Aggregate and import SEG-2 borehole receiver spreads & filter traces & run Smooth invert for Shear-Wave crosshole line TEST_1 Rayfract® 5.02 Nov 2025 :

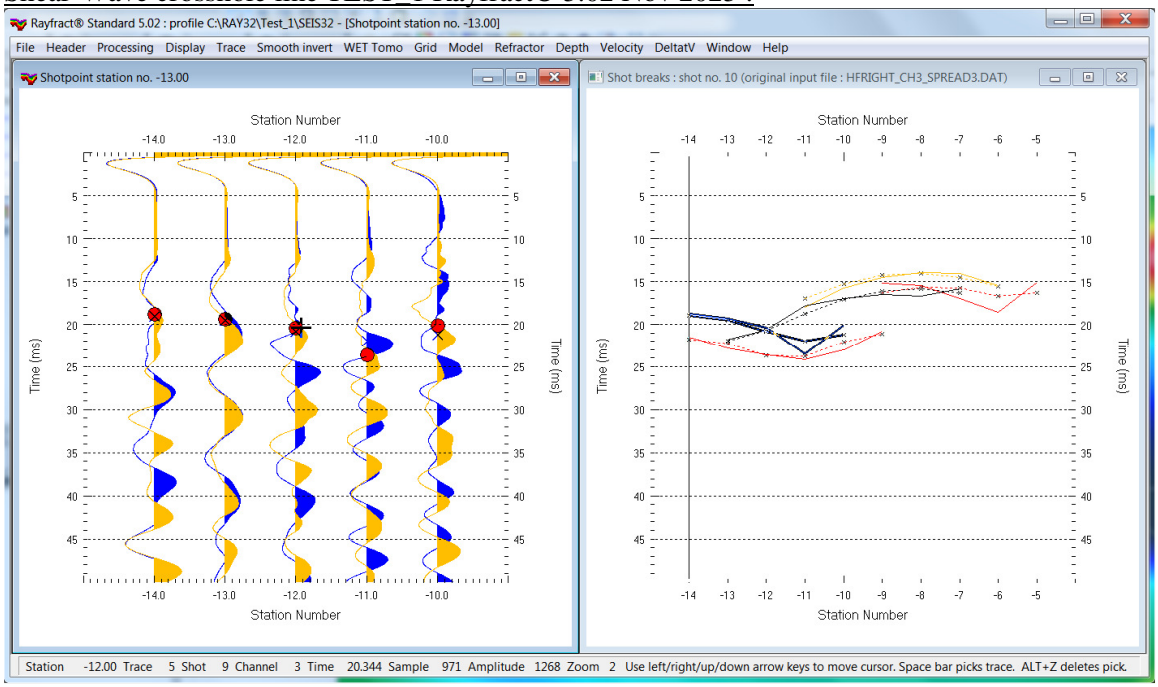

Fig. 1 : Left : *Trace|Shot point gather*, right : *Refractor|Shot breaks*. Shows fit between picked times (solid curve, red circles) and modeled times (dashed curve, blue crosses) after 100 WET iterations (Fig. 23).

To create the profile database, aggregate the SEG-2 borehole receiver channels, import the aggregated .DAT spread files and view the imported aggregated .DAT shear-wave shots do these steps :

1. ***File|New Profile***…, set *File name* to **`TEST_1`** and click *Save*. See our manual (Rohdewald 2025).
2. in the prompt shown next (Fig. 4) click ***No*** button .
3. in ***Header|Profile***… set *Line type* to **`Borehole spread/line`** . Set *Station spacing* to 1.0m. See Fig. 2.
4. unzip archive **`https://rayfract.com/tutorials/TEST_1.zip`** with **`SEG-2 .DAT`** receiver channel files & files **`COORDS.COR & SHOTPTS.SHO & BREAKS.LST`** in profile directory **`C:\RAY32\TEST_1`**
5. download installer **`https://rayfract.com/tools/SEG2HoleMerge.exe`** and run on your PC where you are running your Rayfract® version 5.02 Standard or Pro license.
6. open SEG2 HoleMerge 5.02 program via desktop icon. See Fig. 5 .
7. click on file icon besides uppermost field ***Select one SEG-2 file in INPUT directory***
8. navigate into **`C:\RAY32\TEST_1\5-Left`**. At right bottom of dialog select **`SEG-2 files (*.DAT)`** .
9. click on one file e.g. **`5HFLeft.DAT`** (receiver channels for elevation -5.0) and click *Open* button
10. set field ***Select output directory*** to **`C:\RAY32\Test_1\5Left`**
11. in frame ***Determine geophone channel number to be merged*** click radio button ***S-wave horizontal channel 3/y***. See Fig. 5.
12. in frame ***Distance unit : meters or feet*** click radio button ***Meters***
13. in frame ***Determine aggregated receiver geometry for vertical borehole*** set ***Deepest receiver depth below topo [m]*** to 9. Set next field ***Receiver spacing [m]*** to 1. See Fig. 5.
14. in frame ***Determine source position : horizontal and vertical offset from top of hole*** set ***Source x offset from top-of-hole [m]*** to 12.98. Set ***Source depth below top-of-hole [m]*** to 5.0.
15. click button ***Aggregate SEG-2 files***. Confirm prompts (Fig. 6). Click ***Close*** button.
16. the aggregated SEG-2 receiver spread file **`HFLeft_ch3_Spread3.DAT`** is written into folder **`C:\RAY32\TEST_1\5Left.`**
17. repeat steps 6. to 16 for **`C:\RAY32\TEST_1\5-Right\5HFRight.DAT`**. See Fig. 9. In step 8. navigate into **`C:\RAY32\TEST_1\5-Right`** . In step 9. select **`5HFRight.DAT`**. In step 10. set field ***Select output directory*** to **`C:\RAY32\Test_1\5Right.`** See Fig. 9. In step 16. the aggregated SEG-2 file **`HFRight_ch3_Spread3.DAT`** is written into folder **`C:\RAY32\TEST_1\5Right`** .
18. click on title bar of our opened Rayfract® 5.02
19. check import option *File|SEG-2 import settings and commands|**Receiver coordinates specified***

20. select ***File|Import Data***… . Set *Import data type* to **`SEG-2`**. See Fig. 3.
21. click *Select button* and navigate into **`C:\RAY32\TEST_1\5Left`**
22. leave *Files of type* at **`SEG-2 files (*.DAT)`** and select file **`HFLeft_ch3_Spread3.DAT`** & click *Open*
23. click ***Import shots button*** and confirm prompt
24. in Fig. 7 click ***Skip button*** to skip all other .DAT spread files in the same input directory until the title caption says **`Import C:\RAY32\TEST_1\5LEFT\HFLEFT_CH3_SPREAD3.DAT.`**
25. set ***Shot Number*** to 1 and click ***Read button***. Next click ***End button*** to end the import session.
26. reselect ***File|Import Data*** (Fig. 3). Click ***Select button*** and navigate into **`C:\RAY32\TEST_1\5Right`** .
27. leave *Files of type* at **`SEG-2 files (*.DAT)`** and select file **`HFRight_ch3_Spread3.DAT`** & click *Open*
28. click ***Import shots button*** and confirm prompt
29. in Fig. 7 click ***Skip button*** to skip all other .DAT spread files in the same input directory until the title caption says **`Import C:\RAY32\TEST_1\5RIGHT\HFRIGHT_CH3_SPREAD3.DAT.`**
30. set ***Shot Number*** to 2 and click ***Read button***. Next click ***End button*** to end the import session.
31. select *Trace|Shot point gather* and *Refractor|Shot breaks* and *Window|Tile* to obtain Fig. 1
32. click on title bar of *Refractor|Shot breaks* window (Fig. 1 right). Press ALT+P. Edit *Maximum time* to 50 ms. Press **`ENTER`** key to redisplay. Do the same for *Trace|Shot point gather* window (Fig. 1 left).
33. click on title bar of *Trace|Shot point gather* window and press CTRL+F1 to zoom trace amplitude
34. press CTRL+F3 to toggle trace wiggle display mode. Uncheck ***Display|Color trace outline***.
35. press SHIFT+Q and edit *Band pass filter* as in Fig. 8 . Click *Filter* button.
36. select ***Processing|Pick all shots, in shot point gather***.
37. select ***Display|Show picks on time axis***.

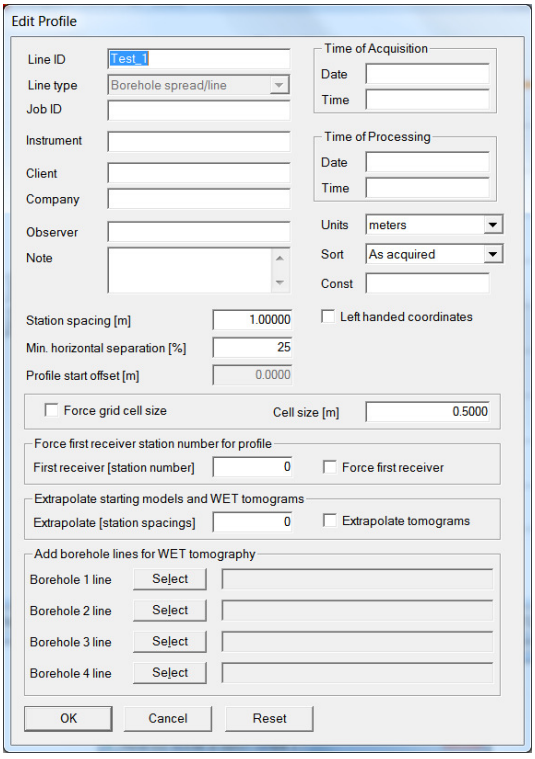

Fig. 2 : *Header|Profile*

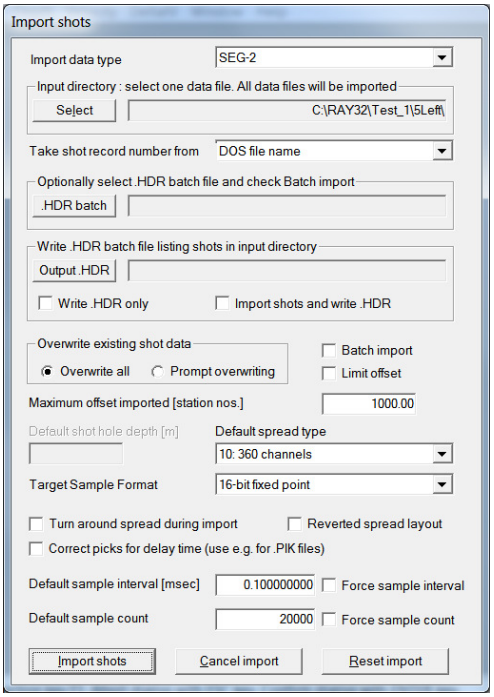

Fig. 3 : *File|Import Data*

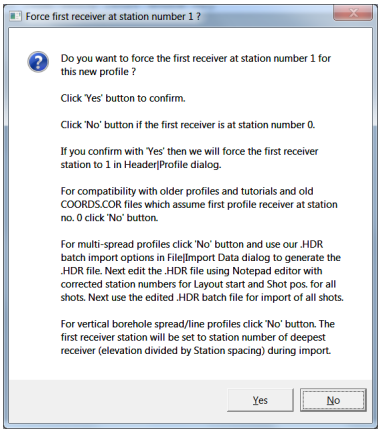

Fig. 4 : click *No* button.

For vertical borehole/spread line profiles click 'No' button. The first receiver station will be set to station number of deepest receiver (elevation divided by *Station spacing*) during import.

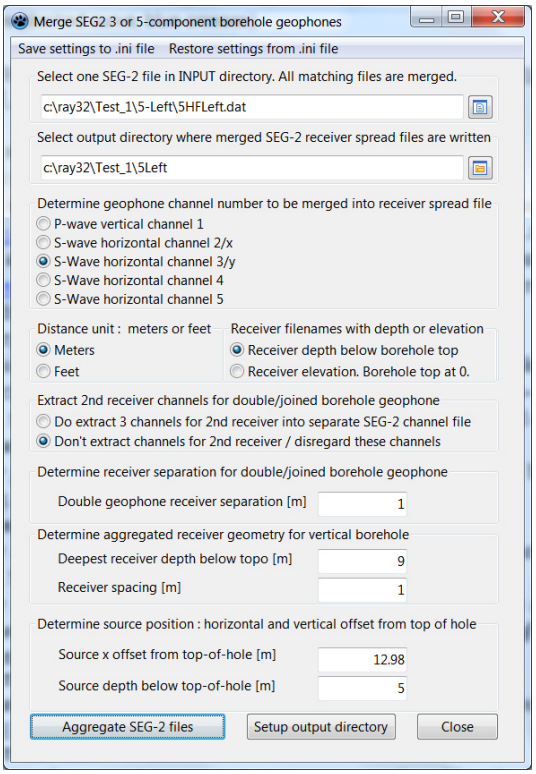

Fig. 5 : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click button ***Aggregate SEG-2 files***.

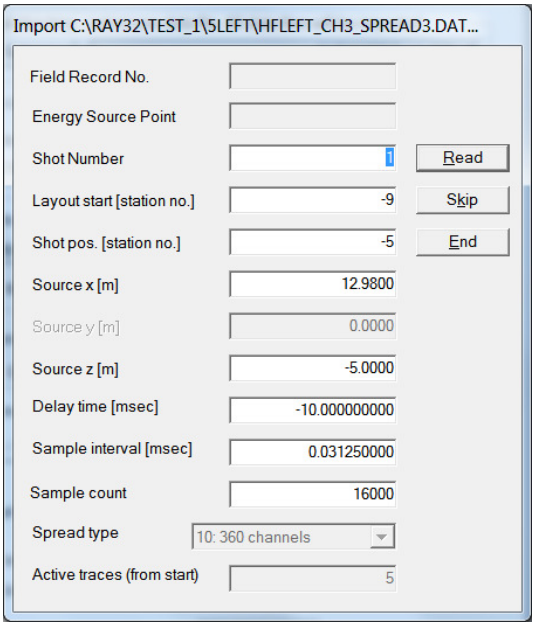

Fig. 7 : *Import Shot dialog* shown when clicking ***Import Shots*** in *File*/*Import Data* (Fig. 3). Skip all other .DAT spread files in the same input directory with click on ***Skip button*** until the dialog caption says HFLEFT_CH3_SPREAD3.DAT . Now set ***Shot Number*** to 1 and click ***Read*** button. Next if necessary click ***End button*** to end the import session.

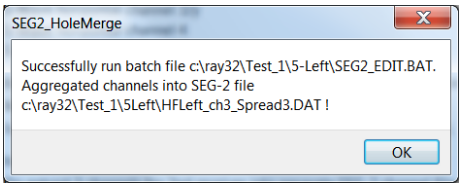

Fig. 6 : prompt shown after clicking button ***Aggregate SEG-2 files***. Click OK to dismiss.

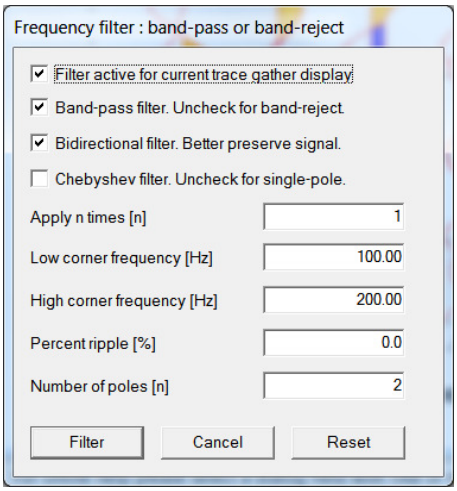

Fig. 8 (above) : Band-pass filter dialog shown with SHIFT+Q. Edit as shown and click ***Filter button***.

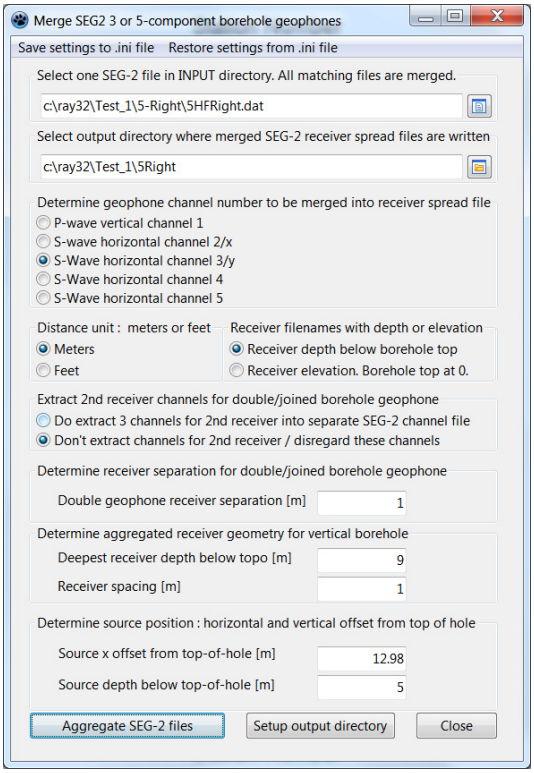

Fig. 9 : click SEG2 HoleMerge 5.02 icon. Edit as shown. Click button ***Aggregate SEG-2 files***.

38. press ALT+Q and edit *High-pass filter* as shown in Fig. 10. Click *Filter* button.
39. press ALT+M and edit *Trace processing parameters* as in Fig. 11. Click *Filter* button.

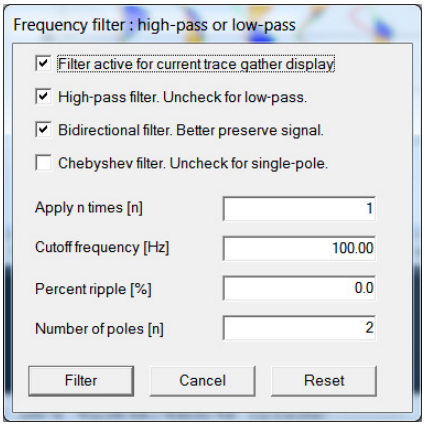

Fig. 10 (left) : High-pass filter dialog shown with ALT+Q. Edit as shown and click ***Filter button***.

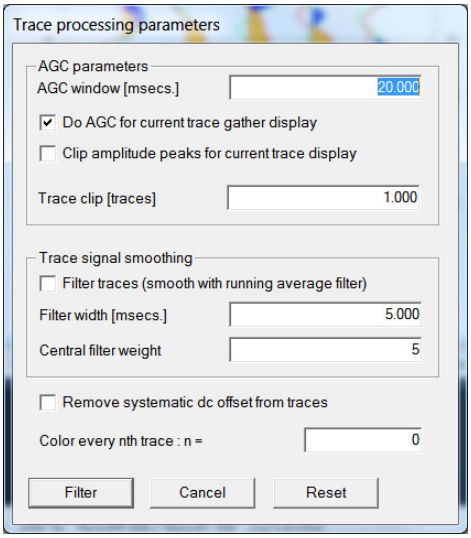

Fig. 11 : Trace processing parameters dialog shown with ALT+M. Edit as shown and click ***Filter button***.

Input folder	Input file	Output folder	Deepest receiver depth below top [m]	Source depth below top [m]
5-Left	5HFLeft.dat	5Left	9	5
5-Right	5HFRight.dat	5Right	9	5
7-Left	6HLeft.dat	7Left	11	7
7-Right	6HFRight.dat	7Right	11	7
9-Left	7HFLeft.dat	9Left	13	9
9-Right	7HFRight.dat	9Right	13	9
11-Left	9HFLeft.dat	11Left	14	11
11-Right	9HFRight.dat	11Right	14	11
13-Left	10HFLeft.dat	13Left	14	13
13-Right	10HFRight.dat	13Right	14	13

Fig. 12 : repeat steps 6. to 16 for input folders shown in first column. In SEG2_HoleMerge program (Fig. 5) in topmost frame ***Input directory*** navigate into input folder and select the input file shown in 2nd column. Edit ***Output directory*** as shown in 3rd column. Edit ***Deepest receiver depth below topo [m]*** as in 4th column. Edit ***Source depth below top-of-hole [m]*** as in 5th column. Click ***Aggregate SEG-2 files button*** to obtain the aggregated receiver spread file named **`HFLeft_ch3_spread3.DAT`** or **`HFRight_ch3_spread3.DAT`** in the output folder.

40. repeat steps 6. to 16. for the remaining input folders 7-Left to 13-Right shown in first column of table in Fig. 12 as in below steps :
41. in SEG2_HoleMerge program (Fig. 5) in topmost frame ***Input directory*** navigate into input folder and select the input file shown in 2nd column of Fig. 12
42. edit ***Output directory*** as shown in 3rd column of Fig. 12
43. edit ***Deepest receiver depth below topo [m]*** as in 4th column of Fig. 12
44. edit ***Source depth below top-of-hole [m]*** as in 5th column of Fig. 12
45. click ***Aggregate SEG-2 files button*** (Fig. 5) to obtain the aggregated receiver spread file named **`HFLeft_ch3_spread3.DAT`** or **`HFRight_ch3_spread3.DAT`** in the output folder

Input directory	Input spread file	Shot Number	Layout start [station]	Shot pos. [station]
C:\Ray32\Test_1\5Left	HFLeft_ch3_spread3.dat	1	-9	-5
C:\Ray32\Test_1\5Right	HFRight_ch3_spread3.dat	2	-9	-5
C:\Ray32\Test_1\7Left	HFLeft_ch3_spread3.dat	3	-11	-7
C:\Ray32\Test_1\7Right	HFRight_ch3_spread3.dat	4	-11	-7
C:\Ray32\Test_1\9Left	HFLeft_ch3_spread3.dat	5	-13	-9
C:\Ray32\Test_1\9Right	HFRight_ch3_spread3.dat	6	-13	-9
C:\Ray32\Test_1\11Left	HFLeft_ch3_spread3.dat	7	-14	-11
C:\Ray32\Test_1\11Right	HFRight_ch3_spread3.dat	8	-14	-11
C:\Ray32\Test_1\13Left	HFLeft_ch3_spread3.dat	9	-14	-13
C:\Ray32\Test_1\13Right	HFRight_ch3_spread3.dat	10	-14	-13

Fig. 13 : select the aggregated receiver spread file (2nd column) in input directory (column 1) in ***File|Import Data*** (Fig. 3) with ***Select button***. Click button ***Import shots***. In *Import Shot dialog* (Fig. 7) skip all other .DAT spread files with ***Skip button*** until the dialog title shows the input spread file for channel 3 as shown in 2nd column. Now edit the ***Shot Number*** to value shown in 3rd column. Leave ***Layout start [station no.]*** and ***Shot pos. [station no.]*** at station numbers shown in 4th and 5th column. Click ***Read button***. Skip all other .DAT spread files in same input directory with ***End button*** if necessary.

46. import the remaining shot numbers 3 to 10 listed in Fig. 13 column 3 using ***File\Import Data*** (Fig. 3) as follows :
47. in ***File\Import Data*** (Fig. 3) click ***Select button***. Navigate into input directory (first column in Fig. 13) and select the input spread file **`HFLeft_ch3_spread3.dat`** or **`HFRight_ch3_spread3.dat`** (2nd column in Fig. 13).
48. click button ***Import shots***. In *Import Shot dialog* (Fig. 7) skip all other .DAT spread files in same input directory with ***Skip button*** until the dialog title shows the input spread file for channel 3 shown in 2nd column.
49. edit ***Shot Number*** to value shown in 3rd column (Fig. 13)
50. leave ***Layout start [station no.]*** at station number shown in 4th column (Fig. 13)
51. leave ***Shot pos. [station no.]*** at station number shown in 5th column (Fig. 13)
52. click ***Read button***. Skip all other .DAT spread files in same input directory with ***End button*** if necessary.
53. repeat above steps 47. to 52. for all remaining shot numbers 3 to 10 listed in Fig. 13.
54. select ***File\Update header data\Update First Breaks*** and BREAKS.LST to update the first break picks for all imported shot numbers.
55. select ***Trace\Shot point gather*** and ***Refractor\Shot breaks*** and ***Window\Tile*** to obtain Fig. 1
56. click on title of *Shot point gather* (Fig. 1 left) and use F7/F8 keys to browse the ***Shotpoint station*** displayed in the window's title. This is the same station number as listed in 5th column in Fig. 13.

Configure and obtain constant-velocity starting model and run Smooth WET inversion (Rohdewald 2025) :

- edit *Grid|Surfer plot Limits* as in Fig. 14
- select *Model|WDVS Smoothing*. Click radio button ***restore WET smoothing*** (Fig. 15). Click *OK*.
- check *Grid|Vertical plot title*. Check *Grid|GS CENTERED FONT* to fix Surfer 11 plot display.
- select ***Smooth invert|WET with constant-velocity initial model***
- wait for the constant-velocity starting model to show as in Fig. 16
- in prompt to continue with WET inversion click *Yes* button to obtain Fig. 17 and Fig. 18

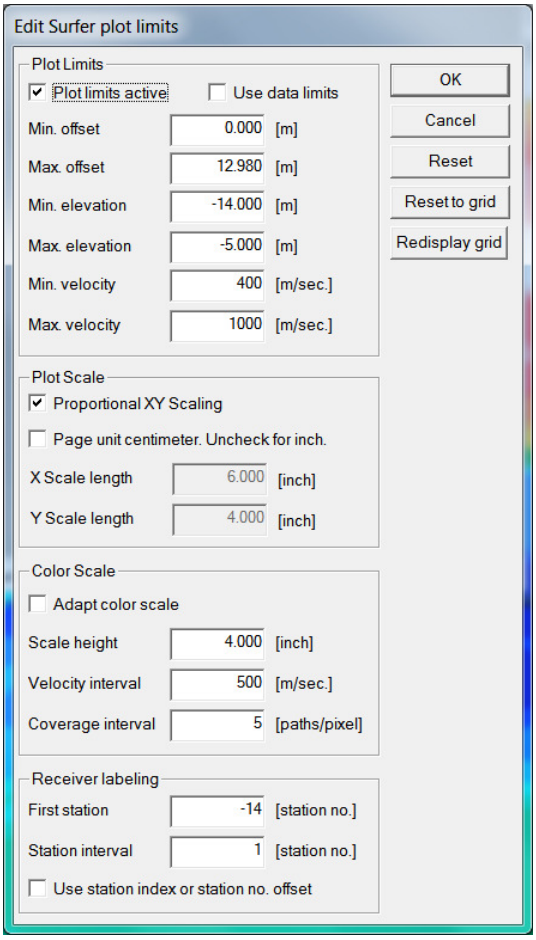

Fig. 14 : *Grid|Surfer plot Limits* dialog. Check box ***Limits active*** and ***Proportional XY scaling***. Edit as shown. Click OK button.

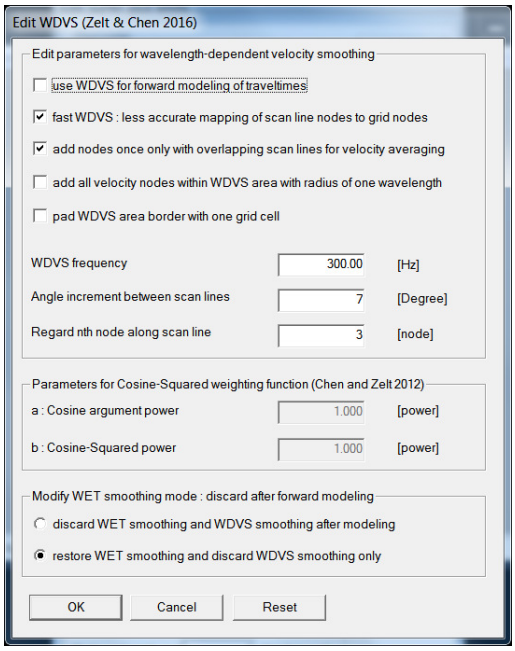

Fig. 15 : *Model|WDVS Smoothing* dialog. Click option ***restore WET smoothing discard WDVS smoothing only***. Click OK button.

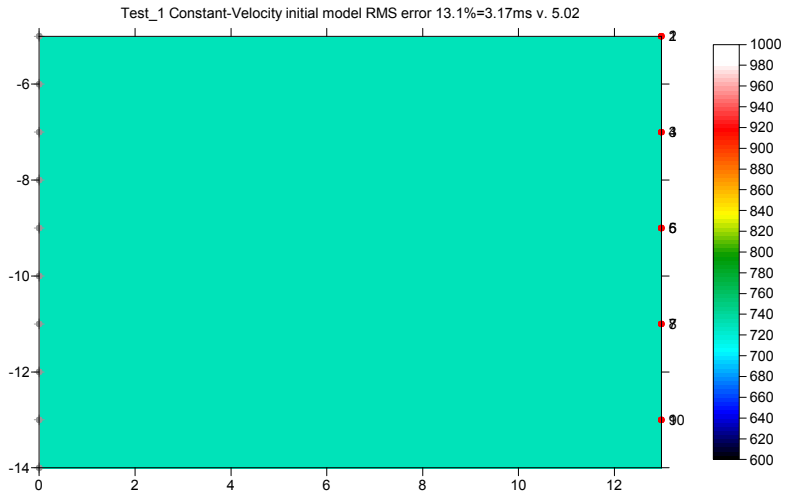

Fig. 16 : Constant-velocity starting model obtained with ***Smooth invert*/*WET with constant-velocity initial model***. Confirm prompt to continue with 2D WET inversion (Schuster 1993) to obtain Fig. 17 & 18.

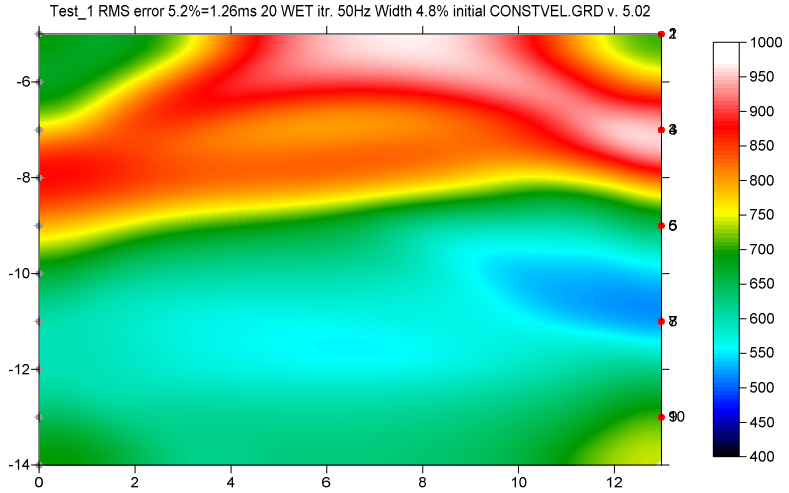

Fig. 17 : default WET tomogram (Schuster 1993) obtained with ***Smooth invert*/*WET with constant-velocity initial model*** and starting model shown in Fig. 16.

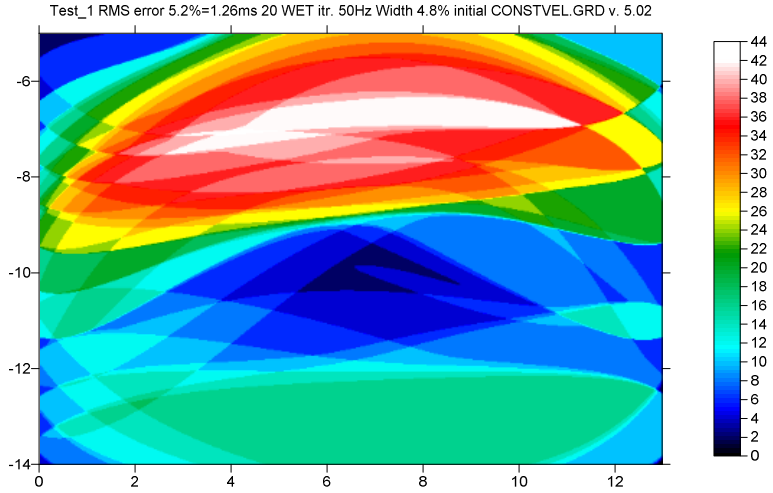

Fig. 18 : WET wavepath coverage plot obtained with Fig. 17. Unit is wavepaths per grid cell.

Interactive WET inversion of crosshole shear-wave first breaks using optimized WET settings :

Next we show optimized WET inversion (Schuster 1993, Rohdewald 2025) :

- select *Header|Profile*. Check box *Force grid cell size*. Set *Cell size[m]* to 0.02. Click *OK* button. See Fig. 19.
- select *Model|WDVS Smoothing*. Check box *discard WET smoothing and WDVS smoothing after modeling*. Leave box *use WDVS for forward modeling of traveltimes* unchecked. Click *OK* button. See Fig. 20.
- select *Grid|Surfer plot Limits*. Edit velocity range as shown in Fig. 21. Click *OK* button.
- select *WET Tomo|Interactive WET tomography*.
- set *Number of WET tomography iterations* to 100. See Fig. 22 (left).
- click button *Edit velocity smoothing*. Click buttons *Reset parameters* and *Accept parameters*. See Fig. 22 (right).
- click button *Start tomography processing* to obtain Fig. 23 and Fig. 24

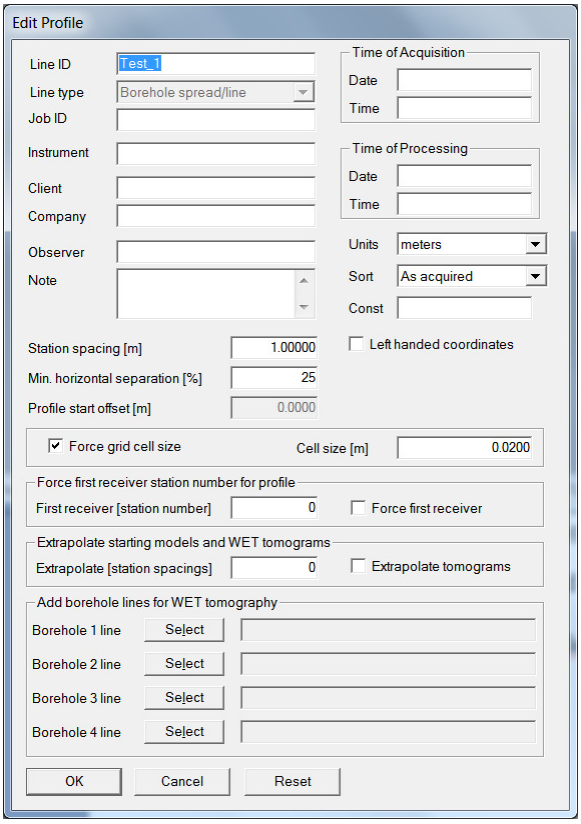

Fig. 19 : select *Header|Profile*. Check box *Force grid cell size*. Set *Cell size[m]* to 0.02. Click button *OK*.

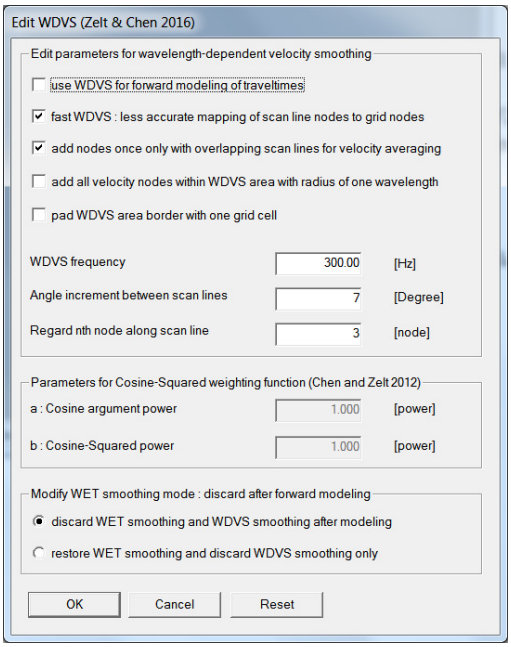

Fig. 20 : select *Model|WDVS Smoothing*. Edit as shown. Check box *discard WET smoothing*. Click *OK* button.

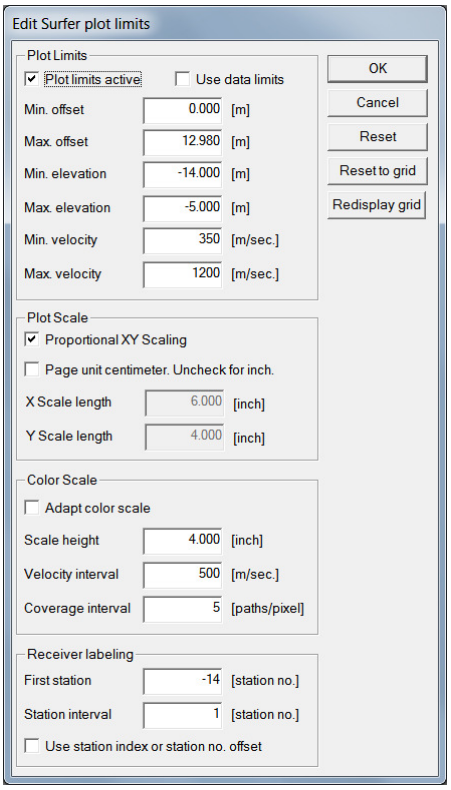

Fig. 21 : select *Grid|Surfer plot limits*. Edit as shown. Adapt *Min. velocity* to 350 m/s. Edit *Max. velocity* to 1,200 m/s. Click *OK* button.

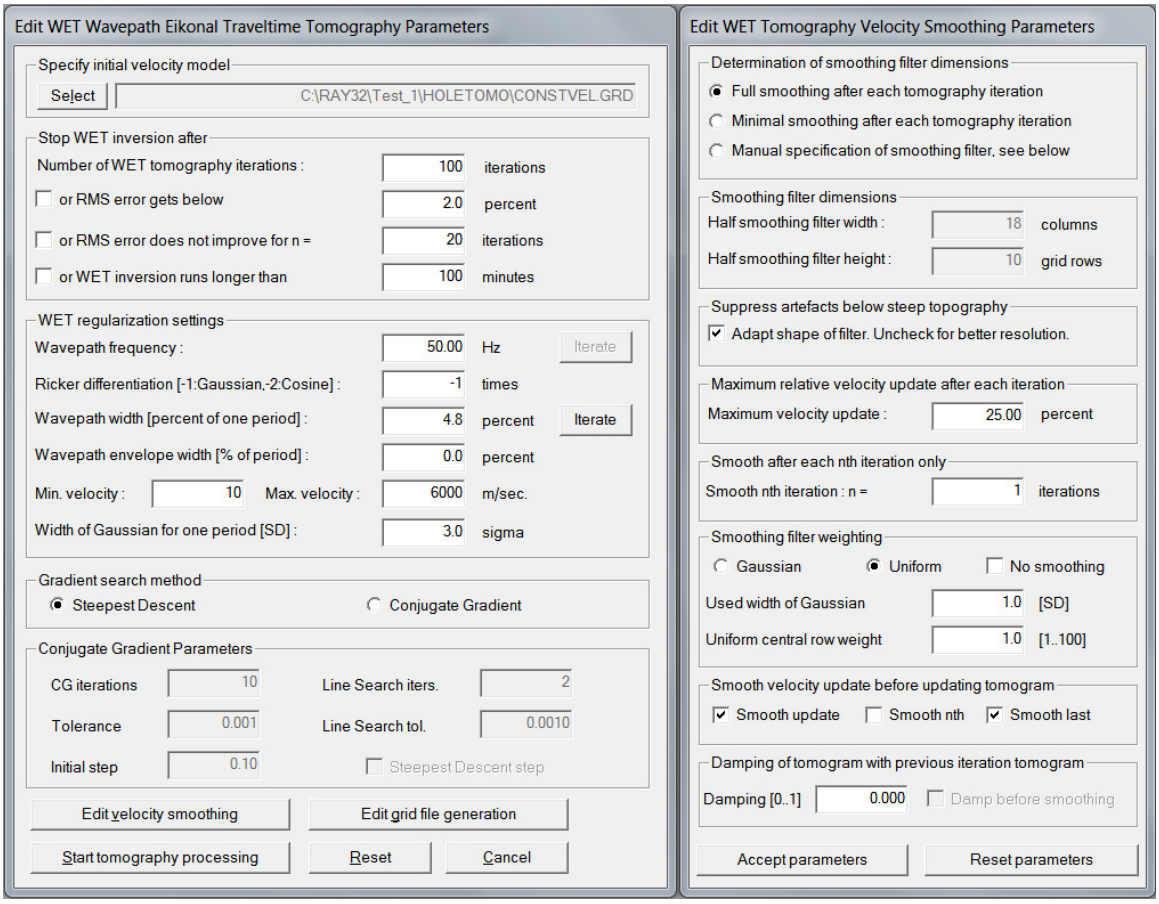

Fig. 22 : *WET Tomo|Interactive WET* main dialog (left). *Edit velocity smoothing* (right).

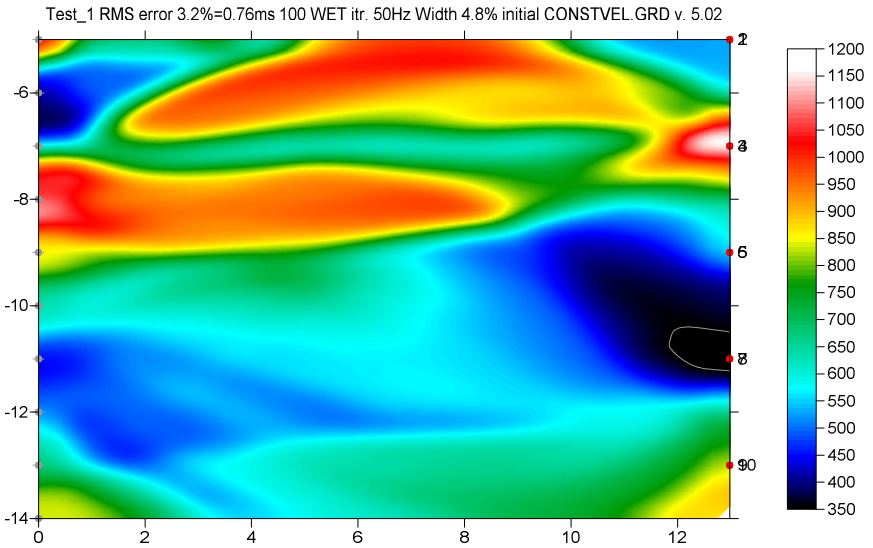

Fig. 23 : WET tomogram obtained with optimized WET (Fig. 22) and WDVS settings (Fig. 20). 100 *WET iterations* (Fig. 22 left). *Discard WET smoothing after forward modeling* (Fig. 20). Edit *Grid|Surfer plot Limits* as in Fig. 21. Constant-velocity starting model shown in Fig. 16.

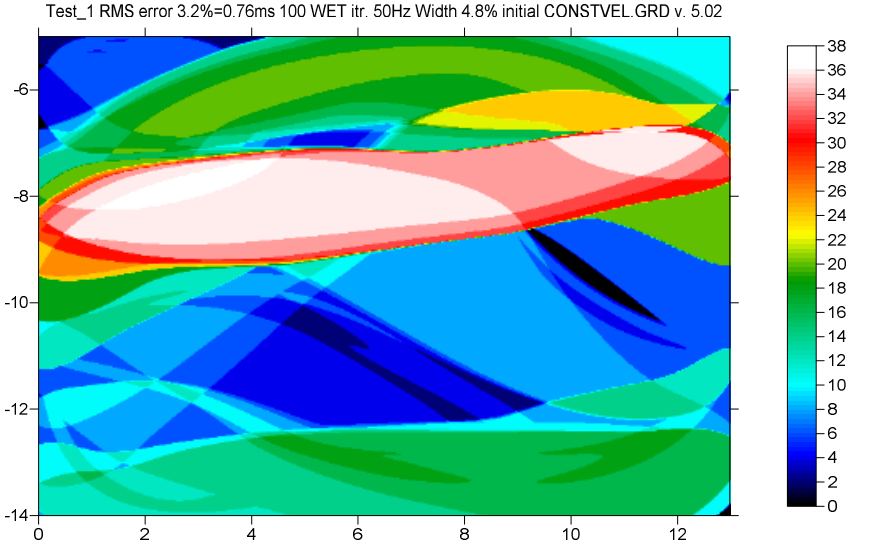

Fig. 24 : WET wavepath coverage plot obtained with Fig. 23. Unit is wavepaths per grid cell.

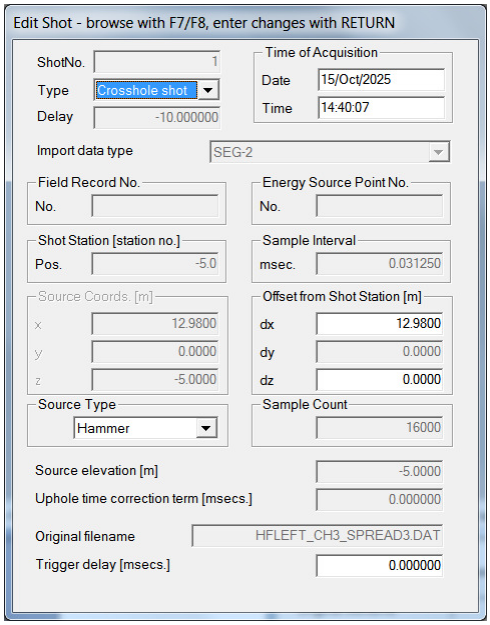

Fig. 25 : *Header|Shot*. Check if fields x and z in frame *Source Coords. [m]* match the *Source x offset from top-of-hole* and *Source depth below top-of-hole* as specified in SEG2_HoleMerge program (Fig. 5).

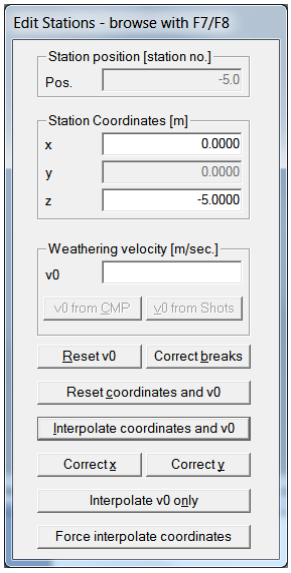

Fig. 26 : *Header|Station*. Use F7/F8 keys to browse to *Station position [station no.]* -5.0 as referenced in above *Header|Shot* (Fig. 23).

Download the .rar archive of the profile folder obtained with above processing (Fig. 18) from DropBox link

https://www.dropbox.com/scl/fi/0bkz8wr1l7ayc6k66bcnr/Test_1_Nov16_25.rar?rlkey=699d1h3h02gsn06ht3euei42z&st=1wbzlqmu&dl=0

Here is the DropBox link to .rar archive for profile folder for Fig. 23 :

https://www.dropbox.com/scl/fi/4rz9698iwh2n756xz0nq8/Test_1_Nov18_25.rar?rlkey=giwt1h3wij1inhl9s04kjw1ma&st=410v5i3z&dl=0

See also our updated 2025 manual

https://rayfract.com/help/rayfract.pdf

chapter ***Crosshole survey interpretation*** and chapter ***Downhole VSP interpretation*** and chapter ***Aggregate AMBROGEO or PASI 3-component borehole geophone channels into SEG-2 borehole spread files***.

See also our VSP tutorial https://rayfract.com/tutorials/PW27_Test.pdf showing P-wave VSP processing and our tutorial https://rayfract.com/tutorials/SH27_Test.pdf showing S-wave shear-wave VSP processing for the same VSP borehole.

See also our 2024 P-wave VSP tutorials https://rayfract.com/tutorials/TTBM6.pdf and https://rayfract.com/tutorials/TTBM4.pdf and our earlier VSP tutorial https://rayfract.com/tutorials/vsp.pdf

See also our crosshole tutorials https://rayfract.com/tutorials/MDW2011_23.pdf and https://rayfract.com/tutorials/b8b9.pdf

and our walkaway VSP tutorial https://rayfract.com/tutorials/walkaway.pdf .

See also our joint inversion of surface refraction spread with borehole receiver spread tutorial

https://rayfract.com/tutorials/11REFR.pdf

and our tutorial with receivers in 3 boreholes https://rayfract.com/tutorials/KING17.pdf .

- Doug Crice describes cross-hole and down-hole shear wave recording geometry in his paper http://geostuff.com/Downhole_Shearwaves.pdf
- we allow picking of shear waves on shot traces recorded with reversed shot polarity in our ***Trace\Shot point gather*** display. See above and our manual https://rayfract.com/help/rayfract.pdf chapter ***Shear wave picking*** and our borehole shear-wave VSP tutorials https://rayfract.com/tutorials/SH27_Test.pdf and https://rayfract.com/tutorials/BOATSH26.pdf .

Discussion

We show gathering of SEG-2 channels recorded with Geotomographie 3-component borehole geophone into SEG-2 receiver spread files sorted by channel number and receiver elevation. ***We assume that the 3-channel receiver trace files are named <receiver_depth><optional wave identifier>.DAT / .SG2 / .SEG2.***

1.DAT / 1HFLeft.DAT / 1HFRight.DAT means the borehole receiver was located at elevation -1m with the borehole top at elevation 0m. HFLeft or HFRight is the wave identifier and stands for "Horizontal force left" or "Horizontal force right" shear-wave source.

30.DAT / 30HFLeft.DAT / 30HFRight.DAT means the borehole receiver was positioned at the elevation of -30m. ***Rename your SEG-2 receiver channel files in Windows Explorer to match this file naming convention***.

Next we import the aggregated SEG-2 borehole receiver spread files into a Rayfract(R) borehole profile database. Next we apply frequency filtering and Automatic Gain Control (AGC) and pick the shear-wave first breaks in *Trace\Shot point gather*. Next we run our default Smooth inversion to obtain the shear-wave velocity tomogram. Finally we run 100 Steepest-Descent WET iterations (Fig. 22; Schuster 1993) and discard the WET smoothing after forward modeling (Fig. 20) to obtain an optimized WET tomogram with a lower RMS error than obtained with our default Smooth inversion.

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We thank our anonymous client for making available this interesting crosshole survey. According to the client : "the scope of this project was to use crosshole tomography to investigate Vs under a concrete cap to find evidence of voids. The shallowest shots were likely above the concrete cap, so it makes sense that some of the Vs values would be high." .

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