About This Version – *ParkSEIS* 3.0

ParkSEIS *PS* **User Guide**

Prepared By

Choon B. Park, Ph.D.

September 2017

Park Seismic

Table of Contents

1. Summary

Updates, additions, and modifications incorporated into the current version (3.0) are explained here.

The most significant upgrade incorporated in this version is the addition of the "AUTO" module that fully automates the complete sequence of dispersion and inversion operations. Minor updates have been made in modules of the dispersion image generation [*(*OT.dat] and the 1D velocity (Vs) display [*.LYR], respectively. All bugs we found were minor and have been fixed. Upgrade and maintenance items are briefly explained below.

AUTO – Automatic Generation of Velocity (Vs) Profiles (1D and 2D) and Dispersion Curve(s)
(Main Menu -> "AUTO")

The generation of the velocity (Vs) profile (1D and 2D) can now be accomplished by one click after preparation of seismic data with proper acquisition geometry encoded [*(SR).dat]. This module implements the task of dispersion image preparation and subsequent fundamental-mode (M0) dispersion-curve extraction through a fully automated process. The algorithm is designed according to the fundamental-mode (M0) pattern-recognition technique that is facilitated by various types of signal-enhancing tactics theoretically and empirically developed during the last three decades of research and development. The following inversion process is also automatically optimized based on the results from the automatic dispersion analysis.

Automatic extraction of dispersion curve(s) can also be executed during the conventional mode of dispersion curve extraction with full manual controls still available.

Performance of this AUTO module has proven highly effective and reliable even in comparison to conventional (manual) processes performed by an experienced operator. In this sense, a novice in MASW analysis can use this module as a tutorial guide during the learning process of the conventional analysis skills. On the other hand, the results from the AUTO process should always be taken with caution because the process may not be perfect in every aspect, especially when the acquired data carries extraordinary complications. It is therefore always recommended even for experienced users in MASW analysis to run both manual and AUTO approaches to crosscheck the results.   More details about the background methodology and how to use this module are explained in section 1. In addition, a separate user guide ("AUTO") is available from the 'Help' in the main menu as well as in the AUTO control dialog.

Dispersion Image Generation [*(*OT).dat] – New Options Added
(Main Menu -> "Dispersion" -> "Make Dispersion Image From...")

Two more options are added in the control dialog; filtering background noise ("Noise Filter") and tapering at lower and upper frequency ends of dispersion image ("OT Tapering"). These options can be used to improve overall signal-to-noise (SN) ratio of the most dominant energy pattern, for example, M0 energy pattern ("Noise Filter") and also to attenuate computational artifacts in those spectral ranges where surface waves have insignificant energy ("OT Tapering").

Seismic Site Characterization (NEHRP vs. Eurocode)
[Main Menu -> "Display" -> "S-Velocity (Vs) Data" -> "1-D Vs Profile (.LYR)"]*

When a site is characterized based on the shear wave velocities (Vs's) in the top 30 m (100 ft), now one of the two standards can be used; one recommended by the National Earthquake Hazard Reduction Program (NEHRP) in USA (www.nehrp.gov) and another adopted among European countries (Eurocode). This option is included in the display module of 1D velocity (Vs) profile (*.LYR). Description tables for both standards (NEHRP and Eurocode) are available within the display module. They are also available by going to "Main Menu" -> "Info" -> "Seismic Site Characterization Table."

Errors Fixed and Minor Updates Made

Updates are listed with brief explanations in Table 1. Bug fixes are listed in Table 2. There are other minor updates, upgrades, and bug fixes incorporated in this version that will be self explanatory during software use.

2. AUTO

2.1 Overview

Extraction of the fundamental-mode (M0) dispersion curve is a critical step during MASW analysis, the accuracy of which has a direct impact on the final velocity (Vs) profile. Up until now, it has been the only step in ParkSEIS (as with all other MASW analysis tools) that required the user's intervention to identify the corresponding energy pattern for the M0 trend. This step can be fairly straightforward if the trend is the only dominant energy pattern present in the dispersion image [also known as "overtone (OT)" image]. Or, as is more commonly the case, it can be a challenging task if the overtone record includes other trends created from multiple causes such as higher modes, ambient noise, energy segments arising from lateral variation of subsurface conditions, computational artifacts due to Gibb's phenomenon and boundary effects, body wave effects, etc.

As of this version of ParkSEIS, detection of the fundamental-mode (M0) dispersion trend is now handled through a fully automated process that works on various (theoretical and empirical) aspects of dispersion image data. The process is similar to a pattern recognition technique that is grounded in the theory of wavefield transformation that generates the overtone record. The actual technical implementation is linked to a significant number of empirical parameters that are properly calibrated for the condition of the original seismic field record as well as the corresponding overtone record. This empirical calibration has been made using several hundred field data sets acquired at sites of diverse subsurface conditions.

The detection of M0 trend is made through a comprehensive evaluation of the overtone record, which evaluates the following five (5) attributes of the record:

- **Pattern**: Recognition of the most dominant surface wave event is assessed in its spectral and phase velocity attributes. Then, the overall strength and continuity of the pattern is estimated from the surface wave dispersion perspectives.
- **Coherency**: Most major energy trends are identified and their relative coherencies are estimated.
- **Definition**: Major energy segments are selected and then evaluated for their strengths in comparison to those of the body wave segments.
- **Amplitude**: Major energy segments are selected and then evaluated for their energy levels with respect to the background noise level.
- **Energy**: An absolute amount of surface wave energy is estimated.

The detection process accounts for all of these attributes (with varying degrees of contribution). The key parameter, however, is the "Pattern" which is calculated first and then upon which other relative contributions are determined. The detected M0 trend is used to set a specific area (called the "Bound OT") in the original overtone image to which the subsequent process of the curve extraction should focus. This is similar to setting the (lower and upper) bounds along the visually identified M0 trend, which is the mode of operation during a manual process. A flowchart of the overall process is presented in Figure 1.
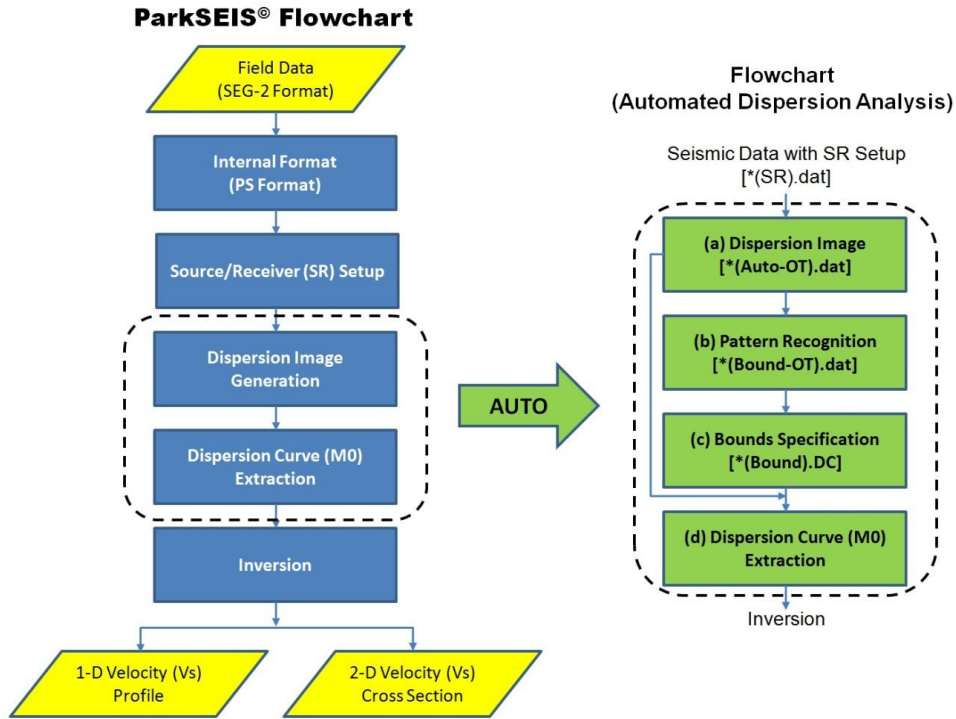
ParkSEIS© Flowchart

Figure 1. A general flowchart of the automatic detection algorithm (right) in reference to the flowchart of ParkSEIS (left).

To briefly explain each step in the flowchart:

(a) A seismic data set with field-geometry encoded [*(SR)*.dat] is used as an input to the 2D wavefield transformation. A dispersion image (overtone) data set [*(Auto-OT).dat] is produced from this process.
(b) Each overtone record is then evaluated by a pattern recognition method for the amount of signal wavefields (i.e., M0 surface waves) with respect to all other wavefields (i.e., for SN ratio). Then, a new set of overtone data [*(Bound-OT).dat] is prepared by applying proper signal-enhancing techniques to the original overtone records [*(Auto-OT).dat].
(c) A special type of dispersion curve [*(BoundDC).dc] is extracted from each record in this new data set. This curve contains information about detected M0 trend in the original overtone record [*(Auto-OT).dat].
(d) An M0 curve is extracted from each of the original overtone records [*(Auto-OT).dat] by using the special dispersion curve from (c) as a bound curve. All extracted curves are then saved and/or passed to the next inversion process to generate a (1D or 2D) velocity (Vs) profile.

To start the automatic process, select "AUTO" item from the main menu (yellow arrow), or select "AUTO" tab from the tool panel (green arrow) as illustrated below.

2.2 AUTO for 2D Velocity (Vs) Cross Section

This section describes the automatic process used to generate a 2D velocity (Vs) cross section at the end [*(2DVs).txt]. It can start from (2.1) original seismic field data in SEG-2 format that may or may not have the source/receiver (SR) setup encoded, (2.2) a seismic field data set previously prepared that has SR setup encoded [*(SR)*.dat], or (2.3) an overtone record data set previously prepared [*(Auto-OT).dat]. If the original SEG-2 seismic data set does not have a proper SR setup encoded, then you have to go through the source/receiver (SR) setup process first before the automatic process takes place.

2.2.1 From Field Seismic Files in SEG-2 Format

From the main menu, select items as shown below:
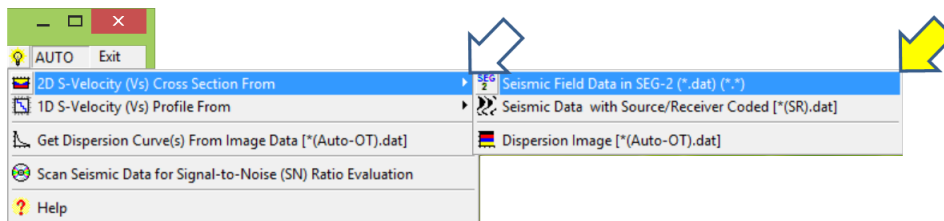
Or, from the tool panel, select the button as shown below:

Select multiple seismic field files (records) in SEG-2 format (e.g., *.dat, *.sg2, etc.).

If the files contain field geometry information [i.e., source/receiver (SR) setup] in the file header, then the program will detect it and ask you for review. Otherwise, the program will direct you to the SR setup process before the automatic process takes place.

6

When clicked "Yes" to view the original SR setup, a chart will be displayed as shown below:

Review the configuration on the chart to see if it is the correct SR setup. Then, close it to have the following dialog displayed:
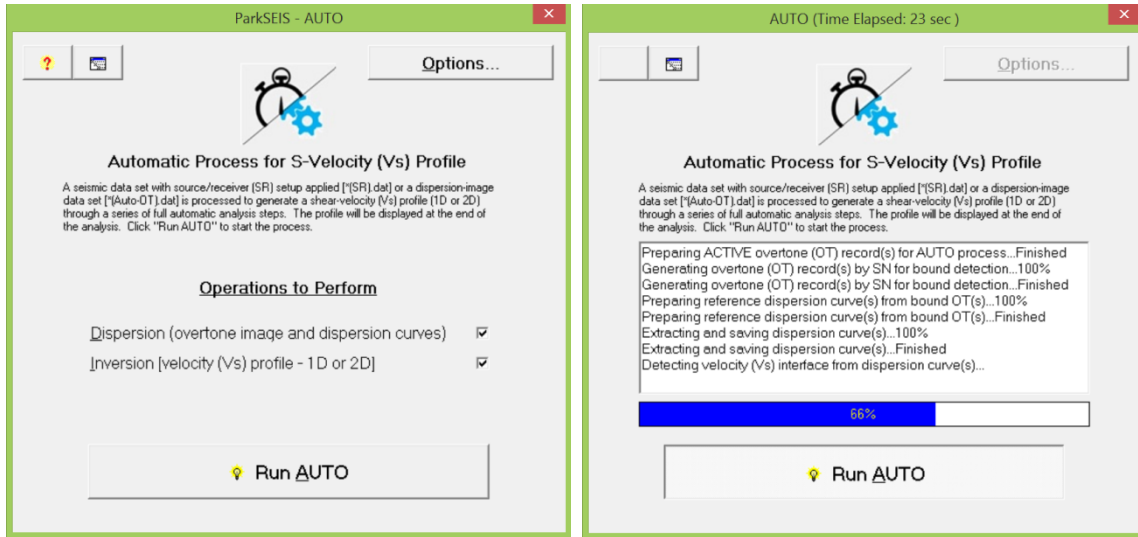

If the original SR setup is correct, then you can save the SEG-2 files as one file [*(SR).dat] and skip the subsequent SR setup process. Otherwise, select "Run source/receiver (SR) setup" to start the SR setup process before the automatic process takes place as shown below [refer to "Setup Source/Receiver (SR)" user guide for instructions]:

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):

At the end of the process, the velocity (Vs) cross section will be displayed as shown below:

2.2.2 From Seismic Data with Source/Receiver (SR) Setup

From the main menu, select items as shown below:

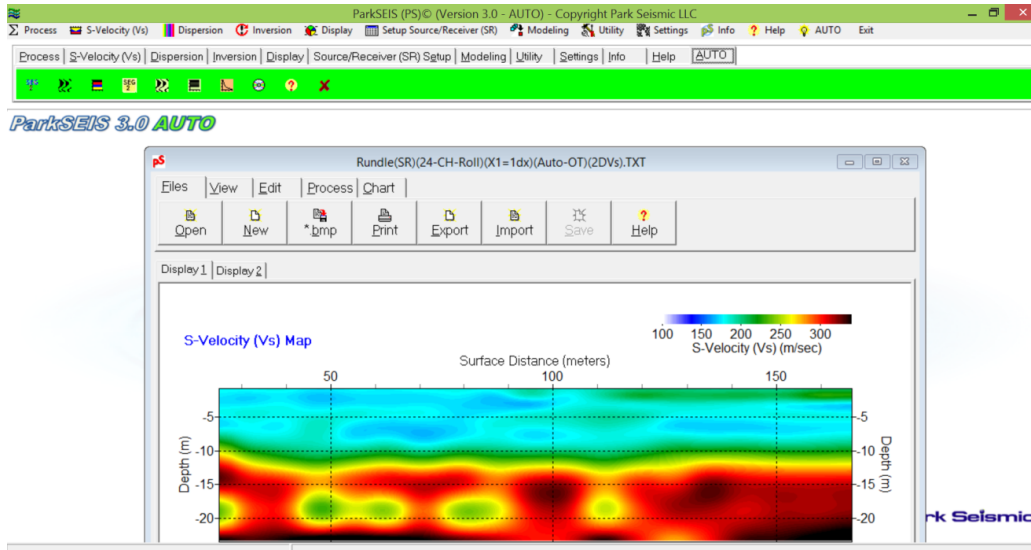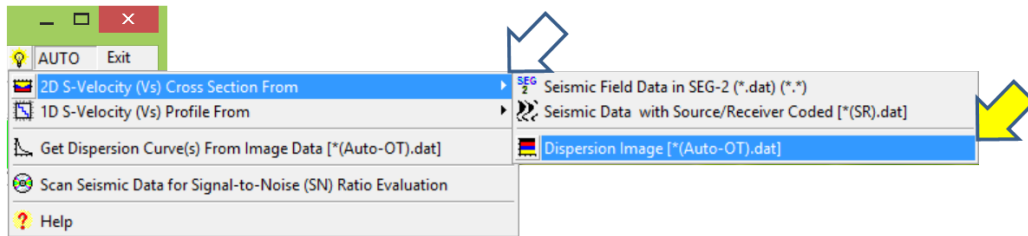

Or, from the tool panel, select the button as shown below:

Select a seismic data file, previously prepared, that has source/receiver (SR) setup encoded [*(SR)*.dat].
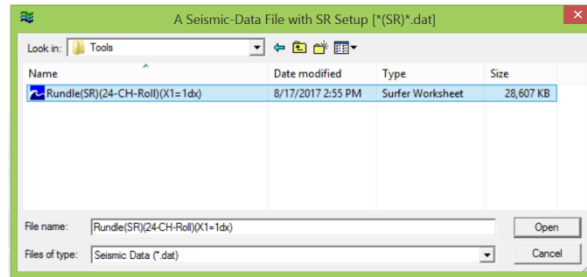
Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
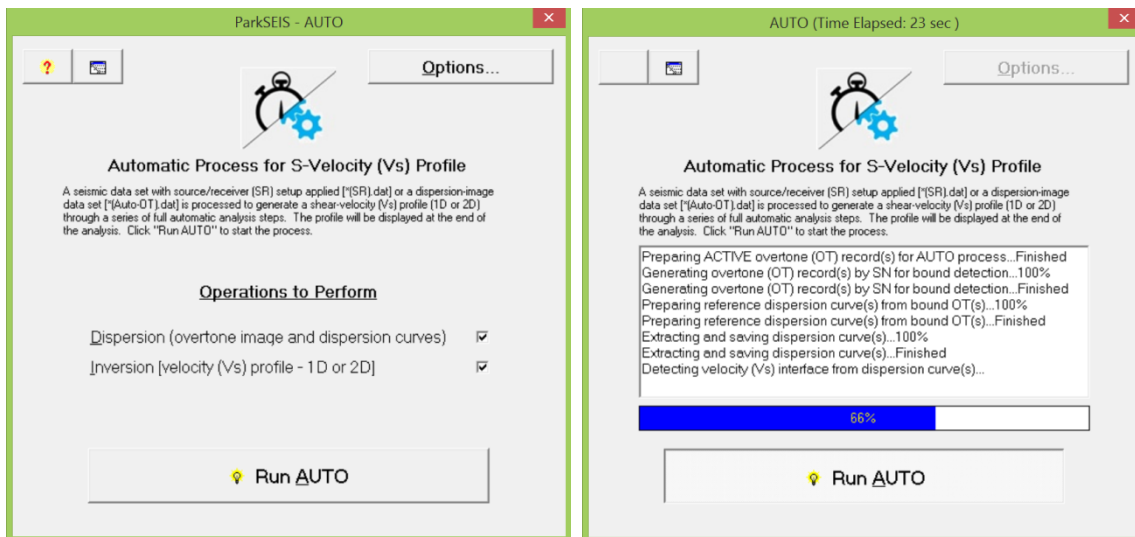
At the end of the process, the velocity (Vs) cross section will be displayed as shown below:

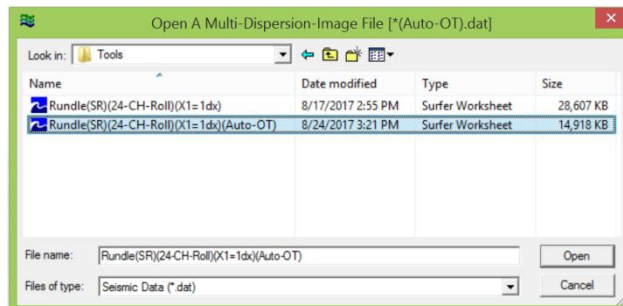## 2.2.3 From Dispersion Image File

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:
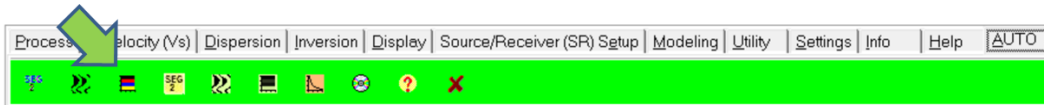
Select an overtone image data file [*(Auto-OT).dat] previously prepared that has multiple number of overtone records.

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
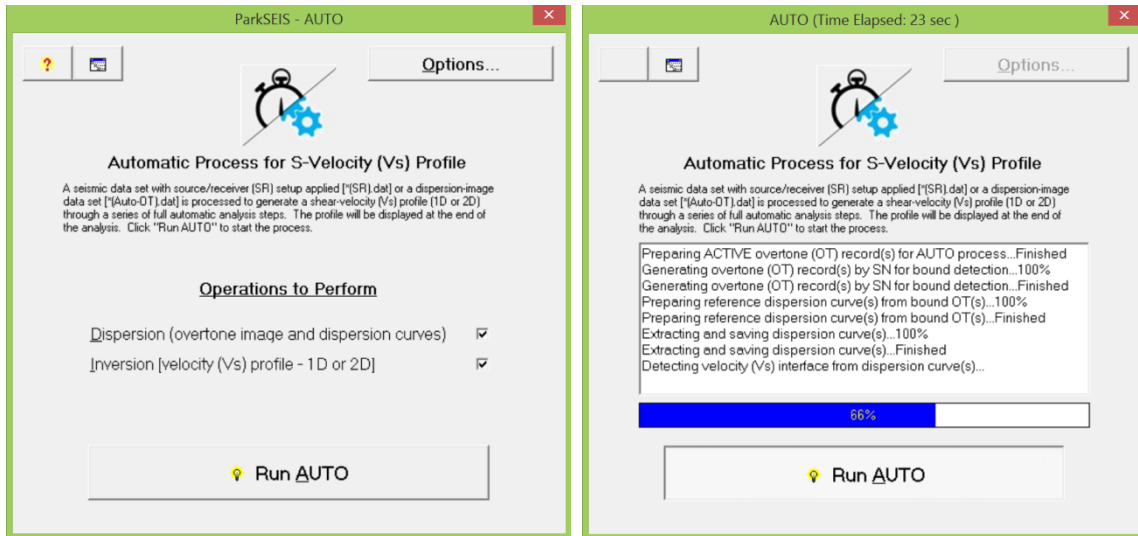
At the end of the process, the velocity (Vs) cross section will be displayed as shown below:
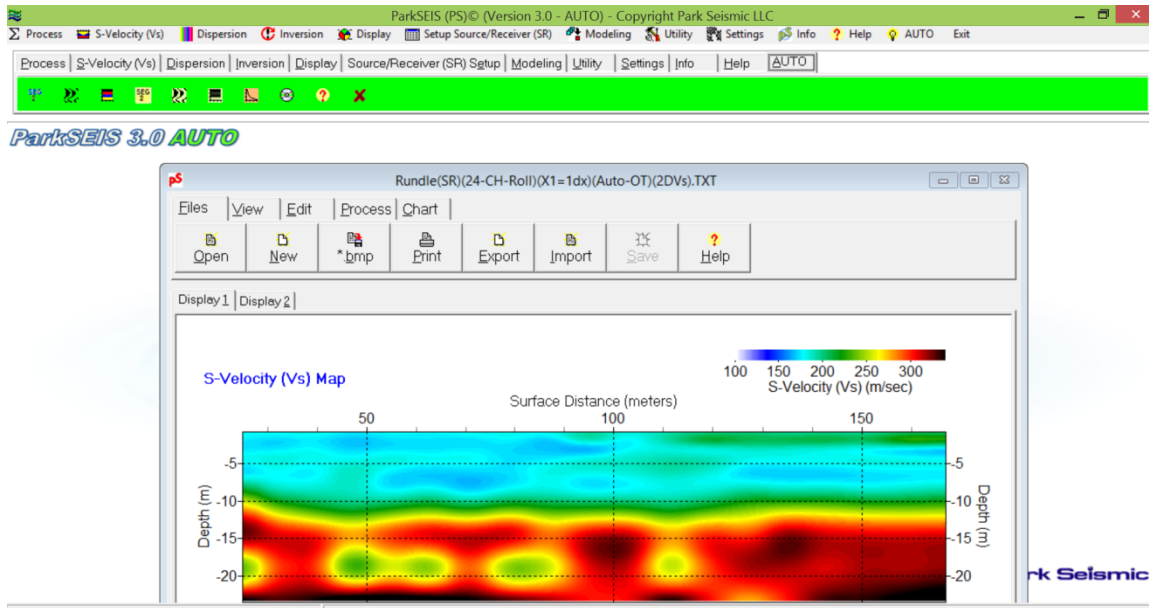
2.3 AUTO for 1D Velocity (Vs) Profile

This section describes the automatic process used to generate a 1D velocity (Vs) profile at the end [*(1DVs).LYR]. It can start from (3.1) original seismic field data in SEG-2 format that may or may not have the source/receiver (SR) setup encoded, (3.2) a seismic field data set previously prepared that has SR setup encoded [*(SR)*.dat], or (3.3) an overtone record data set previously prepared [*(Auto-OT).dat]. If the original SEG-2 seismic data set does not have a proper SR setup encoded, then you have to go through the source/receiver (SR) setup process first before the automatic process takes place.

2.3.1 From Field Seismic Files in SEG-2 Format
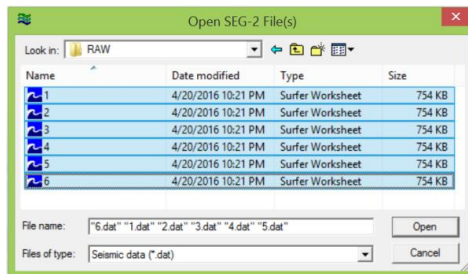
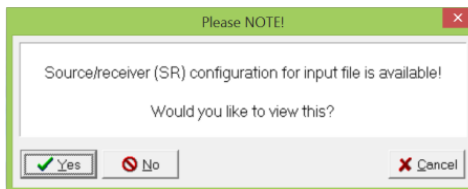From the main menu, select items as shown below:
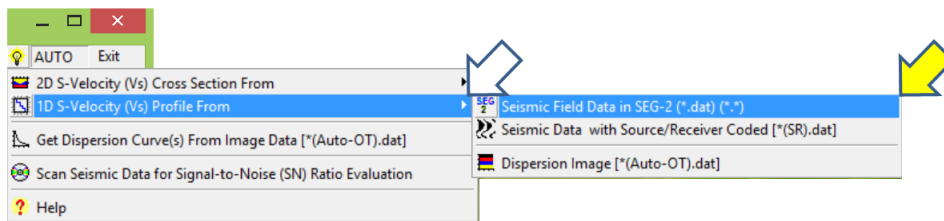
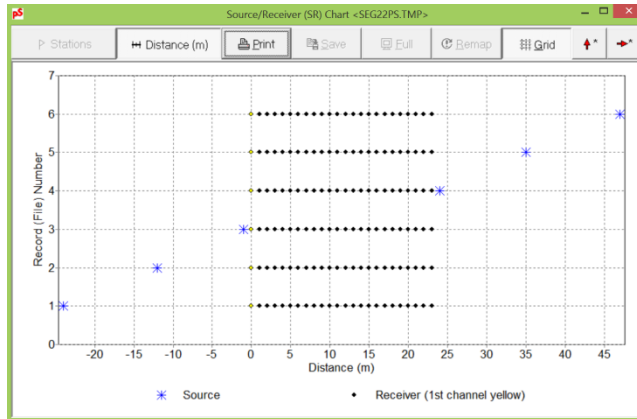Or, from the tool panel, select the button as shown below:

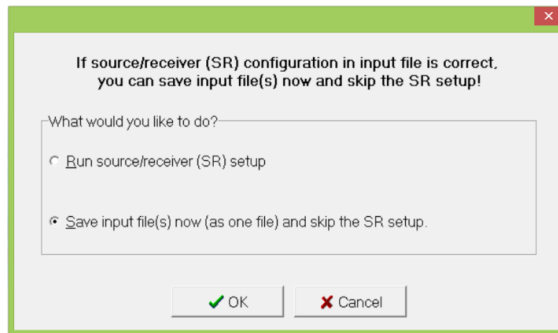Select one or multiple seismic field files (records) in SEG-2 format (e.g., *.dat, *.sg2, etc.).

If the files contain field geometry information [i.e., source/receiver (SR) setup] in the file header, then the program will detect it and ask you for review. Otherwise, the program will direct you to the SR setup process before the automatic process takes place.
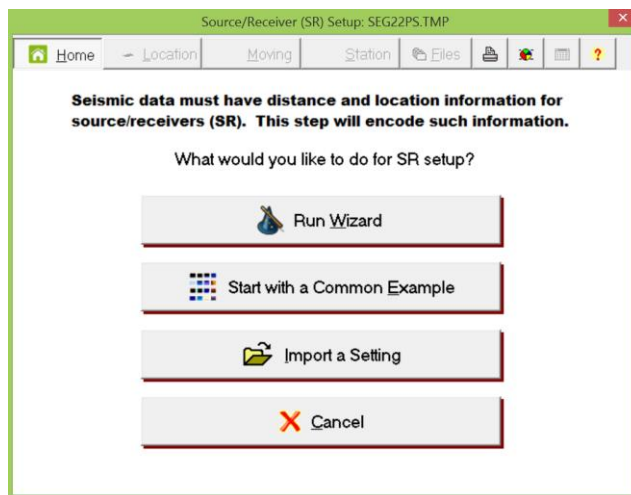
When clicked "Yes" to view the original SR setup, a chart will be displayed as shown below:

Review the configuration on the chart to see if it is the correct SR setup. Then, close it to have the following dialog displayed:
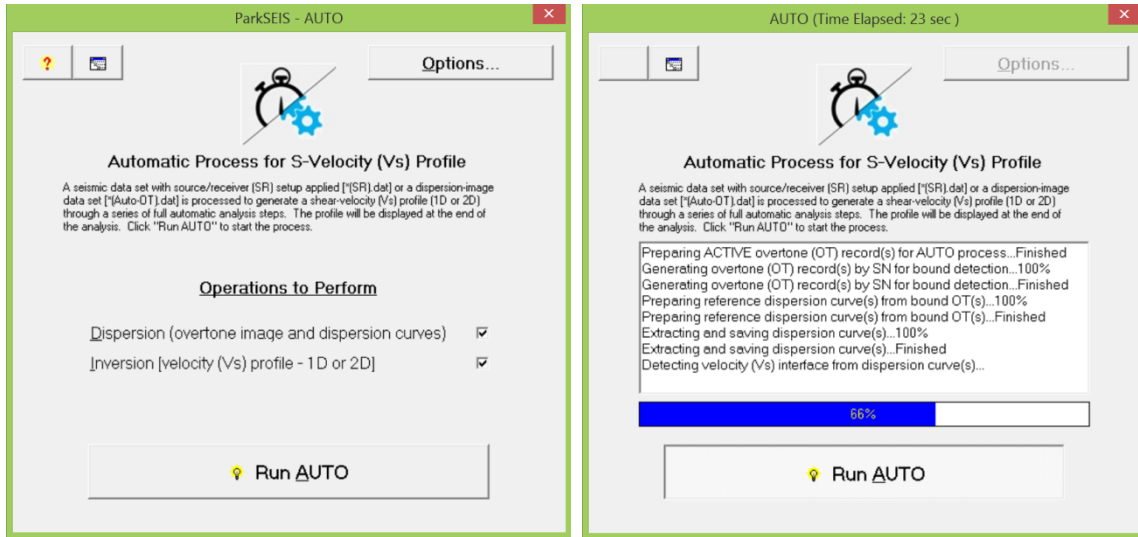

If the original SR setup is correct, then you can save the SEG-2 files as one file [*(SR).dat] and skip the subsequent SR setup process. Otherwise, select "Run source/receiver (SR) setup" to start the SR setup process before the automatic process takes place as shown below [refer to "Setup Source/Receiver (SR)" user guide for instructions]:
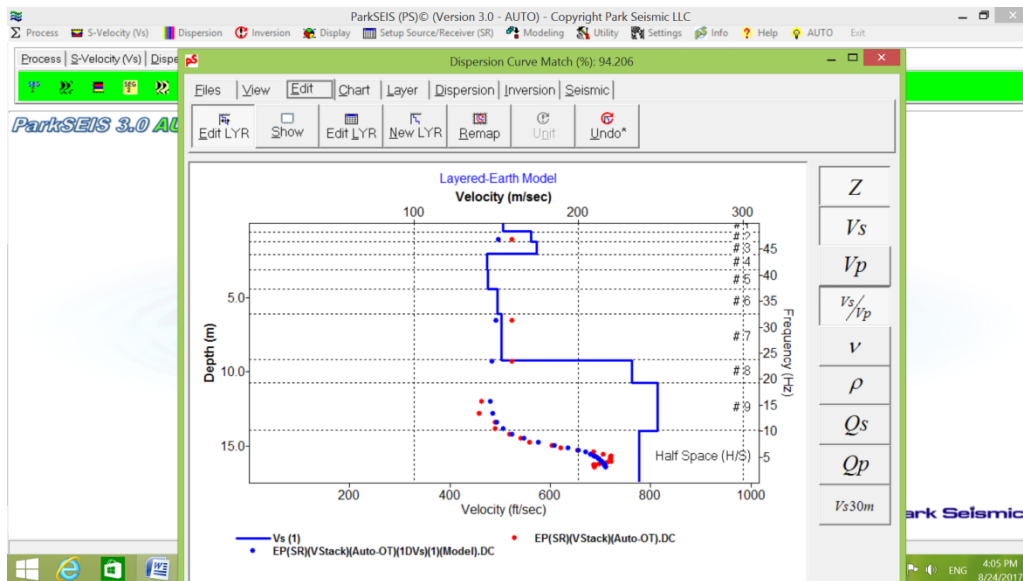
Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):

At the end of the process, a 1D velocity (Vs) profile [*(1DVs).LYR} will be displayed as shown below:

2.3.2 From Seismic Data with Source/Receiver (SR) Setup

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

Select a seismic data file previously prepared that has source/receiver (SR) setup encoded [*(SR)*.dat].

Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
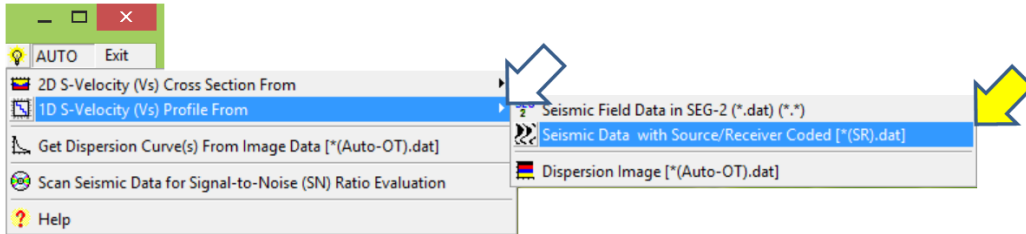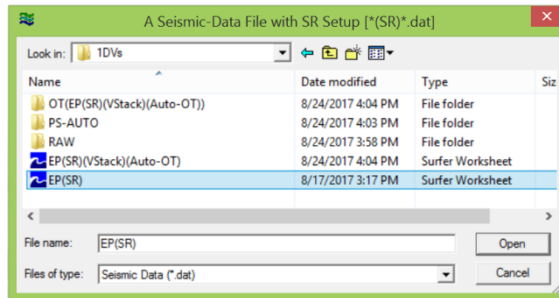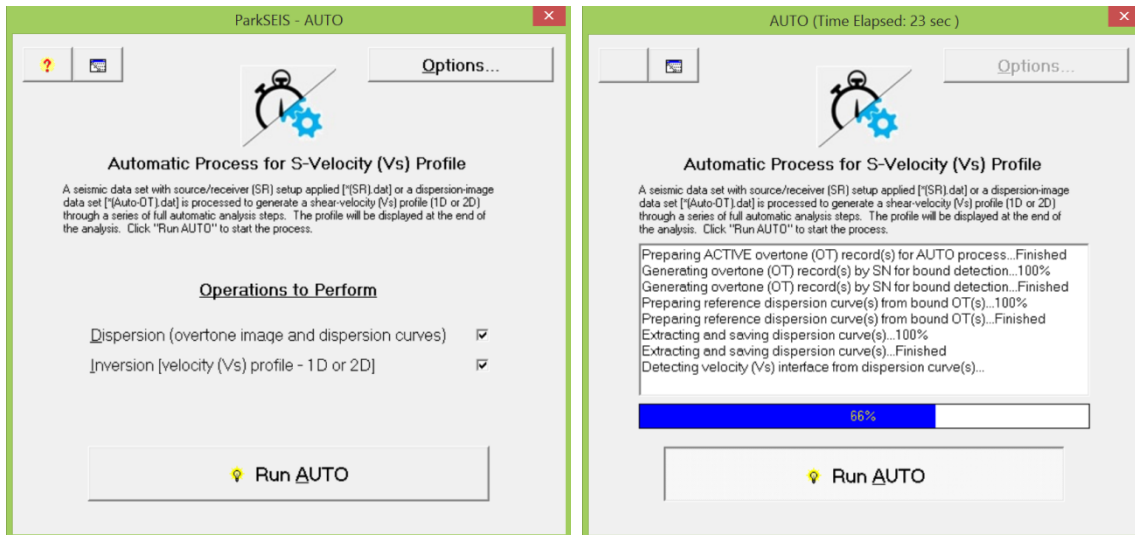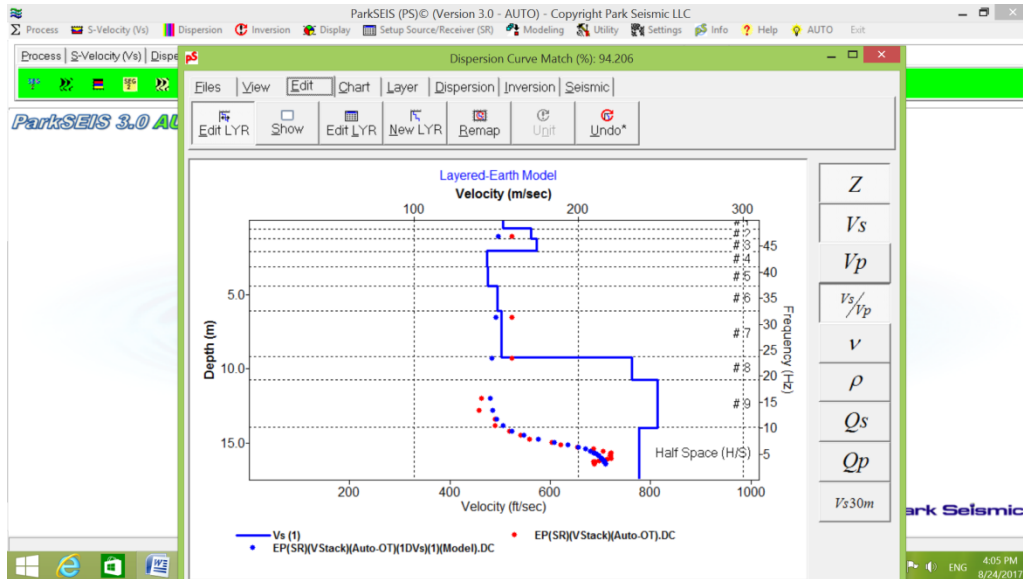

15

At the end of the process, a 1D velocity (Vs) profile [*(1DVs).LYR] will be displayed as shown below:

2.3.3 From Dispersion Image File

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

Select an overtone image data file previously prepared [*(Auto-OT).dat].
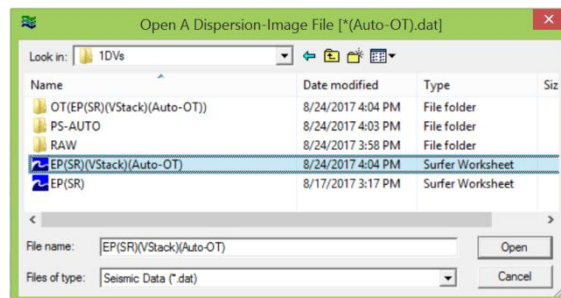
Click "Run AUTO" to start the AUTO process (left). Both (dispersion and inversion) analyses will proceed automatically with the processing status updated in the message panel as shown below (right):
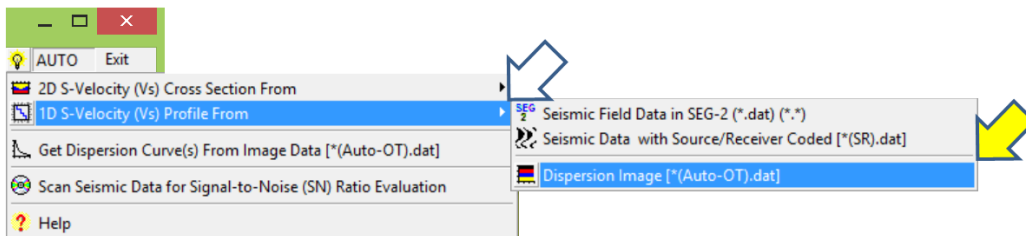

At the end of the process, a 1D velocity (Vs) profile [*(1DVs).LYR] will be displayed as shown below:
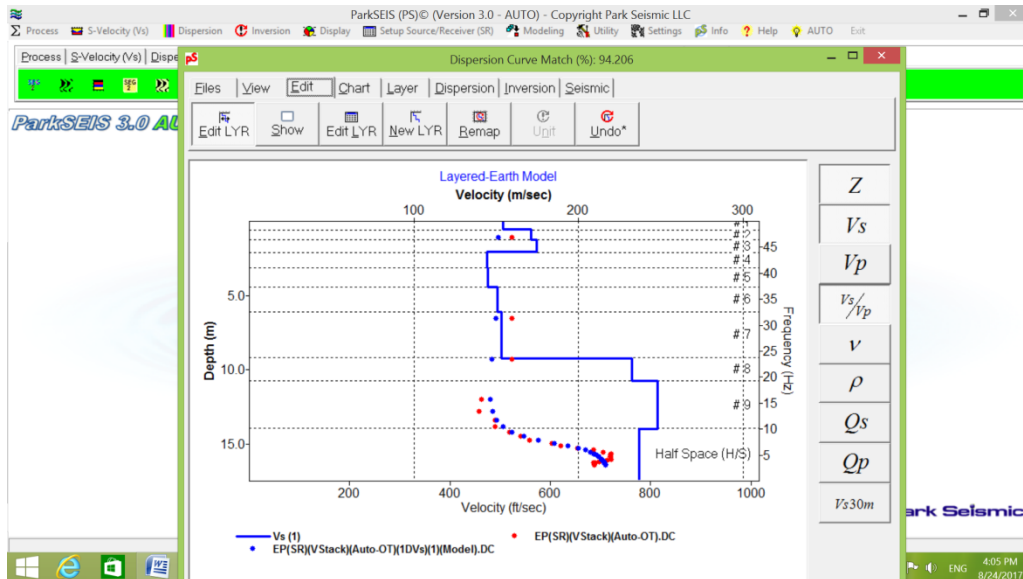
2.4. AUTO for Dispersion Curve Extraction

This section describes the automatic process used to generate dispersion curve(s) (*.DC) from an overtone data file [*(Auto-OT).dat]. Extracted dispersion curve(s) can be used for the inversion process to produce a velocity (Vs) profile (1D or 2D). This automatic process can take place in two different modes; (4.1) a batch mode that generates and saves all dispersion curve(s) without any user intervention, and (4.2) a pseudo-automatic mode that generates a dispersion curve for each overtone record being displayed in the chart. The second mode is available during the manual process to extract dispersion curve(s) from an overtone image file (the 2nd step of manual dispersion analysis).

2.4.1 Batch Process

From the main menu, select items as shown below:

Or, from the tool panel, select the button as shown below:

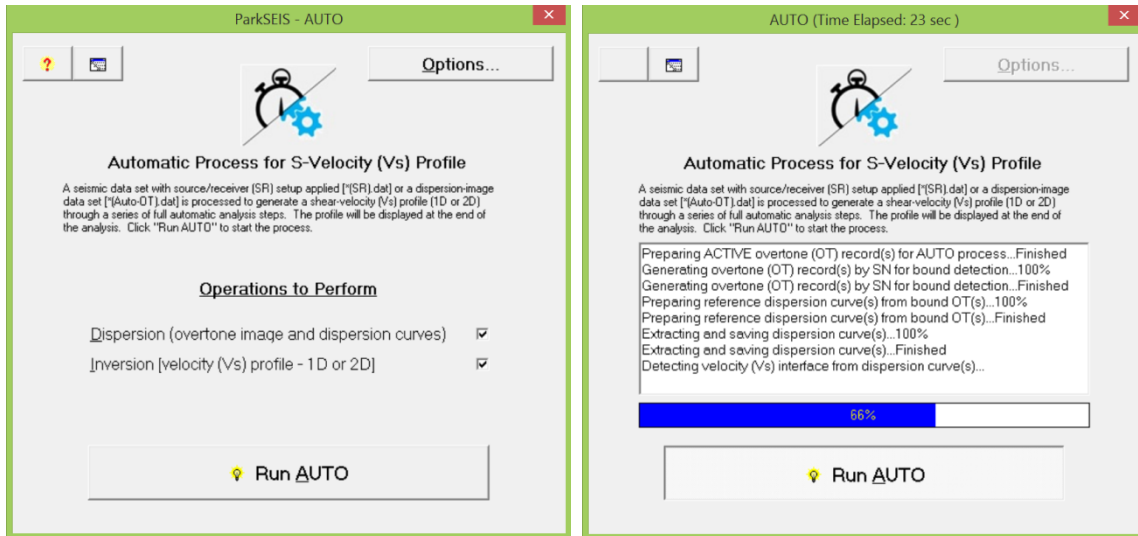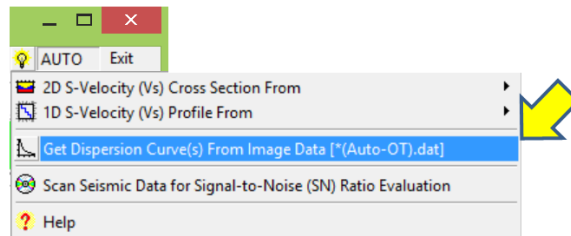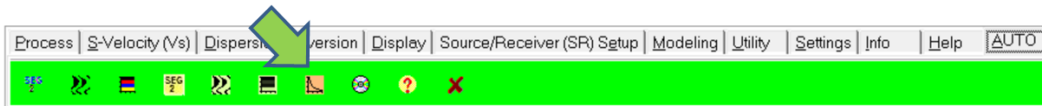Select an overtone image data file previously prepared [*(Auto-OT).dat].
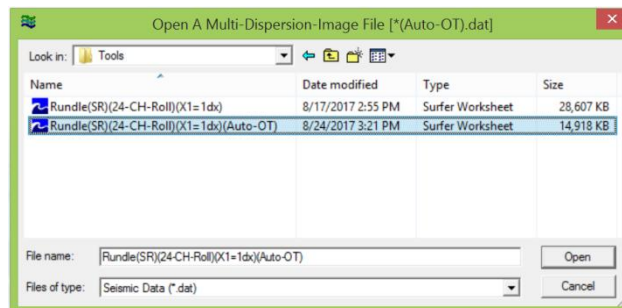
The program will detect the number of overtone records present in the input file and also the field geometry (SR setup) used during the acquisition of the original field files. Then, it will ask the user about the purpose of the process; i.e., 1D or 2D velocity (Vs) profiling. For 2D profiling, one dispersion curve will be extracted and saved from each of the overtone records included in the input file. On the other hand, for 1D profiling, only one dispersion curve will be extracted and saved by stacking all the overtone records included in the input file before the extraction takes place. The default is the most probable option the program detected.
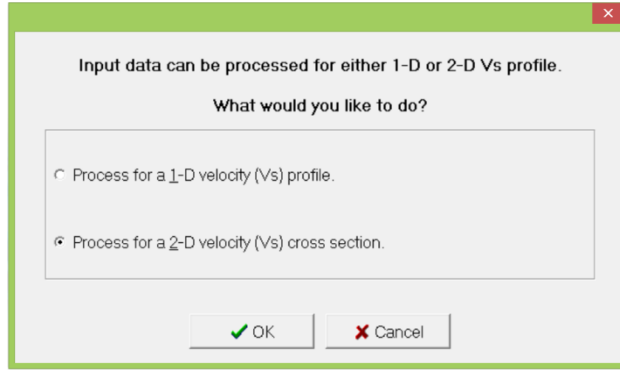
Click "Run AUTO" to start the AUTO process (left). It will proceed automatically with the processing status updated in the message panel as shown below (right):
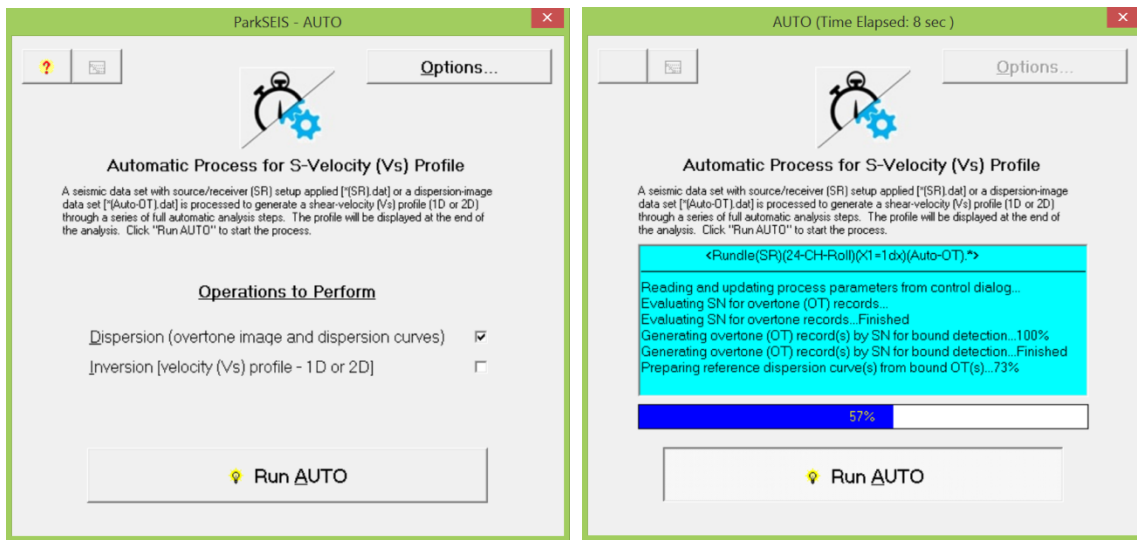
At the end of the process, the file name of the saved dispersion curve(s) will be displayed as shown below:

2.4.2 AUTO Process on Dispersion Image Chart

This section describes an AUTO process that can take place during the previous (manual) mode of dispersion-curve extraction (i.e., the 2nd step of dispersion analysis). Input to this process is an overtone image file [*(*OT).dat]. From the main menu, select items as shown below:
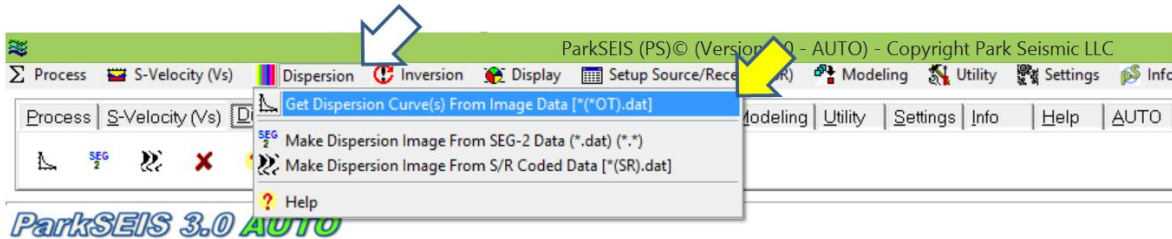

Or, from the tool panel, select the button as shown below:

Select an overtone image file [*(*OT).dat]:
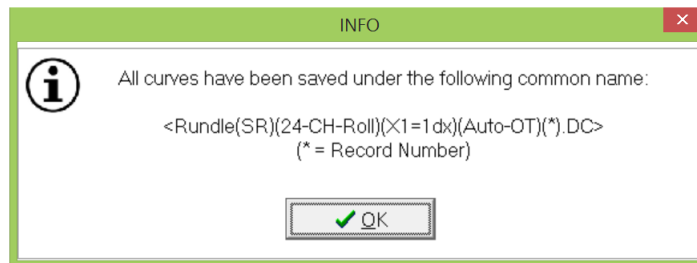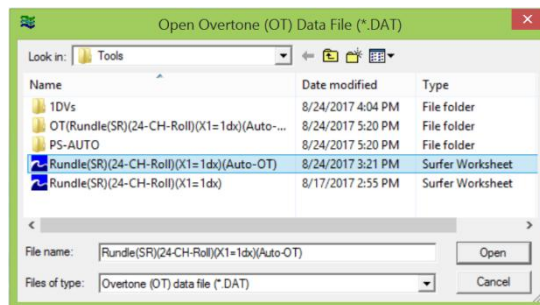

In the top tool panel of the displayed chart, click "AUTO" button:
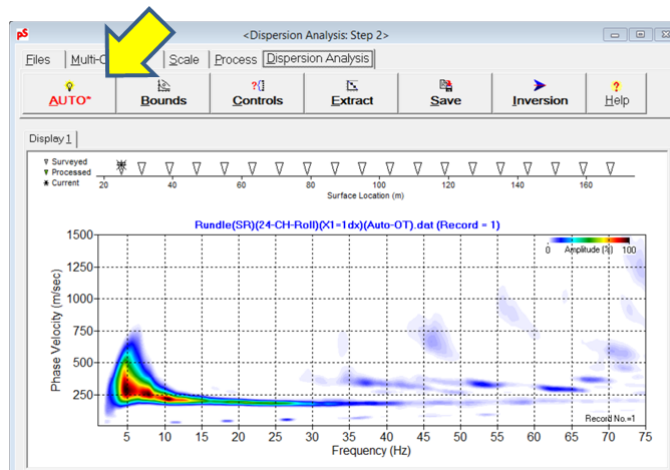
A control dialog will be displayed as shown below. Refer to "Section 6" for options available in this dialog. Click "OK" to proceed with all default parameters.
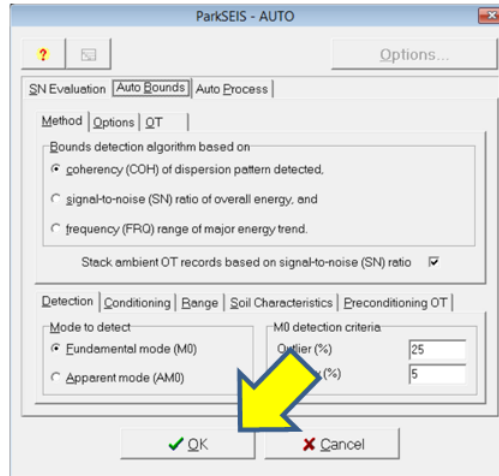
If the input file was generated from a previous AUTO run, then the program will detect it and try to use previous scanning results to facilitate the automatic curve extraction process. Click "Yes" to use them.
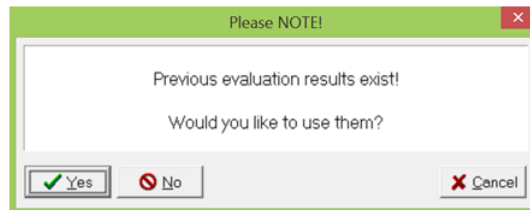
Otherwise, the program would want to proceed and run the "global" evaluation first before the automatic process takes place as shown below. It is always recommended to choose "Yes" (i.e., run the global evaluation) to enhance the effectiveness of the automatic process. If this global evaluation is not pre-performed, then the optimization of parameters for the automatic process will be based only on the local overtone record being processed. This can limit the effectiveness of the automatic process.
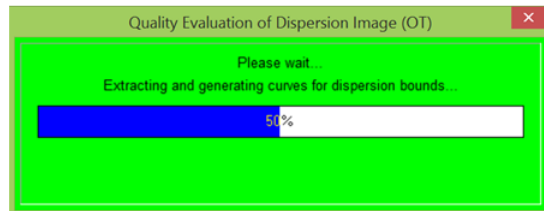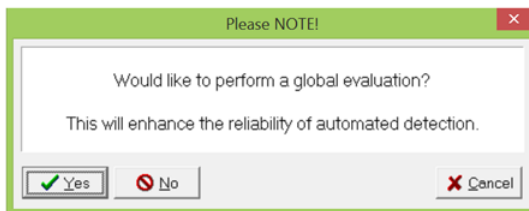
An automatically extracted dispersion curve will be displayed on top of the identified trend of the fundamental-mode dispersion as shown below. Examine the curve and then click "Save" button. The process will move to the next overtone record. Continue to click "Save" button after examination of each extracted curve until all overtone images are processed.
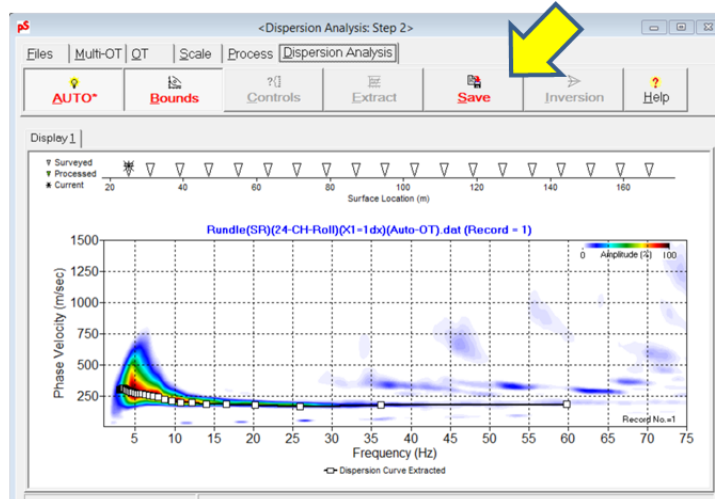
The normal curve-edit process (e.g., delete/add/move data points by using the mouse) can be applied to the extracted curve at any time before clicking the "Save" button as shown below:
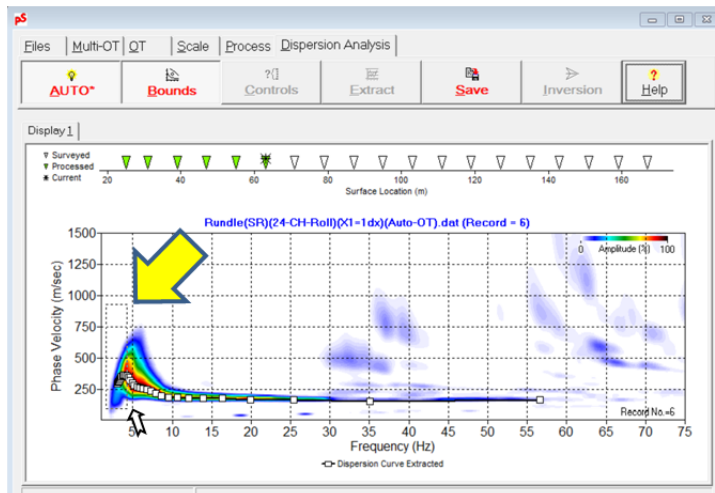
2.5 Scanning Seismic Data for SN Evaluation

This section describes an automatic process used to evaluate the signal-to-noise (SN) ratio of each record in a seismic data file [*(SR)*.dat]. Definition of SN ratio is based on the five attributes of an overtone record (processed from each seismic record) outlined in "Section 1. Overview"; **Pattern**, **Coherency**, **Definition**, **Amplitude**, and **Energy**. The evaluation results can be used to infer the overall "quality" of original seismic field records. In consequence, they can also be used to evaluate the relative confidence level of the final velocity (Vs) cross section by considering the record range that was responsible for specific lateral area in the cross section.

From the main menu, select items as shown below:
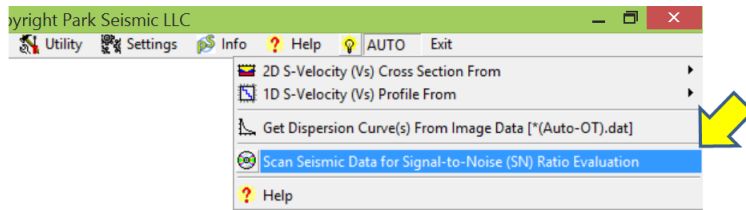
Or, from the tool panel, select the button as shown below:
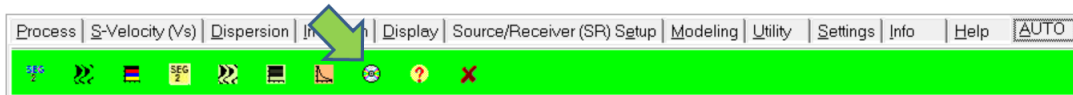
Select a seismic data file previously prepared that has source/receiver (SR) setup encoded [*(SR)*.dat].
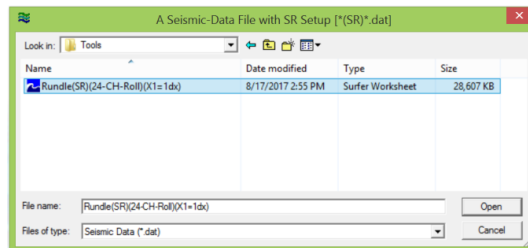
If the file was previously processed in AUTO mode, then the program will detect it and try to utilize the previous results.
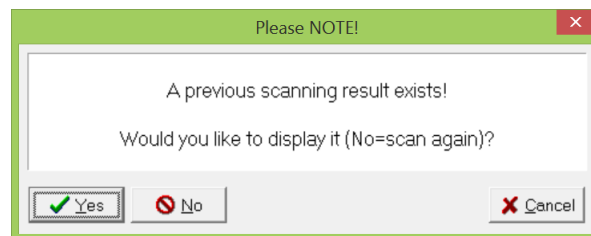
Otherwise, the program will run the scanning again without referring to the previous results as shown below:
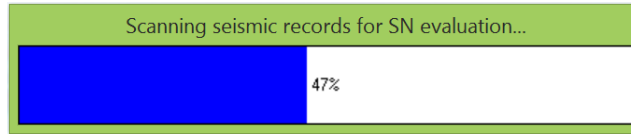
The final scanning results will be displayed in a chart as shown below:
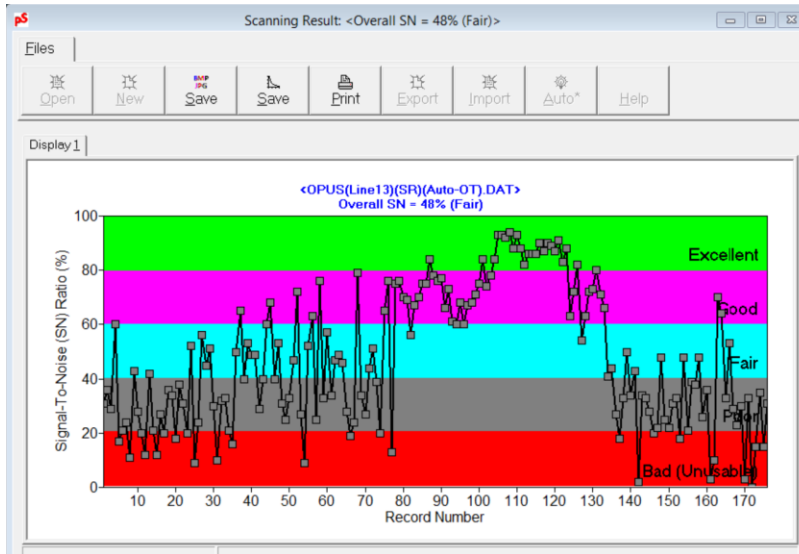
The scanning results shown above indicate that the velocity (Vs) results in 2D cross section corresponding to record numbers approximately in 80-130 are more reliable in comparison to other areas. The relationship between record number of seismic data and lateral distances in the cross section can be found by displaying the table of SR setup from a seismic data display (a button in "View" tab). Range of SN values and corresponding quality descriptions are presented in the table below:

Table 1: Description of SN vs. corresponding attributes.

SN (%)	Category	Quality Description
80-100	**Excellent**	Best quality for AUTO process. Highly reliable results are expected
60-80	**Good**	Good candidate for AUTO process. Reliable results are expected
40-60	**Fair**	Marginal quality for AUTO process. Results should be used with caution.
20-40	**Poor**	Lowest quality for AUTO process. Results should be used with caution.
0-20	**Bad (Unusable)**	Data should not be used for AUTO process.

2.6 "Options..." in AUTO

Options available during an AUTO process are explained here. By nature of an automated process, it is not expected that users will have to visit them often for any better optimization than the default settings the program already provides. **However, only those options that can influence the effectiveness of the overall process are briefly explained in this section to help understand what might have caused some features observed in the final result of velocity (Vs) profile.**

In the main page of the AUTO dialog, there are two main options of "Dispersion" and "Inversion" analyses as shown below. Both of them are always checked to generate the final velocity (Vs) profile unless the purpose is to generate only dispersion curves automatically (as explained in Section 4). To access all other options available, click the "Options..." button as shown below.
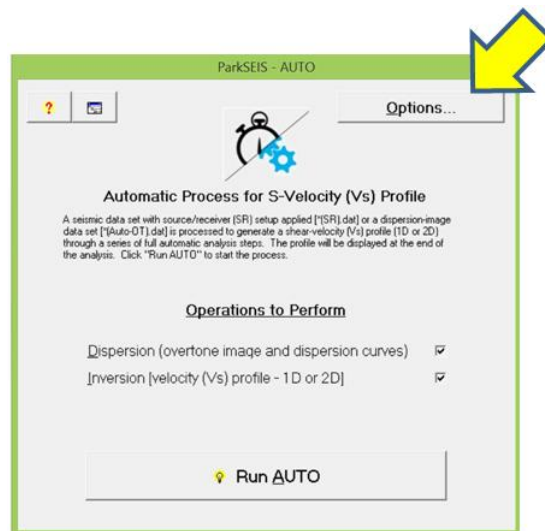
Auto Process Tab

Those options that can directly influence on the final velocity (Vs) profiles are included in this tab. The "**Save graphic (*.jpg) of extracted dispersion curve and image**" will save, if checked, the image (in JPG) of extracted dispersion curve superposed on the corresponding dispersion image during the automatic process of the curve extraction.

Spatial Resolution

This option, shown below, can influence on the (horizontal and vertical) resolution of the final 2D cross section. In theory, the highest resolution is most desirable. However, there are always adverse influences from the noise wavefields (i.e., everything rather than the fundamental-mode dispersion energy trend). Efforts to increase the detection ability of M0 trend in an overtone record will inevitably decrease the resolution at certain parts of dispersion image. Therefore, in practice, the automatic process is a tradeoff between a theoretical resolution and a practical effectiveness. Default values (75%) for both horizontal and vertical resolutions are the most optimum values empirically calibrated. The lower values will decrease the overall spatial resolution, but make the detection process more effective by suppressing adverse influences from the noise wavefields. On the other hand, the higher values may

increase the resolution if noise wavefields are insignificant. Therefore, for a seismic data set with complications (e.g., strong ambient noise and higher modes, severe lateral variation of subsurface conditions, poorly developed surface waves, etc.), the lower values (e.g., 50%) for both "**Horizontal**" and "**Vertical**" resolutions will make the automatic process more reliable. If the data set is in good quality, then the higher values (e.g., 100%) can generate a cross section with the highest spatial resolution the automatic process can ever achieve. The data quality can be assessed by the "Scanning" option described in Section 5. If the overall scanning result is "Good-Excellent" (≥ 60%), then the resolution values can be increased above the default values (e.g., 100%). If the result is "Poor-Bad" (≤ 40%), then it is recommended to lower the values (e.g., 50%).

Dispersion and Inversion

Options to change parameters for dispersion ("**Dispersion Curve**") and inversion ("**Inversion**") analyses are shown below. They are the same options available when performing each analysis in a manual mode.
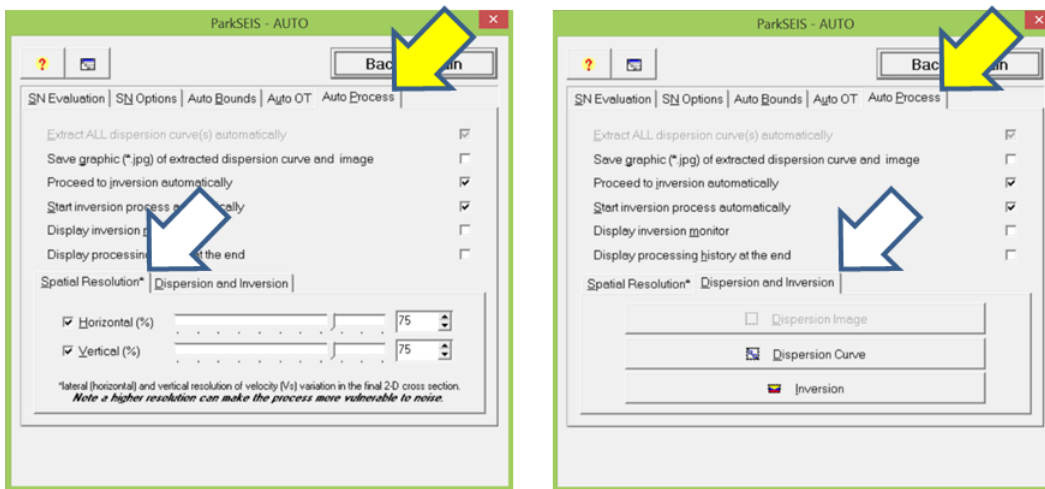
Auto OT Tab

Parameters that can influence some features of the overtone records [*(Auto-OT).dat] are available on this tab. For example, in the "**Frequency range (Hz)**" box, you can change the start ("**MIN**") and ending ("**MAX**") frequencies, as well as the interval ["**Interval (after resampling)**"], of the overtone record.   All options available in this tab are directly related to the suppression of computational artifacts inevitably generated from a 2D wavefield transformation.

Wavelength and Smoothing

The shortest ("**MIN**") and the longest ("**MAX**) wavelengths in the overtone record are specified. Energy outside this bound will be muted (i.e., zeroed). Smoothing of an overtone image is applied by the parameters specified in the "**OT Smoothing (# of samples)**" box as shown below.   A higher number will apply a wilder smoothing along the corresponding axis (i.e., "**Frequency axis**" or "**Phase velocity axis**").

Tapering and Filtering

Tapering at the beginning and ending parts of the frequency axis of an overtone record is specified in the "**Tapering**" box; 0=no tapering, 1=weak tapering, 2=mild tapering, and 3=strong tapering will be applied. The exact amount of tapering for each option (0-3) is determined with reference to the spectral characteristics of the original seismic record. The "**Noise filter**" specifies the extent (%) of filtering background noise wavefields in an overtone record.
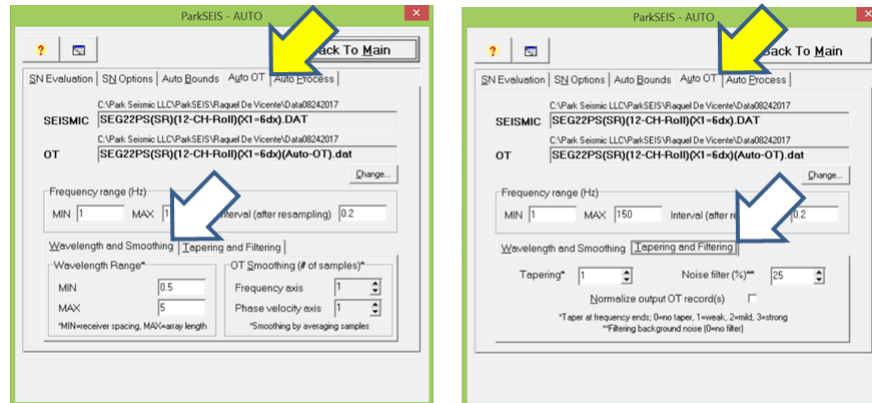
Auto Bounds Tab

Parameters that can influence some features of the special overtone data set [*(Bound-OT).dat] can be changed from this tab. This overtone data set is generated by recognizing patterns in the original overtone record data set [*(Auto-OT).dat]. It is used to generate a special type of dispersion curve [*(BoundDC).DC] for each overtone record that is in turn used to set the (lower and upper) bounds for the subsequent process to extract a dispersion curve from the original overtone record [*(Auto-OT).dat].

The "**Method**" tab shows different options that can be used to extract the bound dispersion curve [*(BoundDC).DC]. Default option ["**coherency (COH) of dispersion pattern detected**"] is always recommended. "**Options**" and "**OT**" tabs contain parameters that are important only from coding perspectives. The "**Detection**" tab at the bottom of the page shows the mode of detection to be chosen ("**Mode to detect**"). The "**Fundamental mode (M0)**" will focus only to the fundamental mode during the detection process, whereas the "**Apparent mode (AM0)**" will focus on the pattern created by the strong energy trend without evaluation of the possible mode(s). All other options are important only from the coding perspectives.
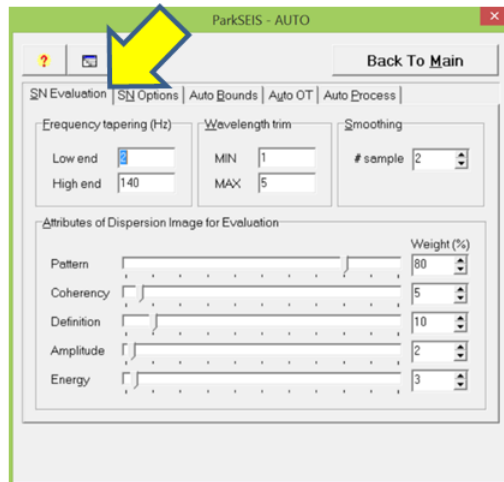
27
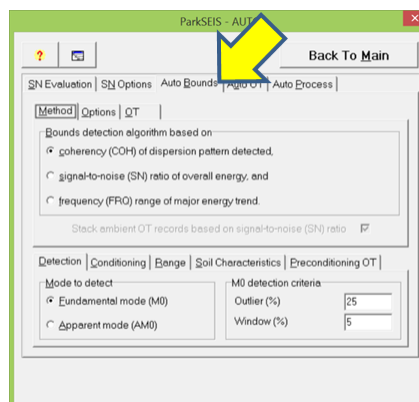
SN Options Tab

Parameters related to a specific method of signal-to-noise (SN) ratio evaluation are gathered on this page. All of them are important only from the coding perspectives.


SN Evaluation Tab

Parameters related to the SN ratio evaluation (by using a specific method) are gathered on this page. All of them are important only from the coding perspectives.

3. Dispersion Image Generation - New Options Added

The two options of "OT Tapering" and "Noise Filter" are added in the dispersion-image generation module that can be reached from the main menu by going to "Dispersion." It can be started by importing seismic file(s) in SEG-2 format or a file in PS format [*(SR).dat] as illustrated below. It is assumed input data already has field geometry encoded.
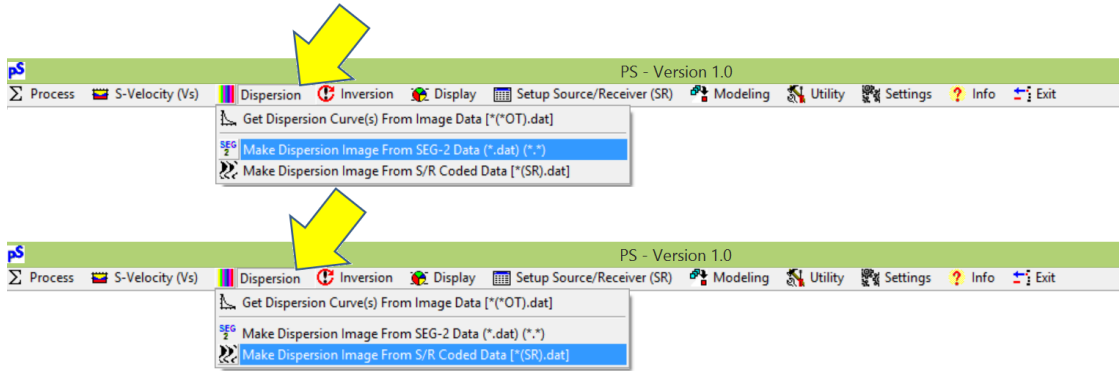
When the control dialog is displayed, click "Options..." and then "Full List" as shown below.
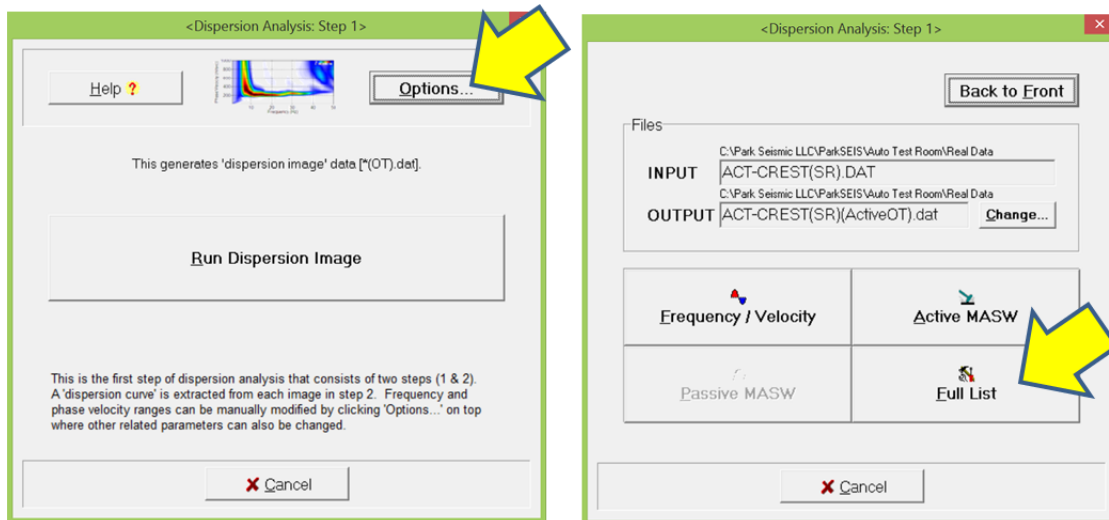
The two options ("OT Tapering" and "Noise Filter") are found in the appropriate tabs as illustrated below.

OT Tapering applies tapering in the dispersion image on both edges of frequency axis. The frequency ranges for tapering are determined from the spectral analysis of input seismic record. The degree of tapering is set by a number in 0-3; 0 = no tapering (default), 1 = weak, 2 = mild, and 3 = strong. Examples with "0" and "2" degrees, respectively, are displayed below.

Noise Filter applies a noise reduction process to attenuate the background energy so that the most dominant energy trend can become more distinguished. A higher number will apply a wilder filtering of background noise. Examples of "0" and "25%" are displayed below.

Locations of "OT Tapering" (left) and "Noise Filter" (right) in the control dialog are illustrated below.
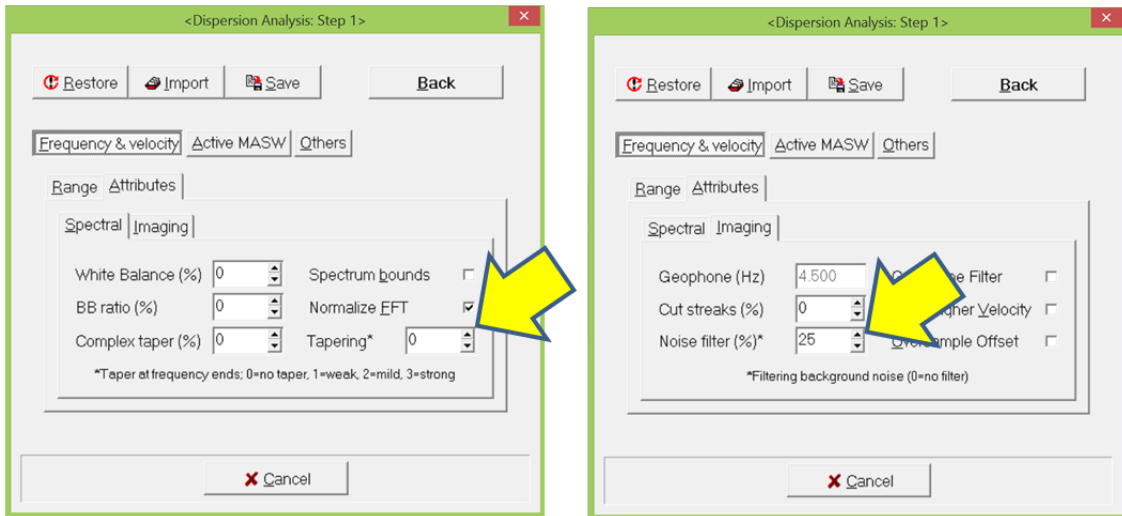
Dispersion images processed with no ("0") (left) and mild ("2") (right) tapering degrees are illustrated below.
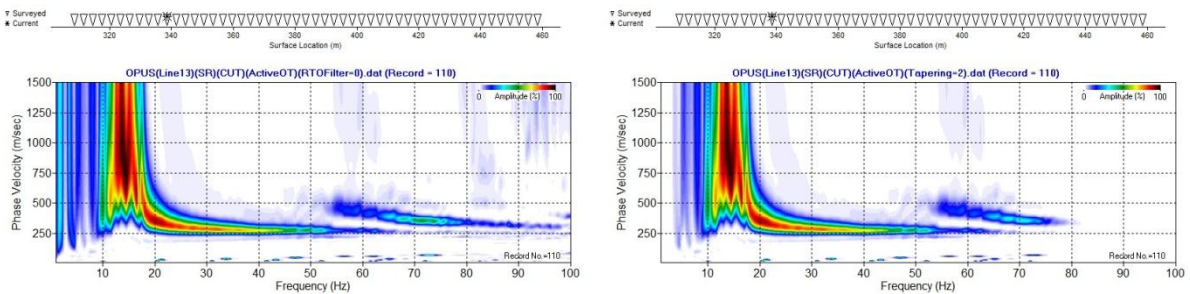
Dispersion images processed with "0%" (left) and "50%" (right) noise filter are illustrated below.
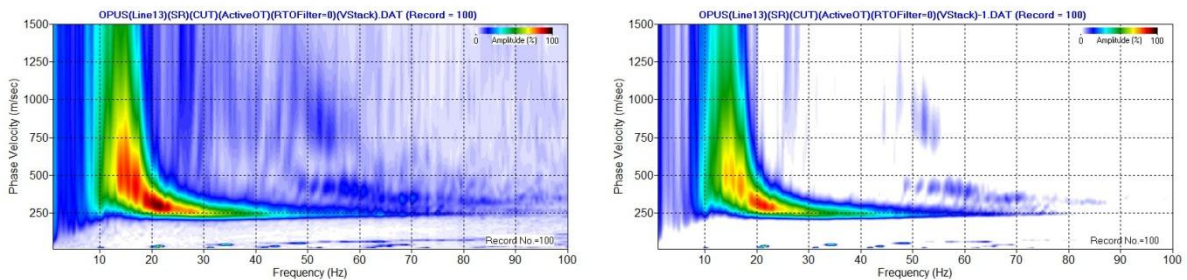
4. Seismic Site Characterization (NEHRP vs. Eurocode)

Open a 1D velocity (Vs) profile by going to "Display" -> "S-Velocity (Vs) Data" -> "1-D Vs Profile (*.LYR)" as shown below.
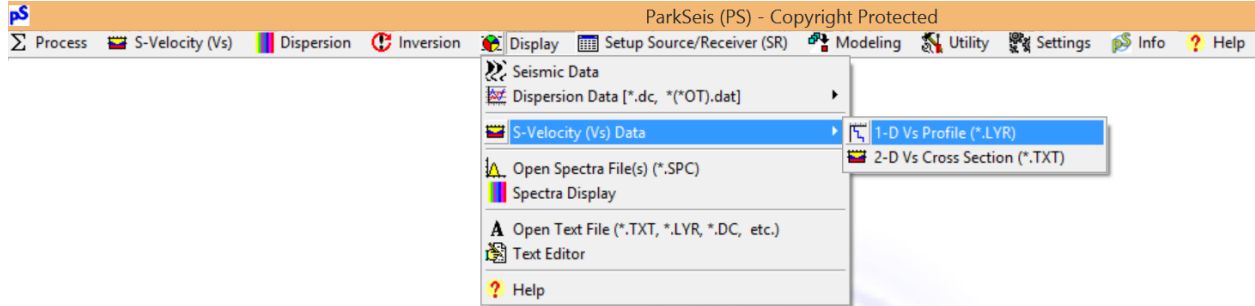
Click "Vs30m" button located at the bottom right corner as shown below.
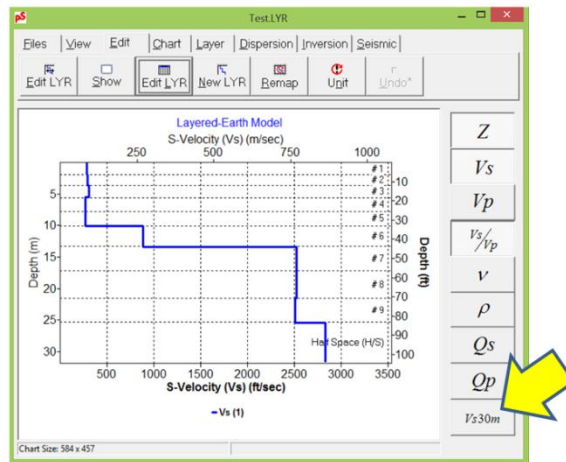
Choose which standard you would like to use to characterize the site from the dialog as shown below; default option for US (ft) unit is "NEHRP", while that for metric (m) unit is "Eurocode."

31
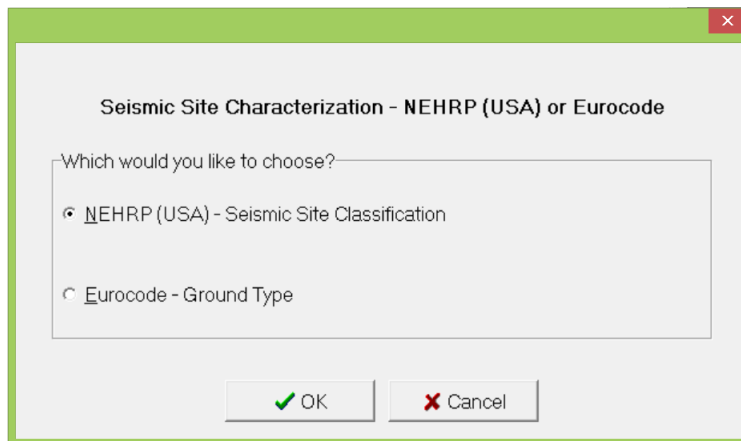
However, any option can be used for the same profile as shown below; "Eurocode" on left and "NEHRP" on right.
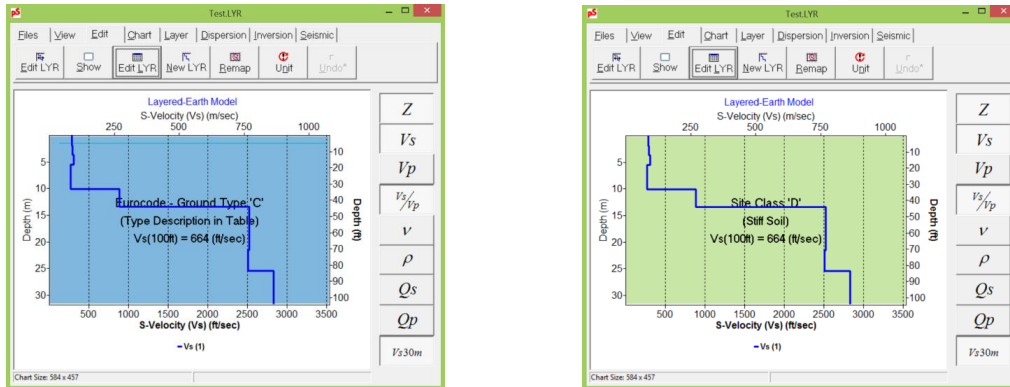
Description table for the corresponding standard is displayed by choosing "Yes" to the following dialog.
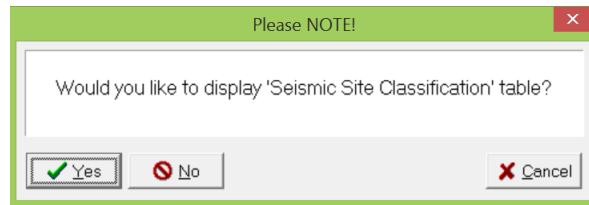
This table can also be displayed by clicking "Vs30m" button in the "View" tab as shown below; normal click for "NEHRP" and right click for "Eurocode" table.
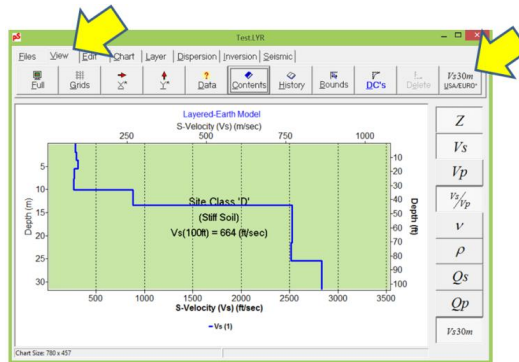
The tables can also be displayed from the main menu by going to "Info" -> "Seismic Site Characterization Table" as shown below. The tables are displayed on next page.

Seismic Site Characterization Tables

"NEHRP (USA)" (top) and "Eurocode" (bottom)

Seismic Site Classification (Vs$^{30\text{-m}}$ or Vs$^{100\text{-ft}}$)
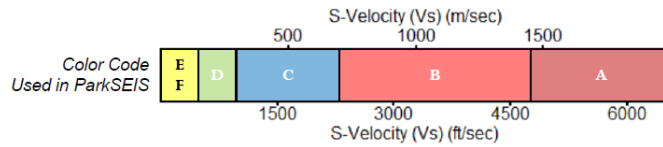
NEHRP* Seismic site classification based on shear-velocity (Vs) ranges.

Site Class	S-Velocity (Vs) (ft/sec)	S-Velocity (Vs) (m/sec)
A (Hard Rock)	> 5,000	> 1500
B (Rock)	2,500 − 5000	760 − 1500
C (Very Dense Soil and Soft Rock)	1,200 − 2,500	360 − 760
D (Stiff Soil)	600 − 1,200	180 − 360
E (Soft Clay Soil)	< 600	< 180
F (Soils Requiring Add'l Response)	< 600, and meeting some additional conditions.	< 180, and meeting some additional conditions.

* National Earthquake Hazard Reduction Program (www.nehrp.gov)

Ground Types - Euro Code*

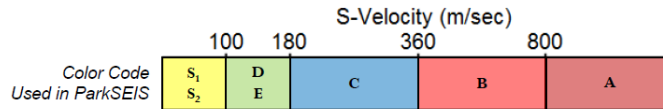| Type	Description	Parameters Vs30[a]	N_{SPT}[b]	C_U[c]
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	–	–
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth.	360 − 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters.	180 − 360	15 − 50	70 − 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with Vs values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with Vs > 800 m/s.			
S$_1$	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	–	10 − 20
S$_2$	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A − E or S1			

* defined by shear wave velocities (Vs's) in the top 30 m, and also by values for N_{SPT} and C_U [from "**Eurocode 8: Seismic Design of Buildings Worked Examples (EUR 25204 EN – 2012)**" by Bisch et al. (2011)]
[a] shear wave velocities in the top 30 m (m/sec), [b] standard penetration test (blows/30cm), [c] undrained cohesive resistance (kPa)

5. Table 1 - Table of Updates

Type Code

    DA: Dispersion Analysis, **DD:** Dispersion Display, **SD**: Seismic Display, **GE:** General, **IA:** Inversion Analysis, **SR:** Source/Receiver (SR) Setup, **Vs1D:** 1-D Vs Display, **UT:** Utility

Type	Content	Applied (√)
DD	When multiple number of dispersion images (OT's) are stacked to generate a stacked image, the program offers an option to filter background noise by providing a dialog where the degree of filtering (%) can be specified (0%=no filtering).	√
SR	When the source/receiver (SR) setup is run by the graphical Wizard, more warning and notification messages can be issued at various stages of the execution to avoid confusions and misconceptions. For example, when a negative value is entered for the source offset (X1), a warning message will pop up to notify it is a distance (not a coordinate) that should always be a positive number. Then, the program resets the number to a positive equivalence of the entered value.	√

6. Table 2 - Table of Bug Fixes

Type Code
    DA: Dispersion Analysis, **DD:** Dispersion Display, **SD**: Seismic Display, **GE:** General, **IA:** Inversion Analysis, **SR:** Source/Receiver (SR) Setup, **Vs1D:** 1-D Vs Display, **Vs2D:** 2-D Vs Display, **UT:** Utility

Type	Content	Fixed (√)
DA	When generating a dispersion image file [*(*OT).dat] from a passive seismic data set, resulting image data sometimes contains invalid header parameters; for example, negative number of samples or a negative frequency interval in the file. This was caused by improper specification of frequency parameters that are used to generate the image file. This has been fixed so that the program notifies the issue and automatically adjusts values to avoid the conflict.	√
DA	When generating a dispersion image file [*(*OT).dat] from a passive seismic data set, the program sometimes hangs during the evaluation stage of input seismic data without issuing any notification. This was caused by a glitch in the spectral evaluation algorithm and has been fixed by replacing it with a more robust algorithm.	√
DD	When dispersion curves [*.DC] are displayed, sometimes (depending on the previous history of the file) the unit in the phase velocity axis is mistakenly labeled as "m/sec" even if it should be "ft/sec." This has been fixed.	√
DD	When a dispersion image file [*(*OT).dat] is displayed, the original features of the image would not be restored when the file has only one image record. This has been fixed.	√
GE	When an input file (of any type) is imported from the file open dialog, the program hangs when there are foreign characters included in the file path without any message. This has been fixed and the program will notify this so that the user can fix the source of the issue.	√
SR	When the source/receiver (SR) setup is run by importing a text file, the comment line indicator ("//") appearing in the 1st line was not recognized by the program causing either system crash or invalid output data. This has been fixed.	√
SR	Decimal points of receiver offsets were previously ignored during the source/receiver (SR) setup run by importing parameters specified in a text file; for example, "1.5" was taken as "1.0" previously. It has been fixed so that up to two (2) decimal points are accounted for if the receiver spacing is smaller than 0.2. Otherwise, at least one (1) decimal point is accounted for.	√
Vs2D	When a bedrock velocity contour is drawn in a velocity (Vs) cross section that has a topographic correction applied, the drawn line does not account for the topographic variation. This has been fixed.	√