

## Tunnel Excavation Disturbed Zone (EDZ) imaging with Rayfract® version 3.35 :

Fig. 1 : left : *Trace*|*Shot gather*, right : *Refractor*|*Shot breaks*. Shows fit between picked times (solid colored curves) and modeled times (dashed colored curves) obtained by forward modeling over Fig. 2.

- File New Profile..., set File name to TUNNEL16 and click Save button
- set Station spacing to 0.2m in Header | Profile. See Fig. 8. Set Line type to Borehole spread/line.
- set Cell size to 0.05m. Check box Force grid cell size. Click button OK.
- unzip tunnel16 seg2 input.zip with SEG-2.DAT files in C:\RAY32\TUNNEL16\INPUT
- check File|Import Data Settings|Import circular borehole survey
- check File|Import Data Settings|X coordinate is corrected for topography already
- select *File Import Data*... and set *Import data type* to SEG-2
- leave *Default spread type* at 10: 360 channels.
- click Select button, navigate into C:\RAY32\TUNNEL16\INPUT, select file 30.DAT & click Open button
- click .HDR batch button and select batch file ...\INPUT\TUNNEL16.HDR . Check box Batch import.
- click Import shots button. All .DAT listed in TUNNEL16.HDR are imported.
- select File|Update header data|Update Station Coordinates...
- click *Select button* and select ...\INPUT\TUNNEL16.COR. *Click button Import and Reset.*
- select *File*|*Update header data*|*Update shotpoint coordinates*... & ...\INPUT\TUNNEL16.SHO .
- select File|Update header data|Update First Breaks... & ...\input\tunnel16.lst
- click Open button and confirm prompt
- select Trace|Shot gather, Window|Tile and browse with F7/F8 to shot no. 29 to obtain Fig. 1
- click title bar of Shot traces window, press ALT+P, set Maximum time to 5 ms and hit ENTER key
- press SHIFT+Q shortcut. Check boxes *Filter active & Bidirectional filter*. Set *Low corner frequency* to 2000Hz. Set *High corner frequency* to 2000Hz. Click *button Filter*.
- click title bar of Refractor|Shot breaks. Press ALT+P, set Maximum time to 5ms and hit ENTER key
- uncheck Mapping|Display raytraced traveltimes. Check Mapping|Color picked traveltime curves
- check WET Tomo|WET tomography Settings|Blank|Blank no coverage after last iteration
- check WET Tomo|WET tomography Settings|Blank|Blank no coverage on top of borehole tomogram
- check WET Tomo WET tomography Settings Edit maximum valid WET velocity
- select Smooth invert Custom 1D-gradient velocity profile and check Force grid limits. See Fig. 5.
- set *Grid bottom elevation* to -2m, *Grid top elevation* to 10m, *Left limit of grid* to -7m, *Right limit of grid* to 7m. Check *Force constant velocity* and set *Forced velocity* to 5000m/s. Click *button OK*.

- uncheck Smooth invert|Smooth inversion Settings|Beydoun weighting for borehole WET
- select WET Tomo | WET Velocity constraints. Click Select blanking file & ...\INPUT\digitized.bln
- check Polygon blanking active. Uncheck Pad polygon border. Check Extrapolate to top & Extrapolate to bottom & Extrapolate to left & Extrapolate to right. Click button OK. See Fig. 6.
- select *Smooth invert*|*WET with constant-velocity initial borehole model* & confirm prompts for default interpretation. Select *Grid*|*Surfer plot Limits*. See Fig. 7.
- click Reset to grid & select C:\RAY32\TUNNEL16\HOLETOMO\CONSTVEL.GRD. Check Plot limits active.
- set Min. velocity to 2000m/s & Max. velocity to 6500m/s. Check Proportional XY scaling. Click OK.
- set *WET Tomo*|*Interactive WET tomography*|*Number of iterations* to 20. Set *Wavepath frequency* to 500Hz, *Wavepath width* to 5%, *Min. velocity* to 3500m/s and *Max. velocity* to 6000m/s. See Fig. 4.
- set Width of Gaussian for one period [sigma] to 50. Click button Edit velocity smoothing . See Fig. 4.
- to disable WET smoothing check box No smoothing
- for older 3.36 builds of our software *disable WET smoothing* by setting *Smooth nth iteration* : *n* = to 100, unchecking *Smooth velocity update* and unchecking *Smooth last iteration*
- click buttons Accept parameters & Start tomography processing to obtain Fig. 2 & 3.



Fig. 2 : WET tomogram obtained with WET settings as in Fig. 4, starting model grid limits and velocity as in Fig. 5, velocity constraints as in Fig. 6, constant-velocity starting model. WET Tomo|WET tomography Settings|Blank no coverage after last iteration checked. Blank no coverage on top of borehole tomogram checked.

- for WET parameters used see archive <u>TUNNEL16 HoleTomo Mar14.rar</u> with starting model files CONSTVEL.GRD & CONSTVEL.PAR, VELOIT20.GRD & .PAR and .SRF Surfer 11 plots
- pick the ...\INPUT\DIGITIZED.BLN blanking file in Golden Software Surfer on CONSTVEL.SRF starting model plot with Surfer *Map|Digitize command* as described in <a href="https://support.goldensoftware.com/hc/en-us/articles/226661208-How-can-I-create-a-BLN-file-in-Surfer">https://support.goldensoftware.com/hc/en-us/articles/226661208-How-can-I-create-a-BLN-file-in-Surfer</a> . Pick points (polygon corners) a little bit inside the circular spread for *WET inversion and blanking* to work reliably.
- once you imported seg-2 .DAT files with ...\INPUT\TUNNEL16.HDR batch file you can export station coordinates with *File Export header data Export Station Coordinates*... to file coords.cor .
- edit COORDS.COR with any editor e.g. Microsoft WordPad and specify correct x & z coordinates in columns 2 & 4 for all station numbers listed in column 1. y coordinate (column 3) is all 0.0.
- export shotpoint coordinates with *File*|*Export header data*|*Export Shot Point Coordinates*... to file SHOTPTS.SHO
- edit SHOTPTS.SHO with Microsoft WordPad and specify correct x & z coordinates in columns 2 & 4 for all shot numbers listed in column 1. y coordinate (column 3) is 0.0 for all shots.

For help on *WET inversion* parameters see *Help menu*|*Contents*|*WET tomography processing* and <u>.pdf</u> reference chapter *WET Wavepath Eikonal Traveltime tomography*.



TUNNEL16 RMS error 2.9%=0.07ms 20 WET iters. 500Hz Width 5.0% initial CONSTVEL.GRD Vers. 3.35

Specify initial velocity model         Select       D:/ray32;TUNNEL16]HOLETOMO/CONSTVEL.GRD         Stop WET inversion after       Full smoothing after each tomography iteration         Number of WET tomography iterations:       20 iterations         or RMS error gets below       2.0 percent         or RMS error does not improve for n =       20 iterations         or WET inversion runs longer than       100 minutes         Wet regularization settings       500 Hz         Wavepath frequency:       500 Hz         Ricker differentiation [-1:Gaussian_2-Cosine] :       1 times         Wavepath envelope width [% of period] :       0.0 percent         Min velocity :       3500 Max velocity :       6000 m/sec.         Width of Gaussian for one period [sigma] :       500 sigma       Smoothing filter weighting         Cradient search method       Conjugate Gradient       0.0010         Min velocity update       25.00 percent       Smoothing filter weighting         CG iterations       10       Line Search iters.       2         Tolerance       0.001       Line Search tol.       0.0010         Initial step       0.10       Steepest Descent steation       Smooth velocity update       Smooth last iteration         Darping of tomogram with previous iteration       Damping [0.1] </th <th>Edit WET Wavepath Eikonal Traveltime Tomography Paramet</th> <th colspan="3">Edit WET Tomography Velocity Smoothing Parameters</th>	Edit WET Wavepath Eikonal Traveltime Tomography Paramet	Edit WET Tomography Velocity Smoothing Parameters		
Stop WET inversion after         Number of WET tomography iterations:         0 or RMS error gets below         20 percent         or RMS error does not improve for n =         20 iterations         or WET inversion runs longer than         100 minutes         Wet regularization settings         Wet regularization settings         Wet regularization settings         Wavepath frequency:         Ricker differentiation [-1:Gaussian-2:Cosine]:         -1 times         Wavepath envelope width [% of period]:         00 percent         Min. velocity:       3500         Width of Gaussian for one period [sigma]:       500         6 Steepest Descent       C Conjugate Gradient         Conjugate Gradient Parameters       C Giterations         CG iterations       10         10       Steepest Descent tot.         0001       Line Search tot.         Initial step       0.10         Edit yelocity smoothing       Edit grid file generation	Specify initial velocity model Select D:\rav32\TUNNEL16\HOLE	Determination of smoothing filter dimensions • Full smoothing after each tomography iteration		
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□ or RMS error does not improve for n =       20       iterations         □ or WET inversion runs longer than       100       minutes         WET regularization settings       500       Hz       terate         Wavepath frequency:       500       Hz       terate         Ricker differentiation [-1:Gaussian-2:Cosine]:       -1       times         Wavepath width [percent of one period]:       50       percent         Wavepath envelope width [% of period]:       0.0       percent         Min. velocity:       3500       Max. velocity:       6000         Gradient search method       6       Steepest Descent       C onjugate Gradient         Conjugate Gradient Parameters       2       Tolerance       0.001       Line Search iters.       2         Tolerance       0.001       Line Search tol.       0.0010       Steepest Descent teration         Edit yelocity smoothing       Edit grid file generation       Damping of tomogram with previous iteration tomogram	or RMS error gets below 2.0	percent	Smoothing filter dimensions	
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Wavepath width [percent of one period]:       5.0       percent       Iterate         Wavepath envelope width [% of period]:       0.0       percent       Smooth after each nth iteration only         Min. velocity:       3500       Max velocity:       6000       m/sec.         Width of Gaussian for one period [sigma]:       50.0       sigma         Gradient search method       Conjugate Gradient       Smooth nth iteration: n =       100         Conjugate Gradient Parameters       Conjugate Gradient Parameters       10       sigma         CG iterations       10       Line Search iters.       2         Tolerance       0.001       Line Search tol.       0.0010         Initial step       0.10       Steepest Descent step       Damping of tomogram with previous iteration tomogram         Edit velocity smoothing       Edit grid file generation       Damping [0.1]       0.000       Demp before smoothing	Ricker differentiation [-1:Gaussian,-2:Cosine] : -1	times	Maximum relative velocity update after each iteration	
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Min. velocity:       3500       Max. velocity:       6000       m/sec.         Width of Gaussian for one period [sigma]:       50.0       sigma       Smooth nth iteration: n =       100       iterations         Gradient search method	Wavepath envelope width [% of period] : 0.0	percent	Smooth after each nth iteration only	
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Gradient search method       Image: Conjugate Gradient         Image: Conjugate Gradient Parameters       Image: Conjugate Gradient Parameters         Conjugate Gradient Parameters       Image: Conjugate Gradient Parameters         CG iterations       Image: Conjugate Gradient Parameters         Tolerance       0.001         Initial step       Image: Conjugate Gradient Parameters         Edit velocity smoothing       Edit grid file generation	Width of Gaussian for one period [sigma] : 50.0	sigma	Smoothing filter weighting	
Image: Steepest Descent       Image: Conjugate Gradient         Conjugate Gradient Parameters       Uniform central row weight         CG iterations       10         Line Search iters.       2         Tolerance       0.001         Initial step       0.10         Edit velocity smoothing       Edit grid file generation	Gradient search method		C Gaussian 🖲 Uniform 🔽 No smoothing	
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CG iterations       10       Line Search iters.       2         Tolerance       0.001       Line Search tol.       0.0010         Initial step       0.10       Steepest Descent step       Damping for tomogram with previous iteration tomogram         Edit velocity smoothing       Edit grid file generation       Damping [01]       0.000       Demp before smoothing	Conjugate Gradient Parameters		Uniform central row weight 1.0 [1100]	
Tolerance       0.001       Line Search tol.       0.0010       Image: Search tol.       Image: Sear	CG iterations 10 Line Search iters.	2	Smooth velocity update before updating tomogram	
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Edit velocity smoothing         Edit grid file generation	Initial step 0.10 Steepest D	lescent step	Damping of tomogram with previous iteration tomogram	
	Edit velocity smoothing Edit grid file generation		Damping [01] 0.000 Damp before smoothing	
Start tomography processing Reset Cancel Accept parameters Reset parameters	Start tomography processing Reset	<u>C</u> ancel	Accept parameters Reset parameters	

Fig. 4 : WET parameter settings for Fig. 2 & 3. left : main interactive WET dialog. right : edit velocity smoothing

Fig. 3 : WET wavepath coverage plot obtained with Fig. 2. Shows number of wavepaths per pixel.

Replace gradient velocity profile					
Force limits of starting model grid					
Force grid limits	Reset limits to grid				
Grid bottom elevation [m] -2.000	Grid top elevation [m] 10.000				
Left limit of grid [m] -7.000 Right limit of grid [m] 7.000					
Replace computed velocity gradient with user velocity profile					
Select velocity profile					
- Force velocity for constant-velocity starting model					
OK Cancel Reset					

Fig. 5 : Smooth invert|Custom 1D-gradient velocity profile dialog. Specify starting model grid limits and velocity.

WET velocity constraints					
Keep velocity unchanged below 1500 m/sec.					
Keep velocity unchanged above 3500 m/sec.					
Blank tomogram in polygon area specified in Surfer BLN blanking file					
✓ Polygon blanking active Blank outside polygon					
Smooth polygon border Pad polygon border					
Select blanking file D:\RAY32\TUNNEL16\INPUT\DIGITIZED.BLN					
Reset blanked tomogram pixels to values in Surfer .GRD mask grid file					
Mask grid file active					
Select mask grid file					
Extrapolate velocity to blanking file polygon boundary					
▼         Extrapolate to top         ▼         Extrapolate to left					
✓ Extrapolate to bottom ✓ Extrapolate to right					
OK Cancel Reset					

Fig. 6 : WET Tomo|WET Velocity constraints dialog. Specify blanking file with Select blanking file button.

Picking first breaks for this data set was difficult because of noisy traces; see Fig. 1.

You can reuse the same recording geometry, import routine and interpretation approach for imaging columns or tree trunks. Plant the circular receiver spread on circumference/perimeter of column or around tree trunk. In Fig. 6 check *Blank outside polygon*. When picking the .BLN boundary polygon on CONSTVEL.SRF plot pick the polygon points a little bit outside the circular receiver spread.

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Edit Surfer plot limit	ts		
-Plot Limits			ОК
Plot limits active			
Min. offset	-7.000	[m]	Cancel
Max. offset	7.000	[m]	Reset
Min. elevation	-2.000	[m]	Reset to grid
Max. elevation	10.000	[m]	
Min. velocity	2000	[m/sec.]	
Max. velocity	6500	[m/sec.]	
Plot Scale Proportional XY Page unit is cent	Scaling timeter. Unche	eck for inch.	
X Scale length	6.000	[inch]	
Y Scale length	4.000	[inch]	
Color Scale	le 4.000 500	[inch] [m/sec.]	
Coverage interval	5	[paths/pixel]	

Fig. 7 : Grid|Surfer plot Limits dialog. Click button Reset to grid and select ... \HOLETOMO \CONSTVEL.GRD

Edit Profile				
Line ID Line type Job ID	TUNNEL16 Borehole spread/line test import SEG-2 with geom	 netry	Time of Acquis	sition
Instrument Client Company	Geometrics SeisModules		Time of Proces	ssing
Observer Note		* *	Units meters Sort As acc Const	s 🗨
Station spacin Min. horizontal Profile start off	g [m] 0   separation [%] 0   set [m] 00	25 0.0000	☐ Left handed ▼ Force grid o Cell size [m]	l coordinates cell size 0.0500
Add borehol Borehole 1 lin Borehole 2 lin Borehole 3 lin Borehole 4 lin	e lines for WET tomography- e Select e Select e Select e Select			
OK	Cancel F	leset		

Fig. 8 : Header|Profile dialog. Check Force grid cell size and set Cell size to 0.05m