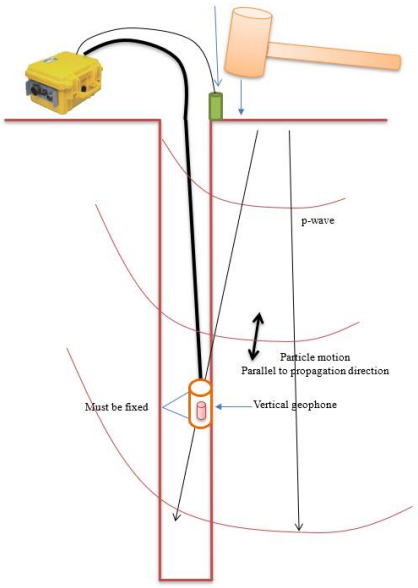
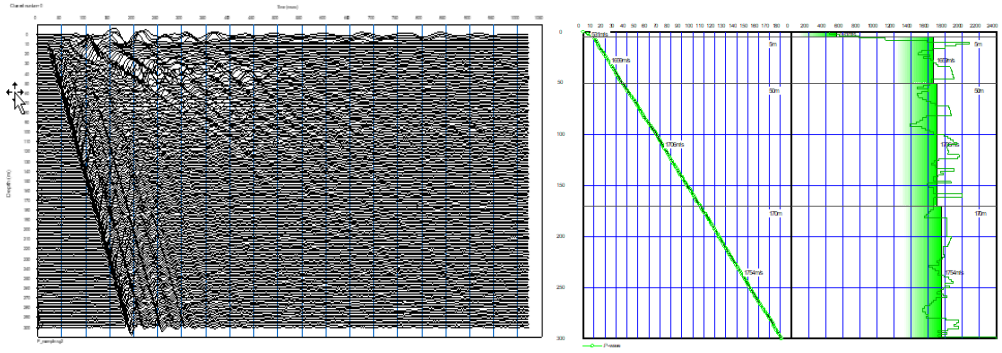
SEISIMAGER/DH
USER'S MANUAL

Software for the Analysis of
Borehole Seismic Data

Version 2.0
PN 770-00119-01

July 2024





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APPENDICES

1 INTRODUCTION

Welcome to SeisImager/DH! SeisImager/DH is an easy-to-use, yet powerful program that allows you to analyze downhole seismic data obtained through various source-receiver configurations. SeisImager/DH includes functions to perform the following basic procedures, and more.

- Input and display data.
- Control how data is displayed.
- Make changes/corrections to data files and save them.
- Handle two horizontal components of data together.
- Show two opposite-direction sources together.
- Pick first arrivals for both p- and s-waves.
- Calculate interval velocities from first arrivals.
- Display travel time curves and velocity models in graphical form.

SeisImager™ is the master program that consists of seven modules for refraction, downhole, and surface wave data analysis. The individual modules are Pickwin™, Plotrefa™, WaveEq™, PSLog™, SPACPlus™, and GeoPlot™. The Surface Wave Analysis Wizard™ is not a separate module but automatically calls on specific functions from Pickwin, WaveEq, and GeoPlot to walk you through the analysis process. The overall structure of SeisImager is shown below:

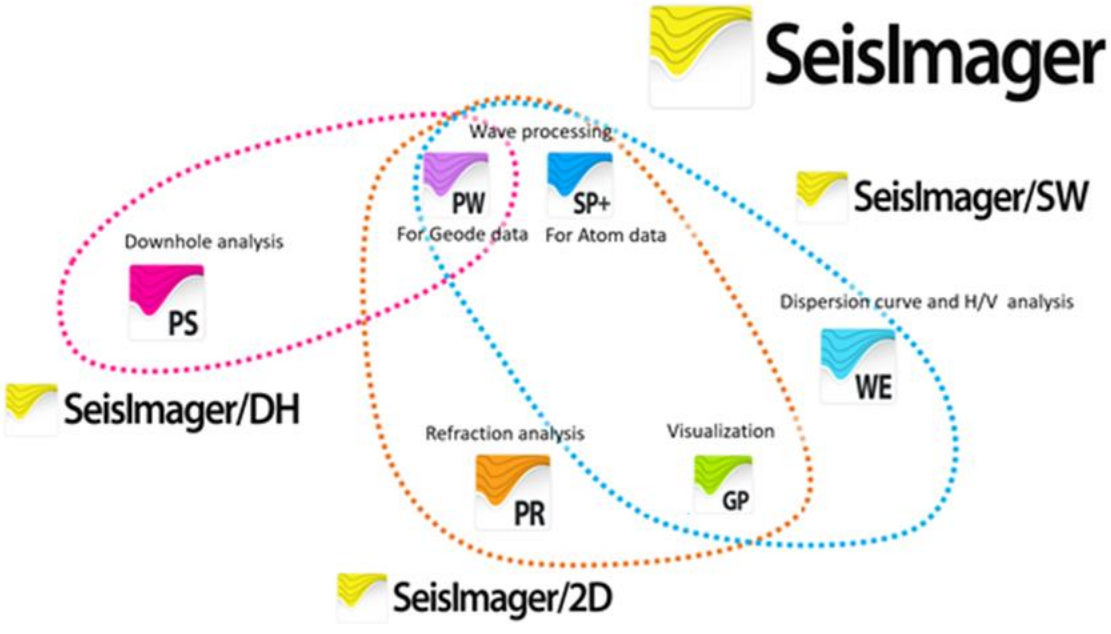


Figure 1: SeisImager family of applications.

Pickwin and PSLog are the main modules used for downhole seismic data analysis, making up the program called SeisImager/DH™.

For seismic refraction data analysis, Pickwin and Plotrefa make up the program called SeisImager/2D™. A separate manual for SeisImager/2D can be found here.

For surface wave data analysis, Pickwin, WaveEq SPAC+ and GeoPlot make up the program called SeisImager/SW™. A separate manual for SeisImager/SW can be found here.

Due to the overlap of Pickwin with SeisImager/DH, reference is made in this manual to the SeisImager/2D and SeisImager/SW manuals for explanation of the common Pickwin menus.

SeisImager is available for rent in run-time periods of 40, 75, and 250 hours. The rental package by default includes both SeisImager/2D and SeisImager/SW-2D.

Although this manual can be printed, **it was designed as an online resource, and includes many internal and external hyperlinks.** It will be updated on a semi-regular basis, and a current version will always be available for download on our site. Be sure to display the navigation toolbar in Acrobat Reader (as of this writing, the toggle switch was F8) to simplify navigation:

Figure 2: Acrobat Reader navigation toolbar.

If your version of Acrobat Reader does not have the above tool bar, use *Alt+Left Arrow* to return to the previous view after clicking on a link.

The manual makes liberal use of color, so if you elect to print it, using color is highly recommended. There are also links to online videos, so an internet connection is useful (these videos are also available here and can be stored on your hard drive for offline viewing).

Finally, we are very interested in your constructive criticism of both this manual and the software itself. Please contact us at sales@geometrics.com with any comments you might have.

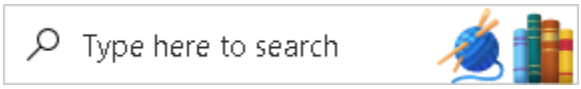
Note: *This is a general manual covering all features of all versions of SeisImager/SW. There are several tiers of software available, all having different sets of features. If you see features described in the manual which are not present in your software, it is because the level of software you purchased does not include those features.*

Note: *SeisImager/SW includes many features that are very rarely used, and only then by a select few, often only those who requested the features in the first place. The average user will generally*

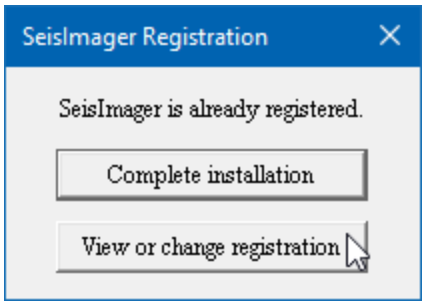
have no need for them. In the interest of completeness, these features, although not described, are included in this manual, with a pointer to our support email. If you see something that you think you might wish to make use of, please contact SeisImager support.

***Note:** SeisImager/SW is very complex software "under the hood" and may grow unstable and give spurious results if many different models are run in one session or if there are unit conflicts between modules. It is therefore best to begin a new instance of the application to run new models. If the program does exhibit instabilities, follow this procedure:*

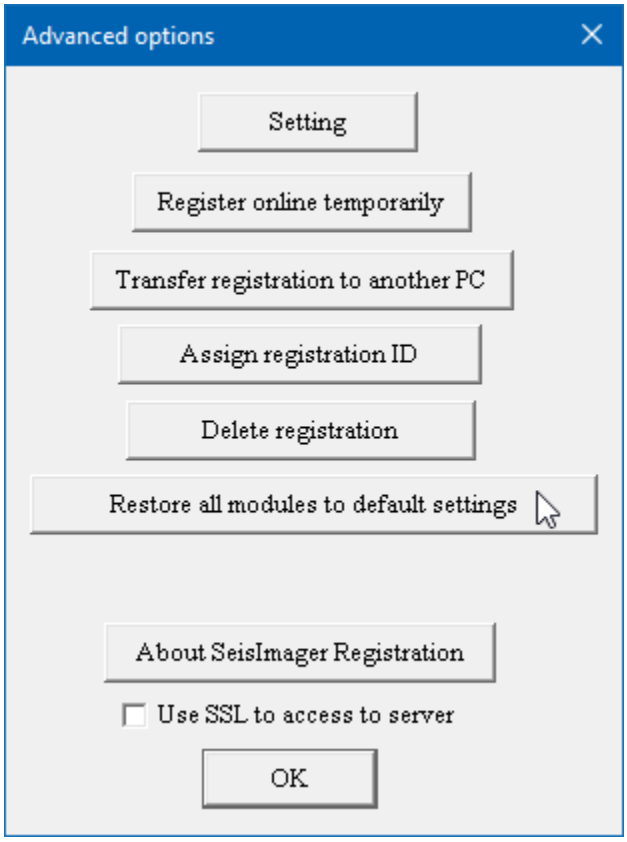
- Close all SeisImager modules.
- In the Windows search box,



Type in "SeisImager Registration." You will see the following:



- Select *View or change registration*. You will be presented with the **SeisImager Registration** dialog box.
- Select Advanced options (upper right) and then press Restore all modules to default settings and then press OK.



Note: *Throughout this manual, you will find that certain menu items are greyed out. There are two reasons for this. The most common is that the feature is not applicable to that dataset or that point in time. The other reason is that some items may not be available under your license.*

2 INSTALLING THE SOFTWARE

The SeisImager USB stick is supplied (1) for trial evaluation of the programs, (2) for purchase, rental, or upgrade of one or more of the programs, or (3) with purchase of an ES-3000™, Geode™, or StrataVisor NZXP™, or Atom™ seismograph, which all include the Lite version of SeisImager/2D. The USB contains all programs and all documentation.

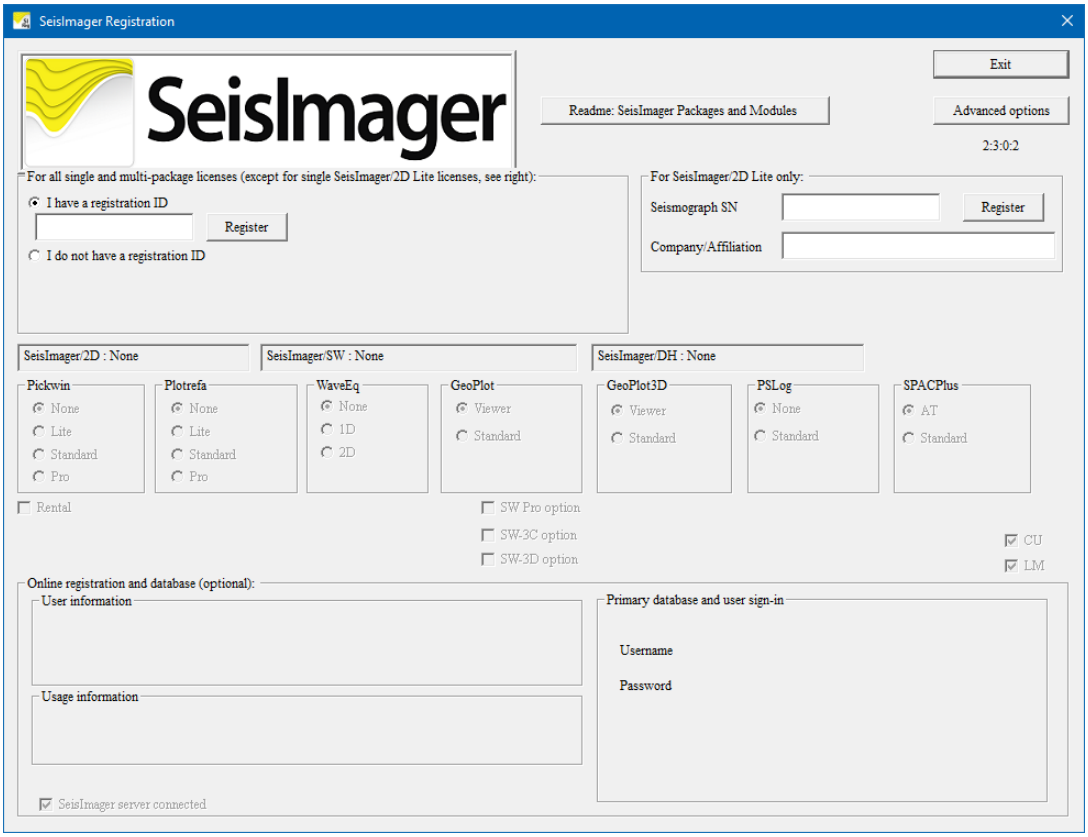
Occasionally, there will be a software release in between USB releases. In this situation, the USB will be labeled with a notice to download the latest version.

Note: *Even if the USB is not labeled with instructions to do so, it is best practice to download and install the latest software prior to installation, as SeisImager is updated frequently. The USB is convenient, especially if you do not have an internet connection. However, if you* ***do*** *have an internet connection, we highly recommend that you skip the USB for installation altogether. If you do so, be sure to download the newest documentation as well.*

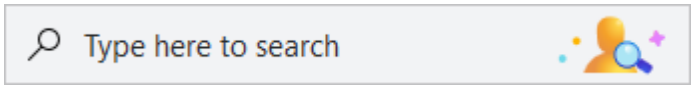
Note: *You must have administrator rights to install the software. After installation by an administrator, users with lower-level privileges can use the software.*

To install or update the software, click on the file named **SeisImager.msi** (or SeisImager_xxxx.msi). If SeisImager is already installed on your computer, you will be prompted to remove it or repair it. Remove the software, run SeisImager.msi again, and then simply follow the prompts.

After the installation is complete, you will be presented with the registration screen:

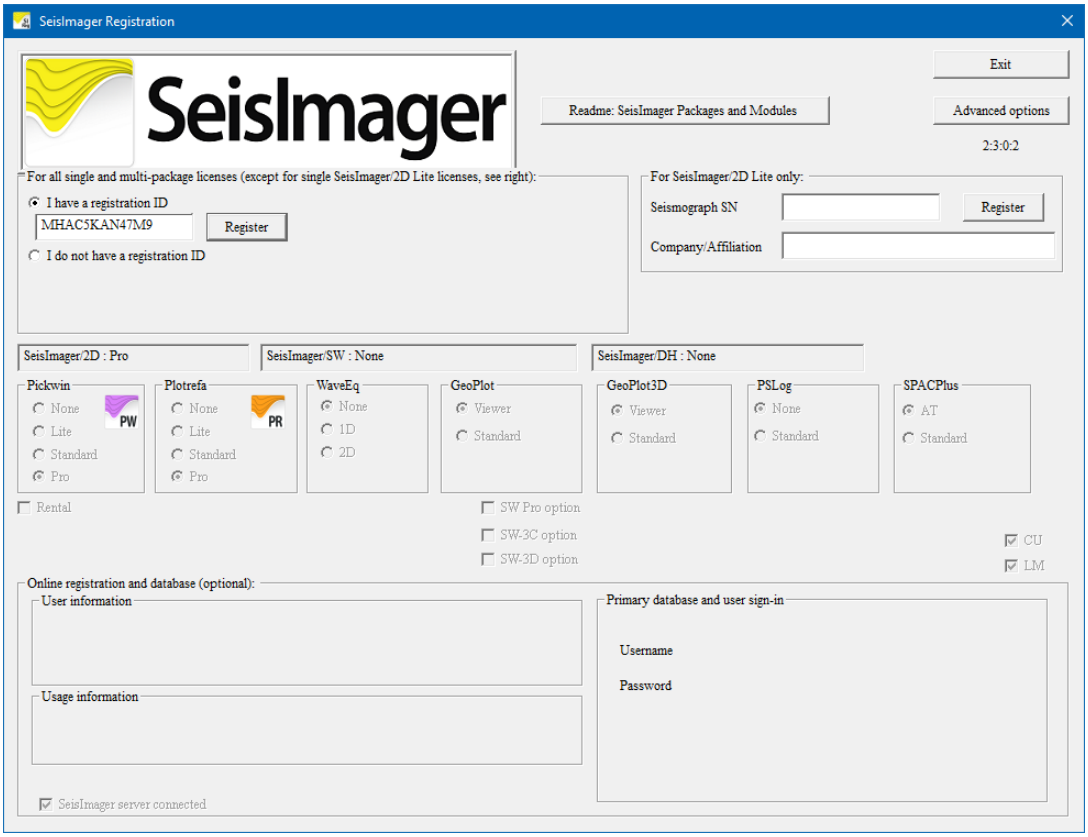


If you already have a registration ID, indicate as such, type it in, and press *Register*. If you do not have an ID, *click I do not have a registration ID*, and send your keyword and order number or seismograph serial number to support@geometrics.com. You will be given a registration ID that will enable the products that you purchased or rented. You may return to this screen later by typing “SeisImager Registration” into the Windows search box at the lower-left of your desktop:



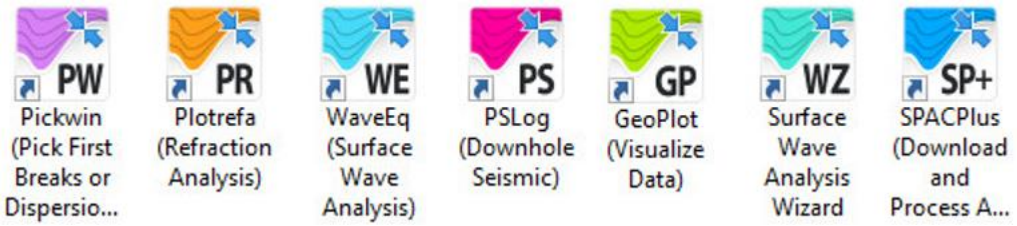
The programs enabled by the registration ID will be reported in a series of messages. Click *OK* to accept each message.

After these messages have appeared, the register will reflect the programs that have been registered, as shown below. In this case, Pickwin Pro™ and Plotrefa Pro™ are the programs that have been registered.



Typically, installing an upgrade of the software does not require re-registration, but if you are upgrading from a version older than April 2007, you will need to re-register.

Once installed, the program modules can be opened directly through the desktop icons shown below:

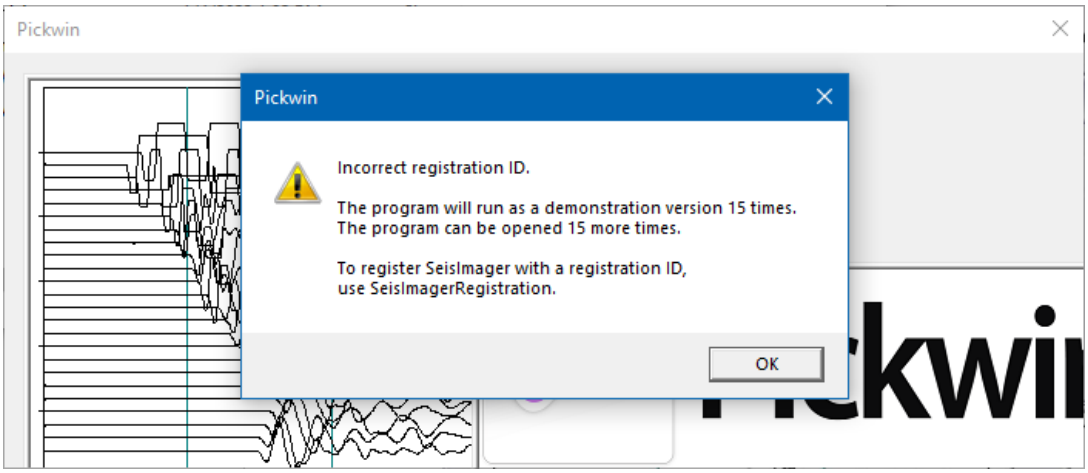


The Surface-wave Analysis Wizard is not a separate module but automatically calls on specific functions from Pickwin, WaveEq, and GeoPlot to walk you through the analysis process. All of the icons (shortcuts) will be copied to your desktop regardless of which program(s) has been purchased or will be used. You may wish to create a folder for the various shortcuts to avoid cluttering on your desktop. Alternatively, you may elect to simply delete the shortcuts that you did not purchase/rent the rights to.

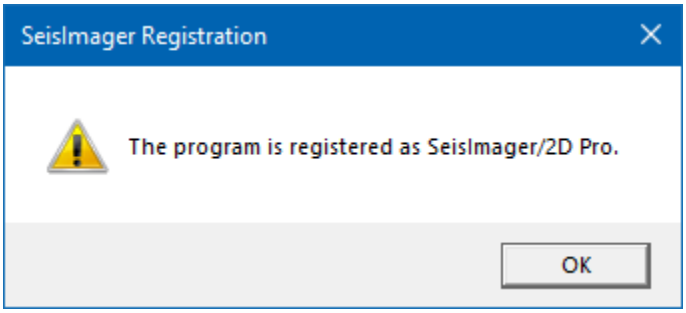
To begin using the software, double-click the appropriate shortcut.

For registered installations, the module opens and is ready for use. The other registered modules are ready for use as well.

For unregistered installations running in demonstration mode, you will be presented with the message shown below. Press *OK*.

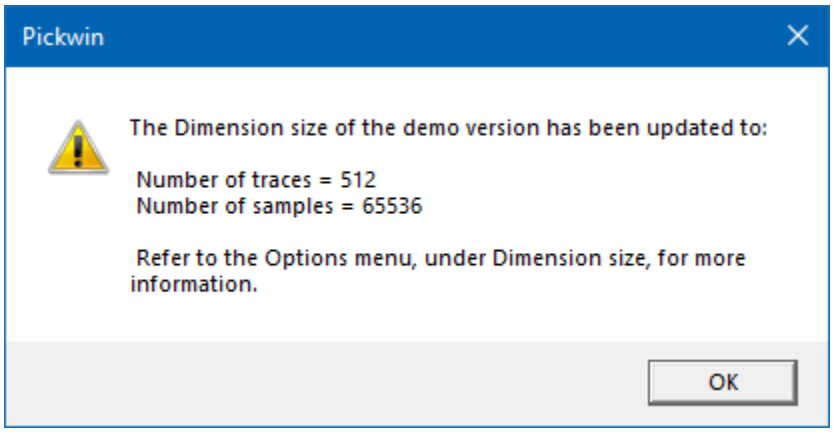


To enter a registration ID after your 15 times in demonstration mode, go to the Windows search box (lower left) and type "SeisImager" to find the SeisImager Registration program as shown above. Open the register and email the keyword to support@geometrics.com with your order number and seismograph serial number (if you purchased the software with a seismograph), and we will reply with a registration ID to enable the version of the software you have purchased. Once received, enter the registration ID press OK. You will see a message like the following:



Once the software is registered, the data input dimensions of the demonstration version will be updated to reflect the limits of the program purchased. You will see a message like the one

below. Press *OK*.



This completes the description of all possible registration pathways.

As mentioned previously, the Lite version of SeisImager/2D comes free with all seismograph purchases, so if you have purchased SeisImager/SW with a seismograph, you are also entitled to the Lite version of SeisImager/2D. If you do not already have a license for SeisImager/2D, Lite or otherwise, but would like to order a copy, please contact us at support@geometrics.com.

A general recommendation when using SeisImager is to close and reopen the software modules or open a second instance of the software modules to start new, separate analyses. The programs are efficient and quickly launch so this is easy to do and will prevent complications when processing data.

Regarding making report graphics and documenting your data processing, SeisImager includes the ability to print graphics to a printer or pdf, as well as save images to PNG, JPG, BMP, or GIF format. You might also find it handy to have a screen capture program such as HyperSnap from Hyperionics. Bitmap screen captures can be quickly and easily made at the desired stages of processing and saved for import into Microsoft Word or other applications.

For more advanced graphics, consider Geometrics GeoPlot.

3 BLOCK DIAGRAM OF PROCESSING FLOW

Figure 3 shows a block diagram of downhole seismic processing using SeisImager/DH. First, Pickwin edits waveform data and picks the first arrivals. Next, PSLog calculates velocity models from first arrivals picked by Pickwin. Generally, the downhole seismic method measures both p- and s-wave velocity. Sources and receivers used in downhole s- and p-wave data acquisition are usually different and measurements of the two types of waves are performed separately. Therefore, Pickwin and PSLog process p- and s-wave data separately and PSLog displays both velocities together at the end.

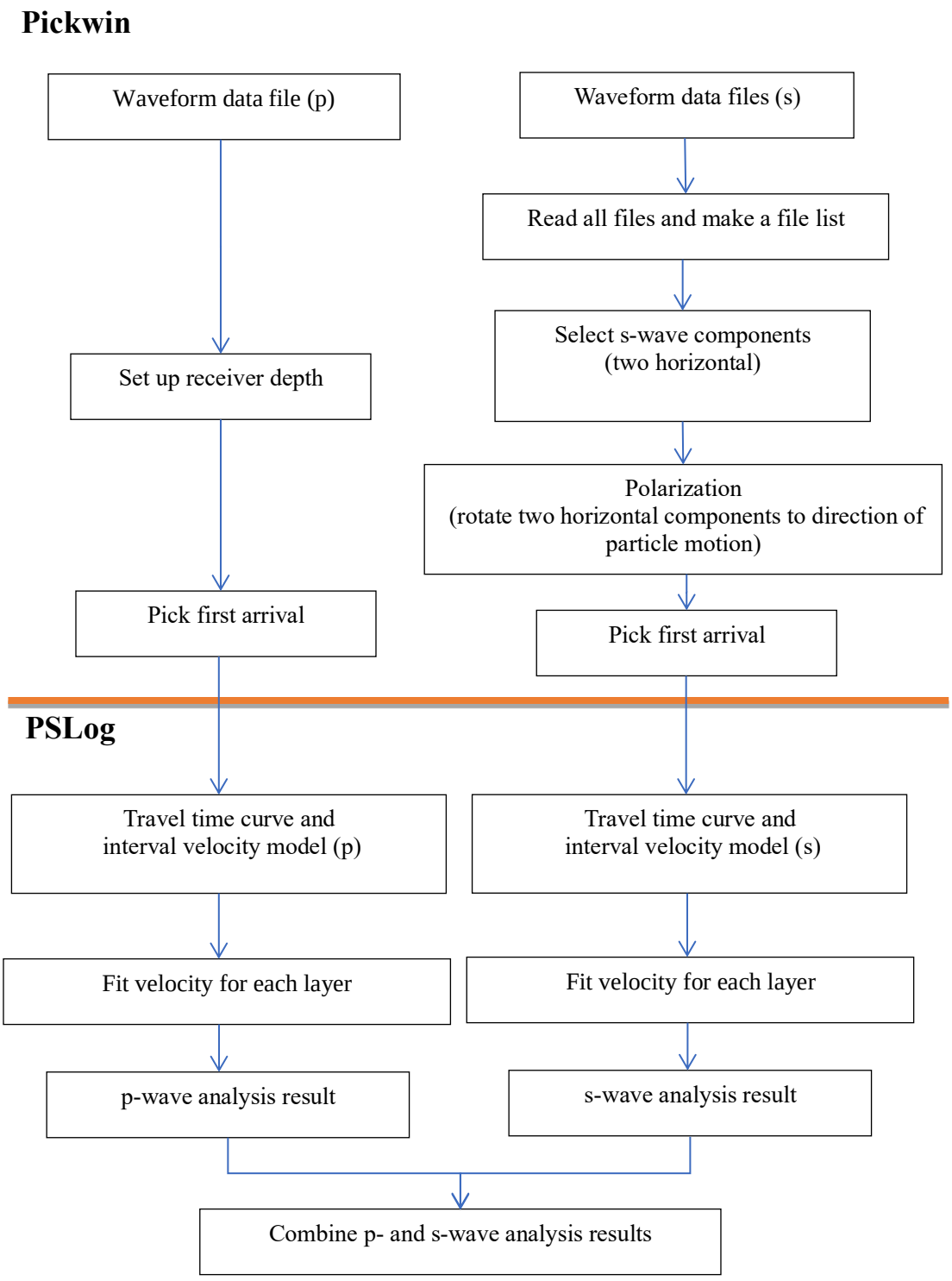
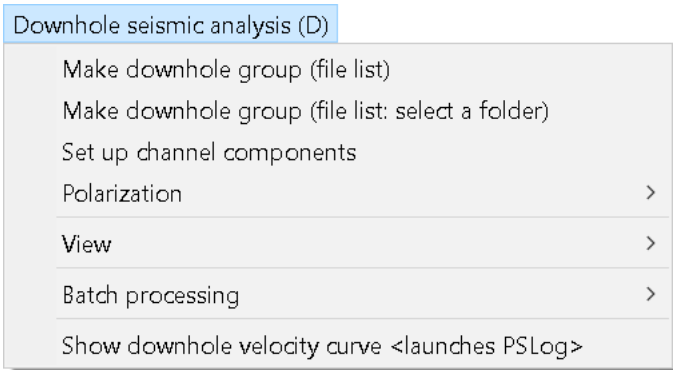


Figure 3: Block diagram of downhole processing flow.

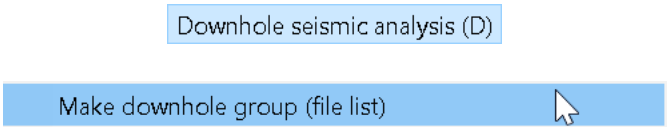
4 THE PICKWIN DOWNHOLE SEISMIC ANALYSIS MENU

The **Downhole seismic analysis** menu includes basic functions used for downhole seismic data analysis.



Separate manuals exist for SeisImager/2D and SeisImager/SW, and due to the overlap of Pickwin with SeisImager/DH, reference is made to the SeisImager/2D and SeisImager/SW manuals for explanation of the common Pickwin menus.

4.1 MAKE DOWNHOLE GROUP (FILE LIST)

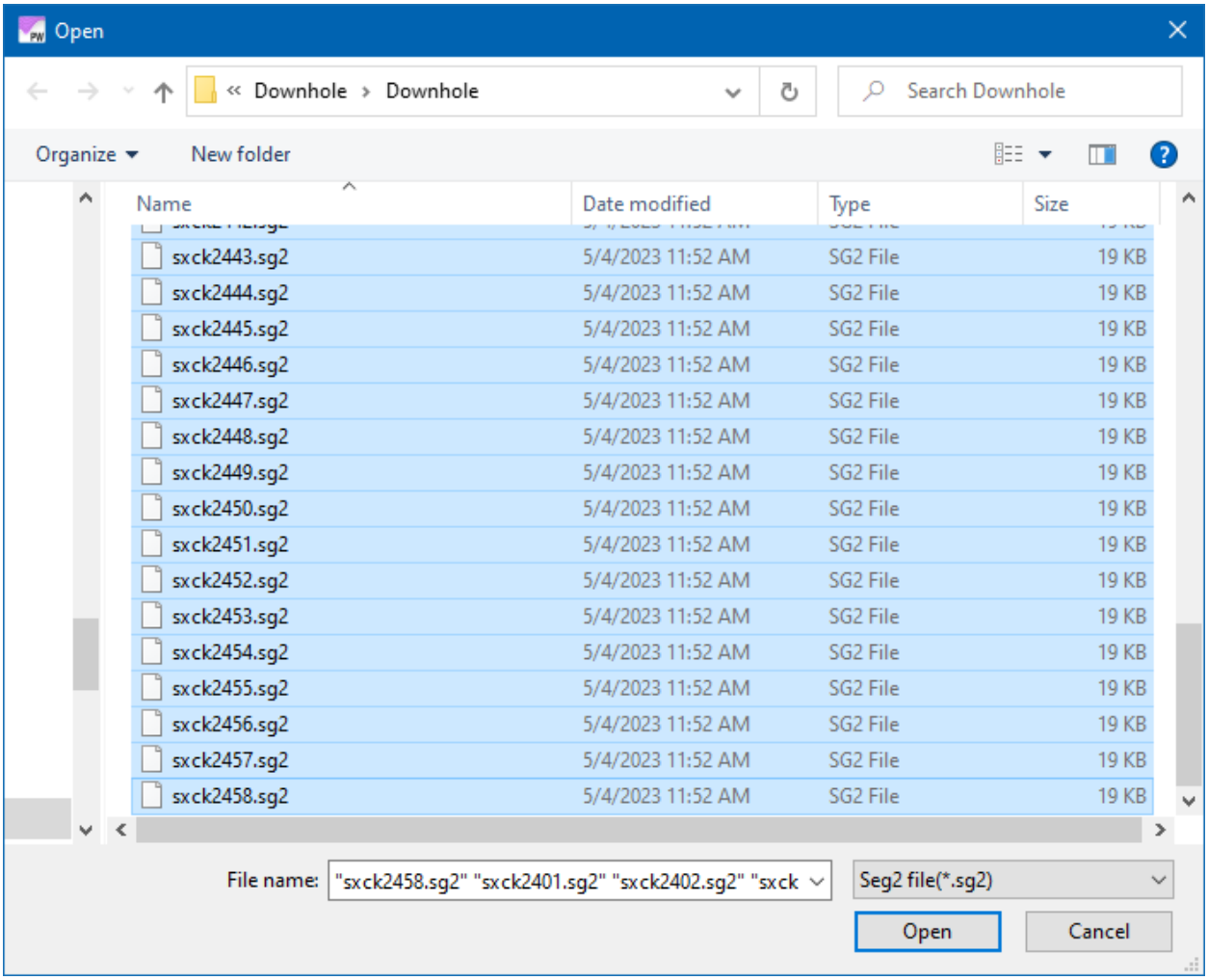


A downhole seismic data analysis is generally started from this menu. A file list is an inventory of data files from any given survey and includes essential information for each waveform trace such as the associated field file identification number and receiver location. In downhole seismic data acquisition, multiple files are generally processed together, and the data set must be input by making a file list.

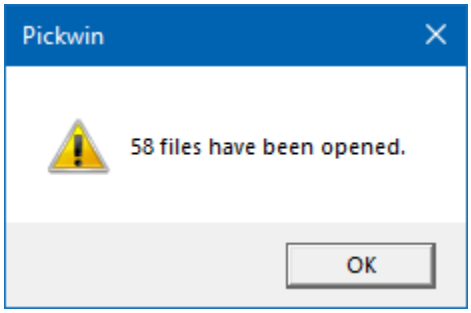
The file list is not only used in downhole seismic data analysis but also in other seismic data analyses such as surface wave data analysis or seismic refraction analysis. A general file list can be made by selecting *File* | *Group (File list)* | *Make file list*. However, downhole seismic data analysis requires unique information, such as source direction and receiver component, and this information can be easily entered by selecting *Downhole seismic analysis* | *Make downhole group (file list).*

To make a list of files, select *Downhole seismic analysis* | *Make downhole group (file list).* Highlight the set of data files to be opened by using the *Shift* key to select a range of files or the *Control* key to select individual files. If *All files* is showing for the *Files of type* setting, take care

not to inadvertently select non-data files as this will cause an analysis error.

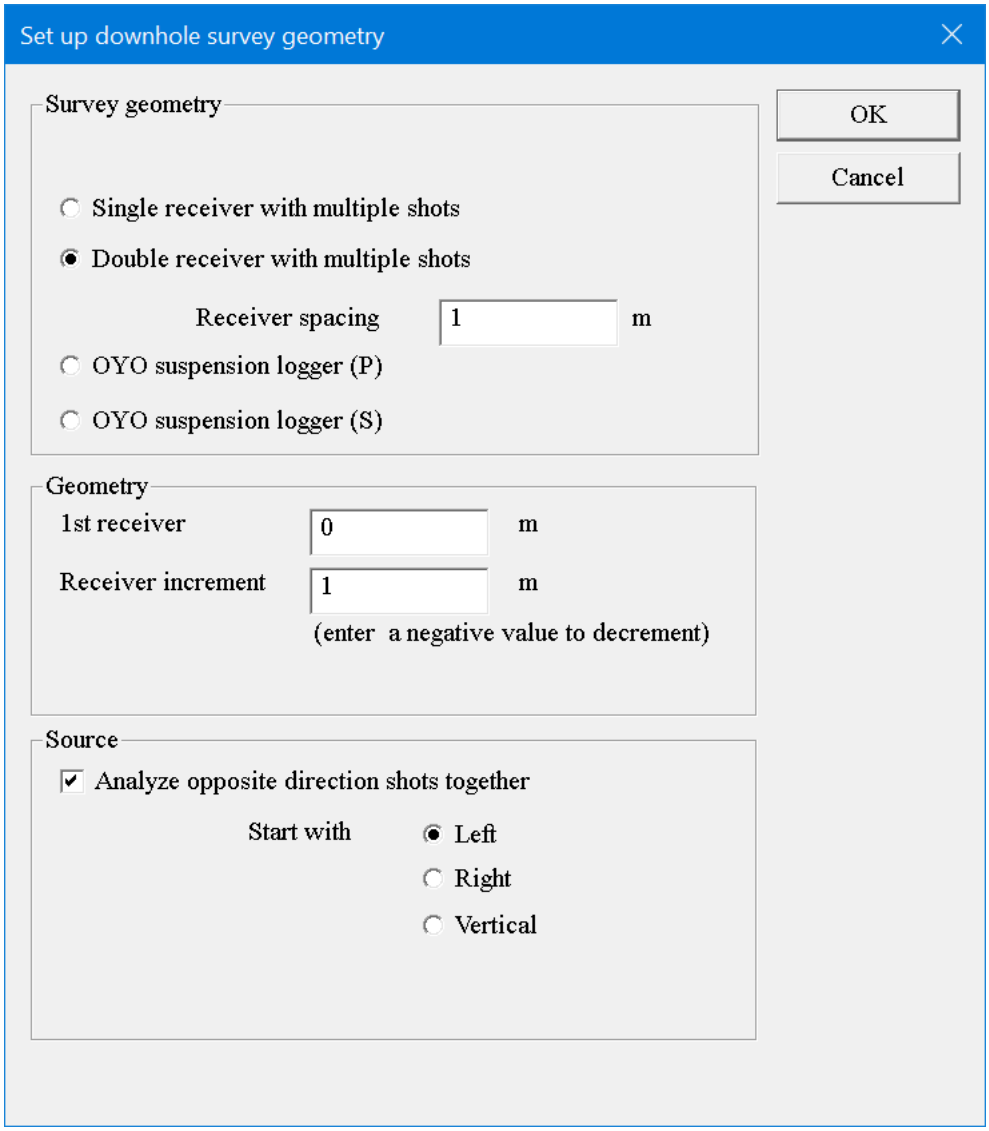


Confirmation that the files have been input will be displayed; press *OK*.



Next, you will be prompted to set up the geometry. Fundamental survey geometry – receiver depth and source direction pattern – must be set up here. As mentioned in previous chapters,

there are many possible source-receiver configurations in downhole seismic data acquisition. Source-receiver configuration can be setup using this dialog box. Typical examples of setup are explained in Appendix: A, beginning on Page A-13.



1) Survey geometry (see Appendix: A, beginning on Page A-1).

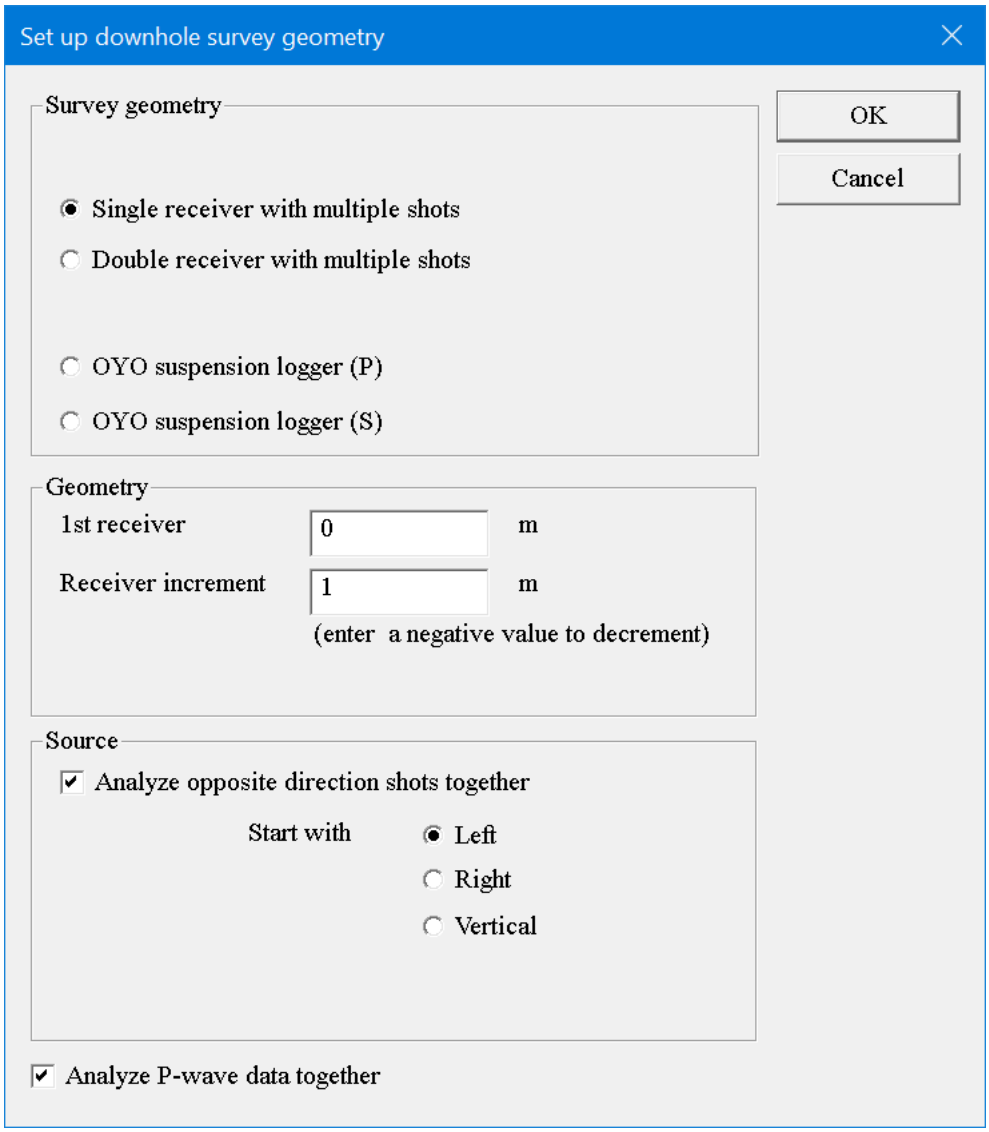
- *Multiple receivers with single shot* – This is typically a 12- or 24-channel hydrophone array, recording only p-waves. Multiple depths are sampled with a single shot; all data are recorded into a single file. See Method A, Appendix: A.1, Page A-4.
- *Single receiver with multiple shots* – Typically a single multi-component geophone that must be clamped in the hole. A single depth is sampled with each shot; each shot is

recorded into a separate file. See Method B, Appendix: A.2, Page A-7, and Method C, Appendix: A.3, Page A-13.

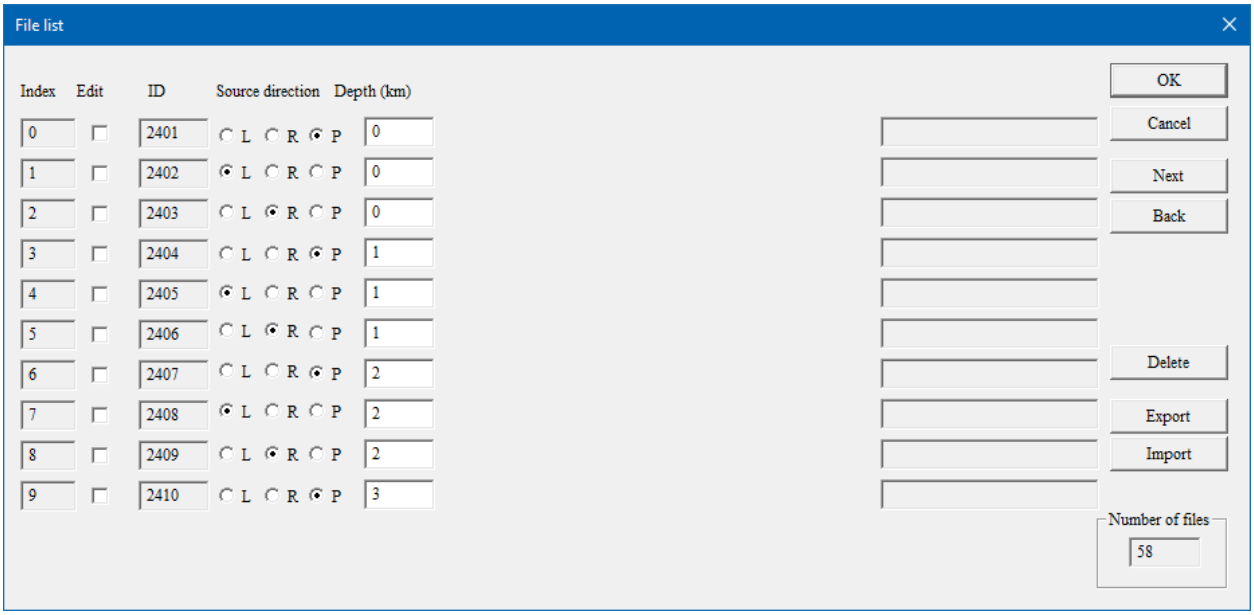
- *Double receiver with multiple shots* – See Method D, Appendix: A.4, Page A-19.
  - *Receiver spacing*
- *OYO suspension logger (P)* – Data acquisition using OYO suspension. Select this for p-wave analysis. See Method E, Appendix: A.5, Page A-25.
- *OYO suspension logger (S)* – Data acquisition using OYO suspension. Select this for s-wave analysis. See Method F, Appendix: A.6, Page A-25.

2) Geometry
   - *Beginning receiver depth* – Depth of the receiver at the beginning of the survey
   - *Receiver increment* – The distance the receiver is moved in the hole between shots.
3) Source
   - *Analyze opposite source direction files together* – For analyzing left and right shots together in an s-wave measurement, check this option and select one of the following:
     - *Start with left* (striking)
     - *Start with right* (striking)
     - *Start with vertical* (striking) (if appropriate box is check; see below)
   - *Each file includes both source directions* – If left- and right-striking shots are recorded to the same file in an s-wave measurement using "hold" or "freeze" function of the seismograph, check this option.
4) *Analyze p-wave and s-wave data together* – check this option for analyzing p- and s-wave data simultaneously. It will enable *Start with vertical* mentioned above.

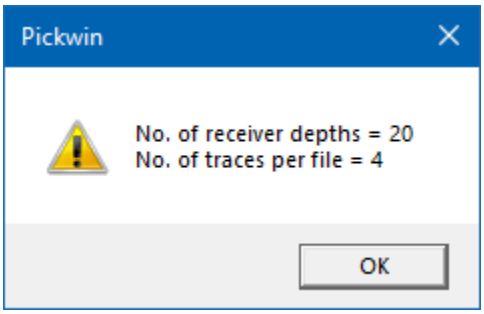
The setup shown below is an example of a source-receiver configuration for s-wave data acquisition using a single 3-component geophone.



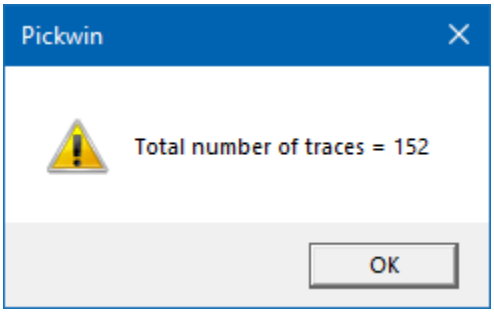
Press *OK* and the **File List** dialog box will present the data files listed by file ID. Confirm *ID*, *Source component* and receiver *Depth*. If the acquisition order of the source component depth is irregular, they can be edited manually.



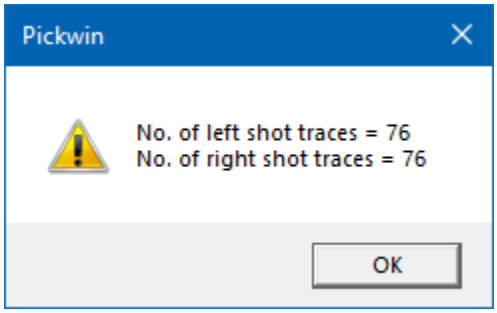
Confirmation of the number of receiver depths and channels is displayed, press *OK*.



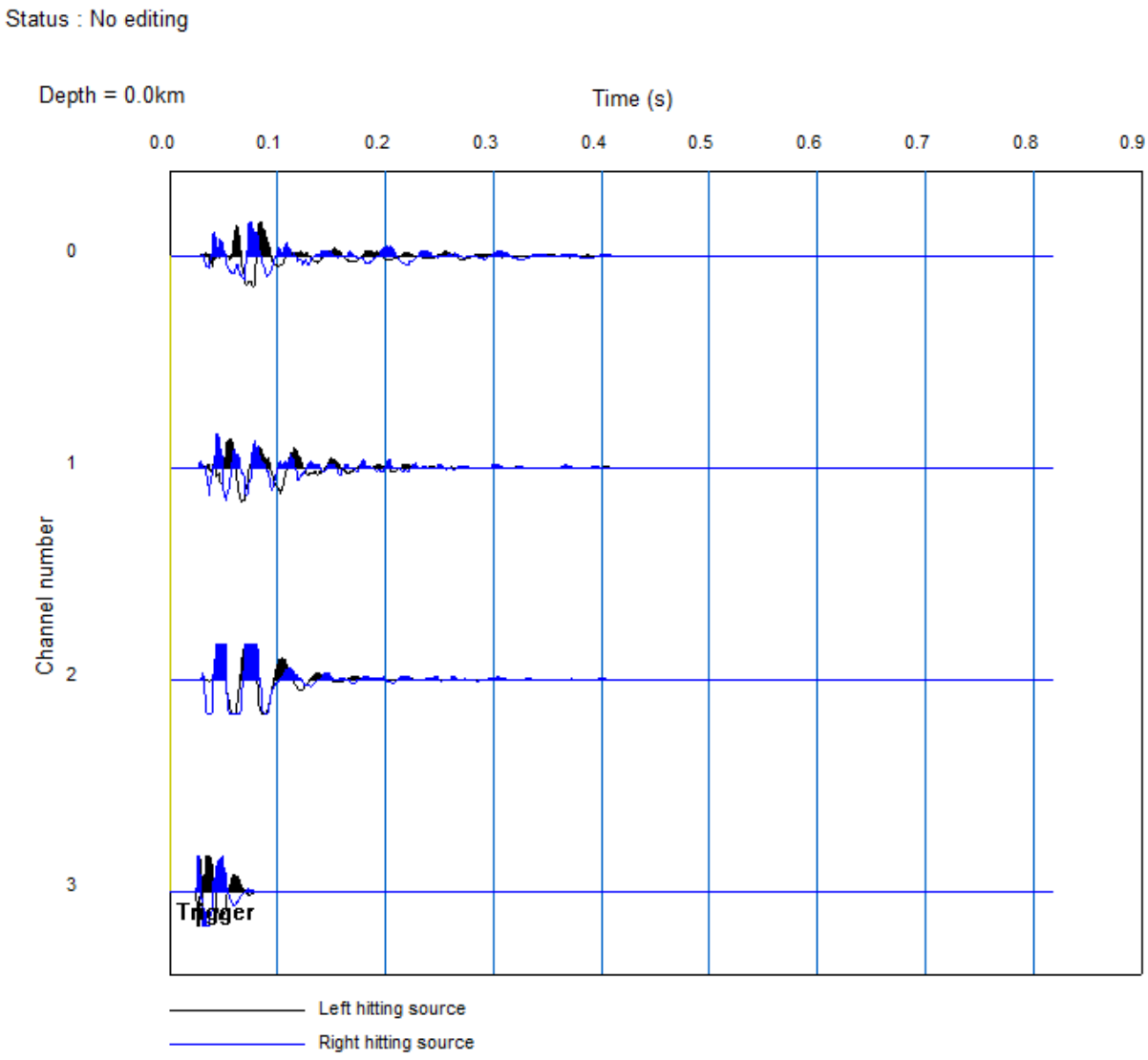
Confirmation of the number of files is displayed, press *OK*.



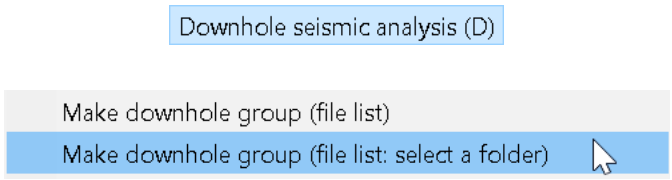
Confirmation that the traces are input is displayed, press *OK*.



Waveforms for left and right shots are displayed.



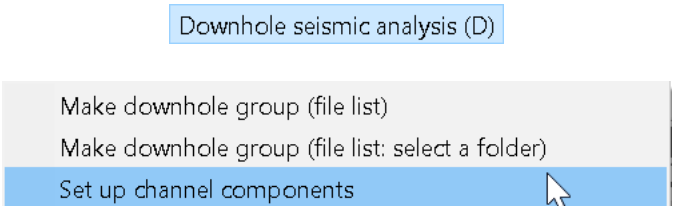
4.2 MAKE DOWNHOLE GROUP (FILE LIST: SELECT A FOLDER)

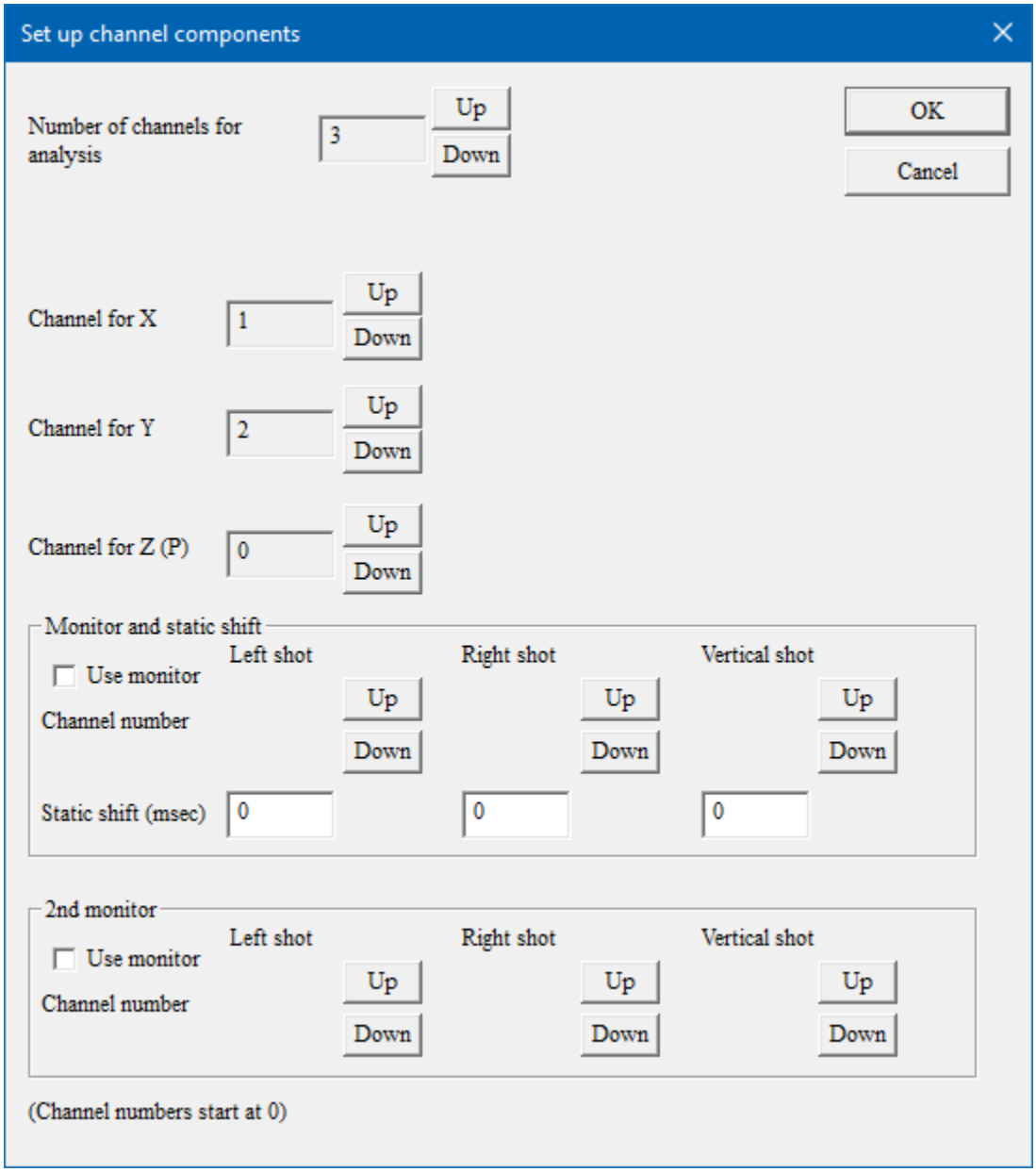


This feature is identical to *Make downhole group (file fist)* above, except that in this case, all you must do is choose the folder that the seismic waveform files are in. You do not need to choose the files – all the waveform files in the folder will be read in. This is convenient when you have many waveform files in a folder.

4.3 SETUP CHANNEL COMPONENTS

The channels which will be used for analysis must be assigned prior to picking first arrivals, except when using multi-channel (depth) receiver (Method A).





1) *Number of channels for analysis*

- Set to 1 for p-wave acquisition or s-wave acquisition using a single-direction shot.
- Set to 2 for s-wave analysis using two opposing shots.
- Set to 3 for analyzing p- and s-wave data simultaneously.

2) *Channel for X, Y, Z (p)*

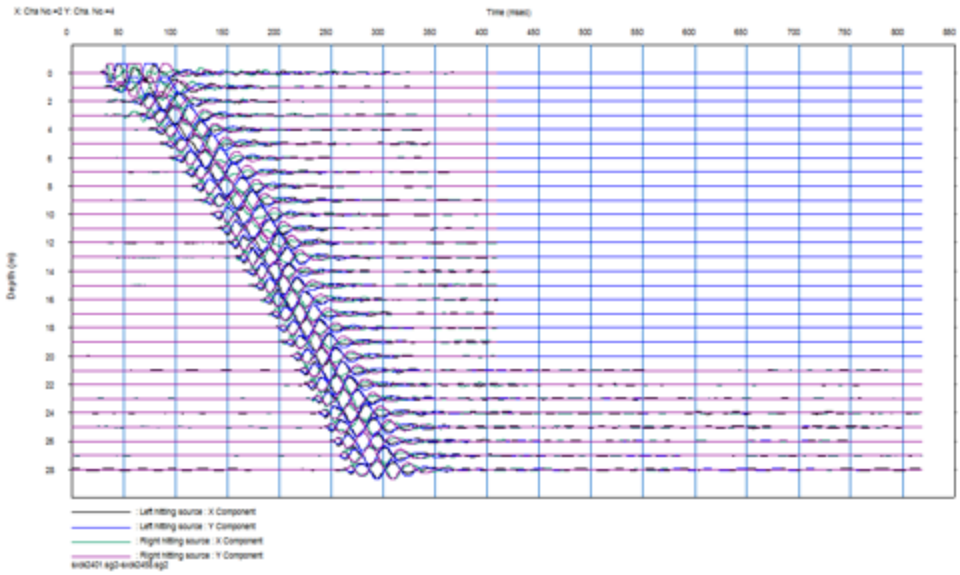
- Set the channel number for each component. **Channel number must start from 0 (i.e., 0, 1, 2….)**.

3) *Monitor and static shift*

- Check *Use monitor* if first arrival time of trigger monitor receivers are used for shot time shift.
- Assign a channel number to each component.
- Sometimes the first breaks themselves are difficult to pick because they are so close to zero time. This is especially true for the geophones closest to the source. In this case, some practitioners pick the positive peak following the first break, and then apply a time shift to correct for the difference. If the shot time of trigger monitor has a static shift, enter that value in *Static shift* so that time shift *t* can be automatically corrected for.

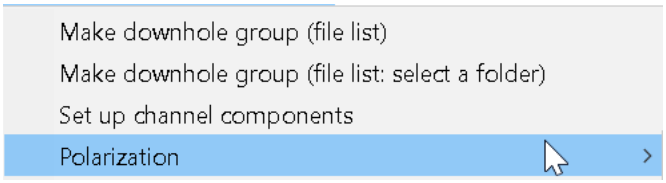
  Most practitioners record pre-trigger data to make it easier to pick first breaks, rather than picking a peak and applying a static shift. If this is the case (most common and recommended), leave *Static shift* set to zero.

Press *OK.* Waveform traces along the borehole will be displayed. At each depth, one trace will be shown when p-wave data is analyzed. Two traces will be shown for s-wave data with a single shot direction, and four traces will be shown for s-wave data with opposing shots.



4.4 POLARIZATION

Downhole seismic analysis (D)



Polarizing s-wave traces tends to enhance the first arrivals and makes them easier to pick. Polarization processing is automatically applied to all traces when s-wave data using two horizontal components is analyzed. One trace will be displayed at each depth for single-direction shots, and two traces will be displayed for opposing shots. Rotation angles of each depth are automatically calculated by the least-squares method. When opposing sources are analyzed together, one common rotation angle is applied to both shots. Figure 4 below is an example of waveform data after polarization.

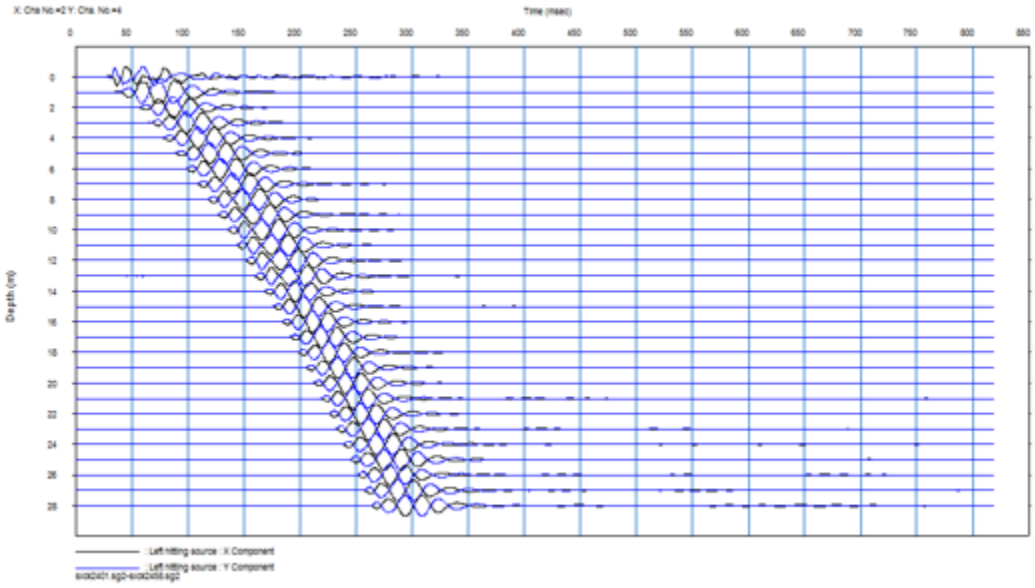
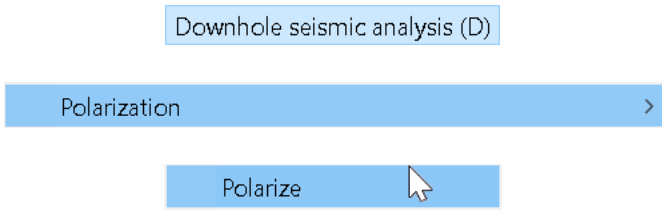


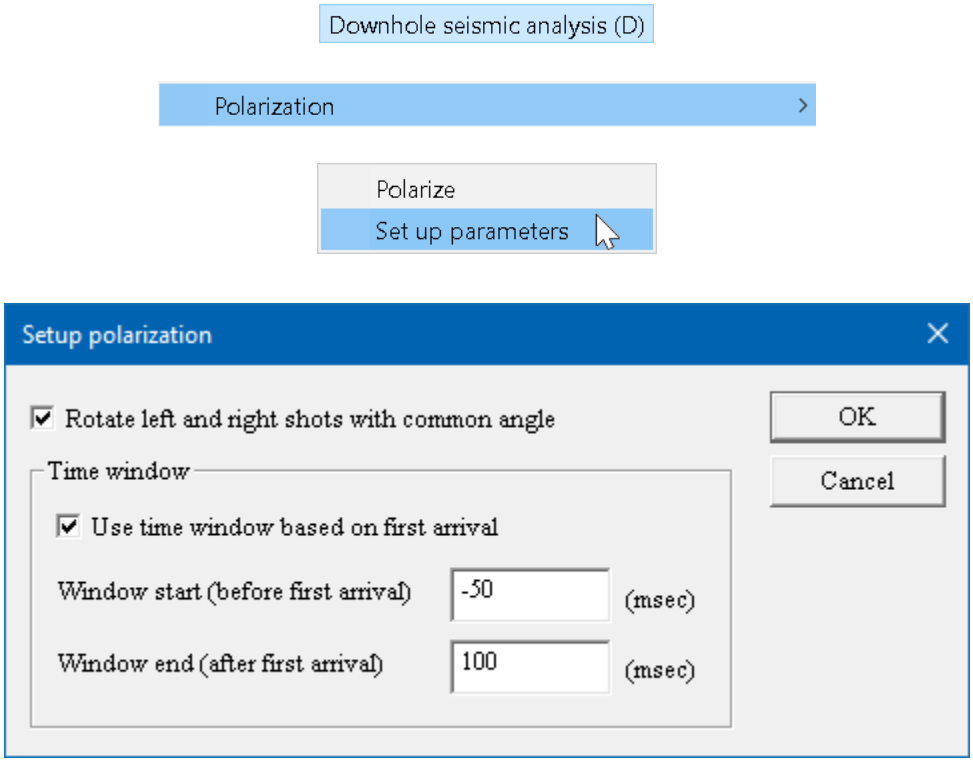
Figure 4: Shear wave traces after polarization.

4.4.1 POLARIZE



This step will polarize the traces per the parameters described in the next section.

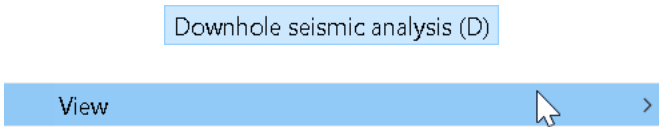
4.4.2 SET UP PARAMETERS



In the above dialog box, checking *Rotate left and right shots with common angle* causes the rotation angle to be calculated from both shots. Otherwise, the rotation angle is calculated separately for each shot. This box is normally checked.

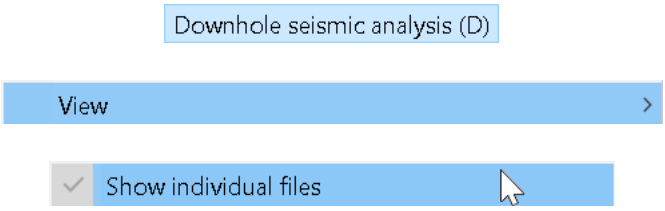
If *Use time window based on first arrival* is not checked, then the time window will be defined from the beginning of the data traces. If it is checked, you must define the *Window start* and the *Window end*.

4.5 VIEW

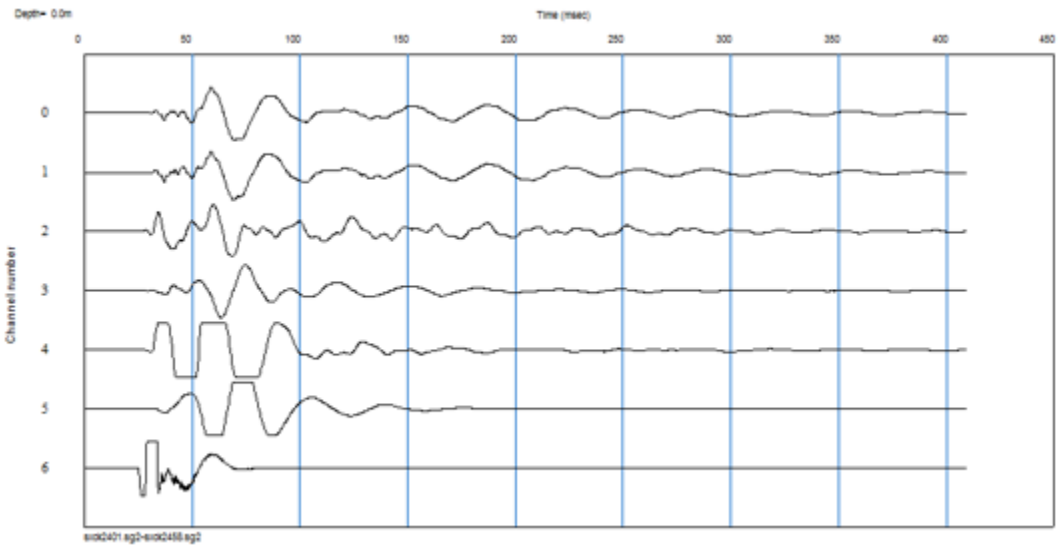


Several waveform display options can be selected in downhole seismic analysis.

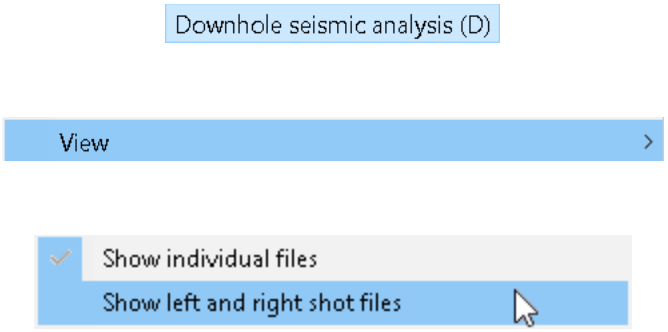
4.5.1 SHOW INDIVIDUAL FILES



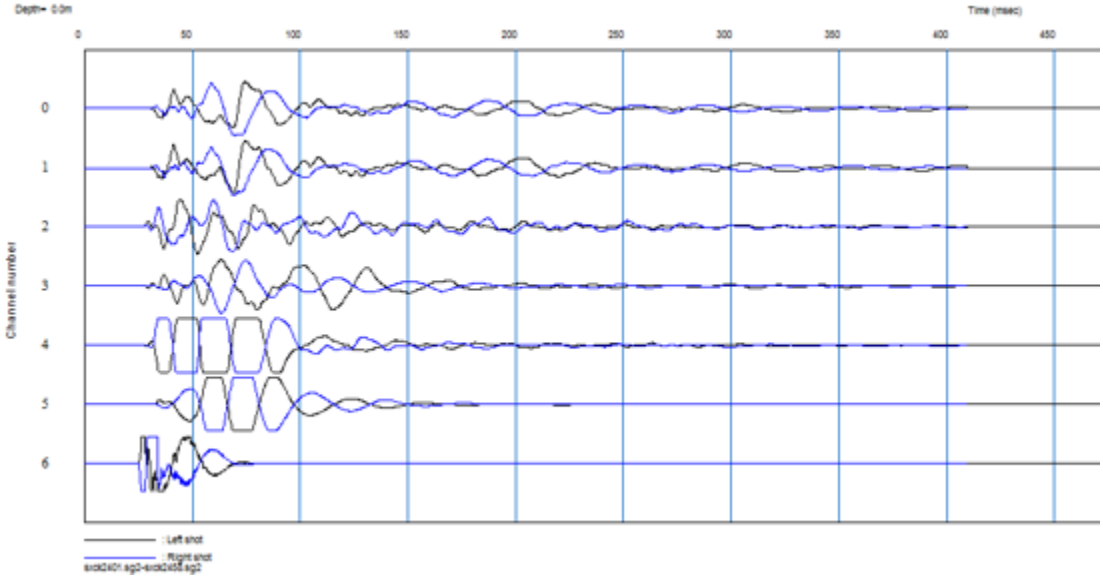
An original single-waveform file from a single shot is displayed. Use and buttons to scroll through depth.



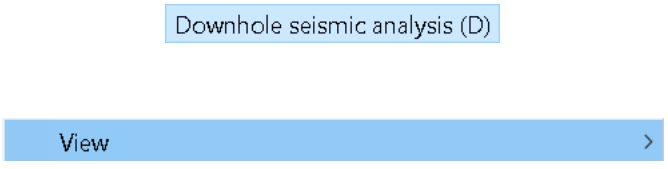
4.5.2 SHOW LEFT AND RIGHT SHOT FILES

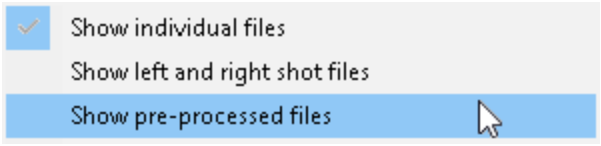


Opposing shot direction files are displayed together. Use and buttons to scroll through depth.



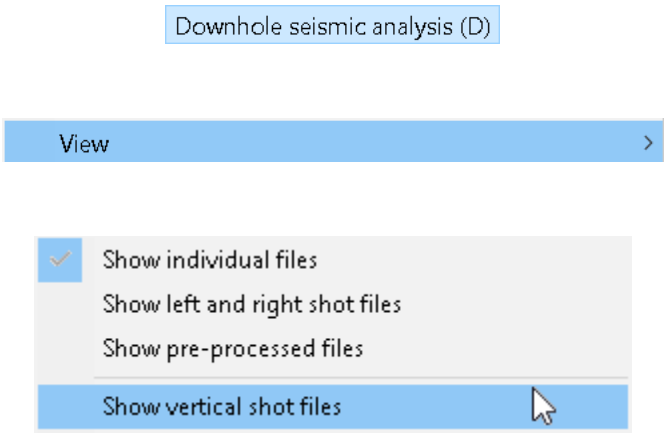
4.5.3 SHOW PRE-PROCESSED FILES





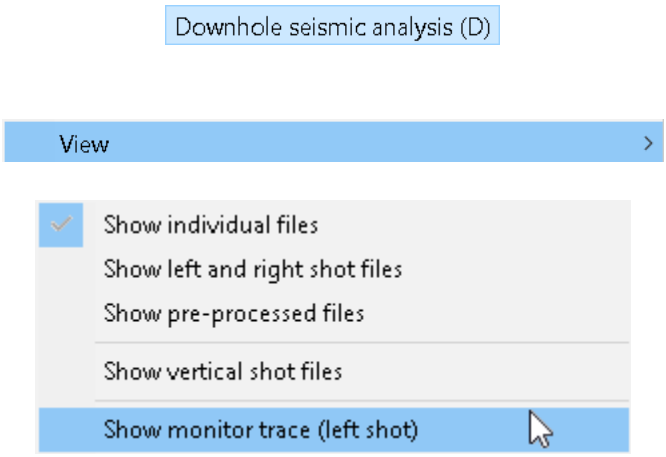
Extracted waveform traces along a borehole are displayed. If p- and s-wave data are processed simultaneously, s-wave data will be displayed.

4.5.4 SHOW VERTICAL SHOT FILES



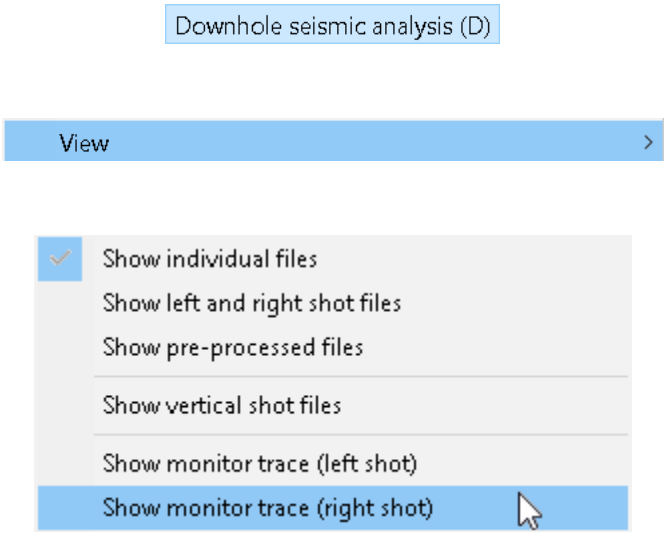
If p- and s-wave data are processed simultaneously, p-wave data will be displayed.

4.5.5 SHOW MONITOR TRACE (LEFT SHOT)



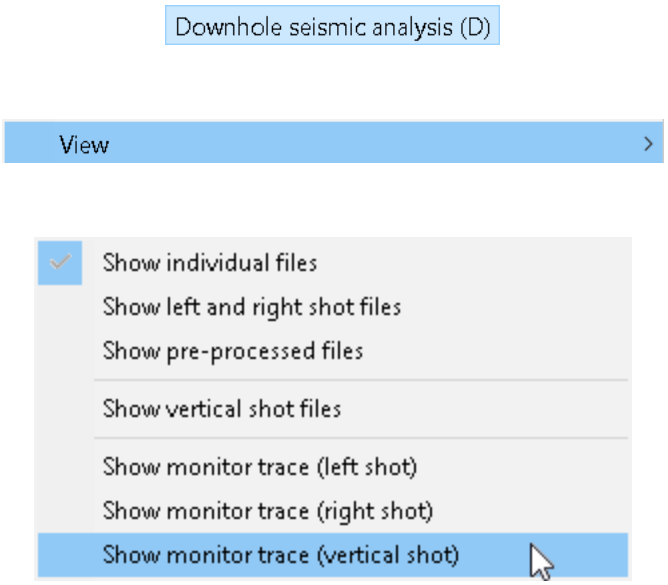
If the trigger monitor receiver channel for the left shot is assigned in the **Setup channel component** dialog, waveform traces of the monitor channel for all depths are displayed.

4.5.6 SHOW MONITOR TRACE (RIGHT SHOT)



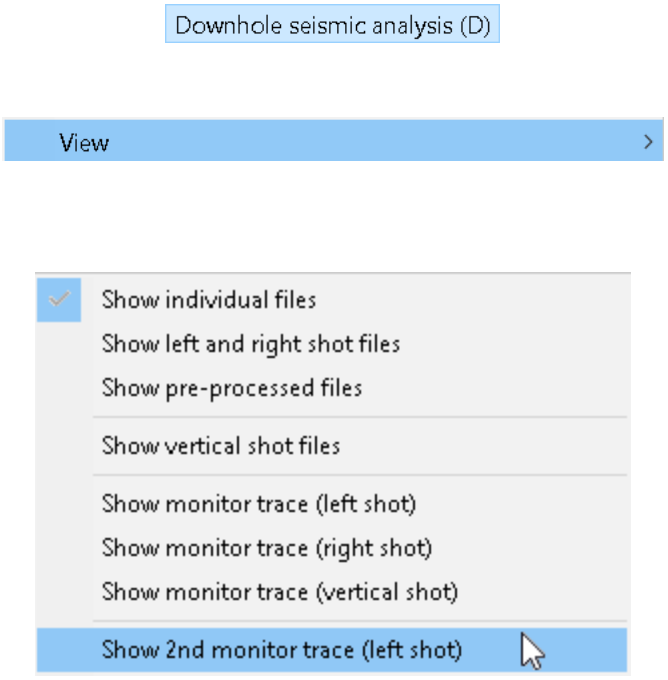
If the trigger monitor receiver channel for the right shot is assigned in the **Setup channel component** dialog, waveform traces of the monitor channel for all depths are displayed.

4.5.7 SHOW MONITOR TRACE (VERTICAL SHOT)



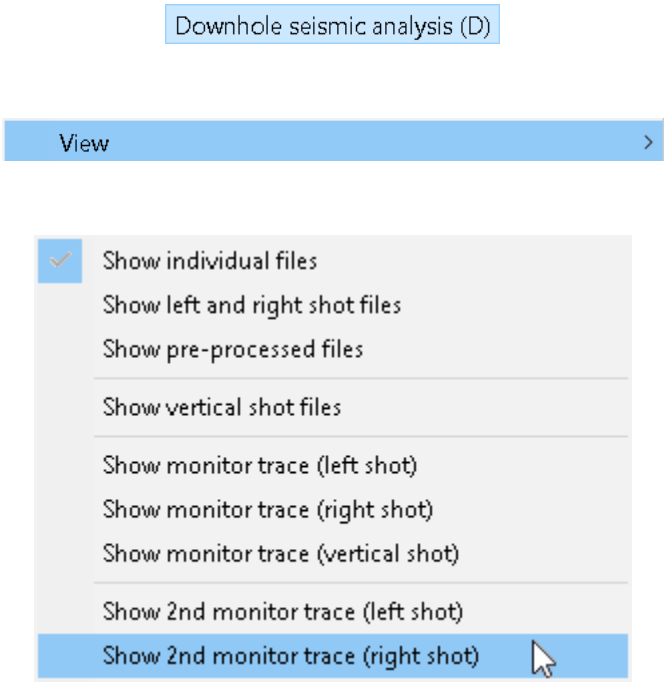
If the trigger monitor receiver channel for the vertical shot is assigned in the **Setup channel component** dialog, waveform traces of the monitor channel for all depths are displayed.

4.5.8 SHOW 2ND MONITOR TRACE (LEFT SHOT)



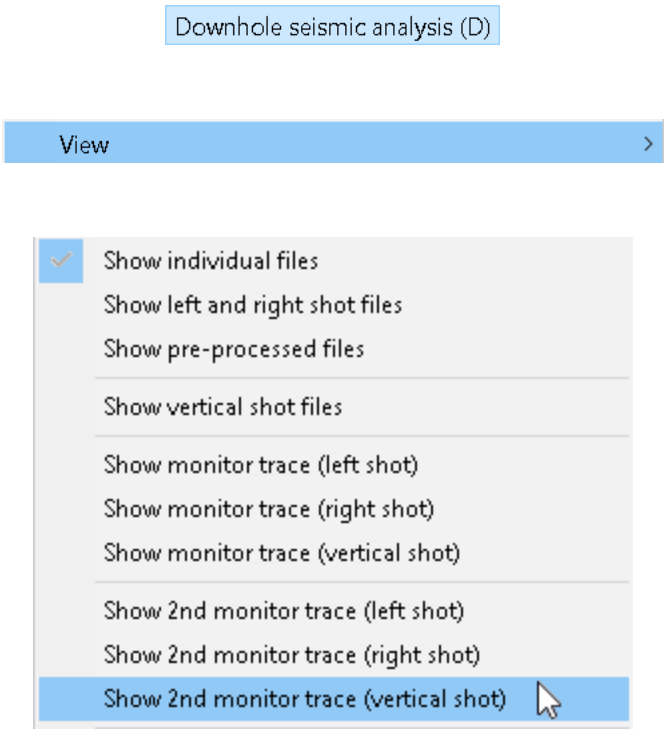
Self-evident.

4.5.9 SHOW 2ND MONITOR TRACE (RIGHT SHOT)



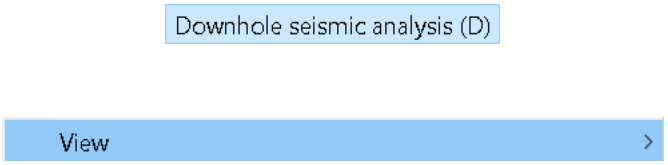
Self-evident.

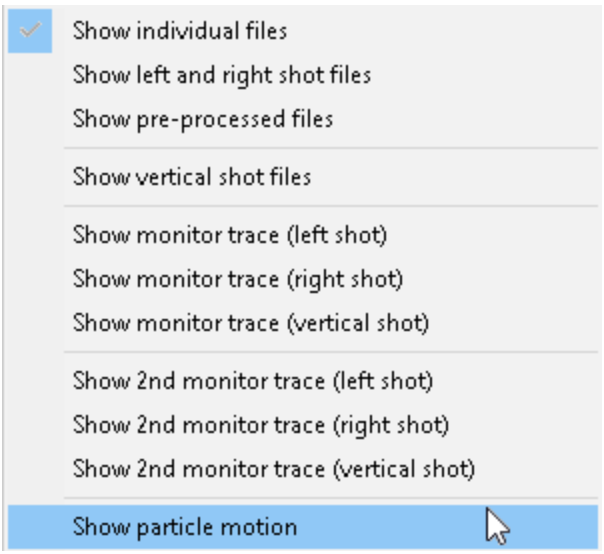
4.5.10 SHOW 2ND MONITOR TRACE (VERTICAL SHOT)



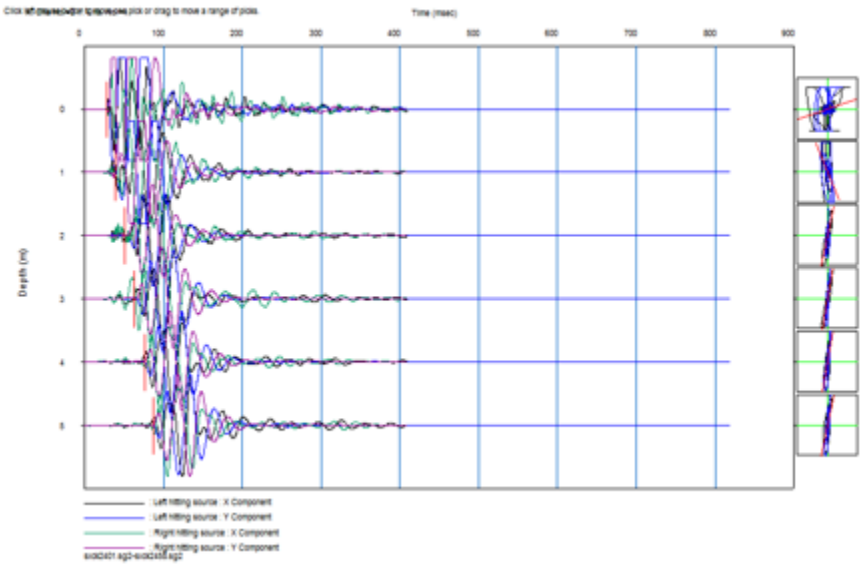
Self-evident.

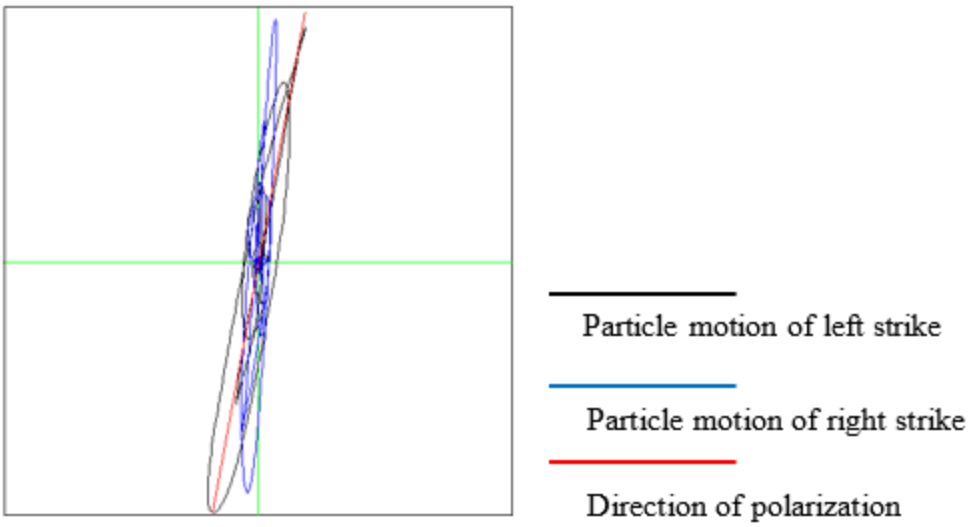
4.5.11 SHOW PARTICLE MOTION



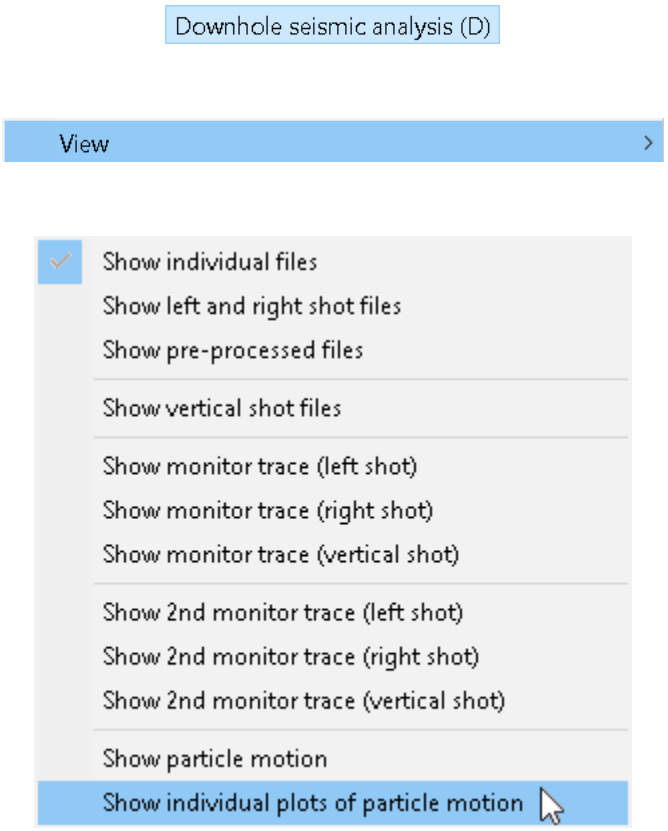


Particle motion is a plan view of receiver motion. When analyzing s-wave data, particle motion can be displayed at the right of the waveform display. This is a toggle switch. An example of particle motion is shown below.



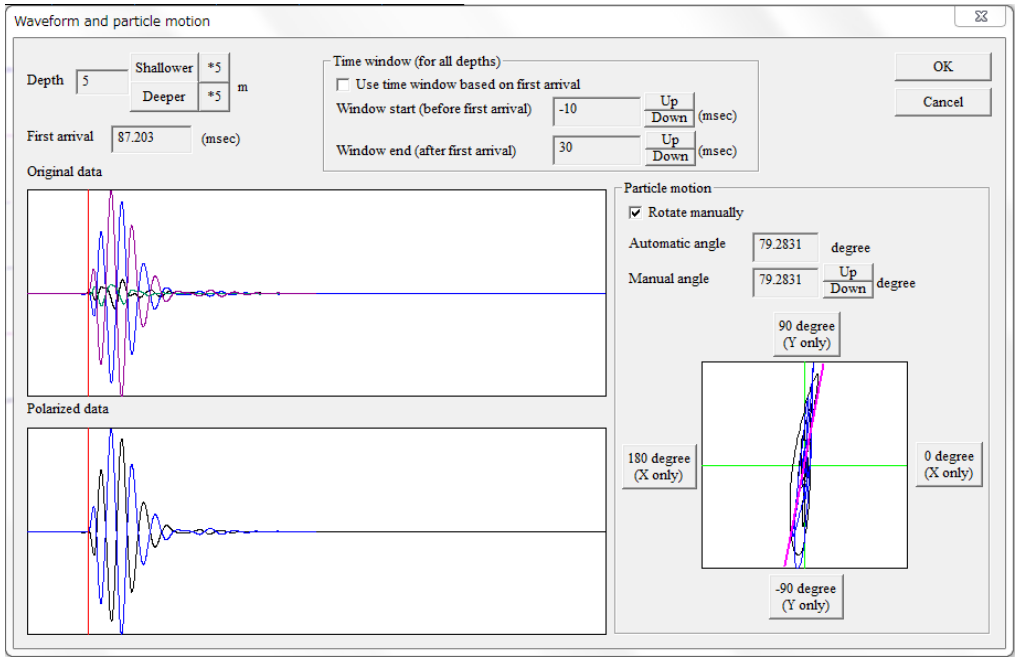


4.5.12 SHOW INDIVIDUAL PLOTS OF PARTICLE MOTION

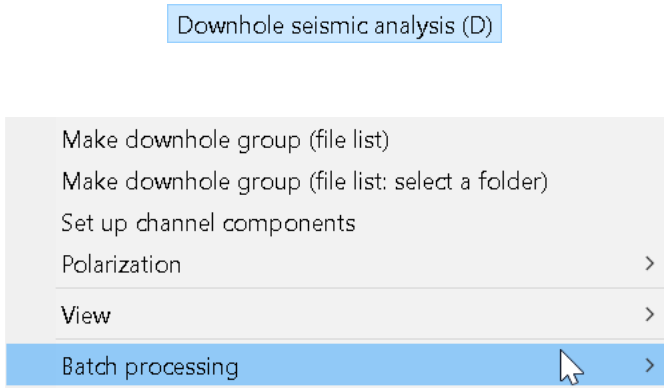


Particle motion described above can be displayed larger in a separate dialog box as shown below. The rotation angle can be manually set by using this dialog box. The time window of particle

motion for calculating rotation angle may also be set. Using this dialog box, detailed parameters for polarization may be manually set for each trace.

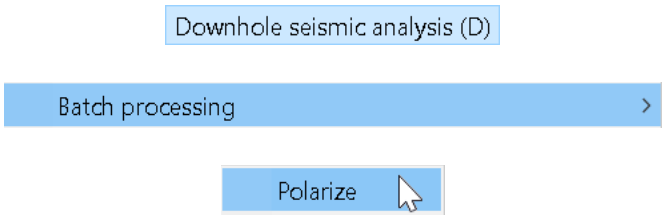


4.6 BATCH PROCESSING



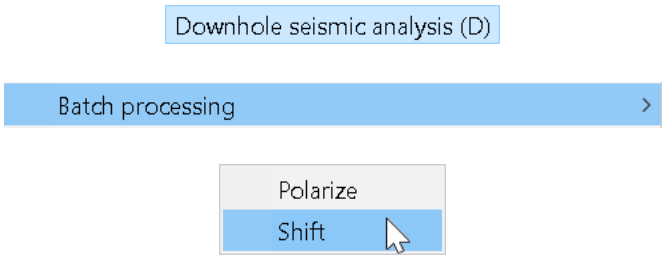
Batch processing can be applied to the analysis of s-wave data using a two-channel receiver (Method D) and s-wave data using OYO suspension. In these analyses, the edited waveform can be scrolled using the ▲ and ▼ buttons, and the traces can be polarized and time-shifted automatically (see below).

4.6.1 POLARIZE



If this toggle switch is enabled, polarization (see Section 4.4.1, Page 23) is automatically applied to scrolled waveform data.

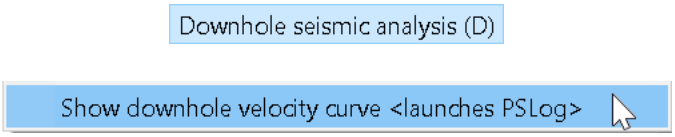
4.6.2 SHIFT



Ideally, the first shear-wave arrival times will be identical for both records. However, it is often the case that they are not – one is often shifted slightly in time. This is quite common when the shear wave source consists of a long plank of wood or other non-point source. To correct the s-waves to coincide at the same arrival times, select *Edit/Display* | *Correct s-wave* (See details in *Correct s-wave* in the SeisImager/2D manual.)

When downhole seismic s-wave data with two receivers (such as seismic cone or OYO suspension) and opposing sources is analyzed, *Correct s-wave* is automatically applied during scrolling if the *Shift* toggle switch is on.

4.7 SHOW DOWNHOLE VELOCITY CURVE <LAUNCHES PSLOG>

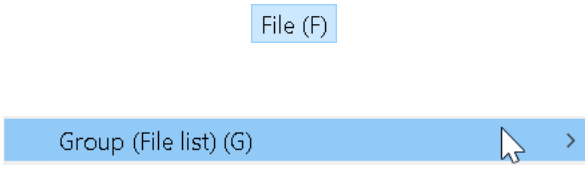


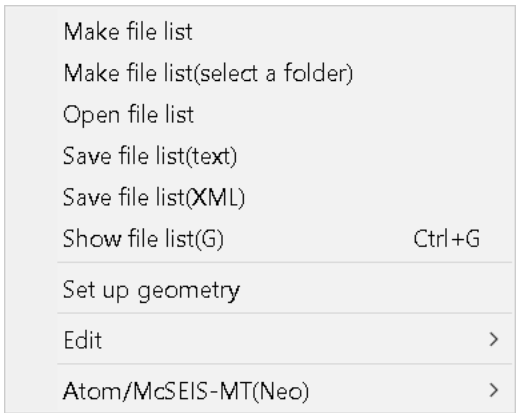
Once the first arrivals are picked in Pickwin, the picks are held in memory for import to PSLog. PSLog is used for detailed editing, analysis and making figures for the final report. PSLog can be opened separately and can read in the XML file that contains first arrival data. But this single step is the easiest way to automatically launch PSLog and import a travel time curve just picked in Pickwin as well as the waveform traces.

To automatically launch PSLog and import the travel time curves from Pickwin, select *Downhole seismic analysis | Show downhole velocity curve <launches PSLog>*.

5 THE PICKWIN FILE MENU

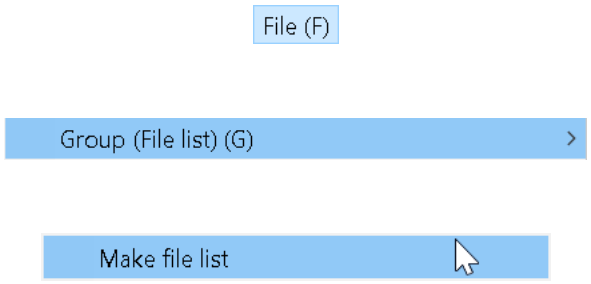
5.1 GROUP (FILE LIST)





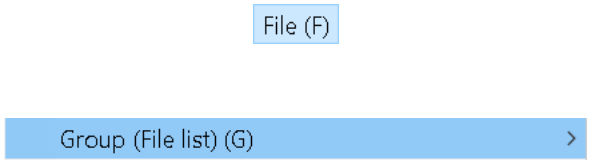
The **Group (File list)** menu contains functions for opening, saving, and editing the file list. See the SeisImager/2D manual for details.

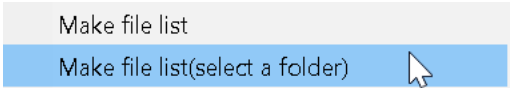
5.1.1 MAKE FILE LIST



Do not use this item for making a file list for downhole seismic analysis. Select *Downhole seismic analysis* | *Make downhole group (file list)* instead.

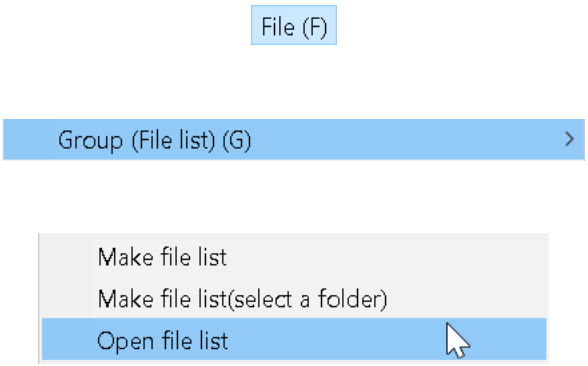
5.1.2 MAKE FILE LIST (SELECT A FOLDER)





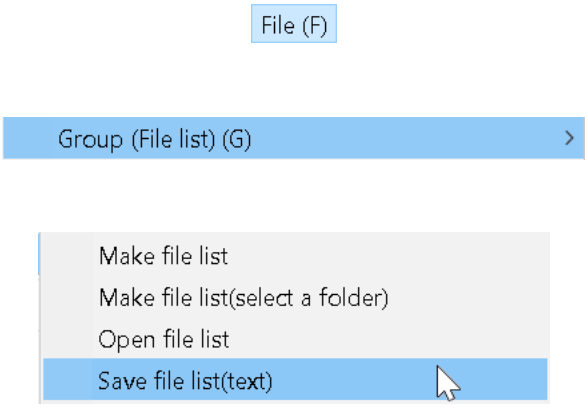
Do not use this item for making a file list for downhole seismic analysis. Select *Downhole seismic analysis* | *Make downhole group (file list: select a folder)* instead.

5.1.3 OPEN FILE LIST



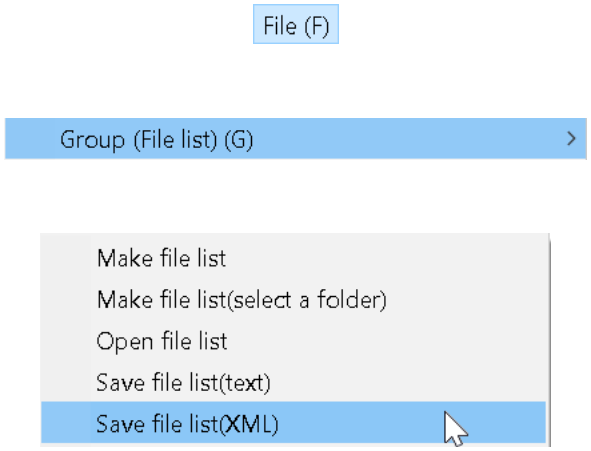
To open an existing file list, select *Open file list*.

5.1.4 SAVE FILE LIST (TEXT)



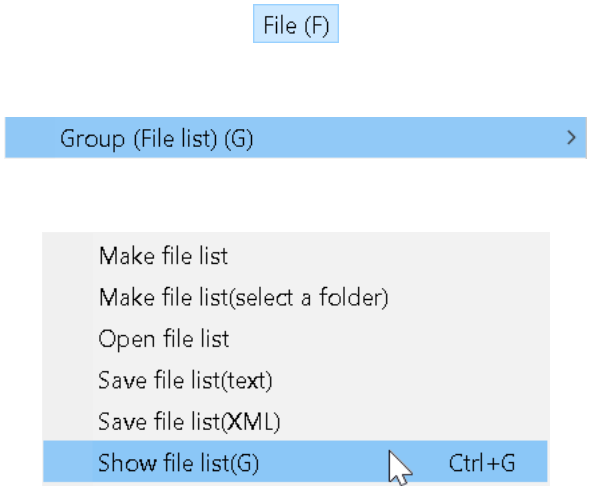
Do not use this menu item for downhole seismic analysis. It only applies for seismic refraction.

5.1.5 SAVE FILE LIST (XML)



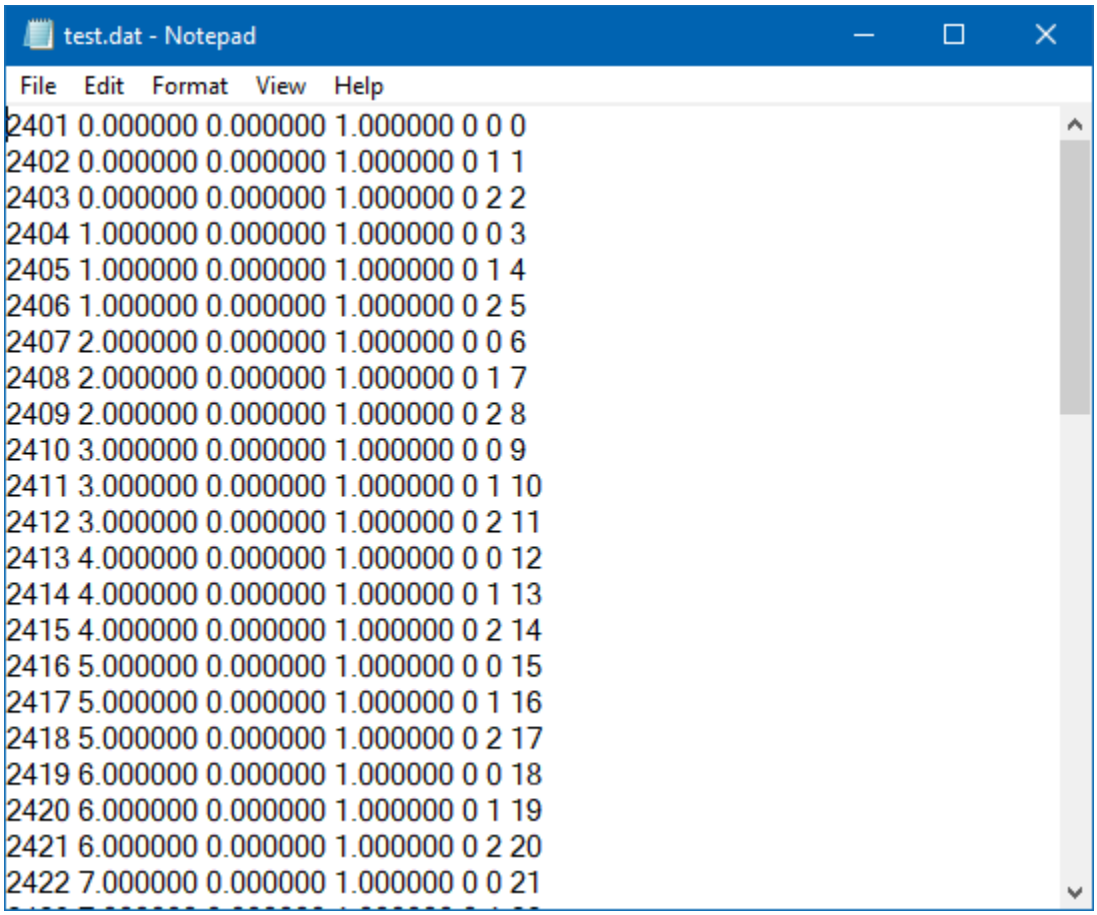
To save the current file list, select *Save file list (XML)*.

5.1.6 SHOW FILE LIST [CTRL+G]



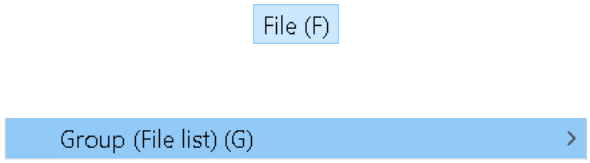
To show and edit the current file list, select *Show file list* or press *CTRL+G*. Source component and receiver depth can be edited.

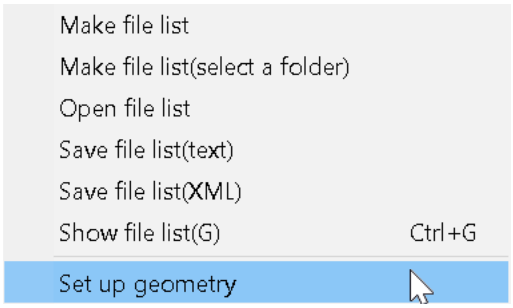
To edit the current file list manually using other software, such as Excel® or Notepad®, export a list to a text file by clicking the *Export* button. Edit the file using Excel or Notepad and read it again by clicking the *Import* button. An example of an exported text file is shown below.



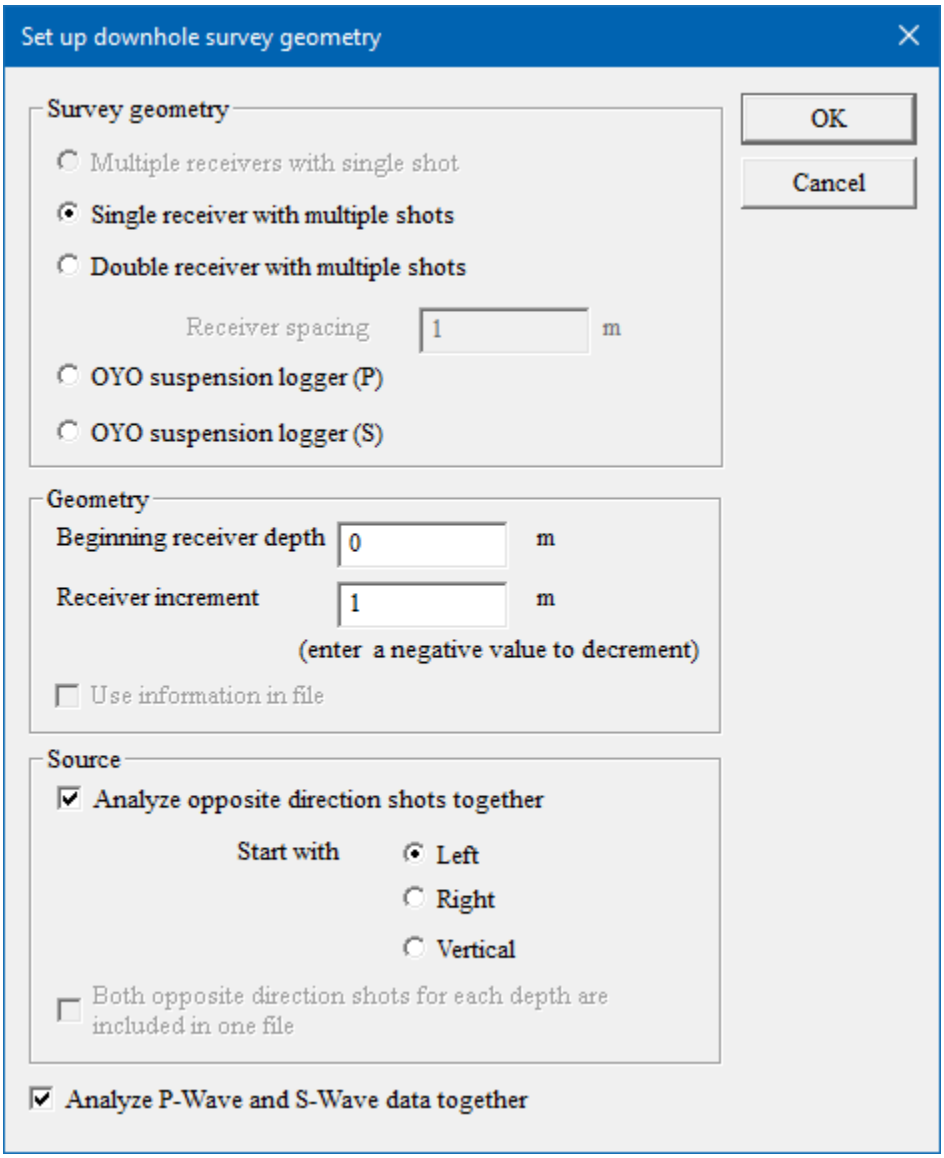
The first column is ID and the second column is receiver depth. You do not need to change the third and fourth columns. The last column indicates source component and 0, 1 and 2 mean left, right and vertical, respectively.

5.1.7 SET UP GEOMETRY

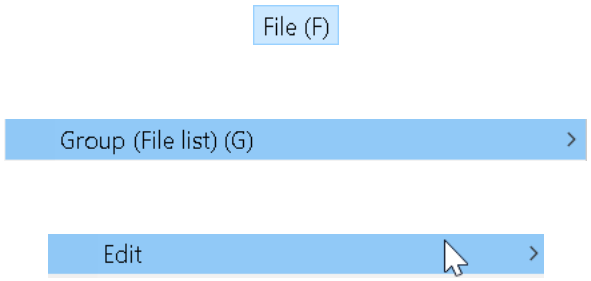




Do not use this item for downhole seismic analysis. The downhole geometry setup menu pops up automatically when you make a file list under *Downhole seismic analysis* | *Make downhole group (file list)*.

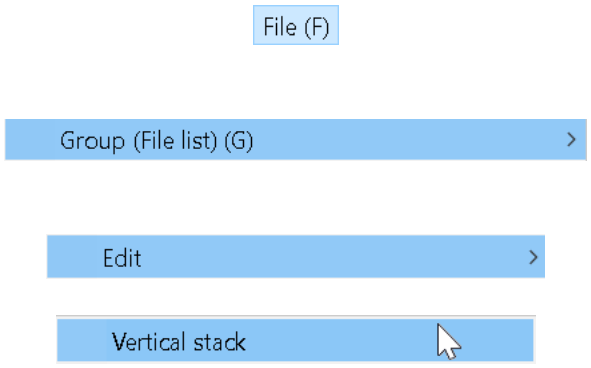


5.1.8 EDIT



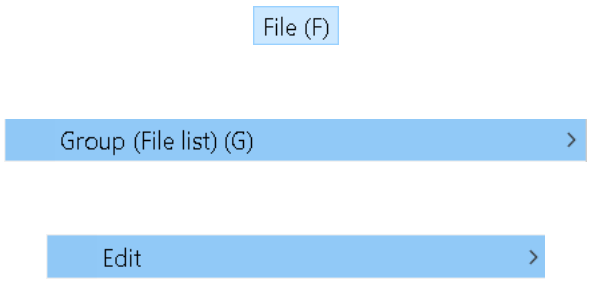
Continue.

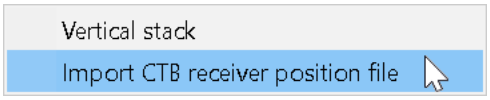
5.1.8.1 VERTICAL STACK



This function is not applicable to downhole data.

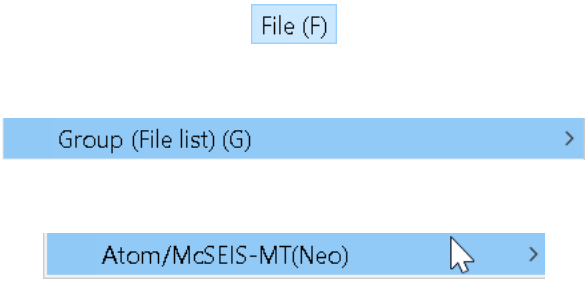
5.1.8.2 IMPORT CTB RECEIVER POSITION FILE





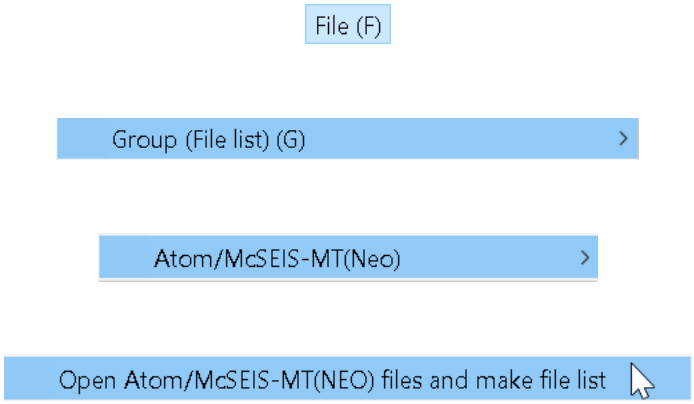
This function is not applicable to downhole data.

5.1.9 ATOM/MCSEIS-MT (NEO)



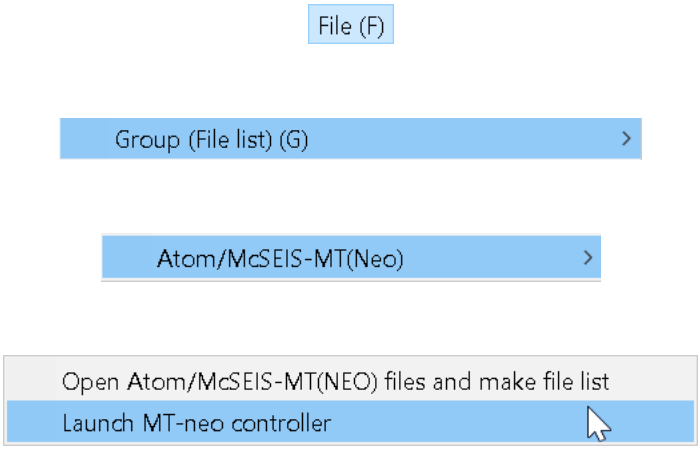
This function is not applicable to downhole data.

5.1.9.1 OPEN ATOM/MCSEIS-MT (NEO) FILES AND MAKE FILE LIST



This function is not applicable to downhole data.

5.1.9.2 LAUNCH MT-NEO CONTROLLER



This function is not applicable to downhole data.

6 THE PSLOG MODULE

The PSLog module calculates velocity models from first arrivals picked in Pickwin and displays travel time curves and velocity models of downhole seismic data. Its display consists mainly of two figures: travel time curves (travel time view) and velocity models (velocity model view).

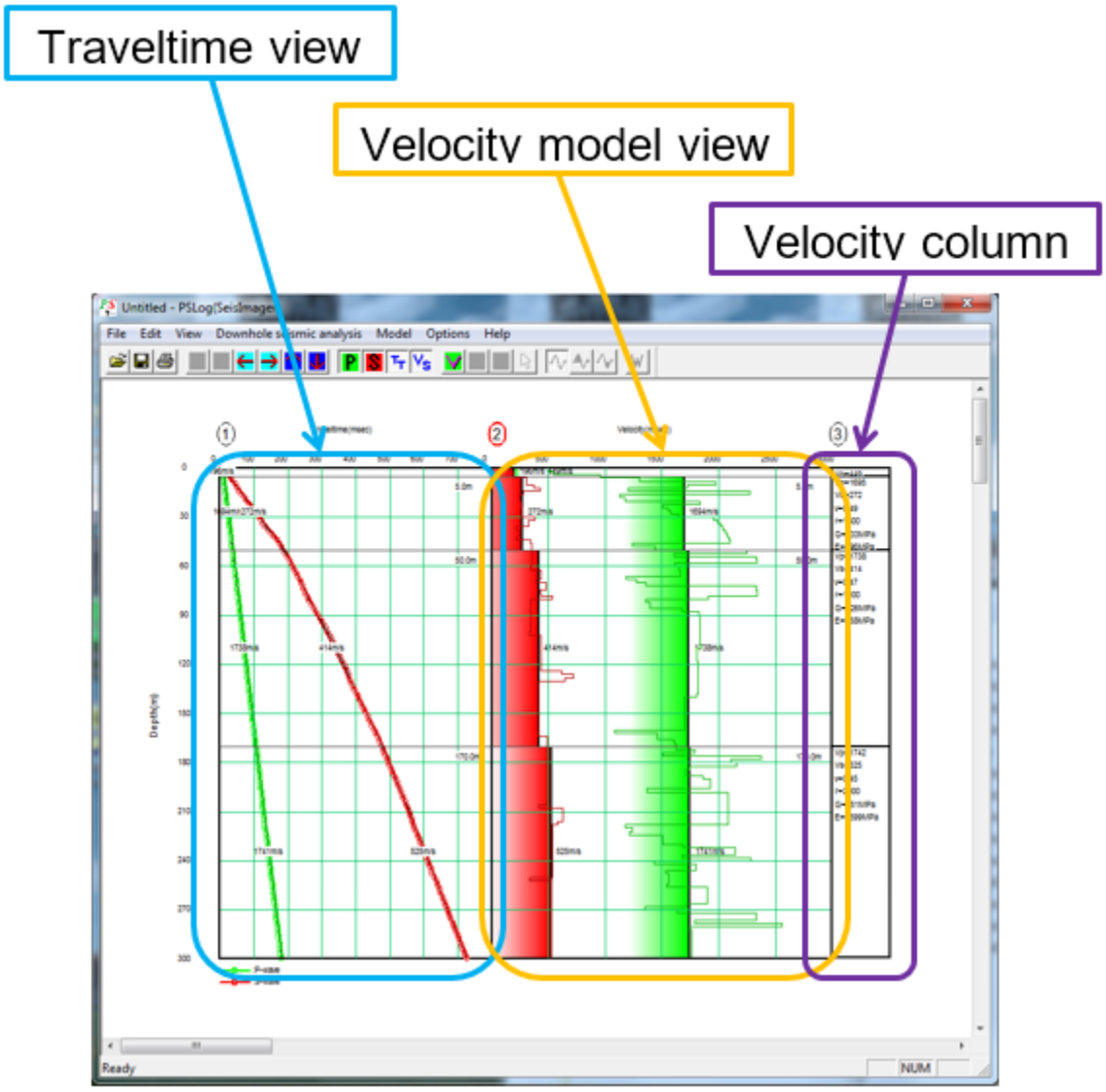
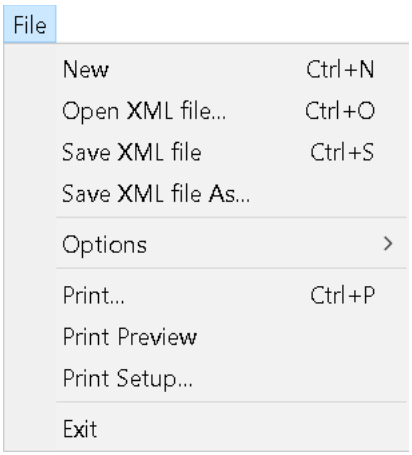


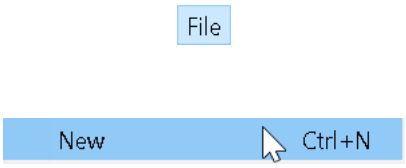
Figure 5: PSLog display.

6.1 THE PSLOG FILE MENU



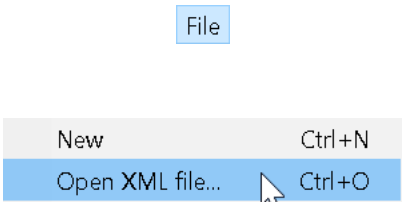
The **File** menu includes functions for opening and saving PSLog result files and printing. The various functions are summarized below.

6.1.1 NEW [CTRL+N]

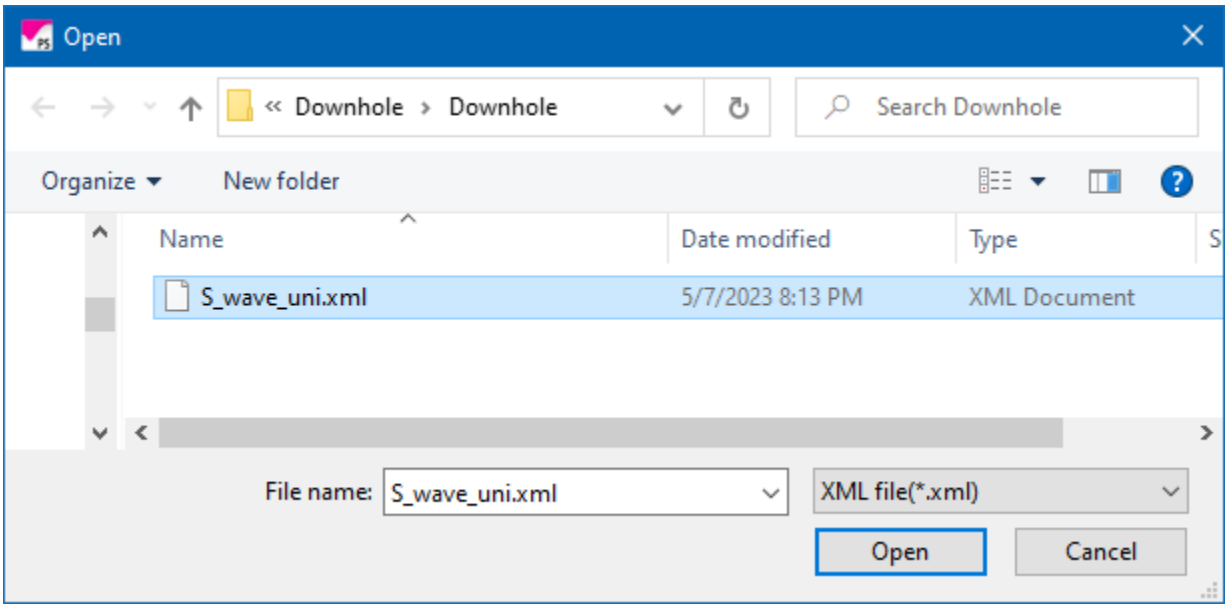


Select *File* | *New* or *Ctrl+N* to clear all data.

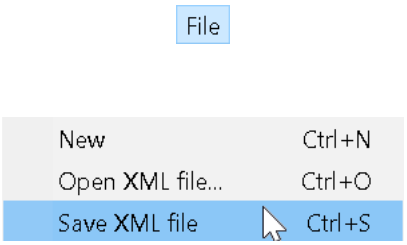
6.1.2 OPEN XML FILE [CTRL+O]



Select *File* | *Open XML file*, press *Ctrl+O*, or click on to open an analyzed result previously saved with an xml extension.

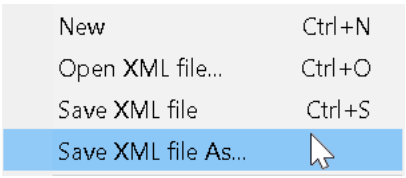


6.1.3 SAVE XML FILE [CTRL+S]

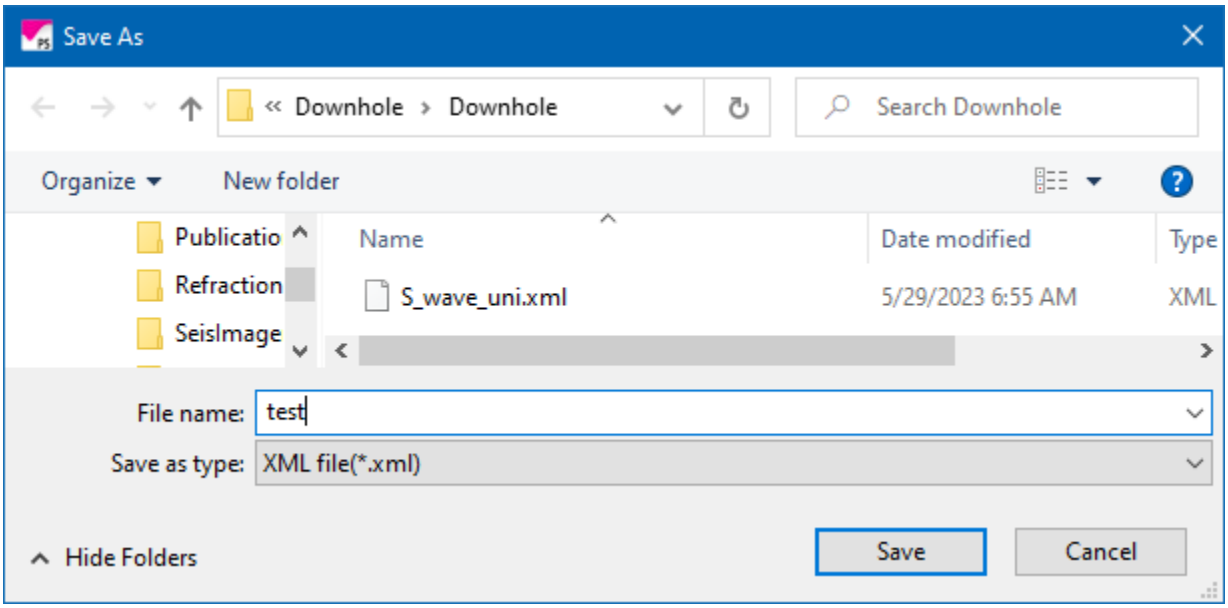


To save your work into the same file, press *File* | *Save XML File*, press *Ctrl+S*, or press . A logging data file can be saved at any time in the processing flow and will reflect the extent of results at the time of save.

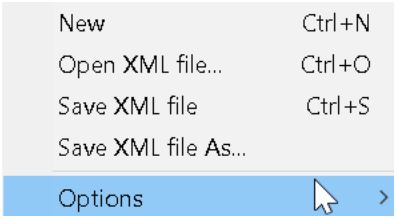
6.1.4 SAVE XML FILE AS



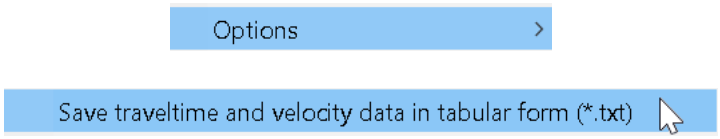
To save to a new XML file, select *File* | *Save XML file as*. Assign file name with the extension *.xml* and click *Save*.



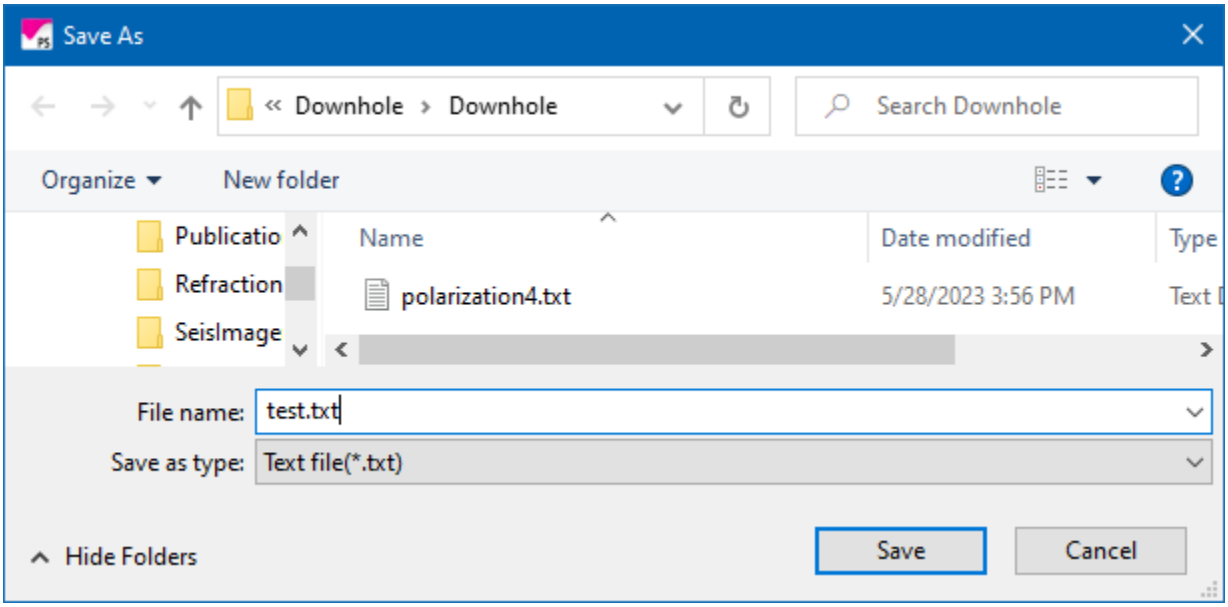
6.1.5 OPTIONS



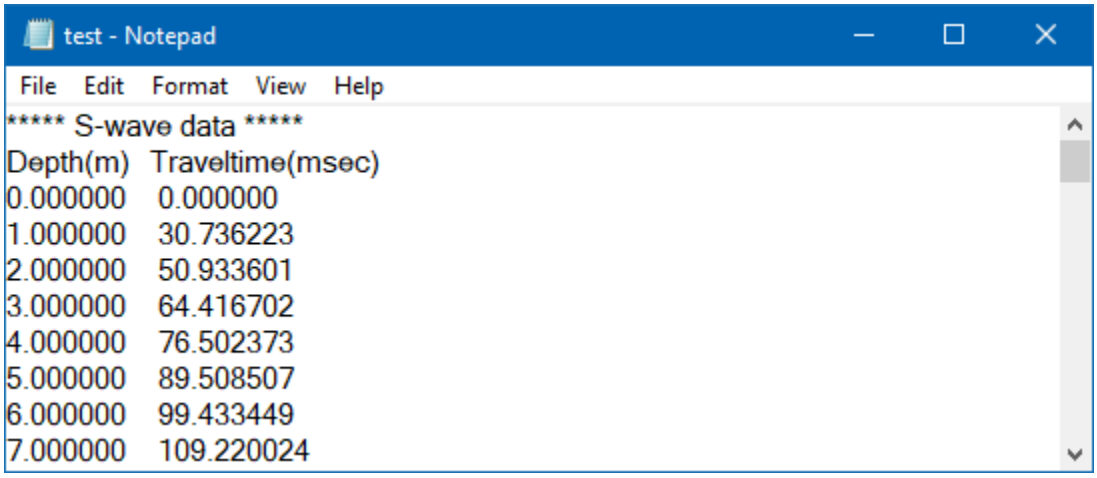
6.1.5.1 SAVE TRAVEL TIME AND VELOCITY DATA IN TABULAR FORM (.TXT)



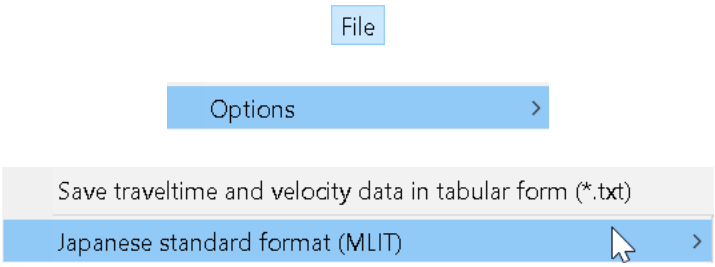
Choose this option to save your data in tabular ASCII format.



Assign a file name with the extension .txt and press *Save*. The resultant file is a simple text file with Depth and Travel time.

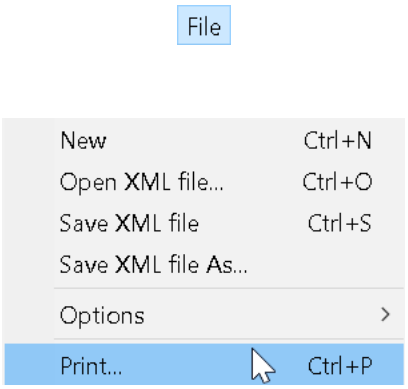


6.1.5.2 JAPANESE STANDARD FORMAT (MLIT)

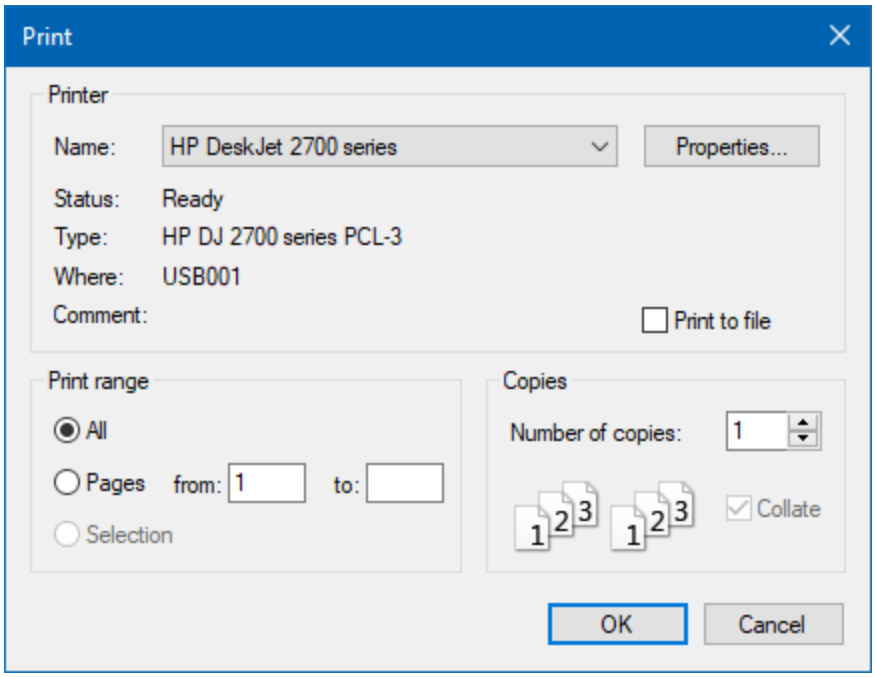


As of this writing, this option was still under development.

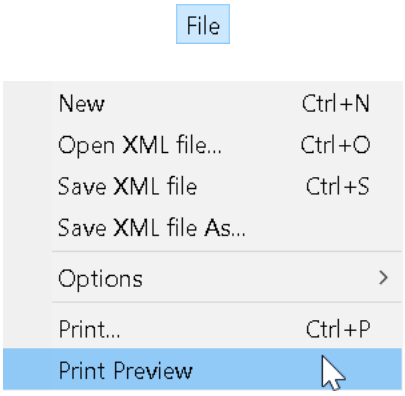
6.1.6 PRINT [CTRL+P]



To print the current PSLog display, choose *Print,* press *Ctrl+P* or press the button.



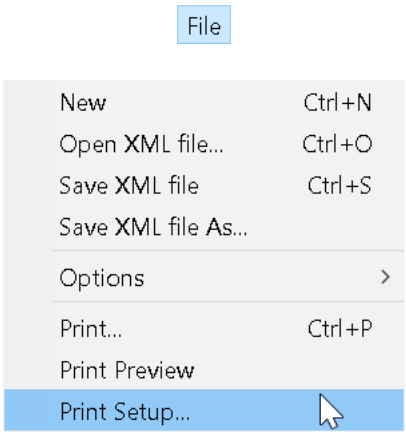
6.1.7 PRINT PREVIEW

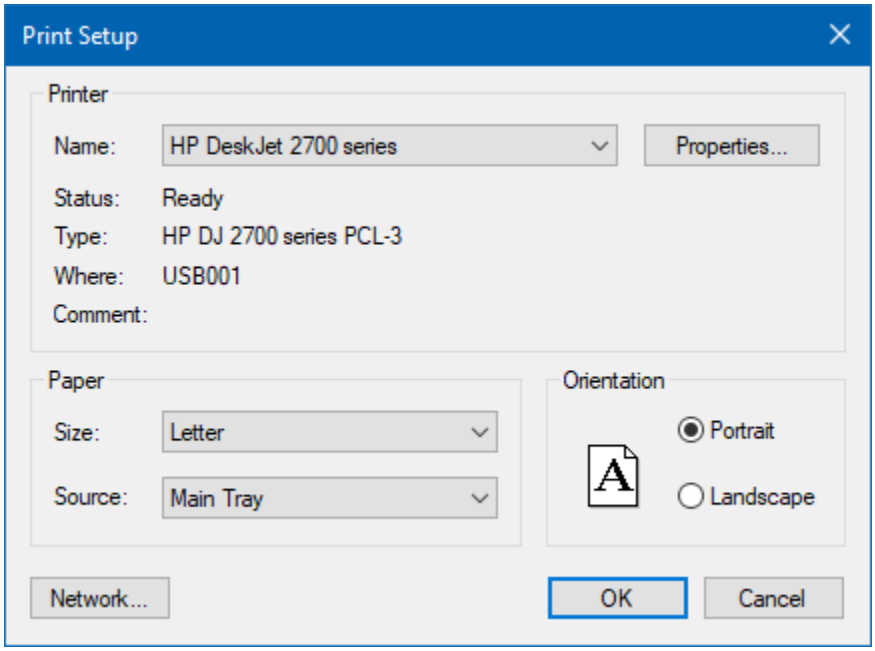


To display the print image, choose *Print preview*.

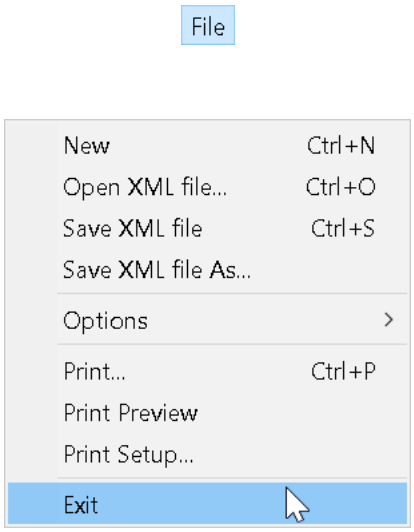
6.1.8 PRINT SETUP

To setup printing parameters, choose *Print setup*.


File
New Ctrl+N
Open XML file... Ctrl+O
Save XML file Ctrl+S
Save XML file As...
Options
Print... Ctrl+P
Print Preview
Print Setup...

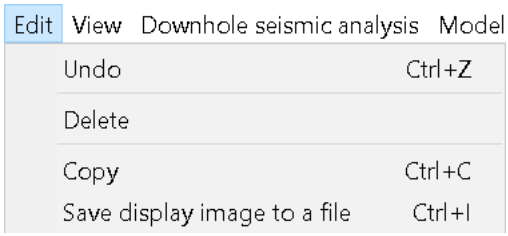

Print Setup
Printer
Name: HP DeskJet 2700 series
Properties...
Status: Ready
Type: HP DJ 2700 series PCL-3
Where: USB001
Comment:
Paper
Size: Letter
Source: Main Tray
Orientation
Portrait
Landscape
Network...
OK
Cancel

6.1.9 EXIT



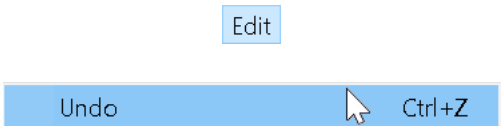
Select *Exit* to close PSLog.

6.2 THE PSLOG EDIT MENU



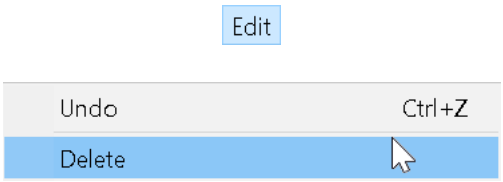
The **Edit** menu is used for copying the displayed image to the clipboard or to a file. It is a simple screen-capture feature.

6.2.1 UNDO [CTRL+Z]



Undoes the previous operation.

6.2.2 DELETE [DELETE KEY]

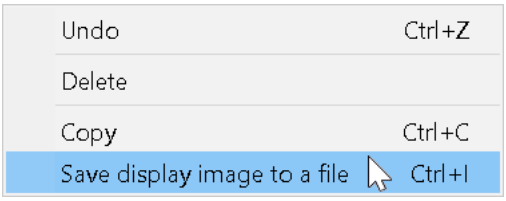


This deletes a highlighted velocity boundary. See Section 6.8.16, Page 120.

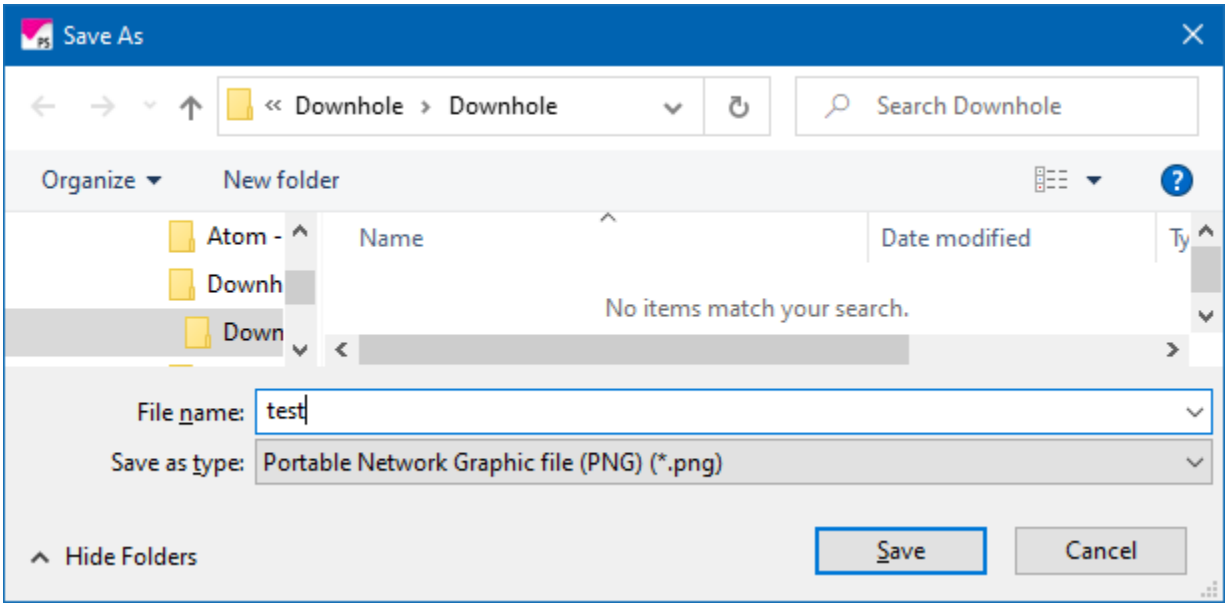
6.2.3 COPY [CTRL+C]

This copies the displayed image to the clipboard.

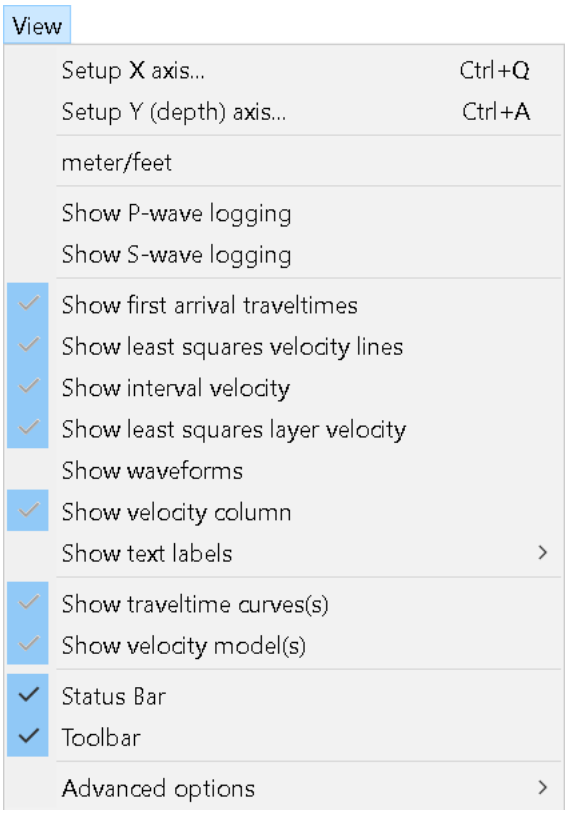
6.2.4 SAVE DISPLAY IMAGE TO A FILE [CTRL+I]



This copies the displayed image to a file. Type in a file name and press *Save*.

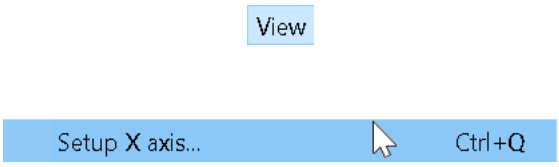


6.3 THE PSLOG VIEW MENU

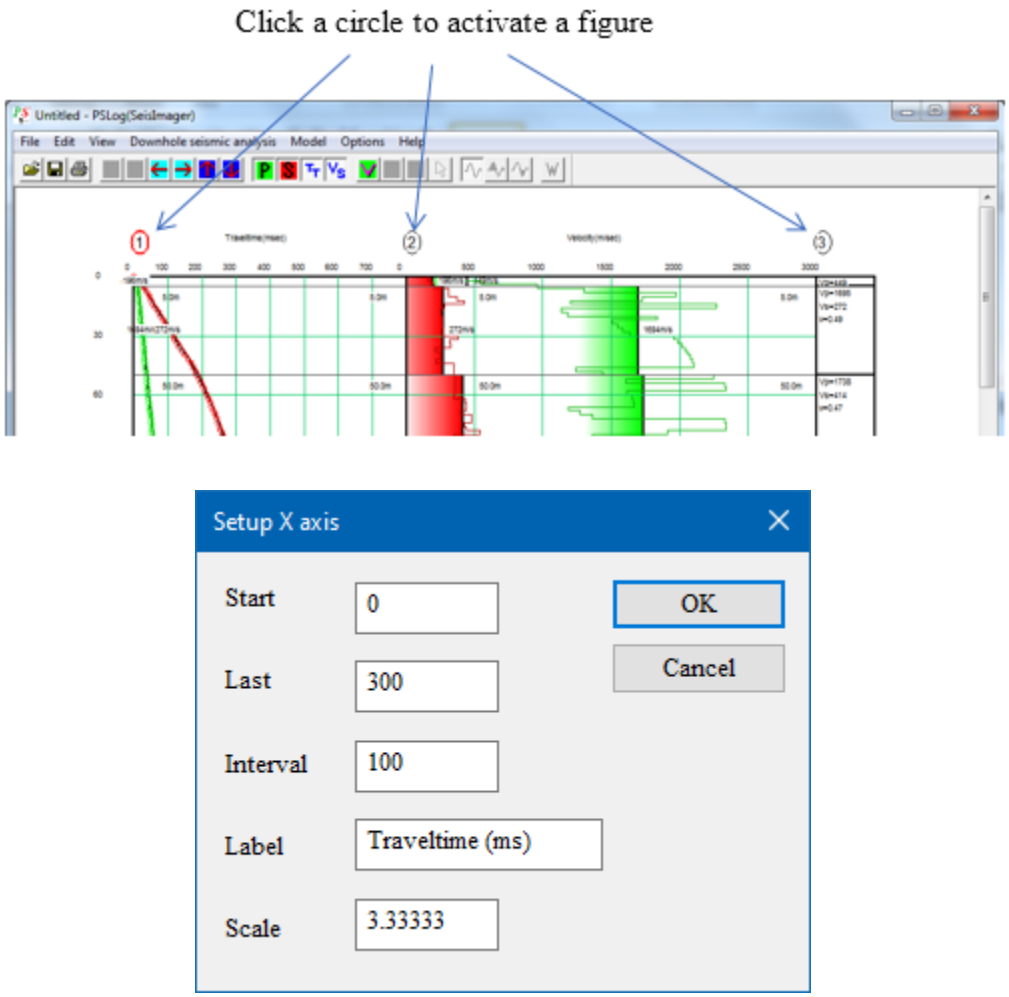


The **View** menu allows you to control what is viewed on the screen.

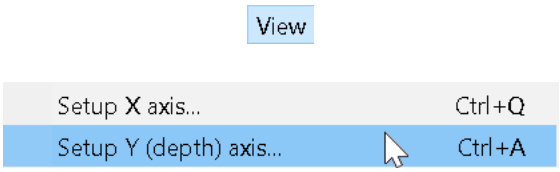
6.3.1 SET UP X AXIS [CTRL+Q]



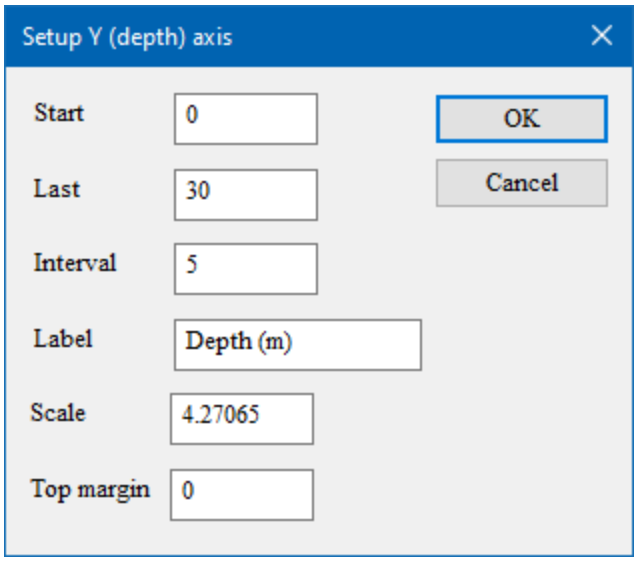
To configure X (horizontal) axis scales on a travel time curve and velocity model, choose a figure whose axis is to be changed by clicking the circle and index number at the left top of the appropriate figure. Then select *Setup X axis*, or press *CTRL+Q*.



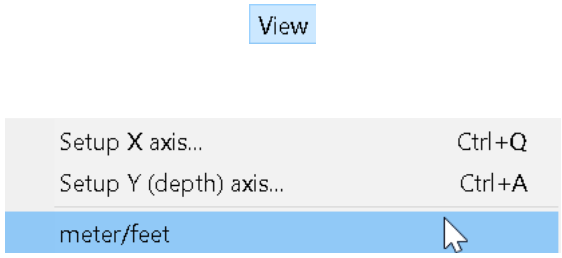
6.3.2 SET UP Y (DEPTH) AXIS [CTRL+A]



To configure the Y (depth) axis scale, select *Setup Y (depth) axis* or press *CTRL+A*. An identical scale setting is applied to all displays.

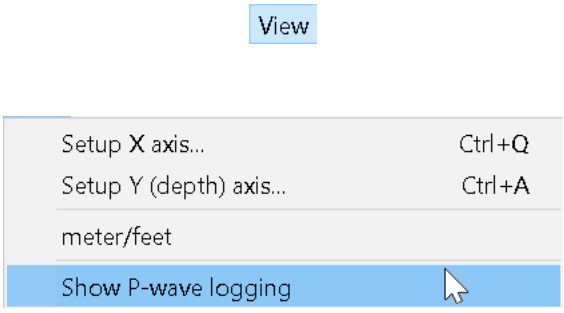


6.3.3 METER/FEET



Select the desired unit labels by switching *meter/feet*. The setting is reflected in the display labels, dialog box labels, and default values where applicable.

6.3.4 SHOW P-WAVE LOGGING P



You can select the type of logging to be shown by switching between *p-wave logging* and *s-wave logging* or by pressing the P and S buttons. To display p-wave logging data, check *View | p-wave logging* or push the P button. Examples of p- and s-wave logging display and p-wave logging only are shown below.

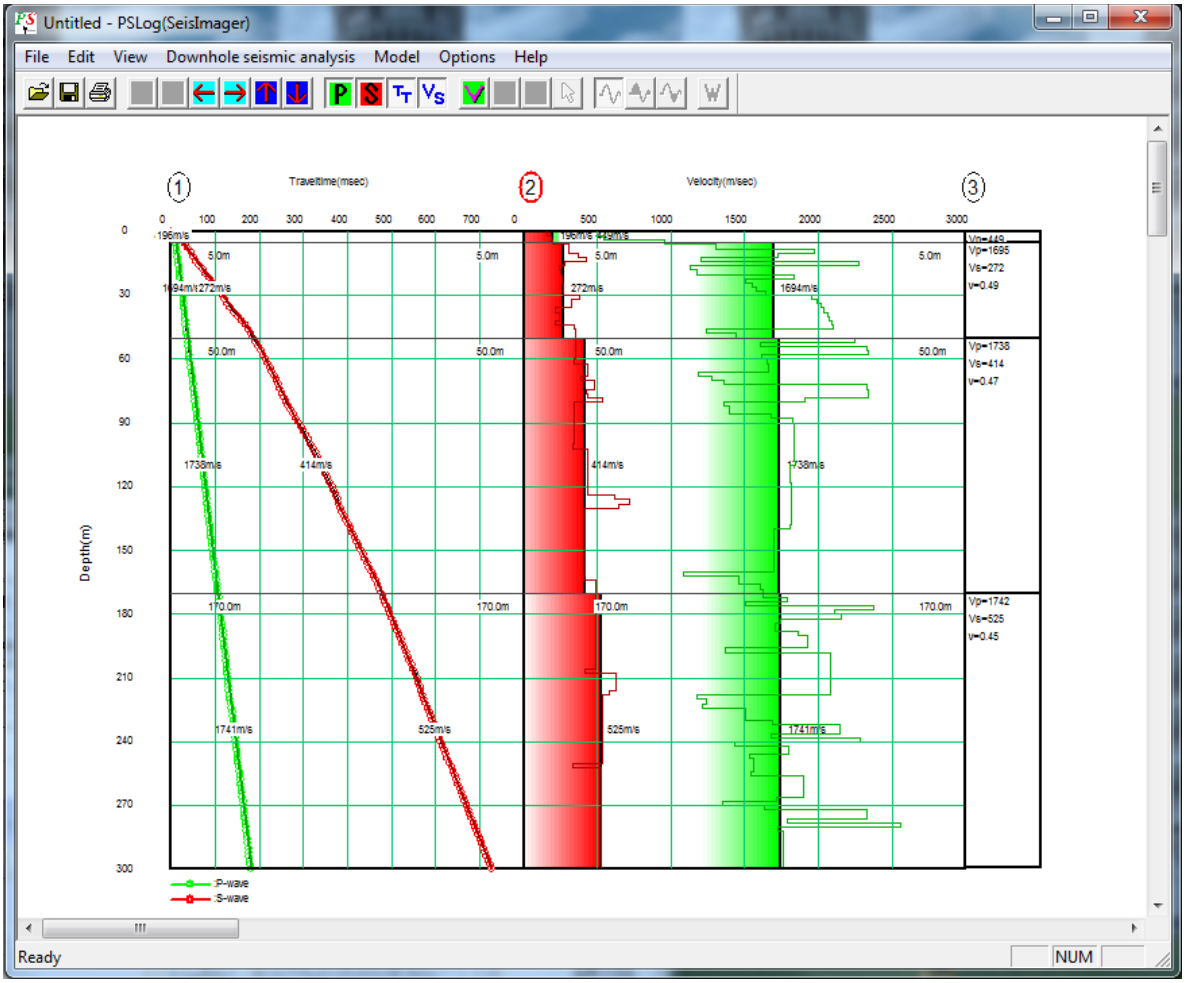


Figure 6: Example showing both p- and s-wave logging.

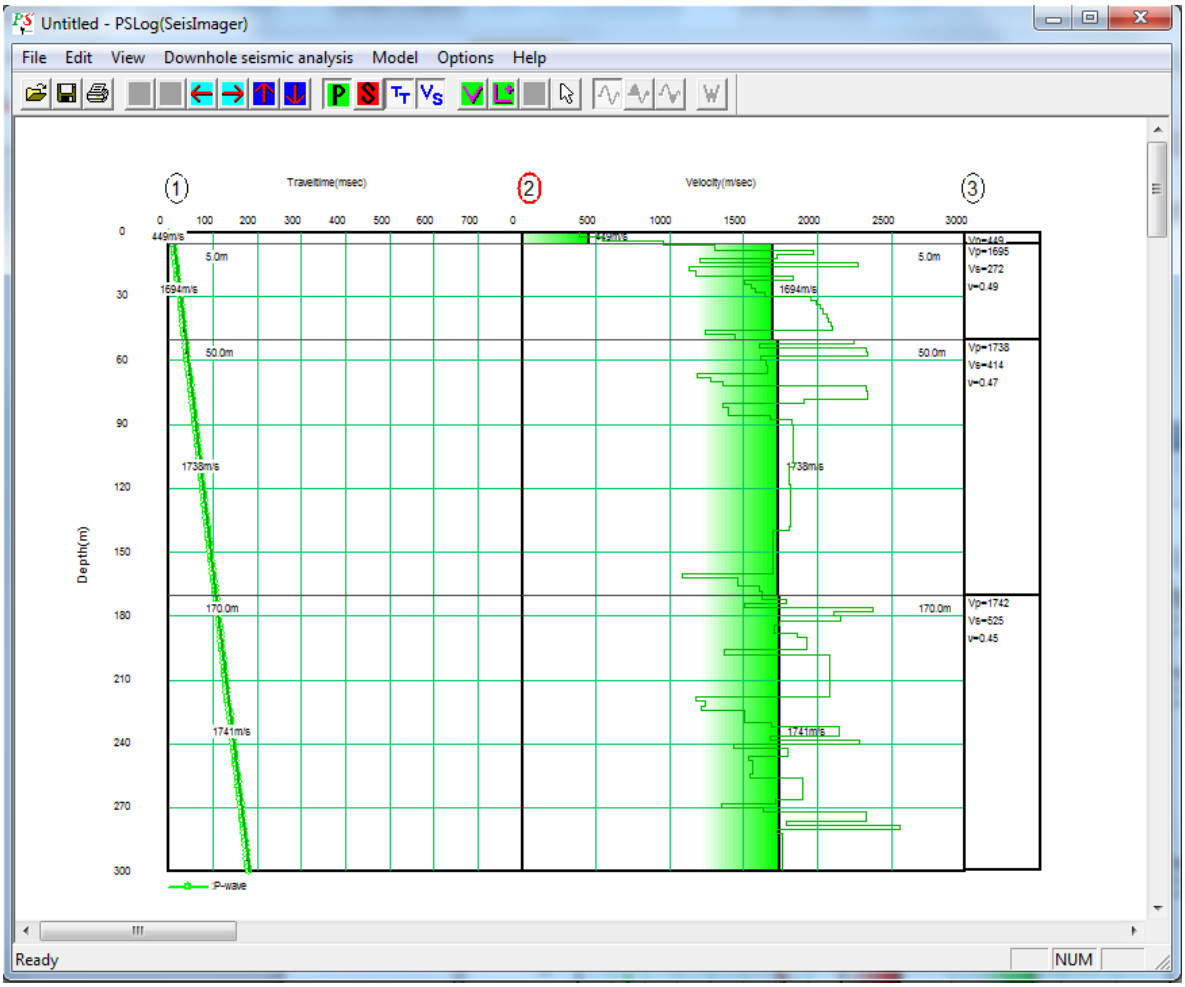
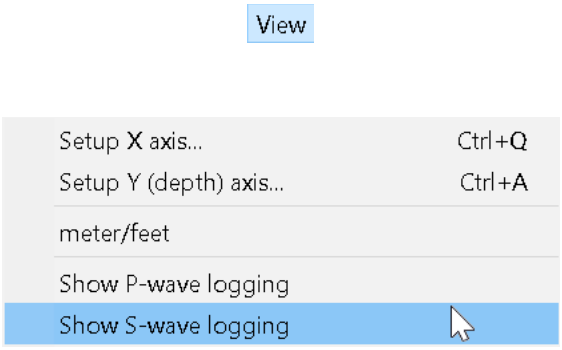
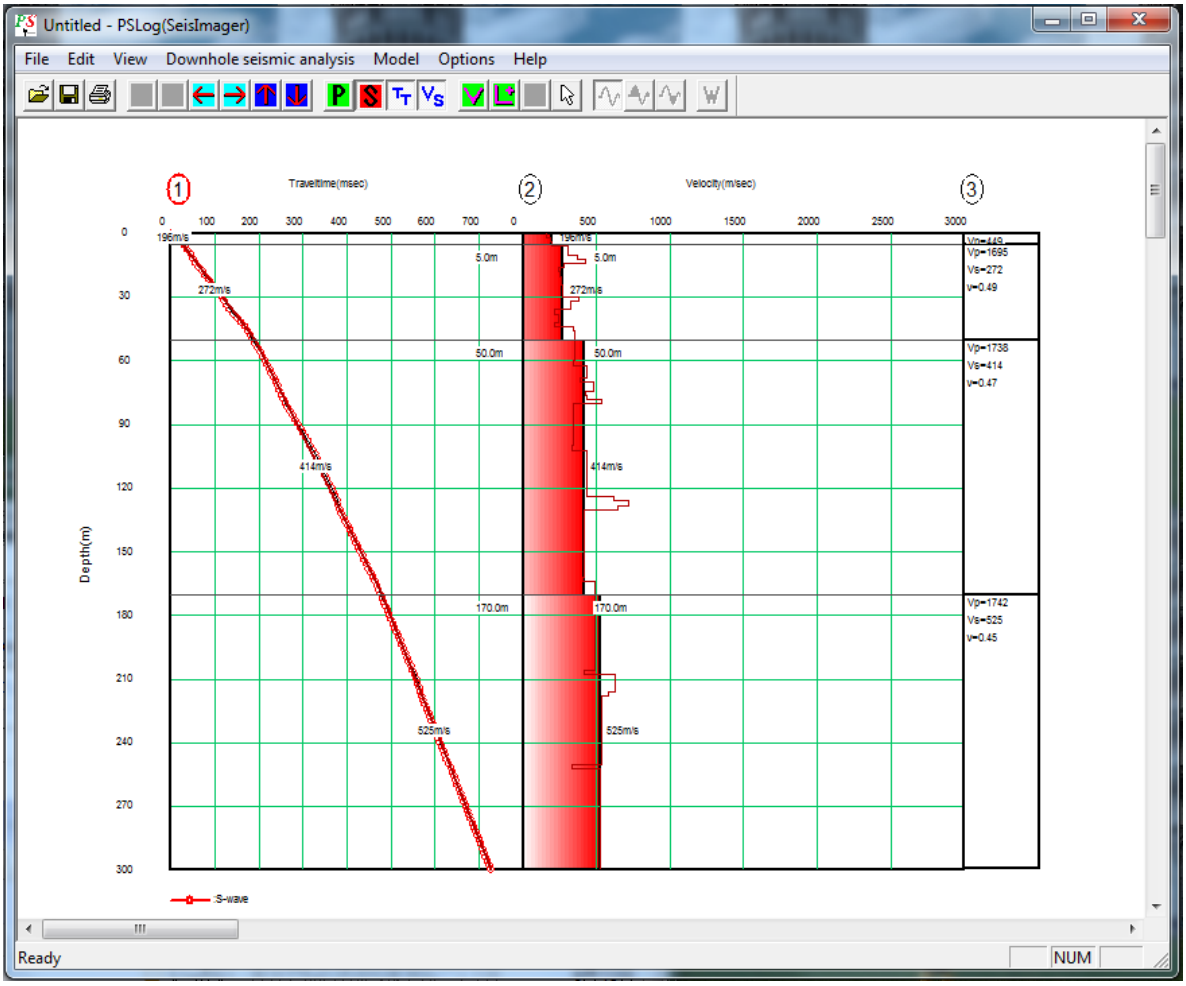


Figure 7: Example of p-wave logging only.

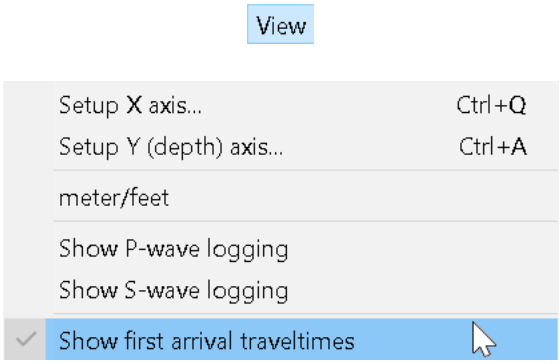
6.3.5 SHOW S-WAVE LOGGING



To display s-wave logging data, check *View* | *s-wave logging* or push the S button. An example of an s-wave logging display is shown below.



6.3.6 SHOW FIRST ARRIVAL TRAVEL TIMES



First arrivals can be toggled on or off. The two options are displayed below:

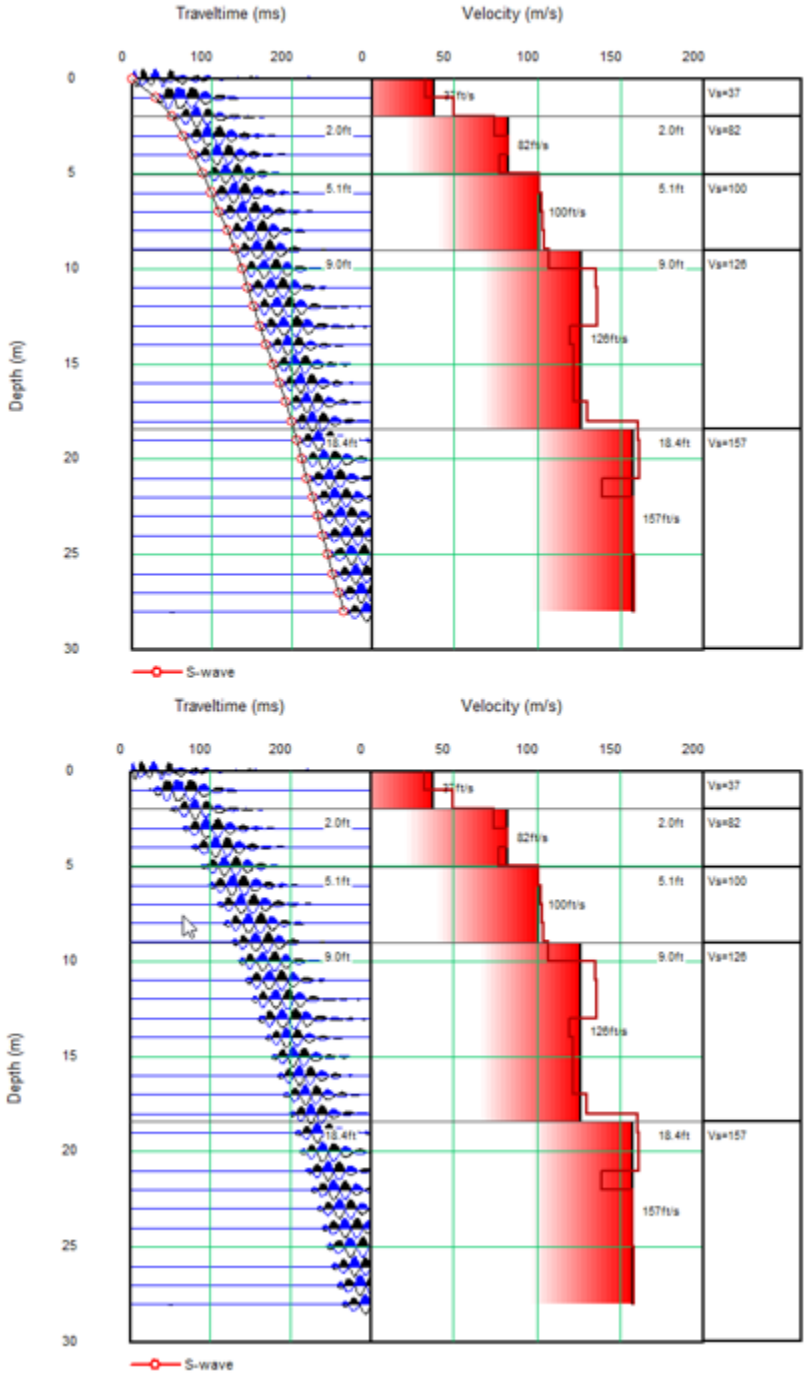
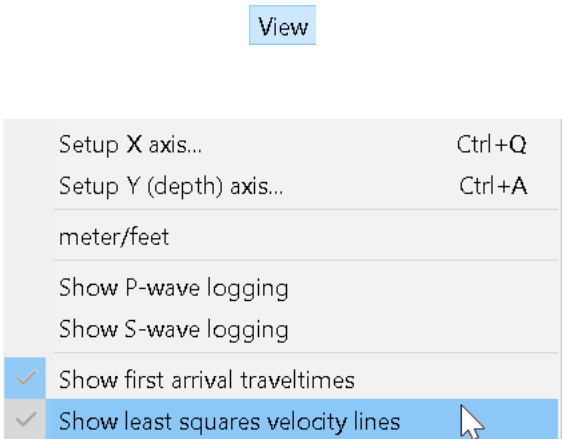


Figure 8: Travel time plot with first breaks displayed (top) and omitted (bottom).

6.3.7 SHOW LEAST-SQUARES VELOCITY LINES



The least-squares velocity line can be toggled on or off. The two options are displayed below:

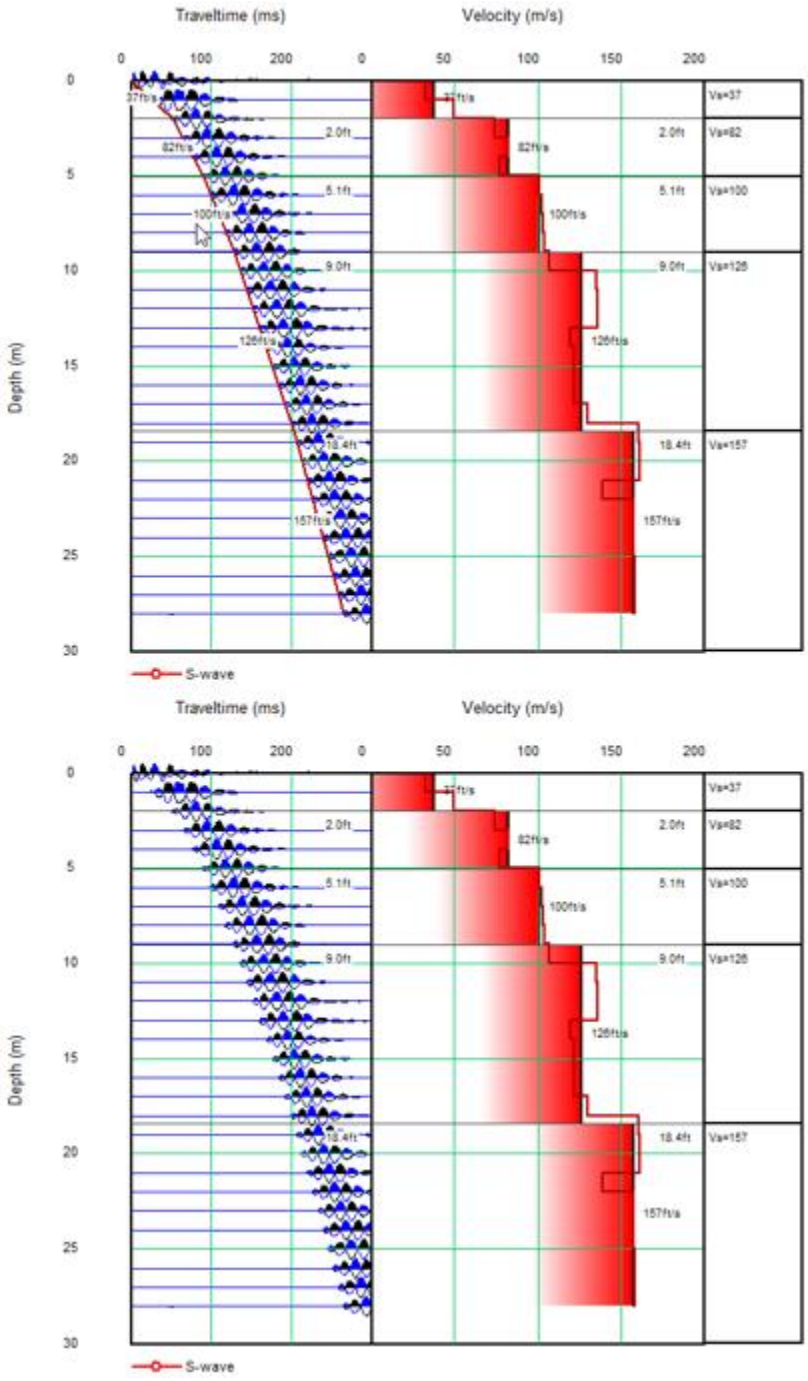
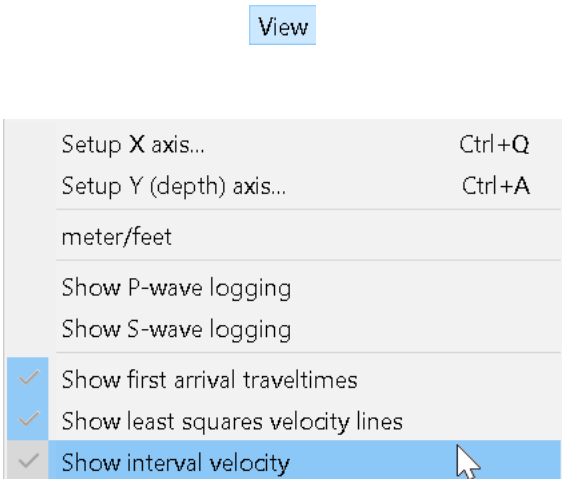


Figure 9: Travel time plot with least-squares line displayed (top) and omitted (bottom).

6.3.8 SHOW INTERVAL VELOCITY



The internal velocities can be toggled on or off. The two options are displayed below:

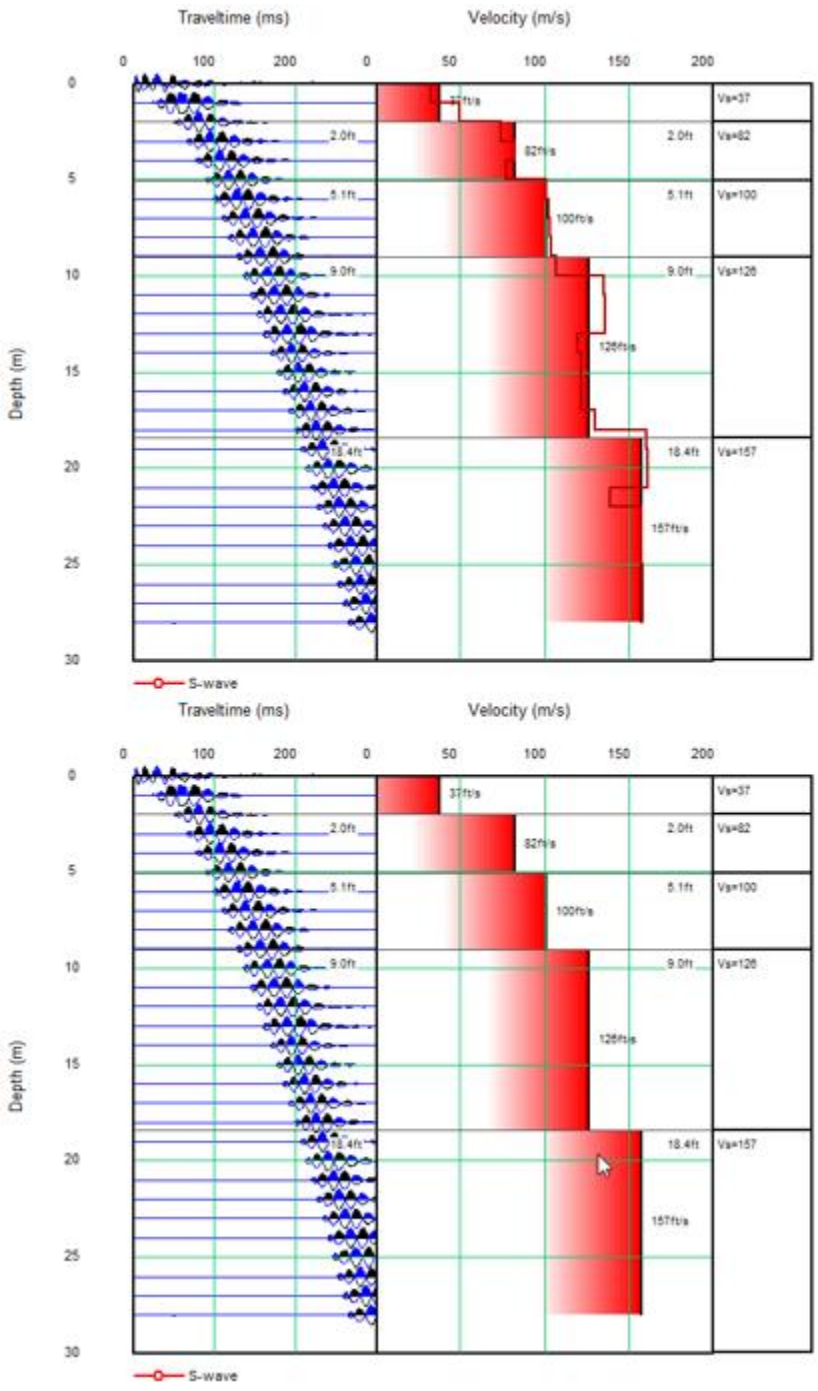
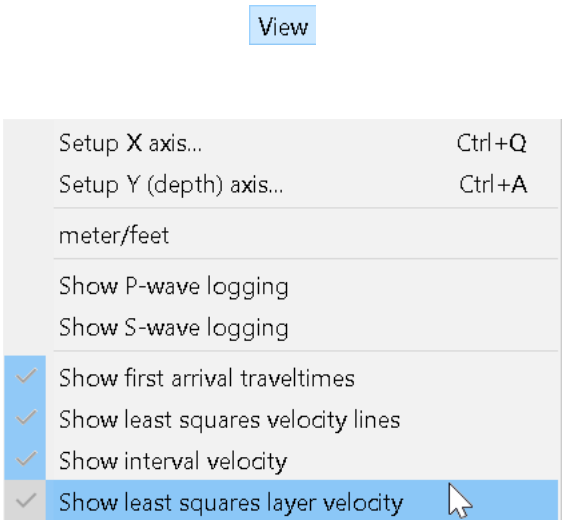


Figure 10: Velocity plot with internal velocities displayed (top) and omitted (bottom).

6.3.9 SHOW LEAST-SQUARES LAYER VELOCITY



The least-squares layer velocities can be toggled on or off. The two options are displayed below:

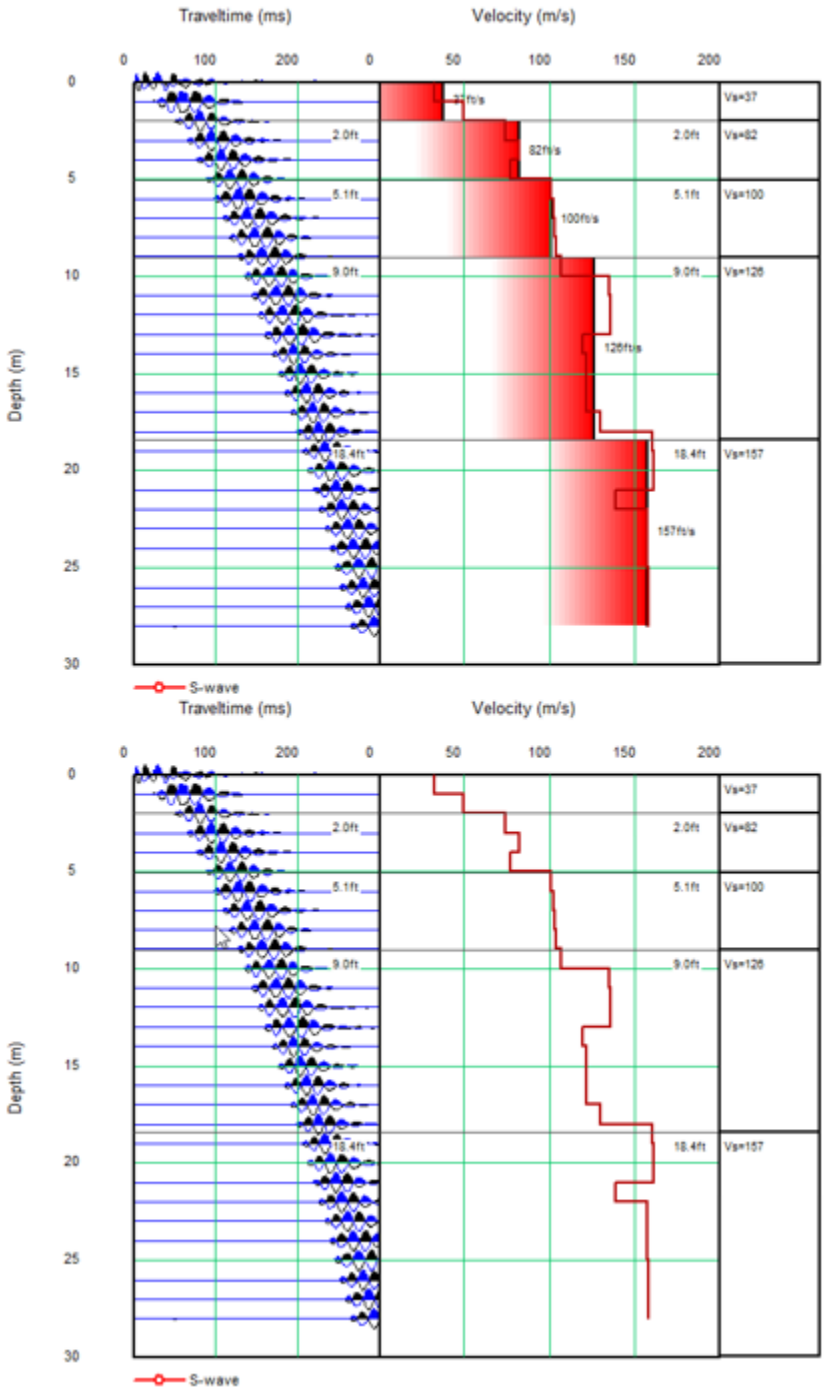
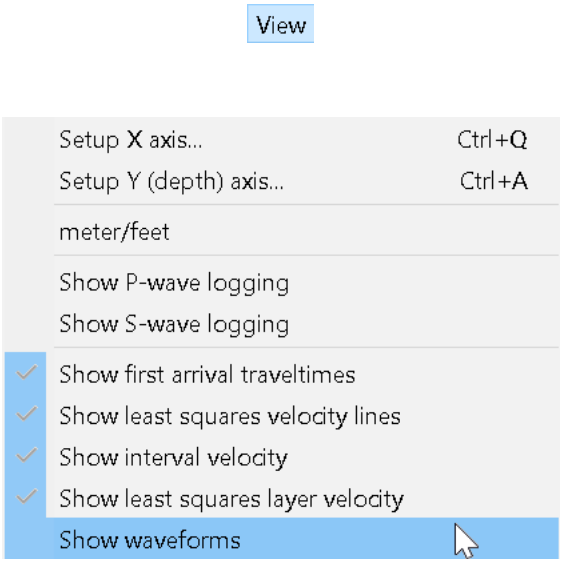


Figure 11: Velocity plot with least-squares layer velocities displayed (top) and omitted (bottom).

6.3.10 SHOW WAVEFORMS



The waveforms can be toggled on or off. The two options are displayed below. Waveform data can be imported to PSLog from Pickwin when you launch PSLog from Pickwin by selecting *Downhole seismic analysis* | *Show downhole velocity curve <launches PSLog>*. Imported waveforms cannot be edited in PSLog.

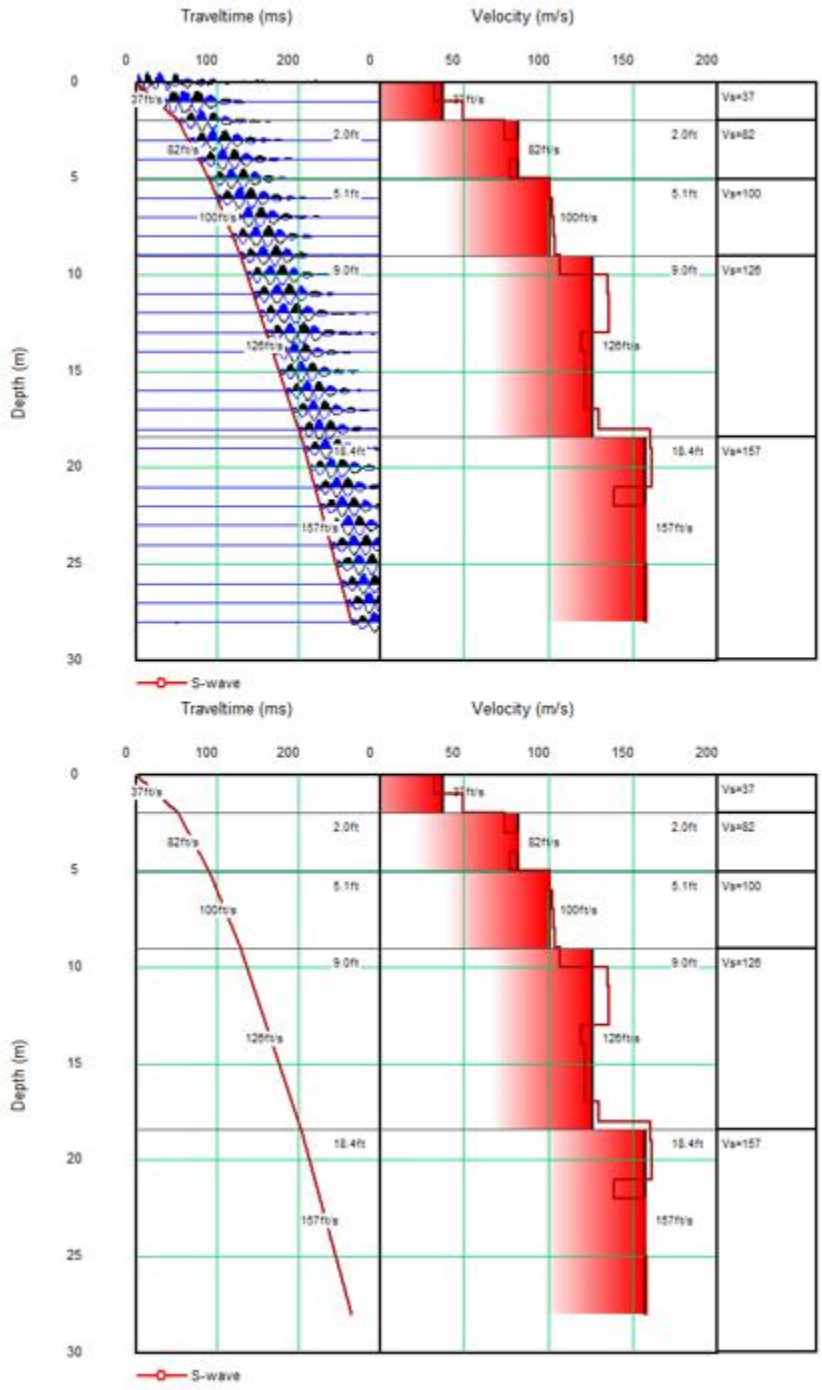
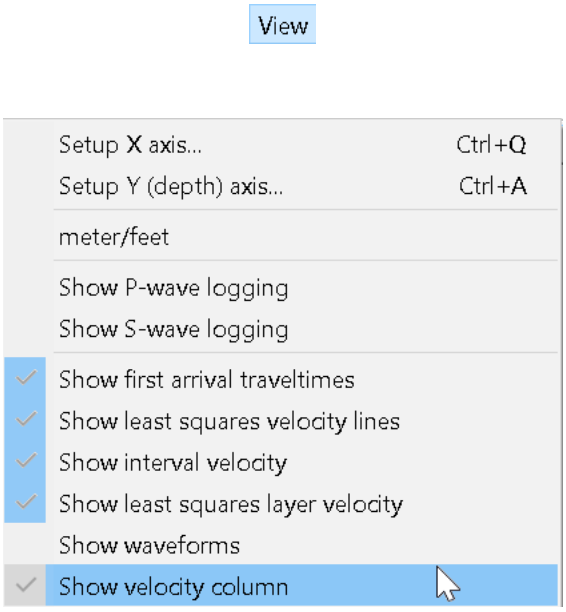


Figure 12: Travel time plot with waveforms displayed (top) and omitted (bottom).

6.3.11 SHOW VELOCITY COLUMN



The velocity column can be toggled on or off. The two options are displayed below. This column can display velocity, Poisson's Ratio, density, and the shear and Young's moduli. In order to display elastic moduli, densities of layers must be entered by selecting *Model* | *Show layered model* in PSLog (see Section 6.5.1, Page 101).

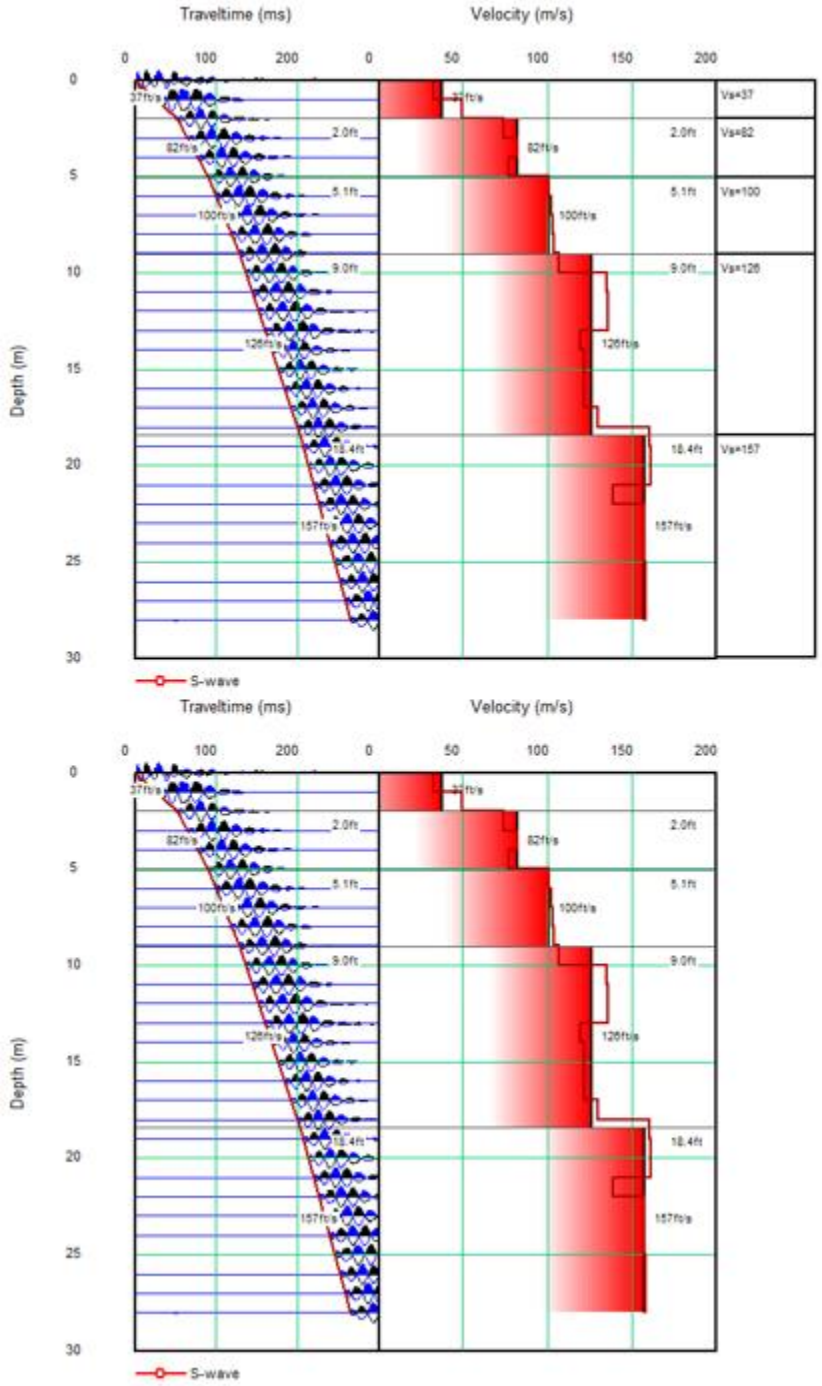
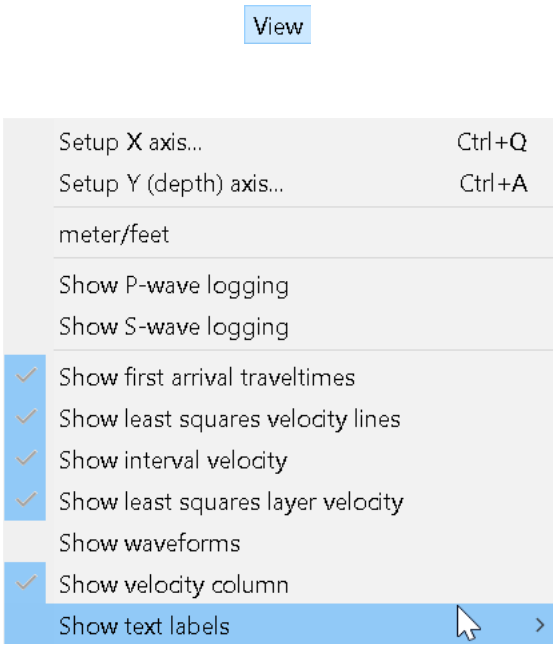


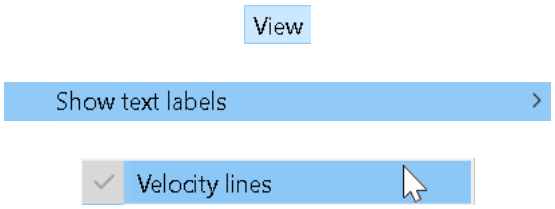
Figure 13: Velocity plot with velocity column displayed (top) and omitted (bottom).

6.3.12 SHOW TEXT LABELS



Continue.

6.3.12.1 VELOCITY LINES



The text labels for the velocity lines can be toggled on or off. The two options are displayed below:

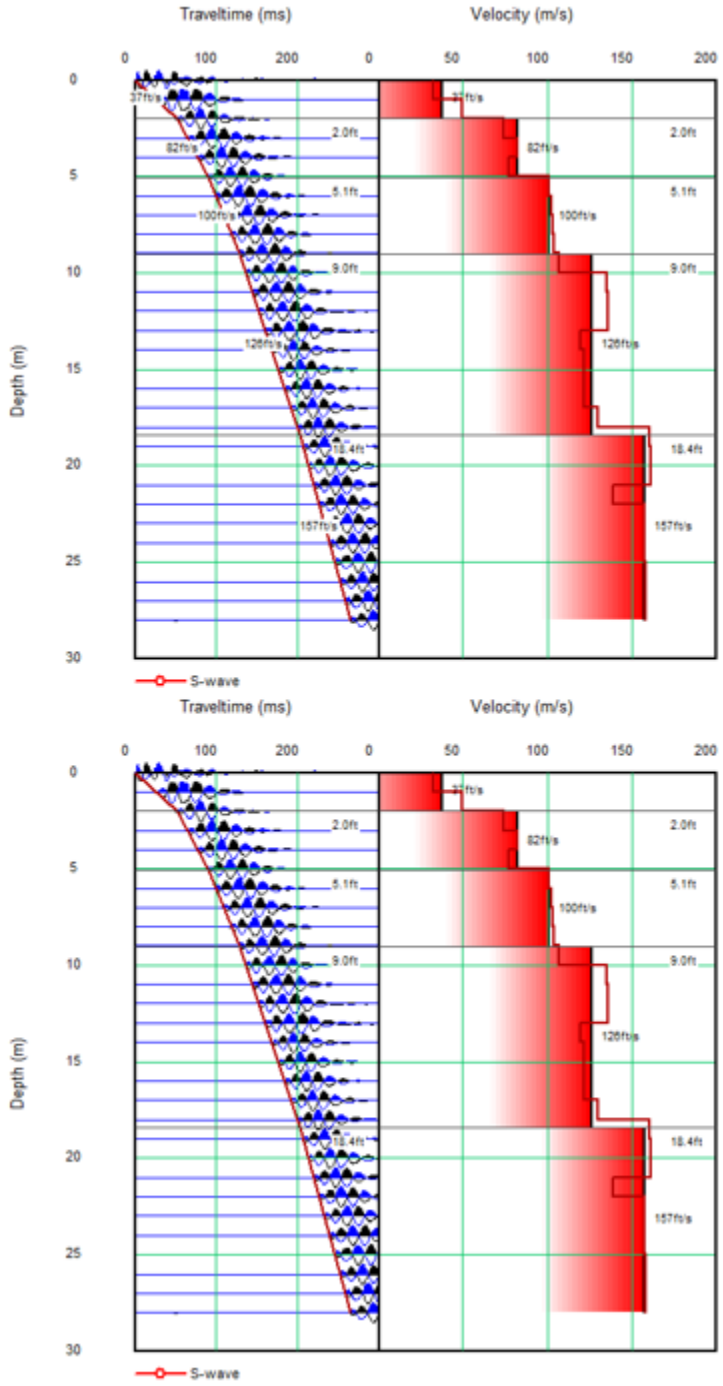
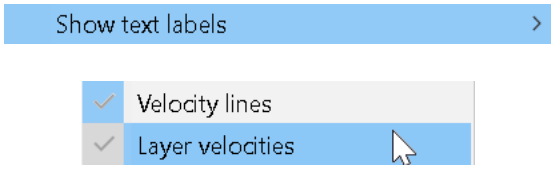


Figure 14: Travel time plot with velocity line text labels displayed (top) and omitted (bottom).

6.3.12.2 LAYER VELOCITIES

View



The text labels for the layer velocities can be toggled on or off. The two options are displayed below:

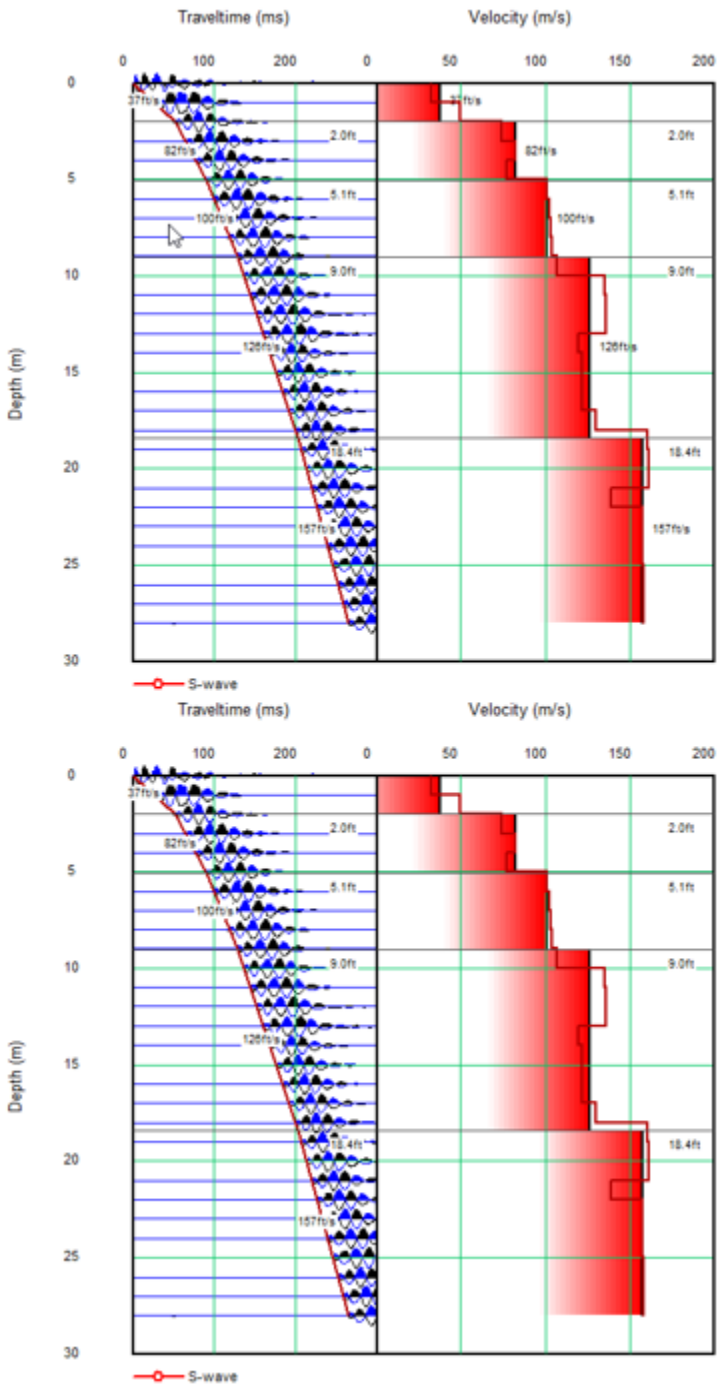
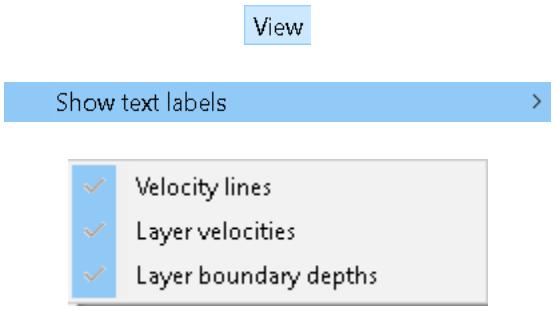


Figure 15: Velocity plot with layer velocity text labels displayed (top) and omitted (bottom).

6.3.12.3 LAYER BOUNDARY DEPTHS



The text labels for the layer boundary depths can be toggled on or off. The two options are displayed below:

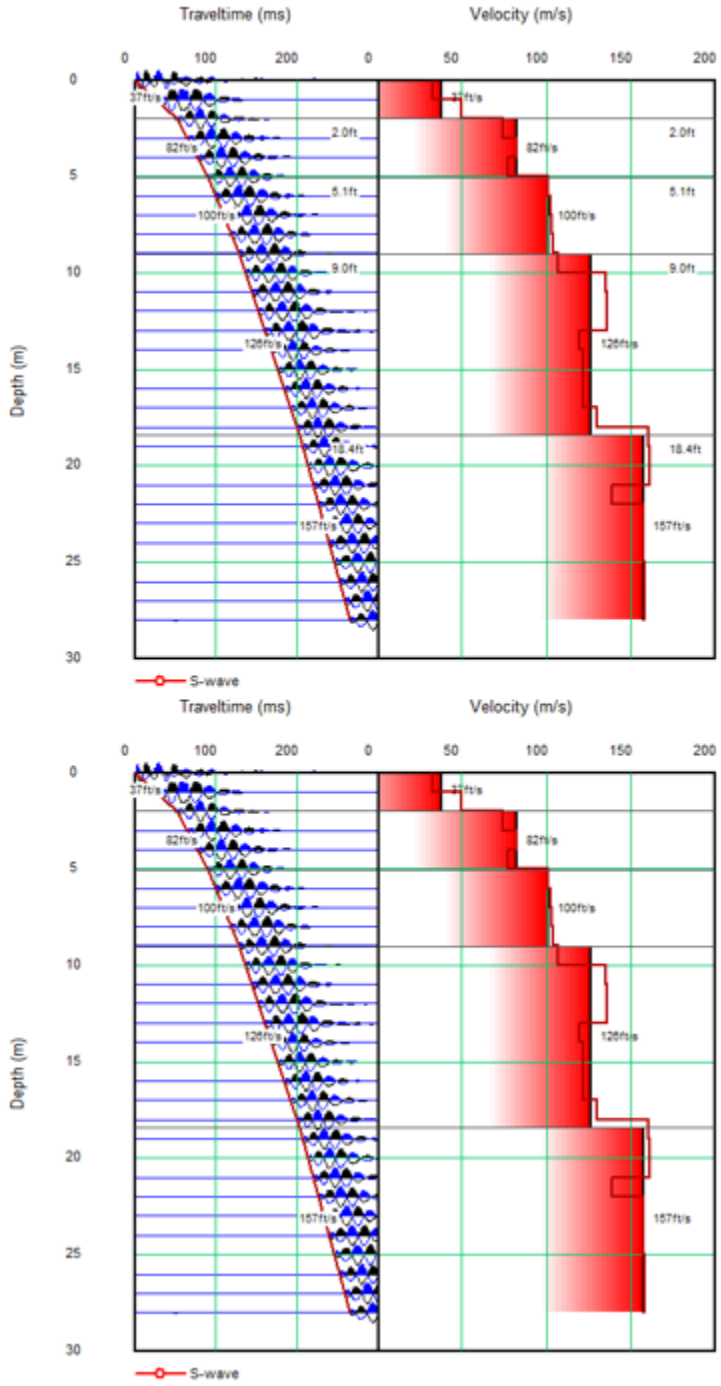
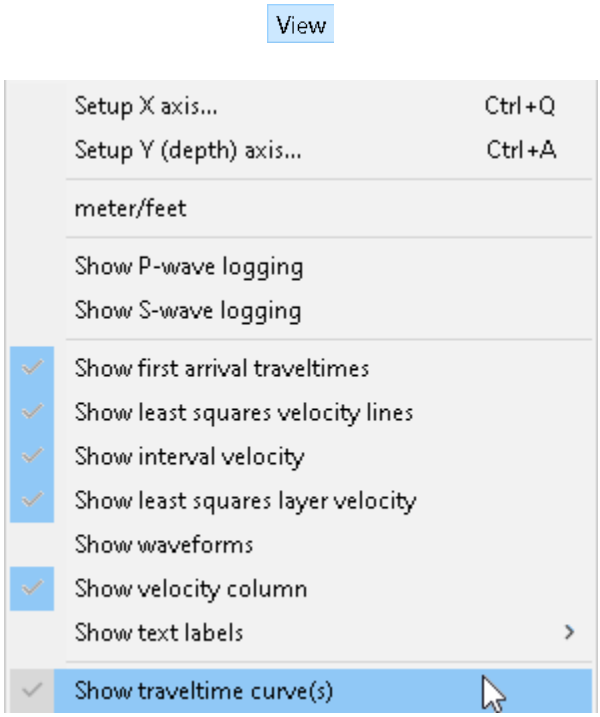


Figure 16; Velocity plot with layer boundary depth text labels displayed (top) and omitted (bottom).

6.3.13 SHOW TRAVEL TIME CURVE(S)



Travel time curve(s) (waveforms) can be toggled on or off. The two options are displayed below:

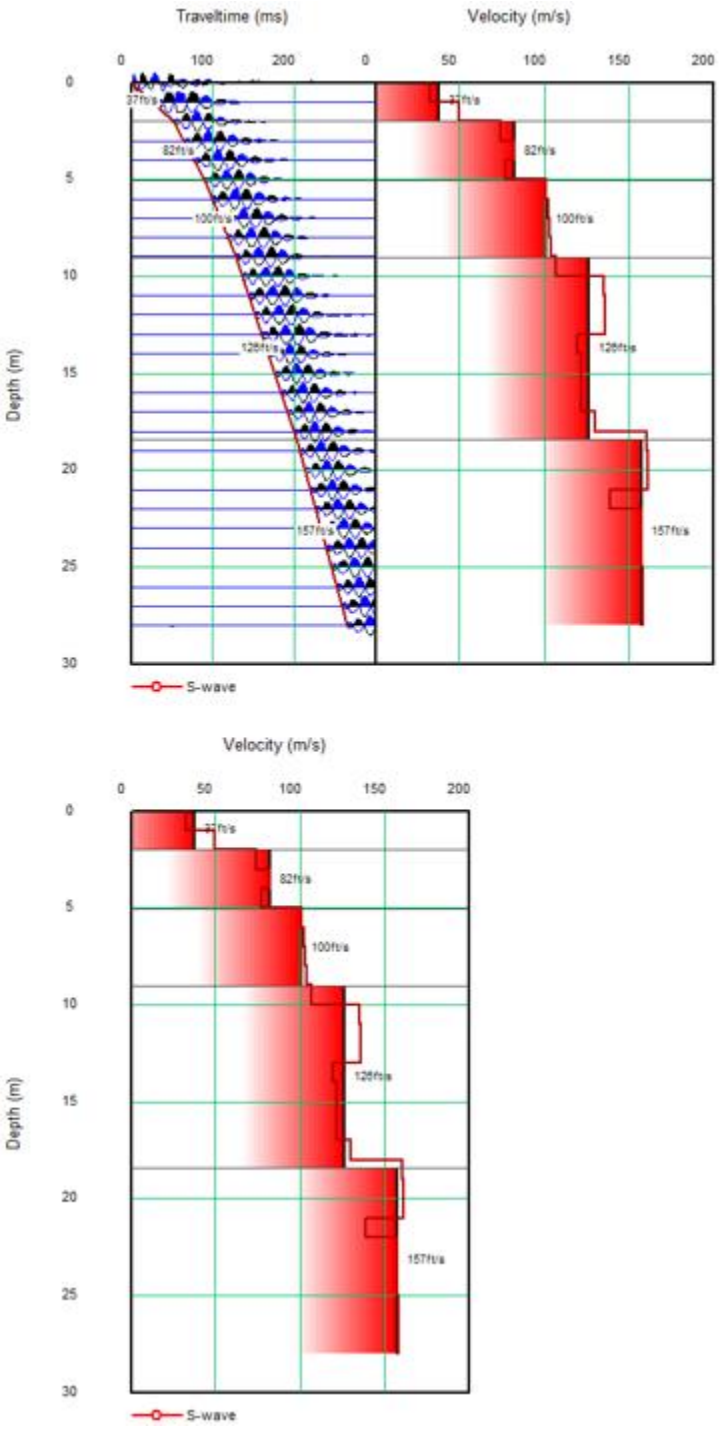
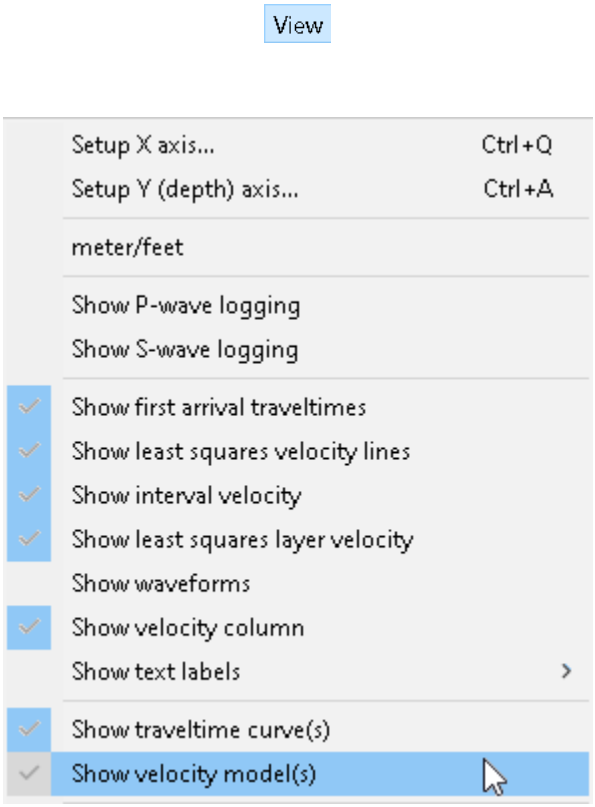


Figure 17: Travel time curve displayed (top) and omitted (bottom).

6.3.14 SHOW VELOCITY MODEL(S)



Velocity model(s) can be toggled on or off. The two options are displayed below:

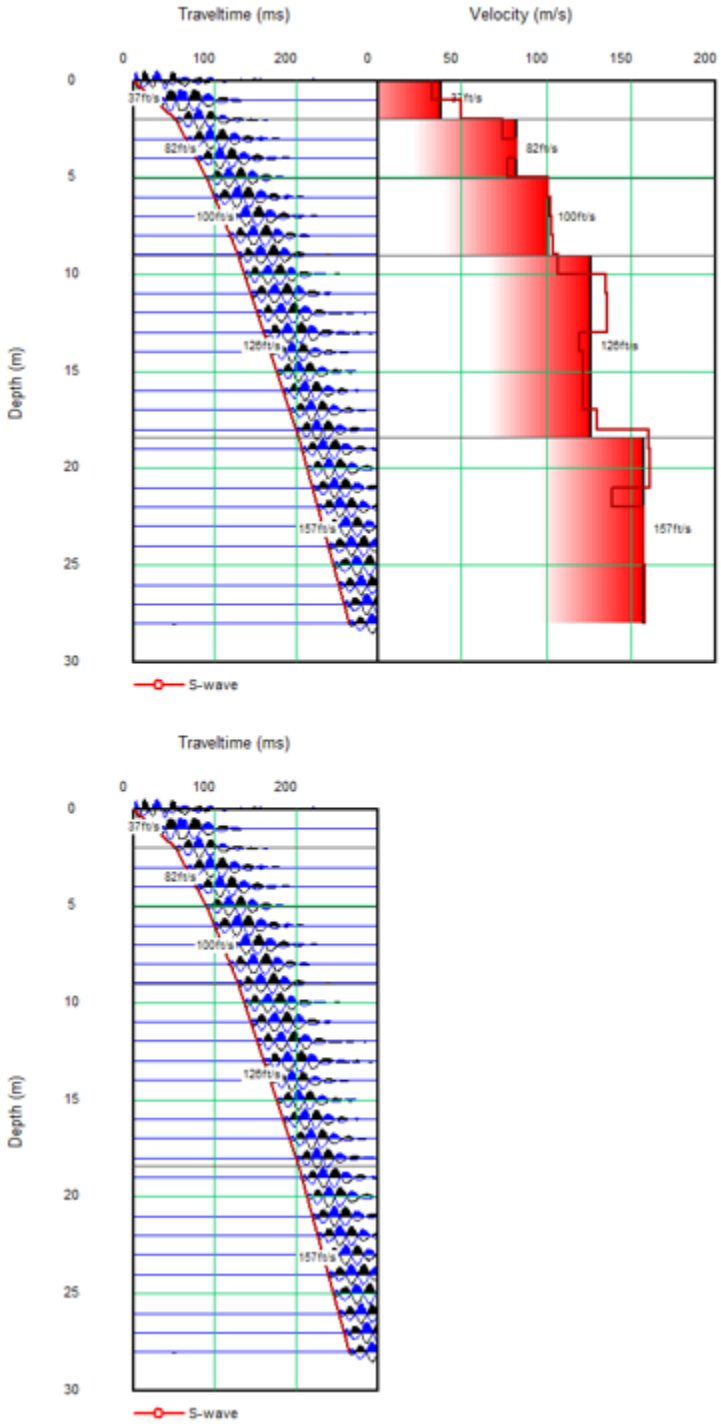
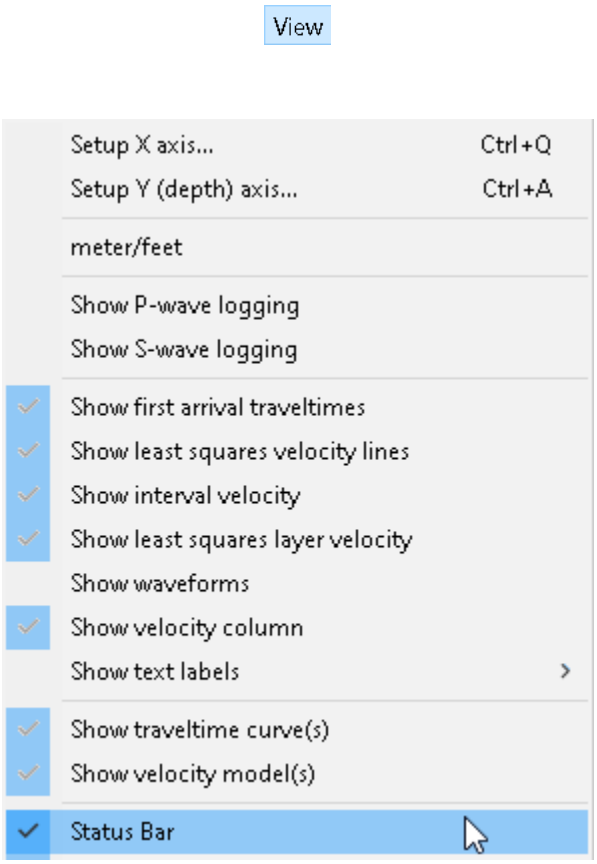


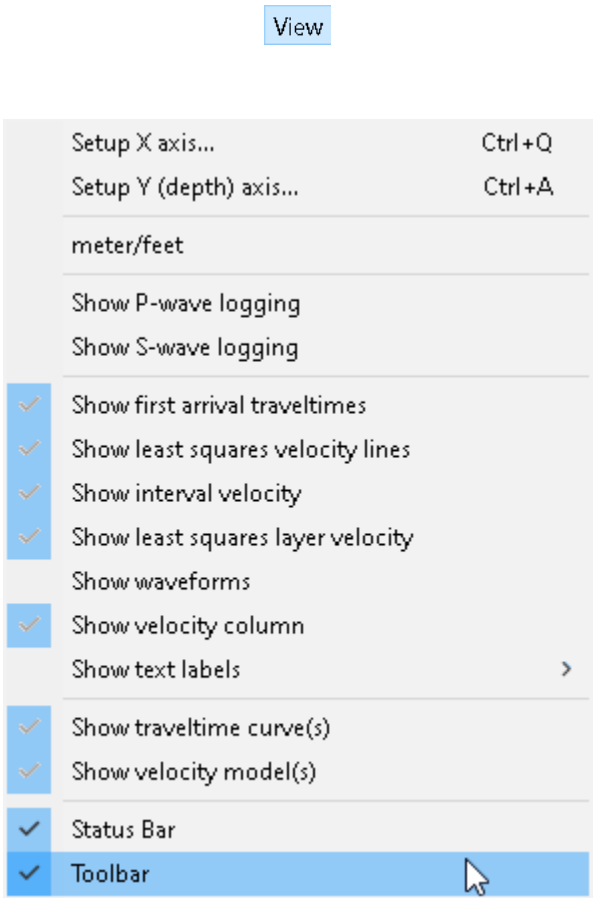
Figure 18: Velocity model displayed (top) and omitted (bottom).

6.3.15 STATUS BAR



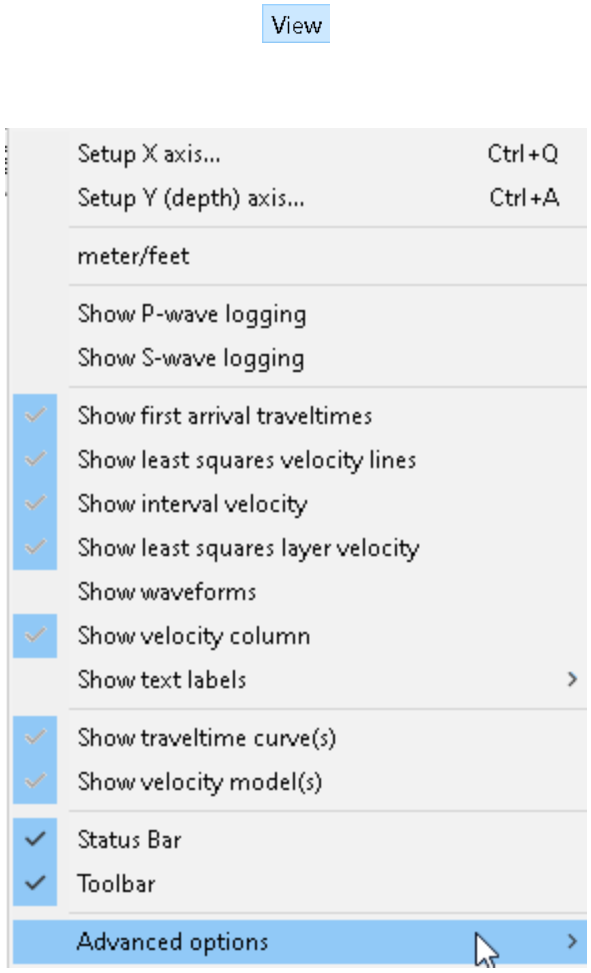
The Status bar, displayed at the bottom of the screen and shown below, can be toggled on and off.

6.3.16 TOOLBAR

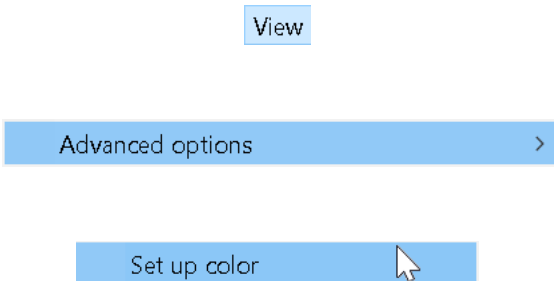


The Toolbar, displayed at the top of the display and shown below, can be toggled on and off.

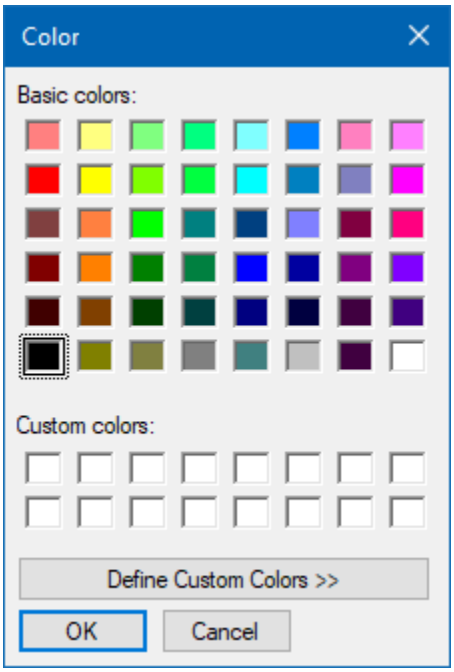
6.3.17 ADVANCED OPTIONS



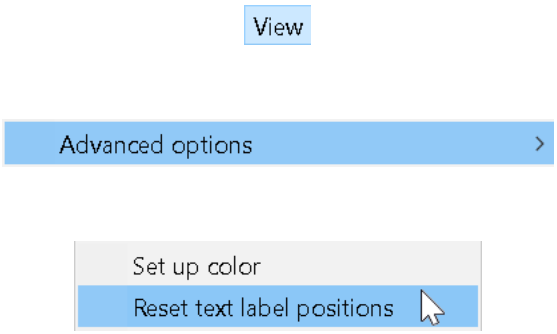
6.3.17.1 SET UP COLOR



Display color may be customized as desired. Feel free to experiment with the color scheme until you find one that is pleasing.

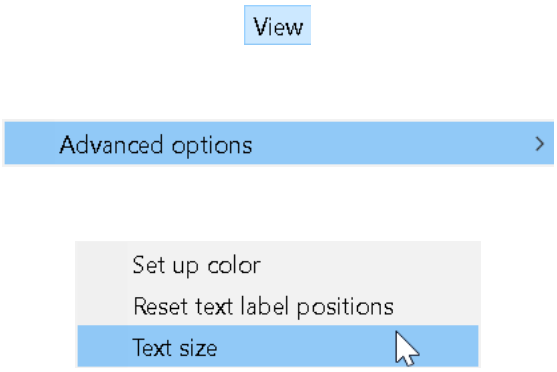


6.3.17.2 RESET TEXT LABEL POSITIONS

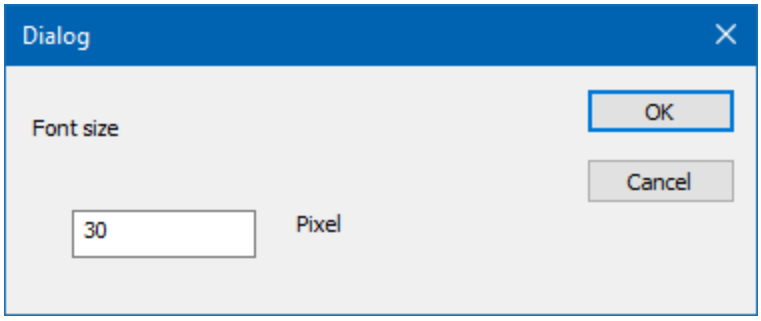


Text label positions are set automatically at the onset but can be moved using your mouse. Selecting *View> Reset text label positions* will move all text labels back to their original default positions.

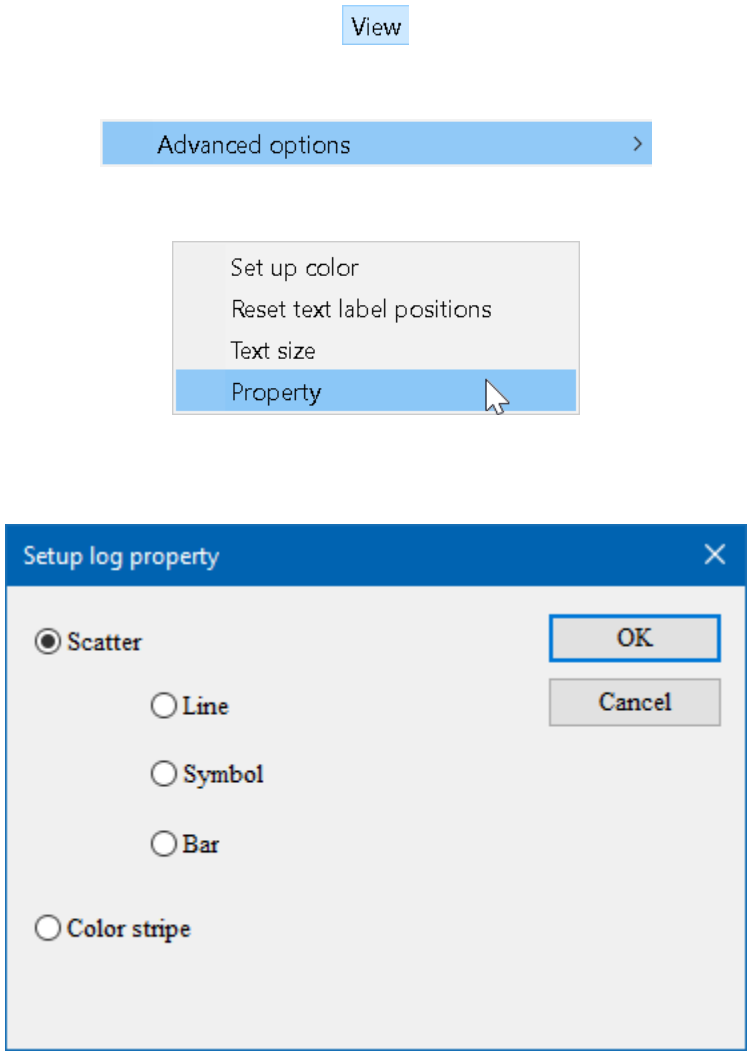
6.3.17.3 TEXT SIZE



Choose a text size that works for you.

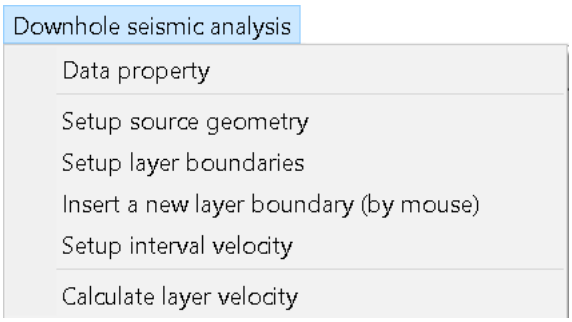


6.3.17.4 PROPERTY



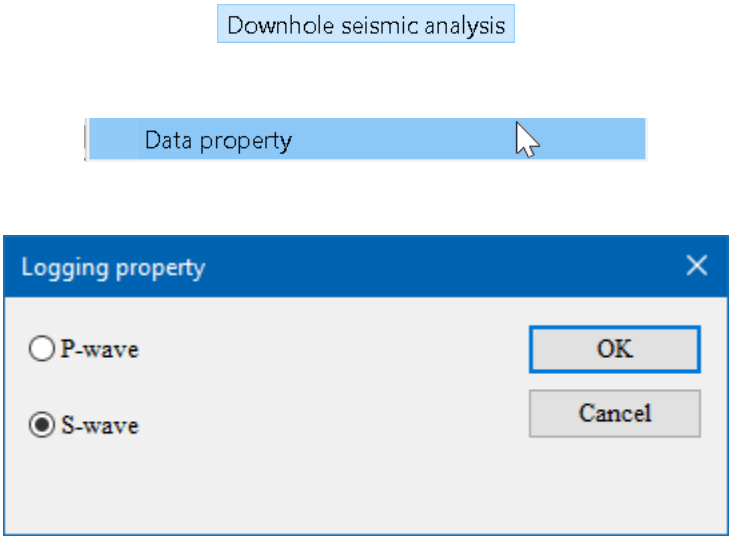
This feature affects the appearance of the velocity log and is best understood by experimentation.

6.4 THE PSLOG DOWNHOLE SEISMIC ANALYSIS MENU



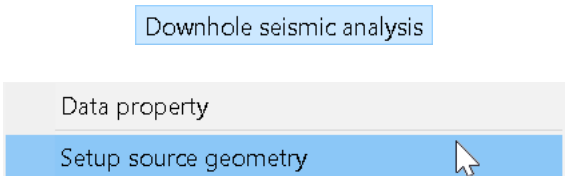
The **Downhole seismic analysis** menu contains functions for analysis travel time data.

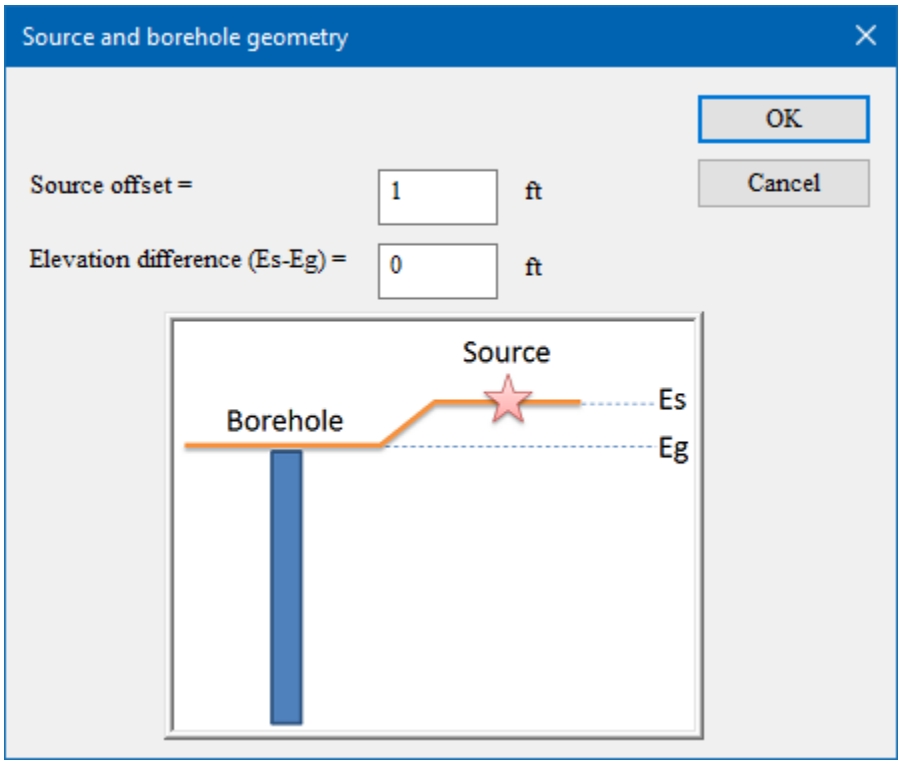
6.4.1 DATA PROPERTY



Indicate which type of data you wish to analyze, *p-wave* or *s-wave*.

6.4.2 SET UP SOURCE GEOMETRY

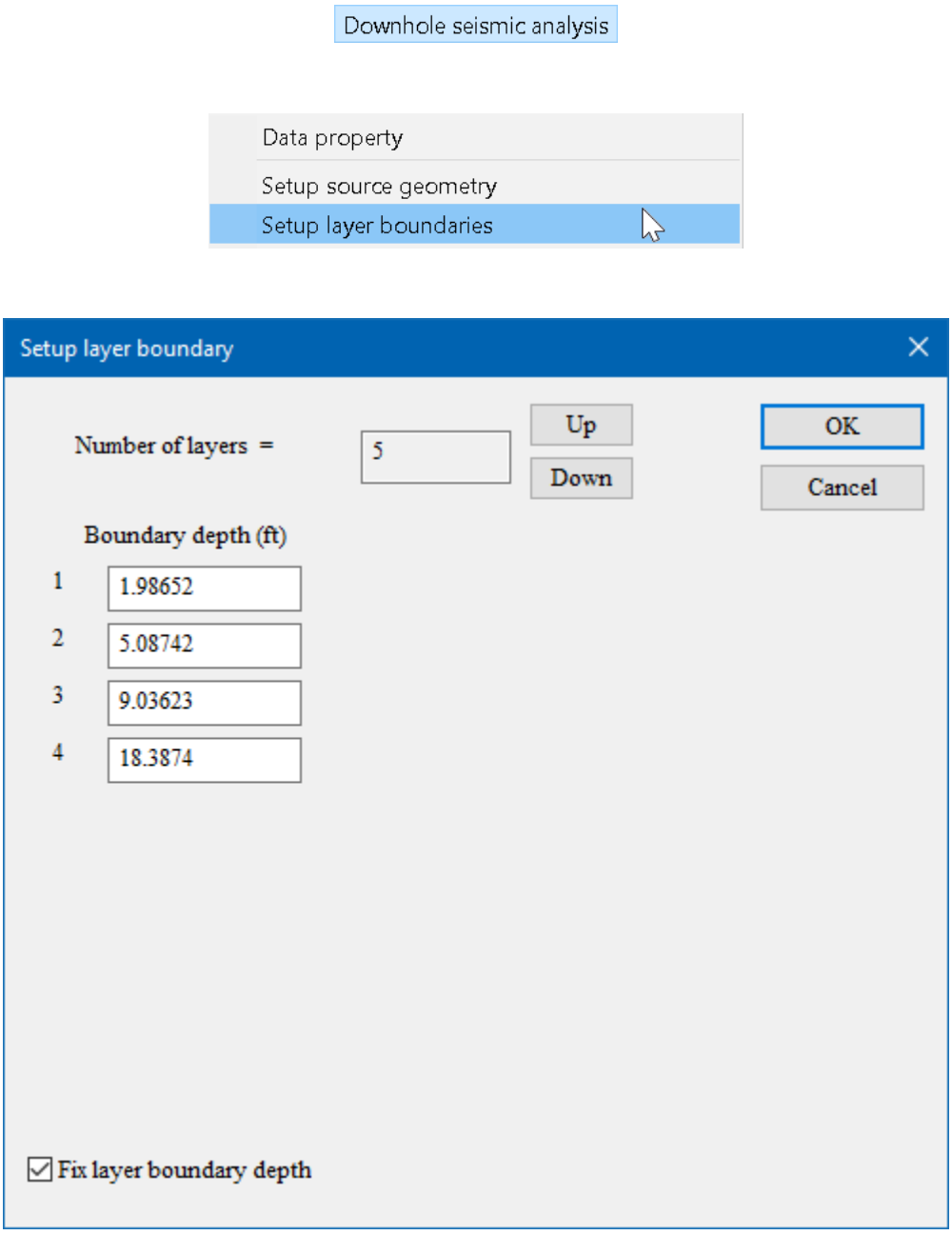




The source geometry is assigned when the data is imported from Pickwin. To see or modify the source geometry, select *Downhole seismic analysis* | *Setup source geometry*.

Enter the *Source offset* from the hole and the *Elevation difference* between the source and the ground surface at the hole. Elevation difference must be positive if the source is higher than the top of the borehole.

6.4.3 SET UP LAYER BOUNDARIES



Indicate the *Number of layers* (up to 20) in the model and the *Boundary depth*, i.e., the depth to the top of each layer, from shallow to deep. The velocity of each layer is automatically calculated from the travel time data by the least-squares method. When *Fix layer boundary depth* is checked, velocity lines obtained by the least-squares method will cross exactly at the assigned depth. This is illustrated in Figure 19 below.

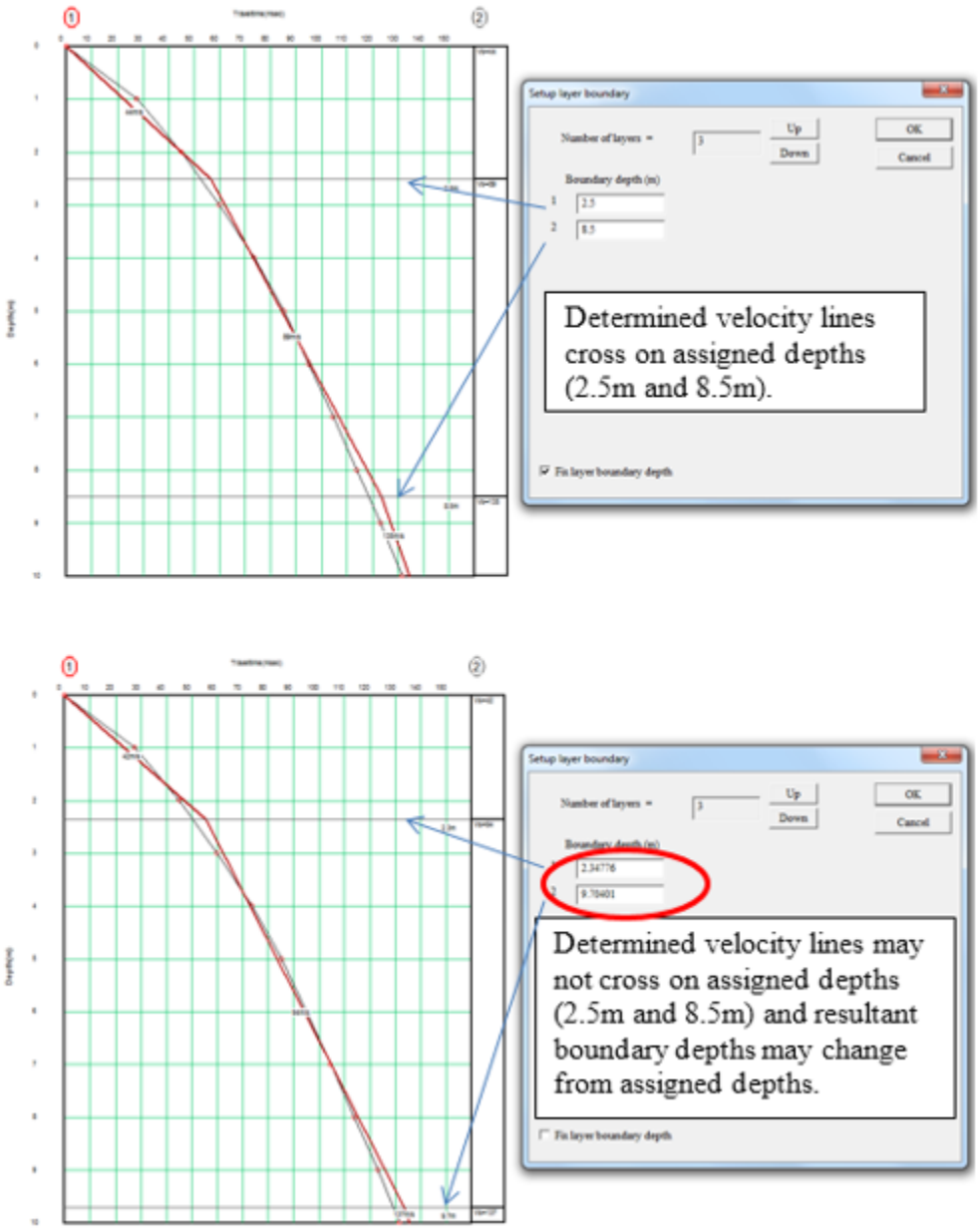


*Figure 19: Illustration of **Fix layer boundary depth**. In the top figure, this parameter is enabled, forcing the slope change of the least-squares line to occur at the assigned boundary depth. In the bottom figure, the parameter is not enabled, and the least-squares line does not coincide with the assigned boundary layer depth.*

Note that when data is imported from Pickwin, *Number of layers* defaults to 1. Part of the interpretation process is assigning a reasonable number of model layers, based partly on the calculated interval velocities, without over-interpreting the data. As you add layers, the velocity model will increasingly approximate the interval velocities. It is generally best to enable *Fix layer boundary depth* in this process. This is best illustrated by example; see the figures below.

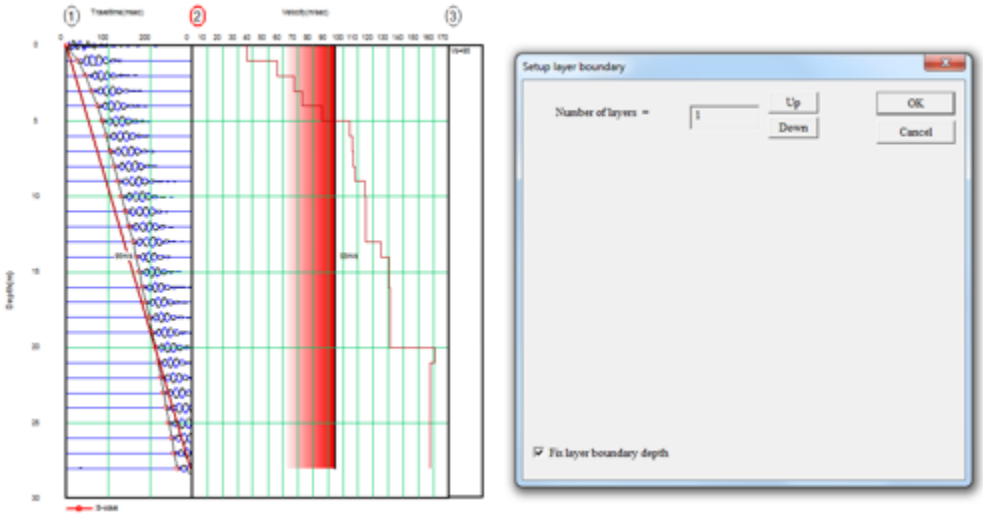


Figure 20: Single-layer interpretation of data.

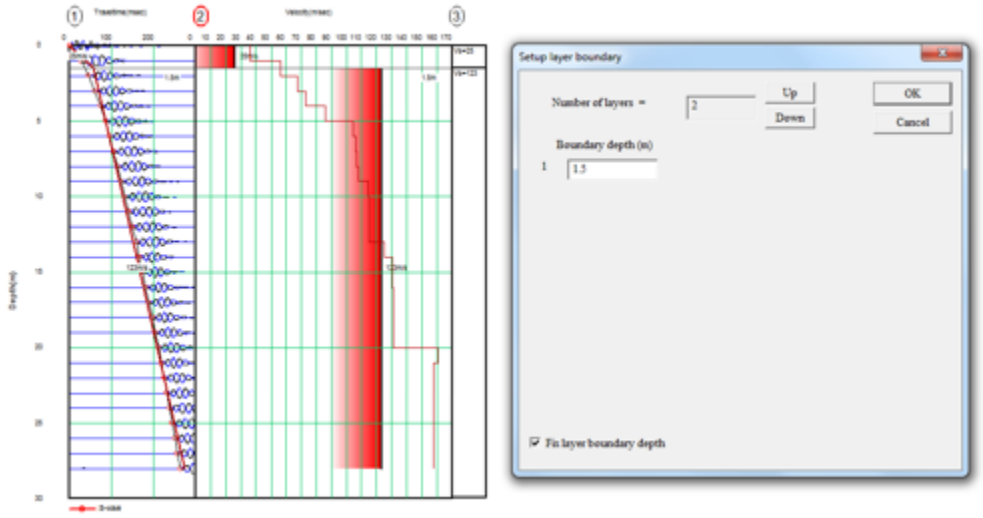


Figure 21: T-wo layer interpretation of data.

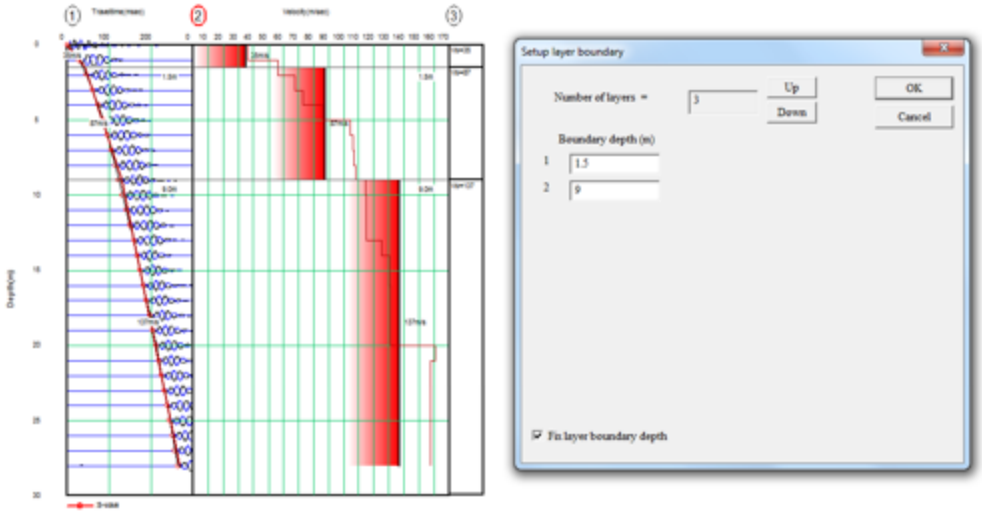


Figure 22: Three-layer interpretation of data.

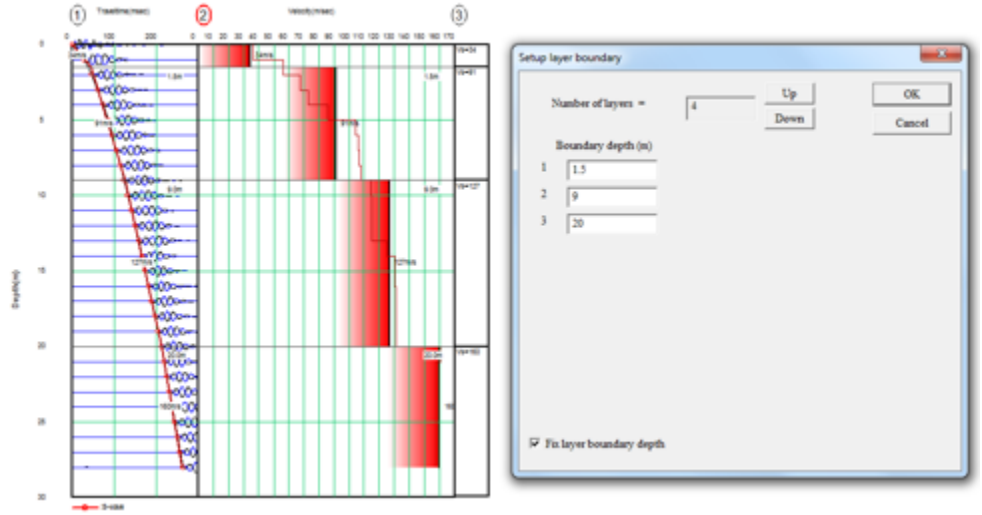
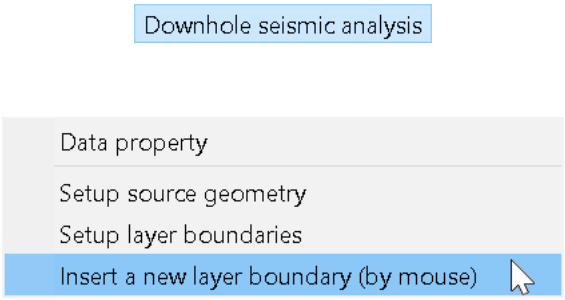


Figure 23: Four-layer interpretation of data. As the number of layers increases, the model matches the interval velocities to a greater and greater degree. The number of layers you assign depends on your confidence level in the interval velocity model. This is similar to assigning layers in refraction, and as a geophysicist you must take care not to over-interpret your data.

6.4.4 INSERT A NEW LAYER BOUNDARY (BY MOUSE)



To insert new layer boundary, select *Insert new layer boundary (by mouse)* or click and then click the depth at which you would like to insert the new layer.

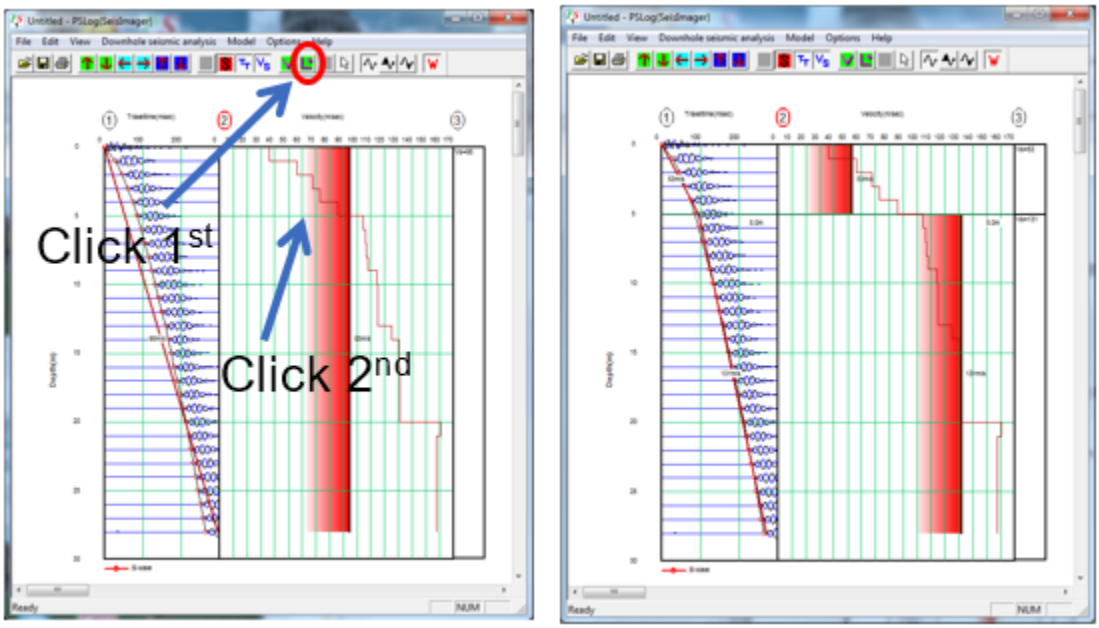
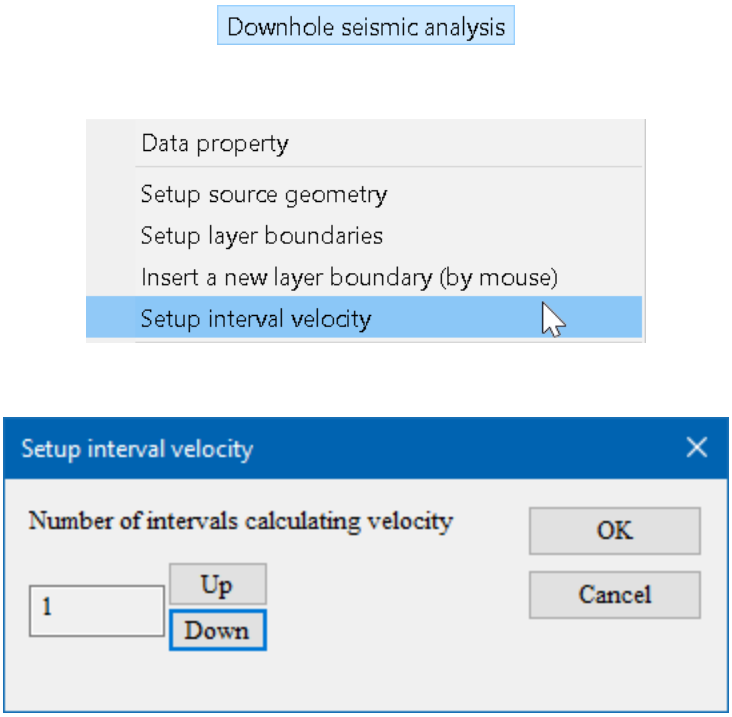


Figure 24: Inserting a new layer using the mouse.

6.4.5 SET UP INTERVAL VELOCITY



The interval velocities are calculated between each pair of travel times and are shown on the velocity model view. If you wish, you may smooth the interval velocity plot by including more travel times in the calculation of each interval velocity; this is effectively a median filter. The more travel times included in the filter, the smoother the result. The number of travel times (or "intervals') included must be odd and start from 1 ("1" means that no filter is applied). Applying a filter can be helpful in assigning layers to the model and is illustrated below.

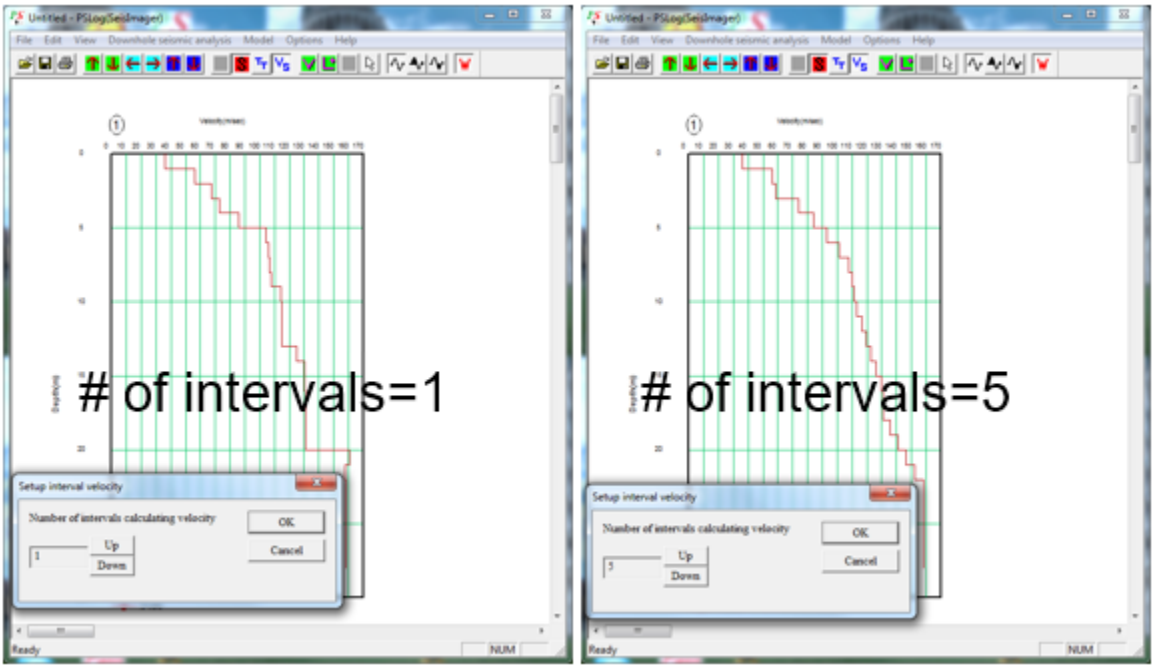
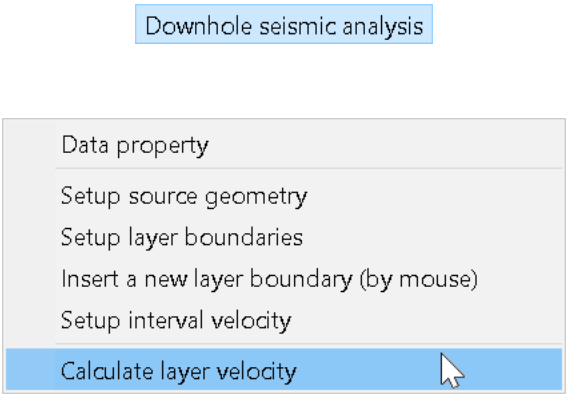


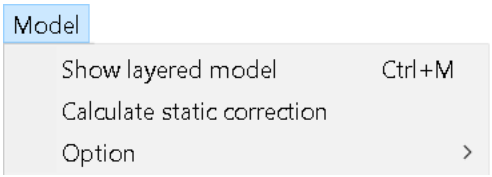
Figure 25: Application of a median filter to interval velocity data.

6.4.6 CALCULATE LAYER VELOCITY



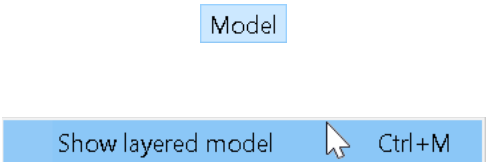
In general, layer velocities are automatically calculated when parameters are changed. When in doubt, select *Calculate layer velocity*.

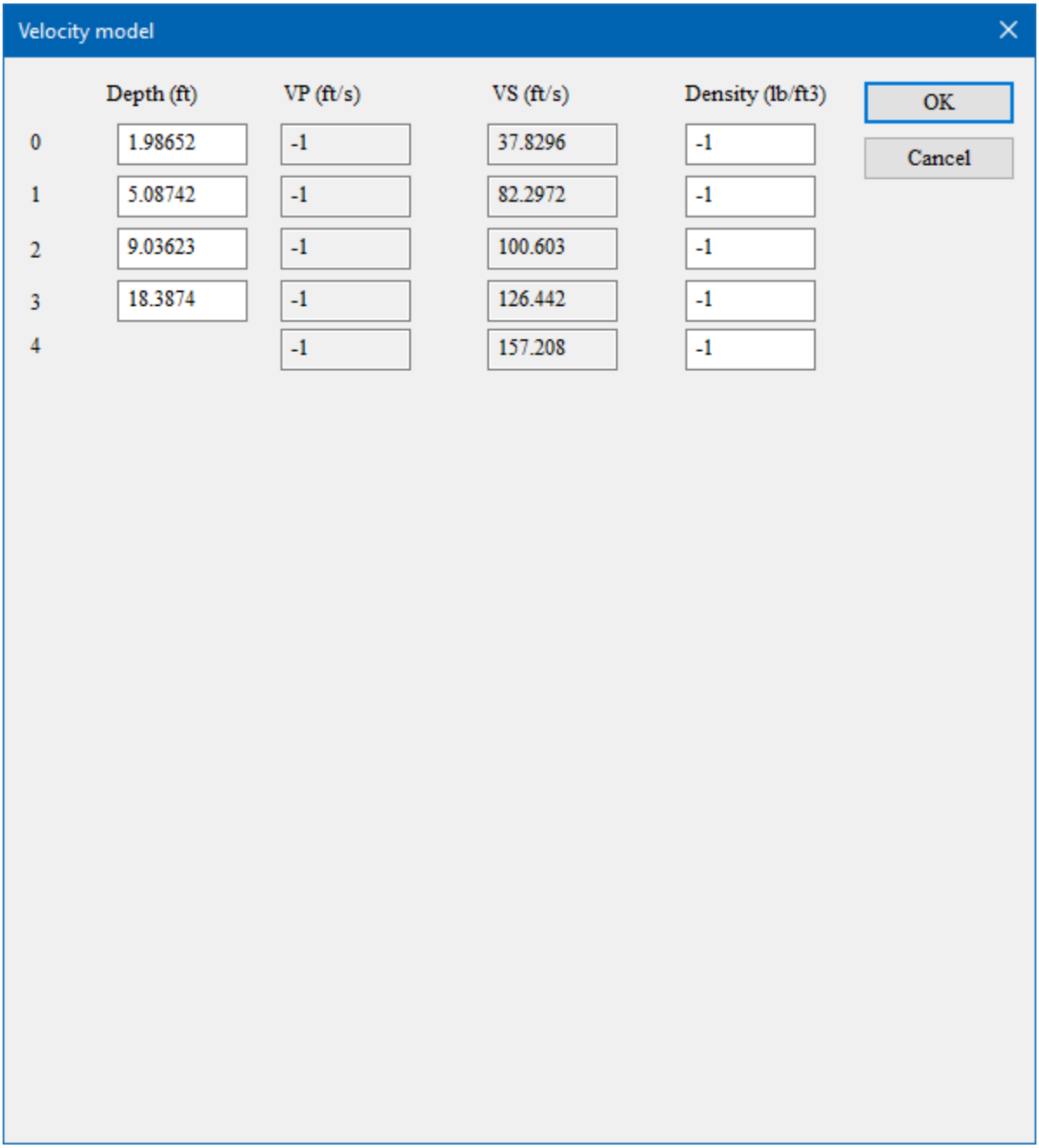
6.5 THE PSLOG MODEL MENU



The **Model** menu contains functions for editing an existing velocity model.

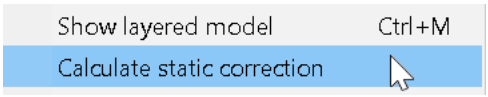
6.5.1 SHOW LAYERED MODEL [CTRL+M]

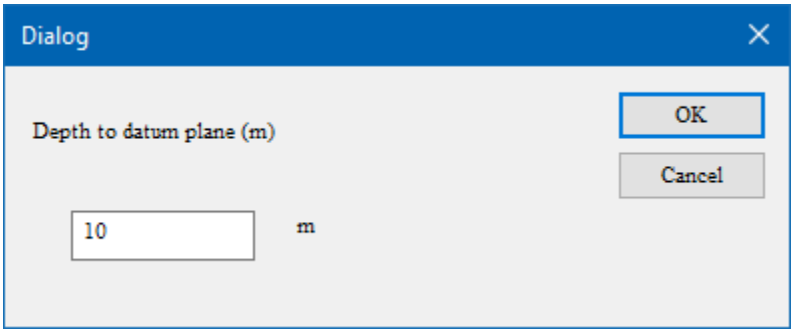




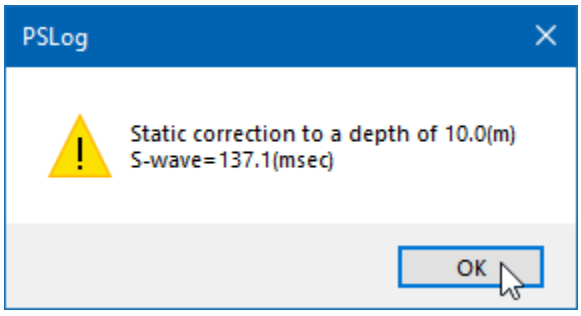
To view and edit a velocity model, select *Show layered model*. The density of each layer can be set with this function. Density is used for calculating shear modulus (G) and Young's modulus (E), each of which can be shown in the velocity column (see Section 6.3.11, Page 73).

6.5.2 CALCULATE STATIC CORRECTION

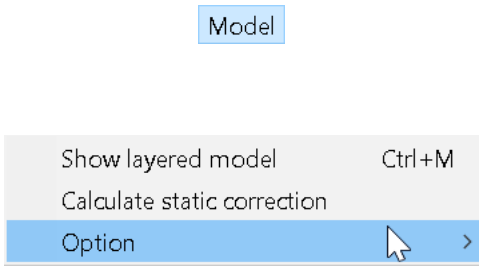




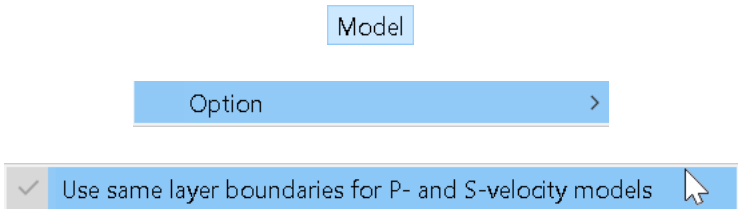
This option calculates a static correction for reflection analysis. Enter the depth to the datum plane, and the static correction based on measured velocities will be provided in msec. An example for s-wave data is shown below.



6.5.3 OPTION

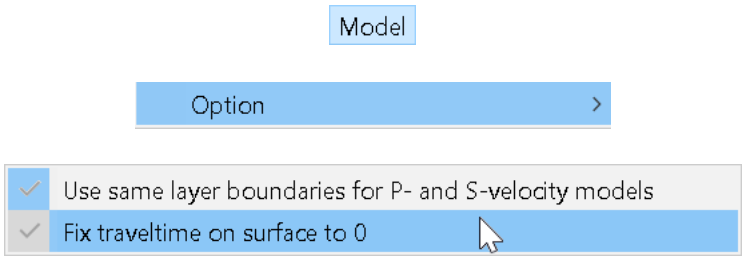


6.5.3.1 USE SAME LAYER BOUNDARIES FOR P- AND S- VELOCITY MODELS



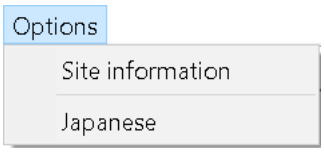
This feature forces p- and s-wave velocities to coincide. If only one profile has a velocity boundary, it creates a boundary at the same depth in the other profile.

6.5.3.2 FIX TRAVEL TIME ON SURFACE TO 0



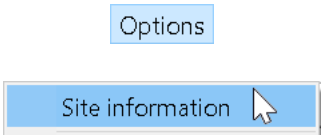
This forces the travel time curve to go through the origin, i.e., zero time at zero depth.

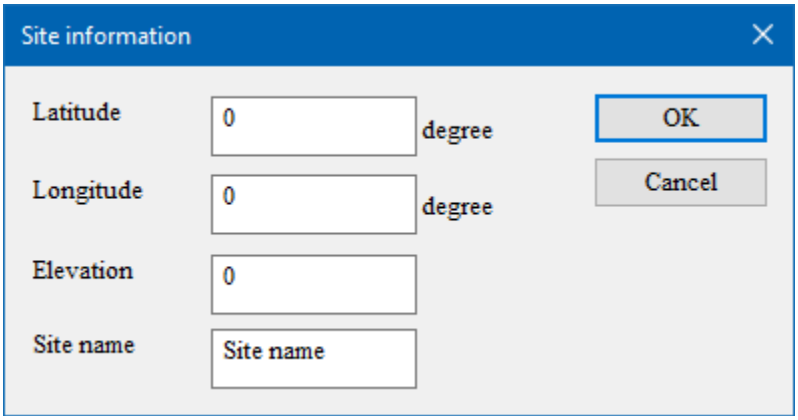
6.6 THE PSLOG OPTIONS MENU



The **Options** menu includes data and display settings.

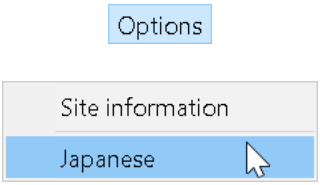
6.6.1 SITE INFORMATION





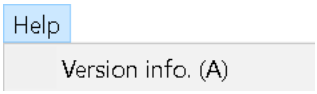
Site coordinates and name can be stored in an XML file. Negative latitude means southern hemisphere and negative longitude means west of the Prime Meridian.

6.6.2 JAPANESE



The program language can be converted between English and Japanese. Obviously, this is not recommended unless you want to use the software in Japanese and have the necessary version of Windows. If strange symbols appear in various places, it is likely that the language is not set to English and Windows is unable to render the program in Japanese.

6.7 THE PSLOG HELP MENU



6.7.1 VERSION INFO

Click on *Version info.*to display the PSLog Version number:

6.8 PSLOG TOOL BUTTONS AND HOT KEYS

Figure 26: PSLog Tool Buttons

PSLog includes numerous tool buttons and “hot keys”, which are detailed below. Some have been mentioned before. You should experiment with them to understand how they work.

6.8.1 OPEN XML FILE [ ]

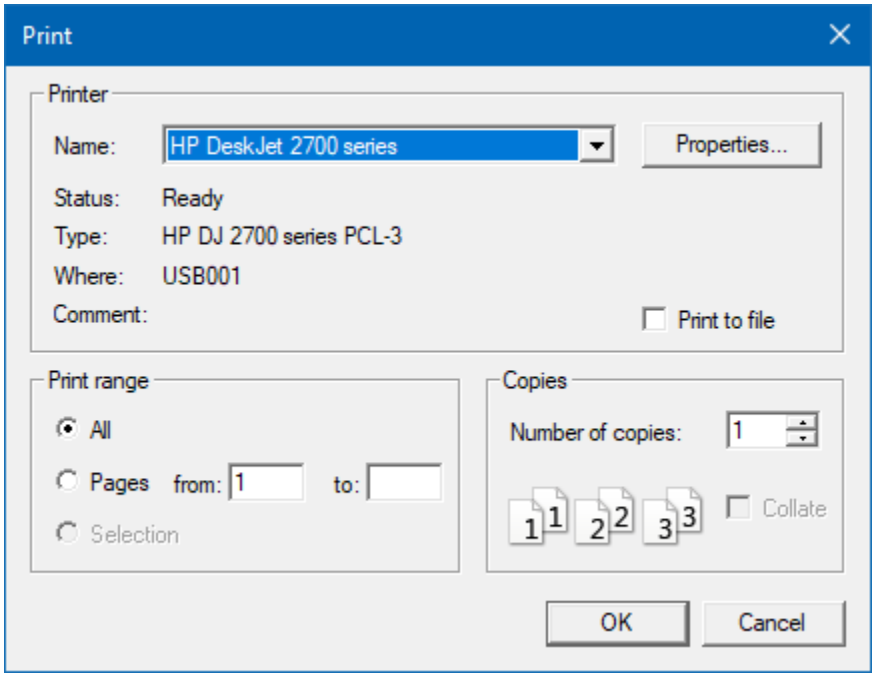
Use this button to open an XML file generated by Pickwin. It is the same as selecting *File | Open XML file [CTRL+O].*

6.8.2 SAVE XML FILE [ ]

This button saves your work as an XML file. It is the same as selecting *File | Save XML file [CTRL+S].*

6.8.3 PRINT [ ]

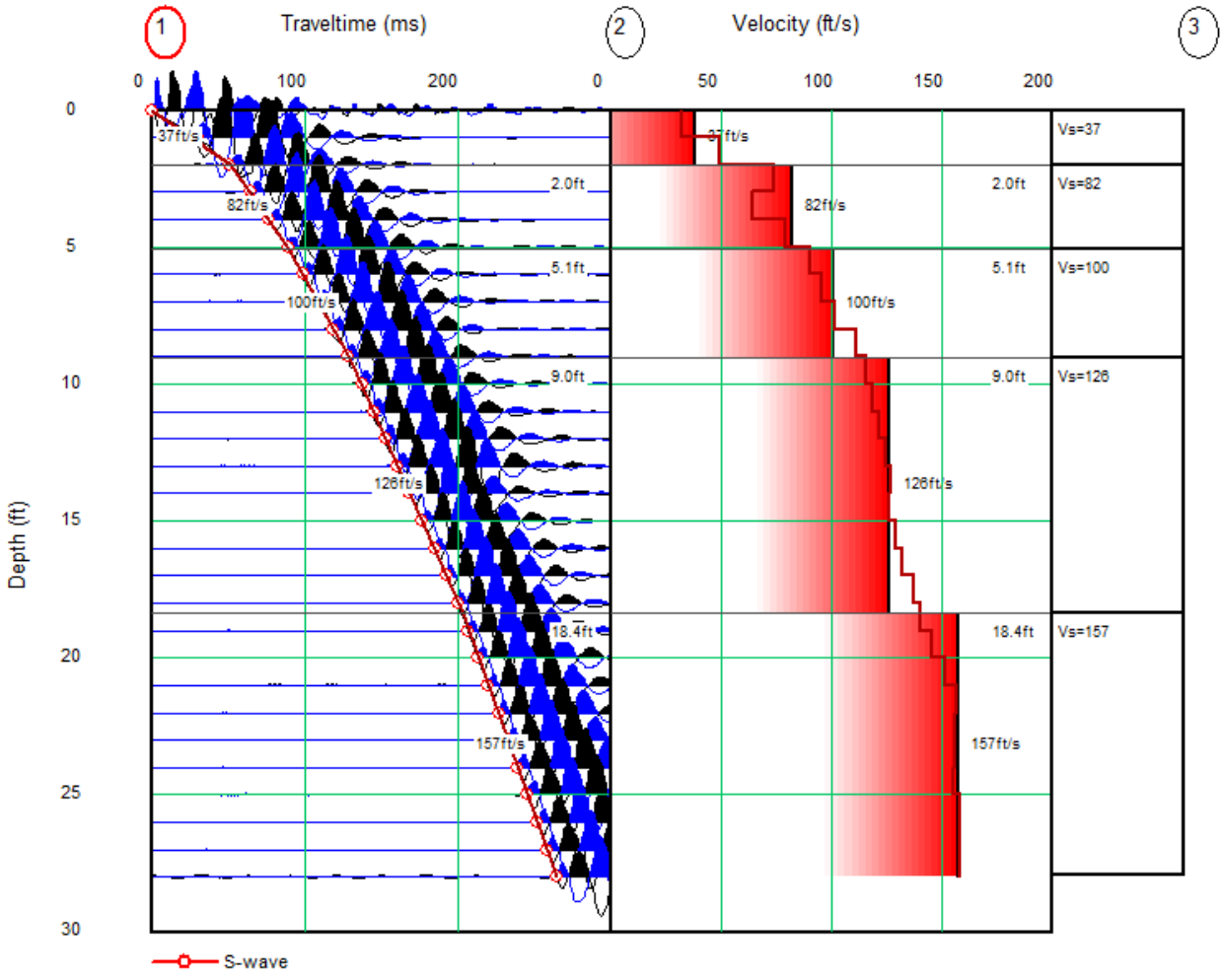
Pressing the *Print* button will display the **Print** dialog:



Choose your print preferences and press *OK*; whatever is on the display will be printed. This is the same as selecting *File | Print.*

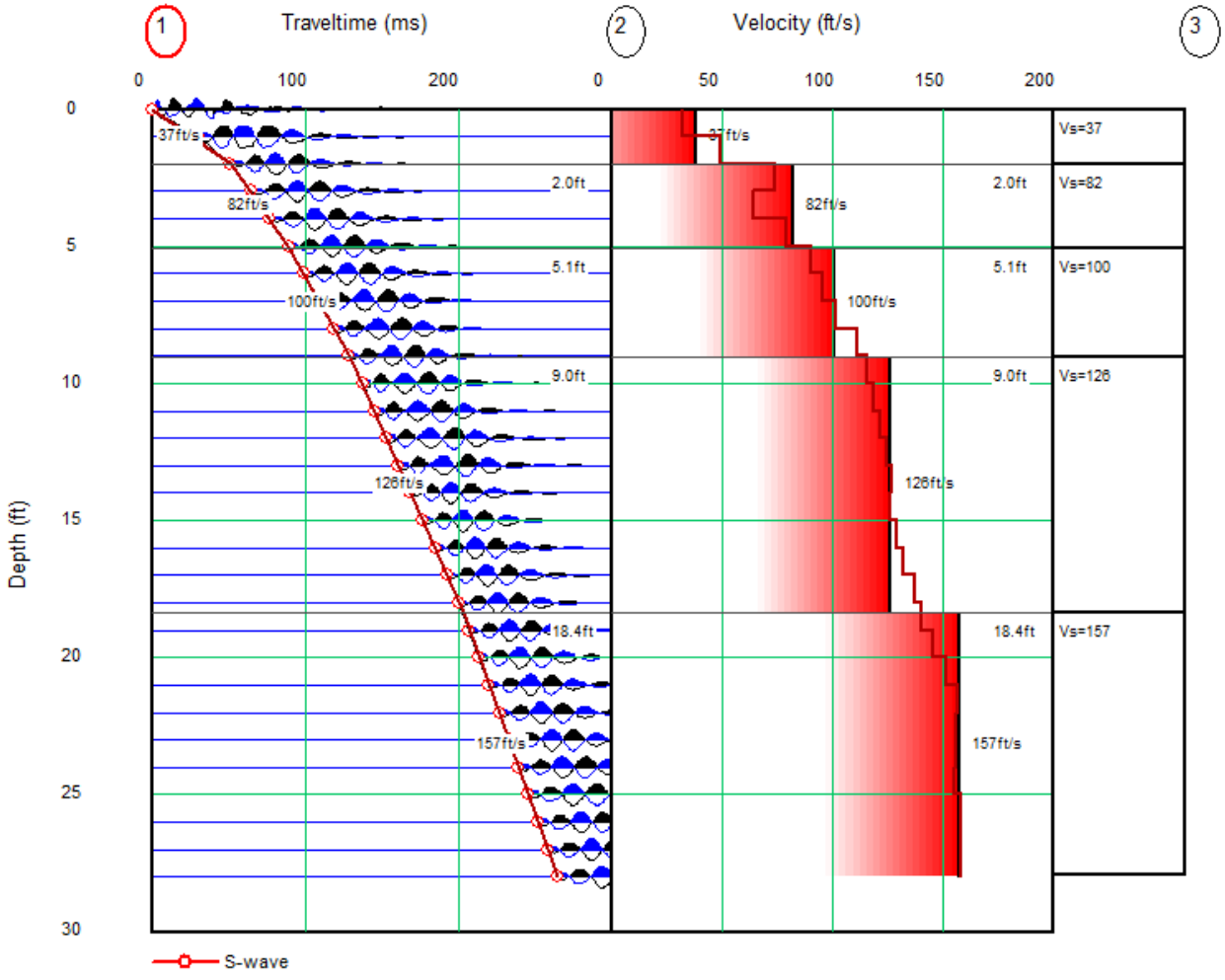
6.8.4 ENLARGE WAVEFORM AMPLITUDE TOOL BUTTON [↑] AND HOT KEY [SHIFT+↑]

The “Enlarge waveform amplitude” tool button increases the amplitude of all of the traces on the display. You may also use the keyboard shortcut [*Shift*+↑].



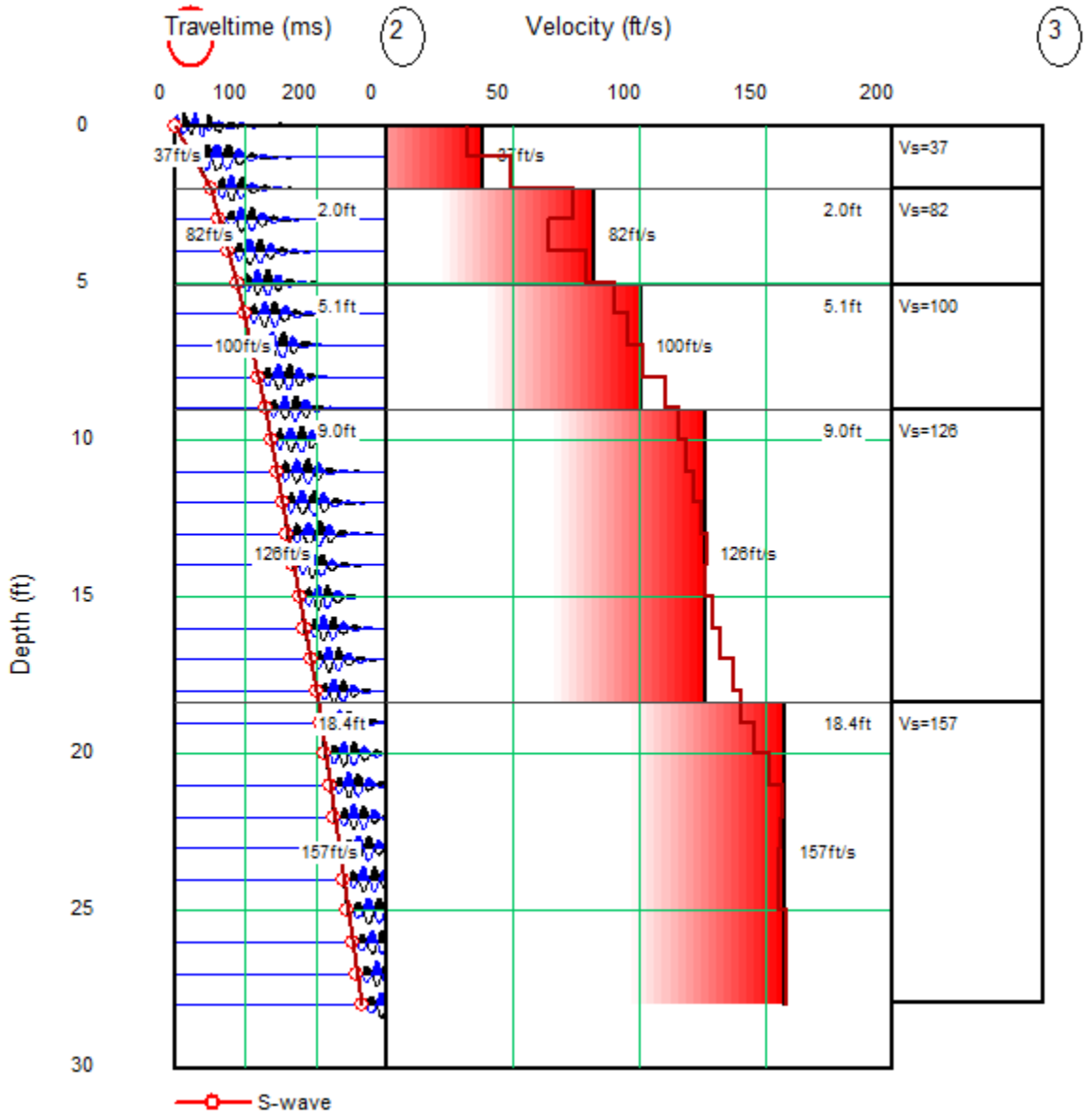
6.8.5 REDUCE WAVEFORM AMPLITUDE TOOL BUTTON [↓] AND HOT KEY [SHIFT+↓]

The "Reduce waveform amplitude" tool button decreases the amplitude of all of the traces on the display. You may also use the keyboard shortcut [*Shift*+↓].



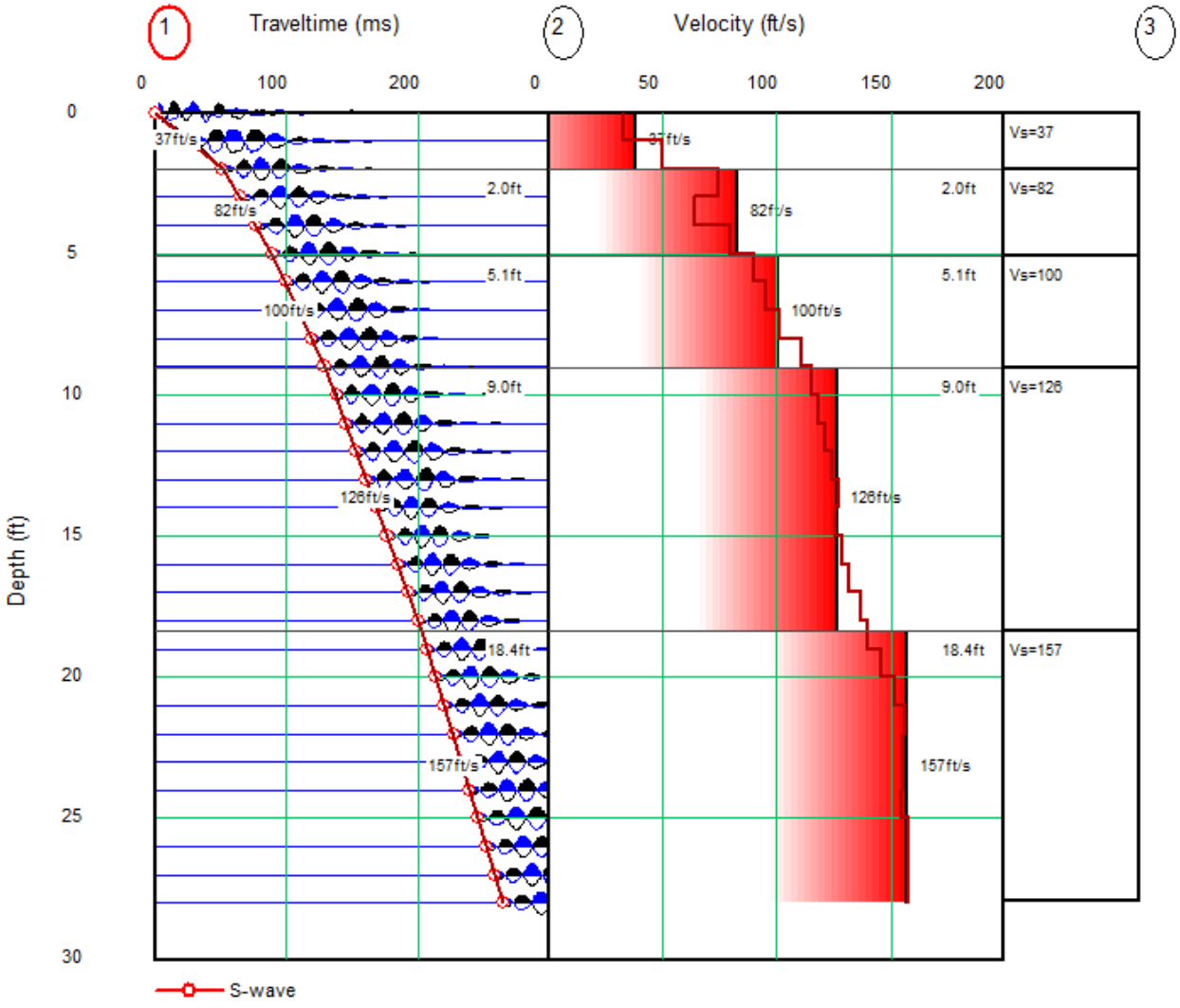
6.8.6 REDUCE HORIZONTAL SCALE TOOL BUTTON [←] AND HOT KEY [←]

The "Reduce horizontal scale" tool button decreases the length of the horizontal (time) axis. The *left-arrow* key (←) on the keyboard accomplishes the same thing.



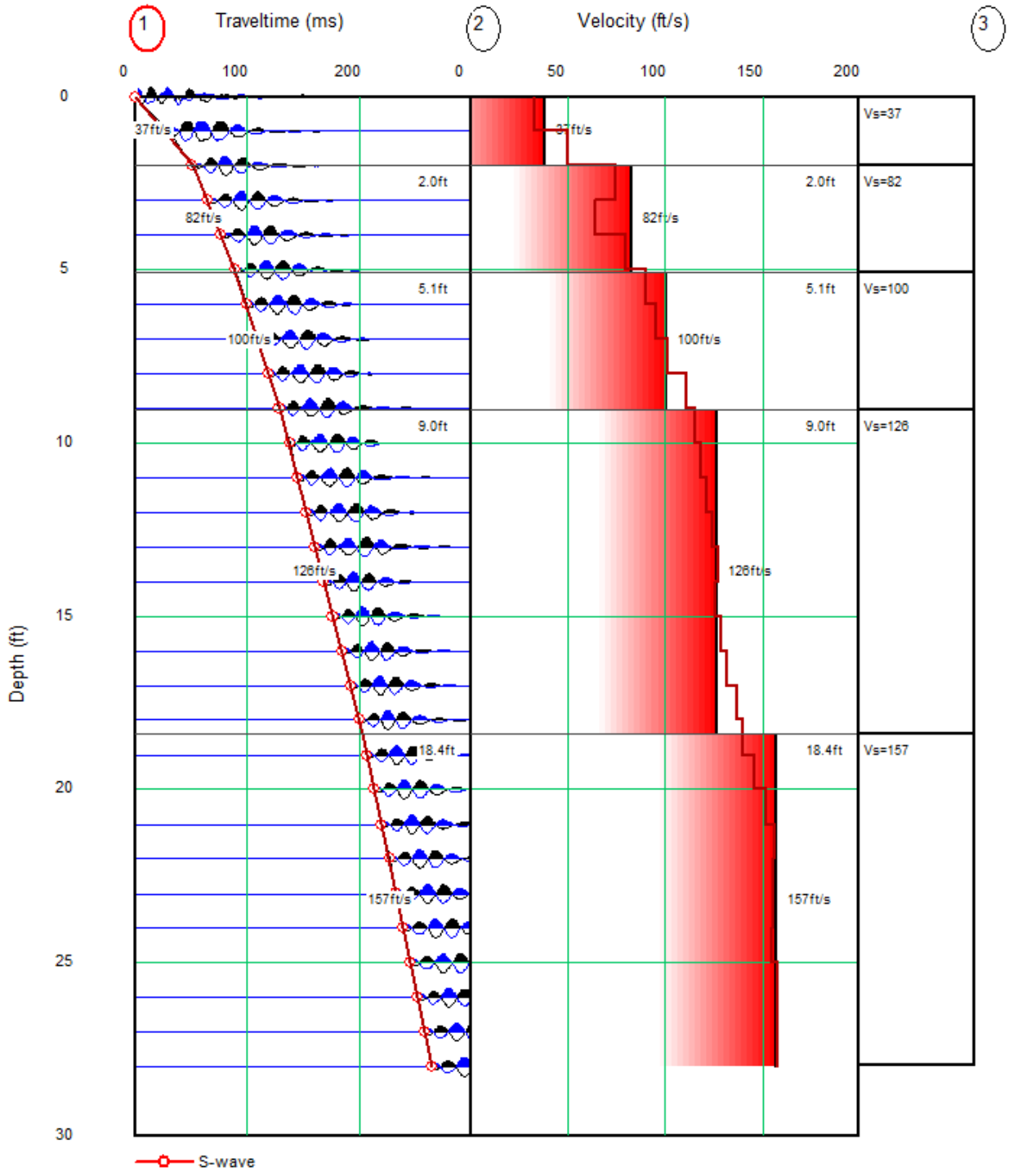
6.8.7 ENLARGE HORIZONTAL SCALE TOOL BUTTON [→] AND HOT KEY [→]

The “Enlarge horizontal scale” tool button increases the length of the horizontal (time) axis. The *right-arrow* key (→) on the keyboard accomplishes the same thing.



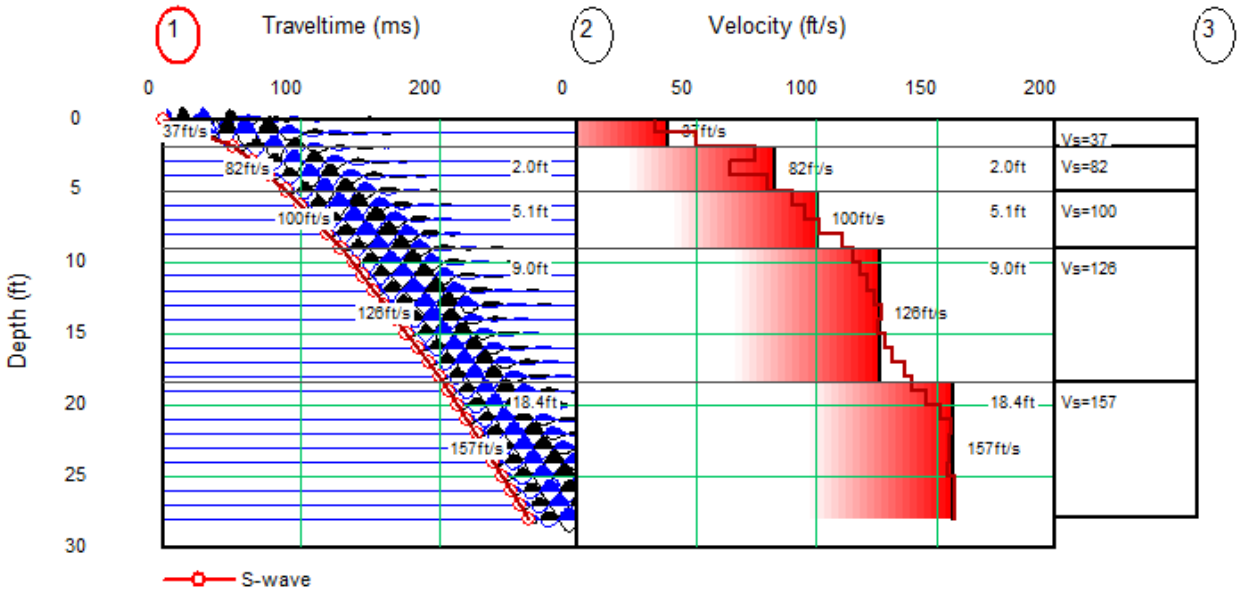
6.8.8 ENLARGE VERTICAL SCALE TOOL BUTTON [↑] AND HOT KEY [↑]

The “Enlarge vertical scale” tool button increases the length of the vertical (depth) axis. Pressing the *up-arrow* key (↑) on the keyboard accomplishes the same thing.



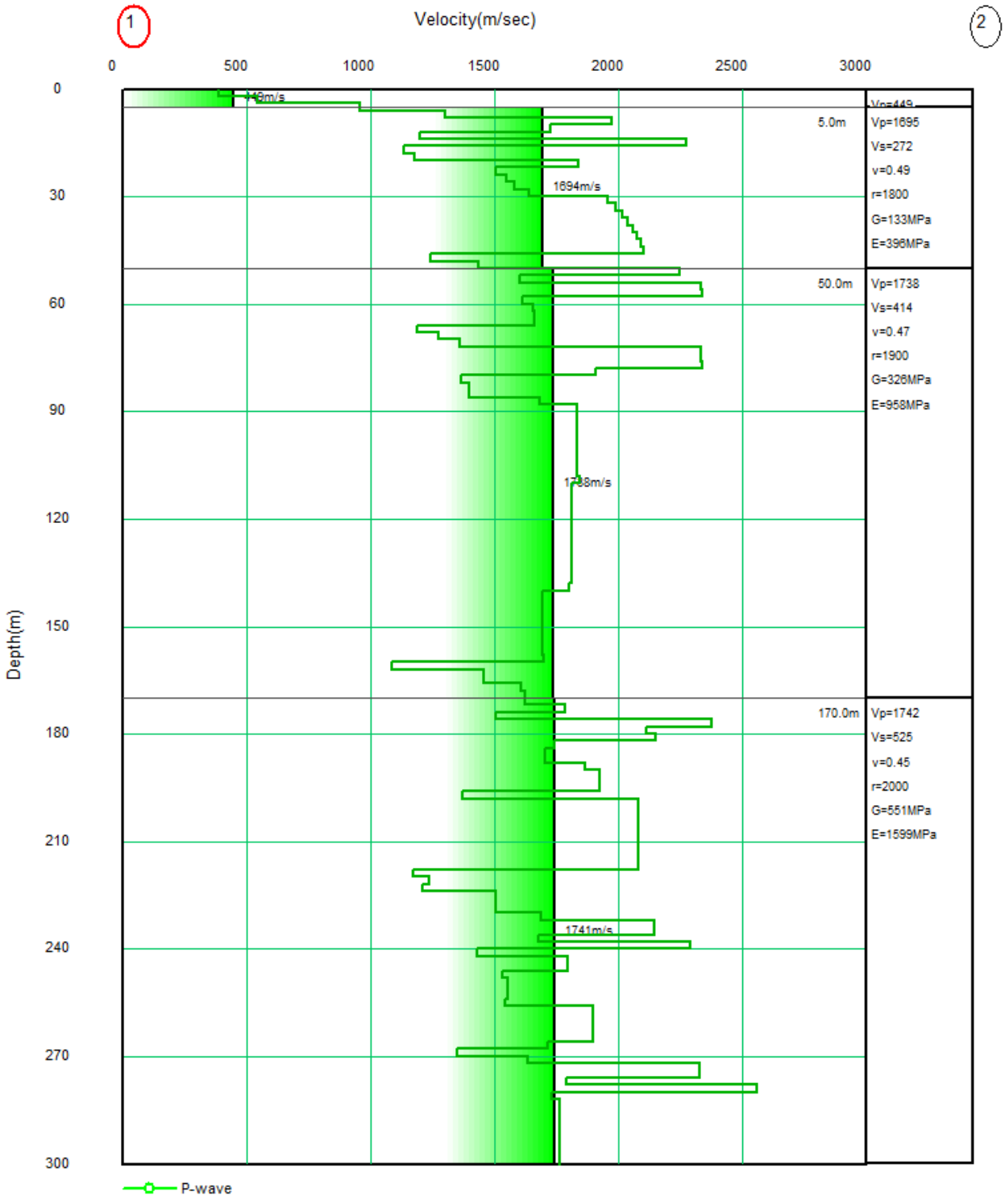
Reduce Vertical Scale Tool Button [ ] and Hot Key [↓]

The “Reduce vertical scale” tool button decreases the length of the vertical (depth) axis. Pressing the *down-arrow* key (↓) on the keyboard accomplishes the same thing.



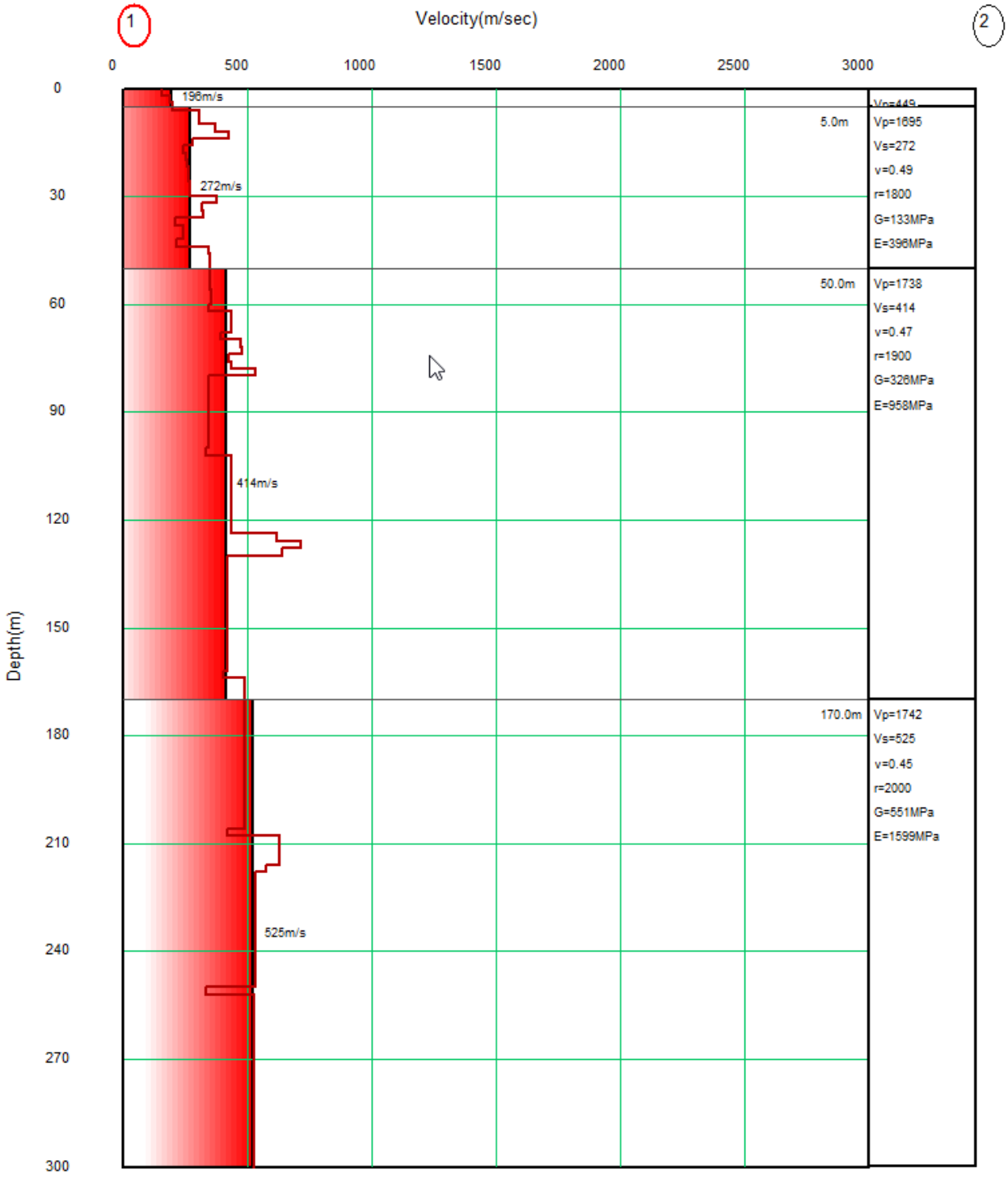
6.8.9 SHOW P-WAVE LOGGING TOOL BUTTON [P]

Pressing the “Show p-wave logging” button displays the p-wave model:

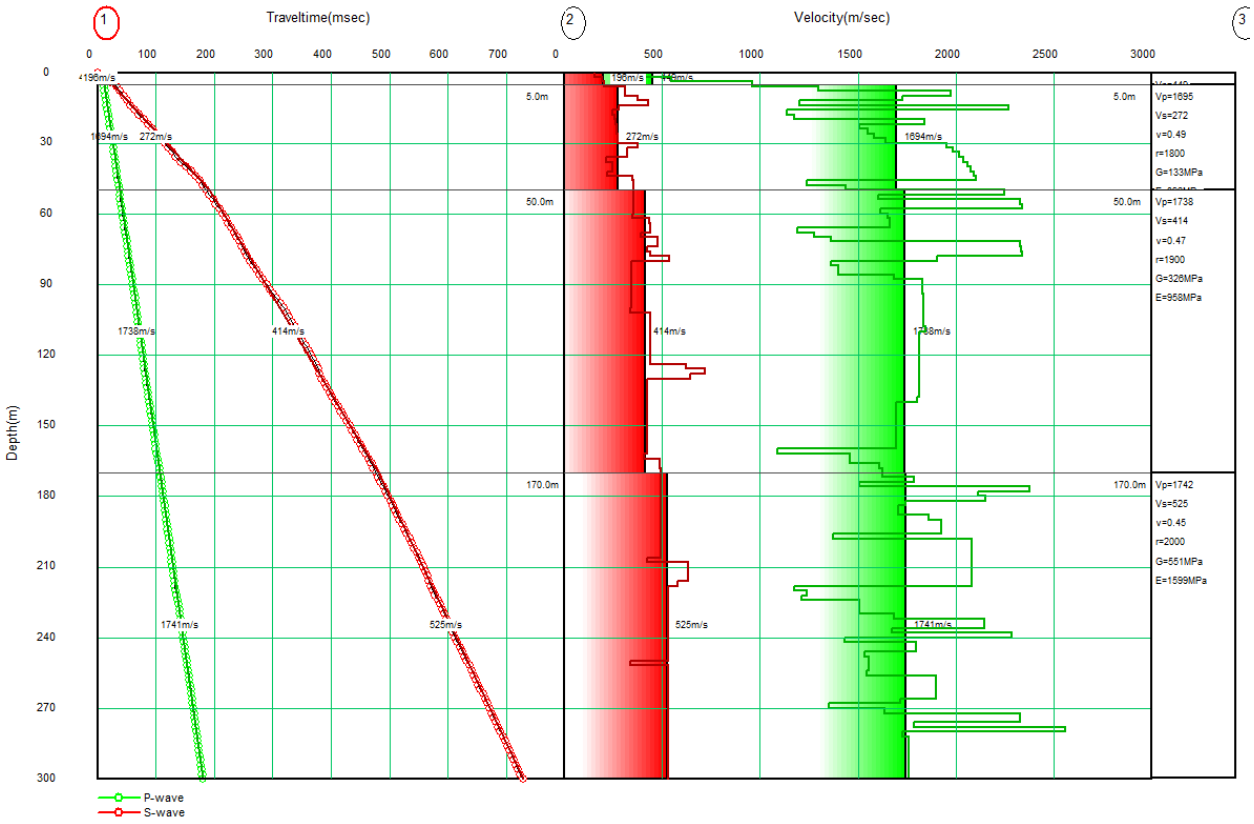


6.8.10 SHOW S-WAVE LOGGING TOOL BUTTON [S]

Pressing the "Show s-wave logging" button displays the s-wave model:

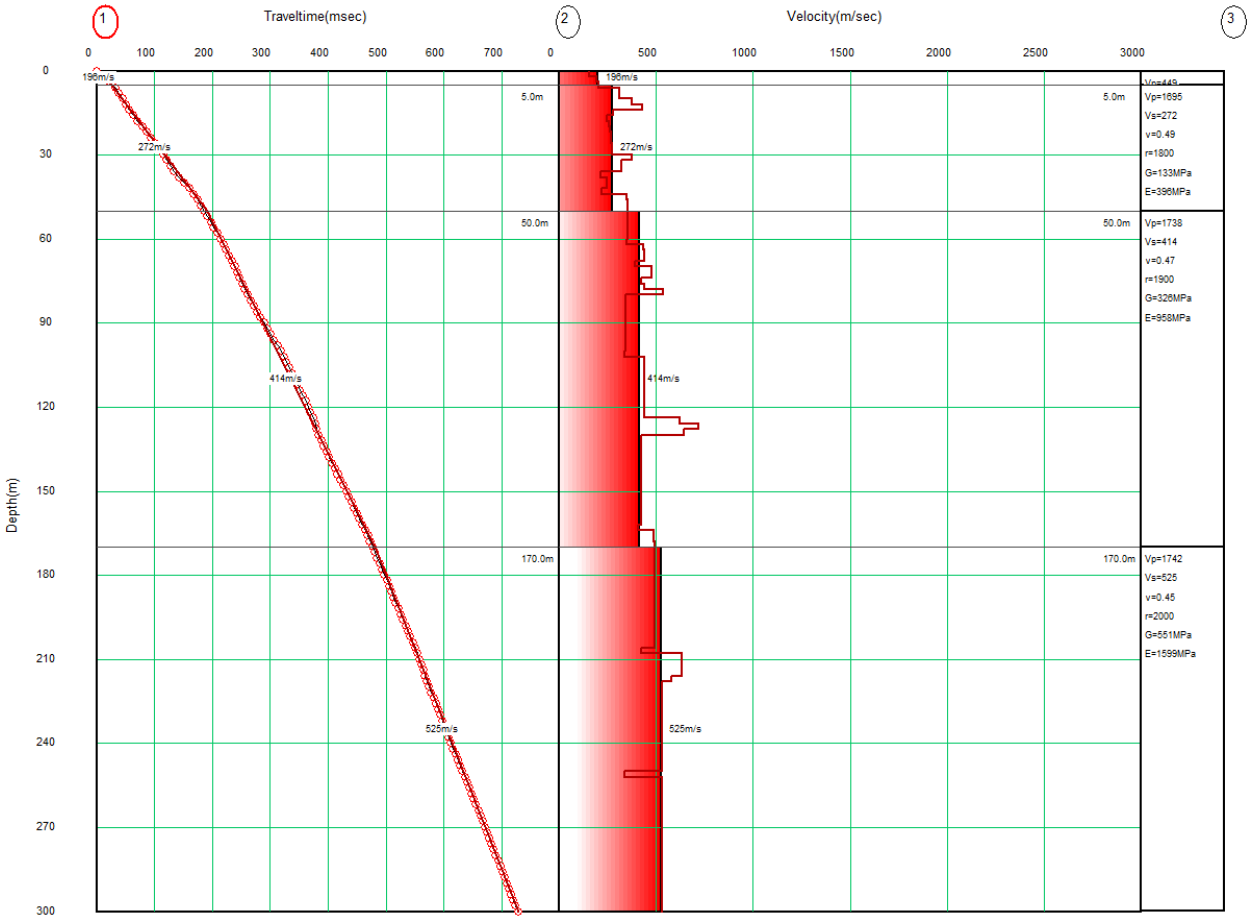


Note: *Both models can be displayed simultaneously by activating both the* P *and* S *buttons:*



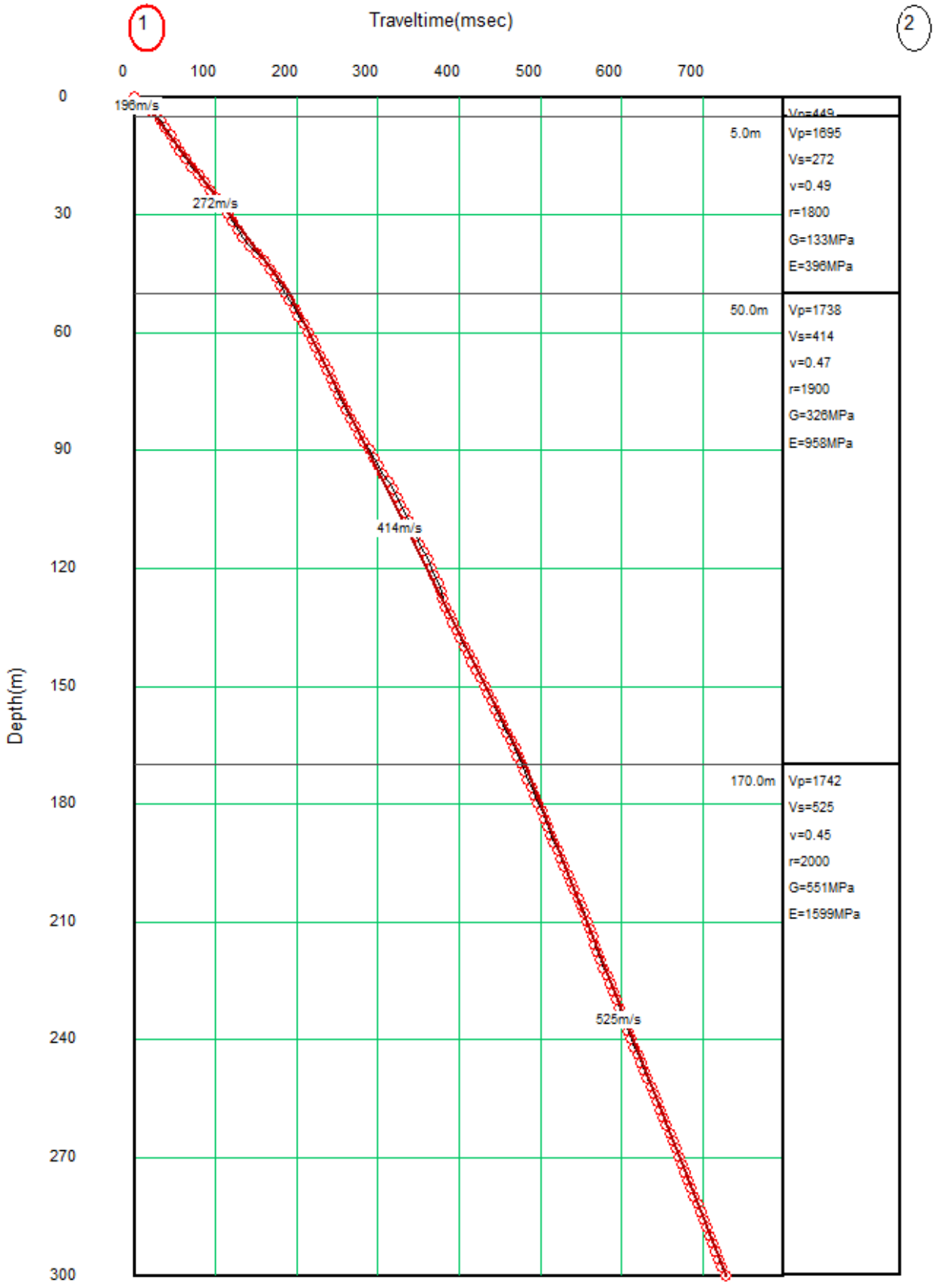
6.8.11 SHOW TRAVEL TIME CURVES TOOL BUTTON [ ]

Pressing the “Show travel time curves” button will toggle the travel time curve display to the left of the velocity model:



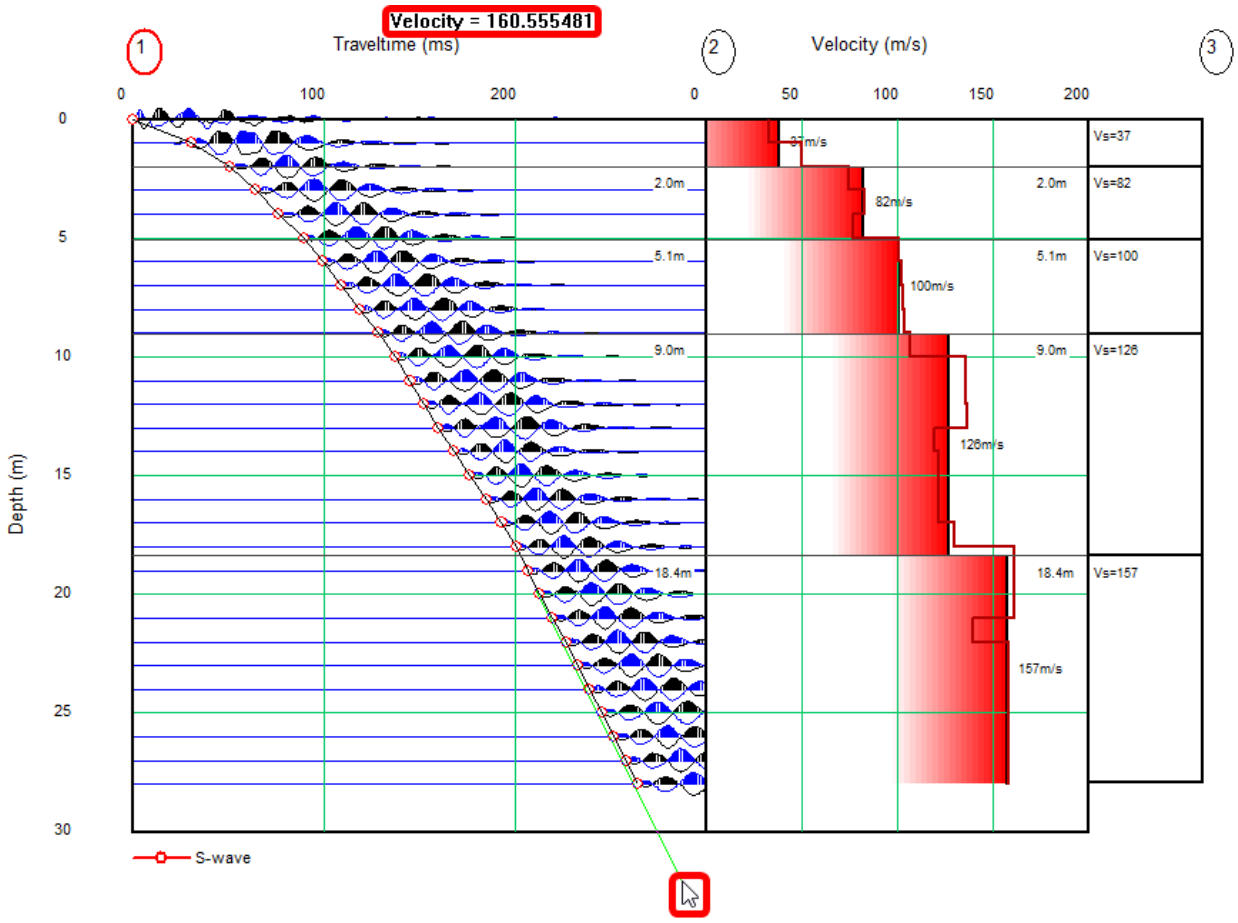
6.8.12 SHOW VELOCITY MODEL TOOL BUTTON [Vs]

Pressing the “Show velocity model” will toggle the velocity model(s). In the below figure it has been toggled off, and all that is displayed is the travel time curve.


1
Traveltime(msec)
2
0
100
200
300
400
500
600
700
Depth(m)
0
30
60
90
120
150
180
210
240
270
300
196m/s
272m/s
414m/s
525m/s
5.0m
Vp=1695
Vs=272
v=0.49
r=1800
G=133MPa
E=396MPa
50.0m
Vp=1738
Vs=414
v=0.47
r=1900
G=326MPa
E=958MPa
170.0m
Vp=1742
Vs=525
v=0.45
r=2000
G=551MPa
E=1599MPa

6.8.13 SHOW VELOCITY USING MOUSE TOOL BUTTON [ ]

Pressing the "Show velocity using mouse" button enters a mode in which you can click and drag the mouse on the waveform plot and the velocity of the line you draw will be displayed:



6.8.14 INSERT A NEW LAYER BOUNDARY TOOL BUTTON [ ]

You may insert a layer boundary into the model by pressing the button and then left-clicking on the velocity model. You may move the layer by dragging it. The least-squares travel time curve will be updated automatically.

6.8.15 EXIT EDIT MODE TOOL BUTTON [ ]

Whenever you press the , , or buttons, you have entered an "edit" mode. You can

ascertain whether you are in an edit mode by looking at the button. If it is illuminated, you are in edit mode. If it is not illuminated ( ), then you are not. To exit the edit mode, press .

Note: *If you are in an edit mode, you may also exit by simply pressing , , or a second time.*

6.8.16 SELECT LAYER BOUNDARY TOOL BUTTON [ ]

Delete any boundary by pressing and then left-clicking on the boundary and pressing the *Delete* key or by selecting *Edit* | *Delete*.

6.8.17 WIGGLE TRACE TOOL BUTTON [ ]

The "Wiggle trace" tool button displays the waveform data in the form of a simple wiggle trace, with no shading of peaks or trough. An example is shown below:

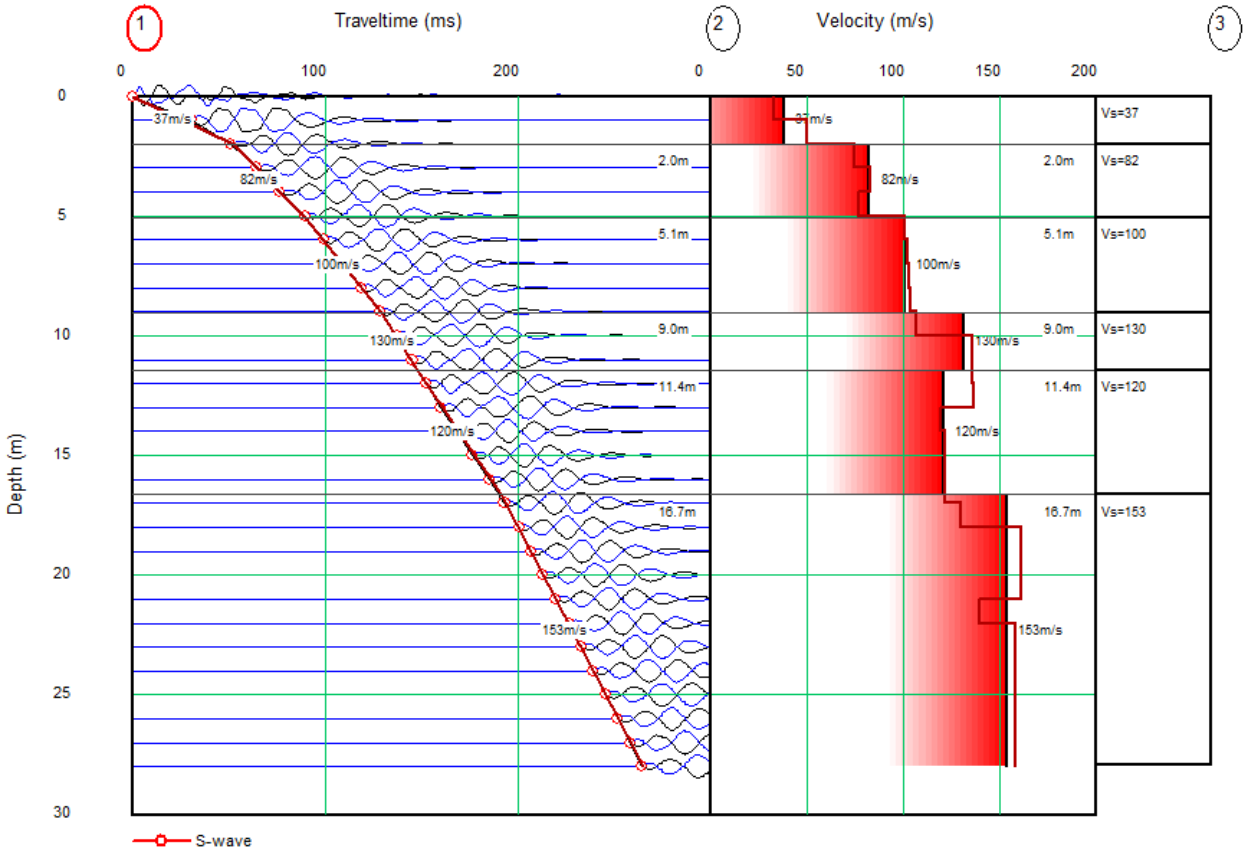


Figure 27: Example of simple wiggle trace display.

6.8.18 WIGGLE TRACE (+ SIDE SHADED) TOOL BUTTON [ ]

This button shades in the positive peaks of the waveform:

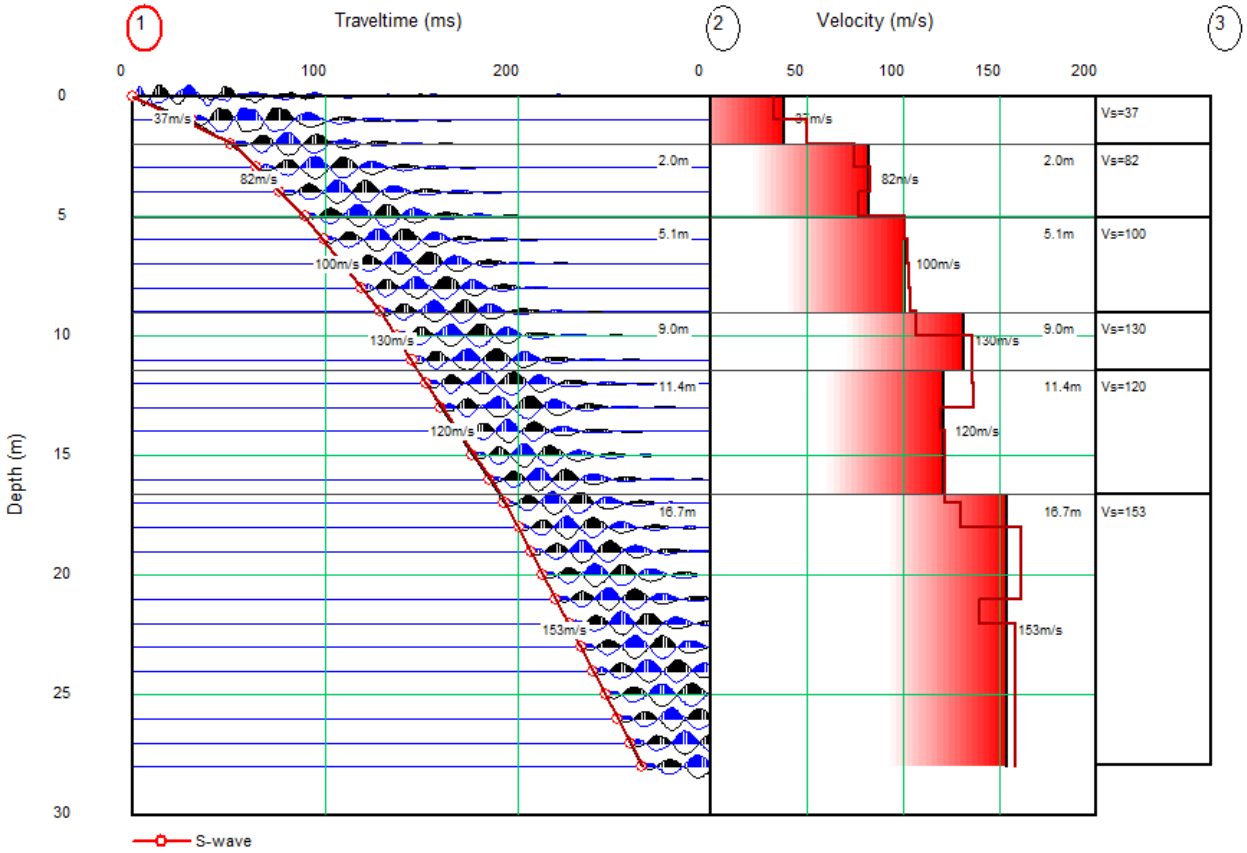


Figure 28: Example of wiggle trace display with positive excursions shaded.

6.8.19 WIGGLE TRACE (- SIDE SHADED) TOOL BUTTON [ ]

Finally, pressing will shade the negative excursions:

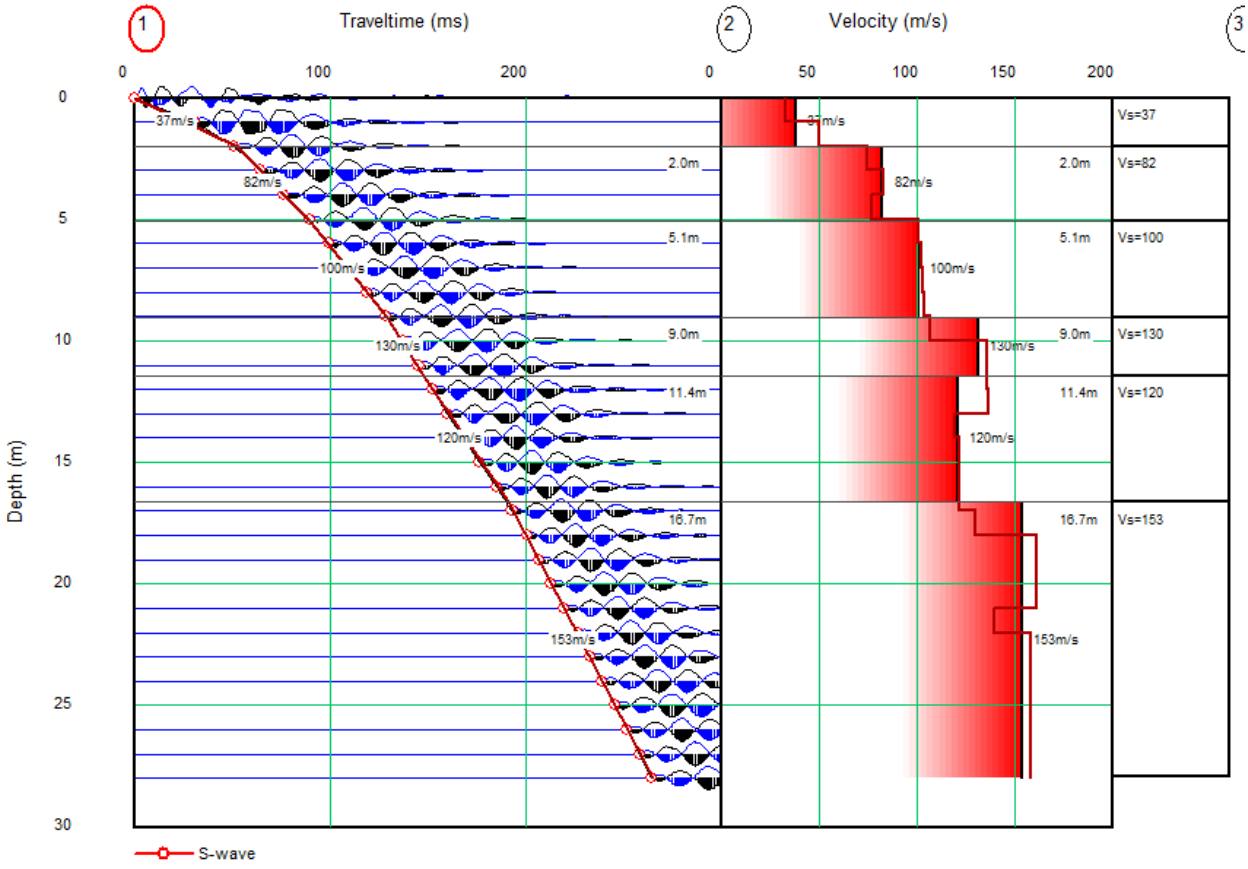
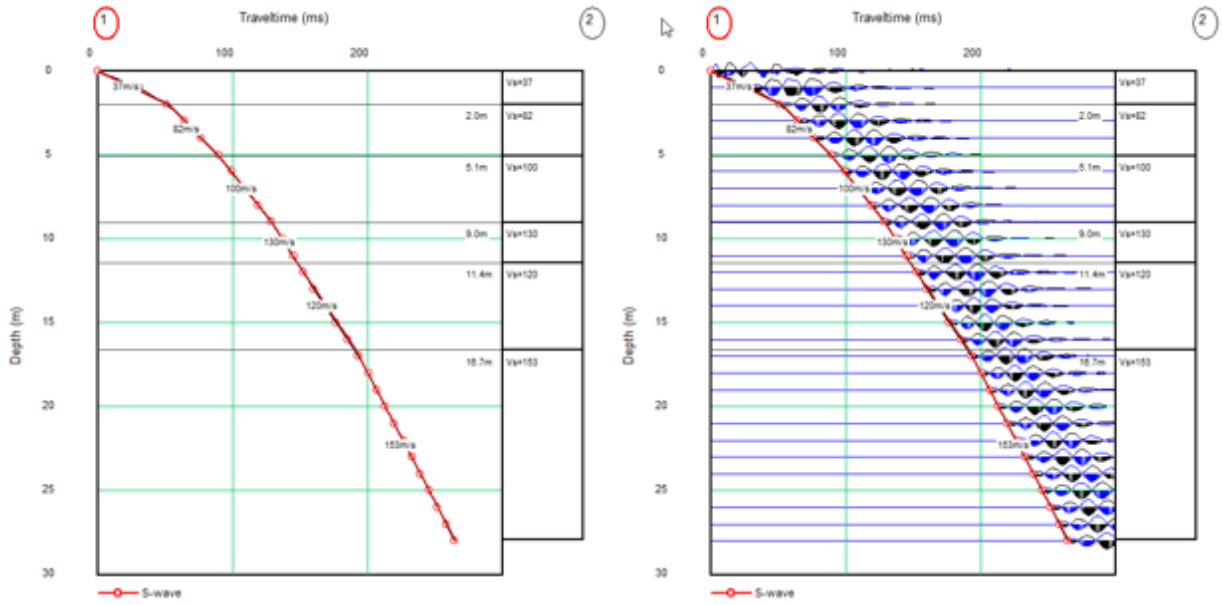


Figure 29: Example of wiggle trace display with negative excursions shaded.

6.8.20 SHOW WAVEFORM TOOL BUTTON [ ]

The "Show waveform" button toggles the waveform display on/off:



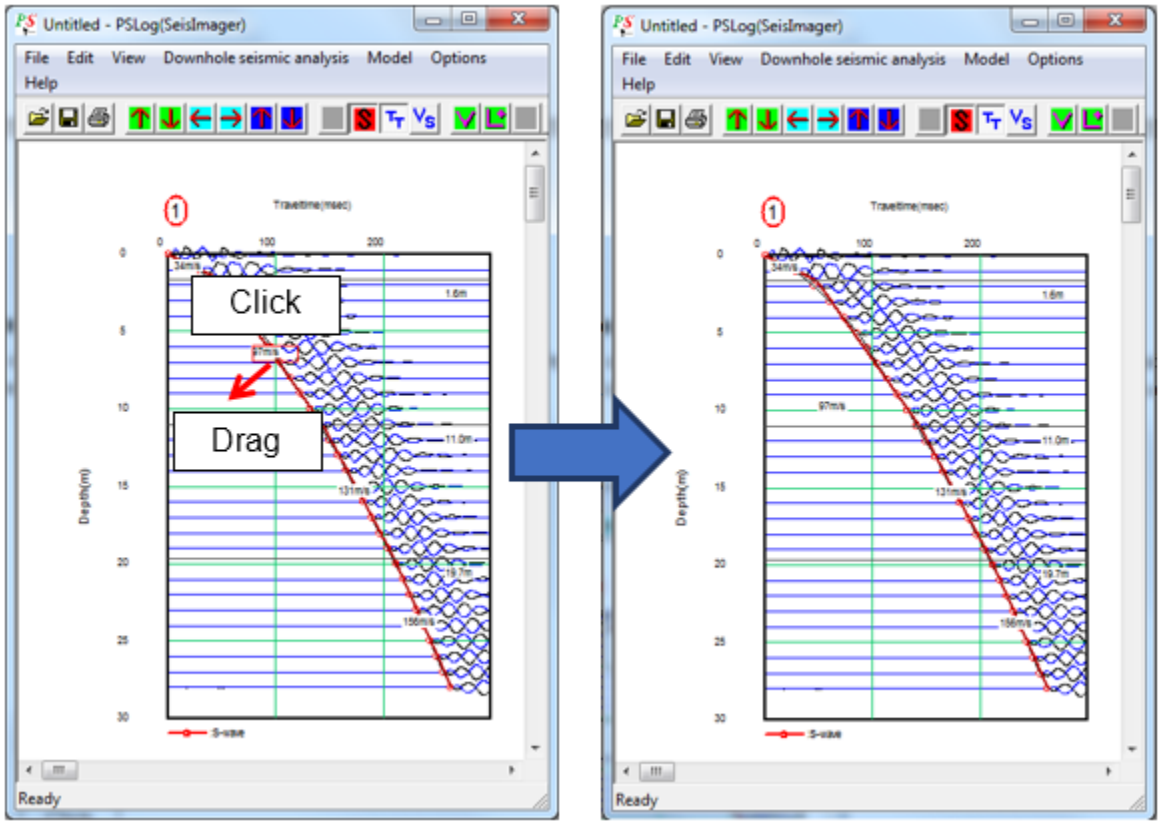
6.9 OTHER OPERATIONS USING A MOUSE

6.9.1 MOVE LAYER BOUNDARY

Existing layer boundaries be moved with the mouse. Simply left-click on the boundary and drag to the desired level. The appropriate least-squares travel time segment will be updated automatically.

6.9.2 MOVE TEXT LABEL

Some text labels can be moved with the mouse. Left-click on the label to highlight it, then drag it to the desired position.


Untitled - PSLog(SeisImager)
File Edit View Downhole seismic analysis Model Options
Help
Click
Drag
Ready
Untitled - PSLog(SeisImager)
File Edit View Downhole seismic analysis Model Options
Help
Ready

APPENDICES

APPENDIX: A. DATA ACQUISITION AND FIRST BREAK PICKING

There are many source-receiver configurations and data acquisition methodologies that can be used for downhole seismic data acquisition. Pickwin and PSLog are very general and can accommodate nearly any configuration or methodology. Several of the most common are discussed in the following sections.

First, a word on nomenclature. The term “receiver”, in this context, can mean a single hydrophone (for measuring p-waves in a water-filled hole), or more commonly, one or more geophones at a common depth. For instance, a common two-receiver borehole geophone (“double” in our nomenclature) may contain four components: two orthogonal horizontal (s-wave) geophones at one depth and two orthogonal horizontal geophones at another depth:

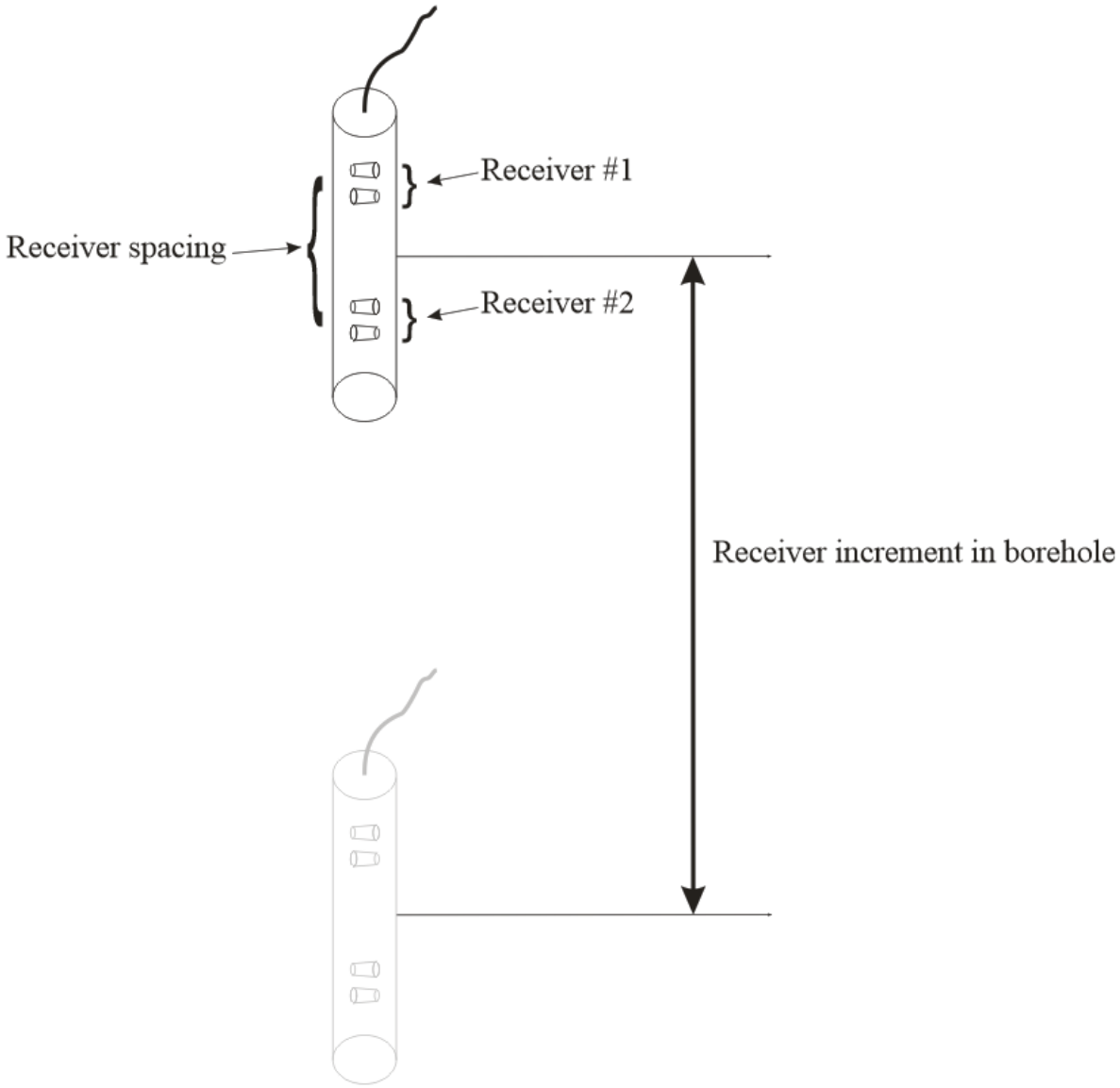


Figure A-1: Common two-receiver, two-component borehole geophone assembly.

This is the most common configuration of a "cone penetrometer", a tool containing geophones that is pushed into the ground when a borehole is unavailable Method D, Appendix: A.4, Page A-19).

Another common type of borehole geophone assembly is the tri-axial geophone, which contains three orthogonal geophones or components: V, H_1, and H_2. In this configuration, the three geophones are commonly clustered closely together, and the receiver *spacing* is generally considered to be zero.

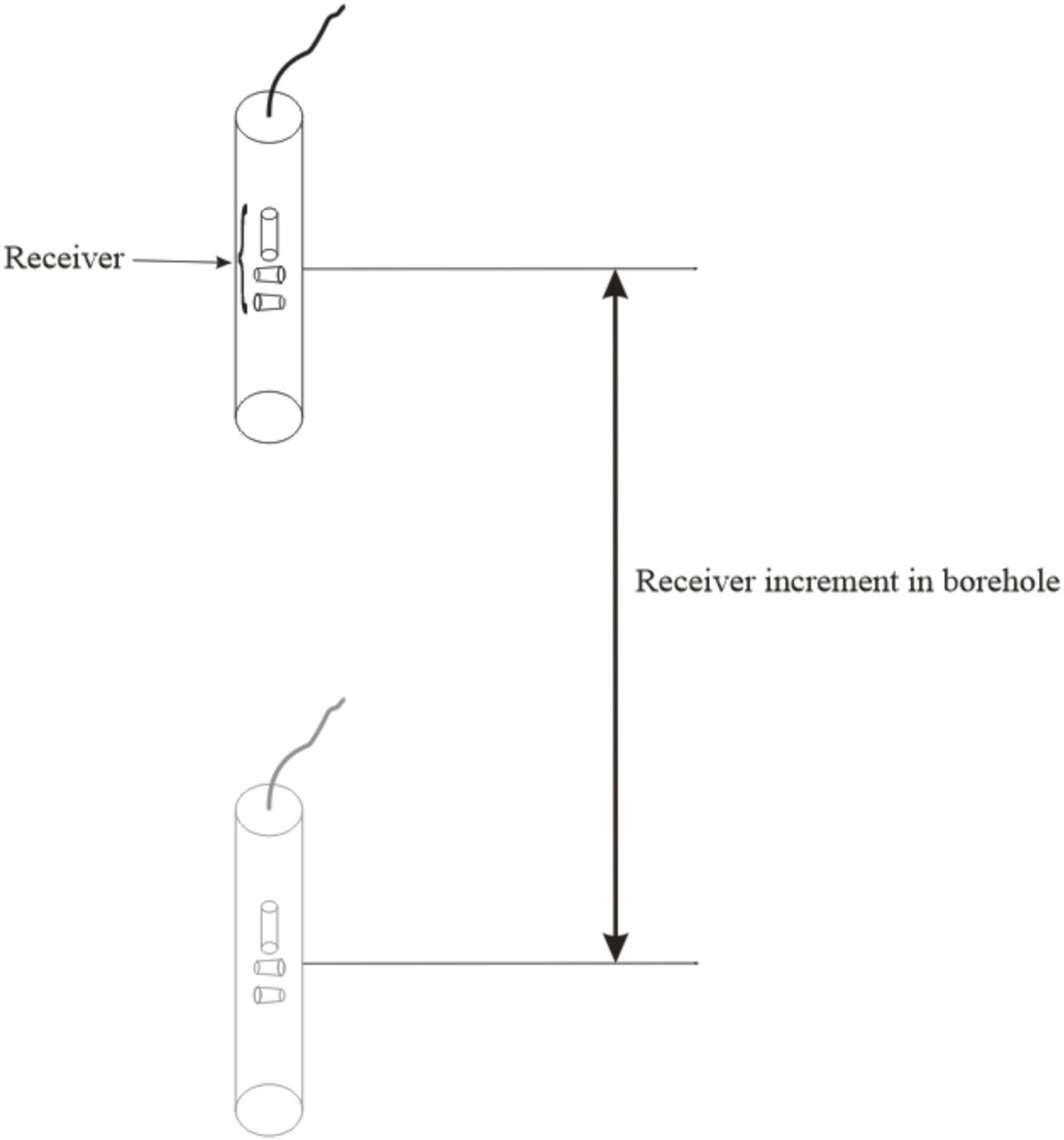


Figure A-2: Tri-axial geophone assembly.

Appendix: A.1 Method A: p-wave data using a multi-channel hydrophone array

If a borehole is filled with water, then using a multi-channel hydrophone array is the easiest way to obtain downhole p-wave data (Figure A-3). This data acquisition method results in one waveform data file (generally 12 or 24 traces) for each shot (Figure A-4). The processing flow is very simple and is illustrated in Figure A-5.

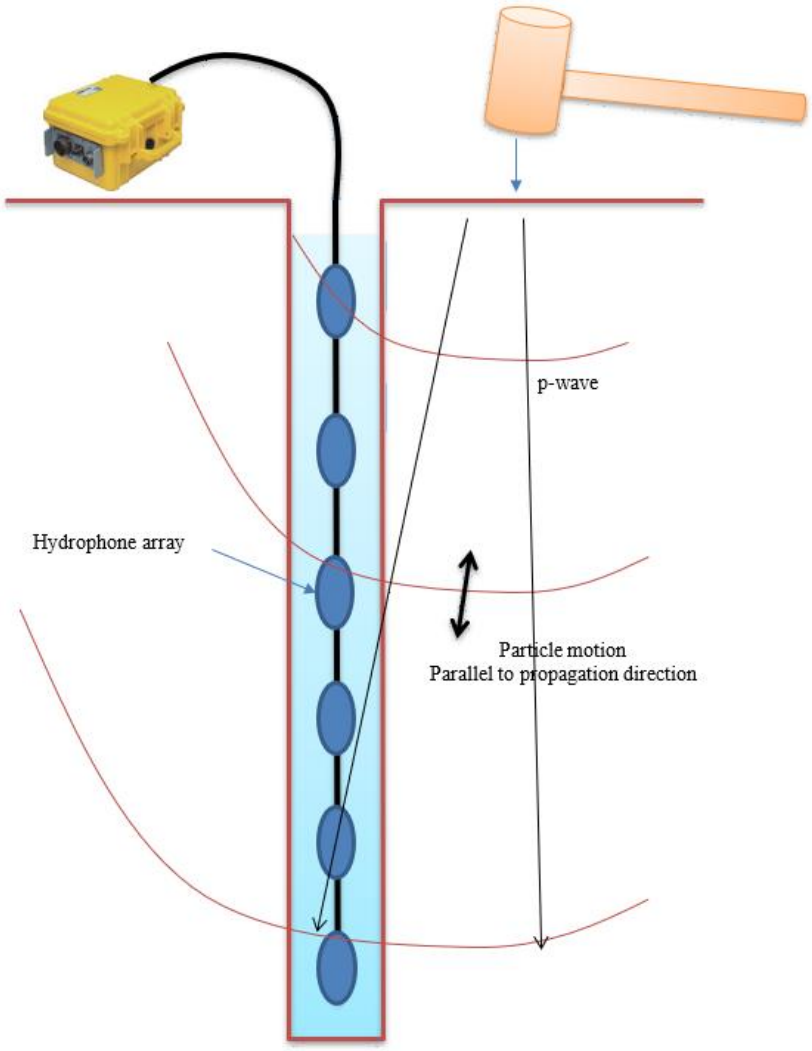


Figure A-3: p-wave data acquisition using a multi-channel, multi-depth hydrophone array (Method A).

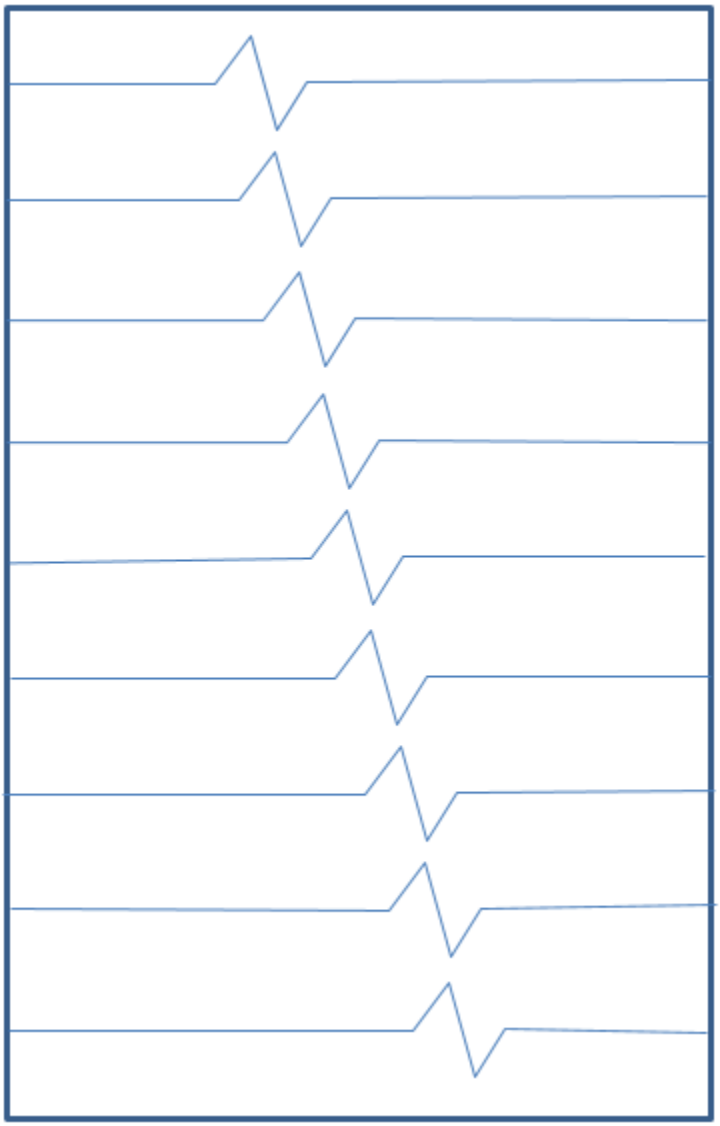


Figure A-4: Schematic of p-wave data obtained by multi-channel hydrophone array (Method A). Analysis uses a single multi-trace waveform file for each shot.

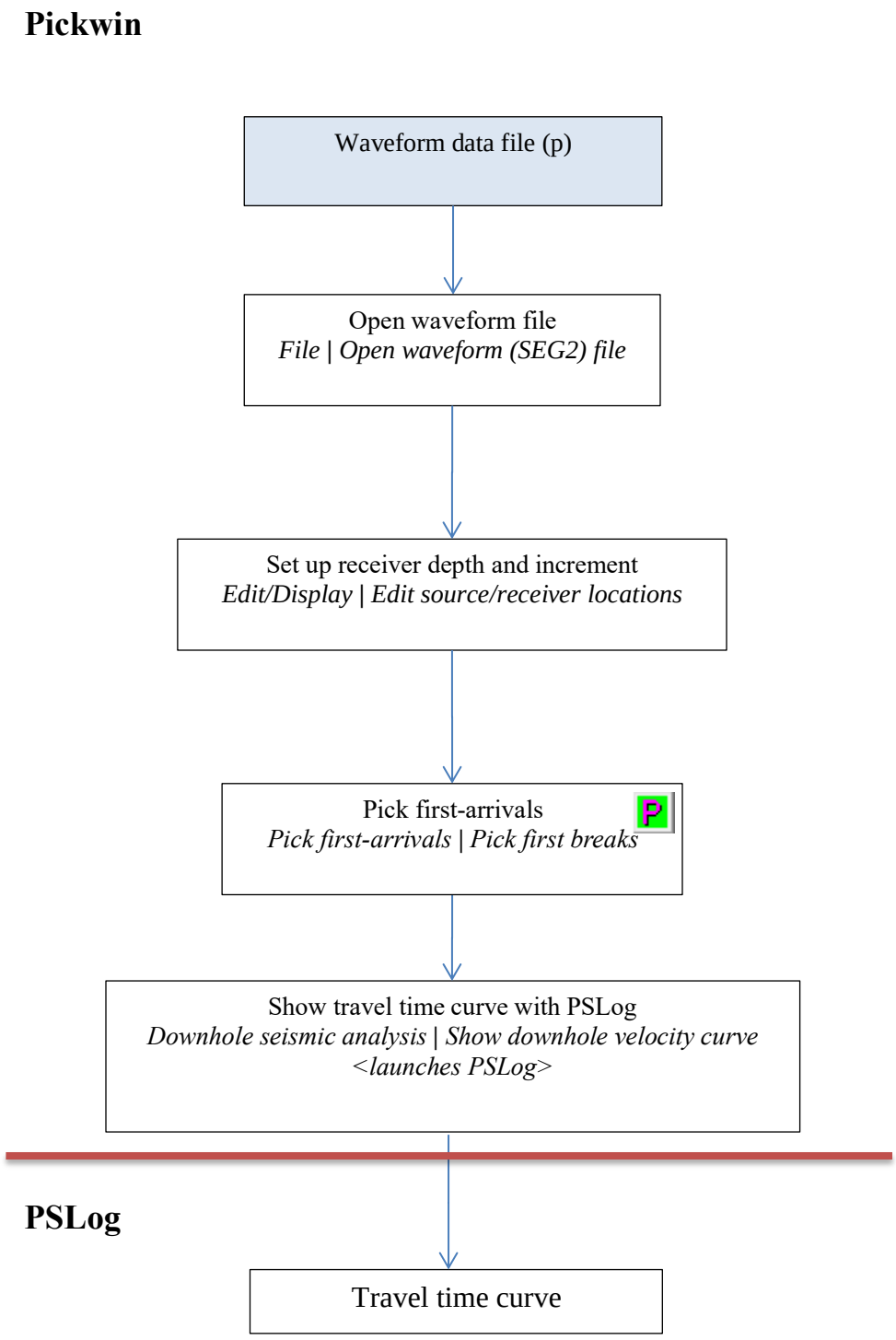


Figure A-5: Processing flow of p-wave data obtained by multi-channel hydrophone array (Method A). Up to and including the picking of first arrivals, it is identical to the processing of a single refraction shot.

Appendix: A.2 Method B: p-wave data using a single-channel vertical geophone

If the borehole is not filled with water, the geophone assembly must be fixed to the borehole wall by a clamp (Figure A-6). A borehole geophone with clamp generally has three orthogonal components (H_1, H_2 [for s-waves], and V [for p-waves]) – see Figure A-2 – and data acquisition must be done at each depth individually. After each set of hammer swings (stacks), the geophone assembly must be unclamped, lowered or raised to the next level, and re-clamped.

In this section, we will consider only the vertical component, because we are measuring p-waves only. As such, Figure A-6 shows only a single vertical geophone to avoid confusion.

Precise shot time is key in this configuration. It is therefore recommended that a separate geophone be placed on the ground surface and used for monitoring the shot time. Data acquisition results in a single waveform file (containing, in this case, a single p-wave waveform along with the monitor trace) for each shot, as illustrated in Figure A-7 (only the p-wave traces are shown). In the analysis, Pickwin opens all the files at once, extracts the needed traces, displays them as a common shot gather, and picks the first arrivals. The processing flow is shown in Figure A-8.

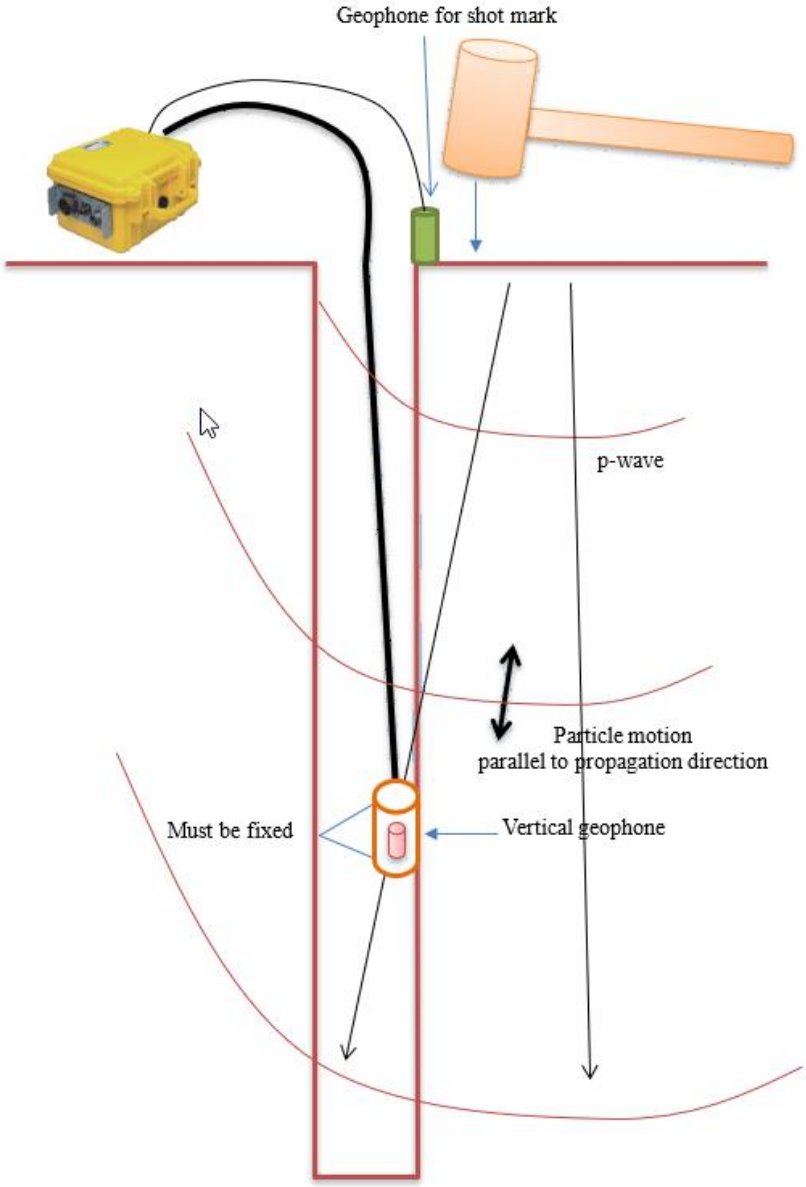


Figure A-6: p-wave data acquisition using a single-channel receiver, in this case a clamped vertical geophone (Method B).

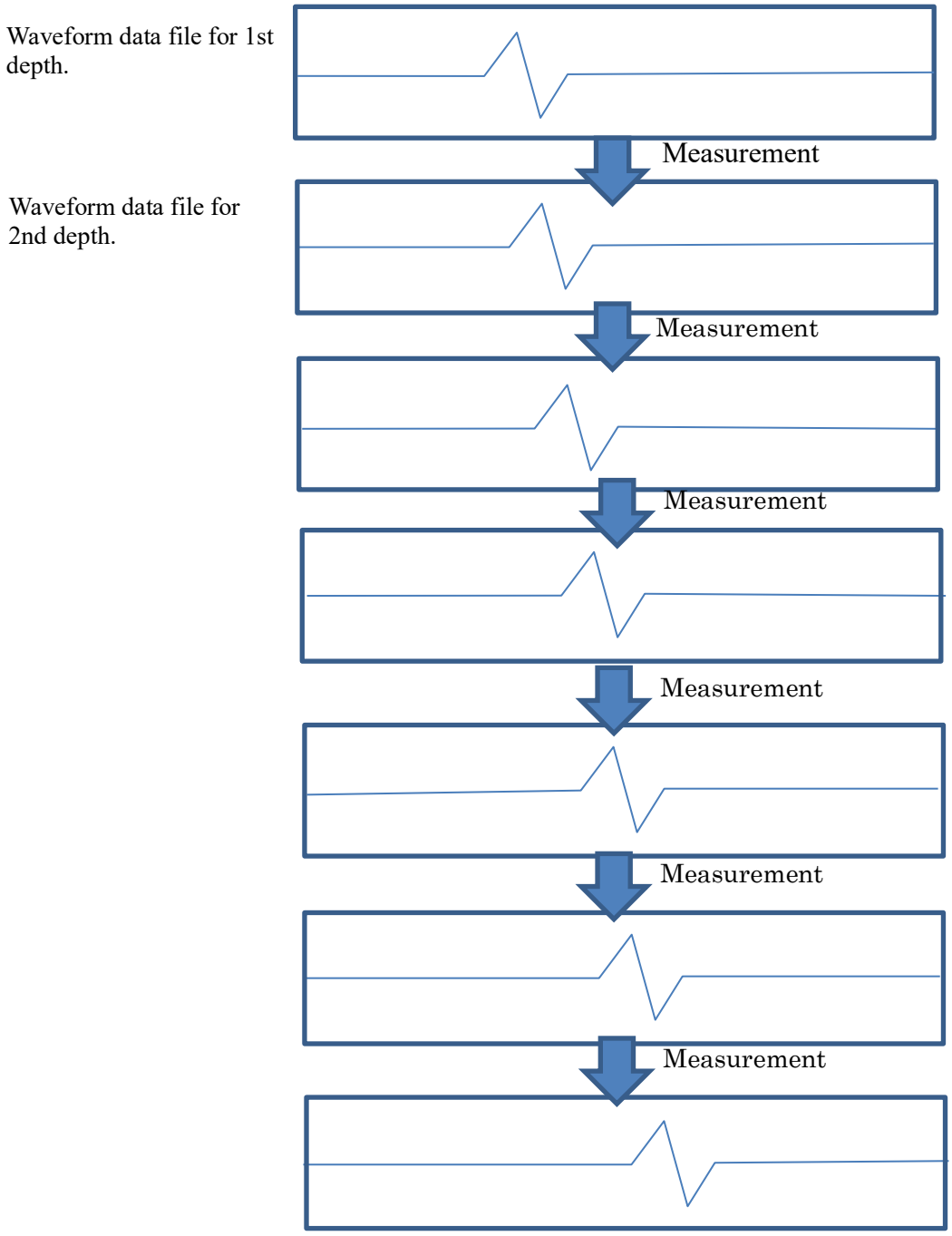


Figure A-7: p-wave data obtained by single-channel vertical receiver, in this case a clamped vertical geophone (Method B). Analysis uses one waveform file containing a single trace for each shot.

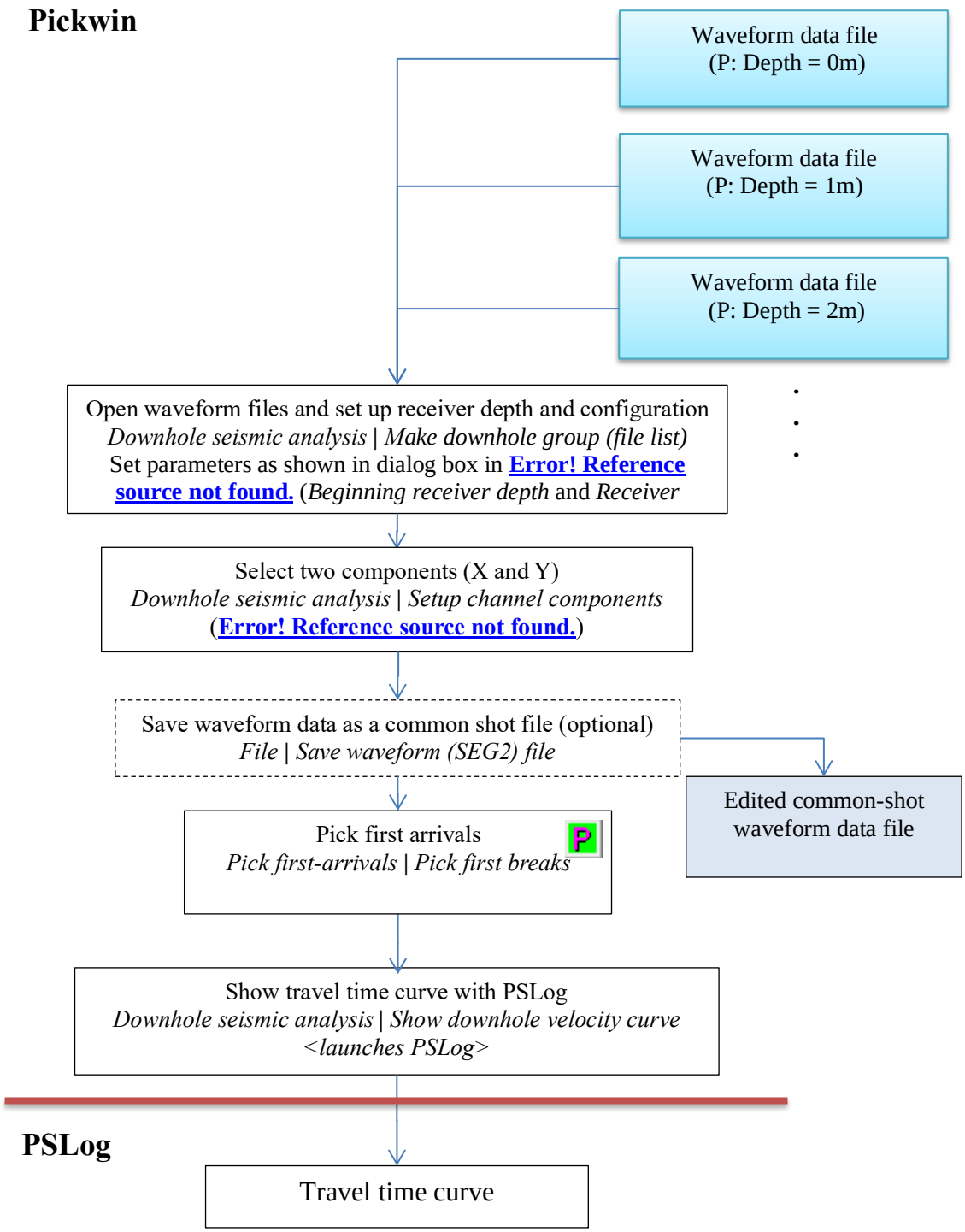


Figure A-8: Processing flow of p-wave data obtained for single-channel receiver (Method B).

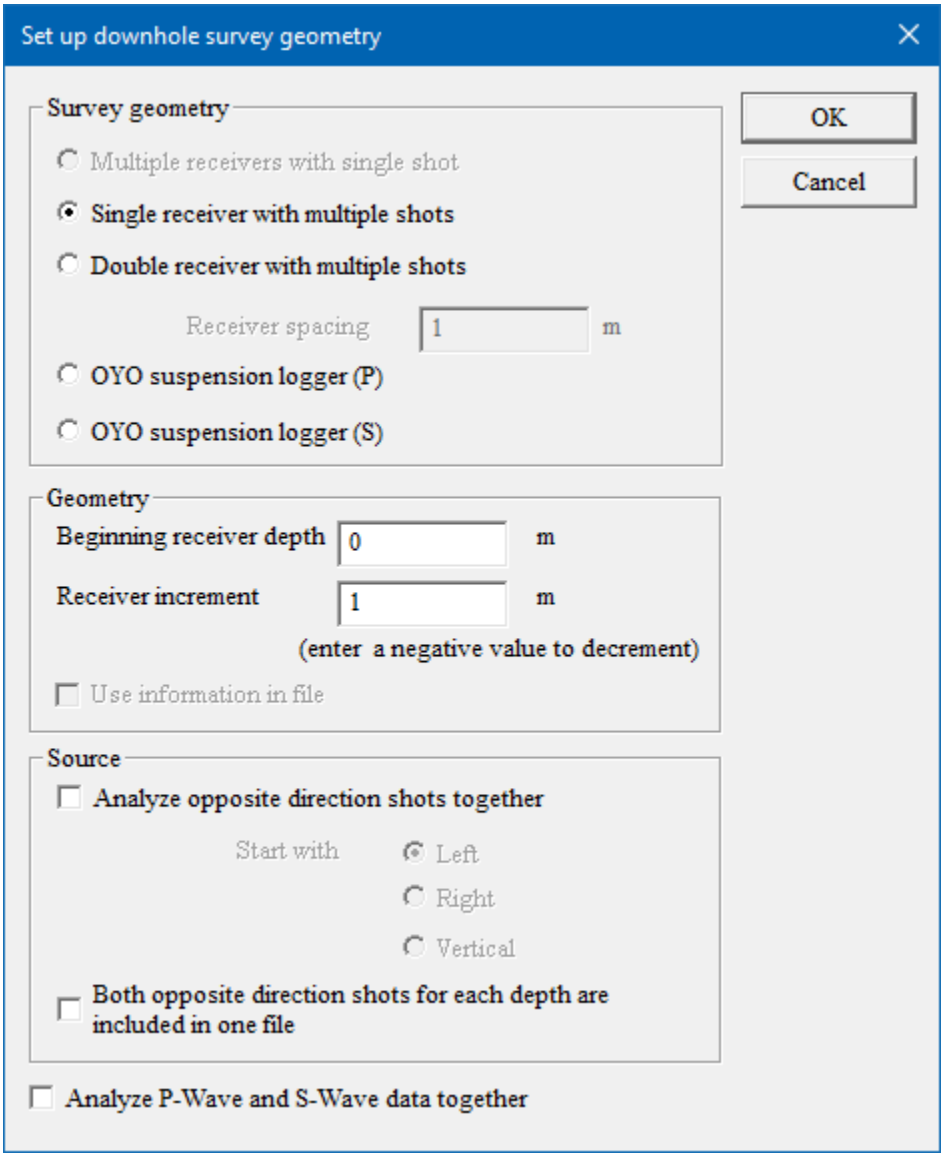


Figure A-9: Geometry parameters for Method B.

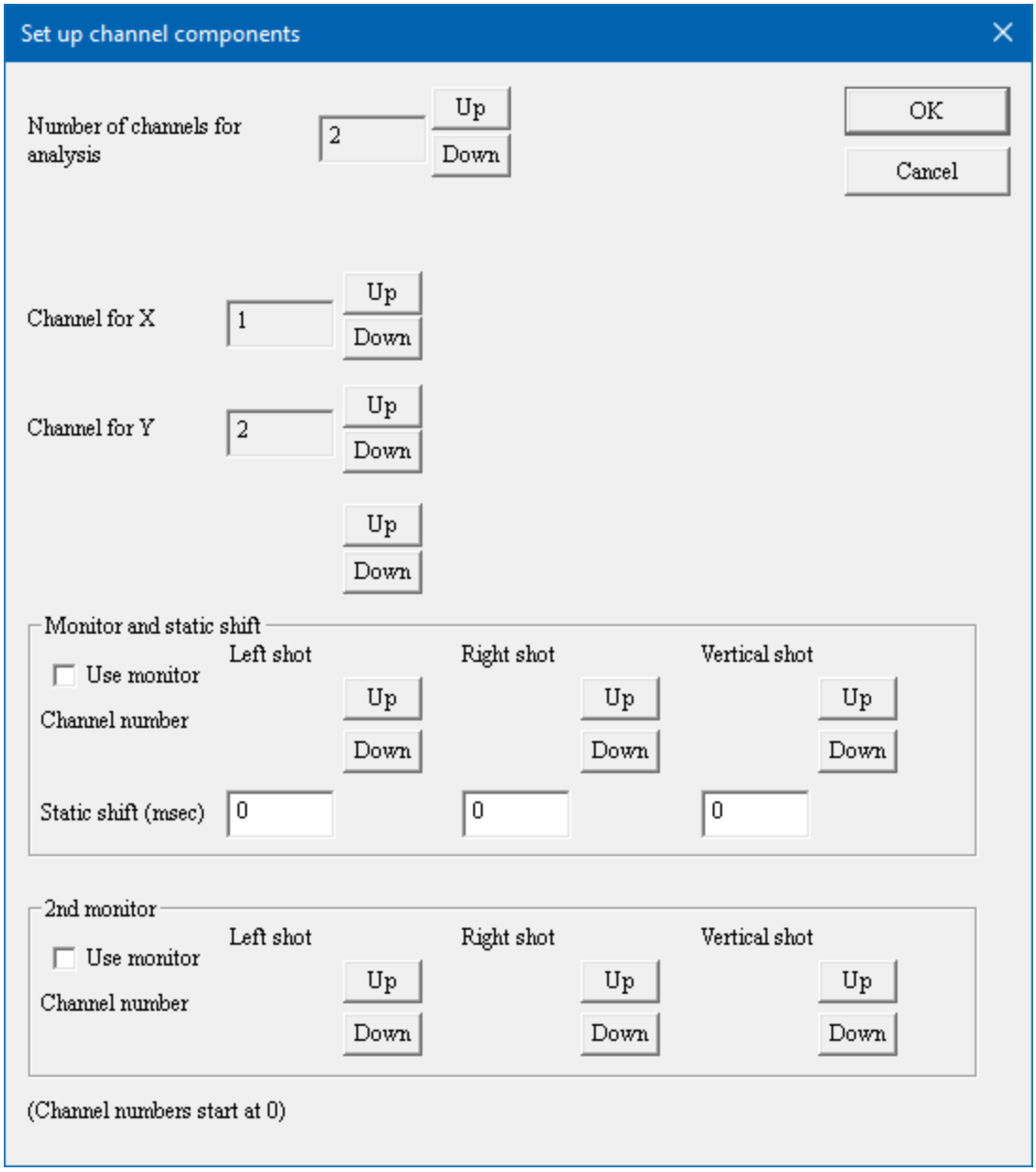


Figure A-10: Channel components for Method B.

Appendix: A.3 Method C: s-wave data using a single two-component (two-channel) horizontal (s-wave) geophone

Shear-waves cannot propagate in water (or air) and horizontal ("shear-wave") geophones must be fixed to the borehole by a wall clamp for data acquisition (Figure A-11).

Note: *This is a different reason from the one requiring the clamping of the vertical (p-wave) geophone in Method B. p-waves* ***do*** *travel through water and air; a p-wave phone is clamped for seismic coupling purposes, not because of propagation limitations.*

As above (Method B), precise shot time is a key in this configuration, and it is recommended that a separate geophone be fixed on the ground surface near or on the plank and used for monitoring the shot time.

A "shear beam" (such as a railroad tie) coupled with a sledgehammer is a common form of s-wave energy source.

Note: *Railroad ties can be purchased at landscape supply outlets. They can endure many impacts because they are impregnated with creosote. A standard 6x6 or 8x8 purchased at a lumber company will splinter badly after a few strikes. A railroad tie is therefore highly recommended.*

It is strongly recommended that you strike **both** ends of the shear beam so that waveform traces with opposite polarity can be observed. Data acquisition results in many waveform files as shown in Figure A-12. At each depth, one waveform file containing two orthogonal horizontal components (H_1 and H_2) and the monitor trace are obtained. In the analysis, Pickwin opens all files at once and extracts the intended traces. Polarization is applied to the two horizontal components and the two traces are rotated in the direction of particle motion. The processing flow is shown in Figure A-13.

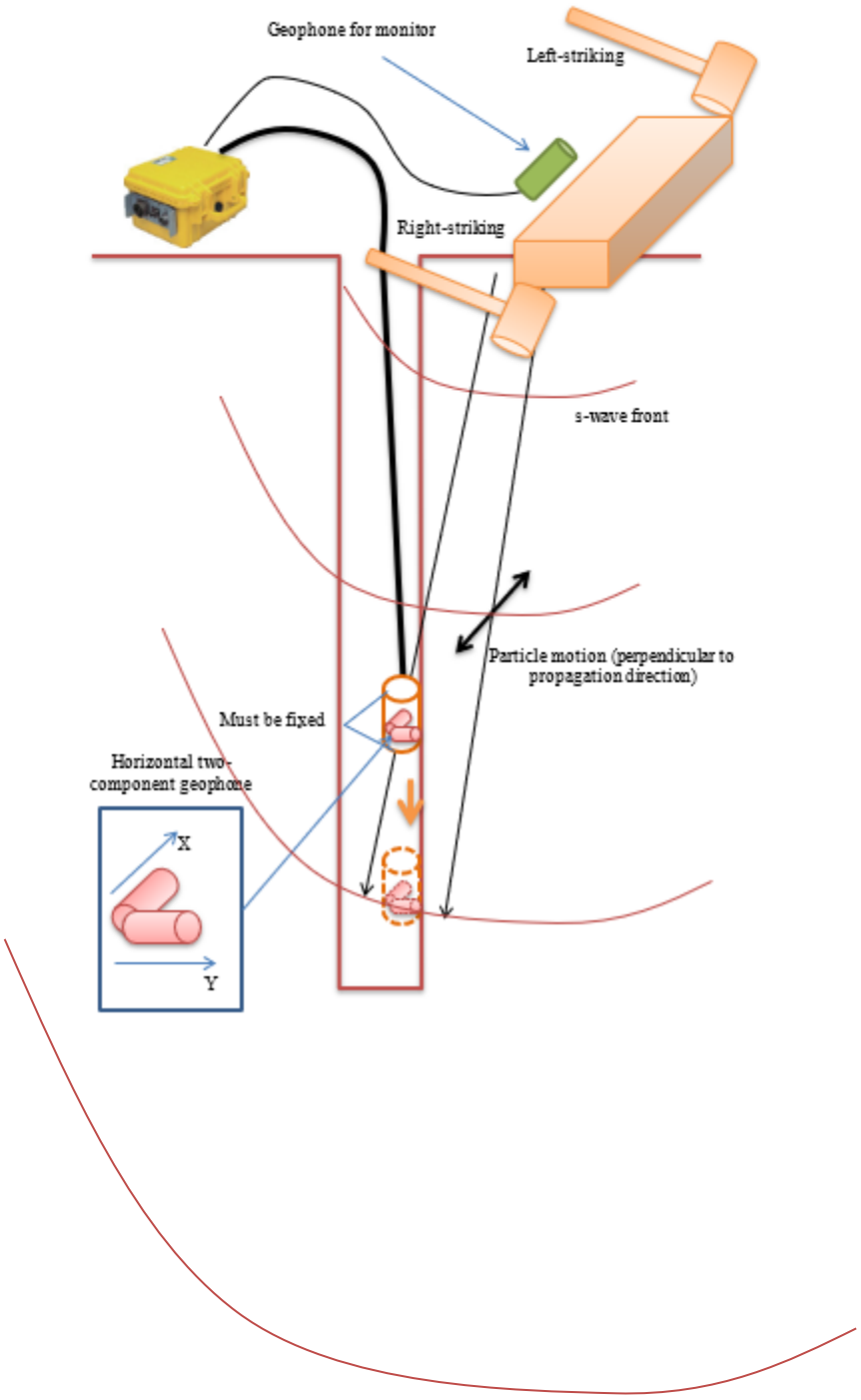


Figure A-11: Acquisition of s-wave data using a single two-component (channel) horizontal (s-wave) geophone Method C).

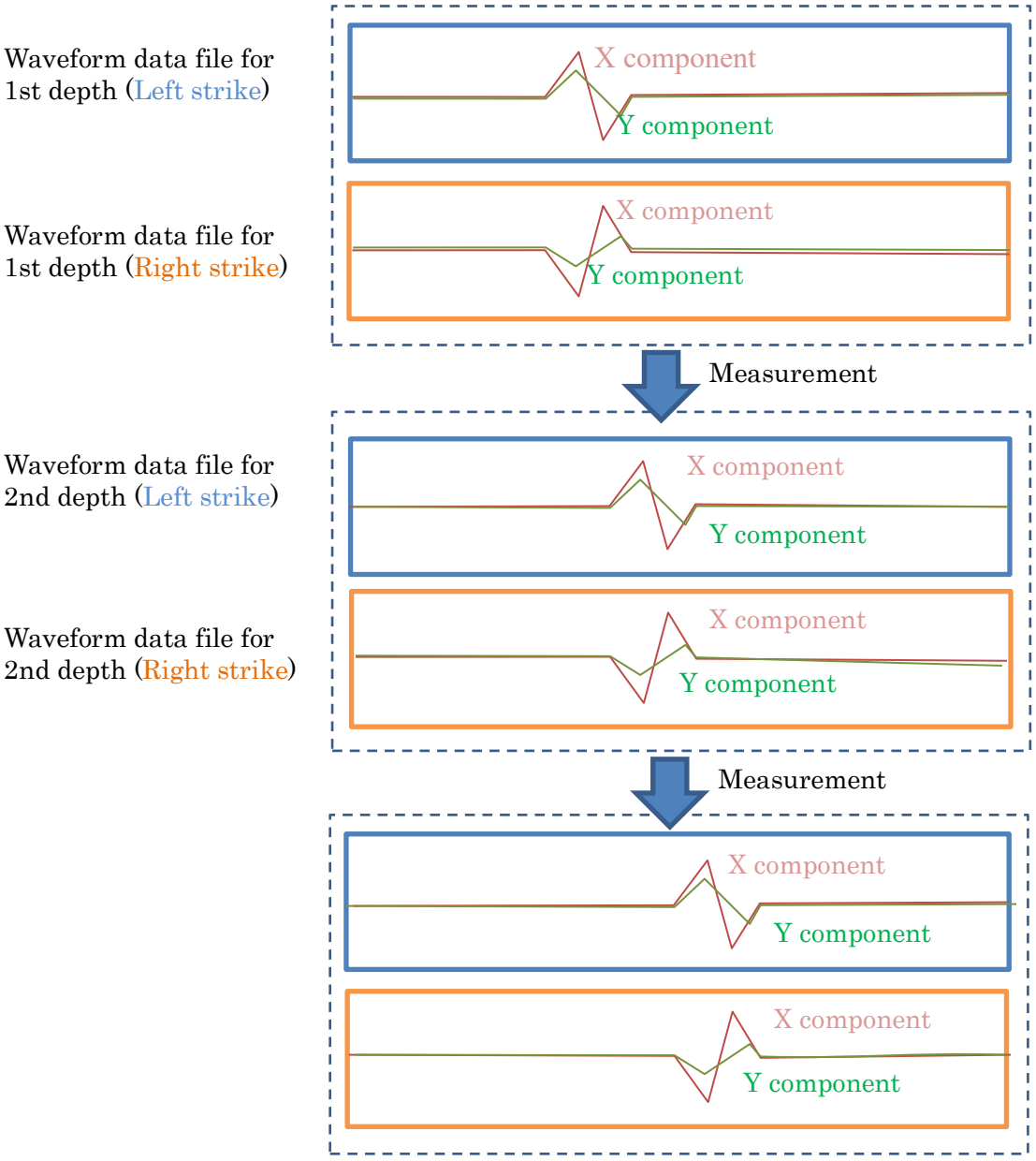


Figure A-12: s-wave data obtained by a two-component geophone (Method C). In this case, a separate file containing H_1 and H_2 (plus the monitor geophone – not shown) is acquired for every strike of the hammer.

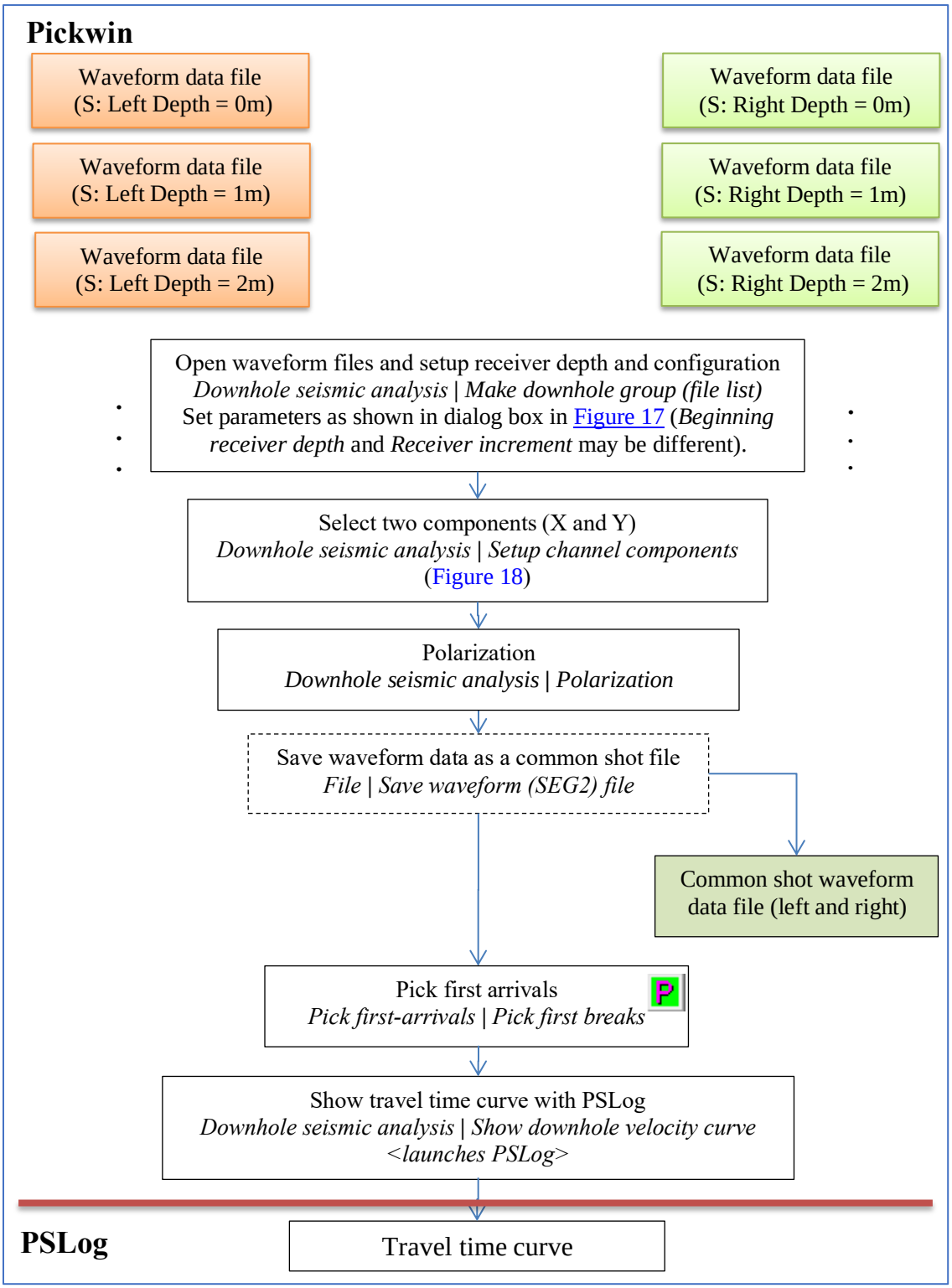


Figure A-13: Processing flow for s-wave data obtained by a two-component geophone (Method C, analyzing left-and right-striking data together).

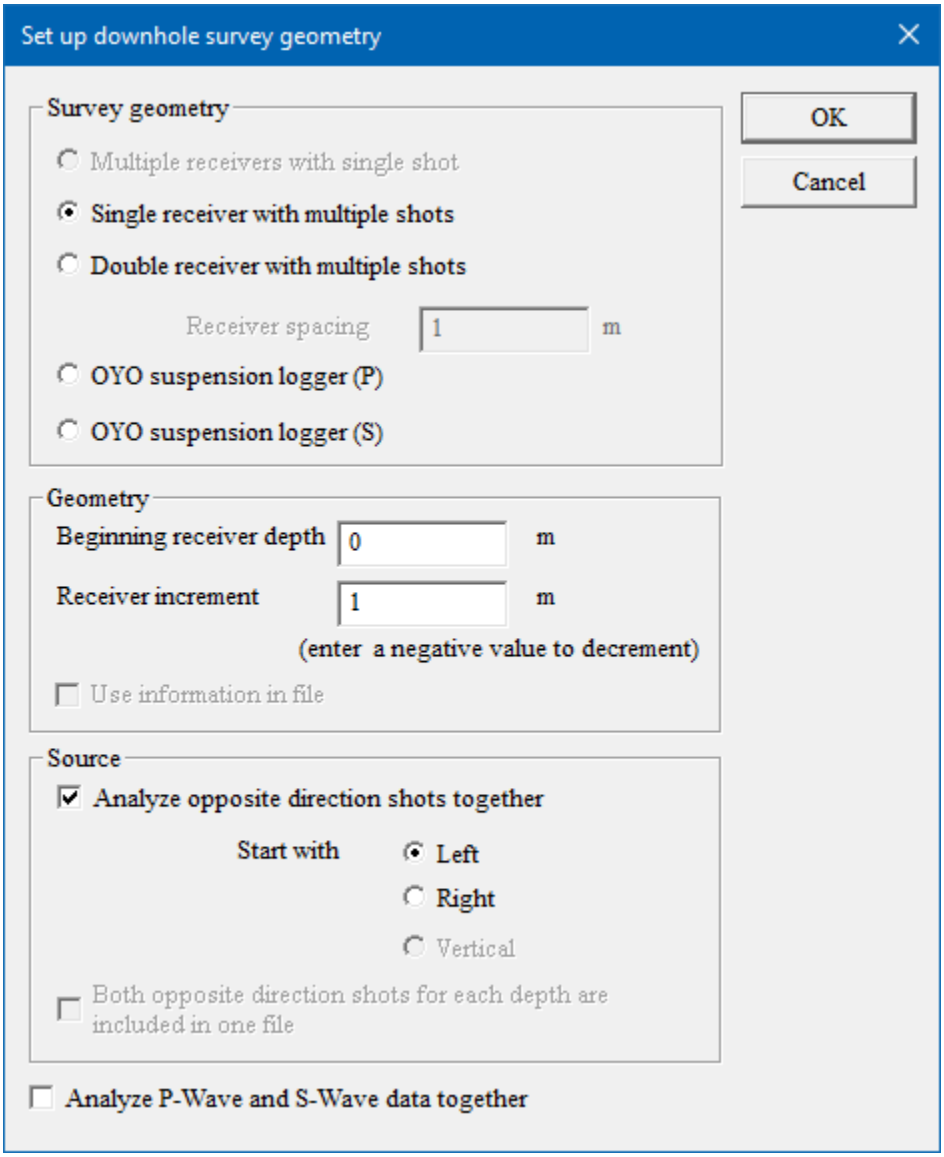


Figure A-14: Geometry parameters for Method C.

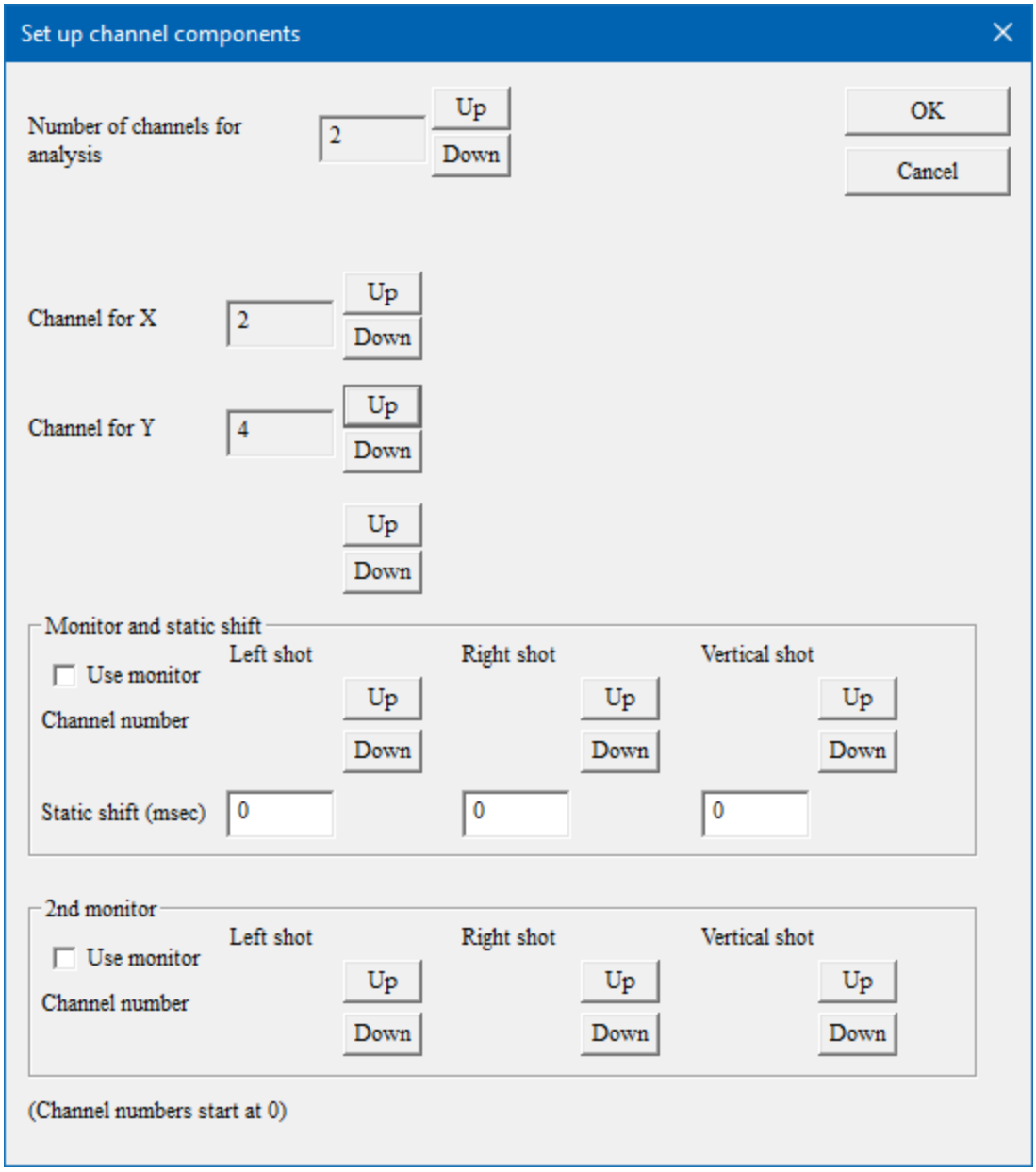


Figure A-15: Channel components for Method C.

Appendix: A.4 Method D: s-wave data acquisition using a cone penetrometer (strike in opposite directions)

A downhole seismic test can be performed without a borehole using a cone penetrating probe, or "cone penetrometer". A downhole seismic test using a cone penetrometer is called a "seismic cone test". One or two sets of orthogonal horizontal geophones are installed in the probe. Analysis using a cone penetrometer with one set of geophones is the same as Method B or Method C. It is recommended that a separate geophone is fixed on the ground surface and used for monitoring the shot time. If the cone penetrometer has two sets of geophones (Figure A-16: s-wave data acquisition using a two-channel receiver (Method D, strike in opposite directions).), travel time can be obtained as the difference of the first arrival times. Travel times can be precisely determined, and accurate shot time is not needed so that the geophone for shot-time monitoring is not necessary.

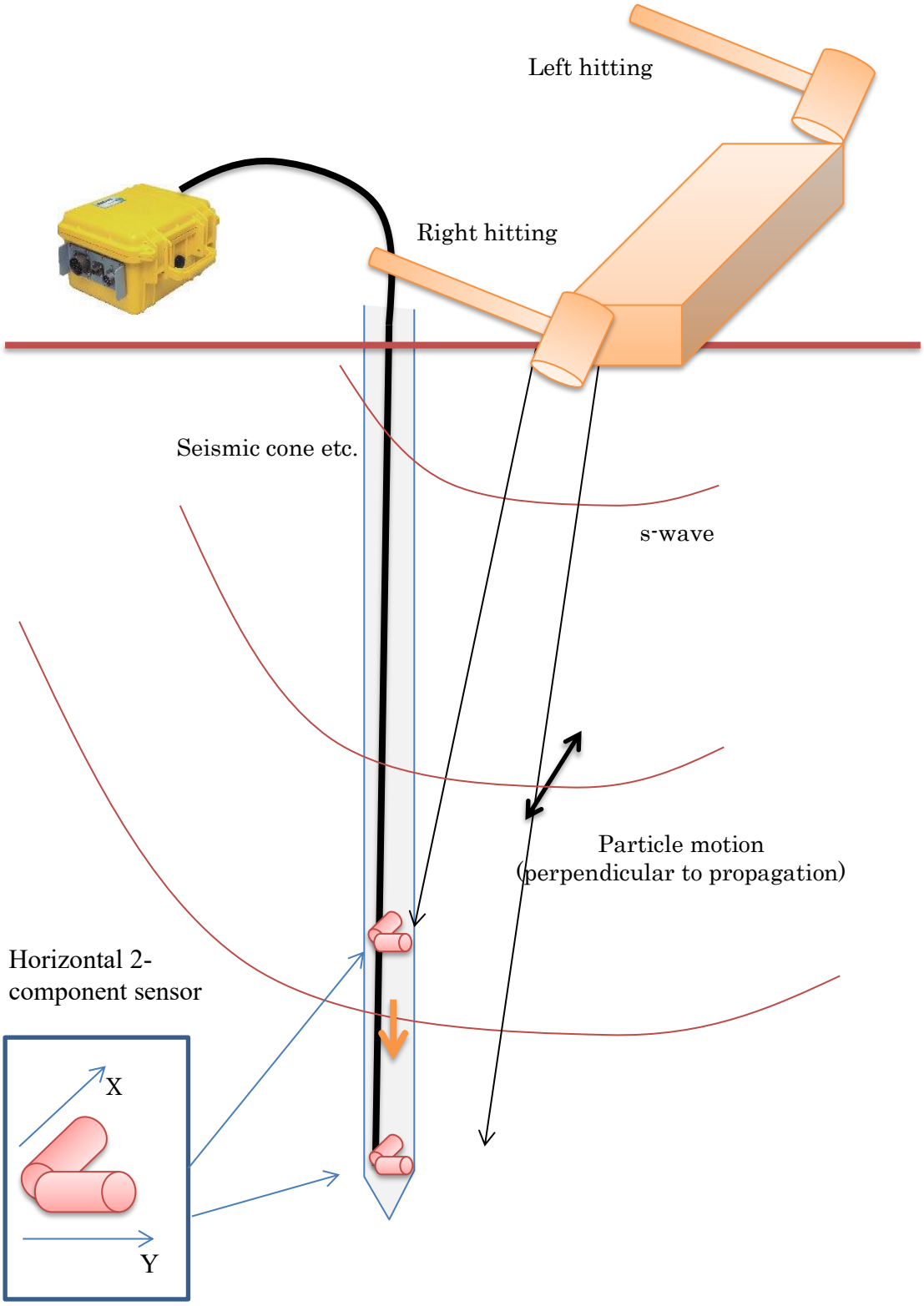


Figure A-16: s-wave data acquisition using a two-channel receiver (Method D, strike in opposite directions).

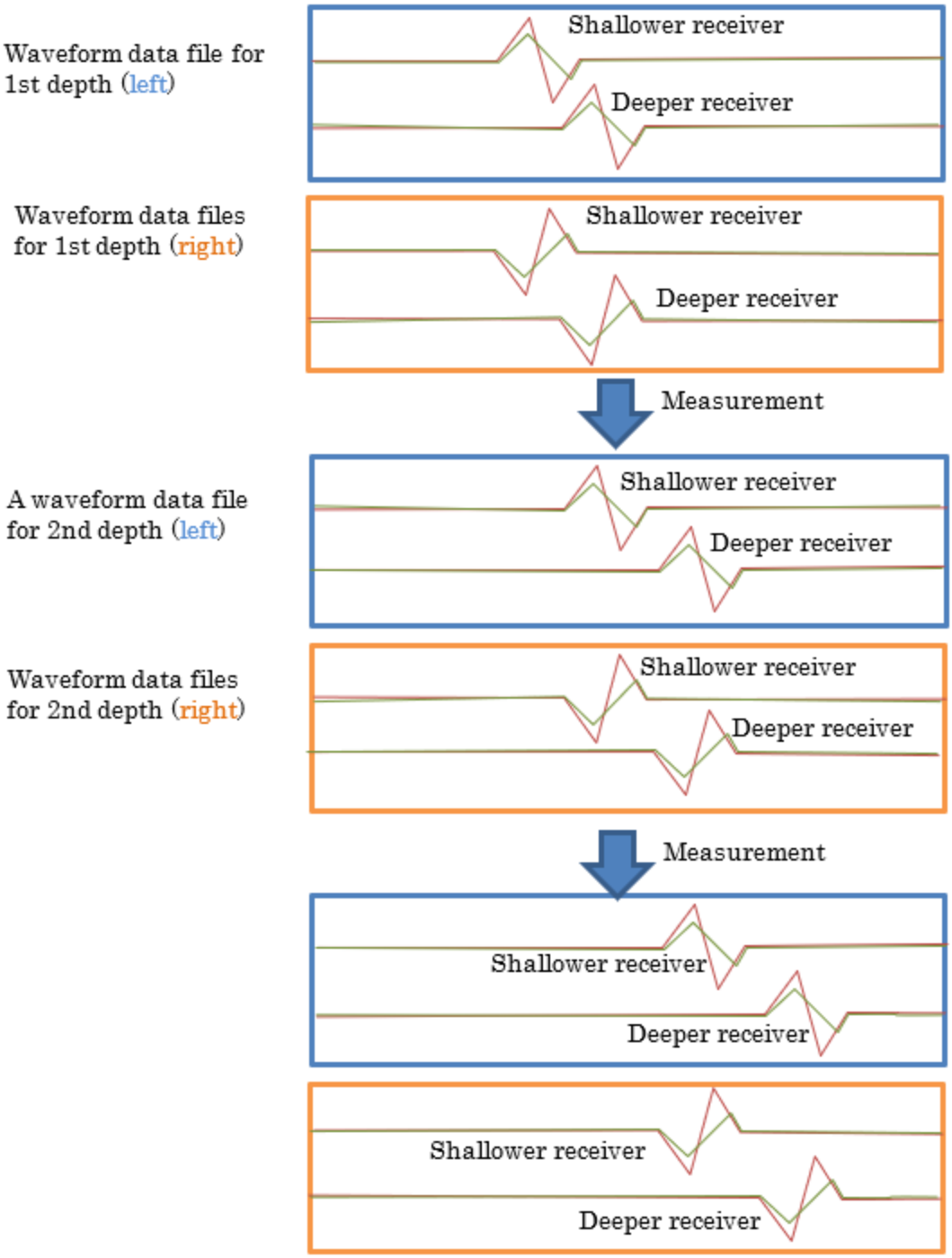


Figure A-17: Acquisition of s-wave data using a cone penetrometer (Method D, strike in opposite directions).

The processing flow is shown in Figure A-18 below:

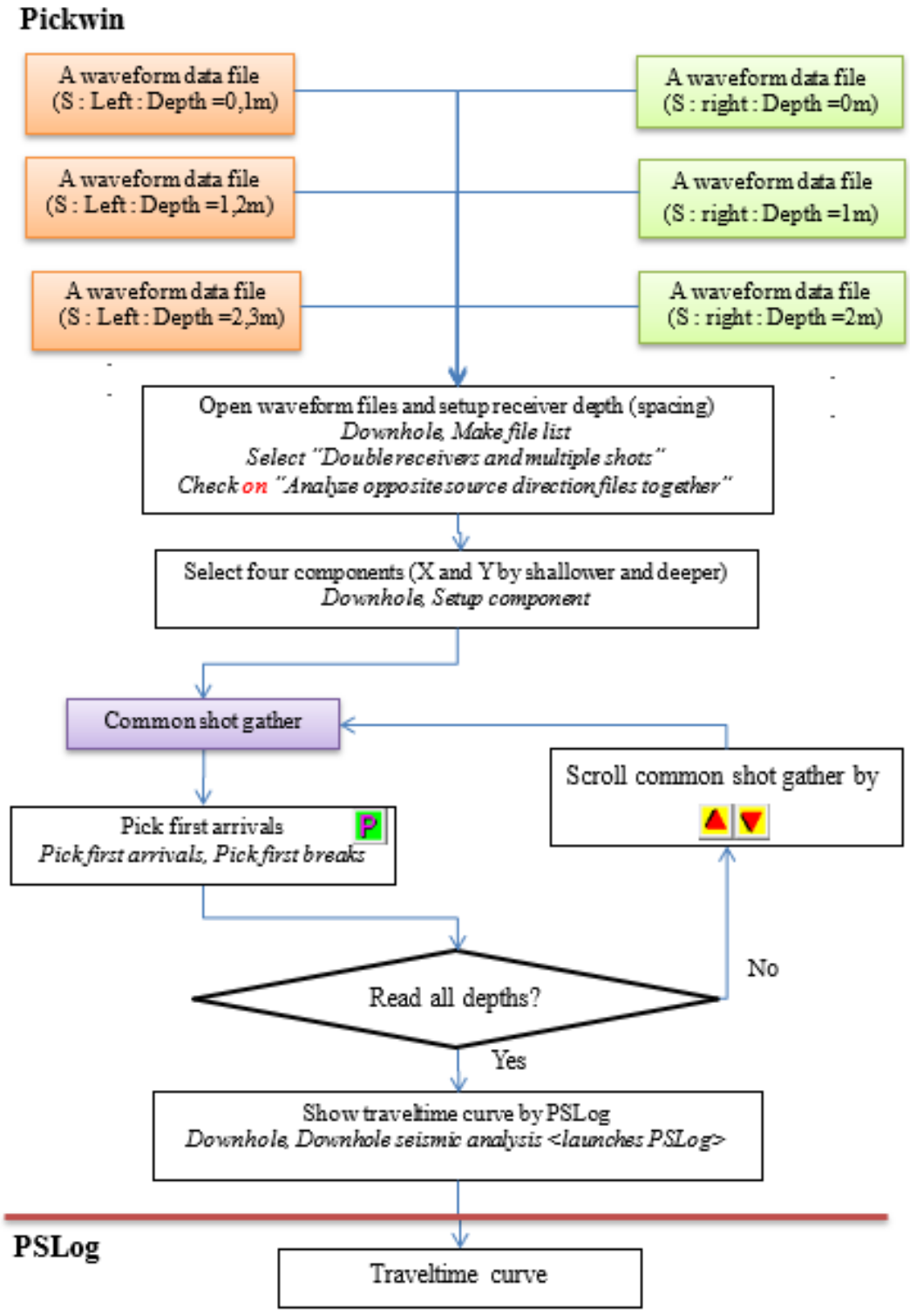


Figure A-18: Processing flow of cone penetrometer data (Method D).

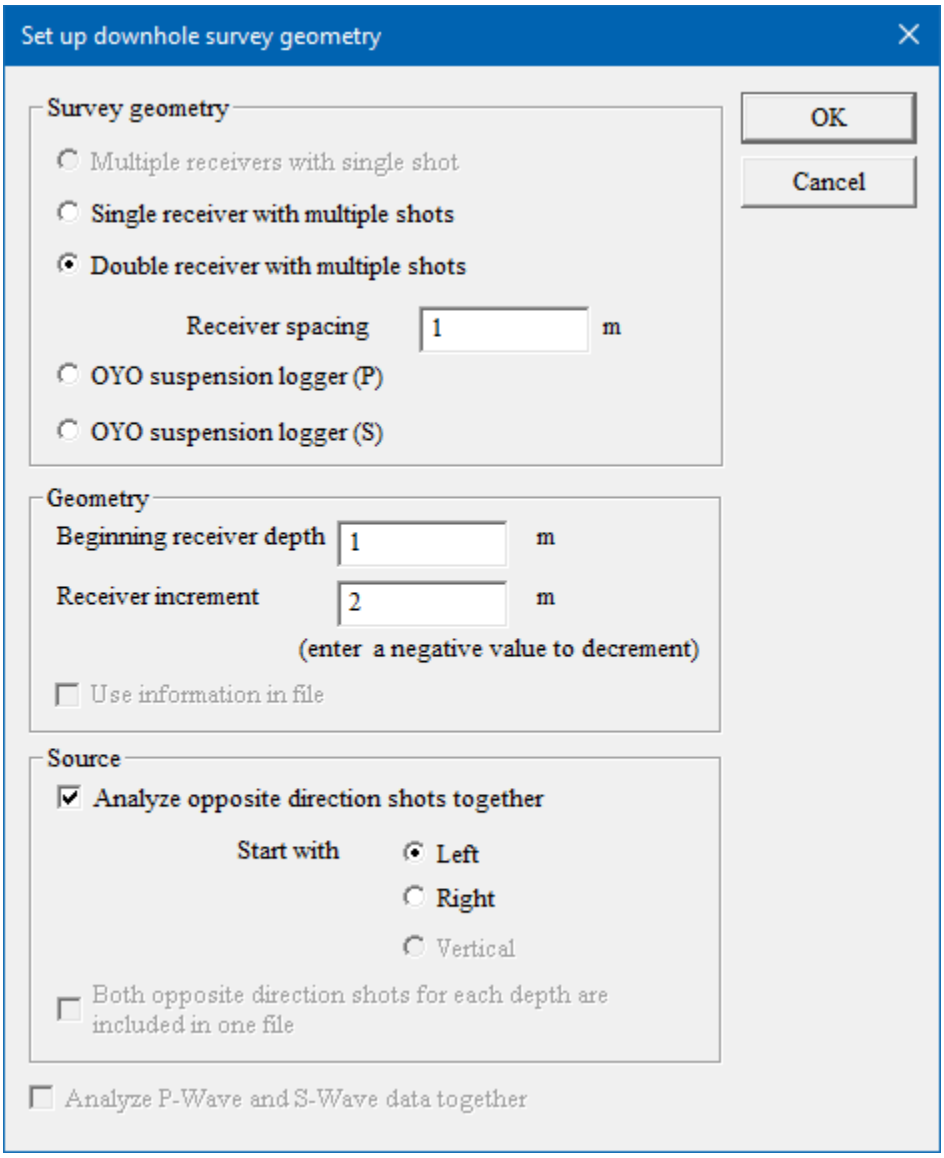


Figure A-19: Geometry parameters for Method D.

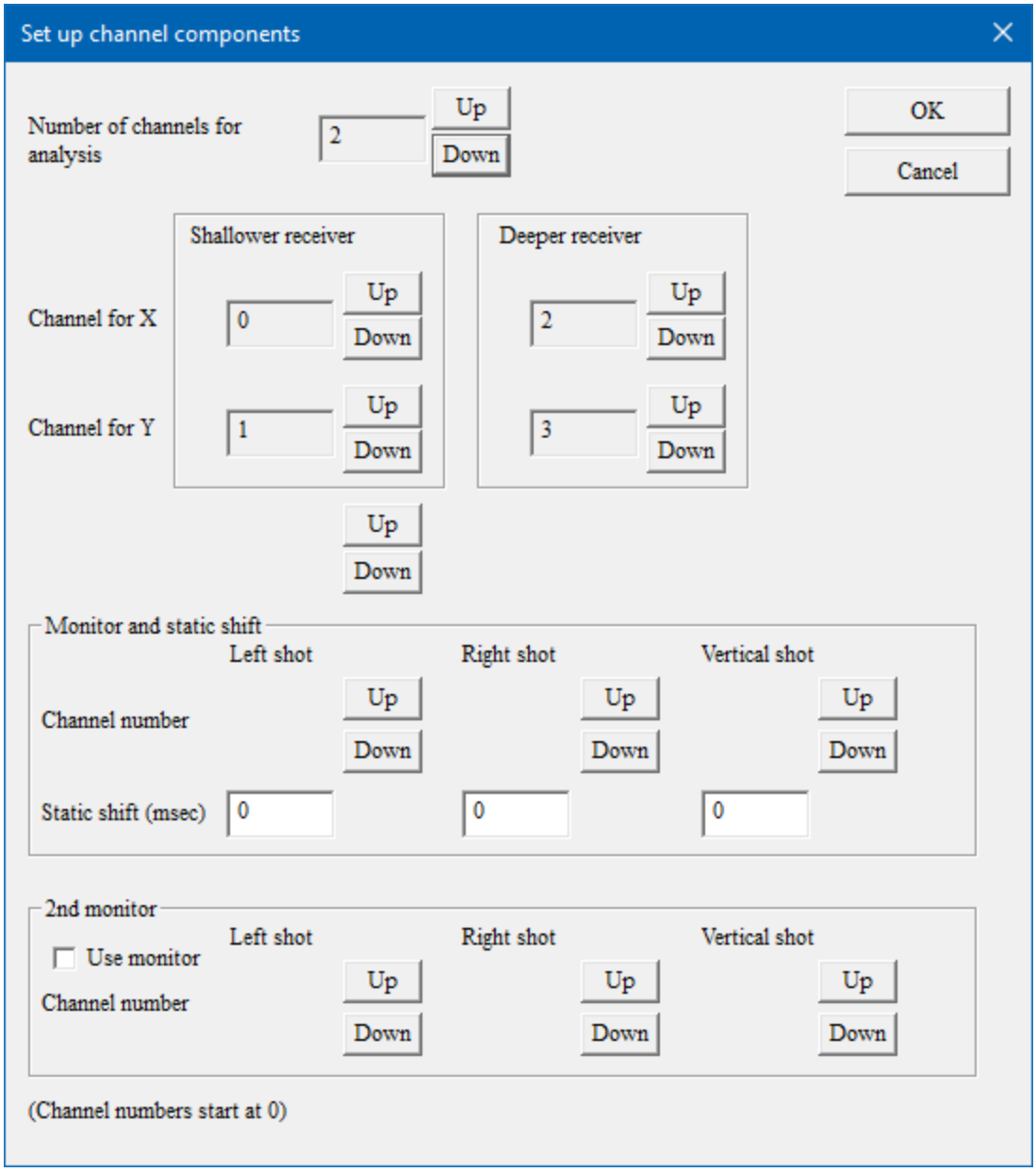


Figure A-20: Channel components for Method D.

Appendix: A.5 Method E: OYO Suspension (P)

p-waveform data obtained by OYO Suspension can be processed by SeisImager/DH. Source-receiver geometry is similar to the configuration described in Method D, except that the source is placed *beneath* the vertical geophones.

Appendix: A.6 Method F: OYO Suspension (S)

s-waveform data obtained by OYO suspension can also be processed by SeisImager/DH. Again, source-receiver geometry is similar to the configuration described in Method D, except that the source is placed *beneath* the horizontal geophones.

APPENDIX: B. OPTIONAL ACQUISITION AND ANALYSIS METHOD USING A TRIGGER MONITOR

In Methods B and C, waveforms at each depth must be acquired separately and the shot time must be very accurate. The accuracy of the trigger depends on the seismograph. The trigger may not be accurate enough in some seismographs. To confirm an accurate shot time, the use of a trigger monitor receiver can be effective. The trigger monitor geophone is connected to a channel of the seismograph and pre-trigger data must be recorded. The configuration of the trigger monitor geophone along with an example of a short record are shown in Figure B-1. Analysis using the trigger monitor receiver is described later in Section Appendix: F.1, Page F-1.

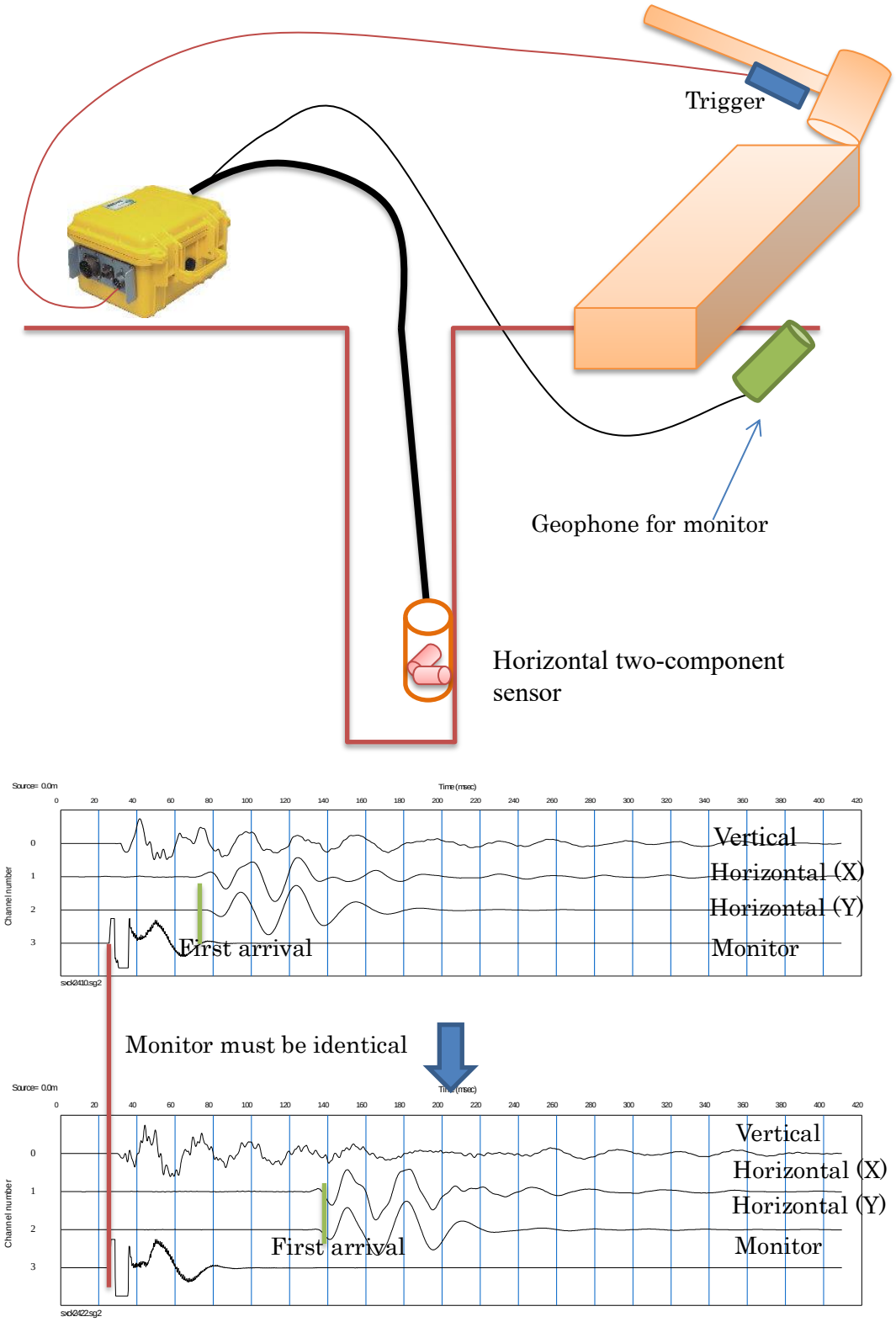


Figure B-1: Configuration of trigger monitor receiver and example of a shot record (vertical component not shown in schematic).

APPENDIX: C. MANUAL POLARIZATION

It is generally difficult to set the direction of the horizontal geophones in the borehole during the data acquisition of s-waves except when using a seismic cone penetrometer. Therefore, two orthogonal horizontal receivers are used for data acquisition and two traces are rotated in processing so that the direction parallel to the shot is obtained. This processing step is called "Polarization". As it is difficult to know the directions of the geophone axes in the borehole, SeisImager/DH guesses the angle of direction by the following procedure:

1) Plot the particle motion from two orthogonal waveform traces.
2) Calculate a straight line passing through the origin using the least-squares method.
3) If there are waveforms for two opposing sources (left-and right-striking), both waveform directions can be handled together.

Figure C-1 shows an example of particle motion. With the default setting, SeisImager/DH obtains the rotation angle automatically by the least-squares method. Sometimes, the appropriate rotation angle cannot be automatically obtained. In this case, SeisImager/DH can also be used to determine the rotation angle manually.

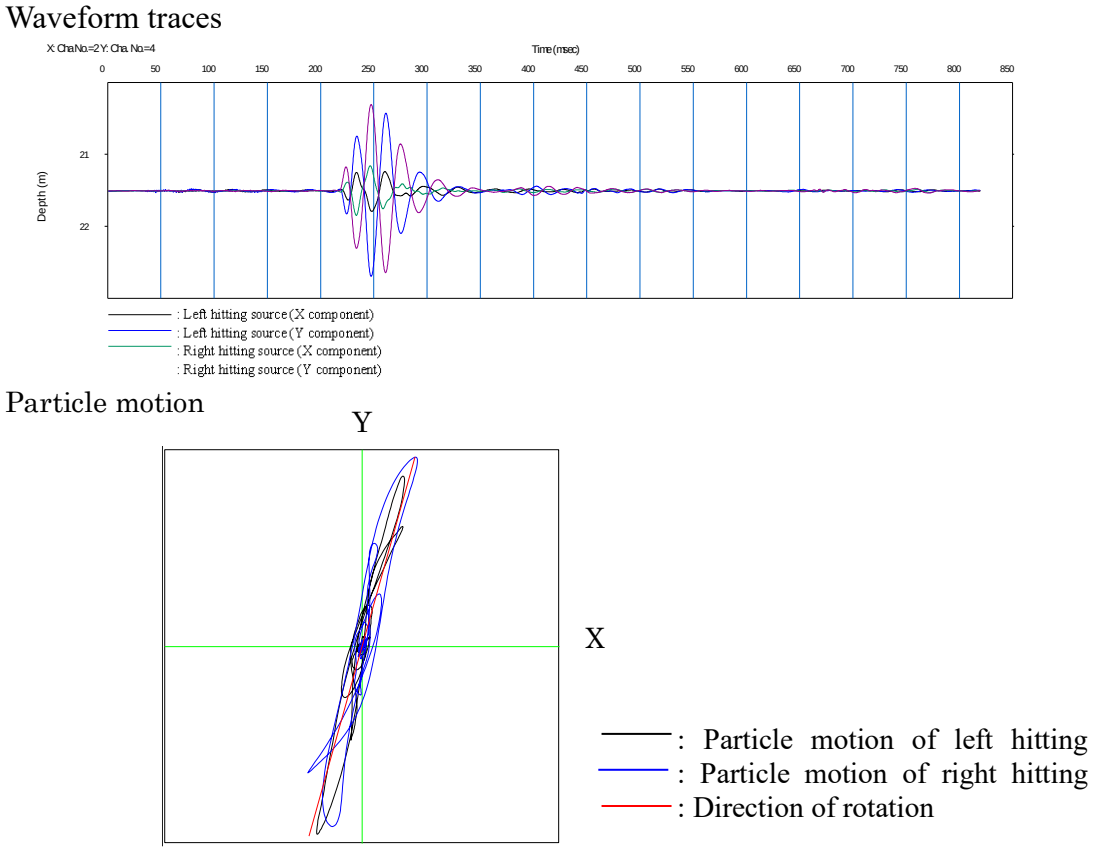
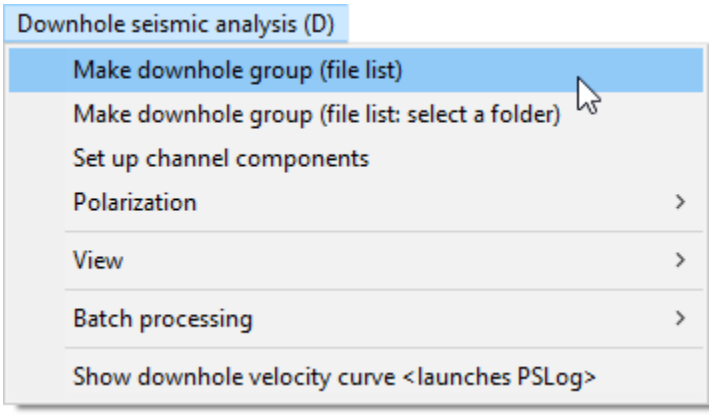


Figure C-1: Example of particle motion.

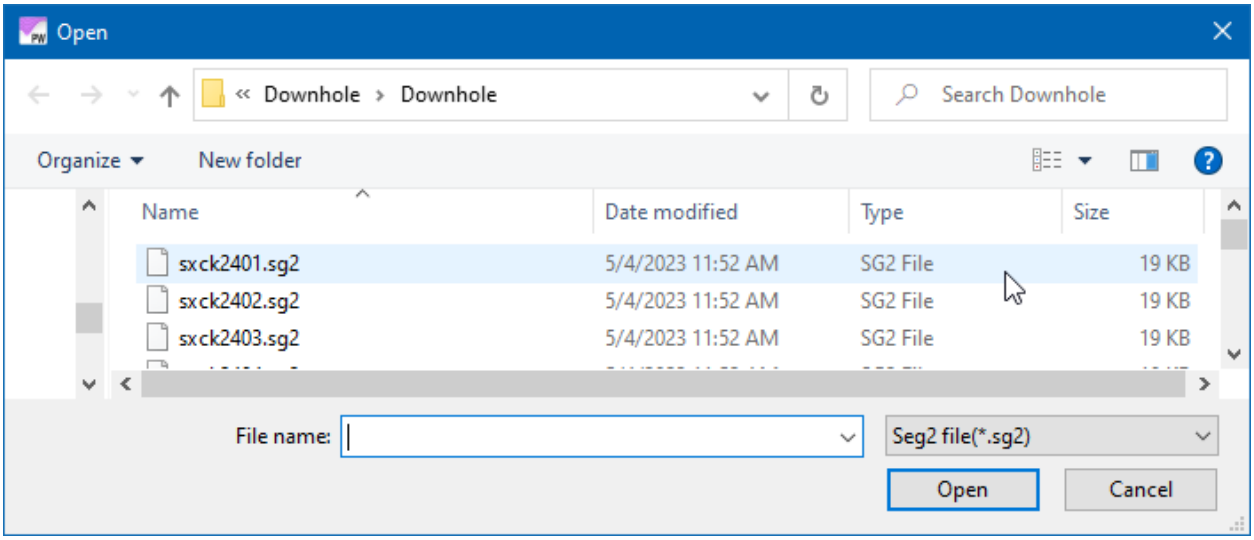
APPENDIX: D. BASIC PROCESSING FLOW

Appendix: D.1 Method A: p-wave data using a multi-channel hydrophone array

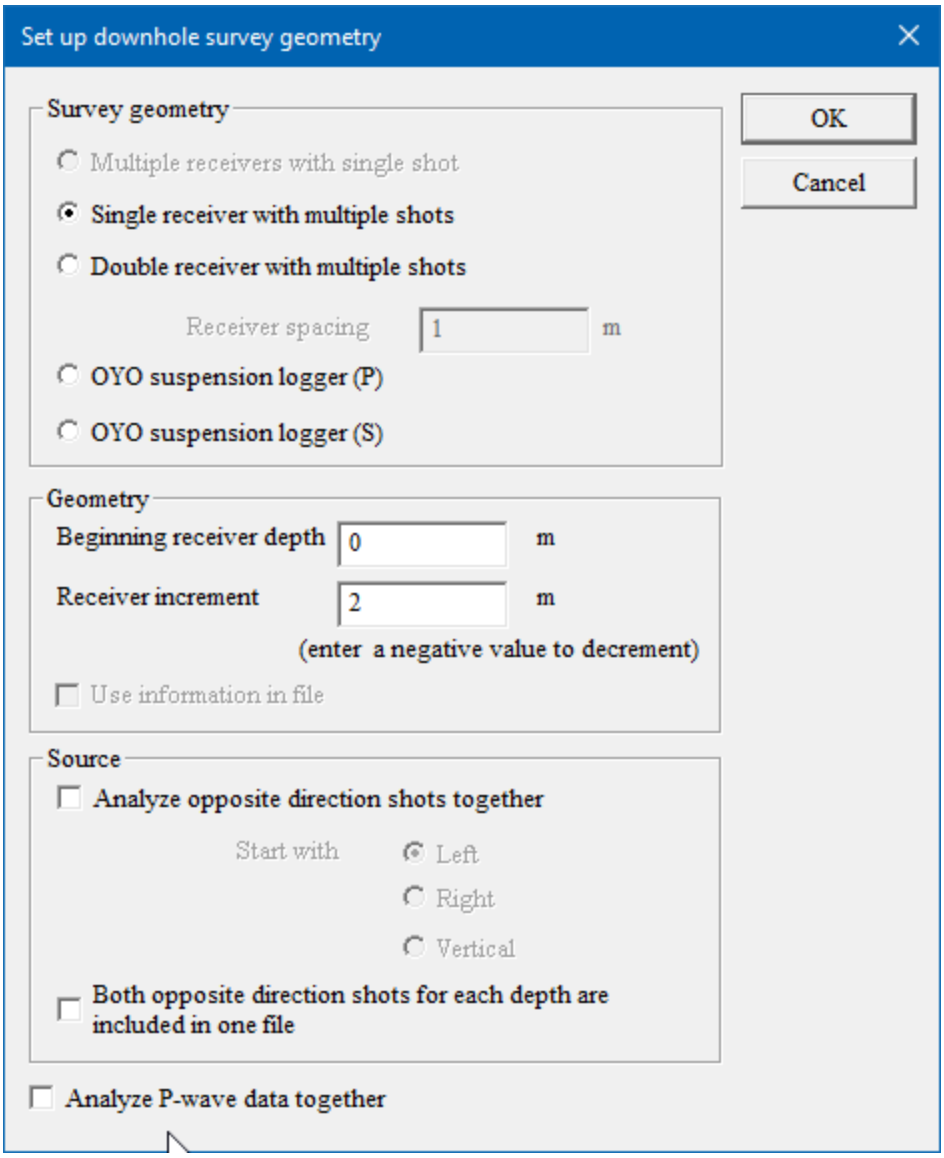
1) Select *Downhole seismic analysis* | *Make downhole group (file list).*



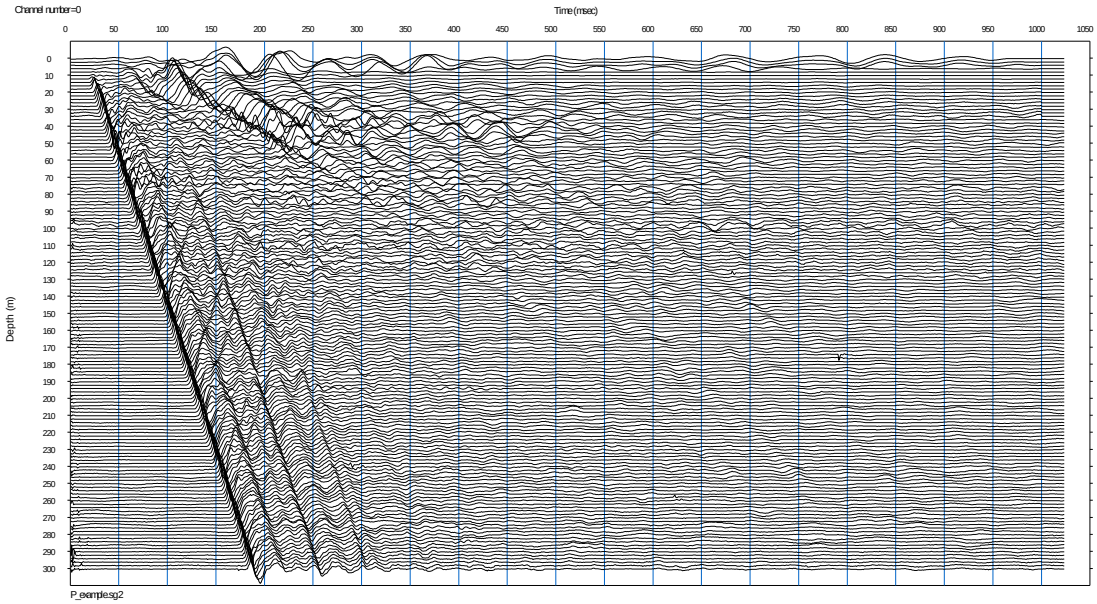
2) Select a single file.



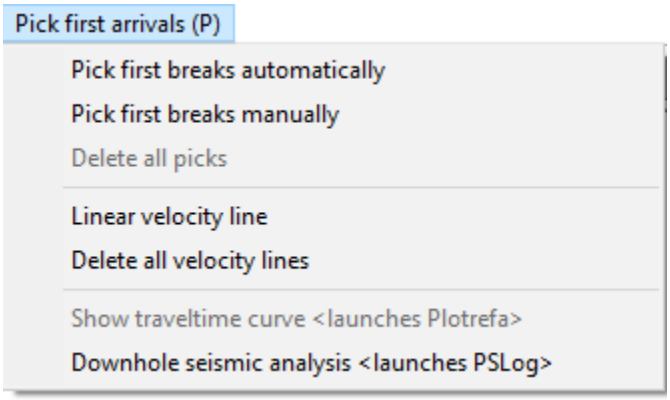
3) Select *Multiple receivers with single shot* and setup *Beginning receiver depth* and *Receiver increment*.

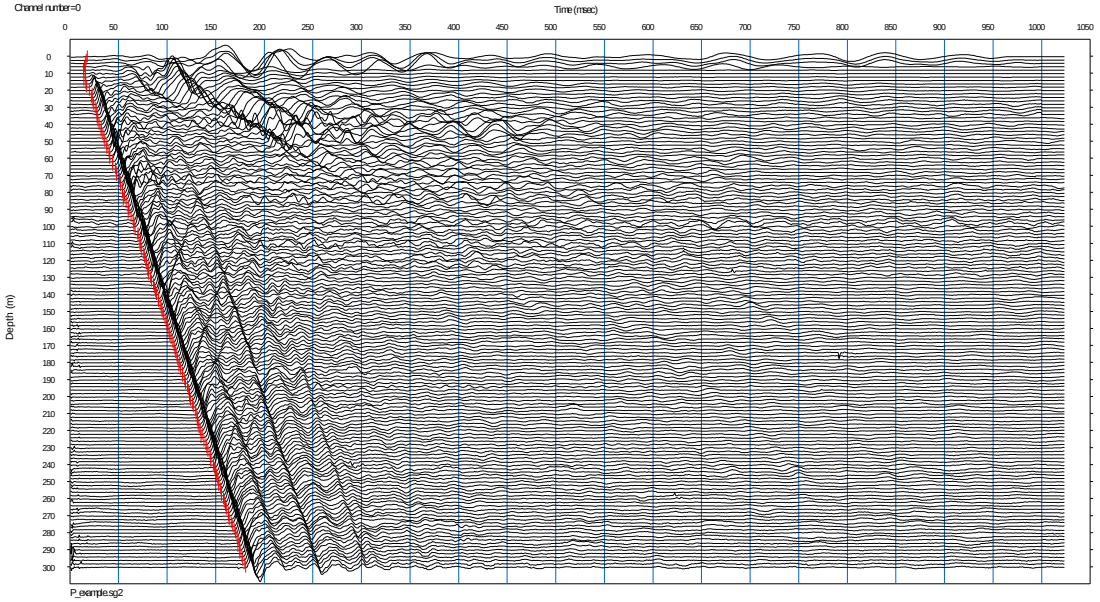


4) The waveform data will be displayed.

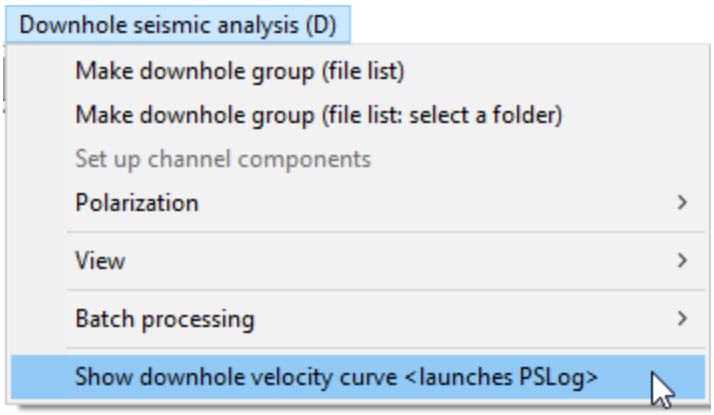


5) Pick first arrivals by selecting *Pick first arrivals* | *Pick first breaks manually* or *Pick first arrivals* | *Pick first breaks automatically.*

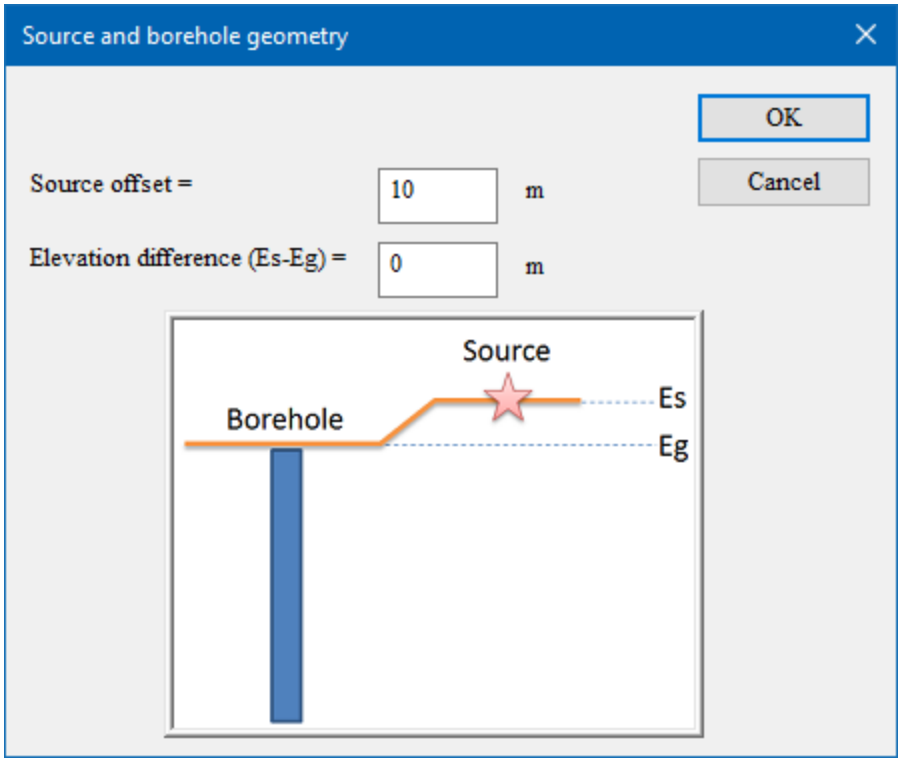




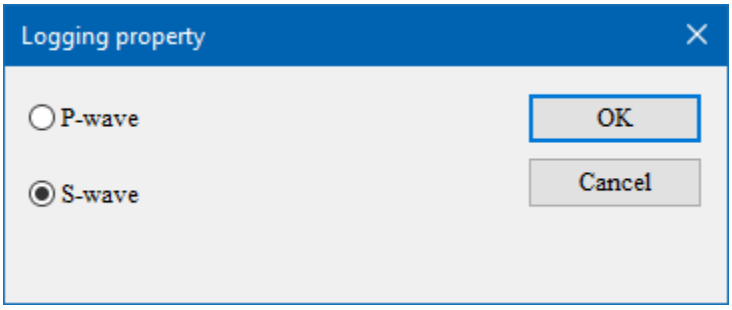
6) Select *Downhole seismic analysis* | *Show downhole velocity curve <launches PSLog>* to show the travel time curve.



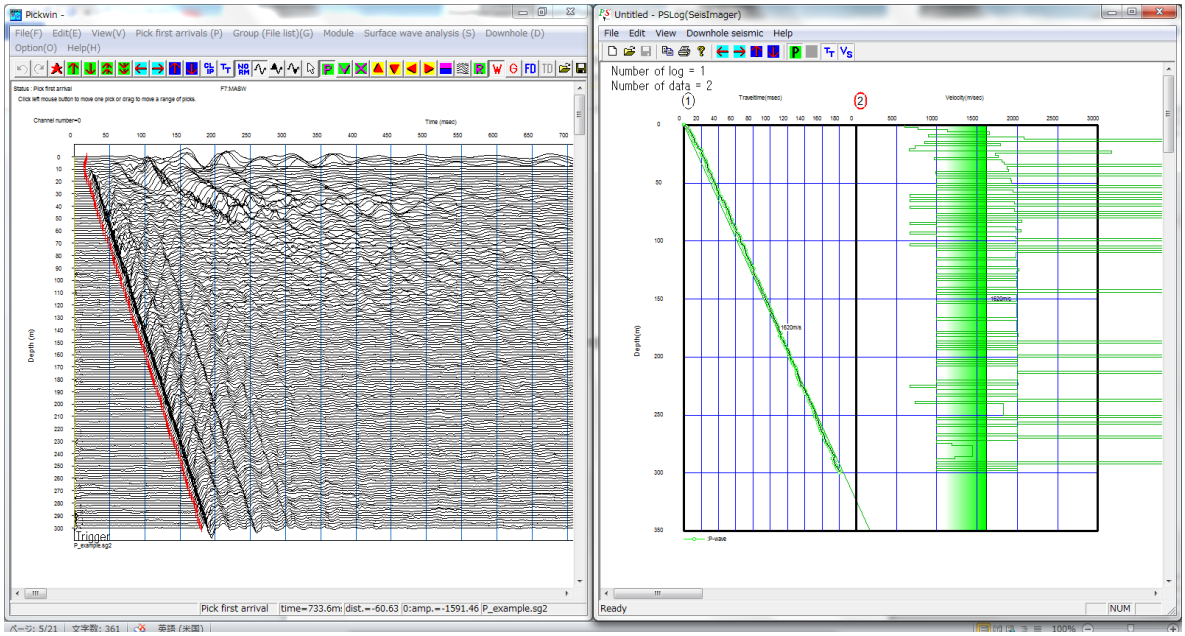
7) Enter *Source offset* and *Elevation difference* (see Section 6.4.2, Page 93, for details).



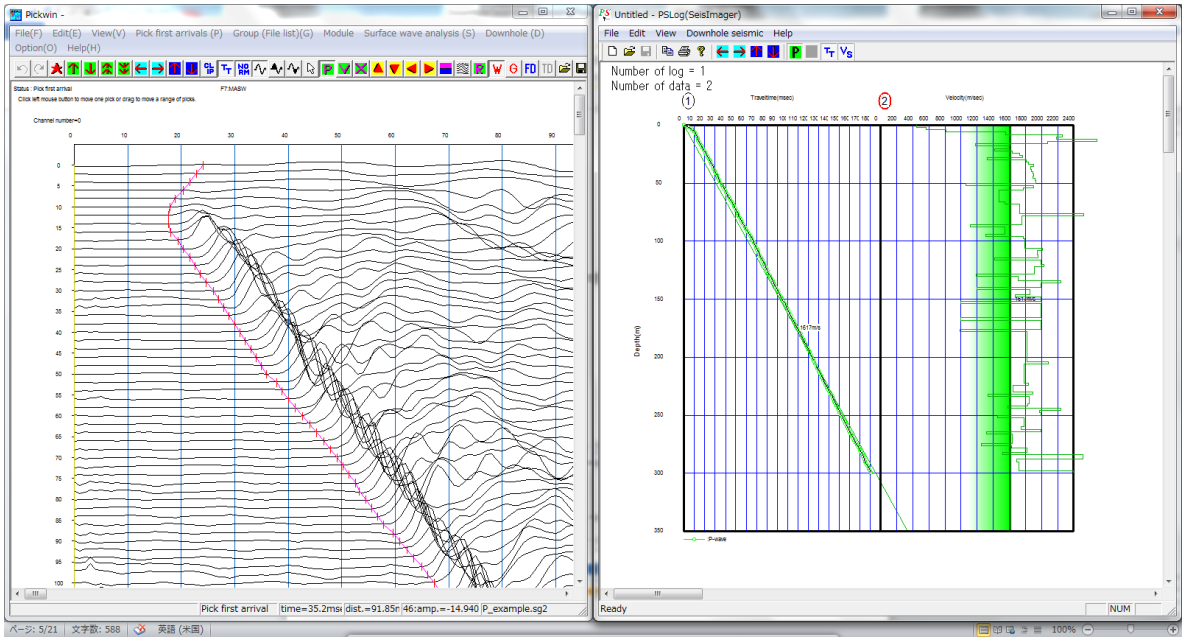
8) Select p- or s-wave.



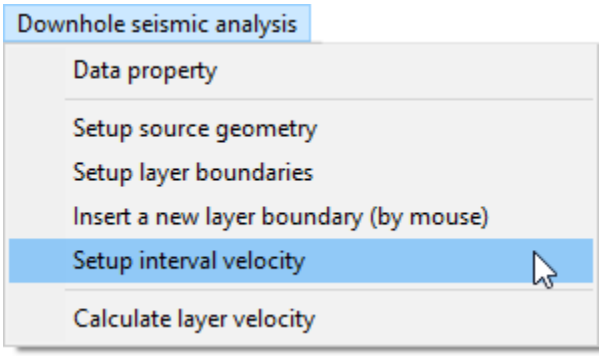
A travel time curve and a velocity model are shown by PSLog.


Pickwin -
File(F) Edit(E) View(V) Pick first arrivals (P) Group (File list)(G) Module Surface wave analysis (S) Downhole (D)
Option(O) Help(H)
Pick first arrival time=733.6m dist.=-60.63 0:amp.=-1591.46 P_example.sg2
Untitled - PSLog(SeisImager)
File Edit View Downhole seismic Help
Number of log = 1
Number of data = 2
Ready
NUM

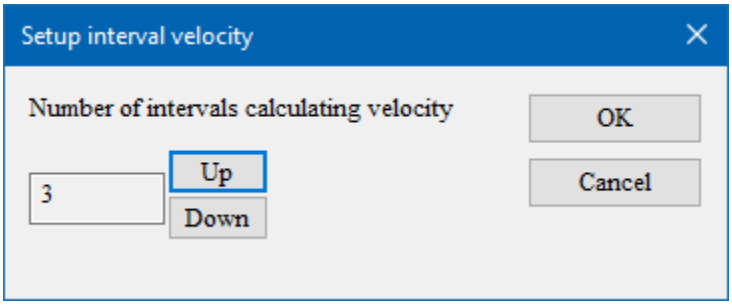
9) Edit first arrival picks and click the red star  in Pickwin, and the travel time curve and velocity model will be automatically updated.



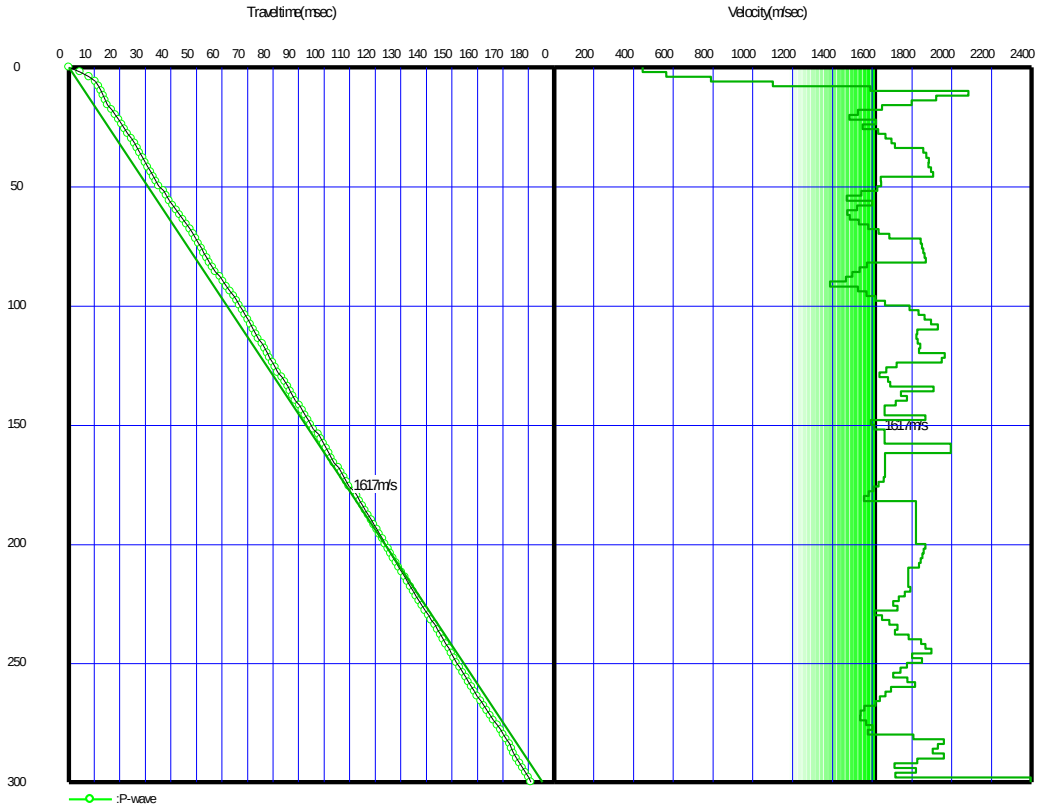
10) Calculation of interval velocity can be changed by selecting *Downhole seismic analysis* | Setup *interval velocity.*



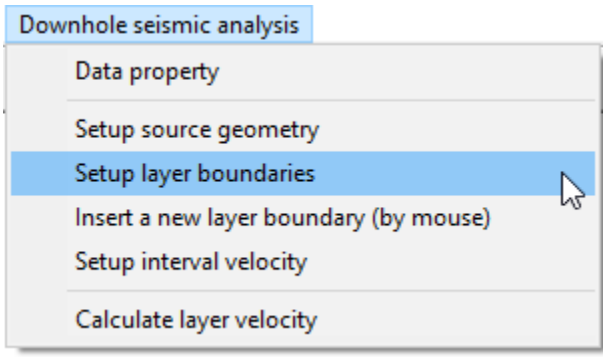
11) Set the *Number of intervals calculating velocity*.



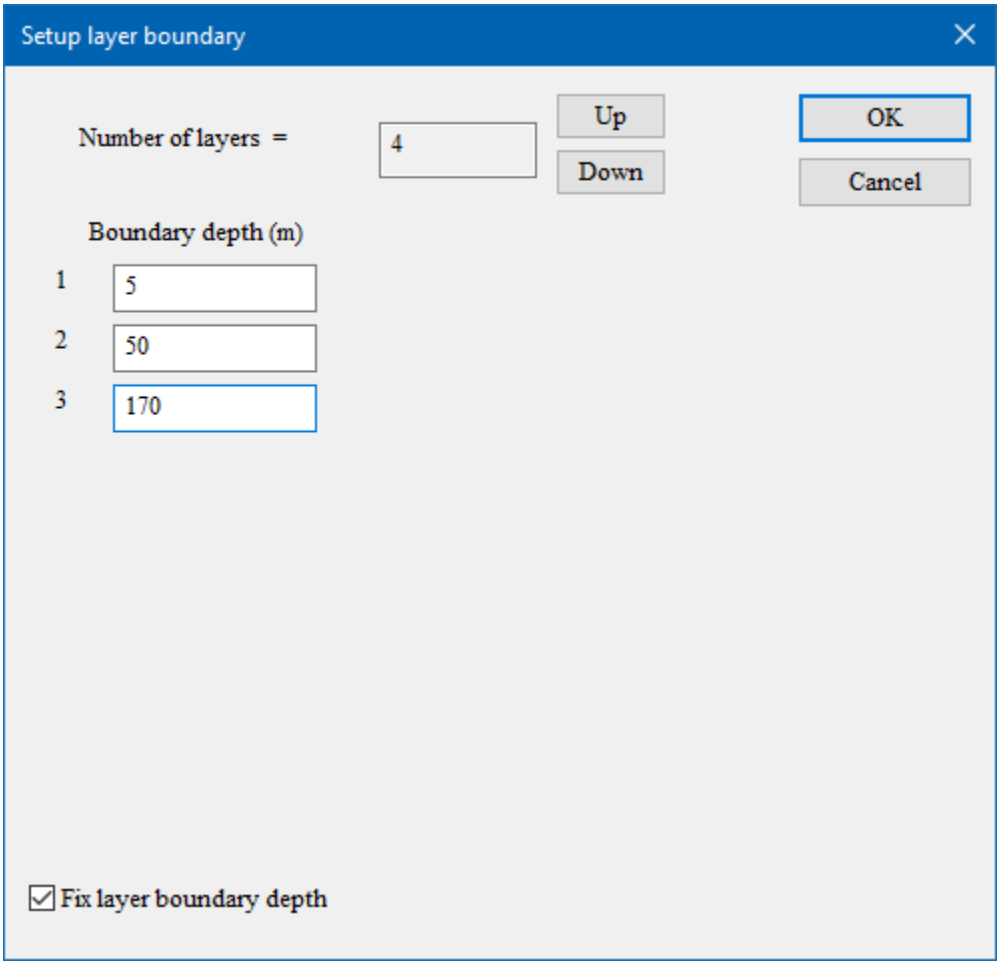
Increasing the number makes the interval velocity curve smoother (see Section 6.4.5, Page 99, for details).



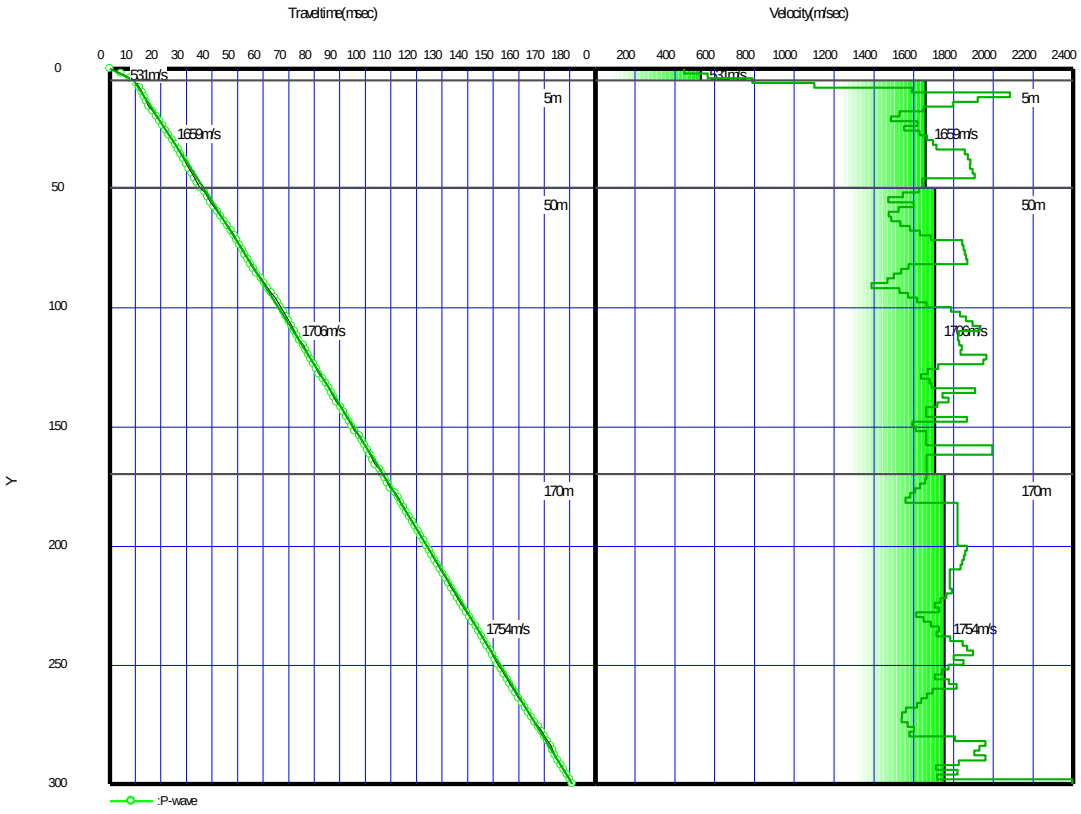
12) At first, a one-layer model is assumed, and the least-squares velocity is shown. To increase the number of layers, select Setup *layer boundaries.*



13) Edit *Number of layers* and setup *Boundary depth* (see Section 6.4.3, Page 94, for details).

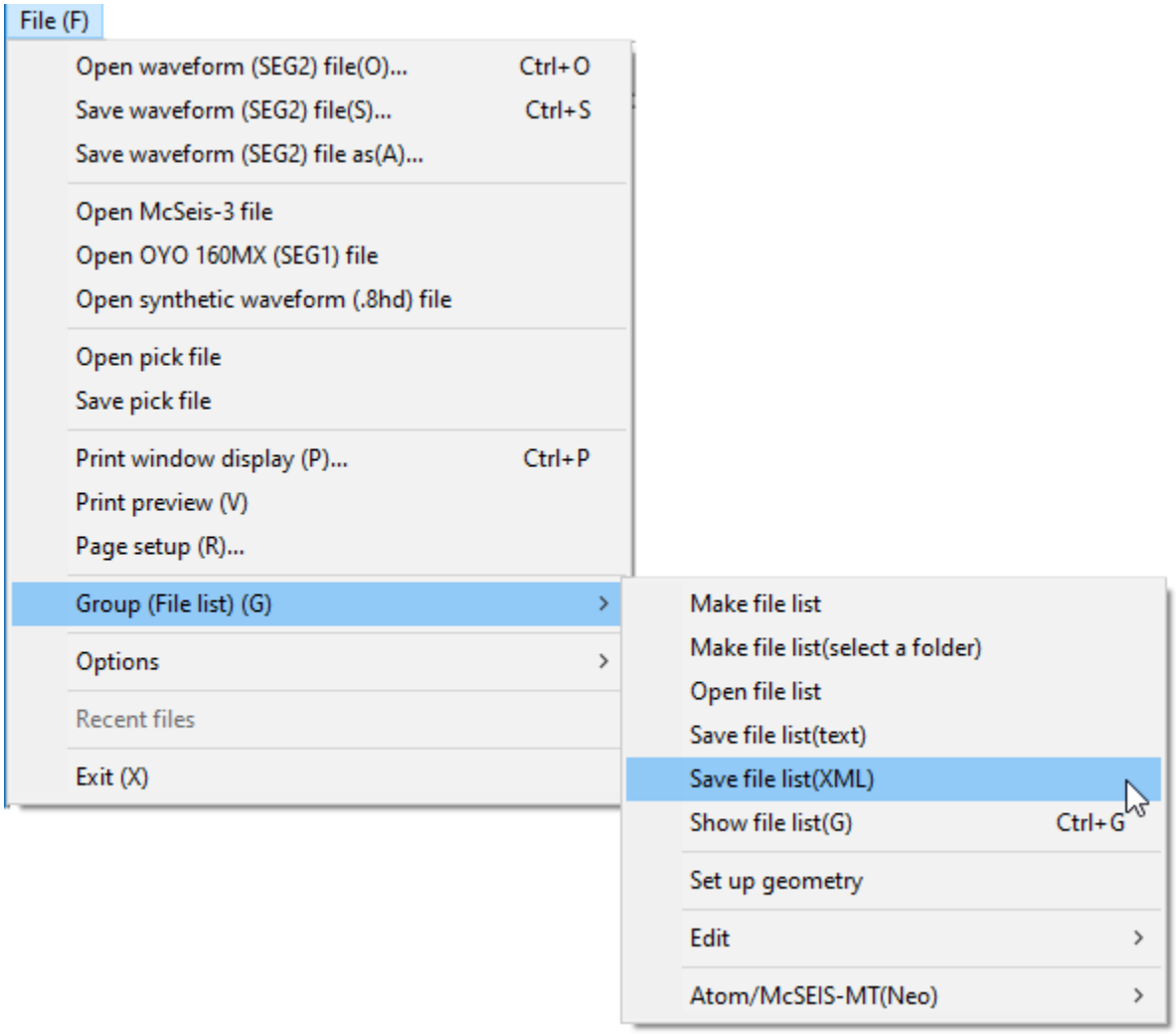


The updated travel time curve and velocity model will be displayed.

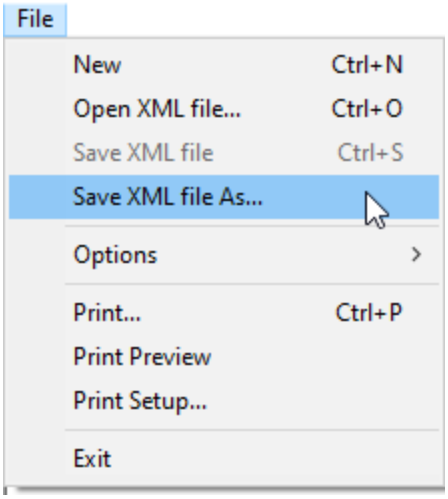


14) At the end of the analysis, save the list of waveform files, source-receiver configuration and first arrivals into an XML file with Pickwin, and save travel time curves and layer velocities into another XML file with PSLog.

In Pickwin, use *File* | *Group (File list)* | *Save file list (XML)* to save the XML file. Extension must be *.xml*.

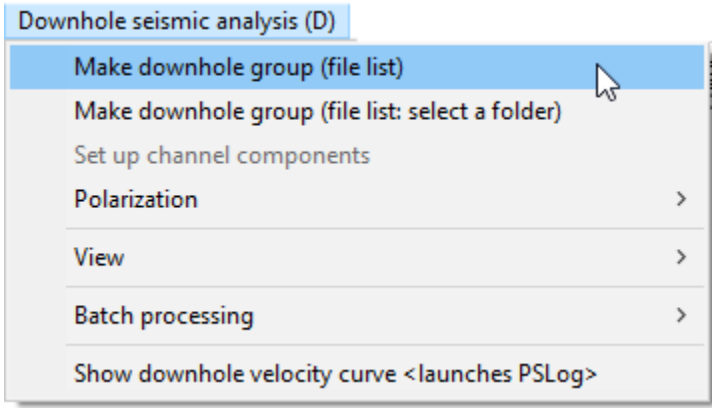


In PSLog, use *File* | *Save XML file* or *Save XML file as* to save the XML file. Extension must be *.xml*.

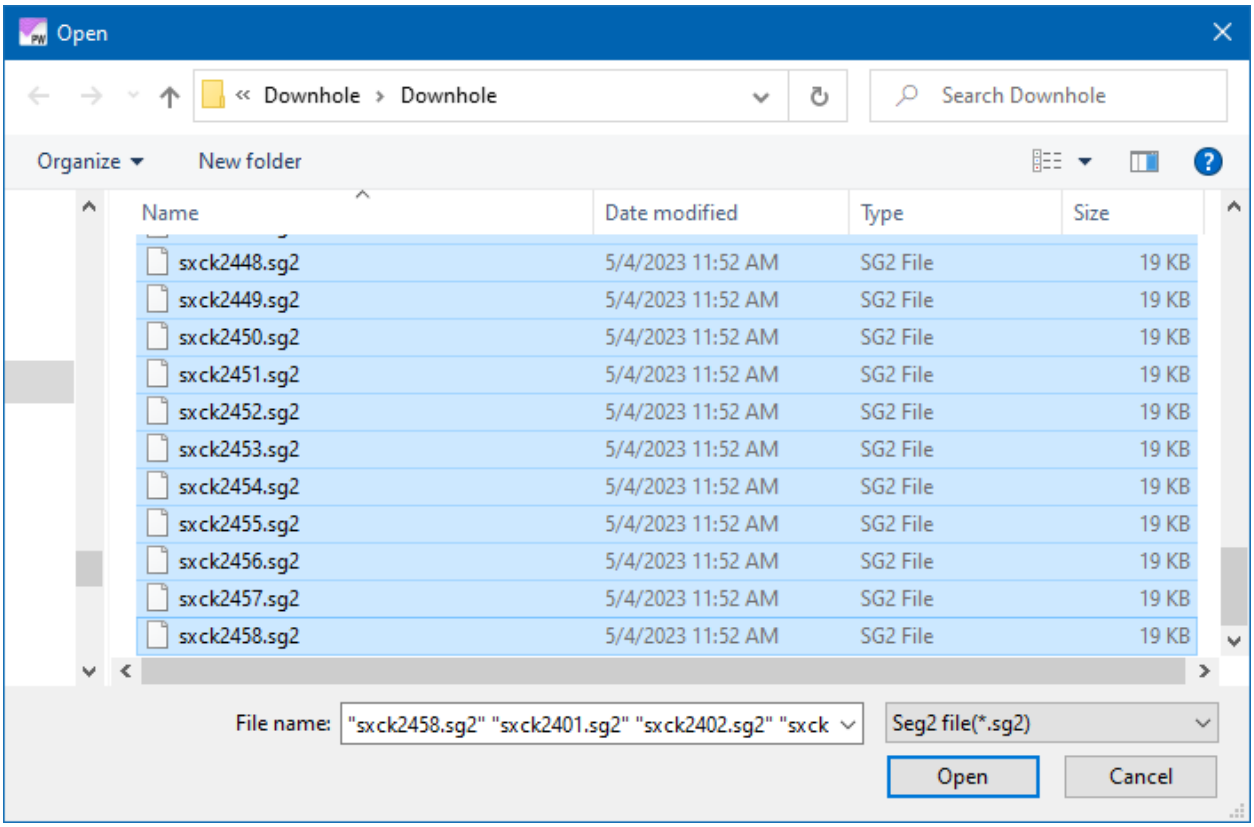

File
New Ctrl+N
Open XML file... Ctrl+O
Save XML file Ctrl+S
Save XML file As...
Options
Print... Ctrl+P
Print Preview
Print Setup...
Exit

Appendix: D.2 Method B: p-wave data using a single-channel receiver

1) In Pickwin, select *Downhole seismic analysis* | *Make downhole group (file list).*

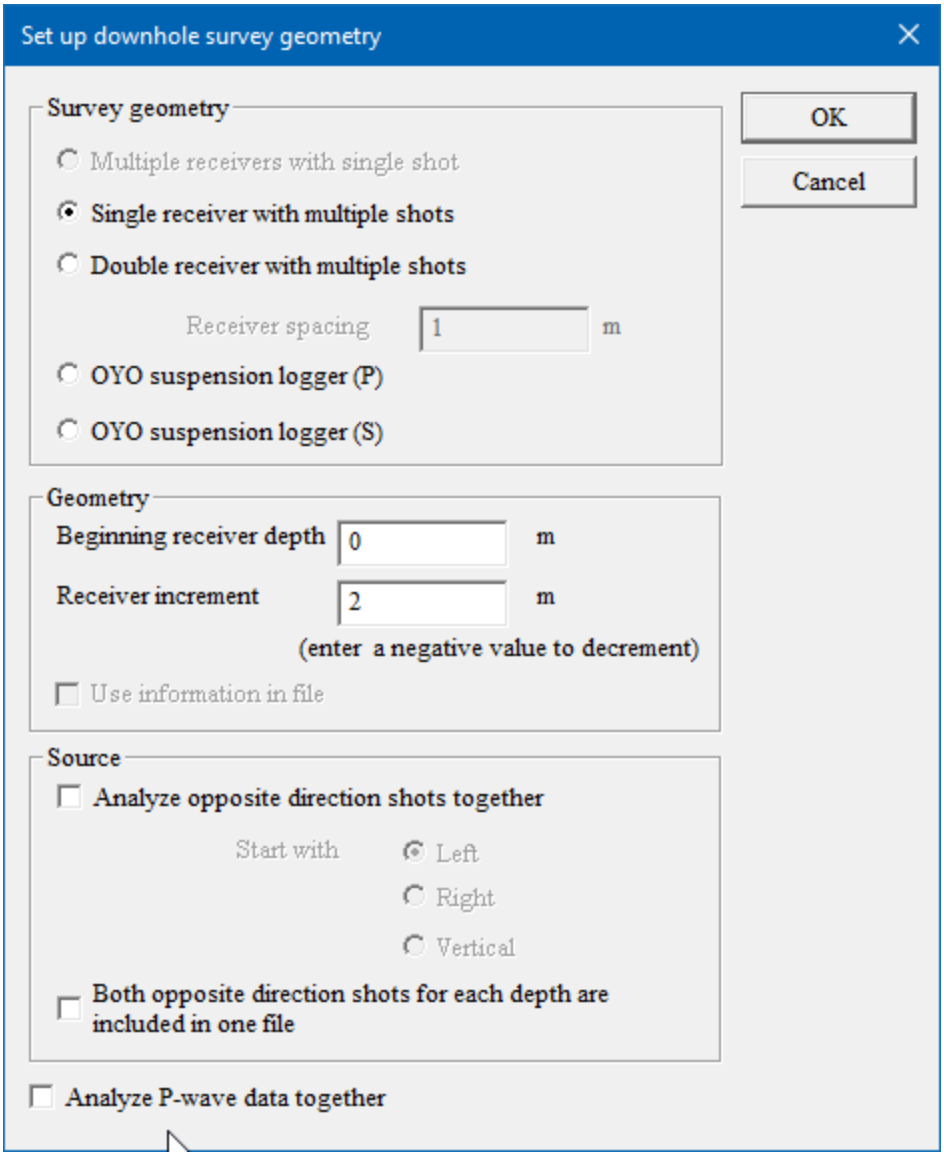


2) Select all files to be processed.

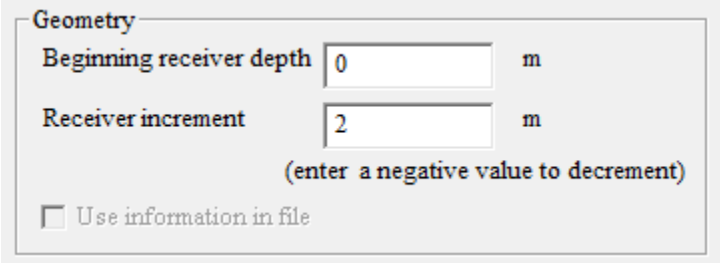


3) Setup *Beginning receiver depth* and *Receiver increment*.

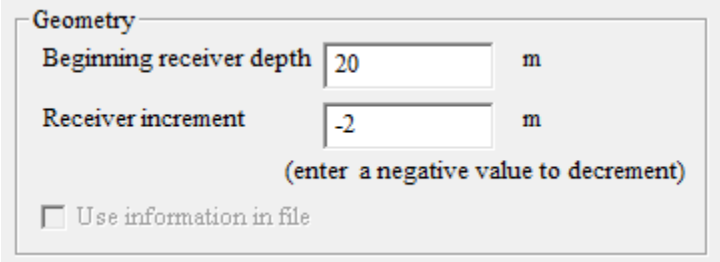
Select *Single receiver with multiple shots.* Uncheck any other check boxes.



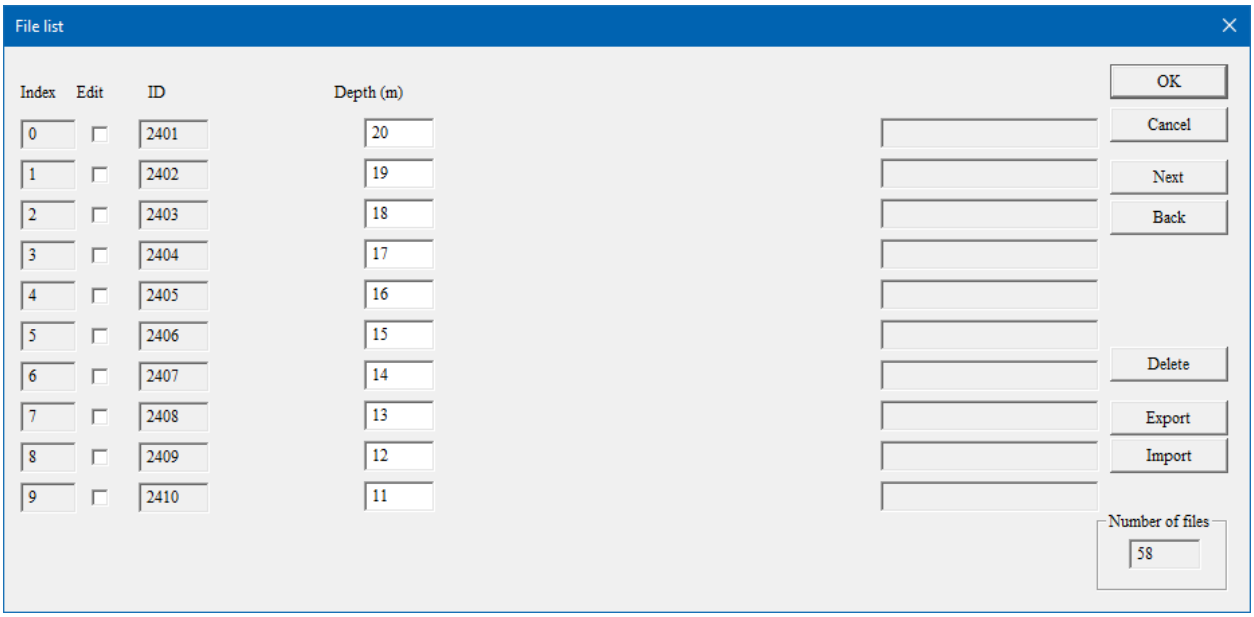
If data acquisition proceeds from the top to the bottom of the borehole, set *Beginning receiver depth* to the shallowest depth and a positive value to *Receiver increment*.



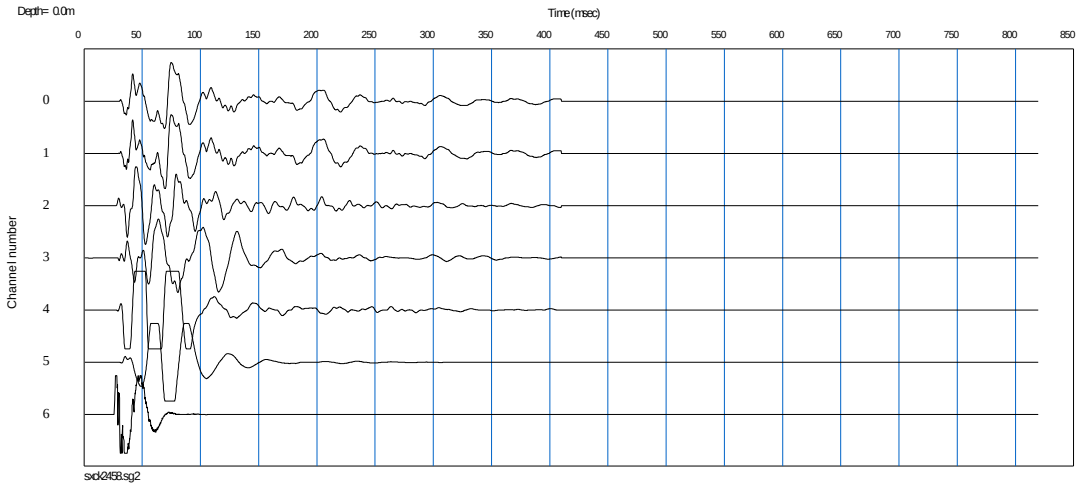
If data acquisition proceeds from the bottom to the top of the borehole, set *Beginning receiver depth* to the deepest depth and a negative value to *Receiver increment*.



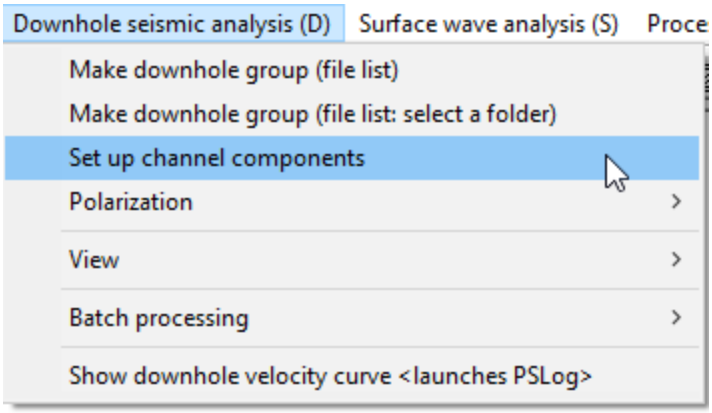
4) Edit the receiver depth as needed.



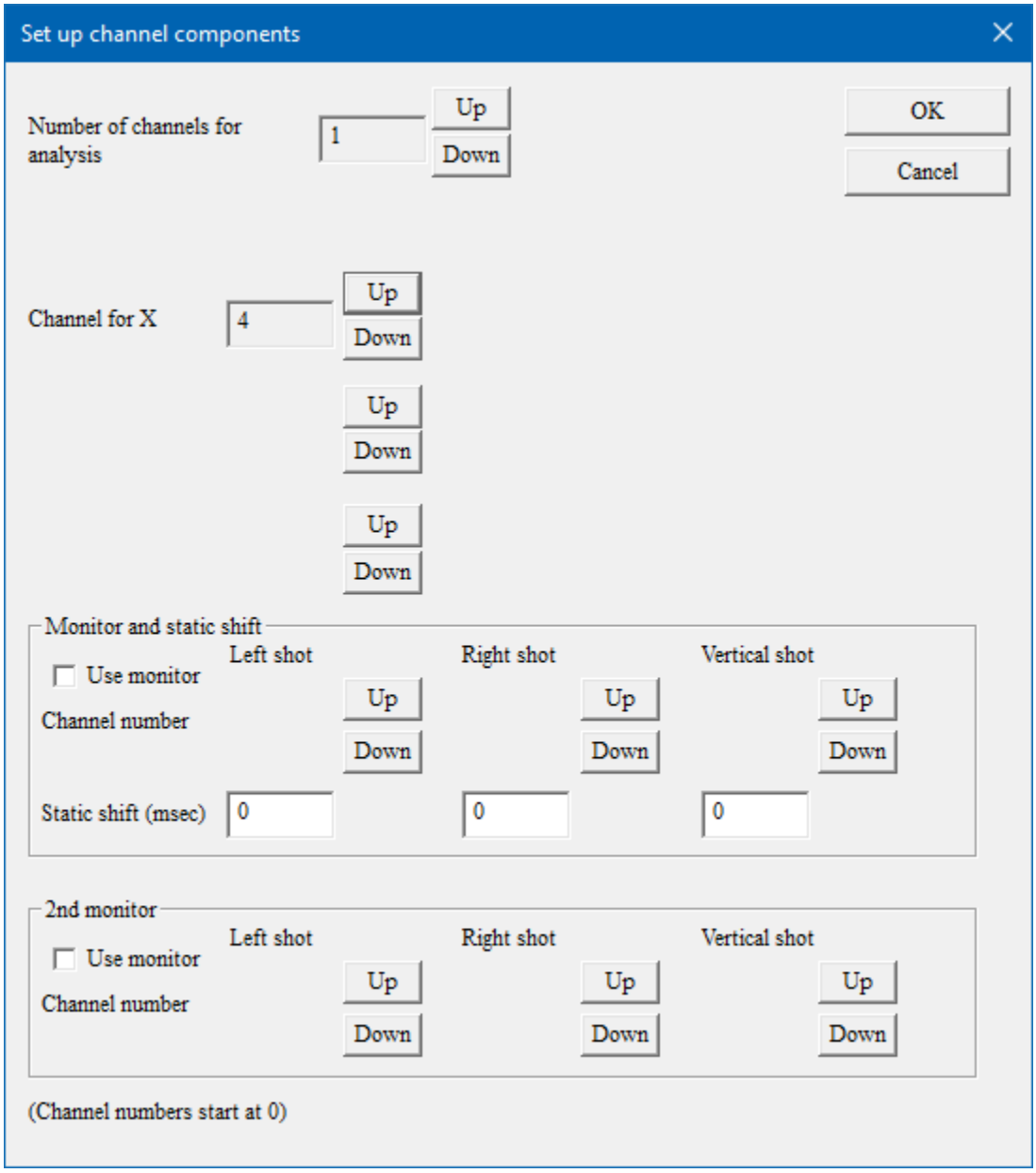
The waveform data for the file will be displayed shown.



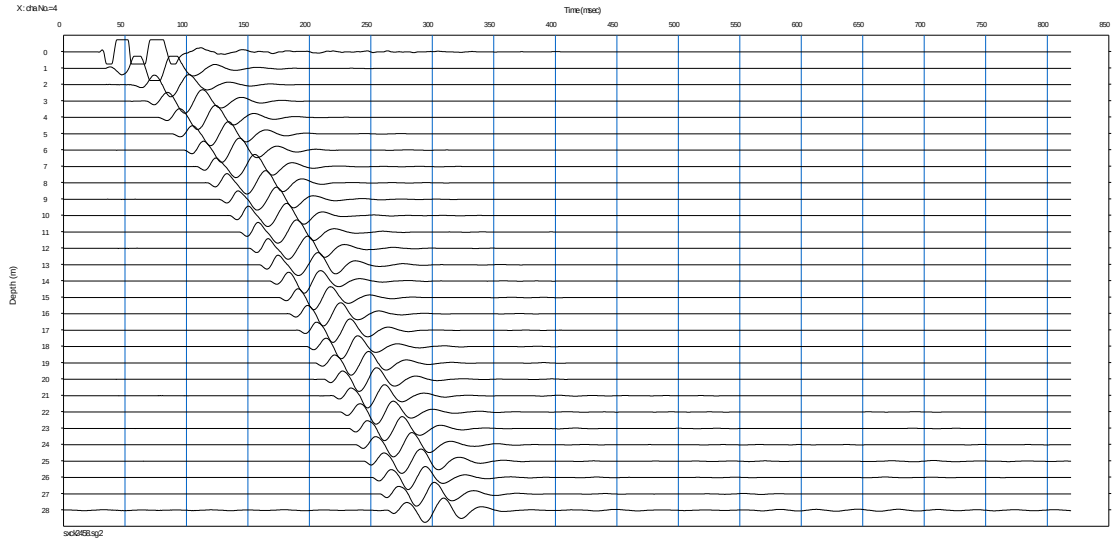
5) Select the component to be used by selecting *Downhole seismic analysis* | Setup *channel components*.


Downhole seismic analysis (D)
Surface wave analysis (S)
Proce
Make downhole group (file list)
Make downhole group (file list: select a folder)
Set up channel components
Polarization
View
Batch processing
Show downhole velocity curve <launches PSLog>

6) Select the components to be used in the dialog box. In this case, set *Number of channels for analysis* to 1 and set *Channel for X* to the appropriate channel number index (channel number index starts from 0).



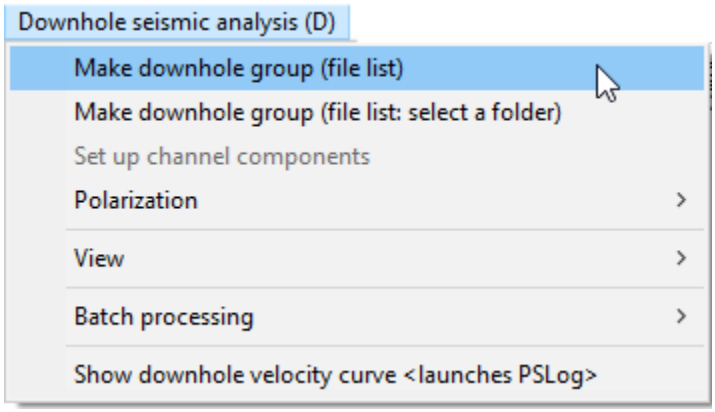
The waveform data will be shown as common shot gather.



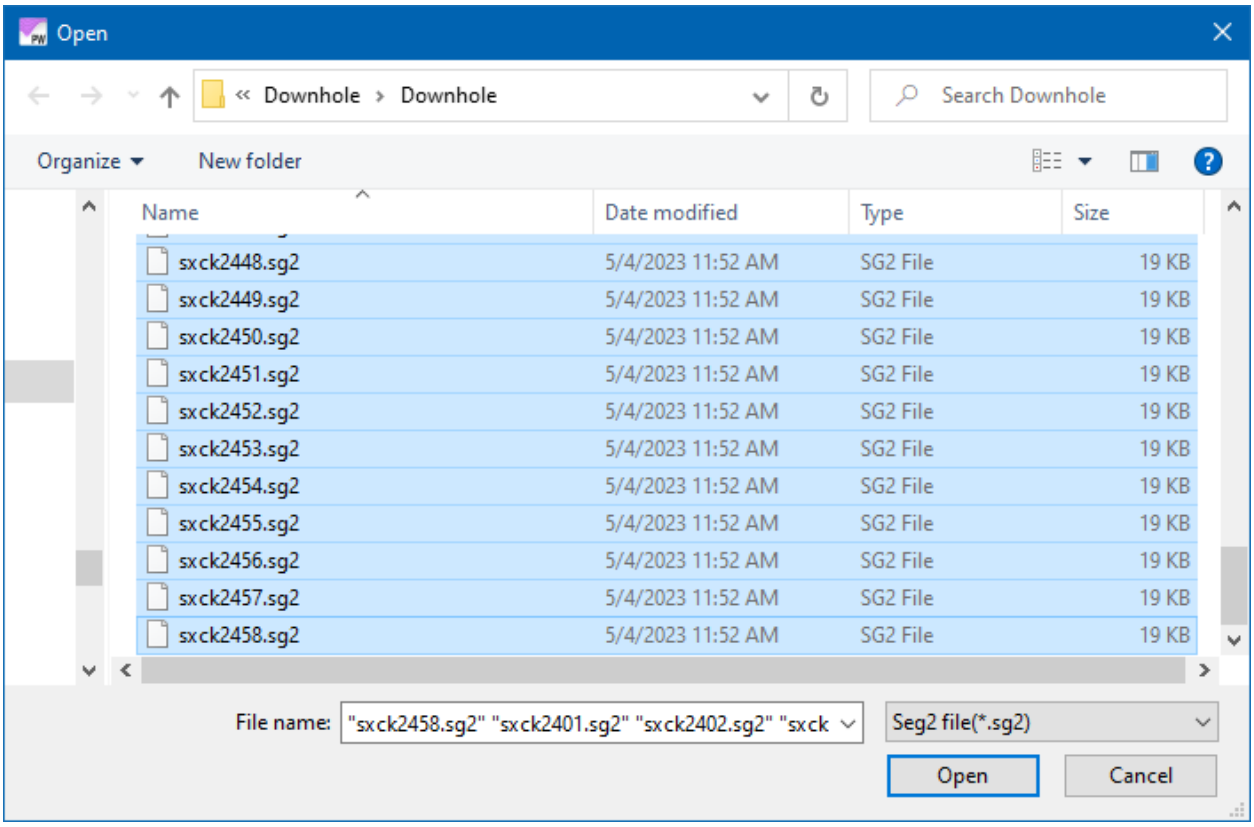
7) See Page D-4 for picking first arrivals, editing and assigning layers.

Appendix: D.3 Method C: s-wave data using a single multi-channel geophone

1) Select *Downhole seismic analysis* | *Make file list for downhole.*

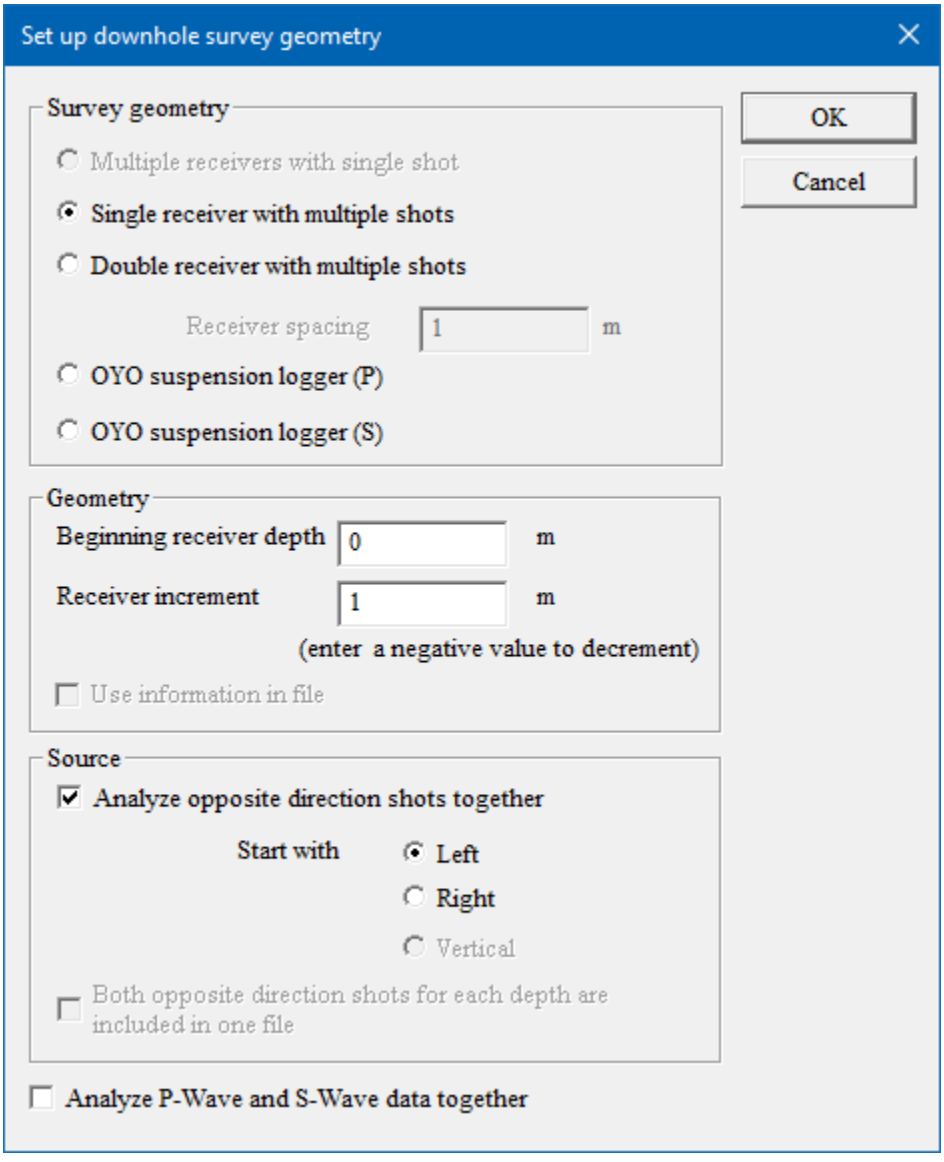


2) Select all files to be processed.

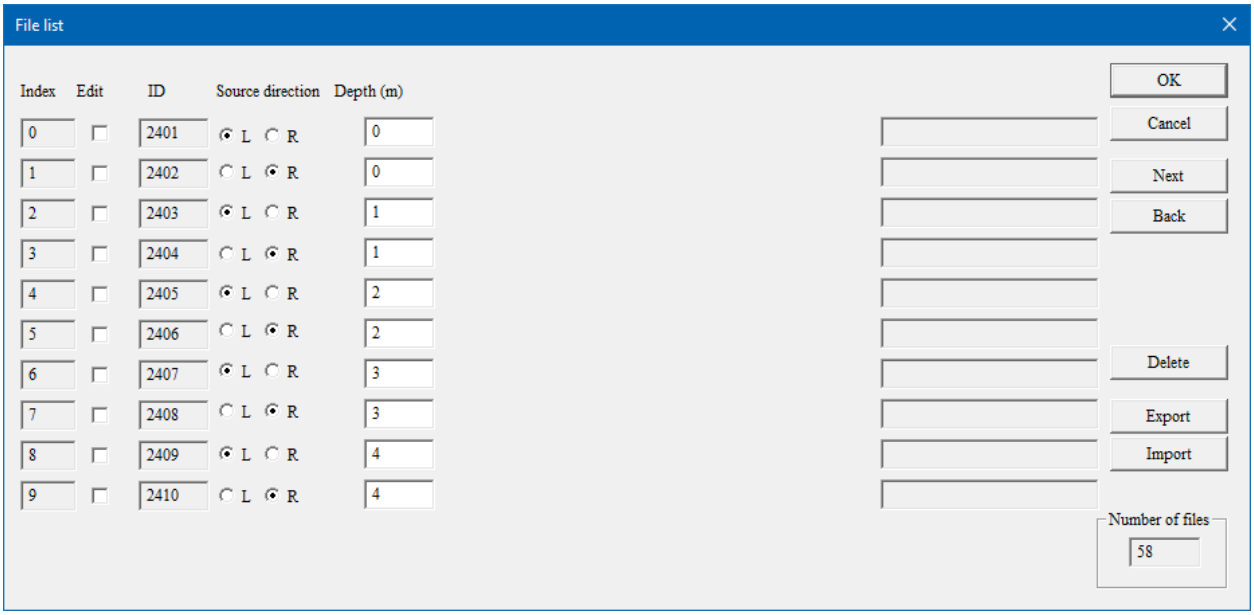


3) Setup geometry.

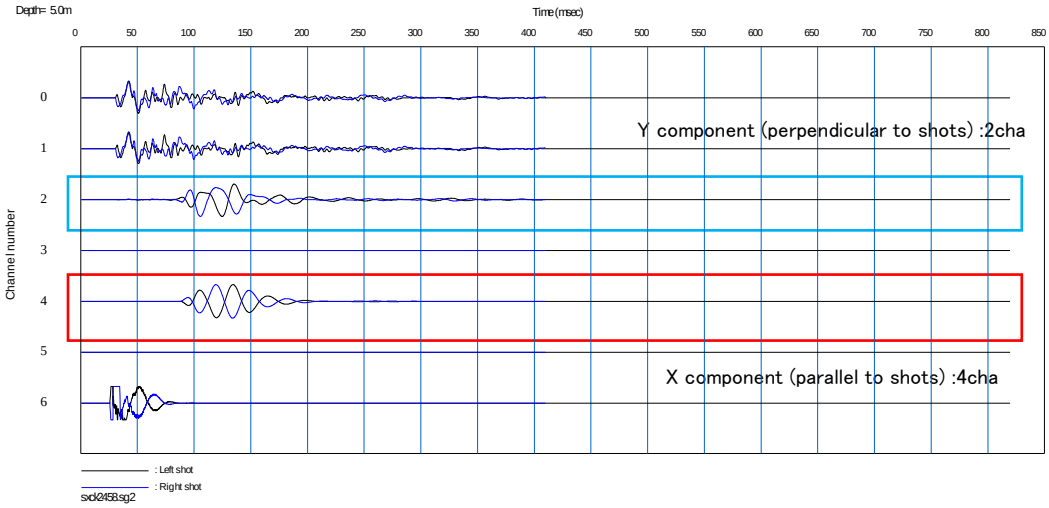
a) Select *Single receiver with multiple shots).*
b) Check *Analyze opposite direction shots together*.
c) In this case, source direction (left or right) has no important meaning, and you can just select *Left*.



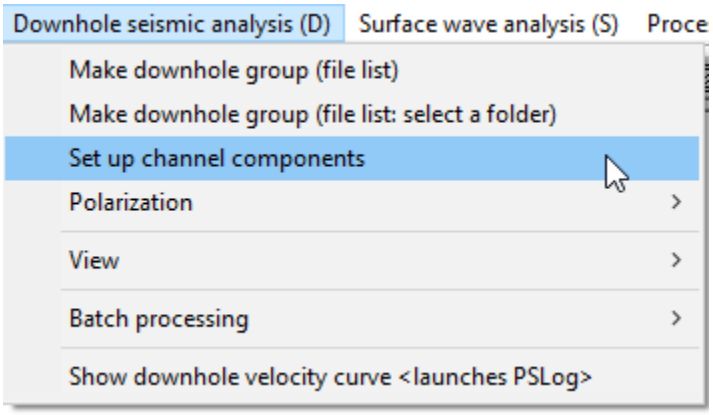
4) Edit receiver *Depth* and *Source direction* as necessary.



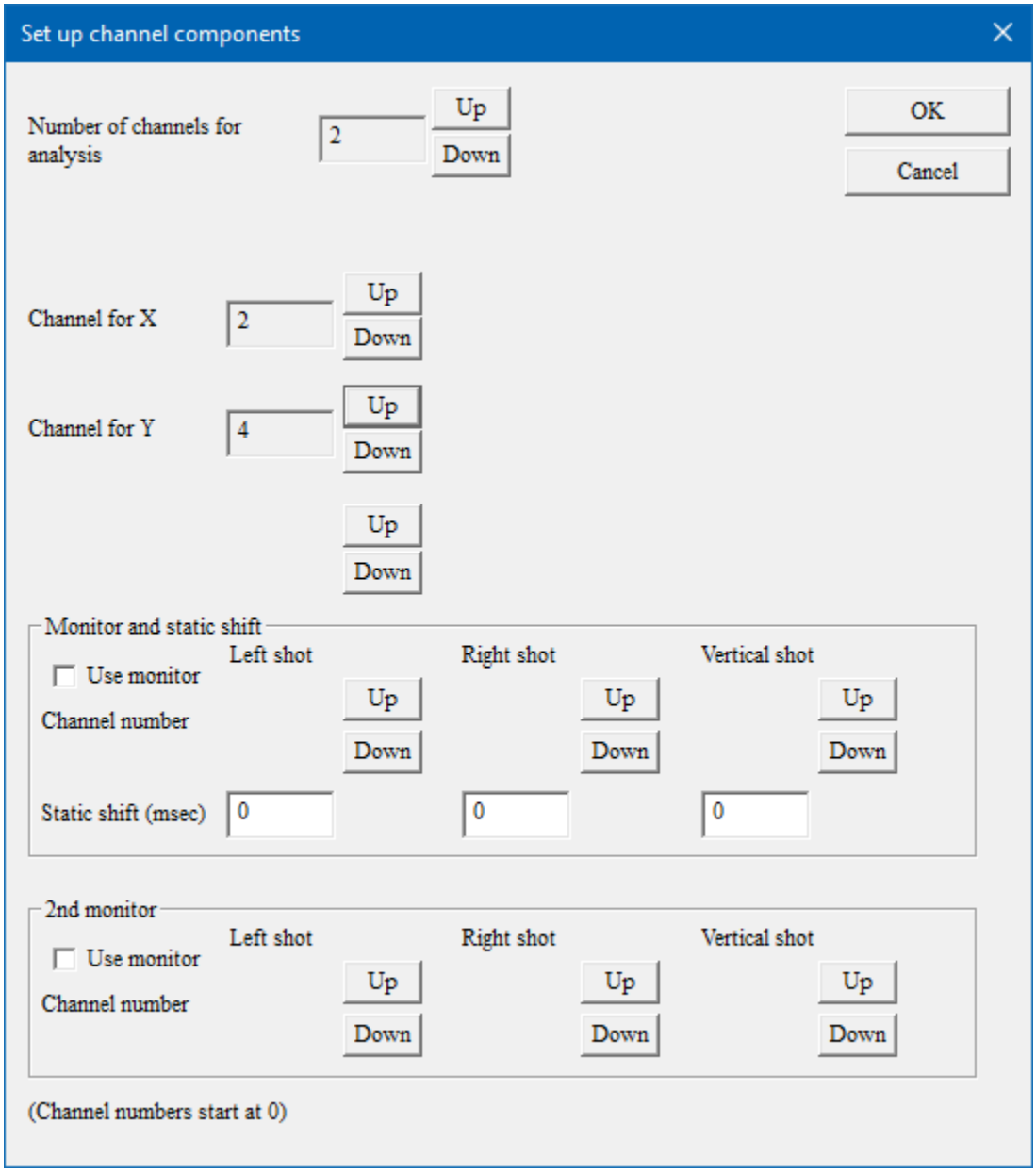
5) The waveform data for one depth (left and right shots) is displayed. You can scroll through the geophones using  and  .



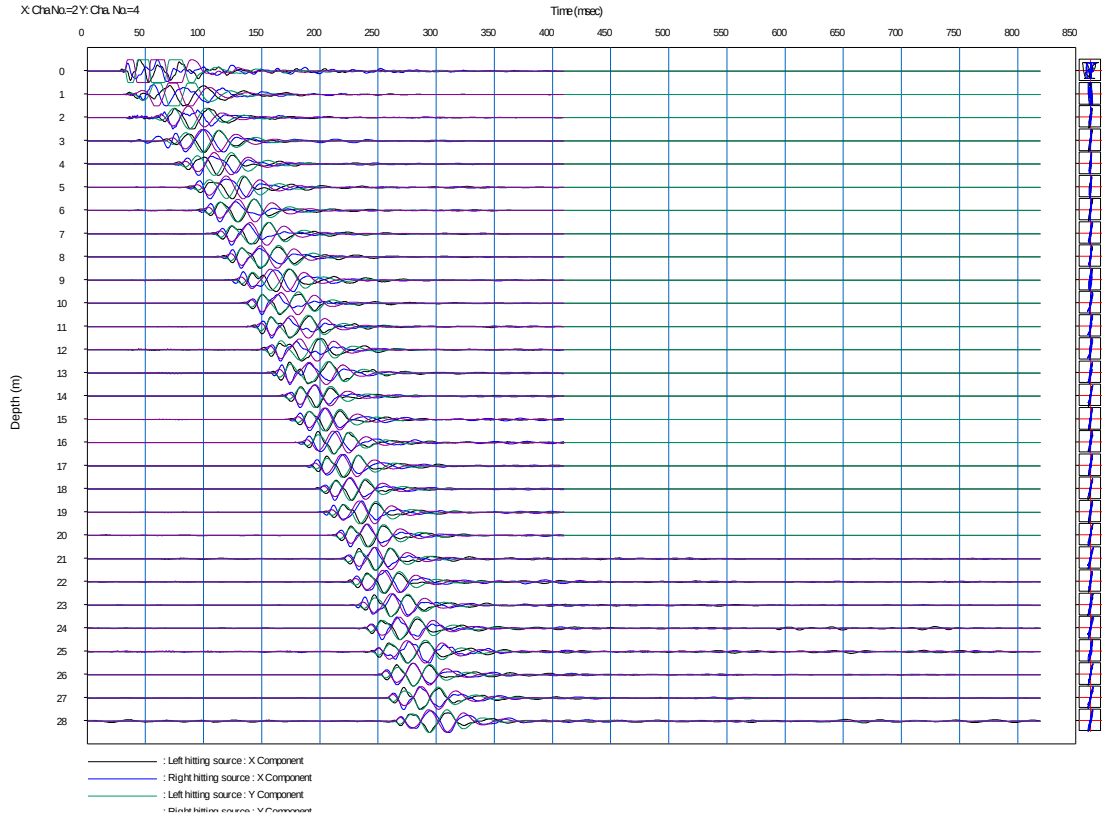
6) Select the component to be used by selecting *Downhole seismic analysis* | Setup *channel components*.



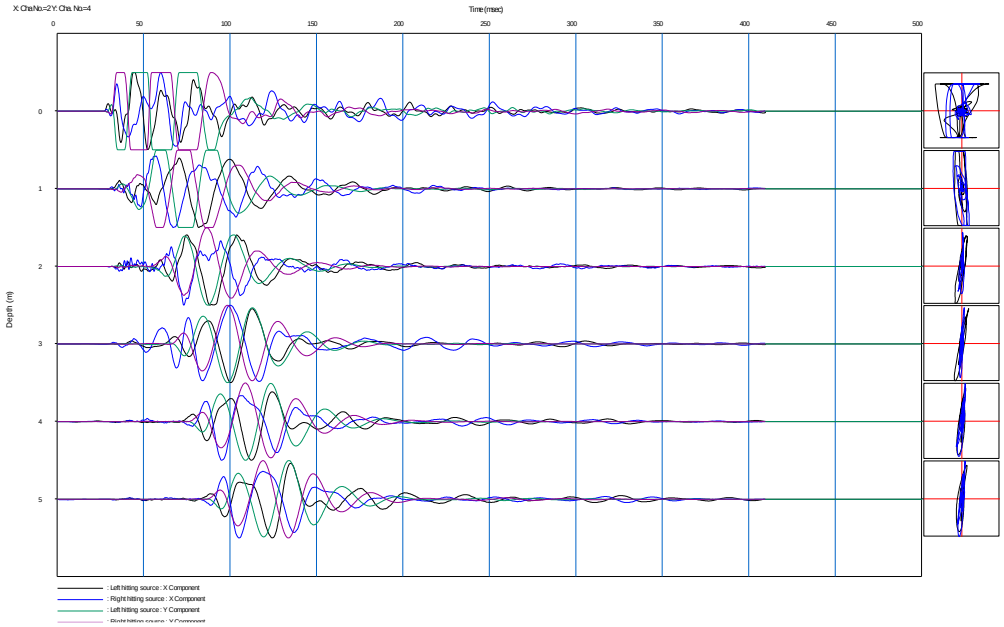
7) Set *Number of channels for analysis* to 2. Then set *Channel for X* and *Channel for Y* to the appropriate channel number indices (channel number index starts from 0).



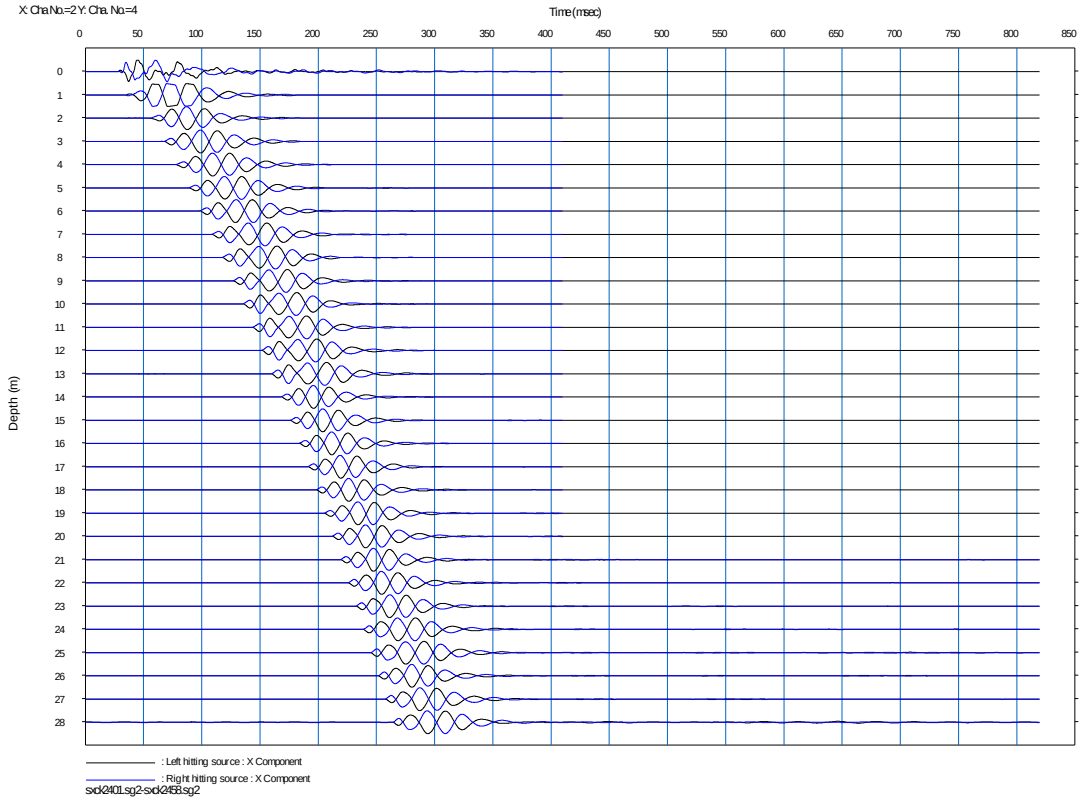
8) The components selected to be processed will be shown. X-components are shown as black (left) and blue (right) and Y-components are shown as green (left) and purple.



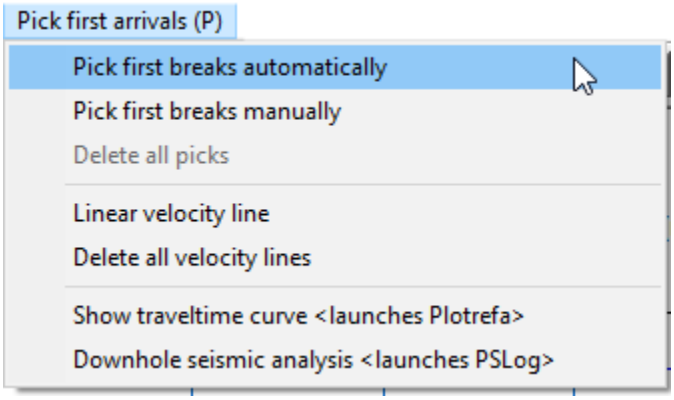
Particle motion of each depth is shown at the right of the traces (if toggled on, see Section 4.5.11, Page 31).

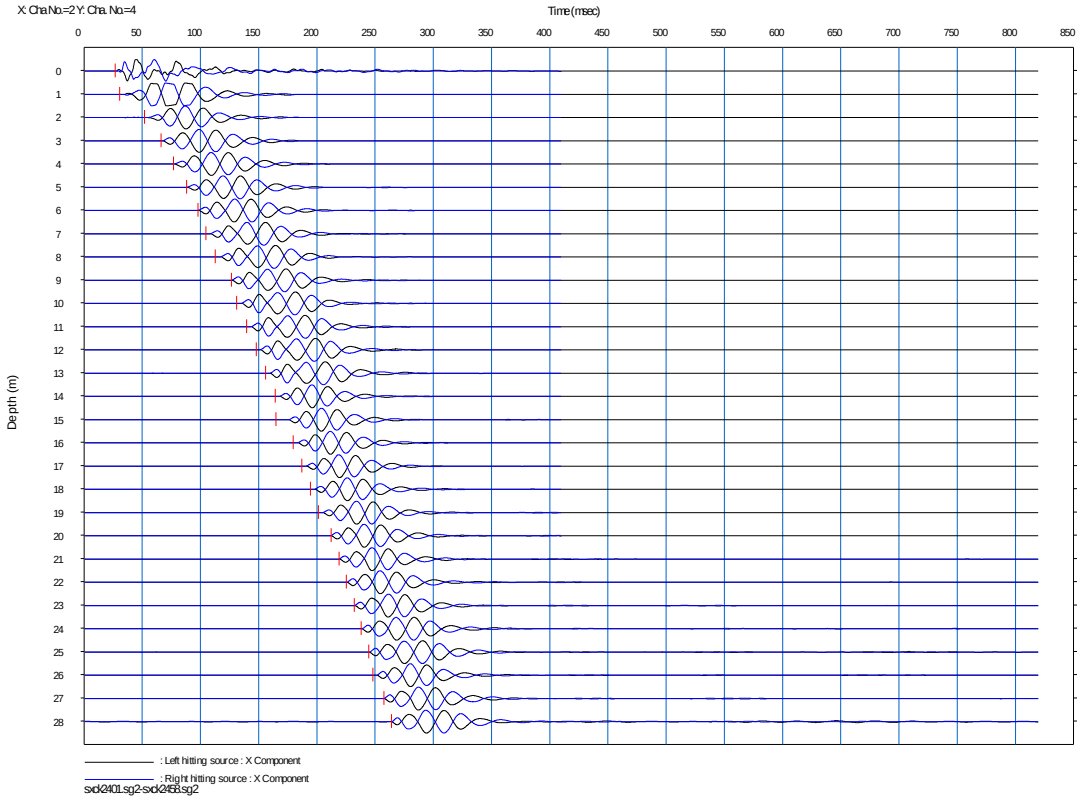


9) Select *Downhole seismic analysis* | *Polarization* for rotating two components. Rotated waveform data (left and right shots) will be displayed.

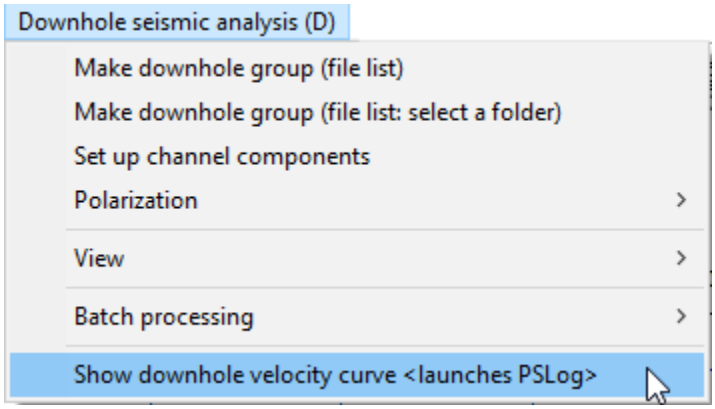


10) Pick first breaks by selecting *Pick first arrivals* | *Pick first breaks automatically* or *Pick first breaks manually.*

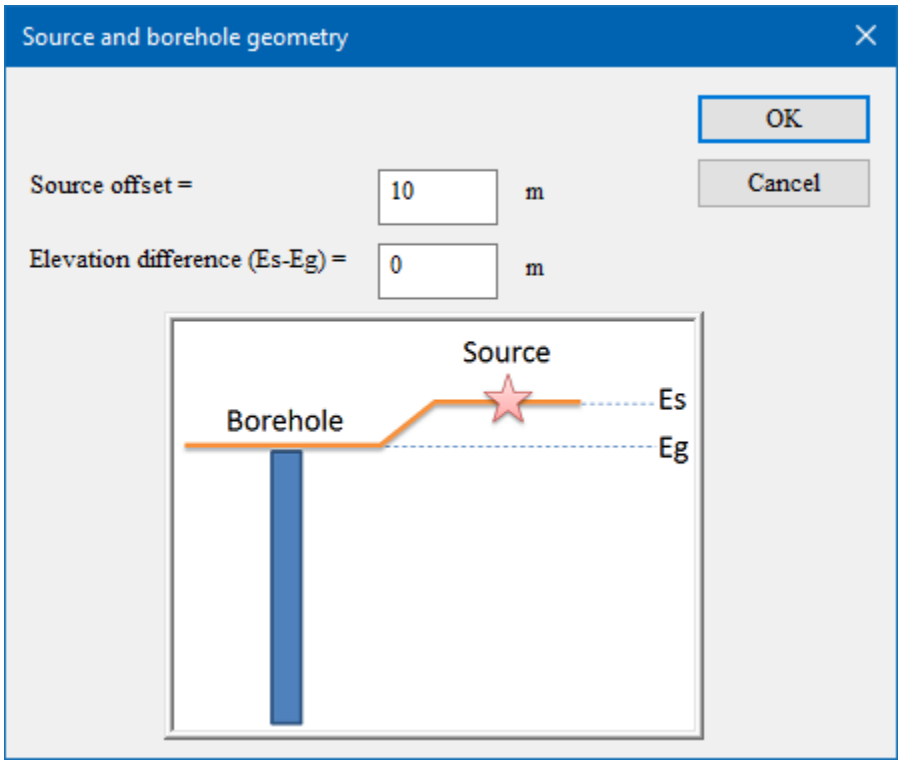




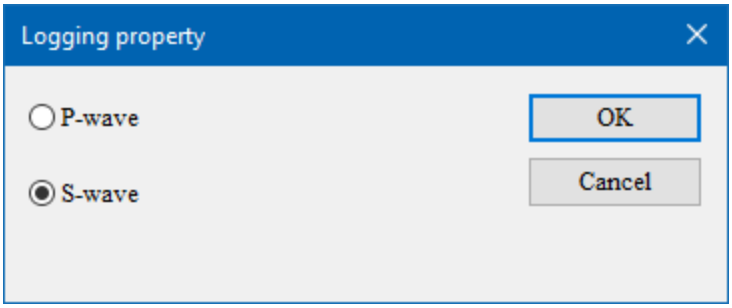
11) Select *Downhole seismic analysis* | *Show downhole velocity curve <launches PSLog>* to show the travel time curve.



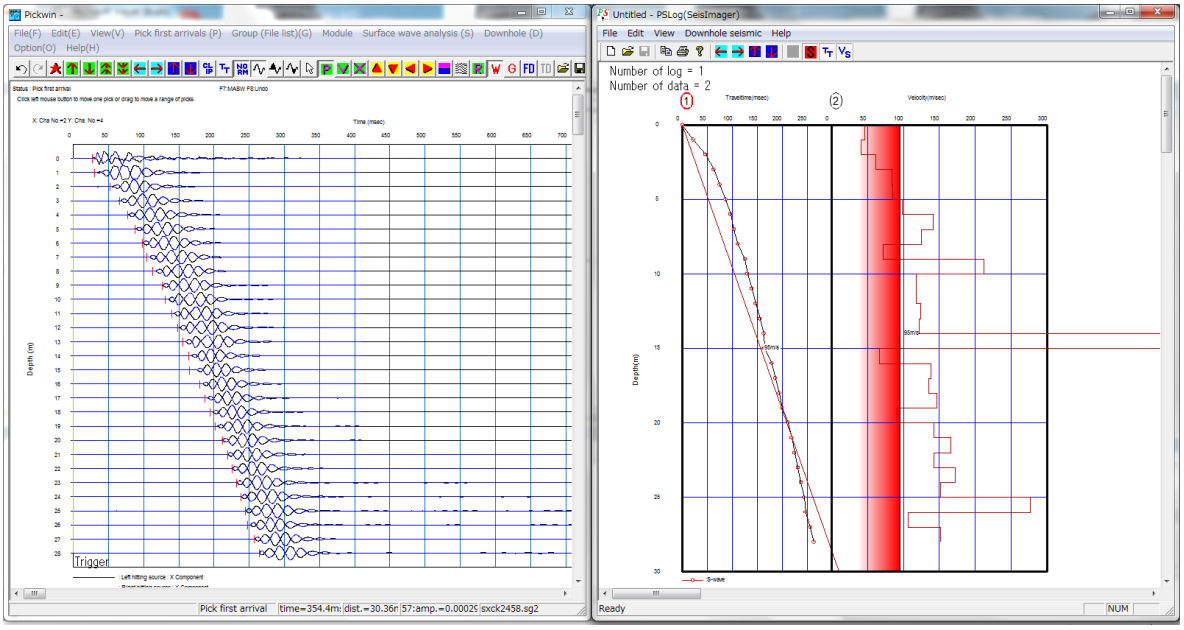
12) Enter *Source offset* and *Elevation Difference* (see Section 6.4.2, Page 93, for details).



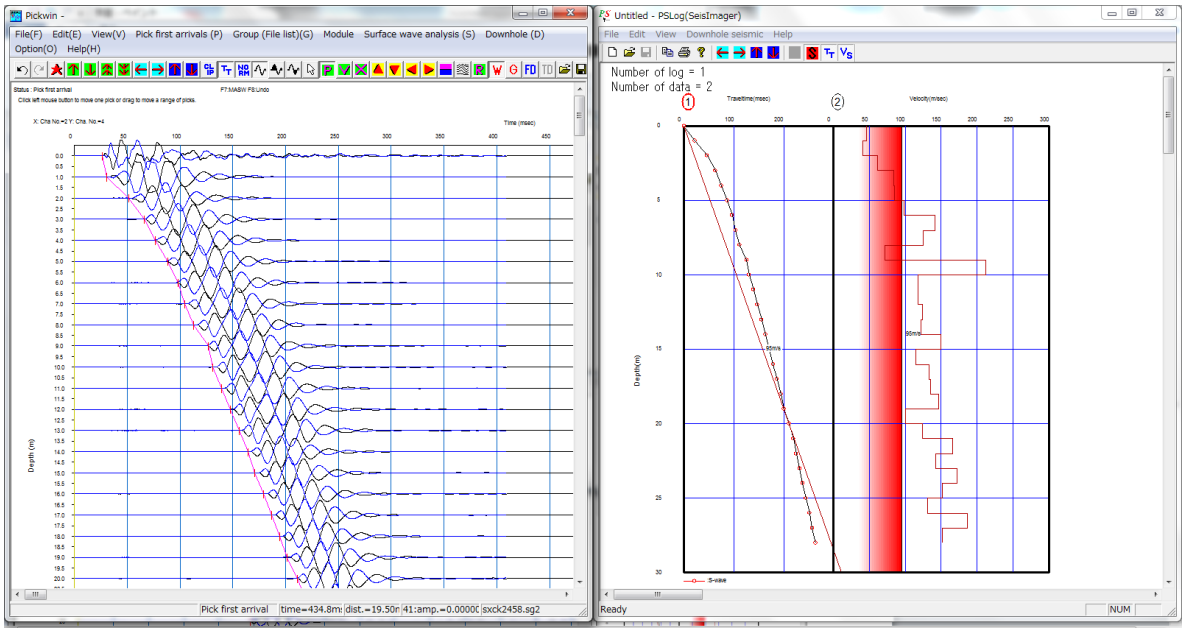
13) Select s-wave.


Logging property
P-wave
S-wave
OK
Cancel

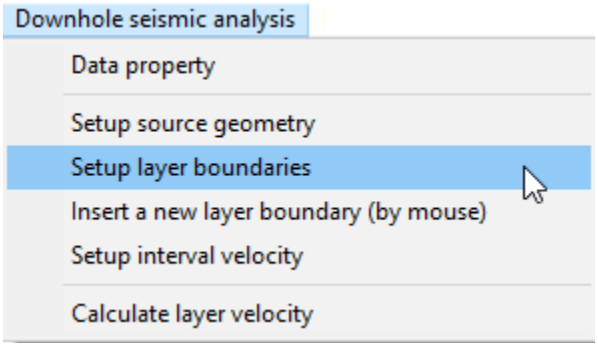
A travel time curve and a velocity model will be displayed.



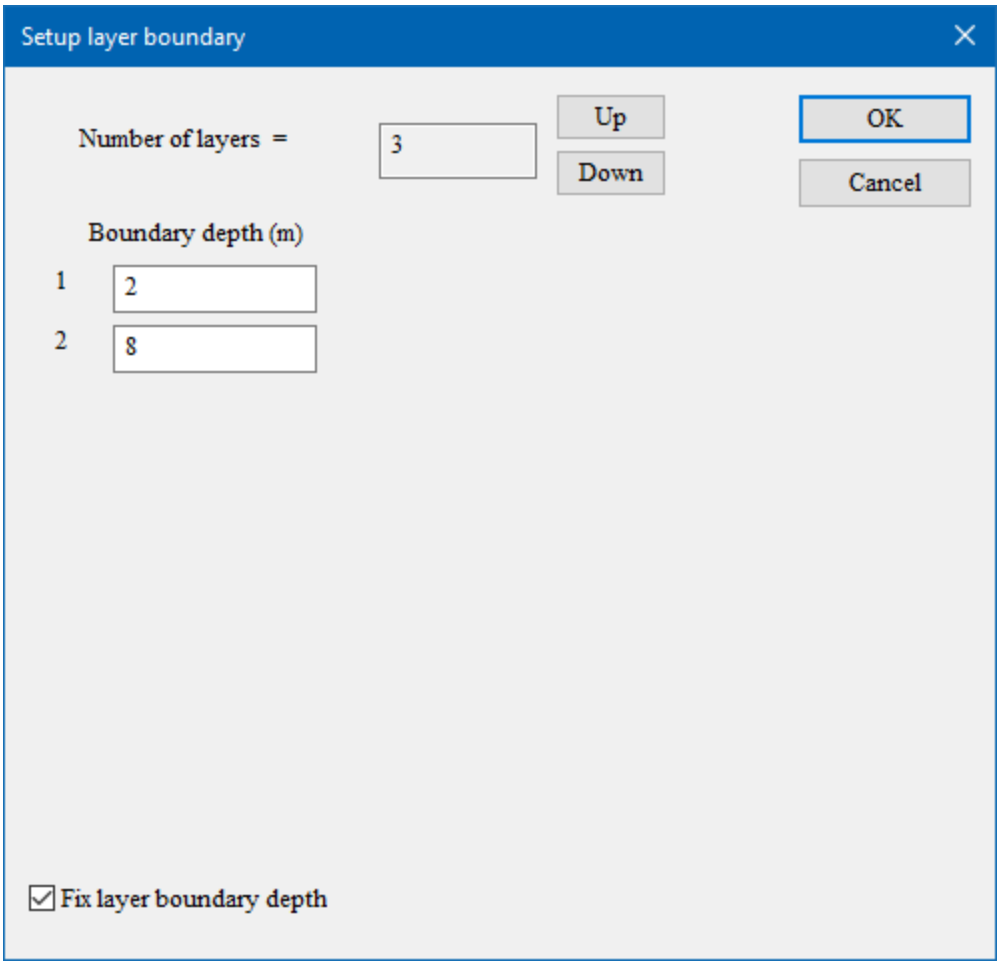
14) Edit first arrivals as needed and click the red star  to update the model.



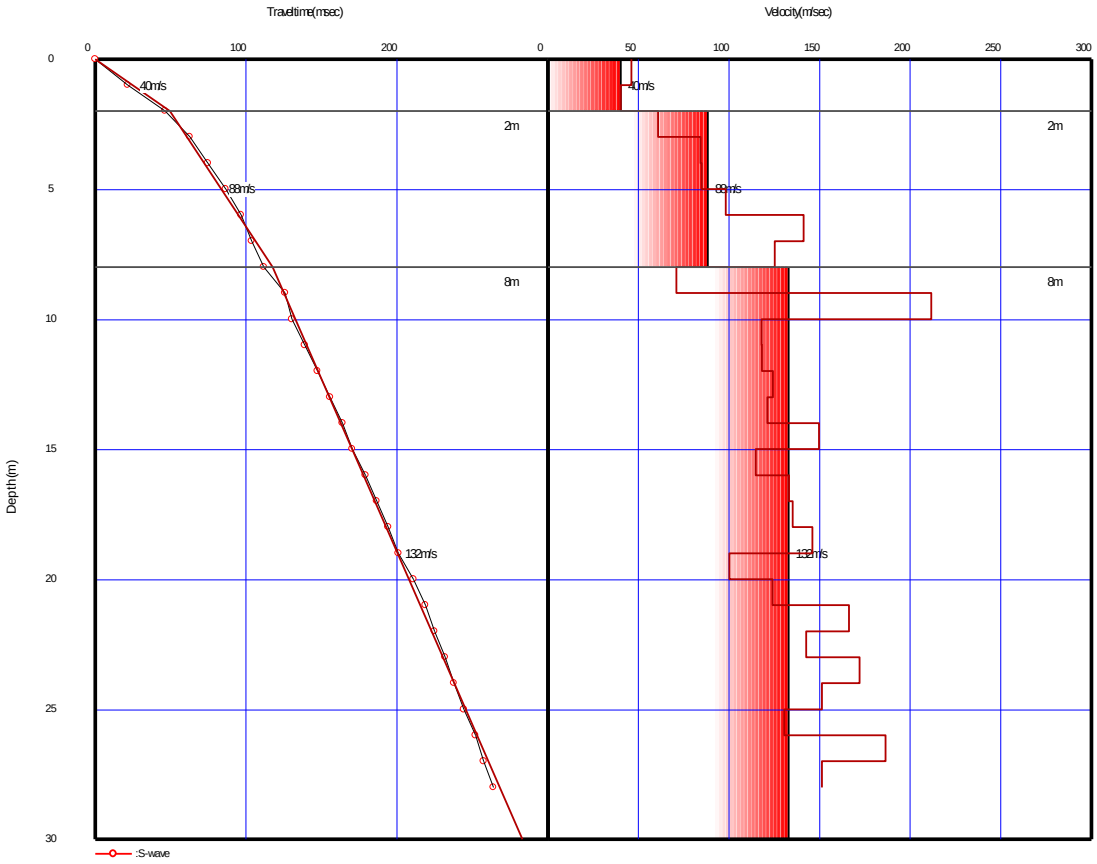
15) At first, a one-layer model is assumed and a least-squares velocity is shown. To increase the number of layers, select Setup *layer boundaries.*



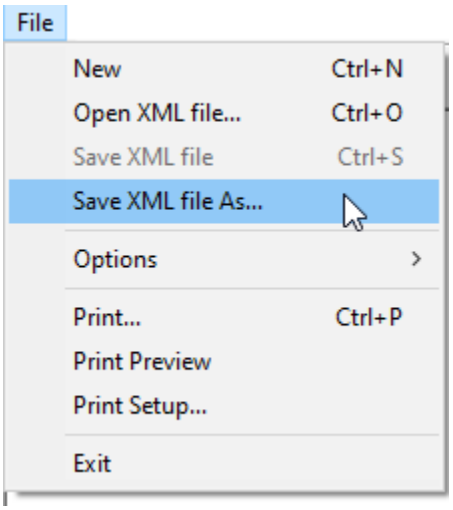
16) Edit *Number of layers* and setup *Boundary depth*.



The updated travel time curve and the velocity model will be displayed.

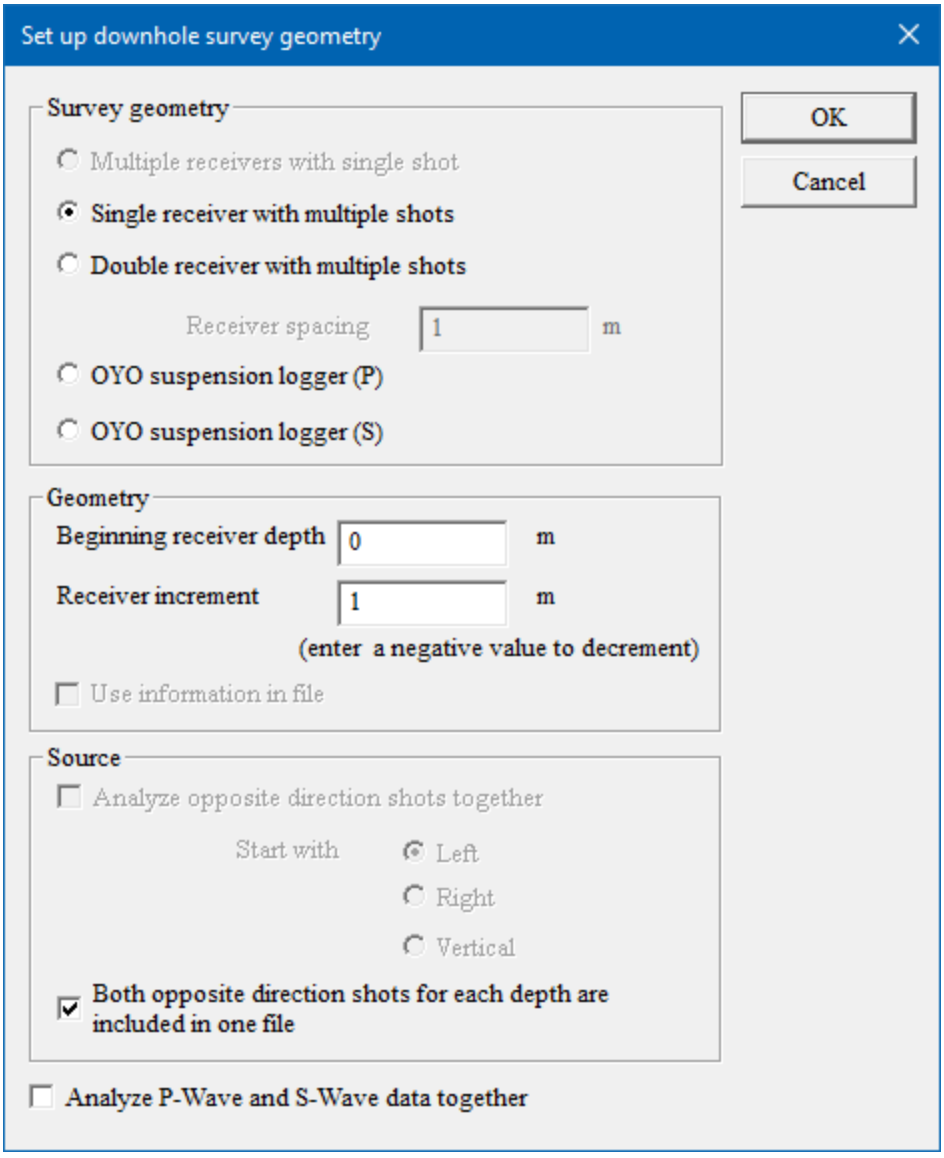


17) Select *File* | *Save XML file* or *Save XML file as to* save the travel time curve and the velocity model into an XML file.

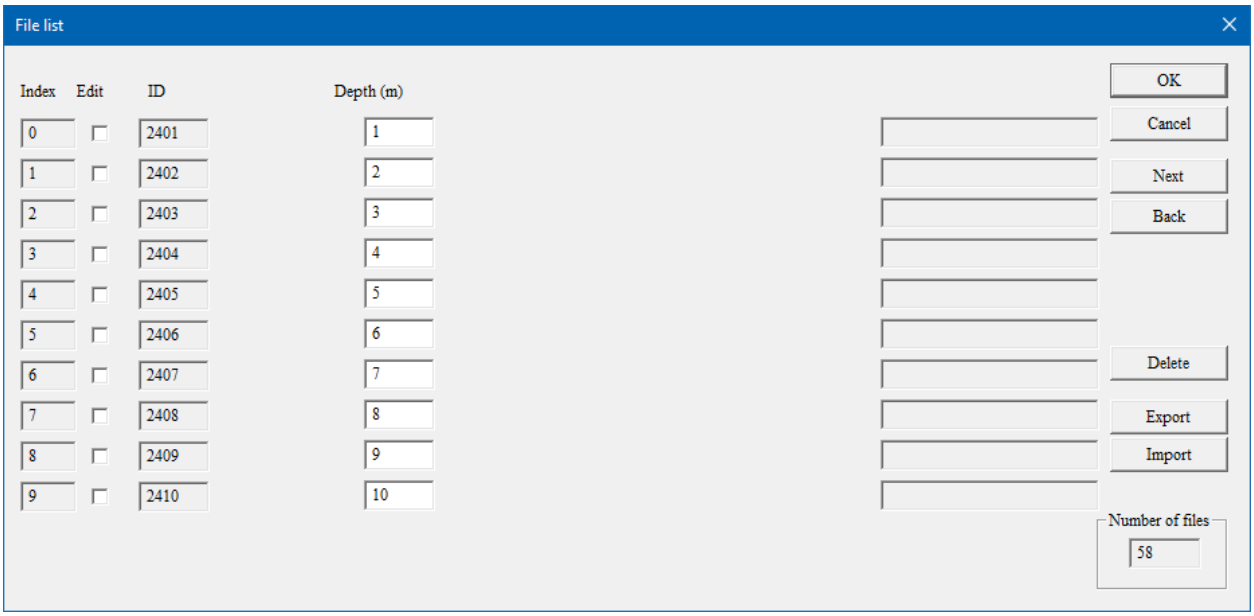


In the geometry setup:

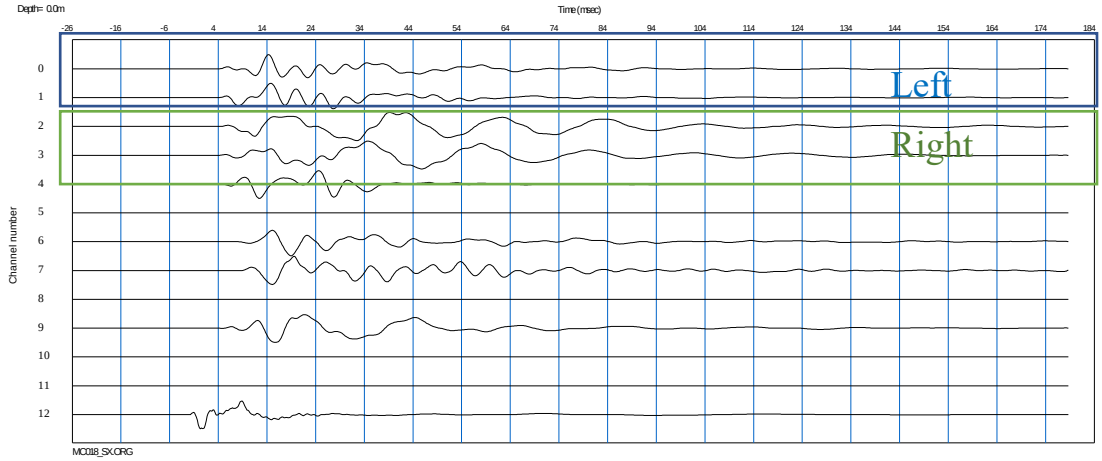
- Choose *Single receiver with multiple shots*.
- Check on *Both opposite direction shots for each depth are included in one file*.



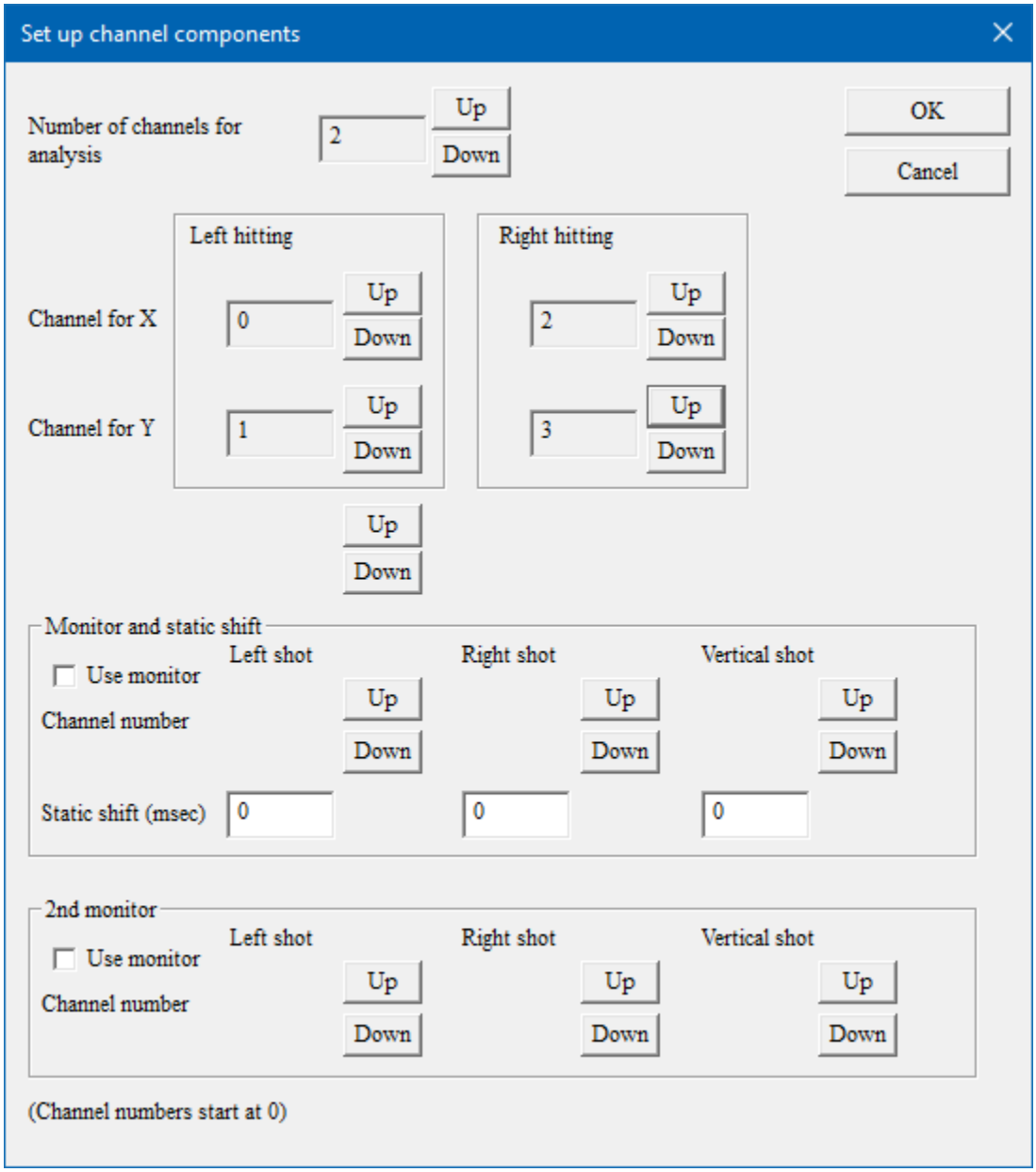
18) Edit receiver *Depth* as necessary.



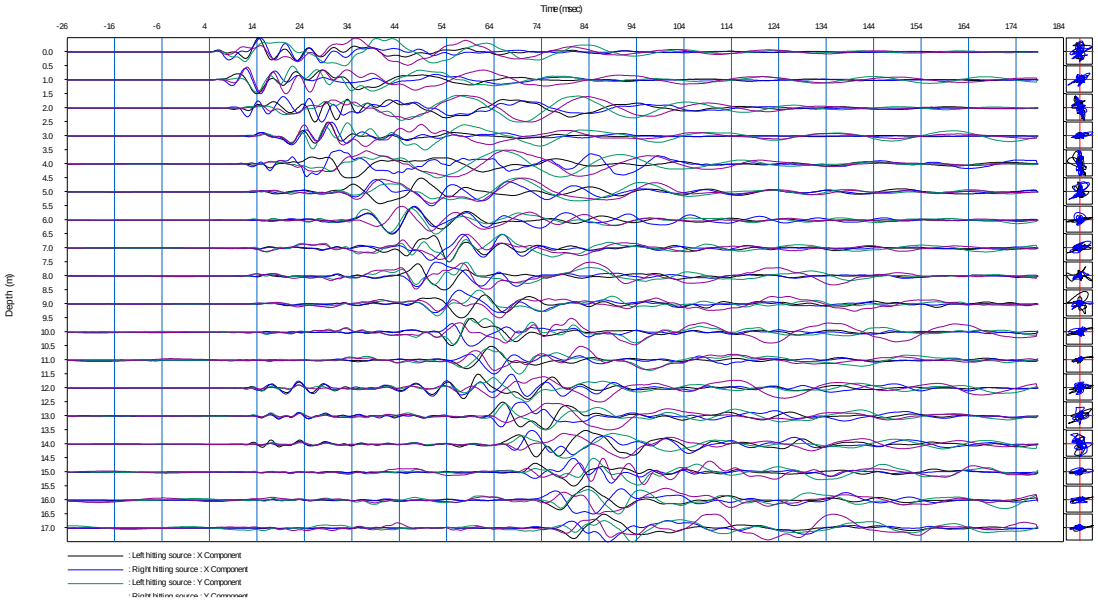
The waveforms for the 1st depth are shown. Both left and right shots are included.



19) Setup components as shown below.



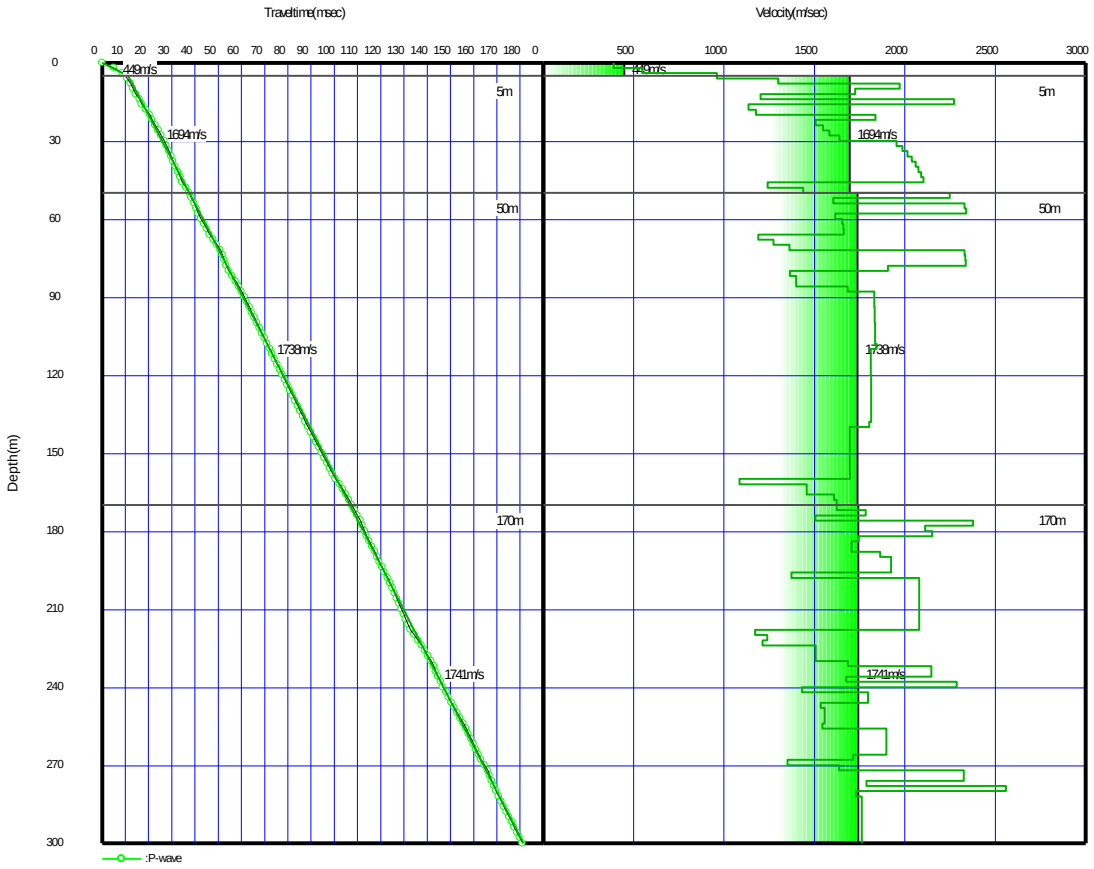
20) Selected components to be processed will be displayed. X-components are shown as black (left) and blue (right) and Y-components are shown as green (left) and purple.



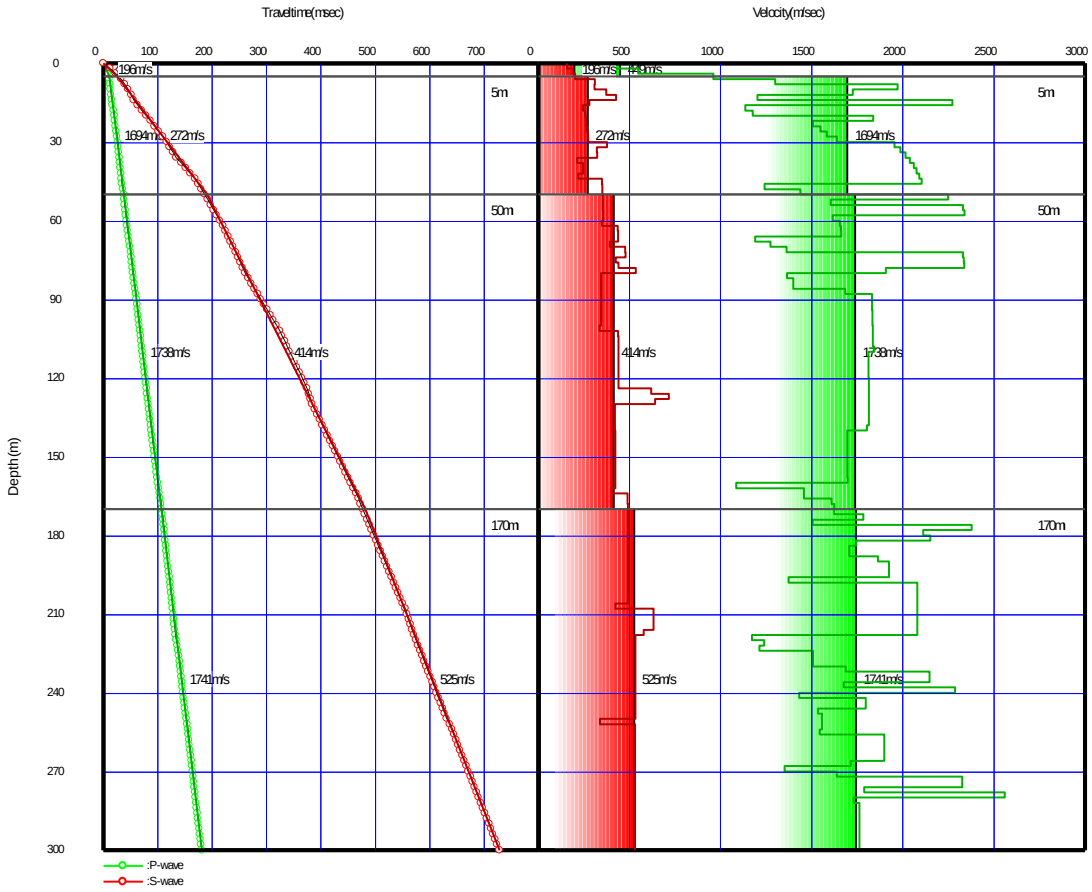
21) See other sections for processing beyond this step, such as picking first breaks, assigning layers, etc.

APPENDIX: E. COMBINING P- AND S-WAVE TRAVEL TIME CURVES AND VELOCITY MODELS

1) Open PSLog. Open p- or s-wave travel time curves and velocity models by selecting *Open XML file*.



2) Open another XML file and choose *Append to present data*. Both p- and s-wave travel time curves and velocity models will be displayed.



APPENDIX: F. OPTIONAL ANALYSIS FOR DETAILED PROCESSING

Appendix: F.1 Processing with a trigger monitor receiver

The processing flow using a trigger monitor receiver can be summarized as follows:

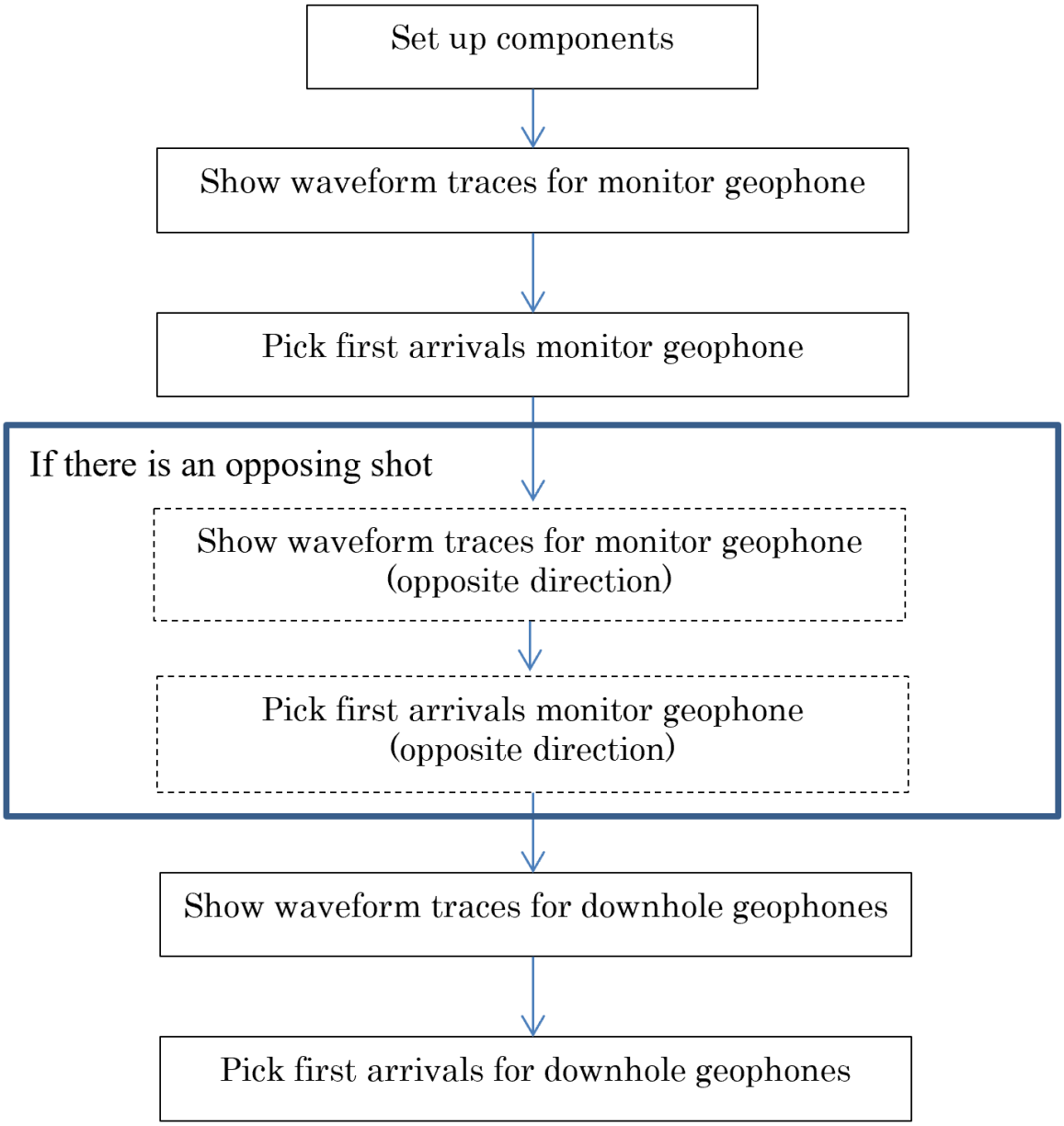
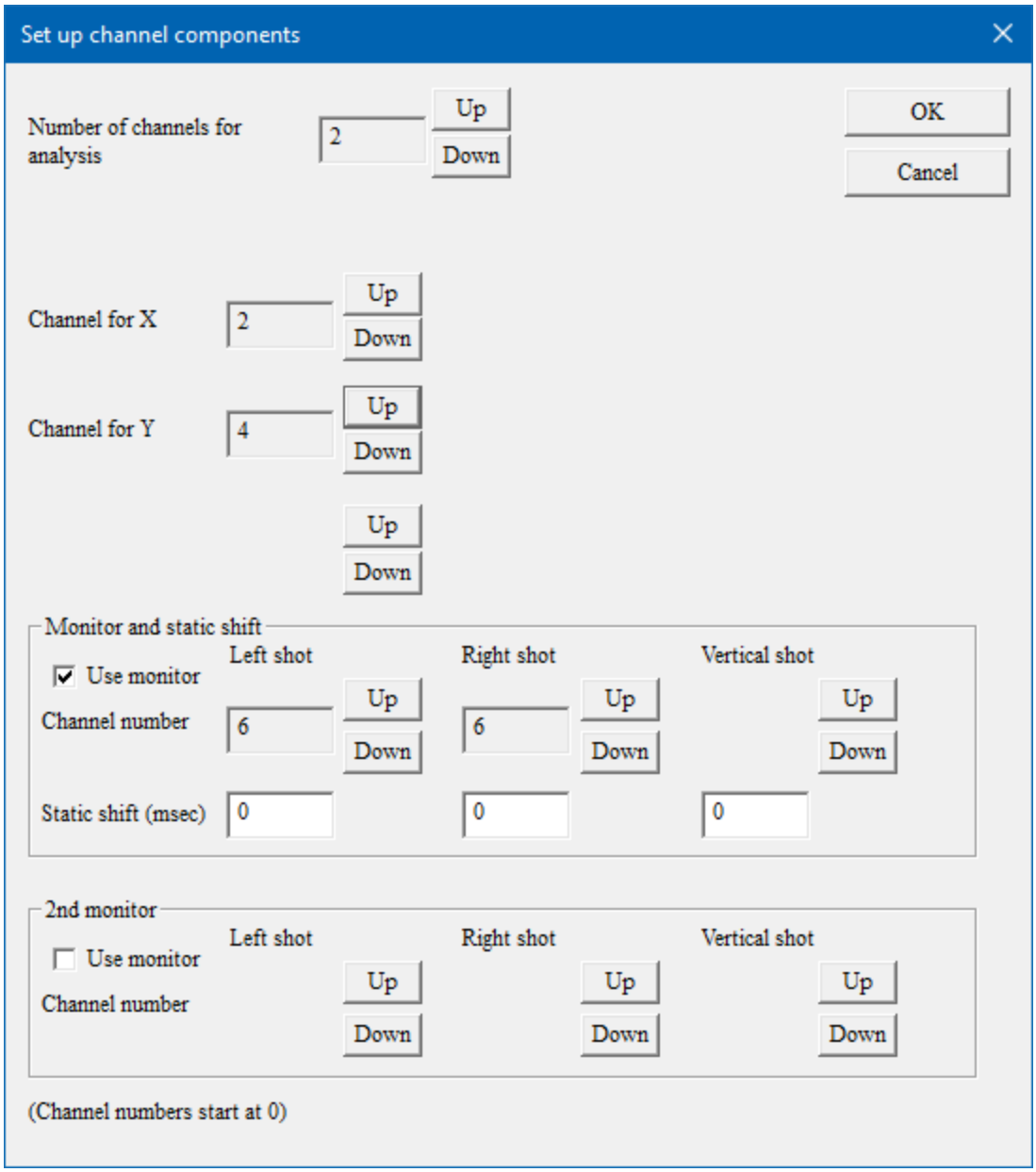
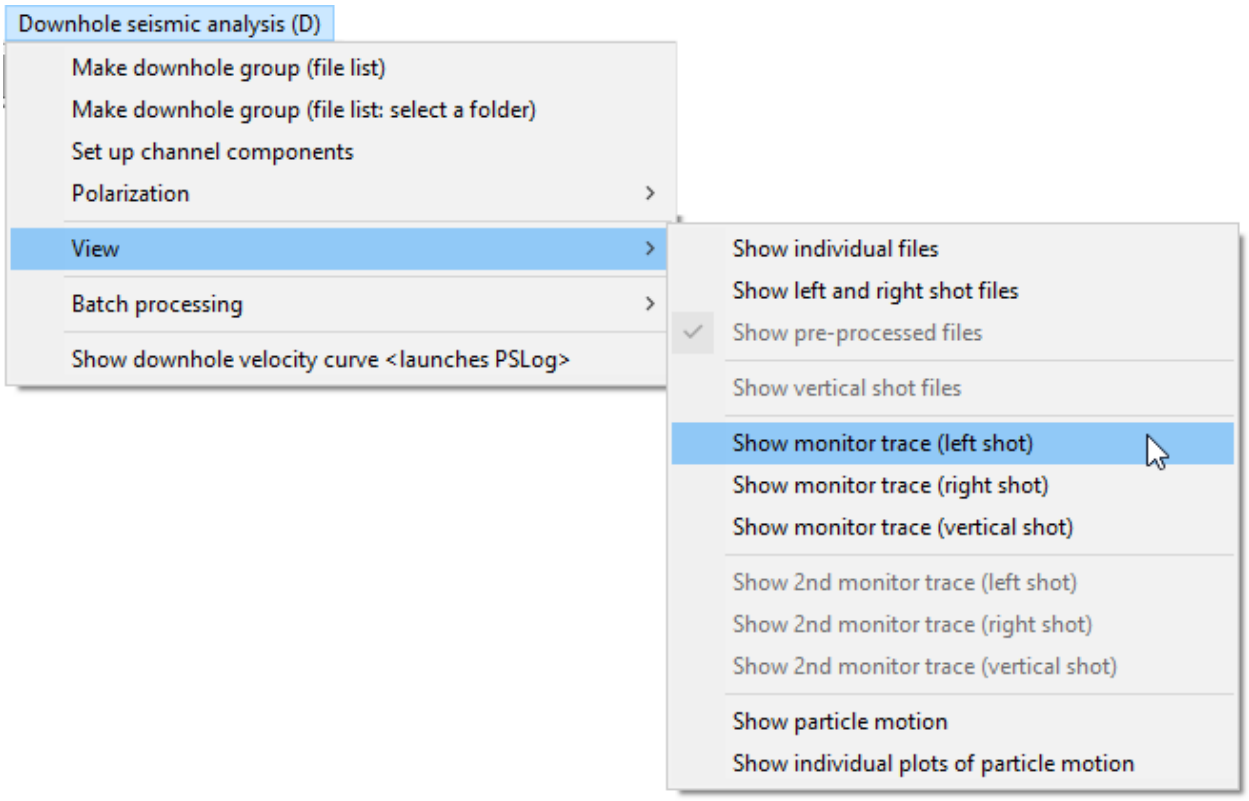


Figure F-1: Processing flow when using a trigger monitor.

1) Select *Downhole seismic analysis* | Setup *channel components* and set the parameters as shown below:

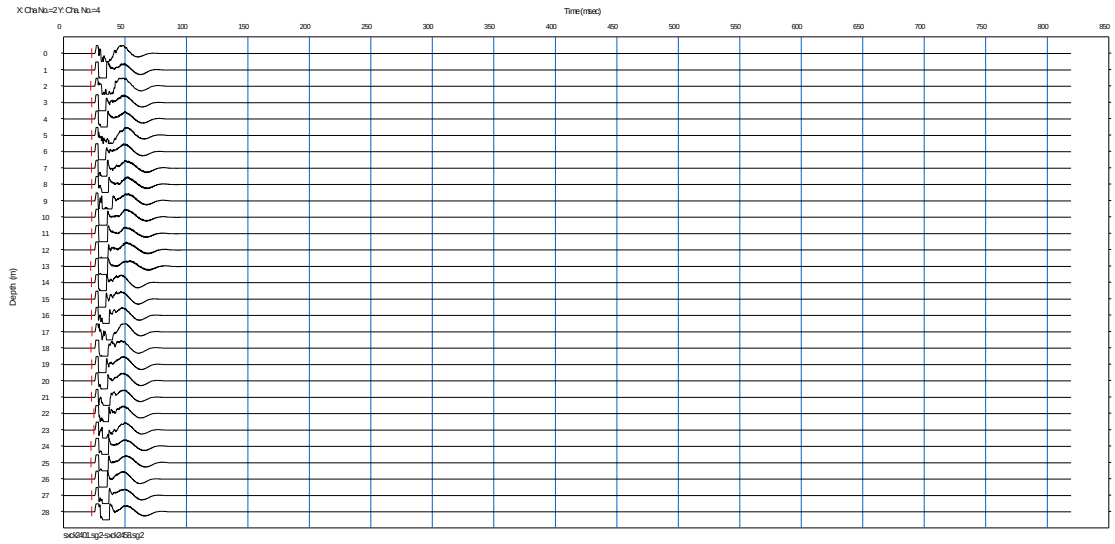


2) To display waveform traces for the trigger monitor receiver, select *Downhole seismic analysis | View | Show monitor trace (left shot)* or *Show monitor trace (right shot)*.



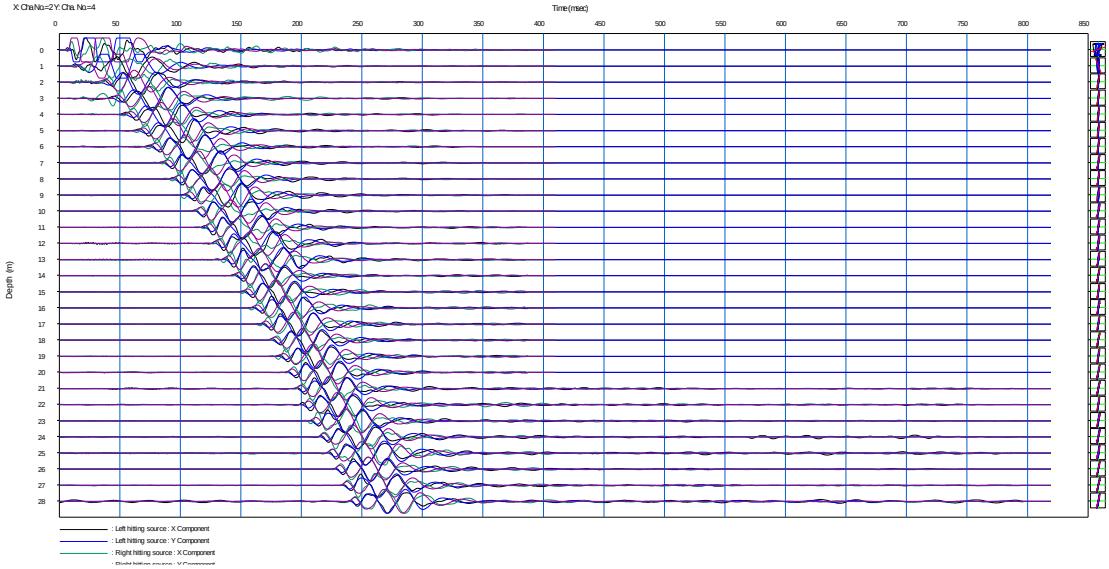
Waveform traces for the trigger monitor receiver will be displayed.

3) Pick the first arrivals of the trigger monitor receiver:


X Chs No.=2 Y Chs No.=4
Time (msec)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
sx0#0Lsg2-sx0#5Rsg2

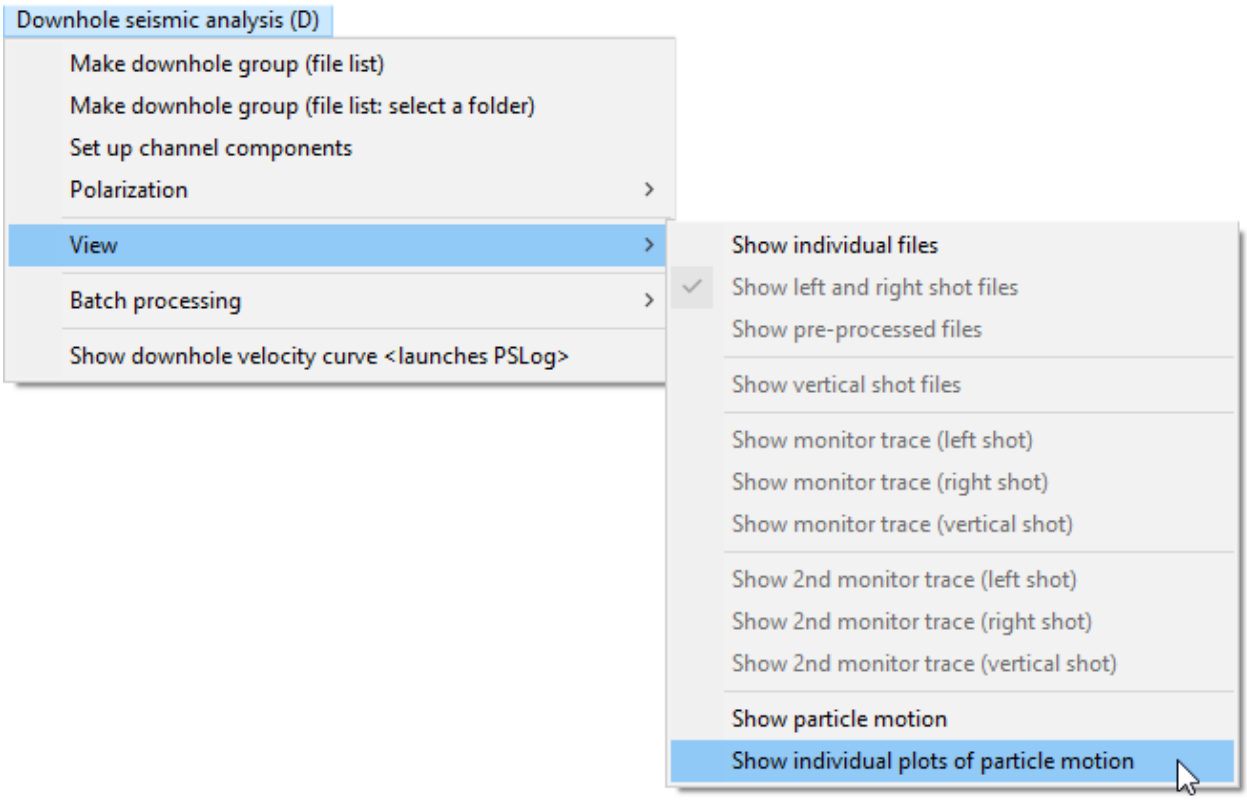
4) Show and pick the first arrivals for the opposing direction:

5) Select *Downhole seismic analysis* | *View* | *Show pre-processed files* to show waveform traces recorded in the borehole. Displayed waveform traces will be automatically shifted by the first arrival time for the trigger monitor traces.

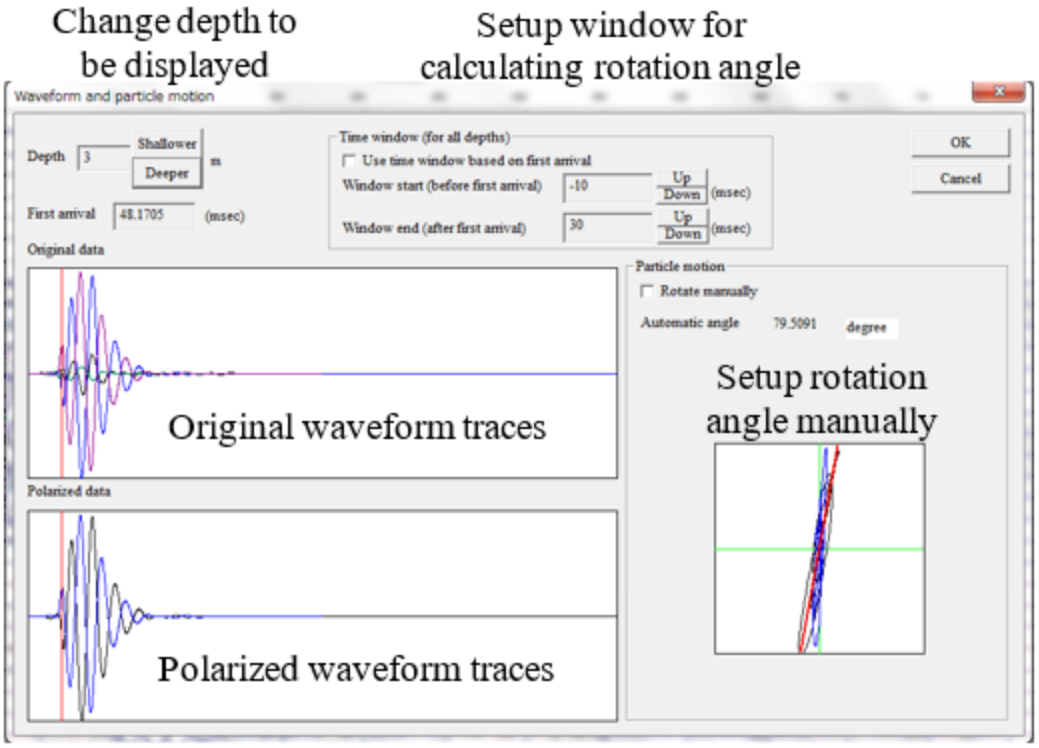


Appendix: F.2 Setup rotation angle for polarization manually

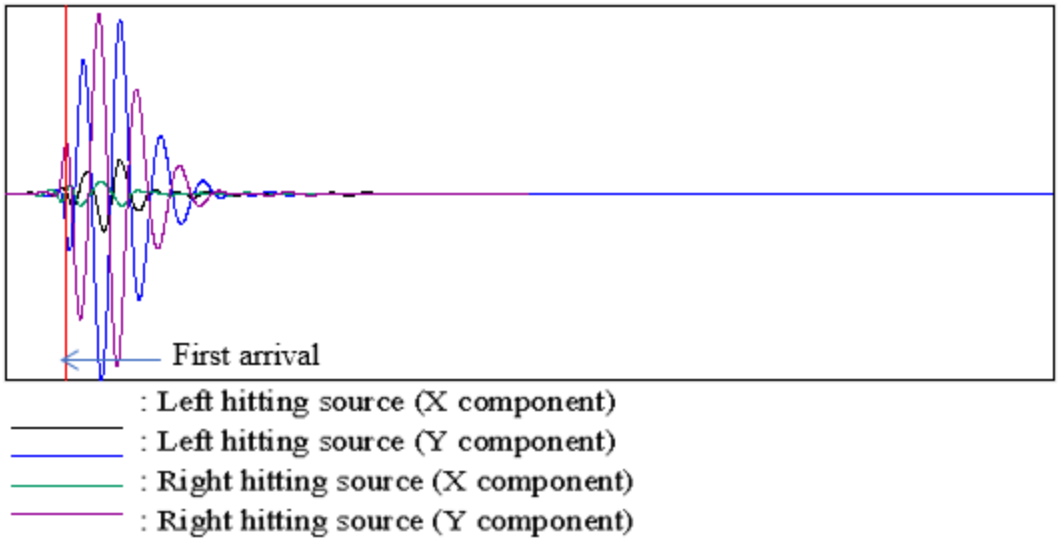
1) In Pickwin, select *Downhole seismic analysis* | *View* | *Show individual plots of particle motion:*



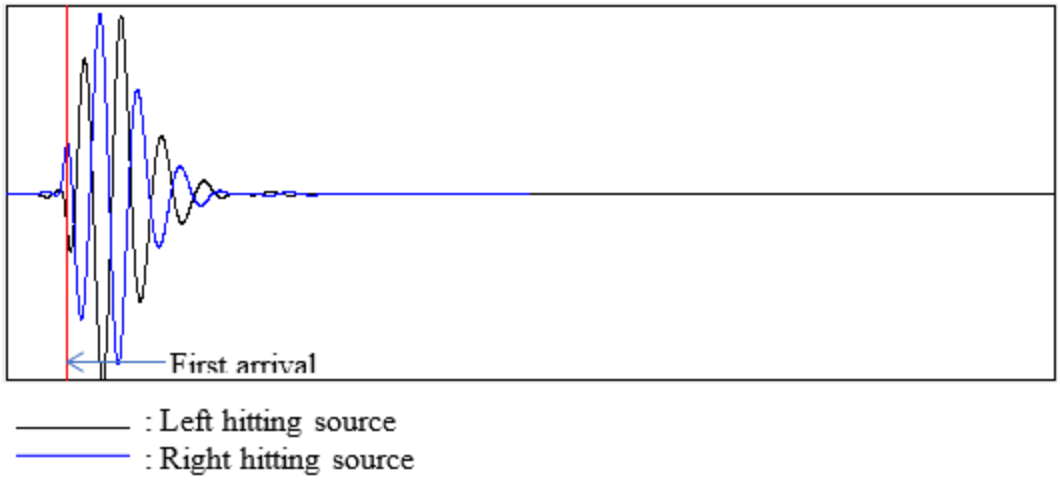
2) Waveform traces for each depth will be displayed in a dialog box:



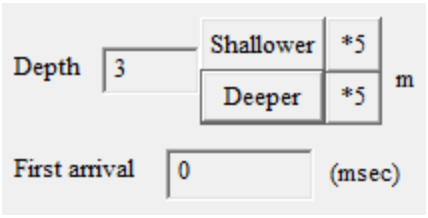
The original (before polarization) waveform traces are shown at the top. The picked first arrival is shown as a vertical red line:



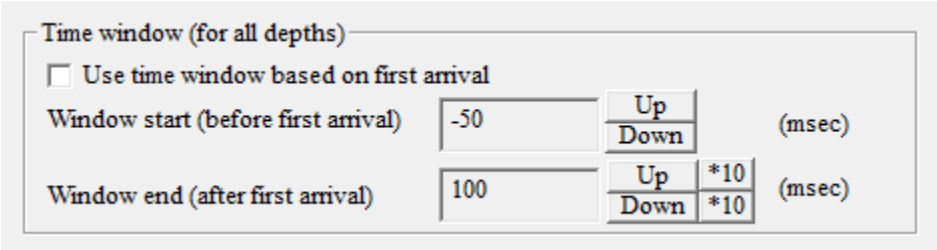
3) Polarized waveform traces are shown at the bottom.



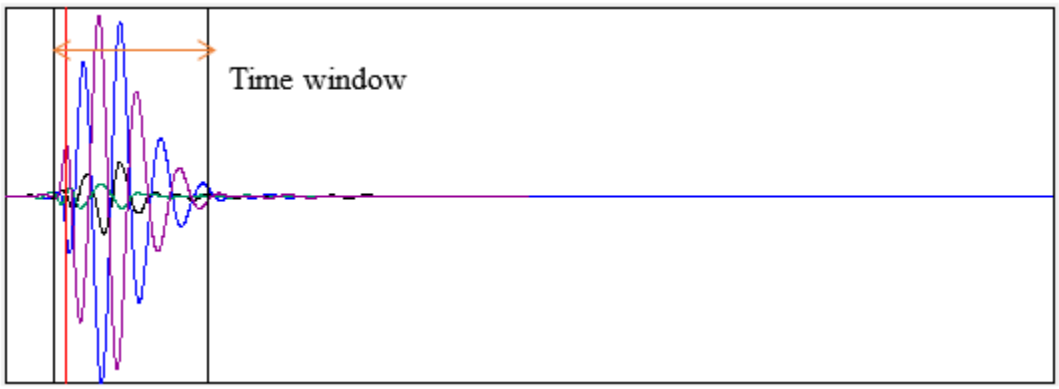
4) Scroll depth to be shown using the *Shallower* and *Deeper* buttons.



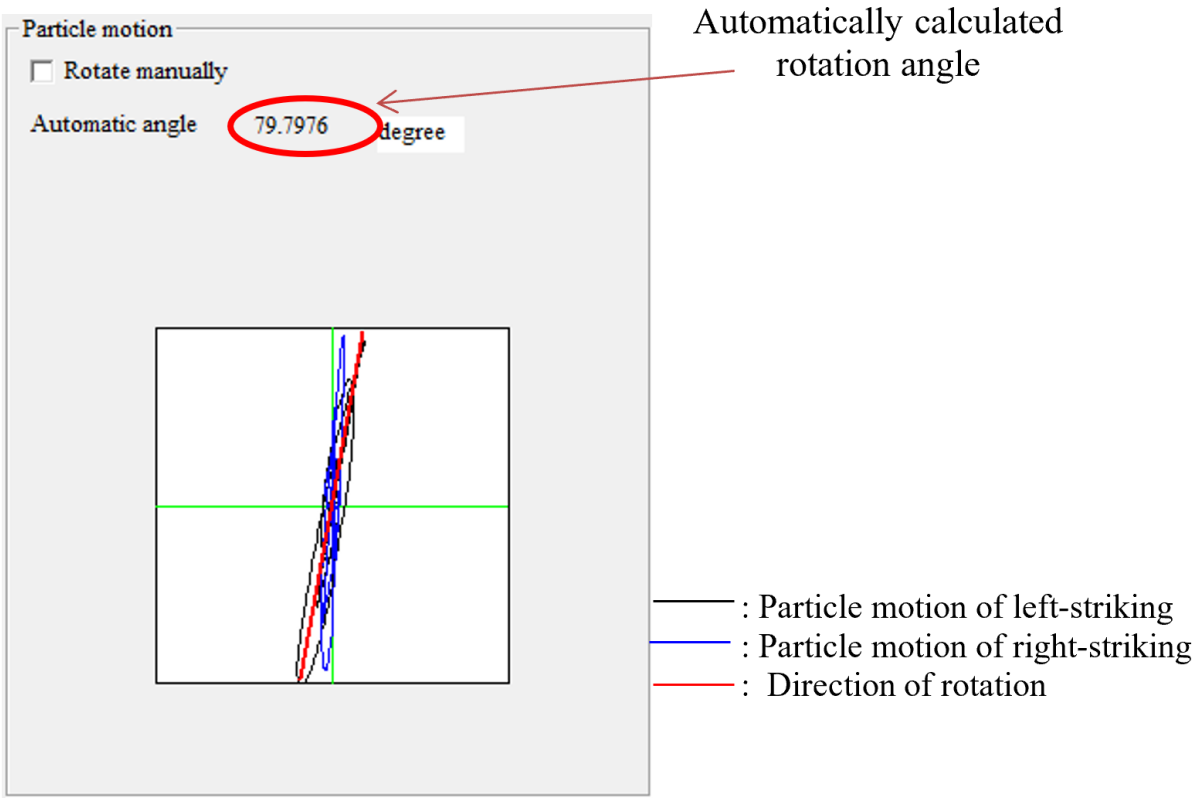
5) Setup time window for calculating the rotation angle automatically by particle motion. The time window can be defined based on the first arrival. The time window is applied to all depths.



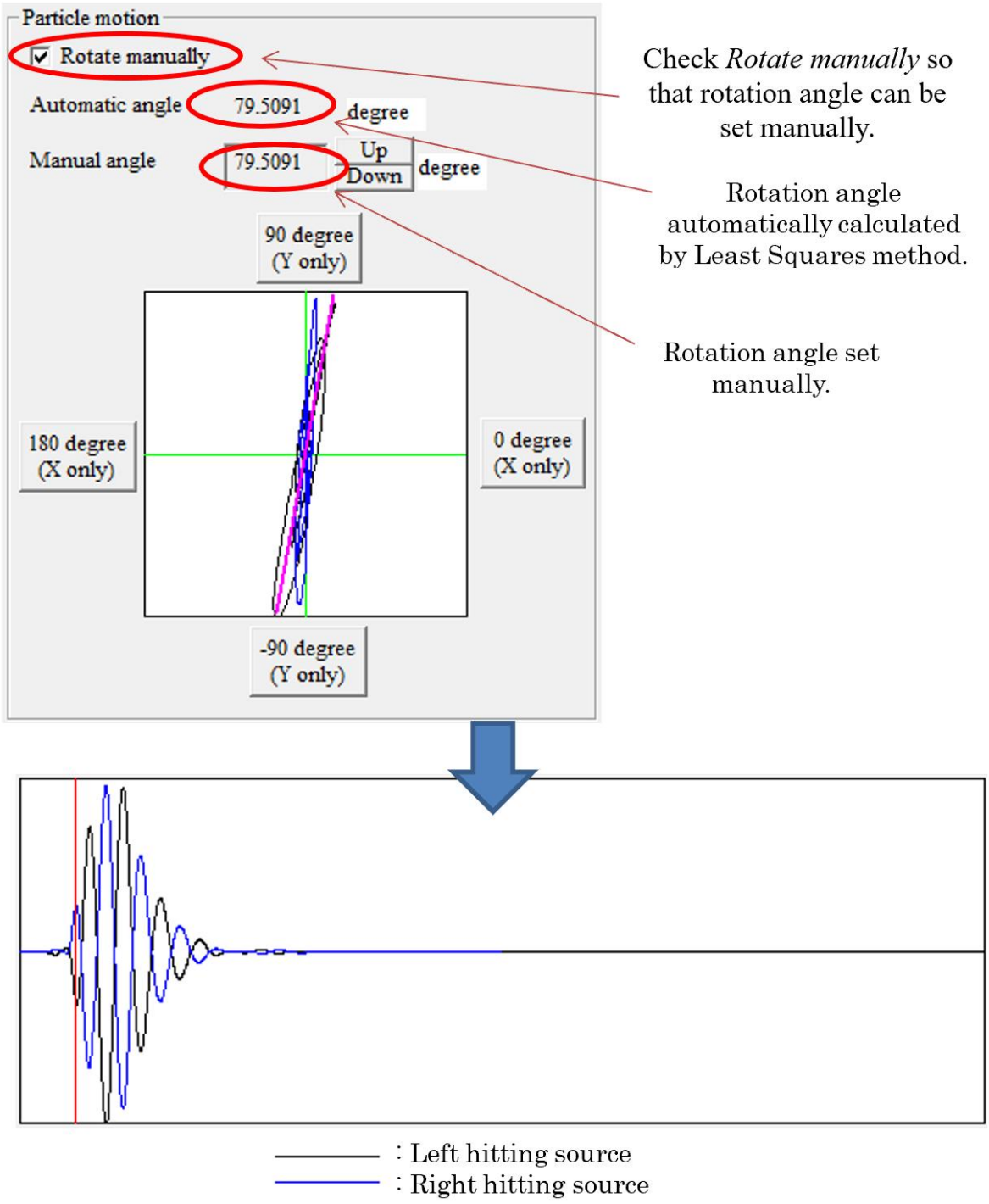
6) Check *Use time window based on first arrival* to apply the time window. If the time window is active, start and end of window are shown as black lines in waveform views at the left. Particle motion view shows the motion only in the window.



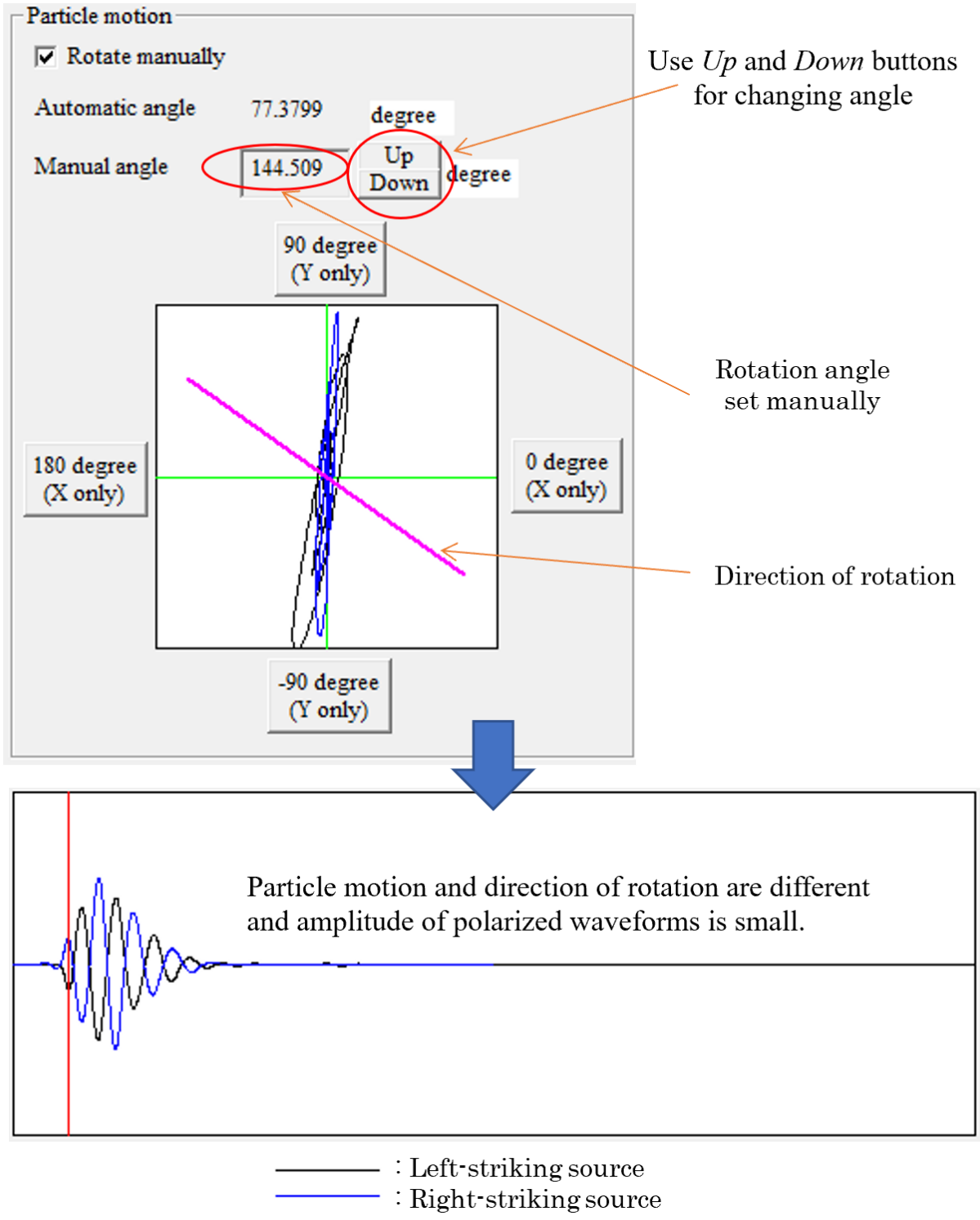
Particle motion and automatically calculated rotation angle is shown at the lower right.



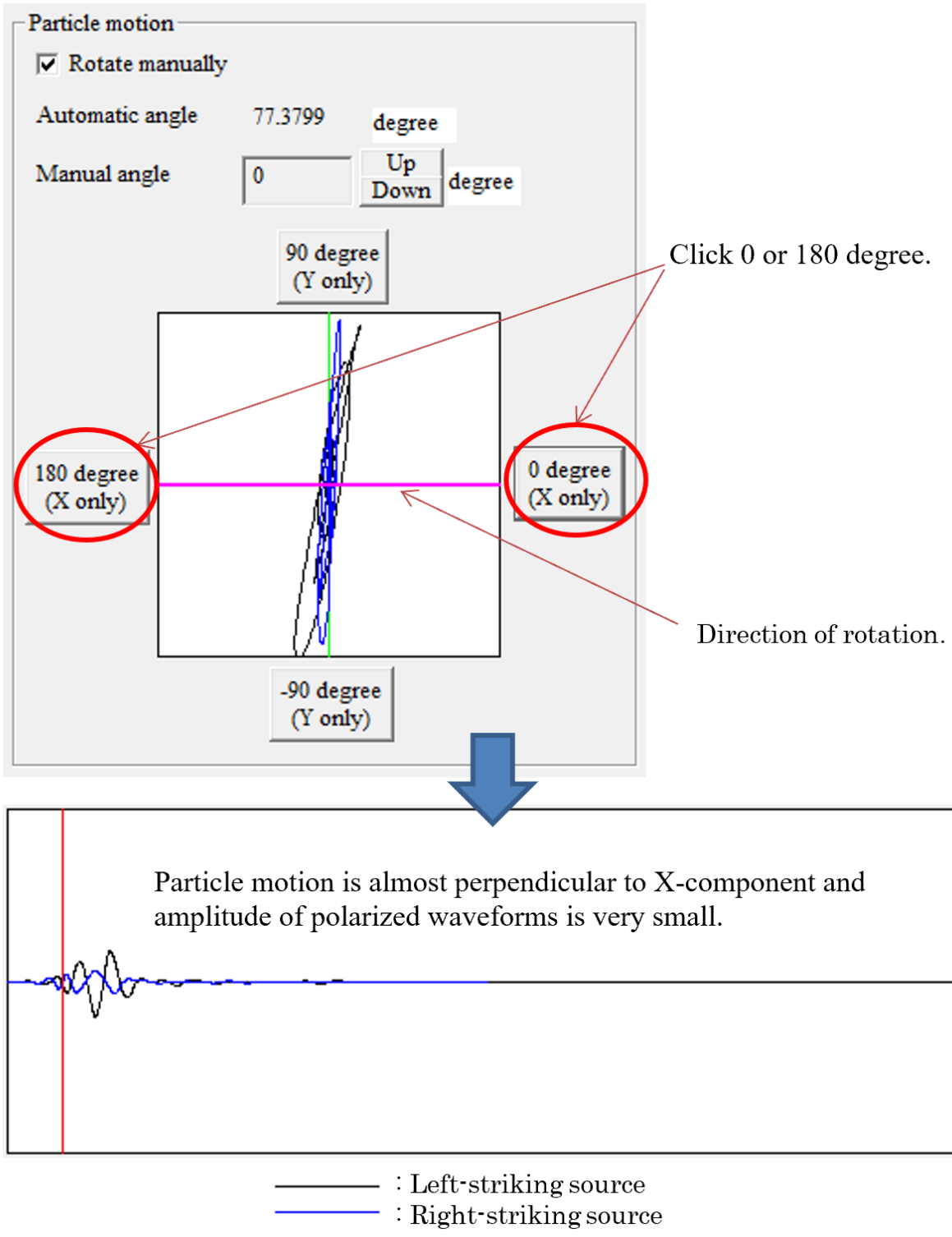
Rotation angle can be set by checking *Rotate manually* in the upper right.



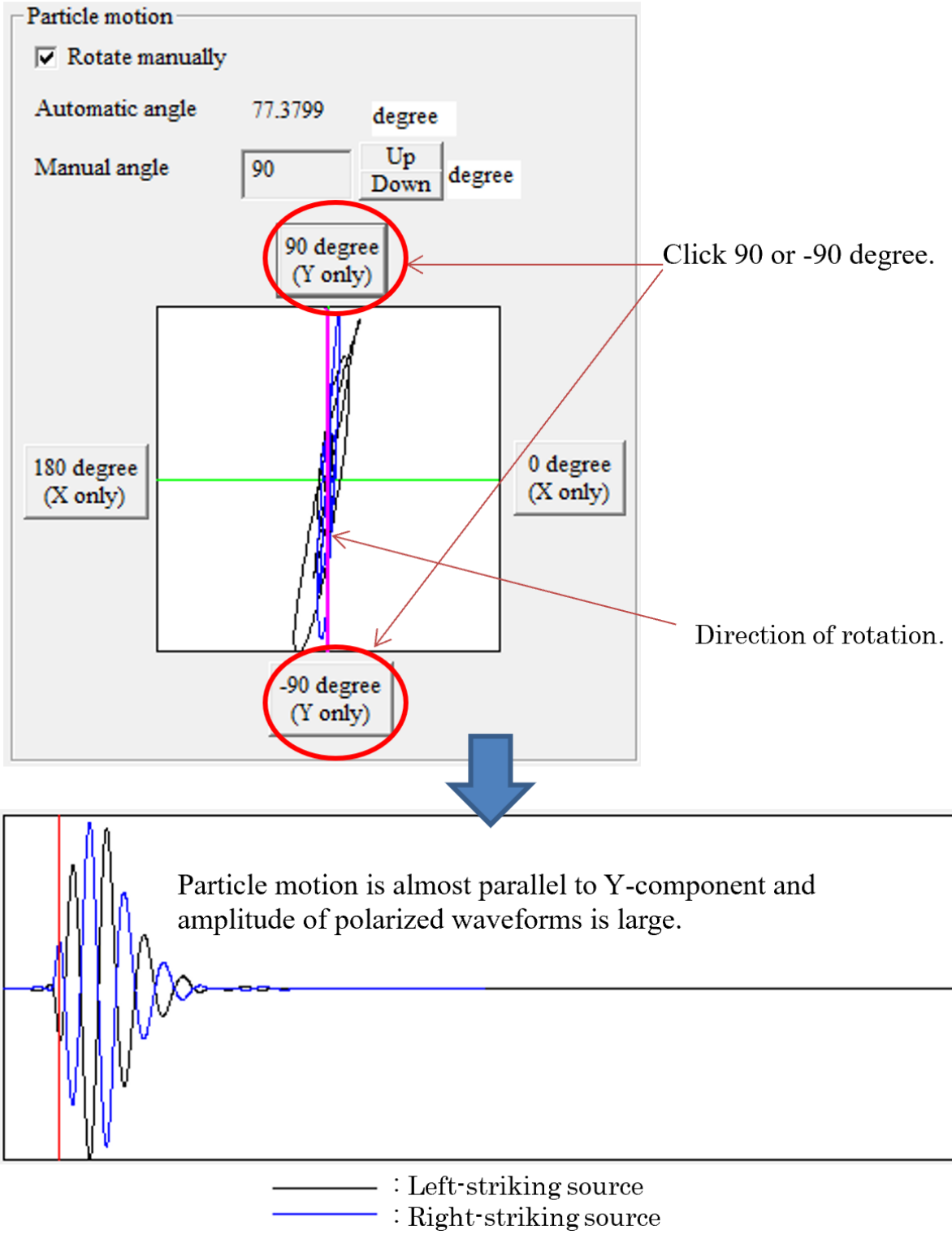
Rotation angle can be changed manually by *Up* and *Down* buttons.


Particle motion
Rotate manually
Automatic angle
77.3799
degree
Manual angle
144.509
Up
Down
degree
90 degree
(Y only)
180 degree
(X only)
0 degree
(X only)
-90 degree
(Y only)
Use *Up* and *Down* buttons for changing angle
Rotation angle set manually
Direction of rotation
Particle motion and direction of rotation are different and amplitude of polarized waveforms is small.
: Left-striking source
: Right-striking source

If you would like to use only the X-component, click 0 or 180 degrees and only the X-component will be used.



If you would like to use only the Y-component, click 90 or -90 degree and only the Y-component will be used.


Particle motion
Rotate manually
Automatic angle
77.3799
degree
Manual angle
90
Up
Down
degree
90 degree
(Y only)
180 degree
(X only)
0 degree
(X only)
-90 degree
(Y only)
Click 90 or -90 degree.
Direction of rotation.
Particle motion is almost parallel to Y-component and
amplitude of polarized waveforms is large.
: Left-striking source
: Right-striking source

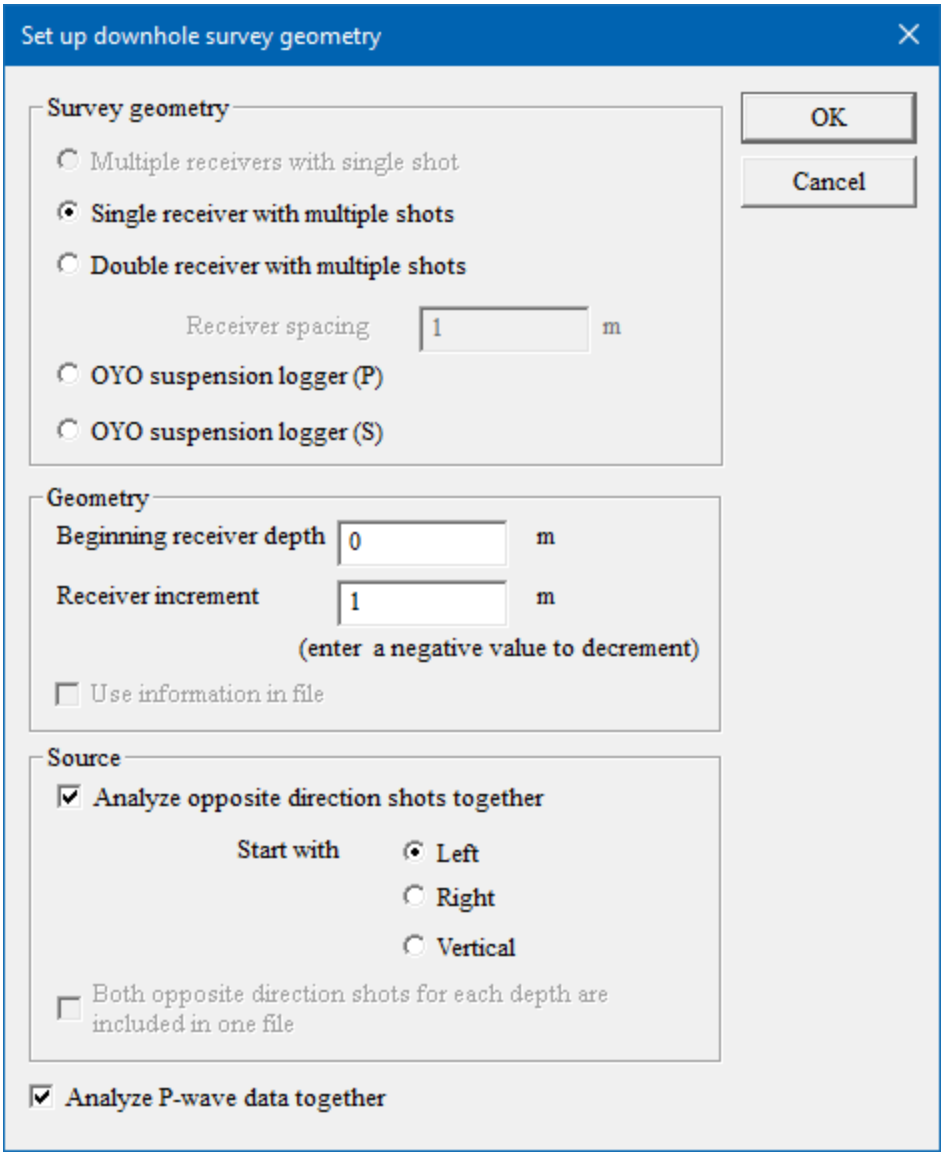
Appendix: F.3 Analyzing p- and s-wave data together

If p- and s-wave data were recorded in the same borehole, both can be processed simultaneously as follows:

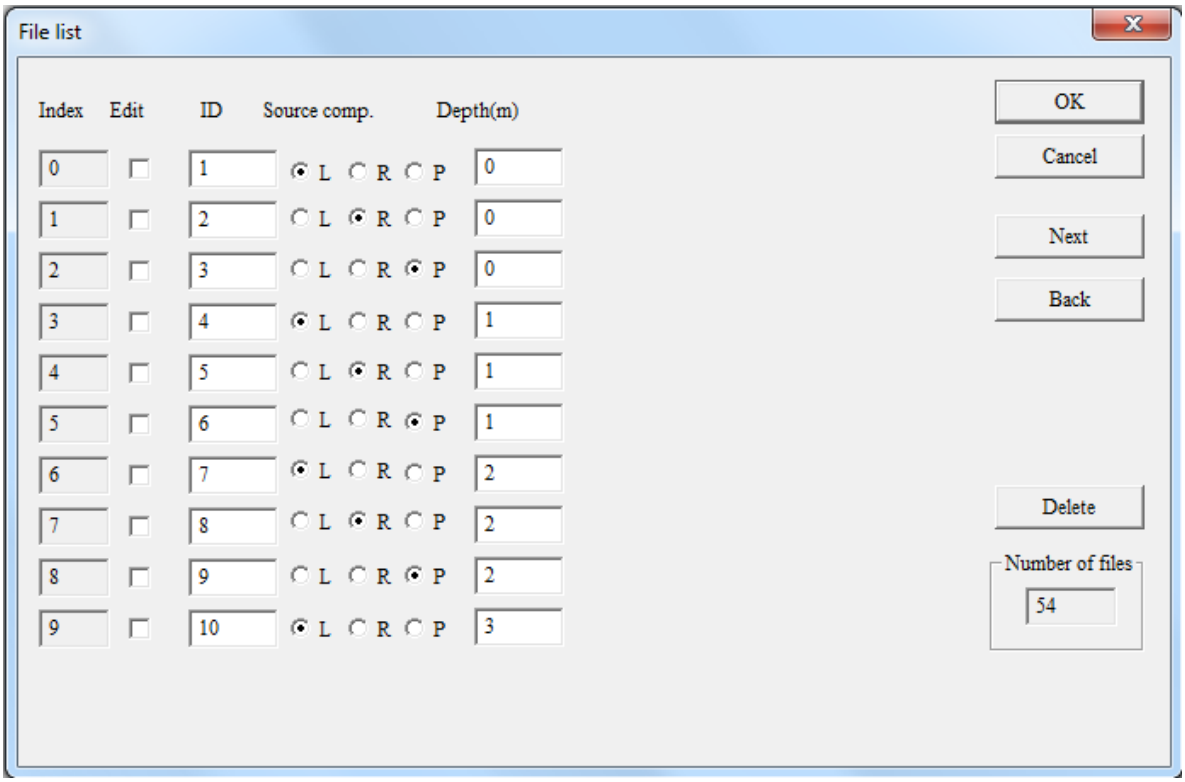
1) In the **Set up downhole survey geometry** dialog (which pops up when you create the group file list):

   a. Set *Beginning receiver depth* and *Receiver increment* (generally, *Receiver increment* and *Receiver spacing* are assumed to be identical throughout the logging process in this configuration).

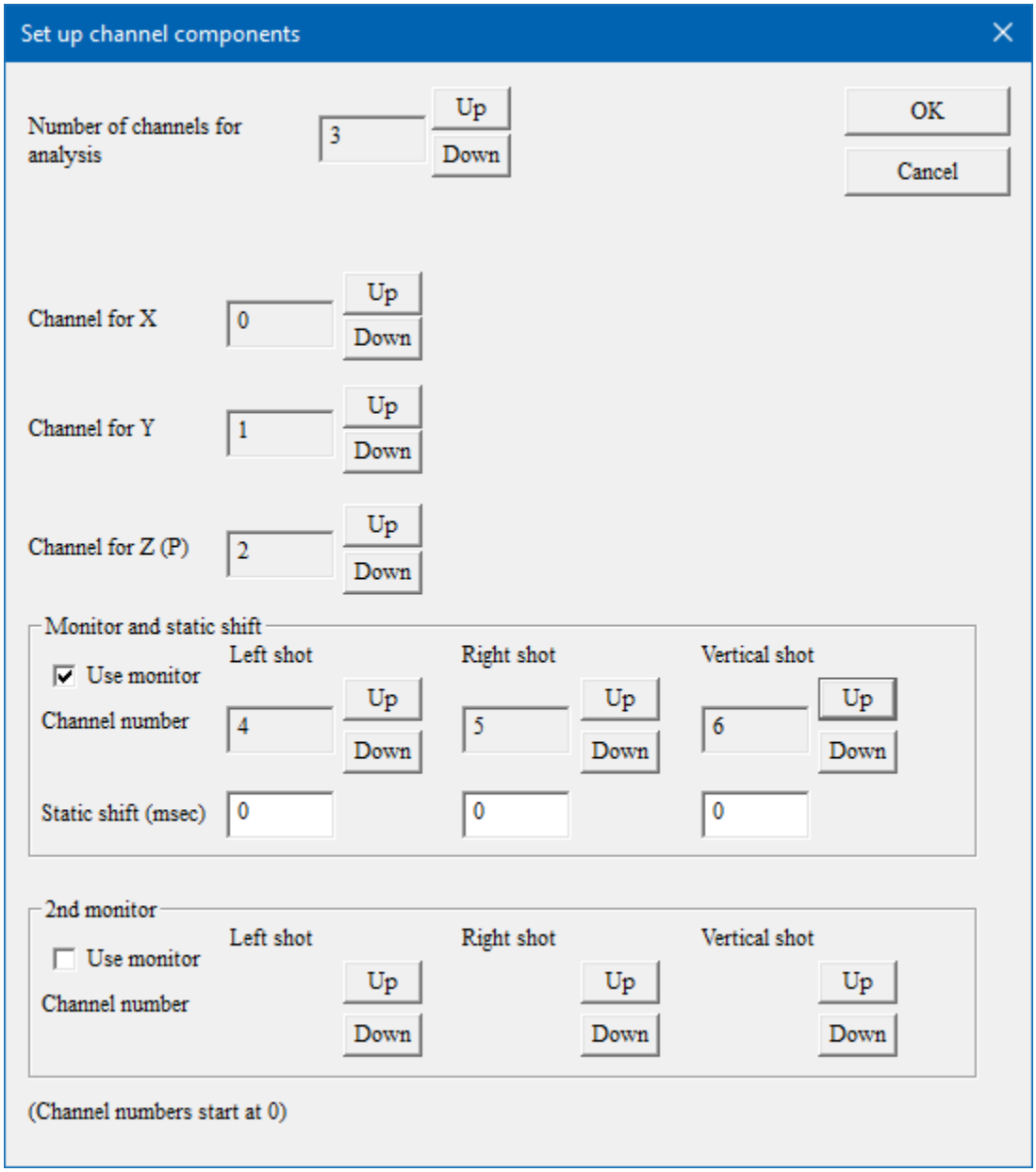
   b. Set other parameters as shown below.


Set up downhole survey geometry
Survey geometry
Multiple receivers with single shot
Single receiver with multiple shots
Double receiver with multiple shots
Receiver spacing
1
m
OYO suspension logger (P)
OYO suspension logger (S)
OK
Cancel
Geometry
Beginning receiver depth
0
m
Receiver increment
1
m
(enter a negative value to decrement)
Use information in file
Source
Analyze opposite direction shots together
Start with
Left
Right
Vertical
Both opposite direction shots for each depth are included in one file
Analyze P-wave data together

2) Edit receiver *Depth* and *Source component* (direction) as needed.



3) Select *Downhole seismic analysis* | *Setup channel components* and select the components to be processed as shown below. Check *Use monitor* if you use trigger monitor receivers.



4) To display s-wave data, click the button. To display p-wave data, click the button. See Section 4.5.1, Page 25, for details.

APPENDIX: G. FILES USED IN ANALYSIS

Files used in downhole seismic analysis are of three different types:

1) Original waveform files (SEG2)

These files contain the original waveform data. The files are used by Pickwin, and a list of the files are saved into a File List (XML file). The waveform files and the XML file must be placed in the same folder.

2) File list (XML)

This XML file contains all information about waveform-related processing, including a list of original waveform files, source-receiver configuration and channel number, rotation angle for polarization and first arrivals picks. The file is created and used by Pickwin. You do not need to save processed waveforms because all information is saved into the XML file list.

3) Analysis result (XML)

All processing information used in PSLog is saved into another XML file. The file contains travel time curves, source geometry (offset and elevation difference), layer boundaries, velocity of each layer and plotting scales. p- and s-wave analysis results can be saved into the same XML file or into two different files.

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