3D SEISMIC DATA ACQUISITION & PROCESSING REPORT, SOUTH BRUCE, ONTARIO

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Geofirma Engineering Ltd.

nwmo
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1 INTRODUCTION

Geofirma Engineering Ltd. (Geofirma) has been contracted by the Nuclear Waste Management Organization (NWMO) to implement 3D seismic investigation project of the NWMO Phase 2 Geoscientific Preliminary Field Investigations within the South Bruce Site, near Teeswater, Ontario as part of the NWMO's Adaptive Phased Management (APM) Site Selection Phase.

As part of this work, Geofirma completed a 3D seismic reflection study to provide further understanding and interpretation of deep subsurface geological conditions in the South Bruce Site. The study area for this 3D seismic reflection study is approximately 13.5 km^2 as shown in Figure 1, comprised of land parcels northwest of the community of Teeswater, Ontario.

Geofirma's Team to complete this work included three subcontracting partners: Seismic Solutions (geophysical technical input and design), Echo Seismic Ltd. (Echo Seismic - data acquisition services), and Absolute Imaging (data processing).

1.1 3D Seismic Project Purpose and Objectives

This work was primarily completed to better understand the subsurface geological conditions in the South Bruce Site with a particular focus optimizing the survey design to target the depth range between 500 to 1,000 m below ground surface (mBGS) and to a maximum depth of 1,500 mBGS. This study included P-wave (compression) to acquire geophysical data with sufficiently high-quality and resolution to allow:

- Target and image key sedimentary rock formations (horizons);
- Image and characterize observable seismic reflections. Such reflections may be the result of lithological contrasts within the subsurface or correspond to fault or fractured zones; and,
- Characterize petrophysical properties of sedimentary formations through seismic inversion and geostatistical techniques using deep boreholes (SB_BH01 and SB_BH02) in the area. Physical properties such as velocity, density, and porosity, as well as dynamic Young's and Bulk moduli are derived from seismic inversion.

A broader objective of this work is to assist the NWMO in evaluating this site as a potential location where Canada's used nuclear fuel can be safely stored and managed in a deep geological repository (DGR).

Note that this technical report documents activities associated with the design, data acquisition, and data processing components of Geofirma's 3D Seismic Reflection Study. Data Interpretation, including seismic inversion, are detailed in a separate report (Geofirma Engineering Ltd., 2023a). Geofirma also completed a 2D seismic reflection study focussing on a buried bedrock valley (paleochannel) within the 3D seismic study area. The data acquisition for this 2D seismic study was executed immediately after the 3D seismic data recording operations were completed and included three E-W oriented source lines along existing roads. Geofirma Engineering Ltd. (2023b) provides a detailed summary and interpretation of the 2D seismic paleochannel study.

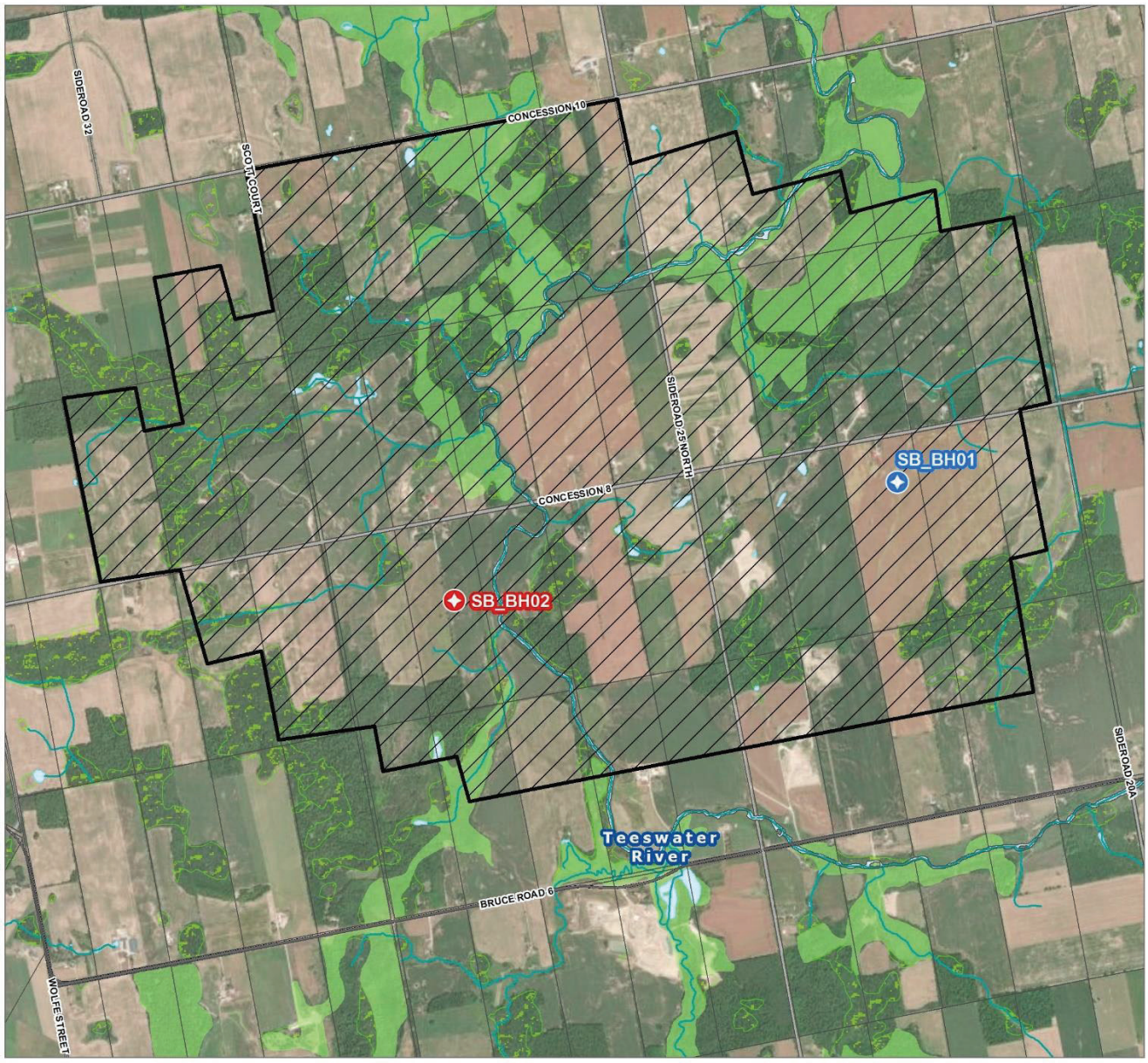


Figure 1 3D seismic survey study area

2 BACKGROUND INFORMATION

2.1 Geological Setting

The Paleozoic bedrock near South Bruce is overlain by variable thicknesses of overburden (unconsolidated) sediments (including sand, gravel, boulders, till, etc.), ranging from tens of meters in average thickness and locally reaching a maximum thickness of approximately 250 m east of the Niagara Escarpment (Gao et al. 2006; Gao 2011). The Paleozoic-aged strata were deposited within the Michigan Basin northwest of the Algonquin Arch in southwestern Ontario. The Michigan Basin is a circular-shaped, carbonate dominated intracratonic basin that is composed primarily of shallow marine carbonates (limestone, dolostone), evaporites, and shales that were deposited while eastern North America was in tropical latitudes (Armstrong and Carter 2006, 2010). West of the Algonquin Arch, the Paleozoic strata tend to gradually dip westward into the Michigan Basin. In the South Bruce area, this succession of Paleozoic strata rests unconformably on an erosional surface of the Precambrian crystalline basement (at approximately 900 m) of the Grenville Province, a tectonic subdivision of the Canadian Shield.

Borehole SB_BH01 and SB_BH02 were drilled through the entire Paleozoic sequence to approximately 20m and 14 m, respectively, into the Precambrian basement, which is composed of high-grade metamorphic rocks of the Grenville Province. Borehole SB_BH01 was drilled through a portion of a reef structure which exhibited varying thicknesses of key Silurian bedrock formations / units compared to the regional average interpretation as exhibited in SB_BH02.

3 DESCRIPTION OF ACTIVITIES

The seismic reflection data acquisition/processing phase of this project involved a series of tasks, including:

- Task 1 - 3D Seismic Survey Design
- Task 2 – 3D Seismic Data Acquisition
  - Layout (Surveying and Line Clearing)
  - Field Testing
  - Data Recording
- Task 3 – 3D Seismic Data Processing

Each of these tasks are described in greater details in Sections 4 through 6, respectively.

3.1 Overview of Fieldwork Execution

All field work associated with 3D seismic data acquisition was completed by Echo Seismic under the supervision of Geofirma personnel. Field work was completed over a single day shift (approximately 12 hours long) from 6:30am to 6:30pm, 7 days a week. All field work was completed between October 18, 2021 and November 22, 2021. Table 1 summarises the main field activities, duration and dates of completion and number of field staff.

Table 1 Summary of 3D Seismic Field Data Acquisition Activity Duration, Dates and Staffing

Field Activity	Duration	Dates	# Field Staff
Surveying / Line Clearing	19 days	Oct 19 to Nov 6, 2021	1-2 Geofirma 5-9 Echo Seismic
Data Recording	14 days	Nov 9 to 21, 2021	1-2 Geofirma 34-35 Echo Seismic

The surveying and line clearing phase of this project was completed over a 19-day period between October 19 and November 6, 2021. During the surveying and line clearing field activities a total of approximately 6 to 11 field staff were onsite, including 1 to 2 Geofirma staff and 5 to 9 Echo Seismic staff.

The entire data recording phase of this project was completed over a 14-day period between November 9 to 21, 2021. During this period, the weather was a mixture of sun, cloud and generally cool, ranging from +3ºC to +10ºC with only minor rain and snow, therefore data acquisition was able to proceed as planned without any major delays. During data recording activities, a total of 1-2 Geofirma staff and 34-35 Echo Seismic field staff (ranged from 31 to 38 staff for single days) were typically on site throughout the data recording phase.

3.2 Permitting and Land Access Agreements

Geofirma acquired Road Occupancy Permits from the Municipality of South Bruce and from Bruce County prior to completing work on their respective local road networks. These permits authorized the operation of seismic equipment on the local road network and placement of seismic receivers in the nearby ditches. Geofrma also provided adequate signage and traffic control support to allow local traffic to safe egress while seismic data acquisition activities were being executed.

NWMO provided all the necessary permits and approvals for private landholders to enable adequate access to perform this work. In total there were 39 property parcels with 25 individual landowners/land renters identified within the planned 3D seismic study area. Geofirma and NWMO completed site visits during June 14 to 16, 2021. Each landowner visit included a summary of the work to be completed, a demonstration of the geophone equipment, and a discussion of specific land-use concerns. Geofirma further communicated with the remaining 6 parties not visited during June 14-16 either by email, text or phone and introduced key field staff and likewise obtained information pertinent to specific land-use concerns. These specific landowner restrictions and/or requirements were documented and incorporated by Geofirma into the field execution plan. Where possible, trails in forested portions of properties were evaluated, with Geofirma capturing GPS waypoints. Geofirma also took GPS coordinates of any private or monitoring wells to follow the regulatory setback distance of 30m from the water wells.

3.3 Identified Challenges for the 3D Seismic Data Acquisition Program in South Bruce Area

Geofirma identified several challenges that required careful planning to ensure a successful execution of this program, including:

- Active farming operations - the primary challenge observed by Geofirma involved ensuring effective communication with landowners/renters pertaining to scheduling of seismic operations due to variable and fluid schedules related to farming practices. The number of landowners with unique livestock operations, crop schedules and requests (e.g. 6 properties growing corn, 2 with wheat, 2 with soybeans) combined with the weather-dependency of harvest timelines and crop seeding, in addition to the risk of crop damage, introduces a scheduling challenge. As such, clear and direct communication with these individuals was critical.
- Operating during hunting season – completing field work in rural and wooded areas during the fall months that overlap with various hunting seasons introduced a scheduling challenge to accommodate land use. While all landowners were accommodating, clear communication with landowners and adherence to planned land access schedules was critical during all field operations.
- Forested areas - the prevalence of forested areas without trail access is another challenged observed by Geofirma. While a small fraction of these areas is accessible by private trails (walked during the site visit), these trails could not accommodate many source points and left large areas without any source points. Source and receiver points were moved to accommodate and optimize these access restrictions.
- Soft ground - some landowners noted areas of soft ground within their fields. A seismic vibrator with float tires was used to reduce the risk of getting stuck in these areas or leaving deep tracks through the fields.

- Surficial gravel deposits - the surficial gravel found across the study area, as shown by the prevalence of open gravel pits and gravelly soil described by farmers, affected the seismic response. Thick surficial gravel layers do not provide a high-quality seismic transmission layer for the source energy and returning reflection energy to the receivers, negatively impacting data quality in those areas. Geofirma adjusted the 3D seismic data acquisition program to optimize source transmission and seismic data collection in the study area.

3.4 Health, Safety, And Environment

All field activities were completed in accordance with the requirements outlined in a project-specific Health, Safety and Environment Plan (HSEP) prepared by Geofirma and accepted by NWMO.

Pre-job briefings were conducted at the beginning of every shift (day and night) by the Geofirma Site Supervisor with mandatory attendance of all personnel onsite to discuss the daily work plan, health and safety concerns, and any relevant changes to procedures. If any staff or contractors arrived at site during the shift, the Geofirma Site Supervisor completed a separate pre-job briefing at that time. All staff signed a pre-job briefing form to acknowledge the planned scope of work and associated risks.

Echo Seismic completed daily inspections of equipment to ensure it was functioning properly and that safety was maintained throughout the field program.

3.5 Data Quality Assurance and Quality Control (QA/QC)

Several data quality assurance and quality control (QA/QC) measures were implemented during the 3D seismic data acquisition and processing program. Verification of results was completed following acceptance criteria and verification procedures outlined in project-specific Test Plan and Project Quality Plan, both prepared by Geofirma and accepted by NWMO.

3.5.1 Field QA/QC Measures

Echo Seismic followed their standard operating procedures for wireless recording that requires a confirmed QC status for all stations deployed before commencement of data acquisition. The relevant section from Echo Seismic's Quality Management System (Section 10) pertaining to operation of Hawk wireless equipment, is provided in Appendix A for reference. QC (BITS Test) includes battery status, GPS acquired & geophone status. The data was collected on the ground by QC Personnel and transferred to the HUB operator on USB drives to verify that all required stations are ready for data acquisition. After the first shot was taken, QC personnel were deployed to collect Wi-Fi data samples from a cross section of the initial patch, to verify that the Field Station Units (FSU's) are recording data. QC status and data QC of the back spread was continuous as the shooting progressed.

Seismic Solutions provided quality control during data acquisition including field processing using VISTA processing software. Regular preliminary assessments of the data were completed during field work to ensure that the target objectives of the program were met, as captured in Data Quality Confirmation (DQC) forms (Appendix B). These QC tests include frequency panels for data bandwidth, first break amplitudes and clarity for refraction analysis, FK panels to establish ground roll interference and optimization of vibroseis sweeps as depicted in Figures 11-14

3.5.2 3rd Party Geodetic Data Audit

Geofirma subcontracted with a 3rd party seismic data audit firm, Santos Inc. (Santos), based in Calgary, Alberta to complete an audit of geodetic accuracy for this study. Santos' primary objective was to verify the geospatial integrity of the survey data by ensuring the proper geodetic parameters and transformation parameters were used for location accuracy (both spatial and elevation). Santos completed a series of auditing tasks at various stages of the project, summarizes below:

- Planning Stages:
    - Confirm geodetic horizontal and vertical control and accuracies for project data;
    - Confirm conventional Celestial Reference System (CRS) of Global Navigation Satellite System (GNSS) data (horizontal datum and projection);
    - Confirm any datum differences are properly managed (i.e. WGS84 versus NAD83);
    - Confirm geoid model to reduce GNSS ellipsoidal heights to elevations expressed relative to mean sea level (MSL);
    - Confirm receiver and source point Real Time Kinematic (RTK) GNSS layout (stakeless), data measurement techniques, and data to be collected; and,
    - Confirm CRS for final Society of Exploration Geophysicists (SEG) P1 files to be submitted upon completion of project.
- Auditing of GNSS field data
    - All field data submitted on a daily/nightly basis (e.g. including GNSS survey control, RTK GNSS receiver and source points, etc);
    - All data submitted; processed daily and any anomalies or questions communicated directly to Geofirma seismic technical lead for discussion/resolution;
    - All field data archived and prepared for delivery to Geofirma at end of project in advance of processing activities; and,
    - Upon completion of field work, Santos provided final receiver, and source SEGP1 and prepared a summary seismic survey audit report.

Appendix C includes a copy of the Santos seismic survey audit report for reference.

4 3D SEISMIC SURVEY DESIGN

4.1 Preliminary 3D Seismic Survey Layout

Seismic Solutions developed a pre-mobilization 3D seismic survey design based on the preliminary survey design outlined in the work plan and adjusting for the final survey area and incorporating access constraints. Figure 2 shows the initial proposed 3D seismic survey design and layout of the source and receiver points along the same lines, spaced 100m apart. This design is based on Megabin concepts as published by Bill Goodway (1996) the idea being that the source points between receiver lines are dropped to minimize the surface impact and not affecting the subsurface imaging. This method relies heavily on advance interpolation routines to fill in the missing source points. By including trails within the bush along random lines and placing source points along the east west road (Concession 8) within the middle of the grid excellent subsurface coverage was achieved.

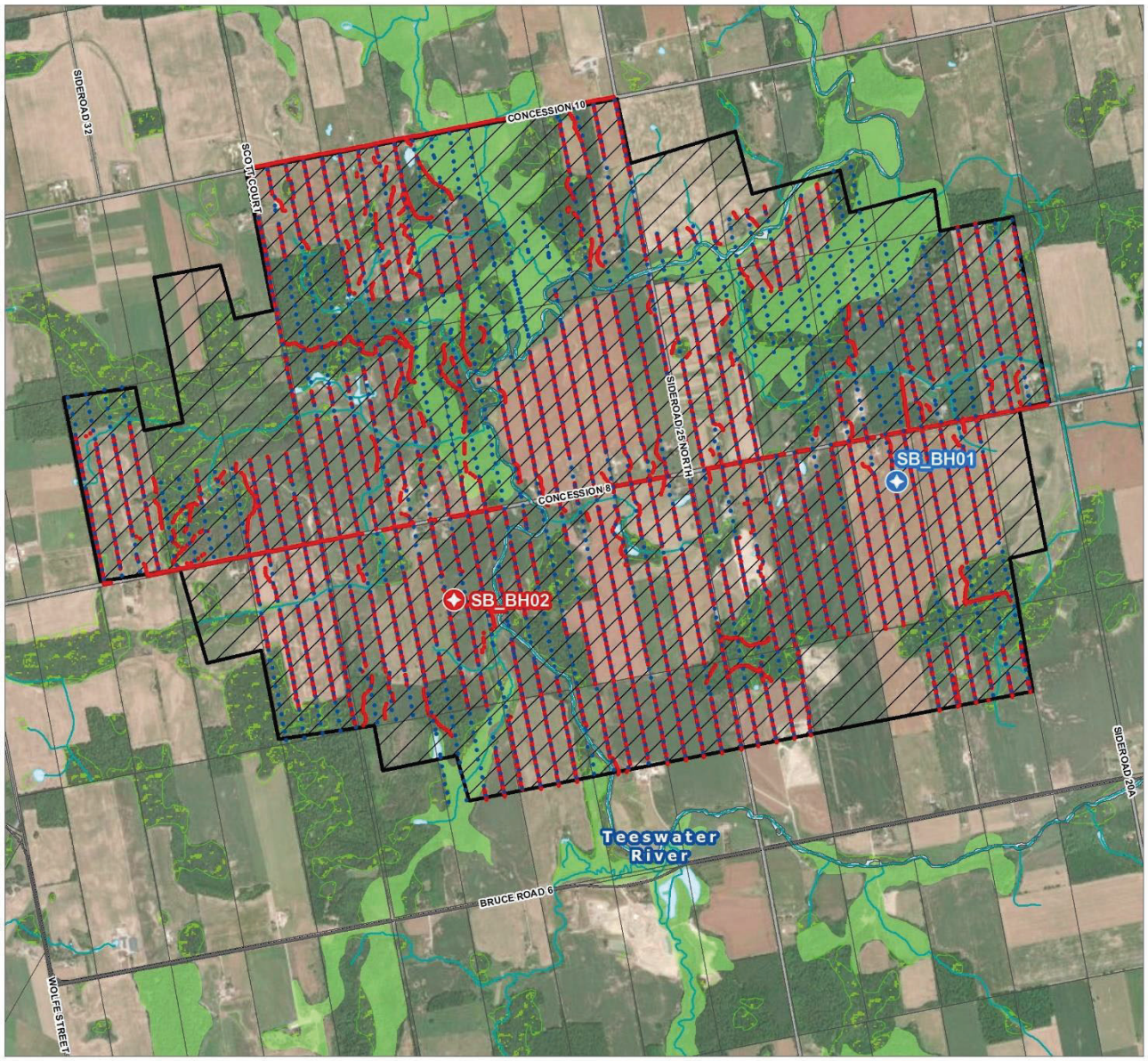
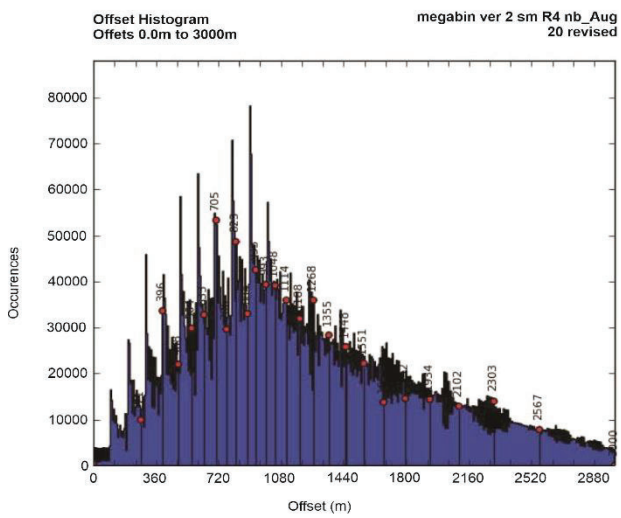


Figure 2 Preliminary layout of source and receiver locations.

Figure 3 shows summary statistics for the planned seismic survey parameters. Figure 3A depicts an offset histogram (number of bins that have a particular offset) of all the subsurface points and the distribution of offsets showing the peak number of offsets (maximum fold) are in the desired range of 700 to 900 mBGS. Figure 3B depicts an azimuthal histogram or rose plot showing the azimuth of the total number of shot-receiver combinations. Within the 900 mBGS range of offsets, blue inner circle, most of the azimuths are NS in orientation.

A



B

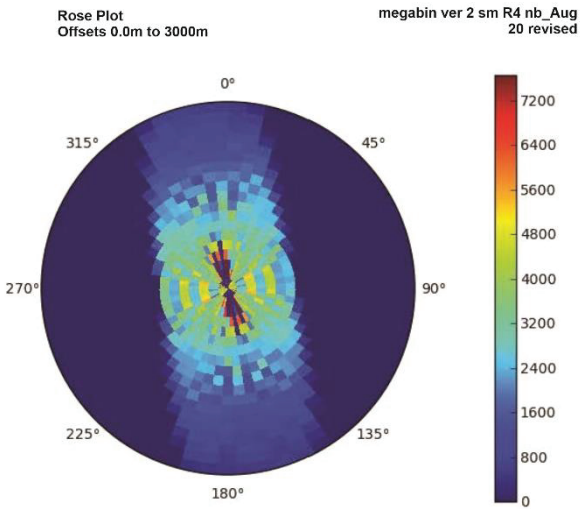


Figure 3 (A): Offset histogram showing the number of bins that have a particular offset; (B): Rose plot of azimuth versus offset for proposed 3D survey.

4.2 Design Adjustments Due to Access Constraints

Several design limitations were identified as part of this project within the entire 3D seismic study area. Figure 4 shows the designated wetland areas with a buffer of 30m (white lines) for the source points shown as red dots. In addition, 50 m setbacks were required for any building or existing wells.

A key design focus of this seismic survey was to minimize impact on the existing land. This required modifications to the original survey design to eliminate source points (vibroseis stations) within sensitive areas such as woodlands or wet/soft ground. The source points originally planned for coverage within these sensitive areas were relocated to open areas to maintain the fold. Many of the source points were relocated along trails and roadways within the bush that were identified during the pre-scout survey completed prior to mobilization. Where it was not possible to relocate onto existing trails, source lines were relocated half way between existing source points thereby reducing the source line spacing (source interval) along these portions of the lines to half of the initially planned distance (6.25 m instead of the planned 12.5 m) to maintain the same number of total source points for the survey.

Table 2 summarizes the corresponding final 3D seismic survey design parameters for this 3D seismic survey. Figure 4 shows the final post-survey design layout of all source and receiver stations over the 3D seismic study area with white 30-m buffer areas identified around surface water features. The planned number of source points was 10,755. After source points were optimally moved and additional source points added

along the east-west roads, there was a total of 10,827 source points. A total of 59 source points were dropped mostly due to areas that became too wet to access, for a total of 10,768 source points (vibration points, VP's) that were acquired. In the case of receiver points they were confined to existing corridors, some moved as much as a few meters from their original positions and a total of 128 receiver points that could not be included, originally a total of 2,696 pre-plot points were reduced to a total of 2,568 points.

Table 2 3D Seismic Acquisition Final Layout Parameters (Post Survey) for 3D Seismic Survey in South Bruce

	Source	Receiver
Total Area (excluding access constraints)	12.78 km^2	12.22 km^2
Total Line Length	134,437.50 m	134,800.0 m
Total Number Stations	10,768	2,568
Interval	12.5 m	50.0 m
Line Spacing	100 m	100 m
Line Direction	North-South	North-South
Number of Lines	56	53
Points per Line	193 (average)	48 (average)
Recording Patch		20 lines x 120 stations

Figure 5 shows the final subsurface fold coverage to a maximum offset of 750 m offset representing the coverage at the targeted repository horizon (Ordovician limestones). Higher fold generally means better signal to noise results in the final stacked volume. This shows that subsurface multiplicity, or number of individual seismic traces per subsurface bin was greater than 200 within most of the study area, with reduced multiplicity around the edges.

Figure 6 shows a similar plot corresponding to subsurface fold coverage to a maximum offset of 350 mBGS representing the coverage within the shallow bedrock. This shows that subsurface multiplicity, or number of individual seismic traces was much lower and generally around 100 within most of the study area, with reduced multiplicity around the edges. Due to the access constraints discussed above, this figure shows the areas in the north where no subsurface coverage exists at this offset depth.

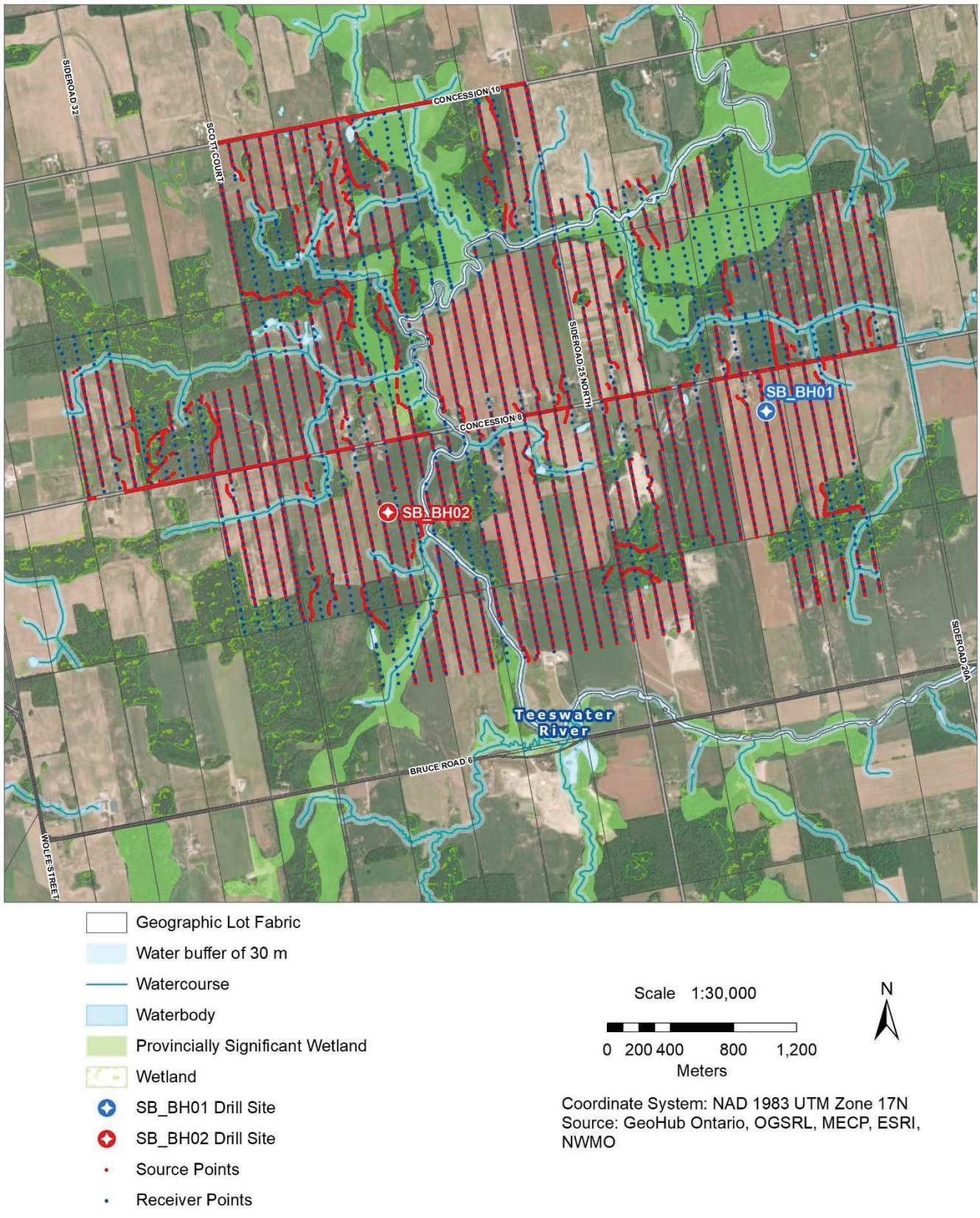


Figure 4 **Final source and receiver layout with waterway buffers shown in white.**

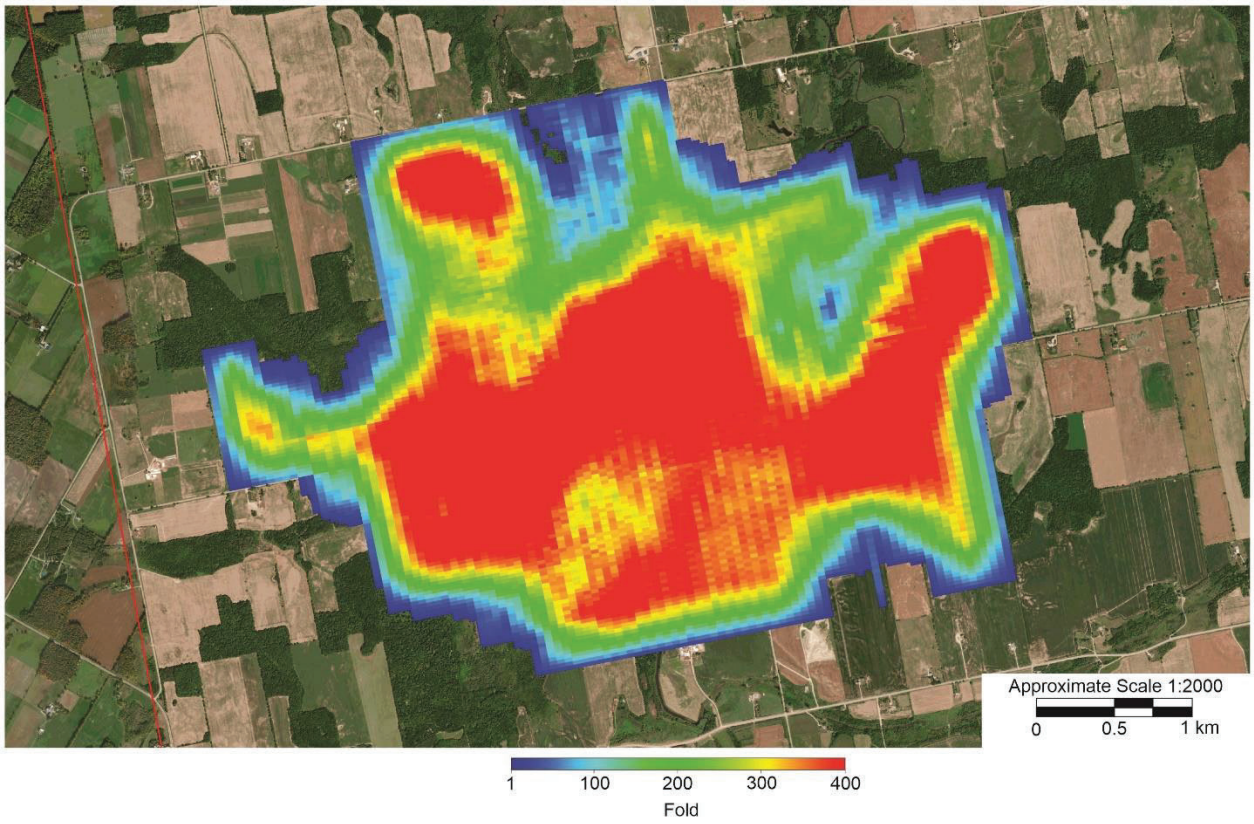


Figure 5 **Final layout subsurface fold plot 0-750m source/receiver offsets, natural bins 25x50m**



Figure 6 **Final fold subsurface fold plot 0-350m source/receiver offsets, natural bin size of 25x50m.**

5 SUMMARY OF SEISMIC DATA ACQUISITION ACTIVITIES

Geofirma was the Lead Contractor for the 3D seismic reflection study at South Bruce. Geofirma contracted Echo Seismic to complete the field data acquisition and recording phase of this project.

Geofirma provided Echo Seismic with a secure equipment staging area that was approximately 60m x 50m in size and was located at the SB_BH01 drilling site. The staging area was enclosed within a fenced perimeter with a lockable double-swing gate for easy access. Geofirma's main field office trailer was also located adjacent to the seismic staging area.

This 3D seismic survey incorporated a source comprised of two vibroseis units operating in tandem, completing two sweeps per source point sweeping for a duration of 24 seconds in a linear fashion over the frequency bandwidth for 8-120 Hz. Table 3 provides a summary of field parameters used in this study.

Table 3 Summary of Field Parameters for 3D Seismic Survey Data Acquisition

Geoid	CGVD2013
Datum	Nad83
UTM Zone	17N
Receiver Array	6 over 1 m
Source Type	IVI Mini 15000 lbs
Instrument	INOVA VibProHD
Geophone Type	Land Geo
Receiver Frequency	10 Hz
Natural Bin Size	50 x 25 m
Final Bin Size (After 5D)	25 x 12.5 m
Number of Vibroseis	Total of 6 including 3 groups of 2 operating in tandem
Sweep Length	24000 ms
Sweep Frequency	Linear 8 – 120 Hz
Number of sweeps	2 (stacked on flag)
Minimum slip time	6 seconds
Sweep Tapers	300 – 500 ms

5.1 Seismic Equipment

A vibroseis energy source provided high frequency signal generation for the survey and conformed to site requirements. A high frequency sweep was selected to enhance vertical resolution and a small subsurface sampling interval was chosen to provide fine detail for structural and stratigraphic interpretation.

5.1.1 Seismic Source

This project was executed using six 17,000 lb small-footprint, buggy-mounted, Enviro-vibe vibroseis energy sources, operating in pairs as shown in Figure 7. These vibrator units were equipped with integrated GPS positioning equipment to allow high precision accuracy of source location mapping. The buggies were equipped with low ground pressure 'Terra tires' which provided a limited footprint and were operated in pairs to provide enough energy for 700-m target depths.

A vibroseis source enables highly repeatable data specific focusing of frequency and energy. In general, for vibroseis sources, multiple sweeps for multiple seconds are collected, correlated with the input signal, and stacked together. Within this process there are multiple filtering options. The observer can choose to include or exclude particular sweeps in the composite record should electronic errors or noise bursts become an issue. As well there are noise blast editing features that can be turned on to effectively edit out traffic or burst type noise prior to correlation and stacking of the individual source points.



Figure 7 Enviro-vibe vibroseis buggies used for South Bruce 3D seismic data acquisition. Left – tandem vibroseis machines during recording phase; Right – closeup view of vibroseis source vibration plate.

5.1.2 Recording System

Echo Seismic provided an Inova Wireless Hawk recording system including the central system, field station units, batteries, and geophone sensors (Figure 8). All geophones and Hawk recording equipment were tested to meet manufacturers' specifications. In total, approximately 3,000 strings of geophone sensors (Hawk GS32CT 10 Hz 6 per string geophones) were used for this project. The geophones deployed were equipped with a marsh-style case that provided optimal ground coupling in wet conditions.





Figure 8 **Left: Inova Wireless Hawk recording equipment ready for layout; Right: Seismic Recording truck and trailer.**

5.1.3 GPS Tracking System

Echo Seismic incorporated the use of GPS technology for tracking and monitoring crew operations. Using GPS satellites and secure internet-based software, Echo monitored the location, speed of travel and seat belt compliance of all road vehicles assigned to this project.

5.2 Surveying and Line Preparation (Layout)

Surveying of the seismic lines included establishing survey control points, chaining, and flagging of source and receiver points. Surveying was generally completed within an area of 15 ft from the road edge. In areas where traffic control was an issue, surveying was done on foot reducing the required area to a 1.5 m (5 ft) width at the edge of the ditch/curb with chaining crew working on the shoulder or ditch eliminating the need for traffic control.

Part of the initial surveying included identifying all buildings and other sensitive structures within the survey area and to design the survey such that these sensitive structures were located a sufficient distance away from any proposed 3D seismic data acquisition line to eliminate any concern for vibration damage. Upon surveying, if a sensitive structure was located within 50 m of a planned seismic data acquisition line, the source point was relocated to the nearest possible position on the line to fulfill the required setback. In addition, ground force monitoring (Figure 9) at the building foundations were conducted to ensure no liabilities resulted from exceeding safe accepted peak particle velocity 2.0 inch/sec.



Figure 9 **(Left) RTK survey base station; (Middle) Seismic source location surveyed in field, marked by blue stake; (Right). Peak Particle Velocity (Vibration) monitor at building foundation.**

All infrastructure along the survey lines was noted including buildings, roads, intersections, utilities, overhead wires, culverts, railroads and other noteworthy items documented in the surveyors 'chaining notes'. All vibroseis points were documented onto a 'source list'. Any relocated points were identified and made aware to the Observer and Lead Vibe operator who followed the source list.

The relocation of the planned source and receiver locations were positioned along same "corridor" and focused on moving source lines outside of wooded areas and keeping receiver lines at approximately 1.75 m wide through the wooded areas. As discussed in Section 4.2, a key design focus of this project was to minimize impact to existing land. No mulching or clearing of lines through bush occurred, however hand cutting or clearing lower branches by hand as necessary to access the receiver lines was critical to subsurface coverage requirements. Figure 10 shows three examples of walking trails cut through wooded areas for the purpose of placing geophones at receiver locations.

The Vibroseis buggies navigated to the pre-surveyed points using a real-time GPS tablet within the lead vibroseis unit so that the source point was exactly between the 1st and 2nd vibe within each group. Once the source point was acquired a time stamp and GPS point was recorded. These GPS points were used as the actual source point for each shot record in the final survey data.



Figure 10 Example of minimal impact trail cutting to accommodate receiver locations through wooded area(s).

Part of the seismic survey audit process (Section 3.5) was to compare these real-time coordinates to all the pre-surveyed points. It is especially important to confirm the acquired elevations within these vibroseis groups was in line with the surveyed elevations as these points had a +/- 50 cm operational error from the satellites whereas the surveyed points using RTK were accurate to +/- 5 cm accuracy. Occurrences where the layout crew was not able to place the geophones within a meter of the survey stakes were noted by the layout crews and the new position was resurveyed where necessary.

5.3 Field Testing – Optimization of Signal to Noise Ratio

Echo Seismic completed a comparison of several vibration sweeps on November 9 and 10 to optimize the sweep parameters for this study including length of sweep, tapers, beginning and end, plus optimal bandwidth to maximize reflections and minimize ground roll noise.

Figures 11-16 show the raw seismic data from some of these sweep tests for comparison. The left plot in each figure depicts the shot record showing seismic signal traces. Trace count is shown on the horizontal axis and time on the vertical axis, in milliseconds. The right plot in each figure depicts seismic wavenumbers along the horizontal axis and temporal frequency along the vertical axis, in Hz. Figure 11 shows these data from one of the tested sweeps with a signal frequency bandwidth range of 8-160 Hz and a vibration (sweep) duration 20 seconds. Figure 12 shows comparison plots with signal frequencies ranging from 20-140 Hz, with a sweep duration of 20 seconds; Figure 13 includes signal frequencies ranging from 8-140 Hz, and sweep duration of 20 seconds; and Figure 14 includes signal frequencies ranging from 80-140 Hz, with a sweep lasting 24 seconds.

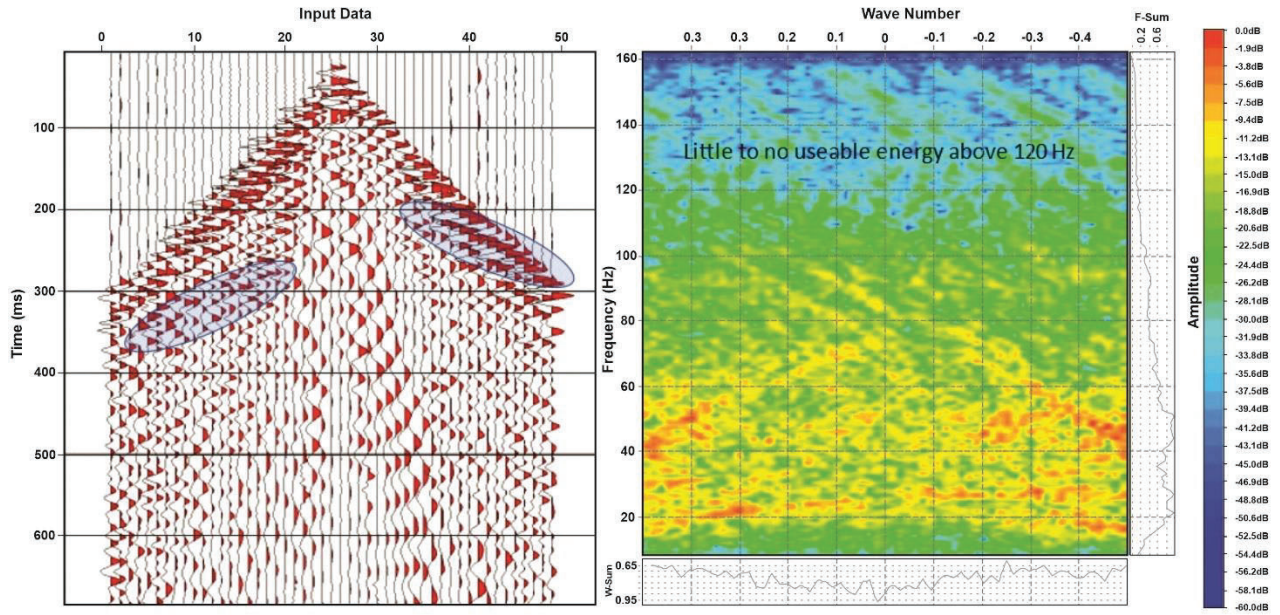


Figure 11 **Test Sweep #1: 20 second vibration duration, 8-160 Hz bandwidth. Left: Shot Record; Right: Energy Amplitude Contoured and Plotted as Signal Frequency vs. Wavenumber.**

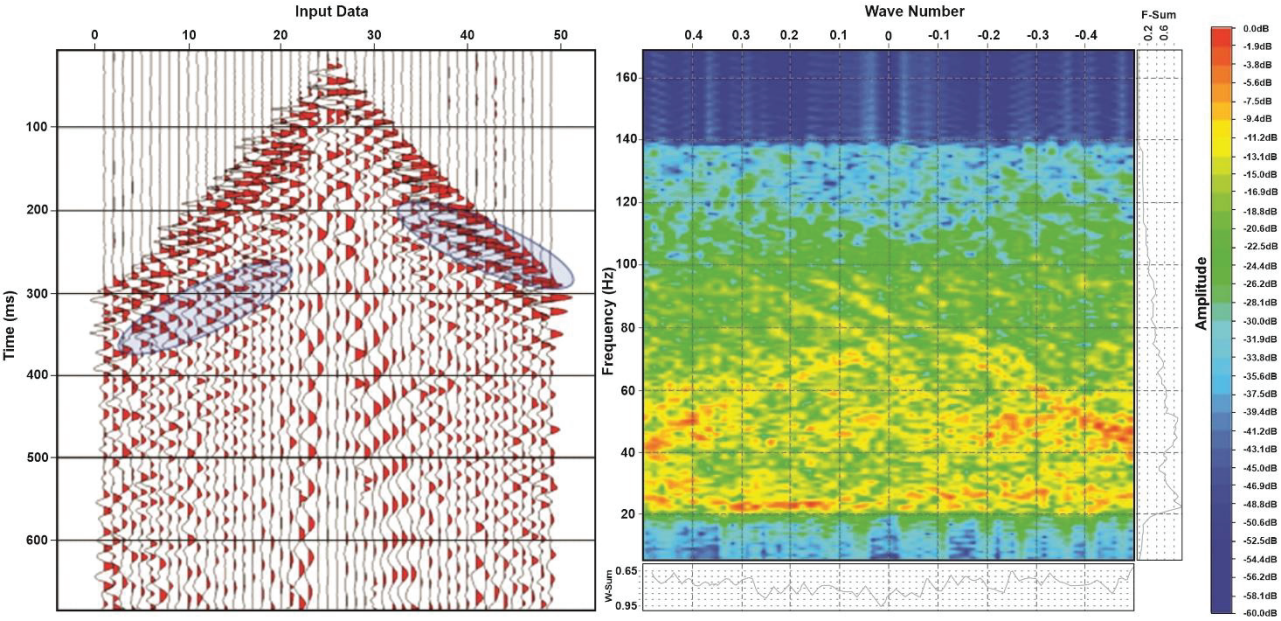


Figure 12 **Test Sweep #2: 20 second vibration duration, 20-140 Hz bandwidth. Left: Shot Record; Right: Energy Amplitude Contoured and Plotted as Signal Frequency vs. Wavenumber.**

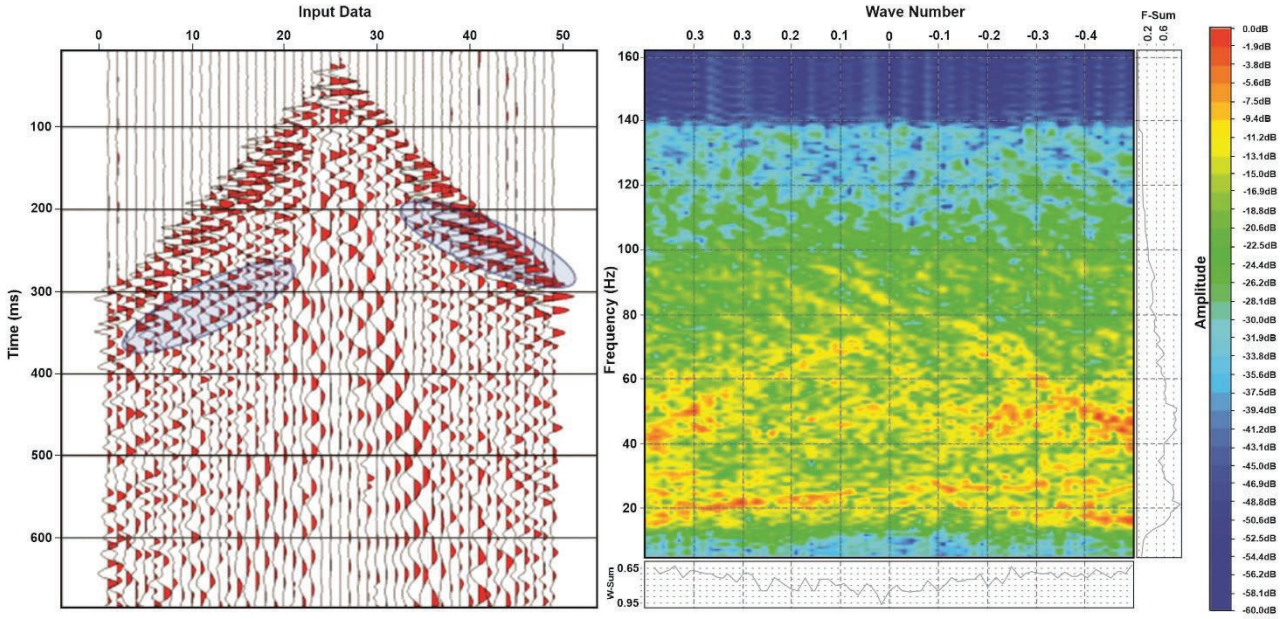


Figure 13 **Test Sweep #3: 20 second vibration duration, 8-140 Hz bandwidth. Left: Shot Record; Right: Energy Amplitude Contoured and Plotted as Signal Frequency vs. Wavenumber.**

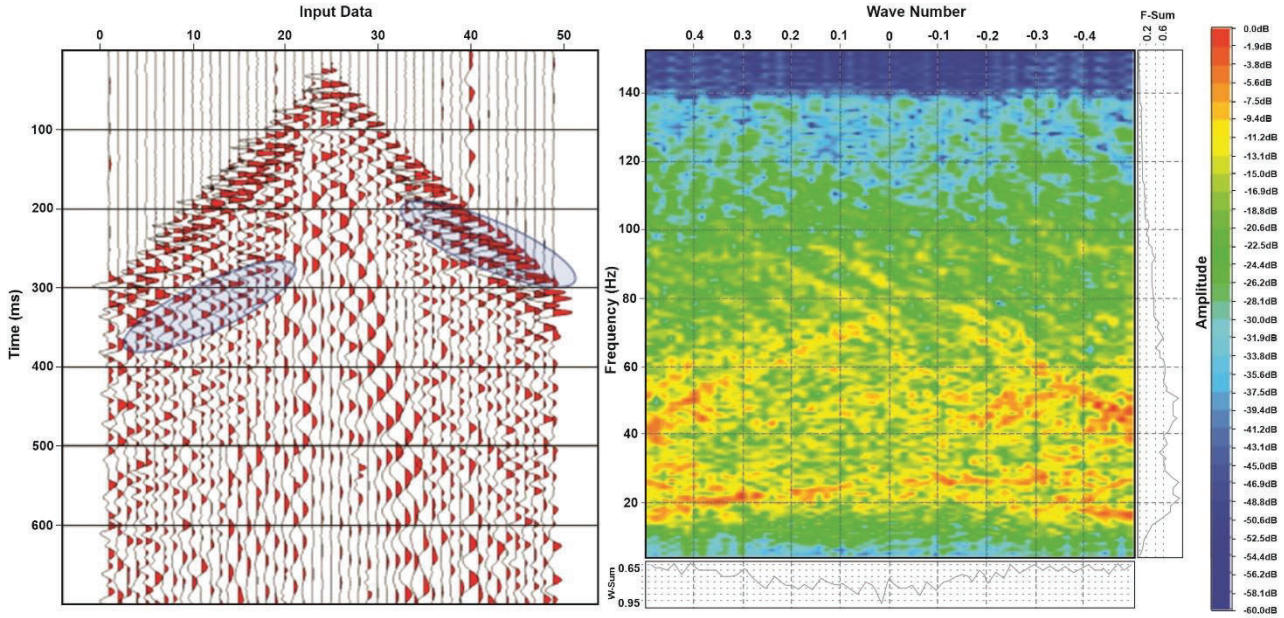


Figure 14 **Test Sweep #4: 24 second vibration duration, 8-140 Hz bandwidth. Left: Shot Record; Right: Energy Amplitude Contoured and Plotted as Signal Frequency vs. Wavenumber.**

Consistent across all the test sweep scenarios, the right plots show little energy above 120Hz. The blue circles on the left plot are potential reflection events that can be compared across all figures. By visually comparing the signal-to-noise ratio on these identified reflection events, the most effective sweep parameters were agreed to be a frequency range of 8-120 Hz, with a vibration duration of 24 seconds long including two vibroseis units centered on the source flag.

Using these parameters, Echo Seismic completed one final test involving two successive sweeps at the same location to improve signal-to-noise ratio. Figure 15 shows each successive sweep individual presented in the Figure 15A and Figure 15B, respectively, and stacking the two sweeps together shown in Figure 15C which provides higher signal-to-noise ratio. Several reflection events were identified on this record as reflection hyperbolae marked with a blue line on the right plot.

Ultimately, the final sweep parameters selected for data acquisition of this 3D seismic study included two vibroseis units operating in tandem, completing two sweeps per source point sweeping for a duration of 24 seconds in a linear fashion over the frequency bandwidth for 8-120 Hz. Figure 16 shows an example of this final production sweep shot record including three receiver lines, one concurrent with the source point and 2 adjacent lines spaced 100 and 200 meters away.

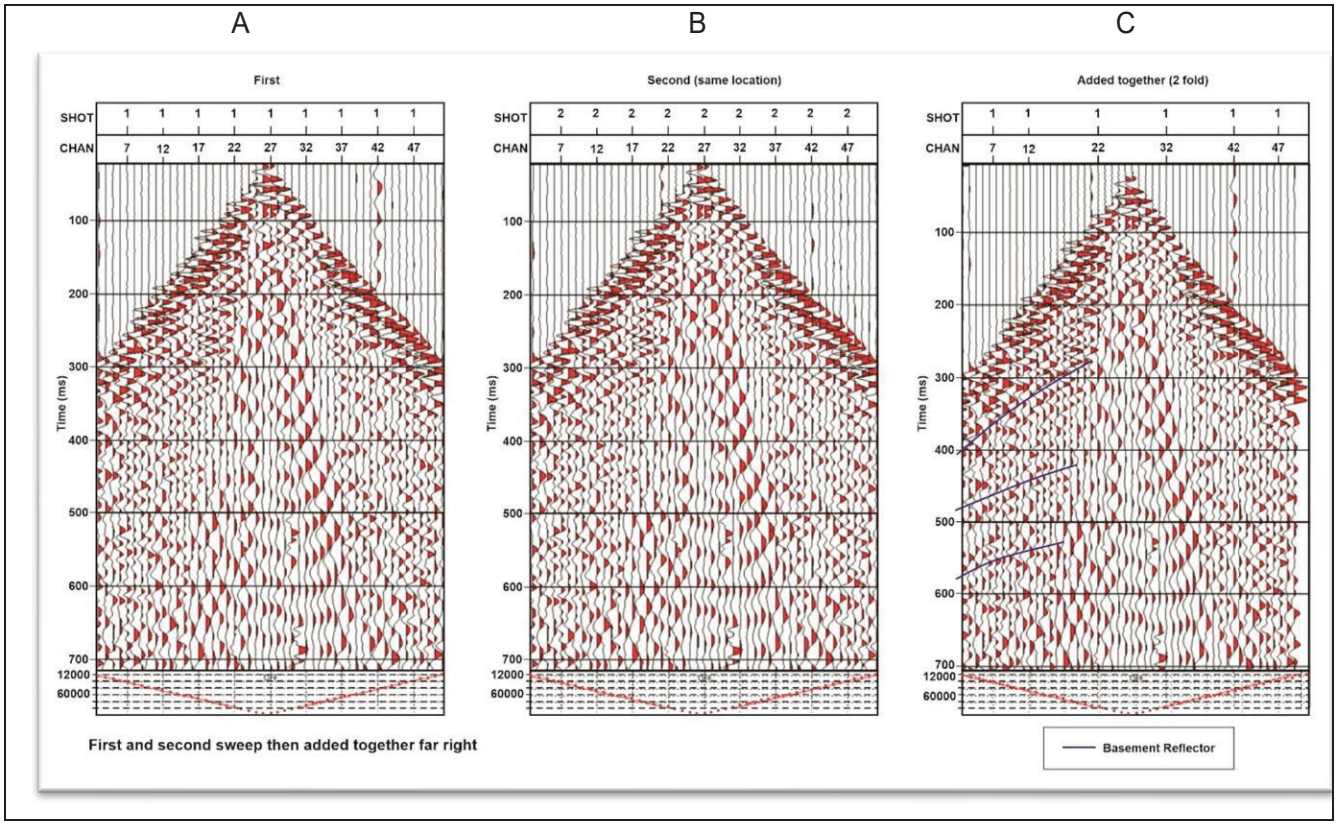


Figure 15 **Test Sweep #5: 24 second vibration duration, 8-120 Hz bandwidth, 2 successive sweeps. (A) 1st sweep; (B) 2nd sweep; (C) 1st and 2nd sweep stacked together.**

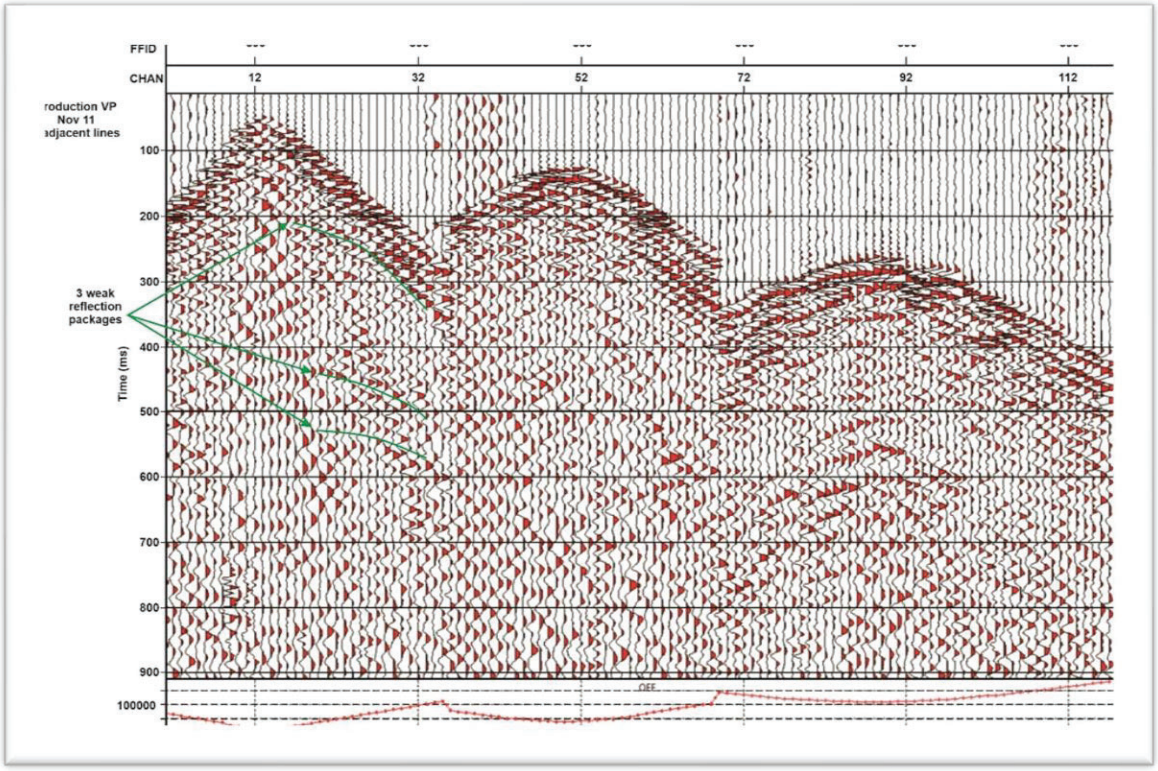


Figure 16 Example of final production sweep showing three adjacent lines of receivers.

5.4 3D Seismic Data Recording Operations

Production recording commenced immediately following completion of field tests and proceeded without significant delay until completion. The seismic receivers were collected, and data was downloaded in the seismic acquisition truck. A copy of the raw data was saved at the end of the data acquisition activities and final data was provided to Absolute Imaging for processing.

The final seismic survey design enabled both source and receiver points to exist along the same surface lines which minimized the surface impact. Megabin survey design uses a multiple of the receiver station spacing for the line spacing, for example a 50 m station would mean a 100 m line spacing and are designed to fill in every second row of subsurface bins. As a result of the new 5D interpolation algorithms this technique can be further improved by randomizing the lines, for example crooked trails within the bush areas or offsets due to structures or wet field areas. The natural subsurface bin size was 50 m (½ the line spacing) by 25 m (½ of the source spacing) but after interpolation this bin size can be accurately transformed into a 25 m by 12.5 m bin size yet minimizing the surface impact. 25m crossline spacing is achieved by infilling every 2nd subsurface bin which was empty due to increasing the effective receiver station spacing which is the same as the line spacing 100m.

Figure 17 shows a pair of vibroseis source buggies (IVI Envirovibes) operating in tandem along an existing road with a staked (blue tip) receiver location immediately adjacent to the road including a small circle (~ 1m diameter) of six geophones connected to a remote acquisition module.



Figure 17 Pair of Vibroseis source buggies with example staked receiver location.

This 3D seismic survey was designed as a slip-sweep survey within which multiple (in this case 3 groups) of two vibrators were operating at staggered times in different areas of the survey. In cases where there were overlapping sweep times the vibrator groups would be greater than 750 m apart and delayed by a minimum of 6 seconds (slip-time) to allow distinction of various signals at receiver locations. The slip-sweep approach used in this survey enabled over 1,000 vibration source points to be completed in a single day shift, including a longer sweep duration (24 seconds) for better data quality. Without using the slip-sweep methodology, conventional vibroseis 3D surveys would require each set of vibes to complete a series of short length sweeps and listen times before initiating a 2nd set of source vibes while the first set moved to a new point and waited. This is referred to as a “ping-pong” type survey and would only be able to achieve approximately 200-300 vibration source points per day.

The slip-sweep method of recording was only developed once asynchronous recording wireless systems became available. The GPS clock enables source records to be assembled from the larger continuous recording data set by time stamp of the start of each sweep. The conventional “ping-pong” style of acquisition was recorded with a cabled system that always initiated data recording at the start of each sweep rather than through out the day such as these newer wireless systems do.

As discussed previously, this 3D seismic survey was designed to minimize long-term impacts on the land. By selecting special tires on the vibroseis buggies and tracked ATV machines for frequent driving over soft ground, larger ruts within agricultural fields were minimized. Figure 18 shows two examples of typical land impact due to vibroseis tire tracks in open fields. Also shown is a picture of a tracked ATV vehicle used to minimize impact from repeated driving on fields during equipment layout, retrieval and data recording operations.



Figure 18 **Example of minimal impact trail cutting to accommodate receiver locations through wooded area(s).**

6 3D SEISMIC DATA PROCESSING

Geofirma contracted Absolute Imaging Inc., based in Calgary, to complete the 3D seismic data processing phase of this project. Absolute Imaging processed these data using an Amplitude-versus-offset (AVO) compliant workflow, preserving relative amplitudes during all signal-processing stages, over the time period from December 2021 to February 2022.

Absolute Imaging executed an 18-step processing workflow, that includes 3 stages with 11 steps (Steps 1 to 11) related to post stack time migration, 4 steps (Steps 12 to 15) related to isotropic pre-stack time migration (PSTM), and 3 steps (Steps 16 to 18) related to AVO gather conditioning. Table 4 summarizes these 18 steps related to seismic reflection processing workflow and each of these steps is described in greater detail in the following sections.

Table 4 Summary of Seismic Reflection Processing Workflow and Parameters

Seismic Reflection Processing Workflow		
Stage 1: Post-Stack Time Migration		
Step #	**Name**	**Additional Details**
Step 1	Geometry Creation / FB Picking / Geometry QC / Bin Optimization	• Processing Grid (Bin) Optimization • Minimum Phase Conversion • First Break Picking • Geometry Quality Control (QC)

Step 2	Pre-Deconvolution AVO Scaling and Noise Suppression	• Ensemble Balance
		• Offset Amplitude Recovery (OAR)
		• Pre-Deconvolution Noise Suppression
		  ○ Linear in Shot Domain – AI Eigen Image Ground Roll Filter
		  ○ Erratic in Shot Domain – AI Time-Frequency (TF) Median Suppression
		• Ground Roll Removal

Step 3	Near Surface Model Building and Refraction Statistics	
Step 4	Deconvolution	• Residual Gain Correction • Surface Consistent Scaling
Step 5	Post Deconvolution Noise Suppression (Shot Domain)	
Step 6	Velocity Analysis and Residual Statics	• Velocity Analysis • Residual Statics Correction
Step 7	Common Depth Point (CDP) Trim Statics	
Step 8	Pre-Stack Noise Suppression on Cross Spreads	
Step 9	Rank Reduction Based 5D Interpolation	
Step 10	Post-Stack Time Migration	
Step 11	Isotropic Pre-Stack Time Migration (PSTM) and Residual Velocity Analysis	
Stage 2: Pre-Stack Time Migration		
Step 12	Post PSTM High Resolution Radon Transformation (HRRT) Demutiple	
Step 13	Post PSTM Dip Filter	
Step 14	Acquisition Footprint Attenuation (AFA)	
Step 15	Post Stack Migration Signal Enhancements (on stack)	

Stage 3: AVO Gather Conditioning		
Step 16	Post PSTM Dip Filter	
Step 17	Ensemble Based Spectral Whitening	
Step 18	Post AVO Ensemble Whitening PSTM Dip Filter	
Additional Processing Parameters		
	Processing Datum	400 metres
	Replacement Velocity	4000 m/s

The South Bruce 3D seismic volume is comprised of 10,768 shot points, including a natural bin size is 50 m by 25 m, a data length (signal subsample duration) of 4 seconds, and a sample rate of 1 ms. Natural bin size refers to half the line spacing (100m) and half of the receiver spacing (50m). Both the source energy and receiver lines are oriented N-S in a Megabin pattern, this essentially means that every 2nd bin in the E-W direction would have no fold or be interpolated thus reducing the crossline or east-west direction spacing to 25 m. This natural binning was used until the 5D interpolation stage (Step 9 in Table 4) at which point the bin size was changed to 25 x 12.5 meters. A processing datum of 400 meters and replacement velocity of 4000 m/s was used.

6.1 Stage 1 Post-Stack Time Migration

6.1.1 Step 1: Geometry Creation / FB Picking / Geometry QC / Bin Optimization

Processing Grid (Bin Optimization)

Table 5 summarizes the location of each of the corners of the final seismic data volume grid, expressed in NAD83 UTM 17N projection referenced to the GRS80 ellipsoid.

Table 5 Summary of Coordinates for Final Seismic Data Volume (Bin Size: 25 m by 12.5 m) NAD83 UTM Zone 17N

	Inline	Crossline	Easting	Northing
NE	1	1	474572.69	4876002.00
SE	1	330	475347.53	4871963.00
NW	250	1	468459.19	4874829.00
SW	250	330	469234.00	4870790.50

Figure 19 depicts the source location (red dots) and receiver locations (blue dots). The term seismic “inline” refers to the line number shown along the top (and bottom) of the seismic study area and is a sequential number for each seismic source line in the direction of data collection (N-S or SW-NE in this study). For this study the natural binning included a total of 124 inlines which doubled to 250 inlines after the interpolation. The term seismic “crossline” or “X-line” refers to the line number shown along the right and left sides of the study area and is a sequential number in a perpendicular direction to data collection (E-W or SW-NE in this study). In total for this study there were 164 crosslines before the interpolation and 330 crosslines after interpolation.

During the pre-scout phase, conducted in June 2021, and during the initial survey step many new pathways were highlighted through the bush areas along existing trails and pathways that were accessible to the small vibroseis source. These additional source points were added at 6.25m source spacing to also attempt to infill the areas that were not accessible along the pre-designed source lines. Figure 20 shows the surface layout after the post-5D interpolation binning with higher resolution 25m X 12.5m bins 125 crossline bins become 250 and 165 inline bins becomes 330 resulting in 4 times improvement in the lateral resolution of the final data volume. The increased “randomness” of the source points along the trails and in some case along the edges of some of the fields improves the 5D interpolation results.

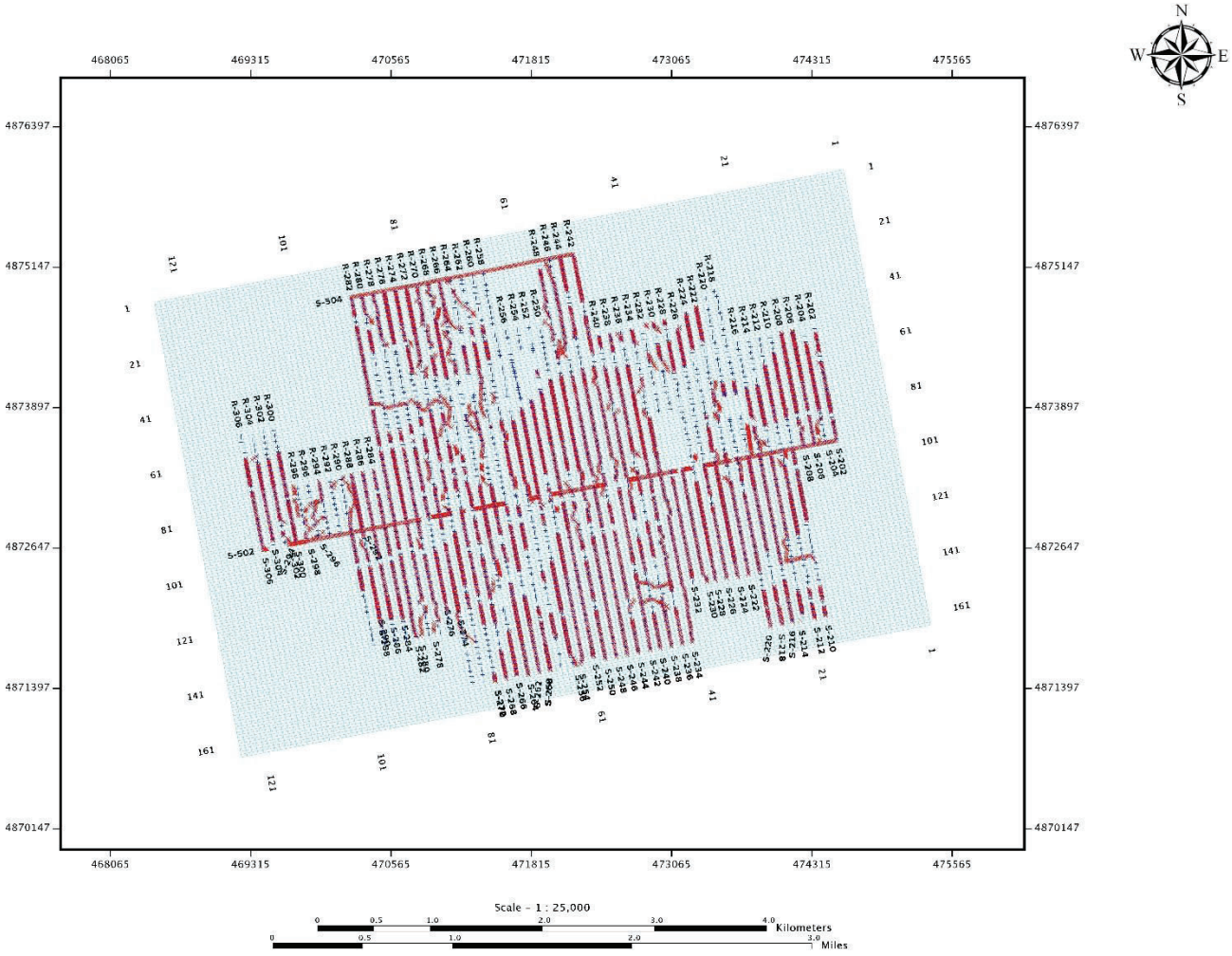


Figure 19 **Natural Processing Grid Map - 50 X 25m bin spacing, source points depicted as red dots (labelled at bottom of each line) and receivers points as blue (labelled along top of each line).**

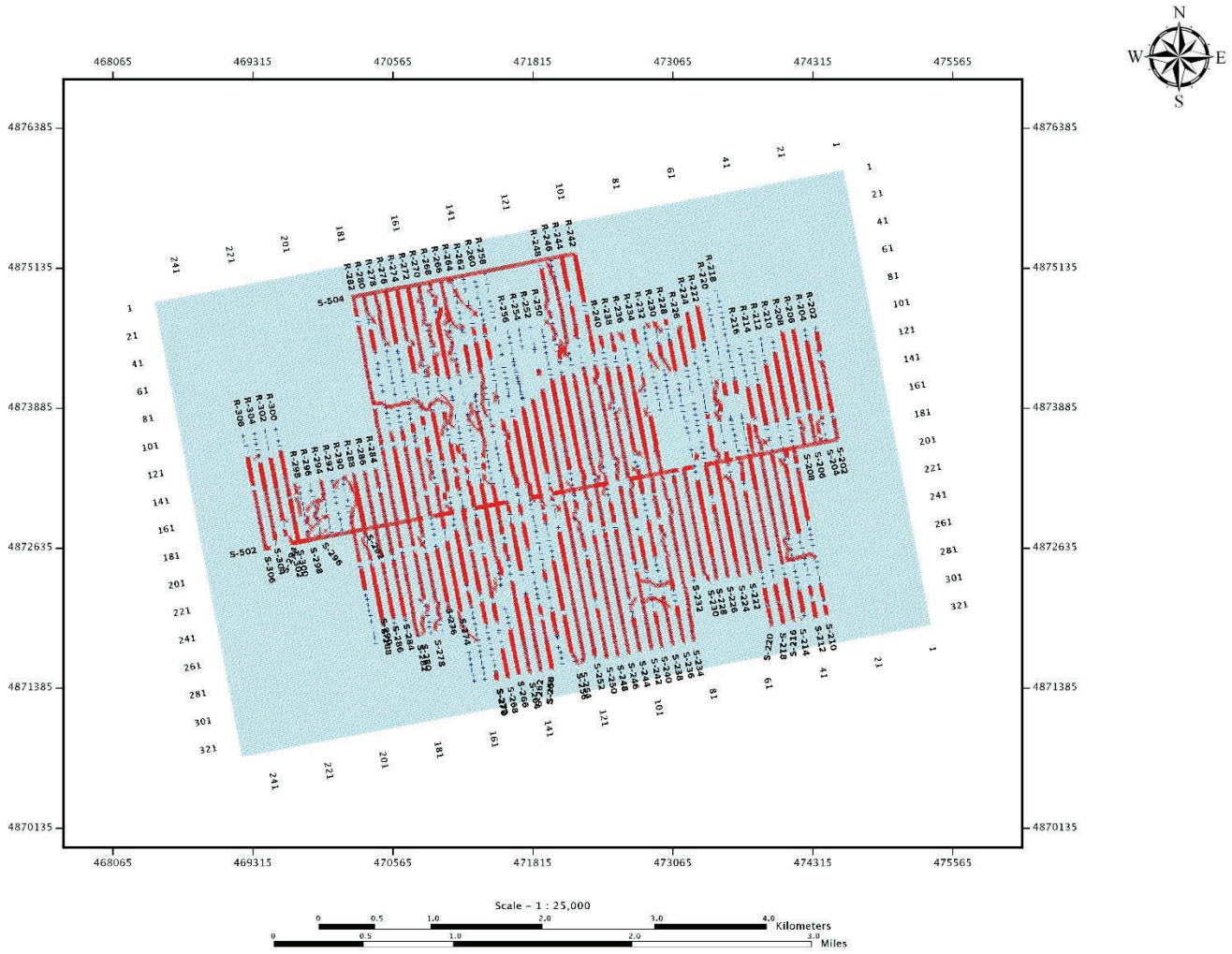


Figure 20 **Processing Grid Map after 5D interpolation - 25 X 12.5m bin spacing source points depicted as red dots (labelled at bottom of each line) and receivers points as blue (labelled along top of each line).**

Minimum Phase Conversion

The seismic wavelet for correlated vibroseis data contains a component that needs to be converted to minimum phase for the wavelet to meet the minimum phase requirement for deconvolution. The minimum phase wavelet has a short time duration and a concentration of energy at the start of the wavelet. It is zero before time zero (causal). An ideal seismic source would be a spike (maximum amplitude at every frequency), but the best practical one is the minimum phase wavelet. Figure 21 is a synthetic Klauder wavelet created using the sweep parameters from this survey before this correction (left plot, showing a zero-phase wavelet) and after this correction (right plot, showing a minimum phase wavelet).

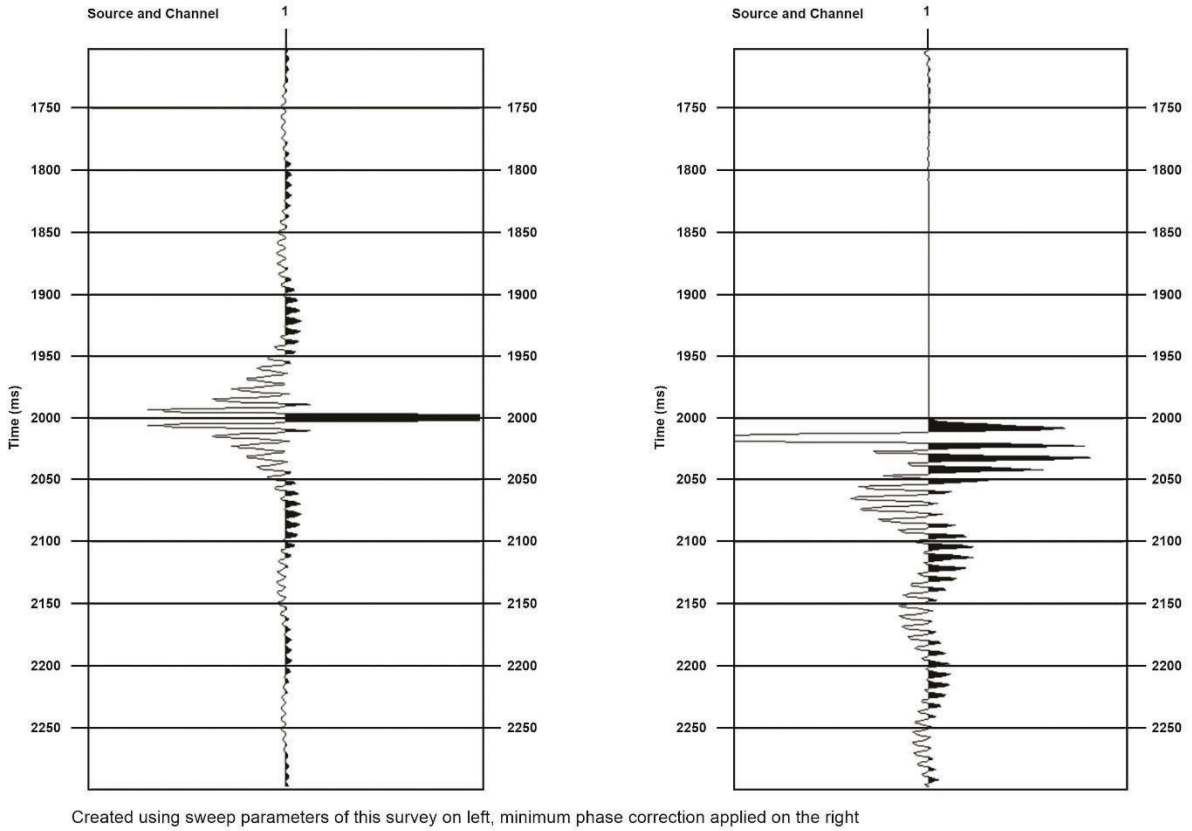


Figure 21 Synthetic Klauder wavelet - Created using sweep parameters of this survey on left, minimum phase correction applied on the right.

First Break Picking

First break picking is the detecting or picking the onset arrivals of refracted signals at each receiver produced from a seismic source point. First break picks associated with the refracted arrival times are used in an inversion scheme to study the near-surface low-velocity zone and subsequent determination of static corrections. A static correction applied to seismic data compensates for the effect of near-surface irregularities to correct the positions of source and receivers for elevation irregularities.

First breaks were picked up to 1900 m (maximum offset) for this study using a trace-by-trace window-based picker with some hand editing required. Figure 22 is an example of a complete seismic record corresponding to line 244 station 264. The data quality of the first breaks was occasionally noisy which did create some scatter in some of the picking. This scatter did not affect a significant number of traces. At the refraction statics stage, the poorer quality first break picks were examined, and erroneous picks were removed.

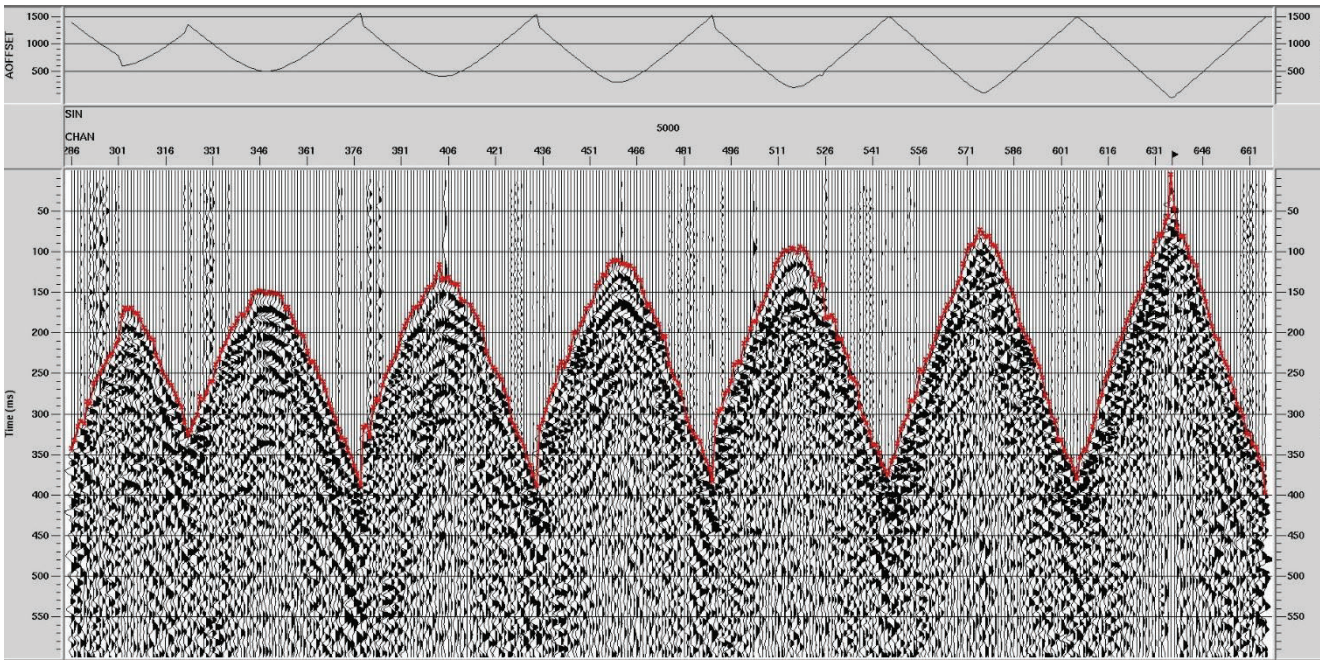


Figure 22 First Break Picks (before scaling), Shot Line: 244 Station: 264

Geometry QC

The 3D seismic data volume was provided to Absolute Imaging in SEG-Y format with geometry information in the trace header. Picked first breaks were processed using a geometry predictor where the data and first breaks were analysed for geometry errors, which were interactively corrected. The surveyed data was also correlated with the infield survey data from the geophones GPS positioning and the real-time source positioning to minimize the errors in source and receiver locations thus improving final results of the processed volume.

6.1.2 Step 2: Pre-Deconvolution AVO Scaling and Noise Suppression

Ensemble Balance

Ensemble balance computes and applies a single scalar for each input of traces. This process uses a single time window gate for each trace that can spatially vary. The scalar in the window was computed on an arithmetic mean basis. This scalar is applied to all samples of every trace in the ensemble. In this way, variations in amplitude between ensembles are reduced. The new amplitude value is equal to the old amplitude value divided by the scalar.

Offset Amplitude Recovery (OAR)

Offset amplitude recovery (OAR) applies time and offset variant gain functions to traces to compensate for loss of amplitude due to wave front spreading, array attenuation, emergence angle, surface reflection and inelastic attenuation. Except for inelastic attenuation, these gain corrections depend on offset and the local velocity. All calculations assume a horizontally layered subsurface. The purpose of OAR is to go a step beyond the normal zero-offset gain recovery to allow greater confidence in amplitude versus offset (AVO) analysis.

$$A(t) = \frac{1}{[v_{rms}(t_{tw})]^2 t_{tw}} \quad \Rightarrow \quad G(t) = [v_{rms}(t_{tw}) \,/\, v(0)]^2 [t_{tw} \,/\, t_{tw}(0)]$$

Pre-Deconvolution Noise Suppression

As part of the Step 7 in the processing workflow, several noise suppression techniques were used for linear and/or erratic noise suppression. Figure 23 shows an example of these noise suppression techniques for a single seismic record at field file identification (FFID) number 7571. The upper image shows the seismic data before any pre-deconvolution noise attenuation while the lower image shows the same data after pre-convolution noise attenuation was applied. The clear difference in signal clarity is evident throughout the images. The following sections describe the three techniques used for this study.

Linear in Shot Domain - AI Eigen Image Ground Roll Filter

This process exploits the lateral predictability of coherent events to construct a reduced-rank approximation of the input data within overlapping windows of operation. If the program is constrained to work on low frequencies only and furthermore to restrict operation to a conical region centered on the source point, then it is likely that the most dominant feature in any window will be ground roll. Hence, any low-rank reconstruction will consist primarily of eigen images associated with such noise. The filtered output is formed by subtracting the modeled noise from the original input.

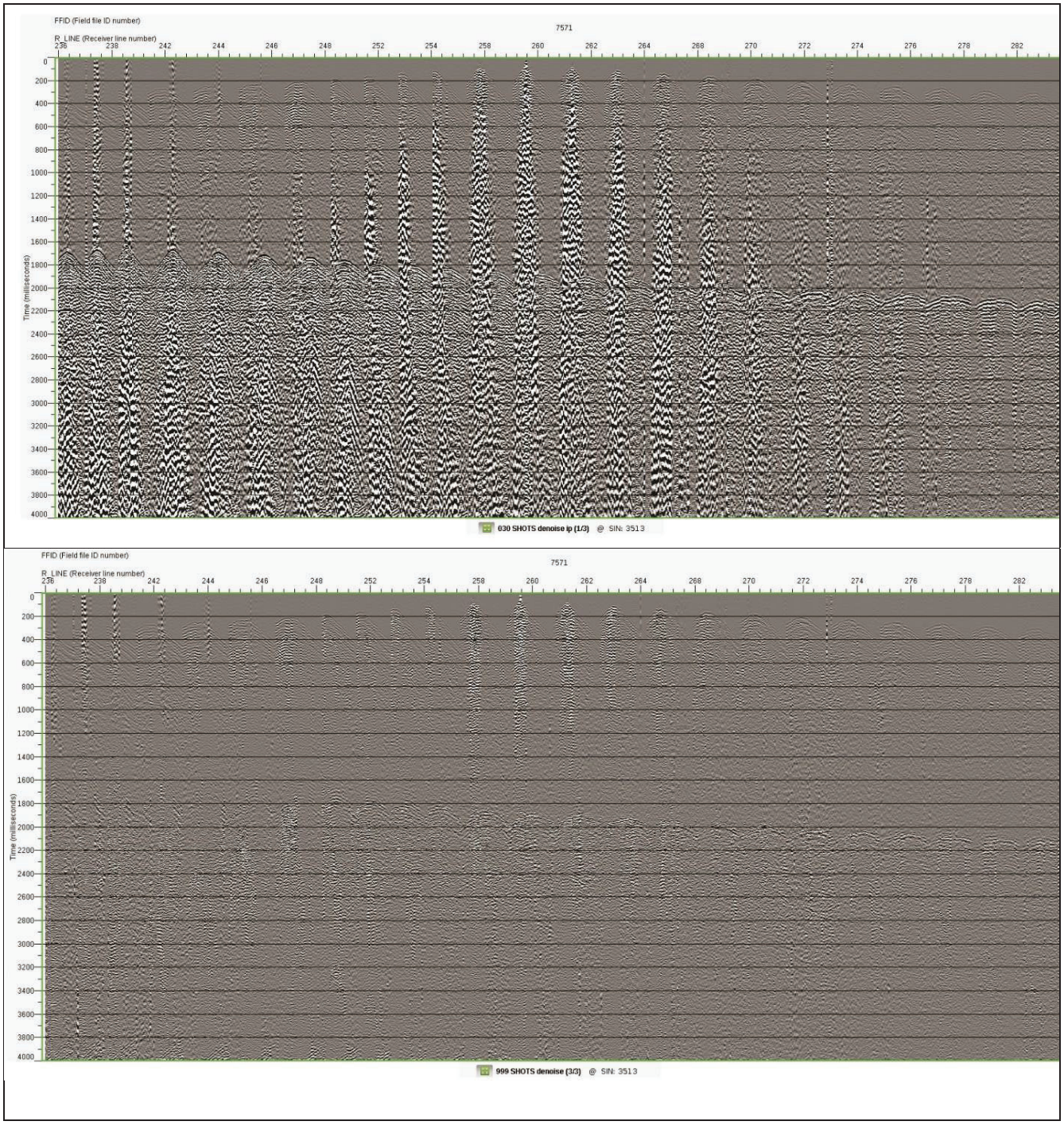


Figure 23 **Field File Identification Number (FFID) 7571. Top: Before Pre-Deconvolution Noise Attenuation; Bottom: After Pre-Deconvolution Noise Attenuation.**

Erratic in Shot Domain - AI Time Frequency Median Suppression

Ensembles of traces are mapped, via the Short-Time Fourier (STF) Transform, to the Time-Frequency (TF) domain where they are processed one frequency-slice at a time to treat for erratic (high amplitude or burst) noise using threshold filtering and/or linear interference using Low-Frequency Array (LFA) filtering. LFA filtering is simply a trace-mix in which the lateral sum-length depends on the current frequency and the apparent velocity or slope of the linear interference. Threshold filtering involves replacing or down-scaling amplitudes which are deemed anomalous by virtue of their having exceeded the expected value by an amount more than some critical tolerance.

Ground Roll Removal

Ground roll is noise within the seismic data caused by surface waves and characterized by signal dispersion, high amplitudes, low frequencies and low velocity. This noise can obscure seismic signal and result in lower seismic data quality, therefore removing this noise is critical for interpretation. Absolute Imaging used the “ground roll removal tool” within the software to reduce the undesirable effects of ground roll, distributing the data in frequency bands and leveling the energy of the components of signal with respect to the noise. This process is known as “pre-deconvolution noise attenuation”.

To further quantify the impact of pre-deconvolution noise attenuation, and to ensure no data was damaged through the ground roll removal process, the difference between pre- and post- processing within the stacked data volume was reviewed. Figure 24 and Figure 25 show examples of the resulting stacked data volumes for five adjacent inline locations centred on Inline 60 (Inlines 58 to 62) and Inline 80 (Inlines 78-82), respectively. The top image shows data from before ground roll removal, the middle image shows data from after ground roll removal, and the bottom image shows the difference between pre- and post- correction which represents the “noise” that has been removed from the stacked data.

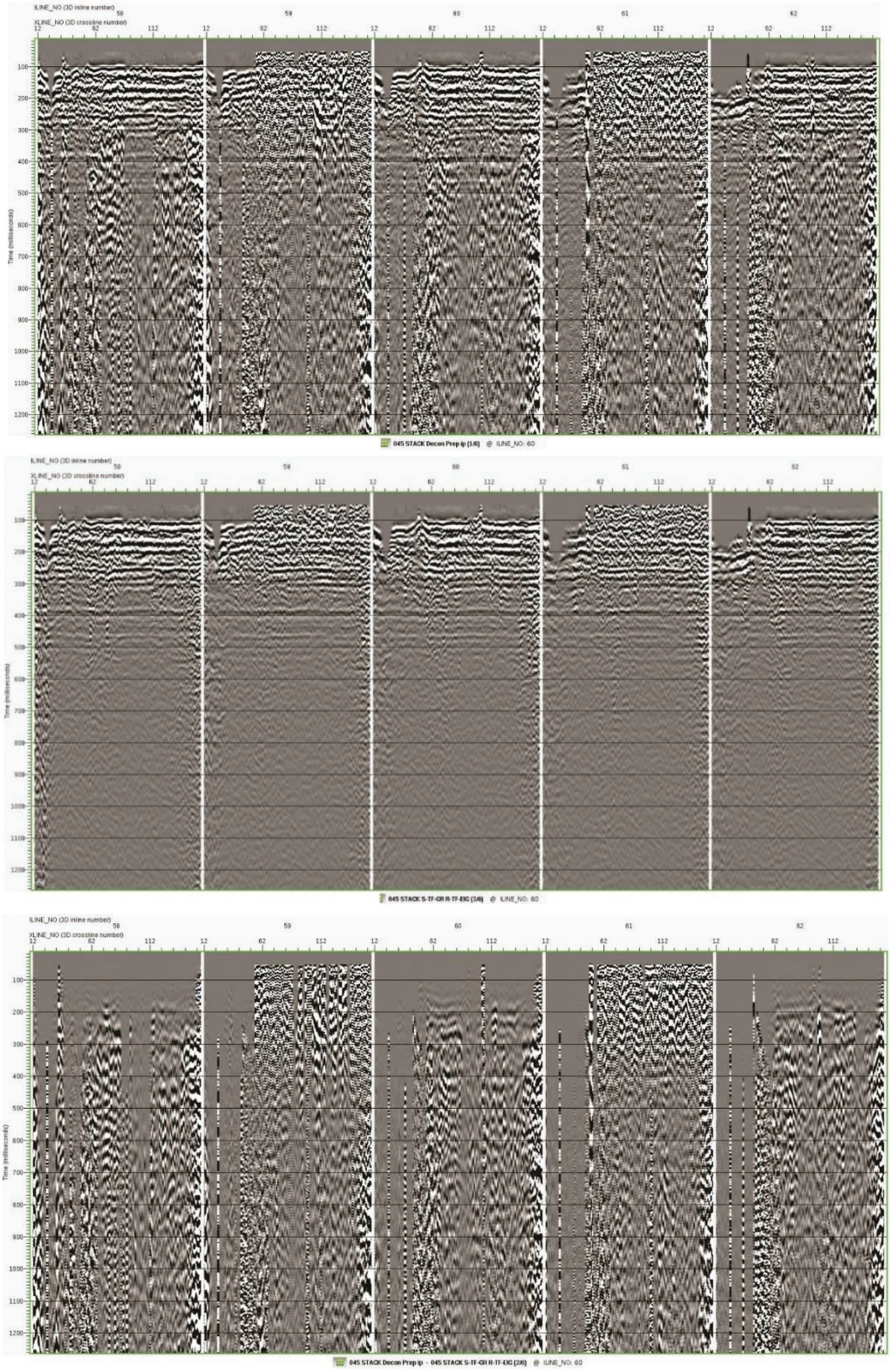


Figure 24 **Example of Ground Roll Removal Effects at Inline 60. Top: Before Pre-Deconvolution Noise Attenuation; Middle: After Pre-Deconvolution Noise Attenuation; Bottom: Difference (Seismic Signal Removed in Process).**

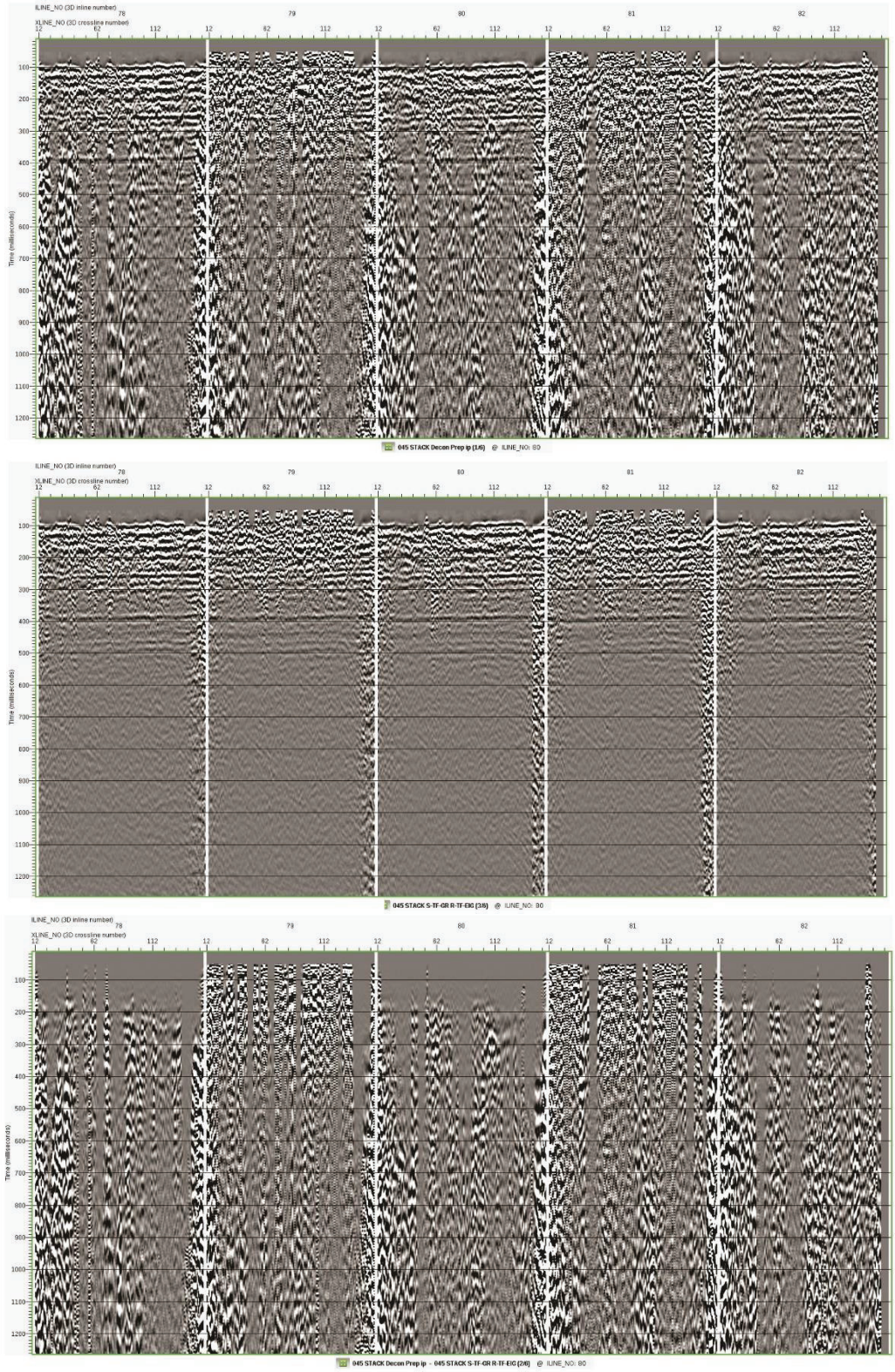


Figure 25 **Example of Ground Roll Removal Effects at Inline 80. Top: Before Pre-Deconvolution Noise Attenuation; Middle: After Pre-Deconvolution Noise Attenuation; Bottom: Difference (Seismic Signal Removed in Process).**

6.1.3 Step 3: Near Surface Model Building & Refraction Statics

Field data often exhibits distortions of primary reflections which are mostly due to near surface traveltime irregularities. Although such irregularities can be due to subsurface structures, most often they are caused by a shallow, low velocity, unconsolidated weathering layer. Field static corrections are applied to compensate for the effects of variations in elevation, and weathering velocity. The objective is to determine the reflection arrival times which would have been observed if all measurements had been made on a flat plane with no weathering or low-velocity material present. These corrections are based on the refraction first breaks and a user-specifiable velocity.

The two methods tested are Generalized Linear Inversion (GLI) and GeoTomo Traveltime Tomography. GLI is a layer-based method that works well in areas with relatively simple near surface geology. Tomography is better suited to areas with larger elevation changes and more complex near surface geology.

For the purpose of this comparison of methods, a replacement velocity (VR= 4000 m/s) and Datum (D=400 m) were selected and used for the final static calculations. This static correction normalizes the data such that it appears to be observed on a flat plane (400 m) with all the near surface data delays removed (i.e. the variations in elevation and the near surface low velocity materials have been removed).

Figure 26 displays the subsurface elevation profile or surface-in-time. The statics or time corrections are made in a surface consistent way meaning a time shift is allocated to each source point and to each receiver point to effectively strip the near surface affects out of these data. The red profile at the bottom of the figure is histogram of the shot/receiver time shifts to correct for near surface impact. The seismic data volumes were stacked using each of these methods and elevation correction stacks compared. Figure 27 shows the results of applying GLI and GeoTomo time shifts on source points and receiver points for comparison. Based on these comparisons, it was determined that the GeoTomo estimation of the near surface resulted in a clearer picture of the reflections so was used for the surface consistent static corrections.

Figure 28 depict several “slices” through the resulting near surface velocity model shown at increasing depths or reducing elevations. The velocities increase with depth and what’s especially noteworthy is the appearance of a valley of low velocities shaped a s a Y from north to south that is interpreted to be a known paleochannel. This data was later compared to the results of near surface seismic investigation of this paleochannel done at much higher resolution along the 3 EW roads (Geofirma Engineering Ltd., 2023b).

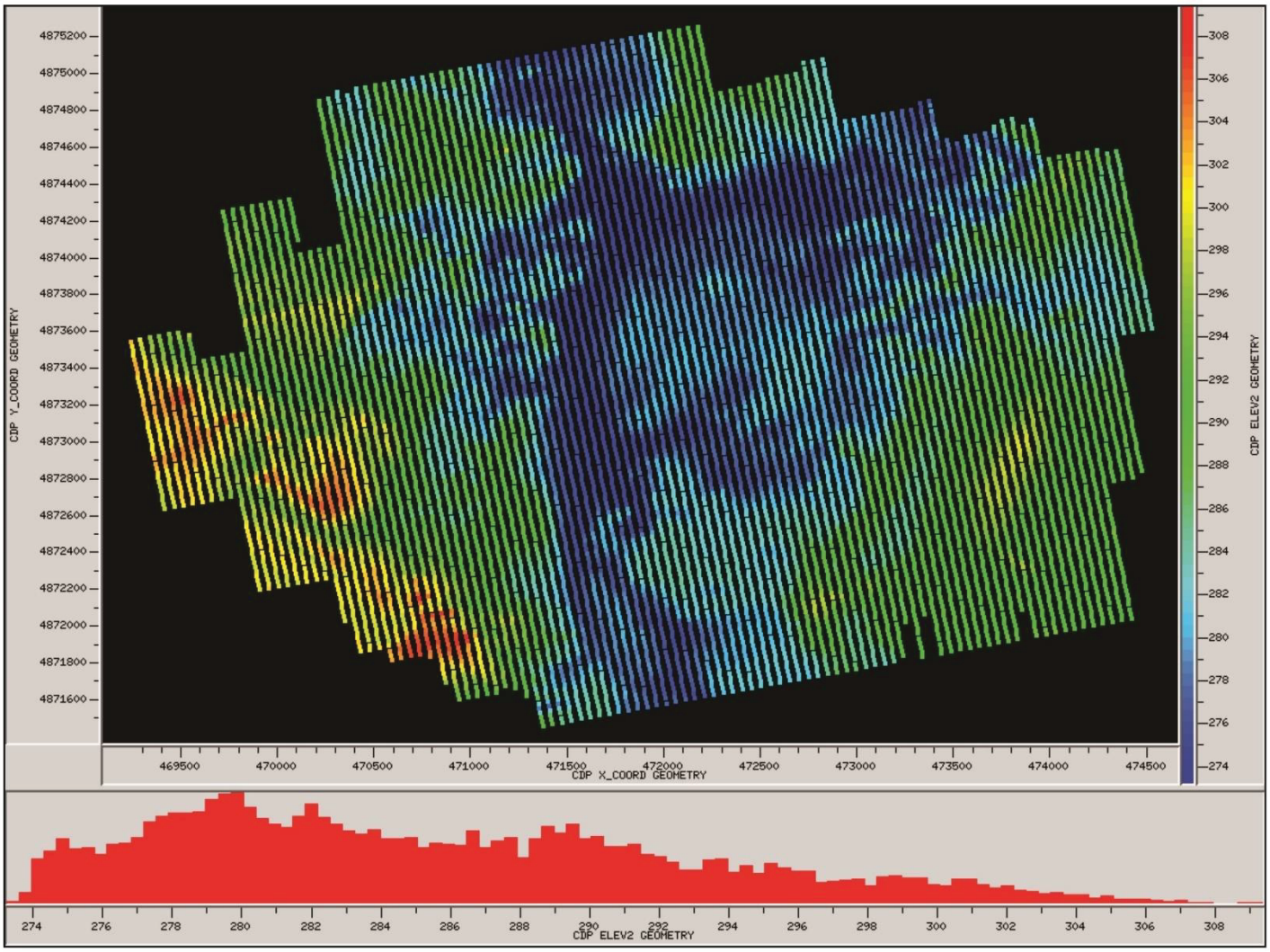


Figure 26 Elevation profile from common depth points (CDP).

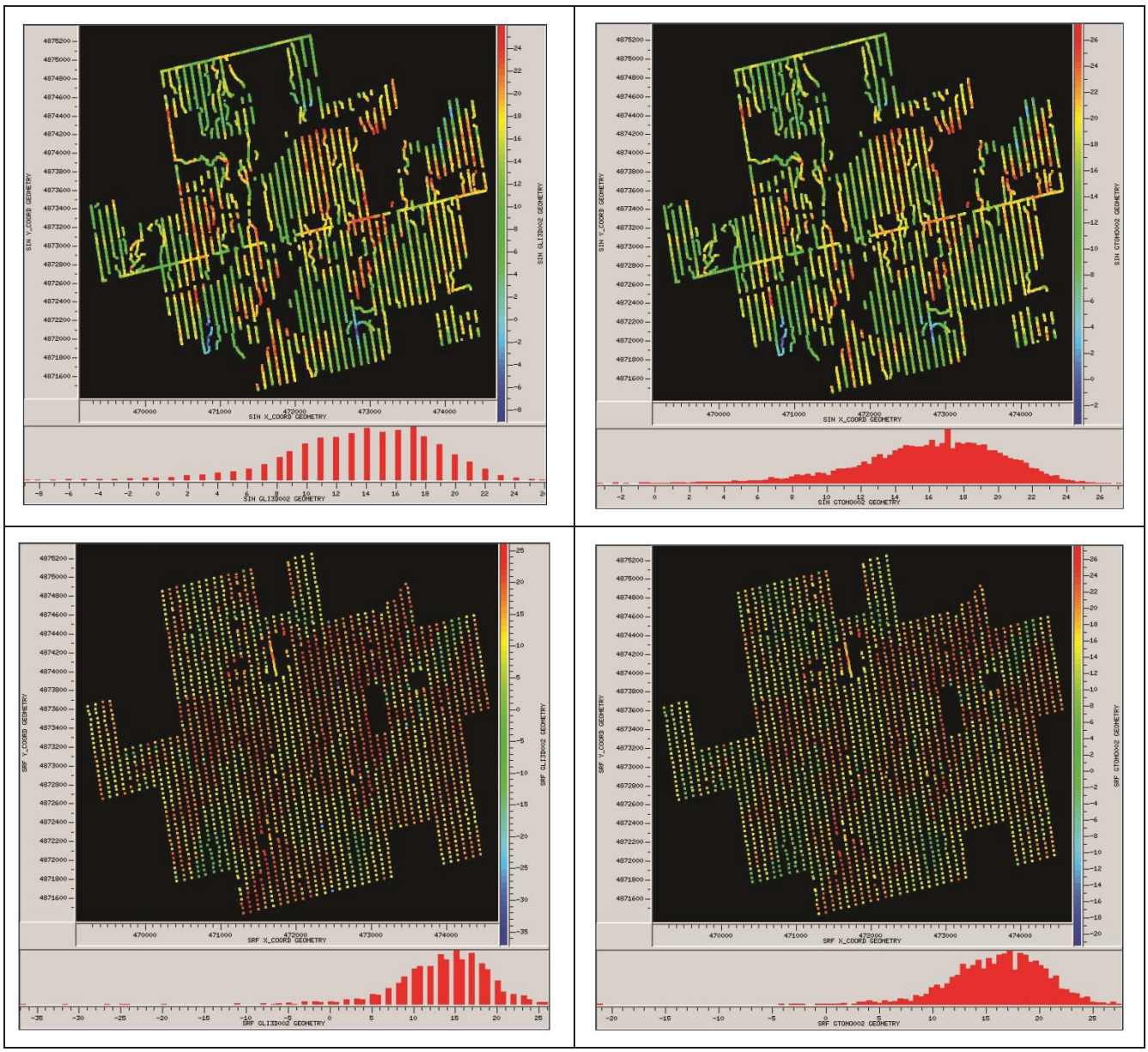


Figure 27 **Top Left: Source Statics GLI; Top Right: Source Statistics GeoTomo; Bottom Left: Receiver Statistics GLI; Bottom Right: Receiver Statistics GeoTomo.**

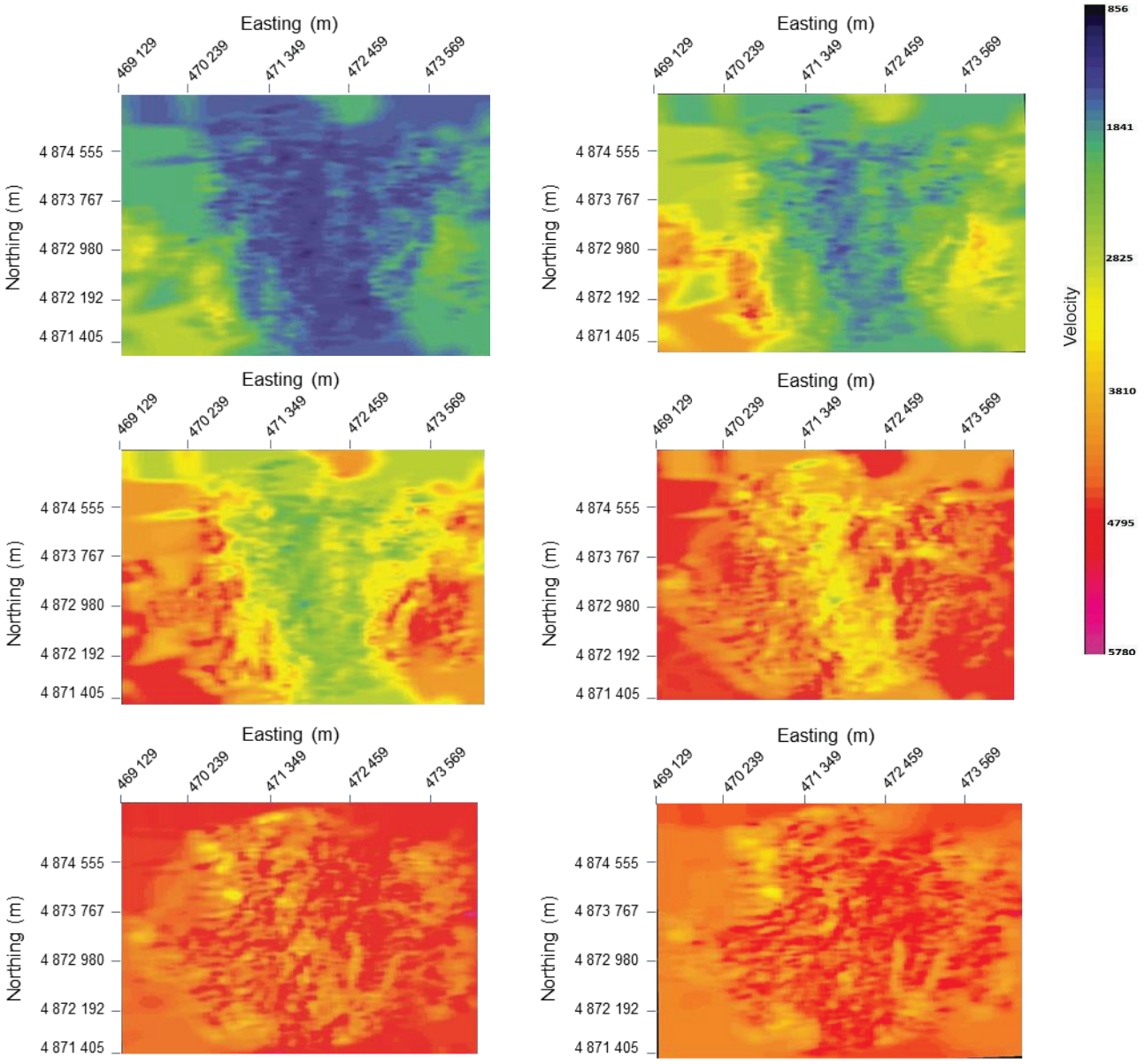


Figure 28 **Top Left: Refraction velocity model slice at depth = 274.5m; Top Right: Depth slice at 262.0m; Middle Left: Depth slice at 250.0m, Middle Right: Depth slice at 237.0m, Bottom Left: Depth slice at 224.0m, Bottom Right: Depth slice at 212.0m.**

6.1.4 Step 4: Deconvolution

The recorded seismic signal may be considered as the convolution of the source signal with the instruments, the geophones, and the response of the earth. The earth response includes some undesirable effects, such as reverberation, attenuation, and ghosting.

Surface consistent spiking deconvolution computes spectral estimates within a given seismic wavelet (time gate / window) which are decomposed into estimates for common source, receiver, offset and common depth point (CDP) ensembles. The objective of deconvolution is to estimate these effects as linear characteristics and then design and apply filters. In this survey all four components were used in the decomposition but only the source and receiver components were applied.

After some initial testing of key processing parameters (e.g. operator length and amount of pre-whitening), an operator length of 100 ms and pre-whitening of 0.1 % were found to be optimal. The design time gate was optimized by interactively picking and reviewing the window along the 3D volume with attention to avoid residual noise leftover after pre-deconvolution denoise shown in green in Figure 29.

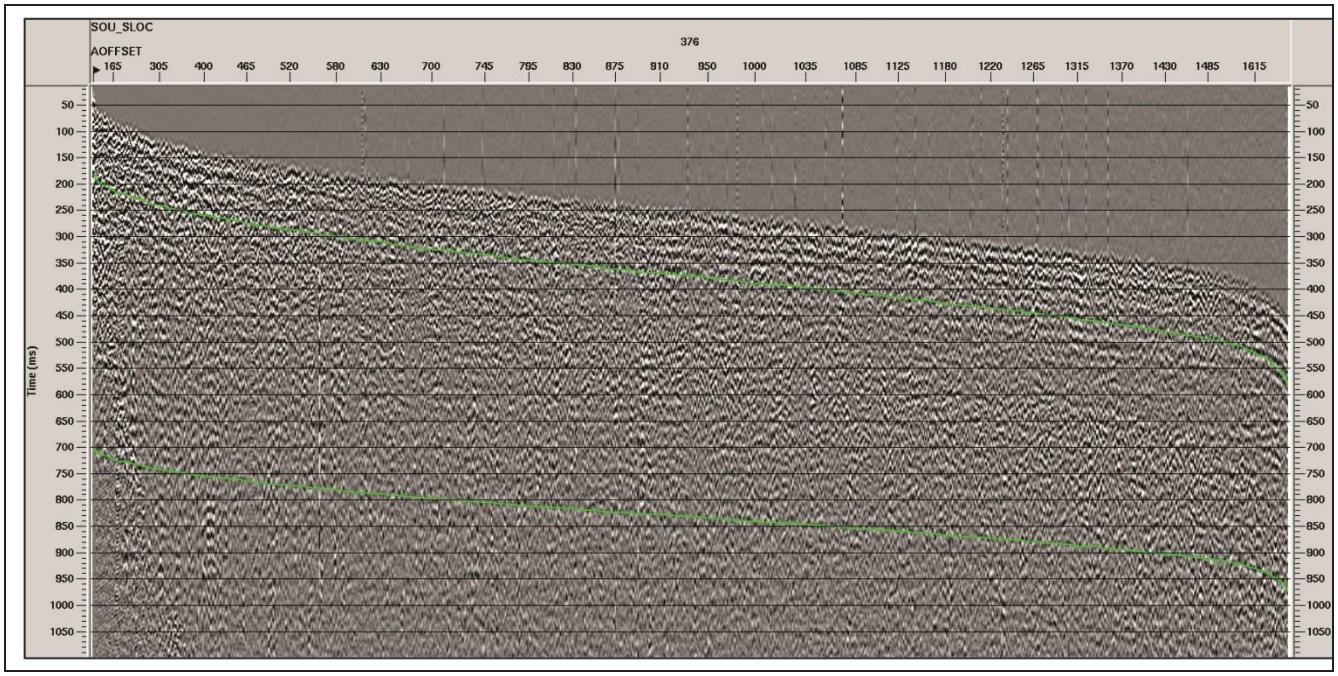


Figure 29 Shot Gather with Deconvolution Gate

Figure 30 shows these effects of deconvolution noise filtering on four stacked sections (Inline 40, 60, 80, and 100) before deconvolution (top) and after deconvolution (bottom). The vertical axis in milliseconds (ms) and horizontal axis as position along each Inline. Note the clearer image in the bottom plot which provides a higher quality image for interpretation.

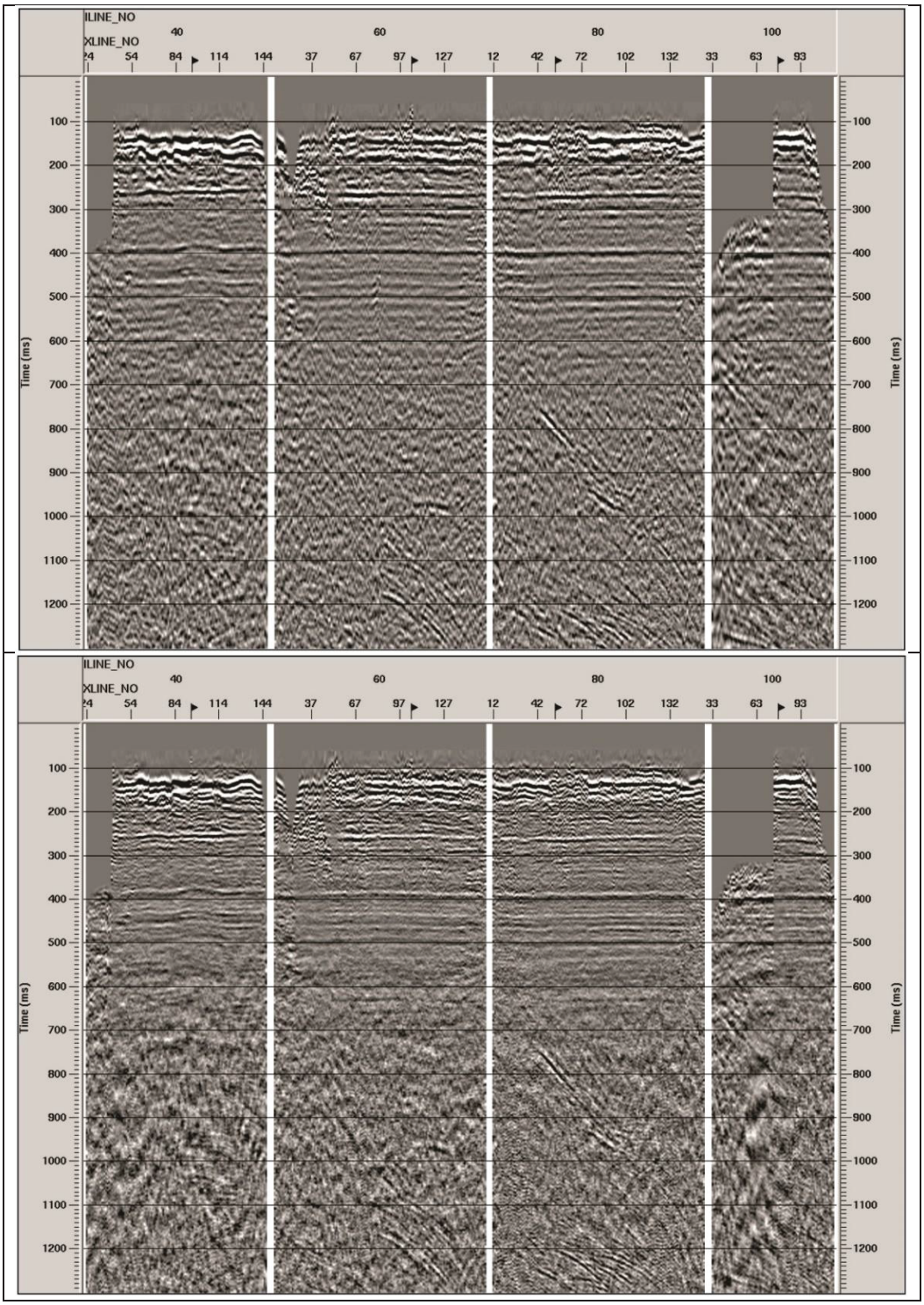


Figure 30 Effects of Deconvolution on Stacked Seismic Data for Inlines 40, 60, 80 and 100. Top: Pre-Deconvolution and Bottom: Post- Deconvolution.

Figure 31B and Figure 32B show the average amplitude spectrum of these seismic data before deconvolution and post-deconvolution, respectively. This amplitude spectrum is a Fourier transform of these autocorrelations showing the results of “balancing” the spectrum. The vertical scale on the amplitude spectrums is relative amplitude in units of decibels (dB), with the highest value being 1 (shown as 0 dB) and the other frequencies shown in amplitudes relative to 1 (shown as a logarithmic scale with increments of -5 dB) with the lowest value being shown as -65 dB.

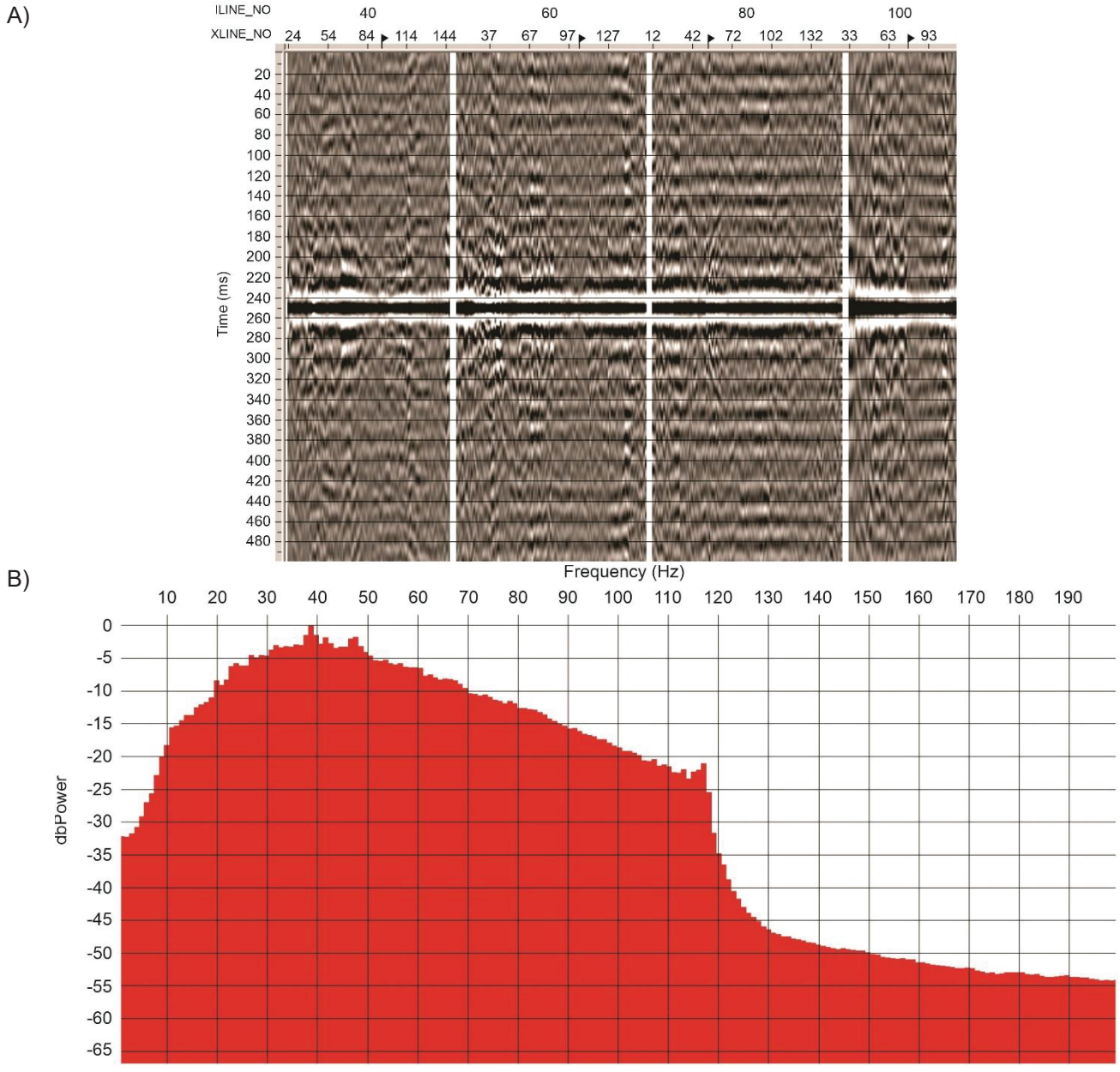


Figure 31 Pre-Deconvolution - Inlines 40, 60, 80 and 100. (A) Autocorrelations from Stacked Seismic Traces; (B) Seismic Signal Amplitude Spectrum.

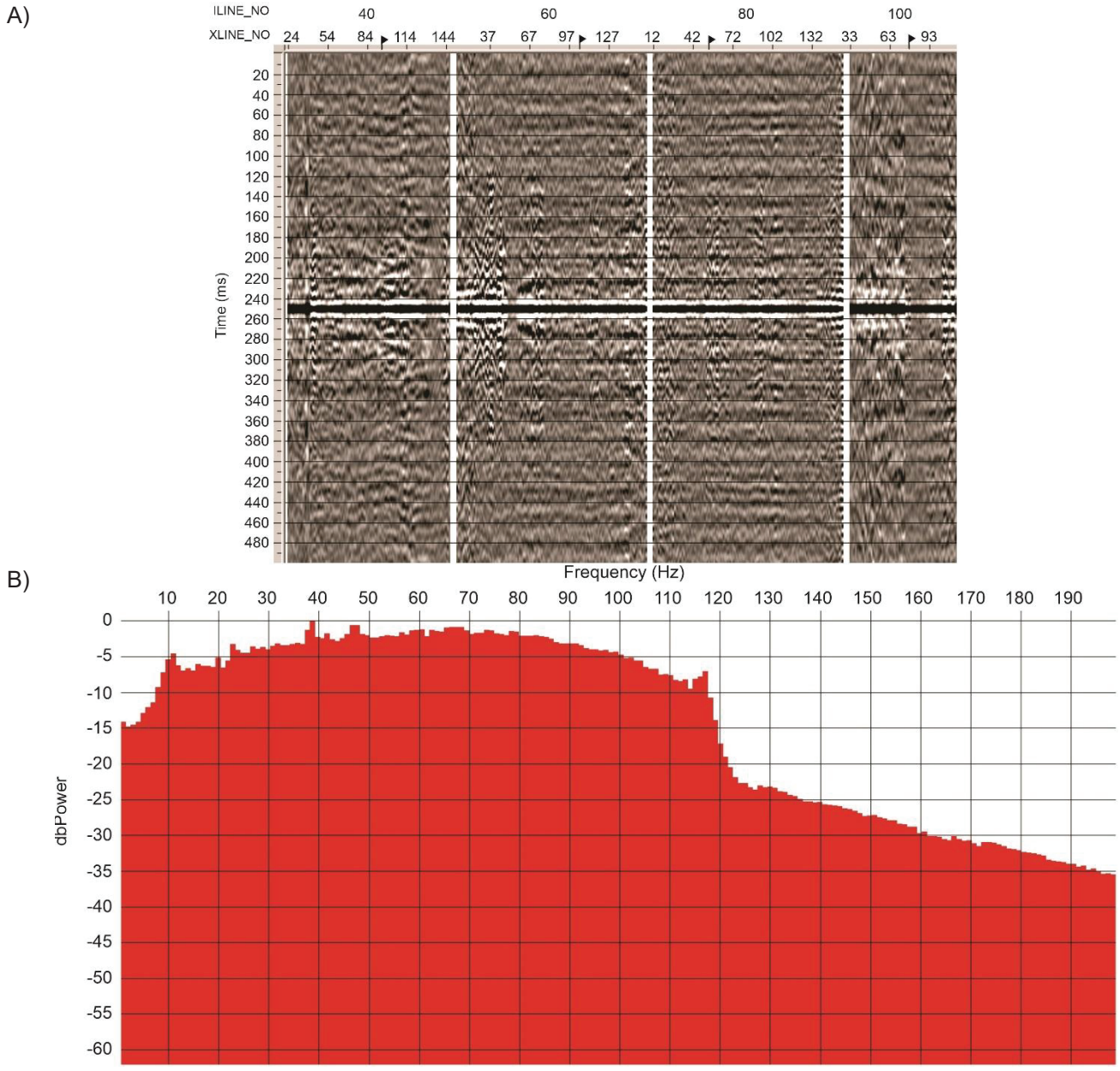


Figure 32 Post-Deconvolution - Inlines 40, 60, 80 and 100. (A) Autocorrelations from Stacked Seismic Traces; (B) Seismic Signal Amplitude Spectrum.

The more balanced spectrum, shown by the wider more balanced range of frequency spectrum in the post-deconvolution Figure 32B, results as an autocorrelation wavelet to be more focused when comparing Figure 31A before deconvolution to the post-deconvolution (Figure 32A). Ideally, the wavelet would collapse to a spike which would contain all frequencies rather showing additional noise which is referred to as a “white” spectrum. The additional noise within the pre-deconvolution data (Figure 31) is evident as a wider white band at a time of approximately 250 milliseconds (ms) which is the mid point of the 500 ms trace compared to the post-deconvolution data (Figure 32). This process is an important quality control during deconvolution and is part of the process for extracting the wavelet during amplitude variation with offset (AVO) processing. Essentially, by removing the wavelet, you attempt to get back to the actual reflectivity sequence.

Residual Gain Correction

Amplitude variation with offset (AVO) is defined as the variation in seismic reflection amplitude with change in distance between source and receiver locations that indicates differences in lithology and fluid content in rocks above and below the reflector. AVO analysis is a technique by which geophysicists attempt to determine thickness, porosity, density, velocity, lithology and fluid content of rocks. Successful AVO analysis requires special processing of seismic data and seismic modeling to determine rock properties with a known fluid content. In AVO processing it is necessary to apply some sort of residual gain recovery to tame amplitudes blown up by the deconvolution process. This noise often has an offset and time dependency and is most problematic earlier in the record.

Surface Consistent Scaling

Surface consistent scaling estimates and adjusts the relative amplitude contributions of sources and receivers in a surface consistent basis. The amplitude of every trace is estimated over a defined window. These trace amplitudes are decomposed into source and receiver components using a Gauss-Seidel iterative inversion method. As these corrections are surface consistent, separate amount of scaling attributes are applied for source and receiver locations to maintain AVO compliance.

In total this process was sequentially completed four times (four separate passes). The corrections were observed to gradually converge with each pass as the amplitudes became more uniform and more noise was removed. Figure 33 shows a summary of the surface consistent scaling on both source points (left column of figures) and receiver points (right column of figures) after each of the four passes. Pass 1 was completed after the first pass of denoise, Pass 2 was completed after deconvolution, Pass 3 was completed after post-deconvolution denoise and Pass 4 was completed after the 5D interpolation.

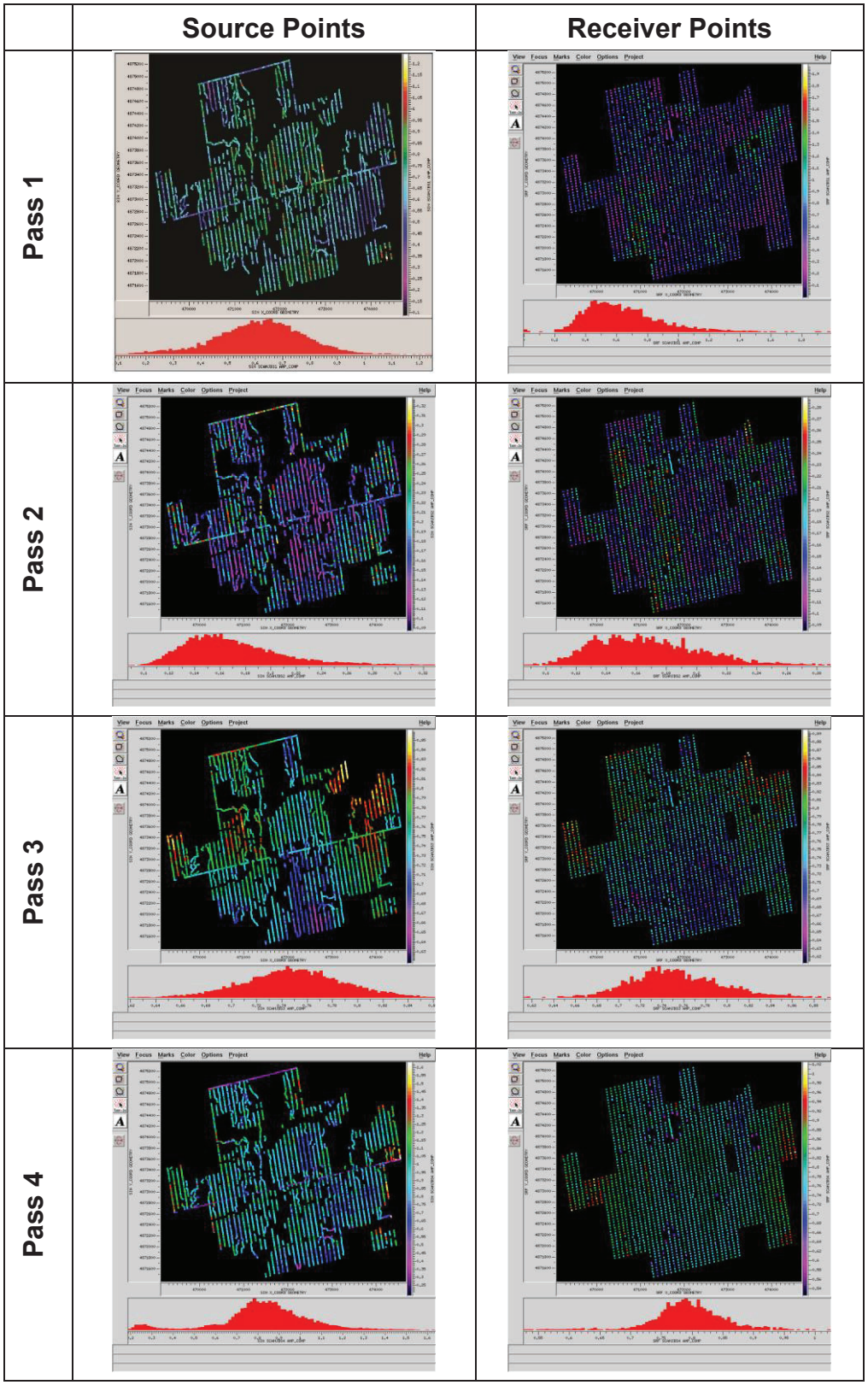


Figure 33 **Surface Consistent Scaling of Source and Receiver Points. (showing progressive improvement in results based on four passes).**

6.1.5 Step 5 : Post Deconvolution Noise Suppression (Shot Domain)

Similar to the pre-deconvolution noise suppression, Figure 34 shows two source records for field file identification number (FFID) 7571 that compare before and after noise suppression. The filtered output is formed by subtracting the modeled noise from the original input. For this project the process was constrained to target frequencies below 12Hz in order to remove the strong ground roll. Figure 35 shows an example of the resulting stacked data volumes for five adjacent inline locations centred on Inline 60 (Inlines 58 to 62). The top image shows data from before ground roll removal, the middle image shows data from after ground roll removal, and the bottom image shows the difference between pre- and post- correction which represents the "noise" that has been removed from the stacked data. Note that in Figures 63 and 66 the differences are not as pronounced as in the previous pre-deconvolution noise suppression.

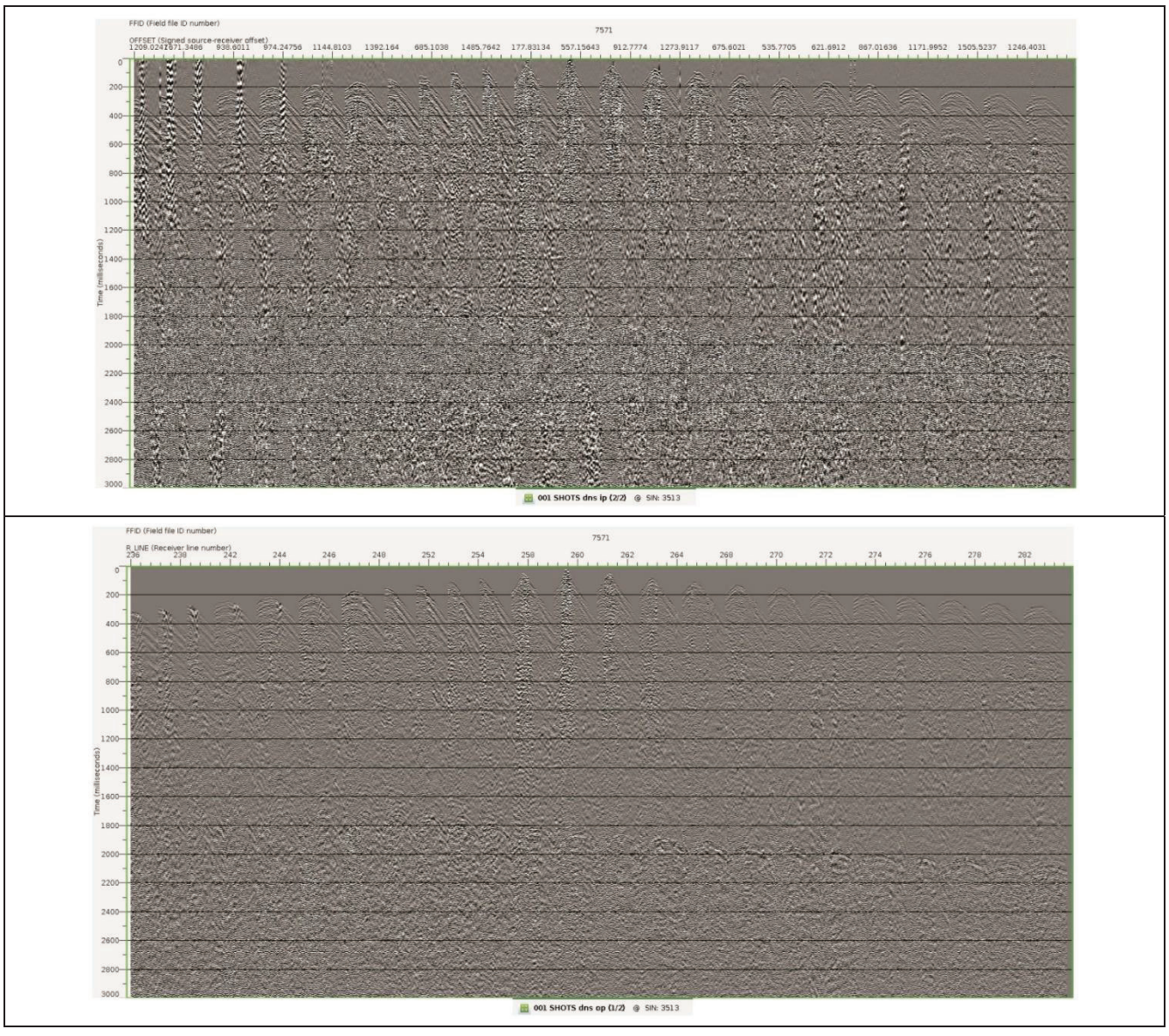


Figure 34 **Field File Identification Number (FFID) 7571. Top: Before Post-Deconvolution Noise Attenuation; Bottom: After Post-Deconvolution Noise Attenuation.**

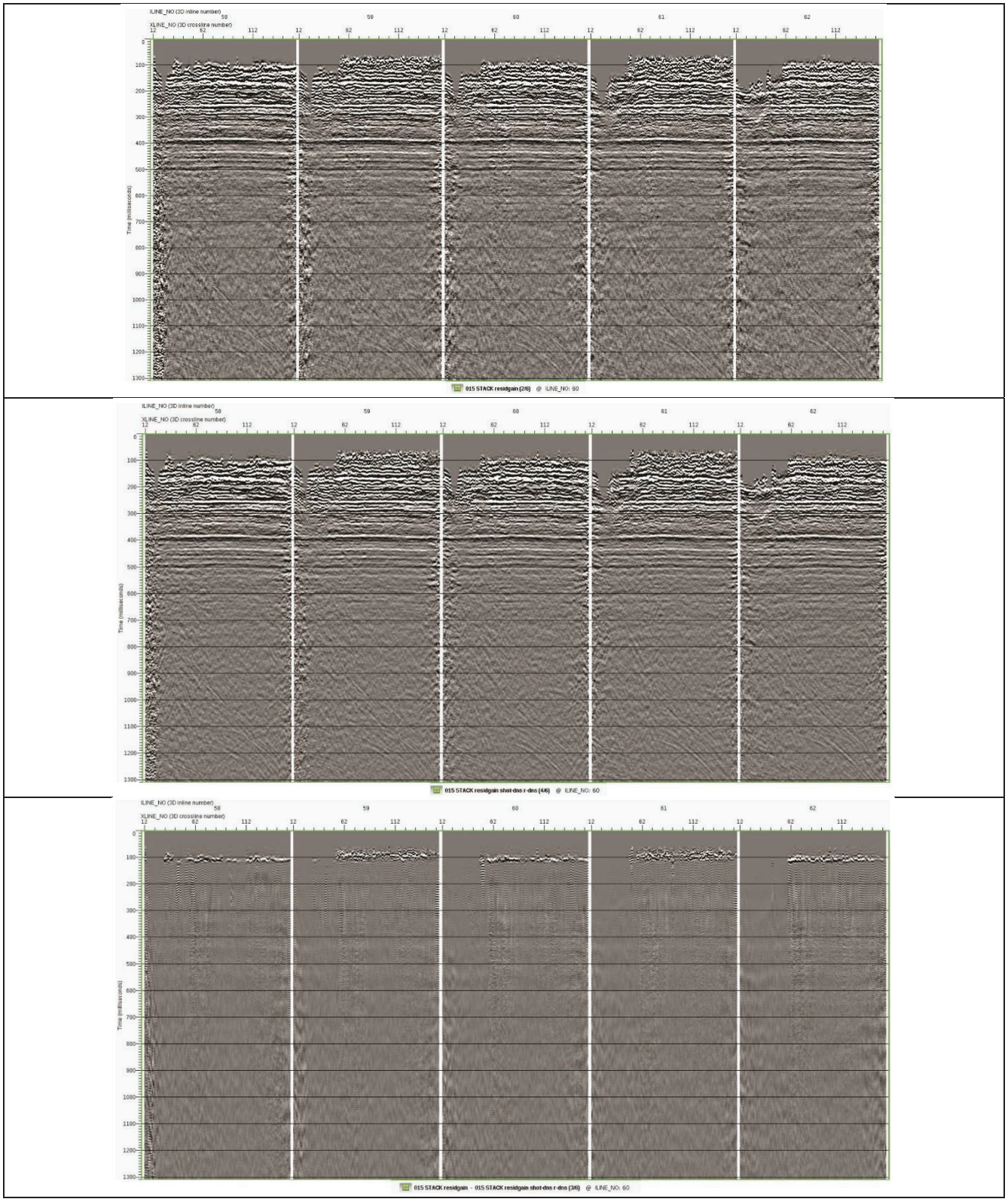


Figure 35 **Example of Post-Deconvolution Noise Attenuation Effects at Inline 60. Top: Before Post-Deconvolution Noise Attenuation; Middle: After Post-Deconvolution Noise Attenuation; Bottom: Difference (Seismic Signal Removed in Process).**

6.1.6 Step 6: Velocity Analysis and Residual Statics

A total of two series of passes or iterations including velocity analysis followed by residual statics correction, plus a final velocity analysis were completed as part of this sequence.

Velocity Analysis

The velocity analysis was carried out using a combination of semblance, super gather, velocity function stacks and dynamic stacks. As part of the velocity analysis, a key technique used to improve the data quality is normal moveout (NMO) correction and time offset mute. This correction consists of applying an offset- and time-dependent shift to each sample of the trace in such a way that all events corresponding to the same reflection will be located at the same time intercept after correction.

The semblance panel displays the stack response as a function of time and velocity in a contour plot. Semblances are computed by performing hyperbolic scans at a specified number of constant velocities between a minimum and maximum stacking velocity on pre-stack data. The gather panel displays a common offset stacked super gather of a specified number of CDPs. The velocity panel (function stacks) displays a series of side- by-side stacked traces for a set of CDPs. These traces are corrected for NMO with a series of different velocities. The dynamic stack panel displays an approximation of a stack generated with the current velocity pick. This panel is used as a quality control of the picked function.

Figure 36 shows two examples of the velocity analysis process, including the top plot for Inline 80 and Crossline 80, and the bottom plot for Inline 70 and Crossline 120. Each plot comprises three panels, including a semblance panel (left), super gather panel (middle), and common velocity panel (right). When the reflection horizon is basically flat a bullseye is seen on the semblance to guide the data processor. When a time and velocity is picked (yellow line is the root mean squared velocity, VRMS) this is interactively applied to the super gather (middle panel) and shows up on the series of common velocity panels shown on the far right. These are sub-sets of the stacked volume at various common velocities so will show a solid peak or focused wavelet at the velocities picked shown in red also to guide the data processor.

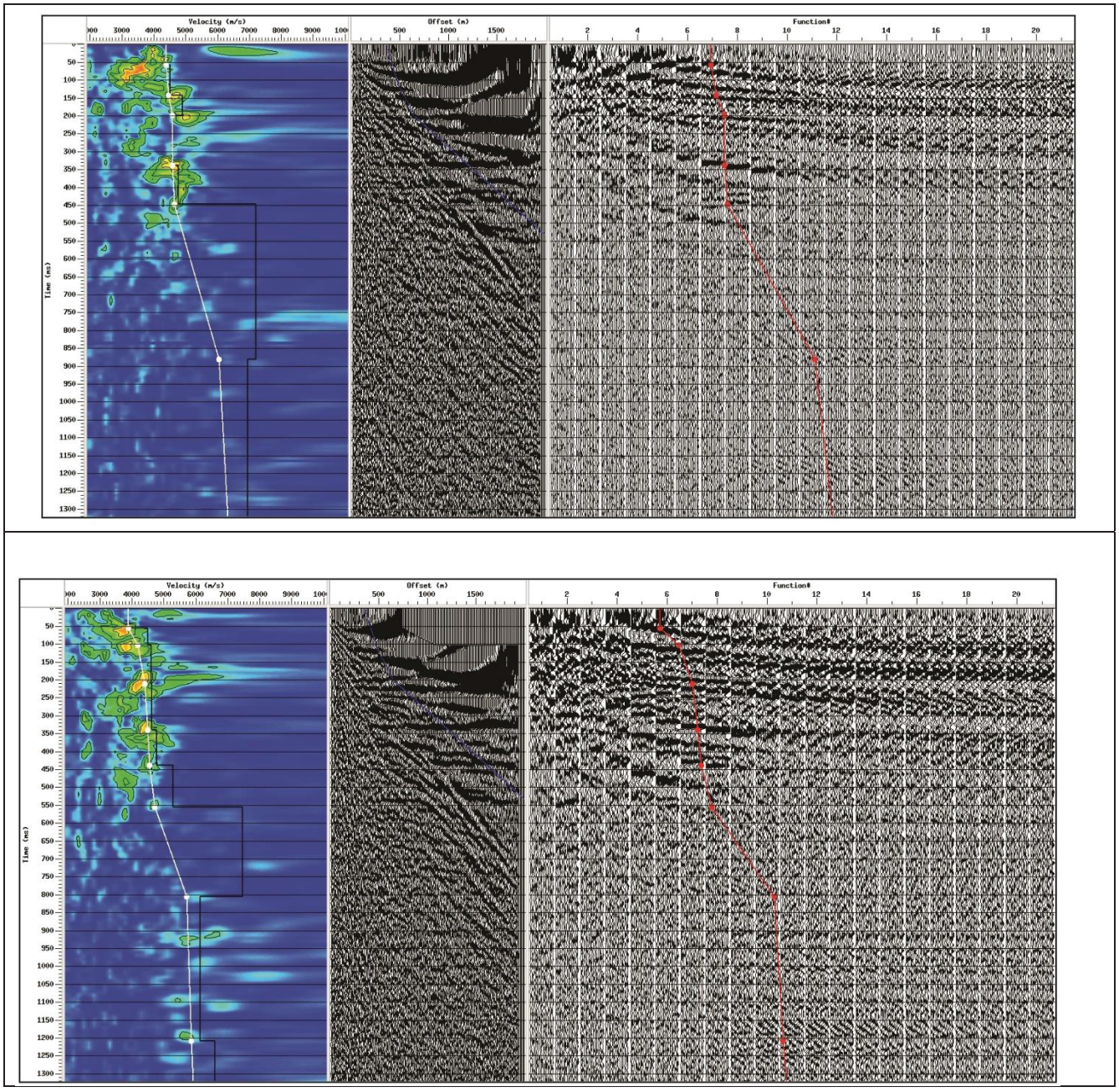


Figure 36 Velocity picking example. Top: Inline 80 & Crossline 80; Bottom: Inline 70 & Crossline 120.

The initial velocities were picked on a 1000 m x 1000 m grid followed by the second pass of velocities on a 500 m x 500 m grid. Each update in the velocity field is applied to the stacked data volume and then a residual static calculation is also run, each successive pass should converge to a solution of the best velocities and best residual statics as discussed in the next section.

Residual Statics Correction

Refraction field statics is a method used to remove a significant portion of the long wavelength travel time irregularities caused by the near surface weathering layer. Residual static corrections are designed to correct small inaccuracies in the near surface model. Their application should lead to an improvement in the final processed section. These residual statics are applied in a surface consistent manner where each trace is cross correlated with other input traces and time shifts applied to the data are the sum of shot consistent and geophone consistent times to ensure AVO compliance.

Two passes of residual statics were applied to the data. The first pass was done after the first pass of velocity analysis and the second pass after the second pass of velocity analysis. Testing of multiple gates (time correlation window) and maximum static shift values (time duration) were run to determine optimum parameters for residual static correction as shown in Table 6.

Table 6 Summary of Residual Static Correction Parameters

Pass Number	Correlation Window	Static Shift	# Iterations
First Pass	200 to 700 ms	+/- 24 ms	5
Second Pass	200 to 700 ms	+/- 12 ms	5

Figure 37 shows the results of the first and second pass residual statics correction for both source points and receiver points. The red histograms at the bottom of the figures show that after the first pass corrections, most of the noise from residual statics is within the range of +/- 4 ms with most +/- 2 ms or less, while after the second pass corrections, the noise from residual statics has diminished to less than +/- 2ms and most only +/- 1 ms or less.

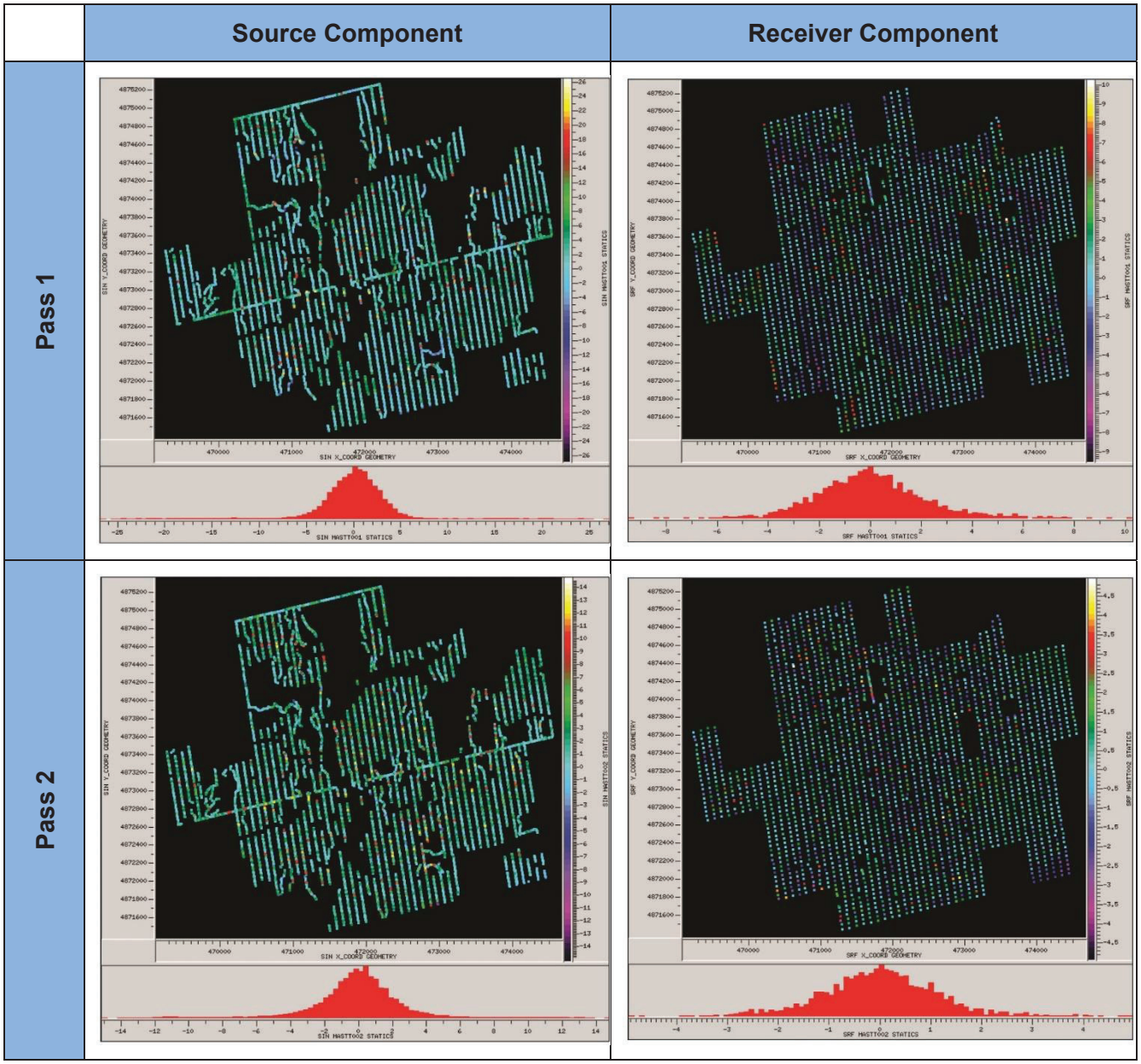


Figure 37 Surface consistent residual statics.

Figure 38 and Figure 39 show the seismic stacked data after each individual step of the velocity analysis and residual statics correction process. These figures show seismic data for five inlines centred at Inline 60 (Inline 58 to 62), the same series of QC lines as used previously for the noise attenuation QC displays.

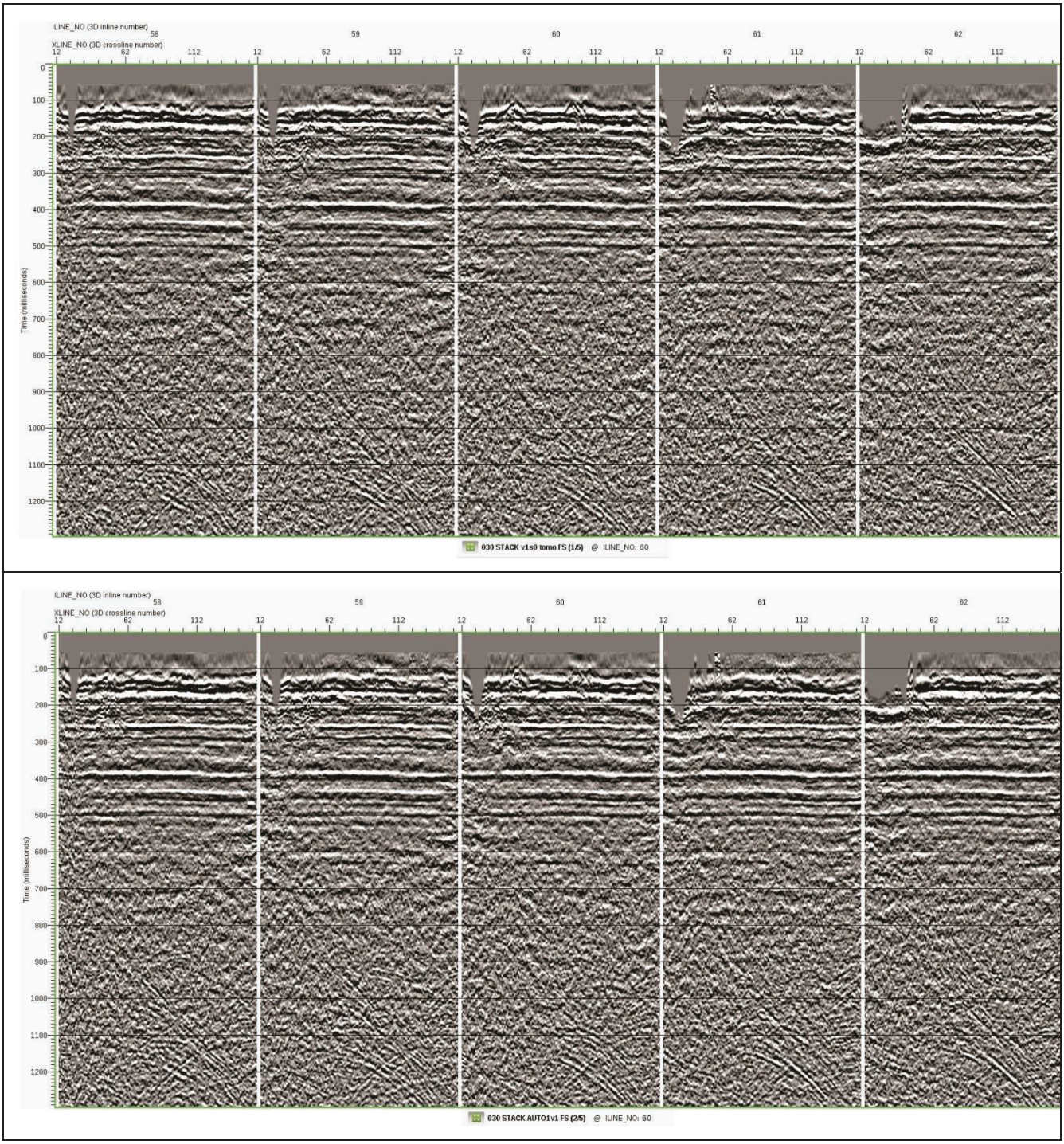


Figure 38 **Velocity Analysis and Statics Correction - Inline 60. Top: After First Pass of Velocity Analysis; Bottom: After First Pass of Velocity Analysis and First Pass of Residual Statics Correction.**

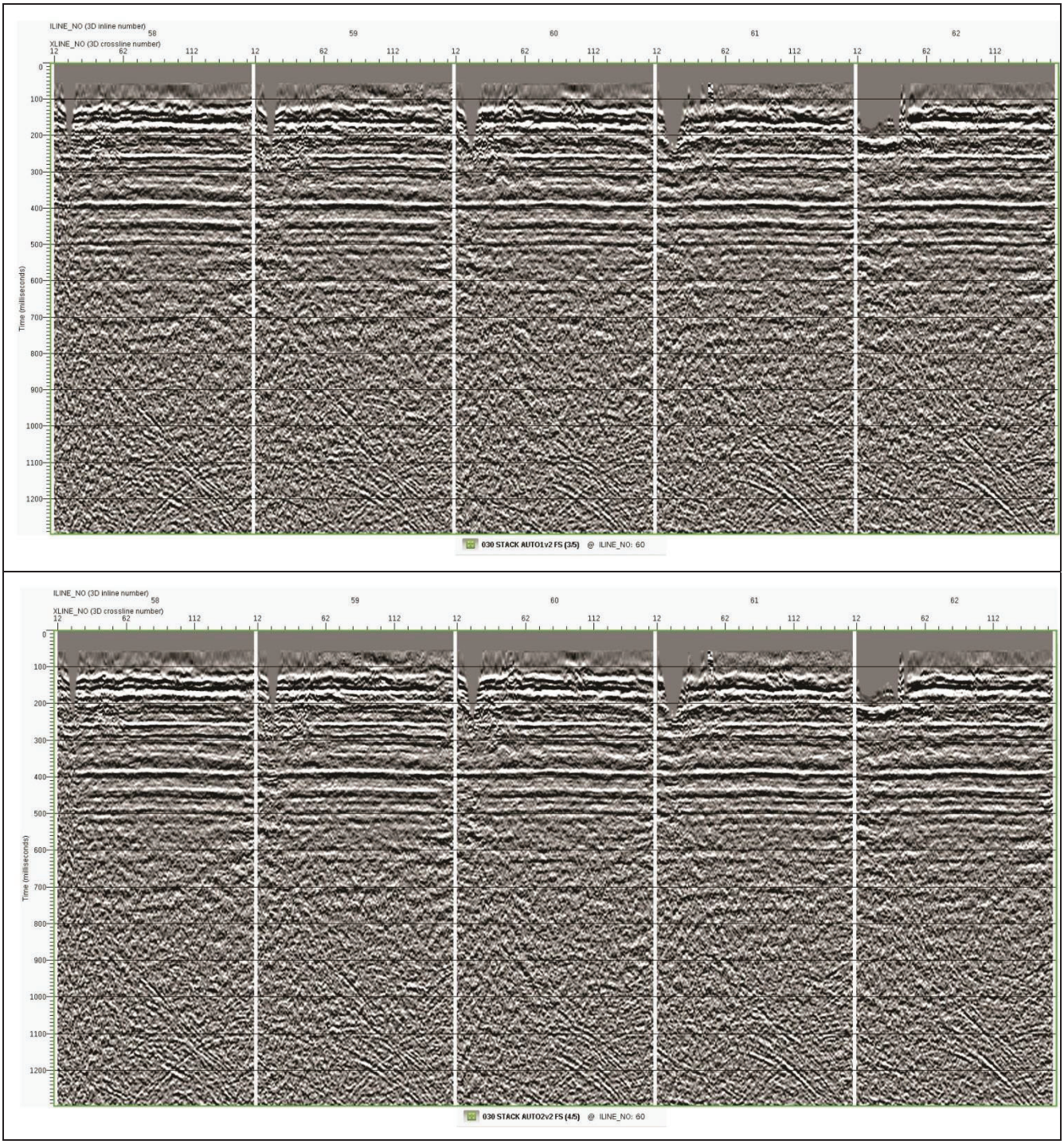


Figure 39 **Velocity Analysis and Statics Correction - Inline 60. Top: After Second Pass of Velocity Analysis and First Pass of Residual Statics Correction; Bottom: After Second Pass of Velocity Analysis and Second Pass of Residual Statics Correction.**

6.1.7 Step 7: Common Depth Point (CDP) Trim Statics

An enhanced version of the stack, known as an external model, is produced and then correlated with the input common depth point (CDP) gathers. These cross correlations are then used for the trim statics application which will do a fine adjustment within the CDP gather. The parameters used for CDP trim statics as part of this project included a correlation window of 200-800 ms and a maximum static shift of +/-10 ms.

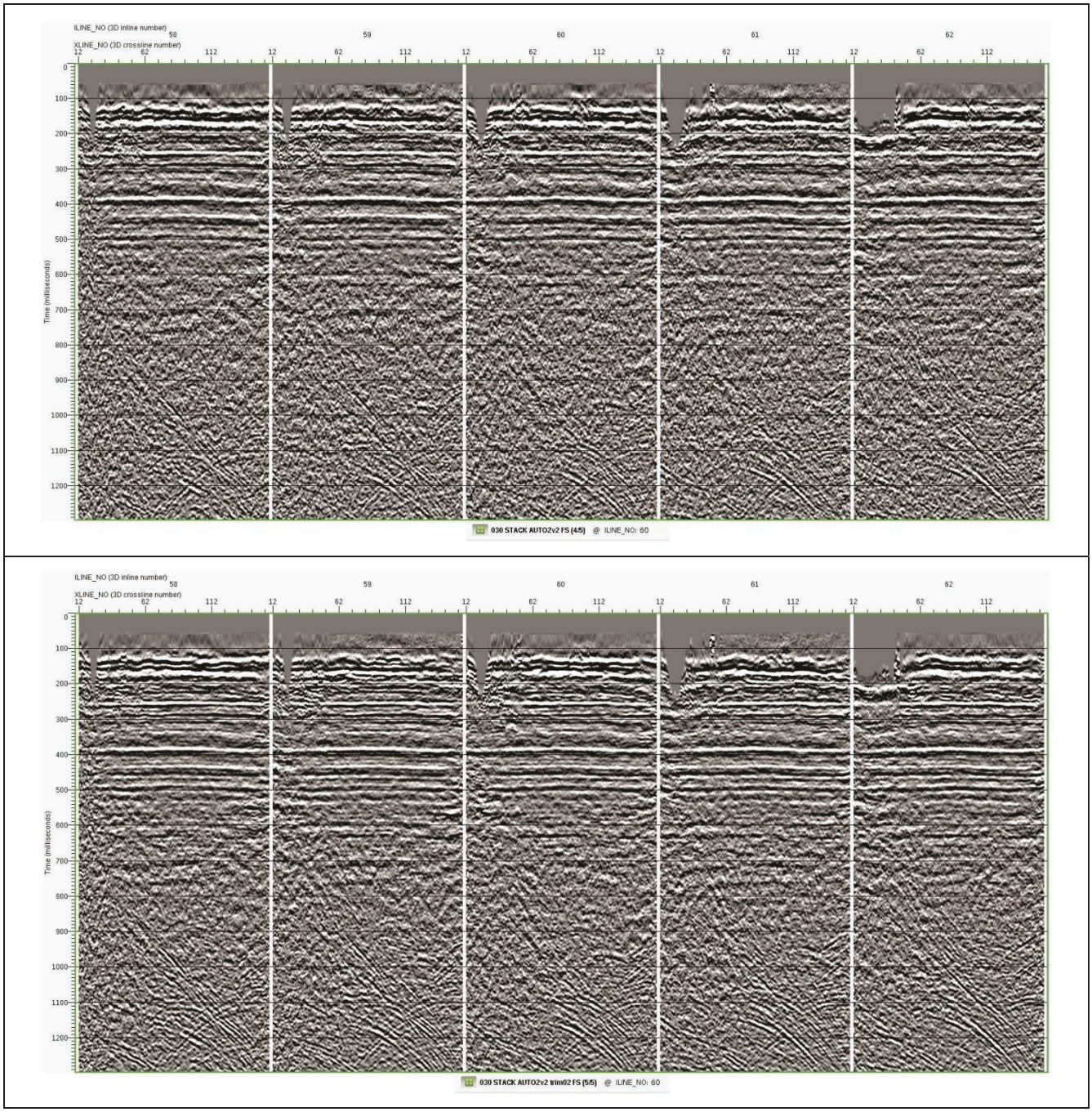


Figure 40 Example of Effects from CDP Trim Statics Correction. Top: Inline 60-before trim statics; Bottom: Inline 60- after trim statics.

6.1.8 Step 8: Pre-Stack Noise Suppression on Cross Spreads

The data acquired with orthogonal geometry can be considered as a collection of cross-spreads. Each intersection of a source line and a receiver line forms the center of a cross-spread. The dense sampling of the sources along the source line and of the receivers along the receiver line creates a dense single fold areal coverage. Ambient noise may be entirely random, or it may be coherent in the cross-spread domain, therefore orthogonal geometry data processing benefits from cross-spread oriented processing steps. Two common filtering techniques employed include traditional Cadzow filtering to constant frequency slices along one spatial dimension, called FXY (frequency-XY plane) to remove random noise, and FKK (frequency-wavenumber-wavenumber) to remove coherent noise. Figure 41 shows an exampled of the effects from noise suppression on cross spreads for the same five inlines centred on Inline 60.

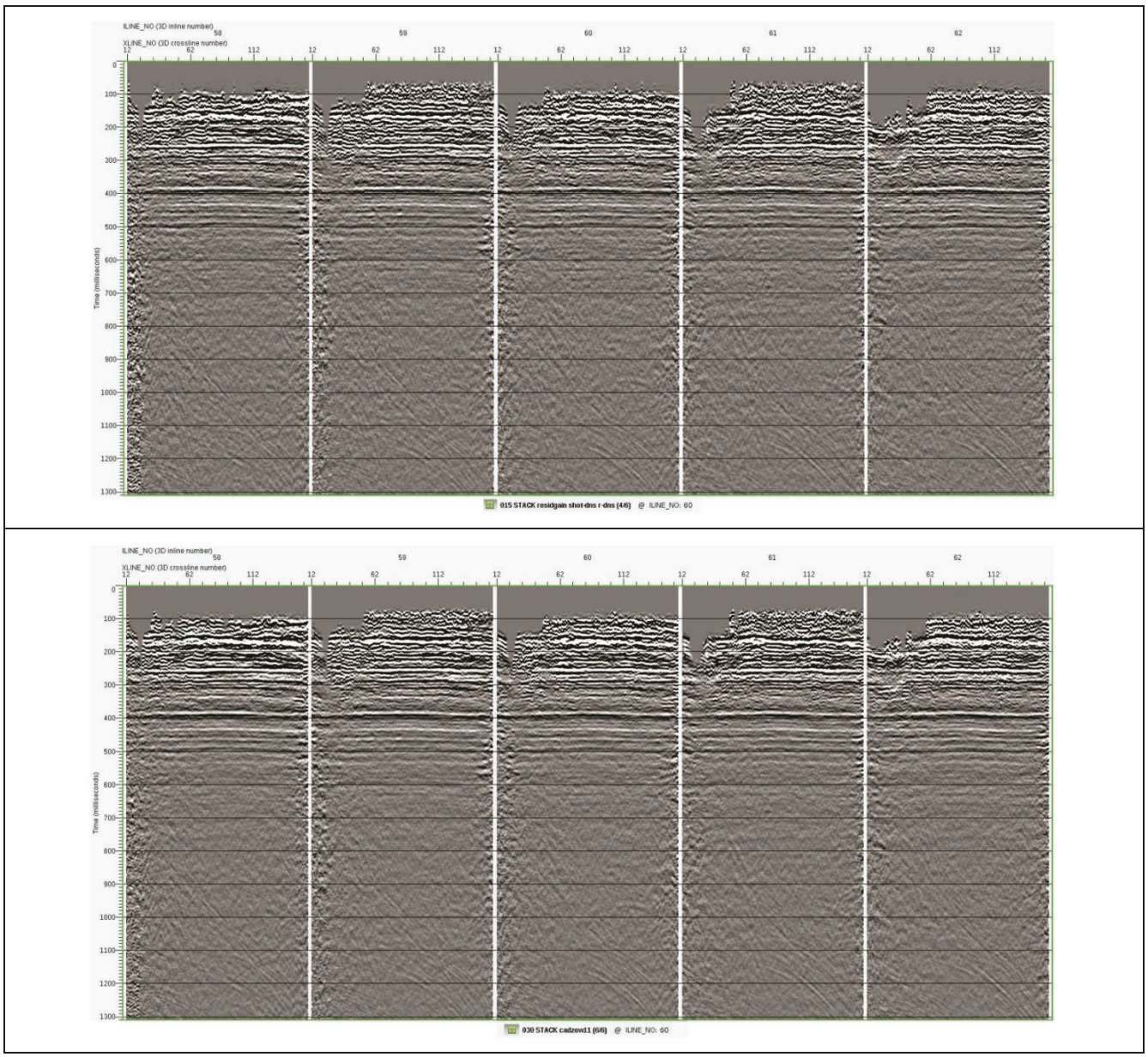


Figure 41 **Example of Effects from Pre-Stack Noise Suppression – Inline 60. Top: Before Cross-Spread Denoise Correction; Bottom: After Cross-Spread denoise Correction.**

6.1.9 Step 9: Rank-Reduction Based 5D Interpolation

5D interpolation, sometimes called 5D reconstruction, takes a pre-stack seismic data set that is sparsely populated in four spatial dimensions, and increases the trace density by interpolating in the four spatial dimensions simultaneously (the fifth dimension is time or temporal frequency, and is not interpolated). The four spatial dimensions include either inline/inline-offset/crossline-offset or inline/crossline/offset/azimuth. In this study, Absolute Imaging used inline-offset and crossline-offset as spatial dimensions which leads to a Common Offset Vector (COV) description of the data.

Absolute Imaging used multidimensional filters to suppress random noise based on matrix-rank reduction of constant-frequency slices and extended these filters to perform multidimensional trace interpolation. This requires rank reduction when some, perhaps most, of the matrix elements are unknown, a procedure called matrix completion or matrix imputation. This new interpolator can be used to improve the spatial sampling of pre-stack seismic data, thus improving the resolution of the final seismic section. It seems particularly effective at suppressing the acquisition footprint. For the 5D binning COV was used as the input data and the interpolated traces that match the binned input data traces were preserved. The decimated volume is then re-interpolated and only the traces that match the input data traces are preserved.

5D Interpolation provided great improvement when sorted back to CDP Gathers by increasing offset and azimuth distribution within the gathers and improved signal to noise ratio of data as well as filling in gaps in the near surface caused during acquisition and conflicting gridding between datasets.

This survey is a Megabin pattern with a natural binning of 50 x 25m. 5D interpolation tests were run on 25 x 25m bins and 25 x 12.5m bins. It was determined that 25 x 12.5m binning improved lateral resolution without a significant increase in noise. This means that inlines and crosslines are multiplied by 2 after 5D interpolation, for example Crossline 60 (before 5D interpolation) becomes identified as Crossline 120 (after 5D interpolation) and similarly Inline 80 becomes Inline 160 after 5D interpolation.

Figure 42 shows effects of 5D interpolation on the subsurface fold or bin multiplicity within the new binning of 25 x 12.5m. The top plot shows the original data before 5D interpolation, and the bottom plot shows the fold distribution after 5D interpolation. Figure 43 shows the actual results of this process on the seismic data around the original Inline 60 which now becomes the new, post-interpolated Inline 120. Most notable is the filling in of the shallow part of the section with no loss of information but 4 times the resolution by using adjacent bins and a surface consistent interpolation algorithm significant improvement to the data set have been made.

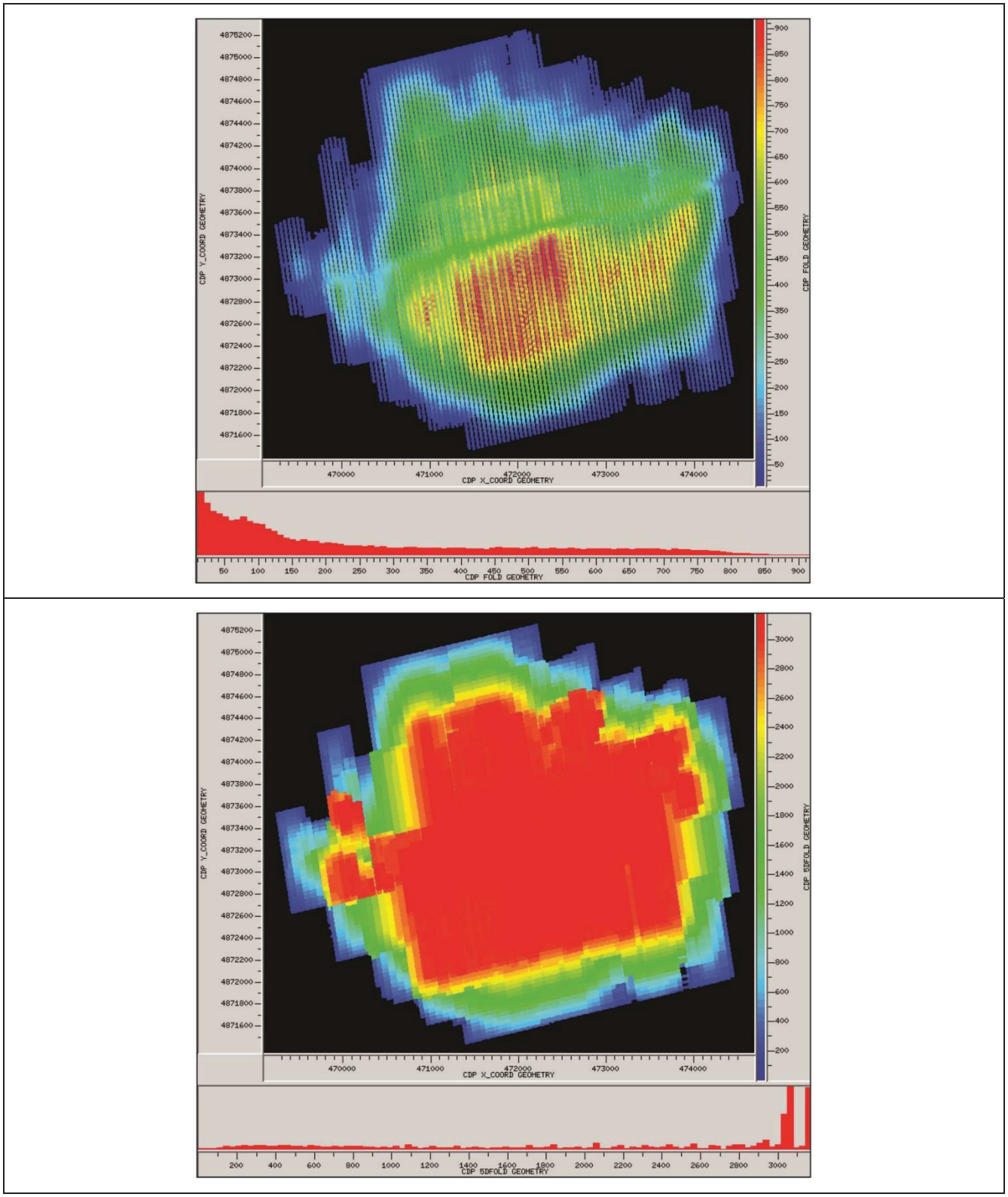


Figure 42 **Effects of Rank Reduction Based 5D Interpolation (25 X 12.5m bins) Top: Fold before 5D; Bottom: Fold after 5D.**

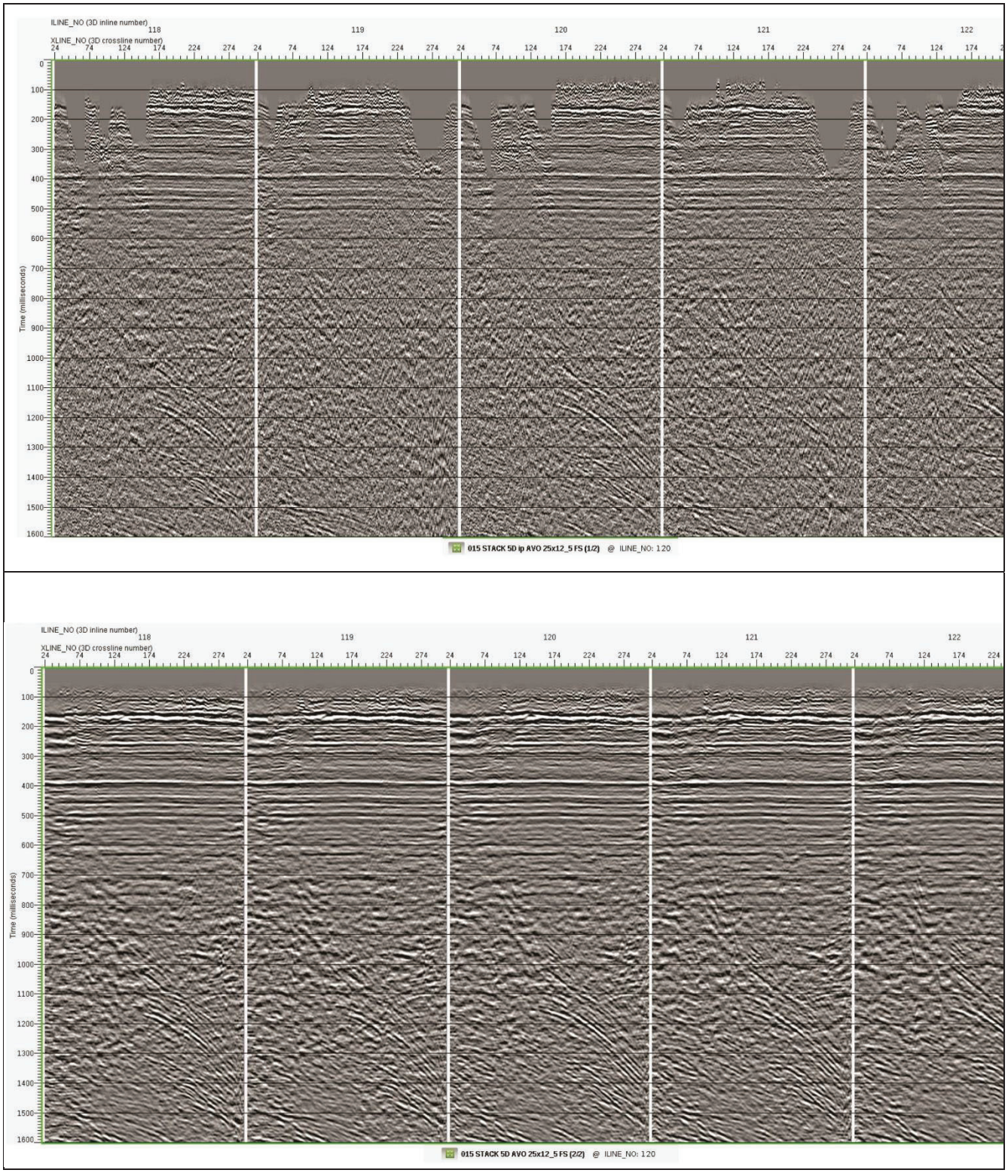


Figure 43 **Effects of Rank Reduction Based 5D Interpolation Top: Inline 60 before 5D; Bottom: Inline 120 (formerly Inline 60) after 5D.**

6.1.10 Step 10: Post-Stack Time Migration

Seismic migration is the process by which seismic events are geometrically re-located in either space or time to the location the event occurred in the subsurface rather than the location that it was recorded at the surface, thereby creating a more accurate image of the subsurface. Migration moves dipping reflectors to their true subsurface positions and collapses diffractions resulting in a migrated image that typically has an increased spatial resolution and resolves areas of complex geology much better than non-migrated images.

Kirchhoff migration essentially stores the results of the addition of amplitudes along a diffraction curve of an input record (shot record or COV) and outputs an accurate image of the subsurface at a particular set of shot and receiver locations.

Once all statics and velocities were calculated, a non AVO Kirchhoff Migration was output to Seg-Y and the following post stack processing was applied. Figure 44 shows two examples from the effects of Kirchhoff migration on the resulting seismic data stacks for Inline 120 (formerly Inline 60) and Crossline 160 (formerly Crossline 80). These plots show a significant increase in data resolution compared to pre- Kirchhoff migration.

The following steps were completed as part of the Kirchoff migration process for the South Bruce data:

1) 5D Interpolation
2) TVSW & FXY Prediction Filter
3) Trace Equalization: 500 ms by 250 ms
4) Post Stack Kirchhoff Time Migration: 100% Stacking Velocities
5) Filter: 6-10-80-100hz {0-1400ms) & 5-10-50-60hz {1400-4000ms.)
6) Trace Equalization: 500 ms by 250 ms

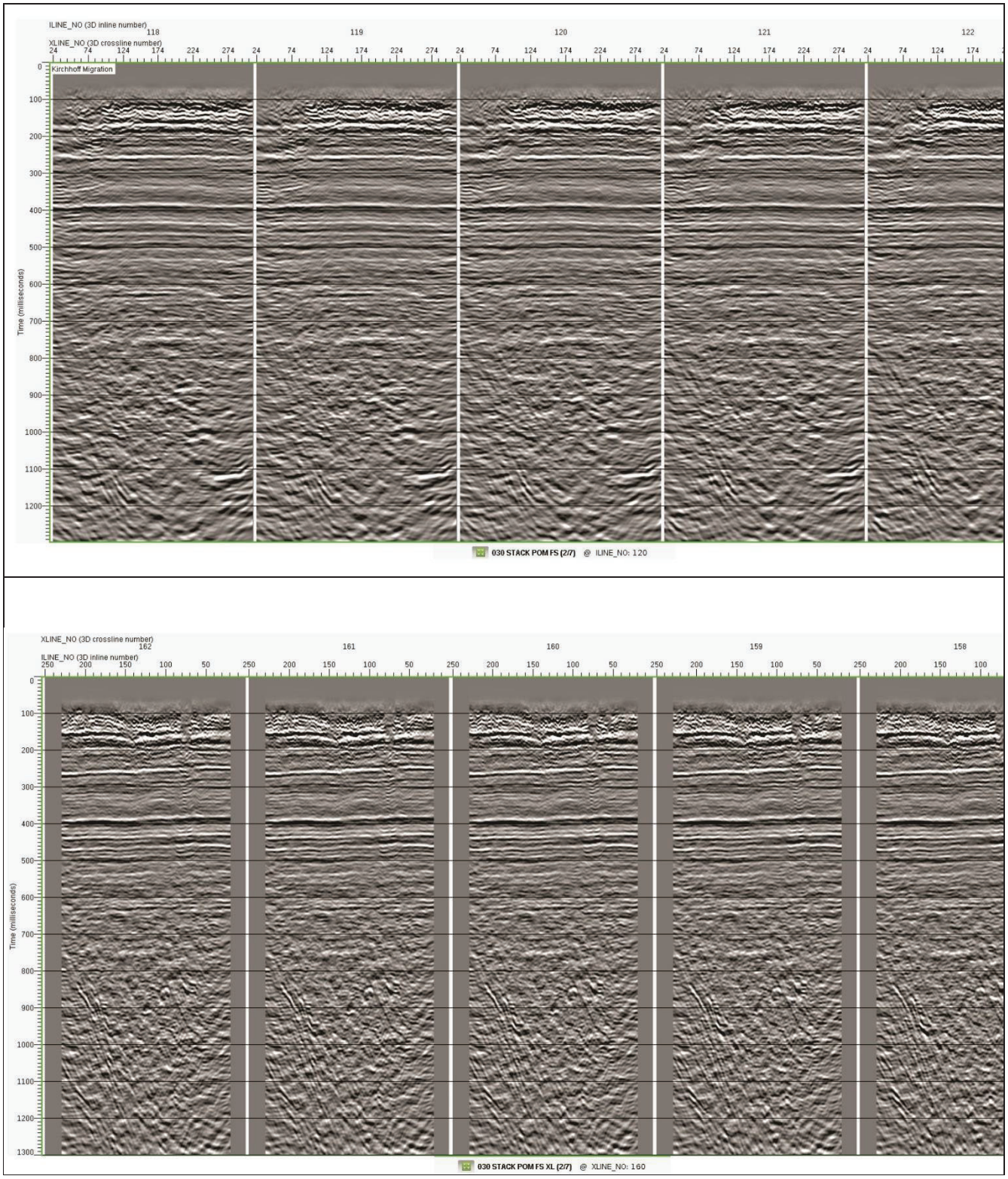


Figure 44 **Example of Effects from Kirchoff Migration (non AVO POM). Top: Inline 120 (formerly Inline 60); Bottom: Crossline 160 (formerly Crossline 80).**

6.2 Stage 2: Pre-Stack Tie Migration (PSTM)

6.2.1 Step 11: Isotropic Pre-Stack Time Migration (PSTM) and Residual Velocity Analysis

Migration velocities were picked using percent migration panels from 85-115% based on the stacking velocities. For the flatter events in the zone of interest between 0 and 600ms there was little change in velocity found between the stacking and ideal migration velocities, however the steeply dipping events below the zone of interest were found to have migration velocities 5 to 10% slower than the stacking velocities, which is typical for dipping events.

Isotropic PSTM and residual PSTM velocity analysis was completed for all offsets using two dip angles (65 degrees at 0 ms and 65 degrees at 4000 ms) for 100% of final PSTM velocities. Migration and residual PSTM velocities were edited every 500 m x 500 m using a semblance calculation. Only minor adjustments to the residual velocities were required and resulted in minimal improvement with no major differences observed in the gathers or stacks before and after the adjustments.

Figure 45 shows three examples of the process for picking the correct % velocity. On the left of the diagrams are a number of panels with stacking velocity ranging from 83% to 115% which is determined by the data processor assessing the best image and interactively picks this percentage velocity. Figure 46 shows the next processing step that involves picking “residual” velocities by examining the semblance of the applications of these various velocities to the gather data and picking additional adjustments to best focus the migration. Figure 47 shows an example of the final migration velocities are depicted in for in-line 140 (top) and crossline 140 (bottom).

Figure 48 and Figure 49 show two examples of the results of the pre-stack time migration before and after the residual velocity analysis for Inline 120, and Crossline 160, respectively.

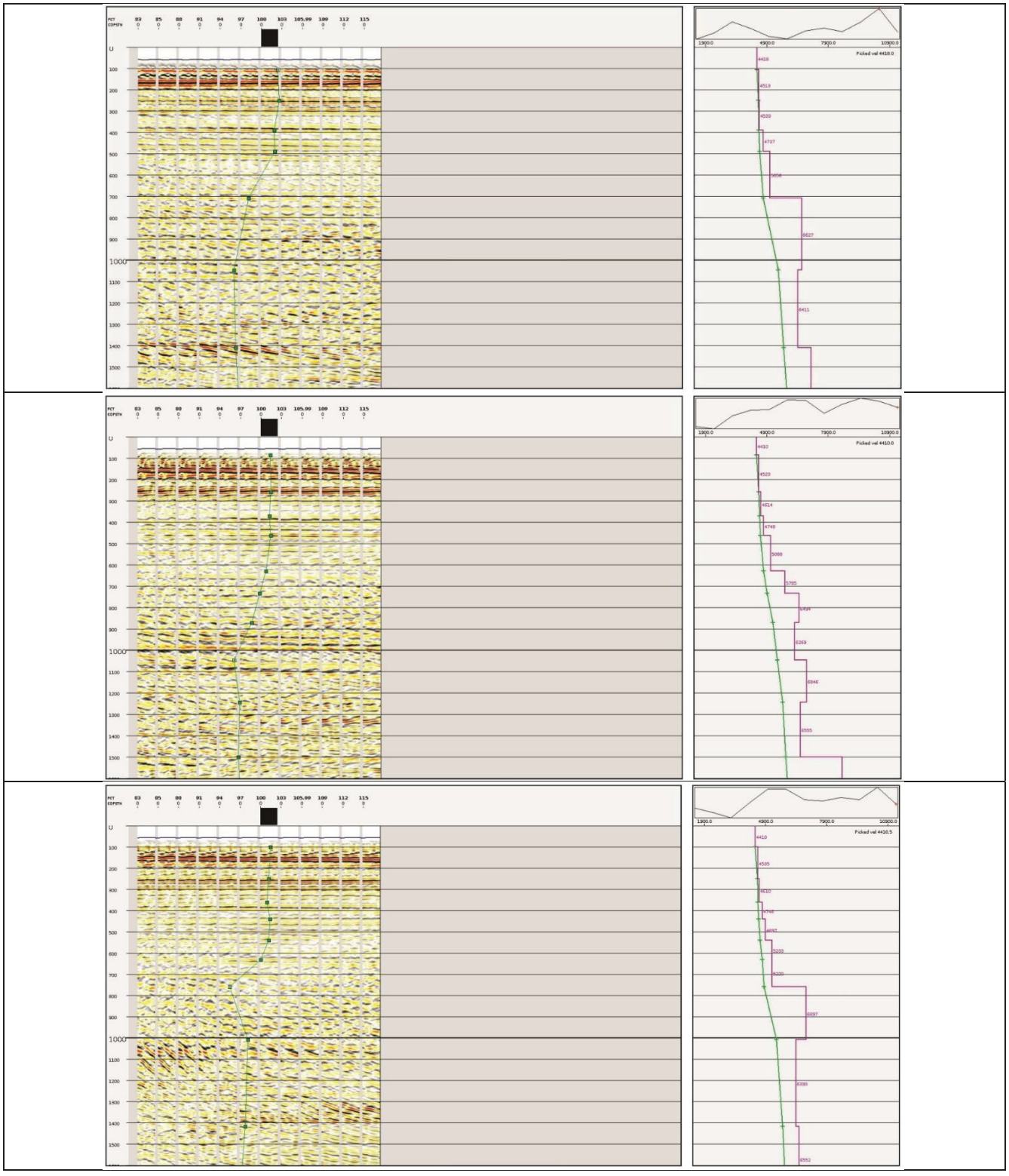


Figure 45 **Example PSTM Velocity Analysis on Percent Migration Panels. Top: Inline 120, Crossline 200; Middle: Inline 140, Crossline 240; Bottom: Inline 160, Crossline 160.**

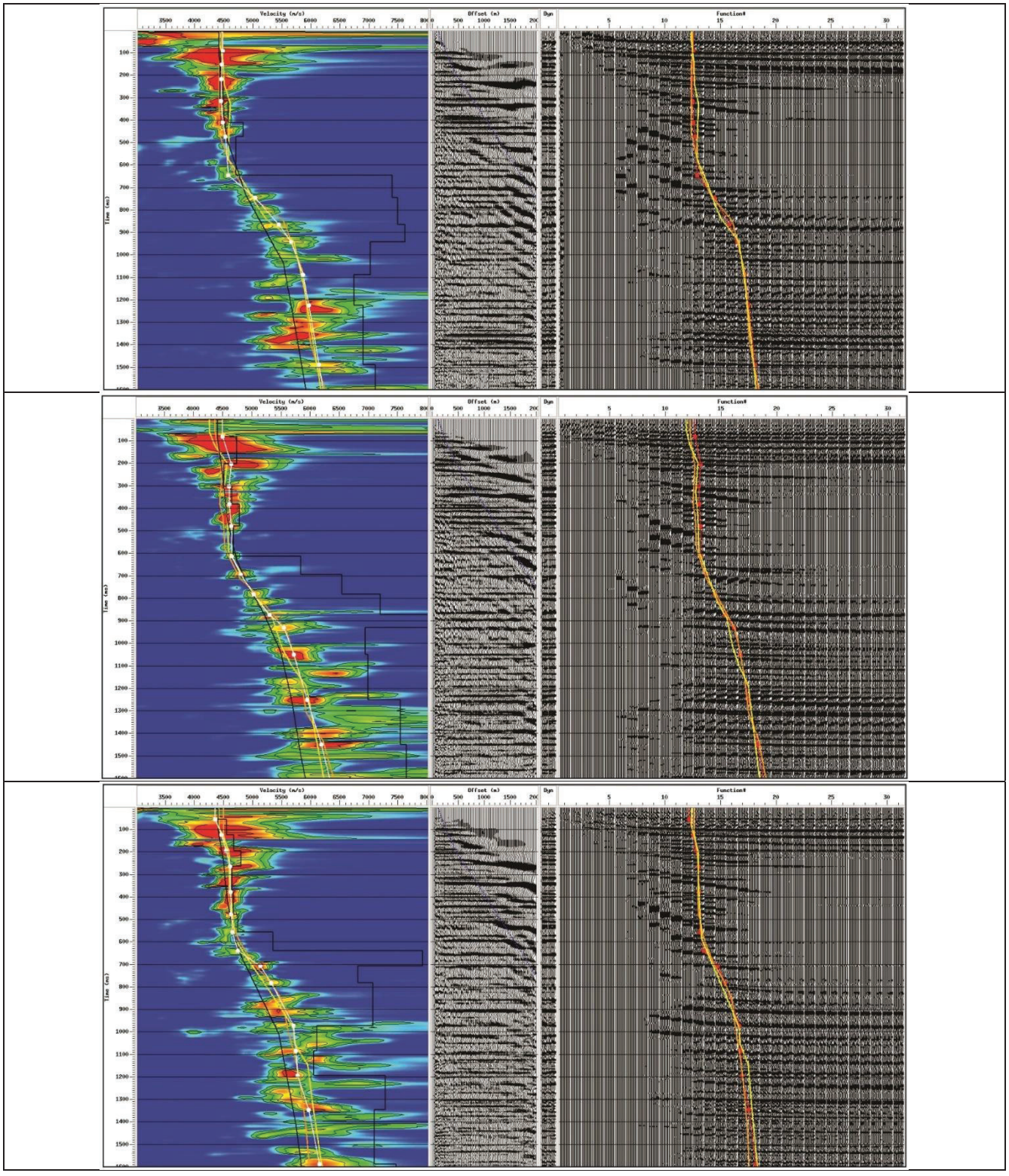


Figure 46 **Example PSTM Residual Velocity Analysis. Top: Inline 120, Crossline 200, Middle: Inline 140, Crossline 240; Bottom: Inline 160, Crossline 160.**

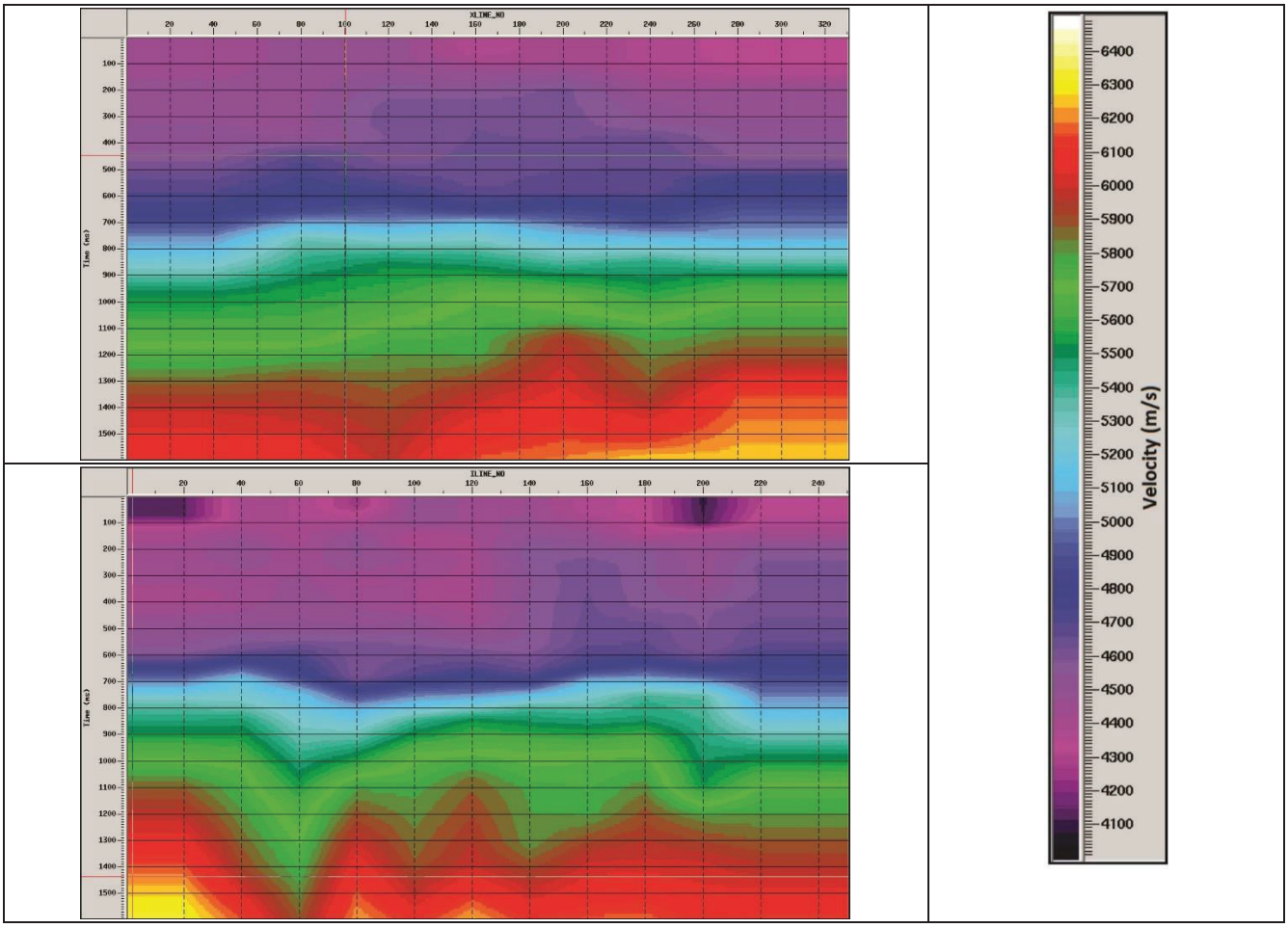


Figure 47 Example PSTM Residual Velocity. Top: Crossline 140; Bottom: Inline 140.

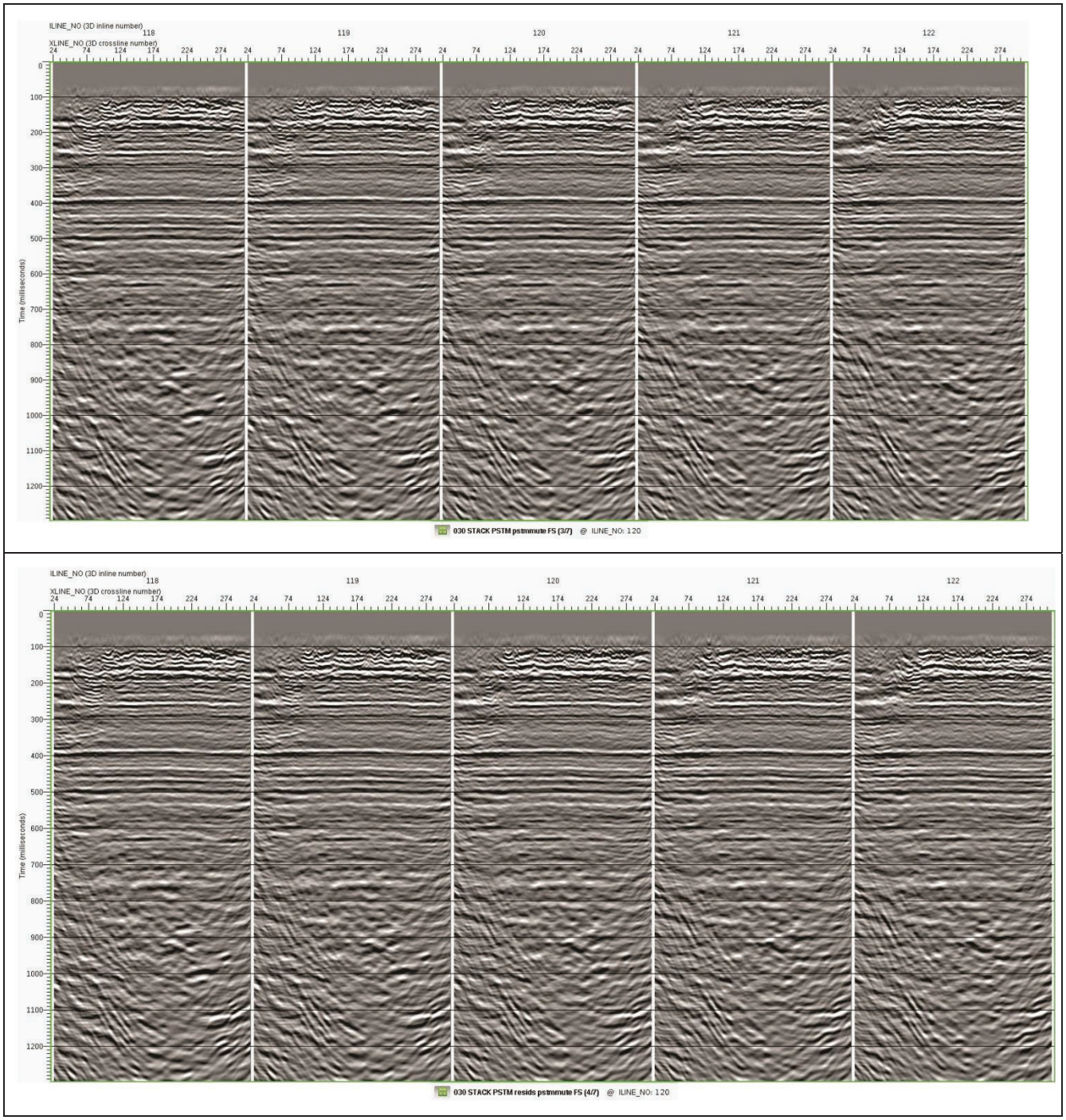


Figure 48 **Example of Effects from Pre-Stack Time Migration - Inline 120. Top: Before Residual Velocity Correction; Bottom: After Residual Velocity Correction.**

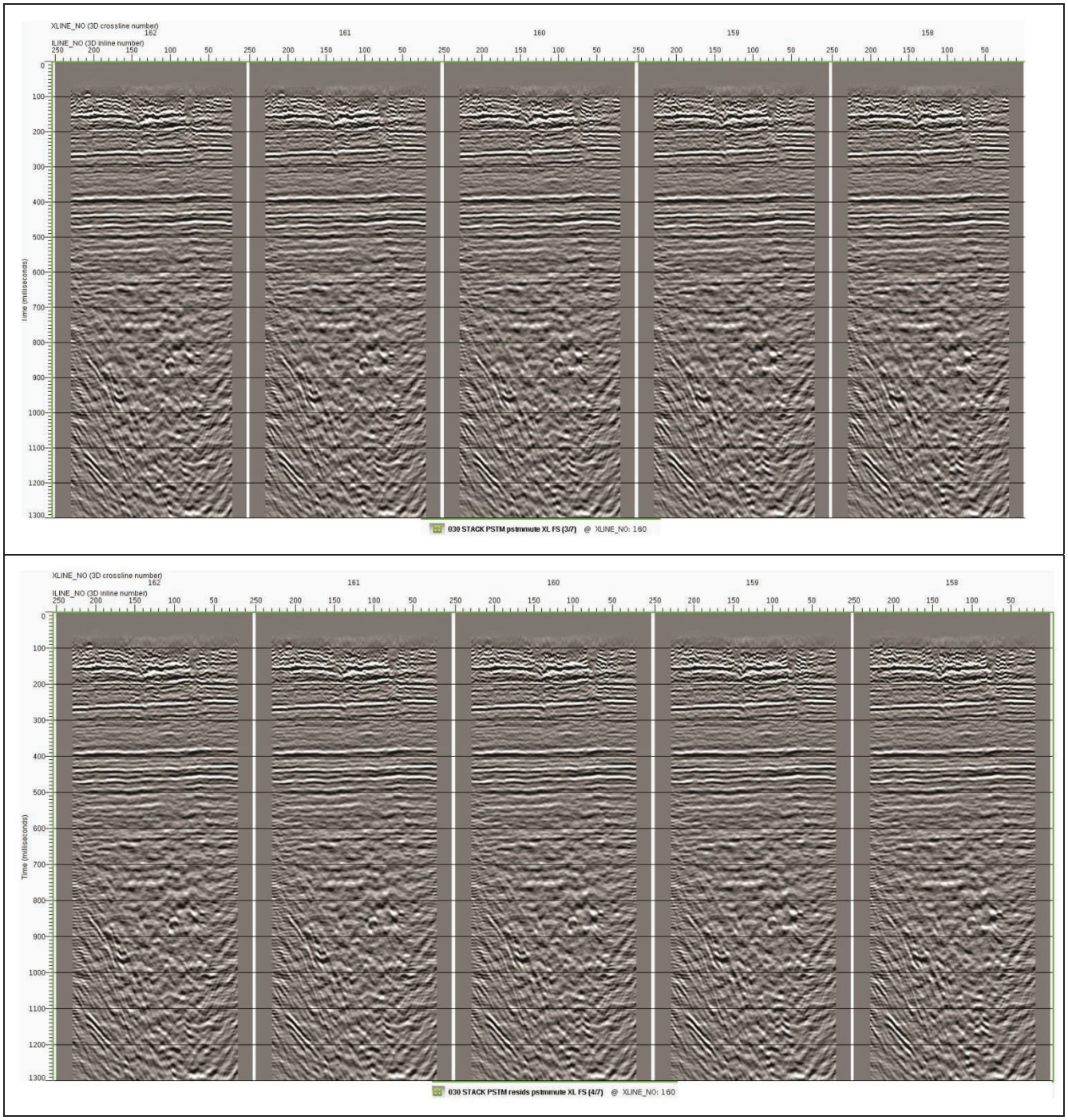


Figure 49 **Example of Effects from Pre-Stack Time Migration - Crossline 160. Top: Before Residual Velocity Correction; Bottom: After Residual Velocity Correction.**

6.2.2 Step 12: Post PSTM High Resolution Radon Transformation (HRRT) Demultiple

High Resolution Radon Transformation (HRRT) is commonly used for suppression or attenuation of multiples. Multiples are events that result from internal reflections between seismic reflection events which often overlay true events but are not real. The use of a radon transform distinguishes between primaries and multiples based on the residual move-out from near to far offset. A parabolic form of the radon transform is used since multiples have an approximately parabolic form after NMO. The sparse transform option of radon will reduce the size of the butterfly in the move-out (P) direction but can cause dispersion of energy in the time (Tau) direction. The sparse transform does this by concentrating energy on the move-out samples which have the most energy. This discrimination against weak events tends to reduce the effect of aliased events as well as enhance those which are desired. For the sparse option to be most effective, the primaries should be flattened by applying NMO before radon Filter. This will align all the primary energy near P=0, giving greatest weight to the primary reflections in the sparse transform.

Multiple attenuation algorithms attempt to removes multiple seismic reflections. Radon demultiplex processing was tested but multiples with move-out that are significantly different from primary events were not found. Ultimately it was decided not to apply radon multiple attenuation. Figure 50 shows the offset panel on the left, the resulting Tau-P transform in the middle and the “model” of the primaries on the right. The similarity of the right and left panels shows very few significant remnant hyperbolic events that are identified as multiples.

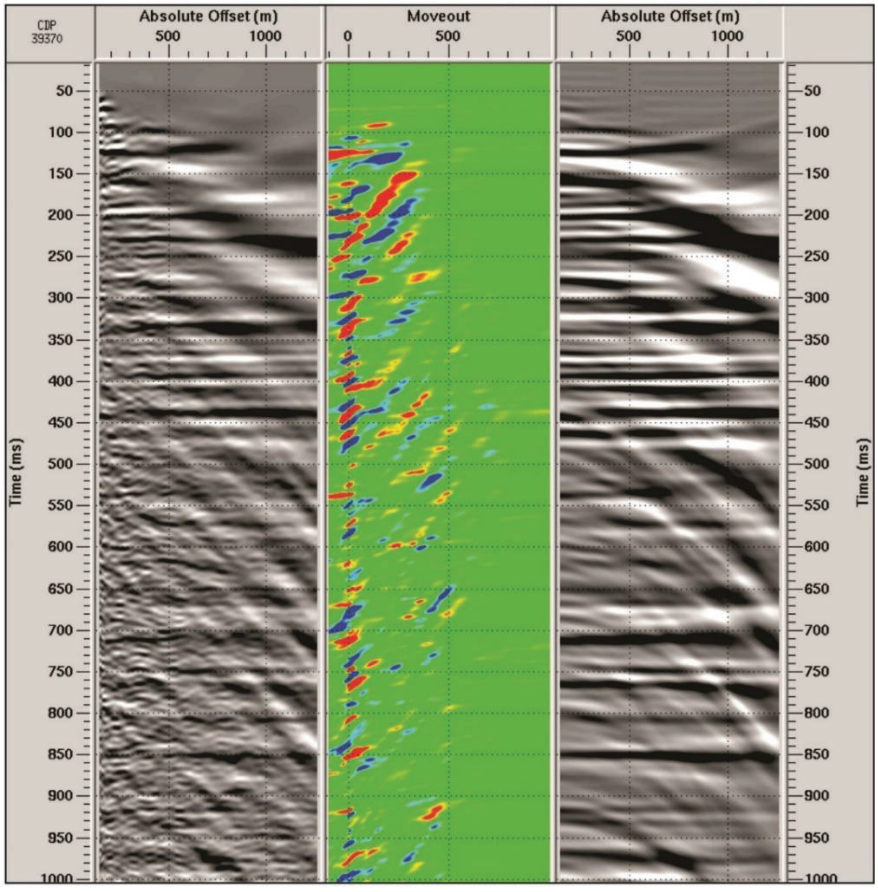


Figure 50 **Post PSTM Radon Demultiple Processing. Left: Offset Panel; Middle: resulting Tau-P transform; Right: Model of the Primary Signal.**

6.2.3 Step 13: Post PSTM Dip Filter

Some residual linear noise was present in the PSTM CDP gathers and an FK domain dip filter was applied within the frequency range of the noise. This improved the signal-to-noise ratio of the CDP gathers Figure 51 show an example of the effect from this processing step for Inline 120 and Crossline 140 (a single gather near the middle of the volume) but did not have a significant effect on the stacked data due to the noise stacking out through the power of stack.

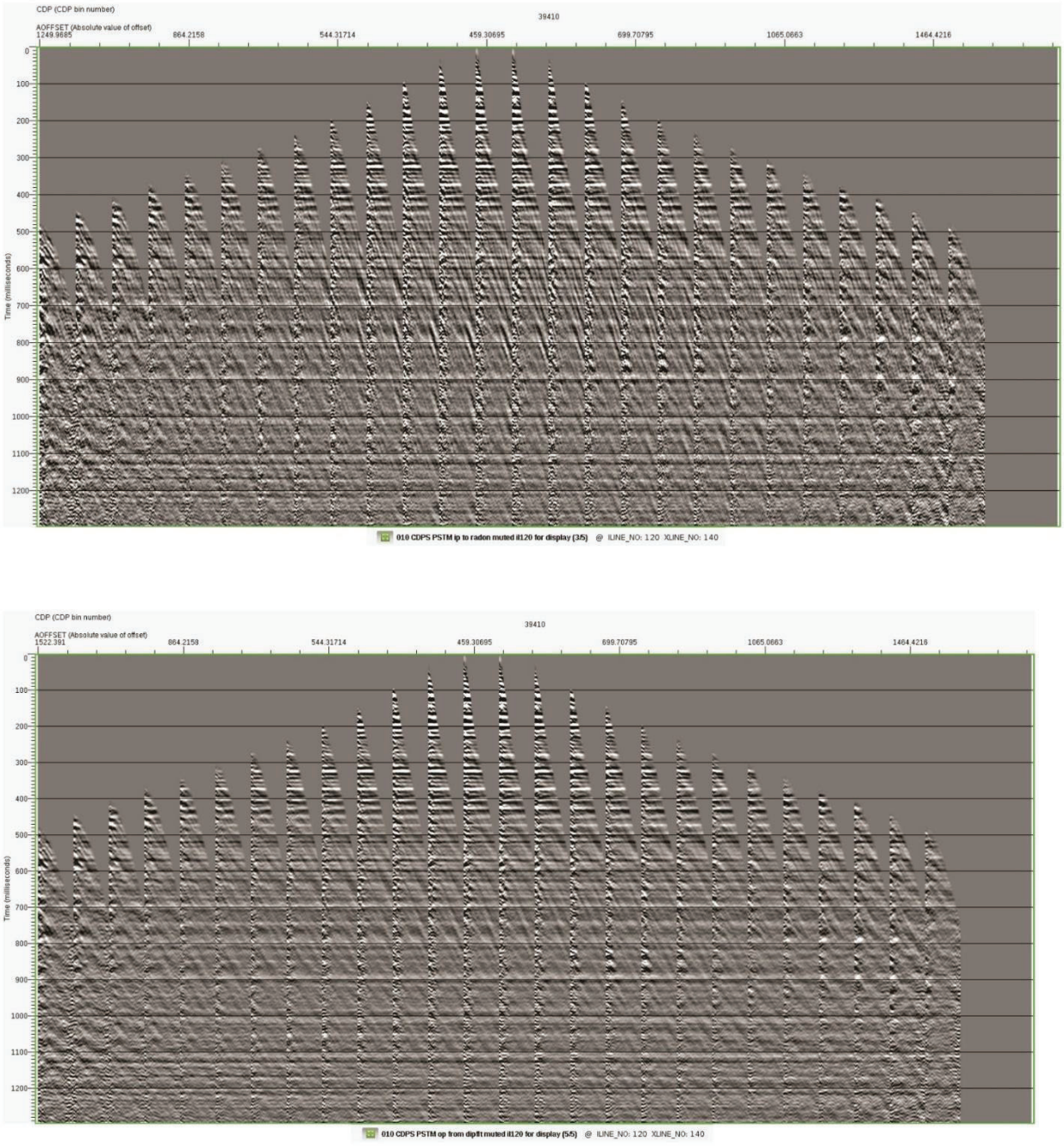


Figure 51 Example of Effects from Post PSTM Dip Filter - Inline 120 & Crossline 140. Top: Before Dip Filter; Bottom: After Dip Filter.

6.2.4 Step 14: Acquisition Footprint Attenuation (AFA)

3D sources and receivers are often laid out with regular or nearly regular line and point spacing leading to interference patterns of alternately dimming and brightening seismic amplitudes. Such interference is most readily observable on time slice displays of stack volumes where it manifests as linear amplitude variations aligned along the acquisition line directions.

If the shooting is orthogonal and if the bin grid alignment coincides with the acquisition grid, then the interference often aligns with the bin grid, however this is not always the case. This program works on stack volumes by transforming each time slice to the Kx-Ky domain and applying a passive filter designed to attenuate high (spatial) frequency energy mapping to the linear trajectories in Kx-Ky space associated with this footprint interference. By default, it is assumed that these trajectories align with the bin grid, but rotations can be applied for situations where this is not appropriate. Figure 52 shows two examples of the effects from applying acquisition footprint attenuation (AFA). The left two plots compare data from a time slice at shallow depth of 160ms where the footprint is most noticeable with data before AFA applied (top) and after AFA applied (bottom). Similarly, the right two plots compare data from a time slice at a deeper time of 380ms where the footprint is no longer noticeable with data before AFA applied (top) and after AFA applied (bottom). Although in this case the effect is no longer noticeable, there is no negative effect by using AFA processing throughout the entire seismic volume.

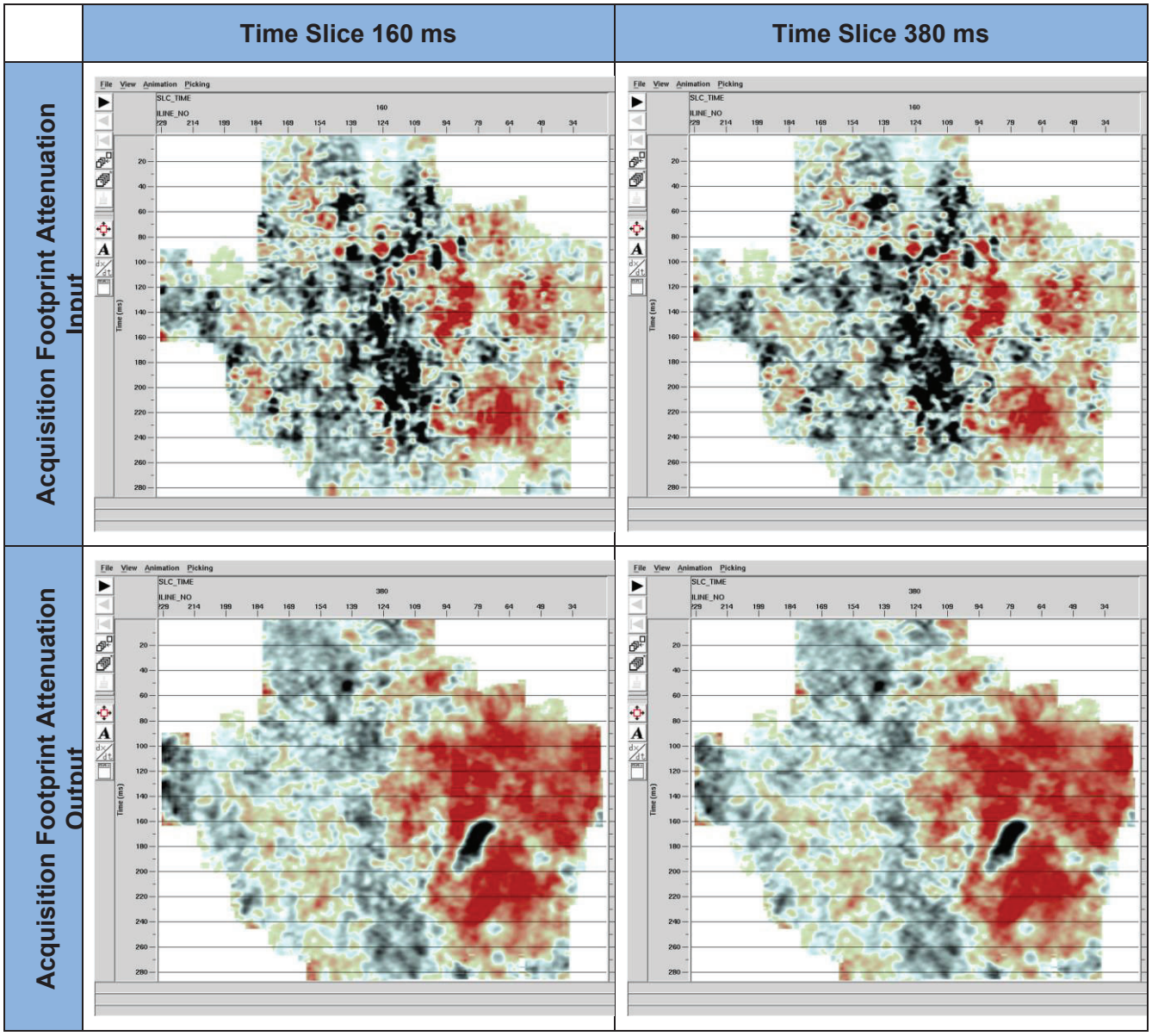


Figure 52 **Examples of Effects from Acquisition Footprint Attenuation (AFA). Left: Time-slice at 160 ms before AFA applied (top) and after AFA applied (bottom); Right: Time-slice at 380 ms before AFA applied (top) and after AFA applied (bottom).**

6.2.5 Step 15: Post Stack Migration Signal Enhancements (on stack)

The post migration signal enhancement processes are designed to improve the final deliverable migrated data volumes without affecting the gathers and original PSTM raw stack. A version of the final PSTM stack was delivered with the following enhancements.

Post Stack Whitening

- Frequency Range: 4-8-120-140 Hz.

Post Stack FXY

- Spatial Gate length: 21x21
- Temporal Gate length: 200ms
- Max Frequency: 500 hz.

Time Variant Bandpass Filter

- Time Variant Filter: 4-8-100-120 (0 to 600ms) 4-8-50-60 (1400 to 4000ms)

Time Variant Scaling

- Rolling Window: 500 ms window, 250 ms overlap

Figure 53 shows an image of the final processed seismic data volumes for inline sets 118-122 (bottom) and for comparison purposes also includes an image on top that is reproduced from Figure 48 showing the previous unfiltered seismic data volume following Step 11, prior to post migration filtering. Similarly, Figure 54 shows an image of the final processed seismic data volumes for crossline sets 158-162 (bottom) and for comparison purposes also includes an image on top that is reproduced from Figure 49 showing the previous unfiltered seismic data volume following Step 11.

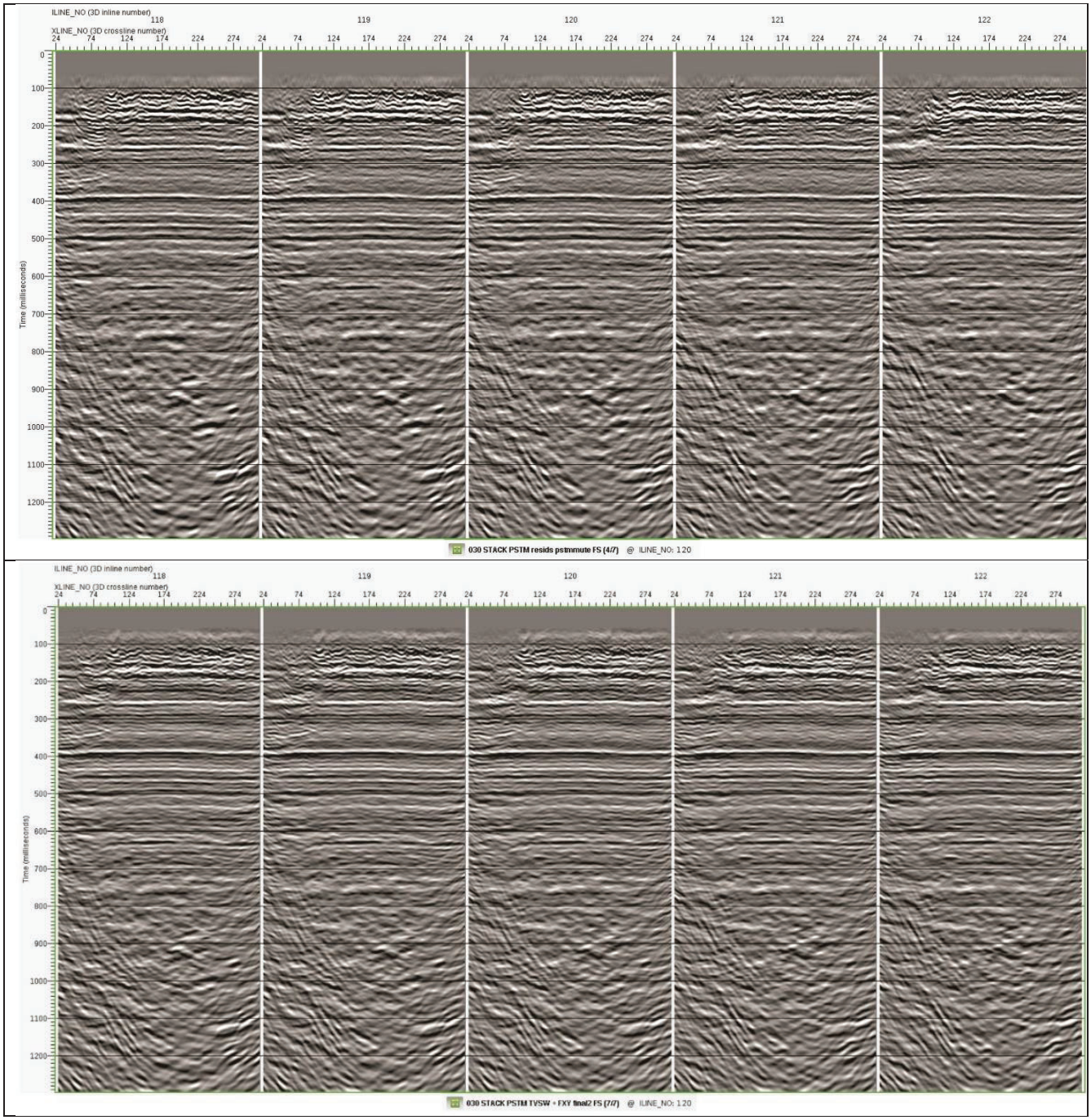


Figure 53 **Example Showing Effects from PSTM Signal Enhancements – Inline 118-122. Top: Seismic Volume Before Signal Enhancements (output from Step 11 shown at bottom of Figure 47); Bottom: Final Processed Seismic Volumes After Signal Enhancements.**

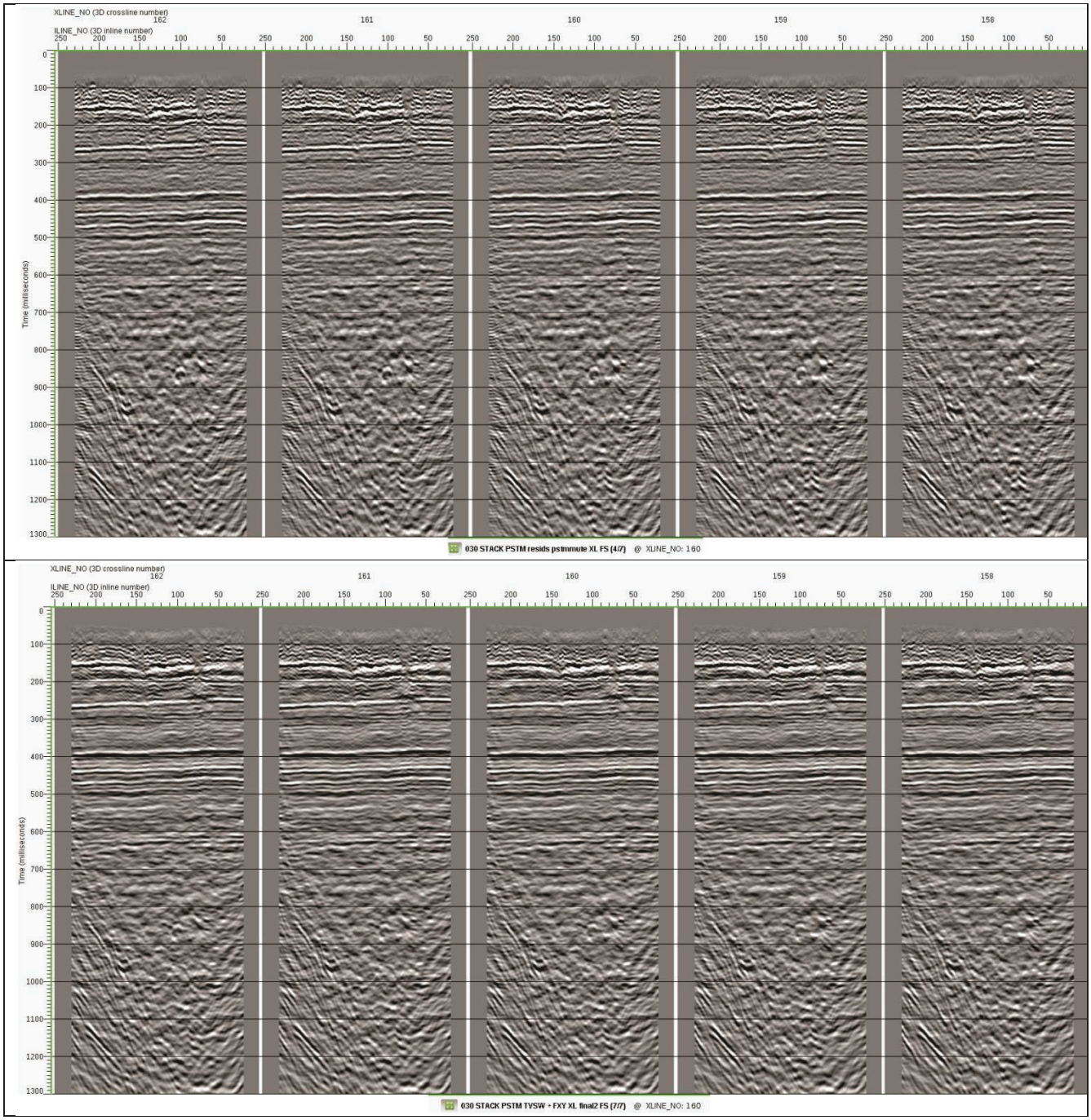


Figure 54 **Example Showing Effects from PSTM Signal Enhancements – Crossline 158-162. Top: Seismic Volume Before Signal Enhancements (output from Step 11 shown at bottom of Figure 48); Bottom: Final Processed Seismic Volumes After Signal Enhancements.**

Once all of these post-stack enhancements were finalized a number of 3D stacked data volumes were provided for further data interpretation including filtered and unfiltered, structure and migrated volumes. These data volumes are in a standardized data format which can easily be imported into a number of additional workstation software.

6.3 Stage 3 – AVO Gather Conditioning

Following initial data processing as outlined above, Geofirma requested Absolute Imaging to complete some additional data processing to better prepare the data for AVO Inversion analysis, as summarized in the following three steps (Steps 16 through 18).

6.3.1 Step 16 – Post PSTM Dip Filter

Some residual linear noise was present in the PSTM CDP gathers and a F-K domain dip filter was applied within the frequency range of the noise. This improved the signal to noise of the CDP gathers but did not have a significant effect on the stacked data due to the noise stacking out through the power of stack. Figure 55 shows an example of the effects from a first pass of post PSTM dip filter application for Inline 120 and Crossline 140.

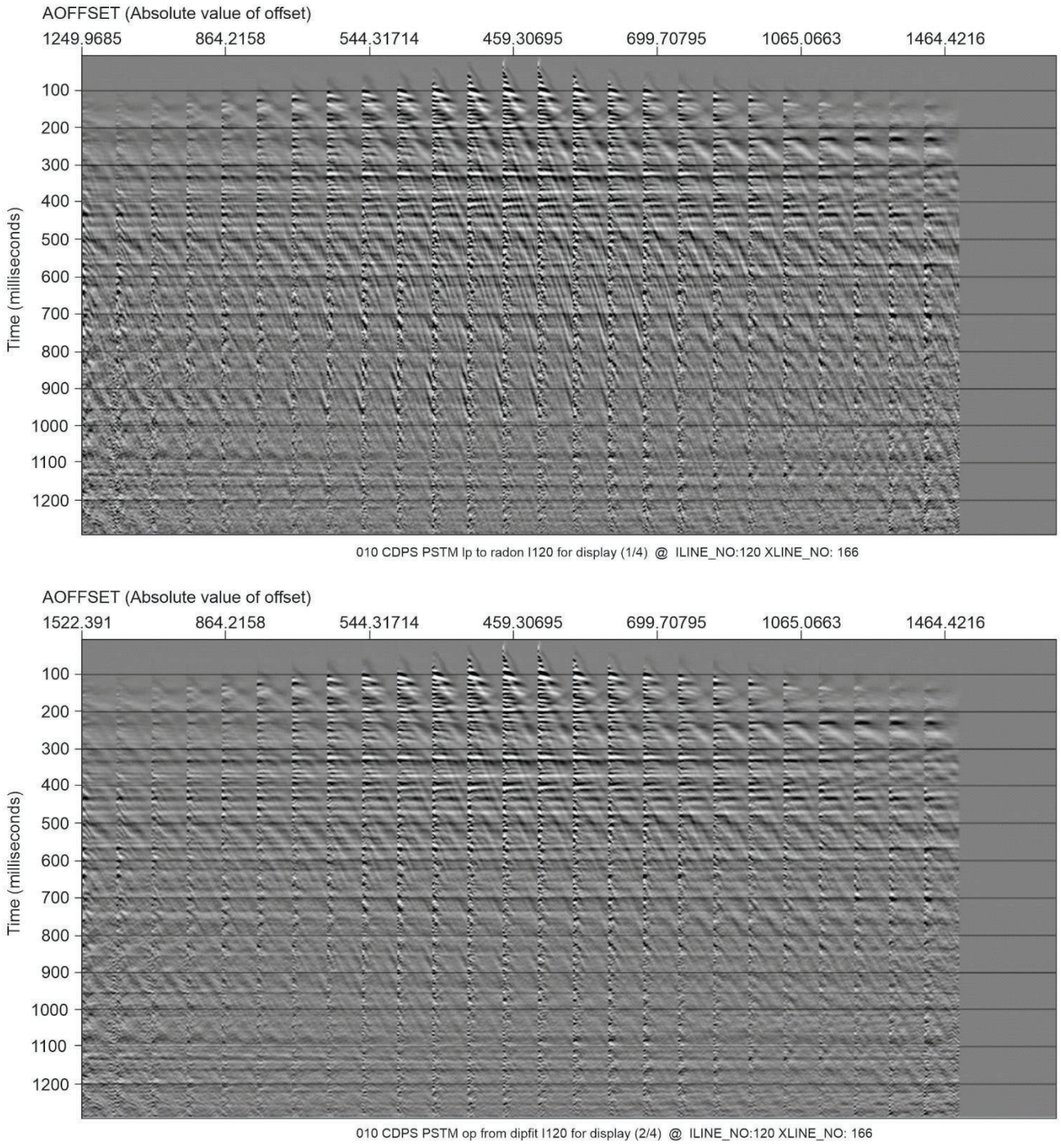


Figure 55 **Example showing effects from Post PSTM dip filter – Inline 120 and Crossline 140. Top: Seismic volume before dip filter; Bottom: Processed seismic volume after dip filter (1st Pass).**

6.3.2 Step 17 – Ensemble Based Spectral Whitening

This tool designed for use in an AVO-compliant processing flow. In the standard single-trace process, each trace is transformed to the frequency domain where it is subjected to a series of narrow-ban filters. These filtered spectra data are then transformed back to the time domain, where they are processed using Automatic Gain Control (AGC) to bring them to a uniform amplitude level, both in time and across the frequency bands. Finally, the sum of the scaled sub-band traces is divided by the sum of the AGC scaling functions to produce the final whitened trace. This process follows the same general plan, but with following differences:

1. All traces in the gather are forward-transformed, filtered, and inverse-transformed before any scaling functions are computed.
2. A single average scaling function, derived from all traces in the gather, is computed for each sub-band.
3. Every trace is then scaled by the appropriate average sub-band scaling function.
4. The scaled traces are summed over sub-bands.
5. Finally, the summed traces are descaled by the overall alpha-trim mean scaling function.

These steps ensure that every trace in the ensemble receives identical scaling and descaling and that there is no offset dependency to the process which may have a deleterious effect on an AVO anomaly. Figure 56 shows an example of the effects from ensemble based spectral whitening for Inline 120 and Crossline 140.

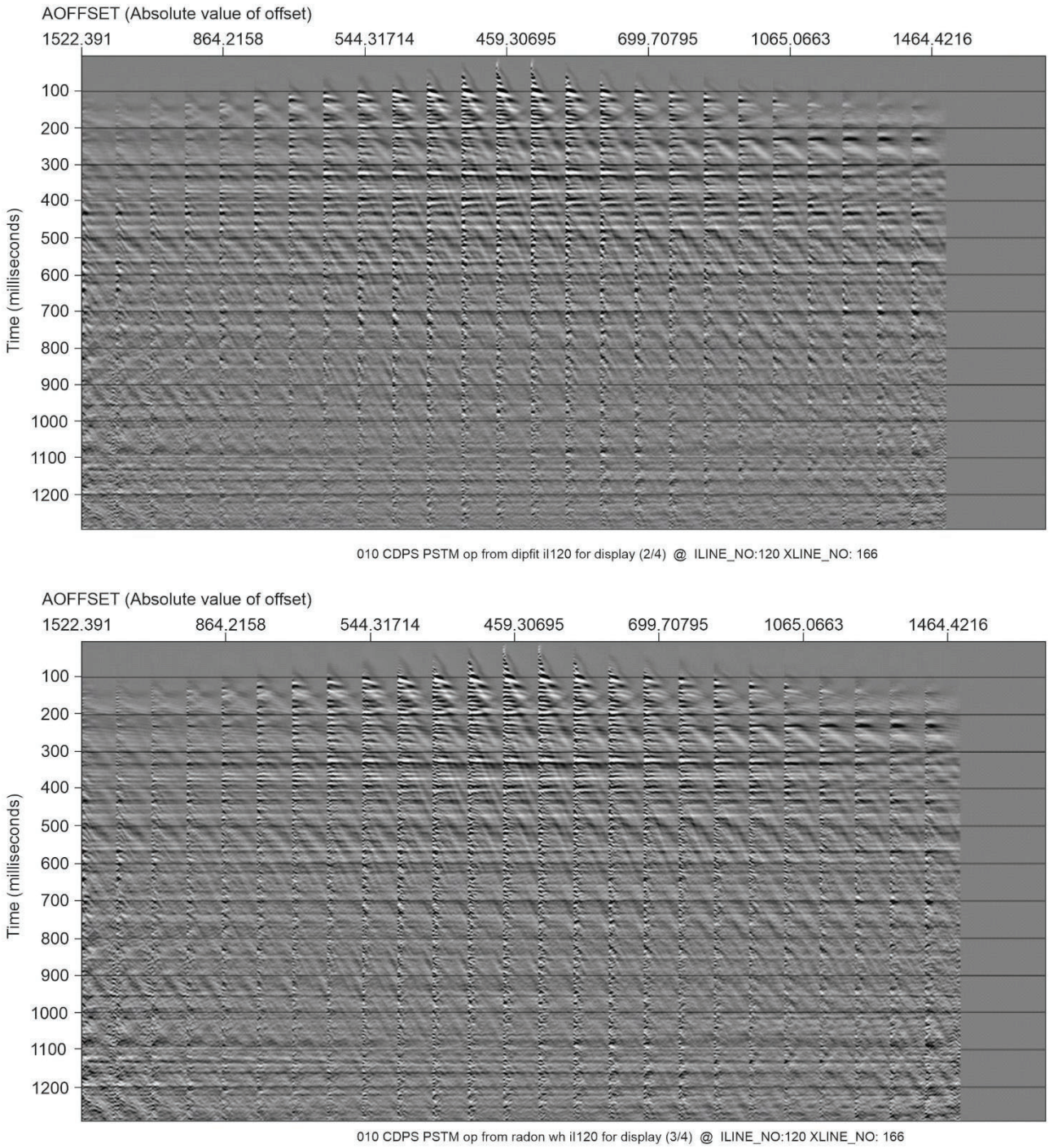


Figure 56 **Example showing effects from Ensemble Based Spectral Whitening – Inline 120 and Crossline 140. Top: Seismic volume before ensemble based spectral whitening; Bottom: Processed seismic volume after ensemble based spectral whitening.**

6.3.3 Step 18 – Post AVO Ensemble Whitening PSTM Dip Filter

Similar to Step 16, a second F-K domain dip filter was applied within the frequency range of the noise to further improve the signal to noise of the CDP gathers. Figure 57 shows the effects from the second pass of post PSTM dip filter application for the same Inline 120 and Crossline 140.

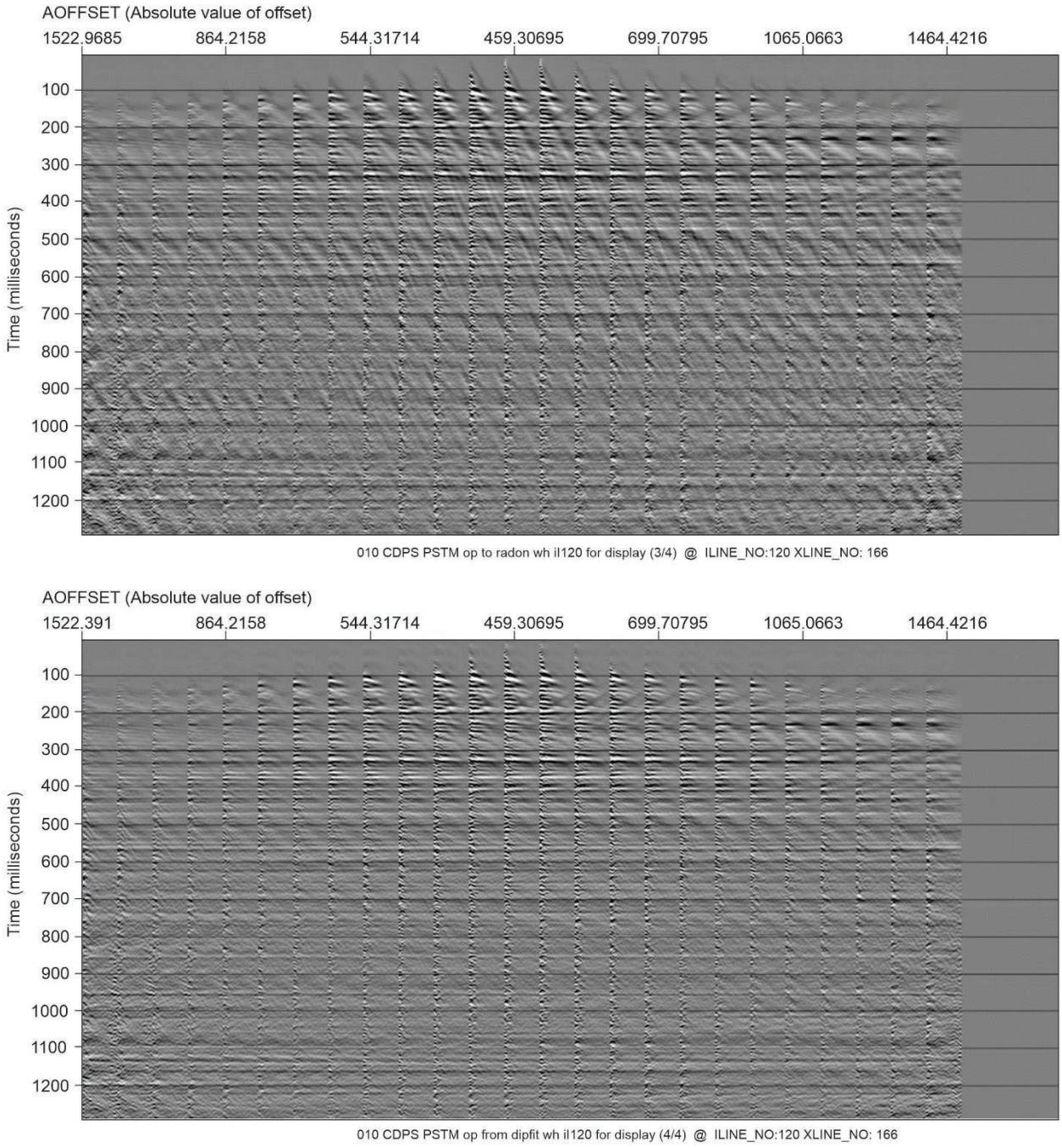


Figure 57 **Example showing effects from Post PSTM dip filter – Inline 120 and Crossline 140. Top: Seismic volume before dip filter; Bottom: Processed seismic volume after dip filter (2nd Pass).**

Once all these steps were finalized a pre-stack data volume of AVO compliant processed gathers was generated for inversion analysis as part of the interpretation of this data volume. These gathers were supplied in a standard SEGY format with headers including importation positioning, azimuthal and offset information necessary for further analysis.

7 CONCLUSIONS

Several challenges pertaining to 3D seismic data collection in the South Bruce Site were encountered and overcome. The resulting dataset proved to be of high quality despite these challenges. The most notable of these challenges that directly affect data quality include significant glaciofluvial deposits with thick gravel filled eskers that are known to prevent suitable transmission of P-waves used for 3D seismic surveys, limited access due to tree cover, and land access constraints due to agricultural operations.

To overcome these challenges, the 3D seismic design and layout included increasing the subsurface density and minimizing the surface impact by using a Megabin design with sources and receivers along the same lines. This was further enhanced by using autonomous recording which enabled slip sweep, high density source points to increase the subsurface fold 10-fold or more to overcome the known near surface issues and limitations.

Advances in 3D seismic processing including 5D interpolation, advanced noise reduction algorithms and multiple attenuation workflows contributed to a successful 3D seismic project despite the challenges described above and resulted in a geologically interpretative 3D seismic volume that can be used for AVO (amplitude versus offset) inversion for rock properties and fluid descriptions.

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Appendix A

Echo Seismic QC standards for Hawk wireless equipment

10. APPENDIX B - GENERAL QUALITY CONTROL MEASURES

Echo Seismic Ltd., hereinafter referred to as Echo, will maintain continuous and effective communication between the senior member(s) of the recording crew and the designated client representative

10.1 GENERAL WORK STANDARDS

10.1.1 CONTRACTOR WORK STANDARDS:

Echo will meet or exceed the minimum work standards as set forth by the client during the acquisition of data.

10.1.2 TECHNICAL PROFICIENCY:

Echo warrants that personnel responsible for field data recording and preparation of reports are fully qualified by virtue of technical experience and/or training. Echo will provide a resume of qualifications for key personnel upon request, for inspection by the client, at any time before or during recording operations.

10.1.3 DATA ACQUISITION:

At all times while acquiring data, Echo will ensure that all instrumentation is performing properly and that all recorded data is readable, accurate, and properly annotated.

10.1.4 AUTHORITY OF SENIOR CREW PERSONNEL:

Nothing in these work standards shall be construed as to override the authority of the senior crew member(s) of any of Echo's crew with respect to their responsibility for the safety of the crew and all recording equipment.

10.1.5 PARAMETERS AND VISUAL QC:

Recording crew managers and observers will review the client's parameters for the program to ensure proper geophone sensor arrays are being placed in the field and that the recording instrument settings and source instrument settings are verified and correct. Client will sign off on agreed parameters prior to start of recording and will sign off on any subsequent alterations to or deviation from agreed to parameters.

All crew members will have an orientation on array distance/3C orientation and placement of geophones before commencing lay out. Once geophone placement has begun, senior crew members will check each crew to ensure proper placement of geophones as per client parameter sheet. During ongoing recording throughout the entire program, visual spot checks will be performed on a regular basis by senior staff so that quality standards for geophone plants are maintained. Along with visual inspection for proper placement, Echo also adheres to a strict set of tests for quality control on recording equipment. Orientation tools will be checked for accuracy prior to commencing work each day. Any orientation tools deemed to be outside of the allowable tolerances will be removed from service immediately.

10.2 HAWK WIRELESS SYSTEM FIELD QUALITY CONTROL PRACTICES

10.2.1 INITIAL DEPLOYMENT

Upon initial deployment, and each subsequent time that FSUs (Field Station Unit) pass through the T3, each FSU will be tested and configured using a configuration file provided by the CSC (Central Software Computer – aka 'The Recorder'). The T3 will run the BITS (Built in Test Suite)[1] on all FSUs prior to deployment in the field. After the FSU is laid out and connected to a battery it will run its own BITS[2] and the information will be sent to a passing line viewer. The initial pass will be primarily to identify issues with connections and/or positioning issues. All line viewer data will be downloaded to the CSC, via direct email or through USB transfer, where the Observer will produce a troubleshooting list of failures. Trouble-shooters will access defective stations by traveling along receiver lines while line viewing to revisit previously viewed channels. This will generate a partial secondary pass identifying any new defects on the spread. The Observer will verify that any failures are within tolerance for the active patch as defined in the job parameters. Trouble-shooters will continue this process throughout the duration of the project.

[1] The FSU BITS only performs instrument tests while connected to the T3 as there is no geophone attached.

[2] The FSU BITS includes instrument tests and sensor tests at this point.

10.2.2 SECONDARY LINE VIEWING

Follow up line viewing will be done in areas of concern. Urban or highly populated areas, high traffic areas, cattle, or farming activities, etc. will be line viewed periodically as deemed necessary by the crew manager, observer, or client. Areas that are found with recurring issues will continue to be monitored and repaired throughout the duration of recording.

10.2.3 DAILY TESTS

HAWK FSUs will run the BITS (Built in Test Suite) once daily at a specified time. Additional test cycles can be programmed into the FSU if necessary. The status of the daily test is available through line viewing.

10.2.4 DATA QC

After the initial source point is acquired, and prior to any further source points being acquired, data will be harvested from both a near and far offset. The full scope of the harvest will be determined based on access and spread parameters, factoring in any environmental and time constraints. Once harvested data is viewed and confirmed in the T3 by senior personnel and/or client representative(s), acquisition will continue.
Acquired data will also be harvested daily (full scope of the harvest will be determined based on access and spread parameters, factoring in any environmental and time constraints) from the start of acquisition to the point where FSUs are being picked up and downloaded in the T3.
Throughout the duration of the program data will be harvested at any time deemed necessary by the Senior Observer and/or crew management.

10.3 BATTERY MANAGEMENT

- All batteries are fully charged prior to initial deployment and recharged as needed throughout the program.
- Batteries are spot tested after charging using an INOVA Battery Tester. This tester removes the surface charge to ensure a correct reading. Any batteries that fail this test are removed from service and sent for repair.
- Vigorous off-season battery maintenance is performed at the Echo shop in Calgary. Batteries are fully charged and then discharged through a fixed 10 Ohm resistance for 11 hours. Batteries pass this test if the battery provides 80% of the 288 Watt hours specified by the manufacturer. Any batteries failing this test and/or show visible signs of damage are removed from service.

10.4 BUILT IN TEST SUITE (BITS)

The BITS includes the following instrument and sensor tests:

Instrument Tests	Sensor Tests
Common-Mode Rejection	CMRR
Cross-feed	Damping
Harmonic Distortion	Distortion
Noise	Impedance
	Leakage
	Natural Frequency
	Powerline Pickup
	Resistance
	Spread Noise

A qualified field technician will be onsite in the T3. A log summary of pass/failures, with serial numbers of boxes will be maintained in the T3. Any channels that fail to pass manufacturers specifications for any of the preceding tests will be sent for repair before use in data acquisition.

10.5 SHOOTING SYSTEMS

All shooting systems for dynamite operations will be tested prior to start-up. Tests performed will verify Encoder and Decoder start times along with Decoder Confirmation Time Break and uphole. Timing will be tested using the recording system, Uphole Simulator and Tera Term or equivalent software program. Decoder tests will be saved to hard drive.

10.5.1 SHOOTER RESPONSIBILITIES

- Each Shooter is responsible for reporting to the Observer the following information on each shot (if applicable):
    - Up hole time registered by the blaster control unit
    - Weak shots
    - Any occurrence of shot hole blow out
    - Excessive ground heaving
    - Any driller skids or offsets that are not surveyed
    - Flowing Holes

10.6 GEOPHONE NOISE

In windy or questionable weather conditions an appropriate sampling of data will be harvested and imported to the T3. The Shot Gather output will be viewed by Crew Management, T3 Operator, Senior Observer, and/or Client Representative(s) to determine if production will continue.

10.7 VIBRATOR PERFORMANCE

10.7.1 START UP TESTS

- Zero Start Time check for each vibrator via hard wire similarity and/or VSS (Vibrator Sweep Similarity) for ESG True Reference Signal as compared to the VCE True Reference Signal.
- A hardwire similarity and/or VSS will be recorded using the determined sweep parameters with an Echo technician onsite. All vibratorunits will be tested at the recording truck at pre start-up and displays provided at the recorder in parallel. Test display traces will include True Reference and Ground Force Response as a minimum. The vibrators measured Time Zero after correlation will also be displayed in decimal milliseconds and GPS timestamp. During these tests, vibrators sweep type, sweep phase, distortion and amplitudes will be verified. As a minimum requirement, a radio similarity will be recorded on each vibe atleast once per shift throughout the normal recording operations and if any hardware changes are made to any vibrator such as instruments, radio, or accelerometers etc., the radio similarity must be recorded to hard drive before that vibe is placed back in service.
- A fully tested radio quality assurance system (i.e. Seismic Source Bird Dog, with included QC software) will be on-site for the duration of the project. All vibrators must show the same results on the Quality Control plots; all vibrators' sweep checksums must be the same, all like vibrators will have the same check-sum numbers.
- Any vibrator that fails to meet the specifications listed in Section 1.7.3 on any of the above tests will be repaired and retested before use in data acquisition.

10.7.2 DAILY TESTS

The following daily vibrator quality assurance testing will be performed:

- Vibrator signatures will be recorded for each vibrator and every sweep throughout the day. The following performance characteristics will be monitored by radio link using the approved and tested radio quality assurance system:
    - Maximum Peak Phase Error
    - Average Phase Error
    - Maximum Peak Force Out
    - Average Force Out
    - High or Low Force Output Error Condition
    - Sweep and Vibrator Checksum
    - System Error Status
    - Maximum Peak Distortion
    - Average Peak Distortion

- Vibrator wireline similarities (hard wire) will be performed on all vibrators at least once per week, after repairs to machine, or at client's request.

10.7.3 STANDARD VIBRATOR PERFORMANCE SPECIFICATIONS

High Peak Force Out Setting	=	70% of Hold-Down Weight
Low Peak Force Out Setting	=	50% of Hold-Down Weight
Maximum Peak Phase Error	=	± 5 degrees NOT including the first 500 milliseconds of the sweep
Maximum Average Phase Error	=	1 degree
High Peak Force Error Limit	=	10% less than High Peak Force
Low Peak Force Error Limit	=	10% less than Low Peak Force
Low Average Force Error Limit	=	20% less than Low Peak Force
High Average Force Error Limit	=	20% less than High Peak Force

Note: The performance specifications above are for generic vibrators. (These parameters may vary due to CLIENT request and inherent ground conditions.)

10.8 VIBRATOR MAINTENANCE

- Any malfunctions in the operation of any vibrator will be communicated at the end of the sweep to the Observer for corrective action and appropriate comments in the observer's log. Source points affected will be re-acquired.
- A qualified vibrator technician will be employed by the crew and be present in the field to provide continuous maintenance of each unit with respect to its operation and specifications. A daily check of each unit's hydraulic lines, reservoir, base plate, airbag pressures and supports will be made prior to production. In addition, a constant check of the high and low pressure accumulator gauges will be standard to ensure proper operating pressures will be maintained.

10.9 VIBRATOR GPS SYSTEMS

- Echo uses Novatel Pro-Pak V3 dual channel GPS receivers with applied corrections from Omni Star Corporation for either GPS or DGPS accuracy. Straight GPS quality of 1 (non-differential), will show vibe pad position to within 3 meters horizontally and 1 meter vertically. DGPS quality of 2 (differentially corrected), at a fixed licensing cost per vibrator if client requested, will show vibrator pad position within sub meter accuracy. These results are viewed in real time at the recorder for each sweep to ensure source and survey accuracy.

10.10 OPERATIONAL SPECIFICATIONS

10.10.1 DATA DOWNLOAD

- The T3 Operator will download data from the FSU in SEG-Y format. A backup copy of data will be written to internal hard disk drives as well as external hard disk drives.
- All necessary steps will be taken to maintain error-free transcription.
- Only certified hard drives shall be used.
- Data shipments will be provided to the client at regular intervals and in a timely manner.

10.11 OBSERVER'S REPORTS

- Each day's Observer's Report shall contain any and all shooting anomalies (i.e. misfires in dynamite acquisition, dropped vibrator points, skids or offsets in Vibroseis production)
- For Vibrator Data production: Each day's Observer's Report shall list all VP's moved from their original surveyed location.

10.12 LOSSES IN COVERAGE

- Losses in coverage where inaccessibility over which Echo has no reasonable control shall be considered acceptable loss of coverage,
- Losses in coverage due to re-positioning of source and/or receiver locations caused by environmental conditions over which Echo has no reasonable control shall be considered acceptable loss of coverage.
- Losses in coverage due to re-positioning of shot points and/or receivers per instructions from the client or the designated client representative shall be considered acceptable loss of coverage.

10.13 SCRIPT FILES AND PATCHES

- Scripts or Patches are to be provided by the client or in some cases an authorized Echo employee in XPS or PRJ format.
- After loading the script files into the recorder, the file will be compared to the criteria supplied on the parameter sheet for proper number of lines lives and proper number of channels to be recorded per line.
- No recording of data shall take place without this verification for patch sizes.

10.14 VEHICLE AND PERSONNEL TRACKING WITH GPS

Echo vehicles and personnel are monitored in real-time using a two-way radio tracking system that is monitored in the staging trailer. Vehicles are also tracked via a web-based program – TOGS – which is available to crew management and where cell service is sufficient, at the staging trailer as well.

Appendix B

Geofirma Data Quality Confirmation (DQC) Forms

DocuSign Envelope ID: 29F8DADB-946E-4E91-84E4-28A41BB72332

Daily Record Form

Project Number: 21-210-1

DATE:	09-Nov-21

Total Source KM: 0 km Total Source Points: 0

Total Receiver KM: -- km Total Receiver Points: 1528

Line Crew Production

Total Receivers Laid Out Today: 901

Lines # Completed: see production log

Total Receivers Picked Up: 0

Line #s Completed: 0

Notes: 8 crews laying out receivers, 3 QC crews checking receiver deployment

Shooting Summary

Daily Total Shot Points: 0

Shot on Line #s: 0

Daily Total KMs: 0

Notes: Echo performed vibe sweep tests in afternoon.

Name: Chrystyn Skinner Date: 10-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/10/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 310110A1-0365-4DEB-871E-48783F8502B1

Daily Record Form

Project Number: 21-210-1

DATE:	10-Nov-21

% Source Complete: 89 %

% Receiver Complete 1.5 %

Total Source Points: 167

Total Receiver Points: 2332

Line Crew Production

Total Receivers Laid Out Today: 804

Lines # Completed: see production log

Total Receivers Picked Up: 0

Line #s Completed: 0

Notes: 7 crews deploying receivers.

Shooting Summary

Daily Total Shot Points: 167

Shot on Line #s: 202, 210

% Complete: 1.50%

Notes: Recording operations began at approx 14:00. Two pairs of 2 vibes in operation in eastern land parcels.

Name: Chrystyn Skinner Date: 11-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/12/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 9B1905AF-ABE5-438B-94B1-8C3A72817D3C

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	11-Nov-21

% Source Complete: 13.0 %

% Receiver Complete 100 %

Total Source Points: 1430

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 288

Lines # Completed: see production log

Total Receivers Picked Up: 0

Line #s Completed: 0

Notes: 7 crews deploying receivers. All receivers completely laid out by early afternoon.

Shooting Summary

Daily Total Shot Points: 1263

Shot on Line #s: 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230

% Total Shot Points Complete: 13.0%

Notes: Two pairs of 2 vibes in operation in eastern land parcels. 1 pair of vibes in operation to northeastern land parcels.

Name: Chrystyn Skinner Date: 12-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/12/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: C1754285-D5B4-4D3B-9E4E-B9241BEC8C6B

Daily Record Form

Project Number: 21-210-1

DATE:	12-Nov-21

% Source Complete: 24.6 %

% Receiver Complete 100 %

Total Source Points: 2706

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: all laid out

Total Receivers Picked Up: 0

Line #s Completed: 0

Notes: All receivers completely laid out, crews checking lines throughout day.

Shooting Summary

Daily Total Shot Points: 1276

Shot on Line #s: 218 - 244

% Complete: 24.6%

Notes: 3 pairs of vies in operation across site.

Name: Chrystyn Skinner Date: 14-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/14/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: C1754285-D5B4-4D3B-9E4E-B9241BEC8C6B

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	13-Nov-21

% Source Complete: 32.7 %

% Receiver Complete 100 %

Total Source Points: 3597

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: all laid out

Total Receivers Picked Up: 0

Line #s Completed: 0

Notes: All receivers completely laid out, crews checking lines throughout day.

Shooting Summary

Daily Total Shot Points: 891

Shot on Line #s: 234-262

% Complete: 32.7%

Notes: 3 pairs of vies in operation across site. Production stopped during intermittent heavy rain, production continued when rain stopped.

Name: Chrystyn Skinner Date: 14-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/14/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 67B11038-5FE1-4304-967D-237D7AD15B5A

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	14-Nov-21

% Source Complete: 42.8 %

% Receiver Complete 100 %

Total Source Points: 4780

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: all laid out

Total Receivers Picked Up: 186

Line #s Completed: 202 - 212

Notes: All receivers completely laid out, crews checking lines throughout day. In afternoon (14:00), began picking up receivers in easternmost lines (7.2% receivers picked up).

Shooting Summary

Daily Total Shot Points: 1183

Shot on Line #s: 234 - 270

% Complete: 42.8%

Notes: 3 pairs of vies in operation across site. Completed all vibe points in eastern portion of site, including eastern segment (~2 km) of Concession Rd 8.

Name: Chrystyn Skinner Date: 15-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/16/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: FE09AED6-7CEF-41DC-AC6D-213161436CD8

Daily Record Form

Project Number: 21-210-1

DATE:	15-Nov-21

% Source Complete: 58.1 %

% Receiver Complete 100 %

Total Source Points: 6391

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: all laid out

Total Receivers Picked Up: 0

Line #s Completed: 0

Notes: No receivers picked up today, will continue to be retrieved tomorrow once more westward progress is made with the vibes.

Shooting Summary

Daily Total Shot Points: 1611

Shot on Line #s: 242- 274

% Complete: 58.1%

Notes: 3 pairs of vies in operation across site. 1 pair in operation along Concession 10 with flagging crew.

Name: Chrystyn Skinner Date: 16-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/17/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: FE09AED6-7CEF-41DC-AC6D-213161436CD8

Daily Record Form

Project Number: 21-210-1

DATE:	16-Nov-21

% Source Complete:	71.4	%	Total Source Points:	7735	
% Receiver Complete	100	%	Total Receiver Points:	2620	

Line Crew Production

Total Receivers Laid Out Today:	0
Lines # Completed:	--
Total Receivers Picked Up:	598
Line #s Completed:	R214 - R228

Notes: see attached production log

Shooting Summary

Daily Total Shot Points:	1344
Shot on Line #s:	242 - 290
% Complete:	71.4%

Notes: 3 pairs of vies in operation across site. 1 pair in operation along section of Concession 8 with flagging crew.

Name: Chrystyn Skinner Date: 17-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/17/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 2059C325-250F-4BB3-92A9-0FD412AB32AD

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	17-Nov-21

% Source Complete:	81.2	%	Total Source Points:	8791	
% Receiver Complete	100	%	Total Receiver Points:	2620	

Line Crew Production

Total Receivers Laid Out Today:	0
Lines # Completed:	all laid out
Total Receivers Picked Up:	131
Line #s Completed:	R230 - R234

Notes: 3 crews picking up available receivers.

Shooting Summary

Daily Total Shot Points:	1056
Shot on Line #s:	254 - 274
% Complete:	81.2%

Notes: 3 pairs of vies in operation across site. 1 pair in operation along segment of Concession 8 with flagging crew for portion of day. Vibes periodically got stuck in soft ground. At 2pm heavy rain shut down recording for ~ 2 hrs. 1 pair of vibes stuck in NWMO-5B at end of day.

Name: Chrystyn Skinner Date: 18-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/18/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: DC98F762-CF21-4C74-9B0E-0EBEE871CD4A

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	18-Nov-21

% Source Complete:	91.4 %	Total Source Points:	9892
% Receiver Complete	100 %	Total Receiver Points:	2620

Line Crew Production

Total Receivers Laid Out Today:	0
Lines # Completed:	all laid out
Total Receivers Picked Up Today:	346 (1076 cumulative)
Line #s Completed:	R236 - R246

Notes: Line crews picking up receivers where available. At EOD, 1544 receivers remaining laid out.

Shooting Summary

Daily Total Shot Points:	1101
Shot on Line #s:	264 - 306
% Complete:	91.4%

Notes: 3 pairs of vies in operation across site. 1 pair in operation along segment of Concession 8 with flagging crew for portion of day. In AM, worked to extract 2 stuck vibes. Vibes periodically got stuck in soft ground. Detours to avoid wet ground caused delays in vibe production.

Name: Chrystyn Skinner Date: 19-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...
Signature

11/21/2021
Date

Geofirma Engineering Ltd

DocuSign Envelope ID: DC98F762-CF21-4C74-9B0E-0EBEE871CD4A

Daily Record Form

Project Number: 21-210-1

DATE:	19-Nov-21

% Source Complete: 100.0 %

% Receiver Complete 100 %

Total Source Points: 10768

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: all laid out

Total Receivers Picked Up Today: 356 (1432 cumulative)

Line #s Completed: R244 - R256

Notes: 4 line crews picking up receivers where available. At EOD, 1188 receivers remaining laid out.

Shooting Summary

Daily Total Shot Points: 876

Shot on Line #s: 270 - 306

% Complete: 100.0%

Notes: Vibes in western land parcels. Finished all vibe points at ~15:00.

Name: Chrystyn Skinner Date: 20-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

11/21/2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 42A46202-AD7B-402E-BF47-555601D68DF0

Daily Record Form

Project Number: 21-210-1

DATE:	20-Nov-21

% Source Complete: 100.0 %

% Receiver Complete 100 %

Total Source Points: 10768

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: line pickup

Total Receivers Picked Up Today: 709 (2141 cumulative)

Line #s Completed: R258 - R276

Notes: 7 line crews picking up receivers . At EOD, 479 receivers remaining laid out.

Shooting Summary

Daily Total Shot Points: 0

Shot on Line #s: vibing complete

% Complete: 100.0%

Notes: All shot points complete.

Name: Chrystyn Skinner Date: 21-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

27-Nov-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 42A46202-AD7B-402E-BF47-555601D68DF0

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	21-Nov-21

% Source Complete: 100.0 %

% Receiver Complete 100 %

Total Source Points: 10768

Total Receiver Points: 2620

Line Crew Production

Total Receivers Laid Out Today: 0

Lines # Completed: line pickup

Total Receivers Picked Up Today: 479

Line #s Completed: R278 - R306

Notes: Line crews picking up receivers. All receivers picked up by 13:00.

Shooting Summary

Daily Total Shot Points: 0

Shot on Line #s: vibing complete

% Complete: 100.0%

Notes: All shot points complete.

Name: Chrystyn Skinner Date: 22-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

27-Nov-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 951CEF55-77A2-4232-9B83-26C04D8B2EEA

Daily Record Form

Project Number: 21-210-1

DATE:	27-Nov-21

% Source Complete: 22.9 %

% Receiver Complete NA %

Total Source Points: 2001

Total Receiver Points: 72

Line Crew Production

Total Receivers Laid Out Today: NA

Lines # Completed: NA

Total Receivers Picked Up Today: NA

Line #s Completed: NA

Notes: No line crew production with 2D landstreamer set up/paleochannel work. All 72 receivers are equally spaced (1.5 m) on geophone string, pulled behind vibe as a unit.

Shooting Summary

Daily Total Shot Points: 458

Shot on Line #s: Line 2 (Concession 8)

% Total Complete: 22.9%

Notes: Ended at station 458. Completed eastern ~1 km of line 2.

Name: Chrystyn Skinner Date: 28-Nov-21 Time: 8:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

28-Nov-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 4695BA08-39E6-48E2-BEF5-1B7E9B95E656

Daily Record Form

Project Number: 21-210-1

DATE:	28-Nov-21

% Source Complete: 32.1 %

% Receiver Complete NA %

Total Source Points: 2001

Total Receiver Points: 72

Line Crew Production

Total Receivers Laid Out Today: NA

Lines # Completed: NA

Total Receivers Picked Up Today: NA

Line #s Completed: NA

Notes: No line crew production with 2D landstreamer set up/paleochannel work. All 72 receivers are equally spaced (1.5 m) on geophone string, pulled behind vibe as a unit.

Shooting Summary

Daily Total Shot Points: 184

Shot on Line #s: Line 3 (Bruce Rd 6)

% Total Complete: 32.1%

Notes: Ended at station 184. Completed eastern Line 3 to avoid weekday traffic near Teeswater Concrete.

Name: Chrystyn Skinner Date: 29-Nov-21 Time: 12:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

29-Nov-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: A9AA553F-28E9-4092-9A25-86D700308903

Daily Record Form

Project Number: 21-210-1

DATE:	29-Nov-21

% Source Complete: 54.3 % Total Source Points: 2001

% Receiver Complete NA % Total Receiver Points: 72

Line Crew Production

Total Receivers Laid Out Today: NA

Lines # Completed: NA

Total Receivers Picked Up Today: NA

Line #s Completed: NA

Notes: No line crew production with 2D landstreamer set up/paleochannel work. All 72 receivers are equally spaced (1.5 m) on geophone string, pulled behind vibe as a unit.

Shooting Summary

Daily Total Shot Points: 445

Shot on Line #s: Line 3 (Bruce Rd 6)

% Total Complete: 54.3%

Notes: Did not fully complete Line 3, to return to finish tomorrow. Minor mechanical issues with vibe fixed in afternoon.

Name: Chrystyn Skinner Date: 30-Nov-21 Time: 12:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

30-Nov-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 28E6AE2A-2453-4F65-9F12-303283B94CE1

Daily Record Form

Project Number: 21-210-1

DATE:	30-Nov-21

% Source Complete: 63.4 %

% Receiver Complete NA %

Total Source Points: 2001

Total Receiver Points: 72

Line Crew Production

Total Receivers Laid Out Today: NA

Lines # Completed: NA

Total Receivers Picked Up Today: NA

Line #s Completed: NA

Notes: No line crew production with 2D landstreamer set up/paleochannel work. All 72 receivers are equally spaced (1.5 m) on geophone string, pulled behind vibe as a unit.

Shooting Summary

Daily Total Shot Points: 182

Shot on Line #s: Line 3 (Bruce Rd 6), Line 2 (Concession 8)

% Total Complete: 63.4%

Notes: Completed acquisition along Line 3, moved and resumed acquisition along Line 2.

Name: Chrystyn Skinner Date: 01-Dec-21 Time: 19:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

07-Dec-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 28E6AE2A-2453-4F65-9F12-303283B94CE1

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	01-Dec-21

% Source Complete: 83.3 %

% Receiver Complete NA %

Total Source Points: 2001

Total Receiver Points: 72

Line Crew Production

Total Receivers Laid Out Today: NA

Lines # Completed: NA

Total Receivers Picked Up Today: NA

Line #s Completed: NA

Notes: No line crew production with 2D landstreamer set up/paleochannel work. All 72 receivers are equally spaced (1.5 m) on geophone string, pulled behind vibe as a unit.

Shooting Summary

Daily Total Shot Points: 398

Shot on Line #s: Line 2 (Concession 8), Line 1 (Concession 10)

% Total Complete: 83.3%

Notes: Completed acquisition along Line 2, moved and continued acquisition along Line 1.

Name: Chrystyn Skinner Date: 02-Dec-21 Time: 12:00

Reviewer Sign Off

Reviewed by:

DocuSigned by: Sean Sterling D69688FA497E43D...

Signature

07-Dec-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 28E6AE2A-2453-4F65-9F12-303283B94CE1

Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic

Daily Record Form

Project Number: 21-210-1

DATE:	02-Dec-21

% Source Complete: 100.0 %

% Receiver Complete NA %

Total Source Points: 2001

Total Receiver Points: 72

Line Crew Production

Total Receivers Laid Out Today: NA

Lines # Completed: NA

Total Receivers Picked Up Today: NA

Line #s Completed: NA

Notes: No line crew production with 2D landstreamer set up/paleochannel work. All 72 receivers are equally spaced (1.5 m) on geophone string, pulled behind vibe as a unit.

Shooting Summary

Daily Total Shot Points: 334

Shot on Line #s: Line 1 (Concession 10)

% Total Complete: 100.0%

Notes: Completed acquisition along Line 1. All data acquisition completed.

Name: Chrystyn Skinner Date: 03-Dec-21 Time: 12:00

Reviewer Sign Off

Reviewed by:

DocuSigned by:
Sean Sterling
D69688FA497E43D...

Signature

07-Dec-2021

Date

Geofirma Engineering Ltd

DocuSign Envelope ID: 9B1905AF-ABE5-438B-94B1-8C3A72817D3C

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks

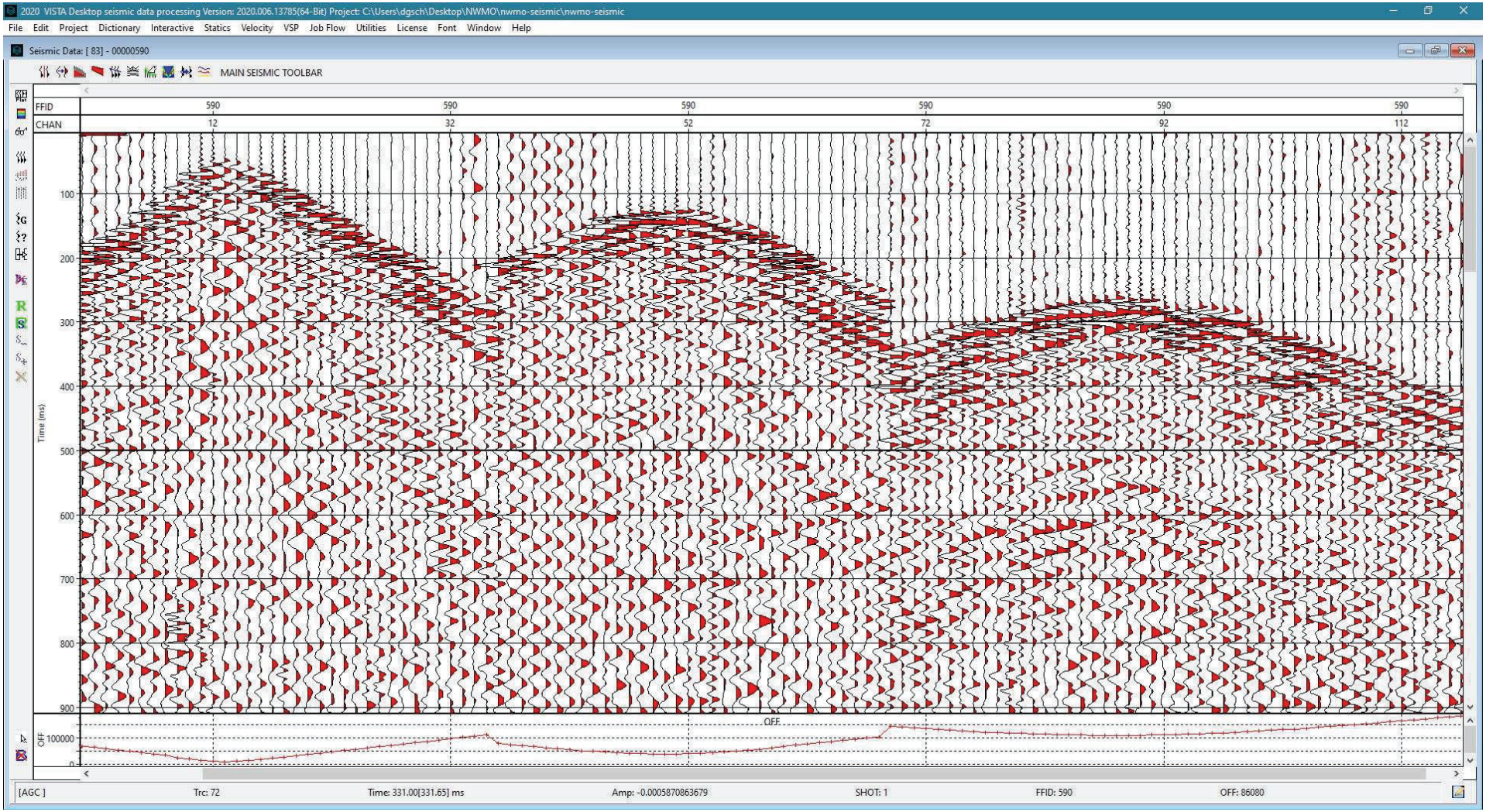
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 11/12/2021

21-210-1: Data Quality Confirmation Report

Date: 11-Nov-21	ATTACHED FIGURE File Name: 590



Geofirma Engineering Ltd

DocuSign Envelope ID: 67B11038-5FE1-4304-967D-237D7AD15B5A

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed

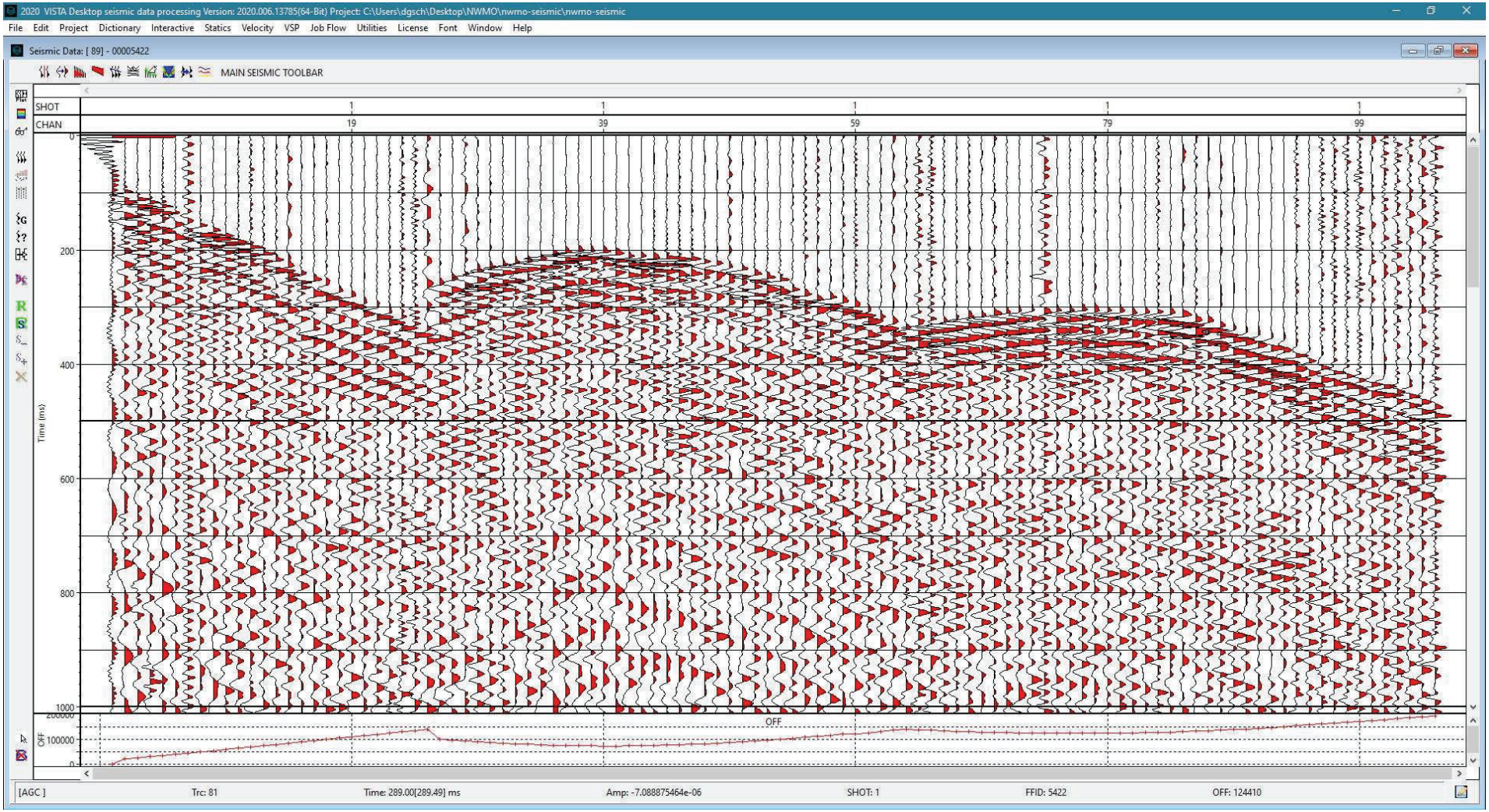
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling 11/16/2021

Date: D69688FA497E43D...

21-210-1: Data Quality Confirmation Report

Date: 12-Nov-21	ATTACHED FIGURE File Name: 5422



DocuSign Envelope ID: 67B11038-5FE1-4304-967D-237D7AD15B5A

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	y	late afternoon 30 km/hr winds and heavy rain shut down crew

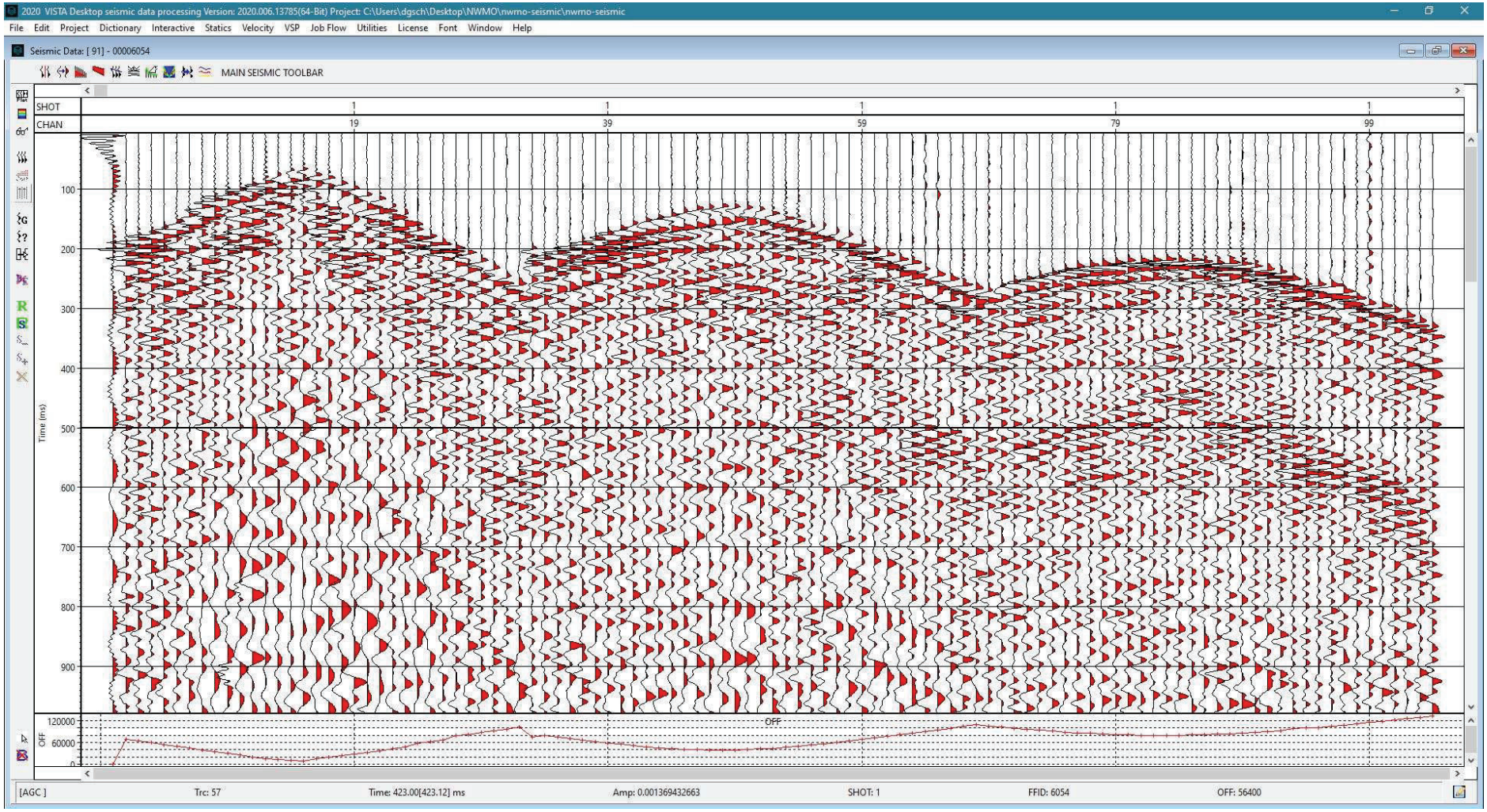
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 11/16/2021

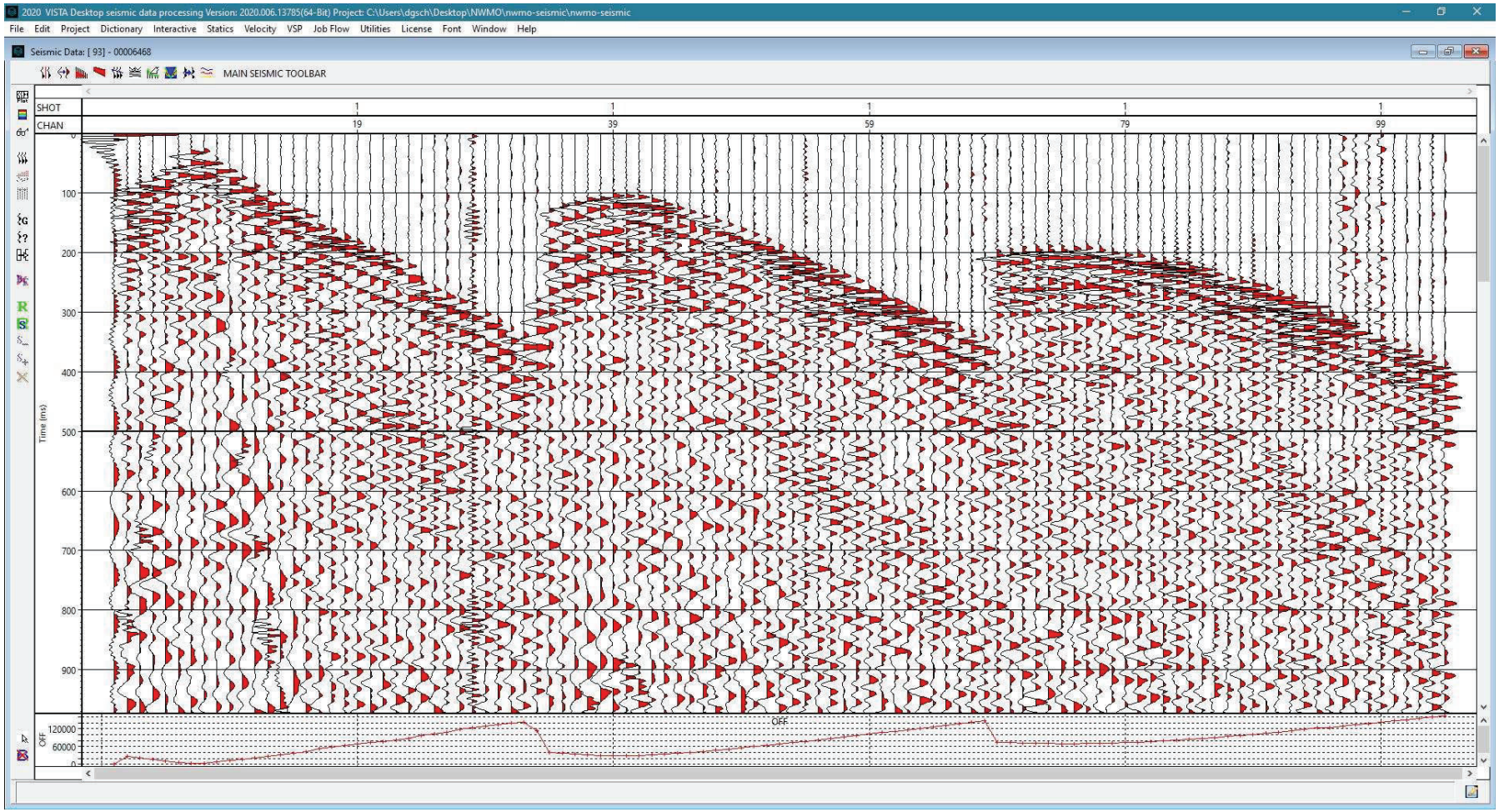
21-210-1: Data Quality Confirmation Report

Date: 13-Nov-21	ATTACHED FIGURE File Name: 6054



21-210-1: Data Quality Confirmation Report

Date: 13-Nov-21	ATTACHED FIGURE File Name: 6468



DocuSign Envelope ID: 67B11038-5FE1-4304-967D-237D7AD15B5A

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	y	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	good	y	light snow, light breeze, source points on road

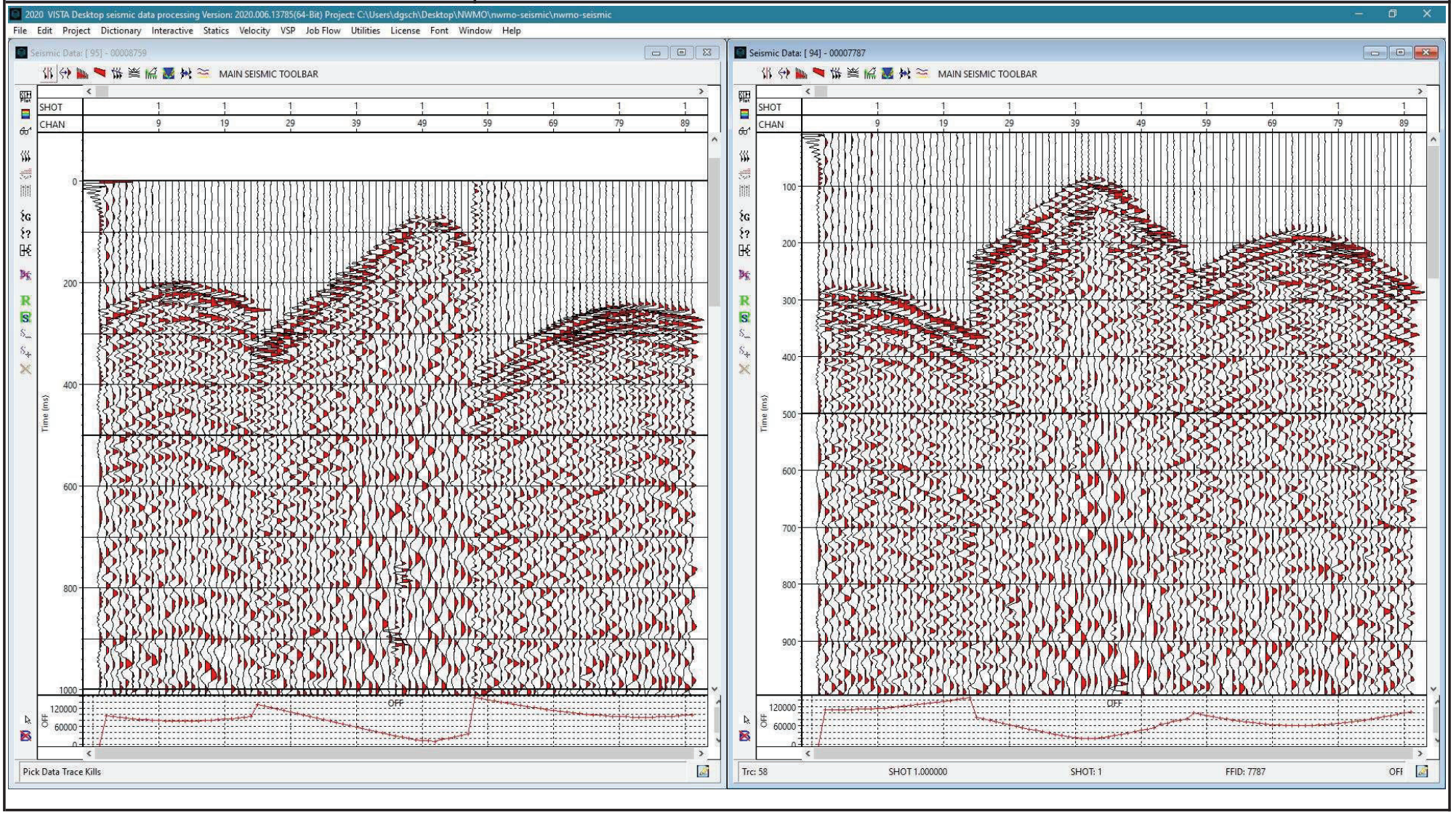
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 11/16/2021

21-210-1: Data Quality Confirmation Report

Date: 14-Nov-21	ATTACHED FIGURE File Name: 8759 & 7787



21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	y	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	ood	y	light snow, light breeze, source points on road
none	none	15-Nov-21						

Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 11/17/2021

DocuSign Envelope ID: FE09AED6-7CEF-41DC-AC6D-213161436CD8

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	y	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	ood	y	light snow, light breeze, source points on road
none	none	15-Nov-21	--	--	--	--	--	--
13899-13895	3D sesimic	16-Nov-21	17-Nov-21	dgs	y	good	y	drilling noise along line 242 (NWMO-04) monitoring, some noise on nearbey 3-4 stations but high frequency/random not ubstantial

Other Comments:

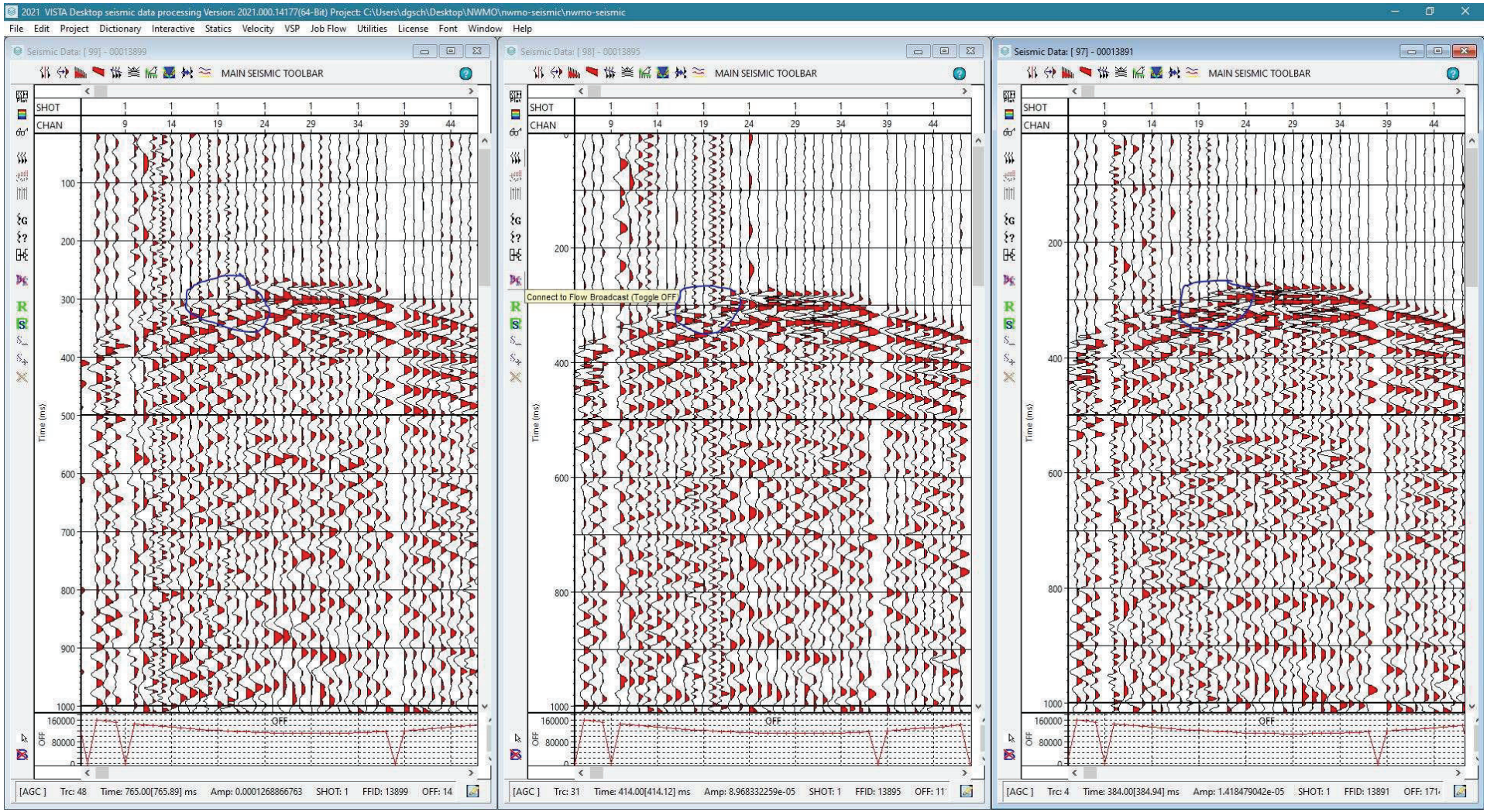
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Date: 11/17/2021

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21-210-1: Data Quality Confirmation Report

Date: 16-Nov-21	ATTACHED FIGURE File Name: 13899-13895



21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	y	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	ood	y	light snow, light breeze, source points on road
none	none	15-Nov-21	--	--	--	--	--	--
13899-13895	3D sesimic	16-Nov-21	17-Nov-21	dgs	y	good	y	drilling noise along line 242 (NWMO-04) monitoring, some noise on nearbey 3-4 stations but high frequency/random not ubstantial
VP 202_236, VP 204-233, VP 218-148	3D sesimic	15-Nov-21	17-Nov-21	dgs	y	fair	y	snow and some wind - noisy data

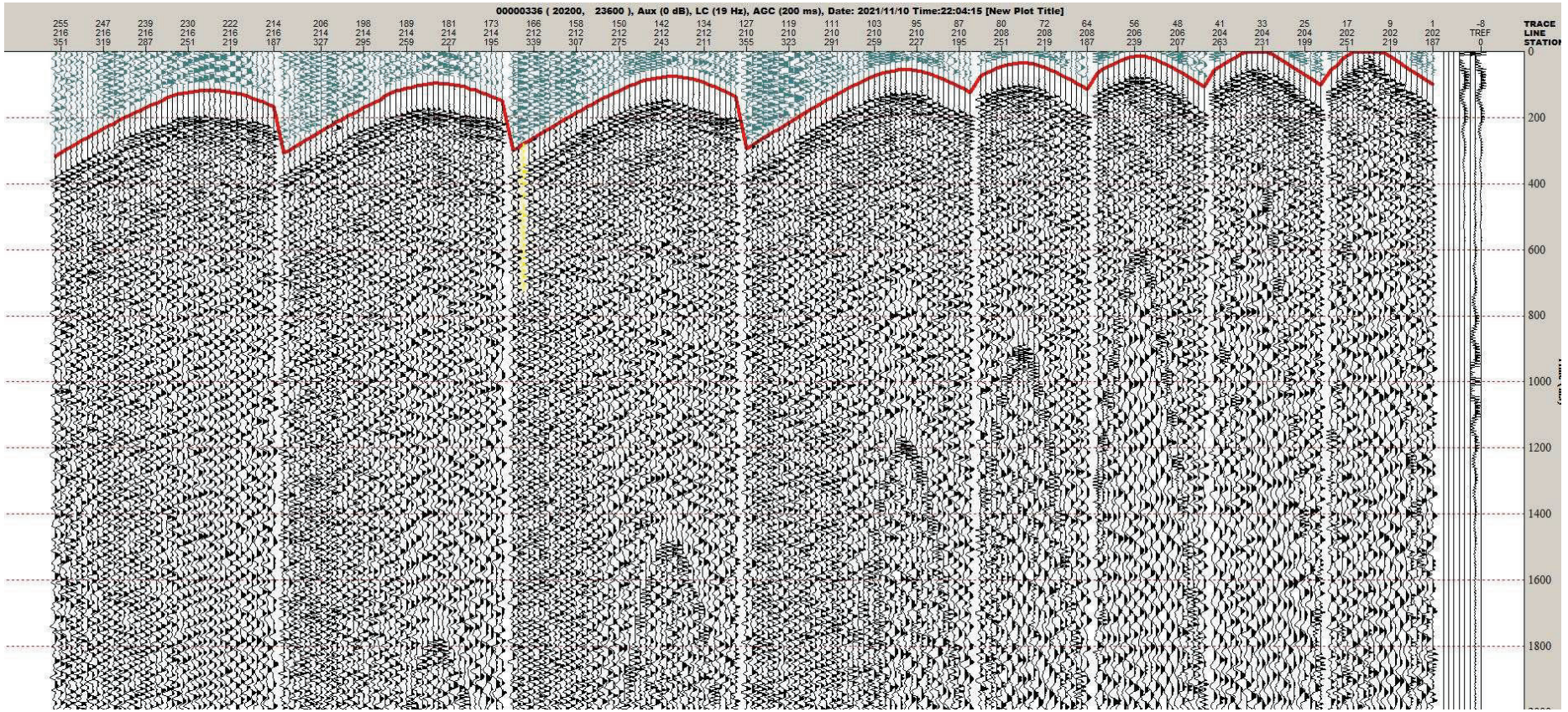
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 11/18/2021

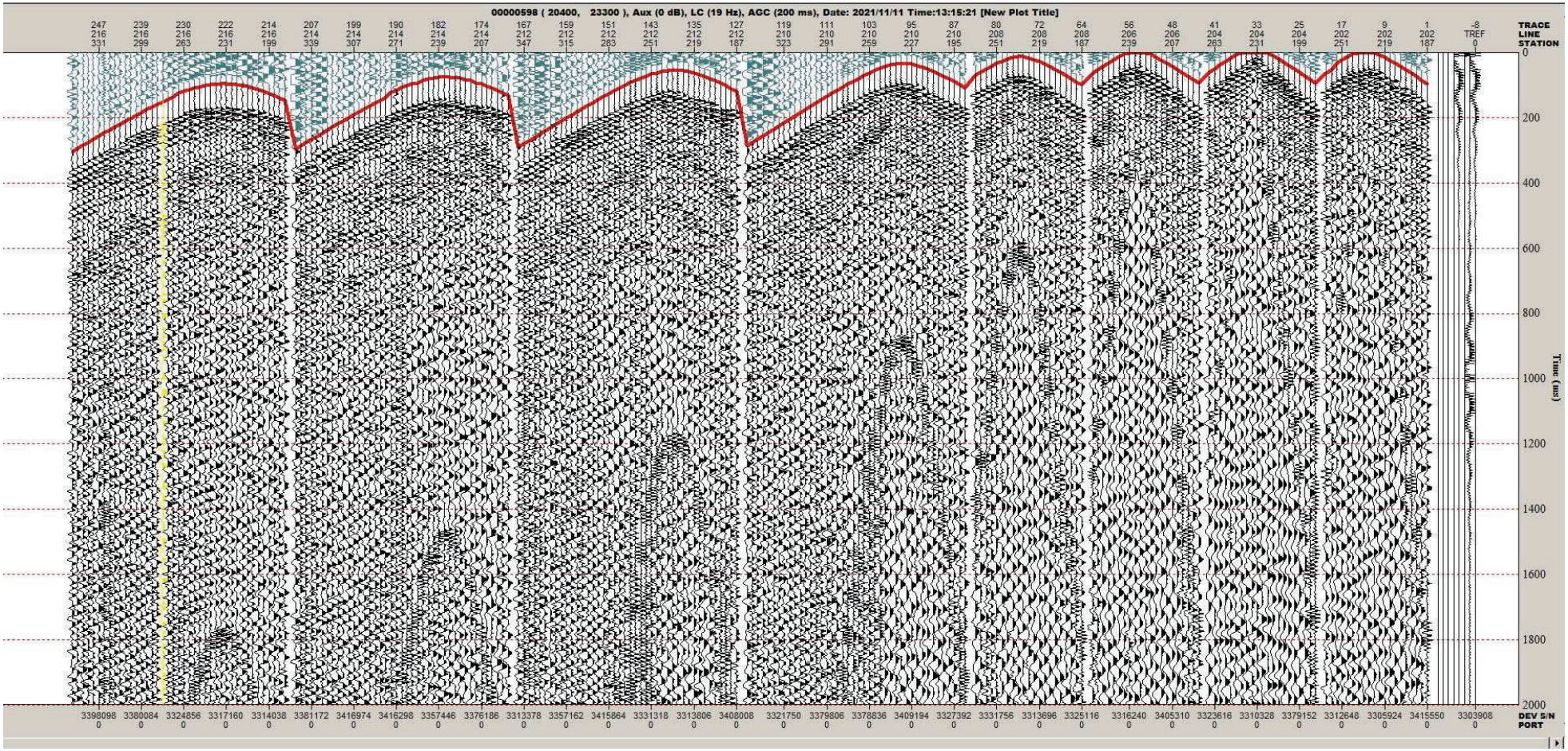
21-210-1: Data Quality Confirmation Report

Date: 17-Nov-21	ATTACHED FIGURE File Name: VP 202_236



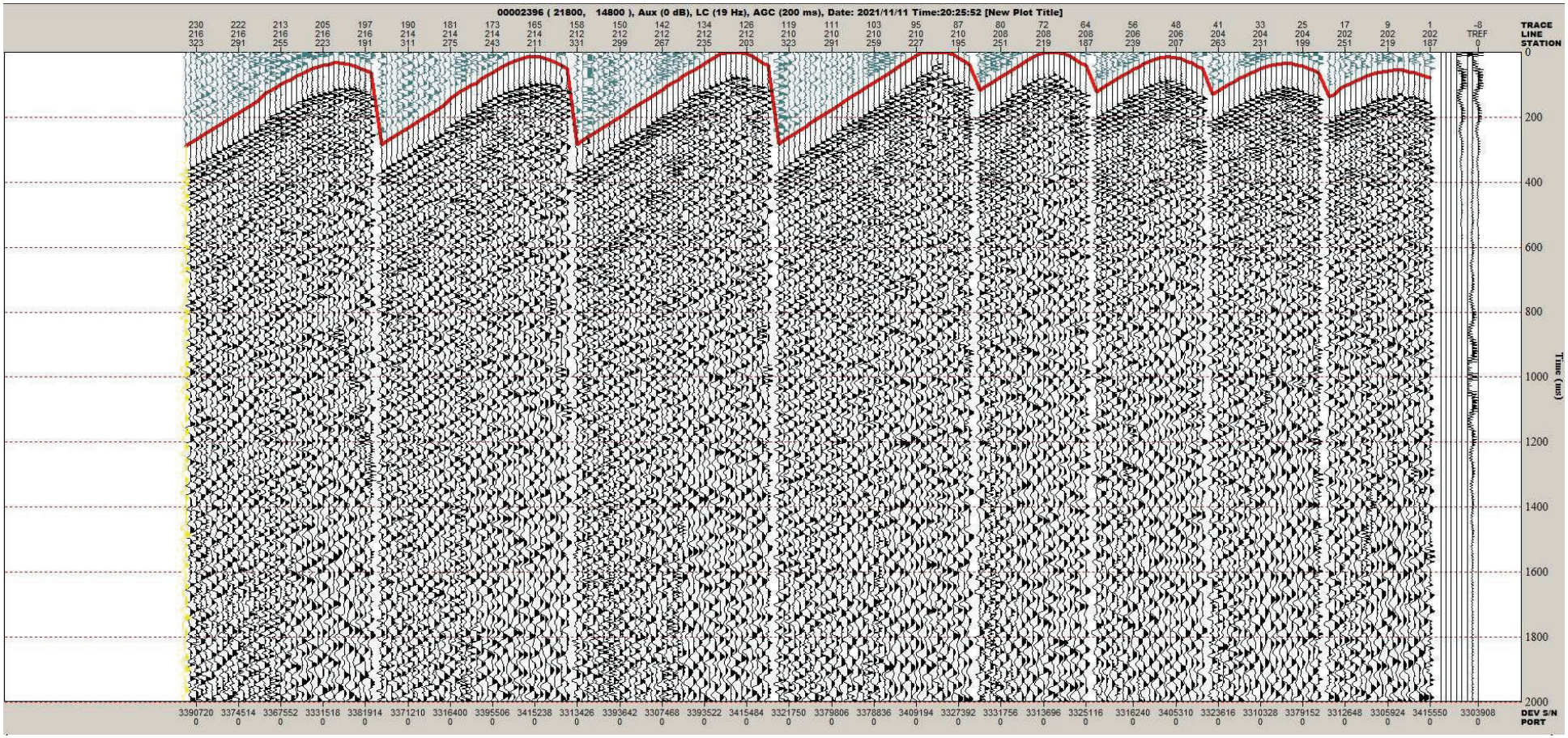
21-210-1: Data Quality Confirmation Report

Date: 17-Nov-21	ATTACHED FIGURE File Name: VP 204-233



21-210-1: Data Quality Confirmation Report

Date: 17-Nov-21	ATTACHED FIGURE File Name: VP 218-148



DocuSign Envelope ID: 56DFEF80-8CAD-43B8-9544-A666AC796AB1

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	y	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	y	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	y	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	ood	y	light snow, light breeze, source points on road
none	none	15-Nov-21	--	--	--	--	--	--
13899-13895	3D sesimic	16-Nov-21	17-Nov-21	dgs	y	good	y	drilling noise along line 242 (NWMO-04) monitoring, some noise on nearbey 3-4 stations but high frequency/random not ubstantial
VP 202_236, VP 204-233, VP 218-148	3D sesimic	15-Nov-21	17-Nov-21	dgs	y	fair	y	snow and some wind - noisy data
SP210_344	3D seismic	17-Nov-21	18-Nov-21	dgs	y	good	y	full record all data, 4 s reveiwed 1,000 records, observed some records ~3% have 2nd shots starting at 1.6s increases 1km lag from 1s to 2s.

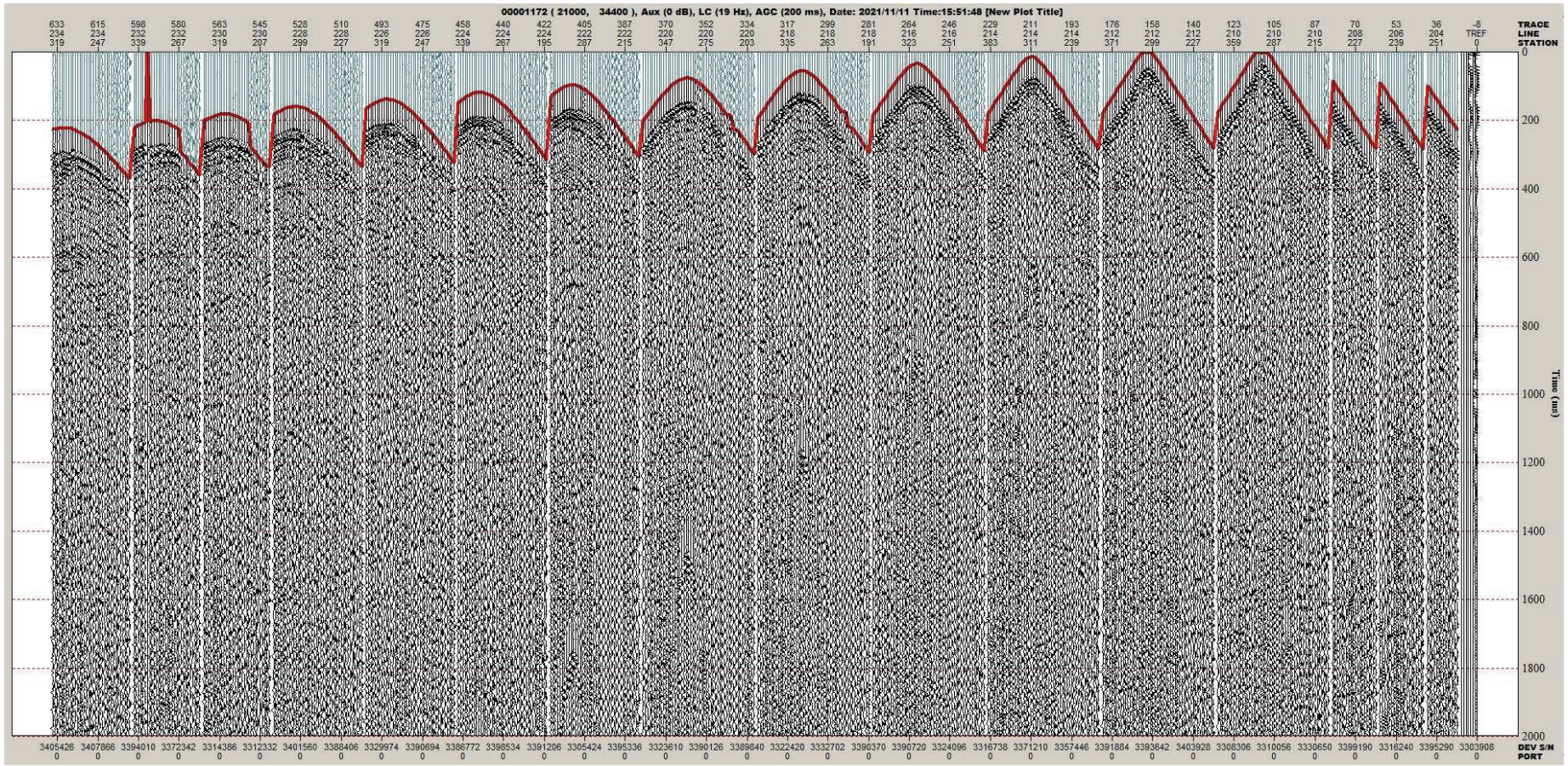
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 29-Nov-2021

21-210-1: Data Quality Confirmation Report

Date: 18-Nov-21	ATTACHED FIGURE File Name: SP210_344



DocuSign Envelope ID: 56DFEF80-8CAD-43B8-9544-A666AC796AB1

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	N	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	N	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	N	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	ood	N	light snow, light breeze, source points on road
none	none	15-Nov-21	--	--	--	--	--	--
13899-13895	3D sesimic	16-Nov-21	17-Nov-21	dgs	y	good	n	drilling noise along line 242 (NWMO-04) monitoring, some noise on nearbey 3-4 stations but high frequency/random not ubstantial
VP 202_236, VP 204-233, VP 218-148	3D sesimic	15-Nov-21	17-Nov-21	dgs	y	fair	n	snow and some wind - noisy data
SP210_344	3D seismic	17-Nov-21	18-Nov-21	dgs	y	good	n	full record all data, 4 s reveiwed 1,000 records, observed some records ~3% have 2nd shots starting at 1.6s increases 1km lag from 1s to 2s.
9539	3D Seismic	18-Nov-21	21-Nov-21	dgs	y	good	Y	completed file, filtered 35 Hz, noisy due to near surface conditions
9919	3D Seismic	19-Nov-21	21-Nov-21	DGS	y	fair	Y	Windy in afternoon had some affect on data as seen from nooise before 1st breaks
12688	3D Seismic	20-Nov-21	21-Nov-21	DGS	Y	good	Y	One of the last VP's from East side of prospect area, clean first breaks so refletors identified

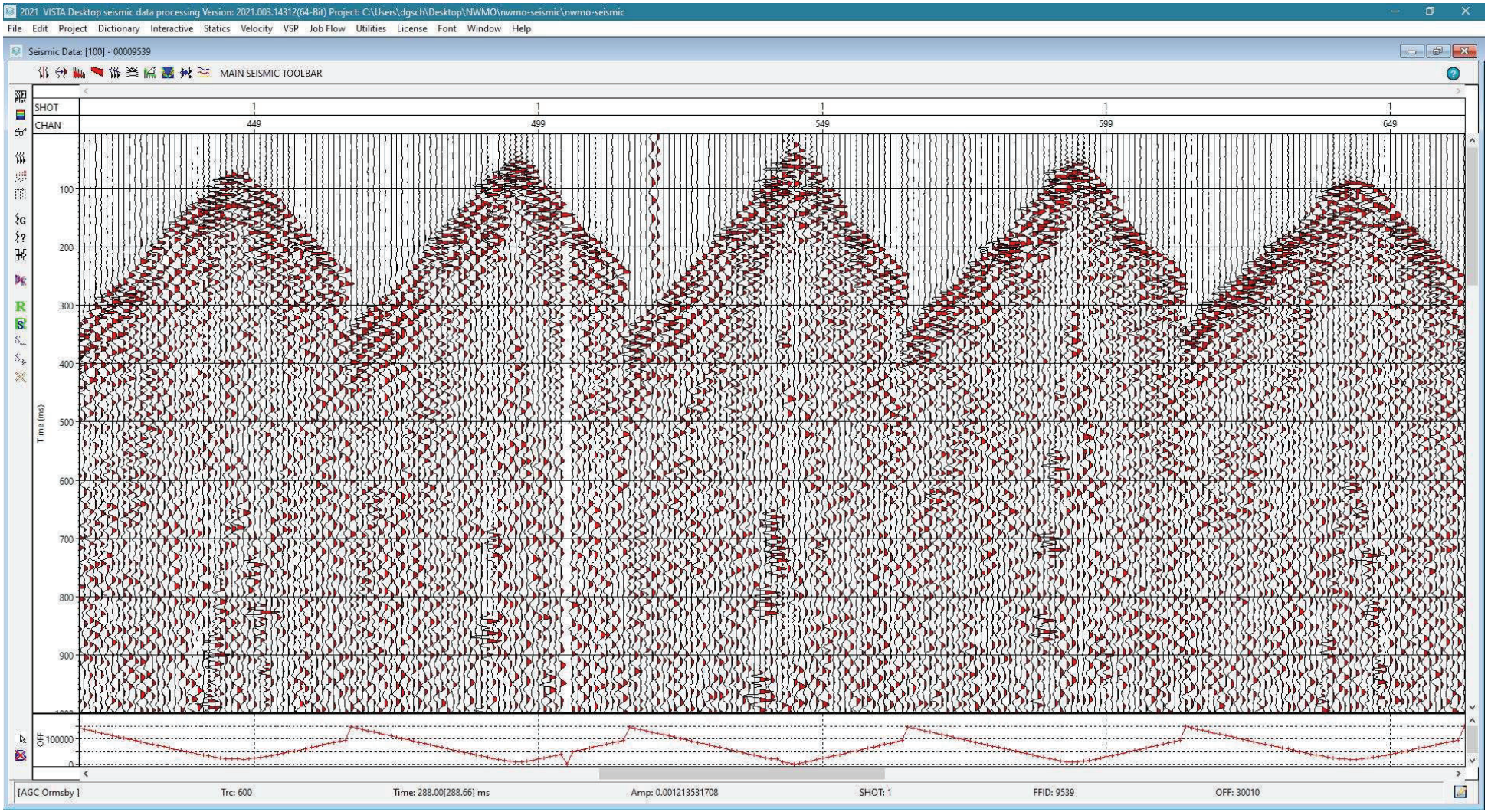
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 29-Nov-2021

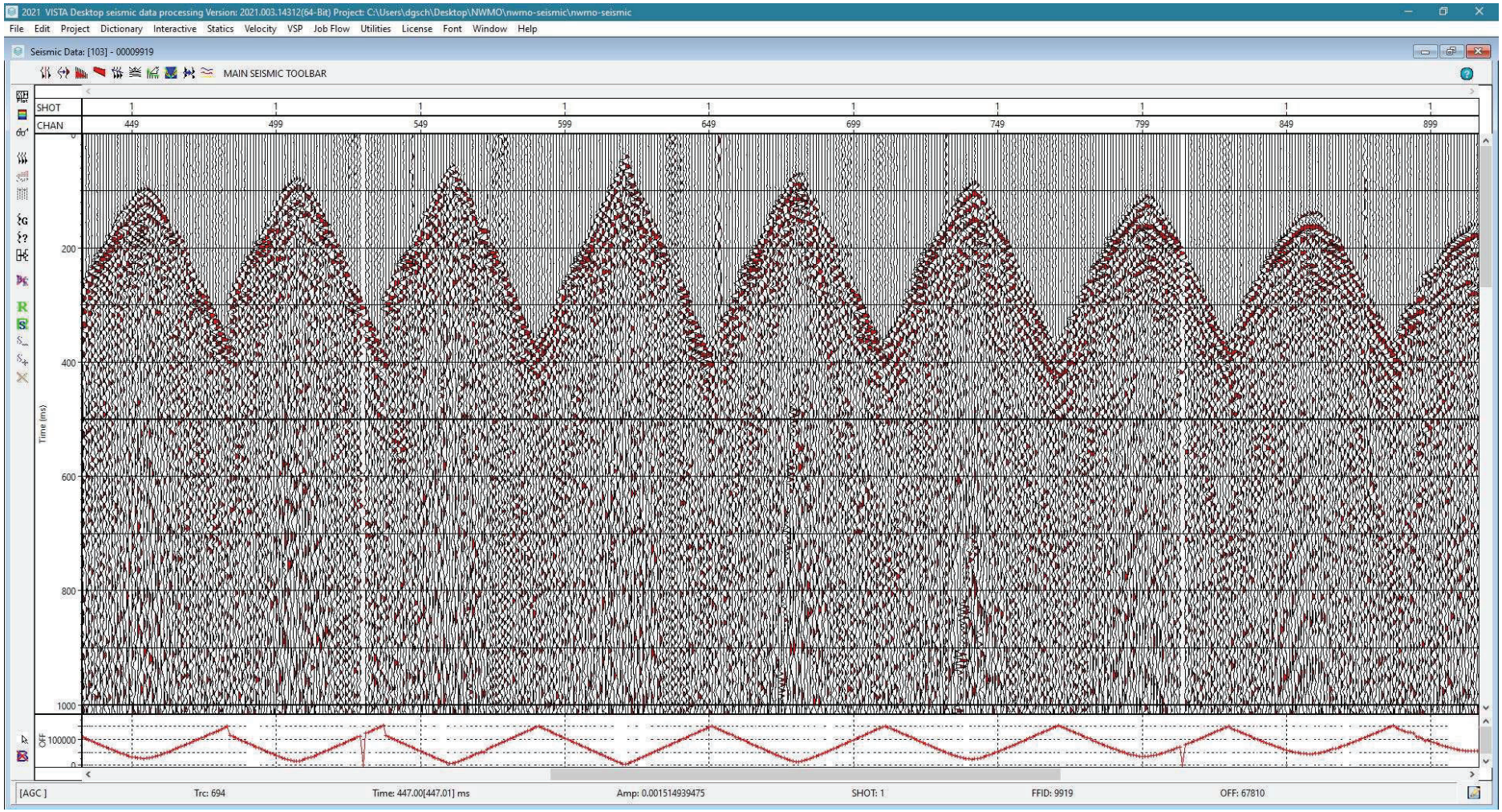
21-210-1: Data Quality Confirmation Report

Date: 18-Nov-21	ATTACHED FIGURE File Name: 9539



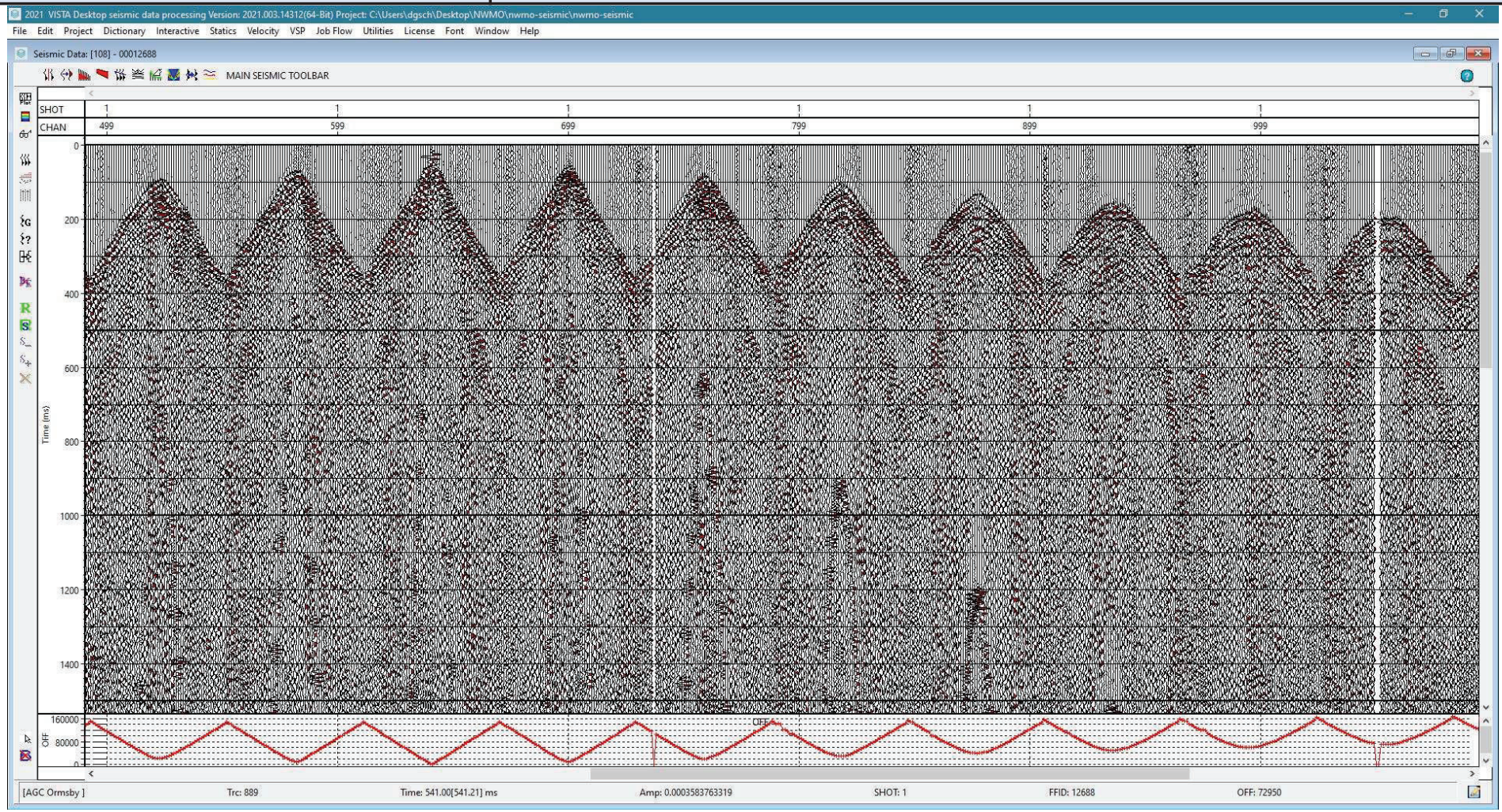
21-210-1: Data Quality Confirmation Report

Date: 19-Nov-21	ATTACHED FIGURE File Name: 9919



21-210-1: Data Quality Confirmation Report

Date: 20-Nov-21	ATTACHED FIGURE File Name: 12688



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21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
590	3D sesimic	11-Nov-21	11-Nov-21	dgs	Y	fair	N	Windy in afternoon had some affect on data as seen from noise before 1st breaks
5422	3D sesimic	12-Nov-21	13-Nov-21	dgs	y	good	N	clear weather, breezy intermittently llittle noise before 1st breaks, reflectors observed
6054 & 6468	3D sesimic	13-Nov-21	14-Nov-21	dgs	y	good	N	late afternoon 30 km/hr winds and heavy rain shut down crew
8759&7787	3D sesimic	14-Nov-21	15-Nov-21	dgs	y	ood	N	light snow, light breeze, source points on road
none	none	15-Nov-21	--	--	--	--	--	--
13899-13895	3D sesimic	16-Nov-21	17-Nov-21	dgs	y	good	n	drilling noise along line 242 (NWMO-04) monitoring, some noise on nearbey 3-4 stations but high frequency/random not ubstantial
VP 202_236, VP 204-233, VP 218-148	3D sesimic	15-Nov-21	17-Nov-21	dgs	y	fair	n	snow and some wind - noisy data
SP210_344	3D seismic	17-Nov-21	18-Nov-21	dgs	y	good	n	full record all data, 4 s reveiwed 1,000 records, observed some records ~3% have 2nd shots starting at 1.6s increases 1km lag from 1s to 2s.
9539	3D Seismic	18-Nov-21	21-Nov-21	dgs	y	good	n	completed file, filtered 35 Hz, noisy due to near surface conditions
9919	3D Seismic	19-Nov-21	21-Nov-21	DGS	y	fair	n	Windy in afternoon had some affect on data as seen from nooise before 1st breaks
12688	3D Seismic	20-Nov-21	21-Nov-21	DGS	Y	good	N	One of the last VP's from East side of prospect area, clean first breaks so refletors identified
12526	3D Seismic	21-Nov-21	22-Nov-21	DGS	Y	good	Y	Fk filter to identify reflectors

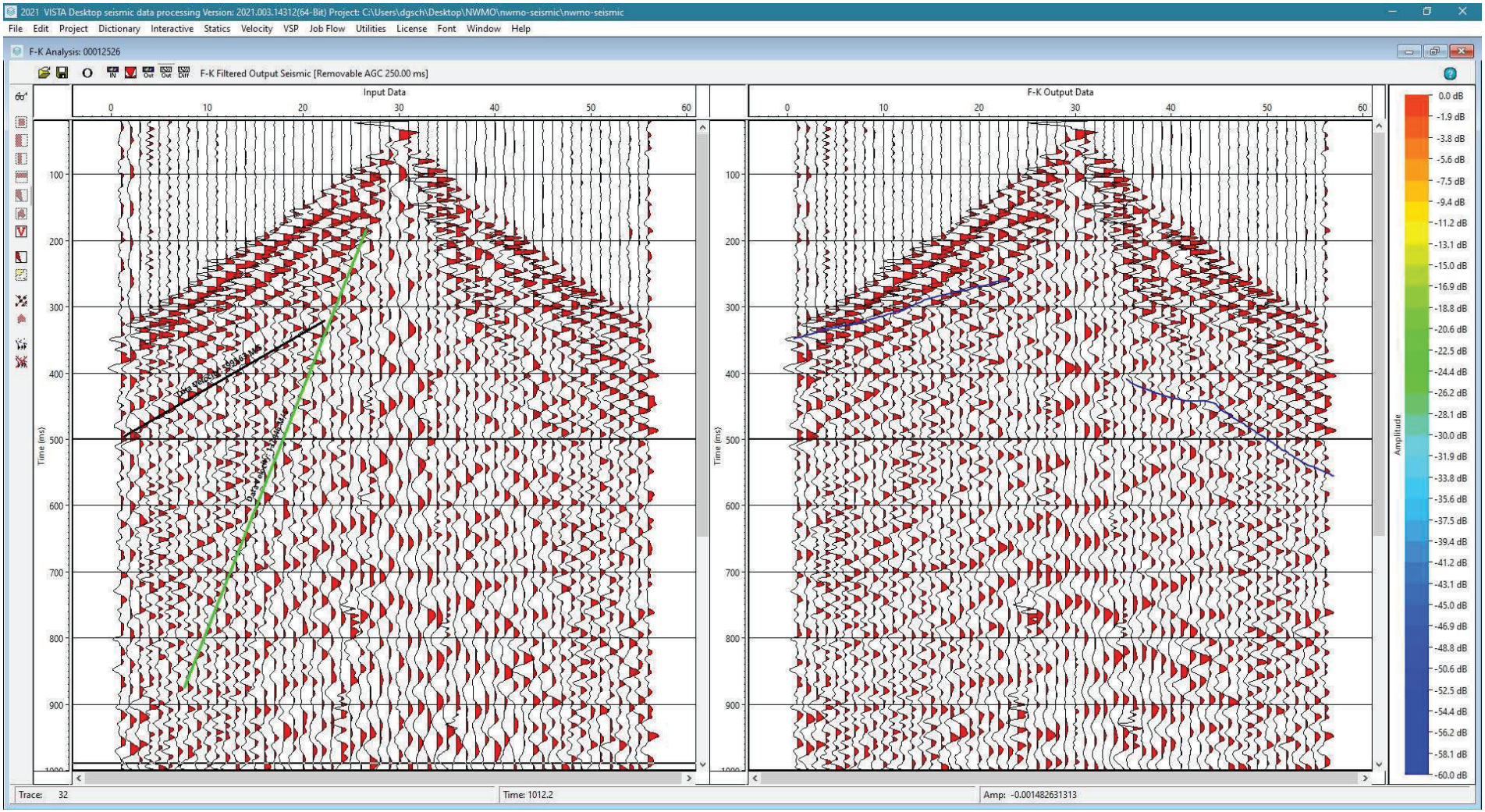
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 29-Nov-2021

21-210-1: Data Quality Confirmation Report

Date: 21-Nov-21	ATTACHED FIGURE File Name: 12526



DocuSign Envelope ID: 951CEF55-77A2-4232-9B83-26C04D8B2EEA

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
Station 337	2D Seismic - P & SH wave records	27-Nov-21	27-Nov-21	DGS	Y	Excellent	Y	Note bedrock reflector at ~130ms roughly 120m assuming average, velocity of 1,800 m/s. SH record on left less clear but approximately 250ms suggesting VP/VS ratio of only 2 so this is very likely a till layer above the bedrock assuming an average velocity of 230m/s typical of these types of sediments. Just look through the raw data were formulated results, this is because of the excellent data quality we are acquiring.

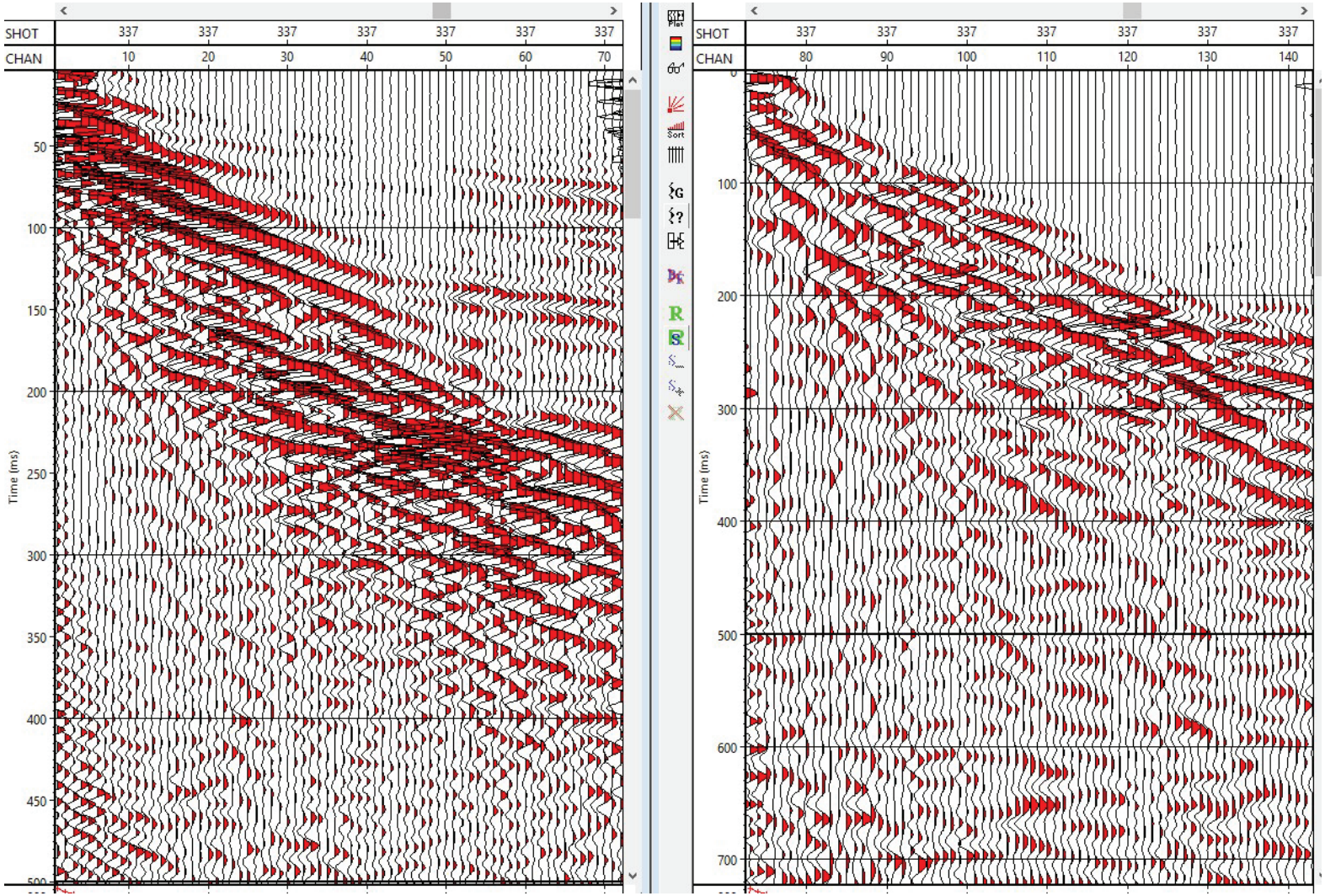
Other Comments:
2D seismic completed for paleochannel characterization

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 8-Nov-2021

21-210-1: Data Quality Confirmation Report

Date: 27-Nov-21	ATTACHED FIGURE File Name: Station 337, P wave on LEFT, SH record on RIGHT



DocuSign Envelope ID: 4695BA08-39E6-48E2-BEF5-1B7E9B95E656

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
Station 337	2D Seismic - P & SH wave records	27-Nov-21	27-Nov-21	DGS	Y	Y	N	Note bedrock reflector at ~130ms roughly 120m assuming average, velocity of 1,800 m/s. SH record on left less clear but approximately 250ms suggesting VP/VS ratio of only 2 so this is very likely a till layer above the bedrock assuming an average velocity of 230m/s typical of these types of sediments. Just look through the raw data were formulated results, this is because of the excellent data quality we are acquiring.
Shot 102 - 103	2D Seismic - P & SH wave records	28-Nov-21	28-Nov-21	DGS	Y	Y	Y	Showing consective VP's, Pwave on the left and SH wave on the right. Circled in blue are what reflections. The SH wave record depicts high quality clear event at about 240ms, assuming velocity of 230m/s this is a depth of 27m

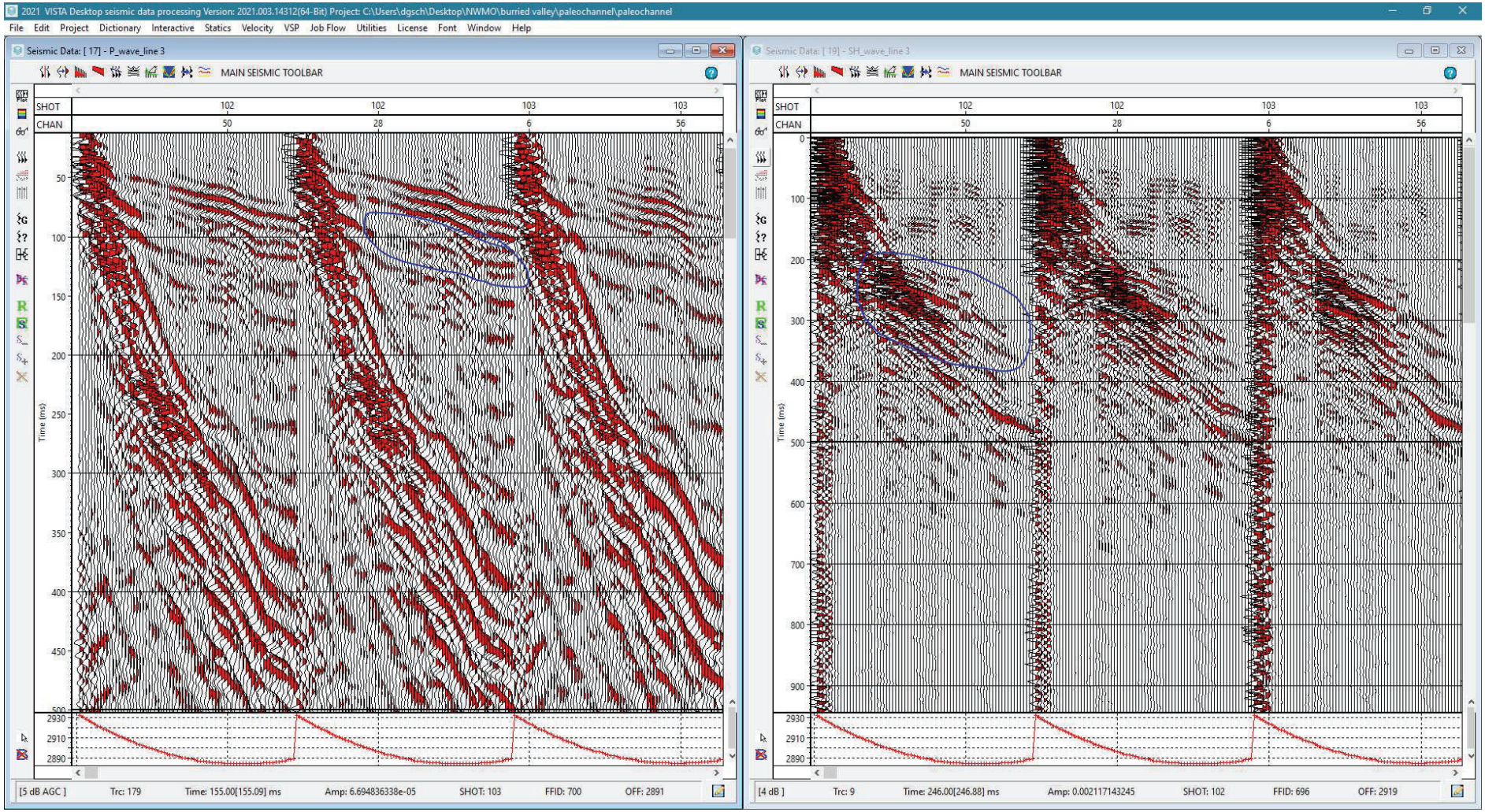
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 29-Nov-2021

21-210-1: Data Quality Confirmation Report

Date: 28-Nov-21	ATTACHED FIGURE File Name: Shot 102 - 103



DocuSign Envelope ID: A9AA553F-28E9-4092-9A25-86D700308903

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
Station 337	2D Seismic - P & SH wave records	27-Nov-21	27-Nov-21	DGS	Y	Y	N	Note bedrock reflector at ~130ms roughly 120m assuming average, velocity of 1,800 m/s. SH record on left less clear but approximately 250ms suggesting VP/VS ratio of only 2 so this is very likely a till layer above the bedrock assuming an average velocity of 230m/s typical of these types of sediments. Just look through the raw data were formulated results, this is because of the excellent data quality we are acquiring.
Shot 102 - 103	2D Seismic - P & SH wave records	28-Nov-21	28-Nov-21	DGS	Y	Y	N	Showing consective VP's, Pwave on the left and SH wave on the right. Circled in blue are what reflections. The SH wave record depicts high quality clear event at about 240ms, assuming velocity of 230m/s this is a depth of 27m
Line 3 Shot 628 - 629	2D Seismic - P & SH wave records	29-Nov-21	30-Nov-21	DGS	Y	Y	Y	Pwave on left, SH wave on right (different vertical scale to account for slower velocities) I've identified a reflector with structure on both records (circled), thought to be till layer within bedrock valley? Note these shot records are from the west end of line 3. I also believe we have a deep bedrock reflection 80ms on Pwave ~50-60m guessing a velocity of 1500 m/s and 320ms on the SH wave similar depths with average velocity of 380 m/s. Note these are just rough guesses until we can process and stack the lines but the data are excellent quality and there is consistancy

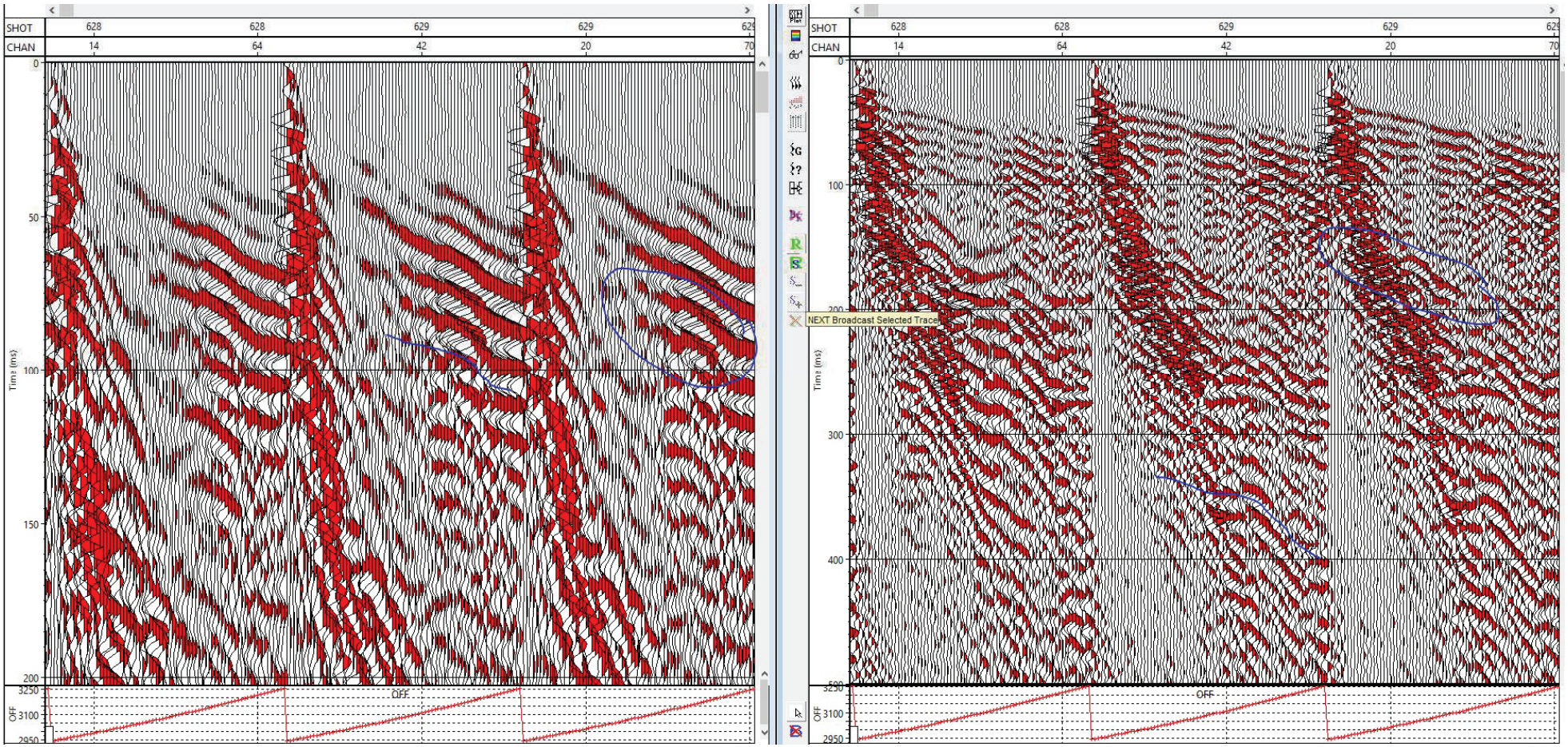
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 30-Nov-2021

21-210-1: Data Quality Confirmation Report

Date: 29-Nov-21	ATTACHED FIGURE File Name: Line 3 Shot 628-629



DocuSign Envelope ID: 28E6AE2A-2453-4F65-9F12-303283B94CE1

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
Station 337	2D Seismic - P & SH wave records	27-Nov-21	27-Nov-21	DGS	Y	Y	N	Note bedrock reflector at ~130ms roughly 120m assuming average, velocity of 1,800 m/s. SH record on left less clear but approximately 250ms suggesting VP/VS ratio of only 2 so this is very likely a till layer above the bedrock assuming an average velocity of 230m/s typical of these types of sediments. Just look through the raw data were formulated results, this is because of the excellent data quality we are acquiring.
Shot 102 - 103	2D Seismic - P & SH wave records	28-Nov-21	28-Nov-21	DGS	Y	Y	N	Showing consective VP's, Pwave on the left and SH wave on the right. Circled in blue are what reflections. The SH wave record depicts high quality clear event at about 240ms, assuming velocity of 230m/s this is a depth of 27m
Line 3 Shot 628 - 629	2D Seismic - P & SH wave records	29-Nov-21	30-Nov-21	DGS	Y	Y	N	Pwave on left, SH wave on right (different vertical scale to account for slower velocities) I've identified a reflector with structure on both records (circled), thought to be till layer within bedrock valley? Note these shot records are from the west end of line 3. I also believe we have a deep bedrock reflection 80ms on Pwave ~50-60m guessing a velocity of 1500 m/s and 320ms on the SH wave similar depths with average velocity of 380 m/s. Note these are just rough guesses until we can process and stack the lines but the data are excellent quality and there is consistancy
Line 2	2D Seismic - rough stack	30-Nov-21	01-Dec-21	DGS	Y	Y	Y	Brute stack of East end of Concession 8 (line 2) showing shallow bedrock dipping to ~30-40m near the bridge. Gaps in shallow data due to missed VP's on bridge and over culvert.

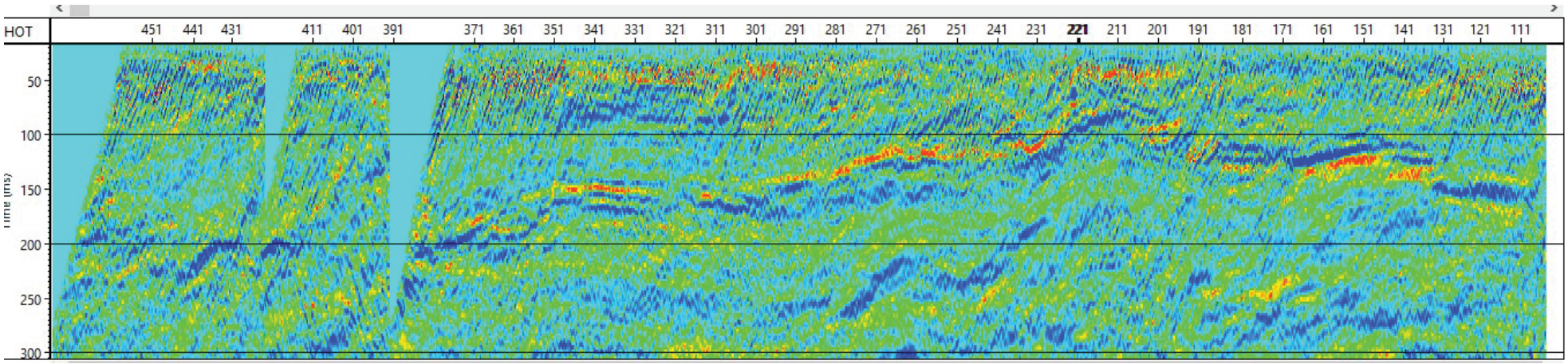
Other Comments:

Reviewed by: DocuSigned by: Sean Sterling D69688FA497E43D...

Date: 07-Dec-2021

21-210-1: Data Quality Confirmation Report

Date: 30-Nov-21	ATTACHED FIGURE File Name: Rough stack of Line 2 data



DocuSign Envelope ID: 28E6AE2A-2453-4F65-9F12-303283B94CE1

21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
Station 337	2D Seismic - P & SH wave records	27-Nov-21	27-Nov-21	DGS	Y	Y	N	Note bedrock reflector at ~130ms roughly 120m assuming average, velocity of 1,800 m/s. SH record on left less clear but approximately 250ms suggesting VP/VS ratio of only 2 so this is very likely a till layer above the bedrock assuming an average velocity of 230m/s typical of these types of sediments. Just look through the raw data were formulated results, this is because of the excellent data quality we are acquiring.
Shot 102 - 103	2D Seismic - P & SH wave records	28-Nov-21	28-Nov-21	DGS	Y	Y	N	Showing consective VP's, Pwave on the left and SH wave on the right. Circled in blue are what reflections. The SH wave record depicts high quality clear event at about 240ms, assuming velocity of 230m/s this is a depth of 27m
Line 3 Shot 628 - 629	2D Seismic - P & SH wave records	29-Nov-21	30-Nov-21	DGS	Y	Y	N	Pwave on left, SH wave on right (different vertical scale to account for slower velocities) I've identified a reflector with structure on both records (circled), thought to be till layer within bedrock valley? Note these shot records are from the west end of line 3. I also believe we have a deep bedrock reflection 80ms on Pwave ~50-60m guessing a velocity of 1500 m/s and 320ms on the SH wave similar depths with average velocity of 380 m/s. Note these are just rough guesses until we can process and stack the lines but the data are excellent quality and there is consistancy
Line 2	2D Seismic - rough stack	30-Nov-21	01-Dec-21	DGS	Y	Y	N	Brute stack of East end of Concession 8 (line 2) showing shallow bedrock dipping to ~30-40m near the bridge. Gaps in shallow data due to missed VP's on bridge and over culvert.
Line 1 (raw)	Pwave left 72 channels, middle SV (inline shear component) and right SH component.	01-Dec-21	02-Dec-21	DGS	Y	Y	Y	Line 1 data (raw) Blue indicates "potentially" eastern edge of channel. Bedrock at start of line ~20m then dipping to deeper depths as the line progress. This is Station 201, the edge is back 50 stations (ie station 150) the line started at side road 25, station 101 so it appears there is the beginning of a channel ~150-200m west of this intersection. Caution this is VERY rough interpretations based on the raw shot records and cannot be confirmed until these data are processed.
Line 1 - Shotpoint 404	2D Seismic - P & SH wave records	01-Dec-21	02-Dec-21	DGS	Y	Y	Y	This is shotpoint 404 (900m west of beginning of line, side rd 25), near the middle of the line showing channel reflections that are (undulating?) starting to come back up 80 ms on the pwave (~60m) and on the SH wave 400ms (~60m at 300m/s average velocity).

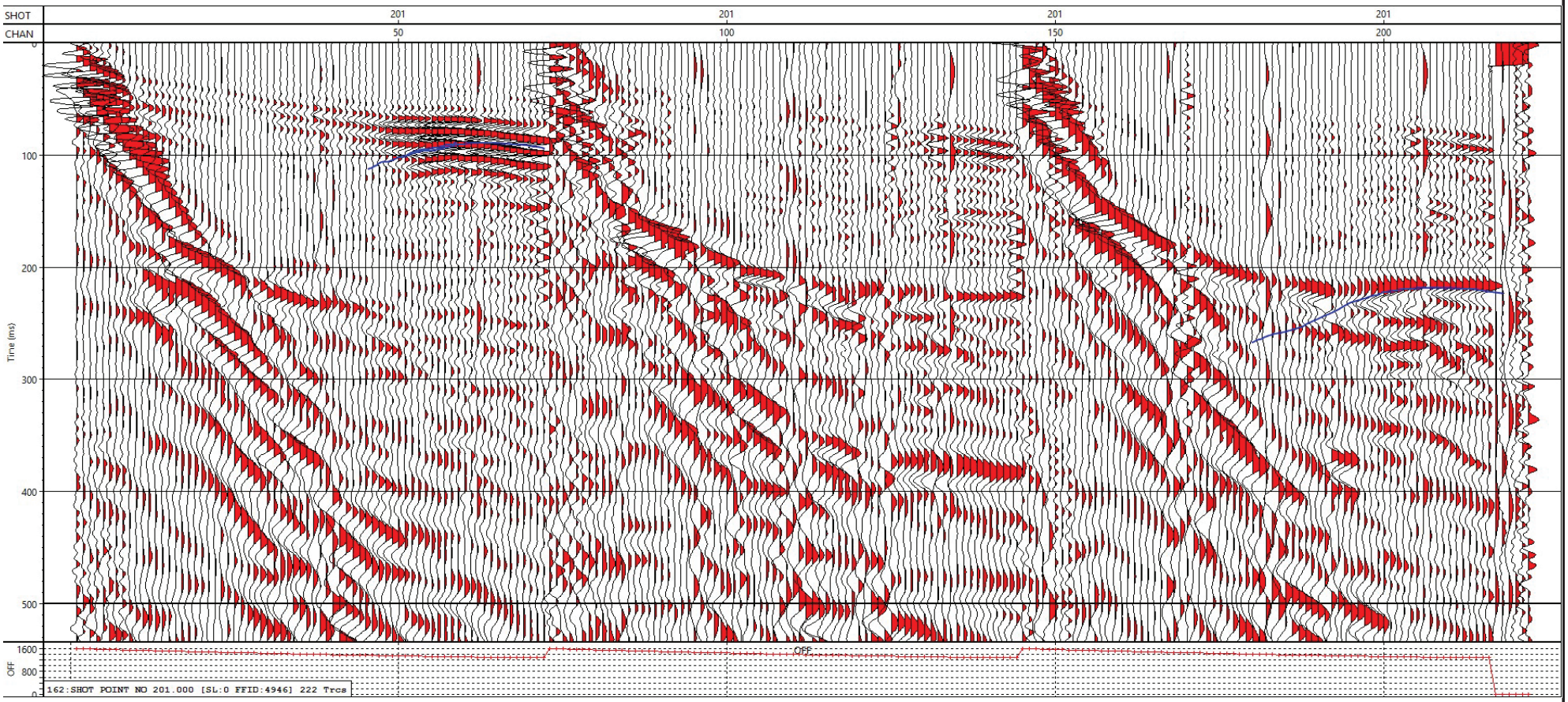
Other Comments:

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Date: 07-Dec-2021

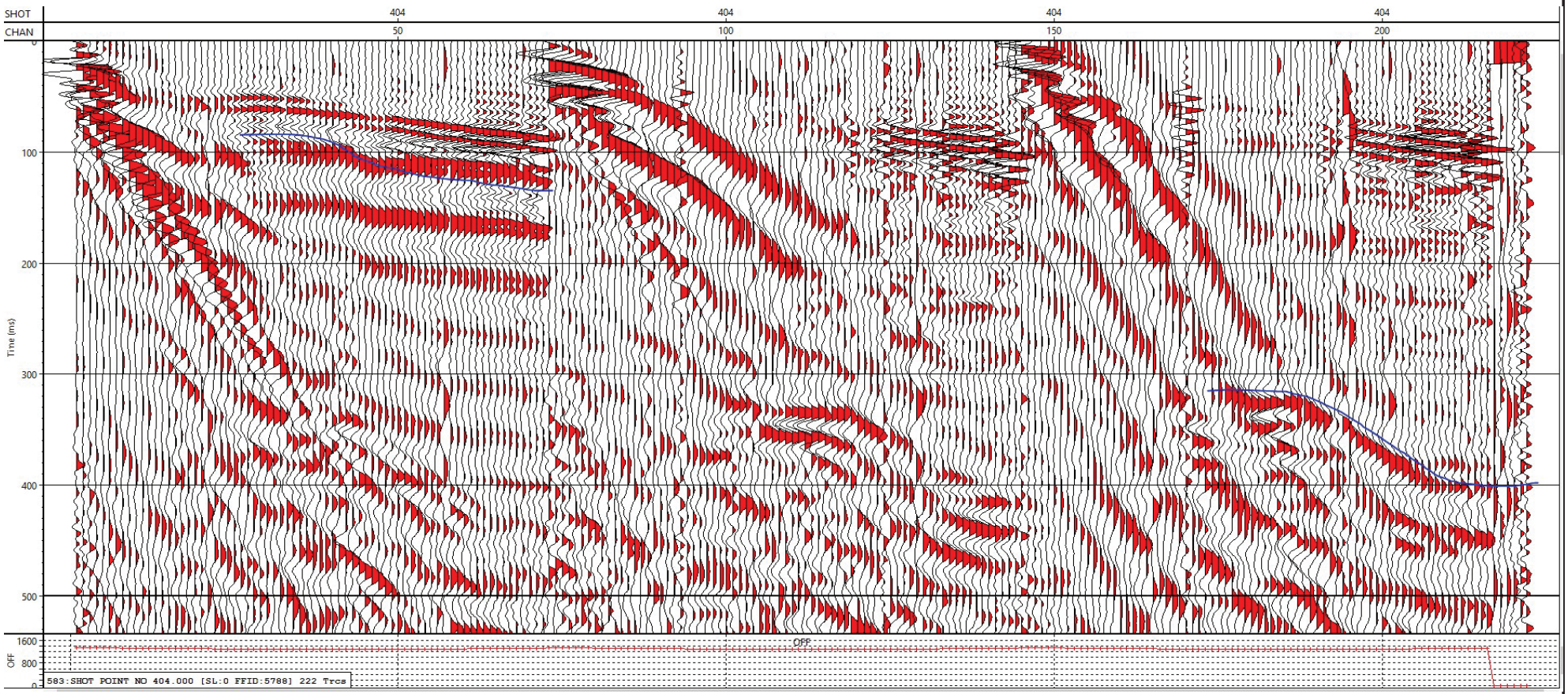
21-210-1: Data Quality Confirmation Report

Date: 01-Dec-21	ATTACHED FIGURE File Name: Line 1 data (raw)



21-210-1: Data Quality Confirmation Report

Date: 01-Dec-21	ATTACHED FIGURE File Name: Line 1 - shotpoint 404



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21-210-1: Data Quality Confirmation Report

Dataset Information			Dataset Review					
Raw File Name(s)	Dataset Description	Collection Date	Reviewed Date	Reviewed By (Initials)	File Type and Format Consistent with Test Plan? (Y/N)	Data Quality? (acceptable, poor, not acceptable)	Figure Attached? (Y/N)	Comments
Station 337	2D Seismic - P & SH wave records	27-Nov-21	27-Nov-21	DGS	Y	Y	N	Note bedrock reflector at ~130ms roughly 120m assuming average, velocity of 1,800 m/s. SH record on left less clear but approximately 250ms suggesting VP/VS ratio of only 2 so this is very likely a till layer above the bedrock assuming an average velocity of 230m/s typical of these types of sediments. Just look through the raw data were formulated results, this is because of the excellent data quality we are acquiring.
Shot 102 - 103	2D Seismic - P & SH wave records	28-Nov-21	28-Nov-21	DGS	Y	Y	N	Showing consective VP's, Pwave on the left and SH wave on the right. Circled in blue are what reflections. The SH wave record depicts high quality clear event at about 240ms, assuming velocity of 230m/s this is a depth of 27m
Line 3 Shot 628 - 629	2D Seismic - P & SH wave records	29-Nov-21	30-Nov-21	DGS	Y	Y	N	Pwave on left, SH wave on right (different vertical scale to account for slower velocities) I've identified a reflector with structure on both records (circled), thought to be till layer within bedrock valley? Note these shot records are from the west end of line 3. I also believe we have a deep bedrock reflection 80ms on Pwave ~50-60m guessing a velocity of 1500 m/s and 320ms on the SH wave similar depths with average velocity of 380 m/s. Note these are just rough guesses until we can process and stack the lines but the data are excellent quality and there is consistancy
Line 2	2D Seismic - rough stack	30-Nov-21	01-Dec-21	DGS	Y	Y	N	Brute stack of East end of Concession 8 (line 2) showing shallow bedrock dipping to ~30-40m near the bridge. Gaps in shallow data due to missed VP's on bridge and over culvert.
Line 1 (raw)	Pwave left 72 channels, middle SV (inline shear component) and right SH component.	01-Dec-21	02-Dec-21	DGS	Y	Y	N	Line 1 data (raw) Blue indicates "potentially" eastern edge of channel. Bedrock at start of line ~20m then dipping to deeper depths as the line progress. This is Station 201, the edge is back 50 stations (ie station 150) the line started at side road 25, station 101 so it appears there is the beginning of a channel ~150-200m west of this intersection. Caution this is VERY rough interpretations based on the raw shot records and cannot be confirmed until these data are processed.
Line 1 - Shotpoint 404	2D Seismic - P & SH wave records	01-Dec-21	02-Dec-21	DGS	Y	Y	N	This is shotpoint 404 (900m west of beginning of line, side rd 25), near the middle of the line showing channel reflections that are (undulating?) starting to come back up 80 ms on the pwave (~60m) and on the SH wave 400ms (~60m at 300m/s average velocity).
Line 1 - Shotpoint 460	2D Seismic - P & SH wave records	02-Dec-21	03-Dec-21	DGS	Y	Y	Y	Shotpoint 460 depicting interesting anomaly, sharp shallowing of bedrock, Pwave on left, SH on the right

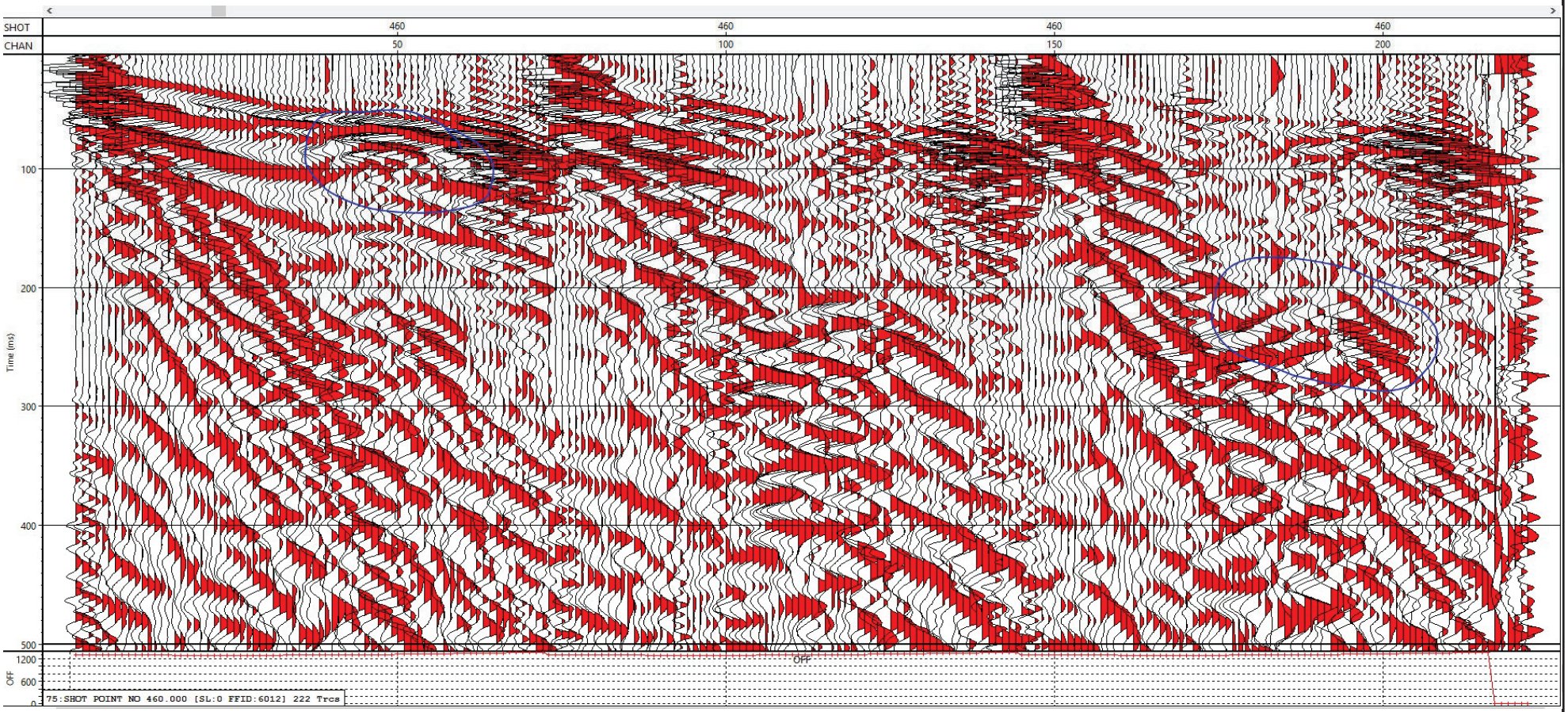
Other Comments:

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21-210-1: Data Quality Confirmation Report

Date: 02-Dec-21	ATTACHED FIGURE File Name: Shotpoint 460 (P wave left, SH on right)



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Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic Production Log

Project Number: 21-210-1

Line Picked Up

Date	Line #	From	To	Total Picked

Line Laid Out

Date	Line #	From	To	Total Laid Out
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49
09-Nov-21	R252	195	387	49
09-Nov-21	R254	195	387	49
09-Nov-21	R256	195	387	49

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10/2021

Production Log

Line Picked Up					Line Laid Out				
Date	Line #	From	To	Total Picked	Date	Line #	From	To	Total Laid Out
					08-Nov-21	R202	187	267	21
					08-Nov-21	R204	187	267	21
					08-Nov-21	R206	187	267	21
					08-Nov-21	R208	187	267	21
					08-Nov-21	R210	187	387	51
					08-Nov-21	R212	187	387	51
					08-Nov-21	R214	187	387	51
					08-Nov-21	R216	187	387	51
					08-Nov-21	R218	187	387	51
					08-Nov-21	R220	187	387	51
					08-Nov-21	R222	187	347	41
					08-Nov-21	R224	187	347	41
					08-Nov-21	R226	227	347	31
					08-Nov-21	R228	227	347	31
					08-Nov-21	R230	271	347	20
					08-Nov-21	R232	271	347	20
					08-Nov-21	R242	179	387	53
					09-Nov-21	R218/R258	147	379	59
					09-Nov-21	R220/R260	151	379	58
					09-Nov-21	R222/R262	159	379	56
					09-Nov-21	R224	159	183	7
					09-Nov-21	R226	167	223	15
					09-Nov-21	R228	163	223	16
					09-Nov-21	R230	163	267	27
					09-Nov-21	R232	163	267	27
					09-Nov-21	R234	163	387	57
					09-Nov-21	R236	163	387	57
					09-Nov-21	R238	163	387	57
					09-Nov-21	R240	163	387	57
					09-Nov-21	R242	103	175	19
					09-Nov-21	R244	103	387	72
					09-Nov-21	R246	103	387	72
					09-Nov-21	R248	195	387	49
					09-Nov-21	R250	195	387	49

Line Picked Up					Line Laid Out				
Date	Line #	From	To	Total Picked	Date	Line #	From	To	Total Laid Out
					09-Nov-21	R250	195	387	49
					09-Nov-21	R252	195	387	49
					09-Nov-21	R254	195	387	49
					09-Nov-21	R256	195	387	49
					10-Nov-21	R248	103	191	23
					10-Nov-21	R250	103	191	23
					10-Nov-21	R252	147	191	12
					10-Nov-21	R254	147	191	12
					10-Nov-21	R256	147	191	12
					10-Nov-21	R258	103	191	23
					10-Nov-21	R260	103	191	23
					10-Nov-21	R262	103	191	23
					10-Nov-21	R264	103	387	72
					10-Nov-21	R266	103	387	72
					10-Nov-21	R268	103	387	72
					10-Nov-21	R270	103	387	72
					10-Nov-21	R272	103	387	72
					10-Nov-21	R274	103	387	72
					10-Nov-21	R276	103	347	62
					10-Nov-21	R278	103	347	62
					10-Nov-21	R280	103	347	62
					10-Nov-21	R282	103	239	35

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Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic Production Log

Project Number: 21-210-1

Line Picked Up

Date	Line #	From	To	Total Picked

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

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Production Log

Line Picked Up					Line Laid Out				
Date	Line #	From	To	Total Picked	Date	Line #	From	To	Total Laid Out
					09-Nov-21	R250	195	387	49
					09-Nov-21	R252	195	387	49
					09-Nov-21	R254	195	387	49
					09-Nov-21	R256	195	387	49
					10-Nov-21	R248	103	191	23
					10-Nov-21	R250	103	191	23
					10-Nov-21	R252	147	191	12
					10-Nov-21	R254	147	191	12
					10-Nov-21	R256	147	191	12
					10-Nov-21	R258	103	191	23
					10-Nov-21	R260	103	191	23
					10-Nov-21	R262	103	191	23
					10-Nov-21	R264	103	387	72
					10-Nov-21	R266	103	387	72
					10-Nov-21	R268	103	387	72
					10-Nov-21	R270	103	387	72
					10-Nov-21	R272	103	387	72
					10-Nov-21	R274	103	387	72
					10-Nov-21	R276	103	347	62
					10-Nov-21	R278	103	347	62
					10-Nov-21	R280	103	347	62
					10-Nov-21	R282	103	239	35
					11-Nov-21	R282	227	347	31
					11-Nov-21	R284	227	347	31
					11-Nov-21	R286	227	347	31
					11-Nov-21	R288	227	347	31
					11-Nov-21	R290	227	351	32
					11-Nov-21	R292	227	267	11
					11-Nov-21	R294	227	267	11
					11-Nov-21	R296	227	267	11
					11-Nov-21	R298	227	267	11
					11-Nov-21	R300	183	267	22
					11-Nov-21	R302	183	267	22
					11-Nov-21	R304	183	267	22
					11-Nov-21	R306	183	267	22

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Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic Production Log

Project Number: 21-210-1

Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

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Line Picked Up					Line Laid Out				
Date	Line #	From	To	Total Picked	Date	Line #	From	To	Total Laid Out
					09-Nov-21	R250	195	387	49
					09-Nov-21	R252	195	387	49
					09-Nov-21	R254	195	387	49
					09-Nov-21	R256	195	387	49
					10-Nov-21	R248	103	191	23
					10-Nov-21	R250	103	191	23
					10-Nov-21	R252	147	191	12
					10-Nov-21	R254	147	191	12
					10-Nov-21	R256	147	191	12
					10-Nov-21	R258	103	191	23
					10-Nov-21	R260	103	191	23
					10-Nov-21	R262	103	191	23
					10-Nov-21	R264	103	387	72
					10-Nov-21	R266	103	387	72
					10-Nov-21	R268	103	387	72
					10-Nov-21	R270	103	387	72
					10-Nov-21	R272	103	387	72
					10-Nov-21	R274	103	387	72
					10-Nov-21	R276	103	347	62
					10-Nov-21	R278	103	347	62
					10-Nov-21	R280	103	347	62
					10-Nov-21	R282	103	239	35
					11-Nov-21	R282	227	347	31
					11-Nov-21	R284	227	347	31
					11-Nov-21	R286	227	347	31
					11-Nov-21	R288	227	347	31
					11-Nov-21	R290	227	351	32
					11-Nov-21	R292	227	267	11
					11-Nov-21	R294	227	267	11
					11-Nov-21	R296	227	267	11
					11-Nov-21	R298	227	267	11
					11-Nov-21	R300	183	267	22
					11-Nov-21	R302	183	267	22
					11-Nov-21	R304	183	267	22
					11-Nov-21	R306	183	267	22

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Geofirma DATA QUALITY CONFIRMATION (DQC) Form: SB_Seismic Production Log

Project Number: 21-210-1

Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51
16-Nov-21	R214	187	387	51
16-Nov-21	R216	187	387	51
16-Nov-21	R218	147	387	61
16-Nov-21	R220	151	387	60
16-Nov-21	R222	159	347	48
16-Nov-21	R224	159	347	48
16-Nov-21	R226	167	347	46
16-Nov-21	R228	163	347	47

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

Line Picked Up					Line Laid Out				
Date	Line #	From	To	Total Picked	Date	Line #	From	To	Total Laid Out
					09-Nov-21	R250	195	387	49
					09-Nov-21	R252	195	387	49
					09-Nov-21	R254	195	387	49
					09-Nov-21	R256	195	387	49
					10-Nov-21	R248	103	191	23
					10-Nov-21	R250	103	191	23
					10-Nov-21	R252	147	191	12
					10-Nov-21	R254	147	191	12
					10-Nov-21	R256	147	191	12
					10-Nov-21	R258	103	191	23
					10-Nov-21	R260	103	191	23
					10-Nov-21	R262	103	191	23
					10-Nov-21	R264	103	387	72
					10-Nov-21	R266	103	387	72
					10-Nov-21	R268	103	387	72
					10-Nov-21	R270	103	387	72
					10-Nov-21	R272	103	387	72
					10-Nov-21	R274	103	387	72
					10-Nov-21	R276	103	347	62
					10-Nov-21	R278	103	347	62
					10-Nov-21	R280	103	347	62
					10-Nov-21	R282	103	239	35
					11-Nov-21	R282	227	347	31
					11-Nov-21	R284	227	347	31
					11-Nov-21	R286	227	347	31
					11-Nov-21	R288	227	347	31
					11-Nov-21	R290	227	351	32
					11-Nov-21	R292	227	267	11
					11-Nov-21	R294	227	267	11
					11-Nov-21	R296	227	267	11
					11-Nov-21	R298	227	267	11
					11-Nov-21	R300	183	267	22
					11-Nov-21	R302	183	267	22
					11-Nov-21	R304	183	267	22
					11-Nov-21	R306	183	267	22

DocuSign Envelope ID: 2059C325-250F-4BB3-92A9-0FD412AB32AD

Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51
16-Nov-21	R214	187	387	51
16-Nov-21	R216	187	387	51
16-Nov-21	R218	147	387	61
16-Nov-21	R220	151	387	60
16-Nov-21	R222	159	347	48
16-Nov-21	R224	159	347	48
16-Nov-21	R226	167	347	46
16-Nov-21	R228	163	347	47
17-Nov-21	R230	163	223	16
17-Nov-21	R230	267	347	21
17-Nov-21	R232	163	223	16
17-Nov-21	R232	267	347	21
17-Nov-21	R234	163	387	57

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

DocuSign Envelope ID: 2059C325-250F-4BB3-92A9-0FD412AB32AD

Production Log

Line Picked Up

Date	Line #	From	To	Total Picked

Line Laid Out

Date	Line #	From	To	Total Laid Out
09-Nov-21	R250	195	387	49
09-Nov-21	R252	195	387	49
09-Nov-21	R254	195	387	49
09-Nov-21	R256	195	387	49
10-Nov-21	R248	103	191	23
10-Nov-21	R250	103	191	23
10-Nov-21	R252	147	191	12
10-Nov-21	R254	147	191	12
10-Nov-21	R256	147	191	12
10-Nov-21	R258	103	191	23
10-Nov-21	R260	103	191	23
10-Nov-21	R262	103	191	23
10-Nov-21	R264	103	387	72
10-Nov-21	R266	103	387	72
10-Nov-21	R268	103	387	72
10-Nov-21	R270	103	387	72
10-Nov-21	R272	103	387	72
10-Nov-21	R274	103	387	72
10-Nov-21	R276	103	347	62
10-Nov-21	R278	103	347	62
10-Nov-21	R280	103	347	62
10-Nov-21	R282	103	239	35
11-Nov-21	R282	227	347	31
11-Nov-21	R284	227	347	31
11-Nov-21	R286	227	347	31
11-Nov-21	R288	227	347	31
11-Nov-21	R290	227	351	32
11-Nov-21	R292	227	267	11
11-Nov-21	R294	227	267	11
11-Nov-21	R296	227	267	11
11-Nov-21	R298	227	267	11
11-Nov-21	R300	183	267	22
11-Nov-21	R302	183	267	22
11-Nov-21	R304	183	267	22
11-Nov-21	R306	183	267	22

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Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51
16-Nov-21	R214	187	387	51
16-Nov-21	R216	187	387	51
16-Nov-21	R218	147	387	61
16-Nov-21	R220	151	387	60
16-Nov-21	R222	159	347	48
16-Nov-21	R224	159	347	48
16-Nov-21	R226	167	347	46
16-Nov-21	R228	163	347	47
17-Nov-21	R230	163	223	16
17-Nov-21	R230	267	347	21
17-Nov-21	R232	163	223	16
17-Nov-21	R232	267	347	21
17-Nov-21	R234	163	387	57
18-Nov-21	R236	163	387	57
18-Nov-21	R238	163	387	57
18-Nov-21	R240	163	387	57
18-Nov-21	R242	103	387	72
18-Nov-21	R244	183	387	52
18-Nov-21	R246	183	387	52

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

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Line Picked Up

Date	Line #	From	To	Total Picked

Line Laid Out

Date	Line #	From	To	Total Laid Out
09-Nov-21	R250	195	387	49
09-Nov-21	R252	195	387	49
09-Nov-21	R254	195	387	49
09-Nov-21	R256	195	387	49
10-Nov-21	R248	103	191	23
10-Nov-21	R250	103	191	23
10-Nov-21	R252	147	191	12
10-Nov-21	R254	147	191	12
10-Nov-21	R256	147	191	12
10-Nov-21	R258	103	191	23
10-Nov-21	R260	103	191	23
10-Nov-21	R262	103	191	23
10-Nov-21	R264	103	387	72
10-Nov-21	R266	103	387	72
10-Nov-21	R268	103	387	72
10-Nov-21	R270	103	387	72
10-Nov-21	R272	103	387	72
10-Nov-21	R274	103	387	72
10-Nov-21	R276	103	347	62
10-Nov-21	R278	103	347	62
10-Nov-21	R280	103	347	62
10-Nov-21	R282	103	239	35
11-Nov-21	R282	227	347	31
11-Nov-21	R284	227	347	31
11-Nov-21	R286	227	347	31
11-Nov-21	R288	227	347	31
11-Nov-21	R290	227	351	32
11-Nov-21	R292	227	267	11
11-Nov-21	R294	227	267	11
11-Nov-21	R296	227	267	11
11-Nov-21	R298	227	267	11
11-Nov-21	R300	183	267	22
11-Nov-21	R302	183	267	22
11-Nov-21	R304	183	267	22
11-Nov-21	R306	183	267	22

DocuSign Envelope ID: DC98F762-CF21-4C74-9B0E-0EBEE871CD4A

Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51
16-Nov-21	R214	187	387	51
16-Nov-21	R216	187	387	51
16-Nov-21	R218	147	387	61
16-Nov-21	R220	151	387	60
16-Nov-21	R222	159	347	48
16-Nov-21	R224	159	347	48
16-Nov-21	R226	167	347	46
16-Nov-21	R228	163	347	47
17-Nov-21	R230	163	223	16
17-Nov-21	R230	267	347	21
17-Nov-21	R232	163	223	16
17-Nov-21	R232	267	347	21
17-Nov-21	R234	163	387	57
18-Nov-21	R236	163	387	57
18-Nov-21	R238	163	387	57
18-Nov-21	R240	163	387	57
18-Nov-21	R242	103	387	72
18-Nov-21	R244	183	387	52
18-Nov-21	R246	183	387	52
19-Nov-21	R244	103	179	20
19-Nov-21	R246	103	179	20
19-Nov-21	R248	103	387	72
19-Nov-21	R250	147	387	61
19-Nov-21	R252	147	387	61
19-Nov-21	R254	147	387	61
19-Nov-21	R256	147	387	61

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

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Production Log

Line Picked Up					Line Laid Out				
Date	Line #	From	To	Total Picked	Date	Line #	From	To	Total Laid Out
					09-Nov-21	R250	195	387	49
					09-Nov-21	R252	195	387	49
					09-Nov-21	R254	195	387	49
					09-Nov-21	R256	195	387	49
					10-Nov-21	R248	103	191	23
					10-Nov-21	R250	103	191	23
					10-Nov-21	R252	147	191	12
					10-Nov-21	R254	147	191	12
					10-Nov-21	R256	147	191	12
					10-Nov-21	R258	103	191	23
					10-Nov-21	R260	103	191	23
					10-Nov-21	R262	103	191	23
					10-Nov-21	R264	103	387	72
					10-Nov-21	R266	103	387	72
					10-Nov-21	R268	103	387	72
					10-Nov-21	R270	103	387	72
					10-Nov-21	R272	103	387	72
					10-Nov-21	R274	103	387	72
					10-Nov-21	R276	103	347	62
					10-Nov-21	R278	103	347	62
					10-Nov-21	R280	103	347	62
					10-Nov-21	R282	103	239	35
					11-Nov-21	R282	227	347	31
					11-Nov-21	R284	227	347	31
					11-Nov-21	R286	227	347	31
					11-Nov-21	R288	227	347	31
					11-Nov-21	R290	227	351	32
					11-Nov-21	R292	227	267	11
					11-Nov-21	R294	227	267	11
					11-Nov-21	R296	227	267	11
					11-Nov-21	R298	227	267	11
					11-Nov-21	R300	183	267	22
					11-Nov-21	R302	183	267	22
					11-Nov-21	R304	183	267	22
					11-Nov-21	R306	183	267	22

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Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51
16-Nov-21	R214	187	387	51
16-Nov-21	R216	187	387	51
16-Nov-21	R218	147	387	61
16-Nov-21	R220	151	387	60
16-Nov-21	R222	159	347	48
16-Nov-21	R224	159	347	48
16-Nov-21	R226	167	347	46
16-Nov-21	R228	163	347	47
17-Nov-21	R230	163	223	16
17-Nov-21	R230	267	347	21
17-Nov-21	R232	163	223	16
17-Nov-21	R232	267	347	21
17-Nov-21	R234	163	387	57
18-Nov-21	R236	163	387	57
18-Nov-21	R238	163	387	57
18-Nov-21	R240	163	387	57
18-Nov-21	R242	103	387	72
18-Nov-21	R244	183	387	52
18-Nov-21	R246	183	387	52
19-Nov-21	R244	103	179	20
19-Nov-21	R246	103	179	20
19-Nov-21	R248	103	387	72
19-Nov-21	R250	147	387	61
19-Nov-21	R252	147	387	61
19-Nov-21	R254	147	387	61
19-Nov-21	R256	147	387	61
20-Nov-21	R258	103	387	72
20-Nov-21	R260	103	387	72

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

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Line Picked Up

Date	Line #	From	To	Total Picked
20-Nov-21	R262	103	387	72
20-Nov-21	R264	103	327	57
20-Nov-21	R266	335	387	14
20-Nov-21	R268	103	387	72
20-Nov-21	R270	103	387	72
20-Nov-21	R272	103	387	72
20-Nov-21	R274	103	387	72
20-Nov-21	R276	103	347	62

Line Laid Out

Date	Line #	From	To	Total Laid Out
09-Nov-21	R250	195	387	49
09-Nov-21	R252	195	387	49
09-Nov-21	R254	195	387	49
09-Nov-21	R256	195	387	49
10-Nov-21	R248	103	191	23
10-Nov-21	R250	103	191	23
10-Nov-21	R252	147	191	12
10-Nov-21	R254	147	191	12
10-Nov-21	R256	147	191	12
10-Nov-21	R258	103	191	23
10-Nov-21	R260	103	191	23
10-Nov-21	R262	103	191	23
10-Nov-21	R264	103	387	72
10-Nov-21	R266	103	387	72
10-Nov-21	R268	103	387	72
10-Nov-21	R270	103	387	72
10-Nov-21	R272	103	387	72
10-Nov-21	R274	103	387	72
10-Nov-21	R276	103	347	62
10-Nov-21	R278	103	347	62
10-Nov-21	R280	103	347	62
10-Nov-21	R282	103	239	35
11-Nov-21	R282	227	347	31
11-Nov-21	R284	227	347	31
11-Nov-21	R286	227	347	31
11-Nov-21	R288	227	347	31
11-Nov-21	R290	227	351	32
11-Nov-21	R292	227	267	11
11-Nov-21	R294	227	267	11
11-Nov-21	R296	227	267	11
11-Nov-21	R298	227	267	11
11-Nov-21	R300	183	267	22
11-Nov-21	R302	183	267	22
11-Nov-21	R304	183	267	22
11-Nov-21	R306	183	267	22

DocuSign Envelope ID: 42A46202-AD7B-402E-BF47-555601D68DF0

Line Picked Up

Date	Line #	From	To	Total Picked
14-Nov-21	R202	187	267	21
14-Nov-21	R204	187	267	21
14-Nov-21	R206	187	267	21
14-Nov-21	R208	187	267	21
14-Nov-21	R210	187	387	51
14-Nov-21	R212	187	387	51
16-Nov-21	R214	187	387	51
16-Nov-21	R216	187	387	51
16-Nov-21	R218	147	387	61
16-Nov-21	R220	151	387	60
16-Nov-21	R222	159	347	48
16-Nov-21	R224	159	347	48
16-Nov-21	R226	167	347	46
16-Nov-21	R228	163	347	47
17-Nov-21	R230	163	223	16
17-Nov-21	R230	267	347	21
17-Nov-21	R232	163	223	16
17-Nov-21	R232	267	347	21
17-Nov-21	R234	163	387	57
18-Nov-21	R236	163	387	57
18-Nov-21	R238	163	387	57
18-Nov-21	R240	163	387	57
18-Nov-21	R242	103	387	72
18-Nov-21	R244	183	387	52
18-Nov-21	R246	183	387	52
19-Nov-21	R244	103	179	20
19-Nov-21	R246	103	179	20
19-Nov-21	R248	103	387	72
19-Nov-21	R250	147	387	61
19-Nov-21	R252	147	387	61
19-Nov-21	R254	147	387	61
19-Nov-21	R256	147	387	61
20-Nov-21	R258	103	387	72
20-Nov-21	R260	103	387	72

Line Laid Out

Date	Line #	From	To	Total Laid Out
08-Nov-21	R202	187	267	21
08-Nov-21	R204	187	267	21
08-Nov-21	R206	187	267	21
08-Nov-21	R208	187	267	21
08-Nov-21	R210	187	387	51
08-Nov-21	R212	187	387	51
08-Nov-21	R214	187	387	51
08-Nov-21	R216	187	387	51
08-Nov-21	R218	187	387	51
08-Nov-21	R220	187	387	51
08-Nov-21	R222	187	347	41
08-Nov-21	R224	187	347	41
08-Nov-21	R226	227	347	31
08-Nov-21	R228	227	347	31
08-Nov-21	R230	271	347	20
08-Nov-21	R232	271	347	20
08-Nov-21	R242	179	387	53
09-Nov-21	R218/R258	147	379	59
09-Nov-21	R220/R260	151	379	58
09-Nov-21	R222/R262	159	379	56
09-Nov-21	R224	159	183	7
09-Nov-21	R226	167	223	15
09-Nov-21	R228	163	223	16
09-Nov-21	R230	163	267	27
09-Nov-21	R232	163	267	27
09-Nov-21	R234	163	387	57
09-Nov-21	R236	163	387	57
09-Nov-21	R238	163	387	57
09-Nov-21	R240	163	387	57
09-Nov-21	R242	103	175	19
09-Nov-21	R244	103	387	72
09-Nov-21	R246	103	387	72
09-Nov-21	R248	195	387	49
09-Nov-21	R250	195	387	49

DocuSign Envelope ID: 42A46202-AD7B-402E-BF47-555601D68DF0

Line Picked Up				
Date	Line #	From	To	Total Picked
20-Nov-21	R262	103	387	72
20-Nov-21	R264	103	327	57
20-Nov-21	R266	335	387	14
20-Nov-21	R268	103	387	72
20-Nov-21	R270	103	387	72
20-Nov-21	R272	103	387	72
20-Nov-21	R274	103	387	72
20-Nov-21	R276	103	347	62
21-Nov-21	R278	103	347	62
21-Nov-21	R280	103	347	62
21-Nov-21	R282	103	239	35
21-Nov-21	R282	227	347	31
21-Nov-21	R284	227	347	31
21-Nov-21	R286	227	347	31
21-Nov-21	R288	227	347	31
21-Nov-21	R290	227	351	32
21-Nov-21	R292	227	267	11
21-Nov-21	R294	227	267	11
21-Nov-21	R296	227	267	11
21-Nov-21	R298	227	267	11
21-Nov-21	R300	183	267	22
21-Nov-21	R302	183	267	22
21-Nov-21	R304	183	267	22
21-Nov-21	R306	183	267	22

Line Laid Out				
Date	Line #	From	To	Total Laid Out
09-Nov-21	R250	195	387	49
09-Nov-21	R252	195	387	49
09-Nov-21	R254	195	387	49
09-Nov-21	R256	195	387	49
10-Nov-21	R248	103	191	23
10-Nov-21	R250	103	191	23
10-Nov-21	R252	147	191	12
10-Nov-21	R254	147	191	12
10-Nov-21	R256	147	191	12
10-Nov-21	R258	103	191	23
10-Nov-21	R260	103	191	23
10-Nov-21	R262	103	191	23
10-Nov-21	R264	103	387	72
10-Nov-21	R266	103	387	72
10-Nov-21	R268	103	387	72
10-Nov-21	R270	103	387	72
10-Nov-21	R272	103	387	72
10-Nov-21	R274	103	387	72
10-Nov-21	R276	103	347	62
10-Nov-21	R278	103	347	62
10-Nov-21	R280	103	347	62
10-Nov-21	R282	103	239	35
11-Nov-21	R282	227	347	31
11-Nov-21	R284	227	347	31
11-Nov-21	R286	227	347	31
11-Nov-21	R288	227	347	31
11-Nov-21	R290	227	351	32
11-Nov-21	R292	227	267	11
11-Nov-21	R294	227	267	11
11-Nov-21	R296	227	267	11
11-Nov-21	R298	227	267	11
11-Nov-21	R300	183	267	22
11-Nov-21	R302	183	267	22
11-Nov-21	R304	183	267	22
11-Nov-21	R306	183	267	22

Appendix C

Santos Inc. Geodetic Accuracy Audit Report

SANTOS
GEOMATICS & GIS SPECIALISTS

Line Name	Area Name	Line Length	SP Range	DATUM	UTM Zone	Method
R-202	SOUTH BRUCE 3D 2021	1.00	202187-202267	NAD 1983	17N	Audit
R-204	SOUTH BRUCE 3D 2021	1.00	204187-204267	NAD 1983	17N	Audit
R-206	SOUTH BRUCE 3D 2021	1.00	206187-206267	NAD 1983	17N	Audit
R-208	SOUTH BRUCE 3D 2021	1.00	208187-208267	NAD 1983	17N	Audit
R-210	SOUTH BRUCE 3D 2021	2.50	210187-210387	NAD 1983	17N	Audit
R-212	SOUTH BRUCE 3D 2021	2.50	212187-212387	NAD 1983	17N	Audit
R-214	SOUTH BRUCE 3D 2021	2.50	214187-214387	NAD 1983	17N	Audit
R-216	SOUTH BRUCE 3D 2021	2.50	216187-216387	NAD 1983	17N	Audit
R-218	SOUTH BRUCE 3D 2021	3.00	218147-218387	NAD 1983	17N	Audit
R-220	SOUTH BRUCE 3D 2021	2.95	220151-220387	NAD 1983	17N	Audit
R-222	SOUTH BRUCE 3D 2021	2.35	222159-222347	NAD 1983	17N	Audit
R-224	SOUTH BRUCE 3D 2021	2.35	224159-224347	NAD 1983	17N	Audit
R-226	SOUTH BRUCE 3D 2021	2.25	226167-226347	NAD 1983	17N	Audit
R-228	SOUTH BRUCE 3D 2021	2.30	228163-228347	NAD 1983	17N	Audit
R-230	SOUTH BRUCE 3D 2021	1.80	230163-230347	NAD 1983	17N	Audit
R-232	SOUTH BRUCE 3D 2021	1.80	232163-232347	NAD 1983	17N	Audit
R-234	SOUTH BRUCE 3D 2021	2.80	234163-234387	NAD 1983	17N	Audit
R-236	SOUTH BRUCE 3D 2021	2.80	236163-236387	NAD 1983	17N	Audit
R-238	SOUTH BRUCE 3D 2021	2.80	238163-238387	NAD 1983	17N	Audit
R-240	SOUTH BRUCE 3D 2021	2.80	240163-240387	NAD 1983	17N	Audit
R-242	SOUTH BRUCE 3D 2021	3.55	242103-242387	NAD 1983	17N	Audit
R-244	SOUTH BRUCE 3D 2021	3.55	244103-244387	NAD 1983	17N	Audit
R-246	SOUTH BRUCE 3D 2021	3.55	246103-246387	NAD 1983	17N	Audit
R-248	SOUTH BRUCE 3D 2021	3.55	248103-248387	NAD 1983	17N	Audit
R-250	SOUTH BRUCE 3D 2021	3.00	250147-250387	NAD 1983	17N	Audit
R-252	SOUTH BRUCE 3D 2021	3.00	252147-252387	NAD 1983	17N	Audit
R-254	SOUTH BRUCE 3D 2021	3.00	254147-254387	NAD 1983	17N	Audit
R-256	SOUTH BRUCE 3D 2021	3.00	256147-256387	NAD 1983	17N	Audit
R-258	SOUTH BRUCE 3D 2021	3.55	258103-258387	NAD 1983	17N	Audit
R-260	SOUTH BRUCE 3D 2021	3.55	260103-260387	NAD 1983	17N	Audit
R-262	SOUTH BRUCE 3D 2021	3.55	262103-262387	NAD 1983	17N	Audit
R-264	SOUTH BRUCE 3D 2021	3.55	264103-264387	NAD 1983	17N	Audit
R-266	SOUTH BRUCE 3D 2021	3.55	266103-266387	NAD 1983	17N	Audit
R-268	SOUTH BRUCE 3D 2021	3.55	268103-268387	NAD 1983	17N	Audit
R-270	SOUTH BRUCE 3D 2021	3.55	270103-270387	NAD 1983	17N	Audit
R-272	SOUTH BRUCE 3D 2021	3.55	272103-272387	NAD 1983	17N	Audit
R-274	SOUTH BRUCE 3D 2021	3.55	274103-274387	NAD 1983	17N	Audit
R-276	SOUTH BRUCE 3D 2021	3.05	276103-276347	NAD 1983	17N	Audit
R-278	SOUTH BRUCE 3D 2021	3.05	278103-278347	NAD 1983	17N	Audit
R-280	SOUTH BRUCE 3D 2021	3.05	280103-280347	NAD 1983	17N	Audit
R-282	SOUTH BRUCE 3D 2021	3.05	282103-282347	NAD 1983	17N	Audit
R-284	SOUTH BRUCE 3D 2021	1.50	284227-284347	NAD 1983	17N	Audit
R-286	SOUTH BRUCE 3D 2021	1.50	286227-286347	NAD 1983	17N	Audit
R-288	SOUTH BRUCE 3D 2021	1.50	288227-288347	NAD 1983	17N	Audit
R-290	SOUTH BRUCE 3D 2021	1.50	290227-290347	NAD 1983	17N	Audit
R-292	SOUTH BRUCE 3D 2021	0.45	292227-292263	NAD 1983	17N	Audit
R-294	SOUTH BRUCE 3D 2021	0.45	294227-294263	NAD 1983	17N	Audit
R-296	SOUTH BRUCE 3D 2021	0.45	296227-296263	NAD 1983	17N	Audit
R-298	SOUTH BRUCE 3D 2021	0.45	298227-298263	NAD 1983	17N	Audit
R-300	SOUTH BRUCE 3D 2021	1.00	300183-300263	NAD 1983	17N	Audit
R-302	SOUTH BRUCE 3D 2021	1.00	302183-302263	NAD 1983	17N	Audit
R-304	SOUTH BRUCE 3D 2021	1.00	304183-304263	NAD 1983	17N	Audit
R-306	SOUTH BRUCE 3D 2021	1.00	306183-306263	NAD 1983	17N	Audit

53 RCV Lines 126.15

S-202	SOUTH BRUCE 3D 2021	1.01	202186-202267	NAD 1983	17N	Audit
S-204	SOUTH BRUCE 3D 2021	1.01	204186-204267	NAD 1983	17N	Audit
S-206	SOUTH BRUCE 3D 2021	1.01	206186-206267	NAD 1983	17N	Audit
S-208	SOUTH BRUCE 3D 2021	1.01	208186-208267	NAD 1983	17N	Audit
S-210	SOUTH BRUCE 3D 2021	2.53	210187-210389	NAD 1983	17N	Audit
S-212	SOUTH BRUCE 3D 2021	2.53	212187-212389	NAD 1983	17N	Audit
S-214	SOUTH BRUCE 3D 2021	2.53	214187-214389	NAD 1983	17N	Audit
S-216	SOUTH BRUCE 3D 2021	2.53	216187-216389	NAD 1983	17N	Audit
S-218	SOUTH BRUCE 3D 2021	3.01	218147-218389	NAD 1983	17N	Audit
S-220	SOUTH BRUCE 3D 2021	3.00	220149-220389	NAD 1983	17N	Audit
S-222	SOUTH BRUCE 3D 2021	2.38	222156-222350	NAD 1983	17N	Audit
S-224	SOUTH BRUCE 3D 2021	2.39	224159-224350	NAD 1983	17N	Audit
S-226	SOUTH BRUCE 3D 2021	2.28	226167-226349	NAD 1983	17N	Audit
S-228	SOUTH BRUCE 3D 2021	2.35	228161-228349	NAD 1983	17N	Audit
S-230	SOUTH BRUCE 3D 2021	1.83	230161-230349	NAD 1983	17N	Audit
S-232	SOUTH BRUCE 3D 2021	1.83	232161-232349	NAD 1983	17N	Audit
S-234	SOUTH BRUCE 3D 2021	2.83	234163-234389	NAD 1983	17N	Audit
S-236	SOUTH BRUCE 3D 2021	2.83	236163-236389	NAD 1983	17N	Audit
S-238	SOUTH BRUCE 3D 2021	2.83	238163-238389	NAD 1983	17N	Audit
S-240	SOUTH BRUCE 3D 2021	2.83	240163-240389	NAD 1983	17N	Audit
S-242	SOUTH BRUCE 3D 2021	3.59	242102-242389	NAD 1983	17N	Audit
S-244	SOUTH BRUCE 3D 2021	3.59	244102-244389	NAD 1983	17N	Audit
S-246	SOUTH BRUCE 3D 2021	3.59	246102-246389	NAD 1983	17N	Audit
S-248	SOUTH BRUCE 3D 2021	3.59	248102-248389	NAD 1983	17N	Audit
S-250	SOUTH BRUCE 3D 2021	3.06	250144-250389	NAD 1983	17N	Audit
S-252	SOUTH BRUCE 3D 2021	3.06	252144-252389	NAD 1983	17N	Audit
S-254	SOUTH BRUCE 3D 2021	2.95	254153-254389	NAD 1983	17N	Audit
S-256	SOUTH BRUCE 3D 2021	3.06	256144-256389	NAD 1983	17N	Audit
S-258	SOUTH BRUCE 3D 2021	3.59	258102-258389	NAD 1983	17N	Audit
S-260	SOUTH BRUCE 3D 2021	3.46	260104-260389	NAD 1983	17N	Audit
S-262	SOUTH BRUCE 3D 2021	3.58	262103-262389	NAD 1983	17N	Audit
S-264	SOUTH BRUCE 3D 2021	3.59	264102-264389	NAD 1983	17N	Audit
S-266	SOUTH BRUCE 3D 2021	3.59	266102-266389	NAD 1983	17N	Audit
S-268	SOUTH BRUCE 3D 2021	3.56	268102-268389	NAD 1983	17N	Audit
S-270	SOUTH BRUCE 3D 2021	3.59	270102-270389	NAD 1983	17N	Audit
S-272	SOUTH BRUCE 3D 2021	3.58	272102-272389	NAD 1983	17N	Audit
S-274	SOUTH BRUCE 3D 2021	3.59	274102-274389	NAD 1983	17N	Audit
S-276	SOUTH BRUCE 3D 2021	3.06	276102-276347	NAD 1983	17N	Audit
S-278	SOUTH BRUCE 3D 2021	3.05	278102-278346	NAD 1983	17N	Audit
S-280	SOUTH BRUCE 3D 2021	3.06	280102-280347	NAD 1983	17N	Audit
S-282	SOUTH BRUCE 3D 2021	3.06	282102-282347	NAD 1983	17N	Audit
S-284	SOUTH BRUCE 3D 2021	1.53	284225-284347	NAD 1983	17N	Audit
S-286	SOUTH BRUCE 3D 2021	1.53	286225-286347	NAD 1983	17N	Audit
S-288	SOUTH BRUCE 3D 2021	1.53	288225-288347	NAD 1983	17N	Audit
S-290	SOUTH BRUCE 3D 2021	1.53	290225-290347	NAD 1983	17N	Audit
S-292	SOUTH BRUCE 3D 2021	0.49	292225-292264	NAD 1983	17N	Audit
S-294	SOUTH BRUCE 3D 2021	0.49	294225-294264	NAD 1983	17N	Audit
S-296	SOUTH BRUCE 3D 2021	0.48	296226-296264	NAD 1983	17N	Audit
S-298	SOUTH BRUCE 3D 2021	0.49	298225-298264	NAD 1983	17N	Audit
S-300	SOUTH BRUCE 3D 2021	1.01	300183-300264	NAD 1983	17N	Audit
S-302	SOUTH BRUCE 3D 2021	1.01	302183-302264	NAD 1983	17N	Audit
S-304	SOUTH BRUCE 3D 2021	1.01	304183-304264	NAD 1983	17N	Audit
S-306	SOUTH BRUCE 3D 2021	1.01	306183-306264	NAD 1983	17N	Audit
S-502	SOUTH BRUCE 3D 2021	5.20	502101-502517	NAD 1983	17N	Audit
S-504	SOUTH BRUCE 3D 2021	2.01	504262-504423	NAD 1983	17N	Audit
		55 SRC Lines	**134.64**			
TOTAL		**108 Lines**	**260.79**			

HORIZONTAL & VERTICAL CONTROL FROM CSRS-PPP
MEGA BIN 3D STATION INCREMENT BY A FACTOR OF 4

CGGn2013 was used to convert ellipsoidal heights to MSL heights for all data
The RTK base position was established by sending static data to CACS-PPP for processing.
Santos confirmed the PPP values by re-processing all static data
along with additional data and comparing the results to know locations.
This program includes several virtual source and receiver points inserted in to the survey
The 8 virtual receiver and 2112 source points have interpolated or extrapolated elevations

Control Information

CSRS-PPP 3.50.0 (2021-03-10)

BASE2910.21o
BASE01

Data Start	Data End	Duration of Observations
2021-10-18 21:22:00.00	2021-10-18 22:26:30.00	1:04:30
Processing Time		**Product Type**
15:39:14 UTC 2021/10/27		NRCan Rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	**Rejected Epochs**	**Fixed Ambiguities**	**Estimation Steps**
7.5 degrees	0.00 %	87.47 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
LEIAX1202GG	L1 = 0.063 m L2 = 0.062 m	H:1.506m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for BASE2910.21o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2010.0)†	44° 0' 35.91419"	-81° 21' 34.28201"	255.979 m
SIG_PPP(95%)‡	0.014 m	0.011 m	0.040 m
SIG_TOT(95%)‡	0.024 m	0.017 m	0.042 m
A priori*	44° 0' 35.94707"	-81° 21' 34.29116"	254.820 m
Estimated – A priori	-1.015 m	0.204 m	1.159 m

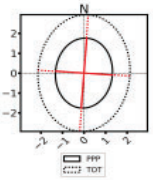
Orthometric Height CGVD2013 (CGG2013a) (2021.8)

291.160 m

(click for height reference information)

95% PPP Error Ellipse (cm)
semi-major: 1.8 cm
semi-minor: 1.3 cm
semi-major azimuth: 4° 14' 17.3"

95% TOT Error Ellipse (cm)
semi-major: 2.9 cm
semi-minor: 2.1 cm
semi-major azimuth: 3° 47' 48.07"



UTM (North) Zone 17

4873043.694 m (N)
471180.404 m (E)

Scale Factors
0.99961021 (point)
0.99957009 (combined)

*(Coordinates from RINEX header used as a priori position)

†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

Survey Summary

-	Receiver	= 2576	(8 virtual)
-	Source	= 10826	(2112 virtual)
-			
-	Phase	= 8726	90.08 % +/- 0.3m
-	Post Processed	= 673	6.9 % +/- 1.0m
-	GPS/GLONASS	= 257	2.7 % +/- 0.9m
-	RTK Extended	= 31	0.3 % +/- 0.6m
-	Virtual	= 2120	
-			
-	Interpolated	= 86	
-	SV's < 5	= 1	(Min 4)
-	DOP s ≥ 6	= 1	(Max 6.02)
-	Hgt. of Ant. (Average)	= 1.5m	(Min 1.5, Max 1.5)
-	Baseline >10kms	= Zero	(Max 2.7 km)

SANTOS
GEOMATICS & GIS SPECIALISTS

PROGRAM: South Bruce 3D 2021
CLIENT: NWMO
SEISMIC COMPANY: Echo Seismic
SURVEY CONTRACTOR: Datum Resources
DATE: Oct/Nov 2021
GEOID: CGVD2013
DATUM: NAD83
UTM ZONE: 17
ORTHOMETRIC HEIGHTS

	Santos NAD83 Static Processing			Published NAD83			Ties			
Station (text)	**East**	**North**	**Ell. Height**	**East**	**North**	**Ell. Height**	**E**		**N**	**Elev**
BASE01	471180.40	4873043.70	255.98	471180.40	4873043.69	255.98	0.00	X	0.00	0.00
CSRS-PPP BASE01 was held fixed in Santos' Static Network										
CHK01	471161.87	4873043.00	255.94							
GOD2	441396.35	4843846.62	145.76	441396.39	4843846.62	145.92	0.04	X	0.00	0.16
KNGV	356382.60	4654222.91	143.50	356382.59	4654222.90	143.52	-0.01	X	-0.02	0.02
OKEE	369822.46	4752482.36	160.82	369822.46	4752482.32	160.84	-0.01	X	-0.03	0.02
PWEL	644555.72	4788641.72	45.00	644555.71	4788641.73	44.98	-0.01	X	0.01	-0.02

	RTK Surveyed NAD83			Santos NAD83 Static Processing			Ties			
	East	**North**	**Height**	**East**	**North**	**Height**	**E**		**N**	**Elev**
CHK01	471161.9	4873043.0	291.1	471161.87	4873043.00	291.13	0.0	X	0.0	0.0
CHK01	471161.9	4873043.1	291.0	471161.87	4873043.00	291.13	0.0	X	-0.1	0.1
						Count	112			
						Min	-0.09		-0.15	-0.05
						Max	0.08		0.06	0.12
						Average	0.00		0.00	0.05
						STDEV	0.03		0.03	0.04

The GNSS RTK field operators occupied a consistent station during field operations
Only the smallest and the largest differnce is shown, but all records are calculated in the summary

Appendix D

Additional Examples of Inline / Crossline Seismic Data Processing

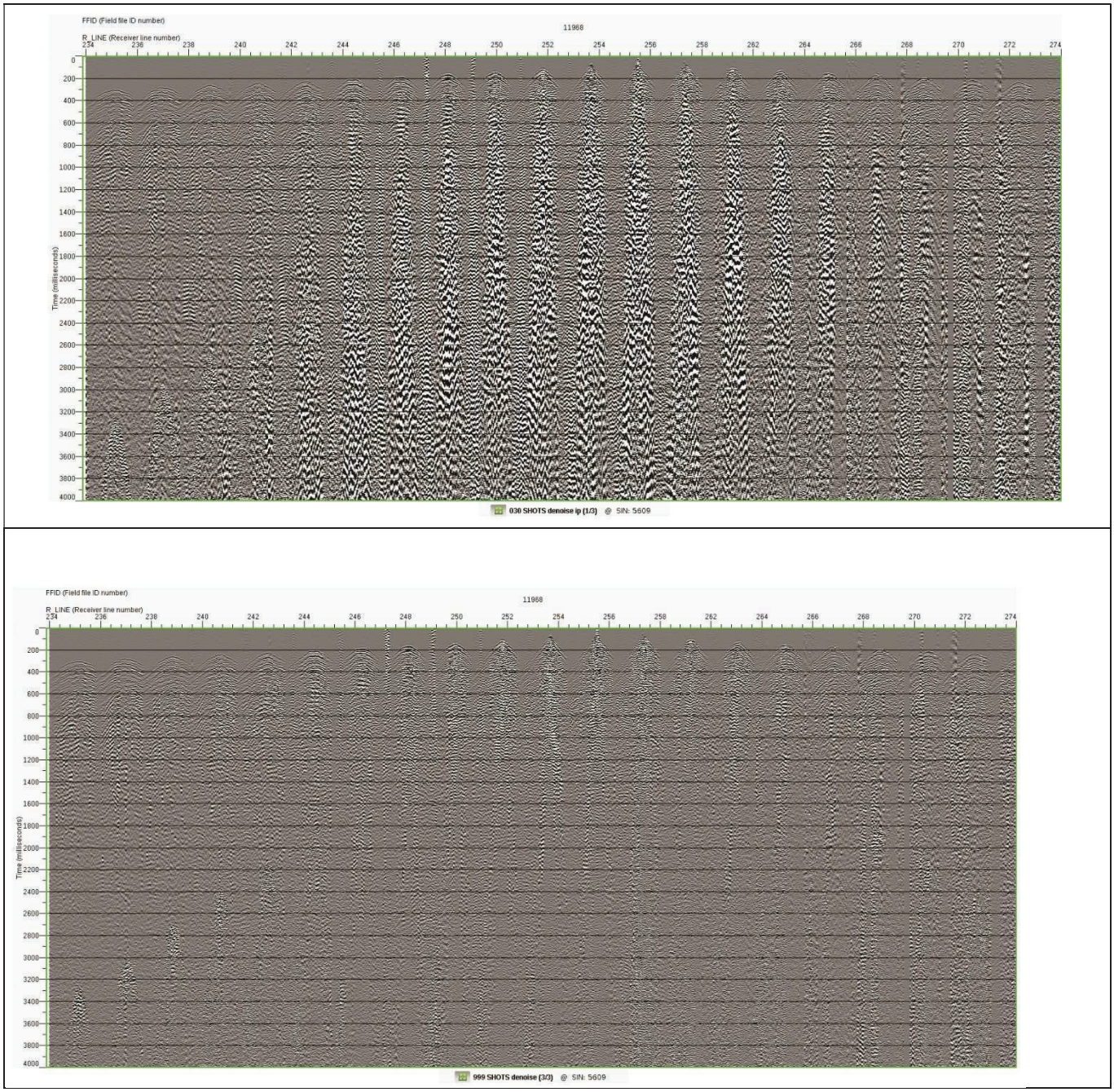


Figure D.1 Field File Identification Number (FFID) 1168. Top: Before Pre-Deconvolution Noise Attenuation; Bottom: After Pre-Deconvolution Noise Attenuation.

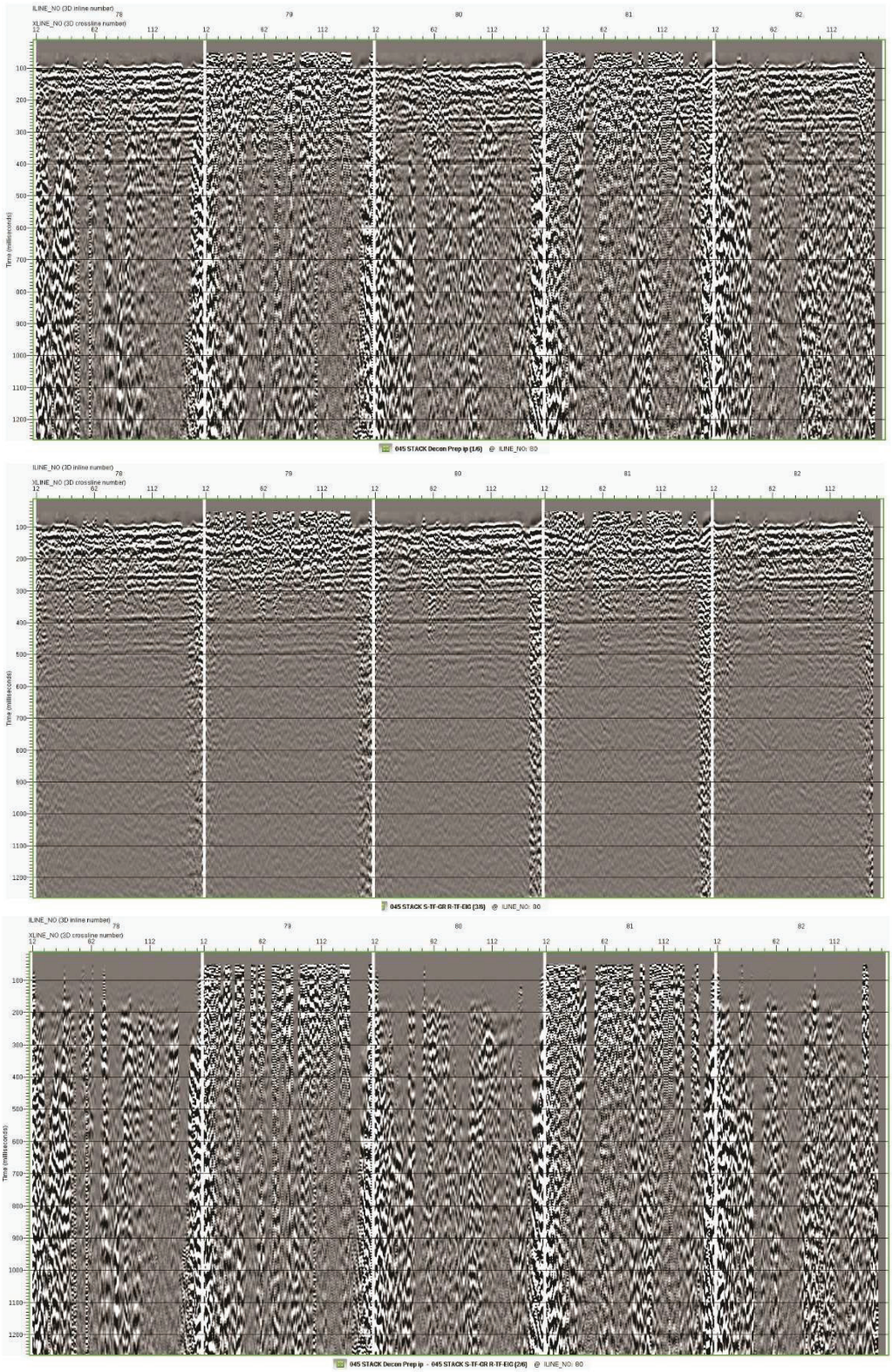


Figure D.2 Example of Ground Roll Removal Effects at Inline 80. Top: Before Pre-Deconvolution Noise Attenuation; Middle: After Pre-Deconvolution Noise Attenuation; Bottom: Difference (Seismic Signal Removed in Process).

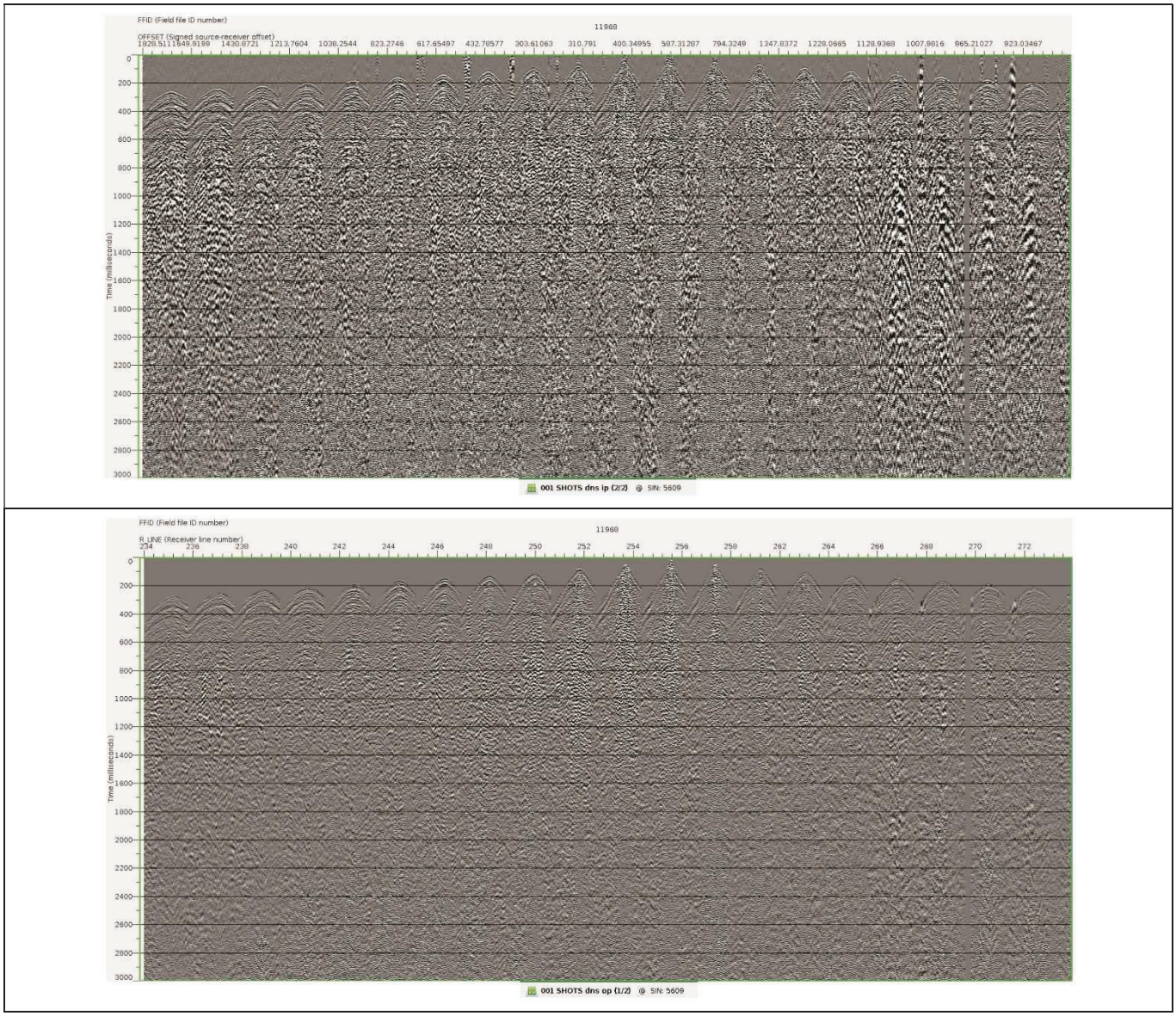


Figure D.3 Field File Identification Number (FFID) 11968. Top: Before Post-Deconvolution Noise Attenuation; Bottom: After Post-Deconvolution Noise Attenuation.

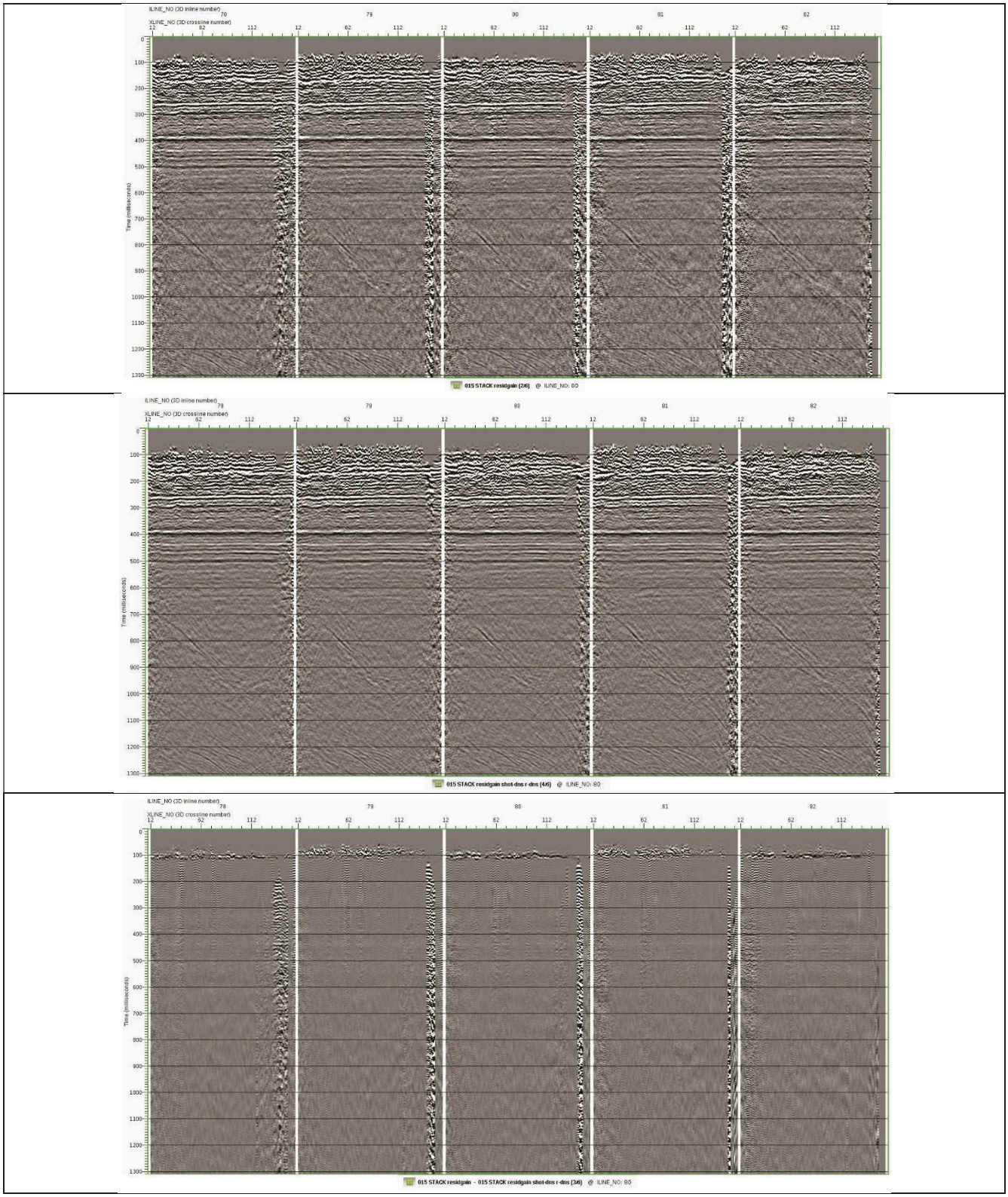


Figure D.4 Example of Post-Deconvolution Noise Attenuation Effects at Inline 80. Top: Before Post-Deconvolution Noise Attenuation; Middle: After Post-Deconvolution Noise Attenuation; Bottom: Difference (Seismic Signal Removed in Process).

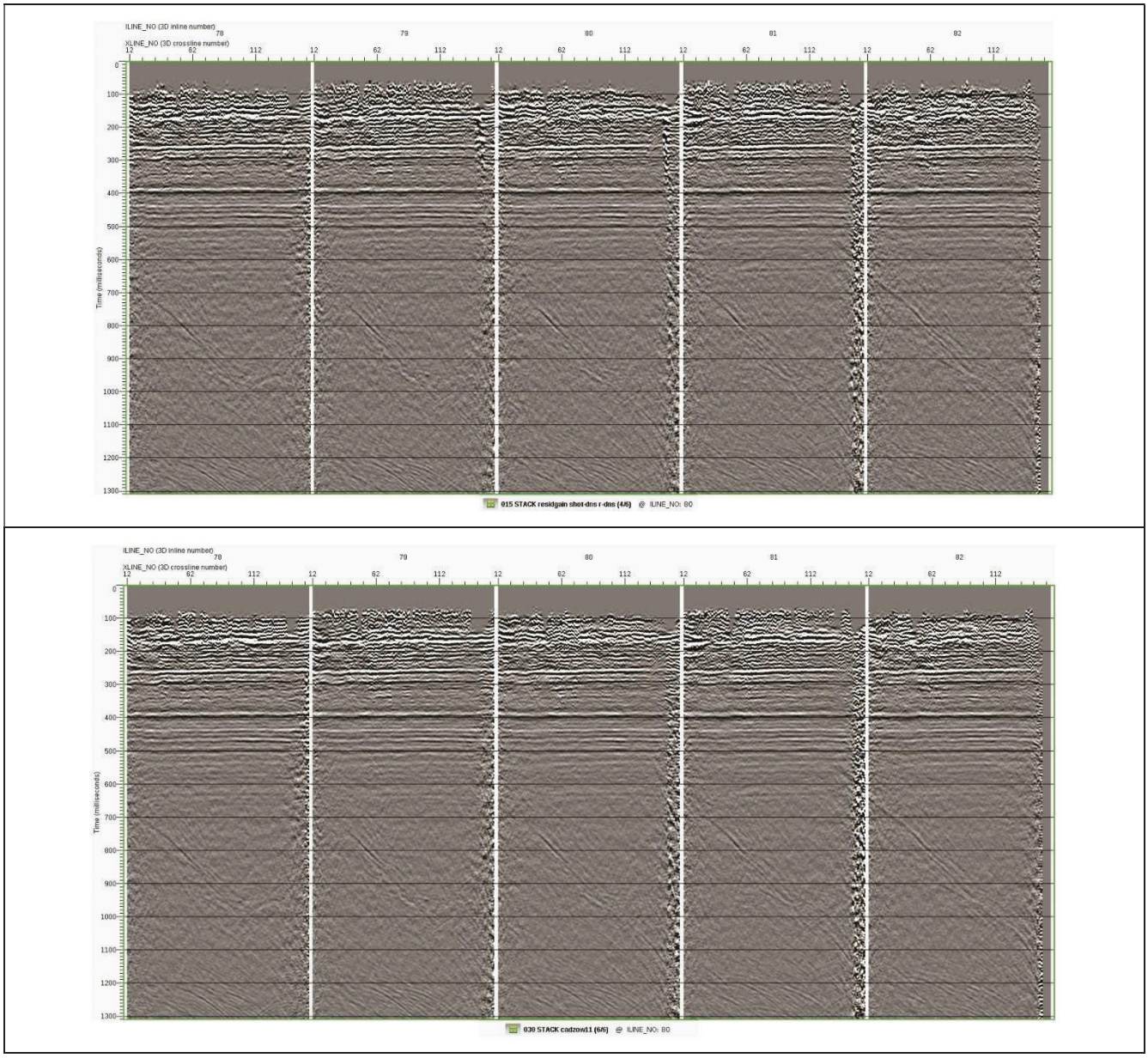


Figure D.5 Example of Effects from Pre-Stack Noise Suppression – Inline 80. Top: Before Cross-Spread Denoise Correction; Bottom: After Cross-Spread denoise Correction.

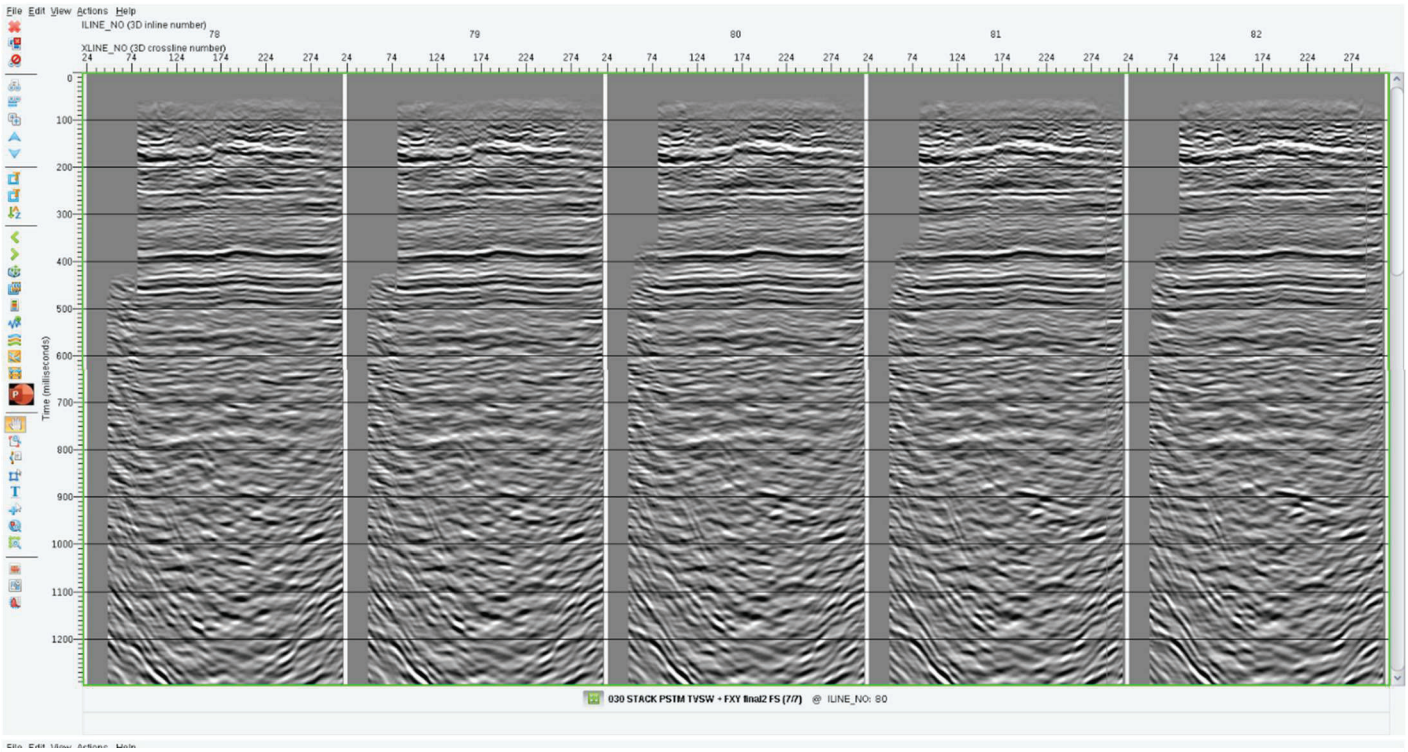


Figure D.6 PSTM with post stack enhancements-Inline 78-82

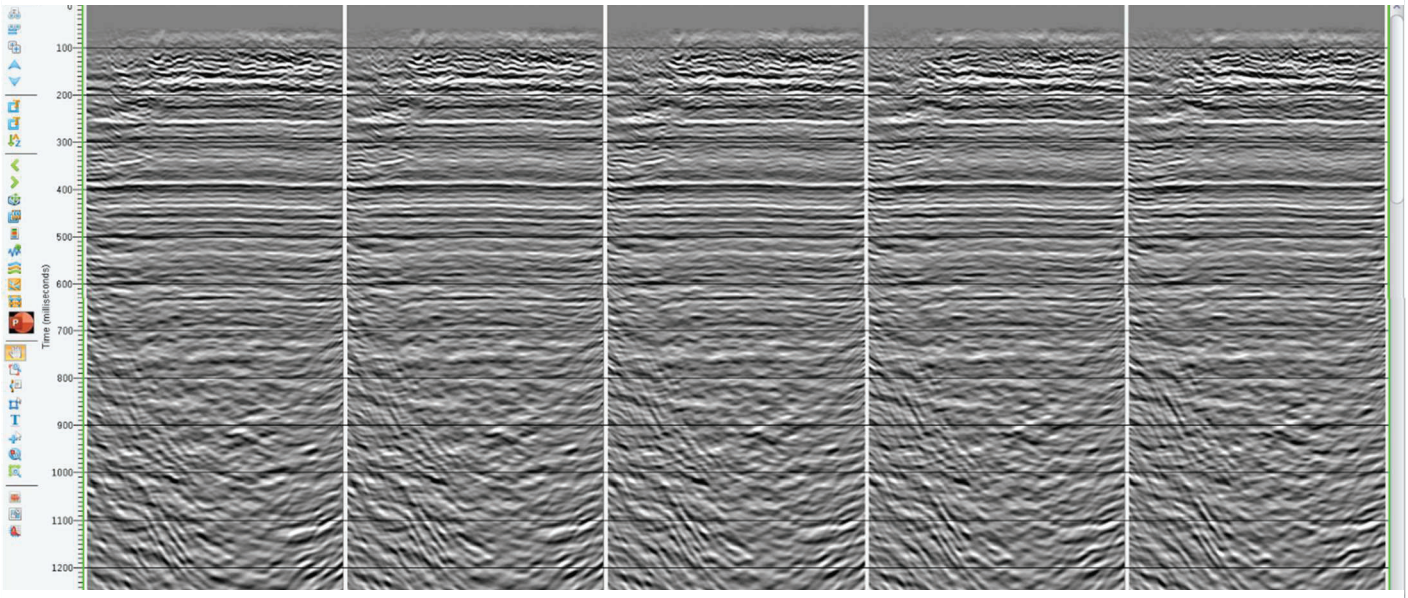


Figure D.7 PSTM with post stack enhancements - Inline 118-122

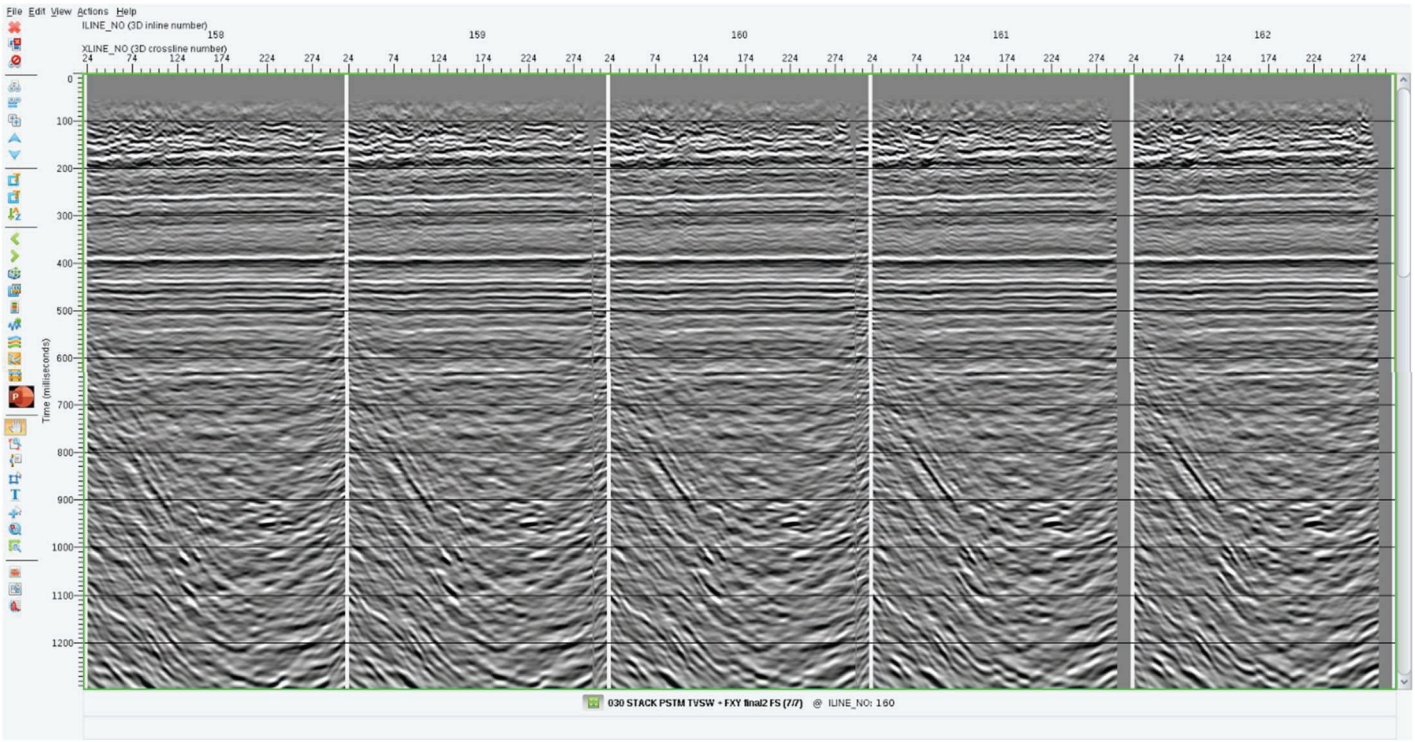


Figure D.8 PSTM with post stack enhancements- Inline 158-162

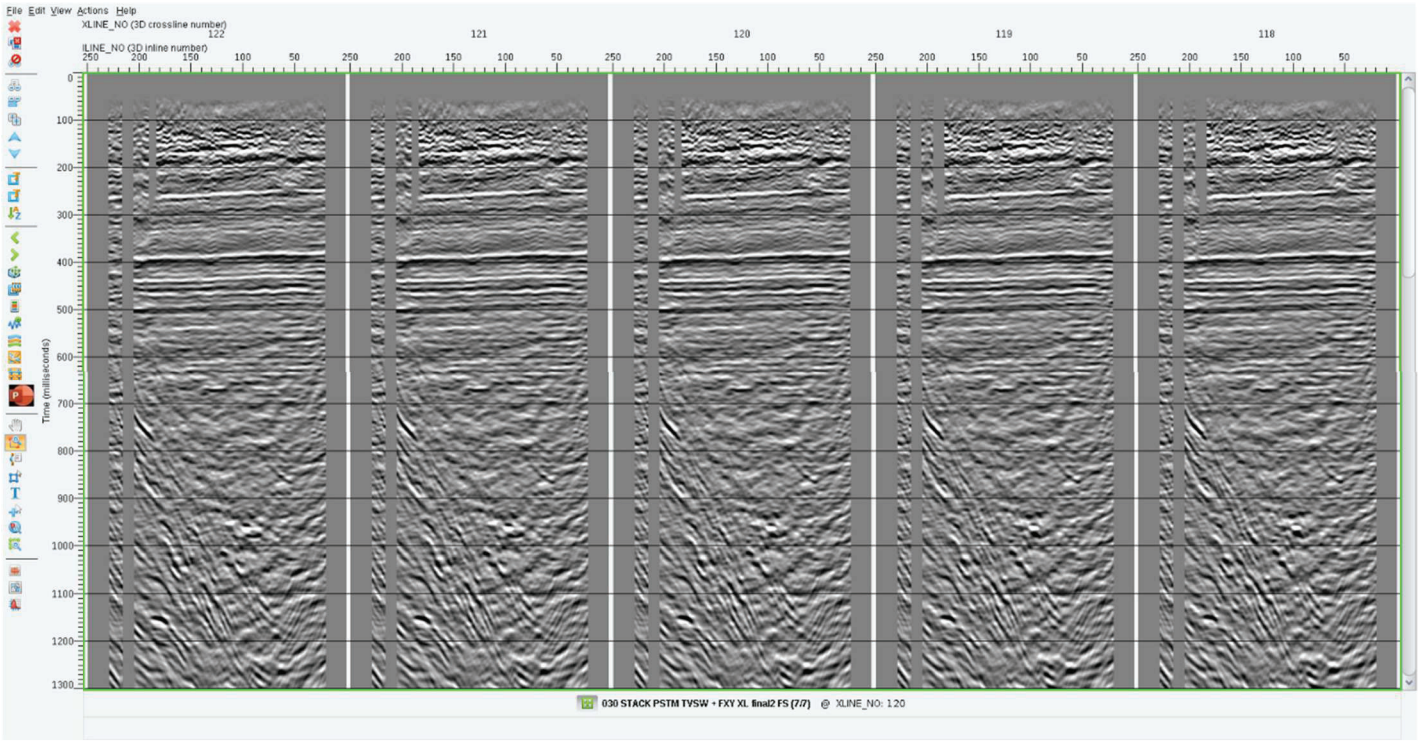


Figure D.9 PSTM with post stack enhancements - Crosslines 118-122

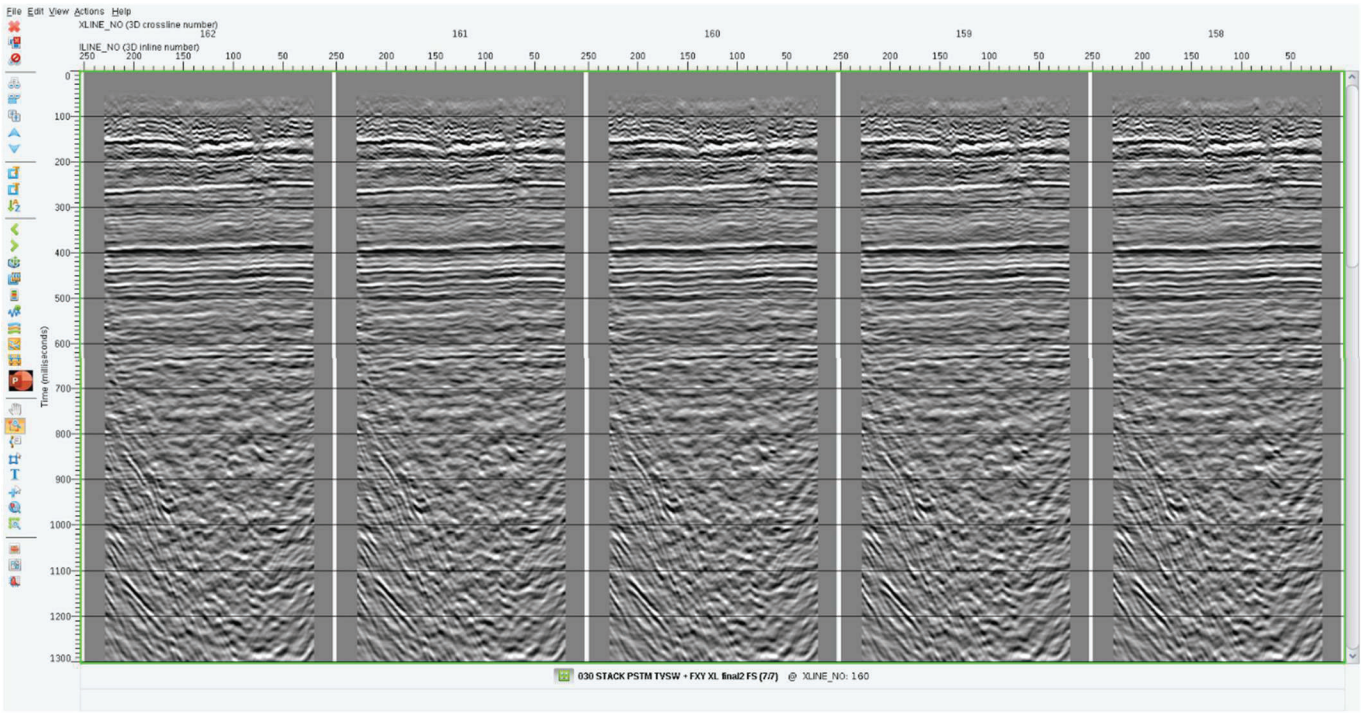


Figure D.11 PSTM with post stock enhancements-crossline 158-162

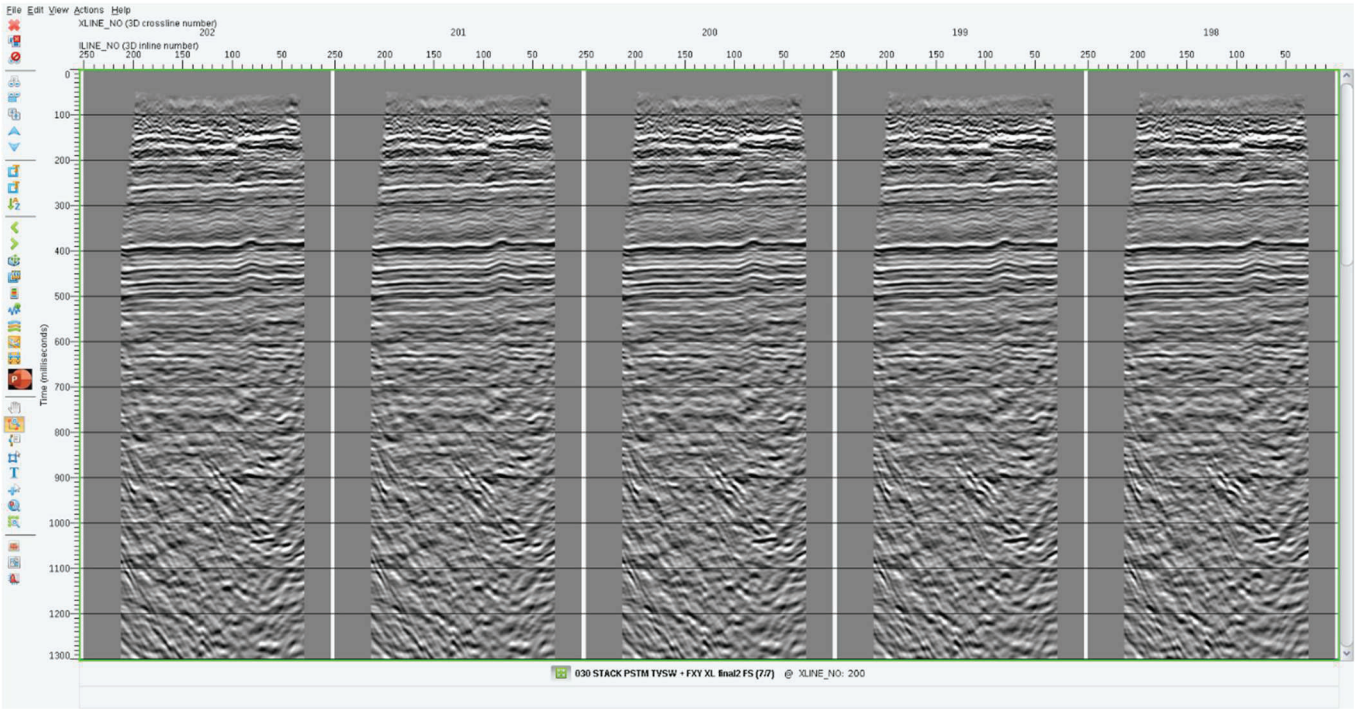


Figure D.10 PSTM with post stack enhancements - crossline 198 - 202