APPENDIX A

Fugro Consultants, Inc. PGEQ-03 R0: Software Validation on Uniseis and Qualification of 2010-2011 High Resolution 3D Offshore Seismic Reflection Data

And

Fugro Consultants, Inc. PGEQ-06 R1: Software Validation for Seismic Processing Workshop and Qualification of 2010-2011 2D High Resolution Seismic Reflection Data

FUGRO	FUGRO CONSULTANTS, INC. PROJECT REPORT COVER SHEET	PR No. PGEQ-PR-03
		Revision 0
		Page 1 of 31

SOFTWARE VALIDATION OF UNISEIS AND QUALIFICATION OF 2010 - 2011 HIGH-RESOLUTION 3D OFFSHORE SEISMIC REFLECTION DATA

DIABLO CANYON POWER PLANT

CENTRAL COASTAL CALIFORNIA SEISMIC IMAGING PROJECT

Prepared for:
PACIFIC GAS & ELECTRIC COMPANY

FSI Project No. 2011-4493
FCL Report No. PGEQ-PR-03

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Project Report Revision Status			
Rev. No.	**Date**	**Description**	**Impacted Document No.**
0	6/13/2012	Initial Issuance of Project Report	None

Text Revision History			
Page No.	**Rev. No.**	**Page No.**	**Rev. No.**

Appendix Revision History					
Appendix No.	**Page No.**	**Rev. No**	**Appendix No.**	**Page No.**	**Rev. No**

FUGRO	FUGRO CONSULTANTS, INC. PROJECT REPORT SUMMARY VERIFICATON SHEET	PR No. PGEQ-PR-03
		Revision: 0
		Page 3 of 31

Item	Parameter	Yes	No	N/A
1	Purpose is clearly stated and Report satisfies the Purpose.	X		
2	Methodology is appropriate and properly applied.	X		
3	Assumptions are reasonable, adequately described, and based upon sound geotechnical principles and practices.			X
4	Input was authorized and correctly incorporated into the Report.	X		
5	Software is properly identified and applied; and validation is referenced, or included, and acceptable.	X		
6	Detailed Discussion is complete, accurate, and leads logical to Results and Conclusions.	X		
7	Results and Conclusions are accurate, acceptable, and reasonable compared to the Input and Assumptions.	X		
8	References are valid for intended use.	X		
9	Appendices are complete, accurate, and support text.	X		

Comments: (use additional pages as necessary)

Verifier: [signature] Digitally signed by Daniel O'Connell DN: cn=Daniel O'Connell, o=Fugro, ou=Fugro Consultants Inc., email=d.oconnell@fugro.com, c=US **Date:** 6/7/12

Dan O'Connell, Ph.D.

Table of Contents

List of Tables

List of Figures

List of Figures (continued)

Appendix

1.0 INTRODUCTION

Fugro Seismic Imaging, Inc. (FSI) was sub-contracted by Fugro Consultants Inc. (FCL) for processing offshore 2010-2011 3D high-resolution seismic surveys for the Pacific Gas & Electric (PG&E) Central Coastal California Seismic Imaging Project (CCCSIP). The FSI Project No. is 2011-4493 and FCL's Report No. is PGEQ-PR-03. The 3D data was processed using Fugro Seismic Imaging's proprietary seismic processing software Uniseis. A software validation of Uniseis has been performed to satisfy United States Nuclear Regulatory Commission NQA-1 Quality Assurance requirements. This report summarizes Uniseis software validation and qualification of 2010-2011 high-resolution 3D seismic reflection data.

1.1 Personnel

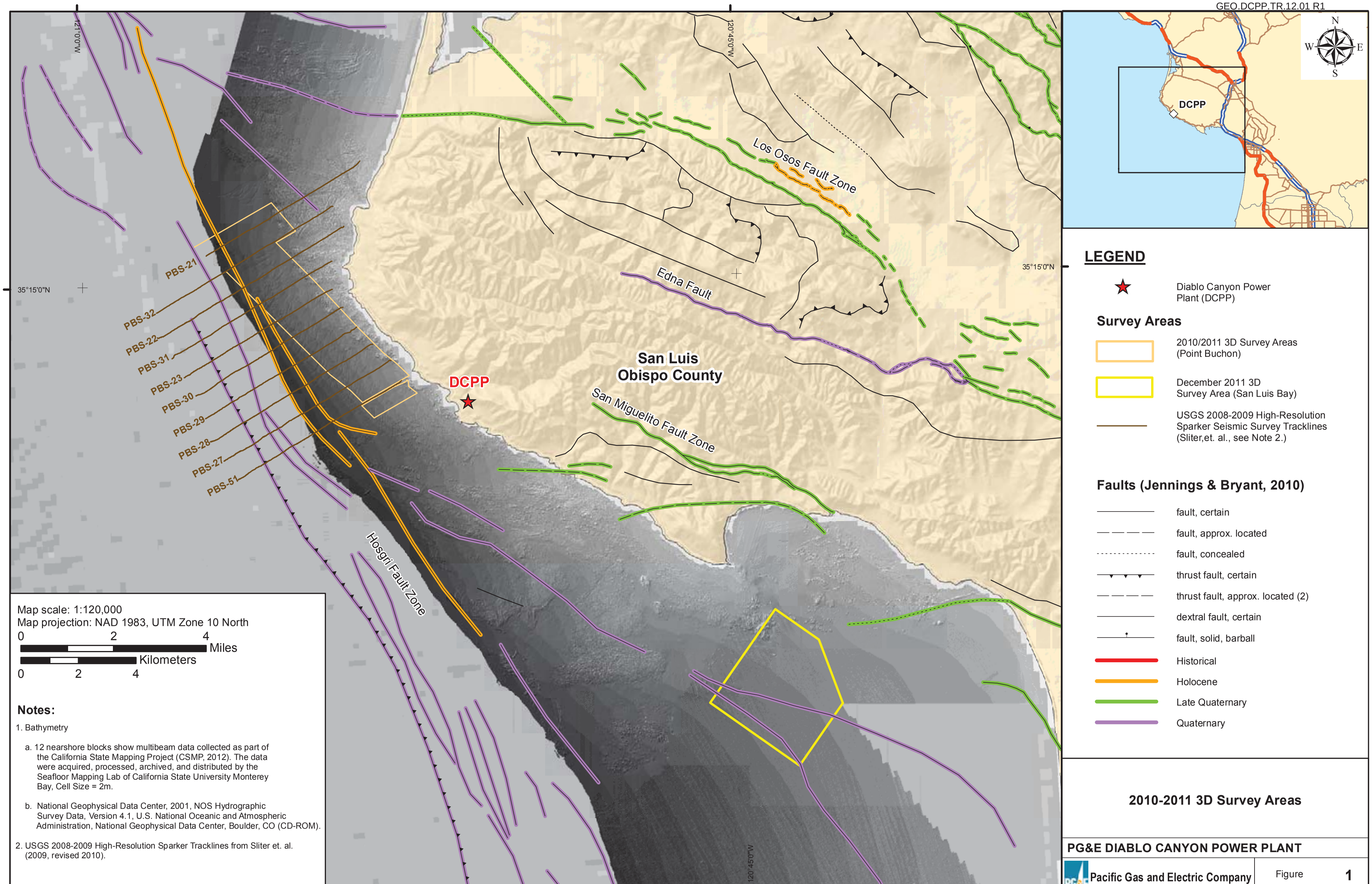
The following personnel worked on this project:

Technical Advisor	Steve Cole	Chief Geophysicist
Lead Investigator	Tal Griffiths	Marine Processing Manager
Project Personnel	Steve Best	Senior Geophysicist
	Melissa Padilla	Staff Geophysicist

2.0 PURPOSE AND SCOPE

FCL requested a software validation of Uniseis, FSI's proprietary seismic processing software in order to satisfy United States Nuclear Regulatory Commission Quality Assurance requirements.

FSI processed 3D low energy data collected by FCL in 2010/2011 for the PG&E Central Coast Seismic Imaging Project (Figure 1). Appendix A of this report presents documentation of Uniseis Software Validation for the Offshore QA Phase of marine seismic reflection data acquisition and processing. Subsequently, FSI carried out the processing at Fugro's offices in Houston, Texas. Procedures were developed and performed to validate Uniseis and qualify the 2010/2011 3D dataset. The software validation and data qualification procedures are outlined in: 1) PI No PGEQ-PI-09, Attachment 6, 2) Offshore Work Instruction WI-09: Perform Validation of Uniseis Software (dated 03/21/12), and 3) in this report.



Notes:

1. Bathymetry

   a. 12 nearshore blocks show multibeam data collected as part of the California State Mapping Project (CSMP, 2012). The data were acquired, processed, archived, and distributed by the Seafloor Mapping Lab of California State University Monterey Bay, Cell Size = 2m.

   b. National Geophysical Data Center, 2001, NOS Hydrographic Survey Data, Version 4.1, U.S. National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, CO (CD-ROM).

2. USGS 2008-2009 High-Resolution Sparker Tracklines from Sliter et. al. (2009, revised 2010).

2010-2011 3D Survey Areas

PG&E DIABLO CANYON POWER PLANT

Pacific Gas and Electric Company | Figure 1

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3.0 3D DATA QUALIFICATION AND UNISEIS SOFTWARE VALIDATION STEPS

A series of exercises were performed to compare 3D seismic survey data acquired during the 2010/2011 low-energy seismic survey campaign offshore of Point Buchon to three public datasets generated by others in the same area (Jennings and Bryant, 2010; Sliter et al., 2009, 2010; California Seafloor Mapping Program [CSMP], 2012). These exercises and procedures have been performed in accordance with the Project Instruction No. PGEQ-PI-09, Attachment 6, as well as Offshore Work Instruction WI-09: Perform Validation of Uniseis Software.

The 2010/2011 3D low-energy seismic reflection data qualification and Uniseis software validation sequence used were as follows:

1. Export depth-converted seafloor horizons from Uniseis, and compare against local High-resolution Multibeam Bathymetry (MBES) dataset (CSMP, 2012) from the same area, collected independently by others.
2. Compare fault, sea floor outcrop, and other relevant geologic structure orientation on 3D seismic data with visible events on MBES dataset (CSMP, 2012) and published fault locations (Jennings and Bryant, 2010).
3. Compare 2D seismic profiles selected from the 2010/2011 3D seismic data with published 2008-2009 USGS mini-sparker 2D seismic dataset (Sliter et al., 2009, 2010) that cross the 2010/2011 survey area (Figure 2).

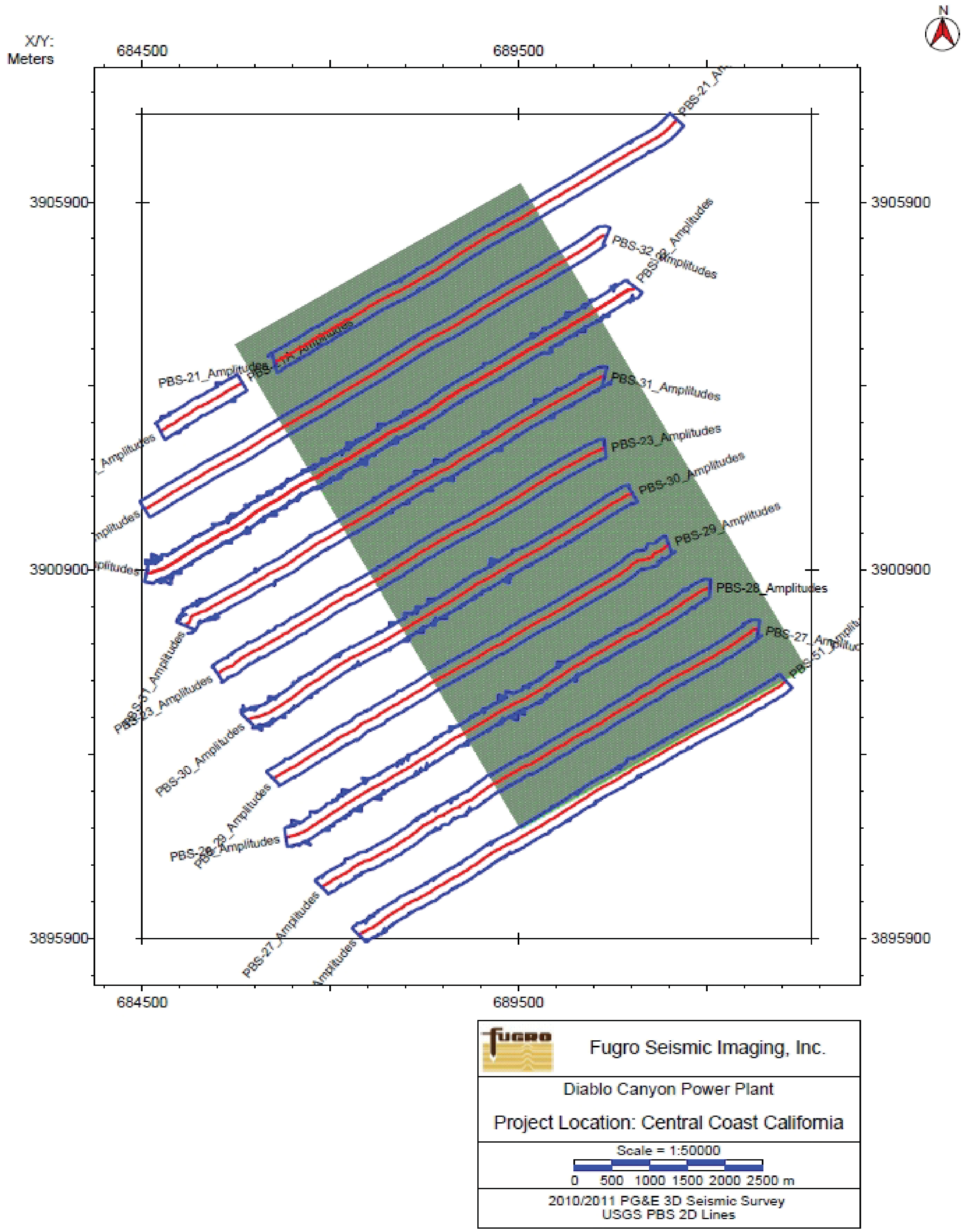

Figure 2. 2010/2011 3D Seismic Survey Processed by FSI (green) with the USGS (Sliter et al., 2009, 2010) PBS 2D Lines (Red).

4.0 UNISEIS SOFTWARE VALIDATION PROCEDURE

The 2010/2011 3D volume processed by FSI, Inc., was compared to three public datasets generated by others (CSMP, 2012; Jennings and Bryant, 2010; Sliter et al., 2009, 2010). Uniseis has been verified to be functioning properly, given that the results are comparable to the three public datasets, which have been accepted and used by government agencies and others for seismic hazard analyses and other purposes. Included in this report are the results from the required exercises, which allowed Uniseis software to be verified and the 2010-2011 PG&E 3D dataset to be qualified. The three steps of the Uniseis software validation and data qualification procedure are summarized in Section 3, and the results are presented in Sections 4.1, 4.2, and 4.3.

4.1 Seafloor Horizon Export and Comparison with MBES Data Vertical and Horizontal Comparisons

The CSMP employs RESON Seabat™ multibeam sonars for nearly all of the mapping surveys (CSMP, 2012). For shallow areas the CSMP uses the Seabat™ 7125 where high frequencies (400kHz) are used for very shallow regions and a lower frequency (200kHz) is used for the deeper end (CSMP, 2012). The MBES data collected at Point Buchon was processed and gridded at a 2 meter bin size. MBES has a high mapping efficiency with the dense pattern able to produce characterized seafloor features.

The 2010/2011 high-resolution 3D marine geophysical survey program utilized four GeoEel Streamers, each with 16 hydrophones (at 3.125 m intervals) allowing a 3-meter bin size. The seismic source used was a triple plate boomer (1500J).

The vertical and horizontal datum employed during the Fugro 2010-2011 3D survey, RESON Seabat™ multibeam (CSMP, 2012) survey, and the December 2011 PCable survey in San Luis Bay are listed in Table 1. The same horizontal datum (NAD83 (cors96 epoch 2002) UTM 10north) was used by all three surveys. Tidal fluctuations were addressed by statistical corrections for statics (variations in tidal elevation, swell, seismic source depth, and streamer depth) during processing of the 2010-2011 3D data collected west of Point Buchon (Figure 1); the vertical datum was Mean Sea Level (MSL). MSL was also used as the vertical datum for the December 2011 Fugro 3D PCable survey in San Luis Bay (Figure 1). A different vertical datum (NAVD88) was used in the RESON Seabat™ multibeam (CSMP, 2012) survey. However, the difference between the two vertical datums is less than 1 meter in the San Luis Bay Area. For the purposes of this comparison and validation procedure, the difference in elevation between the two vertical datum is considered minor, and is not resolvable within the accuracy of the survey equipment.

Table 1: Horizontal and Vertical Datum Information

Survey Database	Horizontal Datum	Vertical Datum
Fugro 2010-2011 3D Survey-West of Pt. Buchon	NAD83 (cors96 epoch 2002) UTM 10north	Mean Sea Level (MSL). Tidal fluctuations addressed in statistics correction data processing step
CSMB MBES Survey (CSMP, 2012)	NAD83 (cors96 epoch 2002) UTM 10north	NAVD88 (geoids03-09)
Fugro December 2011 PCable 3D Survey in San Luis Bay	NAD83 (cors96 epoch 2002) UTM 10north	Mean Sea Level (MSL) (1983-2001 epoch)

4.1.1 Vertical Comparisons

The water depths from high-resolution MBES data from the California Seafloor Mapping Program (CSMB, 2012) were converted to time (milliseconds) using an assumed sound velocity of 1,500 meters/second and loaded into the 2010/2011 3D seismic survey in Uniseis. Initial seafloor mapping results of the seismic data overlain with the time-converted MBES data were remarkably similar (Figures 3a through 3c).

The 3D seismic survey profiles were displayed in Uniseis and the bathymetry data was displayed as a horizon (red line, Figure 4) above the water bottom of the seismic data. Several 3D seismic volume survey in-lines were extracted as 2D lines in order to view the horizon in vertical section (Figures 4 through 8). As visible in the resulting 2D profiles, the MBES data approximately matches the 2D seafloor when static errors are corrected.

Typical MBES grids have a relatively small bin size, while the 3D seismic surveys are substantially coarser. Seismic surveys are intended to image below the seafloor and are not capable of highly accurate measurements of water depth typically associated with MBES surveys. With seismic surveys, the exact location of the seafloor can be obscured by near-surface refractions due to the much lower operating frequencies of seismic sources compared to high-frequency MBES sources. Small-scale bathymetric relief may also lead to localized inconsistencies between the two data sets.

Despite these limitations, only slight differences were noted between the MBES horizon and the 3D seismic seafloor (Figures 6 through 8). These differences are directly attributed to the achievable resolutions between the bathymetric data sets of the two methods. Accuracy requirements for MBES survey data is to the highest level requiring specialized data acquisition and processing systems operated by very experienced and specialized personnel.

These minor vertical inconsistencies where present, are on order of about 1ms (~1.5 meters) (Figure 3d). These inconsistencies are directly attributable to the different survey techniques and are well within or better than the differences that would normally be expected in open water using such disparate systems. It is noted that there were no large-scale time differences found between the two data sets (Table 2), thus validating the vertical accuracy of the Uniseis processed 3D data set.

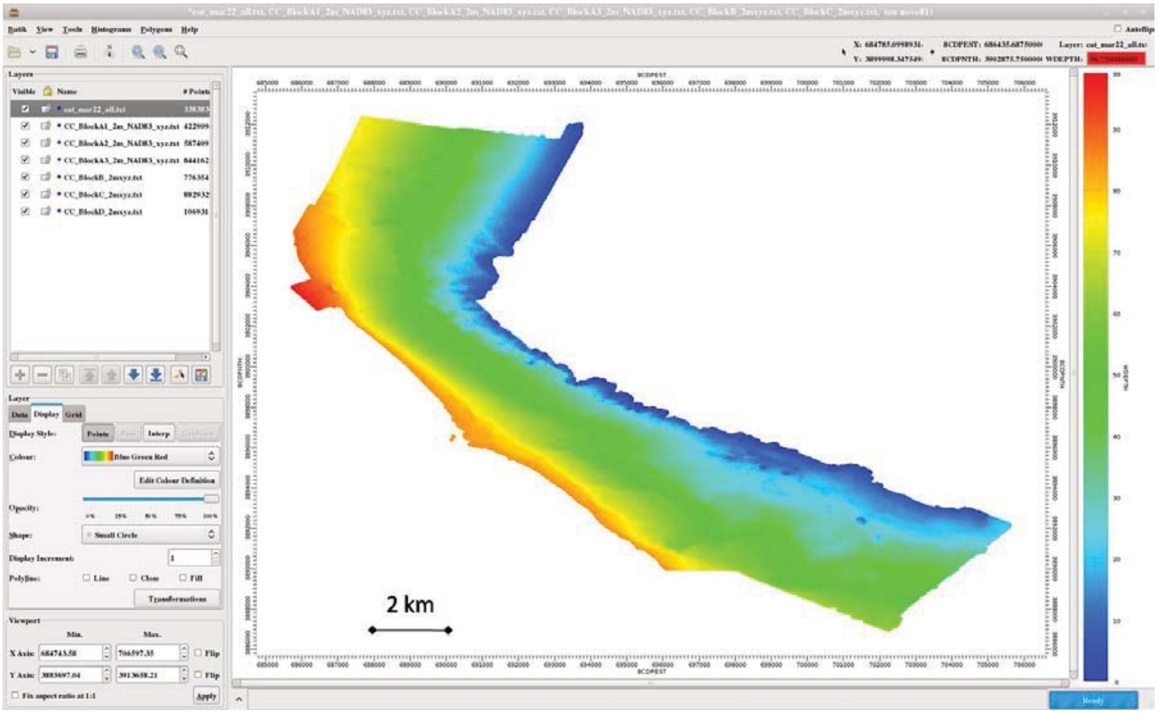

Figure 3a. Central Coast MBES time converted data with the 2010/2011 PG&E 3D seismic survey seafloor times displayed.

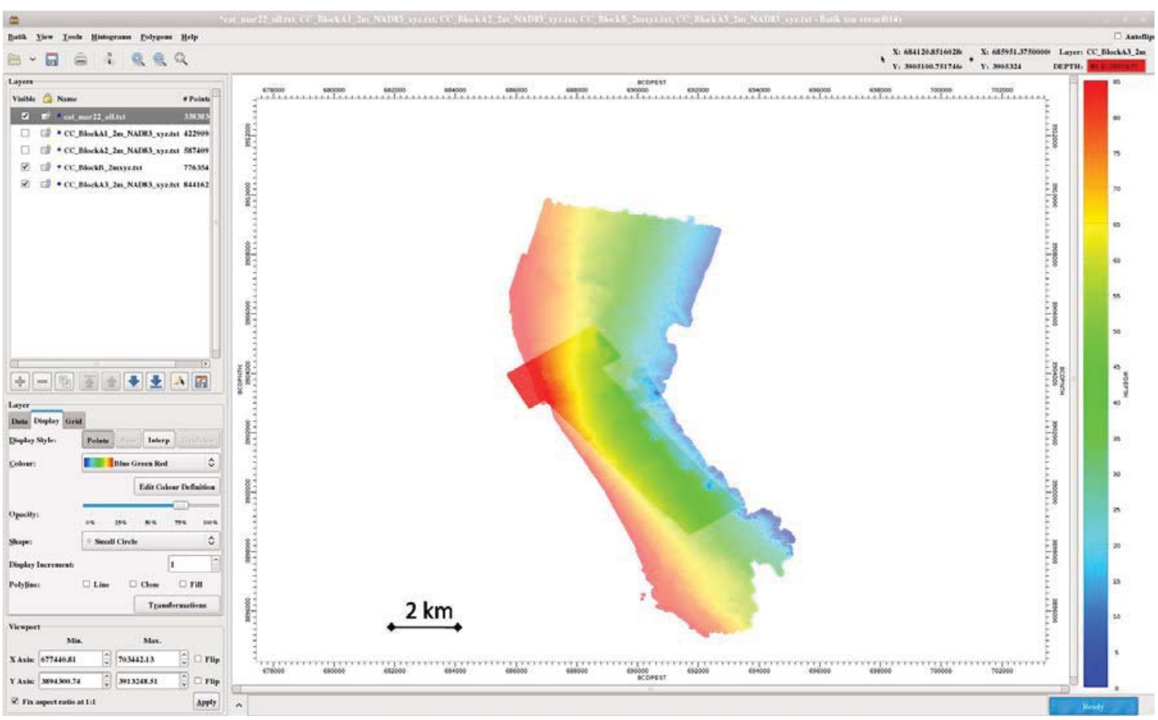

Figure 3b. Central Coast/South of Morro Bay-Avila Bay Blocks A-B MBES converted time data surrounding 2010/2011 PG&E 3D seismic survey.

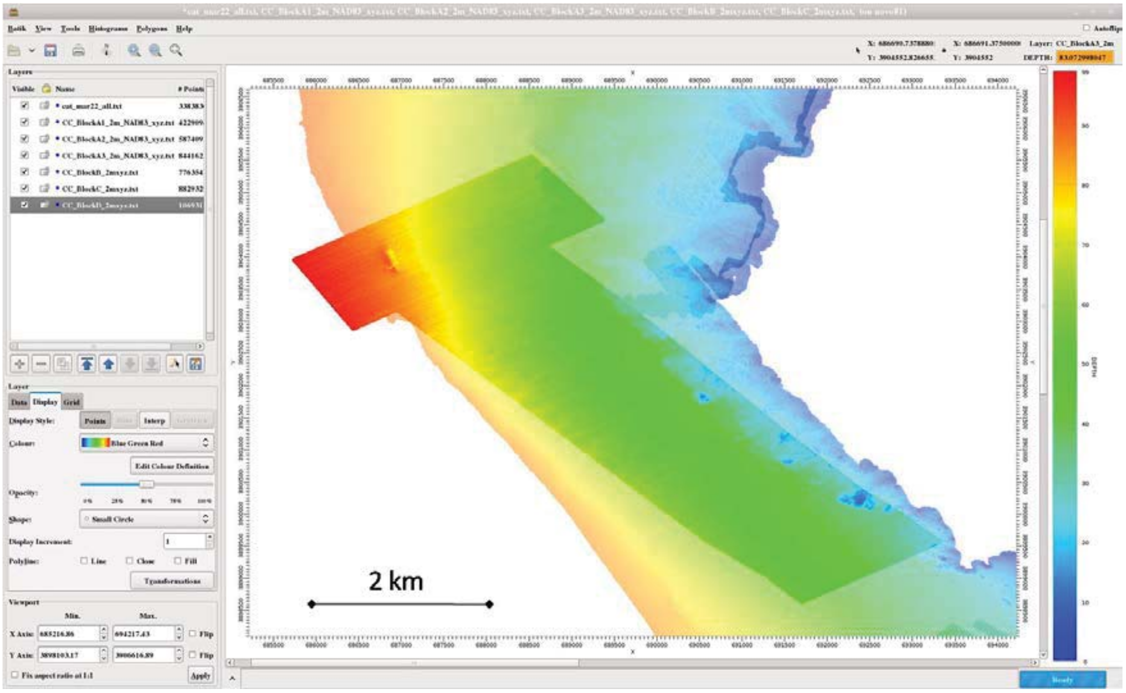

Figure 3c. 2010/2011 3D seismic survey seafloor time highlighted within MBES Data water-bottom time. MBES bathymetry data has been shaded.

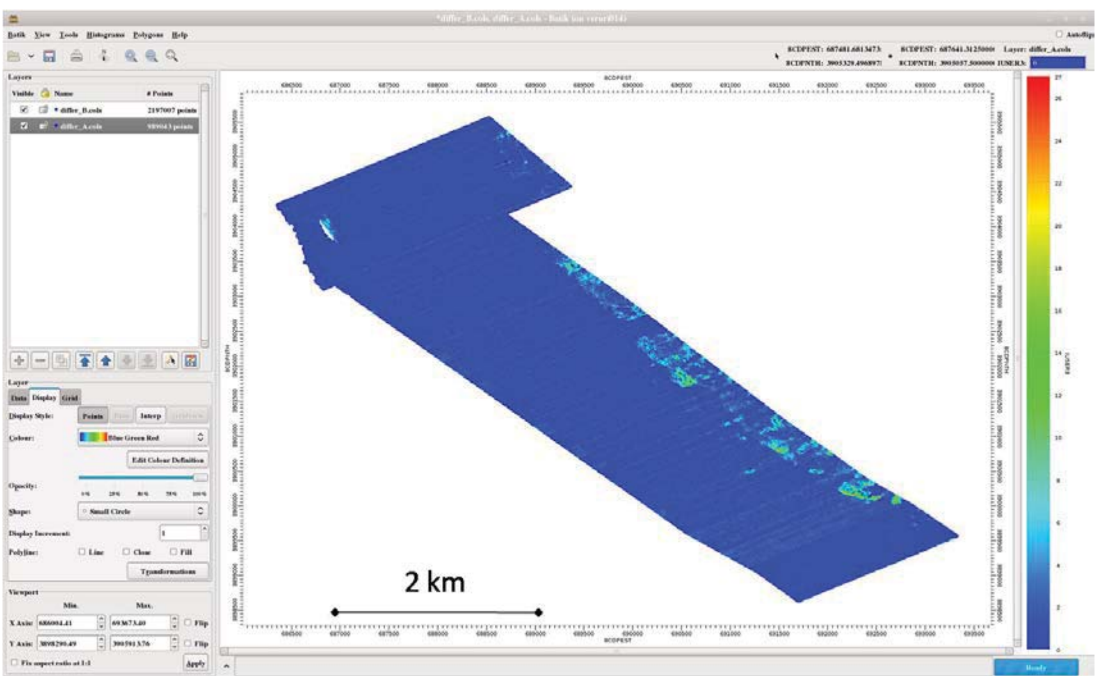

Figure 3d. Variations of sea floor time between the MBES and the 2010/2011 3D Survey. Zero difference=blue; 14 ms=green; 20 ms=yellow; 27 ms=red. Differences are localized, and mostly due resolution differences between the data sets.

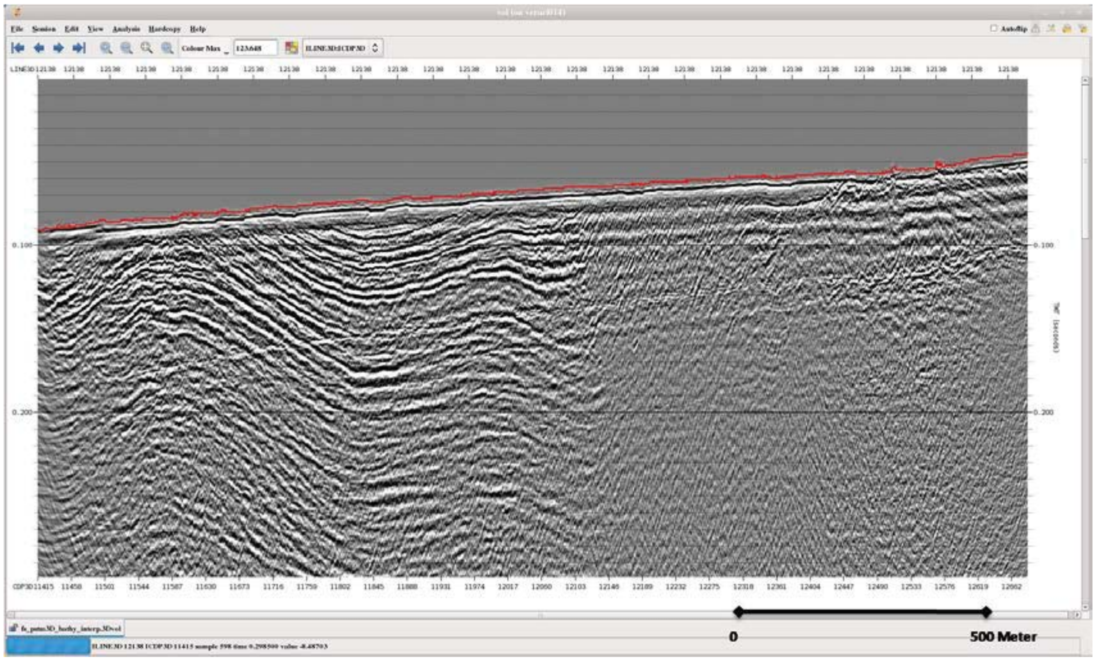

Figure 4. MBES Bathymetry horizon (red line) loaded into the trace headers and displayed on extracted In-Line 12138 Vertical Profile.

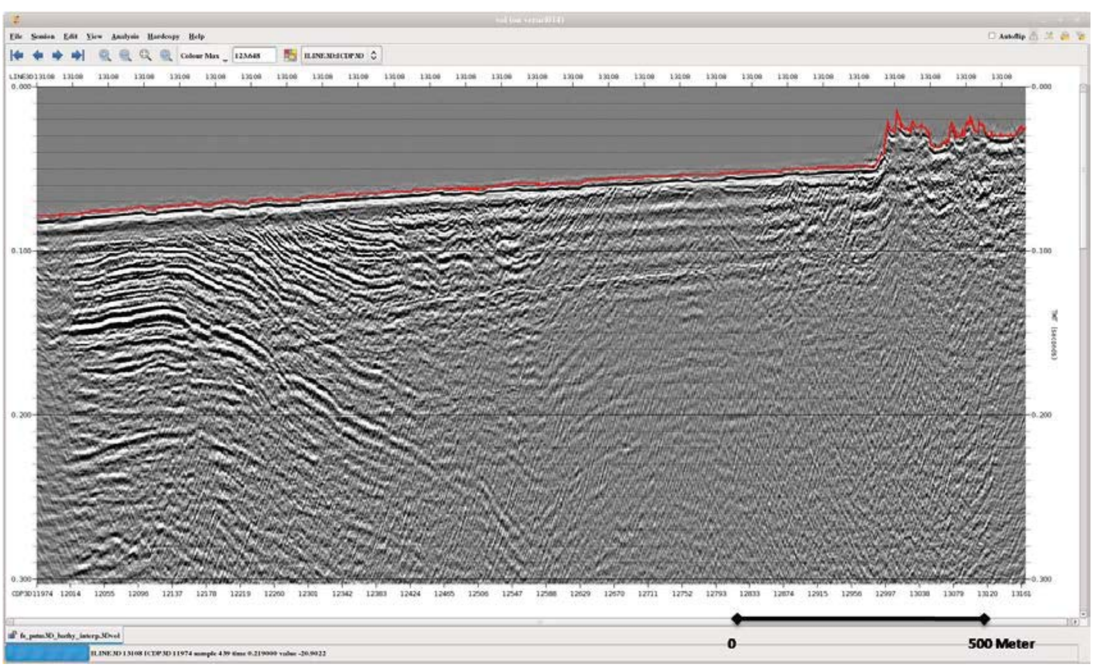

Figure 5. 3D Survey In-Line 13108 with the converted MBES horizon (red line) displayed.

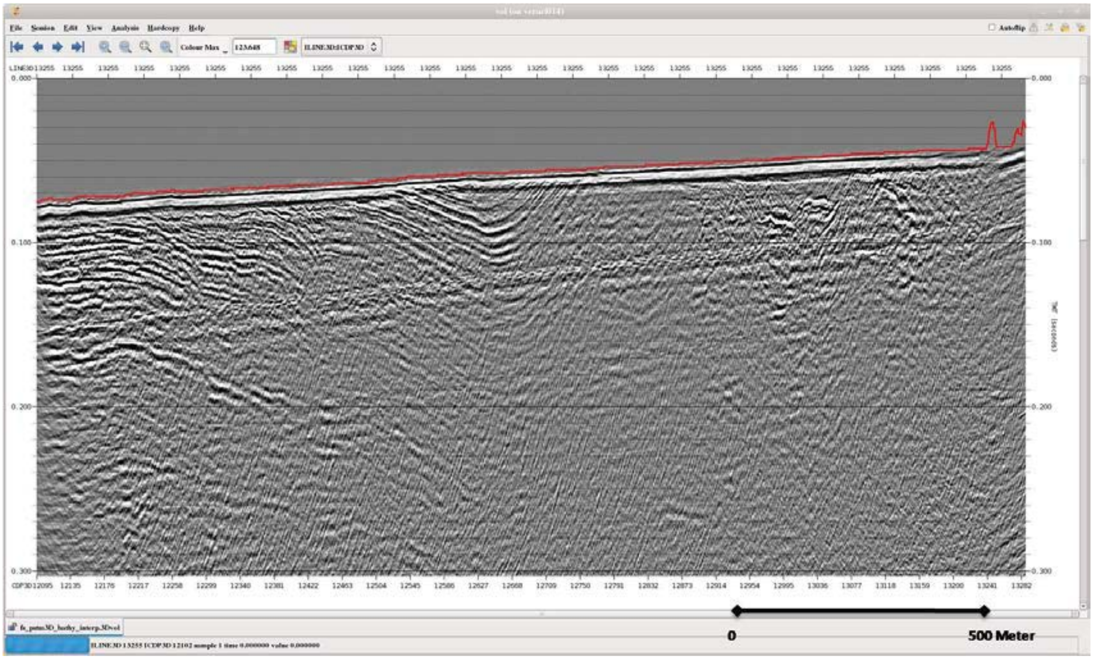

Figure 6. 3D Survey In-Line 13255 with converted MBES horizon (red line) displayed. Slight differences at the seafloor may be related to the relatively lower resolution of the 3D Survey.

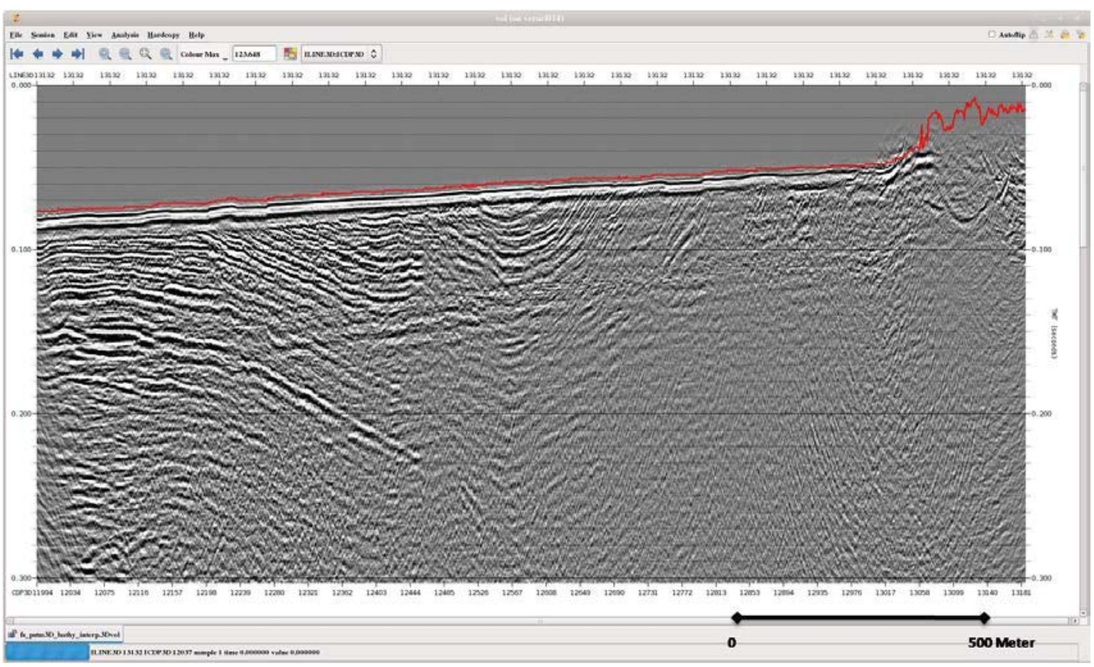

Figure 7. 3D Survey In-Line 13132 with converted MBES horizon (red line) displayed in Uniseis QD. Small scale topography may lead to localized inaccuracies.

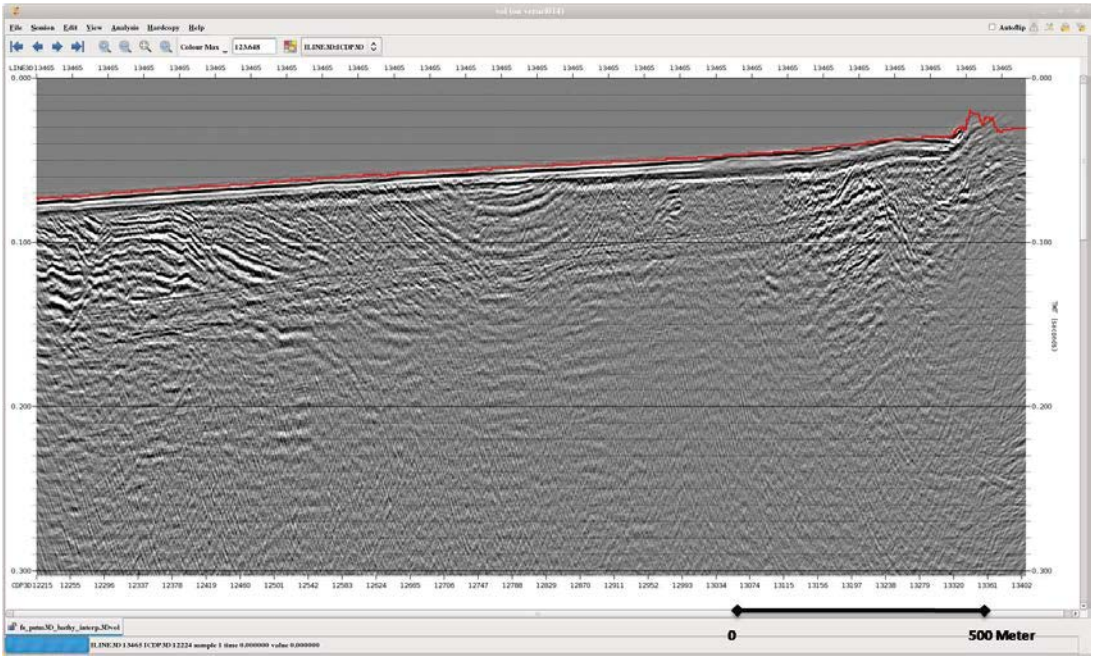

Figure 8. 3D Survey In-Line 13465 with time converted MBES horizon (red line) displayed in Uniseis QD.

Table 2: Difference of MBES depths Converted to Time (ms) and the 3D Survey Seafloor Time (ms).

ILINE3D (In-Line)	ICDP3D (Cross-Line)	8CDPEST (X)	8CDPNTH (Y)	Seafloor Time of 3D data (ms)	CSMP 2D Data Depth Converted to Time (ms)	Difference (ms)
11360	11485	687418.6	3903767	99	98	-1
11360	11486	687419.9	3903768	99	98	-1
11360	11487	687421.3	3903769	99	97	-2
11360	11488	687422.7	3903770	99	98	-1
11360	11489	687424	3903770	98	97	-1
11360	11490	687425.4	3903771	98	97	-1
11360	11491	687426.7	3903772	98	97	-1
11360	11492	687428.1	3903773	98	97	-1
11360	11493	687429.4	3903774	98	97	-1
11360	11495	687432.1	3903775	98	97	-1
11360	11496	687433.5	3903776	98	97	-1
11360	11497	687434.8	3903777	98	97	-1
11360	11498	687436.2	3903777	98	97	-1
11360	11499	687437.5	3903778	98	97	-1
11360	11500	687438.9	3903779	98	97	-1
11361	11340	687223.9	3903651	105	105	0
11361	11343	687228	3903654	105	104	-1
11361	11344	687229.3	3903655	105	104	-1
11361	11345	687230.7	3903655	105	104	-1
11361	11348	687234.7	3903658	104	104	0
11361	11349	687236.1	3903658	104	104	0

4.1.2 Horizontal Comparisons

Utilizing the same figures shown for the vertical comparisons, horizontal comparisons between the MBES and Uniseis processed seismic data have also been analyzed and used for validation purposes. The horizontal comparisons are important to confirm that the Uniseis processed data has the correct spatial positioning.

The validation of the spatial accuracy of the Uniseis processed data can be made using the vertical profile comparisons shown in Figures 4 through 8. The location of seafloor features compares very well between the two data sets on all of these figures, thus validating the horizontal positioning of the processed seismic data.

Figures 5 through 8 show the location of rock outcrops with positive vertical relief at the shallow end of the survey lines. There is a very tight match between the MBES survey and the processed Uniseis seismic data on the location of these areas of positive seafloor relief, thus providing validation of the horizontal component of the processed data.

4.2 Geologic Interpretation Comparison

Fault structure shape files from the California Geologic Survey Quaternary Faults were converted to X&Y locations; however, fault depths were unavailable. The Q-Fault X&Y data was loaded into the Uniseis program Batik, which is a point plotting program, and was viewed in a surface plane display (Figure 9).

Seismic amplitudes from the 2010/2011 3D Survey were extracted from water bottom picks. In Figures 10 and 11, the fault points (red) that overlie the 2010/2011 3D seismic survey are Un-Named Faults; QFLT ID: 18; CGS Source ID 24 (Figure 13; eastern most fault spray); CGS Source ID 25 (Figure 12; central fault spray); CGS Source ID 26 (Figure 14; western-most fault spray). Structural variability manifests itself with amplitude variations. The amplitude anomalies from extracted amplitude from the seafloor of the 3D seismic survey provide a reasonable match with the CGS fault interpretation. The following figures provide confidence correlating the 3D seismic survey with the fault interpretations. However, due to the lack of fault depth information for the Quaternary faults, it was not possible to display the fault features on the 3D Survey in vertical section. The comparison of CGS geologic fault interpretation with the 3D dataset was performed as a cross-check only, and should not be given equal weight to comparisons with other datasets, given the paucity of data that were used as input to the CGS interpretation of fault locations in the area.

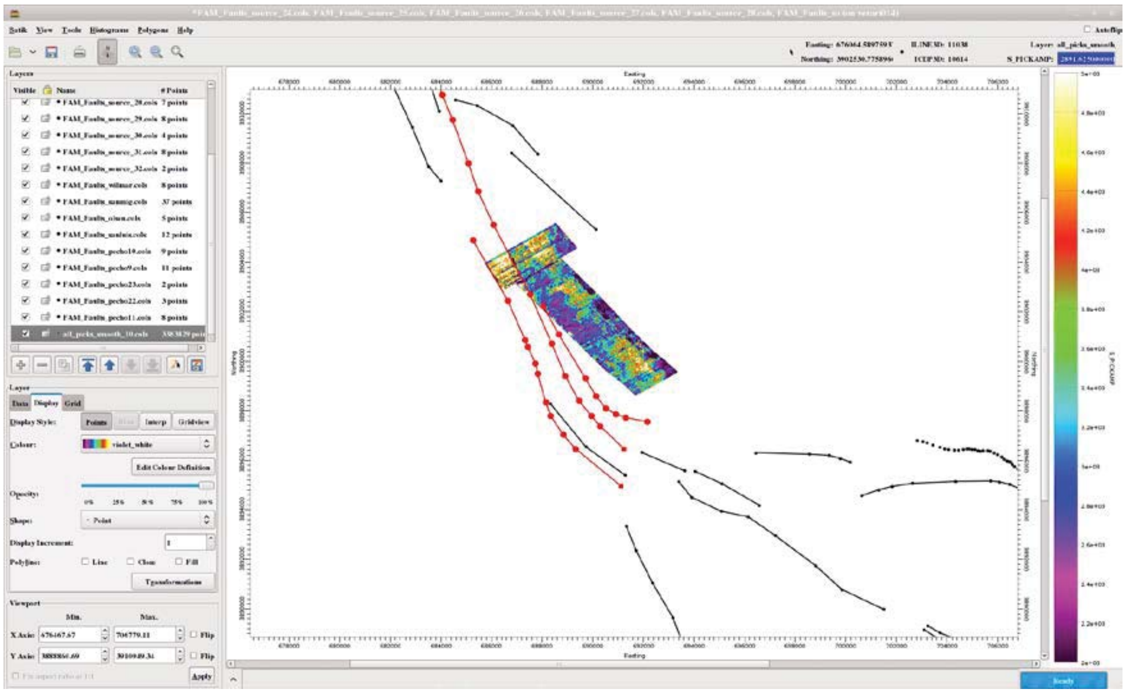

Figure 9. Un-Named Q-Fault locations (in Red) mapped across northern portion of the 3D volume. Data has been displayed using the Batik program in Uniseis.

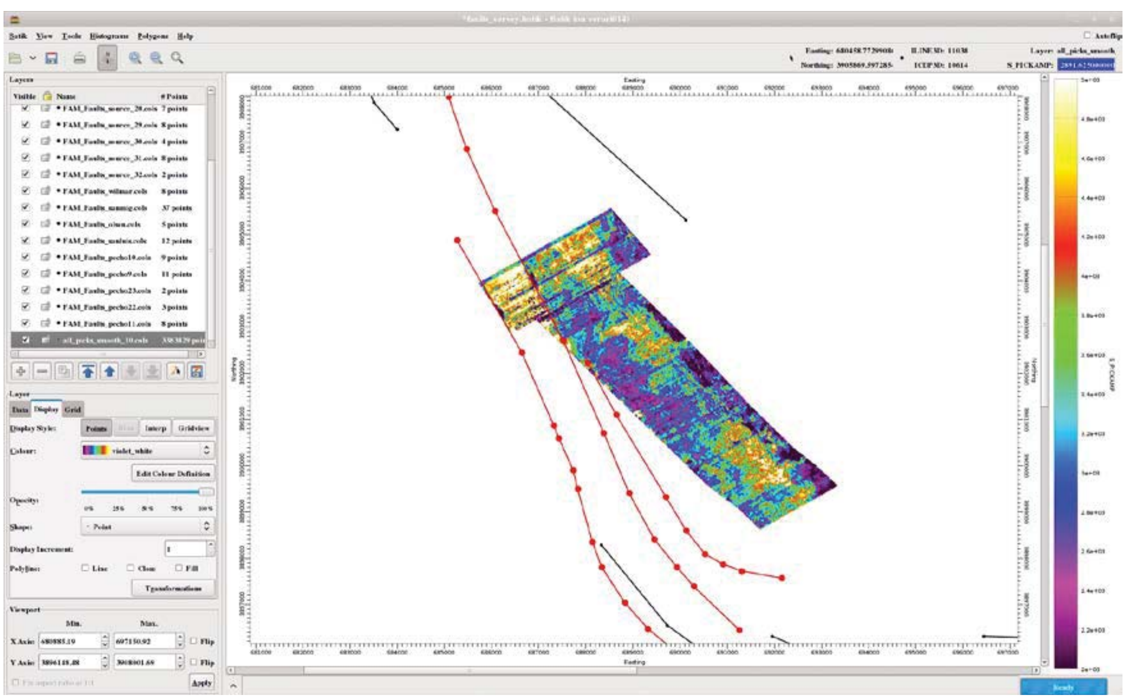

Figure 10. Un-Named fault interpretations mapped on the 3D dataset sea floor amplitudes.

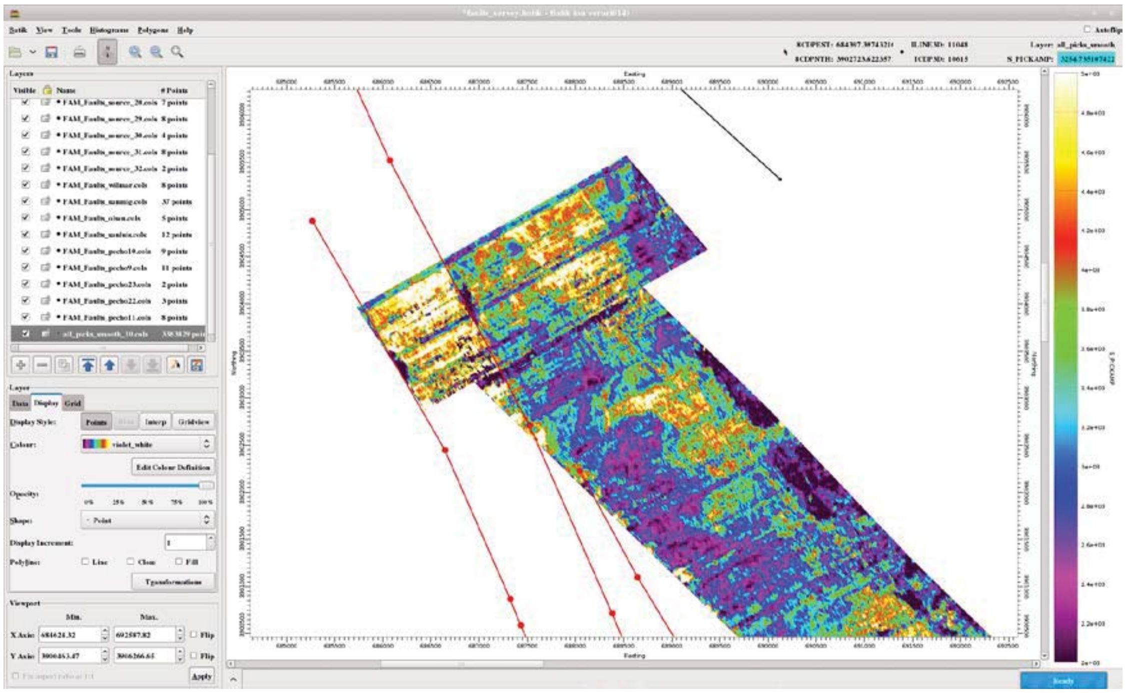

Figure 11. Un-Named fault interpretations (CGS Source ID 24-eastern; 25-central; 26-western).

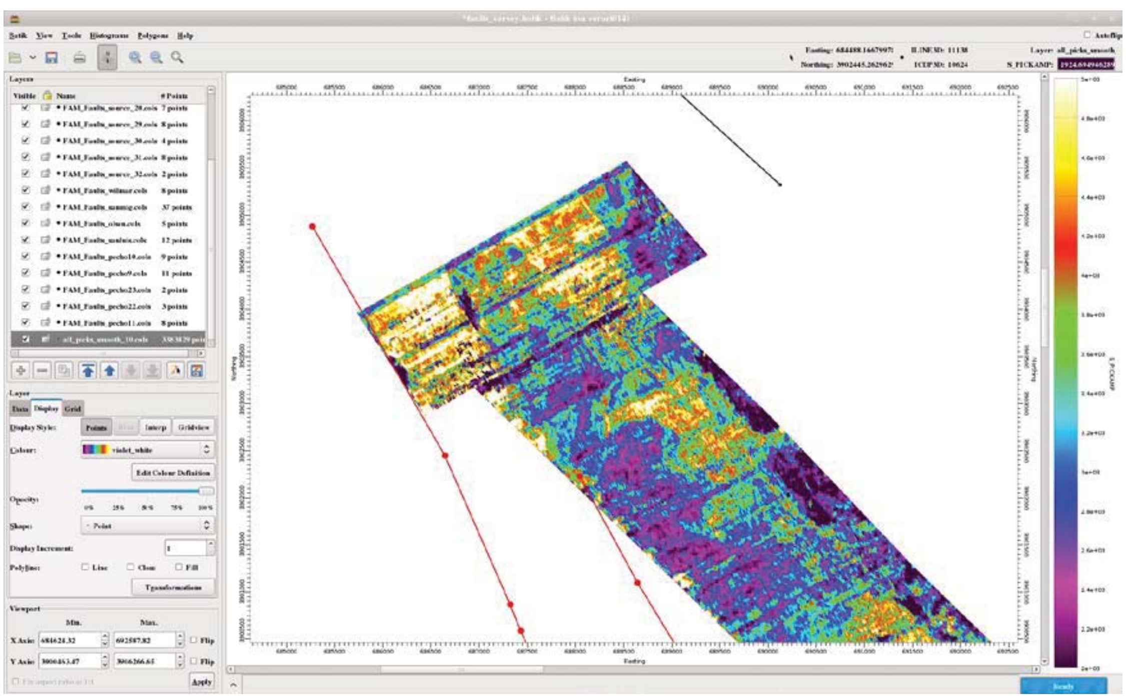

Figure 12. CGS Source ID 25 (Central un-named fault) removed from survey. Amplitude variations usually are due to structural variability.

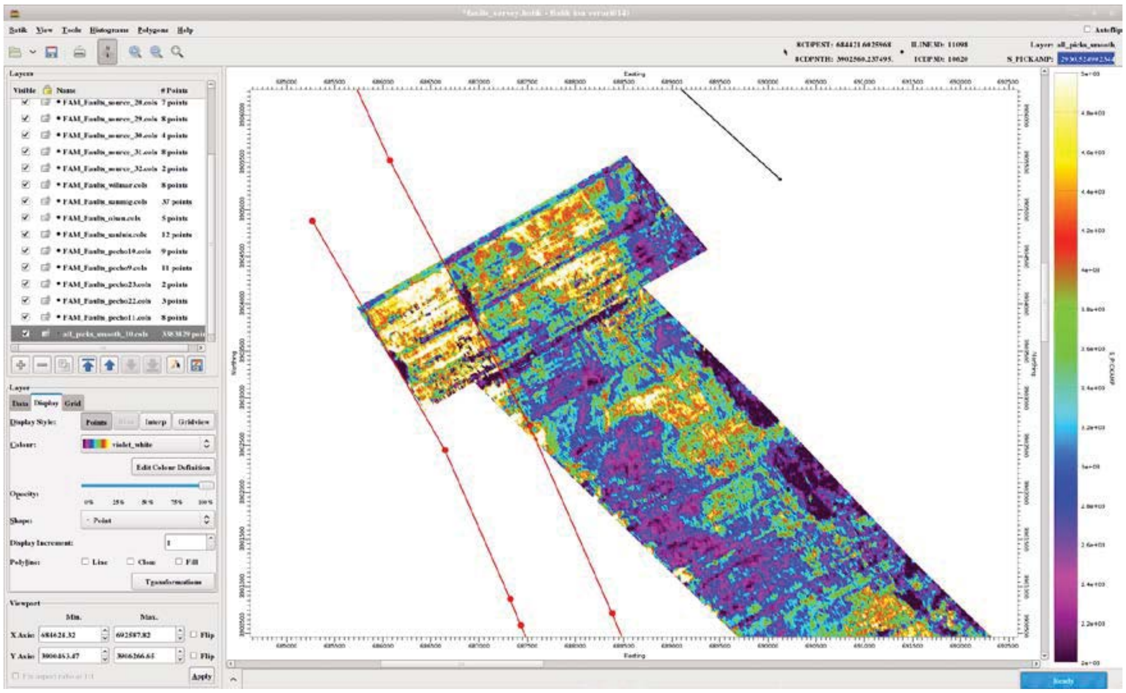

Figure 13. CGS Source ID 24 (Eastern un-named fault) removed from survey.

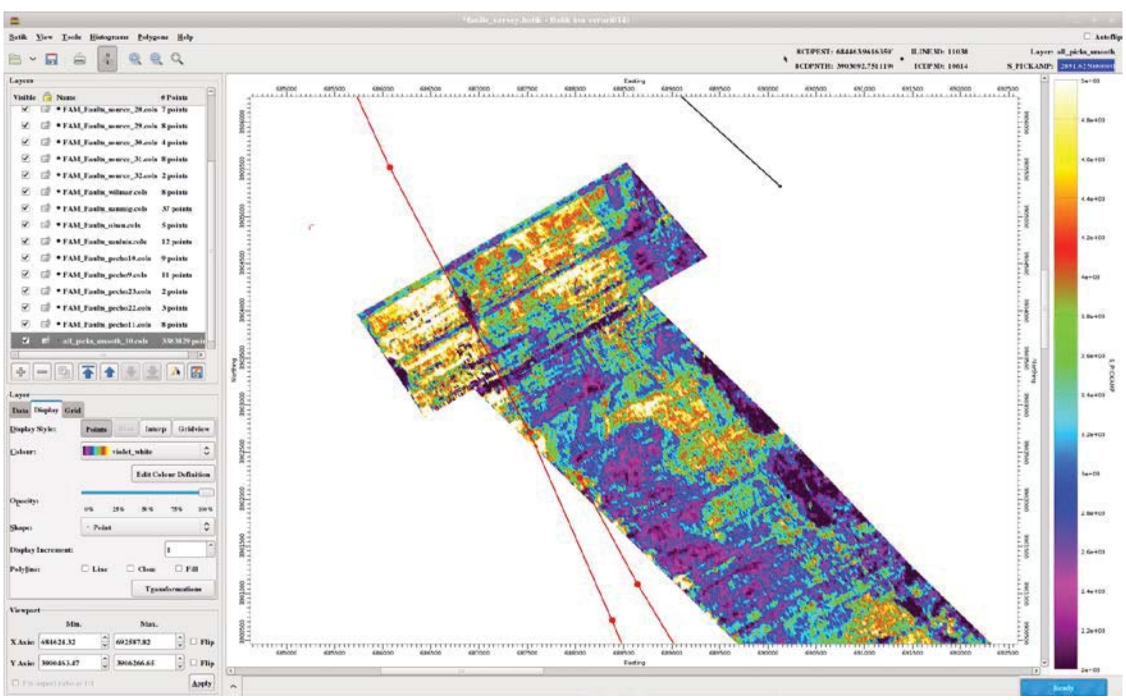

Figure 14. CGS Source ID 26 (Western un-named fault) removed from survey. 3D seismic survey seafloor amplitudes show definite variations across faults.

4.3 USGS 2009/2010 Mini-Sparker Dataset Comparison

USGS collected high-resolution 2D single-channel mini-sparker data which was compared to the 2010/2011 3D Survey processed by FSI. The 2D seismic dataset SEG Y files were initially converted to Uniseis format in order to be viewed in Uniseis.

Several in-lines from the PG&E 3D Survey were extracted as 2D lines to compare with the USGS 2D dataset. The 2D dataset was collected with a mini-sparker source while the 3D Survey was collected with a triple-plate boomer source. Due to the difference in acquisition source the phase of the data sets could not be properly compared (Figure 15). Average Spectra of both data sets can be viewed in Figure 16, these show large differences in source volume and peak frequencies.

Time shift parameters were calculated using Uniseis, which can be used to time-shift the 3D volume to match the 2D dataset. Nine intersections, example intersection of In-Line 12969 and 2D Line PBS-28, (Figure 17) of the 2D data and the 3D data were compared and an average time difference was determined (Table 3). Table 3 illustrates that the time shifts needed to match the datasets are not great, and that the two datasets are approximately equivalent with respect to seafloor two-way travel time.

The 2D seismic profiles were extracted from the 3D Survey; these were then compared with the USGS 2D dataset. Geologic features such as stratigraphic bedding are enhanced and more continuous when viewed in the PG&E/Fugro 2D (triple plate boomer) seismic profiles in comparison with the USGS sparker data. Structural relationships are also better imaged on the PG&E/Fugro seismic data. Several of these comparisons are featured in Figures 18 through 23.

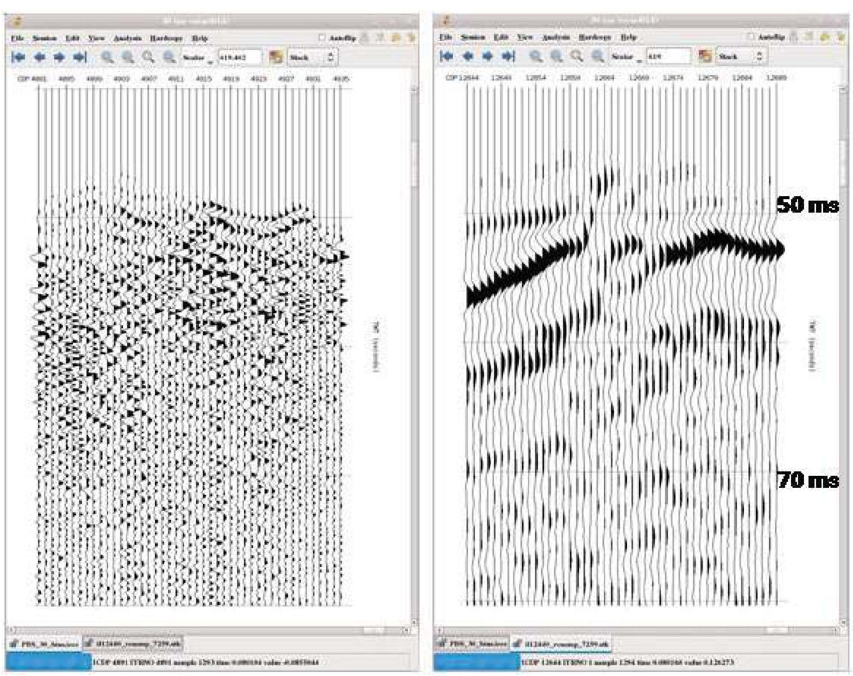

Figure 15. USGS 2D LinePBS-30 in wiggle mode & 3D In-Line 12440 in wiggle mode. Different Acquisition sources construct dissimilar phase and pulse of the two data sets.

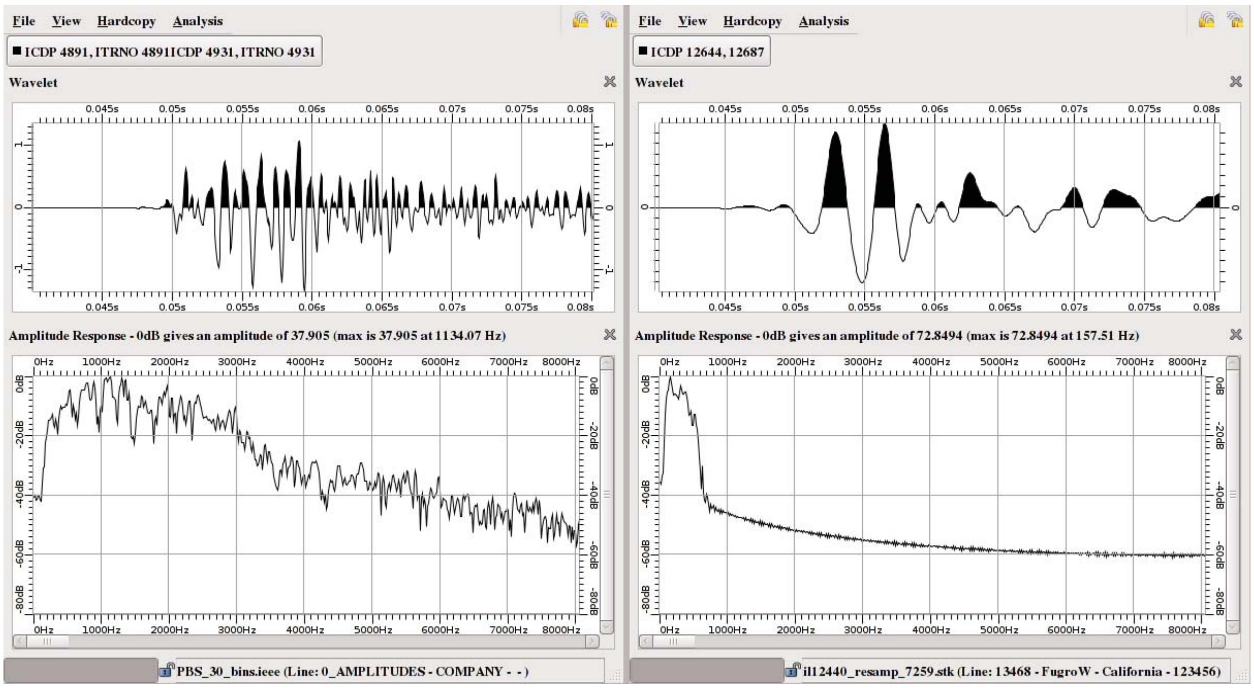

Figure 16. Amplitude Spectrum of USGS 2D Line 30, the Peak Frequency is 1291 Hz (taken from CDP's4935-4891); the 3D In-Line 12440 Amplitude Spectrum show a peak frequency at 189 Hz (taken from CDP's 12689-12644).

Table 3: Time Shifts Calculated to Match the 2009/2010 Mini-Sparker 2D Dataset to the 3D Dataset.

ILINE	2D Intersection	Linear
11188	21	9.68 ms
11177	21	1.59 ms
11697	22	4.43 ms
12203	23	4.89 ms
13211	27	5.31 ms
13211	27	6.92 ms
12969	28	0.09 ms
12713	29	5.24 ms
11947	31	1.59 ms

Figure 17. Intersection display of 3D Line 12969 and USGS 2D Line PBS-28. Time shifts were calculated in order to match the 3D dataset with the 2D data.

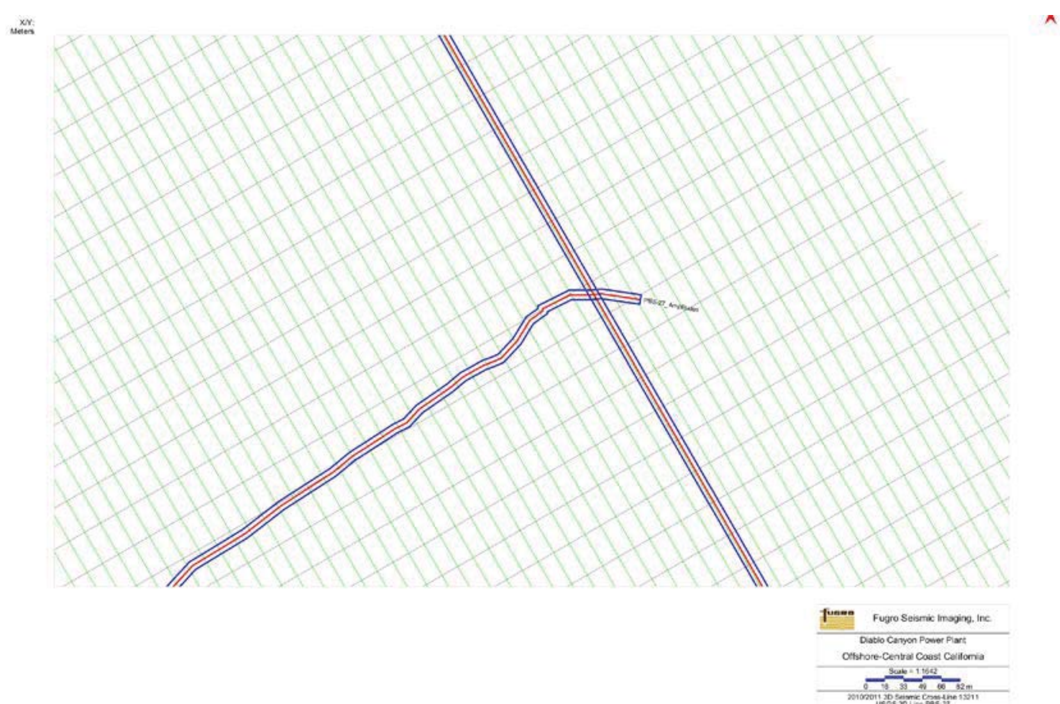

Figure 18. Intersections of 2010/2011 3D Seismic Survey Cross-Line 13211 and USGS 2D Line PBS-22. Several intersections were used to calculate time shifts needed to match the 3D Seismic Data set with the 2D Seismic data.

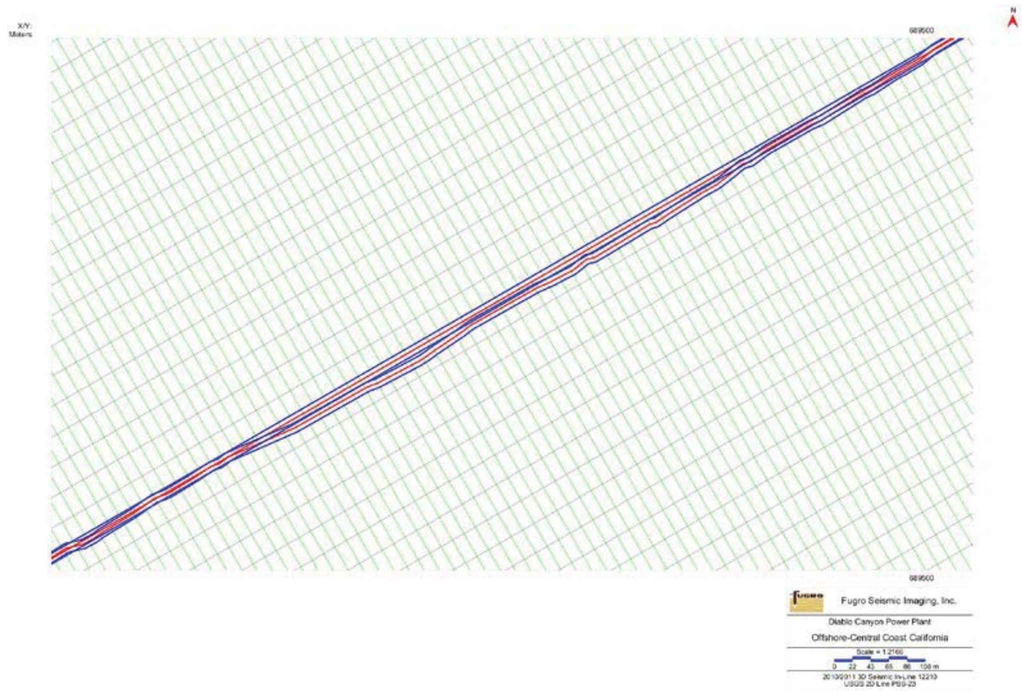

Figure 19. 3D extracted In-Line 12210 is displayed with USGS 2D Line PBS-23. Line separation distances average 16 to 1 meter.

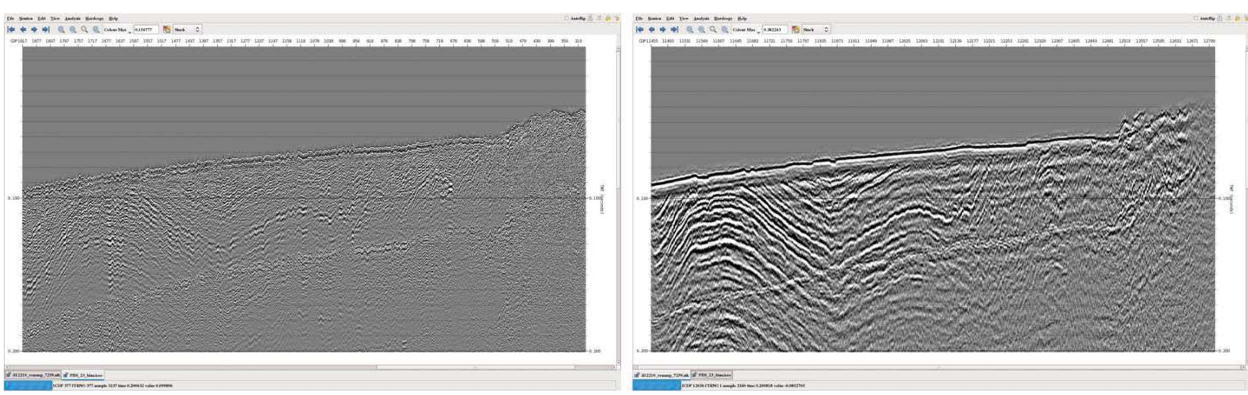

Figure 20. Side-by-Side comparison of 2D Line PBS-23 and 3D extracted In-Line 12210. 3D processing is comparable but has improved imaging when compared to the USGS 2D data. Displays are zoomed in 10-200ms; approximately 2km in cross-section.

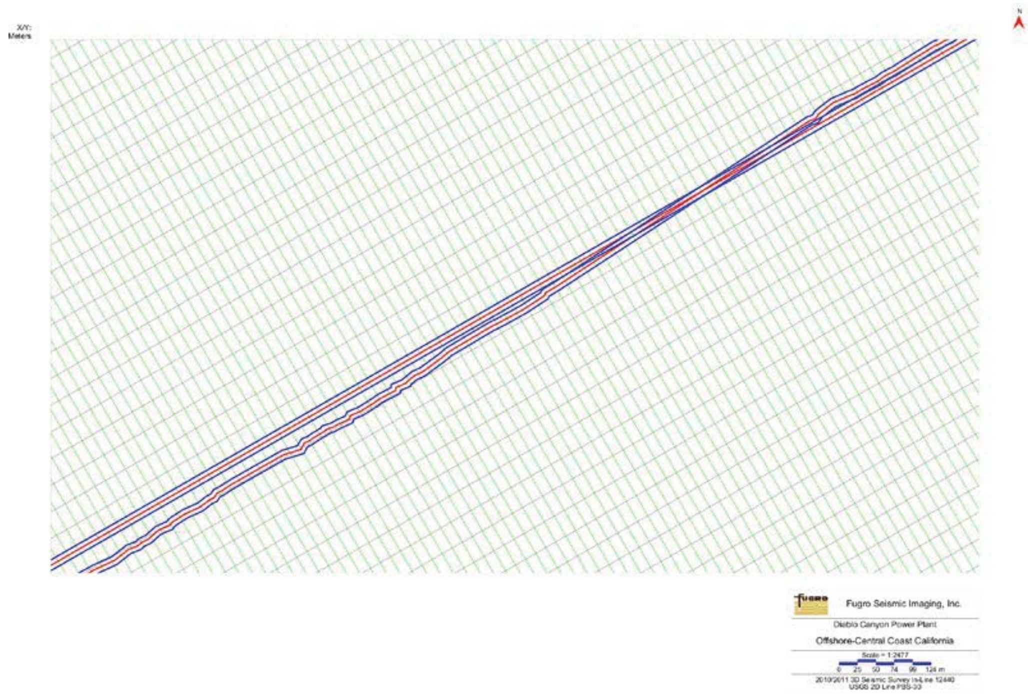

Figure 21. 3D extracted In-Line 12440 and USGS 2D Line PBS-30. Line separation distances average 25 to 35 meters.

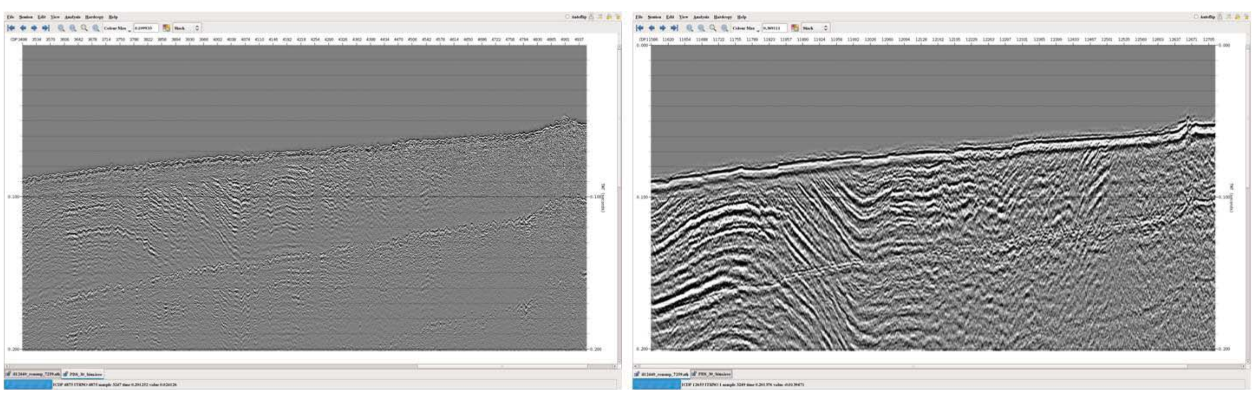

Figure 22. Side-by-Side Comparison of USGS 2S Line PBS-30 with 3D extracted In-Line 12440. Geologic features such as dipping beds are comparable but enhanced in the 3D dataset. Vertical profiles used to compare the datasets are approximately 2km.

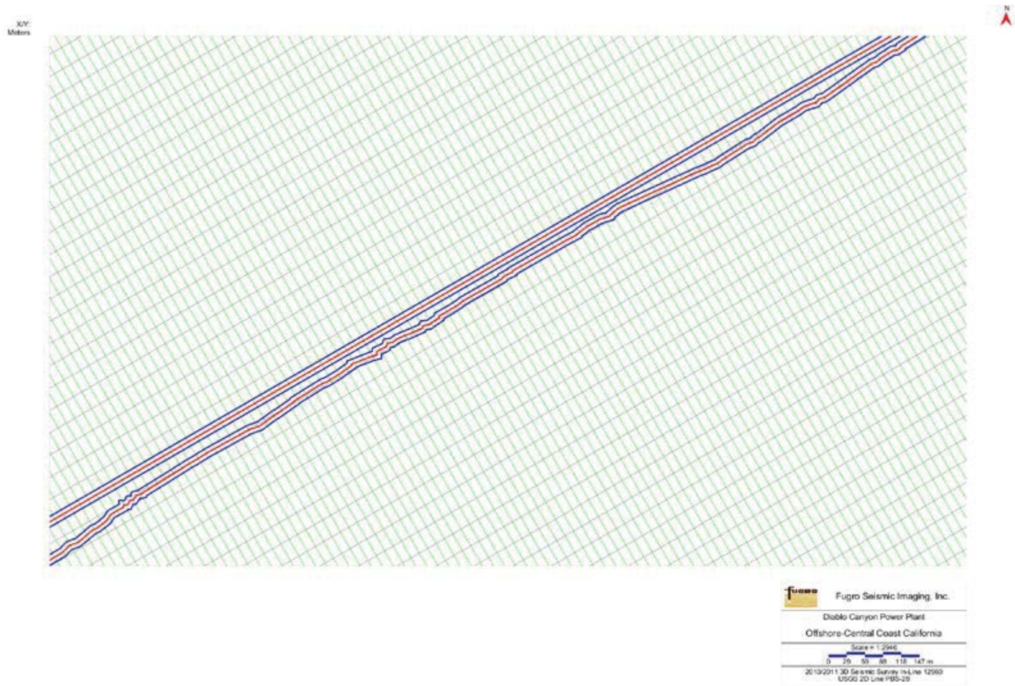

Figure 23. 3D extracted survey In-Line 12960 and USGS 2D Line PBS-28. Line separation distances average 2 to 35 meters across.

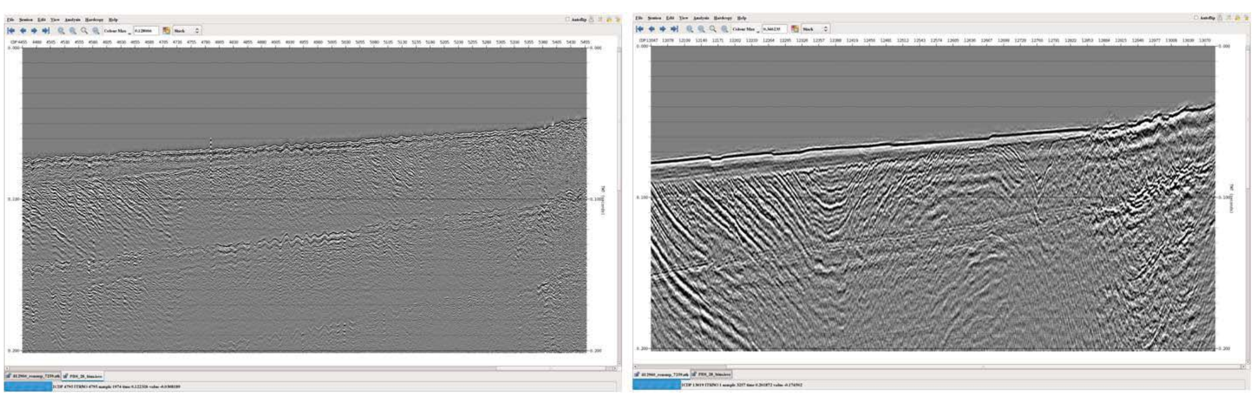

Figure 24. Side-by-Side comparison of USGS 2D Line 28 with 3D extracted In-Line 12960. Similar geologic features are imaged in both the 2D and 3D datasets but the 3D dataset contains more detailed impedance contrasts. The section of data used for comparison is approximately 2km in cross-section.

5.0 CONCLUSIONS

The 3D data processing was performed in accordance with FSI Data Processing Procedure and Work Instructions. Comparing FSI's proprietary seismic processing software with published data from the USGS (Sliter et al., 2009, revised 2010), California Geological Survey (Jennings and Bryant, 2010), and the California Seafloor Mapping Program (CSMP, 2012) has demonstrated that within the expected resolution of the 3D seismic dataset, there are negligible differences between the 3D seismic data and the published data.

When loaded into the headers of the 3D seismic survey, the MBES time-converted water bottom data approximately matches the 3D seismic data within the expected resolution of the 3D seismic data.

Extracted 3D seismic seafloor amplitudes vary strongly and systematically across published fault locations (Jennings and Bryant, 2010) confirming that the 3D seismic data delineate the locations of known faults.

The 3D Survey processed by FSI has enhanced spatial resolution when compared to the USGS 2D mini-sparker data (Sliter et al., 2009, revised 2010). Detailed geologic features are clearly apparent in the 3D Survey data, and are not as well imaged in the USGS 2D mini-sparker dataset. This enhanced detail is very important when interpreting offshore geologic structure and stratigraphy in the region near the Diablo Canyon Nuclear Power Plant.

The data images and statistical data displayed within the report indicate that Uniseis Processing software applied to the 2010-2011 3D seismic survey data provides comparable to superior imaging of faults and structure, in comparison to public datasets available in the region where the 2010/2011 3D Survey was collected. The 2010/2011 3D seismic dataset is thus qualified for use in nuclear safety-related evaluations of seismic hazards, and Uniseis software validated for use in processing seismic data for the CCCSIP.

6.0 ACKNOWLEDGMENTS

Several of the Specific Quality Assurance Procedures could not have been completed without the help and guidance of Kent Stevens (FSI), Steve Cole (FSI), Steve Best (FSI) and Cornelia Dean (FCL).

7.0 REFERENCES

Software Release Notes-UNISEIS 1005 & 1111

Jennings, C.W., and Bryant, W.A. (compilers), 2010, Fault Activity Map of California, Geologic Data Map No. 6, version 3.0: California Geological Survey Web Page, http://www.quake.ca.gov/gmaps/FAM/faultactivitymap.html

California Seafloor Mapping Program (CSMP) (2012), High-resolution Multibeam Bathymetry (MBES) data. Data are available at: http://seafloor.csumb.edu/SFMLwebDATA_c.htm#CCMORROAVILA.

Fugro Consultants, Inc., (2012a), 2D Seismic Data Processing Report, 2010-2011 High-Resolution Marine Survey Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project; Fugro Project No. 04.B0992017; Prepared for PG&E, May 2012.

_____ (2012b), 3D Seismic Data Processing Report, 2010-2011 High-Resolution Marine Survey Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project; Fugro Project No. 04.B0992017, FSI Report No. 2011-4410 (rev3); Prepared for PG&E, May 2012.

____ (2012c), Field Operations Report, 2010 - 2011 High-Resolution Marine Survey, Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project, Fugro Project No. 04.0992017, Prepared for PG&E, May 2012.

____ (2012d), Software Validation of Uniseis and 3D Data Qualification of 2010-2011 High-Resolution Marine Survey Data Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project, FCL Job No. 04.64110031, FCL Report No. PGEQ-PR-03, FSI Project No. 2011-4493, June (Rev0).

PGEQ PI-07, Geophysical Data Collection Plan for 3D Offshore Activities, latest revision.

PGEQ PI-08, Geophysical Work Plan for 3D UHRS Offshore Activities, latest revision.

Sliter, Triezenberg, Hart, Watt, Johnson, and Scheirer (2009, revised 2010), High-Resolution Seismic-Reflection and Marine Magnetic Data Along the Hosgri Fault Zone, Central California: U.S. Geological Survey Open File Report 2009-2010, version 1.1 http://pubs.usgs.gov/of/2009/1100/

8.0 GLOSSARY

CCCSIP	Central Coastal California Seismic Imaging Project
CGS	California Geologic Survey
FSI	Fugro Seismic Imaging, Inc.
FCL	Fugro Consultants, Inc.
PG&E	Pacific Gas and Electric Company
MBES	Multibeam Echo Sounder
USGS	United States Geologic Survey

Appendix A

Uniseis Software Validation Documentation for Offshore QA Phase of Marine Seismic Reflection Data Processing

FUGRO SEISMIC IMAGING, INC.

6100 Hillcroft (77081)
P.O. Box 740010
Houston, TX 77274
U.S.A.
Phone: 713-369-5800
Fax: 713-369-5893

Tuesday, December 20, 2011

William H. Godwin:

Per your request, I have reviewed the Software Validation and Verification of Uniseis report, dated November 2011 and prepared by Fugro Seismic Imaging, Inc. for Project No. 2011-4493. This report has followed the procedures that are detailed in the Uniseis Data Processing Software Validation Procedure (Attachment 2F of PI No. PGEQ-PI-08). The report follows the procedures outlined in the procedure and documents by "screen captures" and tables the outputs of Fugro's proprietary seismic processing software UNISEIS and Paradigm's FOCUS. Both softwares are comparable in their processing outputs. In my opinion, the report validates the requirements for the offshore QC phase of the marine seismic reflection processing.

Kristie G. White
Senior Geophysicist
Fugro Seismic Imaging, Inc.

12/20/11
Date

FUGRO SEISMIC IMAGING, INC.

SOFTWARE VALIDATION & VERIFICATION OF UNISEIS

Project Number 2011-4493

FUGRO CONSULTANTS, INC.
4820 McGrath Street, Suite 100
Ventura, California

November 2011

FUGRO SEISMIC IMAGING, INC.

SOFTWARE VALIDATION & VERIFICATION OF UNISEIS

Report No.: FSI 2011-4493

Client: **FUGRO CONSULTANTS, INC.**
4820 McGrath Street, Suite 100
Ventura, California 93003

Date of Report: **November 2011**

P. O. Box 740010, Houston, Texas 77081, Phone: 713-369-5800, Fax: 713-369-5811

FUGRO SEISMIC IMAGING, INC.

CONTENTS

FUGRO SEISMIC IMAGING, INC.

INTRODUCTION

Fugro Seismic Imaging, Inc. has been sub-contracted for On-Board QC and processing of the Offshore 2011 3-D geophysical survey of the Diablo Canyon and Avila Beach region. The processing will be performed using Fugro Seismic Imaging's proprietary seismic processing software UNISEIS. Prior to performing this work, a Software Validation and Verification of UNISEIS was performed. This report summarizes the Software Validation and Verification effort.

Purpose and Scope

Fugro Consultants, Inc. has requested a Software Validation and Verification of UNISEIS, Fugro Seismic Imaging's proprietary seismic processing software. Paradigm Geophysical's FOCUS seismic processing software was used for comparison. FOCUS is a commercial software package that is widely used in the Oil and Gas Industry. As such, it provides a good comparison in order to validate the performance of UNISEIS.

In 2010 Fugro Seismic Imaging, Inc. was sub-contracted to process the Diablo Canyon Offshore 2010 3-D High-Resolution geophysical survey for the Ventura office of Fugro Consultants, Inc. NCS Subsea acquired 3-D seismic using a triple-plate boomer source and a four-streamer array of hydrophones. Fugro Seismic Imaging, Inc. carried out the processing in Houston, Texas. Several lines from the 2010 Diablo Canyon 3-D seismic data were used for the verification procedure. The processing flow applied here for Validation and Verification is the same flow that will be applied onboard.

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ACQUISITION PARAMETERS

2011 California Diablo Canyon:

Survey Company:	NCS Sub-sea
Dates:	24th November 2010 – 5th February 2011
Vessel:	Michael Uhl
Source:	Triple-Plate Boomer
Source Depth:	0.3 m
Shot Point Interval:	3.125 m
Recording Instrument:	GeoEel
Cable Type:	GeoEel-Geometrics
NRP to First Group:	42.50 m
NRP to Center source:	25.0 m
Navigation Instrumentation:	
4 streamers of 16 channels each:	
Cable Length:	50 m
Group Interval:	3.125 m
Cable Depth:	2 m +/- 0.5 m
Number of Channels:	16
Nominal Fold:	8
Sample Rate:	0.5 ms
Record Length:	2000 ms
Recording Filters:	
Streamer Orientation:	Starboard Streamer = 1, Port Streamer = 4
Inline Offset Streamers 1 - 4:	17.5 m
Lateral Offset Streamer 1:	9.375 m
Lateral Offset Streamer 2:	3.125 m
Lateral Offset Streamer 3:	3.125 m
Lateral Offset Streamer 4:	9.375 m

QC Processing Verification Procedure

For the purpose of testing, the 4 streamers from the 3D dataset were independently processed as 2D lines with 16 channels for each streamer.

The Verifications plan for the proposed offshore QC processing procedures using UNISEIS are as follow:

Transcription/Reformatting of Seismic Field Data

Transcription and data reformatting converted lines from SEGD 8058 format to internal Fugro (UNISEIS) and Paradigm file format. Figure 1 displays raw shot gathers and a difference plot to compare transcription of UNISEIS and FOCUS. Measured amplitude values were recorded for 10 samples of raw shot gathers; there was no difference in amplitude values, as shown in Tables 1 and 2. There is excellent agreement between the two systems.

The direct arrival time, as measured on cable 1 was 12 ms in both systems, as shown in Figure 2.

Figure 3 is a Spectral Analysis of the data was selected for near trace. Figure 4 is a Spectral Analysis of all traces in a shot. Figure 5 is a selected subset in time and space; window dimensions are listed in Table 3. There is very good agreement between the two systems for all spectral comparisons.

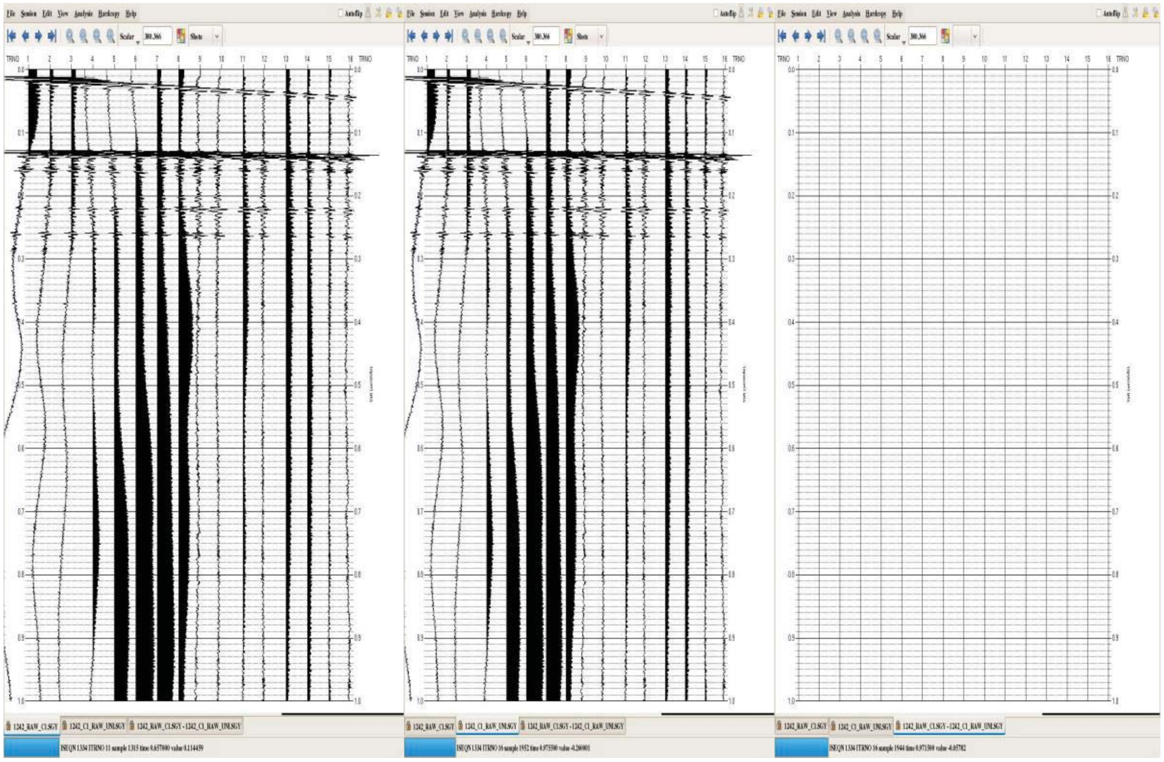

Figure 1 Left: Raw Shot Gathers created from FOCUS. Middle: Raw Shot Gathers created from UNISEIS. Right: Difference Plot.

Table 1 Measured Amplitude Values of first 10 traces on Raw Shot Gather-FOCUS.

Trace	Time (ms)	Amplitude
1	129.5	3.319597
2	130	5.208953
3	131.5	2.891805
4	130.5	3.866054
5	131	1.870412
6	132	1.349937
7	133	2.980897
8	133.5	3.237686
9	137	0.962297
10	140	0.578626

Table 2 Measured Amplitude Values of first 10 traces on Raw Shot Gather-UNISEIS.

Trace	Time (ms)	Amplitude
1	129.5	3.319597
2	130	5.208953
3	131.5	2.891805

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4	130.5	3.866054
5	131	1.8704212
6	132	1.349937
7	133	2.980897
8	133.5	3.237686
9	137	0.962297
10	140	0.578626

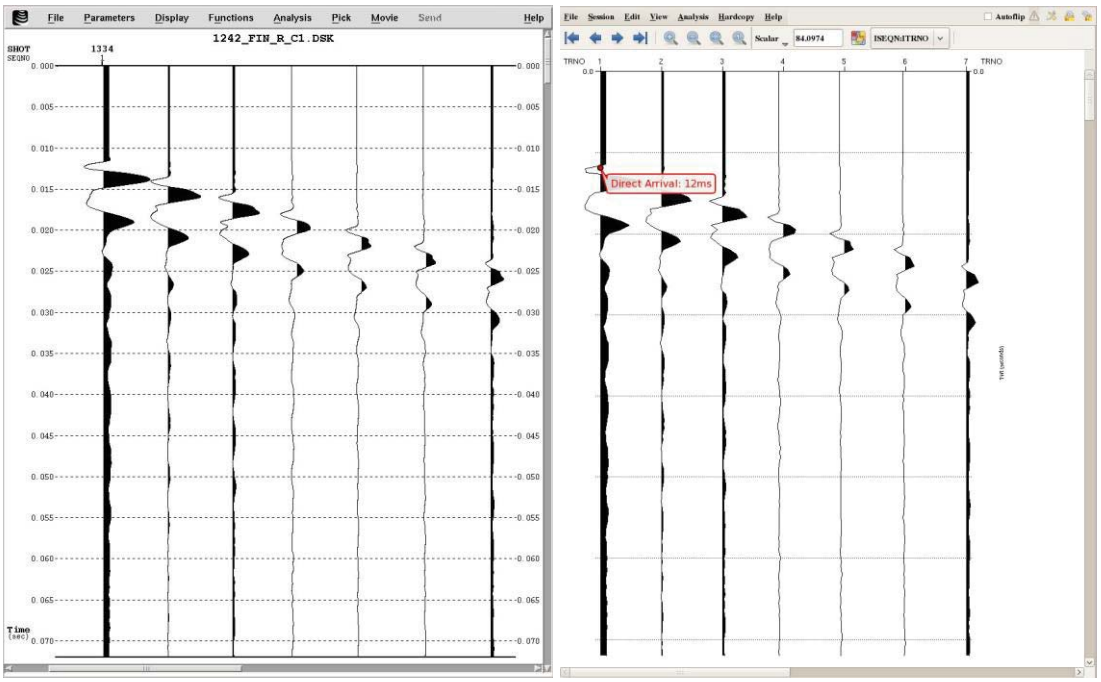

Figure 2 Left: Measure Direct Arrival Time on Near Trace-FOCUS. Right: Measure of Direct Arrival Time on Near Trace-UNISEIS.

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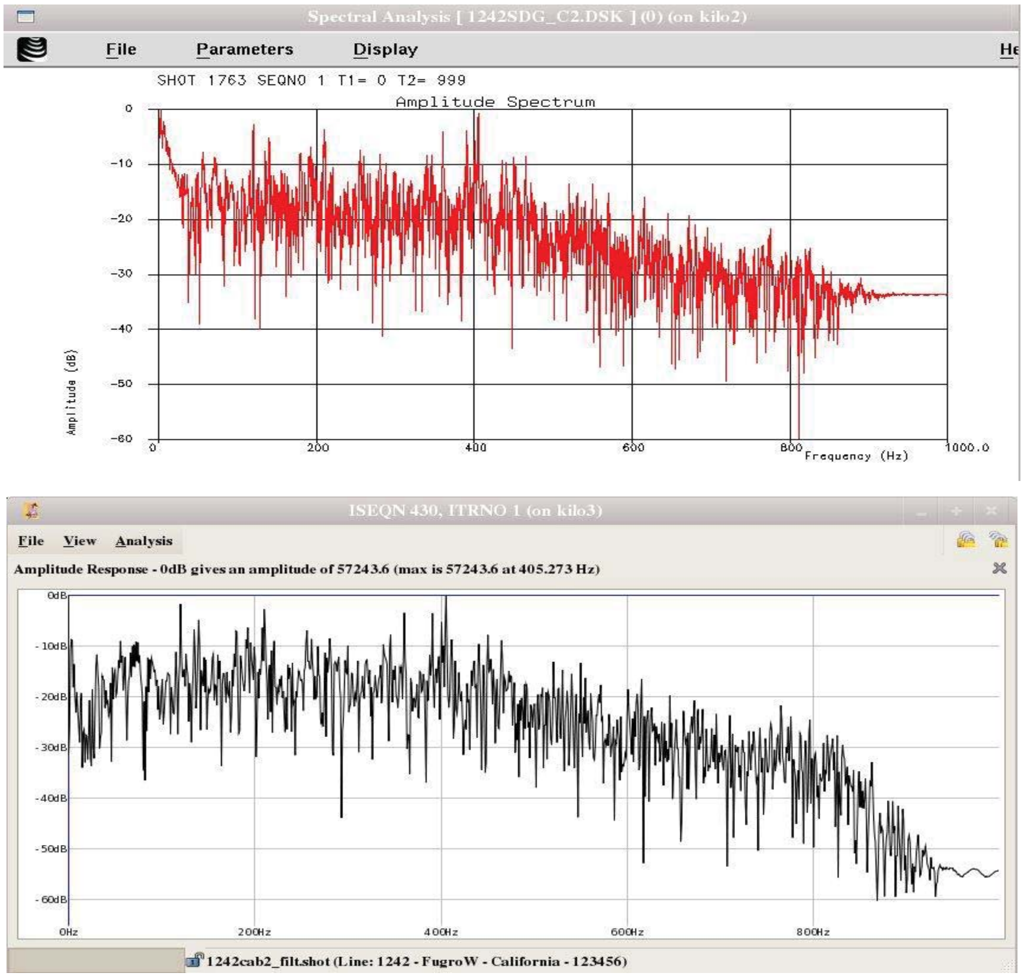

Figure 3 Top: Amplitude Spectra of Near Trace on Raw Shot Gather-FOCUS. Bottom: Amplitude Spectra of Near Trace on Raw Shot Gather-UNISEIS.

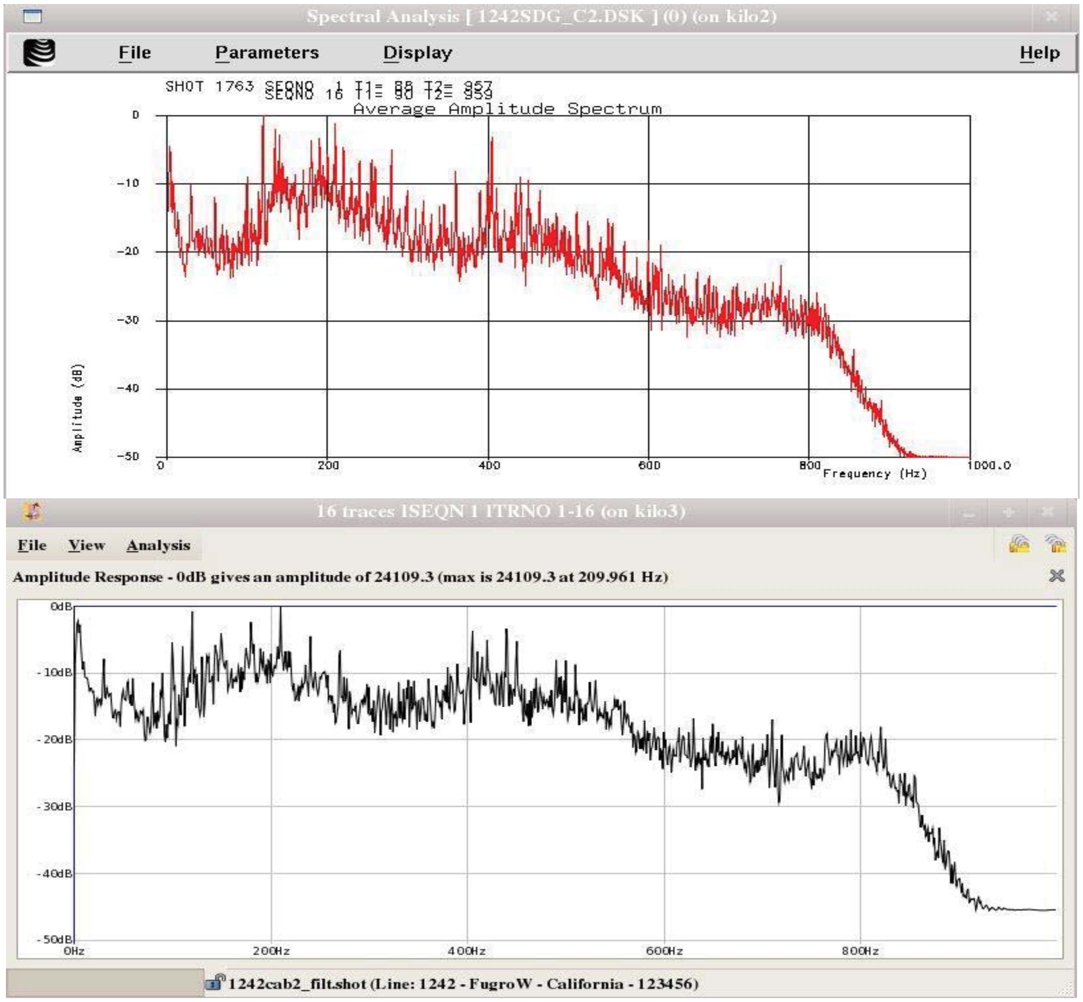

Figure 4 Top: Amplitude Spectra of Whole Shot on Raw Shot Gather-FOCUS. Bottom: Amplitude Spectra of Whole Shot on Raw Shot Gather-UNISEIS.

Table 3 Calculated Amplitude Spectra for a Window on the Raw Shot Gathers.

Window 1			
Trace	**TIME (ms)**	**Trace**	**TIME (ms)**
1	120	1	299
11	130	11	299

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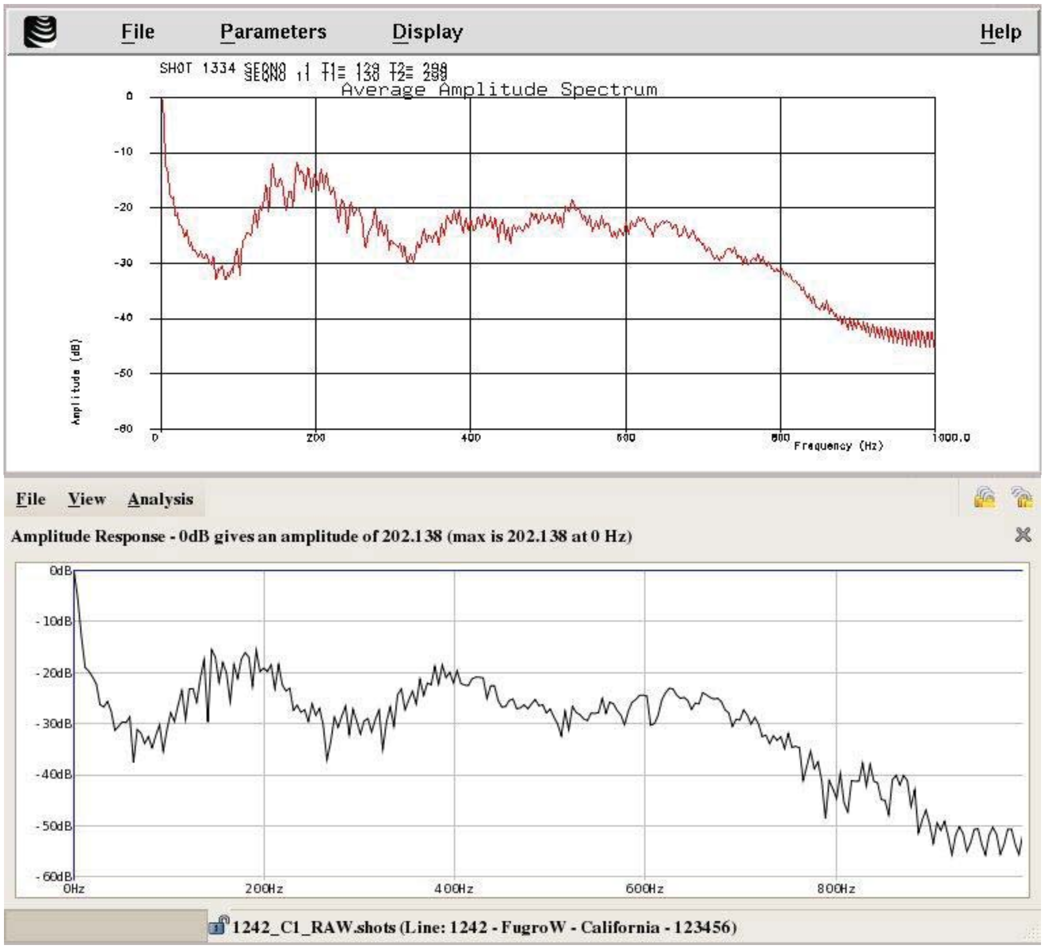

Figure 5 Top Amplitude Spectra of Raw Shot Gather, window-FOCUS. Bottom: Amplitude Spectra of Raw Shot Gather, window-UNISEIS.

Low Cut Filter

A low cut filter of 8 hertz with a slope of 12 decibels per octave was applied to the data in order to attenuate low frequency noise. As low frequency noise is filtered, an impulse response of the filter often appears at the end of the traces. During processing in UNISEIS, the lengths of the traces were artificially extended before the filter was applied in order to reduce the edge effect caused by the filter Figure 6 with Difference Plot. Figure 7 is a Spectral Analysis of the data was selected for near trace. Figure 8 is a Spectral Analysis of all traces in a shot. Figure 9 is a selected subset in time and space. Amplitude values of 10 traces were measure, Table 4. There is very good agreement between the two systems.

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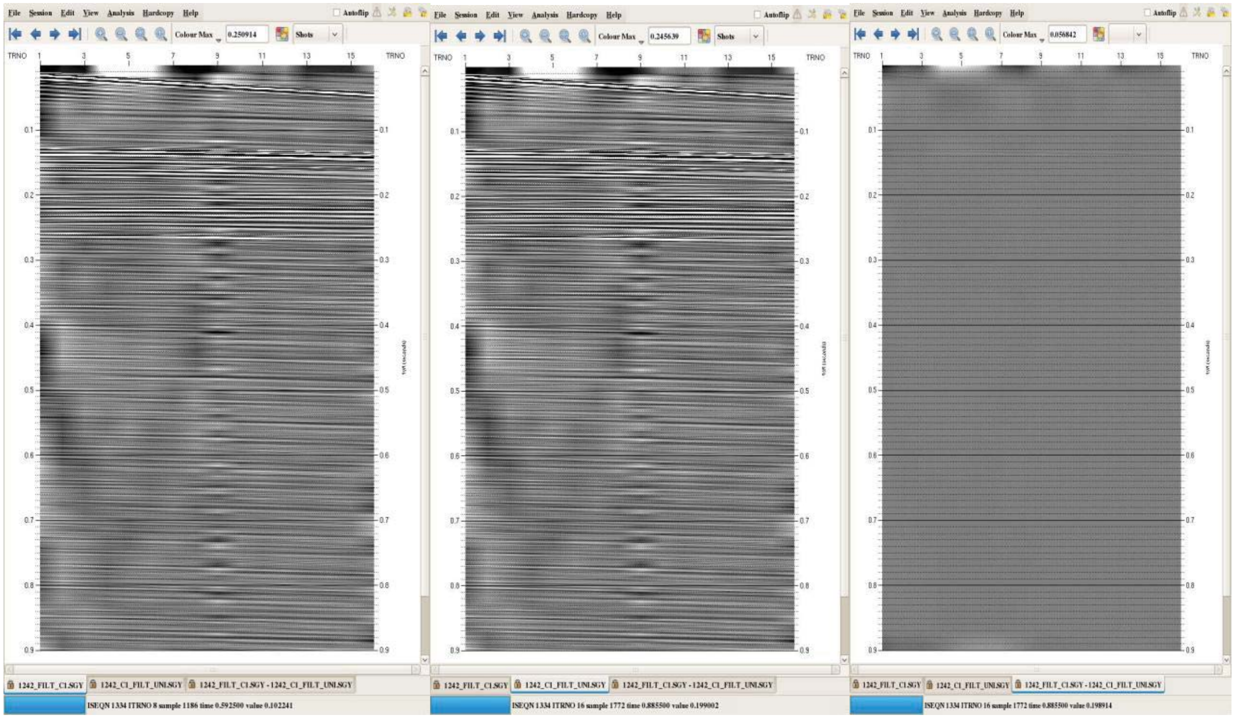
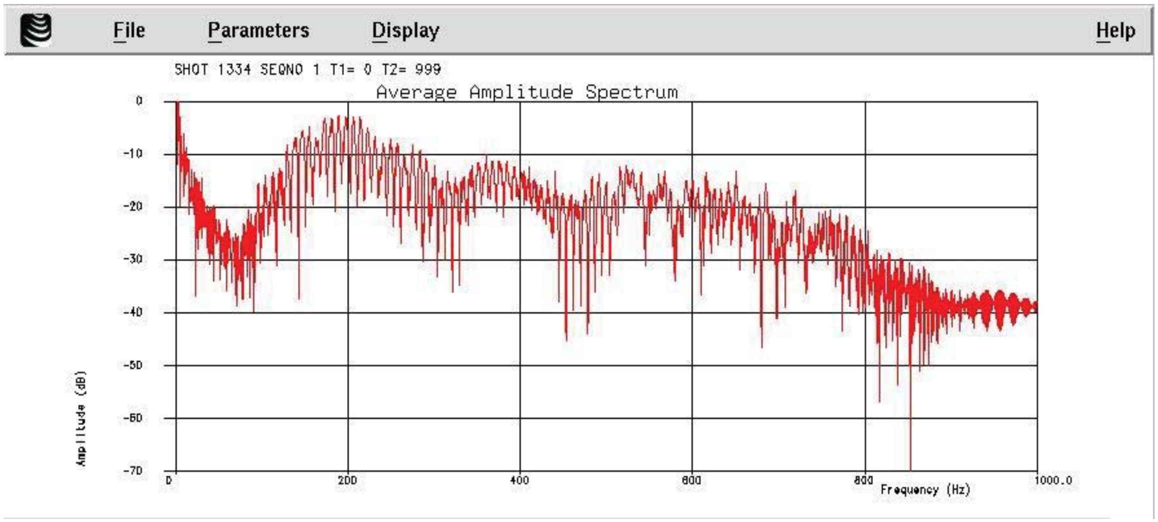


Figure 6 Left: Low Cut Filter Shot 8Hz at 12dB/Oct-FOCUS Middle: Low Cut Filter Shot 8Hz at 12dB/Oct- UNISEIS. Right: Difference Plot, small edge effect artifact, not significant to data processing as we remove it.



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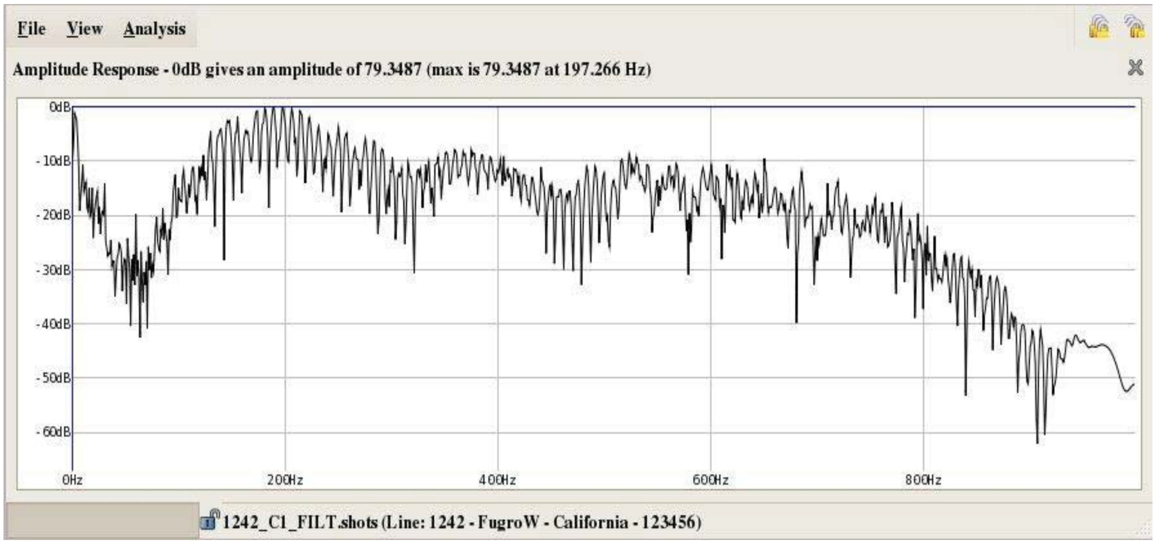
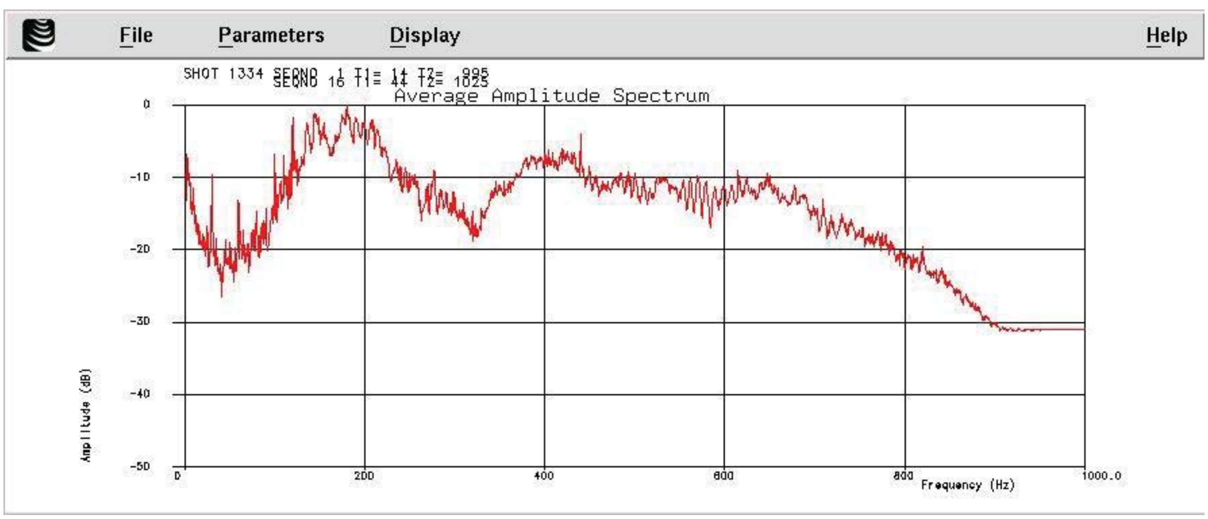


Figure 7 Top: Amplitude Spectra of Near Trace on filtered shot gather-FOCUS. Bottom: Amplitude Spectra of Near Trace of Filtered Shot gather-UNISEIS.



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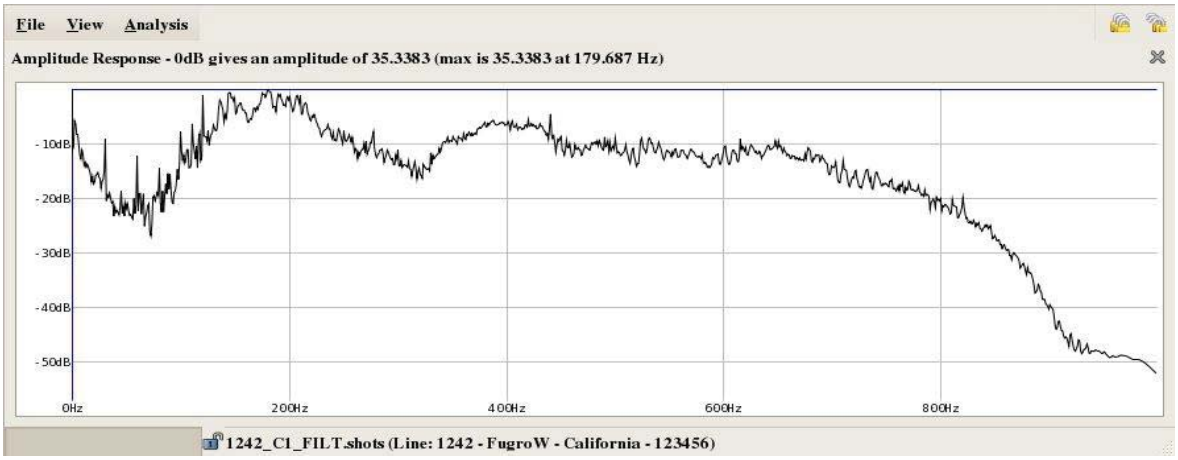
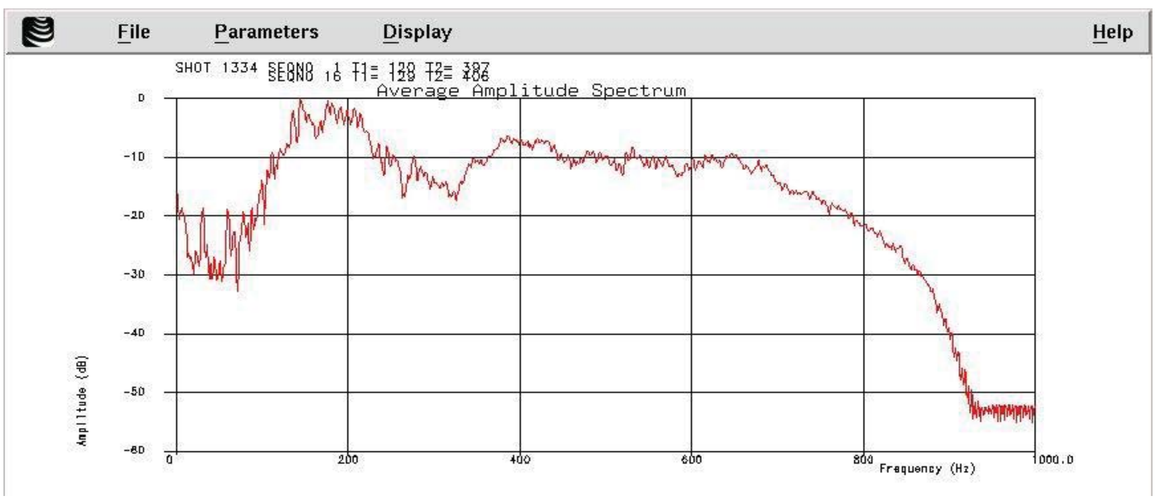


Figure 8 Top: Amplitude Spectra of Whole Shot on Filtered Shot Gather-FOCUS. Bottom: Amplitude Spectra of Whole Shot on Filtered Shot Gather-UNISEIS.



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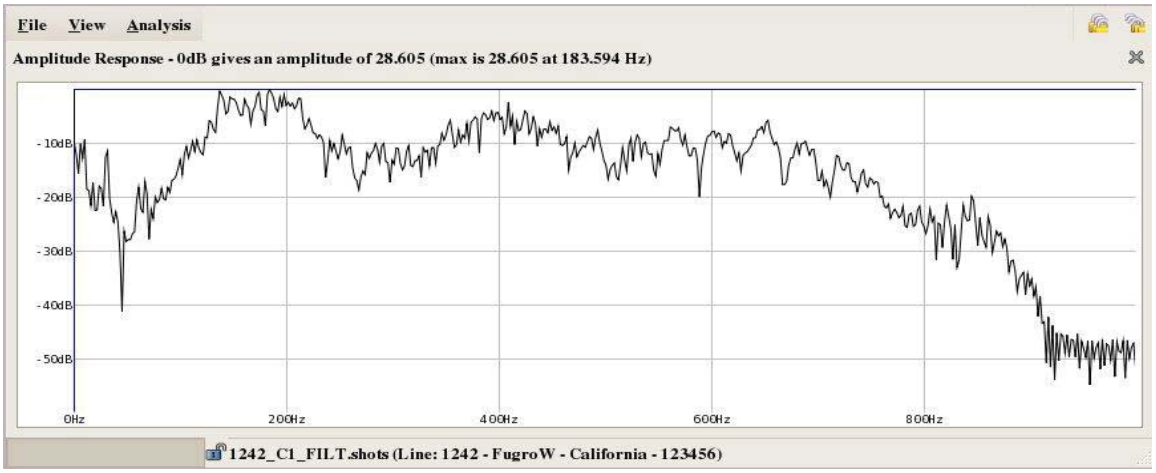

Figure 9 Top: Amplitude Spectra of selected data window of filtered Shot Gather-FOCUS. Bottom: Amplitude Spectra of selected data window of filtered Shot Gather-UNISEIS.

Table 4 Measured Amplitude Values for near 10 traces, FOCUS and UNISEIS.

FOCUS			UNISEIS			
Trace	Time (ms)	Amplitude	Trace	Time (ms)	Amplitude	Difference (%)
1	126.5	5.226876	1	126.5	5.240627	1.375
2	127	3.769466	2	127	3.772306	0.2840
3	128	1.306071	3	128	1.305309	0.0762
4	129	1.284480	4	129	1.284142	0.0338
5	132	0.835676	5	132	0.836940	0.1264
6	134	1.504132	6	134	1.511711	0.7579
7	135	1.315141	7	135	1.319666	0.4525
8	136	0.607470	8	136	0.614492	0.7022
9	140.5	0.205737	9	140.5	0.203727	0.2010
10	143	0.672388	10	143	0.673303	0.0915

Time Squared Exponential Gain

A time-variant, T^2 gain recovery was applied to the shot records. Here again there is very good agreement between the two processing systems.

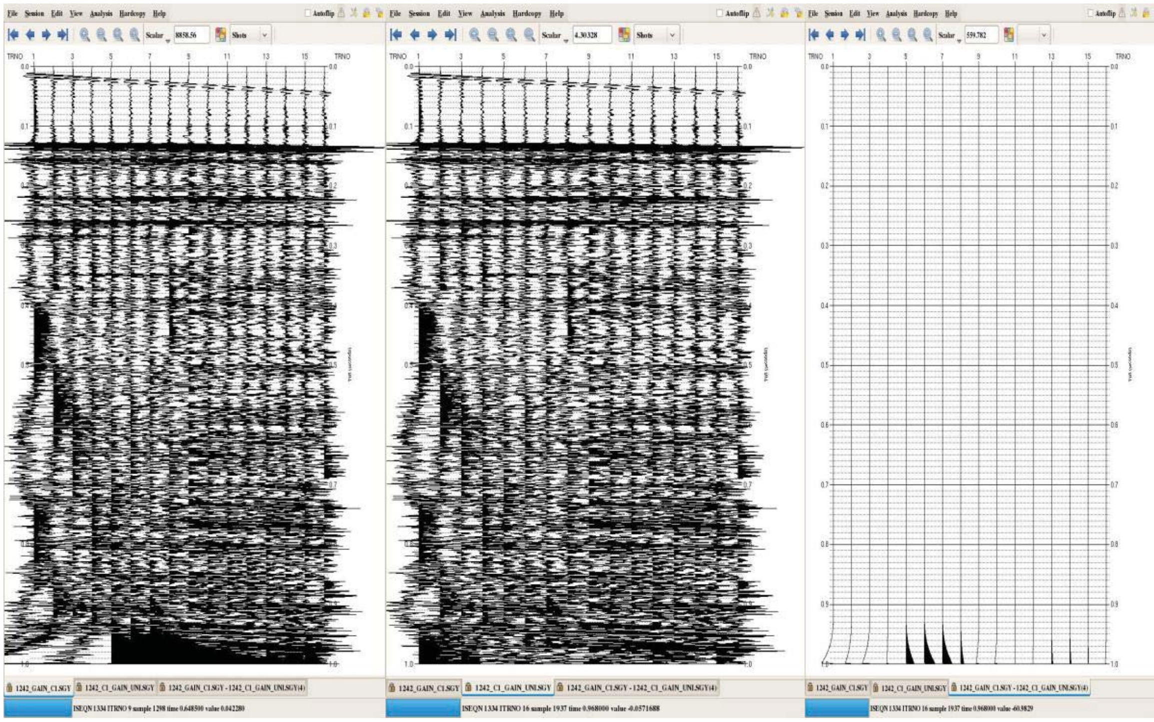

Figure 10 Left: Time Squared Exponential Gain Shot Gather-FOCUS. Middle: Time Squared Exponential Gain Shot Gather-UNISEIS. Right: Difference Plot, small edge effect artifact, not significant to data processing as we remove it.

Establish Acquisition Geometry

Geometry is assigned to the shot database and outputs geometrically corrected CDPs. Table 1 lists offsets calculated based on a 16 channel data set with a CDP interval of 3.125 meters. Trace offsets calculated in FOCUS are rounded to the nearest meter. Trace sets calculated by UNISEIS are specified by floating point distances.

Table 5 Offset Distances for Traces 1 to 16 calculated by FOCUS and UNISEIS.

FOCUS Offset Distances		UNISEIS Offset Distances	
Trace	Offset (m)	Trace	Offset (m)
1	17	1	17.78
2	21	2	20.91
3	24	3	24.03
4	27	4	27.16
5	30	5	30.28
6	33	6	33.40
7	36	7	36.53
8	39	8	39.65
9	42	9	42.78
10	46	10	45.90

11	49	11	49.03
12	52	12	52.15
13	55	13	55.28
14	58	14	58.40
15	61	15	61.53
16	64	16	64.65

Sort to CDP Gathers

The seismic traces are sorted into CDP gathers, 8-fold for the testing data (Table 6). All traces are accounted for when the CDP is output in the displayed CDP gather, as well as in a log file. Figure 11 displays first full fold of the data with traces 2,4,6,8,10,12,14 and 16. Tables 7 and 8 are log outputs of the CDP gathers for FOCUS and UNISEIS.

Table 6 Calculated fold for testing data.

$$\text{fold} = \frac{\tfrac{1}{2}\,(\text{Group Interval x Number of traces})}{\text{Shot spacing}}$$

$$\text{8-fold} = \frac{\tfrac{1}{2}\,(12.5\text{m x } 16)}{12.5\text{m}}$$

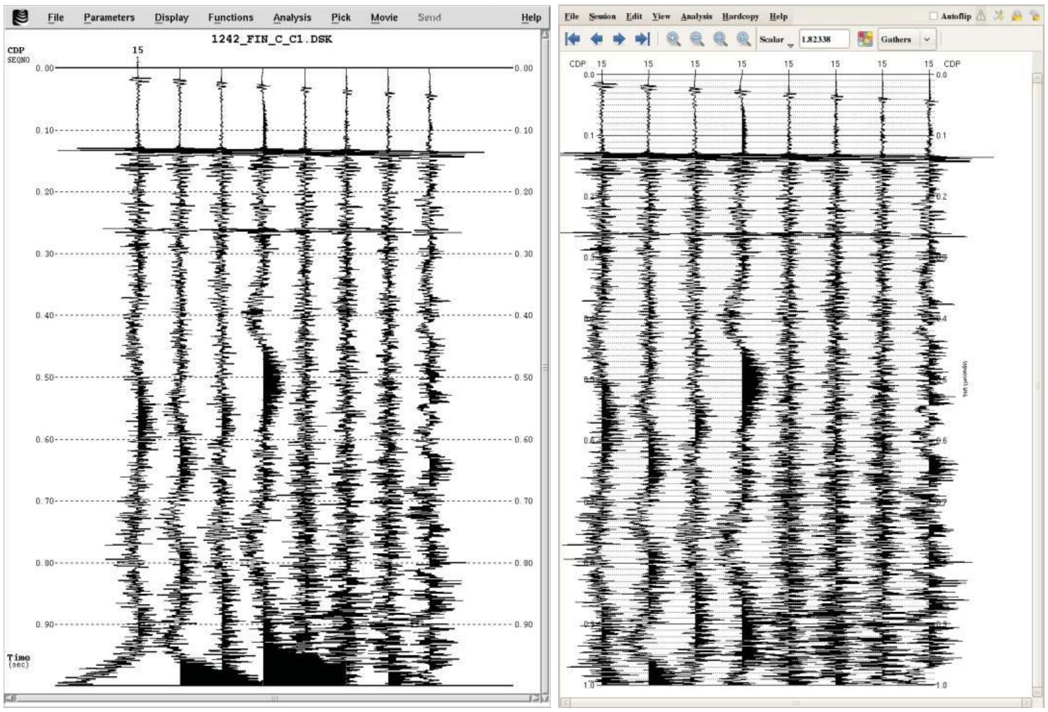

Figure 11 Left: CDP Gather-first full fold CDP 15, 8 traces -FOCUS. Right: CDP Gather, first full fold CDP 15 with 8 traces-UNISEIS.

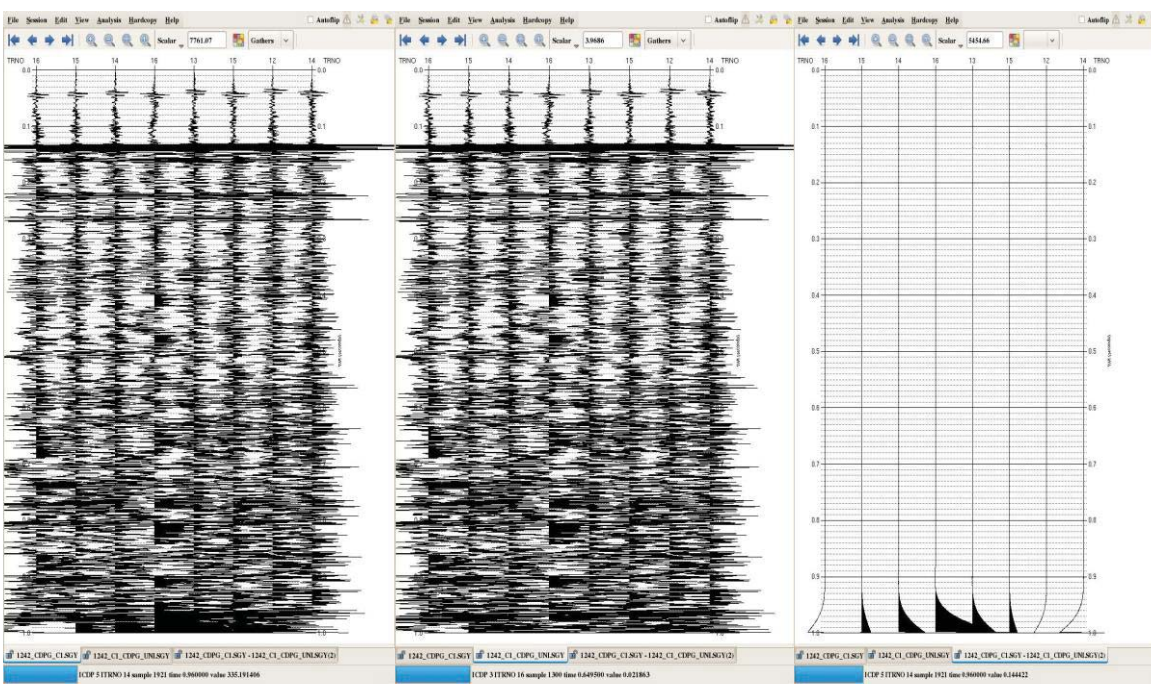

Figure 12 Left: CDP Gather-FOCUS. Middle: CDP Gather-UNISEIS. Right: Difference Plot, small edge effect artifact, not significant to data processing as we remove it.

Table 7 Output Table Displaying Correct Number of Output Gathered Traces-FOCUS

```
                         *** DSKWRT ***


     Filename:(ieee)/sdata2/pge4493/0002_test/1242CDPG_C2.DSK
     Format:VDS
     Sample rate:   500 (Microsecs.)     Trace length: 2000 (Samples)
     Max traces/ensemble:    8           Sorted by:INCREASING   CDP

     Initial PKEY/Initial SEQNO:            1           1
     Ending  PKEY/Ending  SEQNO:         2200           2
```

Table 8 Output Table Displaying Correct Number of Output Gathered Traces-UNISEIS.

```
Uniseis phase number 13 (OUTPUT) - lun 113 - CDP GATHERS

     First     Last
      CDPG     CDPG      Tape/File name
--------------------------------------
         1     2200      /sdata2/pge4493/0002_test/1242cab2_cdpg.gath
```

Velocity Analysis

FOCUS-VELDEF is an interactive velocity analysis program. VELDEF allows for gathers to be displayed and velocity coherence contours, amplitudes of the coherence contours are displayed on a coherency amplitude histogram. Velocity functions are picked at each CDP; picks are stored as time-velocity pairs. For testing purposes one location panel is picked for brute velocity use, Figure 13.

MGIVA is an interactive velocity analysis program in UNISEIS. Constant Velocity panels are created to support the manual picking of brute velocities, Figure 14. Manually selected CDP picks are stored as time-velocity pairs. One brute velocity function is used for testing. MGIVA is used for final velocity Analysis.

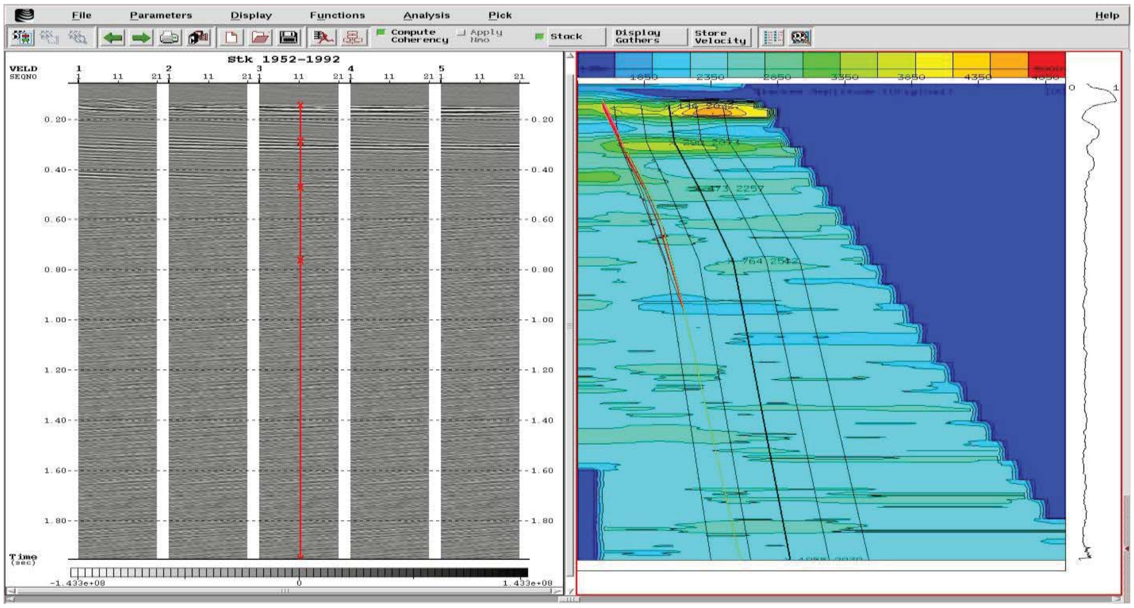

Figure 13 FOCUS Velocity computations. Left: Stack Panels Display. Right: Coherency Display.

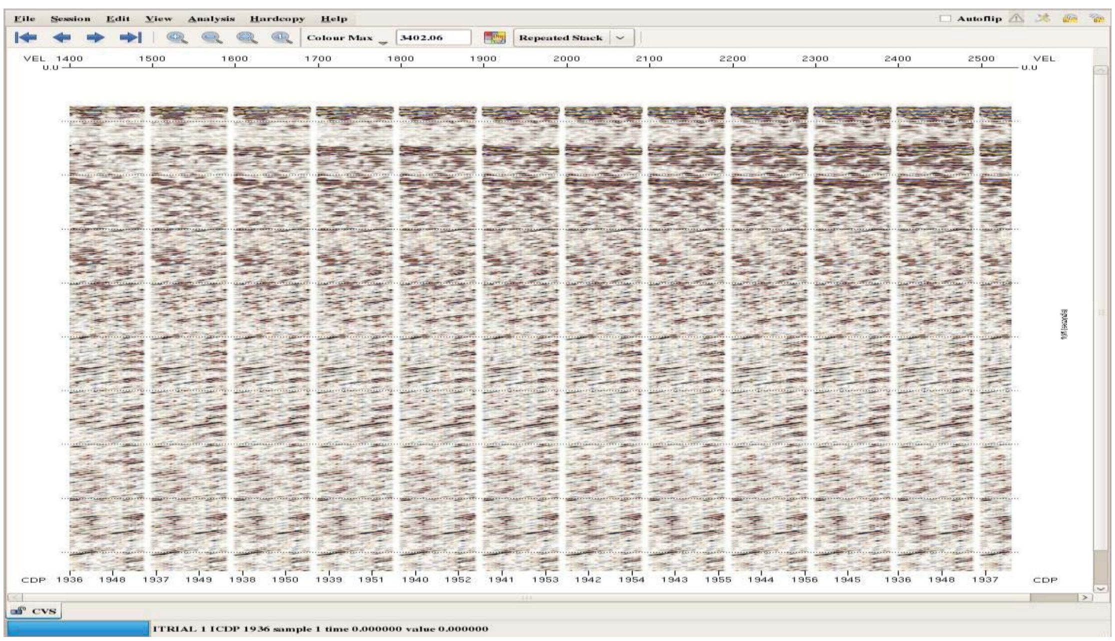

Figure 14 UNISEIS Constant Velocity Stack Display.

NMO Correction

Using the Brute velocity model, NMO is applied for move-out correction; as a result un-stacked traces exhibit flat horizons. There is very good agreement between systems.

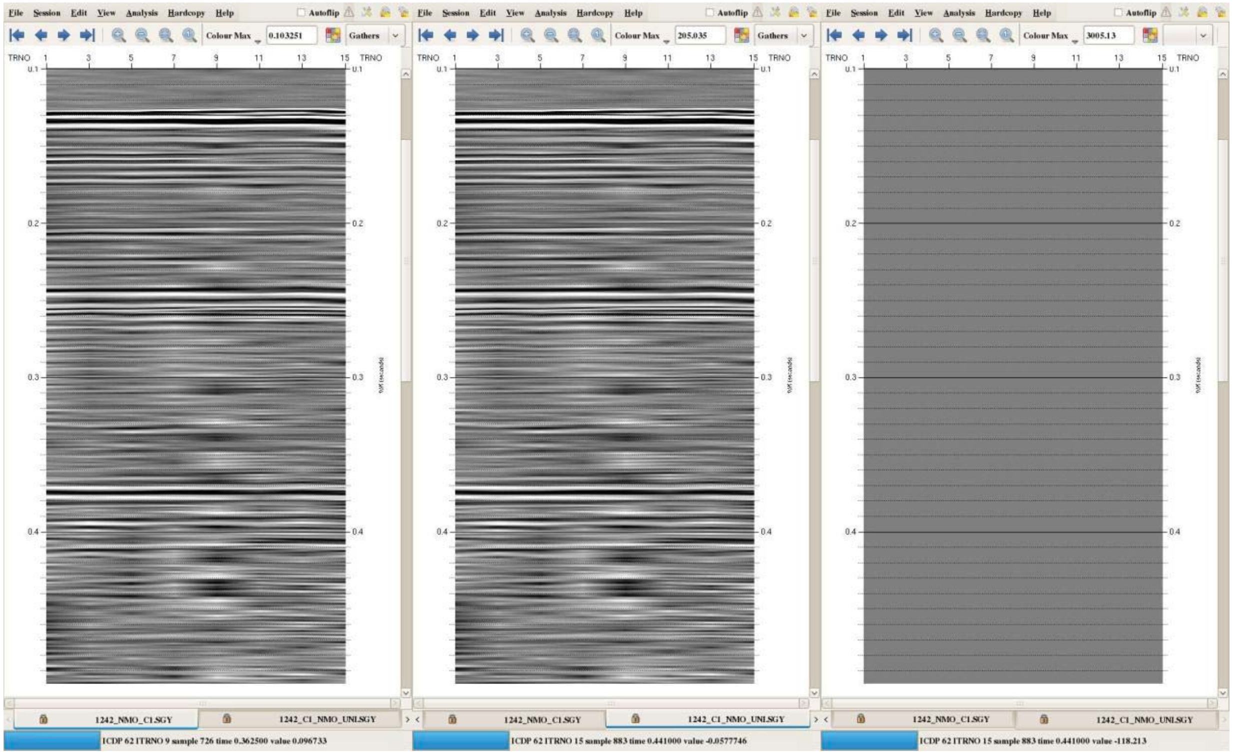

Figure 15 Left: NMO corrected Gather-FOCUS. Middle: NMO Corrected Gather-UNISEIS. Right: Difference Plot.

Outer Trace Mute

FOCUS and UNISEIS have interactive mute picking capabilities, Figure 16 displays a typical front end mute picked on the data. Selected mute times are stored to be used in job decks.

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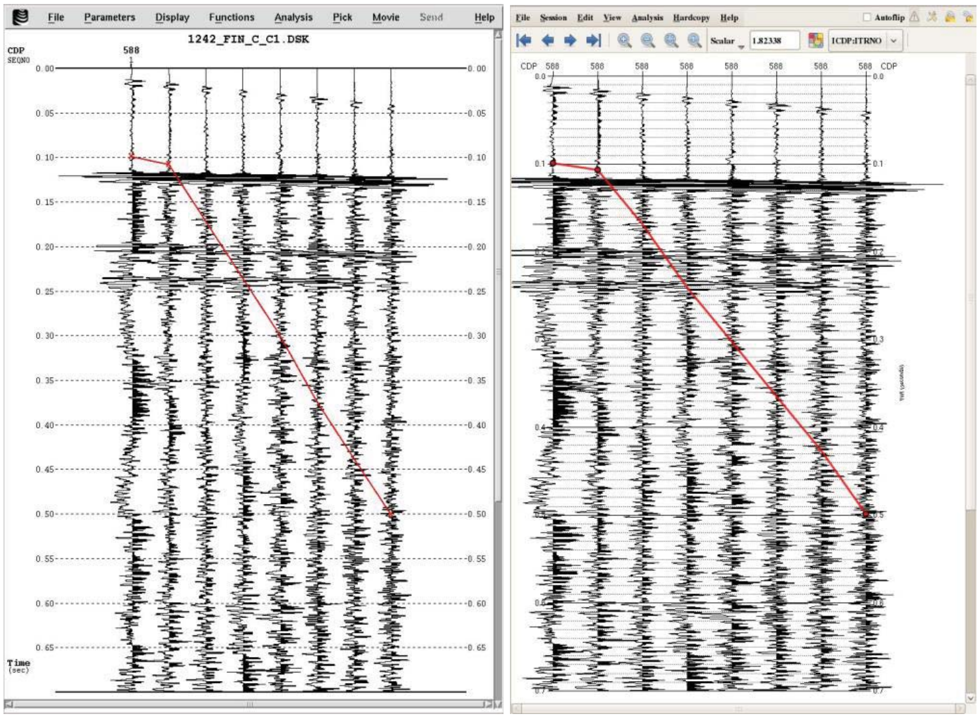


Figure 16 Left: Mute Function Interactively Picked-FOCUS. Right: Mute Function Interactively Picked-UNISEIS.

CDP Stack

The data was then sorted to CDP and a brute stack for each cable was produced using a brute velocity function. 10 locations were measured to ensure sea floor times for Brute stacks created with FOCUS and UNISEIS; sea floor times were recorded in Table 9. Cable 1 Brute Stack Spectral Analysis was calculated over 3 windows, results are displayed in Figures 17-19, with window parameters recorded in Table 8. Figures 20-23 display the Brute stacks.

Table 9 Measured Seafloor Times of Brute Stacks.

FOCUS		UNISEIS	
CDP	Time (ms)	CDP	Time (ms)
489	115.5	489	115.5
781	102	781	102
850	98.5	850	98.5
926	96	926	96
1072	92	1072	92
1482	81.5	1482	81.5
1593	79.5	1593	79.5
1800	75	1800	75
1912	76	1912	76
2198	63.5	2198	63.5

FUGRO SEISMIC IMAGING, INC.

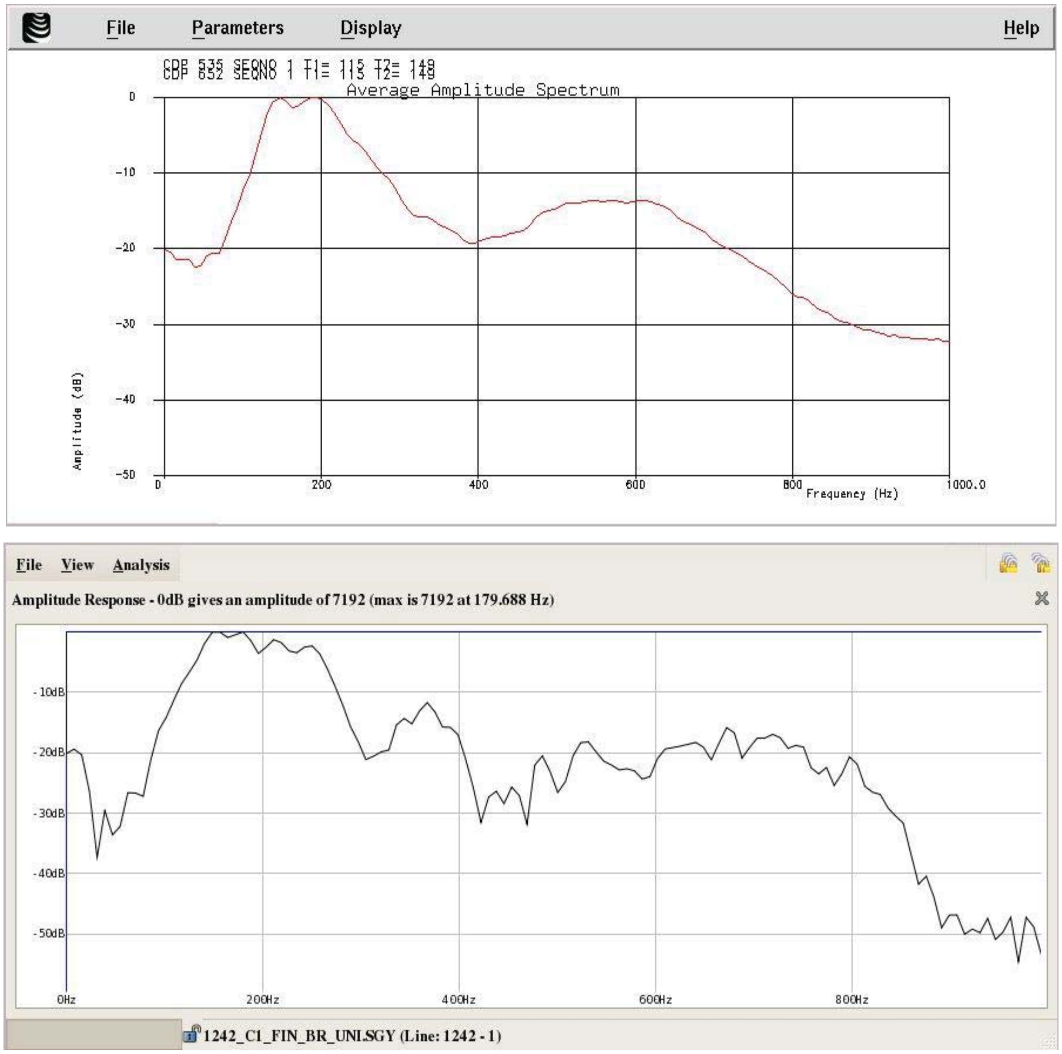


Figure 17 Top: Amplitude Spectra of Brute Stack, Window 1-FOCUS. Bottom: Amplitude Spectra of Brute Stack, Window 1-UNISEIS.

FUGRO SEISMIC IMAGING, INC.

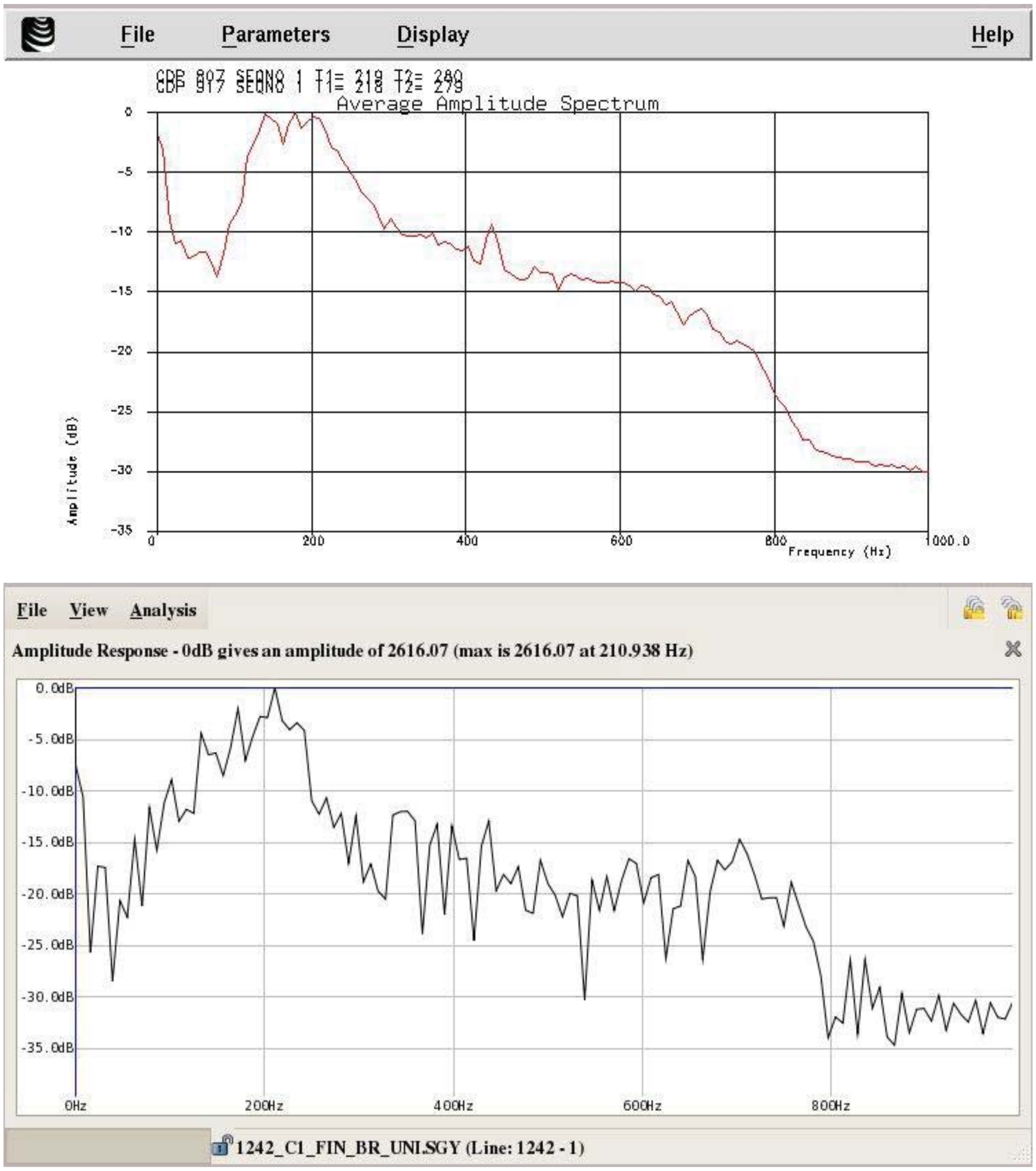


Figure 18 Top: Amplitude Spectra of Brute Stack, Window 2-FOCUS. Bottom: Amplitude Spectra of Brute Stack, Window 2-UNISEIS.

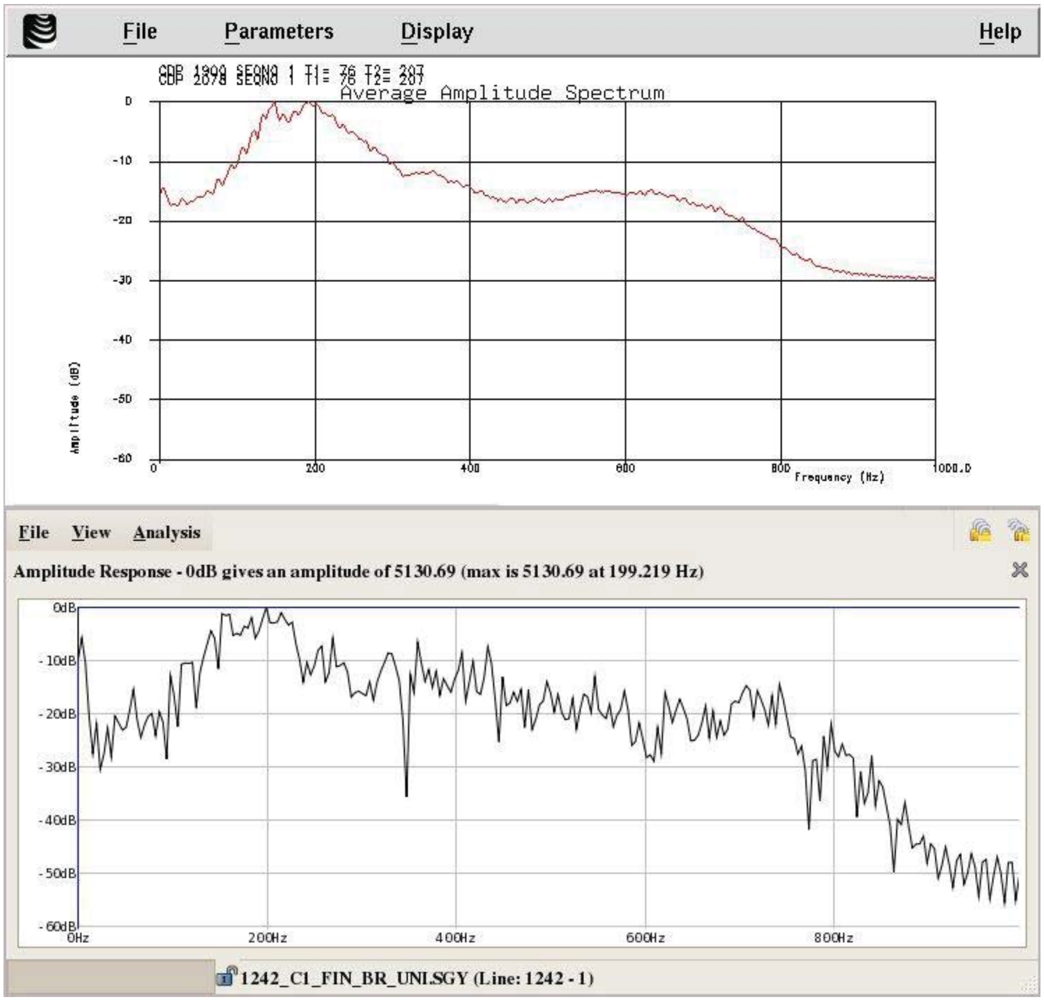


Figure 19 Top: Amplitude Spectra of Brute Stack, Window 3-FOCUS. Bottom: Amplitude Spectra of Brute Stack, Window 3-UNISEIS.

Table 11 Calculated Amplitude Spectra for 3 Windows of Brute Stacks.

Window 1			
CDP	**TIME (ms)**	**CDP**	**TIME (ms)**
535	115	652	115
652	150		
Window 2			
CDP	**TIME (ms)**	**CDP**	**TIME (ms)**
807	220	917	219
917	219		
Window 3			
CDP	**TIME (ms)**	**CDP**	**TIME (ms)**
1900	76	2078	76
2078	209		

FUGRO SEISMIC IMAGING, INC.

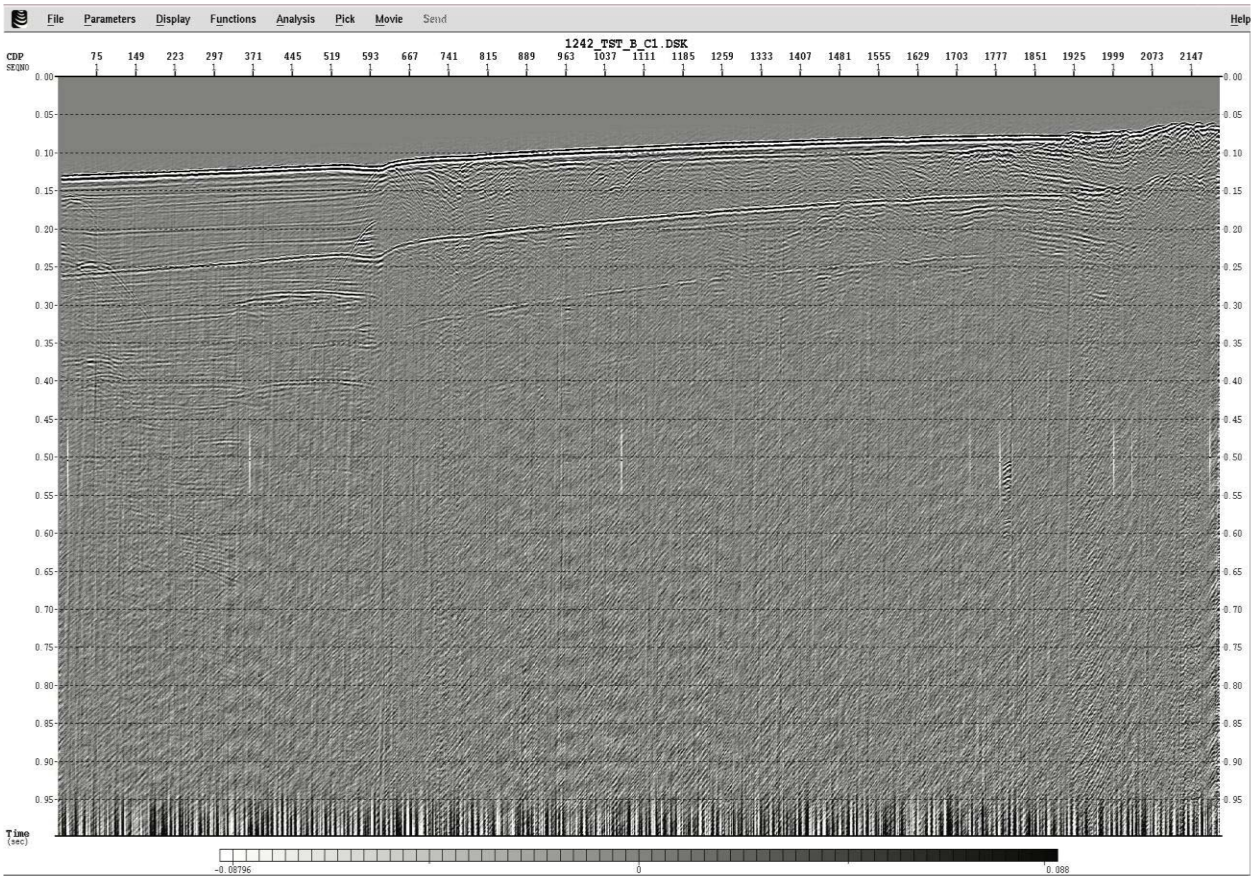


Figure 20 Brute Stack-FOCUS; small edge effect artifact to be removed by re-legnthening the data prior to migration.

FUGRO SEISMIC IMAGING, INC.

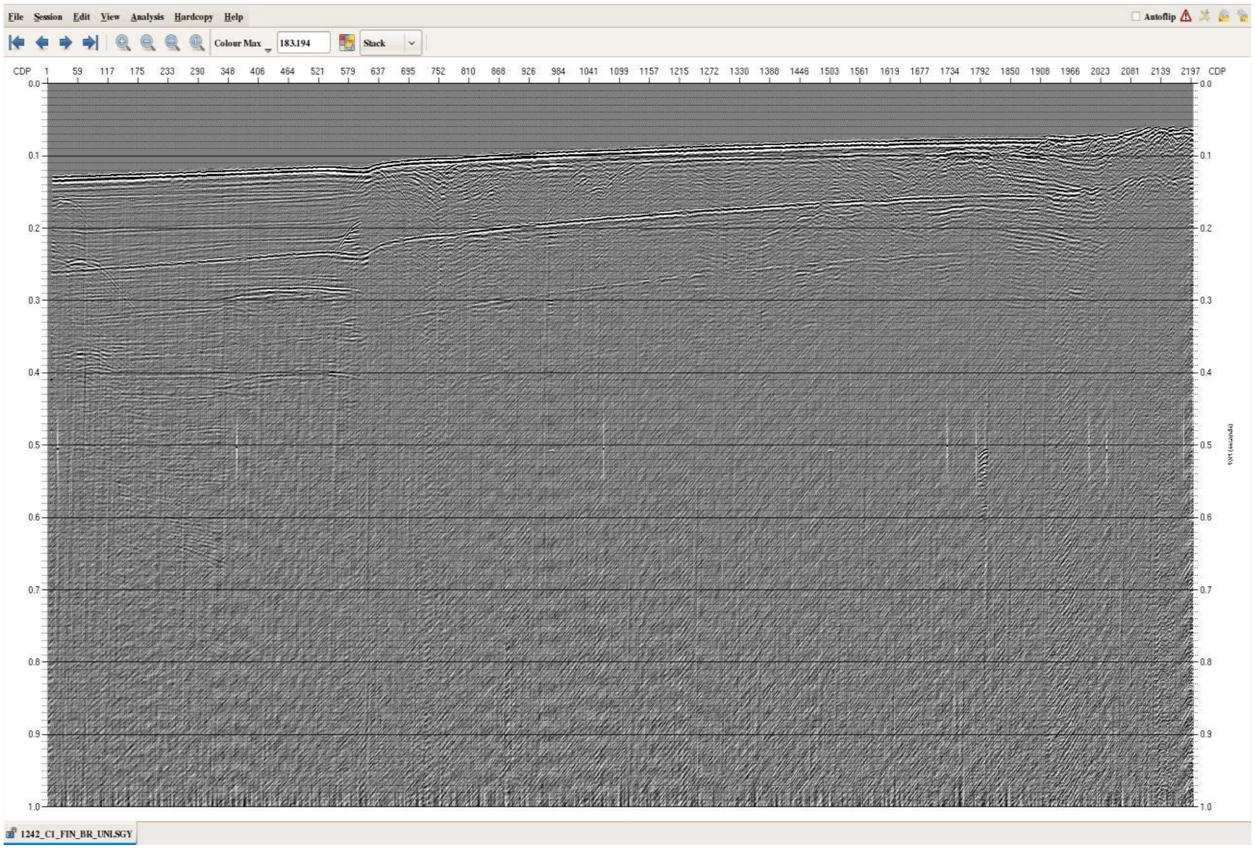


Figure 21 Brute Stack-UNISEIS; slight edge effect artifact to be removed by re-legnthening the data prior to migration.

FUGRO SEISMIC IMAGING, INC.

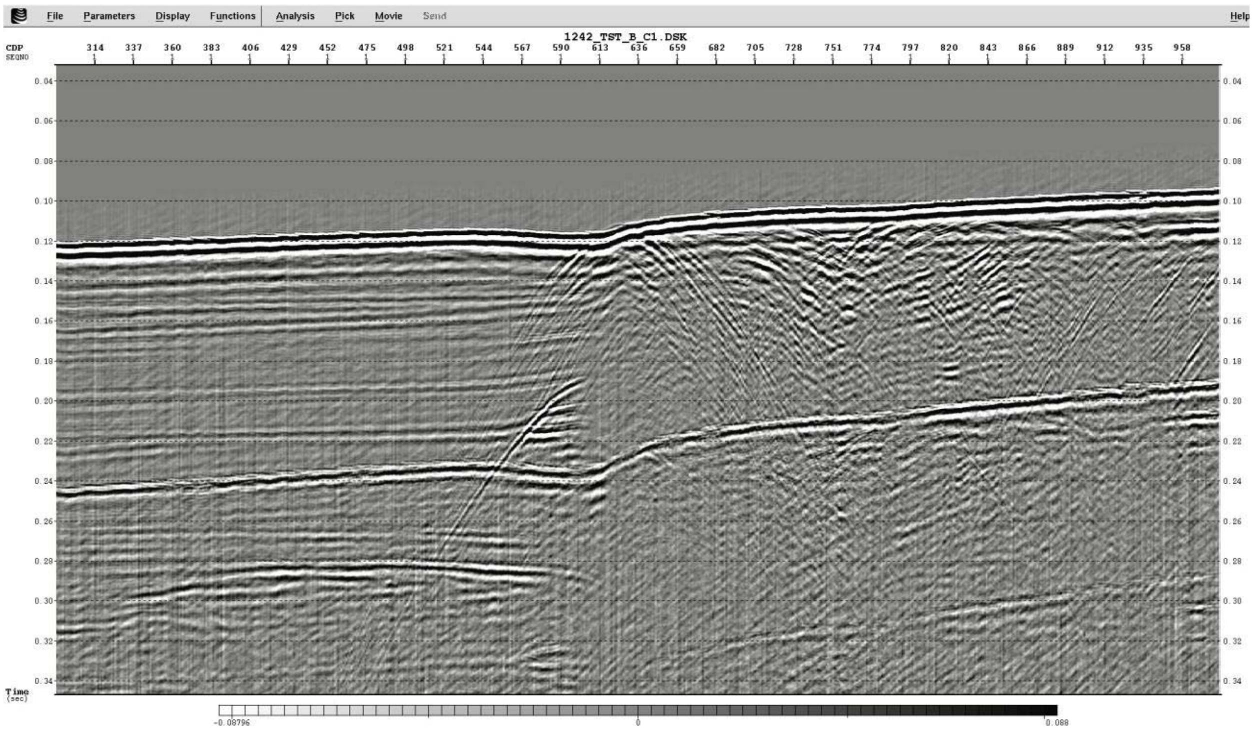


Figure 22 Brute Stack, display CDP 290-974, times 40ms to 350ms-FOCUS.

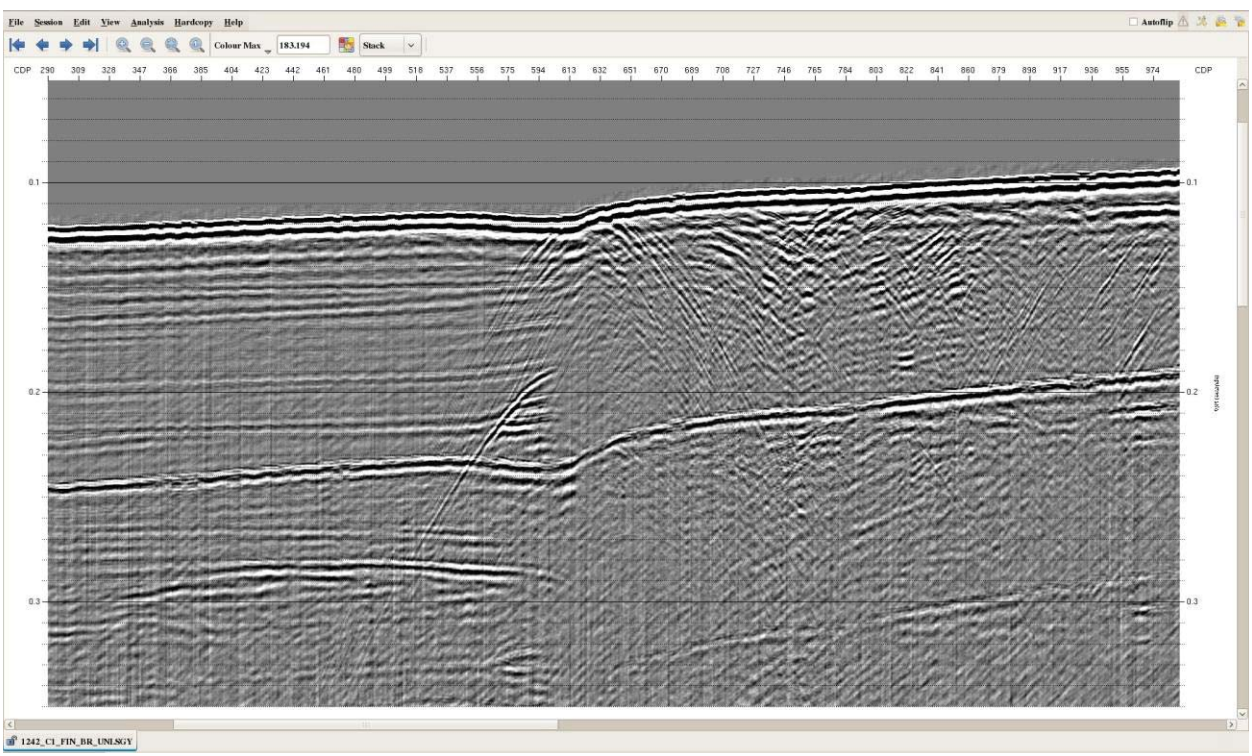


Figure 23 Brute Stack, display CDP 290-990, times 40ms-350ms-UNISEIS.

FINAL PROCESSING SEQUENCE

Brute Stack

1. Reformat SEG-D Data
2. Low Cut Filter
3. Measured Exponential Gain
4. Assign Geometry
5. Gather
6. Velocity Analysis-brute velocity
7. NMO Correction
8. Outer Trace Mute
9. Stack (8 fold)

Conclusions

The processing was performed in accordance with Fugro's Seismic, Inc. Data Processing Procedure and Work Instructions for comparing Fugro Seismic Imaging's proprietary seismic processing software and Paradigm Geophysical's FOCUS seismic processing software.
For every testing stage, the output data and log files were checked to ensure that the data was correct.
The data images displayed within the report will indicate that UNISEIS Processing software is comparable to Paradigm Geophysical's FOCUS seismic processing software.

PERSONNEL

The following personnel worked on this project:

Technical Advisor	Steve Cole	Chief Geophysicist
Lead Investigator	Tal Griffiths	Marine Processing Manager
Project Personnel	Melissa A Padilla	Staff Geophysicist

UNISEIS DATA PROCESSING SOFTWARE VALIDATION PROCEDURE

3D LOW ENERGY SEISMIC SURVEYS

OFFSHORE CENTRAL CALIFORNIA

1.0 INTRODUCTION

As part of Fugro Consultants' ongoing support of Pacific Gas & Electric engineering investigations in the vicinity of the Diablo Canyon Power Plant (DCPP), this document has been prepared to satisfy United States Nuclear Regulatory Commission Quality Assurance and validation requirements for software used for engineering studies of nuclear facilities. Fugro Consultants plans on acquiring high-resolution 3D seismic reflection data offshore Avila Bay (Figure 1) during late 2011 that will be used to constrain possible marine geohazards on the Central California coast.

The 3D seismic reflection data will be processed by personnel from Fugro Seismic Imaging using the UNISEIS processing software. This document details the proposed validation requirements for the offshore, or "QC" phase of the marine seismic reflection processing, and does not include the post-survey UNISEIS software validation plans.

UNISEIS is Fugro's proprietary seismic processing software package that has been used for more than 30 years, and includes applications for 2D, 3D, and 4D processing of land, marine, and transition zone seismic reflection data. An active R&D group is constantly improving UNISEIS processing modules to meet customer needs.

1.1 WORK SCOPE

In order to validate that UNISEIS is functioning properly during QC data processing, Fugro proposes to generate 2D Brute Stacks of two seismic lines acquired during the previous 2010/2011 survey campaign near the proposed survey area (See Figure 1 in Data Collection Plan). By comparing data processing results from UNISEIS and those achieved in 2010/2011, UNISEIS can be verified to be properly functioning and be able to replicate results previously accepted as good quality seismic reflection data. Furthermore, Fugro Seismic Imaging plans on using the industry-standard Paradigm Echos software to prepare Brute Stacks of the same seismic lines to ensure redundancy in the processing results. The QC processing sequence, once verified, will be used in the field to prepare Brute Stacks of seismic for review by project staff. A QC processing Validation report will be prepared documenting the success or failure of each validation exercise, along with relevant data examples.

1.2 PROJECT PARTICIPANTS

Melissa Padilla, Staff Geophysicist, Fugro, will conduct and document the Software Validation of UNISEIS. Tal Griffiths, Marine Processing Manager, will serve as Lead Investigator while Dr. Steve Cole, FSI Chief Geophysicist will serve as technical advisor and will have final technical oversight. A representative from Fugro Consultant's (FCL) Nuclear QA Program will be involved as an advisor during the UNISEIS Software validation procedure.

1.3 QC PROCESSING VERFICATION PROCEDURES

The Validation plan for the proposed offshore QC processing procedures using UNISEIS are as follows:

1.3.1 Transcription/Reformatting of seismic field data

Transcription and data reformatting allows for the selected 2010/2011 lines to be converted from Geometrics' CNT-2 ?) SEGD format to internal Fugro (UNISEIS) or Paradigm file format. Raw shot gathers will be displayed and compared between UNISEIS and Echos.

Display shot gather

- measure amplitude value of 10 samples
- measure direct arrival time of near channel
- calculate amplitude spectra of near trace, whole shot and data window

1.3.2 Low cut filter

- calculate amplitude spectra of near trace, whole shot and data window
- measure amplitude value of 10 samples

1.3.3 Apply a time squared exponential gain

- measure amplitude of 10 samples along near trace at different time intervals

1.3.4 Establish Acquisition Geometry

The acquisition geometry will be assigned using the CMP/shot spacing, as well as the P190 files provided by the navigation contractor, NCS-Subsea. This step allows for the Brute Stack to be loaded into seismic interpretation software such as SMT Kingdom.

1.3.5 Sort to CMP Gathers

Once the acquisition geometry has been assigned, the data will be sorted into CMP gathers. CMP gathers created in UNISEIS and Echos will be compared to confirm proper acquisition geometry has been embedded in the data.

- number of CMPs
- number of traces in first full fold CMP and confirm location along line
- total number of traces

1.3.6 Velocity Analysis

A single velocity function will be picked that will be the same for both UNISEIS and Echos. The velocity functions will be compared and included as data examples in the Validation report.

1.3.7 NMO Correction

In order to prepare a Brute Stack from the CMP gathers, an NMO function using the stacking velocities picked in the previous step must be applied to the data.

1.3.8 Apply outer trace mute

- Display gather and pick mute function.

Mute functions picked in UNISEIS and Echos will be compared.

1.3.9 CMP Stack

The Brute Stacks from both UNISEIS and Echos will be compared to the Brute Stacks previously prepared and included as data examples in the Validation report.

- calculate spectra of 3 windows
- measure seafloor time at 10 locations
- verify number of traces

1.3.10 SEGY Export and SMT Loading (Optional Step)

As an optional step to ensure navigation has been properly applied to each stacked seismic trace, a SEGY file of each Brute Stack processed in UNISEIS and Echos will be created and loaded into SMT Kingdom to compare CMP positioning and data amplitudes.

1.4 SOFTWARE VALIDATION SCHEDULE

It is anticipated that two business weeks will be needed to run the seismic reflection data through the processing steps in UNISEIS and Echos and prepare the report. The work was approved October 14th, 2011, and is scheduled for completion by end October, 2011.

FUGRO	FUGRO CONSULTANTS, INC. PROJECT REPORT COVER SHEET	PR No. PGEQ-PR-06 Revision 1 Page 1 of 41

SOFTWARE VALIDATION FOR SEISMIC PROCESSING WORKSHOP AND QUALIFICATION OF 2010 - 2011 2D HIGH-RESOLUTION SEISMIC REFLECTION DATA

DIABLO CANYON POWER PLANT

CENTRAL COASTAL CALIFORNIA SEISMIC IMAGING PROJECT

Prepared for:
PACIFIC GAS & ELECTRIC COMPANY

FSI Project No. 2011-4493
FCL Report No. PGEQ-PR-06

Prepared by: Robert Dame Date: 11/16/12

Reviewed by: Phillip Hogan Date: 11/16/12

Verified by: Daniel Ebuna Date: 11/16/12

Approved by: William H. Godwin Date: 11/16/12

Project Report Revision Status

Rev. No.	Date	Description	Impacted Document No.
0	08/10/2012	Initial Issuance of Project Report	None
1	11/16/12	Response to comments by PG&E dated 11/02/12	None

Text Revision History

Page No.	Rev. No.	Page No.	Rev. No.
(pg 7) Added text to explain use of data for Pt. Buchon interpretation.	1		
(pg 10) Added text to section 3.0 explaining QA validation scope of work.	1		
(pg 36) Added new section 5.0 QUALIFICATION OF 2010-2011 2D SEISMIC DATA.	1		
(pg 37) added to Conclusion section	1		

Figures Revision History

Figure No.	Page No.	Rev. No	Figure No.	Page No.	Rev. No
20 new	36	1			
21 new	37	1			
22 new	38	1			

Appendix Revision History

Appendix No.	Page No.	Rev. No	Appendix No.	Page No.	Rev. No

	FUGRO CONSULTANTS, INC. PROJECT REPORT SUMMARY VERIFICATON SHEET	PR No. PGEQ-PR-06
		Revision: 1
		Page 3 of 41

Item	Parameter	Yes	No	N/A
1	Purpose is clearly stated and Report satisfies the Purpose.	X		
2	Methodology is appropriate and properly applied.	X		
3	Assumptions are reasonable, adequately described, and based upon sound geotechnical principles and practices.	X		
4	Input was authorized and correctly incorporated into the Report.	X		
5	Software is properly identified and applied; and validation is referenced, or included, and acceptable.	X		
6	Detailed Discussion is complete, accurate, and leads logical to Results and Conclusions.	X		
7	Results and Conclusions are accurate, acceptable, and reasonable compared to the Input and Assumptions.	X		
8	References are valid for intended use.	X		
9	Appendices are complete, accurate, and support text.	X		

Comments: (use additional pages as necessary)

Verifier: Daniel Ebuna **Date:** 11/16/2012

Daniel Ebuna

Table of Contents

List of Tables

List of Figures

Appendix

1.0 INTRODUCTION

As part of Fugro Consultant, Inc. (FCL) ongoing support of the Pacific Gas & Electric Company's (PG&E) geologic and engineering investigations in the vicinity of the Diablo Canyon Power Plant (DCPP), this document has been prepared to satisfy United States Nuclear Regulatory Commission Quality Assurance (QA) and validation requirements for software used for engineering studies of nuclear facilities. FCL acquired high-resolution 2D seismic reflection data offshore of Point Buchon and Avila Bay between November 2010 and February 2011 (Figure 1) and subsequently processed the data using the Seismic Processing Workshop (SPW) software (Fugro Consultants, 2012a-c). These 2D seismic reflection data will be used in safety-related interpretations to constrain possible seismic hazards on the Central California coast. The purposes of this report are to: 1) validate SPW software, and 2) qualify the 2010-2011 low-energy 2D seismic reflection data.

2.0 SOFTWARE

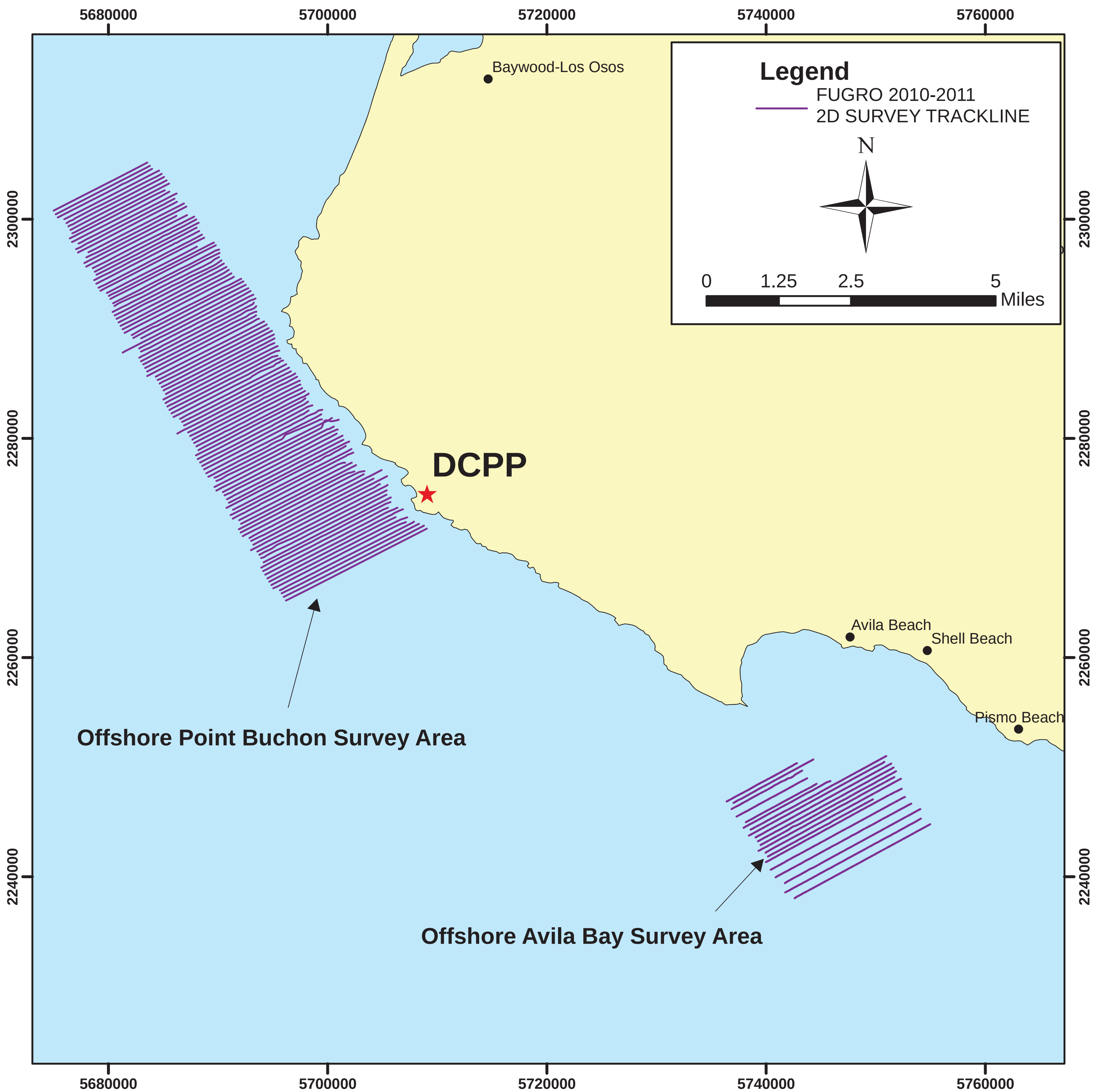
SPW is a Microsoft Windows and Linux compatible seismic data processing software used by marine survey contractors and energy companies worldwide. The software is published by the Parallel Geoscience Corporation (of Nevada, USA), and is currently in use by other Fugro Operating Companies (Fugro Aperio) to process seismic reflection and ground penetrating radar (GPR) data collected for geophysical investigations of nuclear power infrastructure. Fugro used SPW version 2.3 installed on a Microsoft Windows XP 64-bit workstation for both data processing and software validation to ensure consistency between software verification and data processing in 2010-2011.

The SPW Software utilizes four interdependent modules: TapeIO, FlowChart, SeisViewer, and VCalc. TapeIO allows for reformatting of raw field data (SEG Y or SEG D) into internal SPW Format. FlowChart is the main processing control panel of SPW, and allows for a user to perform different processing algorithms through a linked, user-developed processing sequence. SeisViewer allows for the graphical representation of seismic data, either pre- or post-stack. VCalc allows for a variety of mathematical functions to be applied over user-specified traces within a seismic dataset. All four modules were used extensively in the validation of SPW.

3.0 WORK SCOPE

In order to satisfy the "Quality Assurance Requirements for Computer Software for Nuclear Facility Applications, "(ASME NQA-1-1994), FCL performed and documented software validation that evaluated whether the SPW software was functioning properly during data processing. To satisfy the data processing software validation requirements, as detailed in QAP-03E of the FCL QA Manual, Fugro utilized a series of processing exercises from a published seismic processing textbook written specifically for SPW. The textbook, "A Lab Manual of Seismic Reflection Processing," was authored by Professor Roger A. Young, of the University of Oklahoma Geosciences Department and published by the European Association of Geoscientists and Engineers (Young, 2004).

Pacific Gas & Electric Company
Project No. 04.64110031



2010-2011 FUGRO 2D HIGH-RESOLUTION SEISMIC SURVEY LOCATIONS
Offshore Central California
SPW Software Validation Report

FIGURE 1

The text is comprised of 12 exercises that guide a user through an idealized processing flow using a high resolution dataset originally collected for geotechnical engineering purposes. The dataset is similar in bandwidth and resolution to the seismic data Fugro previously acquired in 2010-2011. Solutions to each exercise are provided on a CD that accompanies the text, so a user can verify and document processing results. Moreover, because the Lab Manual Exercises build on results between Exercises, a user can troubleshoot and identify operator errors that may have been introduced into the processing sequence by not using a specific data file or correct parameters when results do not match with the example files that accompany the Text. SPW software validation results are presented in section 4 of this report.

The 2010-2011 2D seismic reflection data are to be qualified in accordance with ASME NQA-1-2008, Part III, Subpart 3.3, Non-mandatory Appendix 3.1, "Guidance on Qualification of Existing Data," using the qualification method of data corroboration. The qualification process is based on data comparisons between 2D survey lines collected by FCL for PG&E in 2010-2011 and published 2D data collected by others (Sliter et al., 2009, revised 2010); these comparisons are presented in Section 5 of this report.

4.0 SPW SOFTWARE VALIDATION PROCEDURE

FCL prepared a Project Instruction (PI-09) that detailed the procedure followed and documented in this report. Attachment 7 of PI-09 was the specific procedure followed, in particular using the 12 exercises or procedures contained in the Lab Manual.

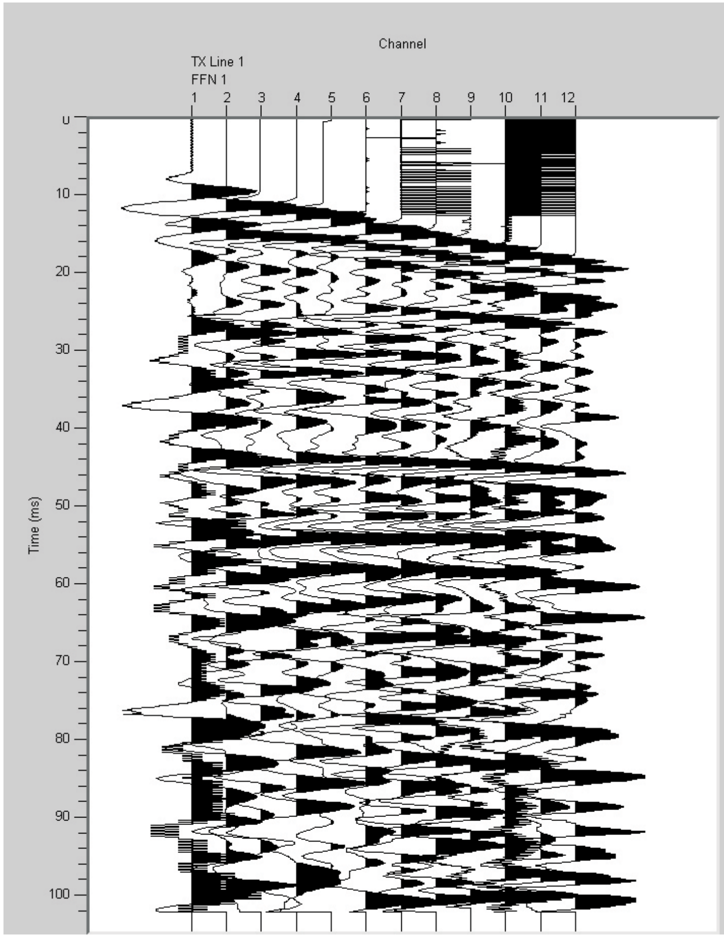
The exercises contained in the Lab Manual evolved from a series of processing laboratories associated with a college course on seismic exploration. Results from 12 exercises are documented in the following sections, which constitute the processing steps necessary to take raw field data to a final, post-stack time migrated section. A table summarizing the success of all processing steps for each Lab Manual Exercise and relevant figures showing processing results are also included. Additionally, a list of minor corrections to the original text published on the Parallel Geoscience web site is included as an appendix with this report.

4.1 Procedure 1 – Reformatting Seismic Data

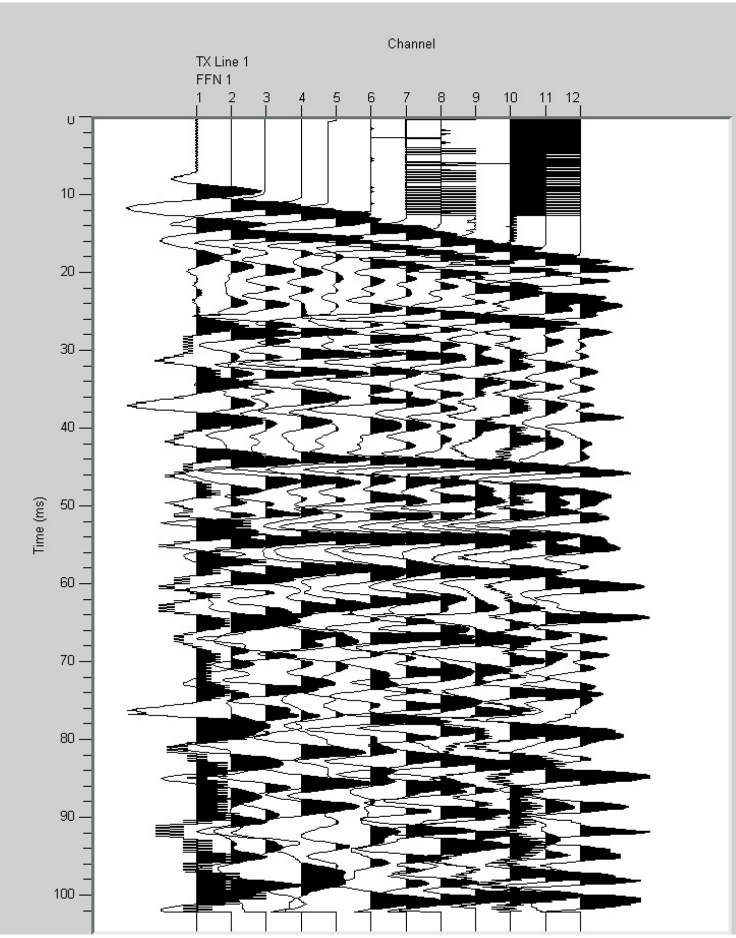
Procedure 1 served as an introduction to SPW, and provided a definition of file types used in SPW, and described the dataset to be used in subsequent exercises throughout the Lab Manual. The validation and verification (V&V) process for Exercise 1 in the Lab Manual included importing seismic data into SPW, assigning acquisition geometry, and displaying data in SeisViewer. All 3 steps were completed successfully (Table 1). Figure 2 shows a comparison of user-prepared and published processing results with relevant images.

Table 1: Procedure 1 Results

Processing Step	Successful (Yes/No)
1) Data Reformatting using TapeIO	Yes
2) Geometry Definition	Yes
3) Display Seismic File in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes



Fugro SPW V&V Results for Procedure 1



Lab Manual Results for for Procedure 1

DISPLAY OF RAW GATHERS - LAB MANUAL PROCESSING SEQUENCE 1
SPW Software Validation Report

FIGURE 2

4.2 Procedure 2 – Trace Gathering

Procedure 2 allowed for a user to gain familiarity with using SeisViewer to display traces gathered by common source, common receiver, common midpoint (CMP), and common offset. The V&V process for Exercise 2 in the Lab Manual included 2 steps: importing seismic data into SeisViewer and selecting and sorting specific traces for viewing on the seismic canvas. Both steps were completed successfully (Table 2). Figure 3 shows the agreement between user-generated and published results for Procedure 2.

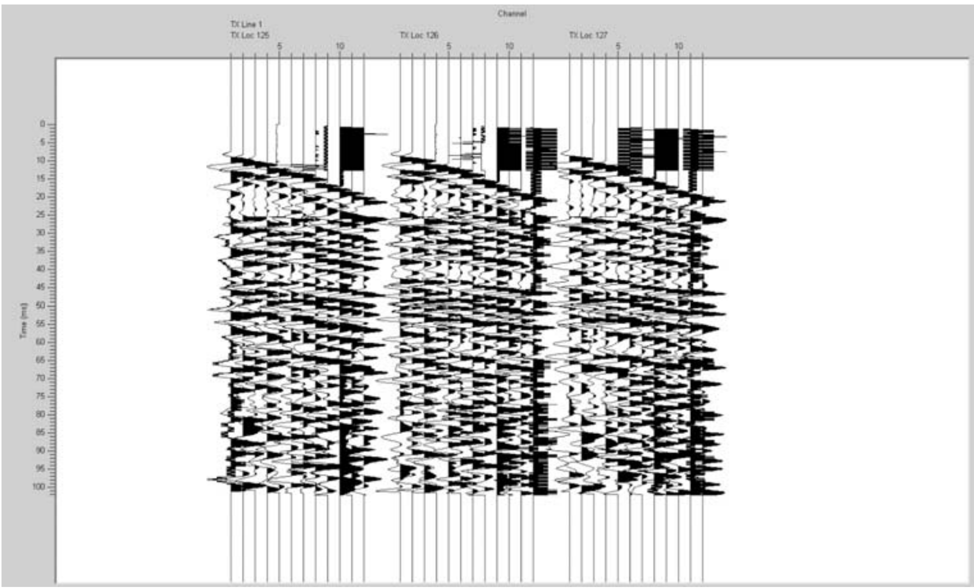
Table 2: Procedure 2 Results

Processing Step	Successful (Yes/No)
1) Import Data into SeisViewer	Yes
2) Display and sort data by trace	Yes
Results Between User-Prepared and Published Data Match	Yes

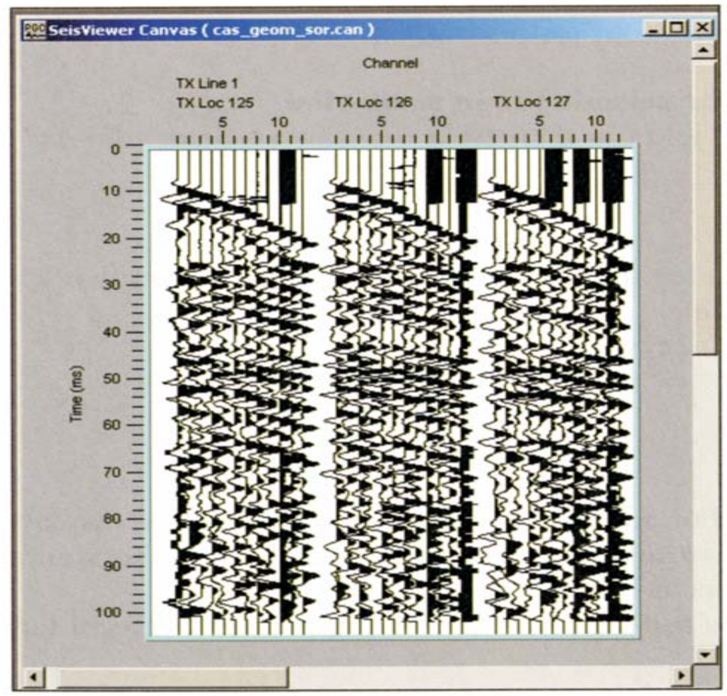
A supplemental exercise was also included in Procedure 2. This short exercise allowed a user to sort a seismic line in SeisViewer by common source locations, common receiver locations, common midpoint locations, and common offset locations. All sorting steps were successful. Figure 4 shows user-generated plots of each set of sorted gathers.

4.3 Procedure 3 – Velocity Analysis Using Semblance

Procedure 3 involved generating and displaying semblance plots of CMP gathers. Three steps were necessary to complete the V&V process for Exercise 3 in the Lab Manual: data import into Flow Chart, link flow items and run flow, and display of semblance plot in SeisViewer. All steps were completed successfully (Table 3). Figure 5 shows the agreement between user-generated and published results for Procedure 3.



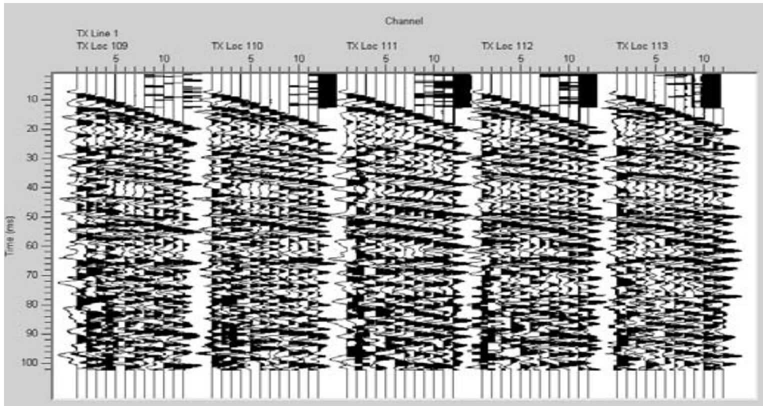
Fugro SPW V&V Results for Procedure 2



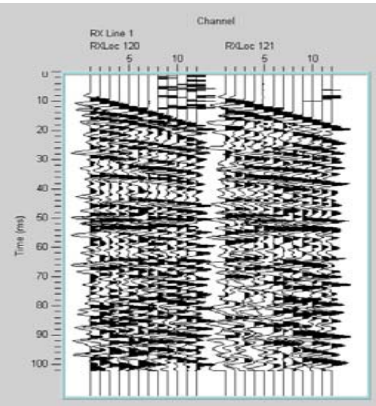
Lab Manual Results for Procedure 2 (Figure 3 from Lab Manual Text)

DISPLAY OF TRACE GATHERS - LAB MANUAL PROCESSING SEQUENCE 2
SPW Software Validation Report

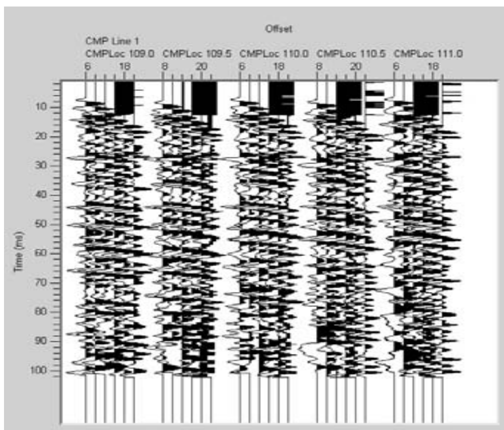
FIGURE 3



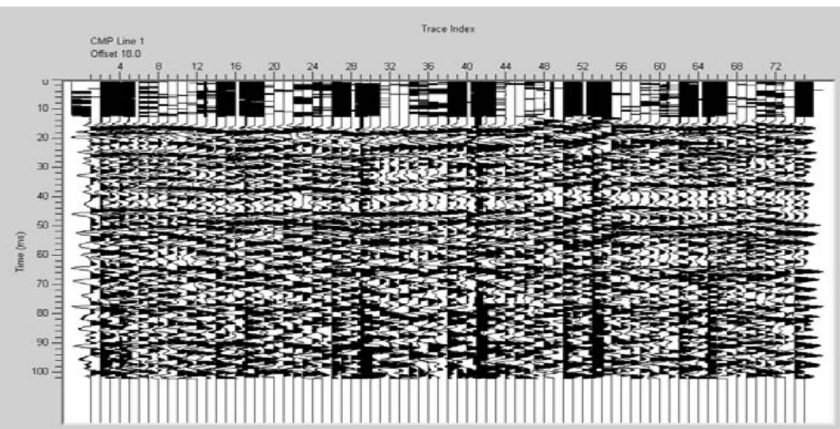
Display of Common Source Gathers



Display of Common Reciever Gathers



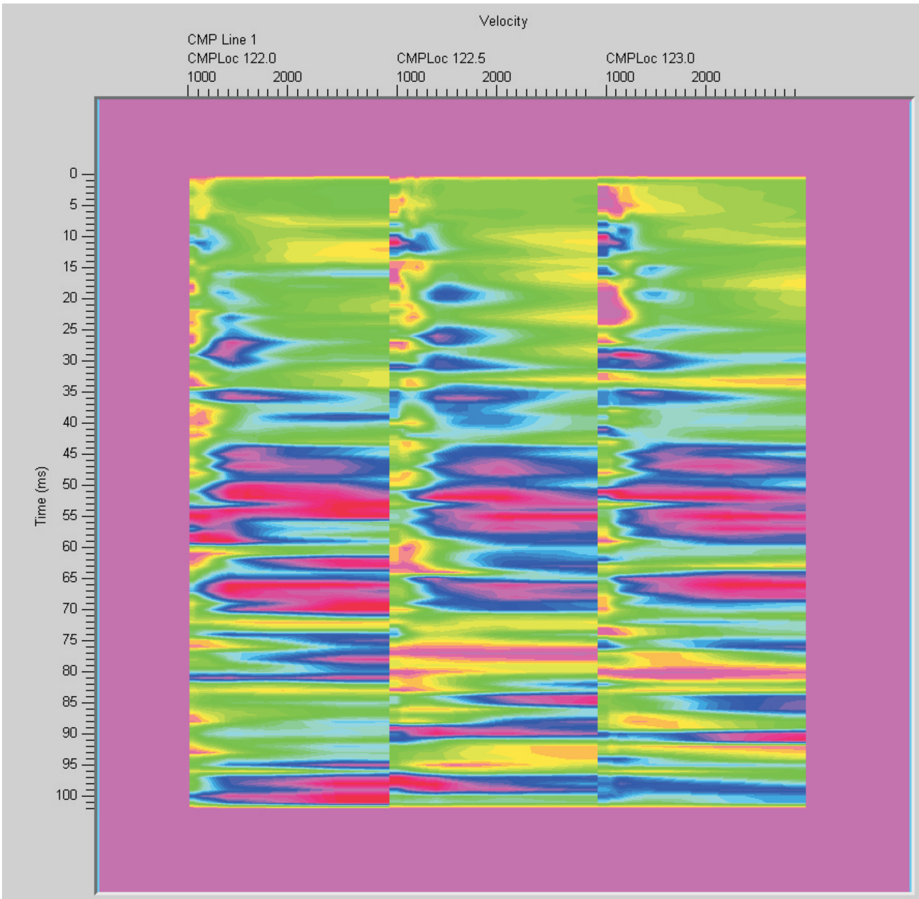
Display of Common Midpoint Gathers



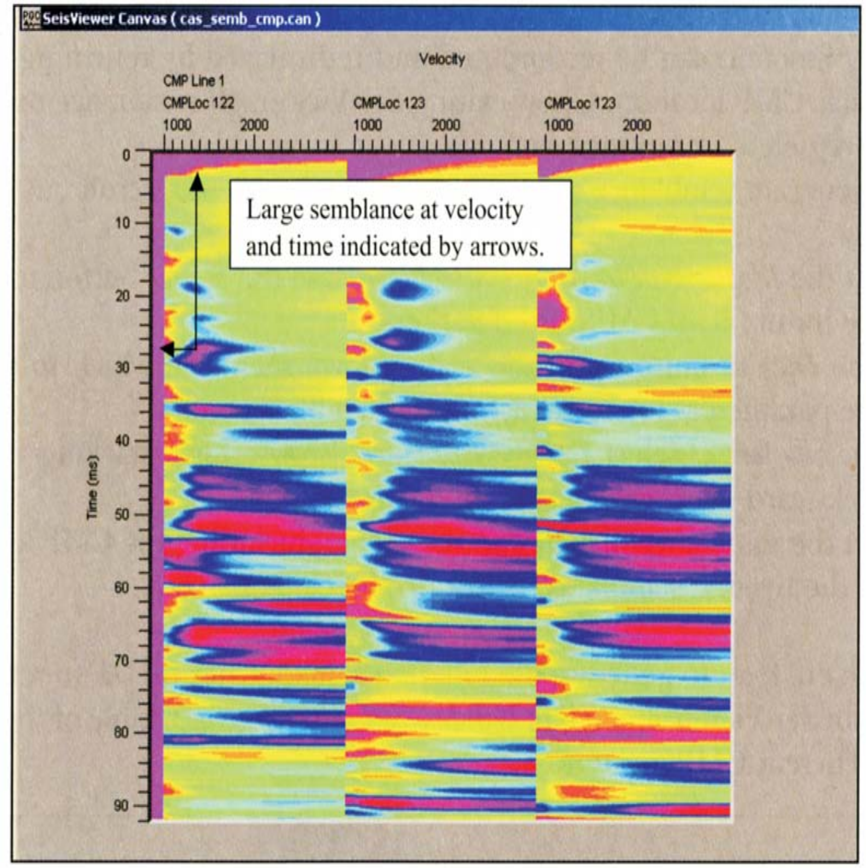
Display of Common Offset Gather

DISPLAY OF SORTED GATHERS - LAB MANUAL PROCESSING SEQUENCE 2
SUPPLEMENTAL EXERCISE
SPW Software Validation Report

FIGURE 4



Fugro SPW V&V Results for Procedure 3



Lab Manual Results for Procedure 3 (Figure 5 in Lab Manual Text)

DISPLAY OF SEMBLANCE PLOT - LAB MANUAL PROCESSING SEQUENCE 3
SPW Software Validation Report

FIGURE 5

Table 3: Procedure 3 Results

Processing Step	Successful (Yes/No)
1) Importing Data into Flow Chart	Yes
2) Link Seismic Objects in Flow Chart and Run Flow	Yes
3) Display Semblance Plot in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes

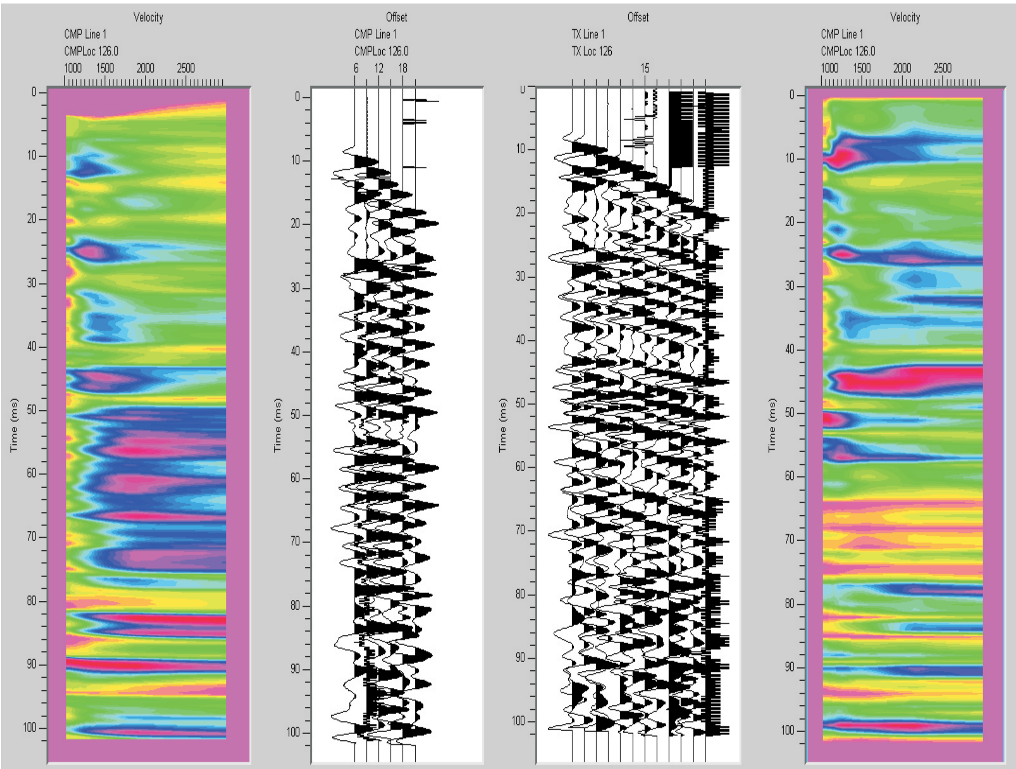
4.4 Procedure 4 – Comparing Semblance Maps

Since stacking velocity functions can be derived from a shot gather as well as CMP gather, Procedure 4 allowed for a user to compare semblance plots generated from shot gathers and CMP gathers.

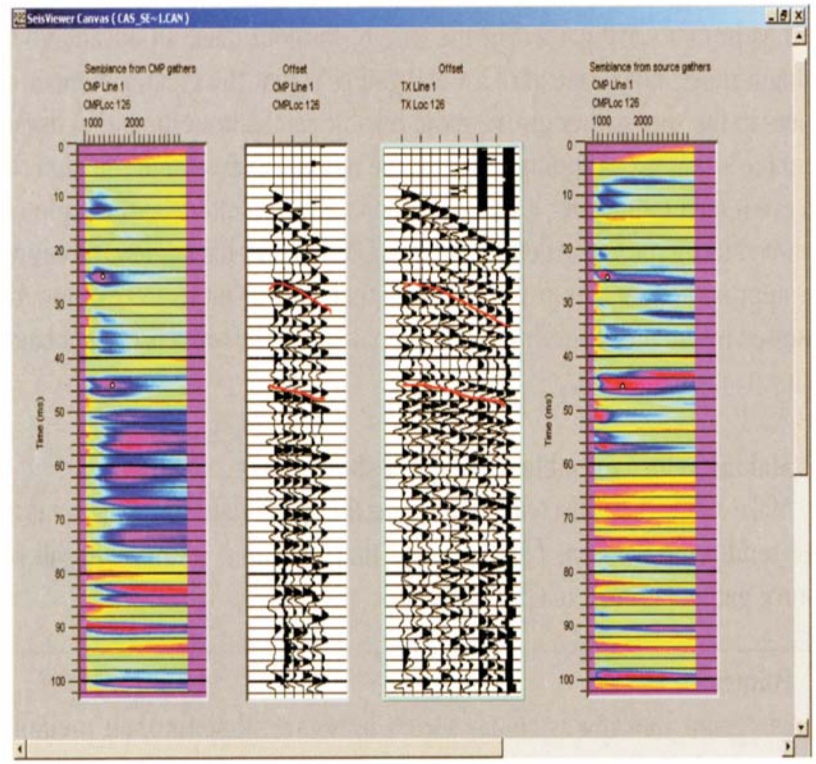
Five steps, all using SeisViewer, were necessary to complete the V&V process for Exercise 4 in the Lab Manual: display of semblance data created from CMP gathers, display of CMP gathers, display of semblance data created from common shot gathers, display of common shot gathers, and saving of the SeisViewer Canvas for future use. All steps were completed successfully (Table 4). Figure 6 shows the agreement between user-generated and published results for Procedure 4.

Table 4: Procedure 4 Results

Processing Step	Successful (Yes/No)
1) Display Semblance Plot created from CMP gathers in SeisViewer	Yes
2) Display of CMP gathers in SeisViewer	Yes
3) Display Semblance Plot created from Shot gathers in SeisViewer	Yes
4) Display of Shot Gathers in SeisViewer	Yes
5) Save SeisViewer Canvas for use in later Lab Manual Procedures	Yes
Results Between User-Prepared and Published Data Match	Yes



Fugro SPW V&V Results for Procedure 4



Lab Manual Results for Procedure 4 (Figure 6 in Lab Manual Text)

DISPLAY OF SEMBLANCE PLOTS AND CORRESPONDING GATHERS
LAB MANUAL PROCESSING SEQUENCE 4
SPW Software Validation Report

FIGURE 6

4.5 Procedure 5– Picking Velocities On A Semblance Map

Procedure 5 involves a user picking velocities on a semblance plot (previously generated in Procedure 3 and displayed in Procedure 4) while analyzing reflection events on an adjacent CMP gather.

Three steps, all within SeisViewer, were necessary to complete the V&V process for Exercise 5 in the Lab Manual: opening of SeisViewer Canvas saved in Procedure 4, selecting a velocity picks file, and picking velocities on the Semblance plot generated from CMP gathers. All steps were completed successfully (Table 5). Figure 7 shows the agreement between user-generated and published results for Procedure 5.

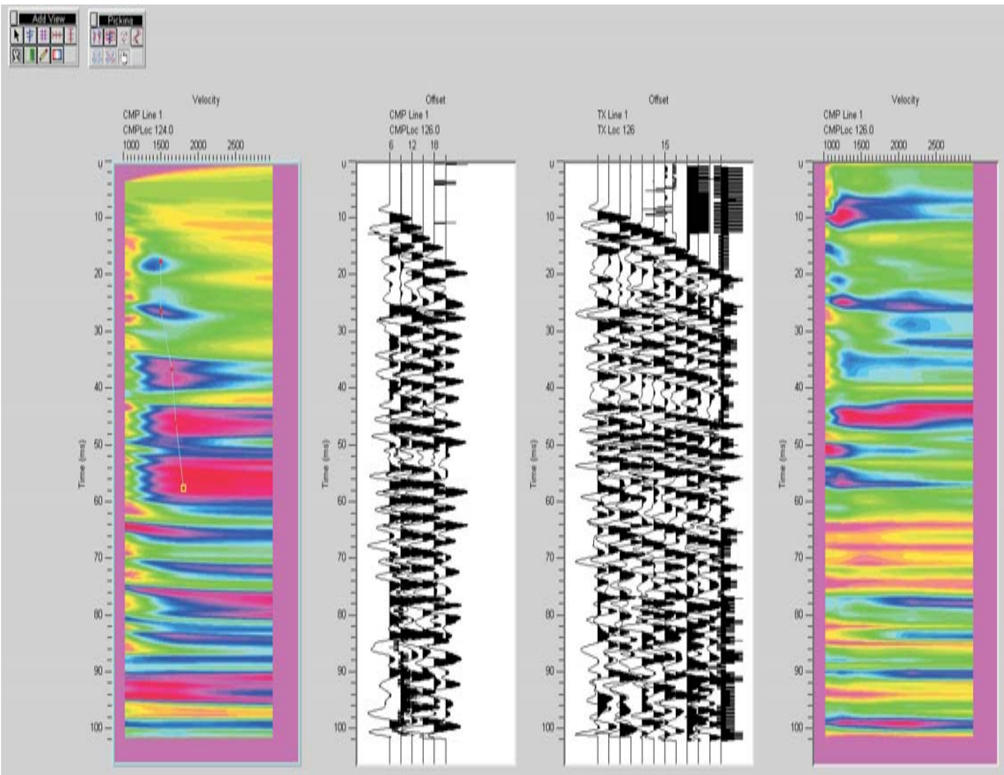
Table 5: Procedure 5 Results

Processing Step	Successful (Yes/No)
1) Open SeisViewer Canvas saved during Procedure 4	Yes
2) Select velocity picks file to be used during velocity analysis	Yes
3) Pick velocities on Semblance plot generated from CMP gathers	Yes
Results Between User-Prepared and Published Data Match	Yes

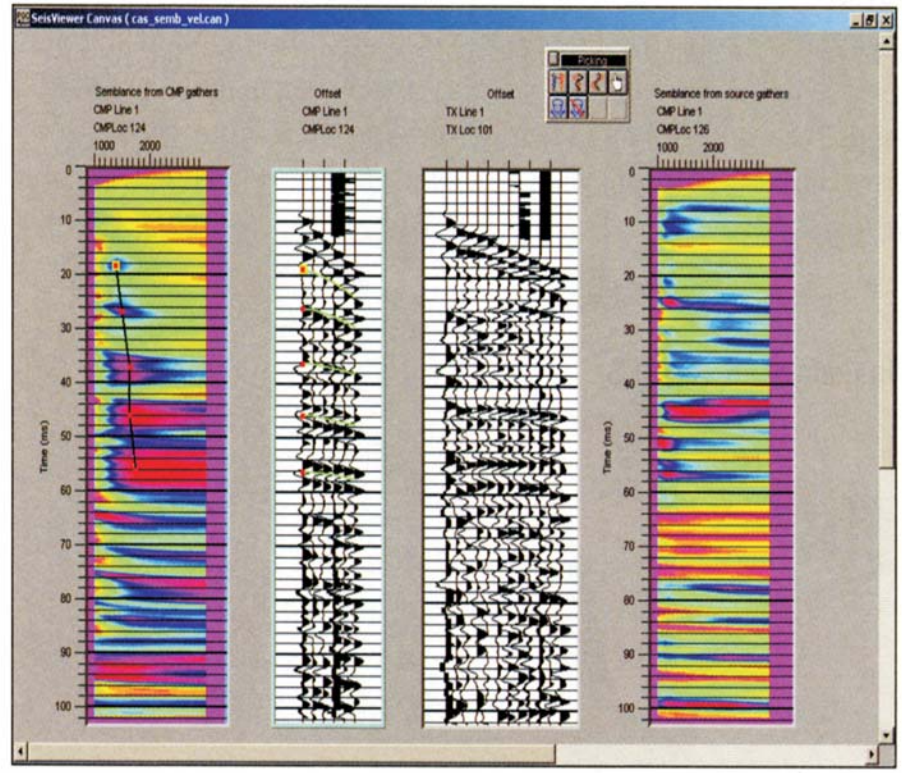
4.6 Procedure 6 – Normal Moveout Correction (NMO) And Stacking CMP Gathers

Typically during an early stage of processing, a QC (or “Brute”) stack will be prepared to serve as a standard against which improvement through further pre-stack processing can be measured. Procedure 6 instructs a user on how to apply an NMO velocity function (picked in Procedure 5) to CMP gathers and create a data stack.

Four steps, all within FlowChart and SeisViewer, were necessary to complete the V&V process for Exercise 6 in the Lab Manual: importing all necessary seismic items into FlowChart, Compiling and Running the processing flow, displaying the NMO and non-NMO corrected gathers in SeisViewer, and comparing the CMP Stack and Common Offset gather. All steps were completed successfully (Table 6). Figures 8 and 9 show the agreement between user-generated and published results for Procedure 6.



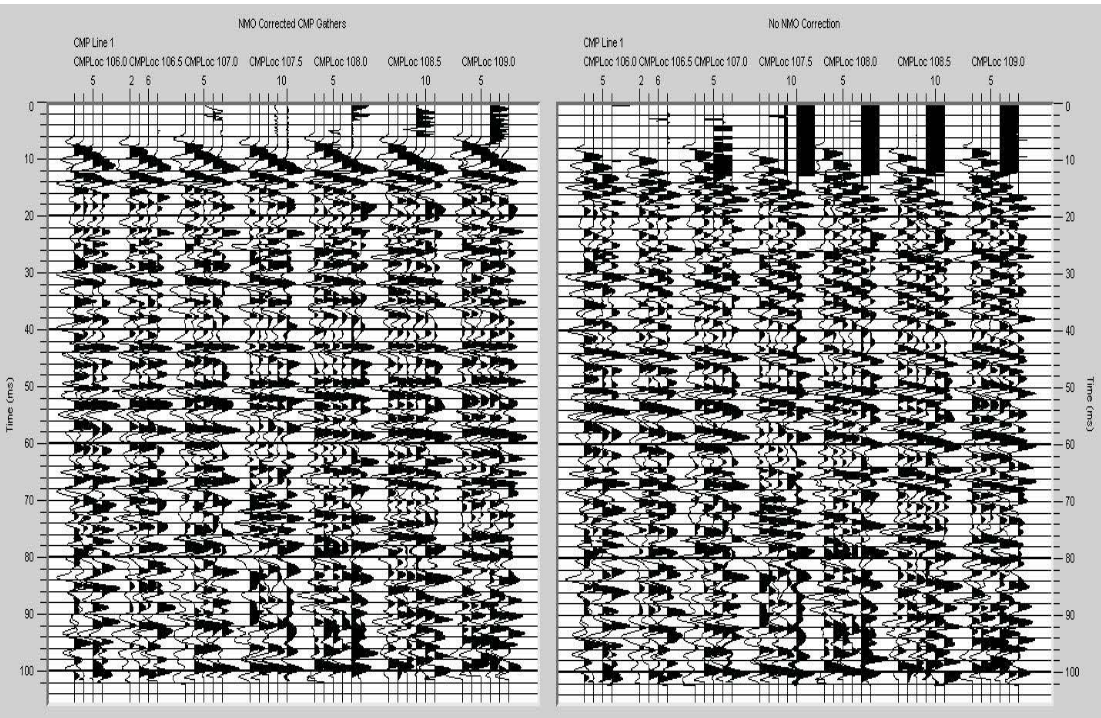
Fugro SPW V&V Results for Procedure 5



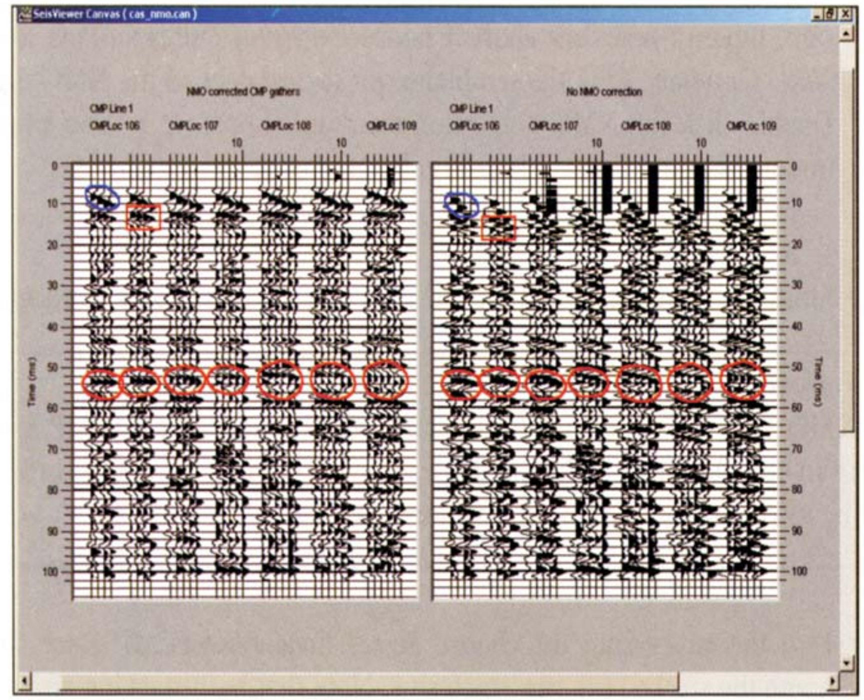
Lab Manual Results for Procedure 5 (Figure 7 in Lab Manual Text)

VELOCITY ANALYSIS AND DISPLAY OF SEMBLANCE PLOTS AND CORRESPONDING GATHERS
LAB MANUAL PROCESSING SEQUENCE 5
SPW Software Validation Report

FIGURE 7



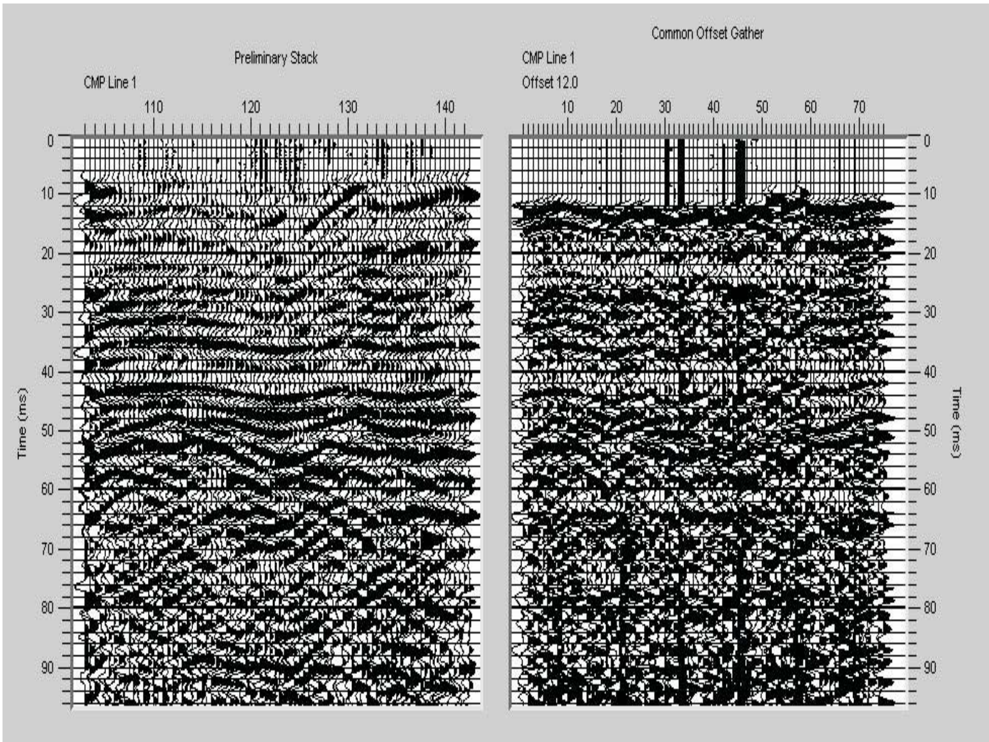
Fugro SPW V&V Results for Procedure 6



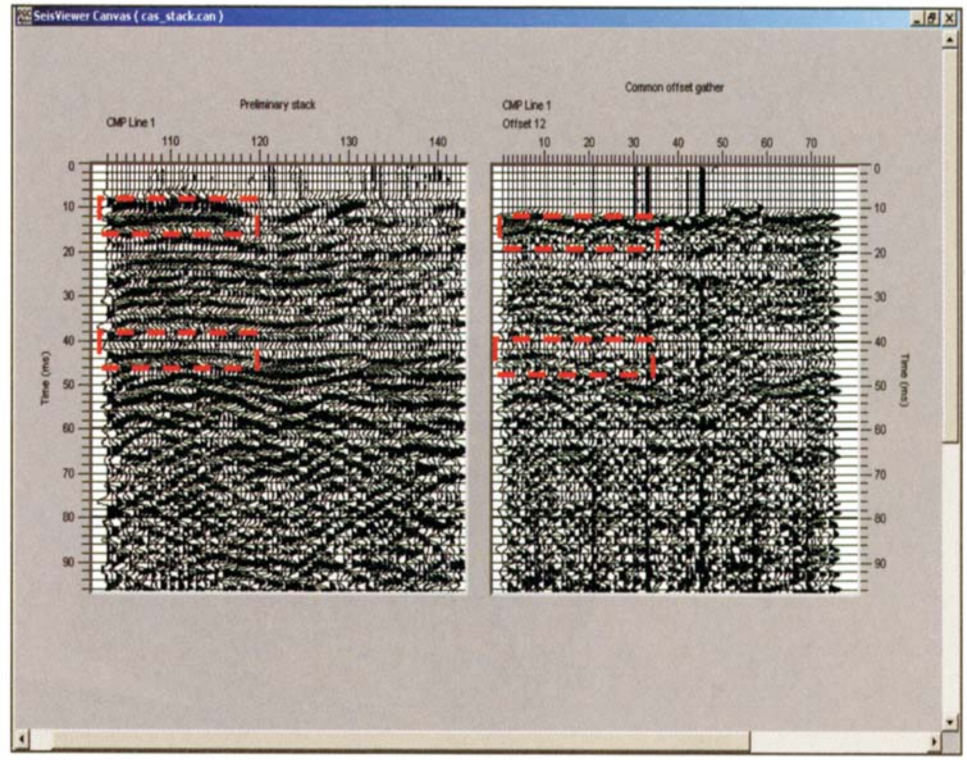
Lab Manual Results for Procedure 6 (Figure 9 in Lab Manual Text)

DISPLAY OF NMO CORRECTED AND NON-NMO CORRECTED CMP GATHERS
LAB MANUAL PROCESSING SEQUENCE 6
SPW Software Validation Report

FIGURE 8



Fugro SPW V&V Results for Procedure 6



Lab Manual Results for Procedure 6 (Figure 10 in Lab Manual Text)

DISPLAY OF CMP STACK AND NON-NMO CORRECTED COMMON OFFSET GATHER
LAB MANUAL PROCESSING SEQUENCE 6
SPW Software Validation Report

FIGURE 9

Table 6: Procedure 6 Results

Processing Step	Successful (Yes/No)
1) Import all necessary flow items into Flow Chart	Yes
2) Compile and Run processing flow in Flow Chart	Yes
3) Compare NMO and non-NMO corrected gathers in SeisViewer	Yes
4) Compare CMP Stack and Common Offset gather in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes

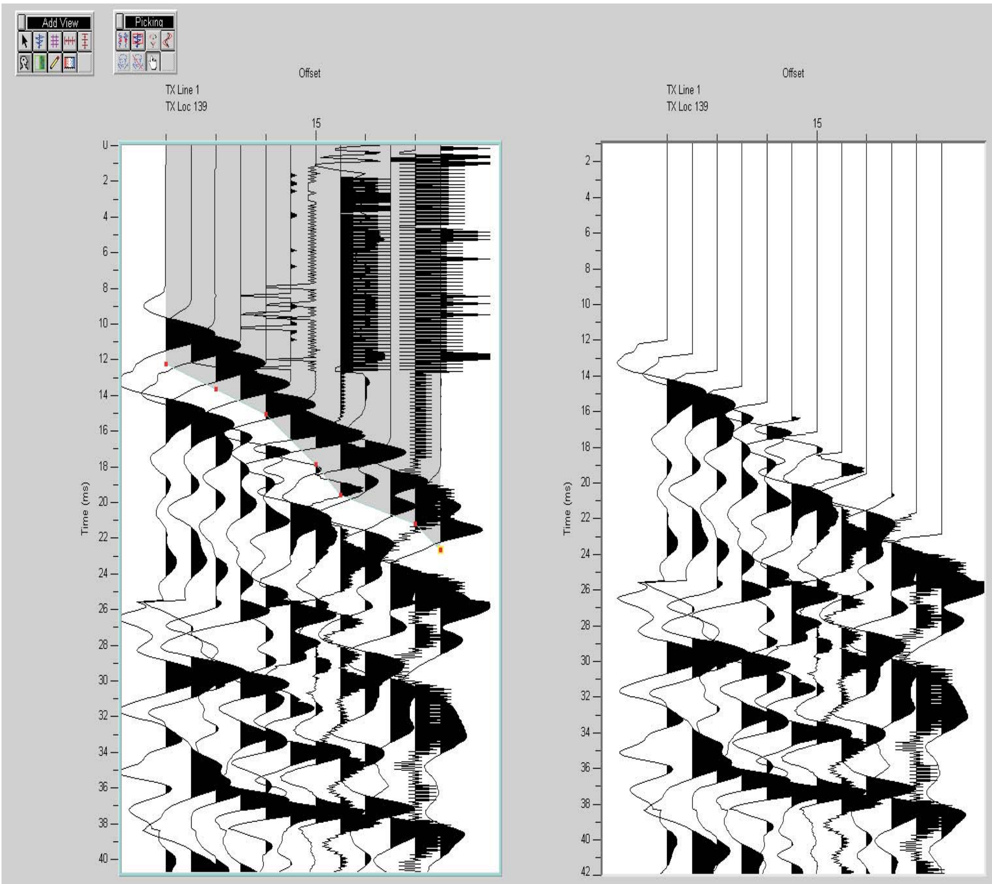
4.7 Procedure 7 – Trace Editing

In some cases, traces from malfunctioning hydrophones may have so small a signal to noise ratio that they degrade a stack. SPW allows for “flagging” of traces to ensure they are muted and not included in the final stack.

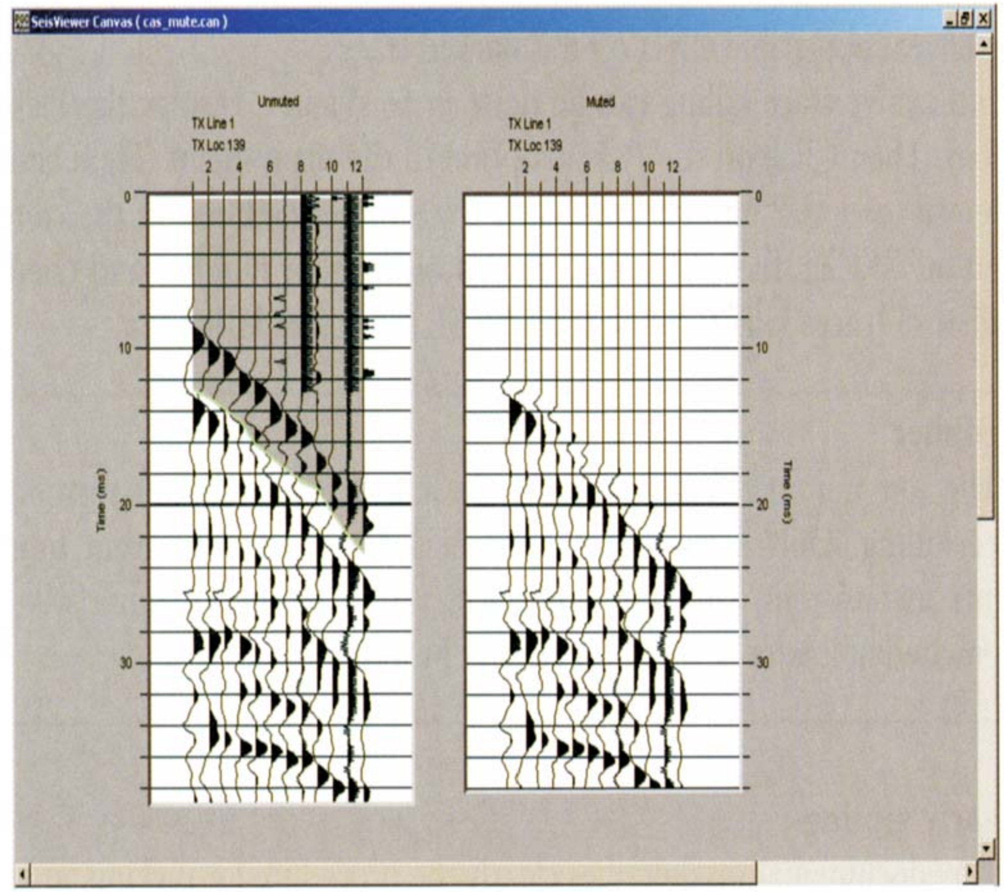
In Procedure 7, early mutes were picked to eliminate unwanted noise above user-picked times on trace gathers. Three steps, all within SeisViewer, were necessary to complete the V&V process for Exercise 7 in the Lab Manual: displaying trace gathers in SeisViewer, picking early mutes and saving a mute picks file, and displaying trace gathers with the mute picks applied. All steps were completed successfully (Table 7). Figure 10 shows the agreement between user-generated and published results for Procedure 7.

Table 7: Procedure 7 Results

Processing Step	Successful (Yes/No)
1) Display Trace Gather in SeisViewer	Yes
2) Select Mute picks file and assign mutes for each trace in gather	Yes
3) Display Trace Gather after mutes have been applied	Yes
Results Between User-Prepared and Published Data Match	Yes



Fugro SPW V&V Results for Procedure 7



Lab Manual Results for Procedure 7 (Figure 11 in Lab Manual Text)

DISPLAY OF UNMUTED AND MUTED TRACE GATHER
LAB MANUAL PROCESSING SEQUENCE 7
SPW Software Validation Report

FIGURE 10

4.8 Procedure 8 – Applying Deconvolution And Bandpass Filtering

Deconvolution and bandpass filtering are two important steps in a typical processing flow used to increase temporal resolution, suppress multiples, and attenuate unwanted low and high frequency noise.

In Procedure 8, five steps were necessary to complete the V&V process within VCalc, SeisViewer, and FlowChart: selecting traces within SeisViewer, analyzing the amplitude spectrum of a seismic dataset in VCalc, testing deconvolution parameters, applying deconvolution, and applying a post-deconvolution bandpass filter. All steps were completed successfully (Table 8). Figures 11, 12, and 13 show the agreement between user-generated and published results for Procedure 8.

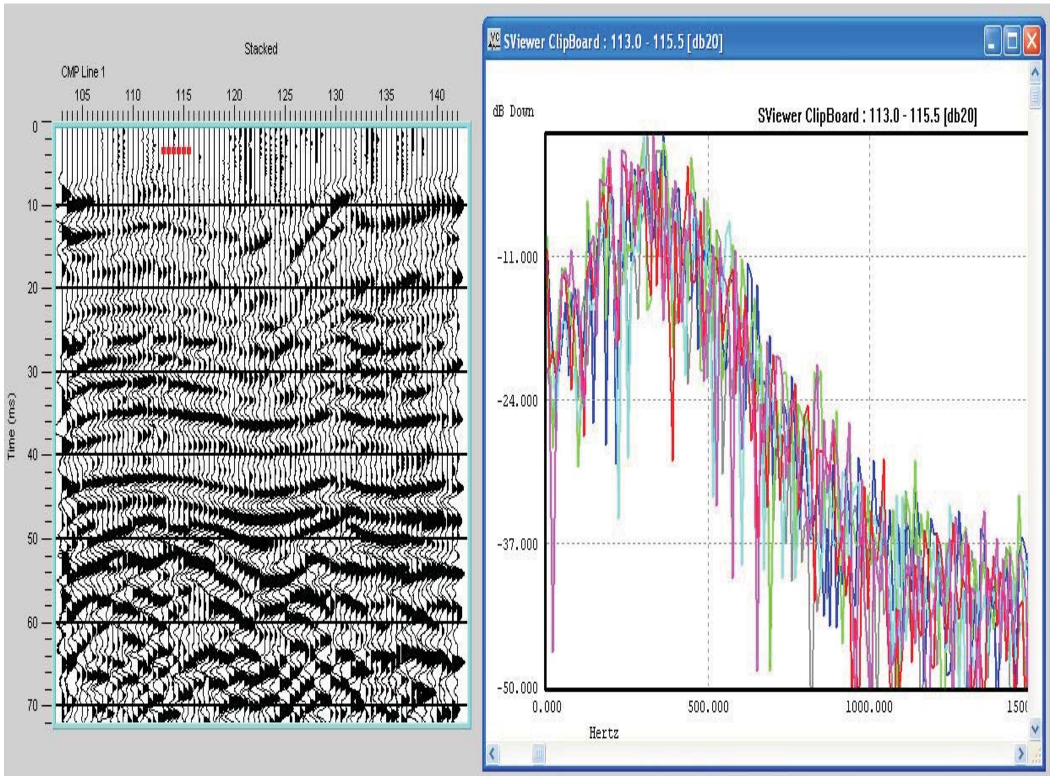
Table 8: Procedure 8 Results

Processing Step	Successful (Yes/No)
1) Select Traces in SeisViewer	Yes
2) Calculate and Display Amplitude Spectrum in VCalc	Yes
3) Test Deconvolution Parameters	Yes
4) Apply Deconvolution	Yes
5) Apply Post-Deconvolution Bandpass Filter	Yes
Results Between User-Prepared and Published Data Match	Yes

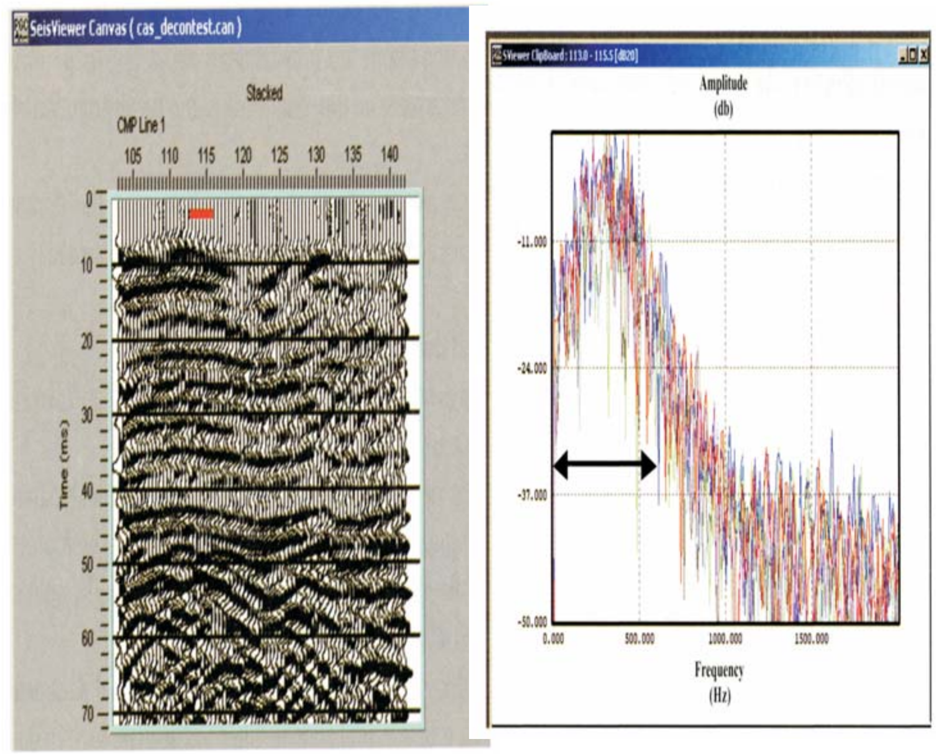
4.9 Procedure 9 – Residual Static Correction

Applying a static correction to a seismic dataset improves the alignment of reflection events along common hyperbolas by removing small trace-to-trace variations in arrival times. A static correction was used previously to process the 2D data in 2011, and was found to greatly increase the alignment and correlation of subsurface reflection events on stacked CMPs.

In Procedure 9, static corrections were applied to trace gathers to improve the agreement between common reflection events on adjacent traces. Procedure 9 was comprised of 3 steps in FlowChart and SeisViewer: calculating residual statics, applying statics to trace gathers, and displaying uncorrected and static corrected trace gathers in a SeisViewer canvas. All steps were completed successfully (Table 9). Figure 14 shows the agreement between user-generated and published results for Procedure 9.



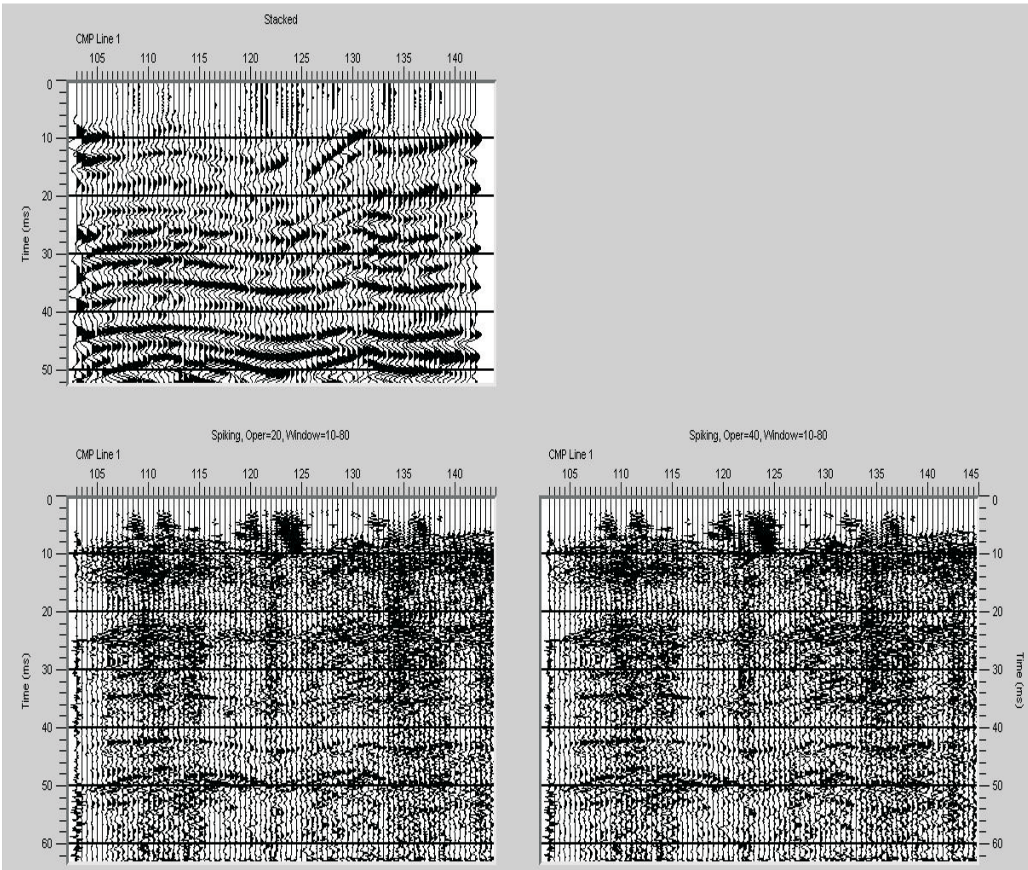
Fugro SPW V&V Results for Procedure 8



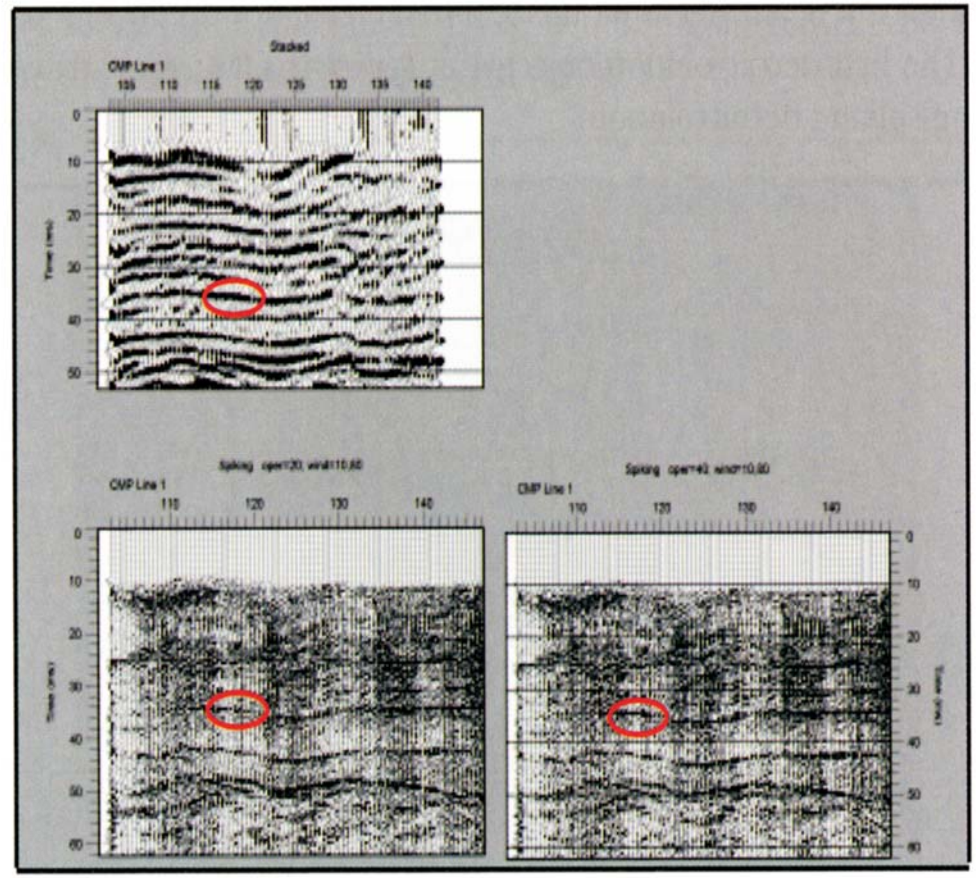
Lab Manual Results for Procedure 8 (Figures 12 and 13 in Lab Manual Text)

PICKED TRACES AND CALCULATED AMPLITUDE SPECTRUM
LAB MANUAL PROCESSING SEQUENCE 8
SPW Software Validation Report

FIGURE 11



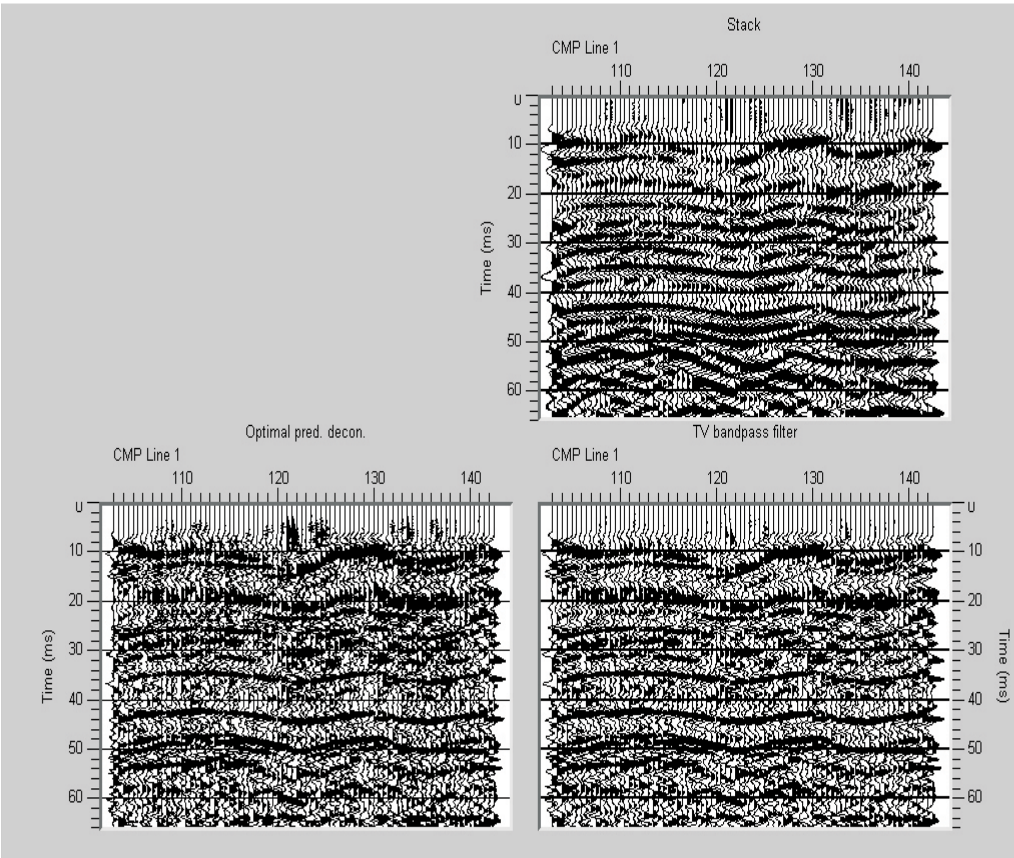
Fugro SPW V&V Results for Procedure 8



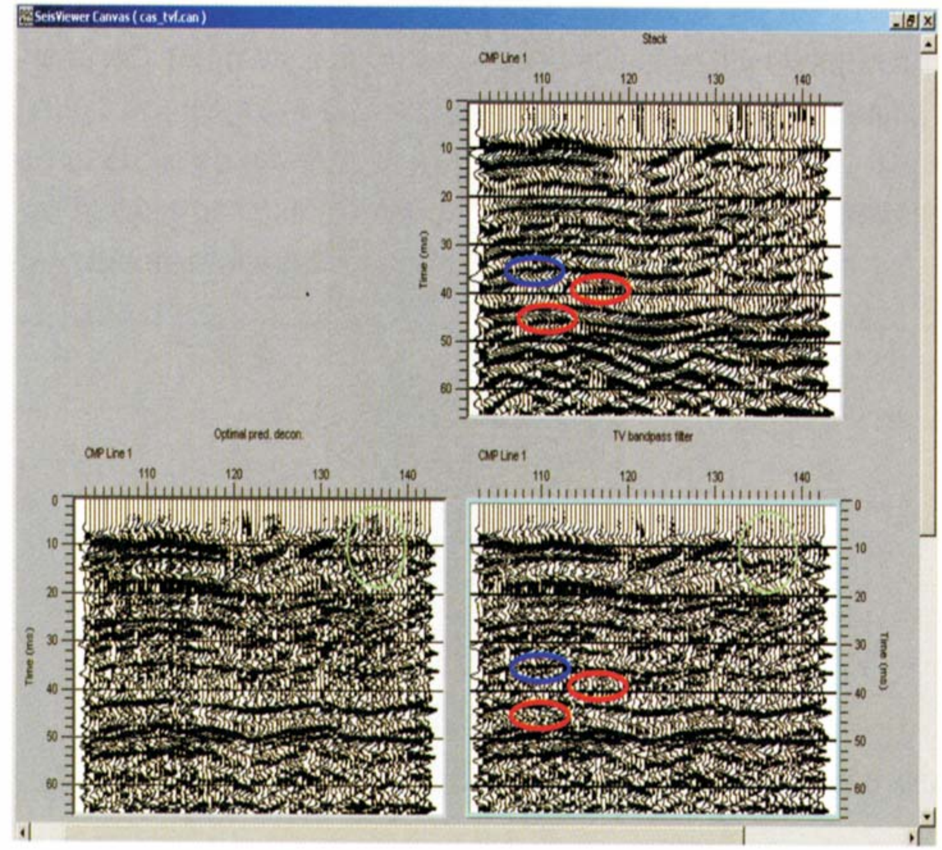
Lab Manual Results for Procedure 8 (Figure 15 in Lab Manual Text)

DISPLAY OF STACKED DATA USING DIFFERENT DECONVOLUTION PARAMETERS
LAB MANUAL PROCESSING SEQUENCE 8
SPW Software Validation Report

FIGURE 12



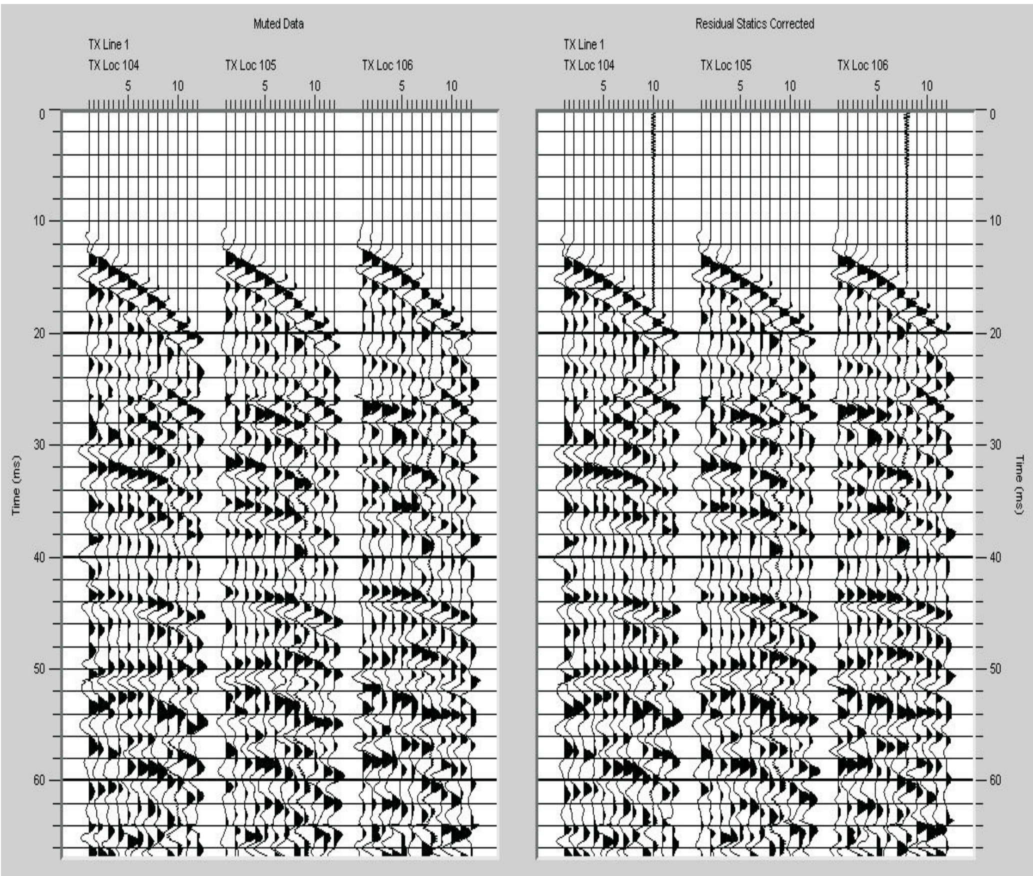
Fugro SPW V&V Results for Procedure 8



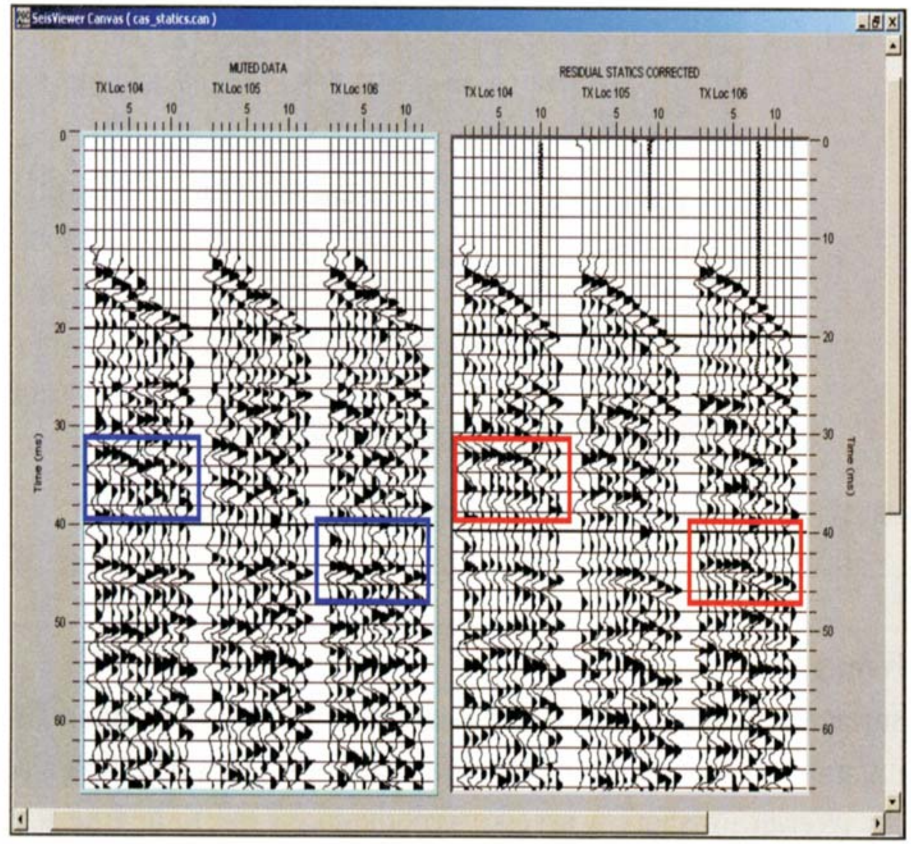
Lab Manual Results for Procedure 8 (Figure 23 in Lab Manual Text)

DISPLAY OF STACKED DATA AFTER DECONVOLUTION AND BANDPASS FILTERING
LAB MANUAL PROCESSING SEQUENCE 8
SPW Software Validation Report

FIGURE 13



Fugro SPW V&V Results for Procedure 9



Lab Manual Results for Procedure 9 (Figure 27 in Lab Manual Text)

DISPLAY OF GATHER DATA BEFORE AND AFTER STATIC CORRECTION
LAB MANUAL PROCESSING SEQUENCE 9
SPW Software Validation Report

FIGURE 14

Table 9: Procedure 9 Results

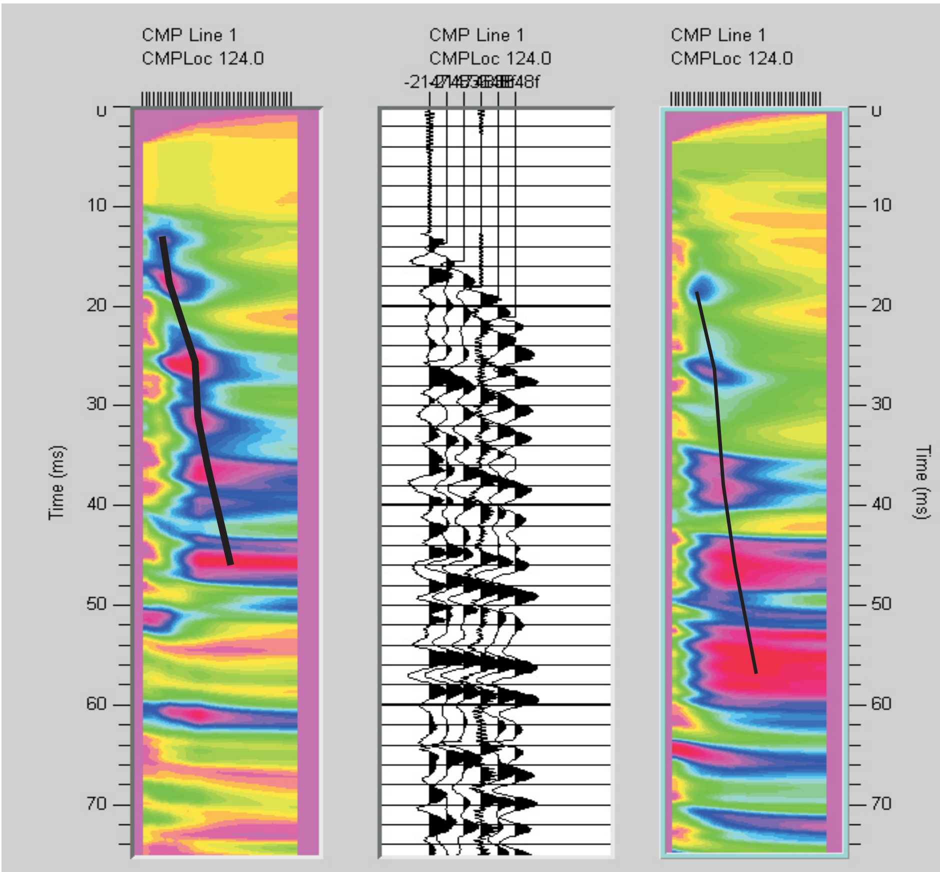
Processing Step	Successful (Yes/No)
1) Calculate Residual Statics in FlowChart	Yes
2) Apply Residual Statics in FlowChart	Yes
3) Display Corrected and Uncorrected Gathers in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes

4.10 Procedure 10 – Second Pass Velocity Analysis

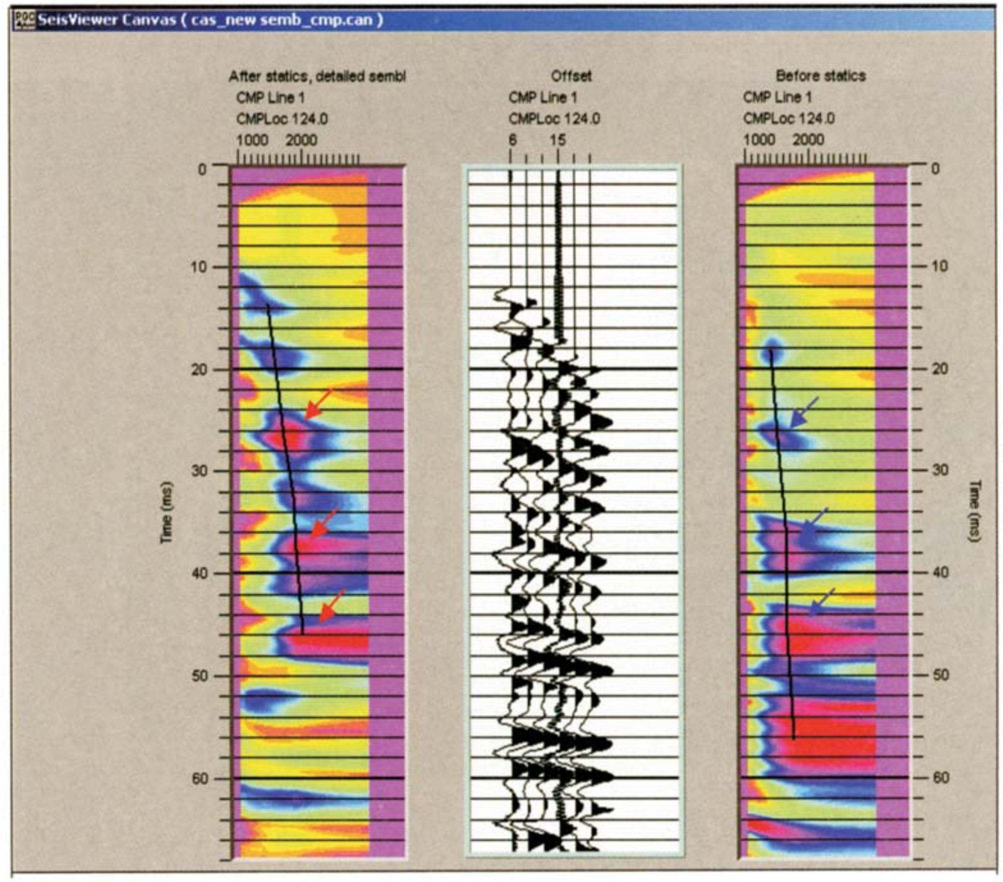
Procedure 10 follows the same sequence as Procedure 5, except semblance plots were generated with static-corrected gathers rather than raw gathers, based on the assumption that reflection events were better aligned down each trace after static correction application. Procedure 10 was comprised of 3 steps in FlowChart and SeisViewer: compiling and running a flow to generate new semblance gathers from static corrected data using FlowChart, velocity analysis in SeisViewer, and comparing a static corrected stack with a static uncorrected stack in SeisViewer. All steps were completed successfully (Table 10). Figures 15 and 16 show the agreement between user-generated and published results for Procedure 10.

Table 10: Procedure 10 Results

Processing Step	Successful (Yes/No)
1) Compile and run flow generating new semblance gathers in FlowChart	Yes
2) Velocity Analysis in SeisViewer	Yes
3) Display Preliminary Stack and Static-Corrected Stack in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes



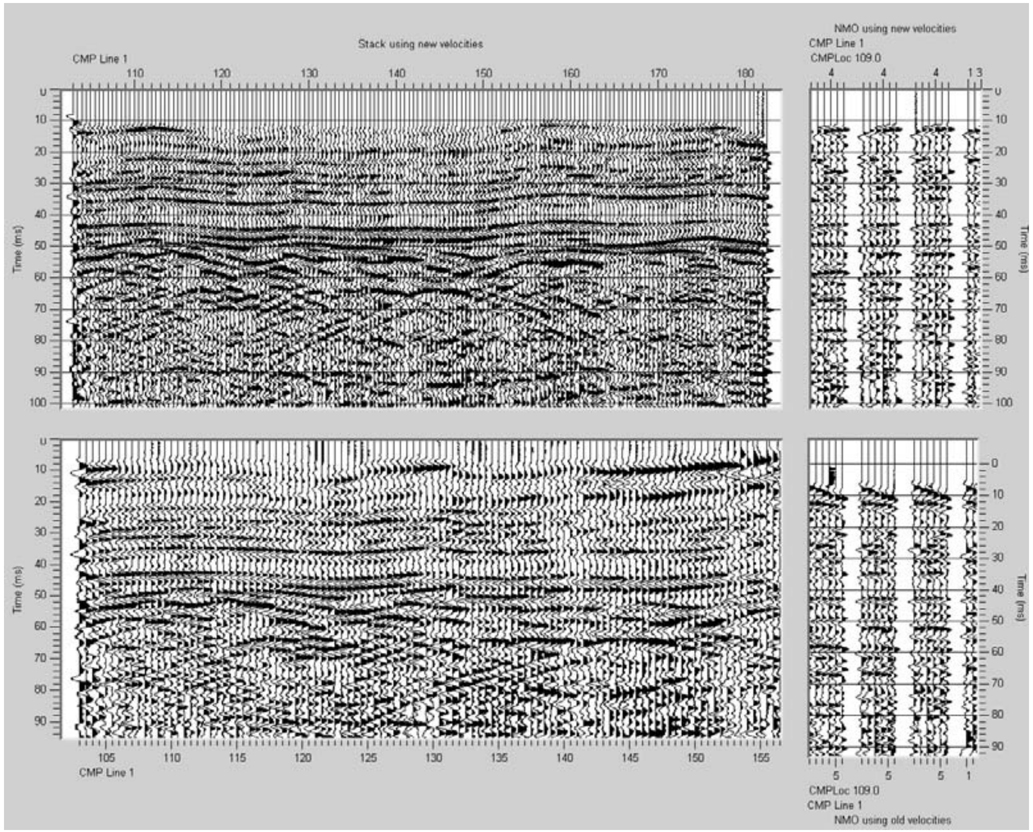
Fugro SPW V&V Results for Procedure 10



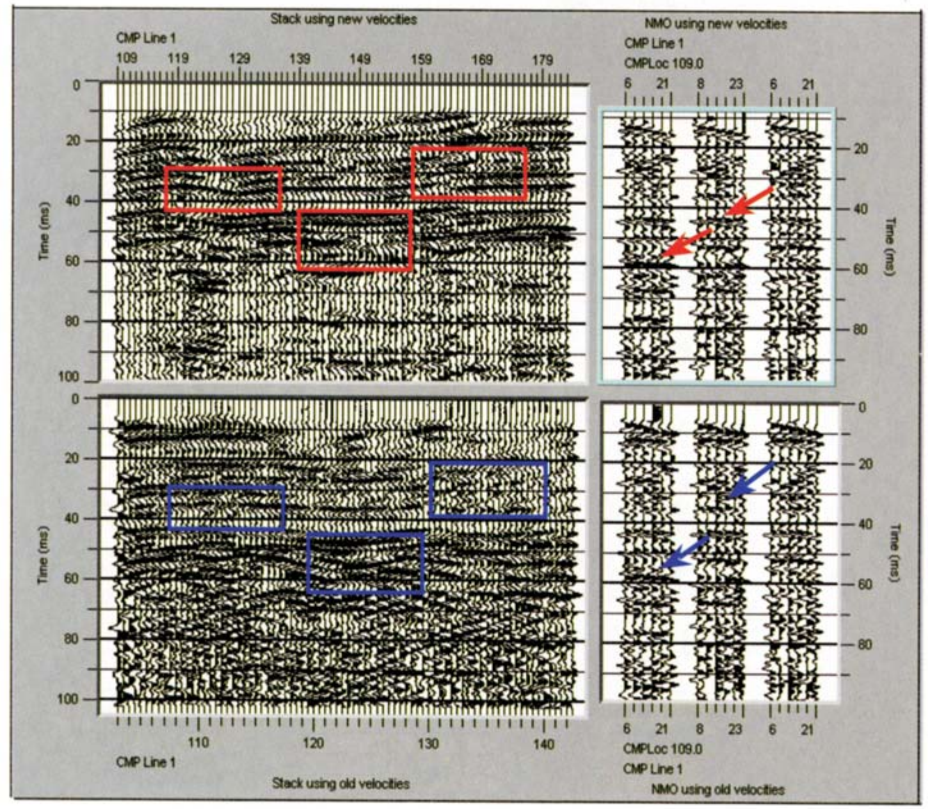
Lab Manual Results for Procedure 10 (Figure 30 in Lab Manual Text)

DISPLAY OF SECOND PASS VELOCITY ANALYSIS IN SEISVIEWER
LAB MANUAL PROCESSING SEQUENCE 10
SPW Software Validation Report

FIGURE 15



Fugro SPW V&V Results for Procedure 10



Lab Manual Results for Procedure 10 (Figure 31 in Lab Manual Text)

COMPARISON DISPLAY OF STACKS BEFORE AND AFTER STATIC CORRECTION
LAB MANUAL PROCESSING SEQUENCE 10
SPW Software Validation Report

FIGURE 16

4.11 Procedure 11 – FINAL STACK

Procedure 11 serves as a composite exercise that combined most steps from previous labs (trace editing, static correction, NMO correction, deconvolution, etc.) into a flow executed as a single step. This procedure served as a final QC that all elements of FlowChart functioned properly within a single linked flow.

Procedure 11 was comprised of 2 steps in FlowChart and SeisViewer: compiling and running a flow containing all elements from previous exercises in FlowChart, and displaying the brute stack and final stack in SeisViewer. Both steps were completed successfully (Table 11). Figures 17 and 18 show the agreement between user-generated and published results for Procedure 11.

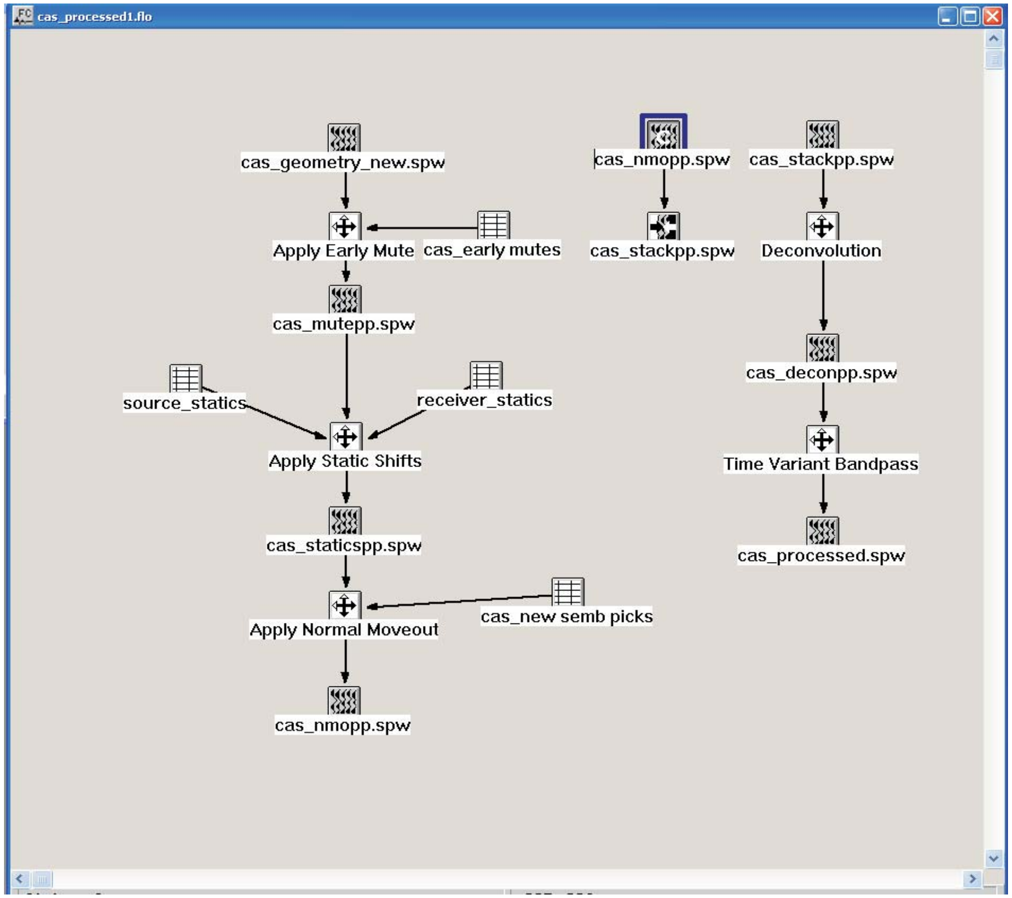
Table 11: Procedure 11 Results

Processing Step	Successful (Yes/No)
1) Compile and run flow generating with elements from previous Exercises in FlowChart	Yes
2) Compare Stacks in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes

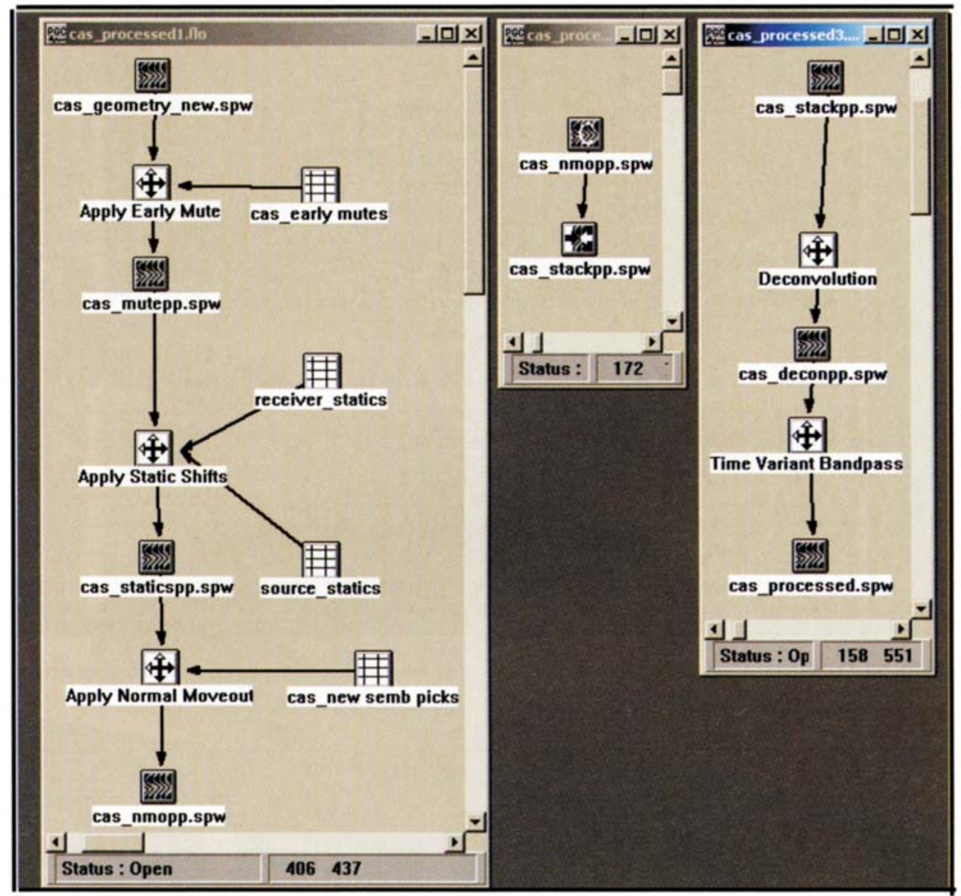
4.12 Procedure 12 – Post Stack Time Migration

The final exercise in the Lab Manual involved applying migration to the stacked seismic section created in Procedure 11. Data migration is a processing algorithm used to reposition reflections to their correct location and restore dip and length that may not have been preserved during stacking of a seismic section.

Procedure 12 was comprised of 2 steps in FlowChart and SeisViewer: compiling and running a flow applying migration to a stacked seismic section in FlowChart, and displaying the migrated and stacked seismic sections in SeisViewer. Both steps were completed successfully (Table 12). Figure 19 shows the agreement between user-generated and published results for Procedure 12.



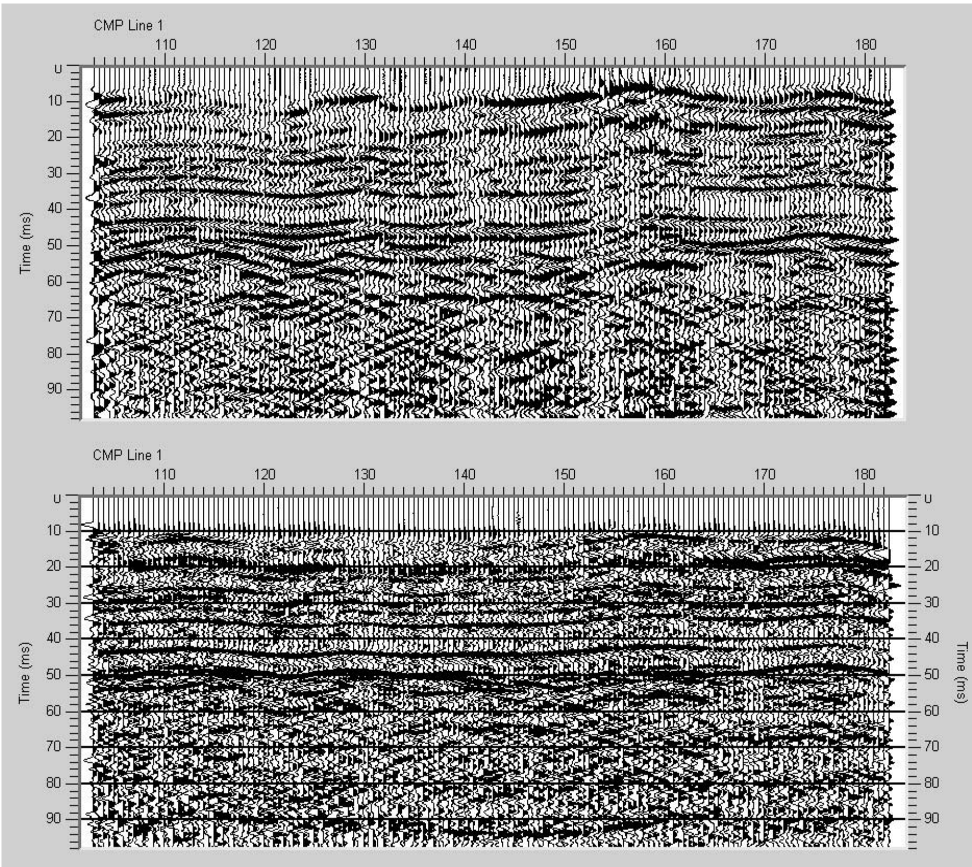
Fugro SPW V&V Results for Procedure 11



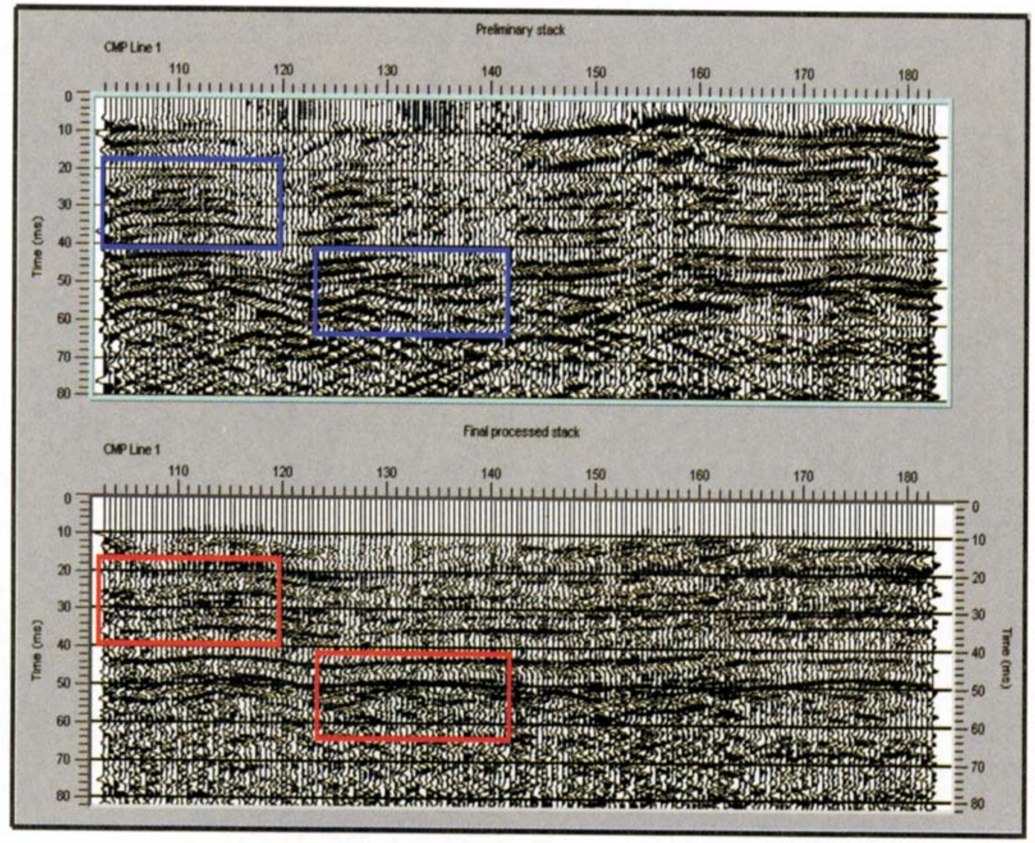
Lab Manual Results for Procedure 11 (Figure 32 in Lab Manual Text)

COMPARISON OF BRUTE STACK (EXERCISE 6) AND FINAL PROCESSED STACK
LAB MANUAL PROCESSING SEQUENCE 11
SPW Software Validation Report

FIGURE 17



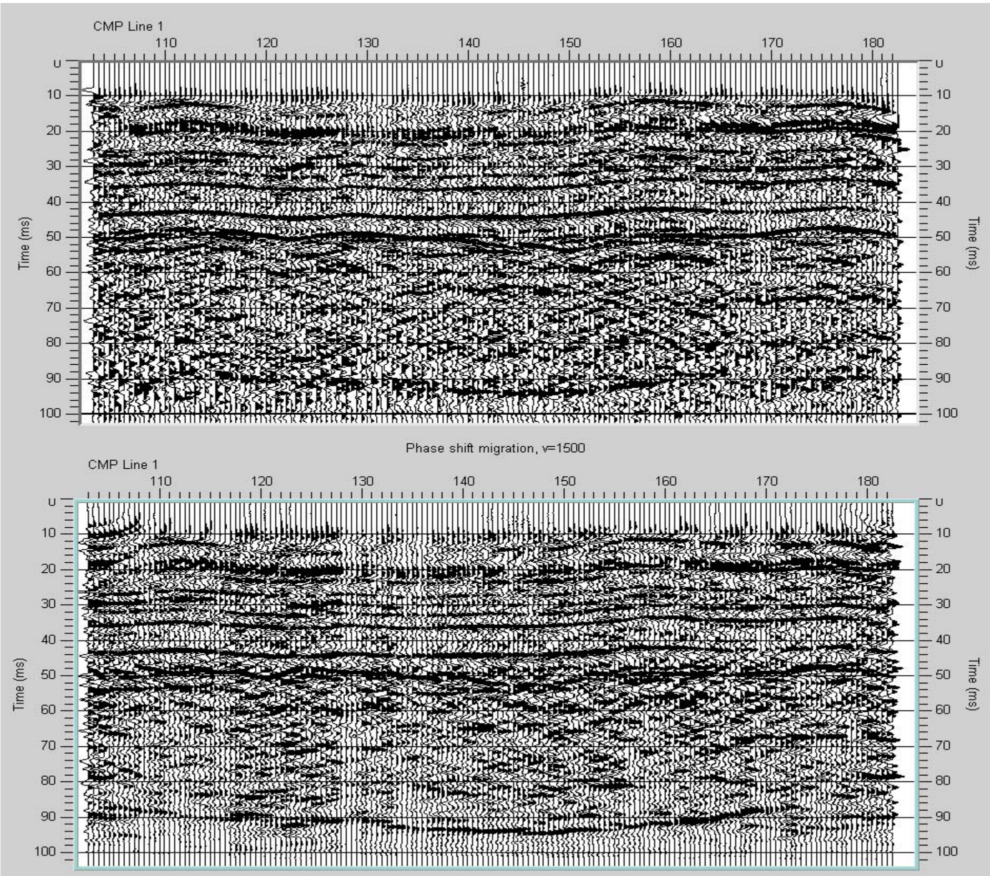
Fugro SPW V&V Results for Procedure 11



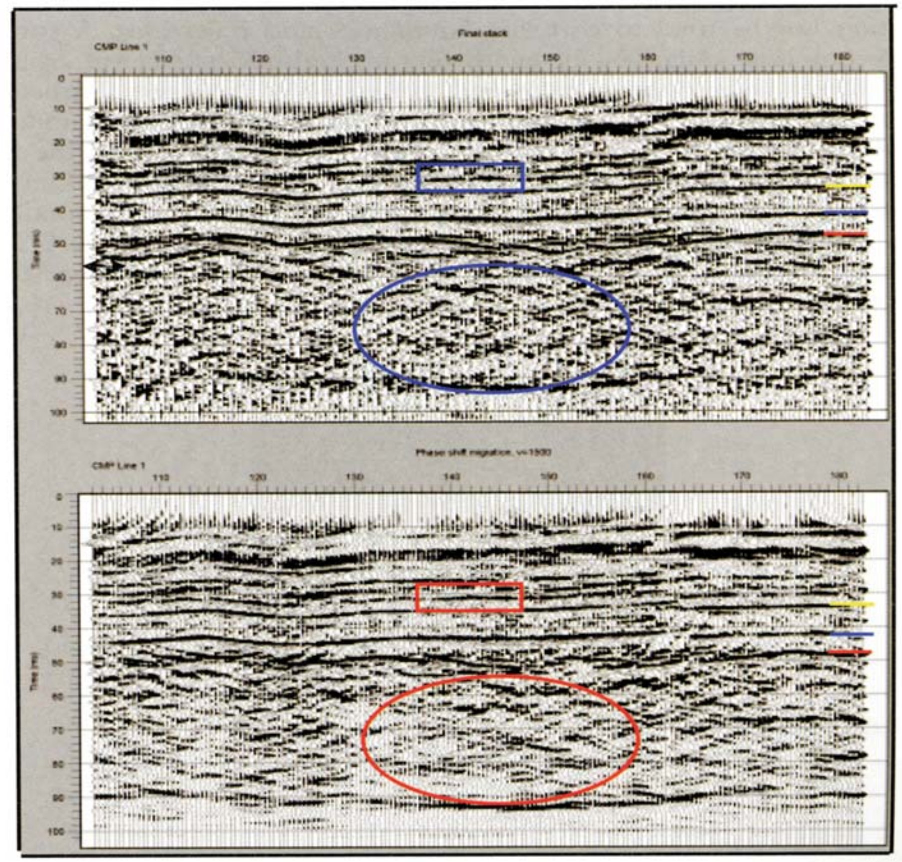
Lab Manual Results for Procedure 11 (Figure 33 in Lab Manual Text)

COMPARISON OF BRUTE STACK (EXERCISE 6) AND FINAL PROCESSED STACK
LAB MANUAL PROCESSING SEQUENCE 11
SPW Software Validation Report

FIGURE 18



Fugro SPW V&V Results for Procedure 12



Lab Manual Results for Procedure 12 (Figure 35 in Lab Manual Text)

COMPARISON OF FINAL STACKED AND MIGRATED SEISMIC SECTIONS
LAB MANUAL PROCESSING SEQUENCE 12
SPW Software Validation Report

FIGURE 19

Table 12: Procedure 12 Results

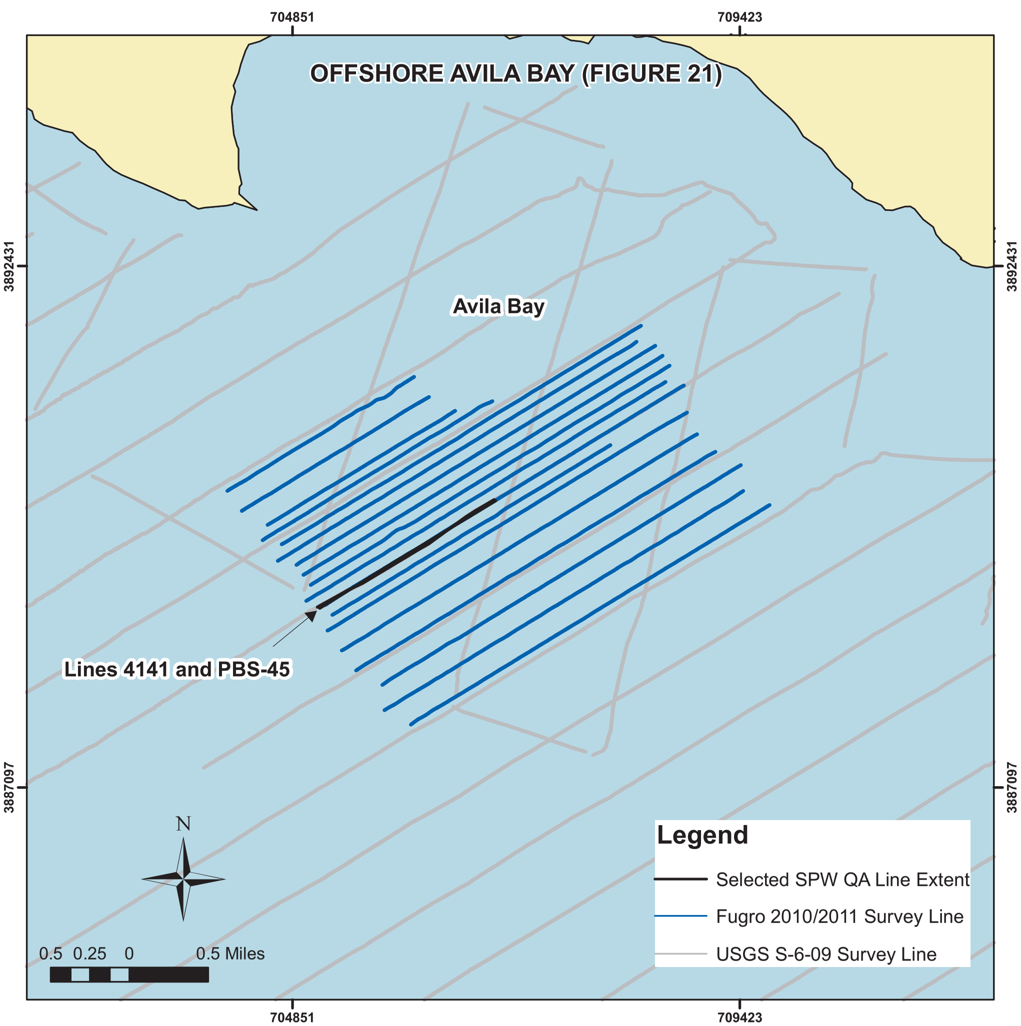
Processing Step	Successful (Yes/No)
1) Compile and run flow generating migrated seismic section in FlowChart	Yes
2) Compare migrated and stacked seismic sections in SeisViewer	Yes
Results Between User-Prepared and Published Data Match	Yes

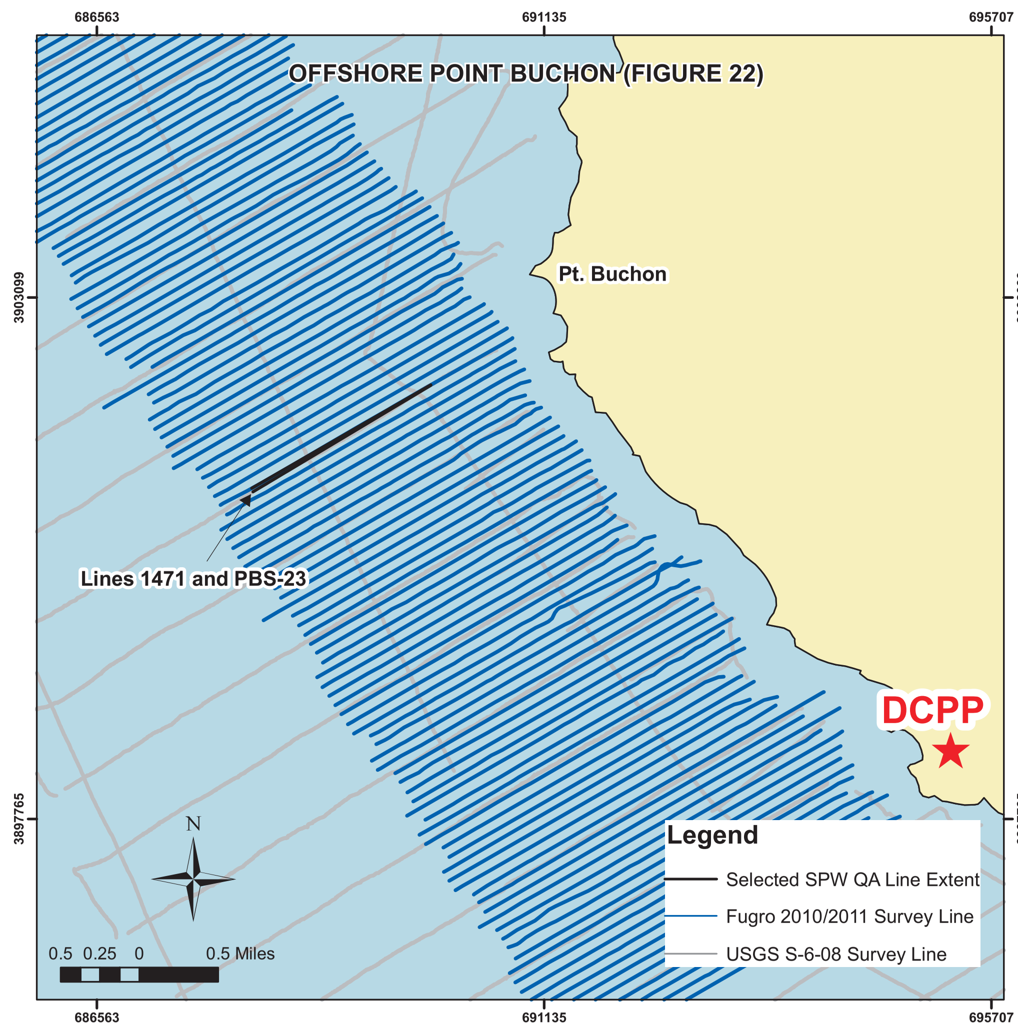
5.0 QUALIFICATION OF 2010-2011 2D SEISMIC DATA

In 2010 and 2011 Fugro West collected 3D and 2D low-energy seismic reflection data in the vicinity of Point Buchon and in northern San Luis Bay for PG&E (Fugro Consultants, 2012 a-c). PG&E anticipates using these data in safety-related activities such as data interpretation and analysis. The 3D data were processed by Fugro Seismic Imaging using UNISEIS software (Fugro Consultants, 2012b). UNISEIS software was validated and the 3D dataset was qualified in FCL Report No. PGEQ-PR-03 (Fugro Consultants, 2012d). SPW software was used by FCL for processing the 2D data, and is validated in Section 4 of this report. Given that PG&E desires to use the 2D data results in safety-related applications, data collection, data processing software and the interpretation and analysis software are being qualified in accordance with ASME NQA-1-2008, Part III, Subpart 3.3, Non-mandatory Appendix 3.1, "Guidance on Qualification of Existing Data," using the qualification method of data corroboration. The qualification process is based on data comparisons between 2D survey lines collected by FCL for PG&E in 2010-2011 and published 2D data collected by others.

Qualification of the processed 2010/2011 Fugro 2D data was accomplished by comparing final processed seismic sections against published data collected by the United States Geologic Survey (USGS). The USGS collected high-resolution 2D single-channel mini-sparker data in 2008 and 2009 (Sliter et al., 2009, revised 2010) between Cambria and Point Sal, offshore Central California. Several of the USGS survey line locations corresponded to 2010/2011 Fugro 2D line locations. Fugro 2D Lines 4141 and 1471 were compared to USGS Lines PBS-45 and PBS-23 (Figure 20). Since the USGS 2D dataset was collected with a mini-sparker source and the Fugro 2D Survey data collected were collected with a triple-plate boomer source, the phase of the two seismic datasets cannot properly be compared due to the difference in acoustic signatures of the source wavelets. However, imaged subsurface physiographic and geologic features were not affected by the difference in signal phase between the two datasets.

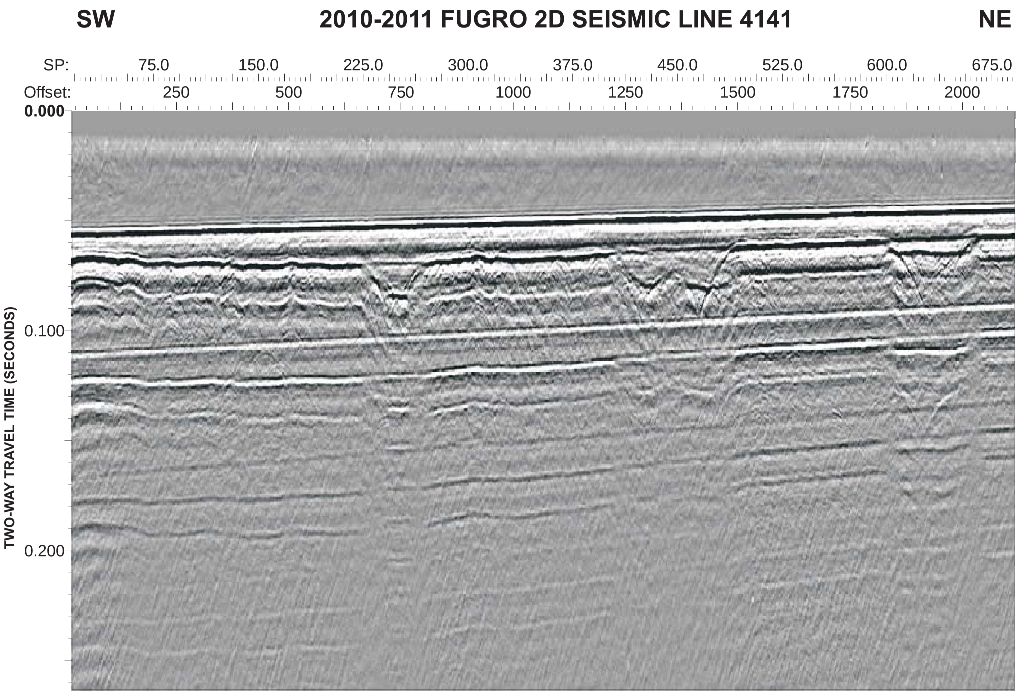
Physiographic features such as paleochannels eroded into pre-Holocene bedrock are visible and are in the same location on both the USGS and PG&E low-energy 2D data (Figure 21) . Geologic features such as folded tertiary strata are enhanced and more continuous when viewed in the PG&E 2D (triple plate boomer) seismic profiles in comparison with the USGS sparker data (Figure 22). Structural relationships such as anticlines and syncline are also visible in the same geographic location on both the Fugro and USGS data (Figure 22). Given this data corroboration, the 2010/2011 2D seismic dataset is thus qualified for use in nuclear safety-related evaluations of seismic hazards.

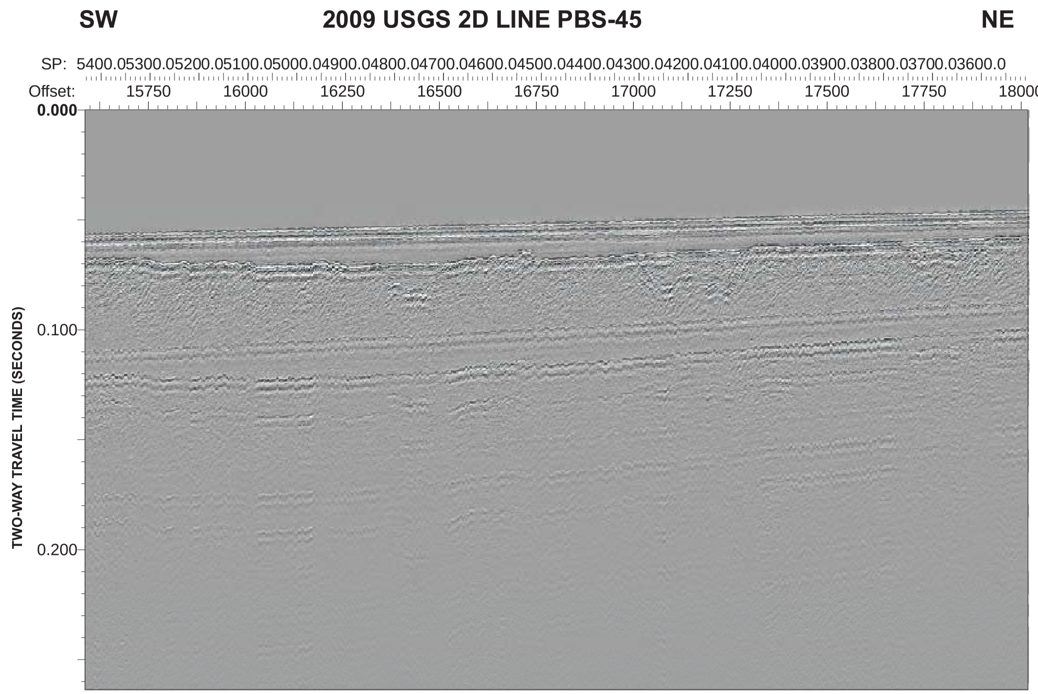




MAP SHOWING LOCATION OF PUBLISHED USGS 2D SPARKER SEISMIC DATA EXAMPLES AND PROCESSED FUGRO 2D SEISMIC DATA EXAMPLES OFFSHORE AVILA BAY AND POINT BUCHON
SPW Software Validation Report

FIGURE 20

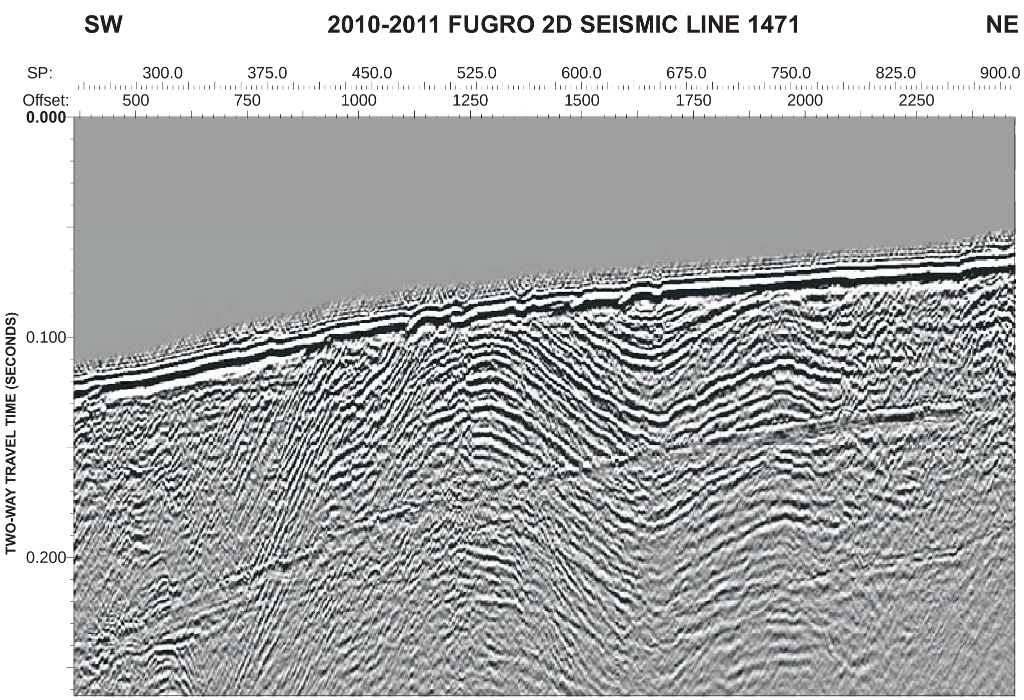


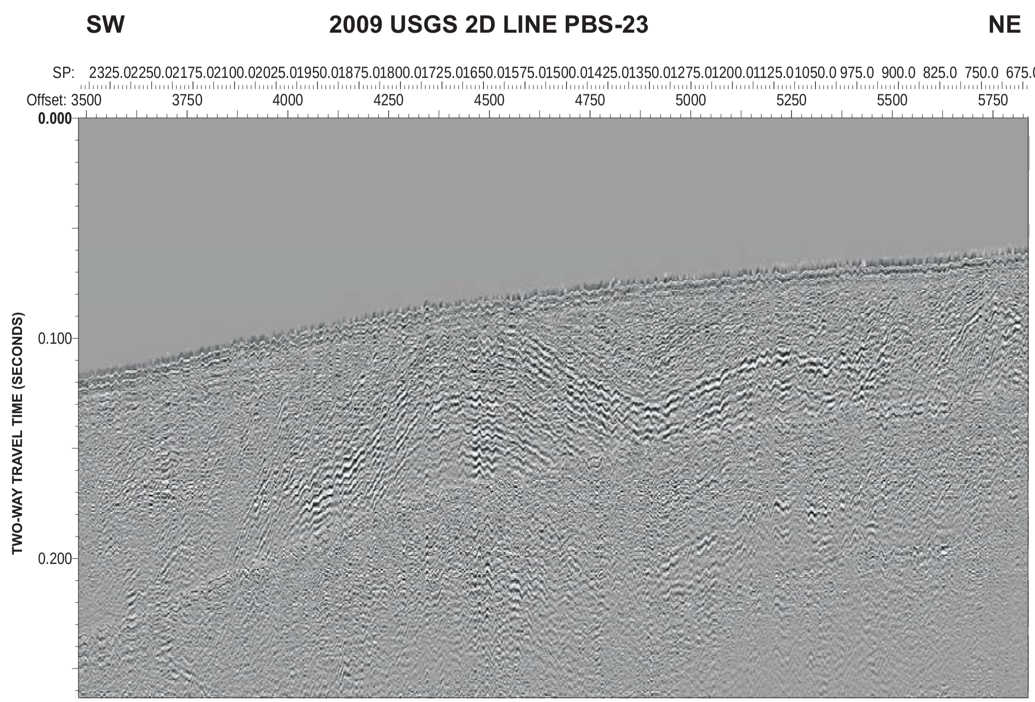


Refer to Figure 20 for Survey Line Extent Locations

COMPARISON PLOT OF 2010/2011 FUGRO 2D LINE 4141 AND 2009 USGS LINE PBS-45
SHOWING SIMILAR SUBSURFACE GEOLOGY OFFSHORE AVILA BAY
SPW Software Validation Report

FIGURE 21





Refer to Figure 20 for Survey Line Extent Locations

COMPARISON PLOT OF 2010/2011 FUGRO 2D LINE 1471 AND 2008 USGS LINE PBS-23
SHOWING SIMILAR SUBSURFACE GEOLOGY OFFSHORE POINT BUCHON
SPW Software Validation Report

FIGURE 22

6.0 CONCLUSIONS

This 2D data processing software validation exercise for SPW was performed in accordance with FCL's PGEQ-PI-09 SPW Data Processing Software Validation Plan (Attachment 7 of Fugro, 2012). By reproducing the published data processing results included with the Lab Manual, the SPW software validation exercise has demonstrated that the software is properly functioning during data processing operations. No differences were observed between FCL's data processing results and the solution data files provided by Parallel Geoscience. Furthermore, given that the processing exercises were successfully completed using many of the same TapeIO, FlowChart, SeisViewer, and VCalc processing modules utilized to process the 2010-2011 2D seismic data, we conclude that SPW software is validated for processing 2D seismic reflection data for the CCCSIP.

The PG&E 2010-2011 2D Low-Energy Survey Data processed by FCL has enhanced spatial resolution when compared to the USGS 2D mini-sparker data (Sliter et al., 2009, revised 2010). Detailed geologic features are clearly apparent in the Fugro 2D/3D Survey data, and are not as well imaged in the USGS 2D mini-sparker dataset. This enhanced detail is very important when interpreting offshore geologic structure and stratigraphy in the region near the Diablo Canyon Power Plant.

The data images and statistical data displayed within this report indicate that SPW Processing software applied to the 2010-2011 3D seismic survey data provides comparable to superior imaging of faults and structure, in comparison to public datasets available in the region where the 2010/2011 3D Survey was collected. The 2010/2011 2D seismic dataset is thus qualified for use in nuclear safety-related evaluations of seismic hazards.

In summary SPW software is validated for use in processing seismic data and the PGE 2010-2011 high-resolution 2D data from offshore Point Buchon and San Luis Bay is qualified for nuclear safety-related evaluations of seismic hazards as part of PG&E's Central Coastal California Seismic Imaging Project.

7.0 REFERENCES

ASME NQA-1-1994 Edition, Quality Assurance Requirements for Nuclear Facility Applications, 1994.

Young, R.A. (2004), A Lab Manual of Seismic Reflection Processing, published by the European Association of Geoscientists and Engineers (EAGE Publications), Netherlands, pp. 126 plus CD.

Fugro Consultants, Inc., (2012a), 2D Seismic Data Processing Report, 2010-2011 High-Resolution Marine Survey Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project; Fugro Project No. 04.B0992017; Prepared for PG&E, May 2012.

Fugro Consultants, Inc., (2012b), 3D Seismic Data Processing Report, 2010-2011 High-Resolution Marine Survey Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project; Fugro Project No. 04.B0992017, FSI Report No. 2011-4410 (rev3); Prepared for PG&E, May 2012.

Fugro Consultants, Inc., (2012c), Field Operations Report, 2010 - 2011 High-Resolution Marine Survey, Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project, Fugro Project No. 04.0992017, Prepared for PG&E, May 2012.

Fugro Consultants, Inc., (2012d), Software Validation of Uniseis and 3D Data Qualification of 2010-2011 High-Resolution Marine Survey Data Offshore Diablo Canyon Power Plant, Central Coastal California Seismic Imaging Project, FCL Job No. 04.64110031, FCL Report No. PGEQ-PR-03, FSI Project No. 2011-4493, June (Rev0).

Fugro Consultants, Inc., (2012e), PGEQ-PI-09 (Attachment 7) SPW Data Processing Software Validation Plan.

Sliter, Triezenberg, Hart, Watt, Johnson, and Scheirer (2009, revised 2010), High-Resolution Seismic-Reflection and Marine Magnetic Data Along the Hosgri Fault Zone, Central California: U.S. Geological Survey Open File Report 2009-2010, version 1.1 http://pubs.usgs.gov/of/2009/1100/

Appendix A

Corrections to Lab Manual Text

Corrections to

A Lab Manual of Seismic Processing

Roger A. Young

2004 EAGE Publications

ISBN 90-73781-34-5

August 2006

The **Lab Manual** uses the Seismic Processing Workshop (SPW) software package to process a near-surface 2-D, reflection dataset from Canada.	The **Lab Manual** comprises material from 12 lab sessions intended to be a self-contained package suitable for individual or group use. The accompanying CD-ROM contains ***1)*** the seismic file for the Casselman survey in SEG-Y format. ***2)*** all SPW files generated by processing in each lab ***3)*** the SPW executable code (v.2.0.3) which will execute the Casselman dataset only ***4)*** all PGC documentation normally bundled with the SPW executable code.	The **Lab Manual** was written in 2004 using SPW version 1.8.19 and version 2.0.3. Later versions of SPW will show some differences in the format of interactive spreadsheets. These differences are generally minor and their impact on the SPW Lab Manual processing flows is small. To download the latest version of SPW see the Parallel Geophysics Corporation website (www.parallelgeo.com).
Page, paragraph in *Manual*	**Erroneous statement**	**Correction**
p.12, para 3	**"Extensive html links permit rapid movement between text and figures and between a list of figures and the figures themselves"**	Disregard sentence: there can be no such links in a hardcopy book.
p. 17, para 4	"To install the software from the CD-ROM, follow instructions given in the file **SPWInstallReadMe.txt**"	"To install the software from the CD-ROM, follow instructions given in the file **SPW Lab Manual README.txt**"
p. 18, para 3	"Locate the folder SPW files**\SPWLa&\)**on the CD-ROM accompanying this manual."	"Locate the folder **Lab Manual.ZIP** on the CD-ROM accompanying this manual." Then unzip entire contents of folder using folder names.
p. 18, para 3	"Copy files cas.**segy**, sx3.tfm, casobs, casrec, cassrc to your user area."	Copy files cas.**spw**, sx3.tfm, casobs, casrec, cassrc to your user area.
p. 20, para 3	"Click **Editing Steps/Geometry Definition** and drag and drop the icon on the flow sheet."	"Click **Geometry/Binning/Geometry Definition** and drag and drop the icon on the flow sheet."
p. 30, para 0	"Choose **Step Animate Forward**".	"Choose **Step/Animate/Forward**."
p.36, para 0	"semblance length 1. ms"	"semblance length 1. **[ms]"**
p. 36	**Wrong** Figure 4	Figure 4
p. 36, para 1	"Choose **16** taper length samples"	"Choose **20** taper length samples"
p. 43, para 4	"Store the output seismic file—the semblance maps of source gathers—**and store** in the seismic file cas_semb_sour.spw."	"Store the output seismic file—the semblance maps of source gathers—in the seismic file cas_semb_sour.spw."
p. 45, para 3	"Only one stacking velocity would have been used at this To, so it would have been **possible impossible** to image both events optimally on the stacked section."	"Only one stacking velocity would have been used at this To, so it would have been **impossible** to image both events optimally on the stacked section."
p. 55, para 4	**"percentage"**	**"percentage (delta f / f)"**
p. 55, para 4	" taper length **15** samples"	" taper length **20** samples"
p. 56, para 1	"Save the flow **cas_stack_flo**, compile it, and execute it."	"Save the flow **cas_stack.flo**, compile it, and execute it."

p. 69, Figure 14	Icon caption reads "**cas_decontest.spw**."	Icon caption should read "**cas_decontest1.spw**."
p. 70, para 0; p. 74 para 2; p. 76, para 1	"Do not click **Range limit trace** "	Disregard instruction: there is no such choice.
p. 70, Figure 15	Figure 15 is **blurry**.	Figure 15
p. 84, para 5	**"percentage"** 130	**"percentage (delta f / f)"** 130
p.86, Figure 26 icon	"**reciever** statics" card deck	**"receiver** statics" card deck
p. 94, Figure 31	There is an apparent mismatch between trace locations for the top and bottom stacked sections.	Top section displays **CMP location** numbers. Bottom section displays **shot location** numbers.
p. 116, Figure 36 caption	"Rays reflecting at the same point for all possible shot/receiver pairs **(red)** define a common midpoint (CMP) gather."	"Rays reflecting at the same point (column of red dots) for all possible shot/receiver pairs define a common midpoint (CMP) gather."
p. 105, Figure 35	Figure 35 is **blurry**.	Figure 35
p. 117, Figure 37	Figure 37 is **blurry**.	Figure 37
	The author is grateful for the assistance of Nicholas Ebner and Matt Ralston for their assistance in identifying parts needing correction.	

Back to Lab Manual Page