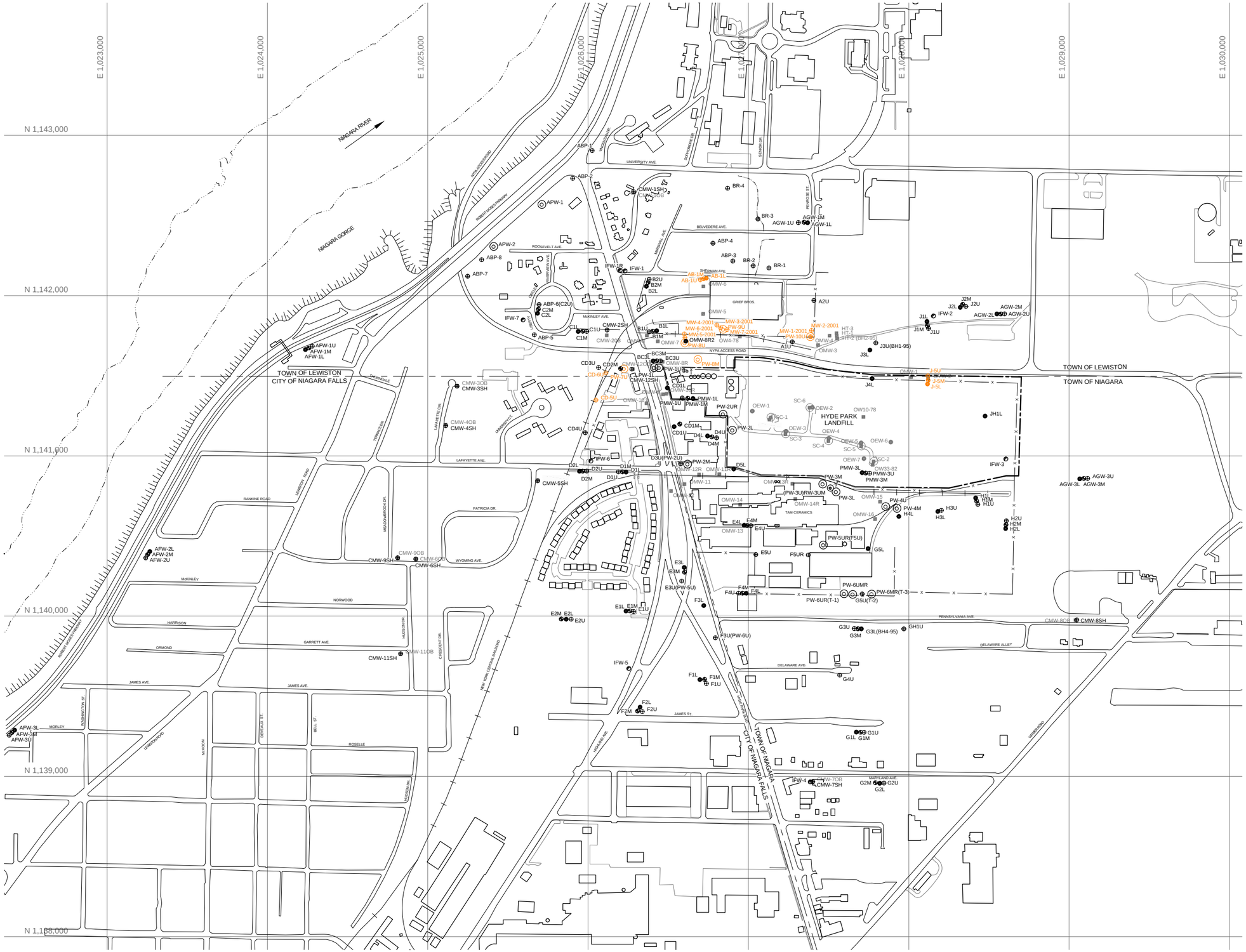


figure 1.1

SITE LOCATION
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

SOURCE: MILLER, KAPPEL, 1987

01069-30(299)GN-WA013 JAN 23/2002



N°	Revision	Date	Initial

N

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- OMW-3 OVERBURDEN MONITORING WELL
- F4U UPPER BEDROCK ZONE MONITORING WELL
- G3M MIDDLE BEDROCK ZONE MONITORING WELL
- B1L LOWER BEDROCK ZONE MONITORING WELL
- IFW-2 INTERMEDIATE FORMATION MONITORING WELL
- SC-1 OVERBURDEN EXTRACTION WELL (SOURCE CONTROL)
- PW-2L BEDROCK EXTRACTION WELL
- RW-3UM BEDROCK RE-INJECTION WELL
- OEW-4 OVERBURDEN EXTRACTION WELL

2001 DRILLING PROGRAM

- CD-5U UPPER BEDROCK ZONE MONITORING WELL
- AB-1M MIDDLE BEDROCK ZONE MONITORING WELL
- J-5L LOWER BEDROCK ZONE MONITORING WELL

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

SITE PLAN

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
JT	BT	JANUARY 2002	
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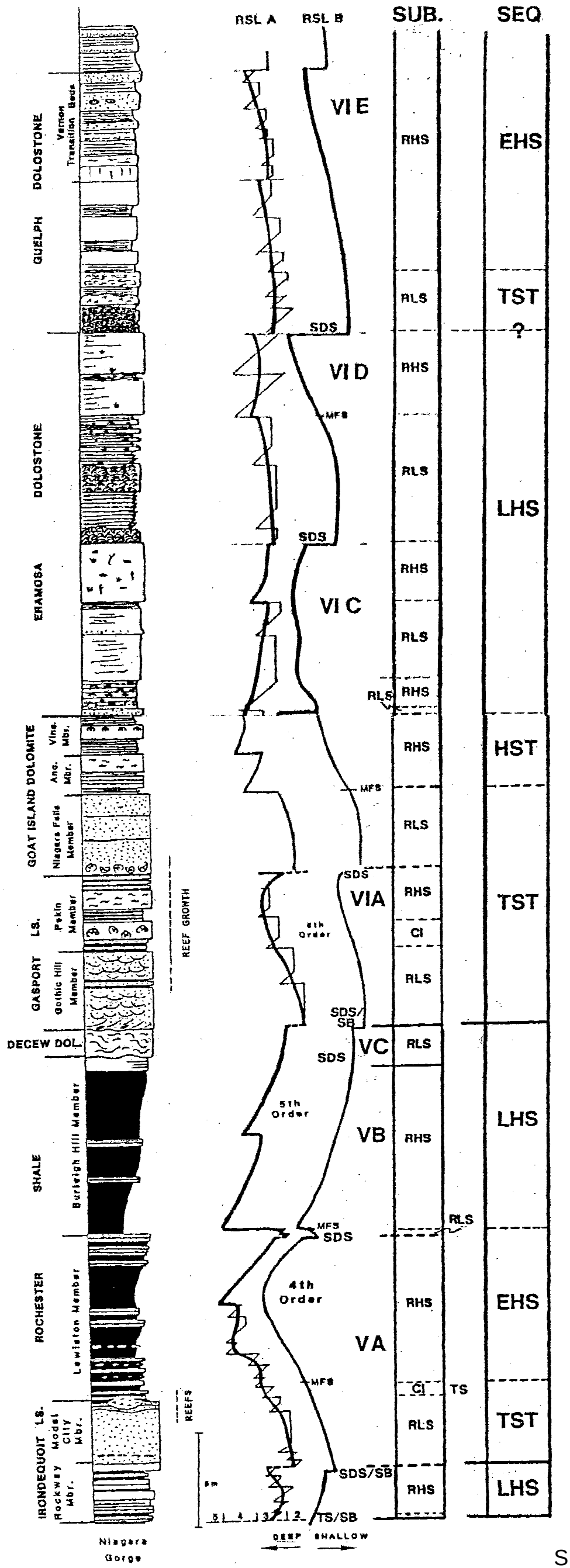


LEGEND

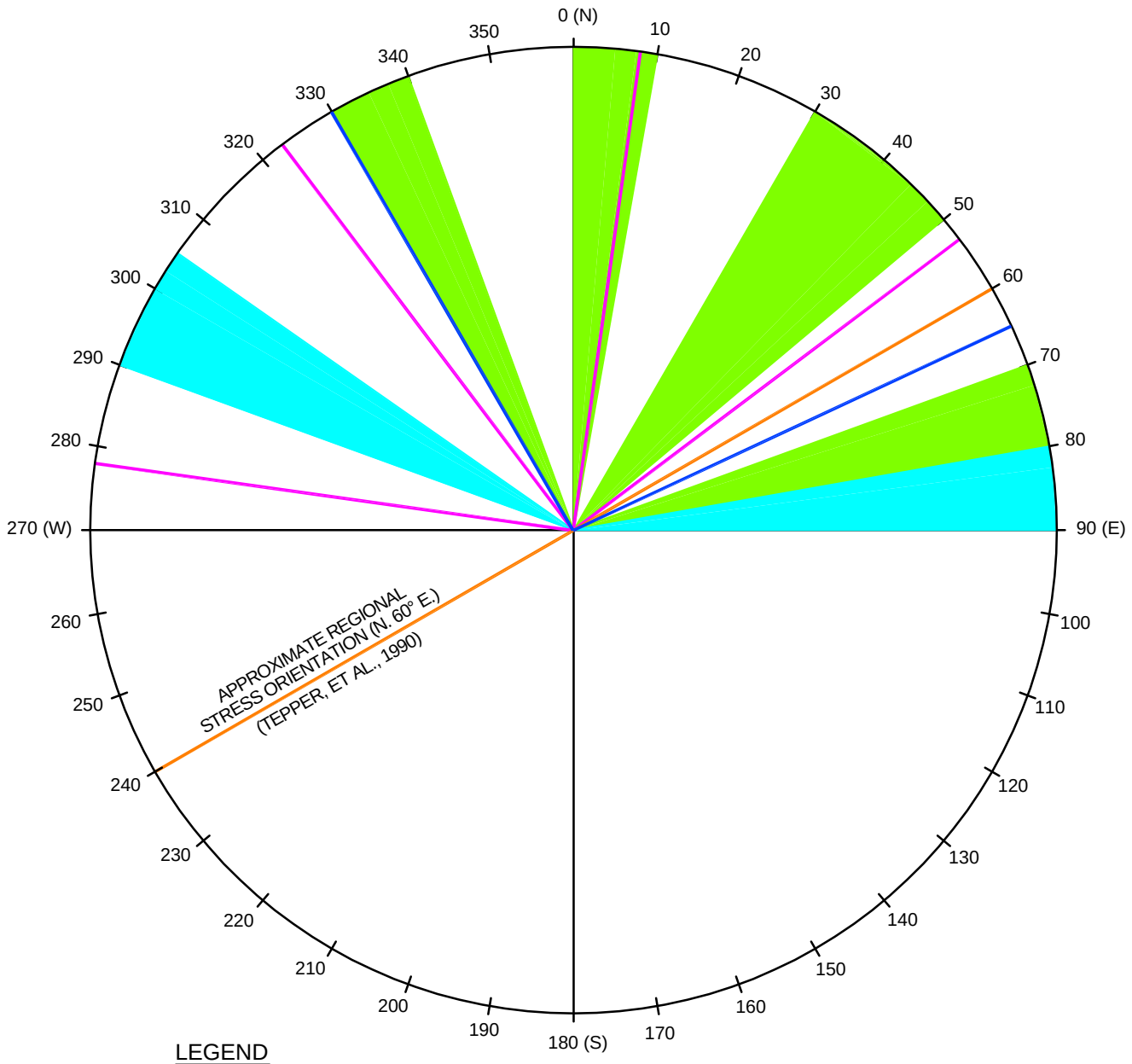
- dark gray shale
- tabular thin wacke- to packstone (dolostone)
- brachiopod-rich grainstone
- biohermal bryozoan wackestone
- coarse crinoidal grainstone
- trough cross-bedded grainstone
- bioturbated, muddy micritic dolostone
- stromatoporoids
- intraclasts
- cherty fine-grained dolomicrite

RSL	RELATIVE SEA LEVEL
RLS	RELATIVE LOWSTAND
RHS	RELATIVE HIGHSTAND
MFS	MARINE FLOODING SURFACE
CI	CONDENSED INTERVAL
TS	TRANSGRESSIVE SURFACE
SDS	SEA LEVEL DROP SURFACE
SB	SEQUENCE BOUNDARY
TST	TRANSGRESSIVE SYSTEMS TRACT
LHS	LATE HIGHSTAND
EHS	EARLY HIGHSTAND
LHS	LATE HIGHSTAND
HST	HIGHSTAND
SUB.	SUBSEQUENCE
SEQ.	SEQUENCE
VA,VIC	SEQUENCE (V,VI) / SUBSEQUENCE (A,C)

figure 3.1

SEQUENCE STRATIGRAPHIC RELATIONSHIPS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

SOURCE: BRETT, ET AL., (1990)(FIGURES 15 AND 16)



LEGEND

IJC (1974)
N. 70° E. - N. 80° E.
N. - N. 10° E.
N. 30° E. - N. 50° E.
N. 20° W. - N. 30° W.

TEPPER, ET AL. (1990)
N. 55° W. - N. 70° W.
N. 80° E. - N. 90° E.

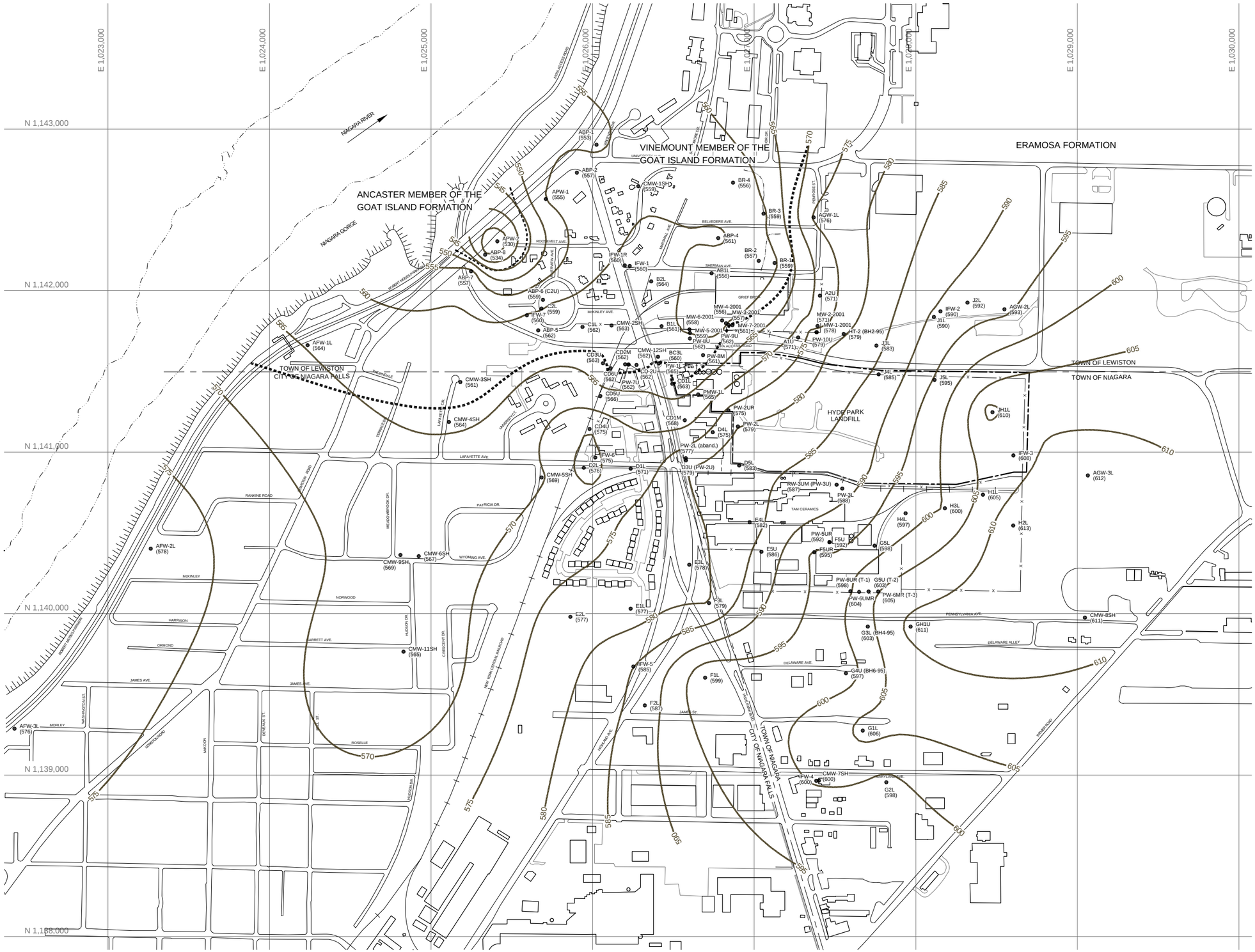
JOHNSTON (1964)
N. 65° E.
N. 30° W.

MEMARIAN (1975)
N. 8° E.
N. 53° E.
N. 82° W.
N. 37° W.

figure 3.2

SUMMARY OF REGIONAL NEAR-VERTICAL JOINT TRENDS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA002 JAN 29/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 TOP OF BEDROCK CONTOUR
- TOP OF ANCASTER MEMBER OR VINEMOUNT MEMBER SUBCROP
- AGW-2L (593) BOREHOLE LOCATION WITH TOP OF BEDROCK ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF BEDROCK ELEVATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
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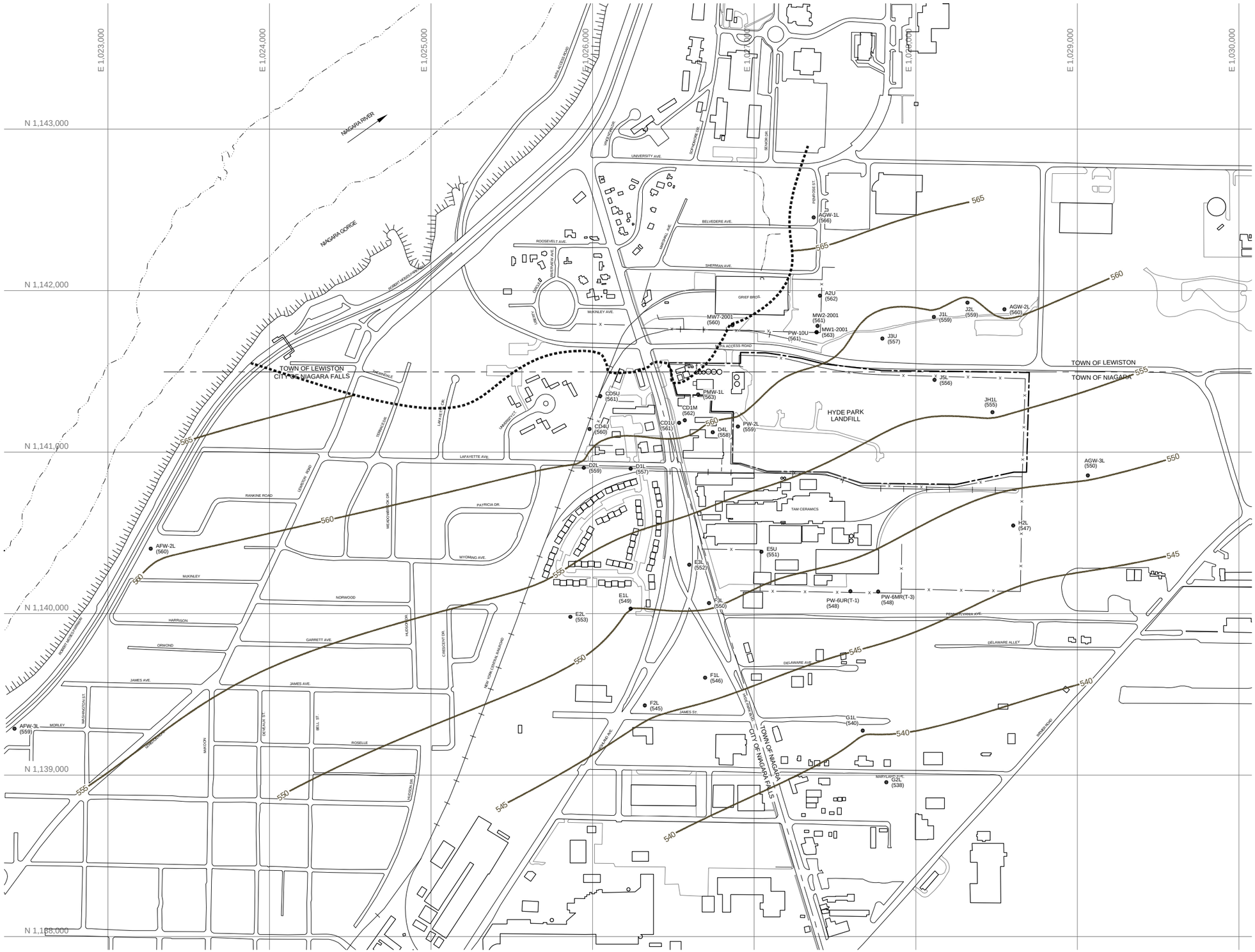

Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 560 TOP OF VINEMOUNT MEMBER CONTOUR
- TOP OF VINEMOUNT MEMBER SUBCROP
- AGW-2L (560) BOREHOLE LOCATION WITH TOP OF VINEMOUNT MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

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DRAWING STATUS

Status	Date	Initial

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HYDE PARK RRT PROGRAM

TOP OF VINEMOUNT MEMBER OF THE GOAT ISLAND FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

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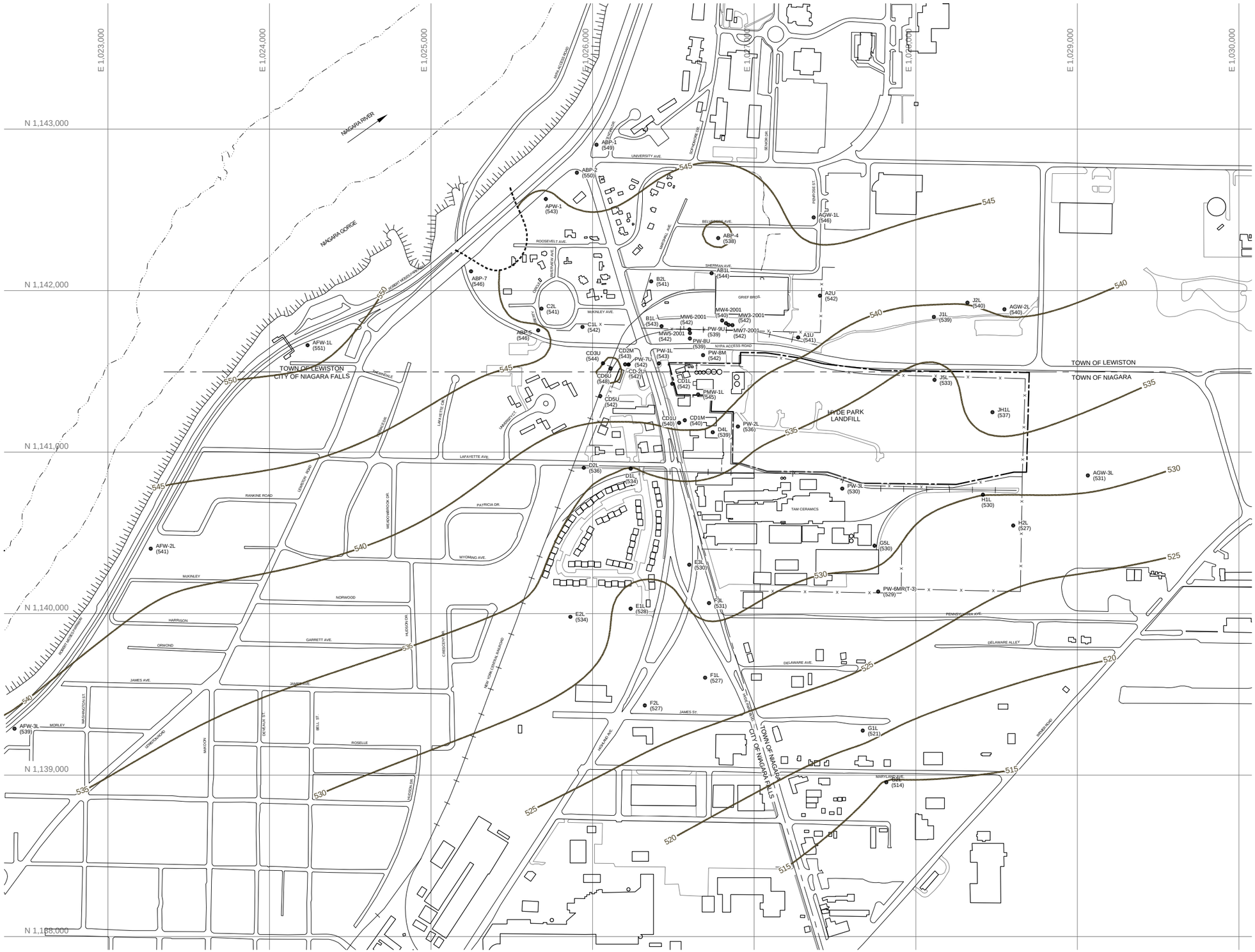

No	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 TOP OF ANCASTER MEMBER CONTOUR
- TOP OF ANCASTER MEMBER SUBCROP
- AGW-2L (540) BOREHOLE LOCATION WITH TOP OF ANCASTER MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF ANCASTER MEMBER OF THE GOAT ISLAND FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
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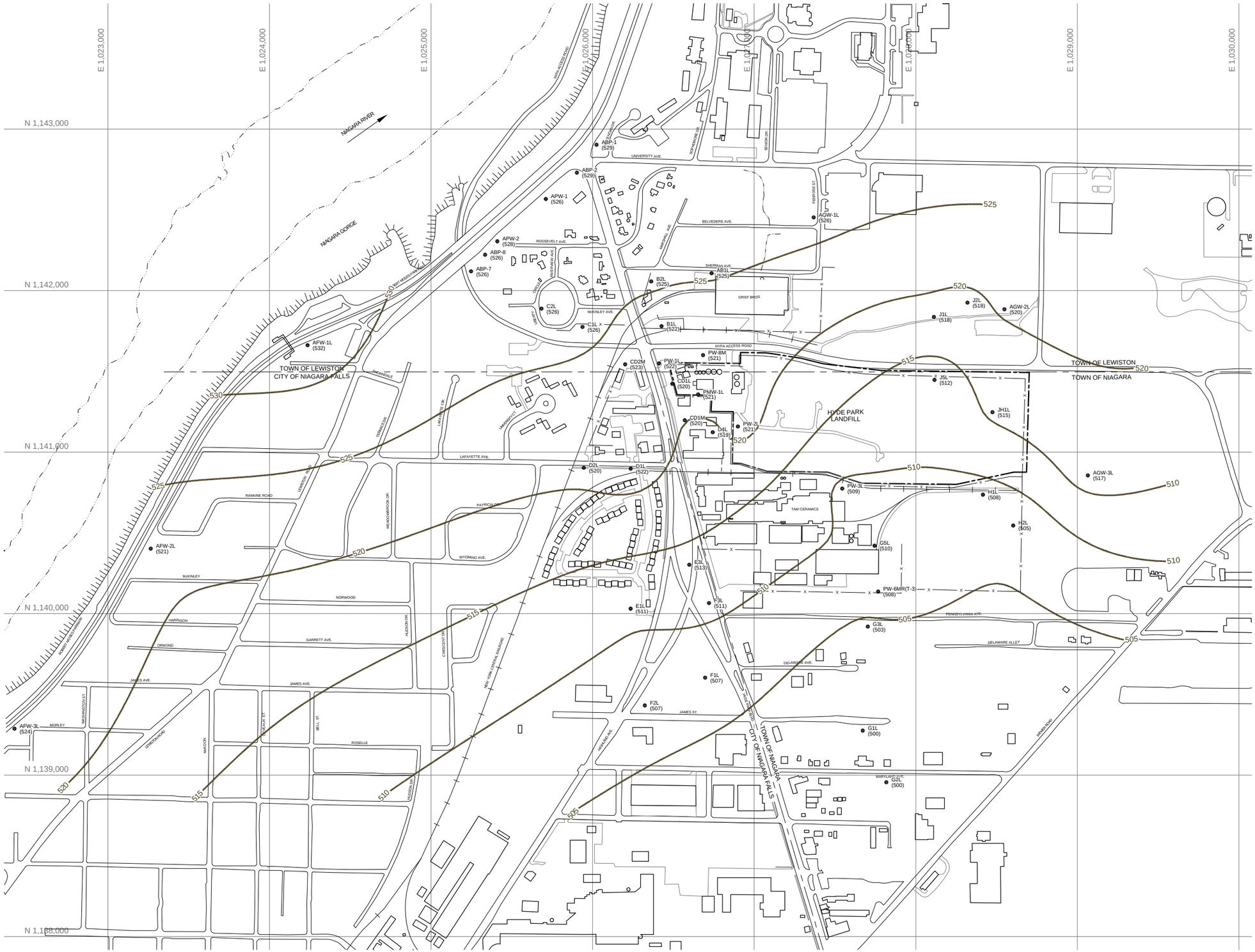
1 = 300'	01069-30	299	3.5

01069-30(299)GN-WA029 JAN 18/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 — TOP OF PEKIN MEMBER CONTOUR
- AGW-2L (520) — BOREHOLE LOCATION WITH TOP OF PEKIN MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF PEKIN MEMBER OF THE GASPORT FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
Scale:	Project Nº:	Report Nº:	Drawing Nº:
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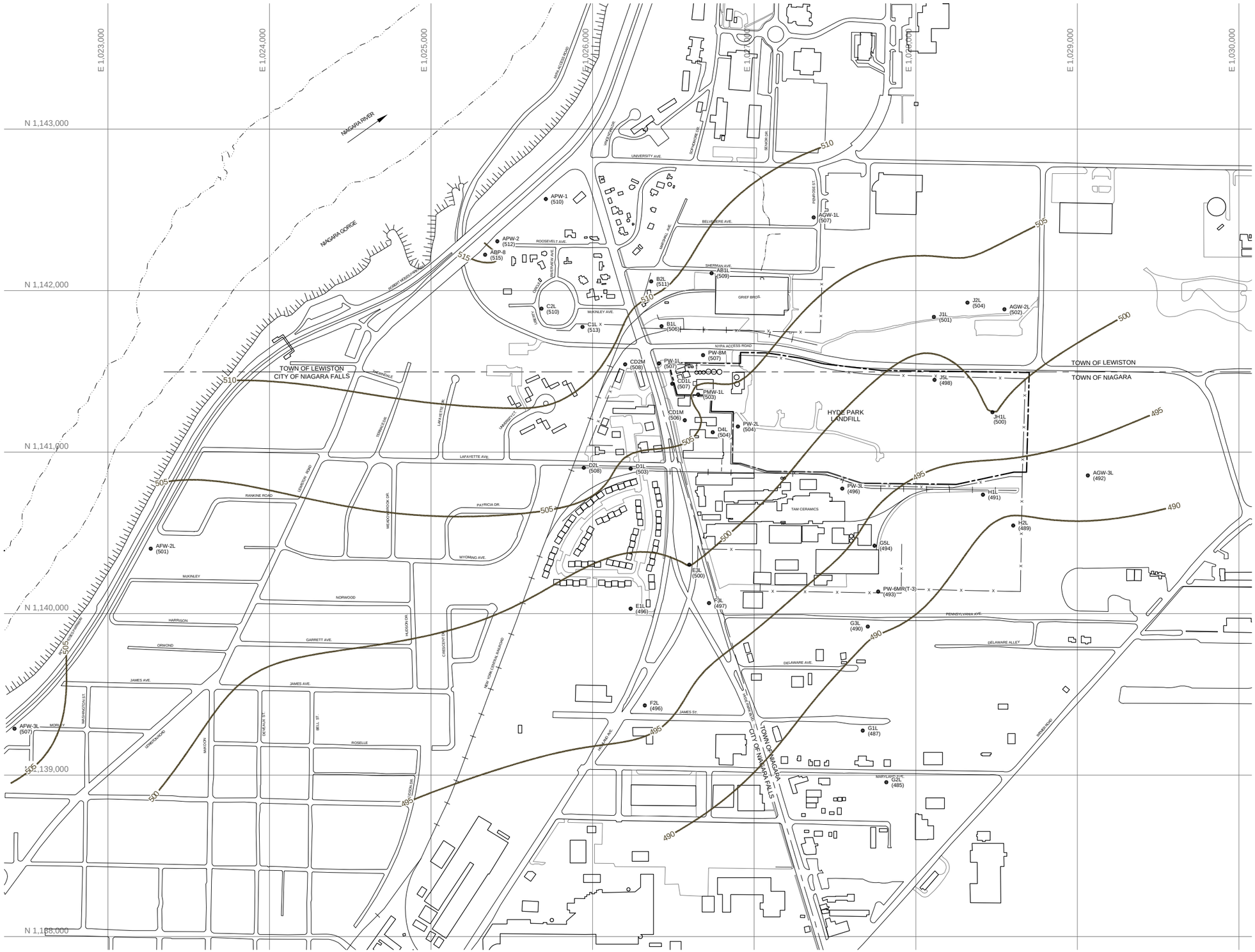
01069-30/299/GN/WA029 JAN 22/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 — TOP OF GOTHIC HILL MEMBER CONTOUR
- AGW-2L (502) — BOREHOLE LOCATION WITH TOP OF GOTHIC HILL MEMBER ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF GOTHIC HILL MEMBER OF THE GASPORT FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
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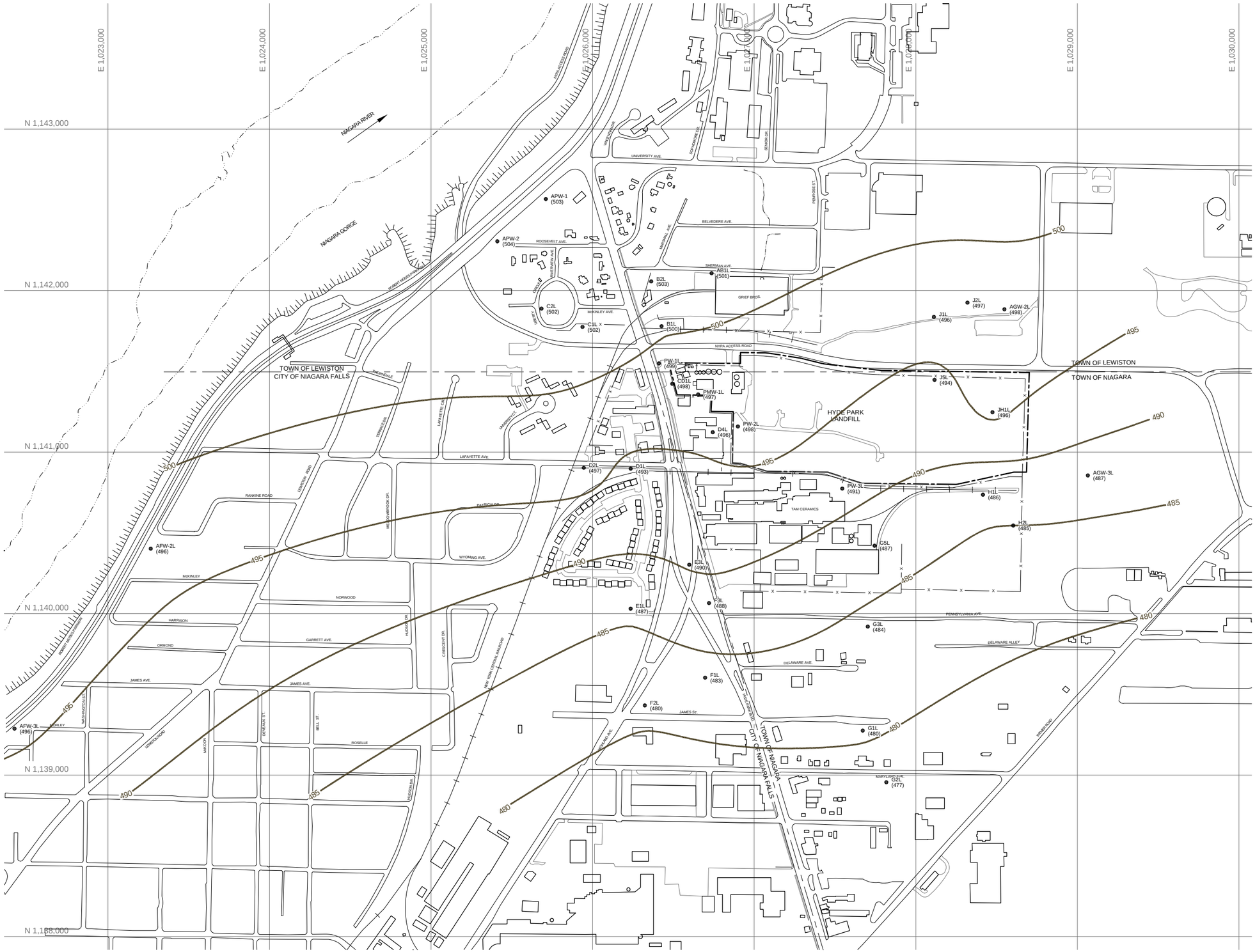
01069-30\299\GN-W021 JAN 18/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 — TOP OF DECEW FORMATION CONTOUR
- AGW-2L (498) — BOREHOLE LOCATION WITH TOP OF DECEW FORMATION ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF DECEW FORMATION

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
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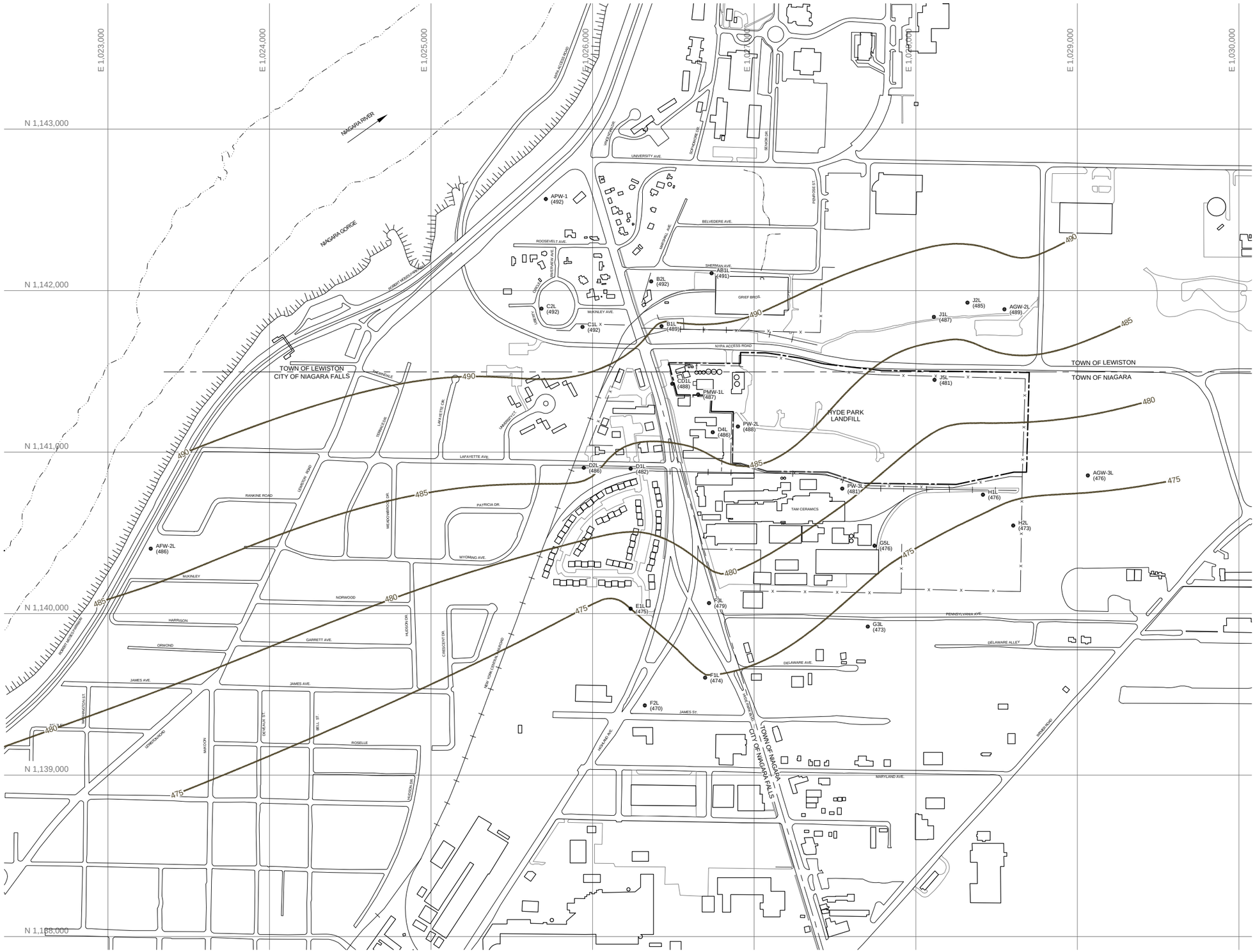
01069-30/299/GN/WA023 JAN 18/2002



Nº	Revision	Date	Initial

0 100 300ft

LEGEND

- DITCH
- POWER TOWER
- MUNICIPAL BOUNDARY
- RAILWAY
- FENCE
- EDGE OF NIAGARA GORGE
- 540 — TOP OF ROCHESTER SHALE CONTOUR
- AGW-2L (489) — BOREHOLE LOCATION WITH TOP OF ROCHESTER SHALE ELEVATION (ft AMSL)

NOTE:

1) SITE BENCHMARK IS A P.K. NAIL SET IN THE EAST FACE OF A POWER POLE LOCATED AT THE WEST END OF THE EXISTING HYDE PARK LANDFILL, ELEVATION = 612.77. DATUM NOT VERIFIED.

SCALE VERIFICATION

THIS BAR MEASURES 1" ON ORIGINAL. ADJUST SCALE ACCORDINGLY.

Approved

DRAWING STATUS

Status	Date	Initial

MILLER SPRINGS REMEDIATION MANAGEMENT INC.

HYDE PARK RRT PROGRAM

TOP OF ROCHESTER SHALE

CONESTOGA-ROVERS & ASSOCIATES

Source Reference:

COORDINATE SYSTEM : CONVERTED FROM SITE SYSTEM TO STATE PLANE BY GIS NOV 2001
AERIAL PHOTO: ABRAMS - NOVEMBER 25, 1998

Project Manager:	Reviewed By:	Date:	
MM	BT	NOVEMBER 2001	
Scale:	Project Nº:	Report Nº:	Drawing Nº:
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01069-30\299\GN-W4023 JAN 18/2002

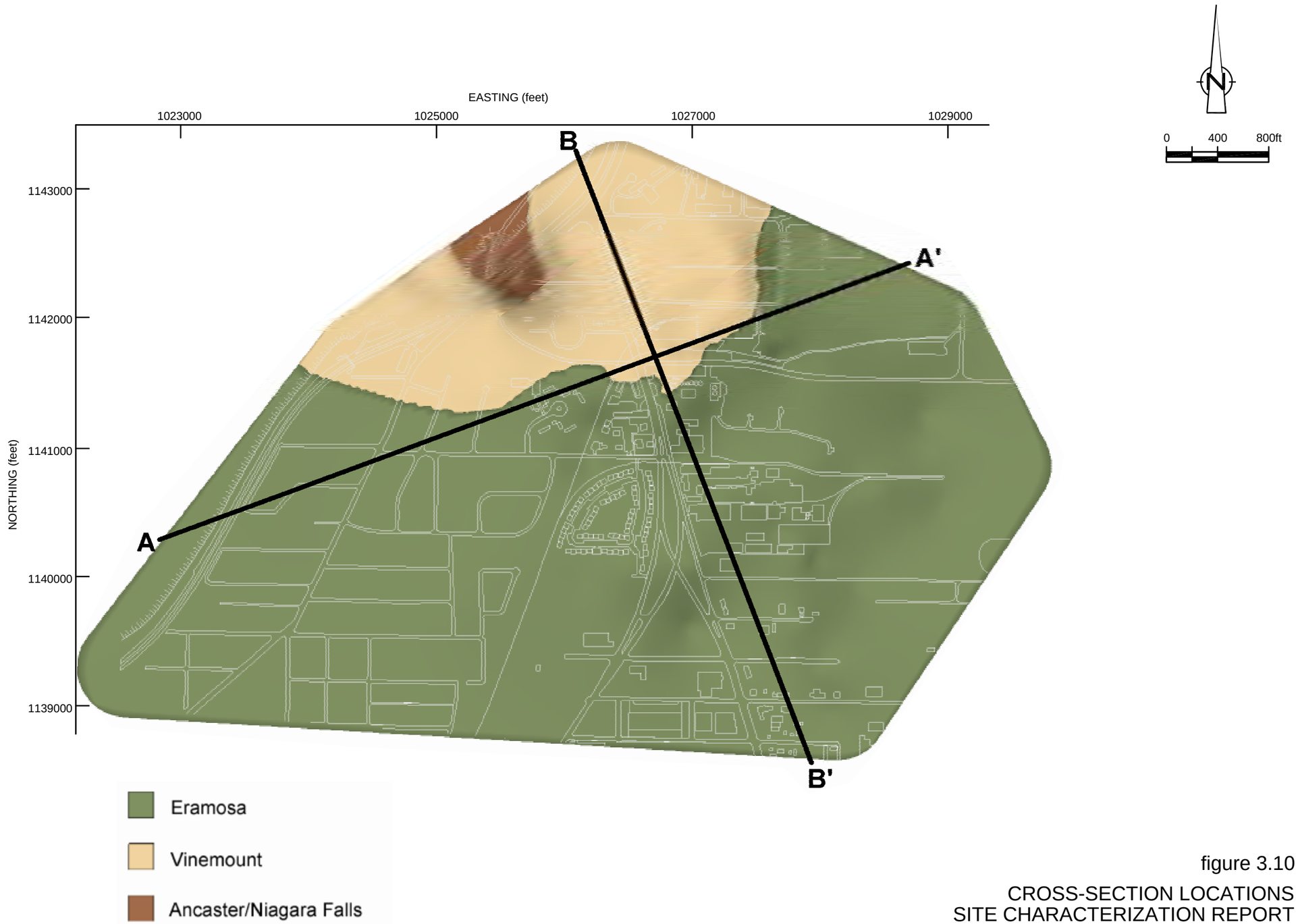
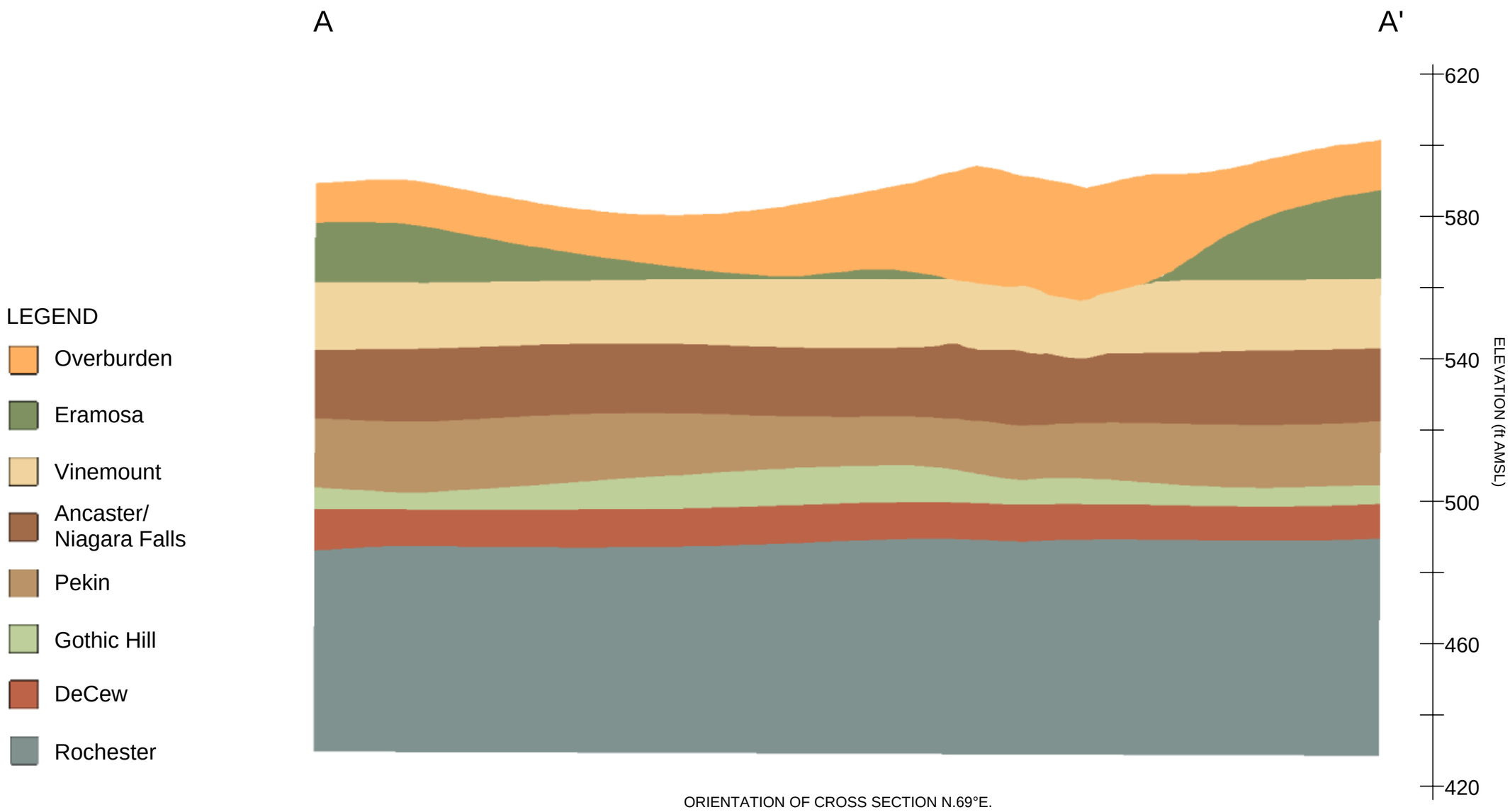


figure 3.10

CROSS-SECTION LOCATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA037 JAN 18/2002



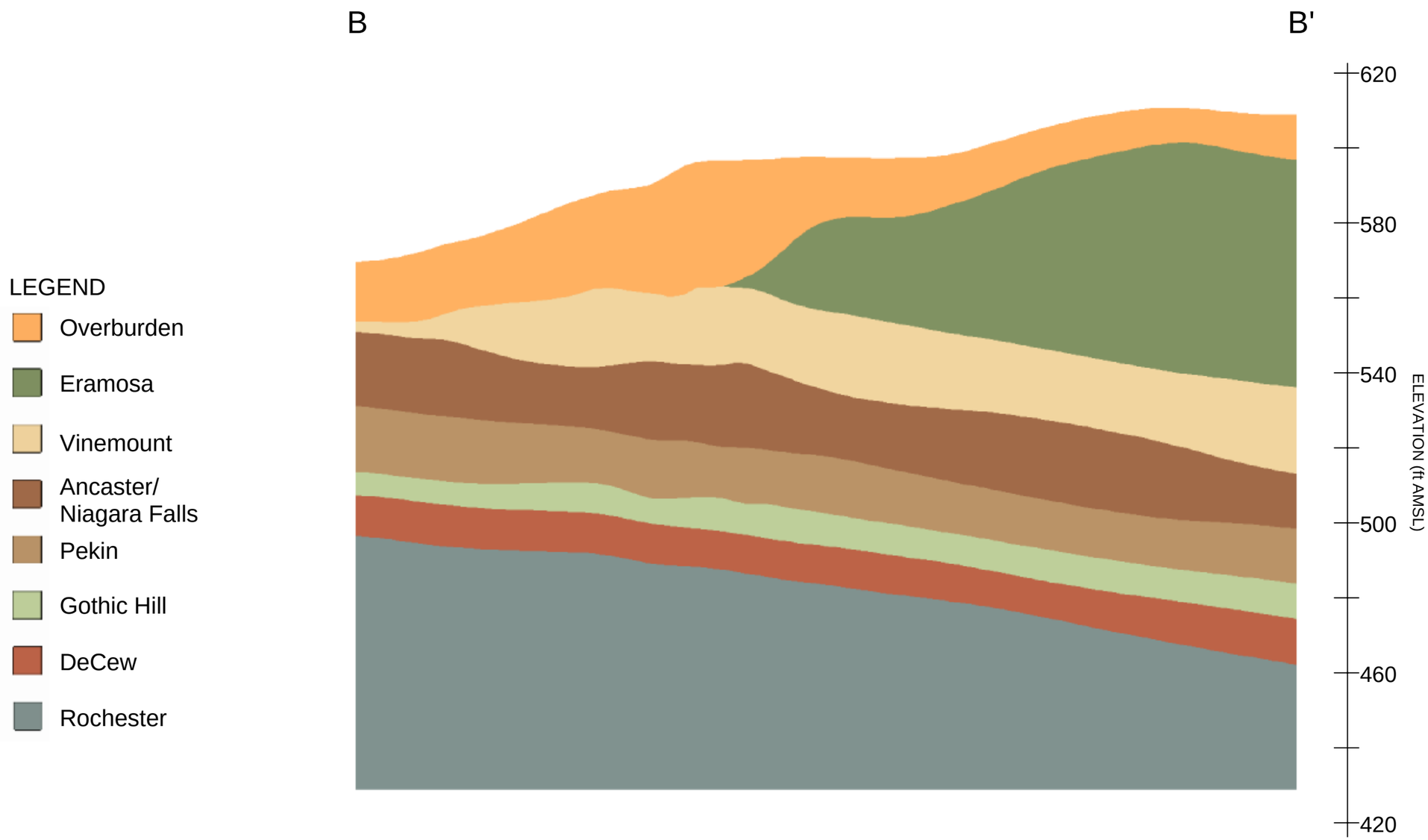
SCALE
HORIZ.: 1" = 600'
VERT.: 1" = 30'

figure 3.11

SCHEMATIC CROSS-SECTION A-A' (ALONG STRIKE)
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

NOTE: VERTICAL EXTENT OF ROCHESTER SHALE IS NOT IMPLIED BY THE FIGURE.

01069-30(299)GN-WA035 FEB 13/2002



ORIENTATION OF CROSS SECTION N.159°E.

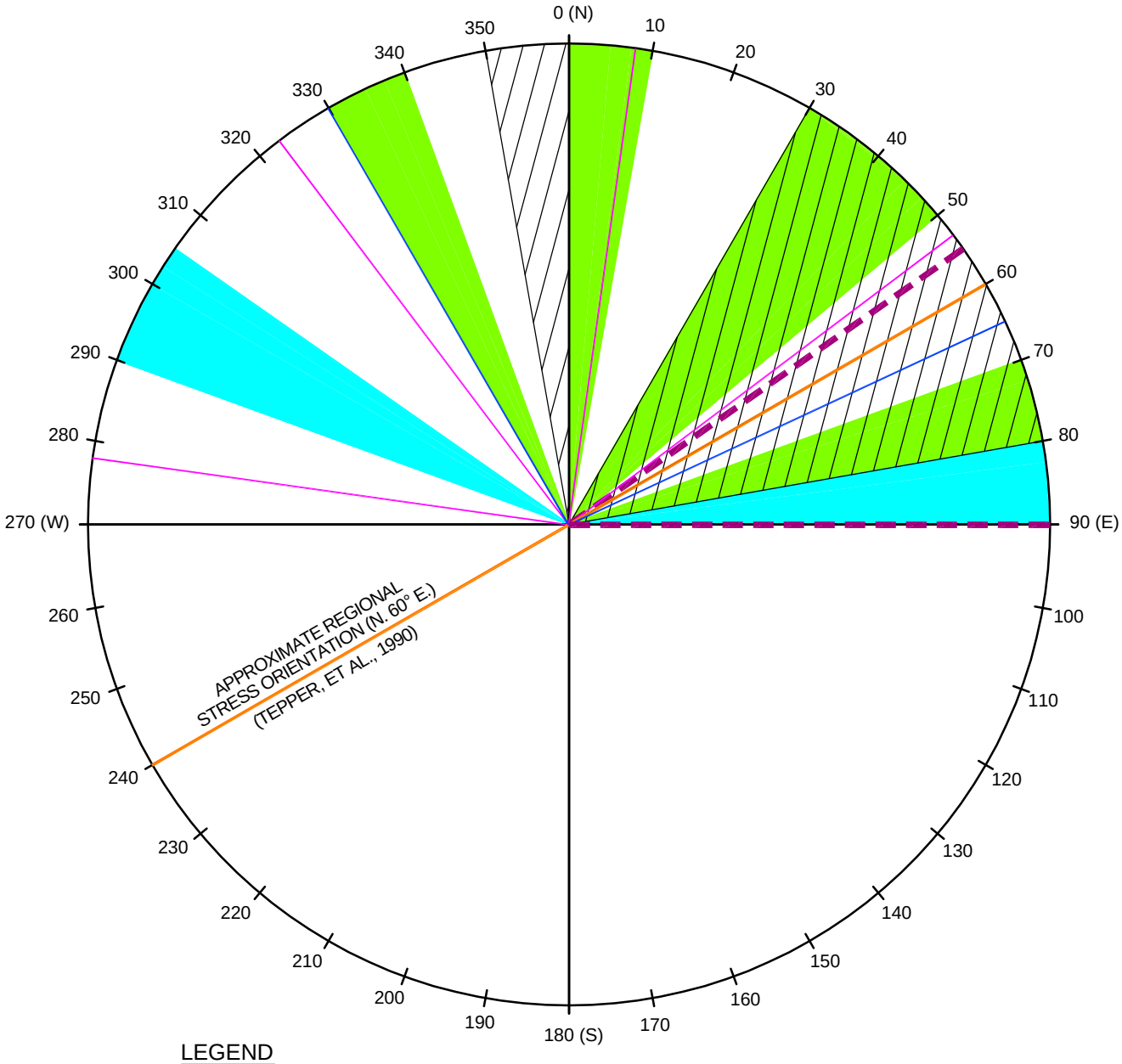
SCALE
HORIZ.: 1" = 600'
VERT.: 1" = 30'

figure 3.12

SCHEMATIC CROSS-SECTION B-B' (ALONG DIP)
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

NOTE: VERTICAL EXTENT OF ROCHESTER SHALE IS NOT IMPLIED BY THE FIGURE.

01069-30(299)GN-WA036 FEB 13/2002



LEGEND

IJC (1974)
N. 70° E. - N. 80° E.
N. - N. 10° E.
N. 30° E. - N. 50° E.
N. 20° W. - N. 30° W.

TEPPER, ET AL. (1990)
N. 55° W. - N. 70° W.
N. 80° E. - N. 90° E.

MEMARIAN (1975)
N. 8° E.
N. 53° E.
N. 82° W.
N. 37° W.

LOCKPORT FORMATION INVESTIGATION (CRA, 1990)
N. 30° E - N. 80° E.
N. 10° W. - N.

OUTCROP MAPPING (CRA, SSP&A, MSRM, 2001)
N. 90° E.
N. 55° E.

JOHNSTON (1964)
N. 65° E.
N. 30° W.

figure 3.13

SITE AND REGIONAL NEAR-VERTICAL JOINT ORIENTATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA002 JAN 23/2002

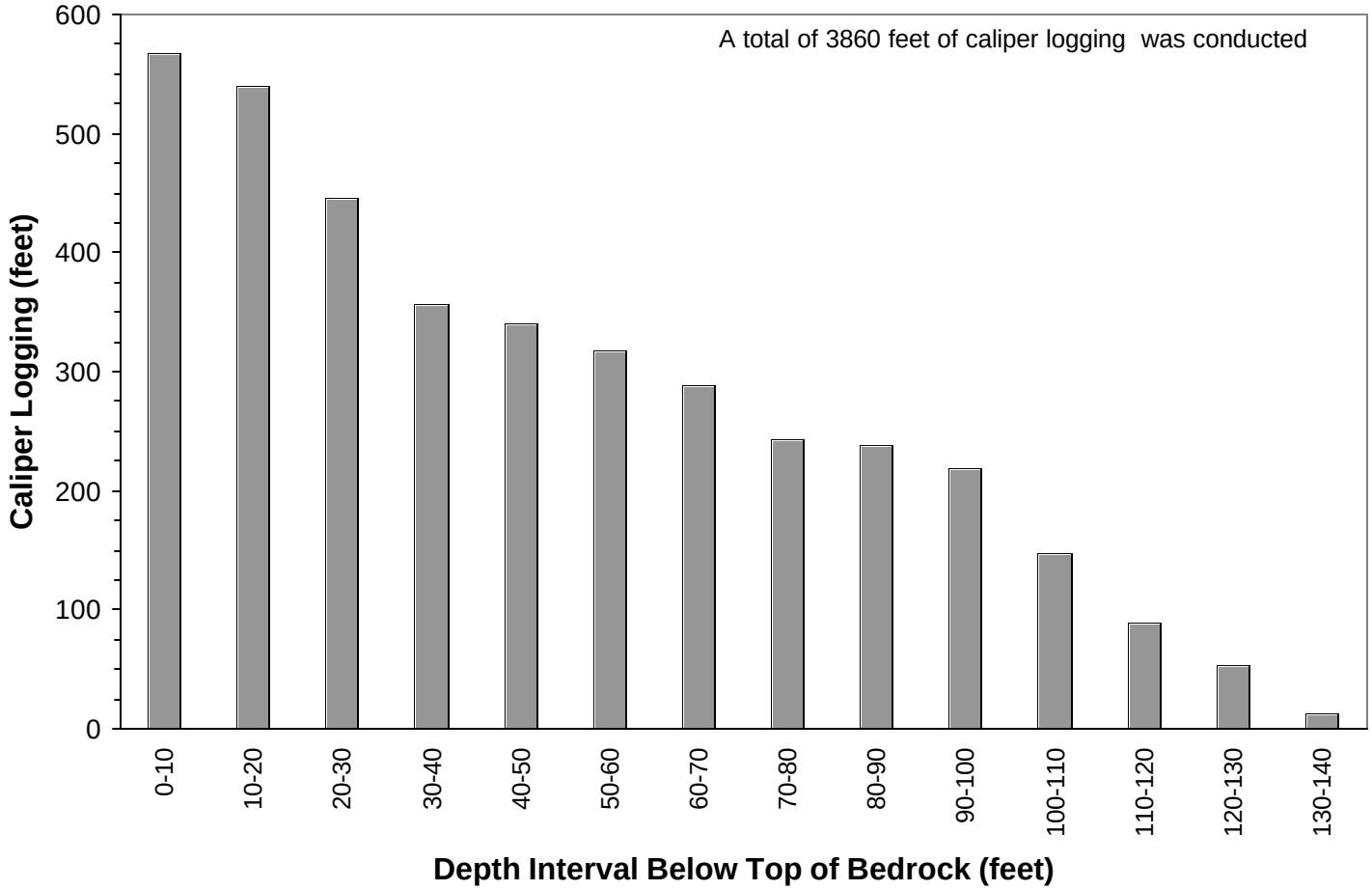


figure 3.14A

NUMBER OF FEET CALIPER LOGGED VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York

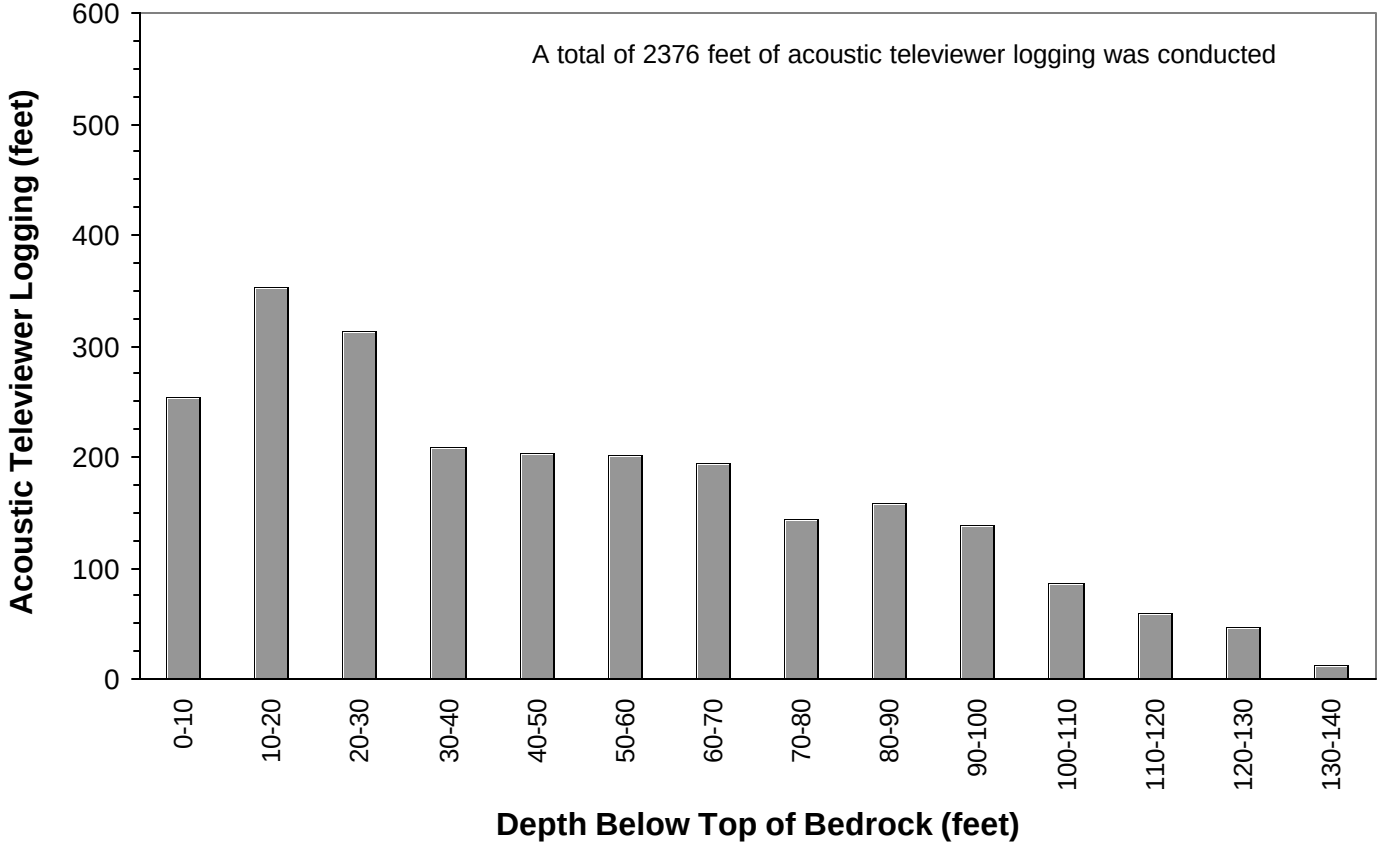


figure 3.14B

NUMBER OF FEET ACOUSTIC TELEVIEWER LOGGED VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York

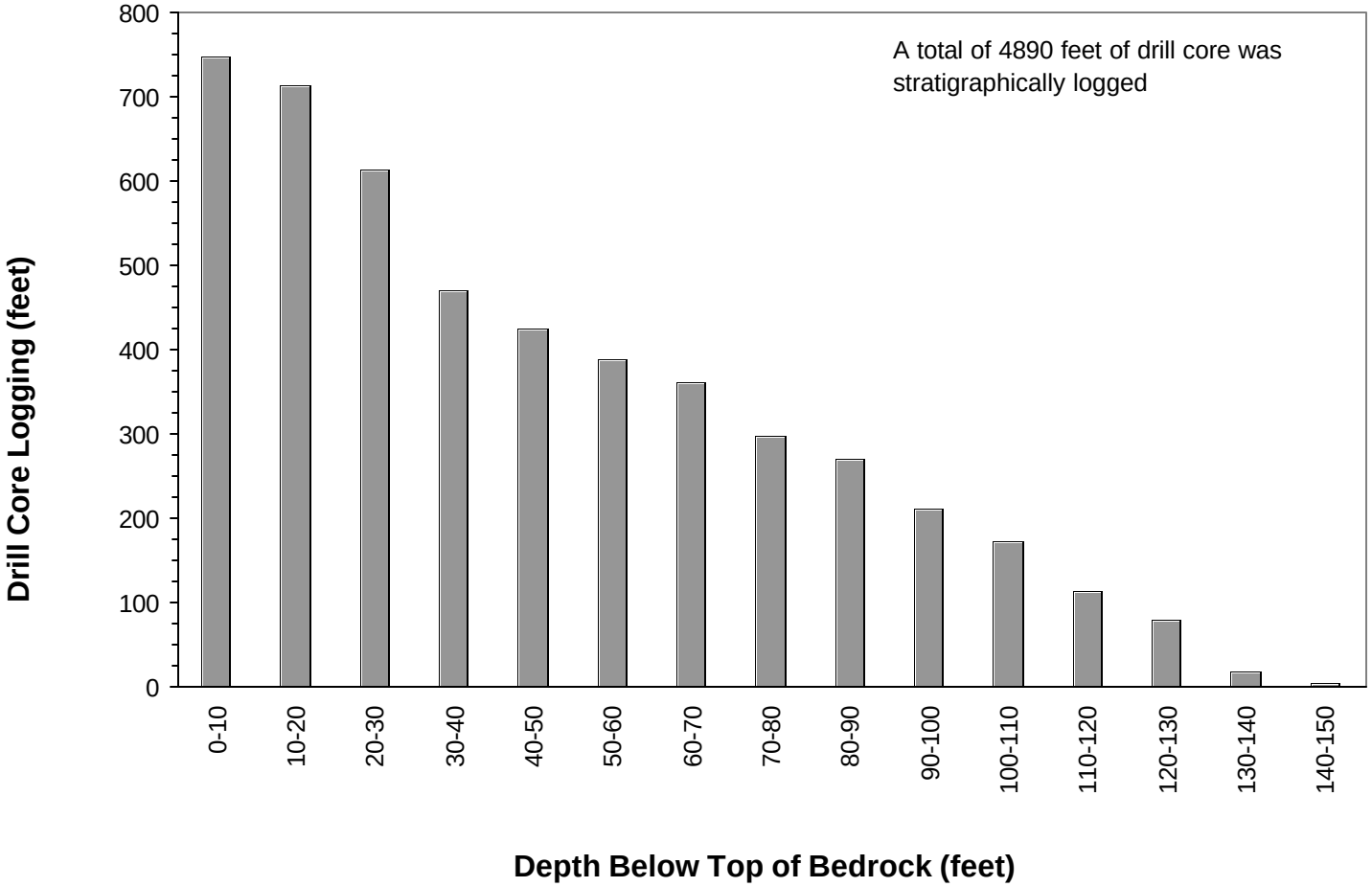


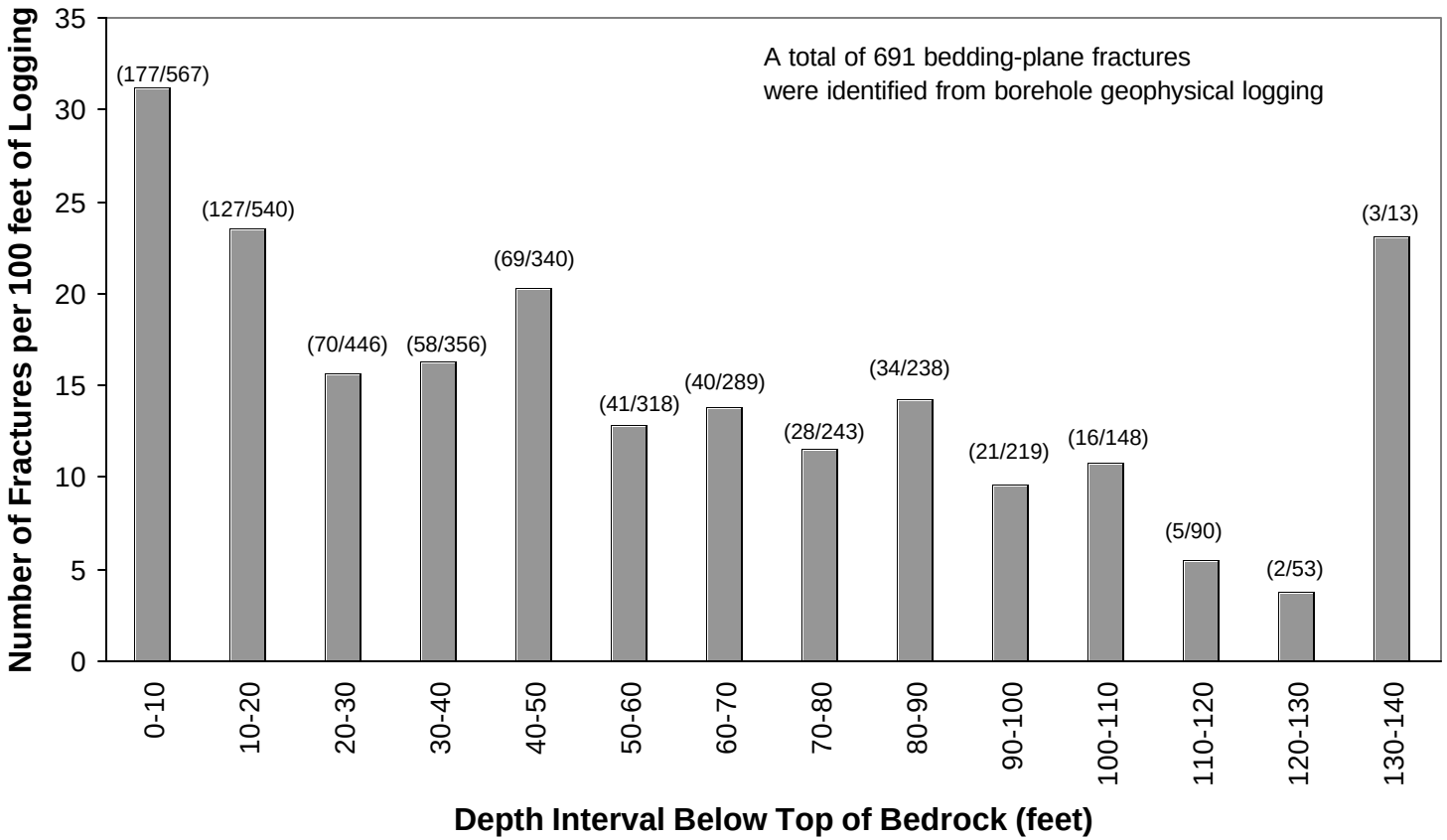
figure 3.14C

NUMBER OF FEET OF DRILL CORE LOGGED VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



Legend
(177/567) = number of bedding-plane fractures identified in the 10 foot interval/
number of feet of caliper logging in the 10 foot interval.

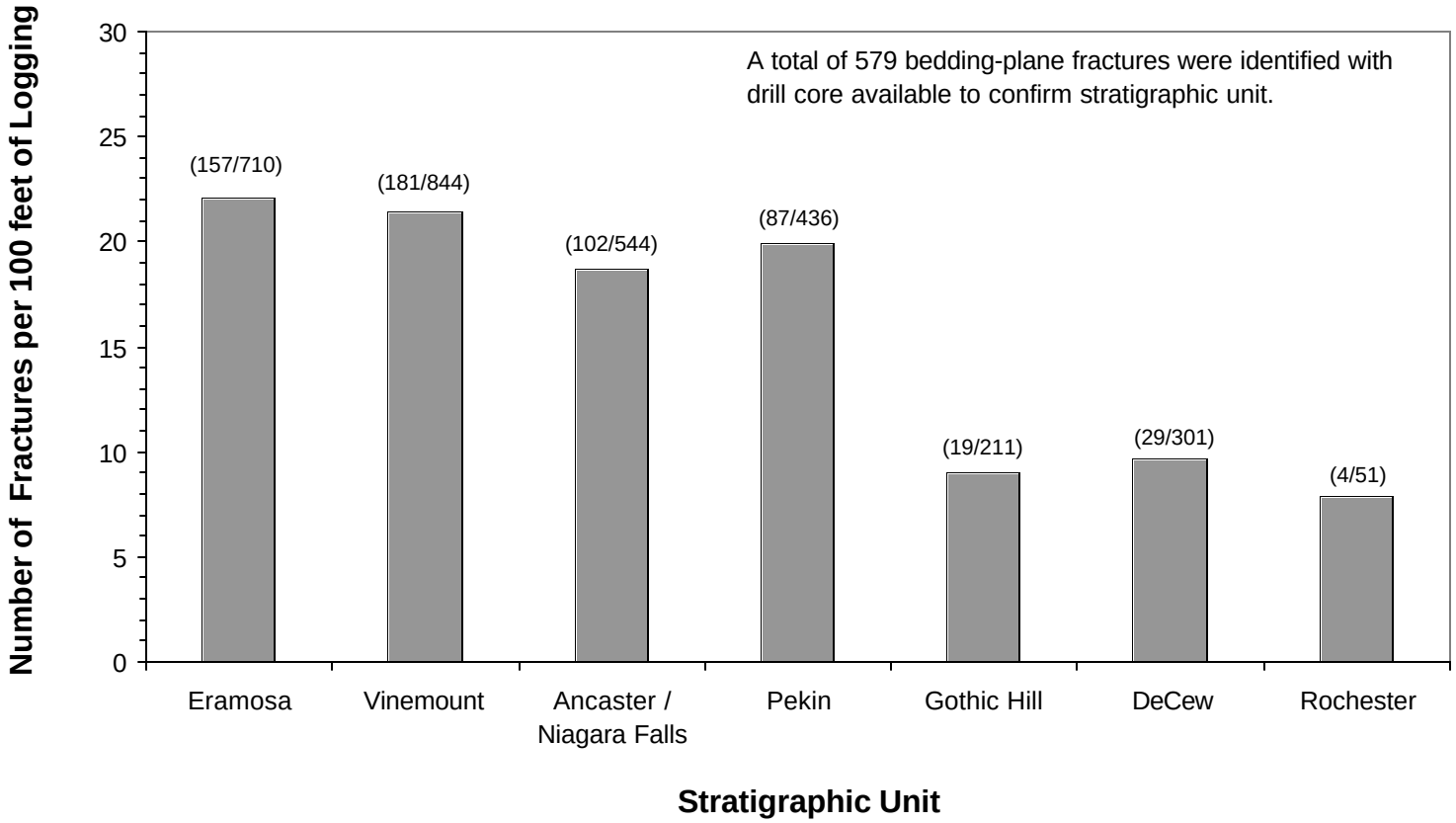
figure 3.15A

DISTRIBUTION OF BEDDING-PLANE FRACTURES VERSUS DEPTH

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



Legend
(157/710) = number of bedding-plane fractures identified per stratigraphic interval/number of feet of caliper logging per stratigraphic interval

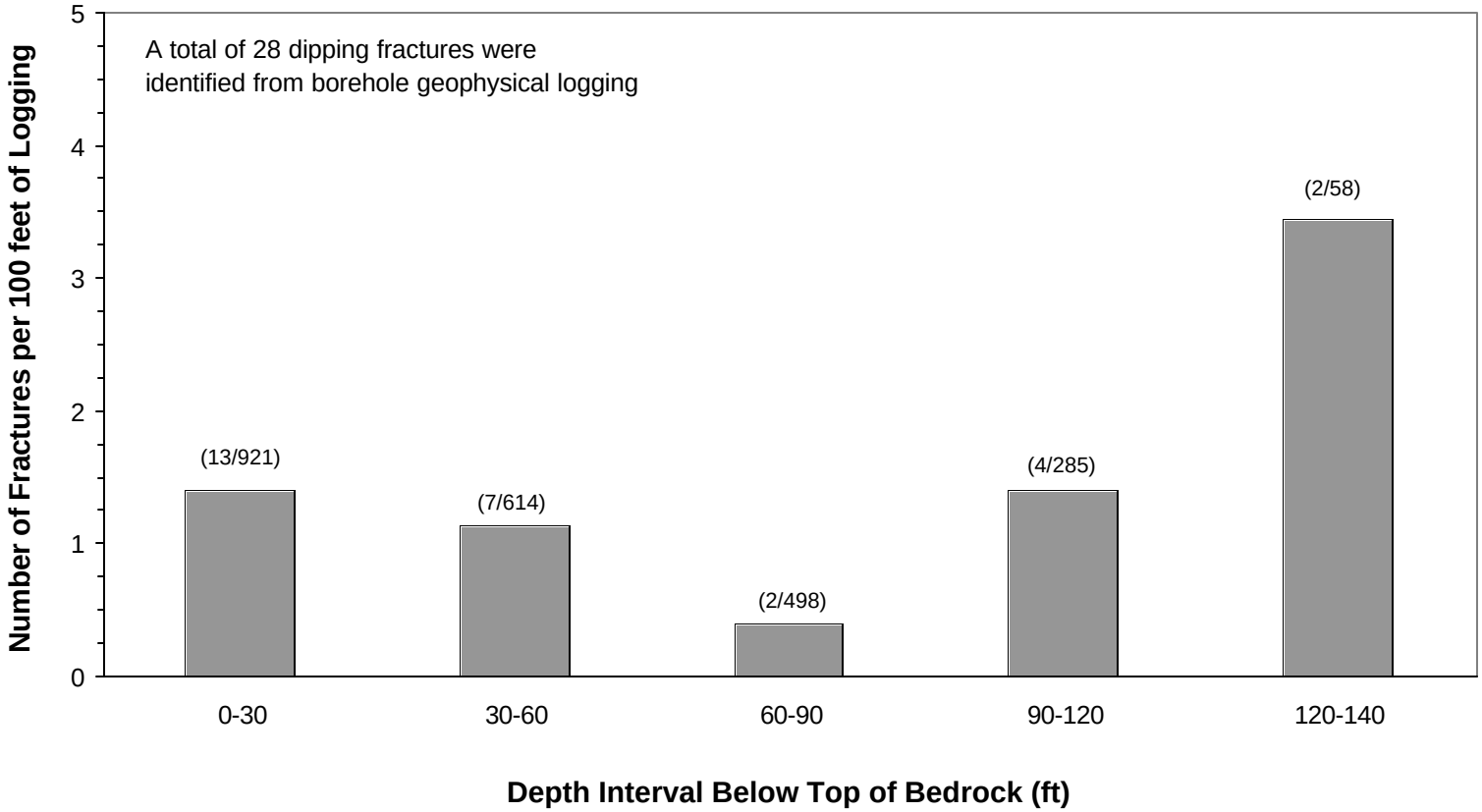
figure 3.15B

DISTRIBUTION OF BEDDING-PLANE FRACTURES VERSUS STRATIGRAPHIC UNIT

SITE CHARACTERIZATION REPORT

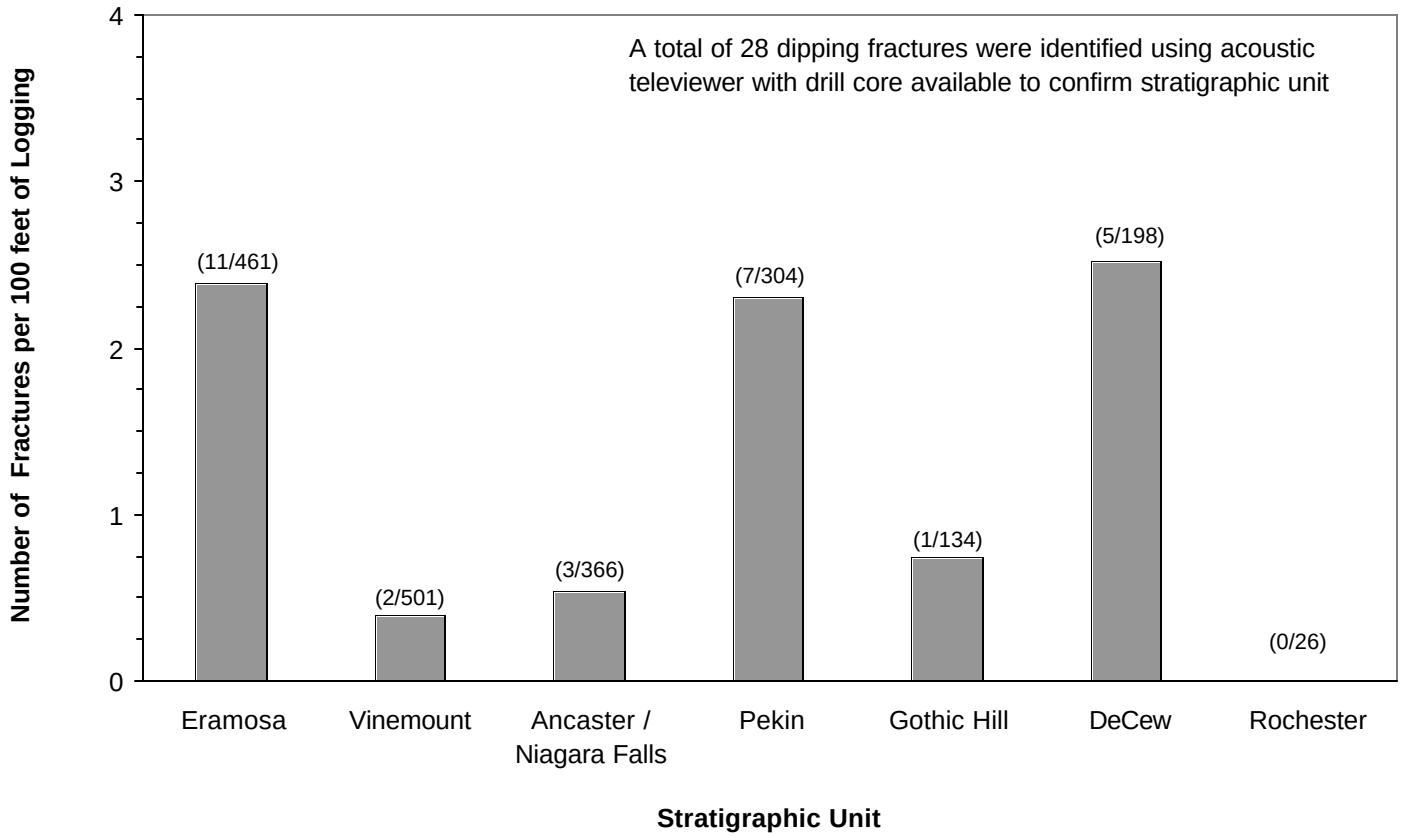
HYDE PARK LANDFILL SITE

Town of Niagara, New York



Legend
(13/921) = number of dipping fractures identified in the 30 foot interval/
number of feet of acoustic televiewer logging in the 30 foot interval.

figure 3.16A
DISTRIBUTION OF DIPPING FRACTURES VERSUS DEPTH
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York



Legend
(11/461) = number of dipping fractures identified in the stratigraphic unit/
total feet of acoustic televiewer logging in the stratigraphic unit

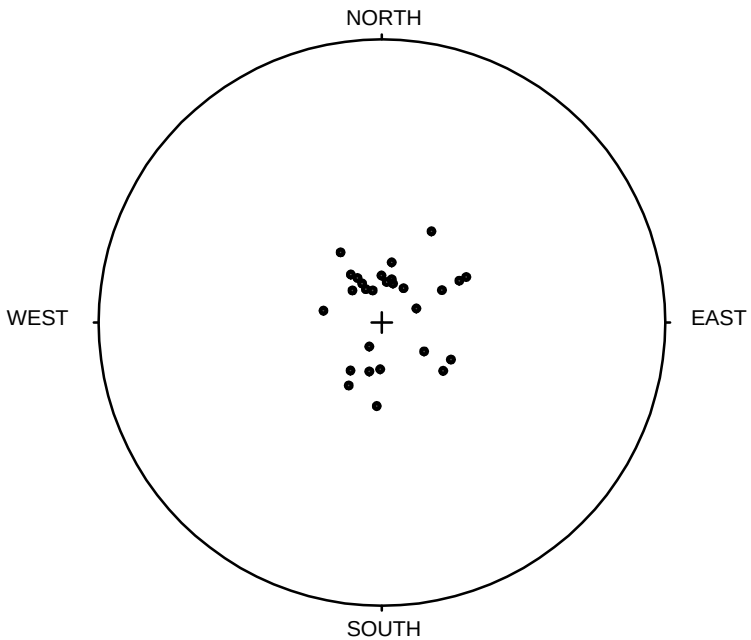
figure 3.16B

DISTRIBUTION OF DIPPING FRACTURES VERSUS STRATIGRAPHIC UNIT

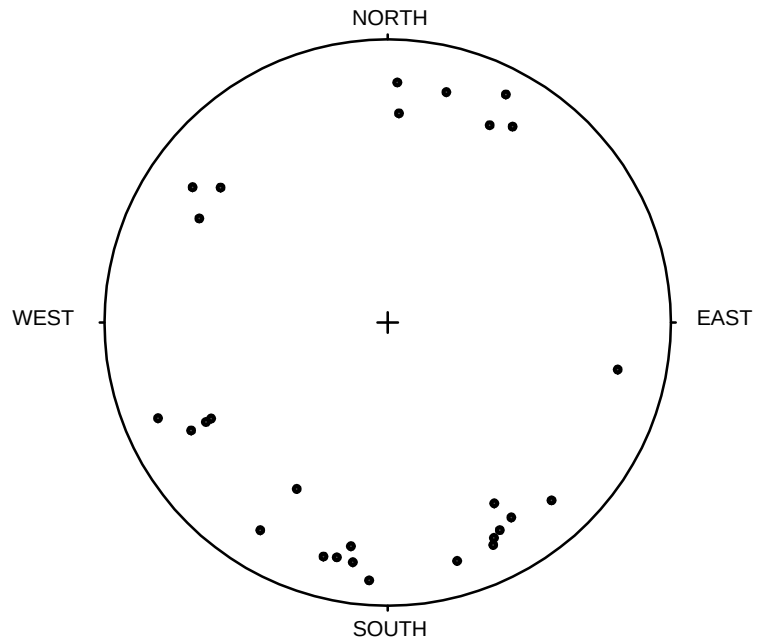
SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



ORIENTATION OF POLES TO THE FRACTURE PLANES
PROJECTION: SCHMIDT NET



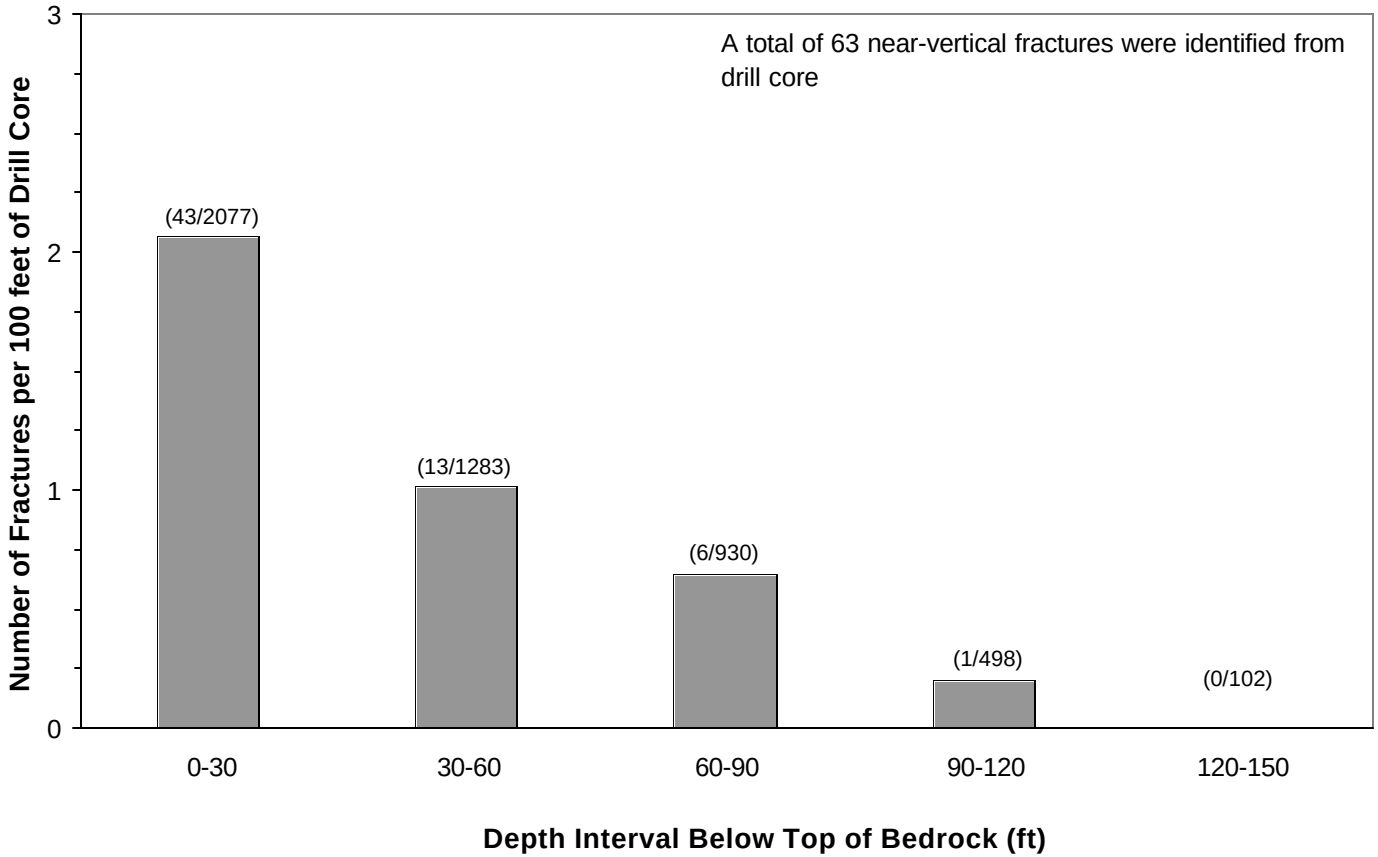
DIP DIRECTION AND DIP OF FRACTURE PLANES
PROJECTION: SCHMIDT NET

n = 28 DIPPING FRACTURES
DOES NOT INCLUDE OFFSITE WELLS

figure 3.17

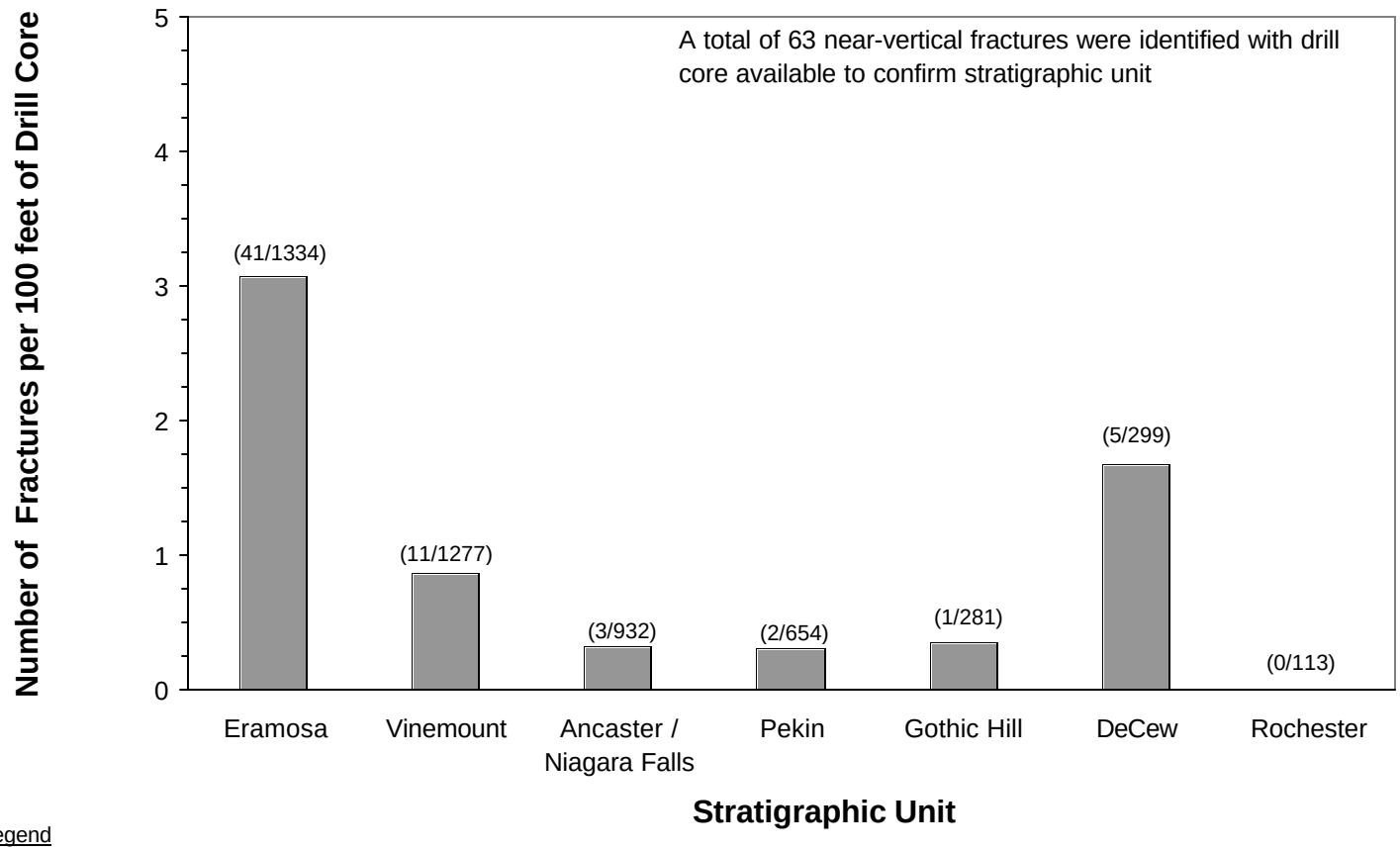
ORIENTATION OF DIPPING FRACTURES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA039 FEB 13/2002



Legend
(43/2077) = number of near-vertical fractures identified in 30-foot interval/total length of drill core logged in the 30 foot interval

figure 3.18A
DISTRIBUTION OF NEAR-VERTICAL FRACTURES VERSUS DEPTH
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York



Legend
(41/1334) = number of near-vertical fractures identified in drill core for the stratigraphic unit/the number of feet of drill core logged in the stratigraphic unit

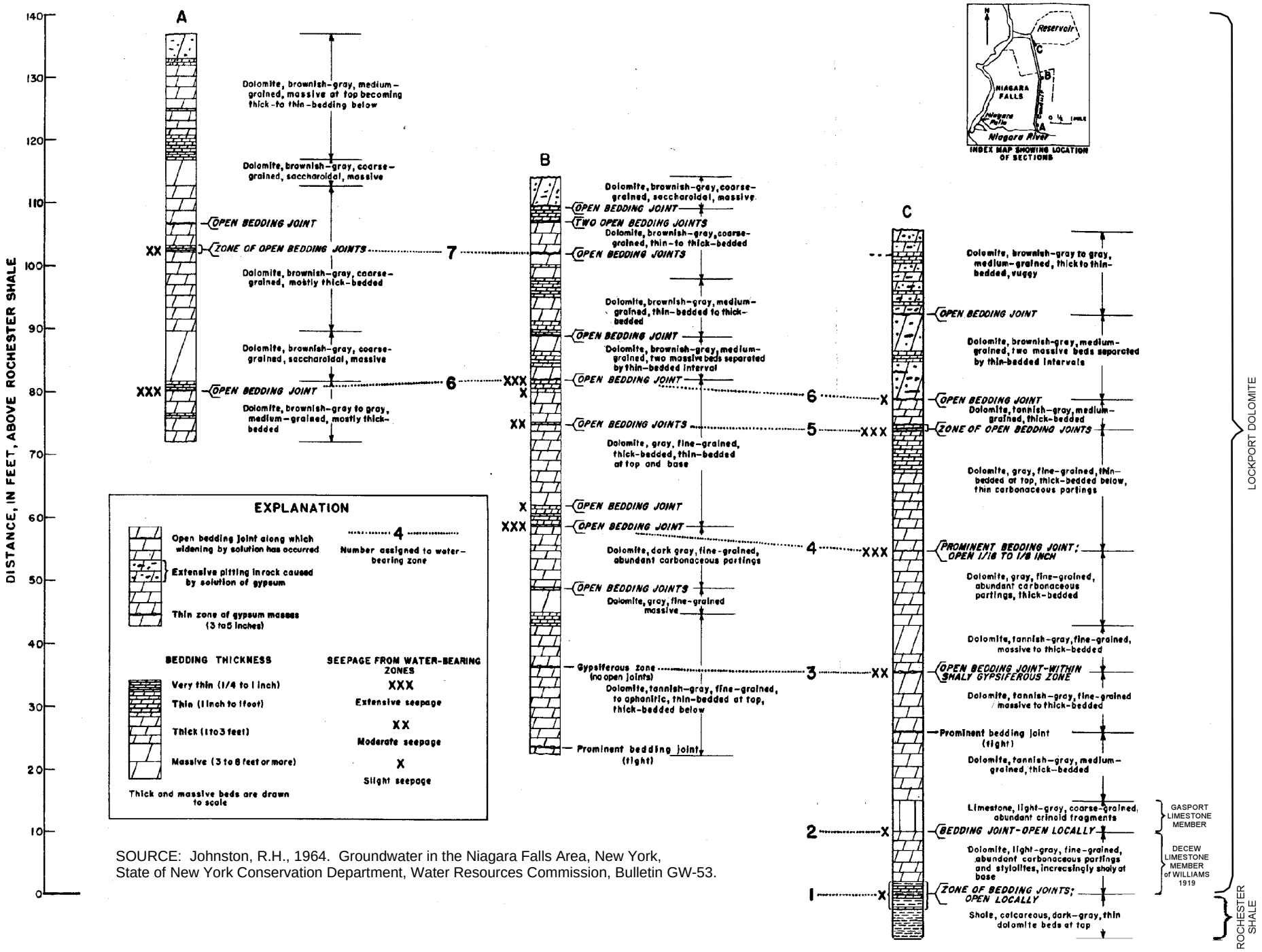
figure 3.18B

DISTRIBUTION OF NEAR-VERTICAL FRACTURES VERSUS STRATIGRAPHIC UNIT

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York



SOURCE: Johnston, R.H., 1964. Groundwater in the Niagara Falls Area, New York, State of New York Conservation Department, Water Resources Commission, Bulletin GW-53.

Figure 4.1 - Flow Zones Identified by Johnston (1964)

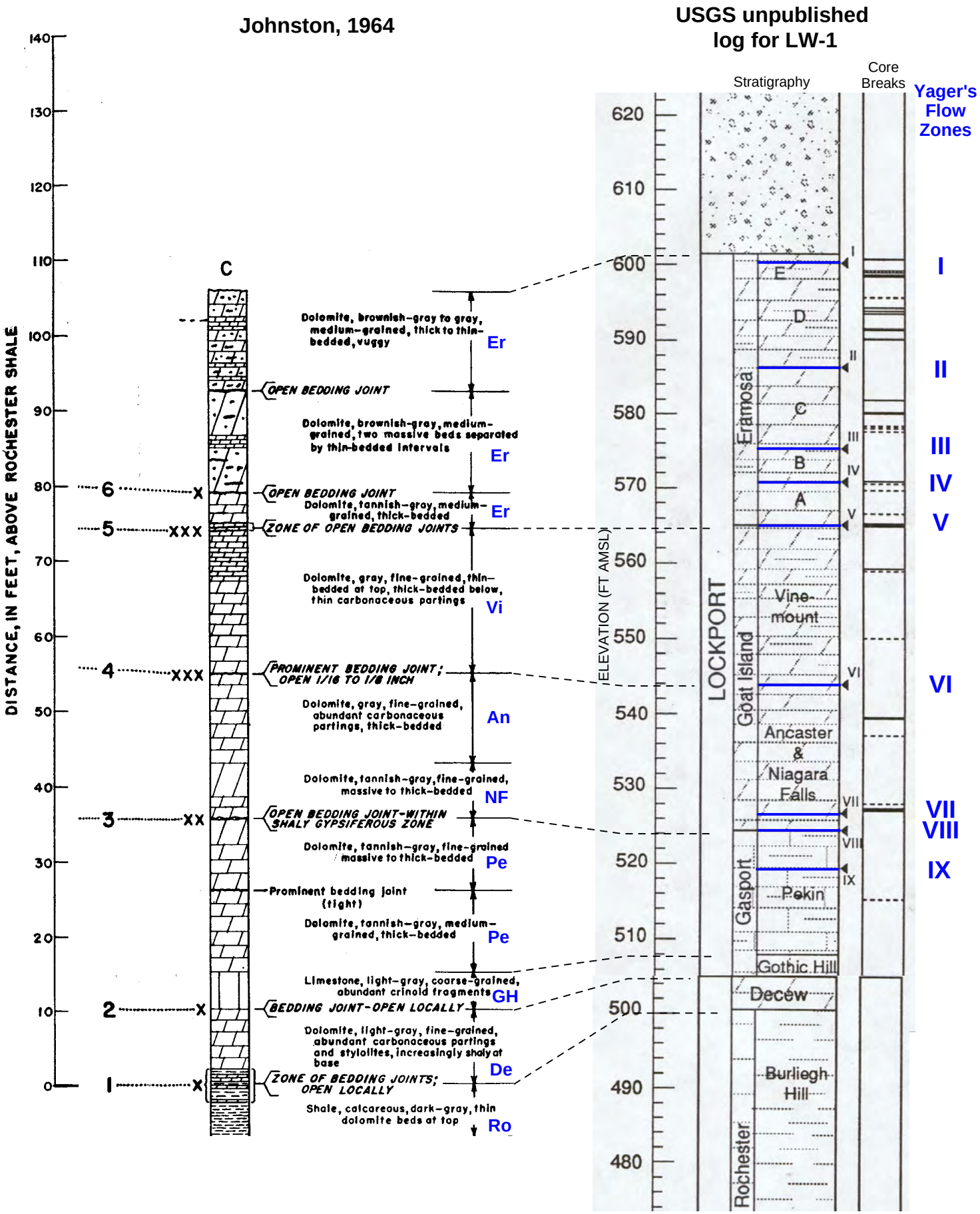


Figure 4.2 - Comparison of Johnston (1964) and USGS (Yager, 1996) flow zones

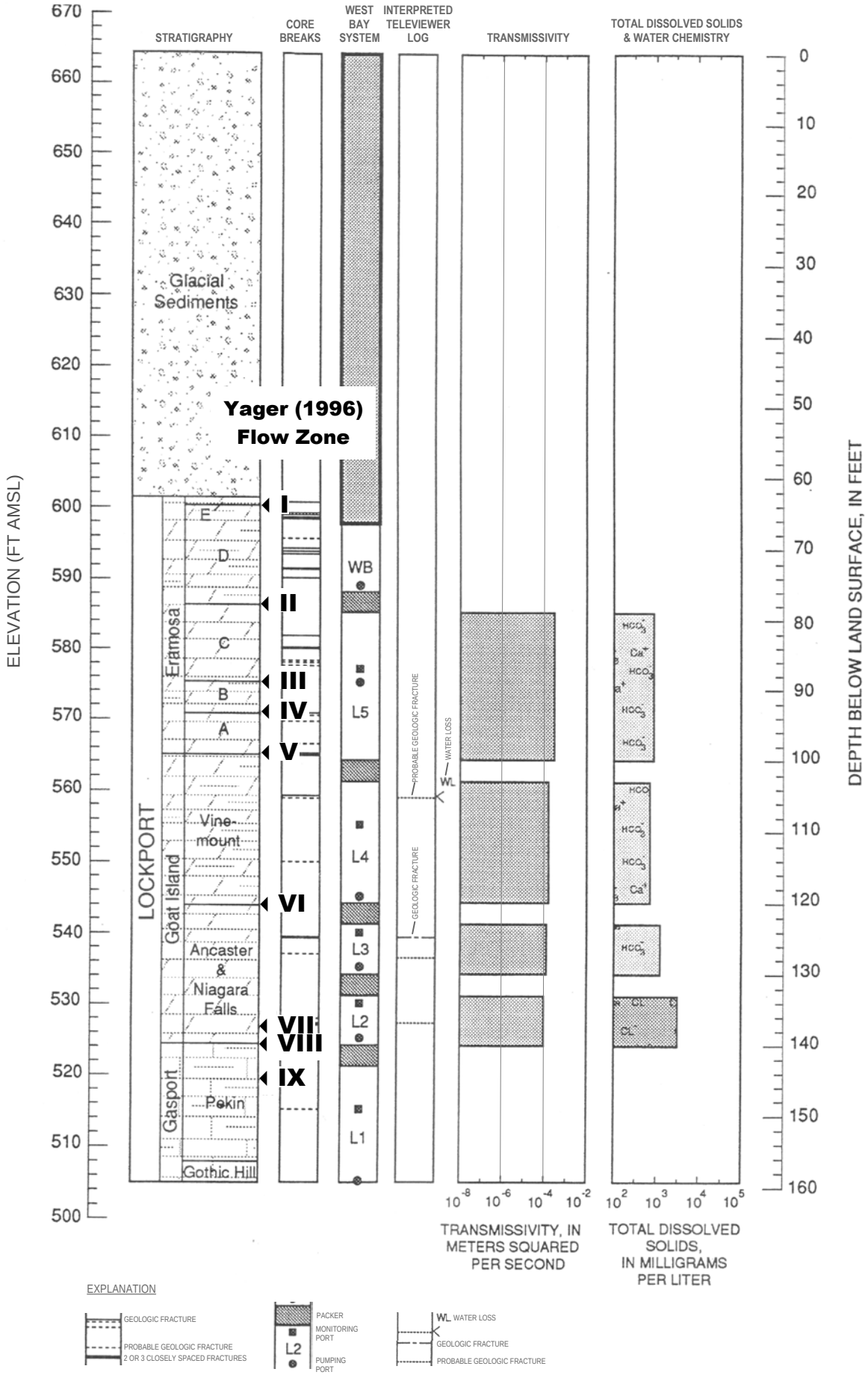
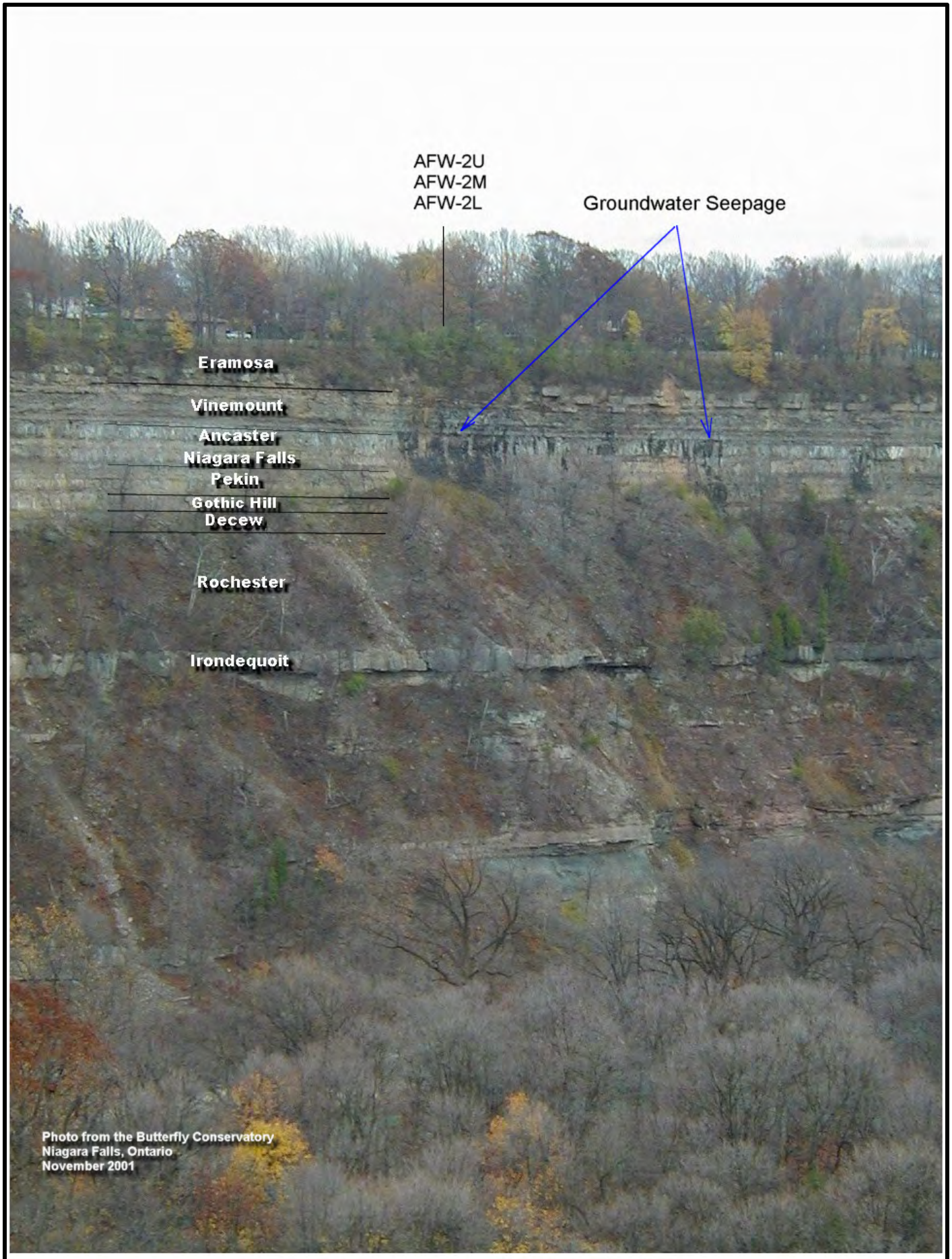


Figure 4.3 - Additional Details of the USGS Log of LW-1



SEDA

Figure 4.4 Groundwater Seepage Along Bedding

Figure 4.5 View of the Niagara River Gorge from Canada

SEDA

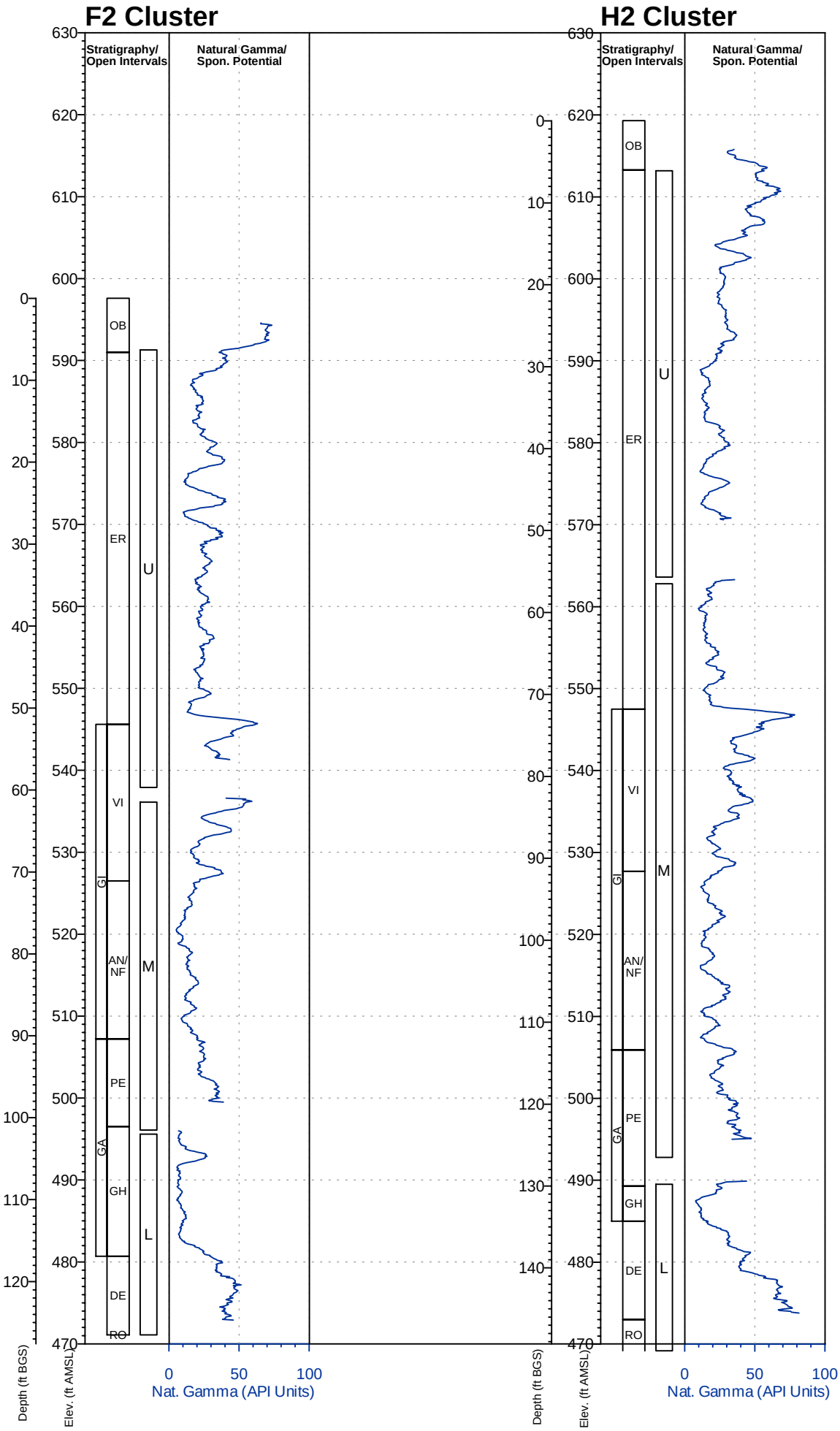


Figure 4.6 Example of Typical Gamma Signatures

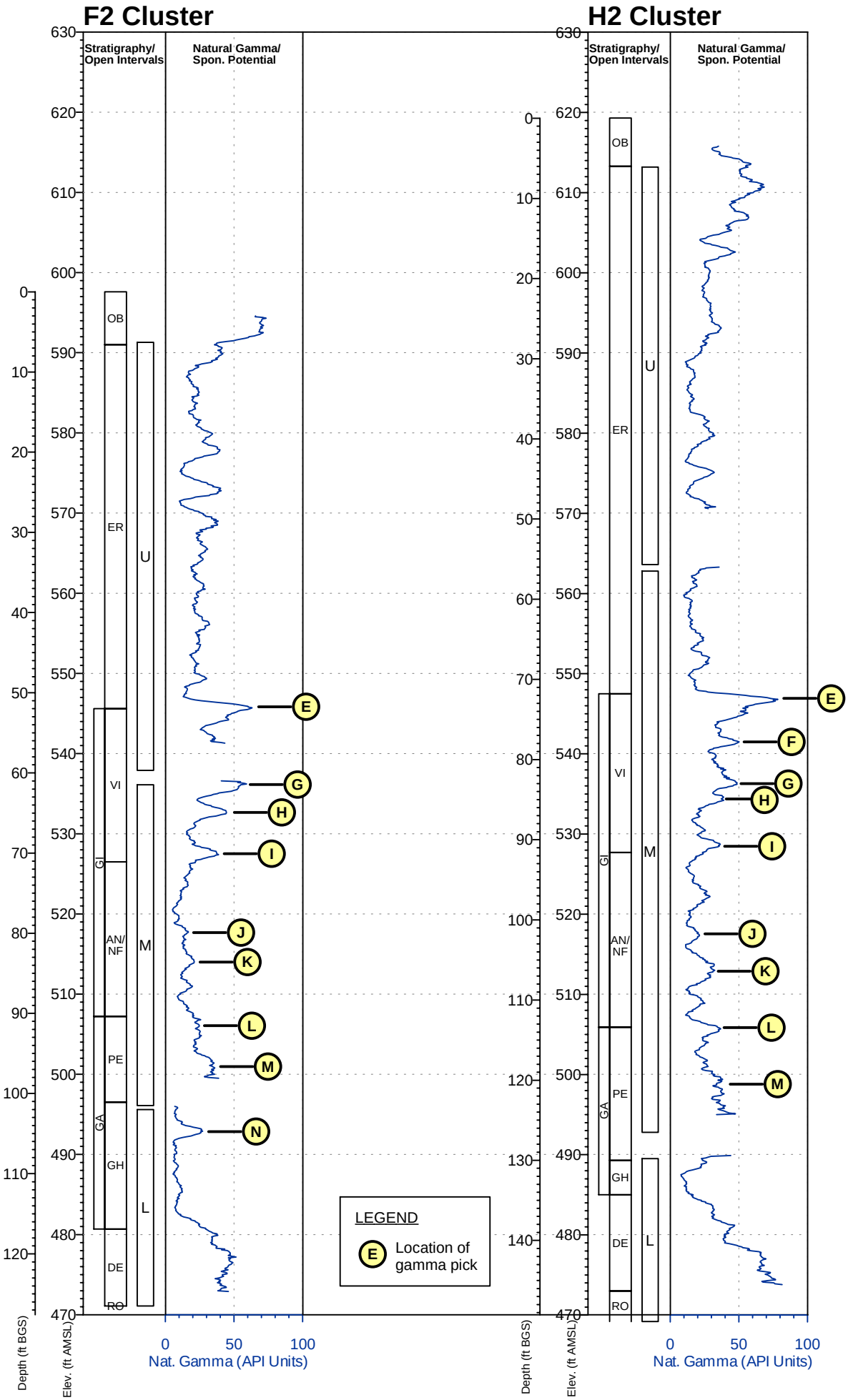


Figure 4.7 F2 and H2 Gamma Signatures With Key Peaks Labeled

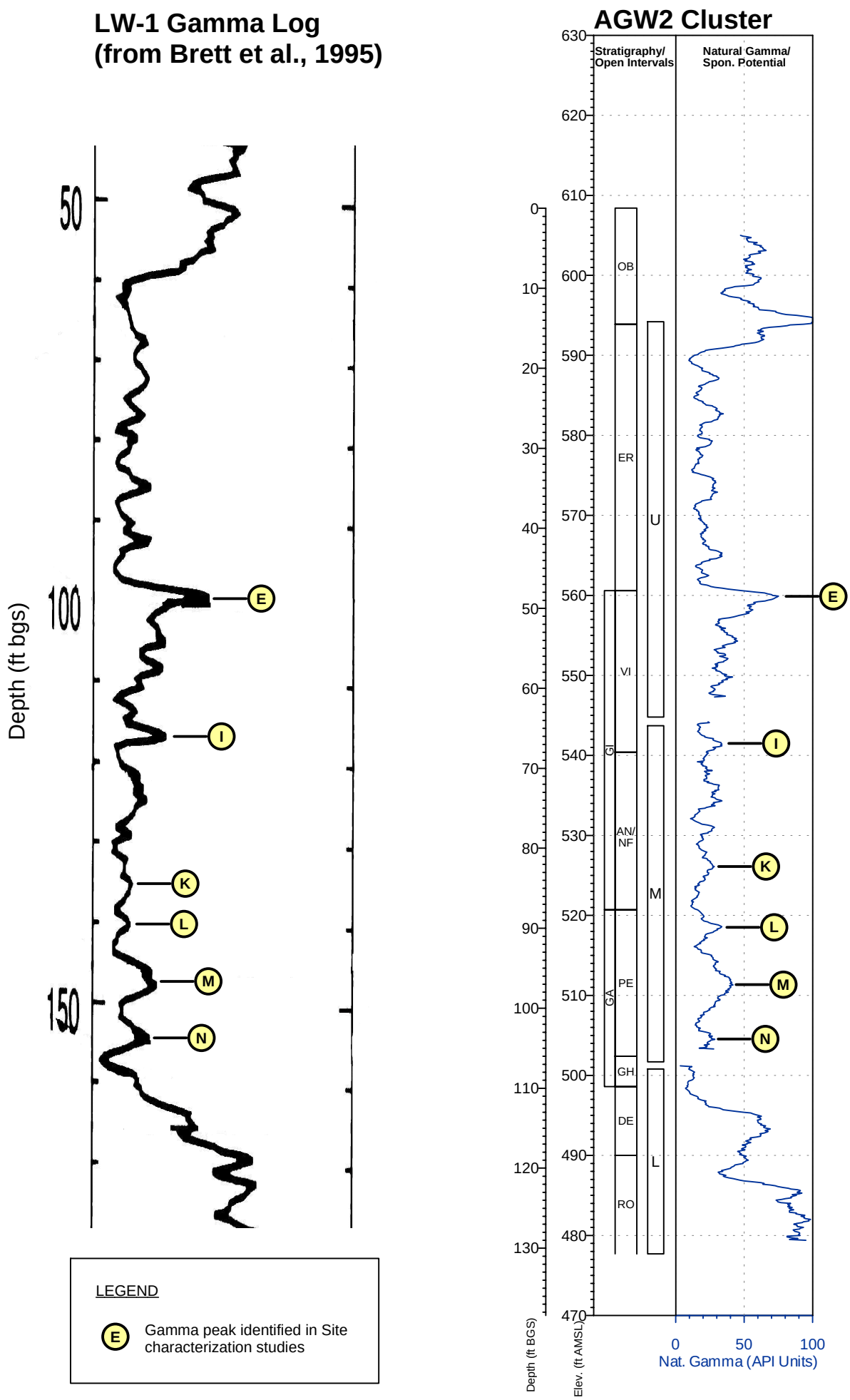


Figure 4.8 Comparison of AGW-2 Gamma Signatures with LW-1 Gamma Signature from Brett et al. (1995)

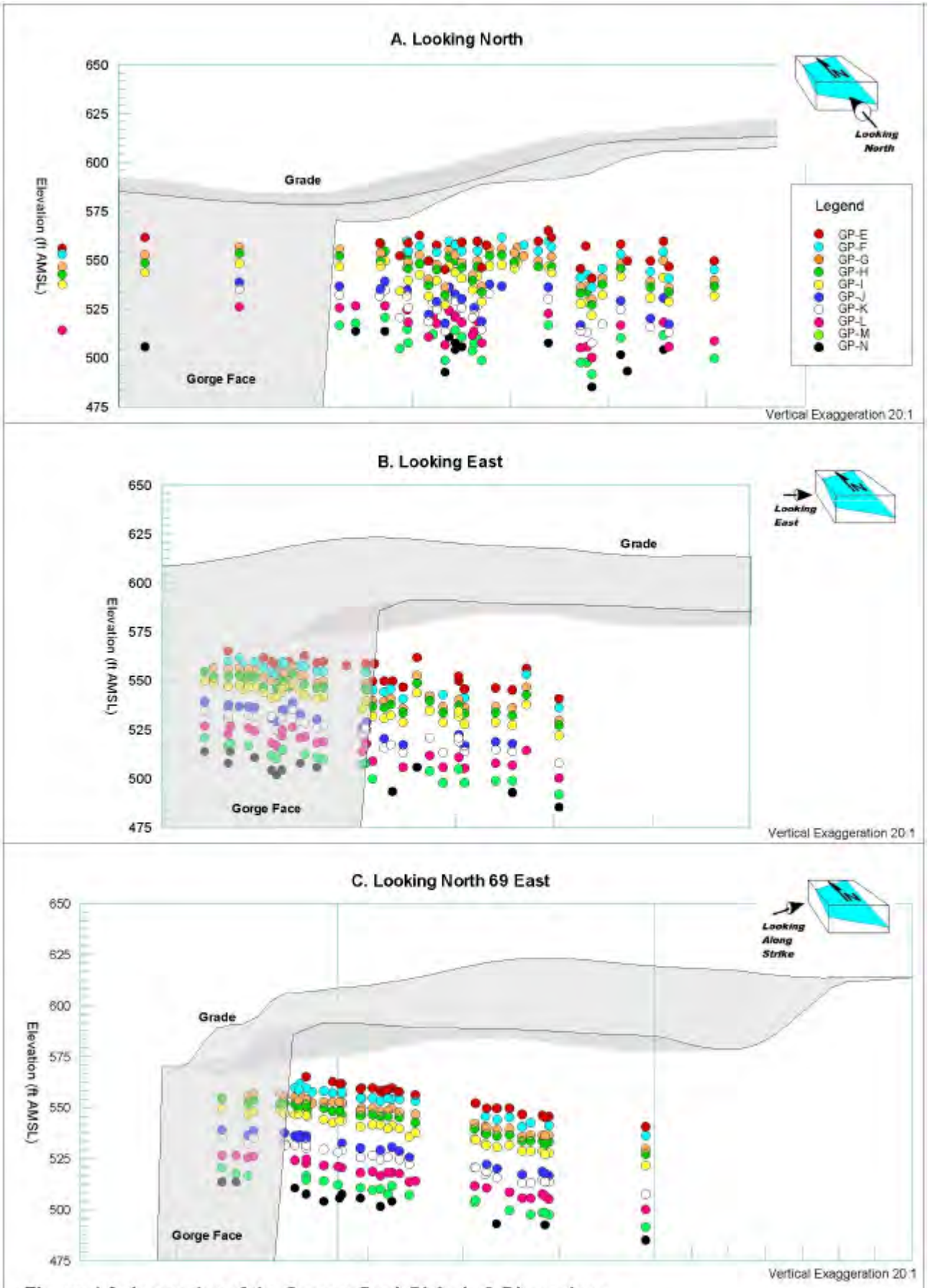


Figure 4.9 Inspection of the Gamma Peak Picks in 3-Dimensions

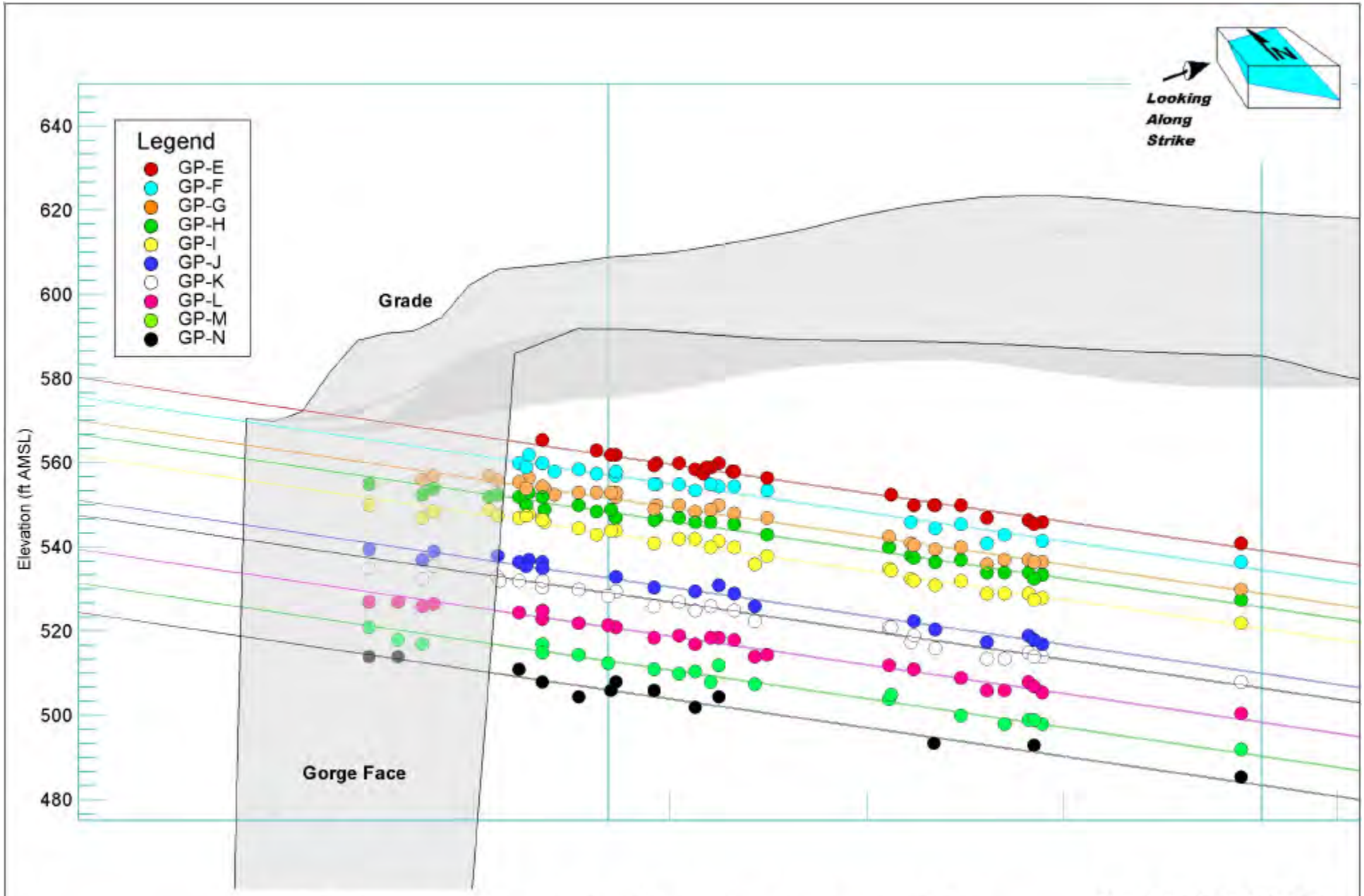
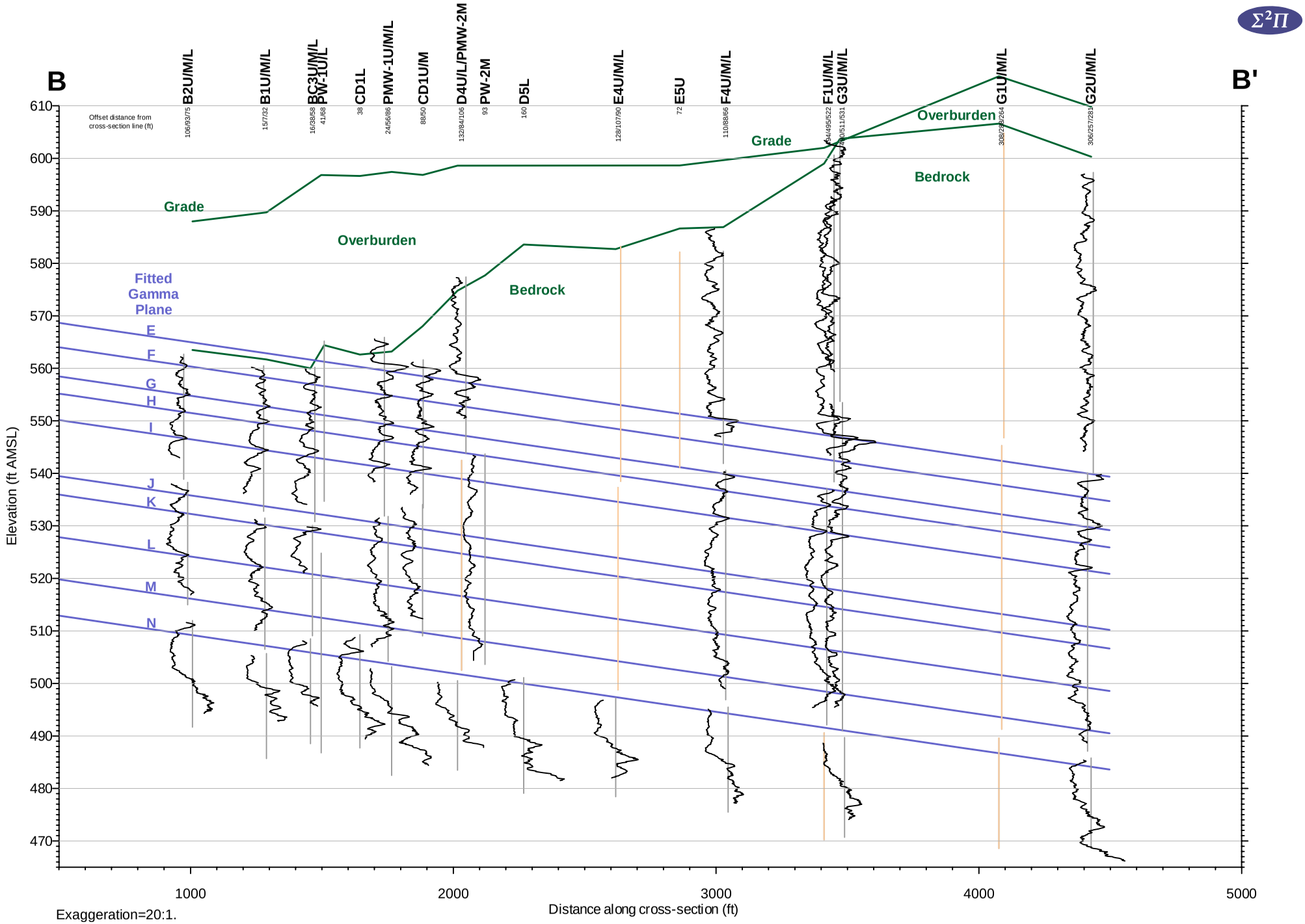


Figure 4.10 Comparison of Gamma Pick and Best-fit Planes. Looking along Strike.

View looking North 69 East
Vertical Exaggeration 20:1

SEDA



Exaggeration=20:1.
Refer to Figure 3.10 for cross-section location.

Figure 4.11 Natural Gamma Signals Along Dip (looking along strike)

Filename: FlowZones_Feb08.xls
Date Printed: 2/12/2002

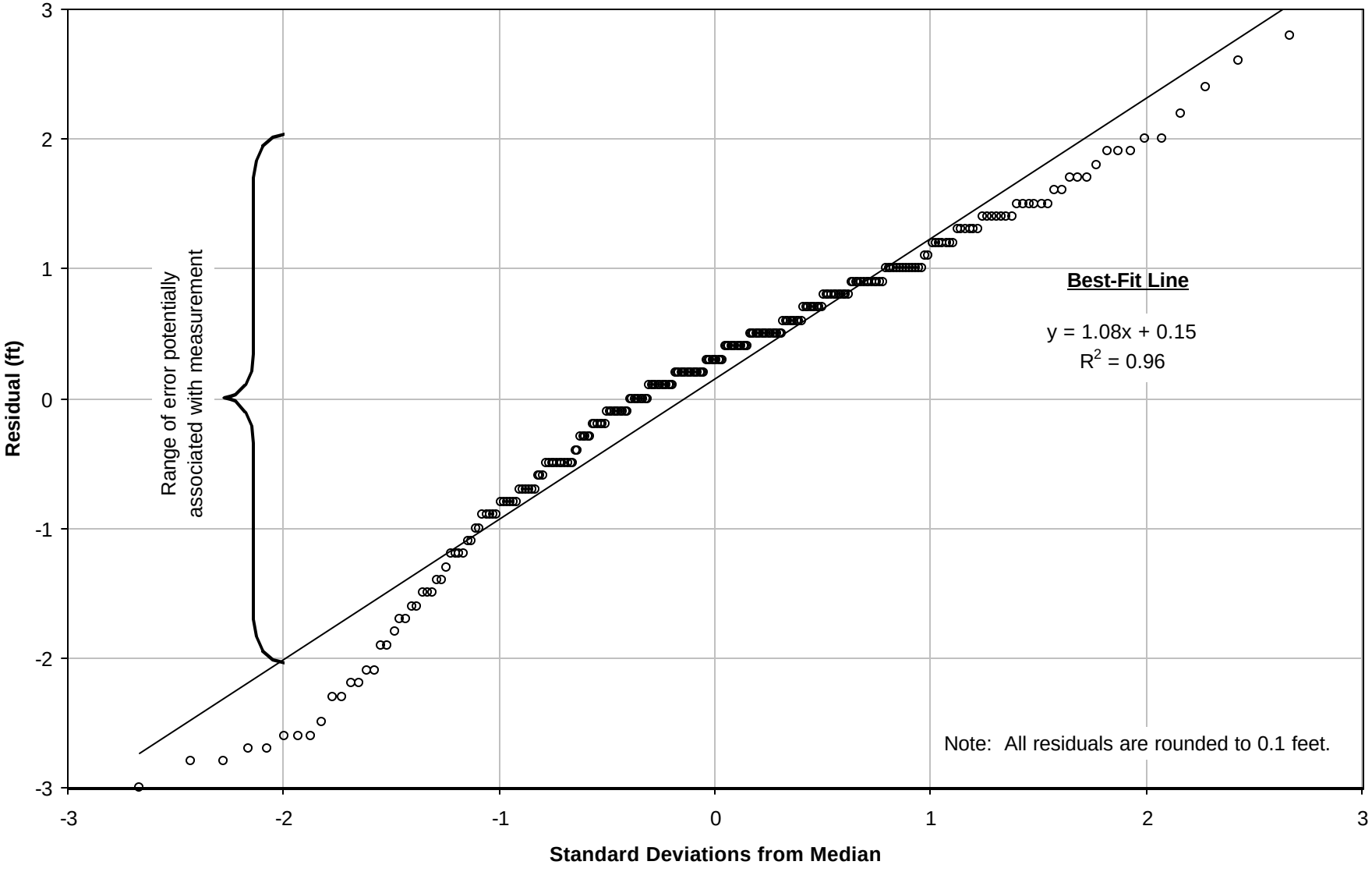


Figure 4.12 Probability Plot of Residuals for Gamma Best Fit Planes

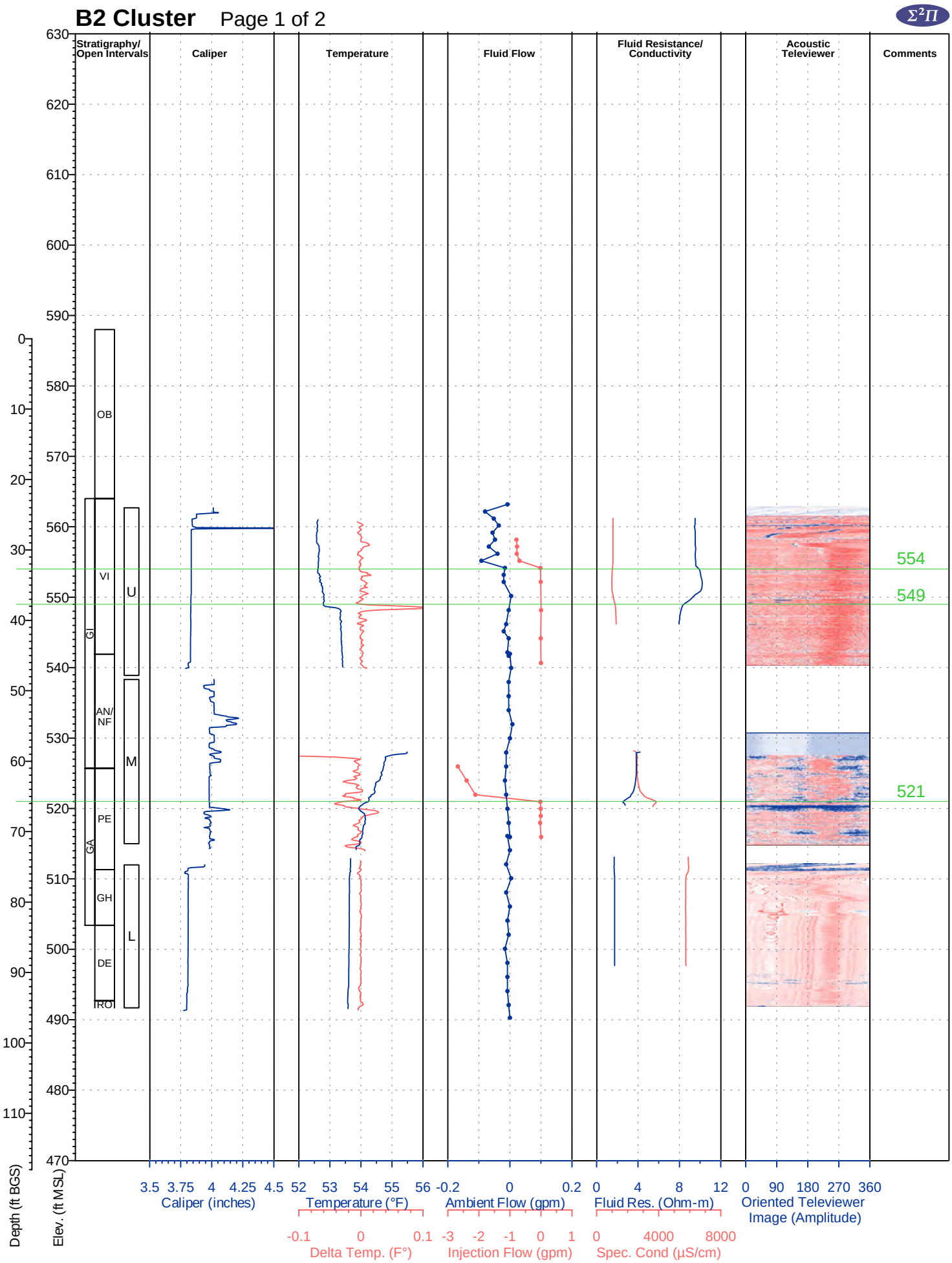


Figure 4.13 Geophysical Log for the B2 Well Cluster

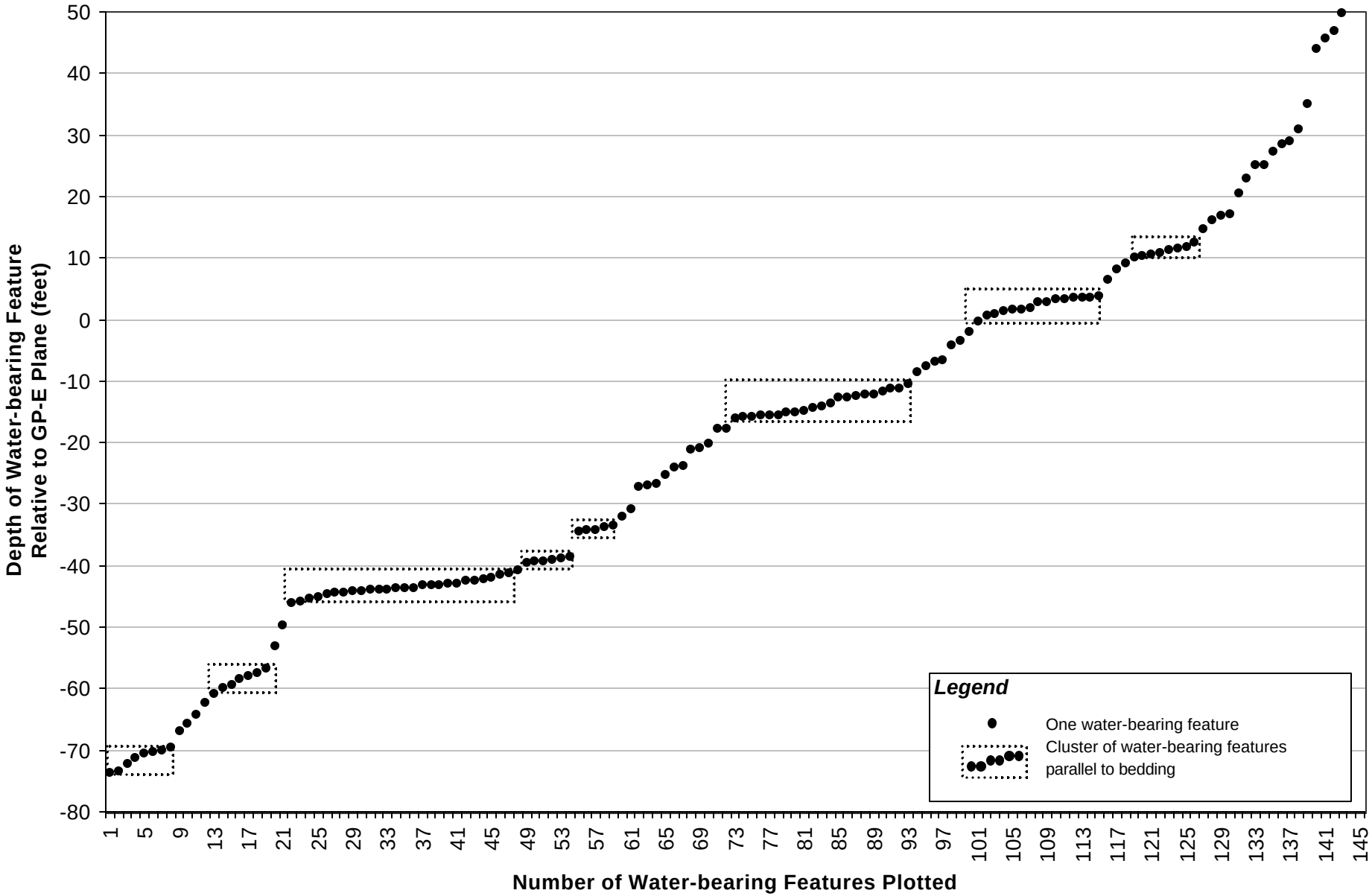


Figure 4.14 Cluster Analysis For Identification of Flow Zones

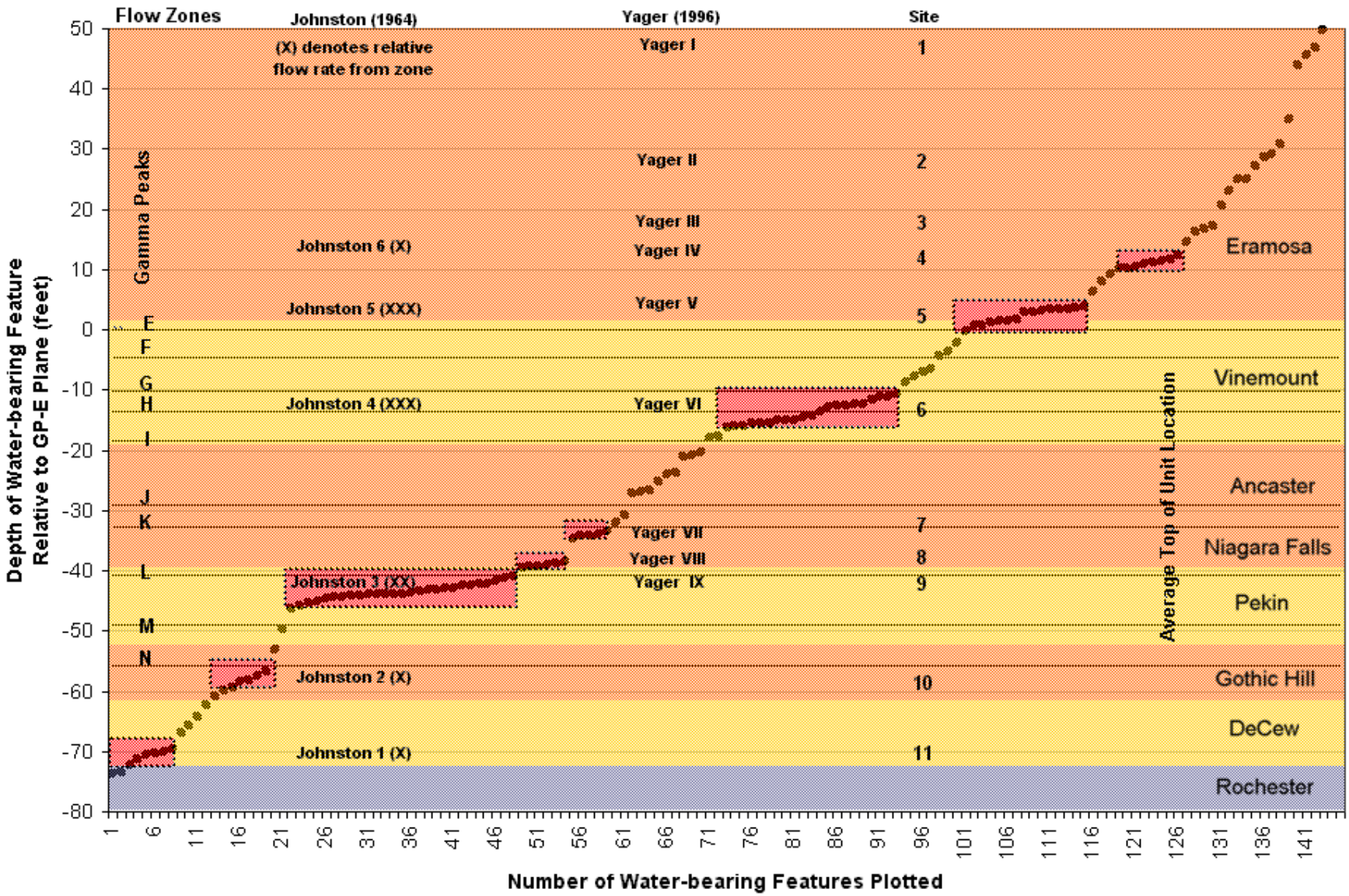


Figure 4.15 Comparison of Water-Bearing Clusters with Published Flow Zones, Stratigraphy, and Gamma Peaks

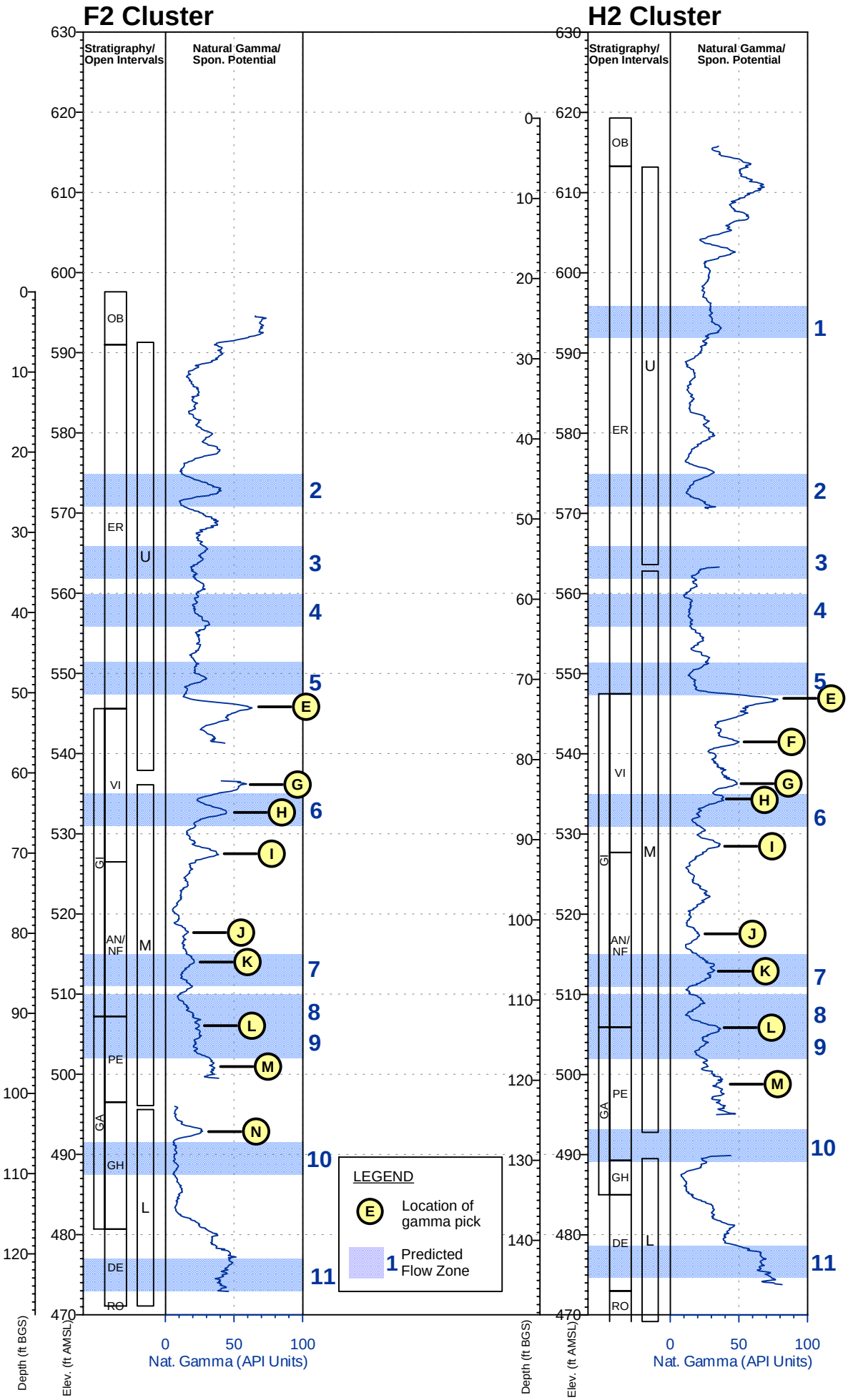
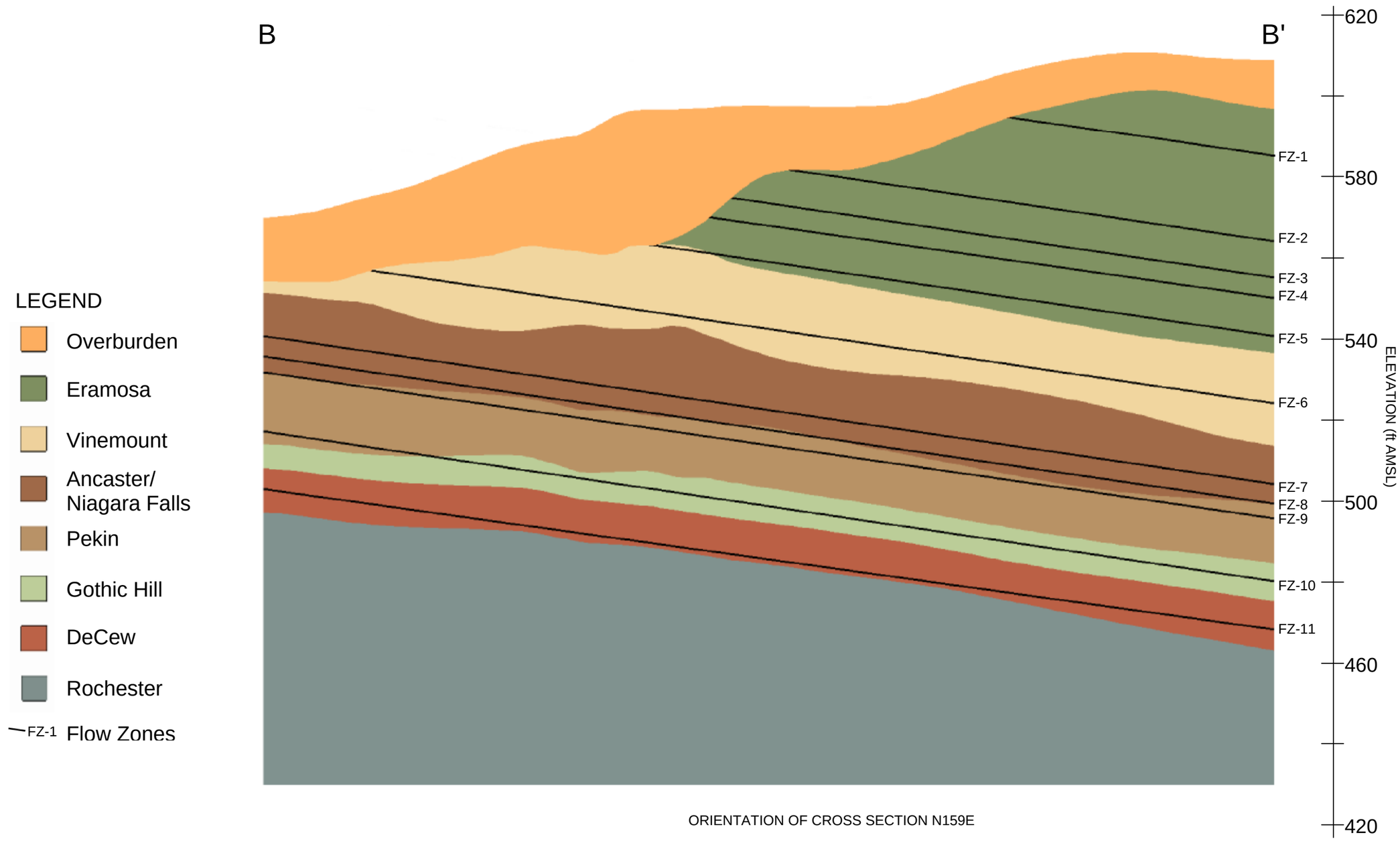


Figure 4.16 Locations of Flow Zones Referenced to the Gamma Peaks



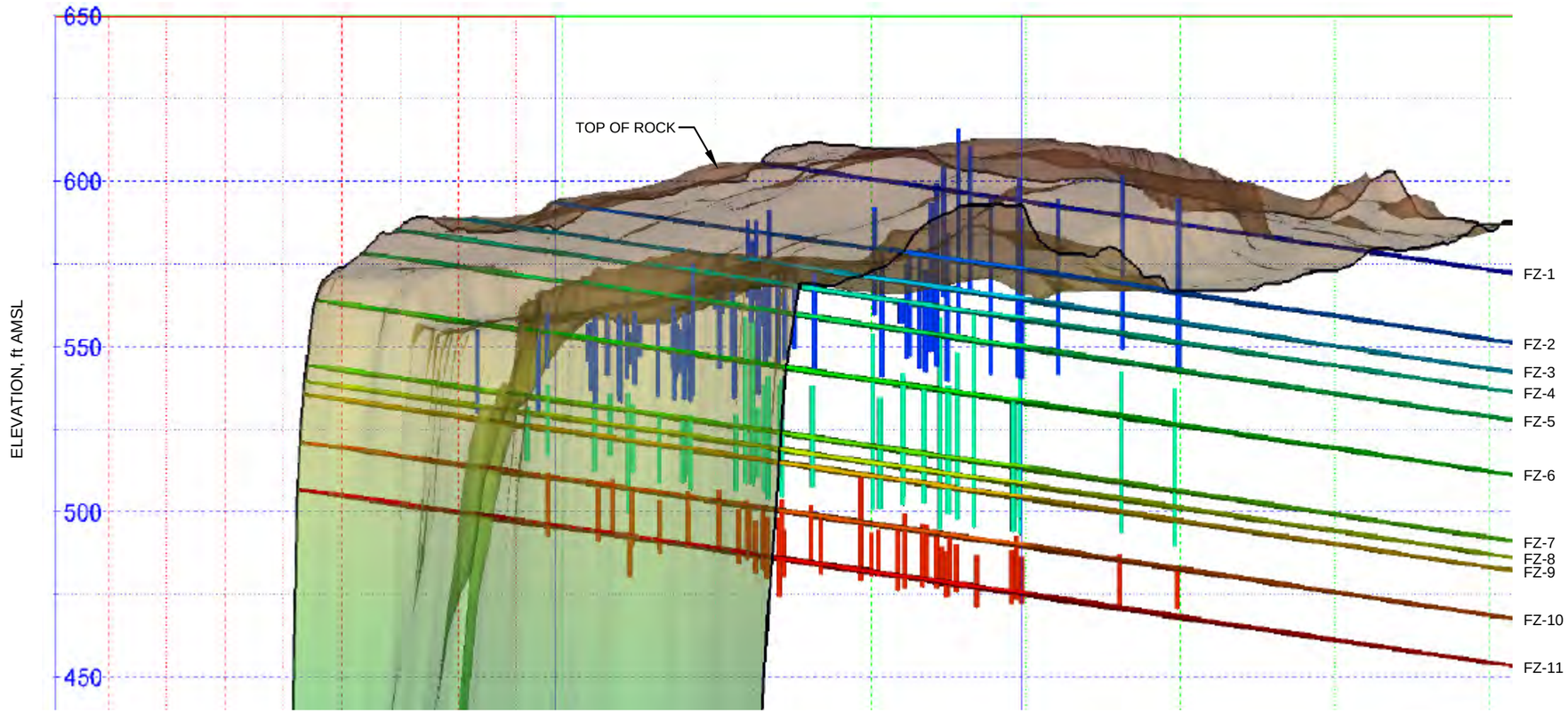
SCALE
HORIZ.: 1" = 600'
VERT.: 1" = 30'

figure 4.17

NORTH TO SOUTH SCHEMATIC CROSS-SECTION B-B' WITH FLOW ZONES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

NOTE: VERTICAL EXTENT OF ROCHESTER SHALE IS NOT IMPLIED BY THE FIGURE.

01069-30(299)GN-WA038 FEB 14/2002



LEGEND

UPPER ZONE WELL

MIDDLE ZONE WELL

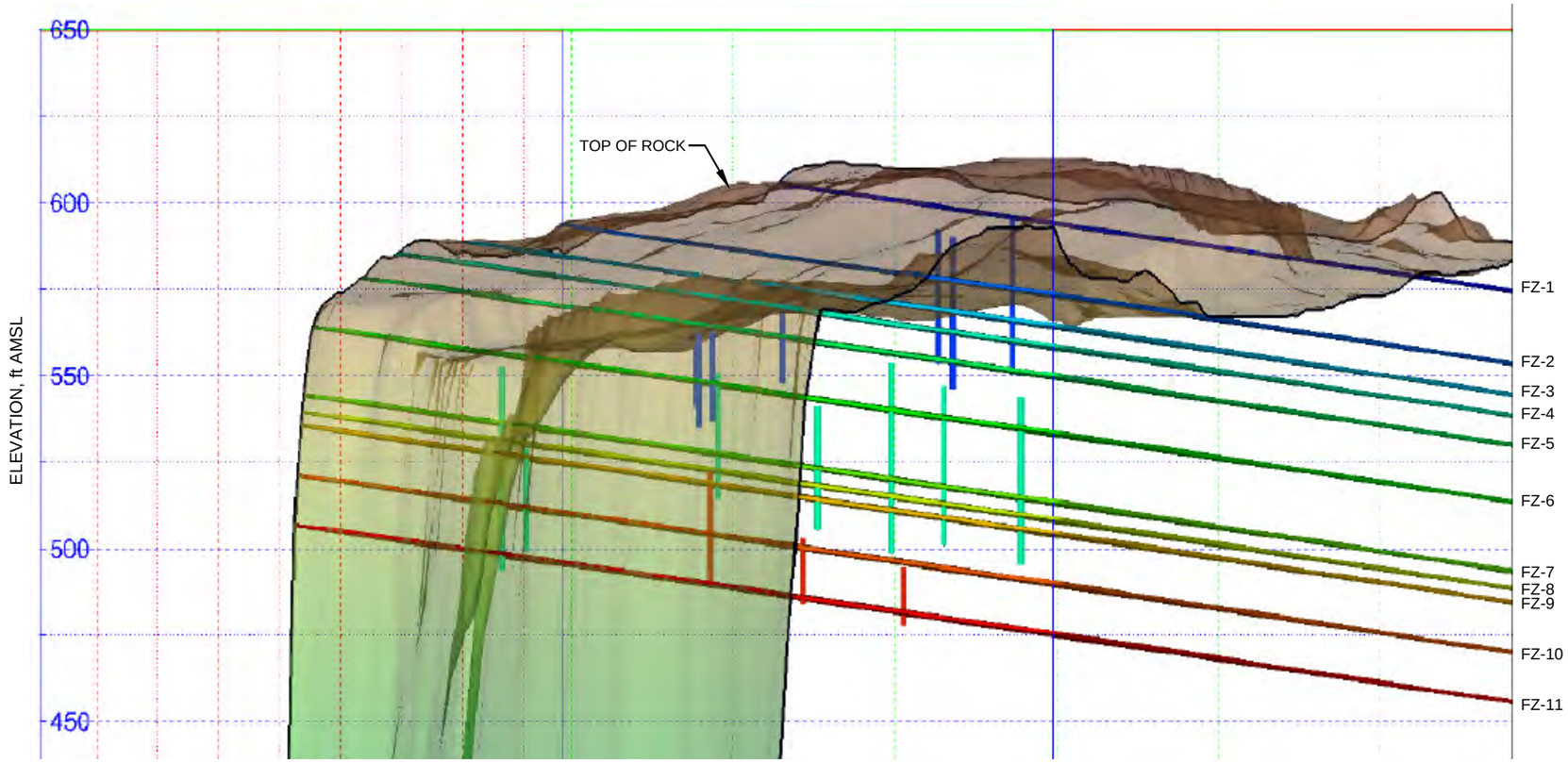
LOWER ZONE WELL

FZ-1 FLOW ZONE

figure 4.18

VIEW LOOKING ALONG STRIKE (N.69° E.) OF MONITORING WELL INTERVALS AND FLOW ZONES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA040 FEB 13/2002



LEGEND

UPPER ZONE WELL

MIDDLE ZONE WELL

LOWER ZONE WELL

FZ-1 FLOW ZONE

figure 4.19

VIEW LOOKING ALONG STRIKE (N.69° E.) OF PURGE WELL INTERVALS AND FLOW ZONES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA041 FEB 14/2002

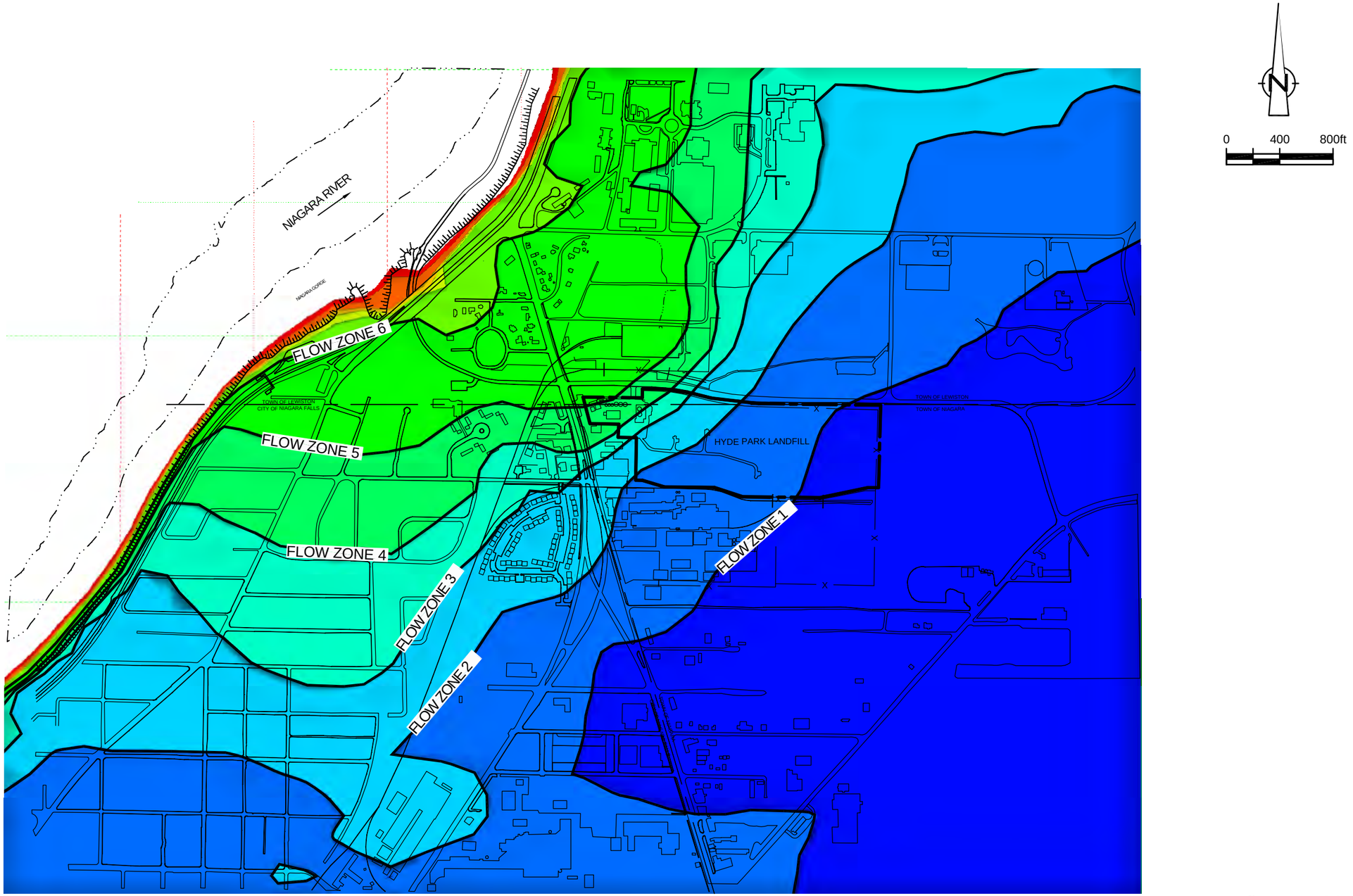


figure 4.20

PLAN VIEW OF AQUITARD SUBCROPS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

01069-30(299)GN-WA042 FEB 14/2002

TABLE 3.1

REGIONAL LITHOLOGIC DESCRIPTIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK
(Brett et al., 1995)

	Lithologic Description	Unit Thickness	Contact With Overlying Unit
Eramosa Formation	Dark brownish-gray, thin to thick bedded, bituminous dolomite, commonly vuggy	38 to 50 feet	Typically sharp, occurs at the basal stromatolitic marker bed of the Guelph Dolomite
Vinemount Member of the Goat Island Formation	Light to dark gray, medium to thin bedded, very fine-grained, argillaceous, bituminous, dolomite with thin shale partings	17 to 20 feet, anomalously thin (9 to 10 feet thick) at two locations in the Niagara region	Commonly gradational, but often sharp where the overlying unit is thick-bedded
Ancaster Member of the Goat Island Formation	Medium ash-gray, thin to medium bedded, fine grained dolomite with abundant chert nodules	2 to 25 feet. The thickness tends to be compensatory, such that the Ancaster Member is thick where the Niagara Falls Member is thin and vice versa	Abrupt and often demarcated by a 1- to 2-inch thick black shale, also described for the Niagara Falls area as being gradational and difficult to establish
Niagara Falls Member of the Goat Island Formation	Light olive to brownish-gray, sucrosic, medium grained, thick to massive bedded, porous and vuggy dolomite, containing stromatoporoids	3 to 15 feet	Sharp but conformable, color and texture typically change from dark and medium-grained below the contact to pale buff and finer-grained above.
Pekin Member of the Gasport Formation	Argillaceous, dark gray, fine-grained, thin to medium bedded, dolomicrite with local bioherms and flanking fossiliferous facies	Up to 33 feet but was noted to vary significantly	Varies from gradational to sharp
Gothic Hill Member of the Gasport Formation	Thick to massive bedded, dark olive gray to light pink, crinoidal grainstone and crinoidal dolomite	3 to 21 feet	Sharp and conformable, obvious due to the distinctive lithological change
DeCew Formation	Dark gray to olive gray, argillaceous to sandy, fine-grained dolomite with stringers of crinoid ossicles, internal soft sediment deformation structures	4.5 to 11.8 feet	Sharp and unconformable
Burleigh Hill Member of the Rochester Shale	Dark to medium gray, highly calcareous to dolomitic mudstone	30 feet near Lewiston to 23 feet thick at the Niagara Falls	Gradational and often difficult to establish in the Niagara region

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval	
				Start Depth	End Depth
Monitoring Wells					
A1U	598.0	600.35	26.0	27	57
A2U	593.5	593.51	22.0	22	52
AB1L	588.0	590.05	27.3	79	98
AB1M	588.0	589.44	22.6	44	86
AB1U	587.9	589.53	28.5	31	45
ABP-1	571.9	571.68	18.0	32 (2)	47 (2)
ABP-2	574.9	576.00	17.2	33 (2)	48 (2)
ABP-3 (1)	591.1 (1)	592.41 (1)	28.5	29	60
ABP-4	588.1	589.41	27.0	27	59
ABP-5	589.3	590.44	28.0	28	57
ABP-6 (C2U)	590.4	590.08	30.6	35 (2)	55 (2)
ABP-7	574.4	575.61	8.0	8	61
ABP-8	575.1	576.43	41.0	41	62
AFW-1L	570.9	570.61	8.0	56	81
AFW-1M	570.6	570.33	7.3	30	55
AFW-1U	570.3	569.84	7.5	8	29
AFW-2L	592.2	591.83	13.4	89	105
AFW-2M	592.2	591.73	13.6	61	88
AFW-2U	592.4	610.94	14.8	15	60
AFW-3L	589.3	588.73	12.4	85	106
AFW-3M	589.0	588.66	15.5	49	84
AFW-3U	588.4	588.10	13.2	14	48
AGW-1L	591.4	592.94	15.2	95	113
AGW-1M	591.4	593.56	14.6	53	94
AGW-1U	590.2	593.52	22.0	22	52
AGW-2L	608.4	611.24	15.3	108	131
AGW-2M	608.7	610.39	14.2	65	107
AGW-2U	608.8	610.94	14.6	15	64
AGW-3L	628.3	628.15	16.1	136	155
AGW-3M	627.8	627.41	8.6	77	132
AGW-3U	627.1	626.64	8.7	9	75
B1L	589.7	592.24	28.0	84	104
B1M	589.5	591.31	28.4	58	83
B1U	589.8	592.40	29.3	29	57
B2L	588.0	590.08	24.5	76	96
B2M	587.9	589.96	26.0	50	73
B2U	587.9	590.17	25.2	25	49
BC3L	595.0	594.70	35.0	87	107
BC3M	595.1	596.55	35.0	65	86
BC3U	595.2	594.93	35.0	35	64
BR-1	582.6	583.35	23.5	24	38
BR-2	581.6	582.07	24.5	25	39
BR-3	582.0	582.55	23.0	23	38
BR-4	583.5	583.84	26.8	27	42
C1L	591.4	593.16	29.5	82	104
C1M	591.5	594.04	29.6	57	82
C1U	591.6	593.66	28.5	29	56
C2L	590.2	589.69	30.6	81	101
C2M	590.1	589.90	24.8	57	80
C2U (ABP-6)	590.1	590.08	30.6	31	56
CD1L	596.8	596.63	34.0	87	109

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval	
				Start Depth	End Depth
CD1M	597.1	596.83	28.8	63	88
CD1U	597.0	596.86	23.6	35	64
CD2M	596.1	598.30	33.0	65	90
CD3U	593.4	595.41	30.0	32	62
CD4U	588.0	588.85	12.0	14	44
CD5U	588.2	588.38	20.0	22	51
CD6U	588.6	588.71	24.5	27	56
CMW-1SH	577.3	576.68	17.7	18	33
CMW-2SH	591.2	589.73	28.0	28	43
CMW-3SH	583.5	582.74	22.3	22	37
CMW-4SH	575.6	574.97	11.2	11	26
CMW-5SH	584.7	584.13	15.3	15	30
CMW-6SH	573.3	572.68	5.4	5	20
CMW-7SH	612.1	611.16	11.8	12	27
CMW-8SH	617.3	617.01	5.9	6	21
CMW-9SH	572.8	572.59	3.5	4	14
CMW-11SH	574.0	573.86	8.5	9	19
CMW-12SH	595.5	597.65	33.0	34	49
D1L	592.7	592.37	21.0	87	110
D1M	592.9	592.53	25.0	52	86
D1U	593.2	592.89	19.1	19	51
D2L	589.4	589.92	13.0	87	109
D2M	589.6	589.40	13.8	49	86
D2U	589.8	589.51	13.3	13	48
D3U (PW-2U)	600.0	600.02	20.1	20	52
D4L	598.6	600.09	23.8	98	115
D4M (PMW-2M)	598.0	598.00	22.1	61 (2)	96 (2)
D4U (PMW-2U)	598.4	598.09	21.0	21	55
D5L	599.1	598.81	15.5	98	120
E1L	594.0	596.59	17.5	95	121
E1M	594.3	596.25	16.7	54	94
E1U	594.4	596.57	18.9	19	54
E2L	591.3	592.36	15.0	90	117
E2M	591.2	593.70	13.5	48	89
E2U	591.7	592.46	14.0	14	48
E3L	593.1	592.90	15.1	96	119
E3M	593.8	593.70	14.0	49	94
E3U (PW-5U)	595.0	591.61	15.3	15	50
E4L	598.2	597.64	15.5	101	120
E4M	598.3	597.98	15.3	61	100
E4U	598.5	598.23	15.3	15	60
E5U	598.6	598.27	12.0	16	57
F1L	602.0	604.32	3.0	111	132
F1M	602.6	602.38	3.0	66	111
F1U	603.4	603.11	2.8	3	65
F2L	597.6	597.63	10.5	102	127
F2M	597.6	597.32	7.2	62	102
F2U	598.4	598.27	7.1	7	61
F3L	597.6	597.41	17.9	106	120
F3U (PW-6U)	610.6	609.76	8.1	8	60
F4L (1)	601.0 (1)	600.3	18.5	106	126
F4M (1)	600.9 (1)	600.41	18.6	60	104

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval	
				Start Depth	End Depth
F4U (1)	601.1 (1)	600.65	18.8	19	59
F5U	604.8	595.03	12.0	12	61
F5UR	604.9	604.63	9.0	9	59
G1L	615.6	617.53	9.0	126	147
G1M	615.3	617.78	9.5	70	124
G1U	615.8	618.33	11.0	11	69
G2L	609.8	609.55	9.5	124	141
G2M	610.1	609.87	11.2	70	123
G2U	609.1	608.87	11.8	12	69
G3L (BH4-95)	617.7	620.67	14.0	128	147
G3M	617.0	618.76	12.0	64	126
G3U	616.7	619.23	13.0	13	63
G4U (BH6-95)	610.6	620.31	13.3	13	72
G5L	605.5	605.46	7.5	115	134
G5U (T-2)	610.6	613.10	13.3	13	72
GH1U	619.5	620.51	8.2	8	59
H1L	618.9	620.84	13.0	128	143
H1M	619.4	621.74	12.8	58	127
H1U	619.8	621.53	13.0	13	57
H2L	619.3	621.57	6.0	130	150
H2M	619.8	621.77	6.0	57	127
H2U	619.6	621.70	6.2	6	56
H3L	612.9	614.95	12.8	118	138
H3U	613.7	615.05	11.8	12	72
H4L	611.2	613.82	13.5	113	133
HT-2 (BH2-95)	600.2	602.2	20.5	21	38
IFW-1	586.2	585.27	25.4	152	177
IFW-1R	586.2	584.96	25.4	152	177
IFW-2	607.3	610.56	16.5	180	205
IFW-3	619.3	622.14	11.3	200	227
IFW-4	612.2	611.78	11.8	206	230
IFW-5	596.1	596.43	11.1	177	207
IFW-6	592.3	592.05	16.7	164	191
IFW-7	590.0	592.27	29.8	156	180
J1L	606.8	609.78	16.0	103	123
J1M	606.9	609.09	15.5	46	100
J1U	606.9	608.86	16.1	16	45
J2L	608.0	610.53	15.3	102	125
J2M	607.4	609.58	18.8	46	101
J2U	607.9	610.18	17.1	17	45
J3L	600.2	602.71	16.4	101	121
J3U (BH1-95)	600.3	603.10	15.2	15	45
J4L	599.9	600.69	14.0	103	122
J5L	606.1	607.79	11.5	99	126
J5M	604.6	606.37	12.0	61	101
J5U	604.5	606.10	13.5	14	61
JH1L	624.4	626.43	14.2	111	147
MW1-2001	595.4	597.16	18.5	17	38
MW2-2001	594.4	596.04	21.5	23	35
MW3-2001	589.8	591.26	30.0	32	50
MW4-2001	588.8	590.90	30.0	32	50
MW5-2001	591.7	593.11	32.5	35	50

TABLE 3.2

BEDROCK WELL COMPLETION DETAILS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Ground Surface Elevation (ft AMSL)	Reference Elevation (ft AMSL)	Depth to Bedrock (feet)	Open Borehole or Screened Interval	
				Start Depth	End Depth
MW6-2001	591.2	592.66	32.5	35	50
MW7-2001	590.3	591.86	29.0	29	56
PMW-1L	597.4	597.37	34.2	94	115
PMW-1M	597.7	597.21	30.3	66	94
PMW-1U	596.9	596.66	31.0	31	65
PMW-3L	604.6	606.51	14.9	108	126
PMW-3M	605.1	607.47	10.6	49	107
PMW-3U	604.9	607.30	9.9	10	48
Purge Wells					
APW-1	569.0	565.53	13.6	14	77
APW-2	574.0	570.55	42.6	43	77
PW-1L	596.8	593.55	15.9	72	110
PW-1U	596.7	593.55	32.3	32	62
PW-2L	600.0	597.53	20.1	95	118
PW-2L (aband.)	598.0	598.00	20.5	20	120
PW-2M (1)	597.6 (1)	596.94 (1)	19.9	54	94
PW-2UR	597.9	598.14	22.0	22	52
PW-3L	602.8	599.35	14.5	106	127
PW-3M	601.4	598.17	13.5	45	105
PW-4M	610.3	607.22	11.8	61	112
PW-4U	607.5	605.23	9.0	13	57
PW-5UR	604.8	595.03	12.0	12	61
PW-6MR (T-3)	612.1	611.09	7.1	66	119
PW-6UMR	612.2	615.51	7.8	8	120
PW-6UR (T-1)	611.3	608.95	12.5	13	63
PW-7U (CD-2U)	596.7	592.98	34.0	32	64
PW-8M	597.0	593.18	36.0	44	86 (3)
PW-8U	593.7	589.78	31.0	31	56
PW-9U	591.8	588.00	29.5	29	55
PW-10U	597.8	594.01	18.5	19	31 (4)
RW-3UM (PW-3U) (1)	602.1 (1)	593.93 (1)	14.4	15	44

Notes:
(1) Survey Elevation uncertain.
(2) Screened interval.
(3) Original pilot hole extended to 89.8 feet bgs.
(4) Original pilot hole extended to 40.5 feet bgs.

TABLE 3.3

SYMMARY OF UNIT THICKNESSES REPORTED IN PUBLICATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Unit Name		Zenger (1965)	IJC (1974)	Novakowski and Lapcevic (1998)	Kappel and Tepper (1992)	Blair and McFarland (1992)	Brett, et al. (1995)	Hyde Park Landfill Site (4)
Zenger (1965) / Rickard (1975)	Brett, et al. (1995)							
Upper Oak Orchard Member / Upper Guelph Formation	Guelph Dolomite (1)	> 120 feet	> 70 feet	120 feet	33 feet	16 - 46 feet	36-37 (3)	--
Lower Oak Orchard Member (1) / Lower Guelph Formation	Eramosa Dolomite (1)				52 feet		38 - 50 feet	0 - 67 feet
Eramosa Member / Eramosa Formation	Vinemount Member of the Goat Island Formation	16 - 18 feet	14 feet	10 - 33 feet		69 - 85 feet (2)	17-20 feet	18 - 24 feet
Goat Island Member / Goat Island Formation	Ancaster Member of the Goat Island Formation	19 - 25 feet	26 feet	16 - 26 feet	41 feet	20 - 33 feet	2-25 feet	13 - 24 feet
	Niagara Falls Member of the Goat Island Formation						3 - 15 feet	
Gasport Member / Gasport Formation	Pekin Member of the Gasport Formation	15 - 23 feet	18 feet	44 feet	33 feet	36 - 46 feet	Varies significantly, 23 feet average	11 - 24 feet
	Gothic Hill Member of the Gasport Formation						3 - 21 feet	4 - 16 feet
Decew Member / DeCew Formation	DeCew Dolomite	8 - 12 feet	10 feet	11 feet	NR	7 - 9 feet	8-12 feet	8 - 13 feet
Rochester Shale	Rochester Shale	NR	~60 feet	55 feet	NR	57 - 61 feet	58 - 65 feet	56 - 63 feet

Notes: NR - Not Reported.
(1) These units are commonly surficial units and tend to be erosionally truncated
(2) These values (21 - 26 meters) do not correspond to other researchers and are suspect. These values may reflect thicknesses reported further north of the Niagara Falls area.
(3) Thickness based on two USGS drill cores.
(4) Based on lithologic logging of available drill core.

TABLE 3.4

REVISED STRATIGRAPHIC CONTACT ELEVATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft AMSL)	Top of Eramosa Formation Elevation (ft AMSL)	Top of Vinemount Member Elevation (ft AMSL)	Top of Ancaster / Niagara Falls Members Elevation (ft AMSL)	Top of Pekin Member Elevation (ft AMSL)	Top of Gothic Hill Member Elevation (ft AMSL)	Top of DeCew Formation Elevation (ft AMSL)	Top of Rochester Formation Elevation (ft AMSL)
A1U	598.0	571 (1)	561	542	--	--	--	--
A2U	593.5	572 (1)	563	542	--	--	--	--
AB1L	588.0	drilled out without coring to near bottom elevation of AB1M					502	492
AB1M	588.0	drilled out without coring to near bottom elevation of AB1U			525	510		
AB1U	587.9	--	559 (2)	546				
ABP-1	571.9	--	554 (2)	549	529	--	--	--
ABP-2	574.9	--	558 (2)	550	529	--	--	--
ABP-3 (4)	591.1 (4)	--	563 (2) (4)	546 (4)	--	--	--	--
ABP-4	588.1	--	561 (2)	538	--	--	--	--
ABP-5	589.3	--	562 (2)	546	--	--	--	--
ABP-7	574.4	--	558 (2)	547	527	--	--	--
ABP-8	575.1	--	--	534 (3)	527	516	--	--
AFW-1L	570.9	--	565 (2)	551	533	core lost during storage		
AFW-2L	592.2	579 (1)	560	542	521	501	497	487
AFW-3L	589.3	577 (1)	560	539	524	507	496	--
AGW-1L	591.4	576 (1)	567	547	527	508	core lost during storage	
AGW-2L	608.4	594 (1)	561	540	521	502	499	490
AGW-3L	628.3	612 (1)	550	531	517	493	487	476
APW-1	569.0	--	556 (2)	544	527	510	504	492
APW-2	574.0	--	--	531 (3)	528	512	504	--
B1L	589.7	--	562 (2)	544	522	507	500	490
B2L	588.0	--	564 (2)	542	526	511	503	493
BR-1	582.6	--	559 (2)	--	--	--	--	--
BR-2	581.6	--	557 (2)	--	--	--	--	--
BR-3	582.0	--	559 (2)	--	--	--	--	--
BR-4	583.5	--	557 (2)	--	--	--	--	--
C1L	591.4	--	563 (2)	543	526	513	503	492
C2L	590.2	--	560 (2)	542	526	511	502	492
CD1L	596.8	--	563 (2)	542	521	508	499	489
CD1M	597.1	568 (1)	562	541	520	507	--	--
CD1U	597.0	573 (1)	562	541	--	--	--	--
CD2M	596.1	--	563 (2)	544	523	509	--	--

TABLE 3.4

REVISED STRATIGRAPHIC CONTACT ELEVATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft AMSL)	Top of Eramosa Formation Elevation (ft AMSL)	Top of Vinemount Member Elevation (ft AMSL)	Top of Ancaster / Niagara Falls Members Elevation (ft AMSL)	Top of Pekin Member Elevation (ft AMSL)	Top of Gothic Hill Member Elevation (ft AMSL)	Top of DeCew Formation Elevation (ft AMSL)	Top of Rochester Formation Elevation (ft AMSL)
CD3U	593.4	--	564 (2)	545	--	--	--	--
CD4U	588.0	575 (1)	560	--	--	--	--	--
CD5U	588.2	566 (1)	562	542	--	--	--	--
CD6U	588.6	--	562 (2)	549	--	--	--	--
D1L	592.7	572 (1)	558	535	522	504	494	483
D2L	589.4	576 (1)	560	536	521	508	497	486
D4L	598.6	576 (1)	558	539	519	504	496	486
E1L	594.0	577 (1)	550	528	511	496	487	475
E2L	591.3	578 (1)	553	534	core lost during storage			
E3L	593.1	578 (1)	553	531	514	500	490	--
E5U	598.6	587 (1)	551	--	--	--	--	--
F1L	602.0	594 (1)	546	528	508	core lost during storage	483	475
F2L	597.6	578 (1)	546	527	507	497	481	471
F3L	597.6	580 (1)	550	531	511	497	489	479
G1L	615.6	607 (1)	540	522	501	487	481	--
G2L	609.8	599 (1)	539	515	501	486	478	--
G3L (BH4-95)	617.7	drilled out to 114' bgs before beginning coring			504	491	484	473
G4U	610.6	597 (1)	--	--	--	--	--	--
G5L	605.5	598 (1)	552	531	510	494	487	476
G5U (T-2)	610.6	603 (1)	548	--	--	--	--	--
H1L	618.9	606 (1)	549	530	508	492	486	476
H2L	619.3	613 (1)	548	528	506	489	485	473
HT2	600.2	580 (1)	--	--	--	--	--	--
J1L	606.8	591 (1)	560	539	519	502	497	487
J2L	608.0	593 (1)	560	540	519	504	497	486
J3U	600.3	583 (1)	558	--	--	--	--	--
J5L	606.1	drilled out without coring to near bottom elevation of J5M				498	494	481
J5M	604.6	drilled out without coring to near bottom of J5U		533	513			
J5U	604.5	594 (1)	556					
JH1L	624.4	610 (1)	555	537	516	500	496	--
MW1-2001	595.4	578 (1)	563	--	--	--	--	--
MW2-2001	594.4	572 (1)	562	--	--	--	--	--

TABLE 3.4

REVISED STRATIGRAPHIC CONTACT ELEVATIONS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft AMSL)	Top of Eramosa Formation Elevation (ft AMSL)	Top of Vinemount Member Elevation (ft AMSL)	Top of Ancaster / Niagara Falls Members Elevation (ft AMSL)	Top of Pekin Member Elevation (ft AMSL)	Top of Gothic Hill Member Elevation (ft AMSL)	Top of DeCew Formation Elevation (ft AMSL)	Top of Rochester Formation Elevation (ft AMSL)
MW3-2001	589.8	--	558 (2)	542	--	--	--	--
MW4-2001	588.8	--	557 (2)	540	--	--	--	--
MW5-2001	591.7	--	559 (2)	542	--	--	--	--
MW6-2001	591.2	--	559 (2)	543	--	--	--	--
MW7-2001	590.3	561 (1)	561	542	--	--	--	--
PMW-1L	597.4	566 (1)	564	546	521	504	498	488
PMW-3L (4)	604.6 (4)	590 (1)(4)	549 (4)	531 (4)	510 (4)	495 (4)	488 (4)	477 (4)
PW-1L	596.8	--	565 (2)	543	523	508	499	--
PW-2L	600.0	580 (1)	560	537	522	505	498	488
PW-3L	602.8	588 (1)	554 (2)	530	509	496	492	481
PW-4M (4)	610.3 (4)	601 (1)(4)	555 (4)	536 (4)	520 (4)	502 (4)	--	--
PW-6UR(T-1)	611.3	599 (1)	549	--	--	--	--	--
PW-6MR(T-3)	612.1	605 (1)	548	529	509	493	--	--
PW-7U (CD-2U)	596.7	--	562 (2)	543	--	--	--	--
PW-8U	593.7	--	563 (2)	539	--	--	--	--
PW-8M	597.0	--	561 (2)	542	522	508	--	--
PW-9U	591.8	--	562 (2)	539	--	--	--	--
PW-10U	597.8	580 (1)	561	--	--	--	--	--

Notes:
ft AMSL - feet Above Mean Sea Level.
The top of the drill core begins at or below the overburden / bedrock interface, depending on the depth of installation of surface casing.
-- Not present or not present in currently available drill core.
Due to the gradational nature of many unit contacts and lithologic similarity of many units, and the resultant difficulties in establishing exact unit contacts, all point should be considered approximate.
1) The Eramosa Formation is the uppermost bedrock unit and the elevation given is for the top of the drill core.
2) The Vinemount Member is the uppermost bedrock unit over part of the site and the elevation given is for the top of the drill core.
3) The Ancaster Member is the uppermost bedrock unit over part of the site and the elevation given is for the top of the drill core.
4) The original ground surface elevation is uncertain, therefore all contact elevations are estimated.

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
A1U	E	560
A1U	F	555
A1U	G	550
A1U	H	547
A2U	E	562
A2U	F	557
A2U	G	552
A2U	H	547
A2U	I	544
ABP-3	F	561
ABP-3	H	553
ABP-3	I	547
ABP-3	J	537
ABP-4	G	556
ABP-4	H	552
ABP-4	I	547
ABP-4	J	538
ABP-4	K	533
ABP-5	F	559
ABP-5	G	554
ABP-5	H	550
ABP-5	I	547
ABP-5	J	536
ABP-7	G	556
ABP-7	H	553
ABP-7	I	547
ABP-7	J	537
ABP-7	K	533
ABP-7	L	526
ABP-7	M	517
AFW-1U	G	557
AFW-1U	H	554
AFW-1U	I	549
AFW-1M	J	539
AFW-1M	K	535
AFW-1M	L	527
AFW-2U	E	562
AFW-2U	G	553
AFW-2U	H	549

Well	Gamma Peak	Elevation (ft msl)
CMW-5SH	E	559
D1U	E	558
D1U	F	554
D1U	G	548
D1U	H	545
D1M	I	540
D1M	J	529
D1M	K	525
D1M	L	518
D2U	E	559
D2U	F	555
D2U	G	549
D2U	H	546
D2M	I	540
D2M	K	526
D2M	L	518
D2M	M	508
D3U	E	555
D4U	E	558
E1U	E	550
E1M	G	540
E1M	H	537
E1M	I	532
E1M	J	522
E1M	K	519
E1M	L	511
E1L	L	504
E2U	E	553
E2M	I	535
E2M	K	521
E2M	M	505
E3M	G	543
E3M	H	540
E3M	I	535
E3M	K	521
E3M	L	512
E3M	M	504
F1U	E	547
F1M	G	537

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
AFW-2U	I	544
AFW-2L	N	506
AFW-3U	E	557
AFW-3U	F	553
AFW-3U	G	547
AFW-3U	H	543
AFW-3M	I	538
AFW-3M	L	514
AGW-1U	E	565
AGW-1U	F	560
AGW-1U	I	547
AGW-1M	J	536
AGW-1M	K	531
AGW-1M	L	523
AGW-1M	M	517
AGW-1M	N	508
AGW-2U	E	559
AGW-2U	F	554
AGW-2U	G	549
AGW-2M	I	542
AGW-2M	J	531
AGW-2M	L	519
AGW-2M	M	512
AGW-2M	N	505
AGW-3M	E	550
AGW-3M	F	545
AGW-3M	G	540
AGW-3M	H	537
AGW-3M	I	532
AGW-3M	L	509
AGW-3M	M	500
APW-1	H	555
APW-1	I	550
APW-1	J	539
APW-1	K	535
APW-1	L	527
APW-1	M	520
APW-1	N	513
APW-2	L	527

Well	Gamma Peak	Elevation (ft msl)
F1M	H	534
F1M	I	529
F1M	J	519
F1M	K	515
F1M	L	508
F1M	M	499
F2U	E	546
F2M	G	537
F2M	H	533
F2M	I	528
F2M	J	518
F2M	K	514
F2M	L	507
F2M	M	499
F2L	N	493
F4U	E	550
F4M	G	540
F4M	H	537
F4M	I	532
F4M	K	518
F4M	L	510
F4M	M	503
G2M	E	541
G2M	F	536
G2M	G	530
G2M	H	527
G2M	I	522
G2M	K	508
G2M	L	500
G2M	M	492
G2L	N	485
G3M	E	546
G3M	F	542
G3M	G	537
G3M	H	534
G3M	I	528
G3M	J	517
G3M	K	514
G3M	L	506

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
APW-2	M	518
APW-2	N	514
B1U	F	559
B1U	G	553
B1U	H	550
B1U	I	545
B1M	K	530
B1M	L	522
B1M	M	515
B1L	N	505
B2U	F	560
B2U	G	555
B2U	H	552
B2U	I	547
B2M	J	536
B2M	K	532
B2M	L	524
B2L	N	511
BC3U	F	558
BC3U	G	553
BC3U	I	544
BC3M	J	533
BC3M	K	529
BC3M	L	521
BC3L	N	508
BR-1	F	558
BR-1	G	553
BR-2	G	554
BR-2	H	549
BR-2	I	546
BR-3	G	557
BR-3	H	552
BR-3	I	549
C1U	F	560
C1U	G	554
C1U	H	552
C1U	I	546
C1M	J	535
C1M	K	532

Well	Gamma Peak	Elevation (ft msl)
G3M	M	498
H1M	E	550
H1M	F	545
H1M	G	540
H1M	H	537
H1M	I	531
H1M	J	521
H1M	K	516
H2M	E	546
H2M	F	541
H2M	G	536
H2M	H	533
H2M	I	528
H2M	J	517
H2M	K	513
H2M	L	506
H3L	N	494
H3U	E	550
J1M	E	559
J1M	F	554
J1M	G	549
J1M	H	546
J1M	I	542
J1M	J	530
J1M	K	525
J1M	L	517
J1M	M	510
J1L	N	502
J3U	E	558
PMW-1U	E	560
PMW-1U	F	555
PMW-1U	G	550
PMW-1U	H	547
PMW-1M	I	542
PMW-1M	K	527
PMW-1M	L	519
PMW-1M	M	510
PW-2M	I	538
PW-2M	J	528

TABLE 4.1
GAMMA PEAK PICKS
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Gamma Peak	Elevation (ft msl)
C1M	L	525
C1M	M	515
C2M	K	532
C2M	L	525
C2M	M	517
CD1U	E	559
CD1U	F	555
CD1U	G	549
CD1U	H	546
CD1U	I	541
CD1M	J	530
CD1M	K	526
CD1M	L	518
CD1M	M	511
CD1L	N	506
CD2M	K	529
CD2M	L	521
CD2M	M	513
CD3U	E	563
CD3U	F	558
CD3U	G	553
CD3U	H	549
CD3U	I	543

Well	Gamma Peak	Elevation (ft msl)
PW-2M	K	525
PW-2M	L	516
PW-2M	M	508
PW-4M	F	546
PW-4M	G	541
PW-4M	H	538
PW-4M	I	533
PW-4M	K	518
PW-6MR	F	543
PW-6MR	G	537
PW-6MR	H	534
PW-6MR	I	529
PW-6MR	K	514
PW-6MR	L	506
PW-6MR	M	498
PW-4M	K	518
PW-6MR	F	543
PW-6MR	G	537
PW-6MR	H	534
PW-6MR	I	529
PW-6MR	K	514
PW-6MR	L	506
PW-6MR	M	498

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
A1U	563	CR	560.1	2.9
A1U	549	CR	560.1	-11.1
A2U	565	CRV	561.6	3.4
A2U	551	CT	561.6	-10.6
ABP-3	562	CSR	564.6	-2.6
ABP-3	558	RT	564.6	-6.6
ABP-3	549	CSR	564.6	-15.6
ABP-4	555	T	565.7	-10.7
ABP-4	553	TRV	565.7	-12.7
ABP-4	539	S	565.7	-26.7
ABP-5	560	CS	564.7	-4.7
ABP-5	557	R	564.7	-7.7
ABP-5	552	T	564.7	-12.7
ABP-5	547	CS	564.7	-17.7
ABP-5	544	T	564.7	-20.7
ABP-5	538	CTR	564.7	-26.7
ABP-7	524	SR	568.3	-44.3
ABP-7	524	SC	568.3	-44.3
ABP-7	521	S	568.3	-47.3
ABP-8	520	S	568.8	-48.8
AFW-1U	548	S	568.0	-20.0
AFW-1U	547	S	568.0	-21.0
AFW-1U	542	S	568.0	-26.0
AFW-1M	520	CS	568.0	-48.0
AFW-1M	516	S	568.0	-52.0
AFW-2L	495	S	561.9	-66.9
AFW-2U	572	TRV	561.7	10.3
AFW-2U	565	RAV	561.7	3.3
AFW-2U	550	T	561.7	-11.7
AFW-2U	544	RV	561.7	-17.7
AFW-3U	560	CT	556.4	3.6
AFW-3U	557	CSR	556.4	0.6
AFW-3U	554	TRV	556.4	-2.4
AFW-3M	514	SR	556.5	-42.5
AGW-1U	567	CSR	564.3	2.7
AGW-1U	560	CT	564.3	-4.3
AGW-1U	552	T	564.3	-12.3
AGW-1M	537	SR	564.2	-27.2
AGW-1M	520	R	564.2	-44.2
AGW-1M	519	CTR	564.2	-45.2
AGW-1M	513	R	564.2	-51.2
AGW-1L	490	SR	564.1	-74.1
AGW-2U	591	CSR	557.8	33.2
AGW-2U	585	CSR	557.8	27.2
AGW-2U	575	RSC	557.8	17.2
AGW-2U	566	CS	557.8	8.2
AGW-2U	561	CS	557.8	3.2
AGW-2U	554	CS	557.8	-3.8
AGW-2M	542	CS	557.9	-15.9

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
AGW-2M	540	CS	557.9	-17.9
AGW-2M	537	CSR	557.9	-20.9
AGW-2M	531	SR	557.9	-26.9
AGW-2M	524	TRC	557.9	-33.9
AGW-2M	519	CR	557.9	-38.9
AGW-2M	517	S	557.9	-40.9
AGW-2M	515	CR	557.9	-42.9
AGW-2L	497	S	557.9	-60.9
AGW-3U	600	CT	549.4	50.6
AGW-3U	595	R	549.4	45.6
AGW-3M	551	CSR	549.5	1.5
AGW-3M	534	R	549.5	-15.5
AGW-3M	511	RT	549.5	-38.5
APW-1	536	TR	570.2	-34.2
APW-1	527	T	570.2	-43.2
APW-1	516	S	570.2	-54.2
APW-2	523	CSR	569.2	-46.2
APW-2	516	SR	569.2	-53.2
APW-2	513	CT	569.2	-56.2
B1U	560	TRV	563.0	-3.0
B1U	547	TR	563.0	-16.0
B1M	529	CF	562.9	-33.9
B1M	525	S	562.9	-37.9
B1M	519	TF	562.9	-43.9
B1L	503	T	562.9	-59.9
B2U	560	CF	565.2	-5.2
B2U	554	FR	565.2	-11.2
B2U	549	TR	565.2	-16.2
B2M	533	CV	565.1	-32.1
B2M	527	CT	565.1	-38.1
B2M	521	TFR	565.1	-44.1
BC3U	558	TR	561.5	-3.5
BC3U	551	CR	561.5	-10.5
BC3U	549	R	561.5	-12.5
BC3M	526	SR	561.6	-35.6
BC3M	519	CT	561.6	-42.6
BR-1	556	CS	563.7	-7.7
BR-2	552	SR	564.0	-12.0
BR-3	557	CR	566.0	-9.0
BR-3	551	SR	566.0	-15.0
BR-4	556	CS	567.8	-11.8
C1U	562	CSR	564.0	-2.0
C1U	557	RT	564.0	-7.0
C1U	549	CS	564.0	-15.0
C1M	524	CR	564.1	-40.1
C1M	520	CRV	564.1	-44.1
C1L	508	TR	564.1	-56.1
C1L	494	CT	564.1	-70.1
C2M	530	CR	565.8	-35.8

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
C2M	525	CSR	565.8	-40.8
C2M	522	CRV	565.8	-43.8
C2L	508	CR	565.6	-57.6
C2L	496	CT	565.6	-69.6
CD1U	561	CSR	558.5	2.5
CD1U	544	CTR	558.5	-14.5
CD1M	525	SR	558.5	-33.5
CD1M	519	T	558.5	-39.5
CD1L	508	CS	560.3	-52.3
CD1L	502	R	560.3	-58.3
CD1L	498	CT	560.3	-62.3
CD1L	489	CT	560.3	-71.3
CD2M	518	CTRV	561.9	-43.9
CD3U	560	CR	562.3	-2.3
CD3U	556	S	562.3	-6.3
CD3U	548	TR	562.3	-14.3
CD3U	541	S	562.3	-21.3
CD4U	572	TR	559.7	12.3
CD4U	560	R	559.7	0.3
CD4U	555	SR	559.7	-4.7
D1U	570	FR	557.6	12.4
D1U	564	FR	557.6	6.4
D1U	559	CFV	557.6	1.4
D1U	543	CS	557.6	-14.6
D1M	514	CFV	557.6	-43.6
D1L	499	S	557.5	-58.5
D2U	570	CFR	558.2	11.8
D2U	560	CFR	558.2	1.8
D2U	555	CSR	558.2	-3.2
D2U	546	FR	558.2	-12.2
D2M	525	T	558.3	-33.3
D2M	519	R	558.3	-39.3
D2M	515	CF	558.3	-43.3
D2L	494	S	558.3	-64.3
D2L	488	S	558.3	-70.3
D3U	565	TC	556.9	8.1
D4U	572	RC	557.3	14.7
D4U	558	TRC	557.3	0.7
D5L	499	R	555.7	-56.7
E1U	568	R	551.1	16.9
E1U	562	FV	551.1	10.9
E1U	554	T	551.1	2.9
E1U	549	TR	551.1	-2.1
E1L	495	S	551.3	-56.3
E2L	494	S	552.1	-58.1
E3M	525	TR	552.1	-27.1
E3M	510	CSR	552.1	-42.1
E3L	494	SR	552.3	-58.3
E3L	481	CR	552.3	-71.3

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
F1U	570	CT	547.0	23.0
F1M	522	R	547.2	-25.2
F1M	513	R	547.2	-34.2
F1M	508	TV	547.2	-39.2
F1M	504	CTV	547.2	-43.2
F2U	572	FTRC	546.9	25.1
F2U	557	FRC	546.9	10.1
F2M	504	FC	547.0	-43.0
F3L	490	CR	550.4	-60.4
F4U	585	CTR	550.1	34.9
F4U	554	CSR	550.1	3.9
F4M	526	CTR	550.1	-24.1
F4M	508	CTRV	550.1	-42.1
G2U	556	CTR	539.8	16.2
G2M	525	TC	540.0	-15.0
G2M	501	TCR	540.0	-39.0
G2L	484	CR	539.9	-55.9
G3M	503	CTR	546.8	-43.8
G3L	473	F	546.8	-73.8
G5U	579	TR	548.1	30.9
G5L	484	R	550.1	-66.1
H1U	600	CF	550.1	49.9
H1U	597	CF	550.1	46.9
H1M	550	CTR	550.3	-0.3
H1M	512	CFR	550.3	-38.3
H1M	509	FRC	550.3	-41.3
H1M	505	FC	550.3	-45.3
H1M	505	CF	550.3	-45.3
H1L	480	CSF	550.5	-70.5
H2U	603	CTR	549.0	54.0
H2U	593	CR	549.0	44.0
H2U	578	CR	549.0	29.0
H2M	558	R	548.8	9.2
H2M	531	SR	548.8	-17.8
H2M	518	CRT	548.8	-30.8
H2M	503	CR	548.8	-45.8
H2L	483	S	548.7	-65.7
H3U	552	TCR	550.5	1.5
H3L	493	T	550.5	-57.5
H3L	481	CTR	550.5	-69.5
J1U	587	FR	558.5	28.5
J1U	569	CT	558.5	10.5
J1M	550	R	558.6	-8.6
J1M	545	V	558.6	-13.6
J1M	524	CF	558.6	-34.6
J1M	517	F	558.6	-41.6
J1M	514	CFRV	558.6	-44.6
J3U	570	CTR	558.7	11.3
J3L	485	F	558.5	-73.5

TABLE 4.2
WATER-BEARING FEATURES
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well	Elevation (ft msl)	Selection Basis	GP-E Elevation (ft msl)	Depth Relative to GP-E (ft)
J4L	485	F	557.3	-72.3
JH1L	510	TR	553.8	-43.8
PMW-1U	563	R	559.6	3.4
PMW-1U	549	R	559.6	-10.6
PMW-1U	544	T	559.6	-15.6
PMW-1M	517	CR	559.5	-42.5
PMW-1L	500	R	559.4	-59.4
PMW-1L	489	CS	559.4	-70.4
PW-1U	562	CR	561.3	0.7
PW-1U	541	T	561.3	-20.3
PW-2M	533	TR	556.8	-23.8
PW-2M	507	T	556.8	-49.8
PW-3M	527	SR	553.6	-26.6
PW-3M	515	S	553.6	-38.6
PW-3L	495	R	553.0	-58.0
PW-3L	490	S	553.0	-63.0
PW-5UR	576	CTR	551.0	25.0
PW-6UR	569	T	548.5	20.5
PW-6UR	560	T	548.5	11.5
PW-6MR	533	T	548.1	-15.1
PW-6MR	527	TR	548.1	-21.1

Column Headings

Elevation (ft msl)
Elevation of feature picked from 2-page geophysical summaries

Selection Basis
T - temperature offset
S - spike in delta temperature
R - offset in fluid resistivity
C - opening based on caliper log
V - P-sonic velocity increase
F - Borehole vertical flow meter

GP-E Elevation (ft msl)
Elevation of the GP-E plane at the well location

Depth Relative to GP-E (ft)
Depth of feature compared to the GP-E plane elevation

SITE CHARACTERIZATION REPORT - REVISED GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION

HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

VOLUME 2 - APPENDICES

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APPENDIX A

GEOPHYSICAL LOGGING PROGRAM

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1.0 INTRODUCTION

A borehole geophysical logging program was conducted at the Hyde Park Landfill Site (Site) during July and August 2001. The borehole geophysical logging program was conducted in response to the USEPA's and NYSDEC's concern with respect to the characterization of the Site. The program was designed to support a reevaluation of the existing site geologic and hydrogeologic characterization.

This appendix discusses the selection and description of geophysical logging tools and how the borehole geophysical logs were interpreted. Tables of the near-horizontal and dipping fractures identified from the borehole geophysical logs are presented in this Appendix. A table of selected water-bearing features identified from the borehole geophysical logs is presented in Section 4.0 of the SCR.

2.0 GEOPHYSICAL LOGGING TOOLS

Century Geophysical Corporation (Century) was contracted by MSRM to provide the bulk of the borehole geophysical logging services. Other geophysical logging services were provided by Schlumberger Limited. Century provided and operated the following four logging tools and their borehole logging vehicle:

- 9065 - Three-Arm Caliper;
- 9041 - SP Multi-Parameter E-log;
- 9300 - P-Wave Sonic; and
- 9800 - Acoustic Televiewer.

Each logging tool and the respective measured properties are briefly described below. These logging tools were selected in order to obtain geophysical data related to fracture position, orientation and hydrogeological characteristics. In addition, some of these logs provide geophysical data related to bulk bedrock and fluid properties. The geophysical data were generated by the electronics within the logging tools and recorded by a field computer. All data were provided to CRA in the form of field-printed strip logs and electronic files.

Three-Arm Caliper

The three-arm caliper tool measures the average diameter of the borehole using three arms. Changes in borehole diameter are related to drilling methods and lithology. Data were recorded at 0.1-foot intervals. Very thin (vertically) changes in borehole diameter may not be detected. The caliper arms are located at the bottom of the tool.

Caliper data were not smoothed for presentation.

SP Multi-Parameter E-Log

The SP Multi-Parameter E-log tool measures the following properties using a single logging tool:

- Natural Gamma;
- Spontaneous Potential;
- Fluid Resistivity (inverse of Fluid Specific Conductance);
- 16-inch Normal Resistivity;
- 64-inch Normal Resistivity;

- Lateral Resistivity;
- Single-Point Resistivity; and
- Fluid Temperature and Delta Temperature.

Data for this logging tool was recorded at 0.1-foot intervals. The various sensors are located at different positions along the tool length.

Natural Gamma

The natural gamma log provides an indication of the relative amount of clay or shale in the formation and is useful for stratigraphic correlation. The gamma rays are emitted by naturally-occurring radioactive elements such as potassium, uranium, thorium, radium, and related daughter elements. These radioactive elements are primarily found in clay minerals and shales in sedimentary rocks. The natural emission of gamma rays was recorded in the logging tool using a 1-inch by 4-inch long Sodium Iodide scintillometer.

Gamma rays pass through the steel surface casing; therefore, the signal may be recorded from within the open borehole interval and the well casing. However, the signal passing through the casing and annular grout is slightly attenuated. Inspection of the gamma signal from the open interval is preferred to inspection of the signal passing through the casing.

The recorded data were smoothed for presentation on the field printed strip logs using a 21-point centered moving average. The 2-page summary logs presented in Attachment 1 use an 11-point centered moving average in order to sharpen the stratigraphic marker horizons (gamma peaks).

Spontaneous Potential

The spontaneous, or self potential, is often useful for identification of the boundary between two lithologies. The spontaneous potential value recorded is a function of the natural flow of current between lithologic contacts, chemical activities of borehole and interstitial fluids, and temperature. An inflection in the spontaneous potential signal will often occur at lithologic interface.

The spontaneous potential data were not smoothed for presentation.

Fluid Resistivity

The resistivity of the fluid within the borehole is recorded with this log. The fluid resistivity (inverse of fluid specific conductance) is inversely related to the total dissolved solids (TDS) content of the borehole fluid (low fluid resistivity indicates high TDS). Changes in fluid resistivity may indicate the introduction of fresher or more saline groundwater into the borehole. Density-related stratification may also occur (less resistive, more dense, water will sink to the bottom of the borehole) unrelated to groundwater flow.

Data were smoothed for presentation on the field printed strip logs and 2-page summary logs using a 5-point centered moving average.

16-inch Normal and 64-Inch Normal Resistivity

The 16-inch normal resistivity (16-N or short-normal) and 64-inch normal resistivity (64-N or long-normal) tools measure apparent resistivity of the bedrock. The measured apparent resistivity is related to the bedrock resistivity, pore fluid resistivity, borehole diameter, and other factors. Changes in bedrock or pore fluid resistivity are the typical source of changes in recorded values. The 16-N and 64-N logging tools have differing electrode spacings which govern the depth of investigation. The 16-N log spherical volume of investigation is approximately 2.5 to 3 feet in diameter while the 64-N spherical volume of investigation is approximately 10 feet in diameter, depending, in part, on the fluid and bedrock resistivity and bed thickness.

The 16-N and 64-N data were smoothed for presentation on the field printed strip logs and 2-page summary logs using a 3-point centered moving average.

Lateral Resistivity

The lateral resistivity log measures apparent resistivity of the bedrock using a different electrode configuration than the 16-N and 64-N logs, to measure apparent resistivity at a greater depth into the bedrock. However, these logs are of limited use in resistive or thin-bedded rocks due to the effect of adjacent beds.

The lateral resistivity data were smoothed for presentation on the field printed strip logs and 2-page summary logs using a 5-point centered moving average.

Single-Point Resistivity

Single-point resistivity logs measure the resistance between an electrode on ground surface and an electrode within the well. These logs respond primarily to porosity and pore fluid salinity with changes in porosity providing a source of changing values on these logs. The volume of investigation is approximately 5 to 10 times the electrode diameter, which is approximately 2 inches.

Single-point resistivity data were not smoothed for presentation.

Fluid Temperature and Delta Temperature

The fluid temperature log records the temperature of the fluid in which it is travelling (air, water, or DNAPL). The borehole fluid temperature measured is a function of ambient groundwater flow within the bedrock, geothermal gradient, and thermal conductance from the air and steel surface casing. The delta temperature log is simply the temperature value at the depth point minus the previous temperature value. Since the temperature sensors are located near the bottom of the logging tool, and the data is recorded while lowering the tool to the bottom of the borehole, relatively undisturbed borehole fluid temperatures are recorded.

Data were recorded at 0.1-foot intervals. Temperature data were smoothed for presentation on the field printed strip logs and 2-page summary logs using a 3-point centered moving average. The delta-temperature data were smoothed for presentation on the field printed strip logs and 2-page summary logs using a 5-point centered moving average.

P-Wave Sonic

The P-wave sonic logging tool measures the travel time of a compressional acoustic wave to travel from a single transmitter to two receivers separated by 1 foot. The acoustic wave travels through the borehole fluid to the bedrock and through the bedrock at a velocity related to the matrix properties (density, grain size, cementation) and back through the borehole fluid to the receiver. This log provides an indication of the potentially more porous zones within the bedrock. The field P-wave sonic log presents the travel time along with a calculated porosity based on an assumed matrix velocity value and travel time. Without reliable measurements of the matrix velocity, usually performed in the laboratory on rock cores, the porosity values indicated on the field P-wave sonic logs are estimates at best. The sonic data and acoustic velocity data from the core samples were forwarded to Occidental Oil and Gas Company, for review and

calibration of porosity based on acoustic travel times. This is further discussed in Section 3.4.5 of the SCR.

The data were recorded at 0.1 foot intervals and were not smoothed for presentation.

The P-wave sonic log often records longer than expected travel time due to the amplitude of the signal being too low to trigger recording. This is known as a "cycle skip". This is commonly caused by fractures, solution openings, and gas in the borehole fluid causing a loss of signal transmission along the borehole wall.

Acoustic Televiewer

The acoustic televiewer log provides a high resolution magnetically oriented acoustic image of the borehole wall. The acoustic travel time and amplitude of the returned signal are recorded at a rate of 256 samples per revolution, 12 revolutions per second. The recorded data is presented in gray scale (or colored) such that the middle travel time/amplitude is approximately mid-range on the gray scale. Thus longer travel times or reduced signal amplitude are darker in color. The resultant output is analogous to an unwrapped picture of the borehole wall. The Century acoustic televiewer logging tool is limited to boreholes of 9 inches in diameter or less.

Horizontal fractures appear as thick dark lines, due to the greater borehole diameter within the fracture. Dipping fractures appear as a sinusoid where the lowest part of the sinusoid is the direction of maximum dip of the fracture. Near-vertical fractures may not be readily apparent. The orientation of each dipping fracture can be mathematically determined based on the amplitude of the sinusoid and the borehole diameter. However, shallow dipping fractures, less than approximately 5 degrees, do not visibly form a sinusoid and thus were not differentiated from the horizontal fractures. Since the data are continuously recorded, no smoothing functions are applicable.

Formation Micro Imager

Schlumberger Limited provided Formation Micro Imager™ borehole logging services (FMI). This tool was used in the 12-inch diameter purge wells, in which the acoustic televiewer would not function.

The FMI logging tool is approximately 41 feet long and thus requires a long saturated interval. The FMI tool produces a magnetically oriented strip log of contact microresistivity using 96 electrodes (24 electrodes on two adjacent pads on each of four arms). The FMI tool was used to log purge wells in which the borehole diameter

exceeded the limits of the acoustic televiewer. The FMI tool was used to log three purge wells, PW-1L, PW-2M, and PW-8M. The saturated interval in the remaining purge wells was insufficient for the FMI tool to be used.

3.0 SELECTION OF WELLS TO BE LOGGED

The selection of wells to be geophysically logged was based on several factors:

- open hole in bedrock through Upper, Middle and / or Lower bedrock;
- diameter greater than 2.5 inches;
- saturated interval generally greater than 5 feet; and
- relatively small amounts of NAPL.

A total of 142 wells were logged including the following:

- 103 existing bedrock monitoring wells;
- 6 newly installed bedrock monitoring wells;
- 17 purge wells (large diameter);
- 8 off-Site wells; and
- 8 Middle bedrock zone wells relogged after shutdown of nearby purge wells.

Most of the bedrock wells completed as open holes were logged. Due to access issues, several of the bedrock wells located within residential areas were not logged. Table A.1 presents a summary of the wells geophysically logged. Eight Middle bedrock wells were logged twice with the SP Multi-Parameter E-log and Acoustic Televiewer tools: once under pumping conditions, and once after shutdown of nearby purge wells. Under pumping conditions, the water level in these eight wells is located well below the top of the open bedrock interval. Several of the multi-parameter tools, and the acoustic televiewer must be submerged to function. Therefore, to log the entire open interval, nearby purge wells were shut down and water levels were allowed to recover. Eight Middle bedrock wells were relogged after water level recovery. The relogged data are considered reliable for the acoustic televiewer. It is uncertain whether sufficient time had elapsed between the water level recovery and relogging for the temperature and fluid resistivity to reestablish an equilibrium. However, gross temperature and fluid resistivity changes indicate an inflow of water of different character.

In wells known to contain NAPL, the P-wave sonic and acoustic televiewer logs were not run due to concern for the potential damage to sensitive components by the decontamination process.

4.0 BOREHOLE GEOPHYSICAL LOGGING PROCEDURES

4.1 LOGGING AND DECONTAMINATION PROCEDURES

Borehole logging was performed by a Century geophysical technician and supported by CRA personnel as required. The logging typically was conducted by first running the SP Multi-Parameter E-log tool to record ambient borehole fluid properties. This log was followed by the 3-arm caliper, P-wave sonic, and acoustic televiewer logs. In several boreholes, the borehole fluid level was too low to run the P-wave sonic tool. Formation Micro Imager logging was performed by a Schumberger technician aided by CRA as required on three purge wells (PW-1L, PW-2M, and PW-8M).

Decontamination consisted of field washing of the logging tools and cable using Alconox and potable water with a potable water rinse. In wells with DNAPL, the decontamination procedures involved wrapping the logging tool in polyethylene sheeting, taking the tools to the on-Site treatment plant, and decontaminating the tools with the solvent ortho-chlorotoluene, followed by Alconox and potable water wash, and potable water rinse. All decontamination fluids were disposed of at the on-Site treatment plant.

4.2 QUALITY ASSURANCE/QUALITY CONTROL

Quality Assurance (QA) procedures were performed by the subcontractor. The geophysical logging tools were maintained and calibrated according to recognized standards including the American Petroleum Institute (API) and others.

Quality control (QC) is provided by logging the same well twice. Because the downhole tools disturb the water column, temperature and fluid resistivity measurements require a long quiescent period between the first and second logging. Rock property measurements by the gamma and caliper tools can be used for QC with no waiting time between logging events.

The QC review was performed using data from the eight Middle bedrock monitoring wells relogged after shutdown of nearby purge wells (Table A.1) and associated water level recoveries. The gamma log provides the best QC comparison due to the sensitivity of the tool and the vertical variability of the data sets. The temperature and fluid resistivity logs are affected by the recovery of water levels in the wells.

Figure A.1 presents the gamma logs for each of the eight Middle bedrock monitoring wells that were relogged. Each graph shows the original log in black, and the relog in red. The overall trend of the data is similar between logging events. The locations of select gamma peaks were compared to assess the precision of the vertical depth measurement. The peaks ranged from a perfect match, to vertical offsets as large as 1.2 feet (at D1M). It is interesting that some wells provided a nearly perfect match at every peak, e.g., D2M with no offset, while others like D1M exhibit a similar gamma signals but the offset between peaks that is variable, ranging from 0.1 to 1.2 feet. A constant offset would likely be related to a difference between the zero depth reference captured in the different logging events. The variable offset is likely related to instrument reading precision and the naturally varying gamma emission rates. Minor differences in the recorded gamma signal are expected due to the random nature of radioactive decay at the molecular level causing slightly different values to be recorded between the initial and the relogging of individual wells. However, the overall trend of the data is similar between logging events.

Based on D1M, the log with the greatest difference between the original and the relog signals, the error associated with alignment of gamma peaks is estimated to be:

- due to zero referencing: about ± 0.6 feet (assuming the midpoint of the range of offsets; and
- due to instrument precision: about ± 0.6 feet (range of offset around the midpoint).

Comparisons of the acoustic televiewer log for the relogged monitoring wells provide further QC. The acoustic televiewer data for the eight Middle bedrock monitoring wells are similar to the relogged geophysical logs. The quality of the image between the two logging events is somewhat variable due to varying image acquisition and tool centering properties, however, the vertical location of identified fractures is similar.

5.0 INTERPRETATION AND PRESENTATION OF BOREHOLE GEOPHYSICAL LOGGING RESULTS

5.1 COMPILATION AND PRESENTATION OF DATA

As discussed in Section 2.0, all data were provided to CRA in the form of a field-printed strip log. The data were also provided electronically. To facilitate comparison of data between tools and boreholes, 2-page geophysical summary logs were prepared for each well or well cluster logged.

2-Page Summary Logs

The 2-page summary logs, provided in Attachment 1 of this Appendix, provide every geophysical borehole measurement collected in 2001, except for the Formation Micro Imager (FMI), on two 8-1/2 x 11 pages. The logs have been adjusted such that every log is referenced to a common elevation scale (as opposed to the field logs that provide depth only). Using the same elevation scale eases the comparison of logs, allowing preparation of clear overlays, and allow identification of specific features by elevation. The current open hole portions of the monitoring wells and the logged formation contacts are also presented. For monitoring wells geophysically logged without available drill core to ascertain unit contacts, no stratigraphy is presented. The 2-page summary logs also include the Quantum electromagnetic flowmeter data.

The geophysical data were smoothed in a similar manner to that used by Century with one exception. The gamma data were smoothed using an 11-point centered moving average (1.1 feet) rather than a 21-point centered moving average (2.1 feet) in order to sharpen the signal. The accuracy of the elevation of geophysical log features is discussed in Section 4, above, and Appendix G. These sections should be reviewed before correlating data between wells.

The data were trimmed as appropriate. For example, the temperature logs were only of interest below the water surface. The recorded temperature data for the air column above the water surface is correct, however, including it in the graphs caused the graph scaling to be so large as to render the data recorded below the water surface appear as a straight line. All temperature, fluid resistivity, acoustic televiewer, resistivity, and sonic wave data were trimmed off at the water surface, or where the water surface was in the steel surface casing, trimmed off at the top of the open borehole.

The gamma logs were presented for the open intervals of the wells, where the best signal occurred (as opposed to the signal recorded through the well casing). Where there were

large gaps, e.g., only a Lower bedrock well was logged, the gamma signal through the well casing was included on the 2-page summary logs. The gamma signal through the casing is shown in a slightly lighter color on the 2-page summary logs.

5.2 INTERPRETATION OF DATA

The borehole geophysical logging tools measured rock and/or fluid properties. The geophysical logs were grouped into those logs that aided in the identification of fractures and those logs that measured bulk rock properties.

5.2.1 FRACTURE IDENTIFICATION LOGS

The field-printed strip logs and 2-page summary logs were utilized to identify fractures. The following logs were used primarily to identify fractures:

- caliper;
- acoustic televiewer;
- P-wave sonic;
- Formation Micro Imager;
- fluid temperature and delta temperature; and
- fluid resistivity.

A fracture was identified on these logs based on the following:

Caliper

Three features were identified in the caliper log:

- fracture: an increase in borehole diameter over a short interval, typically less than 0.5 feet, generally indicates a fracture;
- washout: an increase in diameter over a longer interval, commonly found immediately below the bottom of the surface casing; and
- collapse feature: a reduction in the well bore diameter caused by collapse of the bedrock into the borehole.

Figure A.2 provides an example of a portion of a caliper log with interpretation.

Acoustic Televiewer

A thick black line, either horizontal or sinusoidal (dipping fracture) generally indicates the presence of a fracture. The drilling process may also produce washed out shale partings and shale beds resulting in detectable apertures in the borehole wall. The fracture aperture cannot accurately be determined from the log as the aperture may be artificially enlarged by the drilling process. Where thin black horizontal lines did not extend across the entire televiewer image, the feature was considered to be a probable shale parting rather than a fracture. Voids and vugs were indicated by dark oval to circular features. Partings, voids, and vugs were not utilized in the interpretation of fractures.

Figure A.3 provides an example of a portion of an acoustic televiewer log with interpretation. This figure shows a slightly dipping fracture, as evidenced by the sinusoidal pattern of the dark line. The sinusoidal signature generally cannot be detected on the 2-page summary logs due to the compressed vertical scale.

P-Wave Sonic

The P-wave sonic cycle skips (longer than expected travel time) generally coincided with fractures noted on the caliper and/or acoustic televiewer logs. The P-wave sonic log also provides an indication of bedrock porosity. Increases in travel time may indicate increases in bedrock porosity. Combined with laboratory measured rock properties, the P-wave sonic signal can provide reliable estimates of bulk bedrock porosity.

Formation Micro Imager

The FMI log shows fractures as dark horizontal or sinusoidal (dipping fractures) lines. Again, the fracture aperture may be artificially enlarged due to the drilling process. Partings, vugs, and voids are also visible on the FMI log.

Figure A.4 provides an example of a portion of an FMI log with interpretation.

Fluid Temperature and Delta Temperature

A change in fluid temperature over a short vertical interval is usually accompanied by a short, sharp delta temperature spike. These indicate a disturbance to the water column, generally caused by water flowing in from an adjacent fracture. Cascading water from a fracture above the water column can also provide short, sharp temperature changes over

a short vertical interval close to the top of the water column. These are characteristic of water-bearing fractures with minor amounts of flow.

Where groundwater enters a fracture and flows vertically within the borehole and exits via another fracture in the borehole, the borehole fluid temperature generally shifts in the zone of flow. This is characteristic of water-bearing fractures with significant flow. Figure A.5 provides an example of a fluid temperature and delta temperature log with interpretation.

Fluid Resistivity

Changes in fluid resistivity typically indicate water entering or leaving the bedrock or stagnation of the water column. Low fluid resistivity indicates a high level of total dissolved solids, and a higher water density. Density stratification may occur within a well with essentially no flow. This occurs in many of the Lower bedrock wells and is generally related to a lack of flow. The changes in fluid resistivity caused by water entering or leaving a borehole may not be detected exactly adjacent to a fracture due to vertical flow and fluid mixing. The change in fluid resistivity may also appear as a gradual change in fluid resistivity as mixing occurs.

Figure A.6 provides an example of a fluid resistivity log with interpretation.

5.2.2 FRACTURES

The near-horizontal fractures identified from the borehole geophysics are tabulated in Table A.2. The dipping fractures were identified from an inspection of the field printed acoustic televiewer logs. The strike and dip of the dipping fractures were mathematically determined from the best-fit of a sinusoid to the fracture. The orientations of the dipping fractures are presented in Table A.3. A printout of each individual dipping fracture and fitted sinusoid is presented in Attachment 2.

5.2.3 BEDROCK PHYSICAL PROPERTIES LOGS

The following borehole geophysical logs measured ambient properties of the bedrock:

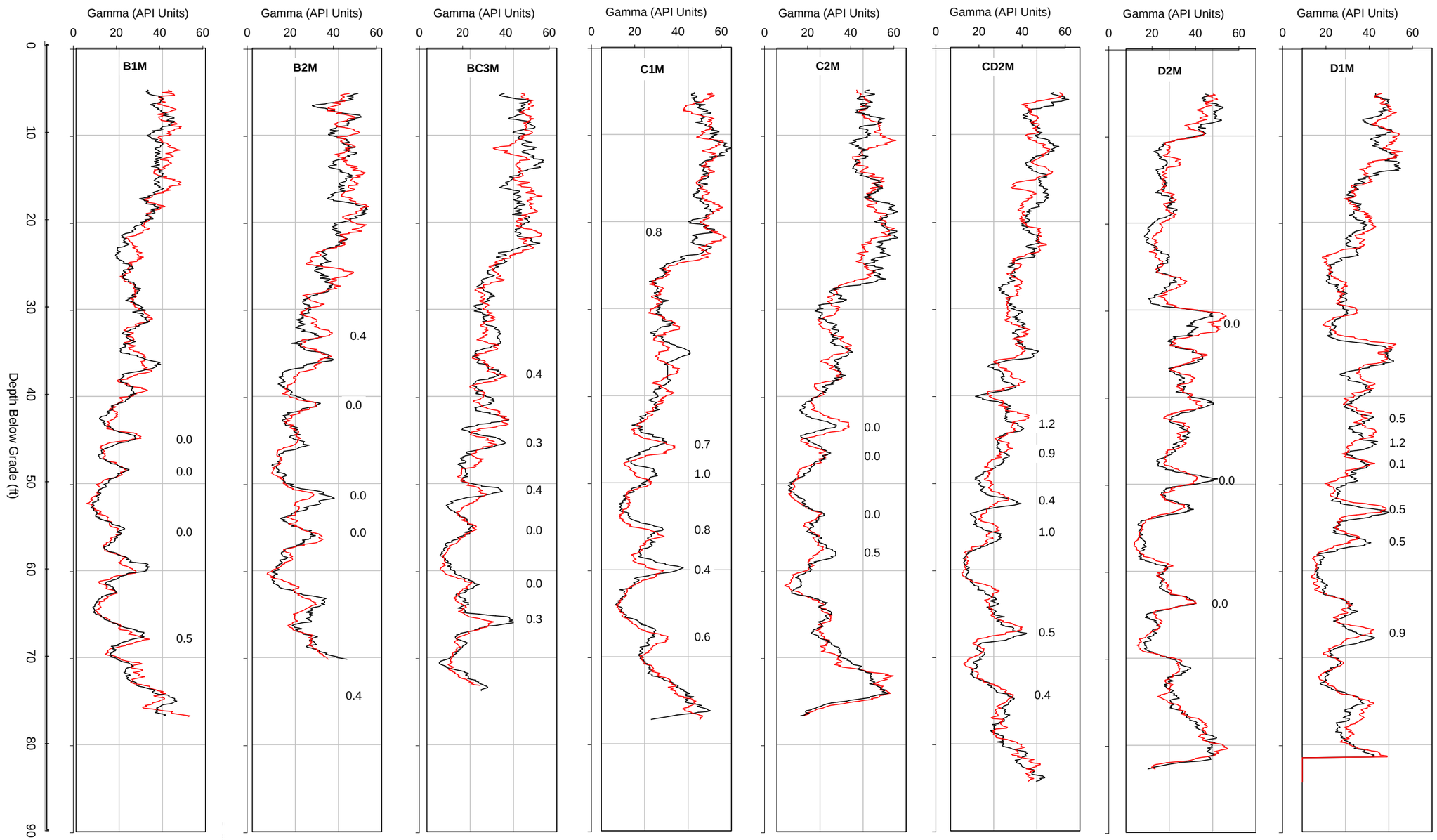
- 16-N resistivity;
- 64-N resistivity;

- lateral resistivity;
- single point resistivity;
- spontaneous potential;
- P-wave sonic; and
- natural gamma.

The four resistivity logs and the spontaneous potential log were not utilized for the overall characterization of the bedrock, although decreasing apparent resistivity with depth was generally noted, an indication of probable higher total dissolved solids content in the pore spaces and fluid filled fractures in the bedrock.

The P-wave sonic cycle skips (longer than expected travel time) generally coincided with fractures noted on the caliper and/or acoustic televiewer logs. The P-wave sonic data, combined with laboratory measured rock properties were used to determine bulk bedrock porosity, as discussed in Section 3.4.5 of the SCR.

The natural gamma log was utilized as an aid to determine stratigraphic marker horizons. The natural gamma log also changed or showed a distinctive character for several of the bedrock formations. These changes were used to highlight stratigraphic logs where the probable formation contacts had originally been misidentified. The use of the natural gamma log is further discussed in the main text of the SCR.



Notes:
Numbers at gamma peaks indicate the offset between the peaks in feet, based on shifting signals to achieve a visual match.
Black line represents the first log collected, red line represents the relog of the same well.
Data smoothed using an 11-point centered moving average.

figure A.1
COMPARISON OF GAMMA LOGS FOR RELOGGED WELLS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL
Town of Niagara, New York

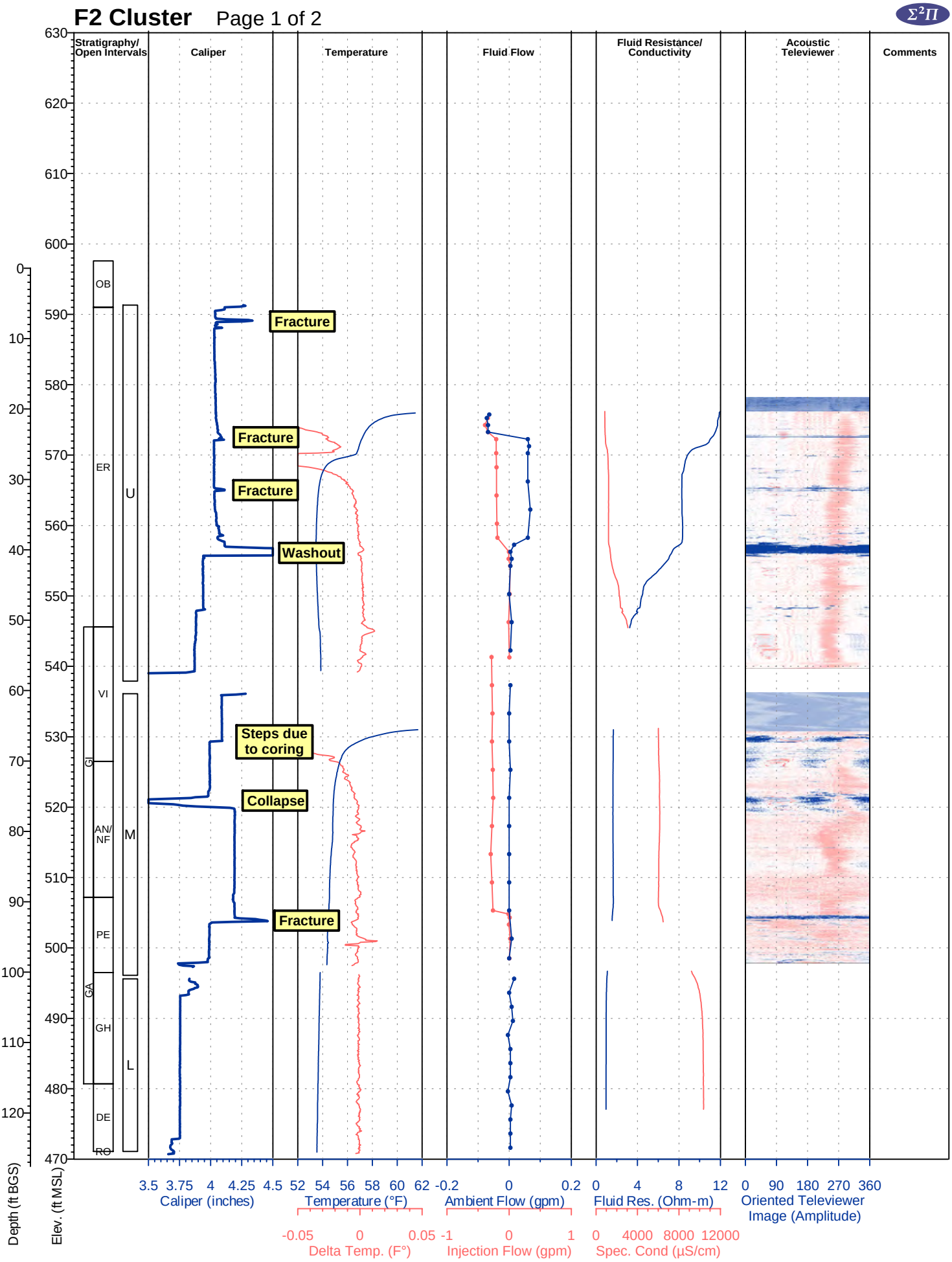


Figure A.2 - Example Caliper Log with Interpretation

figA2_caliper.grf

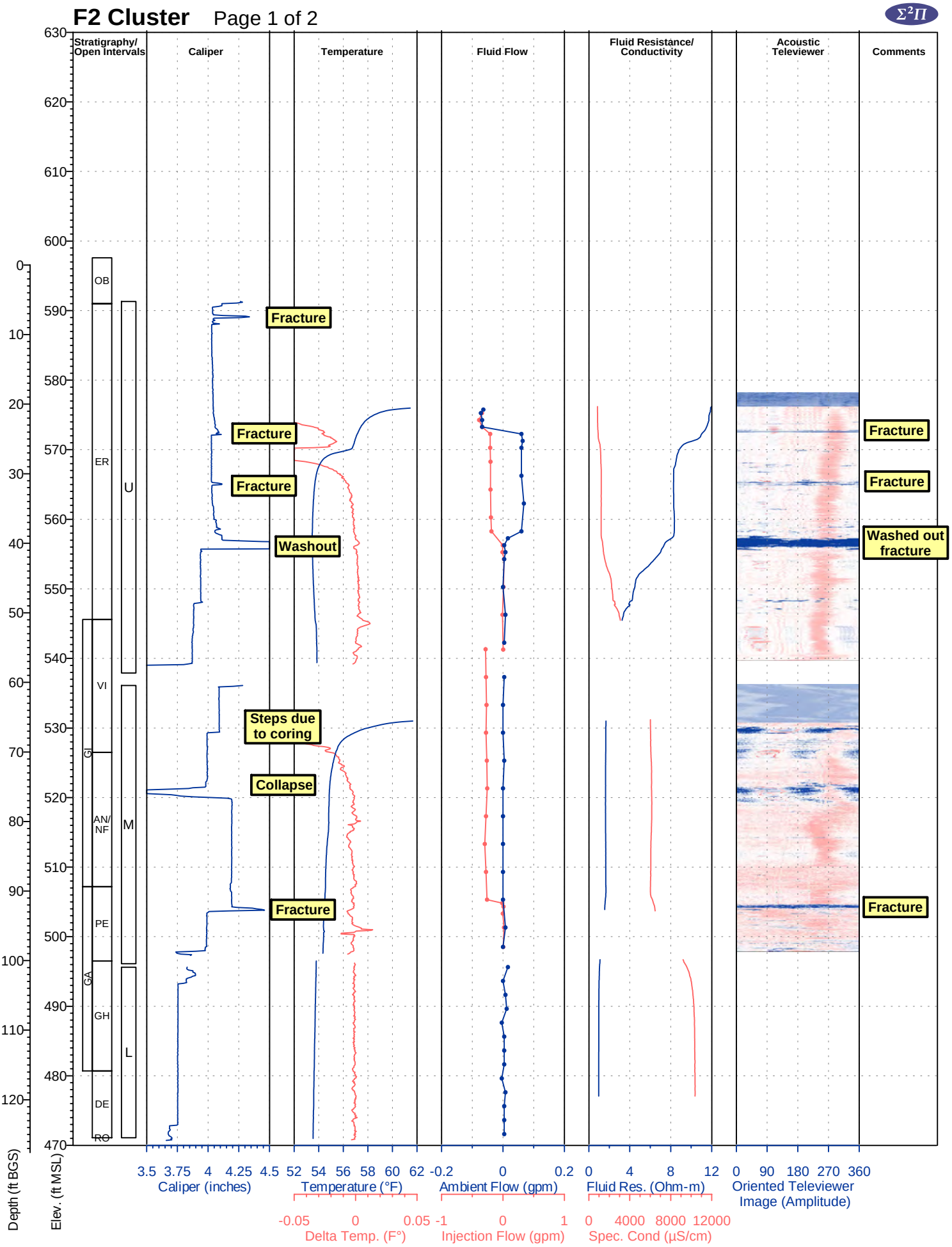


Figure A.3 - Example Acoustic Televiewer Log with Interpretation

figA3_actv.grf

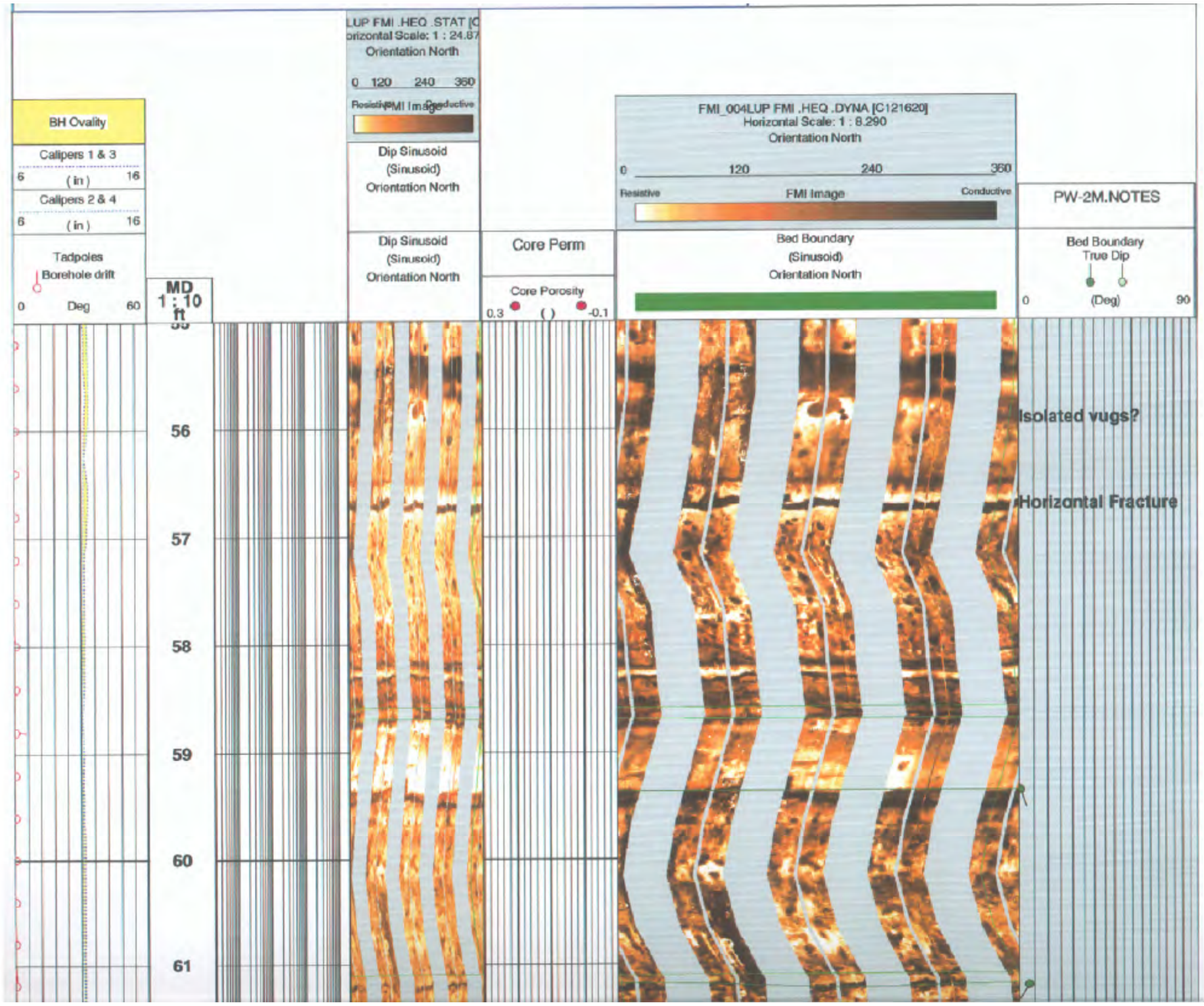


figure A.4

FMI LOG WITH INTERPRETATION
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
Town of Niagara, New York

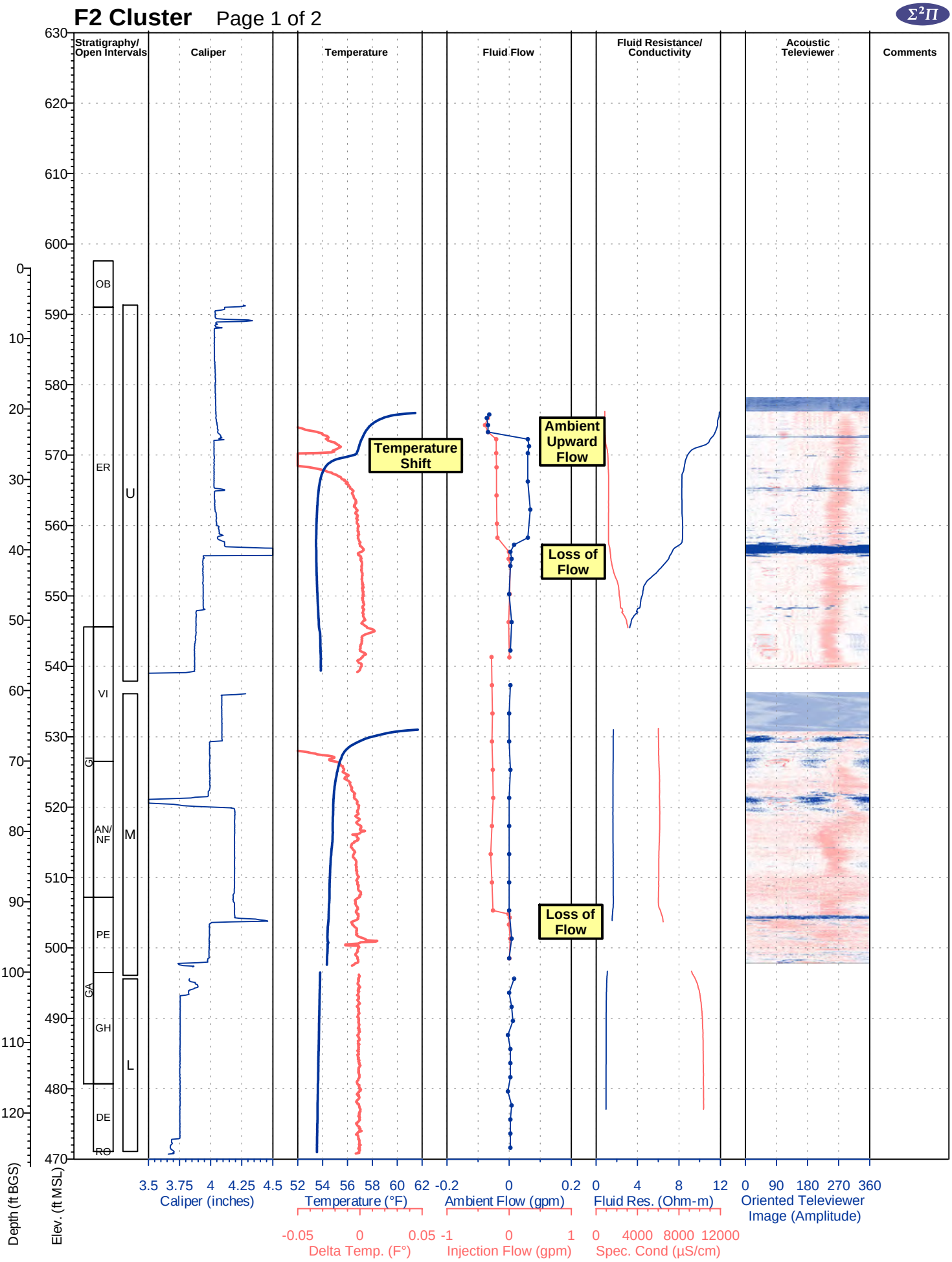


Figure A.5 - Example Temperature Log with Interpretation

figA5_temp.grf

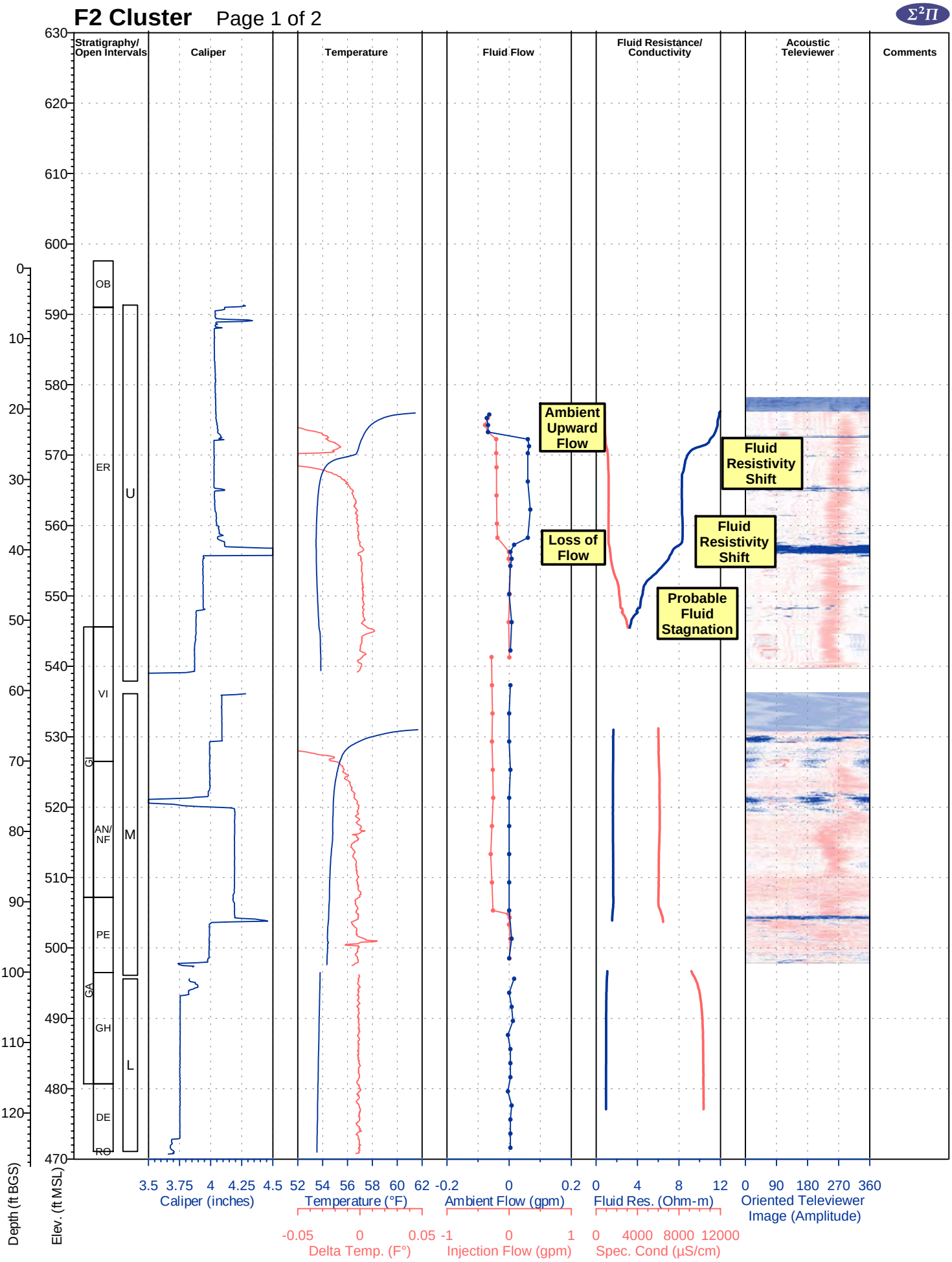


Figure A.6 - Example Fluid Resistivity Log with Interpretation

figA6_f_res.grf

TABLE A.1

SUMMARY OF GEOPHYSICALLY LOGGED BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Date	Caliper	E-log	Sonic	Acoustic Televiewer	FMI	Comments
A1U	21-Aug-01	Y	Y	N	Y	N	
A2U	16-Aug-01	Y	Y	Y	Y	N	
ABP-3	11-Jul-01	Y	Y	Y	Y	N	
ABP-4	11-Jul-01	Y	Y	Y	Y	N	
ABP-5	08-Aug-01	Y	Y	Y	Y	N	
ABP-7	07-Aug-01	Y	Y	Y	Y	N	
ABP-8	07-Aug-01	Y	Y	N	Y	N	Thin saturated interval
AFW-1U	11-Aug-01	Y	Y	N	Y	N	Thin saturated interval
AFW-1M	11-Aug-01	Y	Y	N	Y	N	Thin saturated interval
AFW-1L	11-Aug-01	Y	Y	Y	Y	N	
AFW-2U	13-Aug-01	Y	Y	Y	Y	N	
AFW-2M	14-Aug-01	Y	Y	Y	Y	N	
AFW-2L	13-Aug-01	Y	Y	Y	Y	N	
AFW-3U	13-Aug-01	Y	Y	Y	Y	N	
AFW-3M	13-Aug-01	Y	Y	Y	Y	N	
AFW-3L	13-Aug-01	Y	Y	N	Y	N	Thin saturated interval
AGW-1U	11-Jul-01	Y	Y	Y	N	N	
AGW-1M	11-Jul-01	Y	Y	N	N	N	Narrow diameter (35'-45')
AGW-1L	11-Jul-01	Y	Y	Y	N	N	
AGW-2U	19-Jul-01	Y	Y	N	Y	N	
AGW-2M	20-Jul-01	Y	Y	N	N	N	Narrow diameter
AGW-2L	20-Jul-01	Y	Y	Y	Y	N	
AGW-3U	20-Aug-01	Y	Y	N	Y	N	
AGW-3M	03-Aug-01	Y	Y	Y	Y	N	
APW-1	23-Aug-01	Y	Y	Y	Y	N	
APW-2	23-Aug-01	Y	Y	Y	Y	N	
B1U	17-Jul-01	Y	Y	Y	Y	N	
B1M	17-Jul-01	Y	Y	Y	Y	N	
B1M relog (1)	20-Aug-01	N	Y	N	Y	N	
B1L	17-Jul-01	Y	Y	Y	Y	N	
B2U	16-Jul-01	Y	Y	Y	Y	N	
B2M	14-Jul-01	Y	Y	Y	Y	N	
B2M relog (1)	20-Aug-01	N	Y	N	Y	N	
B2L	16-Jul-01	Y	Y	Y	Y	N	
BC3U	18-Jul-01	Y	Y	Y	Y	N	
BC3M	18-Jul-01	Y	Y	N	Y	N	
BC3M relog (1)	20-Aug-01	N	Y	N	Y	N	
BC3L	18-Jul-01	Y	Y	Y	Y	N	
BR-1	12-Jul-01	Y	Y	Y	Y	N	

TABLE A.1

SUMMARY OF GEOPHYSICALLY LOGGED BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Date	Caliper	E-log	Sonic	Acoustic Televiewer	FMI	Comments
BR-2	12-Jul-01	Y	Y	Y	Y	N	
BR-3	12-Jul-01	Y	Y	Y	Y	N	
BR-4	12-Jul-01	Y	Y	Y	N	N	
C1U	16-Jul-01	Y	Y	Y	Y	N	
C1M	16-Jul-01	Y	Y	N	Y	N	Thin saturated interval
C1M relog (1)	20-Aug-01	N	Y	N	Y	N	
C1L	17-Jul-01	Y	Y	Y	Y	N	
C2M	16-Jul-01	Y	Y	Y	Y	N	
C2M relog (1)	20-Aug-01	N	Y	N	Y	N	
C2L	16-Jul-01	Y	Y	Y	Y	N	
CD1U	21-Aug-01	Y	Y	N	N	N	
CD1M	06-Aug-01	Y	Y	Y	Y	N	
CD1L	18-Jul-01	Y	Y	Y	Y	N	
CD2M	17-Jul-01	Y	Y	Y	Y	N	
CD2M relog (1)	20-Aug-01	N	Y	N	Y	N	
CD3U	17-Jul-01	Y	Y	Y	Y	N	
CD4U	17-Aug-01	N	Y	N	N	N	
CMW-1 SH	15-Aug-01	Y	Dry	Dry	Dry	N	
CMW-4SH	06-Aug-01	Y	Y	N	N	N	Thin saturated interval
CMW-5SH	06-Aug-01	Y	Y	N	N	N	
D1U	14-Aug-01	Y	Y	Y	Y	N	
D1M	19-Jul-01	Y	Y	Y	Y	N	
D1M relog (1)	20-Aug-01	N	Y	N	Y	N	
D1L	14-Aug-01	Y	Y	Y	Y	N	
D2U	20-Jul-01	Y	Y	Y	Y	N	
D2M	20-Jul-01	Y	Y	Y	Y	N	
D2M relog (1)	20-Aug-01	N	Y	N	Y	N	
D2L	15-Jul-01	Y	Y	Y	Y	N	
D3U (PW-2U)	15-Aug-01	Y	Y	N	N	N	Large diameter
D4U (PMW-2U)	06-Aug-01	Y	Y	Y	Y	N	
D4L	06-Aug-01	Y	Y	Y	Y	N	
D5L	23-Aug-01	Y	Y	Y	Y	N	
E1U	28-Jul-01	Y	Y	Y	Y	N	
E1M	28-Jul-01	Y	Y	Y	Y	N	
E1L	28-Jul-01	Y	Y	Y	Y	N	
E2U	30-Jul-01	Y	Y	Y	Y	N	
E2M	30-Jul-01	Y	Y	N	Y	N	
E2L	30-Jul-01	Y	Y	N	Y	N	

TABLE A.1

SUMMARY OF GEOPHYSICALLY LOGGED BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Date	Caliper	E-log	Sonic	Acoustic Televiewer	FMI	Comments
E3M	28-Jul-01	Y	Y	N	Y	N	
E3L	28-Jul-01	Y	Y	N	Y	N	
E4L	17-Aug-01	Y	Y	Y	Y	N	
F1U	31-Jul-01	Y	Y	N	N	N	
F1M	01-Aug-01	Y	Y	Y	Y	N	
F1L	31-Jul-01	Y	N	N	N	N	Narrow diameter well
F2U	01-Aug-01	Y	Y	N	Y	N	
F2M	01-Aug-01	Y	Y	N	Y	N	
F2L	31-Jul-01	Y	Y	N	N	N	
F3L	14-Aug-01	Y	Y	Y	Y	N	
F4U	27-Jul-01	Y	Y	Y	Y	N	
F4M	26-Jul-01	Y	Y	Y	Y	N	
F4L	09-Aug-01	Y	Y	Y	Y	N	
G2U	01-Aug-01	Y	Y	Y	Y	N	
G2M	31-Jul-01	Y	Y	Y	N	N	
G2M	14-Aug-01	N	N	N	Y		
G3U	31-Jul-01	Y	Y	N	N	N	
G3M	02-Aug-01	Y	Y	N	N	N	
G3L (BH4-95)	02-Aug-01	Y	Y	N	Y	N	
G5U (T-2)	17-Aug-01	Y	Y	Y	Y	N	
G5L	17-Aug-01	Y	Y	Y	Y	N	
H1U	08-Aug-01	Y	Y	Y	Y	N	
H1M	07-Aug-01	Y	Y	Y	Y	N	
H1L	08-Aug-01	Y	Y	Y	Y	N	
H2U	07-Aug-01	Y	Y	Y	Y	N	
H2M	08-Aug-01	Y	Y	N	Y	N	
H2L	08-Aug-01	Y	Y	Y	Y	N	
H3U	21-Aug-01	Y	Y	N	N	N	
H3L	09-Aug-01	Y	Y	Y	Y	N	
J1U	27-Jul-01	Y	Y	Y	Y	N	
J1M	26-Jul-01	Y	Y	Y	Y	N	
J1L	27-Jul-01	Y	Y	N	N	N	
J3U (BH1-95)	21-Aug-01	Y	Y	N	Y	N	
J3L	27-Jul-01	Y	Y	Y	Y	N	
J4L	-- (2)	--	--	--	--	--	Not logged
JH1L	26-Jul-01	Y	Y	Y	Y	N	
MW1-2001	19-Jul-01	Y	Y	N	Y	N	
MW2-2001	09-Aug-01	Y	Y	Y	Y	N	
MW3-2001	10-Aug-01	Y	Y	Y	Y	N	

TABLE A.1

SUMMARY OF GEOPHYSICALLY LOGGED BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Number	Date	Caliper	E-log	Sonic	Acoustic Televiewer	FMI	Comments
MW4-2001	09-Aug-01	Y	Y	Y	Y	N	
MW5-2001	09-Aug-01	Y	Y	Y	Y	N	
MW6-2001	10-Aug-01	Y	Y	N	Y	N	
PMW-1U	16-Aug-01	Y	Y	N	N	N	
PMW-1M	15-Aug-01	Y	Y	Y	Y	N	
PMW-1L	16-Aug-01	Y	Y	N	N	N	
PW-1U	16-Aug-01	Y	Y	N	N	N	
PW-1L	15-Aug-01	Y	Y	N	N	Y	
PW-2M	15-Aug-01	Y	Y	N	N	Y	
PW-3M	03-Aug-01	Y	Y	N	N	N	
PW-3L	03-Aug-01	Y	Y	N	N	N	
PW-4U	18-Jul-01	Y	Y	N	N	N	
PW-4M	19-Jul-01	Y	Y	N	N	N	
PW-5UR	21-Aug-01	Y	Y	N	N	N	
PW-6UR (T-1)	10-Aug-01	Y	Y	N	N	N	
PW-6MR (T-3)	10-Aug-01	Y	Y	N	N	N	
PW-7U (CD2U)	23-Aug-01	Y	Y	N	N	N	
PW-8U	10-Jul-01	Y	Y	Y	N	N	
PW-8M	14-Aug-01	Y	Y	N	N	Y	
PW-9U	26-Jul-01	Y	Y	N	N	N	
PW-10U	10-Jul-01	Y	Y	Y	Y	N	
OFF-SITE WELLS							
LR-61	22-Aug-01	Y	Y	Y	Y	N	
LR-62	23-Aug-01	Y	Y	N	Y	N	
R-50	22-Aug-01	Y	Y	N	Y	N	
R-62	22-Aug-01	N	Y	N	Y	N	
R-66	22-Aug-01	Y	Y	N	Y	N	
W-66	22-Aug-01	Y	Y	Y	Y	N	
W-67	22-Aug-01	Y	Y	N	Y	N	
W-70L	23-Aug-01	Y	Y	N	Y	N	

Notes:

The borehole geophysical logging tools measured properties are discussed within the text of the appendix.
1) Only the E-log and the Acoustic Televiewer were run in boreholes that were relogged.
2) J4L was not geophysically logged but electromagnetic borehole flowmeter logging was conducted.

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

A1U Elevation	A2U Elevation	ABP-3 Elevation	ABP-4 Elevation	ABP-5 Elevation	ABP-7 Elevation	ABP-8 Elevation	AFW-1U Elevation	AFW-1M Elevation	AFW-1L Elevation
571	567	562	560	561	534	533	562	520	502
567	566	560	555	560	533	521	555	517	496
564	565	558	554	559	527	520	551		
563	564	555	553	557	525	518	548		
562	563	550	552	552	524		547		
561	556	549	548	548	523		542		
554	551	541	539	544	521				
549			531	538					
543									

AFW-2U Elevation	AFW-2M Elevation	AFW-2L Elevation	AFW-3U Elevation	AFW-3M Elevation	AFW-3L Elevation	AGW-1U Elevation	AGW-1M Elevation	AGW-1L Elevation
575	No fractures noted in this log.	495	574	514	No fractures noted in this log.	567	537	490
572		490	572	507		560	530	
565		488	571			552	529	
563			567				524	
556			564				519	
550			562				513	
546			560					
544			558					
			557					
			554					
			550					
			547					

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

AGW-2U Elevation	AGW-2M Elevation	AGW-2L Elevation	AGW-3U Elevation	AGW-3M Elevation	APW-1 Elevation	APW-2 Elevation	B1U Elevation	B1M (1) Elevation	B1L Elevation
593	542	499	611	551	555	528	560	532	503
591	540	497	610	534	553	523	559	527	498
590	537		608	517	552	516	558	519	492
588	531		600	512	549	514	547	508	
585	524		595	511	546	513			
581	522		589		539	506			
575	519		570		536	503			
574	517				533	501			
572	515				527	499			
568					523				
566					518				
561					516				
558					514				
556					512				
554					498				
549					497				
					496				

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

B2U Elevation	B2M (1) Elevation	B2L Elevation	BC3U Elevation	BC3M (1) Elevation	BC3L Elevation	BR-1 Elevation	BR-2 Elevation	BR-3 Elevation	BR-4 Elevation
562	536	512	558	529	509	559	555	558	556
560	533	495	557	522	499	556	552	557	
558	532		556	519		552	543	556	
554	528		552	518				555	
553	527		550					554	
550	522		549					552	
549	521		547					551	
547	520		546					549	
	518								
	517								

C1U Elevation	C1M (1) Elevation	C1L Elevation	C2M (1) Elevation	C2L Elevation	CD1U Elevation	CD1M Elevation	CD1L Elevation	CD2M (1) Elevation	CD3U Elevation
562	531	507	530	501	569	525	498	533	562
560	524	494	527	496	564	519	490	520	561
557	521	493	525	495	563	515	489	518	560
552	520		524		562				556
549	519		523		561				548
548	514		522		560				546
543			521		558				
			518		544				
			516						
			515						
			513						

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

CD4U Elevation	CMW-1SH Elevation	CMW-4SH Elevation	CMW-5SH Elevation	D1U Elevation	D1M (1) Elevation	D1L Elevation	D2U Elevation	D2M (1) Elevation	D2L Elevation	D3U Elevation
574	560	563	No fractures	570	540	503	573	541	503	577
572	559	562	noted in	564	538		570	536	499	575
567		561	this log.	559	533		563	530	494	569
560		558		544	515		560	526	488	565
555				543	514		558	525		561
							557	519		559
							554	516		558
							552	515		556
							549	514		552
							548	511		
							546	507		
							544	506		
							543			

D4U Elevation	D4L Elevation	D5L Elevation	E1U Elevation	E1M Elevation	E1L Elevation	E2U Elevation	E2M Elevation	E2L Elevation
576	502	501	571	523	496	575	537	494
575		499	568	519		574	510	
572		493	562	513		570	507	
568		489	560	509		569		
558		484	558			568		
557			554			553		
553			549			551		
552								

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

E3M Elevation	E3L Elevation	E4L Elevation	F1U Elevation	F1M Elevation	F1L Elevation	F2U Elevation	F2M Elevation	F2L Elevation	F3L Elevation
530	494	497	598	522	No fractures noted in this log.	589	530	497	492
525	481	489	597	513		588	519	495	
510			585	508		573	518		
			572	504		572	514		
			570			565	513		
						559	504		
						557			
						548			
						545			

F4U Elevation	F4M Elevation	F4L Elevation	G2U Elevation	G2M Elevation	G3U Elevation	G3M Elevation	G3L Elevation	G5U Elevation	G5L Elevation
585	540	485	597	540	594	528	473	598	488
576	527	483	595	525	593	525		597	484
574	524	477	589	523	591	520		595	483
572	507		587	518	590	517		582	481
571	504		585	514	587	507		579	
558			582	501	584	506		550	
554			577	489	578	505			
552			563		567	503			
550			559		564				
548			556		561				
545			549		559				
					558				

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

H1U Elevation	H1M Elevation	H1L Elevation	H2U Elevation	H2M Elevation	H2L Elevation	H3U Elevation	H3L Elevation	J1U Elevation	J1M Elevation	J1L Elevation
604	555	490	611	562	489	601	494	591	553	No fractures
603	550	480	606	558	483	600	493	590	552	noted in
602	512	476	605	550		598	485	586	550	this log.
600	509		603	547		596	481	573	548	
597	505		602	530		592		569	545	
596			601	518		591			534	
593			599	503		587			530	
592			595	497		578			524	
583			593			552			523	
578			592						518	
568			591						514	
			589							
			588							
			585							
			582							
			580							
			579							
			576							
			575							
			574							
			570							

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

J3U Elevation	J3L Elevation	J4L (3) Elevation	JH1L Elevation	MW1-2001 Elevation	MW2-2001 Elevation	MW3-2001 Elevation	MW4-2001 Elevation	MW5-2001 Elevation	MW6-2001 Elevation
575	494	485	510	574	567	557	550	554	557
571	492			569	564	554	548	551	549
570	485			564	562	551	545	547	546
568				563		550	544	546	545
567				562		547	540	545	542
564				561					
559									

PMW-1U Elevation	PMW-1M Elevation	PMW-1L Elevation	PW-1U Elevation	PW-1L (2) Elevation	PW-2M (2) Elevation	PW-3M Elevation	PW-3L Elevation	PW-4U Elevation	PW-4M Elevation
563	527	500	562	521	542	555	490	583	518
561	524	483	560	518	541	553		570	515
560	521		558	517	533	548		552	512
554	519		557	494	529	542			511
549	517		556	492	525	537			
545			555		517	536			
544			554		514	535			
538			553		511	530			
			552		507	529			
			549			527			
			547			514			
			546			510			
						508			

TABLE A.2

SUMMARY OF NEAR-HORIZONTAL FRACTURES IDENTIFIED FROM BOREHOLE GEOPHYSICS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

PW-5UR Elevation	PW-6UR Elevation	PW-6MR Elevation	PW-7U Elevation	PW-8U Elevation	PW-8M (2) Elevation	PW-9U Elevation	PW-10U Elevation
594	591	533	549	551	540	553	578
576	583	527	546	548	526	546	577
571	580	522		547	518	540	572
551	579	517			515		571
	569	507			512		569
	560	504			510		563
							562

Off-Site Wells

LR-61 Elevation	LR-62 Elevation	R-50 Elevation	R-62 Elevation	R-66 Elevation	W-66 Elevation	W-67 Elevation	W-70L Elevation
517	513	493	498	443	569	585	547
513	511	489	490	440	562	583	542
512	510	486	487	439	559	582	533
511	507	484	480		557	581	523
509	505	479	473		555	580	522
507		474	470			569	
		471	465				
		467	463				
		466	462				
		458	461				
		451	460				
		450	449				
		448					

Notes:

(1) Includes fractures identified from relogging after shutdown of nearby purge wells.
(2) Includes fractures identified from FMI logs.
(3) Identified from electomagnetic borehole flowmeter only.

TABLE A.3

ORIENTATION OF DIPPING FRACTURES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

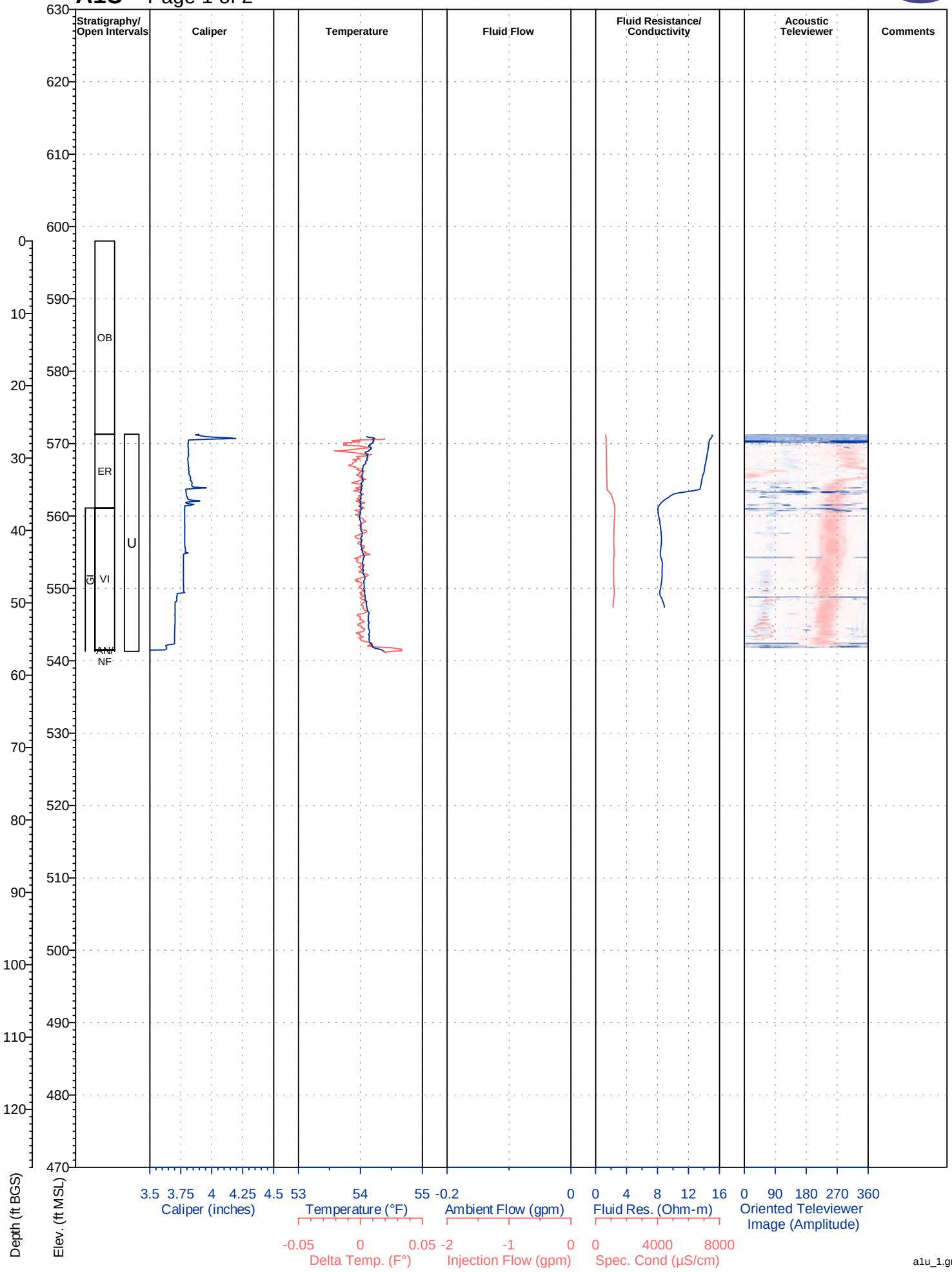
Well Number	Ground Surface Elevation (ft. AMSL)	Depth (ft. bgs)	Fracture Elevation (ft. AMSL)	Dip Direction (Degrees)	Dip (Degrees)
ABP-4	588.1	37	551	188	12
ABP-4	588.1	56	532	208	31
AFW-3L	589.3	103	487	241	28
AGW-2U	608.8	22	587	241	20
AGW-2U	608.8	26	583	241	26
AGW-3M	627.4	111	516	192	13
AGW-3U	627.1	23	604	305	15
AGW-3U	627.1	30	597	299	23
AGW-3U	627.1	64	563	14	15
APW-1	569.0	34	535	211	12
APW-1	569.0	56	513	155	11
APW-1	569.0	69	500	3	25
B1U	589.8	43	547	47	8
C1L	591.4	97	495	138	13
C2M	590.1	76	514	247	11
C2M	590.1	78	512	195	12
C2M	590.1	79	511	164	10
D2M	589.6	82	508	102	17
F1M	602.6	95	508	189	18
F1M	602.6	98	505	184	6
G2U	609.1	21	588	309	23
G2U	609.1	61	548	27	21
G3L (BH4-95)	617.7	144	475	2	14
H1U	619.8	25	595	32	17
J3U (BH1-95)	600.3	24	576	152	15
J3U (BH1-95)	600.3	24	576	150	24
J3U (BH1-95)	600.3	25	576	148	17
JH1L	624.4	139	485	154	13
Off-site Well					
LR-62	603.5	94	510	180	14

Notes:
ft. AMSL - Feet Above Mean Sea Level
ft. bgs - Feet Below Ground Surface

ATTACHMENT 1

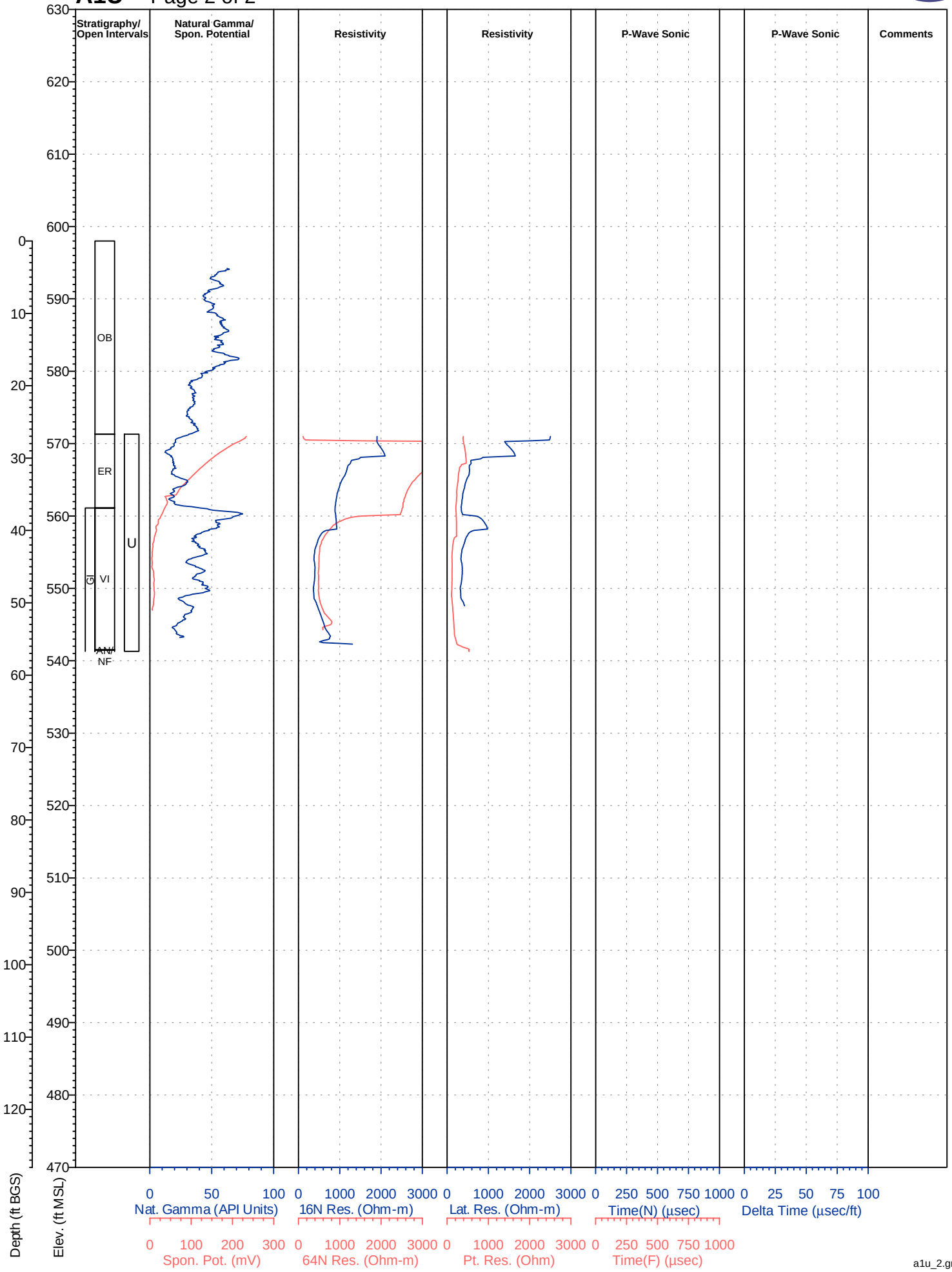
BOREHOLE SUMMARY SHEETS

A1U


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
ER
U
GI
VI
ANF
NF
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
53 54 55
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 4 8 12 16
Fluid Res. (Ohm-m)
0 4000 8000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

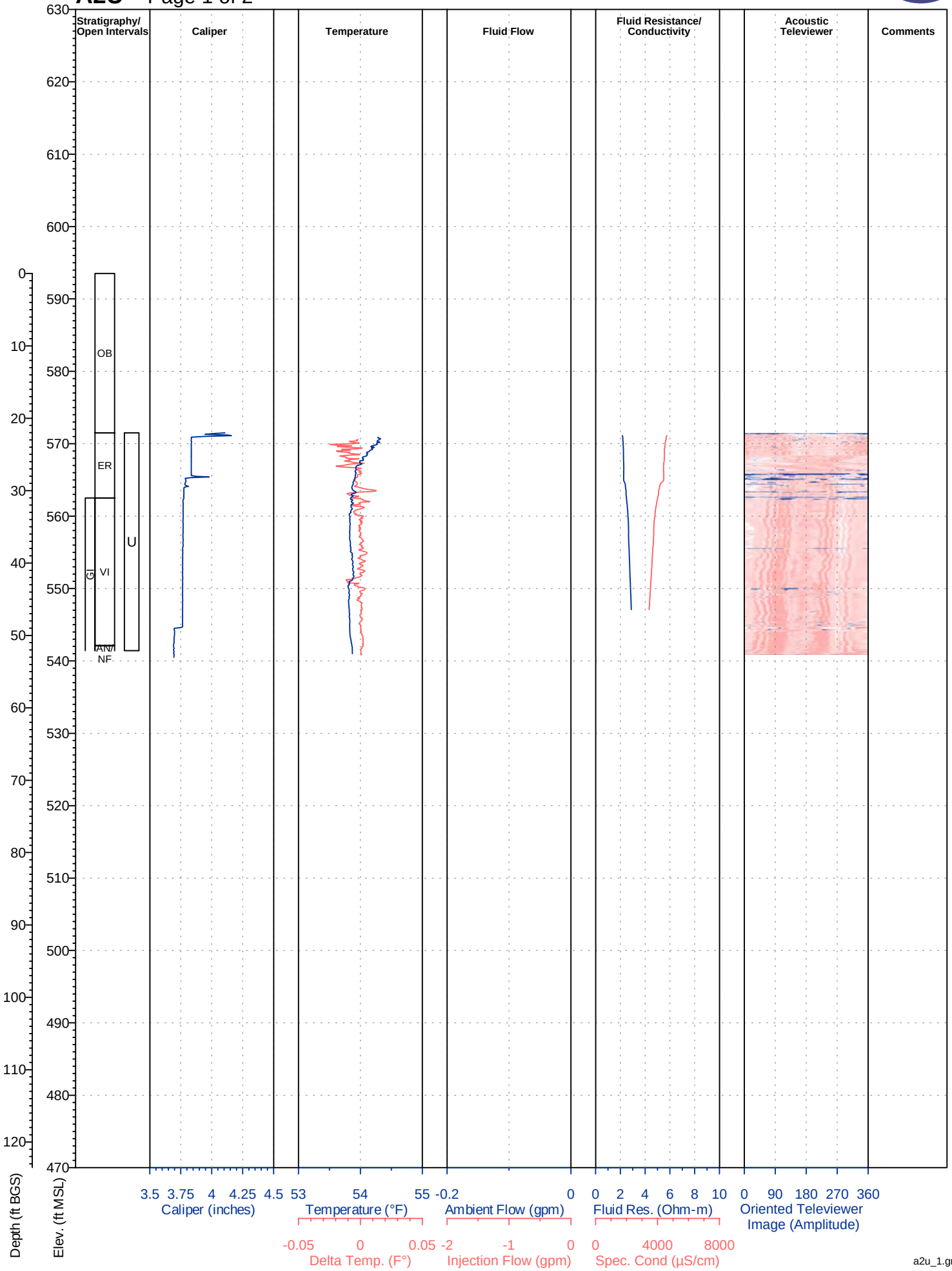
a1u_1.grf

A1U


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
U
GI
VI
ANF
NF
Depth (ft BGS)
Elev. (ft MSL)
0 50 100
Nat. Gamma (API Units)
0 100 200 300
Spon. Pot. (mV)
0 1000 2000 3000
16N Res. (Ohm-m)
0 1000 2000 3000
64N Res. (Ohm-m)
0 1000 2000 3000
Lat. Res. (Ohm-m)
0 1000 2000 3000
Pt. Res. (Ohm)
0 250 500 750 1000
Time(N) (µsec)
0 250 500 750 1000
Time(F) (µsec)
0 25 50 75 100
Delta Time (µsec/ft)

a1u_2.grf

A2U


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
ER
U
GI
VI
ANT
NF
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
53 54 55
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 2 4 6 8 10
Fluid Res. (Ohm-m)
0 4000 8000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

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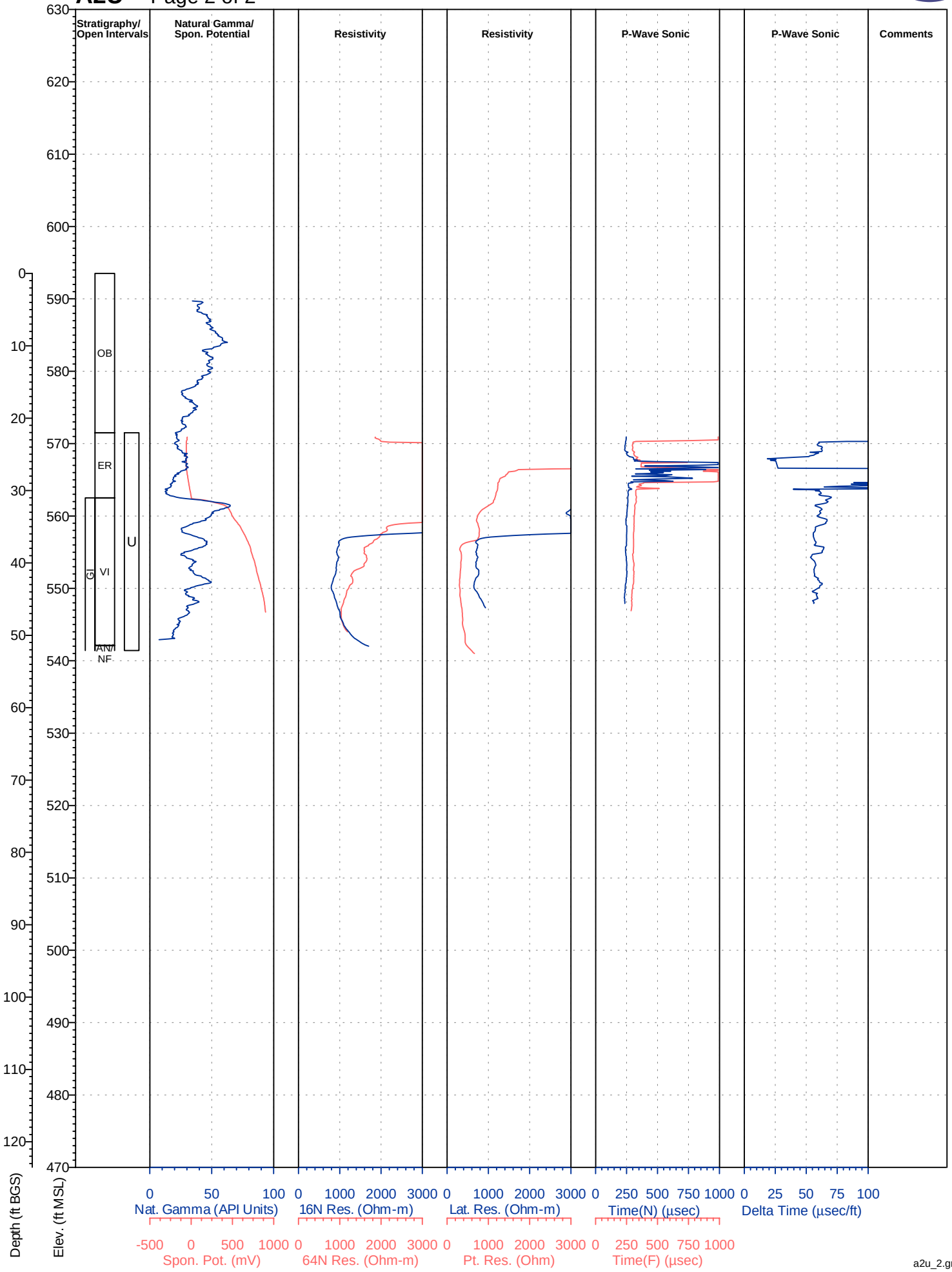
A2U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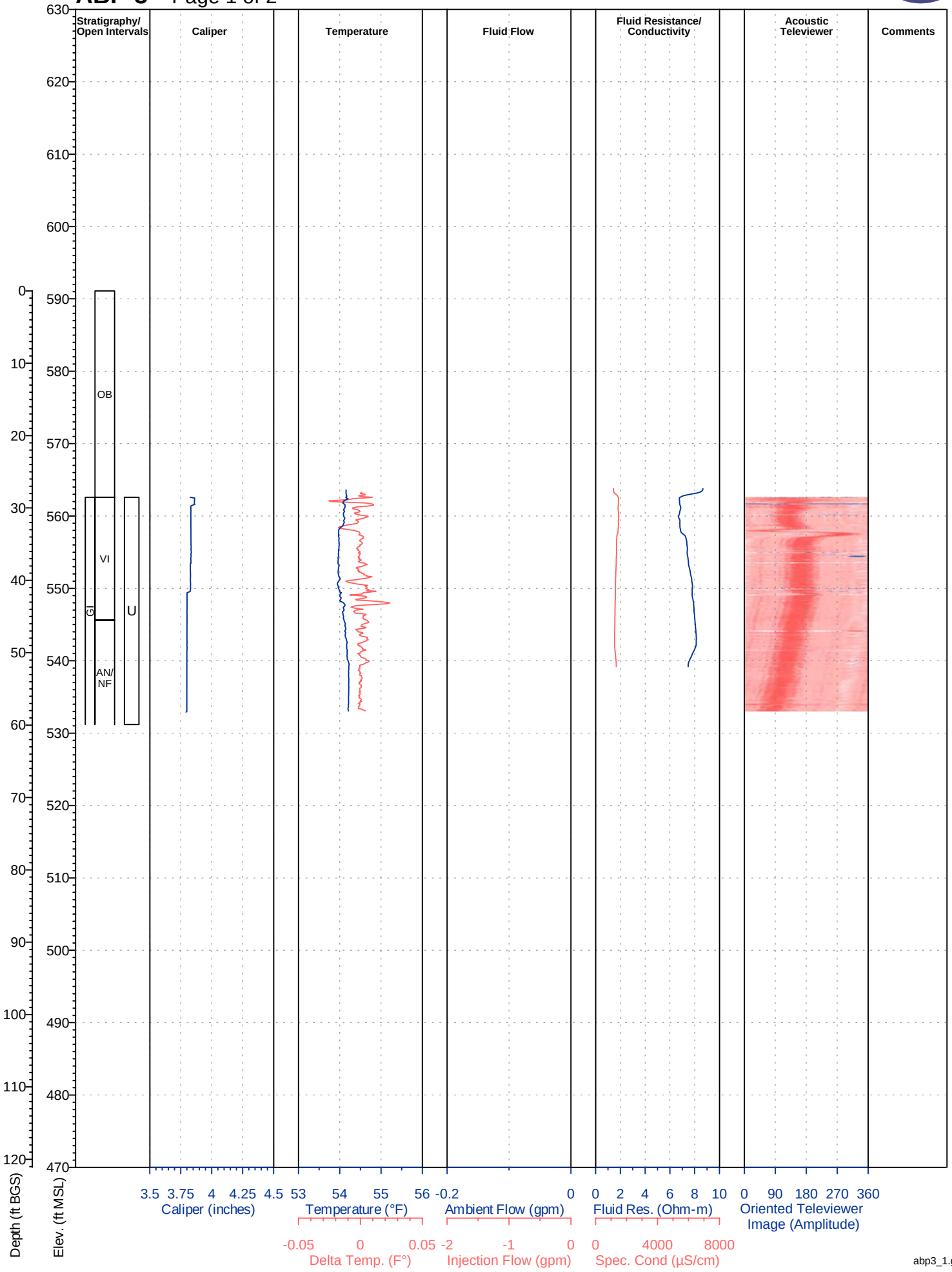
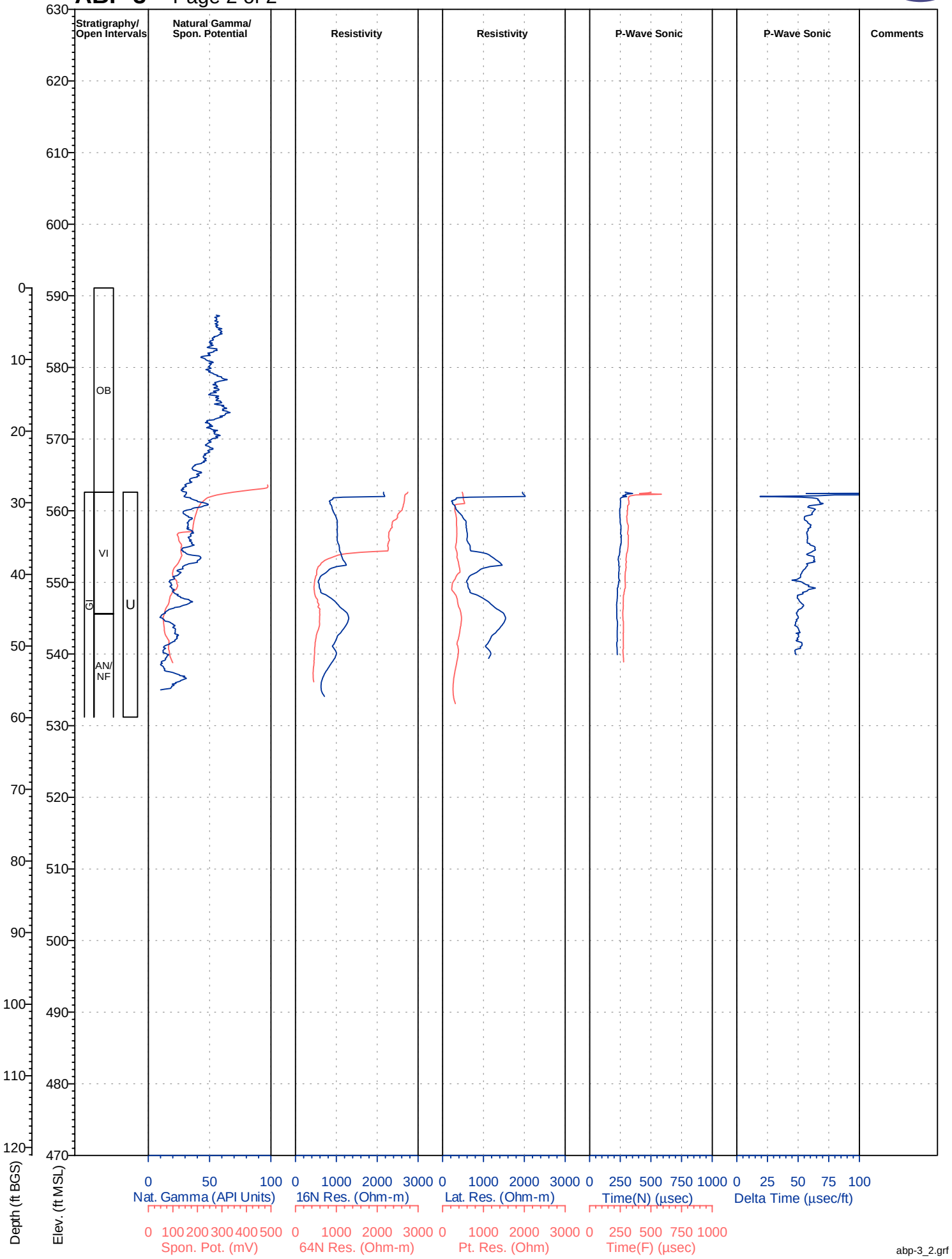
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
U
GI
VI
ANI
NF
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
16N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Time(N) (µsec)
Delta Time (µsec/ft)
Spon. Pot. (mV)
64N Res. (Ohm-m)
Pt. Res. (Ohm)
Time(F) (µsec)

a2u_2.grf

ABP-3


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
VI
GI
U
AN/ NF
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
53 54 55 56
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 2 4 6 8 10
Fluid Res. (Ohm-m)
0 4000 8000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

ABP-3



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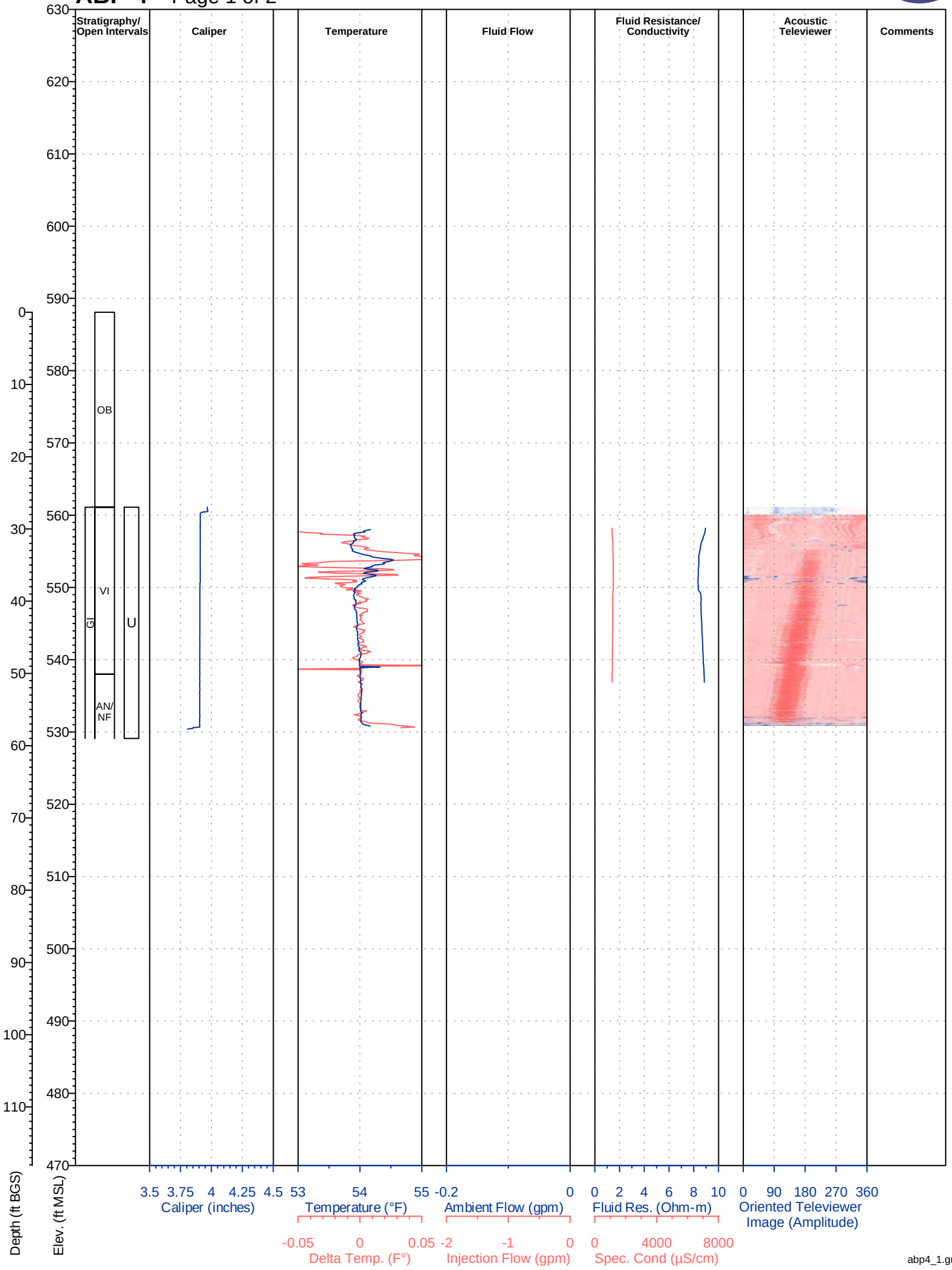

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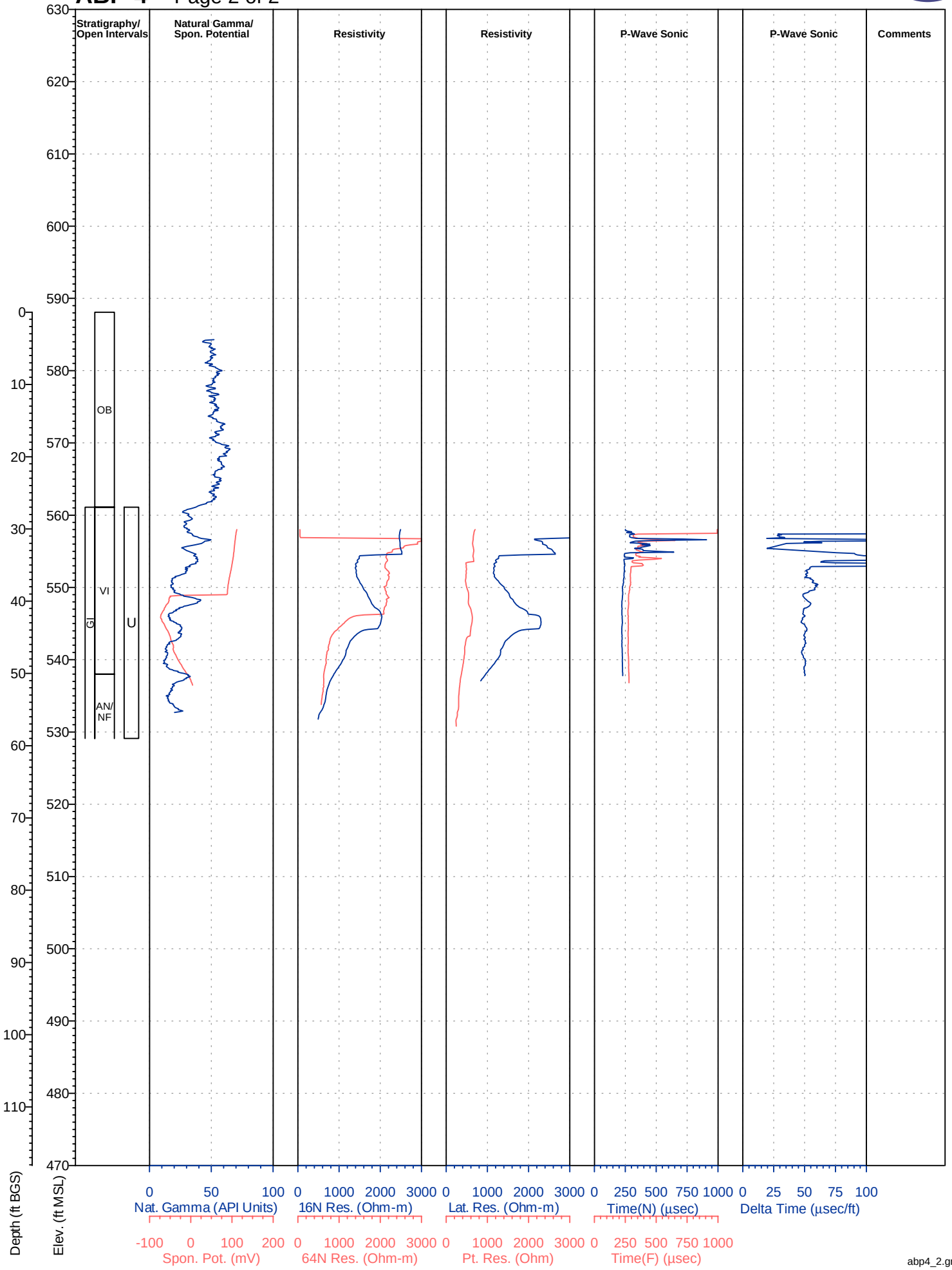
ABP-4 Page 2 of 2



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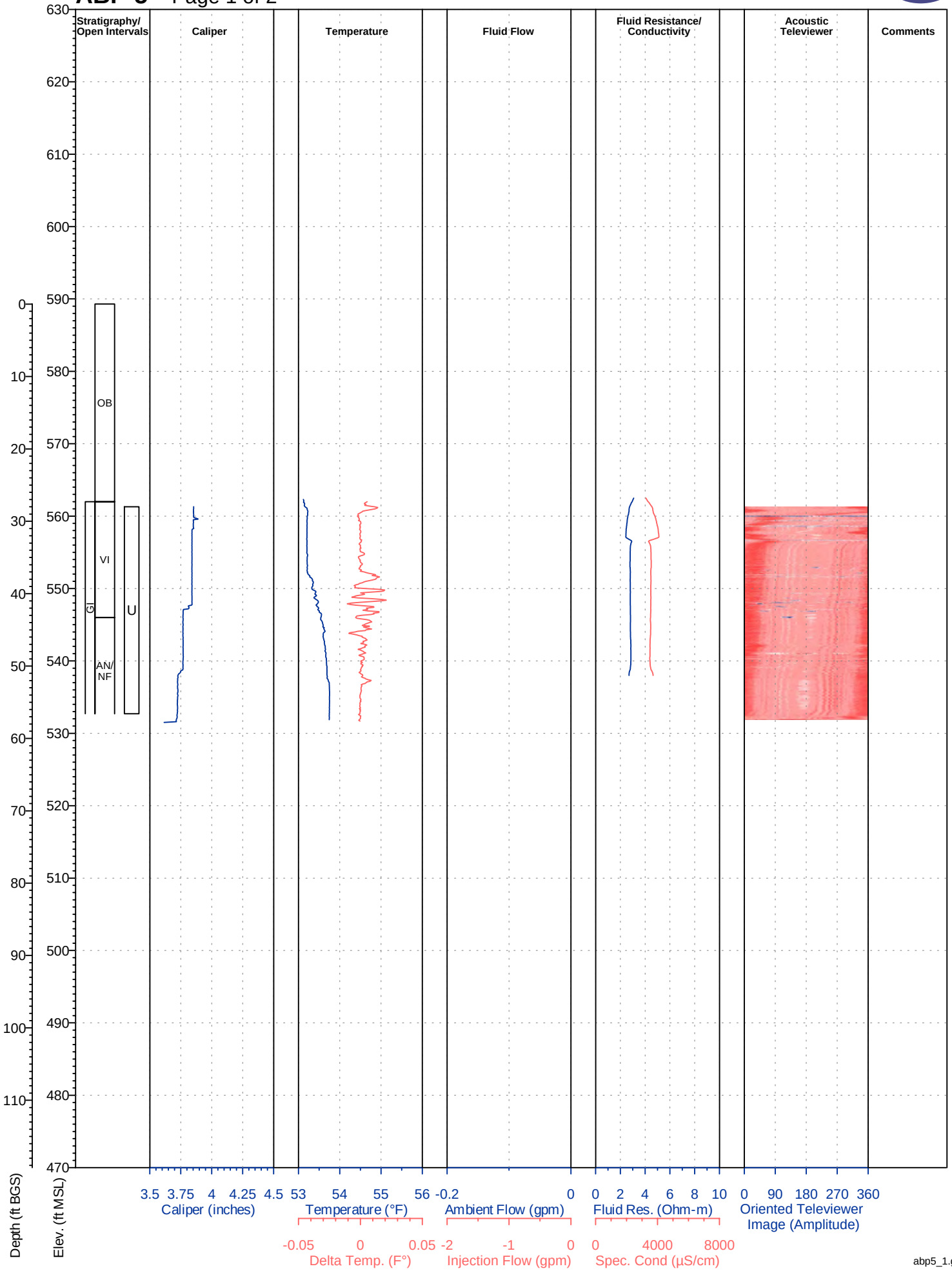
ABP-5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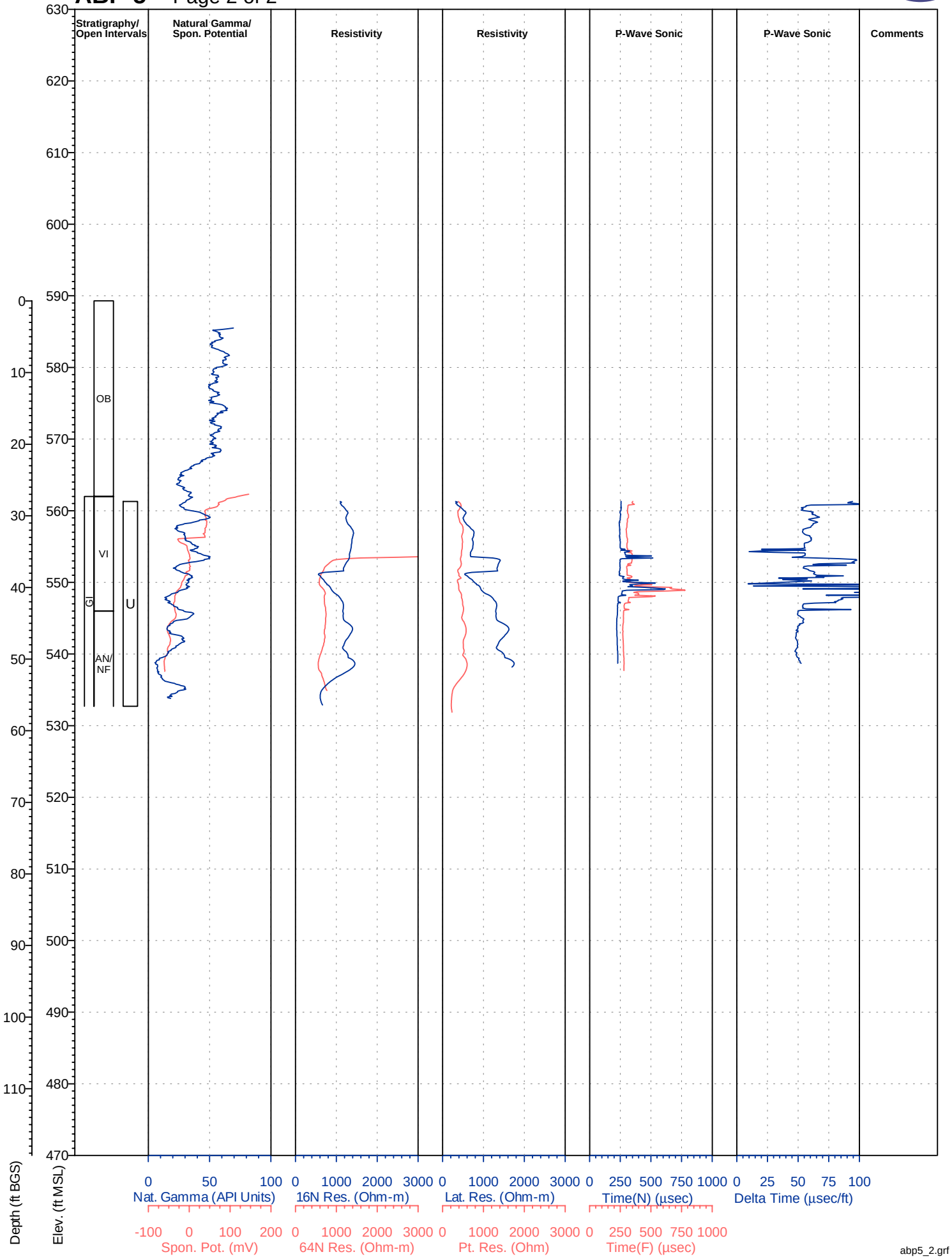
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
VI
GI
U
AN/ NF
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
53 54 55 56
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 2 4 6 8 10
Fluid Res. (Ohm-m)
0 4000 8000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

ABP-5



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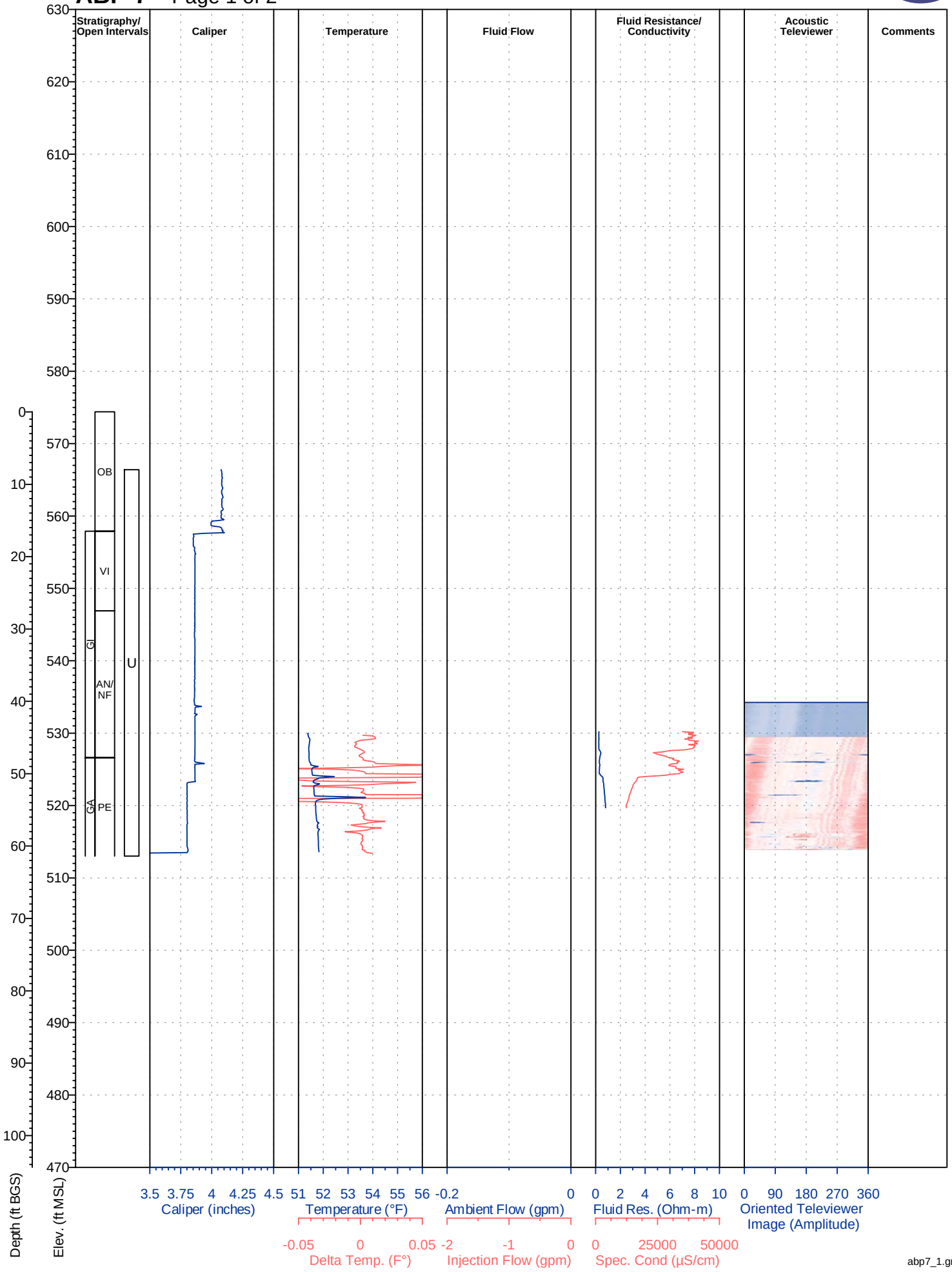

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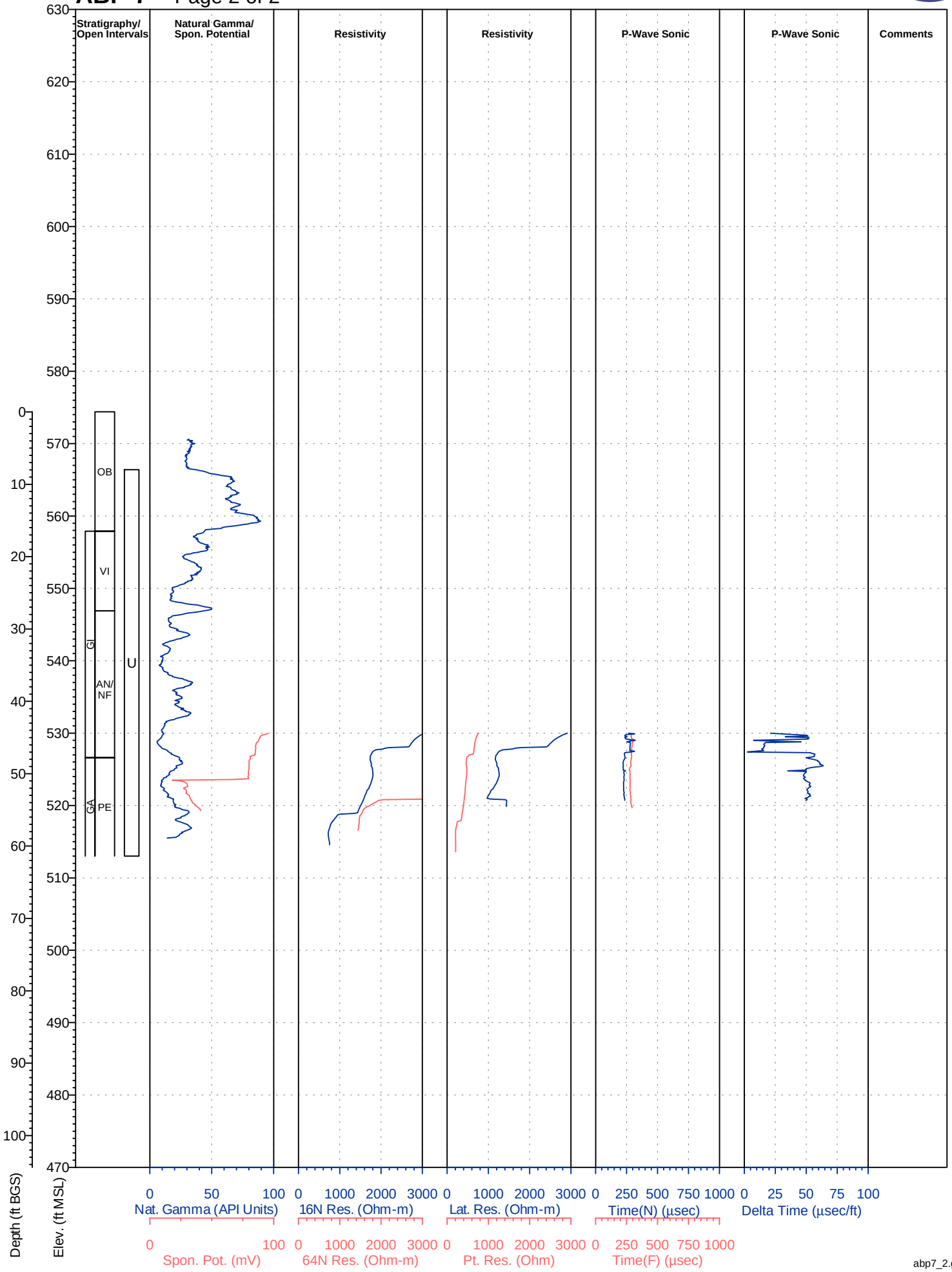
ABP-7



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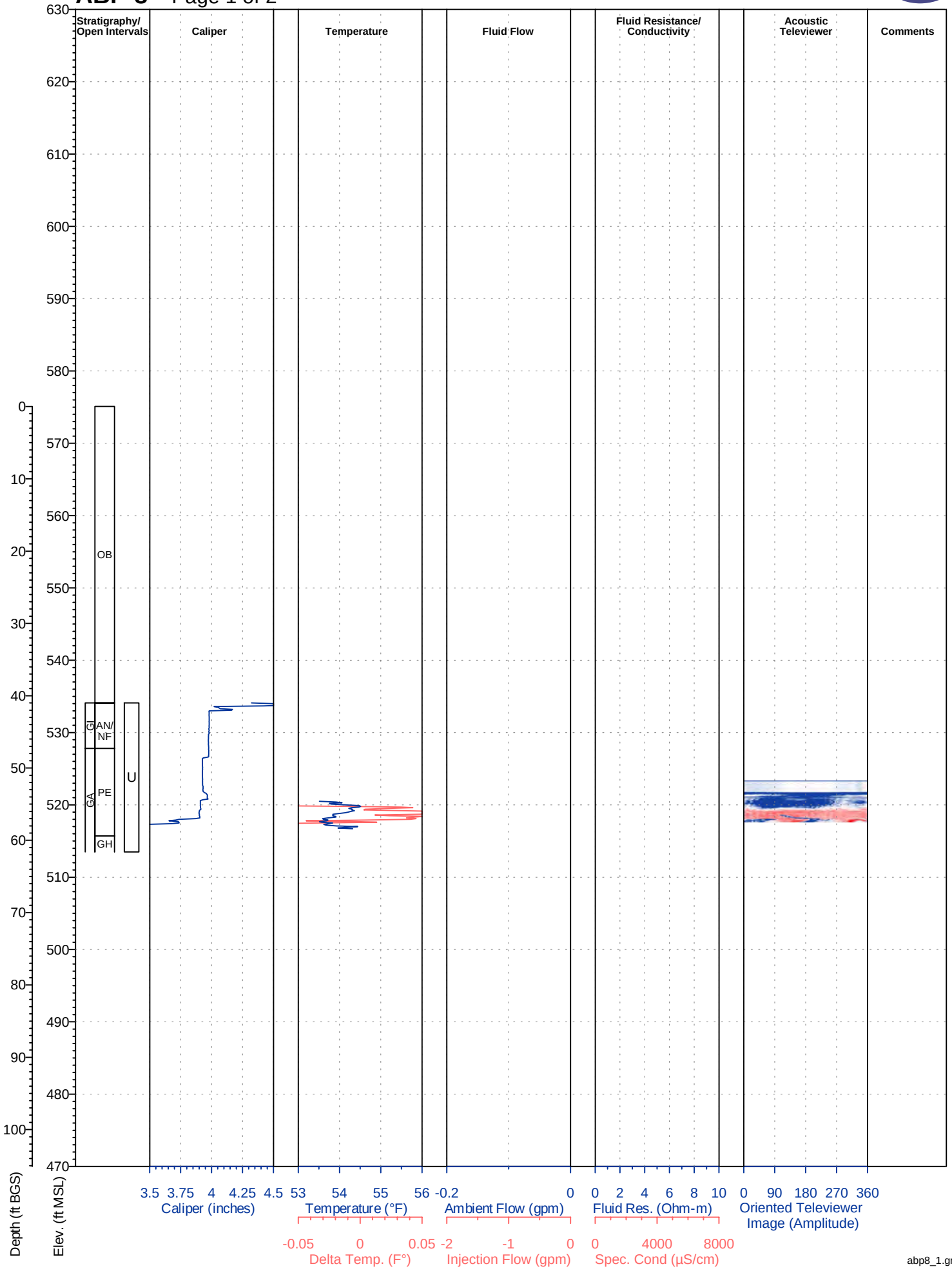

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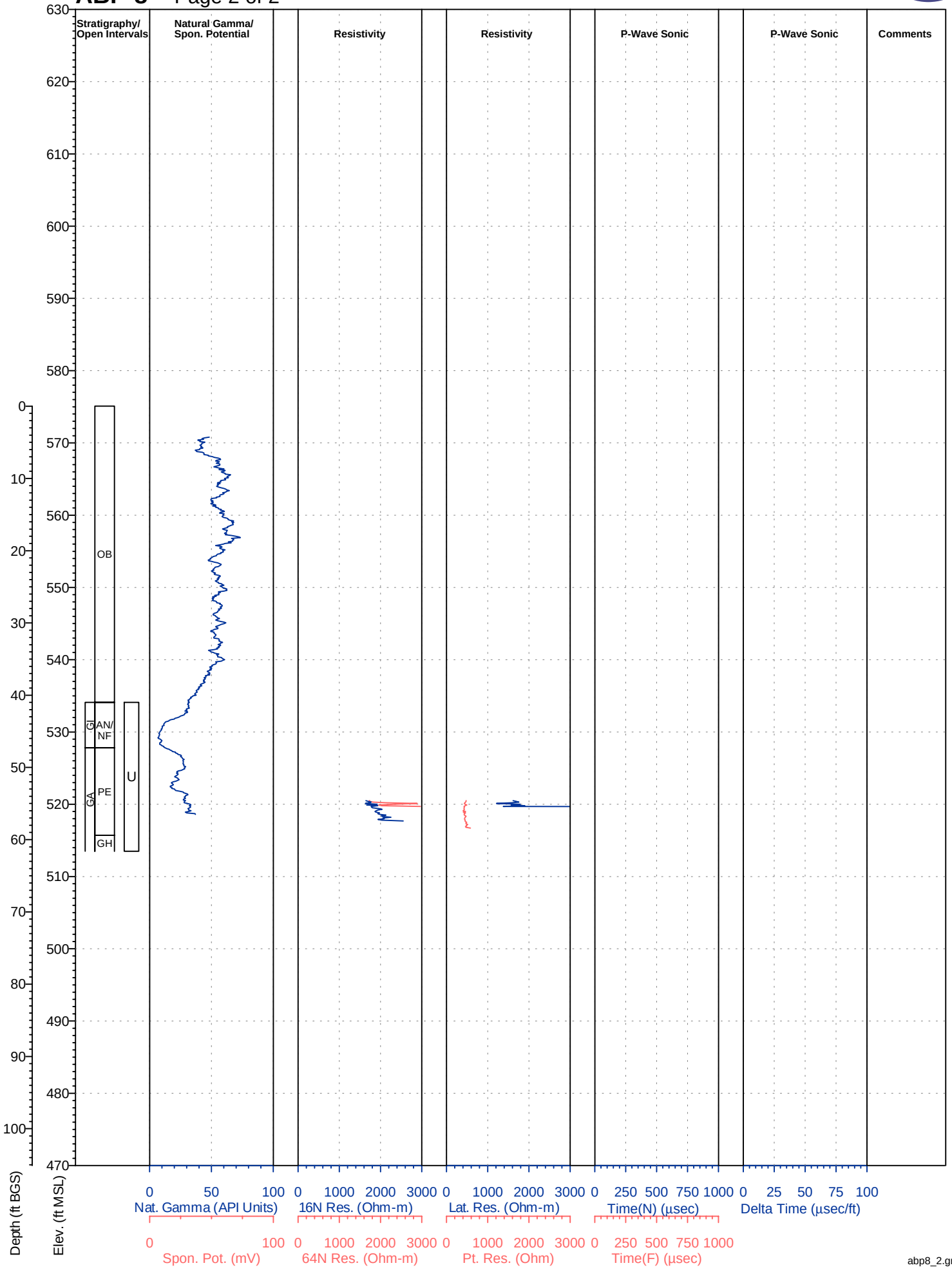
ABP-8 Page 2 of 2



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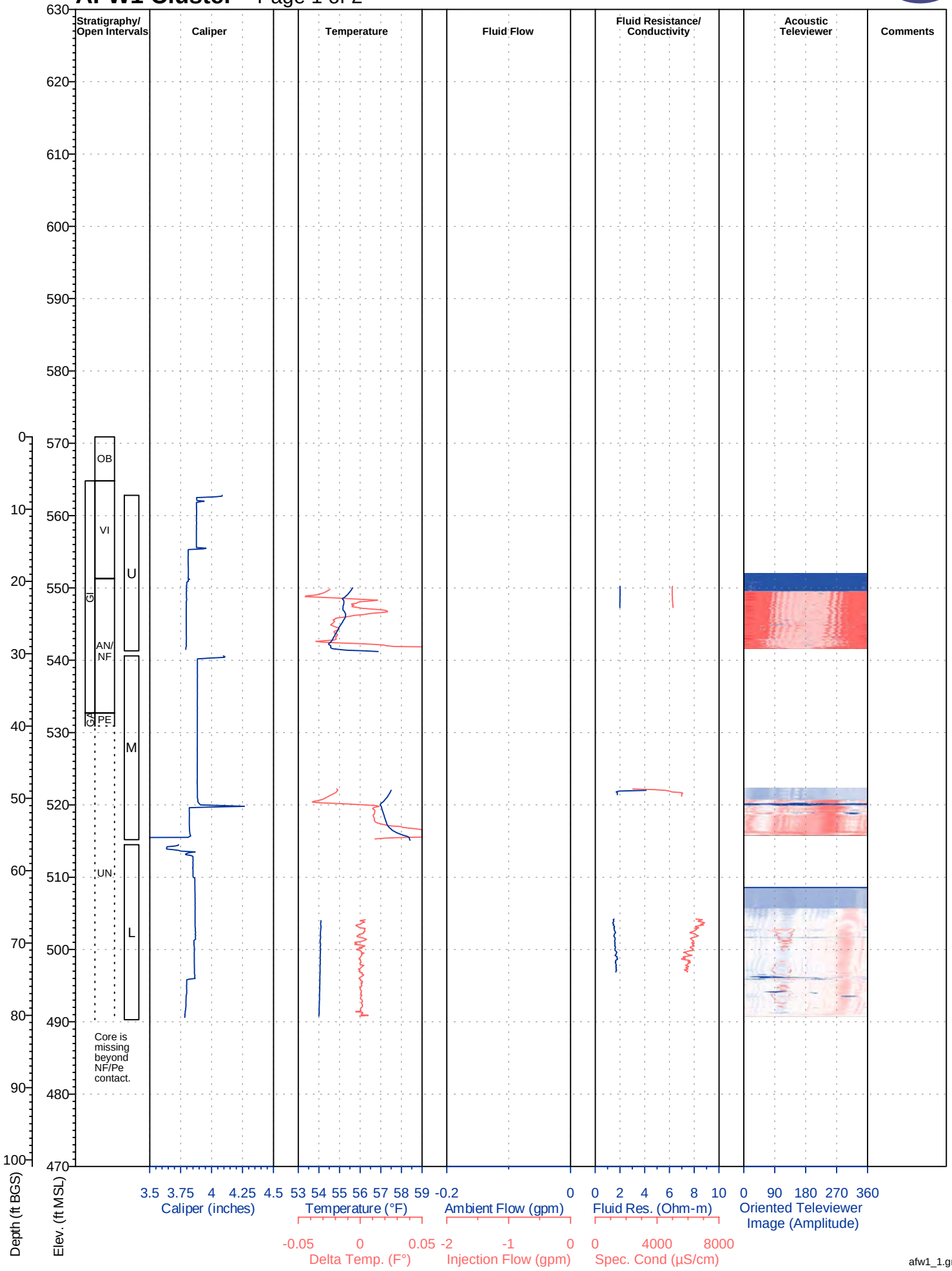

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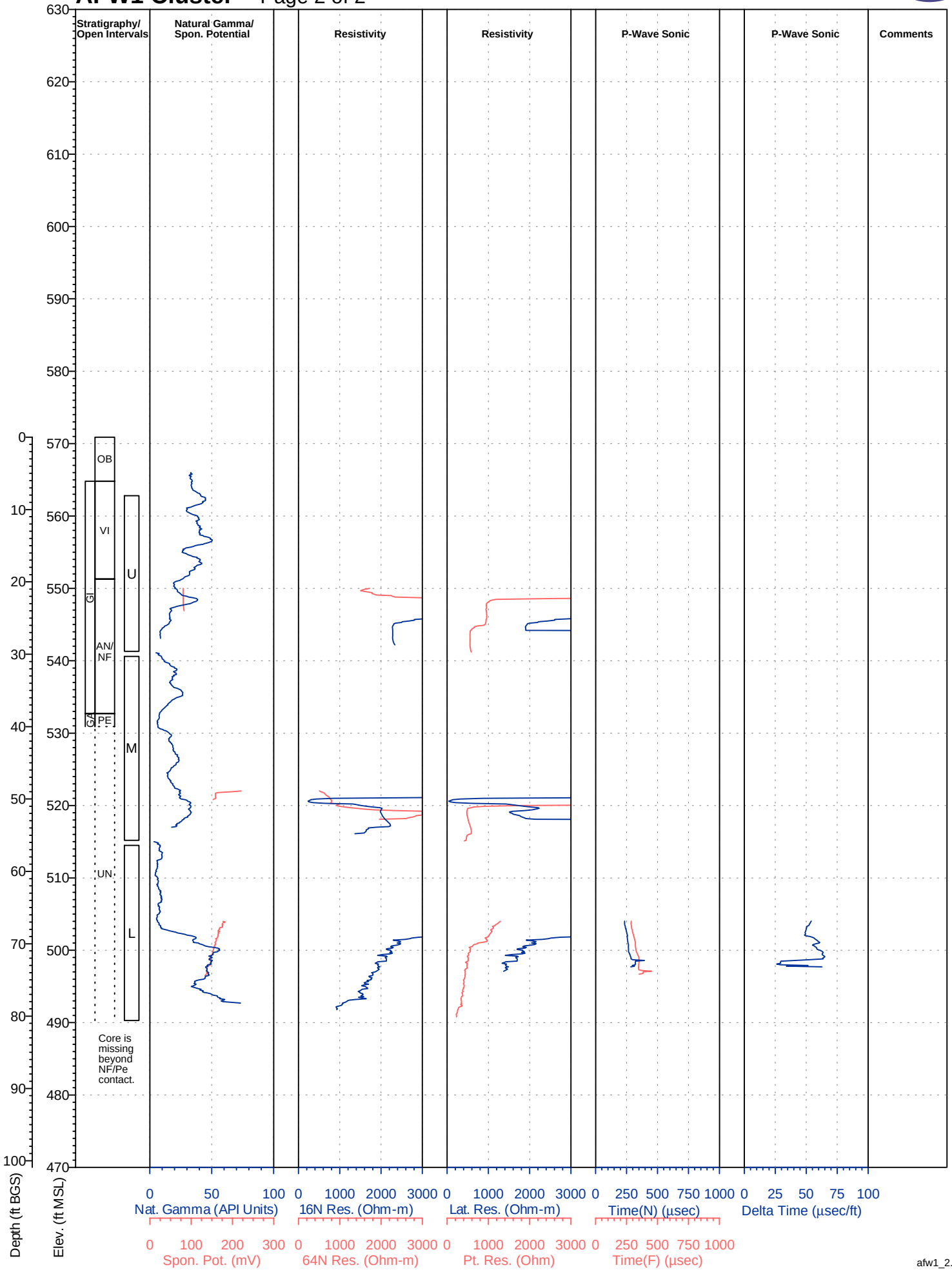

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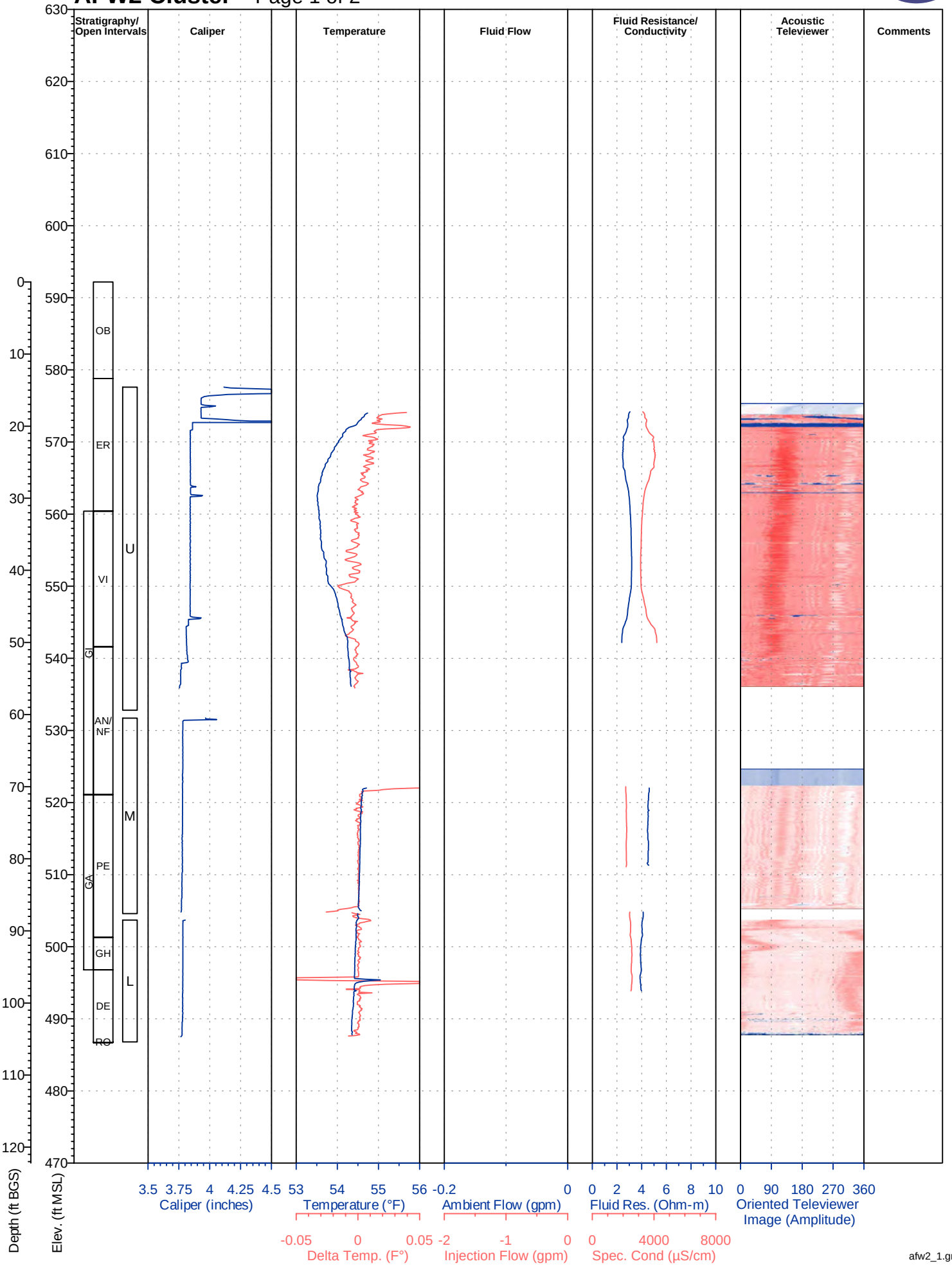

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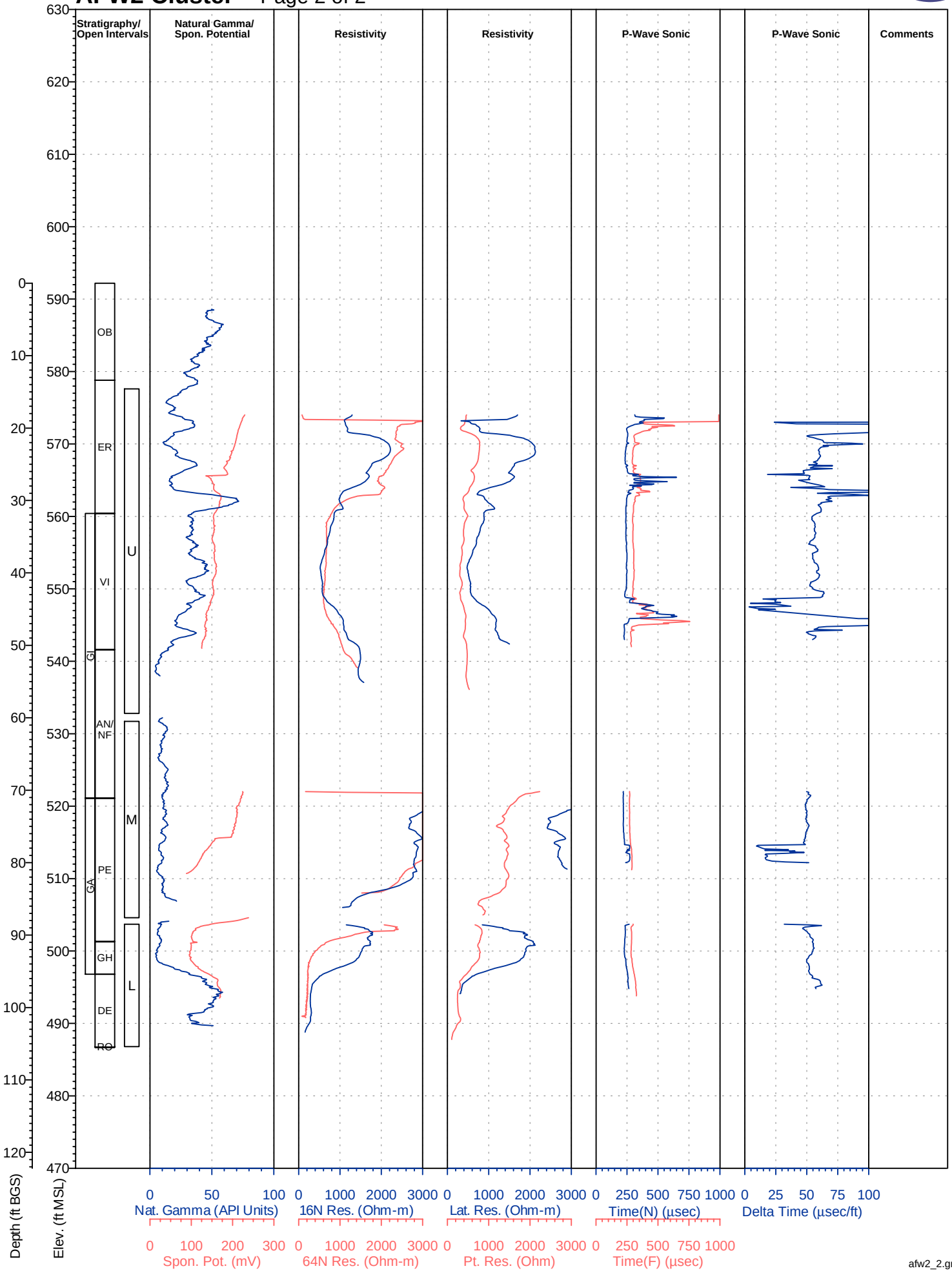

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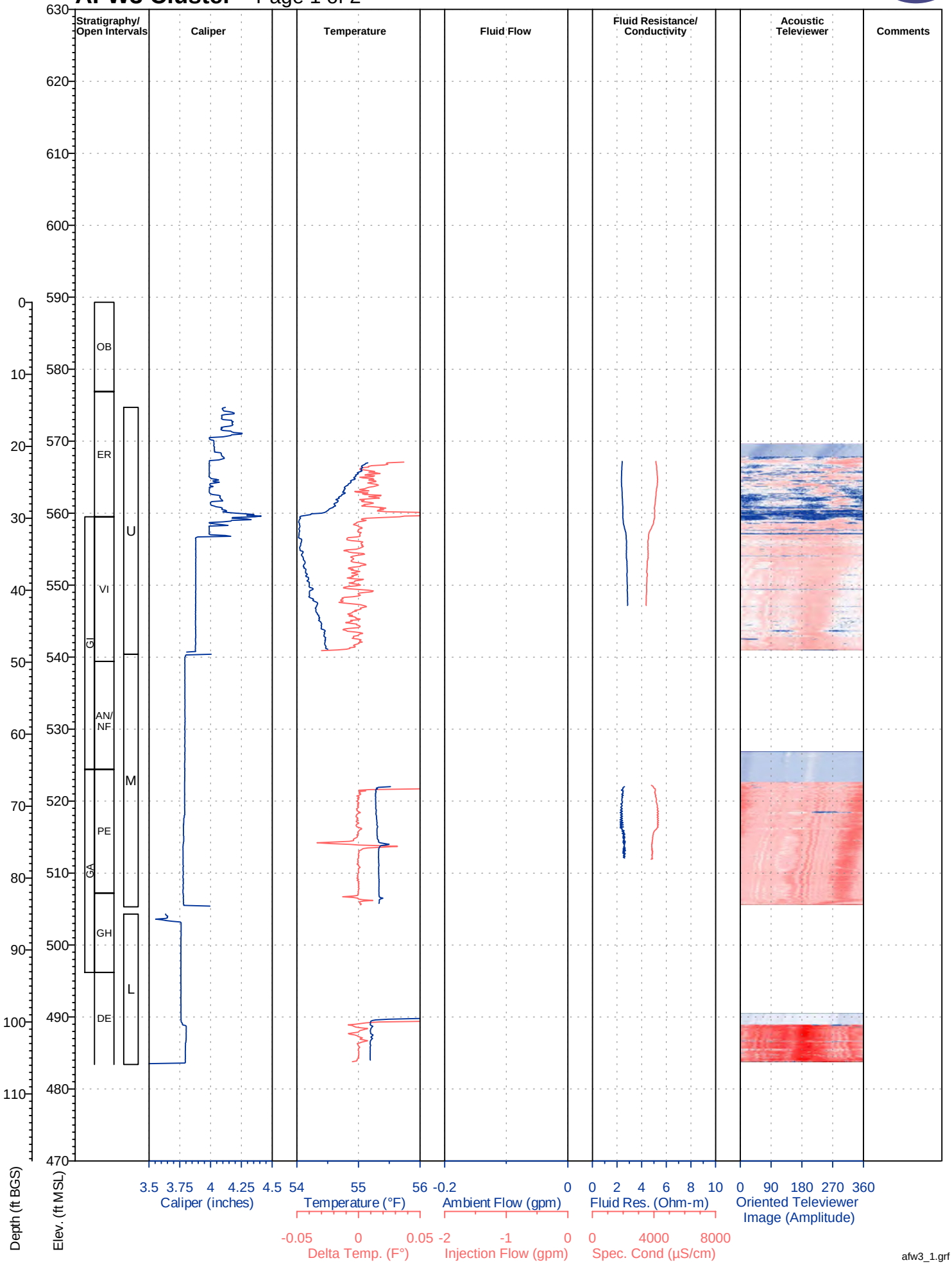

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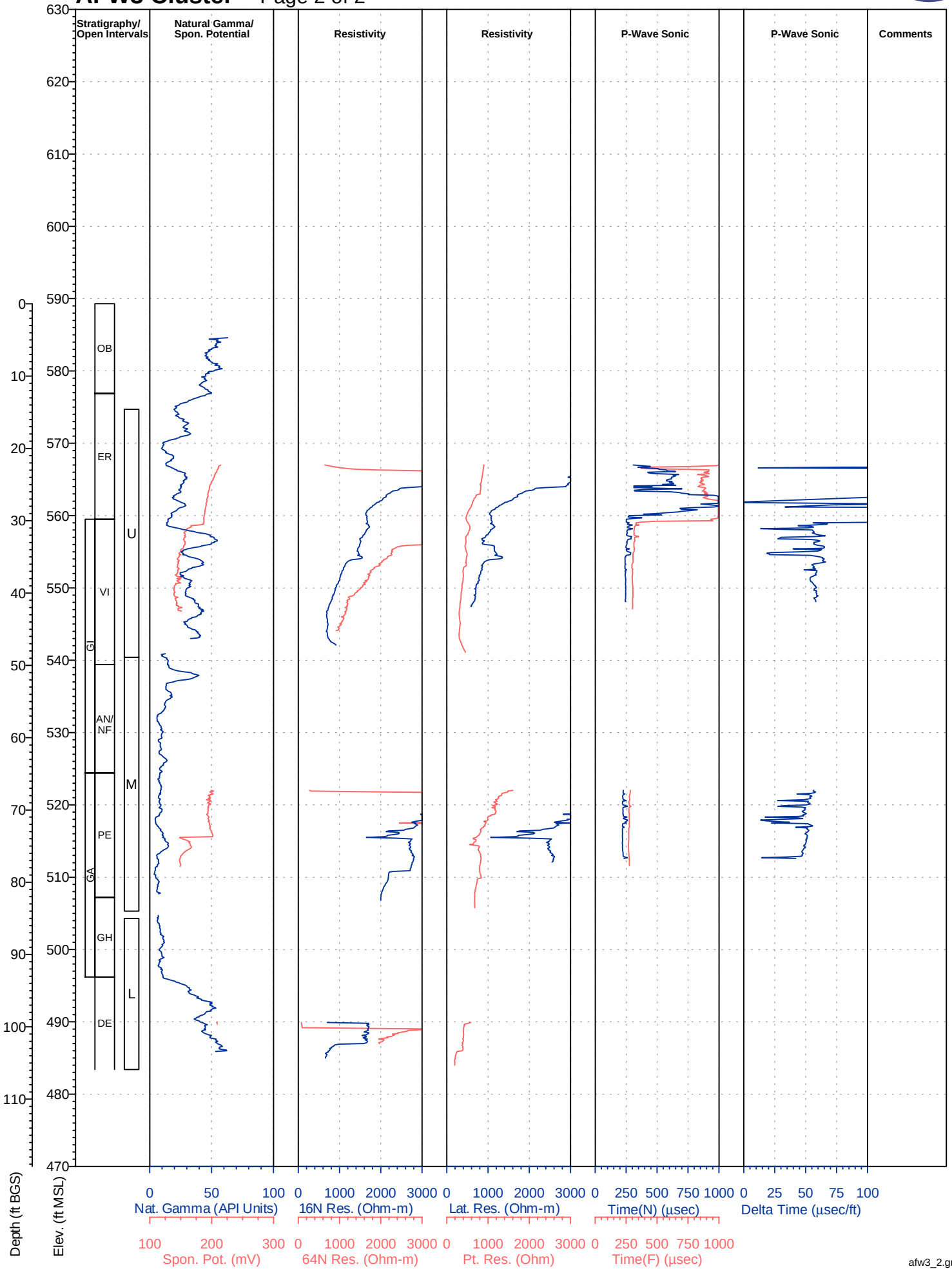

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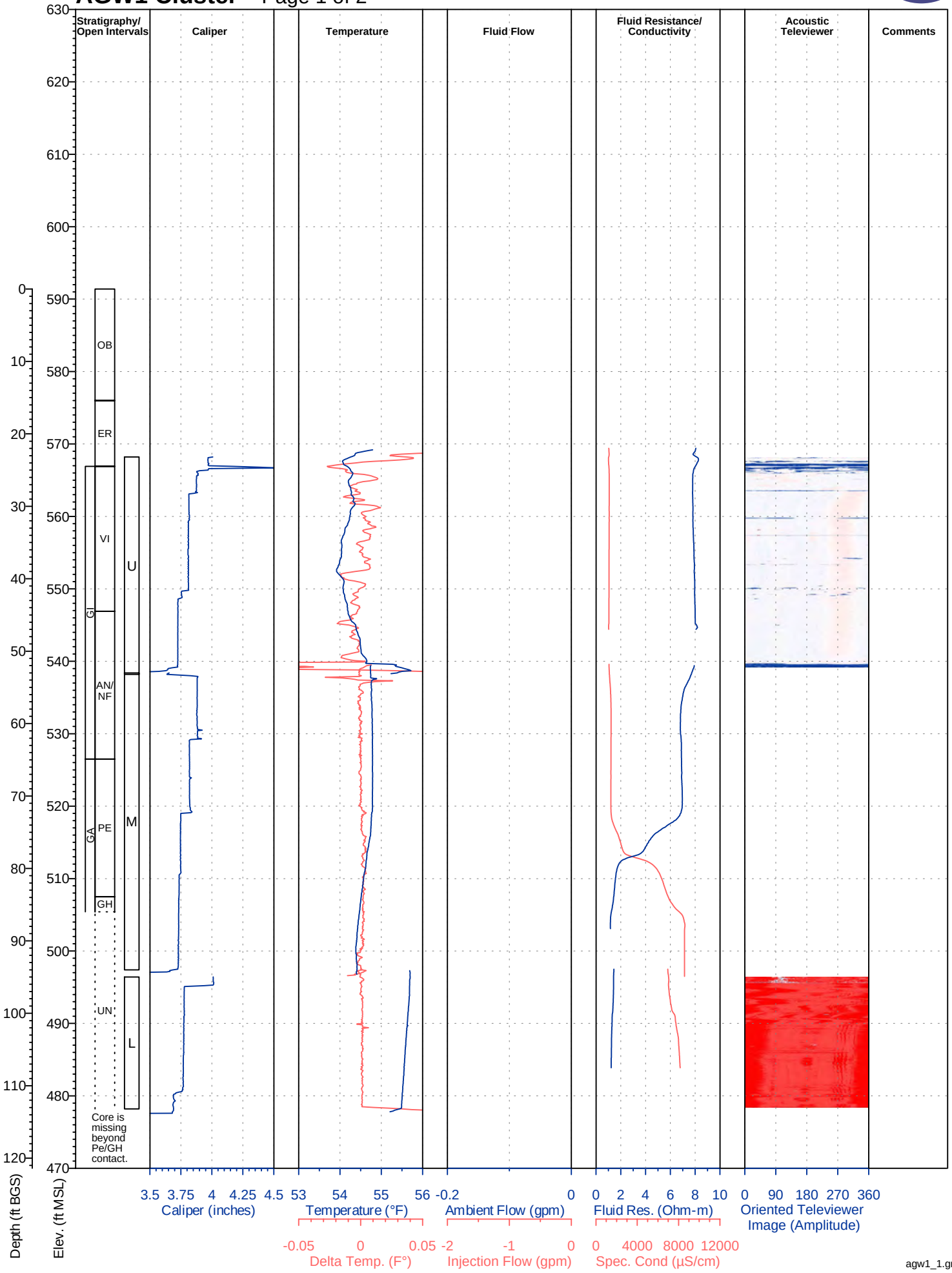

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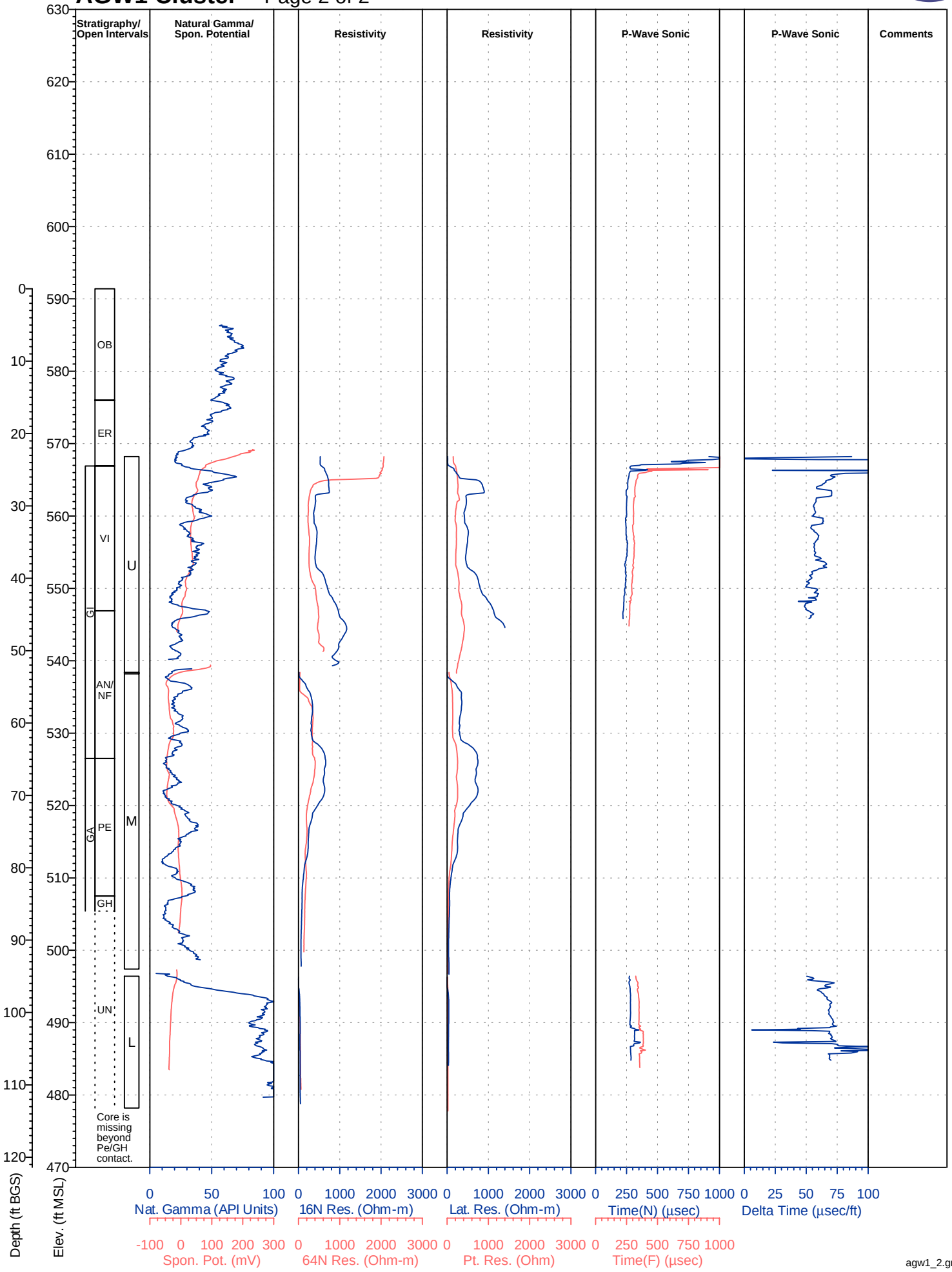

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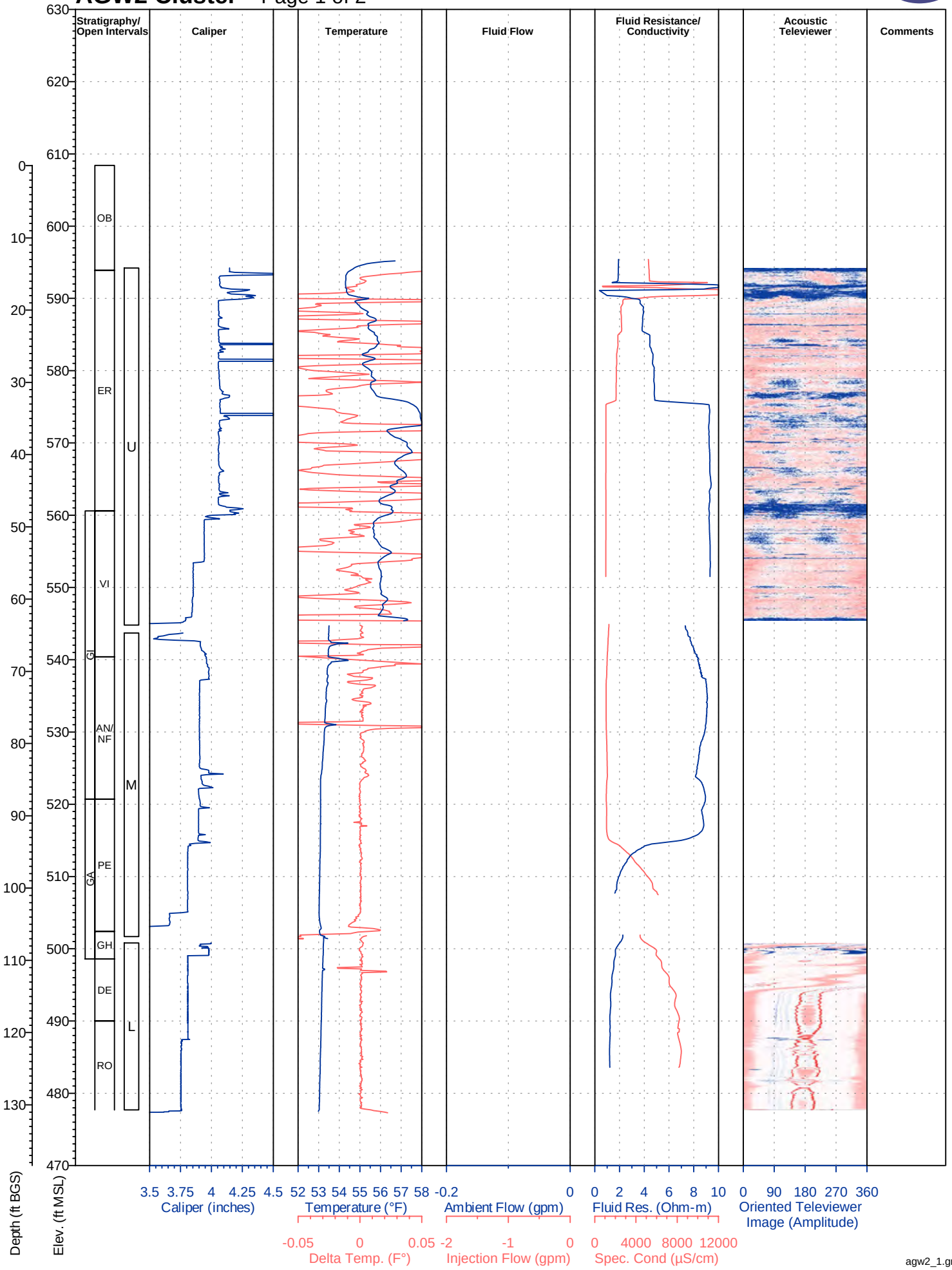

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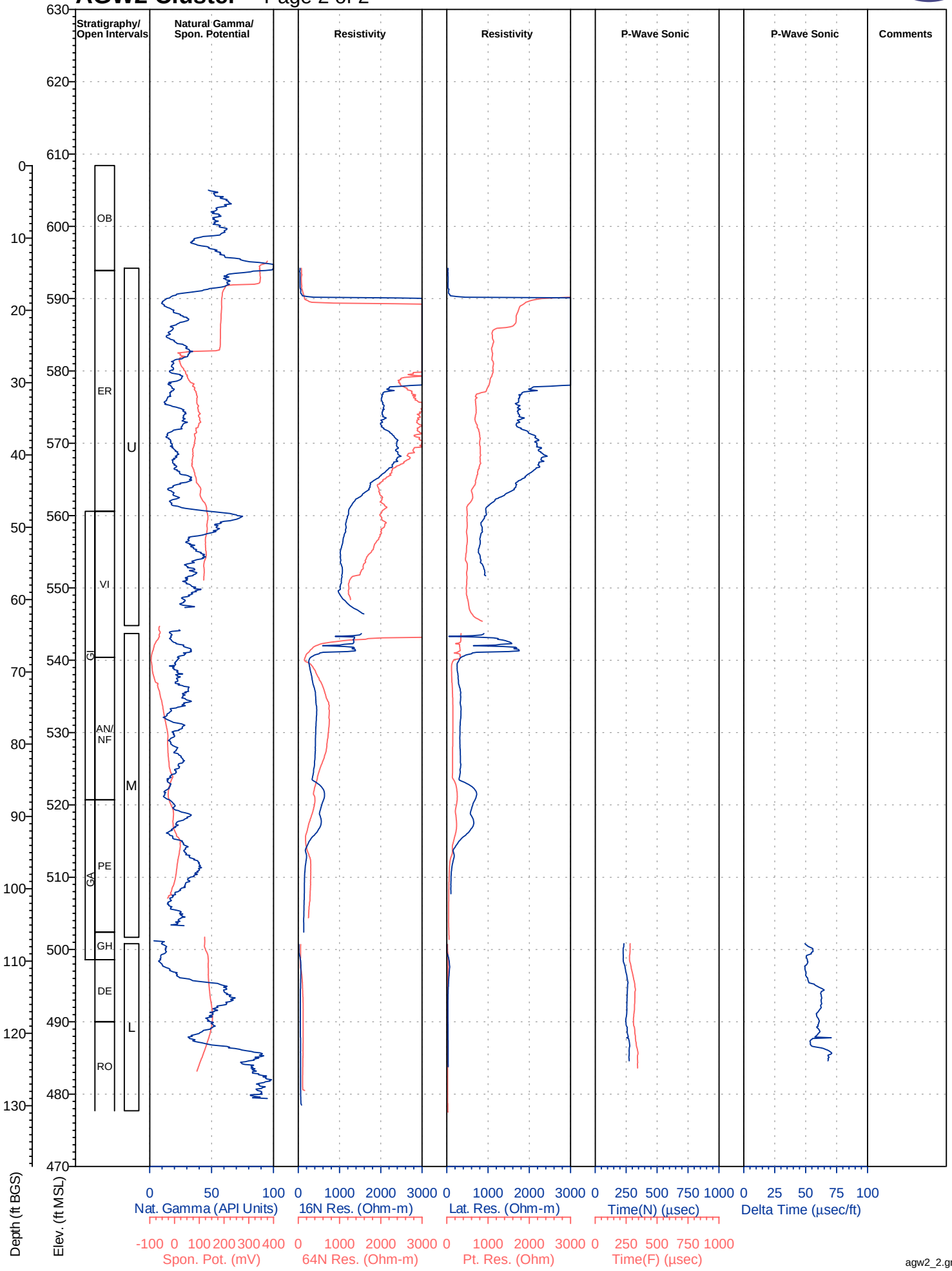

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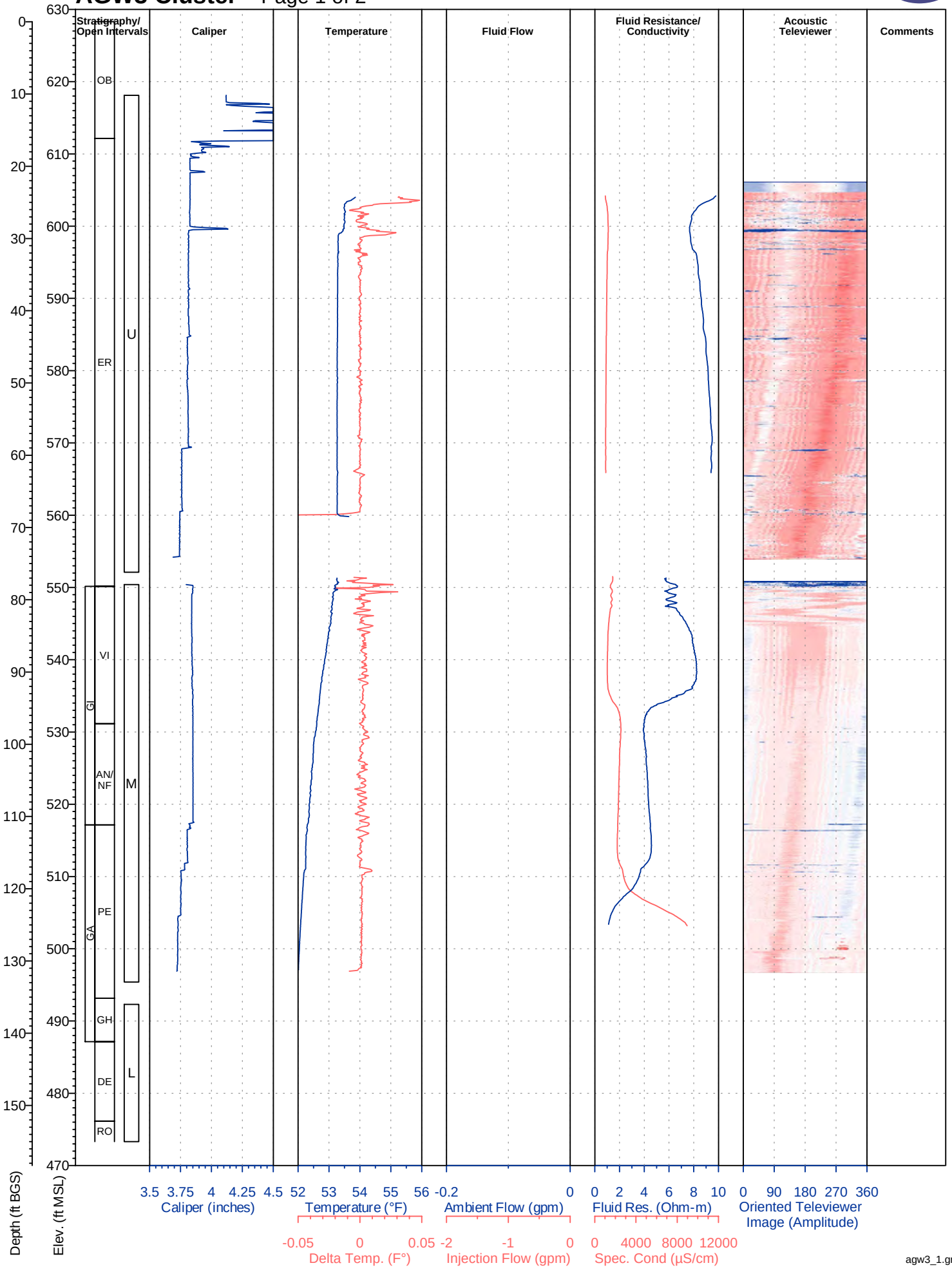

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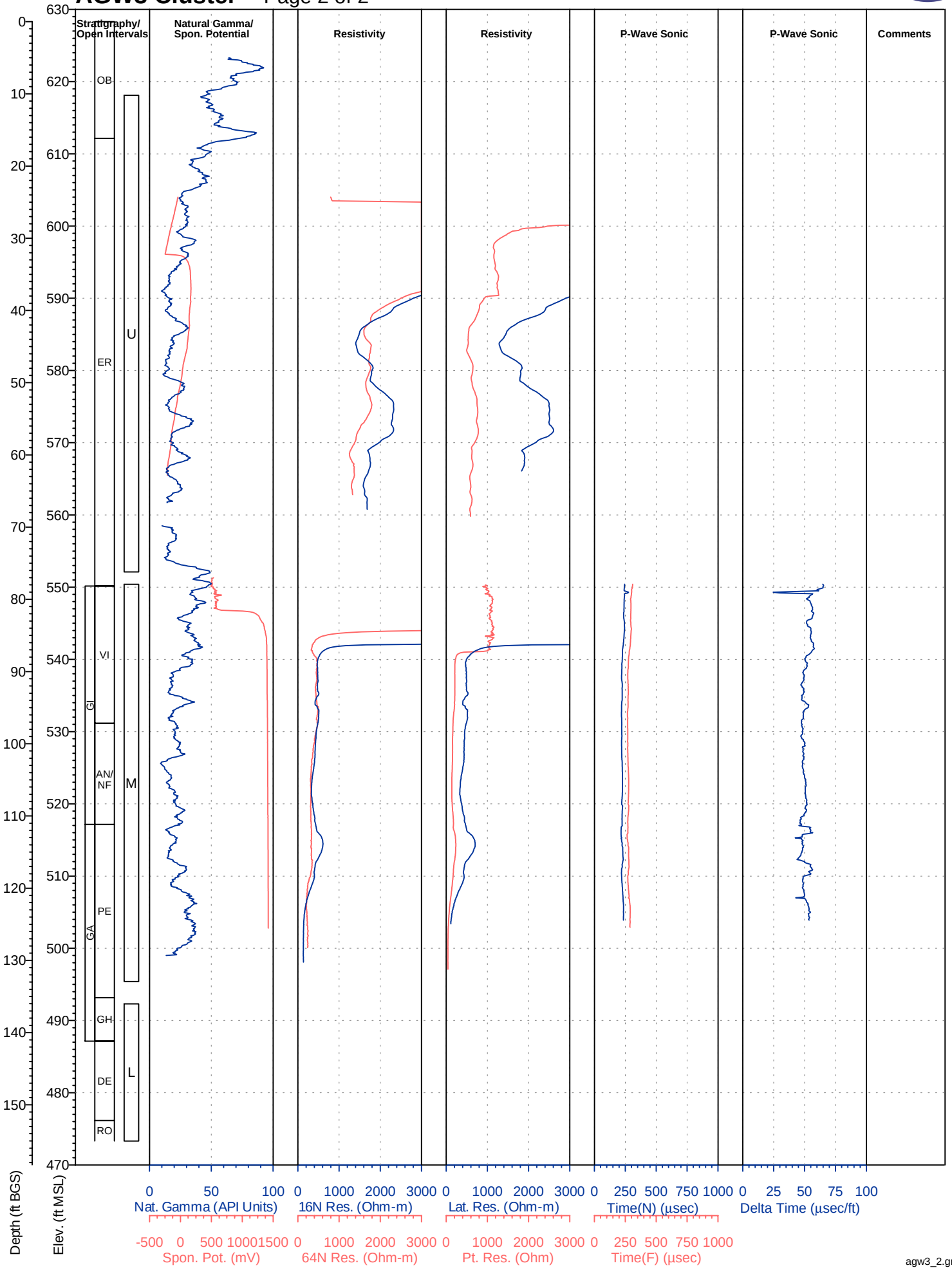

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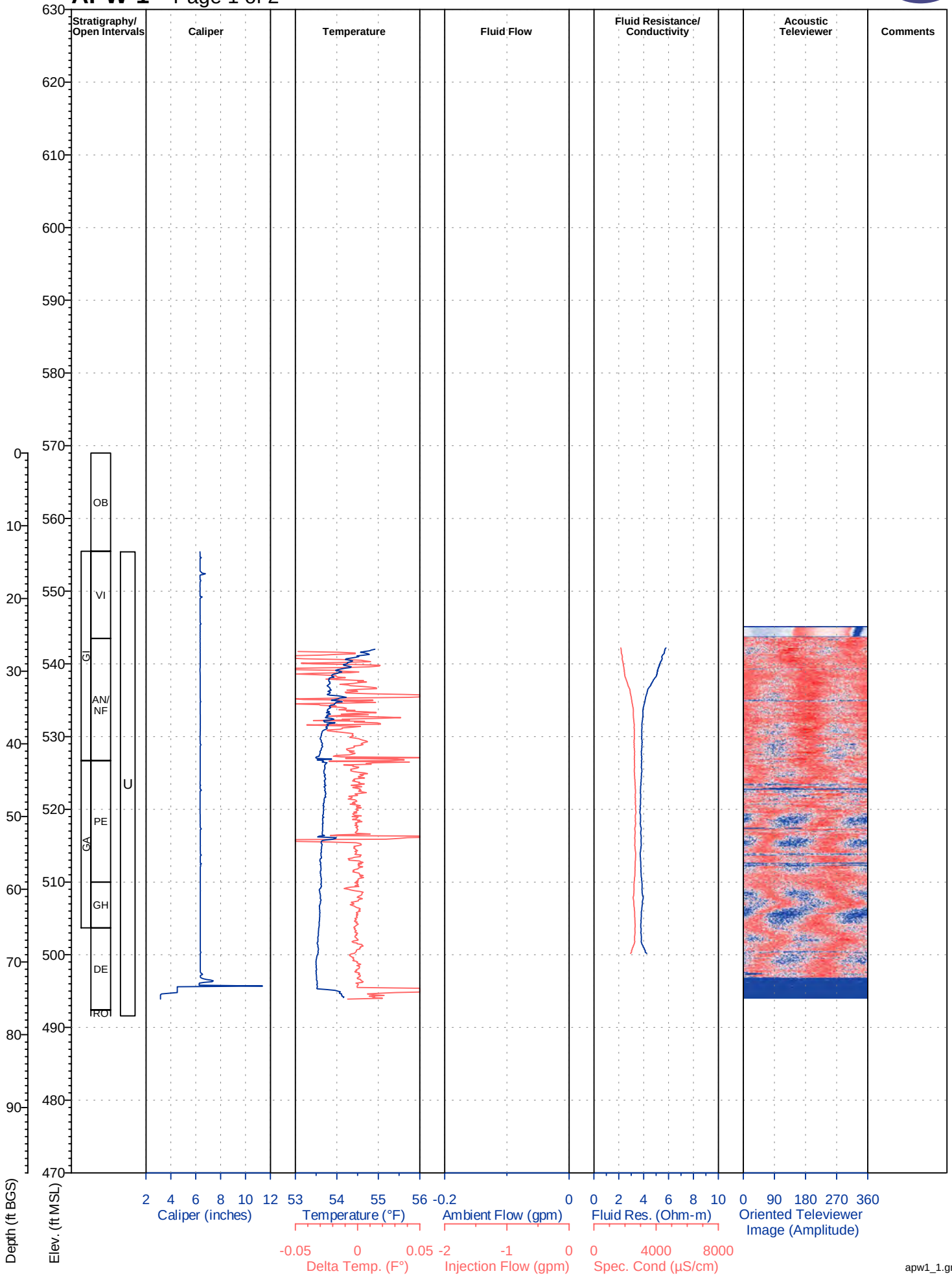

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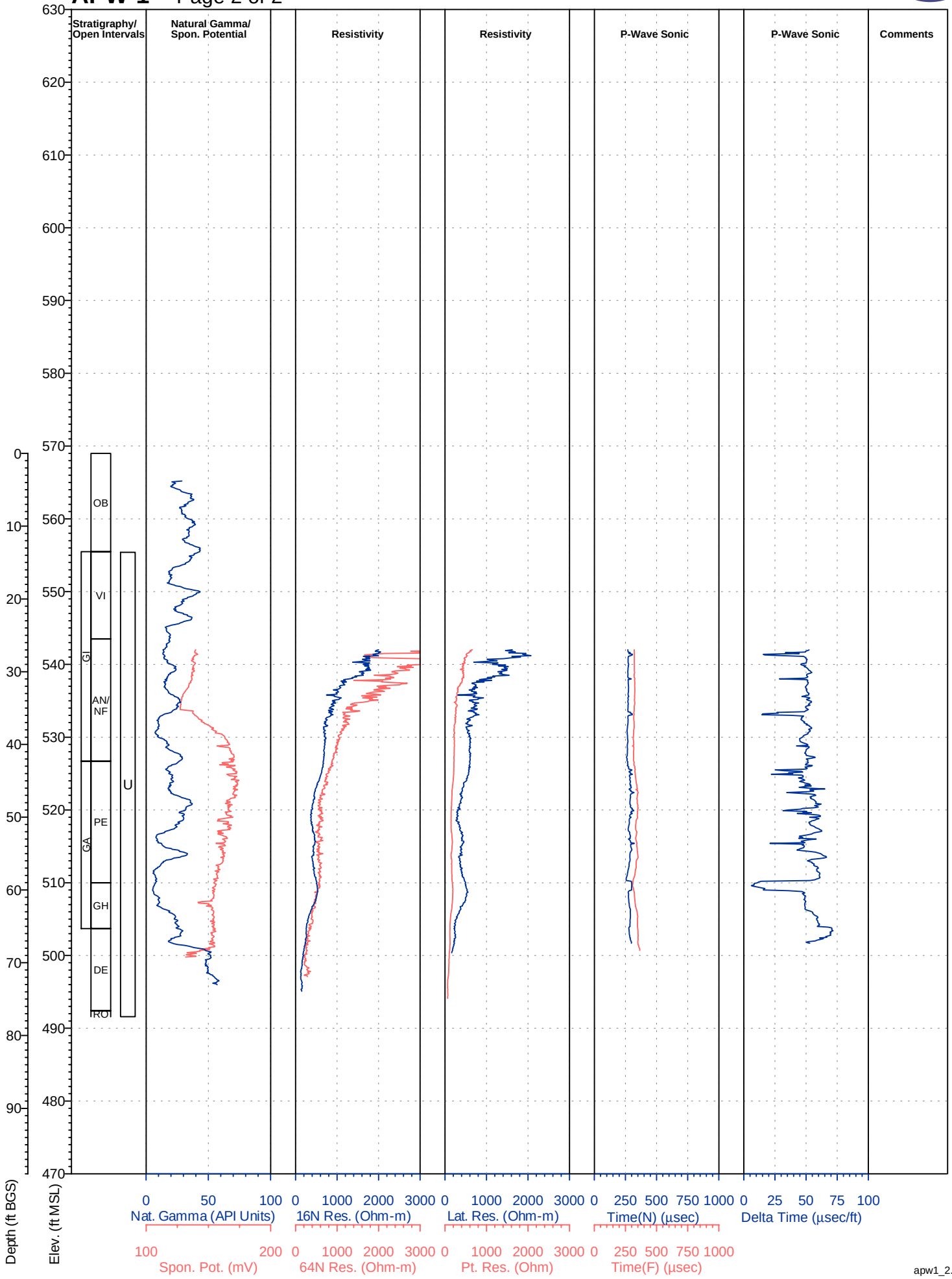
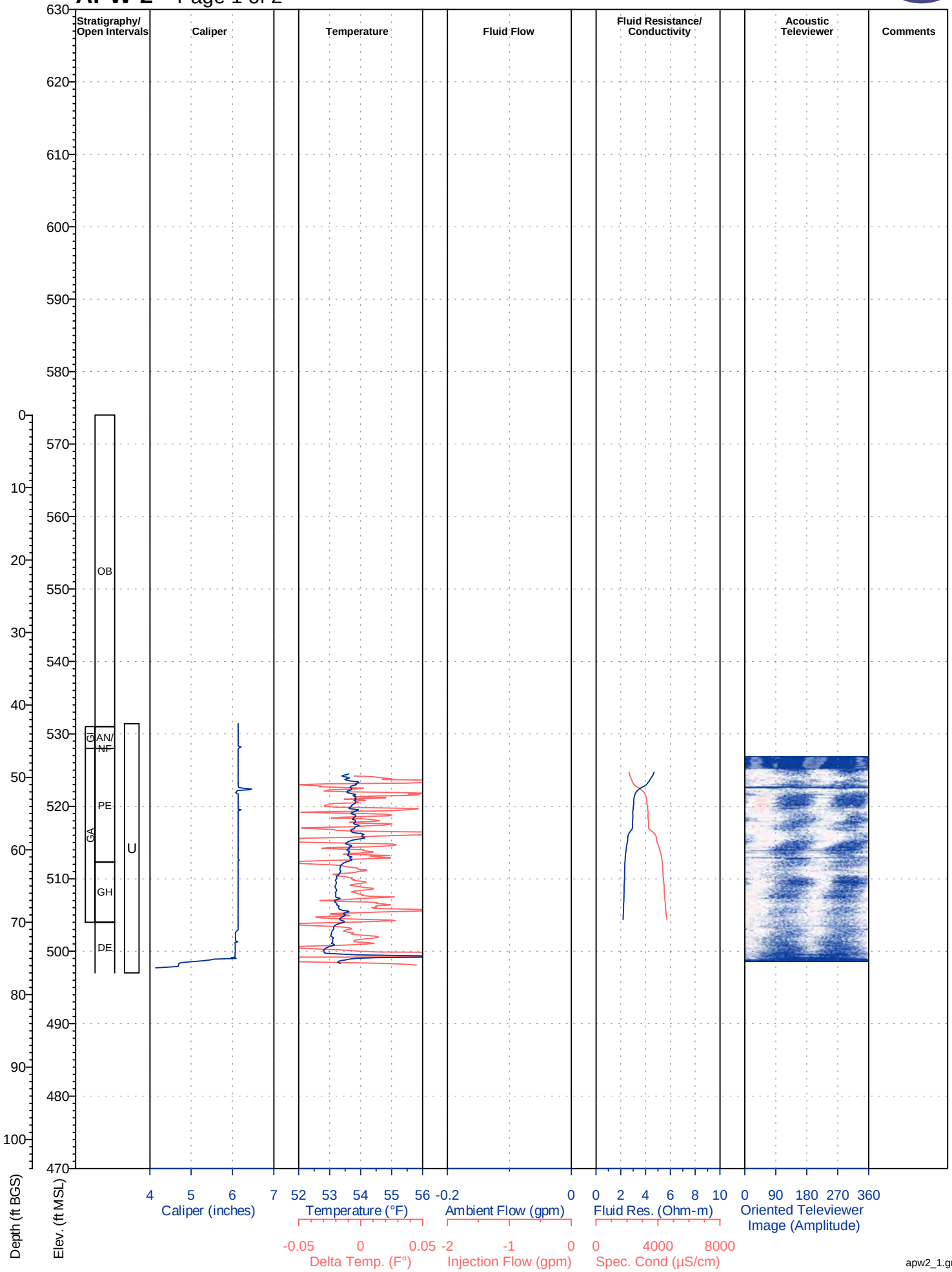

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
VI
AN/ NF
PE
GH
DE
RO
GI
GA
U
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

APW-2



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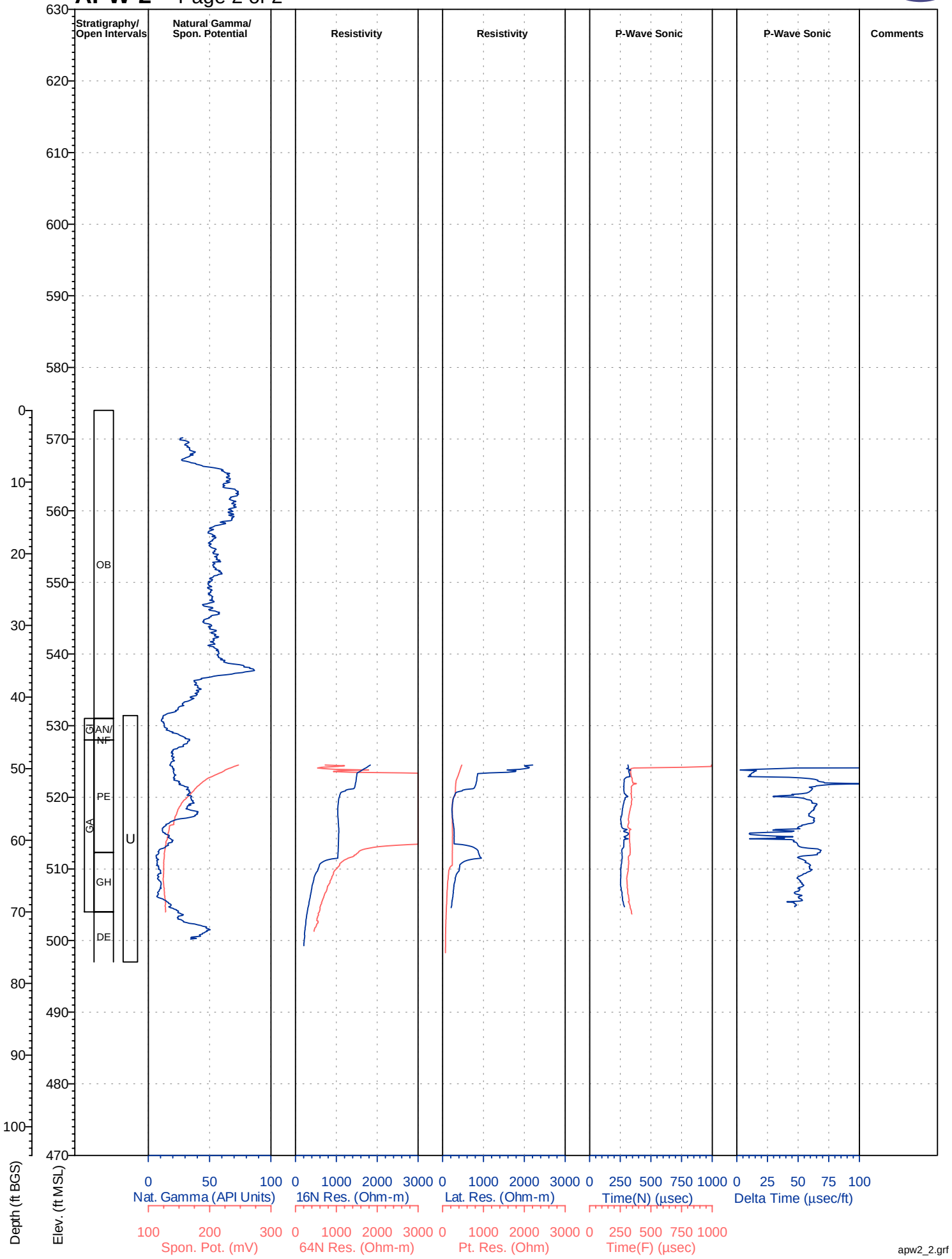

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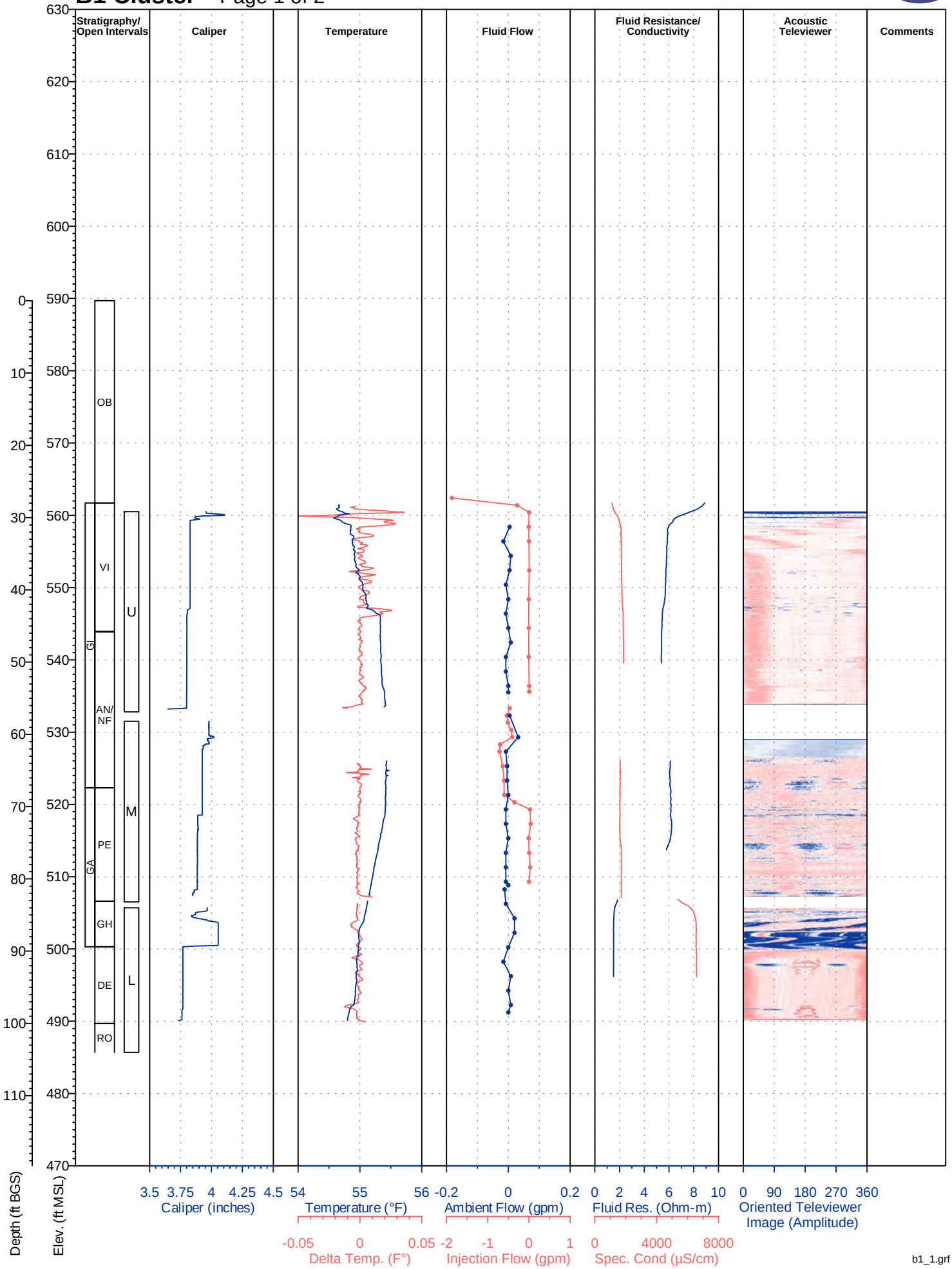

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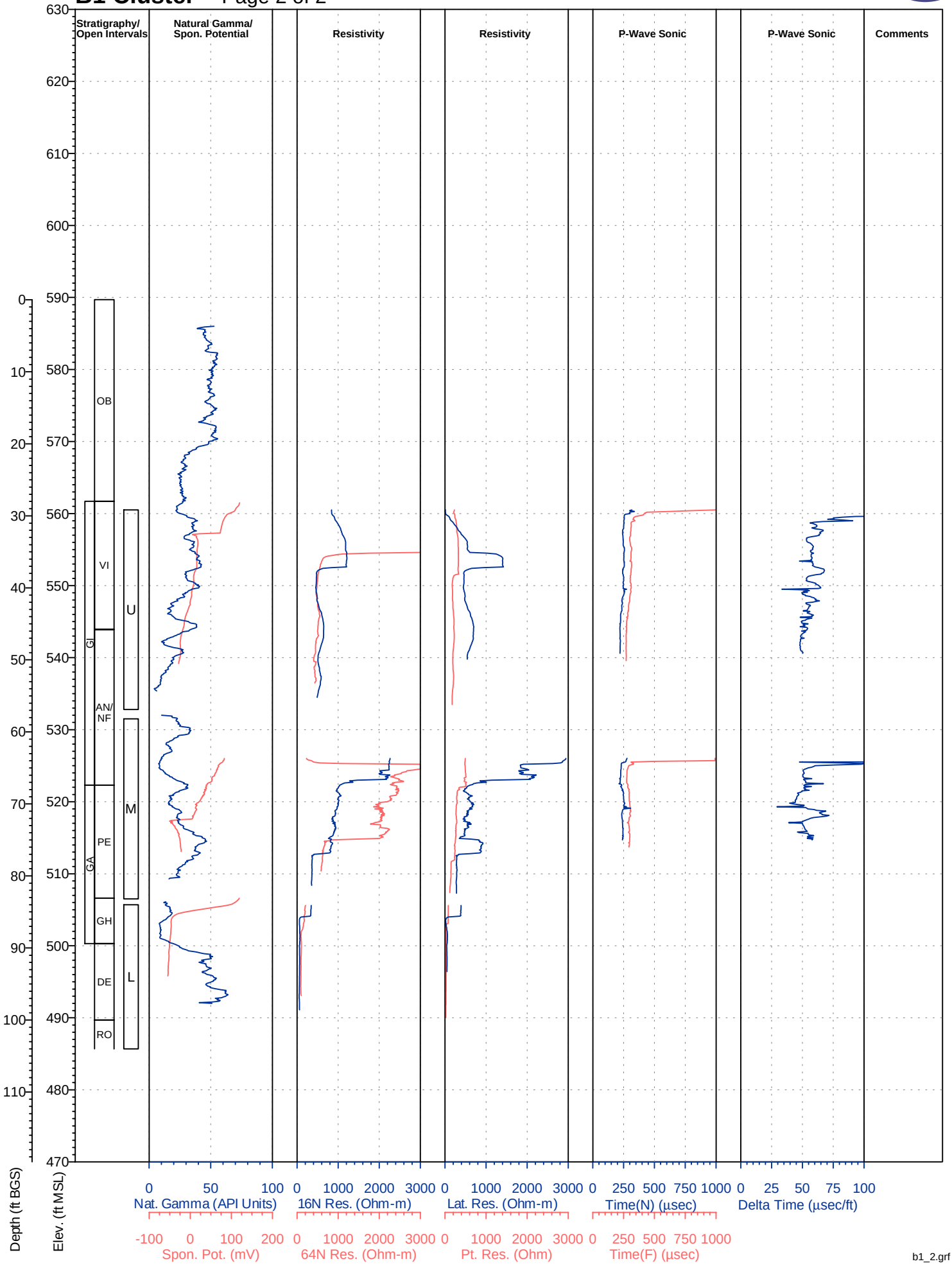
B1 Cluster



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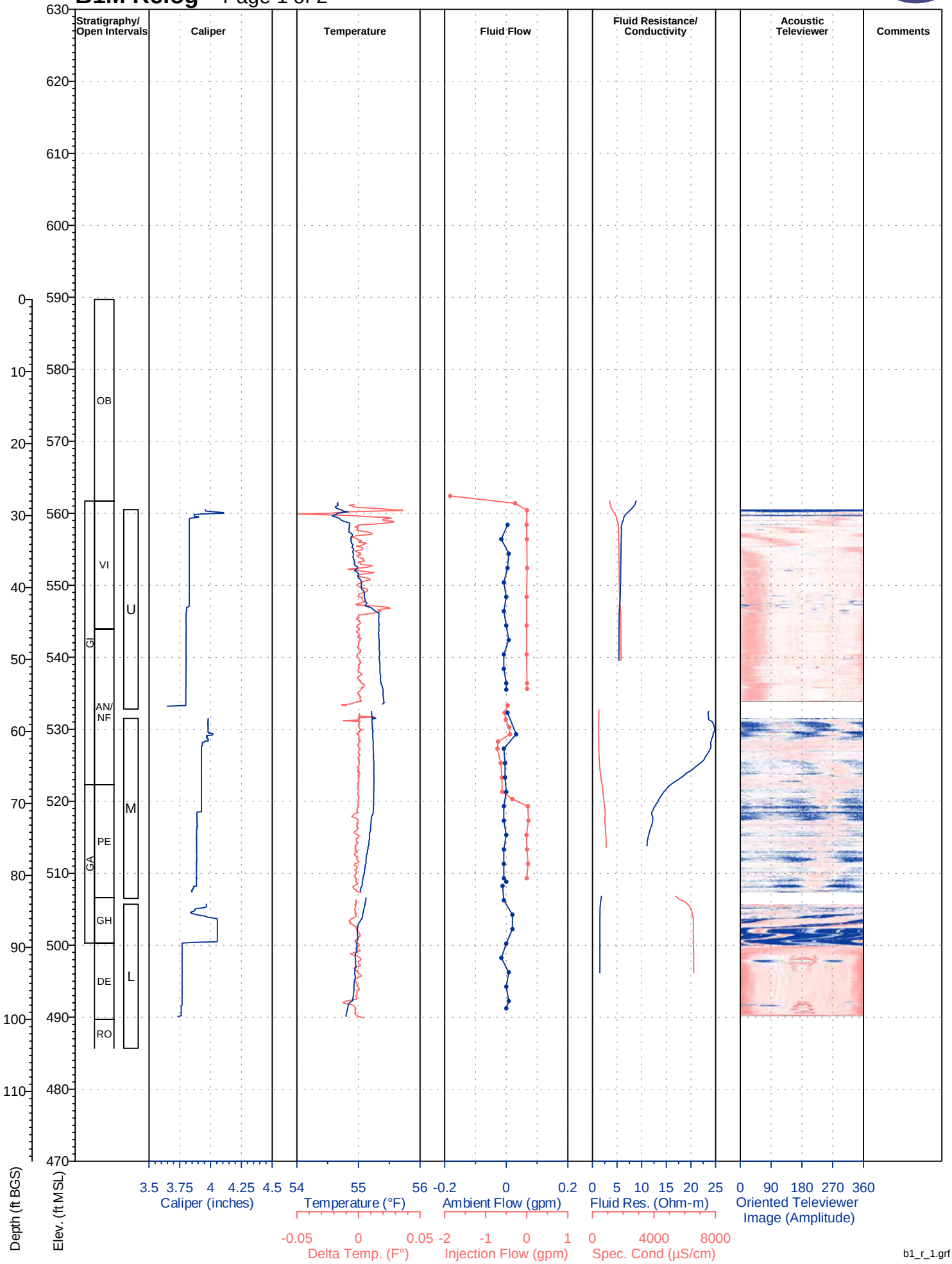

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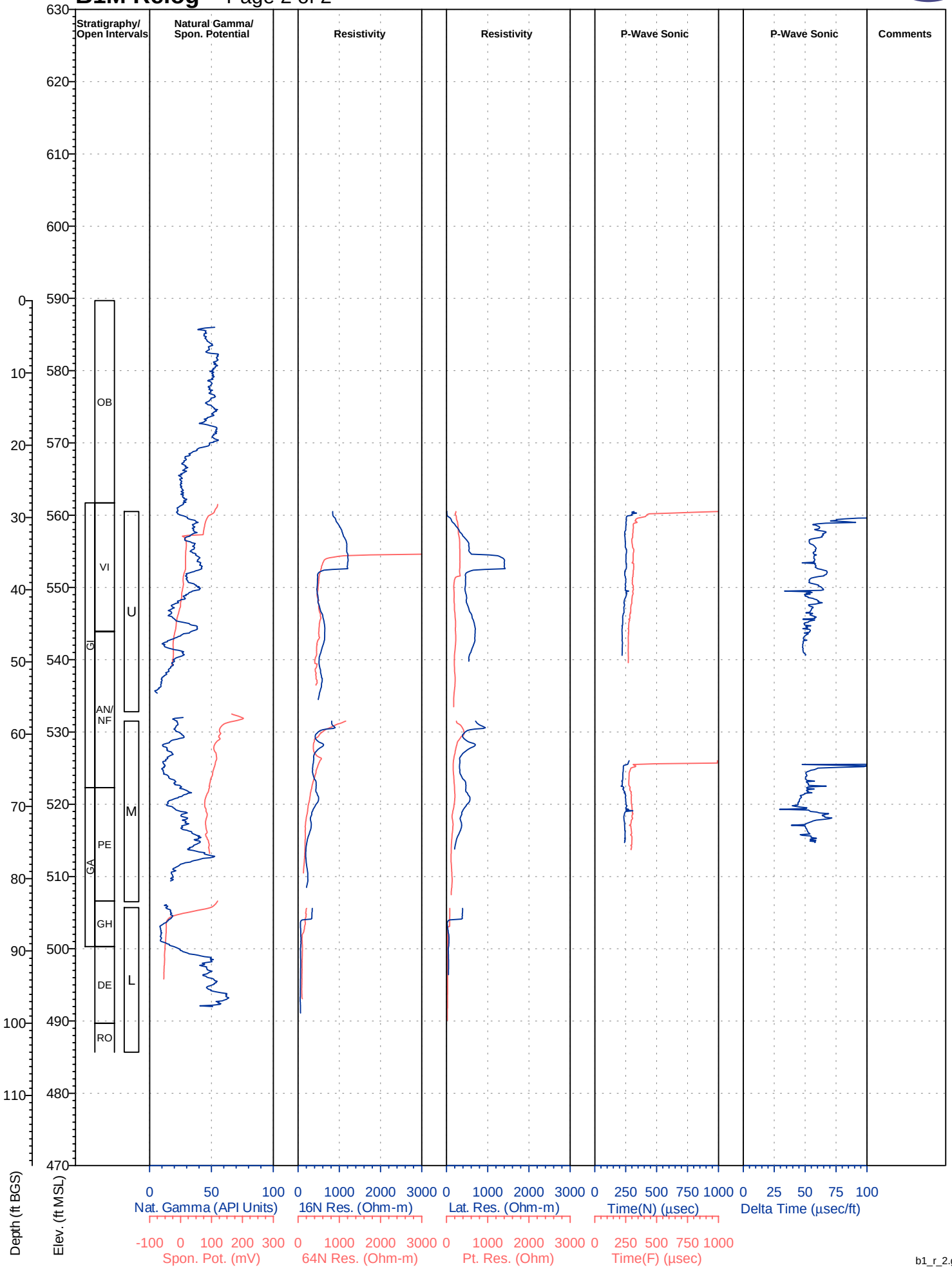
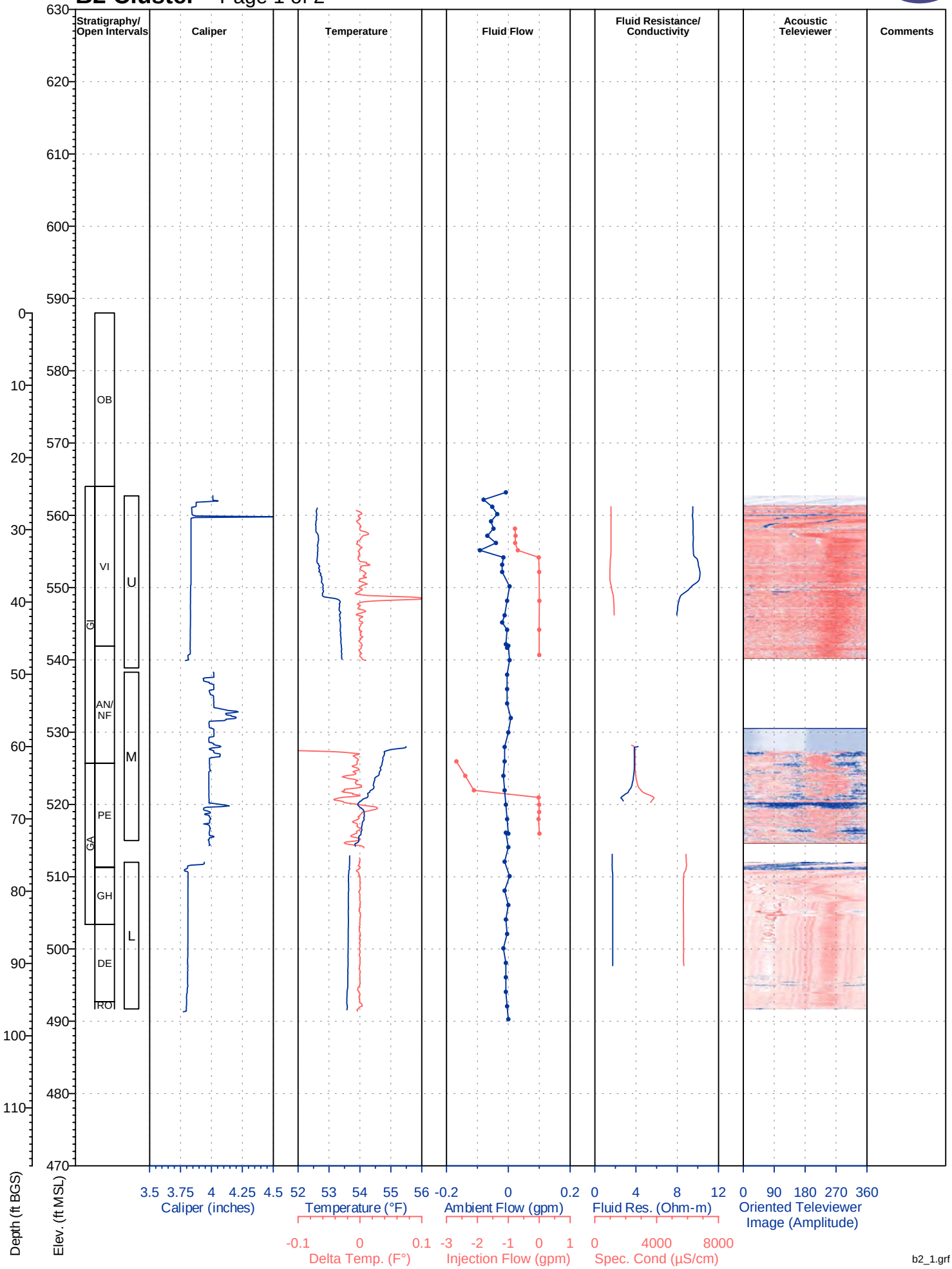
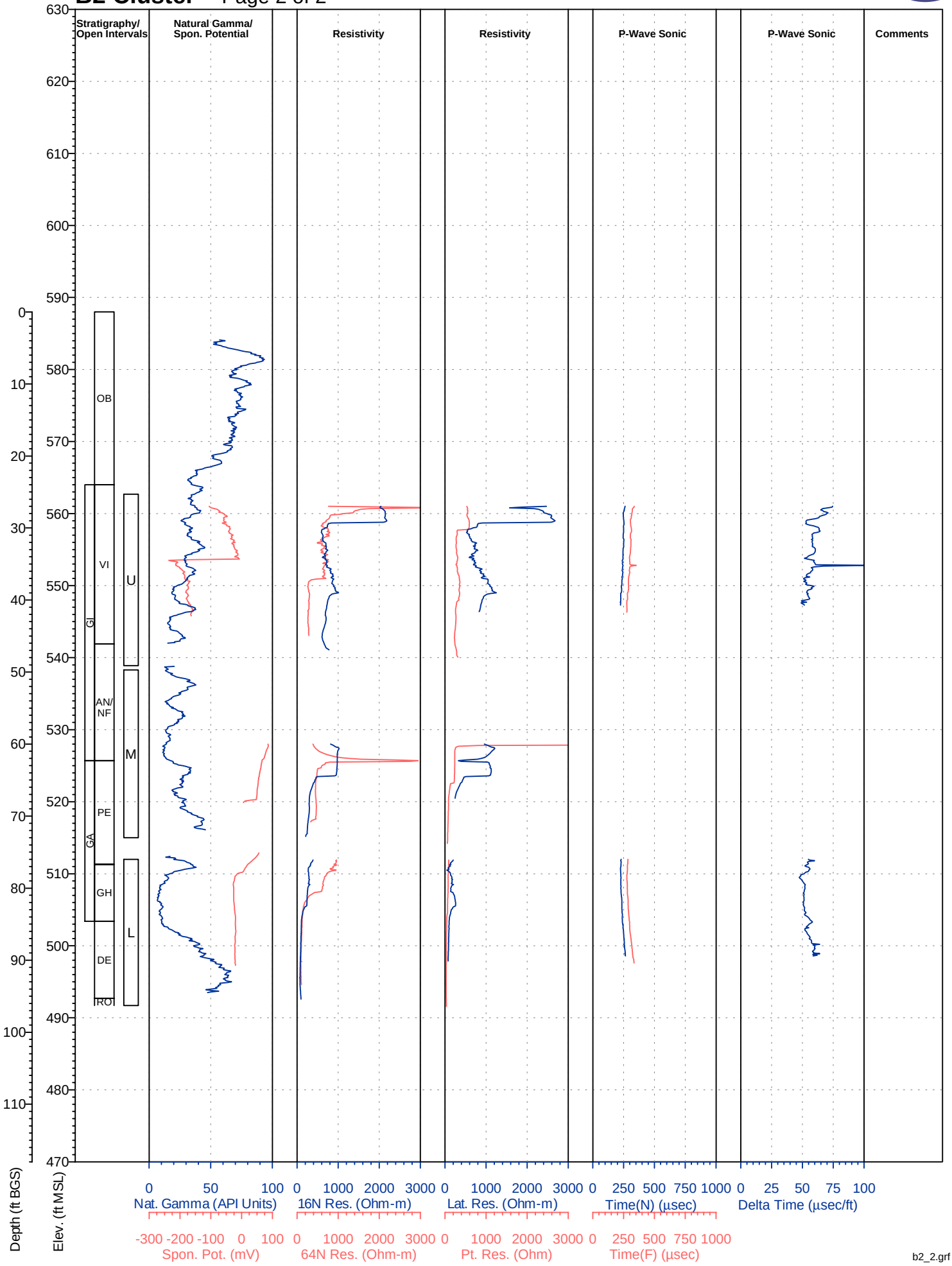

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
VI
AN/ NF
PE
GH
DE
RO
GI
GA
U
M
L
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

B2 Cluster



b2_1.grf

B2 Cluster



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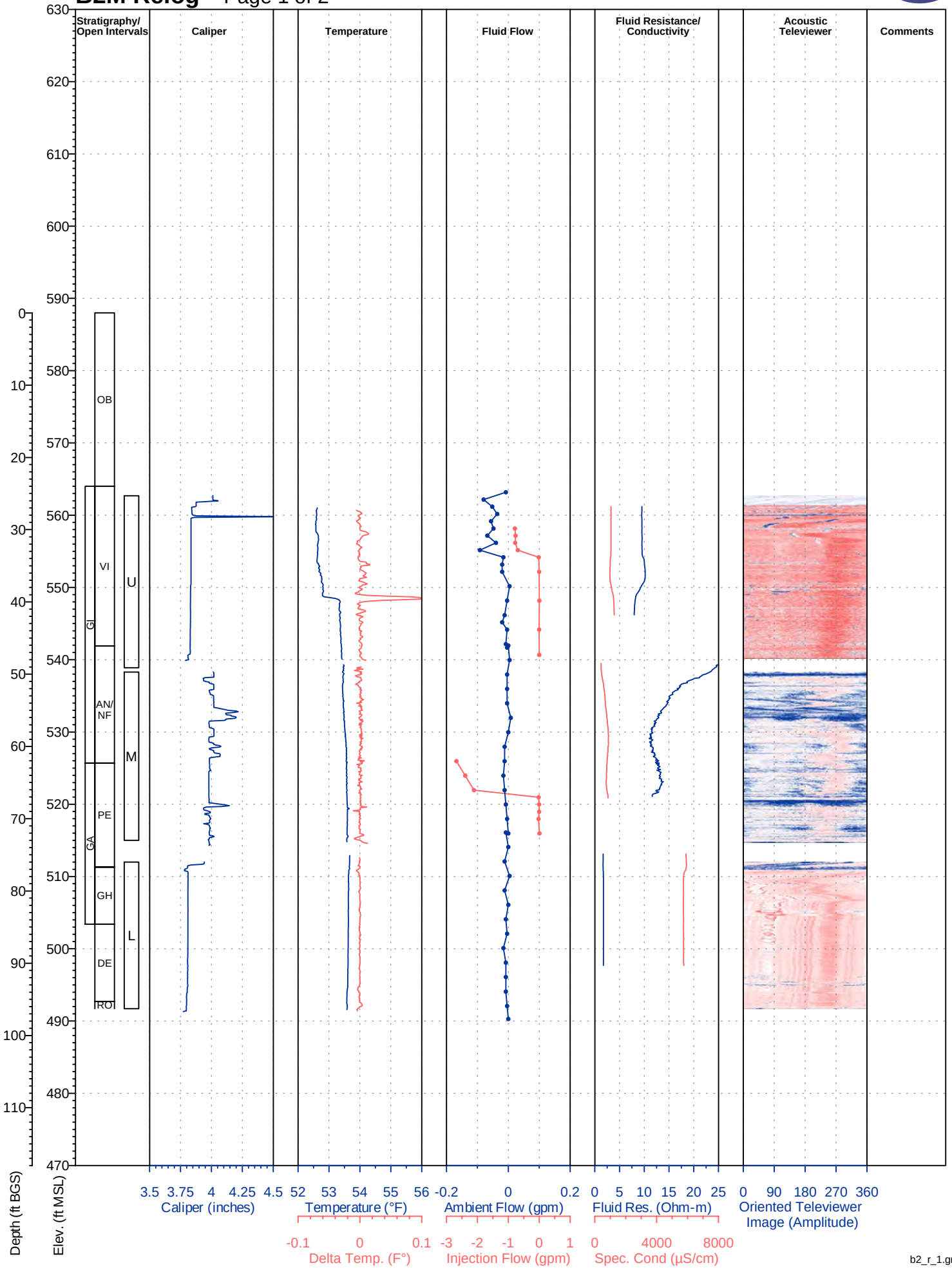

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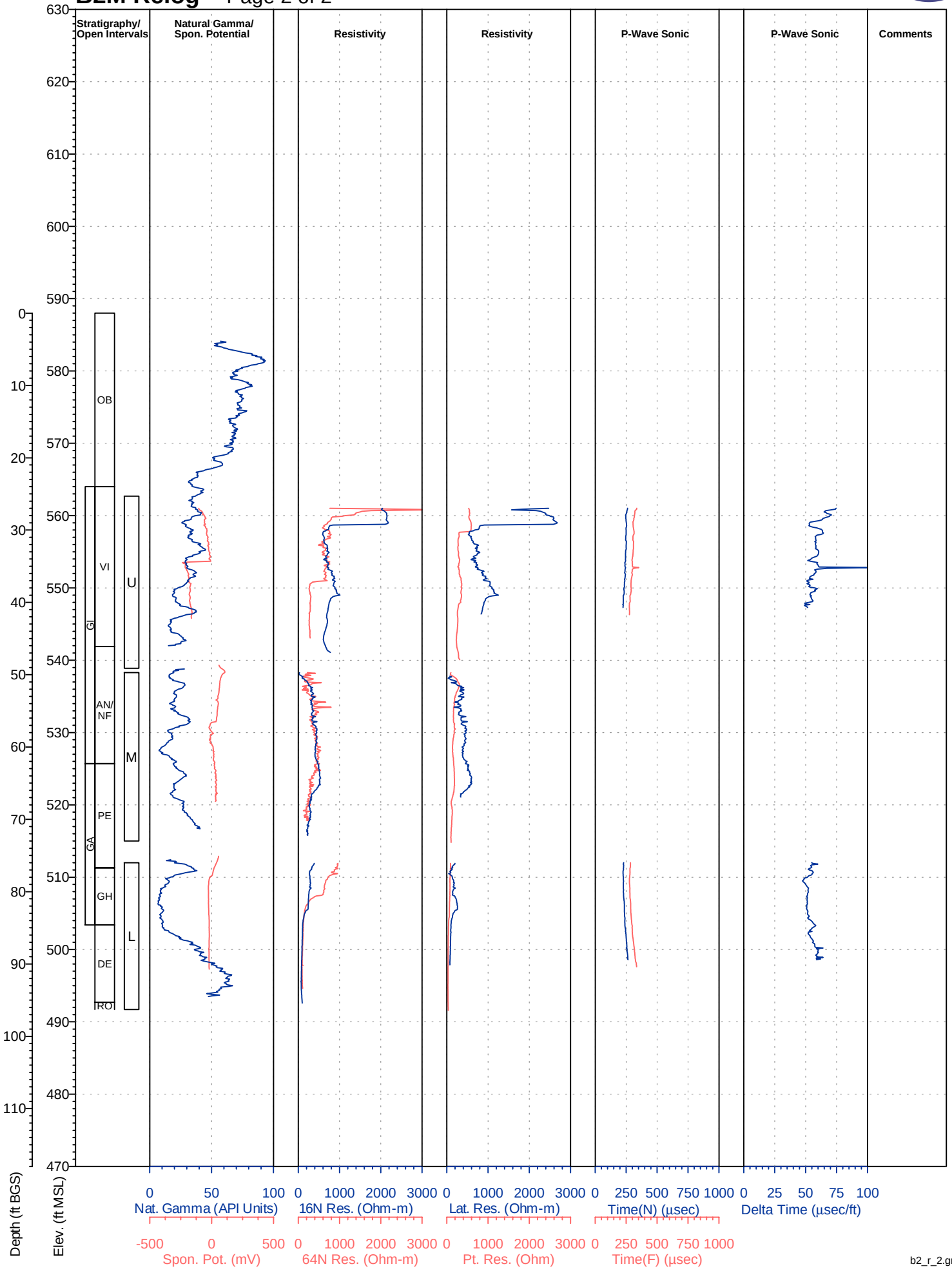
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Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
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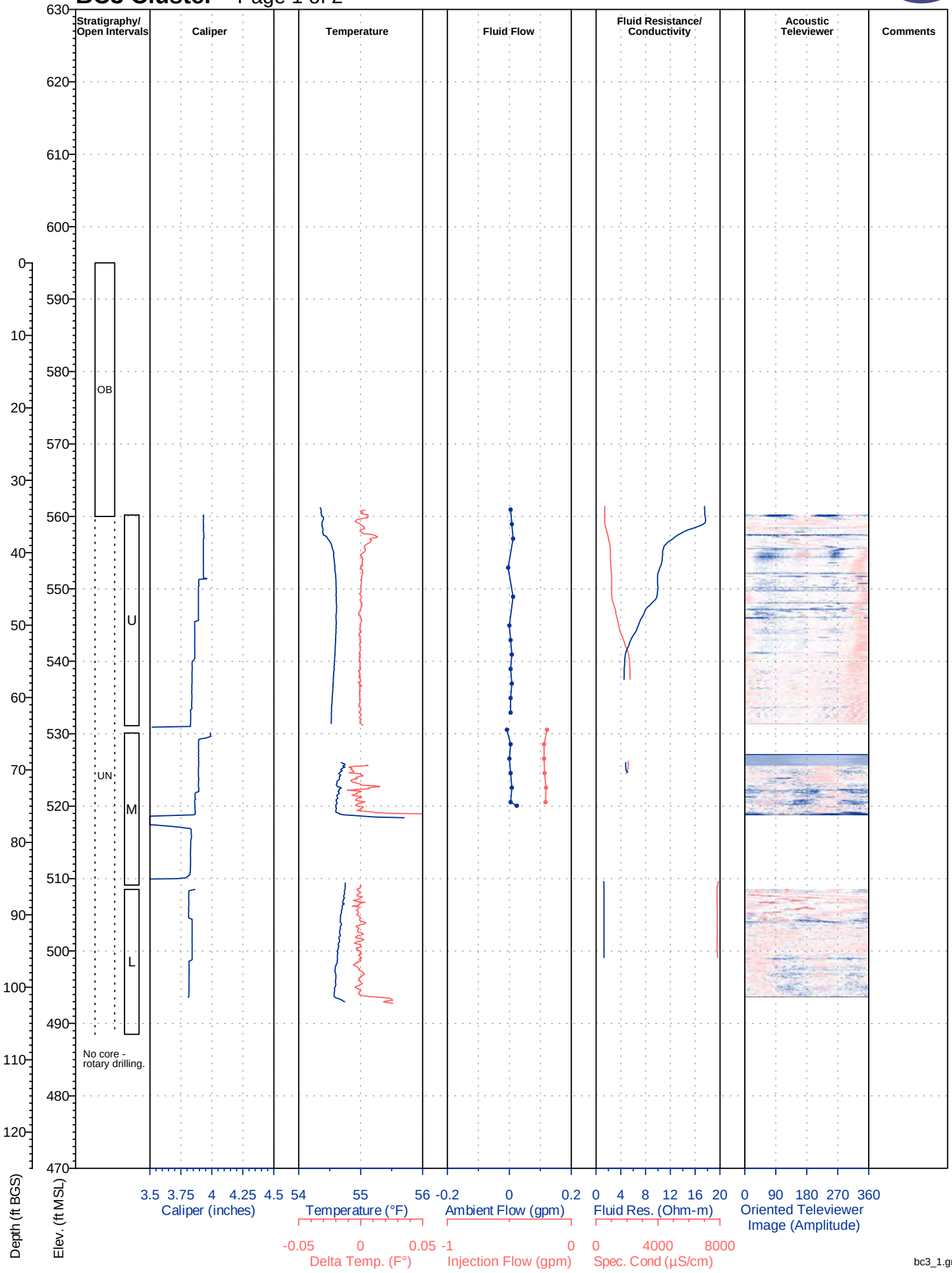
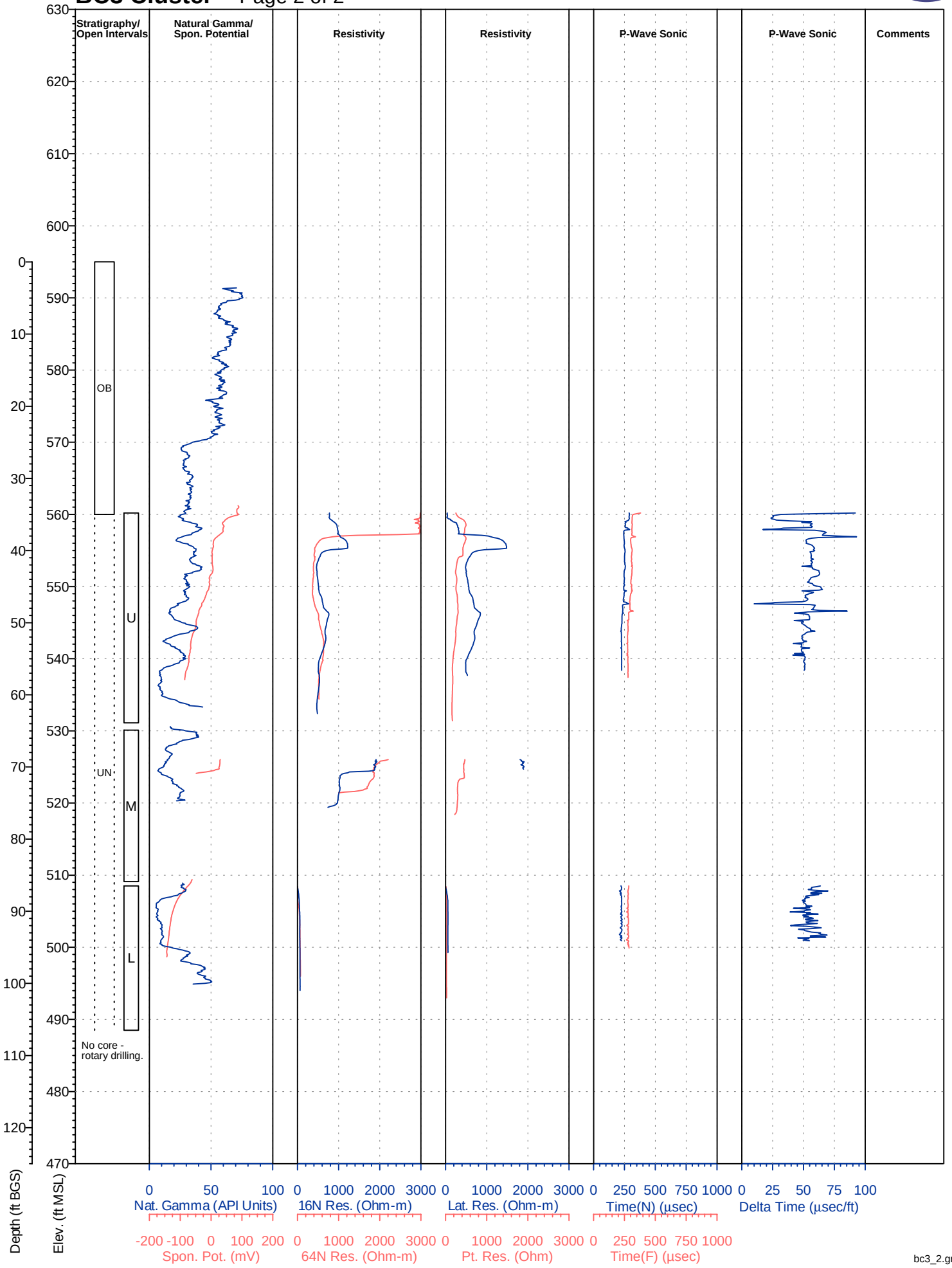
VI
AN/ NF
PE
GH
DE
RO
GI
GA
U
M
L
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

BC3 Cluster



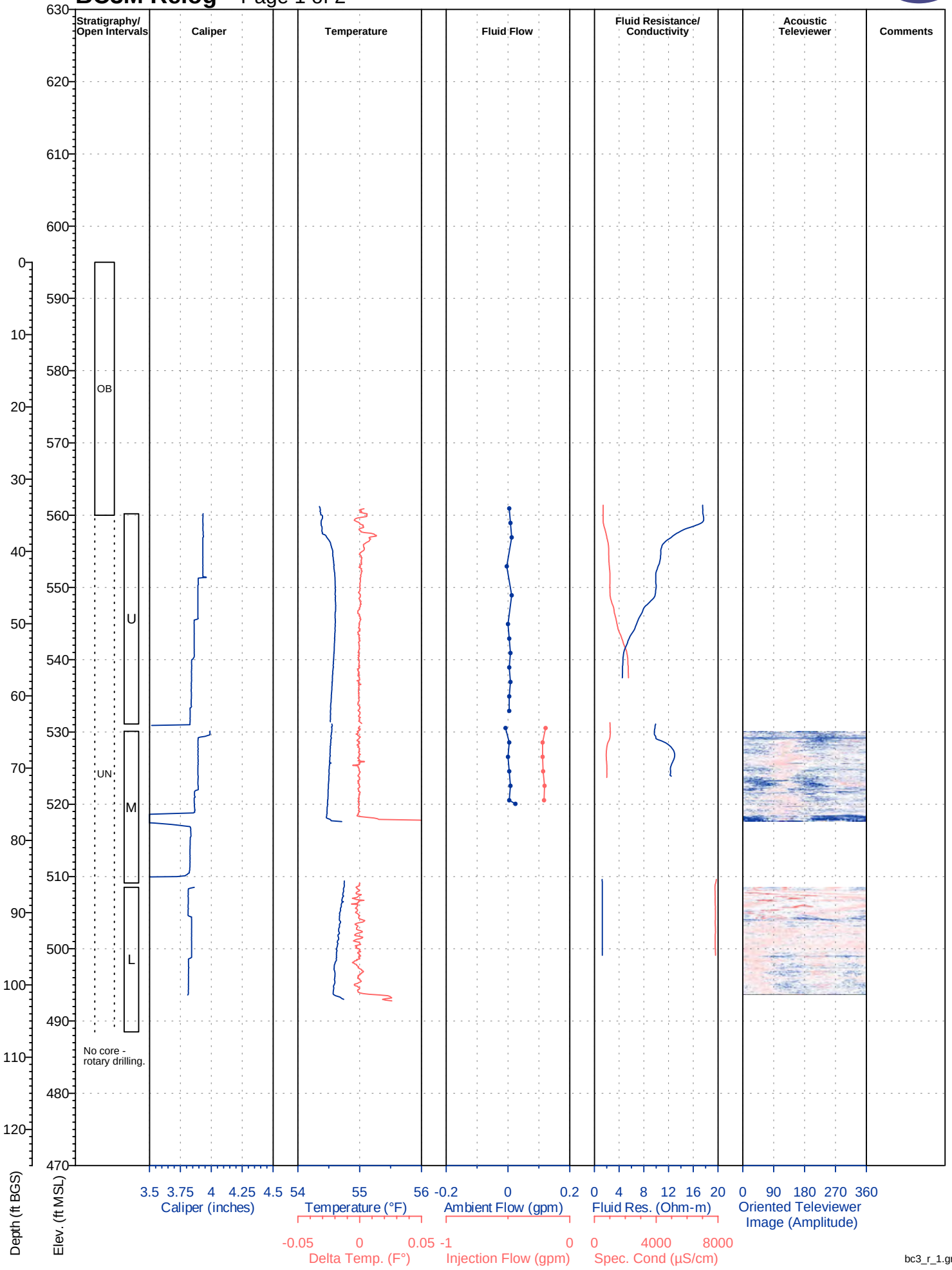
bc3_1.grf

BC3 Cluster



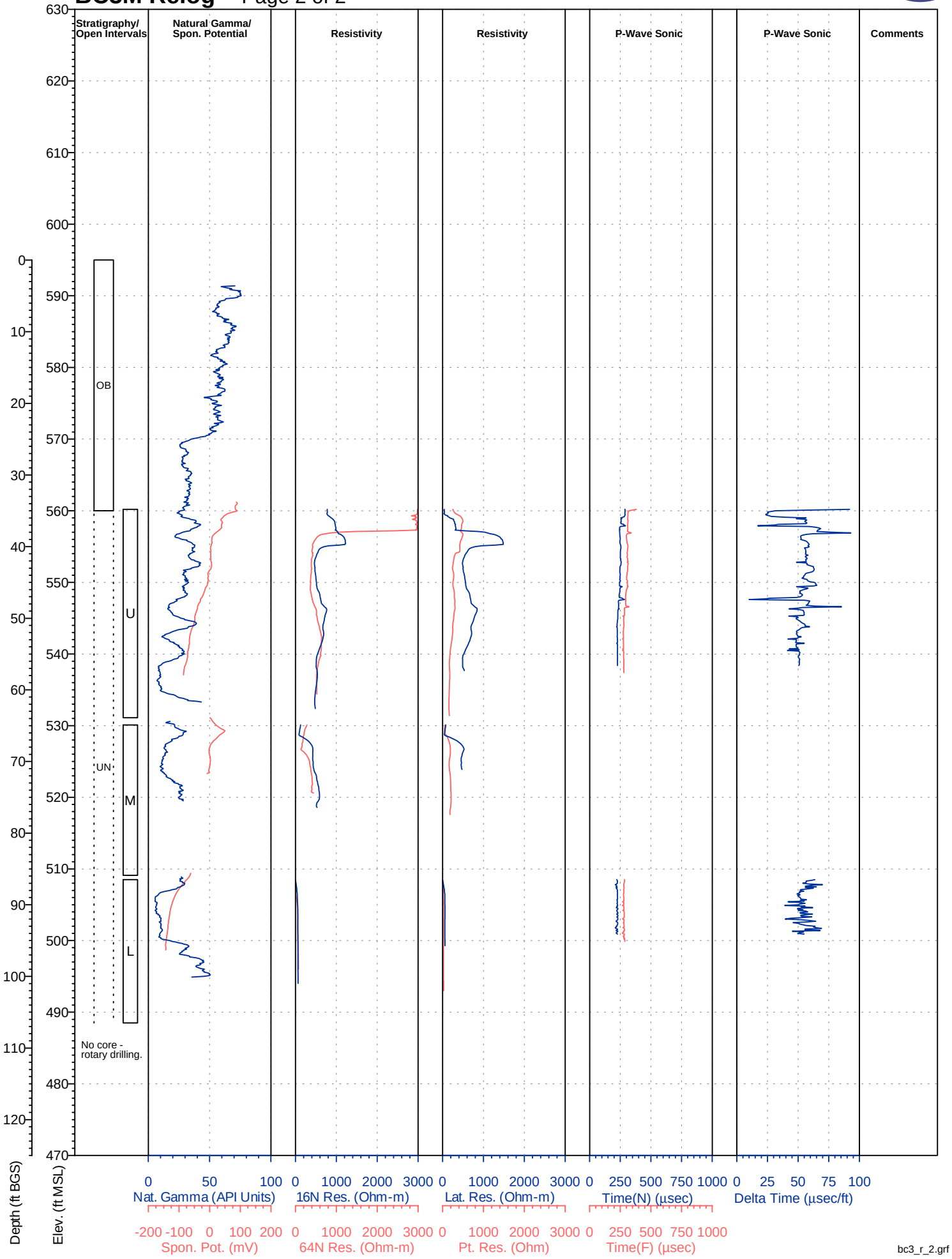
bc3_2.grf

BC3M Relog



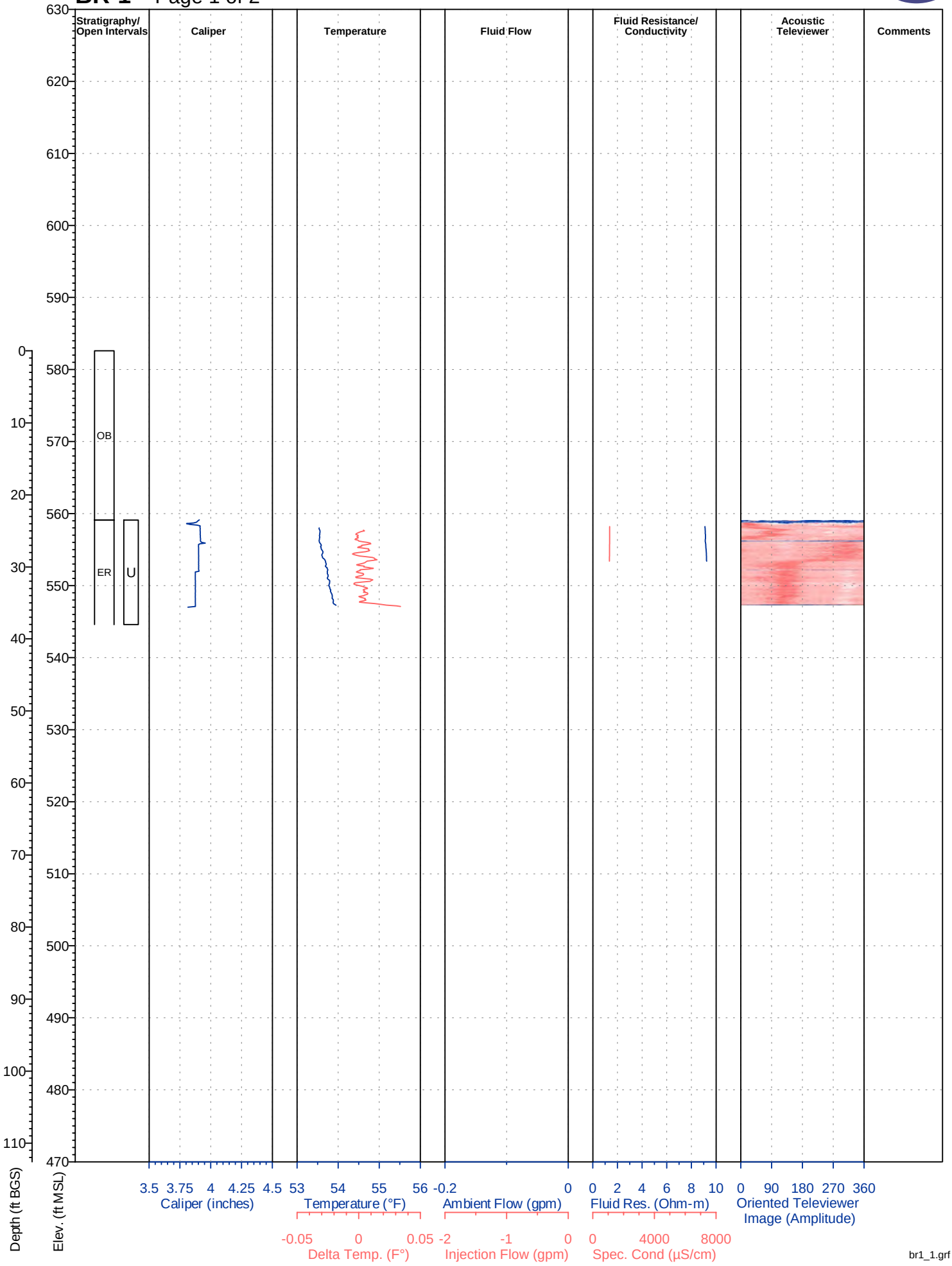
bc3_r_1.grf

BC3M Relog



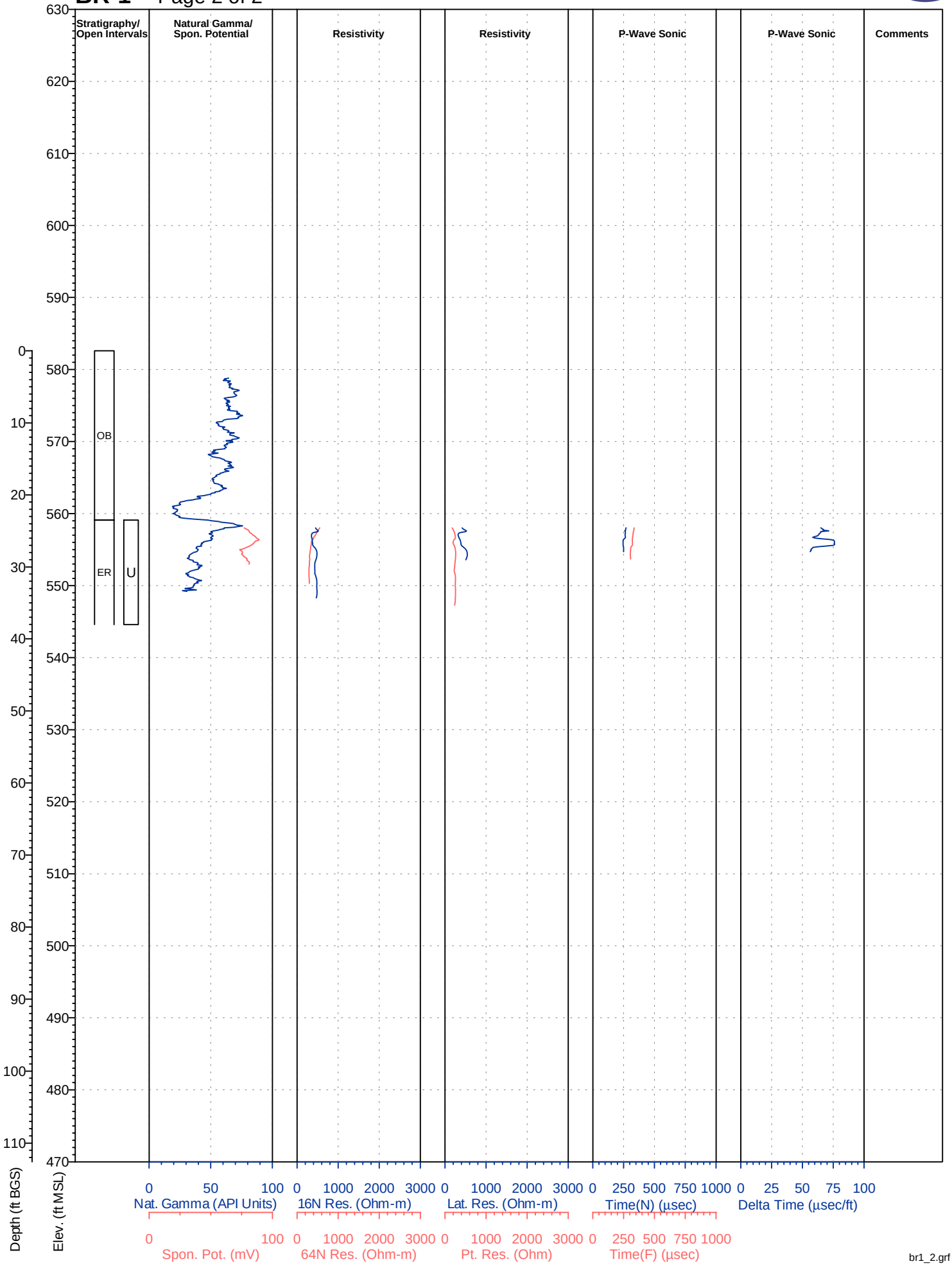
bc3_r_2.grf

BR-1 Page 1 of 2



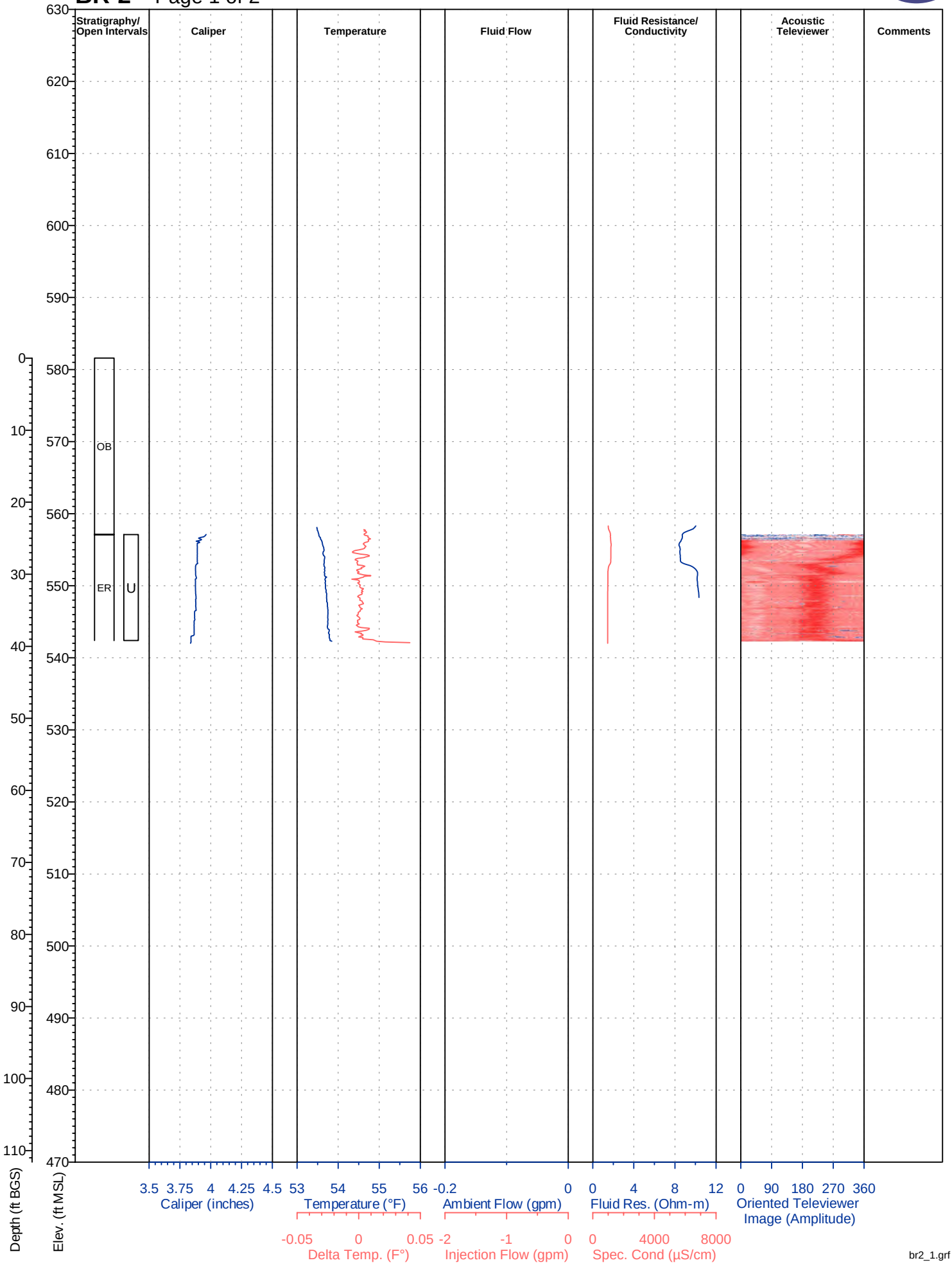
br1_1.grf

BR-1


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
U
Depth (ft BGS)
Elev. (ft MSL)
0 50 100
Nat. Gamma (API Units)
0 100
Spon. Pot. (mV)
0 1000 2000 3000
16N Res. (Ohm-m)
0 1000 2000 3000
64N Res. (Ohm-m)
0 1000 2000 3000
Lat. Res. (Ohm-m)
0 1000 2000 3000
Pt. Res. (Ohm)
0 250 500 750 1000
Time(N) (µsec)
0 250 500 750 1000
Time(F) (µsec)
0 25 50 75 100
Delta Time (µsec/ft)

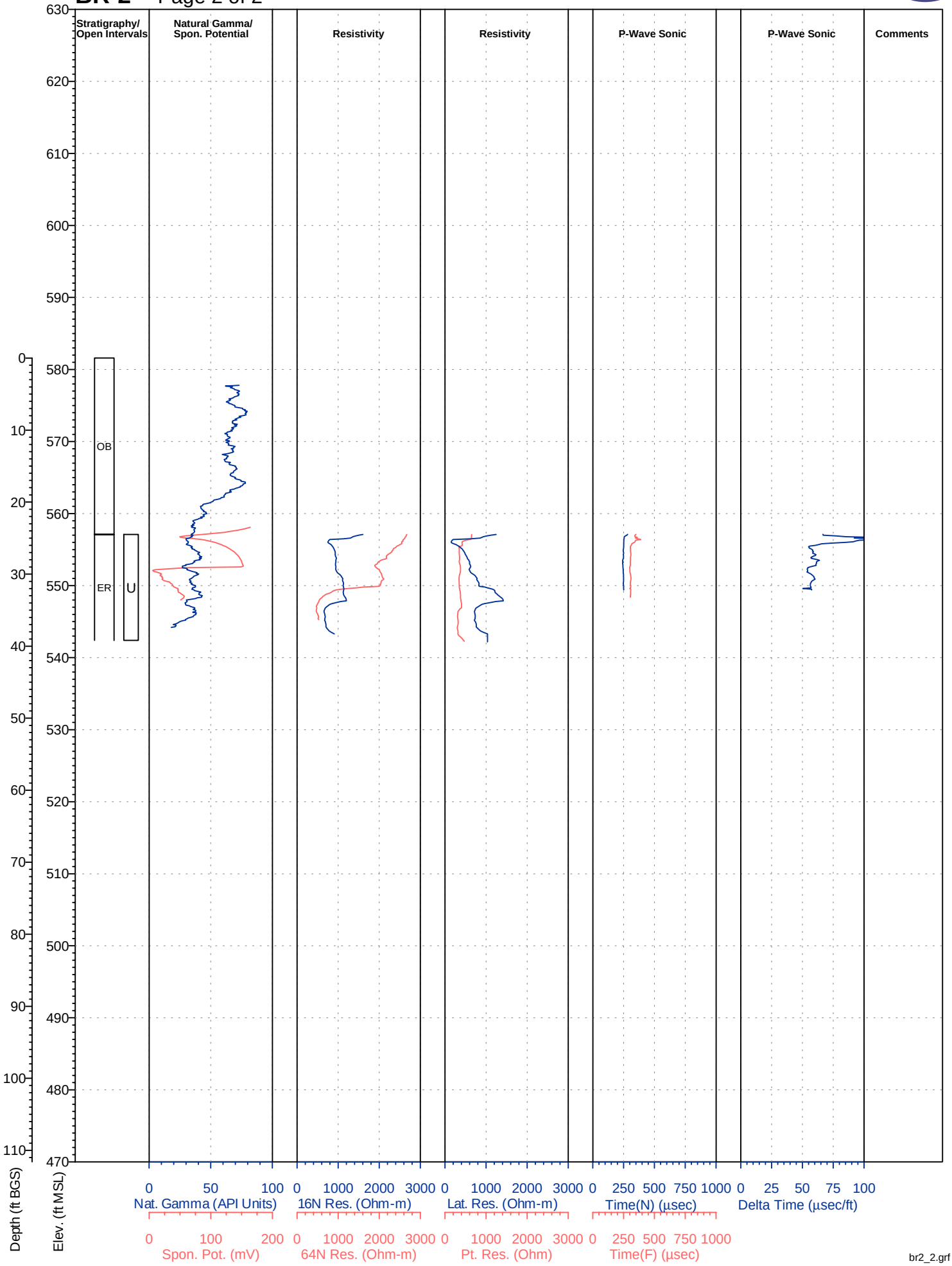
br1_2.grf

BR-2 Page 1 of 2



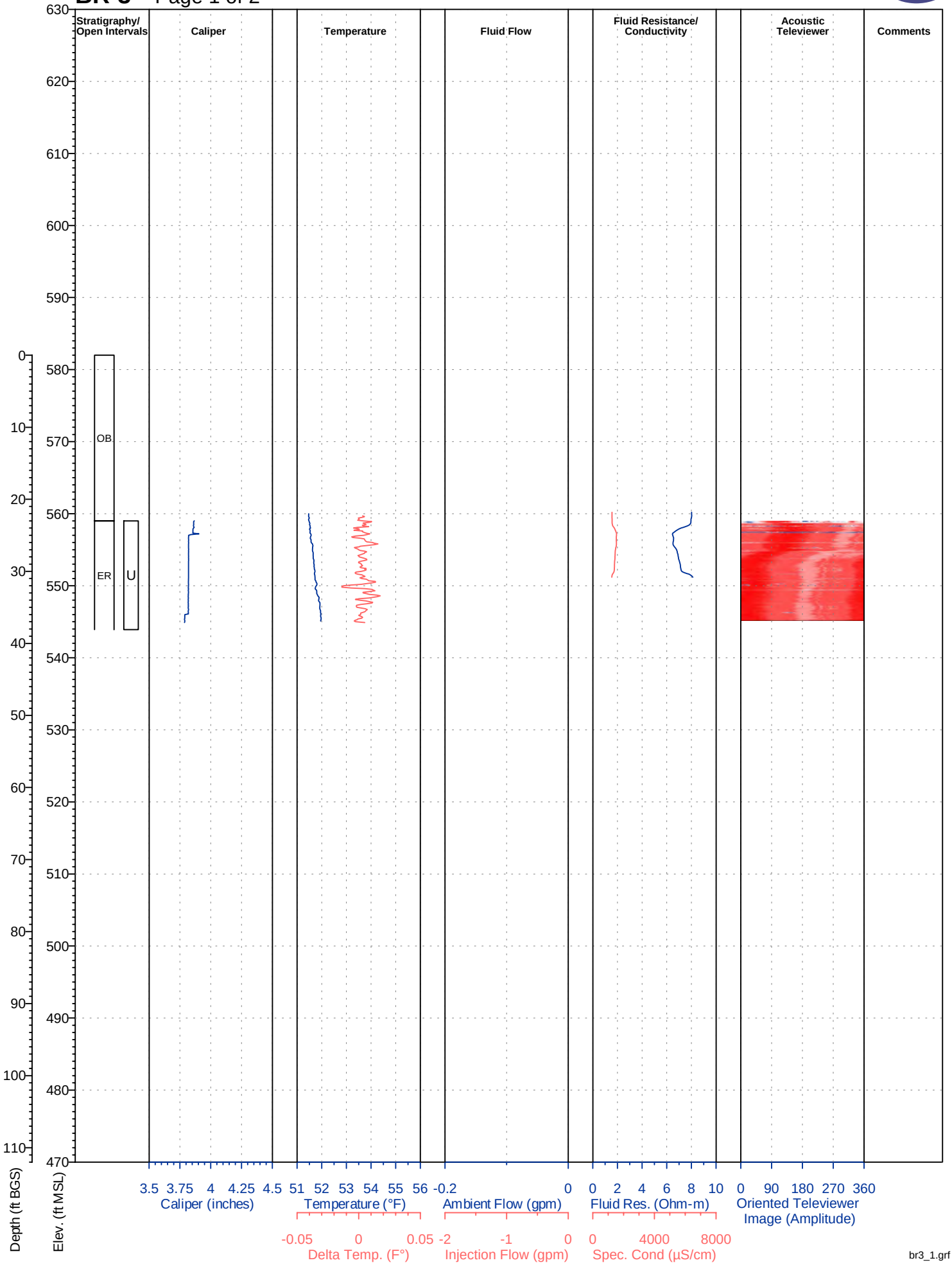
br2_1.grf

BR-2


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
U
Depth (ft BGS)
Elev. (ft MSL)
0 50 100
Nat. Gamma (API Units)
0 100 200
Spon. Pot. (mV)
0 1000 2000 3000
16N Res. (Ohm-m)
0 1000 2000 3000
64N Res. (Ohm-m)
0 1000 2000 3000
Lat. Res. (Ohm-m)
0 1000 2000 3000
Pt. Res. (Ohm)
0 250 500 750 1000
Time(N) (µsec)
0 250 500 750 1000
Time(F) (µsec)
0 25 50 75 100
Delta Time (µsec/ft)

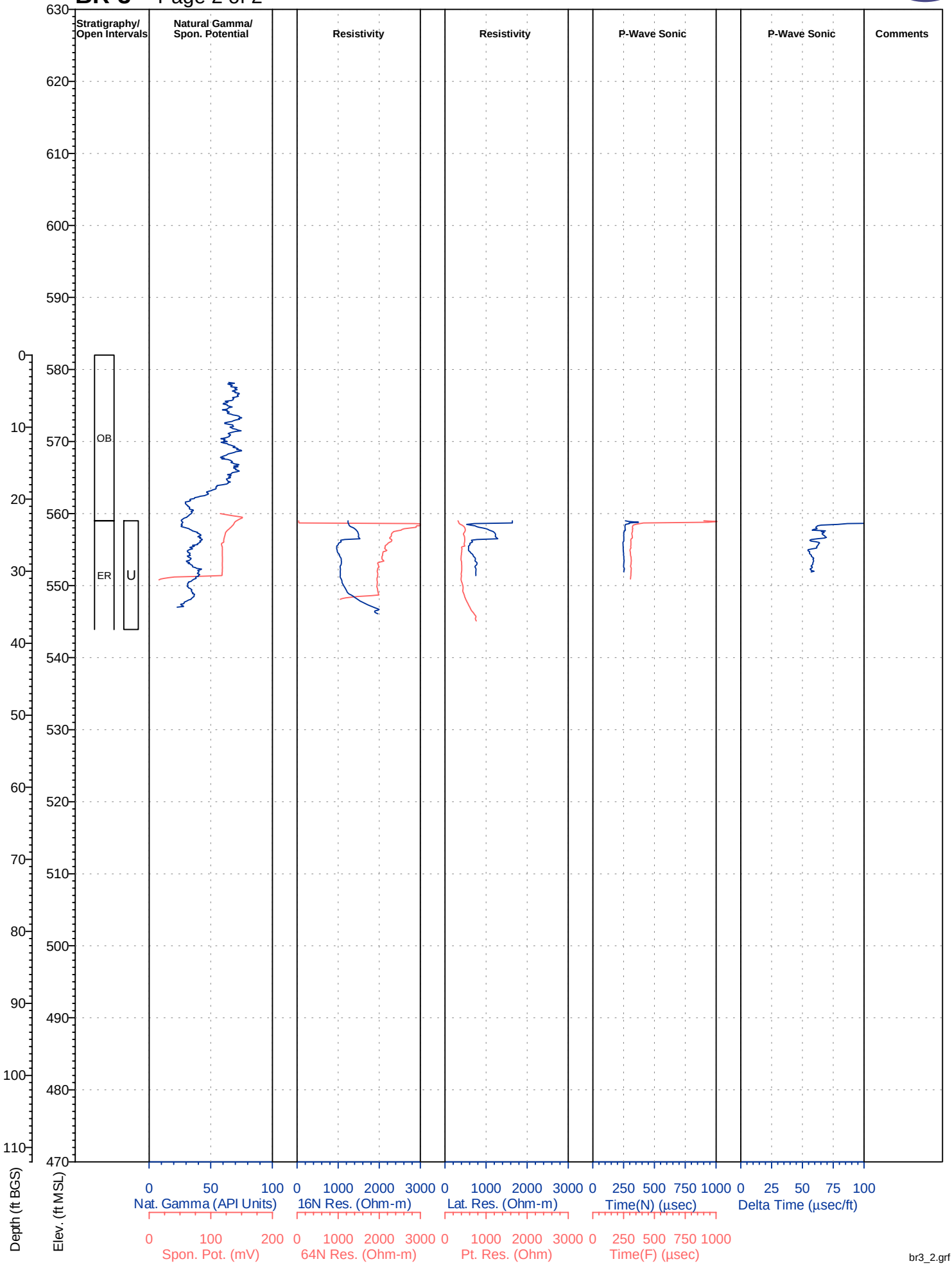
br2_2.grf

BR-3 Page 1 of 2



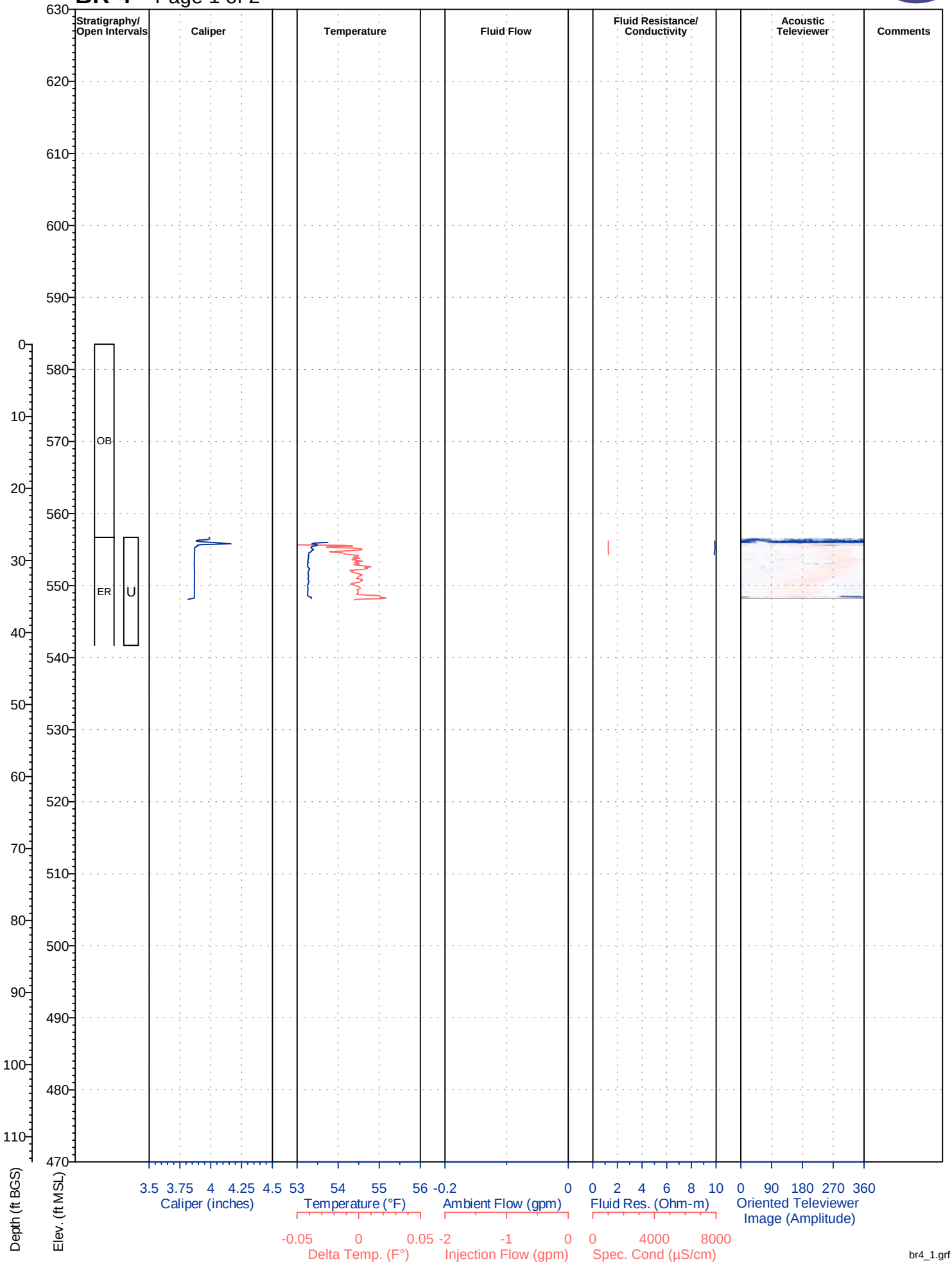
br3_1.grf

BR-3


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
U
Depth (ft BGS)
Elev. (ft MSL)
0 50 100
Nat. Gamma (API Units)
0 100 200
Spon. Pot. (mV)
0 1000 2000 3000
16N Res. (Ohm-m)
0 1000 2000 3000
64N Res. (Ohm-m)
0 1000 2000 3000
Lat. Res. (Ohm-m)
0 1000 2000 3000
Pt. Res. (Ohm)
0 250 500 750 1000
Time(N) (µsec)
0 250 500 750 1000
Time(F) (µsec)
0 25 50 75 100
Delta Time (µsec/ft)

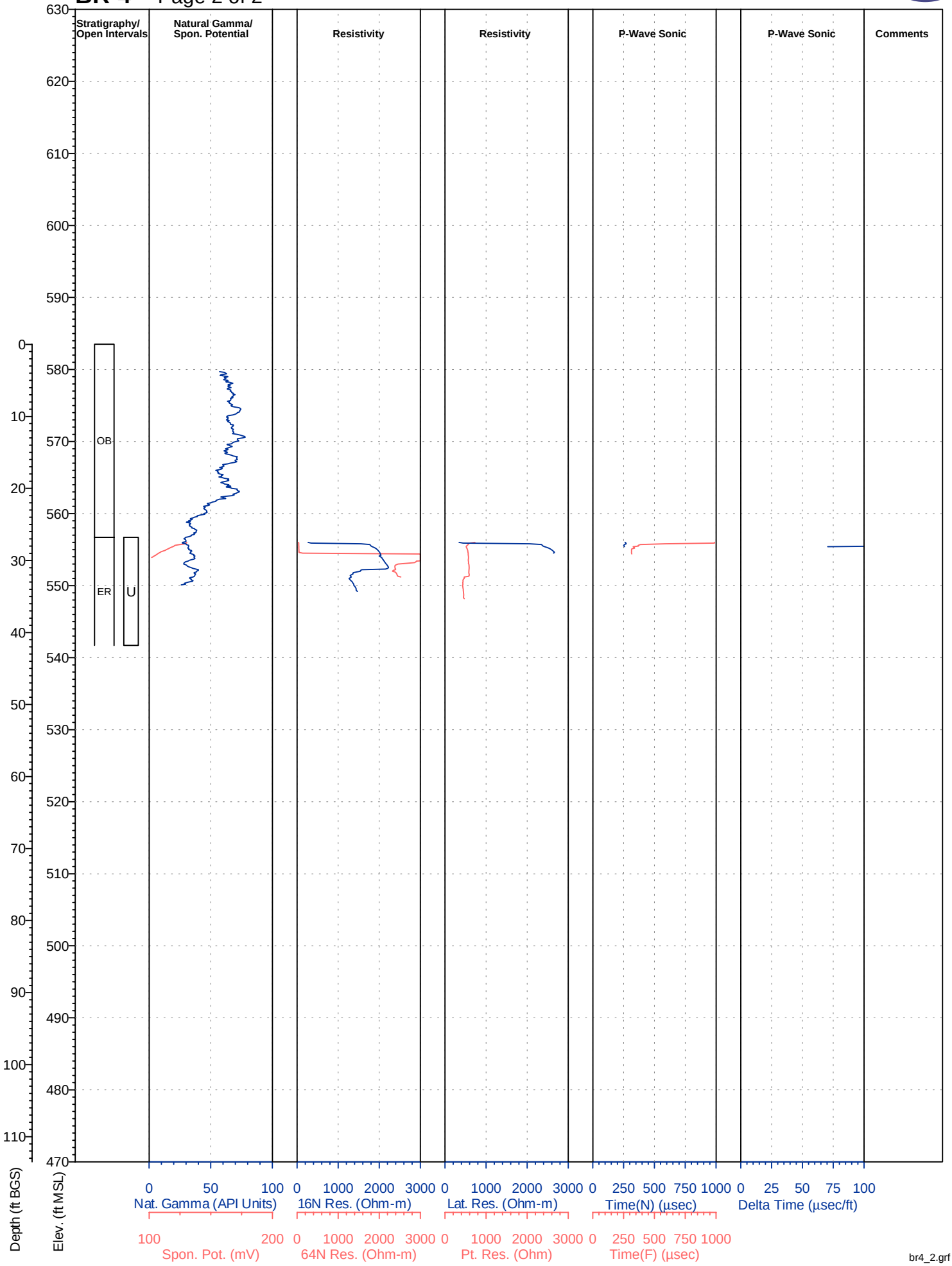
br3_2.grf

BR-4 Page 1 of 2

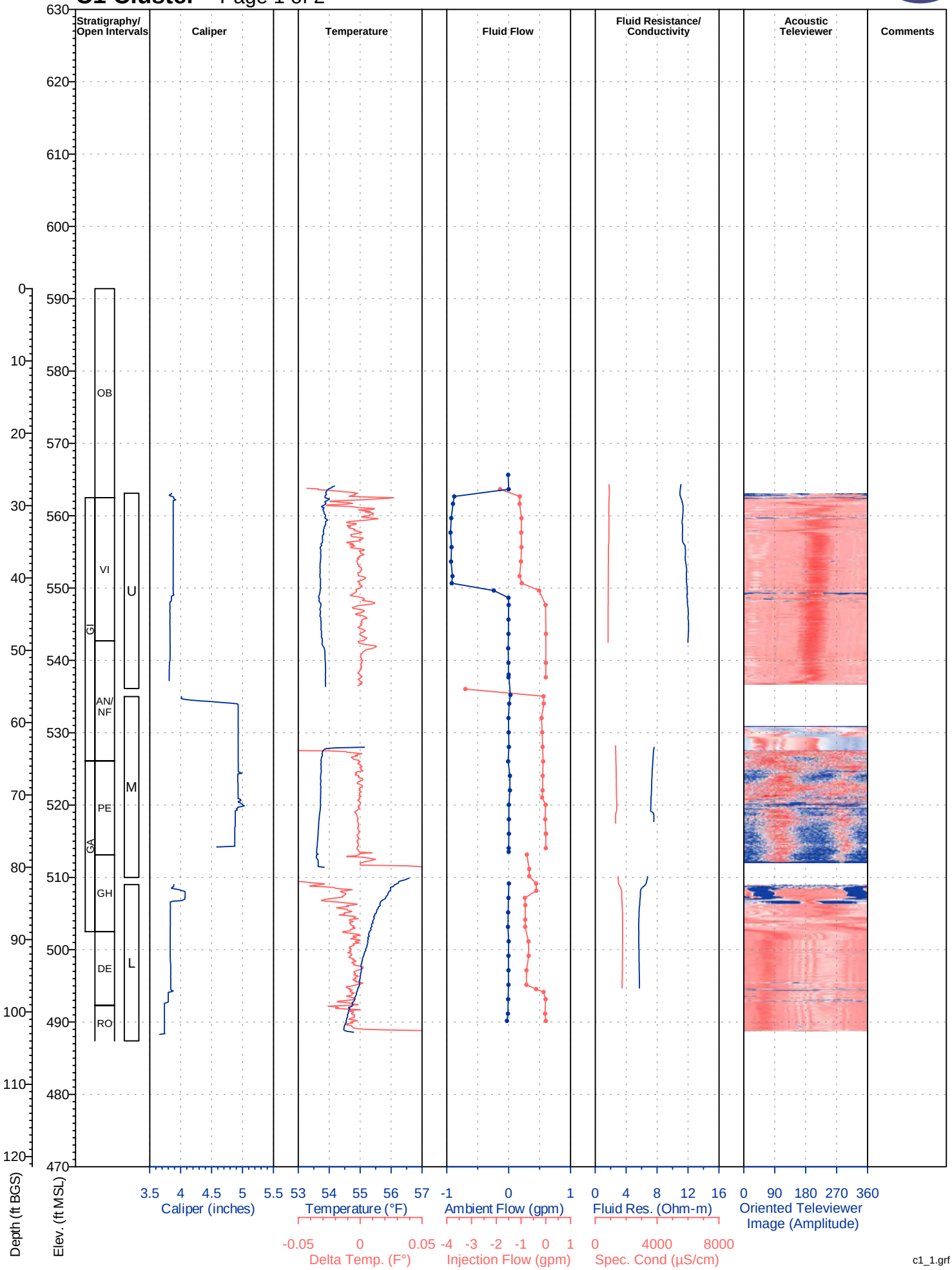


br4_1.grf

BR-4 Page 2 of 2

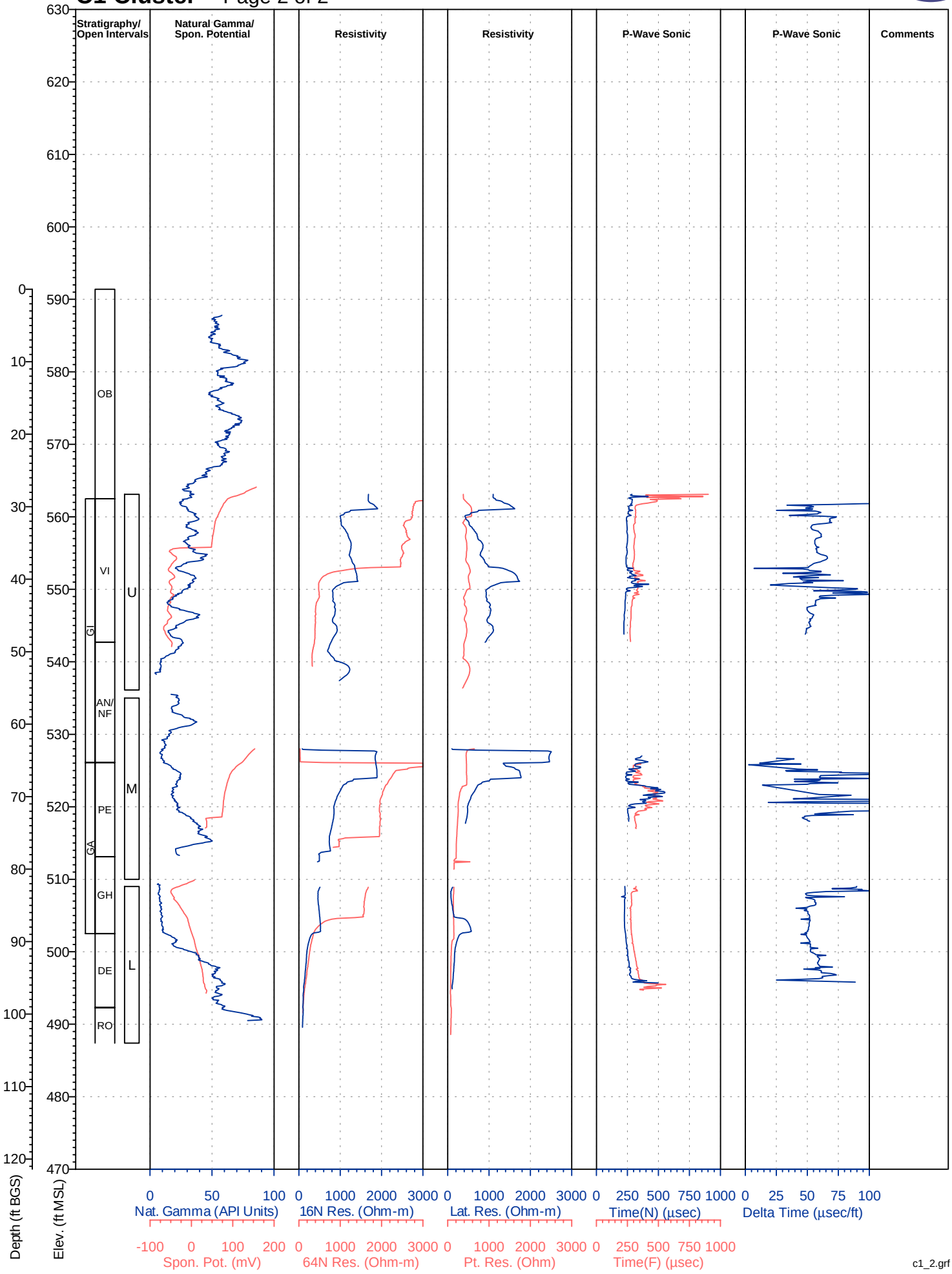


C1 Cluster



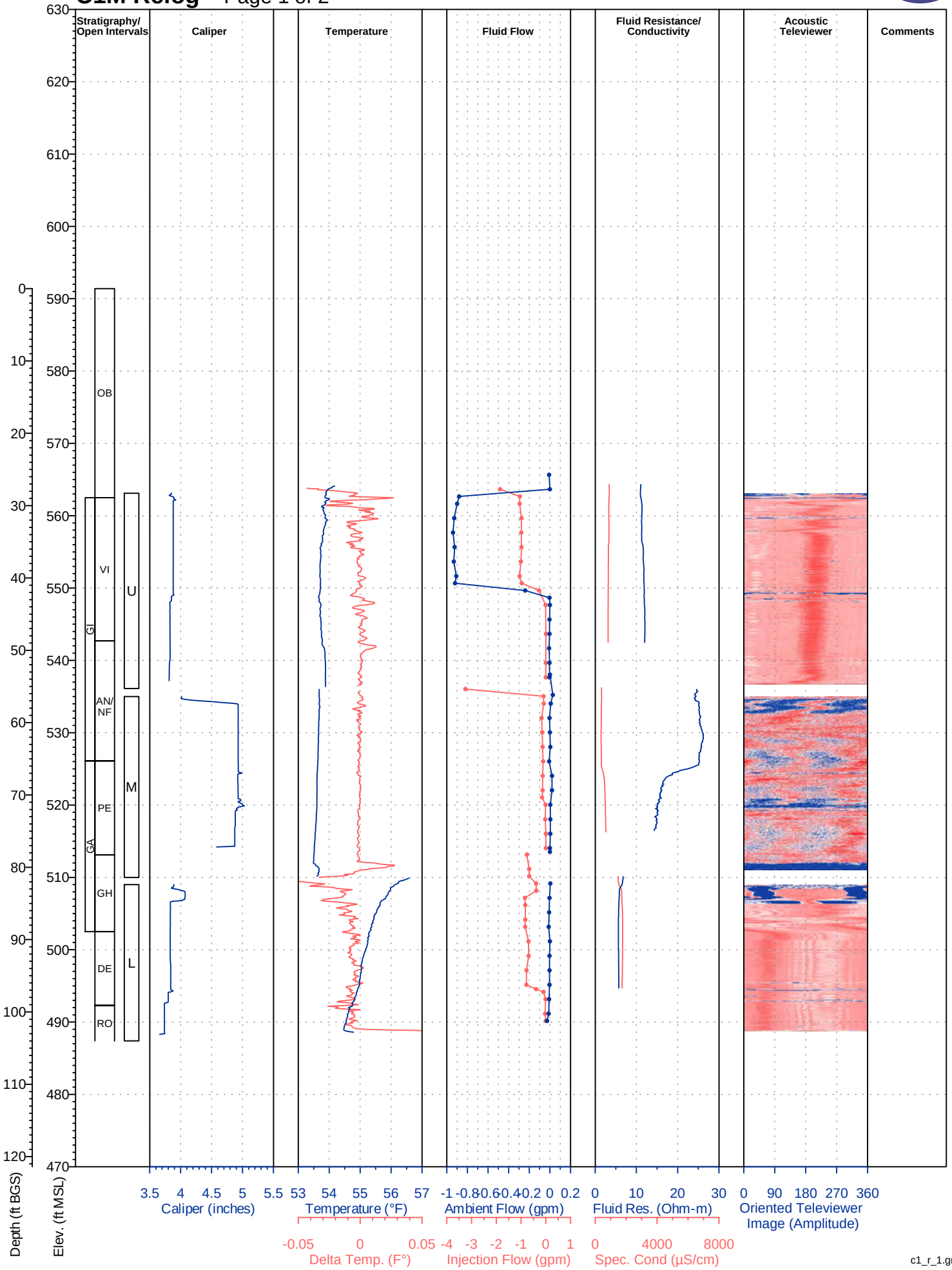
c1_1.grf

C1 Cluster



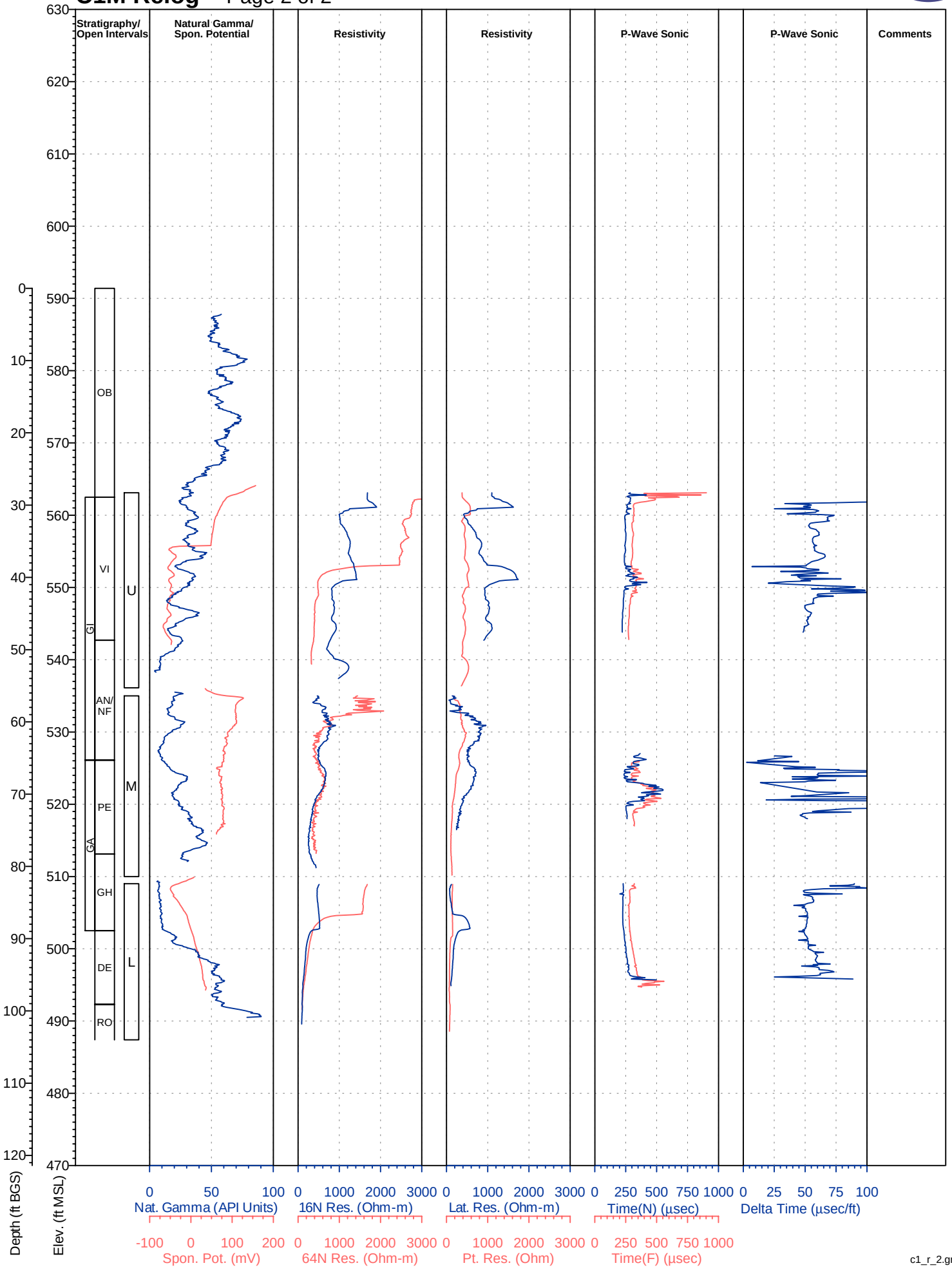
c1_2.grf

C1M Relog

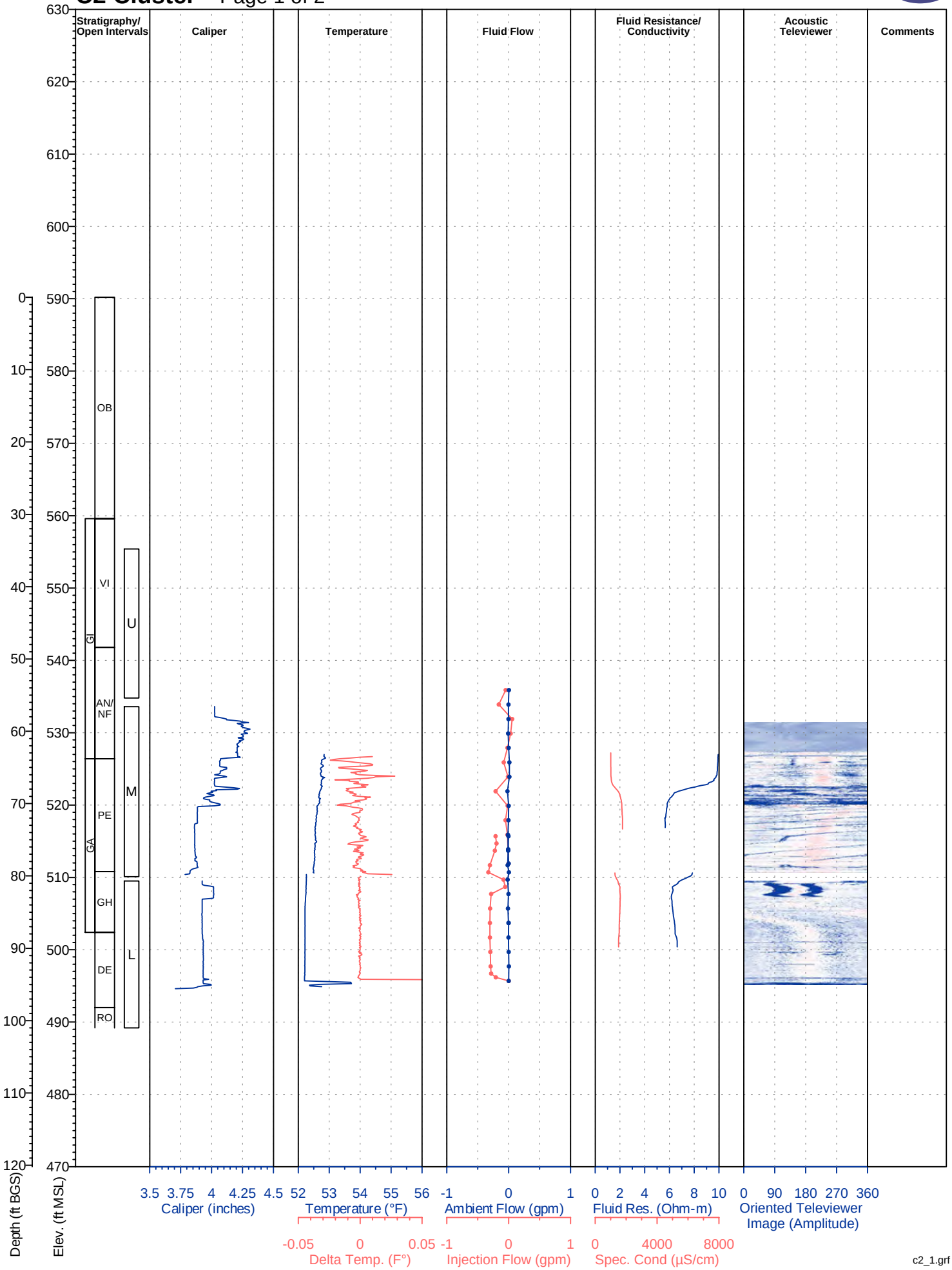


c1_r_1.grf

C1M Relog

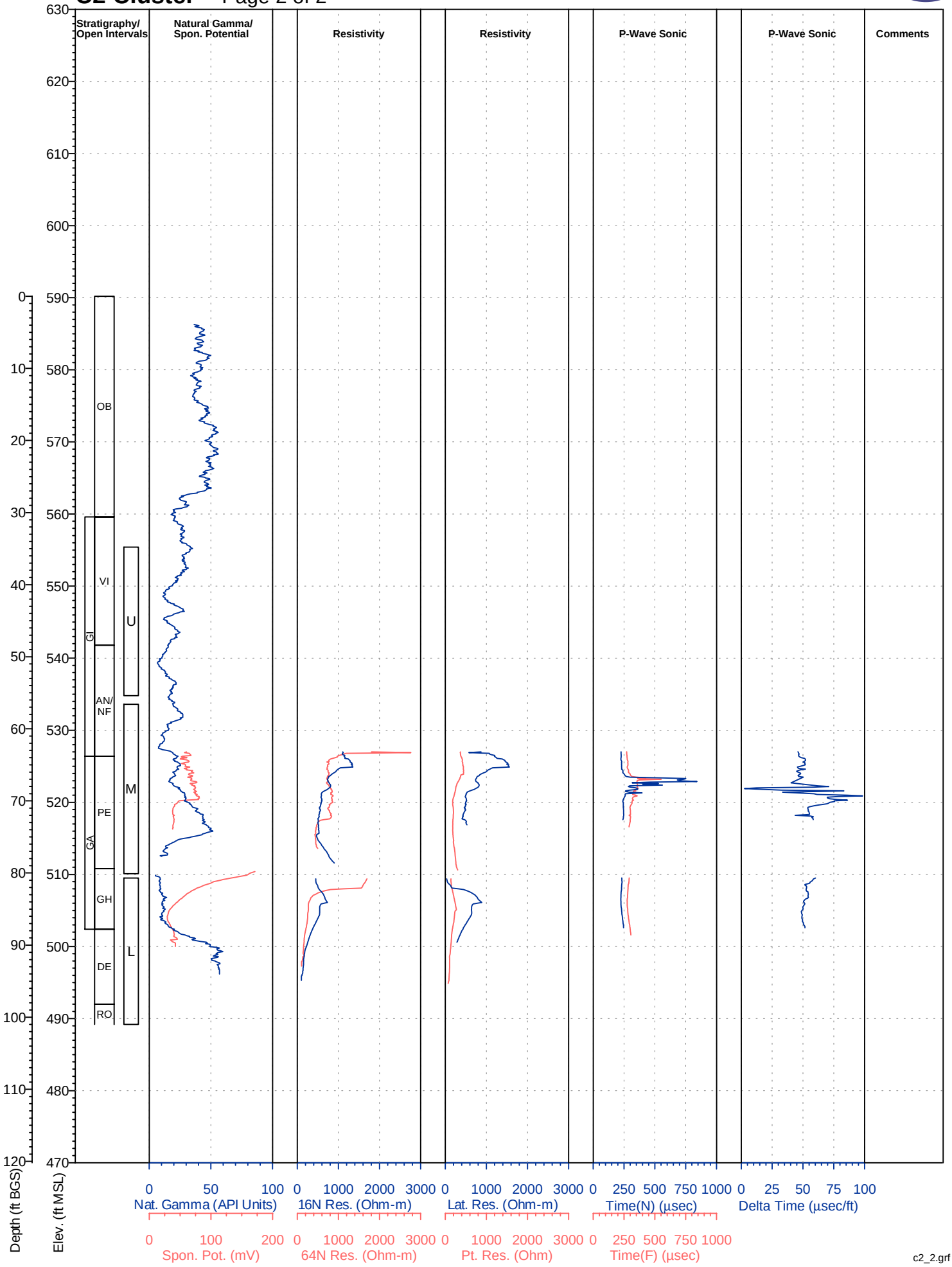

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
VI
AN/ NF
PE
GH
DE
RO
GI
GA
U
M
L
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

C2 Cluster



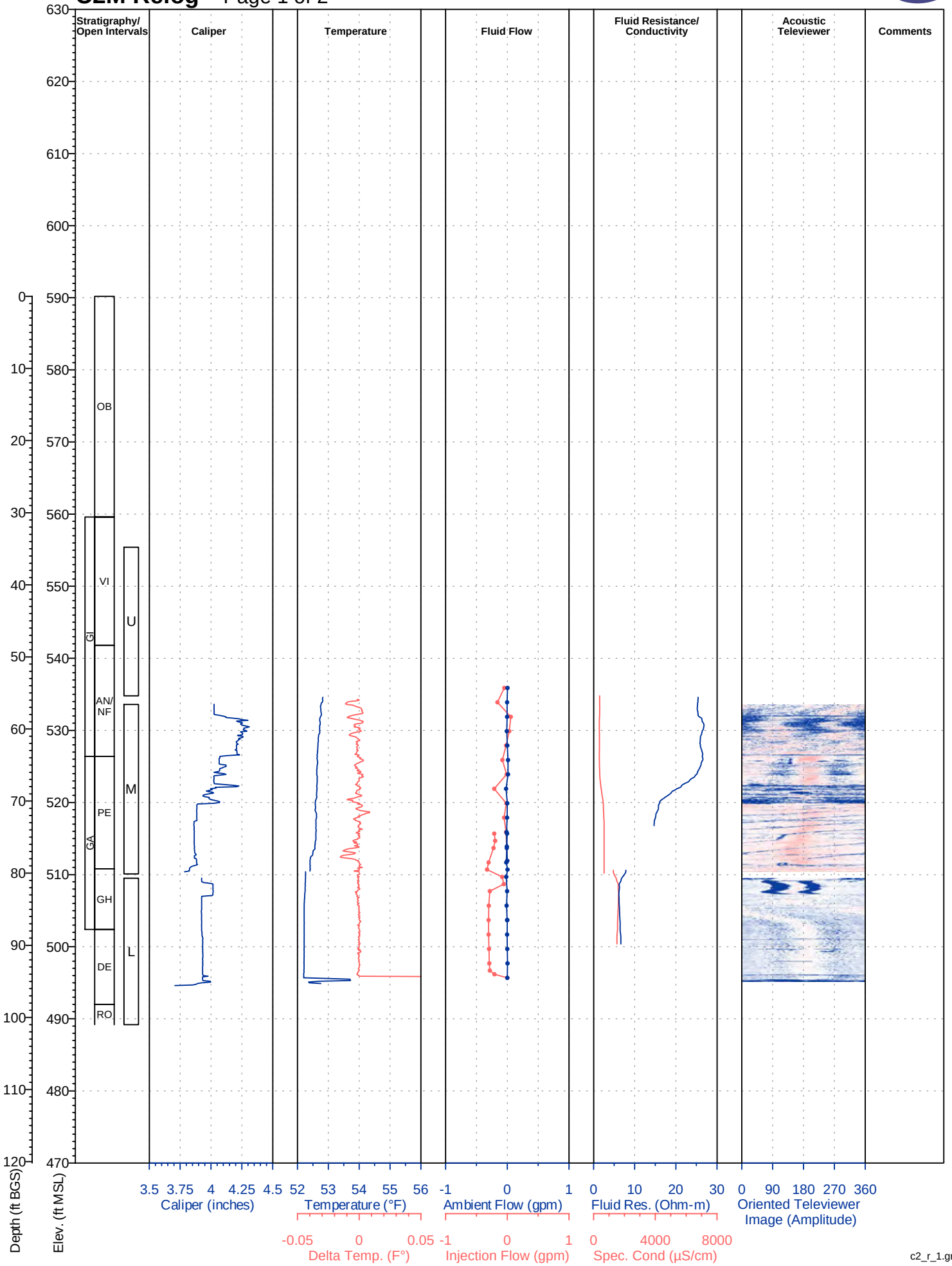
c2_1.grf

C2 Cluster



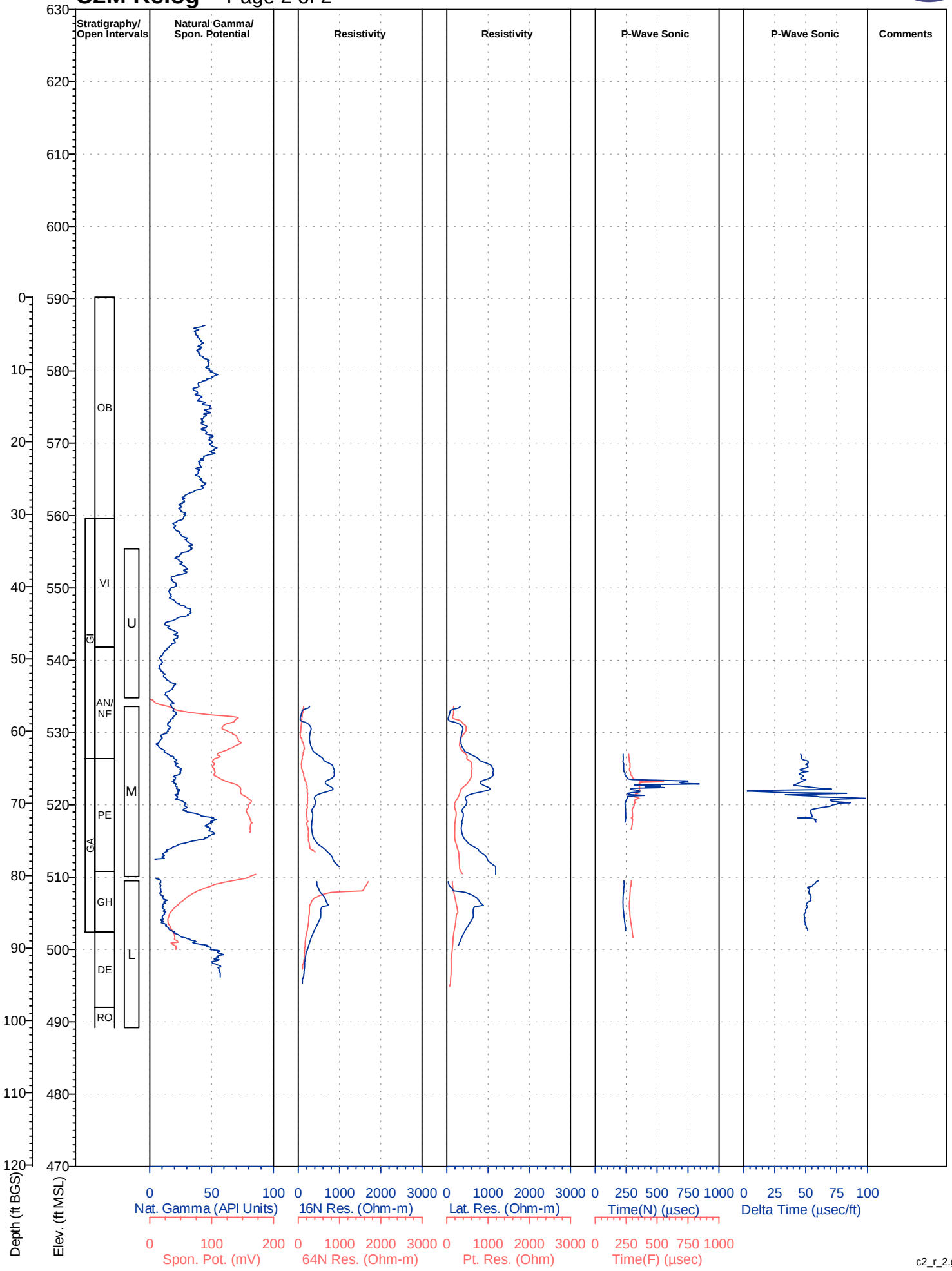
c2_2.grf

C2M Relog

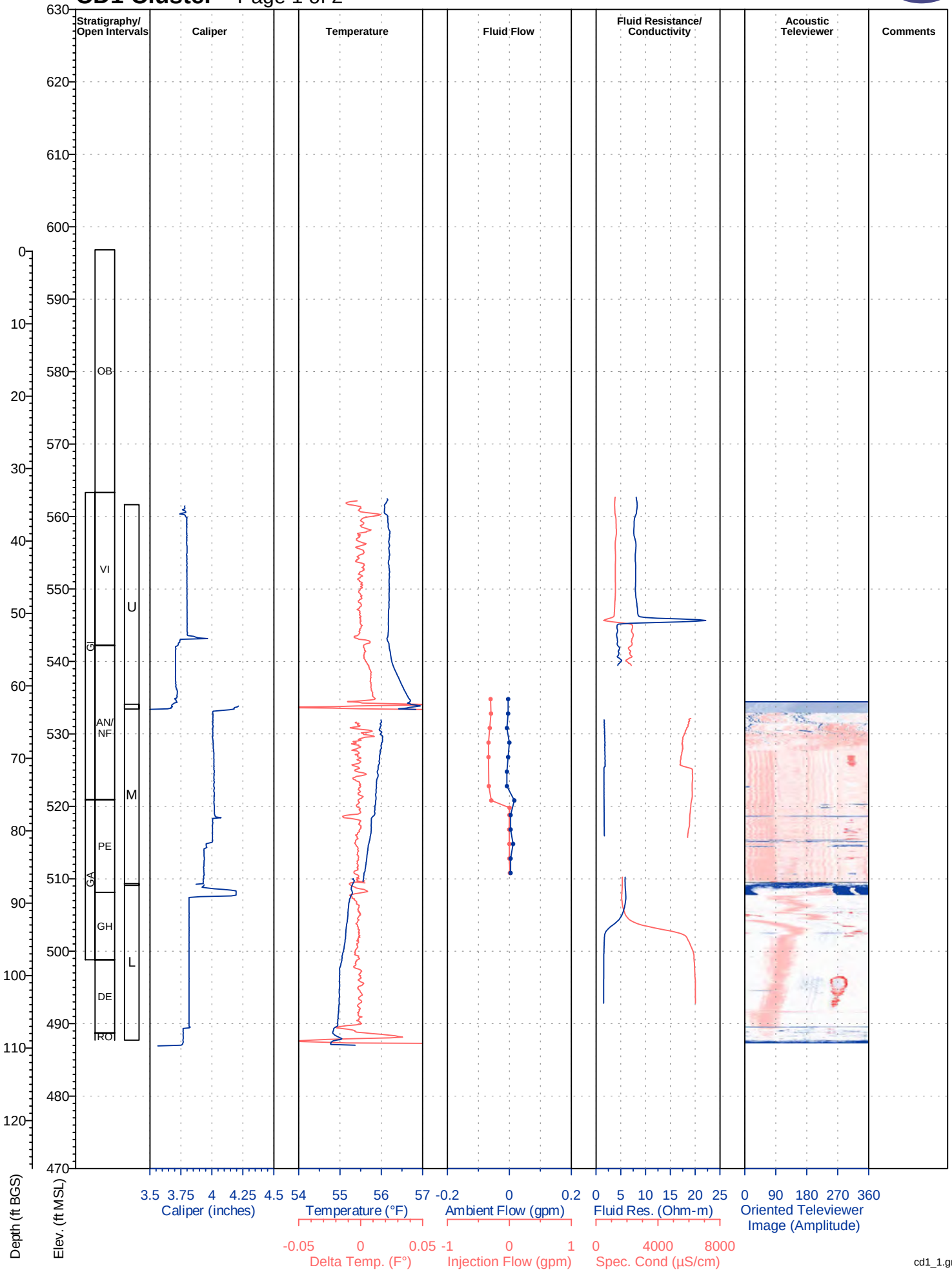


c2_r_1.grf

C2M Relog

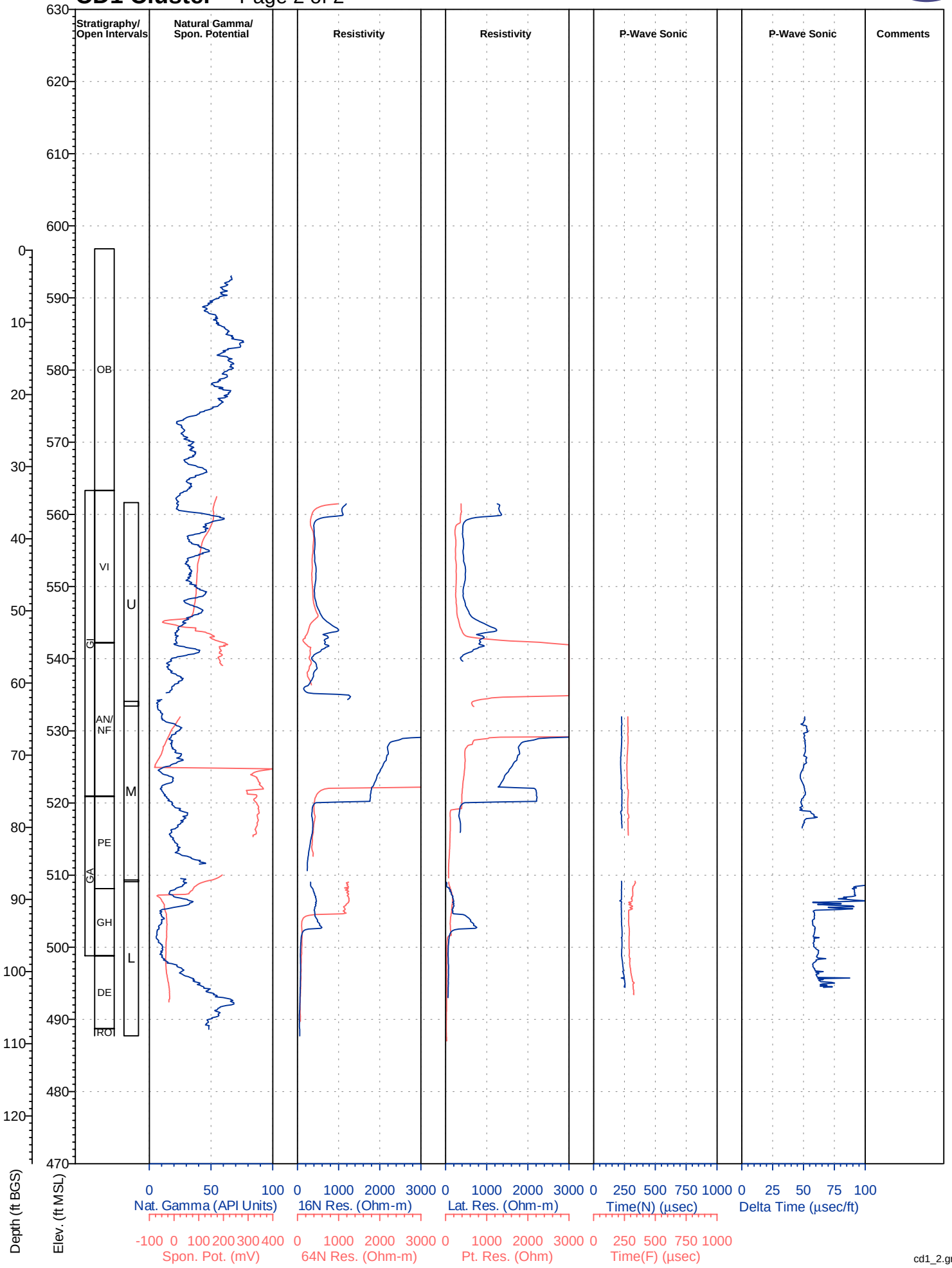

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
VI
AN/ NF
PE
GH
DE
RO
GI
GA
U
M
L
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

CD1 Cluster



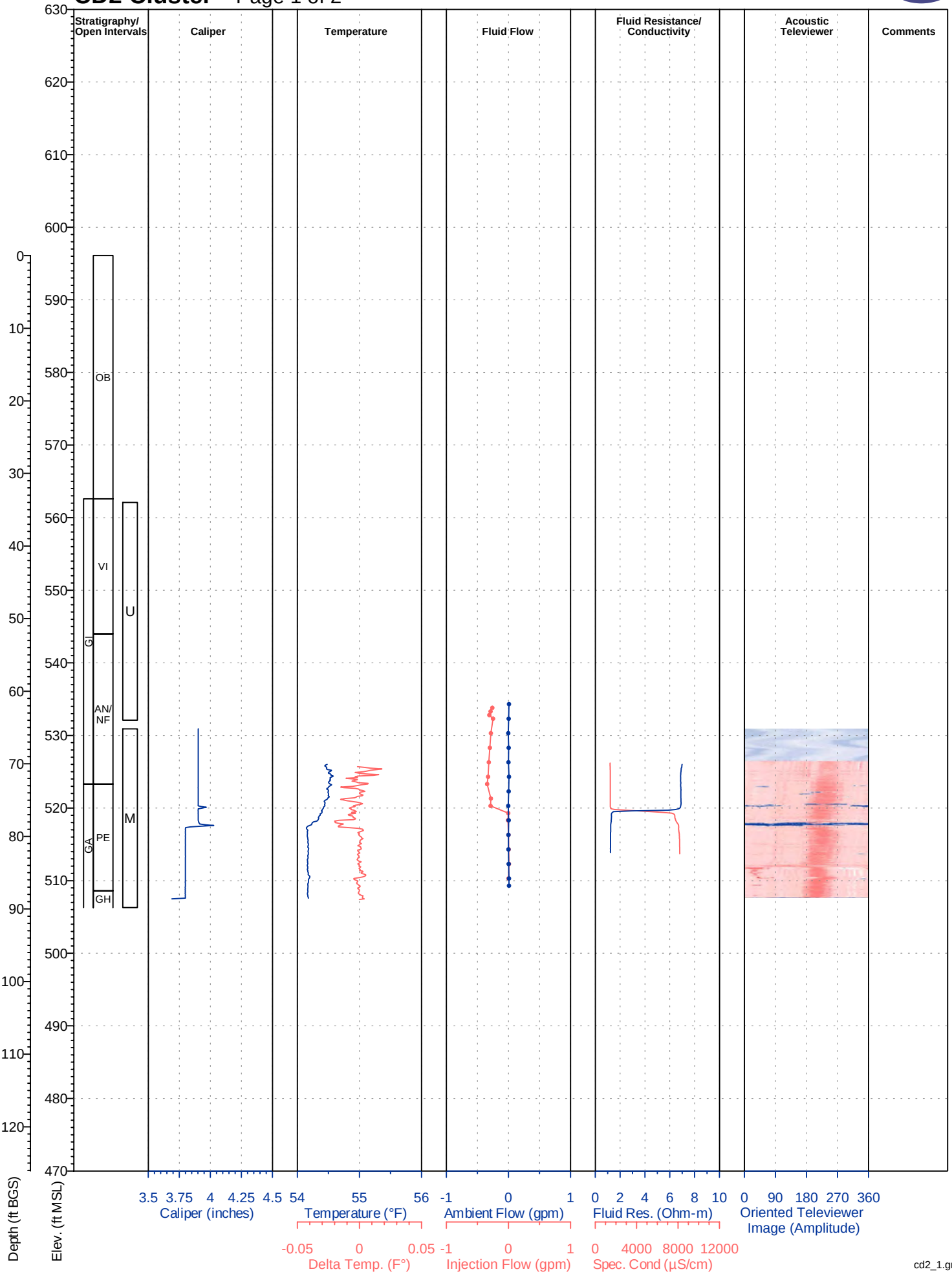
cd1_1.grf

CD1 Cluster



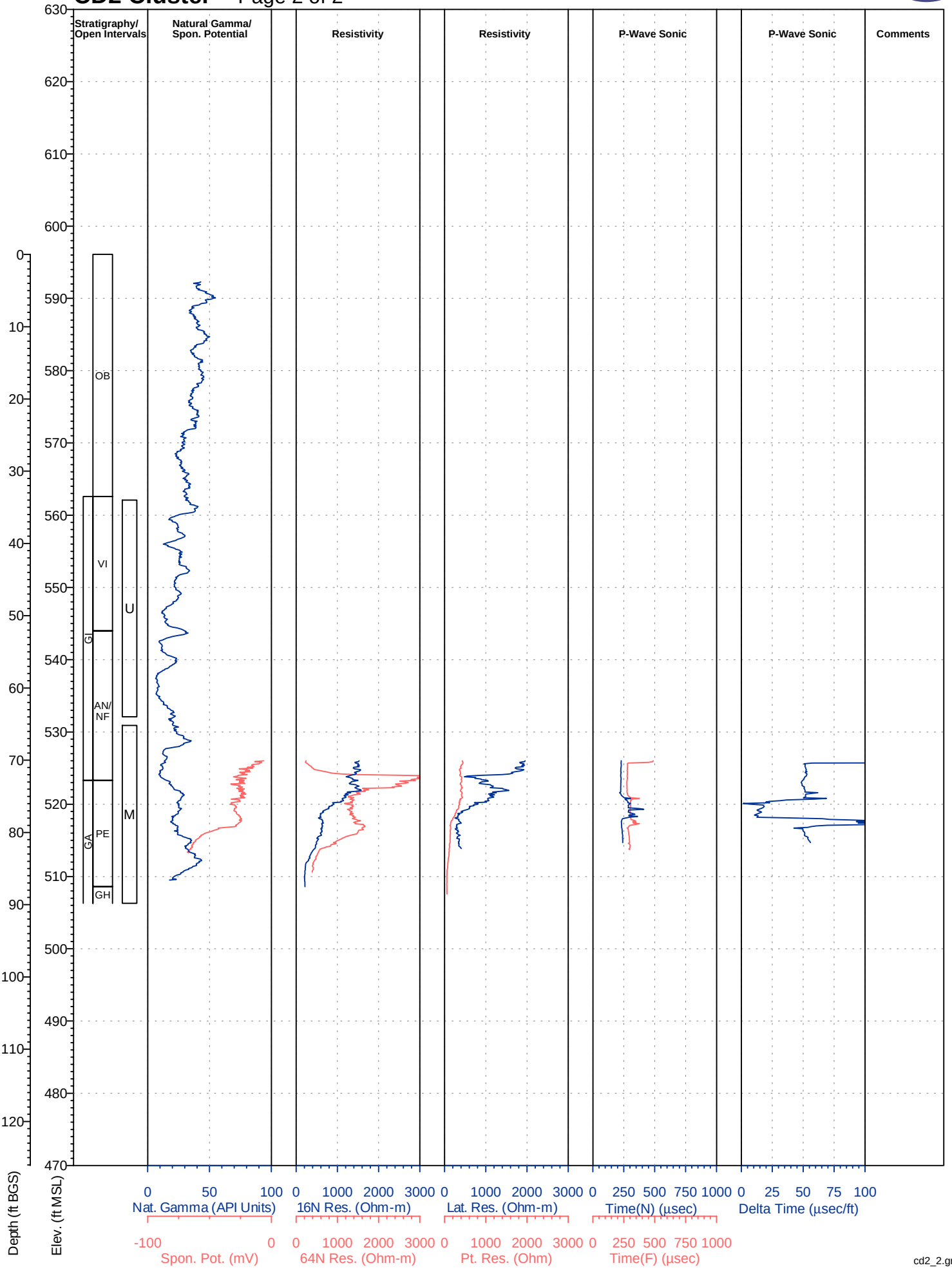
cd1_2.grf

CD2 Cluster



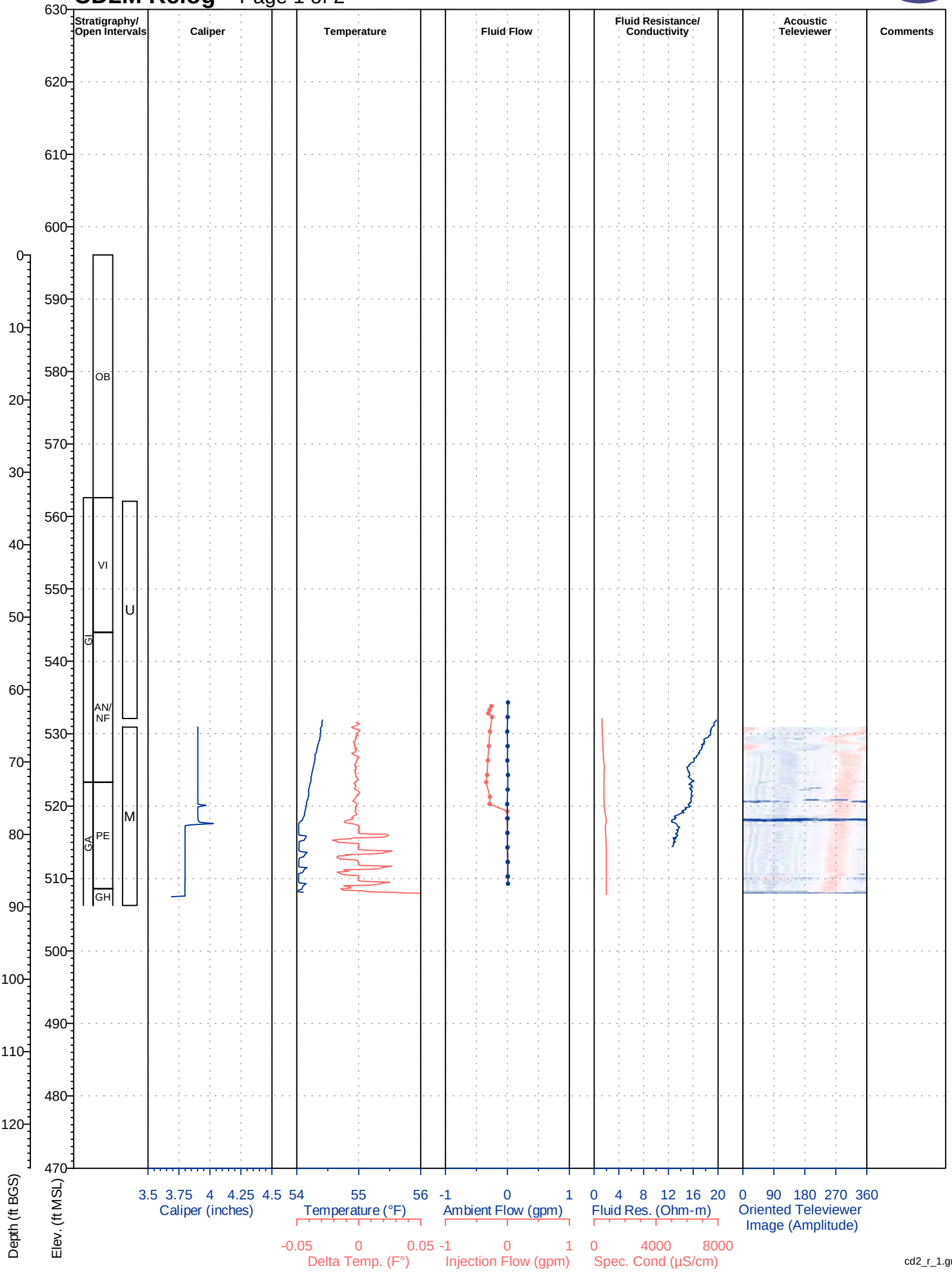
cd2_1.grf

CD2 Cluster



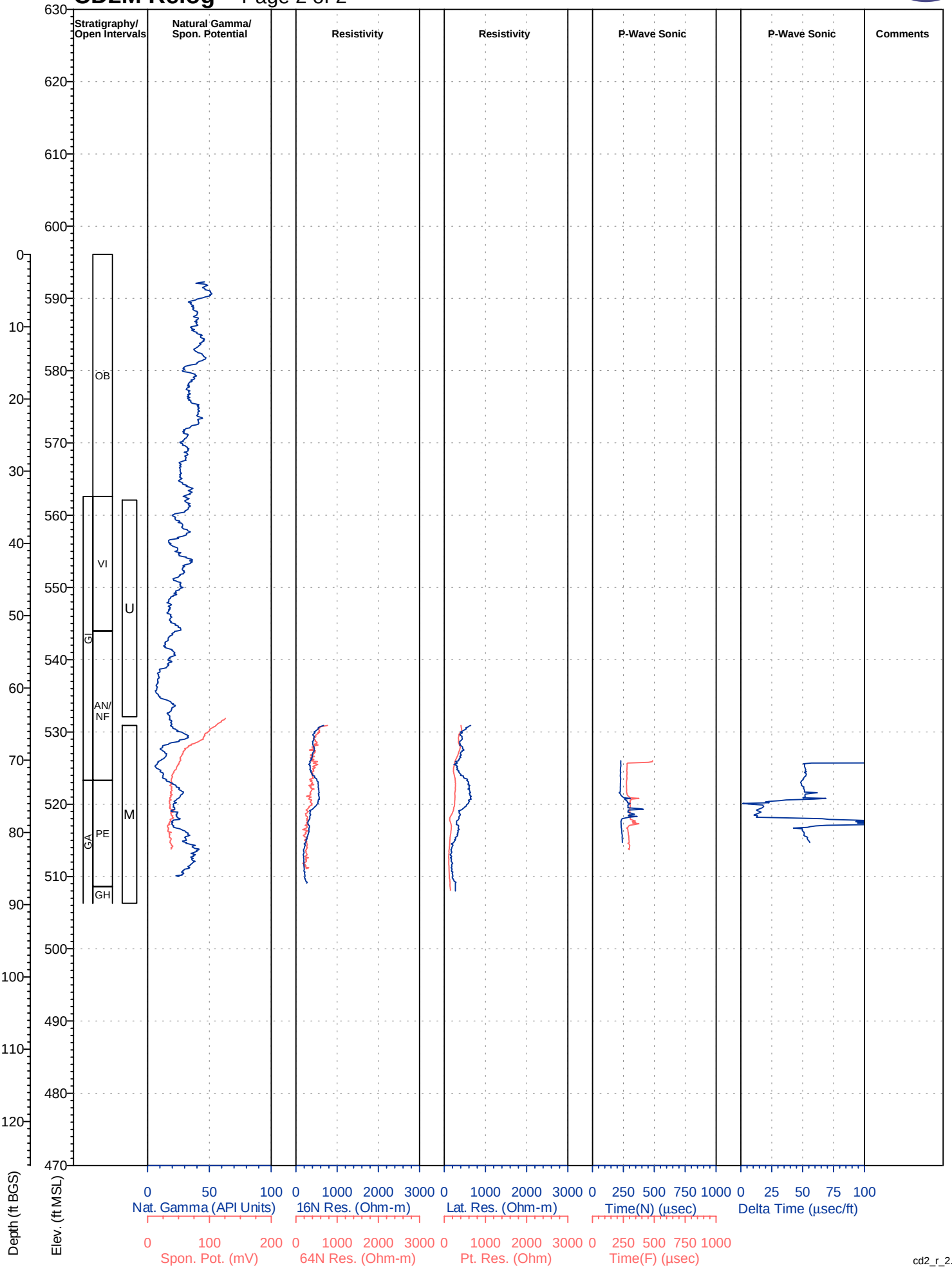
cd2_2.grf

CD2M Relog

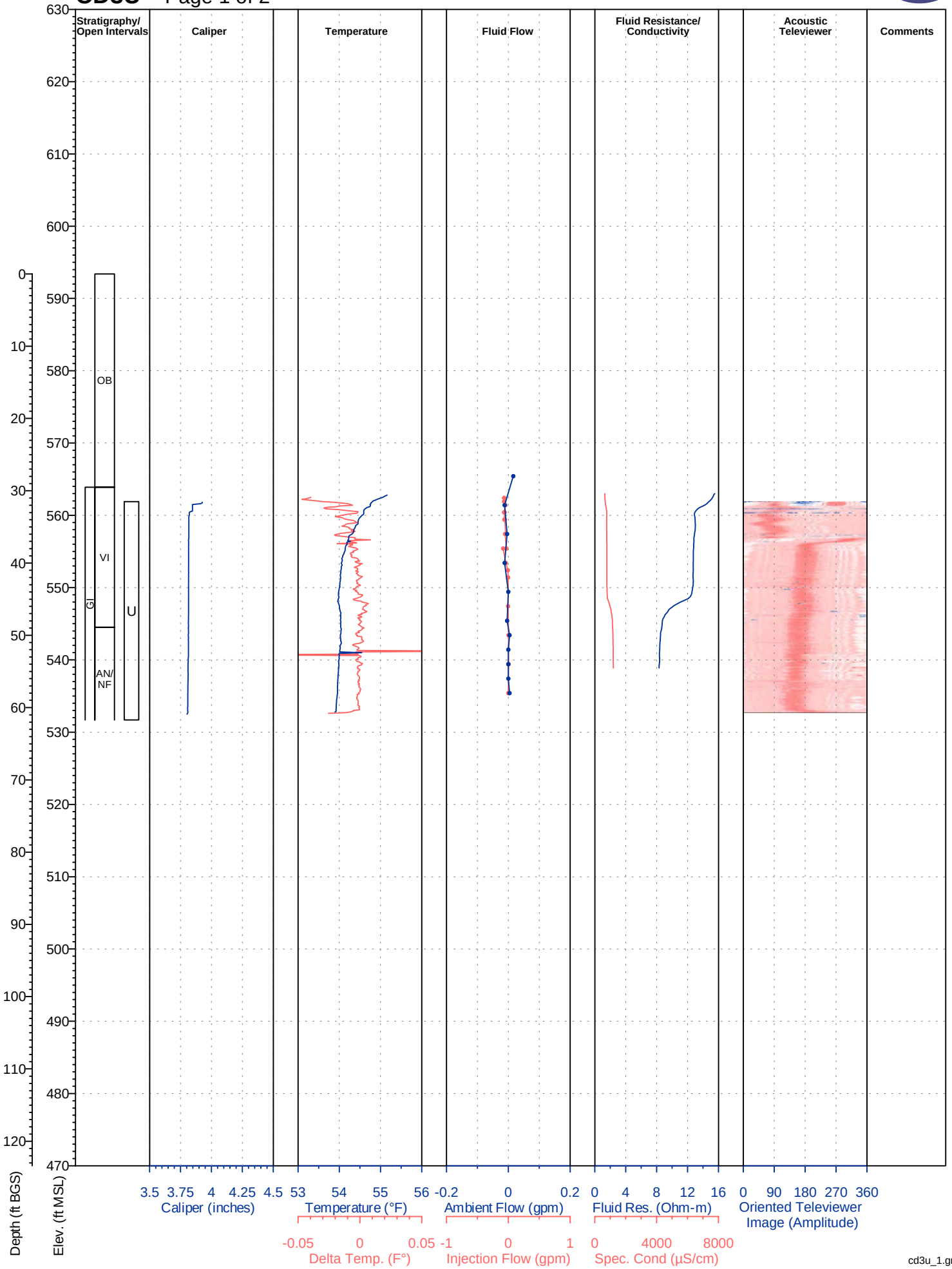


cd2_r_1.grf

CD2M Relog

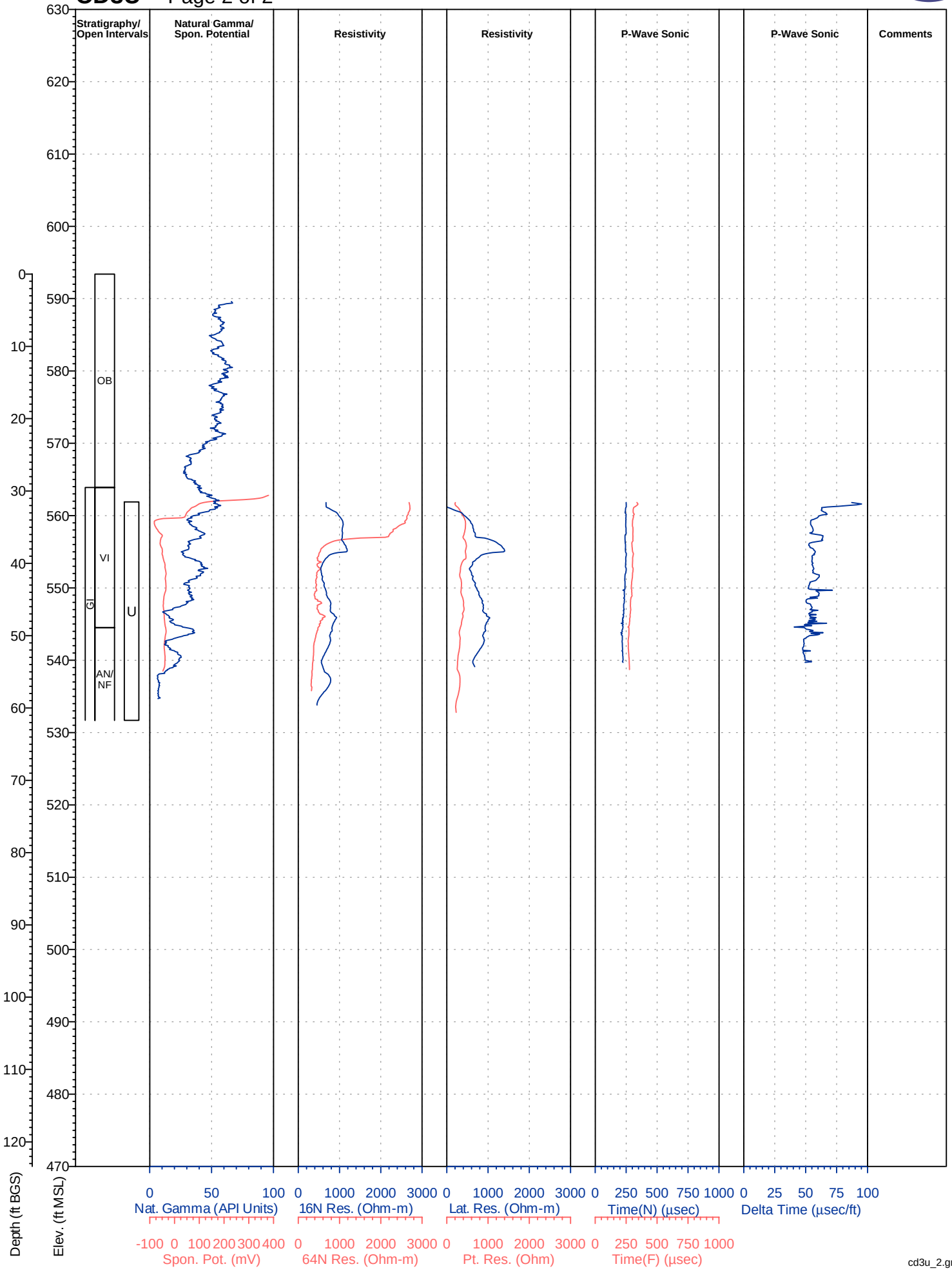

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
VI
AN/ NF
PE
GH
GI
GA
U
M
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

CD3U



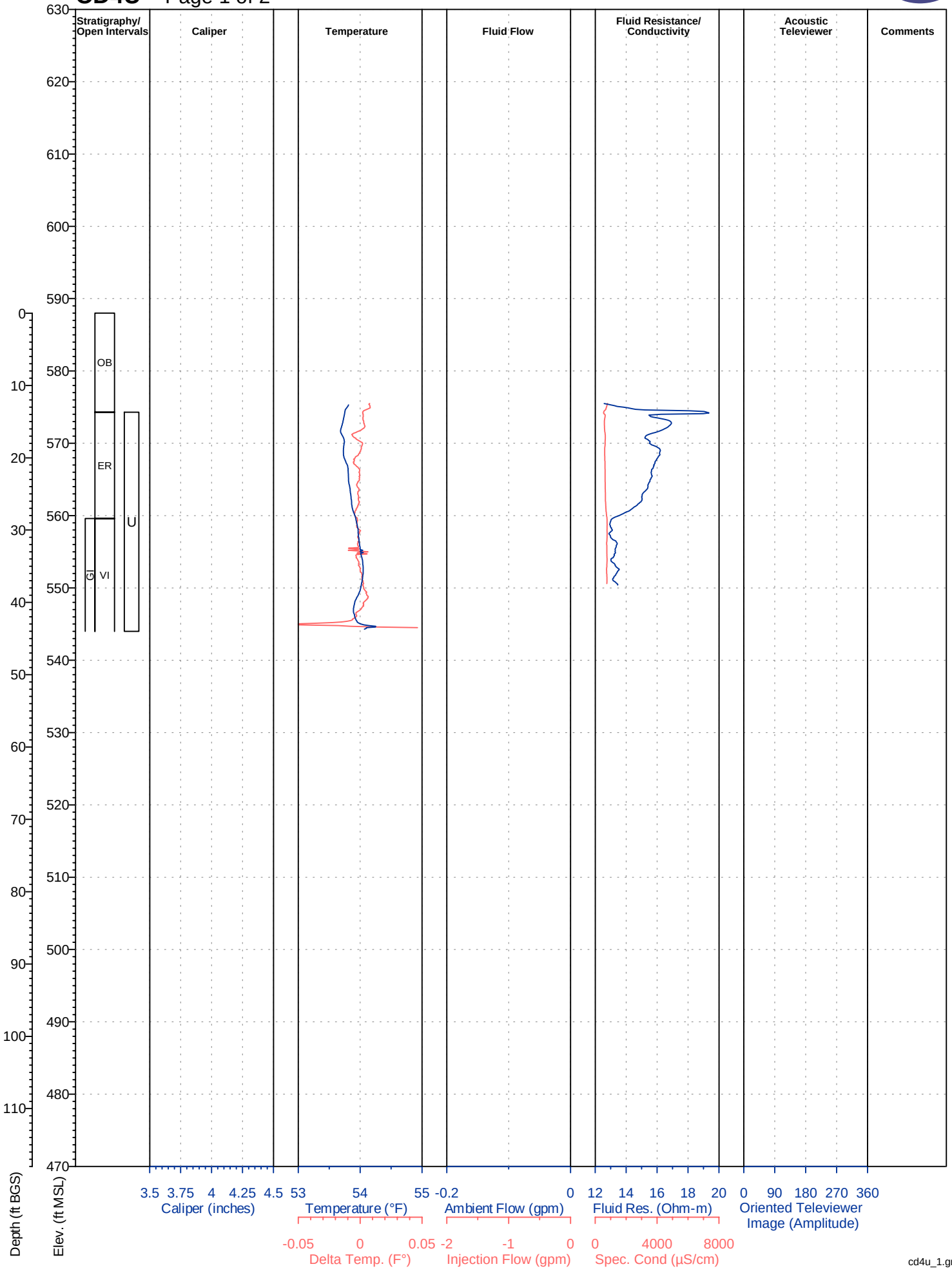
cd3u_1.grf

CD3U

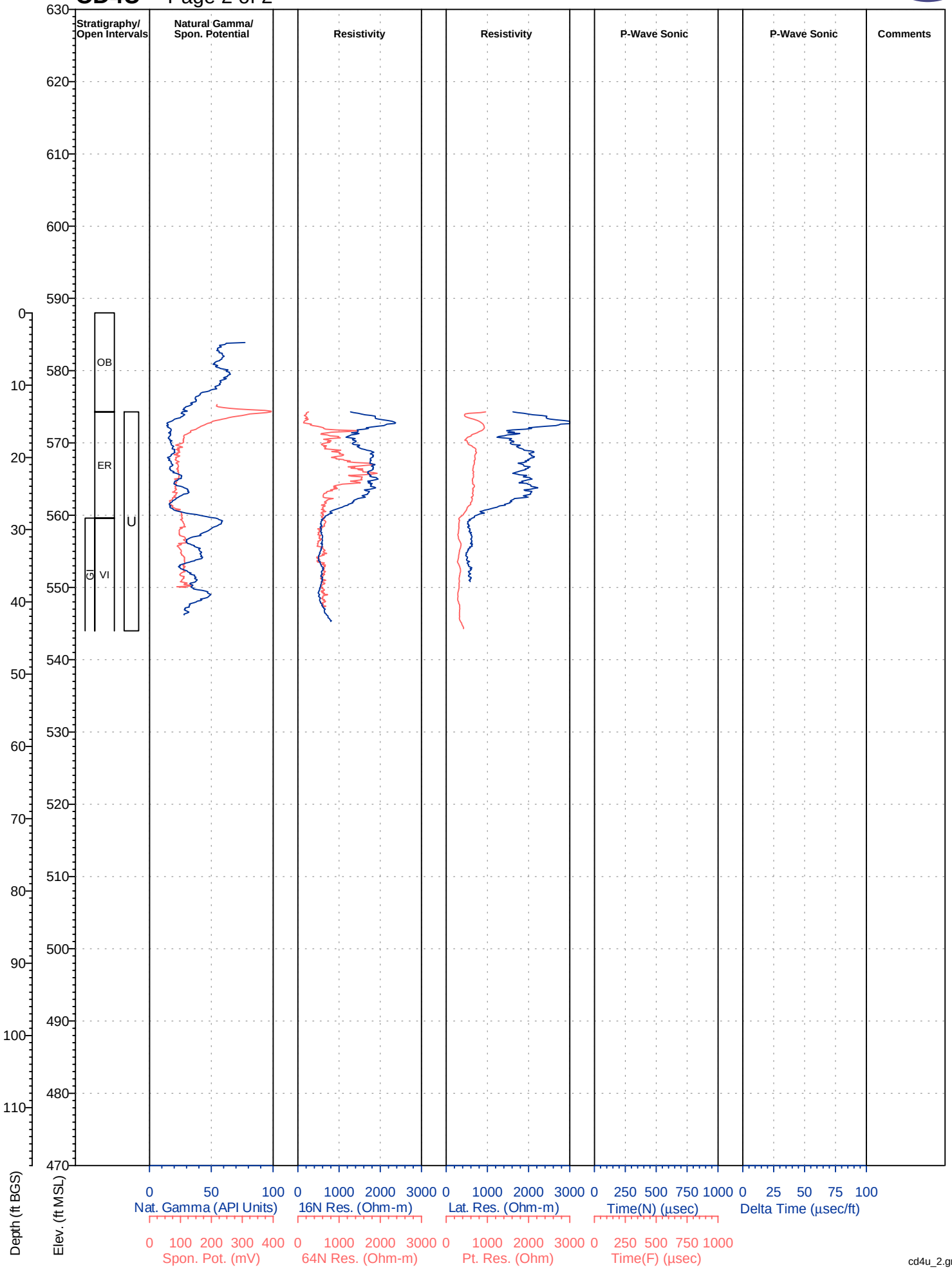


cd3u_2.grf

CD4U

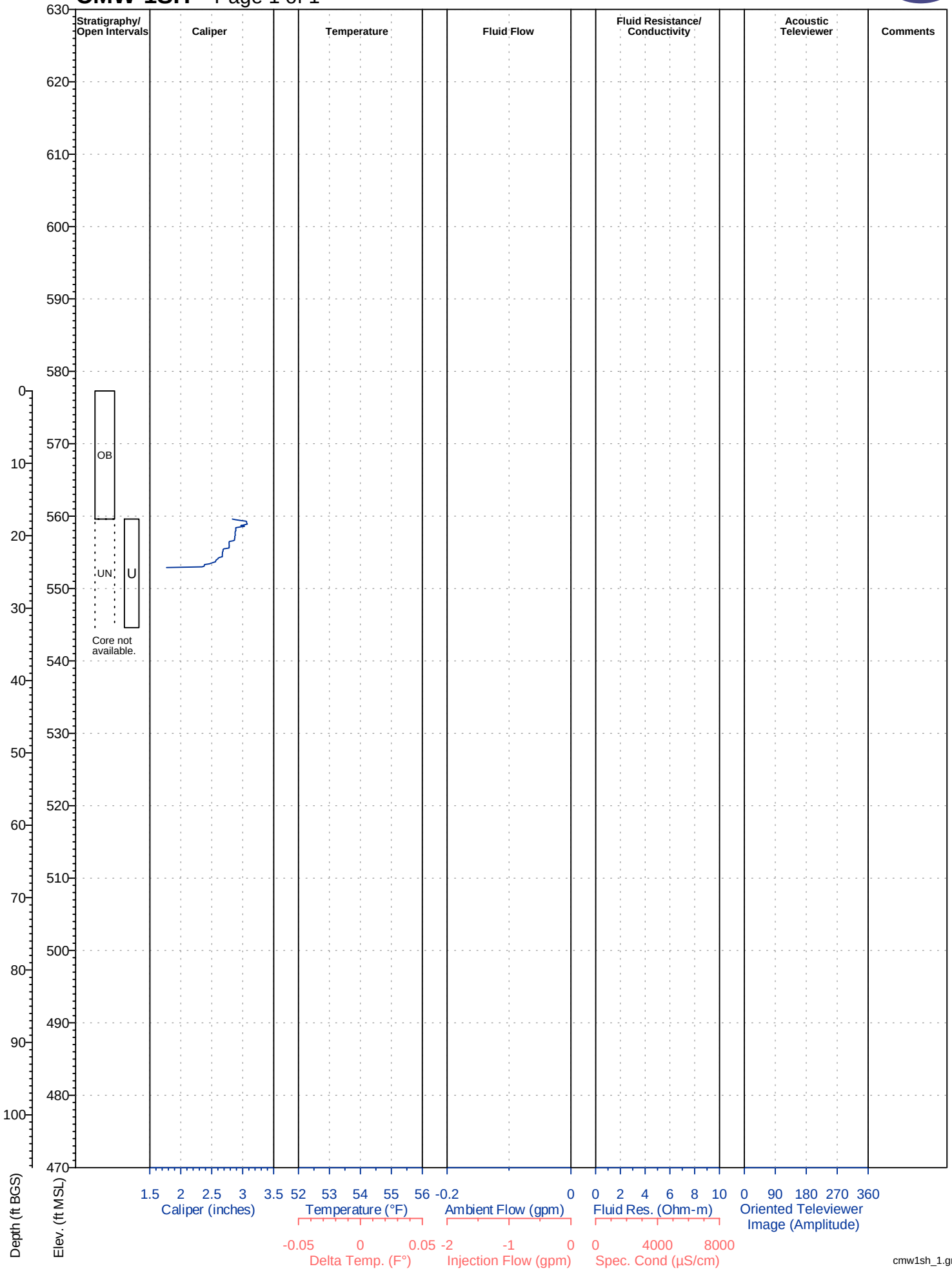

Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
ER
U
GI
VI
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
53 54 55
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
12 14 16 18 20
Fluid Res. (Ohm-m)
0 4000 8000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

CD4U



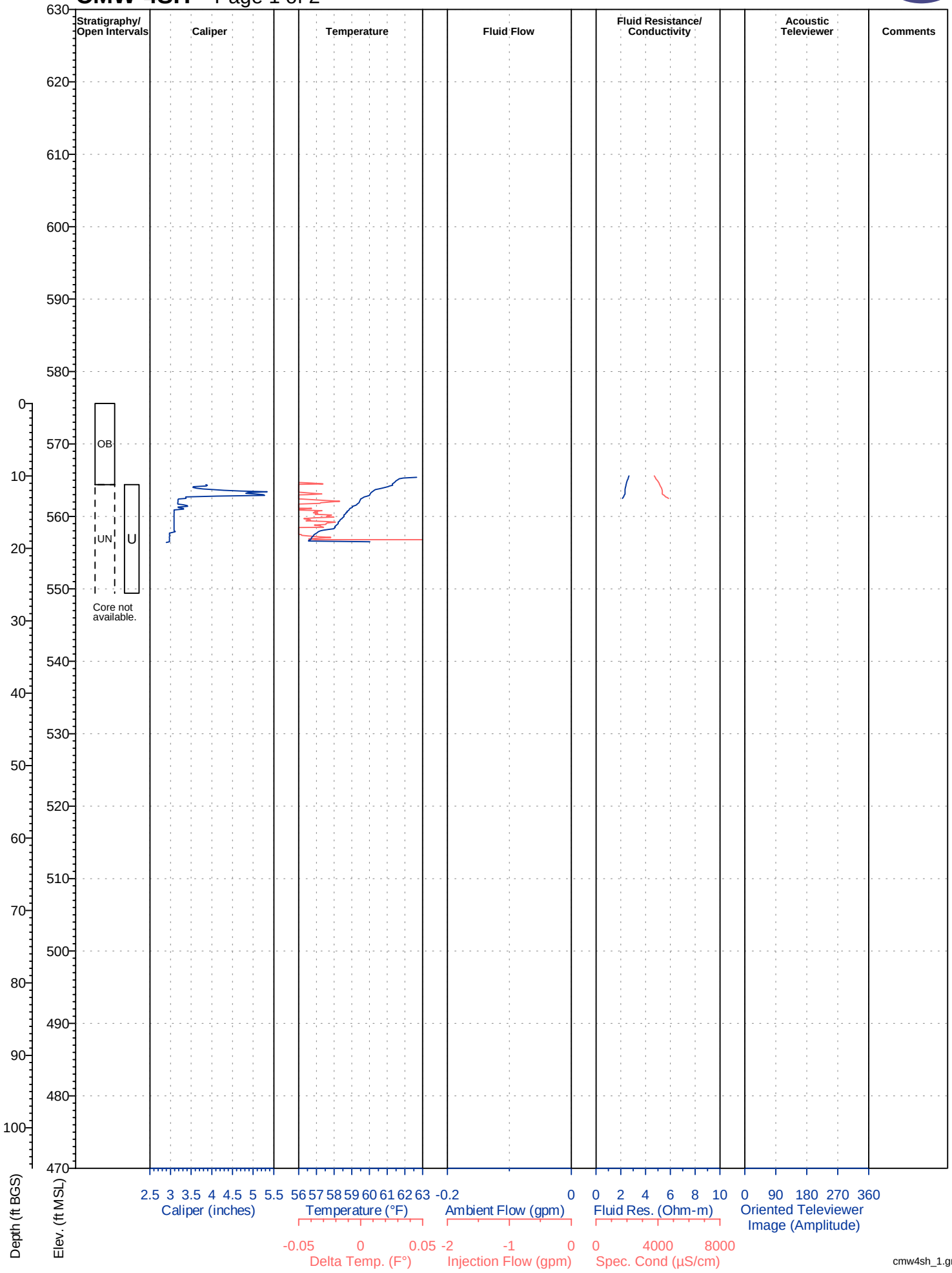
cd4u_2.grf

CMW-1SH



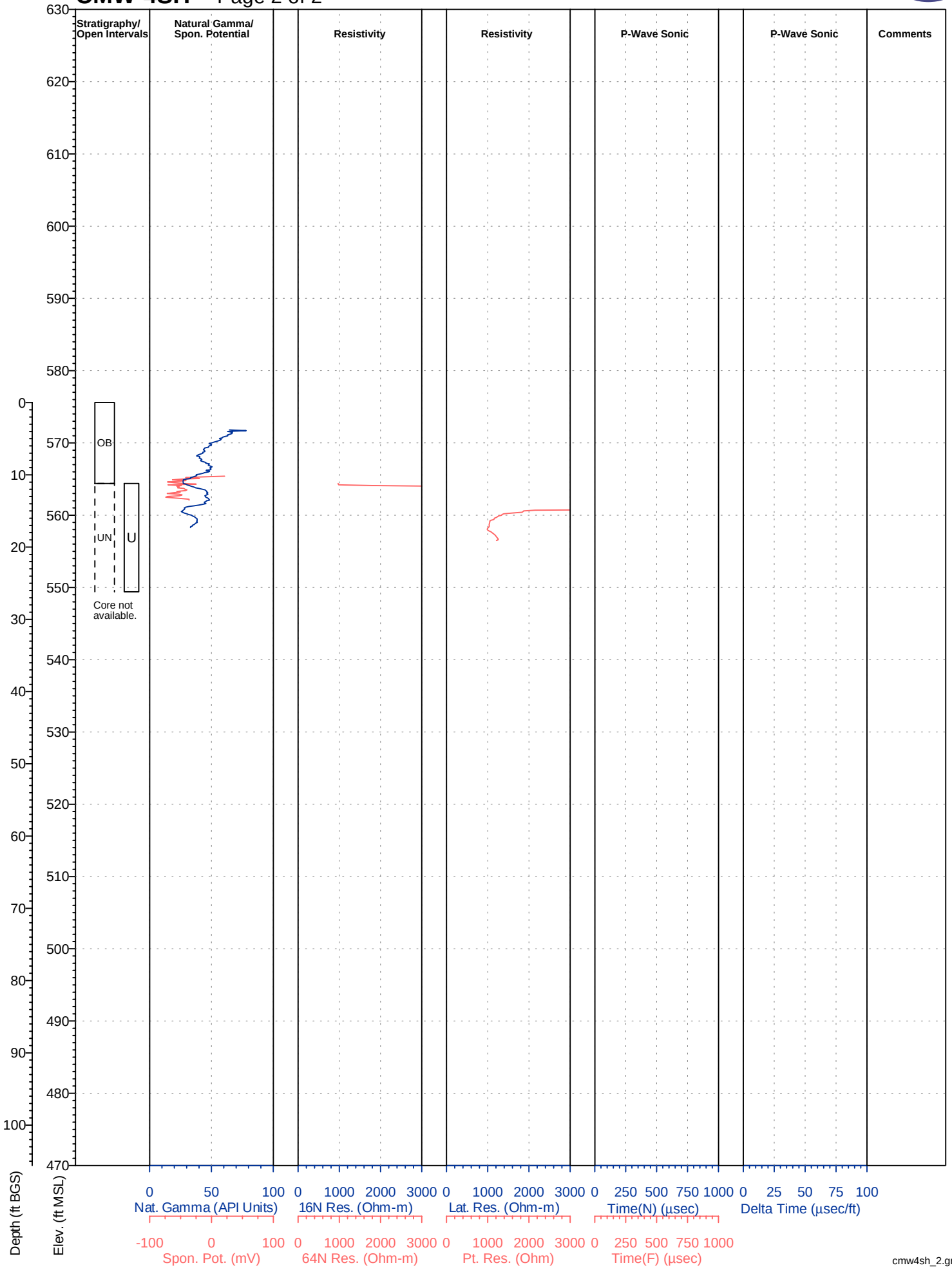
cmw1sh_1.grf

CMW-4SH



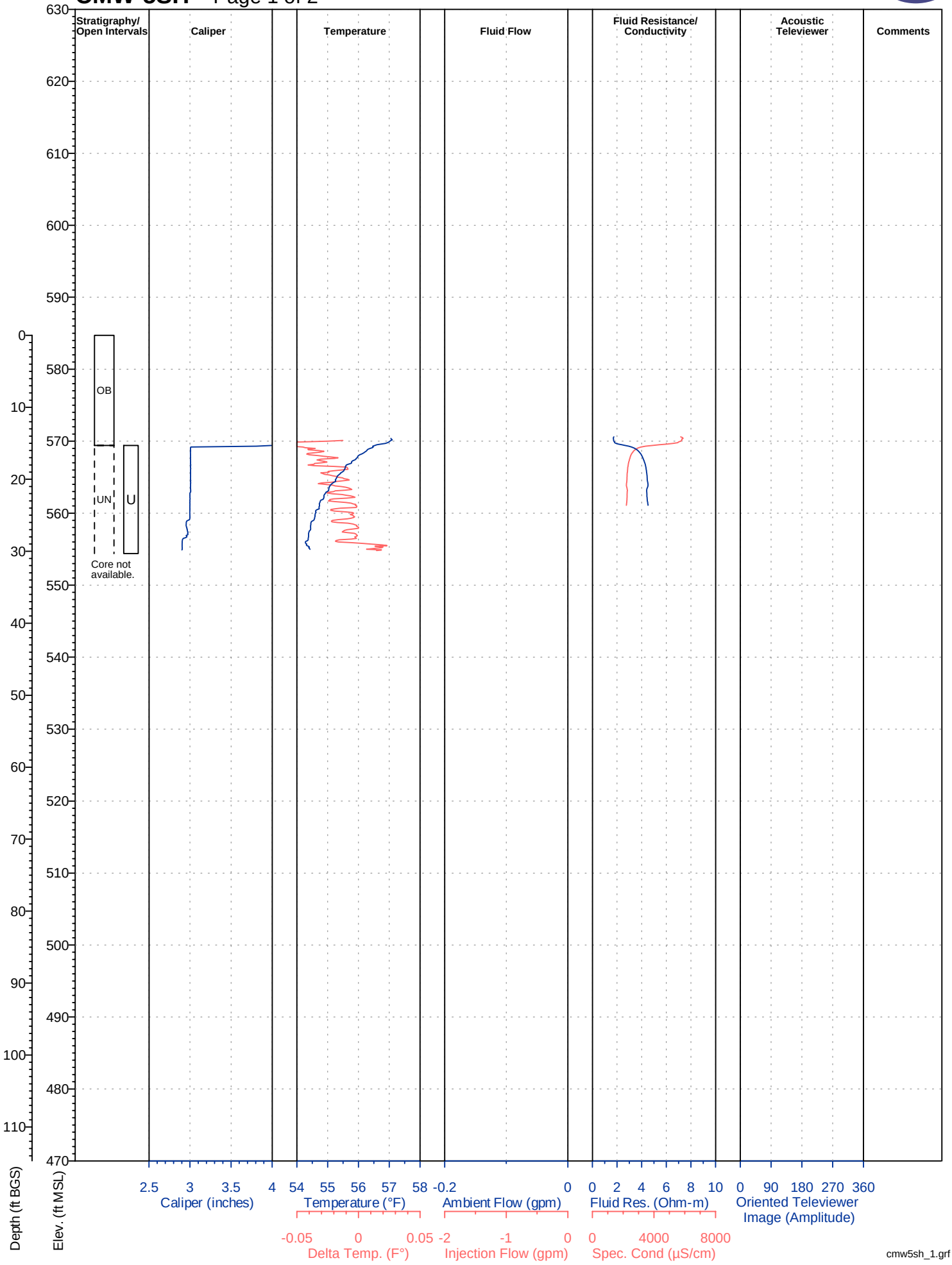
cmw4sh_1.grf

CMW-4SH



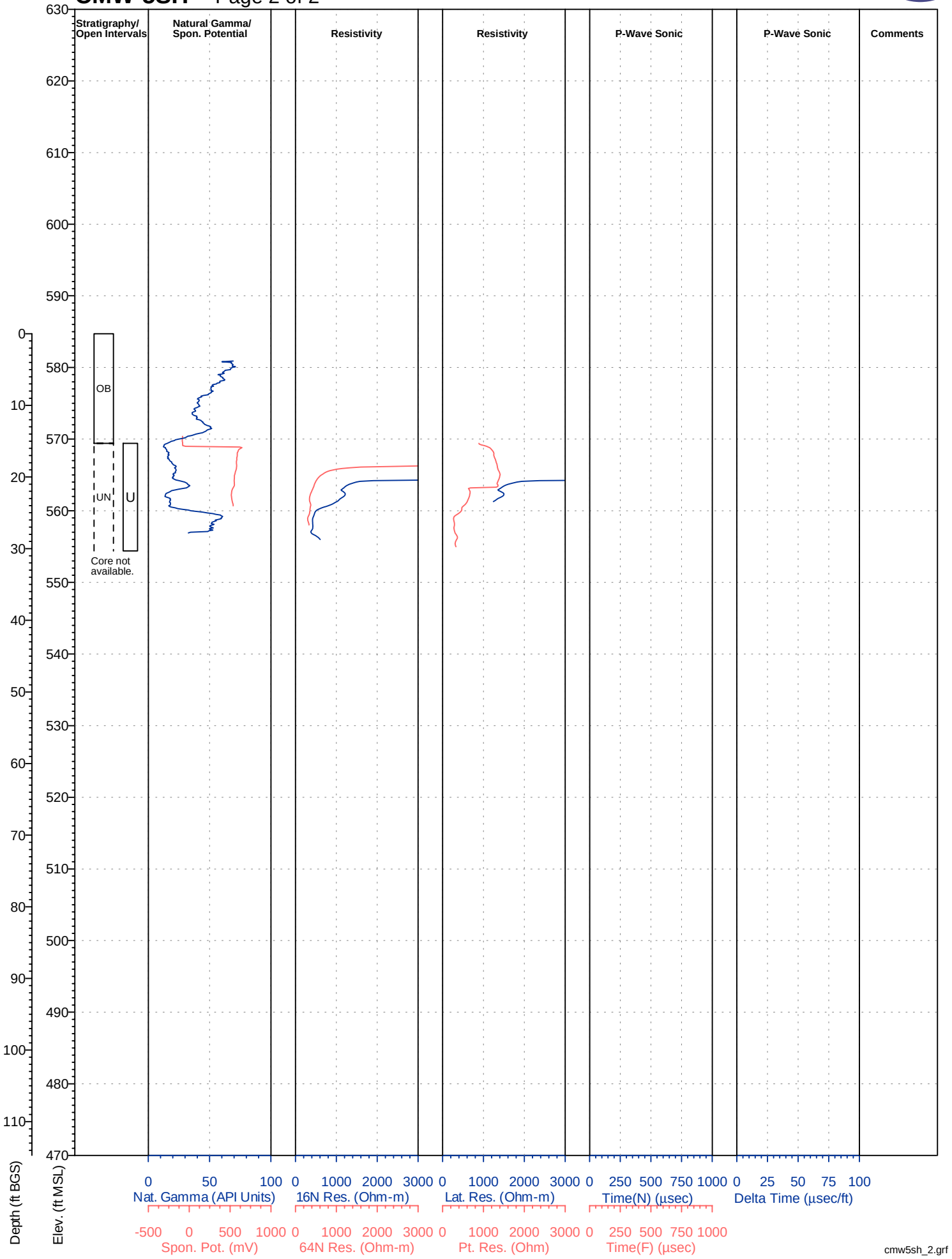
cmw4sh_2.grf

CMW-5SH



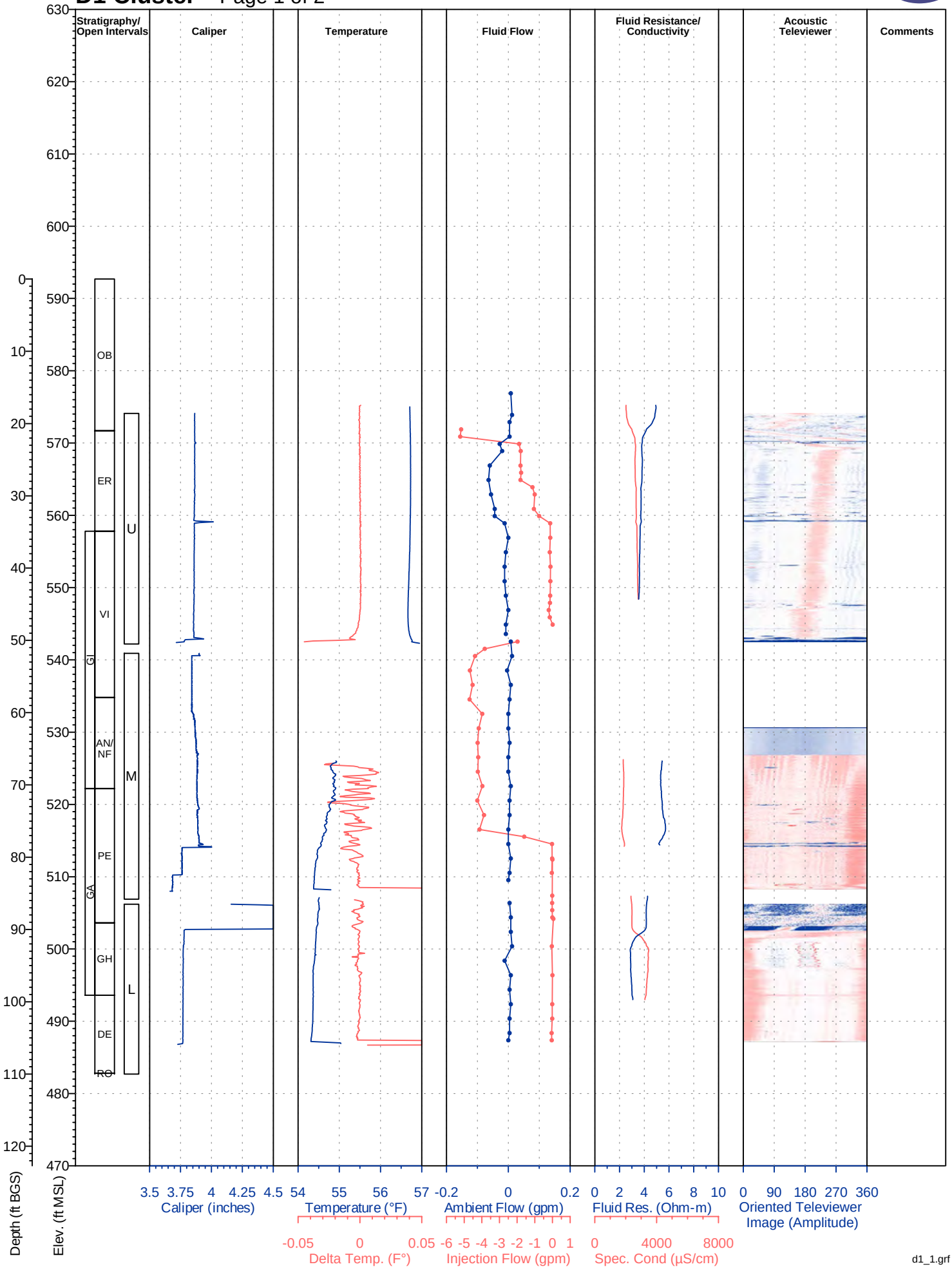
cmw5sh_1.grf

CMW-5SH



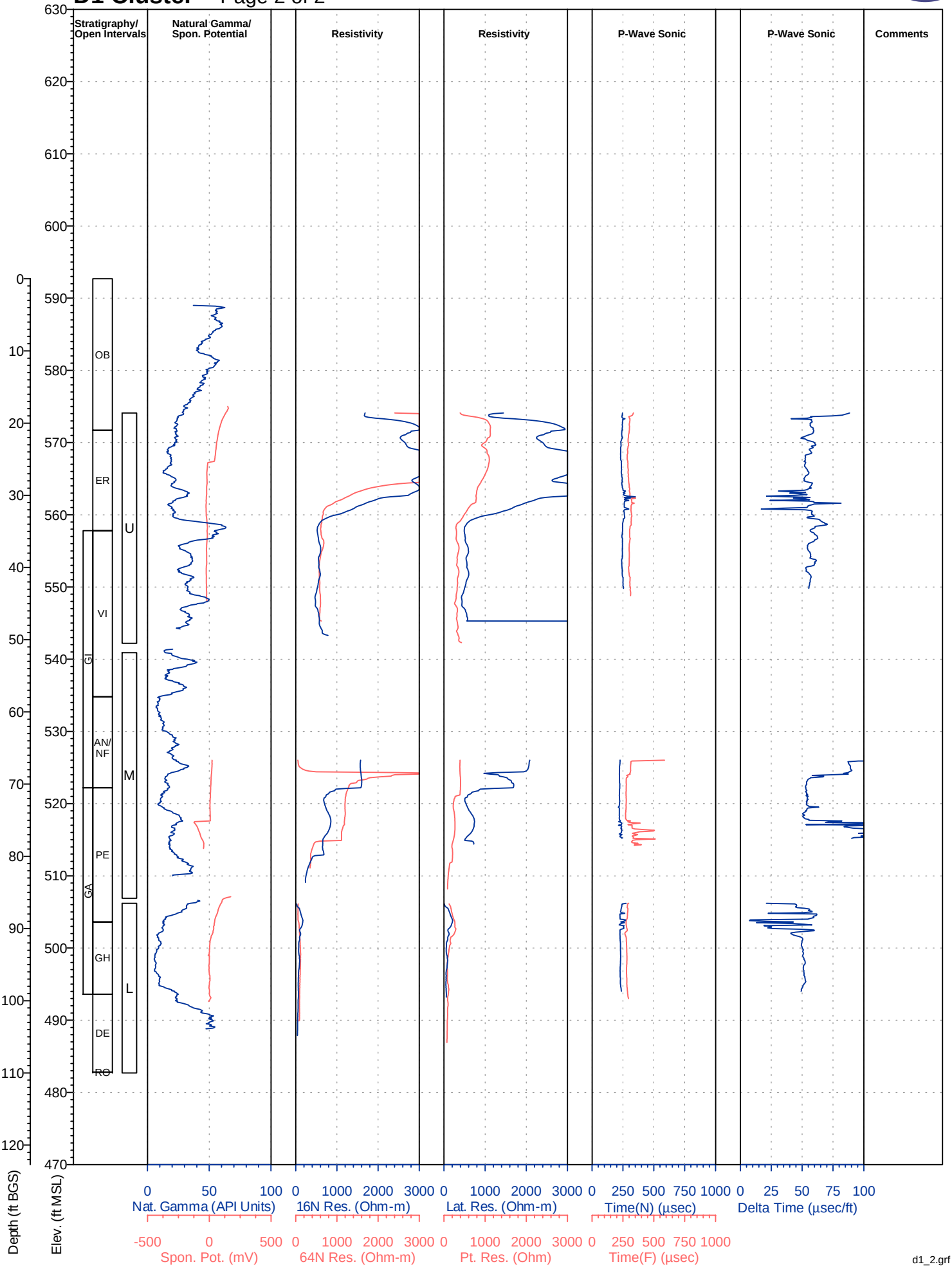
cmw5sh_2.grf

D1 Cluster



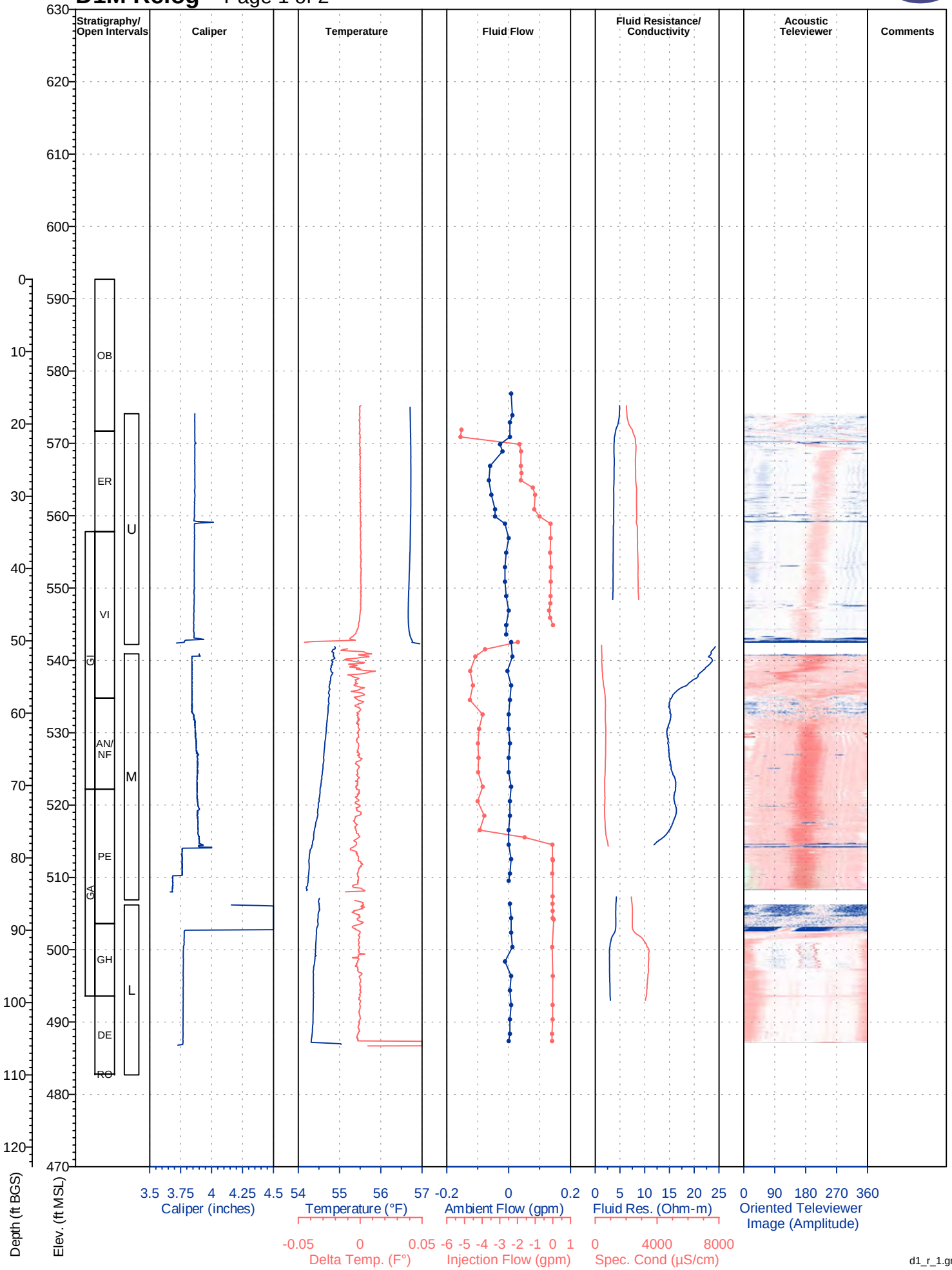
d1_1.grf

D1 Cluster



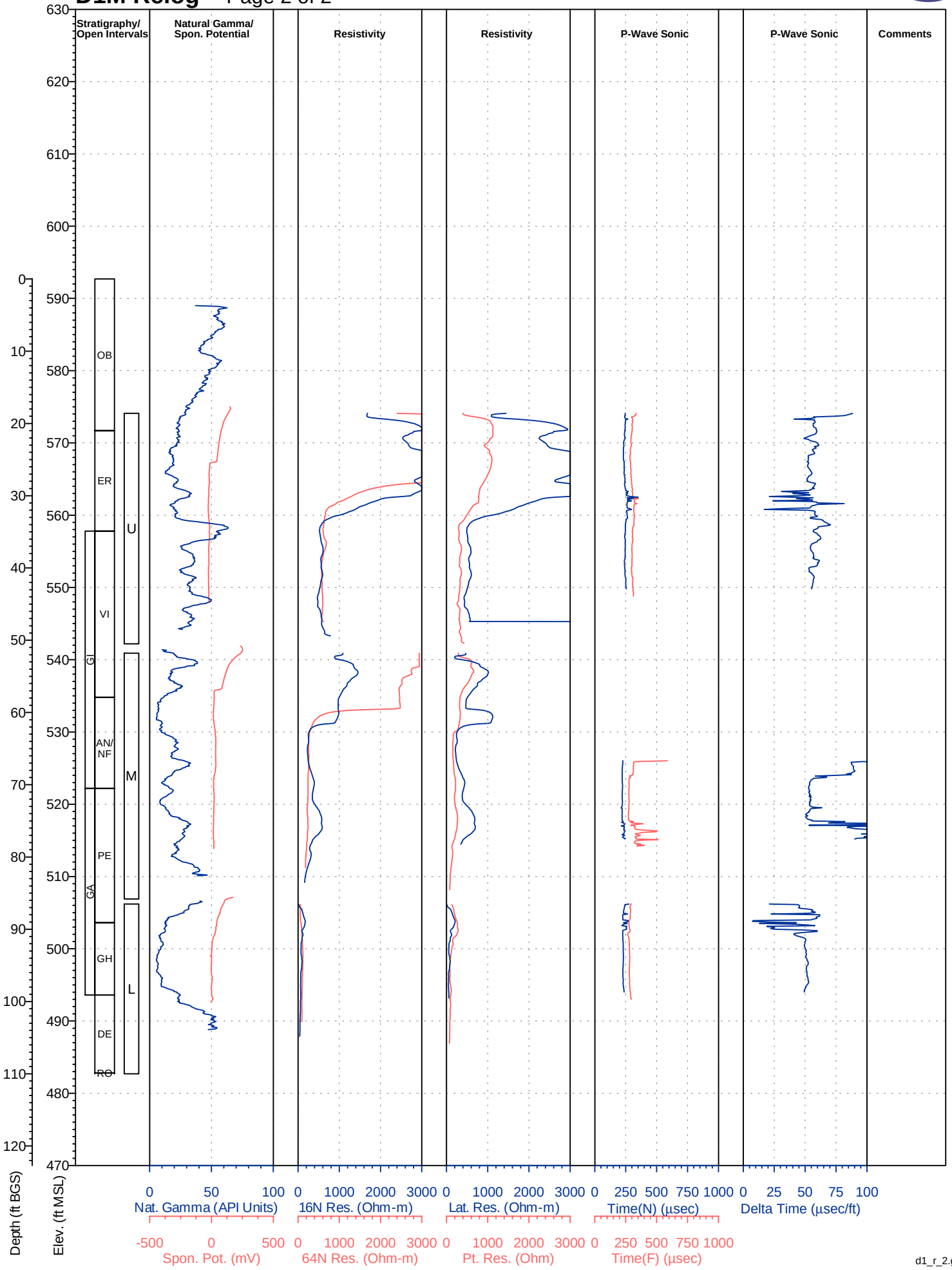
d1_2.grf

D1M Relog



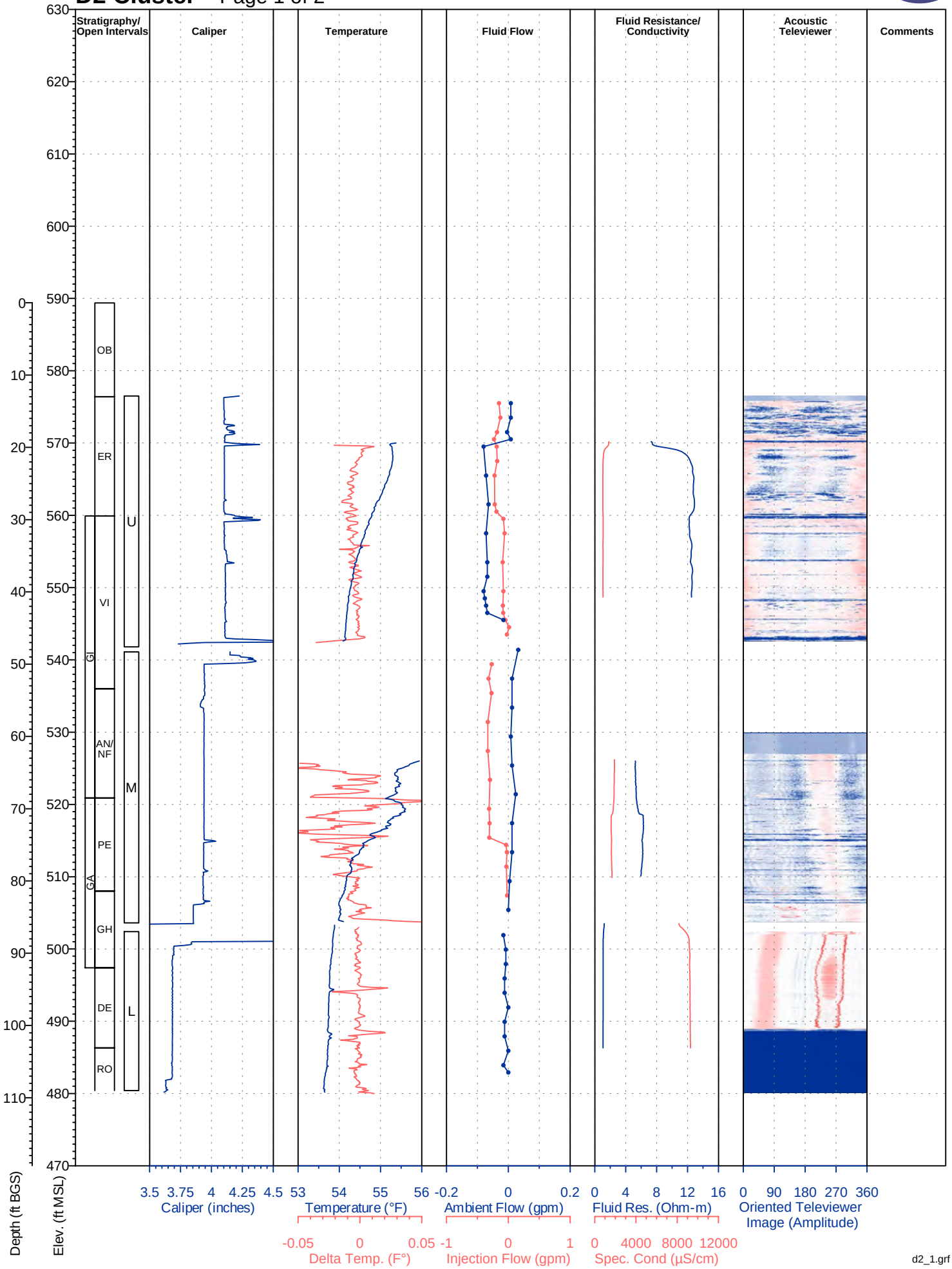
d1_r_1.grf

D1M Relog



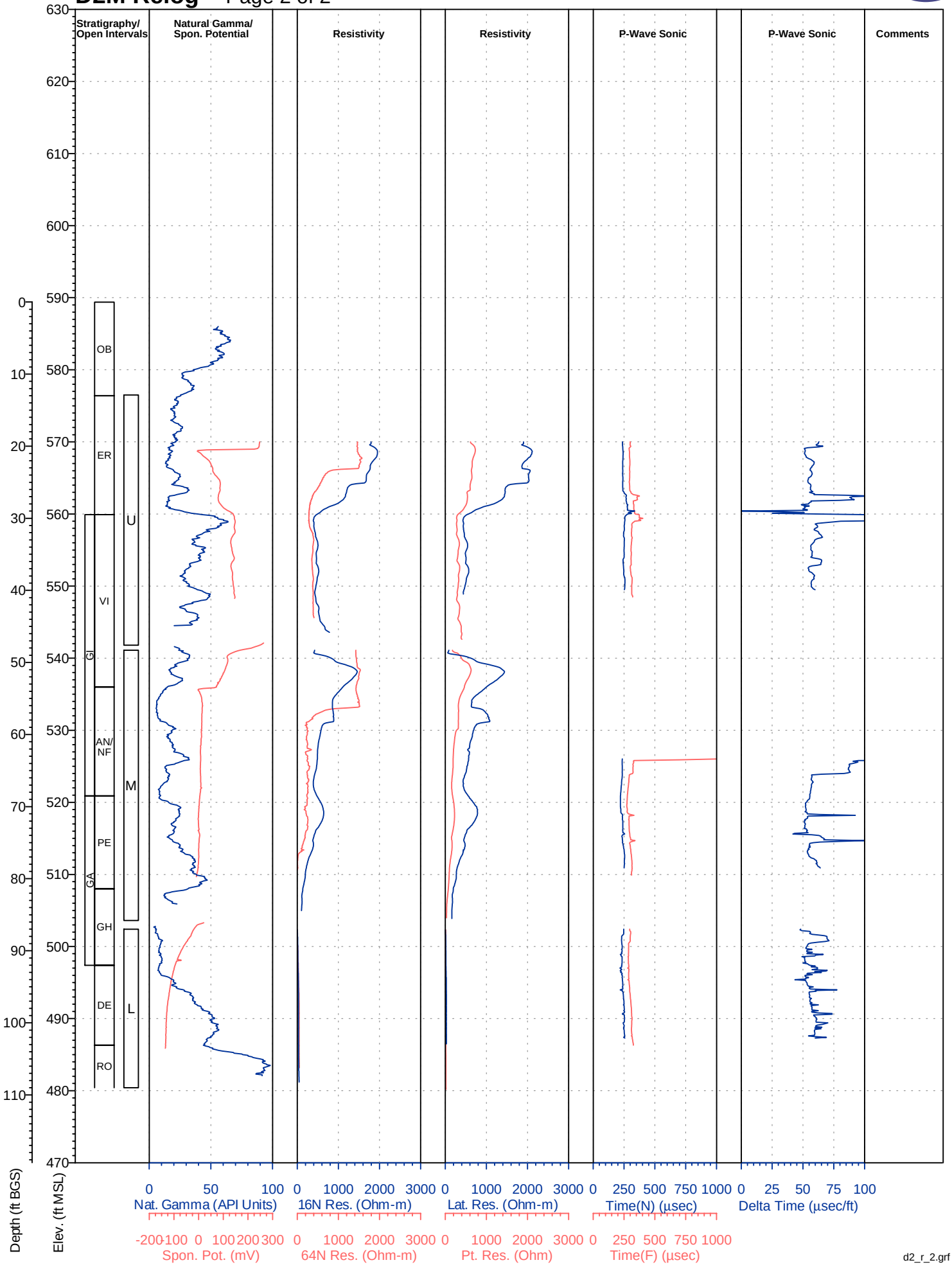
d1_r_2.gr

D2 Cluster



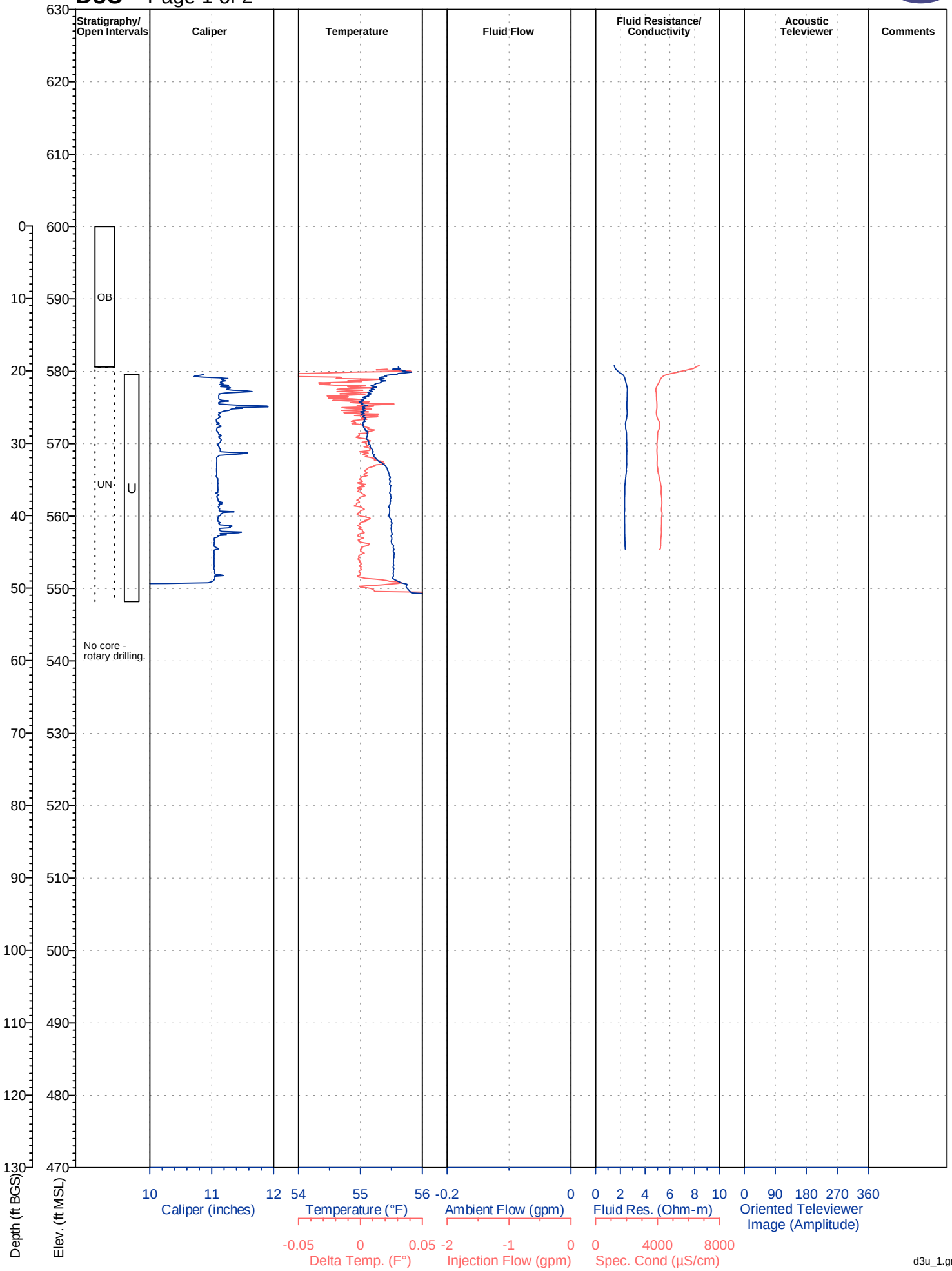
d2_1.grf

D2M Relog



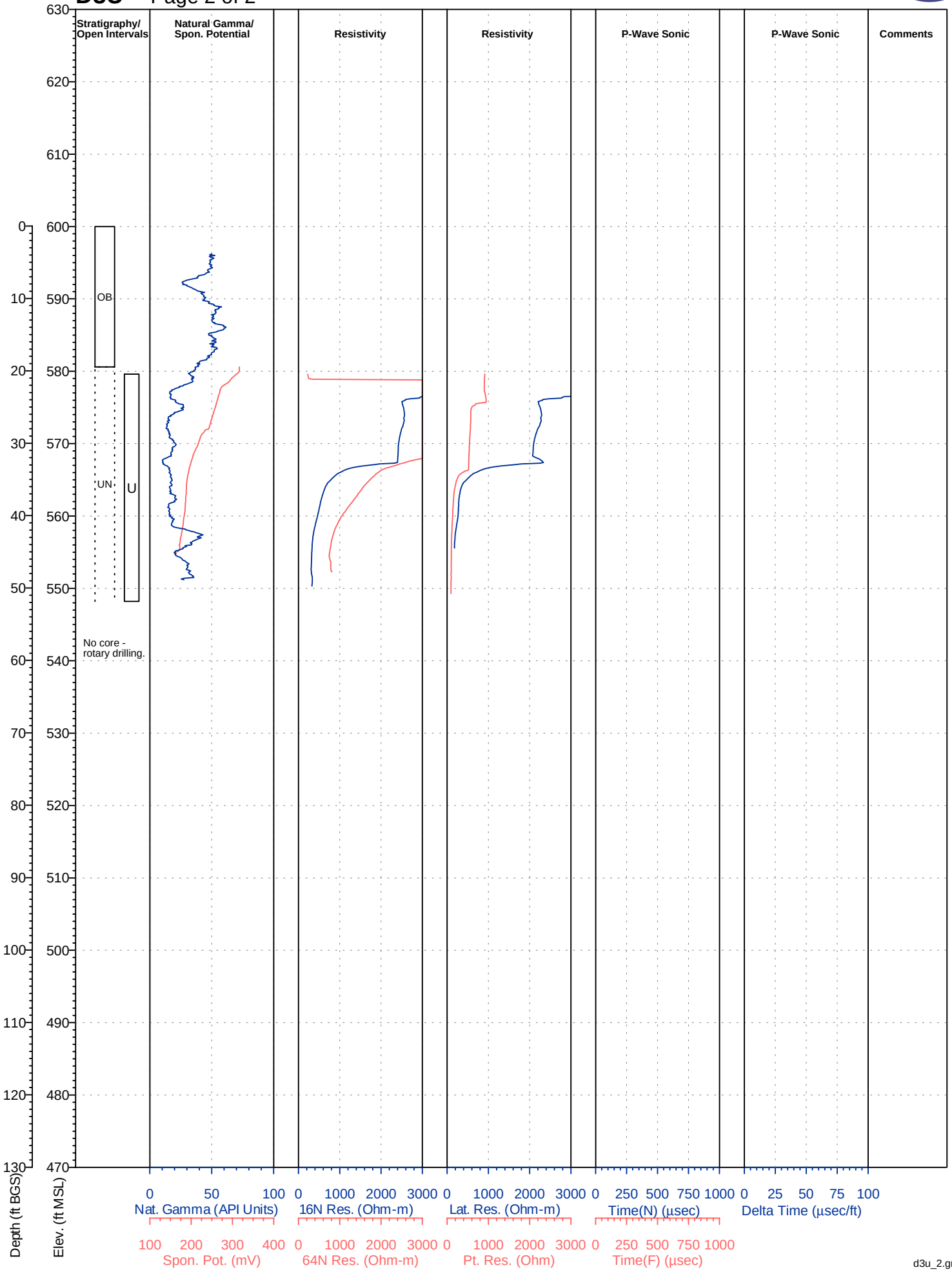
d2_r_2.grf

D3U


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
UN
U
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
Caliper (inches)
Temperature (°F)
Ambient Flow (gpm)
Fluid Res. (Ohm-m)
Oriented Televiewer Image (Amplitude)
Delta Temp. (F°)
Injection Flow (gpm)
Spec. Cond (µS/cm)

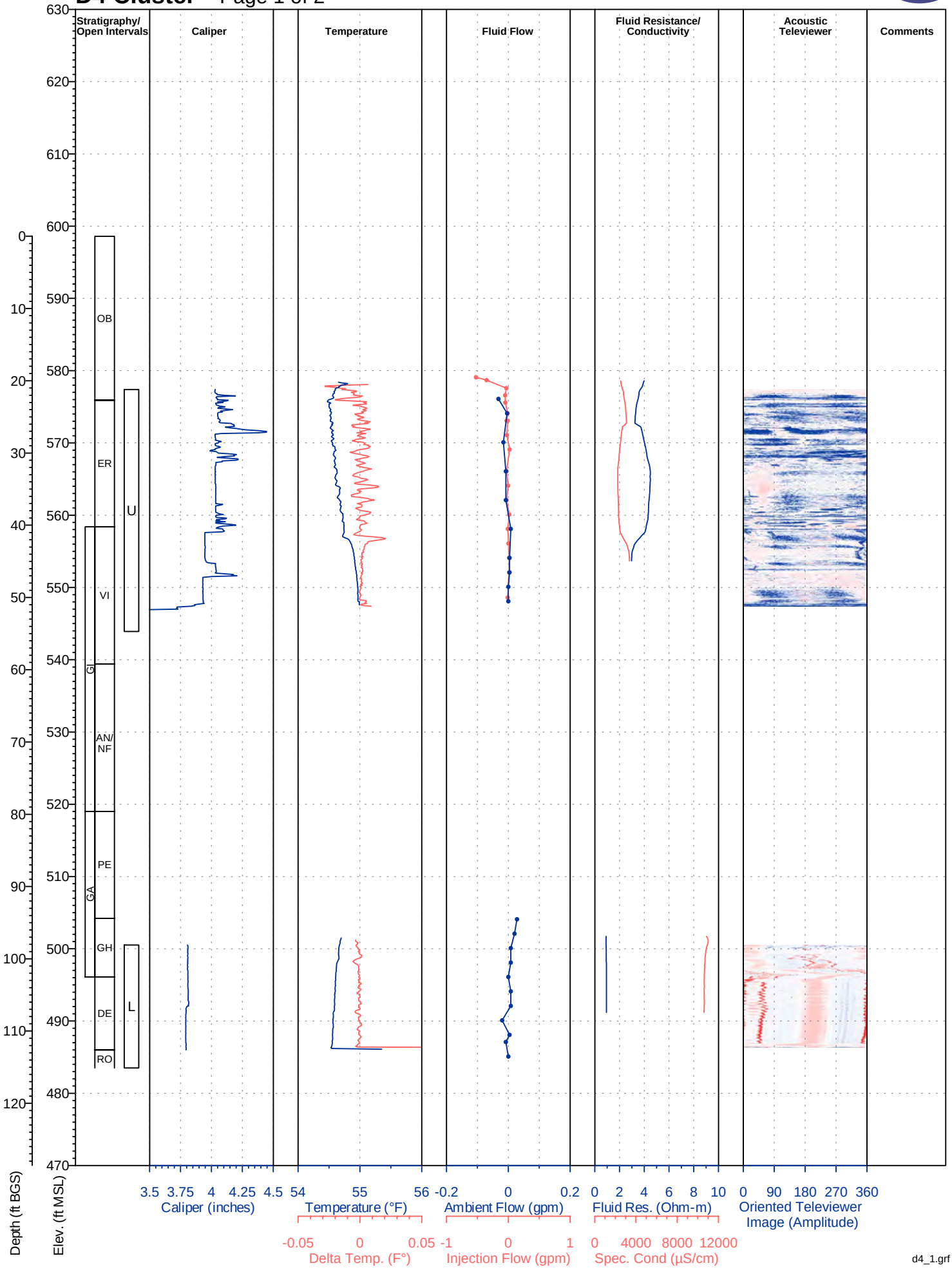
d3u_1.grf

D3U


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
UN
U
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
0 50 100
Nat. Gamma (API Units)
100 200 300 400
Spon. Pot. (mV)
0 1000 2000 3000
16N Res. (Ohm-m)
0 1000 2000 3000
64N Res. (Ohm-m)
0 1000 2000 3000
Lat. Res. (Ohm-m)
0 1000 2000 3000
Pt. Res. (Ohm)
0 250 500 750 1000
Time(N) (µsec)
0 250 500 750 1000
Time(F) (µsec)
0 25 50 75 100
Delta Time (µsec/ft)

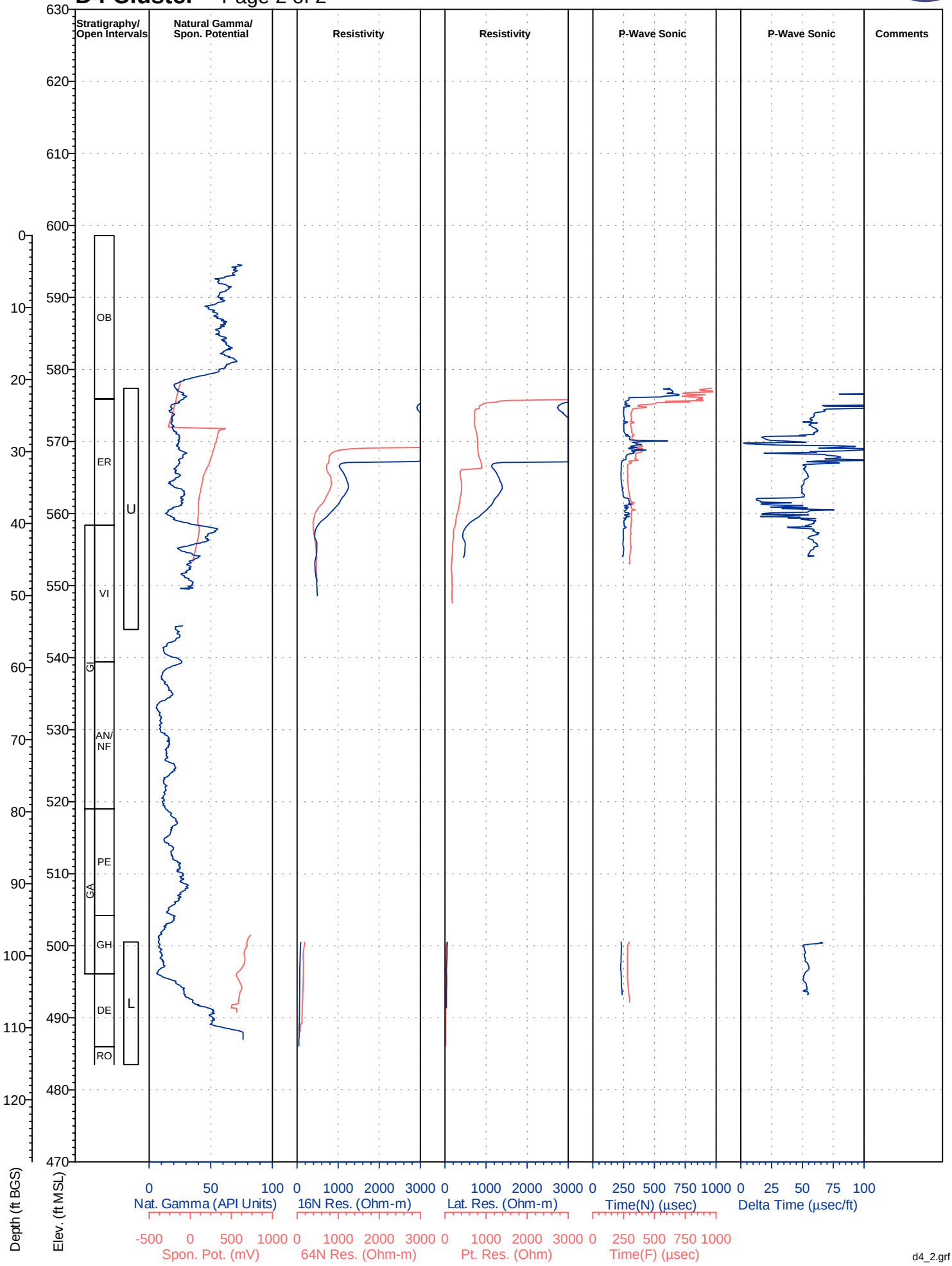
d3u_2.grf

D4 Cluster



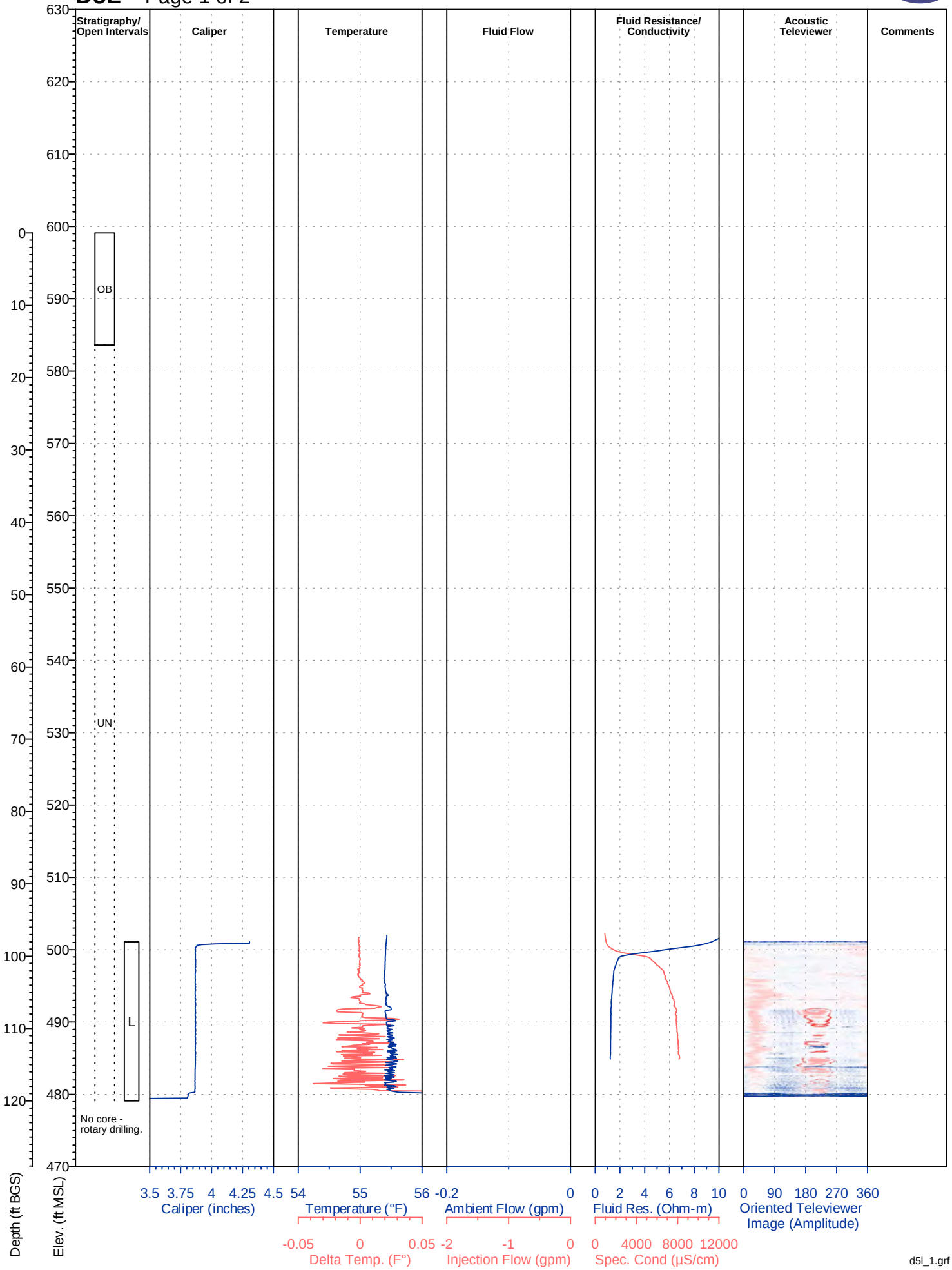
d4_1.grf

D4 Cluster



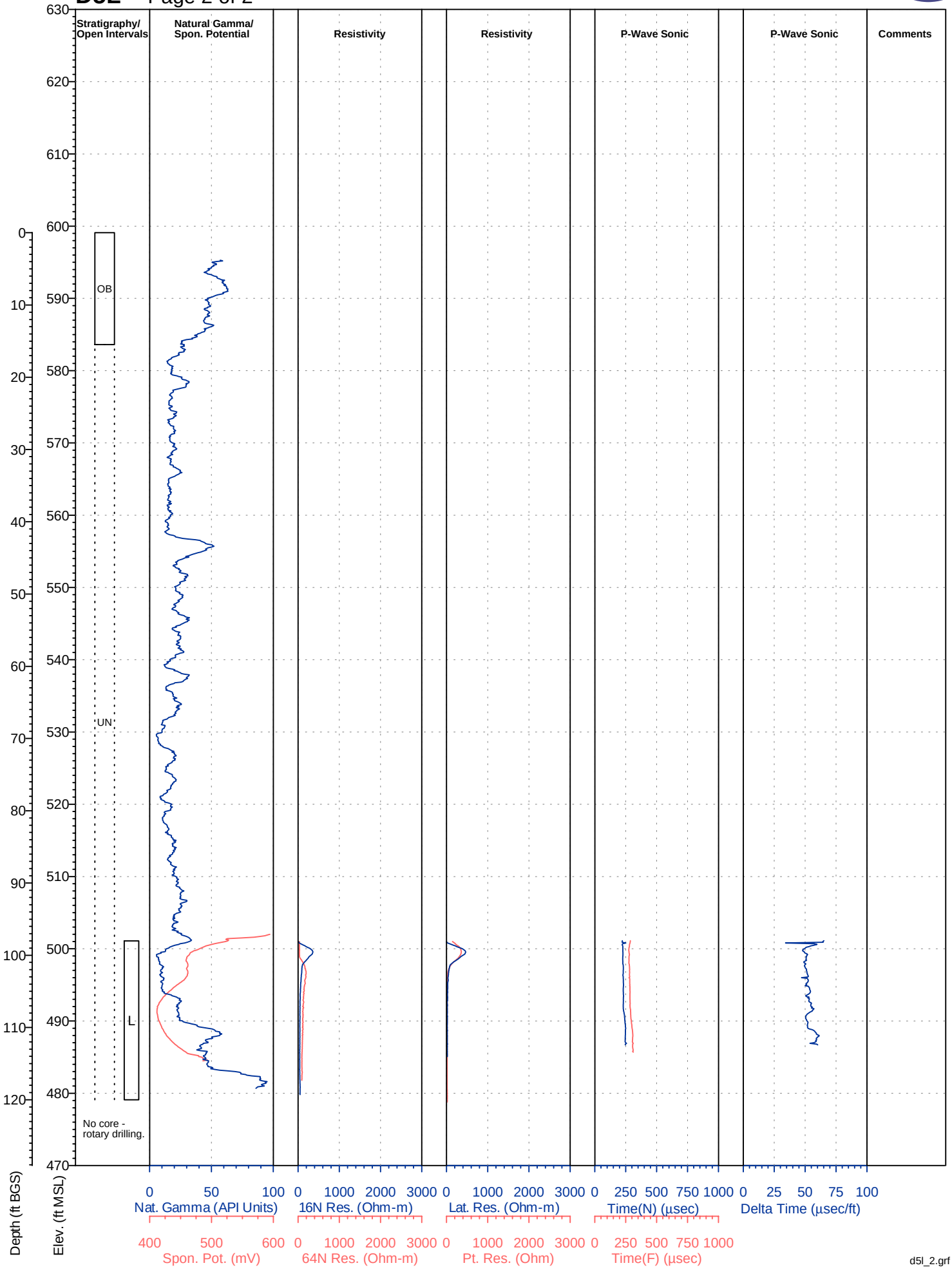
d4_2.grf

D5L


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
UN
L
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
54 55 56
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 2 4 6 8 10
Fluid Res. (Ohm-m)
0 4000 8000 12000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

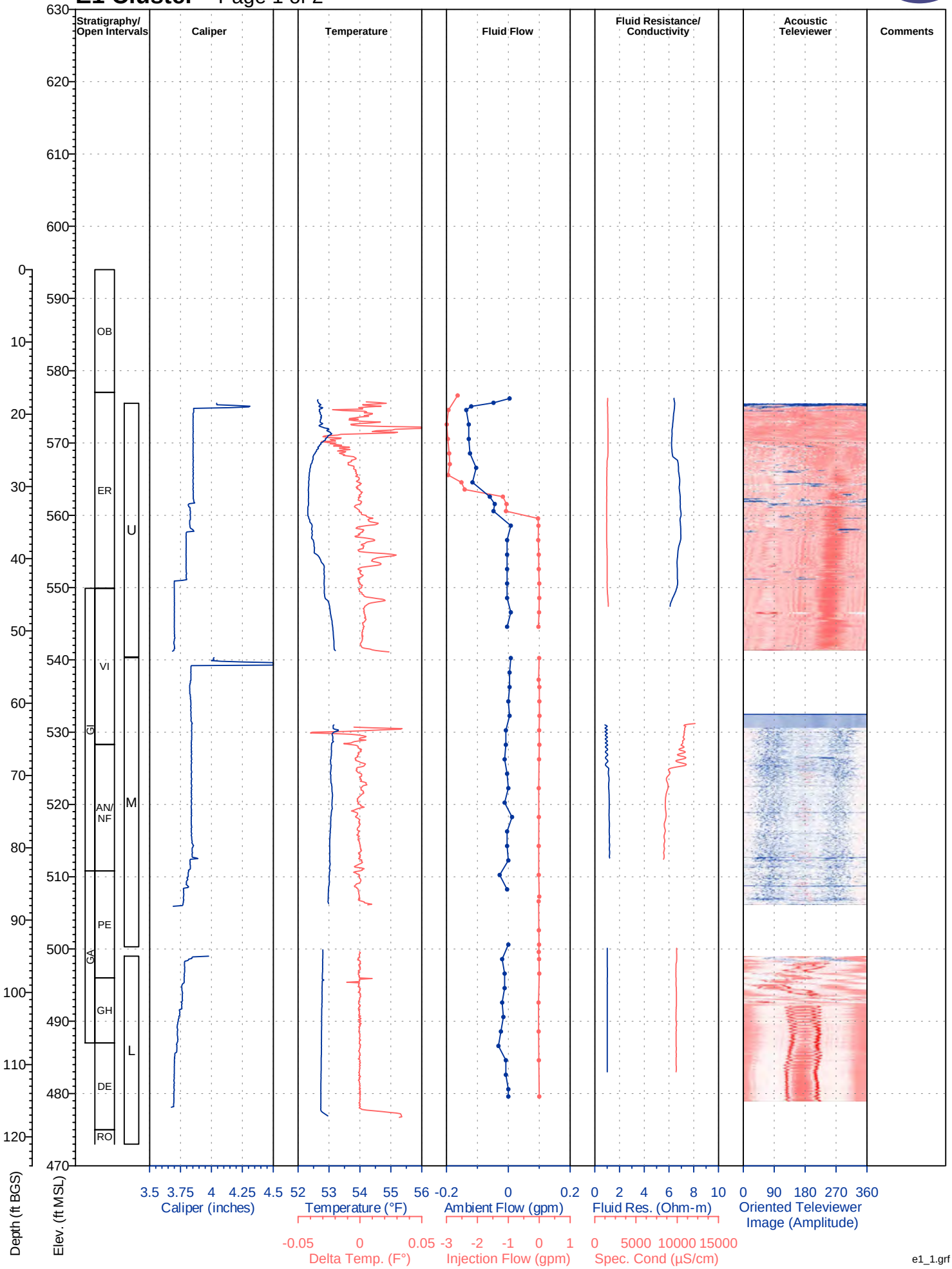
d5l_1.grf

D5L


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
UN
L
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

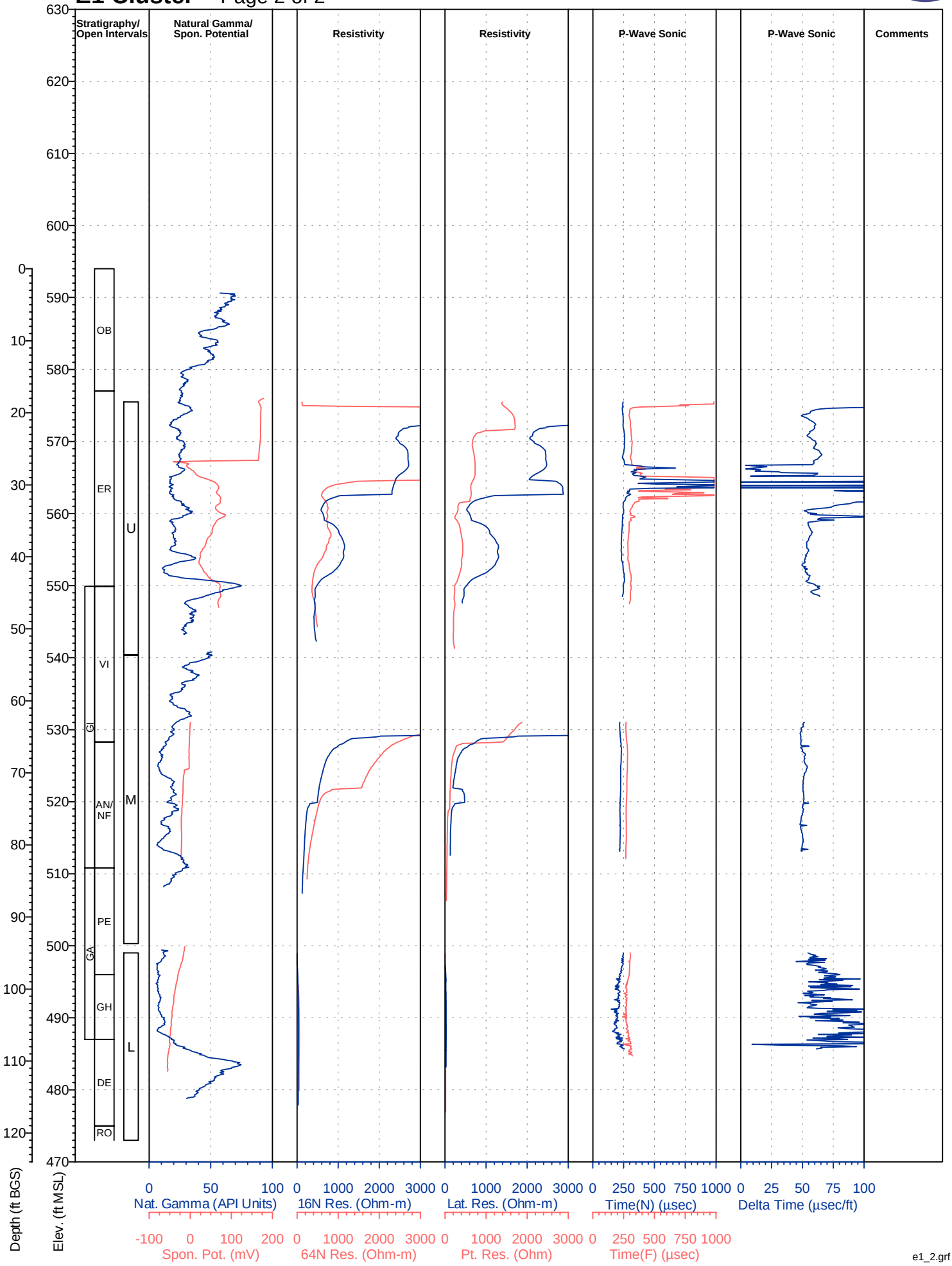
d5l_2.grf

E1 Cluster



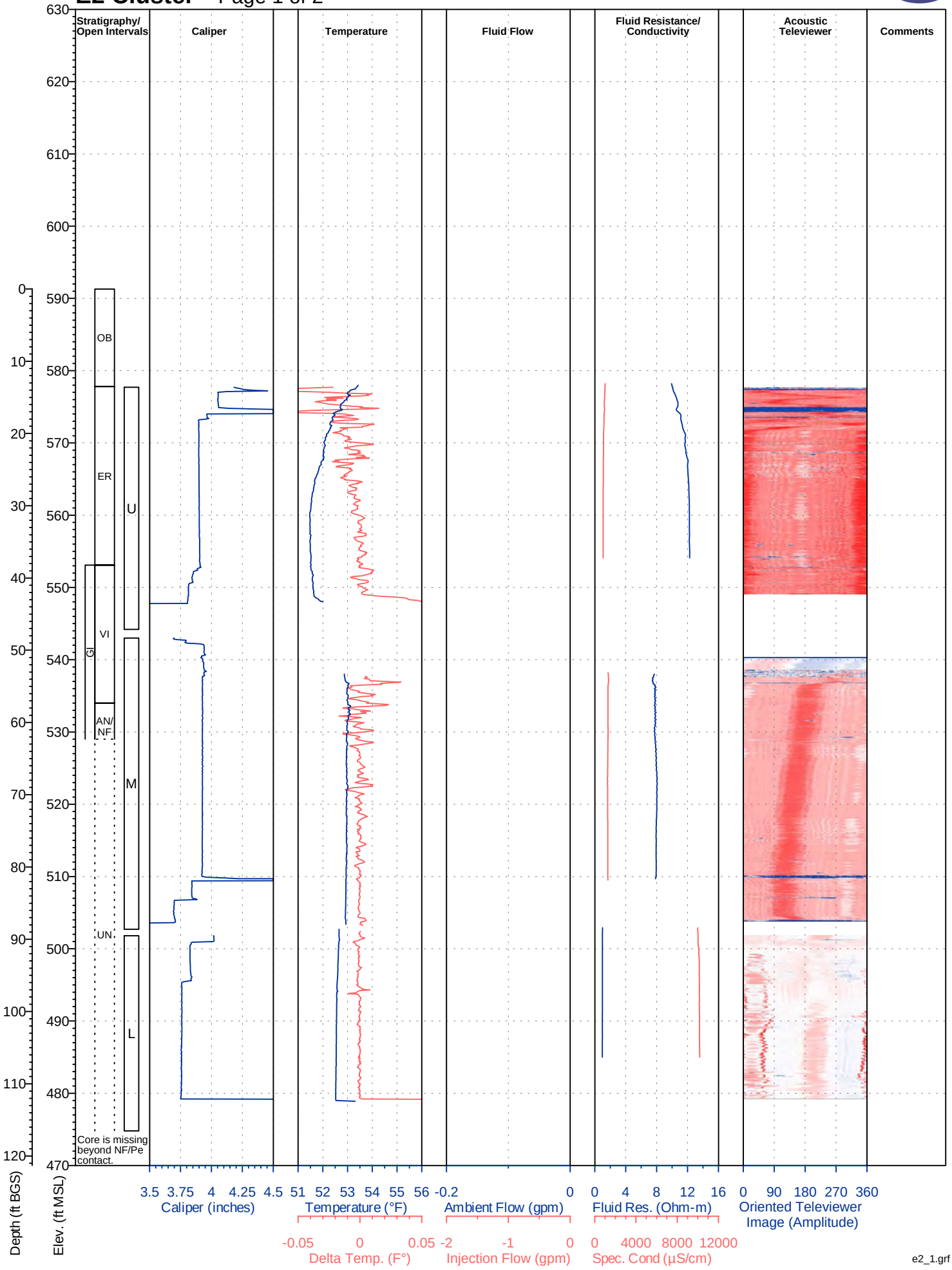
e1_1.grf

E1 Cluster



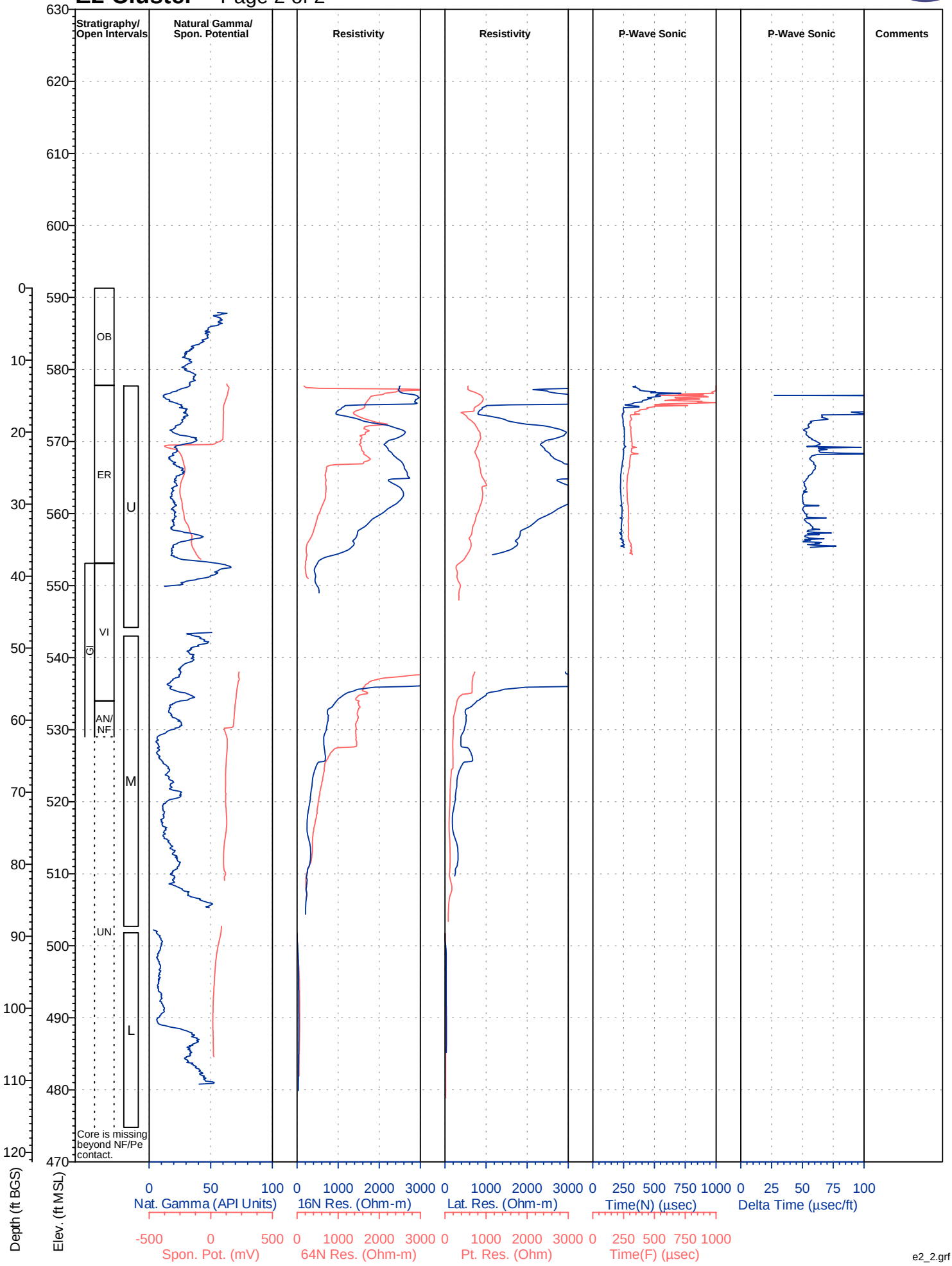
e1_2.grf

E2 Cluster



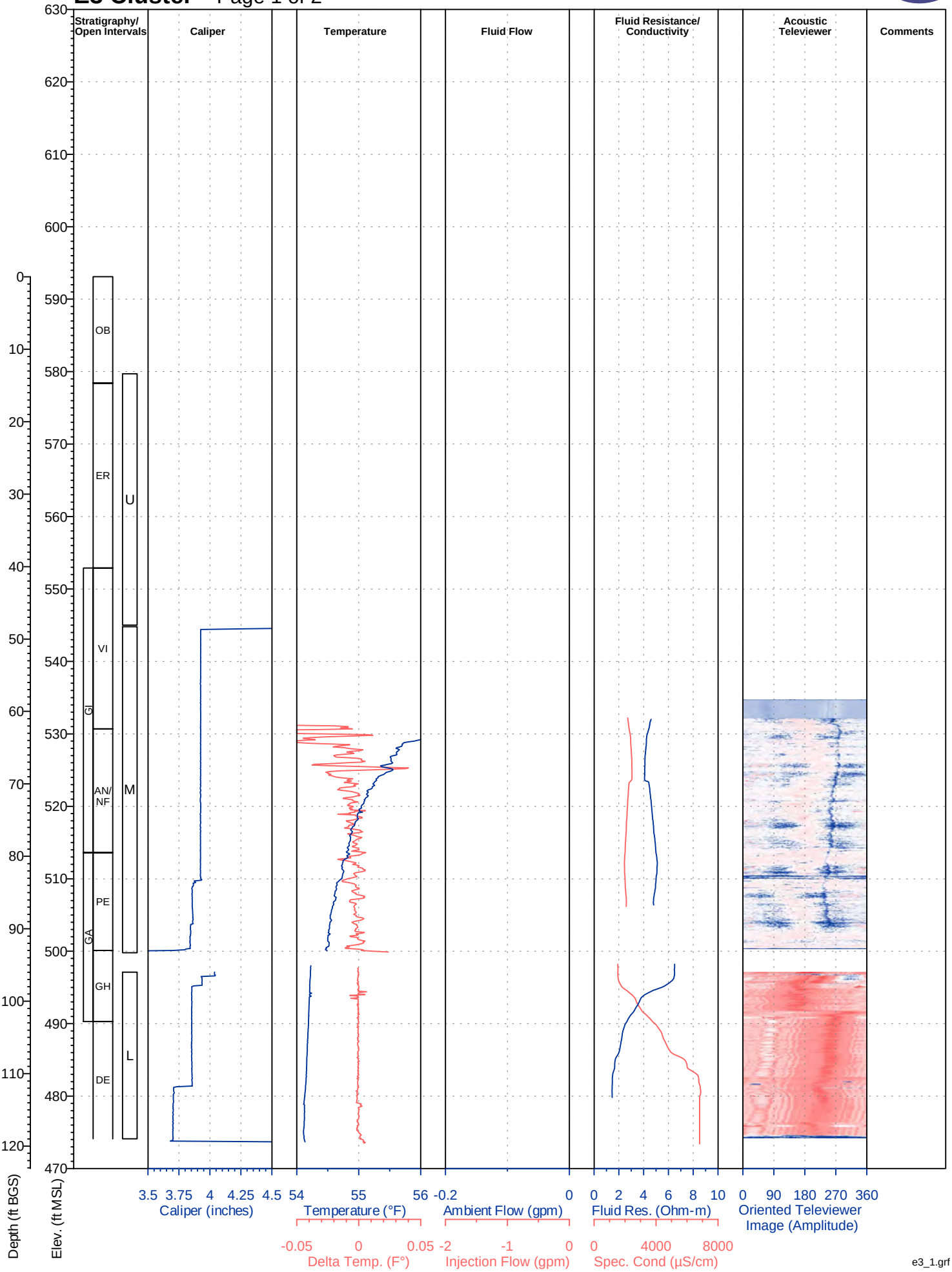
e2_1.grf

E2 Cluster



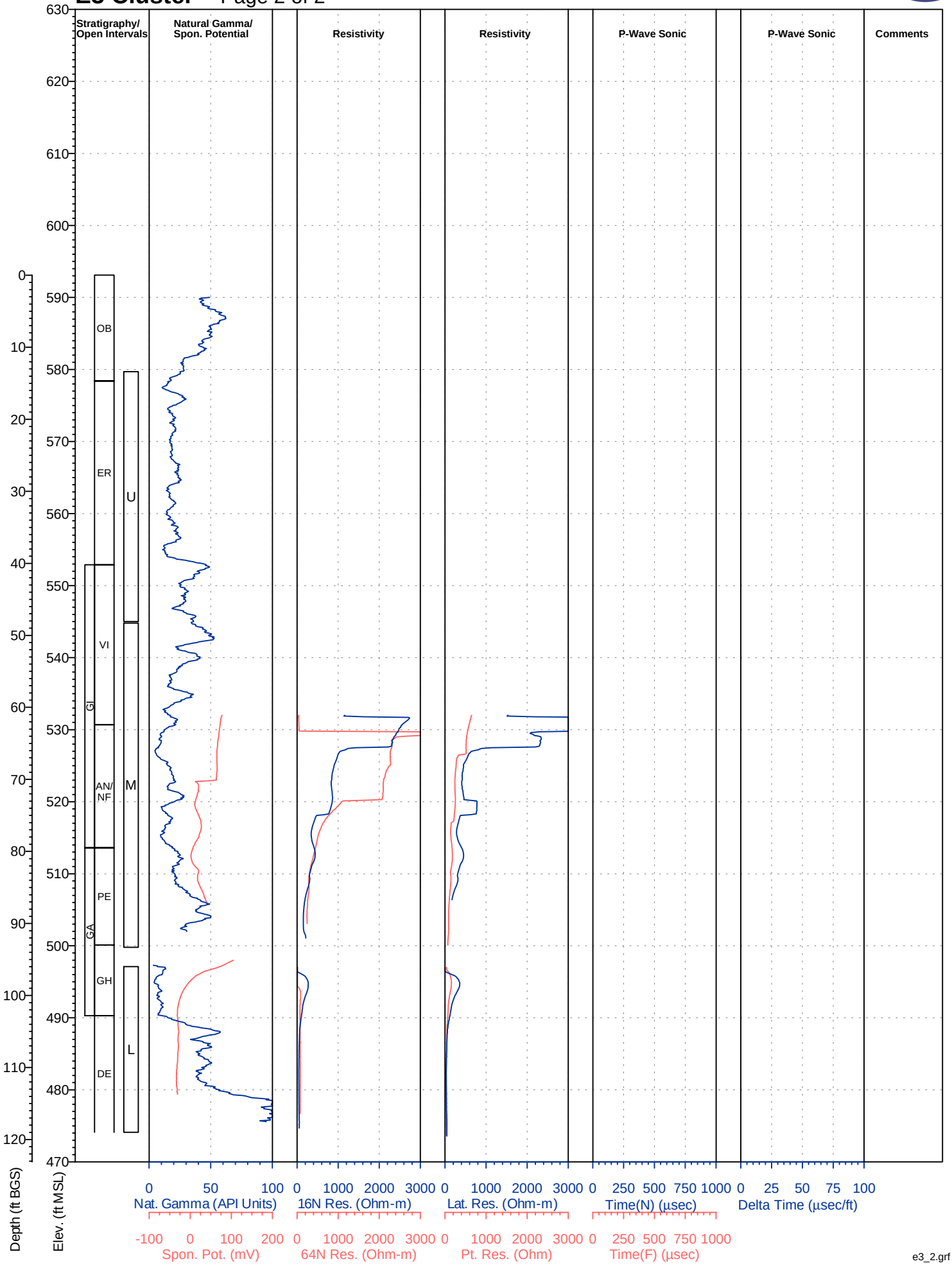
e2_2.grf

E3 Cluster



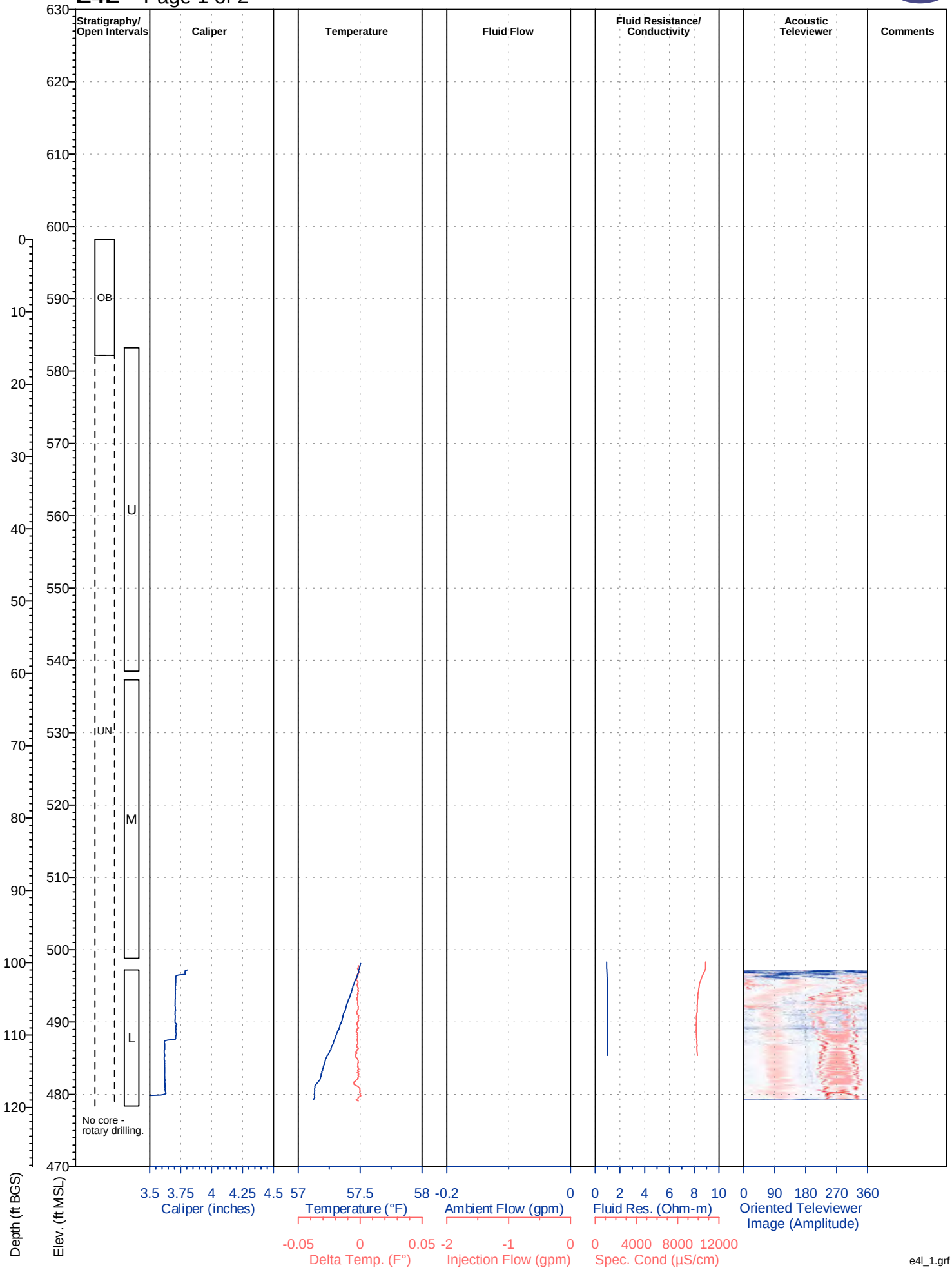
e3_1.grf

E3 Cluster



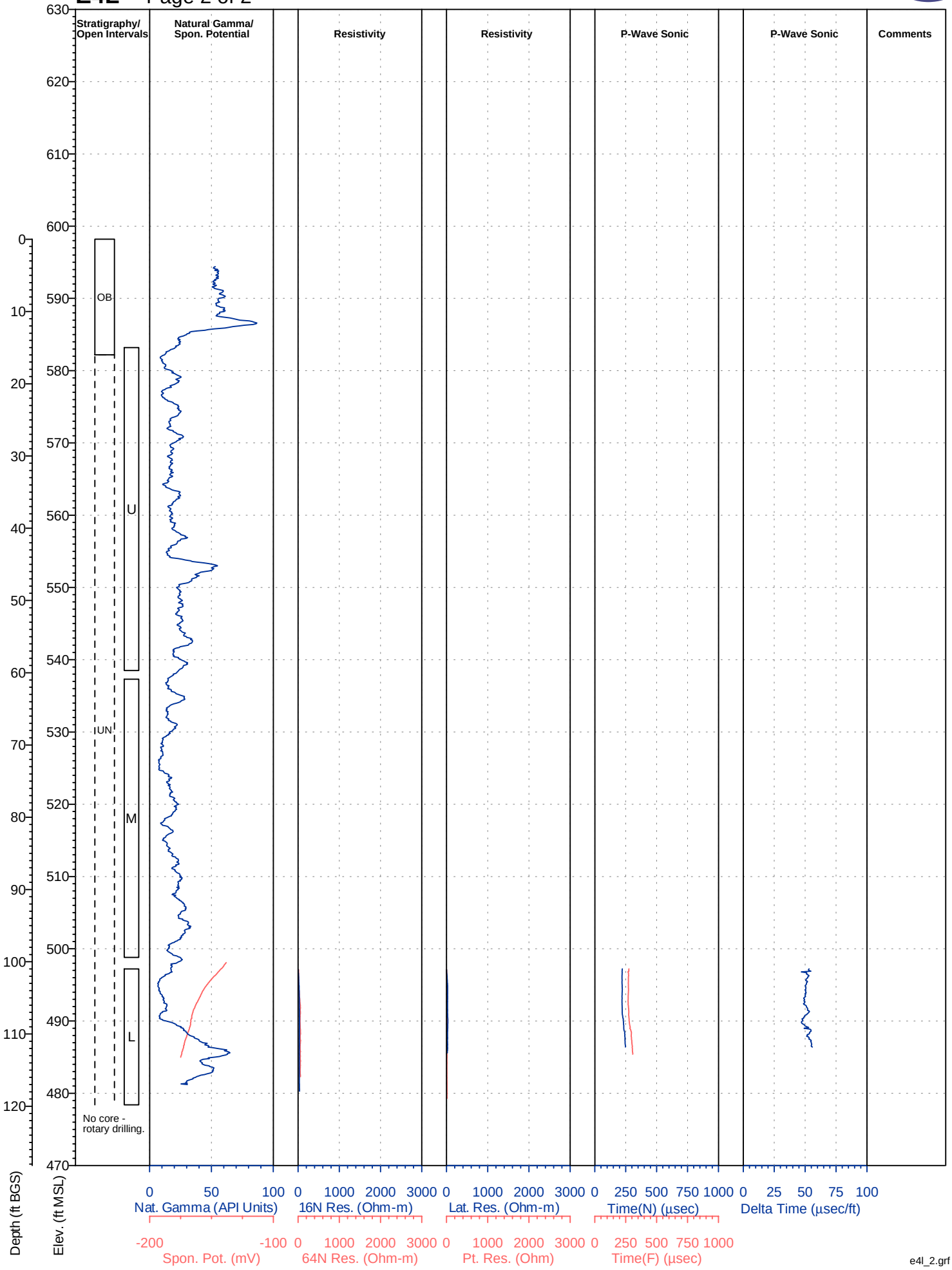
e3_2.grf

E4L


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
U
UN
M
L
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
57 57.5 58
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 2 4 6 8 10
Fluid Res. (Ohm-m)
0 4000 8000 12000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

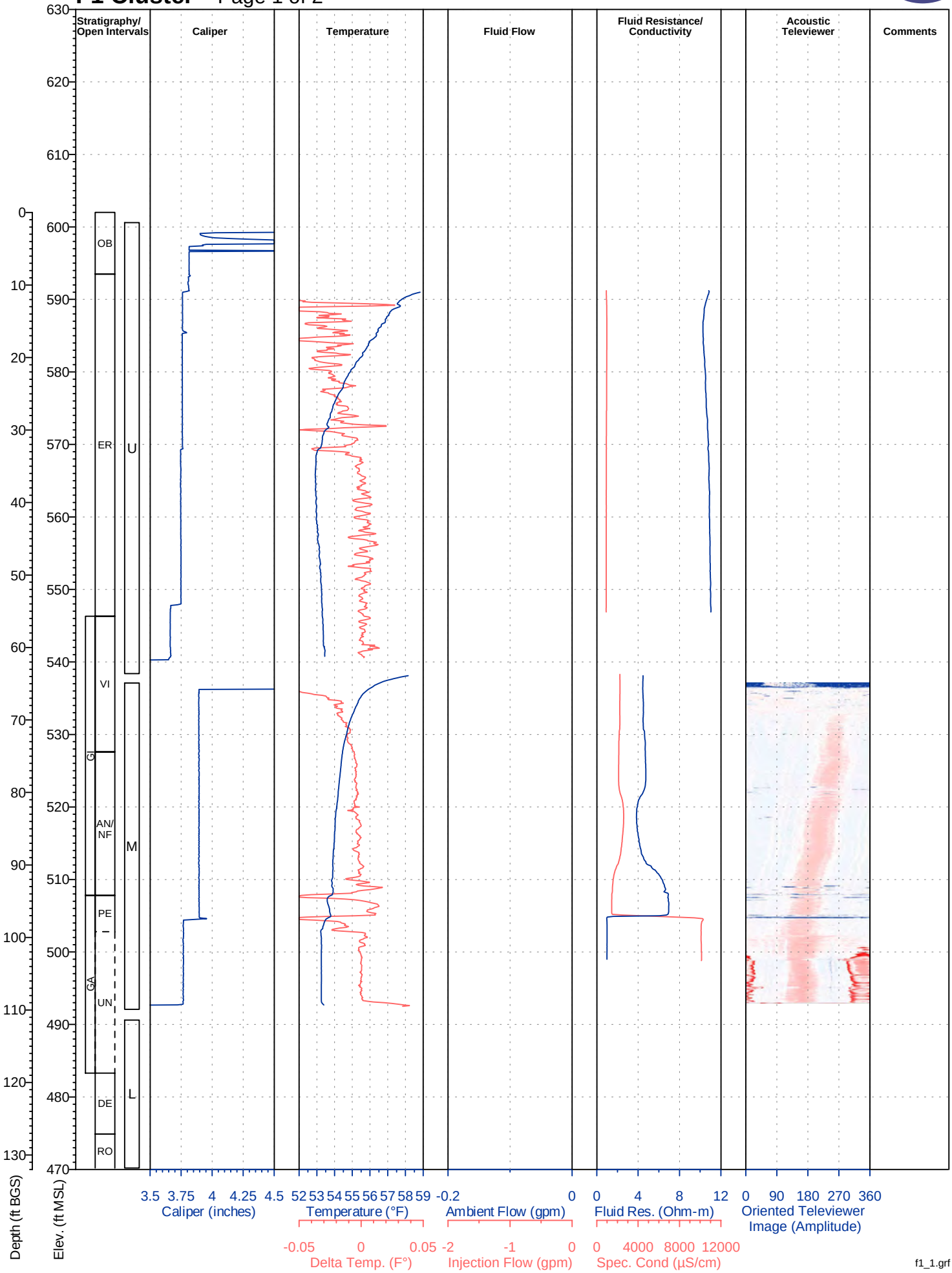
e4l_1.grf

E4L


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
U
UN
M
L
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
16N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Time(N) (µsec)
Delta Time (µsec/ft)
Spon. Pot. (mV)
64N Res. (Ohm-m)
Pt. Res. (Ohm)
Time(F) (µsec)

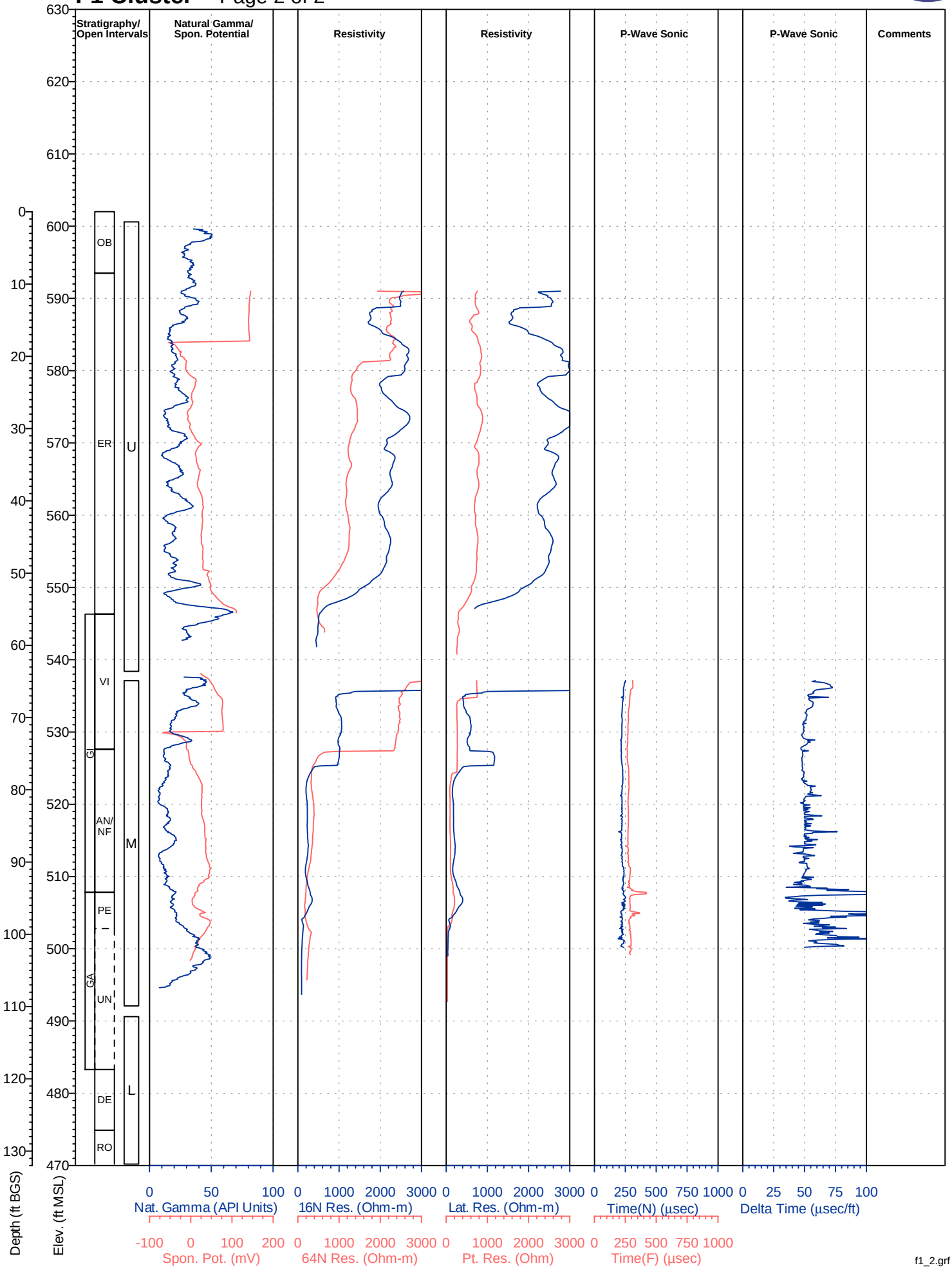
e4l_2.grf

F1 Cluster



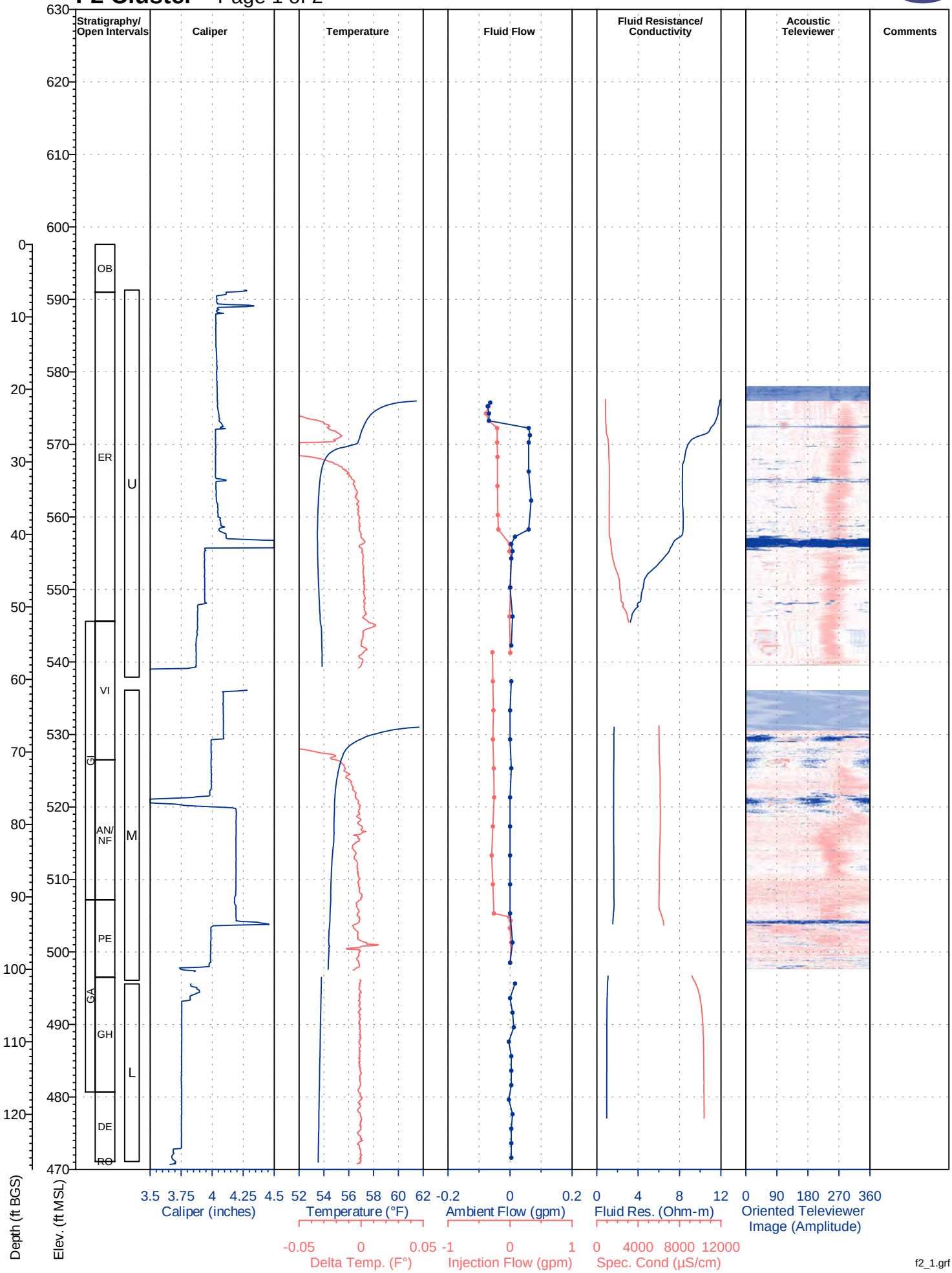
f1_1.grf

F1 Cluster



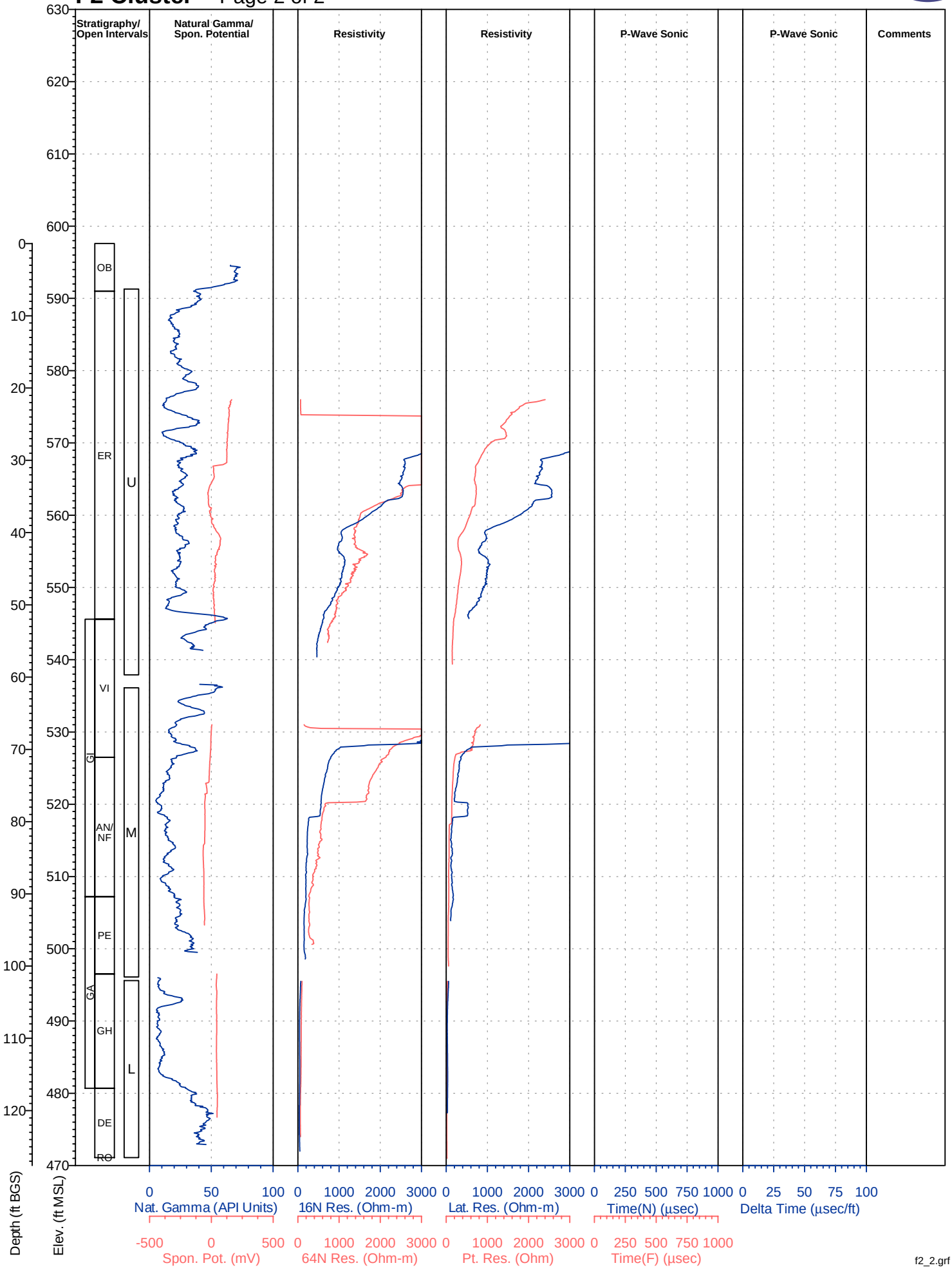
f1_2.grf

F2 Cluster



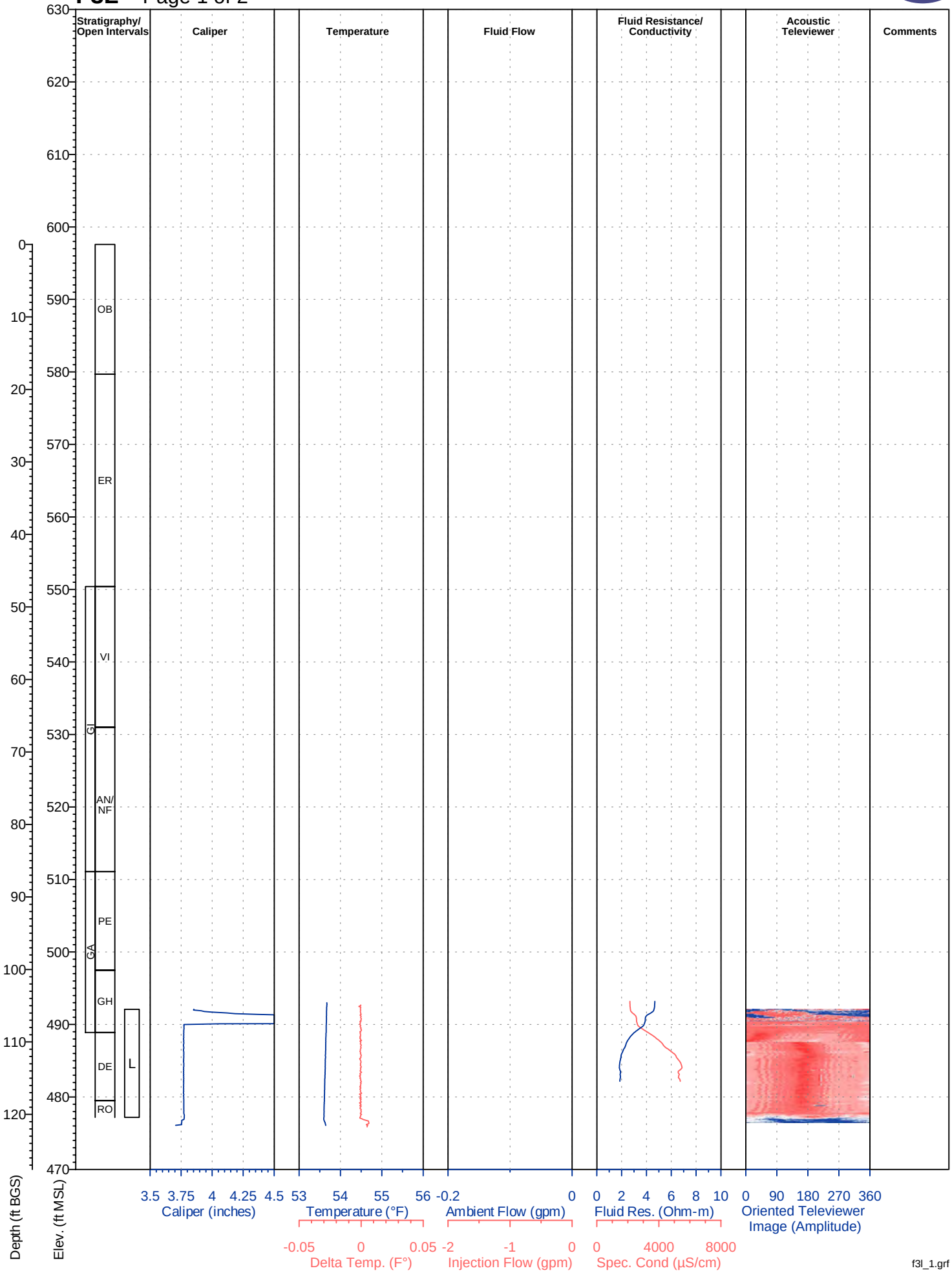
f2_1.grf

F2 Cluster



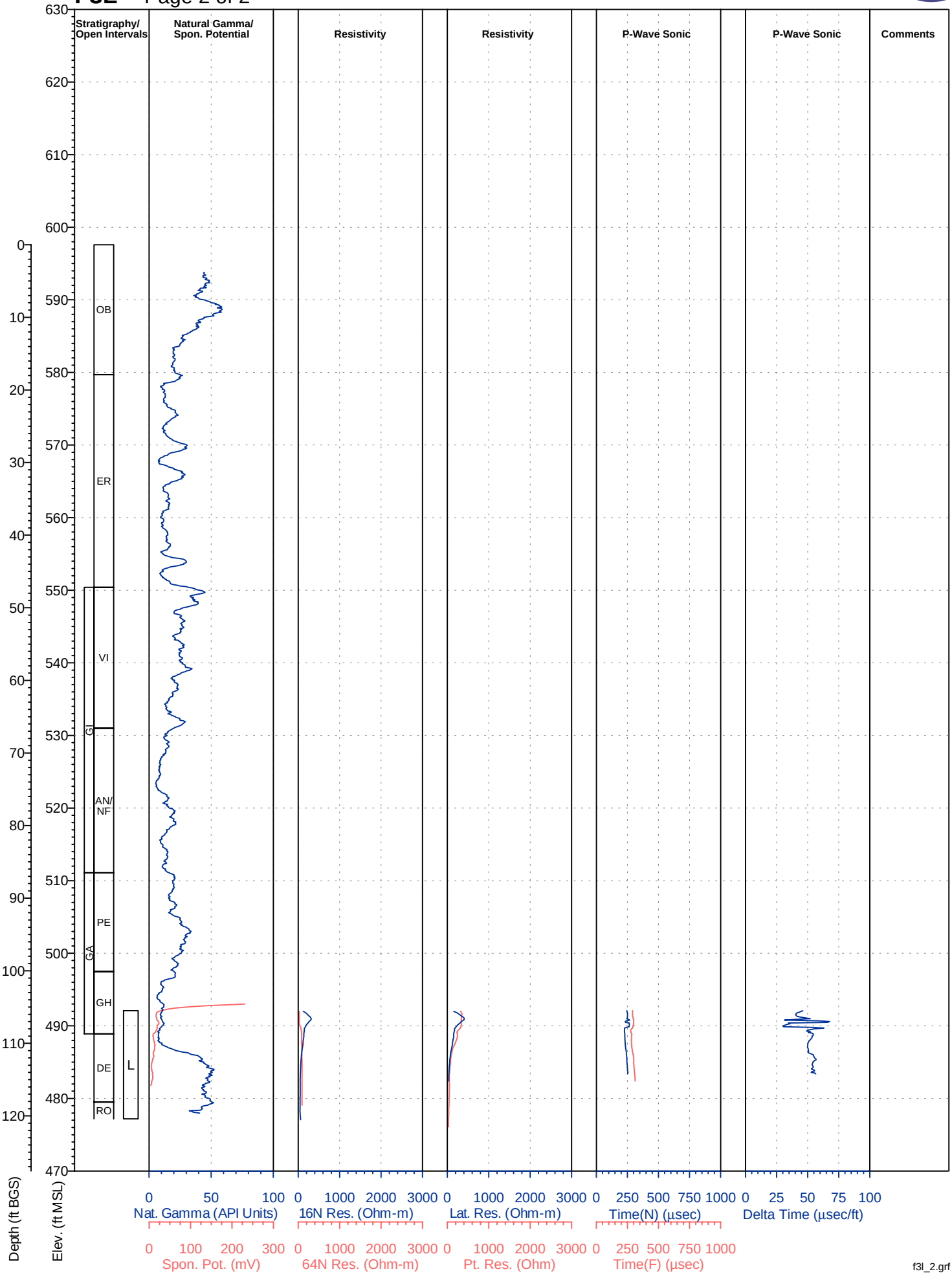
f2_2.grf

F3L


Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
ER
VI
AN/ NF
PE
GH
DE
RO
GI
GA
L
Depth (ft BGS)
Elev. (ft MSL)
3.5 3.75 4 4.25 4.5
Caliper (inches)
53 54 55 56
Temperature (°F)
-0.05 0 0.05
Delta Temp. (F°)
-0.2 0
Ambient Flow (gpm)
-2 -1 0
Injection Flow (gpm)
0 2 4 6 8 10
Fluid Res. (Ohm-m)
0 4000 8000
Spec. Cond (µS/cm)
0 90 180 270 360
Oriented Televiewer Image (Amplitude)

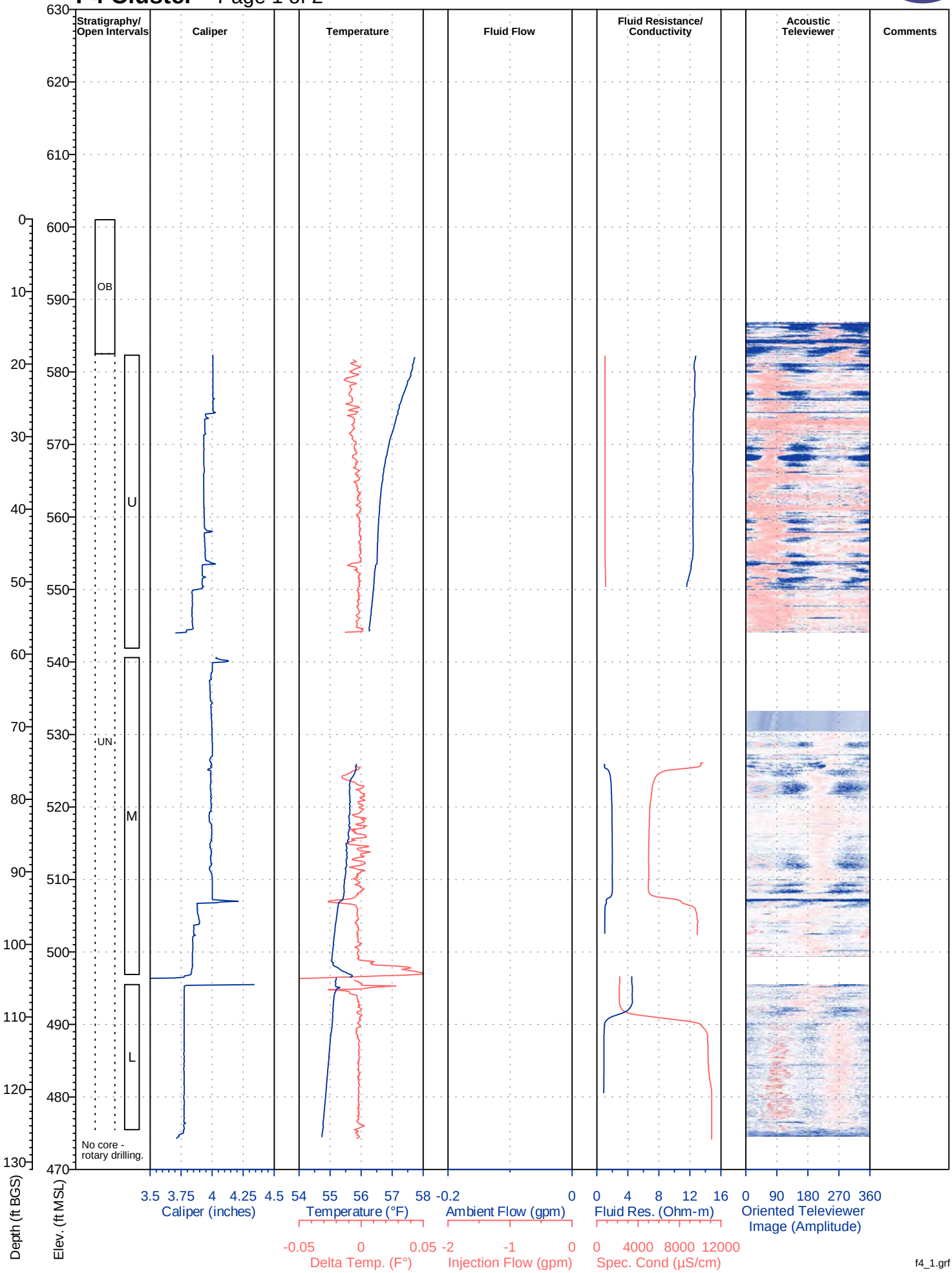
f3l_1.grf

F3L


Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
VI
GI
AN/ NF
PE
GA
GH
DE
RO
L
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

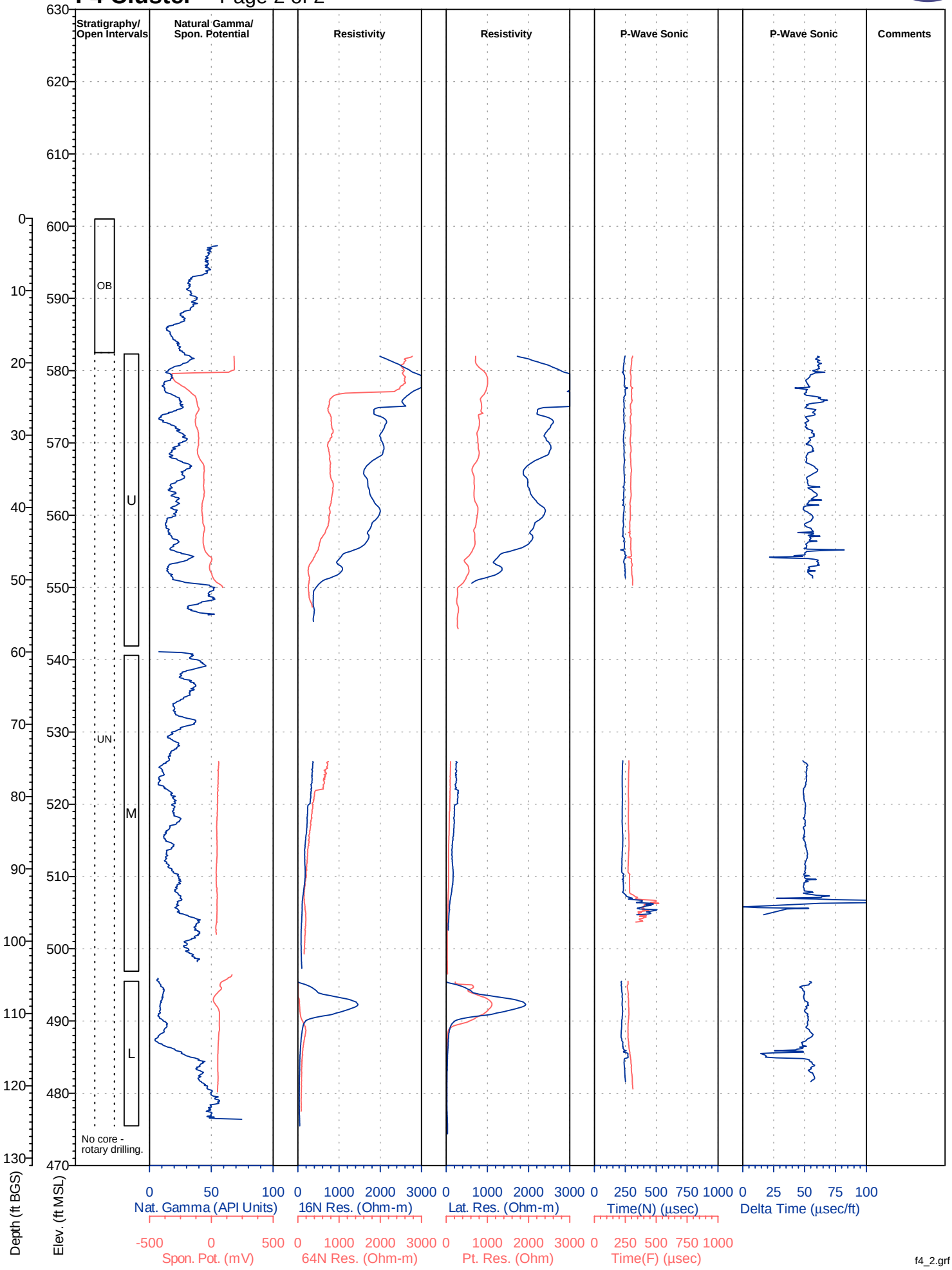
f3l_2.grf

F4 Cluster



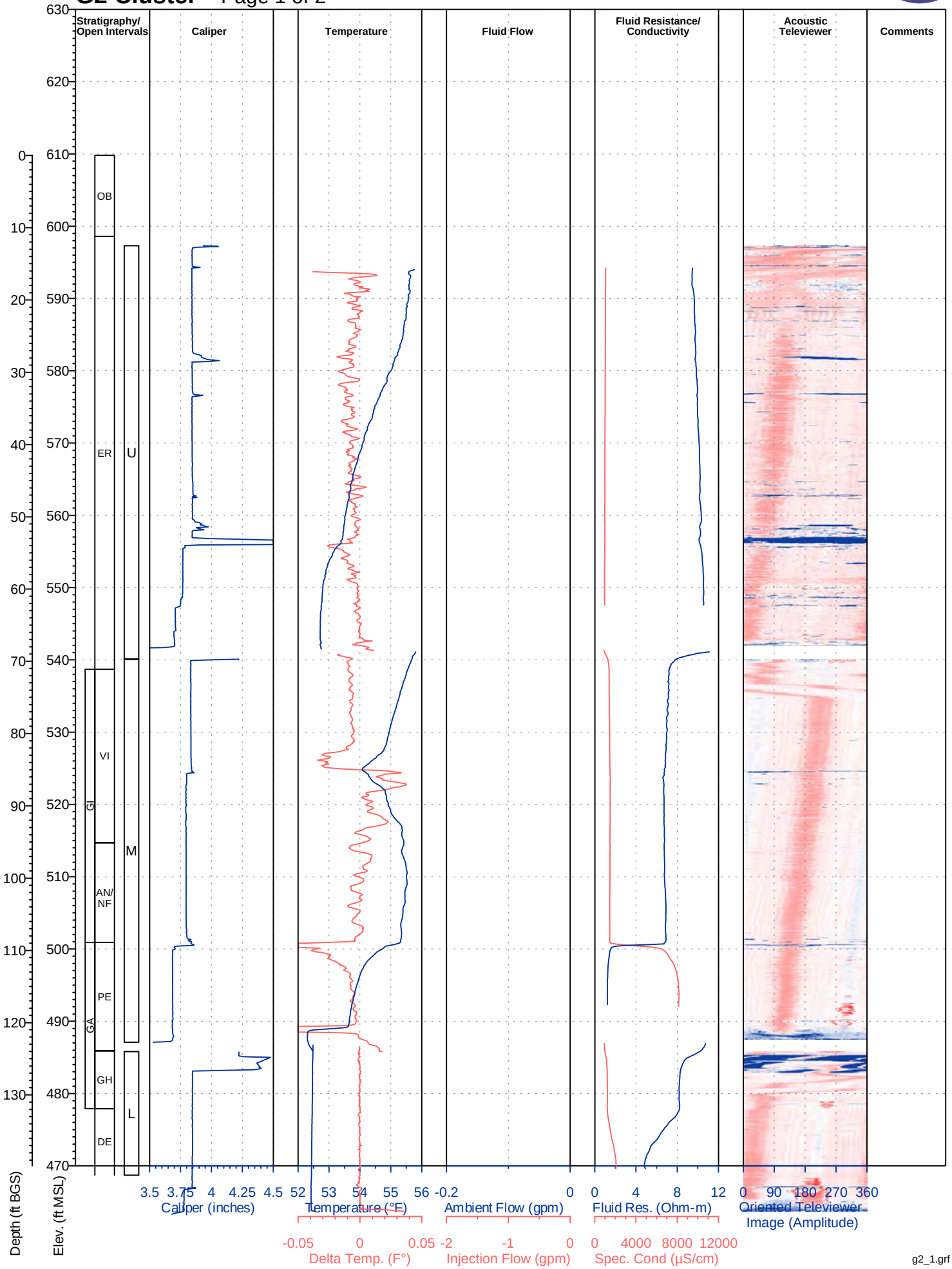
f4_1.grf

F4 Cluster

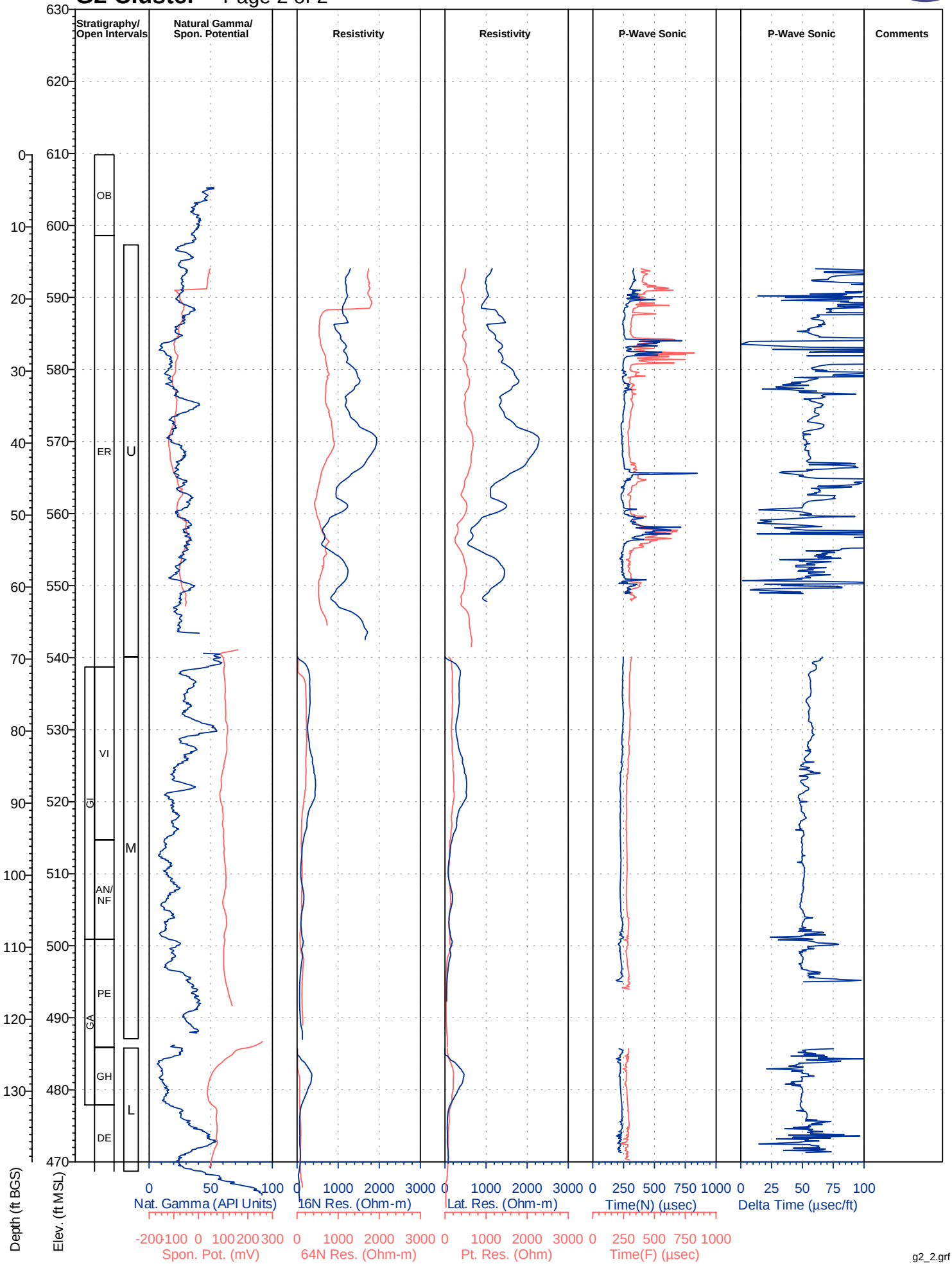


f4_2.grf

G2 Cluster

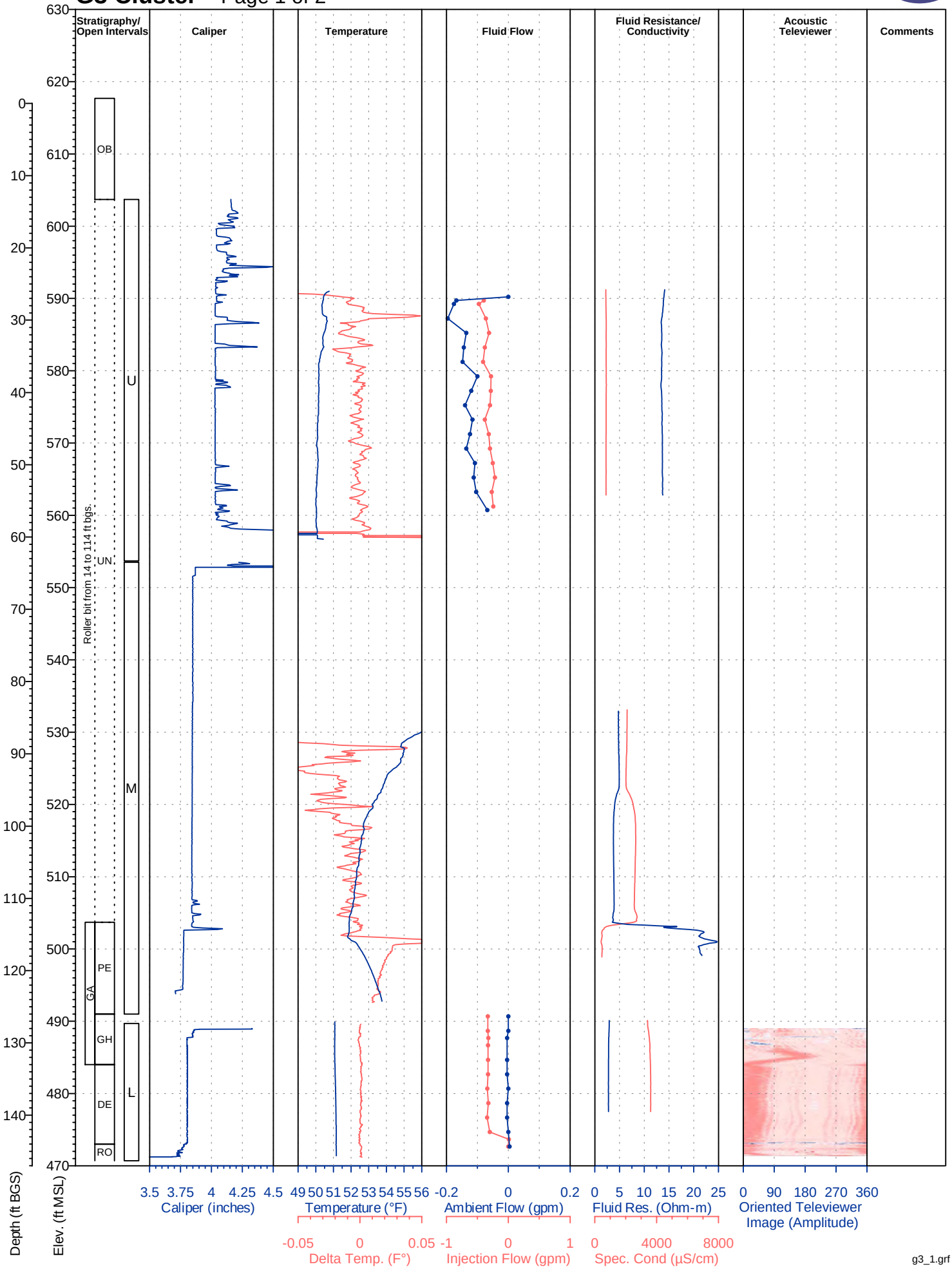

Stratigraphy/ Open Intervals
Caliper
Temperature
Fluid Flow
Fluid Resistance/ Conductivity
Acoustic Televiewer
Comments
OB
ER
U
VI
GI
M
AN/ NF
PE
GA
GH
L
DE
Depth (ft BGS)
Elev. (ft MSL)
Caliper (inches)
Temperature (°F)
Ambient Flow (gpm)
Fluid Res. (Ohm-m)
Oriented Televiewer Image (Amplitude)
Delta Temp. (F°)
Injection Flow (gpm)
Spec. Cond (µS/cm)
g2_1.grf

G2 Cluster



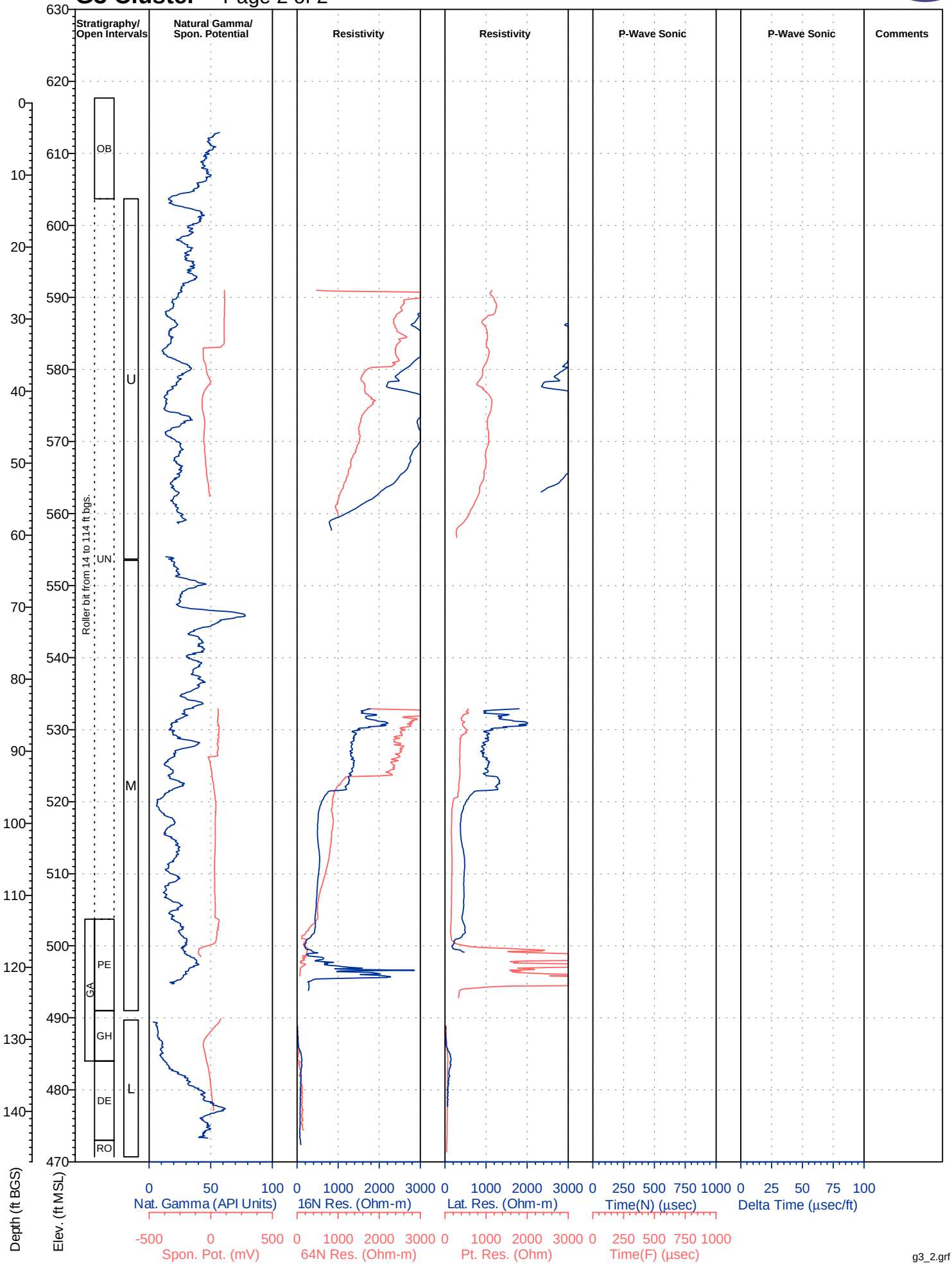
g2_2.grf

G3 Cluster



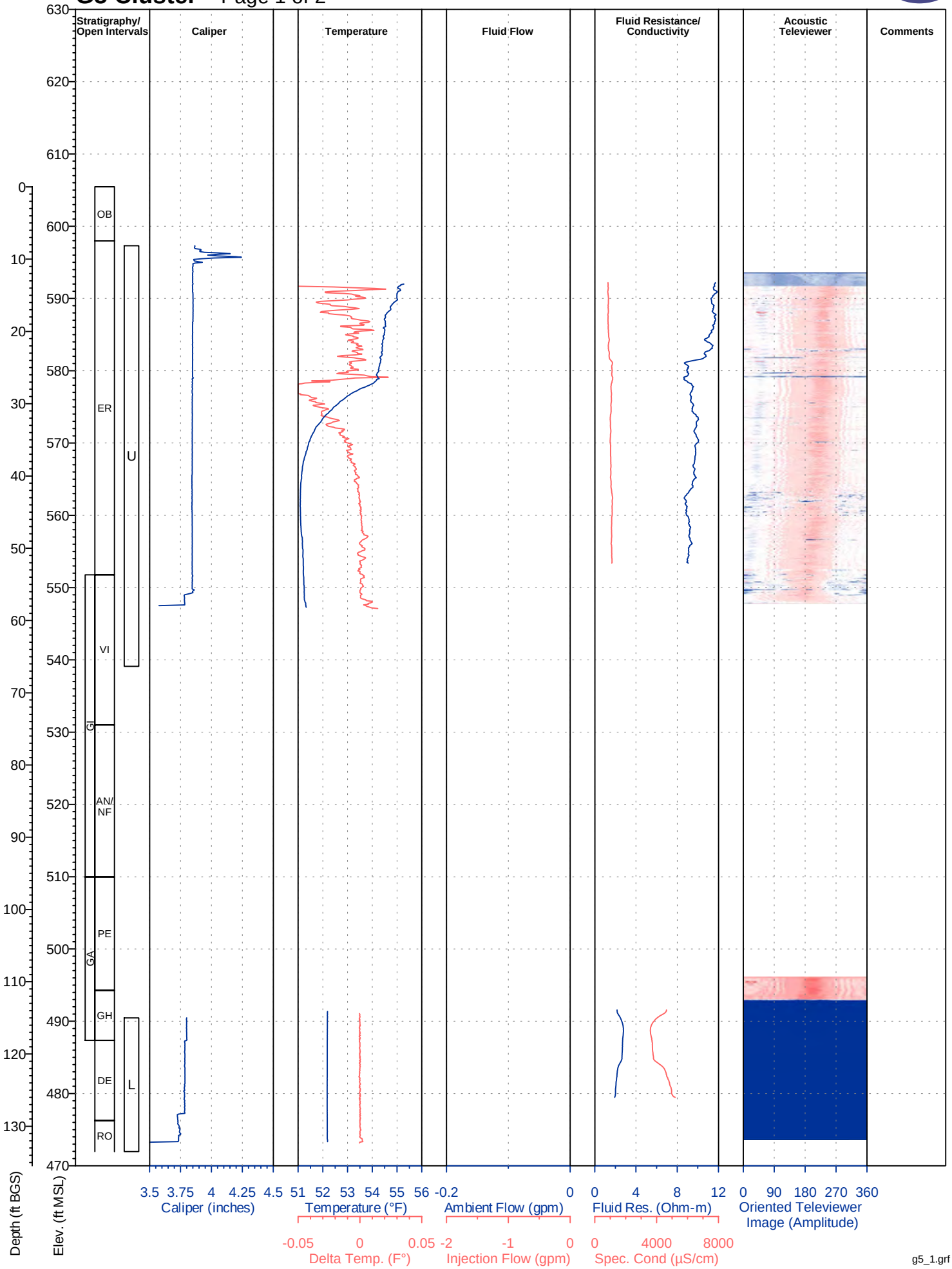
g3_1.grf

G3 Cluster



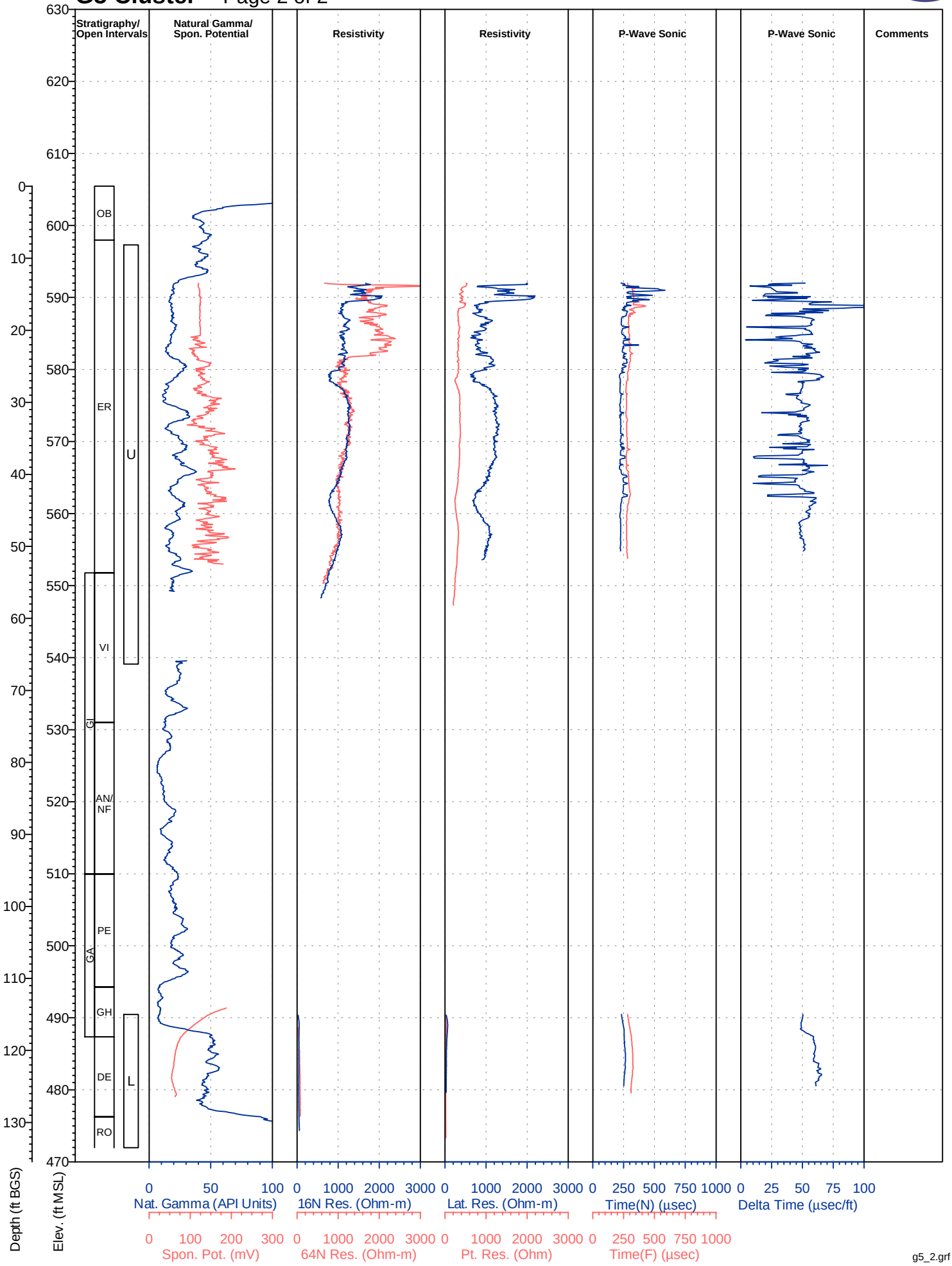
g3_2.grf

G5 Cluster



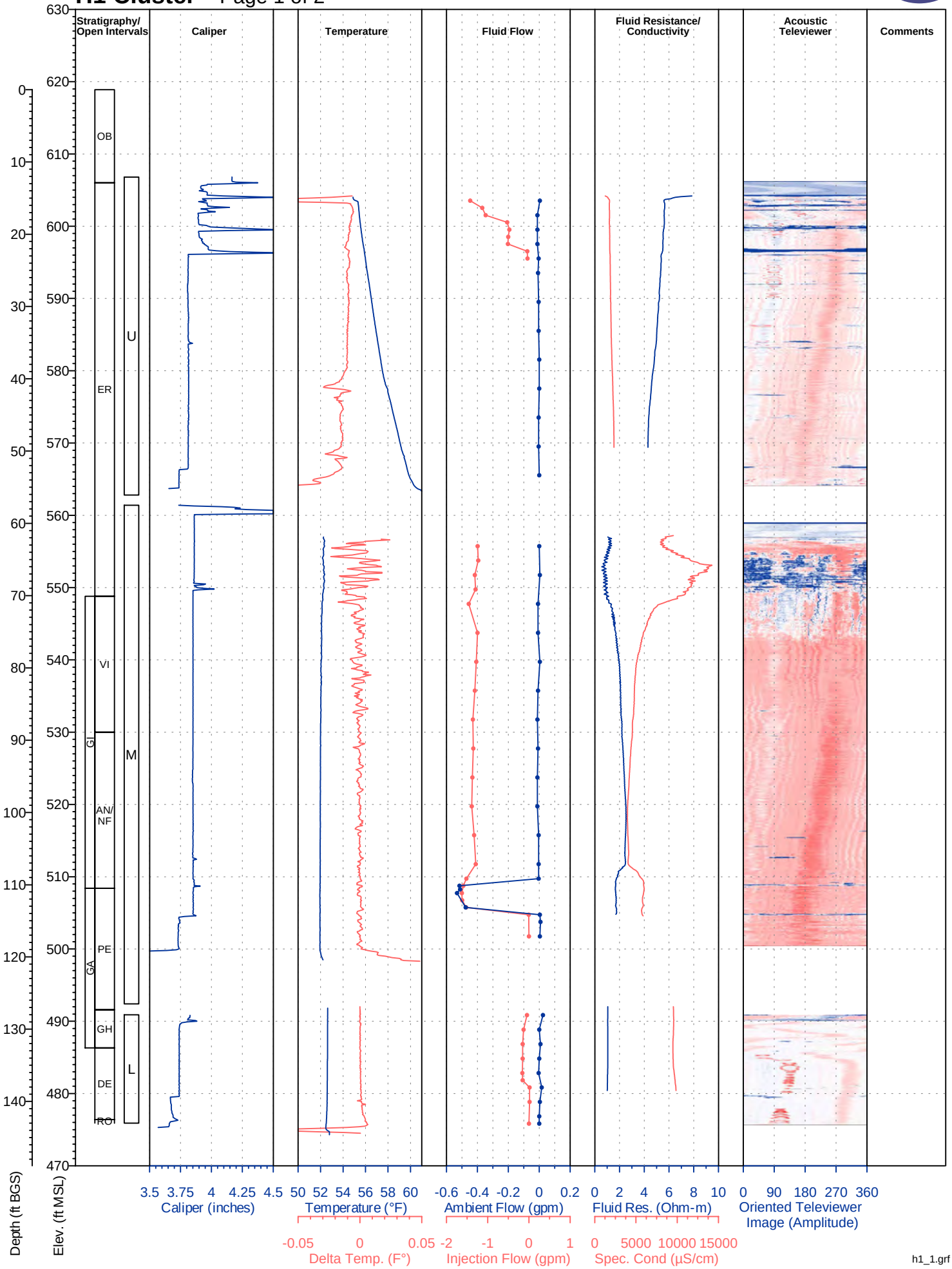
g5_1.grf

G5 Cluster



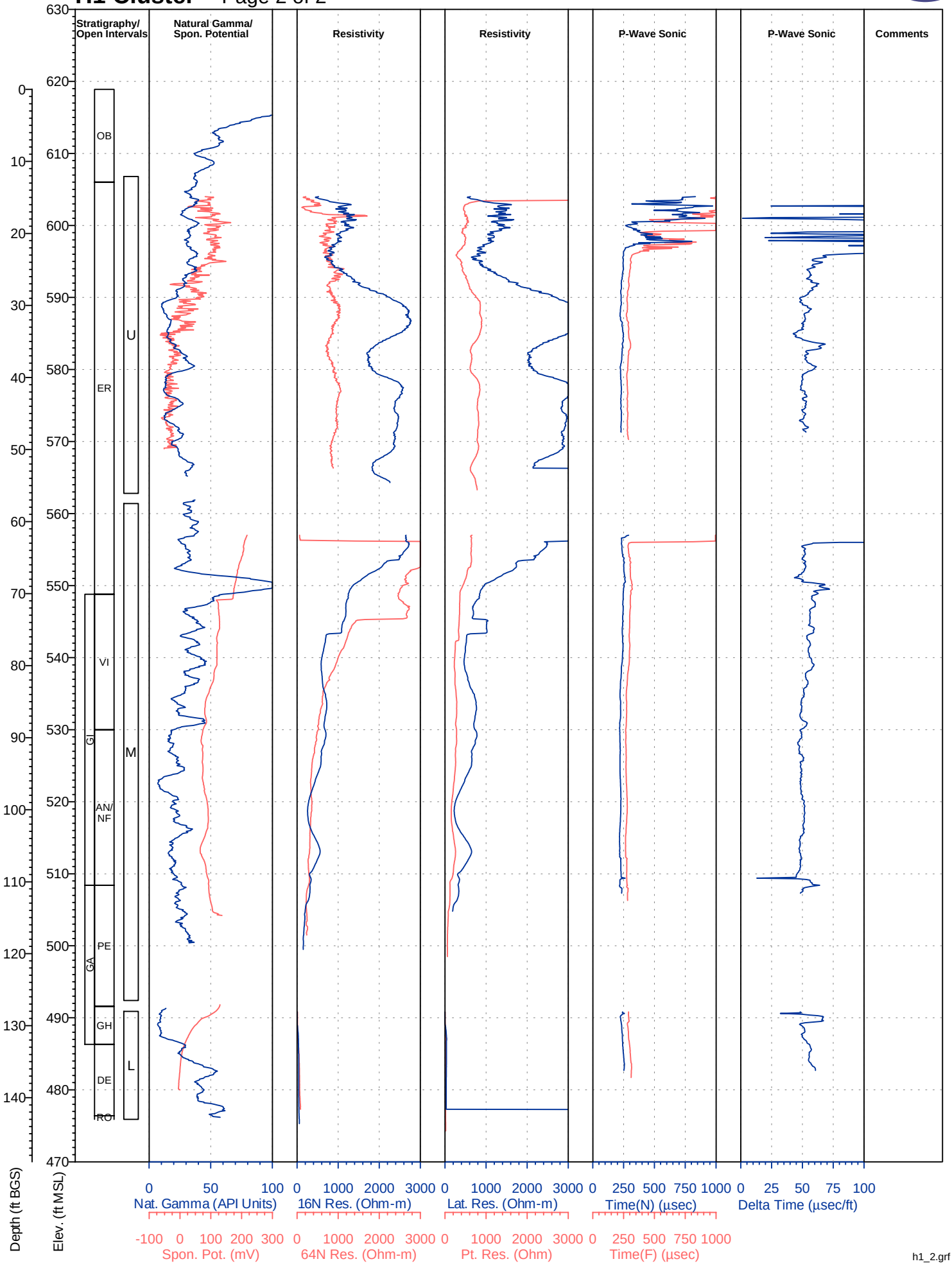
g5_2.grf

H1 Cluster



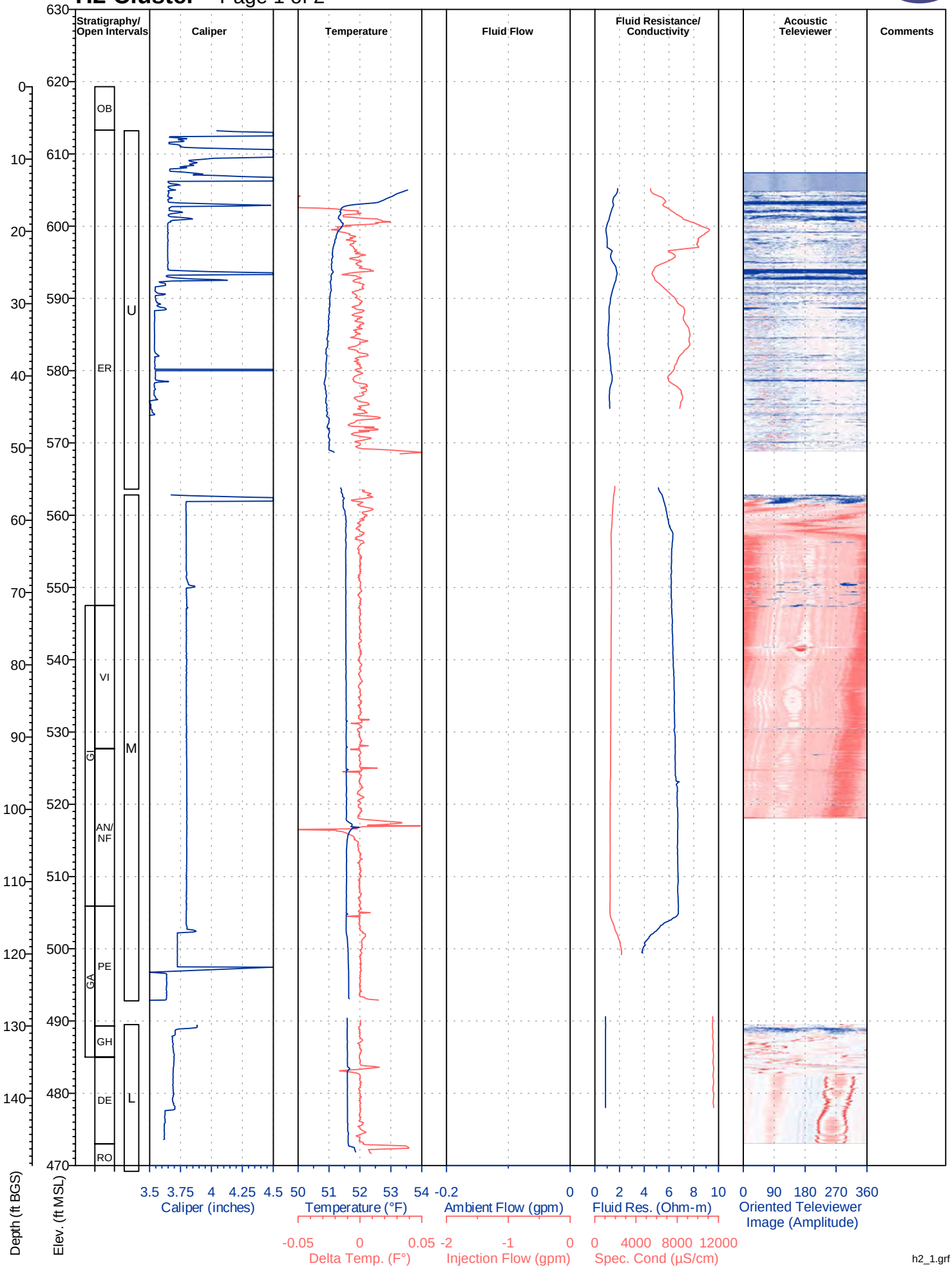
h1_1.grf

H1 Cluster



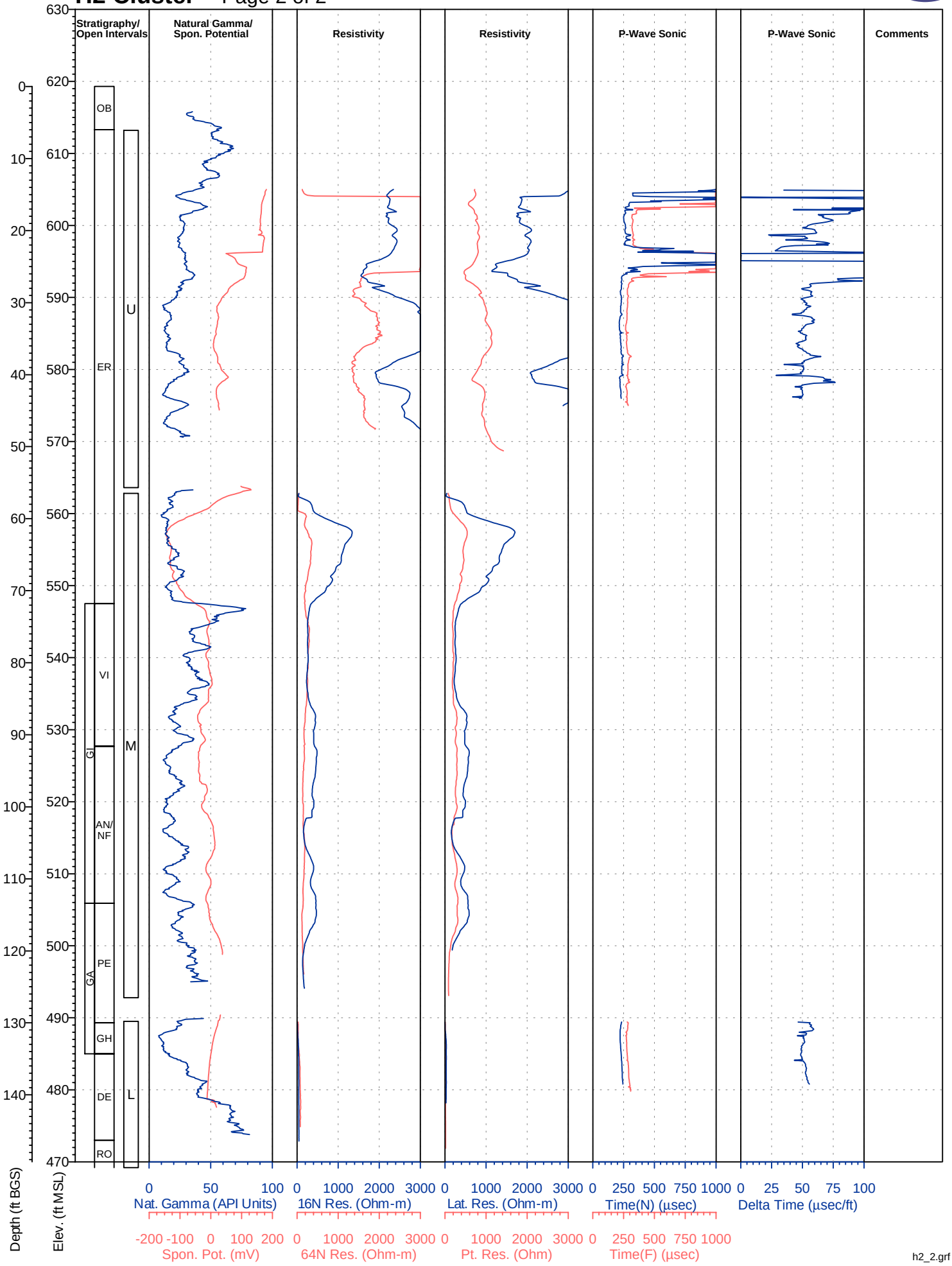
h1_2.grf

H2 Cluster



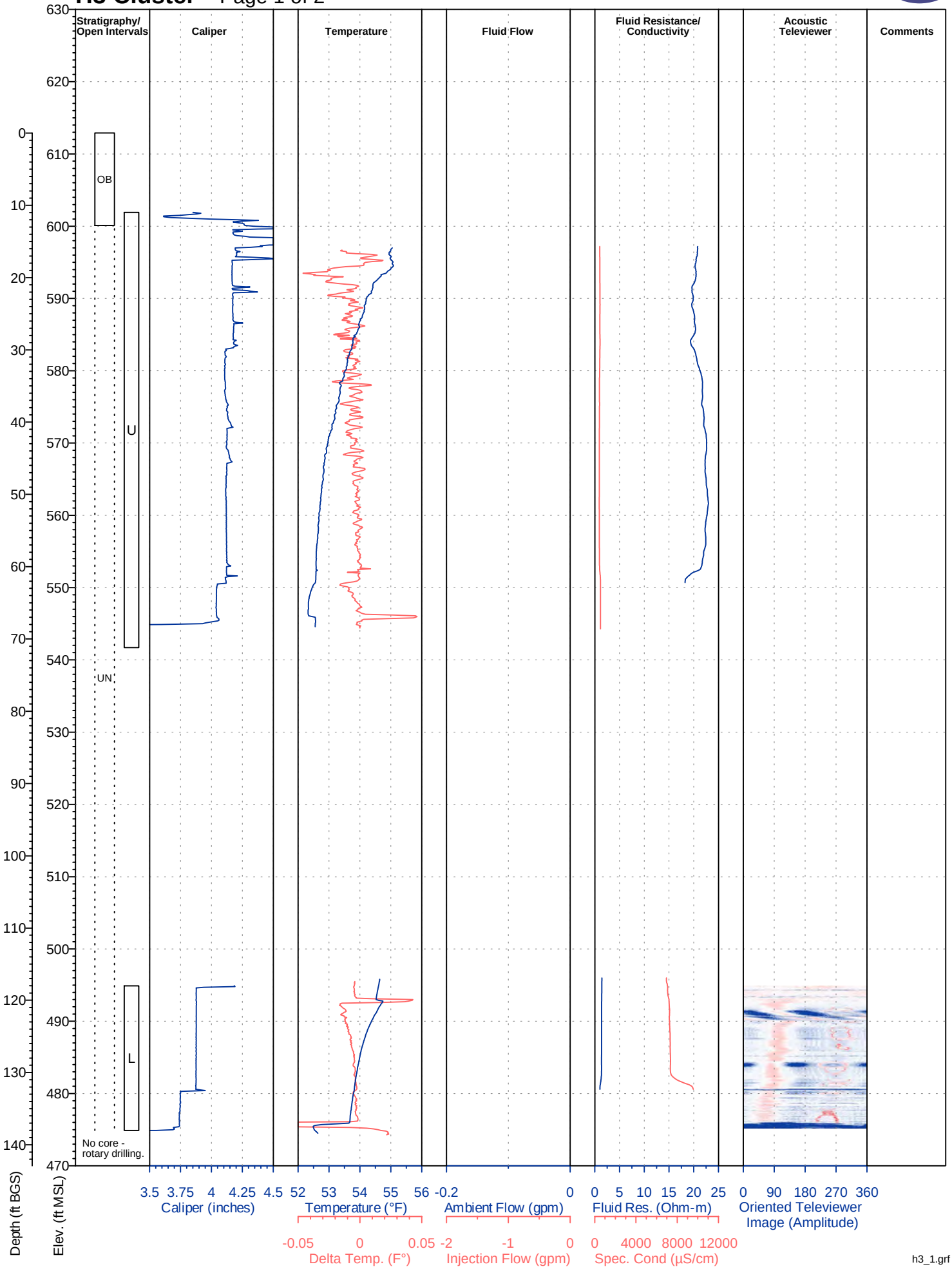
h2_1.grf

H2 Cluster



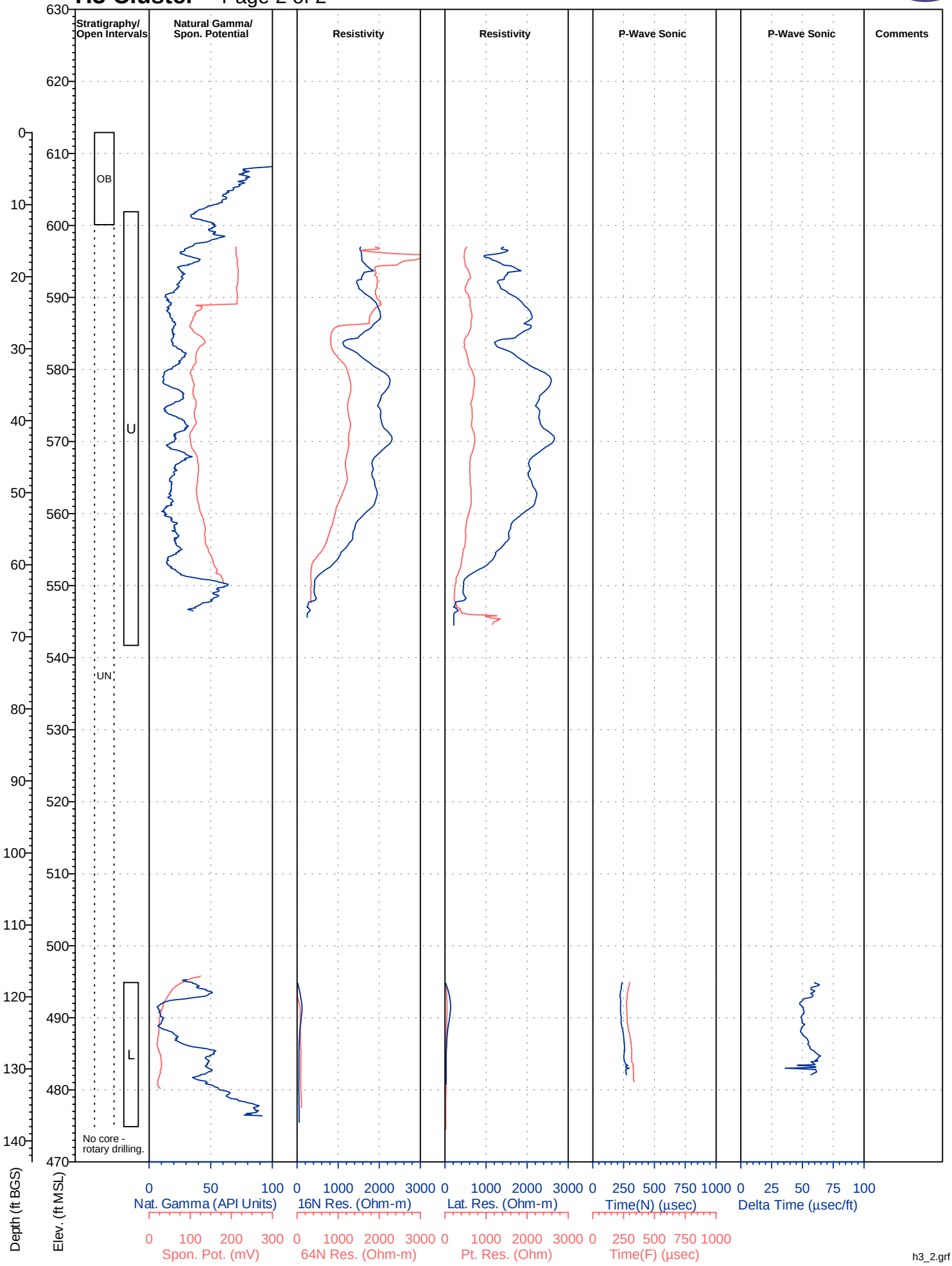
h2_2.grf

H3 Cluster



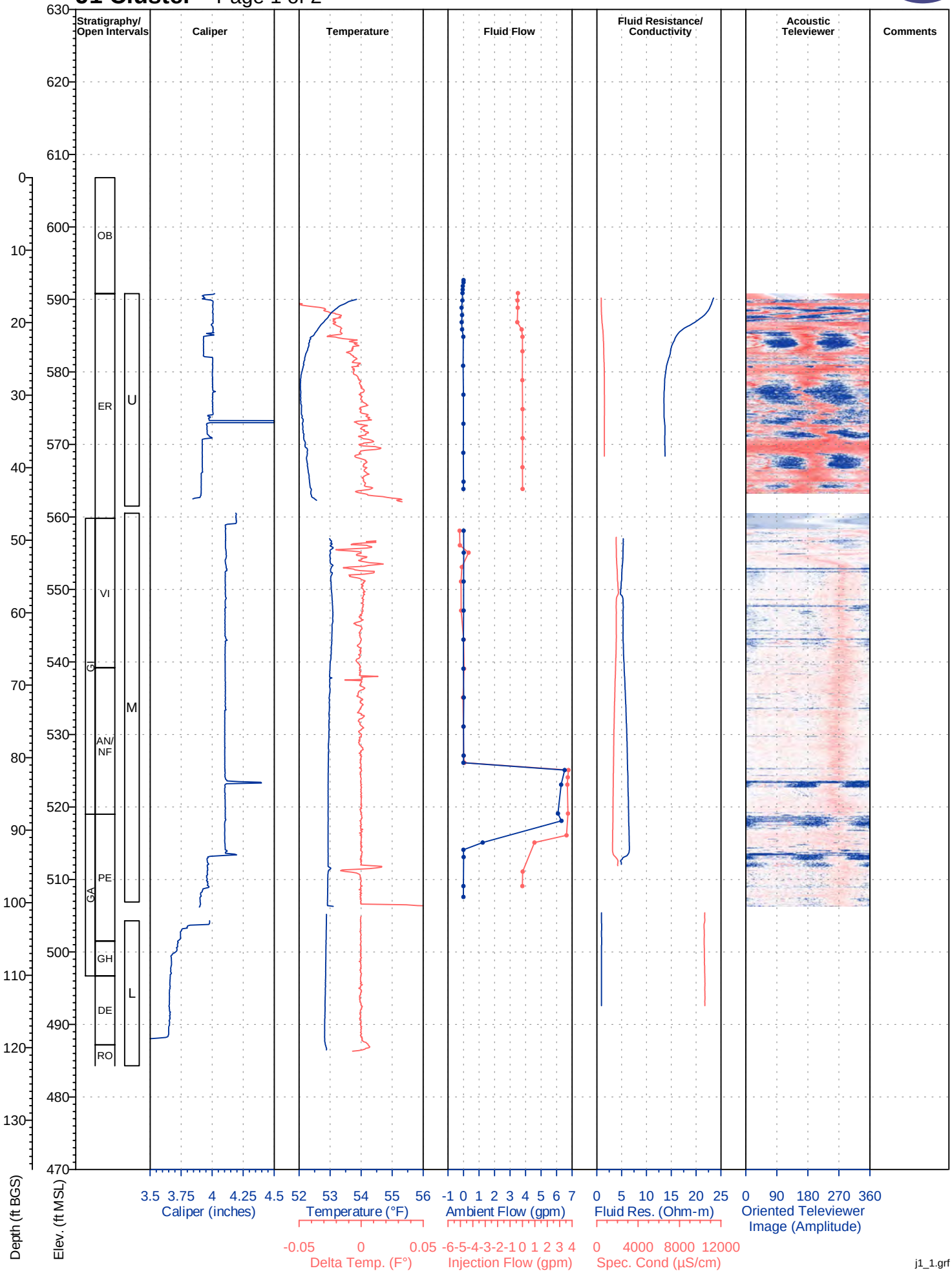
h3_1.grf

H3 Cluster



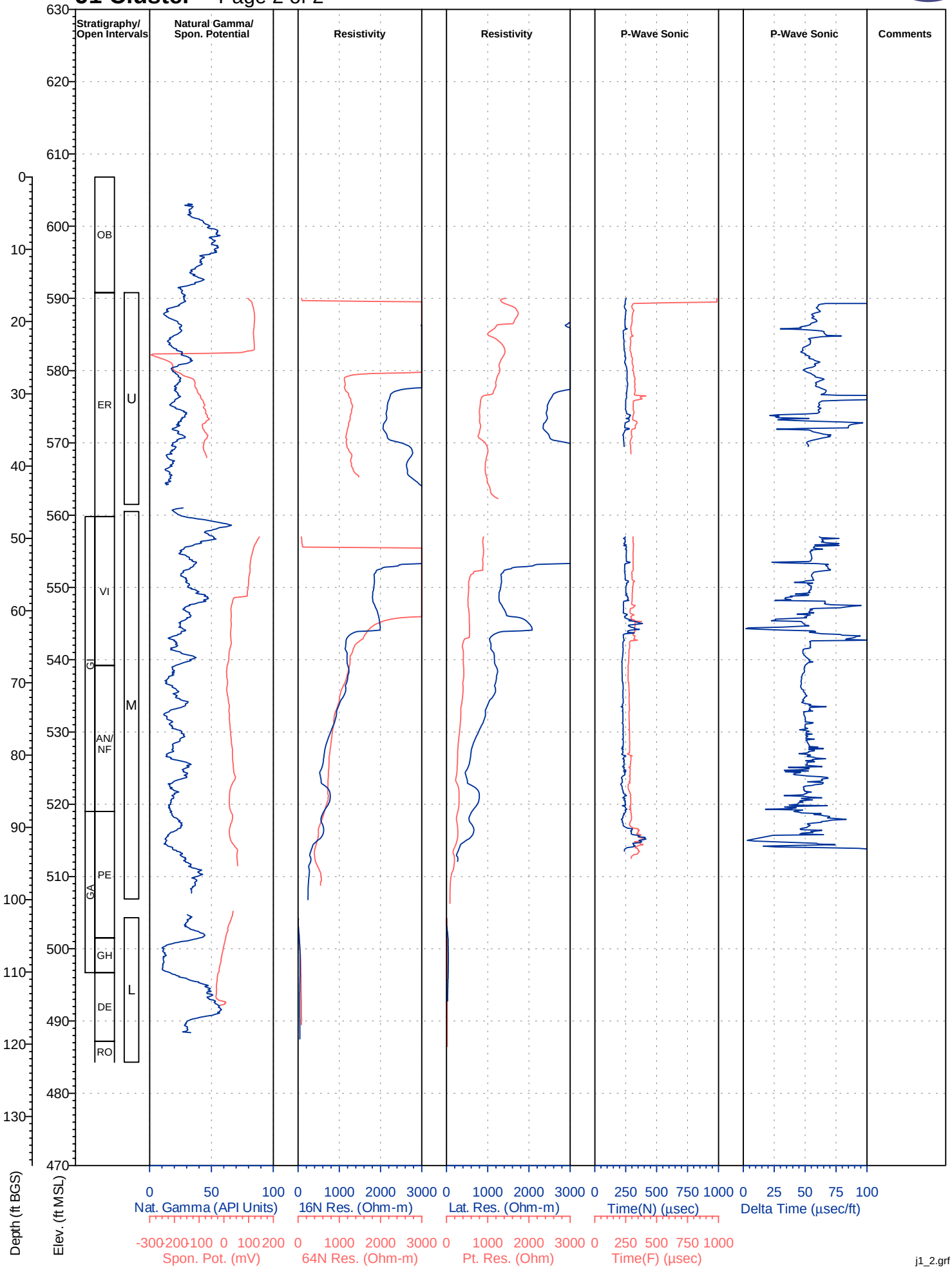
h3_2.grf

J1 Cluster



j1_1.grf

J1 Cluster



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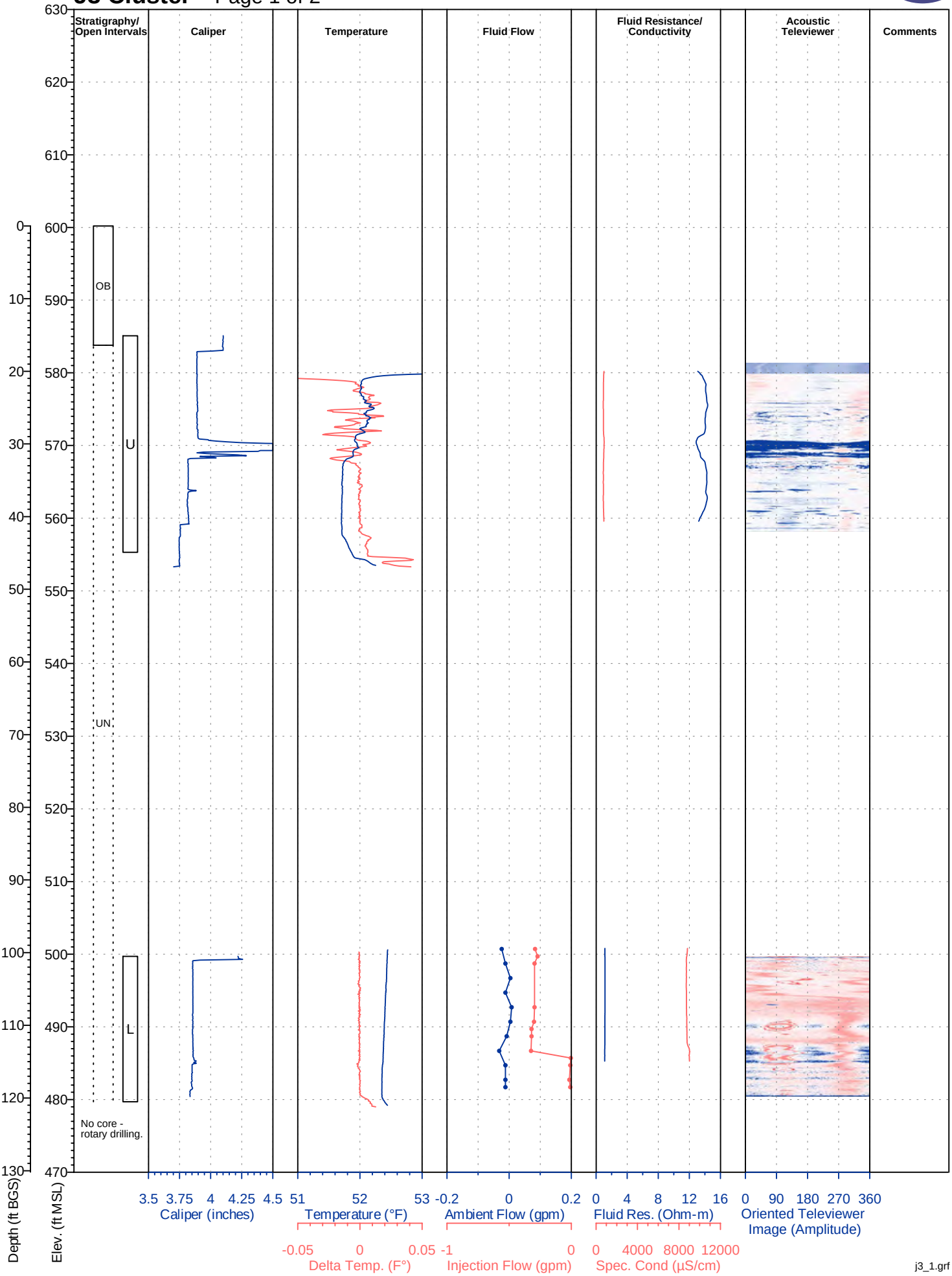
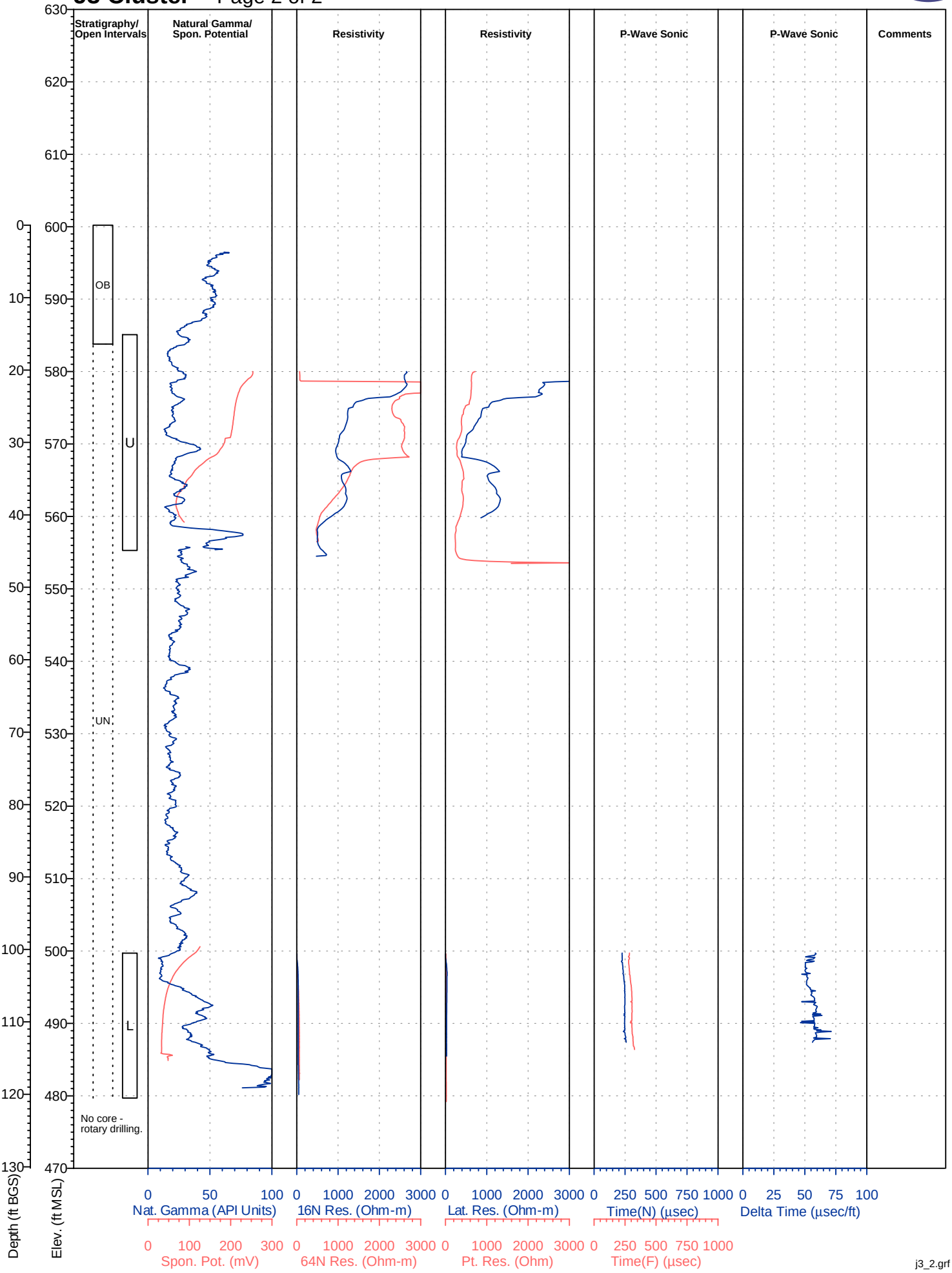
J3 Cluster



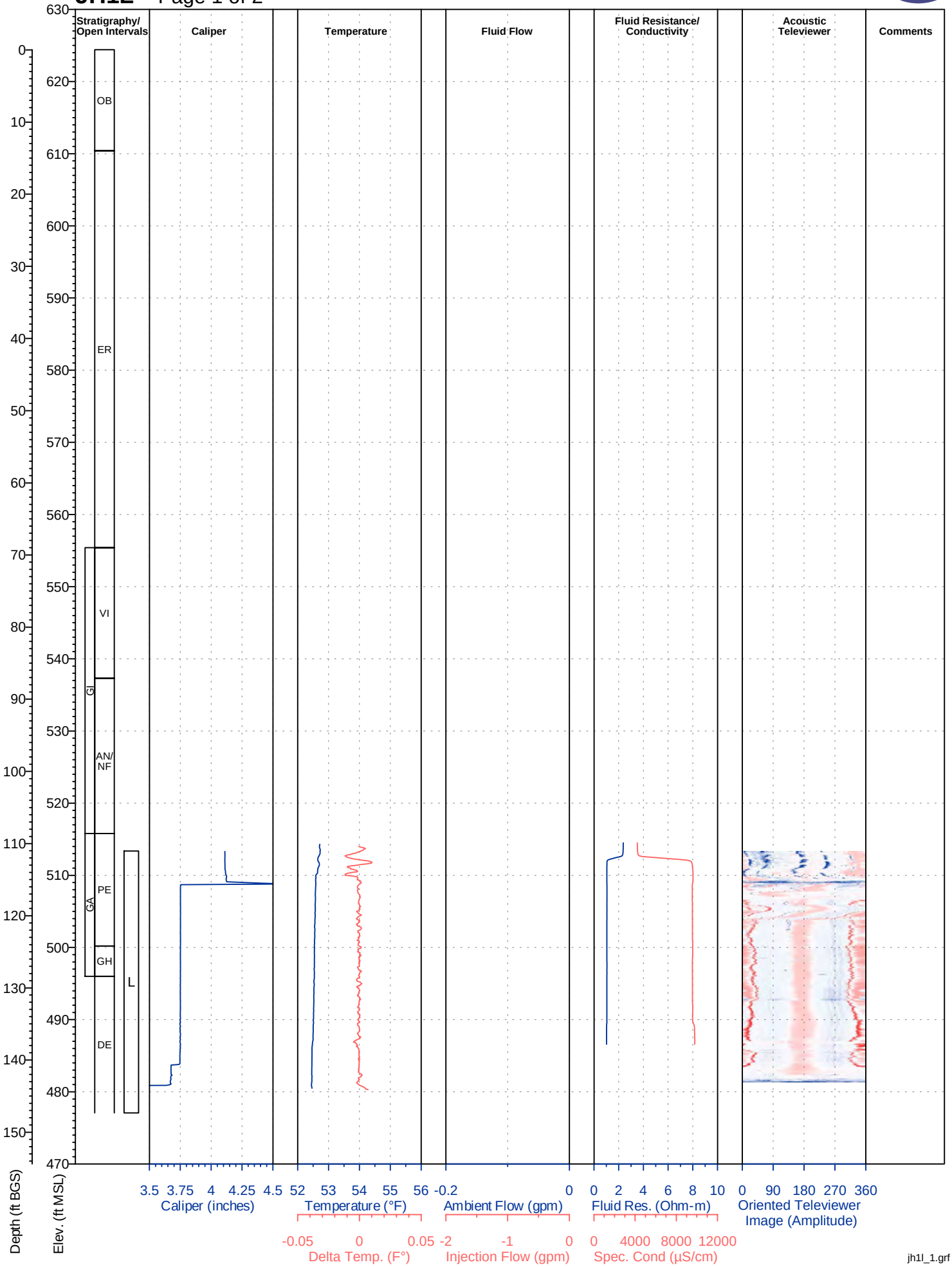
j3_1.grf

J3 Cluster



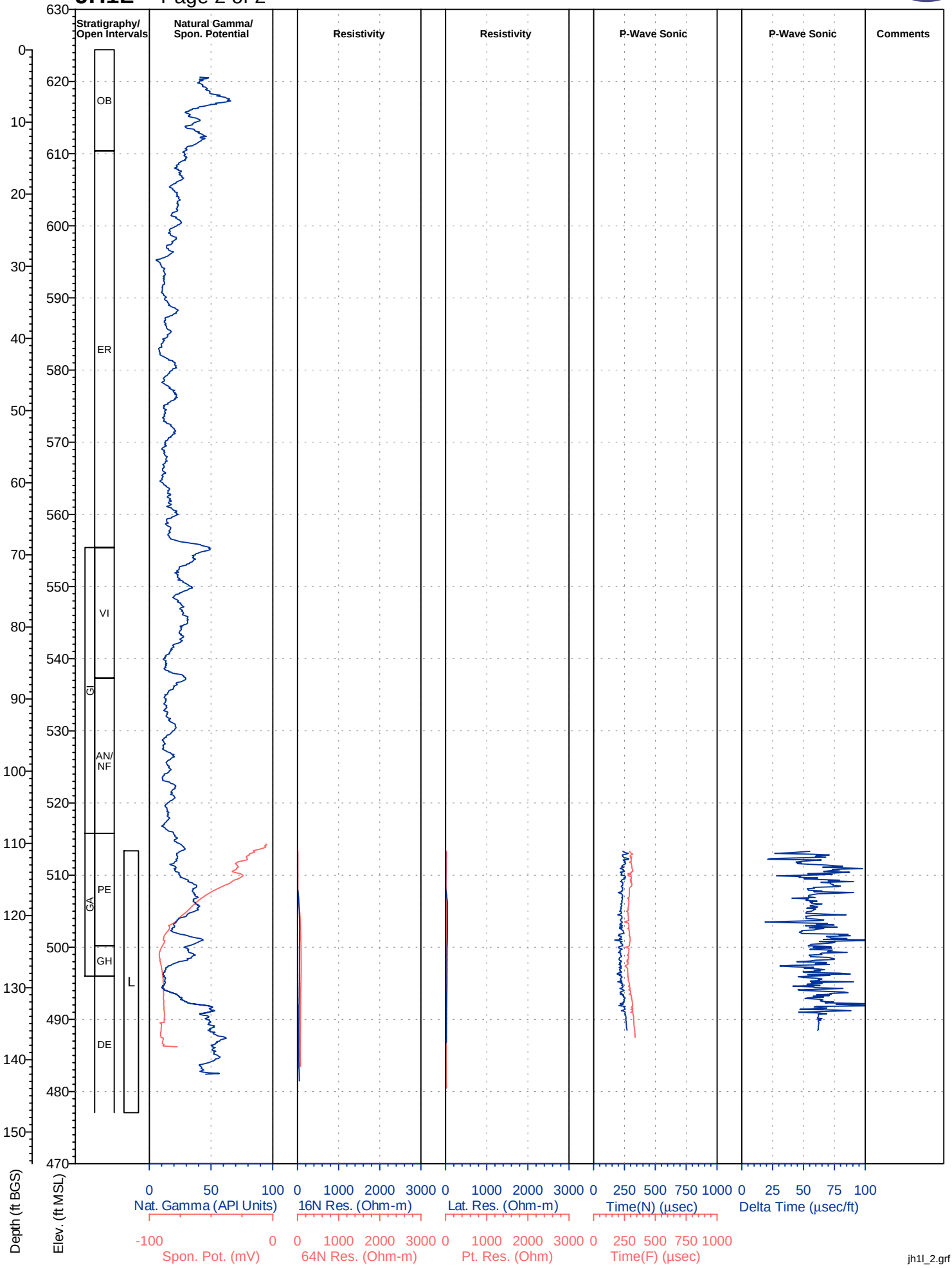
j3_2.grf

JH1L



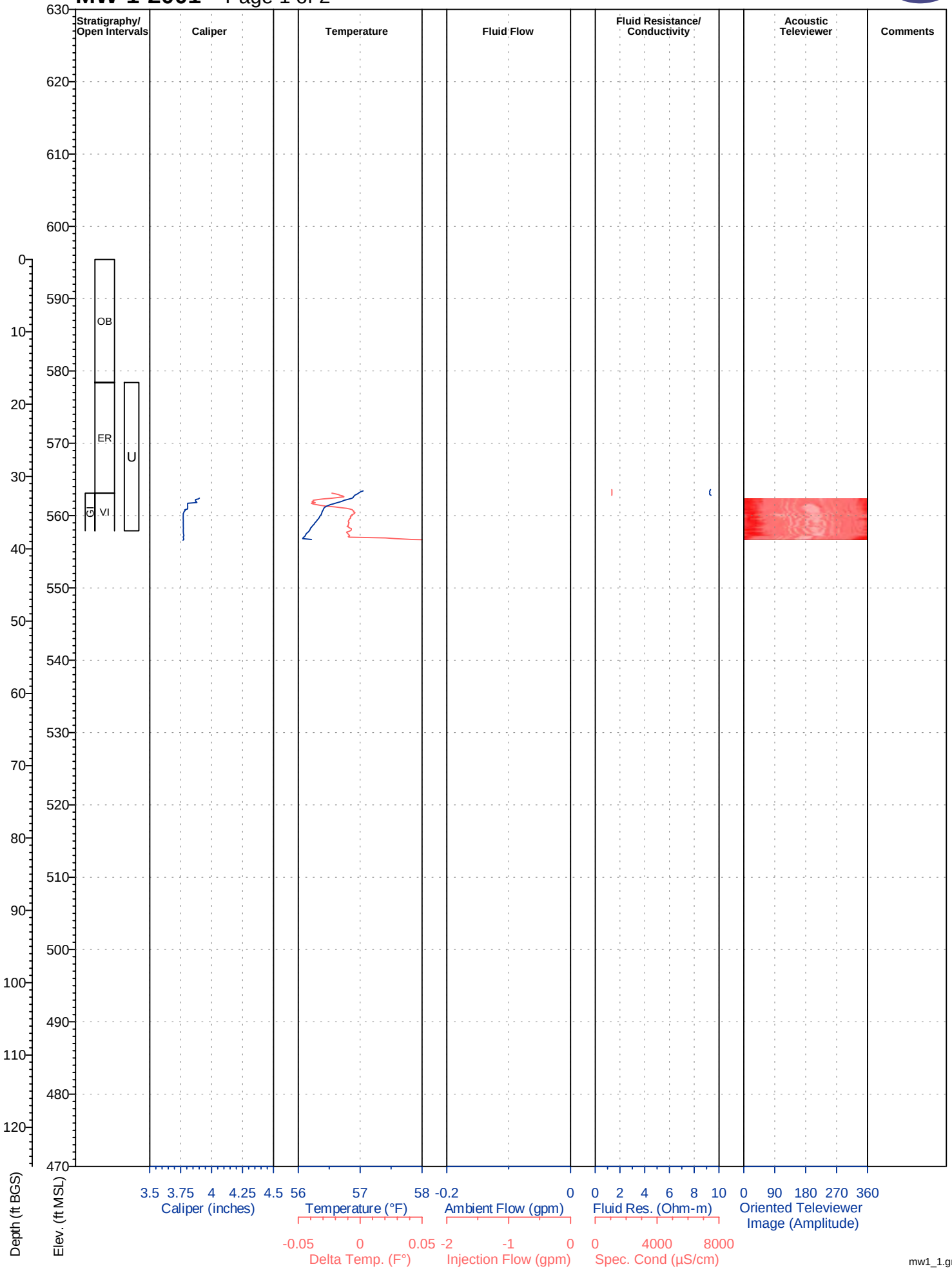
jh1l_1.grf

JH1L



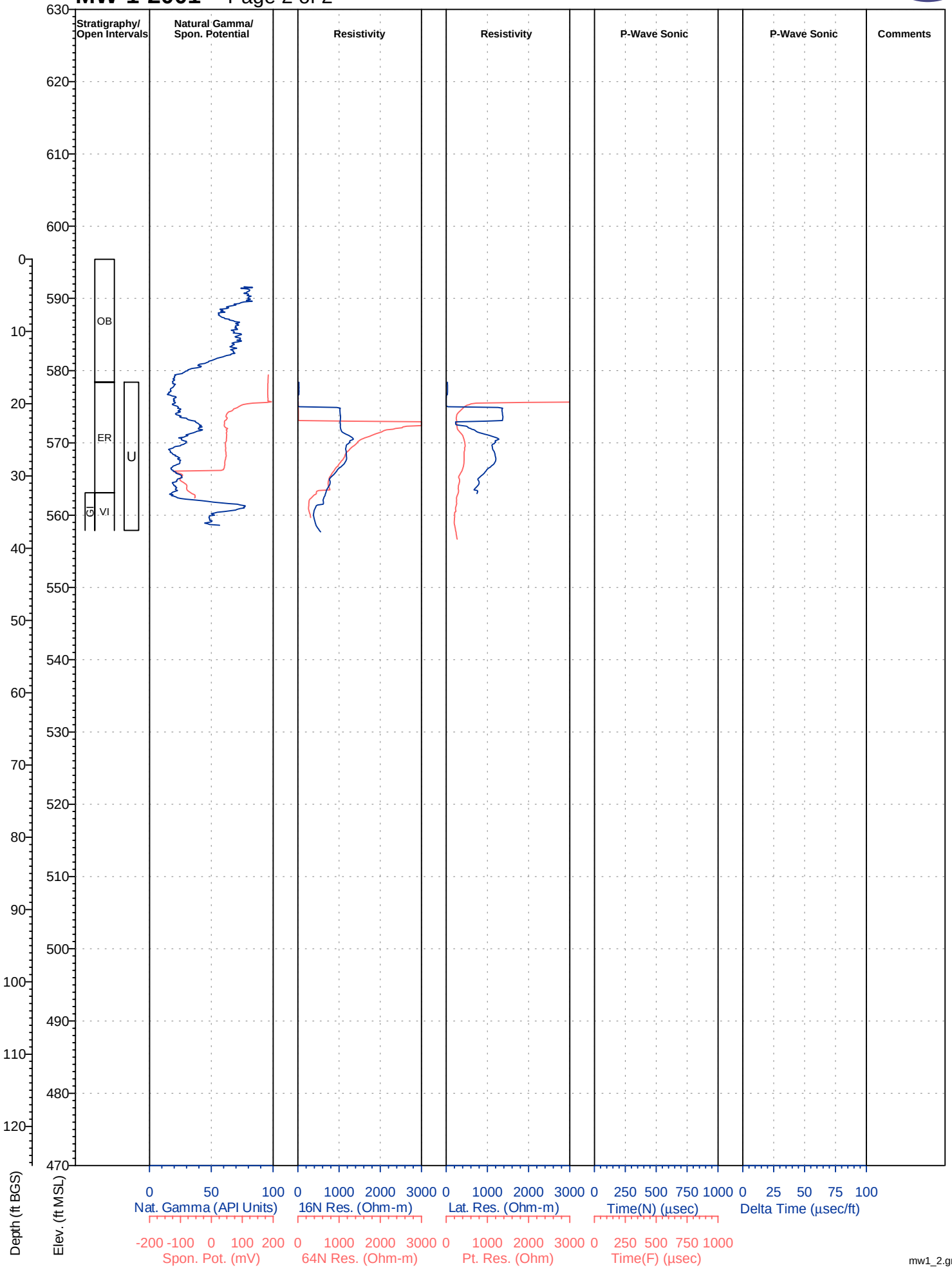
jh1l_2.grf

MW-1-2001



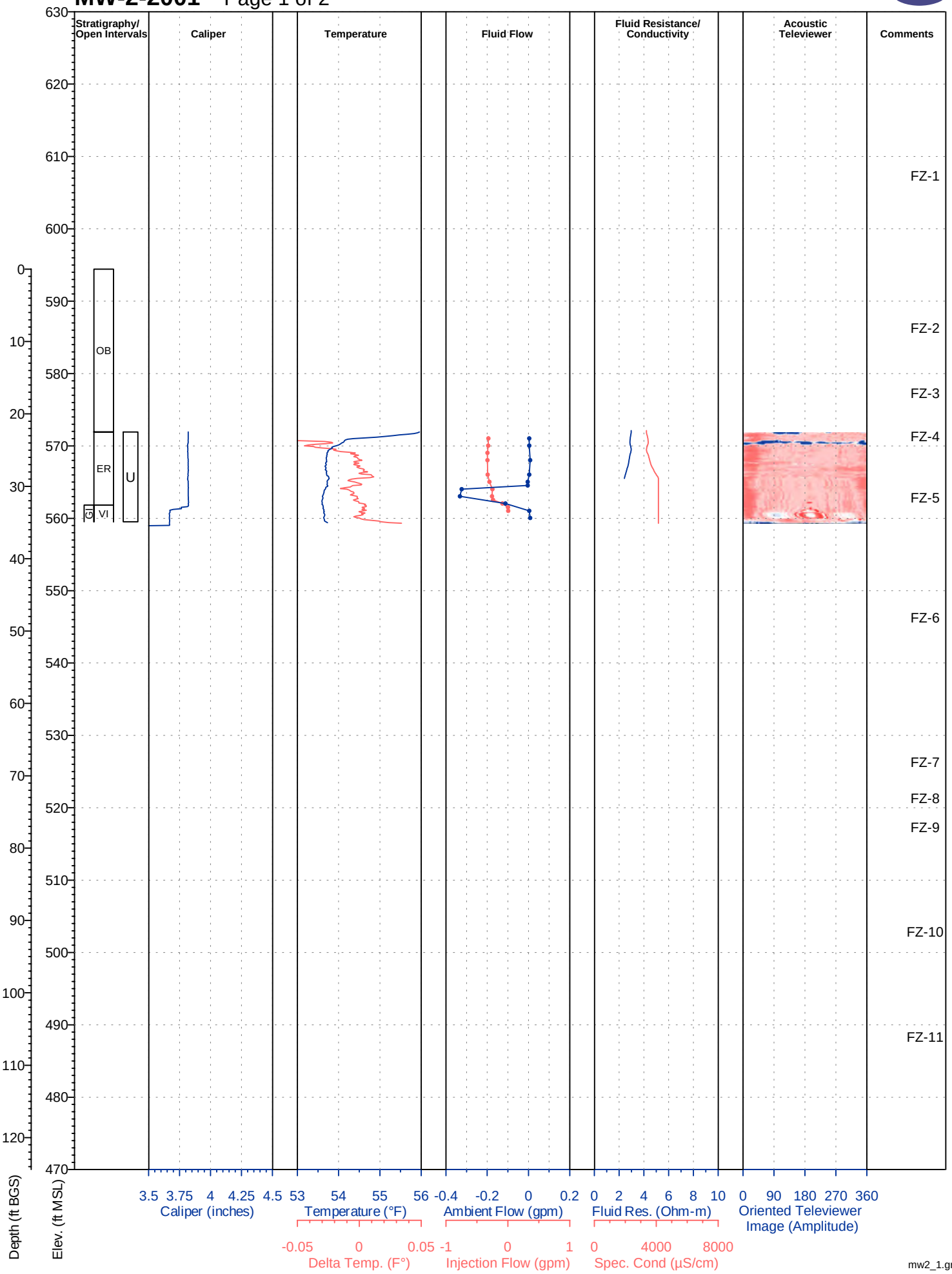
mw1_1.grf

MW-1-2001



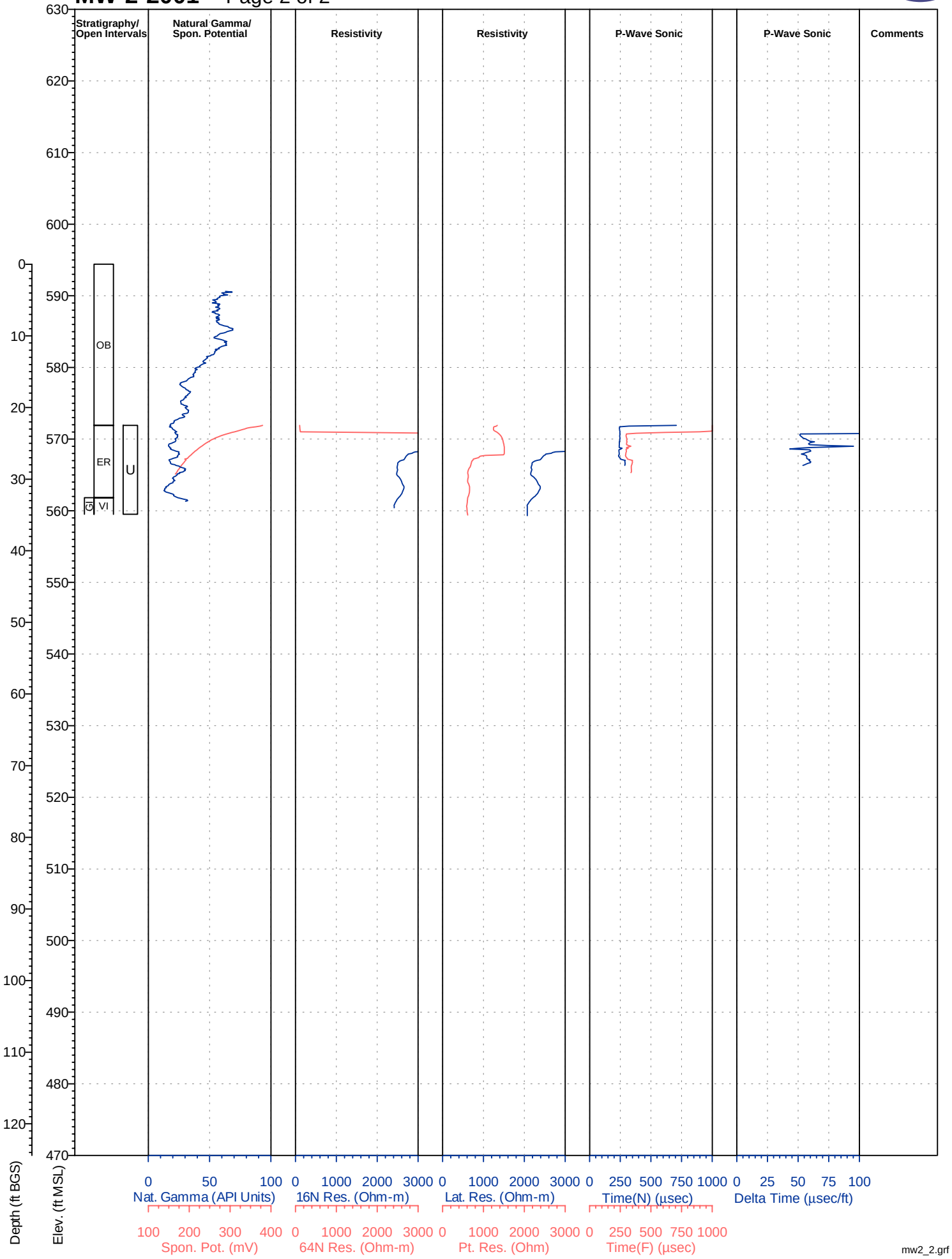
mw1_2.grf

MW-2-2001



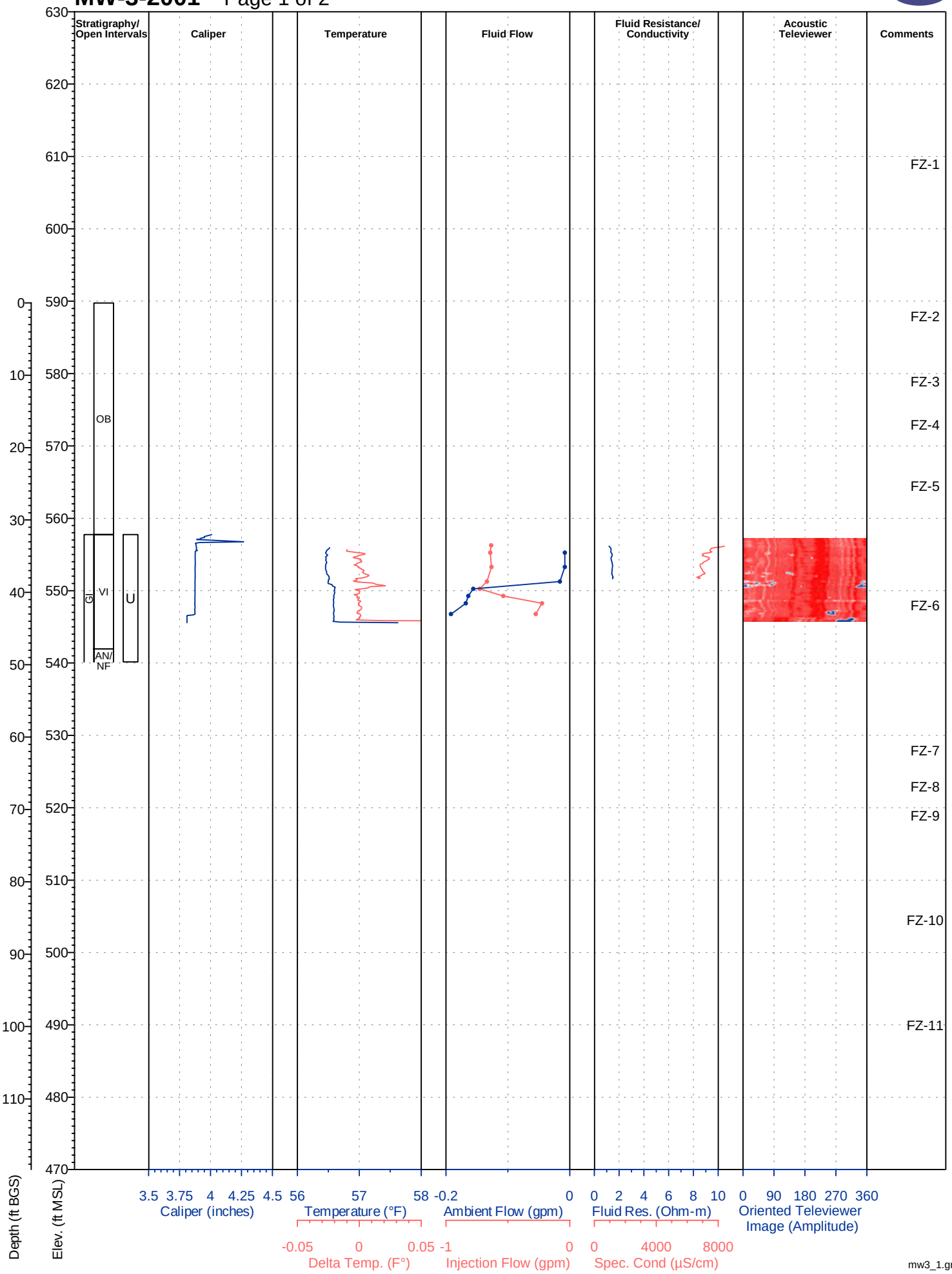
mw2_1.grf

MW-2-2001



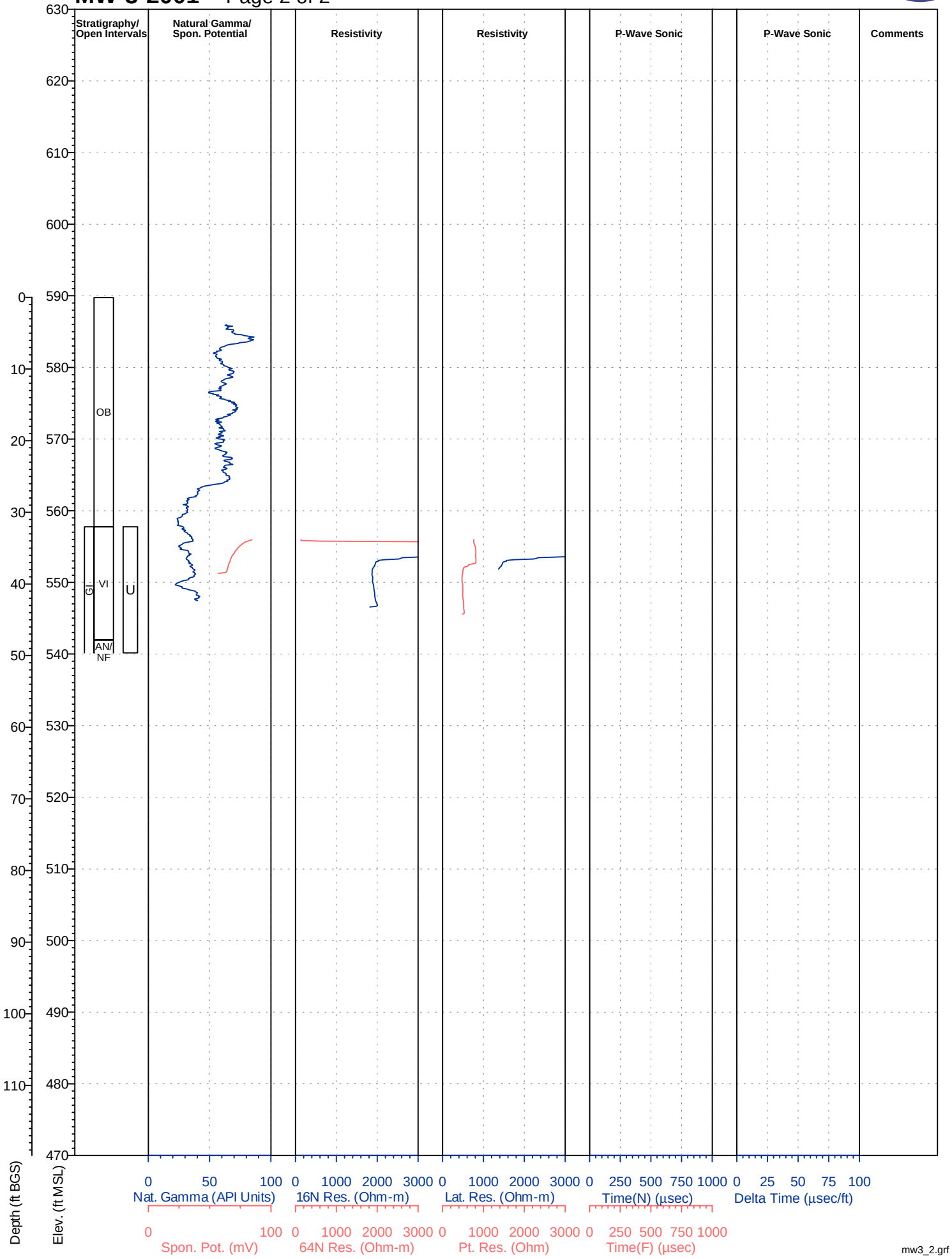
mw2_2.grf

MW-3-2001



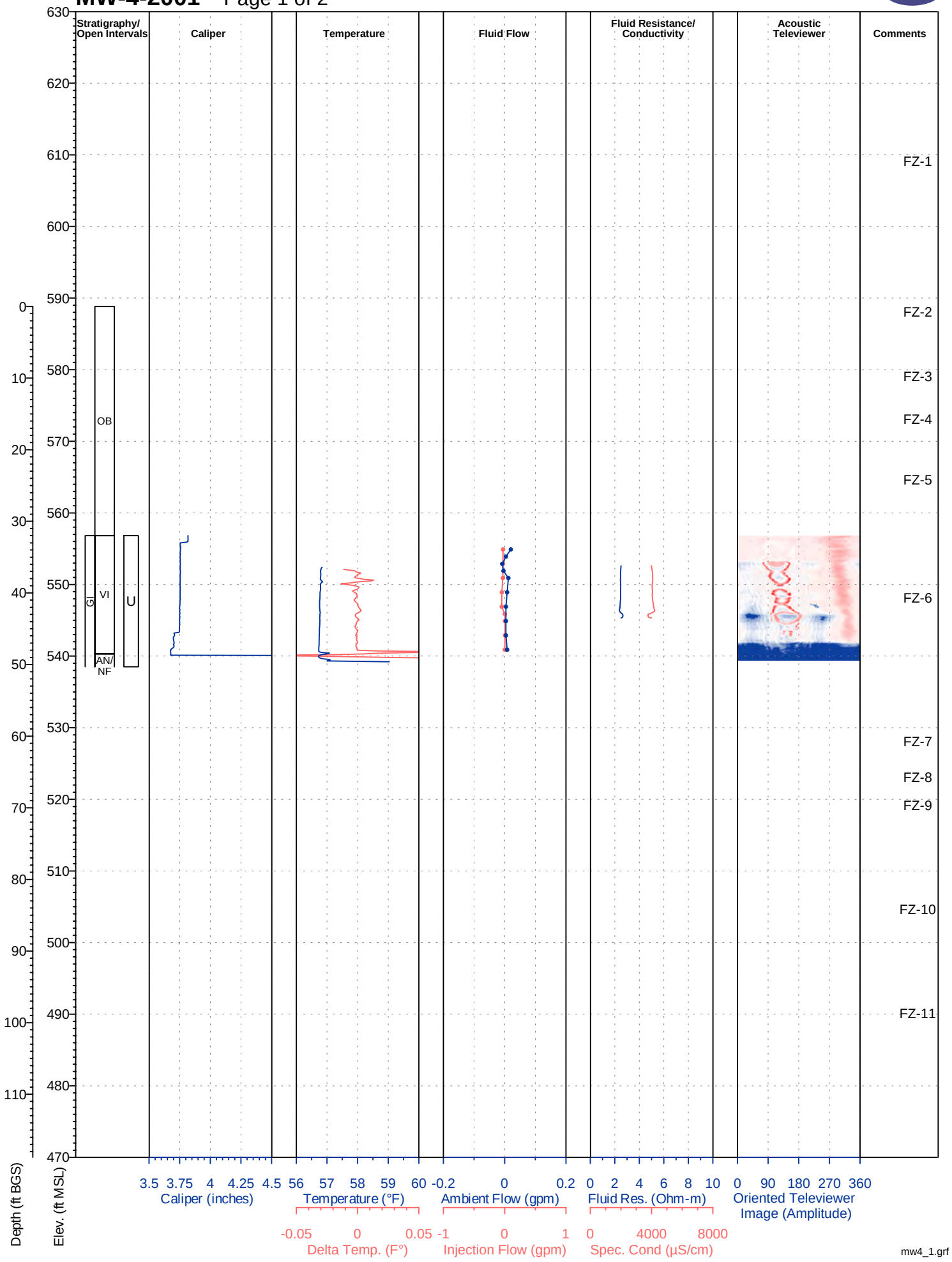
mw3_1.grf

MW-3-2001



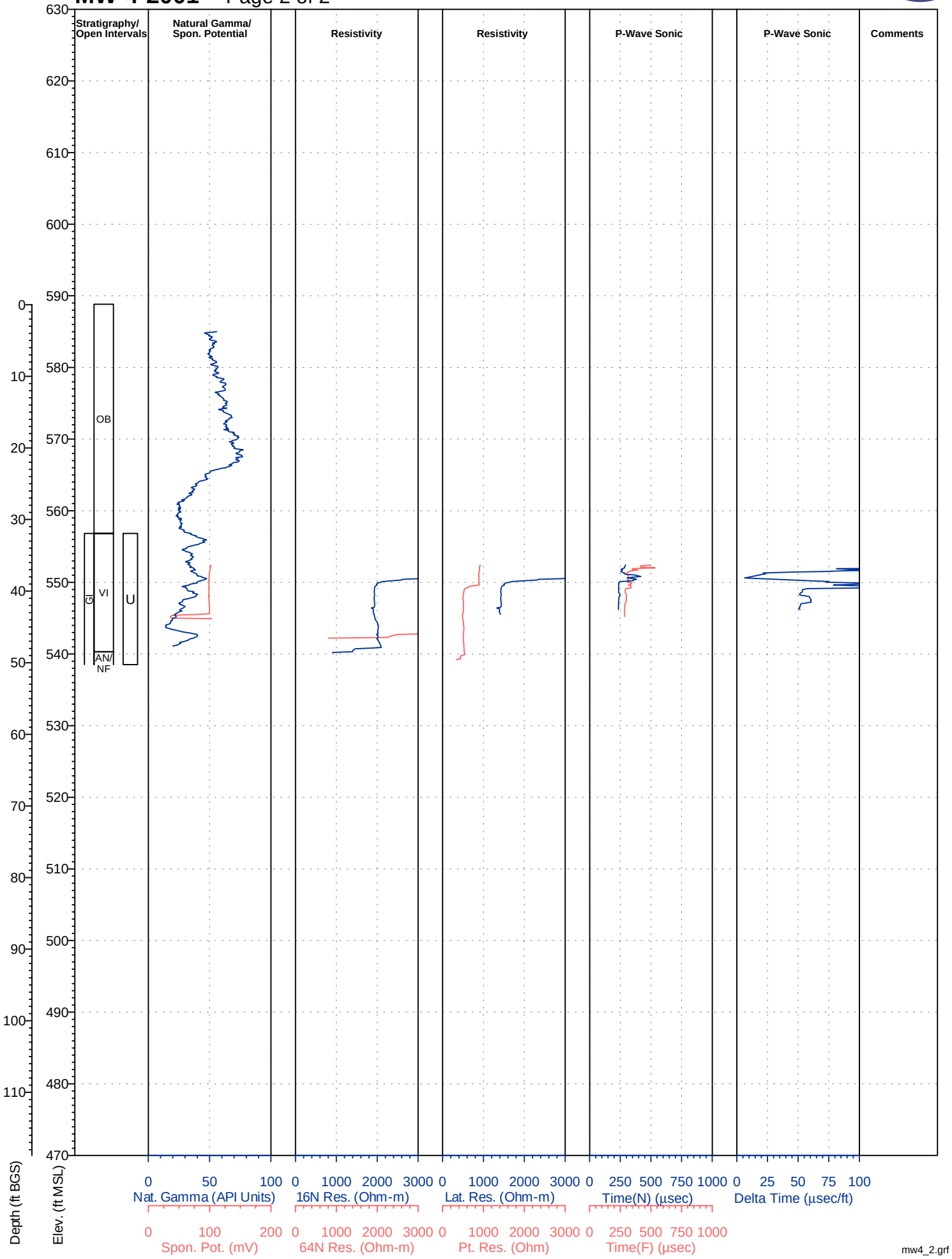
mw3_2.grf

MW-4-2001 Page 1 of 2



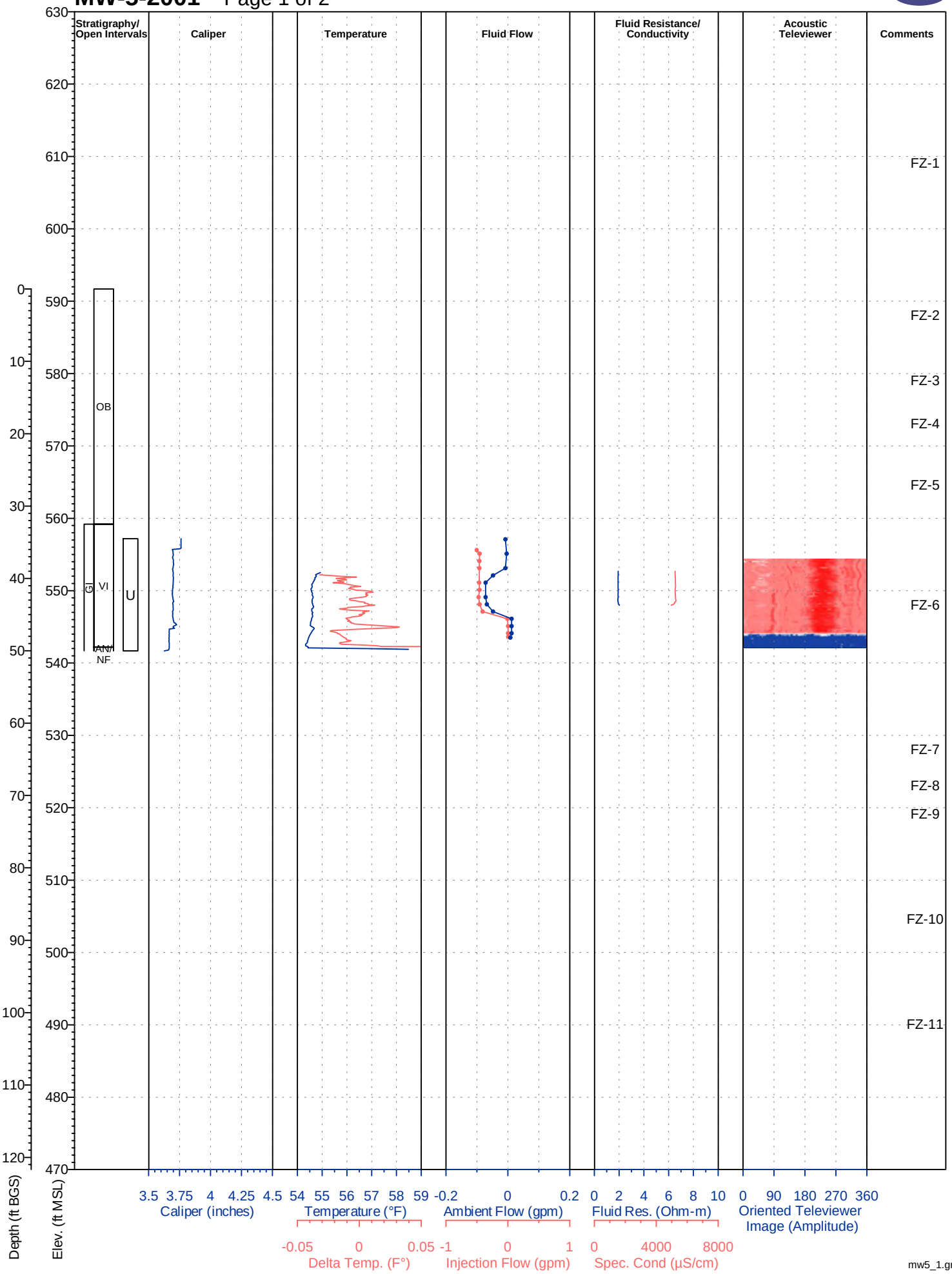
mw4_1.grf

MW-4-2001



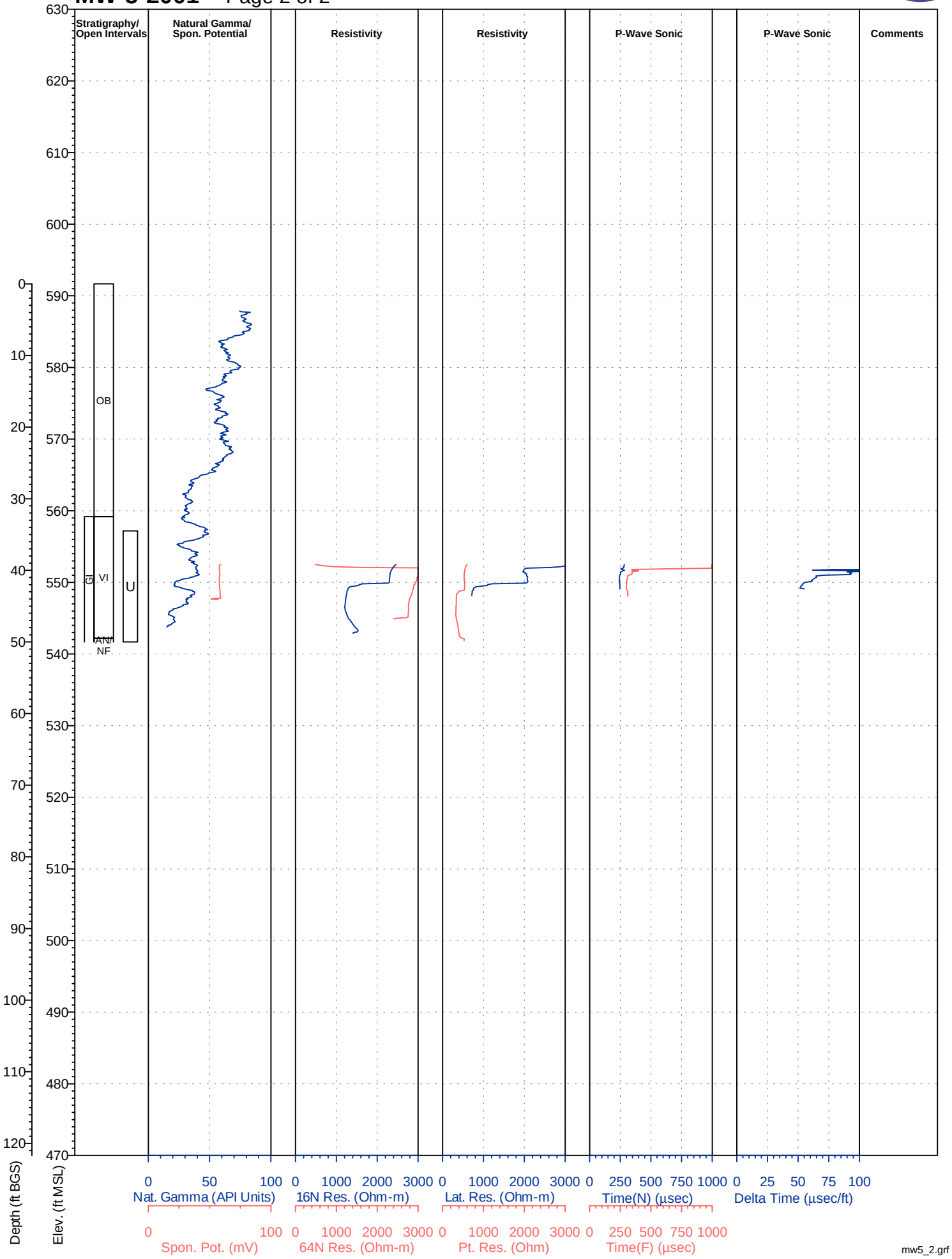
mw4_2.grf

MW-5-2001



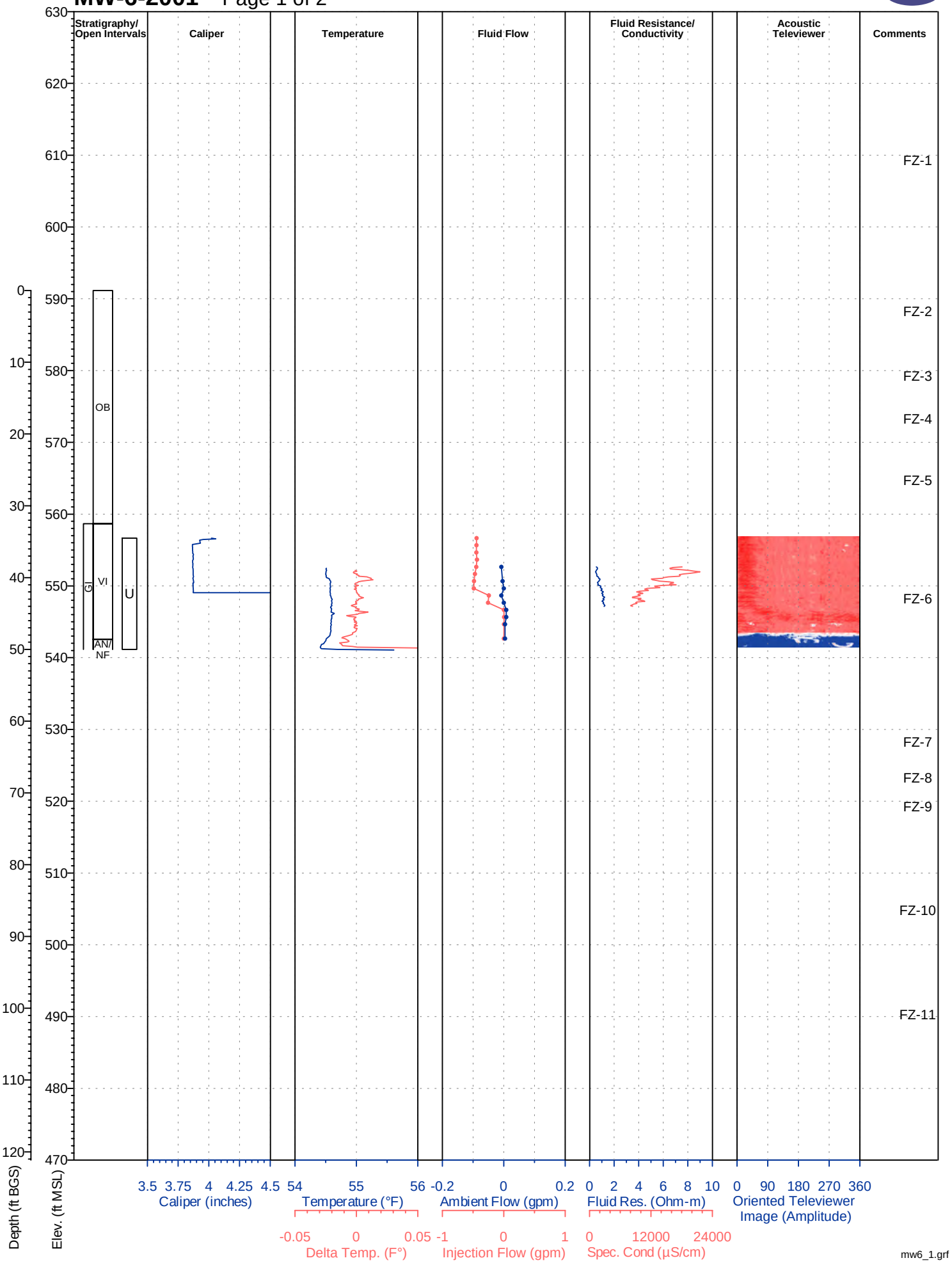
mw5_1.grf

MW-5-2001



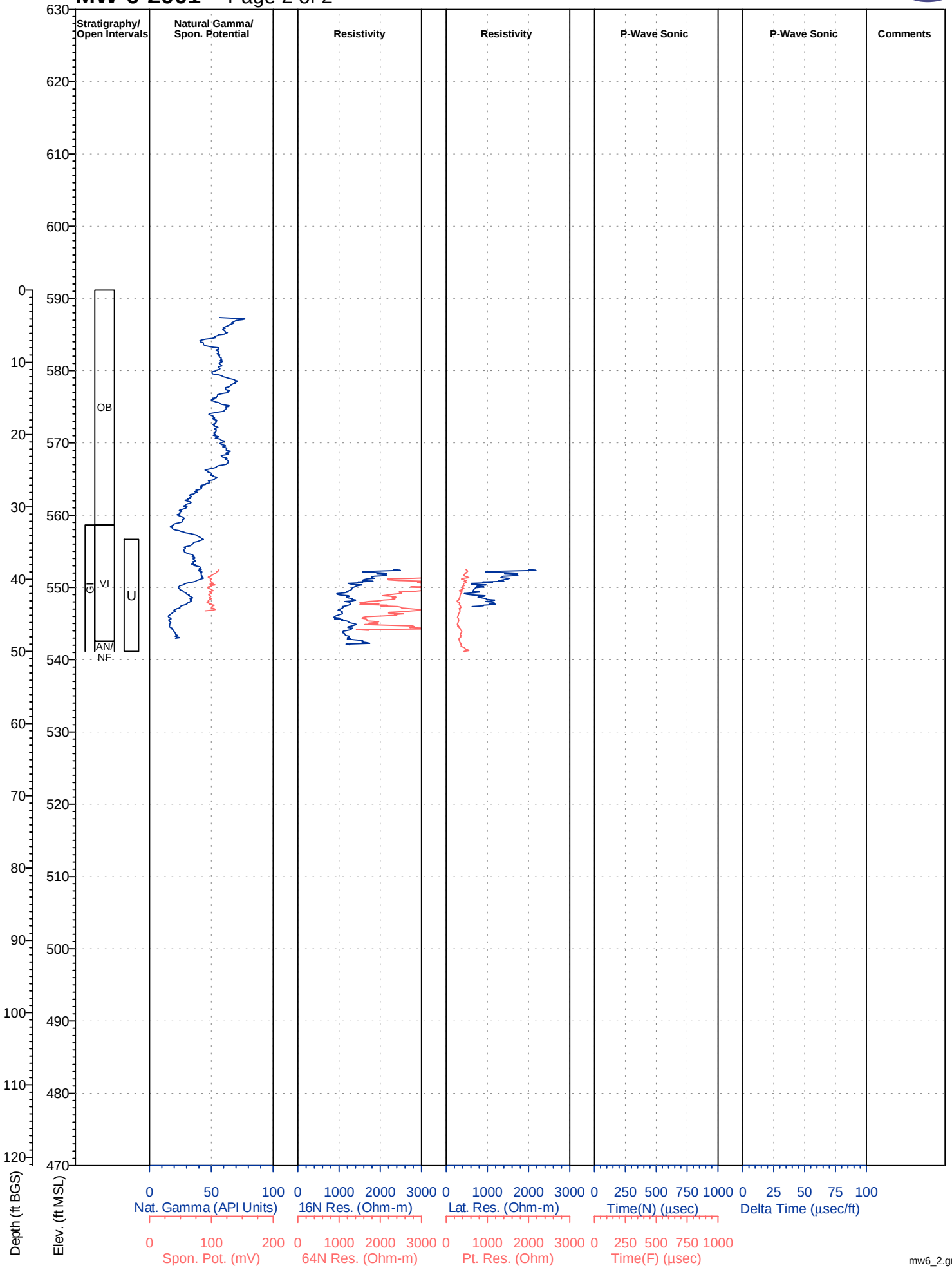
mw5_2.grf

MW-6-2001



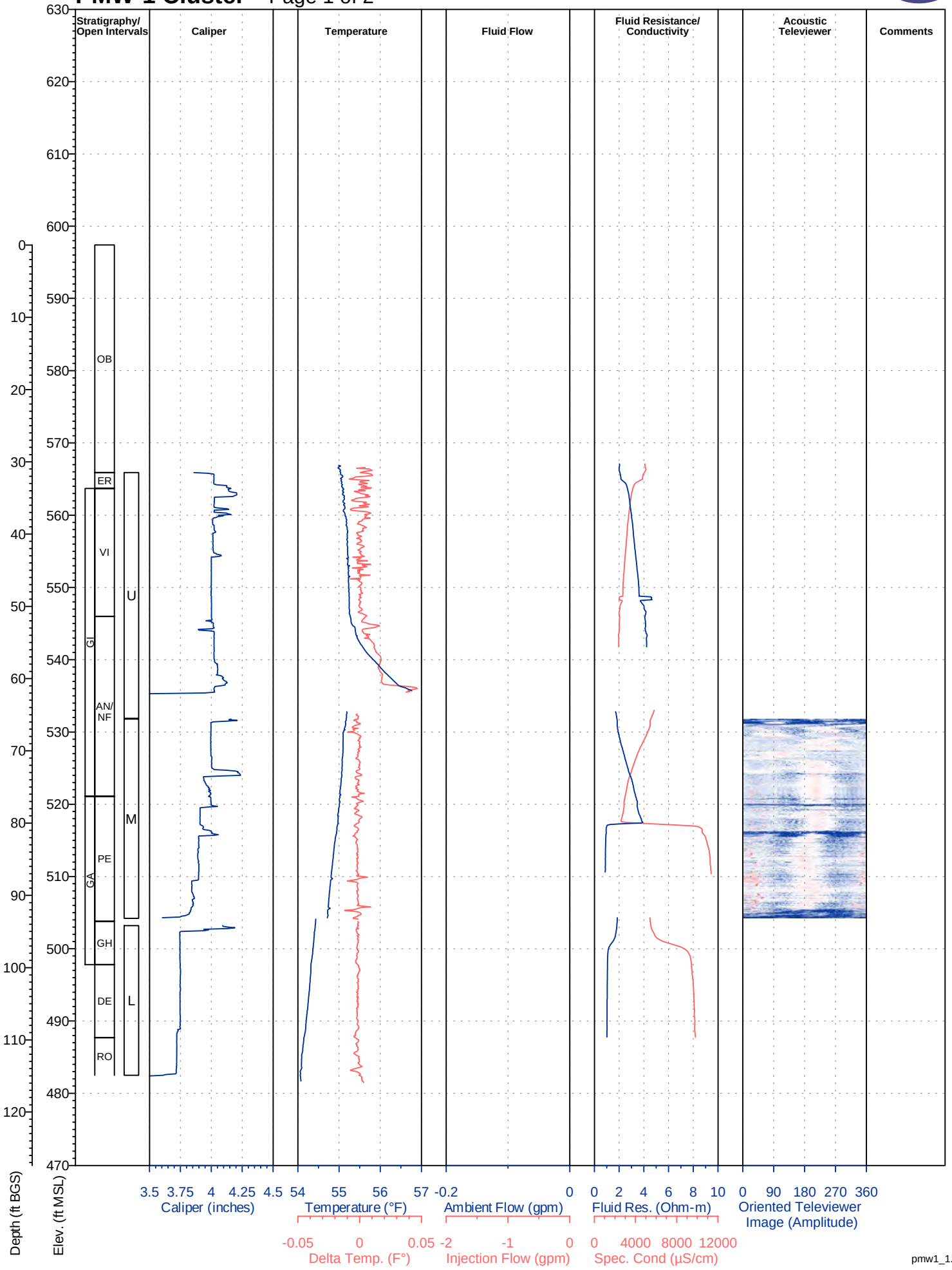
mw6_1.grf

MW-6-2001 Page 2 of 2



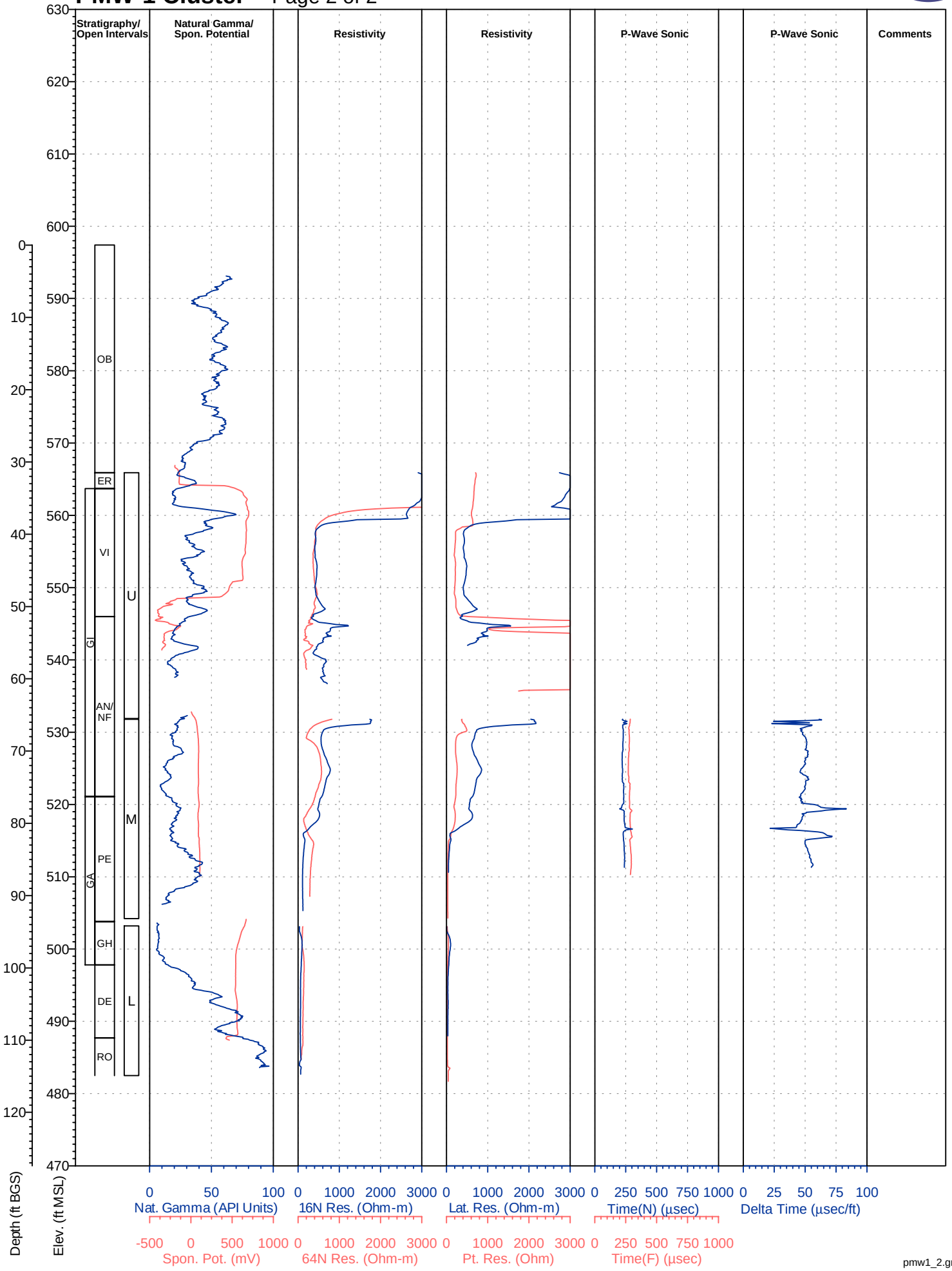
mw6_2.grf

PMW-1 Cluster

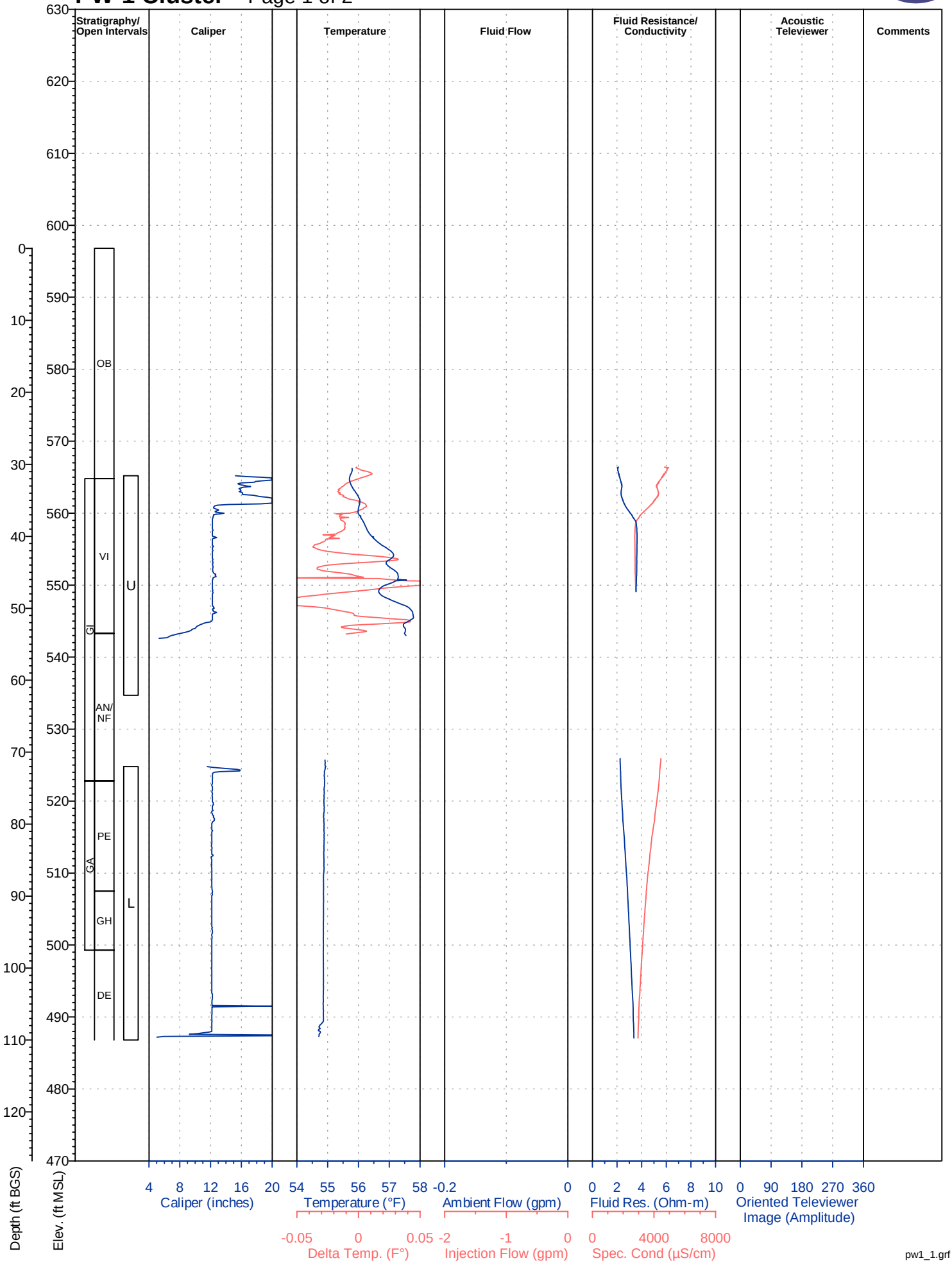


pmw1_1.g

PMW-1 Cluster

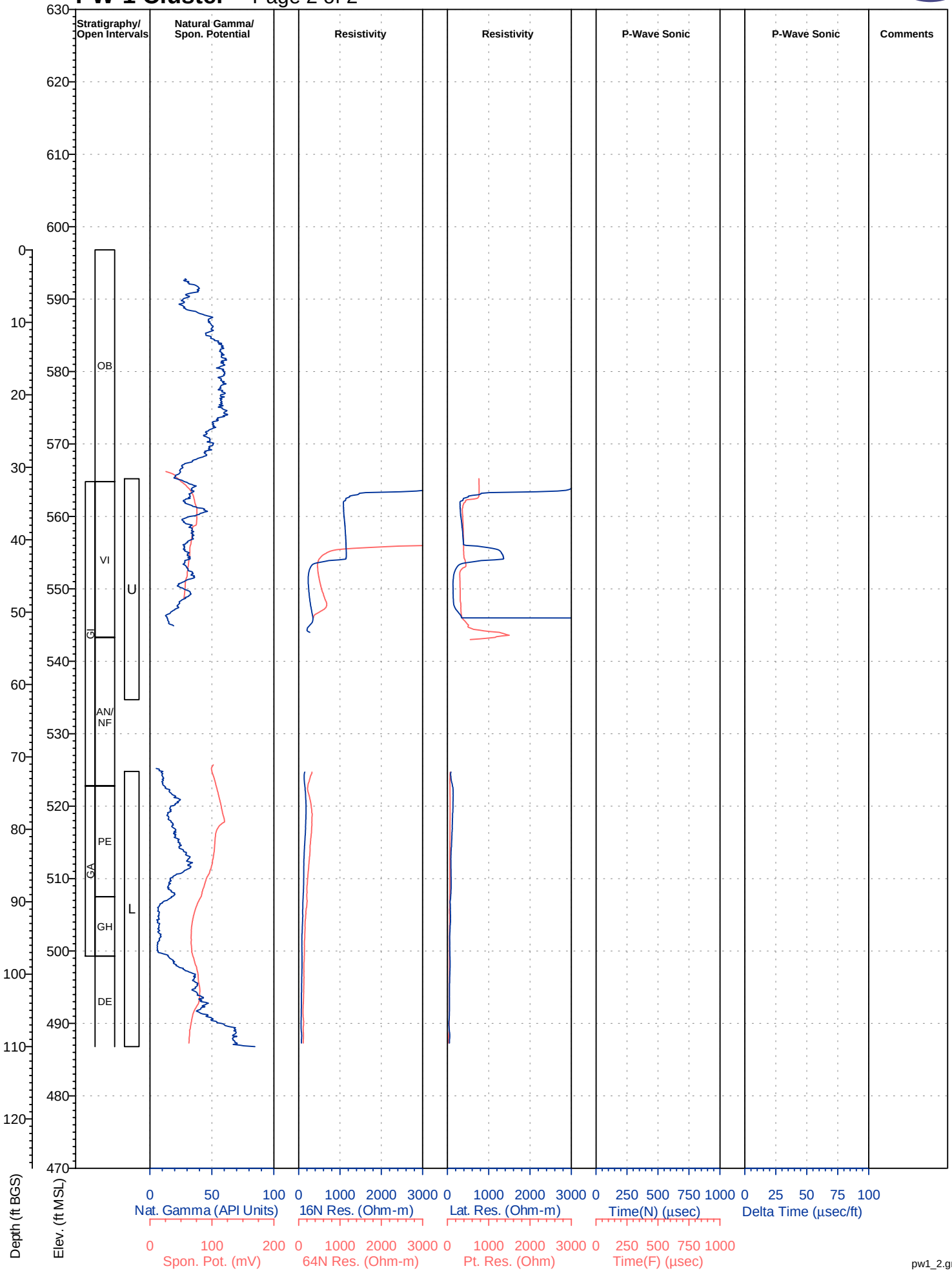


PW-1 Cluster



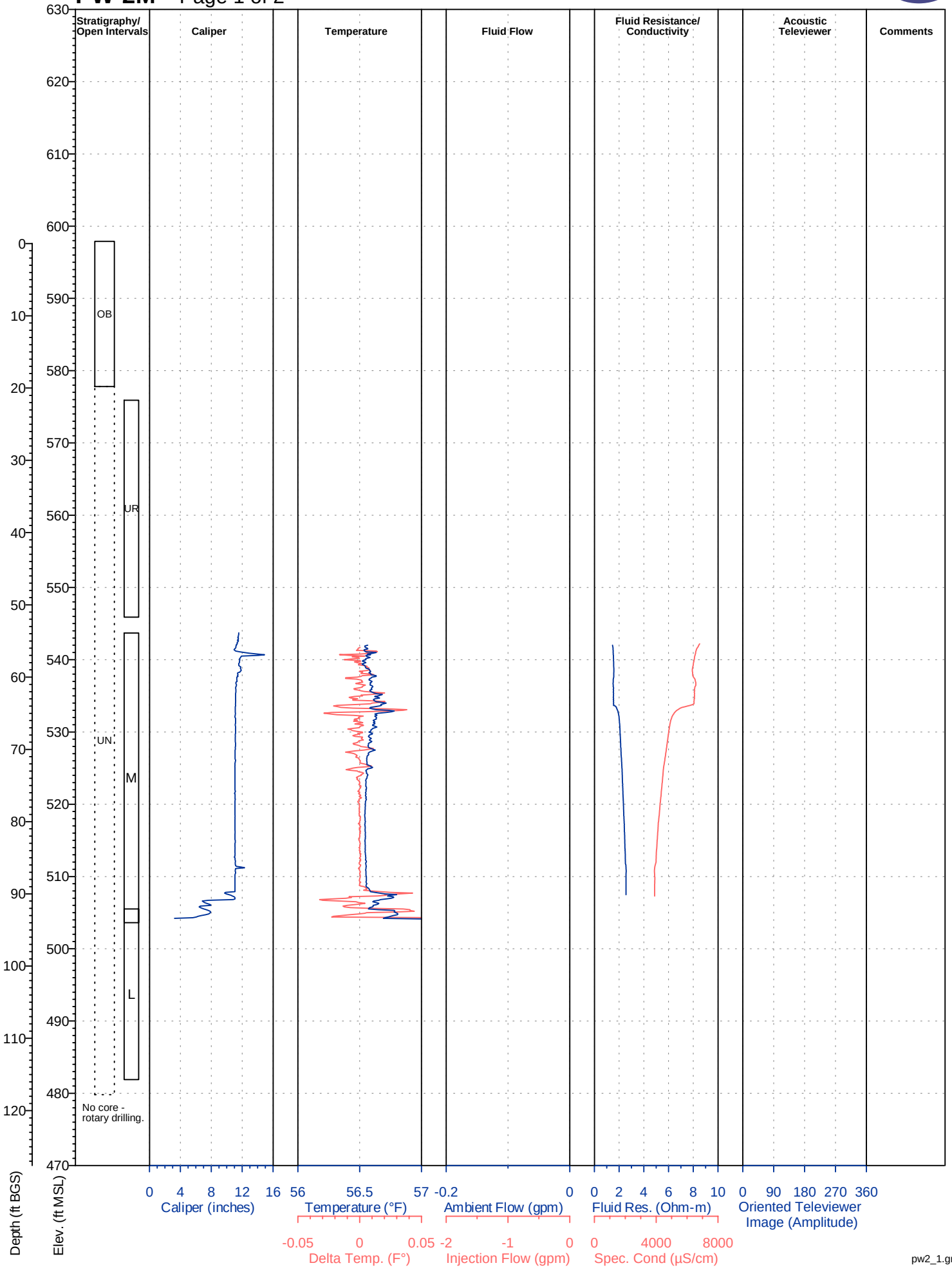
pw1_1.grf

PW-1 Cluster



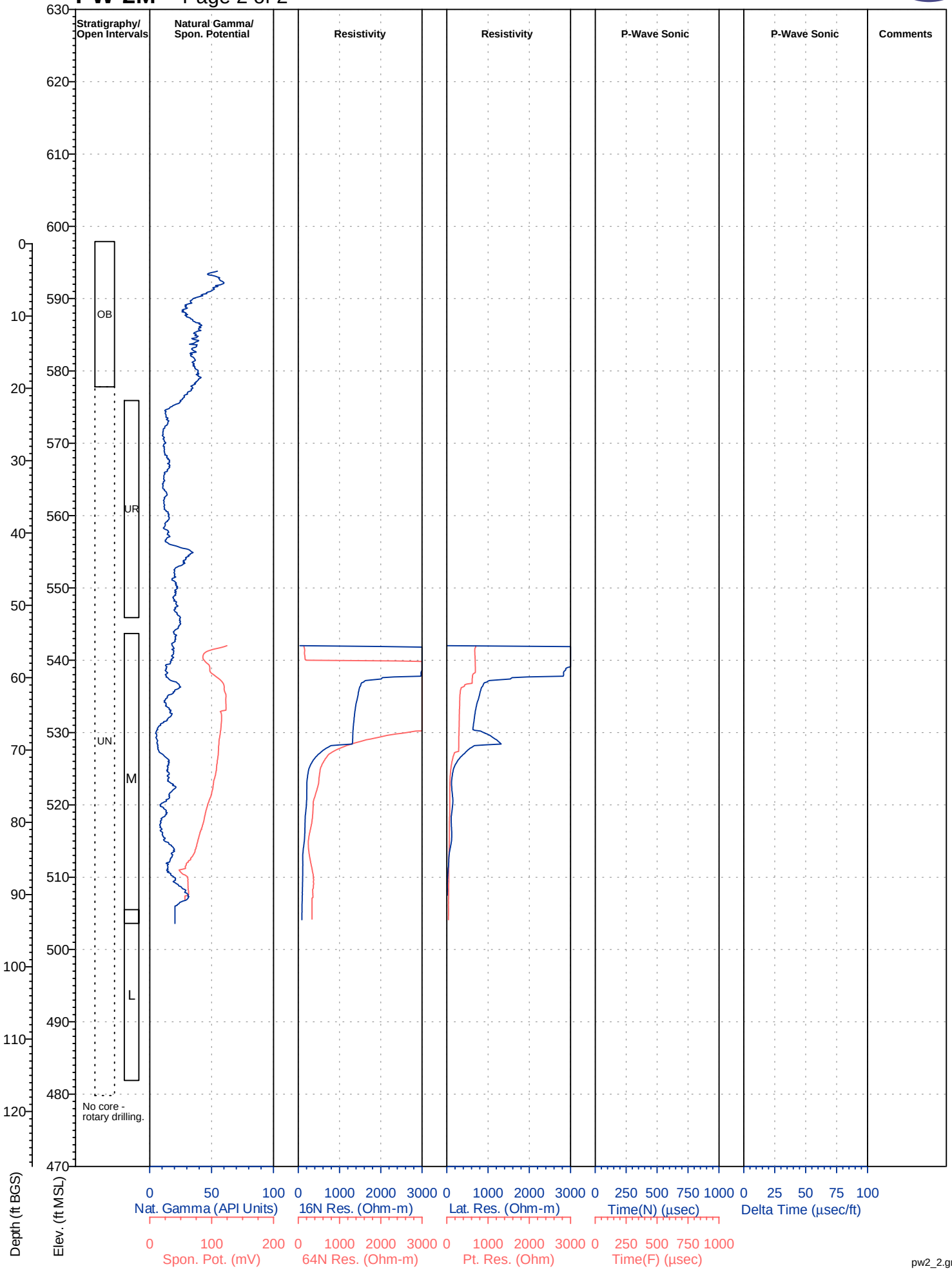
pw1_2.grf

PW-2M

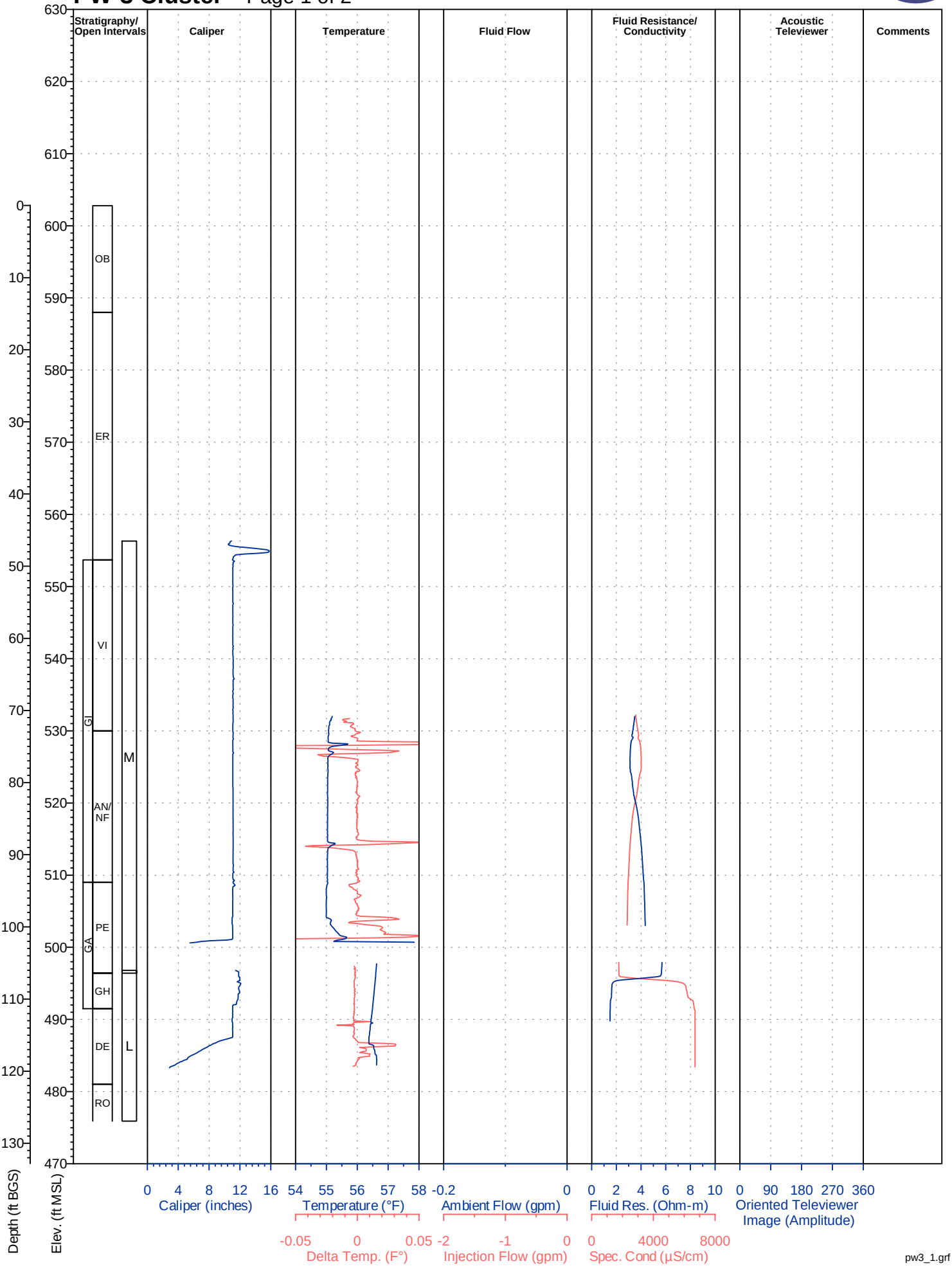


pw2_1.grf

PW-2M

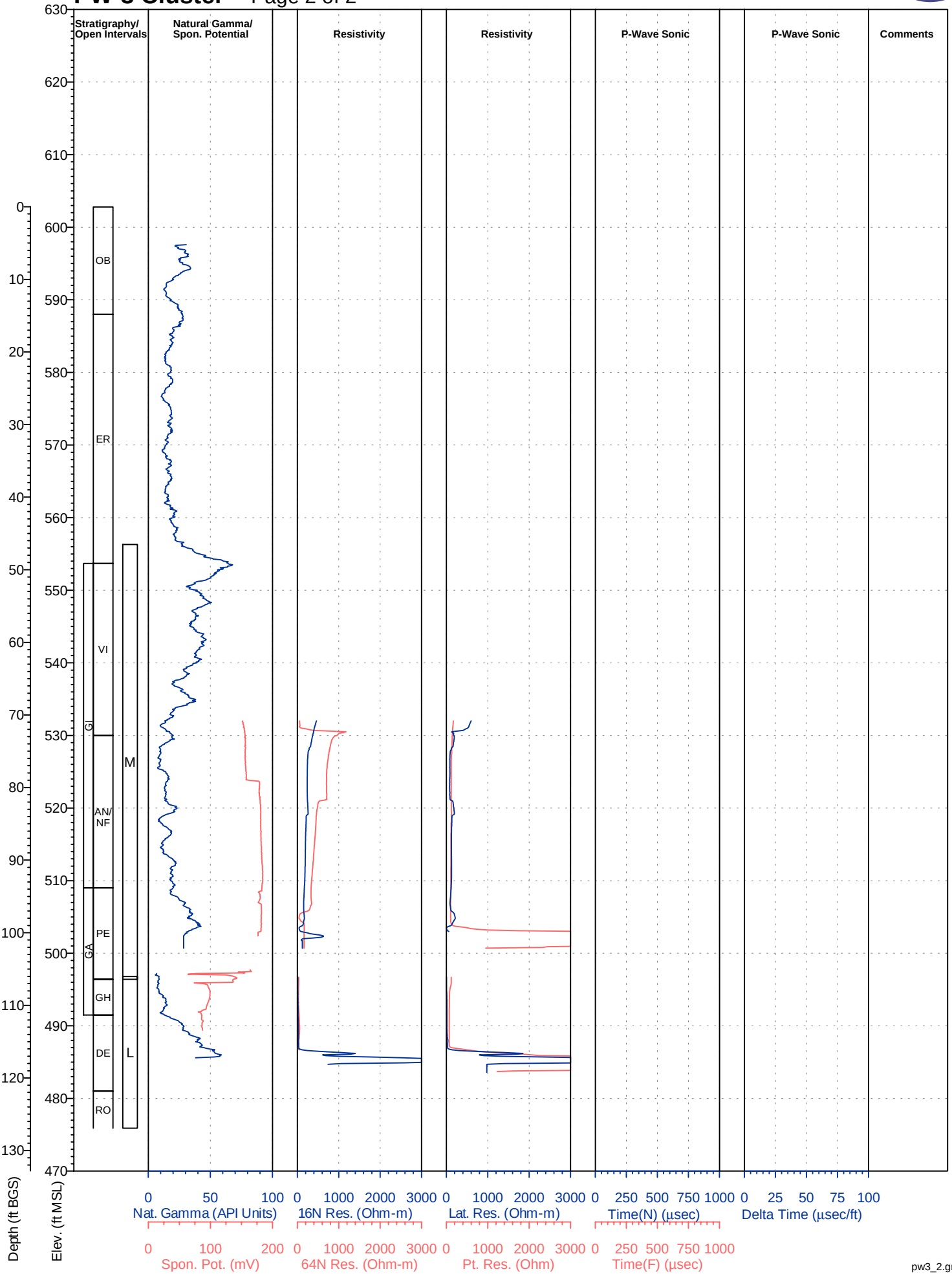

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
UR
UN
M
L
No core - rotary drilling.
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

PW-3 Cluster

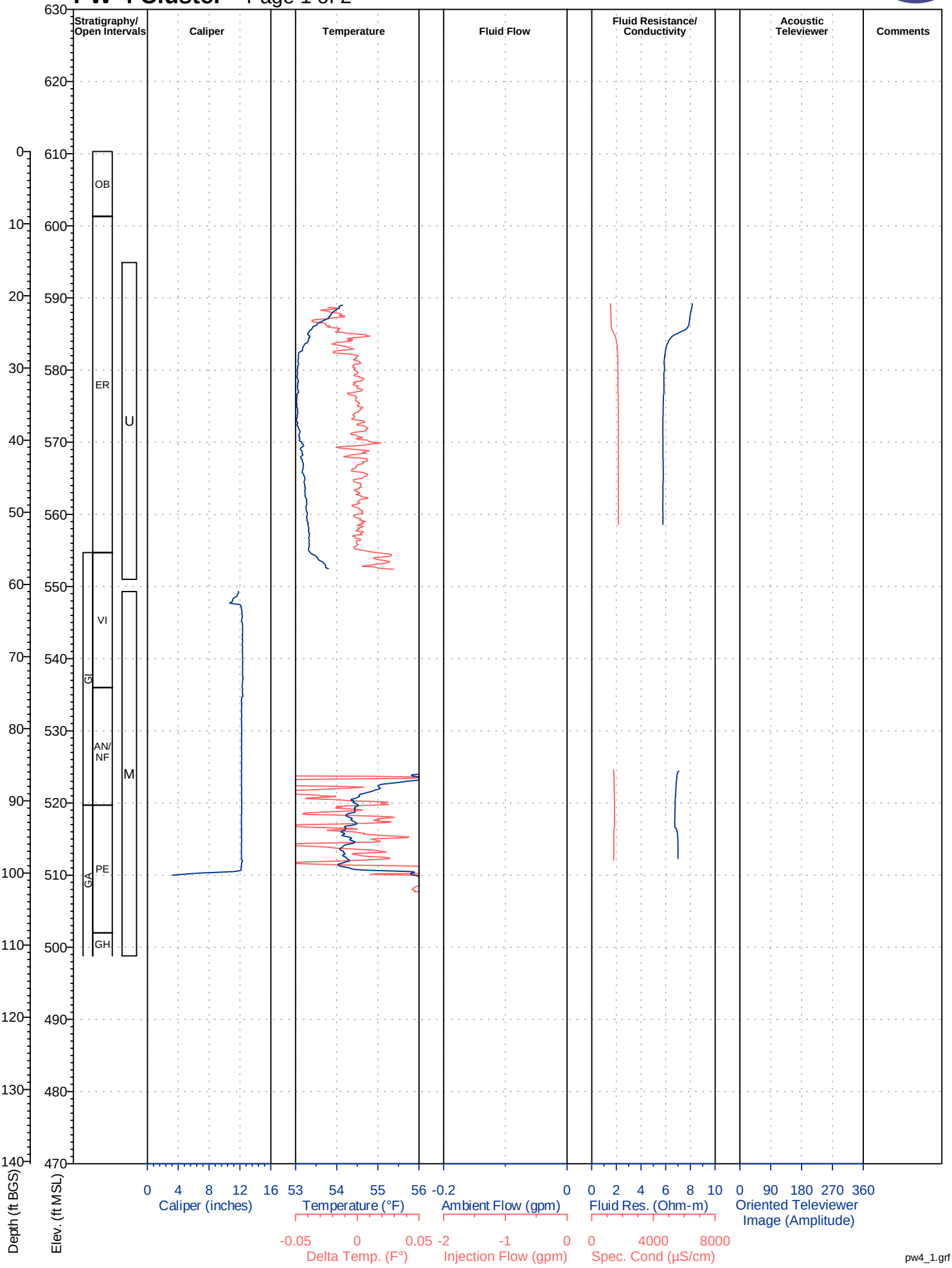


pw3_1.grf

PW-3 Cluster

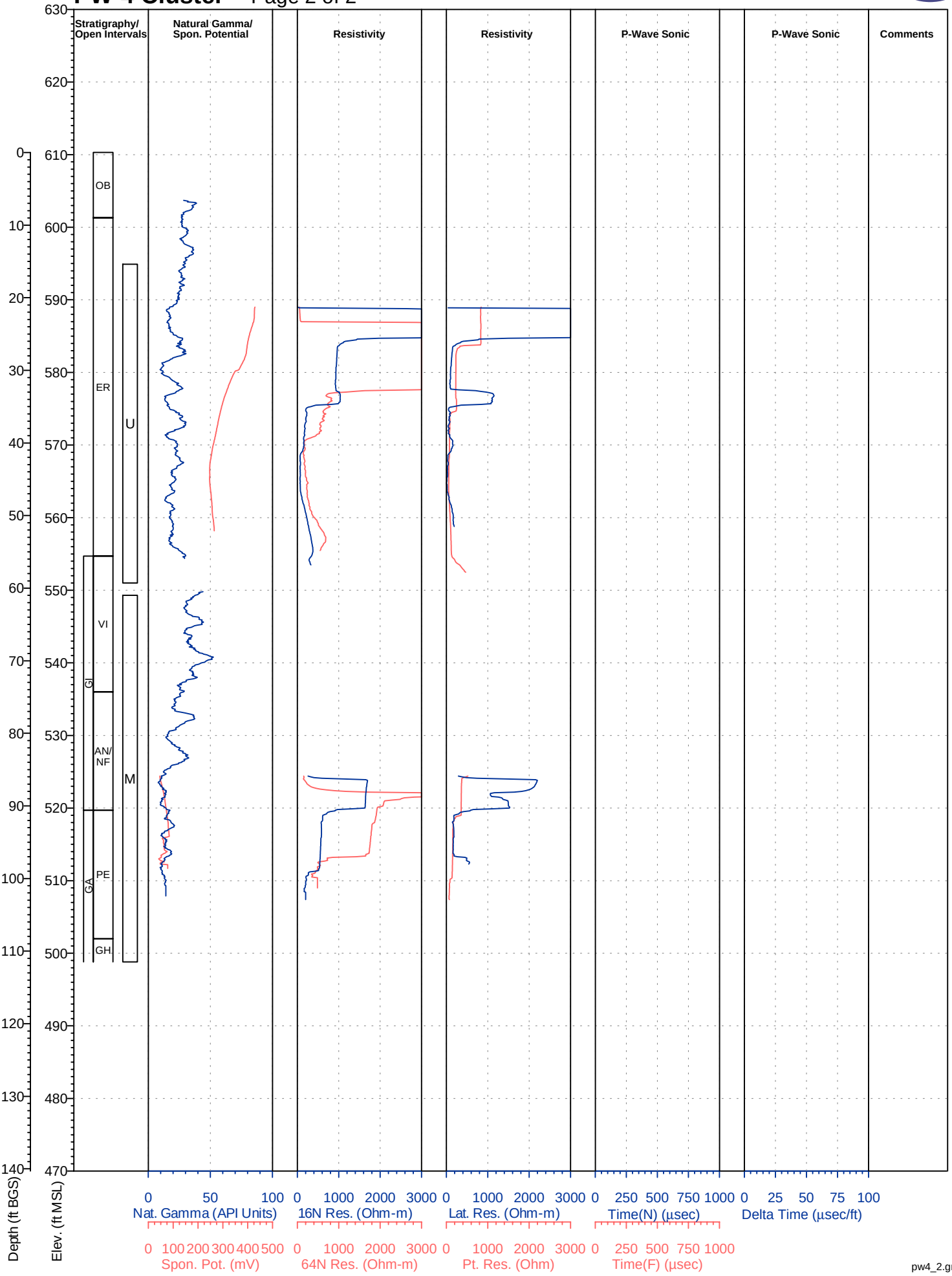

Stratigraphy/ Open Intervals
Natural Gamma/ Spon. Potential
Resistivity
Resistivity
P-Wave Sonic
P-Wave Sonic
Comments
OB
ER
VI
AN/ NF
PE
GH
DE
RO
GI
GA
M
L
Depth (ft BGS)
Elev. (ft MSL)
Nat. Gamma (API Units)
Spon. Pot. (mV)
16N Res. (Ohm-m)
64N Res. (Ohm-m)
Lat. Res. (Ohm-m)
Pt. Res. (Ohm)
Time(N) (µsec)
Time(F) (µsec)
Delta Time (µsec/ft)

PW-4 Cluster



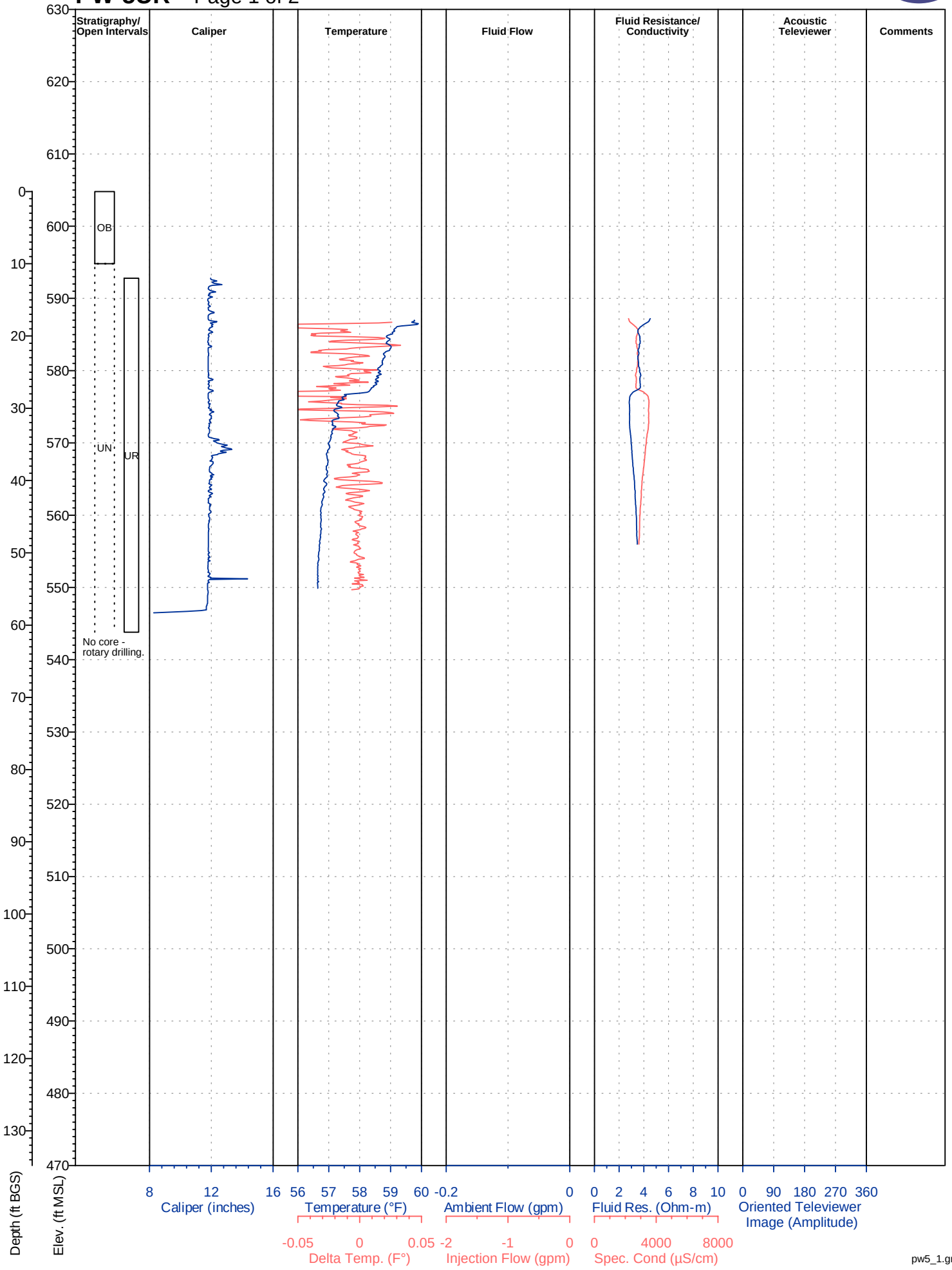
pw4_1.grf

PW-4 Cluster



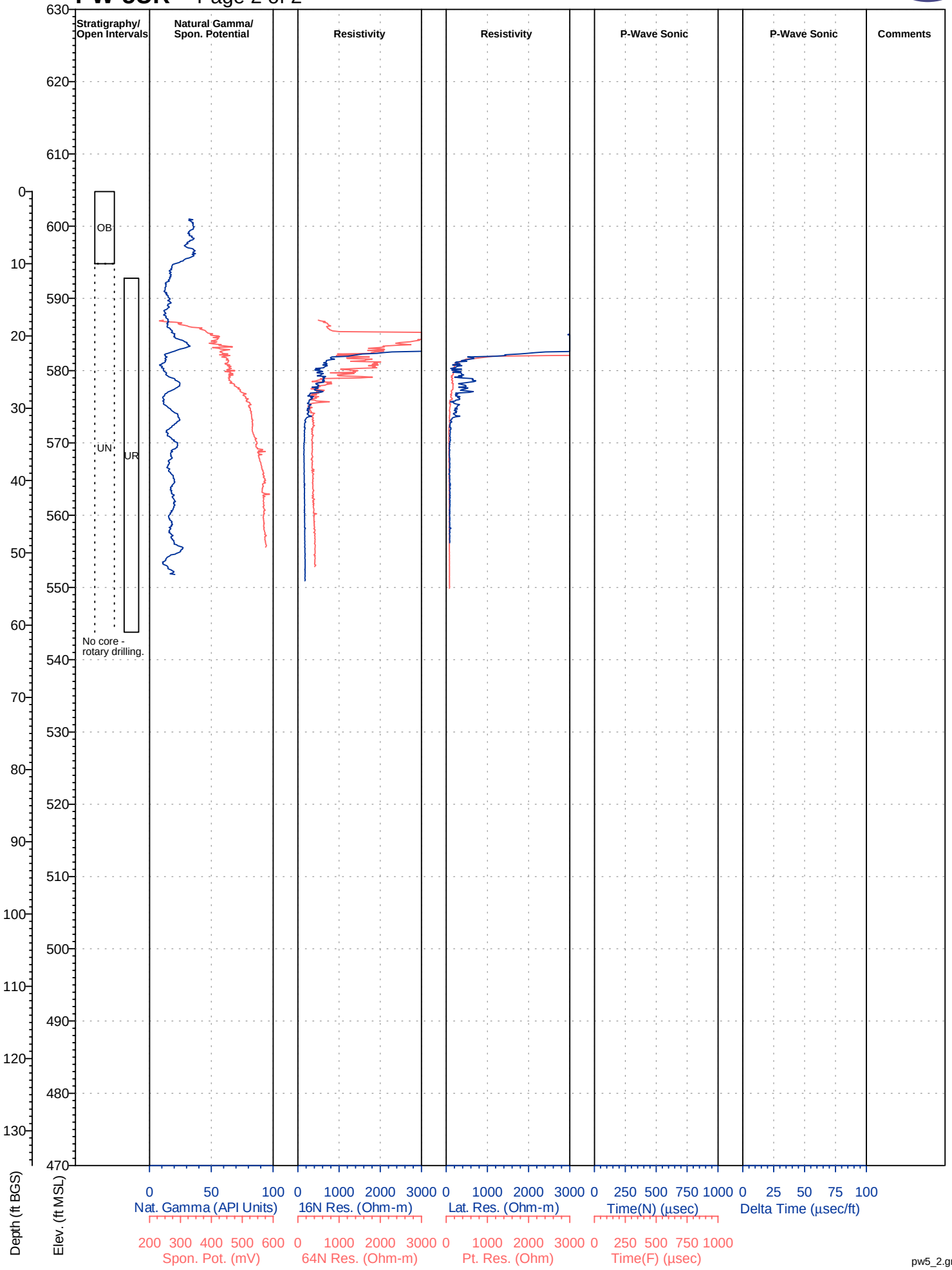
pw4_2.grf

PW-5UR



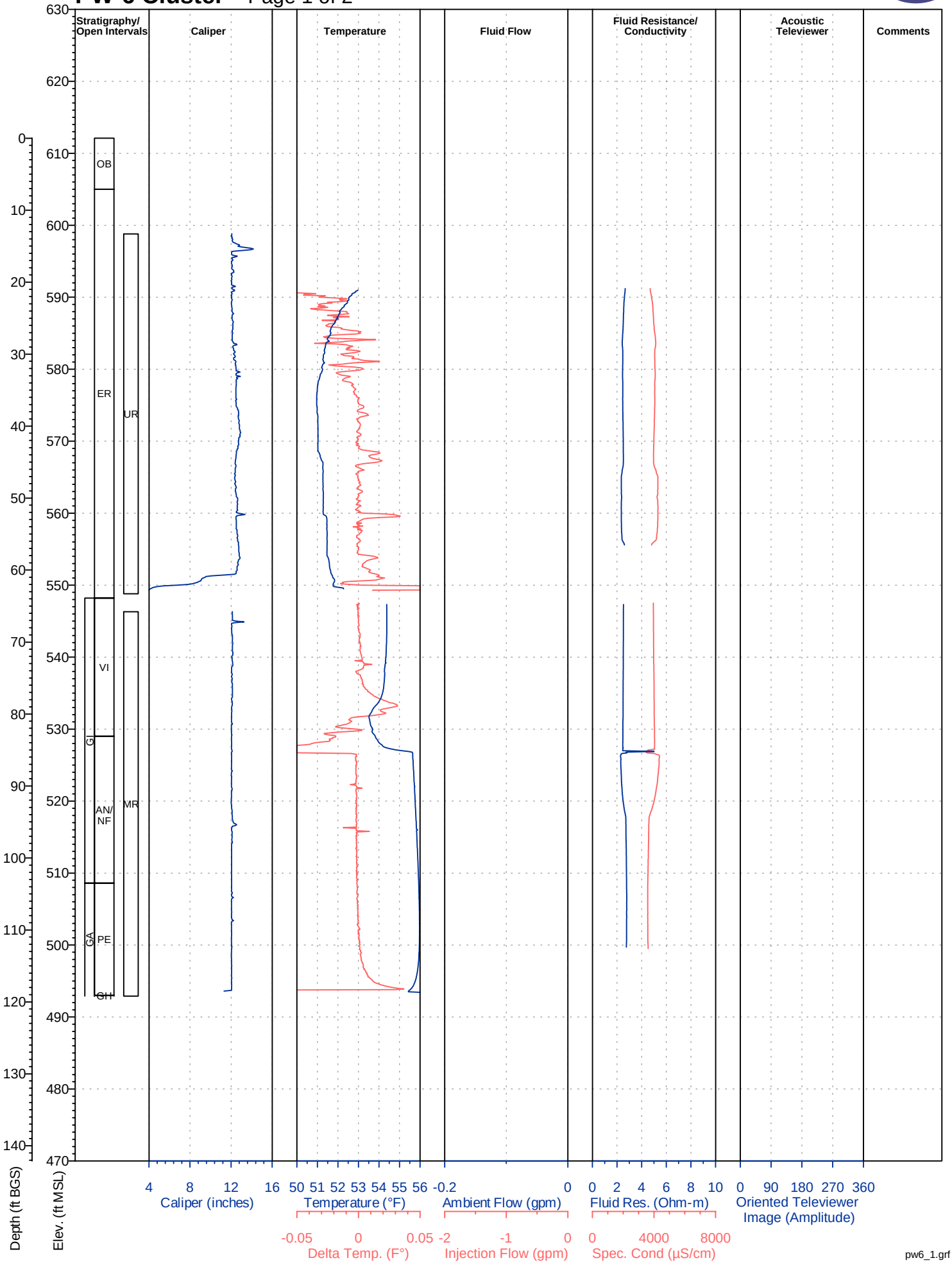
pw5_1.grf

PW-5UR



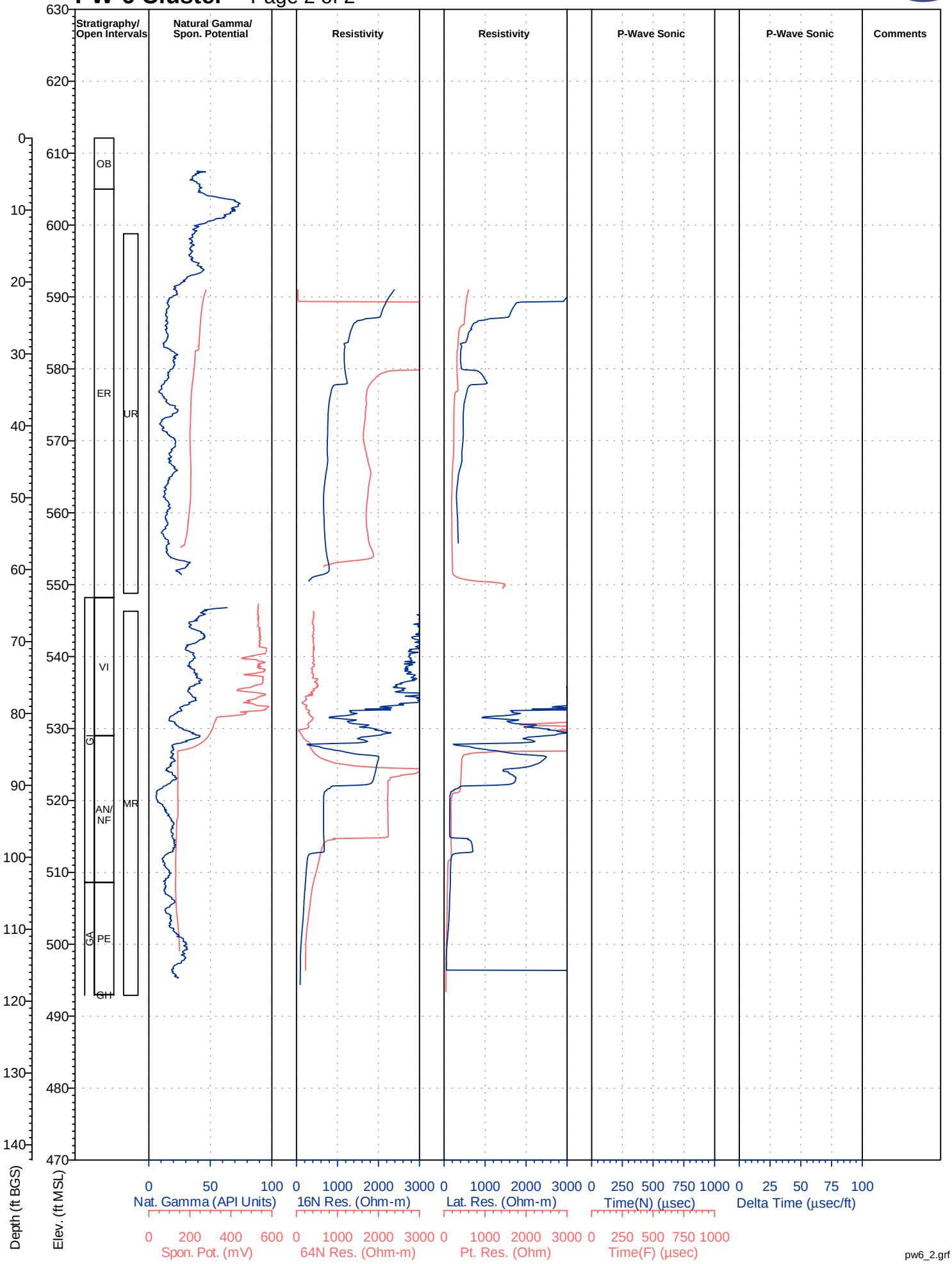
pw5_2.grf

PW-6 Cluster



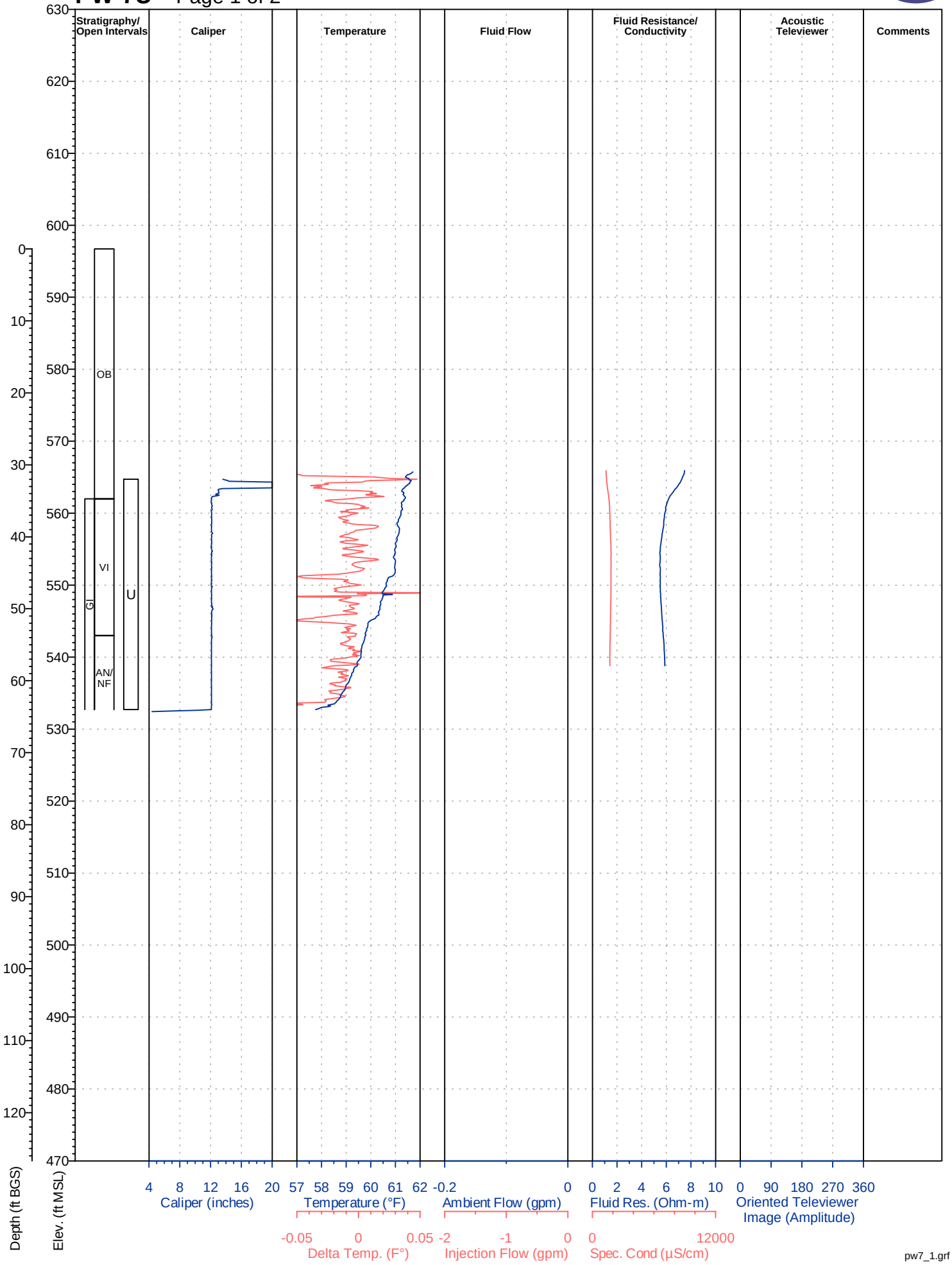
pw6_1.grf

PW-6 Cluster



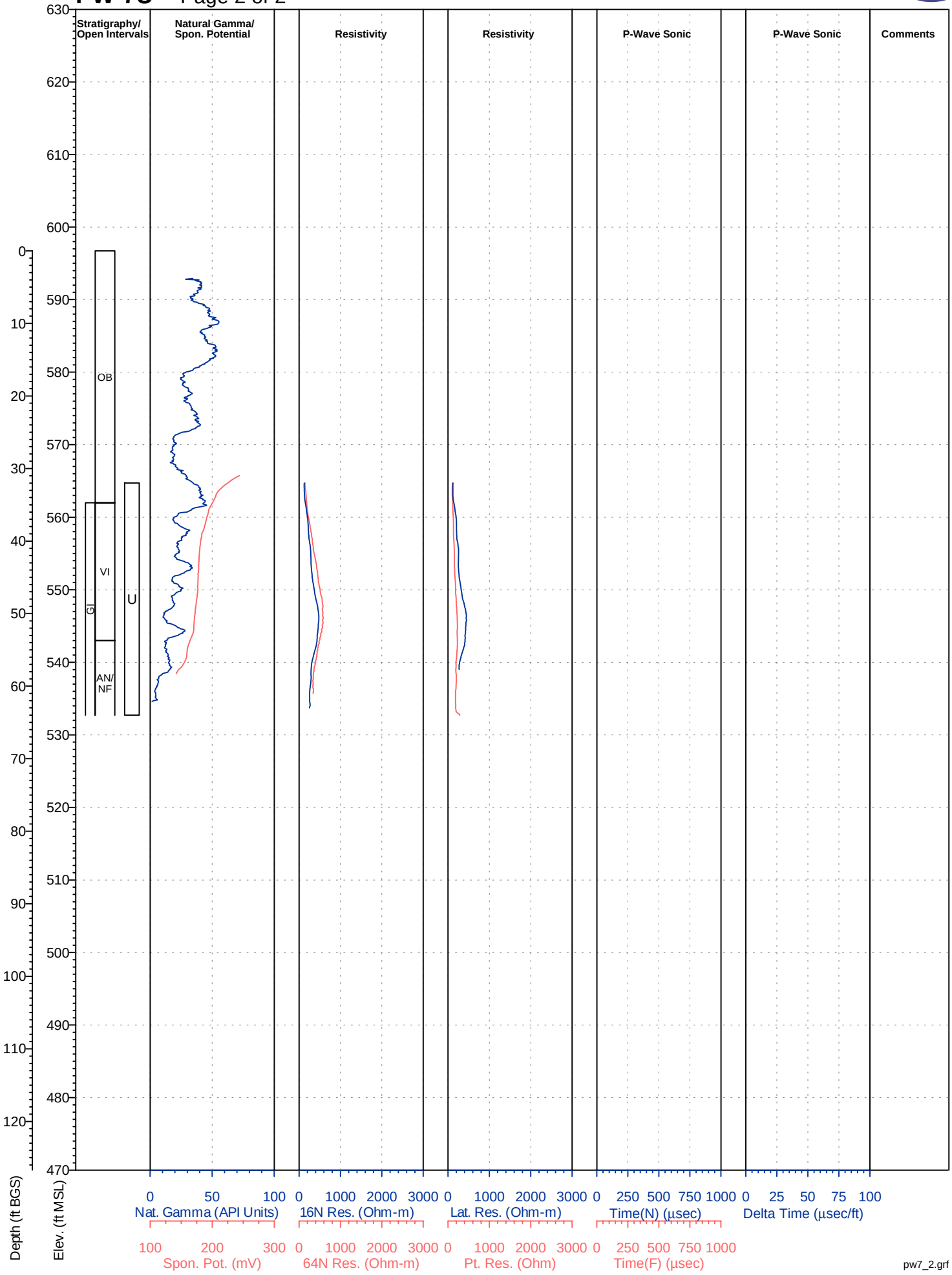
pw6_2.grf

PW-7U



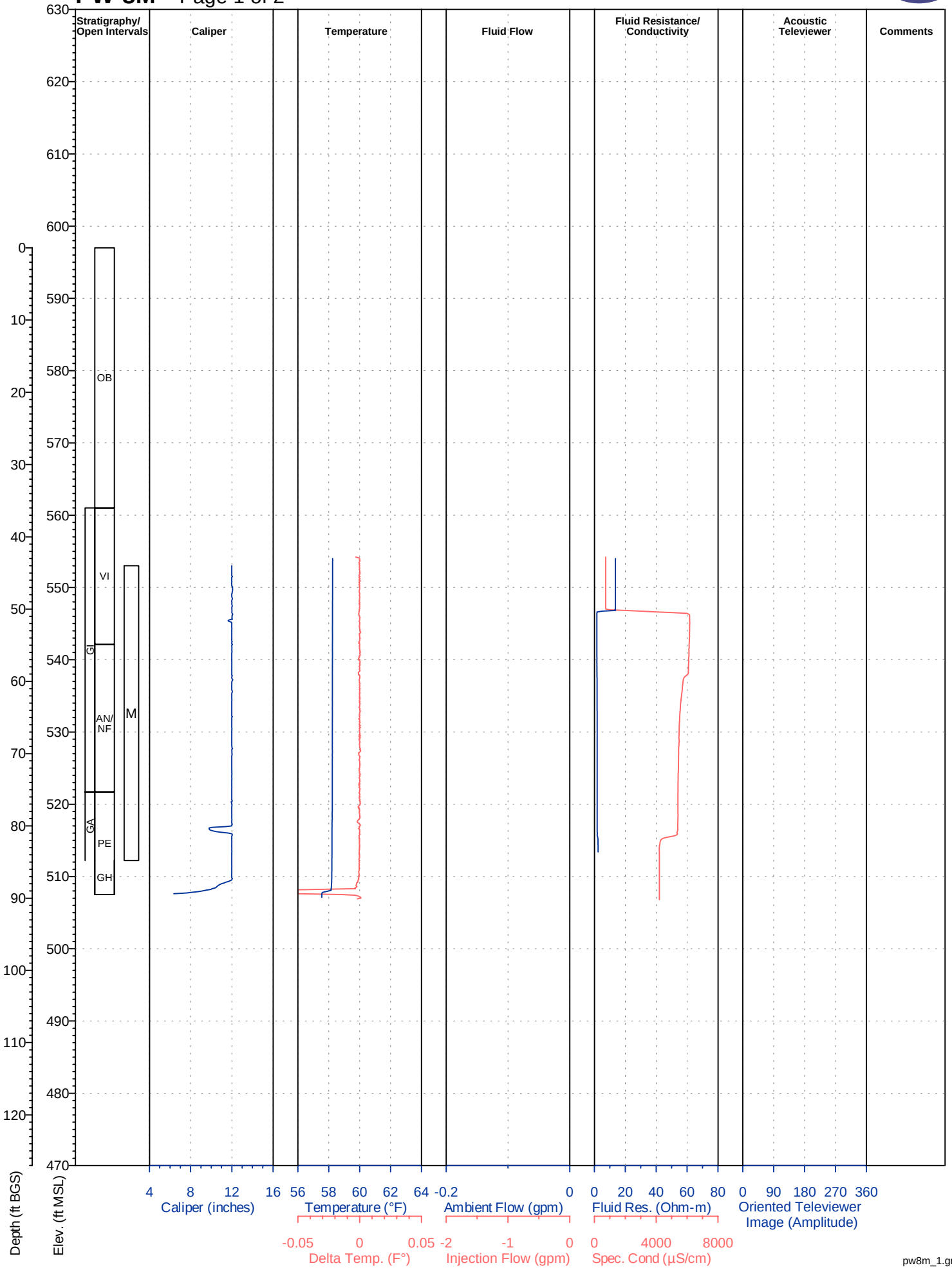
pw7_1.grf

PW-7U



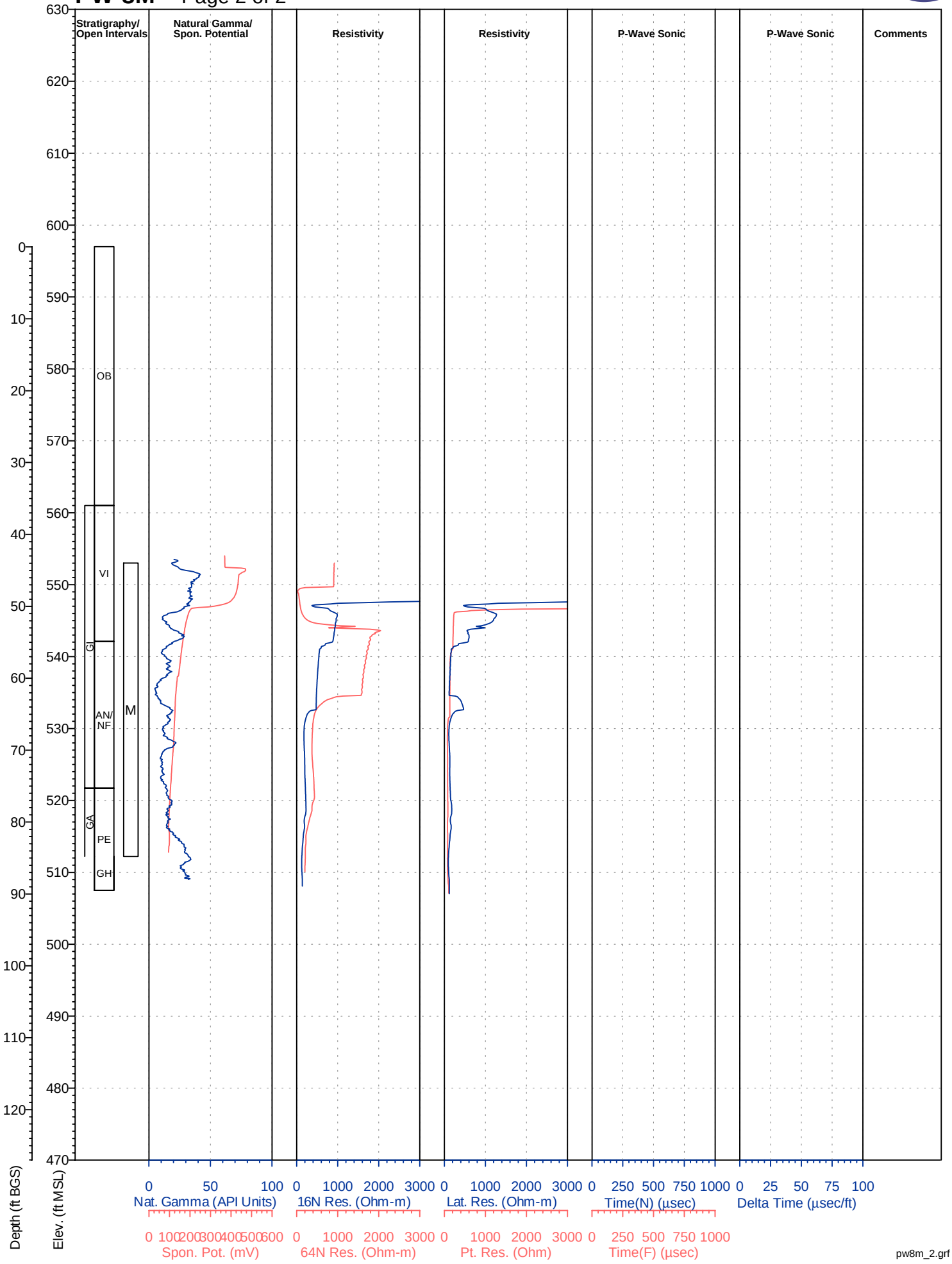
pw7_2.grf

PW-8M



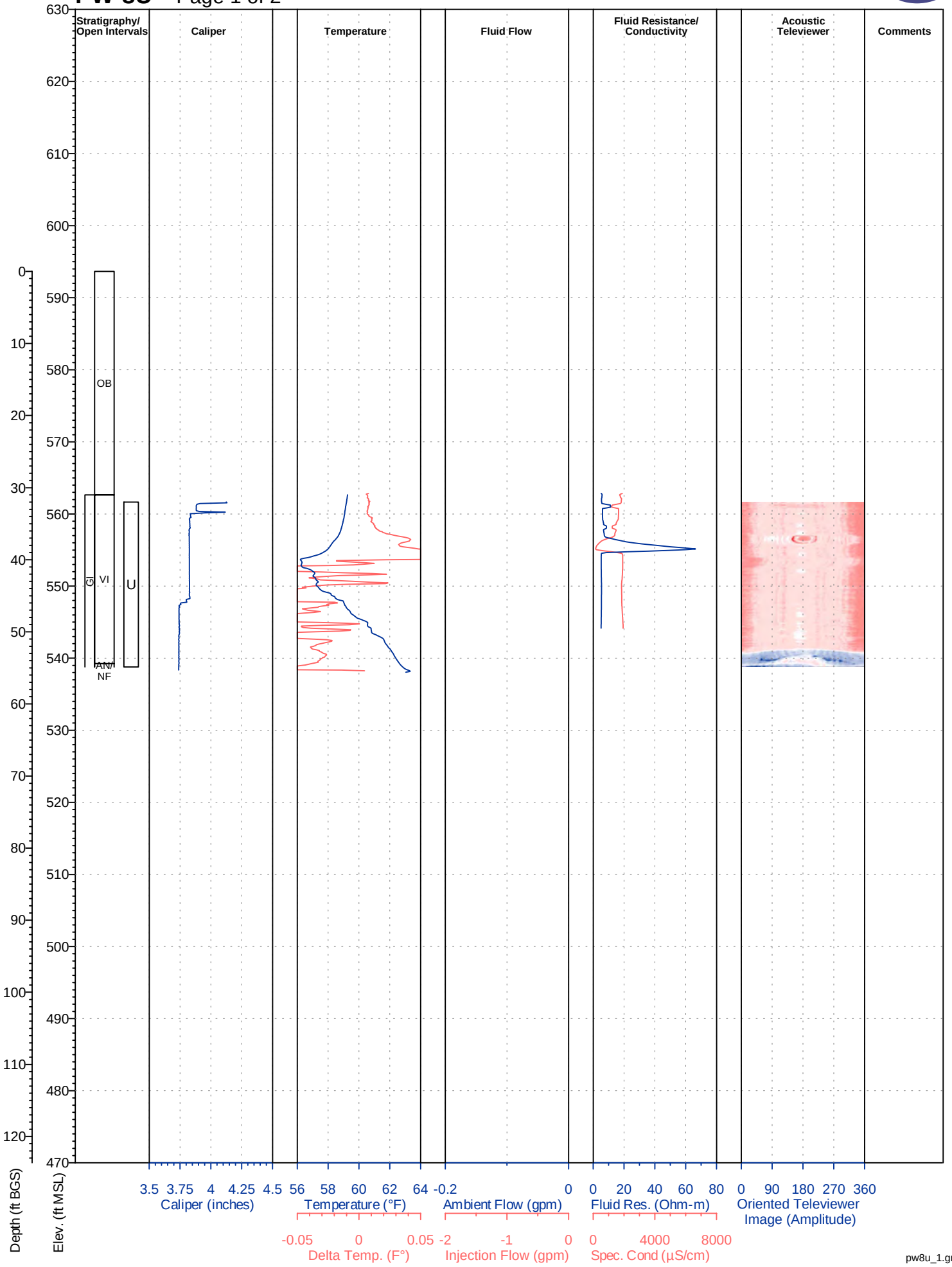
pw8m_1.grf

PW-8M



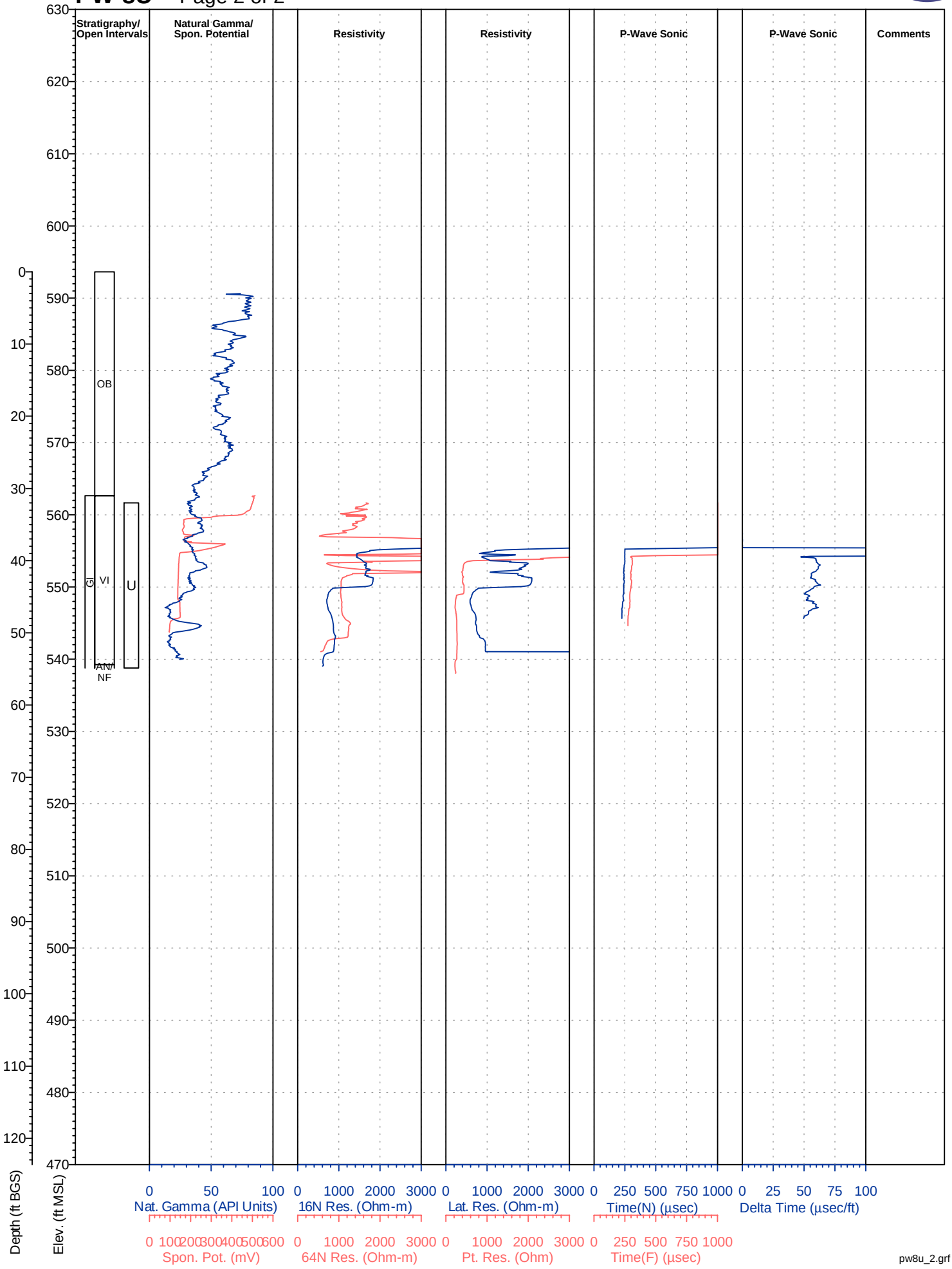
pw8m_2.grf

PW-8U



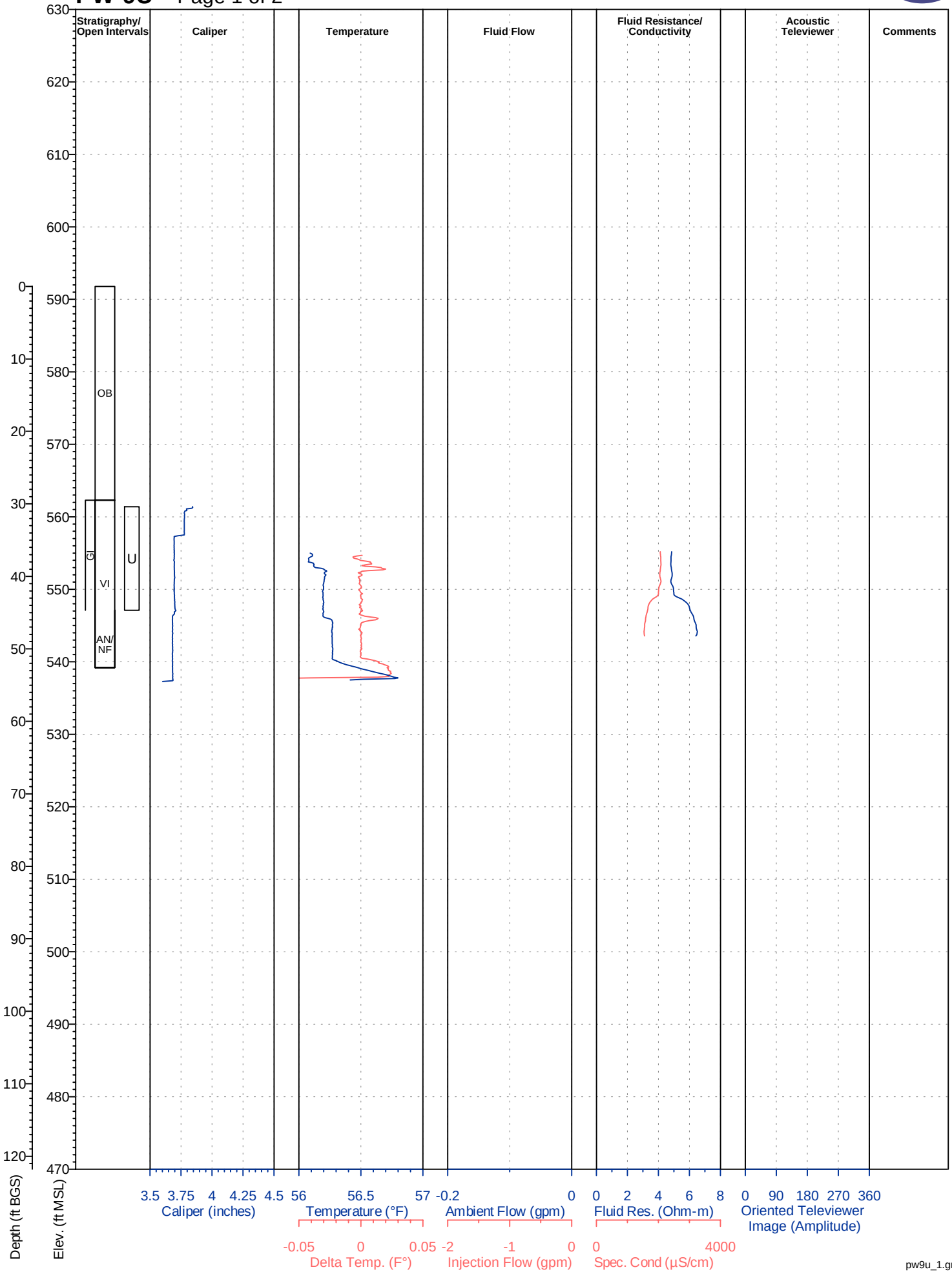
pw8u_1.grf

PW-8U



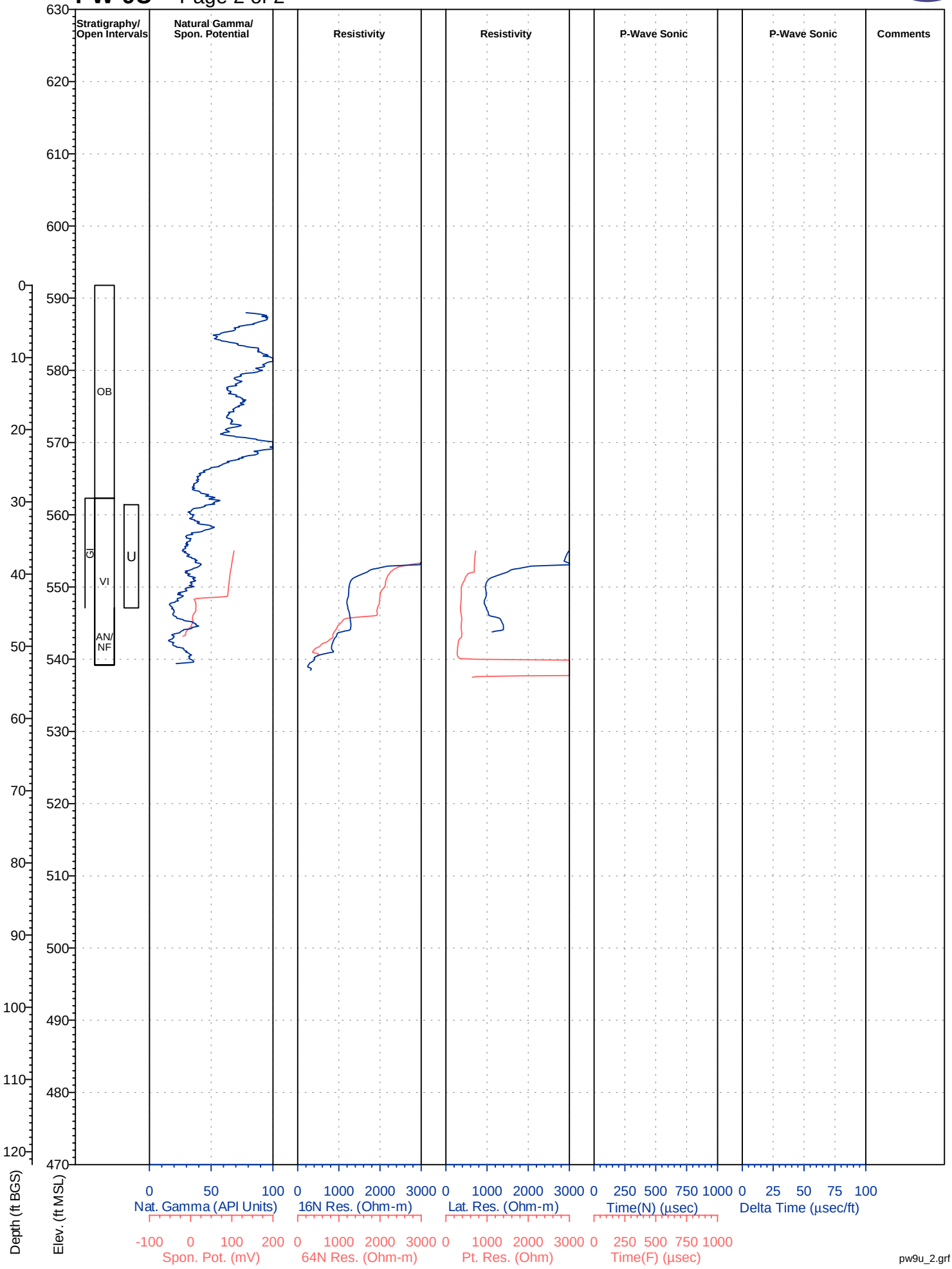
pw8u_2.grf

PW-9U



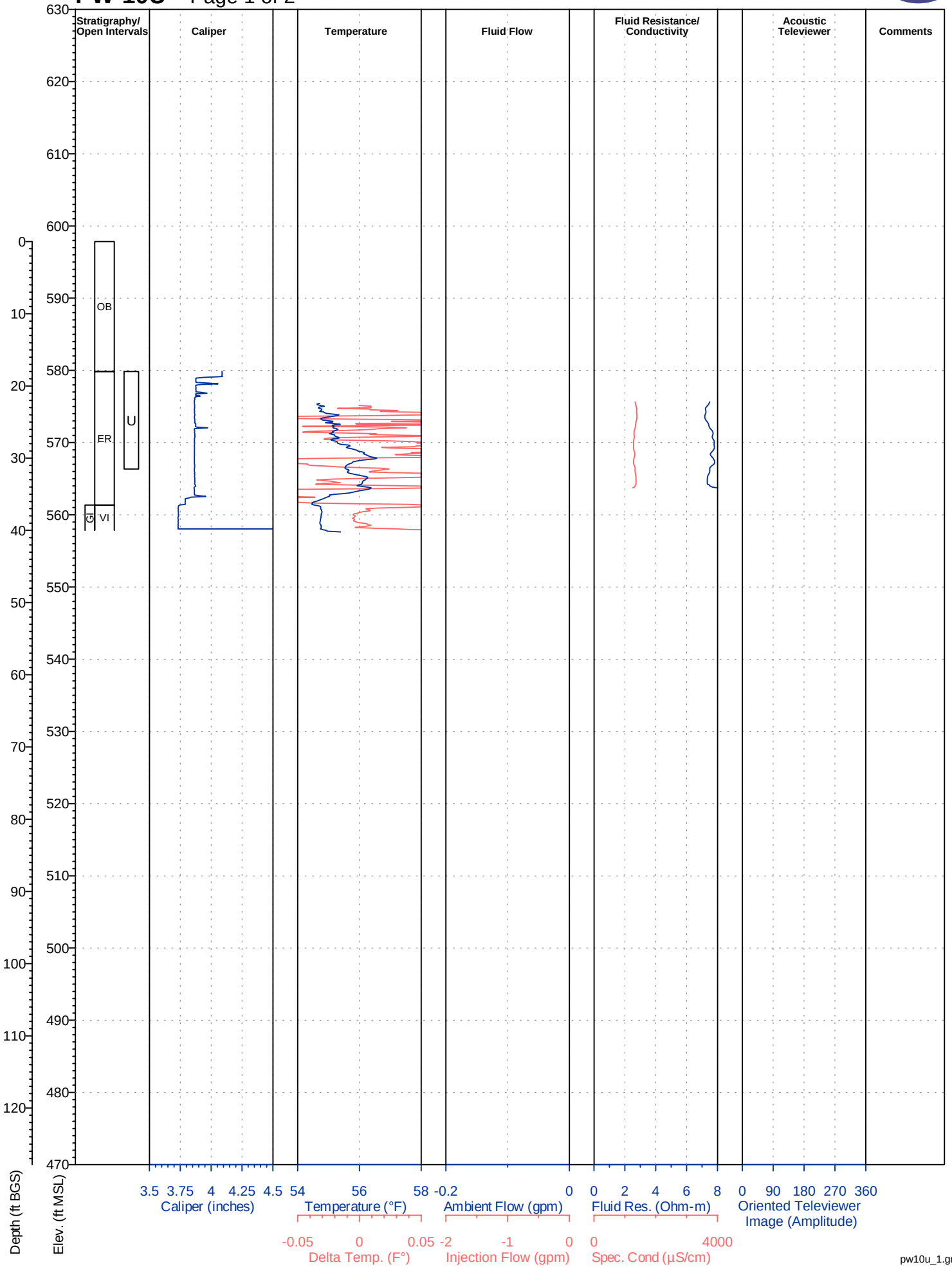
pw9u_1.grf

PW-9U



pw9u_2.grf

PW-10U



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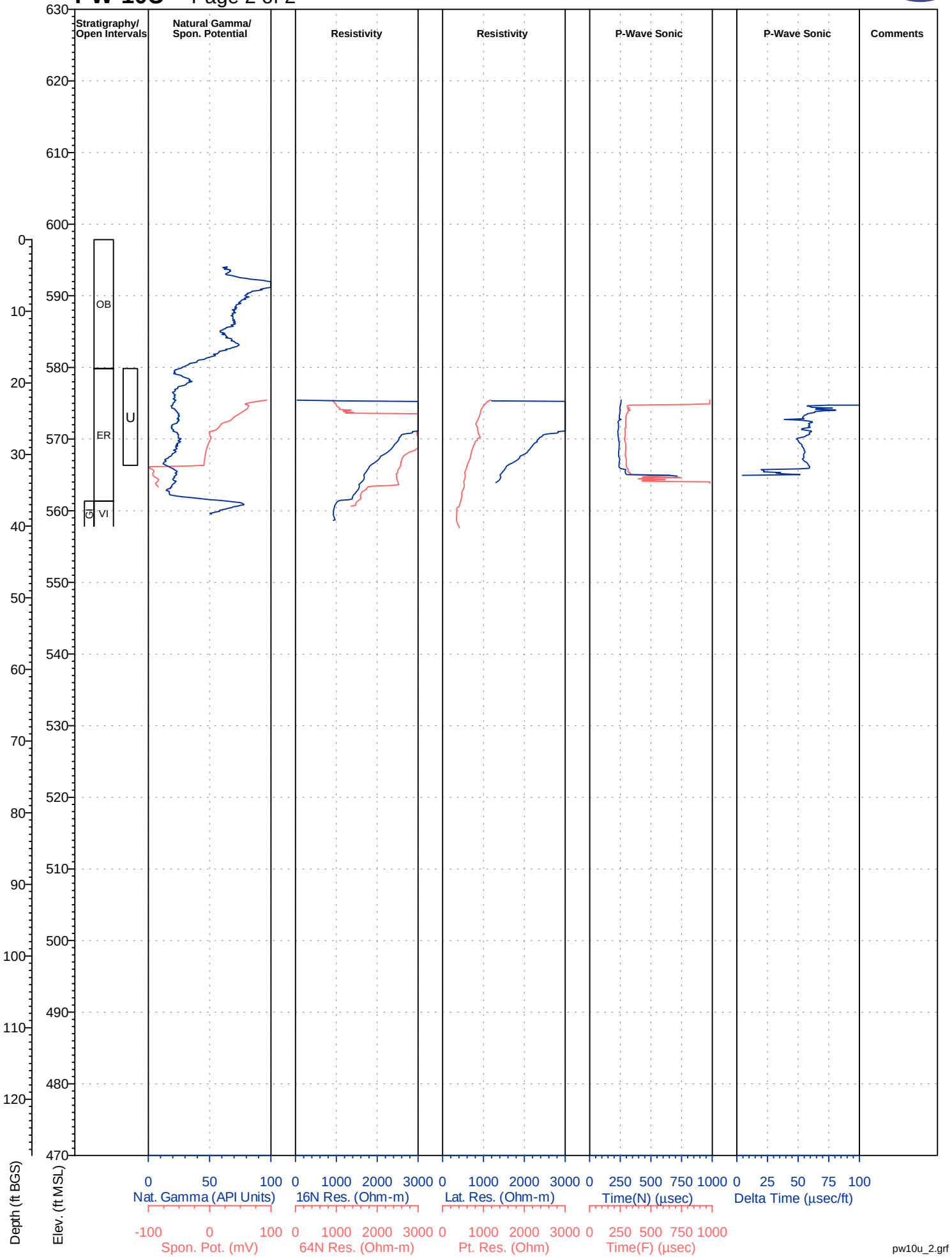
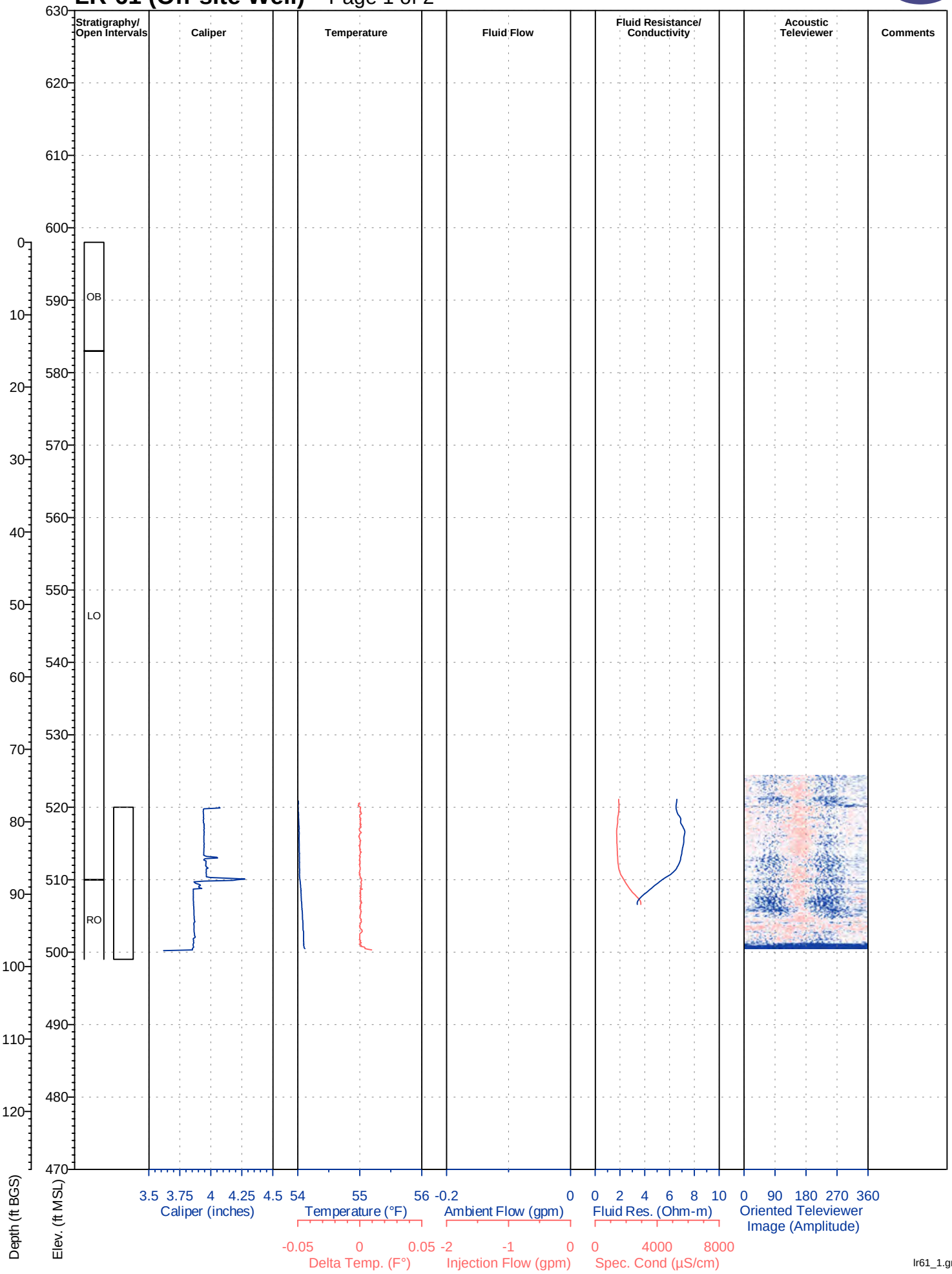
PW-10U



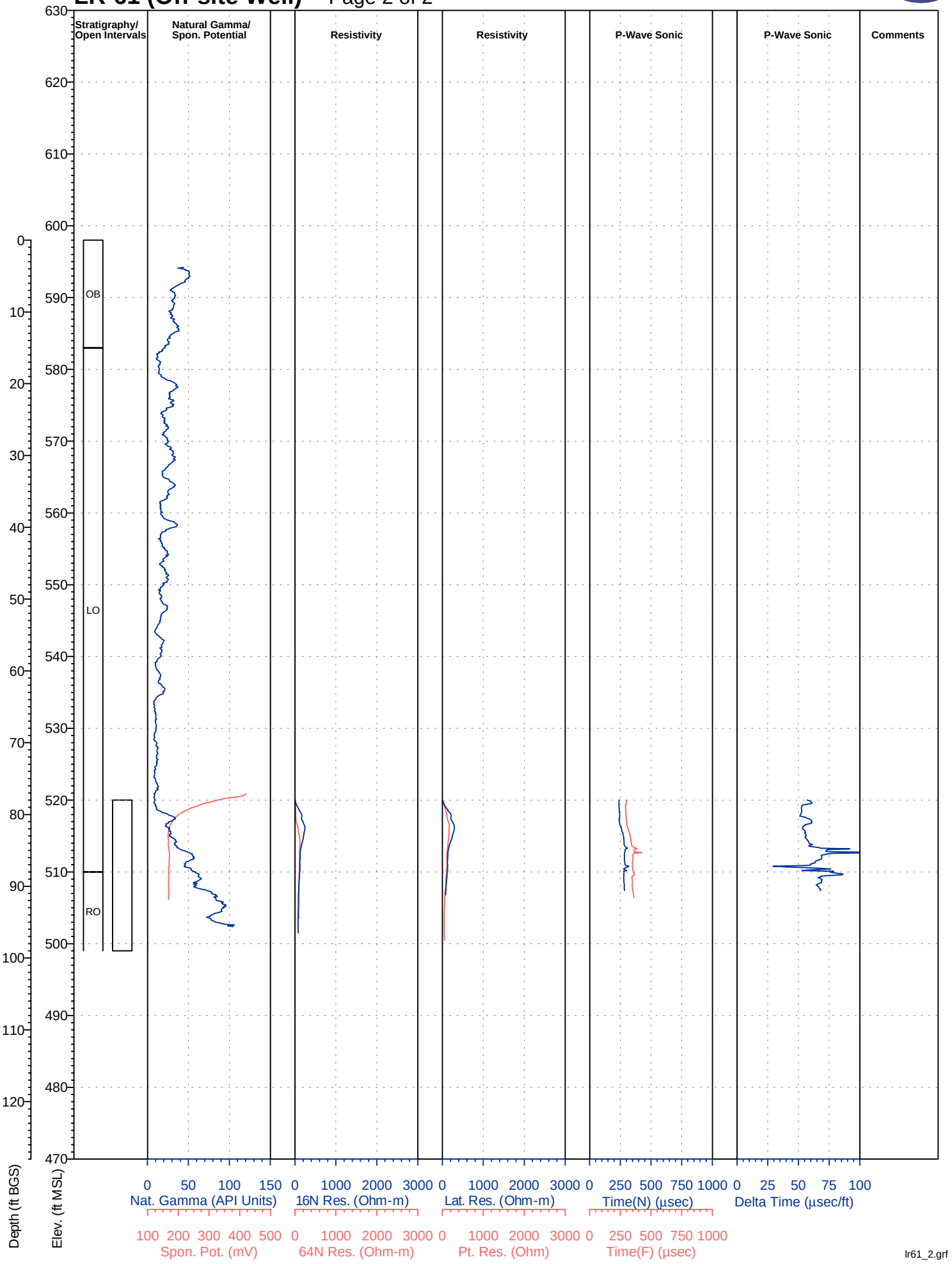
pw10u_2.grf

LR-61 (Off-site Well)



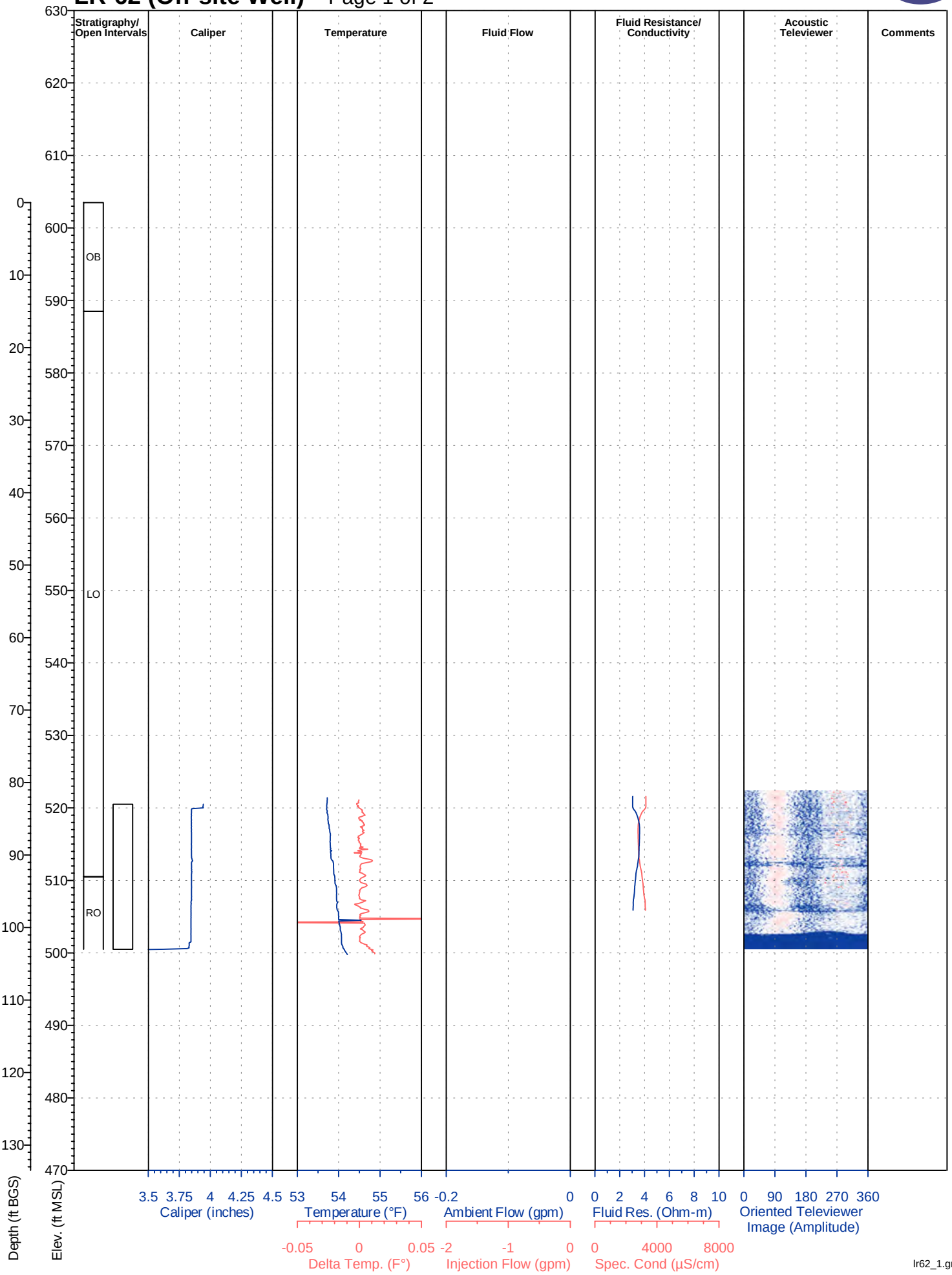
lr61_1.grf

LR-61 (Off-site Well)



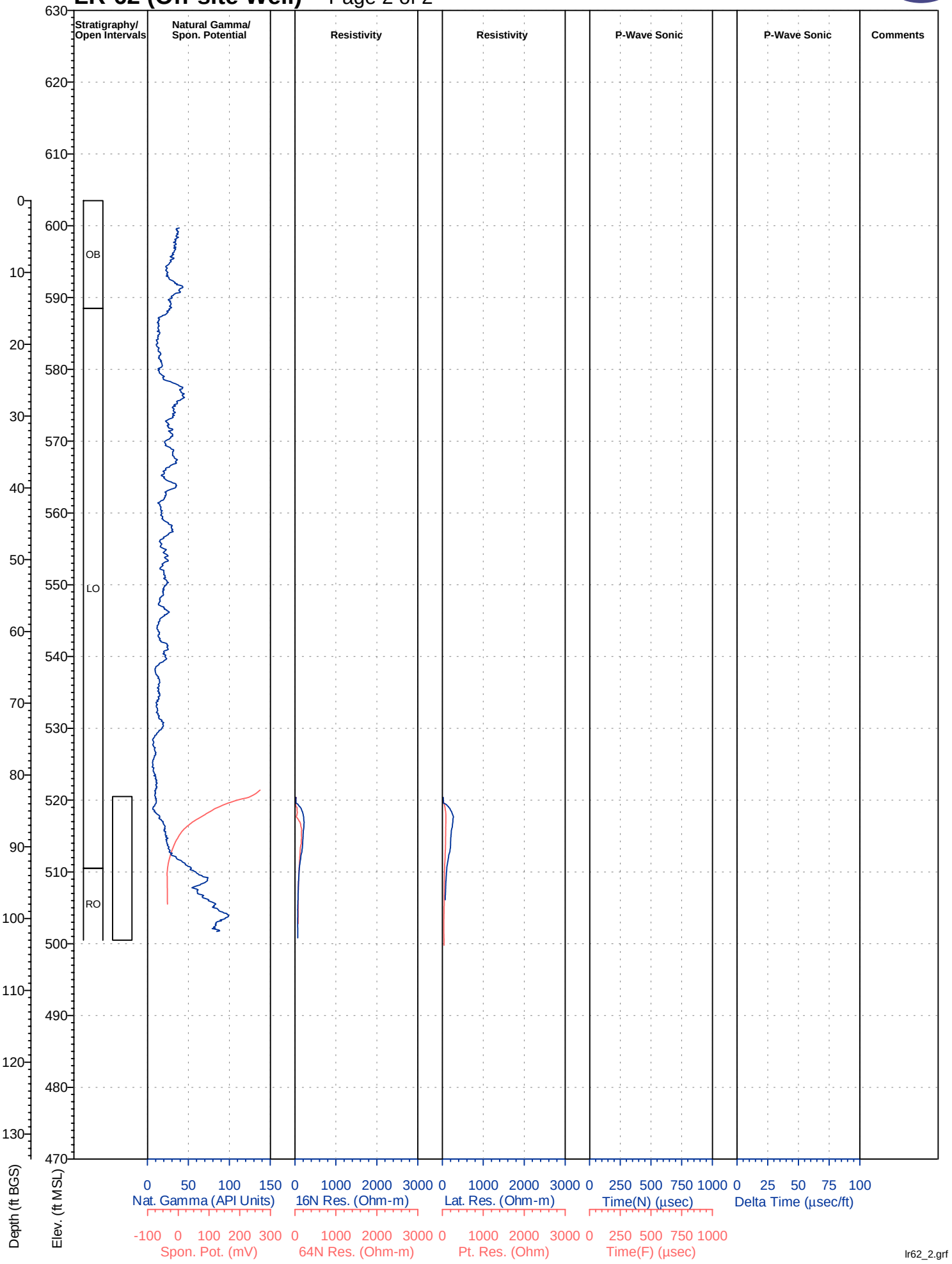
lr61_2.grf

LR-62 (Off-site Well)



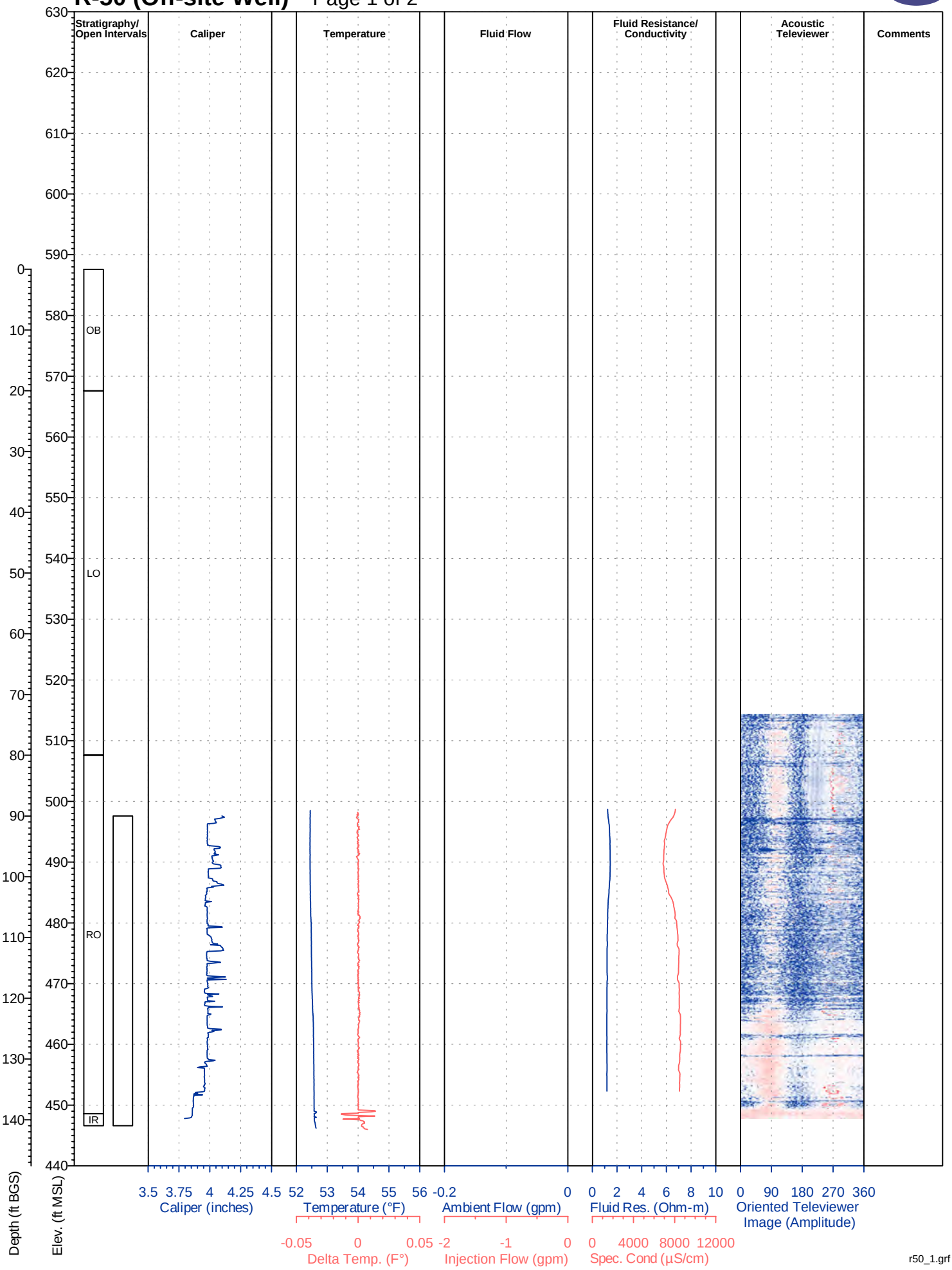
lr62_1.grf

LR-62 (Off-site Well)



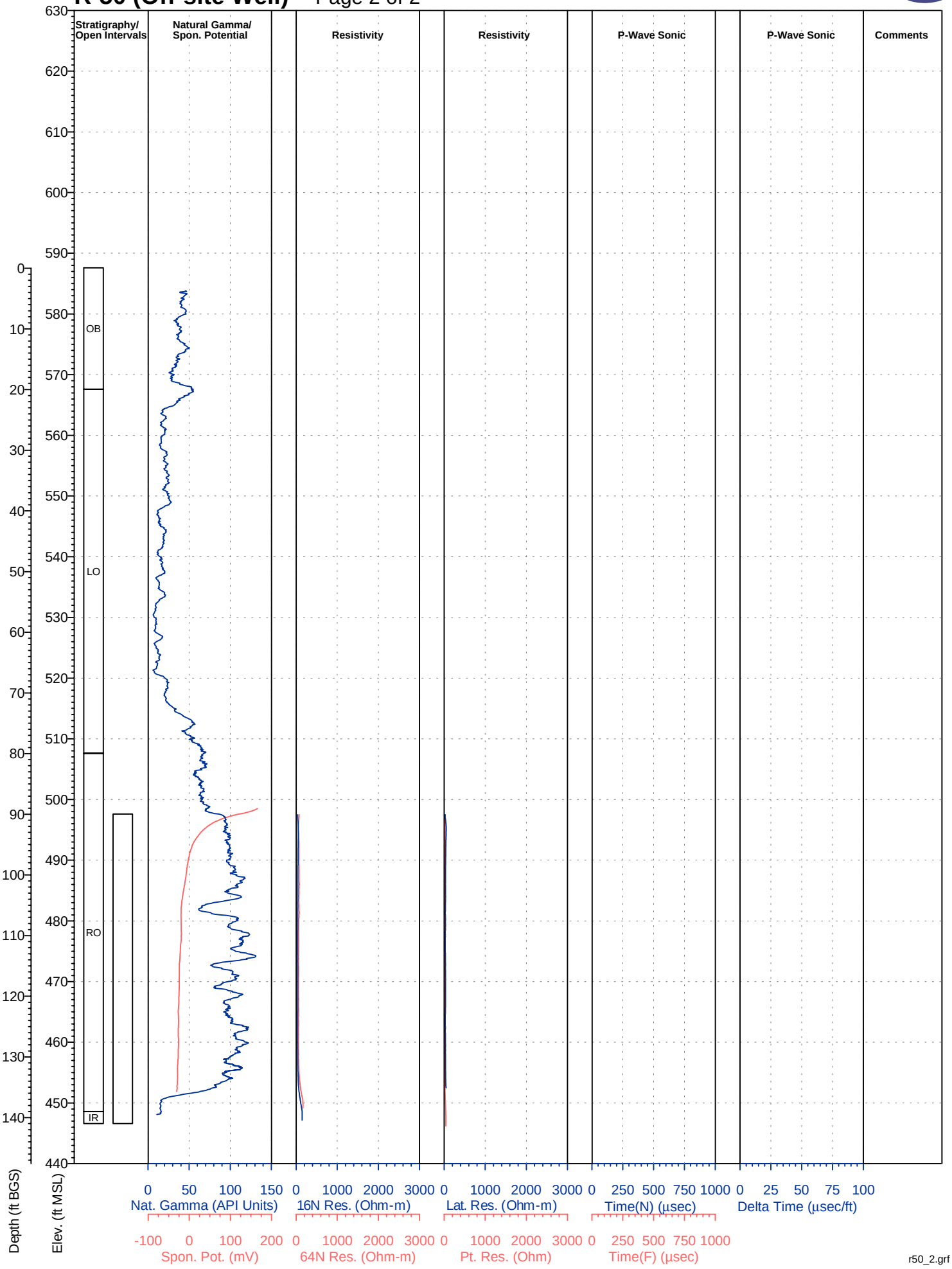
lr62_2.grf

R-50 (Off-site Well)



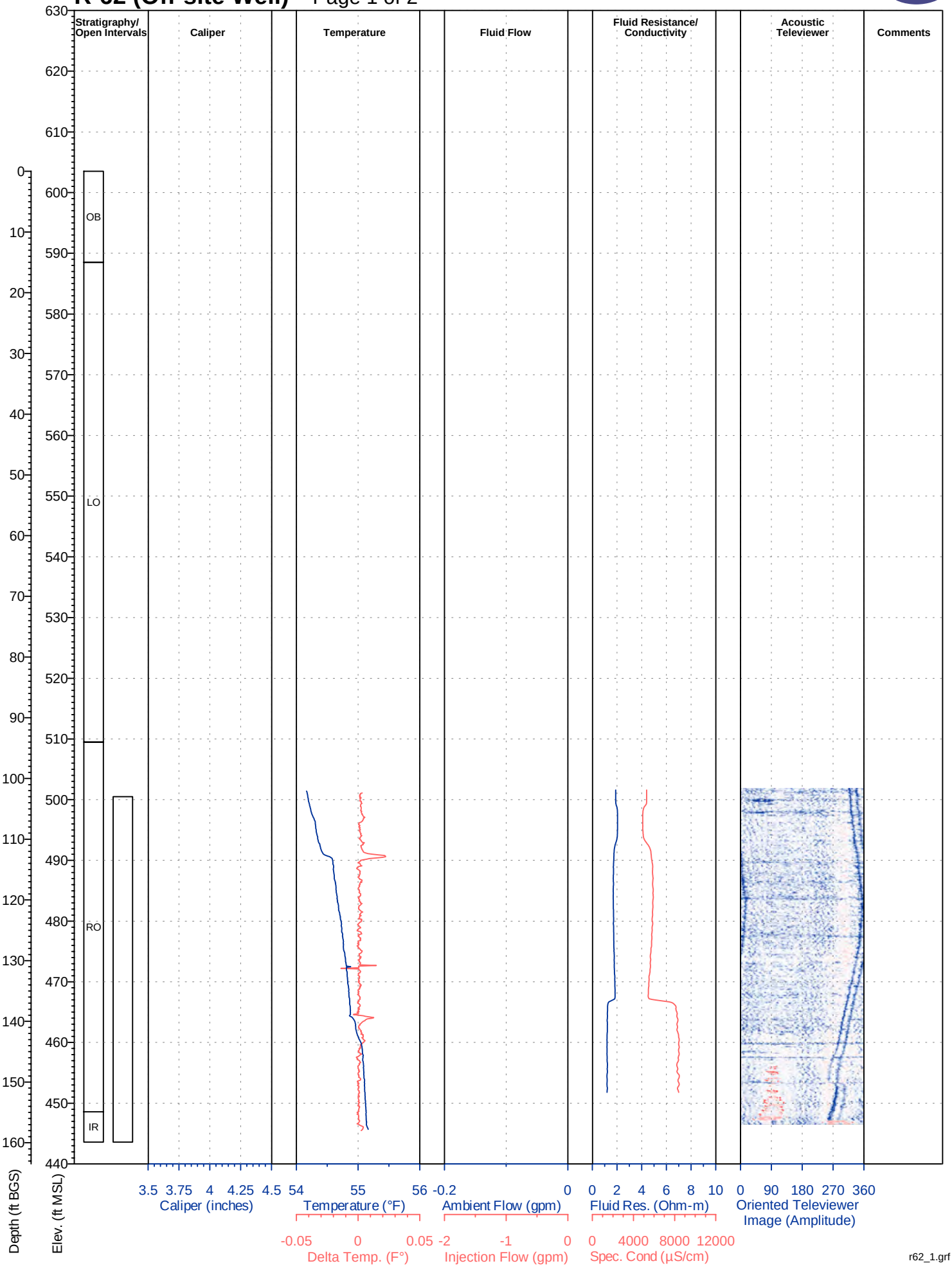
r50_1.grf

R-50 (Off-site Well)



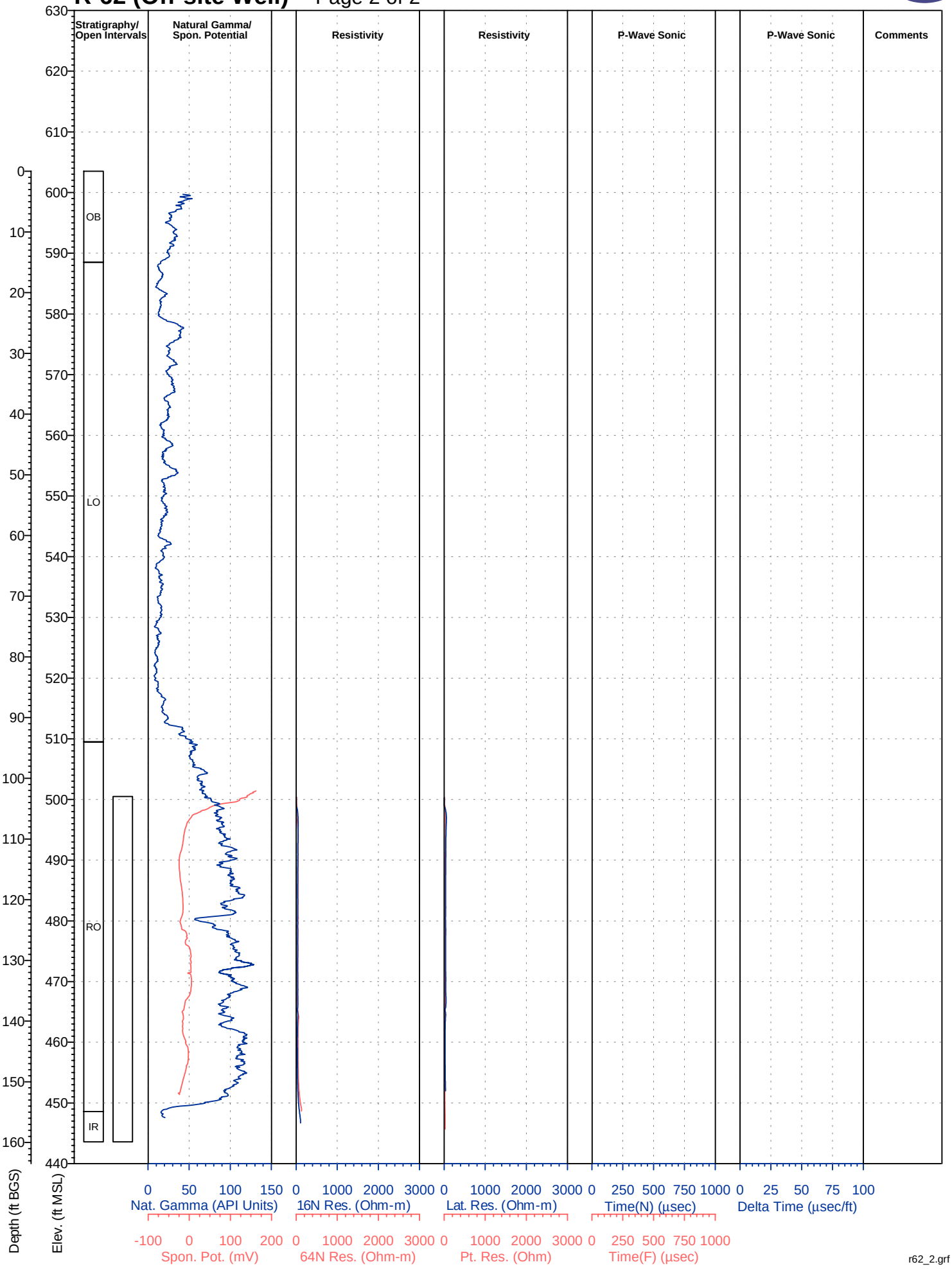
r50_2.grf

R-62 (Off-site Well)



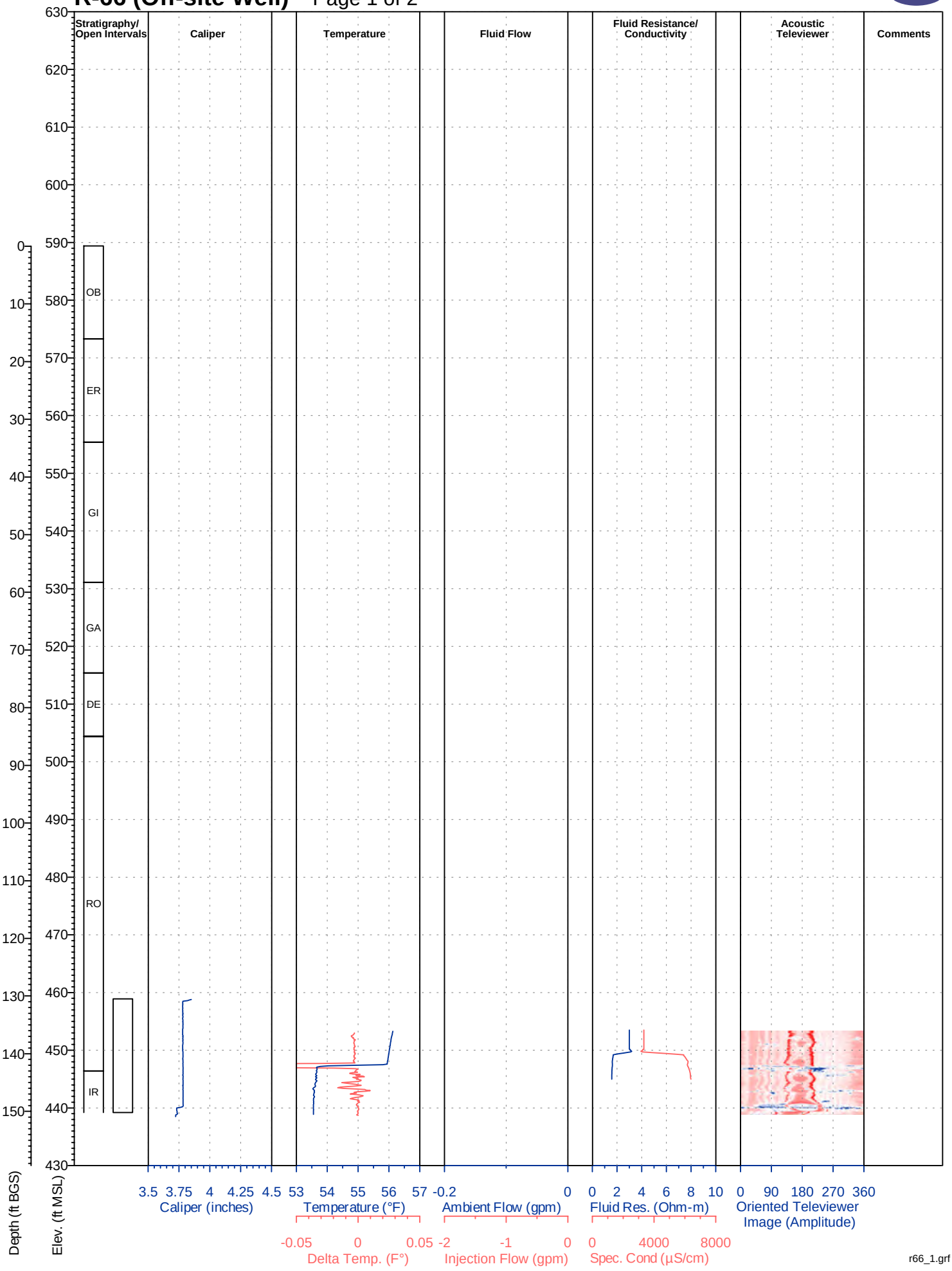
r62_1.grf

R-62 (Off-site Well)

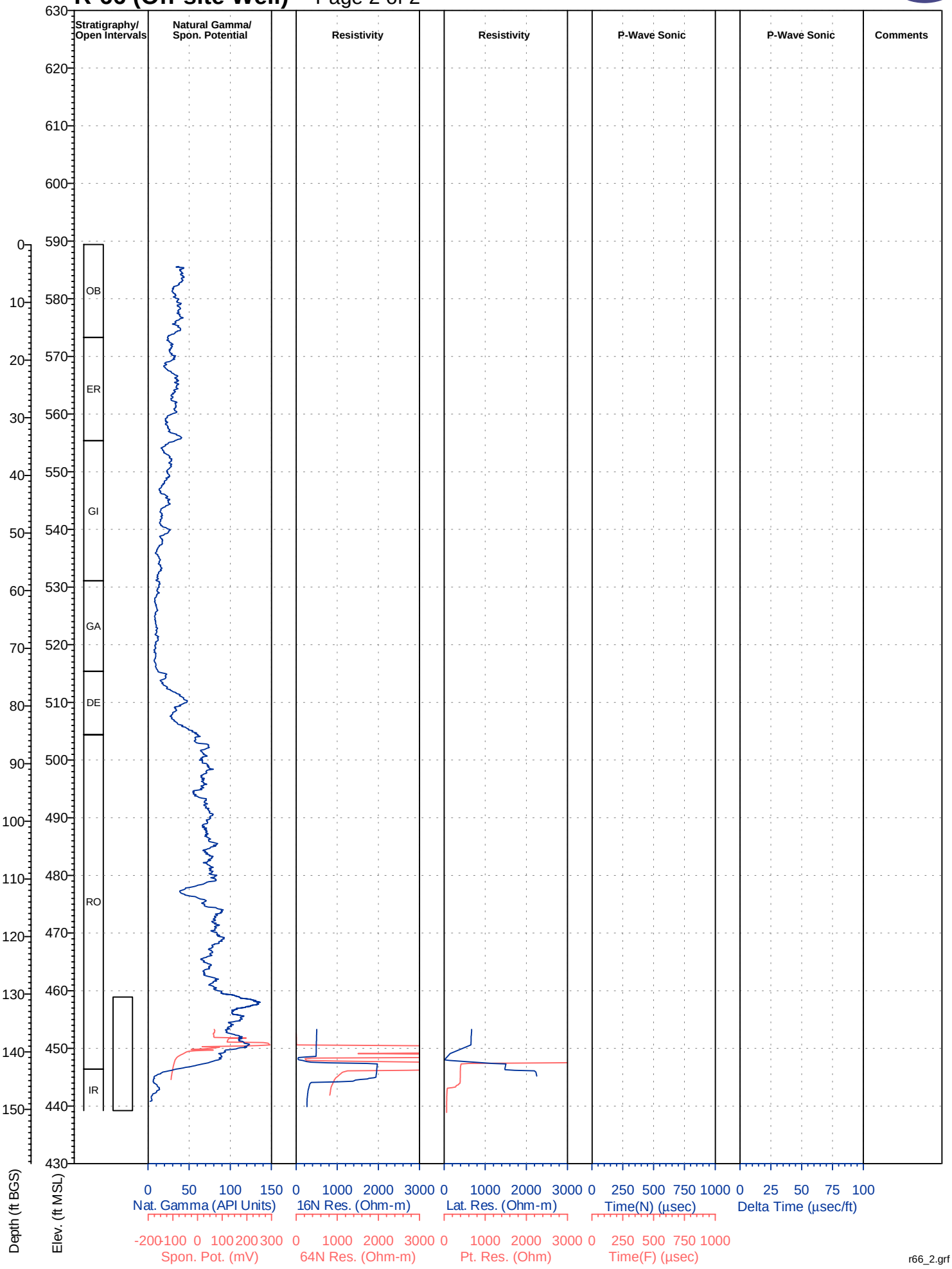


r62_2.grf

R-66 (Off-site Well)

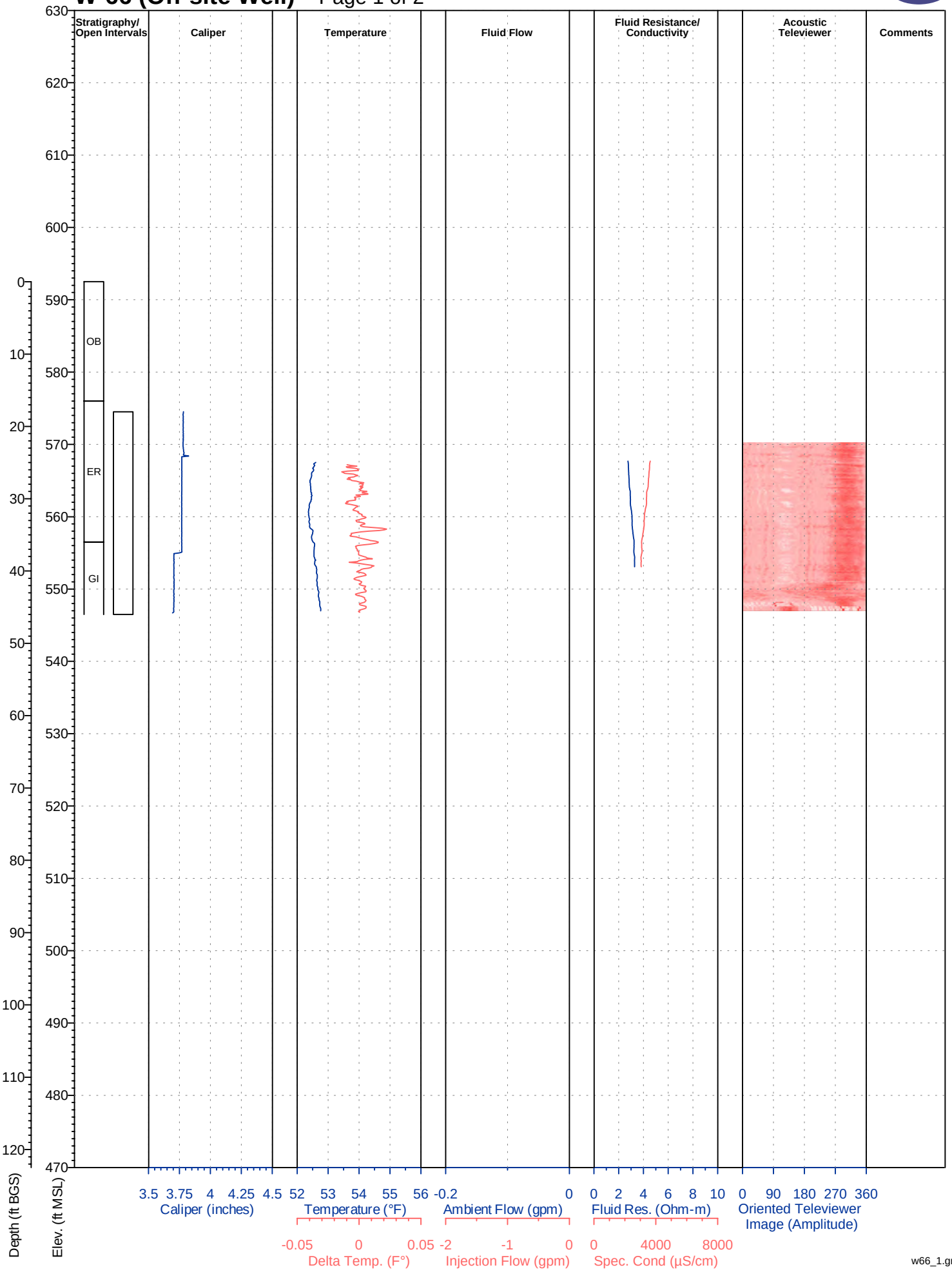


R-66 (Off-site Well)



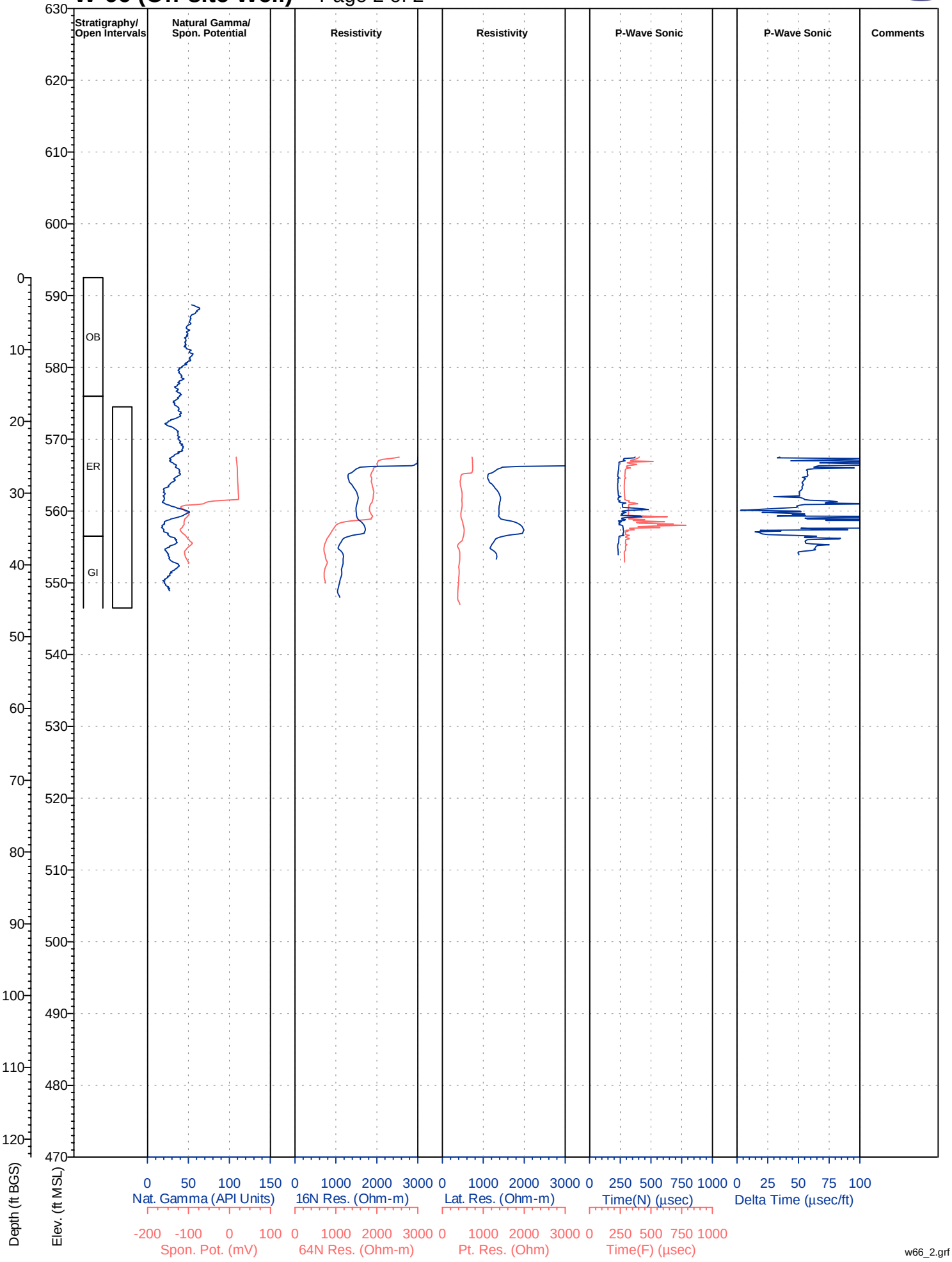
r66_2.grf

W-66 (Off-site Well)



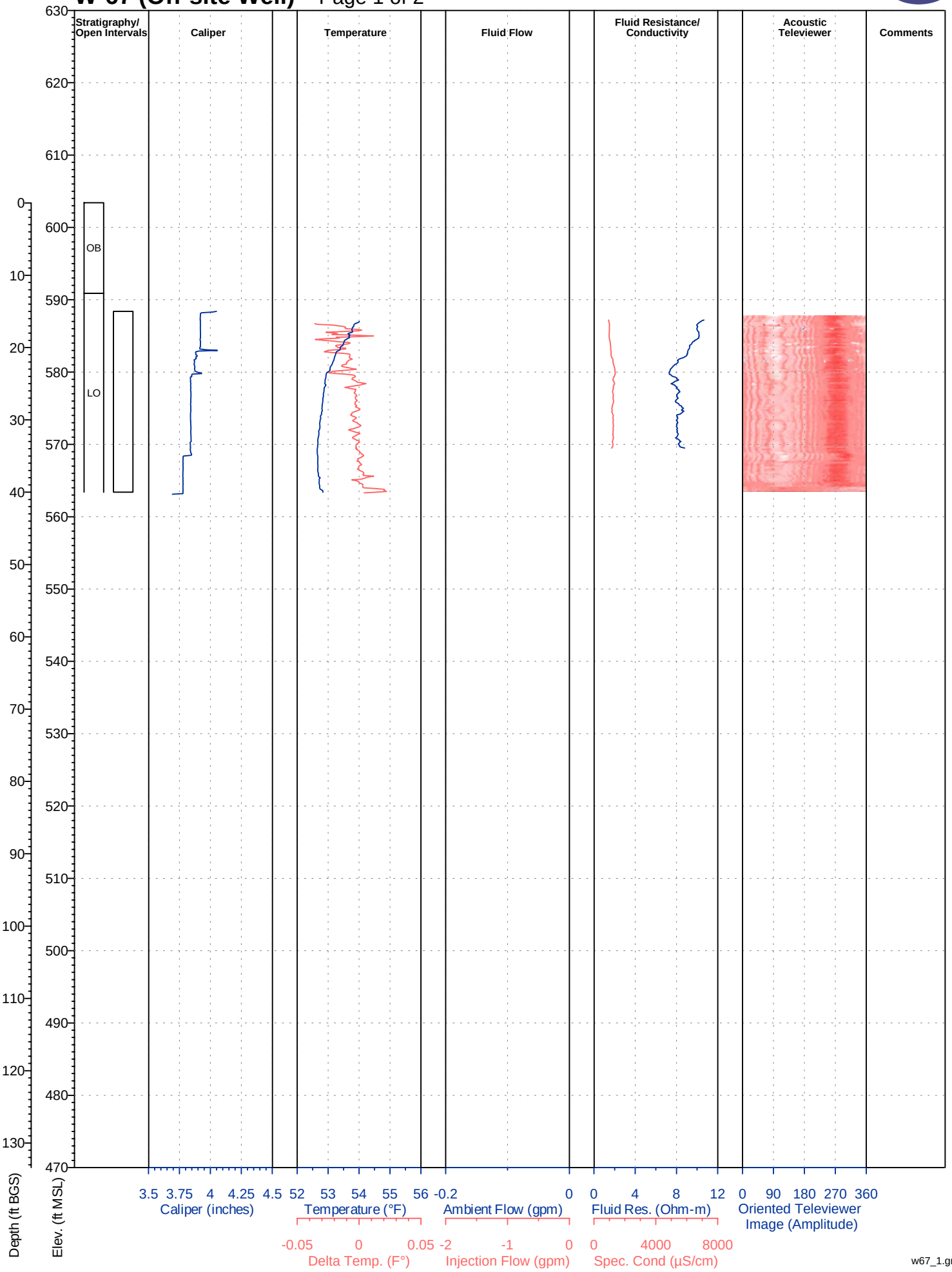
w66_1.grf

W-66 (Off-site Well)



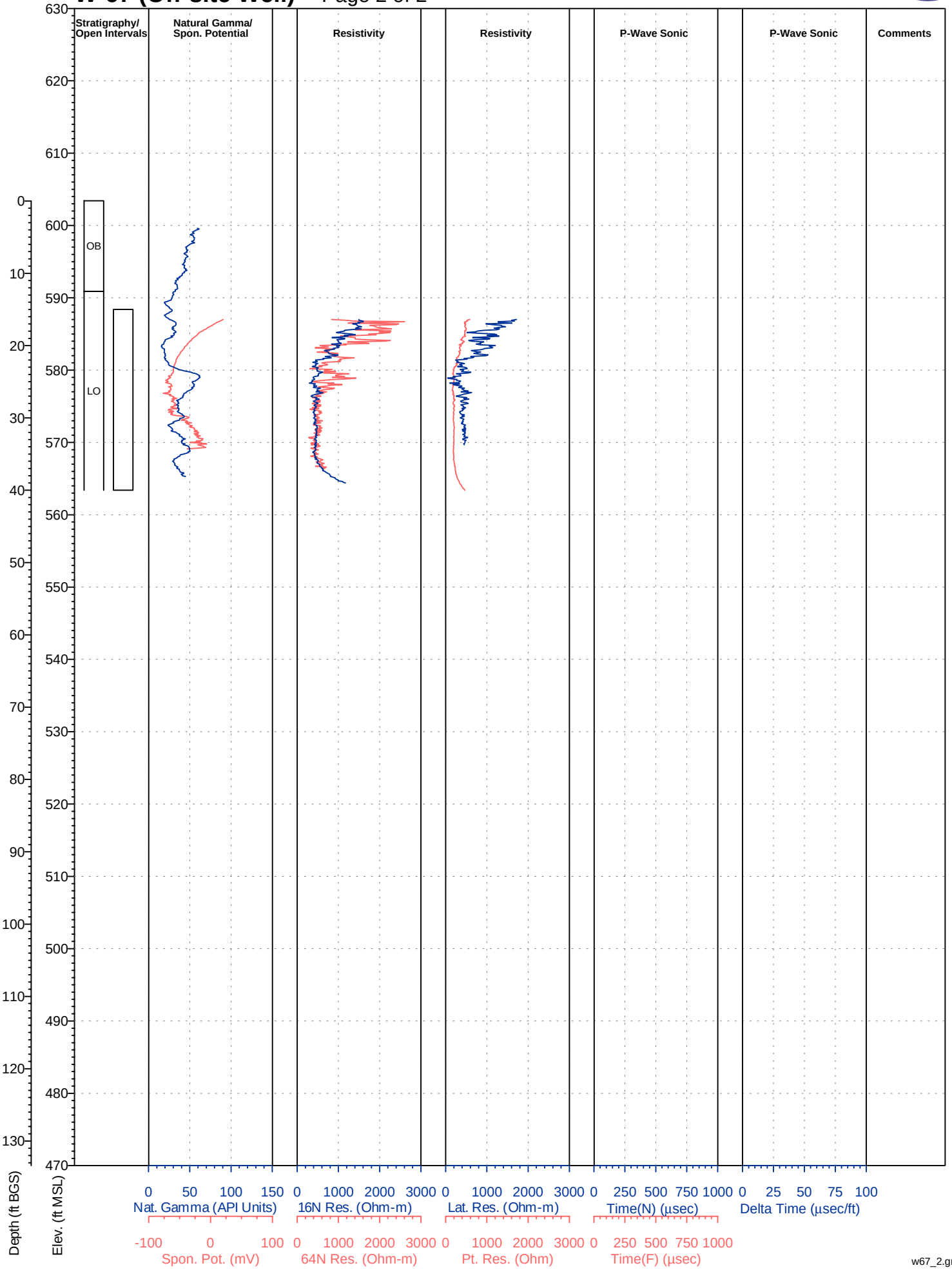
w66_2.grf

W-67 (Off-site Well)



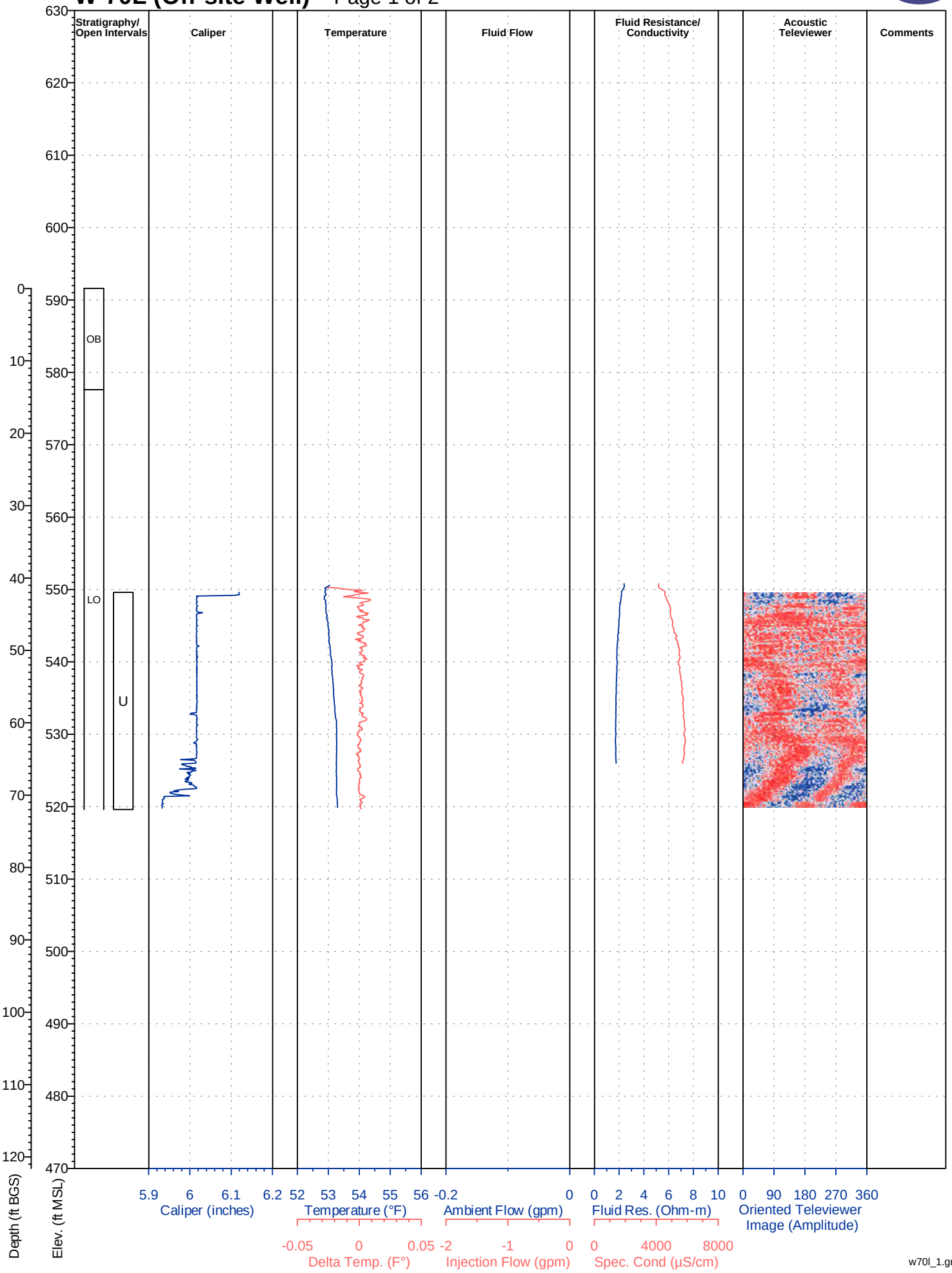
w67_1.grf

W-67 (Off-site Well)



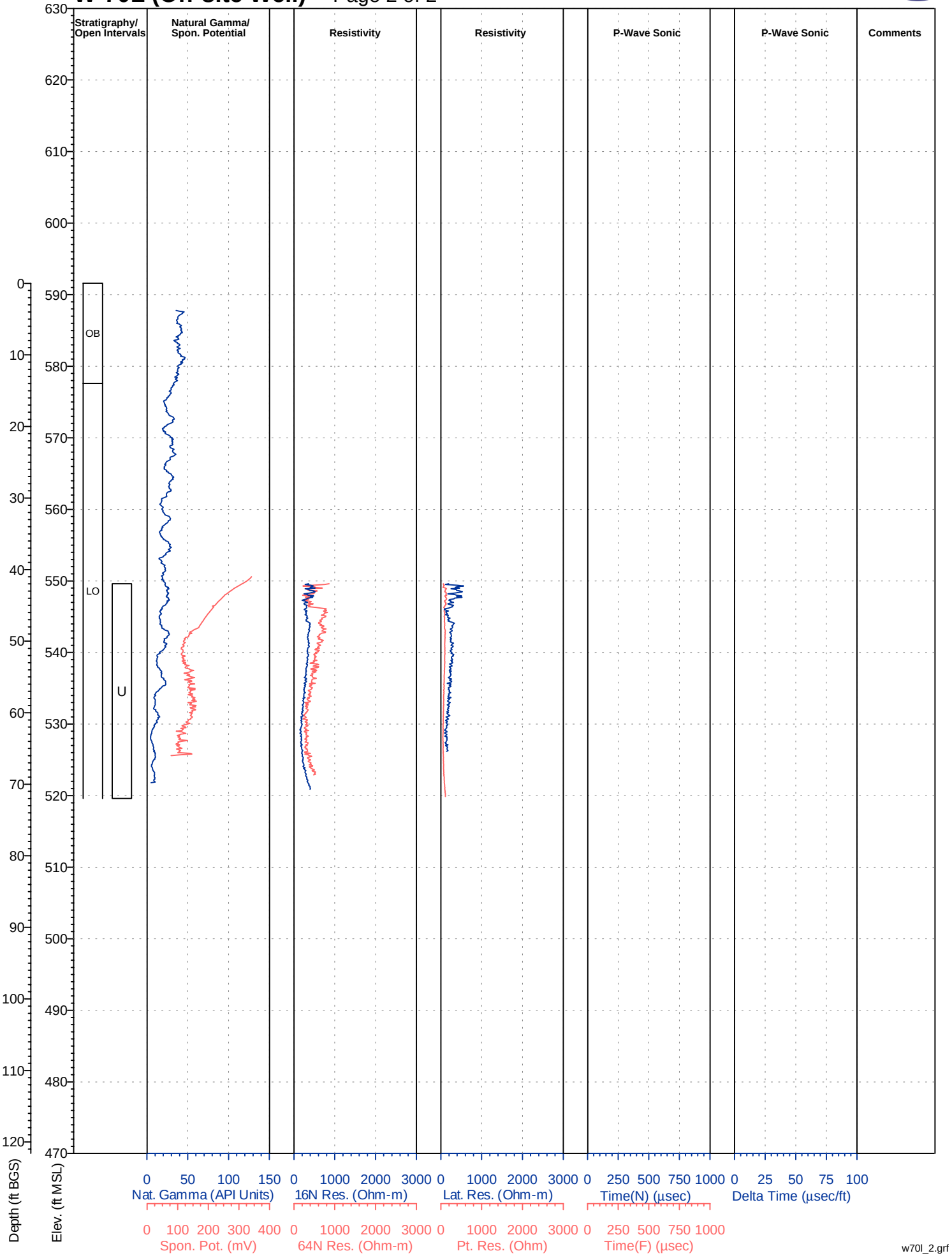
w67_2.grf

W-70L (Off-site Well)



w70l_1.grf

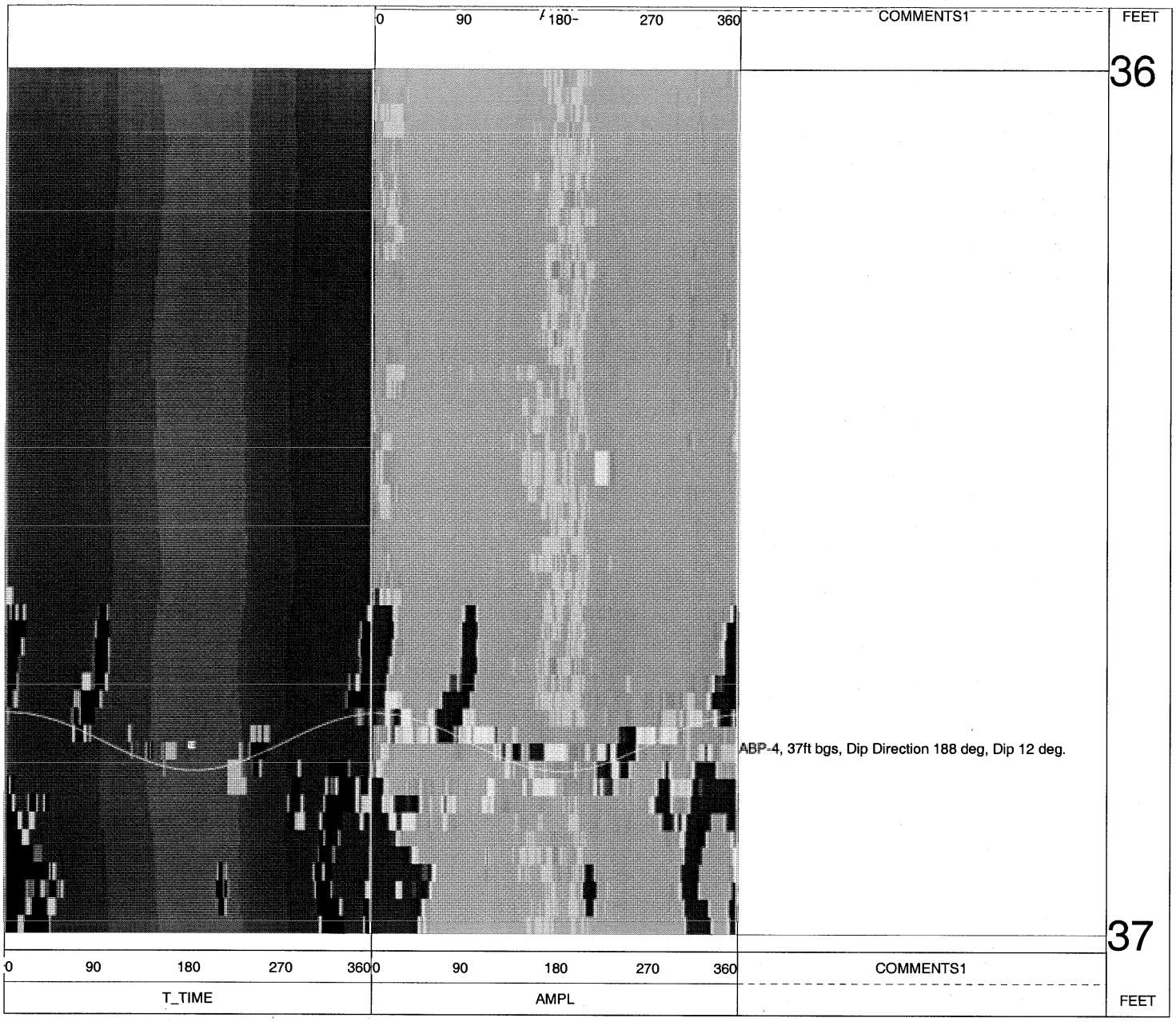
W-70L (Off-site Well)

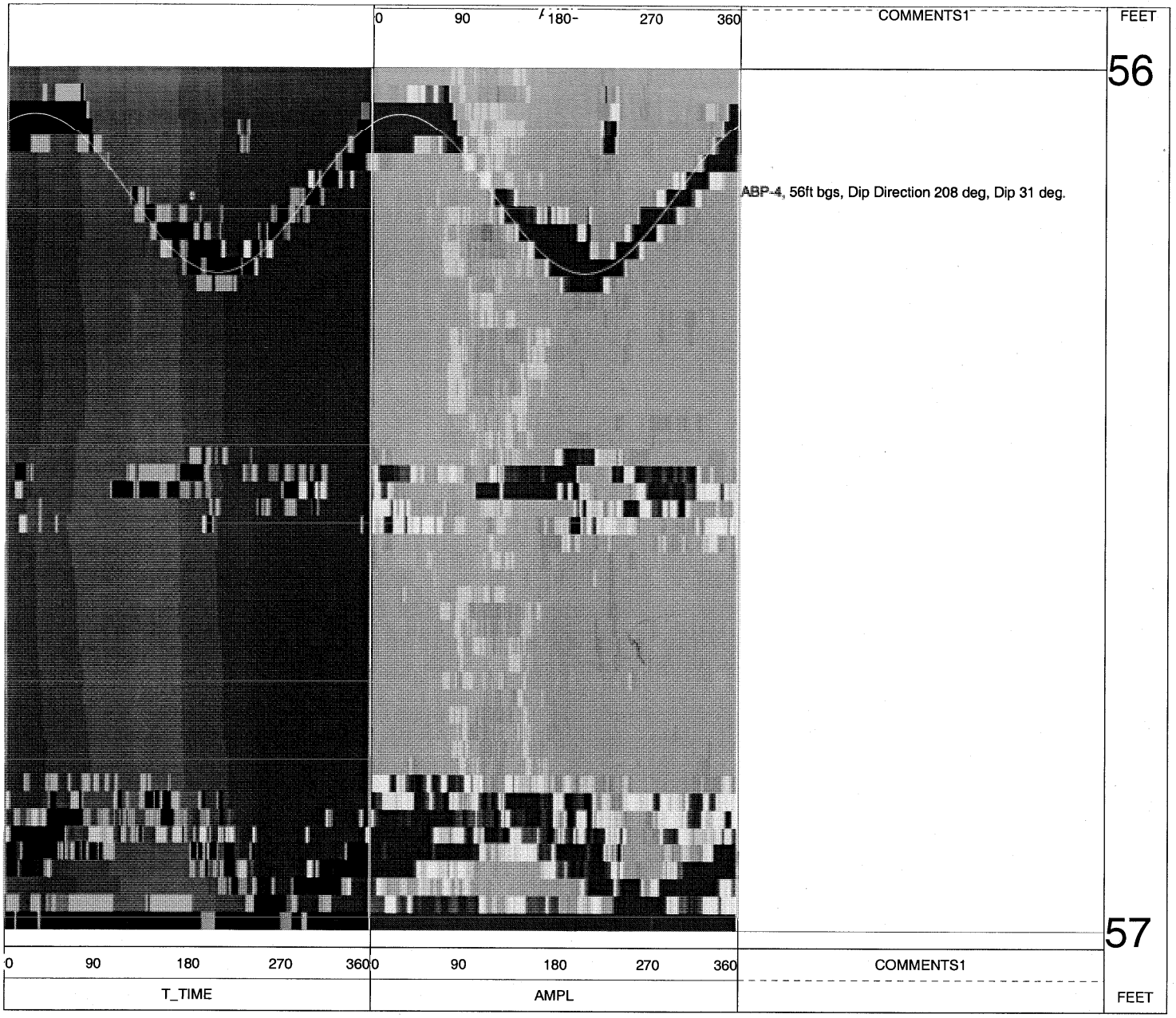


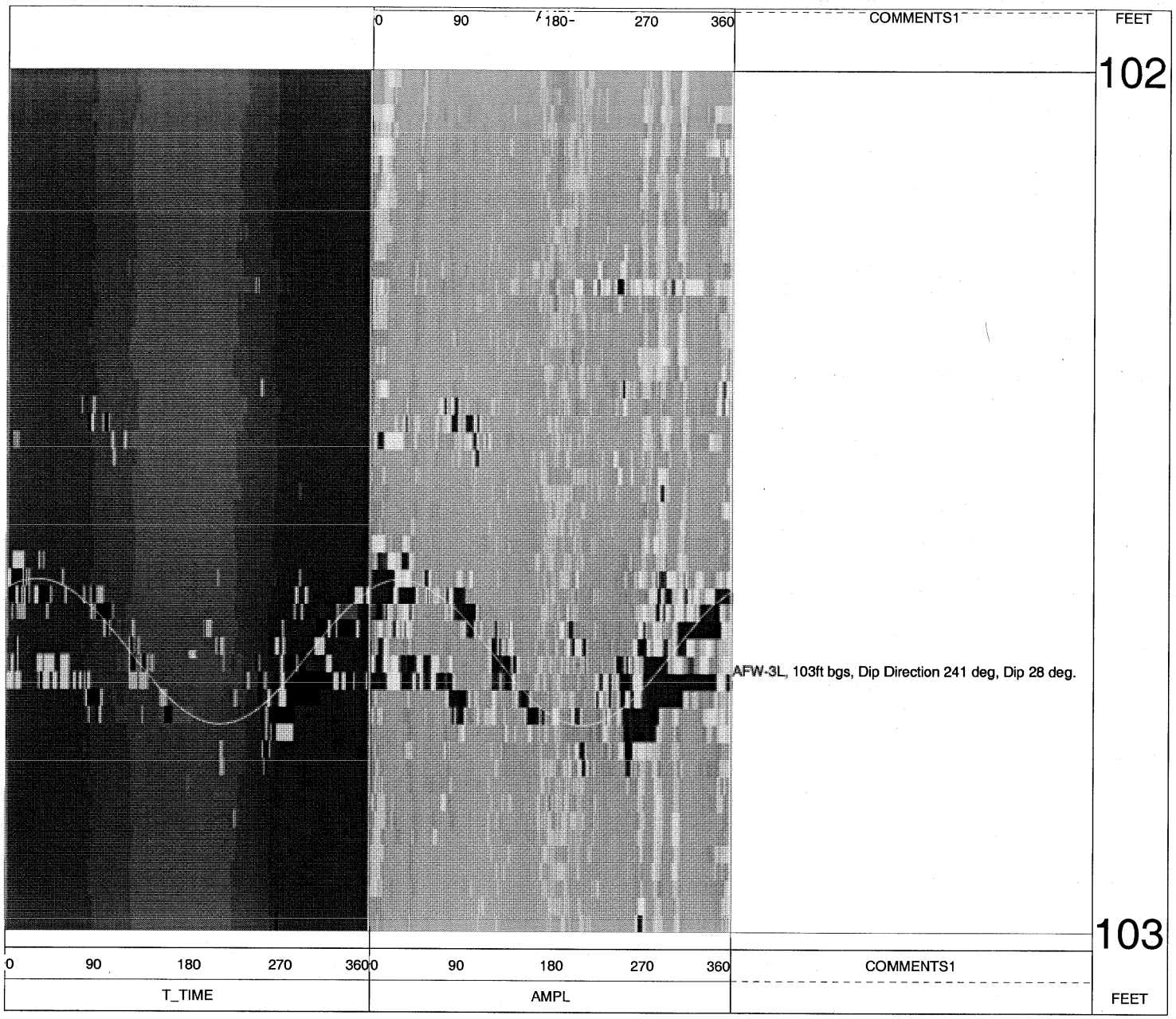
w70l_2.grf

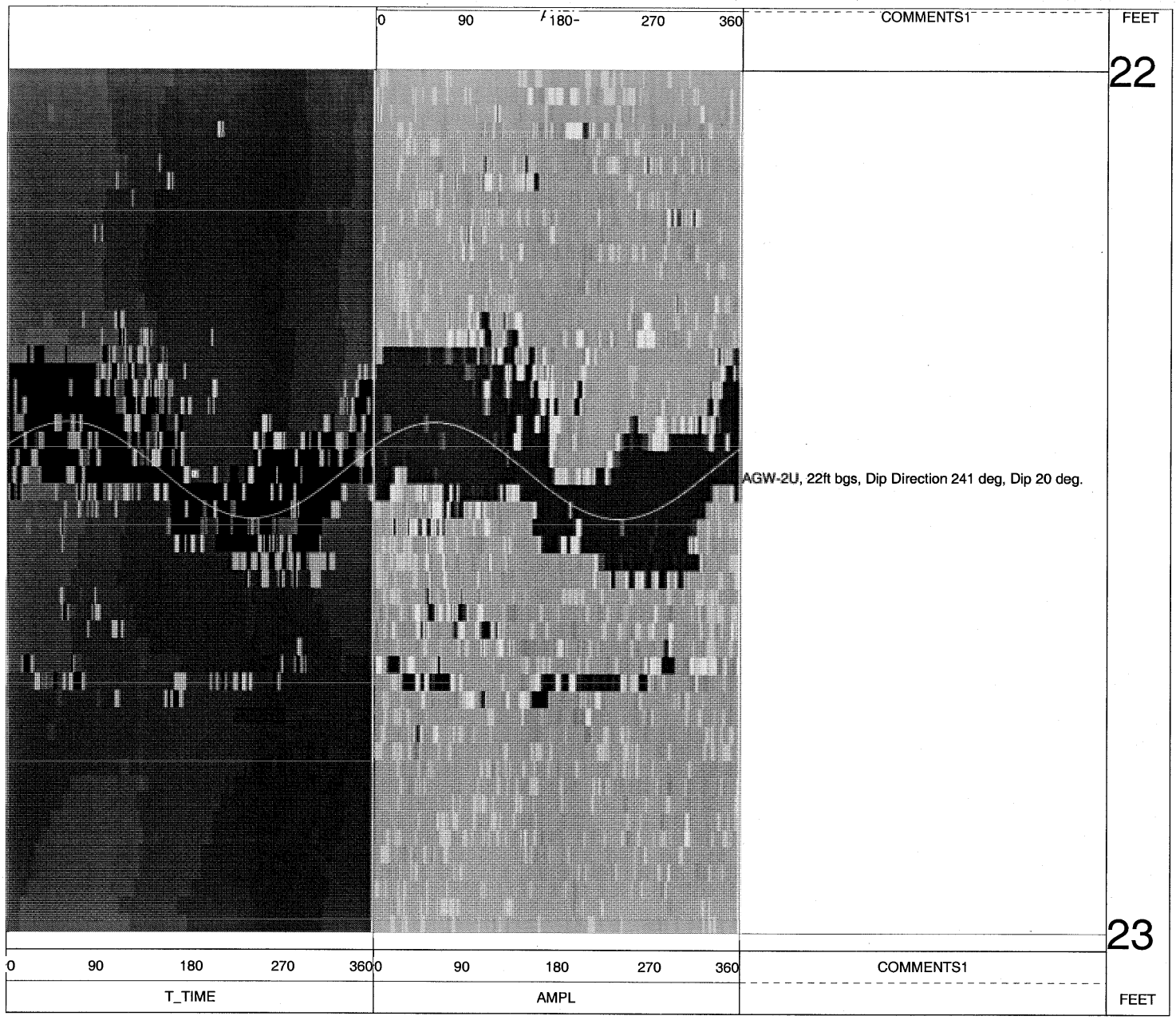
ATTACHMENT 2

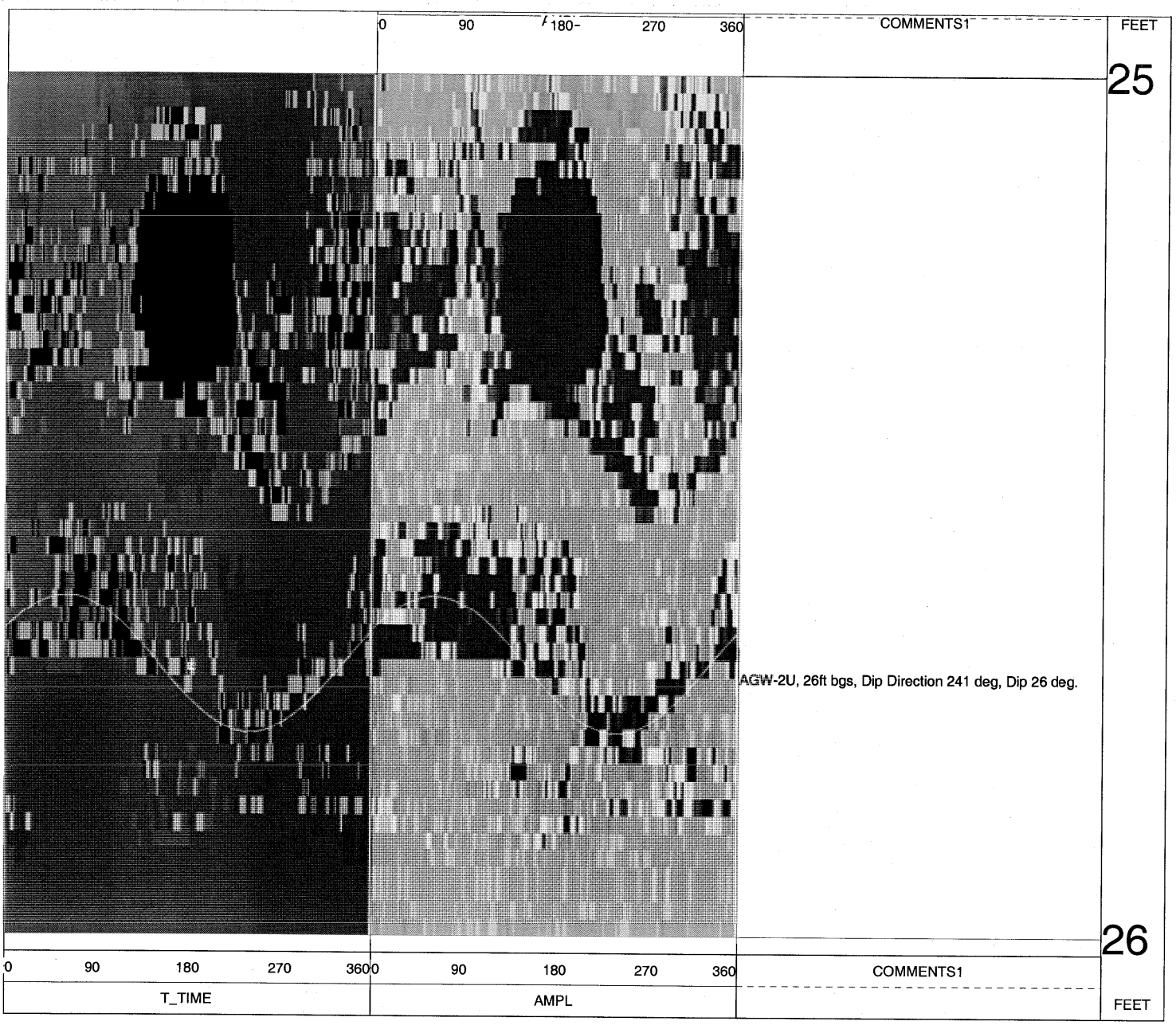
DIPPING FRACTURE PLOTS

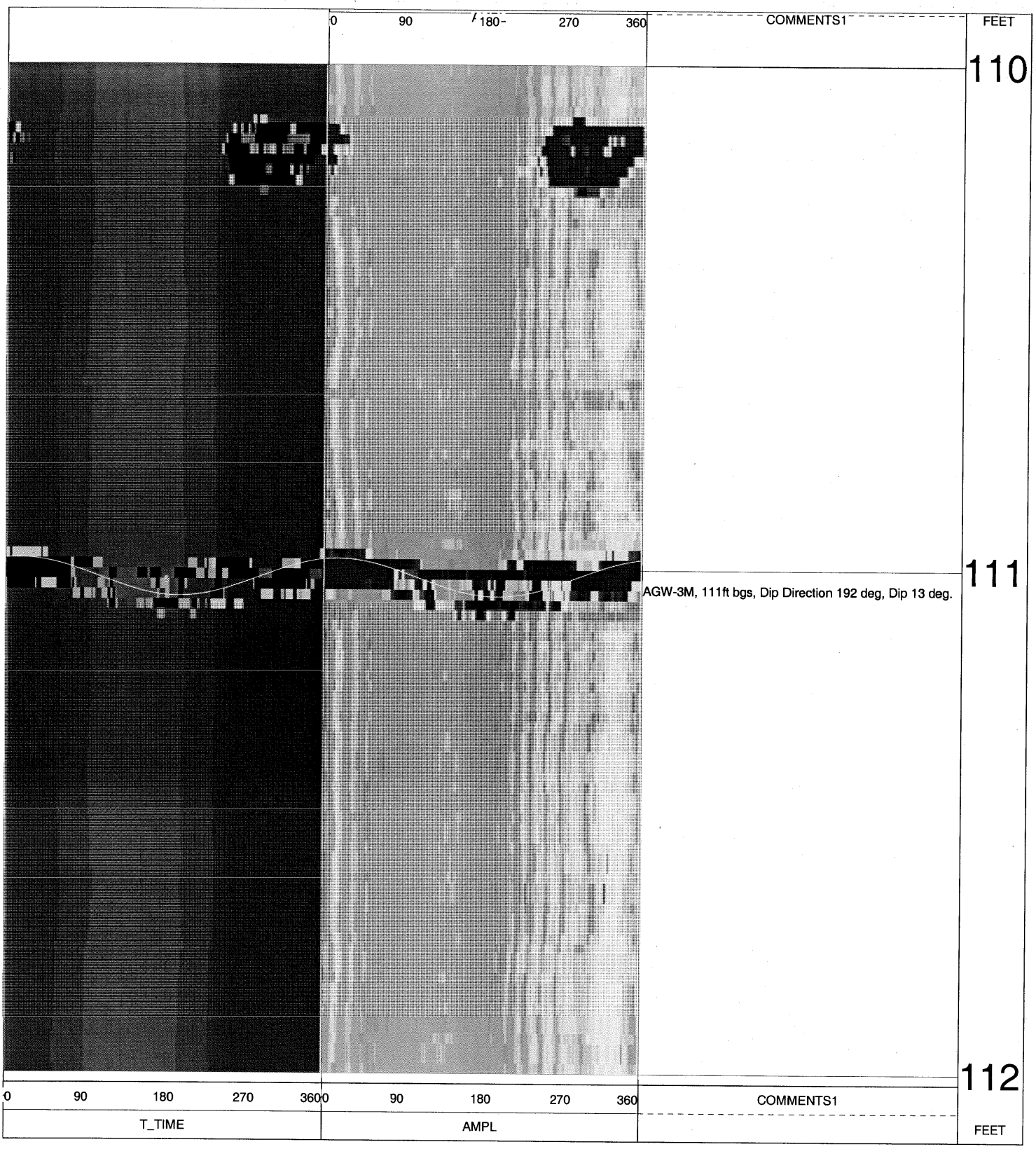

0 90 180 270 360
COMMENTS1
FEET
36
ABP-4, 37ft bgs, Dip Direction 188 deg, Dip 12 deg.
37
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET

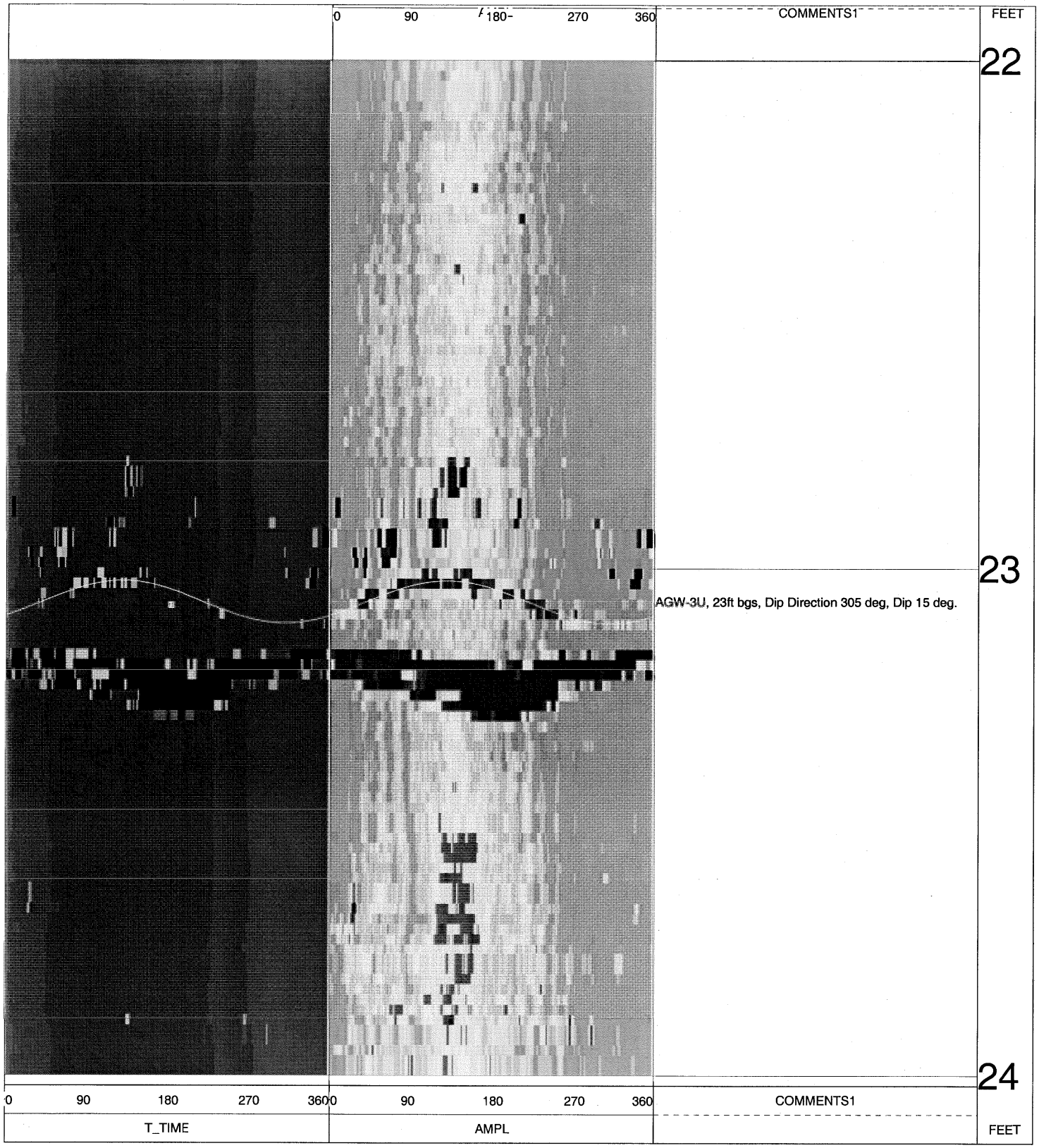

0 90 180 270 360
COMMENTS1
FEET
56
ABP-4, 56ft bgs, Dip Direction 208 deg, Dip 31 deg.
57
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET

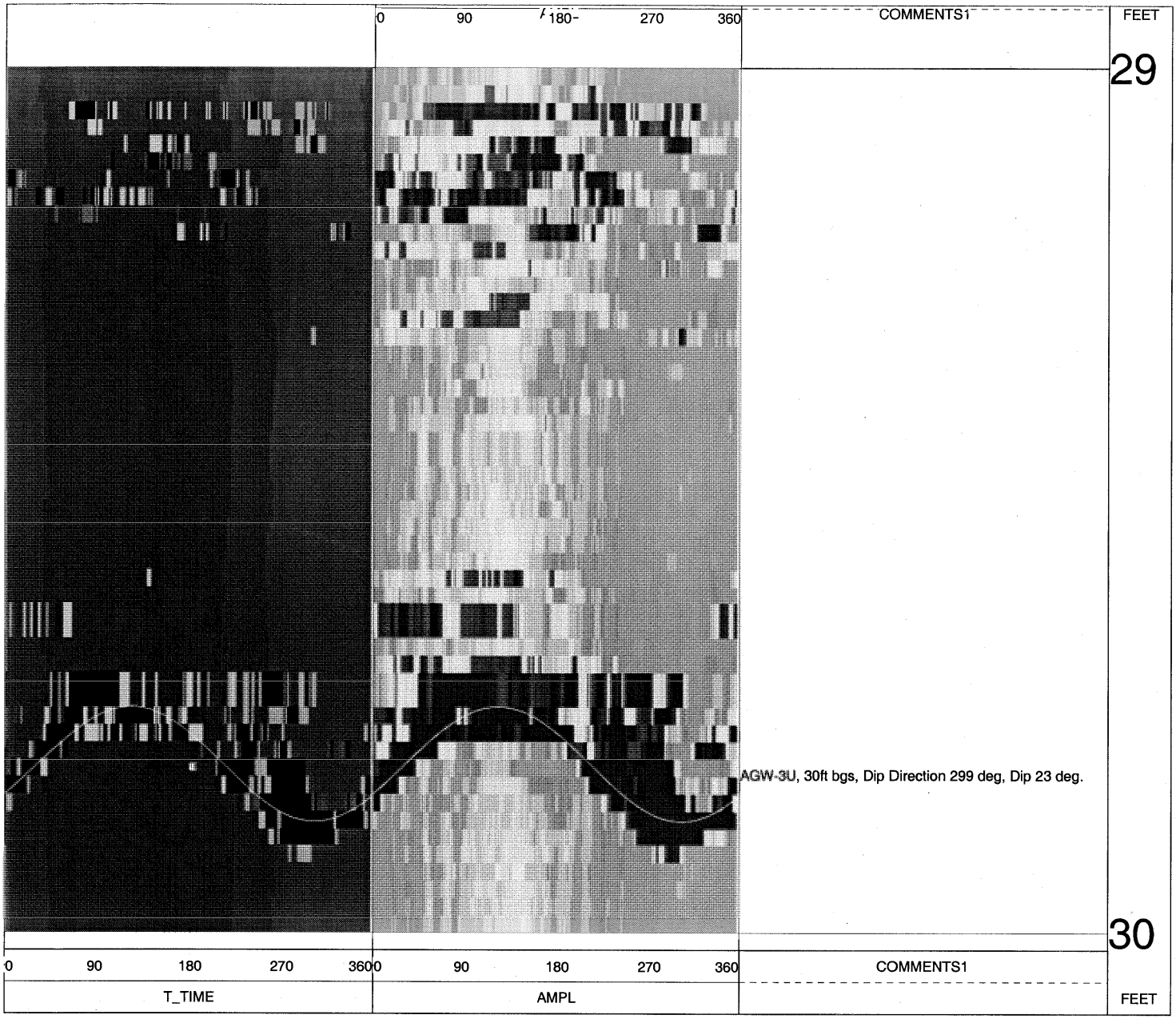

0
90
180
270
360
COMMENTS1
FEET
102
AFW-3L, 103ft bgs, Dip Direction 241 deg, Dip 28 deg.
103
0
90
180
270
360
0
90
180
270
360
COMMENTS1
T_TIME
AMPL
FEET


0 90 180 270 360
COMMENTS1
FEET
22
AGW-2U, 22ft bgs, Dip Direction 241 deg, Dip 20 deg.
23
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET


0 90 180 270 360
COMMENTS1
FEET
25
AGW-2U, 26ft bgs, Dip Direction 241 deg, Dip 26 deg.
26
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET


0
90
180
270
360
COMMENTS1
FEET
110
111
AGW-3M, 111ft bgs, Dip Direction 192 deg, Dip 13 deg.
112
0
90
180
270
360
0
90
180
270
360
COMMENTS1
T_TIME
AMPL
FEET


0 90 180 270 360
COMMENTS1
FEET
22
23
AGW-3U, 23ft bgs, Dip Direction 305 deg, Dip 15 deg.
24
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET


0 90 180 270 360
COMMENTS1
FEET
29
AGW-3U, 30ft bgs, Dip Direction 299 deg, Dip 23 deg.
30
0 90 180 270 360
0 90 180 270 360
COMMENTS1
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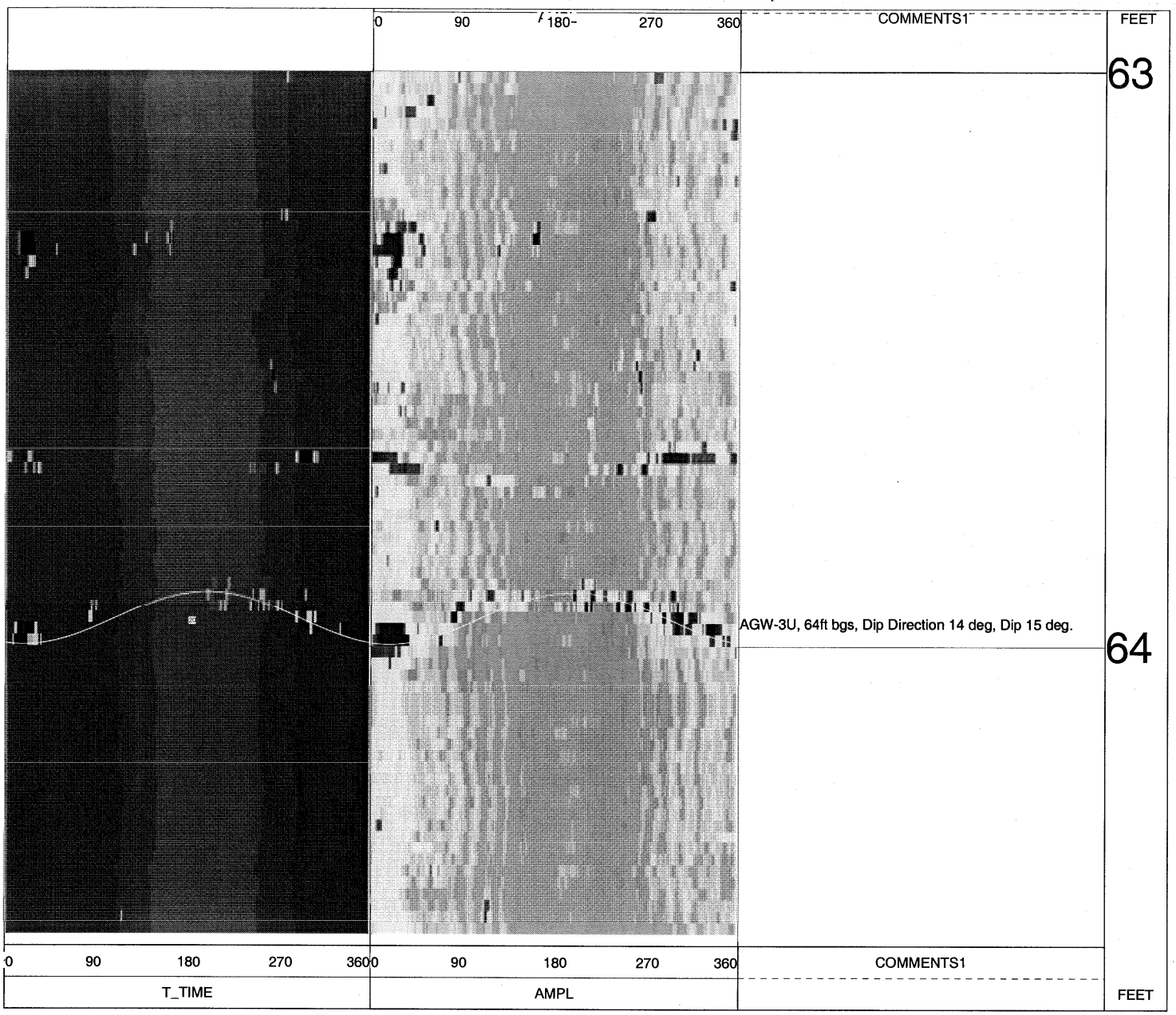
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64
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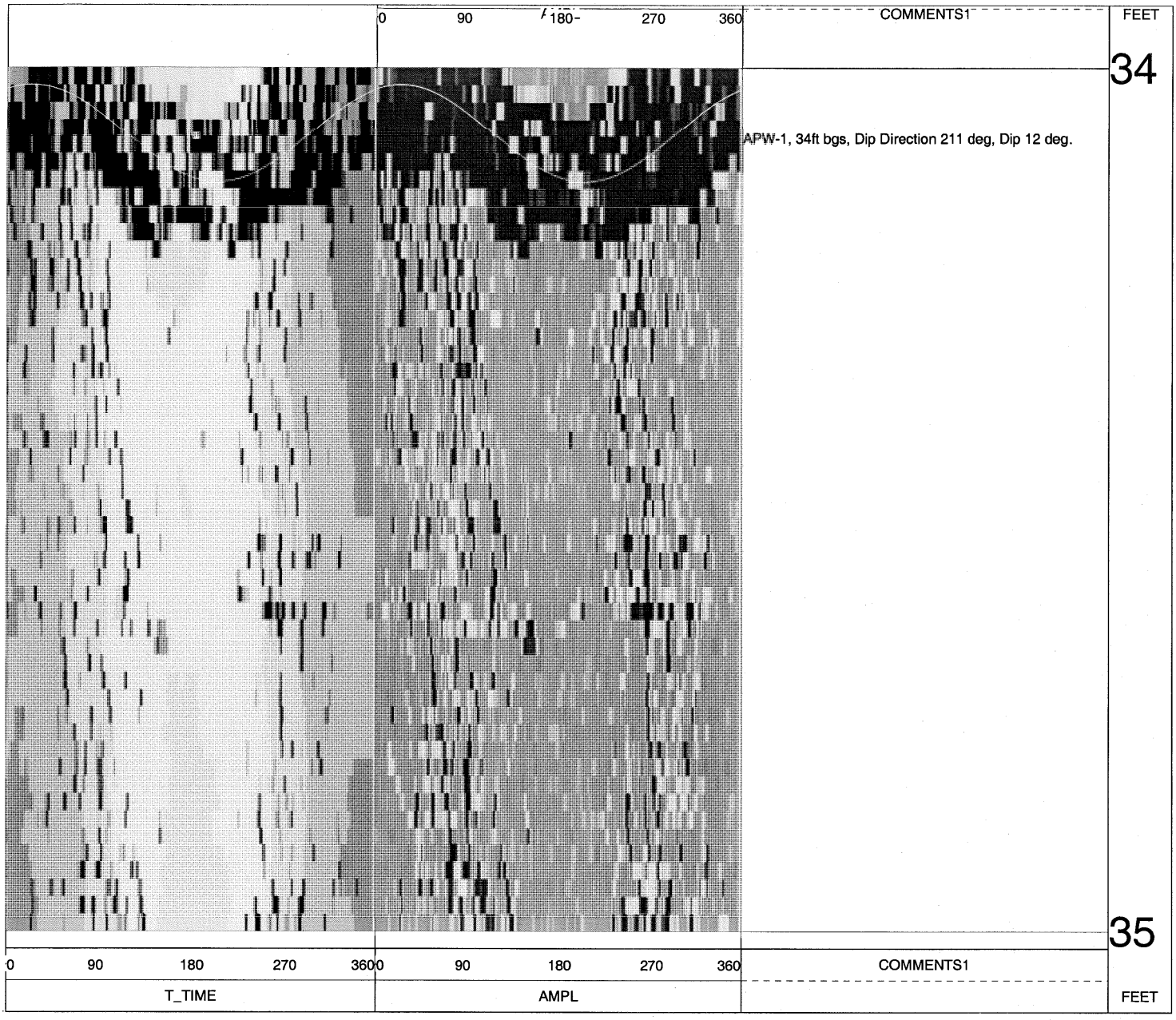
AMPL
FEET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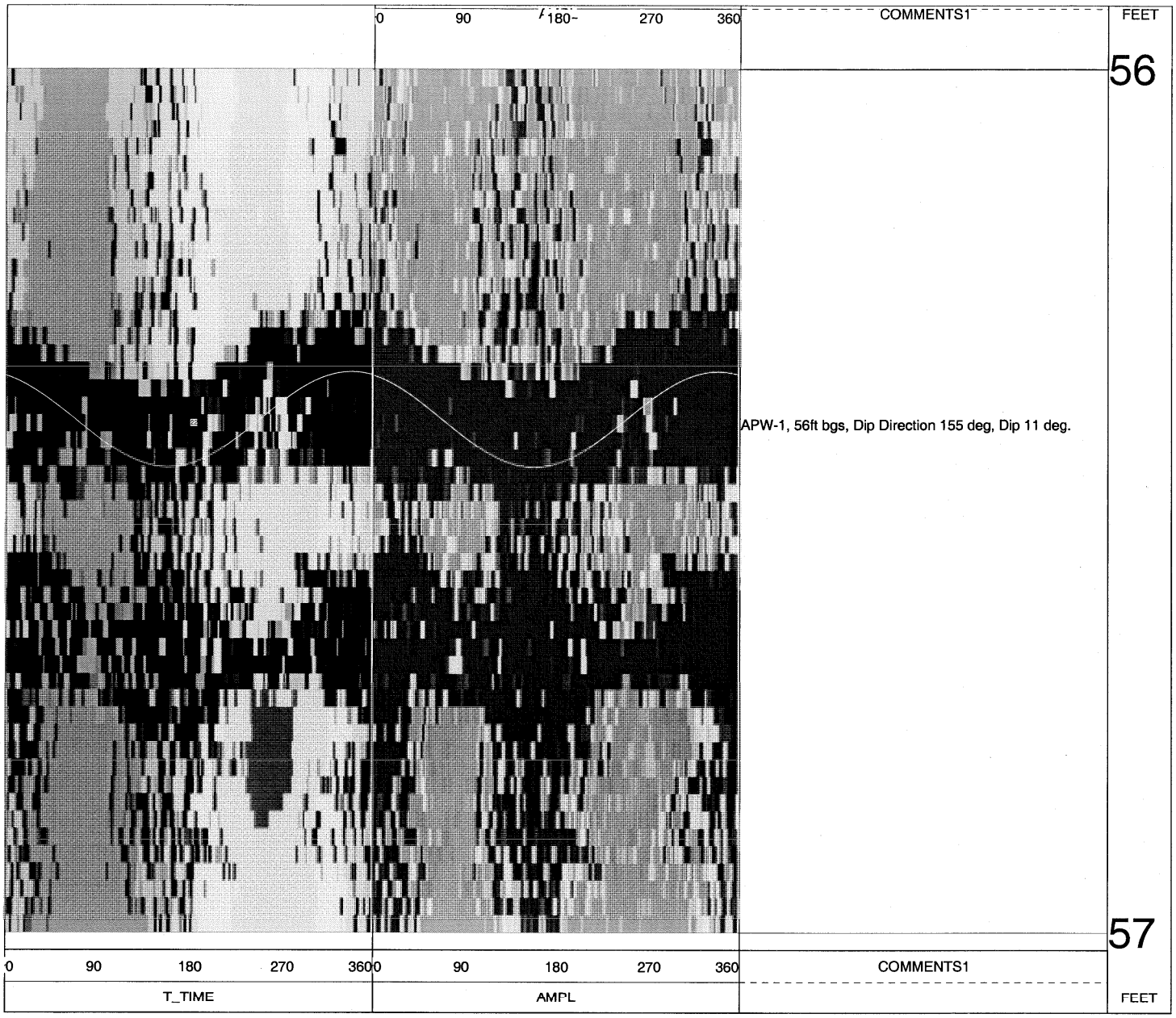
AMPL
FEET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57
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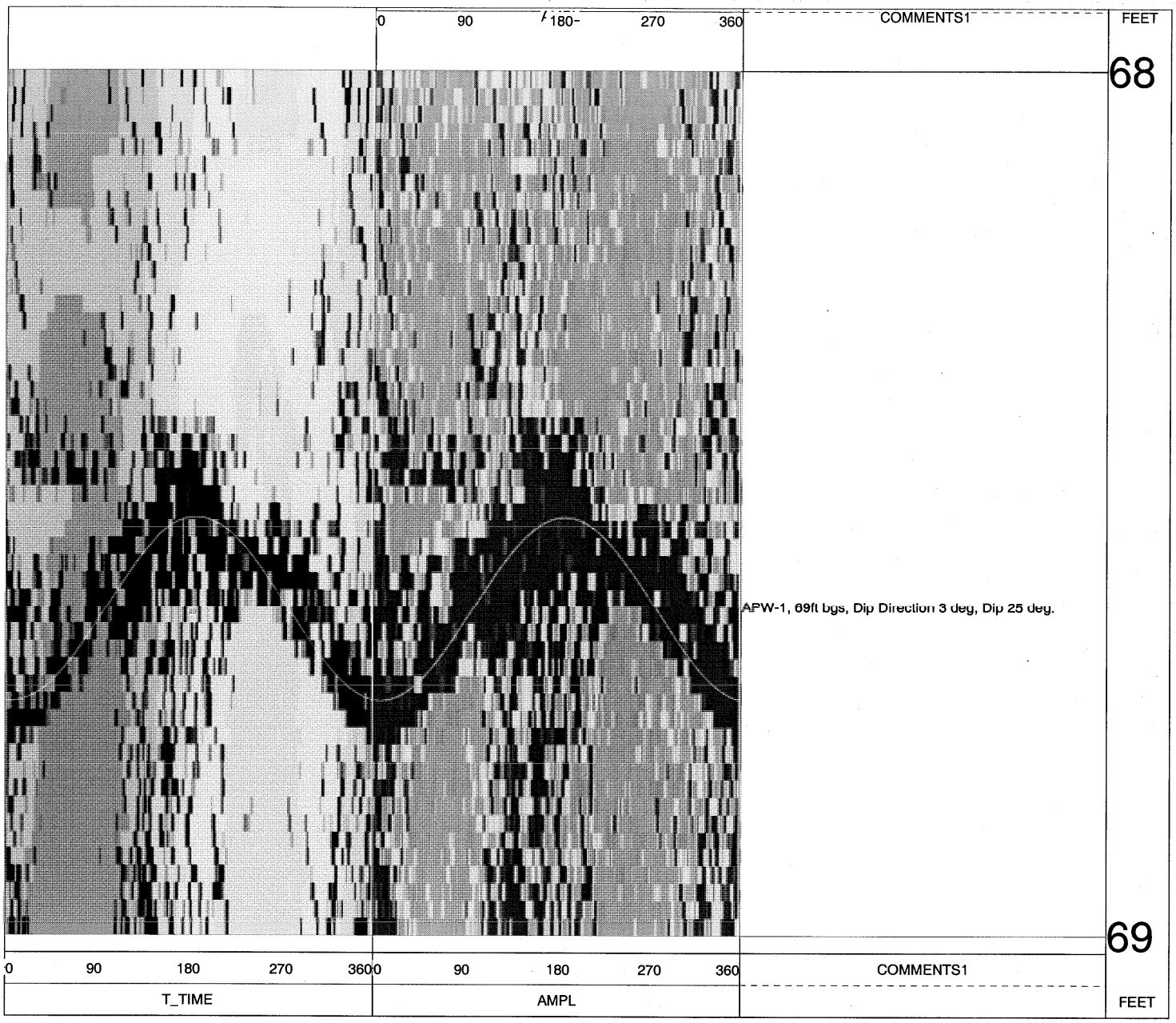
AMPL
FEET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FEET
68
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69
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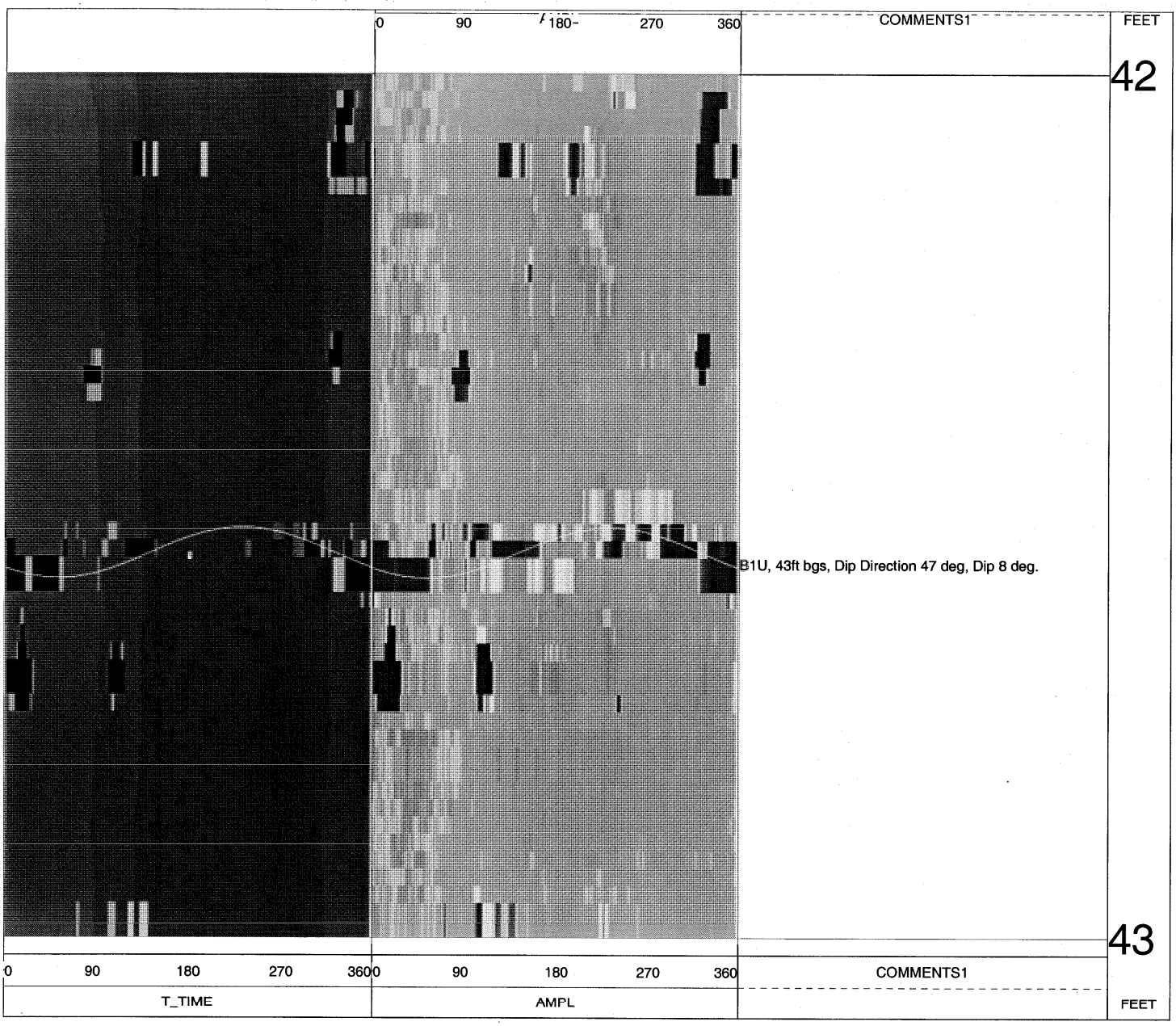
T_TIME
AMPL
FEET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180
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360
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0
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180
270
360
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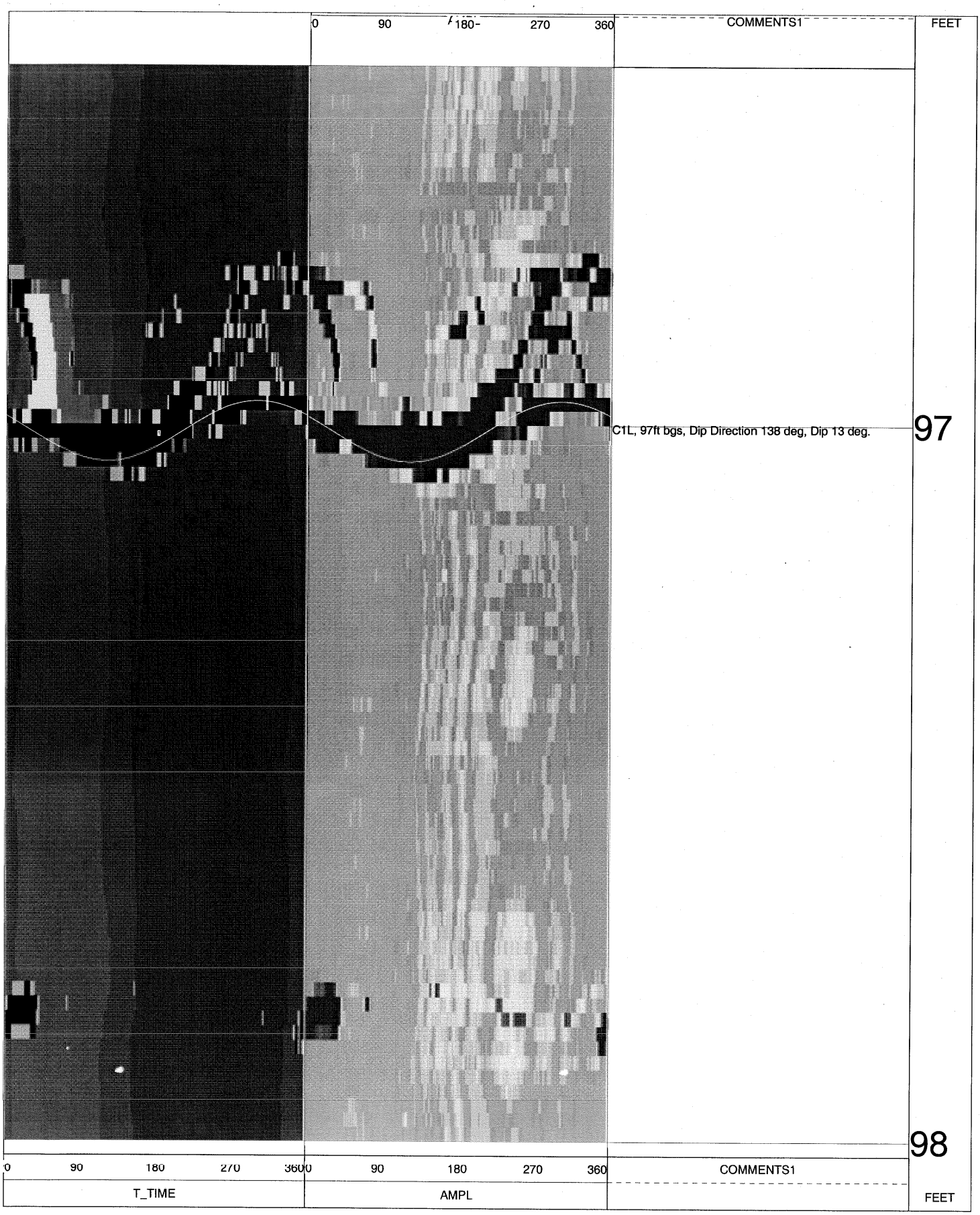
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97
98
0 90 180 270 360
0 90 180 270 360
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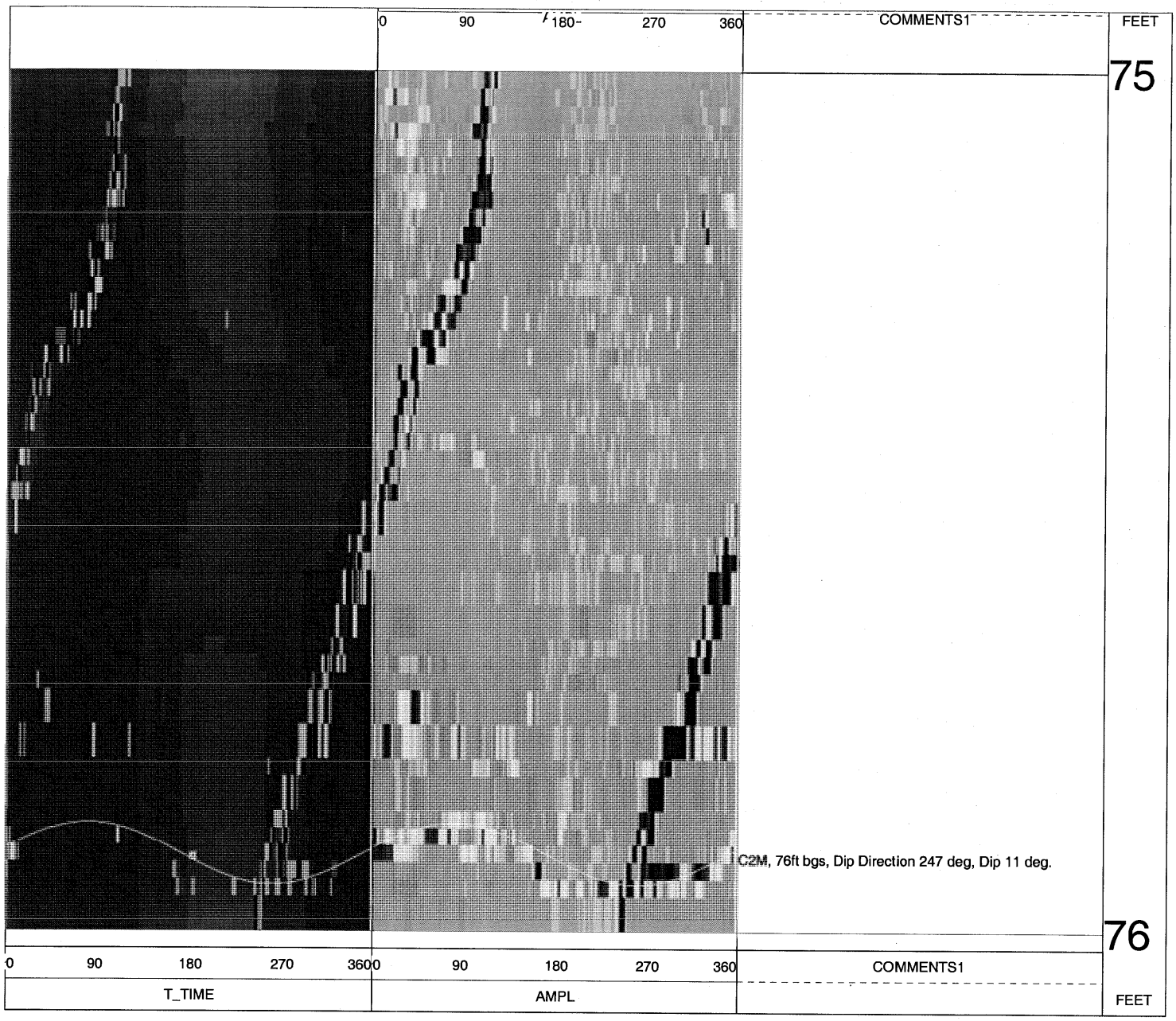
T_TIME
AMPL
FEET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FEET
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0 90 180 270 360
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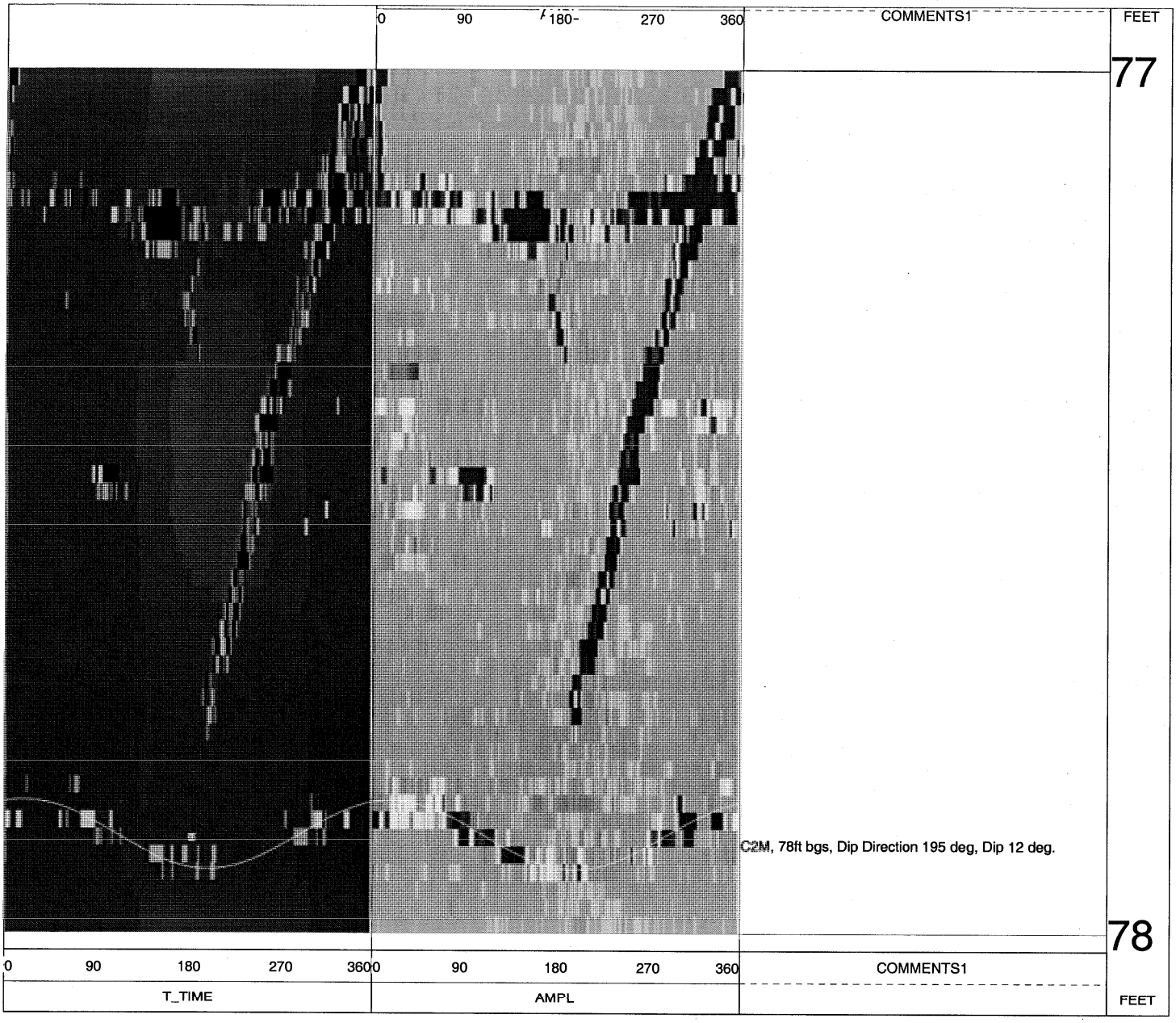
T_TIME
AMPL
FEET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COMMENTS1
FEET
77
C2M, 78ft bgs, Dip Direction 195 deg, Dip 12 deg.
78
0 90 180 270 360
0 90 180 270 360
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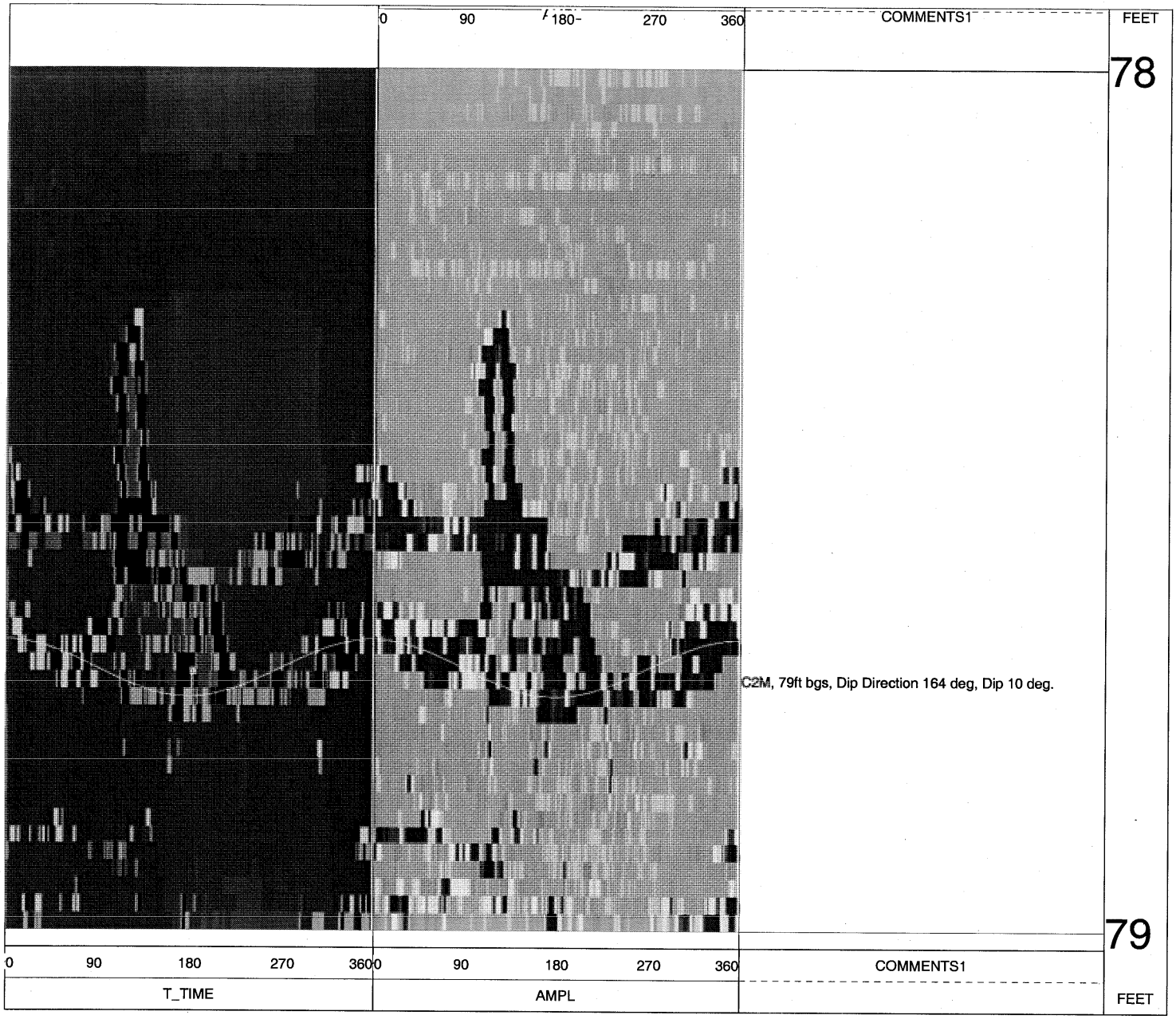
T_TIME
AMPL
FEET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FEET
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C2M, 79ft bgs, Dip Direction 164 deg, Dip 10 deg.
79
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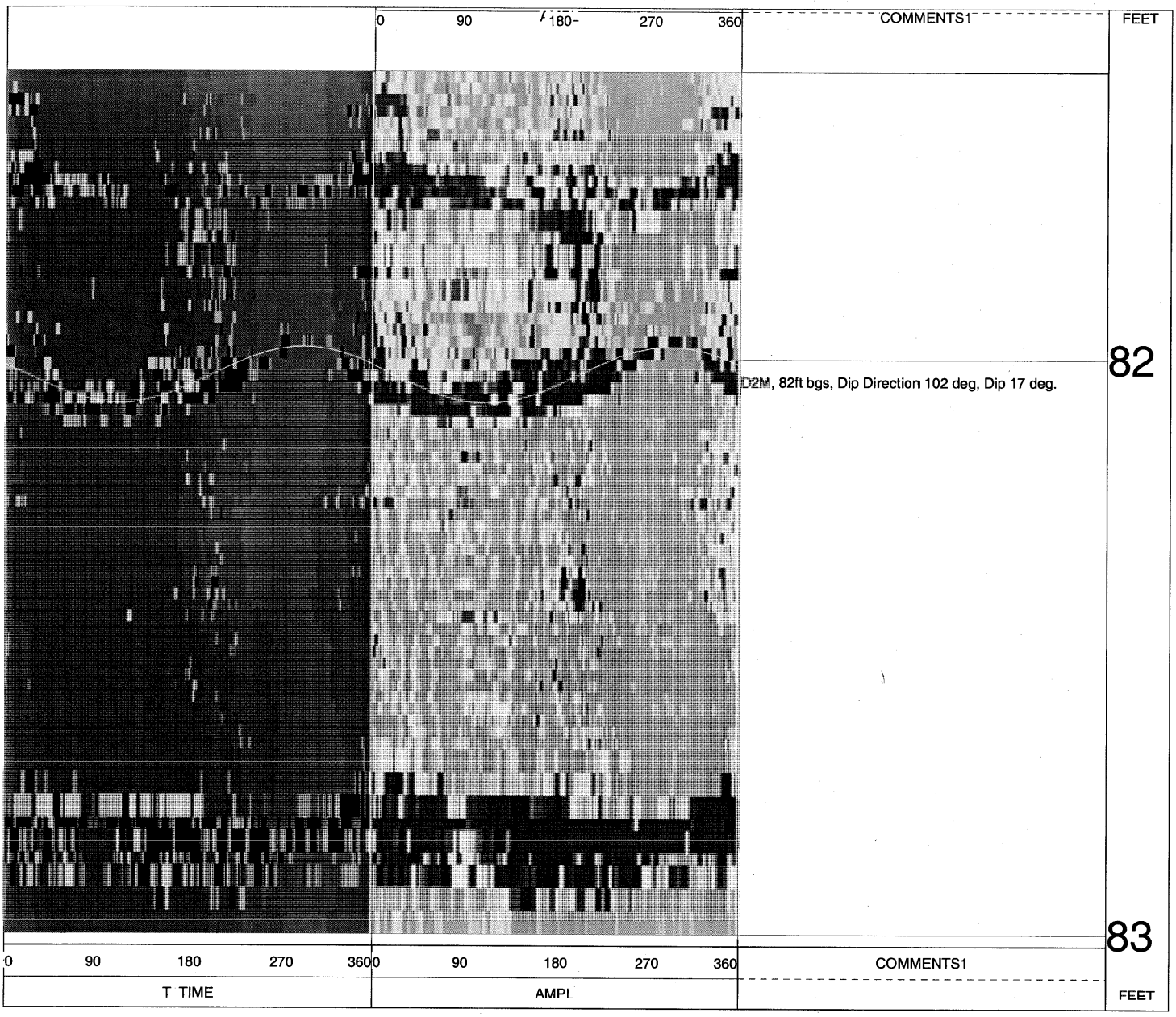
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET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83
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0 90 180 270 360
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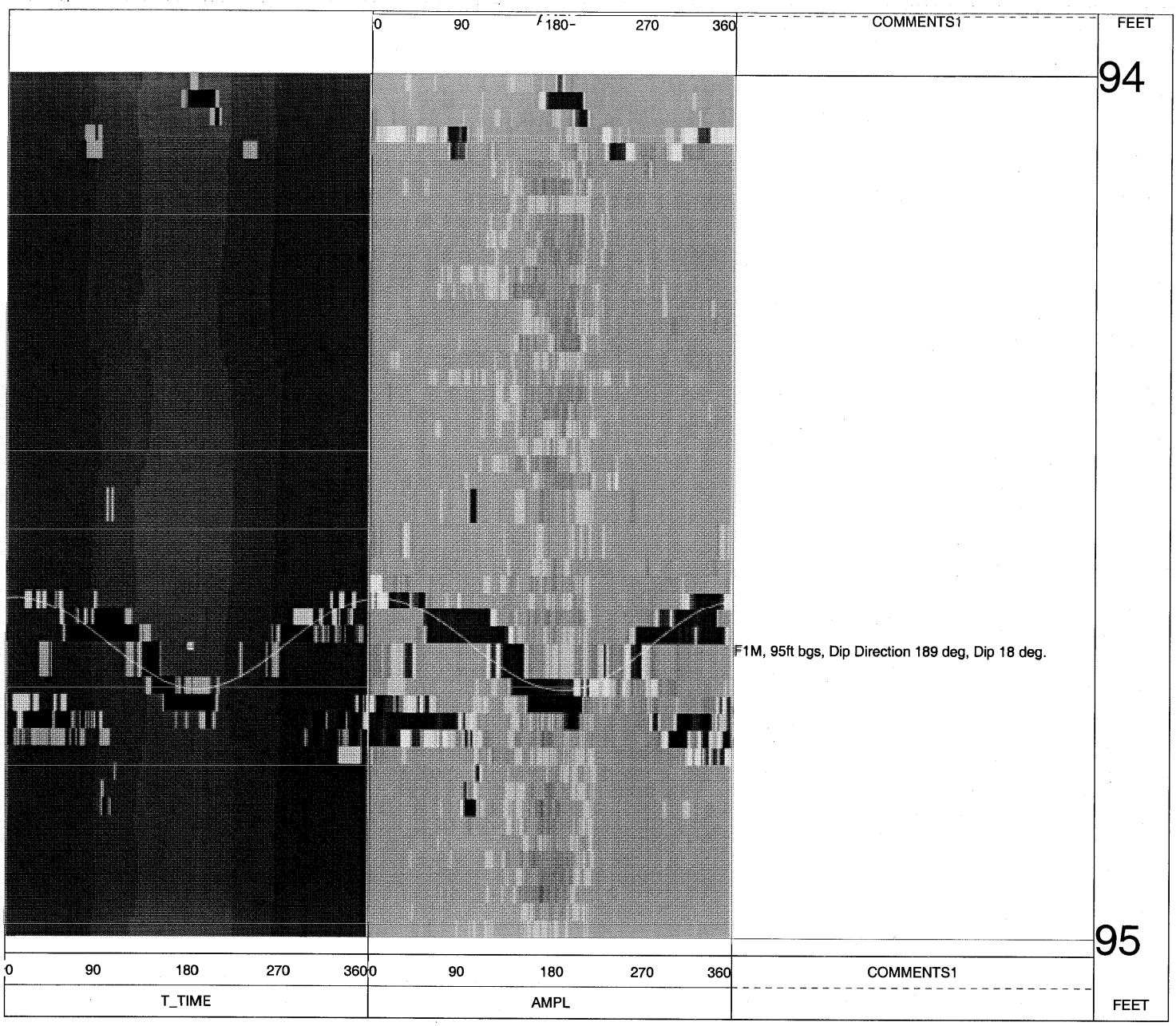
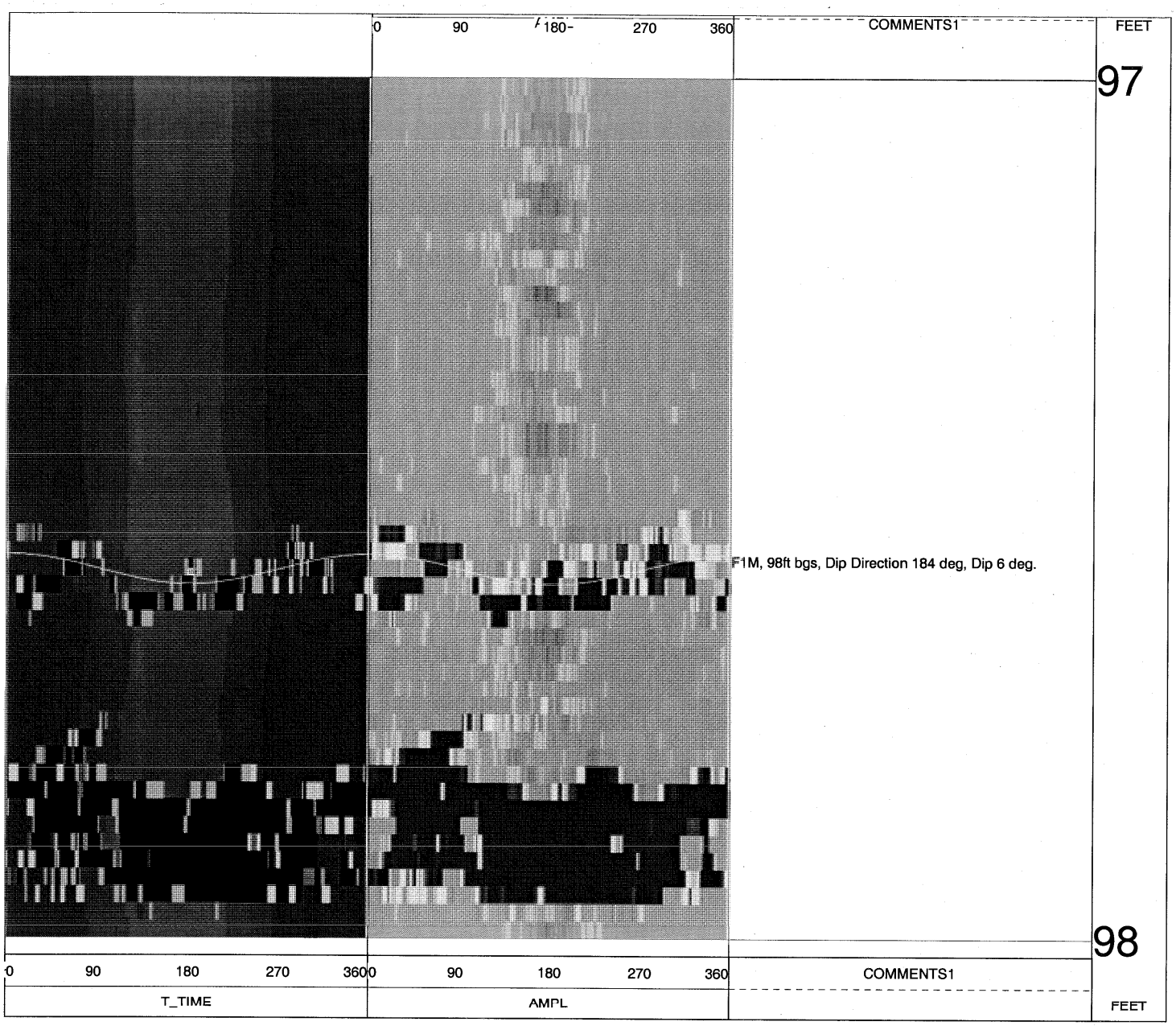
T_TIME
AMPL
FEET


0
90
180
270
360
COMMENTS1
FEET
94
F1M, 95ft bgs, Dip Direction 189 deg, Dip 18 deg.
95
0
90
180
270
360
0
90
180
270
360
COMMENTS1
T_TIME
AMPL
FEET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COMMENTS1
FEET
97
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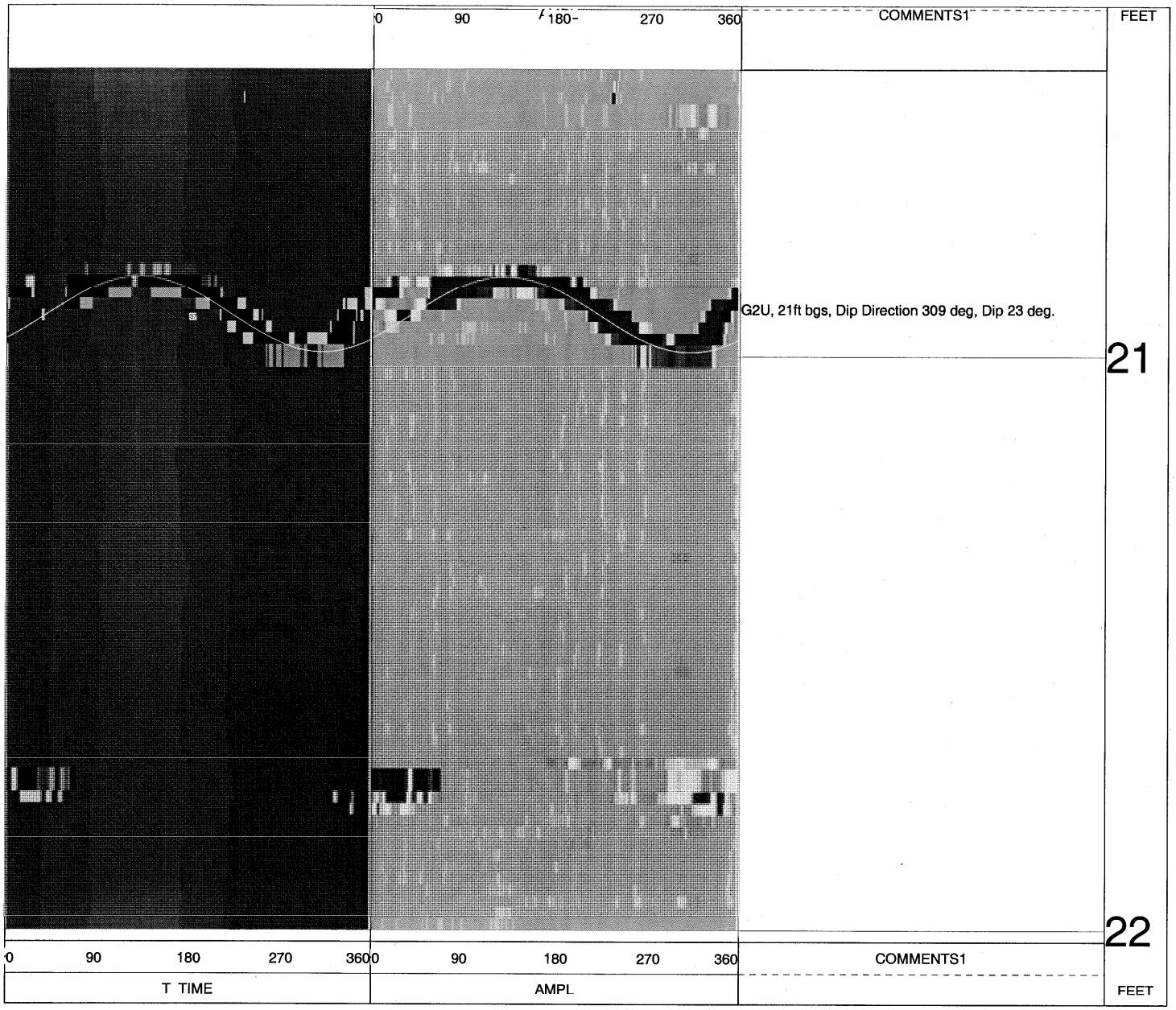
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET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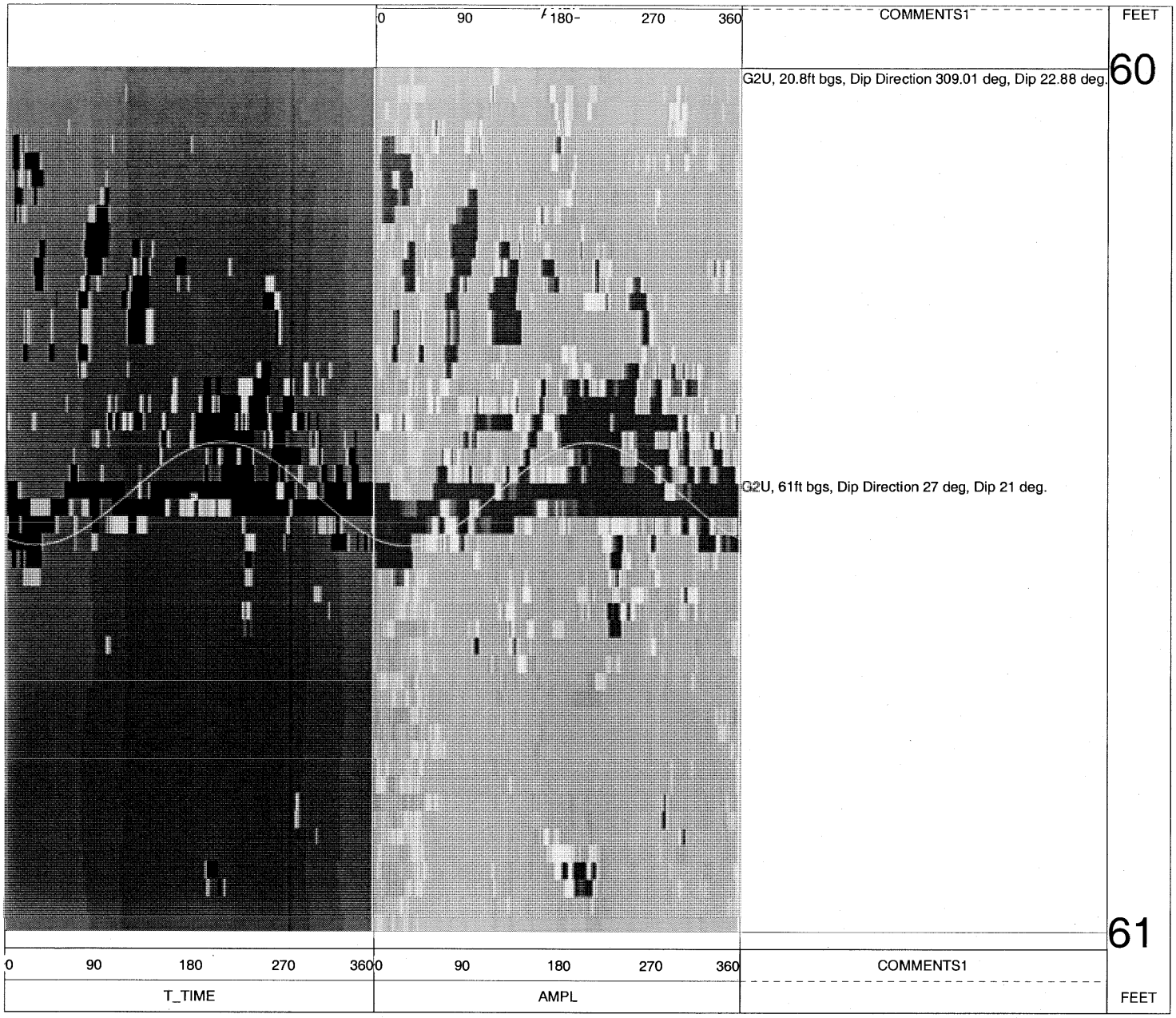
COMMENTS1
FEET
G2U, 21ft bgs, Dip Direction 309 deg, Dip 23 deg.
21
22
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T TIME
AMPL
FEET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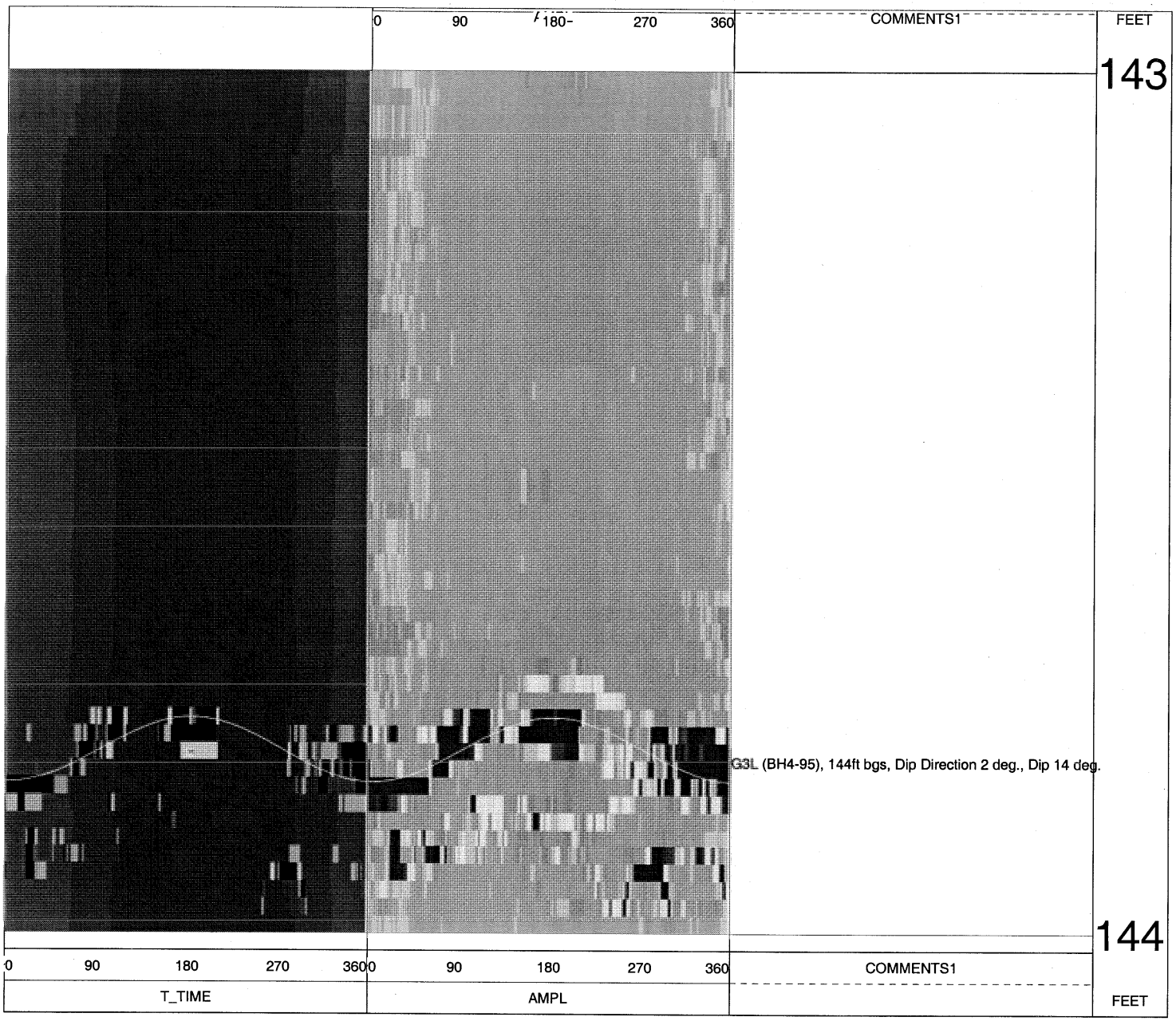
COMMENTS1
FEET
60
G2U, 20.8ft bgs, Dip Direction 309.01 deg, Dip 22.88 deg.
G2U, 61ft bgs, Dip Direction 27 deg, Dip 21 deg.
61
0 90 180 270 360
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET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COMMENTS1
FEET
143
G3L (BH4-95), 144ft bgs, Dip Direction 2 deg., Dip 14 deg.
144
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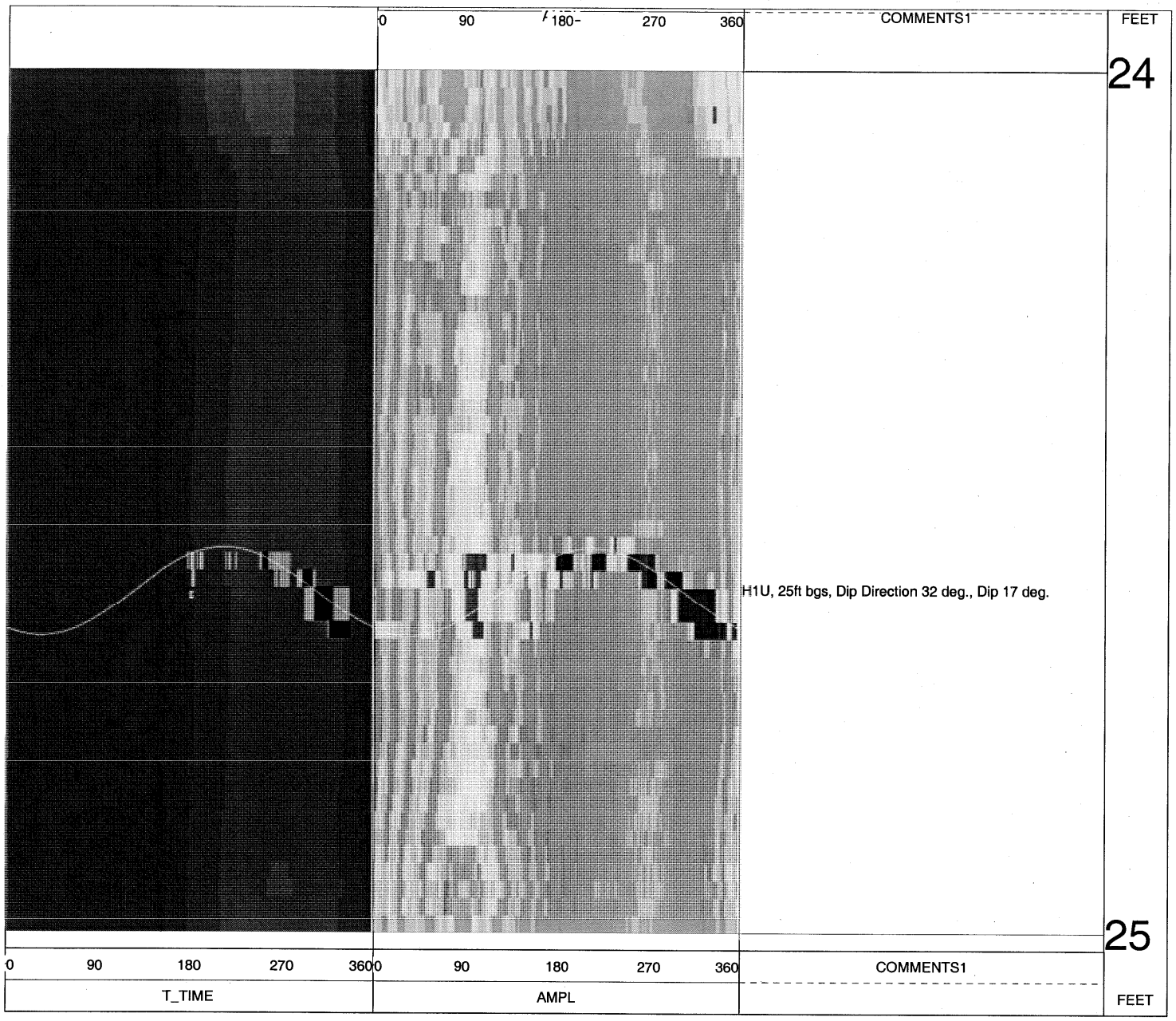
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET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COMMENTS1
FEET
24
H1U, 25ft bgs, Dip Direction 32 deg., Dip 17 deg.
25
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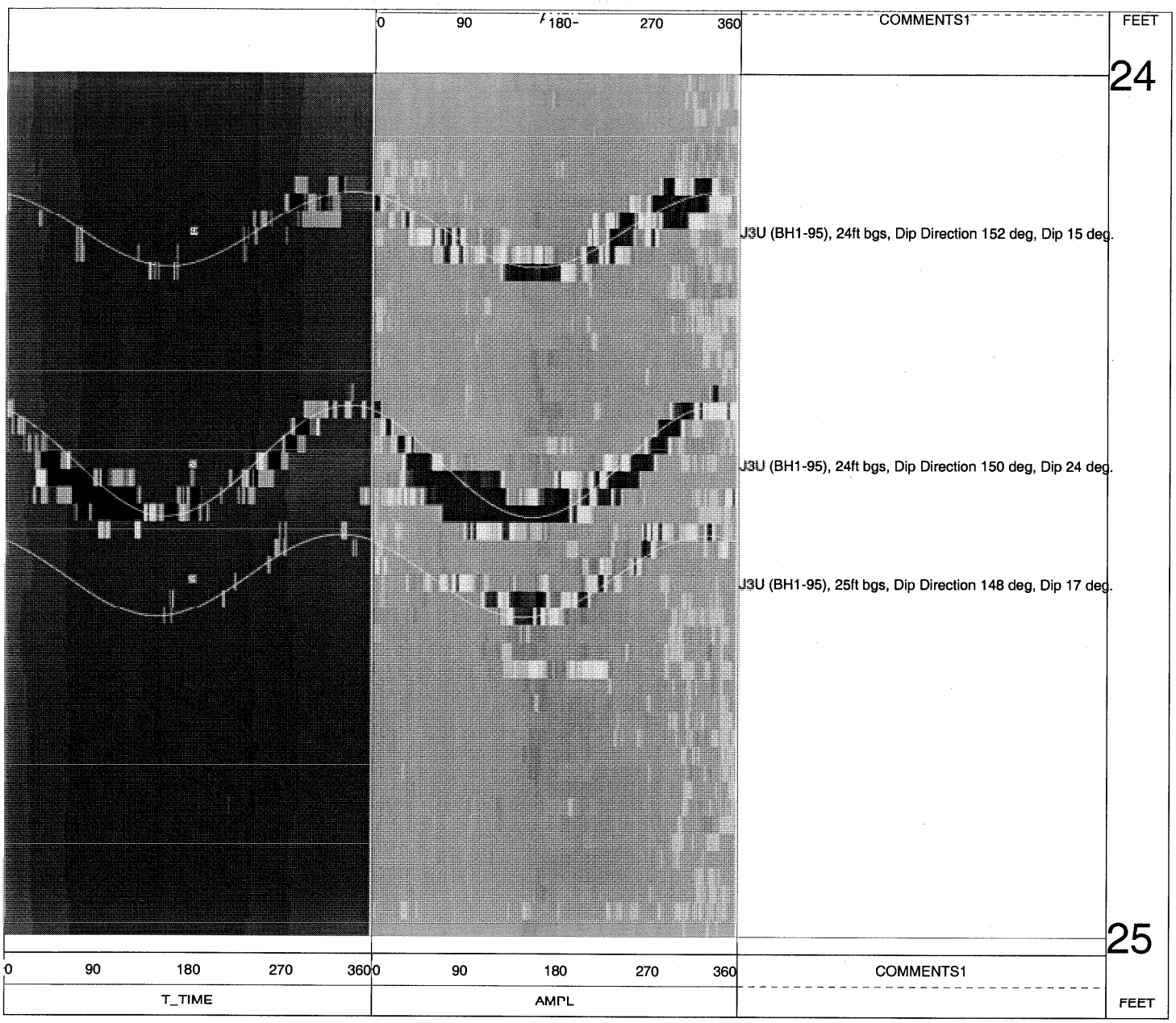
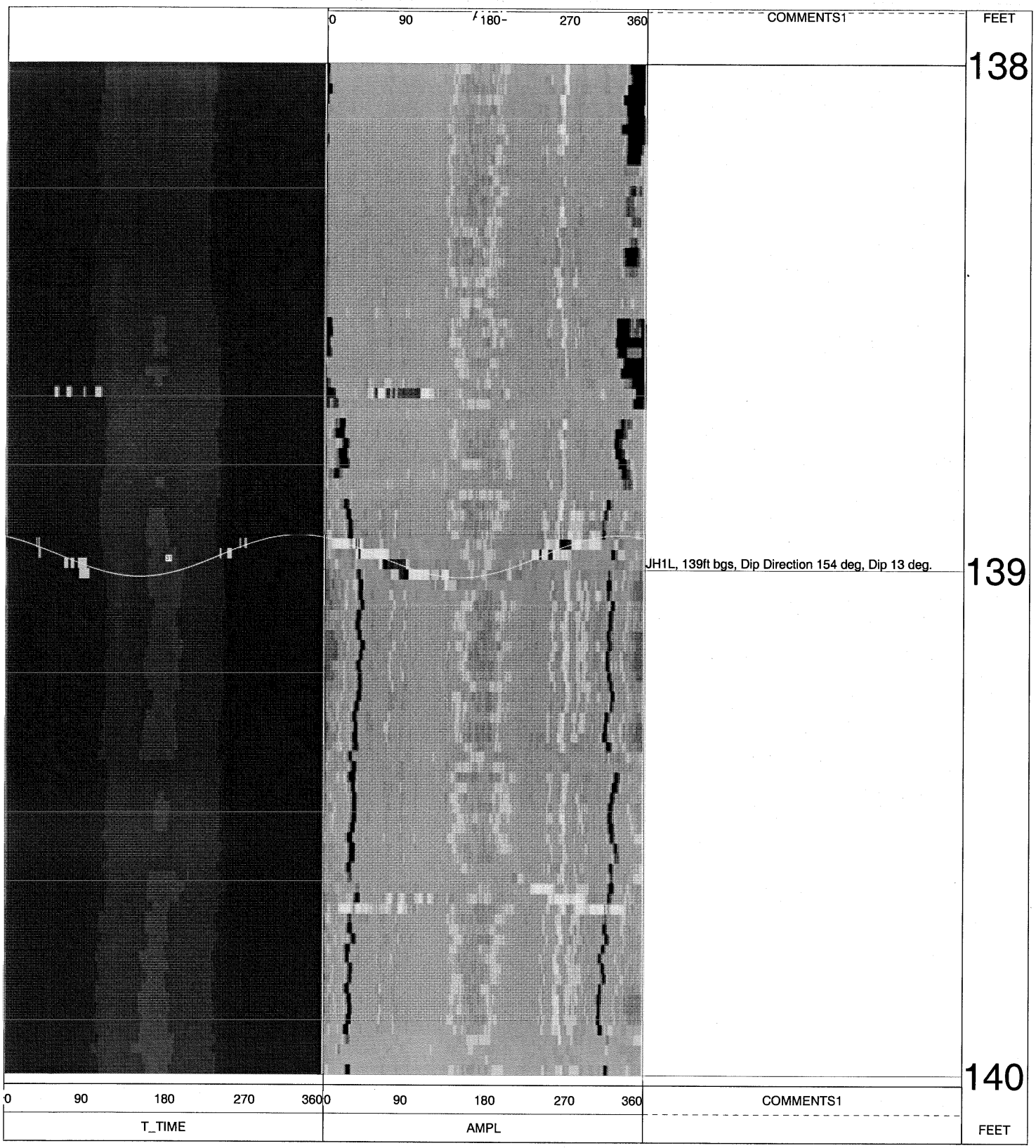
0 90 180 270 360
COMMENTS1
T_TIME
AMPL
FEET


0
90
180
270
360
COMMENTS1
FEET
24
J3U (BH1-95), 24ft bgs, Dip Direction 152 deg, Dip 15 deg.
J3U (BH1-95), 24ft bgs, Dip Direction 150 deg, Dip 24 deg.
J3U (BH1-95), 25ft bgs, Dip Direction 148 deg, Dip 17 deg.
25
0
90
180
270
360
0
90
180
270
360
COMMENTS1
T_TIME
AMPL
FEET


0
90
180
270
360
COMMENTS1
FEET
138
JH1L, 139ft bgs, Dip Direction 154 deg, Dip 13 deg.
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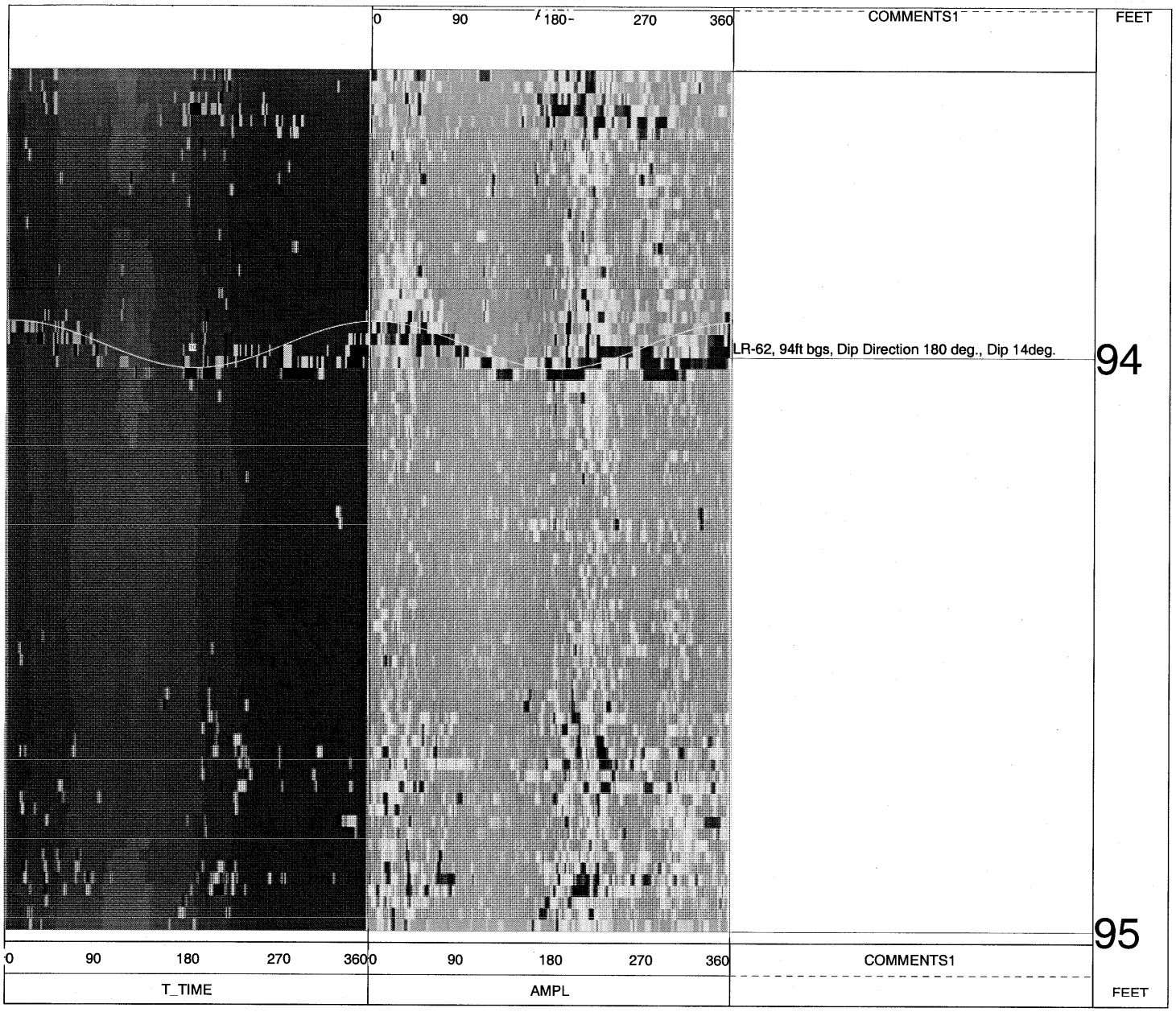
140
0
90
180
270
360
0
90
180
270
360
COMMENTS1
T_TIME
AMPL
FEET


0
90
180
270
360
COMMENTS1
FEET
LR-62, 94ft bgs, Dip Direction 180 deg., Dip 14deg.
94
95
0
90
180
270
360
0
90
180
270
360
COMMENTS1
T_TIME
AMPL
FEET

APPENDIX B

SITE-SPECIFIC LITHOLOGIC DESCRIPTIONS

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(Following Text)

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TABLE B.2 NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES

LIST OF ATTACHMENTS
(Following Text)

ATTACHMENT 1 PHOTOGRAPHS OF NEARBY OUTCROPS AND DRILL CORE

1.0 INTRODUCTION

The logging of drill core with respect to lithology and formation contacts for the bedrock sequence in the vicinity of the Site and the presence of vertical fractures are described in this Appendix. The stratigraphic nomenclature of Brett et al. (1995) is used. These lithologic descriptions are based on the logging of available drill core from boreholes installed from 1991 to the present. Lithologic descriptions are provided only for the units encountered at the Site, the Eramosa Formation, the Goat Island Formation, the Gasport Formation, the DeCew Formation, and the Rochester Shale. The lithology of the deeper stratigraphic units encountered during the drilling of the Intermediate Formation Wells (CRA, 1990) are not discussed in this Appendix.

2.0 LITHOLOGIC UNIT DESCRIPTIONS

The bedrock nomenclature system used in classifying the bedrock units at the Site during previous investigations was based on the nomenclature systems of Zenger (1965) and Rickard (1975). However, two Site-specific variations from these nomenclature systems were noted. Each unit name was essentially that of Rickard (1975), with the exception of the uppermost unit. Rickard (1975) named the uppermost unit the Guelph Formation for the Niagara region, the equivalent of the Oak Orchard Formation found further east in New York State. The nomenclature used at the Site retained the name Oak Orchard Formation for this unit (the previous Oak Orchard Member of Zenger, 1965) (Table B.1). The second variation was in the description and upper contact of the Gasport Formation. During early investigations at the Site, the upper portion of the Gasport Formation (the Pekin Member of Brett et al., 1995) was not recognized, because of the similar lithology to the overlying Goat Island Formation. The Gasport Formation, as defined during historical Site investigations and with concurrence of the NYSDEC, thus consisted only of the lower unit, composed of coarse crystalline, crinoidal dolostone (the Gothic Hill Member of Brett et al., 1995). Consequently, the upper portion of the Gasport Formation (the Pekin Member of Brett et al., 1995) was included in the overlying Goat Island Formation (Table B.1). The following descriptions utilize the nomenclature of Brett et al. (1995) with the previous nomenclature as used by CRA / NYSDEC (1979) in brackets.

The Stratigraphic and Instrumentation Logs from pre-2001 drilling programs utilize the historic nomenclature. The Stratigraphic and Instrumentation Logs for the 2001 drilling program, included in Appendix D, utilized the nomenclature of Brett et al. (1995).

Many of the unit contacts described below are more readily visible in nearby outcrops due to the scale of view and the weathering effects that may accentuate lithologic differences between units. The lack of weathering effects and smaller scale of view in drill core can make determination of unit contacts more difficult and subject to error. Due to the gradational nature of several unit contacts, the lithological similarities of many units, the subjective nature of picking unit contacts, and other potential errors described in Section 3.0 of the main report and in Appendix G, all stratigraphic contacts should be considered accurate to approximately ± 3 feet.

Photographs of nearby outcrops and drill core, referenced in the following discussion, are included in Attachment 1.

Eramosa Formation (Lower Oak Orchard Formation)

The Eramosa Formation is a thick- to thin-bedded, dark brownish-gray, bituminous dolomite that emits a petroliferous odor from fresh surfaces. Some horizons contain small white chert nodules. The Eramosa Formation contains continuous shale partings near the bottom and becomes alternating massive- and thin-bedded. The Eramosa Formation also contains small to large bioherms. The Eramosa Formation appears in outcrop as thick- to massive-bedded, separated by layers of thin-bedded material. The thickness of the Eramosa Formation varies from 0 to 67 feet at the Site and averages 30 feet thick. The Eramosa Formation is the uppermost bedrock unit across the Site, except where missing due to erosion. Thus a true unit thickness cannot be determined in the vicinity of the Site. The Eramosa Formation is not exposed in outcrops in the vicinity of the Site.

Eramosa Formation / Vinemount Member of Goat Island Formation Contact
(Oak Orchard Formation / Eramosa Formation Contact)

The contact between the Eramosa Formation and the Vinemount Member of the Goat Island Formation is generally sharp and easy to identify. The base of the Eramosa Formation becomes very fine-grained and contains numerous, closely spaced, deformed shale layers. Fossils are common within these shale layers. The Vinemount Member begins within the first fine-grained beds that do not contain fossils. There is sometimes a noticeable color change from dark gray to light gray. The Eramosa Formation / Vinemount Member contact is not exposed in outcrops in the vicinity of the Site.

Vinemount Member of the Goat Island Formation (Eramosa Formation)

The Vinemount Member of the Goat Island Formation is a light to dark gray, medium- to thin-bedded, fine-grained, argillaceous dolomite with thin shale partings. The Vinemount Member is commonly bituminous and emits a petroliferous odor from fresh surfaces. The Vinemount Member contains closely spaced shale partings covering approximately 1 foot vertically near the bottom of the unit. The Vinemount Member appears in outcrop near the Site as thin- to medium-bedded with irregular, discontinuous shale layers, and partings. The thickness of the Vinemount Member, where uneroded, ranges from 18 to 24 feet at the Site and averages 20 feet thick (Figure B.1). Across the western portion of the Site, the Vinemount Member forms the uppermost bedrock unit and is erosionally truncated. The bedding of the Vinemount Member is visible on Photograph 1 and the top portion of Photograph 13. The overall competent nature of the drill core is visible on Photographs 14, 15, and 16.

Vinemount Member / Ancaster Member Contact
(Eramosa Formation / Goat Island Formation Contact)

The contact between the Vinemount Member and the Ancaster Member of the Goat Island Formation is difficult to visually identify in drill core. The contact is conformable and gradational and generally there is no color change. At the base of the Vinemount Member, the shale layers become very closely spaced (<1 / 2 inch) over an approximate 1-foot interval. Just below these beds, the grain size of the rock starts to increase from fine-grained to medium-grained. Where the grain size becomes predominantly medium-grained, the Ancaster Member begins. The location of the grain size change beneath the lower shale layers varies across the Site from less than a few inches to greater than 2 feet. The contact between the Vinemount Member and the Ancaster Member is visible on Photograph 2. The contact in drill core is visible, but difficult to see, on Photograph 6.

Ancaster Member of the Goat Island Formation (Upper Goat Island Formation)

The Ancaster Member of the Goat Island Formation is a medium ash-gray, thin to medium-bedded, fine-grained dolomite. The unit weathers to light tan and regionally, contains nodules of distinctive pale, cream-colored chert (Brett et al., 1995). At the Site, chert is uncommonly encountered and was not observed in outcrop. In outcrop, the Ancaster Member appears regularly spaced and medium bedded. The Ancaster and the underlying Niagara Falls Members have previously been grouped together at the Site. The combined thickness of these two members at the Site ranges from 13 to 24 feet and averages 19 feet thick (Figure B.1). The bedding of the Ancaster Member is visible on Photographs 3 and 13. The overall competent nature of the drill core is visible on Photograph 16.

Ancaster Member / Niagara Falls Member Contact
(Upper Goat Island Formation / Lower Goat Island Formation Contact)

The contact between the Ancaster Member and Niagara Falls Member of the Goat Island Formation has not been discretely logged at the Hyde Park Landfill Site.

Niagara Falls Member of the Goat Island Formation (Lower Goat Island Formation)

The Niagara Falls Member of the Goat Island Formation is a light olive to brownish-gray, saccharoidal, medium-grained, thick- to massive-bedded, porous, and vuggy dolomite. The vugs and mineralization in the Niagara Falls Member noted in

Brett et al. (1995) to occur regionally are not commonly encountered in drill core at the Site. In outcrop, the Niagara Falls Member appears massive with few fractures. The bedding of the Niagara Falls Member is visible on Photographs 4 and 13. The overall competent nature of the drill core is visible on Photograph 17.

Niagara Falls Member / Pekin Member Contact
(Goat Island Formation / Gasport Formation Contact)

The contact between the Niagara Falls Member of the Goat Island Formation and the Pekin Member of the Gasport Formation is conformable but generally fairly easy to identify. Toward the base of the Niagara Falls Member the rock becomes very uniform in grain size and color (medium-grained and medium gray) and commonly breaks at stylolites spaced approximately 2 to 3 feet apart. At the top of the Pekin Member, a noticeable textural change in the rock occurs, from lack of structure to a very deformed structure, the color of the rock also becomes slightly darker. Within the first 2 to 3 feet of the Pekin Member, the bedding becomes thin and crinoid fossil fragments may be present. The contact between the Niagara Falls Member and the Pekin Member is visible on Photograph 4. The contact in drill core is visible on Photograph 17.

Pekin Member of the Gasport Formation (Gasport Formation)

The Pekin Member is an argillaceous, dark gray, fine-grained, thin- to medium-bedded dolomicrite. The Pekin Member was not officially recognized historically as part of the Gasport Formation at the Site. In outcrop, the Pekin Member displays deformed, irregular shale partings of limited lateral extent. The shale partings are often closely spaced in outcrop. The Pekin Member ranges in thickness from 11 to 24 feet and averages 16 feet thick at the Site (Figure B.1). The thick bedding is visible on Photographs 5, 6, 7, and the bottom of Photograph 13. The overall competent nature of the Pekin Member is visible in drill core on Photographs 17 and 18.

Pekin Member / Gothic Hill Member Contact
(Goat Island Formation / Gasport Formation Contact)

The contact between the Pekin Member and Gothic Hill Member of the Gasport Formation is generally sharp and easy to identify. The Gothic Hill Member is characterized as being a thick bedded crinoidal grainstone. The base of the Pekin Member often contains thin beds (approximately 4 inches thick) with crinoid fragments separated by thin beds of dolostone with shale layers. The contact between these two units is commonly marked by a shale parting. The contact between the Pekin Member

and the Gothic Hill Member is visible on Photograph 7. The contact is visible in drill core on Photograph 20.

Gothic Hill Member of the Gasport Formation (Gasport Formation)

The Gothic Hill Member of the Gasport Formation is a thick- to massive-bedded, dark olive-gray to light pink, dolomitic limestone (primarily crinoidal grainstone and crinoidal dolomite). The Gothic Hill Member appears in outcrop as a massive unit, which is generally unfractured horizontally. Low-angle cross-stratification is apparent in outcrop and the fossil fragments are commonly visible in relief due to differential weathering. The Gothic Hill Member ranges in thickness from 4 to 16 feet and averages 7 feet thick at the Site (Figure B.1). The massive bedding of this unit and cross-stratification are visible on Photographs 7, 8, 9, and 10. The overall competent nature of the drill core is visible on Photograph 20.

Gothic Hill Member / DeCew Formation Contact
(Gasport Formation / DeCew Formation Contact)

The contact between the Gasport Formation and the DeCew Formation is sharp and easy to identify. This contact is marked by the loss of crinoid fragments and a change from medium- to coarse-grained to fine-grained. The contact between the Gothic Hill Member and the DeCew Formation is visible on Photographs 9 and 10.

DeCew Formation

The DeCew Formation is a variably bedded, dark-gray to olive-gray, argillaceous to sandy, fine-grained dolomite that locally contains shale partings and interbeds up to a few inches thick. It commonly shows contorted and enterolithic bedding. The contorted and enterolithic bedding was postulated by Brett et al. (1995) to be caused by a seismic disturbance. In outcrop, the contorted and enterolithic bedding weathers differentially, showing the bedding details in relief. In outcrop near the Site, the contorted and enterolithic bedding of the DeCew Formation occupies approximately the middle one-third of the unit. The top of the contorted and enterolithic bedding forms an irregular bedding plane surface overlain and draped by similar argillaceous to sandy dolomite with near-horizontal bedding. The DeCew Formation ranges in thickness from 8 to 13 feet and averages 11 feet thick at the Site (Figure B.1). The variations in bedding within the DeCew Formation is readily apparent on Photographs 9, 11, and 12. The upper portion of the DeCew Formation is visible in drill core on Photograph 20. There is no apparent erosion or weathering on the top of the DeCew Formation, at the shale parting that forms the contact with the overlying Gothic Hill Member, although this

contact is considered to be a regional unconformity (Brett et al., 1995). The rust staining visible in drill core on Photograph 20 is caused by oxidation of the core box metallic hardware.

DeCew Formation / Rochester Shale Contact

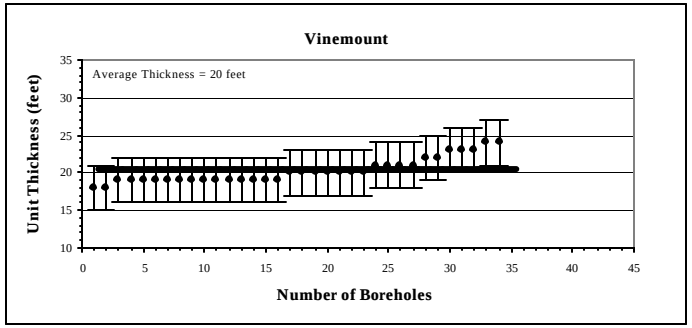
The contact between the DeCew Formation and Rochester Shale is conformable and somewhat difficult to visually identify in drill core. The contact is determined by the flatness of the bedding, the first horizontal bedding marks the top of the Rochester Shale. In addition, the Rochester Shale becomes significantly softer below the DeCew Formation / Rochester Shale contact. The contact between the DeCew Formation and the Rochester Shale is visible on Photograph 12.

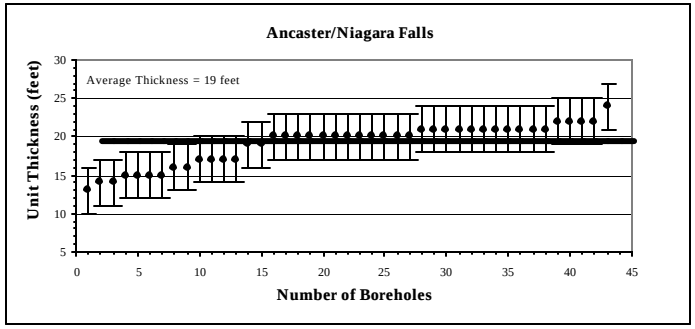
Rochester Shale

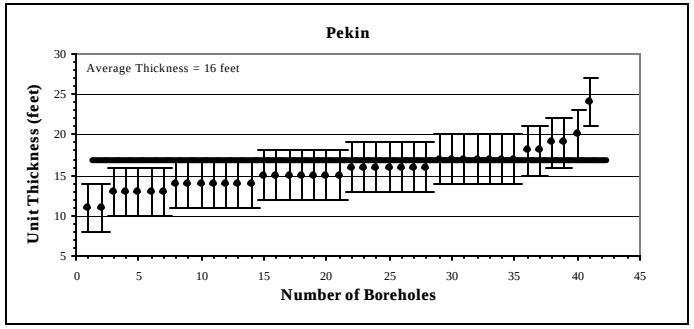
The Rochester Shale is a medium-gray to black calcareous mudstone with thin interbeds of calcareous to dolomitic calcisiltite and calcarenite. In outcrop, the upper portion of the Rochester Shale weathers rapidly to a crumbly texture of small shale fragments partially covered by light colored evaporative mineral coatings. The full thickness of the Rochester Shale was penetrated during the installation of the Intermediate Formation Wells (IFW). The Rochester Shale ranges in thickness from 56 to 63 feet and averages 59 feet based on these seven IFW monitoring wells. The bedding and rapid weathering of this unit are apparent on the lower portion of Photograph 12.

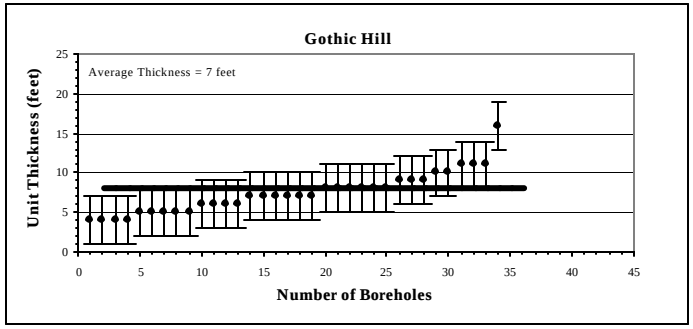
3.0 NEAR-VERTICAL FRACTURES

Near-vertical fractures were encountered in available drill core and were logged during the lithologic logging process. The depths of these vertical fractures from ground surface are presented in Table B.2. As well, this table includes three near-vertical fractures visible from borehole video logging (C1U, C2M) that were not noted to be present in the drill core.









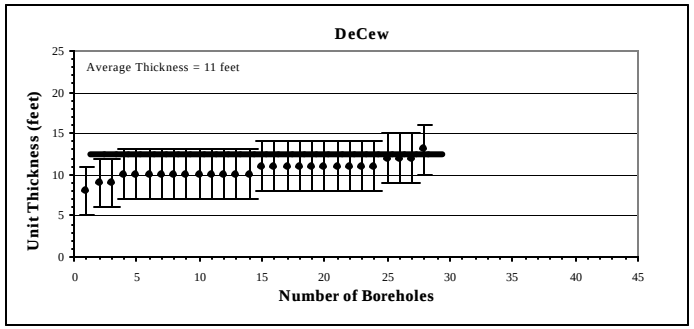


figure B.1

STRATIGRAPHIC UNIT THICKNESSES

SITE CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

Town of Niagara, New York

Note: Error bars represent ± 3 feet.

TABLE B.1

STRATIGRAPHIC NOMENCLATURE COMPARISON
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Zenger (1965) (NY Bull.404)		Rickard (1975) (NY Map Series 24)		CRA/ NYSDEC (1979)		Brett, et al. (1995) (USGS Bull.2086)		
Lockport Formation	Oak Orchard Member	Lockport Group	Guelph Dolomite	Lockport Group	Oak Orchard Formation	Lockport Group	Guelph Dolomite	
							Eramosa Dolomite	
	Eramosa Member		Eramosa Formation		Eramosa Formation		Goat Island Dolomite	Vinemount Member
	Goat Island member		Goat Island Formation		Goat Island Formation			Ancaster Member
								Niagara Falls Member
	Gasport Member		Gasport Formation				Gasport Dolomite	Pekin Member
					Gasport Formation			Gothic Hill Member
	DeCew Member	Clinton Group	DeCew Dolomite		DeCew Formation	Clinton Group	DeCew Dolomite	
Clinton Group	Rochester Shale		Rochester Shale	Clinton Group	Rochester Shale		Rochester Shale	Burleigh Hill Member
								Lewiston Member

Note: The Gasport Formation as used by CRA at the Site is composed of the Gothic Hill Member only.
The Pekin Member of the Gasport Formation was historically included in the overlying Goat Island Dolomite.

TABLE B.2

NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft. AMSL)	Top of Bedrock Elevation (ft. AMSL)	Fracture 1 Top (Depth ft. bgs)	Fracture 1 Bottom (Depth ft. bgs)	Fracture 2 Top (Depth ft. bgs)	Fracture 2 Bottom (Depth ft. bgs)	Fracture 3 Top (Depth ft. bgs)	Fracture 3 Bottom (Depth ft. bgs)	Fracture 4 Top (Depth ft. bgs)	Fracture 4 Bottom (Depth ft. bgs)
A1U	598.0	571	No Vertical Fracturing Noted							
A2U	593.5	572	30.8	31.0						
AB1L	588.0	561	No Vertical Fracturing Noted							
AB1M	588.0	565	No Vertical Fracturing Noted							
AB1U	587.9	559	No Vertical Fracturing Noted							
ABP-1	571.9	554	No Vertical Fracturing Noted							
ABP-2	574.9	558	No Vertical Fracturing Noted							
ABP-3 (1)	591.1 (1)	562 (1)	No Vertical Fracturing Noted							
ABP-4	588.1	561	No Vertical Fracturing Noted							
ABP-5	589.3	561	No Vertical Fracturing Noted							
ABP-7	574.4	566	No Vertical Fracturing Noted							
ABP-8	575.1	534	No Vertical Fracturing Noted							
AFW-1L	570.9	565	57.0	61.0						
AFW-2L	592.2	579	15.2	15.6	17.5	19.5	21.5	22.5		
AFW-3L	589.3	577	12.5	13.2	17.0	18.0				
AGW-1L	591.4	576	19.5	21.5	23.6	23.8				
AGW-2L	608.4	593	16.0	17.5	31.5	32.0				
AGW-3L	628.3	612	38.4	38.6	51.8	52.1	56.6	56.8	86.5	89.8
APW-1	569.0	555	No Vertical Fracturing Noted							
APW-2	574.0	531	No Vertical Fracturing Noted							
B1L	589.7	562	28.0	29.0						
B2L	588.0	564	55.9	56.0						
BR-1	582.6	559	23.6	23.8						
BR-2	581.6	557	No Vertical Fracturing Noted							
BR-3	582.0	559	24.4	24.5						
BR-4	583.5	557	No Vertical Fracturing Noted							
C1U	591.6	562	30.5 (1)	32.5 (1)						
C1L	591.4	562	91.0	93.0	95.0	97.0				
C2M	590.1	560	59 (1)	63 (1)	71 (1)	79 (1)				

TABLE B.2

NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft. AMSL)	Top of Bedrock Elevation (ft. AMSL)	Fracture 1 Top (Depth ft. bgs)	Fracture 1 Bottom (Depth ft. bgs)	Fracture 2 Top (Depth ft. bgs)	Fracture 2 Bottom (Depth ft. bgs)	Fracture 3 Top (Depth ft. bgs)	Fracture 3 Bottom (Depth ft. bgs)	Fracture 4 Top (Depth ft. bgs)	Fracture 4 Bottom (Depth ft. bgs)
C2L	590.2	560	59.0	63.0	71.0	76.0				
CD1L	596.6	563	36.5	37.4						
CD1M	596.8	568	No Vertical Fracturing Noted							
CD1U	596.9	573	33.3	38.1	52.7	52.8				
CD2M	596.1	563	No Vertical Fracturing Noted							
CD3U	593.4	562	31.1	31.4						
CD4U	588.9	574	13.7	16.5						
CD5U	588.2	566	No Vertical Fracturing Noted							
CD6U	588.6	562	No Vertical Fracturing Noted							
D1L	592.7	572	23.6	24.2						
D2L	589.4	576	No Vertical Fracturing Noted							
D4L	598.6	575	No Vertical Fracturing Noted							
E1L	594.0	577	21.0	21.5						
E2L	591.3	576	No Vertical Fracturing Noted							
E3L	593.1	578	23.7	23.8						
E5U	598.6	587	No Vertical Fracturing Noted							
F1L	602.0	599	44.2	44.8						
F2L	597.6	587	29.2	29.4	34.8	35.0				
F3L	597.6	580	No Vertical Fracturing Noted							
G1L	615.6	607	9.5	10.5	13.2	16.0				
G2L	609.8	600	45.2	45.8	51.5	53.4				
G3L (BH4-95)	617.7	60604	No Vertical Fracturing Noted							
G4U	610.6	597	No Vertical Fracturing Noted							
G5L	605.5	598	126.5	126.8						
G5U (T-2)	610.6	603	8.2	8.5	14.5	14.8	49.9	50.2		
H1L	618.9	606	No Vertical Fracturing Noted							
H2L	619.3	613	14.3	14.5						
HT-2 (BH2-95)	600.2	579	No Vertical Fracturing Noted							
J1L	606.8	591	18.2	18.4	30.2	30.4				

TABLE B.2

NEAR-VERTICAL FRACTURES LOGGED IN BOREHOLES
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Well Location	Ground Surface Elevation (ft. AMSL)	Top of Bedrock Elevation (ft. AMSL)	Fracture 1 Top (Depth ft. bgs)	Fracture 1 Bottom (Depth ft. bgs)	Fracture 2 Top (Depth ft. bgs)	Fracture 2 Bottom (Depth ft. bgs)	Fracture 3 Top (Depth ft. bgs)	Fracture 3 Bottom (Depth ft. bgs)	Fracture 4 Top (Depth ft. bgs)	Fracture 4 Bottom (Depth ft. bgs)
J2L	608.0	593	24.2	24.8	33.0	33.2				
J3L	600.2	584	No Vertical Fracturing Noted							
J5L	606.1	591	No Vertical Fracturing Noted							
J5M	604.6	593	No Vertical Fracturing Noted							
J5U	604.5	591	No Vertical Fracturing Noted							
JH1L	624.4	610	No Vertical Fracturing Noted							
MW1-2001	595.4	577	18.0	20.0						
MW2-2001	594.4	573	No Vertical Fracturing Noted							
MW3-2001	589.8	560	No Vertical Fracturing Noted							
MW4-2001	588.8	559	No Vertical Fracturing Noted							
MW5-2001	591.7	559	No Vertical Fracturing Noted							
MW6-2001	591.2	559	No Vertical Fracturing Noted							
MW7-2001	590.3	561	No Vertical Fracturing Noted							
PMW-1L	597.4	563	100.5	100.8	102.6	102.9				
PMW-3L	604.6	590	No Vertical Fracturing Noted							
PW-1L	596.8	581	No Vertical Fracturing Noted							
PW-2L	600.0	580	No Vertical Fracturing Noted							
PW-3L	602.8	588	No Vertical Fracturing Noted							
PW-4M	610.3	599	11.2	11.5	30.9	31.1	35.8	36.0	39.7	40.0
PW-6UR(T-1)	611.3	604	No Vertical Fracturing Noted							
PW-6MR(T-3)	612.1	605	8.1	8.5	12.5	12.7	45.8	46.2	67.5	67.6
PW-7U (CD-2U)	596.7	563	No Vertical Fracturing Noted							
PW-8U	593.7	563	No Vertical Fracturing Noted							
PW-8M	597.0	561	No Vertical Fracturing Noted							
PW-9U	591.8	562	No Vertical Fracturing Noted							
PW-10U	597.8	579	19.0	19.5	26.2	26.5				

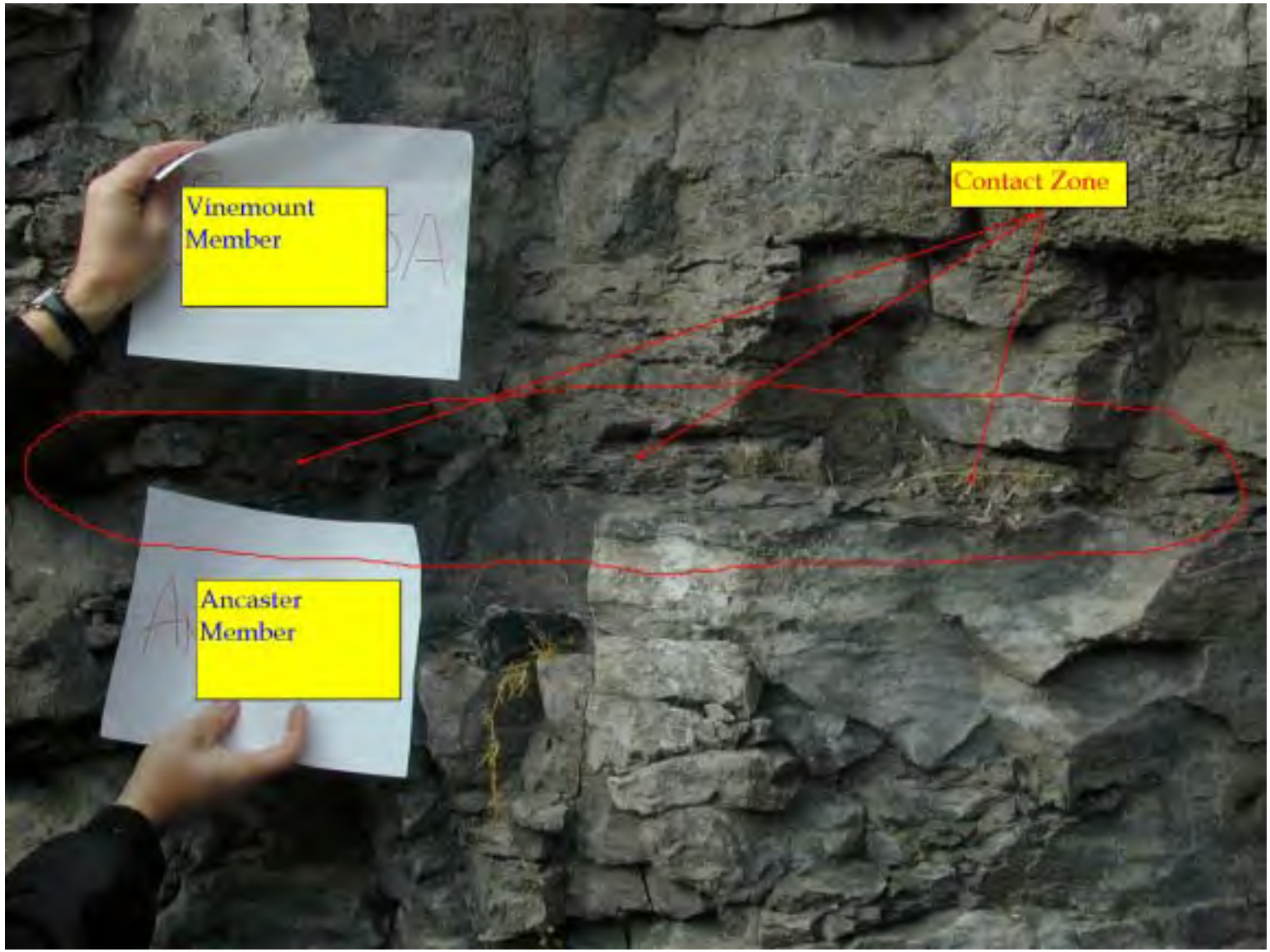
Notes:

ft. AMSL - feet Above Mean Sea Level.
ft. bgs - feet below ground surface
Only boreholes for which drill core was available are listed.
(1) Fracture identified from borehole video log.

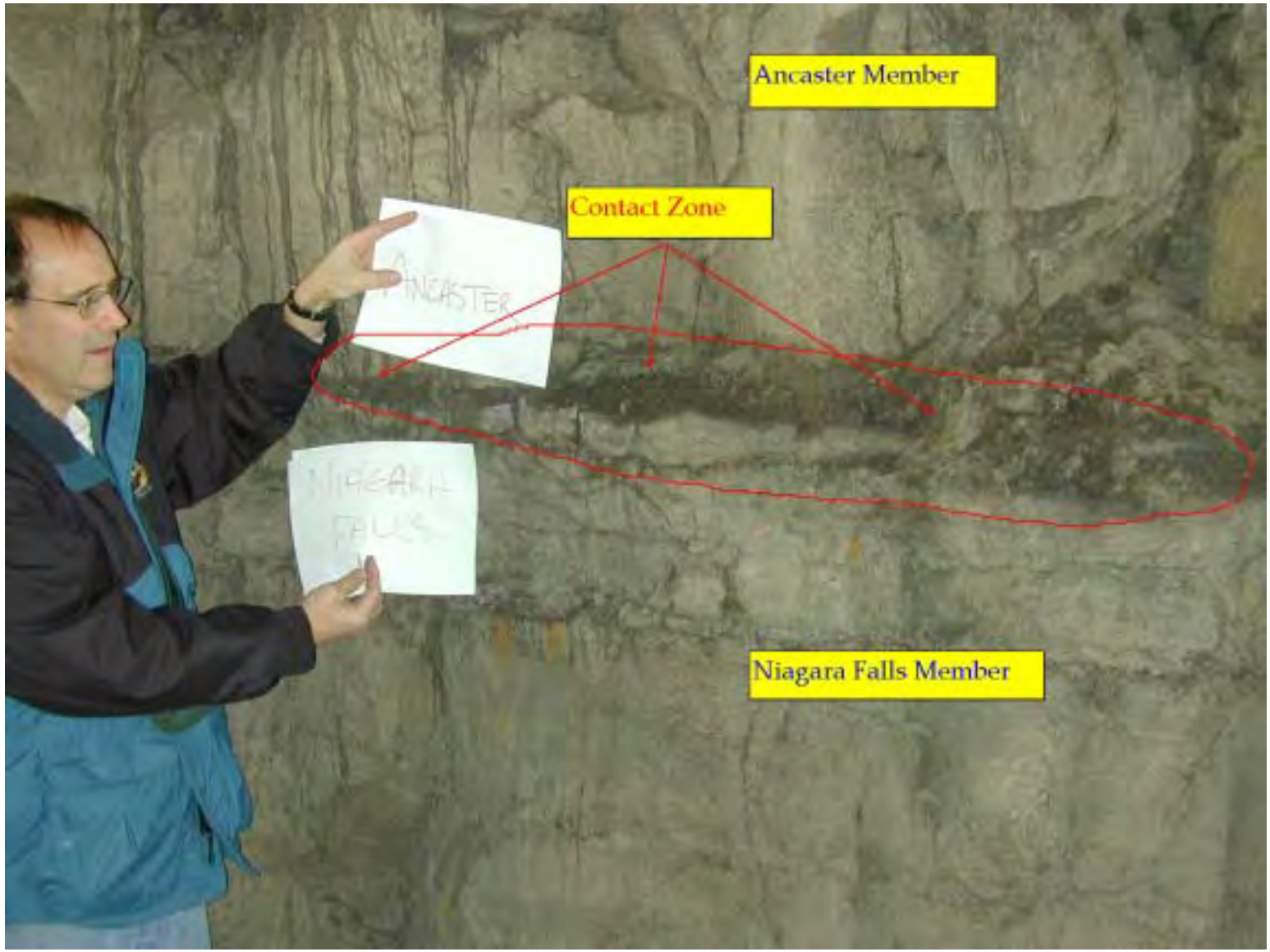
ATTACHMENT 1

PHOTOGRAPHS OF NEARBY OUTCROPS AND DRILL CORE

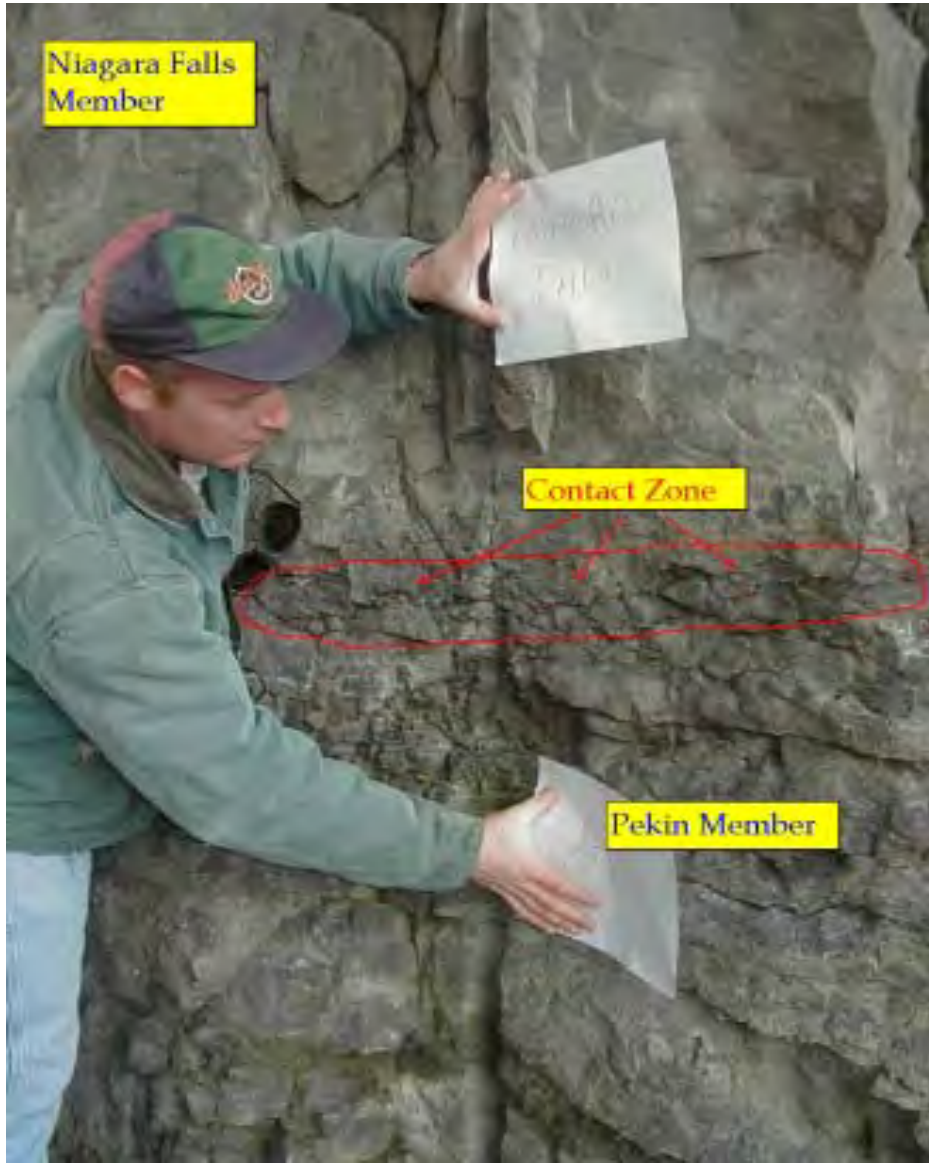
Photograph 1. Horizontal bedding, bedding plane fractures, and vertical fractures in the Vinemount Member of the Goat Island Formation. NYPA Access Road.



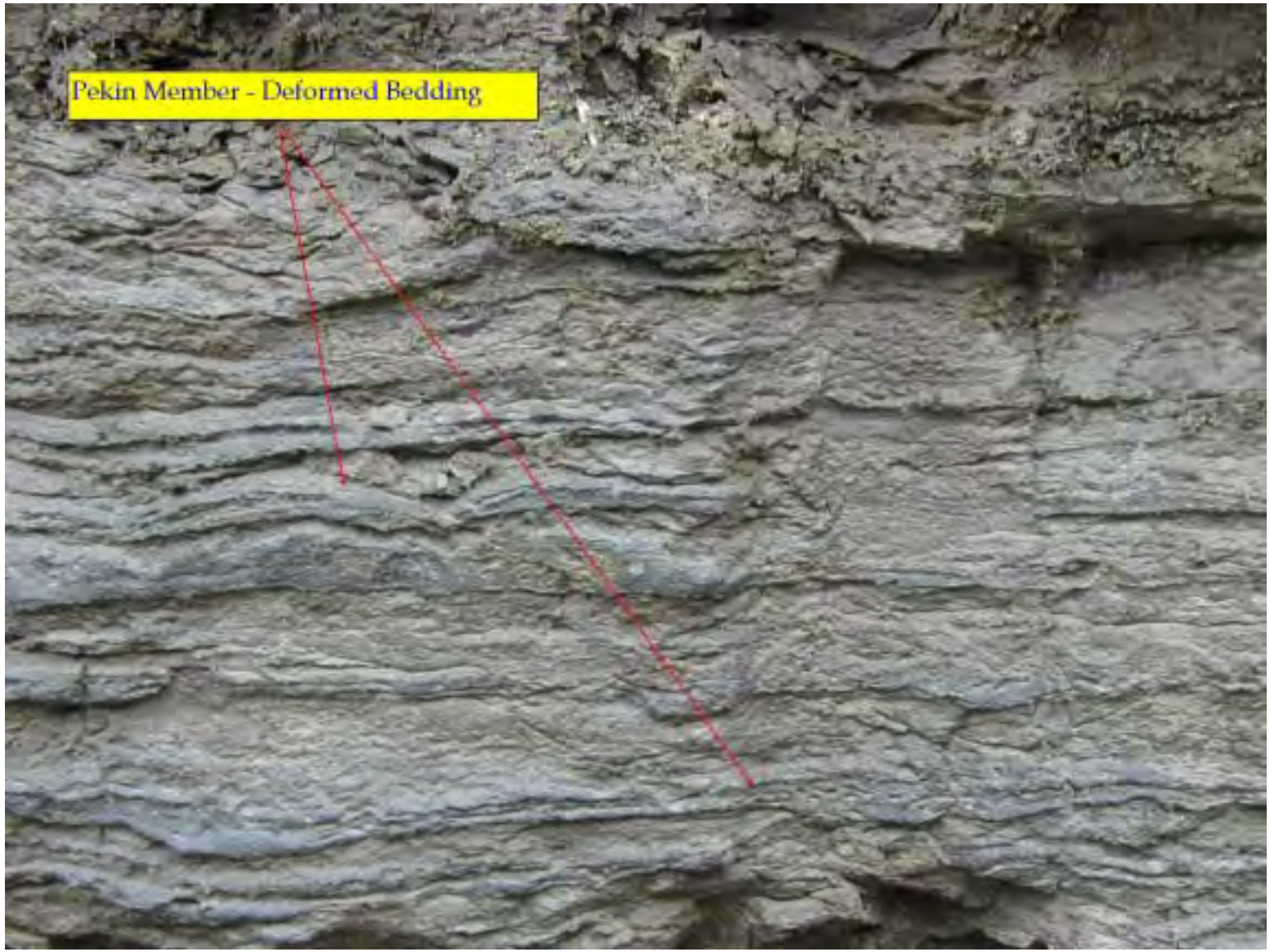
Photograph 2. Contact between the Vinemount Member and the Ancaster Member of the Goat Island Formation. NYPA Access Road.



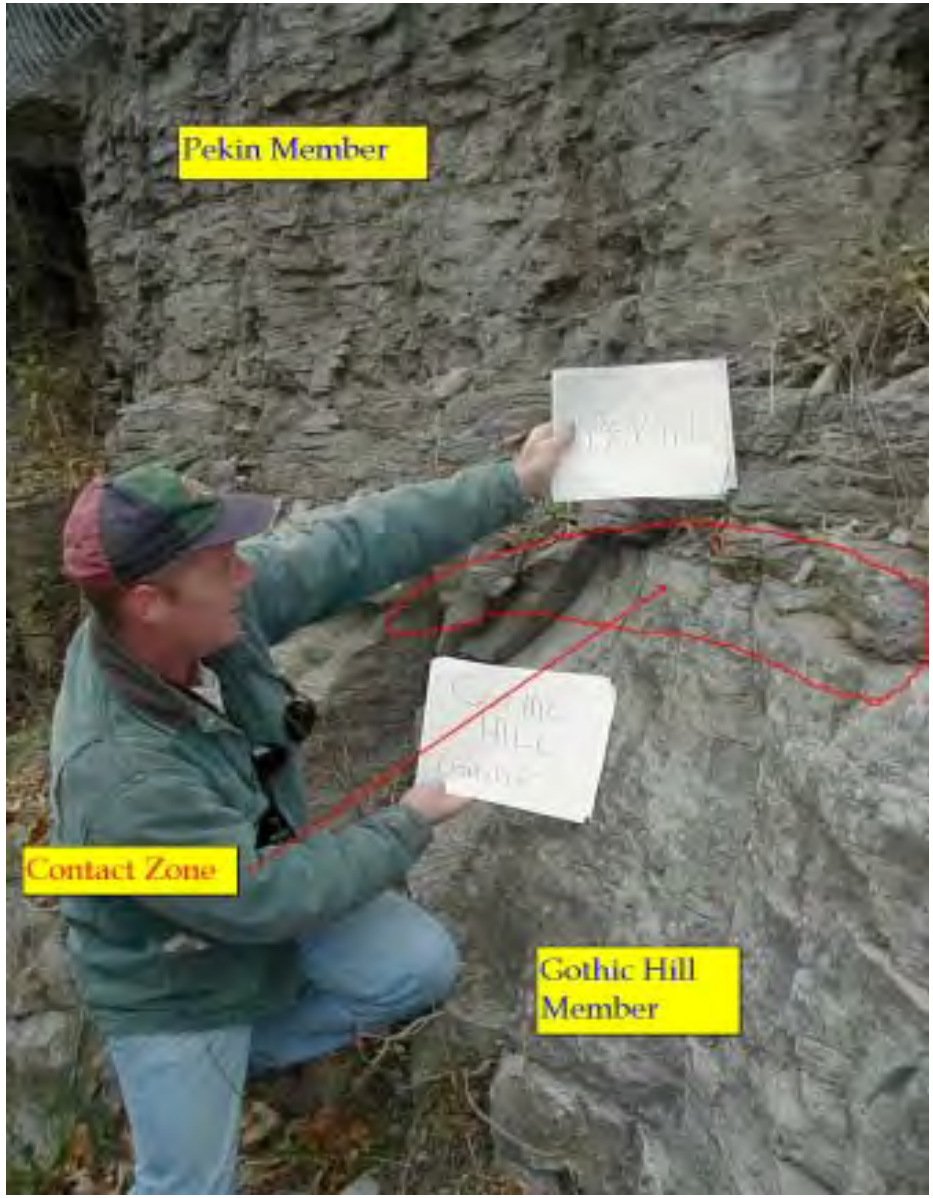
Photograph 3. Contact between the Ancaster Member and the Niagara Falls Member of the Goat Island Formation. Note the thick to massive bedding in each member. NYPA Access Road.



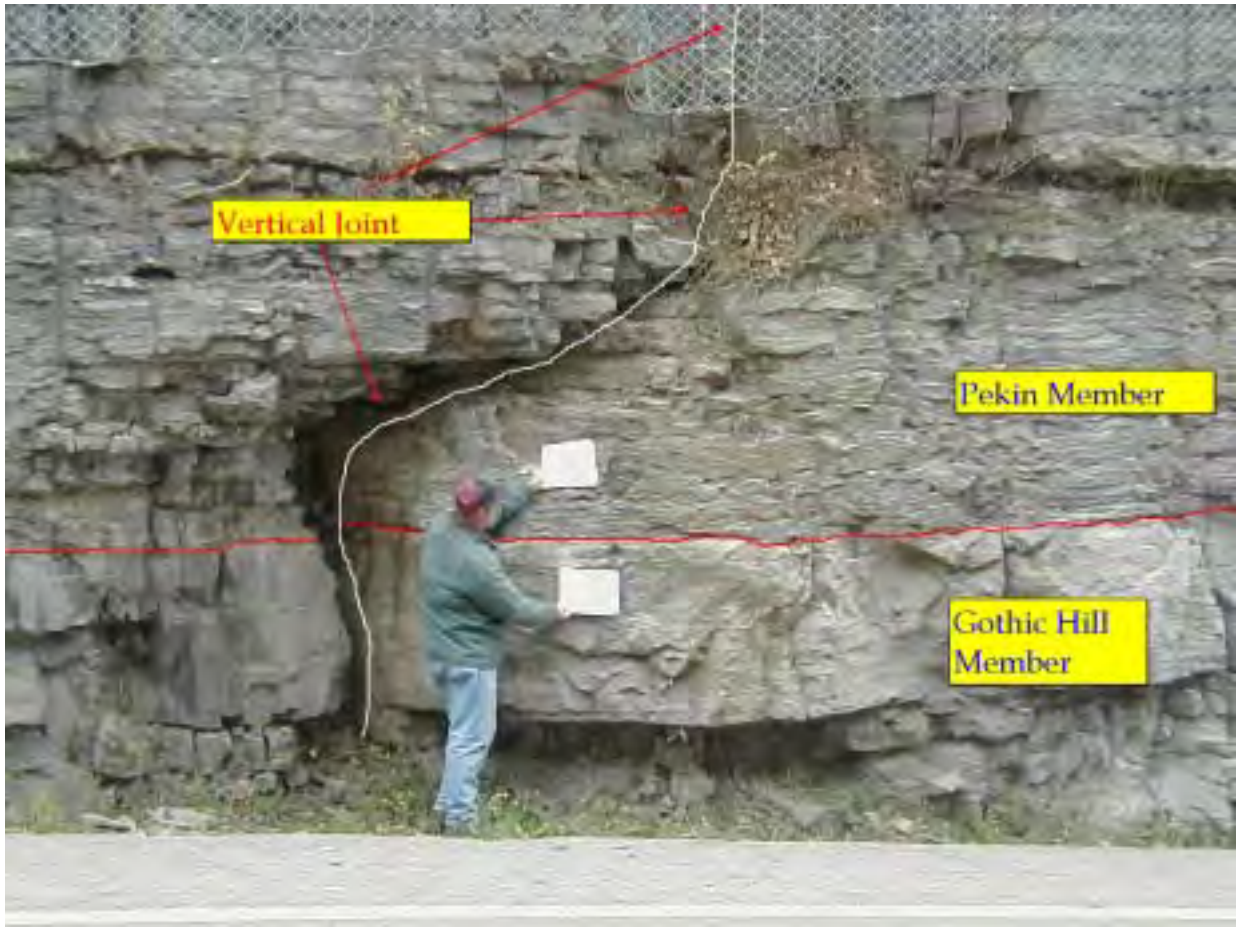
Photograph 4. Contact between Niagara Falls Member of the Goat Island Formation and the Pekin Member of the Gasport Formation. NYPA Access Road.



Photograph 5. Deformed bedding of the Pekin Member of the Gasport Formation, probably caused by stromatolites. NYPA Access Road.

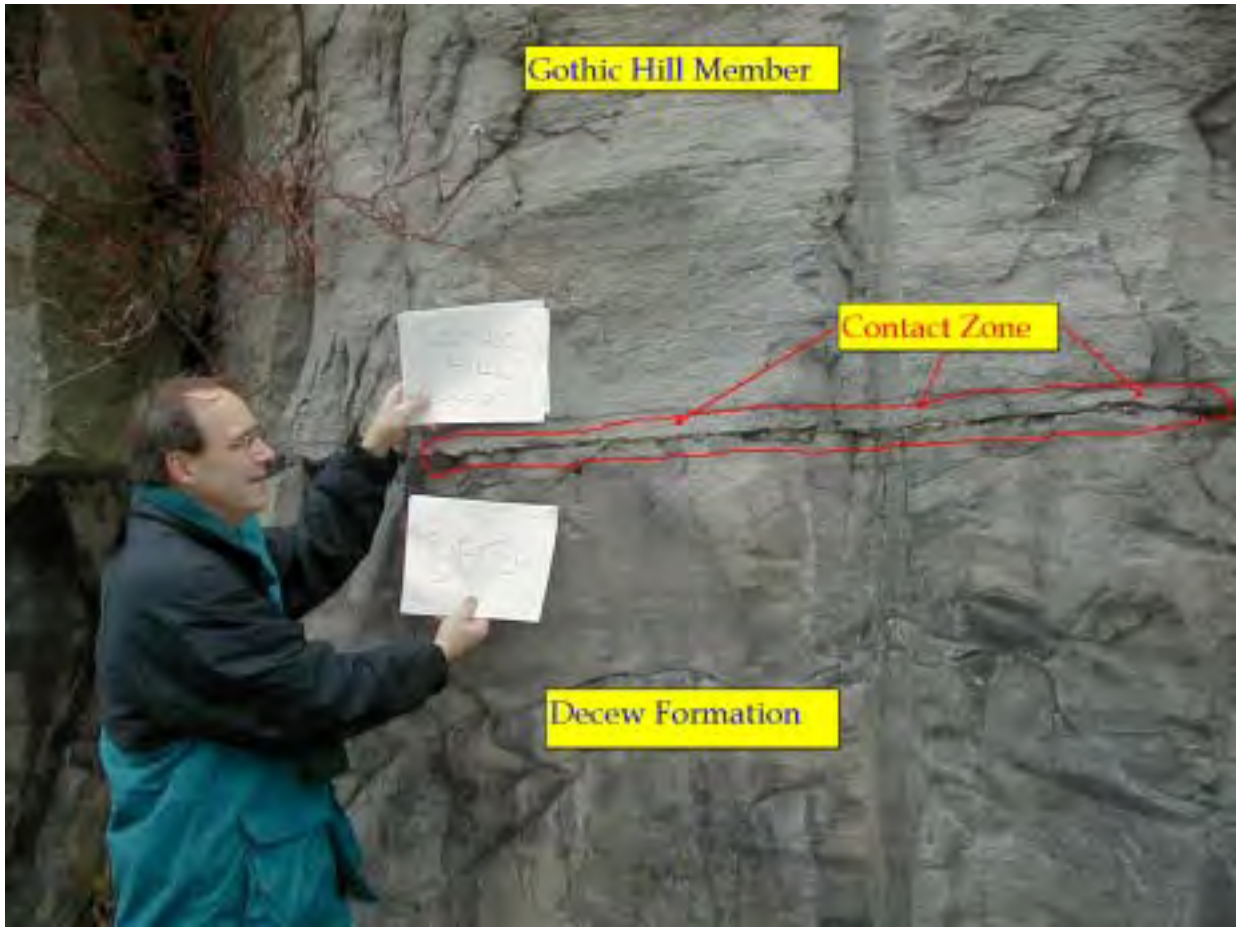


Photograph 6. Contact between the Pekin Member and the Gothic Hill Member of the Gasport Formation. NYPA Access Road.

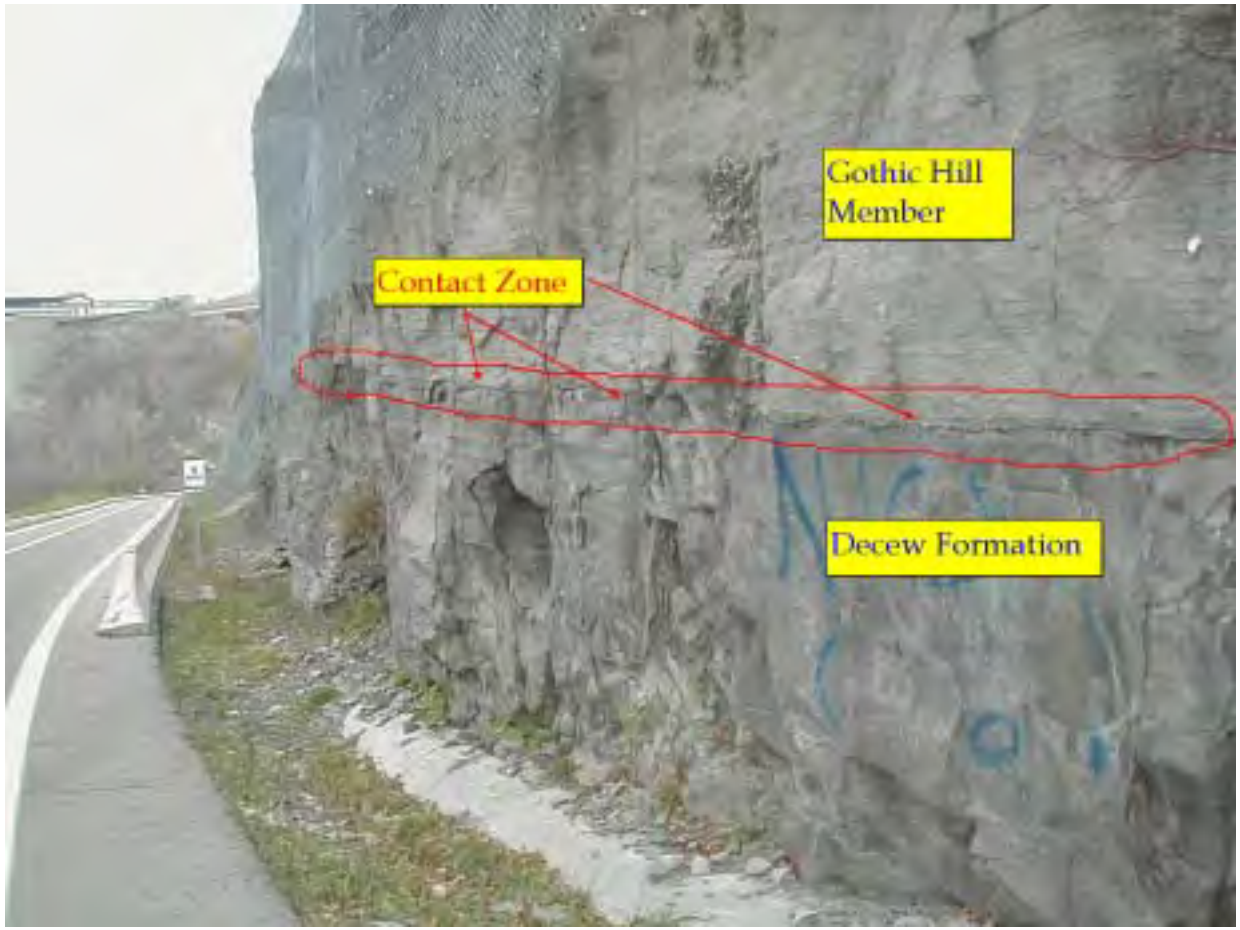


Photograph 7. Contact between the Pekin Member and the Gothic Hill Member of the Gasport Formation. Note the large vertical joint (steeply dipping in the center of the photograph) within the Pekin Member. NYPA Access Road.

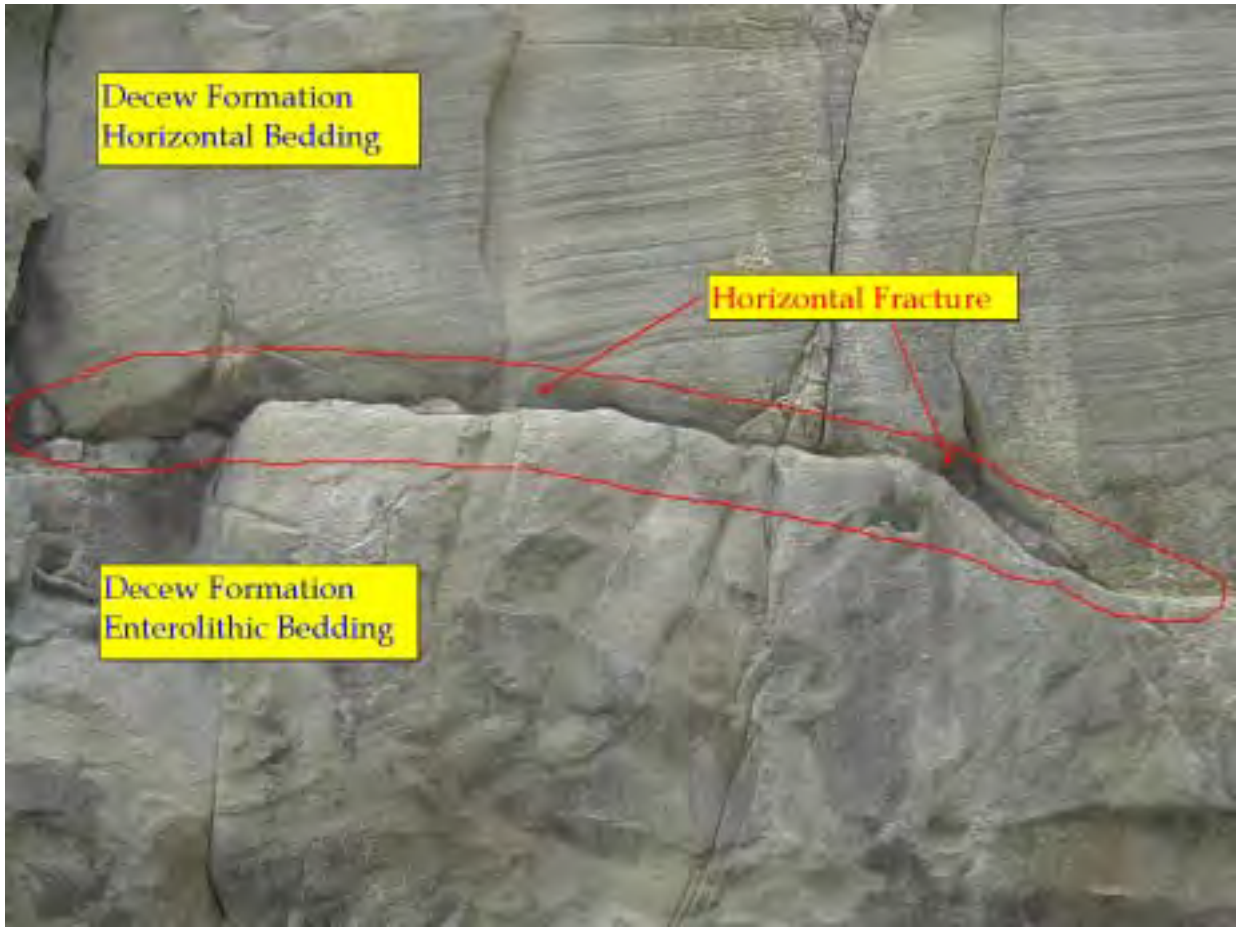
Photograph 8. Cross-bedding within the coarse-grained Gothic Hill Member of the Gasport Formation. Note the vertical joint and lack of bedding plane fractures. NYPA Access Road.



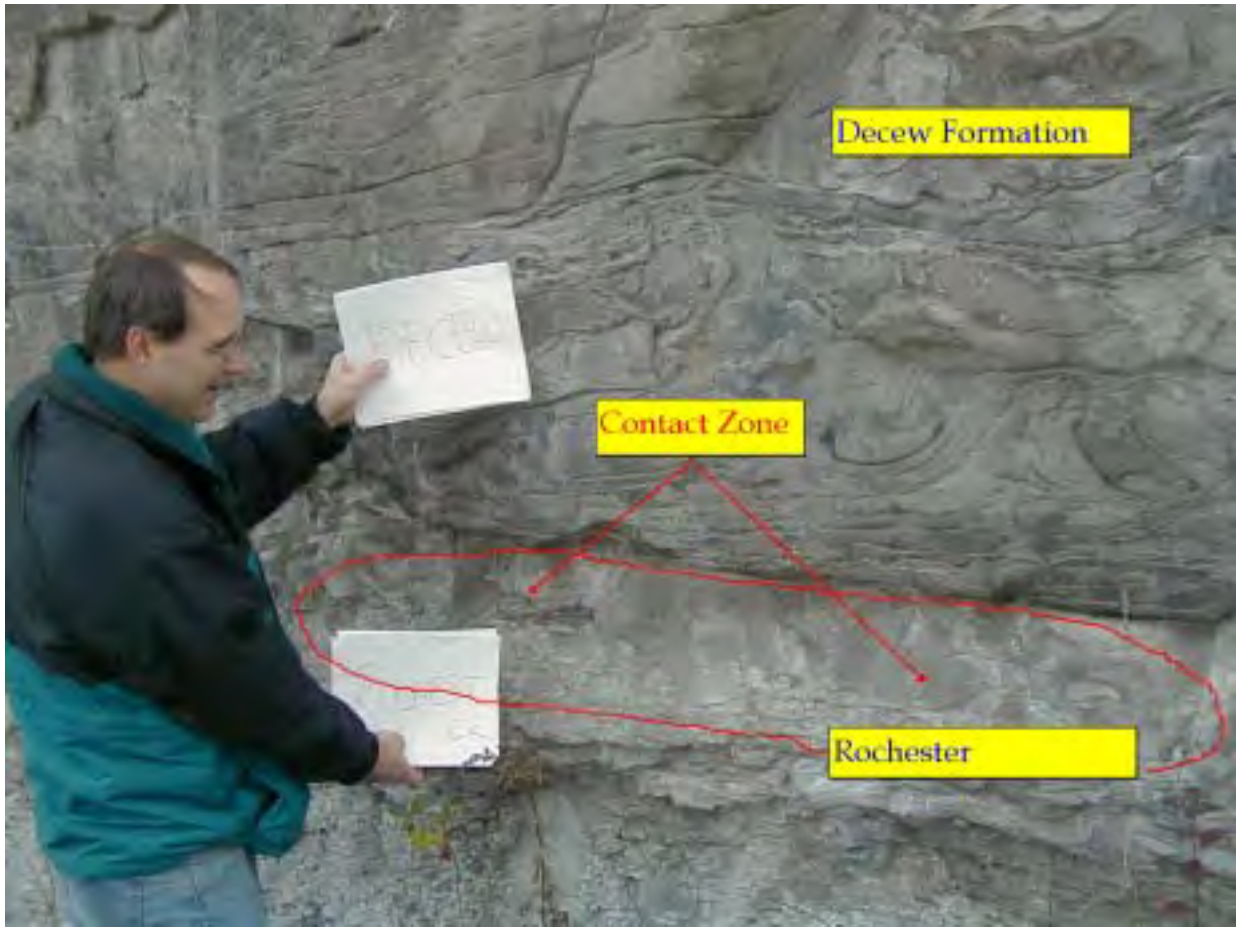
Photograph 9. Contact between the Gothic Hill Member of the Gasport Formation and the DeCew Formation. Note large vertical joint on left side of photograph. NYPA Access Road.



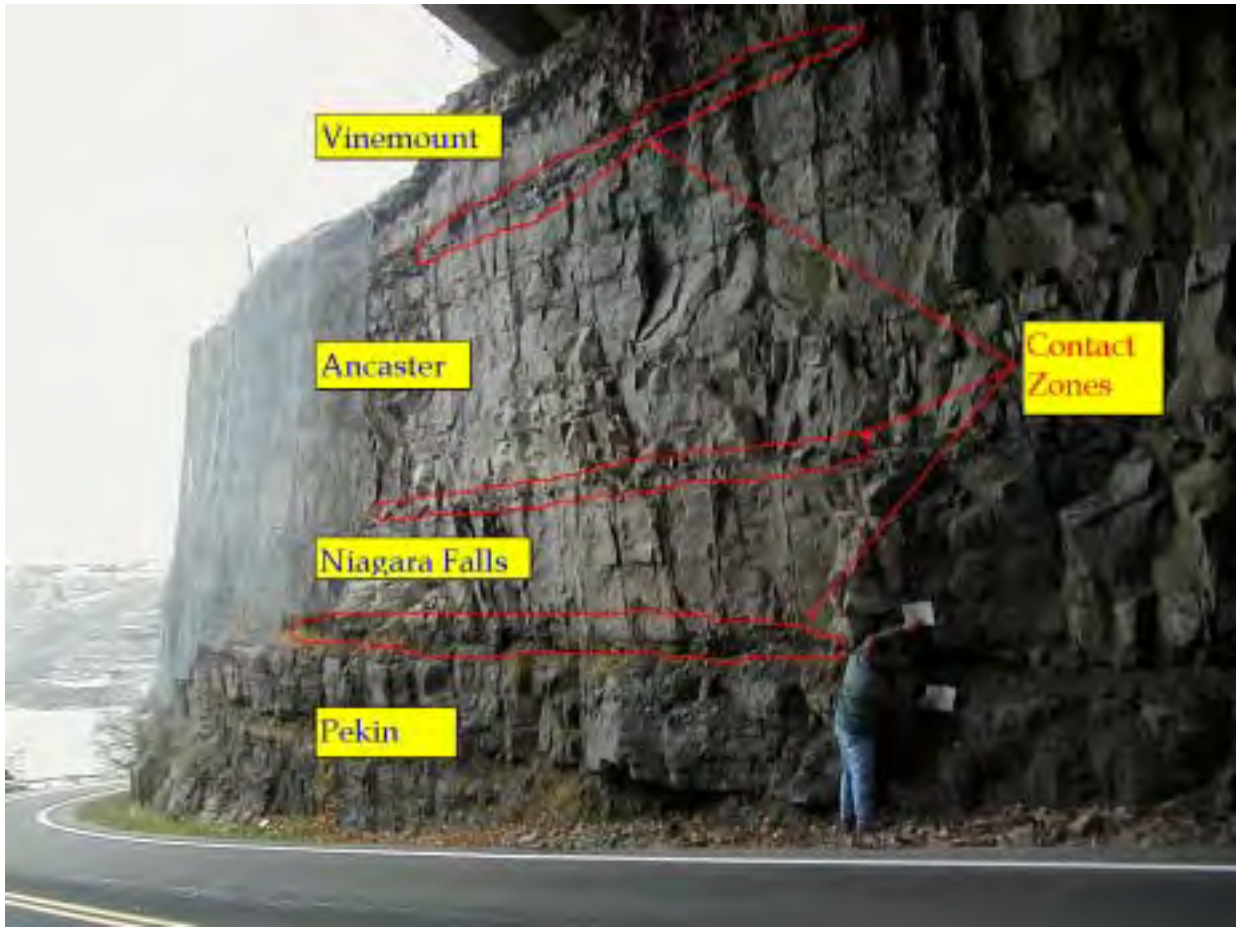
Photograph 10. Contact between Gothic Hill Member of the Gasport Formation and the DeCew Formation. Note the massive nature of each unit and overall lack of bedding plane fractures. NYPA Access Road.



Photograph 11. Bedding plane contact between near-horizontal bedding and enterolithic bedding within the DeCew Formation. NYPA Access Road.



Photograph 12. Contact between the DeCew Formation and the Rochester Shale. Note the enterolithic bedding in the DeCew Formation near the “Contact Zone” label and overlying near-horizontal bedding near the “DeCew Formation” label. NYPA Access Road.



Photograph 13. Stratigraphic section and contact zones, Goat Island Formation and Pekin Member of the Gasport Formation. NYPA Access Road.

Photograph 14. B2L core showing Vinemount Member of Goat Island Formation.

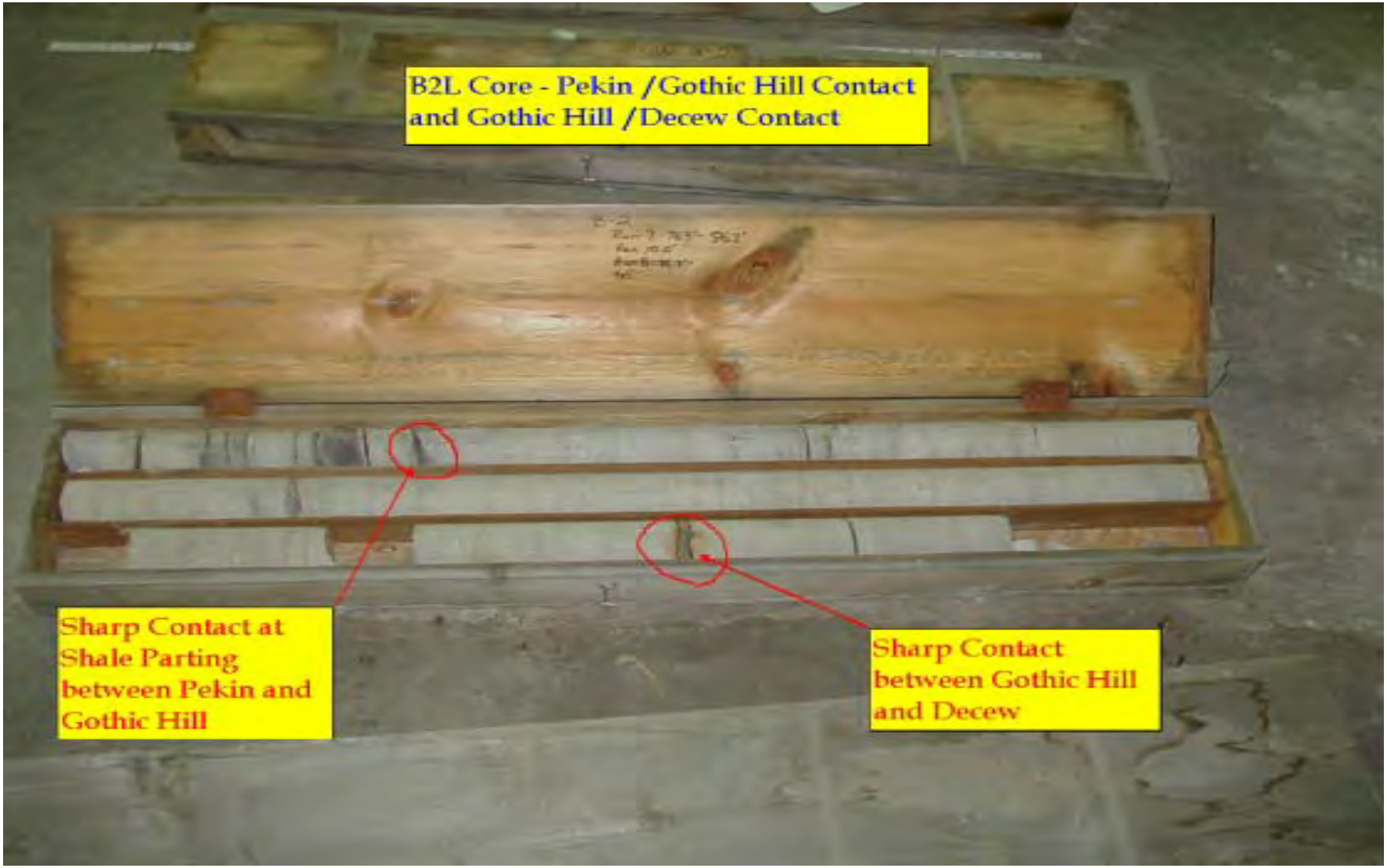
Photograph 15. B1L core showing Vinemount Member of Goat Island Formation.

Photograph 16. B1L core showing Vinemount Member / Ancaster Member contact.

Photograph 17. B2L core showing Niagara Falls Member / Pekin Member contact.

Photograph 18. B1L core showing Pekin Member of Gasport Formation.

Photograph 19. Close-up of C1L core showing Pekin Member of Gasport Formation.



Photograph 20. B2L core showing Pekin Member / Gothic Hill Member contact and Gothic Hill Member / DeCew Formation contact.

APPENDIX C

QUANTUM ENGINEERING CORPORATION ELECTROMAGNETIC BOREHOLE FLOWMETER TESTING REPORT

QEC

QEC - T - 142

Results of Field Tests with the Electromagnetic Borehole Flowmeter At the Hyde Park Landfill Site Niagara Falls, NY

by

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And
Hubert S. Pearson

November 2001

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Introduction

Quantum Engineering Corporation (QEC) conducted flowmeter tests at the Hyde Park Landfill in Niagara Falls, New York. The tests were performed under subcontract to Conestoga-Rovers & Associates, Inc. (CRA) of Niagara Falls, New York. The instrument system used, the Electromagnetic Borehole Flowmeter (EBF), was designed expressly for such tests as performed at the Hyde Park Landfill (Young and Waldrop, 1989). Data from this procedure provide a cost-effective method to define a profile of hydraulic conductivity throughout the screened or uncased portion of the saturated zone. It also provides the hydrogeologic flow conditions occurring naturally in each well. The QEC team that performs EBF tests are inventors of the instrument system. They have conducted similar tests for a wide range of geohydrology throughout the United States.

Field data were collected at 44 wells at the site during an 11-day period in August 2001. The tests were conducted according to a scope of work developed jointly by staff of QEC, CRA and S.S. Papadopulos & Associates, Inc. (SSP&A). This report presents results from the field tests as well as describes the test protocol and the EBF system used.

The Borehole Flowmeter Method

The flowmeter method represents a reasonably simple approach for assessing the relative hydraulic conductivity in porous media or flow through fractured rock at discrete positions in a screened well or uncased borehole. This method is equally effective for evaluating the direction of ambient flow caused by vertical hydrostatic pressure gradients throughout the depth of a borehole. The technique involves measuring at arbitrarily selected intervals as water is transmitted through a well under ambient and induced pumping conditions.

In principal, the flowmeter method is very straightforward. Consider the test setup for the well shown in Figure 1. When water is pumped into or from the well at a constant rate for an extended time (i.e. typically about 10 minutes), then the water surface level inside the well will adjust until it reaches equilibrium. At that time, water is being induced into (or from) the well at the same rate as that being pumped near the surface. Water is entering or exiting the well horizontally throughout the screened or open interval of the well and flowing vertically within the well. The objective is to measure the vertical distribution of the horizontal flow into or from the well. The horizontal flow rate at each stratum is indicative of the hydraulic conductivity of those strata as discussed by Molz, et.-al. (1990).

Under ideal conditions, the probe is sealed to the wall such that any vertical flow must pass through the recording zone of the meter. Then the flow into or from the well below the meter is recorded as it flows vertically in the well. For some applications, it is not possible to effect a complete seal with the wall and prevent bypass flow. For such cases, it is often desirable, but not essential, to determine the percentage of flow rate bypassing the recording section of the probe and correct the probe readings accordingly.

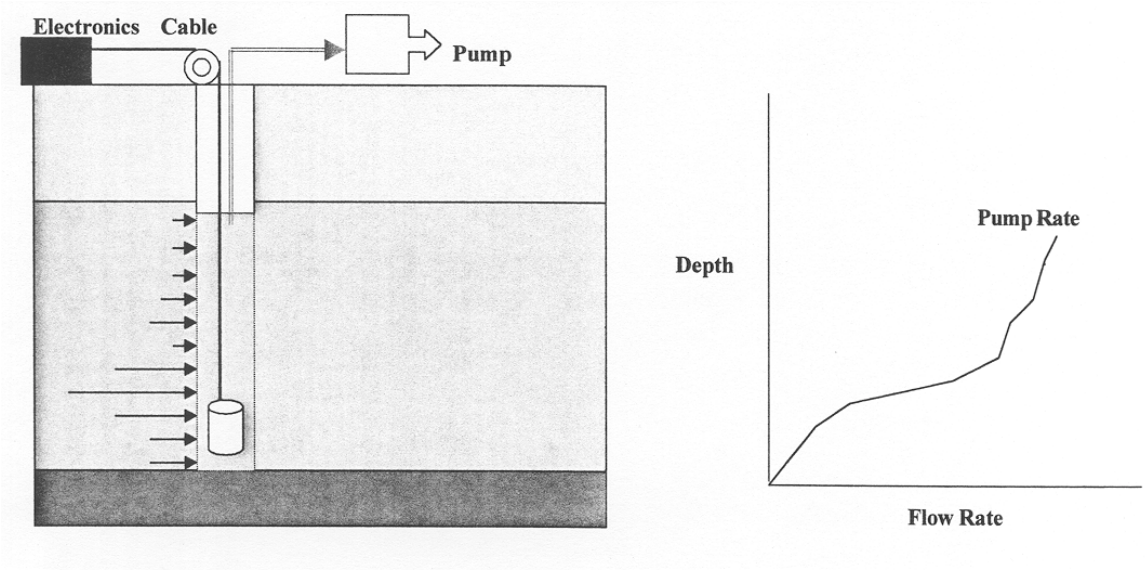

Figure 1. Apparatus and Geometry of a Borehole Flowmeter Test

A flowmeter test for a well is initiated by measuring for ambient flow throughout the screened or uncased section of the well. This is typically initiated with the flowmeter at the bottom of the screen where flow rates should be zero. The probe is then raised one increment. After any flow disturbance caused by the probe movement has subsided, the vertical flow at that station is recorded. This process is repeated throughout the entire screened or uncased region. These ambient flows reveal the presence of vertical pressure gradients, positive or negative, between strata, and provide a baseline for analyzing induced flow into the well during pumping.

Once the ambient flow pattern has been recorded, the induced flow test is initiated by pumping into or from the well at a constant rate. The water surface is monitored to determine when equilibrium conditions have been achieved. At that time, the probe is systematically moved vertically with flow rates recorded at predetermined intervals throughout the well screen or uncased region. Data at each depth are displayed on a digital readout and stored in a data file of a portable computer. These tests can be

performed with equal accuracy by injecting flow into the well at a constant rate instead of pumping.

Data analysis is also relatively simple. The lateral inflow from each stratum is calculated by successively subtracting the cumulative flow measured at those strata from the cumulative flow recorded at the level immediately below. Hydraulic conductivity can be calculated for those strata by using the Cooper-Jacob formula for horizontal flow to a well. The ratio of local hydraulic conductivity K_i to average K_{ave} for each well is computed using Equation 7 from Molz and Young (1993),

$$K_i / K_{ave} = ((\text{Delta } Q_i - \text{Delta } q_i) / \text{Delta } z) / (Q_{pump} / b) \; ; \; i = 1,2, \ldots n$$

where

Delta Q_i = Flow from the ith layer in the well;

Delta q_i = Ambient flow from the ith layer of the well;

Delta z = ith layer thickness;

Q_{pump} = Flow rate pumped from the well during the induced flow test; and

b = Aquifer thickness.

Additional details are presented in Molz, et. al., (1994).

The Electromagnetic Borehole Flowmeter

The EBF measures flow using Faraday's Law of Induction. This principal states that the voltage induced by a conductor moving at right angles through a magnetic field is directly proportional to the velocity of the conductor through the field. The flowing water is the conductor, the electromagnet generates the magnetic field, and the electrodes measure the induced voltage. The electronics attached to the electrodes transmit a voltage directly proportional to the velocity of the water flowing through the interior of the probe. The voltage produced by the water movement through the probe is insensitive to the conductivity of the water as long as the water is conductive.

This method of measuring velocity provides essentially an instantaneous response to changes in flow rates. Data are typically recorded and averaged over 60 seconds for each data point during a static test of a particular stratum. The total time required to position the probe to a desired depth, allow the flow to settle from the disturbance of movement, record a data point, and document notes is about five minutes.

The external dimension of the downhole probe is designed to fit snugly into a Schedule 40 two-inch diameter pipe. Two probes are available - one with a half-inch inside throat diameter and another with a one-inch throat diameter. The performance specifications of both probes are presented in Table 1.

Table 1: Performance Specifications of the EBF Probes

	1/2 Inch id Probe	**1 Inch id Probe**
Minimum Flow	10 mL/min (0.0026 gpm)	40 mL/min (0.011 gpm)
Minimum Velocity	0.131 cm/sec (0.0043 fps)	0.131 cm/sec (0.0043 fps)
Maximum Flow	10 L/min (2.64 gpm)	40 L/min (10.6 gpm)
Maximum Velocity	131 cm/sec (4.3 fps)	131 cm/sec (4.3 fps)

Both probes are designed such that the electromagnets, electrodes and electronic components are fixed in place, tested and then potted with a watertight epoxy. The probes have no moving parts and have smooth exterior surfaces for easy cleaning.

Because the EBF can accurately record extremely low flow rates, it is possible to record ambient flow rates occurring naturally in wells, as well as the influx of flows during pumping. The flowmeter measures flow in either direction with equal accuracy.

This new instrument system has proved to be useful in support of environmental groundwater investigations throughout the USA during the seven years that it has been produced commercially. The publications by Young, et al (1998), Molz, et al (1994), Hutchins and Acree (2000) and Molz and Young (1993) provide examples of results from several such applications available in the scientific literature. Examples of data and analysis methods are also presented in the QEC web site at www.qec-ebf.com.

The downhole probe, cable, and aboveground electronics box is shown in Figure 2. The compactness of the system makes it easy to transport, ship and handle in the field.

Figure 2: The Electromagnetic Borehole Flowmeter System

Test Results

Hubert Pearson of QEC, a member of the invention team and experienced in conducting EBF tests, served as test engineer. Staff of CRA and SSP&A assisted throughout in conducting these tests. Jon Williams of CRA and Christopher Neville of SSP&A provided guidance for test objectives to assure that test data would be consistent with their needs for defining the hydrogeology at this site.

The flowmeter test was performed with the QEC EBF system using the one-inch inside diameter (i.d.) probe. A one-half inch diameter probe was available, but was not used. Although the one-half inch probe provides better resolution for ambient flow, it was found in the field that the larger i.d. probe is more effective in uncased boreholes where it is sometimes not possible to achieve a complete seal to the walls. The impact of the coarser resolution of the larger i.d. probe on the identification of flow zones was considered to be negligible. This was because the primary results used for the identification of the flow zones were obtained under injection conditions. The injection testing was conducted at rates that were much higher than the 0.011 gpm lower flow limit for the one-inch probe.

Calibration of the EBF system was checked prior to the initial test, but no adjustments were required. Experience has shown that the EBF system is not subject to calibration drift. This is attributable to the design features of the electronics and the fabrication method by which the electronics of the probe are encased in watertight epoxy. The calibration curve for the EBF system used is presented in Figure 3.

The EBF system produced a linear signal throughout the range of flows tested. Upward flows were designated as positive as the sign convention used throughout all testing. QEC furnished the EBF system, and a water level measuring device. CRA provided a portable generator and a potable water supply used for injection during the test.

The wells were drilled to a pre-determined depth before solid steel casings were installed in the upper portion of each well. The EBF tests were performed in the lower uncased

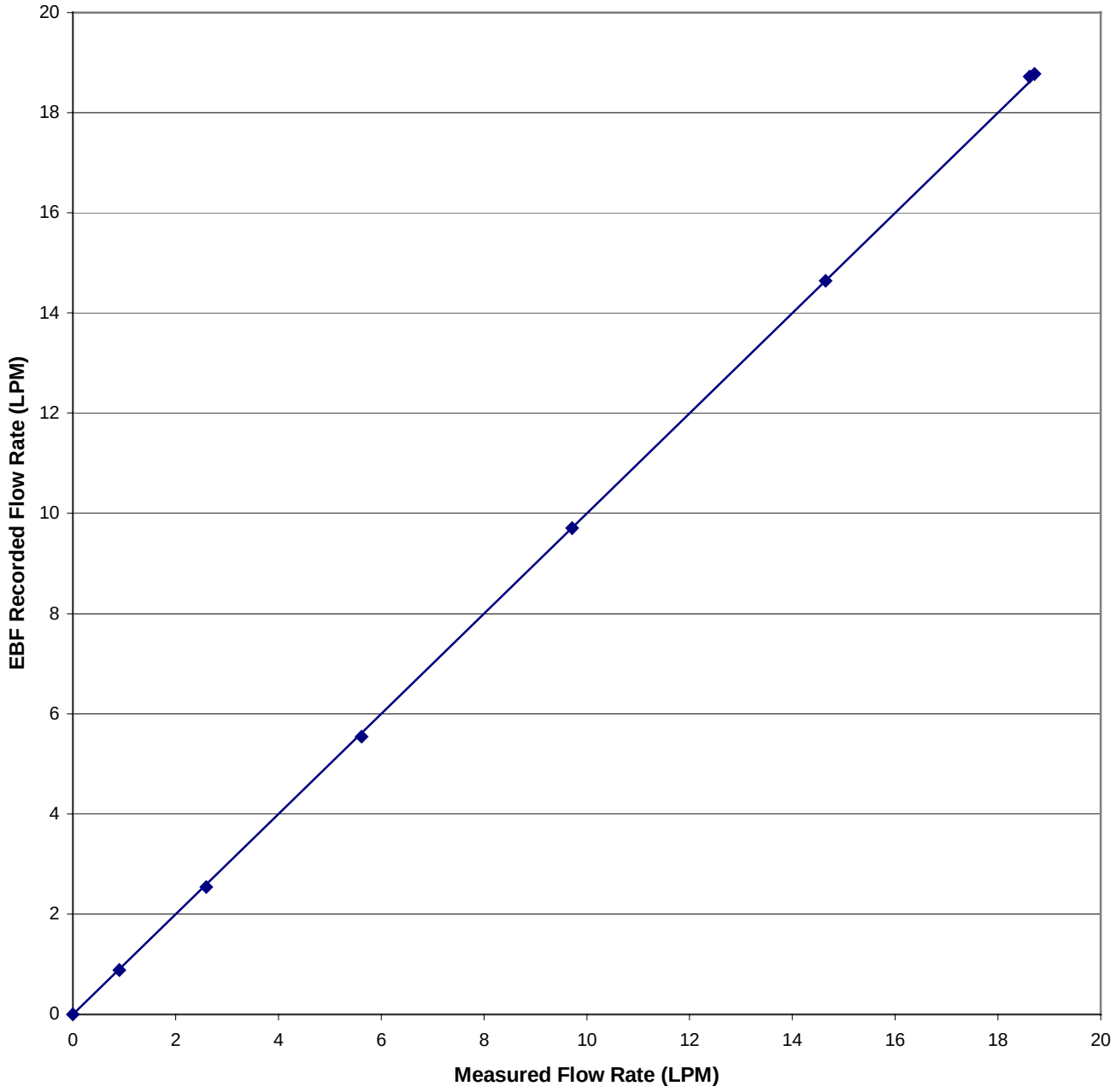

Figure 3: Calibration Curve for the One Inch EBF System

portion of rock. The wells tested fell into three classes depending upon the depth of each well. Wells were labeled U, M, and L denoting the uncased portion in the Upper, Middle, and Lower zones, respectively. The uncased portion of the wells of the Upper zone typically extended between depths of 25 and 50 feet below grade, the Middle zone between 50 and 80 feet, and the Lower zone between 80 and 110 feet, depending on the depth of the overburden. Five new monitoring wells, with depths of up to 50 feet, were also tested. The locations of all wells tested relative to the Hyde Park Landfill are shown in Figures 4 through 6.

The solid casings of the wells were nominally 3 7/8 inches in diameter. This precluded use of the inflatable packer since this is slightly less than the outside diameter of the inflatable packer for the EBF downhole probe. Instead of using the packer to prevent bypass flow around the exterior of the probe, a collar with a hard rubber outer ring cut to the approximate size of the uncased borehole was used to restrict vertical flow around the probe. This collar restricted much of the vertical flow, but being of a fixed diameter in an uncased hole, the seal was sometimes incomplete. Nevertheless, this approach was usually adequate for isolating flow rates into or from major fractures during ambient and injection testing. Since the objective of the flowmeter testing was to identify flow zones, no attempt was made to correct probe readings to account for leakage around the probe.

The test for each well was initiated with a test of ambient flow in the well. This was followed by an induced flow test. Water was injected at a constant rate instead of pumping for the induced flow test. Equilibrium conditions were established by injecting water into the well for about 10 minutes at a low sustained flow rate of about 1.0 gpm or less. This provided a vertical profile of flow rate throughout the uncased interval of the well. Well parameters including the effect on water surface due to injecting water are shown in Table 2. The vertical profile of flow rate combined with the ambient flow rate for each well provided the location and relative importance of fractures throughout the uncased portion of each well. The engineers also attempted to test well J1L, but the test was aborted when they encountered an obstruction at a depth of 95 feet. However, a slug test conducted at the time indicated that this well was very tight.

A discrepancy exists between the recorded injection flow rate and the maximum flow rate recorded by the flowmeter at the uppermost test measurement for several wells. This was the case for four of the five monitoring wells tested. This discrepancy is likely caused by an incomplete seal with the wall to prevent bypass flow. As long as the percentage of bypass flow was reasonably consistent, then the recorded flow profile is adequate for predicting the location of significant fractures. An abrupt change in the flow rate recorded between different depths indicates that flow has entered or exited the well. Bypass flow may affect the magnitude of the recorded flow rate, but not the percentage change between stations. However, in such cases, some discretion is advised when interpreting results.

Graphs of the vertical profile of induced and ambient flow rates for each well are presented in Appendix A. The profiles of ambient and induced flow rates were plotted as recorded. Whenever ambient flow rates were considered significant, a profile of Net Induced Flow Rate was computed by subtracting ambient flow rate from the induced flow at corresponding depths. Each graph also contained an additional profile that included QEC's interpretation of the data. This profile is intended to eliminate such effects as variations in cross-sectional diameter of the uncased borehole and other data anomalies. The Interpreted profile reflects an intended correction to the Net Induced profile.

Each graph also includes notation based on the authors' interpretation of fracture locations, explanation of unusual data, or other information noted while conducting the test or analyzing the data. Much of this information is based on the experience of the authors, but is obviously open to different interpretations of others. It is included to assist those using these data in conjunction with results from other geophysical tests. Combining results from the EBF tests with those from geophysical tests should provide hydrogeologists with a reasonable understanding of the hydrogeology in the vicinity of each well.

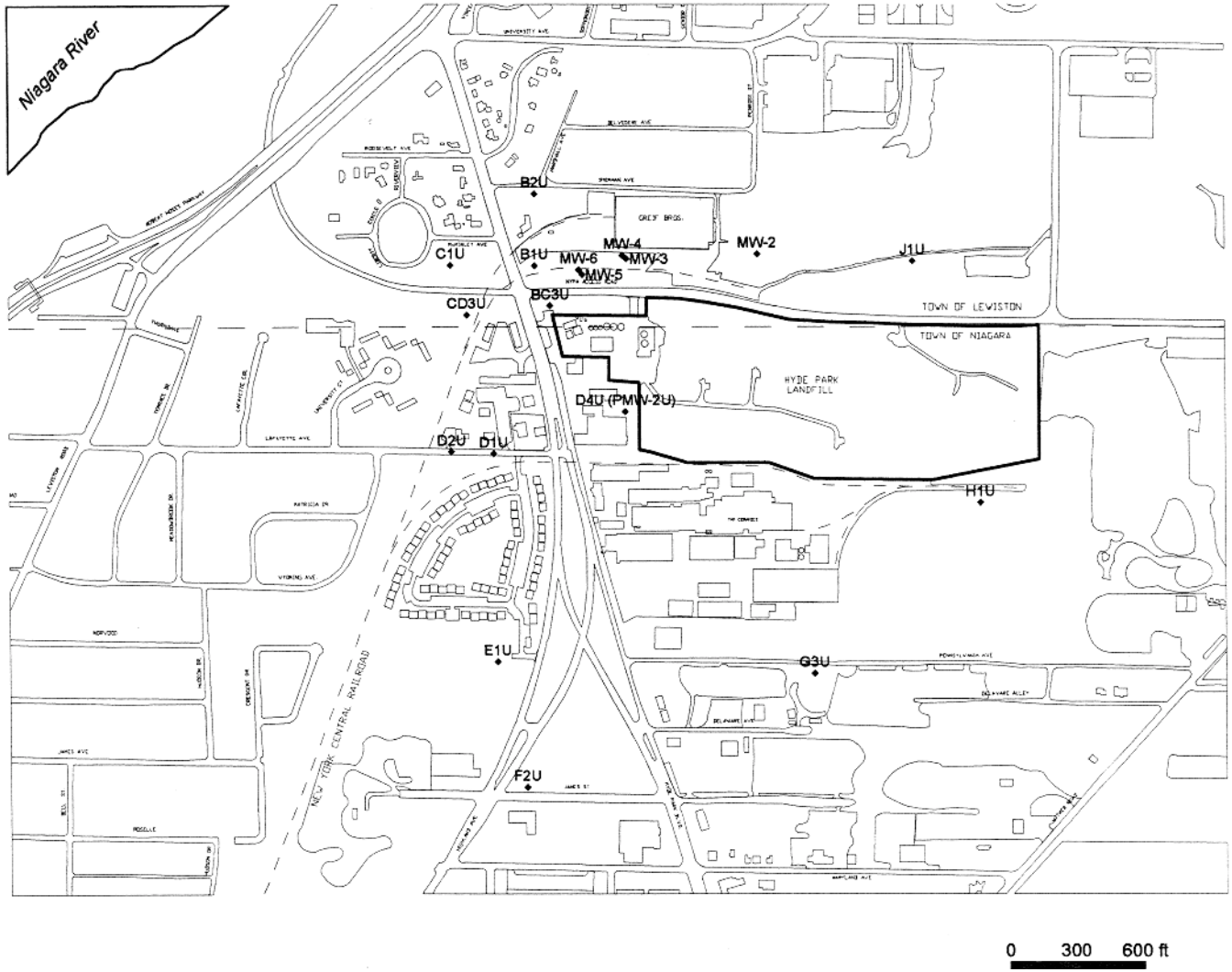

Figure 4: Location of Upper Zone Wells Tested

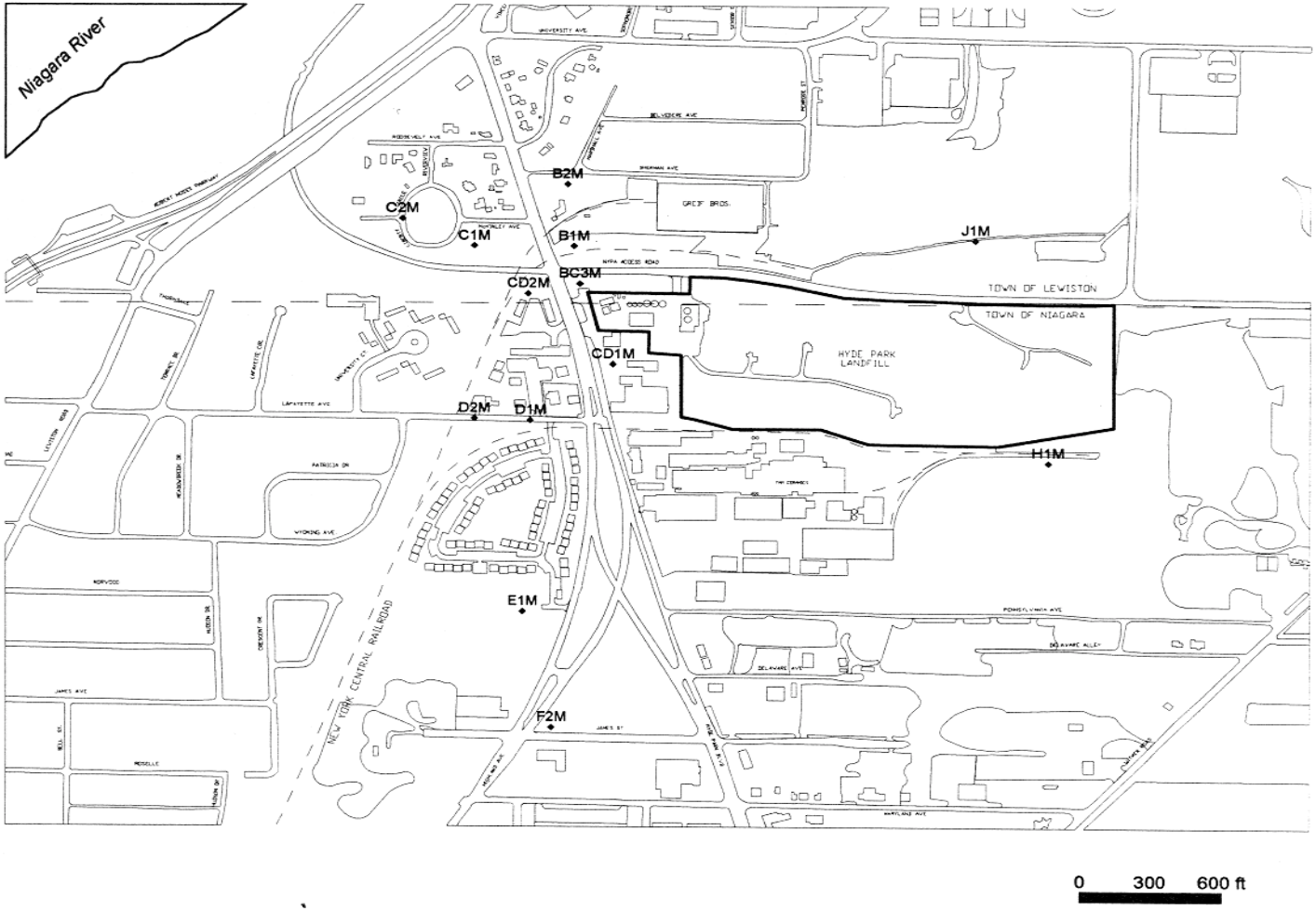

Figure 5: Location of Medium Zone Wells Tested

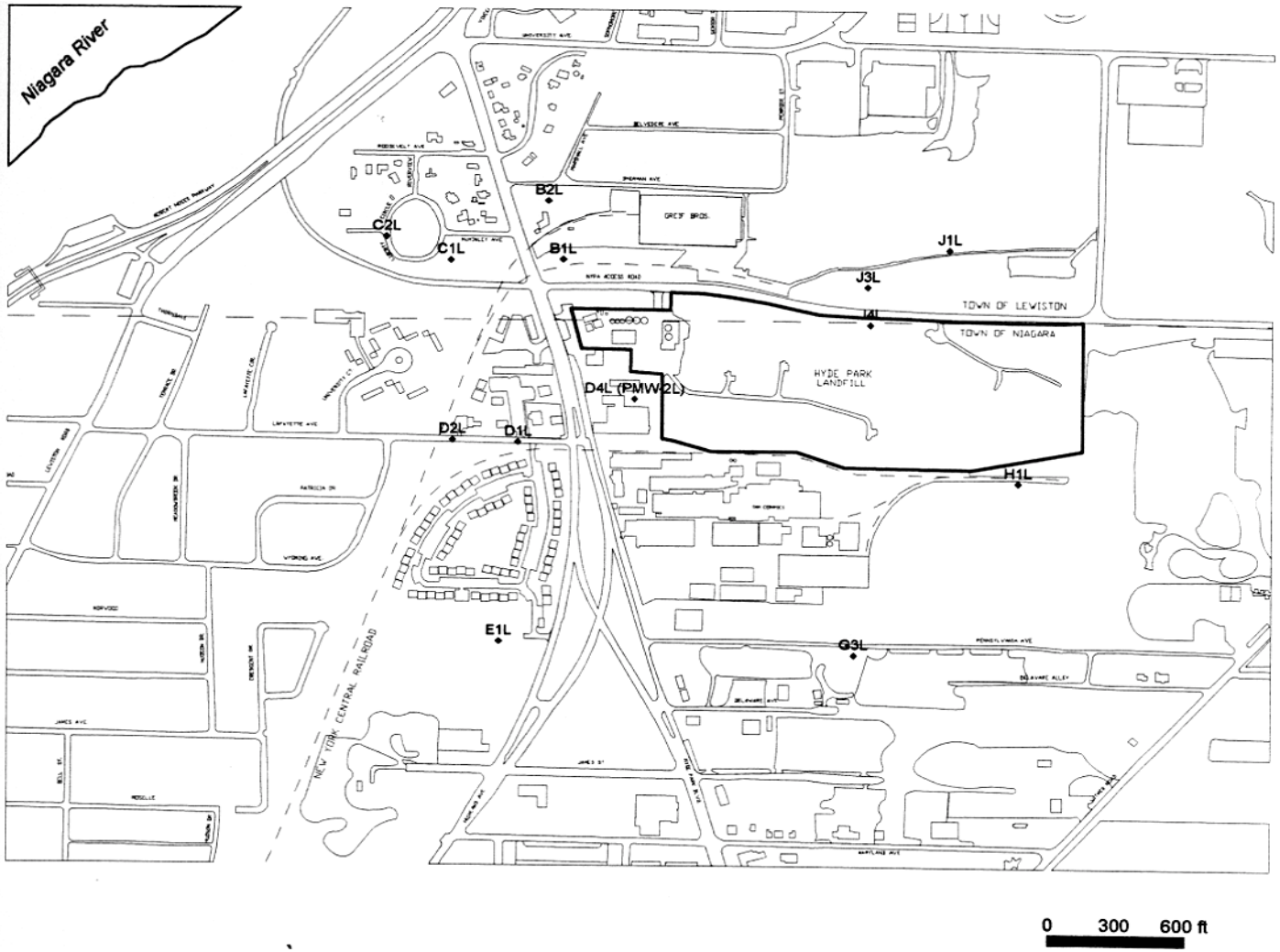

Figure 6: Location of Lower Zone Wells Tested

Table 2: Parameters of Wells Tested

Well No.	Bottom of Casing (Note 1) (ft.)	Bottom of Well (Note 1) (ft.)	Ambient Flow Direction	Injection Test Successful (Note 2)	Static Depth to Water (ft.)	Injected Depth to Water (ft.)	Injection Rate (gpm)
B1L	87	107	Negligible	No	49.05	-	-
B1M	60	85	Negligible	Yes	43.40	42.90	0.87
B1U	32	60	Negligible	Yes	25.63	24.30	1.90
B2L	78	98	Negligible	No	48.70	-	-
B2M	52	75	Negligible	Yes		42.60	2.85
B2U	27	51	Down	Yes	26.95	20.85	0.80
BC3M	66	87	Negligible	Yes	52.14	49.60	0.34
BC3U	35	62	Negligible	No	29.08	-	-
C1L	85	103	Negligible	Yes	55.00	53.20	3.4
C1M	59	81	Negligible	Yes	49.15	48.55	3.4
C1U	31	58	Down	Yes	28.60	28.60	1.8
C2L	80	101	Negligible	Yes	49.40	38.30	0.30
C2M	56	80	Negligible	Yes	44.24	29.60	0.20
CD1M	64	88	Negligible	Yes	52.08	51.70	0.33
CD2M	64	90	Negligible	Yes	53.45	53.45	0.34
CD3U	28	60	Negligible	Yes	28.33	13.35	0.35
D1L	86	110	Negligible	No	61.00	11.88	0.1
D1M	50	86	Negligible	Yes	47.08	46.83	5.9
D1U	20	50	Down	Yes	15.58	3.40	5.9
D2L	88	110	Negligible	No	55.70	-	-
D2M	48	87	Up	Yes	43.78	43.53	0.34
D2U	13	48	Down	Yes	13.30	12.05	0.30
D4L	98	128	Negligible	No	61.94	N/A	0.30
D4U	21	55	Negligible	Uncertain	17.28	16.85	0.52
E1L	98	121	Negligible	No	46.29	28.40	0.24
E1M	56	96	Negligible	No	49.91	-	0.27
E1U	21	56	Down	Yes	20.24	19.33	3.8
F2L	102	126	Negligible	No	40.95	-	-
F2M	61	99	Negligible	Yes	52.12	51.65	0.29
F2U	7	57	Down/Up	Yes	22.40	22.11	0.32
G3L	131	150	Negligible	Yes	37.15	36.85	0.34
G3U	15	66	Down	Yes	28.95	27.85	0.48

Table 2: Parameters of Wells Tested (Continued)

Well No.	Bottom of Casing (Note 1) (ft.)	Bottom of Well (Note 1) (ft.)	Ambient Flow Direction	Injection Test Successful (Note 2)	Static Depth to Water (ft.)	Injected Depth to Water (ft.)	Injection Rate (gpm)
H1L	130	145	Negligible	Yes	62.90	49.00	0.16
H1M	60	129	Negligible	Yes	65.28	63.10	1.30
H1U	15	59	Negligible	Yes	16.73	14.78	1.40
J1M	50	101	Up	Yes	51.03	50.10	5.1
J1U	18	47	Down	Yes		16.32	0.39
J3L	103	123	Down	Yes	44.99	42.15	0.33
J4L	103	122	Negligible	Yes	41.84	41.10	0.30
MW 2	23	35	Down	Yes	23.90	34.0	1.13
MW 3	35	51	Down	Yes	35.75	33.6	0.75
MW 4	34	50	Negligible	Yes	36.60	34.0	0.30
MW 5	37	52	Down	Yes	40.40	38.7	1.76
MW 6	37	52	Negligible	Yes	39.55	31.2	2.30

1) Well depths shown are approximate based on measurements from the top of casing during EBF tests.
2) An unsuccessful injection test usually indicates the well would not accept water at a sustained rate. See notes on graphs of the profile of flow rates in Appendix A for an explanation for individual wells.

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Appendix A

Profiles of Ambient and Induced Flow Rates

Figure A-1: Profile of Flow Rate in Well B1L

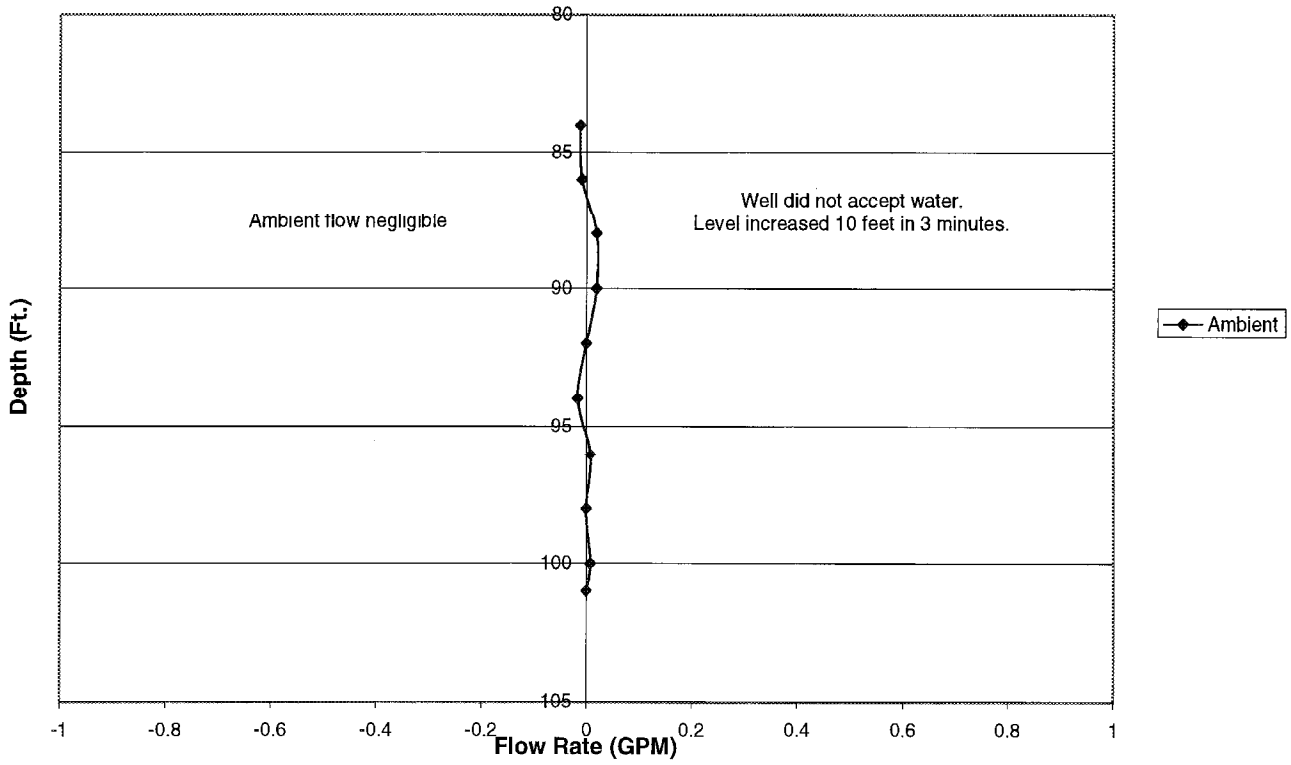


Figure A-2: Profile of Flow Rates in Well B1M

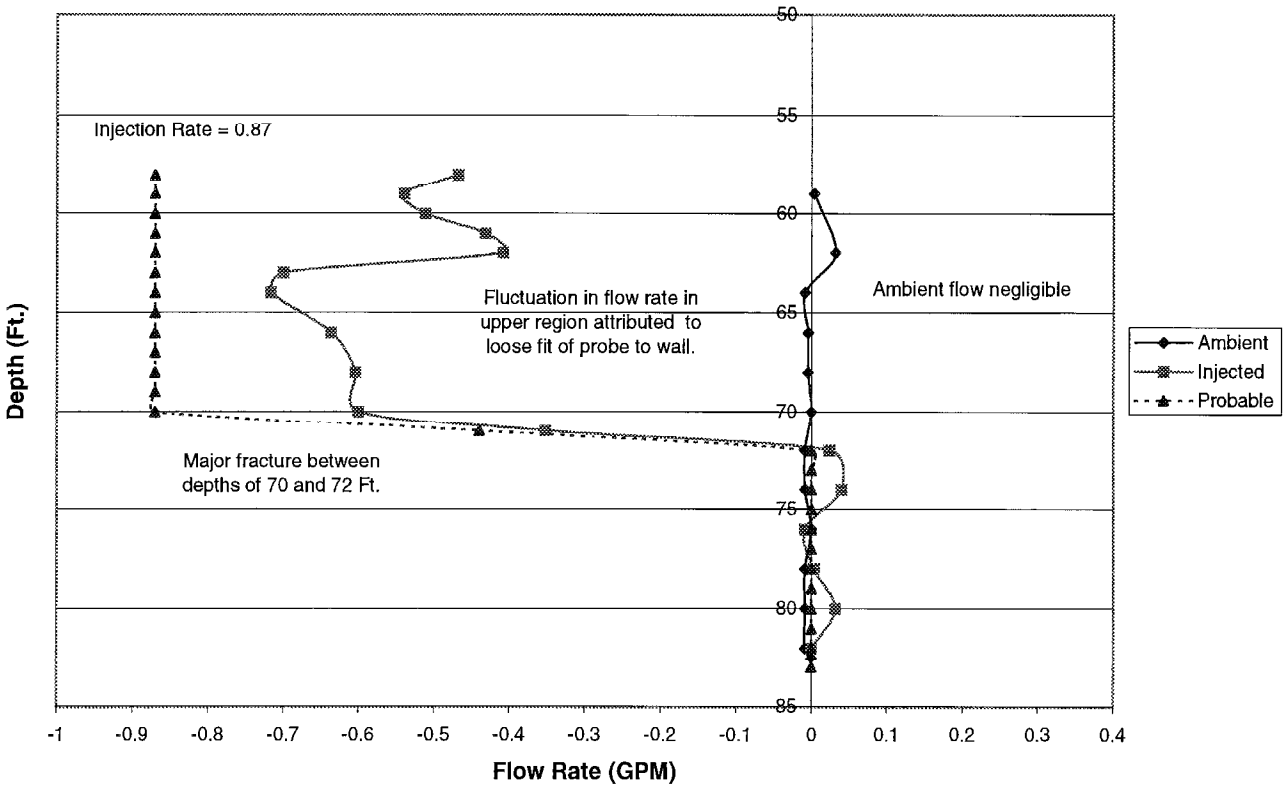


Figure A-3: Profile of Flow Rates in Well B1U

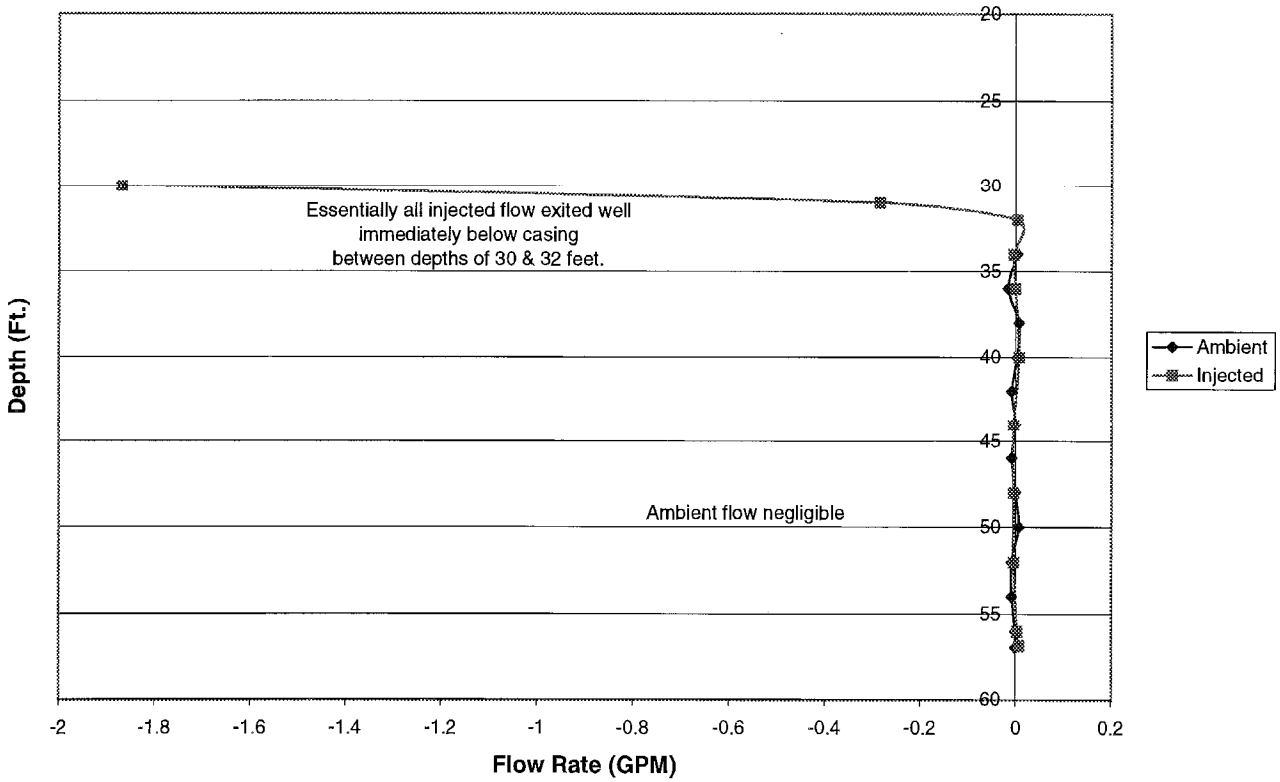


Figure A-4: Profile of Flow Rates in Well B2L

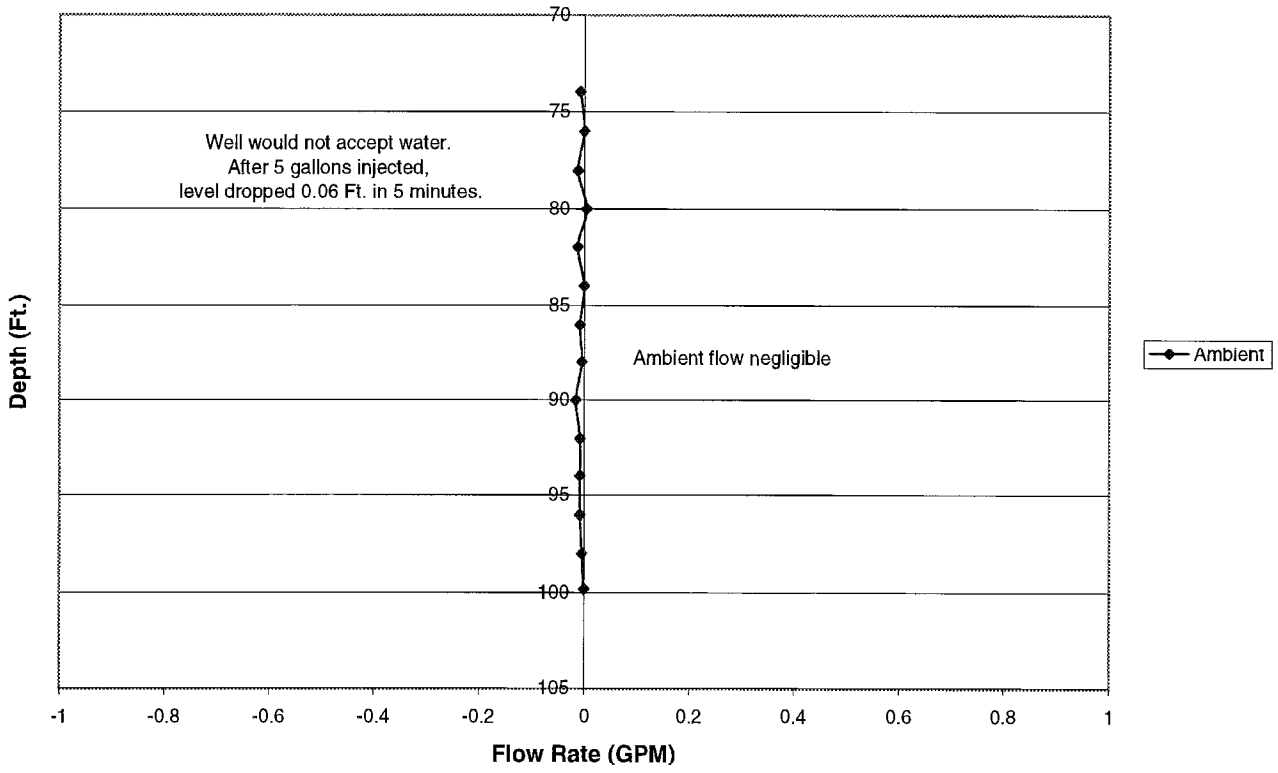


Figure A-5: Profile of Flow Rates in Well B2M

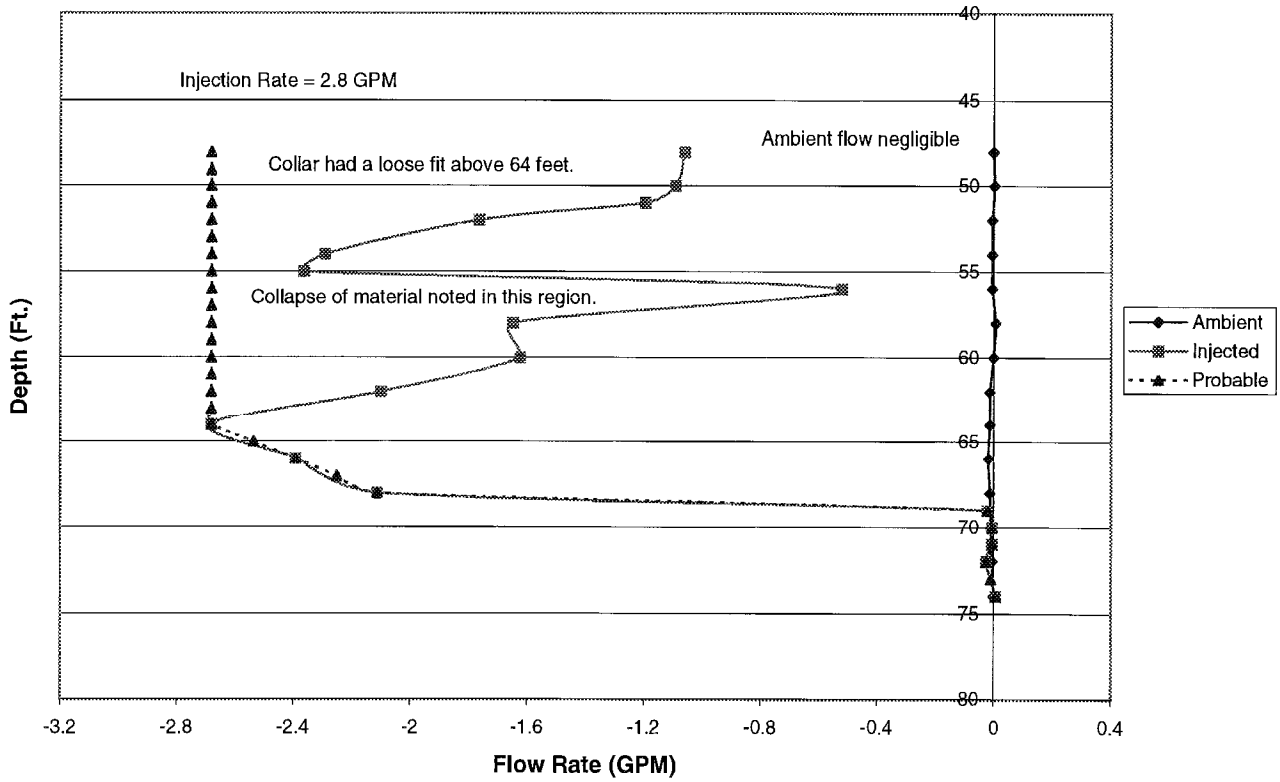


Figure A-6: Profile of Flow Rates in Well B2U

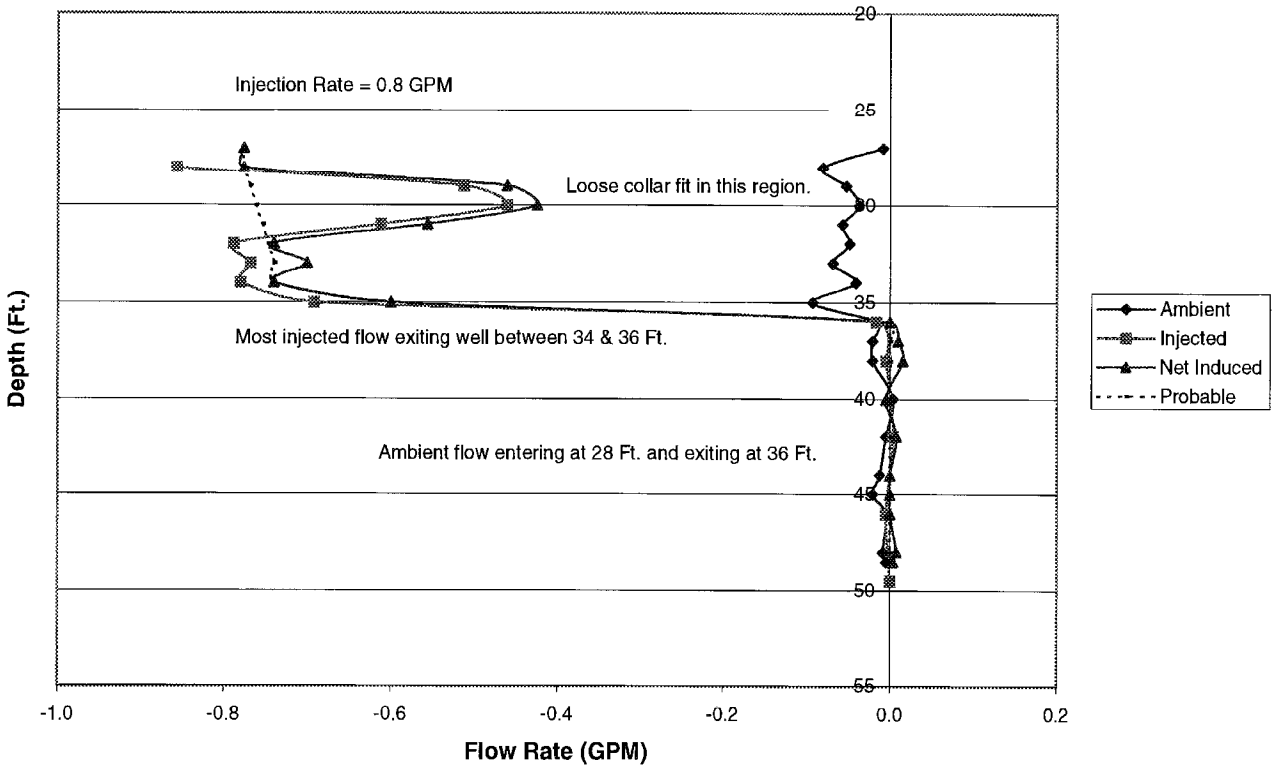


Figure A-7: Profile of Flow Rates in Well BC3M

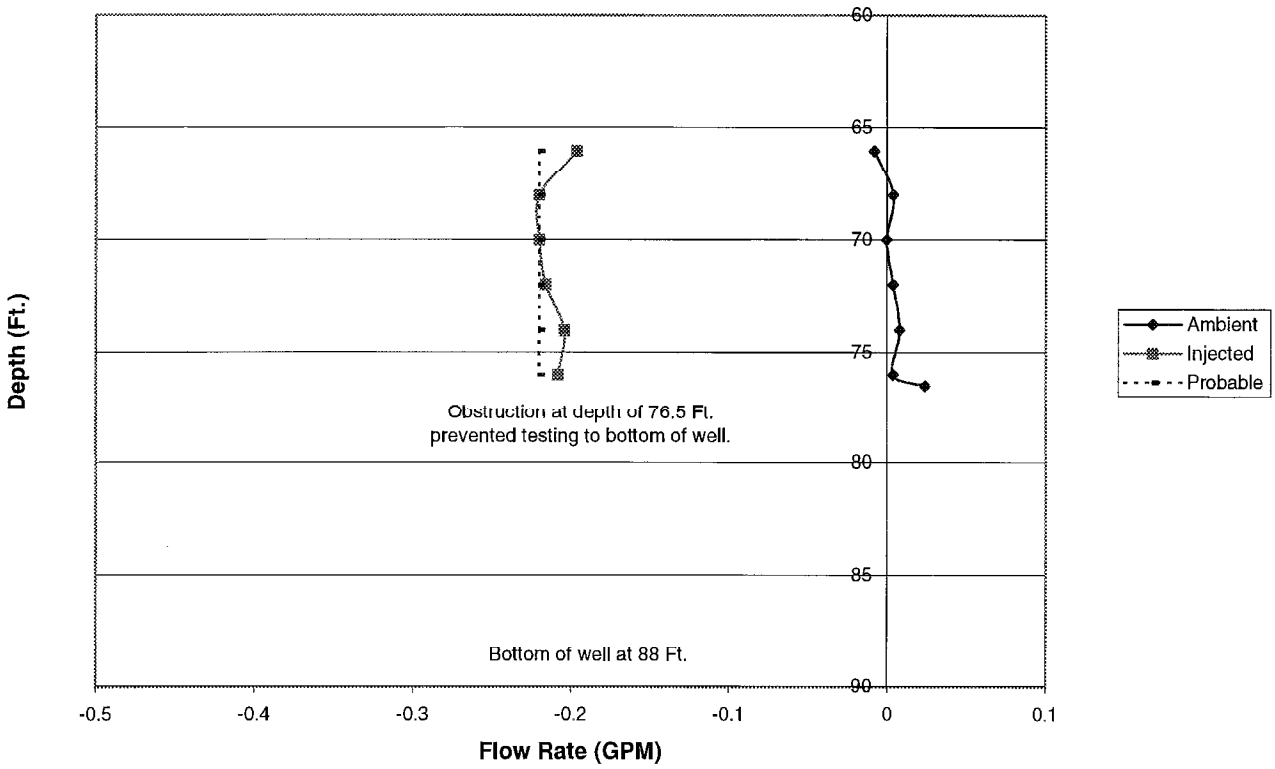


Figure A-8: Profile of Flow Rate in Well BC3U

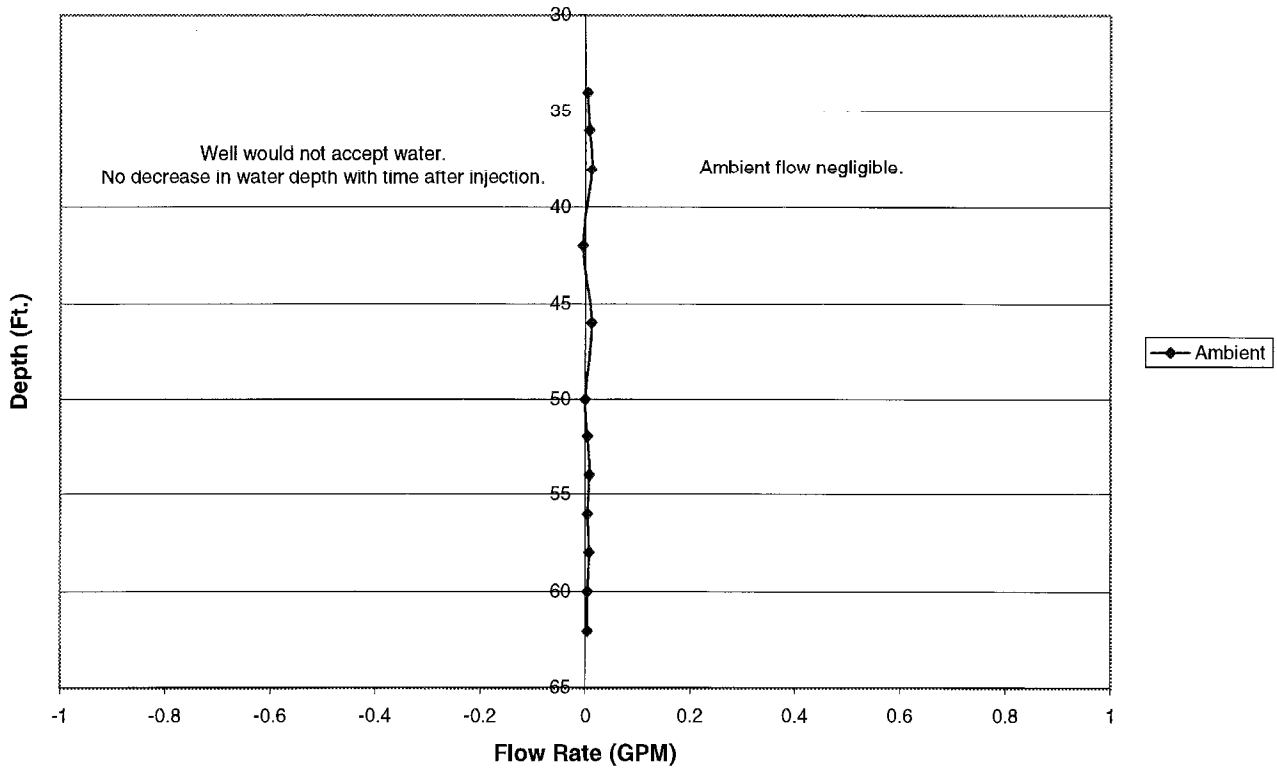


Figure A-9: Profile of Flow Rates in Well C1L

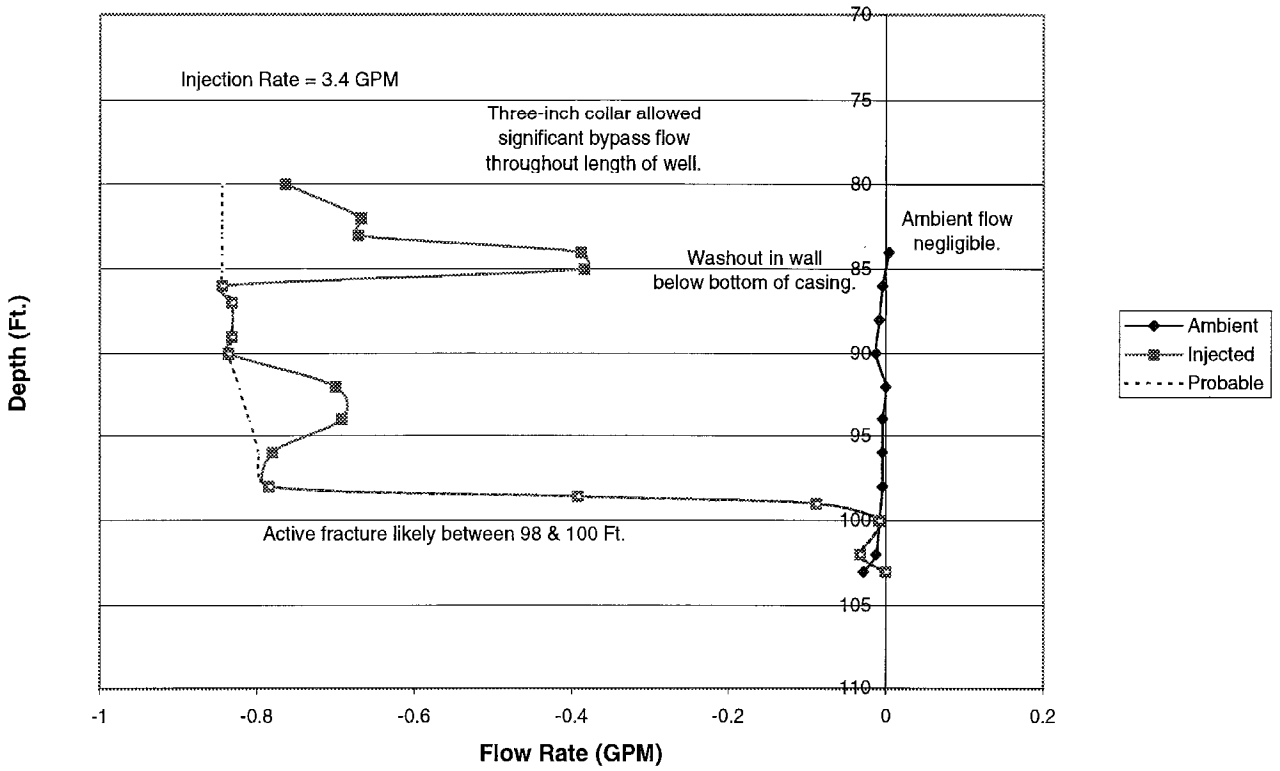


Figure A-10: Profile of Flow Rates in Well C1M

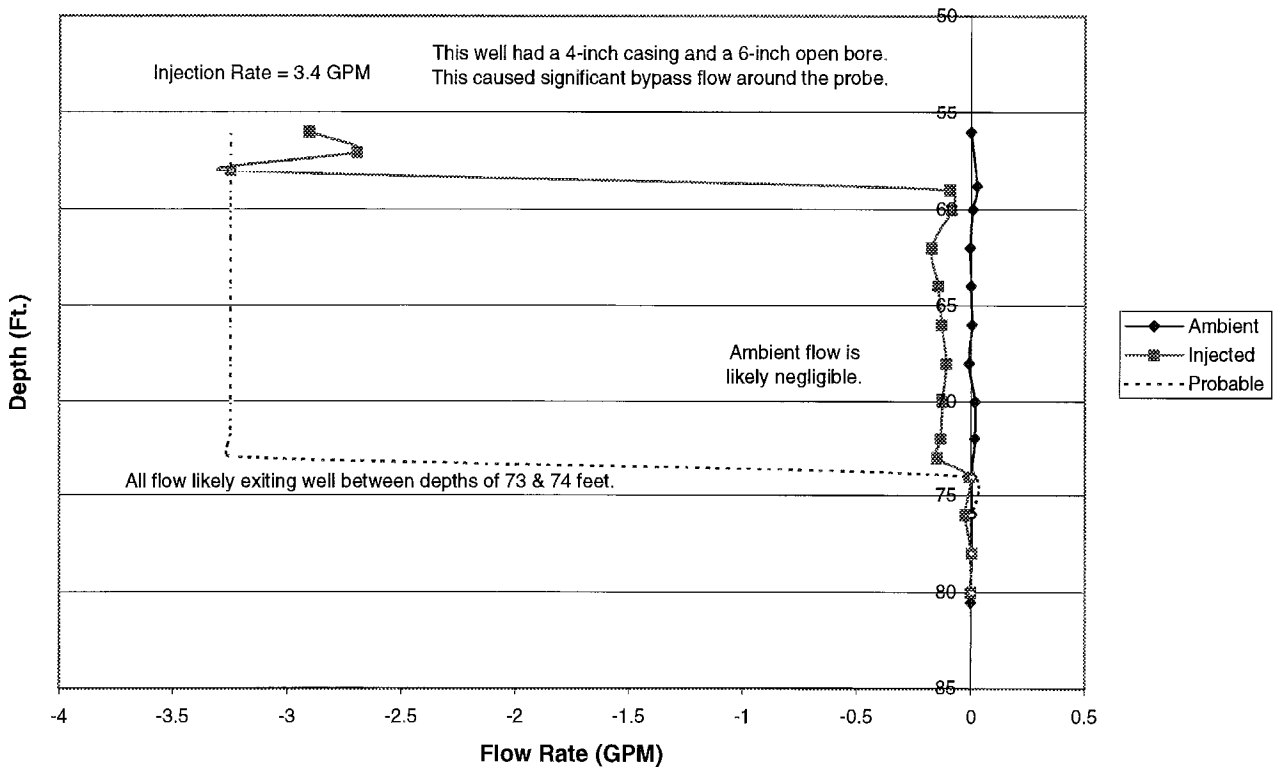


Figure A-11: Profile of Flow Rates in Well C1U

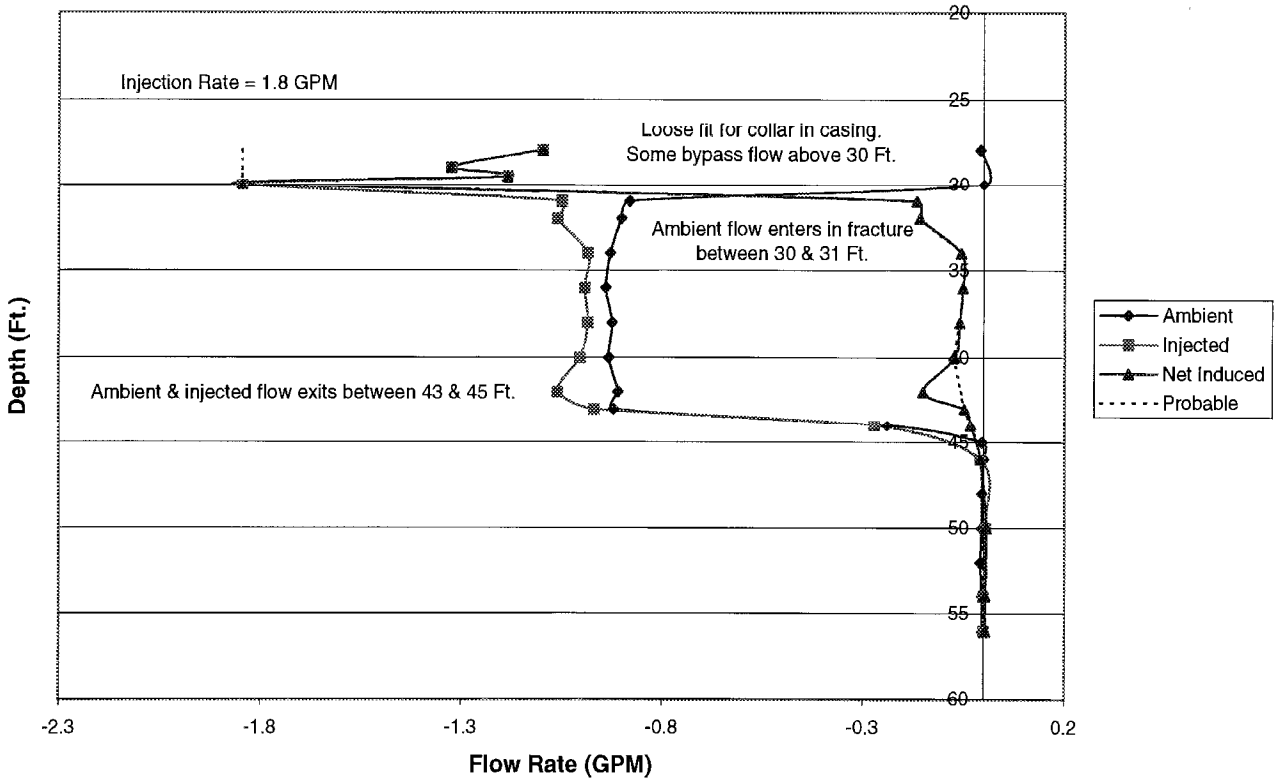


Figure A-12: Profile of Flow Rates in Well C2L

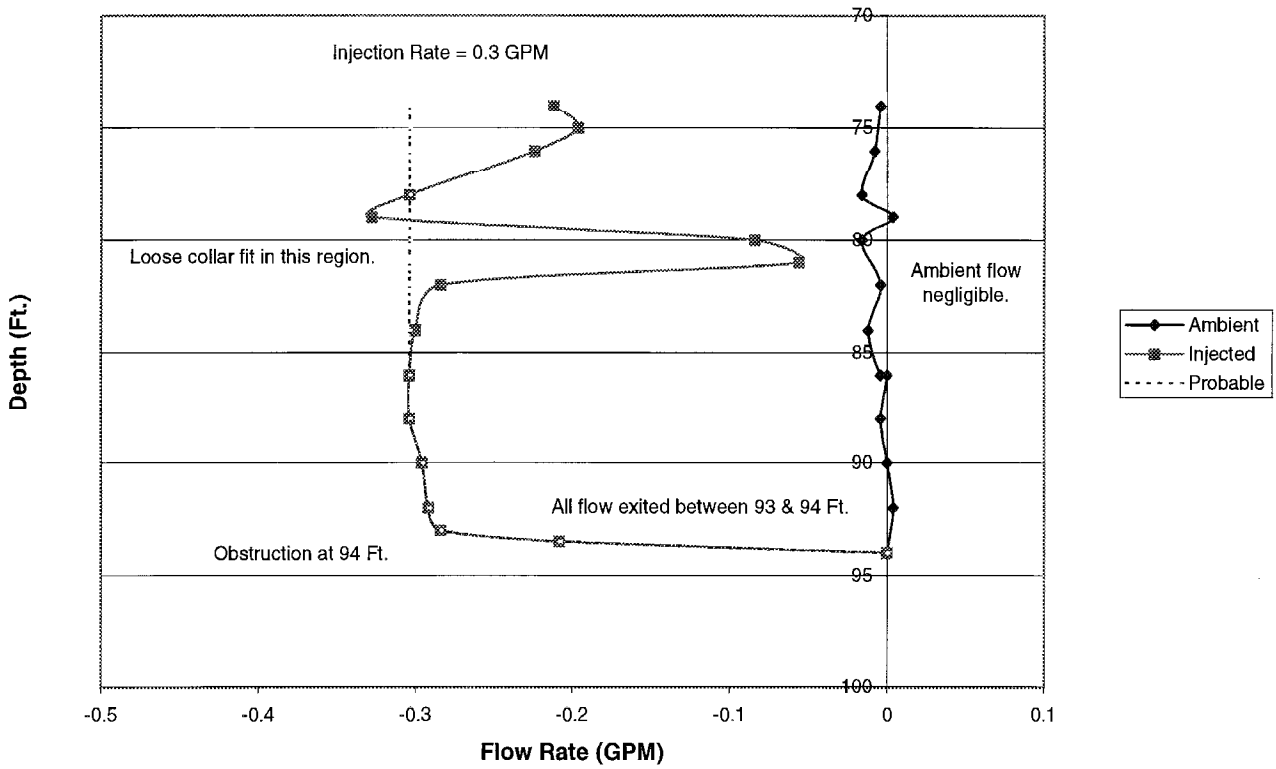


Figure A-13: Profile of Flow Rates in Well C2M

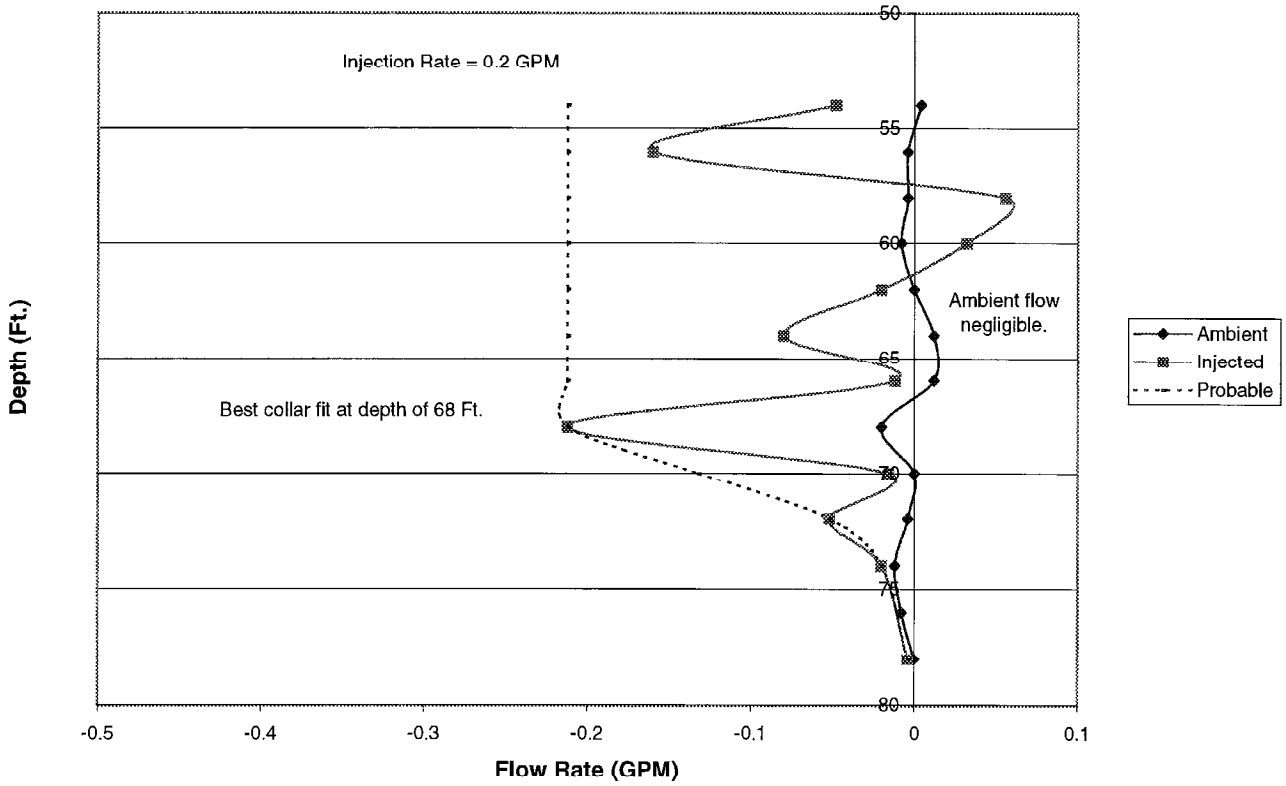


Figure A-14: Profile of Flow Rates in Well CD1M

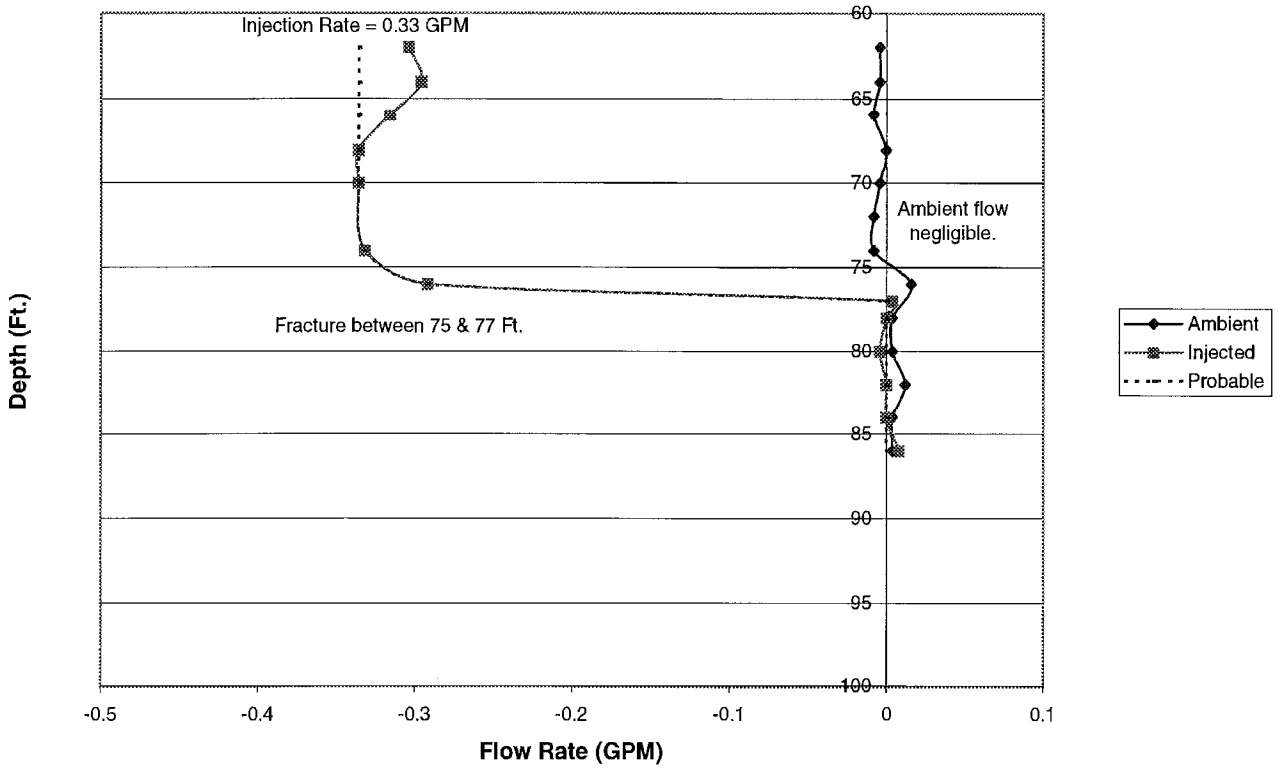


Figure A-15: Profile of Flow Rates in Well CD2M

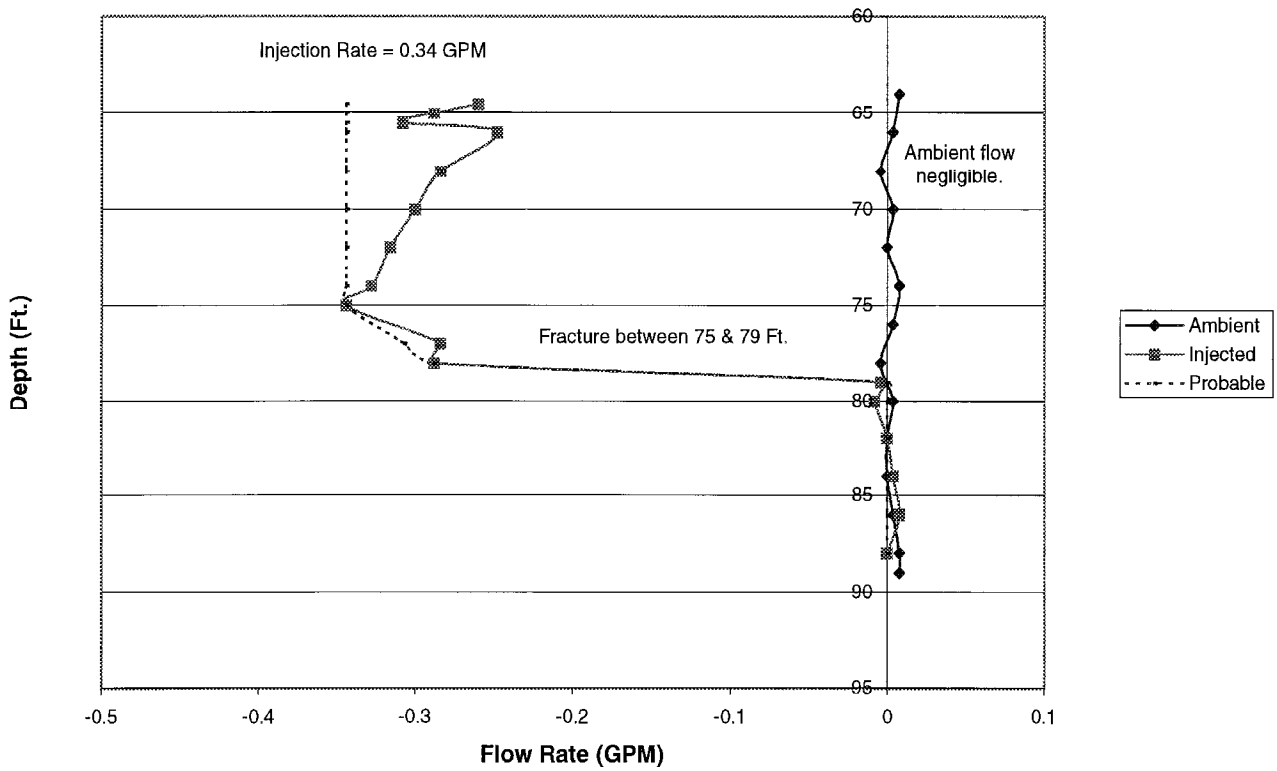


Figure A-16: Profile of Flow Rates in Well CD3U

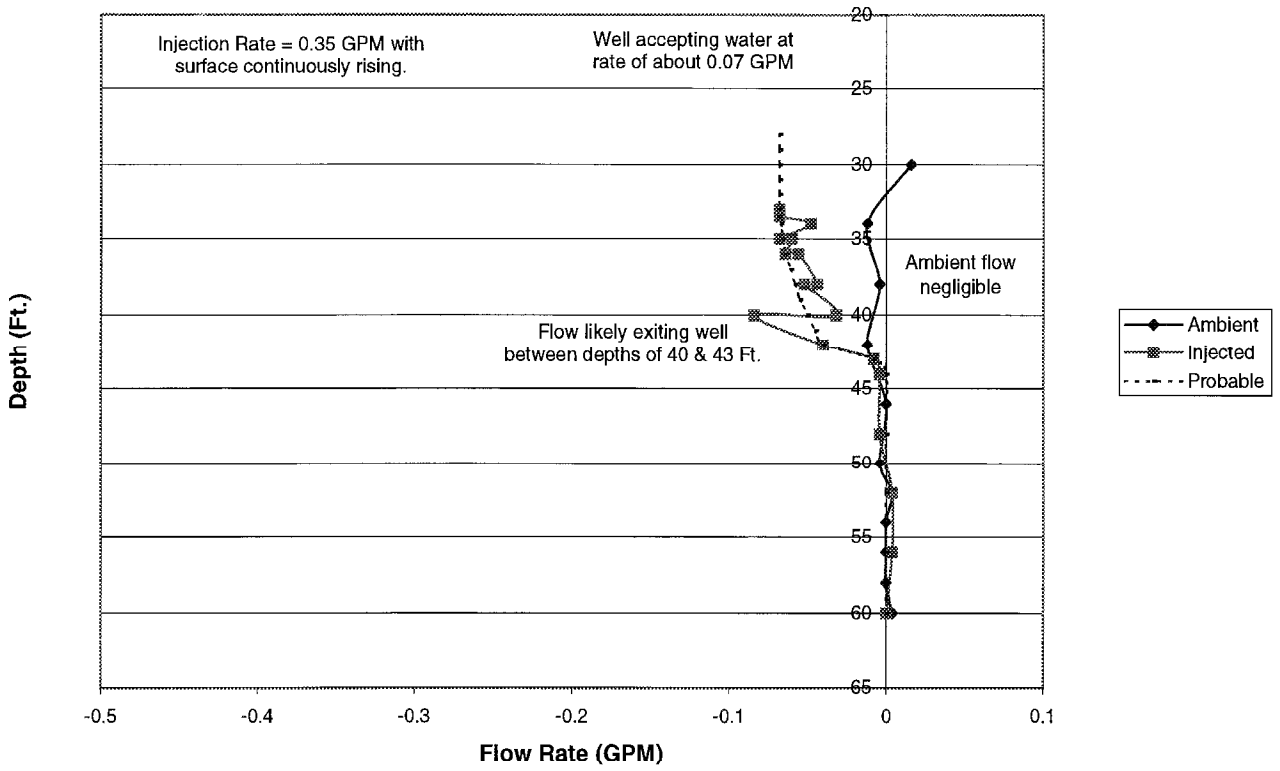


Figure A-17: Profile of Flow Rates in Well D1L

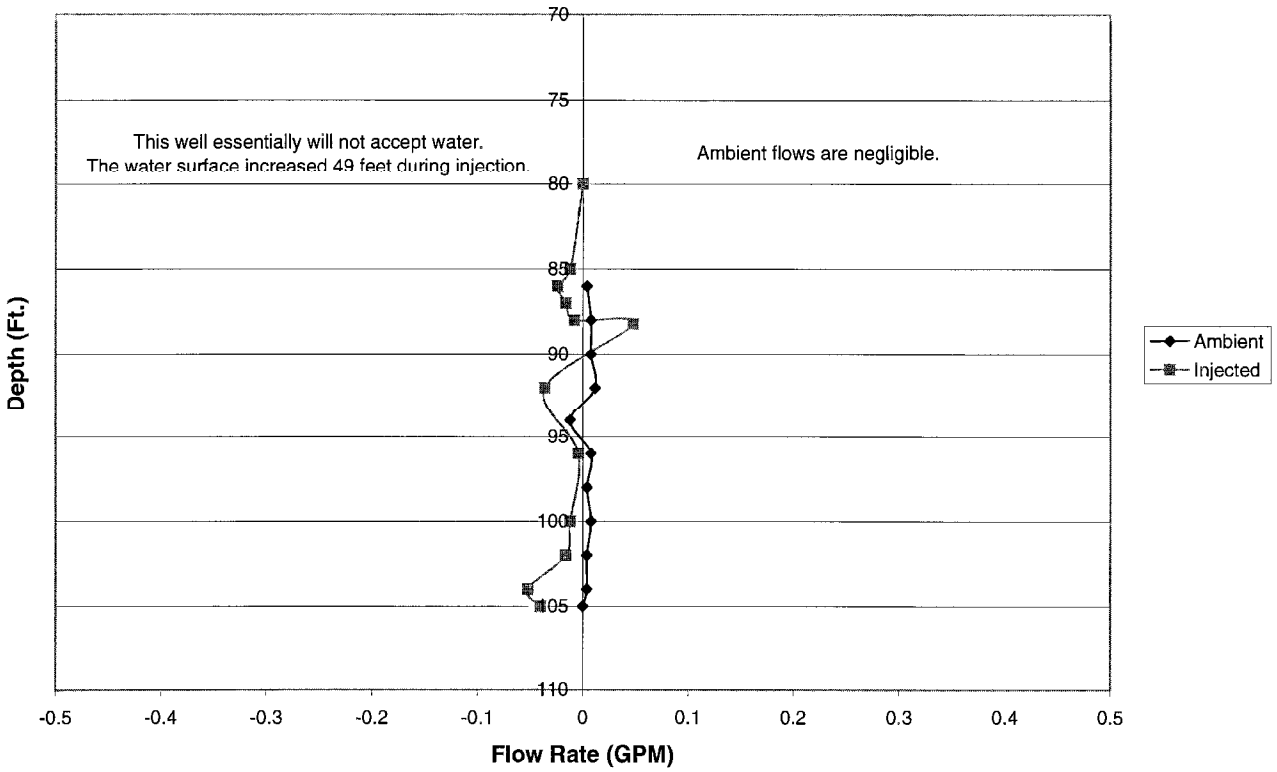


Figure A-18: Profile of Flow Rates in Well D1M

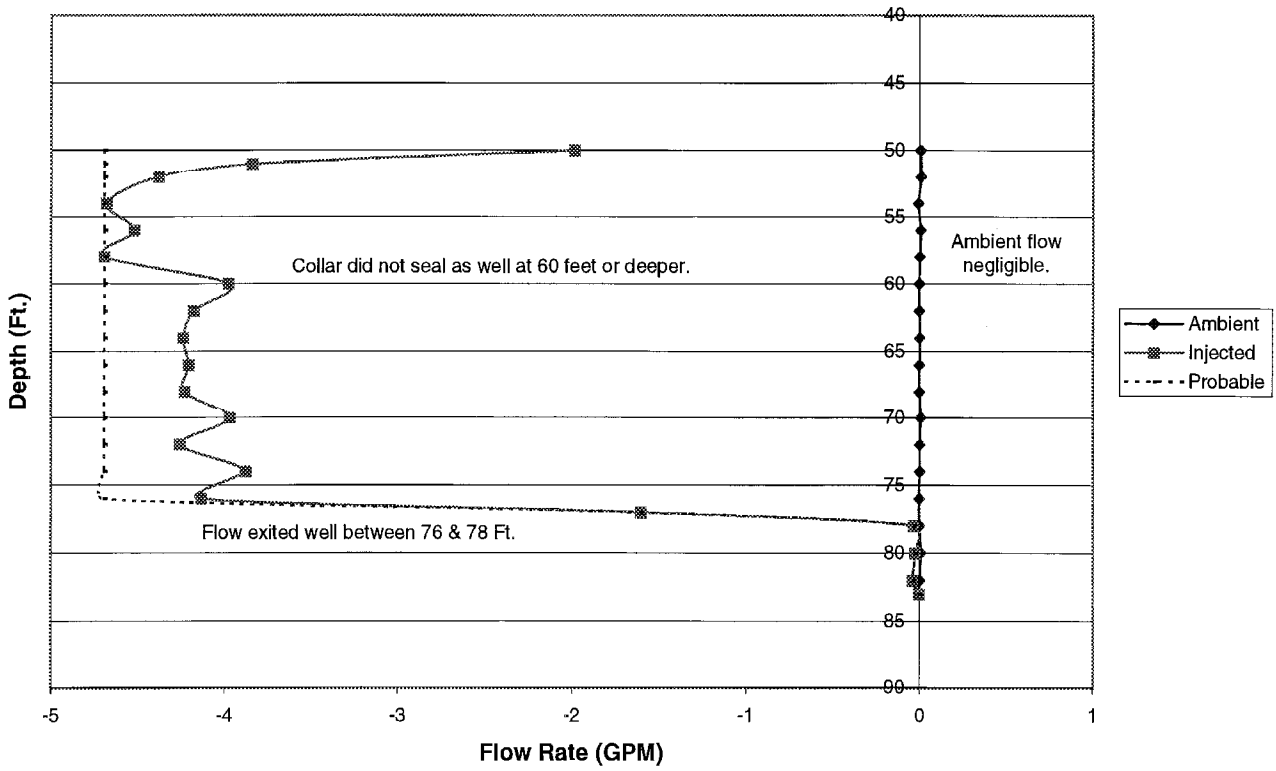


Figure A-19: Profile of Flow Rates in Well D1U

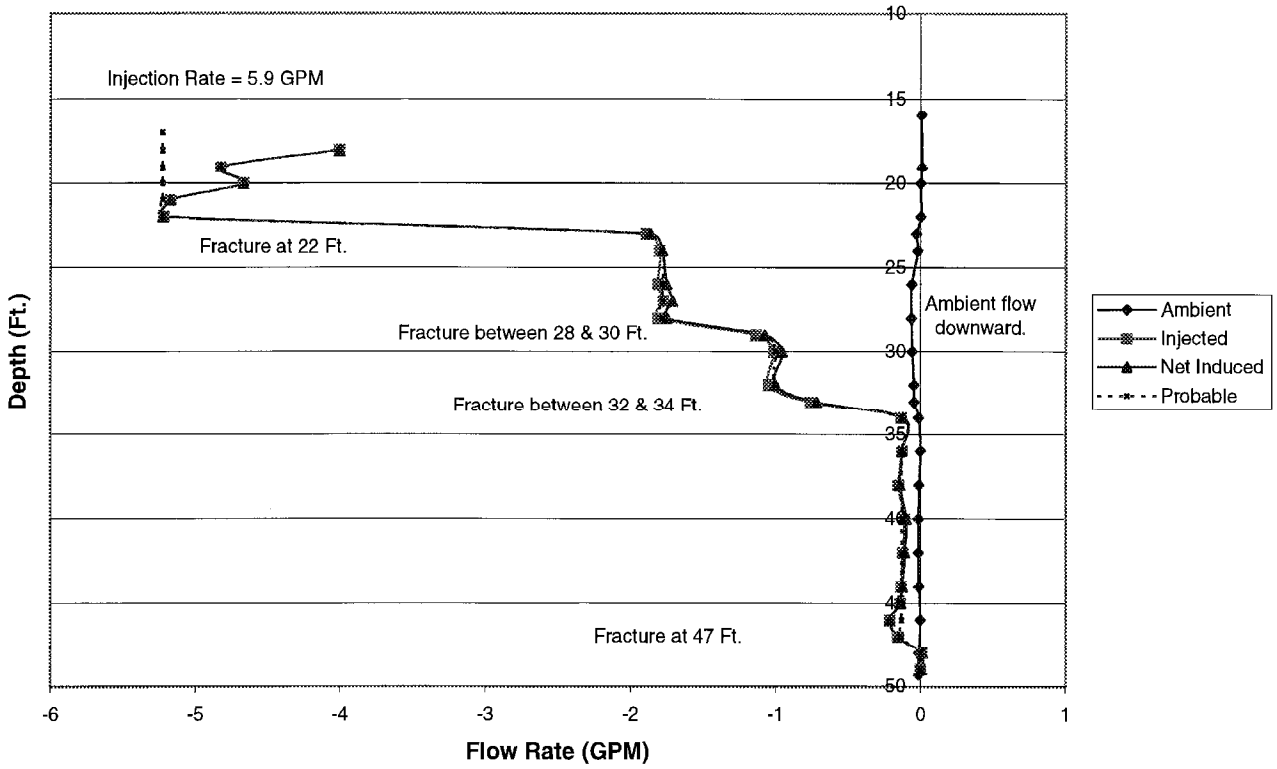


Figure A-20: Profile of Flow Rate in Well D2L

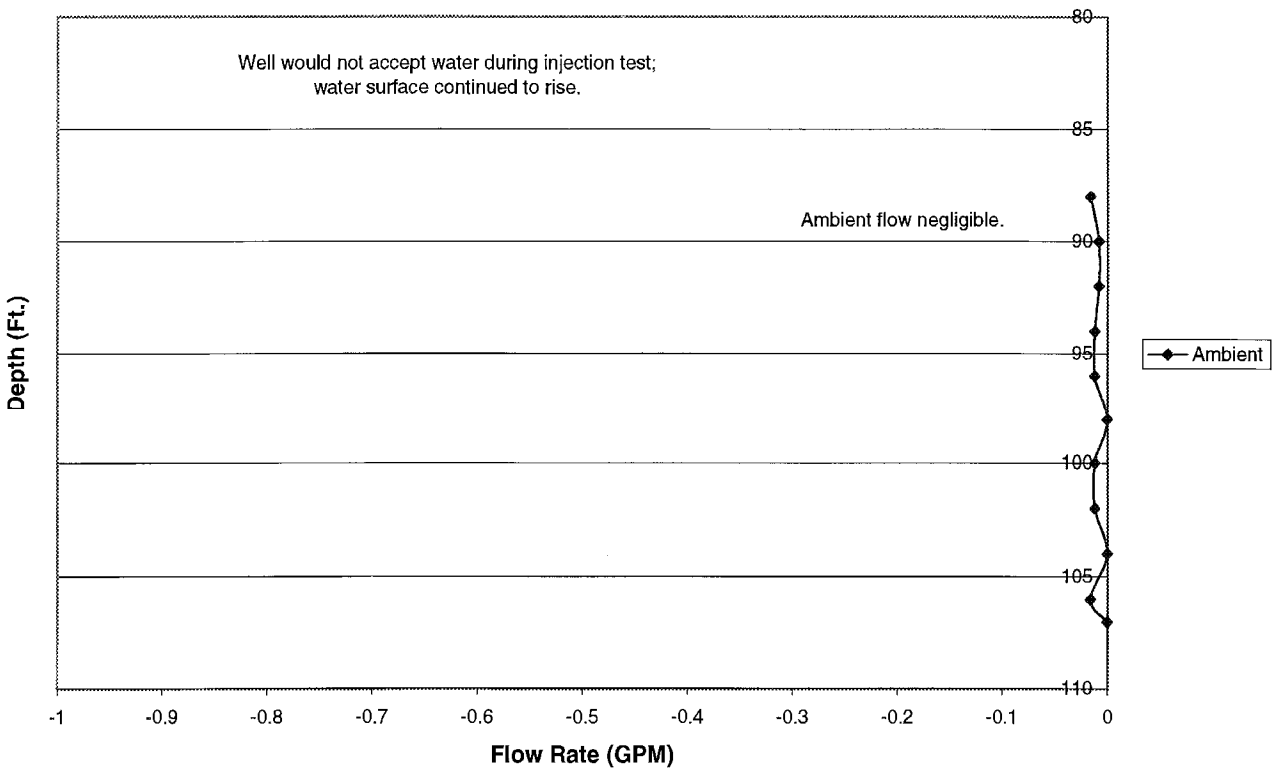


Figure A-21: Profile of Flow Rates in Well D2M

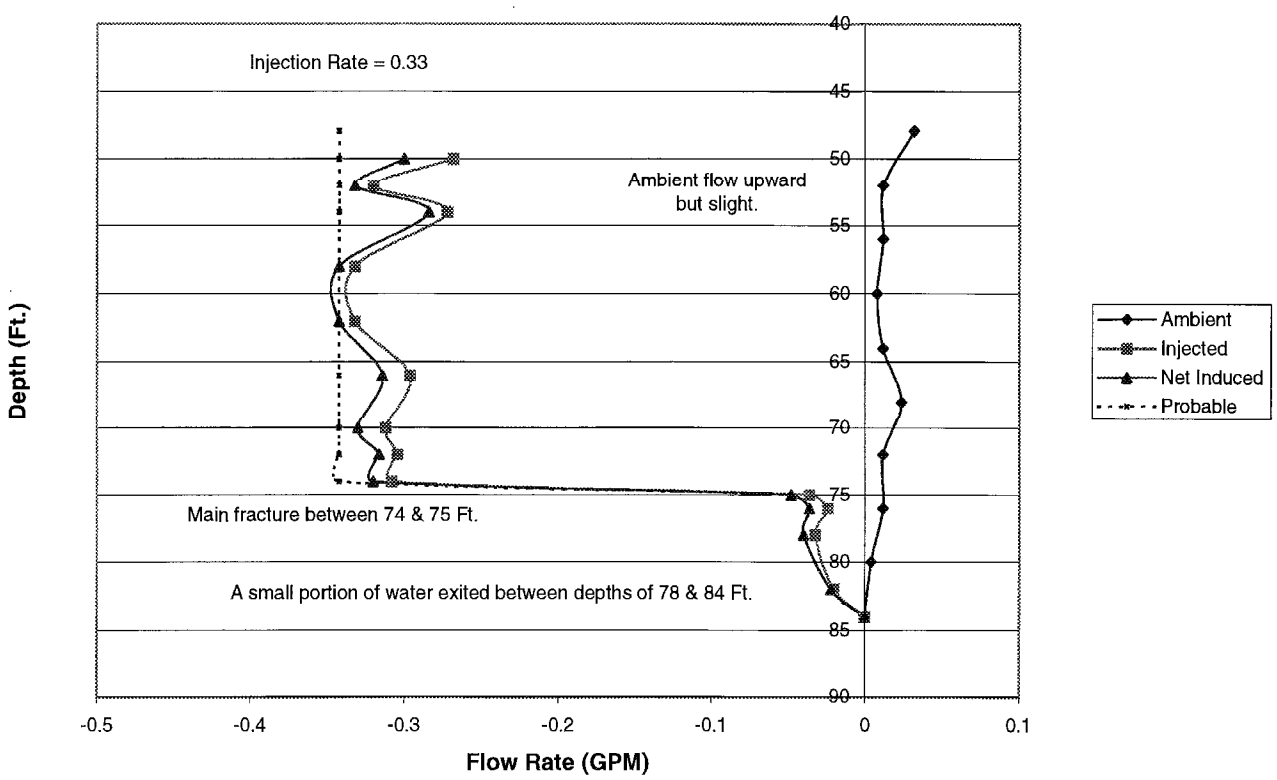


Figure A-22: Profile of Flow Rates in Well D2U

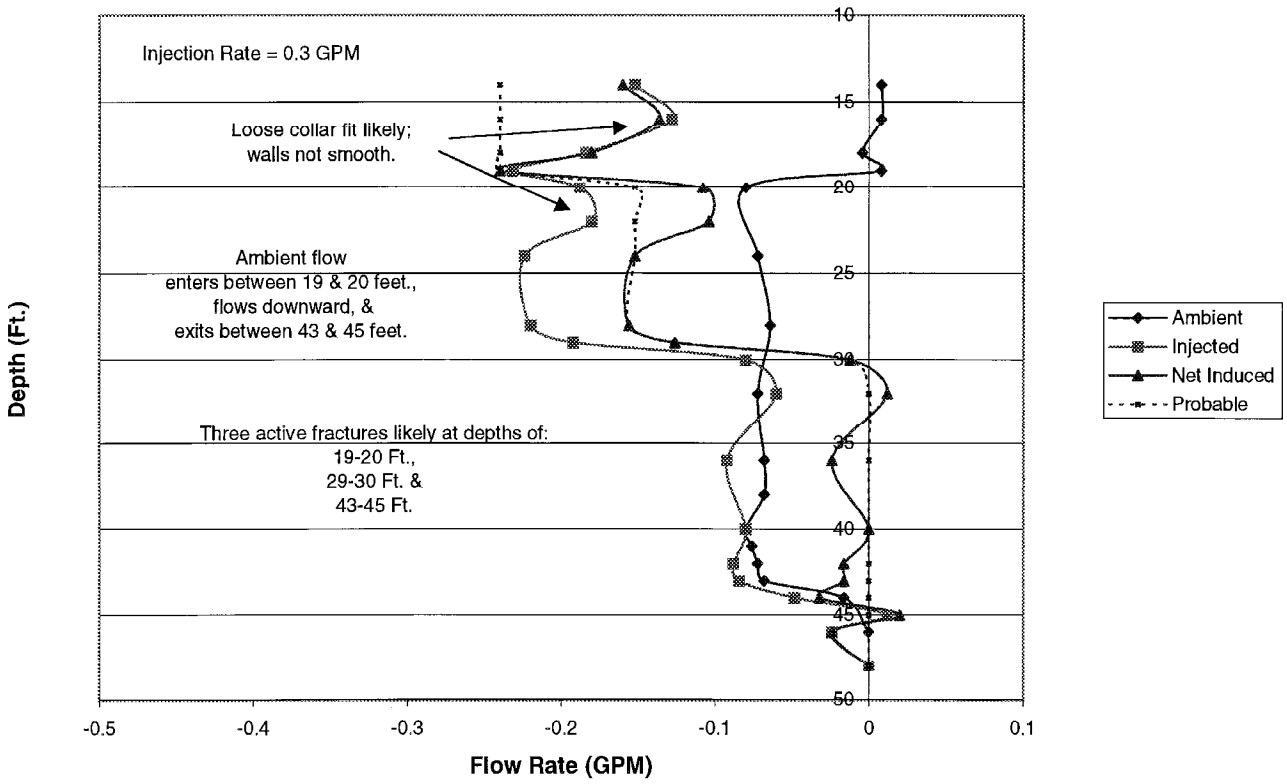


Figure A-23: Profile of Flow Rate in Well D4L

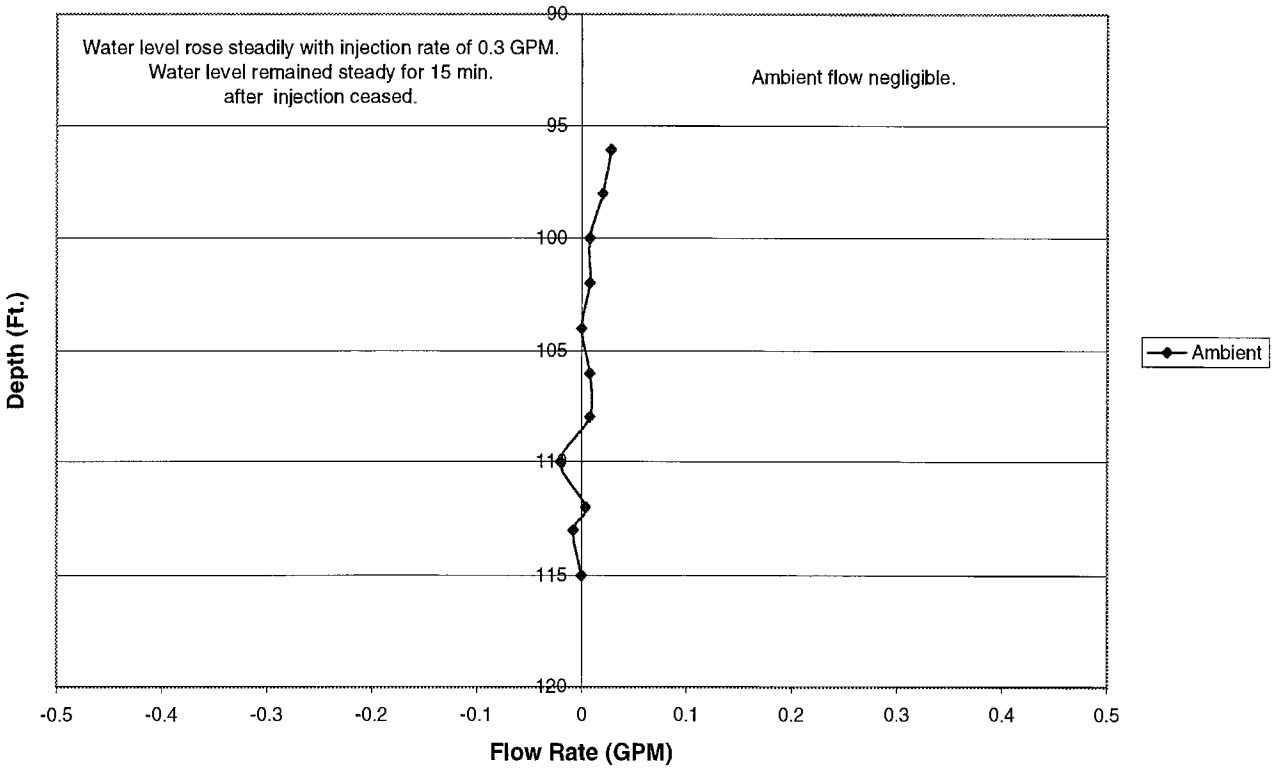


Figure A-24: Profile of Flow Rates in Well D4U

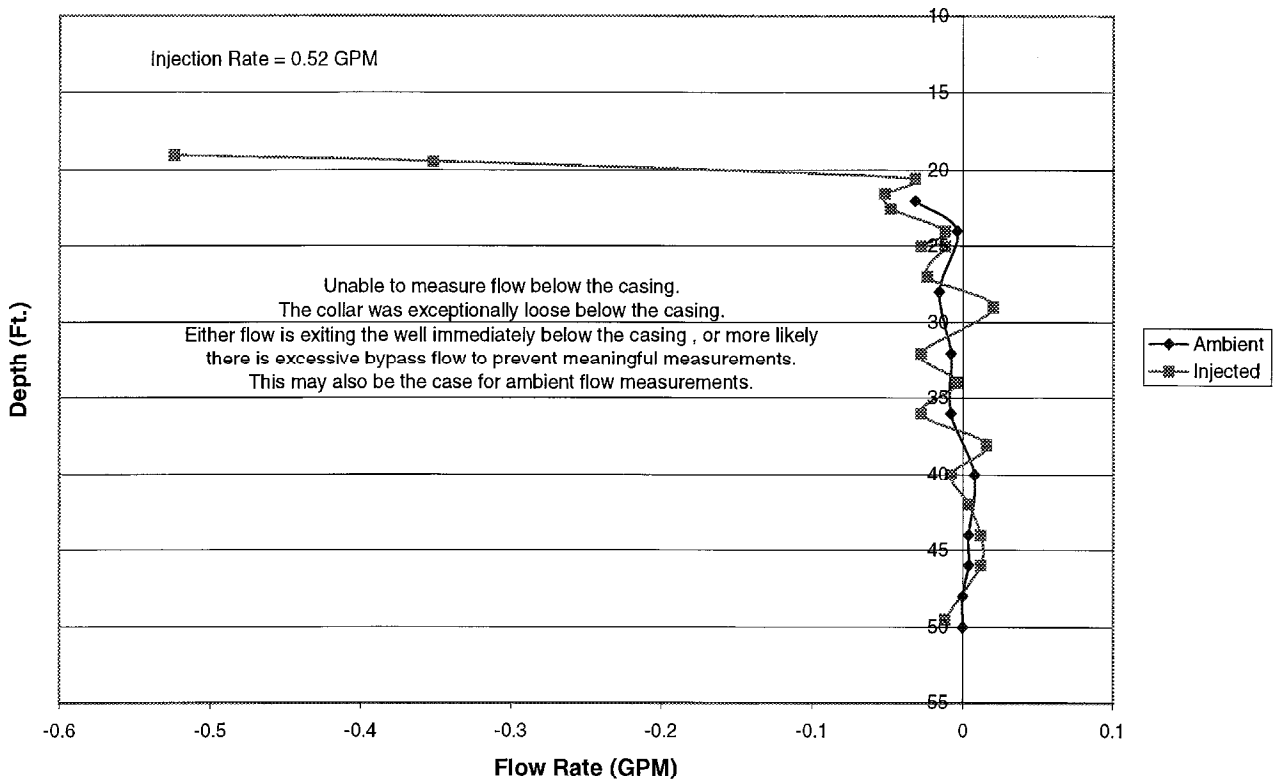


Figure A-25: Profile of Flow Rates in Well E1L

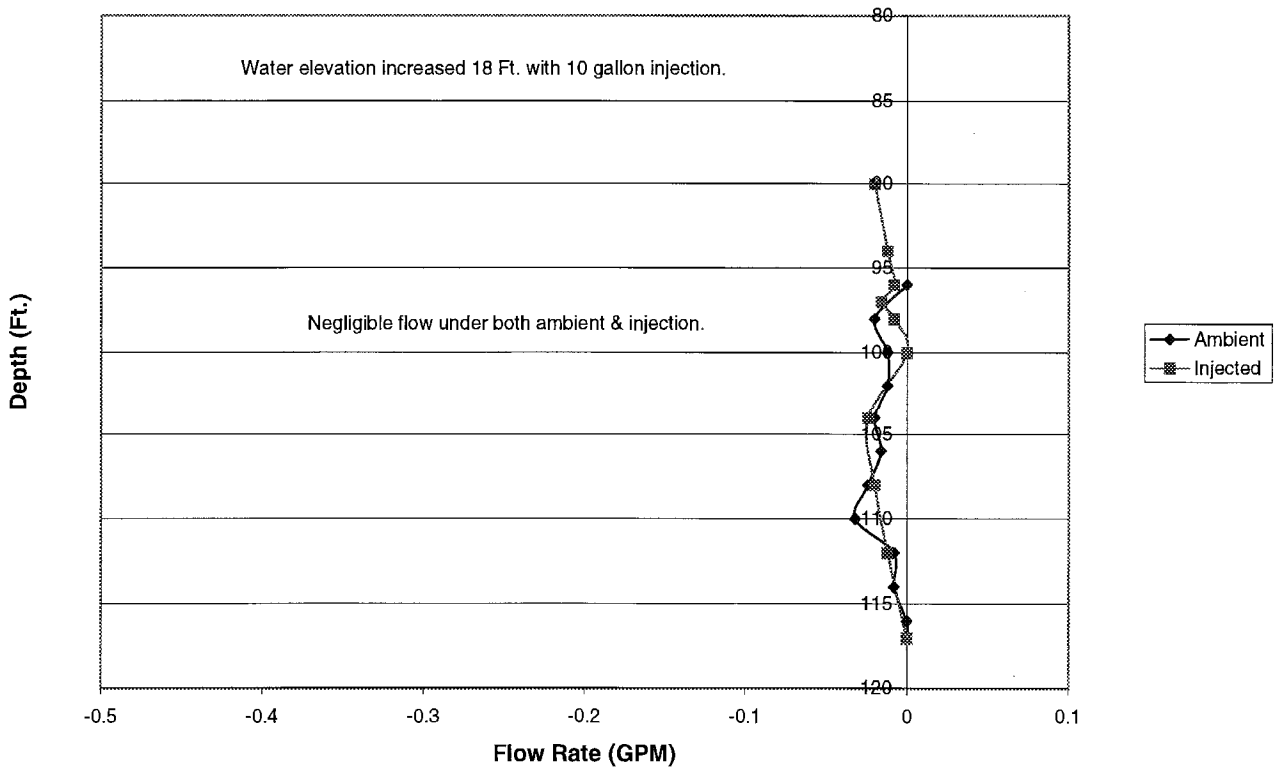


Figure A-26: Profile of Flows in Well E1M

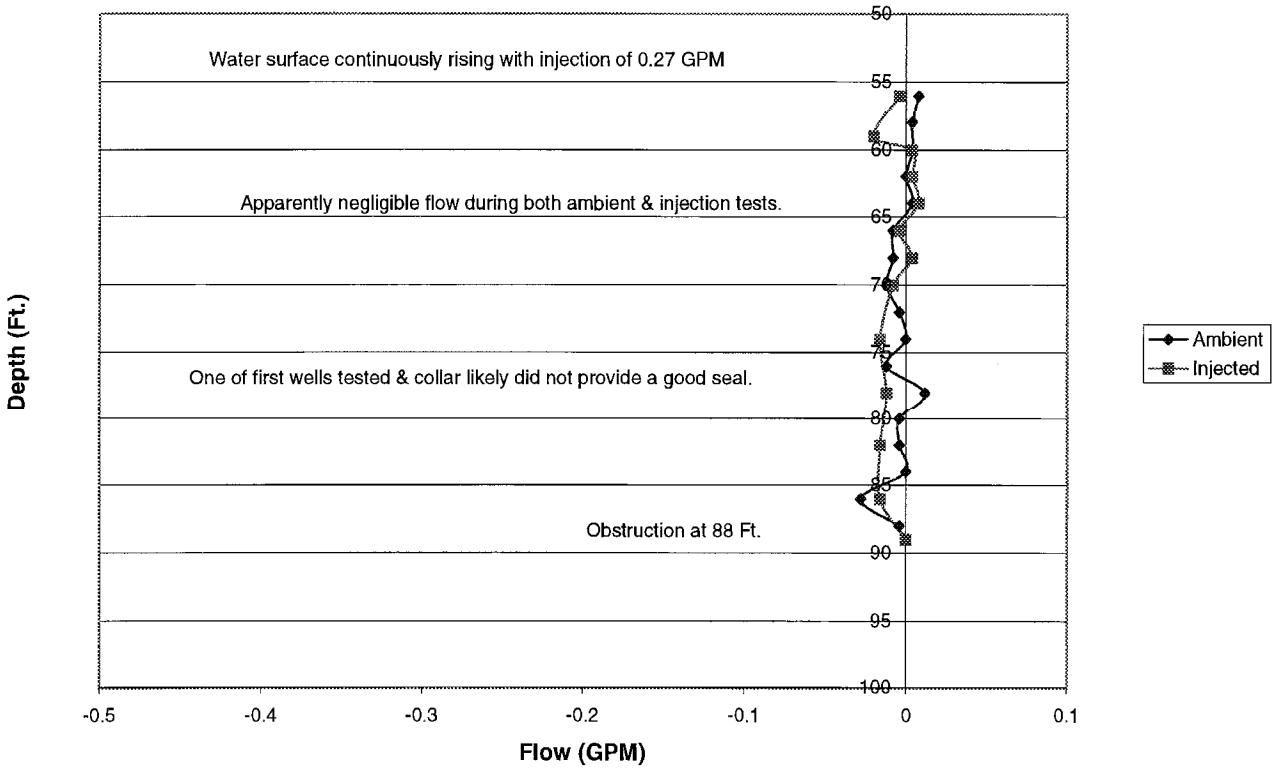


Figure A-27: Profile of Flow Rates in Well E1U

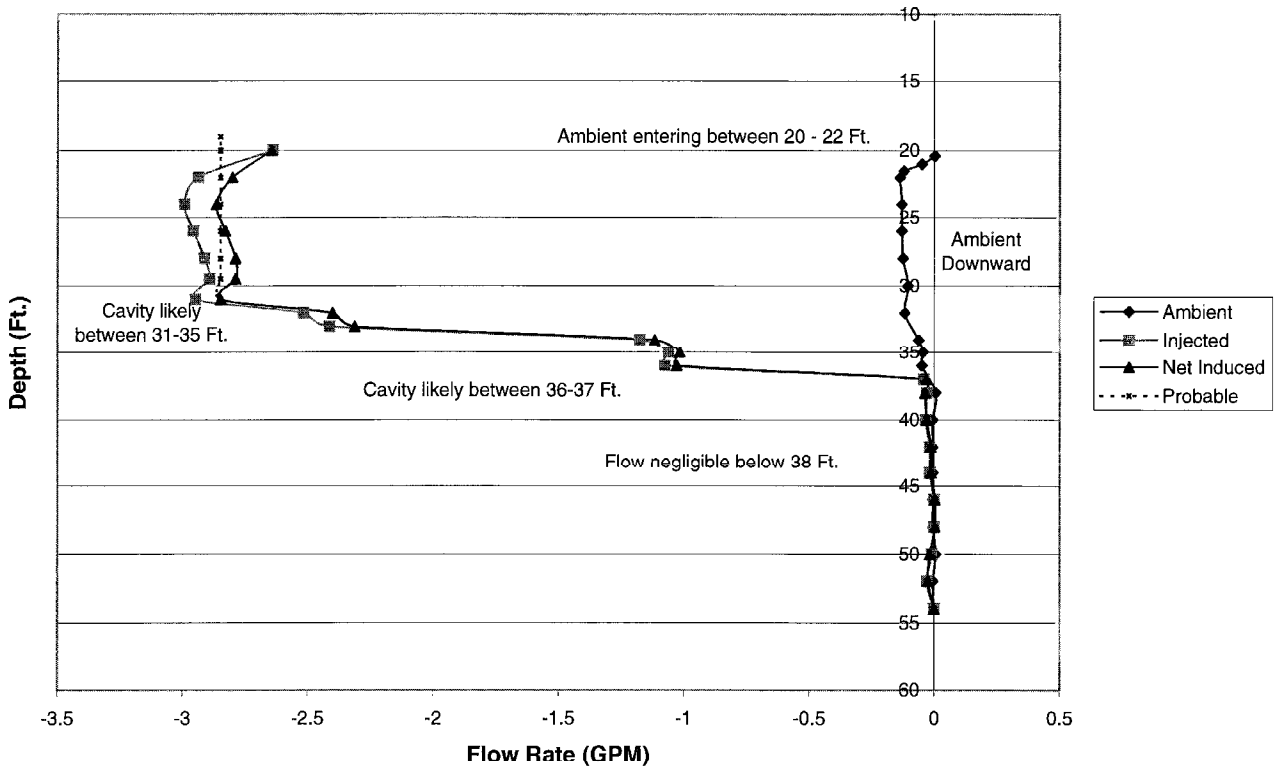


Figure A-28: Profile of Ambient Flow in Well F2L

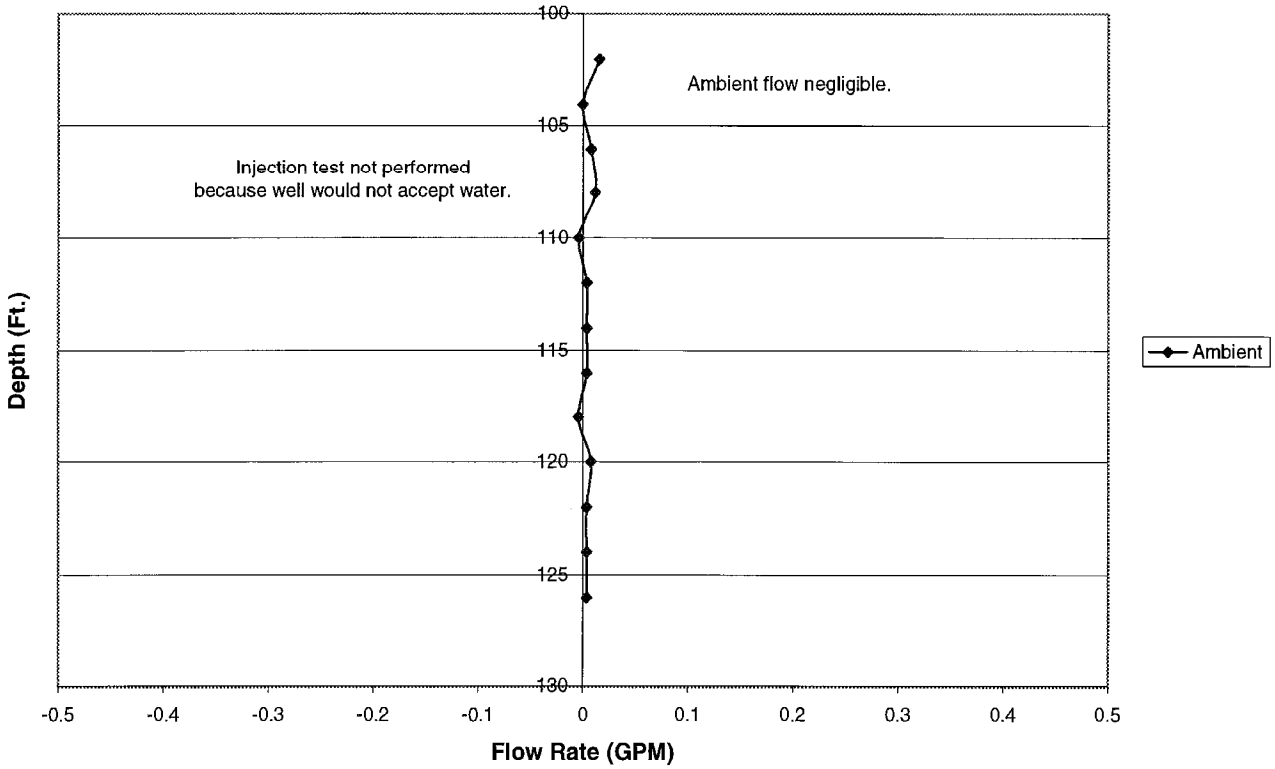


Figure A-29: Profile of Flow Rates in Well F2M

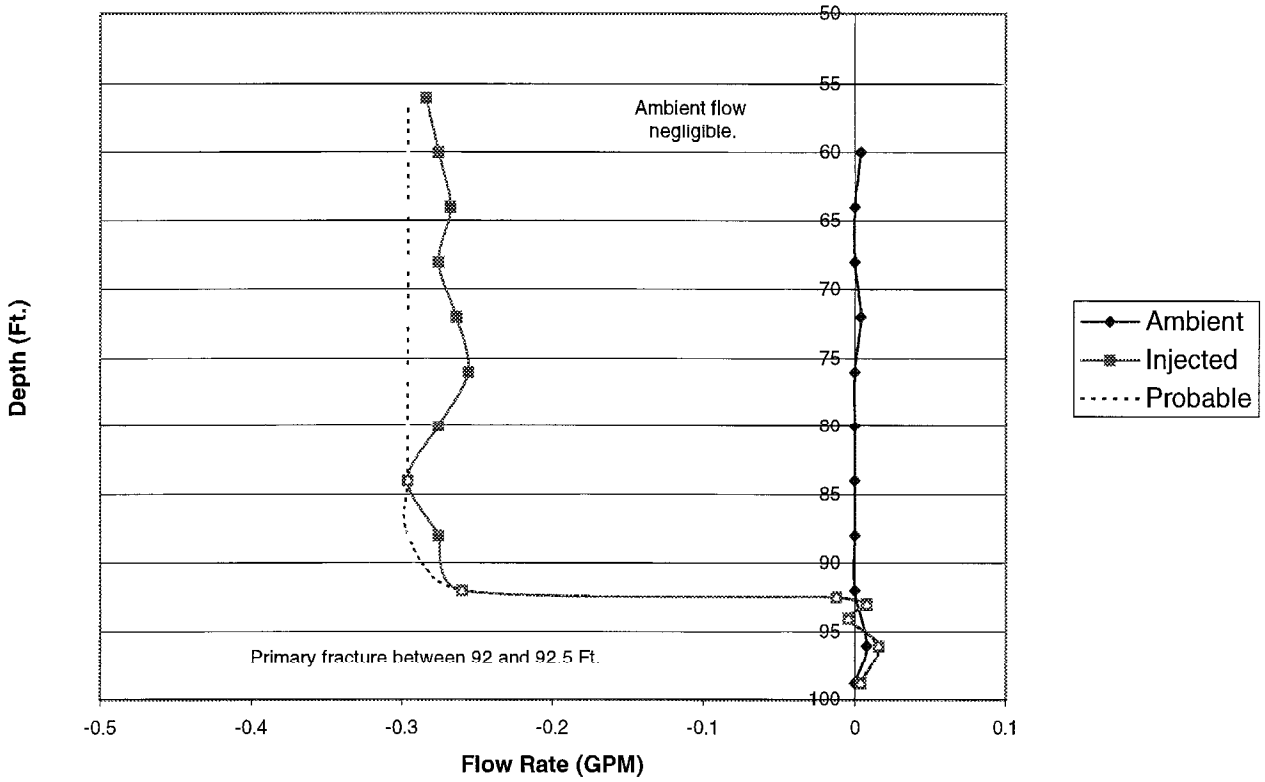


Figure A-30: Profile of Flow Rates in Well F2U

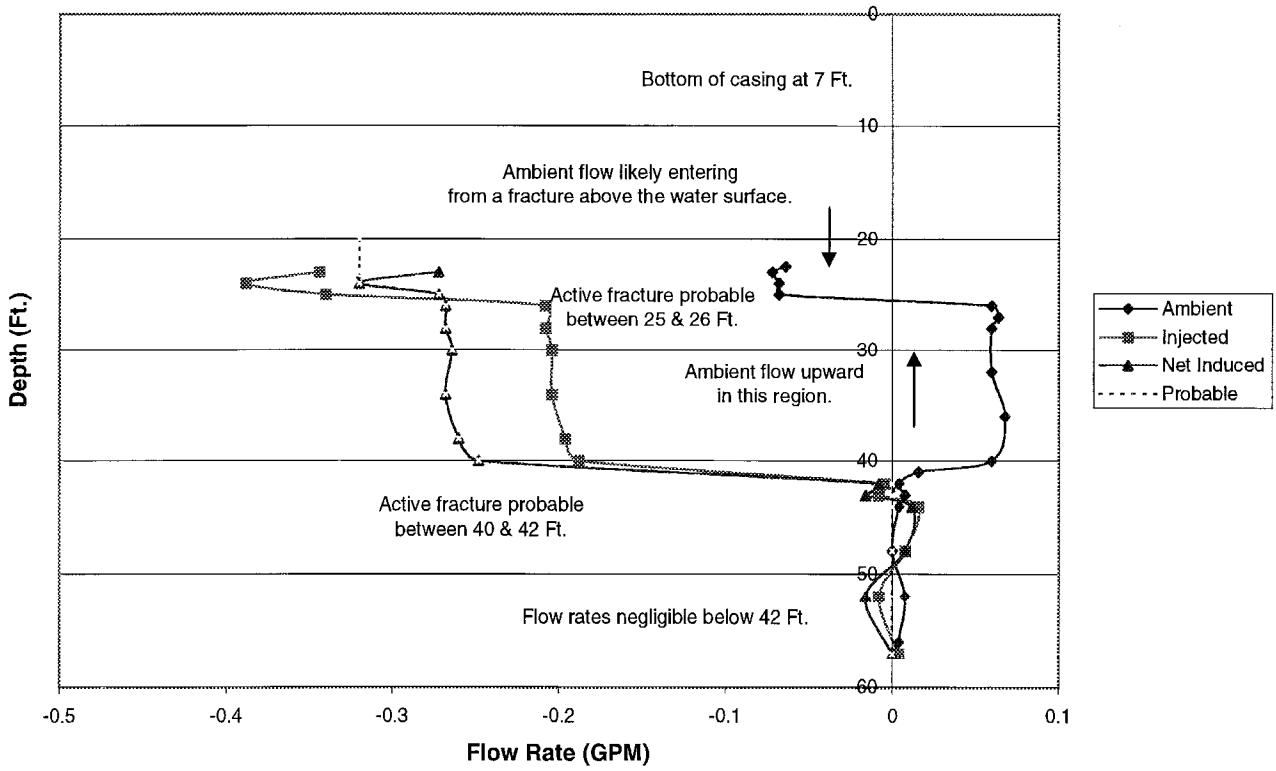


Figure A-31: Profile of Flow Rates in Well G3L

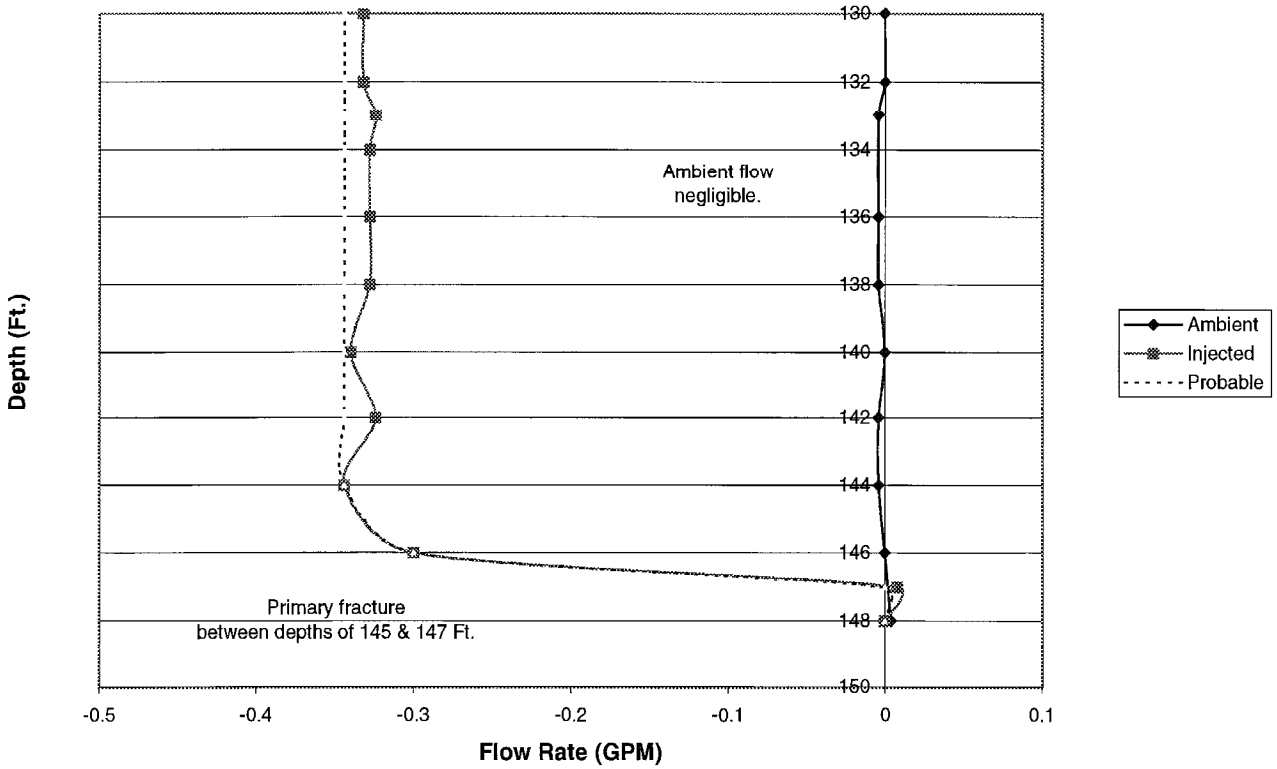


Figure A-32: Profile of Flow Rates in Well G3U

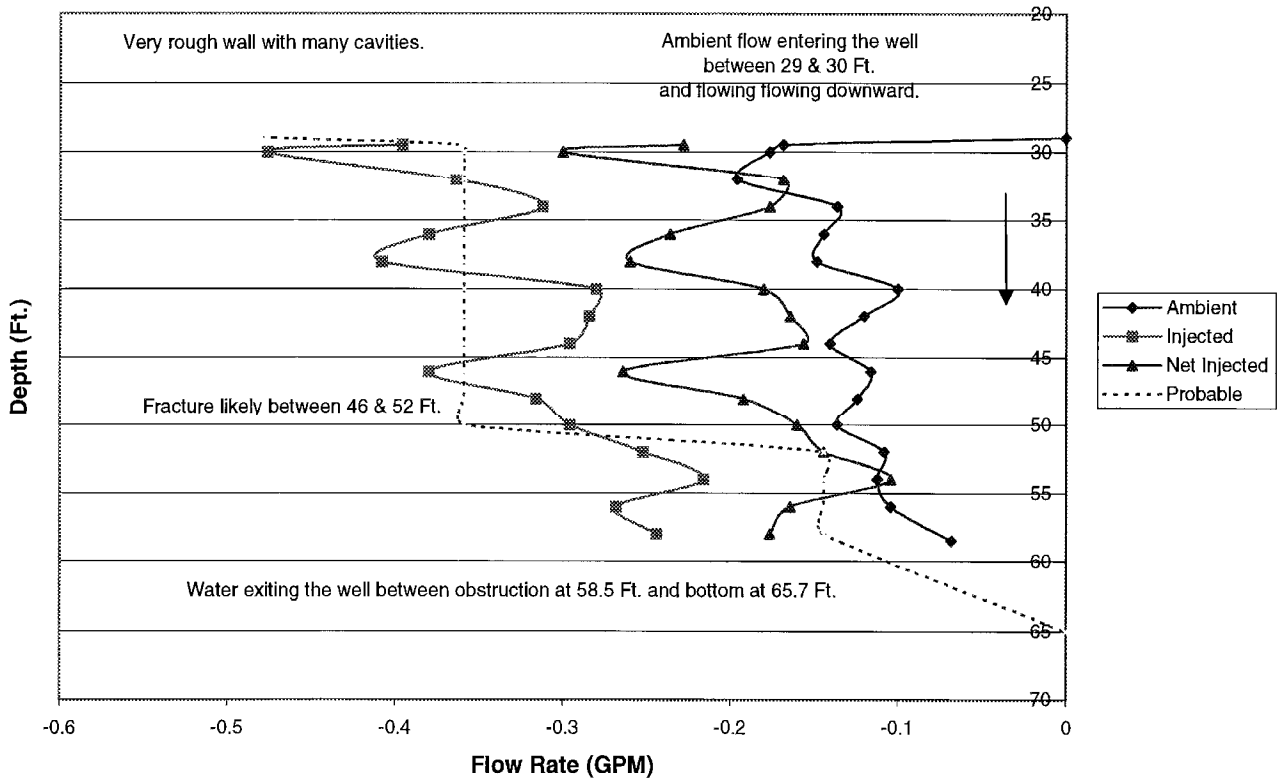


Figure A-33: Profile of Flow Rates in Well H1L

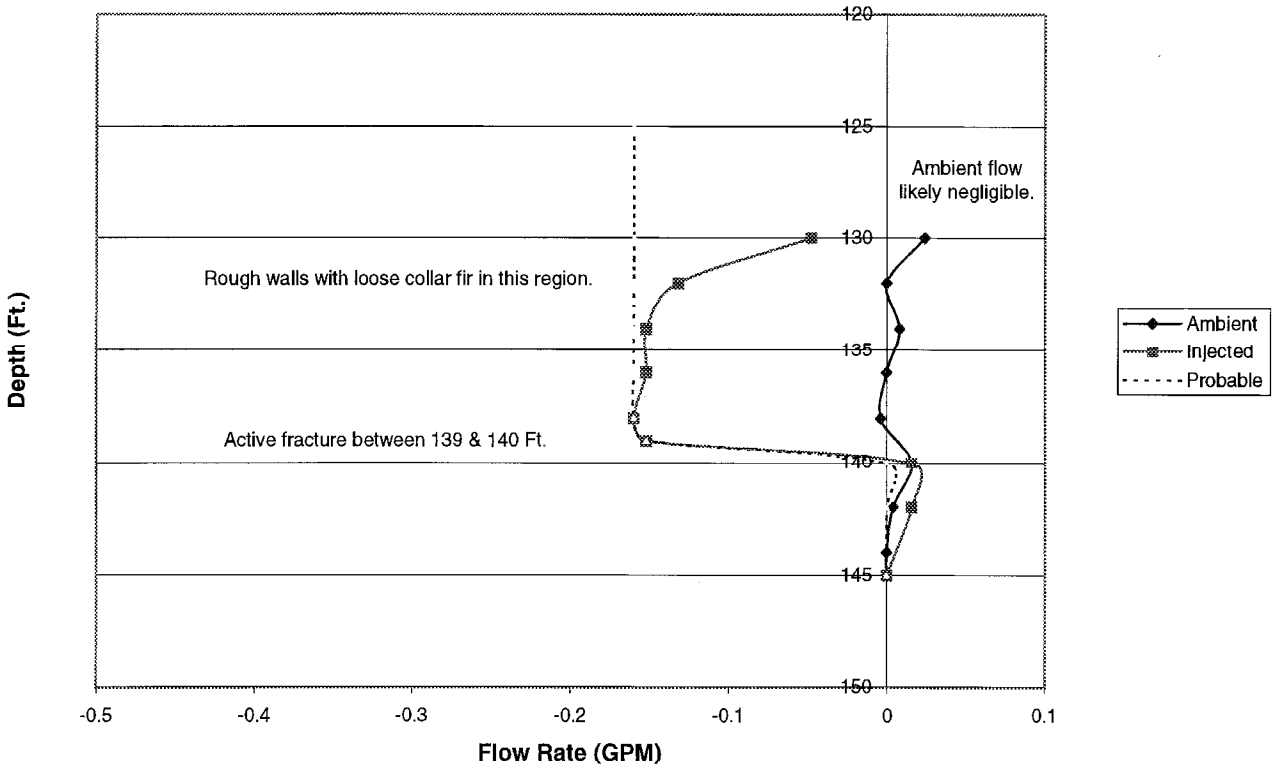


Figure A-34: Profile of Flow Rates in Well H1M

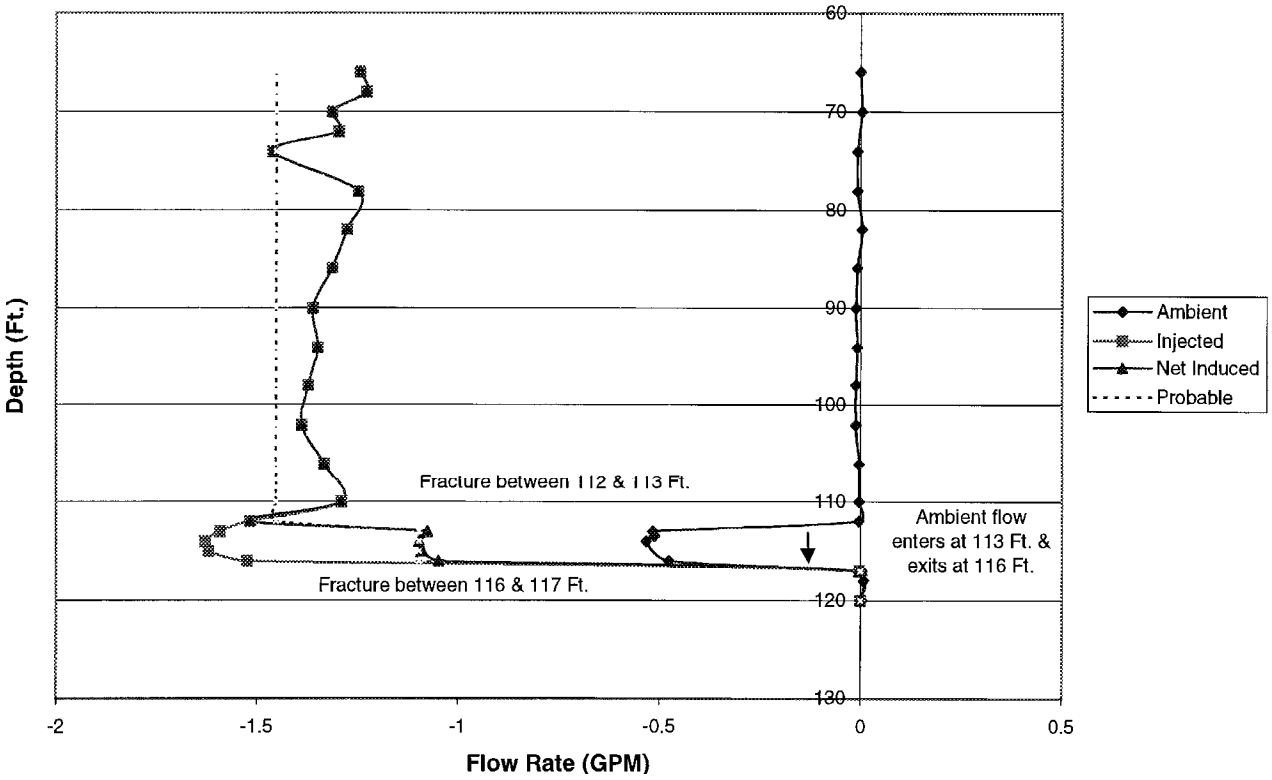


Figure A-35: Profile of Flow Rate in Well H1U

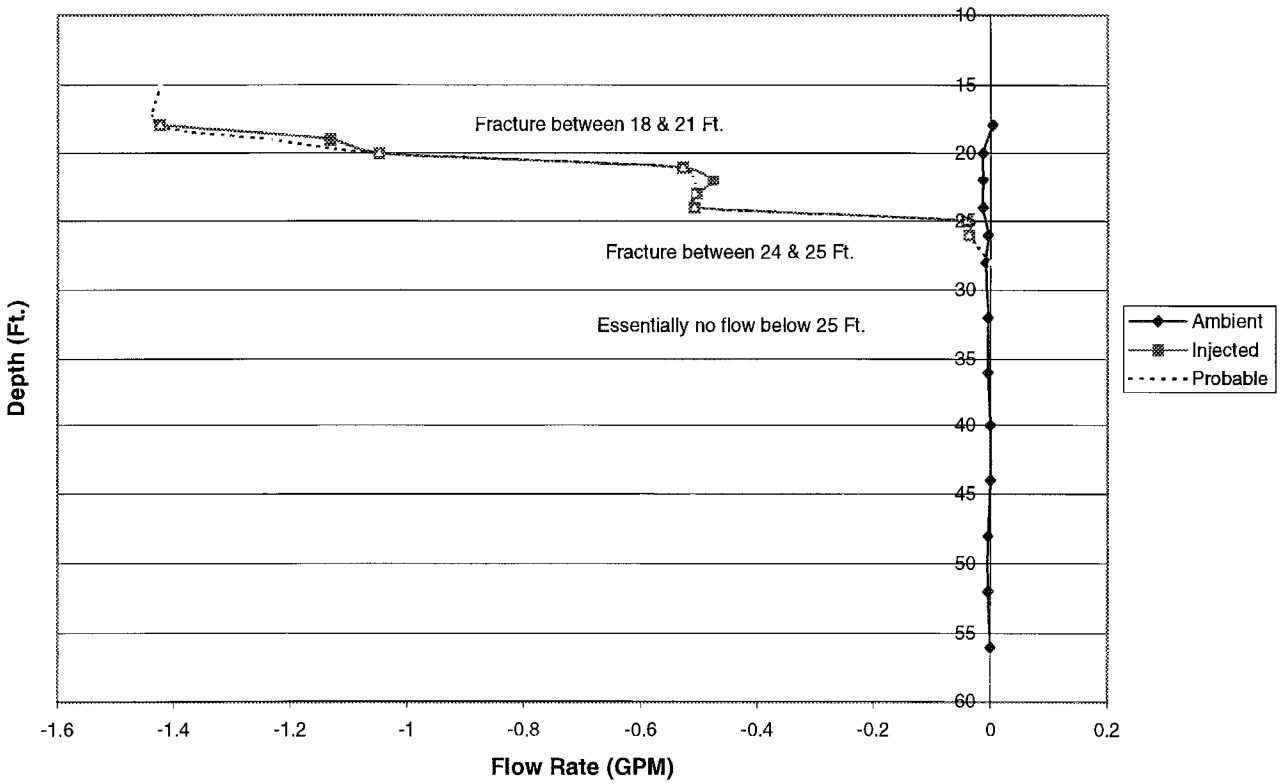


Figure A-36: Profile of Flow Rates in Well J1M

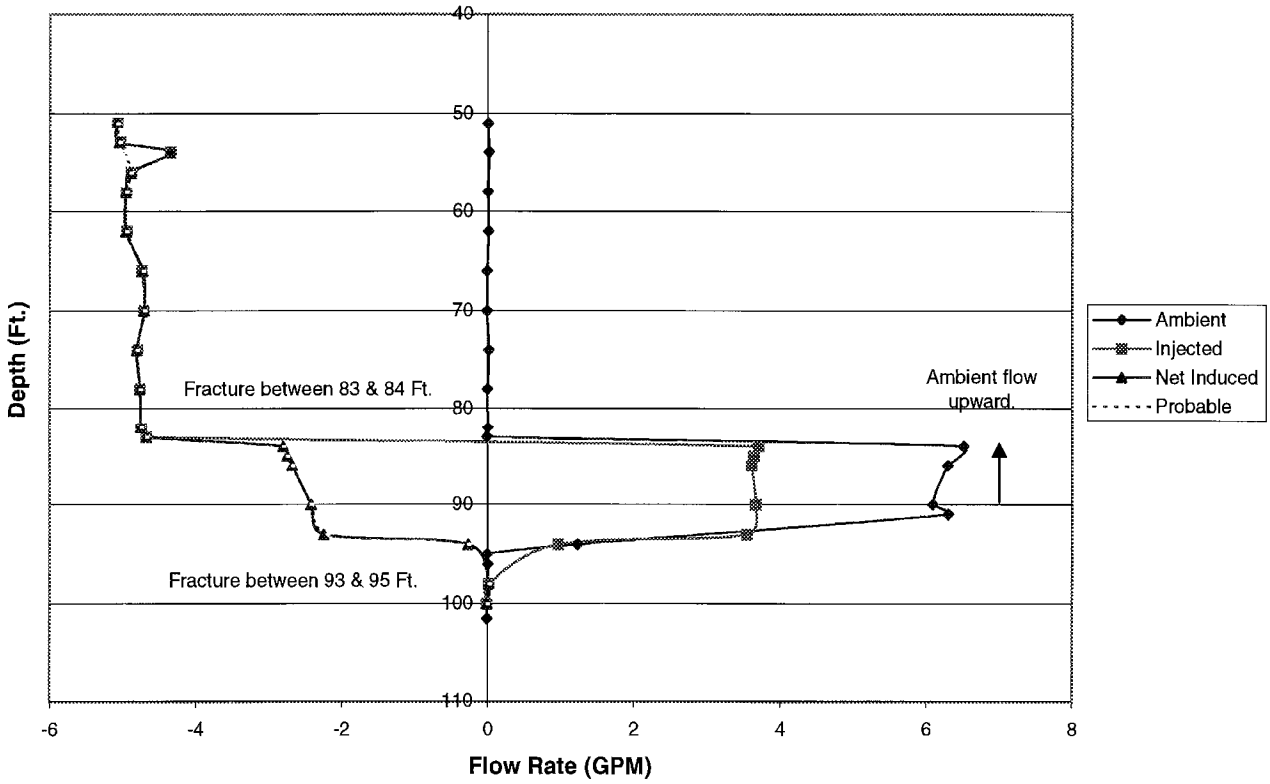


Figure A-37: Profile of Flow Rates in Well J1U

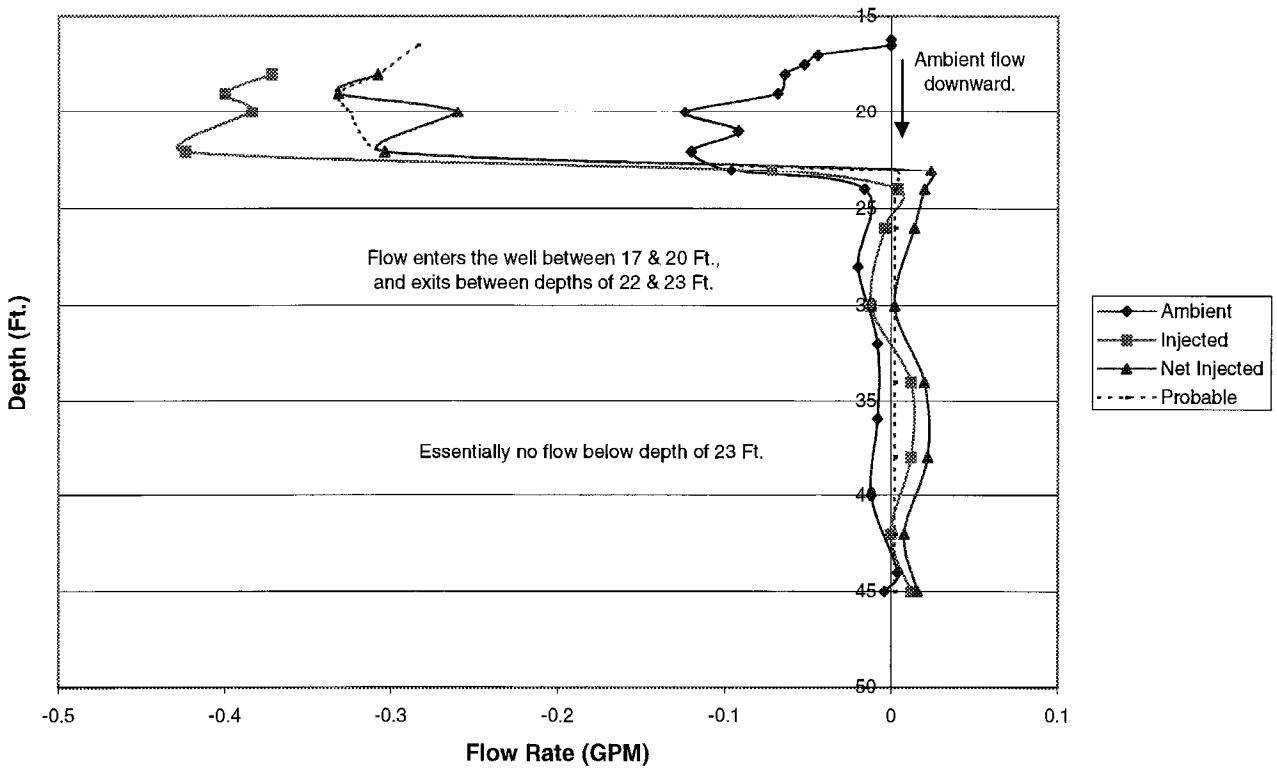


Figure A-38: Profile of Flow Rates in Well J3L

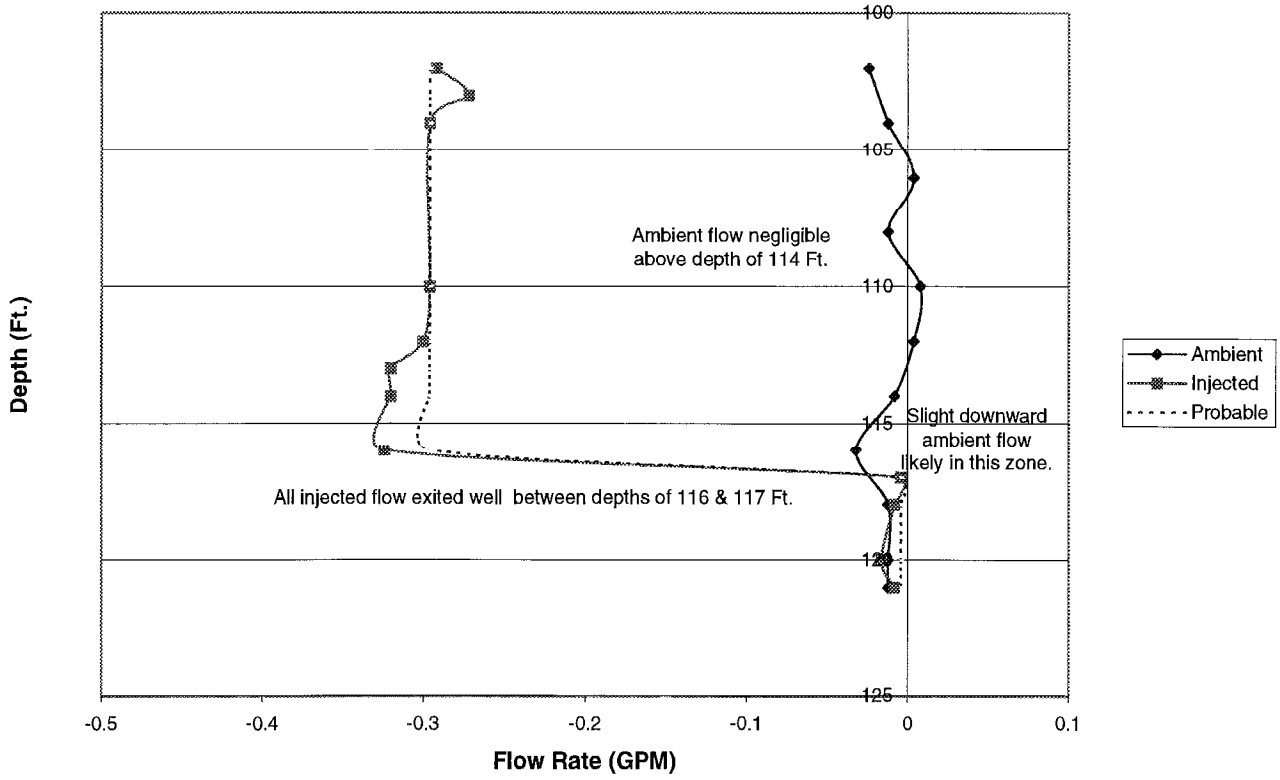


Figure A-39: Profile of Flow Rates in Well J4L

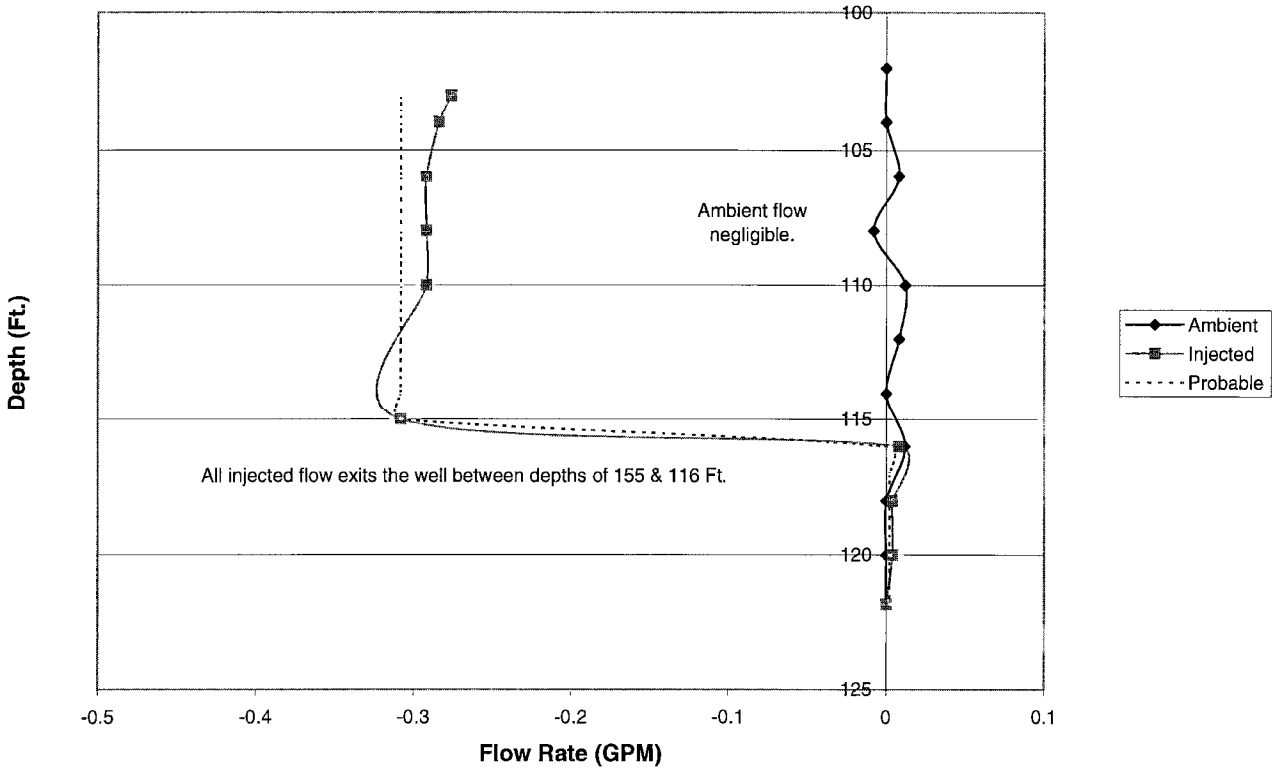


Figure A-40: Profile of Flow Rates in Well MW 2

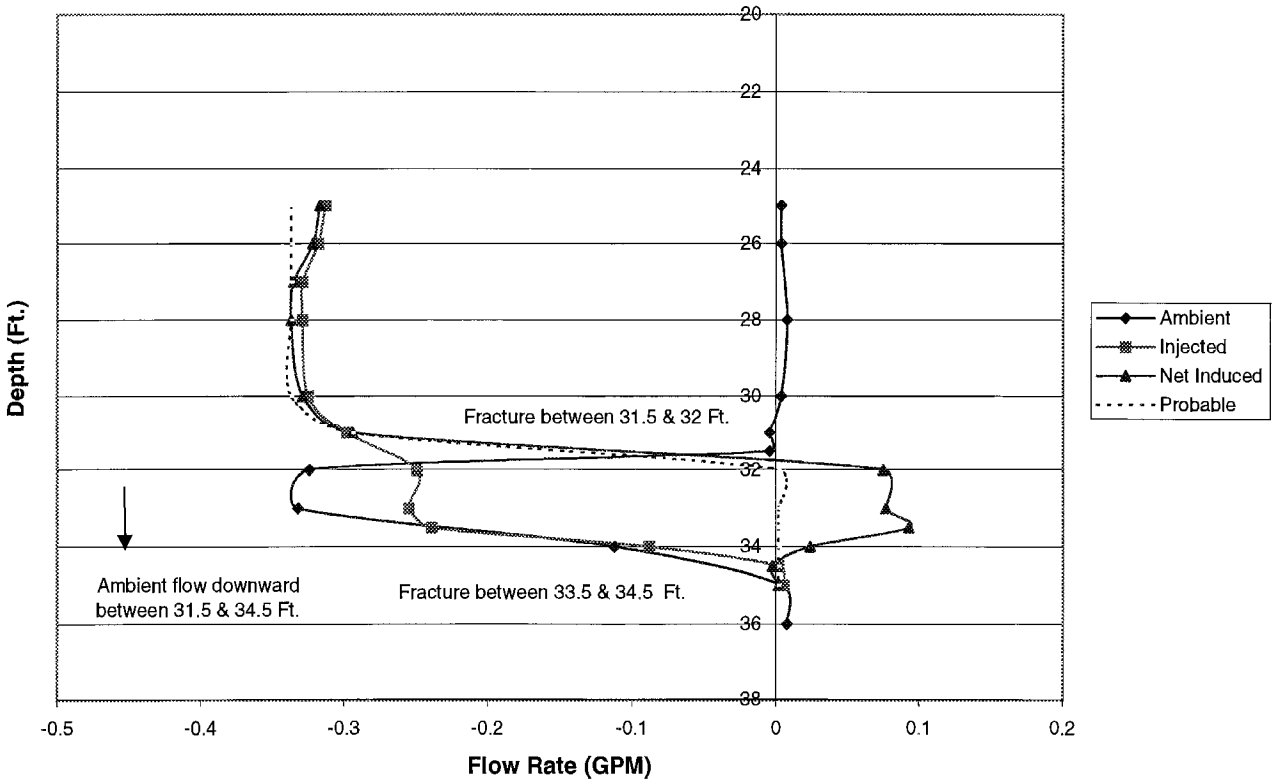


Figure A-41: Profile of Flow Rates in Well MW 3

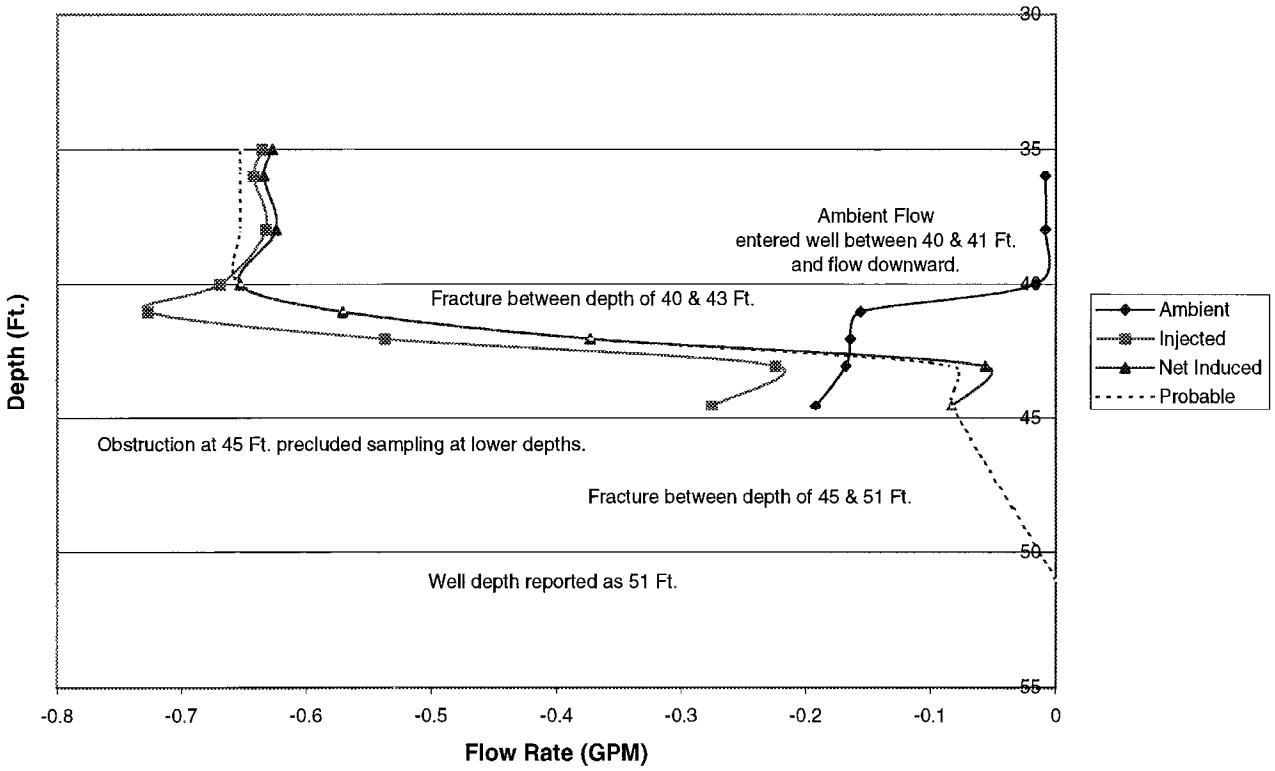


Figure A-42: Profile of Flow Rates in Well MW 4

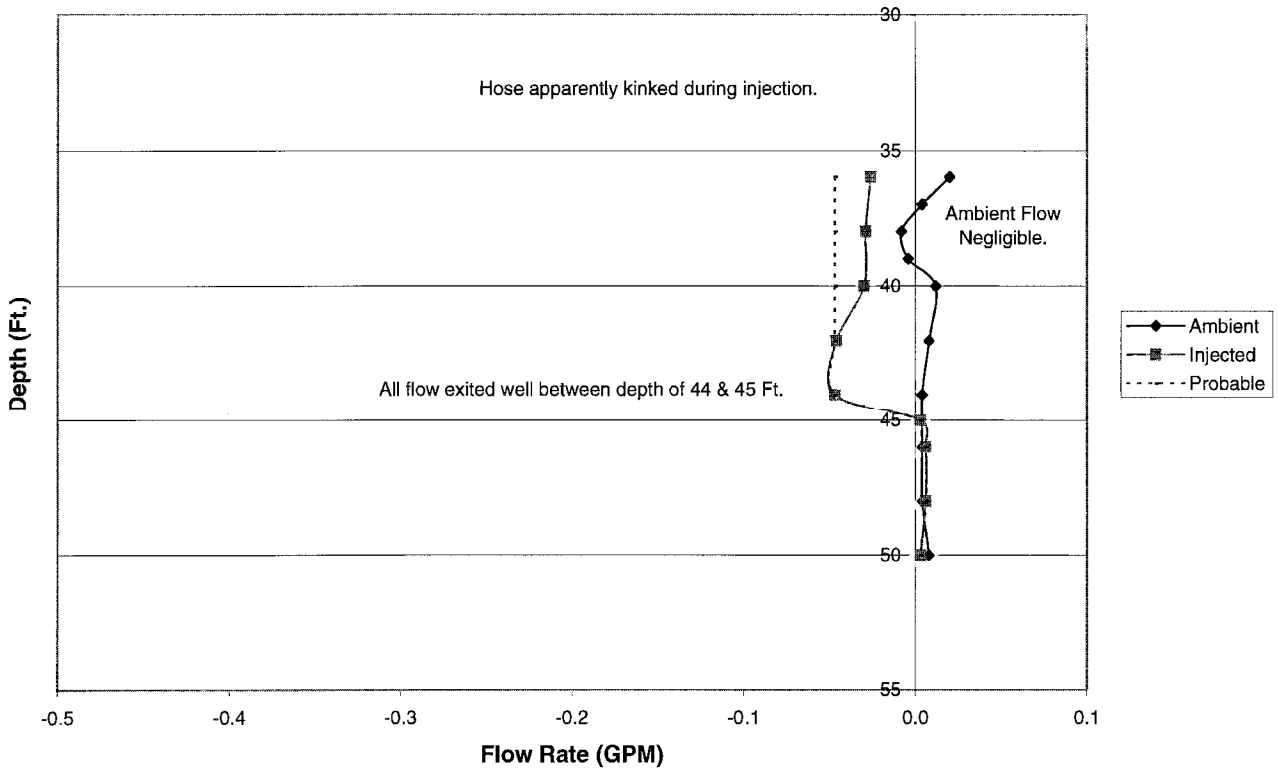


Figure A-43: Profile of Flow Rates in Well MW 5

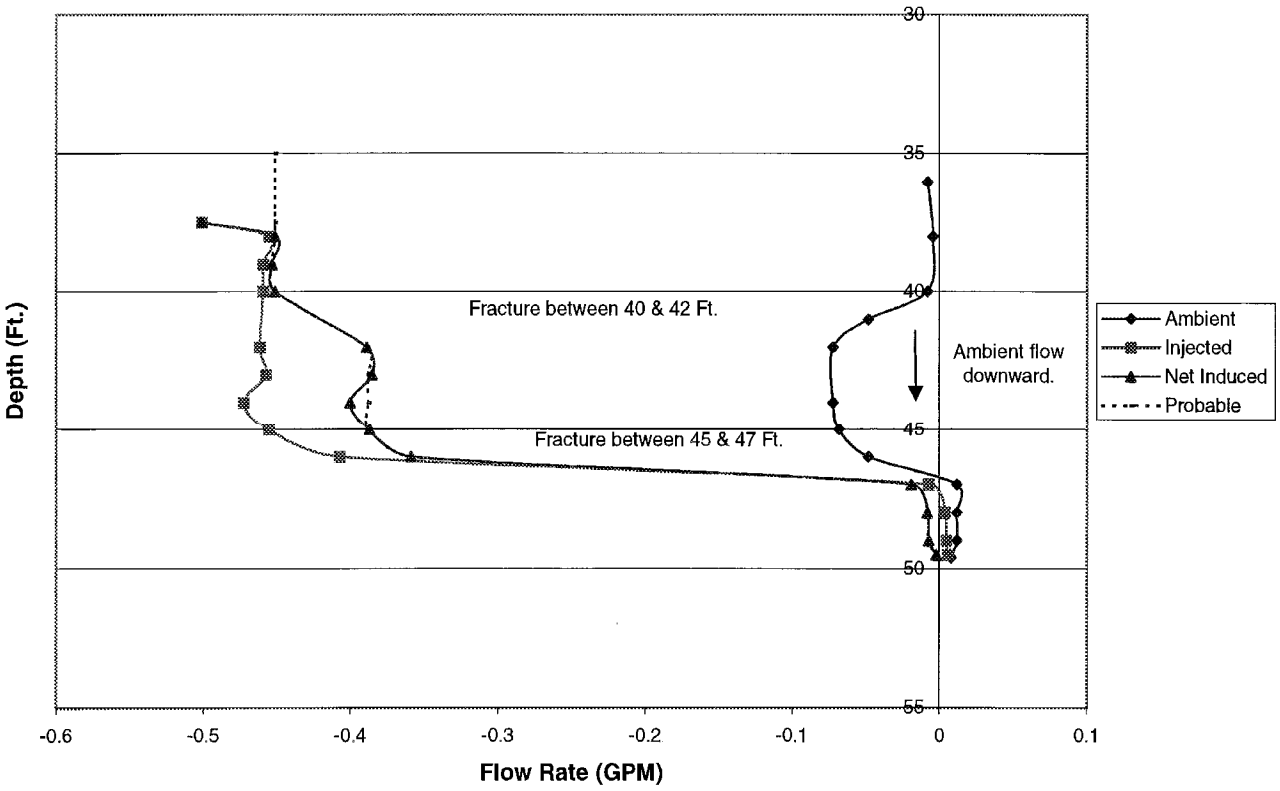
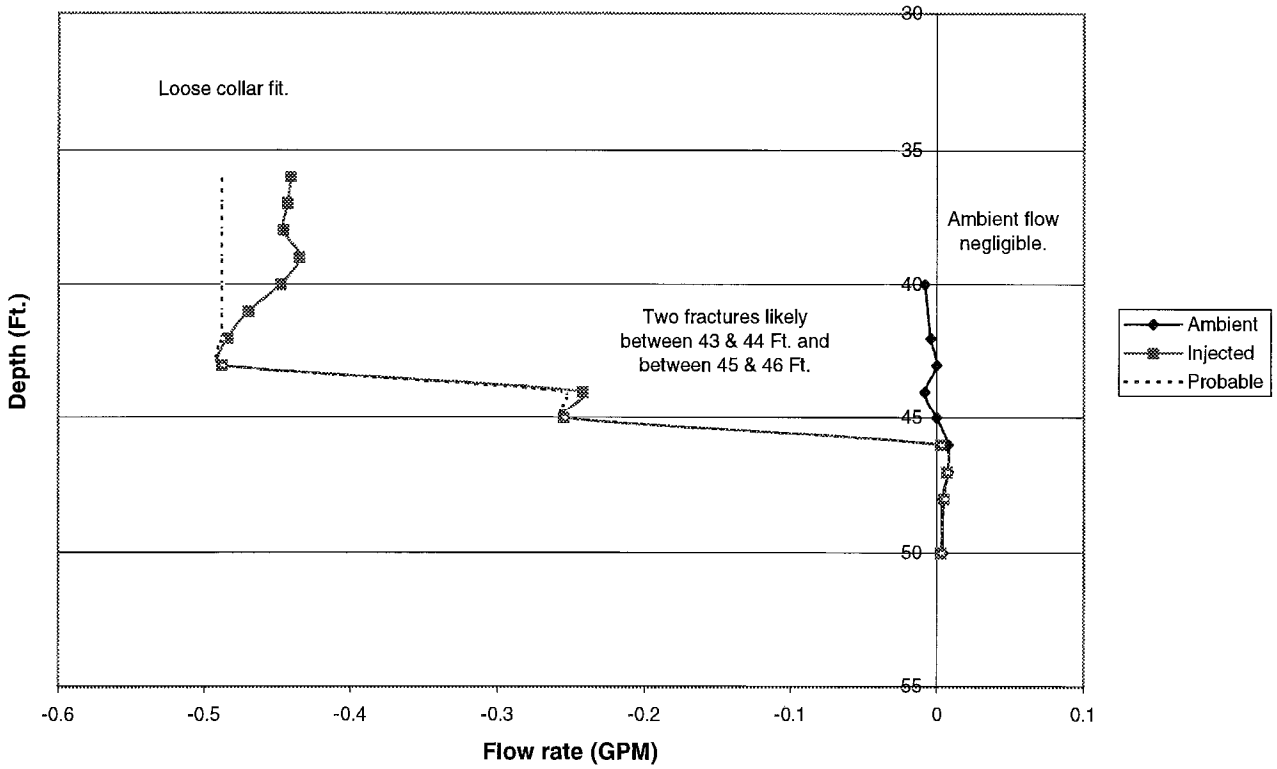


Figure A-44: Profile of Flow Rates in Well MW 6



APPENDIX D

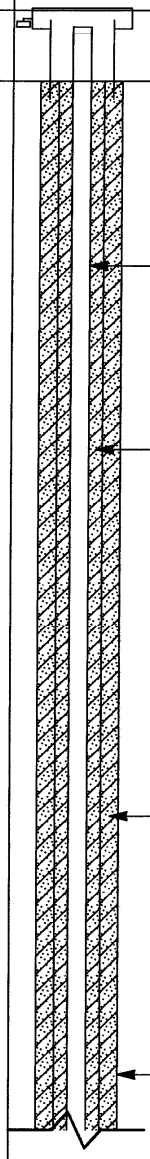
STRATIGRAPHIC AND INSTRUMENTATION LOGS

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1U
DATE COMPLETED: September 12, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1142098.7 EASTING: 1026699.49	TOP OF RISER 589.53 GROUND SURFACE 587.86					
	OVERBURDEN (not sampled) (see overburden stratigraphy for well AB1L)						
2							
4							
6			4"Ø BLACK STEEL CASING				
8							
10			CEMENT/ BENTONITE GROUT				
12							
14							
16							
18							
20			CEMENT/ BENTONITE GROUT				
22							
24							
26							
28			10"Ø BOREHOLE				
	END OF OVERBURDEN HOLE @ 28.5ft BGS						
30							
32							
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1U
DATE COMPLETED: September 12, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
28			10"Ø BOREHOLE				
	BEDROCK (not sampled)	559.36	CEMENT/ BENTONITE GROUT				
30	- mechanical breaks: 30.8 and 34.6 ft BGS	557.36	6"Ø BOREHOLE				
32	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces			1	92	67	100
34	- shaley partings: 31.4, 31.9, 32.0, 32.4, 32.9, 33.1, 33.4, 33.8, 34.3, and 35.5 ft BGS						
36	- vugs: 38.4 and 35.1 ft BGS						
	- shaley partings: 35.6, 36.2, 36.6, 37.2, and 38.0 ft BGS						
38	- closed horizontal fracture, gypsum coated @ 38.2 ft BGS						
	- vugs: 38.4 and 40.0 ft BGS						
40	- mechanical breaks: 39.0, 39.7, 39.9, and 40.1 ft BGS			2	100	86	80
	- shaley partings: 41.3, 41.6, 41.7, 42.2, 42.8, and 42.9 ft BGS						
42	- closed horizontal fracture coated with gypsum and sphalerite @ 42.6 ft BGS	545.46	HQ COREHOLE				
44	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	542.86					
46	END OF BOREHOLE @ 45.0ft BGS						
48							
50							
52							
54							
56							
58							
60							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1M
DATE COMPLETED: August 28, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1142105.06 EASTING: 1026719.93	TOP OF RISER 589.44 GROUND SURFACE 588.02					
	OVERBURDEN (not sampled) (see overburden for well AB1U)						
2			4"Ø BLACK STEEL CASING				
4							
6			6"Ø BOREHOLE				
8							
10			8"Ø BLACK STEEL CASING				
12							
14			CEMENT/BENTONITE GROUT				
16			CEMENT/BENTONITE GROUT				
18			10"Ø BOREHOLE				
20							
22	END OF OVERBURDEN HOLE @ 22.6ft BGS						
24							
26							
28							
30							
32							
34							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1M
DATE COMPLETED: August 28, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
22							
	BEDROCK (not sampled) (see bedrock for well AB1U)	565.42					
24							
26							
28							
30							
32			4"Ø BLACK STEEL CASING				
34							
36							
38			CEMENT/BENTONITE GROUT				
40							
42							
44	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	544.52		1	100		100
46							
48			HQ COREHOLE				
50	- mechanical breaks: 43.9, 45.0, 45.5, 47.4, 48.0, 50.8, 54.3, 56.2, 57.1, 57.9 (shaley), 58.5 (shaley), 60.1, 61.6, 62.6, 63.1, 64.9, 65.2, 65.4, 67.8, 68.0, 68.8, 69.3, 69.7, 70.7, 71.0, 71.6, 72.3, 73.2, 73.6, 74.3, 74.6, 76.3, 77.0, 77.6, 77.8, and 78.3 ft BGS			2	100	80	100
52							
54							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1M
DATE COMPLETED: August 28, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	FQD %	Water Return (%)
56, 58, 60, 62				3	99	92	75
64, 66, 68, 70, 72, 74, 76, 78	DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous -abundance of crinoids at Goat Island/Gasport contact - slightly weathered horizontal fractures: 64.1 and 64.2 ft BGS - very broken and fractured, slightly weathered between 64.5 and 64.7 ft BGS - gypsum-lined closed fracture @ 77.2 ft BGS	525.42	HQ COREHOLE	4	93	81	50
80, 82, 84, 86, 88	DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite - mechanical breaks: 79.0, 80.4, 80.5, 81.8, and 83.5 ft BGS	509.62		5	100	93	50
	END OF BOREHOLE @ 85.5ft BGS	502.52					

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

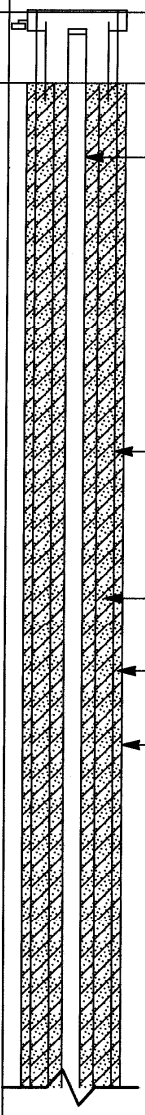
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

NORTHING: 1142109.27
EASTING: 1026737.66

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL
	TOP OF RISER	590.05
	GROUND SURFACE	587.97
	ASPHALT	587.77
	GW-GRAVEL, fill	
2	CL-CLAY, some silt, yellowish-orange, dry, slight plasticity, dense	585.97
4		
6		
8		
10		
12		
14		
16	- moist below 17 ft BGS	
18		
20	- wet below 20 ft BGS	
22		
24		
26		
28	END OF OVERBURDEN HOLE @ 27.3ft BGS	
30		
32		
34		

MONITOR INSTALLATION



SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE	PID
SS1		0.8	19	0
SS2		1.7	15	0
SS3		1.4	13	0
SS4		1.3	26	0
SS5		1.9	20	0
SS6		1.5	7	0
SS7		2.0	22	0
SS8		2.0	9	0
SS9		2.0	19	0
SS10		2.0	WH	0
SS11		2.0	WH	0
SS12		2.0	4	0
SS13		1.7	1	0
SS14		1.3	>50	0

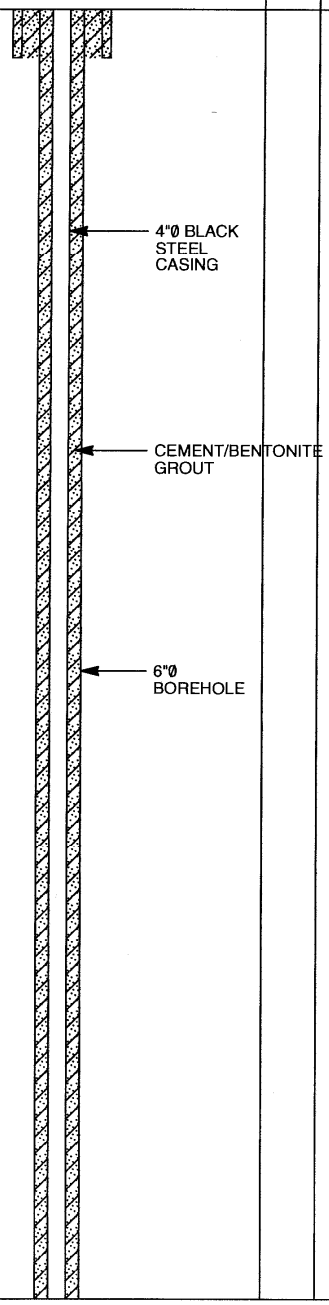
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
	BEDROCK (not sampled) (see bedrock stratigraphy for well AB1U and AB1M)	560.67					



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
62, 64, 66, 68, 70, 72, 74, 76, 78			4"Ø BLACK STEEL CASING; CEMENT/BENTONITE GROUT; 6"Ø BOREHOLE; HQ COREHOLE				
80, 82, 84, 86	DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite - mechanical breaks: 79.9, 83.7, and 85.1 ft BGS - shaley partings: 79.6 and 80.1 ft BGS	508.97		1	100	80	100
88, 90, 92, 94	DOLOMITE (Decew Formation): medium-grey, fine-grained, thin to thick-bedded, argillaceous - mechanical breaks: 87.5, 88.5, 90.1, 90.6, 93.1, 93.7, 94.0, 94.3, and 94.5 ft BGS	501.67		2	100	95	100
	- shaley parting @ 95.1 ft BGS	492.47		3	97	90	100

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: AB1L
DATE COMPLETED: September 11, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
98	SHALE (Rochester Shale Formation): dark-grey to black, massively bedded, dolomitic - shaley parting @ 97.1 ft BGS END OF BOREHOLE @ 97.5ft BGS	490.47					
100							
102							
104							
106							
108							
110							
112							
114							
116							
118							
120							
122							
124							
126							
128							
130							

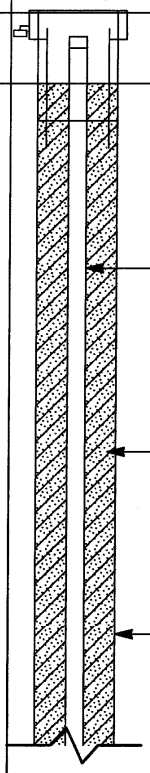
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-5U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141348.77 EASTING: 1026048.56	TOP OF RISER 589.38 GROUND SURFACE 588.17					
	OVERBURDEN (not sampled)						
2							
4							
6			4"Ø BLACK STEEL CASING				
8							
10			CEMENT/ BENTONITE GROUT				
12							
14							
16			10"ØBOREHOLE				
18	END OF OVERBURDEN HOLE @ 18.0ft BGS						
20							
22							
24							
26							
28							
30							
32							
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-5U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
18	BEDROCK (not sampled)	570.17					
20							
22	DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules - fractures: 22.6, 22.8, and 23.4 ft BGS - mechanical break @ 24.8 ft BGS - shaley parting @ 26.4 ft BGS	566.17		1	85	50	0
24							
26							
28	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces - mechanical breaks: 25.9, 26.9, 28.1, 28.2, 28.3, 28.7, 29.5, 34.1, 34.5, 36.1, 37.2, 37.7, 37.8, 38.8, 39.4, 40.0, 40.4, 42.2, and 42.25 ft BGS - shaley partings: 26.6, 26.65, 27.2, 27.3, 27.5, 27.7, 30.3, 35.3, 41.2, 41.7, 43.1, 43.3, 44.8, 45.1, and 45.3 ft BGS	561.57		2	96	66	0
30							
32							
34							
36			HQ COREHOLE	3	100	92	0
38	- faractures: 38.0 (with mineralization) and 46.1 ft BGS						
40							
42							
44							
46	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert - fractures: 46.4 and 48.2 ft BGS - mechanical breaks: 48.6, 49.6, 49.8, and 49.9 ft BGS	542.47		4	100	87	0
48							
50							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-5U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
	END OF BOREHOLE @ 51.0ft BGS	537.17					
52							
54							
56							
58							
60							
62							
64							
66							
68							
70							
72							
74							
76							
78							
80							
82							
84							

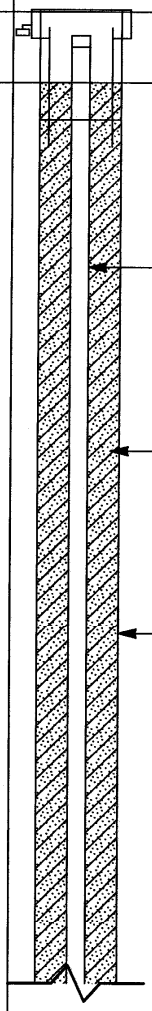
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-6U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141518.27 EASTING: 1026111.43 — TOP OF RISER / GROUND SURFACE	588.71 588.61					
	OVERBURDEN (not sampled)						
2							
4			4"Ø BLACK STEEL CASING				
6							
8							
10			CEMENT/ BENTONITE GROUT				
12							
14			10"ØBOREHOLE				
16							
18							
20							
22							
24	END OF OVERBURDEN HOLE @ 24.5ft BGS						
26							
28							
30							
32							
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: CD-6U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
24							
	BEDROCK (not sampled)	564.11					
26		562.11					
28	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces			1	100	46	100
30	- mechanical breaks: 26.6, 26.7, 26.8, 26.9, 27.05, 27.1, 27.7, 28.3, 29.0, 29.2, 29.5, 29.7, 29.8, 30.2, 30.4, 32.6, 34.4, 34.65, 35.5, 35.7, 38.7, 38.0, 39.6, 40.8, and 43.2 ft BGS						
32	- fractures: 32.2 and 36.6 ft BGS						
34	- shaley partings: 30.7, 33.5, 33.55, 34.6, 38.4, and 39.8 ft BGS		HQ COREHOLE				
36				2	99	80	90
38							
40	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	548.51					
42	- fracture @ 41.9 ft BGS						
44	- mechanical breaks: 44.9, 46.0, 48.0, 48.9, 49.9, 50.6, 52.8, 52.9, 54.4, and 54.9 ft BGS						
46	- shaley partings: 43.7, 43.8, 45.0, 46.8, 48.6, and 50.8 ft BGS			3	100	90	90
48							
50							
52							
54				4	98	96	80
56	END OF BOREHOLE @ 56.2ft BGS	532.41					

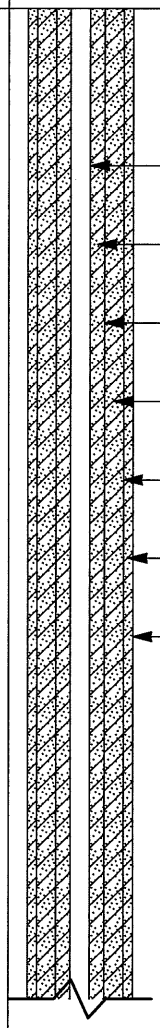
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: IFW-1R
DATE COMPLETED: August 14, 1991
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: P. Smith

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS	MONITOR INSTALLATION	SAMPLE NUMBER	SAMPLE INTERVAL	SAMPLE REC (ft)	SAMPLE 'N' VALUE
	OVERBURDEN (see overburden stratigraphy for well IFW-1)		4"Ø STEEL CASING CEMENT/ BENTONITE GROUNT 6"Ø STEEL CASING CEMENT/ BENTONITE GROUNT 8"Ø STEEL CASING CEMENT/ BENTONITE GROUNT 12"Ø BOREHOLE				
	END OF OVERBURDEN HOLE @ 25.2ft BGS						



2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34

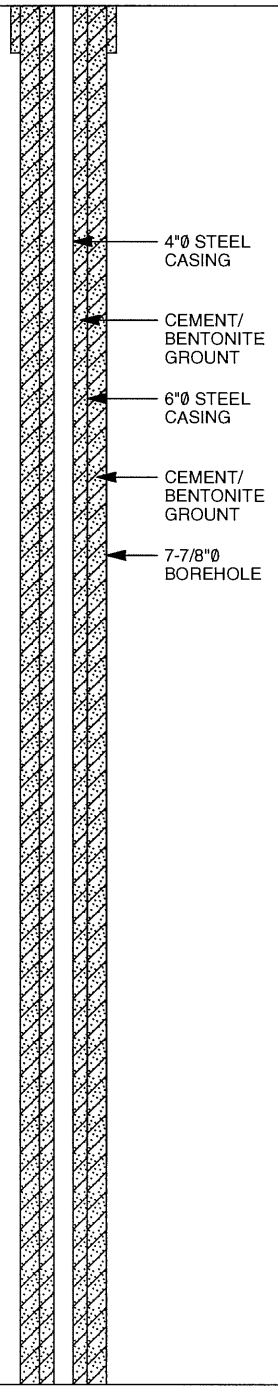
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: IFW-1R
DATE COMPLETED: August 14, 1991
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: P. Smith

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %
	BEDROCK (see bedrock stratigraphy for well IFW-1)	25.20				



26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: IFW-1R
DATE COMPLETED: August 14, 1991
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: P. Smith

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %
60						
62						
64						
66			4"Ø STEEL CASING			
68			CEMENT/ BENTONITE GROUNT			
70			6"Ø STEEL CASING			
72			CEMENT/ BENTONITE GROUNT			
74			7-7/8"Ø BOREHOLE			
76						
78						
80						
82						
84						
86						
88						
90						
92						

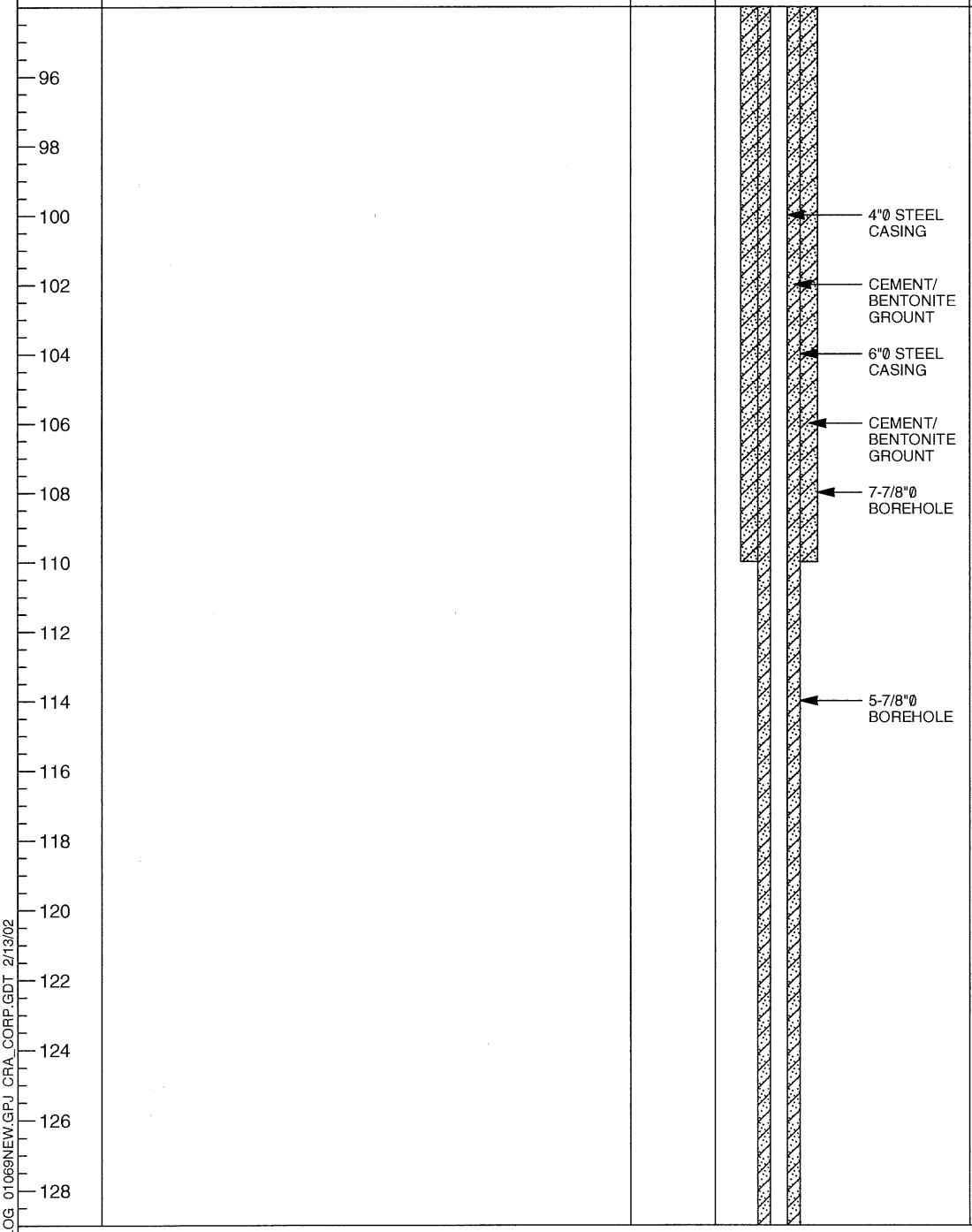
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: IFW-1R
DATE COMPLETED: August 14, 1991
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: P. Smith

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: IFW-1R
DATE COMPLETED: August 14, 1991
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: P. Smith

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	
130							
132			4"Ø STEEL CASING				
134			CEMENT/ BENTONITE GROUNT				
136			5-7/8"Ø BOREHOLE				
138							
140							
142							
144							
146							
148							
150							
152			3-7/8"Ø BOREHOLE				
154							
156							
158							
160							
162							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG (BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: IFW-1R
DATE COMPLETED: August 14, 1991
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: P. Smith

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	
166							
168							
170			3-7/8"Ø BOREHOLE				
172							
174							
176	END OF BOREHOLE @ 176.0ft BGS	176.00					
178							
180							
182							
184							
186							
188							
190							
192							
194							
196							
198							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5U
DATE COMPLETED: August 14, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	SAMPLE INTERVAL	SAMPLE REC (ft)	SAMPLE 'N' VALUE
	NORTHING: 1141499.79 EASTING: 1028119.09 — TOP OF RISER / GROUND SURFACE	606.10 604.52					
	Not sampled.						
	OH-SILT and CLAY (TOPSOIL), gravel	603.52	CEMENT/ BENTONITE GROUT	SS1	X		32
2							
	ML/CL-SILT and CLAY	601.52		SS2	X		33
4							
	ML/CL-CLAY and SILT, brown, dry	599.52	10"Ø BOREHOLE	SS3	X		19
6			CEMENT/ BENTONITE GROUT				
8				SS4	X		34
	ML-SILT (TILL), some gravel, brown, wet	595.52	4"Ø BLACK STEEL CASING	SS5	X		45
10							
	Weathered Bedrock	593.52		SS6	X		
12			6"Ø BOREHOLE				
14	END OF OVERBURDEN HOLE @ 13.5ft BGS						
16							
18							
20							
22							
24							
26							
28							
30							
32							
34							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5U
DATE COMPLETED: August 14, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
		591.02	6"Ø BOREHOLE				
14	DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules			1	60	0	50
16							
18	- fractures with iron staining (possible overburden washing down into fracture): 17.8 and 18.2 ft BGS						
20	- fractures: 13.8, 14.0, 14.1, 14.3, 14.5, 14.6, 20.2 (broken along plane of calcite-filled vugs), 22.7, and 32.3 ft BGS			2	100	73	20
22							
24	- mechanical breaks: 15.0, 15.8, 16.1, 16.4, 16.7, 17.7, 18.9, 19.2, 19.8, 21.4, 21.85, 21.9, 22.5, 24.0, 26.1, 28.0, 28.9, 29.55, 30.3, 30.4, 31.7, 36.3, 37.0, 37.3, 37.4, 38.3, 39.2, 41.0, and 44.3 ft BGS		HQ COREHOLE				
26							
28	- shaley partings: 15.9, 17.2, 17.35, 22.3, 25.6, 25.9, 27.2, 27.5, and 43.5 ft BGS						
30	- fracture with extensive mineralization (gypsum, calcite, and very small amounts of shpalerite and galena) @ 30.0 ft BGS			3	97	78	0
32	- fracture with extensive mineralization (gypsum and calcite) @ 30.9 ft BGS - abundant fossils (colonial corals) between 33.0 and 36.5 ft BGS						
34							
36	- mineral partings: 24.5, 25.0, 44.9, and 45.0 ft BGS						
38							
40				4	98	95	0
42	- abundant vugs, partially/wholely infilled with gysum, samll vugs cotain visible calcite crystals between 42.0 and 47.0 ft BGS						
44	- fractures with mineralization: 45.9, 46.0, 46.5, 47.2, 47.5, and 47.6 ft BGS						
46	- mecahnical break @ 46.2 ft BGS						

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5U
DATE COMPLETED: August 14, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
48							
	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces - mecahnical breaks: 48.3, 48.6, 49.1, 50.2, 50.7 (on small galena-filled vug), 52.5, 53.5, 53.9, 54.0, 54.3, 56.2, 56.8, and 60.3 ft BGS - partings with gypsum-filled vugs: 50.5, 58.1, and 58.6 ft BGS - shaley partings: 48.1, 51.7, and 54.7 (on vug with gypsum and calcite crystalization), 57.8, and 58.05 ft BGS	556.42	HQ COREHOLE	5	100	81	0
50							
52							
54							
56							
58	- fracture with gypsum @ 58.9 ft BGS			6	100	96	0
60							
	END OF BOREHOLE @ 60.5ft BGS	544.02					
62							
64							
66							
68							
70							
72							
74							
76							
78							
80							

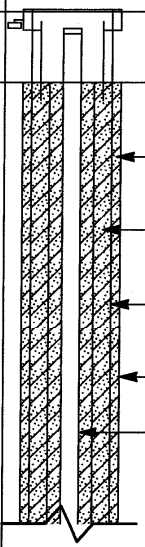
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ▽

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141471.71 EASTING: 1028121.17 — TOP OF RISER / GROUND SURFACE	606.37 604.62					
	OVERBURDEN (not sampled) (see overburden stratigraphy for well J5U)						
2			CEMENT/BENTONITE GROUT				
4			CEMENT/BENTONITE GROUT				
6			8"Ø BLACK STEEL CASING				
8			10"Ø BOREHOLE				
10			4"Ø BLACK STEEL CASING				
12	END OF OVERBURDEN HOLE @ 12.0ft BGS						
14							
16							
18							
20							
22							
24							
26							
28							
30							
32							
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
12	BEDROCK (not sampled) (see bedrock stratigraphy for well J5U)	592.62					
14							
16							
18							
20			6"Ø BOREHOLE				
22							
24							
26							
28							
30			4"Ø BLACK STEEL CASING				
32							
34							
36							
38			CEMENT/BENTONITE GROUT				
40							
42							
44							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
46, 48, 50, 52, 54, 56, 58, 60	- shaley partings: 60.0, 62.1, 66.4, and 67.0 ft BGS		4"Ø BLACK STEEL CASING; 6"Ø BOREHOLE; CEMENT/BENTONITE GROUT				
62, 64, 66, 68, 70	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces - mechanical breaks: 61.7, 61.9, 63.6, 65.6, 66.1, 68.8, 69.5, 70.8, and 70.9 ft BGS - fractures: 62.8, 65.2, and 71.2 ft BGS	544.12	HQ COREHOLE	1	97	94	100
72, 74, 76, 78	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert - mechanical breaks: 71.4, 72.4, 72.5, 73.2, 73.6, 74.6, 75.3, 76.6, 77.0, 77.5, 79.1, 80.6, 82.9, 84.3, 84.8, 87.1, 91.1, 92.3, 92.4, 93.2, 94.0, 97.2, and 98.7 ft BGS - fractures: 71.7, 80.6, 82.8, 83.2 (with gypsum), 86.5 (with gypsum), 86.7 (with gypsum and sphalerite), 88.4, 90.2, 91.9 (very	533.32		2	100	85	90

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5M
DATE COMPLETED: August 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
	vuggy with gypsum mineralization) ft BGS						
82							
84	- shaley partings: 81.6, 89.7, 95.7, 99.0, and 99.05 ft BGS						
86				3	97	92	0
88							
90			HQ COREHOLE				
92	DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous	512.52					
94	-abundance of crinoids at Goat Island/Gasport contact						
96				4	100	96	0
98							
100							
	END OF BOREHOLE @ 100.5ft BGS	504.12					
102							
104							
106							
108							
110							
112							
114							

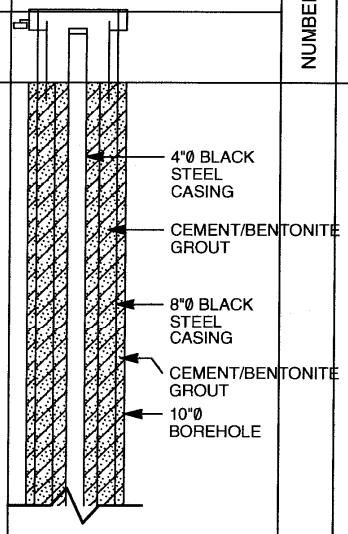
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141449.01 EASTING: 1028117.61 — TOP OF RISER GROUND SURFACE	607.79 606.08					
	OVERBURDEN (not sampled) (see overburden stratigraphy for J5U)						
12	END OF OVERBURDEN HOLE @ 11.5ft BGS						



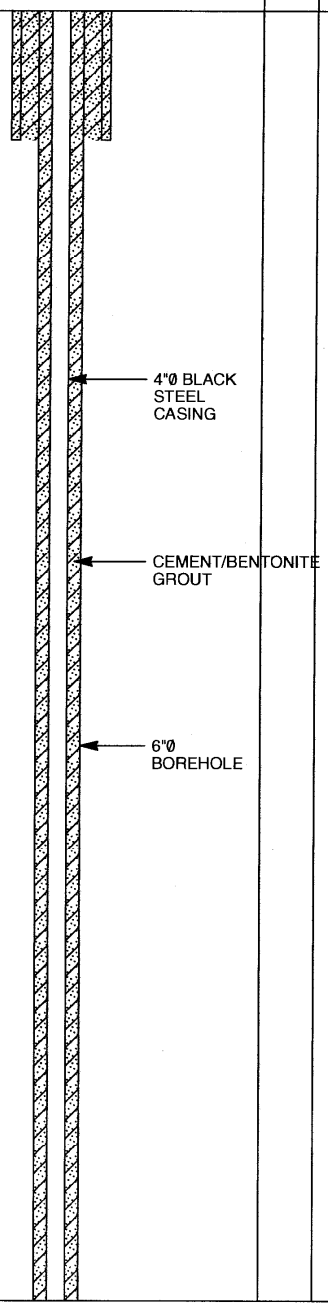
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	FQD %	Water Return (%)
	BEDROCK (not sampled) (see Bedrock stratigraphy for well J5M)	594.58					



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
46							
48							
50			6"Ø BOREHOLE				
52							
54			CEMENT/BENTONITE GROUT				
56							
58							
60			4"Ø BLACK STEEL CASING				
62							
64							
66							
68							
70							
72							
74							
76							
78							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
82							
84							
86			6"Ø BOREHOLE				
88							
90			CEMENT/BENTONITE GROUT				
92							
94							
96			4"Ø BLACK STEEL CASING				
98							
100	DOLOMICRITE (Gasport Formation-Pekin Member): dark-grey, fine-grained, thin to medium-bedded, argillaceous	506.98		1	100	100	100
102	-abundance of crinoids at Goat Island/Gasport contact - mechanical breaks: 99.6, 100.1, 101.6, 101.9, 102.1, 104.0, 104.0, 105.0, 106.0, 109.0, 110.1, and 110.8 ft BGS			2	100	58	100
104			HQ COREHOLE				
106	- fractures: 104.3 and 107.6 ft BGS - shaley partings: 103.8, 104.8, 107.5, and 114.3 ft BGS			3	100	91	100
108	DOLOMITIC LIMESTONE (Gasport Formation-Gothic Hill Member): dark olive-grey to light pink, thick to massive-bedded, primarily crinoidal grainstone and crinoidal dolomite	498.08					
110							
112	DOLOMITE (Decew Formation): medium-grey, fine-grained, thin to thick-bedded, argillaceous	494.08					
114							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: J5L
DATE COMPLETED: September 10, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
116	- mechanical breaks: 113.8, 114.9, 116.5, 117.1, 118.9, 121.3, 122.8, 123.0, 125.2, 125.3, and 125.4 ft BGS - shaley partings: 114.3, 118.7, and 119.7 ft BGS - fractures: 120.0, 122.5, 123.9, and 124.1 ft BGS		HQ COREHOLE	4	100	94	100
118							
120							
122							
124				5	100	77	100
	SHALE (Rochester Shale Formation): dark-grey to black, massively bedded, dolomitic	481.48					
126	END OF BOREHOLE @ 126.0ft BGS	480.08					
128							
130							
132							
134							
136							
138							
140							
142							
144							
146							
148							

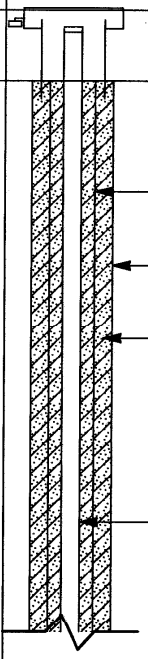
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW1-2001
DATE COMPLETED: July 18, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141743.95 EASTING: 1027388.74 — TOP OF RISER / GROUND SURFACE	597.16 595.41					
2, 4, 6, 8, 10, 12, 14	OVERBURDEN See stratigraphy for well PW-10U for Overburden.		6"Ø BOREHOLE 10"Ø BOREHOLE CEMENT/ BENTONITE GROUT 4"Ø BLACK STEEL CASING				
16, 18, 20, 22, 24, 26, 28, 30, 32, 34	END OF OVERBURDEN HOLE @ 15.0ft BGS						



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW1-2001
DATE COMPLETED: July 18, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
	BEDROCK (not sampled)	580.41	6"Ø BOREHOLE; 4"Ø BLACK STEEL CASING				
16		578.41					
18	DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules						
20	-extensive fracturing and weathering (vertical fracture from 17.2 to 19.5), small vugs, some colonial corals @ 17.0 to 19.5 ft BGS			1	98	66	0
22	- abundance of small vugs @ 19.5 to 21.3 ft BGS						
24	- weathered fractures: 18.2, 19.0, 19.8, 20.8, 21.3, 29.5, 29.8, 30.6, 31.0, and 31.2 ft BGS						
	- no vugs, chert inclusions, higher shale content @ 21.3 to 23.9 ft BGS						
26	- shaley partings: 22.0, 22.9, 27.5, and 28.2 ft BGS						
	- highly weathered fracture @ 23.8 ft BGS						
28	- abundance of vugs (some with calcite of sphalerite crystals) and corals with some stylolites @ 23.9 to 31.0 ft BGS			2	100	75	0
	- mechanical breaks: 25.8 and 31.5 ft BGS						
30			HQ COREHOLE				
	- mineral parting @ 31.6 ft BGS						
32	- small vein with calcite crystals on perimeter and sphalerite crystals on the inside @ 31.6 to 31.8 ft BGS	563.21					
34	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces			3	100	67	0
36	- shaly partings: 32.25, 32.5, 32.7, 32.8, 33.7, 34.5, 34.7, 35.0, 35.7, 36.3, and 37.1 ft BGS	557.91					
38	END OF BOREHOLE @ 37.5ft BGS						
40							
42							
44							
46							
48							

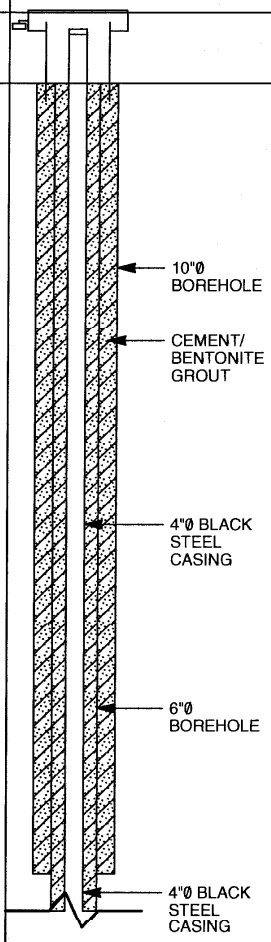
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW2-2001
DATE COMPLETED: July 19, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	SAMPLE INTERVAL	SAMPLE REC (ft)	SAMPLE 'N' VALUE
	NORTHING: 1141702.65 EASTING: 1027393.5	TOP OF RISER 596.04 GROUND SURFACE 594.42					
	OVERBURDEN See stratigraphy for well PW-10U for Overburden.						
22	BEDROCK (not sampled)	572.92					
	END OF OVERBURDEN HOLE @ 22.5ft BGS						



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW2-2001
DATE COMPLETED: July 19, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
	BEDROCK (not sampled)	572.92	4"Ø BLACK STEEL CASING				
	DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules - mechanical breaks: 26.7, 28.6, and 31.7 ft BGS	571.92		1	100	100	100
			HQ COREHOLE	2	100	89	100
	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces - mechanical breaks: 32.6, 32.8, 33.1, and 33.9 ft BGS	561.92					
	END OF BOREHOLE @ 35.1ft BGS	559.32					

22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54

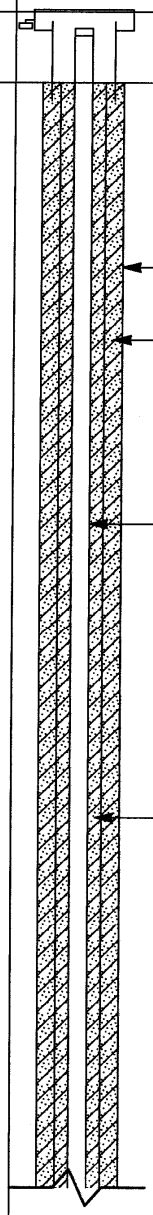
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW3-2001
DATE COMPLETED: July 26, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141799.31 EASTING: 1026826.96	TOP OF RISER 591.26 GROUND SURFACE 589.76					
	OVERBURDEN See stratigraphy for well PW-9U for Overburden.						
2							
4			10"Ø BOREHOLE				
6			CEMENT/ BENTONITE GROUT				
8							
10							
12			4"Ø BLACK STEEL CASING				
14							
16							
18							
20			CEMENT/ BENTONITE GROUT				
22							
24							
26							
28							
30	END OF OVERBURDEN HOLE @ 30.0ft BGS						
32							
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW3-2001
DATE COMPLETED: July 26, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	FQD %	Water Return (%)
30	BEDROCK (not sampled)	559.76	6"Ø BOREHOLE; 4"Ø BLACK STEEL CASING				
32	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces	557.76		1	83	79	100
34							
36	- shaly partings: 35.1, 36.2, 41.4, 41.5, 46.5, and 47.2 ft BGS - mechanical breaks: 32.1 to 33.2, 34.3, 35.4, 36.7, 37.4, 38.6, 38.8, 38.95, 39.85, 40.2, 40.7, 41.0, and 43.0 ft BGS						
38							
40				2	99	89	70
42	- partially filled void/fracture @ 42.45 ft BGS						
44	- vugs with mechanical breaks: 43.8 and 43.9 ft BGS - vug @ 44.0 ft BGS - partially filled fracture		HQ COREHOLE				
46							
48	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	542.26		3	91	86	70
50	- mechanical breaks: 48.0 and 48.2 ft BGS	539.76					
52	END OF BOREHOLE @ 50.0ft BGS						
54							
56							
58							
60							
62							

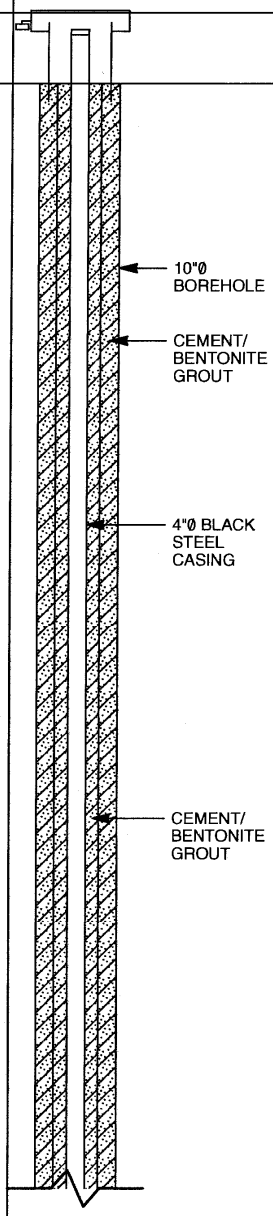
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW4-2001
DATE COMPLETED: July 27, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	SAMPLE INTERVAL	SAMPLE REC (ft)	SAMPLE 'N' VALUE
	NORTHING: 1141816.56 EASTING: 1026802.81	TOP OF RISER 590.90 GROUND SURFACE 588.82					
	OVERBURDEN See stratigraphy for well PW-9U for Overburden.						
30	END OF OVERBURDEN HOLE @ 30.0ft BGS						



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW4-2001
DATE COMPLETED: July 27, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
30	BEDROCK (not sampled)	558.82	6"Ø BOREHOLE; 4"Ø BLACK STEEL CASING				
32	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous. emits a petroliferous odor from fresh surfaces	556.82		1	71	66	100
34							
36	- mechanical break: 33.1, 33.5, 33.6, 34.5, 34.9, 35.4, 36.8, 38.4, 38.7, 39.1, 39.8, 40.6, 40.95, 42.4, 42.9, 43.6, 43.8, 44.25, 46.7, 47.7, 48.2, and 49.8 ft BGS						
38	- shaly partings: 36.6, 37.8, 38.2, 38.8, 40.0, 41.0, and 43.5 ft BGS						
40				2	100	85	75
42							
44	- partially infilled fracture @ 44.5 ft BGS		HQ COREHOLE				
46							
48	- possible fracture with partial gypsum infilling @ 48.35 ft BGS	540.32		3	100	99	70
50	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey. thin to medium-bedded. fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	538.52					
52	END OF BOREHOLE @ 50.3ft BGS						
54							
56							
58							
60							
62							

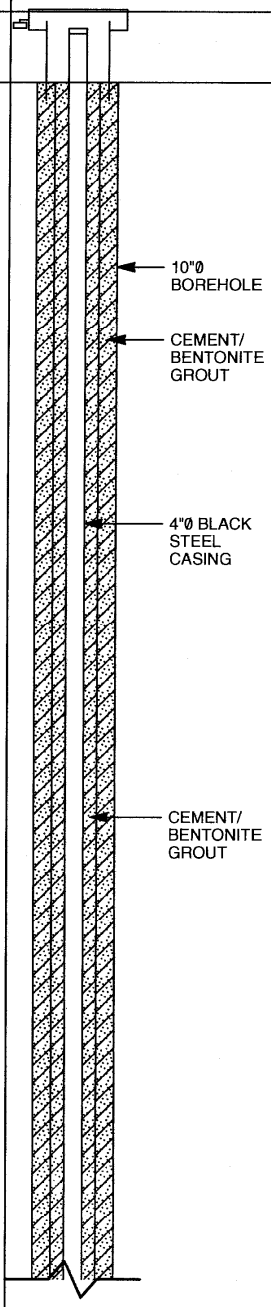
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW5-2001
DATE COMPLETED: July 25, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141738.31 EASTING: 1026603.95	TOP OF RISER 593.11 GROUND SURFACE 591.69					
	OVERBURDEN (See overburden stratigraphy for well PW-8U.)						
	END OF OVERBURDEN HOLE @ 32.5ft BGS						



2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW5-2001
DATE COMPLETED: July 25, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
32							
	BEDROCK (not sampled)	559.19	6"Ø BOREHOLE 4"Ø BLACK STEEL CASING				
34		557.19					
36	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces			1	100	100	90-95
38	- mechanical breaks: 33.1, 33.5, 35.9, 37.7, 38.2, 40.3, 41.47, 43.3, 47.6, and 47.9 ft BGS						
40	- shaly partings: 33.8, 37.8, 39.0, 40.75, 41.3, 43.4, 43.75, 44.5, 45.5, 45.8, 46.5, 48.6, and 49.3 ft BGS			2	100	100	90-95
42							
44	- fracture with gypsum mineralization @ 44.05 ft BGS		HQ COREHOLE				
46	- vugs: 45.5 and 46.5 to 47.0 ft BGS						
48	- fracture with extensive mineralization (probably plugged)			3	100	90	90-95
50	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	542.19 541.69					
52	END OF BOREHOLE @ 50.0ft BGS						
54							
56							
58							
60							
62							
64							

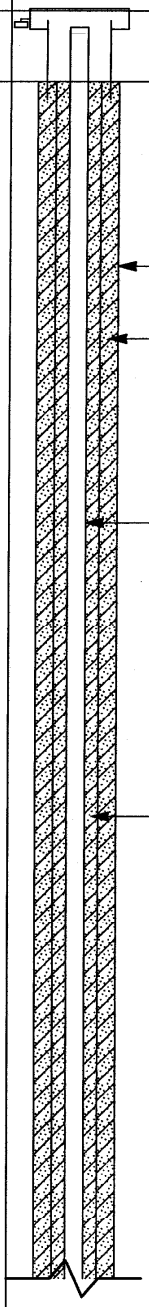
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW6-2001
DATE COMPLETED: July 25, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE
	NORTHING: 1141760.93 EASTING: 1026600.12 — TOP OF RISER GROUND SURFACE	592.66 591.16					
	OVERBURDEN (See stratigraphy for well PW-8U for Overburden.)						
2							
4							
6			10"Ø BOREHOLE				
8			CEMENT/ BENTONITE GROUT				
10							
12			4"Ø BLACK STEEL CASING				
14							
16							
18							
20			CEMENT/ BENTONITE GROUT				
22							
24							
26							
28							
30							
32	END OF OVERBURDEN HOLE @ 32.5ft BGS						
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW6-2001
DATE COMPLETED: July 25, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	FQD %	Water Return (%)
32							
	BEDROCK (not sampled)	558.66	6"Ø BOREHOLE 4"Ø BLACK STEEL CASING				
34		556.66		1	100	100	90
36	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained. argillaceous. thin shale partings. commonly bituminous, emits a petroliferous odor from fresh surfaces						
38	- mechanical breaks: 33.1, 33.3, 33.7, 33.8, 35.8, 36.4, 36.5, 36.7, 38.3, 38.9, 40.0, 40.6, 43.0, and 49.4 ft BGS						
40	- shaly partings: 35.6, 40.7, 42.5, 42.9, 48.1, 48.7, and 49.6 ft BGS			2	100	81	90
	- large gypsum filled vugs @ 41 ft BGS						
42	- gypsum filled fracture @ 41.1 ft BGS						
44			HQ COREHOLE				
46	- gypsum filled fracture @ 46.4 ft BGS						
48				3	100	85	70-75
		542.56					
50	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert	541.16					
52	- fracture and/or mechanical break with gypsum and sphalerite crystals @ 49.2 ft BGS						
54	END OF BOREHOLE @ 50.0ft BGS						
56							
58							
60							
62							
64							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

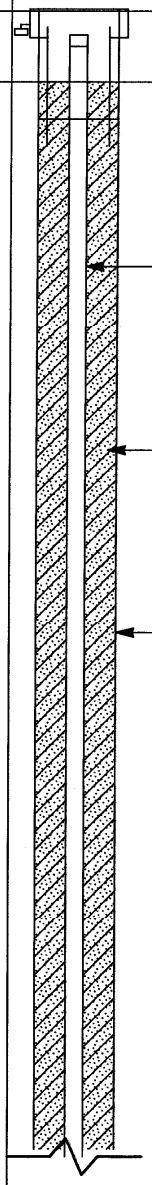
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW7-2001
DATE COMPLETED: July 3, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

NORTHING: 1141707.04 — TOP OF RISER: 591.86
EASTING: 1026866.6 — GROUND SURFACE: 590.28

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL
	TOPSOIL	589.68
	CL-CLAY, trace medium sand, light brown, dry, medium plasticity with added moisture	
12	- moist below 12 ft BGS	
24	- wet below 24.5 ft BGS	
26	- Rock fragments	
	END OF OVERBURDEN HOLE @ 29.2ft BGS	561.28

MONITOR INSTALLATION



SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE	PID
SS1	X	1.3	7	0
SS2	X	0.7	19	0
SS3	X	1.6	11	0
SS4	X	0.8	14	0
SS5	X	1.0	10	0
SS6	X	1.6	10	0
SS7	X	2.0	19	0
SS8	X	2.0	12	0
SS9	X	2.0	16	0
SS10	X	1.7	8	0
SS11	X	2.0	8	0
SS12	X	2.0	9	0
SS13	X	1.4	7	0
SS14	X	1.7	43	0

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: MW7-2001
DATE COMPLETED: July 3, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	Water Return (%)
	BEDROCK DOLOMITE (Eramosa Formation): dark brownish-grey, thick to thin-bedded, bituminous, emits a petroliferous odor from fresh surfaces, some horizons contain small white chert nodules	561.08 560.88		1	100	33	100
30 32	DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces - fractures: 29.0-29.3, and 45.5 (fracture with open vug) - Shaley parting: 29.55, 29.95, 30.75, 31.0, 32.35, 33.1, 33.5, 34.0, 34.4, 34.5, 38.7, 39.2, 39.9, 40.1, 40.2, 42.8, 43.8, 44.2, 47.3, and 47.9 ft BGS - mechanical breaks: 29.7, 33.7, 36.6, 37.0, 37.6, 37.8, 39.6, 40.7, 42.0, 42.3, 42.4, 44.2, 45.2, 45.3, and 45.7 ft BGS		HQ - COREHOLE	2	94	75	100
34 36 38 40 42 44 46				3	100	88	100
48 50 52 54	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abundant nodules of distinctive pale, cream-colored chert - Shaley parting: 50.8, 53.0, 53.55 ft BGS - mechanical breaks: 48.9, 50.3, 51.3, 52.1, 53.9, and 54.5 ft BGS	542.18		4	100	96	80-90
56 58 60 62	END OF BOREHOLE @ 55.5ft BGS	534.78					

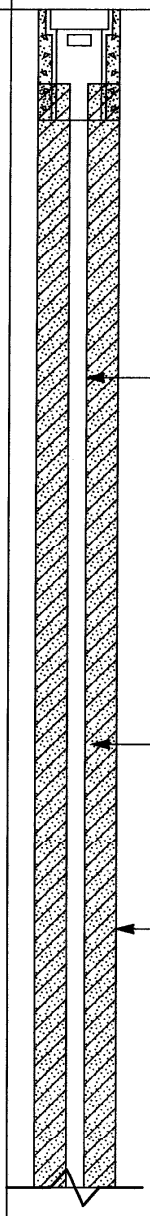
NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-7U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	SAMPLE NUMBER	SAMPLE INTERVAL	SAMPLE REC (ft)	SAMPLE 'N' VALUE
	NORTHING: 1141543.65 EASTING: 1026223.72	GROUND SURFACE 596.72 TOP OF RISER 592.98					
	OVERBURDEN (see overburden stratigraphy for well CD-2U)						
2			EXTRACTION WELL CHAMBER				
4							
6							
8							
10			12"Ø STEEL CASING				
12							
14							
16							
18							
20			CEMENT/ BENTONITE GROUT				
22							
24			20" Ø BOREHOLE				
26							
28							
30							
32	END OF OVERBURDEN HOLE @ 32.0ft BGS						
34							



NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-7U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %
32	BEDROCK (see bedrock stratigraphy for well CD-2U)	564.72				
34						
36						
38						
40			11 7/8"Ø BOREHOLE			
42						
44						
46						
48						
50						
52						
54						
56						
58						
60						
62						
64		532.72				

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-7U
DATE COMPLETED:
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	RQD %	
	END OF BOREHOLE @ 65.0ft BGS						
66							
68							
70							
72							
74							
76							
78							
80							
82							
84							
86							
88							
90							
92							
94							
96							
98							

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

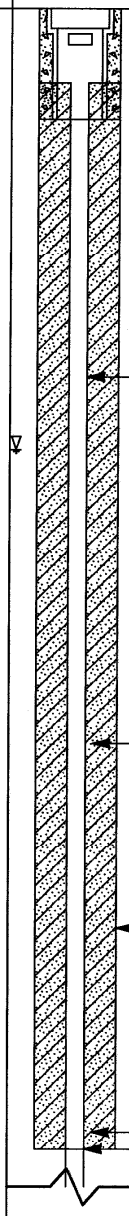
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8U
DATE COMPLETED: July 5, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

NORTHING: 1141704.94
EASTING: 1026603.26

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL
	GROUND SURFACE	593.65
	TOP OF RISER	589.78
	TOPSOIL	593.45
	CL-CLAY, trace medium grained sand, light brown, dry, high plasticity, dense	
	FILL, brick, cinders, black	589.15
	CL-CLAY, trace medium grained sand, light-brown, dry, high plasticity, dense	587.35
	- becomes moist	
	- becomes wet	
	- some rock fragments	
	WEATHERED ROCK	563.65
	END OF OVERBURDEN HOLE @ 32.0ft BGS	

MONITOR INSTALLATION



SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE	PID
1	X	0.8	17	0
2	X	1.0	28	0
3	X	0.4	17	0
4	X	1.8	15	0
5	X	1.5	13	0
6	X	1.1	11	0
7	X	2.0	15	0
8	X	2.0	12	0
9	X	2.0	12	0
10	X	2.0	5	0
11	X	2.0	4	0
12	X	2.0	6	0
13	X		WH	0
14	X	2.0	14	0
15	X	0.9	9	0
16	X	0.7	9	0

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

STRATIGRAPHIC AND INSTRUMENTATION LOG
(BEDROCK)

PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8U
DATE COMPLETED: July 5, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby, P. Kryger

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL	MONITOR INSTALLATION	RUN NUMBER	CORE RECOVERY %	FQD %	Water Return (%)
	WEATHERED ROCK	563.65	CEMENT/ BENTONITE GROUT 12"Ø STEEL CASING				
32	BEDROCK DOLOSTONE (Goat Island Formation-Vinemount Member): light to dark-drey, medium to thin-bedded, very fine grained, argillaceous, thin shale partings, commonly bituminous, emits a petroliferous odor from fresh surfaces -fractured @ 31.0 to 31.6 ft BGS - gypsum and calcite filled vugs: 41.5, 42.1, 42.7, 44.0, 46.25 - shaley partings: 32.1, 34.0, 34.7, 37.4, 37.75, 39.5, 39.9, 40.4, 40.8, 43.25, 43.6, 45.45, 48.2, 48.8 ,49.9, 52.0, 53.8, and 54.5 - mechanical breaks: 33.7, 34.5, 35.6, 37.3, 38.6, 39.4, 40.6, 40.9, 45.7, 46.6, 50.5, 55.0 - fractures with small, well formed calcite crystals @ 42.8 ft BGS - sphalerite filled vug	561.65	11 7/8"Ø BOREHOLE	1 2 3 4	60 100 100 99	70 60 86 96	100% 100% ~100% 75
54	DOLOSTONE (Goat Island Formation-Ancaster/Niagara Falls Member): medium ash-grey, thin to medium-bedded, fine-grained, weathers to light tan, typically contains abumdant nodules of distinctive pale, cream-colored chert	539.25 538.15					
58	END OF BOREHOLE @ 55.5ft BGS						

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ▽

STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

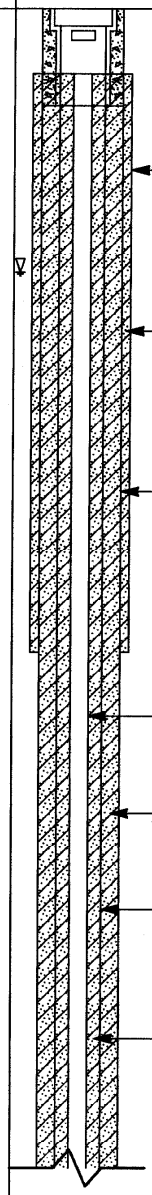
PROJECT NAME: Hyde Park RRT
PROJECT NUMBER: 01069-30
CLIENT: MSRM
LOCATION: Niagara Falls, NY

HOLE DESIGNATION: PW-8M
DATE COMPLETED: June 30, 2001
DRILLING METHOD: HSA/Wet Rotary
FIELD PERSONNEL: J. Raby

NORTHING: 1141602.21
EASTING: 1026685

GROUND SURFACE 597.01
TOP OF RISER 593.18

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	ELEV. ft AMSL
	TOPSOIL	596.41
2	CL-CLAY, trace medium grained sand, light brown, dry, high plasticity, dense	
4		
6	FILL, black ash, wood fragments, glass	591.11
8	ML-SILT, some clay, trace to little fine grained sand, light brown, moist, low plasticity	588.81
10		
12		
14	CL-CLAY, trace sand, light brown, dry, high plasticity, dense	583.01
16		
18		
20		
22	- rock fragments	
24		
26		
28		
30		
32		
34		
36	END OF OVERBURDEN HOLE @ 36.0ft BGS	
38		



SAMPLE NUMBER	INTERVAL	REC (ft)	'N' VALUE	PID
1		1.2	18	0
2		0.9	21	0
3		1.5	39	0
4		1.3	22	0
5		0.9	17	0
6		1.1	26	0
7		1.1	37	0
8		1.2	13	0
9		2.0	21	0
10		1.2	16	0
11		0.5	19	0
12		1.0	18	0
13		2.0	16	0
14		2.0	9	0
15		1.9	7	0
16		2.0	4	0
17		2.0	11	0

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ∇

APPENDIX E.1

MAPPING OF VERTICAL FRACTURES NEAR THE HYDE PARK LANDFILL SITE

Hyde Park Landfill Site
Niagara Falls, New York

Mapping of Vertical Fractures Near the Hyde Park Landfill Site

Prepared For:

Miller Springs Remediation Management Inc. and
Glenn Springs Holdings, Inc.

Prepared By:

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water Resource Consultants

February 12, 2001

207 King Street South, Waterloo, Ontario N2J 1R1 (519) 579-2100

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Figure 2 Summary of Lockport Group nomenclature in the Niagara region (from Brett and others, 1995)
Figure 3 Locations of vertical fractures
Figure 4 Locations and orientations of vertical fractures
Figure 5 Hypothesized vertical fractures
Figure 6 Joint orientations determined from Silurian and Devonian rocks in the Niagara Peninsula (after Williams and others, 1985)

Section 1
Introduction

On Thursday, September 6, Rick Passmore (GSHI), Jon Williams (CRA) and Chris Neville (SSP&A) examined the face of the Niagara River gorge close to the Hyde Park Landfill Site. This examination was intended to be a quick survey to identify major water-bearing vertical fractures, and thereby obtain additional basic data that might be useful in understanding the structure of the zones of different hydraulic response at the Site. If these fractures can be correlated to features at the Site, they may be incorporated in the revised characterization and groundwater model of the Site.

Location of mapping

The fracture mapping was conducted along the access road to the New York Power Authority (NYPA) Niagara Project. This is the same rock cut that was examined for the *Lockport Formation Investigation* in 1983, reported in CRA (1983).

The location of the mapping is shown on Figure 1. For this mapping, we examined the full length of the NYPA access road between the Robert Moses Parkway and the powerhouse. To obtain a better impression of fracture orientations, we examined vertical fractures along both faces of the rock cut, where possible. The western face of the rock cut drops off about 200 ft north of the Parkway, and along this side we examined the gorge face along a path that follows the river. Our walk along the path terminated back at the Limestone Cave.

Geologic setting

The cut for the NYPA access road exposes the rocks of the Lockport Dolomite, the Decew Dolomite and Rochester Shale of the Clinton Group, and units below the Rochester Shale. Although we observed a horizontal groundwater seep near the contact between the Decew Dolomite and the Rochester (indicated by wetness on the rock face and by a horizontal fringe of vegetation), we did not observe any vertical fractures that extended into the Rochester Shale.

Several stratigraphic nomenclatures have been adopted for the rocks of the Niagara region. These nomenclatures are summarized on Figure 2. In all previous investigations at the Site, the nomenclature of Zenger has been adopted (Zenger, 1962; Zenger, 1965; Zenger, 1966). The United States Geological Survey suggests that the most appropriate stratigraphic designations are described in Brett and others (1995).

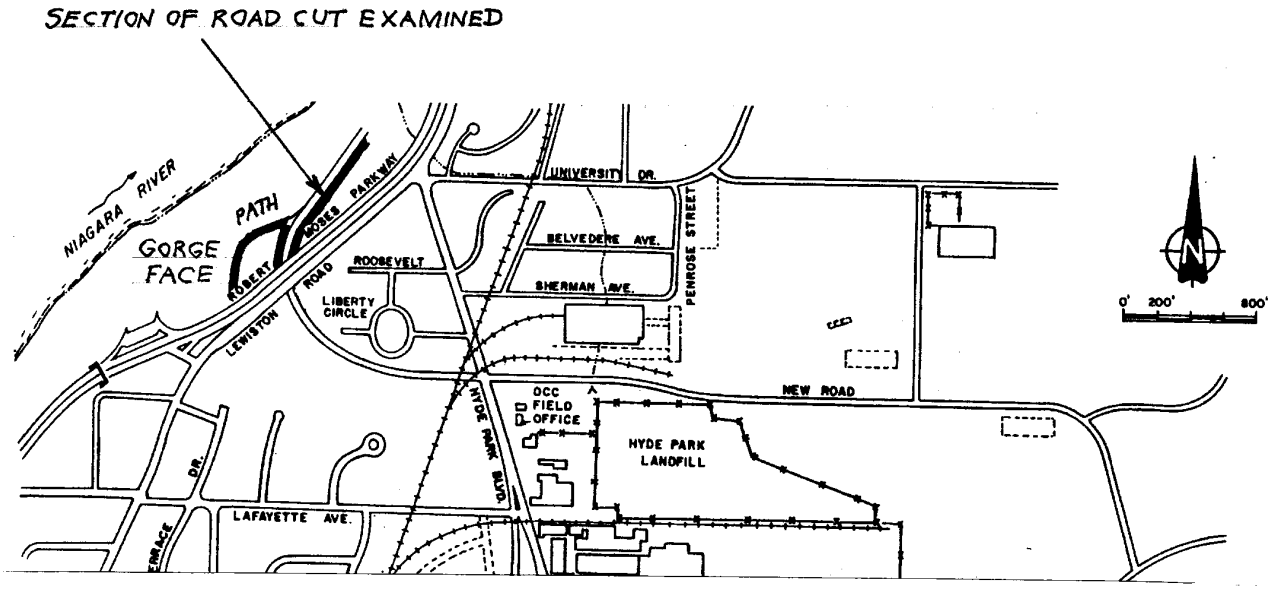

Figure 1. Location of vertical fracture mapping from exposed bedrock

<table>
<tr><th colspan="2">Zenger</th><th colspan="2">USGS (1995)</th></tr>
<tr><td colspan="2">Overburden</td><td colspan="2">Overburden</td></tr>
<tr><td rowspan="5">Lockport Group</td><td rowspan="2">Oak Orchard</td><td rowspan="2">Eramosa
(Dolomite &
Argilaceous Dolomite)</td><td rowspan="7">Lockport Group</td></tr>
<tr></tr>
<tr><td>Eramosa</td><td>Vinemount
(Argilaceous Dolomite)</td></tr>
<tr><td rowspan="2">Goat Island</td><td>Ancaster &
Niagara Falls
(Dolomite)</td></tr>
<tr><td>Pekin
(Argilaceous Limestone)</td></tr>
<tr><td></td><td>Gasport</td><td>Gothic Hill
(Limestone)</td></tr>
<tr><td></td><td>Decew</td><td>Decew
(Dolomite)</td><td rowspan="2">Clinton Group</td></tr>
<tr><td>Clinton Group</td><td colspan="2">Rochester (Shale)</td></tr>
</table>

Figure 2. Summary of Lockport Group nomenclature at the Hyde Park Site

Section 2
Vertical Fracture Mapping

In this limited investigation, we attempted to identify accessible fractures that appeared to provide a significant vertical conduit to fluid flow near the Site. Our criteria included fracture length, visual evidence of flowing water, presence of vegetation, and where possible, continuity across both faces of the rock cut.

Table 1 lists the locations and orientations of the identified vertical fractures. The locations of the fractures were estimated in the field using a hand-held GPS unit. Field coordinates were converted from the reported latitude and longitude, based on the NAD 83 datum. Figure 3 shows the locations of the fractures. Our experience with this GPS unit at the Site suggests that its reported locations are correct within approximately ±150 ft. Where possible, the strike orientations of the fractures were also measured with a hand compass. The corrected strike orientations of the fractures are shown on Figure 4.

Table 1. Fracture locations and orientations

Vertical fracture	Measurement Point	Latitude	Longitude	Strike angle, from true North
1	VF001	43.13445	-79.04459	272
	VF002	43.13449	-79.04439	106
2	VF003	43.13449	-79.04429	nm
	VF004	43.13467	-79.04451	nm
3	VF005	43.13475	-79.04443	nm
	VF006	43.13481	-79.04425	nm
4	VF007	43.13519	-79.04405	nm
5	VF008	43.13499	-79.04446	220
6	VF009	43.13483	-79.04485	230
7	VF010	43.13462	-79.04495	272
8	VF011	43.13454	-79.04501	280
9	VF012	43.13440	-79.04510	nm
10	VF013	43.13380	-79.04527	268

Note: “nm” indicates that a bearing was not estimated.

Observations on the individual fractures

Ten vertical fractures were identified along our traverse of the NYPA access road and the path along the Niagara River gorge. Notes on the individual fractures are presented below.

1. Vertical Fracture 1 is located along the NYPA access road, below the Robert Moses Parkway. The fracture can be identified across both sides of the road. Measuring point VF001 is located on the western side of the road (that is, the side closest to the Niagara River), and VF002 is located on the eastern side of the road. The fracture extends from the top of rock (Eramosa) into the Gasport. The fracture is nearly vertical in the Eramosa and Goat Island; it angles off slightly after entering the Gasport.

2. Vertical Fracture 2 is located further down the NYPA access road. The fracture can be identified across both sides of the road. Measuring point VF003 is located on the eastern side of the road, and VF004 is located on the western side of the road. The fracture extends from the top of the Goat Island into the Gasport. The fracture was not accessible for measuring its orientation with a compass.

3. Vertical Fracture 3 is the third fracture encountered proceeding down the NYPA access road. The fracture can be identified across both sides of the road, and its position is determined by measuring points VF005 and VF006. The fracture extends from the top of the Goat Island through the Decew. The fracture is close to vertical – I estimated its inclination to be about 10° from the vertical. The fracture was not accessible for measuring its orientation with a compass.

4. Vertical Fracture 4 is the fourth fracture encountered proceeding down the NYPA access road. At this point, there is no longer a rock cut along the western side of the road. Its position is given by point VF007. The fracture extends from the top of rock (Eramosa) through the Decew to the top of the Rochester Fm. The fracture was not accessible for measuring its orientation with a compass.

5. Vertical Fracture 5 is the first fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF008. The fracture can be identified in the Gasport.

6. Vertical Fracture 6 is the second fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF009. It was possible to identify the fracture in the Gasport and Decew.

7. Vertical Fracture 7 is the third fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF010. It was possible to identify the fracture in the Gasport and Goat Island.

8. Vertical Fracture 8 is the fourth fracture encountered proceeding southwards along the path running along the gorge face. Its position is given by point VF011. It was possible to identify the fracture in the Gasport and Goat Island.

9. Vertical Fracture 9 is the fifth fracture encountered proceeding southwards along the path running along the gorge face. It is located in the crown on the Limestone Cave, and its position is given by point VF012. The fracture extended the full length of the cave. It was possible to identify the fracture in the Gasport and Goat Island.

10. Vertical Fracture 10 is the located along the stairs leading up from the Limestone Cave. Its position is given by point VF013. The fracture extends almost parallel to the face of the gorge. The fracture extends from the top of rock (at this location the Eramosa) to the Goat Island. Rick Passmore was able to determine its location at the sidewalk of the Robert Moses Parkway.

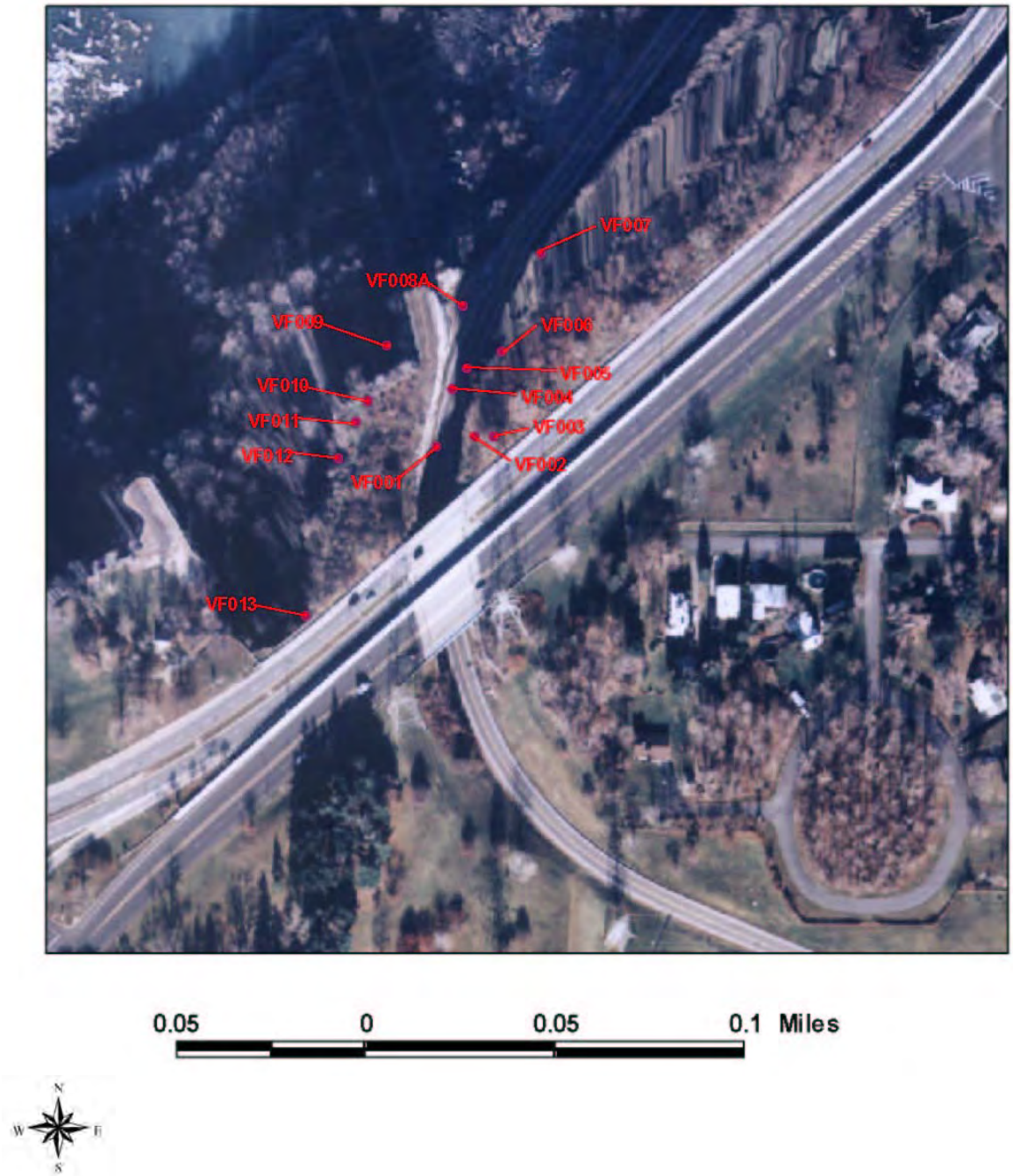

Figure 3. Locations of vertical fractures

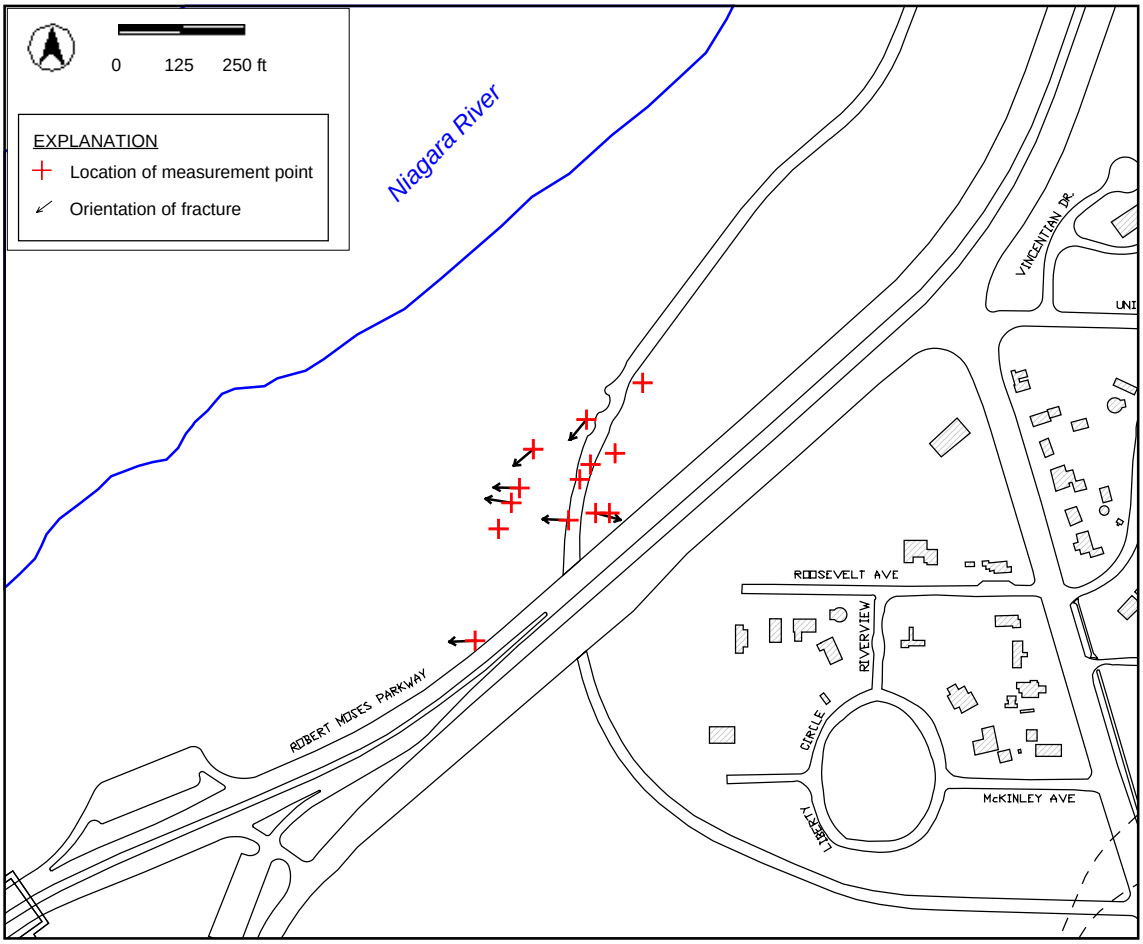

Figure 4. Locations and orientations of vertical fractures

Section 3
Interpretations

The investigation was intended as a quick survey of major water-bearing features close to the Site, rather than as a comprehensive study. A comprehensive study would consist of a survey of all outcrops in the vicinity of the Site, as well as lineament studies from topographic maps and air photos. Since only two outcrops at the gorge were examined in this study, there is not sufficient data to support definitive determination of fracture patterns at the gorge (or by extrapolation, at the Site). We can draw only some preliminary inferences from the mapping.

The mapping data suggest that there are two fracture sets in the vicinity of the gorge. The first set of fractures runs almost east-west, the strike of the second set is about 55° from north. The spacing between fractures in each set is between 50 and 100 ft. We have used the limited data to sketch "mean" vertical fracture orientations. The hypothesized distribution of fractures is shown on Figure 5.

We recognize that the fracture patterns shown on Figure 5 are speculative, being based only on the data available from a deliberately limited field examination. However, our interpretations are consistent with other data from regional geologic interpretations. Figure 6 shows the joint orientations identified by Williams and others (1985) in the Niagara region. Williams and others (1985) identified a dominant East-West fracture set with an orientation consistent with our mapping. Williams and others identified another fracture set with an orientation that is similar to the second set we show on Figure 6; however, this is not a dominant set.

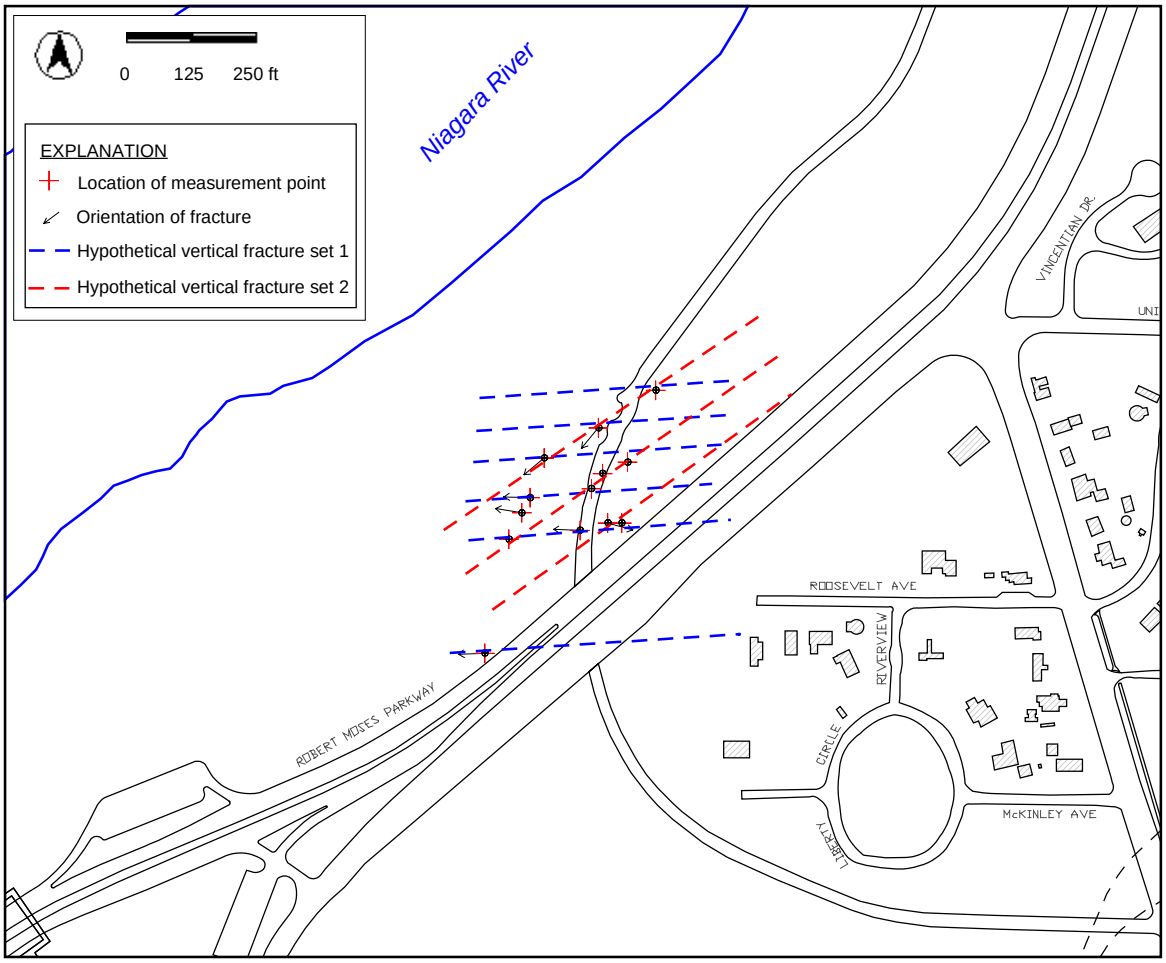

Figure 5. Hypothesized vertical fractures

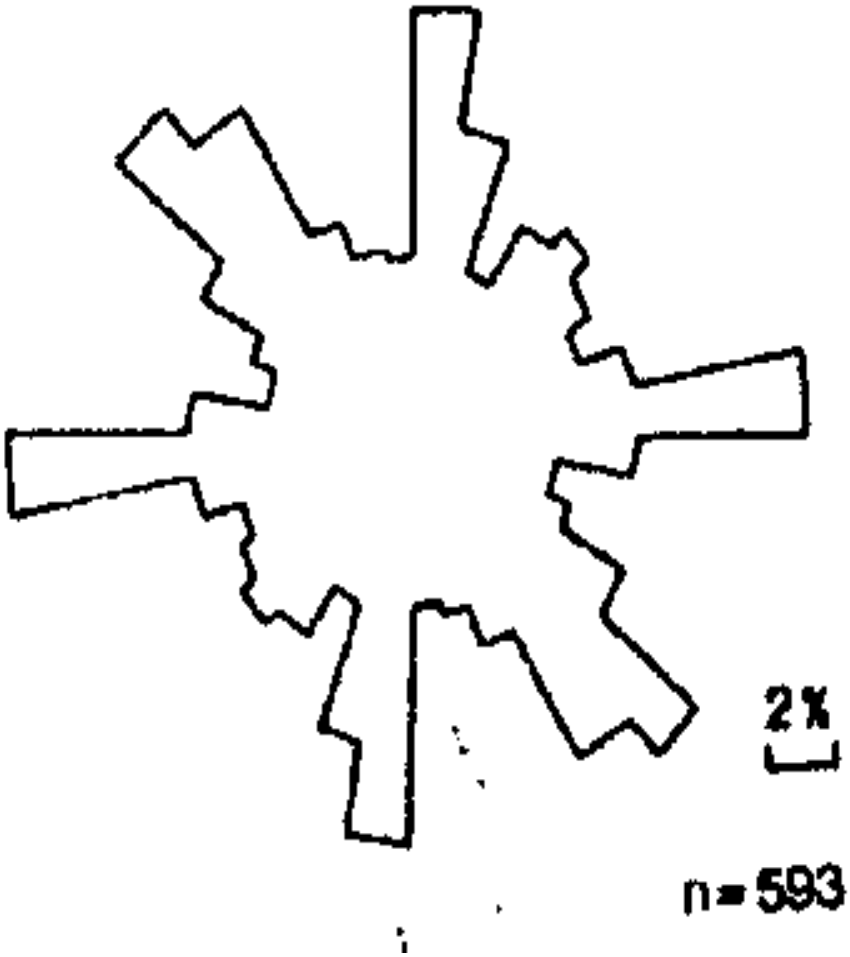

Figure 6. Joint orientations determined from Silurian and Devonian rocks in the Niagara Peninsula (after Williams and others, 1985)

Section 4
References

Brett, C.E., D.H. Tepper, W.M. Goodman, S.T. LoDuca, and B.-Y. Eckert, 1995: Revised Stratigraphy and Correlations of the Provincial Series (Medina, Clinton, and Lockport Groups) in the Type Area of Western New York, United States Geological Survey, Bulletin 2086, Washington DC.

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APPENDIX E.2

LOCKPORT FORMATION INVESTIGATION (CRA, 1983)

APPENDIX J

LOCKPORT FORMATION INVESTIGATION

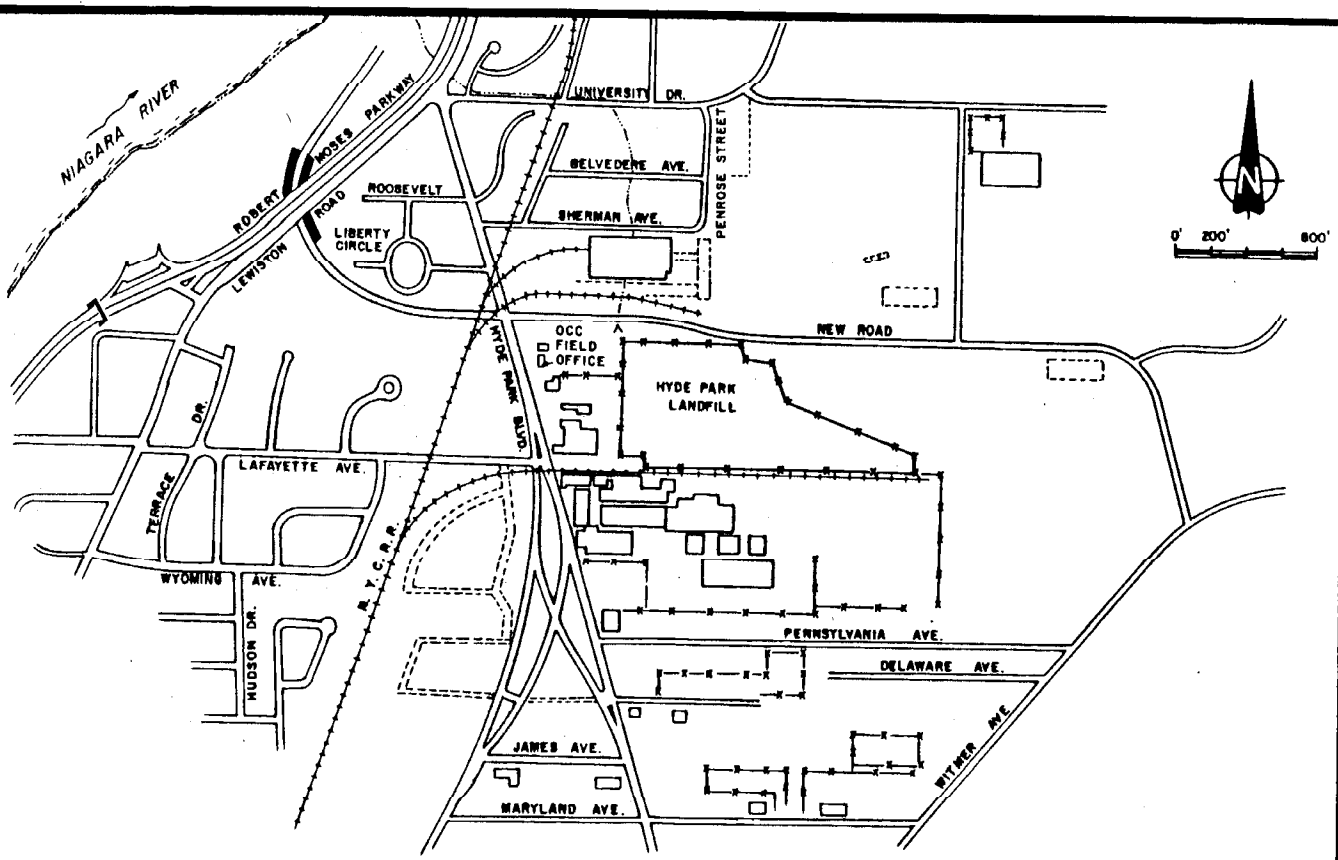
APPENDIX J

LOCKPORT FORMATION INVESTIGATION

On August 25, 1983 the Lockport Formation was examined and the fractures were recorded with respect to frequency, aperature, length and orientation. This fracture mapping was conducted at the rock cut along New Road above the PASNY hydroelectric station in the Niagara Gorge shown on Figure 1. The general stratigraphy for the Lockport Formation is presented in Figure 2.

A representative area on the rock face was outlined for each Member of the Lockport Formation as the Members were encountered along New Road. The contacts between the Oak Orchard, Eramosa and Goat Island Members were inferred during the fracture mapping. However, the results of the mapping for these 3 Members were compiled as the precise contacts were too ambiguous to plot the data separately.

Many of the natural fractures throughout the Formation showed a distinct dark brown or gray staining along the fracture face. However, some of the fractures that appeared to be natural by their orientation and magnitude, did not exhibit any evidence of staining.



CRA 0008244

LEGEND

SECTION OF ROAD CUT EXAMINED

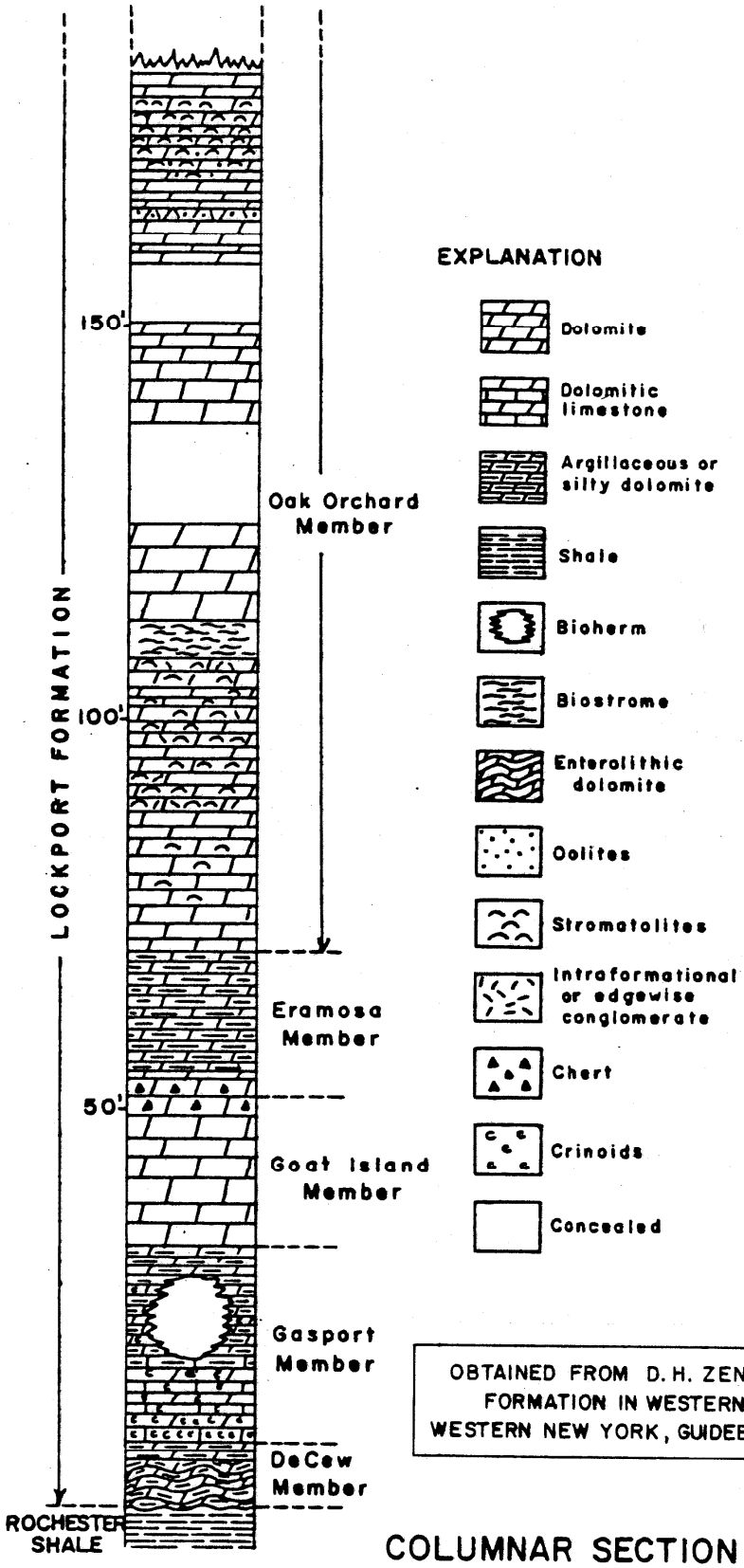
figure I

FRACTURE MAPPING FROM EXPOSED BEDROCK – LOCKPORT FORMATION HYDE PARK REMEDIAL PROGRAM

Occidental Chemical Corporation

CRA

1069-24/11/83



CRA 0008245

OBTAINED FROM D.H. ZENGER, 1966, 'THE LOCKPORT FORMATION IN WESTERN NEW YORK' IN GEOLOGY OF WESTERN NEW YORK, GUIDEBOOK, E.J. BUEHLER ed. 115 p.

figure 2

COLUMNAR SECTION OF THE LOCKPORT FORMATION IN THE NIAGARA FALLS AREA
HYDE PARK REMEDIAL PROGRAM
Occidental Chemical Corporation

CRA

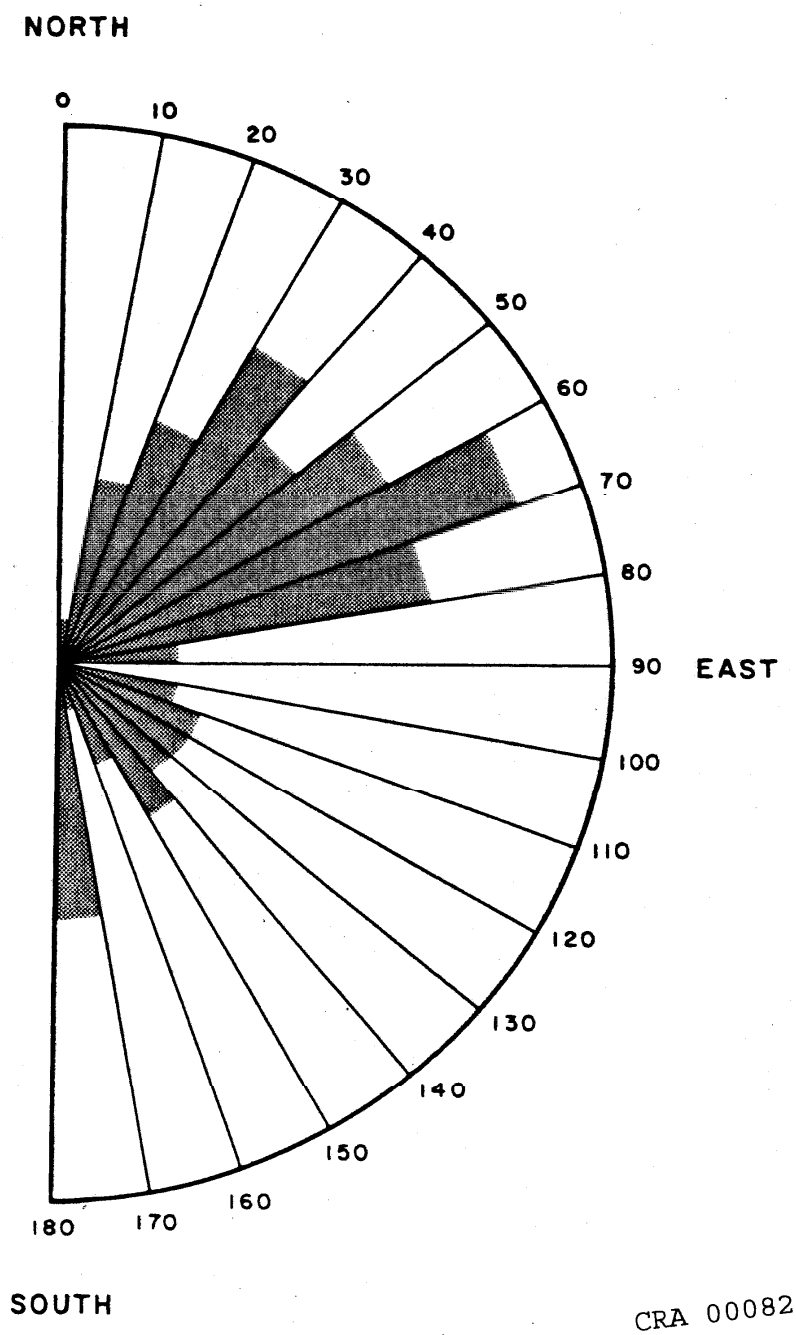
1069-24/11/83

Therefore, all of the fractures observed were recorded even though several fractures may have been the result of blasting during the excavation of the road cut. The natural fractures or joint sets are expected to represent a family of fractures along a distinct orientation, if the joints are well developed. The induced fractures are expected to represent a more random statistical variation. The fracture orientations were plotted with respect to true north.

The fractures were observed to be significantly more frequent in the upper part of the Formation, particularly the Oak Orchard, Eramosa and Goat Island Members. In general, the fractures were vertical to near vertical.

The frequency and orientation of the fractures are shown in Figure 3 for the upper 3 Members, in Figure 4 for the Gasport and Decew Members and in Figure 5 for all of the Lockport Formation. Generally, the fracture aperatures were less than 1/32" wide with irregular fracture surfaces. Fracture lengths were typically 0.5 to 2 feet long.

Figure 4 illustrates the low frequency of fractures in the lower portion of the Lockport Formation. The dimensions of the fractures in this section



CRA 0008247

figure 3

STRIKE OF JOINT SETS FOR OAK ORCHARD, ERAMOSA AND GOAT ISLAND MEMBERS FROM ROAD CUT IN NEW ROAD ABOVE P.A.S.N.Y. HYDROELECTRIC STATION

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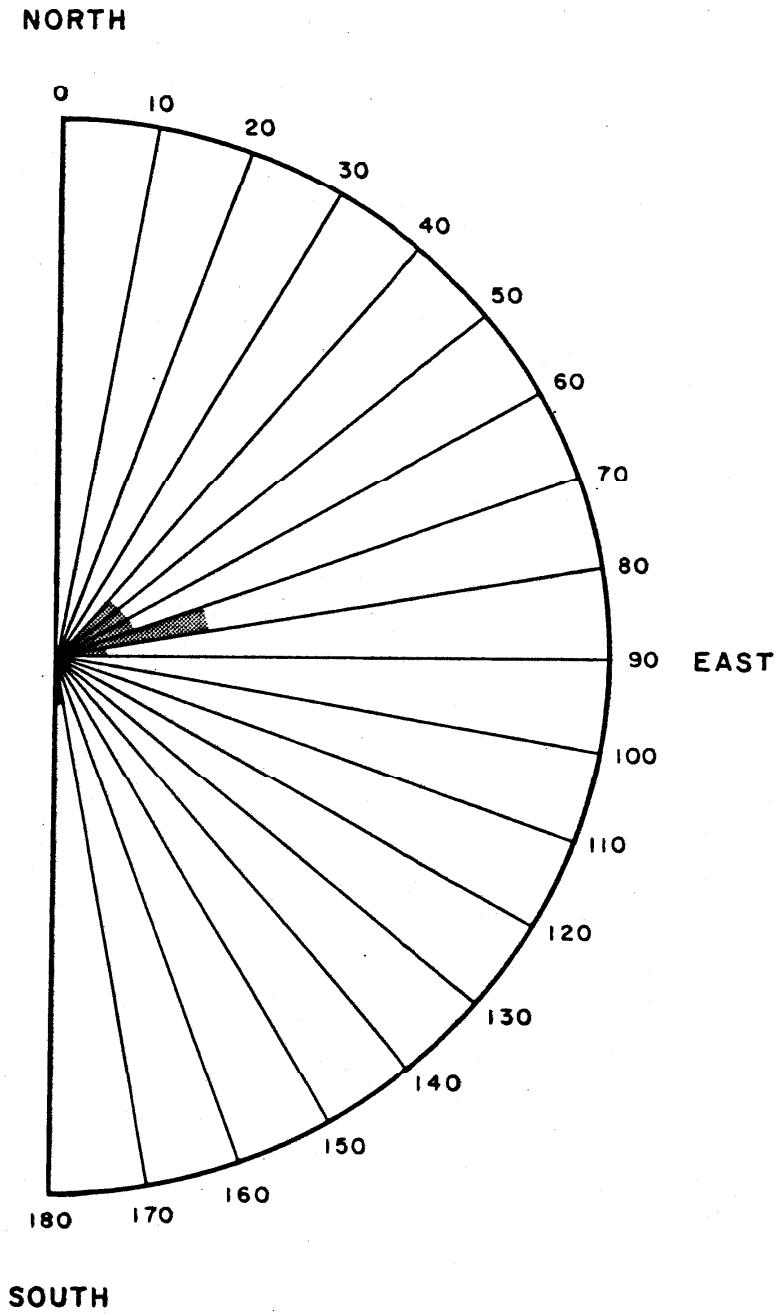

CRA 0008248

figure 4

STRIKE OF JOINTS IN
GASPORT AND DECEW MEMBERS
FROM ROAD CUT IN NEW ROAD ABOVE
P.A.S.N.Y. HYDROELECTRIC STATION

CRA

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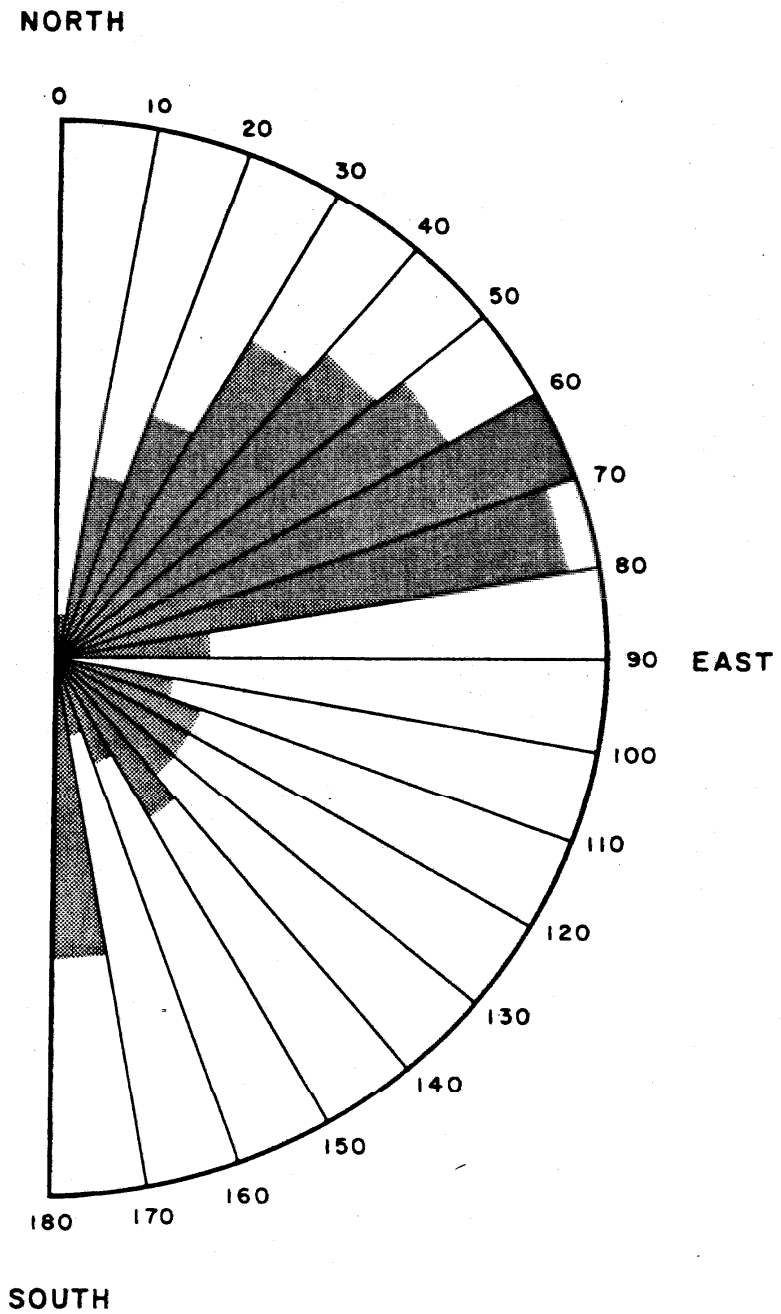

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figure 5

STRIKE OF JOINTS IN LOCKPORT FORMATION FROM ROAD CUT IN NEW ROAD ABOVE P.A.S.N.Y. HYDROELECTRIC STATION

CRA

1069-24/11/83

were much larger than those in the rest of the Formation. Five large fractures, with aperatures of <1/32" to 4" and extending from 15 to over 40 feet, were observed in the Gasport and Decew Members. The trend of these fractures is N68°E to N86°E.

Figure 5 shows a broad variation in the attitude of the main joint set with an average strike of N50°E. The secondary joint set trends N130°E. There is a tertiary joint set trending N.S.

APPENDIX F

PETROPHYSICAL TESTING RESULTS

Hyde Park Landfill Site
Niagara Falls, New York

Report on the Results of Petrophysical Tests Conducted on Samples from the Hyde Park Landfill Site

Prepared For:

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Glenn Springs Holdings, Inc.

Prepared By:

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February 12, 2002

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Section 1
Introduction

Core Laboratories in Houston, Texas conducted petrophysical tests on samples of bedrock drill core from the Site. The core testing was conducted to determine fundamental properties of the intact rock materials. The physical properties that were determined included:

- Bulk density;
- Porosity;
- Grain density;
- Permeability; and
- Acoustic velocity.

This memorandum documents the test methods, summarizes the results of the tests, and discusses the reliability of the results and their physical significance.

The petrophysical testing was undertaken at the suggestion and direction of Mr. Michael Metz, Chief Petrophysical Engineer, Occidental Oil and Gas Corporation (OOGC). The documentation of the petrophysical testing incorporates the technical contributions of several individuals. Staff of Core Laboratories provided details on the test methods (Art Curby, Di Jiao, and John Dacy), and Jon J. Williams, CRA, provided details on the rock sampling. Mr. Metz and members of the Hyde Park Technical Team have reviewed the final report.

Section 2
Core Samples

Core samples were obtained from the drilling of well cluster J5, installed in August 2001. The locations of the samples relative to the geologic contacts are shown on Figure 1. This figure incorporates the stratigraphic nomenclature of Brett et al. (1995), and the stratigraphic contacts developed for the revised Site characterization. The locations of the core samples were chosen to provide samples from each bedrock type at the Site, based on the previous stratigraphic model developed for the Site. According to the previous nomenclature for the Site, the sample locations correspond to:

- Samples 1 and 2: Oak Orchard Formation;
- Samples 3 and 4: Eramosa Formation;
- Samples 5 and 6: Goat Island Formation;
- Samples 7 and 8: Gasport Formation; and
- Samples 9 and 10: Decew Formation.

It was not possible to obtain an intact sample from the Rochester Shale.

The core samples were prepared following the instructions of Michael Metz (OOGC) and shipped to Core Laboratories. The samples consisted of intact rock, typically 0.5 feet long with a diameter of 3 inches.

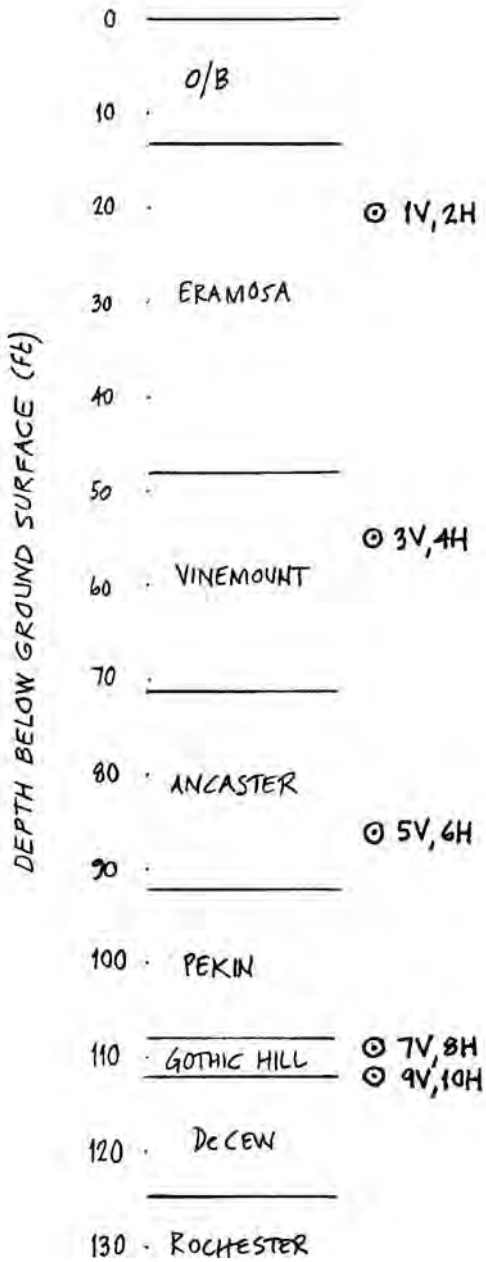

Figure 1. Locations of J5 core samples

Section 2
Results of the Petrophysical Tests

2.1 Summary of results

The results of the petrophysical tests are assembled on Table F.1. The upper portion of the table provides the results from the porosity, permeability, and grain density determinations. The quantities b(He), Beta, and Alpha are intermediate quantities for the determination of permeability. A total of 10 samples were tested from five locations; two samples from each sample were tested to obtain independent estimates of horizontal and vertical permeability.

The lower portion of Table F.1 provides the results from the bulk density determinations, and the results of the acoustic tests. The acoustic tests provided estimates of velocities, moduli and Poisson's ratios.

2.2 Bulk density

Bulk densities of five core samples were determined by estimating the volume of the samples, and measuring their mass under room temperature and pressure. The sample volumes were estimated from the average of five measurements of the diameter of each cylindrical sample. The bulk densities are summarized below.

Sample	Bulk density (g/cm^3)
1V	2.73
3V	2.73
5V	2.76
7V	2.71
9V	2.71

The bulk density values are highly consistent, suggesting that the rocks of the Lockport Group have similar material properties.

2.3 Porosity and grain density

The porosity and grain density of ten core samples were determined at ambient conditions, using the Boyle's Law double-cell technique (American Petroleum Institute RP-40). With this technique, the porosity is calculated from:

Porosity = Pore Volume / (Pore Volume + Grain Volume) X 100

Grain volumes were determined using the double-cell technique with helium as the expansion gas (API RP-40, Sec 5.3.2.1). Pore volumes were determined with the double-cell technique at a net confining stress (NCS) of 800 psig, in a hydrostatic core holder (API RP-40, Sec 5.3.2.2). The final porosity and grain density determinations are summarized below.

Sample	Porosity (%)	Grain density (g/cm^3)
1V	4.82	2.841
2H	5.45	2.840
3V	4.30	2.830
4H	4.31	2.828
5V	3.91	2.849
6H	3.53	2.844
7V	5.39	2.846
8H	4.79	2.846
9V	5.37	2.843
10H	7.55	2.839

The reported porosities of the samples vary over a relatively narrow range, from about 3% to 8%. This range is consistent with the general range cited by Freeze and Cherry (1979) for limestone and dolomite of 0 to 20%. The reported grain densities of the samples also vary over a relatively narrow range, from about 2.828 to 2.849 g/cm^3. This range is consistent with the mineral density of dolomite, 2.85 g/cm^3. The mineral density of dolomite is slightly higher than the typical value of 2.65 g/cm^3 typically assumed for mineral soils (Freeze and Cherry, 1979). The value reported by Freeze and Cherry is representative of shales and quartz sands.

The narrow ranges of the reported porosities and grain densities again suggest that the rocks of the Lockport Group have similar material properties.

The internal consistency of the bulk density, porosity, and grain density measurements can be checked. If it is assumed that the samples are dry, then the bulk density can be calculated from:

$$\rho_b = (1-\phi)\,\rho_s$$

If it is assumed that the samples are saturated, the bulk density is given by:

$$\rho_b = \phi\rho_w + (1-\phi)\,\rho_s$$

In these relations, ϕ denotes the porosity, and ρ_s and ρ_b denote the grain and bulk density, respectively. The calculated bulk densities tabulated below have been determined by substituting the reported values of porosity and grain density into the two theoretical relations.

Sample	**Reported Bulk density (g/cm^3)**	**Calculated Bulk density-Dry (g/cm^3)**	**Calculated Bulk density-Wet (g/cm^3)**
1V	2.73	2.704	2.752
3V	2.73	2.685	2.751
5V	2.76	2.708	2.777
7V	2.71	2.693	2.747
9V	2.71	2.690	2.744

The reported bulk densities generally lie between the two corresponding calculated values. This suggests that the samples underwent some drying before the bulk density determinations. The close agreement between values confirms the internal consistency of the reported measurements.

2.4 Permeability

Permeabilities were measured on ten samples, using methods described in Jones (1972, 1987, 1988) and Amaefule et al. (1988). The laboratory measurements were made by passing air through the samples. The measured permeability is "apparent", and must be corrected for the effects of gas slippage (the Klinkenberg effect). This "corrected" permeability is determined from:

$$k_{app} = k_{\infty}\left(1+\frac{b}{P}\right)$$

where k_{app} is the measured permeability, and k_{∞} is the corrected permeability. In this relation, b denotes the Klinkenberg factor, and P denotes the mean air pressure at which the permeability was measured. The corrected permeability represents the apparent permeability extrapolated to infinite air pressure. The Core Labs results are tabulated below; these values represent the corrected permeability, the appropriate measure for subsequent estimation of the hydraulic conductivity.

Sample	Reported Permeability (md)
1V	4.51E-03
2H	5.50E-01
3V	5.82E-04
4H	5.31E-04
5V	1.40E-03
6H	1.11E-03
7V	1.99E-03
8H	2.45E-03
9V	1.07E-03
10H	2.44E-02

The analysis assumes that the samples are dry. The values have not been corrected for a possible reduction in permeability due to the presence of water in the pore spaces.

Equivalent hydraulic conductivities

The hydraulic conductivity (K) is related to the permeability (k) according to:

$$K = \frac{\rho g}{\mu} k$$

where ρ is the density of water and μ is the dynamic viscosity of water, and g is the acceleration due to gravity. The groundwater temperatures determined during the geophysical logs range from between 52°F and 56°F (11°C to 13°C). For an average temperature of 12°C, the density and dynamic viscosity of water are 999.5 kg/m^3 and 1.235 cP, respectively. To estimate the hydraulic conductivity in units of *cm/sec*, the reported permeabilities must be multiplied by a factor of 7.8388×10^{-7}. This factor incorporates the conversion from the oil-field units of millidarcies (md) defined in Muskat (1937). The estimated hydraulic conductivities are listed on the following table.

Sample	Reported Permeability (md)	Hydraulic Conductivity (cm/sec)
1V	4.51E-03	3.53E-09
2H	5.50E-01	4.31E-07
3V	5.82E-04	4.56E-10
4H	5.31E-04	4.16E-10
5V	1.40E-03	1.10E-09
6H	1.11E-03	8.70E-10
7V	1.99E-03	1.56E-09
8H	2.45E-03	1.92E-09
9V	1.07E-03	8.39E-10
10H	2.44E-02	1.91E-08

The hydraulic conductivities of the samples range from about 4×10^{-10} to 4×10^{-7} cm/sec. Figure 2 shows the envelope of reported values superimposed on the general ranges cited by Freeze and Cherry (1979). The plot shows that the hydraulic conductivities of the core samples are consistent with literature values for intact dolomites and shales. The measured values are several orders of magnitude lower than the values inferred from slug tests at the Site. This suggests that the permeability of the bedrock at the Site is controlled by fractures, and not by flow in the matrix.

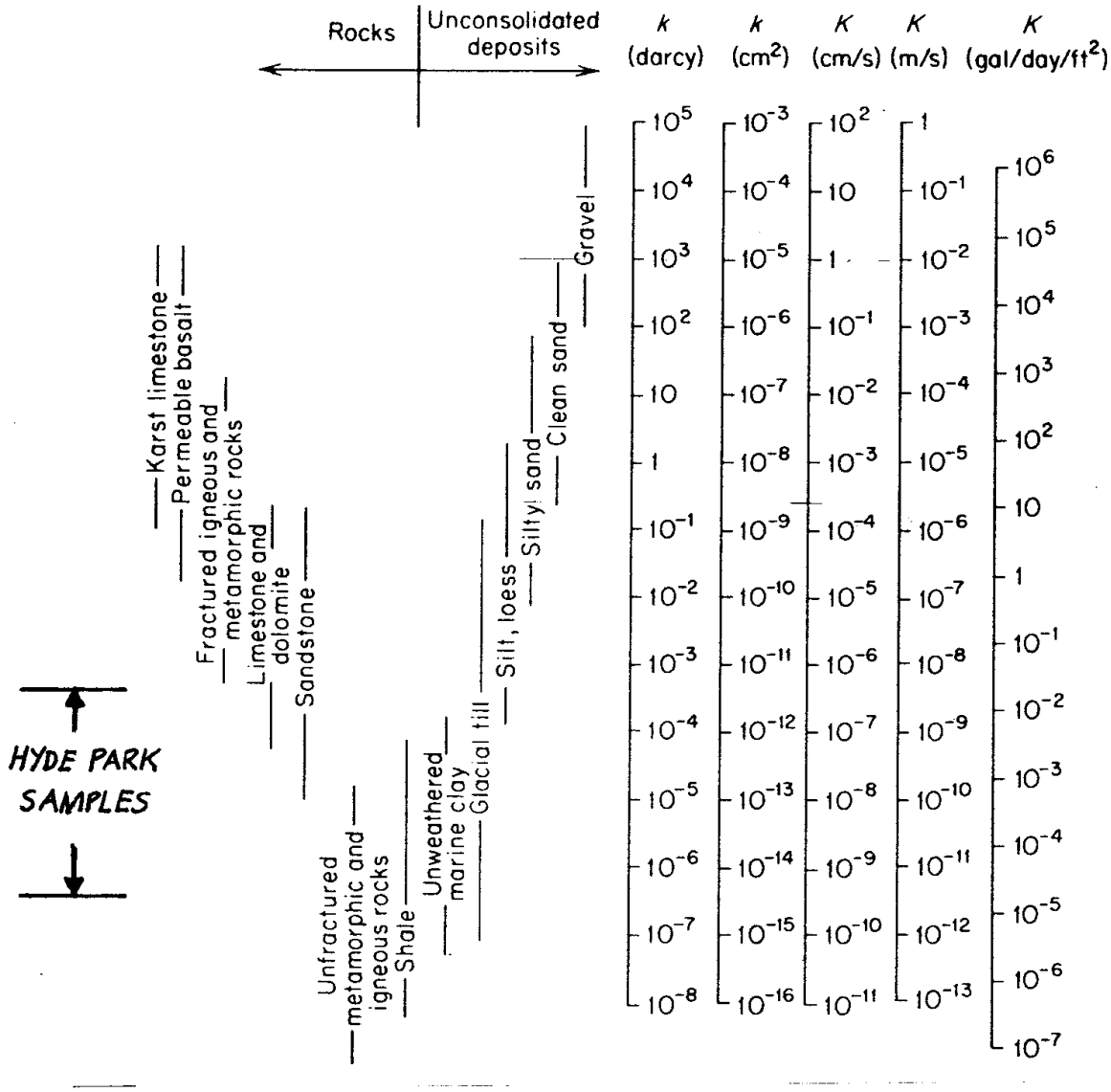

Figure 2. Range of permeabilities for the Hyde Park Landfill samples (Adapted from Freeze and Cherry, 1979)

2.5 Compressional velocity

Compressional velocities were measured on five samples, using laboratory techniques consistent with ASTM Standard D2845-1995 "Method for Laboratory Measurement of Pulsed Sonic Velocities and Ultrasonic Elastic Constants of Rock". Ultrasonic waves are passed through the sample, and the waveforms stored for subsequent analysis of the compressional and shear wave velocities. The wave velocities are calculated using the arrival times of the P and S waves and length of the sample. The dynamic moduli and dynamic Poisson's ratio are also calculated.

The compressional velocities have been used to calibrate the sonic geophysical logs used to estimate the rock porosity. The Core Labs results are tabulated below.

Sample	**Compressional velocity, *v* (ft/s)**
1V	18,172
3V	16,785
5V	18,921
7V	18,769
9V	17,931

The reported compressional velocities represent the properties of the rock minerals (matrix) and pore space, and are consistent with typical values from other dolomite samples (M. Metz, OOGC, personal communication, January 2002). The difference between the measured compressional velocities and tabulated values for the matrix constitutes the basis for the estimation of porosity from the sonic logs. For the matrix alone, tabulated velocity values for dolomite range from 21,000 to 24,000 ft/s (Keys, 1989; Schlumberger, 1987). Century Geophysics assumed a value of 22,700 ft/s for the interpretation of the sonic logs.

Section 3
Summary of Findings

1. The bulk density values are highly consistent, suggesting that the rocks of the Lockport Group have similar material properties.

2. The narrow ranges of the reported porosities and grain densities again suggest that the rocks of the Lockport Group have similar material properties.

3. The reported bulk densities are internally consistent with the reported porosities and grain densities.

4. The hydraulic conductivities of the core samples are consistent with literature values for intact dolomites and shales. The measured values of hydraulic conductivity are several orders of magnitude lower than the values inferred from slug tests at the Site. This suggests that the permeability of the bedrock at the Site is controlled by fractures, and not by flow in the matrix.

5. The reported compressional velocities are consistent with typical values for dolomite.

Section 4
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TABLE F.1

BEDROCK PHYSICAL PROPERTIES TEST RESULTS
SITE CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
TOWN OF NIAGARA, NEW YORK

Sample Location	Depth (ft. bgs)	Unit	Test Orientation	Depth (ft)	Net Confining Stress (psig)	Porosity (%)	Permeability Klinkenberg (mD)	Permeability Klinkenberg (cm^2)	Permeability Kair (mD)	Permeability Kair (cm^2)	b(He) (psi)	Beta (per ft)	Alpha (microns)	Grain Density (g/cm^3)	Description
J5U	20.17 - 21.05	Eramosa Fm.	Vertical	20.17	800	4.82	0.005	4.88E-09	0.010	1.09E-08	110.88	1.99E+16	2.77E+05	2.841	Dol gry xln
J5U	20.17 - 21.05		Horizontal	20.50	800	5.45	0.550	5.95E-07	0.593	6.42E-07	5.14	6.79E+11	1.17E+03	2.840	Dol gry xln svug
J5M	54.95 - 55.5	Vinemount	Vertical	54.95	800	4.30	0.001	6.30E-10	0.002	1.71E-09	176.70	1.82E+16	3.82E+04	2.830	Dol gry
J5M	54.95 - 55.5	Member	Horizontal	55.35	800	4.31	0.001	5.74E-10	0.001	1.59E-09	182.28	2.32E+16	4.29E+04	2.828	Dol gry
J5M	86 - 86.5	Niagara Falls	Vertical	86.00	800	3.91	0.001	1.51E-09	0.003	3.74E-09	142.75	9.20E+16	4.59E+05	2.849	Dol gry
J5M	86 - 86.5	Member	Horizontal	86.35	800	3.53	0.001	1.20E-09	0.003	3.05E-09	152.60	1.95E+17	7.42E+05	2.844	Dol gry
J5L	109 - 109.6	Gothic Hill	Vertical	109.00	800	5.39	0.002	2.15E-09	0.005	5.15E-09	132.04	1.25E+17	8.58E+05	2.846	Dol gry
J5L	109 - 109.6	Member	Horizontal	109.30	800	4.79	0.002	2.65E-09	0.006	6.21E-09	125.48	1.50E+16	1.27E+05	2.846	Dol gry
J5L	112 - 112.65	DeCew	Vertical	112.00	800	5.37	0.001	1.16E-09	0.003	2.94E-09	150.64	5.30E+15	2.13E+04	2.843	Dol gry styl
J5L	112 - 112.65	Formation	Horizontal	112.40	800	7.55	0.024	2.64E-08	0.028	3.06E-08	12.77	8.35E+15	6.73E+05	2.839	Dol gry

Sample Location				Depth (ft)	Net Stress (psi)	Bulk Density, (g/cm^3)	Acoustic Velocity Compressional (ft/sec)	Acoustic Velocity Compressional (µs/ft)	Acoustic Velocity Shear (ft/sec)	Acoustic Velocity Shear (µs/ft)	Dynamic Bulk Modulus, 1.00E+06	Dynamic Young's Modulus, 1.00E+06	Dynamic Shear Modulus, 1.00E+06	Dynamic Poisson's Ratio	Description
J5U	20.17 - 21.05	Eramosa Fm.	Vertical	20.17	0	2.73	18172	55.0	10833	92.3	6.40	10.58	4.32	0.22	Dol gry xln
J5M	54.95 - 55.5	Vinemount M.	Vertical	54.95	0	2.73	16785	59.6	10259	97.5	5.20	9.30	3.87	0.20	Dol gry
J5M	86 - 86.5	Niagara Falls M	Vertical	86.00	0	2.76	18921	52.9	11095	90.1	7.22	11.35	4.58	0.24	Dol gry
J5L	109 - 109.6	Gothic Hill M.	Vertical	109.00	0	2.71	18769	53.3	10794	92.6	7.21	10.68	4.26	0.25	Dol gry
J5L	112 - 112.65	DeCew Fm.	Vertical	112.00	0	2.71	17931	55.8	10556	94.7	6.32	10.05	4.07	0.23	Dol gry styl

Notes:
Dol = dolomite
gry = gray
xln = crystalline
svug = small vugs
styl = stylolite

APPENDIX G

ACCURACY OF ELEVATION MEASUREMENTS

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FIGURE G.5 CHANGE IN LITHOLOGIC CONTACT PICKS

1.0 INTRODUCTION

Numerous elevation measurements are presented in this report, and correlations made across the Site based on these measurements. The accuracy of these measurements is an important consideration in the interpretation of data. This appendix presents an estimate of the uncertainty associated with certain measurements, and a discussion of how the uncertainty affects data interpretation.

Figure G.1 presents a hypothetical set of elevation measurements made along a cross section. For the purposes of this discussion, the measurements are assumed to represent the interpreted elevation of a peak on the gamma geophysical log. Each estimated elevation measurement is plotted as a dot with an associated measurement error, depicted by the error bars extending above and below the data points. Assuming that all measurements and reference points have been accurately documented, the actual elevation of the measurement is not the point, but is somewhere between the error bars. There are two key elements affecting measurement error:

- the surface elevation survey; and
- the accuracy of the downhole measuring tool (e.g., a tape along a core, a depth-to-water meter, or a geophysical instrument).

Figure G.2 presents three interpretations of the data plotted on Figure G.1:

- connects all of the reported values with straight lines;
- fits a smooth curve to the reported values; and
- provides a best-fit line to the reported values that falls within the error bars.

All three interpretations are equally valid, none are exactly right, and unless we know a-priori the actual line, there is no way to know which interpretation is the closest to being correct. In general, it is not possible to quantitatively establish the 'best' approach for presenting the relation between the data points because the shape of the surface containing them is unknown. However, it is possible to establish the most appropriate approach. According to the principle of parsimony (also referred to as Occam's Razor), if multiple hypotheses can explain the data, then the most appropriate hypothesis is the one that is simplest. Additional details can be found at http://pespmc1.vub.ac.be/OCCAMRAZ.html).

Regardless of which interpretation is presented, the accuracy of the measurements underlying the reported values must be understood to avoid over-interpreting the data.

1.1 MAGNITUDE OF THE MEASUREMENT ERROR

In the following discussion, the magnitude of the two error factors discussed above is estimated.

1.2 SURFACE ELEVATION SURVEY

During the evaluation of geophysical data for the Site Characterization Report, a number of potential outliers were identified. The investigation of these outliers included a resurvey of the grade elevation for the wells in question. Figure G.3 presents a summary of the difference between the original elevation and the December 2001 resurvey.

There are several sources for the errors in elevation plotted on Figure G.3. Three examples are described below:

- At ABP-3, the grade was lowered by 6 feet, and the well was cut down. The original grade was retained in the database, because the lithologic contacts are recorded in depth below grade at the time of drilling. Changing grade would result in calculation of incorrect contact elevations. However, the database grade elevation was used for the 2001 geophysical survey reference, resulting in an error in the calculation of elevations in the 2001 geophysical survey;
- There was no change in grade at the F4 well cluster. This 5-foot error is either related to an inaccurate survey, or an inaccurate transfer of the survey data into the database; and
- Well J5L was installed in 2001. The original elevation of the survey was determined upon completion of the well. The difference between the two values is 0.9 feet. Grade has probably not changed by 0.9 feet between the first survey and December 2001. The difference suggests that the survey accuracy, possibly the placement of the stadia rod, introduce an error close to 1 foot.

In this inspection of 21 resurvey measurements, there were five locations where the survey error was outside of the primary cluster of data. These five are considered to be "mistakes". That is, a transcription error or a change in grade that was not properly recorded. The remaining 16, clustered between –1 and 0 feet, are considered to reflect the precision of the measurement.

It is unusual that there were no errors between 0 and +1 feet. This may be because the wells selected for resurvey were identified as outliers, and were therefore a biased data set. It is also unlikely that the 'rate' of errors (5 mistakes in a sample of 21, or 24 percent), represents the general population. Based on the results of this error analysis, the error associated with grade survey is estimated to be ±1 foot.

1.3 ACCURACY OF THE DOWNHOLE ELEVATION MEASUREMENTS

The accuracy of a downhole elevation measurement, e.g., the elevation of a gamma peak, is difficult to quantify. It is typically assumed to be the equivalent to the measuring increments of the measuring tool. For example, depth-to-water meters are typically graduated in 0.01-foot increments. However, the water level data collected during the May/June shutdown of the bedrock purge well system demonstrated that the error associated with a carefully performed hand water level measurement is much greater than the 0.01-foot graduations on the tape. The analysis demonstrated that the hand measurement errors were normally distributed with a standard deviation of 0.08 feet; that is, 36 percent of the measurements made have an error >0.08 feet (data to be published in the May/June Shutdown Report). The analysis excluded mistakes, e.g., incorrectly recording numbers, gross errors, and does not account for error associated with the survey of the top of the well casing.

The analysis of water level errors was relatively easy to perform because water levels were collected both by hand and with electronic data loggers. In contrast, downhole measurements of a gamma response or other geophysical measurement only have one set of measurements.

A simple review of the data from one well cluster, AGW-1, provides insight into the elevation error associated with the geophysical measurements. Figure G.4 shows the gamma logs from AGW-1U, AGW-1M, and AGW-1L down to an elevation of 500 ft AMSL. The gamma signals for AGW-1U and AGW-1M are from the open interval of these wells. The AGW-1L signal is through the well casing. The gamma signal passes through the well casing although it is somewhat attenuated and slightly averaged. The gamma signals of AGW-1U and AGW-1M should overlay directly on the AGW-1L signal.

Well AGW-1L is 23 feet from AGW-1M and 58 feet from AGW-1U. Because the wells are not exactly on top of each other, the comparison is potentially flawed. Consider

however, how data are interpreted. When data points separated by 500 feet or more are contoured, as is done for the Hyde Park data and at many other sites, there is an implicit assumption that the measurement taken at locations close together are very similar. This assumption is the basis of geostatistical kriging. Conceptually, the same measurement from three closely spaced wells may be interchanged, e.g., rather than using the three clustered data points, the data from any one well in the cluster will suffice. Alternatively, the mathematics of most contour routines effectively averages the values from clustered readings.

Recognizing the assumptions associated with the analysis, the comparison of the three gamma signals clearly suggests that there is an error. Two peaks are compared between AGW-1M and AGW-1L, and one between AWG-1U and AGW-1L. The peaks are offset by approximately 2 feet, 1 foot, and 1 foot, respectively. These differences appear to represent the combined error arising from a ±1-foot measurement error associated with the precision of the gamma tool and an offset associated with the zero-referencing of the log of the gamma tool.

This estimate of ±1 foot measurement error is consistent with the QA/QC discussion presented in Appendix A. The comparison of gamma logs collected in the same well on two different occasions (relogs of the well), concluded that there was approximately ± 0.6 feet of uncertainty associated with referencing the instrument to grade, and ± 0.6 feet of uncertainty in the vertical location of the gamma peak by the gamma tool. The total uncertainty estimated in Appendix A is ±1.2 feet.

2.0 ERRORS ASSOCIATED WITH THE IDENTIFICATION OF LITHOLOGIC CONTACTS

The previous discussion addressed errors associated with the physical downhole measurement. This section considers the uncertainty associated with the identification of a lithologic contact.

One reason for the uncertainty in the identification of a lithologic contact appears to be the description of the contact. Brett et al. (1995) refers to the Vinemount-Ancaster contact as having a "shaly interval" at the interface. Is the contact always at the lowest shaly marker, regardless of whether or not it is the same bed? Most frequently, the Vinemount-Ancaster contact is picked just below gamma peak I (GP-I) (see Section 4 of the Site Characterization Report for details). Brett et al. (1995) also state that, "a groundwater seepage zone is recognized at this contact in many outcrops." Our review has led us to the conclusion that GP-H, about 5 feet above GP-I, is where the flow zone occurs at the Site. Occasionally, the Vinemount-Ancaster has been picked at a shaly interval that appears as a gamma peak about 5 feet below GP-I (this gamma peak is not obvious in all gamma logs). Brett et al. also states that "one or more beds of coarse crinoidal debris are typically observed near the top of the Ancaster Member." The multiple criteria for the nature of a contact, and the potential for different interpretations of a contact, create a potential for different investigators, inspecting the same core or outcrop, to pick the contact at different elevations. The description of the Vinemount-Ancaster contact suggests the possibility of picking the contact ±5 feet from its true value, based on which description of the contact is given priority.

To assess the uncertainty at the Site, a comparison was made between the contact picks made when the cores collected at the Site were first inspected, right after installation, and when the cores were relogged in 2001. Obvious recording errors were not included in the comparison.

Figures G.5A, B, and C present probability plots of the change in elevation of the contact picks between the first and second logging of the cores. Changes of 4 to 5 feet may be observed. However, 2 to 3 feet of change appears to be a more typical range.

3.0 CONCLUSIONS

Three topics have been discussed in this appendix:

- Interpretation of data with errors;
- Measurement errors associated with downhole geophysics measurements; and
- Errors associated with the identification of lithologic contacts.

The discussion of the interpretation of data that contain errors demonstrates that there are multiple equally correct (or equally incorrect) ways of interpreting the same data set. It is impossible to know which method is the best. The straight line fit, being the simplest interpretation, would be selected based on the principle of parsimony. The example values presented were generated as a random error added to a straight line, and the straight line was in fact the closest to reality.

The evaluation of downhole measurement errors suggests that there is about 1 foot of error associated with the grade reference elevation, and ±1 foot of error associated with the precision of the geophysical measurement. No other factors were considered. Based on the two factors considered, any elevation measured from the geophysical tools has an error of approximately ±2 feet.

The review of errors associated with selection of a lithologic contact suggests that the ambiguity of the criteria used for picking a contact results in the potential for the contact to be identified at different elevations by different geologists. The graphical analysis presented compares the contact picks at two different times by the same geologist, likely reducing uncertainty. The graphical analysis suggests that the ±3 feet error is common and errors as large as 4 to 5 feet are occasionally observed.

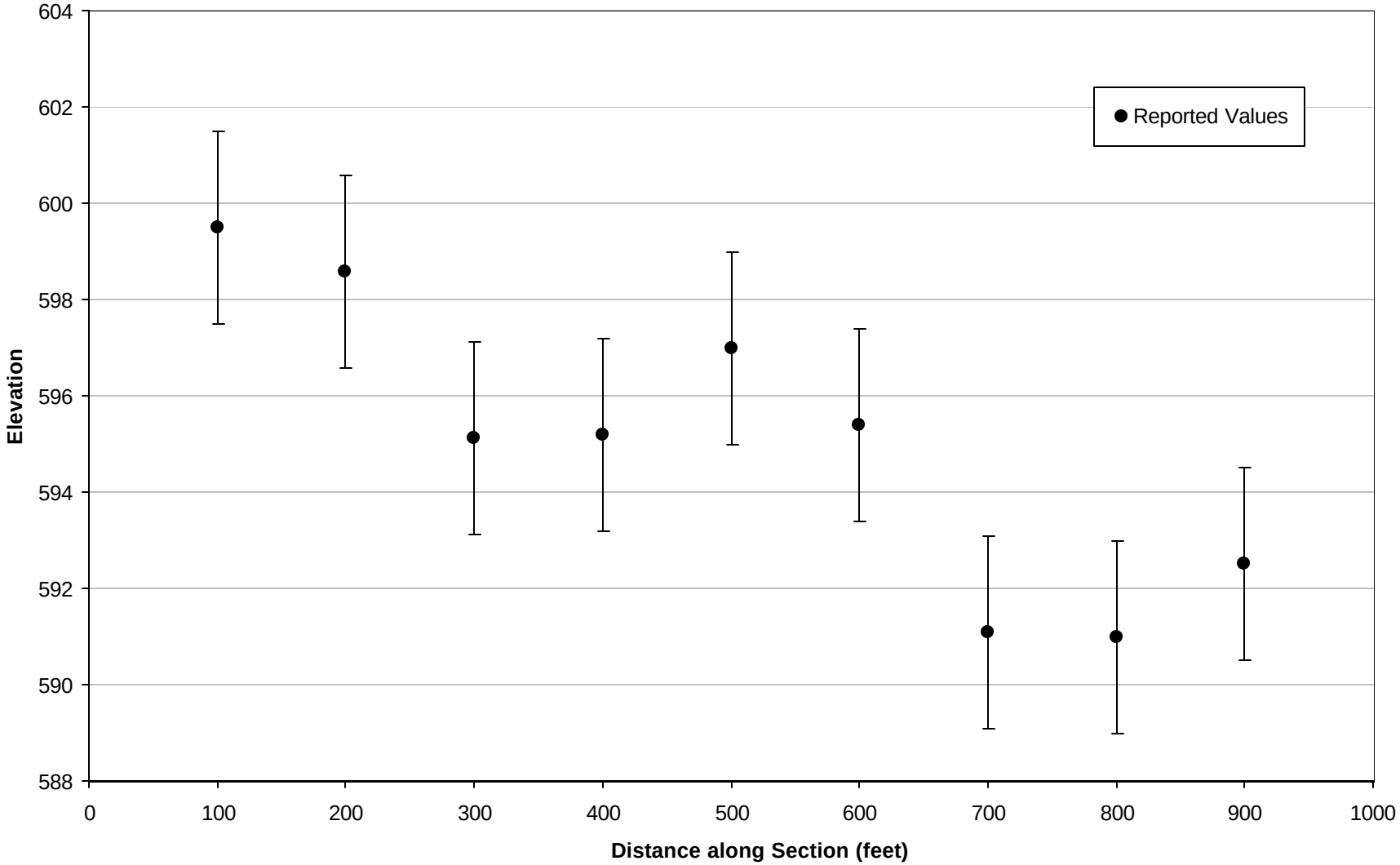


Figure G.1 Data with Measurement Error Bars

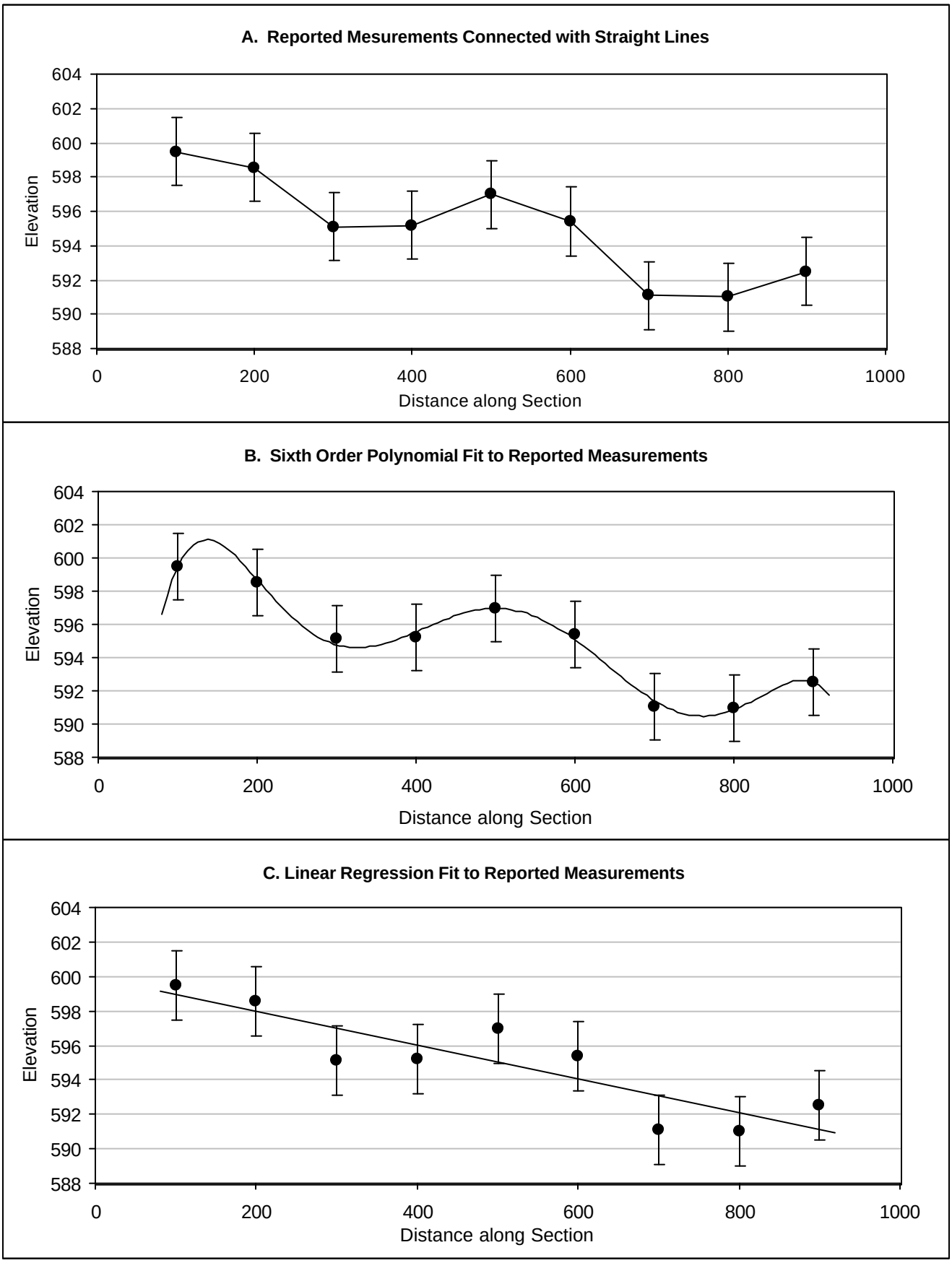


Figure G.2 Interpretation of Data with Measurement Error

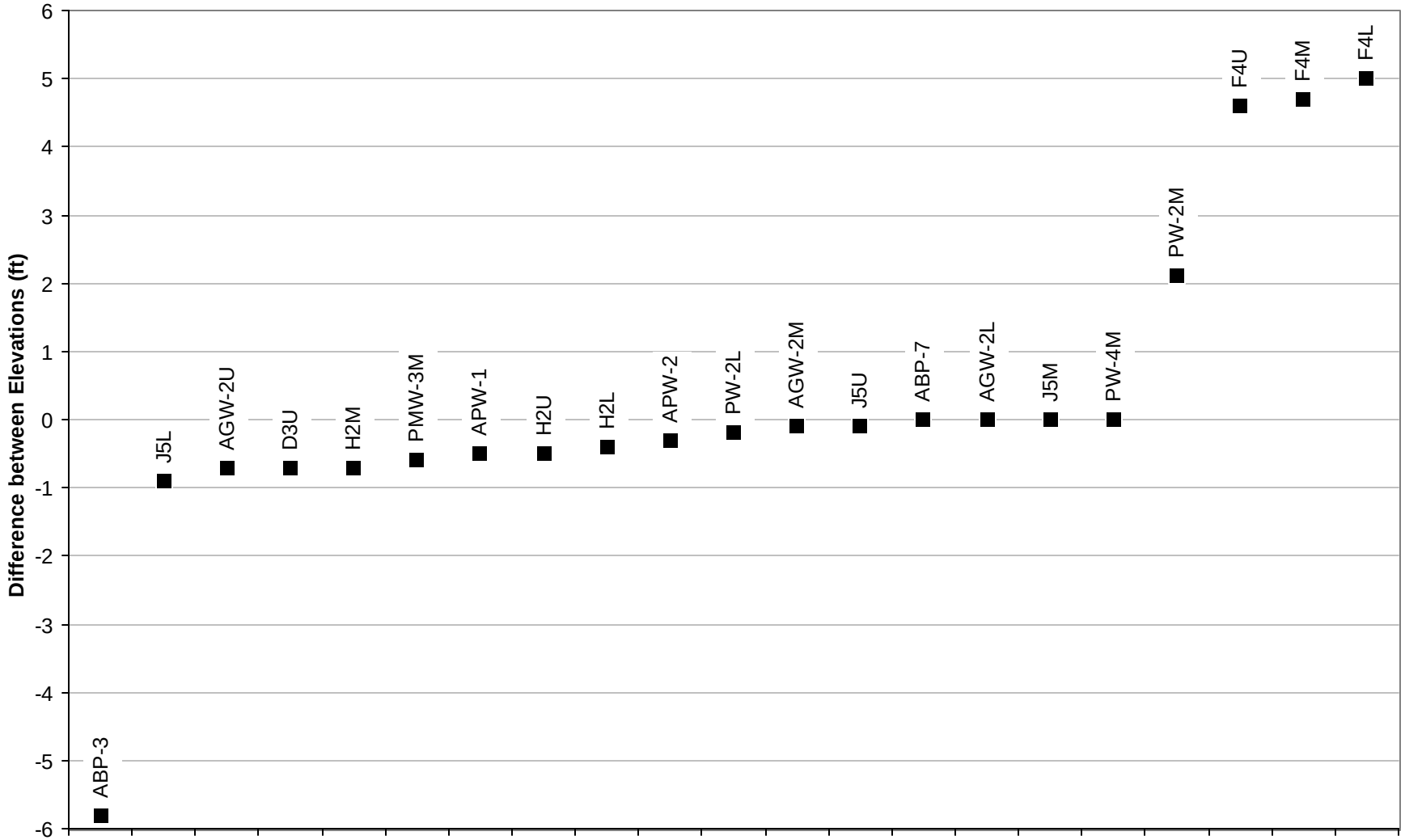
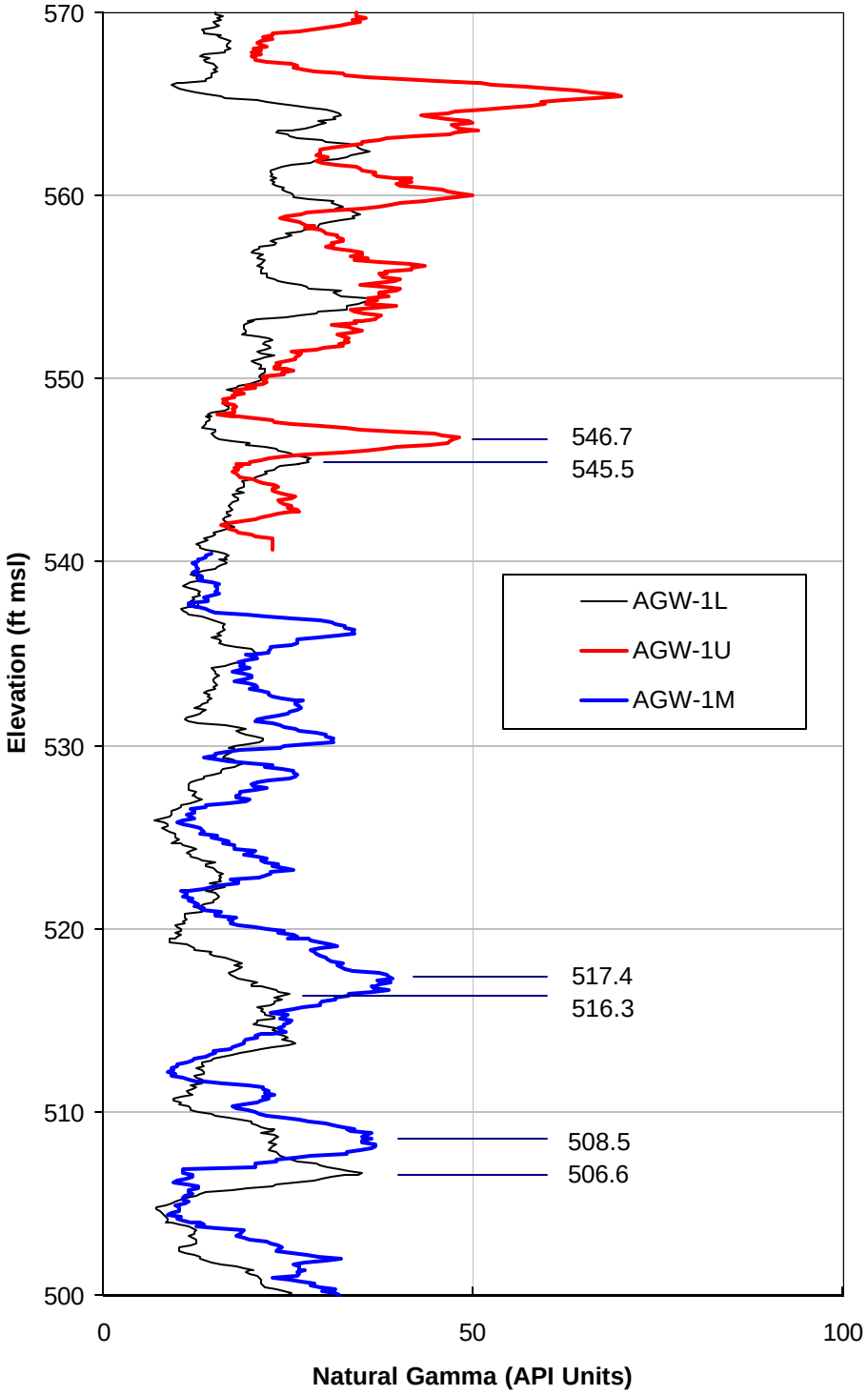


Figure G.3 Difference between Grade Elevations in Site Database and 2001 Survey



AGW-1

Figure G.4 Comparison of Natural Gamma Signals From AGW-1U, AGW-1M, and AGW-1L

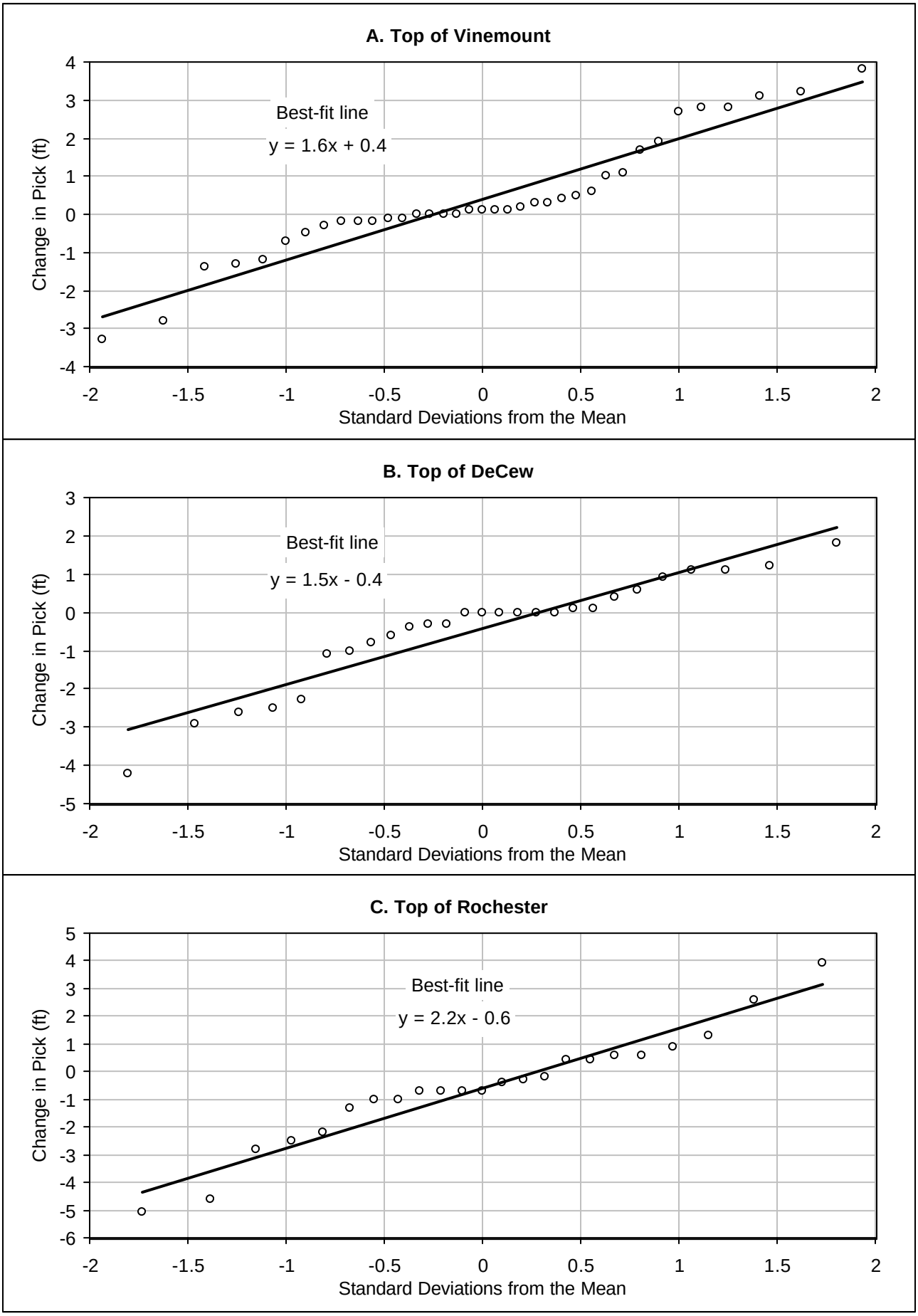


Figure G.5 Change in Lithologic Contact Picks

APPENDIX H

SUMMARY OF PACKER FLOW TESTS AND SINGLE WELL RESPONSE TESTS

S. S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

Memorandum

Date: June 28, 2001

From: Christopher J. Neville and Mark A. Kuhl

To: File

SSPA Project: SSP-610

Subject: Hyde Park Landfill: Single well response tests

A relatively large number of single well response tests have been conducted at the Hyde Park Landfill Site. These tests include packer tests in boreholes and slug (recovery)/evacuation tests in completed wells. The results from the tests were not re-analyzed or used directly during the development of the Site groundwater model. The results from the single well tests were not used to assign hydraulic conductivity distributions. This was a deliberate decision based on our experience that single-well tests provide an impression of conditions only in very close proximity to the well being tested (a few well diameters). Research in settings similar to the Hyde Park Landfill has shown that interpretations are heavily weighted towards the source well (Novakowski, 1989).

Instead of using the single-well tests directly, the specifications of the bulk hydraulic properties of the bedrock were constrained by the results of the purge well tests. The constant-rate pumping tests with multiple observation wells yield better estimates of "effective" properties; however, they do not provide a detailed impression of local-scale heterogeneities. The review of the model by the USEPA and USGS provides us with an opportunity to take a closer look at all of the hydraulic conductivity data. In this memo we summarize the results of our re-examination of the results of the single well tests. Our specific objectives in re-examining the data are:

- to identify local variations in hydraulic conductivities in the bedrock zones;
- to check that the results of the packer tests are consistent with the slug test results; and
- to compare the results of the packer tests with the available hydrostratigraphic conceptualizations.

I. Slug testing

Results of 64 slug tests conducted in active wells at the Site are available. Some wells have been tested more than once, and 5 of the responses were not interpretable. For wells that have been tested more than once, we use the geometric mean to assign a single well. A total of 51 wells can be assigned hydraulic conductivities from slug tests (17 Upper; 10 Middle; 24 Lower). The hydraulic conductivities estimated from slug tests are plotted on attached Figures 1, 2 and 3 for the Upper, Middle, and Lower zones, respectively.

<u>Comments on the slug test results</u>

1. The figures of hydraulic conductivities suggest that there is relatively good spatial coverage over the Site. The spatial coverage is least dense in the Middle zone, and most extensive in the Lower zone. Coverage is most complete immediately west and south of the Site.

2. The figures of hydraulic conductivities suggest that there is relatively good spatial coverage over the Site. The spatial coverage is least dense in the Middle zone, and most extensive in the Lower zone. Coverage is most complete immediately west and south of the Site, but there are relatively few results available for the areas north and northwest of the landfill.

3. The hydraulic conductivity values indicate that there is significant heterogeneity at the Site.
   - In the Upper zone, the slug test K values range from 8×10^{-7} to 3×10^{-3} cm/sec.
   - In the Middle zone, the slug test K values range from 4×10^{-10} to 4×10^{-3} cm/sec.
   - In the Lower zone, the slug test K values range from 5×10^{-8} to 2×10^{-3} cm/sec.

4. The results from all slug tests close to the Niagara River gorge indicate low hydraulic conductivity (10^{-10} to 10^{-6} cm/sec) across all three bedrock zones.

5. In the Upper zone, K values vary abruptly across the Site. There are no obvious spatial trends. However, there does appear to be a band of relatively high conductivity connecting wells C1U, CD3U, D1U, and E5U.

   Figure 4 shows the Upper zone high transmissivity zones inferred during calibration of the groundwater flow model. There are no slug tests to confirm or refute our inference of a higher T zone north of the Site. Two of the three slug tests conducted in wells that lie within the southern high T zone have higher hydraulic conductivities ($> 10^{-4}$ cm/sec).

5. In the Middle zone, there appears to be a band of high conductivity connecting wells B1M, BC3M, and CD1M. It is impossible to determine whether this is actually a zone of elevated permeability, because the test results at C1M, CD2M and D1M were not interpretable.

   Figure 5 shows the Middle bedrock high transmissivity zone inferred during model calibration. The high-*K* band lies within the high transmissivity zone, providing some independent suggestion of its existence.

6. In the Lower zone, *K* values vary abruptly over relatively small distances across the Site. The slug test *K* values suggest there is an area south and west of the zone that has low permeability. This area includes the gorge wells AFW-1L, AFW-2L and AFW-3L, and the off-Site wells D2L, E1L, E3L, F1L, and F2L. We have plotted this zone on Figure .

II. Packer testing

Packer tests were carried out in 19 boreholes at the Hyde Park Landfill Site between January and September 1991. The test results were reported in the 1991 Drilling Summary Report (CRA, 1991). The average spacing between packers was 15 ft. Slug tests have been conducted in some of the wells that were installed subsequently. As far as I am aware, no attempt was ever made to display the packer test results graphically, or to compare the results of the packer and slug testing. Although they have not been examined in detail before, the packer test data provide valuable information on the distribution of horizontal hydraulic conductivity with depth. These data are an important addition to the Site characterization. The additional slug test results also provide an excellent opportunity to evaluate the consistency between parameter estimates derived from the packer and slug tests. An assessment of the consistency between test results will be important for anticipating the value of possible future packer testing at the Site.

The wells that were packer-tested are listed on the attached table. The table also indicates whether a slug test was conducted in the corresponding completed well. Profiles of the horizontal hydraulic conductivity distribution have been prepared for each well. The profiles also include the slug test estimate of *K* where available. The profiles also show the "detection limit" of the packer tests. Our review of the data suggests that the lower limit on the packer-derived conductivities is 10^{-7} cm/sec, although in reality it may be an order of magnitude higher.

<u>Comments on the packer test results</u>

1. The packer test *K* profiles confirm that the bedrock properties are heterogeneous at the Site. Hydraulic conductivities vary by orders of magnitude along each borehole, and at the same elevation at two boreholes.

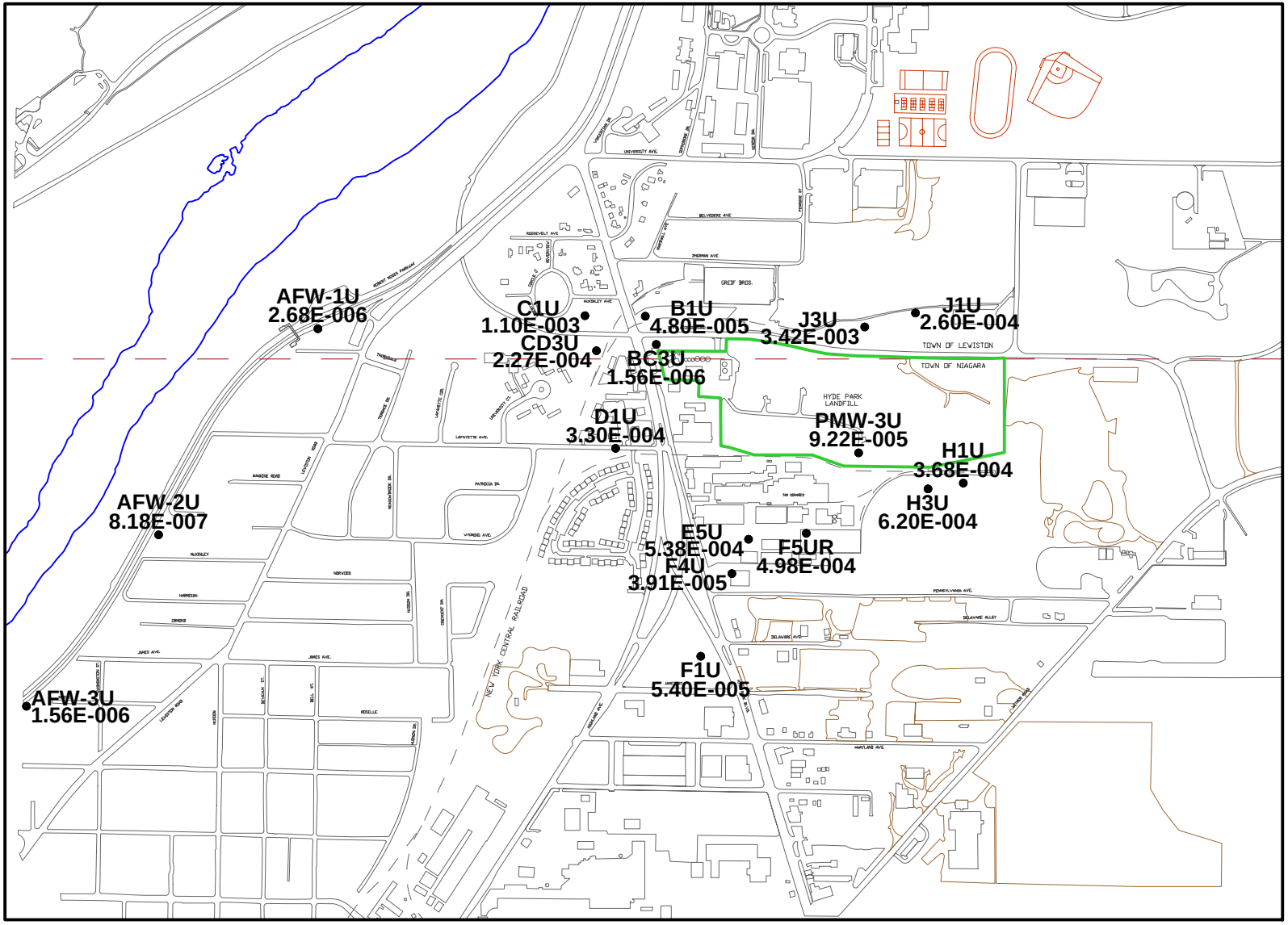
2. There appears to be only a weak Site-wide trend of hydraulic conductivity as a function of depth. In general, hydraulic conductivities tend to be higher at the top of the borehole. However, the variations in *K* along each profile do not show a clear demarcation between Upper, Middle, and Lower bedrock zones.

3. In most wells, there is a relatively close correlation between packer and slug test derived estimates of hydraulic conductivity. This is an encouraging result because it suggests that the packer tests can be used to obtain a reliable estimate of the near-well conductivities.

Listing of packer test profiles

Borehole	Slug tests
AFW-1L	AFW-1U, AFW-1M, AFW-1L
AFW-2L	AFW-2U, AFW-2M, AFW-2L
AFW-3L	AFW-3U, AFW-3M, AFW-3L
AGW-1L	
AGW-2L	
AGW-3L	
B1L	B1U, B1M, B1L
C1L	C1U, C1M (nir), C1L
D2L	D2L
E1L	E1L
F1L	F1L
G1L	G1L
H1L	H1U, H1M
J1L	J1U, J1L
PMW-1L	PMW-1L
PMW-2L	
PMW-3L	PMW-3U, PMW-3M
PW-2L	
PW-3L	

Note: nir means “not an interpretable response”



EXPLANATION

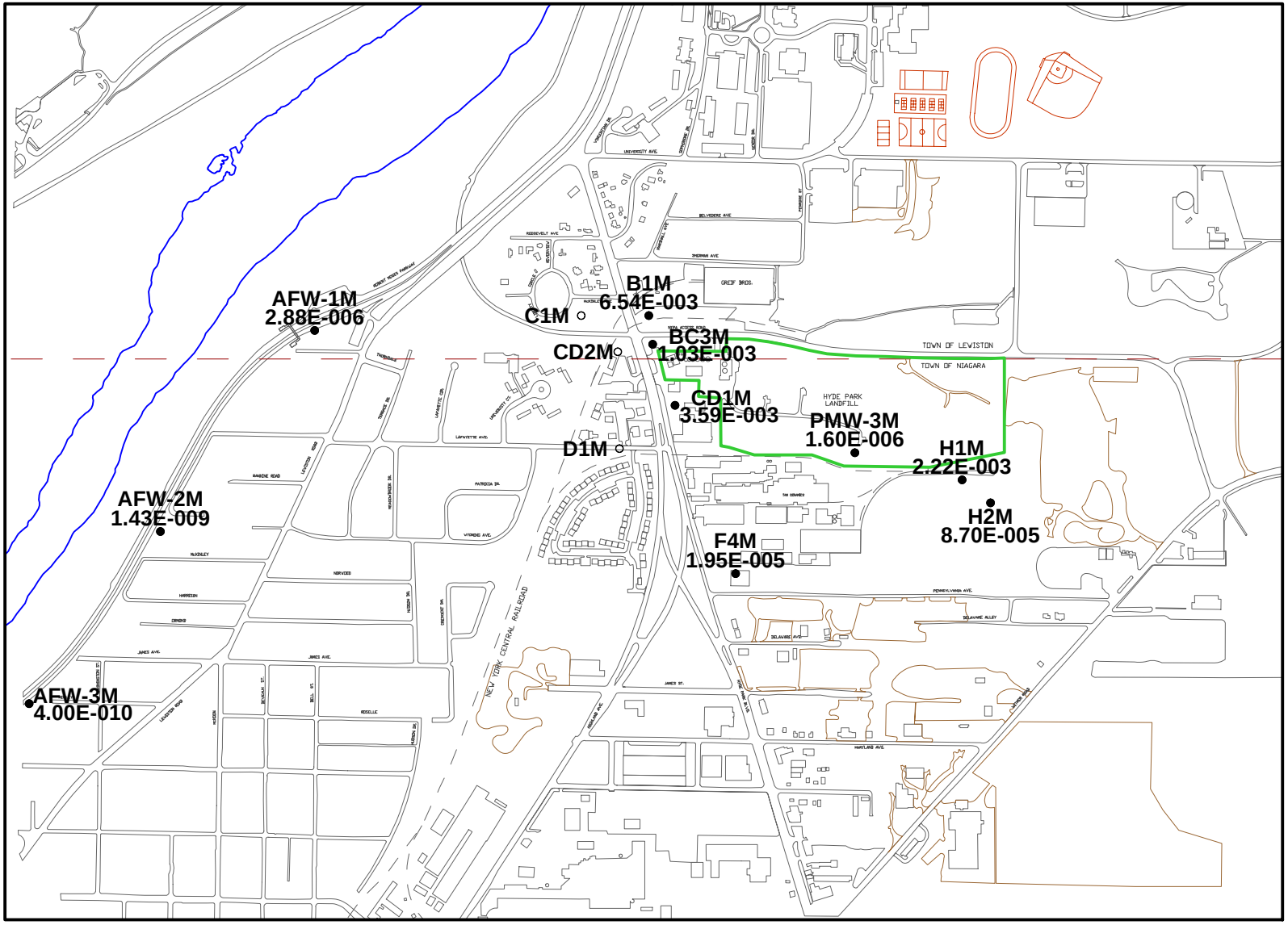
Site boundary

C1U
1.10E-003
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

Figure 1 - Slug Test Hydraulic Conductivities - Upper Zone

28-Jun-2001



EXPLANATION

Site boundary

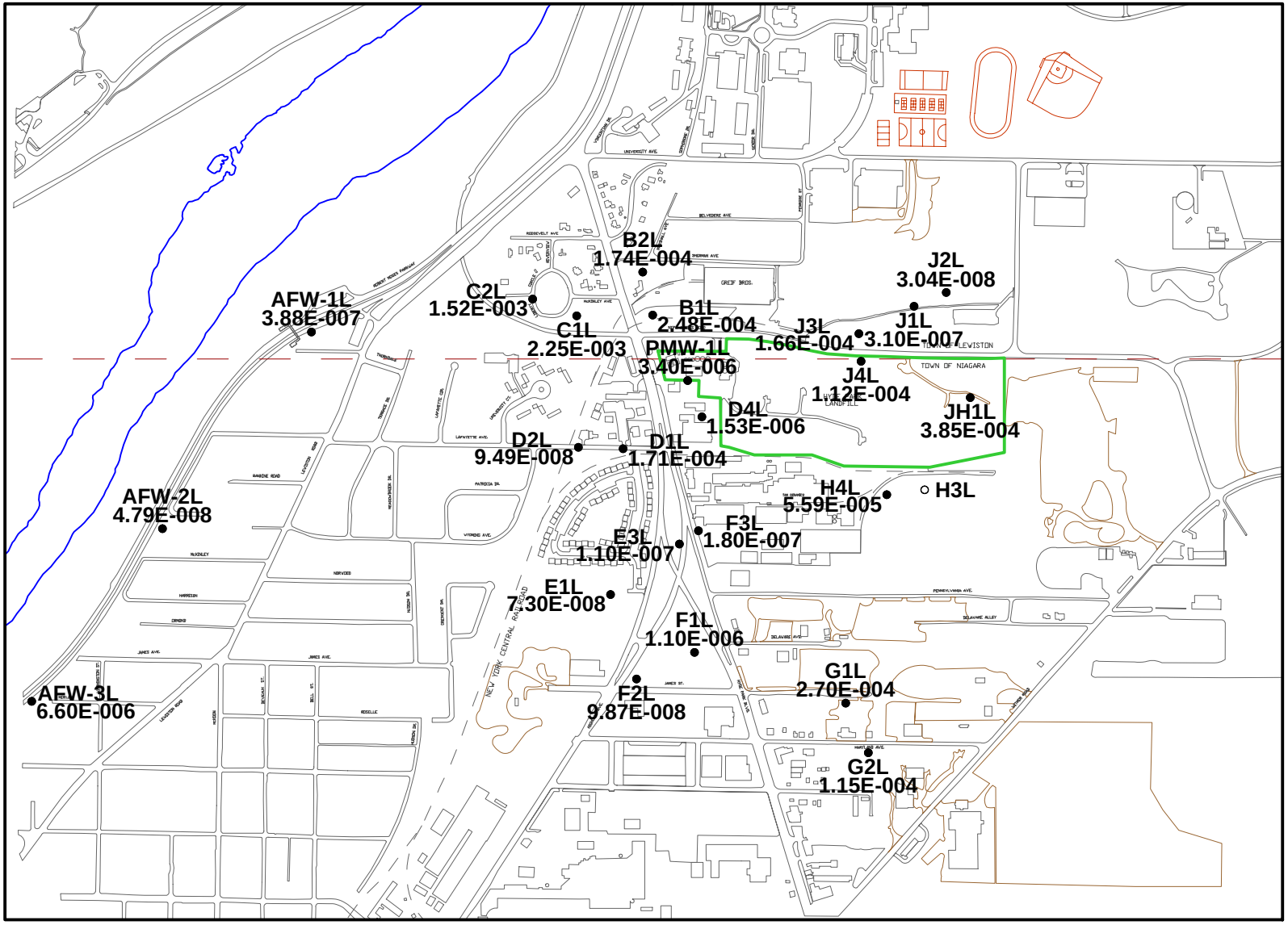
Well tested, response not interpretable

B1M
6.54E-003
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

Figure 2 - Slug Test Hydraulic Conductivities - Middle Zone

28-Jun-2001



EXPLANATION

Site boundary

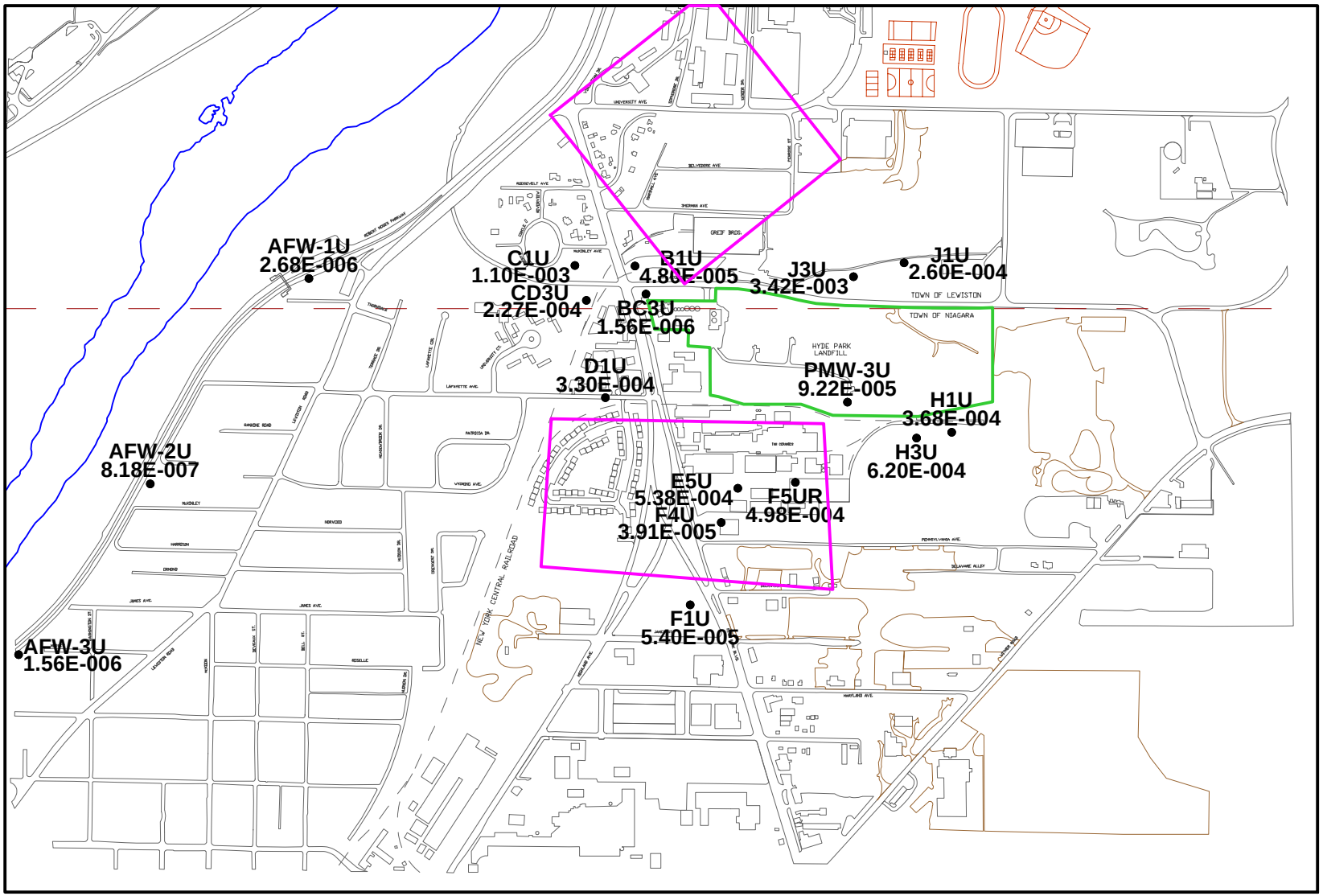
Well tested, response not interpretable

G2L
1.15E-004
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

Figure 3 - Slug Test Hydraulic Conductivities - Lower Zone

28-Jun-2001



EXPLANATION

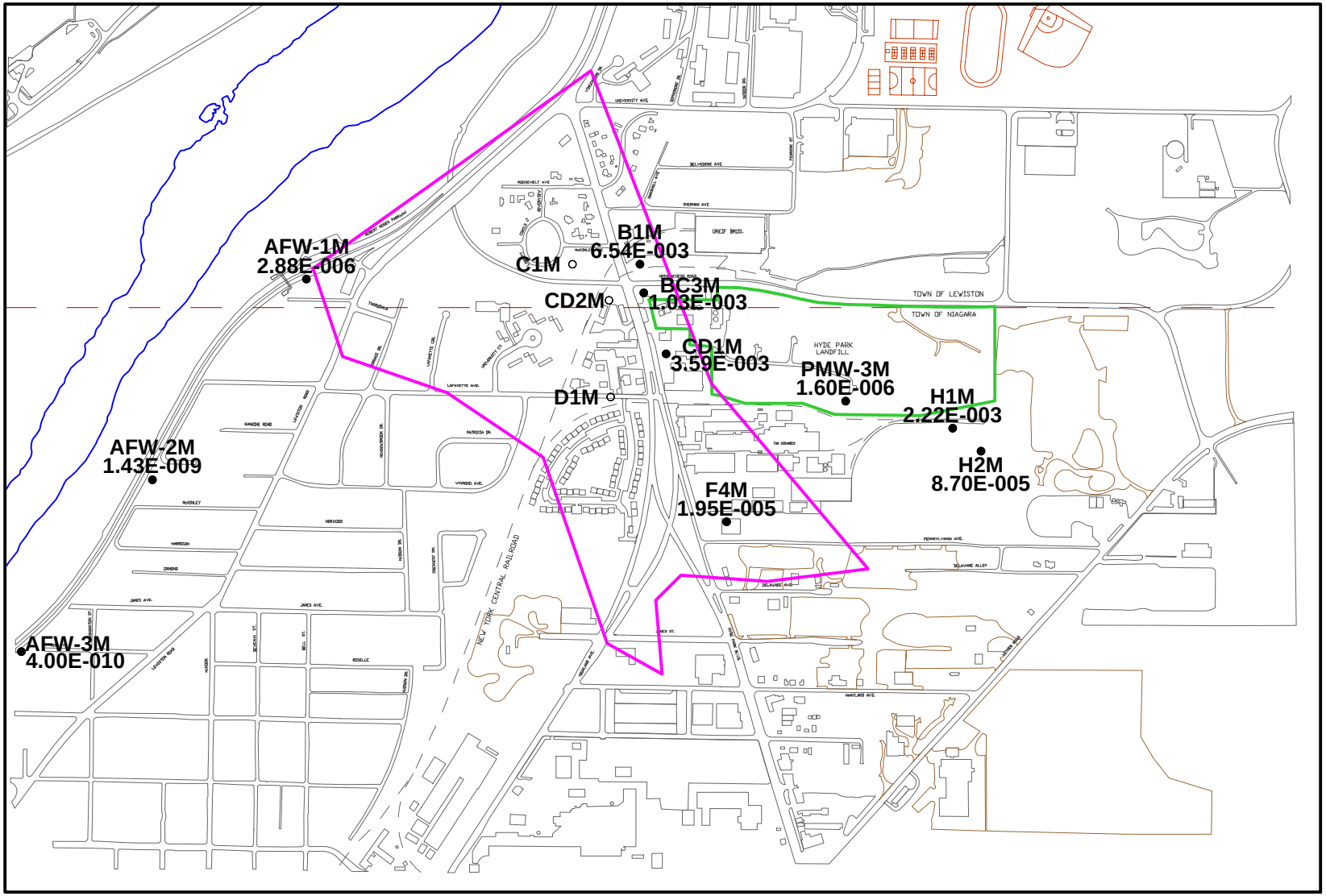
Site boundary

C1U
1.10E-003
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

Figure 4 - Slug Test Hydraulic Conductivities - Upper Zone

28-Jun-2001



EXPLANATION

Site boundary

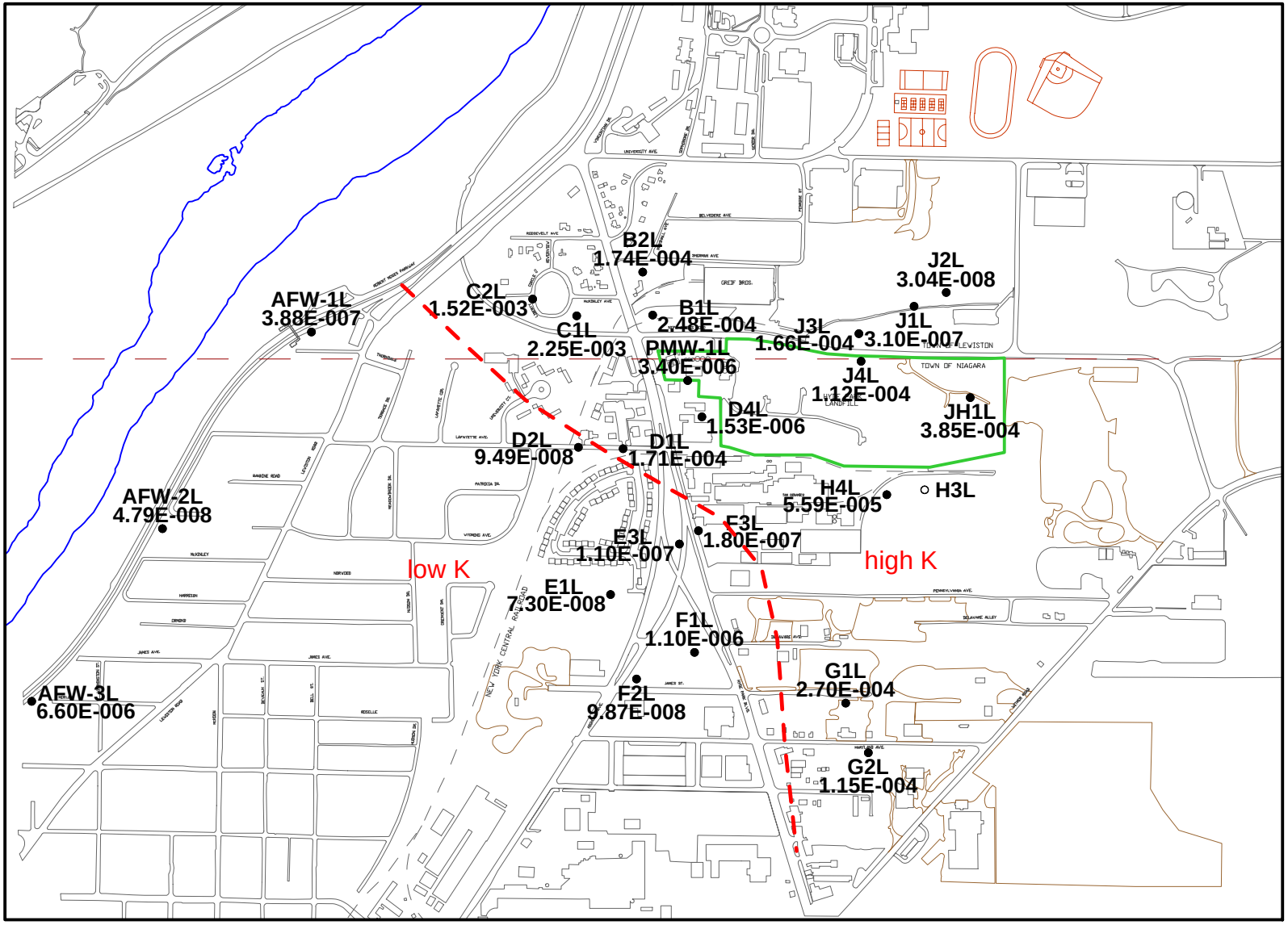
Well tested, response not interpretable

B1M
6.54E-003
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

Figure 5 - Slug Test Hydraulic Conductivities - Middle Zone

28-Jun-2001



EXPLANATION

Site boundary

Well tested, response not interpretable

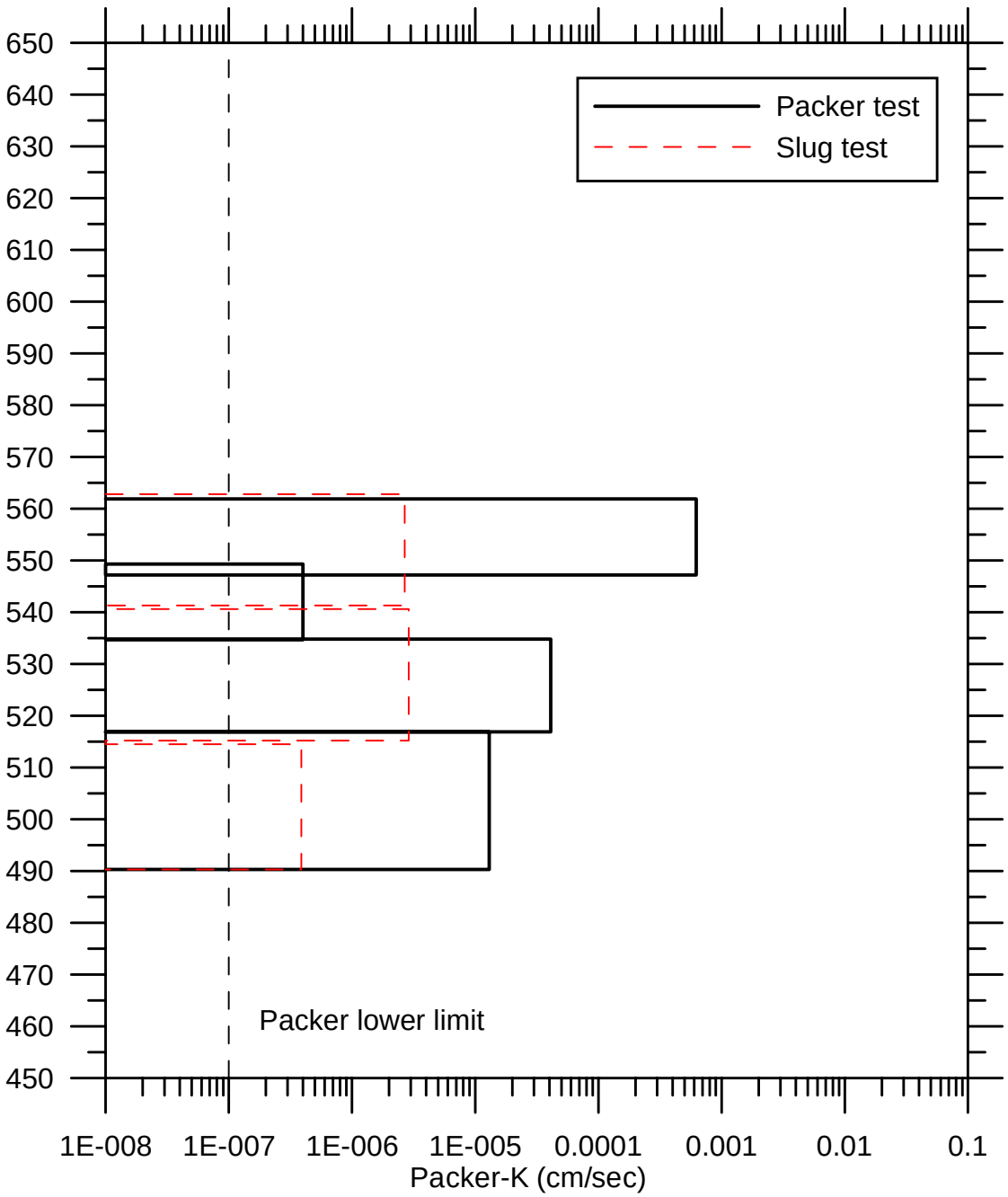
G2L
1.15E-004
Well, hydraulic conductivity (cm/sec)

0 500 1,000 ft

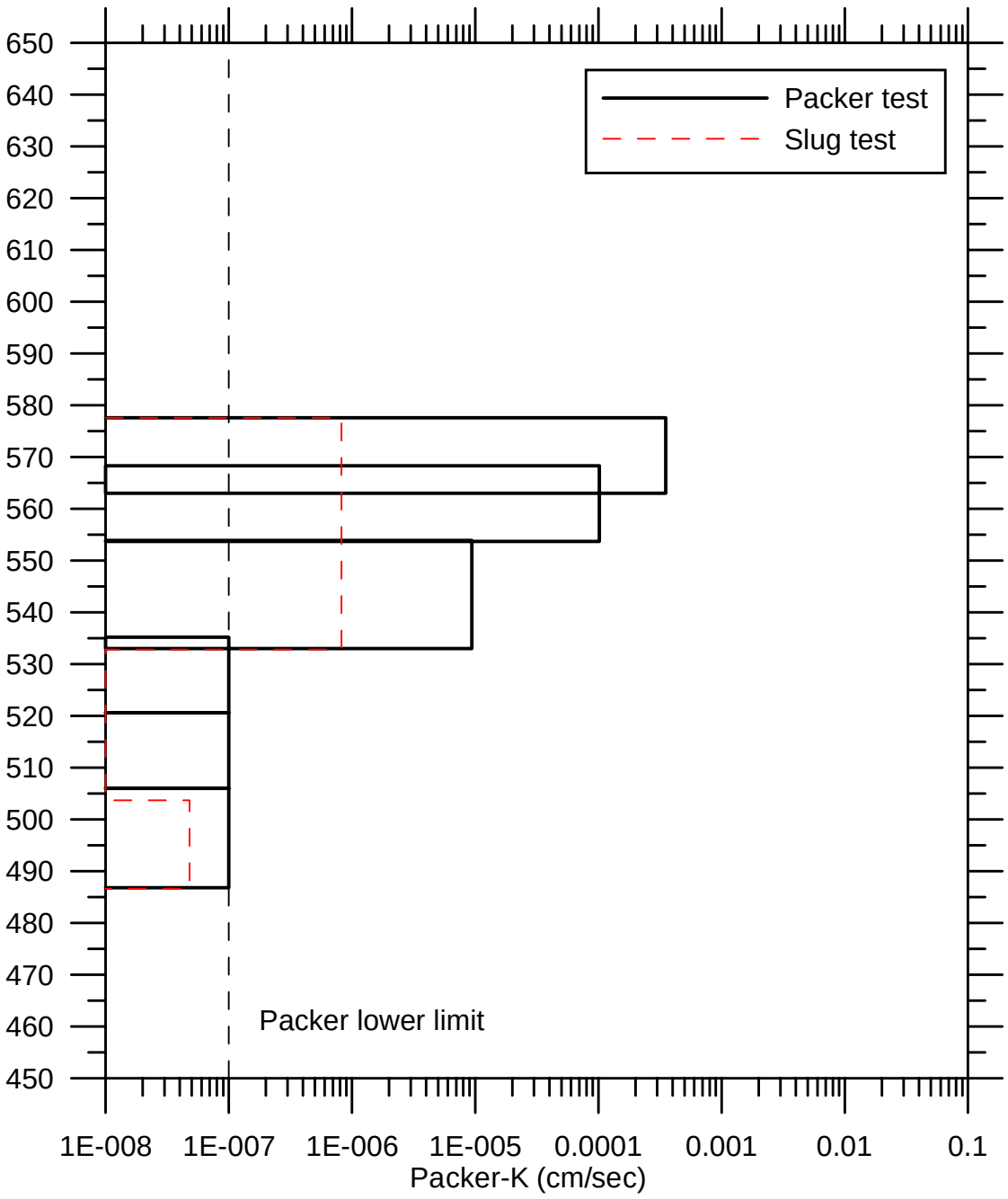
Figure 6 - Slug Test Hydraulic Conductivities - Lower Zone

28-Jun-2001

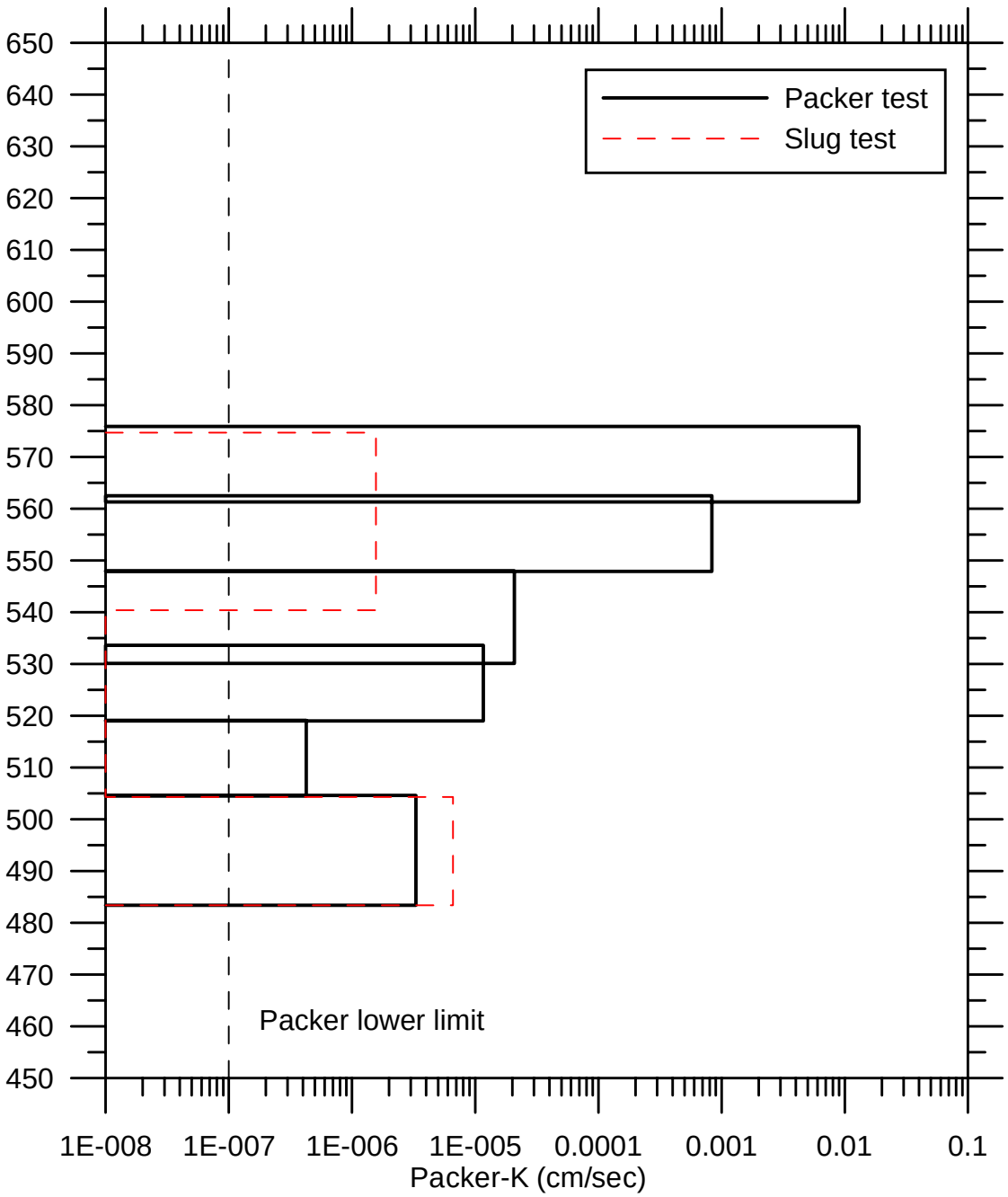
AFW-1 Packer testing, July 1991



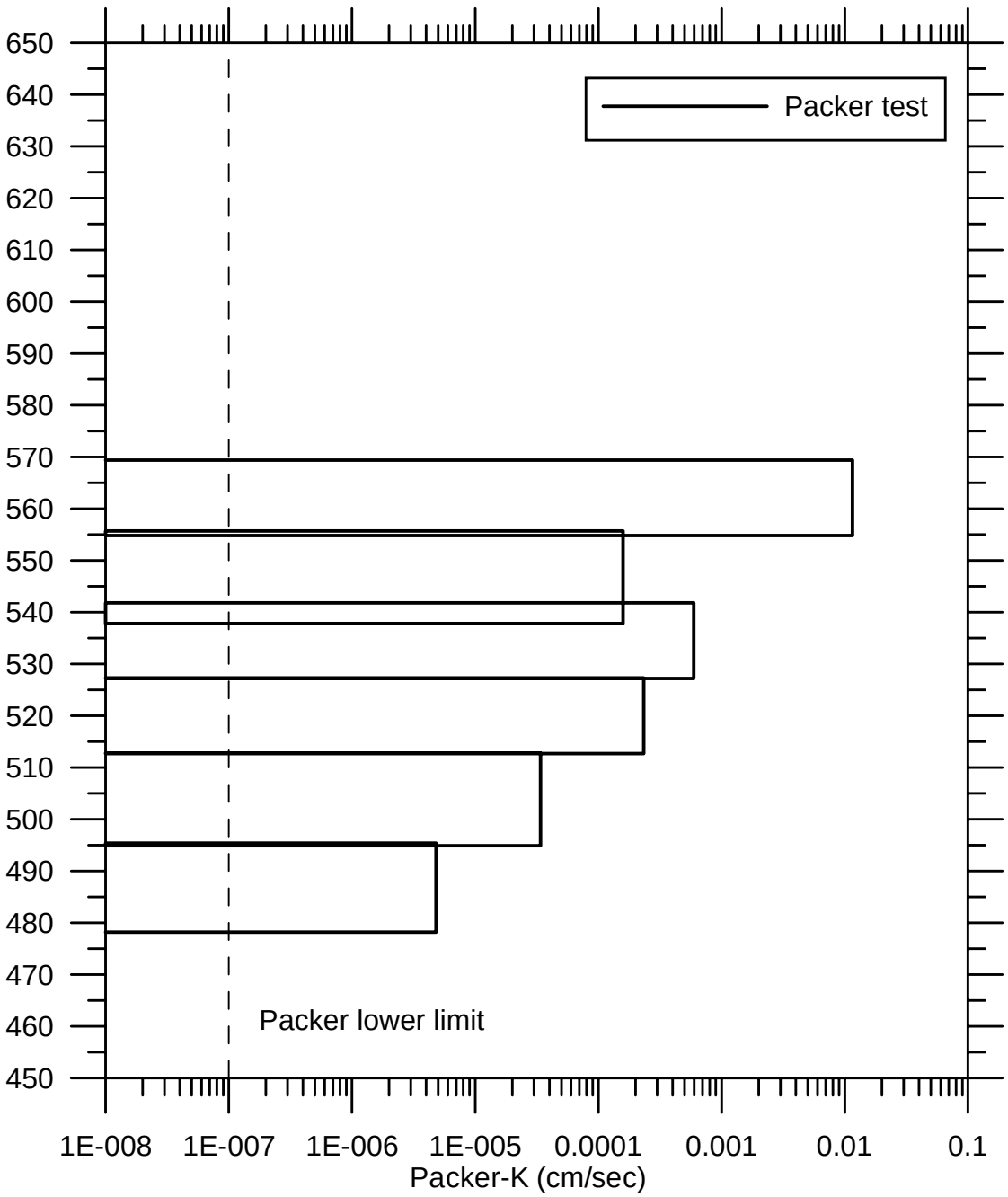
AFW-2 Packer testing, July 1991



AFW-3 Packer testing, July 1991



AGW-1 Packer testing, Sept. 1991



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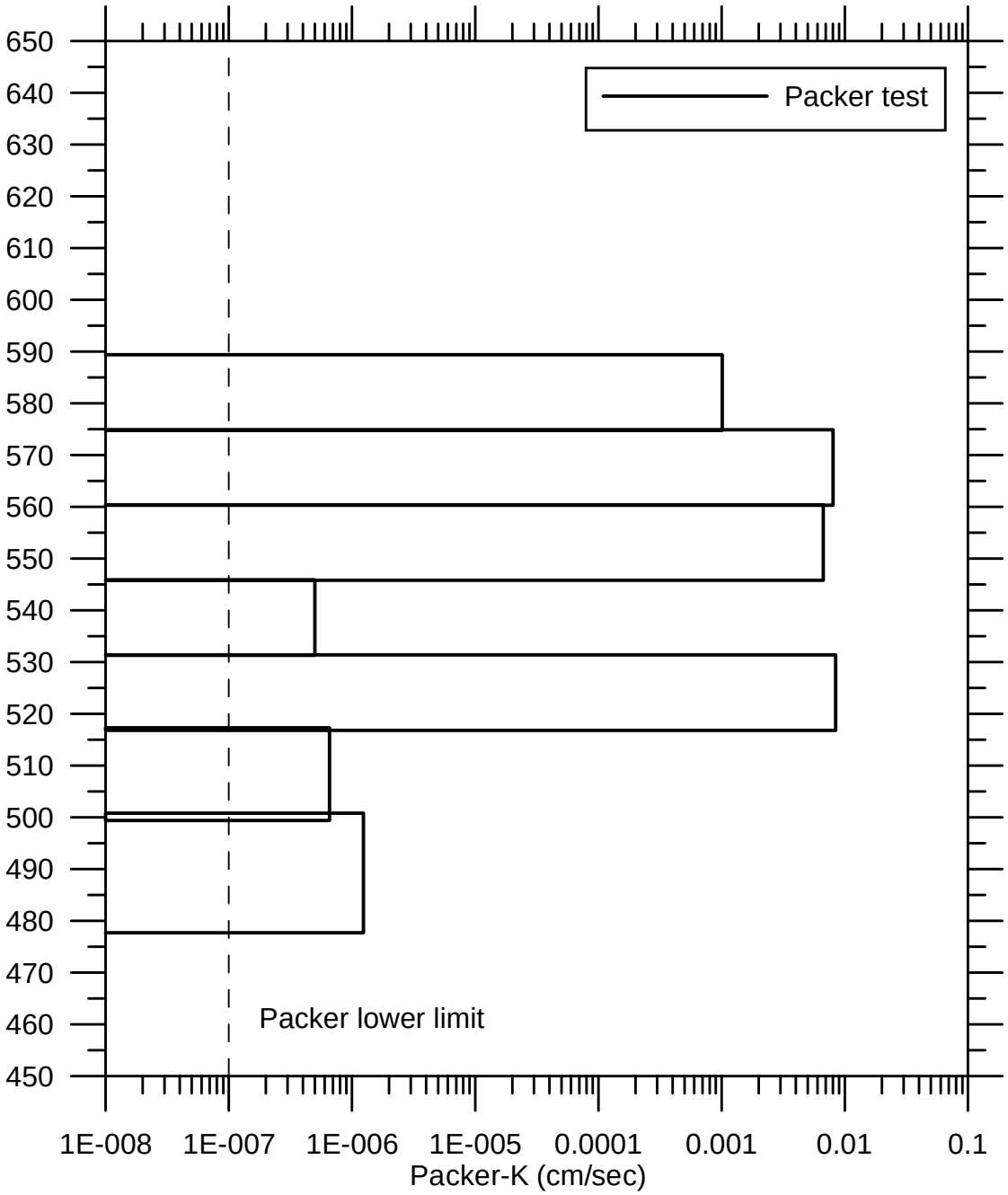
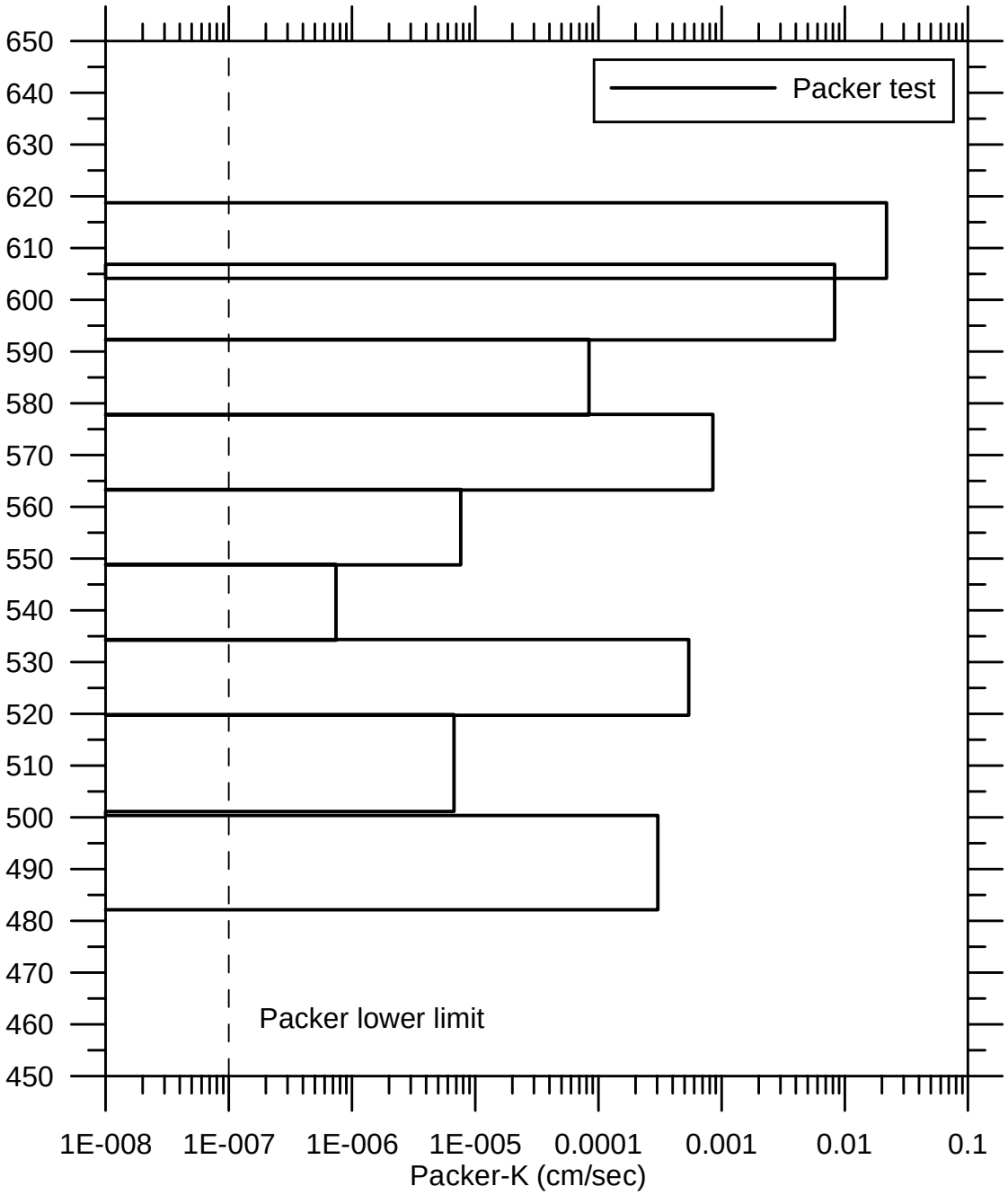
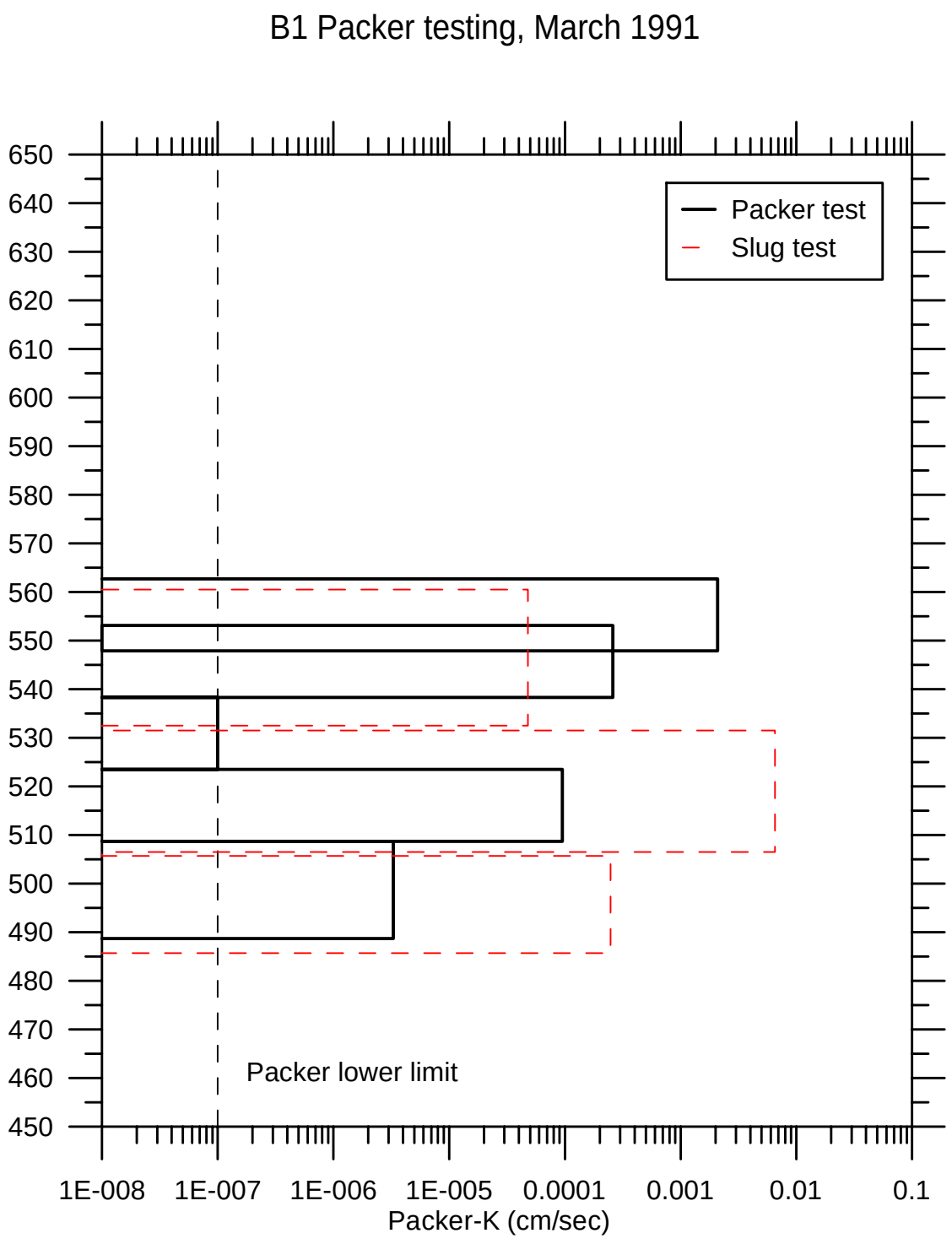
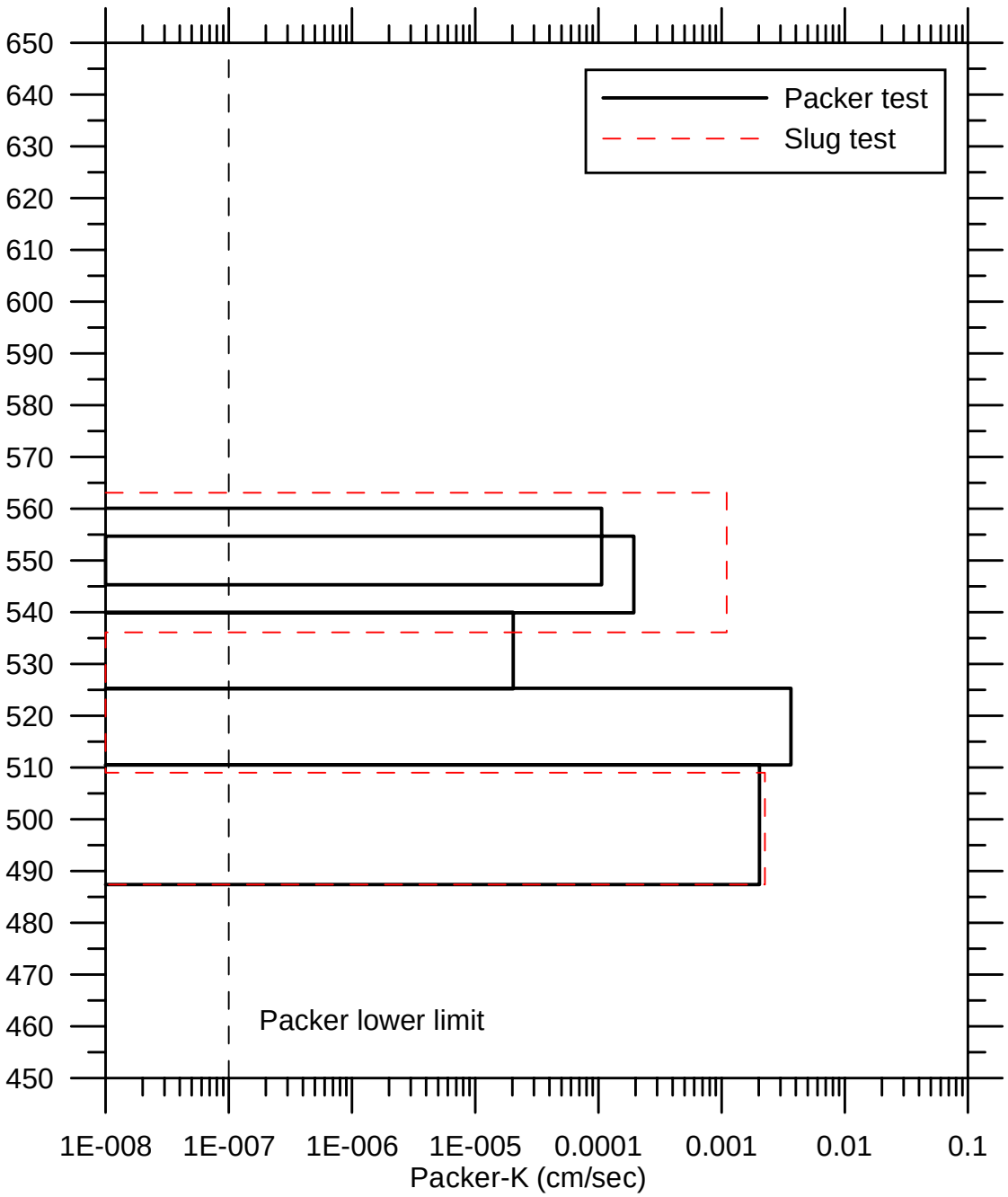


AGW-3 Packer testing, Sept. 1991

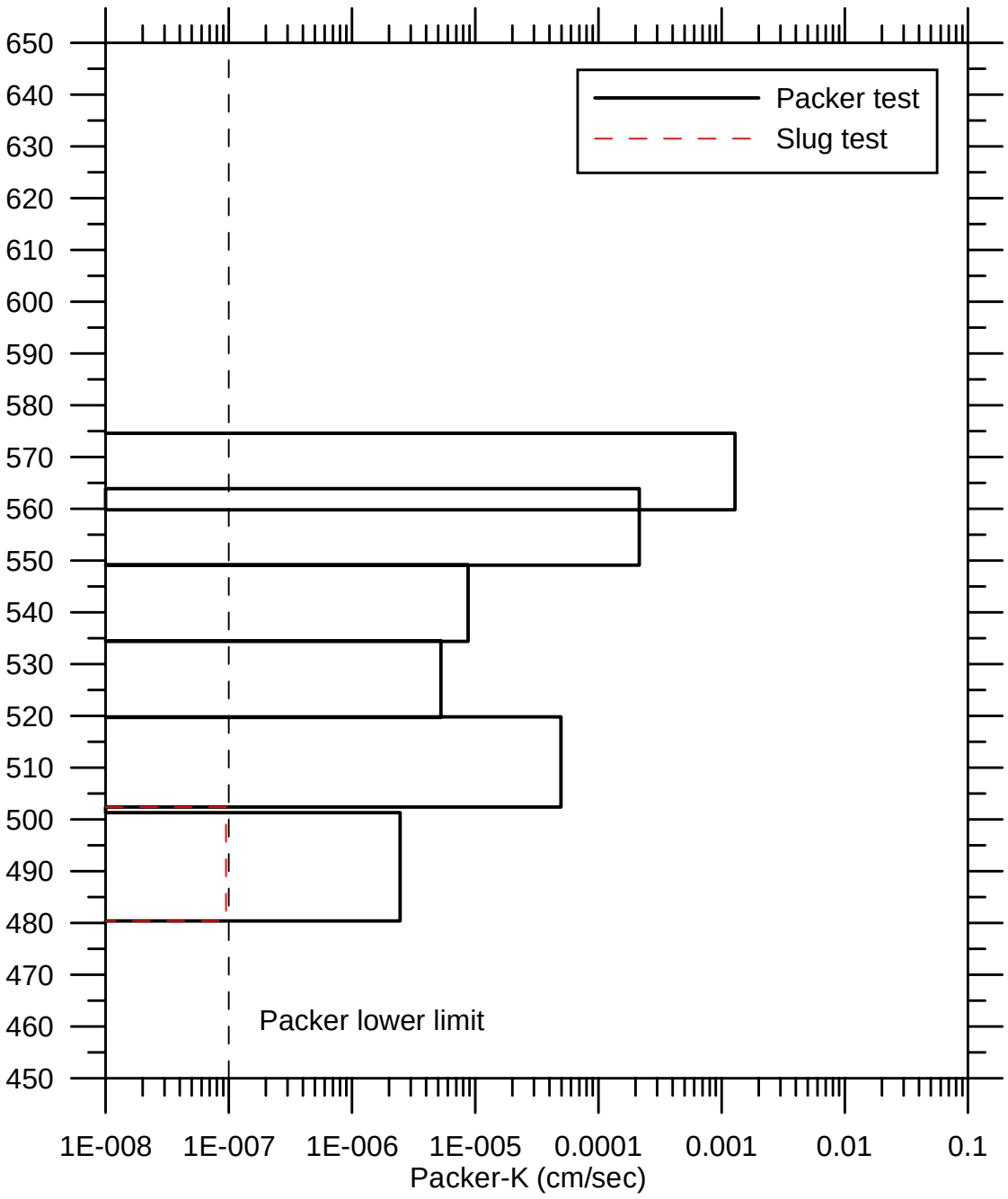



B1 Packer testing, March 1991
Packer test
Slug test
Packer lower limit
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
1E-008
1E-007
1E-006
1E-005
0.0001
0.001
0.01
0.1
Packer-K (cm/sec)

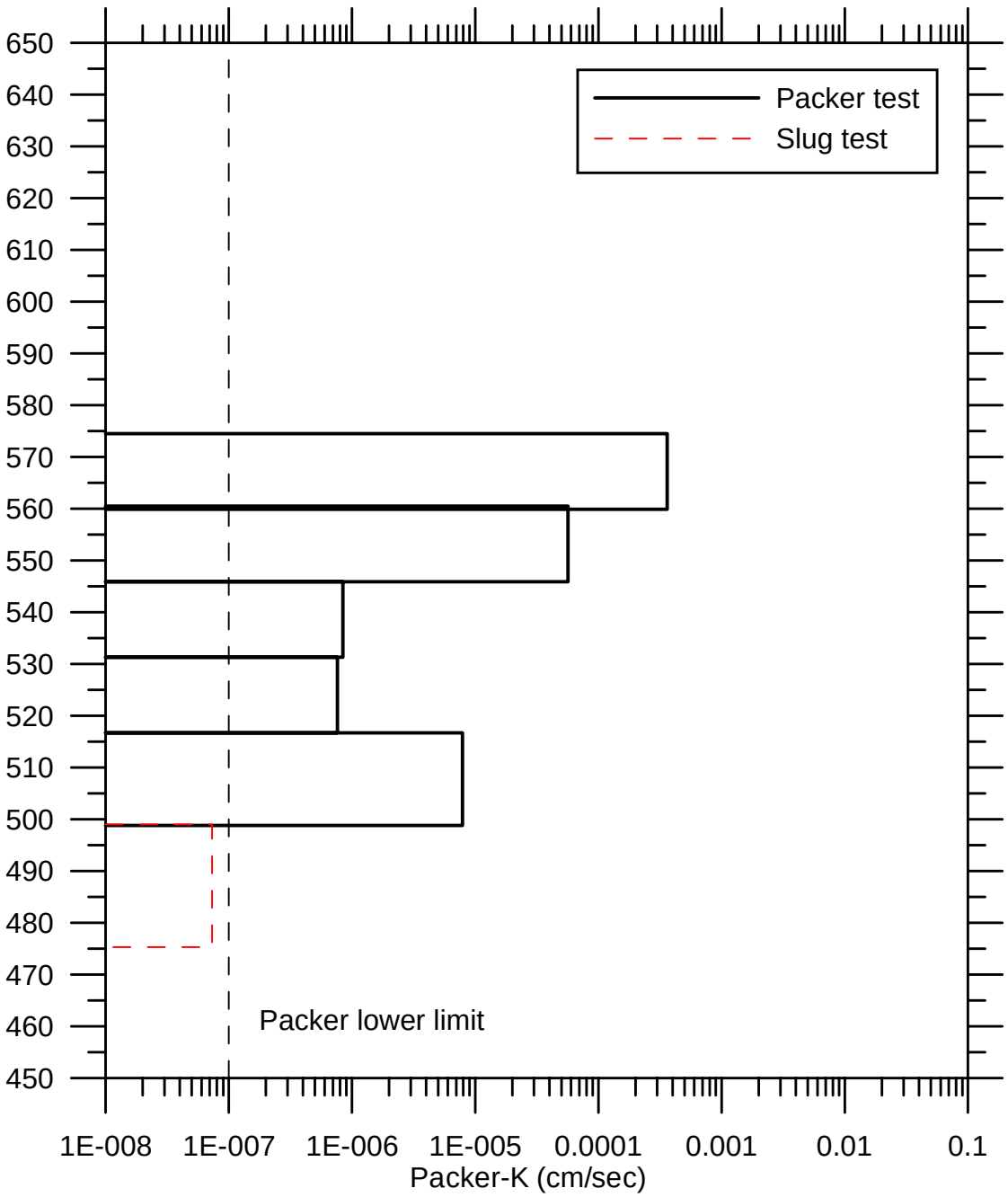
C1 Packer testing, Jan. 1991



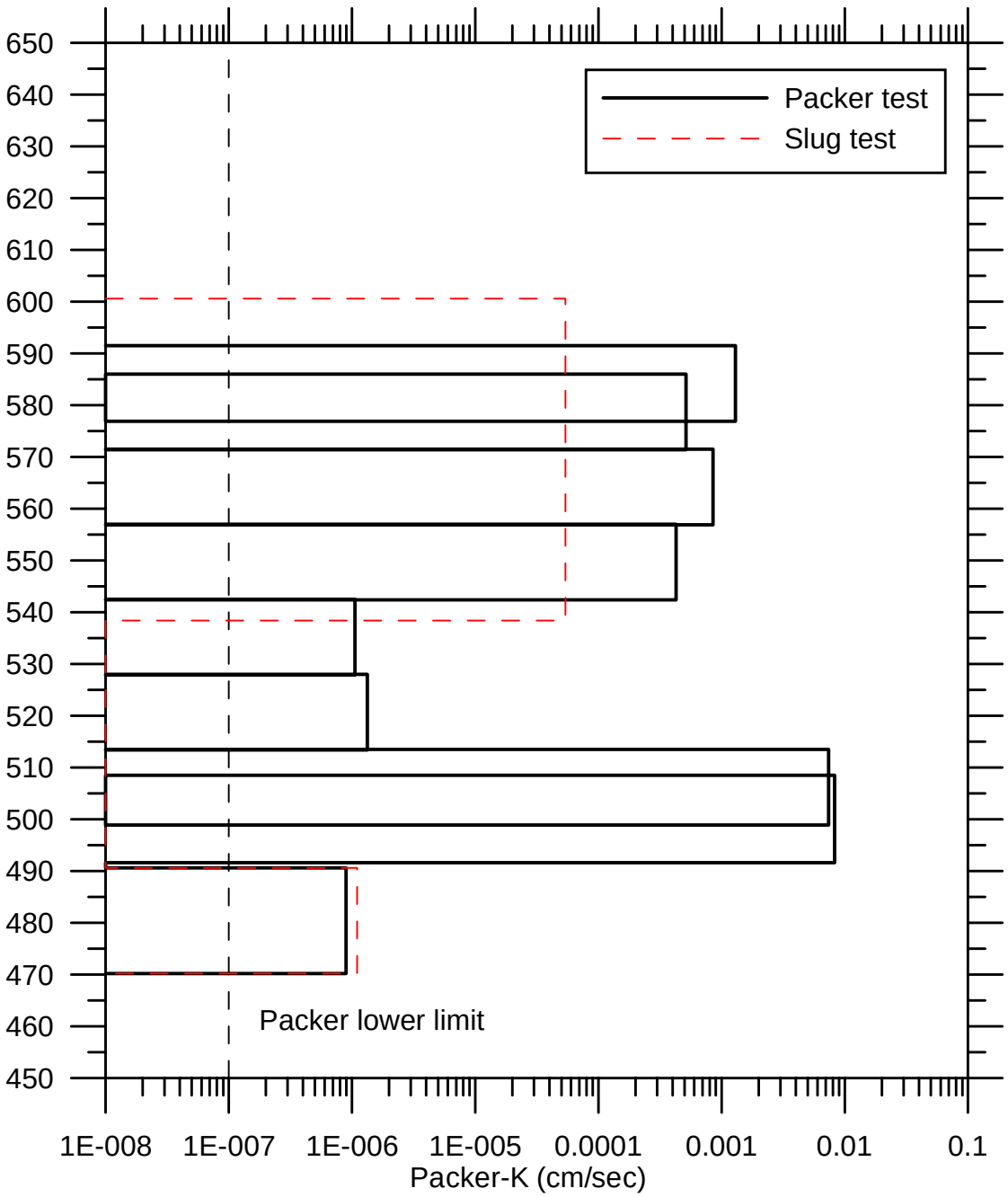
D2 Packer testing, April 1991



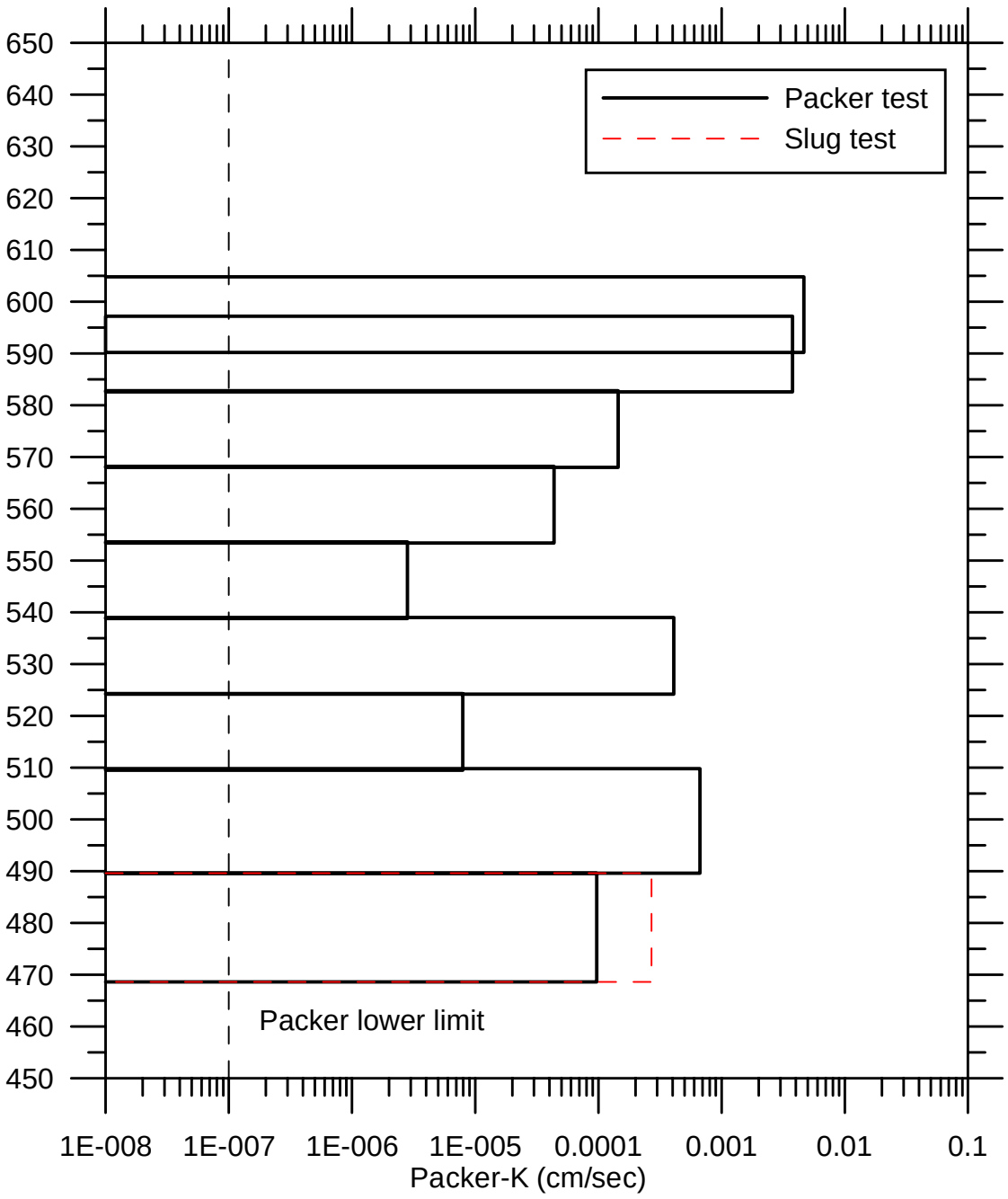
E1 Packer testing, April 1991



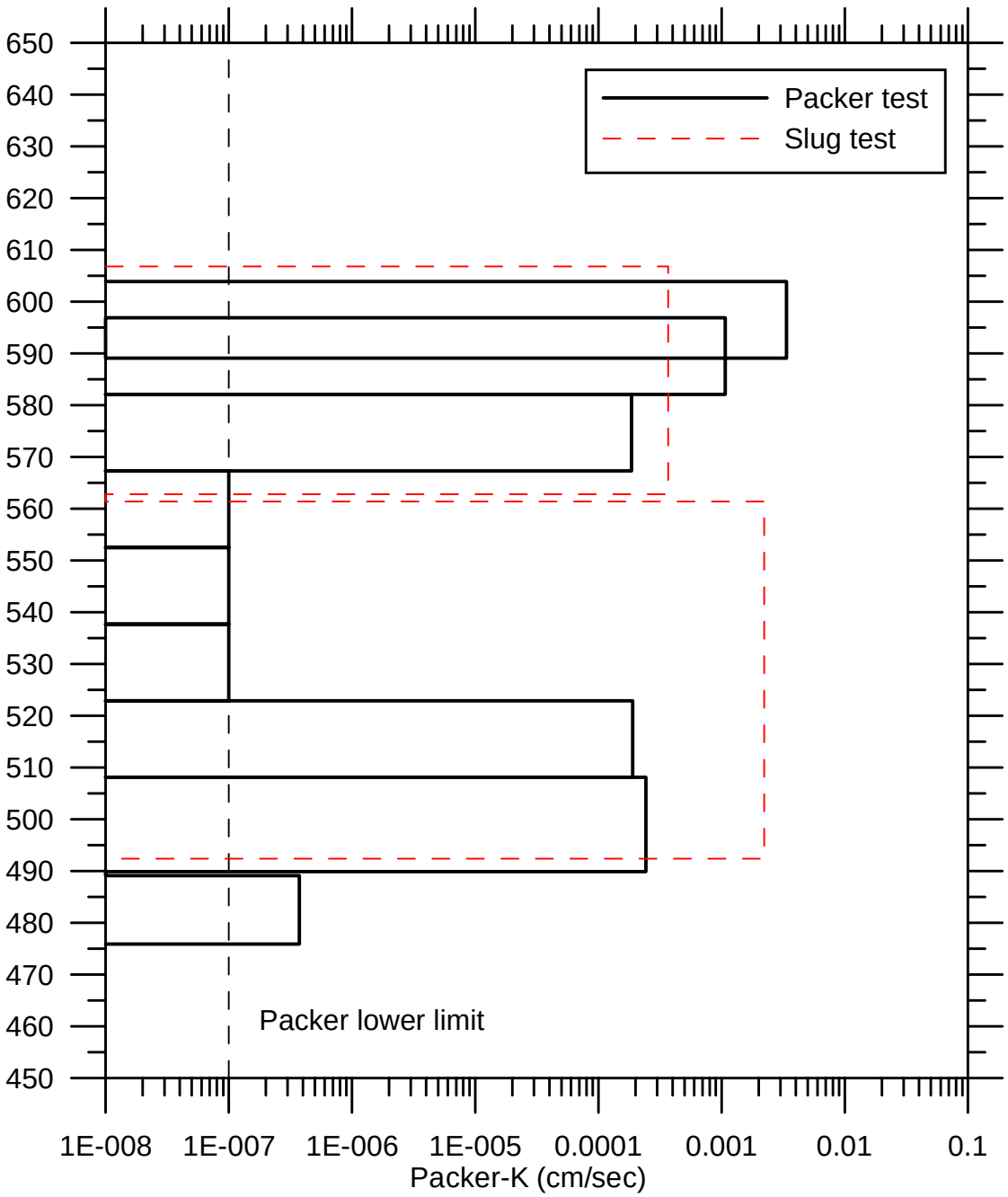
F1 Packer testing, Aug. 1991



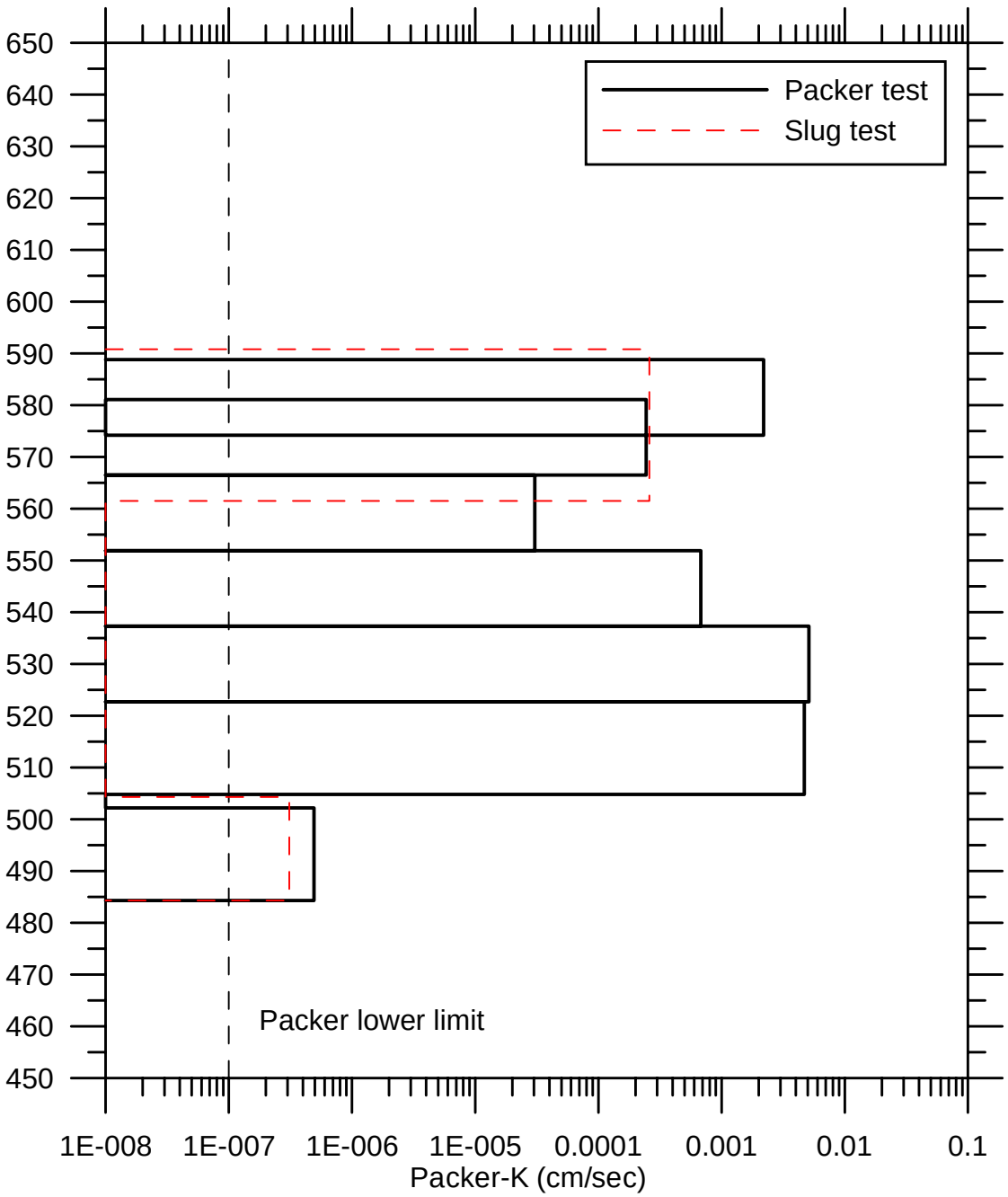
G1 Packer testing, Feb. 1991



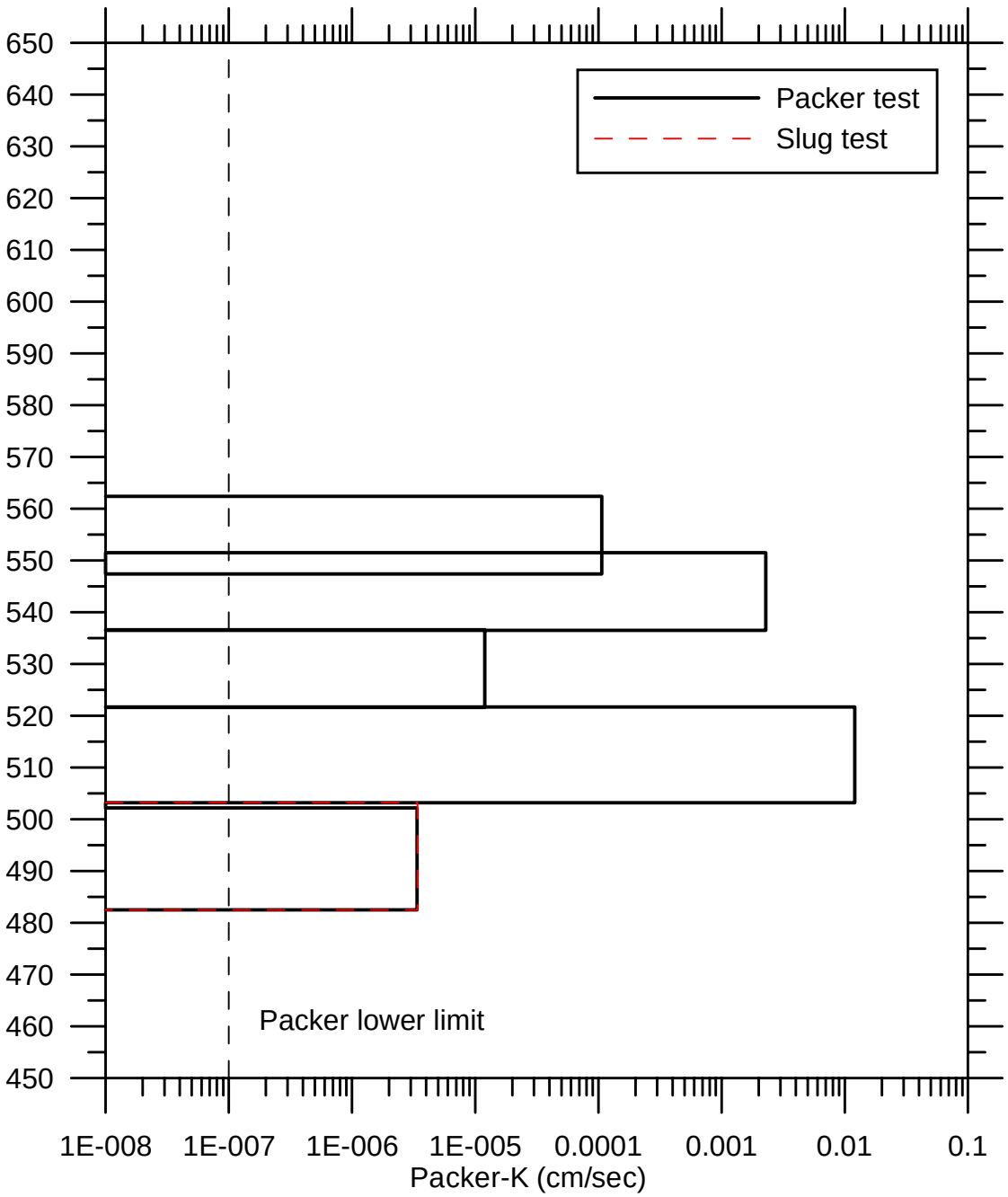
H1 Packer testing, Feb. 1991



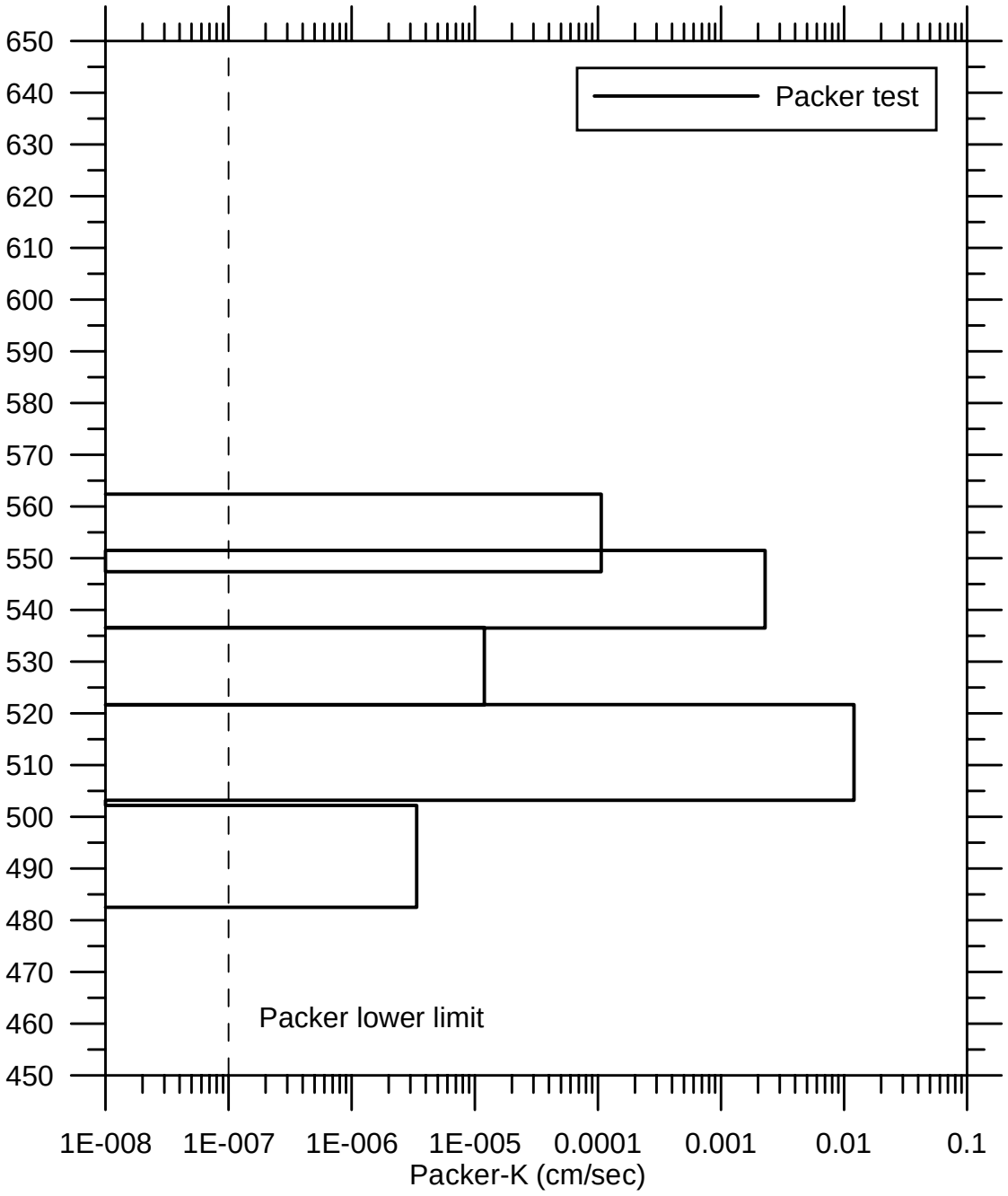
J1 Packer testing, March 1991



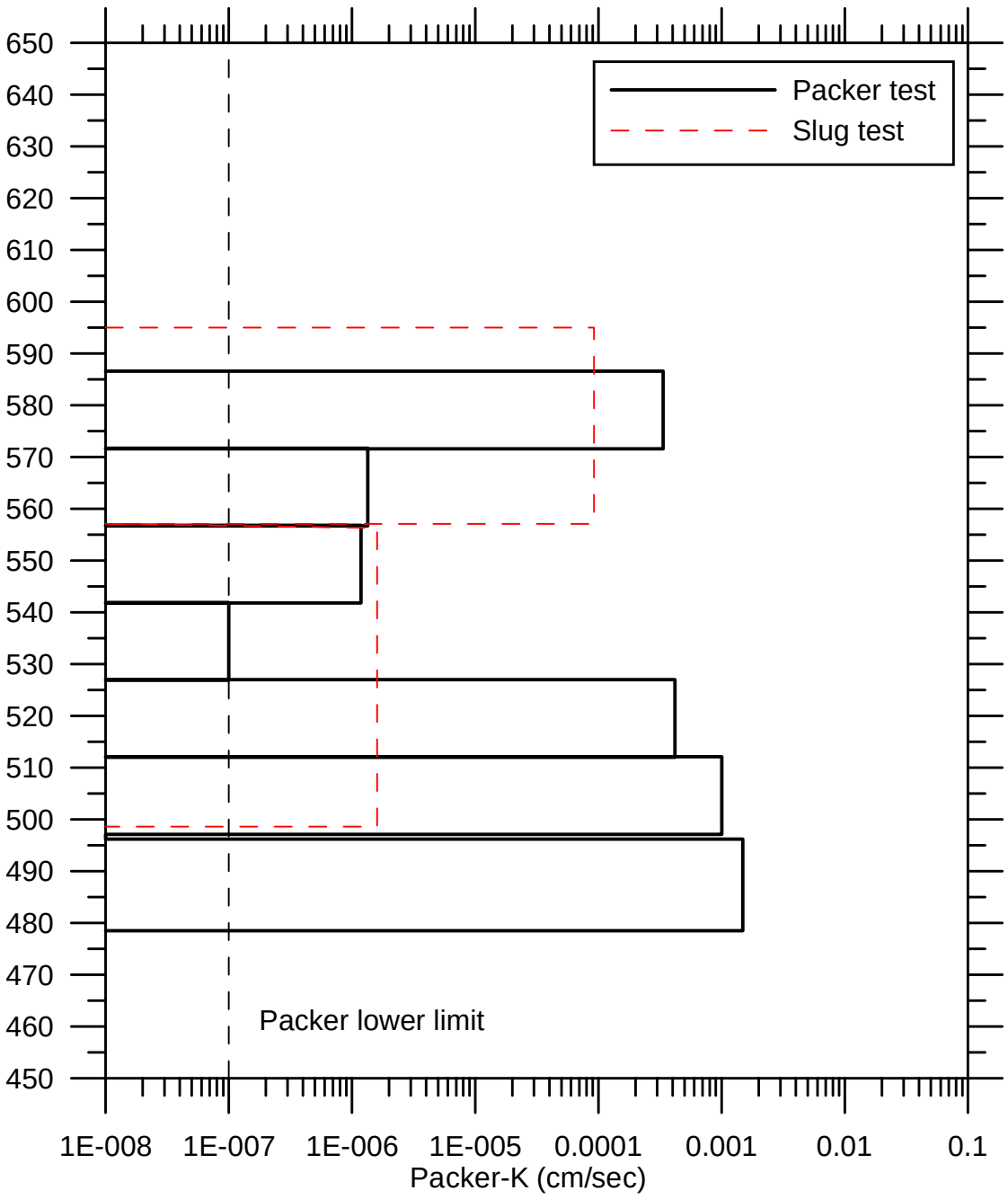
PMW-1 Packer testing, June 1991



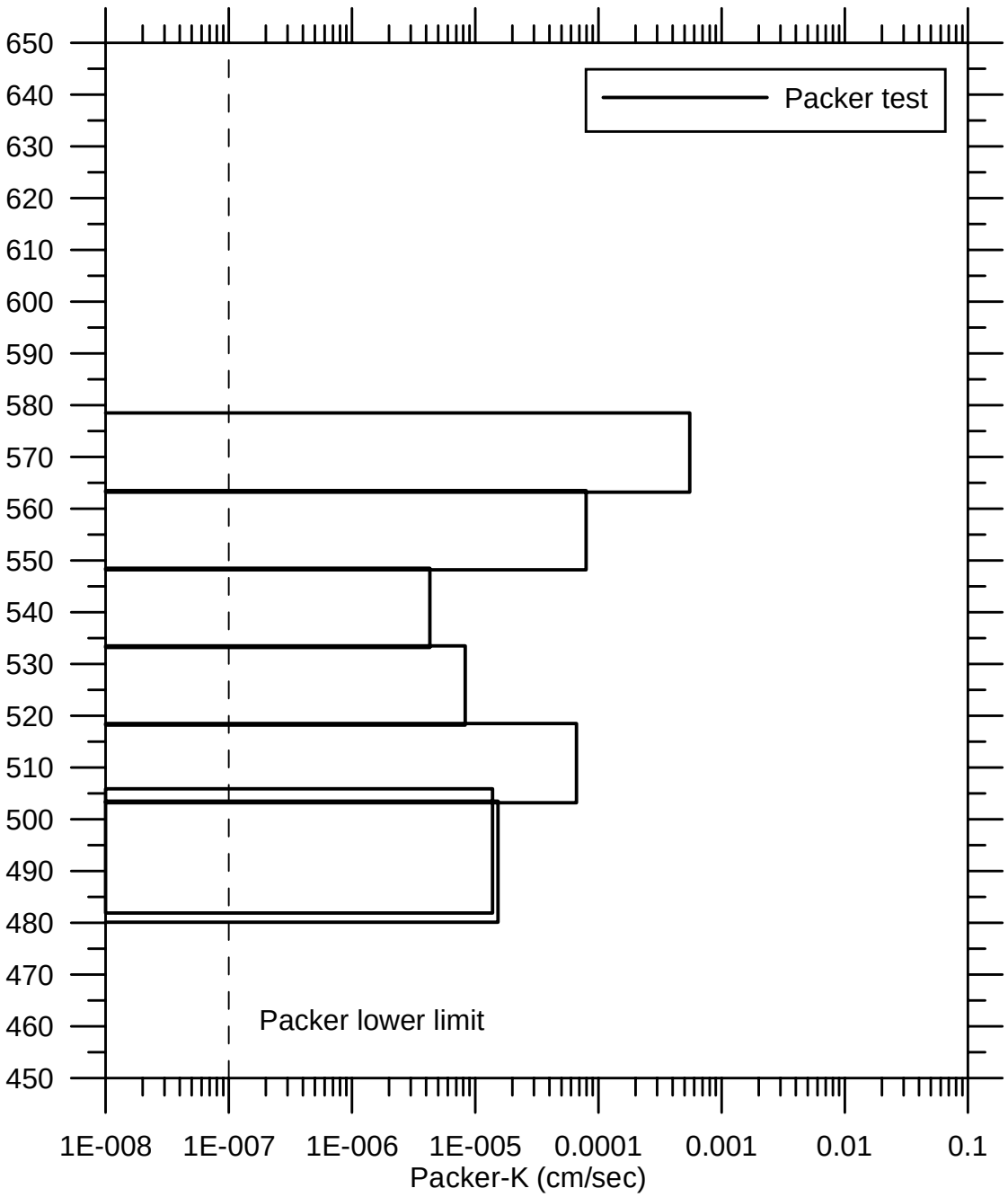
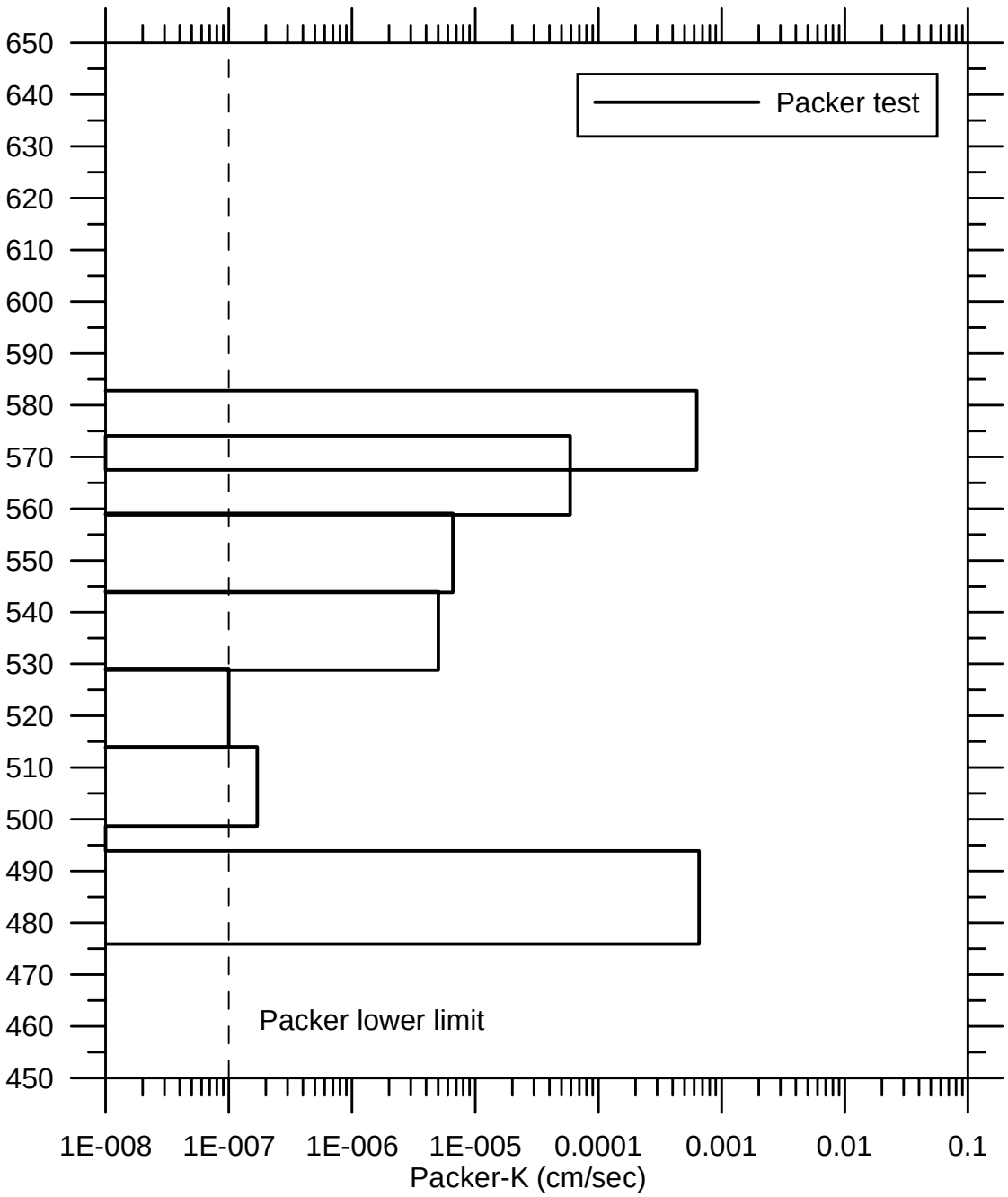
PMW-2 Packer testing, May 1991



PMW-3 Packer testing, April 1991



PW-2L Packer testing, March 1991



PW-3L Packer testing, Feb. 1991