Stillwater Model Dam line D1P2NO24 P-wave refraction, 100 WET iterations @30Hz using wavepath width 30 percent and Ricker wavelet for back-projection of residuals





Fig. 1 : 1D-gradient starting model obtained with Smooth invert|WET with 1D-gradient initial model. Default settings. Grid cell size forced to 0.04m in Header|Profile (Fig. 7). Red circles are sources. Grey symbols are geophones.

Nov. 2010, D1, P2 RMS error 3.1%=0.95ms 100 WET itr. 30Hz Width 30.0% initial GRADIENT.GRD v. 4.02



Fig. 2 : 100 WET iterations, WET frequency 30Hz, Wavepath width 30%. Starting model is Fig. 1. Ricker differentiation 0. Minimal WET smoothing. Don't adapt shape of filter. See Fig. 5. No WDVS smoothing.



Nov. 2010, D1, P2 RMS error 3.0%=0.94ms 100 WET itr. 30Hz Width 30.0% initial GRADIENT.GRD v. 4.02

Fig. 3 : WET wavepath coverage plot obtained with Fig. 2. Unit is summed wavepath weight squared. Wavepath coverage plot is sharpened with *Raise wavepath weight to power* = 2.0. See Fig. 8.



Nov. 2010, D1, P2 RMS error 3.0%=0.94ms 100 WET itr. 30Hz Width 30.0% initial GRADIENT.GRD v. 4.02

Fig. 4 : Same WET inversion as Fig. 2 but with WDVS smoothing activated @600Hz (Fig. 6).

We reprocessed the original data used for Stillwater Model Dam Fig. 3.13 in PhD Thesis Leti Wodajo (Wodajo, 2018) to better image two constructed low-velocity regions in the dam.

Compare our optimized interpretation in Fig. 4 with Fig. 3.13 (Wodajo, 2018). While Fig. 3.13 was obtained with default WET frequency 50Hz and default wavepath width 5%, we lowered the WET frequency to 30Hz and increased the wavepath width to 30% (Fig. 5). Also we changed the Ricker differentiation from default -1 (Gaussian) to 0 (Ricker wavelet; Schuster 1993).

Edit WET Wavepath Eikonal Traveltime Tomography Parameters	Edit WET Tomography Velocity Smoothing Parameters		
Specify initial velocity model	Determination of smoothing filter dimensions		
Select D:\ray32\D1P2No24\GRADTOM0\GRADIENT.GRD	C Full smoothing after each tomography iteration		
- Stop WET inversion offer	Minimal smoothing after each tomography iteration		
Number of WET tomography iterations 100 iterations	C Manual specification of smoothing filter, see below		
	- Smoothing filter dimensions		
	Half smoothing filter width : 3 columns		
or RMS error does not improve for n = 50 iterations	Half smoothing filter height :		
or WET inversion runs longer than 100 minutes			
WET regularization settings	Suppress artefacts below steep topography		
Wavepath frequency : 30.00 Hz Iterate	Adapt shape of filter. Uncheck for better resolution.		
Ricker differentiation [-1:Gaussian,-2:Cosine] : 0 times	Maximum relative velocity update after each iteration		
Wavepath width [percent of one period] : 300 percent	Maximum velocity update : 25.00 percent		
Wavepath any alapa width 1% af pariod :			
wavepaul envelope widul [% of period].	Smooth after each nth iteration only		
Min. velocity : 10 Max. velocity : 3000 m/sec.	Smooth nth iteration : n = 1 iterations		
Width of Gaussian for one period [sigma] : 3.0 sigma	Smoothing filter weighting		
Gradient search method	C Gaussian		
Steepest Descent Conjugate Gradient	Used width of Gaussian 1.0 sigma		
Conjugate Cradient Recomplete	Uniform central row weight 1.0 [1100]		
CG iterations 10 Line Search iters. 2	Smooth velocity update before updating tomogram		
Tolerance 0.001 Line Search tol. 0.0010	Smooth update Smooth nth Smooth last		
Initial step 0.10 V Steepest Descent 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		

Fig. 5 : WET Tomol Interactive WET main dialog (left). Edit velocity smoothing (right).

We sharpened the *Wavepath coverage plot* (Fig. 3) with *Raise wavepath weight to power* = 2.0 (Fig. 8) to optimally visualize and match low-velocity anomalies (Fig. 2 and Fig. 4) on the coverage plot.

We used the default 1D-gradient starting model (Fig. 1) obtained by laterally averaging the DeltatV pseudo-2D velocity (<u>Sheehan, 2005</u>). We used optimized WET inversion settings and smoothing as in Fig 5. When enabling *Wavelength-Dependent Velocity Smoothing* (WDVS; <u>Zelt and Chen 2016</u>; <u>Rohdewald, 2021a</u>; <u>Rohdewald, 2021b</u>) at 600Hz (Fig. 6) for WET inversion the two central low-velocity zones get separated horizontally more clearly (Fig. 4).

We set *Ricker differentiation* to 0 (Fig. 5) using a Ricker wavelet for weighting of WET velocity update across the wavepath during back-projection of residuals (Schuster, 1993). Ricker wavelet weighting works better than default Gaussian update weighting (Ricker differentiation = -1) for this line.

Before running our WET inversion (Fig. 5) also check option *Model*|*Forward modeling Settings*|*Normalize RMS error with maximum picked time* to be compatible with RMS error display on top of Fig. 3.13 (Wodajo, 2018) obtained with version 3.20 of our software.

For this line we observed that the lower the WET *Wavepath frequency* and the wider the WET *Wavepath width* (Fig. 5) the deeper the low-velocity zone in center of tomogram is imaged. This *dependence of imaged anomaly depth on WET wavepath frequency and width* confirms that you need a-priori information about the depth of low-velocity zones for optimal interpretation with our WET inversion (<u>Wodajo, 2018</u>). Also this dependence on WET parameters reconfirms that SRT interpretation is non-unique especially in case of decreasing velocity with increasing depth.

Edit WDVS (Zelt & Chen 2016)	-	1.10		
Edit parameters for wavelength-dependent velocity smoothing use WDVS for forward modeling of traveltimes				
▼ fast WDVS : less accurate mapping of scan line nodes to grid nodes				
WDVS frequency 6	00.00 [Hz	1		
Angle increment between scan lines	7 [De	gree]		
Regard nth node along scan line	3 [no	de]		
Parameters for Cosine-Squared weighting function (Chen and Zelt 2012)				
a : Cosine argument power	1.000 [po	wer]		
b : Cosine-Squared power	1.000 [po	wer]		
Modify WET smoothing mode : discard after forward modeling				
C discard WET smoothing and WDVS smoothing after modeling				
restore WET smoothing and discard WDVS smoothing only				
OK Cancel Reset				

Fig. 6 : Model|WDVS Smoothing

Edit Profile	"Pallentat	NAME OF TAXABLE PARTY.
Edit Profile	vv. 2010. D1, P2 straction spread/line v wave refraction sode, Ver. geophone SDA SPA	Time of Acquisition Date 11/30/2010 Time 09:30 AM Time of Processing Date 12/13/2011 Time 02:07 PM Units meters
Note da	m was loaded for 18 hrs	Sort As acquired
Station spacing [m Min. horizontal sep Profile start offset [First receiver [stati	n] 0.34000 paration [%] 25 (m] 0.0000 ion number] 0	Left handed coordinates Force grid cell size Cell size [m] 0.0400 Force first receiver
Add borehole line Borehole 1 line Borehole 2 line Borehole 3 line Borehole 4 line	es for WET tomography Seject Seject Seject Seject	
ОК	Cancel Reset	

Fig. 7 : Header|Profile

Wavepath coverage plot
Specify thinning of wavepath coverage Coverage plot thinning active Plot wavepaths for every nth shot: n = 3 Wavepaths for every nth receiver: n =
Sharpen wavepaths in coverage plot Image: Sharpen wavepaths active Raise wavepath weight to power 20
OK Cancel Reset

Fig. 8 : WET Tomo|Coverage plot setup

- The profile database is available at https://rayfract.com/tutorials/D1P2No24_seis32_50ms_July21_2021.rar
- download above .rar archive to your hard disk
- > open Windows Explorer
- navigate into your download directory
- ▶ select the .rar archive with left mouse button
- ▶ right-click the selected .rar archive and select "Copy" command
- in Windows Explorer navigate into your C:\RAY32 root directory
- click "New folder" and create a new directory C:\RAY32\D1P2NO24
- > navigate into this new folder by left-clicking it
- > paste above .rar archive with "Paste" command in Windows Explorer "Organize" menu
- right-click the .rar archive in your C:\RAY32\D1P2NO24 directory and select "Extract here" command
- start up Rayfract[®] via desktop icon
- select File|Open Profile and C:\RAY32\D1P2NO24\SEIS32.DBD
- see our <u>download instructions</u> for details on usage of Windows Explorer and how to get started with our tutorials.



Fig. 9 : Trace|Shot gather (left). Red circles are picked first breaks. Blue crosses are modeled first breaks. Refractor|Shot breaks (right). Solid grey&blue curves are picked traveltimes. Dashed blue curves are modeled times.



Fig. 10 : Trace|Offset gather for common offset of 4.59 meters (top). Refractor|Offset breaks (bottom).

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