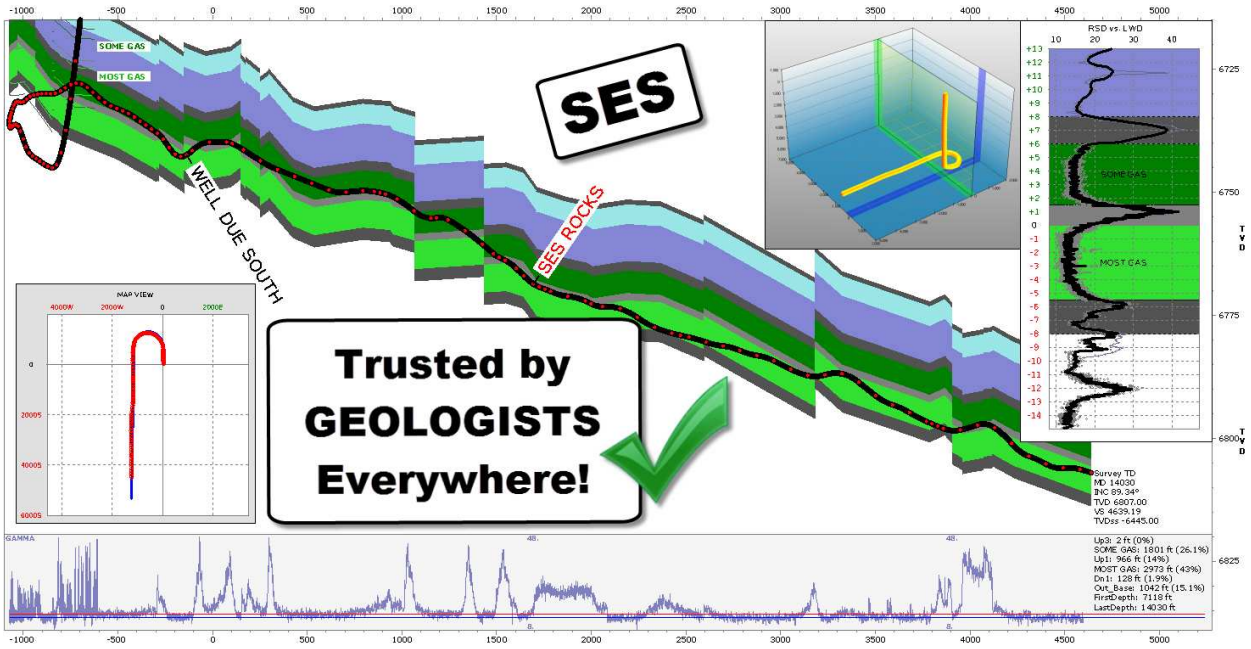
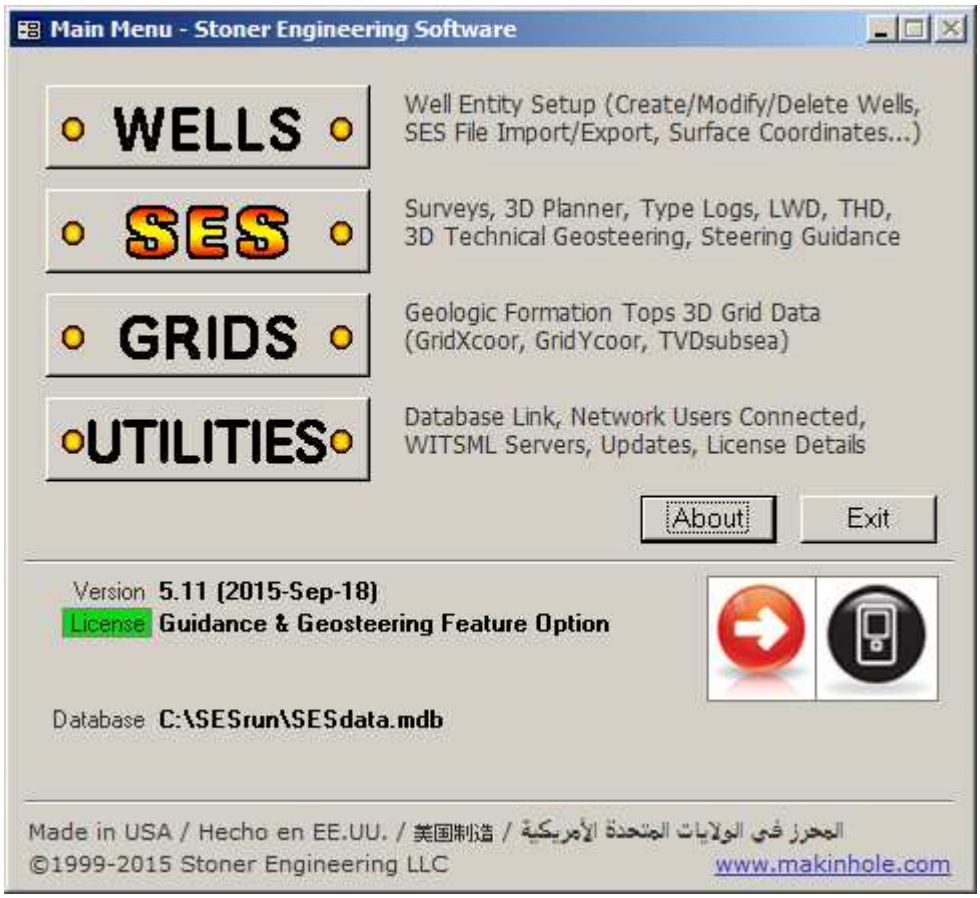
Stoner Engineering Software v5.11

SES USER MANUAL

English Edition





SES User Manual
September 24, 2015

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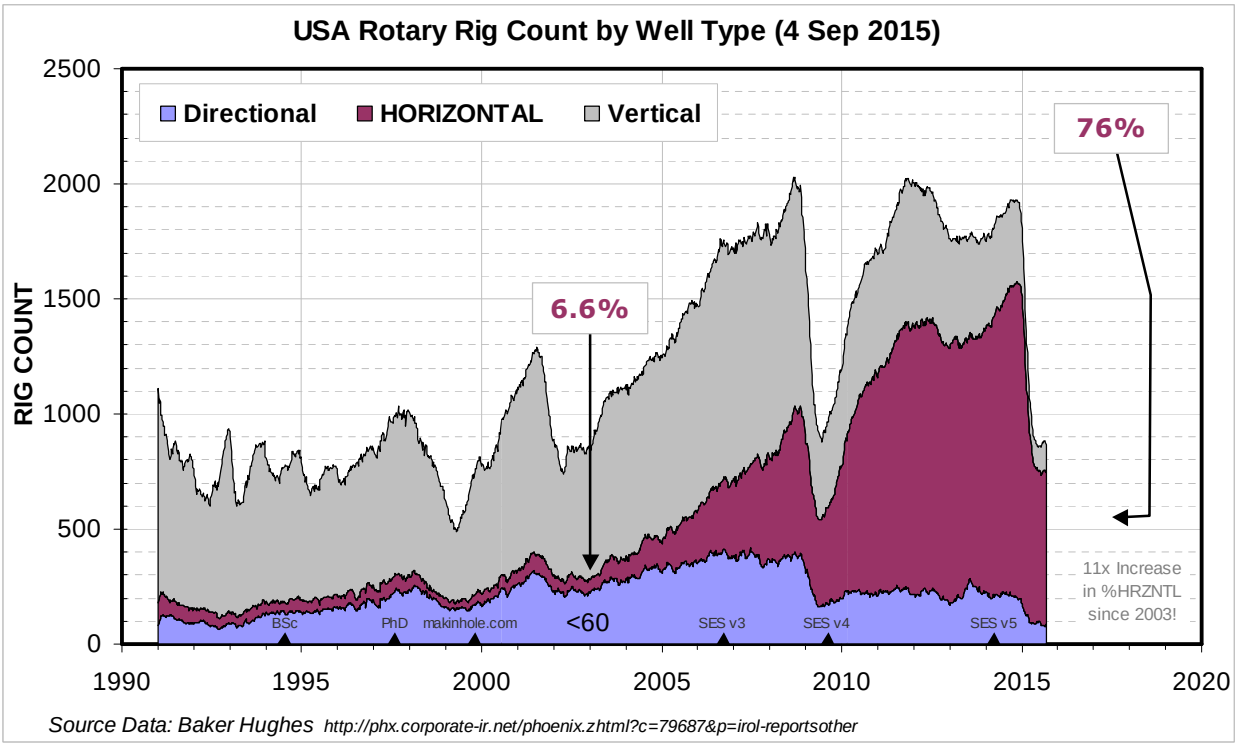


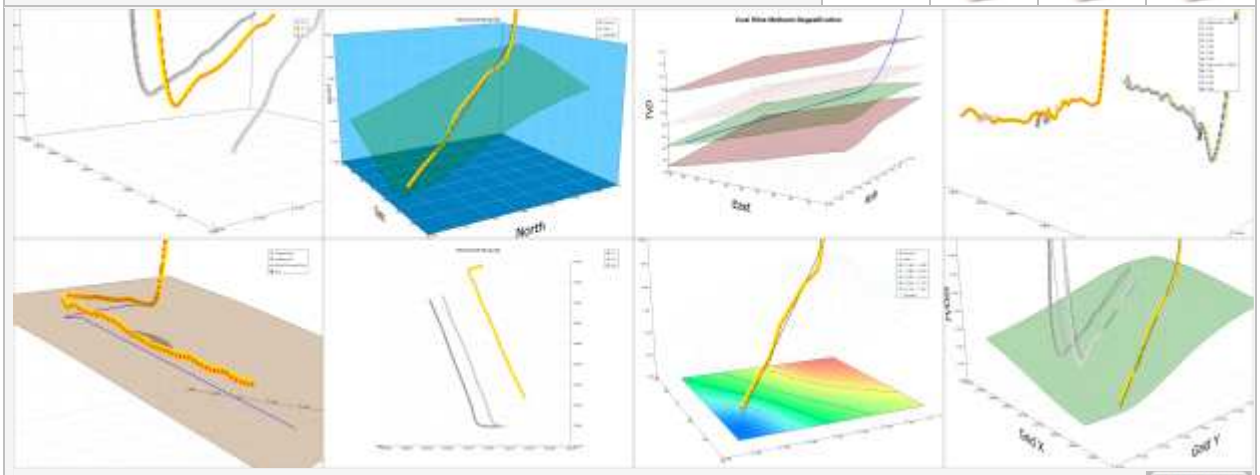
1. INTRODUCTION

Oil and natural gas horizontal drilling operations significantly surged starting in the early-to-middle 2000s and with it created a new level of demand for improved software technology that could simplify and enhance the process of tracking and managing such operations from geometric AND geologic perspectives. **Stoner Engineering Software** (**SES**) is a full-suite solution to this demand. SES continues to evolve to the changing and refined everyday needs of industry participants that choose SES.

SES is specialized horizontal and directional well planning and execution software, including 3D technical geosteering and directional steering guidance from Fuzzy Logic based directional control technology.

Key features of **SES** include:

FREE Feature Option	FREE	BASIC	G	G&G
Easily load/update data	✓	✓	✓	✓
Compute directional survey, with 2D and 3D graphing	✓	✓	✓	✓
Interpolate survey for Cartesian coordinates at any MD	✓	✓	✓	✓
Compute 3D directional well plan with unlimited targets	✓	✓	✓	✓
Vertical section azimuth set by individual survey or plan	✓	✓	✓	✓
Bearings north reference set by individual survey or plan	✓	✓	✓	✓

Simultaneous multi-user access to database on network drive	✓	✓	✓	✓
Run multiple instances independently from one computer	✓	✓	✓	✓
Easily transfer data between SES users or databases	✓	✓	✓	✓
Easily transfer data to other O&G software applications	✓	✓	✓	✓
Create directional survey or plan report for regulatory filing	✓	✓	✓	✓
USA & metric units supported	✓	✓	✓	✓
BASIC Feature Option		**BASIC**	**G**	**G&G**
Compute Technical Hole Deviation (THD)		✓	✓	✓
Create THD Logs, with vertical section and plan views		✓	✓	✓
View geologic model from 3D grid/seismic data interpolation		✓	✓	✓
Explore 3D graphs of wellbore paths & grid surfaces		✓	✓	✓
 SES 3D Viewer: surveys, plans, single-well, multi-well, and grids; click-n-drag rotate/zoom/pan Enlarge				
Multiple license formats supported		✓	✓	✓
GEOSTEERING Feature Option ("G")			**G**	**G&G**
Industry's *most advanced* 3D Technical Geosteering logic			✓	✓
Huge assortment of features to enhance interpretation quality			✓	✓
Use multiple type logs to help improve interpretation accuracy			✓	✓
Create interpretation gaps/overlaps while actively geosteering			✓	✓

Graph up to 8 LWD data curves while actively geosteering			✓	✓
Easily create a "derived" type log from interpretation portions			✓	✓
Smooth noisy LWD data on the fly while still displaying raw data			✓	✓
Rescale type log and/or LWD data on the fly			✓	✓
Easily manage multiple working hypotheses/interpretations			✓	✓
Generate detailed/annotated TVD vs. MD|VS cross-sections			✓	✓
Display well paths, payzone, and multiple tracks of LWD data			✓	✓
Display multiple offset layers for enhanced visualization			✓	✓
Display interpolated 3D grid data along wellbore & ahead of bit			✓	✓
Post center-line & parallels for new planned well path for ops			✓	✓
Calculate & post current footage and percent-in-zone stats			✓	✓
Export layer properties/coordinates to revise 3rd-party software			✓	✓
Display and size inset map view of survey(s) & plan			✓	✓
Display and size inset RSD track of interpretation			✓	✓
Size main cross-section graph width and set paper size			✓	✓
Display one custom image/logo			✓	✓
GUIDANCE & GEOSTEERING Feature Opt. ("G&G")				**G&G**
Display up to four custom images/logos on cross-sections				✓
Generate and display image logs from 8-sector Azimuthal data				✓
 SES-generated image log from 8-sector azimuthal gamma ray data Enlarge				
RT data loading/updating via WITSML server import via internet				✓
Receive steering guidance from Fuzzy Logic control technology				✓
Guidance calculated from geometric plan or from geosteering target				✓

1.1 Client Care

Our website contact form is the most reliable method of contacting Stoner Engineering LLC for any reason (e.g., for technical assistance, licensing/pricing, training options/resources). You may also send email directly to support at makinhole dot com or call using the phone numbers provided online. Please, feel free to contact us for any reason!

1.2 User Manual Brief

SES User Manual presents all main screens found within SES and details their purposes and functionalities.

Main Menu is the front door to SES.

UTILITIES screen is used to set SES Database, list computers using SES Database, setup WITSML server access, check for available SES updates, and address licensing-related issues.

GRIDS screen is used to transfer 3D grid/seismic geologic model data into SES for general interpolation within SES.

WELLS screen is used to manage the Wells in SES Database.

SES screen is the heart of SES and is comprised of multiple other screens presented in tab format.

- **Surveys** - manage directional survey data and annotations
- **Planner** - manage directional well plan designs and transfers
- **Type Log** - manage logging correlation data from offset wells and derived datasets
- **LWD** - manage drilling/correlation data from the wellbore being analyzed
- **Geosteer** - manage geologic correlation creation (**ParamTuner**)
- **THD Technology** - calculate THD and directional steering guidance, and generate THD logs
- **Cross-Sections** - manage the visual presentation of final interpretation and related results

1.3 System Requirements

SES requires **Microsoft Windows** (64-bit or 32-bit, 10/8/7/Vista/XP/2000/NT) operating system and **32-bit Microsoft Access/Excel** (2016/2013/2010/2007/2003/2002/2000). Currently we recommend 64-bit Microsoft Windows 7 with Microsoft Access/Excel 2010, but all 32-bit Access/Excel versions mentioned are fully supported. A free run-time version of Microsoft Access may be available from Microsoft. Running SES with an older version of Microsoft Access/Excel requires its respective Service Pack 3.

A CPU speed of 2.4GHz or better and a monitor screen resolution of 1024x768 or larger are recommended. Some SES screens can effectively resize only up to 22 inches horizontally or 22 inches vertically. SES has been altered and tested to be compatible with the simplified Chinese version of Microsoft Office/Windows.

In order to successfully run SES, the user must have full file permissions (read/write/create/delete) to the folder containing the SES run-time file (SES.mde) and to the folder containing SES Database (SESdata.mdb). UTILITIES screen, Network tab displays the path to the SES run-time folder and file. The default SES installation folder is C:\SESrun\ and may be changed during installation. Main Menu and UTILITIES screen, SES Database tab display the location of SESdata.mdb to which SES is attached.

1.4 Installation/Licensing

SES Installer, named something like "SES_5_49_Setup.exe", may be downloaded from SES Download page. Fully downloading SES Installer to a hard drive is recommended over directly running SES Installer from a browser. With SES not running (i.e., from a prior installation) and with Windows Admin privileges, run SES Installer and follow the on-screen instructions. SES Installer creates the "SES 5" icon on your

desktop with which to launch SES. In rare cases Windows desktop may initially need refreshed to see the icon.

SES includes both free and paid software. A valid, non-expired License is required to run paid SES. SES supports multiple license formats including machine-specific, flash-drive, floating-network, and magic-password (for emergencies and mass training). Please contact us or view SES Licensing page for more information about licensing and pricing. A free trial-period license is typically available and may be requested from within SES (UTILITIES screen, License tab, "Request Machine-Specific License").

A security/registry installation of SES occurs upon *first use* of SES and is Windows user-login dependent. During this step four numbers are presented to the user for manual keyboard entry in order to acknowledge and accept the End User License Agreement and to proceed. To perform an SES **Virtual Machine Install**, enter 0000 when prompted at this step. The SES Virtual Machine Install disables SES machine-specific licensing. An SES Virtual Machine Install is required if SES is being deployed via virtual-machine/application-virtualization, which would also require SES floating-network license format use. Temporary floating-network license check-out, whereby a floater seat is temporarily converted to a machine-specific license for SES use away from the network for up to nine (9) days, is NOT supported with the SES Virtual Machine install option.

1.5 SES Run (SES.mde)

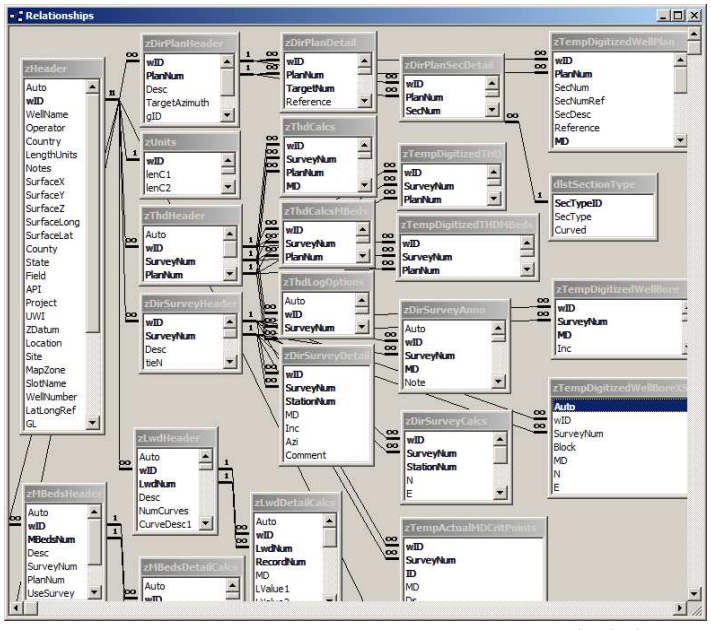
SES Installer adds program group "Stoner Engineering" to your Windows Start—All Programs menu. Under "Stoner Engineering" is the "SES 5" icon that when clicked will launch SES, assuming the above system requirements are met. The SES icon on the desktop may also be double-clicked to run SES. Yet another alternative method to launch SES is to manually open SES.mde—the SES run-time file—directly from Microsoft Access or by using Windows Explorer.

With most versions of Microsoft Access, you may be prompted with security warning messages upon running SES. Select "Open" or "Enable" or otherwise navigate through the dialog boxes to get SES opened without restrictions. **To permanently change Microsoft Access settings so you never have to click "Open" when launching SES**, follow these instructions. An alternative method is to open Microsoft Access stand-alone and change the security settings to "Low" using menu Tools…Macro…Security.

SES may be run multiple times from the same computer at the same time (i.e., **SES supports multiple instances**, as long as SES is connected to the same SES Database). Some SES users find it easier to monitor multiple wells simultaneously using multiple instances of SES and multiple monitors.

1.6 SES Database (SESdata.mdb)

SES data (e.g., directional surveys, surface coordinates, offset type log data, LWD data, well plans, geologic grids, geologic bed interpretations, THD, etc.) are all stored in a Microsoft Access relational database in a particular but open format. A fresh SES installation will include a *default* database populated with examples and named "SESdata.mdb". Installing an SES version upgrade *or uninstalling* SES will *not* delete or overwrite or change your existing SES database(s)!



The SES v5.x *default* SESdata.mdb file, which contains multiple technical geosteering, grid use, THD, and well plan examples, may also be downloaded from SES Technical

Support page. An *empty* SESdata.mdb file may be downloaded from the same page. An "empty" SES Database file may also manually be generated by deleting all wells using WELLS screen; see **4.5 Multi Edit/Delete**.

It is important to understand to which SESdata.mdb your SES is connected and where the file is located. SESdata.mdb should be backed-up regularly as a safe-computing precautionary measure in order to recover from hard drive failure, catastrophic database file corruption, or the like. The SESdata.mdb file location is displayed on Main Menu and UTILITIES screen, SES Database tab. UTILITIES screen, SES Database tab is used to connect SES to a specific SES database file (e.g., SESdata.mdb located on a network hard drive).

In addition to running multiple instances of SES at the same time, **SES also allows simultaneous multi-user access to the same SES Database**.

1.7 SES User Settings (SESuser.mdb)

User-specific settings are stored in a custom Microsoft Access database file named SESuser.mdb. This file is automatically generated if not present and it is automatically upgraded from time to time when applicable. SESuser.mdb is located in the same folder from where SES is being run.

User-specific settings stored in SESuser.mdb include:

- last ten (10) SES Databases to which SES has been connected (for fast recall/switching)
- WITSML server login details (username, password, URL, proxy server, etc.)
- WITSML well-specific parameters encountered using SES WITSML features from multiple screens
- custom colors (up to 16) saved using the custom color palette
- width of calculated results table on Planner screen
- width of log strip graph on Type Log screen
- width of left and right RSD tracks on ParamTuner
- initial cross section zoom setting from Cross-Sections screen

1.8 Last SES Database (LDB.bin)

Each time SES is closed an SES system file (LDB.bin) is updated. LDB.bin contains the path and file of the connected SES Database when SES was closed. When upgrading SES, LDB.bin is used by SES to automatically connect SES to the last SES Database so upgrading SES is seamless for the user. However, in some corporate environments, network administrators use the behavior of LDB.bin to control the SES Database to which their users are connected by default when launching SES, initially and/or after upgrading. Such activity is usually accompanied by internal software deployment protocols external to SES norms.

1.9 Training

There are at least two general levels of training associated with SES technical geosteering. First, there is the learning curve to SES logistics...knowing which button clicks and screens do the task at hand. Second, there is the craft, or developed skill that comes from analyzing data with SES and extracting value based on what is discovered from knowing how to interpret respective data, i.e., how to "read the results" and then act. As might be expected, the latter takes much more time (relatively) to acquire and requires the user to "think like a geologist" and grasp local geology for best results.

Fortunately, climbing the SES logistics learning curve can be done reasonably quickly. SES User Manual is one resource to help accomplish this task, but perhaps equally important are the online training videos published on SES Screen Video page and Formal SES Training. Approximately 70+ minutes of online video including a "cradle-to-grave" example have been created to help new users get acquainted with SES, and formal classroom training is offered multiple times per year.

Valuable, general concepts surrounding geosteering that go well beyond your software selection are presented as end-matter to SES User Manual. Please see **16. GEOSTEERING TRADE SECRETS** after getting comfortable with technical geosteering basics.

1.10 Program/Data Flow

General SES program/data flow to perform typical **TECHNICAL GEOSTEERING** is shown below. If your sole interest in SES is "raw" technical geosteering, then please review at a minimum the hyperlinked user manual sections below marked "*required*".

⇓ (optional) Grid data (**3. GRIDS Screen**)
⇓ (optional) Well plan (**7. SES Screen – PLANNER**)
⇓ (*required*) Type log data from offset penetration (**8. SES Screen – TYPE LOG**)
⇓ (*required*) Directional survey data (**6. SES Screen – SURVEYS**)
⇓ (optional) THD calcs and related logs (**12. SES Screen – THD**; **14. TECHNICAL HOLE DEVIATION & THD WELLS LOGS**)
⇓ (*required*) LWD data (**9. SES Screen – LWD**)
⇓ (*required*) Geosteer (**10. SES Screen – GEOSTEER**; **11. SES Screen – GEOSTEER – ParamTuner**)
⇓ (*required*) Cross-Sections (**13. SES Screen – CROSS-SECTIONS**)

General SES program/data flow to utilize **STEERING GUIDANCE** technology is shown below. If your sole interest in SES is steering guidance technology and application, then please review at a minimum the hyperlinked user manual sections below marked "*required*".

⇓ (optional) Grid data (**3. GRIDS Screen**)
⇓ (*required*) Well plan (**7. SES Screen – PLANNER**)
⇓ (*required*) Directional survey data (**6. SES Screen – SURVEYS**)
⇓ (*required*) THD calcs and related logs (**12. SES Screen – THD**; **14. TECHNICAL HOLE DEVIATION & THD WELLS LOGS**)
⇓ (optional) LWD data (**9. SES Screen – LWD**)
⇓ (optional) Cross-Sections (**13. SES Screen – CROSS-SECTIONS**)

1.11 Paste/Insert/Delete/Undo

For live drilling operations, WITSML server downloads or LAS file imports for directional survey and LWD data produce the quickest means of SES data updating. However, key-punch and copy/paste (e.g., from Excel) are also fully supported and sometimes the only option. Key-punch can be handy when a survey station estimate at TD is necessary in order to use downhole-measured correlation data that is beyond/deeper-than the survey tool. Key-punch is also (at times) paramount to correcting or removing erroneous data, which is very simple to do with SES.

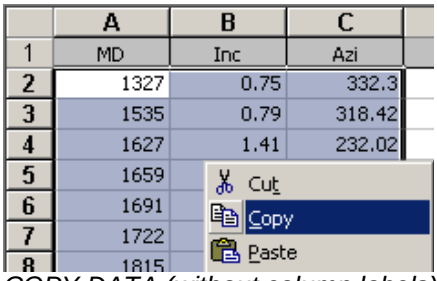
How To Paste Data From Excel into SES

Only select and copy *data values* with columns in the proper order (i.e., do *not* copy column heading labels). SES automatically handles row numbering when applicable. Each Excel cell should contain one value or no value (i.e., not two or more values). In some cases, data may first need to be parsed into one-value-per-cell using Excel's Text-to-Columns command.

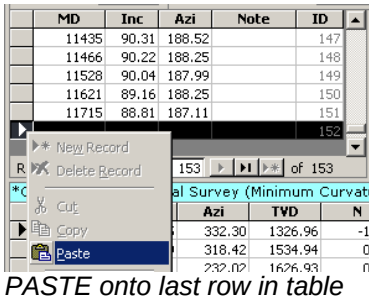
Any copied data, which are tab-delimited, may be pasted directly into an SES data table. Excel automatically tab-delimits data when cell values are copied to the clipboard. However, data may also manually be made tab-delimited using a text editor such as UltraEdit.

To paste data into an SES data table after copying, *right*-click on the bottom row selector (asterisk or triangle) and select Paste from the shortcut menu; or, left-click on the bottom row selector (asterisk or triangle) and press CTRL+V.

Sorting (using the SES toolbar button ) and/or calculating *may* be necessary after pasting data into SES.



COPY DATA (without column labels)



PASTE onto last row in table

How To Insert Data Between Existing Data in SES

All new data are added at the bottom of an SES data table. In some cases, sorting may be necessary after adding and/or deleting data. Click the 'A to Z' toolbar button () to sort data when applicable.

How To Delete A Row in SES

Click the row selector () at the far left side of a data table to select a row (or rows) to delete. Right-click over the selection and click 'Delete Record' from the shortcut menu, or press the keyboard 'Delete' key after making the selection.

*How To Undo Data Changes *While* In Edit Mode in SES*

Press the keyboard 'Esc' key *WHILE* in edit mode to undo a cell/record data change. A "pencil…icon" () may appear at the left side of the row on some screens *WHILE* SES is in edit mode.

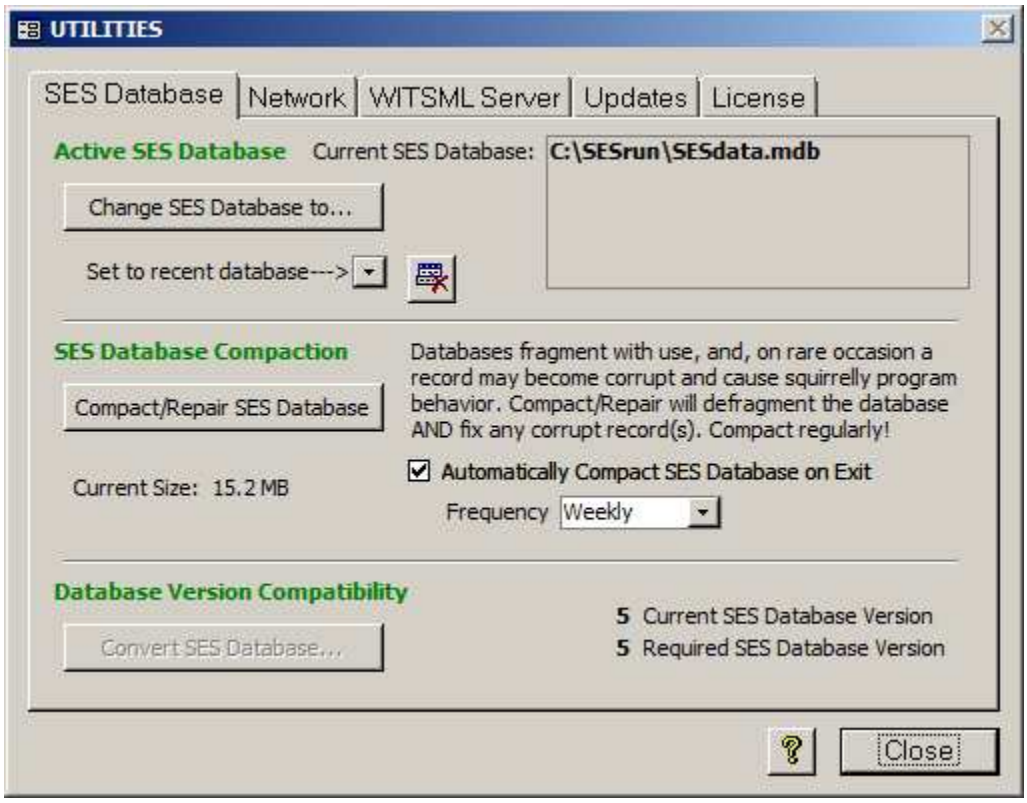
1.12 Status Bar, Tool Tips, and Examples

The status bar at the far bottom of the application window is used extensively to inform you of various information. If SES is working OR if the mouse cursor shows 'busy', *please let processing complete before clicking or typing*.

There are several screen tips throughout SES. Just place your mouse over a control and if available the tip will appear. Clicking into a text box usually provides more information in the status bar too.

Several example wells accompany SES. In some cases after example inspection, you may easily answer your question!

2. UTILITIES Screen



2.1 General

UTILITIES is used to manage database connectivity, configure access to WITSML servers, check for SES updates availability, and address Licensing matters.

SES DATABASE tab can be used to:
1.) Connect SES to an SES Database (SESdata.mdb), which is a Microsoft Access database (mdb) file in a special format.
2.) Compact/Repair SES Database to minimize its file size and enhance general SES performance, and to repair any corrupt records that may on rare occasion be present.
3.) Determine the format version of the connected SES Database.
4.) Upgrade the connected SES Database to be compliant with the SES run-time version.

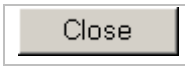
NETWORK tab can be used to:
Determine computer names currently using SES Database and the computer name of the user running SES. The SES run-time file and path are also displayed.

WITSML SERVER tab can be used to:
Configure access to up to three WITSML servers for on-demand data transfer to SES using the internet.

UPDATES tab can be used to:
Query www.makinhole.com to check for SES upgrade availability. Your version is compared to the most current release. A link to Release Notes is here too.

LICENSE tab can be used to:
Determine current in-use Licensed feature option, format, expiration date, and address other SES Licensing matters.

 Click "?" button to display UTILITIES abridged help screen.

 Click "Close" button to close UTILITIES and return to Main Menu.

2.2 SES Database

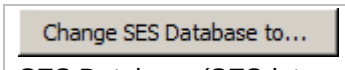
SES data (e.g., directional surveys, surface coordinates, offset type log data, LWD data, well plans, geologic surfaces, geologic bed interpretations, THD, etc.) are all stored in a Microsoft Access relational database in a particular but open format, normally named SESdata.mdb. To fully run, SES must be connected to a valid SES Database. Through the course of ordinary business within a company it is not uncommon for multiple SES Databases to be populated and accessed. SES Database tab is used to set the SES Database to which SES is currently attached.

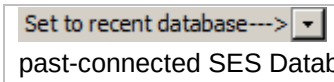
In addition to running multiple instances of SES at the same time from one computer, SES also allows for simultaneous access to the same SES Database from multiple users/computers. WELLS screen can be used to transfer entire well and grid data in and out of SES Database through export and import of individual SES xml files.

SES Database (SESdata.mdb) may eventually contain data from dozens to hundreds of different wells. Eventually its file size may grow (e.g., to 100s of MB) and general day-to-day SES performance may become affected. It is perfectly acceptable to work with multiple SES Databases and place them strategically in a file folder structure that inherently groups information with applicable subsets of your company's wells/needs (e.g., user 'A' or field 'B' or division 'C' or client 'D', etc.). Another popular practice is to manage a "working" version of SESdata.mdb for active/drilling/recent wells and use an "archive" version of SESdata.mdb to save final version data and interpretations, where SESdata.mdb exists in two or more different folders. The archive database(s) for example can safely be as large as 2GB.

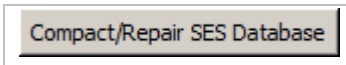
SES allows SES Database (SESdata.mdb) to have *any* file name with an "mdb" extension and it may be located on most any type of drive (e.g., network drive, fixed media drive, or removable media drive). "SES formatted" databases from SES versions 4.x, 3.x, and 2.1 may be converted into the current format using SES Database tab.

Microsoft Access databases in general may become corrupt from time to time and the most common causes are: 1) faulty networking (e.g., dropped connections, faulty cables/switches/switch-ports/hubs, and malfunctioning disc controllers), 2) closing SES/Access or Windows via an "inelegant" shutdown, 3) power failures, and 4) Windows hanging while the database is open. The "Compact/Repair SES Database" function on SES Database tab can recover most corrupt SES databases. Use Compact/Repair often (e.g., daily or weekly) for best performance and to minimize the chance of problems associated with a corrupt Microsoft Access database.

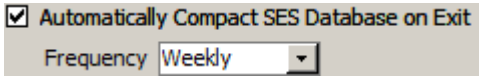
 Click "Change SES Database to..." button to browse and select a specific SES Database (SESdata.mdb) to which to connect your SES.

 Use "Set to recent database--->" dropdown box to one-click connect SES to a past-connected SES Database (SESdata.mdb) file. With this option, SES connects AND automatically closes UTILITIES and returns to Main Menu.

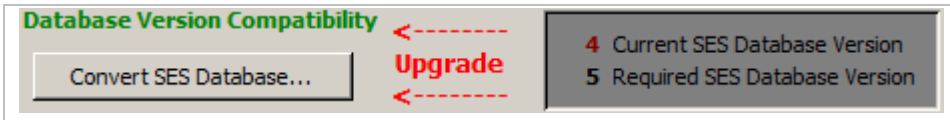
 Click this button to clear the most-recently-used SES Database file list in the dropdown box.



Click "Compact/Repair SES Database" button to compact/repair the currently attached SES Database (SESdata.mdb) file. To ensure optimal performance, SES Database should be compact/repaired on a regular basis. SES Database may only be compacted/repaired when no one has the database file open.

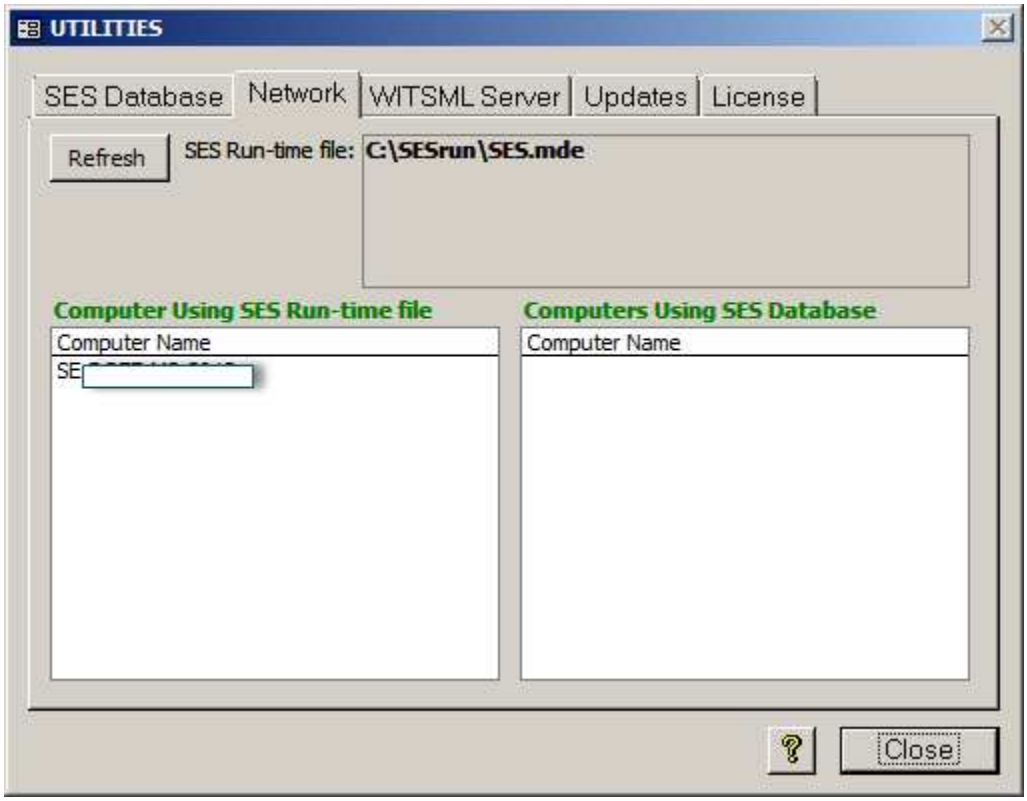


If checked, "Automatically Compact SES Database on Exit" option sets SES to automatically compact/repair SES Database upon closing SES and will only occur if no one has the database file open. Frequency options include "Daily", "Odd Days", "Even Days", "Weekly", and "Monthly". "Daily" means compact/repair every time SES is closed. "Weekly" means compact/repair whenever SES is closed on the 7th/14th/21st/28th of the month. "Monthly" means compact/repair whenever SES is closed on the 1st of the month. To ensure optimal performance, SES Database should be compact/repaired regularly.



Click "Convert SES Database..." button to convert SES Database (SESdata.mdb) to the version required by the SES version being run. This button will only be enabled when applicable. During SES Database conversion, SES can automatically make a back-up copy of the original/non-converted SES Database (highly recommended). Most SES features will not function if the attached SES Database version differs from the required version.

2.3 Network

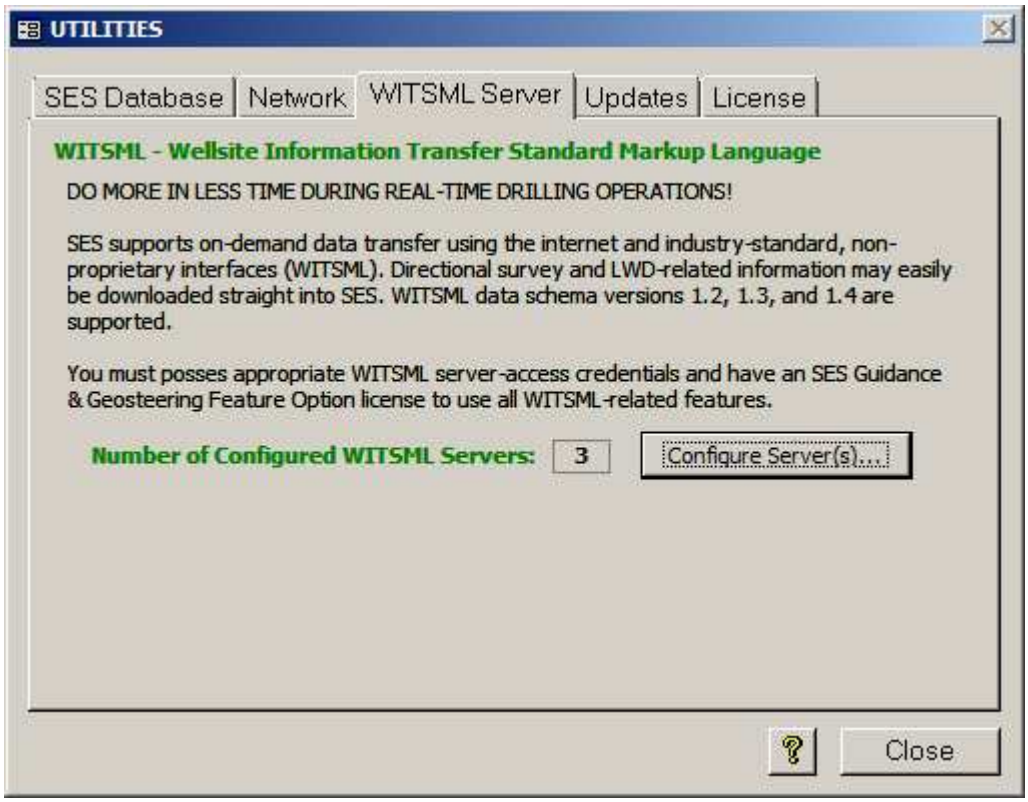


Network tab displays the SES run-time file and folder from where SES is being run. The user must have full file permissions to this folder for SES to properly execute. This tab also displays the computer name of the current SES user and the computer names of all others currently using the same SES Database.

Exclusive SES Database file access is required in order to compact/repair SES Database (SESdata.mdb). If SES Database needs to be compact/repaired in a multi-user environment, then Network tab is helpful to identify whom needs contacted to close their SES.

Refresh Click "Refresh" button to refresh the computer name list of "Computers Using SES Database".

2.4 WITSML Server



SES supports on-demand data transfer using the internet and the industry-standard, non-proprietary interface WITSML (Wellsite Information Transfer Standard Markup Language). A WITSML server/service is not an application with a graphical user interface, but rather, it is simply a server computer from which a client application like SES can directly request and receive data for processing. In other words, directional survey and LWD-related information may easily be downloaded straight into SES from within SES.

To get started with WITSML, the SES user needs an account with a WITSML server service provider. SES has successfully been tested with multiple WITSML server service providers. An SES G&G Feature Option license is required to actually download data from a WITSML server, but even with an expired SES license SES allows access to WITSML server configuration and available well list queries.

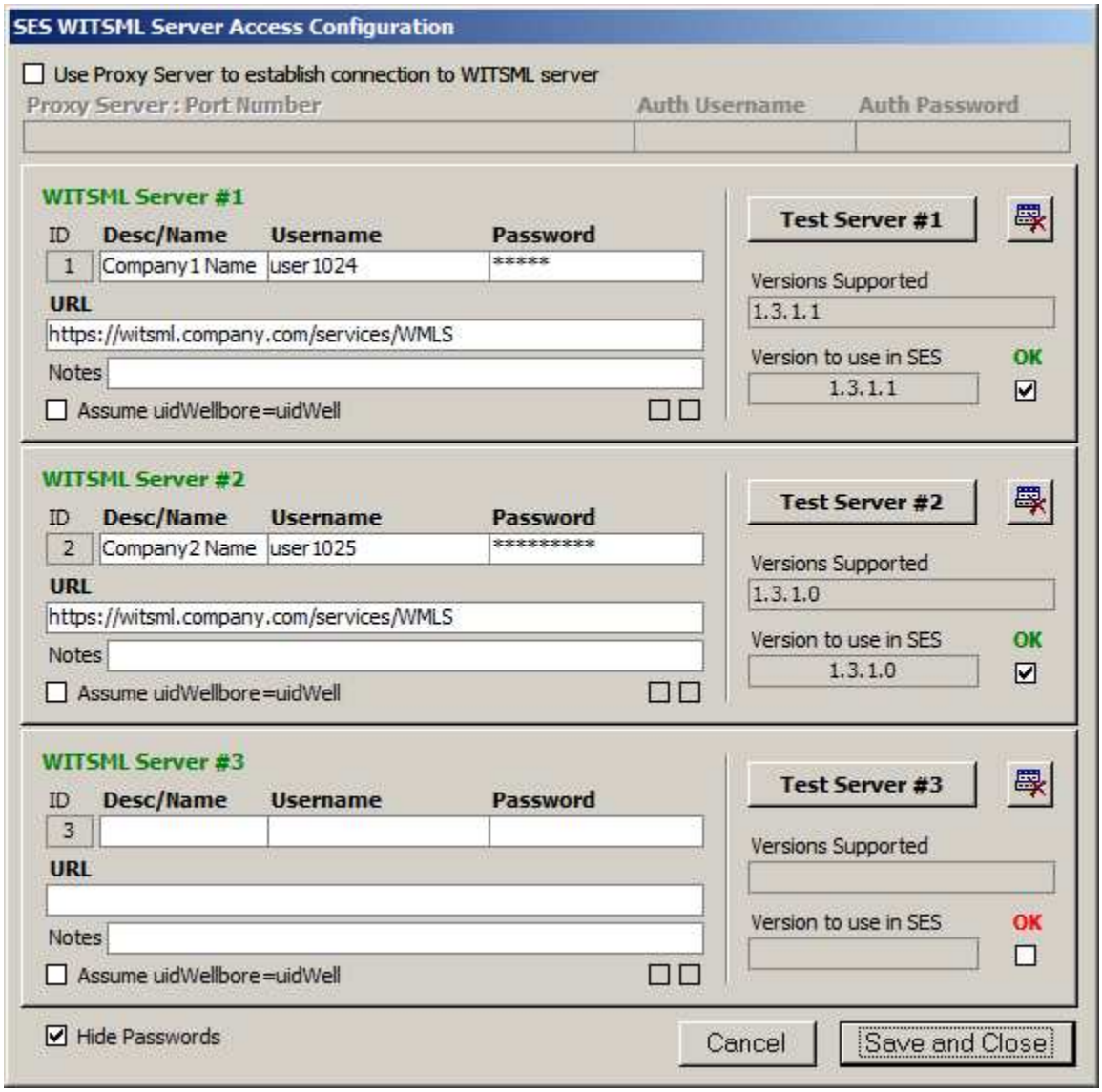
SES supports: WMLS GetFromStore, GetVersion, and GetCap API functions; WITSML data schema versions 1.2, 1.3, and 1.4; and the following WMLS GetFromStore objects:

- well
- wellbore
- trajectory

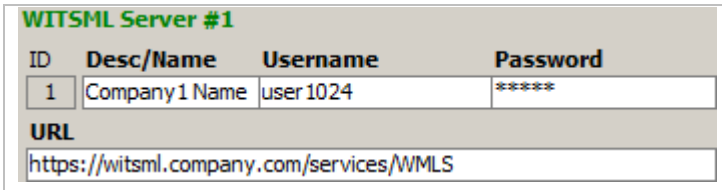
- log

Up to three (3) different WITSML servers may be configured to be accessed from SES. If a WITSML server supports unit of measure conversion, then SES automatically requests data from the server in the units configured in SES for the respective Well.

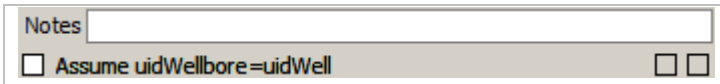
Configure Server(s)... Click "Configure Server(s)..." button to load a dialog to setup access to WITSML servers.



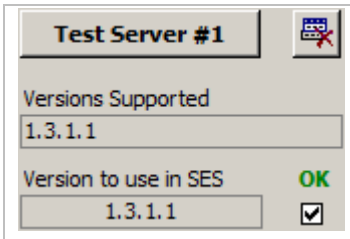
Use Proxy Server to establish connection to WITSML server Check "Use Proxy Server to establish connection to WITSML server" option only if internet access from your computer requires use of a proxy server. If such is applicable, acquire the port number and authorization credentials from your Network Administrator.



Enter the WITSML server reference name for SES internal use, along with the appropriate username, password, and server URL.

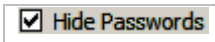


Enter internal reference notes (optional). Only check "Assume uidWellbore=uidWell" if designated to do so (see "NOTES" column here). Most WITSML servers require this option NOT checked.



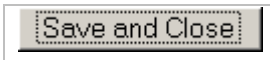
Click button "Test Server #1" to call the WITSML server using the entered information, during which SES determines among other things which data schema versions the WITSML server supports and which data schema version SES should subsequently use within SES (defaults to latest version, but can be overwritten manually by user). If the call to the WITSML server is successful, "OK" is checked and the WITSML server may be used elsewhere in SES.


Click this button to clear all settings for the respective WITSML server.



Check/uncheck "Hide Passwords" option to hide/show passwords displayed on the dialog.

Click "Cancel" button to close the dialog without saving changes made since the dialog was opened, and return to UTILITIES, WITSML Server tab.



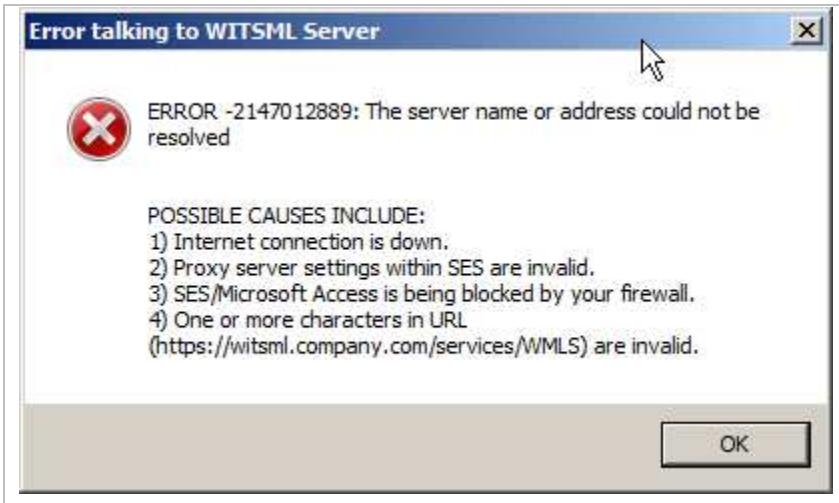
Click "Save and Close" button to save current settings displayed on the dialog and return to UTILITIES, WITSML Server tab. The settings are not saved in SES Database and are not contained within SES xml files, but rather, they are stored in SESuser.mdb.

WITSML Basic Trouble-shooting

Numerous possibilities exist where problems may arise with WITSML servers. If SES has worked with a WITSML server in the past and then it quits working, the problem is very likely not with SES but with the WITSML server service provider and such provider should be contacted instead of SES Support.

The two most common error screens are discussed below.

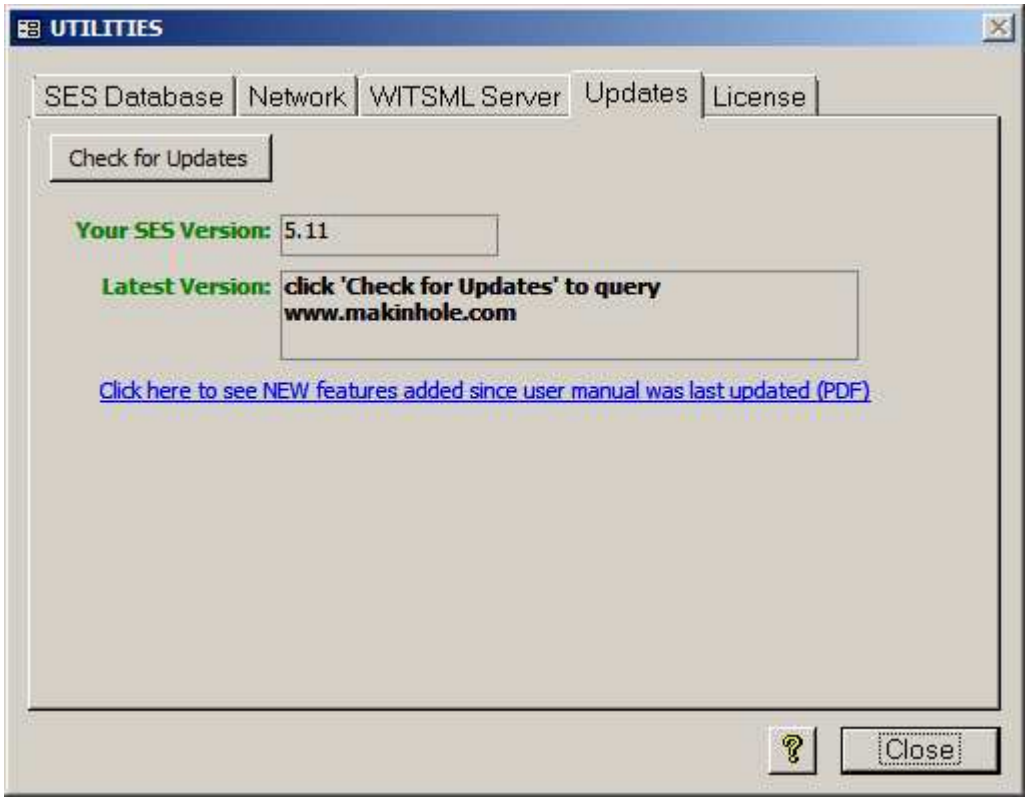
A message like this is displayed if the username and password are not recognized by the WITSML server, or if such user's permissions to the service have expired. Verify the accuracy of username and password and then contact the WITSML server service provider if applicable.



Common problems not associated with SES or the WITSML server service provider include: no internet connection or connectivity is intermittent; the proxy server settings within SES WITSML Server Access Configuration are invalid; SES/Microsoft Access is being blocked by your firewall or otherwise from being able to access the internet; and one or more characters in the URL are invalid.

Again, if SES has successfully worked with a WITSML server in the past and then it quits working, the problem is very likely not with SES but with the WITSML server service provider and such provider should be contacted instead of SES Support.

2.5 Updates



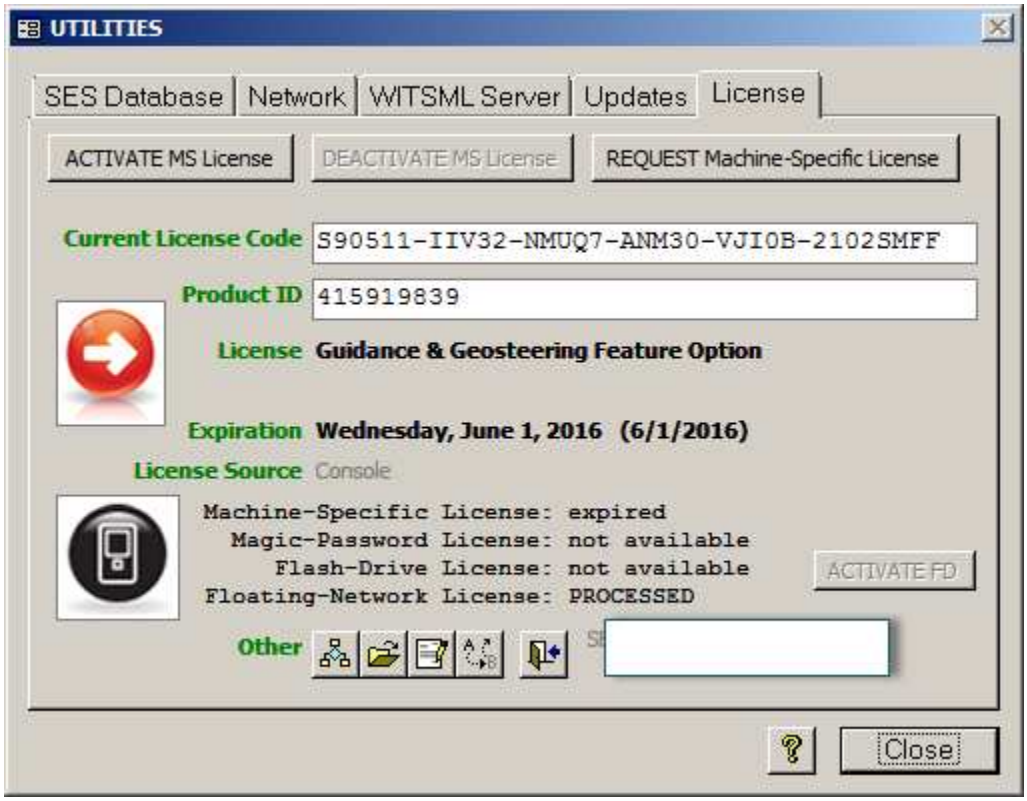
SES is regularly enhanced based on SES user feedback and SES long-term design plans. This has been the case for many years. Some features take weeks and others take multiple months to develop, but we strive to make every enhancement as obvious as possible to understand and navigate using clear industry language, tool tips with mouse-over, status bar summary text when an object has the focus, and an incremental approach in general.

Check for Updates Click "Check for Updates" button to query www.makinhole.com and check for SES upgrade availability. Your SES run-time version is compared to the most current release and the results are reported.

This button also serves as a quick check to see if your computer is blocking access to the internet from Microsoft-Access/SES, or if your network is blocking access to www.makinhole.com. Some SES licensing logistics require internet connectivity to www.makinhole.com. However, SES does not transmit over the internet without the SES user first giving explicit permission to do so, each and every time.

A link to SES Release Notes is also presented from Updates tab. Especially between SES user manual updates, SES enhancements are documented with each version to help both the frequent updater and the infrequent updater see what's new and improved in SES. Updating SES is typically voluntary. Some updates are required in order to resolve bugs related to Windows, Office, or SES. All SES licensees have access to the latest version of SES so there's never a financial reason not to upgrade!

2.6 License



A valid, non-expired License is required to run featured SES. SES supports multiple license formats including machine-specific, flash-drive, floating-network, and magic-password. Please contact us or view SES Licensing page for more information about licensing and pricing. License tab conveys which licensed feature option and license format are currently in use and the license expiration date.

SES Licensed Feature Option	Icon
BASIC	
GEOSTEERING ("G")	
GUIDANCE & GEOSTEERING ("G&G")	

SES License Format	Icon
Machine-Specific (MS): license activation is configured for each physical computer and is Windows user-login specific; may also be used for trialing, training, temporary, and emergencies.	
Flash-Drive (FD): provided USB flash drive is attached to a USB port for SES use; fully network & computer independent; maximum license portability.	
Floating-Network (FN): limited concurrent use determined by license count; compatible with Citrix/virtual; license manager on network drive for LAN/WAN access; temporary license check-out supported if not using virtual machine install.	
Magic-Password (MP): for emergencies (e.g., scheduled network outages), select mass training, and select mass trialing.	

REQUEST Machine-Specific License Click "REQUEST Machine-Specific License" button to request an SES machine-specific format license, be it for free trial or funded term or temporary license purpose (e.g., when an SES flash drive is in transit).

ACTIVATE MS License Click "ACTIVATE MS License" button to activate or to re-activate an SES machine-specific format license on the current computer be it for free trial or funded term or temporary license purpose. This function uses the internet to call SES. In many cases the SES user will have received an email from SES Support advising that their SES machine-specific license is ready for activation/re-activation, which means to click this button.

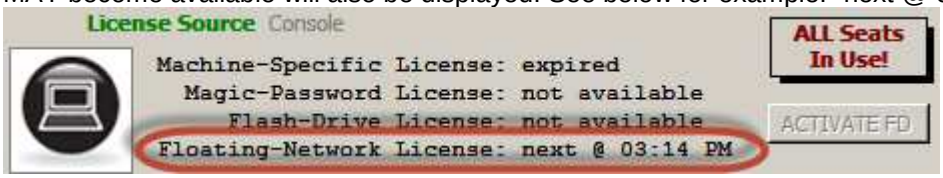
DEACTIVATE MS License Click "DEACTIVATE MS License" button to de-activate an SES machine-specific format license. This button will only be enabled if the computer is currently using a non-expired SES machine-specific format license. This button may be required to effect an SES license transfer for a multitude of possible reasons, or to check-in early a floating-network license that was temporarily converted to SES machine-specific for SES use while away from the valid network.

ACTIVATE FD Click "ACTIVATE FD" button to activate or to re-active an SES flash-drive format license. This button will only be enabled if an SES flash drive is connected to the computer and is recognized by SES. This function uses the internet to call www.makinhole.com. In most cases the SES user will have received an email from SES Support advising that their SES flash-drive format license is ready for activation/re-activation, which means to click this button.

Virtual Machine Install The "Virtual Machine Install" caption is displayed in the lower left portion of License tab if the current installation was performed with the SES Virtual Machine Install option. The SES Virtual Machine Install option does not allow for temporary license check-out and does require floating-network license format use. See **1.4 Installation/Licensing** for more information.

The "ALL Seats In Use!" caption is displayed if all floating-network license seats are currently in use and thus a license seat is unavailable to a new user request. License seat denials are logged and their frequency of occurrence may be reviewed in the SES floating-network license seat Activity Report (see  below).

Under "License Source" and across from "Floating-Network License:" a time approximation when a seat MAY become available will also be displayed. See below for example: "next @ 03:14 PM".



The "Other" toolbar near the bottom of License tab has several special-case functions. Some commands will only be enabled if they currently apply.


Click this button to perform an SES floating-network license seat status check. A dialog showing the total license seats available for use and the current status of each seat is displayed. If Licensee has many seats, SES generates the license seat status content in a text file and opens the file with the SES user's default text editor.

This button can also lead to generating a detailed Activity Report of SES floating-network license seat use, including the following report sections:

- System Summary (Date, Number Users, Number Denials)
- Session Summary by User (Date, Number Sessions, Denial Flag, SES Version)
- FN to Temp MS Check-out Summary (Date, Time, Duration, SES Version, User)
- Notes (regarding activity logging and report details)


This button should only be used if directed to do so by SES Support. Click this button to browse to a folder on a mapped drive that shall be the future location of an SES floating-network license manager file. This button is only used to manually provide SES Support with information; it does nothing to change how SES runs and it does not permanently "point" SES to anything for any purpose!


This button should only be used if directed to do so by SES Support. Click this button to manually perform machine-specific license activation, or to remove an SES virtual machine option install.


Click this button to temporarily—up to maximum of nine (9) days—convert an SES floating-network license seat into a temporary machine-specific license seat. With this feature, a computer that normally has company network access may operate SES standalone and without network access during the check-out period (e.g., taking a laptop home for the weekend or to the field for brief duration). The license check-out duration is selected at the time of license check-out/conversion. Checked-out licenses automatically expire at the end of the pre-selected duration, OR, they may be checked-back-in at any time with network connectivity by clicking button "DEACTIVATE MS License" shown above.

 Click this button to release an SES floating-network license seat immediately and quit/close SES, and without trying to compact SESdata.mdb (if applicable). However, there are two other easy ways to perform this same task and SESdata.mdb will be compacted if applicable and possible.

For instantaneous release of an SES floating-network license seat, close SES by using any of these methods:

1) Click "Exit" button from Main Menu screen. SESdata.mdb will be compacted if applicable/possible.
2) Choose "File" menu, "Exit" from any screen. SESdata.mdb will be compacted if applicable/possible.
3) Click the leave/quit button from License tab. SESdata.mdb will NOT be compacted if applicable.

If SES is closed by any other means, then the corresponding license seat will automatically expire after two (2) hours. Please note the same SES user may immediately re-open SES and close it "properly" for immediate seat release if the first close wasn't one of those mentioned above. Similarly, if an SES user has left SES open and been inactive with SES for two (2) or more hours, AND if someone else needs a seat, then inactive SES user "1" would be bumped and the seat would be given to active SES user "2".

2.7 Critical

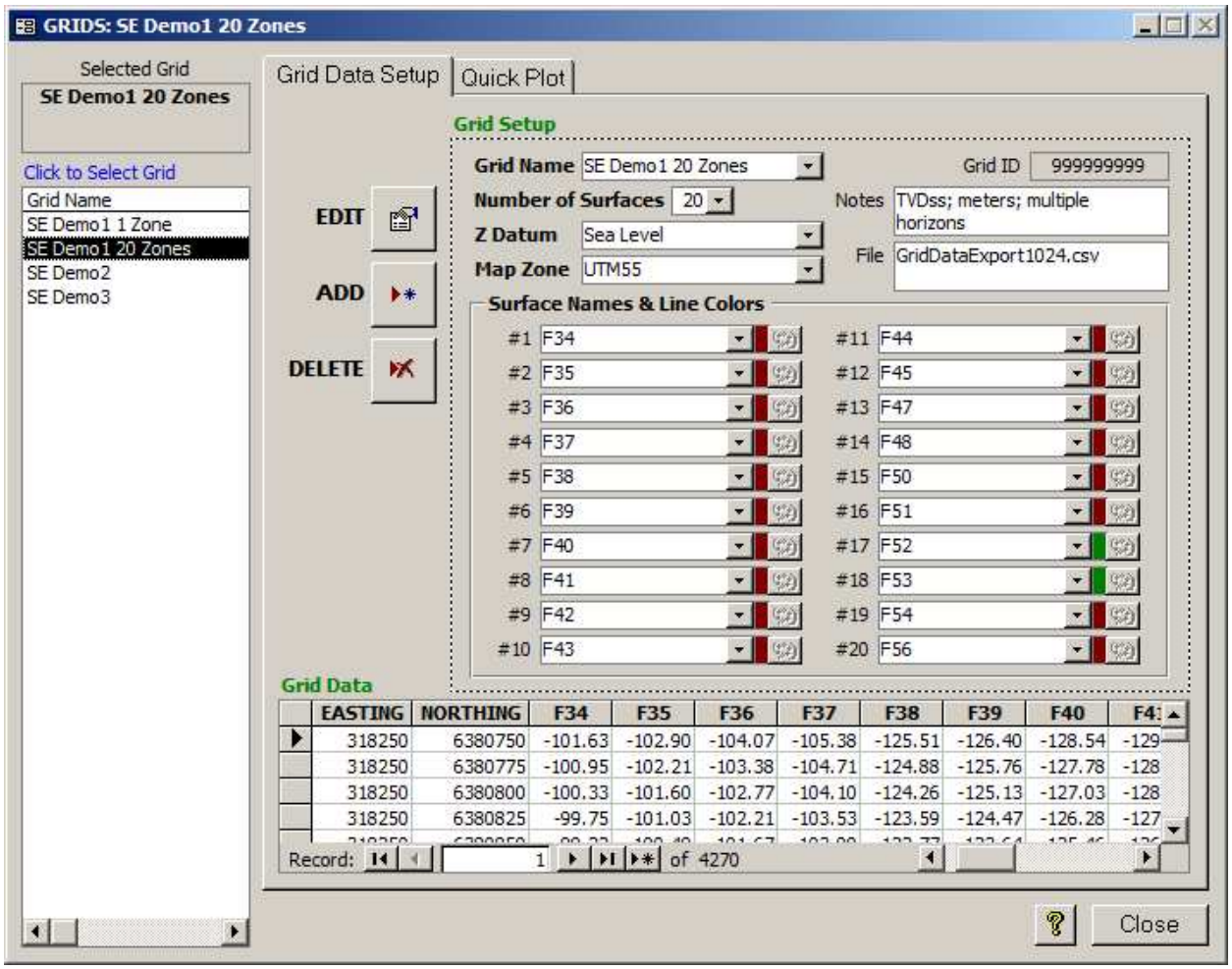
1.) If your license to SES has unexpectedly changed to "Expired", please give careful inspection to "License Source" section of UTILITIES screen, License tab, for often important information. It may be that it is simply time to re-activate your SES license according to the applicable license format to which you are subscribed.

2.) Understand where your SES Database (SESdata.mdb) is located for backup purposes, new computer purposes, and recovery from catastrophic drive failure. The file location is reported from Main Menu and UTILITIES screen.

3.) If behavior of SES suddenly changes and/or error messages start to display for no seemingly apparent reason, it could be that a record somewhere in one or more tables in SES Database has become corrupt. In the overwhelming majority of cases, Compact/Repair of SES Database from UTILITIES screen will immediately resolve the issue and return SES to normal behavior. In rare cases, SES may need to be reinstalled.

4.) If the version of Microsoft Access or Excel is changed on your computer after SES has been installed, then reinstall SES.

3. GRIDS Screen

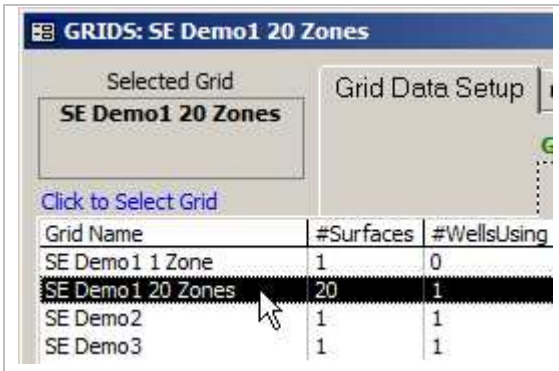


3.1 General

GRIDS is used to store surfaces from a geologic model. A "Grid" is a global reference dataset from 3rd party software that represents the digitized 3D location of a geologic surface, or a group of multiple geologic surfaces (X, Y, Z1, Z2, Z3, etc.). The X-Y spacing may be variable and null/missing Z values may exist, however square (deltaX=deltaY) grid spacing is recommended. GRIDS may also be used to setup drilling target TVD windows (e.g., Top, Target, Base) with coordinates from as few as three points.

GRID DATA SETUP tab can be used to:
1.) Add a new Grid to SES Database by first naming and configuring the Grid and its surface/layer/zone names and then pasting the actual grid data into the Grid Data table section of the screen.
2.) Delete the selected existing Grid and all associated data from SES Database.
3.) Modify/edit numerous Grid properties.
4.) Select Grids in SES Database and see their properties and how many wells are associated to them.

QUICK PLOT tab can be used to:
1.) Plot the X-Y locations where data exists for the selected Grid.
2.) Print the graph to any system printer or copy the graph to the clipboard for paste into other applications.



A Grid dataset may cover a large expanse and be used by multiple wells. To edit or delete an existing Grid dataset, first select it in the list box along the left side of GRIDS screen. Extra columns will display when the mouse is moved over the list box and then collapse after clicking a "Grid Name". Grid Name is the internal reference name of a Grid dataset. "#Surfaces" is the number of Z-layers—one to a maximum of twenty—that are set for the respective Grid dataset. "#WellsUsing" is a well count of the number of wells in SES Database that point to the respective Grid dataset from at least one directional survey or from at least one well plan. The Grid setup, data table, and quick plot are updated after a different Grid is selected.

 Click "?" button to display GRIDS abridged help screen.

 Click "Close" button to close GRIDS and return to Main Menu.

3.2 Grid Data Setup

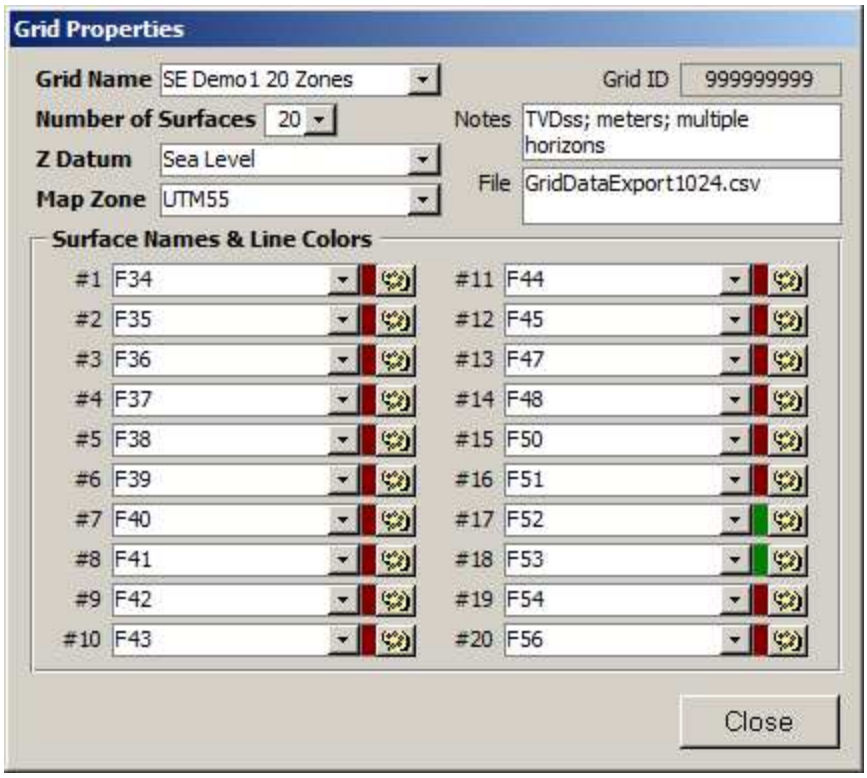
Grid Data Setup tab is used to add a new Grid to SES Database, edit Grid settings of an existing Grid, or delete an existing Grid. A Grid has a "header" section for general settings and a "detail" table to store Grid data content.

 Click this button to load a dialog to edit Grid settings of the selected Grid.

 Click this button to load a dialog to create and append a new Grid dataset to SES Database.

 Click this button to delete the selected Grid from SES Database.

Next, Grid Properties dialog of Grid Data Setup tab is detailed. The example below shows a Grid dataset with twenty surfaces, named F34, F35, etc., and with eighteen surfaces colored maroon and two surfaces colored green (F52 and F53). At least one surface must be defined for any Grid dataset.



Close Click "Close" button to close Grid Properties dialog and return to GRIDS screen.

Cancel Click "Cancel" button to close Grid Properties dialog and return to GRIDS screen. Any changes made to Grid Properties are NOT saved.

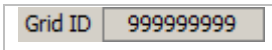
SAVE Click "SAVE" button to close Grid Properties dialog and return to GRIDS screen. All changes made to Grid Properties are saved.

Grid Name SE Demo1 20 Zones Enter a concise Grid dataset name for internal reference purposes.

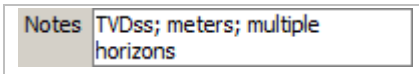
Number of Surfaces 20 Enter the total number of surfaces the Grid dataset contains. For example, if the Grid dataset contains the top and bottom boundaries of a payzone layer, select 2. The maximum number of surfaces is 20.

Z Datum Sea Level Enter a concise description of the global Z-direction coordinate value datum (example: Sea Level). **SES assumes Grid data Z-values are positive above datum and negative below datum** (e.g., Z=TVDss is positive above sea level and negative below sea level).

Map Zone UTM55 Enter a concise description of the Grid dataset's coordinate/projection system reference of Easting (X) and Northing (Y) values. SES assumes a Grid's X-Y coordinate system reference and units and a Well's SurfaceX and SurfaceY coordinate system reference and units are identical.

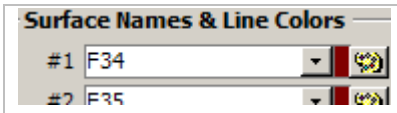


Grid ID is automatically determined by SES when a new Grid is added.



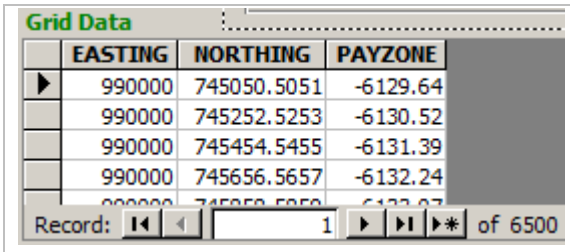
Enter any optional notes pertaining to the Grid dataset.

Enter any optional notes, such as the data source filename, pertaining to the Grid dataset.



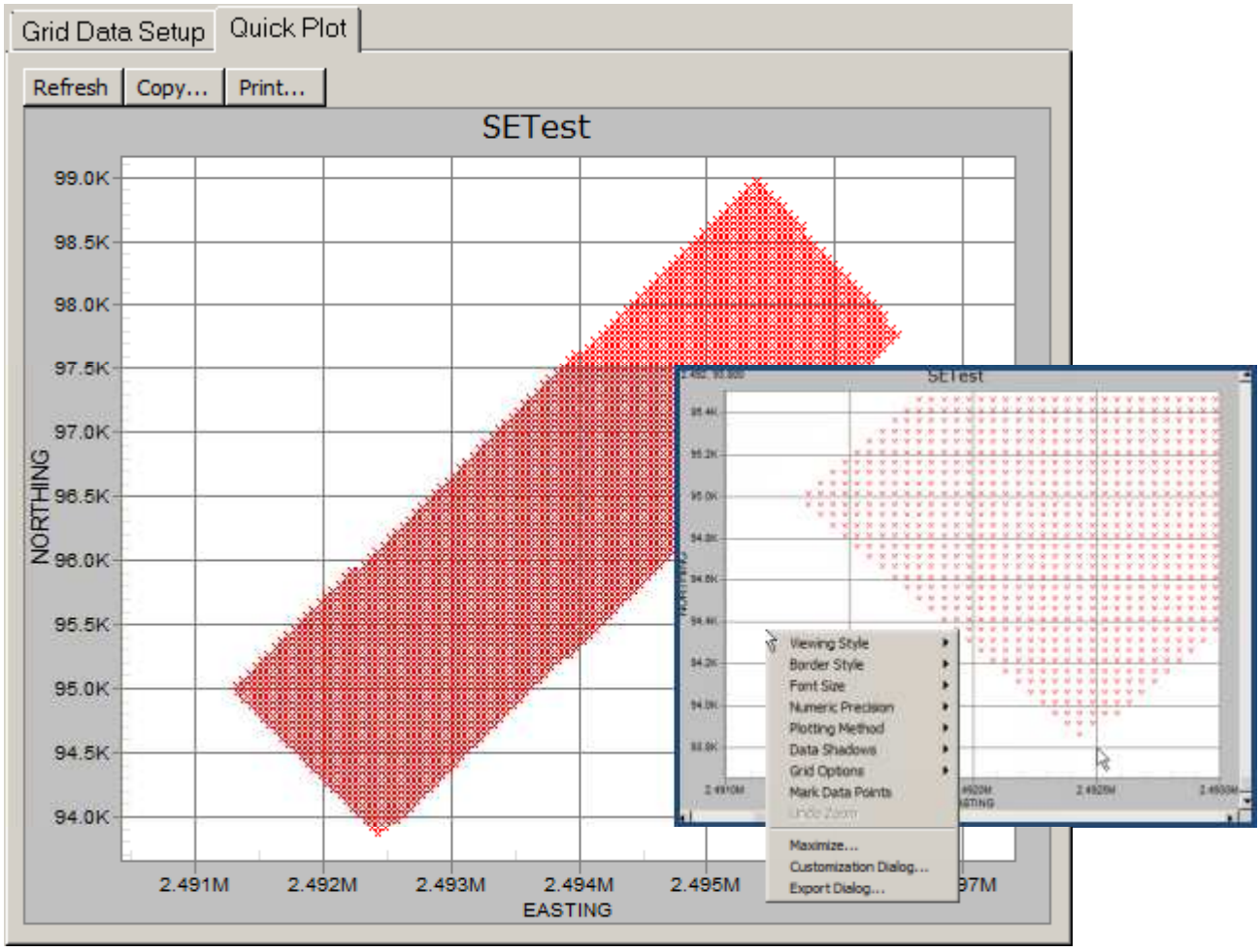
Enter the reference name of each surface. The surface name posts on Surveys and Planner screens' vertical section views. Grid surfaces may be interpolated and then displayed from Surveys, Planner, and Cross-Sections screens. Respective surface line colors set here are applied on Surveys, Planner and Cross-Sections screens. Click the adjacent color palette button to change its surface line color. Custom colors may be created and are stored for recall in SESuser.mdb.

3.3 Grid Data Transfer



Actual Grid data digits are transferred to SES via copy/paste, usually from an ASCII/text-format file exported from 3rd party geologic modeling or gridding/contouring software. **Copied data must simply be tab-delimited to paste into SES**. Data copied from Excel for example are tab-delimited. Data may also be made tab-delimited manually using a text editor (e.g., UltraEdit). The trick to pasting into SES is to first select the bottom row of the data table. More information is detailed in **How To Paste Data From Excel into SES**.

3.4 Quick Plot



Quick Plot tab is used to generate a basic X-Y scatter plot of X-Y locations where Grid dataset map coordinates exist. Click and drag a window over the graph to zoom. Right-click over the graph to set a variety of options and to access special functions, such as "Maximize..." to resize the graph to full screen.

Refresh Click "Refresh" button to requery SES Database and regenerate the graph, such as after changing the data for the select Grid. Graph settings will return to default values upon refresh.

Copy... Click "Copy..." button to load a dialog to export the graph in one of a variety of possible image file formats, with selection of export destination (clipboard, file, or printer) and export size/resolution.

Print... Click "Print..." button to load a dialog to export the graph in one of a variety of possible image file formats, with selection of export destination (clipboard, file, or printer) and export size/resolution.

3.5 Critical

1.) "Z" (e.g., TVDss) depths are assumed to be positive above datum (e.g., sea level) and negative below datum.

2.) A Grid may be associated to a Well's Survey or Plan using SES screen. For proper Grid interpolation, the X-Y coordinate system reference must be the same as the well's Surface X-Y coordinate system reference and units of measure should be identical.

3.) While not technically required, equidistant-spaced Grid data are recommended for optimum Grid interpolation (e.g., if Grid data spacing is 200 ft in the X-direction, it should also be 200 ft in the Y-direction as opposed to 50 ft for example).

4.) For proper Grid interpolation in cases where azimuthal north reference of a directional survey or well plan is True North instead of Grid North, the SES user should determine Grid Convergence at the Well's surface location and enter it accordingly on Surveys and/or Planner screens.

3.6 Tips

- Typically, Grid data are created in 3rd party engineering/geologic software. However, results from SES geosteering are by design setup to help update such geologic models after or during drilling. Digitized points of geosteered beds may be exported from SES Cross-Sections screen and subsequently used in the gridding process that creates Grid data.

- GRID DATA FOR DRILLING TARGET WINDOW FROM SPARSE GEO MODEL

    - In some cases it may be desirable to display TVD drilling window targets in select graphs using an extremely limited geologic model (e.g., three offset wells). This may easily be handled in SES by using Grid Data to define such drilling boundary limits. The *minimum* requirement is three points whose X-Y-Z coordinates in-turn define a plane or multiple planes as in the case of top/target/base. An example follows whereby the Grid dataset is comprised of three data point locations and three planes (top, target, and base).

Grid Data Setup | Quick Plot

Grid Setup

EDIT | ADD | DELETE

Grid Name: JBD23: Target Window | Grid ID: 468621212

Number of Surfaces: 3 | Notes:

Z Datum: Sea Level | File:

Map Zone: UTM15N FT NAD27

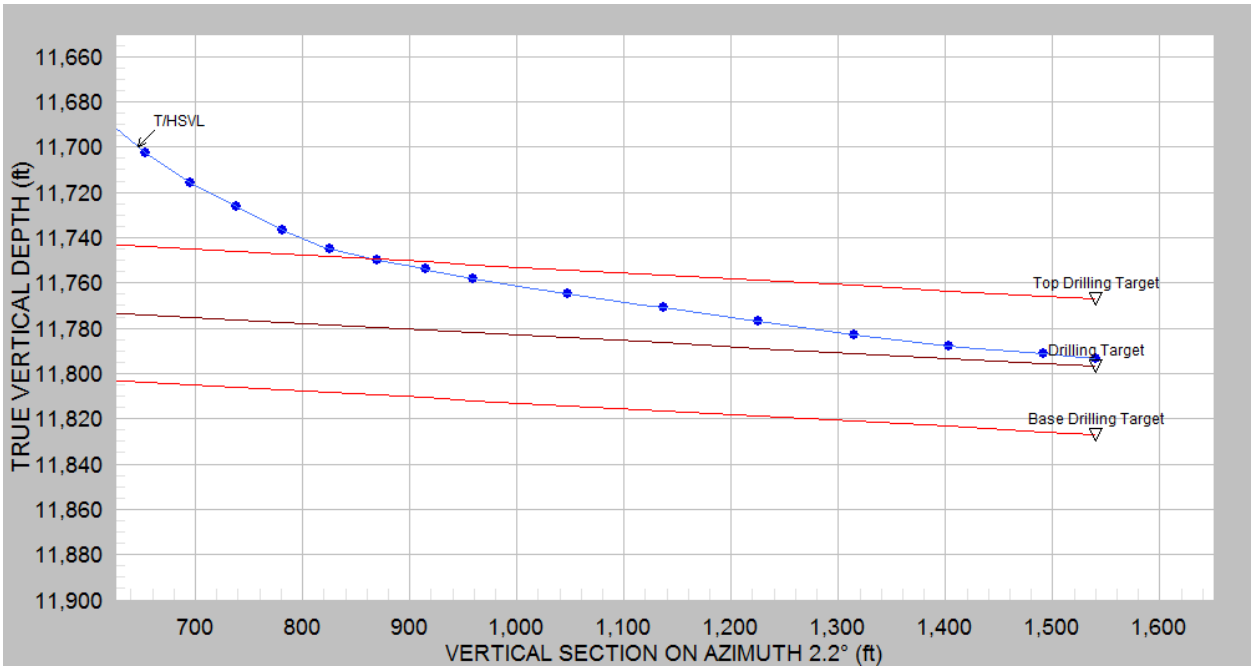
Surface Names & Line Colors

#1	Top Drilling Target	#11	
#2	Drilling Target	#12	
#3	Base Drilling Target	#13	
#4		#14	
#5		#15	
#6		#16	
#7		#17	
#8		#18	
#9		#19	
#10		#20	

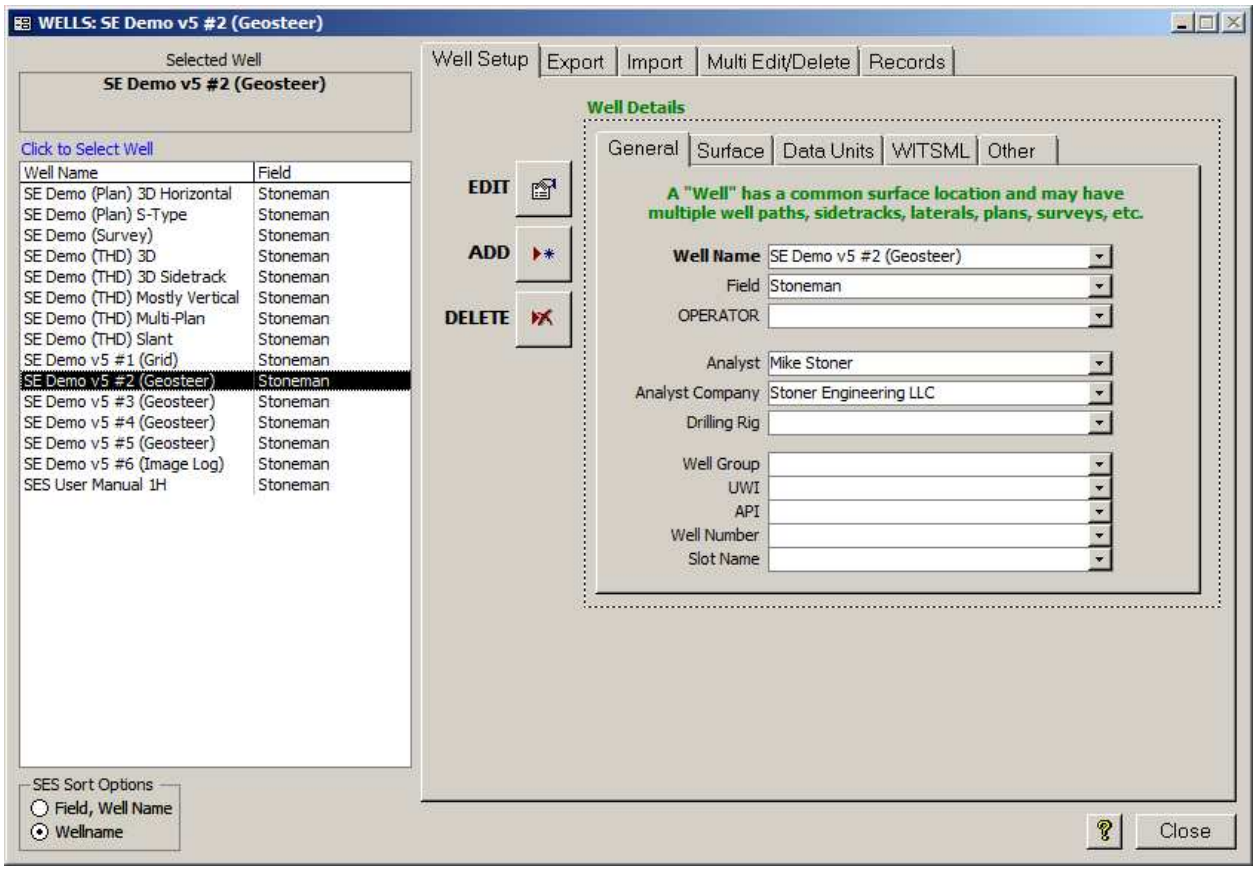
Grid Data

EASTING	NORTHING	Top Drilling Target	Drilling Target	Base Drilling Target
1403969	11712734	-11451.00	-11481.00	-11511.00
1404077	11714271	-11491.00	-11521.00	-11551.00
1404144	11717900	-11586.00	-11616.00	-11646.00

Record: 1 of 3



4. WELLS Screen



4.1 General

WELLS is used to manage the Wells in SES Database. An SES Well has a common surface location and will have multiple datasets associated to it, such as directional Surveys, directional Plans, Type Logs, LWD measurements, Marker Beds (Interpretations), THD calculations, and Cross-Sections.

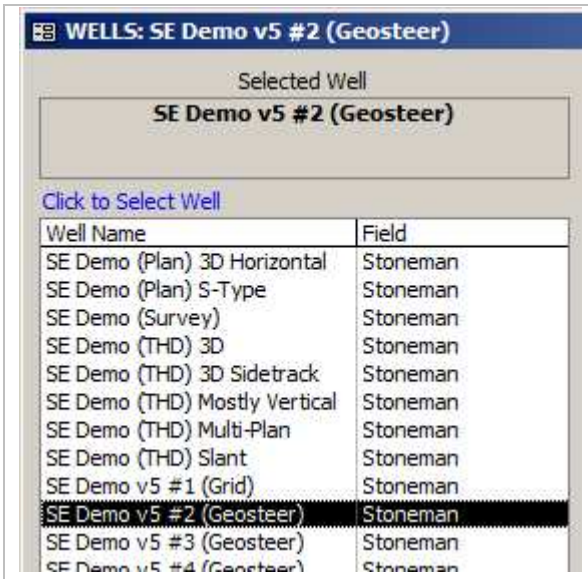
WELL SETUP tab can be used to:
1.) Add a new Well to SES Database.
2.) Delete the selected existing Well and all associated data from SES Database.
3.) Modify/edit numerous Well properties.
4.) Navigate to Wells in SES Database and view their properties.

EXPORT tab can be used to:
Create a "flat" file in "SES XML" text format containing all SES Well-related and Grid-related data, which may be used to transfer such data to other SES users and/or to other SES Databases.

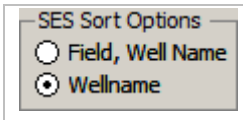
IMPORT tab can be used to:
Import an SES XML file created with the SES Export feature.

MULTI EDIT/DELETE tab can be used to:
Select and then delete multiple Wells at once, or, more easily edit Well properties of multiple Wells due to a table layout format.

RECORD COUNTS tab can be used to:
Inspect a listing of data record counts in all SES Database data tables for the selected Well.



An SES "Well" has a common surface location and may contain multiple directional surveys and well plans (i.e., multiple wellbores). To edit or delete an existing Well, first select it in the list box along the left side of WELLS screen. Well Name is the internal reference name of a Well dataset. Well Details are updated and displayed after a different Well is selected.



Select the preferred Well list sort option. This controls how Wells are listed on WELLS screen and Multi Edit/Delete tab, and how Wells are listed in SES screen Wells dropdown box.

Click "?" button to display WELLS abridged help screen.

Click "Close" button to close WELLS and return to Main Menu.

4.2 Well Setup

WELLS screen, Well Setup tab is used to add a new Well to SES Database, edit settings of an existing Well, or delete an existing Well. A Well has multiple well properties accessed through a tabbed dialog. Note that the multiple tabs of Well Details may be clicked for content viewing, but to *change* data Edit button first needs clicked.

Click this button to load a dialog to change properties of the selected Well in SES Database.

Click this button to load a dialog to create and append a new Well to SES Database.

Click this button to permanently remove the selected Well from SES Database.

4.2.1 Well Setup - General

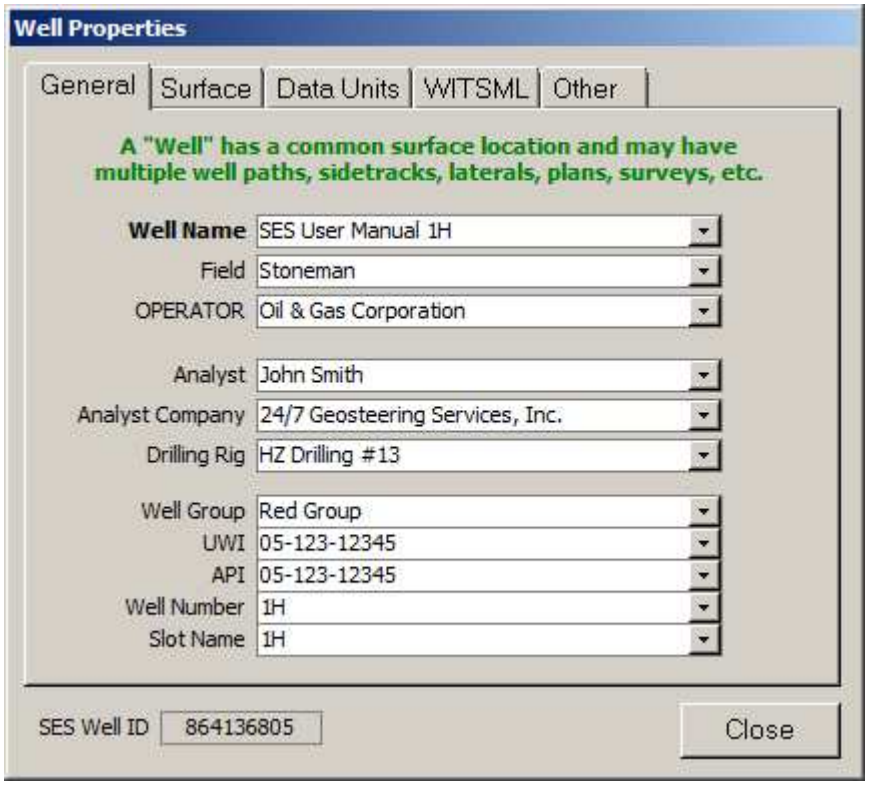
The General tab of Well Setup is used to enter common Well properties. A Well Name must be entered. All else is optional.

Close Click "Close" button to close Well Properties dialog and return to WELLS screen.

Cancel Click "Cancel" button to close Well Properties dialog and return to WELLS screen. Changes made to Well Properties on any tab are NOT saved.

SAVE Click "SAVE" button to close Well Properties dialog and return to WELLS screen. All changes made to Well Properties on any tab are saved.

SES Well ID 864136805 SES Well ID is automatically determined by SES when a new Well is added.



Well Name SES User Manual 1H Enter a concise Well Name for general reference.

Field Stoneman Enter the field name to which the Well belongs. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports. Field may also be used to set how Wells are sorted on WELLS and SES screens. For example, if you wish to see Wells listed first by Field and then by Well Name, select option "Field, Well Name" under SES Sort Options from WELLS screen.

OPERATOR Oil & Gas Corporation Enter the name of the operating company of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports and on Cross-Sections screen cross sections.

Analyst John Smith Enter the name(s) of the geosteering analyst(s). This property is displayed in the header on Cross-Sections screen cross sections.

Analyst Company 24/7 Geosteering Services, Inc. Enter the service company name performing geosteering services, if applicable. This property is displayed in the header on Cross-Sections screen cross sections.

Drilling Rig HZ Drilling #13 Enter the name of the Drilling Rig of the Well. This property is not yet displayed in any reports.

Well Group Red Group Enter a Well Group name to which the Well is associated.

This property value controls which wells are included in multi-well 3D view displays available from Surveys screen **6.4 3D Viewer** and from Planner screen **7.7 3D Viewer**.

UWI 05-123-12345 Enter the unique well identifier of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

When exporting TopsTVD or TopsTVDss data from **13. SES Screen – CROSS-SECTIONS** to an external file (e.g., csv, las, xls, txt, prn, or clipboard) a WellboreID column is inserted into the first column of the data file. WellboreID is determined by concatenating UWI and Survey Number minus one. For example, if UWI is 0512312345 and Survey Number is 2, WellboreID is 05123123450100.

API 05-123-12345 Enter the American Petroleum Institute well identifier of the Well, if applicable. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

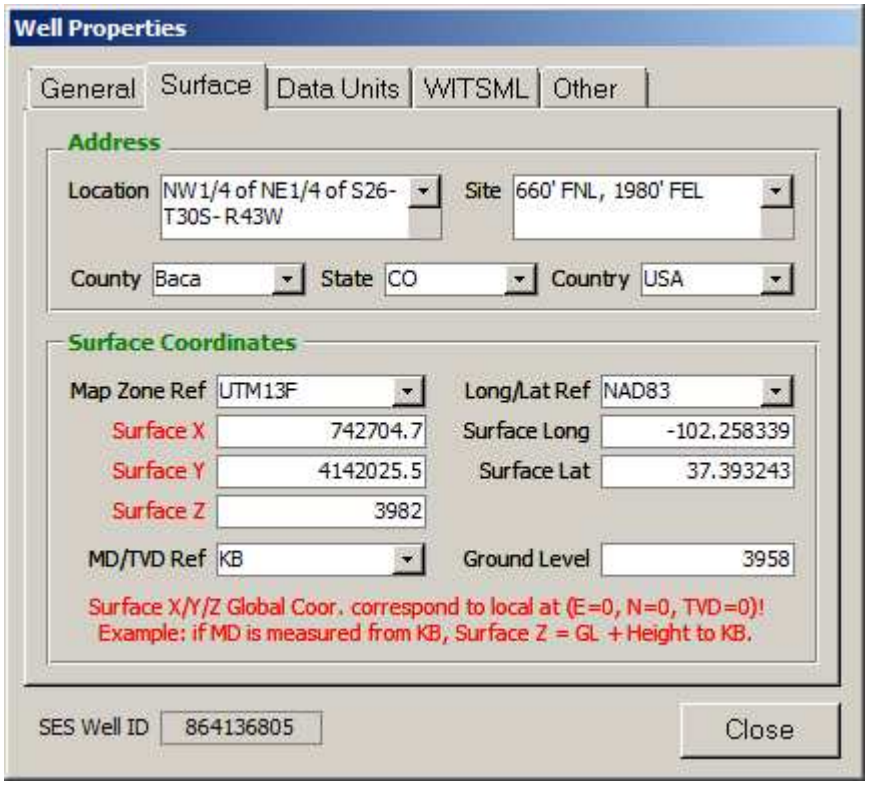
When exporting TopsTVD or TopsTVDss data from **13. SES Screen – CROSS-SECTIONS** to an external file (e.g., csv, las, xls, txt, prn, or clipboard) a WellboreID column is inserted into the first column of the data file. WellboreID is determined by concatenating UWI and Survey Number minus one. If UWI is null/blank then API well identifier is used. For example, if API is 0512312345 and Survey Number is 1, WellboreID is 05123123450000. If both UWI and API are null/blank then WellboreID is determined using the SES Well ID and Survey Number.

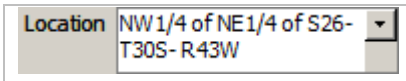
Well Number 1H Enter the well number of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

Slot Name 1H Enter the slot name of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

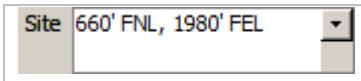
4.2.2 Well Setup - Surface

The Surface tab of Well Setup is used to enter a Well's surface location information. Most values appear in select report headers. For Grid data interpolation features in SES, accurate surface coordinates of the Well are required.

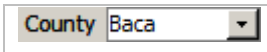




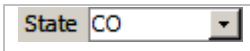
Enter a description of the surface location of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.



Enter a description of the surface location/site of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

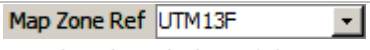


Enter the county (or similar equivalent) of the surface location of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.



Enter the state (or similar equivalent) of the surface location of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

Enter the country (or similar equivalent) of the surface location of the Well. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.



With respect to entered SurfaceX and SurfaceY coordinates, enter a concise description of the map coordinate/projection system reference. It is important that a Grid's X-Y coordinate system reference and a Well's SurfaceX and SurfaceY coordinate system reference be identical and with same length units (feet or meters).

Surface X 742704.7 The Easting (eastward-measured distance) geographic Cartesian coordinate for the Well's wellhead surface location, with respect to the chosen global map zone coordinate/projection system. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports. This property is used to interpolate and then display Grid data on Surveys, Planner, and Cross-Sections screens, and it is used to calculate wellbore/wellpath global coordinate (X/MapE/GridX) from local coordinates and relevant properties.

Surface Y 4142025.5 Enter the Northing (northward-measured distance) geographic Cartesian coordinate for the Well's wellhead surface location, with respect to the chosen global map zone coordinate/projection system. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports. This property is used to interpolate and then display Grid data on Surveys, Planner, and Cross-Sections screens, and it is used to calculate wellbore/wellpath global coordinate (Y/MapN/GridY) from local coordinates and relevant properties.

Surface Z 3982 With respect to a global Z-direction coordinate system such as distance from mean sea level, Surface Z is the elevation that corresponds to the Well's local vertical reference datum, i.e., where measured depth and true vertical depth equal zero. Most common protocols reference either kelly bushing (KB) or drilling-floor/rotary-table (DF/RT), but what matters is uniformity with associated Grid data if applicable. If using KB, enter the value equal to ground level elevation plus the height from ground level to the top of the rig's kelly bushing. If using DF/RT, enter the value equal to ground level elevation plus the height from ground level to the drilling-floor/rotary-table. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports. This property is used to interpolate and then display Grid data on Surveys, Planner, and Cross-Sections screens, and it is used to calculate wellbore/wellpath global coordinate (Z/SysTVD/TVDss) from local coordinates.

MD/TVD Ref KB Enter the Well's local vertical reference datum, i.e., where measured depth and true vertical depth equal zero. Typical selections are either kelly bushing (KB), drilling floor (DF), rotary table (RT), or ground level (GL). This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

Long/Lat Ref NAD83 With respect to entered Surface Longitude and Surface Latitude geodetic coordinates, enter a concise description of geodetic system/datum reference. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

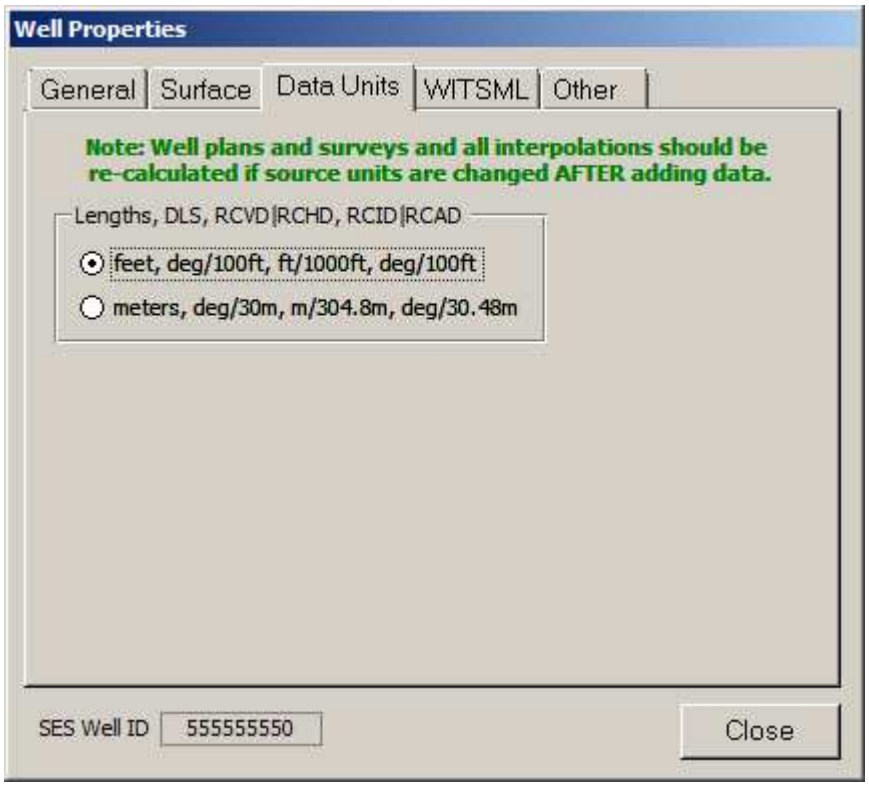
Surface Long -102.258339 Enter the Well's surface location longitude in decimal form. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

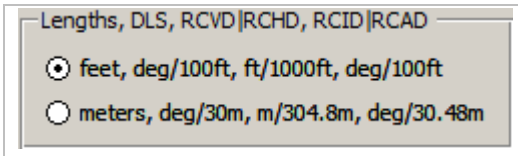
Surface Lat 37.393243 Enter the Well's surface location latitude in decimal form. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

Ground Level 3958 Enter the ground level elevation at the Well's surface location. This property is displayed in the header on Surveys and Planner screens' regulatory filing reports.

4.2.3 Well Setup - Data Units

The Data Units tab of Well Setup is used to designate the appropriate unit of measure of the Well. The *default* Data Units selection for a newly added Well is the same as the last added Well's Data Units selection. If the Data Units selection is changed after adding Well data to SES, values should be re-calculated from all possible screens.

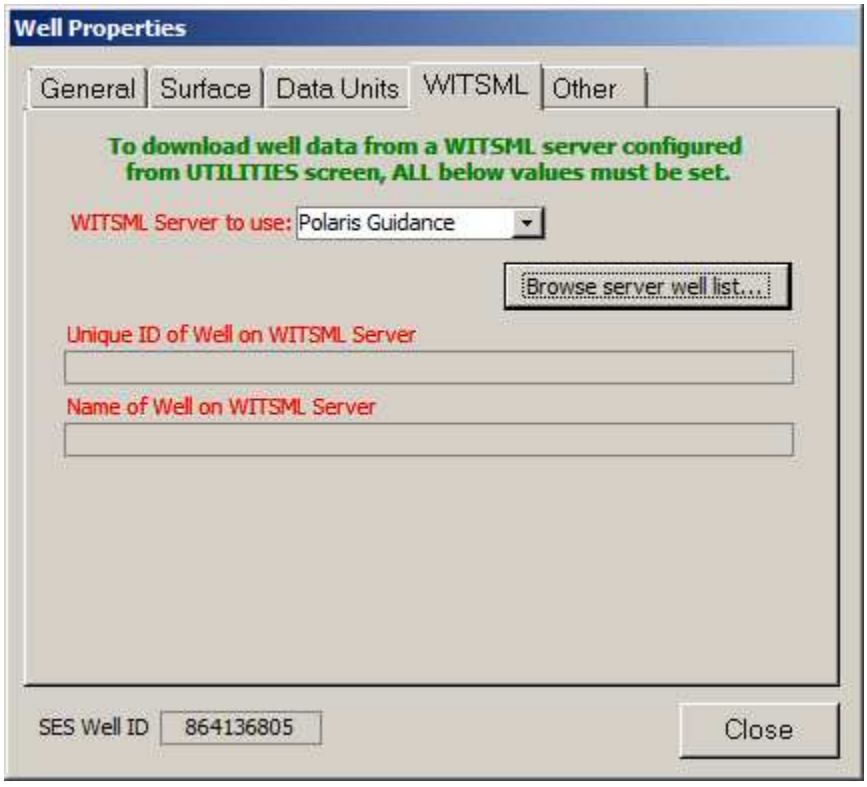




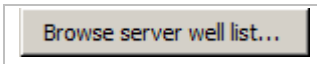
Select the unit of measure of the Well. The options are either feet or meters. (DLS = dogleg-severity. RCVD = relative change in vertical deviation. RCHD = relative change in horizontal deviation. RCID = relative change in inclinational deviation. RCAD = relative change in azimuthal deviation.)

4.2.4 Well Setup - WITSML

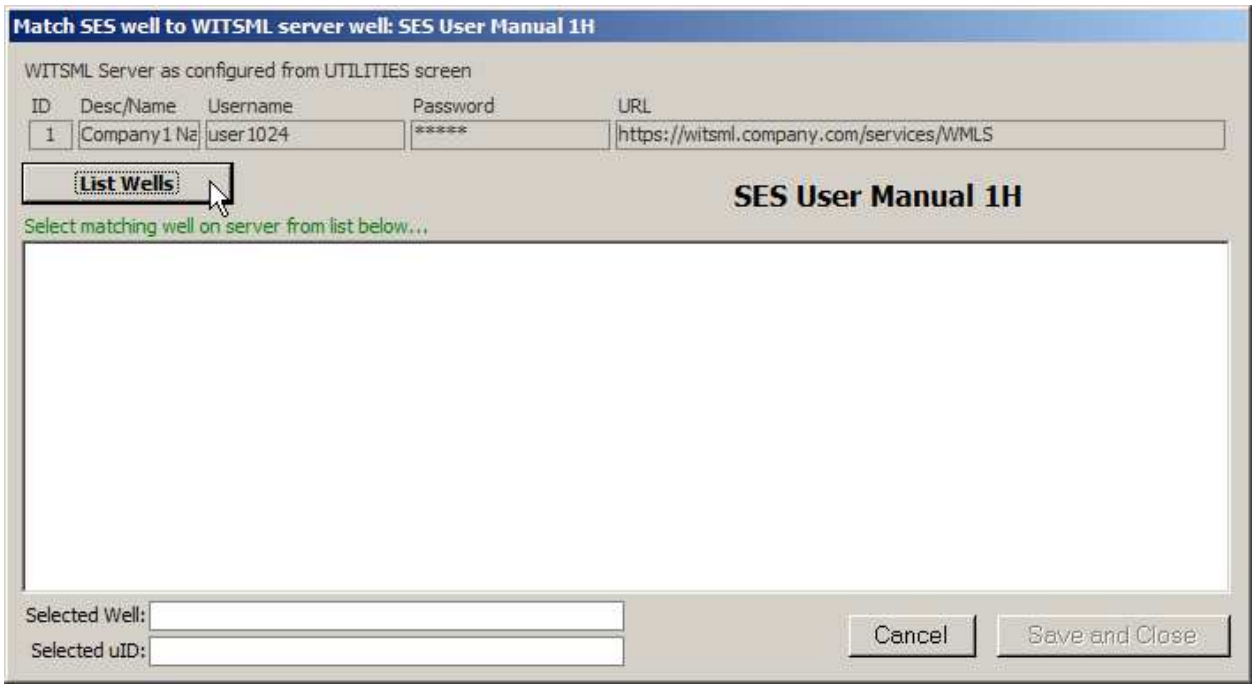
The WITSML tab of Well Setup is used to designate which WITSML server has data for the selected Well, and to identify the unique ID of the Well as it exists on the WITSML server. Access to a WITSML server must be configured before performing this step. See **2.4 WITSML Server** for more information.



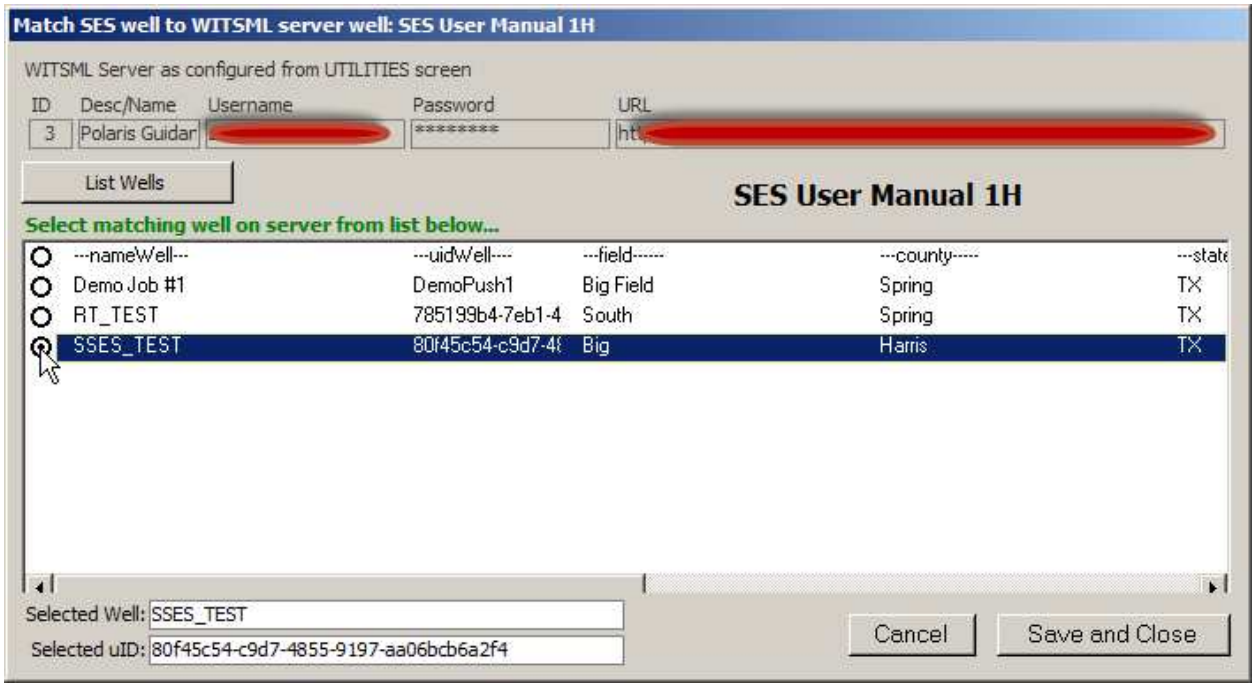
Select the WITSML server that hosts information for the selected SES Well. Only WITSML servers with "OK" status will be displayed in the dropdown box. See **2.4 WITSML Server** for more information.



Click "Browse server well list..." button to load "Match SES well to WITSML server well" dialog to list all available WITSML server wells and then select the corresponding well that matches the SES Well.

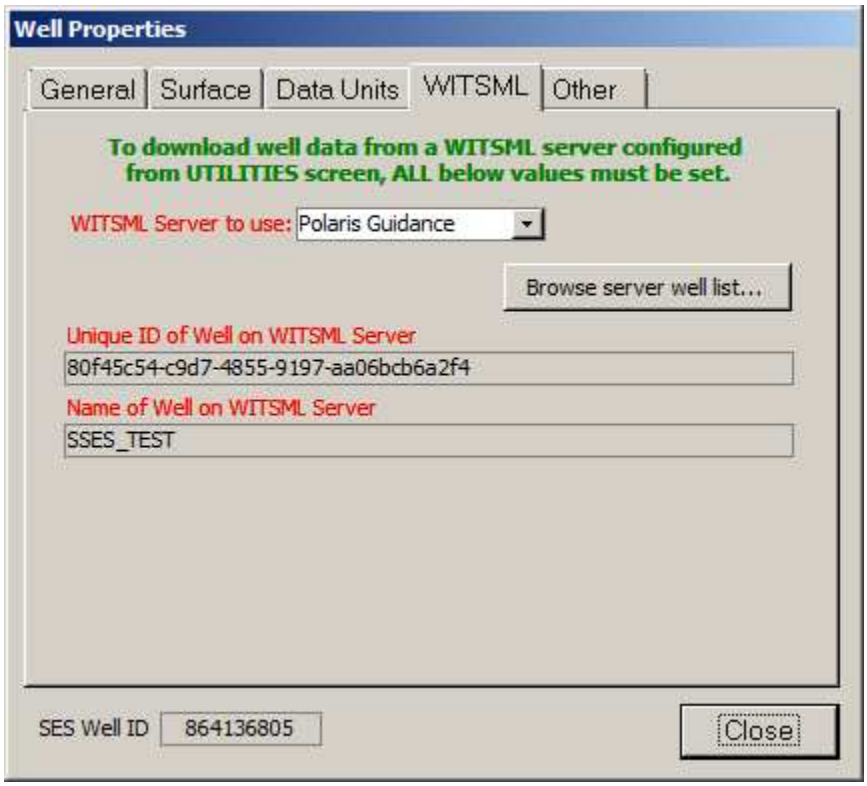


List Wells Click "List Wells" button to query the WITSML server for a list of all wells on the WITSML server for which the subscribed user of the WITSML server service has permission to access. After the list is returned, select the corresponding server well that matches the current SES Well. In the example below, well "SSES_TEST" has been selected.



Cancel Click "Cancel" button to close "Match SES well to WITSML server well" dialog and return to WITSML tab of WELLS screen. Any changes made are NOT saved.

Save and Close Click "Save and Close" button to close "Match SES well to WITSML server well" dialog and return to WITSML tab of WELLS screen. Any changes made are saved and WITSML tab is updated, as shown below in this example.

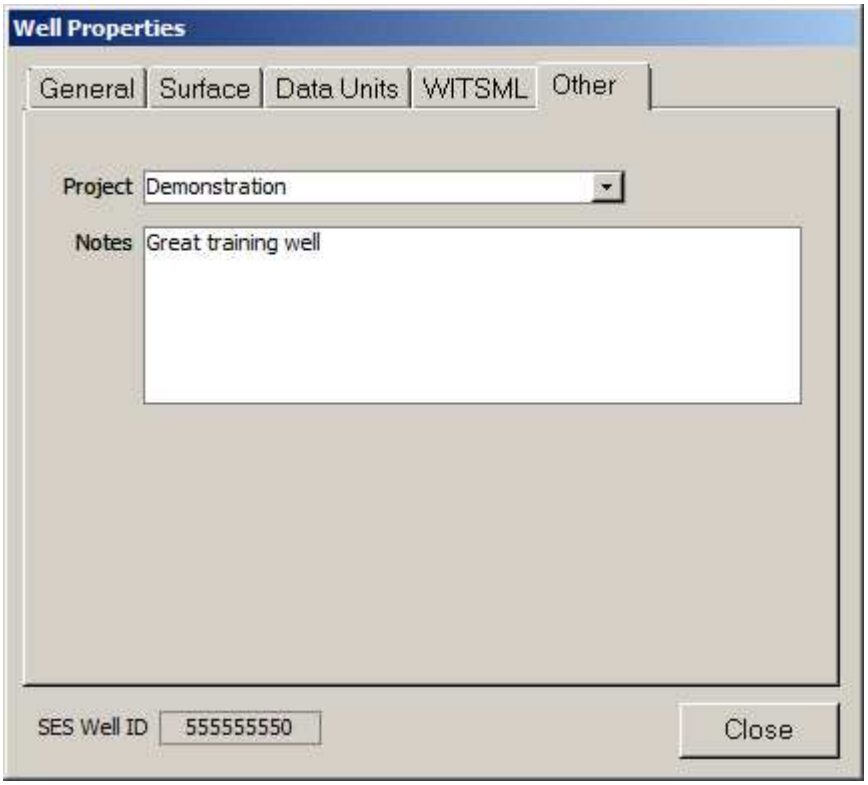


Unique ID of Well on WITSML Server
80f45c54-c9d7-4855-9197-aa06bcb6a2f4 After "Browse server well list..." has been successfully performed, the unique ID of the SES Well as it was selected from the WITSML server is displayed here. This is for informational purposes.

Name of Well on WITSML Server
SSES_TEST After "Browse server well list..." has been successfully performed, the well name of the SES Well as it was selected from the WITSML server is displayed here. This is for informational purposes.

4.2.5 Well Setup - Other

The Other tab of Well Setup is used to enter optional additional information about the Well.

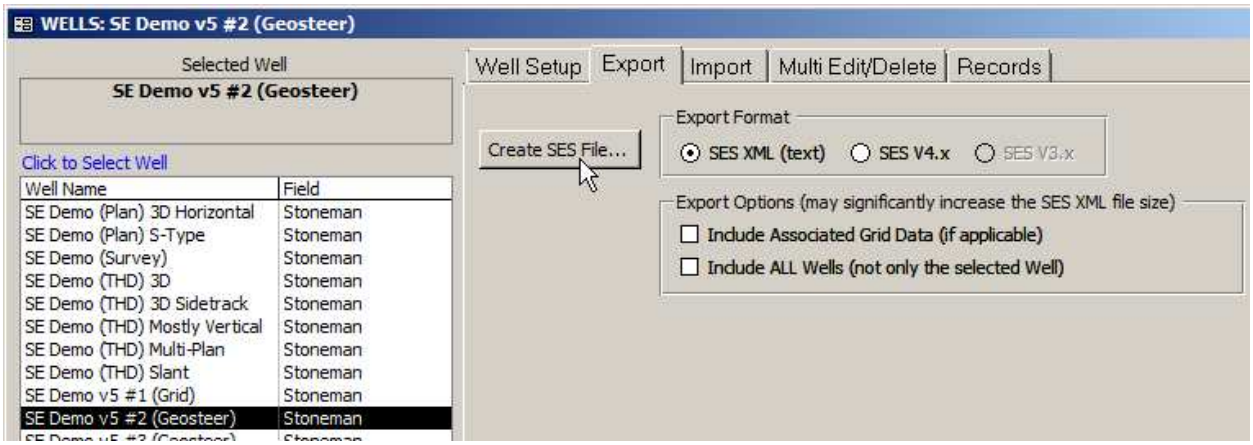


Project Demonstration Enter the project or other classed information to which the Well belongs. This property is not displayed in any reports.

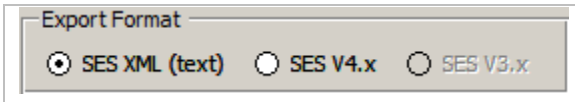
Notes Great training well Enter any other pertinent information about the Well. This property is not displayed in any reports.

4.3 Export

WELLS screen, Export tab is used to generate a file containing SES-related data for transfer to other SES users or Databases.



Create SES File... Click "Create SES File..." button to set the output path and name the file and then generate an "SES xml" file, which is a text file in a special format that contains SES Well data and may contain SES Grid data from one or multiple SES Wells and SES Grids. The generated SES xml file may then be zipped and emailed or otherwise transferred to others for subsequent Import. The generated SES xml file may also be used to produce a full copy of a Well in the current SES Database.



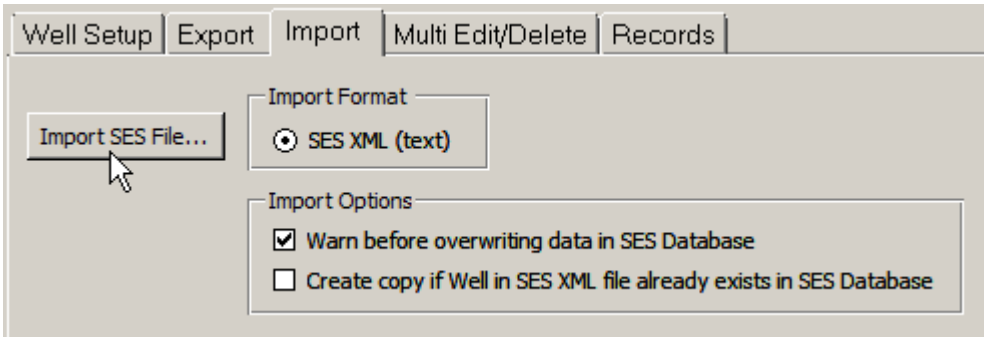
Select the export format of the SES xml file to generate. Usually the current format is best. If intended file recipients are known to be using an older version of SES then select the older version export format option before creating the SES xml file.

☐ Include Associated Grid Data (if applicable) Check "Include Associated Grid Data (if applicable)" option if the SES xml file should also contain any Grid data that the selected Well or all Wells use. Checking this option may significantly increase the SES xml file size.

☐ Include ALL Wells (not only the selected Well) Check "Include ALL Wells (not only the selected Well)" option to generate an SES xml file that contains data from all Wells in SES Database; not only the one selected Well. This option is helpful when merging data from one SES Database to one or more other SES Databases. Checking this option may significantly increase the SES xml file size.

4.4 Import

WELLS screen, Import tab is used to transfer the contents of an SES xml file created with the Export feature into SES Database.



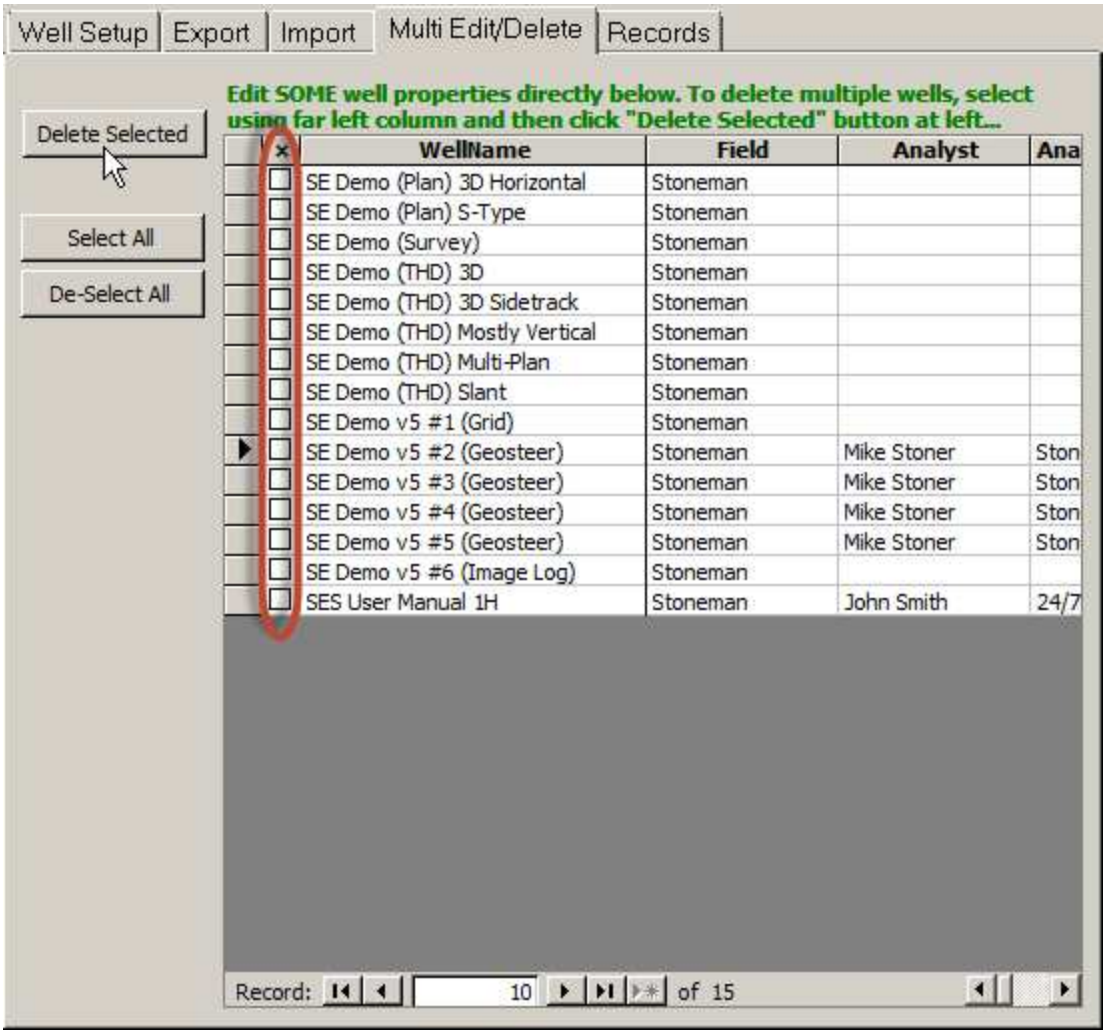
Import SES File... Click "Import SES File..." button to browse and select an existing SES xml file to import into SES Database. The selected file must have been generated using SES Export tab. The selected file may contain data from one SES Well or multiple SES Wells and one or multiple SES Grids. SES will automatically import SES xml files generated with older versions of SES.

☑ Warn before overwriting data in SES Database Check "Warn before overwriting data in SES Database" option if SES should interrupt the import procedure if it is discovered that a Well with the same wID or a Grid with the same gID, will overwrite data currently present in SES Database. Uncheck this option if SES should replace the data within SES Database with the data contents contained within the SES xml file being imported and provide no warning.

☐ Create copy if Well in SES XML file already exists in SES Database Check "Create copy if Well in SES XML file already exists in SES Database" option to instruct SES to create a copy of a Well in SES Database if it is discovered that a Well and/or Grid in the SES xml file already exists in SES Database. In the situation where a copy is generated, a time stamp is added to the Well's Well Name to help differentiate multiple such copies.

4.5 Multi Edit/Delete

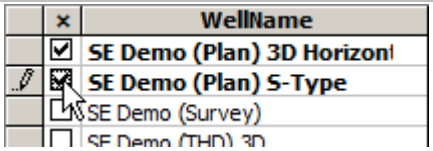
WELLS screen, Multi Edit/Delete tab is used to delete multiple Wells at once from SES Database and/or to more-easily edit select Well properties because of a table layout format.



Delete Selected Click "Delete Selected" button to delete the Wells selected in the table. There is an SES reserved Well that may not be deleted, however, its name may be changed to control where it displays in the Well list.

Select All Click "Select All" button to select all Wells in the table.

De-Select All Click "De-Select All" button to de-select all Wells in the table.



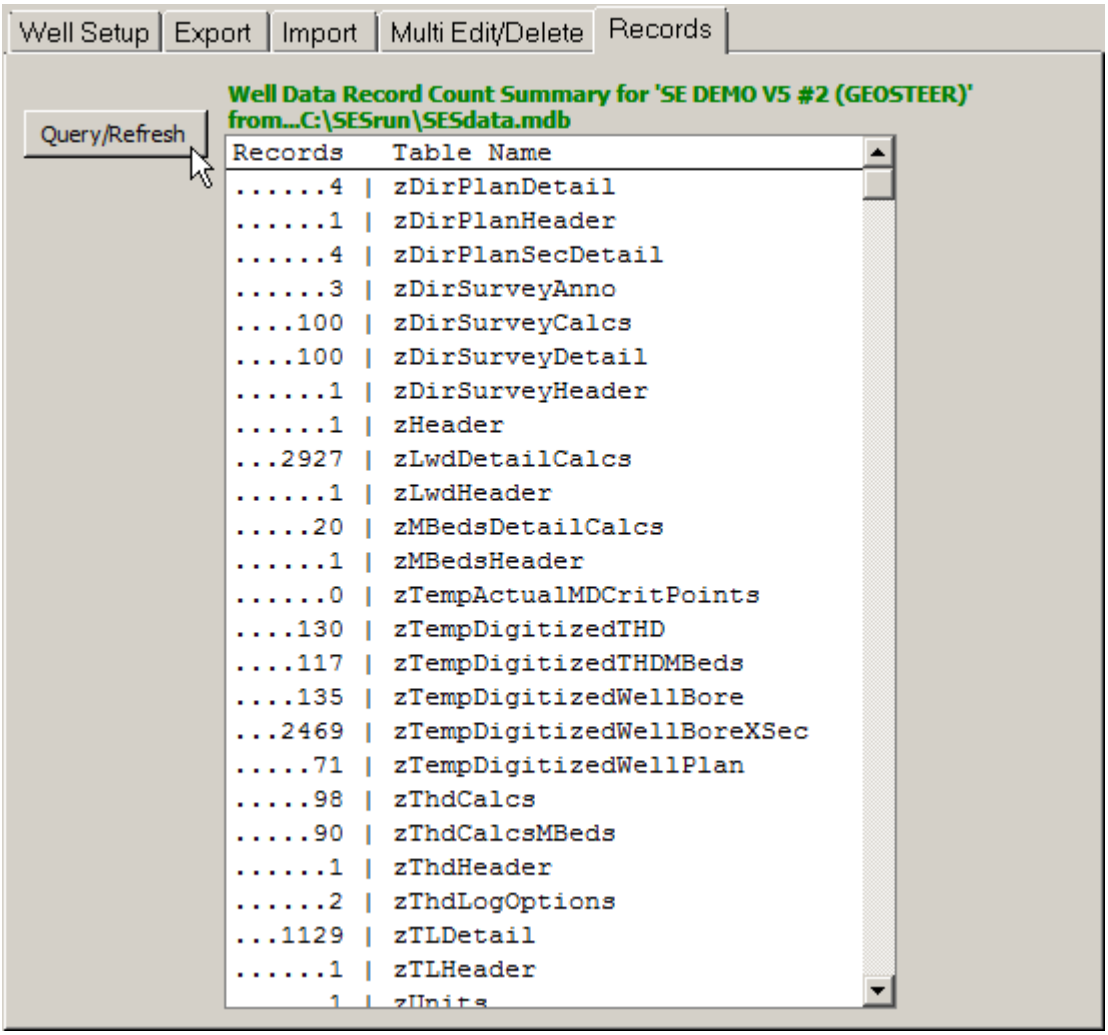
Click under the far left "x" column on the respective row to select or de-select a Well for deletion.

	×	WellName	Field	Analyst	A
	☐	SE Demo (Plan) 3D Horizontal	Stoneman	Mike Stoner	
	☐	SE Demo (Plan) S-Type	Stoneman		
	☐	SE Demo (Survey)	Stoneman		

Displayed Well properties may be changed by clicking into a cell and editing accordingly. Arrow, Tab, and Shift+Tab keys may be used to navigate between Wells (rows) and Well properties (columns).

4.6 Records

WELLS screen, Records tab is used to inspect a listing of data record counts in all SES Database data tables for the selected Well.



Query/Refresh Click "Query/Refresh" button to query SES Database and produce a summary table of record counts in each table for the selected Well. This report may be helpful at times to determine different versions of the same well name for subsequent/appropriate deletion.

4.7 Critical

1.) If a new Well has been added to SES Database from WELLS screen while SES screen is open, simply close SES screen and re-load it from Main Menu to refresh the Well list on SES screen.

2.) If a Well's Data Units selection is changed after data (e.g., directional survey data) have been added to SES, re-calculate ALL survey-related data using SES screens.

3.) If a geologic model via Grid data will be displayed in Surveys, Planner, and/or Cross-Sections, then the Well's surface coordinates (SurfaceX, SurfaceY, SurfaceZ) must be entered and referenced using the same coordinate system (e.g., UTM13, Colorado Central Zone, etc.) and units (e.g., feet) as the Grid data.

4.8 Tips

- The Well selected when WELLS screen is closed is the default Well selected/loaded when SES screen is loaded.

- Some find it helpful to create a "Template Well" that has as much as possible about a new Well already entered with the typical options and values and desired settings across WELLS, Surveys, Planner, Type Log, LWD, Geosteer, and/or Cross-Sections screens, to more quickly setup a brand new Well in SES.

- To create a full copy of a Well, use WELLS screen and Export it to an SES xml file and then Import the same file with 'Create copy…' checked on Import tab and then change the Well Name accordingly.

- Another method to archive Wells is to save an SES xml file of each Well.

5. SES Screen

5.1 General

SES screen is the "command center" of SES and contains multiple other screens. Each tab or "screen" addresses a unique aspect of SES including smart data integration by design.

SES screen can be used to:

1.) Set the Active Well and display its current data by selecting a Well Name from the drop-down box.

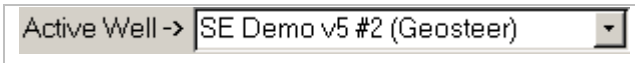
2.) Create and navigate to multiple datasets regarding directional surveys, well plans, type logs, LWD data, marker beds (interpretations) from geosteering, technical hole deviation (THD) technology, and cross sections.

3.) Get more information by clicking the Help icon ("?") on any screen.

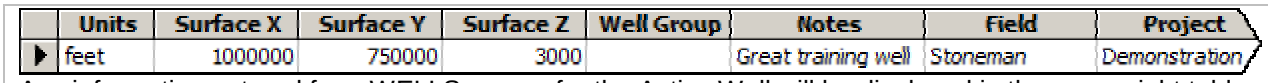
5.2 Toolbar 

Control	Control Tip | Detailed Description
	close SES screen | Close SES screen and return to Main Menu.
	Main Menu | Return to Main Menu without closing SES screen. This may be helpful in order to open WELLS screen or GRIDS screen while SES screen remains open with a Well loaded.
	refresh (sometimes needed in network environment) | Requery all datasets for the current Well. This is like selecting the Well Name from the dropdown box. This can be helpful when multiple people are working on the same Well at the same time from different computers, or if multiple instances of SES are being run from one computer while working on the same Well.
	SES help | Display SES screen abridged help.
	edit Active Well properties | Display Well Properties dialog for the Active Well to make edits or to add new content. This dialog is the same as clicking "Edit" button from WELLS screen. For example, click this button to change the Well's well name or surface coordinates. All content currently entered for the Active Well is displayed in the upper-right table on SES screen.

5.3 Other Functions/Features



Select a Well from the dropdown box to load and make it the Active Well. If a recently added Well is not listed in the dropdown box but exists on WELLS screen, close and then re-open SES screen.



	Units	Surface X	Surface Y	Surface Z	Well Group	Notes	Field	Project
▶	feet	1000000	750000	3000		Great training well	Stoneman	Demonstration

Any information entered from WELLS screen for the Active Well will be displayed in the upper-right table on SES screen. This information in the table is read-only. To change the information, click  .

5.4 Critical

1.) Wells are added or deleted to SES Database only by using WELLS screen.

2.) Closing and re-loading SES screen refreshes the Active Well dropdown box.

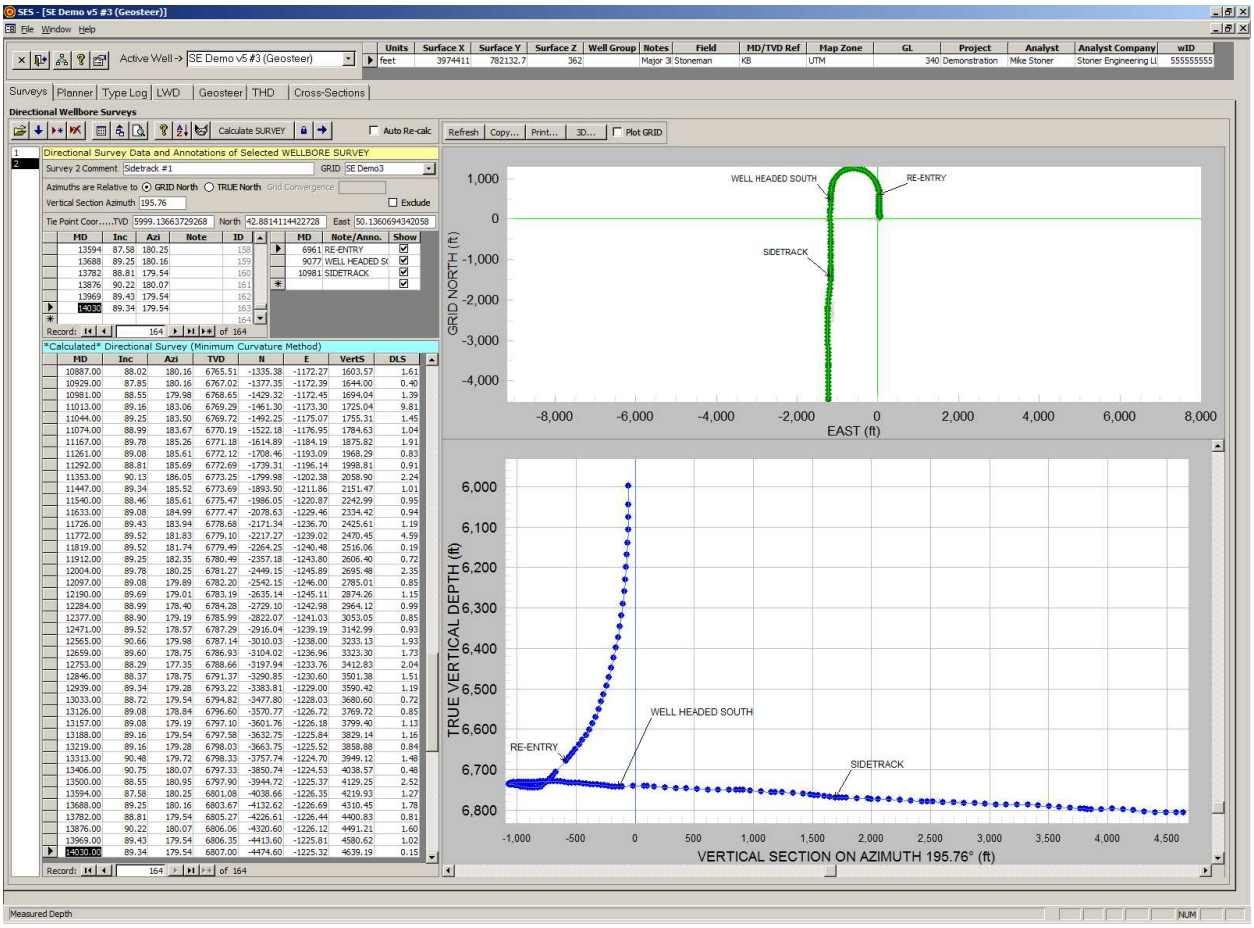
3.) "Gracefully" exiting SES screen is recommended. This means to close SES screen using the upper-LEFT "X" button, which saves the Active Well for subsequent initial load if possible when next returning to SES screen.

4.) "Gracefully" exiting the SES application is also recommended. This means to click "Exit" button from Main Menu (or "File, Exit" menu from almost any screen).

5.5 Hot Keys

- CTRL - hold down Control key while selecting different Well from dropdown box and Surveys/Planner graphs are NOT updated (navigation/dataload is faster without updating graphs; click "Refresh" respectively to update graphs)

6. SES Screen – SURVEYS



6.1 General

The wellbore directional survey is fundamental to many SES features. All directional survey calculations are performed internal to SES. The survey calculational method is minimum curvature, including interpolation between stations.

SURVEYS screen can be used to:

1.) Input wellbore directional survey station data (MD/Inclination/Azimuth) by keypunch, by paste from Excel, by import from an LAS file, or by download/import from a WITSML server; manually enter tie point coordinates and vertical section azimuth.

2.) Designate the north reference from which azimuths are relative (grid north or true north).

3.) Calculate the local Cartesian coordinates (true vertical depth - TVD, north - N, east - E), dogleg-severity - DLS, and vertical section - VertS from wellbore survey data.

4.) Set each directional survey vertical section azimuth independent of other Surveys.

5.) Create vertical section view and plan/map view standard directional plots of a wellbore.

6.) Associate a geologic Grid dataset to a Survey and then 3D plane-interpolate it and display the formations/surfaces on certain views.

7.) Interpolate a Survey at arbitrary measured depths for coordinates (TVD,N,E,INC,AZI,DLS,VERTS) and for annotation/note posting on the vertical section view and Cross-Sections screen cross sections.

8.) Create a "digitized" wellbore survey table with extra interpolated values for smoother graphing, including local coordinates converted into global X, Y, TVDss coordinates.

9.) Print/Preview a formal directional survey report for regulatory reporting or otherwise.

10.) Print the standard directional plots on any system printer (including Adobe/PDF).

11.) Copy the standard directional plots for paste into another application.

12.) View the wellbore survey station coordinates in 3D with full rotate/zoom/pan capabilities.

13.) Zoom the 2D graphs by dragging a window with the mouse; then pan by clicking the scroll bars.

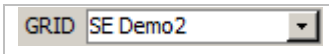
14.) Temporarily change a variety of graph properties (including full-screen/maximize mode) by right-clicking over the graph and selecting from the shortcut menu.

6.2 Toolbar

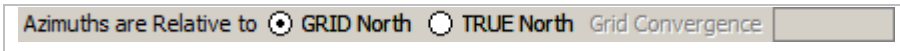
Control	Control Tip | Detailed Description
	import Survey MD/Inc/Azi from LAS file... | Open "Import 3rd-Party Data File" dialog to browse and open an LAS file, designate the respective columns in the LAS file that match MD/Inc/Azi, and import directional survey data into the selected Survey. For more information see **6.6 Import Survey Data from LAS File**.
	import Survey MD/Inc/Azi from WITSML server... | Open "Import 3rd-Party Data" dialog to download and then import directional survey data from a WITSML server. For more information see **6.7 Import Survey Data from WITSML Server**, **4.2.4 Well Setup - WITSML**, and **2.4 WITSML Server**.
	add Survey | Add a new Survey dataset and select it. SES automatically copies Survey header properties (vertical section azimuth, tie point coordinates, etc.) from the largest numbered existing Survey and initializes the new Survey with such values.
	delete Survey | Delete the selected Survey dataset (and potentially renumber the remaining existing Survey datasets). Survey #1 may only be deleted if there are at least two Survey datasets before deleting Survey #1. Survey datasets are numbered starting at #1. To delete Survey #1 when there is only one Survey dataset, first Add a new Survey dataset and then select and delete Survey #1, after which empty Survey #2 will become Survey #1.
	view digitized Survey table | Display a data table containing the entire Survey dataset including input survey station data, calculated coordinates, interpolated coordinates/angles between stations, global coordinates X, Y, Z (TVDss), and such values at arbitrary user-entered Survey Annotation measured depths. Values from the data table may easily be copied for paste into other Windows applications.
	export Survey data to LAS file... | Export the calculated directional survey data to an LAS file after setting the output path and filename. In addition to being CWLS LAS v3 compliant, LAS files generated by SES are also created to present the data content in both space delimited and fixed width text formats for greater versatility.
	print preview Survey report | Display a directional survey print preview report that is often suitable for regulatory reporting. The report header may contain much Well metadata and the report data content contains the entire Survey dataset including input survey station data, calculated coordinates, global coordinates MapE, MapN, SysTVD, and such values at arbitrary user-entered Survey Annotation measured depths (e.g., casing setting depths). The report may easily be printed (right-click for options).

	SURVEYS help | Display Surveys screen abridged help.
	sort Survey data on MD & Renumber ID (occasionally needed) | Sort the selected Survey dataset on MD and re-determine the "ID" column values. "ID" is an SES internal index number. Because all new data must be added to the bottom of the data table, sometimes resorting is necessary to ensure MD increases as is needed by SES. Deleting one or more interior survey stations can also require sorting using this button.
	check Survey for possible problems | Check the selected Survey header and table data for conditions that are known or suspected to cause problems during or after the calculation of the directional survey. This data quality check is applied each time a Survey is calculated whether or not the SES user clicks this button. Sometimes called the "cat button", the icon is actually intended to represent two hands shaking. ☺
	Calculate SURVEY (F6) Compute Survey & Digitize for Graphing | Calculate local coordinates TVD, N, E, and vertical section from directional survey inputs MD, Inc, Azi, tie point coordinates, and vertical section azimuth; calculate minimum curvate interpolated values for smoother plotting; update the calculated/output table; update the map view; and update the vertical section view.
	lock graph extents (when zoomed) between refreshes | Maintain/lock current axes minimum and maximum values after subsequent survey calculation and/or graph refreshes. This toggle button is enabled only when the map view and/or the vertical section view is zoomed. To zoom, click and drag a zoom window on the graph. By default, SES re-determines a graph's axes extents after survey calculation or refresh and this toggle button allows the SES user to temporarily override that behavior.
	convert Survey to new SES Plan | Convert the selected and calculated Survey dataset into a new Planner screen Plan dataset. Often, this method of 3rd-party well plan transfer to SES is the easiest and most numerically accurate method due to minimum round-off error inherent in how well plans are stored in software and then formatted to two decimal places when disseminated to clients.
	Auto Re-calc auto-update after key punch; leave un-checked if pasting data from clipboard | Set/check "Auto Re-calc" option if SES should immediately calculate the survey after any directional survey station data are changed or added. If Survey data are normally entered manually by key punch, this option may be helpful. This is an alternative to clicking Calculate SURVEY or pressing F6 to re-calculate the survey. ALWAYS leave this option un-checked when pasting data from the clipboard!

6.3 Other Functions/Features

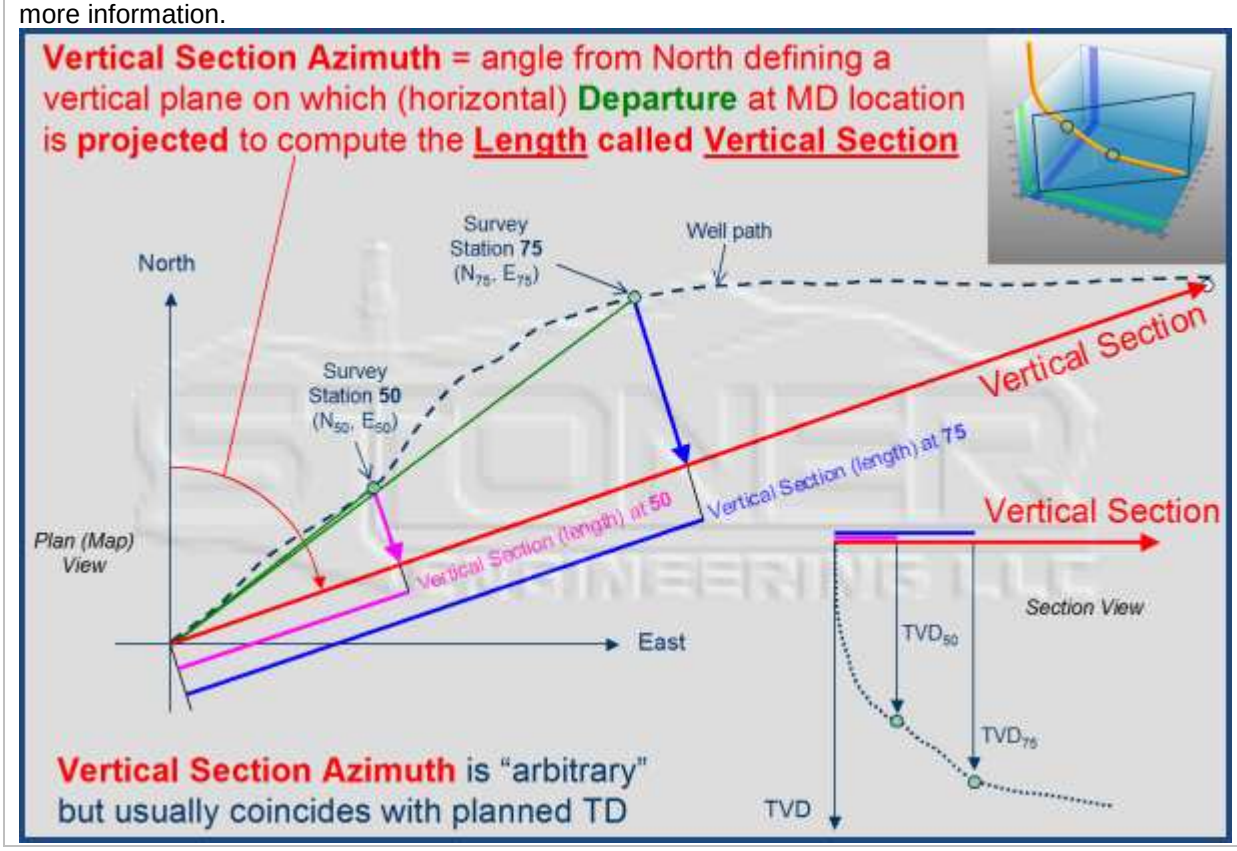


Select the corresponding Grid dataset associated with the Well. When "Plot Grid" is checked on Surveys screen and/or Cross-Sections screen, this Grid is interpolated for respective display.



Designate the north reference from where azimuths are relative, for the selected Survey dataset. Azimuthal bearings are typically measured downhole with respect to magnetic north and then converted to either true north or grid north before data dissemination. This selection is also reflected in Surveys screen map view north/y axis label. If the Survey dataset azimuths are relative to true north, then also enter the respective grid convergence angle. Grid convergence is the angle in degrees from true north to grid north at the Well's surface location, with the convention of clockwise/counterclockwise being a positive/negative value. Azimuthal bearings north reference affects the calculation of global X-Y coordinate values and the display of surfaces from interpolating global X-Y-TVDss Grid data at local N-E coordinate locations. North reference designation is included in the header portion of any LAS file created by exporting respective data from SES Surveys, Planner, LWD, THD, and Cross-sections screens.

Vertical Section Azimuth 195.76 Enter the angle in degrees from north defining a vertical plane on which (horizontal) departure is projected to compute the length called vertical section. See the slide below for more information.



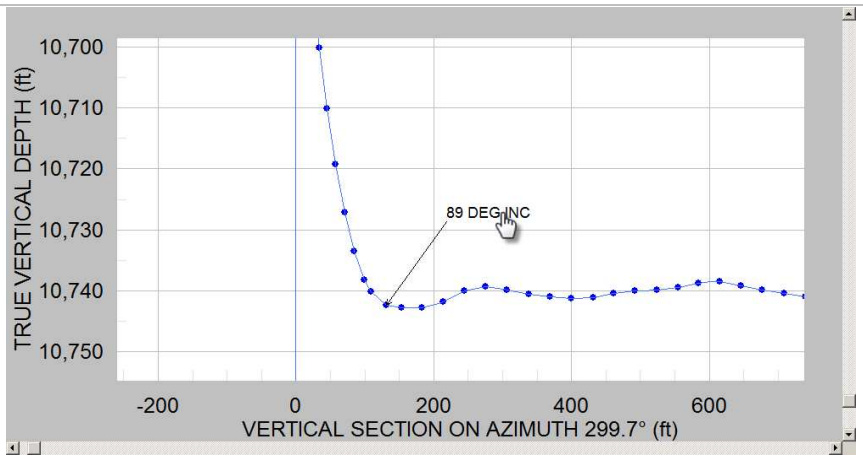
☐ Exclude Set/check "Exclude" option if SES should exclude plotting points from the selected Survey on the map view and vertical section view of *other* Surveys of the same Well AND from Surveys considered "Others" on Cross-Sections screen cross sections. Unless excluded, SES displays a gray symbol at unique stations of other Surveys on the current Surveys screen map view and vertical section view (assuming vertical section azimuths are identical), which can be helpful at times (e.g., seeing the original hole after sidetracking; quickly comparing planned to actual when one survey is the well plan).

Tie Point Coor.....TVD 7936.62344404656 North 10.5325025184668 East -23.906666796254 Enter the tie point coordinates of the selected Survey. The tie point coordinates are the local Cartesian coordinates TVD, N, E that correspond to the first/starting MD of the Survey dataset.

	MD	Inc	Azi	Note	ID
	13594	87.58	180.25		158
	13688	89.25	180.16		159
	13782	88.81	179.54		160
	13876	90.22	180.07		161
	13969	89.43	179.54		162
▶	14030	89.34	179.54		163
*					164

Record: 164 of 164

Directional survey input data measured depth (MD), inclination (INC), and azimuth (AZI) are populated in the upper-left Survey input table. User notes may be entered under the Note column on the respective row. These notes do not display elsewhere in SES. "ID" column values are determined by SES.



	MD	Note/Anno.	Show
▶	10828	89 DEG INC	☑
	11941	SIDETRACK	☑
*			☑

Directional survey notes/annotations at specific MDs are entered in the upper-right annotation input table, for interpolation and display on Surveys screen vertical section view and on Cross-Sections screen cross sections. The Survey needs to be calculated after entering annotation data. The digitized coordinates table displays full coordinates at annotation MDs. Check "Show" for the annotation to display in respective tables and cross sections. Displayed annotations on the vertical section view may be moved by dragging the text to a new location.

Calculated Directional Survey (Minimum Curvature Method)

	MD	Inc	Azi	TVD	N	E	VertS	DLS
	13688.00	89.25	180.16	6803.67	-4132.62	-1226.69	4310.45	1.78
	13782.00	88.81	179.54	6805.27	-4226.61	-1226.44	4400.83	0.81
	13876.00	90.22	180.07	6806.06	-4320.60	-1226.12	4491.21	1.60
	13969.00	89.43	179.54	6806.35	-4413.60	-1225.81	4580.62	1.02
▶	14030.00	89.34	179.54	6807.00	-4474.60	-1225.32	4639.19	0.15

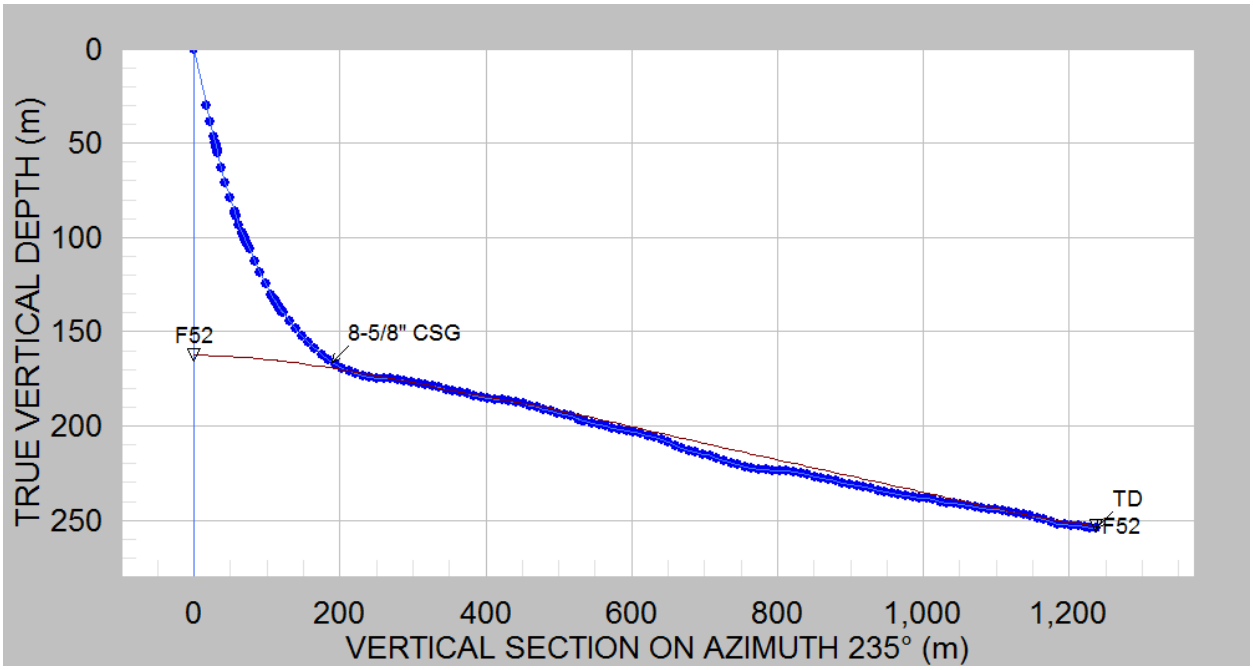
Local Cartesian coordinates true vertical depth (TVD), north (N), and east (E) are calculated using the minimum curvature survey calculational method. Vertical section (VertS) and dogleg-severity (DLS) are also calculated. Calculated results are displayed in the lower output data table on Surveys screen.

Refresh Redraw the map view and vertical section view graphs for the currently selected Survey. This request does not re-calculate the directional survey but it does process any changes made regarding the display of Grid data, Survey annotation show/hide settings, zoom-lock off setting, and which Survey is currently selected. To automatically redraw the graphs when selecting different Surveys, press and hold the CTRL key when selecting the Survey number in the list box along the left side of the screen.

Copy... Display a dialog that reminds how to **copy** a graph. To **copy** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (**clipboard**/file/printer), size, and resolution/dpi.

Print... Display a dialog that reminds how to **print** a graph. To **print** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (clipboard/file/**printer**), size, and resolution/dpi.

Plot GRID Check "Plot GRID" option to interpolate and display the surface(s) of the associated Grid dataset at locations along the selected Survey on the vertical section view. The Well's surface location coordinates in the same global coordinate system need to be entered for Grid dataset interpolation. SES uses planar triangulation to interpolate. At each respective Survey north and east coordinate, SES finds the three nearest Grid dataset coordinates and calculates a plane. The plane is then interpolated to yield the respective "Z" value. Surface layer colors and names may be set from Grids screen (see **3.2 Grid Data Setup** for more information). Plotting Grid surface interpolations may also be performed from Cross-Sections screen at known wellbore locations and/or at wellbore-extrapolated locations.



"Plot GRID" option also effects 3D Viewer. Grid dataset data points and surfaces may be viewed with 3D Viewer (see **6.4 3D Viewer**).

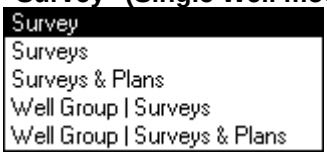
6.4 3D Viewer

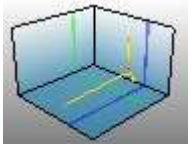
SES can display 3D views of well paths and related grid data. Different default display settings are initially applied based on the selected mode when 3D Viewer screen is opened. 3D Viewer may be opened in Single Well mode or Multi Well mode from Surveys screen and from Planner screen.

Display an interactive 3D view of selected data, starting with a particular display mode/template. In addition, "Plot Grid" option and a Well's "Well Group" value can effect 3D Viewer.

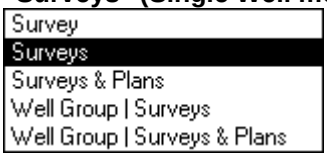
From Surveys screen there are five 3D Viewer display modes available from the dropdown box.

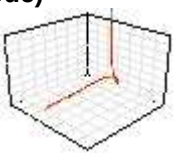
"Survey" (Single Well mode)



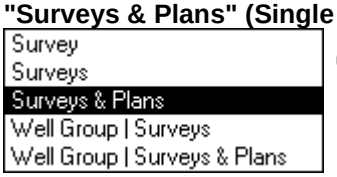

Graph selected survey using legacy display settings.

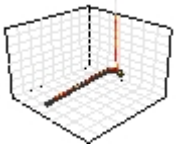
"Surveys" (Single Well mode)



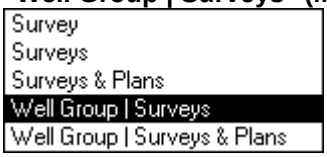

Graph selected survey and other surveys from same Well.

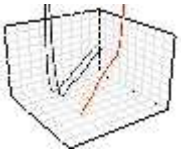
"Surveys & Plans" (Single Well mode)



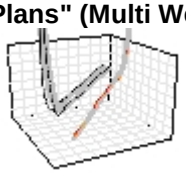

Graph selected survey, other surveys, and well plans from same Well.

"Well Group | Surveys" (Multi Well mode)

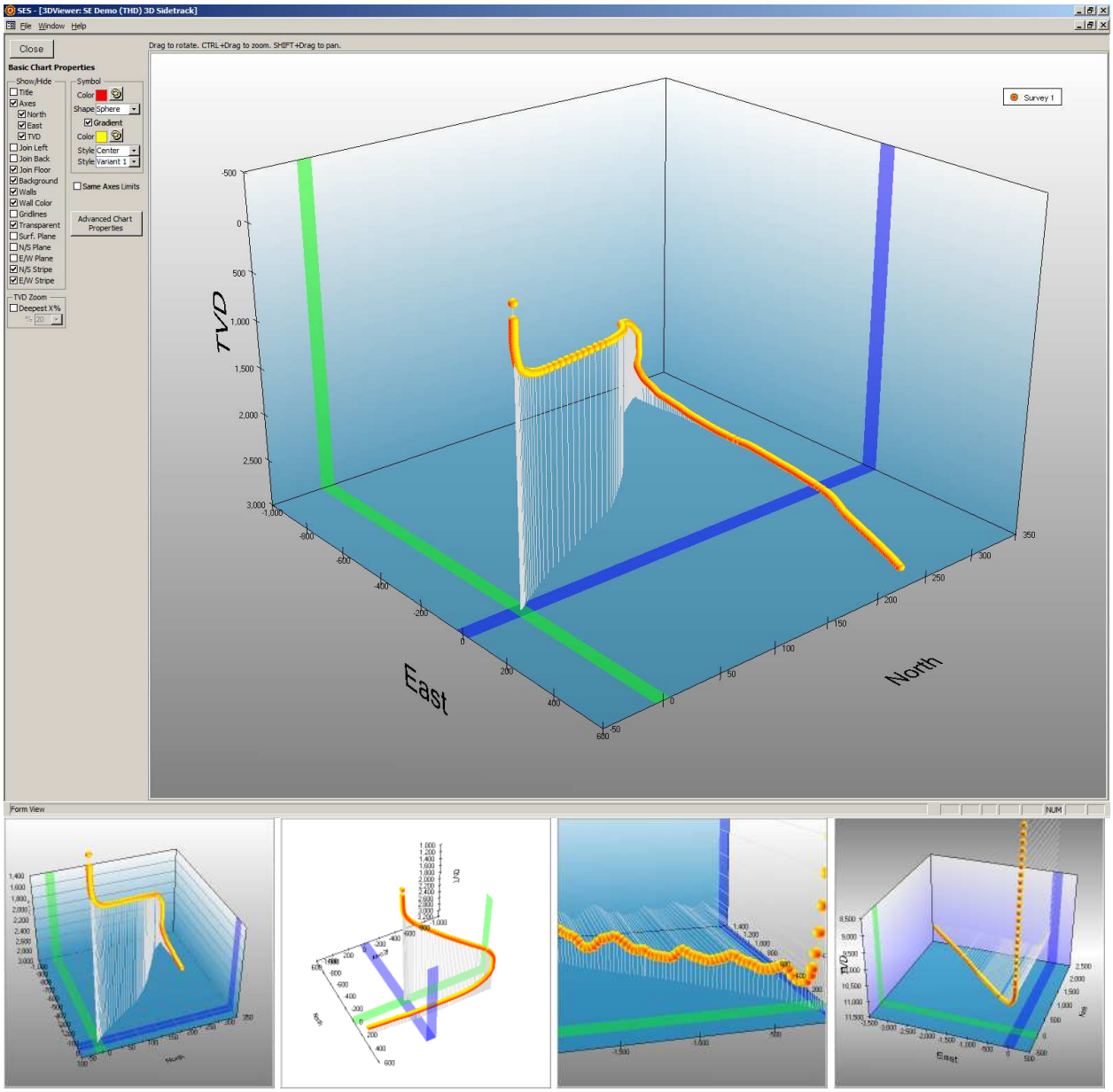



Graph surveys from all Wells with same "Well Group" value.

"Well Group | Surveys & Plans" (Multi Well mode)


Graph surveys and plans from all Wells with same "Well Group" value.

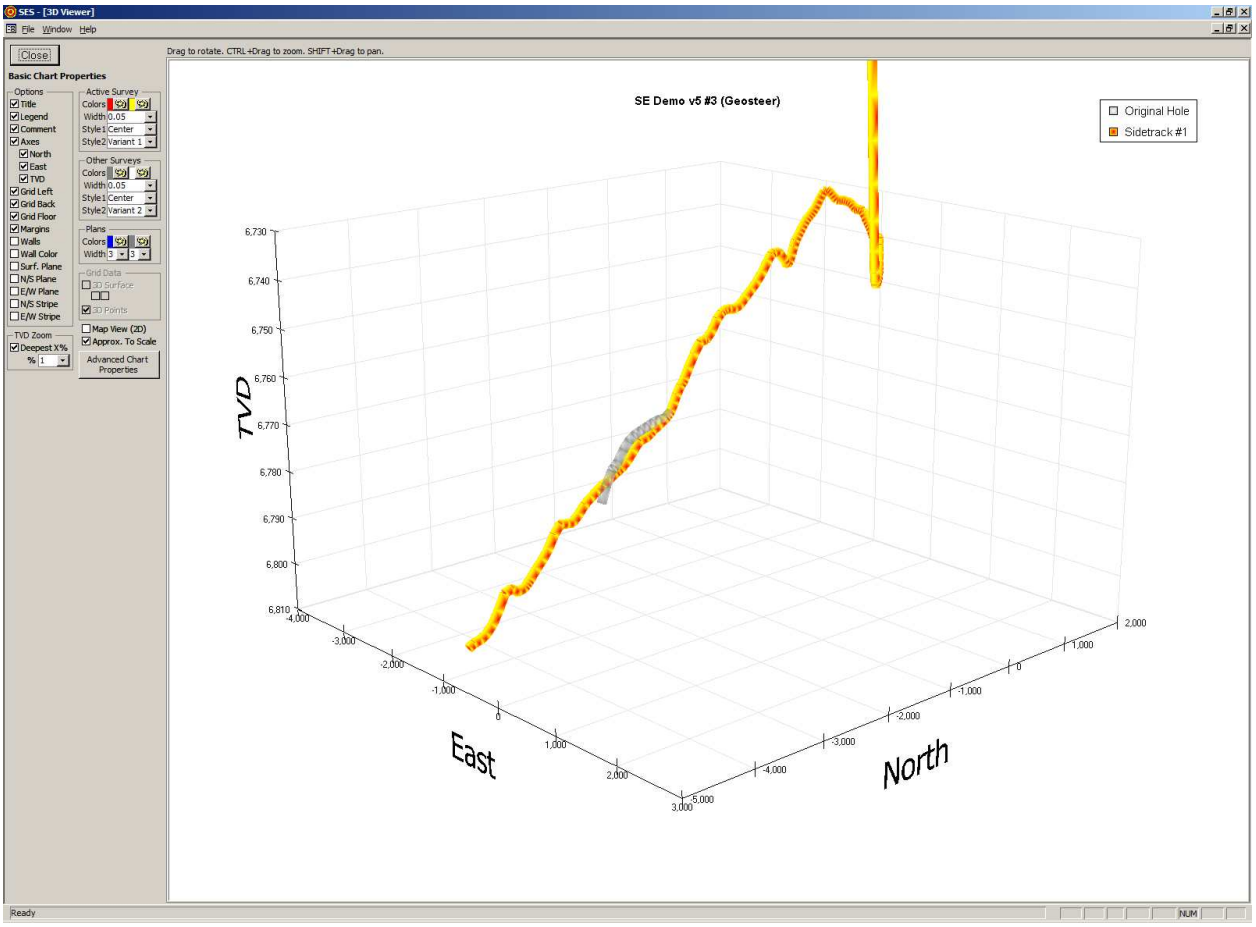
A variety of viewing options are available along the left side of 3D Viewer screen and the graph supports interactive rotate/zoom/pan (drag graph with mouse to rotate the view; press and hold CTRL key and then drag mouse up/down to zoom in/out; press and hold SHIFT key and then drag mouse to pan) and image export. Below is a screen shot of the **legacy** 3D Viewer screen, which is accessed using "Survey" mode. Survey stations are displayed as a 3D scatter chart.



6.4.1 Viewer Options

An improved 3D Viewer screen is included in this version of SES. Multiple surveys and multiple plans from one or multiple wells—and grid data surfaces—may now be displayed and explored in SES. Options set from Surveys screen tell SES how to initialize 3D Viewer and which data to include.

3D Viewer options are detailed next. Several common options are integrated on-screen for quick access while more advanced options are accessible through the "Advanced Chart Properties..." button.



Advanced Chart Properties... Open "Properties" dialog to access a plethora of session options to further configure the 3D chart view. For reference below, "ACP" refers to this dialog of Advanced Chart Properties.

☑ Title Set/check "Title" option to display a well name label as 2D text at the top of the graph. See ACP, "Labels" tab for more settings.

☑ Legend Set/check "Legend" option to display a legend on the right side of the graph that lists the datasets being graphed. See ACP, "Legend" tab for more settings. Also, see ACP, "Presentation Groups" tab, select the row of a specific dataset, click "Properties", and see "Legend" tab for additional settings.

☑ Comment Set/check "Comment" option if SES should use a dataset's Comment value instead of an automatic generic dataset description (e.g., "Survey 1", "Plan 2", etc.) in the legend.

☑ Axes Set/check "Axes" option to display North, East, and TVD axes, respective tick marks, and respective tick mark labels on the graph. See ACP, "Axes" tab, select "Left" (TVD), "Categories" (East), or "Series" (North) and then click "Properties" button for more settings.

☐ North
☐ East
☐ TVD Set/check options "North", "East", and/or "TVD" to display the respective axis label on the graph. If 3D Viewer has been opened in Multi Well mode, these options will read as "Grid Y", "Grid X", and "TVDss" respectively.

 If 3D Viewer has been opened in Single Well mode, datasets are graphed using local coordinates N, E, TVD. If 3D Viewer has been opened in Multi Well mode, then North, East, and TVD coordinates are transformed global coordinates GridY, GridX, and TVDss, respectively, including proper true north to grid north rotations wherever applicable.

☑ Grid Left Set/check "Grid Left" option to display gridlines on the left wall (TVD vs. North plane at minimum East). See ACP, "Axes" tab, select "Left" or "Series", click "Properties" button, then "Gridlines" tab for more settings.

☑ Grid Back Set/check "Grid Back" option to display gridlines on the back wall (TVD vs. East plane at maximum North). See ACP, "Axes" tab, select "Left" or "Categories", click "Properties" button, then "Gridlines" tab for more settings.

☑ Grid Floor Set/check "Grid Floor" option to display gridlines on the floor wall (East vs. North plane at maximum TVD). See ACP, "Axes" tab, select "Categories" or "Series", click "Properties" button, then "Gridlines" tab for more settings.

☑ Margins Set/check "Margins" option to add extra white space about the general 3D graph area.

☑ Walls Set/check "Walls" option to display solid surfaces at the left wall, back wall, and floor wall of the 3D graph. The default wall color is white, but may be changed to a variety of settings using ACP, "Walls" tab for more settings.

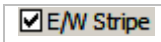
☑ Wall Color Set/check "Wall Color" option to set the left wall, back wall, and floor wall to a non-white color. See ACP, "Walls" tab for more settings.

☑ Surf. Plane Set/check "Surf. Plane" option to display a partially-transparent horizontal plane at TVD=0 (or TVDss=0). If "TVD Zoom Deepest X%" is checked, this horizontal plane may not be visible at the current scale limits. See ACP, "Axes" tab, select "Left", click "Properties" button, then "Const Lines" tab for more settings.

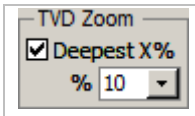
☑ N/S Plane Set/check "N/S Plane" option to display a partially-transparent vertical plane at East=0. See ACP, "Axes" tab, select "Categories", click "Properties" button, then "Const Lines" tab for more settings.

☑ E/W Plane Set/check "E/W Plane" option to display a partially-transparent vertical plane at North=0. See ACP, "Axes" tab, select "Series", click "Properties" button, then "Const Lines" tab for more settings.

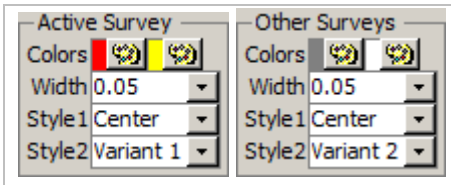
☑ N/S Stripe Set/check "N/S Stripe" option to display a partially-transparent colored stripe that highlights the North/South axis at East=0. See ACP, "Axes" tab, select "Categories", click "Properties" button, then "Stripes" tab for more settings.



Set/check "E/W Stripe" option to display a partially-transparent colored stripe that highlights the East/West axis at North=0. See ACP, "Axes" tab, select "Series", click "Properties" button, then "Stripes" tab for more settings.

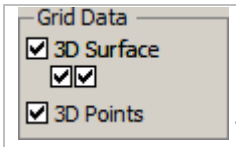


Set/check “Deepest X%” to change the minimum TVD axis limit in a manner that effectively zooms the vertical scale and moves shallow data out of view. When “Deepest X%” is checked, the “X%” zoom level may be selected from the dropdown box to better customize the view. For manual setting of the TVD axis min/max extents, see ACP, "Axes" tab, click "Left", click "Properties" button, then "Scale" tab for those settings.



When 3D Viewer is loaded from Surveys screen, the Surveys screen selected Survey dataset is considered the “Active Survey” and every other survey (if applicable) is considered an “Inactive Survey”. Click the respective color palate button to change the respective color. Select Width to change the display tube width of the respective survey path, including 0 to change the tube to a 3D line. Selecting an option under “Style 1” or “Style 2” can change how the gradient fill of the tube is drawn or other display customizations. For more options, see ACP, "Presentation Groups" tab, select the row of a specific survey, click "Properties" button, and make setting changes from there (e.g., "Uniform Appearance" tab, select the row containing "Line", click "Fill Effect" button, and change the gradient end point colors, transparency, etc.).

When 3D Viewer is loaded from Planner screen, the selected Planner screen Plan dataset is considered the “Active Plan” and every other plan (if applicable) is considered an “Inactive Plan”. When 3D Viewer is loaded from Surveys screen using a template including "Plans", then all plans are considered to be "Inactive Plan". Click the respective color palate button to change the respective color. Select a line width to change the display width of the planned well path. For more options, see ACP, "Presentation Groups" tab, select the row of a specific plan, click "Properties" button, and make setting changes from there (e.g., "Uniform Appearance" tab, select the row containing "Line", click "Border" button, and change the line color, line width, etc.).



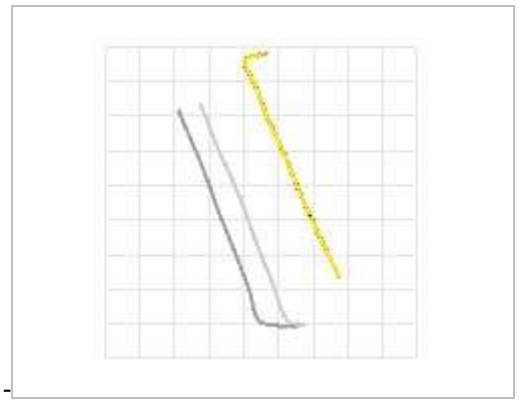
When “Plot Grid” is checked from Surveys screen when 3D Viewer is loaded, Grid data are queried and returned in the vicinity of the well path and made available for display. Grid data may be displayed—as 3D scatter points ("3D Points") and/or as a surface ("3D Surface")—for each available grid layer. The associated Grid dataset is selected from Surveys screen for the respective Survey dataset.

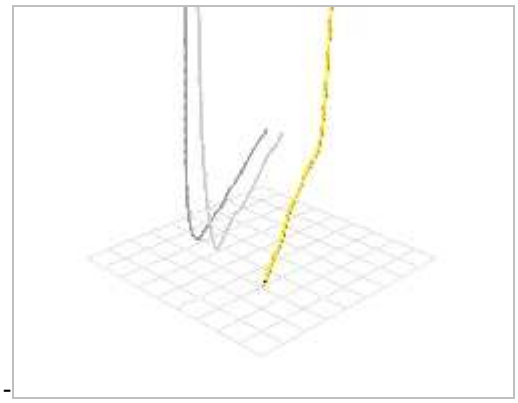
Set/check "3D Surface" option to display respective Grid data as a surface. Set/check "color sync'd to TVD" option to vary the 3D surface color by true vertical depth instead of as a constant "zone" color. Set/check "contour on floor" option to "flatten" the grid data view to display the surface at the deepest TVD level. For example, setting "color sync'd to TVD" and "contour on floor" displays a contour map type of display within the 3D graph.

Set/check "3D Points" option to display symbols at each respective grid data point. 3D points may be displayed with or without the 3D Surface option. 3D points act as a "skeleton" view and the 3D graph may be rotated and zoomed faster than when surfaces are also displayed. Dense grids may be sampled.

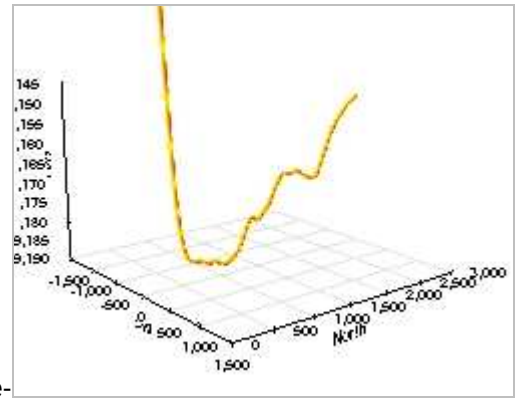
See ACP, "Presentation Groups" tab, select the row of a specific "Surface" or "Point" dataset display type, and click "Properties" for additional settings.

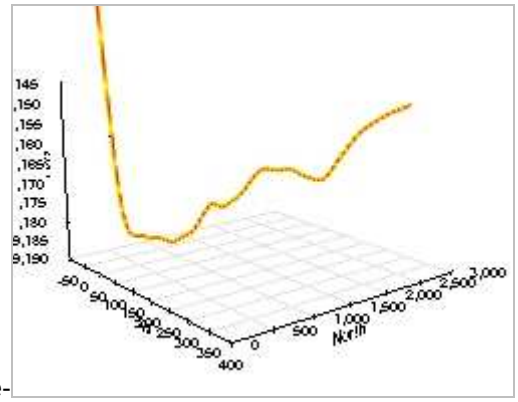
☐ Map View (2D) Set/check “Map View (2D)” to display the 3D view from the top; effectively a 2D map view format (North vs. East). Uncheck this display option to return the graph to 3D view.

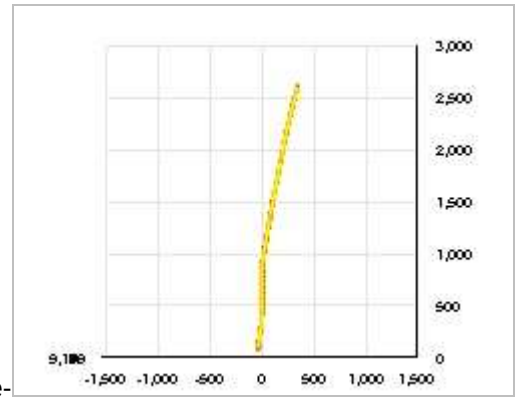
2D - 

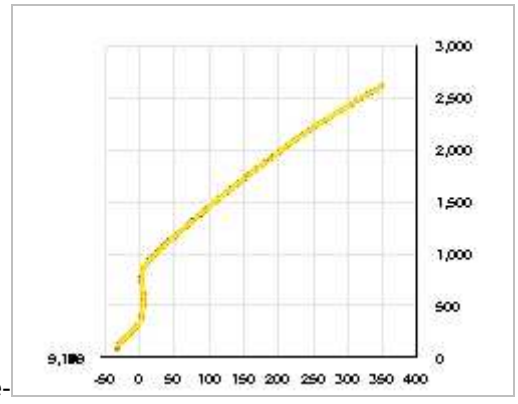
3D - 

☑ Approx. To Scale Set/check "Approx. To Scale" to display the North/South and East/West axes generally to scale; i.e., where major grid values are equal. If “Approx. To Scale” option is unchecked the East axis range and North axis range are determined from respective data ranges and respective axis major grid values may differ and thus the map may not appear drawn to horizontal scale.

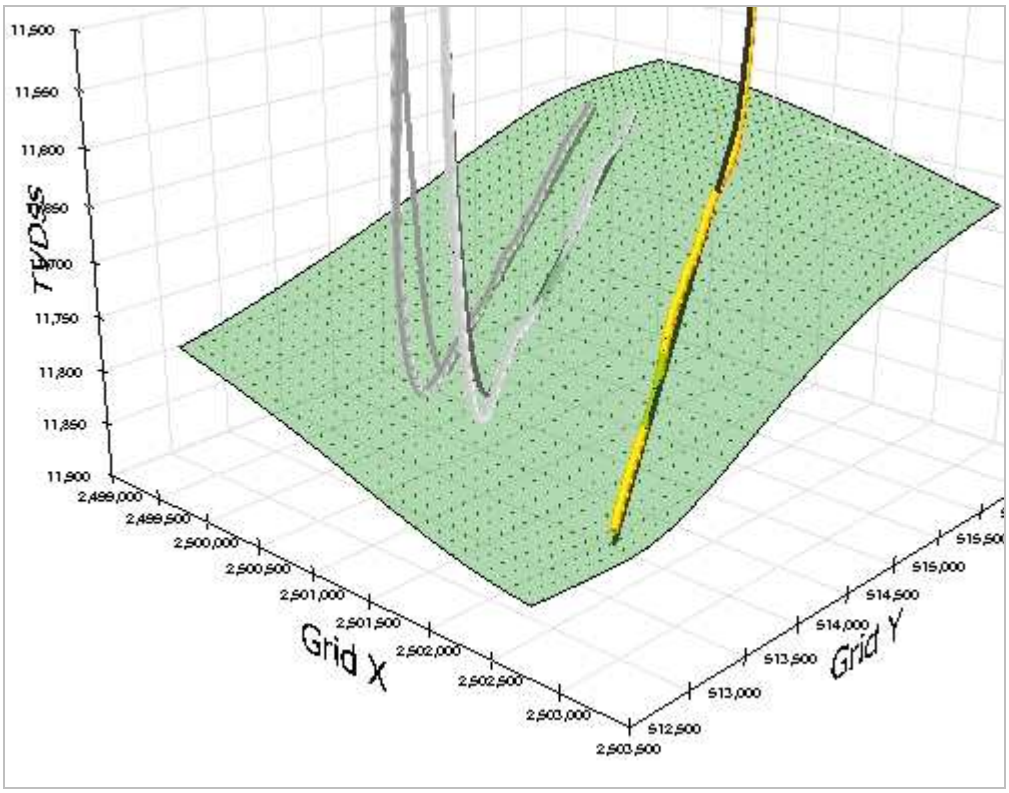
Scale- 

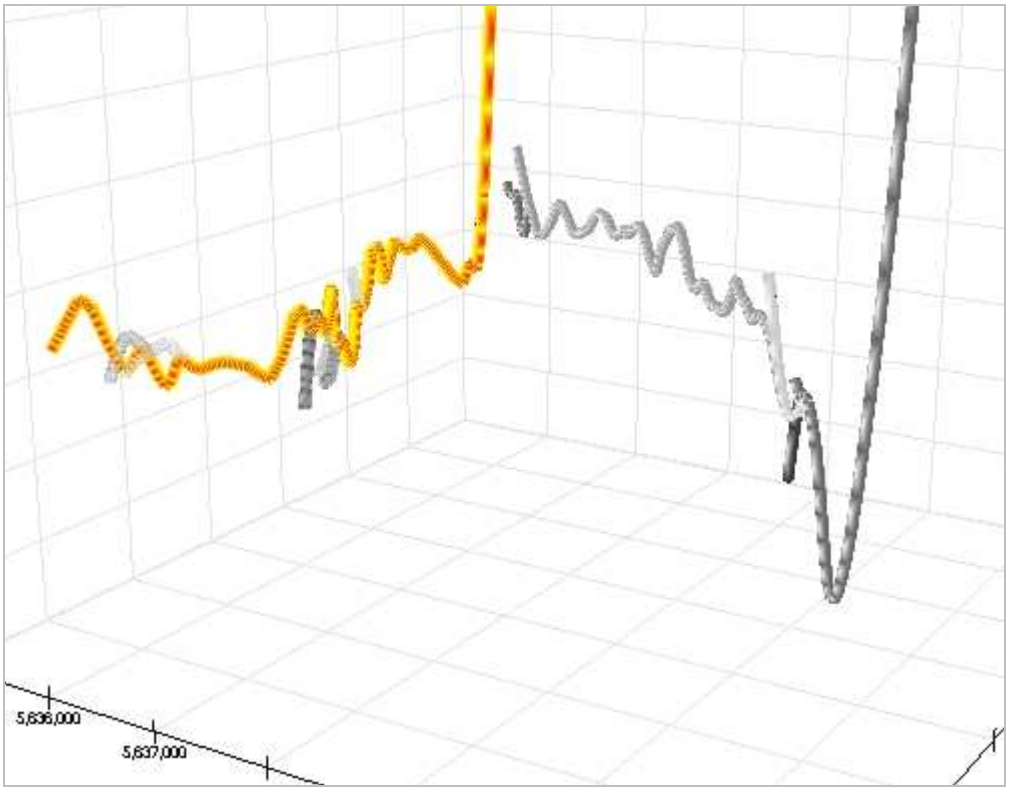
Not to Scale- 

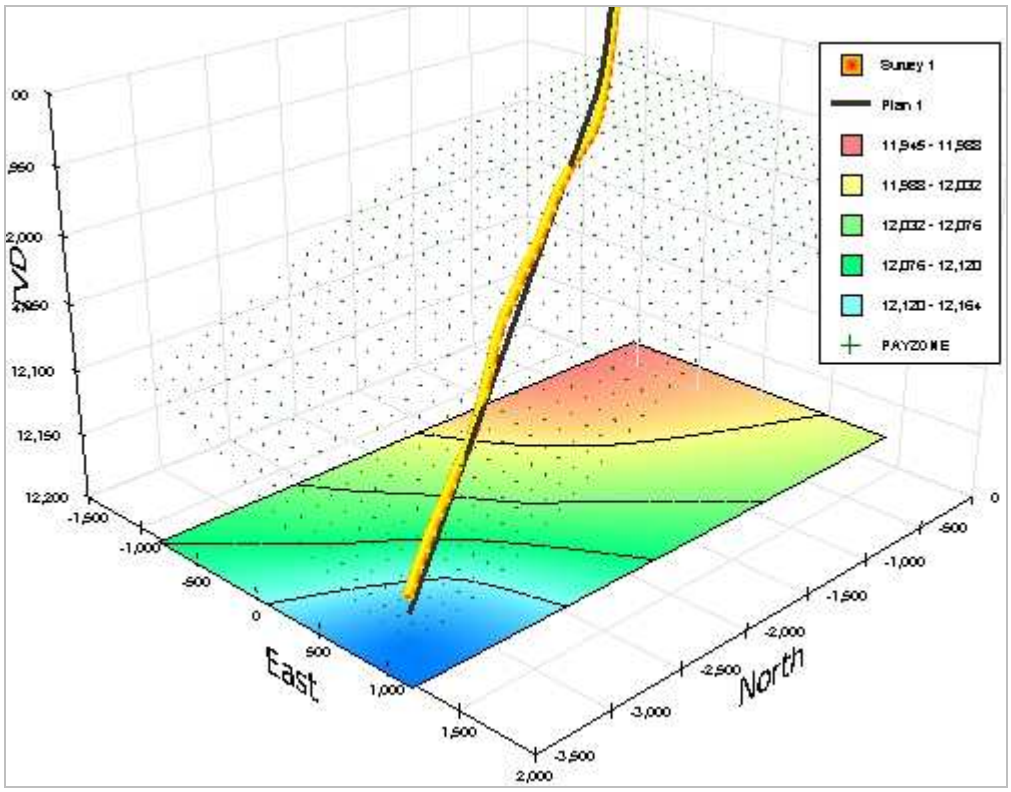
Scale- 

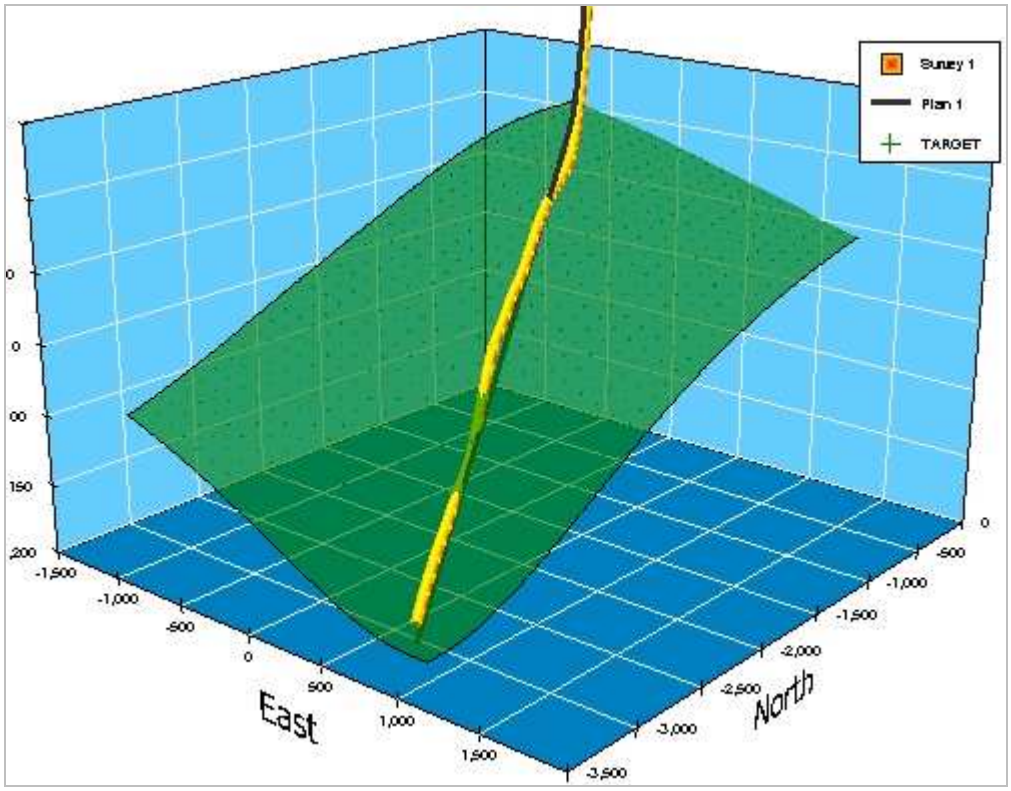
Not to Scale- 

6.4.2 Viewer Examples









jpg, 500x390, 100 quality, tick labels 8 font size

6.5 Survey Data and Survey Calculations

An SES Survey dataset may represent an as-drilled wellbore or the wellbore of a theoretical well plan. Directional surveys are calculated within SES from entered source data measured depth (MD), inclination (Inc), and azimuth (Azi). SES uses the industry-standard minimum curvature survey calculational method to both calculate local Cartesian coordinates true vertical depth (TVD), north (N), and east (E), and to interpolate TVD, N, E, Inc, and Azi between directional survey stations.

To calculate a directional survey the SES user must supply directional survey station data MD, Inc, and Azi, the tie point coordinates of the survey, and the vertical section azimuth on which to calculate vertical section. Directional survey tie point coordinates are the local Cartesian coordinates that correspond to the first MD station of the survey dataset. If the first MD is non-zero then non-zero tie point coordinates must also be entered. If the Survey dataset starts at surface (i.e., at MD=0), then tie point coordinates are also usually zero.

By definition, survey station azimuth is referenced to north. The SES user should designate whether this north reference is with respect to grid north or true north. If azimuth is with respect to true north, then the grid convergence angle should also be entered IF there is to be any use of Grid dataset interpolation or any use of global X-Y coordinates via cross section export or other SES exports/reports. Grid convergence is the angle in degrees at surface from true north to grid north, with the convention of clockwise being a positive value.

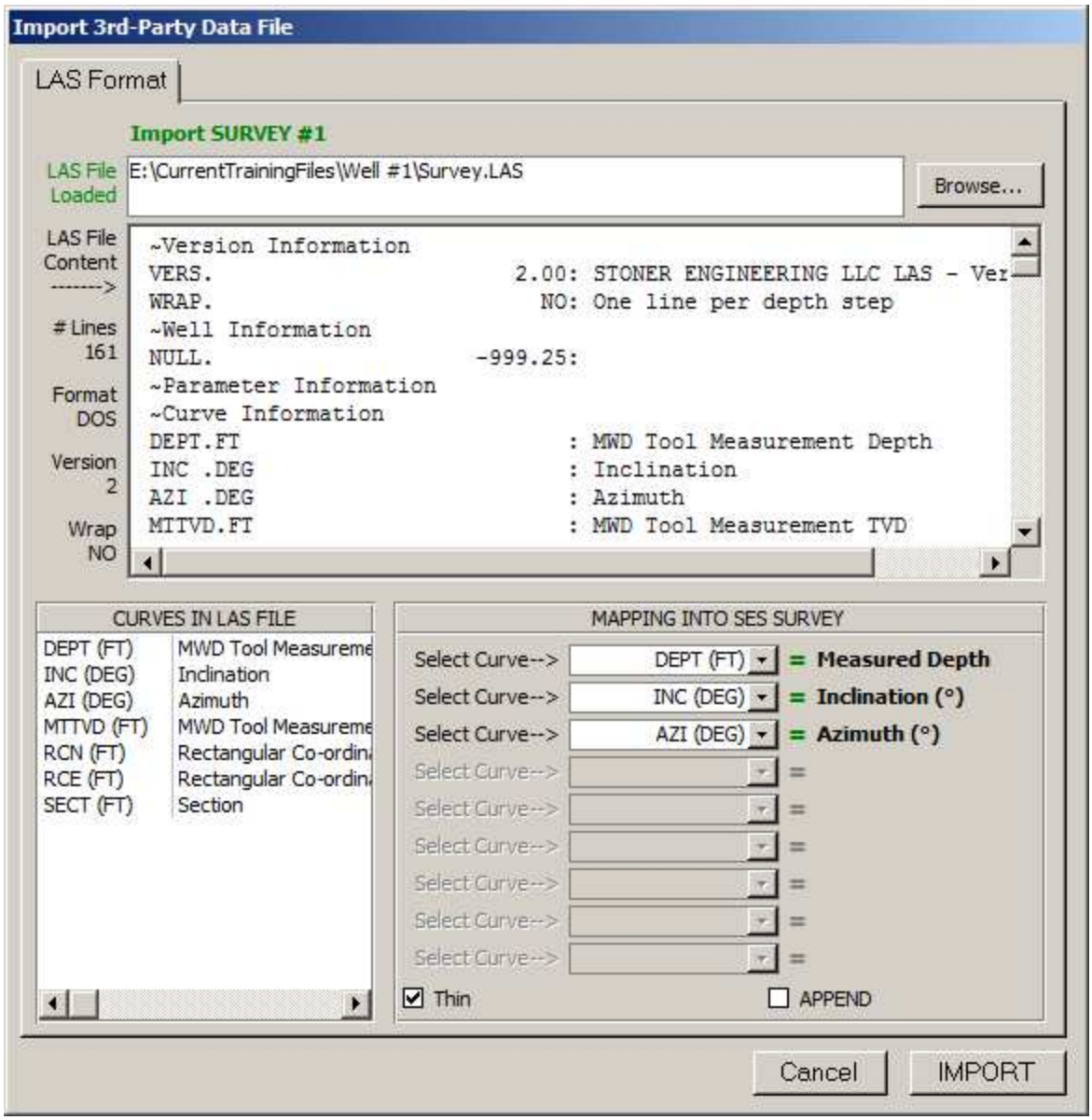
Directional survey data are entered into SES by one or more of the following methods: keyboard manual entry; copy/paste of tab delimited data (e.g., data copied from Excel are tab-delimited); LAS file import; and/or import after downloading respective data from a WITSML server. For more information about data transfer via copy/paste, see **How To Paste Data From Excel into SES**.

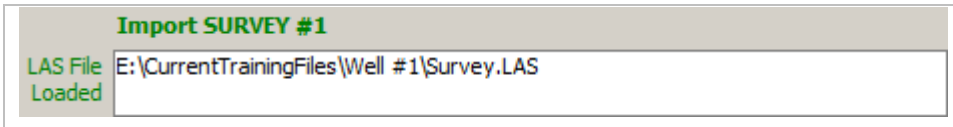
6.6 Import Survey Data from LAS File

With wellsite data transfer coming via LAS files, directional survey data updates can be performed efficiently and often better than spreadsheet copy/paste methods. LAS files tend to be preferred over spreadsheet copy/paste methods during live operations because if up-hole survey station data are subsequently changed SES will automatically incorporate the data adjustments, and, via LAS file import there is no chance a survey station is inadvertently skipped, which is possible via manual copy/paste.

On occasion an error message may be displayed when opening an LAS file for import, or while SES tries to import the loaded data. In almost all such circumstances the error is caused by the LAS file not being compliant with LAS specifications. If possible SES will report the line/row number of the offending condition, which may help you or others resolve the issue through subsequent file editing. With the routines in SES having being honed for more than a decade, SES can overcome many LAS specification inaccuracies, but not all! When applicable the best resolution may be to contact the LAS file distributor for correction/re-creation.

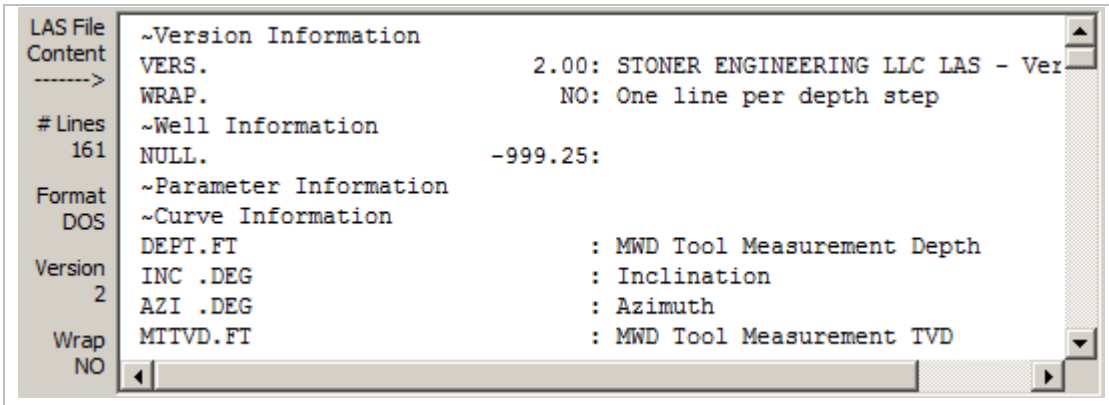
 "Import 3rd-Party Data File" dialog is used to browse and open an LAS file, designate the respective columns in the LAS file that match measured depth (MD), inclination (Inc), and azimuth (Azi), and import the directional survey data into the selected SES Survey dataset.



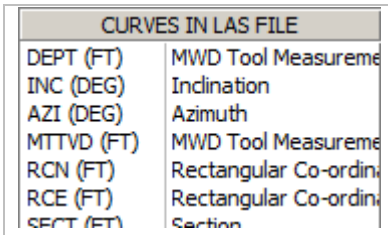


Enter the path and filename of the LAS file to load for processing; or, this text box displays the path and filename of the currently loaded LAS file as a result of using "Browse..." to specify such LAS file. The last LAS file from which survey data were imported is the attempted default LAS file loaded when "Import 3rd-Party Data File" dialog is opened.

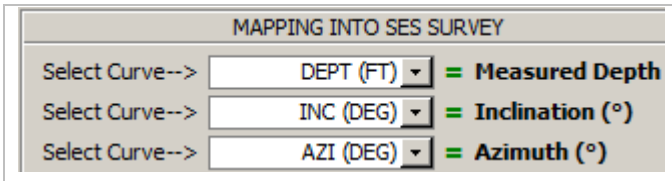
Click "Browse..." button to browse the computer's file system and select an LAS file to load for processing.



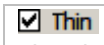
This textbox displays a full copy of the LAS file contents. Its content may be viewed using the scroll bars and ~ASCII data content may be edited and/or rows deleted for subsequent actual import into SES. The left border portion displays LAS file information including the number of lines of data in the file, the text file line terminator format (DOS or Unix), the CWLS LAS file version, and the file "wrap" status. SES will import both DOS and Unix LAS files, CWLS LAS file versions 2 and 3, and wrapped or non-wrapped formatted LAS files.



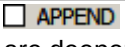
This textbox displays a listing of all data curves in the LAS file and the data curve descriptions.



Select the data curve that corresponds to the respective data content required by SES. For Survey data import, SES requires measured depth (MD), inclination (Inc), and azimuth (Azi). Tie point coordinates, when applicable, must manually be entered in the header portion of Surveys screen.



Select/check "Thin" option if SES should not import depth stations/rows from the LAS file in situations where Inc and Azi are null/blank. This can be helpful when importing from LAS files that contain much more data than only survey data.



Select "APPEND" option if SES should only import depth stations/rows from the LAS file that are deeper than the deepest MD already in the current Survey dataset. This can be helpful when importing from LAS files that contain a different survey dataset than what is being populated within SES. For example, use Append mode to effectively splice the contents of two or more LAS files. Using Append mode for Survey data import is rare.

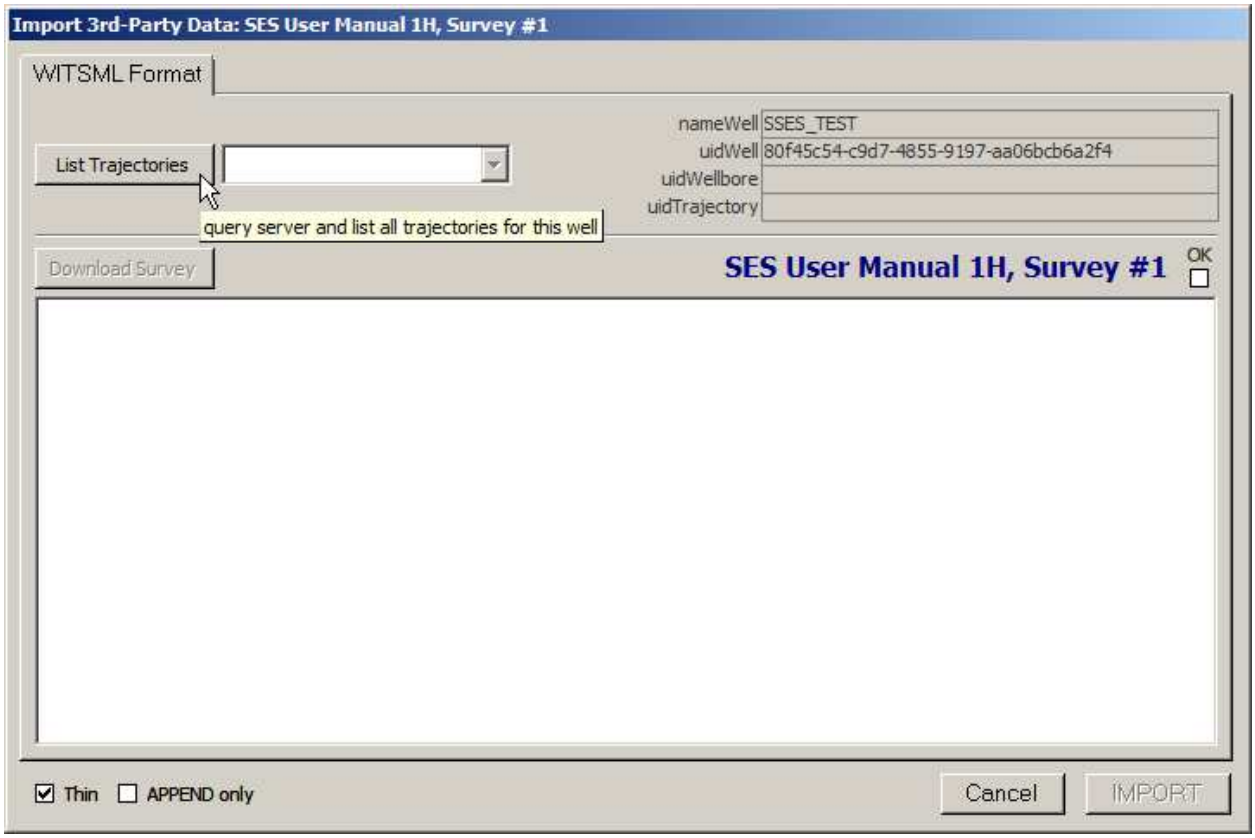
Click "Cancel" button to close the "Import 3rd-Party Data File" dialog without making any changes to the existing Survey dataset in SES.

IMPORT Click "IMPORT" button to import the respective LAS file data content into the currently selected Survey dataset in SES. Unless "Append" option is checked, SES compares the content of the LAS file with pre-existing content in SES (when applicable) and if any differences are present the pre-existing content in SES is deleted and replaced with the LAS file content. After importing, the directional survey is automatically calculated and Surveys screen map and vertical section views are updated. The last LAS file successfully imported becomes the default LAS file loaded when Surveys screen  is next clicked. Thus, to update directional survey data in this fashion after the dialog has been opened requires one click.

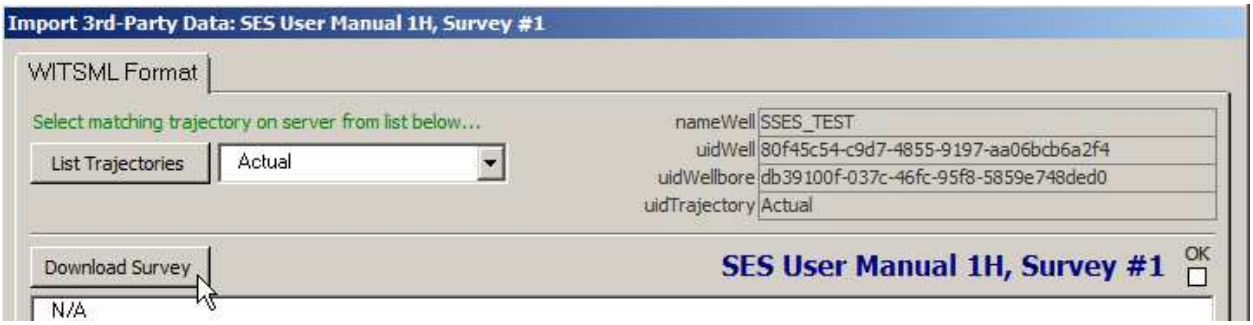
6.7 Import Survey Data from WITSML Server

With WITSML server connectivity, data updates can be performed on-demand and usually take less total time because everything can be done without leaving SES (e.g., no time is spent opening and saving LAS files from emails!).

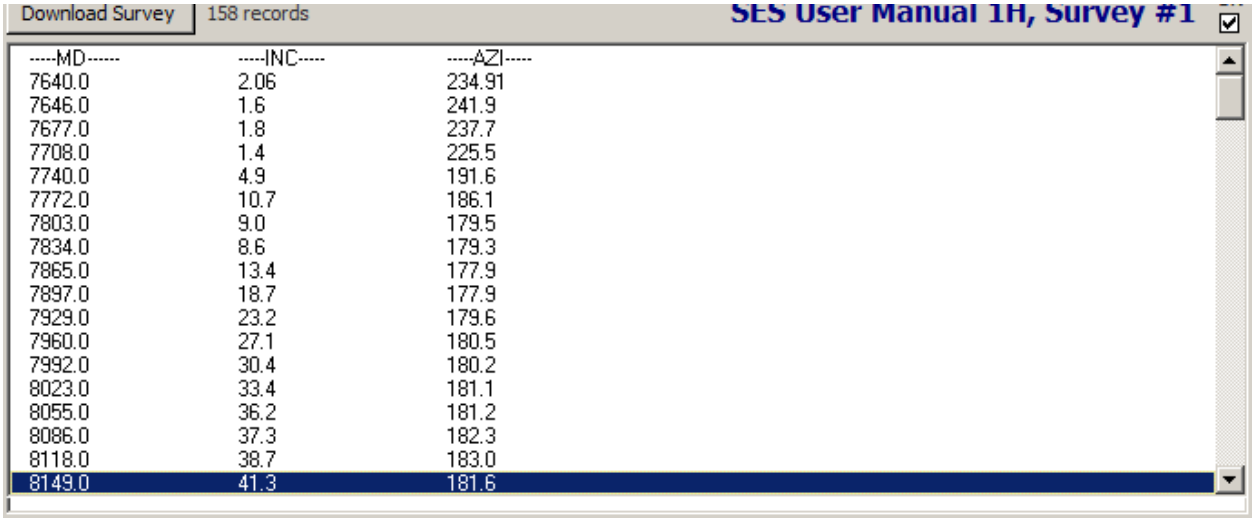
 "Import 3rd-Party Data" dialog is used to download and then import directional survey data from a WITSML server. The steps discussed in **2.4 WITSML Server** and **4.2.4 Well Setup - WITSML** must be complete before using this feature.



List Trajectories Click "List Trajectories" button to query the WITSML server for a list of available trajectories on the WITSML server for the current Well. After the list is returned, select the corresponding trajectory that matches the current SES Survey. The WITSML server *may* only expose one trajectory, even if the current Survey represents a wellbore sidetrack. If the trajectory name/unique-ID has not changed since the last time survey data were imported from the WITSML server, this step can be skipped. In the example below, trajectory "Actual" is being selected for the first time.



Download Survey Click "Download Survey" button to download the directional survey data content stored on the WITSML server and display it directly in the textbox below this button. In the example below, 158 directional survey stations were downloaded from the WITSML server, starting with MD = 7640. The tie point MD of this Survey is 7640.



☑ Thin Select/check "Thin" option if SES should not import depth stations/rows from the WITSML-server-returned dataset in situations where Inc and Azi are null/blank. This feature is rarely applied due to how WITSML servers typically perform.

☐ APPEND only Select "APPEND only" option if SES should only import depth stations/rows from the WITSML-server-returned dataset that are deeper than the deepest MD already in the current Survey. Using Append for Survey data import is rare, but this can be helpful when importing from WITSML server datasets that contain a different Survey dataset (e.g., one survey may start from surface while another has a non-surface tie point) than what is being populated within SES.

Cancel Click "Cancel" button to close "Import 3rd-Party Data" dialog and return to Surveys screen. Any changes made are NOT saved.

IMPORT Click "IMPORT" button to import the downloaded data displayed on screen into the currently selected SES Survey and return to Surveys screen. Unless "Append" option is checked, SES compares the content from the WITSML server with the pre-existing content in SES (when applicable) and if any differences are present the pre-existing content in SES is deleted and replaced with the WITSML server data. After importing, the directional survey is automatically calculated and Surveys screen map and vertical section views are updated.

SES WITSML server data download parameters are Well and Survey number specific, which makes it even easier to manage data-updating for multiple wells. After survey data have successfully been imported once from a WITSML server for a specific Well and Survey, the default parameters are restored when Surveys screen  is next clicked. Thus, at this time, updating directional survey data in this fashion after the dialog has been opened requires two clicks ("Download" and then "IMPORT").

6.8 Critical

1.) The tie point coordinates (TVD, North, East) in the header section of Surveys screen are the Cartesian coordinates of the first station (i.e., at the first MD in the survey dataset) and must be manually entered if non-zero.

2.) If directional input data, tie point data, or vertical section azimuth are changed in any way, click "Calculate SURVEY" or press F6 to refresh the survey calculation of the selected Survey.

3.) From Well Properties, coordinates SurfaceX, SurfaceY, SurfaceZ must equal local coordinates at (MD,TVD,N,E)=(0,0,0,0) for proper geologic Grid dataset interpolation and display.

4.) For proper geologic surface display, coordinates SurfaceX and SurfaceY must be in the same coordinate system as the associated Grid dataset, and grid convergence angle in degrees needs to be entered if azimuths are relative to true north.

5.) If the Well's units are changed (e.g., from ft to m), select each Survey and re-calculate each Survey.

6.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

6.9 Hot Keys

- Drag rectangular window on graph to zoom
- With graph zoomed roll mouse wheel to scroll horizontally
- F6 – same as clicking Surveys screen toolbar button "Calculate SURVEY"
- CTRL – hold down Control key while clicking different Survey # and graphs are updated (navigation/dataload is faster without updating graphs; click "Refresh" to update graphs)
- CTRL – hold down Control key while selecting different Well from dropdown box and Surveys/Planner graphs are NOT updated (navigation/dataload is faster without updating graphs; click "Refresh" respectively to update graphs)

6.10 Tips

TIPS

- Step one for any SES technical geosteering operation is to **ensure the SES calculated directional survey (e.g., at total depth) matches "exactly" with the service company** supplying the source directional survey data. If they don't match, **resolve the difference before proceeding** (*a common cause is tie point differences…see Critical point #1 above*). The calculated digits should closely match because most drilling service companies employ the minimum curvature survey calculational method, as does SES. Some round-off error will normally be present because tie point coordinates and potentially other data input are rarely made available with full 32-bit precision but instead are often rounded to two decimal places.

- Repeat! Step one for any SES technical geosteering operation is to ensure the SES calculated directional survey closely matches that from the service company supplying the source directional survey data. It is critical to operations communications that everyone be on the same page. Resolve any differences before proceeding with LWD data loading or any analyses.

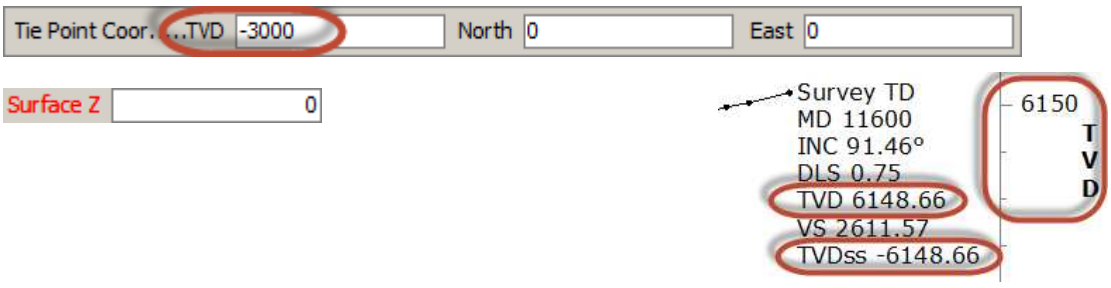
- If SES calculated vertical section does not match the field but north/south and east/west coordinates do match, then the vertical section azimuth (VSA) within SES and the value in use by the field are not the same. Determine the applicable VSA from the official directional survey report header or footer. VSA is entered into SES in the header portion of Surveys screen.

- A Survey dataset can contain the survey data from an as-drilled wellbore or from a theoretical well plan. The easiest and often most accurate method of transferring a pre-designed well plan to SES Planner screen is to use Surveys screen and then the toolbar command  .

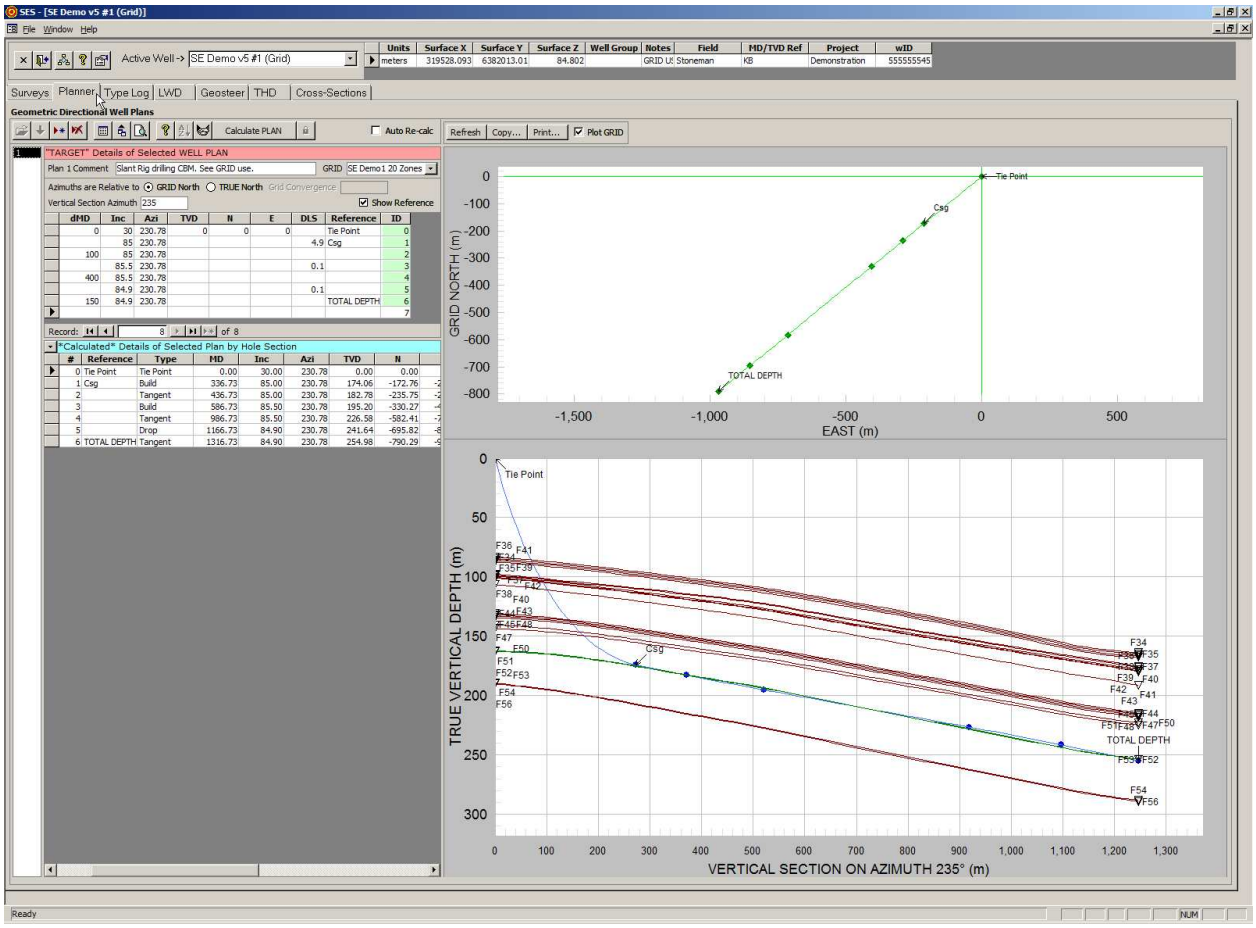
- If interpolating Grid data in SES or if exporting calculated global X-Y-TVDss values from SES for use in other software, it is important to correctly set the directional survey north reference. The official directional survey will normally report whether azimuthal bearings are from grid north or from true north. If azimuths are relative to true north, the respective grid convergence value (angle in degrees from true north to grid north at surface, clockwise positive) should be obtained from the individual that generated the Grid dataset and be entered into the header portion of Surveys screen.

- In this version, TVDss is not displayed along any TVD axes in SES. To "trick" SES into making all Survey "TVD" values and axes be TVDss values with positive-down convention, do the following:

  1.) Set Survey Tie Point TVD equal to its TVDss equivalent, BUT use negative-above mean sea level (MSL) convention. For example, if the survey starts at surface (MD=0 at first directional survey station) and KB elevation is 3000 ft, enter -3000 into tie point TVD coordinate from Surveys screen, as shown below. **2.)** Enter zero for "Surface Z" as shown below from Edit Active Well. (Note: Grid data should still be entered into Grids screen as usual for SES—positive-above MSL and negative-below MSL for all TVDss values.)



7. SES Screen – PLANNER



7.1 General

Any type of directional or horizontal well plan comprised of linear and circular-arc hole sections can be designed with SES, including a circular arc in an oblique plane in any octant(s). SES complies with O&G industry standards of directional/horizontal well planning.

PLANNER screen can be used to:

1.) Design and calculate the critical point values of a 3D or 2D well plan by combining multiple successive "targets" as needed.

2.) Determine the minimum curvature necessary to intersect a specified 3D coordinate (target).

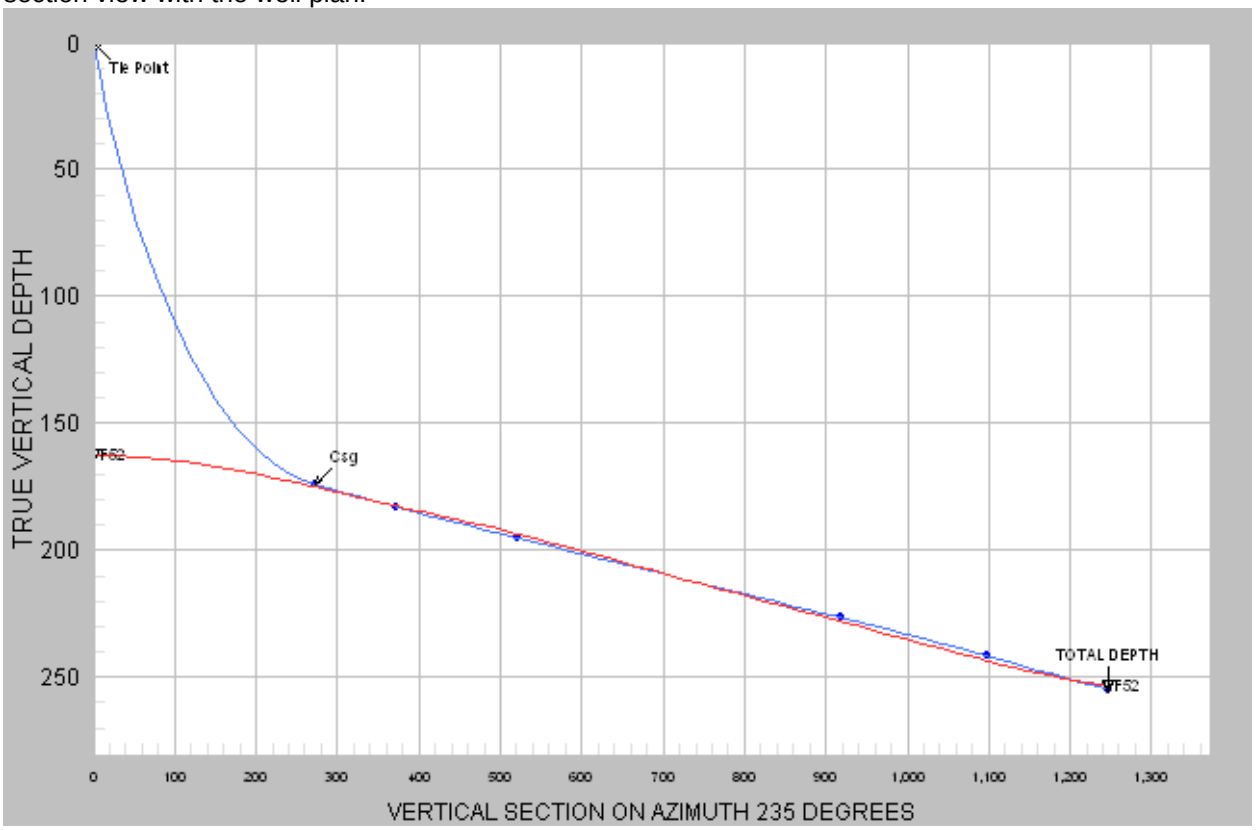
3.) Implement a "target" that extends a straight line of specified length in 3D space.

4.) Implement a "target" that is a circular arc in 3D space by specifying dogleg-severity (DLS) and ending inclination and azimuth.

5.) Set each well plan's vertical section azimuth, independent from other well plans of the same Well.

6.) Create vertical section view and map view standard directional plots of a well plan.

7.) 3D plane-interpolate associated geologic Grid data and display the formations/surfaces on the vertical section view with the well plan.



8.) Create a "digitized" well plan survey table with extra interpolated values for smoother graphing.

9.) Print/Preview a professional well plan survey report for regulatory reporting or otherwise.

10.) Print the standard directional plots on any system printer (including Adobe/PDF).

11.) Copy the standard directional plots for paste into another application.

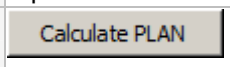
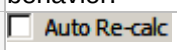
12.) Zoom a graph by dragging a window with the mouse; then pan by clicking scroll bars.

13.) Temporarily change a variety of graph properties (including full-screen/maximize mode) by right-clicking over the graph and selecting from the shortcut menu.

14.) Move graph annotations by simply dragging the text to a new location.

7.2 Toolbar

Control	Control Tip | Detailed Description
	N/A | Directional or horizontal well plans may not be imported from an LAS file. Instead, well plans are manually entered/created using the well plan input table, or by converting a Survey dataset (see Surveys screen **6.3 Other Functions/Features** "convert Survey to new SES Plan"  for more information).
	N/A | Directional or horizontal well plans may not be downloaded/imported from a WITSML server.

	add Plan | Add a new Plan dataset and select it. SES automatically copies Plan header properties (vertical section azimuth, Grid association, etc.) from the largest numbered existing Plan and initializes the new Plan with such values.
	delete Plan | Delete the selected Plan dataset (and potentially renumber the remaining existing Plan datasets). Plan #1 may only be deleted if there are at least two Plan datasets before deleting Plan #1. Plan datasets are numbered starting at #1. To delete Plan #1 when there is only one Plan dataset, first Add a new Plan dataset and then select and delete Plan #1, after which empty Plan #2 will become Plan #1.
	view digitized Plan table | Display a data table containing the entire Plan dataset including input target data, calculated coordinates/angles, interpolated coordinates/angles between well plan critical points, and global coordinates X, Y, Z (TVDss). Values from the data table may easily be copied for paste into other Windows applications.
	export Plan data to LAS file... | Export the calculated directional well plan data to an LAS file after setting the output path and filename. In addition to being CWLS LAS v3 compliant, LAS files generated by SES are also created to present the data content in both space delimited and fixed width text formats for greater versatility.
	print preview Plan report | Display a directional well plan print preview report that is often suitable for regulatory reporting. The report header may contain much Well metadata and the report data content contains the entire Plan dataset including input target data, calculated coordinates, and global coordinates MapE, MapN, SysTVD. The report may easily be printed (right-click for options).
	PLANNER help | Display Planner screen abridged help.
	N/A | Sorting on MD is not applicable from Planner screen. To effectively "re-sort" input well plan targets, target data can be pasted at the bottom of the input data table and interior target rows may be deleted by selecting the respective row and pressing the Delete key. SES automatically controls the "ID" number of each input target when targets are added or deleted and ID number controls how the targets are sorted.
	check Plan for possible problems | Check the selected Plan header and target data for conditions that are known or suspected to cause problems during or after the calculation of the directional well plan. This data quality check is applied each time a Plan is calculated whether or not the SES user clicks this button. Sometimes called the "cat button", the icon is actually intended to represent two hands shaking. ☺
	 (F6) Compute Plan & Digitize for Graphing | Calculate the full well plan based on target inputs, which vary based on well plan design specifics. Calculate minimum curvature interpolated well plan values for smoother plotting; update the calculated/output table; update the map view; and update the vertical section view. A calculated well plan includes MD, Inc, Azi, TVD, N, E, DLS (dogleg-severity), and VertS (vertical section) at every well plan critical design station and per O&G industry standards requires smooth Inc and Azi continuity between stations. A critical design station corresponds to a unique wellbore hole section in a well plan where the wellbore hole section changes from linear to curved, curved to linear, or curved to curved-at-a-different-DLS. Some critical design stations correspond one-to-one with target inputs and others may be generated by SES as necessary. See **7.4 General Well** Plan Design Notes for more information.
	lock graph extents (when zoomed) between refreshes | Maintain/lock current axes minimum and maximum values after subsequent plan calculation and/or graph refreshes. This toggle button is enabled only when the map view and/or the vertical section view is zoomed. To zoom, click and drag a zoom window on the graph. By default, SES re-determines a graph's axes extents after plan calculation or refresh and this toggle button allows the SES user to temporarily override that behavior.
	 auto-update after key punch; leave un-checked if pasting data from clipboard | Set/check "Auto Re-calc" option if SES should immediately calculate the plan after any input plan

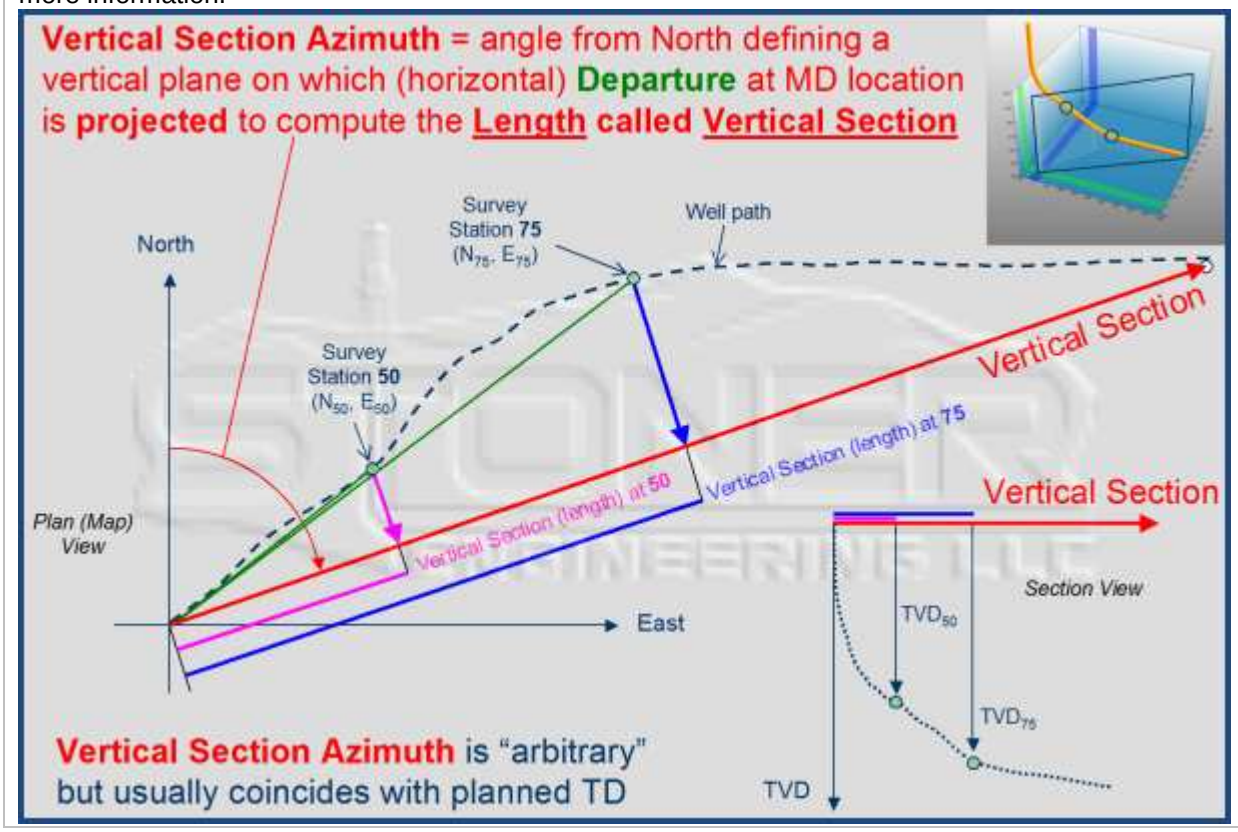
target data are changed or added. This is an alternative to clicking Calculate PLAN or pressing F6 to re-calculate the plan. ALWAYS leave "Auto Re-calc" option un-checked when pasting data from the clipboard!

7.3 Other Functions/Features

GRID SE Demo2 Select the corresponding Grid dataset associated with the Well. When "Plot Grid" is checked on Planner screen, this Grid is interpolated for respective display.

Azimuths are Relative to ◉ GRID North ○ TRUE North Grid Convergence Designate the north reference from where azimuths are relative, for the selected Plan dataset. This selection is also reflected in Planner screen map view north/y axis label. If the Plan dataset azimuths are relative to true north, then also enter the respective grid convergence angle. Grid convergence is the angle in degrees from true north to grid north at the Well's surface location, with the convention of clockwise/counterclockwise being a positive/negative value. Azimuthal bearings north reference affects the calculation of global X-Y coordinate values and the display of surfaces from interpolating global X-Y-TVDss Grid data at local N-E coordinate locations. North reference designation is included in the header portion of any LAS file created by exporting respective data from SES Surveys, Planner, LWD, THD, and Cross-sections screens.

Vertical Section Azimuth 195.76 Enter the angle in degrees from north defining a vertical plane on which (horizontal) departure is projected to compute the length called vertical section. See the slide below for more information.



☑ Show Reference Set/check "Show Reference" option if SES should post well plan input target Reference text/annotations on Planner screen map view and vertical section view. Click "Refresh" to update graphs after changing this option.

tie_MD	tie_Inc	tie_Azi	tie_TVD	tie_N	tie_E	DLS	Reference	ID
8300	0	0	8300	0	0		Tie-In	0
392	0	0					KOP	1
	91.2	0				12	Landed	2
2200	91.2	0					TD	3
								4

The upper Planner screen table is populated with input target data to design a well plan. Every well plan starts with a full definition of the well plan tie point MD, Inc, Azi, TVD, N, E (DLS is by definition null/undefined at the tie point). When the first row (ID=0) of the input target data table has the focus, the column labels change to include "tie_" as a reminder. When tie point data have been fully specified, the ID=0 cell background is colored light green (green means good).

dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
8300	0	0	8300	0	0		Tie-In	0
392	0	0					KOP	1
	91.2	0				12	Landed	2
2200	91.2	0					TD	3
								4

Enter input target data to design a well plan. SES supports four target types (see **7.4 General Well** Plan Design Notes for more information) and follows O&G industry directional well planning conventions. On a given target data row, if SES recognizes the target type based on the columns containing numbers, the respective ID column cell background is colored light green (green means good). SES Planner can be used to string together an unlimited number of "target" hole sections to represent any well plan comprised of 3D linear and 3D circular-arc hole sections.

Calculated Details of Selected Plan by Hole Section

#	Reference	Type	MD	Inc	Azi	TVD	N	E	DLS	VertS
0	Tie-In	Tie Point	8300.00	0.00	0.00	8300.00	0.00	0.00		0.00
1	KOP	Vertical	8692.00	0.00	0.00	8692.00	0.00	0.00	0.00	0.00
2	Landed	Build	9452.00	91.20	0.00	9169.36	487.46	0.00	12.00	487.46
3	TD	Horizontal	11652.00	91.20	0.00	9123.29	2686.98	0.00	0.00	2686.98

Calculated results at well plan critical points are displayed in the lower output data table on Planner screen. A calculated well plan fully completes the MD/Inc/Azi/TVD/N/E/DLS/VertS table based on target input data and O&G industry well planning conventions. Admittedly, Planner screen is probably the most complicated of all screens in SES, but very much can be done from only one input table! If an error is reported when trying to calculate a well plan, carefully read the error message for help. See **7.4 General Well Plan Design Notes** for more information.

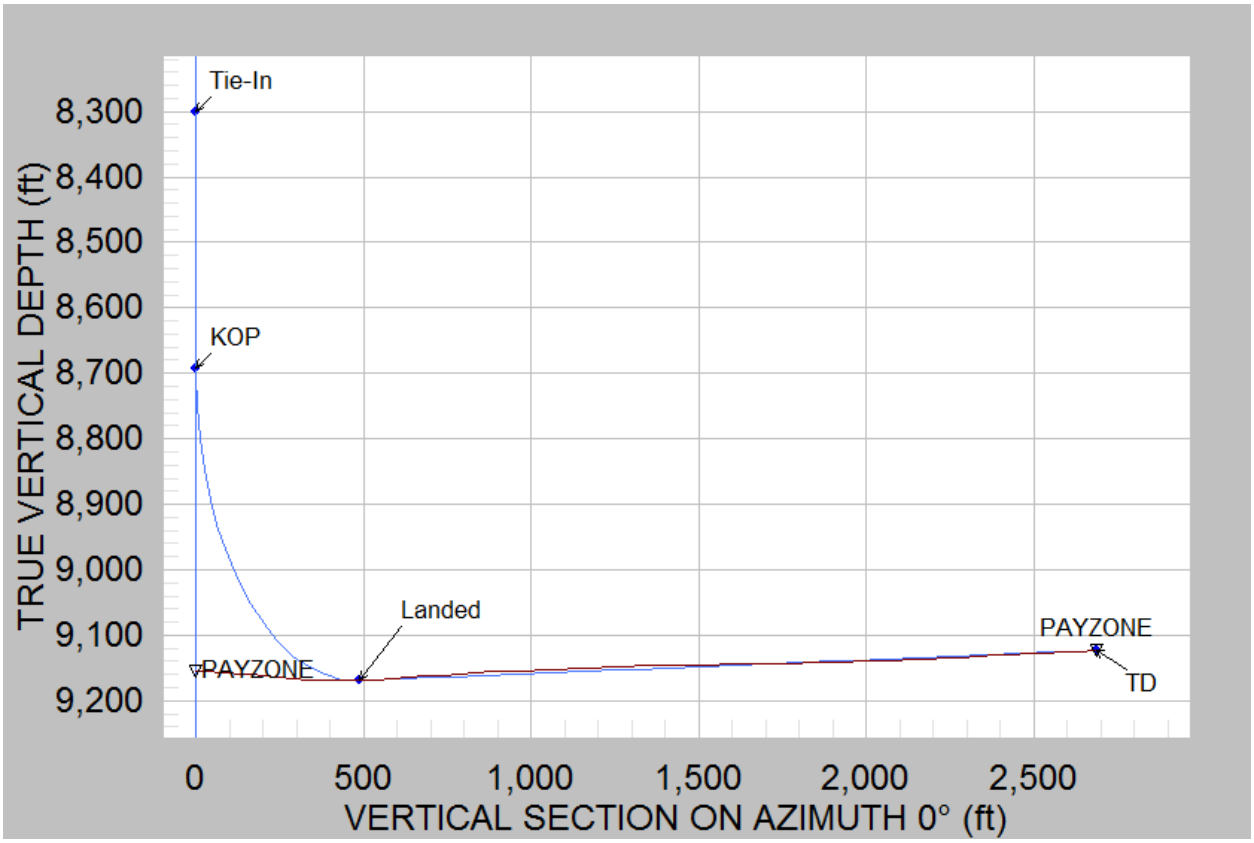
Refresh Redraw the map view and vertical section view graphs for the currently selected Plan. This request does not re-calculate the directional well plan but it does process any changes made regarding the display of Grid data, Plan Reference show/hide settings, zoom-lock off setting, and which Plan is currently selected. To automatically redraw the graphs when selecting different Plans, press and hold the CTRL key when selecting the Plan number in the list box along the left side of the screen.

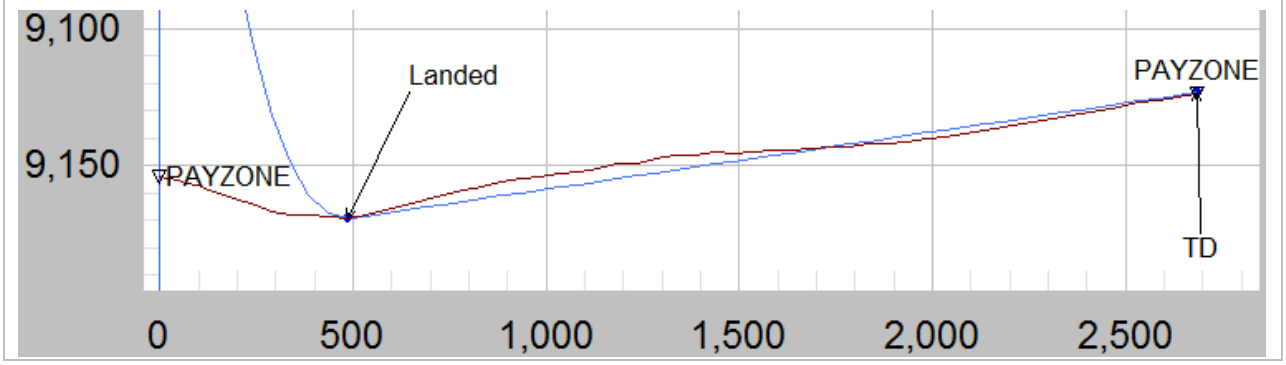
Copy... Display a dialog that reminds how to **copy** a graph. To **copy** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (**clipboard**/file/printer), size, and resolution/dpi.

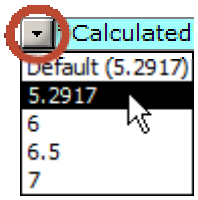
Print... Display a dialog that reminds how to **print** a graph. To **print** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (clipboard/file/**printer**), size, and resolution/dpi.

Plot GRID Check "Plot GRID" option to interpolate and display the surface(s) of the associated Grid dataset at locations along the selected Plan on the vertical section view. The Well's surface location coordinates in the same global coordinate system need to be entered for Grid dataset interpolation. SES uses planar triangulation to interpolate. At each respective plan-interpolated north and east coordinate, SES finds the 3 nearest Grid dataset coordinates and calculates a plane. The plane is then interpolated to yield the respective "Z" value. Surface layer colors and names may be set from Grids screen (see **3.2 Grid Data Setup** for more information).

In the below picture, "PAYZONE" is a Grid surface being interpolated along the planned wellbore path. The well plan was in fact calibrated using the Grid surface. Zooming the vertical section view and applying the lock toolbar toggle can be helpful when fine-tuning a well plan using a Grid surface. For this example, dMD to the KOP and then the landing inclination angle were calibrated to setup the well plan using the 3D Grid dataset for expectation guidance given a 12 deg/100ft performing bottom hole assembly.

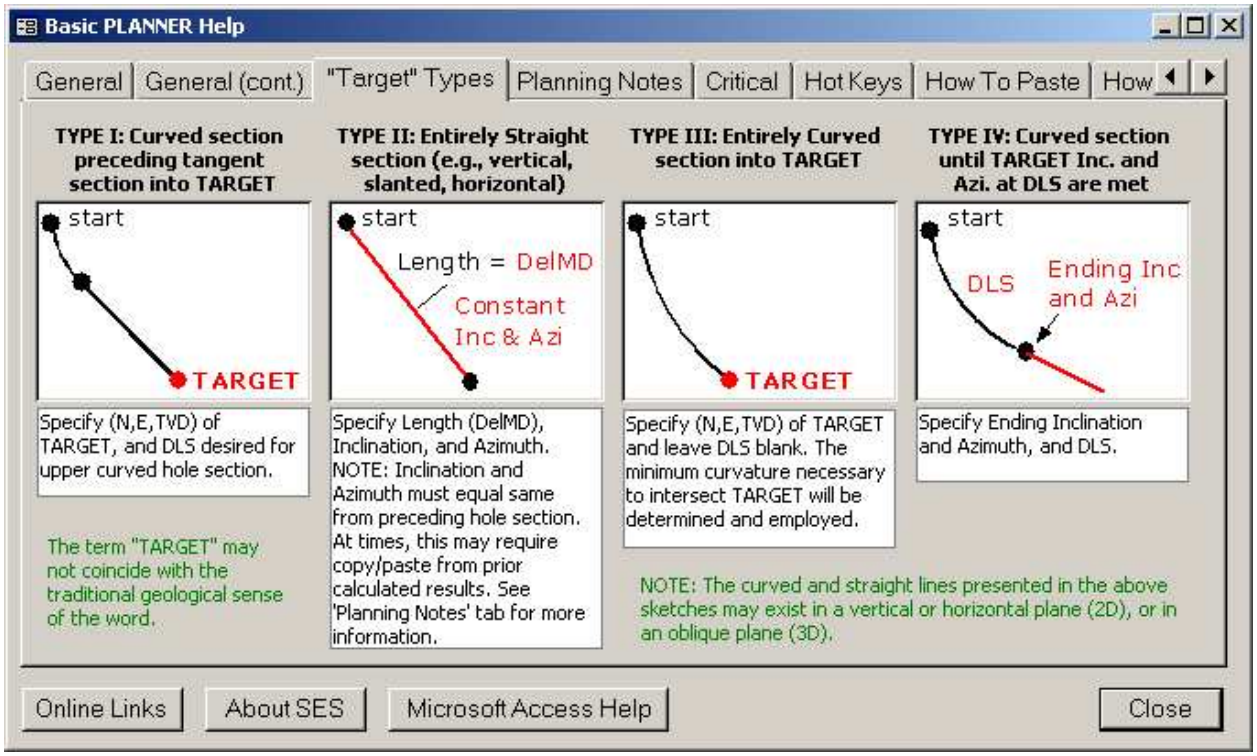






This SES custom user setting (upper-left dropdown box) can be used to set the width of the calculated results output table. If the computer monitor is wide, the bottom selection is often picked to display the full width of the output table negating the need for horizontal scroll bars on the output table.

7.4 General Well Plan Design Notes



When designing or specifying a well plan, consider calculating the plan after the addition of each new input target. This helps to ensure that the well plan parameters are valid and within accordance to what SES expects based on industry conventions. Calculated results are presented in the lower part of Planner screen.

It is highly recommended to follow the preceding suggestion when using Type II or Type IV Target Types, especially if Inclination and/or Azimuth are not "simple" numbers. Copy and Paste of non-simple numbers (e.g., 23.435980298 degrees) is highly recommended in cases that require calculating the plan to determine the numbers to feed into the next "Target".

For 2D wells, the following may assist in the respective design. In each case, it is assumed that Target ID=0 is the tie point and Target ID=1 is Type II to Kick-Off point, both of which have already been specified.

SLANT (BUILD-AND-HOLD or DROP-AND-HOLD): Type I to wellbore Total Depth.

DOUBLE BUILD: Type I to start of lower build section, Type I to wellbore Total Depth.
-OR-

DOUBLE BUILD: Type I to start of lower build section, Type IV to final Inclination and Azimuth, Type II to wellbore Total Depth.

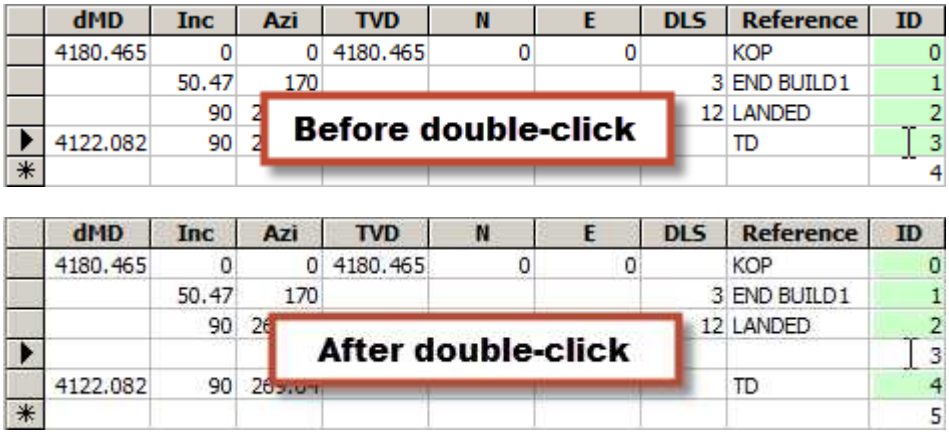
S-TYPE: Type I to start of drop section, Type I to wellbore Total Depth.
-OR-
S-TYPE: Type I to start of drop section, Type IV to final Inclination and Azimuth, Type II to wellbore Total Depth.

The foregoing are only suggestions. Given the four "Target" types allowed, there are multiple ways to create an identical well plan.

7.5 How to Insert Targets between Existing Targets

New well plan targets are usually added at the bottom of the well plan target input table. However, there are times when a target needs to be inserted above an existing target. There are two methods to perform **target insertion** in the well plan target input table.

Method 1: Double-Click within "ID" Cell to Insert Blank Row Above



	dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
	4180.465	0	0	4180.465	0	0		KOP	0
		50.47	170				3	END BUILD1	1
		90	2				12	LANDED	2
▶	4122.082	90	2					TD	3
✳									4

	dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
	4180.465	0	0	4180.465	0	0		KOP	0
		50.47	170				3	END BUILD1	1
		90	2				12	LANDED	2
▶									3
	4122.082	90	2					TD	4
✳									5

Double-click within the "ID" cell to insert a blank plan target row above the current row. For example, assume as shown above there are 3 targets and now you want to insert a new target between targets 2 and 3. Double-click inside the column labeled "ID" on row 3 and a new blank target row will be inserted above what was ID=3 (old row ID=3 becomes ID=4).

Method 2: Add New Target at Bottom and then Cut and Paste

Combine row Cutting and Pasting to essentially insert. For example, assume there are 3 targets (rows) and now you want to insert a new target between targets 2 and 3. Enter the new target data as a new record at the bottom. Then select rows 3 and 4 and Cut by right-clicking over the selection and clicking Cut. Then right-click on the asterisk at the bottom left part of the table and click Paste on the shortcut menu.

7.6 Complex 3D Horizontal Well Design

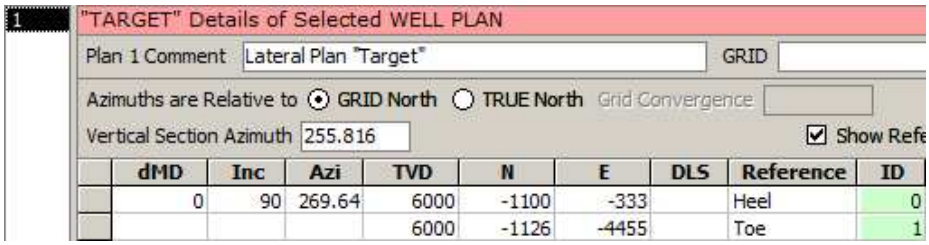
A "3D well" as it is termed is a directional well path comprising one or more hole sections with turn in map view, i.e., a hole section in which planned azimuth changes. Another definition of a 3D well is a well plan that does not exist entirely within a single vertical plane. Designing a 3D well is inherently more complicated than designing a 2D (constant azimuth) well because the number of degrees of freedom at the designer's disposal is increased.

Constraints that normally exist in the design of a complex 3D horizontal well is the surface location, the payzone structure TVD proximity, a maximum allowable design dogleg-severity of any hole section due to

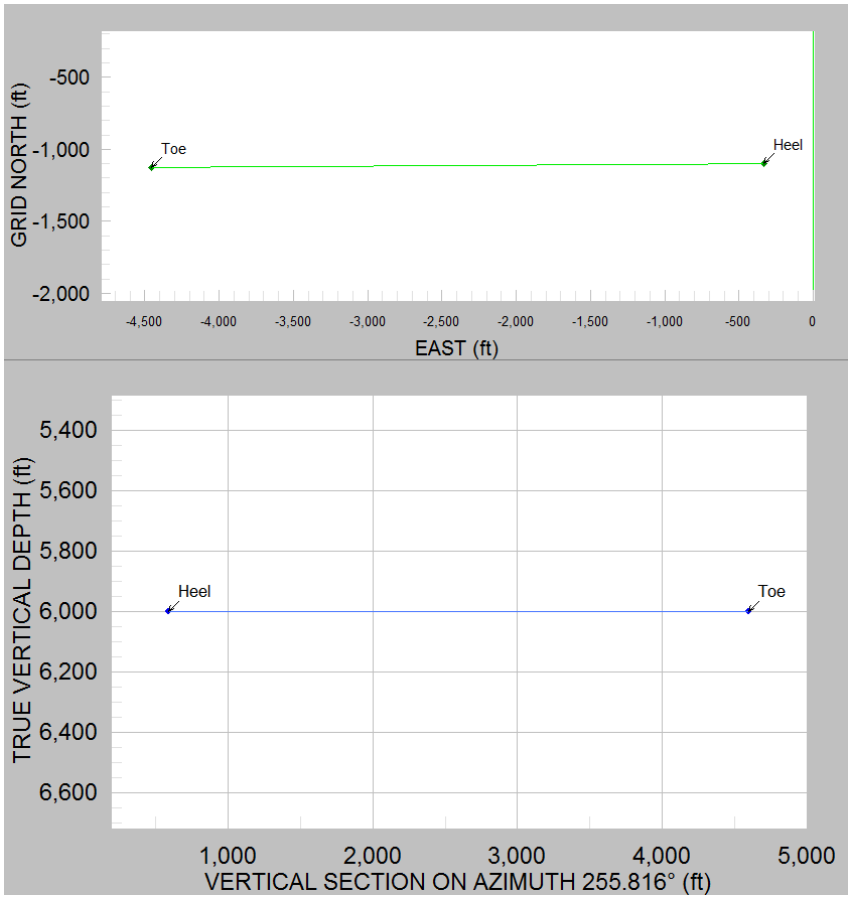
multiple factors, and finally a line defined by at least two points in map view along which the planned path in the payzone should be drilled (lateral target azimuth). For a 3D well, this lateral target line is non-collinear with a straight line drawn from the well's surface location, hence the need for turn.

Given the preferred lateral target line/azimuth and the target structure TVD proximity, there are an infinite number of planned paths that could be designed to "land" on the lateral target line/azimuth and structure. There isn't one-size-fits-all in designing this type of well and based on distances and azimuths and build/turn gradient preferences and perhaps nearby wells, a design structure will be created to satisfy all constraints. Some sort of iteration/solving is normally required to design a complex 3D horizontal well.

SES can be used to design a complex 3D horizontal well. A "trick" to solve this very open-ended mathematical problem is to breakup the design in SES into two steps. In step one, a "dummy" well plan (Plan #1) is created in SES that merely represents the lateral target line/azimuth. For example, below we are given north and east coordinates of a horizontal well's preferred heel and toe, from which an azimuth of 269.64 degrees was calculated external to SES using basic trigonometry. TVD is set to 6000 feet as an approximate value but is not actually important in step one because Plan #1 is merely to provide a map view of where the 3D horizontal well should exist.



	dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
	0	90	269.64	6000	-1100	-333		Heel	0
				6000	-1126	-4455		Toe	1



Next, in step two, another plan is added (Plan #2) and populated with a well plan design structure that satisfies all constraints for the 3D well. When calculating Plan #2, SES displays gray symbols on the map view at locations from Plan #1. Together with zooming and locking graph extents and iterating to see where Plan #2 is fitting compared to Plan #1, Plan #2 may be calibrated properly.

1
2

"TARGET" Details of Selected WELL PLAN

Plan 2 Comment: Double-Build Design (3 build & 12 build/turn) GRID:

Azimuths are Relative to: (•) GRID North ( ) TRUE North Grid Convergence:

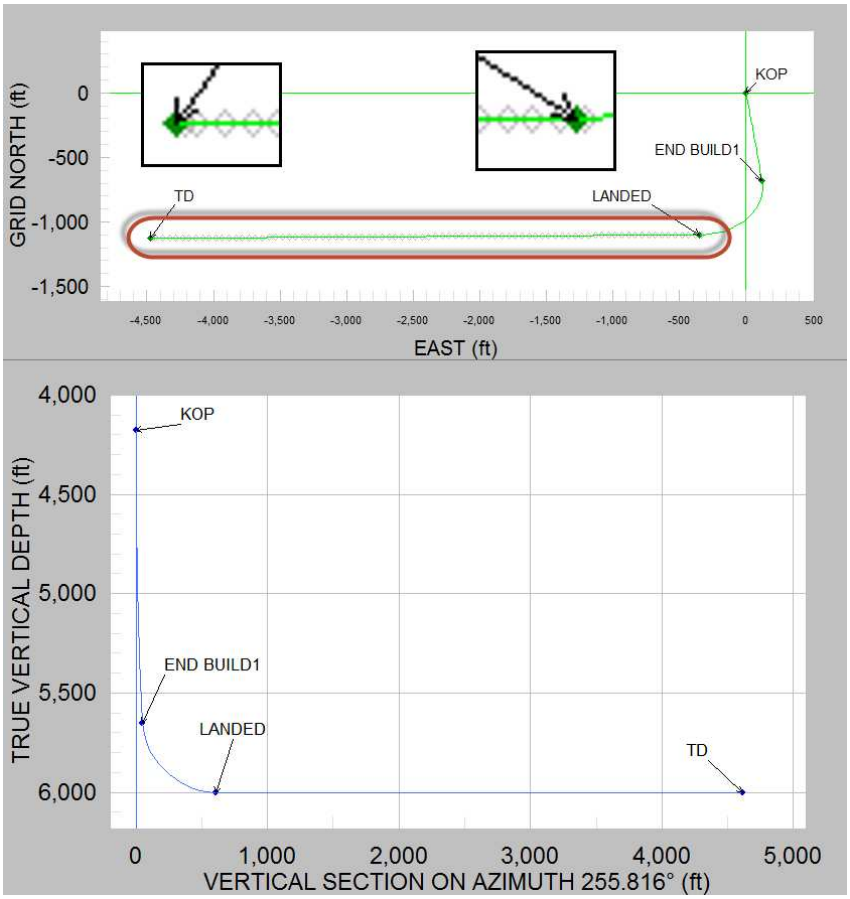
Vertical Section Azimuth: 255.816 [x] Show Reference

dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
4180.465	0	0	4180.465	0	0		KOP	0
	50.47	170				3	END BUILD1	1
	90	269.64				12	LANDED	2
4122.082	90	269.64					TD	3
								4

Record: 5 of 5

Calculated Details of Selected Plan by Hole Section

#	Reference	Type	MD	Inc	Azi	TVD	N	E	DLS	VertS
0	KOP	Tie Point	4180.46	0.00	0.00	4180.46	0.00	0.00		0.00
1	END BUILD1	Build	5862.80	50.47	170.00	5653.52	-683.72	120.56	3.00	50.65
2	LANDED	Build/Right	6674.63	90.00	269.64	5999.56	-1100.11	-350.29	12.00	609.18
3	TD	Horizontal	10796.71	90.00	269.64	5999.56	-1126.11	-4472.29	0.00	4611.89



In the preceding example the well plan is designed from kick-off point (KOP) to total depth (TD). It was determined that initial build and/or turn gradient should not exceed 3 deg/100ft to reduce uphole pipe stress, and final build and/or turn gradient should not exceed 12 deg/100ft due to the planned bottom hole assembly capabilities, total departure required at TD, and planned completion. The chosen 3D design was an initial build section followed by a final build-and-right-turn section into the lateral. Therefore, in this example the critical parameters to calibrate were ending inclination (50.47 deg) and azimuth (170 deg) of the first build section, which then leads into the second build-and-right-turn hole section that lands on the preferred lateral target line/azimuth. With that part solved, KOP TVD (equal to tie point MD) was determined easily by back-calculating to land at 6000 feet TVD. Finally, dMD of the lateral target line was determined by ensuring its length landed on TD portrayed from Plan #1. Vertical section azimuth (VSA) 255.816 deg was determined from the final planned TD. Well planning in SES is further advanced with use of Grid data for immediate feedback of the geologic model during well plan design. Eventually, a solver mechanism specific to complex 3D well plan design may be added to SES to simplify the calibration/iteration process.

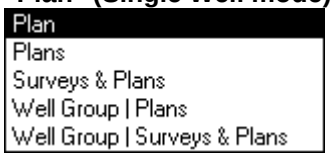
7.7 3D Viewer

SES can display 3D views of well paths and related grid data. Different default display settings are initially applied based on the selected mode when 3D Viewer screen is opened. 3D Viewer may be opened in Single Well mode or Multi Well mode from Planner screen and from Surveys screen.

Display an interactive 3D view of selected data, starting with a particular display mode/template. In addition, "Plot Grid" option and a Well's "Well Group" value can effect 3D Viewer.

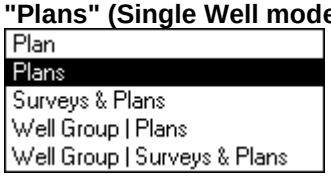
From Planner screen there are five 3D Viewer display modes available from the dropdown box.

"Plan" (Single Well mode)



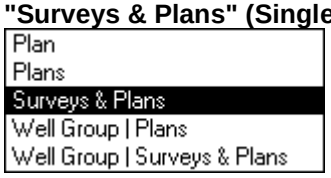
Graph selected plan using legacy display settings.

"Plans" (Single Well mode)



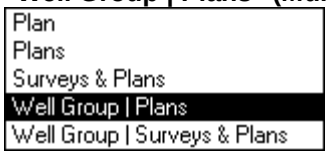
Graph selected plan and other plans from same Well.

"Surveys & Plans" (Single Well mode)



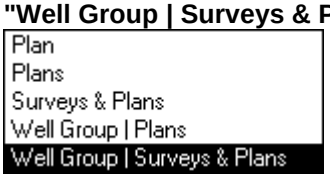
Graph selected plan, other plans, and surveys from same Well.

"Well Group | Plans" (Multi Well mode)



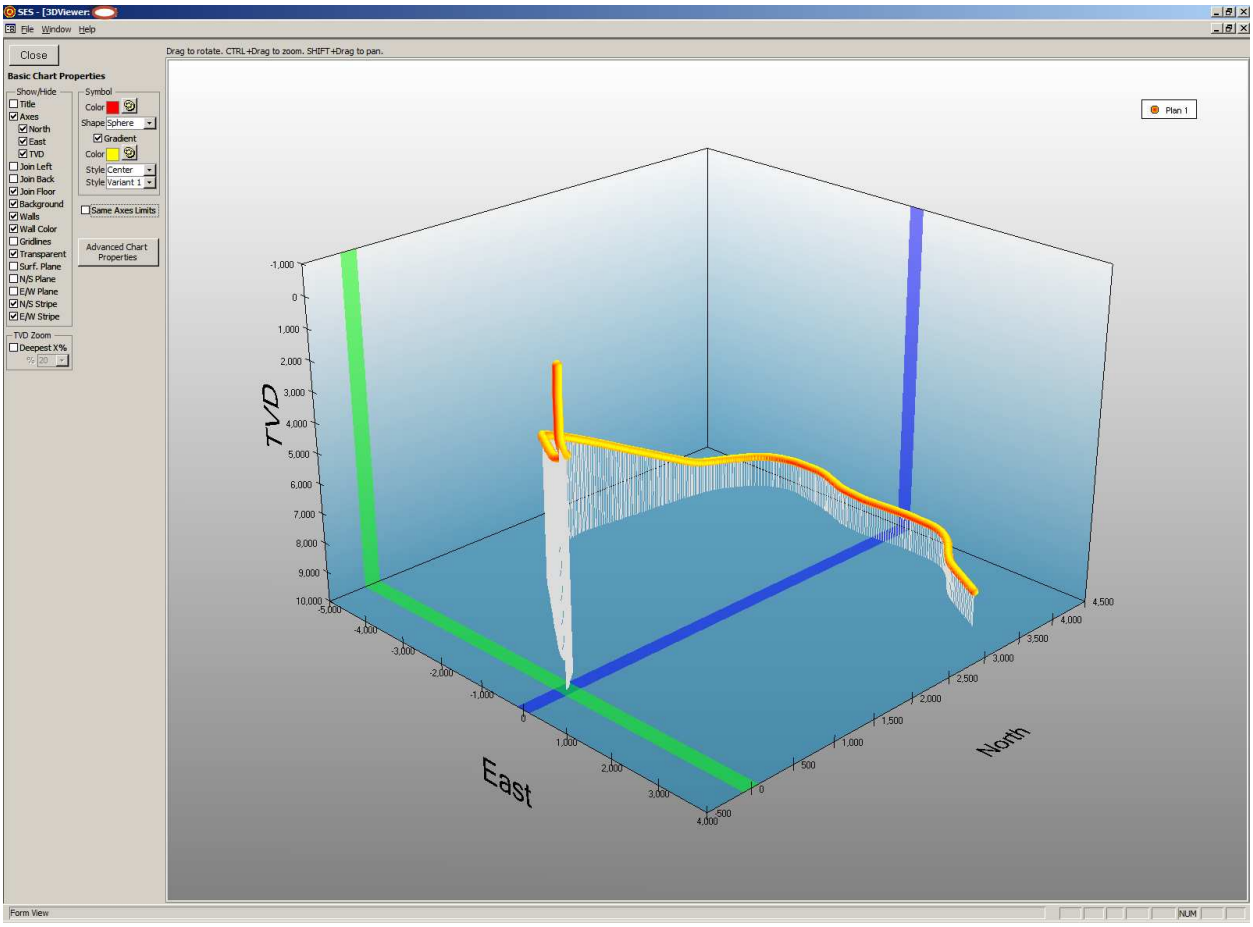
Graph plans from all Wells with same "Well Group" value.

"Well Group | Surveys & Plans" (Multi Well mode)



Graph plans and surveys from all Wells with same "Well Group" value.

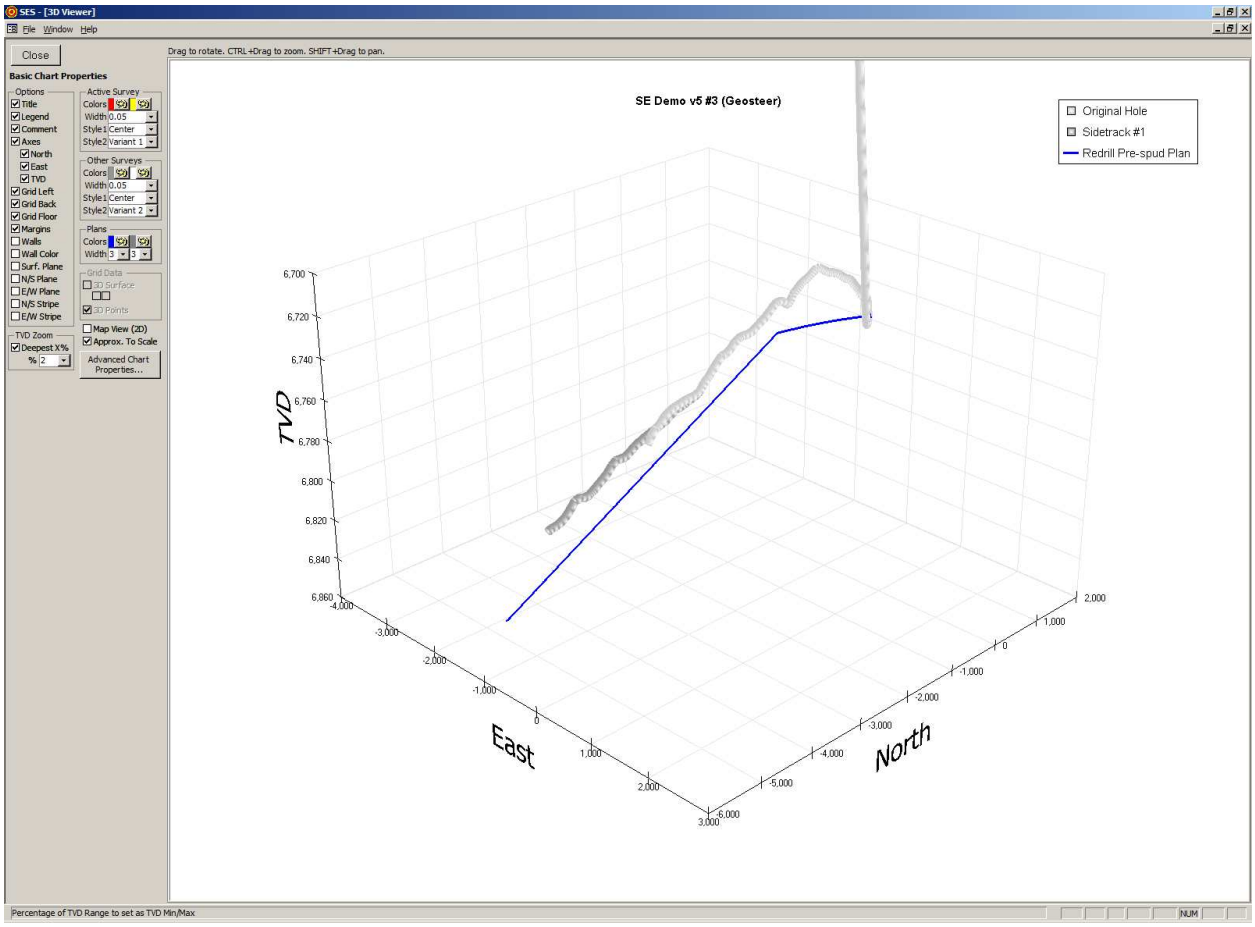
A variety of viewing options are available along the left side of 3D Viewer screen and the graph supports interactive rotate/zoom/pan (drag graph with mouse to rotate the view; press and hold CTRL key and then drag mouse up/down to zoom in/out; press and hold SHIFT key and then drag mouse to pan) and image export. Below is a screen shot of the **legacy** 3D Viewer screen, which is accessed using "Plan" mode. Plan "stations" are displayed as a 3D scatter chart, and the below real example is a complex 3D well from the Alaskan North Slope.



7.7.1 Viewer Options

An improved 3D Viewer screen is included in this version of SES. Multiple surveys and multiple plans from one or multiple wells—and grid data surfaces—may now be displayed and explored in SES. Options set from Planner screen tell SES how to initialize 3D Viewer and which data to include.

3D Viewer options are detailed next. Several common options are integrated on-screen for quick access while more advanced options are accessible through the "Advanced Chart Properties..." button.



Advanced Chart Properties... Open "Properties" dialog to access a plethora of session options to further configure the 3D chart view. For reference below, "ACP" refers to this dialog of Advanced Chart Properties.

☑ Title Set/check "Title" option to display a well name label as 2D text at the top of the graph. See ACP, "Labels" tab for more settings.

☑ Legend Set/check "Legend" option to display a legend on the right side of the graph that lists the datasets being graphed. See ACP, "Legend" tab for more settings. Also, see ACP, "Presentation Groups" tab, select the row of a specific dataset, click "Properties", and see "Legend" tab for additional settings.

☑ Comment Set/check "Comment" option if SES should use a dataset's Comment value instead of an automatic generic dataset description (e.g., "Plan 2", "Survey 1", etc.) in the legend.

☑ Axes Set/check "Axes" option to display North, East, and TVD axes, respective tick marks, and respective tick mark labels on the graph. See ACP, "Axes" tab, select "Left" (TVD), "Categories" (East), or "Series" (North) and then click "Properties" button for more settings.

☐ North
☐ East
☐ TVD Set/check options "North", "East", and/or "TVD" to display the respective axis label on the graph. If 3D Viewer has been opened in Multi Well mode, these options will read as "Grid Y", "Grid X", and "TVDss" respectively.

 If 3D Viewer has been opened in Single Well mode, datasets are graphed using local coordinates N, E, TVD. If 3D Viewer has been opened in Multi Well mode, then North, East, and TVD coordinates are transformed global coordinates GridY, GridX, and TVDss, respectively, including proper true north to grid north rotations wherever applicable.

☑ Grid Left Set/check "Grid Left" option to display gridlines on the left wall (TVD vs. North plane at minimum East). See ACP, "Axes" tab, select "Left" or "Series", click "Properties" button, then "Gridlines" tab for more settings.

☑ Grid Back Set/check "Grid Back" option to display gridlines on the back wall (TVD vs. East plane at maximum North). See ACP, "Axes" tab, select "Left" or "Categories", click "Properties" button, then "Gridlines" tab for more settings.

☑ Grid Floor Set/check "Grid Floor" option to display gridlines on the floor wall (East vs. North plane at maximum TVD). See ACP, "Axes" tab, select "Categories" or "Series", click "Properties" button, then "Gridlines" tab for more settings.

☑ Margins Set/check "Margins" option to add extra white space about the general 3D graph area.

☑ Walls Set/check "Walls" option to display solid surfaces at the left wall, back wall, and floor wall of the 3D graph. The default wall color is white, but may be changed to a variety of settings using ACP, "Walls" tab for more settings.

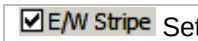
☑ Wall Color Set/check "Wall Color" option to set the left wall, back wall, and floor wall to a non-white color. See ACP, "Walls" tab for more settings.

☑ Surf. Plane Set/check "Surf. Plane" option to display a partially-transparent horizontal plane at TVD=0 (or TVDss=0). If "TVD Zoom Deepest X%" is checked, this horizontal plane may not be visible at the current scale limits. See ACP, "Axes" tab, select "Left", click "Properties" button, then "Const Lines" tab for more settings.

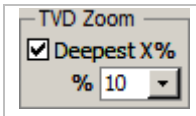
☑ N/S Plane Set/check "N/S Plane" option to display a partially-transparent vertical plane at East=0. See ACP, "Axes" tab, select "Categories", click "Properties" button, then "Const Lines" tab for more settings.

☑ E/W Plane Set/check "E/W Plane" option to display a partially-transparent vertical plane at North=0. See ACP, "Axes" tab, select "Series", click "Properties" button, then "Const Lines" tab for more settings.

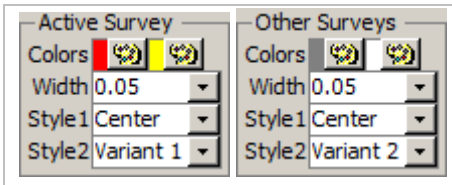
☑ N/S Stripe Set/check "N/S Stripe" option to display a partially-transparent colored stripe that highlights the North/South axis at East=0. See ACP, "Axes" tab, select "Categories", click "Properties" button, then "Stripes" tab for more settings.



Set/check "E/W Stripe" option to display a partially-transparent colored stripe that highlights the East/West axis at North=0. See ACP, "Axes" tab, select "Series", click "Properties" button, then "Stripes" tab for more settings.

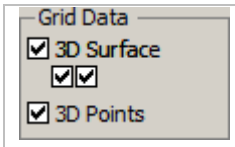


Set/check “Deepest X%” to change the minimum TVD axis limit in a manner that effectively zooms the vertical scale and moves shallow data out of view. When “Deepest X%” is checked, the “X%” zoom level may be selected from the dropdown box to better customize the view. For manual setting of the TVD axis min/max extents, see ACP, "Axes" tab, click "Left", click "Properties" button, then "Scale" tab for those settings.



When 3D Viewer is loaded from Surveys screen, the Surveys screen selected Survey dataset is considered the “Active Survey” and every other survey (if applicable) is considered an “Inactive Survey”. Click the respective color palate button to change the respective color. Select Width to change the display tube width of the respective survey path, including 0 to change the tube to a 3D line. Selecting an option under “Style 1” or “Style 2” can change how the gradient fill of the tube is drawn or other display customizations. For more options, see ACP, "Presentation Groups" tab, select the row of a specific survey, click "Properties" button, and make setting changes from there (e.g., "Uniform Appearance" tab, select the row containing "Line", click "Fill Effect" button, and change the gradient end point colors, transparency, etc.).

When 3D Viewer is loaded from Planner screen, the selected Planner screen Plan dataset is considered the “Active Plan” and every other plan (if applicable) is considered an “Inactive Plan”. When 3D Viewer is loaded from Surveys screen using a template including "Plans", then all plans are considered to be "Inactive Plan". Click the respective color palate button to change the respective color. Select a line width to change the display width of the planned well path. For more options, see ACP, "Presentation Groups" tab, select the row of a specific plan, click "Properties" button, and make setting changes from there (e.g., "Uniform Appearance" tab, select the row containing "Line", click "Border" button, and change the line color, line width, etc.).



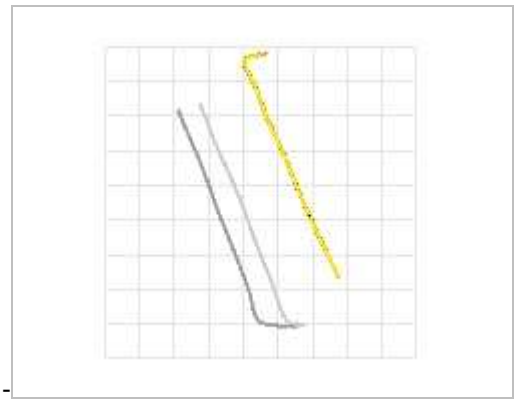
When “Plot Grid” is checked from Planner screen when 3D Viewer is loaded, Grid data are queried and returned in the vicinity of the well path and made available for display. Grid data may be displayed—as 3D scatter points ("3D Points") and/or as a surface ("3D Surface")—for each available grid layer. The associated Grid dataset is selected from Planner screen for the respective Plan dataset.

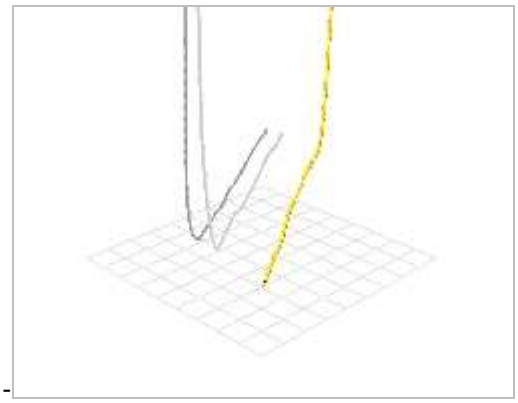
Set/check "3D Surface" option to display respective Grid data as a surface. Set/check "color sync'd to TVD" option to vary the 3D surface color by true vertical depth instead of as a constant "zone" color. Set/check "contour on floor" option to "flatten" the grid data view to display the surface at the deepest TVD level. For example, setting "color sync'd to TVD" and "contour on floor" displays a contour map type of display within the 3D graph.

Set/check "3D Points" option to display symbols at each respective grid data point. 3D points may be displayed with or without the 3D Surface option. 3D points act as a "skeleton" view and the 3D graph may be rotated and zoomed faster than when surfaces are also displayed. Dense grids may be sampled.

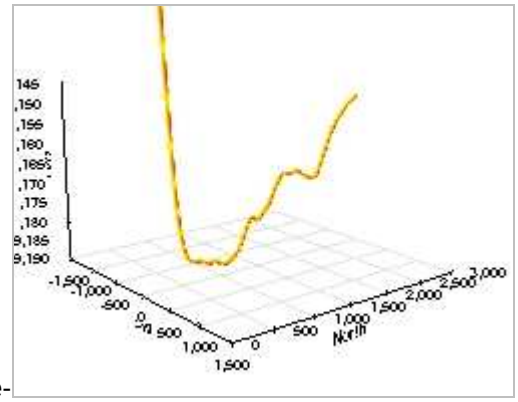
See ACP, "Presentation Groups" tab, select the row of a specific "Surface" or "Point" dataset display type, and click "Properties" for additional settings.

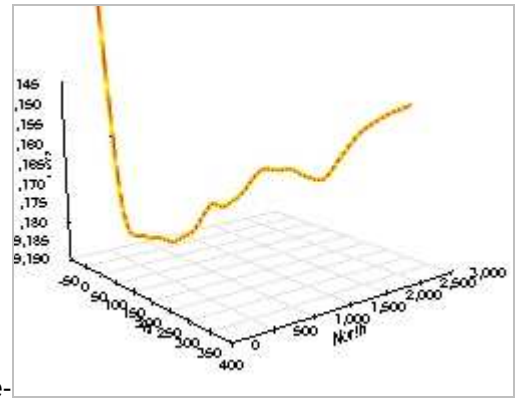
☐ Map View (2D) Set/check “Map View (2D)” to display the 3D view from the top; effectively a 2D map view format (North vs. East). Uncheck this display option to return the graph to 3D view.

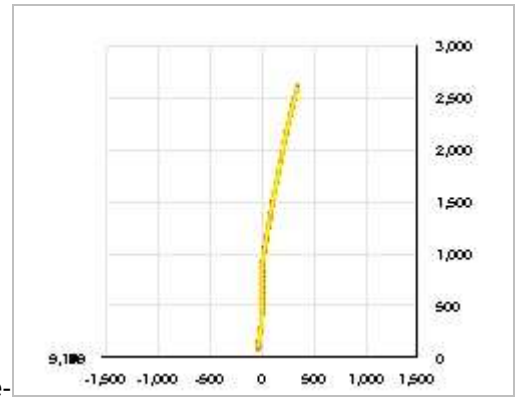
2D - 

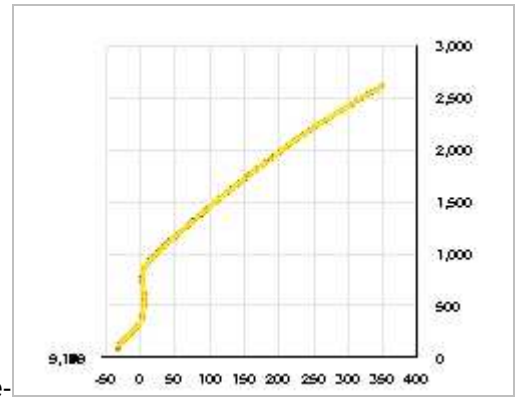
3D - 

☑ Approx. To Scale Set/check "Approx. To Scale" to display the North/South and East/West axes generally to scale; i.e., where major grid values are equal. If “Approx. To Scale” option is unchecked the East axis range and North axis range are determined from respective data ranges and respective axis major grid values may differ and thus the map may not appear drawn to horizontal scale.

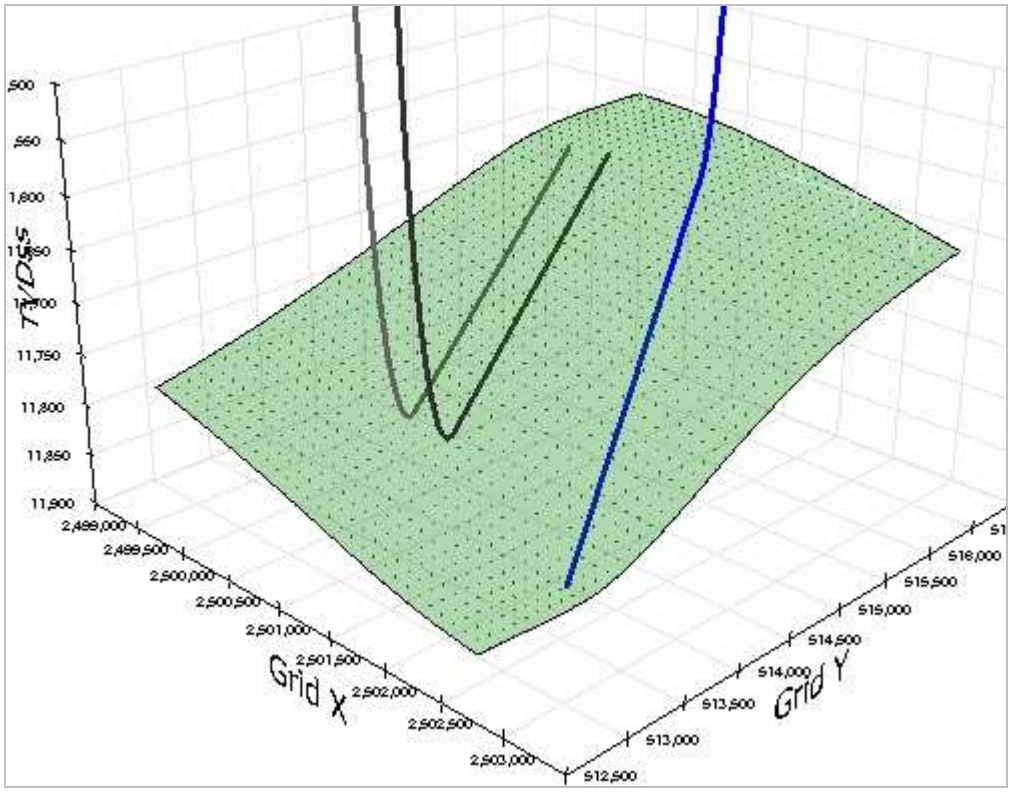
Scale- 

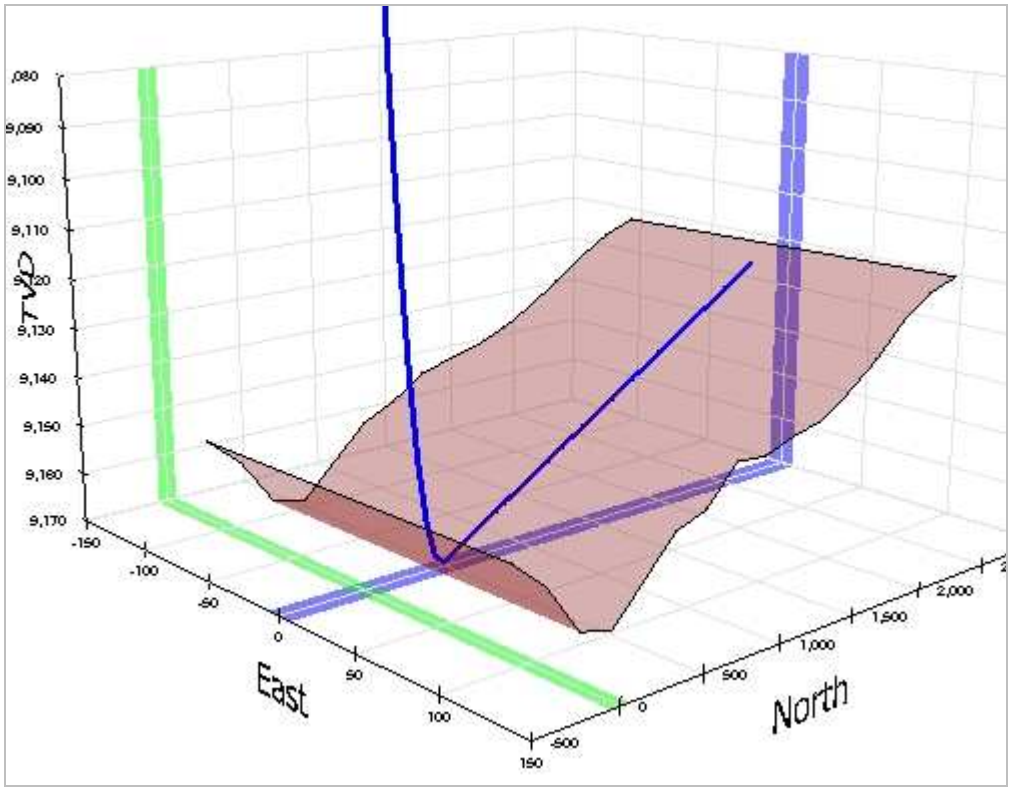
Not to Scale- 

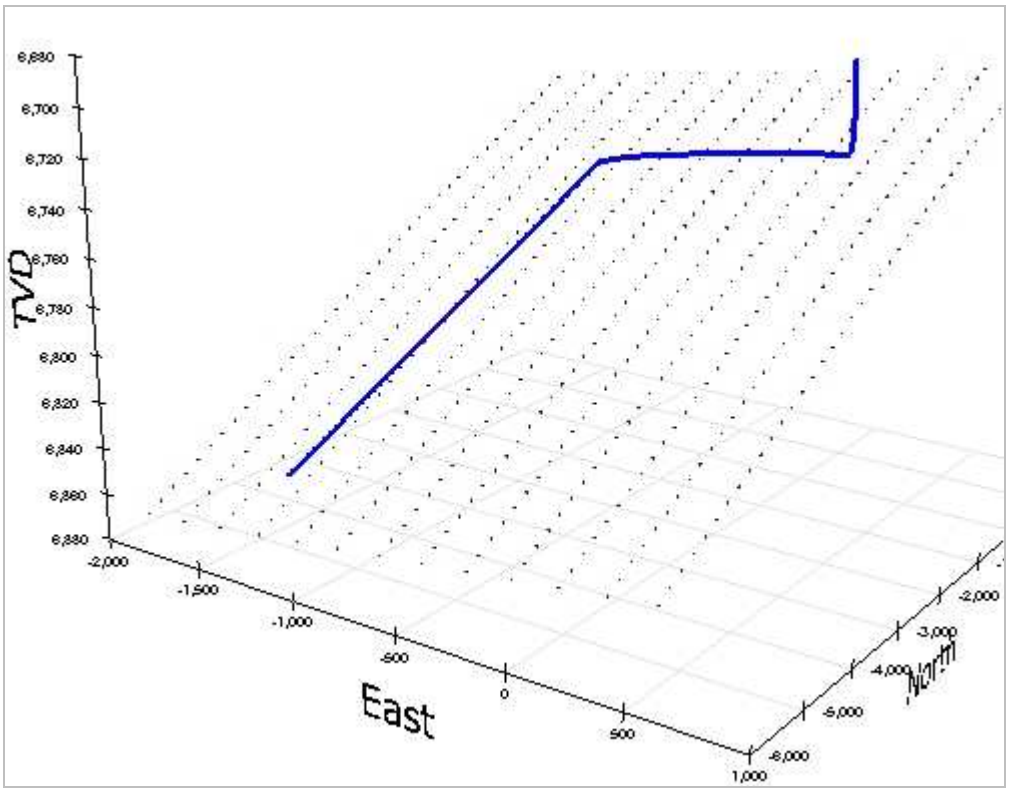
Scale- 

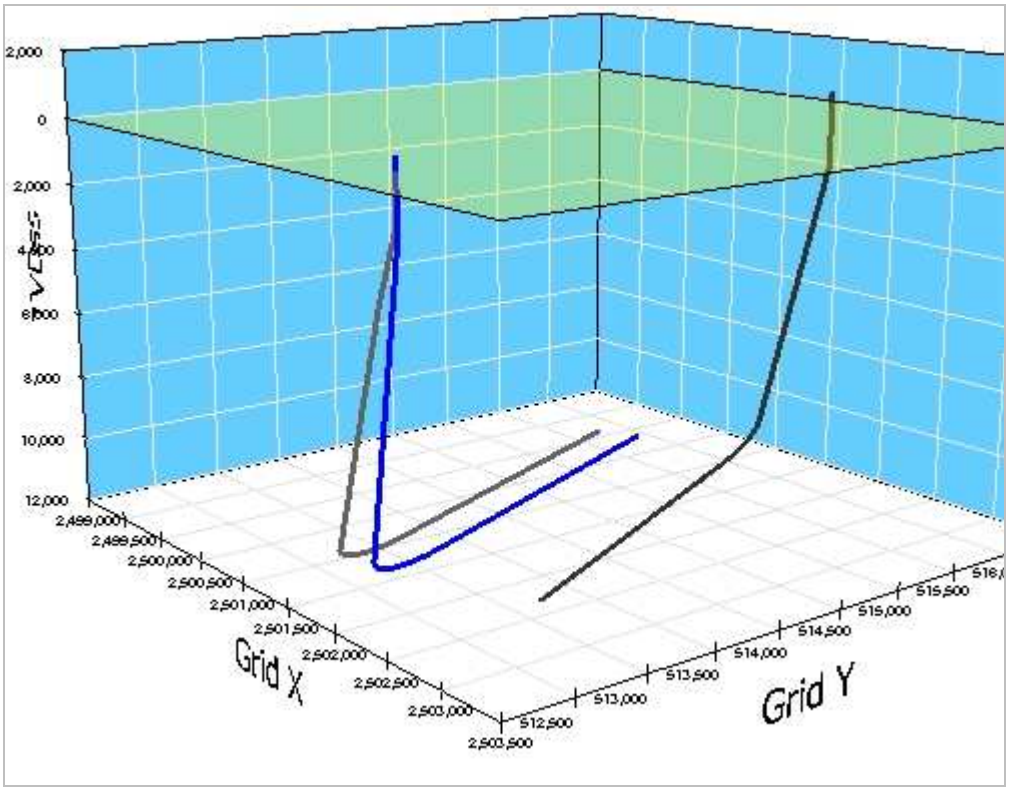
Not to Scale- 

7.7.2 Viewer Plan Examples






TVD
6,680
6,700
6,720
6,740
6,760
6,780
6,800
6,820
6,840
6,860
6,880
East
-2,000
-1,500
-1,000
-500
0
500
1,000
North
-2,000
-3,000
-4,000
-5,000
-6,000


2,000
0
2,000
4,000
6,000
8,000
10,000
12,000
Grid X
2,499,000
2,499,500
2,500,000
2,500,500
2,501,000
2,501,500
2,502,000
2,502,500
2,503,000
2,503,500
Grid Y
S12,500
S13,000
S13,500
S14,000
S14,500
S15,000
S15,500

7.8 Critical

1.) The well plan tie point coordinates and angles (MD, Inc, Azi, TVD, N, E) are entered on the first row of the input table (at ID=0).

2.) If well plan data or vertical section azimuth are changed in any way, click "Calculate PLAN" or press F6 to refresh the well plan calculation of the selected Plan.

3.) From Well Properties, coordinates SurfaceX, SurfaceY, SurfaceZ must equal local coordinates at (MD,TVD,N,E)=(0,0,0,0) for proper geologic Grid dataset interpolation and display.

4.) For proper geologic surface display, coordinates SurfaceX and SurfaceY must be in the same coordinate system as the associated Grid dataset, and grid convergence angle in degrees needs to be entered if azimuths are relative to true north.

5.) If the Well's units are changed (e.g., from ft to m), select each Plan and re-calculate each Plan.

6.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

7.9 Hot Keys

- Double-click inside "ID" cell to insert blank input target row directly above current row
- Drag rectangular window on graph to zoom
- With graph zoomed roll mouse wheel to scroll horizontally
- F6 – same as clicking Planner toolbar button "Calculate PLAN"
- CTRL – hold down Control key while clicking different Plan # and graphs are updated (navigation/dataload is faster without updating graphs; click "Refresh" to update graphs)
- CTRL – hold down Control key while selecting different Well from dropdown box and Surveys/Planner graphs are NOT updated (navigation/dataload is faster without updating graphs; click "Refresh" respectively to update graphs)

7.10 Tips

- A well plan is not required to use SES to perform technical geosteering. A well plan defined and calculated in Planner screen may be available for use from THD, Geosteer/ParamTuner, and Cross-Sections screens.
- If SES calculated vertical section does not match the field but north/south and east/west coordinates do match, then the vertical section azimuth (VSA) within SES and the value in use by the field are not the same. Determine the applicable VSA from the official directional well plan report header or footer. VSA is entered into SES in the header portion of Planner screen.
- If interpolating Grid data in SES or if exporting calculated global X-Y-TVDss values from SES for use in other software, it is important to correctly set the well plan north reference. The SES user should discern whether well plan azimuthal bearings should be from grid north or from true north. If azimuths should be relative to true north, the respective grid convergence value (angle in degrees from true north to grid north at surface, clockwise positive) should be obtained from the

individual that generated the Grid dataset and be entered into the header portion of Planner screen.

- There are three common methods to "transfer" an already-designed well plan from a service company into SES Planner screen. They are:

    1. Use Surveys screen with the well plan's critical design stations and simply duplicate the well plan as if it were a Survey; then click the Surveys screen toolbar command  . This is often the **easiest and most accurate** method to transfer a directional/horizontal plan to SES Planner screen.

    2. Use dogleg-severity (DLS…value of zero means the hole section is linear; value of non-zero means the hole section is curved) to manually by inspection transform a digitized plan into a finite number of either Type II or Type IV "target" types after fully defining the tie point (first station/row, ID=0). Enter the respective values into SES Planner input target table and calculate the well plan. See **7.4 General Well Plan Design Notes** for more information on target types supported in SES.

Method 2 example…(formatted, digitized) well plan from a service company…

MD*	INC*	AZI*	TVD*	N*	E*	VertS*	DLS*	Reference
5936.00	0.00	0.00	5936.00	0.00	0.00	0.00	0.00	KOP
6000.00	4.68	188.73	5999.93	-2.58	-0.40	2.61	**7.31**	
6100.00	11.99	188.73	6098.81	-16.90	-2.59	17.09	7.31	
6200.00	19.30	188.73	6195.04	-43.53	-6.68	44.04	7.31	
6300.00	26.61	188.73	6287.06	-82.05	-12.60	83.01	7.31	
6400.00	33.92	188.73	6373.37	-131.83	-20.24	133.38	7.31	
6500.00	41.23	188.73	6452.57	-192.06	-29.49	194.31	7.31	
6600.00	48.54	188.73	6523.38	-261.76	-40.20	264.83	7.31	
6700.00	55.85	188.73	6584.64	-339.80	-52.18	343.79	7.31	
6800.00	63.16	188.73	6635.35	-424.91	-65.25	429.89	7.31	
6900.00	70.47	188.73	6674.70	-515.71	-79.19	521.75	7.31	
6920.95	**72.00**	**188.73**	6681.44	-535.32	-82.20	541.59	7.31	P.P./CSNG PNT
7000.00	76.58	188.73	6702.83	-610.51	-93.75	617.67	**5.80**	
7100.00	82.38	188.73	6721.07	-707.65	-108.67	715.95	5.80	
7200.00	88.18	188.73	6729.29	-806.12	-123.79	815.57	5.80	
7216.64	**89.15**	**188.73**	6729.68	-822.56	-126.31	832.20	5.80	
7300.00	89.15	188.73	6730.92	-904.94	-138.96	915.55	**0.00**	
7400.00	89.15	188.73	6732.40	-1003.78	-154.14	1015.54	0.00	
7500.00	89.15	188.73	6733.88	-1102.61	-169.31	1115.53	0.00	
7600.00	89.15	188.73	6735.37	-1201.44	-184.49	1215.52	0.00	
7700.00	89.15	188.73	6736.85	-1300.27	-199.67	1315.51	0.00	
7800.00	89.15	188.73	6738.33	-1399.10	-214.84	1415.50	0.00	
7900.00	89.15	188.73	6739.82	-1497.93	-230.02	1515.49	0.00	
8000.00	89.15	188.73	6741.30	-1596.76	-245.19	1615.47	0.00	
8100.00	89.15	188.73	6742.78	-1695.59	-260.37	1715.46	0.00	
8200.00	89.15	188.73	6744.27	-1794.42	-275.55	1815.45	0.00	
8300.00	89.15	188.73	6745.75	-1893.25	-290.72	1915.44	0.00	
8400.00	89.15	188.73	6747.23	-1992.08	-305.90	2015.43	0.00	
8500.00	89.15	188.73	6748.72	-2090.91	-321.07	2115.42	0.00	
8600.00	89.15	188.73	6750.20	-2189.74	-336.25	2215.41	0.00	
8700.00	89.15	188.73	6751.68	-2288.57	-351.43	2315.40	0.00	
8800.00	89.15	188.73	6753.17	-2387.40	-366.60	2415.39	0.00	
8900.00	89.15	188.73	6754.65	-2486.23	-381.78	2515.38	0.00	

9000.00	89.15	188.73	6756.13	-2585.06	-396.96	2615.36	0.00
9100.00	89.15	188.73	6757.62	-2683.90	-412.13	2715.35	0.00
9200.00	89.15	188.73	6759.10	-2782.73	-427.31	2815.34	0.00
9300.00	89.15	188.73	6760.58	-2881.56	-442.48	2915.33	0.00
9400.00	89.15	188.73	6762.07	-2980.39	-457.66	3015.32	0.00
9500.00	89.15	188.73	6763.55	-3079.22	-472.84	3115.31	0.00
9600.00	89.15	188.73	6765.04	-3178.05	-488.01	3215.30	0.00
9700.00	89.15	188.73	6766.52	-3276.88	-503.19	3315.29	0.00
9800.00	89.15	188.73	6768.00	-3375.71	-518.37	3415.28	0.00
9900.00	89.15	188.73	6769.49	-3474.54	-533.54	3515.27	0.00
10000.00	89.15	188.73	6770.97	-3573.37	-548.72	3615.25	0.00
10100.00	89.15	188.73	6772.45	-3672.20	-563.89	3715.24	0.00
10200.00	89.15	188.73	6773.94	-3771.03	-579.07	3815.23	0.00
10300.00	89.15	188.73	6775.42	-3869.86	-594.25	3915.22	0.00
10400.00	89.15	188.73	6776.90	-3968.69	-609.42	4015.21	0.00
10500.00	89.15	188.73	6778.39	-4067.52	-624.60	4115.20	0.00
10600.00	89.15	188.73	6779.87	-4166.35	-639.77	4215.19	0.00
10700.00	89.15	188.73	6781.35	-4265.18	-654.95	4315.18	0.00
10800.00	89.15	188.73	6782.84	-4364.02	-670.13	4415.17	0.00
10900.00	89.15	188.73	6784.32	-4462.85	-685.30	4515.16	0.00
11000.00	89.15	188.73	6785.80	-4561.68	-700.48	4615.14	0.00
12000.00	89.15	188.73	6800.64	-5549.98	-852.24	5615.03	0.00
13000.00	89.15	188.73	6815.47	-6538.29	-1004.00	6614.92	0.00
13100.00	89.15	188.73	6816.96	-6637.12	-1019.18	6714.91	0.00
13200.00	89.15	188.73	6818.44	-6735.95	-1034.35	6814.90	0.00
13300.00	89.15	188.73	6819.92	-6834.78	-1049.53	6914.89	0.00
13400.00	89.15	188.73	6821.41	-6933.61	-1064.71	7014.88	0.00
13500.00	89.15	188.73	6822.89	-7032.44	-1079.88	7114.87	0.00
13600.00	89.15	188.73	6824.37	-7131.27	-1095.06	7214.86	0.00
13700.00	89.15	188.73	6825.86	-7230.10	-1110.24	7314.85	0.00
13800.00	89.15	188.73	6827.34	-7328.93	-1125.41	7414.84	0.00
13900.00	89.15	188.73	6828.82	-7427.76	-1140.59	7514.83	0.00
14000.00	89.15	188.73	6830.31	-7526.59	-1155.76	7614.81	0.00
14100.00	89.15	188.73	6831.79	-7625.42	-1170.94	7714.80	0.00
14200.00	89.15	188.73	6833.28	-7724.25	-1186.12	7814.79	0.00
14300.00	89.15	188.73	6834.76	-7823.09	-1201.29	7914.78	0.00
14400.00	89.15	188.73	6836.24	-7921.92	-1216.47	8014.77	0.00
14438.64	89.15	188.73	6836.82	-7960.11	-1222.33	8053.41	0.00

…can be transferred into the following equivalent SES well plan INPUT…

dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
0	0	0	5936	0	0		KOP	0
	72	188.73				7.31	P.P./Csng Pnt	1
	89.15	188.73				5.8	LANDED	2
7222	89.15	188.73					TD	3

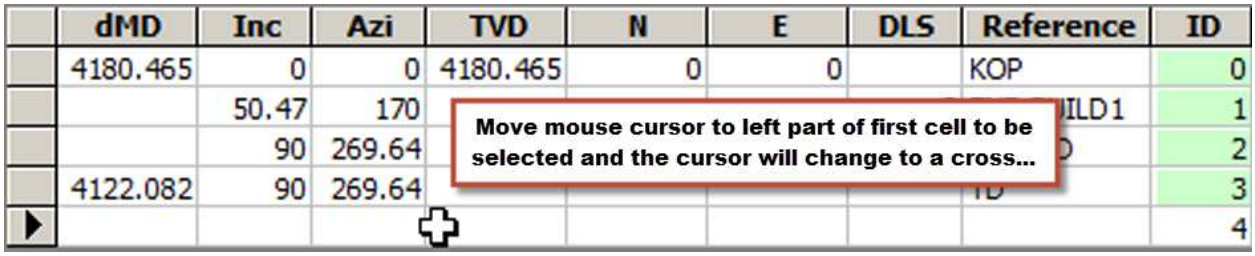
…with SES well plan calculated OUTPUT…

#	Reference	Type	MD	Inc	Azi	TVD	N	E	DLS	VertS
0	KOP	Vertical	5936.00	0.00	0.00	5936.00	0.00	0.00		0.00
1	P.P./Csng Pnt	Build	6920.95	72.00	188.73	6681.44	-535.32	-82.20	7.31	541.59
2	LANDED	Build	7216.64	89.15	188.73	6729.68	-822.56	-126.31	5.80	832.20
3	TD	Horizontal	14438.64	89.15	188.73	6836.82	-7960.11	-1222.33	0.00	8053.41

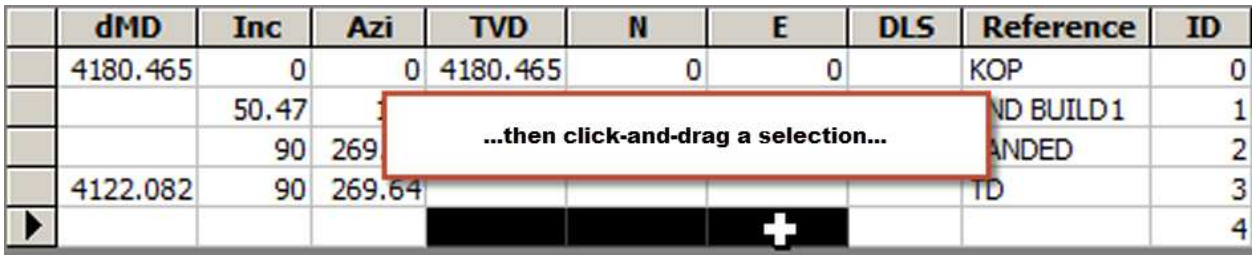
3. Fully specify the well plan's tie point coordinates and angles (entered on first row, ID=0) and then simply paste the Cartesian coordinates (TVD, N, E) of the well plan into SES. This method ONLY works "perfectly" if the source data are full precision (i.e., NOT formatted; for example the number 23.435980298 is formatted if it is reported as 23.44).

   The "trick" to pasting into SES when not pasting into the left-most columns of a data table is to first select the proper columns on the bottom row onto which you want to paste data from the clipboard, and then Paste using CTRL+V or by right-clicking over the selection and choosing Paste from the shortcut menu.

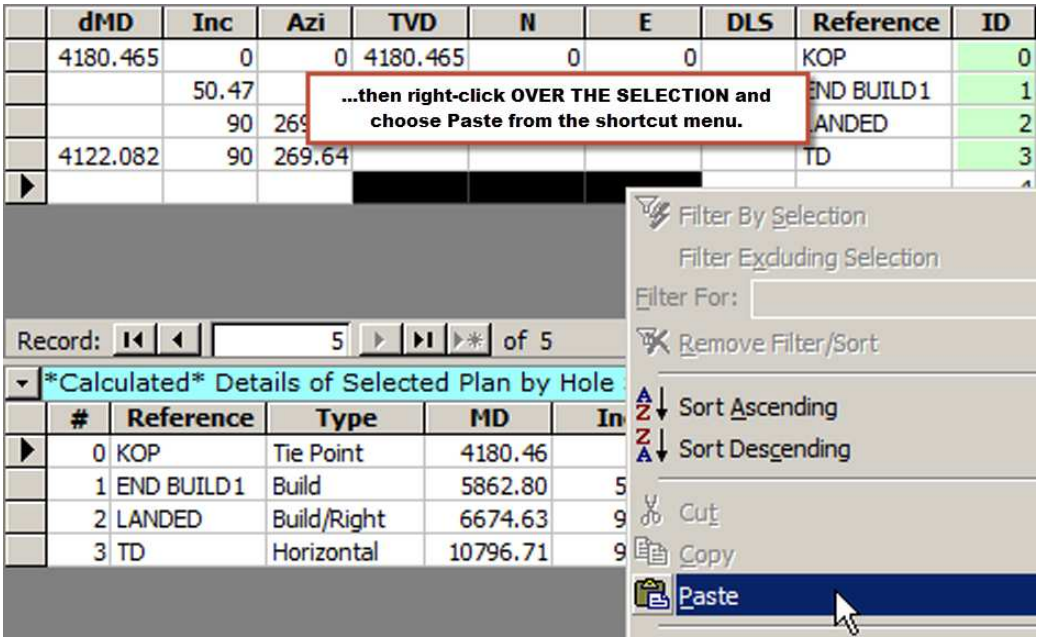
   To perform this "special" selection, move the mouse cursor to the left edge of the respective cell and the mouse cursor will turn to a cross...



   ...at which time you may click-and-drag a selection window...



   ...then right-click over the selection and choose Paste from the shortcut menu **to perform pasting of data into "interior" columns of an SES data table**.



dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
4180.465	0	0	4180.465	0	0		KOP	0
	50.47						END BUILD1	1
	90	269					LANDED	2
4122.082	90	269.64					TD	3

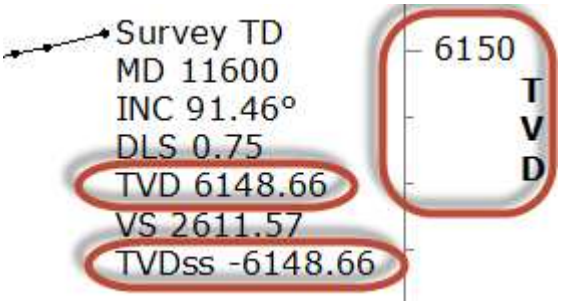
#	Reference	Type	MD	In
0	KOP	Tie Point	4180.46	
1	END BUILD1	Build	5862.80	5
2	LANDED	Build/Right	6674.63	9
3	TD	Horizontal	10796.71	9

- In this version, TVDss is not displayed along any TVD axes in SES. To "trick" SES into making all "TVD" values and axes actually be TVDss values with positive-down convention, do the following:

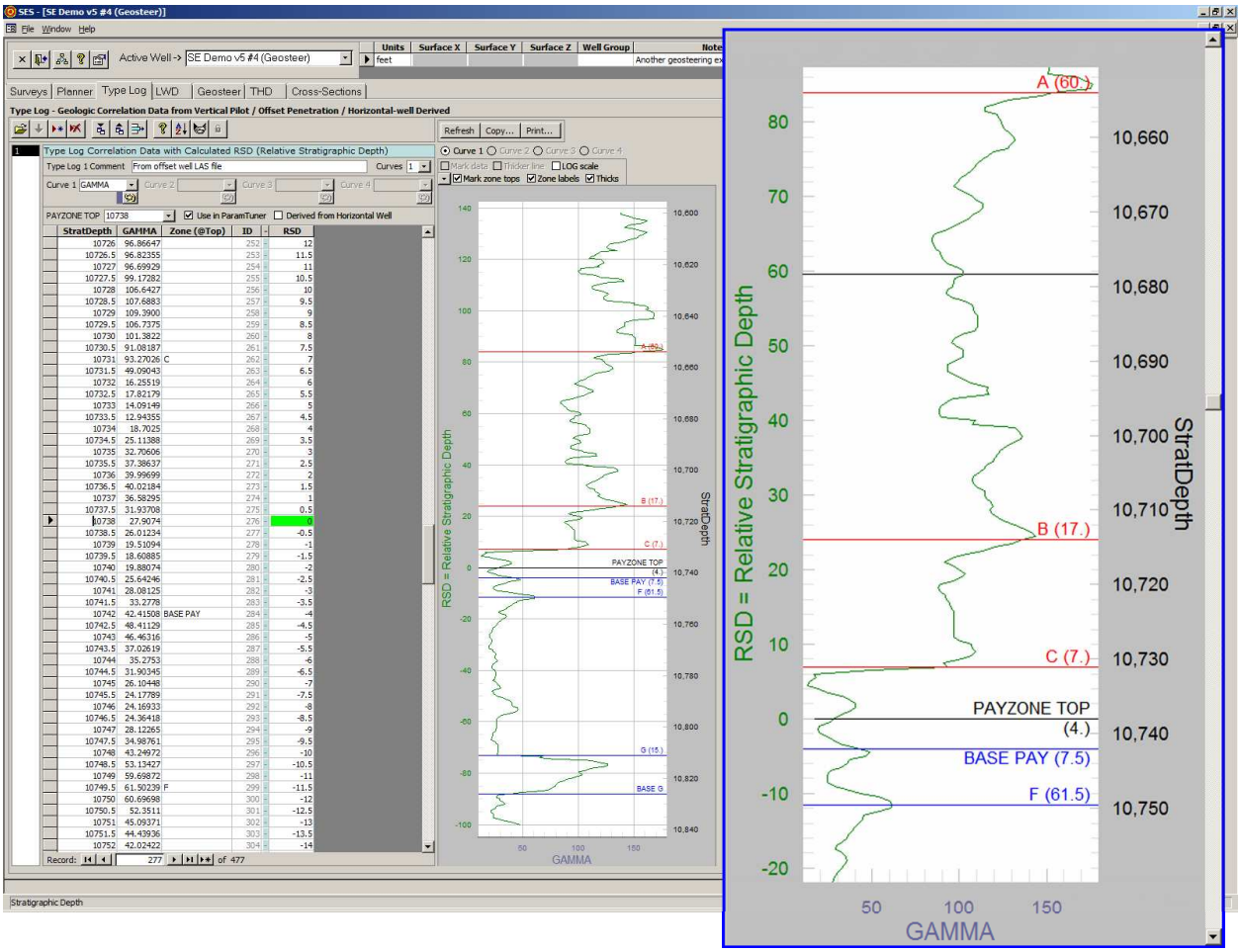
  1.) Set Plan Tie Point TVD equal to its TVDss equivalent, BUT use negative-above mean sea level (MSL) convention. For example, if the plan starts at 8300 ft and KB elevation is 3000 ft and the wellbore is assumed vertical to this point, enter 5300 into tie point TVD coordinate from Planner screen, as shown below. **2.)** Enter zero for Surface Z as shown below. (Note: Grid data should still be entered into Grids screen as usual for SES—positive-above MSL and negative-below MSL for all TVDss values.)

tie_MD	tie_Inc	tie_Az	tie_TVD	tie_N	tie_E	DLS	Reference	ID
8300	0	0	5300	0	0		TIE	0

Surface Z 0



8. SES Screen – TYPE LOG



8.1 General

A type log dataset provides geologic guidance for stratigraphic correlation of a horizontal well's landing and lateral hole sections. Each type log dataset may include from one to four curves of quantitative correlation information. All such data curves and multiple Type Logs may be used for geosteering.

TYPE LOG screen can be used to:

1.) Input or import quantitative stratigraphic correlation "type log" data (e.g., gamma ray, resistivity, porosity, etc.) that source from offset payzone and shallower measurements.

2.) Manage and navigate Type Logs from multiple vertical offset wells, vertical pilot holes, dip-corrected calculated logs, and derived type logs from horizontal well correlations.

3.) Designate each type log dataset's curve name and curve color (color is applied in ParamTuner and Cross-Sections screens), with up to four curves per Type Log.

4.) Convert "Stratigraphic Depth" (which in most cases is MD from a vertical well with beds of low dip) to "Relative Stratigraphic Depth" (RSD) by entering the depth of the PAYZONE TOP. RSD is required for geosteering.

5.) Designate which Type Log(s) to currently display in ParamTuner when geosteering (multiple Type Logs may be displayed simultaneously and/or switched on/off as needed); may also be set from ParamTuner.

6.) Recall if a Type Log was derived from a horizontal well using ParamTuner.

7.) Graph a type log dataset's curve on linear or Log10 scale.

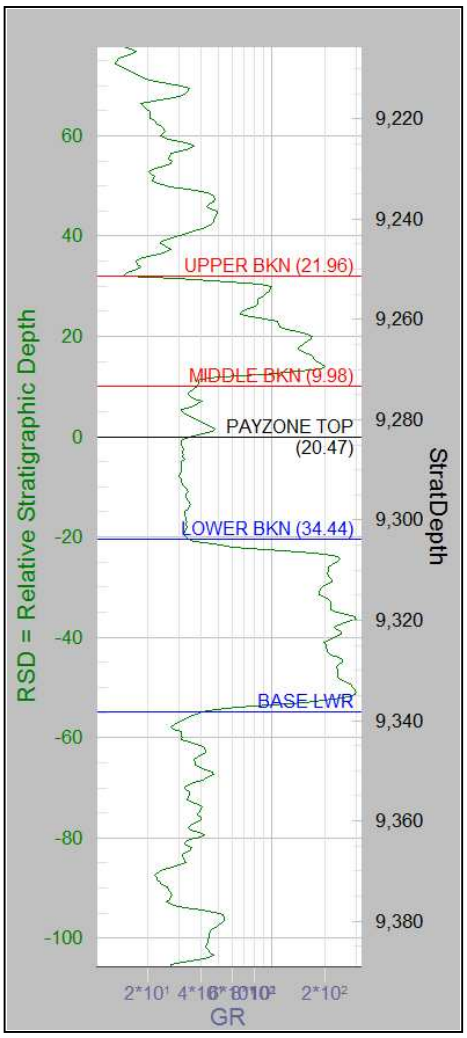
8.) Print the graph on any system printer (including Adobe/PDF).

9.) Copy the graph for paste into another application.

10.) Zoom a section of the log track graph by dragging a window with the mouse within the graph; then pan by clicking the scroll bars or rolling the mouse wheel.

11.) Temporarily change a variety of graph properties (including full-screen/maximize mode) by right-clicking over the graph and selecting from the shortcut menu.

12.) Display annotated (e.g., formation name) horizontal lines on the graph by entering text into the "Zone (@Top)" column at a particular depth. Thicknesses between such lines may also be posted (see adjacent picture).



13.) Set "PAYZONE TOP" by double-clicking a data point while the graph is zoomed.

14.) Delete an exterior range of data (e.g., shallow-depth and deep-depth data far from the landing and payzone proximities).

15.) Import/copy/transfer a Type Log from another Well in SES database to the selected Type Log.

16.) Export a Type Log (e.g., a type log dataset derived from a horizontal well correlation) to an LAS file for use in 3rd party software.

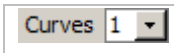
17.) Reset or change "PAYZONE TOP" in the middle of an interpretation, with optional automatic correction to all respective existing interpretation parameters and 3DStratBlock (3DSB) stored views.

8.2 Toolbar

Control	Control Tip | Detailed Description
	import Type Log data from LAS file... | Open "Import 3rd-Party Data File" dialog to browse and open an LAS file, designate the respective columns in the LAS file that match StratDepth/Curve1|Curve2|Curve3|Curve4, and import stratigraphic correlation data into the selected Type Log. For more information see **8.5 Import Type Log Data from LAS File**.
	N/A | Type Log data may not be downloaded/imported from a WITSML server.
	add Type Log | Add a new Type Log dataset and select it. SES automatically copies some Type Log header properties (total curves count, curve names, curve colors) from the largest numbered existing Type Log and initializes the new Type Log with such values.
	delete Type Log | Delete the selected Type Log dataset (and potentially renumber the remaining

	existing Type Log datasets). Type Log #1 may only be deleted if there are at least two Type Log datasets before deleting Type Log #1. Type Log datasets are numbered starting at #1. To delete Type Log #1 when there is only one Type Log dataset, first Add a new Type Log dataset and then select and delete Type Log #1, after which empty Type Log #2 will become Type Log #1.
	import/copy Type Log data from within SESdata... | Open "Copy Type Log from Another Well" dialog to copy an existing Type Log dataset to the currently selected Type Log. Any existing header or table data of the currently selected Type Log are replaced with the contents of the copied Type Log dataset. A Type Log from any Well in SESdata.mdb may be copied/imported.
	export Type Log data to LAS file... | Export the Type Log dataset to an LAS file after setting the output path and filename. In addition to being CWLS LAS v3 compliant, LAS files generated by SES are also created to present the data content in both space delimited and fixed width text formats for greater versatility.
	delete unneeded Type Log data... | Open "Clean-up Type Log Data Range" dialog to delete shallow-depth and deep-depth Type Log data that is far from the landing and payzone proximities. This feature is helpful because often LAS files used for Type Logs source from wells that were logged from surface casing to total depth and usually contain much more wellbore depth range than is needed for geosteering. The "extra data" unnecessarily increases file sizes and internal memory needs, and adds computational overhead. For best ParamTuner performance, delete all Type Log data that isn't necessary for geosteering your payzone. Keeping 1000ft of data above the payzone and 100ft of data below the payzone is usually sufficient, and this dialog often simplifies the process of deleting such records. This dialog also circumvents a Microsoft Access bug where after manually deleting many records from a data table the screen is not properly refreshed and as a result requires changing the SES Active Well or selected Type Log in order to receive a proper screen refresh/redraw.
	TYPE LOG help | Display Type Log screen abridged help.
	sort TypeLog data on StratDepth & Renumber ID (occasionally needed) | Sort the selected Type Log dataset on StratDepth and reset the calculated "ID" column values. "ID" is an SES internal index number and SES assumes elsewhere that Type Log data are sorted ascending on StratDepth. Because all new data must be added to the bottom of the data table, sometimes resorting is necessary to ensure StratDepth increases. Deleting one or more interior depth stations can also require sorting using this button because "ID" column values will need reset. Also, in rare cases an LAS file's depth data are descending in which case the data after importing into SES require re-sorting using this button.
	check TypeLog for possible problems | Check the selected Type Log header and table data for conditions that are known or suspected to cause problems in ParamTuner. This data quality check is applied each time ParamTuner is loaded whether or not the SES user has ever clicked this button. Sometimes called the "cat button", the icon is actually intended to represent two hands shaking. ☺
	lock graph extents (when zoomed) between refreshes | Maintain/lock current Type Log graph y-axis minimum and maximum values upon graph refresh. This toggle button is enabled only when the log track graph is zoomed. To zoom, click and drag a y-axis zoom range on the graph. Successive click and drag to zoom is supported. By default, SES re-determines a graph's y-axis extents after refreshing and this toggle button allows the SES user to temporarily override that behavior.

8.3 Other Functions/Features

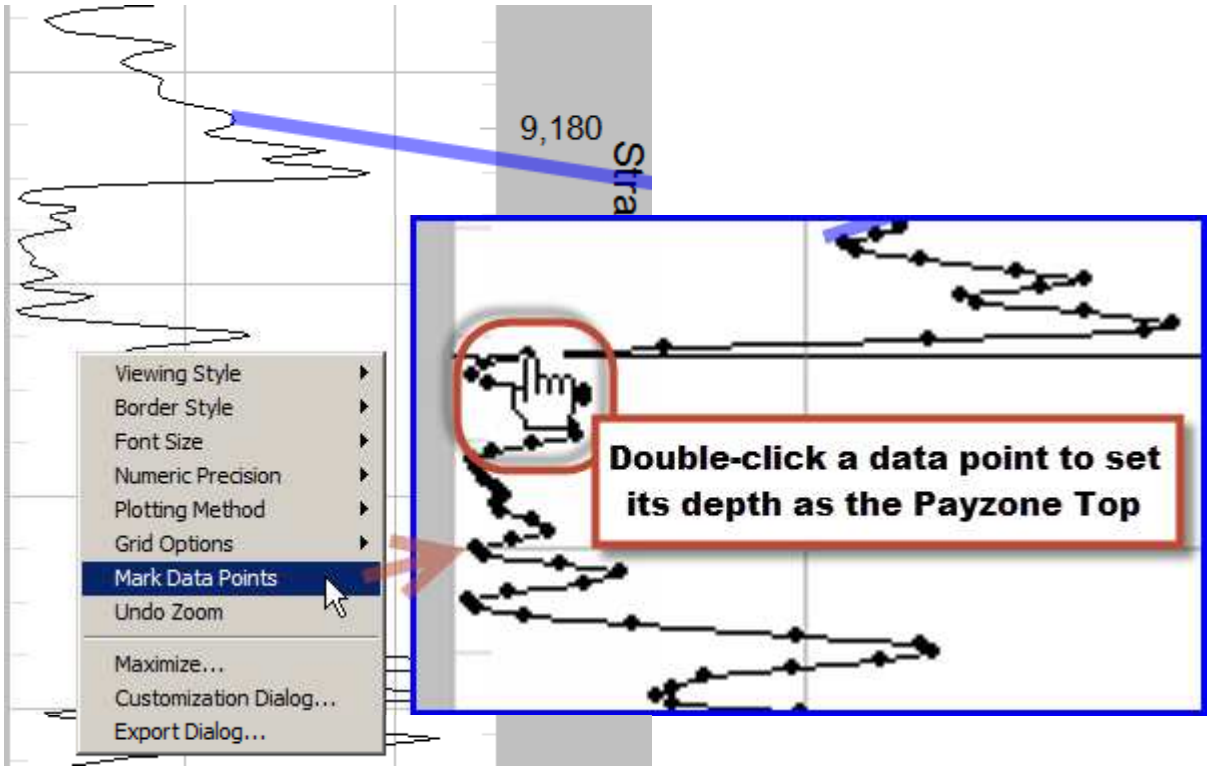


Select the maximum number of data curves the Type Log dataset will contain. For example, if gamma ray and resistivity will be measured anywhere within the horizontal well being drilled, select a total curve count of 2.

Curve 1 GAMMA For each data curve, enter its name and pick its corresponding color. The selected curve color is applied in ParamTuner and Cross-Sections screen inset RSD track view. Usually it is best to populate curve 1 with gamma ray. When geosteering in ParamTuner, SES assumes Type Log curve 1 corresponds to LWD curve 1. For example, if geosteering with two separate signals gamma ray and resistivity, Type Log curve 1 and LWD curve 1 should both contain gamma ray while Type Log curve 2 and LWD curve 2 should both contain resistivity.

PAYZONE TOP 9187 Enter the StratDepth of the top of the payzone. In SES geosteering, the payzone has a top, a base (and therefore some stratigraphic thickness), and a specific target depth within the top and base range (see Geosteer screen header section to set the offset depth from Payzone Top to the specific target depth). Payzone Top depth must be the exact depth value of an existing StratDepth data point within a Type Log dataset.

To set Payzone Top graphically, drag a window to zoom the log track and then double-click the corresponding data point. The mouse cursor turns to a hand when hovering over a data point when zoomed. Enabling "Mark Data Points" can be helpful to discern exactly where data point depths exist.



Mouse cursor tracking is also reported in the upper right corner of the graph area when the mouse is moved over the log track.

☑ Use in ParamTuner One or multiple Type Logs may be used while geosteering, or Type Logs may be switched accordingly. "Use in ParamTuner" option sets whether the selected Type Log is displayed the next time ParamTuner is loaded. This option may also be set directly from ParamTuner.

☐ Derived from Horizontal Well "Derived from Horizontal Well" option is automatically checked when a Type Log dataset is created using ParamTuner. Its setting value essentially only serves as a reminder of its source. Type Log datasets may come from offset wells or they may be created ("derived") from an interpretation of horizontal well data that originally depended on an offset well Type Log. Because derived type logs often contain more character about the strata being analyzed, they may be preferred. For example, an area near a drilling pad may contain one nearby vertical well that is used for Type Log purposes during the drilling of the first lateral pad well. A derived type log is then created after correlating the first lateral pad well. Subsequent horizontal pad wells may be better served using this derived Type Log instead of the original nearby vertical well log because the vertical well had much less exposure and more layer averaging than what was gleaned from the horizontal well interpretation dataset.

Refresh Redraw the log track graph for the currently selected Type Log and the currently selected curve. This request processes any changes made regarding the display of "Zone @ Top" annotations and/or curve name/color changes.

Copy... Display a dialog that reminds how to **copy** a graph. To **copy** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (**clipboard**/file/printer), size, and resolution/dpi.

Print... Display a dialog that reminds how to **print** a graph. To **print** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (clipboard/file/**printer**), size, and resolution/dpi.

◉ Curve 1 ○ Curve 2 ○ Curve 3 ○ Curve 4 Select the data curve to plot on the log track. Only curves up to the total curve count will be enabled.

☐ Mark data When the log track is zoomed, select "Mark Data" option to mark data points with a small solid symbol. Marked data points make it easier to pick the Payzone Top depth by double-clicking a data point.

☐ Thicker line Check "Thicker line" option to thicken the plotted line on the log track.

☑ LOG scale Check "LOG scale" option to plot the selected curve on a Log10 scale. Uncheck this option to plot the selected curve on a linear scale.

This SES custom user setting (upper-left dropdown box) can be used to set the width of the Type Log screen log track graph.

☑ Mark zone tops When text (e.g., formation name) has been entered into the column labeled "Zone (@Top)" at a particular depth, an annotated horizontal line is displayed on the log track if "Mark zone tops" option is checked. Annotated horizontal lines above the Payzone Top depth are colored red and below the Payzone Top depth are colored blue.

☑ Zone labels Check "Zone labels" option to post the annotation (e.g., formation name) on the log track. If this option is unchecked, the horizontal line remains displayed but the annotation text is not displayed.

☑ Thicks Check "Thicks" option to calculate and post the thickness between two horizontal line annotations. This feature can be helpful when setting-up offset layers (Geosteer screen, Tab View, Bed Thickness & Color tab) for ultimate display on Cross-Sections screen cross sections. These thicknesses

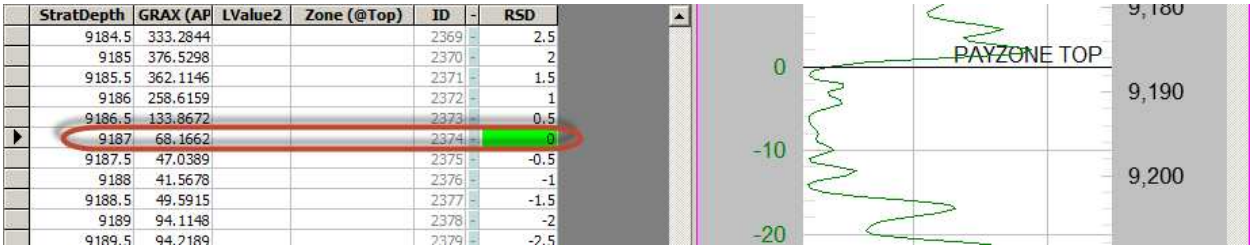
may also be transferred to a Marker Bed (Interpretation) by right-clicking the log track graph and choosing "Send Thicks to Marker Bed..." or "Send Thicks & Zone Names to Marker Bed...".

8.4 Type Log RSD Calculation

By specifying the Payzone Top depth of a Type Log, SES can convert StratDepth to Relative Stratigraphic Depth (RSD). RSD equals StratDepth at Payzone Top minus StratDepth, thus, RSD is positive above Payzone Top depths and negative below Payzone Top depths. RSD is required for technical geosteering and is displayed in the far right column of the data table.

Through RSD, SES performs a "disconnect" from absolute depth coordinates and effectively creates a dynamic coordinate system that travels along the wellbore being analyzed, while referencing this known "anchored" stratigraphic horizon.

After Payzone Top has been set, the data curve is plotted in green on the Type Log screen log track, and, the RSD cell background color at the Payzone Top depth (where RSD=0) is also colored green (green means good).

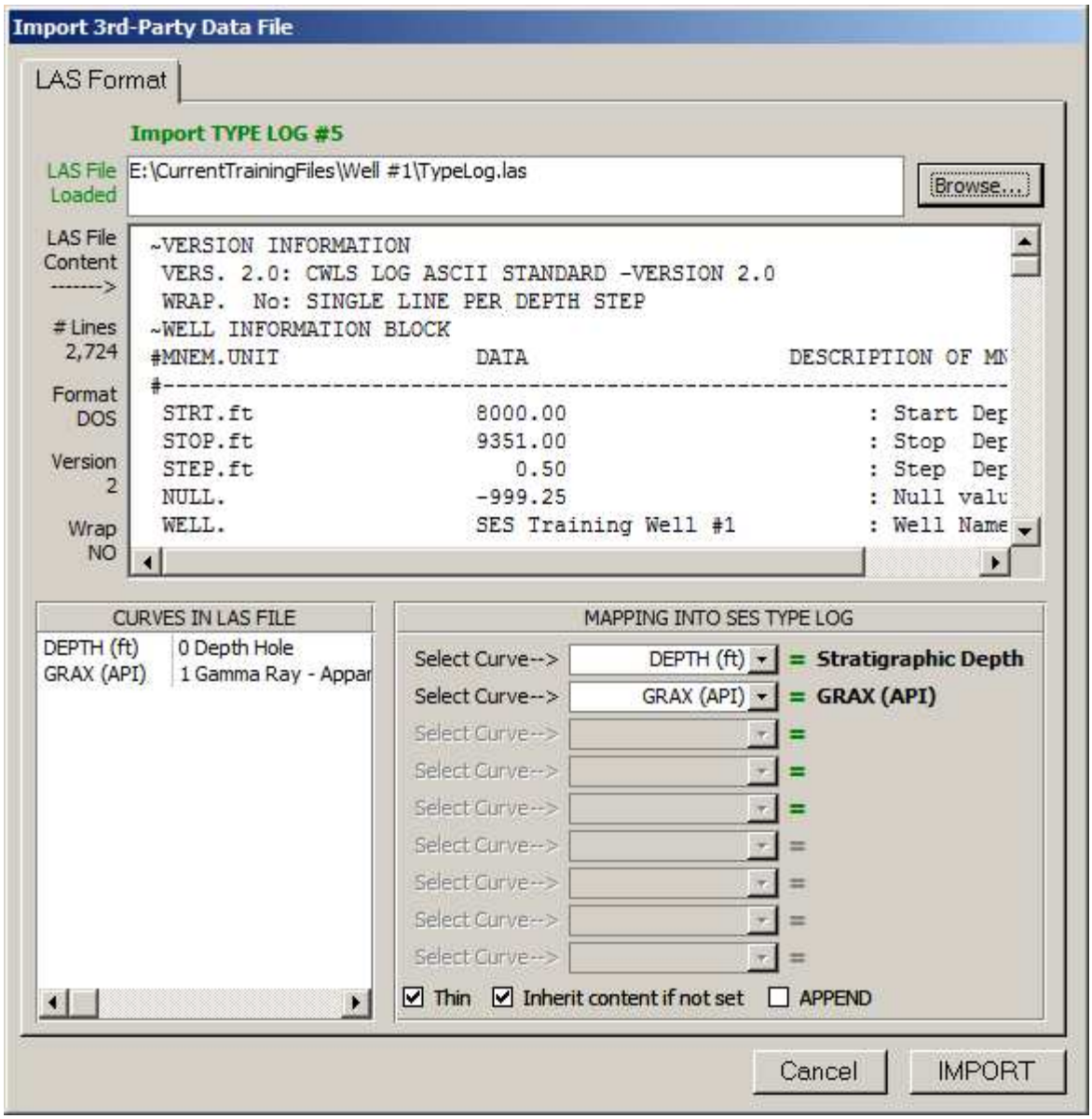


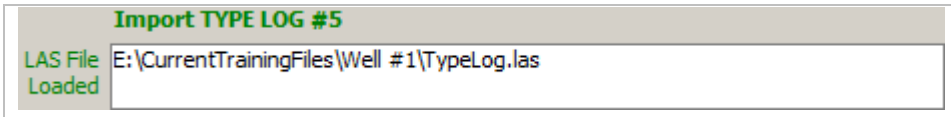
8.5 Import Type Log Data from LAS File

Original (i.e., non-derived) Type Log datasets usually source from a logged vertical pilot hole, a logged vertical offset wellbore, or a logged offset directional wellbore. The data are often contained in an LAS file so SES Type Log data are usually imported using the LAS file importer.

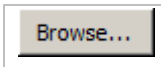
On occasion an error message may be displayed when opening an LAS file for import, or while SES tries to import the loaded data. In almost all such circumstances the error is caused by the LAS file not being compliant with LAS specifications. If possible SES will report the line/row number of the offending condition, which may help you or others resolve the issue through subsequent file editing. With the routines in SES having being honed for more than a decade, SES can overcome many LAS specification inaccuracies, but not all! When applicable the best resolution may be to contact the LAS file distributor for correction/re-creation.


"Import 3rd-Party Data File" dialog is used to browse and open an LAS file, designate the respective columns in the LAS file that match StratDepth and the necessary log correlation data curves for the selected SES Type Log dataset, and to import data.

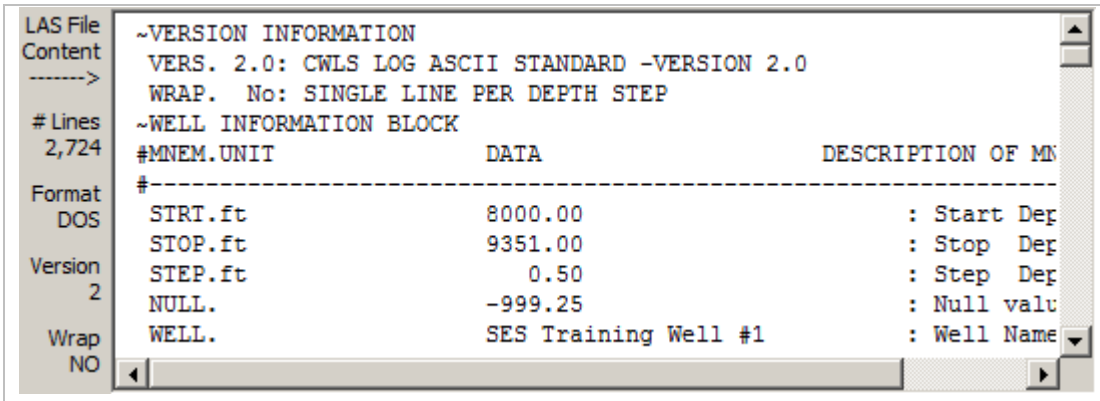




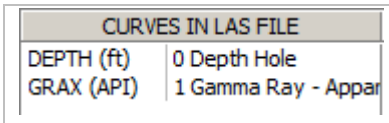
Enter the path and filename of the LAS file to load for processing; or, this text box displays the path and filename of the currently loaded LAS file as a result of using "Browse..." to specify such LAS file. The last LAS file from which Type Log data were imported is the attempted default LAS file loaded when "Import 3rd-Party Data File" dialog is opened.



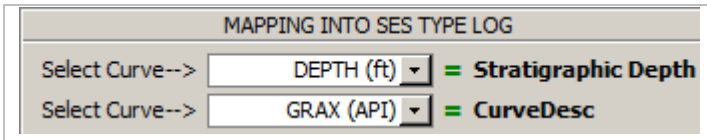
Click "Browse..." button to browse the computer's file system and select an LAS file to load for processing.



This textbox displays a full copy of the LAS file contents. Its content may be viewed using the scroll bars and ~ASCII data content may be edited and/or rows deleted for subsequent actual import into SES. The left border portion displays LAS file information including the number of lines of data in the file, the text file line terminator format (DOS or Unix), the CWLS LAS file version, and the file "wrap" status. SES will import both DOS and Unix LAS files, CWLS LAS file versions 2 and 3, and wrapped or non-wrapped formatted LAS files.

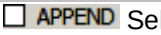


This textbox displays a listing of all data curves in the LAS file and the data curve descriptions if available.



Select the data curve that corresponds to the respective data content required by SES. For Type Log data import, SES requires Stratigraphic Depth (StratDepth), and at least one stratigraphic correlation curve (usually Gamma Ray). The total curve count is set in the header portion of Type Log screen before the dialog is opened. If the well data are from a "vertical" wellbore with "horizontal" beds, then StratDepth can be measured depth (MD). If the well data are from a directional wellbore with "horizontal" beds, then StratDepth can be true vertical depth (TVD). If the well data are from a directional wellbore with beds inclined at true dips exceeding roughly five degrees or if such data are from a "vertical" wellbore with beds inclined at true dips exceeding roughly ten degrees, some trigonometric corrections may need to be performed to "raw" MD or TVD before using such in SES as StratDepth.

Select/check "Thin" option if SES should not import depth stations/rows from the LAS file in situations where all imported curve data values are null/blank. This can be helpful when importing from LAS files that contain many curves of log data with depth stations containing null values for curve data of interest.



Select "APPEND" option if SES should only import depth stations/rows from the LAS file that are deeper than the deepest StratDepth already in the current Type Log dataset. This can be helpful when importing from LAS files that contain a different Type Log dataset than what is being populated within SES. For example, use Append mode to effectively splice the contents of two or more LAS files. Needing Append mode for Type Log data import is rare.

Click "Cancel" button to close the "Import 3rd-Party Data File" dialog without making any changes to the existing and currently selected Type Log dataset.

IMPORT Click "IMPORT" button to import the respective LAS file data content into the currently selected Type Log dataset. Unless "Append" option is checked, SES compares the numeric content of the LAS file with pre-existing numeric content in SES (if applicable) and if any differences are present the pre-existing content in SES is deleted and replaced with the LAS file content. After importing, the Type Log screen log track graph is updated. The user is reminded to set Payzone Top if applicable because RSD can not be calculated without Payzone Top being set. The last LAS file successfully imported becomes the default LAS file loaded when Type Log screen  is next clicked.

8.6 Critical

1.) PAYZONE TOP, which defines where Relative Stratigraphic Depth (RSD) equals zero, must be specified in the header portion of Type Log screen.

2.) PAYZONE TOP must exactly match a StratDepth value in the data table. The cell where RSD equals zero displays a green background. Each log curve value must be non-null at the Payzone Top StratDepth.

3.) SES assumes Type Log dataset and LWD dataset curves are consistent when they are selected for geosteering. For example, if gamma ray is being used to geosteer, setup curve 1 to contain gamma ray for both Type Log and LWD datasets. For another example, if both gamma ray and resistivity are being used to geosteer, setup curve 1 to contain gamma ray and curve 2 to contain resistivity, for both Type Log and LWD datasets.

4.) Exported SES XML files will be smaller if unnecessary Type Log data have been deleted from the respective dataset. For example, if 1000 to 7000 ft of Type Log data exist but the Payzone Top depth is located at 6800 ft, then consider deleting the unneeded data from 1000 to 6000 ft for smaller related files and faster ParamTuner performance.

5.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

8.7 Hot Keys

- Drag vertical window on graph to zoom; roll mouse wheel to then scroll
- With graph zoomed, double-click data point to graphically set Payzone Top depth
- Right-click graph to "Send Thicks & Zone Names to Marker Bed..."

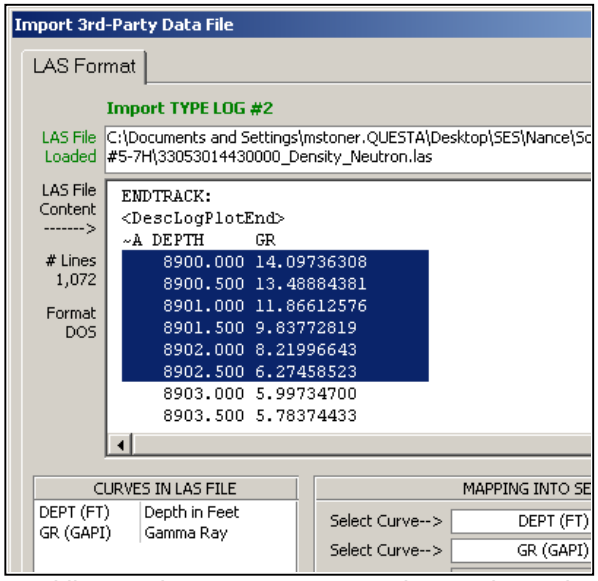
8.8 Tips

- ParamTuner is the interactive technical geosteering screen in SES where Type Log data are displayed with other data from the horizontal well being analyzed. Frequently, initial Type Log (e.g., gamma ray) data come from a vertical well in the vicinity of the horizontal well and the data are imported from an LAS file that contains data for the entire vertical well logged interval. In many cases the depth range spanned is far more than what is needed for technical geosteering and as a result the "shallow"/"deeper" data creates unneeded overhead through larger-than-necessary array sizes. ParamTuner performance may be enhanced if such non-needed data are deleted from SES or never imported in the first place. Three common different methods to address this concept are discussed below:

1. After importing the full Type Log dataset into Type Log screen of SES, use toolbar button  "delete unneeded Type Log data..." to open a dialog to easily remove unnecessary data.

2. After loading the full Type Log dataset into Type Log screen of SES, manually select and then delete the non-needed (e.g., shallow) depth data. In some cases clicking to a different Type Log # and then back—or selecting a different well and then returning—may be required to "clean-up" or otherwise refresh/repaint the screen.

3. If using the LAS file importer, non-needed rows of data can be selected and deleted from within the viewer window (see adjacent picture showing data selection just prior to pressing the delete key) prior to clicking IMPORT. This action will *not* affect the source LAS file data.



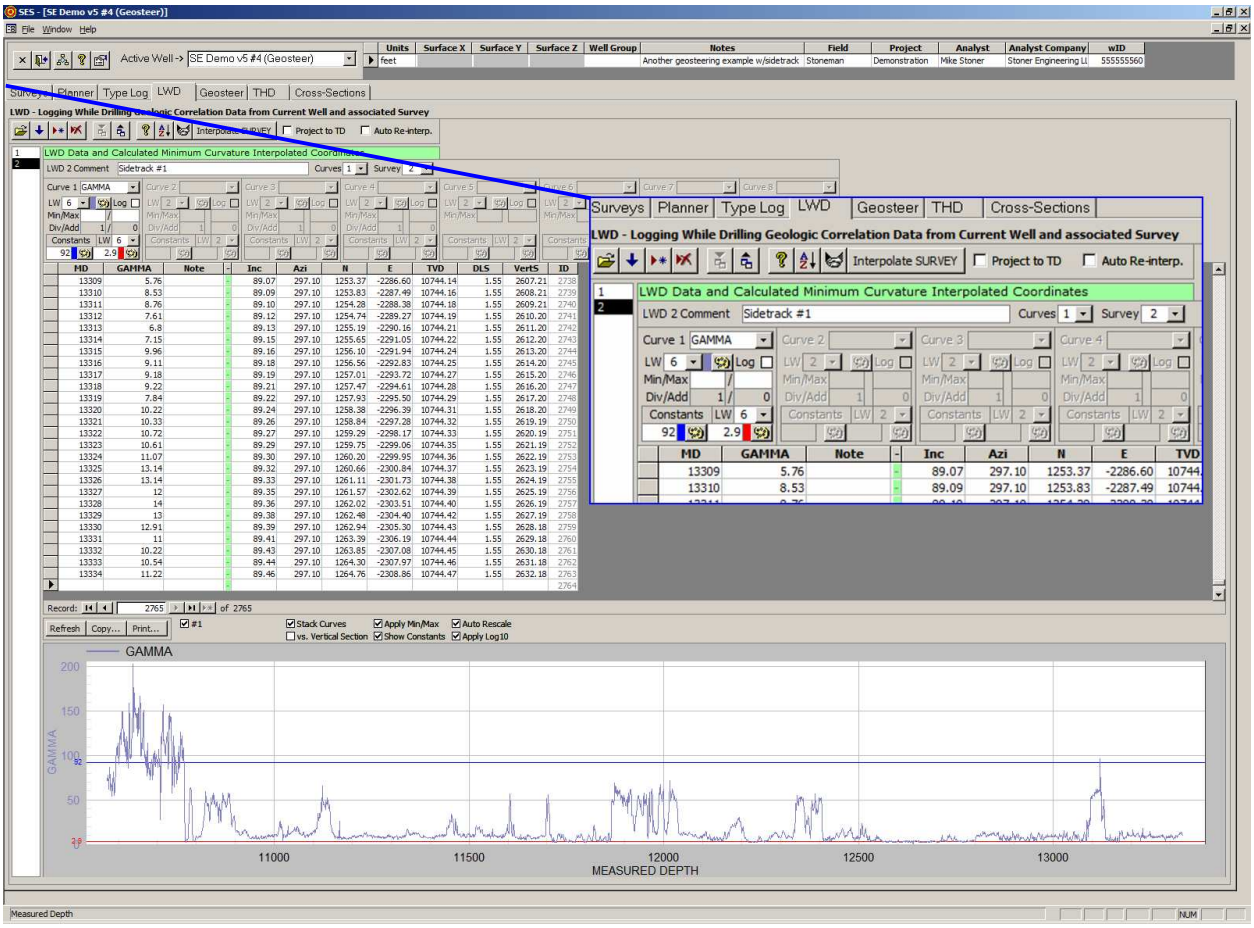
- Cross-sections in SES can include up to ten stacked beds above and five stacked beds below the primary payzone layer. Type Log screen is often helpful to determine what those offset beds thicknesses should be if the color/layer scheme also has some sort of direct stratigraphic reference. Entering a comment in the "Zone (@Top)" column at a particular depth will produce an annotated horizontal line on the Type Log screen log track graph. Moving the mouse cursor over the graph and observing the cursor tracking coordinates may further assist with determining desired stacked bed thicknesses for input on Geosteer screen (Tab View - Bed Thickness & Color tab). Alternatively, you may right-click the log track after setting-up horizontal line annotations to "Send Thicks & Zone Names to Marker Bed..." automatically.

- ParamTuner screen ( "camera" toolbar button) may be used to create a Type Log dataset, which is derived from select 3DSBs of an analyst's interpretation. If performed, the derived type log dataset will appear on Type Log screen with the next incremental Type Log datasets count number.

- One or more Type Logs may be used when geosteering. In some cases, during the landing for example, it makes sense to use multiple Type Logs to better understand thickness variations to expect. In other cases with plentiful nearby Type Logs, it may make sense to switch from generally honoring one Type Log for another, due to "current" relative proximity or for switching to a derived type log. The Type Log(s) in use at any given time may be set directly from ParamTuner screen ( "pick type log(s) to show..." button).

- One of the data organization "tricks" some people practice is to populate a Well with all of their area's Type Log datasets, already "marked-up" and named (using Type Log Comment) with a S-T-R type of location description, for easy subsequent retrieval. Recall, Type Log screen toolbar button  "Copy Type Log from Another Well" can be used to copy a Type Log dataset from one well in SESdata.mdb to the Active Well's selected Type Log dataset.

9. SES Screen – LWD



9.1 General

"Logging While Drilling" (LWD) data in SES are any quantitative MD-associated measurement available to help discern wellbore stratigraphic location, or, anything to be graphed on a cross section. Such data are often measured at uninformed MDs and between directional survey stations. SES uses minimum curvature interpolation to determine the 3D location of where such data were measured.

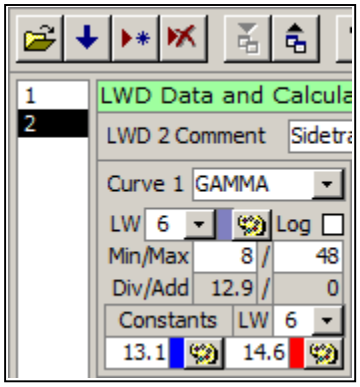
LWD screen can be used to:

1.) Input LWD data (e.g., gamma ray, high-side/low-side gamma ray, total gas, ROP, casing pressure, 8-sector azimuthal resistivity, etc.) by keypunch, by paste from Excel, by import from an LAS file, or by download/import from a WITSML server.

2.) Associate an LWD dataset to its corresponding wellbore (directional survey) from which its data were measured. Each LWD dataset may contain up to eight curves of information.

3.) Interpolate the associated directional survey at LWD MDs for Cartesian coordinates and wellbore angles, for use when performing technical geosteering.

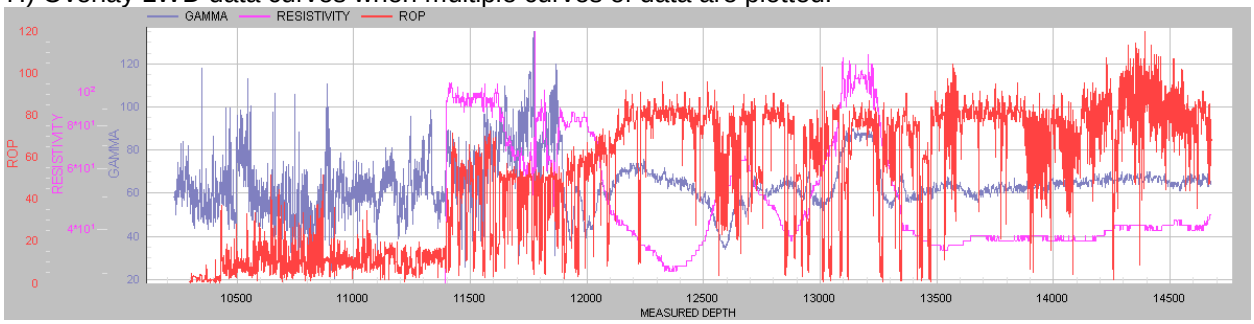
4.) Set each LWD curve's name, line width, color, linear|log scale format, override min, and override max; for graphing from LWD, ParamTuner, and Cross-Sections screens. Store "Adder" and "Divisor" values, for use with LWD and Type Log normalization/re-scaling when geosteering (normally set from ParamTuner).



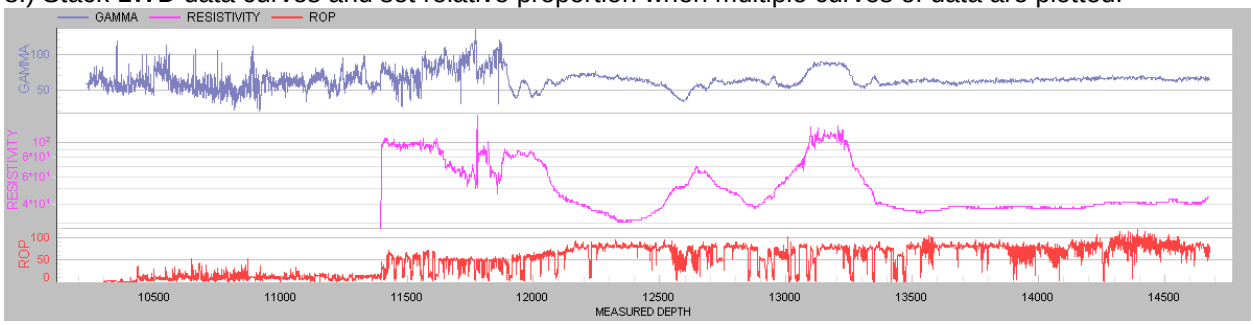
5.) Manage and view multiple LWD datasets from the current Well (e.g., datasets from multiple wellbores/sidetracks).

6.) Plot LWD curve data versus MD or vertical section, and set which curve(s) to display on the graph.

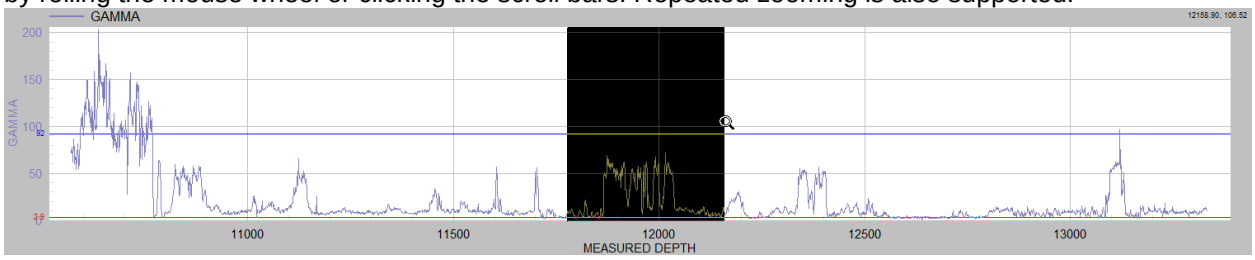
7.) Overlay LWD data curves when multiple curves of data are plotted.



8.) Stack LWD data curves and set relative proportion when multiple curves of data are plotted.



9.) Zoom a section of graph by dragging a horizontal window with the mouse within the graph; then pan by rolling the mouse wheel or clicking the scroll bars. Repeated zooming is also supported.



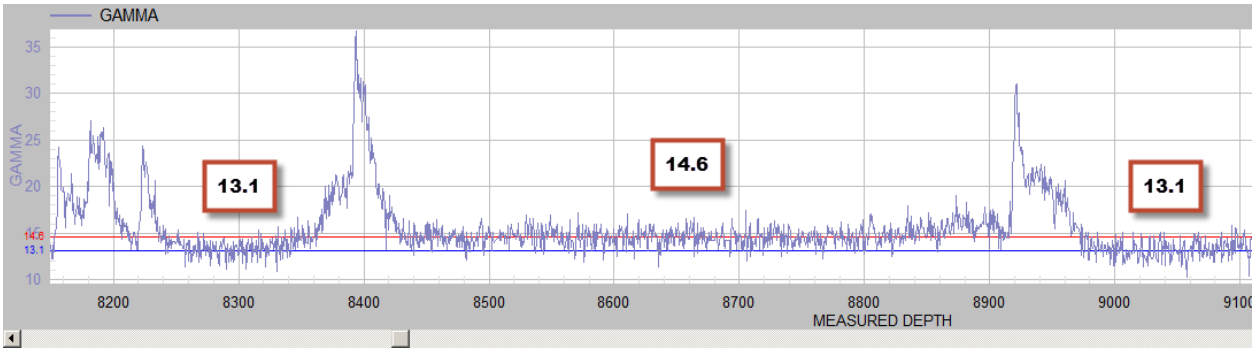
10.) Navigate to a data record in the data table by clicking a graph data point while the graph is zoomed.

11.) Print the graph on any system printer (including Adobe/PDF).

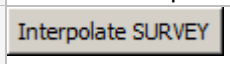
12.) Copy the graph for paste into another application.

13.) Temporarily change a variety of graph properties (including full-screen/maximize mode) by right-clicking over the graph and selecting from the shortcut menu.

14.) Set LWD curve constant values and their colors for selective display from LWD, ParamTuner, and Cross-Sections screens.



9.2 Toolbar

Control	Control Tip | Detailed Description
	import LWD data from LAS file... | Open "Import 3rd-Party Data File" dialog to browse and open an LAS file, designate the respective columns in the LAS file that match StratDepth/Curve1|Curve2|Curve3|Curve4|Curve5|Curve6|Curve7|Curve8, and import drilling data into the selected LWD. For more information see **9.4 Import LWD Data from LAS File**.
	import LWD data from WITSML server... | Open "Import 3rd-Party Data" dialog to download and then import LWD data from a WITSML server. For more information see **9.5 Import LWD Data from WITSML Server**, **4.2.4 Well Setup - WITSML**, and **2.4 WITSML Server**.
	add LWD | Add a new LWD dataset and select it. When clicked, the user is prompted to enter the LWD dataset number to copy. SES copies LWD header properties (number of curves, associated Survey number, curve names, curve color, etc.) from the existing source and initializes the new LWD dataset with such values.
	delete LWD | Delete the selected LWD dataset (and potentially renumber the remaining existing LWD datasets). LWD #1 may only be deleted if there are at least two LWD datasets before deleting LWD #1. LWD datasets are numbered starting at #1. To delete LWD #1 when there is only one LWD dataset, first Add a new LWD dataset and then select and delete LWD #1, after which empty LWD #2 will become LWD #1.
	N/A | LWD data may not be copied from another Well.
	export LWD data to LAS file... | Export the numeric LWD and interpolated survey data to an LAS file after setting the output path and filename. In addition to being CWLS LAS v3 compliant, LAS files generated by SES are also created to present the data content in both space delimited and fixed width text formats for greater versatility.
	LWD help | Display LWD screen abridged help.
	sort LWD data on MD & Renumber ID (occasionally needed) | Sort the selected LWD dataset on MD and re-determine the "ID" column values. "ID" is an SES internal index number. Because all new data must be added to the bottom of the data table, sometimes resorting is necessary to ensure MD increases as is needed by SES. Deleting one or more interior LWD records can also require sorting using this button.
	check LWD for possible problems | Check the selected LWD header and table data for conditions that are known or suspected to cause problems during or after the calculation of directional survey interpolation. This data quality check is applied each time a Survey is interpolated whether or not the SES user clicks this button. Sometimes called the "cat button", the icon is actually intended to represent two hands shaking. ☺
	 (F6) Interpolate Survey | Interpolate the associated Survey at LWD MDs and return minimum curvature calculated local coordinates Inc, Azi, N, E, TVD, DLS, and vertical

	section.
	Project to TD LINEARLY extrapolate SURVEY at LWD MDs greater than Survey TD (NOT RECOMMENDED IN BUILD SECTION) | It is common while drilling that LWD total depth (TD) is greater than the associated directional survey TD. By default, SES does NOT extrapolate the deepest directional survey station values in order to interpolate local coordinates etc. at LWD MDs that exceed current survey TD. Check "Project to TD" option to override the default SES behavior in order to be able to use all available LWD data to geosteer since its 3D measurement location is required in ParamTuner, however, the interpolated values that fall within the survey-extrapolated portion will change somewhat as additional directional survey data are eventually acquired. If non-negligible wellbore curvature is expected between current survey TD and bottom hole TD, and the SES user wants to use every available LWD measurement possible in ParamTuner, this option should not be checked but instead, estimated non-linear survey station data at bottom hole TD should be entered into Surveys screen as a best estimate of wellbore (survey) extrapolation to TD.
	Auto Re-interp. auto-update after key punch; leave un-checked if pasting data from clipboard | Set/check "Auto Re-interp." option if SES should immediately interpolate the survey after any LWD data records are changed or added. If LWD data are normally entered manually by key punch, this option may be helpful. This is an alternative to clicking Interpolate SURVEY or pressing F6 to re-interpolate the survey. ALWAYS leave "Auto Re-interp." option un-checked when pasting data from the clipboard!

9.3 Other Functions/Features

Curves 1 Select the maximum number of data curves the LWD dataset will contain.

Survey 1 Select the corresponding wellbore (directional survey) from which the LWD data were measured.

Curve 1 GAMMA For each data curve, enter its name as it's to be displayed in SES. Usually it's best to populate curve 1 with gamma ray. When geosteering in ParamTuner, SES assumes Type Log curve 1 corresponds to LWD curve 1. For example, if geosteering with two separate signals gamma ray and resistivity, Type Log curve 1 and LWD curve 1 should both contain gamma ray while Type Log curve 2 and LWD curve 2 should both contain resistivity.

LW 6 Log Select the data curve's line width, line color, and linear|Log10 scale preference. Line width is applied on Cross-Sections screen. The selected curve line color is applied on LWD, ParamTuner, and Cross-Sections screens.

Min/Max 0 / Enter the data curve's minimum and maximum override values, if desired. When these settings are left null or when "Apply Min/Max" is not checked, axes min/max values are determined automatically by the data within the respective view. Curve min/max values may be applied on LWD screen graph, selectively and saved by 3DStratBlock on three different graphs on ParamTuner, and on Cross-Sections screen cross sections.

NOTE: For 8-sector azimuthal data, Curve 1 Min/Max is applied to ALL curves when generating an image log on Cross-Sections screen.

Div/Add 1 / 0 "Adder" and "Divisor" values are used with LWD and Type Log normalization/re-scaling when geosteering and are typically set from ParamTuner ().

Constants LW 6
16 Enter up to two constant values per data curve to help "tag" certain data curve magnitudes that may assist to identify wellbore stratigraphic location. Select the constant value's line width and line color. Line width is applied on Cross-Sections screen. The selected line color is applied on LWD, ParamTuner, and Cross-Sections screens. The color palette is only enabled when a constant value number is entered.

	MD	GAMMA	Note	-	Inc	Azi	N	E	TVD	DLS	VertS	ID
	11561	157.87		-	91.17	14.60	2573.84	340.32	9149.55	0.75	2573.84	2919
	11562	187.77		-	91.17	14.60	2574.81	340.58	9149.53	0.75	2574.81	2920
	11563	208.36		-	91.18	14.60	2575.78	340.83	9149.51	0.75	2575.78	2921
	11564	231.95		-	91.19	14.60	2576.75	341.08	9149.49	0.75	2576.75	2922
	11565	250.22		-	91.20	14.60	2577.71	341.33	9149.47	0.75	2577.71	2923
	11566	261.82		-	91.20	14.60	2578.68	341.58	9149.45	0.75	2578.68	2924
	11567			-	91.21	14.60	2579.65	341.84	9149.43	0.75	2579.65	2925
▶	11568			-	91.22	14.60	2580.62	342.09	9149.40	0.75	2580.62	2926
*				-								2927

LWD data are entered along the left side of the LWD data table. All values to the right of the green separator column are calculated or determined by SES. User notes may be entered under the Note column on the respective row. These notes do not display elsewhere in SES. From the entered MD, SES determines the 3D location of the measurement by interpolating the associated directional survey. "ID" column values are determined by SES.

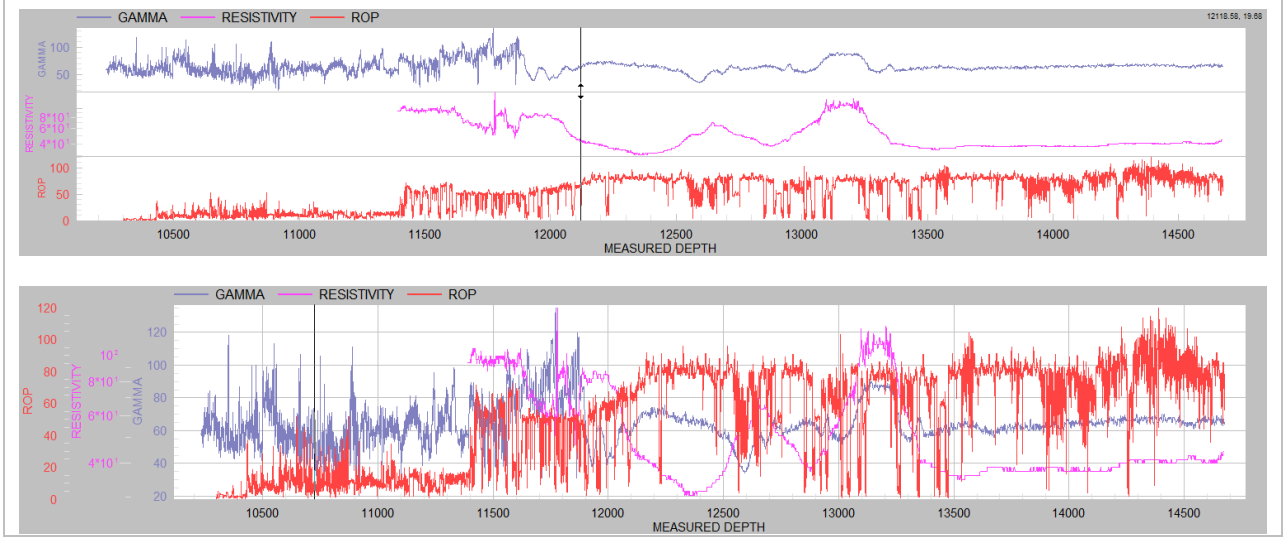
Refresh Redraw the LWD screen graph for the currently selected LWD. This request does not re-interpolate the directional survey but it does process any changes made regarding curve header properties, graph plotting options, and which LWD is currently selected.

Copy... Display a dialog that reminds how to **copy** a graph. To **copy** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (**clipboard**/file/printer), size, and resolution/dpi.

Print... Display a dialog that reminds how to **print** a graph. To **print** a graph double-click or right-click the respective graph and use the graph "Export..." feature. When exporting you may choose/set the image format (emf/wmf/bmp/jpg/png), destination (clipboard/file/**printer**), size, and resolution/dpi.

☑ #1 ☑ #3 ☑ #5 ☑ #7
☑ #2 ☑ #4 ☑ #6 ☑ #8 Check or uncheck the LWD data curve number to control which data curves display on the graph.

☑ Stack Curves Check "Stack Curves" option to display each curve on its own portion of graph (see top picture below). Relative portions may be adjusted. Uncheck this option to overlay all curves displayed on the graph (see bottom picture below).



☐ vs. Vertical Section Check "vs. Vertical Section" option to display LWD curve data versus vertical section instead of versus measured depth on the graph.

☑ Apply Min/Max Check "Apply Min/Max" option to override data driven auto scaling and instead fix the y-axis minimum and/or maximum value(s) with those entered in the header section of the LWD data curve.

☑ Show Constants Check "Show Constants" option to post a horizontal line at constant values entered in the header section of the LWD data curve. The horizontal line is also annotated with the constant value.

☑ Auto Rescale When the graph is zoomed by dragging a zoom window, data content can be scrolled by rolling the mouse wheel or by clicking the scroll bars. By default, the y-axis limits are adjusted automatically to the data in the current view. Uncheck "Auto Rescale" option to keep the y-axis limits constant.

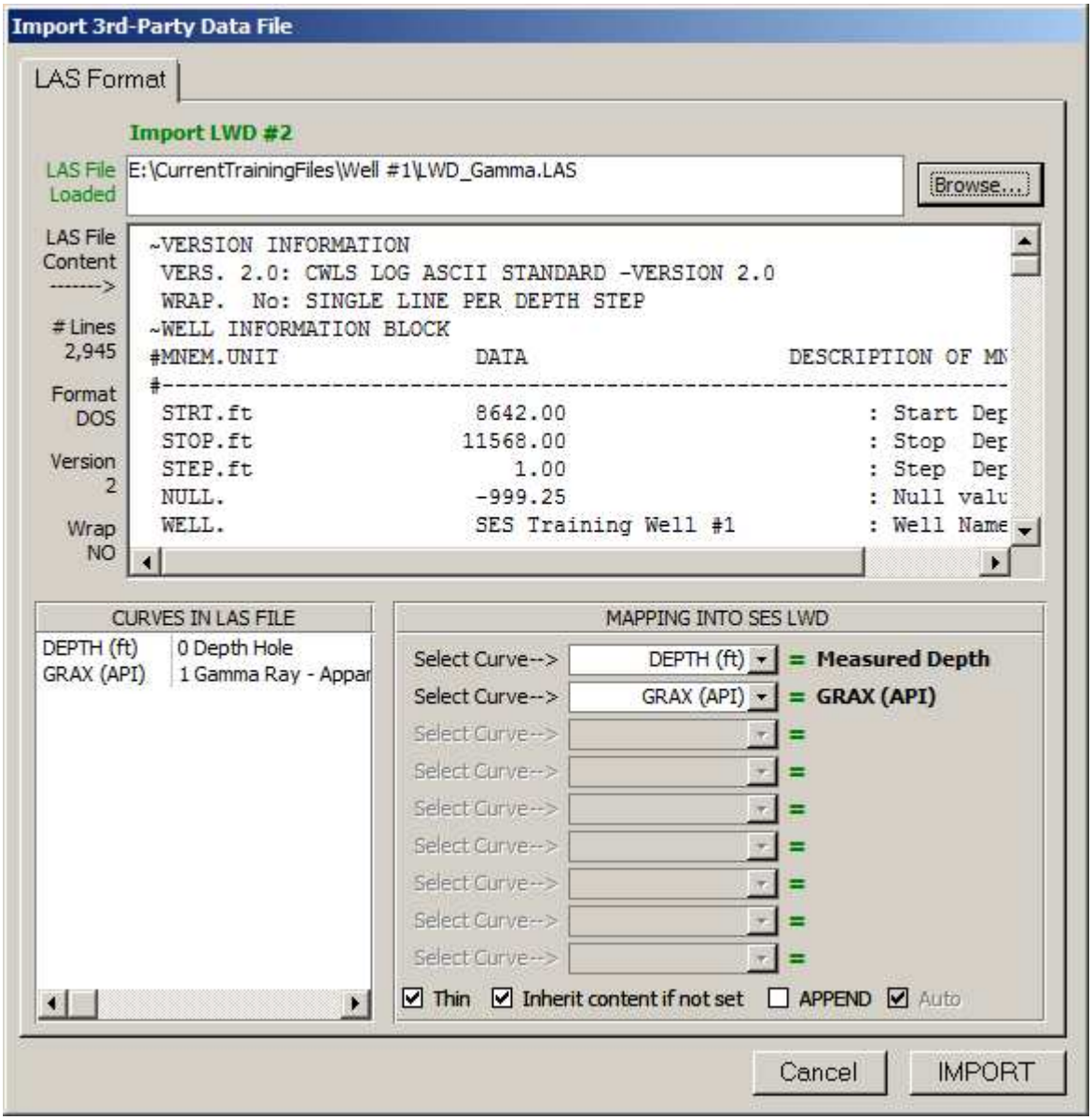
☑ Apply Log10 Check "Apply Log10" option to enforce a Log10 scale format if an LWD data curve has been configured in the header section to be Log10.

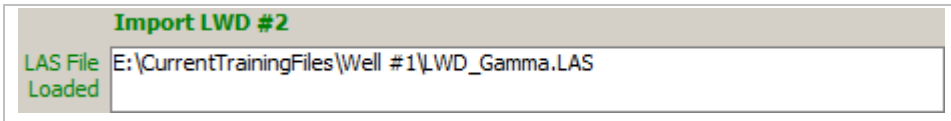
9.4 Import LWD Data from LAS File

It is very typical for wellsite LWD data to be transferred to SES via import from LAS files. This method of data transfer is efficient and usually better than spreadsheet copy/paste methods.

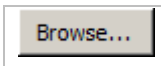
On occasion an error message may be displayed when opening an LAS file for import, or while SES tries to import the loaded data. In almost all such circumstances the error is caused by the LAS file not being compliant with LAS specifications. If possible SES will report the line/row number of the offending condition, which may help you or others resolve the issue through subsequent file editing. With the routines in SES having being honed for more than a decade, SES can overcome many LAS specification inaccuracies, but not all! When applicable the best resolution may be to contact the LAS file distributor for correction/re-creation.


"Import 3rd-Party Data File" dialog is used to browse and open an LAS file, designate the respective columns in the LAS file that match measured depth (MD) and the LWD data curves of interest, and import the LWD data into the selected SES LWD dataset.

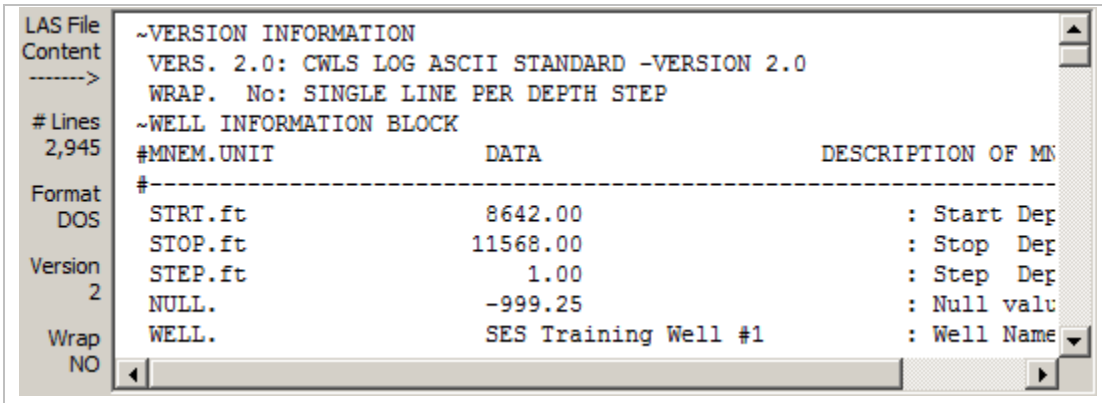




Enter the path and filename of the LAS file to load for processing; or, this text box displays the path and filename of the currently loaded LAS file as a result of using "Browse..." to specify such LAS file. The last LAS file from which LWD data were imported is the attempted default LAS file loaded when "Import 3rd-Party Data File" dialog is opened.

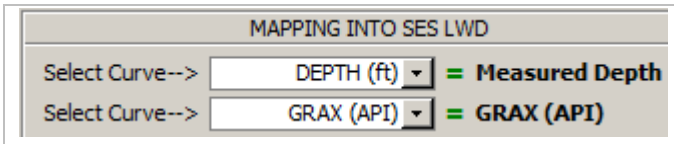


Click "Browse..." button to browse the computer's file system and select an LAS file to load for processing.

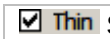


This textbox displays a full copy of the LAS file contents. Its content may be viewed using the scroll bars and ~ASCII data content may be edited and/or rows deleted for subsequent actual import into SES. The left border portion displays LAS file information including the number of lines of data in the file, the text file line terminator format (DOS or Unix), the CWLS LAS file version, and the file "wrap" status. SES will import both DOS and Unix LAS files, CWLS LAS file versions 2 and 3, and wrapped or non-wrapped formatted LAS files.

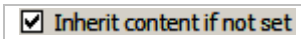
This textbox displays a listing of all data curves in the LAS file and the data curve descriptions if available.



Select the depth and data curves that correspond to the respective content desired for import. For LWD data import, SES requires measured depth (MD) and at least one data curve. The dropdown box listing is how the information is listed in the LAS file, while the name to the right of the "=" sign is how the SES user has setup the reference to the respective curve. The curve name in SES may be changed from LWD screen, regardless of how the curve is labeled in the LAS file.



Select/check "Thin" option if SES should not import depth stations/rows from the LAS file in situations where all data curves are null/blank. This can be helpful when importing from LAS files that contain much more data than the data content being imported.



Select "Inherit content if not set" option to name data curves in SES as they are referenced in the LAS file, if the data curve names have not been set in SES. This option also copies the LAS file name to the LWD comment if the comment is initially null/blank.

Select "APPEND" option if SES should only import depth stations/rows from the LAS file that are deeper than the deepest MD already in the current LWD dataset. This can be helpful when importing from LAS files that contain a different LWD dataset than what is being populated within SES. For example, use Append mode to effectively splice the contents of two or more LAS files. "Auto" makes the append process smarter by first looking at all curves and finding the first curve with a null/blank value in SES and that depth determines the starting append depth (helpful when curve data have different depth lags due to different relative sampling locations).

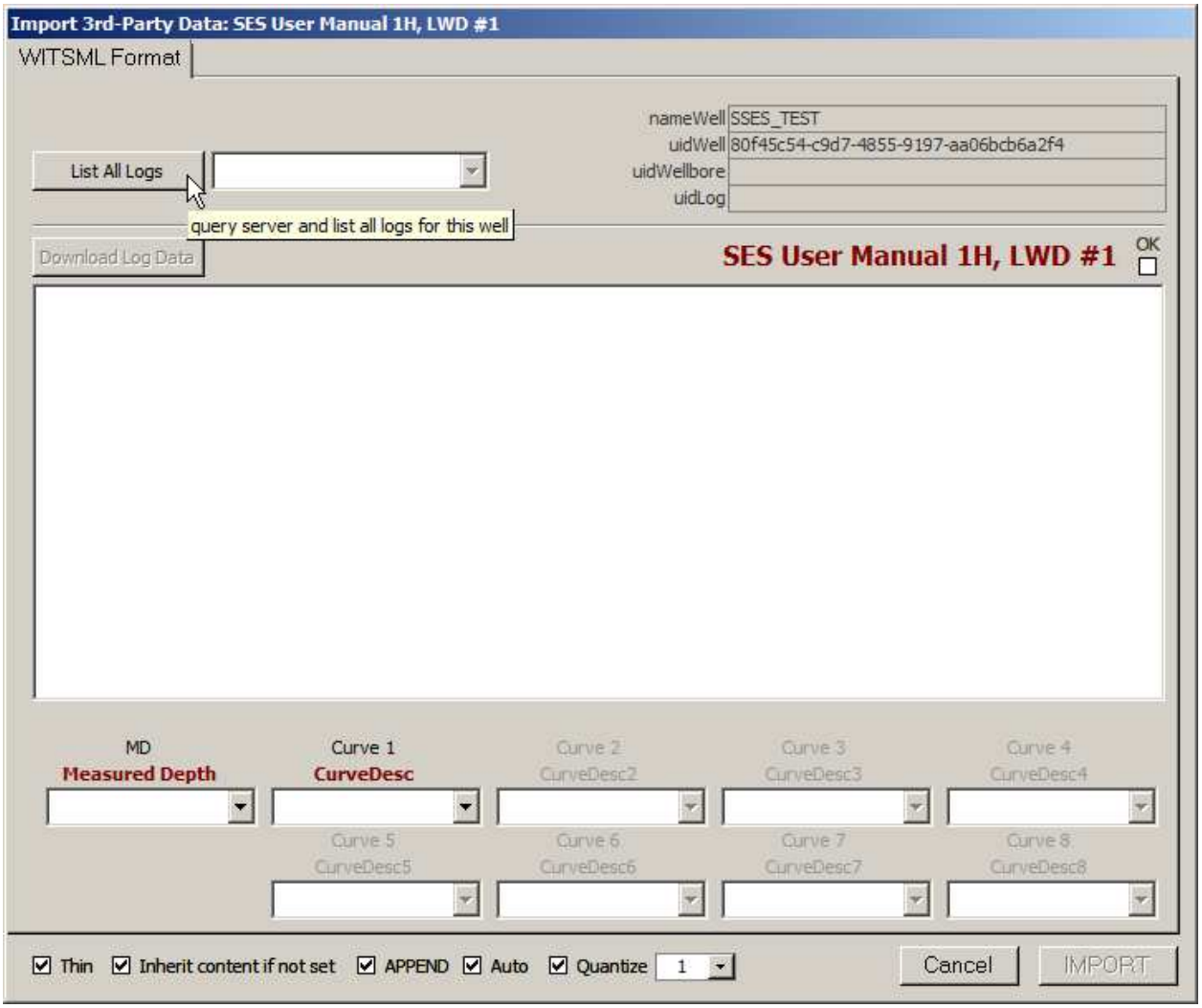
Click "Cancel" button to close the "Import 3rd-Party Data File" dialog without making any changes to the existing LWD dataset in SES.

IMPORT Click "IMPORT" button to import the respective LAS file content into the currently selected LWD dataset in SES. Unless "Append" option is checked, SES compares the content of the LAS file with pre-existing content in SES (when applicable) and if any differences are present the pre-existing content in SES is deleted and replaced with the LAS file content. After importing, the associated directional survey is automatically interpolated and the LWD screen table and graph are updated. The last LAS file successfully imported becomes the default LAS file loaded when LWD screen is next clicked. Thus, to update LWD data in this fashion after the dialog has been opened requires one click.

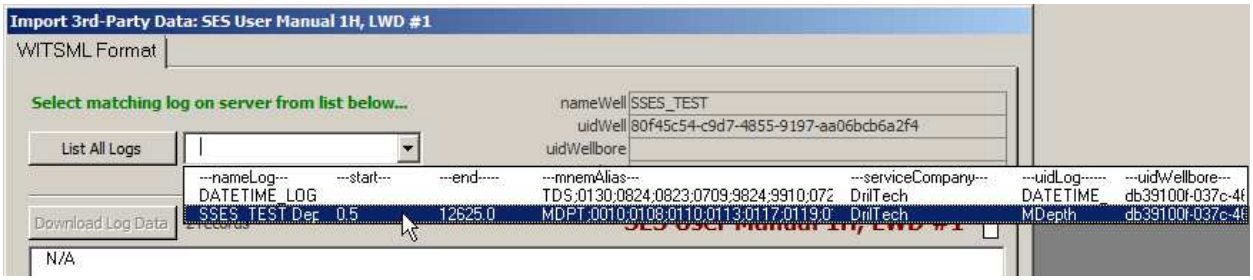
9.5 Import LWD Data from WITSML Server

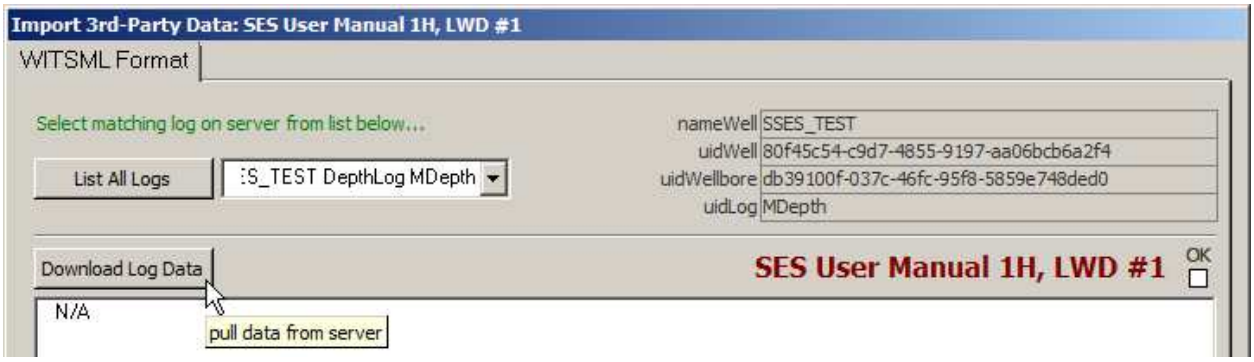
With WITSML server connectivity, data updates can be performed on-demand and usually take less total time because everything can be done without leaving SES (e.g., no time is spent opening and saving LAS files from emails!).

"Import 3rd-Party Data" dialog is used to download and then import LWD data from a WITSML server. The steps discussed in **2.4 WITSML Server** and **4.2.4 Well Setup - WITSML** must be complete before using this feature.

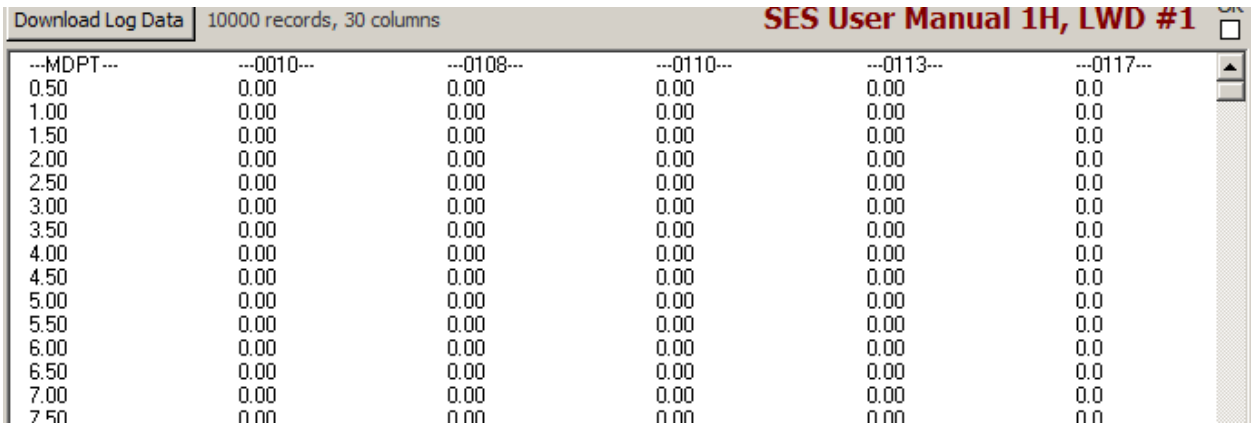


List All Logs Click "List All Logs" button to query the WITSML server for a list of available logs on the WITSML server for the current Well. After the list is returned, select the corresponding log that contains content for the current SES LWD. The WITSML server may only expose logs from one trajectory, even if the current Survey represents a wellbore sidetrack. If the log name/unique-ID has not changed since the last time LWD data were imported from the WITSML server, this step can be skipped. In the example below, log "SSES TEST DepthLog MDepth" is being selected for the first time.





Download Log Data Click "Download Log Data" button to download the log data content stored on the WITSML server and display it directly in the textbox below this button. In the example below, 10000 records and 30 columns of data were downloaded from the WITSML server, starting at MD = 0.5. Some WITSML servers restrict the number of records returned on any single data request and therefore sometimes it may take multiple requests to "chunk" the full dataset into SES (successive downloads to "catch-up" to TD). Also, some logs on WITSML servers may be raw and in need of being quantized (e.g., averaged to every 0.5 feet) and other logs on WITSML servers may already be quantized (as shown below).



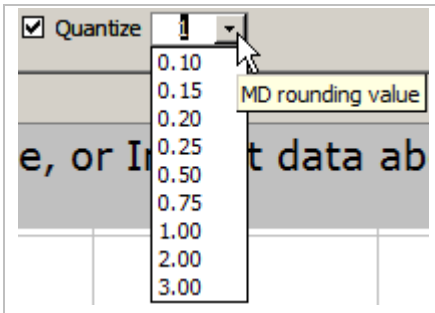
---MDPT---	---0010---	---0108---	---0110---	---0113---	---0117---
0.50	0.00	0.00	0.00	0.00	0.0
1.00	0.00	0.00	0.00	0.00	0.0
1.50	0.00	0.00	0.00	0.00	0.0
2.00	0.00	0.00	0.00	0.00	0.0
2.50	0.00	0.00	0.00	0.00	0.0
3.00	0.00	0.00	0.00	0.00	0.0
3.50	0.00	0.00	0.00	0.00	0.0
4.00	0.00	0.00	0.00	0.00	0.0
4.50	0.00	0.00	0.00	0.00	0.0
5.00	0.00	0.00	0.00	0.00	0.0
5.50	0.00	0.00	0.00	0.00	0.0
6.00	0.00	0.00	0.00	0.00	0.0
6.50	0.00	0.00	0.00	0.00	0.0
7.00	0.00	0.00	0.00	0.00	0.0
7.50	0.00	0.00	0.00	0.00	0.0

☑ Thin Select "Thin" option if SES should not import depth stations/rows from the WITSML-server-returned dataset in situations where selected data curve values are all null/blank. This feature is rarely applied due to how WITSML servers typically perform.

☑ Inherit content if not set Select "Inherit content if not set" option to name data curves in SES as they are referenced on the WITSML server, if the data curve names have not been set in SES. This option also copies the WITSML server log name to the LWD comment if the comment is initially null/blank.

☑ APPEND Select "APPEND" option if SES should only request/import depth stations/rows from the WITSML server that are deeper than the deepest MD already in the current LWD dataset. Using Append for LWD data import is very common because often times WITSML servers won't allow for a Well's entire LWD dataset to be downloaded with one request (too many records) and often there is variable depth lag with different log measurements.

☑ Auto Request from server and start appending after last MD with no null values in any curve. This is helpful when different curves have different depth lags. For example, if one measurement is acquired 25 feet from the drill bit and another measurement is acquired 50 feet from the drill bit, SES would request/import all data from the depth where the "50 feet from the drill bit" measurement was first null.



Select "Quantize" option to quantize/average the downloaded data upon import into SES. This feature is critically important if the WITSML server data are raw. By raw we mean high resolution samples in their as-recorded depth domain "un-averaged" state. For example, over the course of one minute while drilling there may be X samples of ROP and Y samples of gamma ray that were recorded in time and then cross-referenced to measured depth at their respective sampling times. To inspect a table of this raw data, some depths may have only ROP and some only gamma ray and normally there would be multiple measures of both over 1 foot. Quantizing is the process of averaging/binning raw LWD data to a common multiple of measured depth; 0.5 feet or 1.0 feet for example.

If the WITSML server data to which you have access are raw data, they should be quantized upon import into SES! For example, 5000 feet of drilled wellbore could easily have 200000 raw data records. Raw data for geologic/engineering analyses is overkill and would likely invoke errors due to LWD record count limitations in SES (~32000). Distributed LWD LAS files are almost always the end result of some system's quantizing/averaging/binning. Some WITSML server service companies are (finally) starting to store logs on the server that are identical to distributed LAS files, i.e., post-processed from raw datasets.

Cancel Click "Cancel" button to close "Import 3rd-Party Data" dialog and return to LWD screen. Any changes made are NOT saved.

IMPORT Click "IMPORT" button to quantize and import the downloaded data displayed on screen into the currently selected SES LWD and return to LWD screen. If "APPEND" option is unchecked, SES compares the content from the WITSML server with the pre-existing content in SES (when applicable) and if any differences are present the pre-existing content in SES is deleted and replaced with the

WITSML server data. After importing LWD data, the associated directional survey is automatically interpolated and the LWD screen graph is updated.

SES WITSML server data download parameters are Well and LWD number specific, which makes it even easier to manage data-updating for multiple wells. After LWD data have successfully been imported once from a WITSML server for a specific Well and LWD, the default parameters are restored when LWD screen  is next clicked. Thus, at this time, updating LWD data in this fashion after the dialog has been opened requires two clicks ("Download" and then "IMPORT").

9.6 Critical

1.) Each LWD dataset must be correctly associated to its corresponding directional survey in the header portion of LWD screen.

2.) If directional survey data (or Well units) are changed after importing or pasting LWD data, click "Interpolate SURVEY" or press F6 to refresh the survey interpolation at LWD MDs.

3.) Interpolating the survey only does so for the currently selected LWD dataset.

4.) Curve 1 min/max setting values govern all curves while generating an 8-sector azimuthal image log from Cross-Sections screen.

5.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

9.7 Hot Keys

- Drag horizontal window on graph to zoom
- With graph zoomed roll mouse wheel to scroll
- With graph zoomed click data point to move table cursor to corresponding data record
- F6 – same as clicking LWD toolbar button "Interpolate SURVEY"

9.8 Tips

- During live geosteering operations, a typical bottom-hole assembly configuration has (for example) the gamma ray measuring tool closer to the drill bit than the survey tool, and thus, gamma ray data will lead survey data. In order to use LWD data while geosteering with SES, the 3D spatial locations from where the LWD signals were measured are required. Therefore, in some cases, it might be necessary to first provide a directional survey station *estimate* (e.g., at current bottomhole TD) in order to fully use all available LWD data. Such estimate could be quite different during the landing than during the horizontal section, to account for significantly different/intentional anticipated build and or turn gradients. Consulting with the directional driller is recommended for non-linear angle estimations at TD. If minimal build gradient is anticipated as is often the case while drilling the lateral, LWD screen toolbar option "Project to TD" may be used.

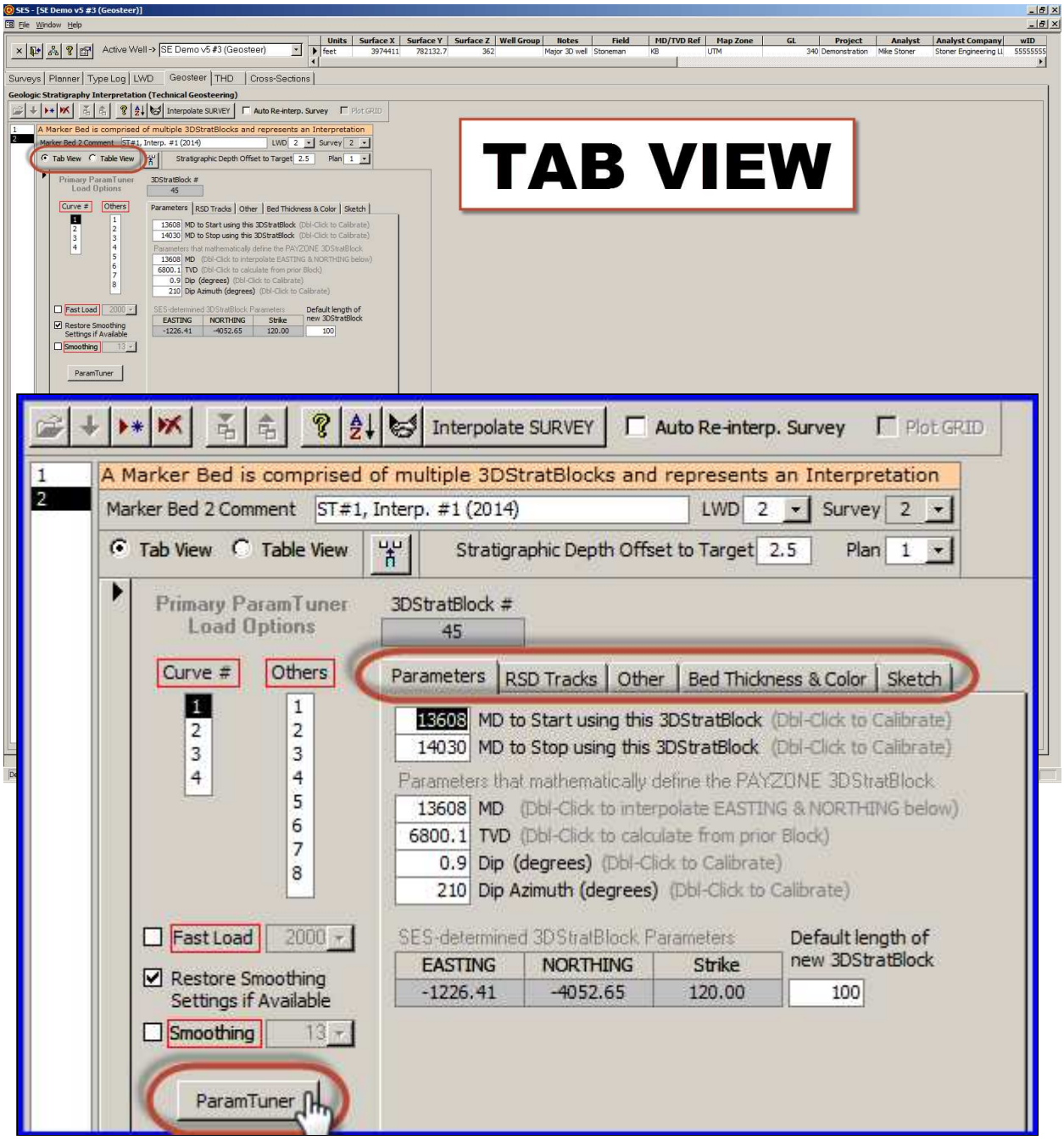
- LWD screen can be used to effectively create a Type Log dataset from a logged offset directional wellbore. Load the directional survey and LWD data and interpolate the directional survey from LWD screen. Then export the LWD dataset to an LAS file, for subsequent import from Type Log

screen for the respective well to be analyzed. Use TVD for StratDepth, assuming low regional true bed dip (<5°). For larger true dips an additional trigonometric correction may be necessary.

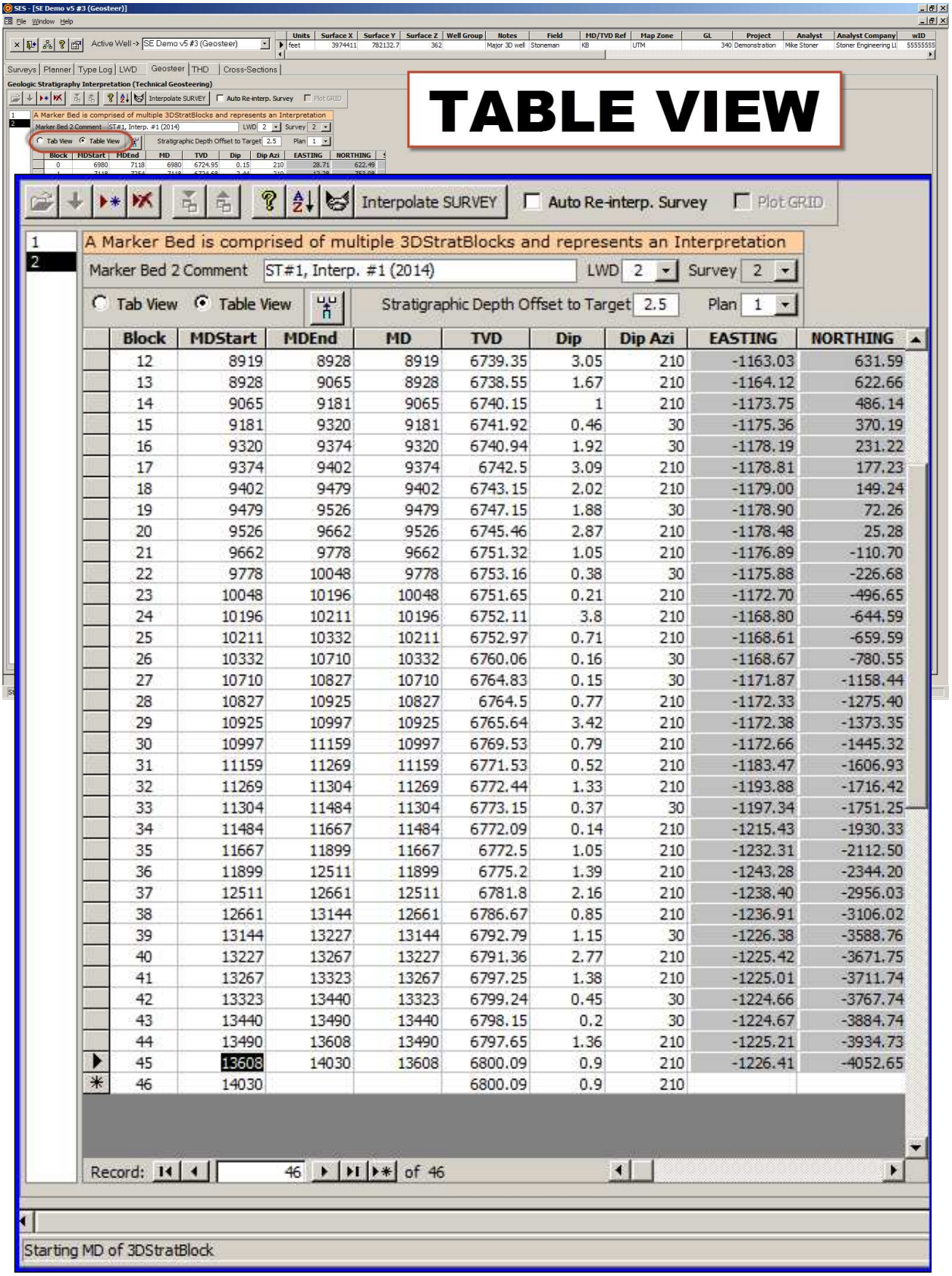
- Navigating to data in order to "clean" erroneous LWD data is easy. Click and drag a window near the suspect data to "zoom" and then click a data point and the table selection will automatically move to the clicked data point. Manual data editing may then commence, including making data values null/blank. An alternative method to manage suspect/extreme/bogus data is to enter curve minimum and maximum override values for select application on ParamTuner and Cross-sections screens.

- Curve 1 minimum and maximum values are special for 8-sector azimuthal LWD data. Curve 1 min/max values govern all curves while generating an image log from Cross-Sections screen when Apply Min/Max is checked.

10. SES Screen – GEOSTEER



SES Screen – GEOSTEER (continued)



Block	MDStart	MDEnd	MD	TVD	Dip	Dip Azi	EASTING	NORTHING
12	8919	8928	8919	6739.35	3.05	210	-1163.03	631.59
13	8928	9065	8928	6738.55	1.67	210	-1164.12	622.66
14	9065	9181	9065	6740.15	1	210	-1173.75	486.14
15	9181	9320	9181	6741.92	0.46	30	-1175.36	370.19
16	9320	9374	9320	6740.94	1.92	30	-1178.19	231.22
17	9374	9402	9374	6742.5	3.09	210	-1178.81	177.23
18	9402	9479	9402	6743.15	2.02	210	-1179.00	149.24
19	9479	9526	9479	6747.15	1.88	30	-1178.90	72.26
20	9526	9662	9526	6745.46	2.87	210	-1178.48	25.28
21	9662	9778	9662	6751.32	1.05	210	-1176.89	-110.70
22	9778	10048	9778	6753.16	0.38	30	-1175.88	-226.68
23	10048	10196	10048	6751.65	0.21	210	-1172.70	-496.65
24	10196	10211	10196	6752.11	3.8	210	-1168.80	-644.59
25	10211	10332	10211	6752.97	0.71	210	-1168.61	-659.59
26	10332	10710	10332	6760.06	0.16	30	-1168.67	-780.55
27	10710	10827	10710	6764.83	0.15	30	-1171.87	-1158.44
28	10827	10925	10827	6764.5	0.77	210	-1172.33	-1275.40
29	10925	10997	10925	6765.64	3.42	210	-1172.38	-1373.35
30	10997	11159	10997	6769.53	0.79	210	-1172.66	-1445.32
31	11159	11269	11159	6771.53	0.52	210	-1183.47	-1606.93
32	11269	11304	11269	6772.44	1.33	210	-1193.88	-1716.42
33	11304	11484	11304	6773.15	0.37	30	-1197.34	-1751.25
34	11484	11667	11484	6772.09	0.14	210	-1215.43	-1930.33
35	11667	11899	11667	6772.5	1.05	210	-1232.31	-2112.50
36	11899	12511	11899	6775.2	1.39	210	-1243.28	-2344.20
37	12511	12661	12511	6781.8	2.16	210	-1238.40	-2956.03
38	12661	13144	12661	6786.67	0.85	210	-1236.91	-3106.02
39	13144	13227	13144	6792.79	1.15	30	-1226.38	-3588.76
40	13227	13267	13227	6791.36	2.77	210	-1225.42	-3671.75
41	13267	13323	13267	6797.25	1.38	210	-1225.01	-3711.74
42	13323	13440	13323	6799.24	0.45	30	-1224.66	-3767.74
43	13440	13490	13440	6798.15	0.2	30	-1224.67	-3884.74
44	13490	13608	13490	6797.65	1.36	210	-1225.21	-3934.73
45	13608	14030	13608	6800.09	0.9	210	-1226.41	-4052.65
46	14030			6800.09	0.9	210		

10.1 General

A 3DStratBlock (3DSB) is a planar surface that defines a geologic marker (normally the payzone top) over a MD range of associated wellbore, above which and below which multiple layers may be stacked for visualization. A "Marker Bed" dataset is a collection of 3DSBs that defines one geologic interpretation of strata. SES technical geosteering involves determining 3DSB MD extent and orientation such that LWD data are acceptably mapped onto a type log using Relative Stratigraphic Depth (RSD) mapping transformation. RSD is the minimum 3D distance to a 3DSB from the wellbore measurement location and then also RSD is given in the form of a type log and thus calibration resolves the differences.

GEOSTEER screen can be used to:

1.) Select the LWD dataset to geosteer using ParamTuner. ParamTuner is the screen used to visually calibrate/tune 3DStratBlock (3DSB) parameters of 3DSBs of the selected Marker Bed...THIS IS GEOSTEERING!

2.) Manage and navigate multiple Marker Bed datasets of the current well (multiple interpretations; multiple wellbores/sidetracks).

3.) Designate the stratigraphic depth offset to target, i.e., the stratigraphic depth difference between RSD=0 (payzone top) and the target line within the payzone layer.

4.) Designate a well plan that optionally may be displayed in ParamTuner if THD has been calculated.

5.) Set which Type Log and LWD curve to load into the RSD domain on the two left RSD tracks in ParamTuner (curve 1 is most common). Up to 8 LWD curves may also be graphed.

6.) View/edit/enter individual 3DSB parameter values and display them in Tab or Table display format.

7.) Interpolate the associated directional survey at 3DSB control point MDs to set respective control point Northing and Easting coordinate values.

8.) Set the name/thickness/color of the primary ("payzone") layer and same for offset layers--up to 10 above and 5 below--for outer/left RSD track display in ParamTuner and for full-well cross section generation using Cross-Sections screen. See Tab View, Bed Thickness & Color tab.

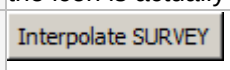
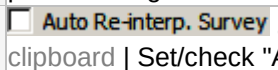
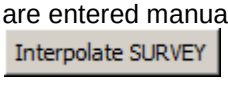
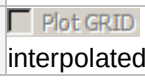
9.) Import/copy layer thicknesses/colors/names from any Marker Bed in SES Database to the current Marker Bed. See Tab View, Bed Thickness & Color tab.

10.) Set the default length of new 3DSBs for when a new 3DSB is appended from ParamTuner.

11.) Set ParamTuner to operate in "Fast Load" mode, where user set depth-range of 3DSB/LWD data relative to the active 3DSB MD are loaded instead of all such data (on occasion, helpful for interpretations with many 3DSBs and very long laterals).

12.) Let SES try to guess the parameters of the first 3DSB (#0) of a brand new interpretation, in order to load ParamTuner for initial/first-3DSB calibration (simply click "ParamTuner" for a Marker Bed with no 3DSBs yet defined).

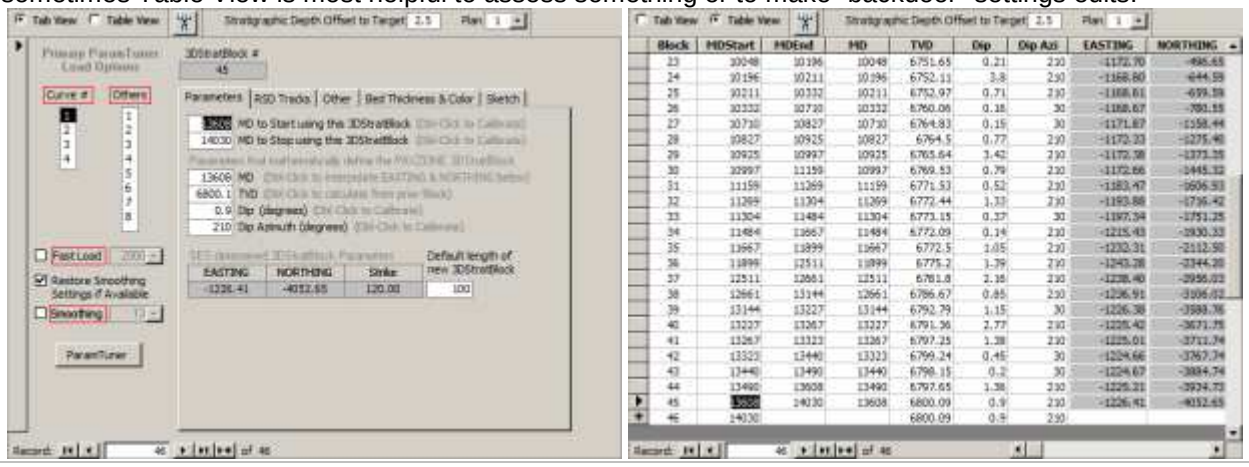
10.2 Toolbar 

Control	Control Tip | Detailed Description
	N/A | Marker Bed datasets may not be directly imported from a file.
	N/A | Marker Bed datasets may not be downloaded/imported from a WITSML server.
	add Marker Bed | Add a new Marker Bed dataset and select it. When clicked, the user is asked whether to copy 3DSBs from an existing Marker Bed (interpretation) or to start from scratch. In either case, SES copies Marker Bed header properties from the respective source (or default) and initializes the new Marker Bed dataset with such values.
	delete Marker Bed | Delete the selected Marker Bed dataset (and potentially renumber the remaining existing Marker Bed datasets). Marker Bed #1 may only be deleted if there are at least two Marker Bed datasets before deleting Marker Bed #1. Marker Bed datasets are numbered starting at #1. To delete Marker Bed #1 when there is only one Marker Bed dataset, first Add a new Marker Bed dataset and then select and delete Marker Bed #1, after which empty Marker Bed #2 will become Marker Bed #1.
	N/A | Marker Bed datasets may not automatically be copied from another Well. However, they may manually be copy/pasted from Table View. Please note 3DSB control point MDs must be within the MD range of associated LWD data!
	N/A | Marker Bed datasets may not be exported to an LAS file.
	GEOSTEER help | Display Geosteer screen abridged help.
	sort on Starting MD & Renumber 3DStratBlock# (occasionally needed) | Sort the selected Marker Bed dataset on MDStart and re-determine the 3DStratBlock numbers. This command is normally not needed but may become needed if manual edits/deletions to 3DSBs have been made or if complicated overlapping 3DSBs have inadvertently been created in ParamTuner.
	check Marker Bed for possible problems | Check the selected Marker Bed header and table data for conditions that are known or suspected to cause problems during or after the calculation of directional survey interpolation. This data quality check is applied each time a Survey is interpolated whether or not the SES user clicks this button. Sometimes called the "cat button", the icon is actually intended to represent two hands shaking. ☺
	 (F6) Interpolate each 3DStratBlock MD to get EASTING and NORTHING parameters | Interpolate the associated Survey at 3DSB control point MDs and return control point Easting and Northing coordinate values.
	 auto-update after key punch; leave un-checked if pasting data from clipboard | Set/check "Auto Re-interp. Survey" option if SES should immediately interpolate the survey after any 3DSB data records are changed or added. If 3DSB data are entered manually by key punch, this option may be helpful. This is an alternative to clicking  or pressing F6 to re-interpolate the survey. ALWAYS leave "Auto Re-interp. Survey" option un-checked when pasting data from the clipboard!
	 N/A | Displaying Grid surfaces in ParamTuner is not yet supported. Grid data may be interpolated and displayed from Surveys, Planner, and Cross-Sections screens.

10.3 Other Functions/Features

LWD 1 Survey 1 Select the corresponding LWD dataset with which to geosteer in ParamTuner. SES will automatically set/inherit the LWD dataset's corresponding wellbore (directional survey) from which the LWD data were measured.

Tab View Table View Select the preferred display format to view/edit/enter 3DStratBlock (3DSB) parameter values of the selected Marker Bed. Some settings are only displayed in Tab View and sometimes Table View is most helpful to assess something or to make "backdoor" settings edits.

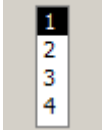


Search the 3DSBs of the selected Marker Bed for MD interpretation gaps and if any such gaps are found then create new 3DSBs to fill the gaps and renumber existing 3DSBs as needed. This command is rarely needed from Geosteer screen, as a more sophisticated version of this functionality is available from ParamTuner.

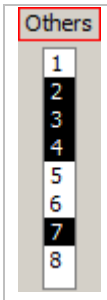
Stratigraphic Depth Offset to Target 6 Enter the stratigraphic depth difference between where RSD=0 (payzone top) and the target line (typically) within the payzone layer. A positive value is deeper and a negative value is shallower. The target line displays in ParamTuner on both RSD tracks and on the structural cross section between the payzone top and payzone base. The target line is used to define the target when Technical Hole Deviation (THD) is calculated with planned TVD/Dip being set by a Marker Bed. The target line is displayed on Cross-Sections screen cross sections and can be colored differently than the payzone layer color.

Plan 1 Select the well plan to optionally be displayed in ParamTuner. To display a well plan in the MD domain (e.g., in ParamTuner or from Cross-Sections screen using MD mode), Technical Hole Deviation (THD) must first be calculated (see **12. SES Screen – THD**).

Curve #

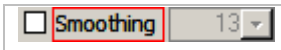


Select the data curve to process in the Relative Stratigraphic Depth (RSD) domain. In other words, set which Type Log & LWD curve to load on the RSD tracks in ParamTuner. Curve 1 is most common but in some situations (e.g., where both gamma ray AND resistivity are being measured downhole) something other than curve 1 may be applicable for processing. SES assumes that the Type Log curve and the LWD curve are synchronized/comparable. For example, in most cases Type Log and LWD curve 1 should contain average gamma ray data values.



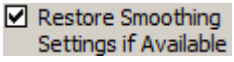
Select any "other" LWD curves to be graphed in ParamTuner on the track beneath the structural cross section. Up to 8 data curves may be displayed, and multi-select is supported as shown.

Check "Fast Load" option to process a subset of LWD data when ParamTuner is loaded. The selected/entered corresponding depth amount is the total feet/meters of data from the active 3DSB loaded in ParamTuner. This feature may be helpful when analyzing very long laterals and/or Marker Beds with many 3DSBs. ParamTuner load time is normally reduced when this option is checked but less data are available for viewing/processing, which may be beneficial depending on specific matters.

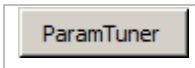


SES supports on-the-fly LWD data smoothing from ParamTuner. Usually, data smoothing should NOT be applied in the build section of a horizontal well; only in the lateral section. Smoothing can be extremely helpful to reduce noisy LWD data where signal variation may originate from a variety of sources (e.g., geologic setting, tool issues within the geologic setting, tool placement such as near-bit within the BHA, etc.). The LWD data smoothing option is typically enabled from ParamTuner and includes a window size. Data smoothing is a central moving average window with a user-set window size. The window size is an odd number and is centralized about the respective data point. A window size of 3 is the least amount of smoothing possible, as it averages the current data point and one data point to the left and one from the right. A large window size will create more smoothing/averaging. When a 3DSB is saved, the LWD curve smoothing state and window size is saved, and the setting is both curve-specific and 3DSB-specific.

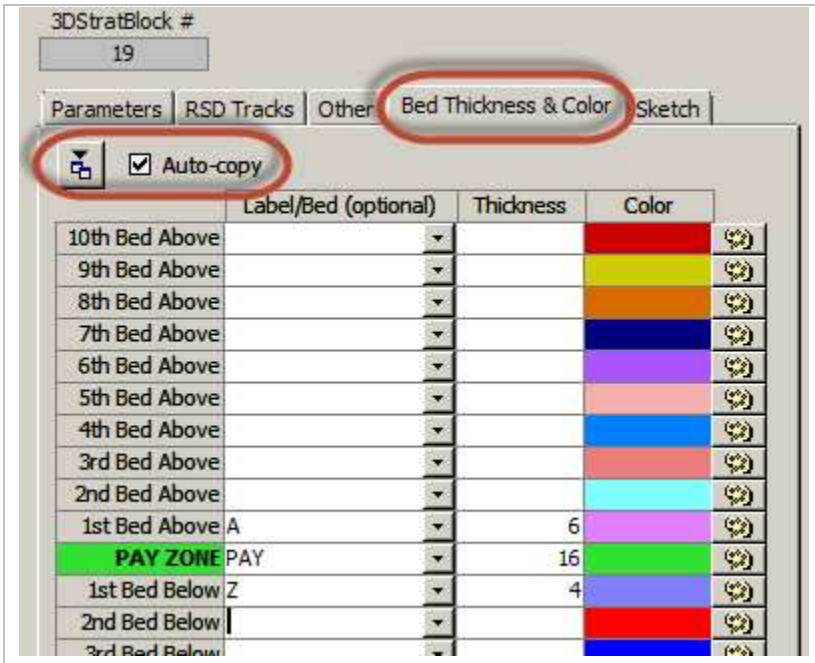
When smoothing is enabled, LWD data are smoothed on both RSD tracks and Type Log data are unchanged. On the LWD graph below the structural cross section on ParamTuner, SES displays both the smoothed data and the "raw" unsmoothed LWD data behind it.



"Restore Smoothing Settings if Available" is an SES custom user setting, saved on the user's computer only. If this option is checked, SES applies the 3DSB-saved settings upon 3DSB loading/review. If this setting is unchecked, then smoothing settings are overridden with the current user's smoothing setting and window size (shown above) on Geosteer screen. Where this feature may have purpose is when user "B" is inspecting user "A's" analysis in ParamTuner but user "B" doesn't prefer the smoothing options originally set/not-set/saved by user "A". The smoothing settings in force when a 3DSB is saved governs what is saved in SES Database for the Well/Marker Bed/3DSB.

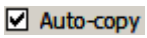


Click "ParamTuner" button to make ParamTuner the top window and refresh it with any respective data changes and make the currently selected 3DSB (if one exists) ACTIVE. If no 3DSB currently exists for the selected Marker Bed, SES will ask the user if SES should attempt to initialize the first 3DSB (#0) by looking at the various respective datasets and then load ParamTuner accordingly so 3DSB #0 may be appropriately calibrated. SES will not automatically create 3DSB #0 until certain thresholds are recognized in the datasets (e.g., a certain wellbore inclination magnitude needs reached). The alternative to SES automatically creating 3DSB #0 is to manually enter 3DSB parameter values into Geosteer screen (Tab or Table View) so that one 3DSB/record exists, after which ParamTuner may be loaded and then calibrated appropriately. The easiest way to load a particular 3DSB in ParamTuner from Table View is to double-click inside the respective row's Block cell.



The "payzone" layer is represented in ParamTuner as a 3DStratBlock (3DSB). Its thickness and orientation is set from ParamTuner. Offset layers for presentation purposes may be "stacked" above (up to ten) and below (up to five) the payzone layer. The offset layers may be named and colored as desired. Offset layers display on the outer/left RSD track in ParamTuner as a labeled horizontal line annotation. Offset layers are fully displayed on Cross-Sections screen cross sections. Geosteer screen, Tab View, Bed Thickness & Color tab is where offset layer settings are entered.

 Click this button to load a dialog to copy offset bed thicknesses/names/colors from any well in SES Database. At least one 3DSB must exist before using this command. It is common for a consistent layers color scheme to develop in a given drilling play.

 Check "Auto-copy" option to apply a thickness/name/color edit to the current 3DSB to all 3DSBs in the current Marker Bed. Uncheck this option for selective single-3DSB editing, such as to create variable thickness of offset layers across the lateral *after* originally saving 3DSBs.

Bed Thicknesses and names can be set from Table View but colors must be set using the respective color palette button from Tab View.

10.4 Critical

1.) SES assumes the selected "Curve #" is comparable/synchronized for Type Log and LWD datasets. For example, if geosteering with gamma ray, ensure Type Log curve 1 and LWD curve 1 both contain gamma ray.

2.) From Geosteer screen, Tab View, click "ParamTuner" with a blank/empty interpretation and SES will try to initialize 3DStratBlock #0 in order to get started geosteering with ParamTuner.

3.) It is recommended practice that a 3DStratBlock's control point MD and MDStart are equal. The control point MD must fall within the portion of LWD MD range for which there are known Survey data.

4.) A 3DStratBlock's control point appears on the TVD vs. MD plot in ParamTuner as a black dot symbol and LWD curve data that fall within the current/active 3DStratBlock MD start/end range are colored **magenta**.

5.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

10.5 Hot Keys

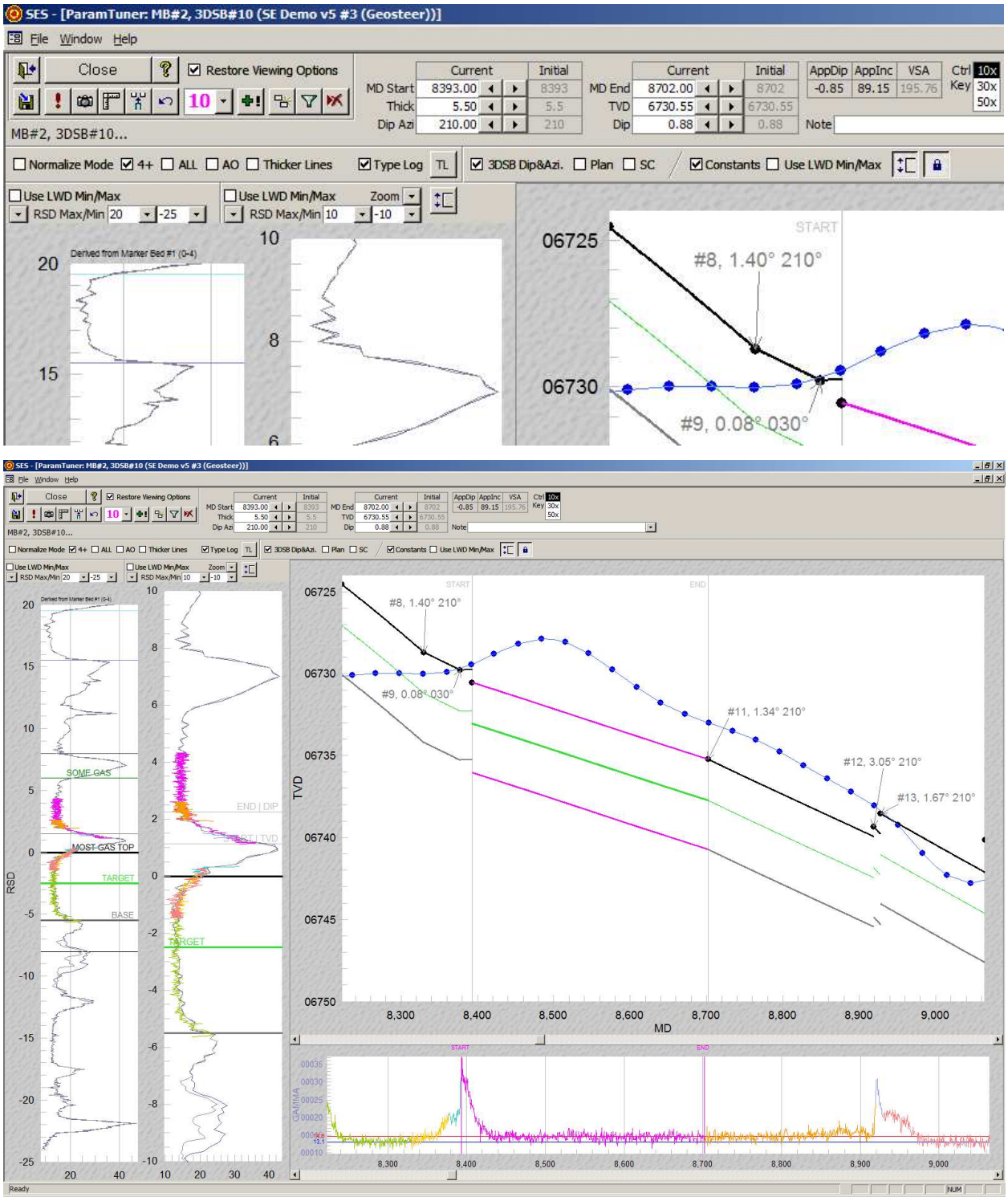
- Double-click within Block, MDStart, Dip, or Dip Azi to make the 3DSB active in ParamTuner
- Double-click bottom row MDEnd to create new/next 3DSB and load it in ParamTuner (adds default length to MDStart; uses MDStart as control point MD; interpolates survey; determines control point TVD from end of prior 3DSB; and sets the new 3DSB active in ParamTuner)
- Double-click MD to interpolate Survey to get control point Easting and Northing coordinates
- Double-click TVD to calculate and set its value to the ending TVD of the prior 3DSB
- F6 – same as clicking Geosteer screen toolbar button "Interpolate SURVEY"

10.6 Tips

- After data (Survey / Type Log / LWD, at a minimum) have been populated in SES and correct Marker Bed header settings have been set or entered from Geosteer screen, click "ParamTuner" button to get started interpreting data. The below screen will be displayed, to which normally the analyst should click "Yes".

- Most 3DStratBlock (3DSB) settings discussed in chapter **10. SES Screen – GEOSTEER** and displayed in Tab/Table view are normally controlled and set entirely from ParamTuner and do not require direct manual editing from Geosteer screen! The primary exception to this statement at this time is "Bed Thickness & Color" settings. However, in most cases, after bed thickness and color settings are populated through copy and/or direct entry, no further edits are required for the rest of the Well.
- The easiest way to load a particular 3DSB in ParamTuner *from Geosteer screen Table View* is to double-click inside the respective row's Block cell.

11. SES Screen – GEOSTEER – ParamTuner



11.1 General

Technical geosteering is quantitative log correlation and analyses that ultimately provides explicit location approximation of nearby geologic beds relative to a wellbore (directional survey). **Param**eter **Tuner** ("ParamTuner") screen is used to perform SES 3D technical geosteering through 3DStratBlock (3DSB)

calibration/tuning, which relies on relative stratigraphic depth (RSD) data transformation. Correlatable LWD data measured along the horizontal wellbore are transformed to map onto a type log "expected profile", first gleaned from offset-wellbore beds penetration. ParamTuner is opened from Geosteer screen (see **10. SES Screen – GEOSTEER**). For a more technical introduction to 3DSB and RSD, see this article published in 2007. For more in-depth and experienced discussion about geosteering, see **11.9 Tips**.

ParamTuner can be used to:

1.) Create geologic interpretation by integrating and analyzing multiple data sources.

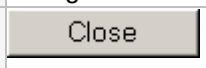
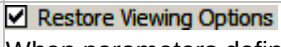
2.) Visualize data and calibrate 3DSB parameters MDStart, MDEnd, control point TVD, and true dip (& its azimuthal direction) in order to control how a segment of wellbore data are mapped onto one or more stratigraphically representative type logs, thereby creating geologic interpretation.

3.) Visualize data and calibrate 3DSB parameter values through multiple mouse and keyboard mechanisms, with instantaneous visual feedback in BOTH structural and RSD domains.

4.) Set multiple options and properties to preserve the general view of structural and RSD domains, as they looked to the analyst at the time of 3DSB calibration, for subsequent recall on demand.

5.) Observe the wellbore's stratigraphic progression into the landing and its status within the lateral and at current survey TD by loading and observing respective 3DSBs and associated data.

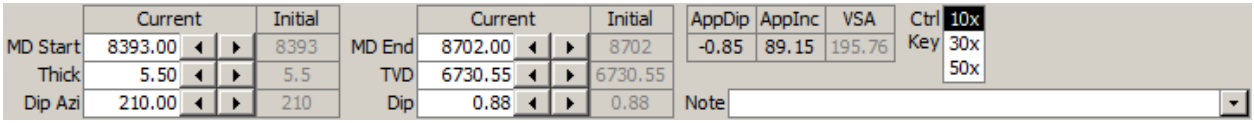
11.2 Toolbar

Control	Control Tip | Detailed Description
	toggle back to SES (Ctrl+B) | Return to SES screen. Please note, if 3DSB changes have NOT been saved before using this button AND IF ParamTuner is subsequently reloaded, such changes would be lost.
	close ParamTuner without saving changes | Close ParamTuner and return to SES screen. Any unsaved edits are not saved. If ParamTuner is subsequently opened it will be reloaded from scratch, which takes more processing time compared to when ParamTuner is already open and data are simply requeried and recalculated.
	ParamTuner help | Display ParamTuner screen abridged help.
	on load if available (otherwise override with options as-checked below) | When parameters defining a 3DSB are saved, certain viewing options are also saved (e.g., "Thicker Lines", "4+", "AO", etc.). When "Restore Viewing Options" is checked, all such settings in effect when a 3DSB was originally saved are restored in ParamTuner when the 3DSB is made active. If "Restore Viewing Options" is unchecked, then applicable viewing options are governed by how ParamTuner is currently set, which may differ from how the 3DSB was originally saved. Thus, with this feature "User 2" may override certain settings and preferences by "User 1" and view the data with User 2's preferences. However, the setting values set in ParamTuner when "Save" is clicked controls what setting values are saved in SES Database for the respective Well/Marker Bed/3DSB.
	save and update 'Initial' (Ctrl+S) | Save the current 3DSB parameter values and viewing options for the active 3DSB currently loaded in ParamTuner. Saving can not be undone with the Undo button.
	reload current 3DStratBlock | Re-Load the current active 3DSB in ParamTuner, which means to requery SES database, recalculate, reset default view properties, and manifest any changes made from any other SES screen.

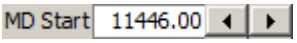
	create 'Derived' Type Log... | Open "Create Type Log Setup" dialog to select 3DSBs from which to generate a new Type Log dataset that is sourced from the current interpretation. For more information see **11.5 Create Derived Type Log**.
	re-assess/refresh horizontal scale limits on RSD / Type Curve tracks | Inspect the data content now present on the RSD tracks and re-determine/reset the x-axis auto scale limits accordingly to show all data. This command is sometimes needed when MDStart and/or MDEnd are changed in a way where LWD data at higher magnitudes and/or lower magnitudes have been brought into view while calibrating and are currently plotting "off-scale". This command has no effect if "Use LWD Min/Max" for the respective RSD track is checked.
	insert blocks into MD gaps...(Ctrl+G) | Open "Confirm 3DStratBlock Insertion into Existing Gaps" dialog to analyze the Marker Bed for any MD intervals that are not currently spanned by a 3DSB. Up to seven gaps may be discovered and each gap found is quantitatively described. One or multiple gaps may selectively be filled in one step. SES automatically renumbers pre-existing 3DSBs accordingly, and the user can set which 3DSB to make active after gap insertion processing completes.
	undo (restore 'Initial' values) | Restore 3DSB parameter values and viewing options to their original/last-saved values. The 3DSB calibration process often requires experimentation and using "Undo" can be very helpful when an experiment doesn't lead to a better condition.
	select 3DSB to make Active (identical to Dbl-clicking 'Block' # from GeoSteer) | Select which 3DSB is Active in ParamTuner, or click this dropdown to observe multiple 3DSB properties of all 3DSBs including saved Notes. The Active 3DSB has its parameter values loaded in ParamTuner and are subject to calibration by the user while other 3DSBs' properties remain constant. Special LWD curve segment color coding is applied on the RSD tracks and on the log strip below the structural cross section to the Active 3DSB and to nearby (±3) 3DSBs. Active 3DSB segments are colored **magenta**. An alternative method to set which 3DSB is Active is to double-click the 3DSB# annotation label on the structural cross section (TVD vs. MD).
	append new 3DStratBlock (Ctrl+A) | Add/append a new 3DSB to the end of the current Marker Bed (interpretation). By default, SES adjoins the new 3SBD to the end of the last 3DSB with no fault appearance and copies all respective 3DSB properties (dip, dip direction azimuth, etc.) and viewing options from the last 3DSB to the new 3DSB. The new 3DSB default MD length is controlled by parameter "Default length of new 3DStratBlock", which may be set from Geosteer screen, Tab View, Parameters tab.
	enable primary LWD curve smoothing | Click this toggle button to enable/disable LWD curve smoothing. The applied averaging method is central moving average window, centered about the data point of interest, and the window size is set by the analyst. When this button is toggled from off to on, the analyst is prompted for the central moving average window size (number of data points), which must be an odd number. Both RSD tracks display only smoothed LWD curve data and Type Log data are unchanged. The LWD log strip below the structural cross section displays both smoothed and raw LWD data. Data smoothing can be extremely helpful in geologic environments with highly variable LWD curve measurement values (e.g., many shale plays), and often times with near-bit tool measurements. Smoothing status and window size are saved at the 3DSB level and are curve-specific. Smoothing should only be applied in the lateral hole section; NOT in the build section.
	change LWD divisor/adder values (for normalize mode) | Open "Set LWD Divisor/Adder for Normalize Mode..." dialog to set or change/test parameters that transform how LWD data are plotted on the RSD tracks when "Normalize Mode" is applied. Normalize Mode is helpful when Type Log and LWD data magnitudes are—for whatever reason—significantly different even though they represent the same LWD measurement. For more information see **11.6 Rescale LWD on RSD Tracks (Normalize Mode)**.
	delete 3DStratBlock(s)...(Ctrl+D) | Open "Confirm 3DStratBlock Deletion" dialog to selectively delete the current 3DSB and/or any ±10 3DSBs from the Active 3DSB. One or multiple 3DSBs may selectively be deleted in one step, SES automatically renumbers the existing 3DSBs accordingly, and the user can set which 3DSB to make active after deletion completes.

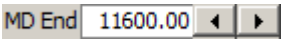
11.3 Other Functions/Features

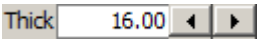
A 3DStratBlock (3DSB) spans a MD interval range of wellbore/survey over which the respective geologic beds are "modeled" to act in a 3D planar fashion. Relative Stratigraphic Depth (RSD) is the minimum 3D distance from a wellbore location to the top of the 3DSB surface. When nature sufficiently curves or faults, a new 3DSB is created to approximate the new reality. A 3DSB is an independent 3D object. The wellbore/survey is an independent 3D object. By changing how a 3DSB is positioned in space, RSD is adjusted and LWD data being mapped onto a type log are affected.



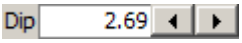
Six parameter values collectively define each 3DSB. They include:

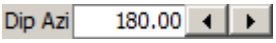
- MD Start (and control point MD)..... 

- MD End..... 

- 3DSB Stratigraphic Thickness..... 

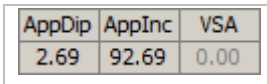
- 3DSB TVD (at control point)..... 

- 3DSB True Dip..... 

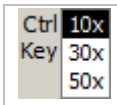
- 3DSB True Dip Direction Azimuth ..... 

ParamTuner screen is used to study and ultimately determine the values of these parameters. There are multiple logistical ways to set parameter values from ParamTuner, and each method has its best time of application when analyzing data. The multiple ways include:

- Various mouse-interactive click-and-drag methods specific to a graph and linked to a parameter value or values (discussed in following sections)
- Clicking or click-and-holding the decrement/increment spin button  adjacent to the respective parameter value text box (ideal for fine-tuning and sometimes necessary when other methods are not presently handy)
- Clicking or click-and-holding the associated decrement/increment spin button while simultaneously pressing the CTRL key for 10x|30x|50x amplified-tuning
- Manual keypunch value entry, followed by hitting Enter or "clicking-away" from the respective text box



It is normally recommended that the Dip calibrated in ParamTuner is true dip. This is performed by setting Dip Azi to the best estimate of true dip direction azimuth, regardless of how the horizontal wellbore is oriented relative to true dip direction azimuth. However, if Dip Azi is set to something other than true (e.g., vertical section azimuth if different than true), the Dip calibrated is of an apparent nature. When Dip Azi and vertical section azimuth are different and Dip is non-zero, Apparent Dip ("AppDip") and Dip will differ. ParamTuner calculates and displays Apparent Dip (and Apparent Inclination - "AppInc") along the vertical section azimuth plane, FYI.



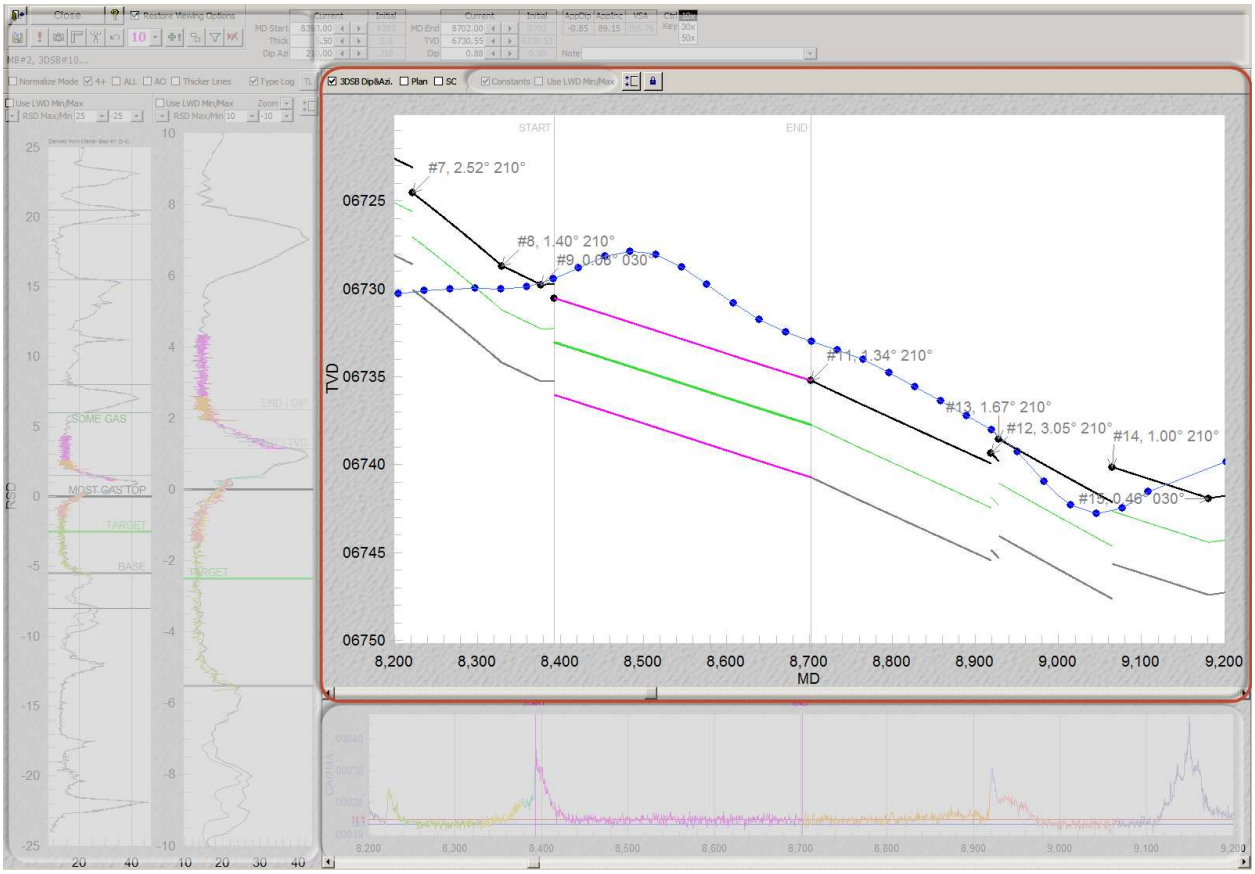
Select the amplification amount to be applied with CTRL key use. Pressing CTRL key while also clicking or click-and-holding a decrement/increment spin button  adjacent to a parameter value text box will amplify the default decrement/increment amount by 10x or 30x or 50x as selected.

Note BLOCK OF CLARITY Enter pertinent calibration or correlation notes specific to the Active 3DSB or otherwise. SES also lists in the Note drop-down box displayed here all such notes present in SES Database for easy lookup/re-use, but any new text may also be entered. The Notes lookup list is refreshed after any Note content is changed/added/deleted and the 3DSB saved. Notes from all 3DSBs display under the main dropdown box used to select the 3DSB to make Active in ParamTuner.

11.4 Graph Details & Features

Each graph in ParamTuner has special options and click-and-drag functionalities. Those details and features are explained next.

11.4.1 Structural Cross Section (TVD vs. MD)



11.4.1.1 Respective Features/Options (TVD vs. MD)

☑ 3DSB Dip&Azi. Each non-Active 3DSB has an annotation with its respective 3DSB number and a gray arrow pointing to its control point, which is displayed on the structural cross section (TVD vs. MD) graph as a black symbol at MD Start. Check "3DSB Dip&Azi." option to include the respective 3DSB calibrated dip and dip direction azimuth values in this label annotation. This display setting is stored by 3DSB.

Other ways to inspect/see 3DSB calibration values are to view the 3DSB selection drop-down box from ParamTuner or to look at Geosteer screen, Table view.

☐ Plan Check "Plan" option to post the associated well plan on the structural (TVD vs. MD) cross section. The specific well plan dataset to display must have been calculated from Planner screen and selected from Geosteer screen for the current Marker Bed. In order to display a well plan in the survey's MD

domain, THD is required to have been calculated for the respective Survey|Plan pair. This display setting is stored by 3DSB.

☐ SC Check "SC" option to post "survey callouts" at every third directional survey station. A survey callout includes the directional survey information MD/Inc/Azi/DLS/TVD/VS. This information is always included at survey TD and then "every third station" counts backwards from TD. This display setting is stored by 3DSB.

 Enable this toggle button to lock the current TVD axis min/max range on the structural cross section (TVD vs. MD) while the MD range view is changed by rolling the mouse wheel, adjusting scroll bars, zooming, etc. Click this button to toggle the setting on or off. When this toggle is not set on, the TVD axis minimum and/or maximum value changes based on the data range in current view. This display setting is temporary to the current session; it is not stored by 3DSB.

 Enable this toggle button to lock the current MD axis min/max range on the structural cross section and the LWD track beneath it. When a new 3DSB is added or if an existing 3DSB is made Active, SES by default will calculate and set a MD range to display. Sometimes this behavior is helpful and sometimes not. This toggle is a means to override or return-to default SES behavior. This display setting is temporary to the current session; it is not stored by 3DSB.

11.4.1.2 More Details (TVD vs. MD)

The structural cross section displays the location of the wellbore (directional survey) and the payzone top/target/base 3DSBs, as calibrated. The Active 3DSB (magenta-colored, available for editing) and other nearby 3DSBs are normally in view by default. A well plan may also be displayed. These data are presented in TVD vs. MD and so there are no distortions, unlike what can occur in projected views (e.g., vertical section). In some cases the 3DSB(s) will display with curvature if the wellbore sufficiently turns in map view in a non-zero dip environment.

3DSB parameters MD Start and MD End define the MD extents of the 3D-curved wellbore over which geologic beds are behaving in a 3D planar fashion. When nature faults or sufficiently curves, a new 3DSB is needed to approximate the geometric location of the payzone and its associated stacked layers.

Two gray vertical lines labeled "START" and "END" are displayed at the current extremities of the Active 3DSB. The "**START**" line is tied-to 3DSB parameter **MD Start**. The "**END**" line is tied-to 3DSB parameter **MD End**. Hover over the respective line and the mouse cursor changes to a double-headed arrow, and then click-n-drag to change its value. Often times while dragging one of these vertical lines, the analyst's eyes are looking at the right/inner RSD track to help determine where to cease movement and thus the extent of a 3DSB.

When 3DSB parameter values are being changed by respective click or click-and-drag means, SES temporarily changes the back-color of the respective 3DSB parameter text box to magenta to reiterate what's being calibrated.

While calibrating 3DSBs (interpreting data) it is possible to have 3DSBs that overlap or wellbore intervals that contain "gaps"—i.e., where a 3DSB's settings have not yet been determined—however these conditions are intended to be temporary and ultimately resolved before final interpretation presentation.

MD Start and MD End may also be changed by dragging the same-labeled vertical lines in the log track directly below the structural cross section.

3DSB control point MD is also tied-to MD Start. Control point MD is automatically updated when MD Start is changed, and control point northing and easting are also automatically determined via minimum curvature interpolation. When the "START" line is dragged and thus MD Start and control point MD

change, SES also automatically calculates and updates control point TVD so that the control point "Z" value "slides" along the identical 3D surface.

3DSBs that aren't the Active 3DSB are annotated on the structural cross section with a label "#X" with an arrow pointing to the respective 3DSB control point (start of block). To make a non-active 3DSB active for editing, double-click the "#X" label. A particular 3DSB may also be made active by selecting its number from the toolbar drop-down box.

11.4.1.3 Zooming, Scrolling, Maximizing, Exporting (TVD vs. MD)

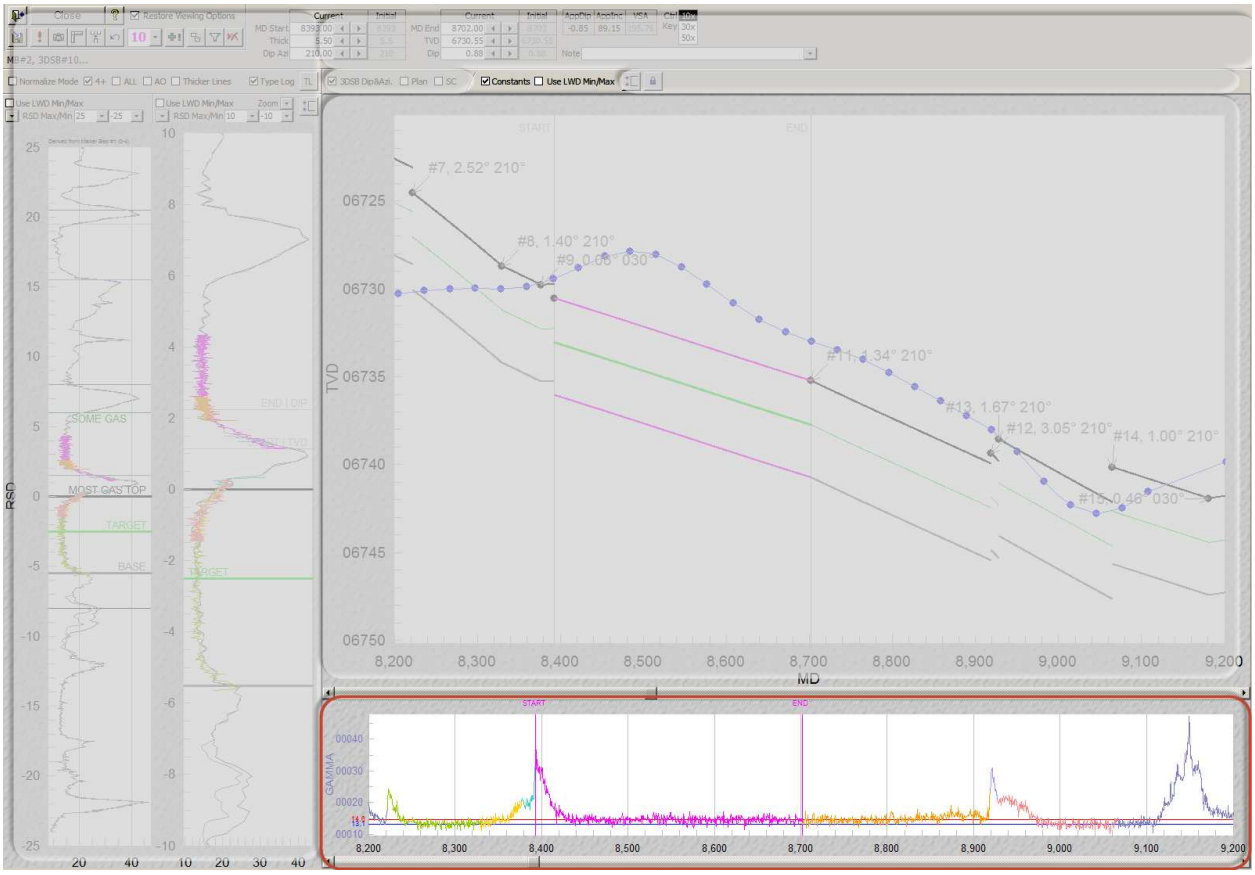
The structural cross section (TVD vs. MD) and the LWD vs. MD log track beneath it are normally depth-synchronized (MD). To scroll back-and-forth through a depth range of data roll the mouse wheel or click the respective scroll bars. Multiple zoom features are available. For example, click-and-drag a section of the graph to zoom the MD range of the selection.

Right-clicking the structural cross section displays a shortcut menu (see adjacent picture) with menu items including "Undo Zoom" and "Restore Initial Zoom" among others. "Undo Zoom" un-synchronizes the structural cross section and LWD log track depth ranges and each graph's respective depth ranges are zoomed to display all possible respective data. "Restore Initial Zoom" sets the viewable MD range to an SES-calculated range determined when a 3DSD is first loaded or is last saved, and the MD range is synchronized between the two graphs.

Successive zooming and custom zooming are also supported. Set a custom zoom MD range by click-and-dragging a horizontal window selection over the TVD vs. MD cross section graph depth range to then zoom, once or multiple times. Identical functionality may also be performed on the LWD log track. Performing this after clicking "Undo Zoom" is another way to custom-set the zoom size/MD-range to a desired amount visually and via a mouse drag. Using "Customization Dialog..." and the Axis tab is another way to precisely set x-axis and y-axis graph extents via keyboard value entry.

The right-click shortcut menu has multiple other features, most of which are reset during a subsequent screen load. Choose "Maximize..." to temporarily enlarge the graph to full screen (maximize mode). Choose "Export Dialog..." to set export size properties and export the graph to a picture format (emf, wmf, bmp, jpg, or png) with export destinations including the clipboard, a printer, or a file.

11.4.2 LWD Track (LWD vs. MD)



11.4.2.1 Respective Features/Options (LWD vs. MD)

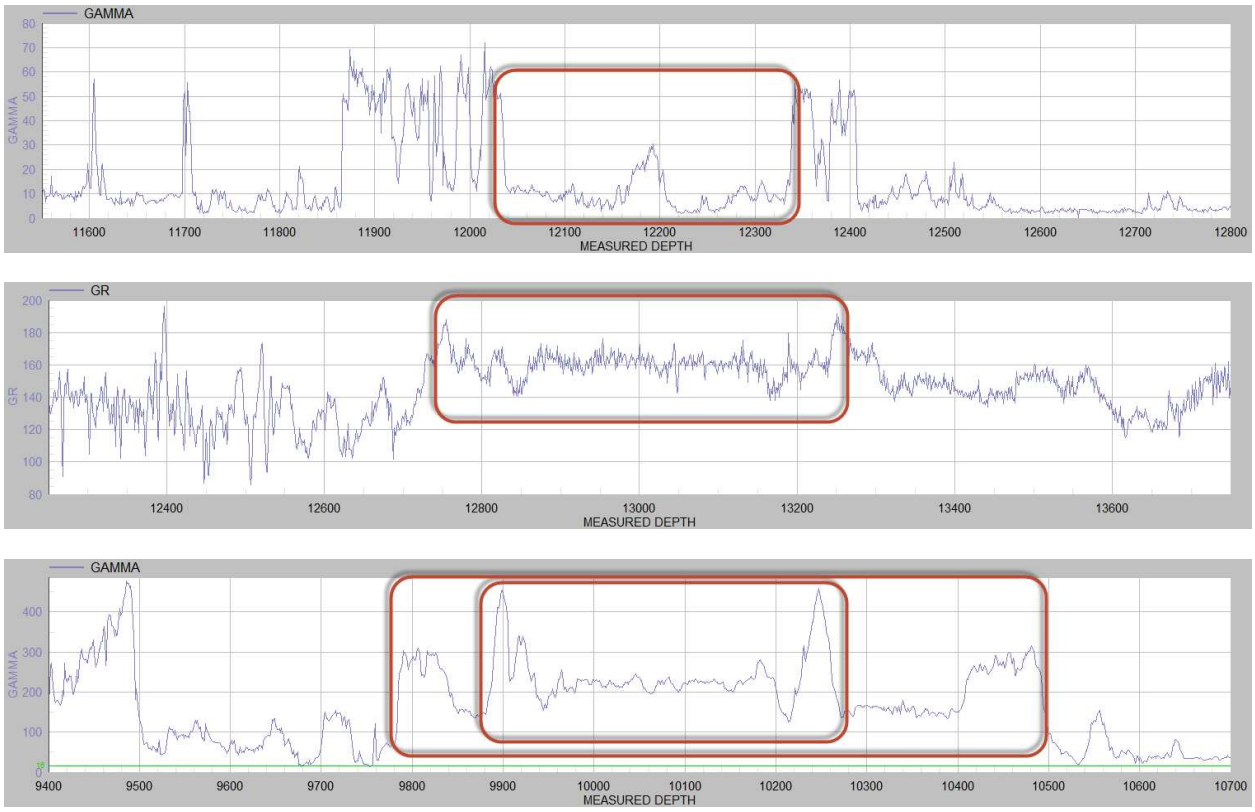
☐ Constants Check "Constants" option to post LWD lines of constant value on the LWD vs. MD log track. Any such constant is set for the specific LWD dataset and specific curve from LWD screen (see **9.3 Other Functions/Features**). Some analysts at times find that "tagging" certain data curve magnitudes assists to identify wellbore stratigraphic location. This display setting is stored by 3DSB.

☐ Use LWD Min/Max Check "Use LWD Min/Max" to apply a fixed scale instead of an automatic data-driven scale to the LWD (y-axis) scale on the LWD vs. MD log track. Any such min/max preference is set for the specific LWD dataset and specific curve(s) from LWD screen (see **9.3 Other Functions/Features**). Some analysts at times prefer to see LWD data on a fixed scale instead of on an adaptive data-driven scale. This display setting is stored by 3DSB.

11.4.2.2 More Details (LWD vs. MD)

The LWD vs. MD log track is directly beneath the structural cross section and displays LWD data measured along the wellbore being analyzed. The MD scales of the two graphs are usually synchronized. From one (e.g., gamma ray) to a maximum of eight (e.g., resistivity, total gas, ROP, casing pressure, flare height, high-side gamma, low-side gamma, etc.) LWD data curves may be displayed and such curve selection is controlled based on how ParamTuner is opened from Geosteer screen (see "Curve #" and "Others" at **10.3 Other Functions/Features** for more information).

Sometimes it's helpful to isolate the extents of the Active 3DSB to a particular portion of LWD signal character, such as a "signal mirror" section that potentially suggests up-and-then-down or down-and-then-up stratigraphic movement along a portion of wellbore. After such isolation, experiments with parameter values of 3DSB dip and control point TVD using the right/inner RSD track often follow.



Whether "traceback" of signal representing stratigraphic movement up-and-then-down or down-and-then-up (when legitimately identified) can be modeled with one 3DSB depends on if nature was acting linearly or not over the respective portion of wellbore. If nature was curving, then multiple 3DSBs may be required to construct the traceback using the type log as a guide for specifics. However, simply finding valid traceback can be a welcomed observation by the analyst.

While calibrating 3DSBs (interpreting data) it is possible to have 3DSBs that overlap or wellbore intervals that contains "gaps"—where a 3DSB's settings have not yet been determined—however these conditions are intended to be temporary and ultimately resolved before final interpretation presentation.

The primary LWD curve data over the MD range of the Active 3DSB are colored magenta on the LWD vs. MD log track. LWD data from ±3 3DSBs from the Active 3DSB are also specially color-coded in a fixed manner. LWD data over other MD portions of the wellbore (including gaps between interpreted intervals) are colored as set from LWD screen.

If LWD data smoothing is enabled, then both the "raw" (i.e., un-smoothed) and smoothed data will be displayed on the LWD vs. MD log track and only the smoothed curve is color-coded. See "Smoothing" under **10.3 Other Functions/Features** or "enable primary LWD curve smoothing" under toolbar commands of this chapter for more information about LWD data smoothing in ParamTuner.

3DSB parameters MD Start and MD End define the MD extents of the 3D-curved wellbore over which geologic beds are behaving in a 3D planar fashion. When nature faults or sufficiently curves, a new 3DSB is needed to approximate the geometric location of the payzone and its associated stacked layers.

Two gray vertical lines labeled "START" and "END" are displayed at the current extremities of the Active 3DSB. The "**START**" line is tied-to 3DSB parameter **MD Start**. The "**END**" line is tied-to 3DSB parameter **MD End**. Hover over the respective line and the mouse cursor changes to a double-headed arrow, and then click-n-drag to change its value. Often times while dragging one of these vertical lines, the analyst's

eyes are looking at the right/inner RSD track to help determine where to cease movement and thus the extent of a particular 3DSB.

When 3DSB parameter values are being changed by respective click or click-and-drag means, SES temporarily changes the back-color of the respective 3DSB parameter text box to magenta to reiterate what's being calibrated.

MD Start and MD End may also be changed by dragging the same-labeled vertical lines in the structural cross section above the LWD vs. MD log track.

3DSB control point MD is also tied-to MD Start. Control point MD is automatically updated when MD Start is changed, and control point northing and easting are also automatically determined via minimum curvature interpolation. When the "START" line is dragged and thus MD Start and control point MD change, SES also automatically calculates and updates control point TVD so that the control point "Z" value "slides" along the identical 3D surface.

11.4.2.3 Zooming, Scrolling, Maximizing, Exporting (LWD vs. MD)

The LWD vs. MD log track and the structural cross section (TVD vs. MD) above it are normally depth-synchronized (MD). To scroll back-and-forth through a depth range of data roll the mouse wheel or click the respective scroll bars. Multiple zoom features are supported. For example, click-and-drag a section of the graph to zoom the MD range of the selection.

Right-clicking the LWD vs. MD log track displays a shortcut menu (see adjacent picture) with menu items including "Undo Zoom" and "Restore Initial Zoom" among others. "Undo Zoom" un-synchronizes the structural cross section and LWD log track depth ranges and each graph's respective depth ranges are zoomed to display all possible respective data. "Restore Initial Zoom" sets the viewable MD range to an SES-calculated range determined when a 3DSD is first loaded or is last saved, and the MD range is synchronized between the two graphs.

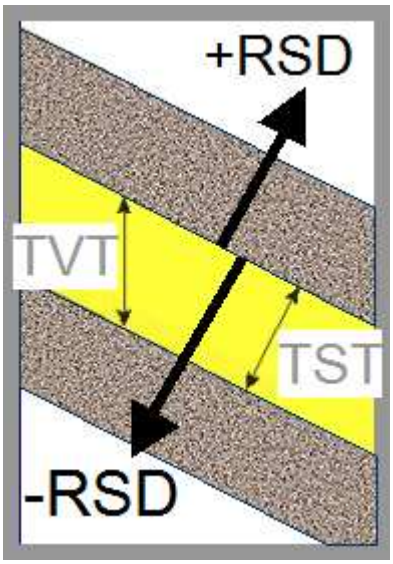
Custom zooming and successive zooming are also supported. Set a custom zoom MD range by click-and-dragging a horizontal window selection over the LWD vs. MD log track graph depth range to zoom, once or multiple times. Identical functionality may also be performed on the structural cross section. Performing this after clicking "Undo Zoom" is another way to custom-set the zoom size/MD-range to a desired amount visually and via a mouse drag. Using "Customization Dialog..." and the Axis tab is another way to precisely set x-axis and y-axis graph extents via keyboard value entry.

The right-click shortcut menu has multiple other features, most of which are reset during a subsequent screen load. Choose "Maximize..." to temporarily enlarge the graph to full screen (maximize mode). Choose "Export Dialog..." to set export size properties and export the graph to a picture format (emf, wmf, bmp, jpg, or png) with export destinations including the clipboard, a printer, or a file.

11.4.3 RSD Tracks

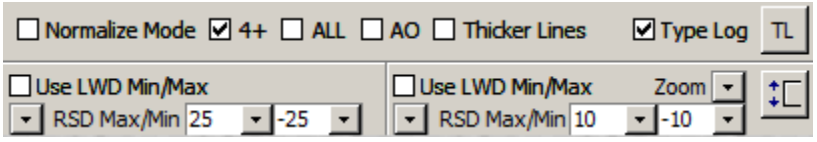
The heart of SES technical geosteering relies on mapping data acquired in the structural domain along the horizontal wellbore and into the stratigraphic depth domain. Relative Stratigraphic Depth (RSD) means that the depth in question is oriented in the stratigraphic depth direction and is relative to a geologic marker, such marker typically chosen from Type Log screen to be the top of the payzone/target layer. The actual drilling target or "sweet spot" is located at an offset stratigraphic distance from the top of the payzone layer (see "Stratigraphic Depth Offset to Target" at **10.3 Other Functions/Features** for more information).

It should be understood that anywhere along the wellbore ΔRSD ≠ ΔTVD if 3DSB dip is non-zero! (In the sketch below, "TVT" is true vertical thickness in TVD direction, "TST" is true stratigraphic thickness in stratigraphic direction, and "RSD" is relative stratigraphic depth from top of yellow marker bed.)



There are multiple features in ParamTuner specific to the two RSD tracks. Different conditions and different points in the general progression of analyzing a horizontal wellbore often require different needs. Furthermore, ParamTuner is designed to capture the analyst's view over a specific portion of wellbore, as it looked at the time of calibration. The view may subsequently be recreated by the analyst or their associate.

The "top row" set of RSD track features shown below are discussed in this section while specific left/right RSD track features are discussed in the next two sections.



☑ Normalize Mode Check "Normalize Mode" option to enable Type Log and LWD data re-scaling through a tunable transform process capable of linear and non-linear mapping. Sometimes there are scaling issues between Type Log data and LWD data for a variety of potential reasons and "Normalize Mode" allows for a quick and easy way to mathematically rescale data within SES and without having to create any additional permanent datasets. Please see **11.6 Rescale LWD on RSD Tracks (Normalize Mode)** for detailed information. This display setting is stored by 3DSB and can flow through to Cross-Sections screen RSD Inset graphs.

☑ 4+ Check "4+" option to calculate and post a single line/curve that averages RSD-mapped data from all 3DSBs that are 4 and more 3DSBs behind the Active 3DSB. Thus, the "4+" line, which is colored gray, is essentially an evolving derived type log. This feature is abbreviated "4+" because the Active 3DSB and ±3 3DSBs from the Active 3DSB are always color-coded in a fixed manner, represent "nearby" data, and are not included in the "4+" line calculation. This display setting is stored by 3DSB.

Eventually, in the course of analyzing data from a horizontal well, it is quite common that the analyst will give more weight to the "4+" line than to the official offset well type log. This is because the "4+" line will normally possess better subtle/pertinent character than what is evidenced in the offset well type log

because of signal averaging that took place by the tool when the measurements were taken in the offset well. For example, a gamma ray tool in a vertical wellbore with horizontal beds will measure and then average the signal within an ellipsoidal rock volume 4-6 inches in the circumferential direction and 30+ inches vertically as the tool passed and ultimately reported a single data value at a single depth value. However, this described "extra weight" employed by the analyst does not necessarily pertain to bed stratigraphic thickness in general! Normally, stratigraphic thicknesses are assumed to be understood and bed dip is calibrated accordingly. Nothing definitive/unique is necessarily learned about stratigraphic thickness AND dip from only drilling a horizontal well because both attributes at a map location between vertical wells are unknown. It normally makes the most sense in oil and gas horizontal drilling to assume stratigraphic thickness is known (either as a constant or its thickening or thinning tendencies over the specific drilling area as learned from multiple vertical well penetrations and 3D modeling/mapping) and to calibrate local "average" bedding dip over 10s to 100s of feet.

Another important benefit of the "4+" line is that the signal magnitude is with respect to the LWD tool in the horizontal well, which is often different than the logging tool used to take signal measurements in the offset well. Because both **signal functional form** and **magnitude** fuel the tricks-to-the-trade of geosteering, the "4+" line can at times be extremely valuable to confidently discern stratigraphic depth likelihood of wellbore portions.

☐ ALL Check "All" option to display all individual 3DSB signal mapping traces that are or can be averaged to produce the "4+" line described above. These individual RSD signal mapping lines are colored black. What can happen while geosteering is that too many traces and/or aberrant traces can create distracting "noise", making it more difficult to interpret data. The "4+" option can help with this, and the "All" option shows exactly just what values are being averaged. Applying "All" option is sometimes a temporary look at data or simply an analyst preference. This display setting is stored by 3DSB.

☐ AO Check "AO" to display RSD signal from the Active 3SBD only. This option is helpful to fully isolate RSD signal from a specific portion of the wellbore and not be "distracted" from color-coded RSD signal from other 3DSBs. This display setting is stored by 3DSB.

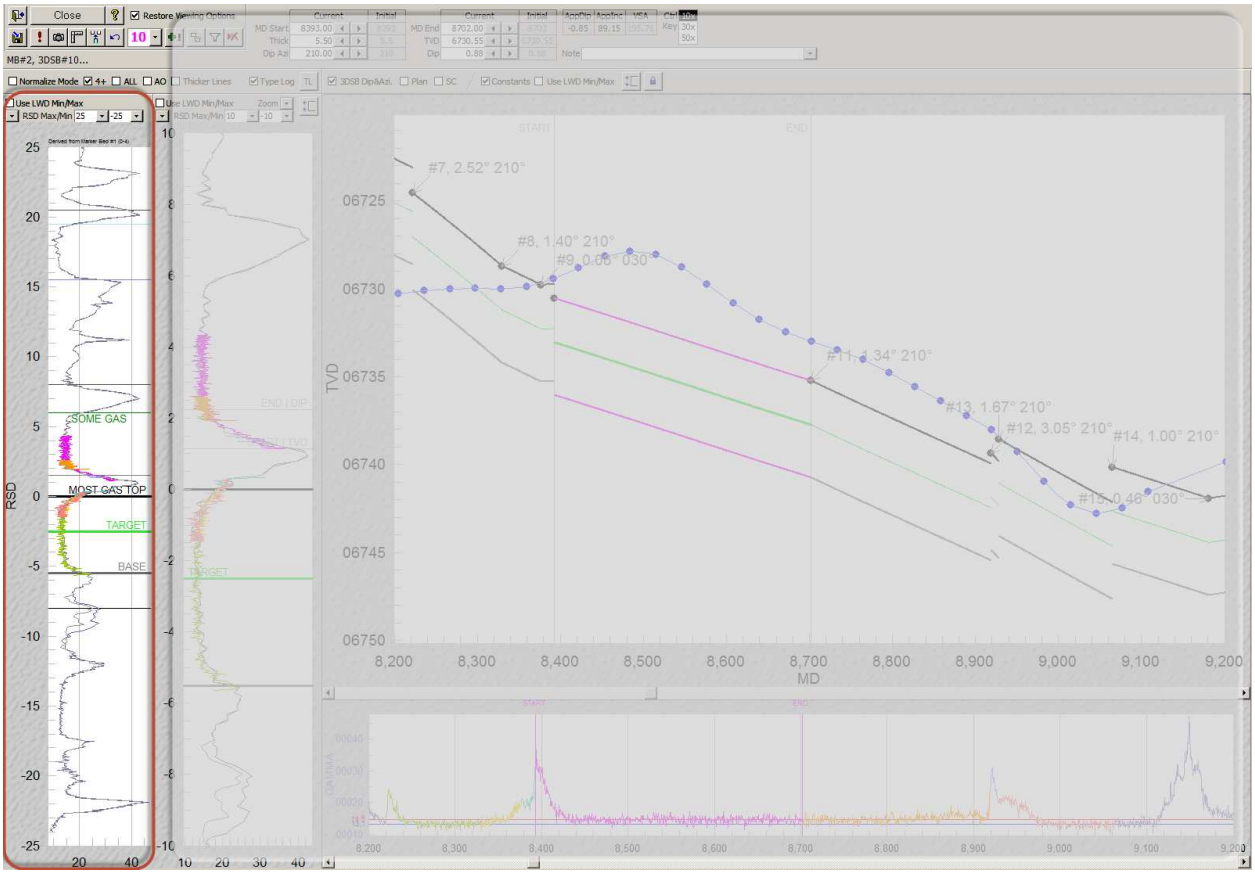
☐ Thicker Lines Check "Thicker Lines" to enable RSD domain curves and LWD data curves to have larger line widths than the default setting. This display setting is stored by 3DSB.

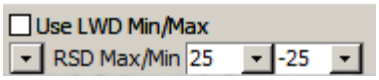
☑ Type Log Check "Type Log" option to display type log datasets currently set to "Use in ParamTuner" from Type Log screen. Such type log datasets could source from offset wells or they could be derived. If a "4+" evolving type log is well formed, it may at times be preferred by the analyst to uncheck this option to disable display of the "formal" type log(s). This display setting is stored by 3DSB.

Open "Pick Type Log(s)" dialog to set which type log(s) to currently display in ParamTuner. The type log datasets would need to exist from Type Log screen. SES can display multiple type logs in ParamTuner, which can be helpful to the analyst for example to better understand expected uphole thickness variations when drilling the curve. Switching type logs is also practiced at times, for example when there are multiple offset wells in the drilling vicinity or as a different offset well becomes closer at a point or points between the heel and toe along the horizontal well being analyzed/drilled. Switching to a derived type log (see **11.5 Create Derived Type Log**) after its creation can also easily be performed using this button.


When switching type logs, it's usually a good idea to document the change in the Note field, which is saved by 3DSB. 3DSB Notes are viewable from the 3DSB selection drop-down box.

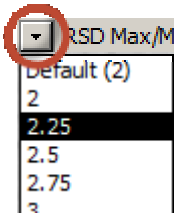
11.4.4 Outer/Left RSD Track (RSD vs. LWD)



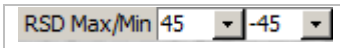


11.4.4.1 Respective Features/Options (Outer/Left RSD vs. LWD)

☐ Use LWD Min/Max Check "Use LWD Min/Max" to apply a fixed scale instead of an automatic data-driven scale to the LWD (x-axis) scale on the outer/left RSD track. Any such min/max preference is set for the specific LWD dataset and specific curve from LWD screen (see **9.3 Other Functions/Features**). Some analysts prefer to see LWD data on a fixed scale instead of on an adaptive data-driven scale. At other times, there may be a large dynamic range that need not be fully seen to best calibrate the 3DSB in question because it may be suppressing signal character that is more prevalent on a different scale range. This display setting is stored by 3DSB.



Use this dropdown box to set the width of the outer/left RSD track. If the computer monitor is wide for example, a different-than-default setting may be desired. This is an SES custom user setting saved on the user's computer only (SESuser.mdb); not by 3DSB.



Select or enter a value in the respective Max or Min dropdown box to set the RSD (y-axis) extent on the outer/left RSD track. These values may also be set with the mouse, as described in the next paragraph. The **outer/left RSD track range** is always a **superset** of the inner/right RSD track range. These display settings are stored by 3DSB to preserve by 3DSB the data view at time of calibration.

While manual keyboard entry of this setting is supported, it is normally easier to set it graphically by click-and-drag on the graph itself. If the **first click is in the upper half** of the log track, the **Max** is adjusted with subsequent dragging/panning. If the **first click is in the lower half** of the log track, the **Min** is adjusted with subsequent dragging/panning. Repeat as necessary to control the range of data in view for current 3DSB calibration.

11.4.4.2 More Details (Outer/Left RSD vs. LWD)

The outer/left RSD track is especially helpful when landing and then with keeping the "big picture" in view. This track accommodates quickly exploring for most logical options after a fault has been crossed or when the correlation becomes complex due to the acquisition of unexpected signal. The outer/left RSD track extents/range is always equal to or larger than the subset inner/right RSD track. The inner/right RSD track is for "zooming" closer to the details and for calibration itself.

Geosteering correlation often begins soon after downhole formation evaluation LWD data are being recorded or shortly after the kick-off point (KOP). As geosteering correlation analysis progresses through the build section of the well, the RSD range of data needed to be seen changes. After the analysis is at the landing, the outer/left RSD track data range may not require much altering for the remainder of the well.

At the outset, the outer/left RSD track Max may be set to include the KOP and the Min may be set to show the full payzone thickness and some buffer below the payzone. During the build, RSD Max is manually adjusted after each new 3DSB is added. After landing, leaving the outer/left RSD track data extents/range too large is not helpful to the analyst. Normally it should be set to display 2-5 times the payzone thickness to be most beneficial.

The payzone layer top, target, and base are displayed and labeled on the outer/left RSD track. If offset bed layers (thickness - required; name - optional) have been set from Geosteer screen (see **10.3 Other Functions/Features**), horizontal line annotations will display on the left/outer RSD track accordingly. In a future version of SES, offset beds will be configured directly from the outer/left RSD track and additional ways to adjust RSD track extents will exist.

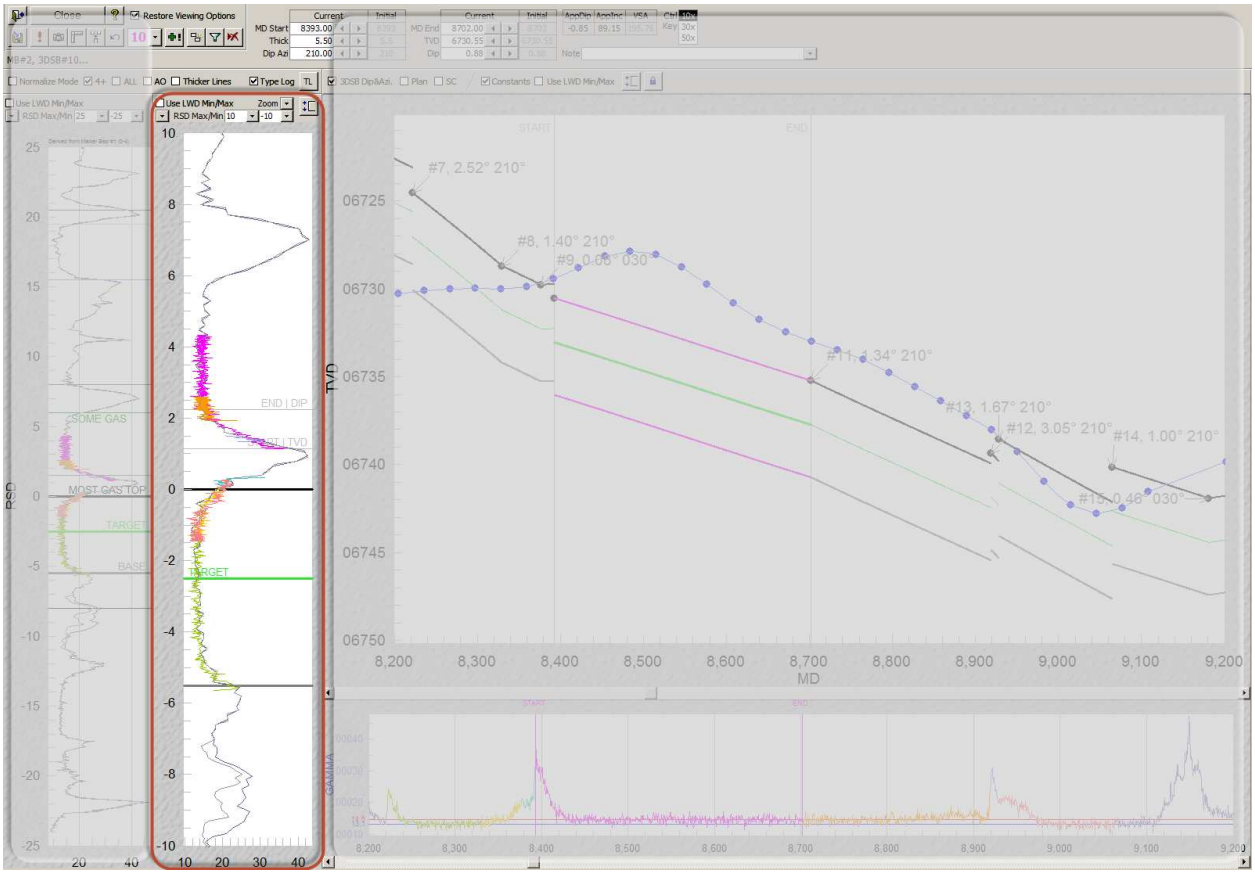
If LWD data smoothing is enabled, then only smoothed RSD data will be displayed on the RSD tracks. See "Smoothing" under **10.3 Other Functions/Features** or "enable primary LWD curve smoothing" under toolbar commands of this chapter for more information about LWD data smoothing in ParamTuner.

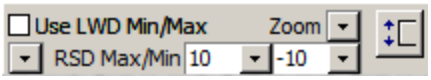
11.4.4.3 Zooming, Scrolling, Maximizing, Exporting (Outer/Left RSD vs. LWD)

Change the RSD Max/Min dropdown box values above the outer/left RSD vs. LWD log track OR click-and-drag on the graph itself to effectively zoom/scroll data. If the **first click is in the upper half** of the graph, the **Max** is adjusted with subsequent dragging/panning. If the **first click is in the lower half** of the graph, the **Min** is adjusted with subsequent dragging/panning.

The right-click shortcut menu has display features, most of which are reset during a subsequent screen load. Choose "Maximize..." to temporarily enlarge the graph to full screen (maximize mode). Choose "Export Dialog..." to set export size properties and export the graph to a picture format (emf, wmf, bmp, jpg, or png) with export destinations including the clipboard, a printer, or a file.

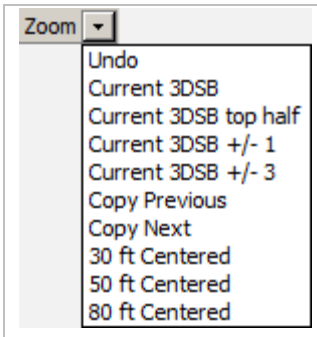
11.4.5 Inner/Right RSD Track (RSD vs. LWD)





11.4.5.1 Respective Features/Options (Inner/Right RSD vs. LWD)

☐ Use LWD Min/Max Check "Use LWD Min/Max" to apply a fixed scale instead of an automatic data-driven scale to the LWD (x-axis) scale on the inner/right RSD track. Any such min/max preference is set for the specific LWD dataset and specific curve from LWD screen (see **9.3 Other Functions/Features**). Some analysts prefer to see LWD data on a fixed scale instead of on an adaptive data-driven scale. At other times, there may be a large dynamic range that need not be fully seen to best calibrate the 3DSB in question because it may be suppressing signal character that is more prevalent on a different scale range. This display setting is stored by 3DSB.



Multiple Zoom Presets are available that on occasion have applicability and save the analyst time in setting the inner/right RSD (y-axis) scale extents/range. In some cases, it may be

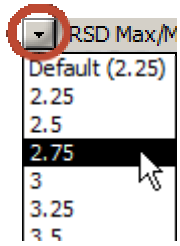
best to first save the current 3DSB before choosing a zoom preset. The available options whereby RSD Max/Min values are automatically determined and set are:

- "Undo" – return to values that were last saved for the 3DSB (often after experimentation)
- "Current 3DSB" – sets them so the current 3DSB's RSD range fills most of the graph
- "Current 3DSB top half" – sets them so the current 3DSB's RSD range fills the top ½ of the graph
- "Current 3DSB ±1" – sets them to include all RSD signal from the current 3DSB ±1 3DSB
- "Current 3DSB ±3" – sets them to include all RSD signal from the current 3DSB ±3 3DSBs
- "Copy Previous" – sets them to equal the settings from the previous 3DSB
- "Copy Next" – sets them to equal the settings from the next 3DSB
- "30 ft Centered" – sets them with current 3DSB centered and with total RSD range at 30 ft
- "50 ft Centered" – sets them with current 3DSB centered and with total RSD range at 50 ft
- "80 ft Centered" – sets them with current 3DSB centered and with total RSD range at 80 ft

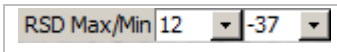
"Current 3DSB top half " is often helpful during the build section. "Copy Previous" and "Copy Next" often find application when working with an inserted 3DSB from addressing interpretation gaps and reworking portions of wellbore. "30|50|80 ft Centered" may be handy when a general "reset" and centering are needed.

The Zoom Presets may immediately be followed with manual click-and-drag/pan of the graph for additional RSD Max/Min extents tuning, assuming "disable RSD Max/Min re-sizing" is not toggled-on (see next command).

 Click this toggle button to enable or to disable RSD Max/Min extents panning. The inner/right RSD track has multiple click-and-drag features and sometimes analysts find it helpful to temporarily disable changing the graph's y-axis extents in order to more easily click-and-drag other objects. This toggle may also be flipped on/off by double-clicking anywhere within the inner/right RSD track graph grid area.



Use this dropdown box to set the width of the inner/right RSD track. If the computer monitor is wide for example, a different-than-default setting may be desired. This is an SES custom user setting saved on the user's computer only (SESuser.mdb); not by 3DSB.



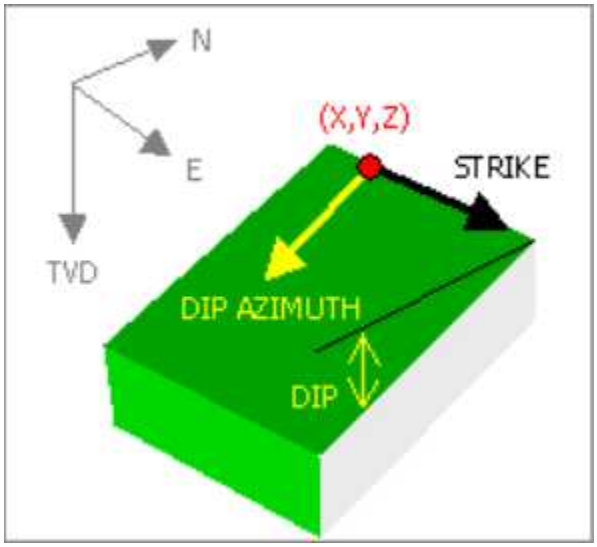
Select or enter a value in the respective Max or Min dropdown box to set the RSD (y-axis) extent on the inner/right RSD track. These values may also be set with the mouse, as described below. The **inner/right RSD track range** is always a **subset** of the outer/left RSD track, i.e., this RSD track is for zooming and getting closer to signal details. These display settings are stored by 3DSB to preserve the data view at time of 3DSB calibration.

While manual keyboard entry of this setting is supported, it is normally easier to set it graphically by click-and-drag on the graph itself. If the **first click is in the upper half** of the log track, the **Max** is adjusted with subsequent dragging/panning. If the **first click is in the lower half** of the log track, the **Min** is adjusted with subsequent dragging/panning. Repeat as necessary to control the range of data in view for current 3DSB calibration.

11.4.5.2 More Details (Inner/Right RSD vs. LWD)

The inner/right RSD track is used to "zoom" close to RSD-domain details, and for 3DSB dip and control point TVD calibration, whether analyzing the curve or the lateral hole section. Stratigraphic horizons displayed and labeled on this track include the payzone top (black line), the target, and the payzone base (gray line).

3DSB parameter TVD defines the "Z" value of the control point used to define a 3D plane, which is the top of the 3DSB. 3DSB parameters Dip and Dip Azi (dip direction azimuth) define the orientation in space of this same 3D plane.



Two gray horizontal lines labeled "START | TVD" and "END | DIP" are displayed at the current extremities of the Active 3DSB. The "**START | TVD**" line is tied-to 3DSB parameter **TVD**. The "**END | DIP**" line is tied-to 3DSB parameter **Dip** (and **Dip Azi** when coupling is applicable). "Start" and "End" are included in the label as a reminder of where the Active 3DSB in the MD domain in fact starts and ends, which isn't always obvious when interpreting data within the lateral hole section. Hover over the respective line and the mouse cursor changes to a double-headed arrow, and then click-and-drag to change its associated 3DSB parameter value.

By chosen 3D vector convention, 3DSB Dip is always zero or positive in SES because Dip Azi handles the dipping orientation. Currently, the largest dip magnitude allowed through "END | DIP" line click-and-drag is 50°. With manual entry or with spin button use, the domain of 3DSB Dip in SES is [0°,90°) and the domain of Dip Azi is [0°, 360°).

When 3DSB parameter values are being changed by respective click or click-and-drag means, SES temporarily changes the back-color of the respective 3DSB parameter text box to magenta to reiterate what's being calibrated.

If "START | TVD" line is changed, a faulted 3DSB appearance may result assuming there are no interpretation gaps on either side of the Active 3DSB. To reset the Active 3DSB to start at the end of the prior 3DSB ("TVD-wise"), double-click inside the control point TVD text box.

If LWD data smoothing is enabled, then only smoothed RSD data will be displayed on the RSD tracks. See "Smoothing" under **10.3 Other Functions/Features** or "enable primary LWD curve smoothing" under toolbar commands of this chapter for more information about LWD data smoothing in ParamTuner.

11.4.5.3 Zooming, Scrolling, Maximizing, Exporting (Inner/Right RSD vs. LWD)

Change the RSD Max/Min dropdown box values above the inner/right RSD vs. LWD log track OR click-and-drag on the graph itself to effectively zoom/scroll data. If the **first click is in the upper half** of the graph, the **Max** is adjusted with subsequent dragging/panning. If the **first click is in the lower half** of the graph, the **Min** is adjusted with subsequent dragging/panning.

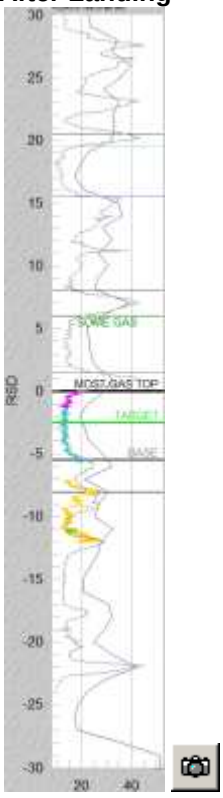
The right-click shortcut menu has display features, most of which are reset during a subsequent screen load. Choose "Maximize..." to temporarily enlarge the graph to full screen (maximize mode). Choose "Export Dialog..." to set export size properties and export the graph to a picture format (emf, wmf, bmp, jpg, or png) with export destinations including the clipboard, a printer, or a file.

11.5 Create Derived Type Log

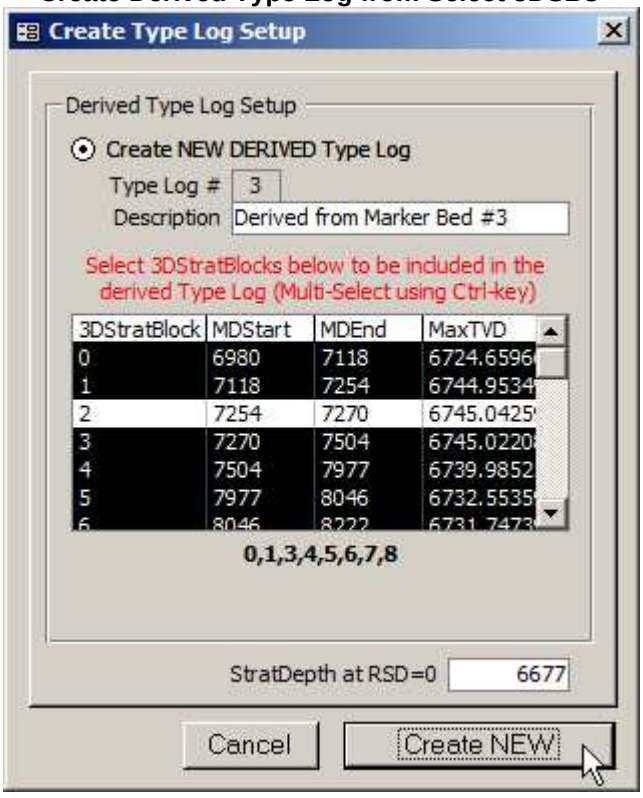
Type Log datasets may come from offset wells or they may be created ("derived") from an interpretation of horizontal well data that originally depended on an offset well Type Log. Because derived type logs often contain more character about the strata being analyzed, they may be preferred. For example, an area near a drilling pad may contain one nearby vertical well that is used for Type Log purposes during the drilling of the first lateral pad well. A derived type log is then created after correlating the first lateral pad well. Subsequent horizontal pad wells may be better served using this derived Type Log instead of the original nearby vertical well log because the vertical well had much less exposure and more layer averaging than what was gleaned from the horizontal well interpretation dataset.

Click ParamTuner toolbar button  to load a dialog from which to create a new Type Log dataset, which is calculated/derived from signal from a selection of 3DSBs created in an interpretation. From dialog "Create Type Log Setup", select all 3DSBs to be included in the dataset (multi-select is supported). See pictures below for an example.

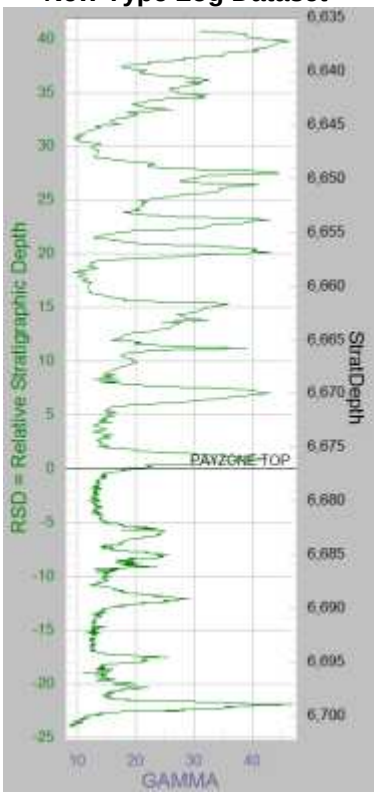
After Landing



Create Derived Type Log from Select 3DSBs



New Type Log Dataset

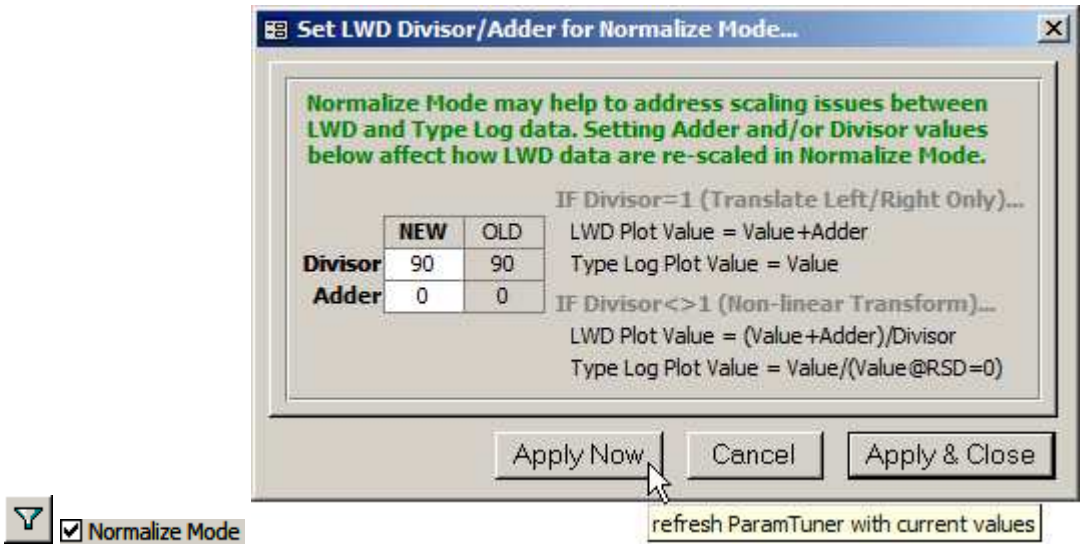


SES sets the default value for "StratDepth at RSD=0" equal to the payzone top from an active type log, to which derived RSD values are added when creating the new Type Log dataset. This default value may be changed to some other number, but all resulting StratDepths should be kept as positive numbers to comply with SES assumptions. After button "Create new" is clicked, a new Type Log dataset will appear from Type Log screen (e.g., Type Log #2). From ParamTuner, button "TL" may be used to enable/disable Type Log datasets currently displayed in ParamTuner.

11.6 Rescale LWD on RSD Tracks (Normalize Mode)

Sometimes Type Log and LWD data magnitudes are—for multiple possible reasons—significantly different even though they represent the same LWD measurement (e.g., gamma ray). "Normalize Mode" is a helpful feature to deal with this condition by allowing for Type Log and LWD data re-scaling through a tunable transform process capable of linear and non-linear mapping.

Click ParamTuner toolbar button  to load a dialog from which to set/test parameters that transform how Type Log and LWD data are plotted on the RSD tracks when option "Normalize Mode" is checked. Data rescaling is performed mathematically in memory and directly within SES and without having to create any additional permanent Type Log or LWD datasets.



From "Set LWD Divisor/Adder for Normalize Mode..." dialog, Divisor and/or Adder values may be entered.

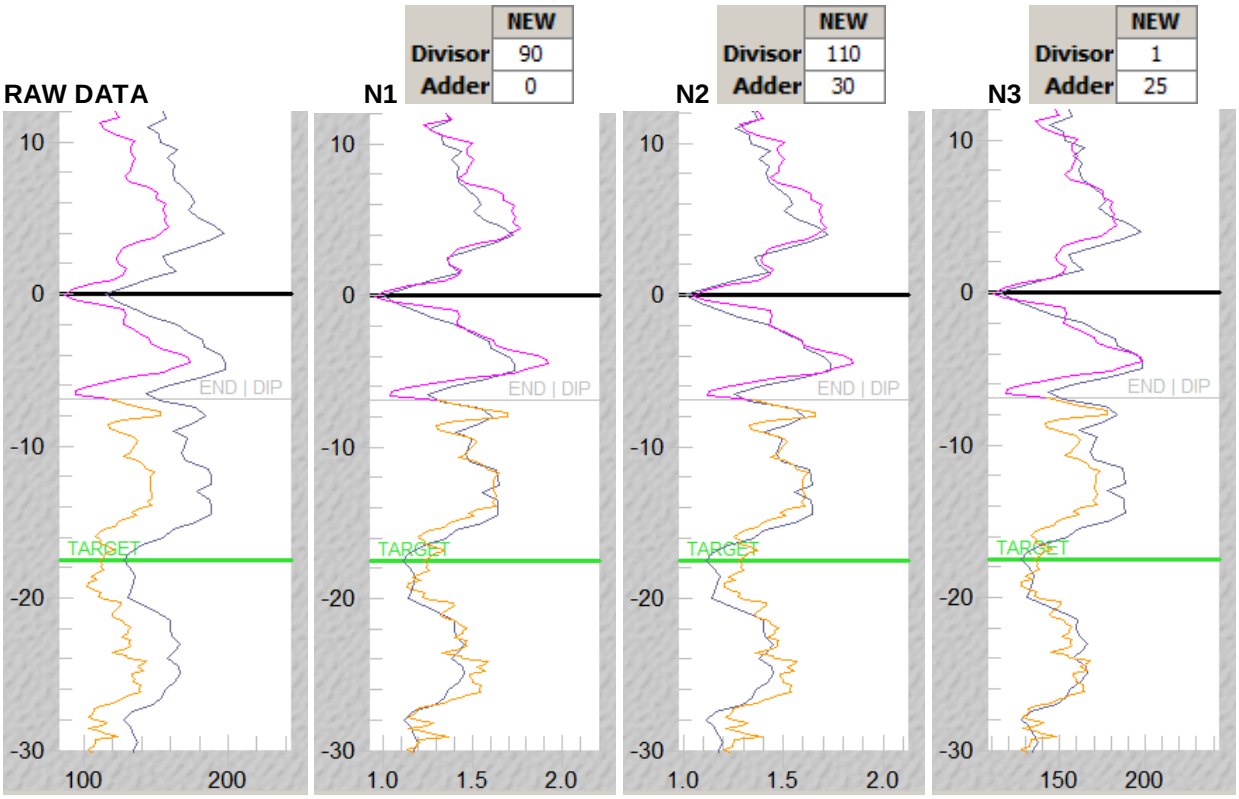
If Divisor=1, then only LWD data are changed through an arithmetic translation controlled by the Adder value. For this case, a linear left/right shift of LWD data with respect to Type Log data is performed.

$$LWD = LWDValue + Adder \qquad TypeLog = TypeLogValue$$

If Divisor<>1, then LWD and Type Log data are plotted as ratios as defined below. With this formulation, the Type Log curve is essentially fixed and the LWD curve is transformed per the set divisor/adder parameter values that are tuned by the analyst. Adder is often set to zero while Divisor is adjusted to produce an acceptable new overlay of data.

$$LWD = \frac{LWDValue + Adder}{Divisor} \qquad TypeLog = \frac{TypeLogValue}{TypeLogValue_{@\ RSD=0}}$$

The pictures below display signal examples using "Normalize Mode" with different transform parameters.



11.7 Critical

1.) ParamTuner is accessed through **10. SES Screen – GEOSTEER** screen by double-clicking within a 3DSB# cell in Table or Tab view or by clicking ParamTuner button in Tab view.

2.) Structural domain, stratigraphic domain, and LWD domain data on all four ParamTuner graphs that fall within the Active 3DSB MD Start to MD End range are colored **magenta**.

3.) Unlike most places in SES where "clicking-away" immediately saves information to SES Database, with ParamTuner the analyst clicks the "Save"  toolbar button to permanently save changes to SES Database. This facilitates experimentation and "Undo"  , which frequently are needed during calibration.

4.) How to address "erratic" 3DSB dip evidenced while dragging "END | DIP" line on **11.4.5 Inner/Right RSD Track (RSD vs. LWD)**:

a.) If wellbore inclination angle is less than ≈50°, set dip to zero or approximate regional average true dip and true dip direction azimuth values as determined from a relevant contour map over the horizontal wellbore-path vicinity. Consider using the "Tie-on" Method to interpret the early landing (see **16.4 Interpreting the Early Landing**).

b) If 3DSB dip direction azimuth has been set approximately 90° different than wellbore azimuth AND if true dip in the wellbore vicinity is low (e.g., less than ≈1.5°), change 3DSB dip direction azimuth to a value closer to wellbore azimuth or simply make it equal to vertical section azimuth or its 180° counterpart (see **16.11 3DSB Dip Azimuth...What should I use?**).

c) If the total RSD range on **11.4.5 Inner/Right RSD Track (RSD vs. LWD)** is large (e.g., 200 ft), change the RSD Max/Min extents to create a smaller range (e.g., 80 ft or less) for enhanced mouse sensitivity/depth-resolution.

d) Double-check that LWD and MarkerBed datasets are associated with the correct Survey dataset. If an error is found, correct the disassociation and then re-interpolate survey from LWD and Geosteer screens and try 3DSB calibration again.

e) If following all above suggestions does not resolve the issue, use the spin buttons  to make dip changes instead of dragging the "END | DIP" line on **11.4.5 Inner/Right RSD Track (RSD vs. LWD)**. It could be that a more fine-tune adjustment is presently needed.

11.8 Hot Keys

- Double-click within MD End to change its value to equal current Survey TD
- Double-click within TVD to change its value to "snap" to the end of the prior 3DSB (removes fault appearance between non-gapped adjacent 3DSBs)
- Double-click within Dip Azi to manually toggle/"flip" its value 180° (this occurs automatically when dragging "END | DIP" line)
- Click-and-drag a horizontal selection on the structural cross section or LWD track beneath the structural cross section to zoom a specific wellbore section (right-click for other related features)
- Click-and-drag on either RSD track graph grid to adjust RSD Max/Min extents (first click in upper half adjusts Max with up/down drag and release; first click in lower half adjusts Min with up/down drag and release)
- Double-click right/inner RSD track graph grid to enable/disable RSD Max/Min adjusting via click-and-drag on graph grid
- Press/release keyboard CTRL key to amplify/resume spin button default response (click and hold down spin button with mouse while simultaneously pressing CTRL key to amplify response by selected 10x|30x|50x amount)
- CTRL+S (save and update displayed "Initial" values) 
- CTRL+A (append new 3DStratBlock) 
- CTRL+D (delete 3DStratBlock(s)...) 
- CTRL+G (insert blocks into MD gaps...) 
- CTRL+B (return to SES screen) 
- CTRL+F6 (in most Microsoft Office versions) or ALT+TAB to cycle between open windows

11.9 Tips

- The *typical minimum* data required to apply SES technical geosteering are directional surveys from the horizontal well, type log gamma ray signal from an offset/pilot "vertical" payzone penetration well, and gamma ray signal from the horizontal well. A geometric well plan (see **7. SES Screen – PLANNER**) can be quite helpful to initialize 3DSB #0 and to plainly see the directional driller's target. THD first needs calculated to display a well plan in ParamTuner because ParamTuner's structural domain graph is in the MD domain (not in a projected/potentially-distorted domain like vertical section).

- If technical geosteering is new for you, it is recommended to first analyze multiple historical horizontal wells before applying SES geosteering to live horizontal drilling operations. In addition to climbing the software learning curve and not being burdened with data lag issues inherent to live operations, "practicing" and geologic thought will introduce you to the geologic features that are present in your field that without technical geosteering software analysis were likely not fully appreciated.

- The inclination-build hole section and the lateral hole section penetrate the reservoir at unique locations that are different than at the type log location! As a result, bed thicknesses and dependable geologic marker depths may vary. After landing, a constant payzone stratigraphic thickness is most commonly assumed and 3DSB dip is calibrated.

- SES technical geosteering does not have variable-dip-calibration application until the wellbore at the start of the 3DSB is significantly inclined. Before significant wellbore inclination is attained, normally control point TVD should be adjusted to map LWD signal onto the type log and dip should be left at zero or regional average.

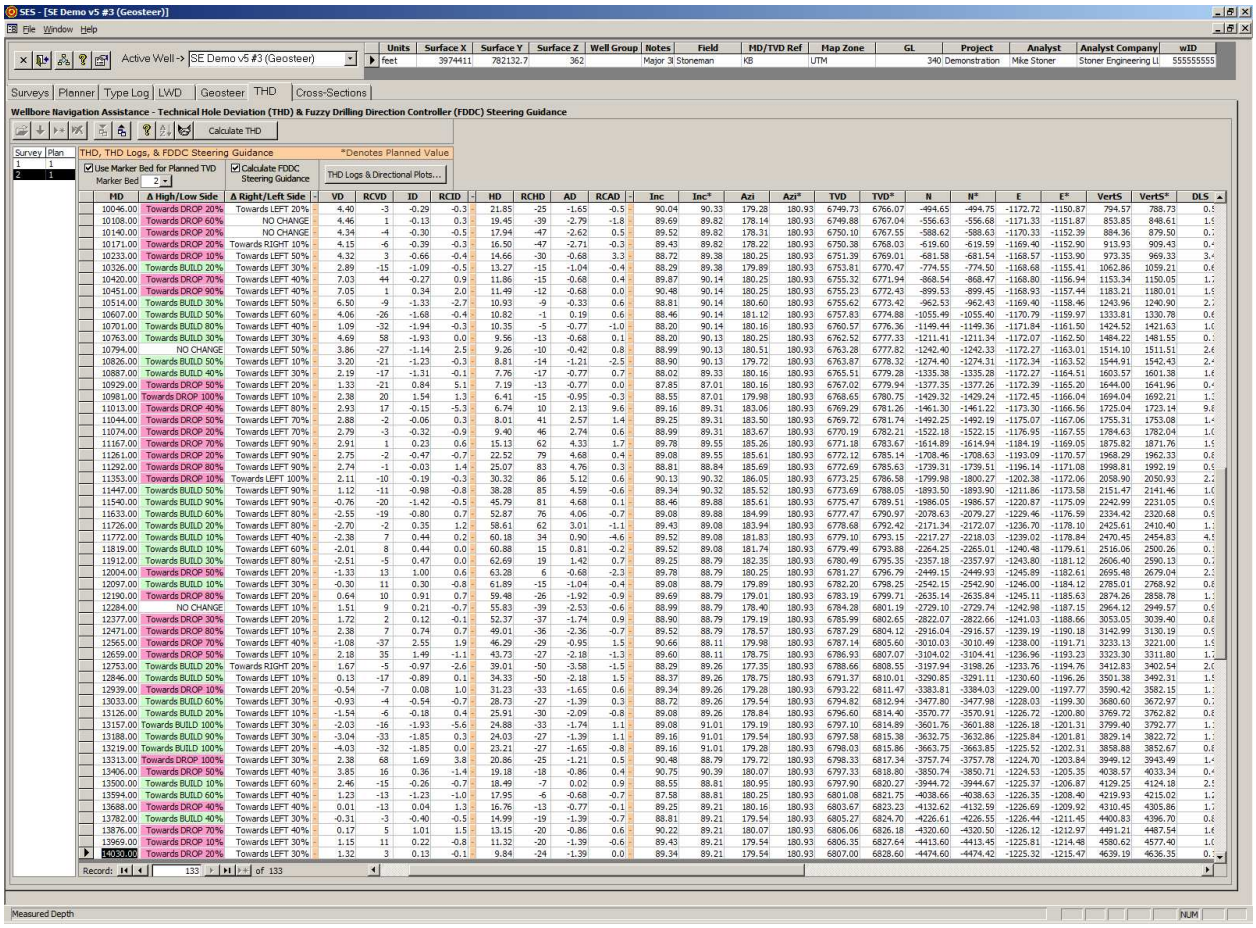
- It is possible while geosteering to reach data analysis conditions where multiple different interpretations are equally likely; at least until some other signal signature is evidenced later in the wellbore. SES by design is setup to easily handle the management of multiple simultaneous interpretations (Marker Beds). Geosteer screen "Add" (asterisk) toolbar button allows an existing Marker Bed to be copied for subsequent alternative tuning/calibration and multiple cross sections may be generated from Cross-Sections screen with each pointing to a different Marker Bed.

- All four ParamTuner graphs automatically resize to fill the screen. However, due to a Microsoft Access form limitation, contained objects may only be resized to fill ≈22 inches vertically and ≈22 inches horizontally.

- To display a payzone as thinning or thickening along the lateral due to significant stratigraphic thickness certainty gleaned from nearby vertical well penetrations through the payzone layer within a respective geologic environment (such as one with an erosional surface), change 3DSB thickness (which is stratigraphic thickness) accordingly at different depths/3DSBs along the lateral.

- Additional essential geosteering concepts are discussed in **16. GEOSTEERING TRADE SECRETS**.

12. SES Screen – THD



12.1 General

Technical Hole Deviation (THD) mathematically quantifies spatial differences between planned and actual well paths for the purposes of directional control monitoring and for supporting real-time rationalization of tool setting adjustments that affect directional steering. SES Steering Guidance is calculated using THD. "THD Logs" present THD in conventional well log format. Please see **14. TECHNICAL HOLE DEVIATION & THD WELLS LOGS** for more information about THD.

THD screen can be used to:

1.) Calculate THD for a Survey|Plan pair, with the option to inherit planned TVD and planned inclination from an associated Marker Bed (geosteering interpretation) target line ("THD Geosteer Mode").

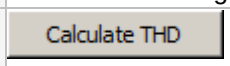
2.) Calculate steering guidance using the patented Fuzzy Logic Drilling Direction Controller (FDDC).

3.) Create and view THD Logs.

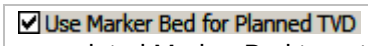
4.) View any Survey|Plan THD dataset for which THD has been calculated.

5.) Assist directional steering decision-making (e.g., tool setting adjustments, duration of slide/rotate drilling modes, etc.).

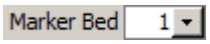
12.2 Toolbar 

Control	Control Tip | Detailed Description
	N/A | THD datasets may not be imported from an LAS file.
	N/A | THD datasets may not be downloaded/imported from a WITSML server.
	N/A | THD datasets are not added from THD screen. Available THD datasets are controlled by the available Survey and Plan datasets that exist for the current Well. THD is calculated for a specific Survey|Plan pair.
	N/A | Respective THD datasets are automatically deleted when Survey or Plan datasets are deleted.
	N/A | THD datasets may not be copied from another Well.
	export THD data to LAS file... | Export the selected THD dataset to an LAS file after setting the output path and filename. In addition to being CWLS LAS v3 compliant, LAS files generated by SES are also created to present the data content in both space delimited and fixed width text formats for greater versatility.
	THD help | Display THD screen abridged help.
	N/A | Sorting on MD is not applicable from THD screen.
	check Survey/Plan/Marker Bed for possible problems | Check the selected Survey, Plan, and Marker Bed for conditions that are known or suspected to cause problems during or after the calculation of THD. Sometimes called the "cat button", the icon is actually intended to represent two hands shaking. ☺
	 (F6) Calculate THD | Calculate Technical Hole Deviation (THD) and directional steering guidance for the selected Survey|Plan pair. For more introduction about THD please see **14. TECHNICAL HOLE DEVIATION & THD WELLS LOGS**.

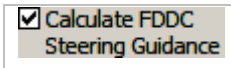
12.3 Other Functions/Features



Check "Use Marker Bed for Planned TVD" option if SES should use the associated Marker Bed target line as *the* planned TVD and the respective 3DSB dip as *the* effective planned inclination, in the calculation of THD. This is called THD Geosteer mode. The well plan's north, east, and azimuth remain unchanged from the respective geometric well plan. In THD Geosteer mode, column VD (vertical deviation) is equal to RSD (relative stratigraphic depth) +/- the respective depth offset to the target line; in other words VD and RSD are parallel-offset values.



Select the respective Marker Bed (Interpretation) to use in THD Geosteer mode.



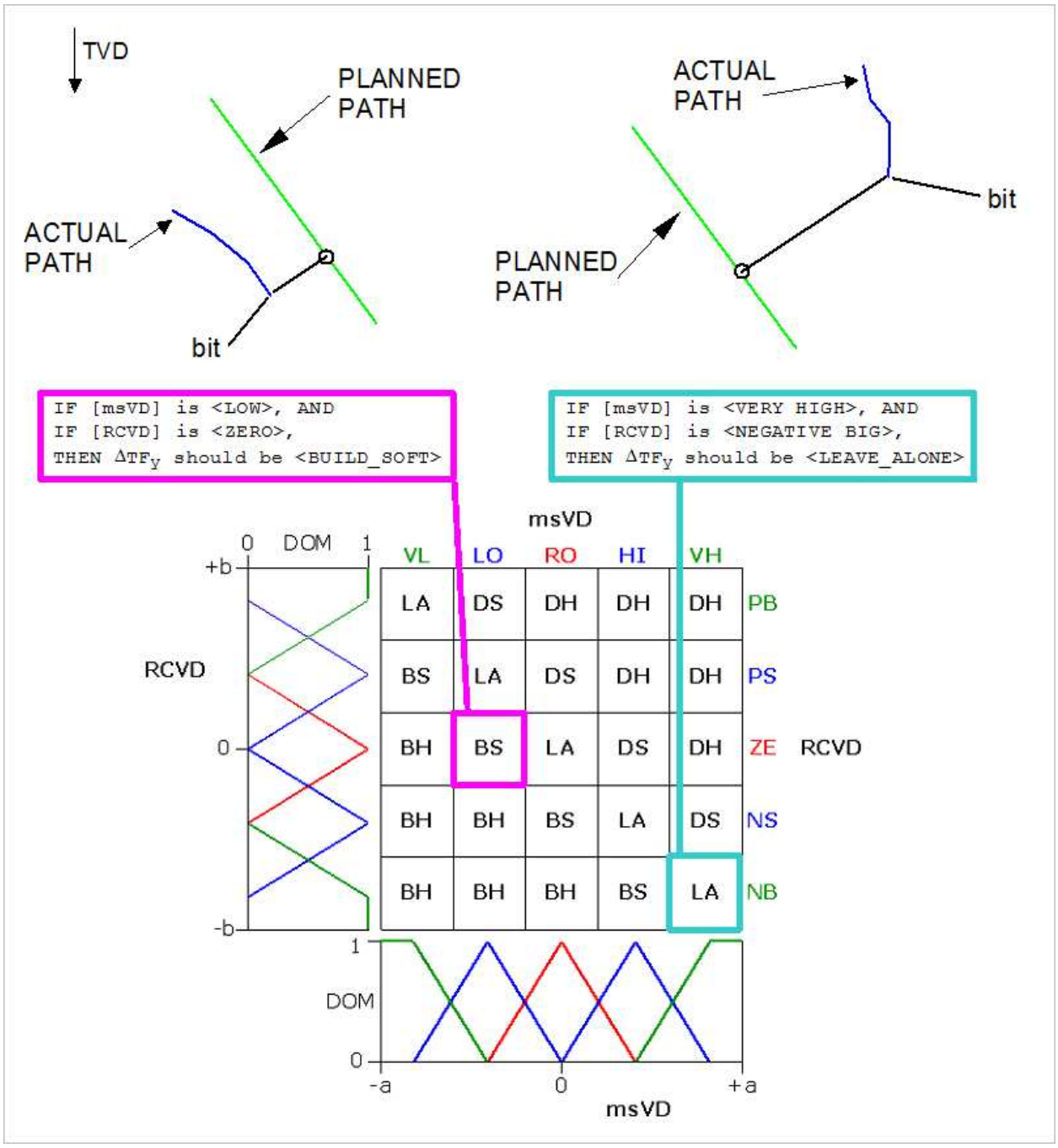
Check "Calculate FDDC Steering Guidance" option if SES should apply the patented **Fuzzy Logic Drilling Direction Controller** (**FDDC**) to calculate and report directional steering guidance. Such results are displayed in the two far left columns labeled "Δ High/Low Side" and "Δ Right/Left Side" within the THD data table. "Δ High/Low Side" is with respect to "vertical" trajectory control and "Δ Right/Left Side" is with respect to "horizontal" trajectory control.

12.4 SES Steering Guidance

FDDC steering guidance is relative (how to *change*); not absolute. For example, "Towards DROP 40%" could mean to continue drilling high side, but less of such is advised with respect to what occurred during the last survey station interval and with respect to what in general is considered to be a very large steering adjustment towards "changing angle" for the current bottom hole assembly setup. SES

calculated steering guidance is provided with each new survey station after sufficient well plan inclination/azimuth are attained.

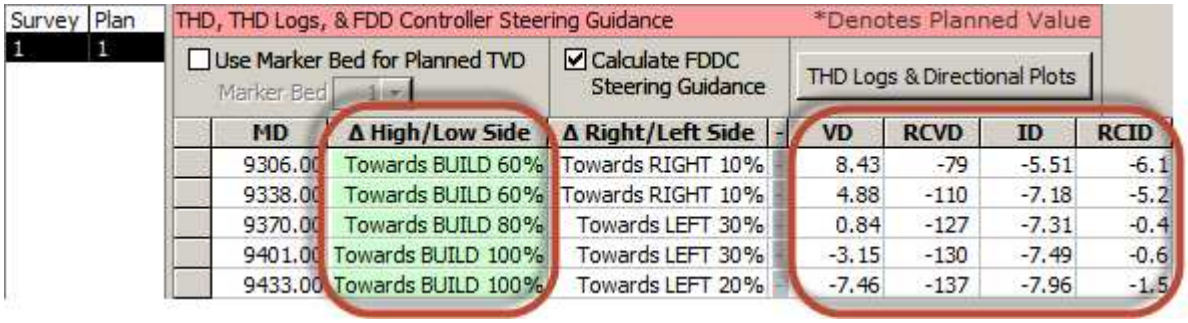
Two example Fuzzy Logic Drilling Direction Controller (FDDC) rules (of which there are 486 in total) are detailed below.



A technical paper about FDDC steering guidance was published in 2003 (click here). A similar paper may be found here. The respective U.S. patent document here is also quite informative.

For example, in the below picture, FDDC output steering guidance at MD (9306 ft) from THD VD (8.43 ft high of plan) and RCVD (-79 ft/1000ft) and ID (5.51 deg low of planned inclination) and RCID (-6.1

deg/100ft) is..."Towards BUILD 60%"; in other words significantly more steering towards high-side is being advised even though the wellbore is currently 8.43 *high* of the well plan.



MD	Δ High/Low Side	Δ Right/Left Side	VD	RCVD	ID	RCID
9306.00	Towards BUILD 60%	Towards RIGHT 10%	8.43	-79	-5.51	-6.1
9338.00	Towards BUILD 60%	Towards RIGHT 10%	4.88	-110	-7.18	-5.2
9370.00	Towards BUILD 80%	Towards LEFT 30%	0.84	-127	-7.31	-0.4
9401.00	Towards BUILD 100%	Towards LEFT 30%	-3.15	-130	-7.49	-0.6
9433.00	Towards BUILD 100%	Towards LEFT 20%	-7.46	-137	-7.96	-1.5

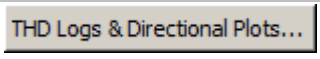
"Δ High/Low Side" FDDC output is a % value with respect to what's considered to be a large respective change. For example, if the last "Kelly-down"—or more-precisely the last measured depth distance between two successive directional survey stations—the wellbore was largely drilled in rotary mode and if steering guidance was then advised to be "Towards BUILD 100%", this could be interpreted as suggesting that the next Kelly-down be drilled predominantly in a high-side manner, whether that be via PDM TFO high-side sliding, or by rotary-steerable means. For another example, if the last Kelly-down was largely drilled low-side and steering guidance was then advised to be "Towards BUILD 100%", this could be interpreted as suggesting that the next Kelly-down be drilled predominantly in a rotary or non-oriented/non-sliding manner (i.e., a large change from drilling entirely low-side prior). Thus, SES steering guidance output is relative to what's considered to be a large change and it is contextual, i.e., with respect to recent directional control actions.

If an SES user is using steering guidance to generally monitor directional control performance while drilling, successive directional survey stations with repeated "**Towards XXX 100%**" may instigate communications with the directional driller to determine the root cause, especially if still drilling the curve before the horizontal landing. Even when drilling a horizontal wellbore that will be geosteered, the geometric well plan is usually honored until ≅ 50-75 degrees wellbore inclination is achieved. If repeated "**Towards XXX 100%**" is occurring while the live drilling wellbore is in the curve, there could be multiple explanations ranging from a break-down in well plan communications and steering desires or simply a bottom hole assembly that is not currently performing; or even a personnel problem.

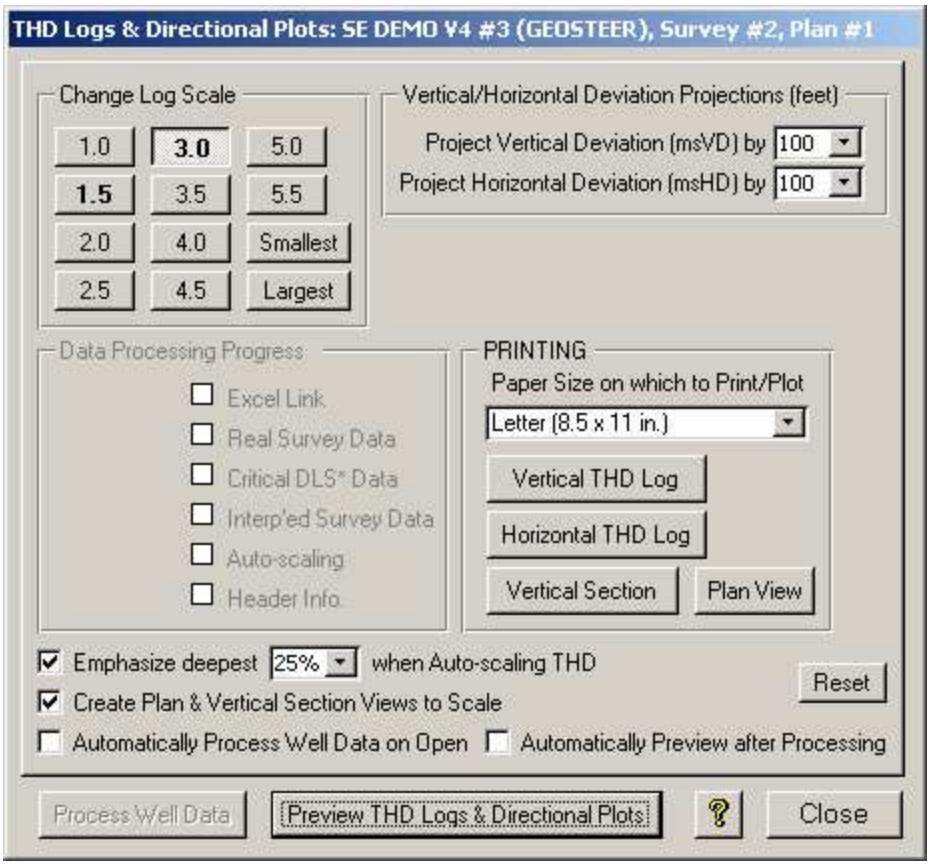
Caution is often applicable when viewing steering guidance on an already-drilled well. Because well plans may change frequently with varying levels of documentation, recreating what transpired during past live operations can be challenging or effectively impossible without complete relevant records.

12.5 THD Logs and Directional Plots

THD Logs present technical hole deviation (THD) and other actual/planned well path values in a traditional well log format. They may be created for geometric or geosteered well plans, dependent on how the screen is loaded. Please see **14.2 THD Well Logs** for more information.



Click "THD Logs & Directional Plots..." button from THD screen to load a dialog to setup and generate THD well logs for the currently selected Survey|Plan pair.



THD Logs & Directional Plots dialog can be used to:

1.) Create a Vertical THD Log and a Horizontal THD Log to be viewed in Microsoft Excel.

2.) Print THD Logs or standard directional plots on the system default printer.

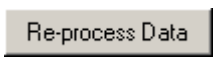
3.) Change the approximate MD scale of either THD Log.

4.) Affect the auto-scaling of THD log tracks.

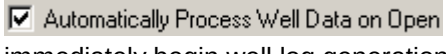
5.) Project THD ahead of the last survey station (black line extension on THD Log).

6.) Assist with directional tool setting adjustment decision-making.

Click "Process Well Data" to create the THD logs and directional plots for the loaded Survey|Plan pair. An instance of Microsoft Excel is automatically opened and a temporary xls file is generated that contains the two well logs on two separate worksheets named "VD" (vertical deviation) and "HD" (horizontal deviation). Various options exist to further customize the generated well logs.



If certain display option values are changed after the THD logs have been generated, the "Process Well Data" button will change to "Re-process Data". Click "Re-process Data" to effect the applicable new option value settings and update the THD logs accordingly.

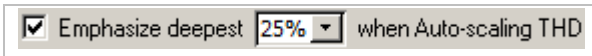


Check "Automatically Process Well Data on Open" if SES should immediately begin well log generation as soon as "THD Logs & Directional Plots..." button has been

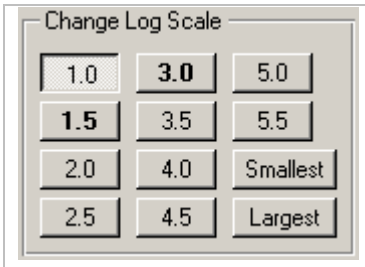
clicked from THD screen. When this option is checked, "Process Well Data" will not initially be enabled and a delay will exist before the above dialog or the THD logs are viewable.

Click "Preview THD Logs & Directional Plots" to attempt to switch to Microsoft Excel to view the THD logs. With some versions of Microsoft Office or Microsoft Windows or for other various reasons, the Excel application icon on the Windows Start row may instead just blink and manual selection of Excel via mouse click or keystroke ALT+TAB is required to preview the THD logs.

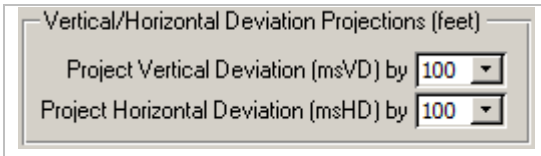
Check "Automatically Preview after Processing" if SES should immediately attempt to switch to Microsoft Excel after the THD logs have been generated. This option is often used in conjunction with "Automatically Process Well Data on Open" so that one click from THD screen results in THD logs being "immediately" viewable.



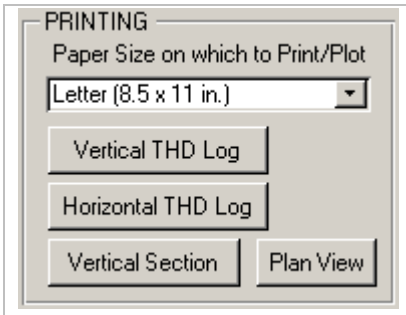
Check "Emphasize deepest X%" when Auto-scaling THD" to tweak the scaling algorithm in SES and thereby affect the resulting x-axis scale limits on the THD log tracks (two right tracks).



Click a toggle button to set the preferred log scale value. The displayed options depend on whether the Well's length units are feet or meters. For example, toggle button value "1.0" means to set the log scale to approximately 1 inch per 1000 MD feet; "3.0" means 3 inches per 1000 MD feet; etc. Toggle button values "Smallest" and "Largest" set the log scale to 2500 MD feet per inch and X MD feet per inch (depending on the total MD range of log data processed), respectively.



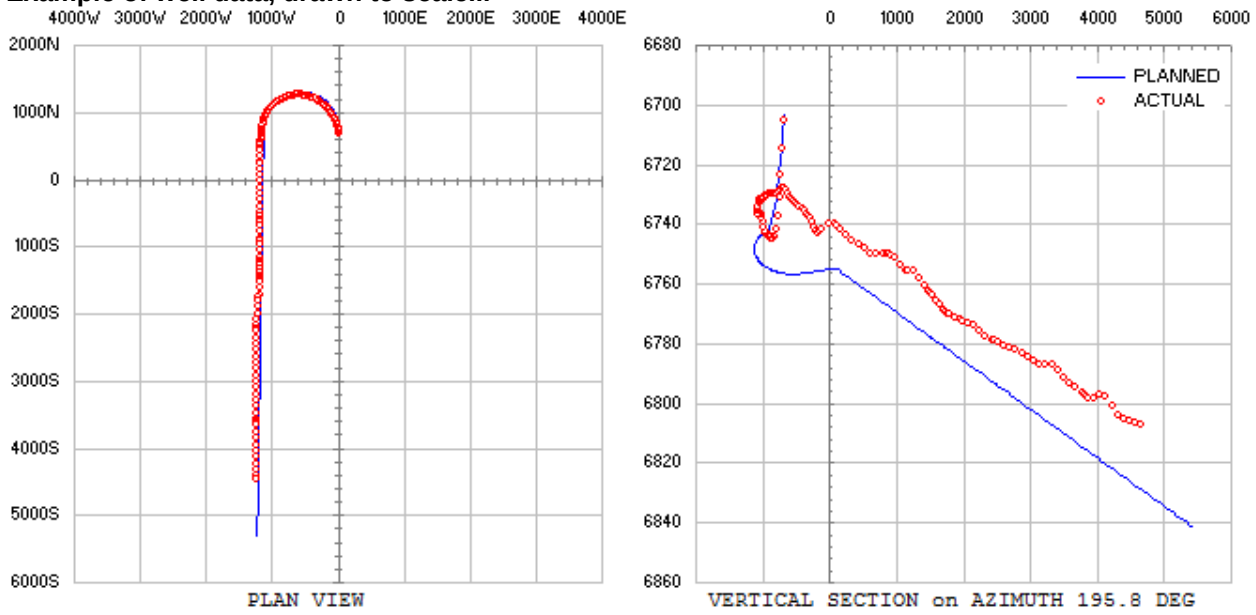
Select the length that the respective lineal deviation should be projected on the respective THD log, or select option "none" for no projection. A projection displays as a thick, black line starting at Survey total depth. Please see **14.2.2 THD Projections** for more information.



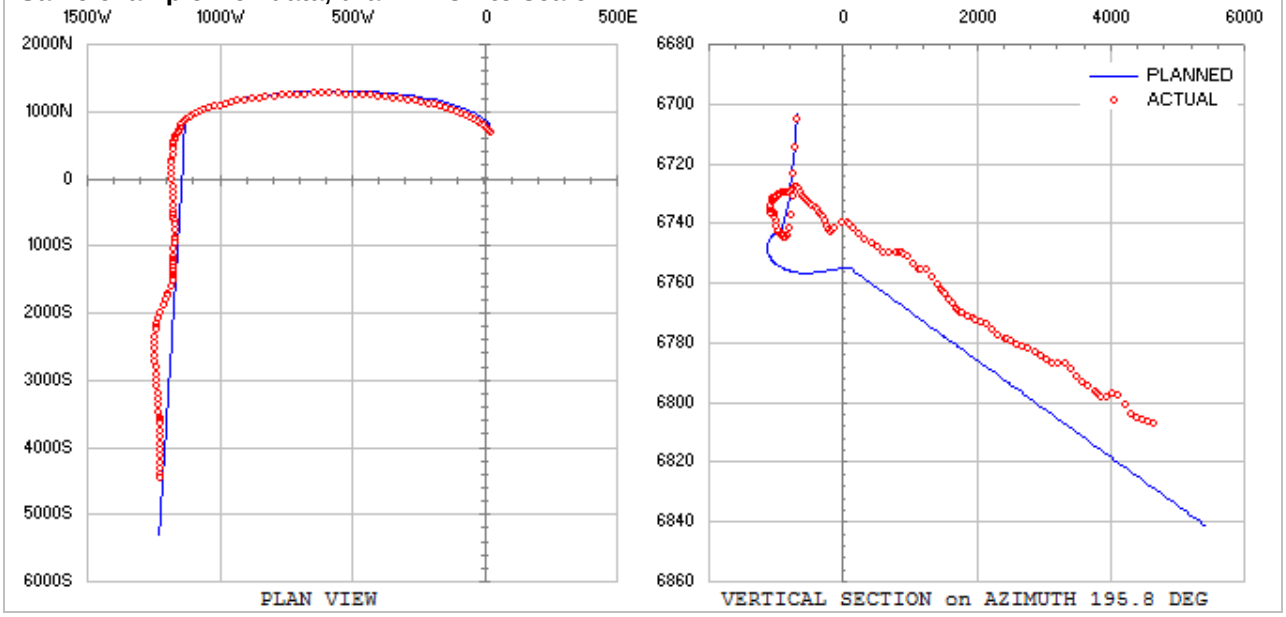
THD Logs may be printed directly from SES to the default Windows system printer. Select the preferred Paper Size if different than the default. Click "Vertical THD Log" button to print the vertical THD log. Click "Horizontal THD Log" button to print the horizontal THD log. Click "Vertical Section" button to print the vertical section view. Click "Plan View" button to print the plan/map view.

☑ Create Plan & Vertical Section Views to Scale Check "Create Plan & Vertical Section Views to Scale" if SES should create the map view axes range and vertical section view vertical section axis range to be the same. These industry standard graphs are located in the footer section below the log strips of either THD log.

Example of well data, drawn to scale...



Same example well data, drawn NOT to scale...



Reset Click "Reset" button to restore THD Logs & Directional Plots dialog settings to default setting values. Setting values are automatically saved when the dialog is closed.

Display THD Logs & Directional Plots dialog abridged help.

Close Click "Close" button to save setting values, close Microsoft Excel if it is still open, and return to THD screen. To preserve a THD Log for subsequent reference outside of SES, save it from Microsoft Excel using "File" menu "Save As..." or print the THD Log to PDF or the like, before clicking this "Close" button.

12.6 Critical

1.) If the directional Survey, Plan, or Marker Bed (if applicable) data change, click "Calculate THD" or press F6 to refresh the THD calculation.

2.) THD Geosteer Mode...THD when using a Marker Bed to determine planned TVD and Inclination is only calculated at depths below the start of the first 3DStratBlock.

3.) THD Geometric Mode...If "Use Marker Bed for Planned TVD" option is not checked, the displayed THD data table represents the selected geometric Survey|Plan pair.

4.) If a different Marker Bed is newly selected from the dropdown box, click "Calculate THD" or press F6 to refresh the THD calculation.

5.) Printing options from "THD Logs & Directional Plots" dialog apply to the Windows default system printer. To change your system default printer, use Windows Control Panel.

12.7 Hot Keys

- F6 – same as clicking THD screen toolbar button "Calculate THD"

12.8 Tips

- The Microsoft Excel THD log template file is password-protected. Contact us if you require the password to (carefully) make custom changes to the template file.

- The **most common commercial application of FDDC Steering Guidance by *geologists*** is to monitor its output, especially during the landing phase of a horizontal well where the geometric well plan is dominant. In general (landing or otherwise), repeated FDDC output at the 90% or 100% level should typically raise a "red flag" and may instigate communication with the directional driller for clarification about deviation from the planned path. With good oversight and communication some sidetracks can fully be prevented.

- FDDC Steering Guidance was calibrated to produce smooth steering adjustments (6 degrees per 100 feet or less) for minimum but realistic DLS variance.

- When using FDDC Steering Guidance with a Marker Bed (i.e., in THD Geosteer mode planned TVD and inclination are determined by respective 3DSB properties), please realize that the orientation of the leading 3DSB in real-time application is often subject to change as the interpretation is fined-tuned with additional data. In this respect, "historical" observation of FDDC Steering Guidance and what actually transpired during real-time operations may be difficult to fully reproduce. This is not an issue when drilling a purely geometric plan, such as some horizontal well landings or when drilling any general directional well where the target doesn't change during the course of drilling.

- In THD Geosteer mode (i.e., "Use Marker Bed for Planned TVD" is checked when THD is calculated) planned TVD and inclination are mathematically defined by respective 3DSBs. Thus, THD can easily be used to help fine-tune the horizontal landing and/or to enhance communication with directional drillers. Vertical Deviation (**VD**) for example is the minimum 3D distance between a directional survey station and the 3D target plane, which is defined by the parallel offset target plane from the respective 3DSB surface. Based on current survey and target (3DSB) landing inclinations, the build gradient in the landing can be fine-tuned on the approach using THD.

  For example:

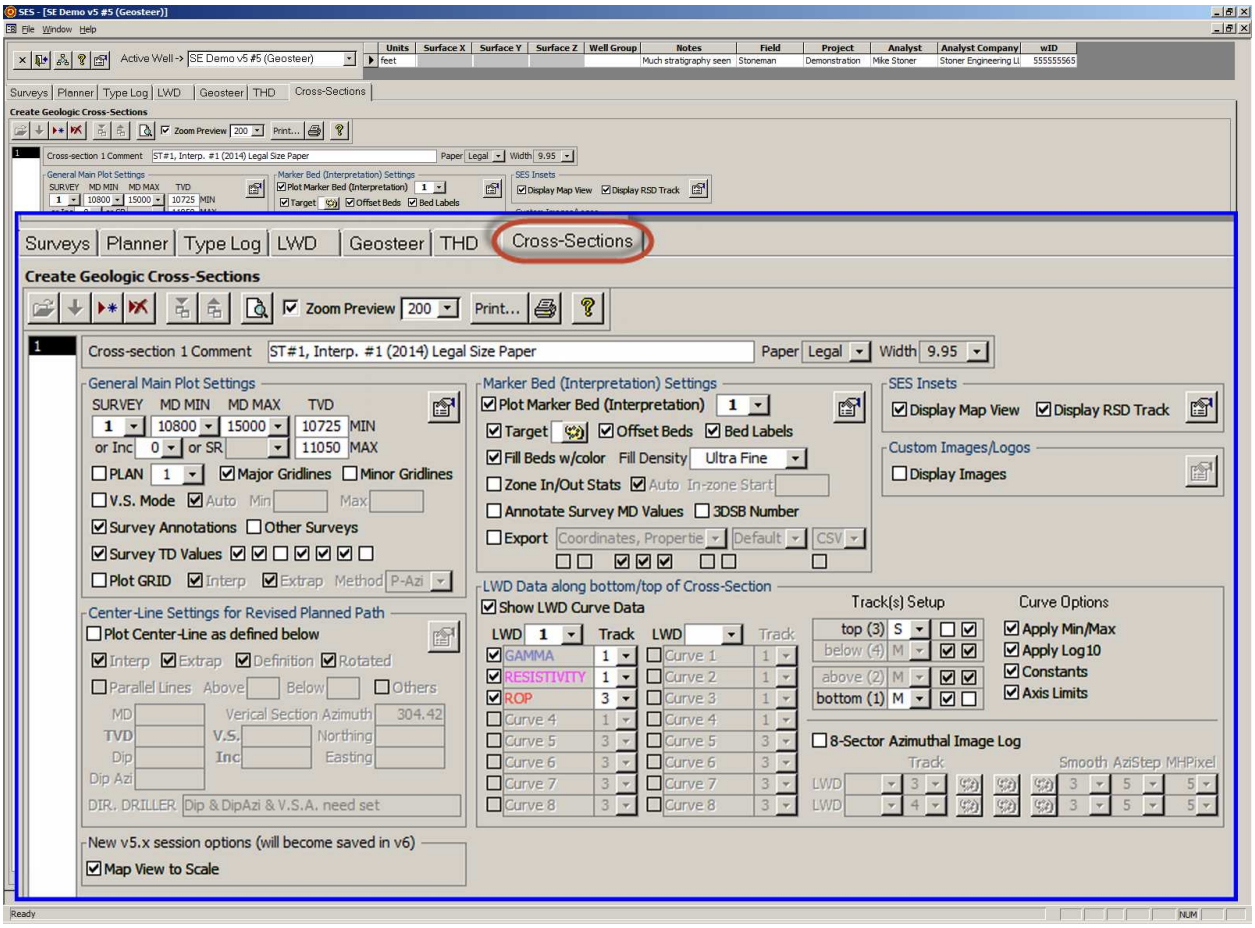
  - 1) At 7050 ft MD, vertical deviation (**VD**) is 54.46 ft and wellbore inclination (**INC**) is 72.63 degrees. The wellbore is already on target azimuth.
  - 2) Current planned landing inclination (**INC***) is 91.50 degrees as set by the calibrated 3DSB. Therefore, inclinational deviation (**ID**) = 91.50–72.63 = 18.87 degrees.
  - 3) **Question: What is the current revised build gradient to hit the target zone on depth *and* on inclination?**
  - 4) **Answer: It's easy with THD!**

    - $$\frac{11459.15590261646\left(\mathrm{Sin}\left(\frac{\mathrm{ID}}{2}\right)\right)^2}{\mathrm{VD}} = \frac{5.65°}{100\ ft}$$

      - Try to drill at 5.65 degrees/100 ft until the next directional survey station or 3DSB calibration change, and then respectively repeat steps 1 through 4 to reassess.

- By SES default—since a vertical hole doesn't technically have a high side—during a planned vertical hole section, Vertical Deviation (**VD**) is actual North minus planned North and Horizontal Deviation (**HD**) is actual East minus planned East.

13. SES Screen – CROSS-SECTIONS



13.1 General

Cross-Sections screen creates wellbore path TVD vs. MD|VS cross sections with a plethora of possible display options that incorporate multiple SES datasets and other custom features. Data contents options include wellbore surveys, planned path, interpreted geologic beds, LWD curve data, center-line drilling target for well plan revision, 3D grid surfaces interpolation, inset graphs and images, depth in zone statistics, and more. An SES Cross-Section dataset holds the particular view settings of a specific cross section. A Well may have multiple Cross-Section datasets for a variety of possible reasons. A cross section is often displayed on-screen, printed to PDF, or its processed numeric data exported to a file for transfer to 3rd party software.

CROSS-SECTIONS screen can be used to:

1.) Configure and display a full-well cross section for viewing/printing/data-exporting and screen capture.

2.) Plot a wellbore interval of TVD vs. MD or TVD vs. Vertical Section with Marker Bed dataset (interpreted geologic payzone and offset beds) and automatic zone in/out statistics.

3.) Plot synchronized LWD curve data along bottom and/or top tracks of cross section, with optional constant-value lines, axis min, axis max, and log/linear scale format inherited from LWD curve setup.

4.) Control track position, track size, background, and gridline settings, on which up to sixteen LWD data curves may be plotted.

5.) Plot associated well plan.

6.) Plot interpolated 3D grid surface(s) at wellbore-interpolated and at well path extrapolated locations.

7.) Post MD/Inc/Azi/DLS/TVD/VS/TVDss annotation at survey TD, MD annotations at select/fixed depth frequency, and general user annotations at any MD and including rotated text, leader line, and font control capabilities.

8.) Post a drilling center-line and parallel lines to convey a revised well plan and drilling window.

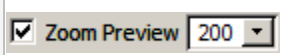
9.) Create and post up to two image logs from 8-sector azimuthal LWD data, with low/mid/high color controls and three dimensions of smoothing controls.

10.) Post inset map view, inset correlation view (RSD track), and custom images/logos (jpeg, tiff, etc.).

11.) Toggle zoom from fit-to-page to 200% (or up to 1000%) at cursor by clicking cross section.

12.) Export cross section numeric data (e.g., coordinates, 3DSB properties, zone/completion summaries, tops TVD) in CSV/LAS/XLS/TXT/PRN text file formats at high-resolution depth frequency or user-set sampled depth frequency for use in 3rd party software.

13.2 Toolbar

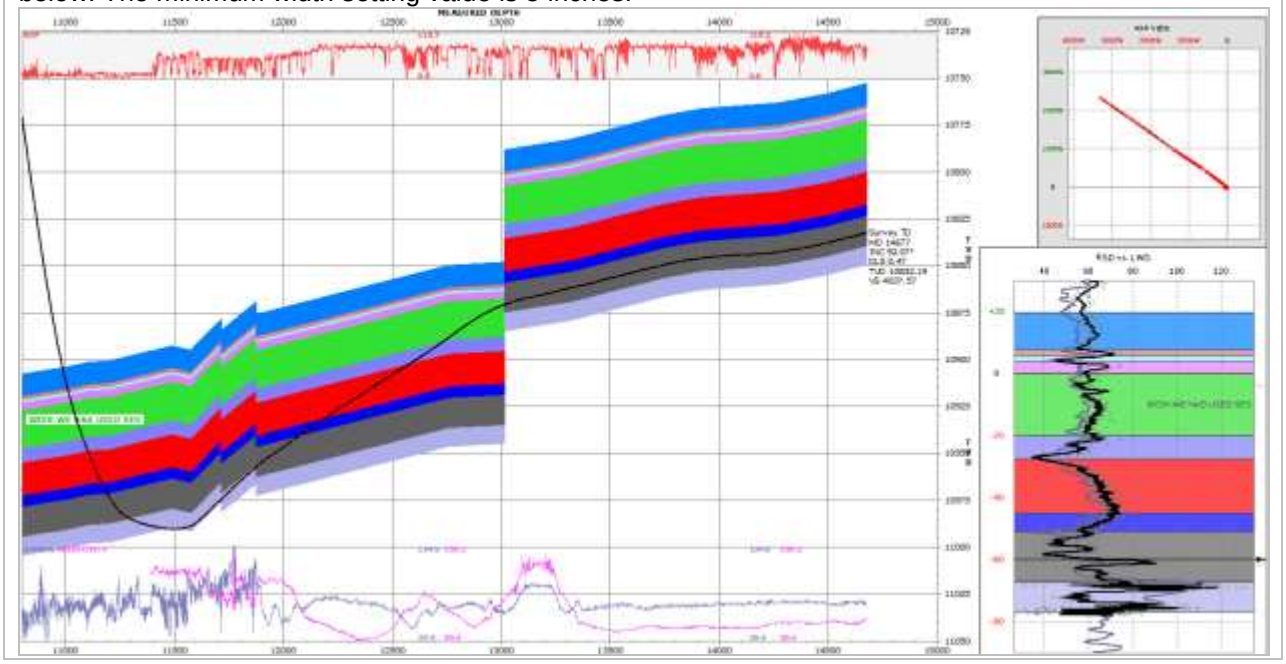
Control	Control Tip | Detailed Description
	N/A | Cross-Section datasets may not be imported from an LAS file.
	N/A | Cross-Section datasets may not be downloaded/imported from a WITSML server.
	add Cross-Section | Add a new Cross-Section dataset and select it. When clicked, the user is prompted to enter the Cross-Section dataset number to copy, or the user may enter 0 to start from system default (blank) settings.
	delete Cross-Section | Delete the selected Cross-Section dataset (and potentially renumber the remaining existing Cross-Section datasets). Cross-Section #1 may only be deleted if there are at least two Cross-Section datasets before deleting Cross-Section #1. Cross-Section datasets are numbered starting at #1. To delete Cross-Section #1 when there is only one Cross-Section dataset, first Add a new Cross-Section dataset and then select and delete Cross-Section #1, after which Cross-Section #2 will become Cross-Section #1.
	N/A | Cross-Section datasets may not be copied from another Well.
	N/A | Cross-Section datasets may not be exported to an LAS file.
	preview cross section | Create a cross section with the respective specified settings and display it on screen for preview. SES uses the Windows Default system printer driver to display the cross section preview on screen. The Default system printer should support the paper size selected for the cross section.  zoom initial view | zoom setting | This SES custom user setting can be used to set whether the *initial* cross section preview is zoomed or fit-to-page. Set/check "Zoom Preview" option if SES should set the initial zoom level to a specific setting value. If this option is NOT checked the initial cross section preview is fit-to-page.

	Click the cross section preview to toggle between zoom and fit-to-page. The zoom setting value—up to 1000%—may also be changed/entered from the cross section preview through the right-click shortcut menu. To generate a hard copy or PDF print of the cross section it is often best to use the Print... toolbar button from Cross-Sections screen instead of using the right-click shortcut menu from the preview.
Print...	send cross section to select printer | Click "Print..." button to load a dialog to select a system printer and print the currently selected Cross-Section. Using this button is recommended to generate a hard copy or PDF print of the cross section because it circumvents a known bug with Microsoft Access that may arise when printing directly from the preview.
	send cross section to *default* printer | Send the currently selected Cross-Section directly to the Windows system Default printer.
	CROSS-SECTIONS help | Display Cross-Sections screen abridged help.

13.3 Other Functions/Features

Paper Letter Select the preferred paper size on which to generate the cross section. The Windows system Default printer should support this paper size. Paper sizes supported include Letter, Legal, and A4.

Width 10 Select the preferred width of the main cross section plot (TVD vs. MD|VerticalSection). Landscape paper orientation and 0.5 inches top/bottom/left/right page margins are assumed and fixed. Inset graphs may be positioned to overlay the main cross section plot or this Width setting may be changed to effectively place inset graphs free-standing along the right side of the canvas as shown below. The minimum width setting value is 5 inches.



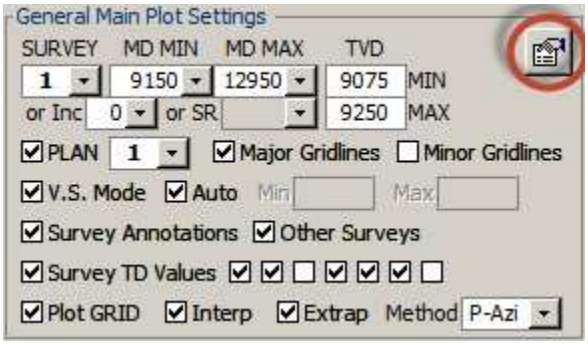
13.4 Cross Section Settings

The SES Cross-Sections screen cross section is a highly customizable, printable, custom "graph" that is drawn entirely from scratch using only lines, circles, and text printing as has evolved over years of SES use and is based on input from hundreds of oil & gas geologists, geophysicists, and petroleum engineers. In other words it is not a commercial-off-the-shelf graph or chart object where the application simply feeds the control with data and hopes for the best.

Cross-Sections screen is divided into six main sections and include access to other screens of respective display setting features. These main sections include "General Main Plot Settings", "Center-Line Settings for Revised Planned Path", "Marker Bed (Interpretation) Settings", "LWD Data along top/bottom of Cross Section", "SES Insets", and "Custom Images/Logos". Links to respective discussion are provided below:

13.4.1 General Main Plot Settings
13.4.2 Center-Line Settings for Revised Planned Path
13.4.3 Marker Bed (Interpretation) Settings
13.4.4 LWD Data along Cross Section (Standard Curves)
13.4.5 LWD Data along Cross Section (Azimuthal Image Logs)
13.4.6 SES Insets
13.4.7 Custom Images/Logos

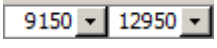
13.4.1 General Main Plot Settings

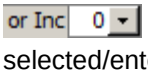


A Survey dataset is required to generate a cross section. Most other settings are optional. Please note additional General Main Plot Settings are accessible using the "other properties" button () circled above.

SURVEY

Select the primary Survey dataset (usually an as-drilled wellbore calculated from directional survey data) to draw on the cross section, and from which some properties and pairings are inherited (e.g., associated Grid dataset; THD). See "other properties" to set survey line width, survey line color, and survey symbol size/color at directional survey stations.

MD MIN MD MAX

Enter the Survey's measured depth minimum and/or maximum values to manually set the survey data's depth range to include in the cross section as well to set the cross section x-axis (MD|VS) scale limits. MD min/max dropdown boxes display survey station depths and other survey data, but any MD may be entered. Normally, MD max is set to a value larger than planned TD to give right margin space to the cross section.


Alternatively and mutually exclusively, a minimum Survey inclination angle ("Inc") may be selected/entered as the means to set the MD filter.

TVD
9075 MIN
9250 MAX Enter the cross section TVD minimum and/or maximum values to manually set the cross section y-axis (TVD) scale limits for the desired data presentation.

SR Alternatively and mutually exclusively, select the MD:TVD scale ratio ("SR") to affect the y-axis (TVD) scale limits accordingly for desired/consistent fixed scale appearance.

☑ PLAN 1 Check "PLAN" option to display a well plan on the main graph and select the corresponding Plan dataset. The selected Plan dataset applies to the main graph and/or to the well plan displayed on the inset map view (see **13.4.6.1 Inset Map View Properties**).

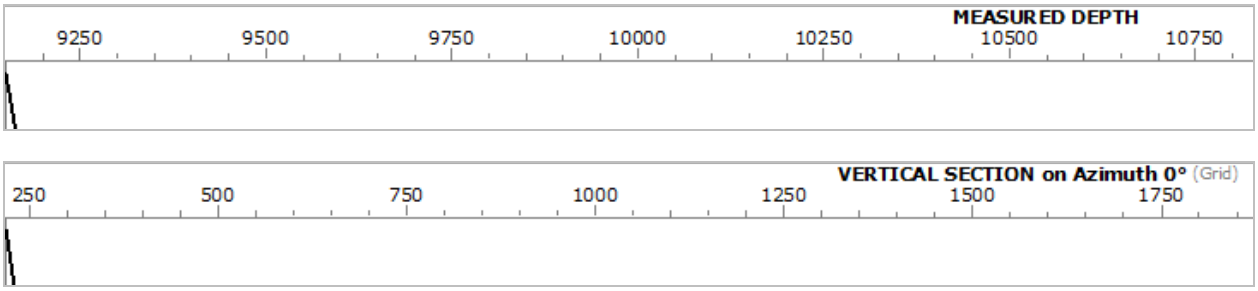
To display a Plan using cross section MD mode, THD for the respective Survey|Plan pair must be calculated (see "Calculate THD" toolbar button from **12. SES Screen – THD**). THD need not be calculated if using cross section Vertical Section mode.

The respective Plan must be defined/calculated with Planner screen. For information on how to most easily and accurately transfer a well plan into SES that was designed by others, see **7.10 Tips** (➔).

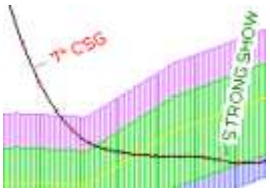
See "other properties" to set plan line width and plan line color.

☑ Major Gridlines ☐ Minor Gridlines Check "Major Gridlines" and/or "Minor Gridlines" to display respective gridlines on the main graph.

☑ V.S. Mode ☑ Auto Min Max Uncheck "V.S. Mode" to process the cross section using MD, whereby the x-axis of the main graph is measured depth. Check "V.S. Mode" to process the cross section using Vertical Section, whereby the x-axis of the main graph is vertical section. MD MIN and MD MAX still apply regardless of V.S. Mode setting. Displaying information (e.g., plan, center-line, interpolated grid data) at a wellbore/survey-extrapolated location normally requires Vertical Section Mode. "Auto" vertical section axis extents may be overridden with manual min/max values by unchecking "Auto" and entering a respective value into the respective text box. Azimuthal north reference (grid or true) is included in the axis label if "V.S. Mode" is checked.

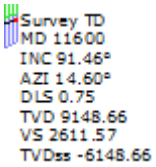


☑ Survey Annotations Check "Survey Annotations" to post text annotations on the cross section. Annotations are entered from Surveys screen (upper-right input table) and associated with the Survey. See "other properties" to set a variety of annotation display options including individual annotation show/hide, leader-line line width/length/color, annotation font settings, background, automatic MD insertion, and text rotation angle (default angle is perpendicular to survey at respective MD, but can be overridden at individual annotation level).



☑ Other Surveys Check "Other Surveys" to post directional survey well paths from all Survey datasets not equal to the primary one and not marked "Exclude". This option may be helpful when the primary Survey is a sidetracked wellbore or if it is desired to see other Survey datasets in general, when applicable. This display option affects both the main graph and the inset map view (if applicable). See "other properties" to set line width/color of "Other Surveys" line(s).

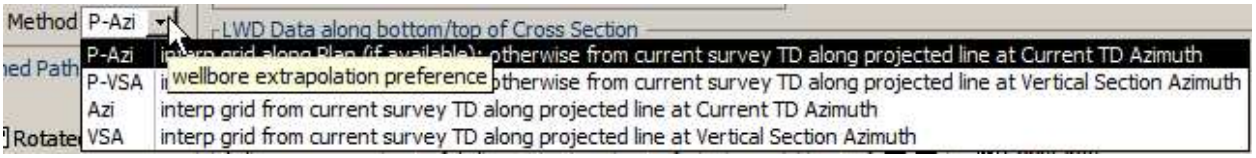
☑ Survey TD Values ☑ ☑ ☐ ☑ ☑ ☑ ☐ Check "Survey TD Values" to post survey properties at current survey total depth ("TD"). From onscreen left to right, wellbore path options that may be posted include: measure depth ("MD"), inclination ("Inc"), azimuth ("Azi"), dogleg severity ("DLS"), true vertical depth ("TVD"), vertical section ("VS"), and true vertical depth subsea ("TVDss"). Applicable units are industry standard, as chosen for the Well, and are reported in the cross section header next to "Units".



☑ Plot GRID ☑ Interp ☑ Extrap Method P-Azi Check "Plot GRID" to interpolate the Grid dataset associated with the Survey and display such surface(s) on the cross section. This may occur at wellbore-interpolated locations (current depth range spanned by the Survey dataset) and at wellbore-extrapolated locations (depth range beyond current Survey total depth and thus, speculative, since such true 2D locations are not yet known).

☑ Interp Check "Interp" to display interpolated Grid data surface(s) over the respective cross section depth interval where Survey data are known.

☑ Extrap Check "Extrap" to display interpolated Grid data surface(s) over the respective cross section depth interval where Survey data are NOT yet known, that is, at depths beyond current Survey total depth. Cross section **Vertical Section Mode** is required for this display feature. Because the "future" location of the actual wellbore is unknown in this "look-ahead" perspective, logic must be applied to determine the forecast wellbore X-Y locations at which to interpolate Grid data for onscreen display. Four methods are available for this purpose, as shown and described below:



"**P-Azi**" – interpolate Grid data at "future" X-Y's along the selected Plan. If valid Plan data are not available for any reason at required locations of interest, interpolate Grid data at X-Y's along a line calculated from survey (North, East) at total depth and oriented along the azimuth at survey total depth.

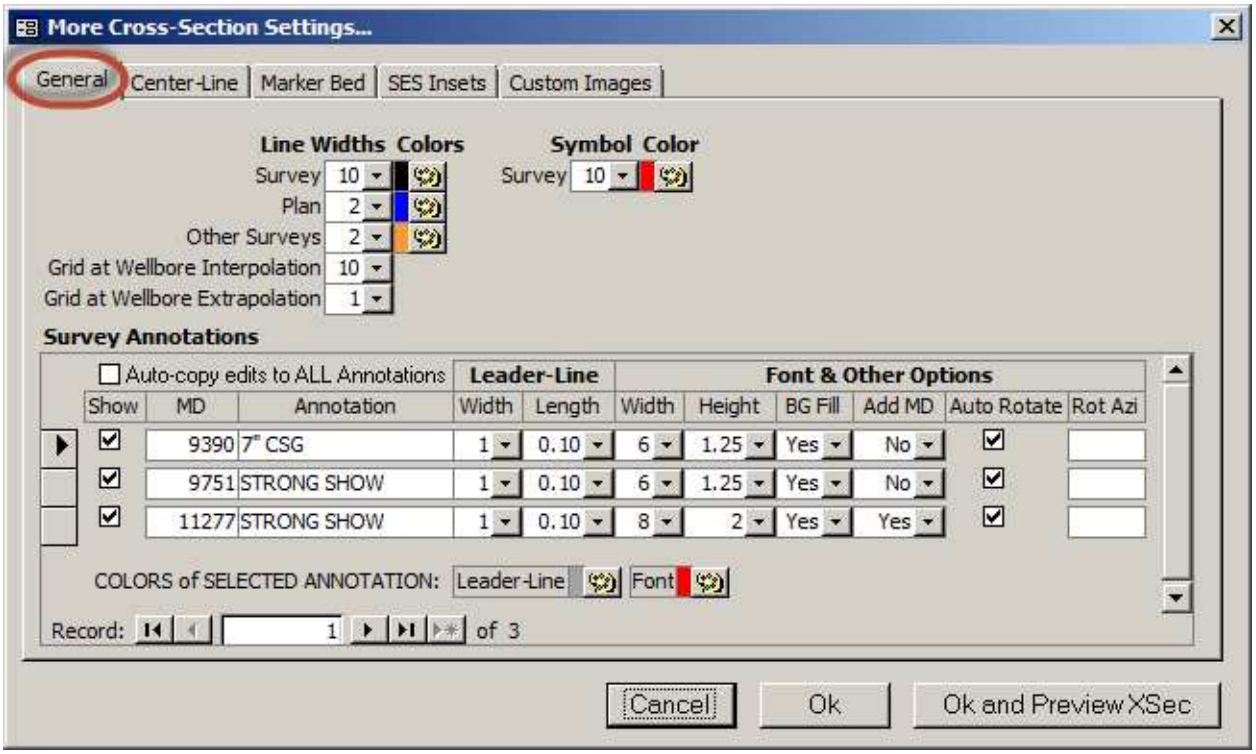
"**P-VSA**" – interpolate Grid data at "future" X-Y's along the selected Plan. If valid Plan data are not available for any reason at required locations of interest, interpolate Grid data at X-Y's along a line calculated from survey (North, East) at total depth and oriented along an azimuth equal to vertical section azimuth.

"**Azi**" – interpolate Grid data at X-Y's along a line calculated from survey (North, East) at total depth and oriented along the azimuth at survey total depth.

"**VSA**" – interpolate Grid data at X-Y's along a line calculated from survey (North, East) at total depth and oriented along an azimuth equal to vertical section azimuth.

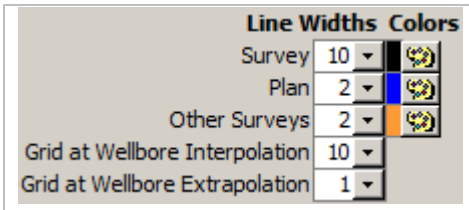
Depending on multiple factors including map view well plan complexity, closeness of drilling relative to plan at survey TD, and the point of drilling progress along the general well plan, discontinuities understandably may be present between "Interp" and "Extrap" surface(s) near Survey TD. Extrapolated well path locations are always to some degree speculative and thus imperfect. Using Grid data "Extrap" should be interpreted within the realm of general drilling guidance and various modeling uncertainties.

General – More Settings

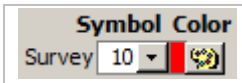


As shown above, **General** Main Plot Settings have additional feature properties that are accessible through the respective "other properties" button () from Cross-Sections screen. These properties are described below.

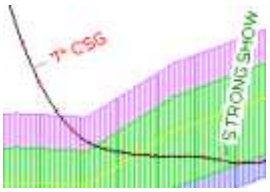

With the intention of saving the user time ☺, the dropdown boxes from all tabs of "More Cross-Section Settings..." dialog (excluding those on subforms, such as "Survey Annotations" shown above) will automatically "open" to display their options when the respective text box receives the focus. Clicking the dropdown box itself  instead of within the text box effectively cancels the dropdown and may give the impression that the dropdown box is not correctly functioning by effectively requiring two clicks. Therefore, the **quickest/best way to see dropdown box options is to click inside the text box portion of the dropdown box from "More Cross-Section Settings..." dialog**.



Use the respective dropdown box to set the line width in pixels of Survey, Plan, Other Surveys, Grid at Wellbore Interpolation, and Grid at Wellbore Extrapolation. Use the respective color palette to set the line color of Survey, Plan, and Other Surveys. Note: Grid surface line colors are set from GRIDS screen.



A solid circle is posted at directional survey stations on the main plot of the cross section. Use the dropdown box to set the circle radius in inch 1000ths. Use the color palette to set the circle color.



A "Survey Annotation" is a general note associated with a measured depth (MD) of a Survey dataset. The note may be posted on the cross section with a leader line connecting the respective location along the Survey to the start of the note text. Survey annotations are first entered from Surveys screen, upper-right input table, and the directional survey then calculated. Survey annotations also display on Surveys screen vertical section view. "Survey Annotations" table on "More Cross-Section Settings..." dialog contains single annotation-level control of how annotations are displayed on the main plot of the cross section.

Survey Annotations

	Auto-copy edits to ALL Annotations		Leader-Line		Font & Other Options					
	Show	MD	Annotation	Width	Length	Width	Height	BG Fill	Add MD	Auto Rotate	Rot Azi
▶	☑	9390	7" CSG	1	0.10	6	1.25	Yes	No	☑	
	☑	9751	STRONG SHOW	1	0.10	6	1.25	Yes	No	☑	
	☑	11277	STRONG SHOW	1	0.10	8	2	Yes	Yes	☑	

COLORS of SELECTED ANNOTATION: Leader-Line Font

Record: 1 of 3

☐ Auto-copy edits to ALL Annotations Check "Auto-copy edits to ALL Annotations" to apply any single leader-line or font/other property change to all other annotations.

COLORS of SELECTED ANNOTATION: Leader-Line Font A black arrow is displayed on the far left "row" to indicate the currently selected annotation. To change the leader-line color or the annotation font color, click the respective color palette button with the correct annotation selected.

Show
☑ Check "Show" to display the annotation on the cross section. Uncheck "Show" to hide the annotation.

MD	Annotation
9390	7" CSG

"MD" is the tagged measured depth and "Annotation" is the display text. MD may not be changed from this screen, but instead may be changed from Surveys screen (upper right data input table) and the survey then re-calculated when applicable. "Annotation" display text may be changed directly from this screen.

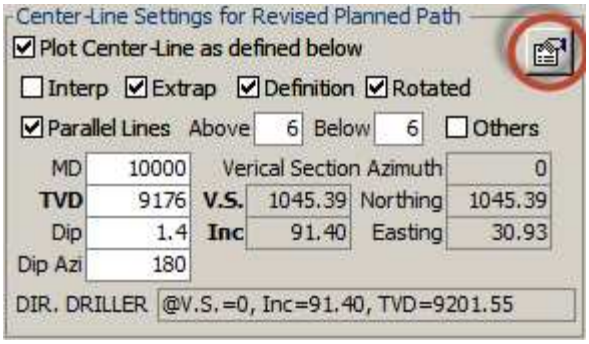
Leader-Line	
Width	Length
1	0.10

Select the leader-line line width in pixels and line length in inches.

Font & Other Options					
Width	Height	BG Fill	Add MD	Auto Rotate	Rot Azi
6	1.25	Yes	No	☑	

Annotations are drawn with lines using a custom-designed font we created, in order to enable rotated text capabilities. Select the annotation font line width in pixels, and font height adjustment factor in fraction of default size. "BG Fill" is an option to place the annotation on a white background. "Add MD" is an option to automatically insert the measured depth into the annotation text. Check "Auto Rotate" to place the annotation parallel to the survey well path tangent at the respective MD (the leader-line is perpendicular to the well path). Uncheck "Auto Rotate" and enter "Rot Azi" (rotation azimuth) to manually set the rotation angle of the annotation text on the cross section.

13.4.2 Center-Line Settings for Revised Planned Path



Horizontal drilling operations may require planned well path revisions from time-to-time, such as during the landing and/or after local geologic structure has been gleaned from geosteering interpretation. To communicate a new well plan to operations, a fully bona fide industry-convention-following well plan may be created using **7. SES Screen – PLANNER** and displayed on the cross section. However, a simpler alternative to accomplish this task—for cross section purposes when a sloping plane will work—employs the SES "Center-Line" feature described in this section.

The "Center-Line" feature of SES Cross-Sections screen is more precisely described as a "Center-Plane", that is, a single general horizontal/dipping 3D plane that is "cut" along the actual survey/wellbore path over the "Interp" interval and then for the "Extrap" portion is sliced along the vertical section line. The 3D plane definition—defined like a 3DSB—is transformed into the lingo required by the directional driller, with respective corrections into the apparent domain automatically made when applicable as math and logic dictate.

Determining the preferred Center-Line orientation is a subjective and speculative undertaking. Updating the planned drill path may occur once or twice (or even dozens of times) during drilling depending on a variety of factors and on the drilling practices that have evolved in a given field. In some cases simply a new inclination is provided to drilling personnel, but providing a line is always better than providing a future point in space as the next "target".

Please note additional Center-Line Settings for Revised Planned Path are accessible using the "other properties" button ( ) circled above.

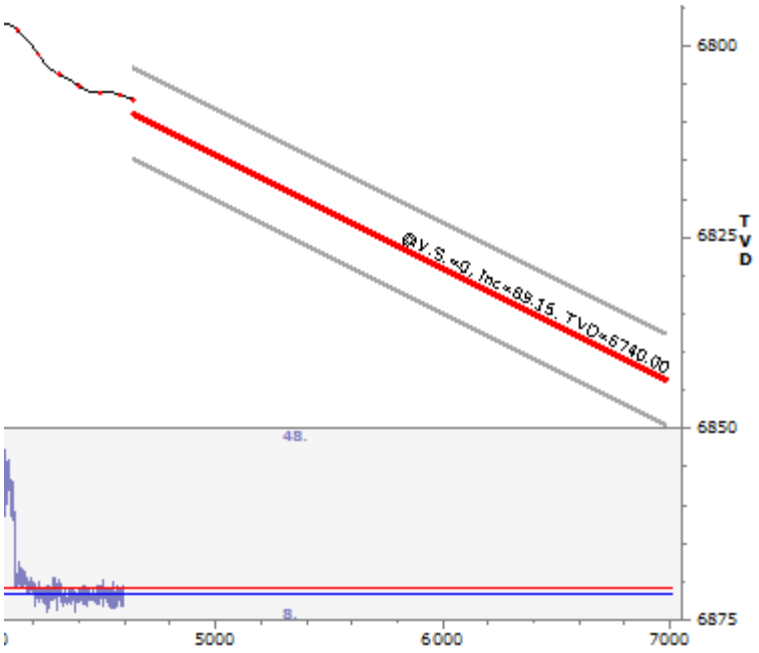
☑ Plot Center-Line as defined below Check "Plot Center-Line as defined below" to calculate and post a cut or slice target line, derived from a 3D plane that represents a planned drilling surface.

☑ Interp Check "Interp" to plot the Center-Line along the surveyed portion of wellbore. For "Interp", the displayed Center-Line path is along the "as-drilled" portion and may therefore display curvature depending in general on the non-linear nature of the surveyed path in map view. This is always true when using MD Mode, but only true using Vertical Section Mode if the Center-Line Dip Azimuth is not set parallel to the survey Vertical Section Azimuth. However, normally, Center-Line Dip Azimuth is indeed chosen to be set parallel to survey Vertical Section Azimuth and is defaulted as such by SES.

☑ Extrap Check "Extrap" to plot the Center-Line beyond survey total depth. For "Extrap", Vertical Section Mode is required and the displayed Center-Line path is a plot of the Center-Line plane at X-Y's along the remaining portion of the vertical section line, that is, along the projected path between survey total depth and the right-side axis extent of the cross section. Some data conditions may produce a visual discontinuity in the Center-Line between "Interp" and "Extrap" because of the leap from actual X-Y at TD to its coupled X-Y location along the vertical section line. However, often, for presentation purposes after

some tuning has occurred to determine the preferred Center-Line orientation, "Interp" is hidden and only "Extrap" is displayed.

☑ Definition ☑ Rotated Check "Definition" to post the 2D mathematical representation of the Center-Line on the cross section, near the right-side/end of the Center-Line. Check "Rotated" to post the definition using rotated text parallel to the Center-Line. This feature allows for simple and accurate communication with directional drilling personnel, straight from the cross section.



☑ Parallel Lines Above 6 Below 6
Check "Parallel Lines" to add one or two parallel lines about the Center-Line to help communicate a preferred vertical drilling window. Enter the preferred "Above" and "Below" amounts—which are simply ΔTVD-up and ΔTVD-down—to set the size of the drilling window (see adjacent picture for an example).

☑ Others Check "Others" to display Center-Lines from all other Cross-Section datasets that post the same Survey dataset. Because the Center-Line is stored with the Cross-Section dataset and because multiple Cross-Section datasets may easily be created, a record of planned path changes may be preserved (if desired) and post-well tendencies observed/analyzed.

MD	10000			Verical Section Azimuth	0
TVD	9176	**V.S.**	1045.39	Northing	1045.39
Dip	1.4	**Inc**	91.40	Easting	30.93
Dip Azi	180				

Enter control point "MD", "TVD", "Dip" and "Dip Azi" to define a 3D plane (the Center-Line plane) that represents a planned drilling surface. "Vertical Section Azimuth" is inherited from the Survey. "Northing", "Easting", and "V.S." (vertical section) correspond to the entered MD value and the Survey. "Inc" is the corresponding apparent inclination angle of the 3D plane as sliced by the vertical plane defined by vertical section azimuth and at N=E=V.S.=0 (surface).

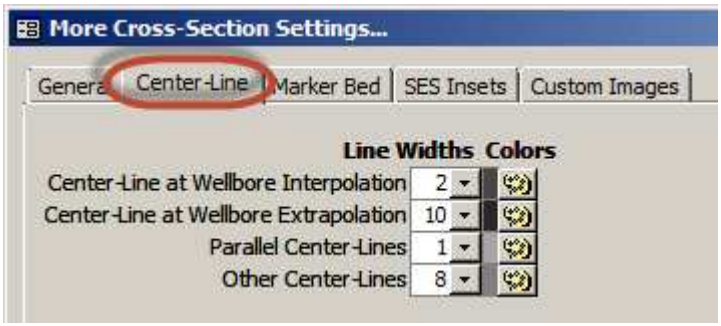
Normally, control point "**TVD**" and "**Dip**" are modified until the resulting Center-Line orientation is preferable. This may require iterating with cross section inspection. Setting MD=0 is common.

If the Center-Line dips in the wrong direction (e.g., up-dip when down-dip is desired), **toggle "Dip Azi" by 180 degrees by double-clicking** inside the "Dip Azi" text box.

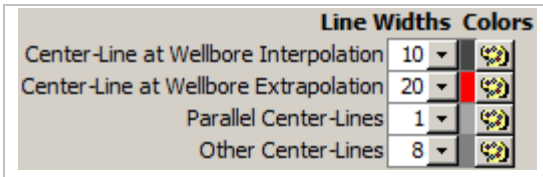
"Dip Azi" is normally chosen to be parallel to vertical section azimuth, and when so, the 3D plane intersected by the vertical section azimuth plane is the Center-Line. However, any azimuth is supported.

DIR. DRILLER @V.S.=0, Inc=91.40, TVD=9201.55 Text offsetting "DIR. DRILLER" is the mathematical definition of the Center-Line plane along the vertical section azimuth plane. With this information the directional driller (DD) can represent the analyst's preferred drilling path in the DD's software. This text may be posted on the cross section.

Center-Line – More Settings

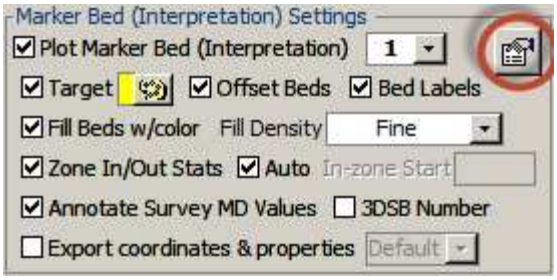


As shown above, **Center-Line** Settings for Revised Planned Path have additional feature properties that are accessible through the respective "other properties" button () from Cross-Sections screen. These properties are described below.

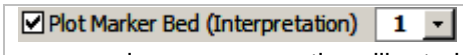


Use the respective dropdown box to set the line width in pixels of Center-Line at Wellbore Interpolation, Center-Line at Wellbore Extrapolation, Parallel Center-Lines, and Other Center-Lines. Use the respective color palette to set respective line colors.

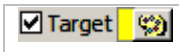
13.4.3 Marker Bed (Interpretation) Settings



A "Marker Bed" dataset refers to a collection of 3DStratBlocks (3DSBs) that defines one geologic interpretation of strata, as calibrated using ParamTuner (see **11. SES Screen – GEOSTEER – ParamTuner**). At a minimum there is a single "payzone" layer with a top and base and "target line" or "sweet spot" horizon between the top and base. Above and/or below the marker bed surface, multiple additional layers are normally stacked for stratigraphic cross section visualization. Please note additional Marker Bed (Interpretation) Settings are accessible using the "other properties" button () circled above.



Check "Plot Marker Bed (Interpretation)" to plot the primary payzone layer, as currently calibrated. Select the Marker Bed dataset of interest to process and draw on the cross section. See "other properties" to set line widths or MD annotation properties to further customize the appearance of the view.



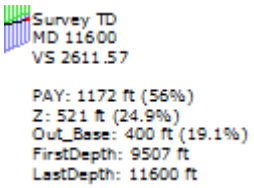
Check "Target" to display a target line within the primary payzone layer. To change the target-line line color to be different than the payzone layer color, click this color palette button. See "other properties" to set the target-line line width in pixels.

☑ Offset Beds Check "Offset Beds" to display stacked beds/layers about the payzone layer, as configured for the Marker Bed. Offset bed properties are set from Geosteer screen, Tab View, Bed Thickness & Color tab. See "other properties" to set the offset bed boundary line width in pixels.

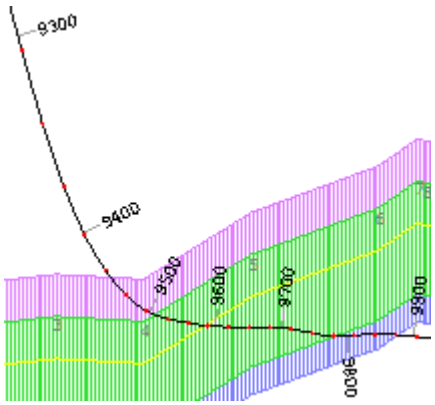
☑ Bed Labels Check "Bed Labels" to post defined bed/layer/zone names on the cross section. Bed/layer/zone names are entered from Geosteer screen, Tab View, Bed Thickness & Color tab. Label font color is inherited from the respective layer color and is automatically altered if insufficient contrast difference against a white background is detected.

☑ Fill Beds w/color Fill Density Fine Check "Fill Beds w/color" to shade each layer's region with colored vertical lines across the display. Select a "Fill Density" from the dropdown box to set the effective frequency of vertically drawn lines used to create the shading appearance. See "other properties" to set the fill vertical-line line width in pixels.

☑ Zone In/Out Stats ☑ Auto In-zone Start Check "Zone In/Out Stats" to compare the Survey path to the geologic interpretation and report the amount of wellbore length—and its percentage—drilled in each defined bed layer. The trigger to start assessing zone statistics (reported as "FirstDepth") is automatically determined if "Auto" is checked. The auto trigger mechanisms include: any Survey MD within the payzone layer or deeper; TVD decreasing (i.e., up-dip drilling); or survey inclination decreasing after 80 degrees wellbore inclination has been reached. Uncheck "Auto" to override auto and manually enter FirstDepth. Entered bed layer names are used if available, otherwise SES-generated zone names (Up1, Dn2, etc.) are used. Any wellbore length penetration below the deepest defined layer is termed "Out_Base". Zone stats are posted under "Survey TD Values".



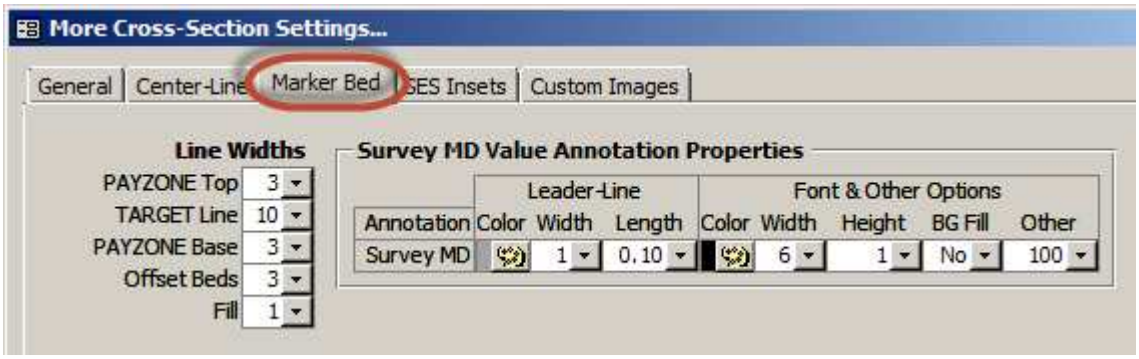
☐ Annotate Survey MD Values Check "Annotate Survey MD Values" to post MD as annotations along the Survey wellbore path. This feature is available in both MD and Vertical Section Mode. The leader line is drawn perpendicular to the Survey wellbore path at the respective MD (see adjacent picture for an example). See "other properties" to set a variety of display options including leader-line line width/length/color, font settings, background, and the delta-MD posting interval.



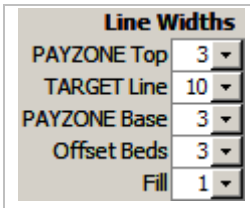
☐ 3DSB Number Check "3DSB Number" to post the 3DStratBlock number along the cross section at roughly the payzone layer height near the start of the 3DSB. Please see adjacent picture for an example.

☑ Export Coordinates, Propertie Default CSV Click "Export" and then Print-Preview button to generate a text file populated with data from the cross section. This feature has multiple options and file formats. Please see **13.5 Export Cross Section Data for 3rd Party Software** for in-depth discussion.

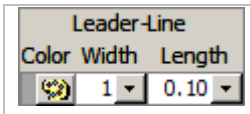
Marker Bed – More Settings



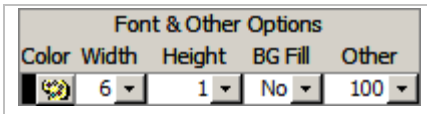
As shown above, **Marker Bed** (Interpretation) Settings have additional feature properties that are accessible through the respective "other properties" button () from Cross-Sections screen. These properties are described below.



Use the respective dropdown box to set the line width in pixels of payzone top, target line, payzone base, offset bed boundaries, and vertical fill line.

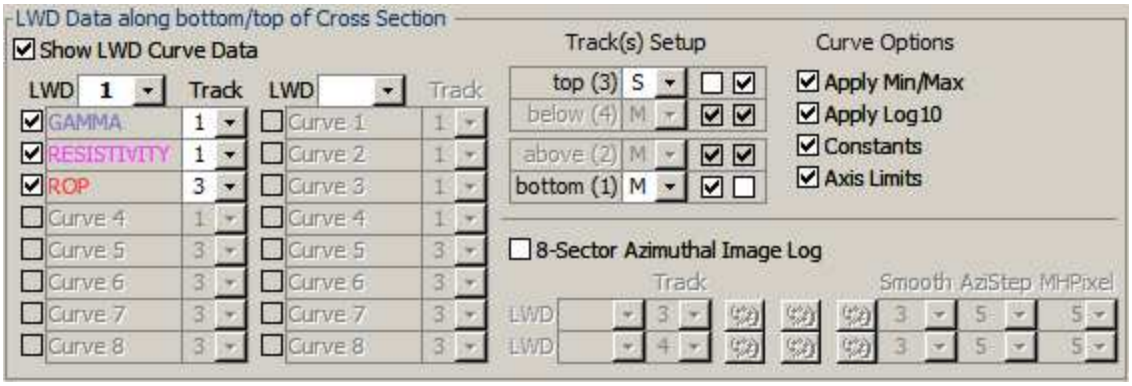


Set the leader-line line color using the color palette button. Select the leader-line line width in pixels and line length in inches.

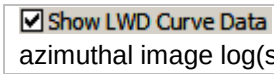


MD annotations are drawn with lines using a custom-designed font we created, in order to enable rotated text capabilities. Set the font color using the color palette button. Select the font line width in pixels, and font height adjustment factor in fraction of default size. "BG Fill" is an option to place the MD annotation on a white background. The MD annotation orientation is parallel to the well path tangent at the respective MD (the leader-line is perpendicular to the well path). Under "Other", select the uniform frequency at which to post MDs on the cross section.

13.4.4 LWD Data along Cross Section (Standard Curves)

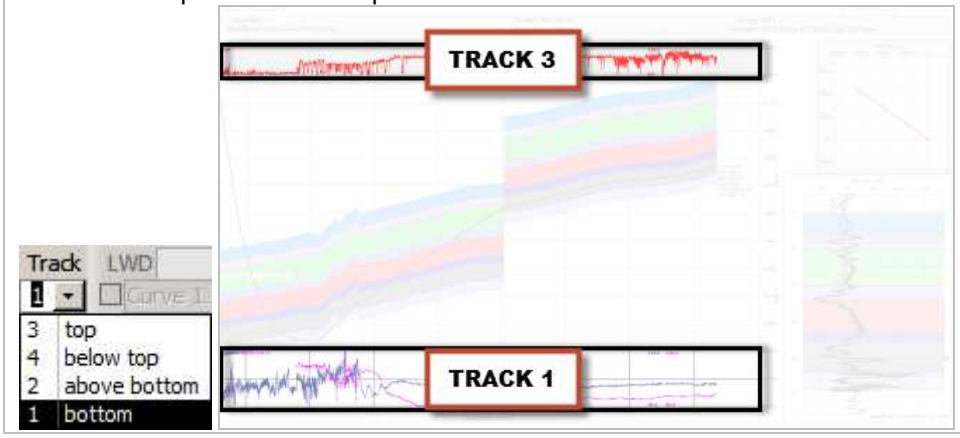


"Logging While Drilling" (LWD) data in SES are any quantitative MD-associated measurement to be graphed on a cross section. Data from LWD datasets may be plotted as regular line graphs or as azimuthal image logs. LWD data are graphed near the top and/or bottom of the main cross section plot. Up to 2x8=16 LWD data curves in any combination may be plotted on one to four tracks.

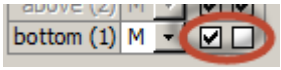


Check "Show LWD Curve Data" to plot respective LWD data curves and/or azimuthal image log(s) that are checked to be graphed.

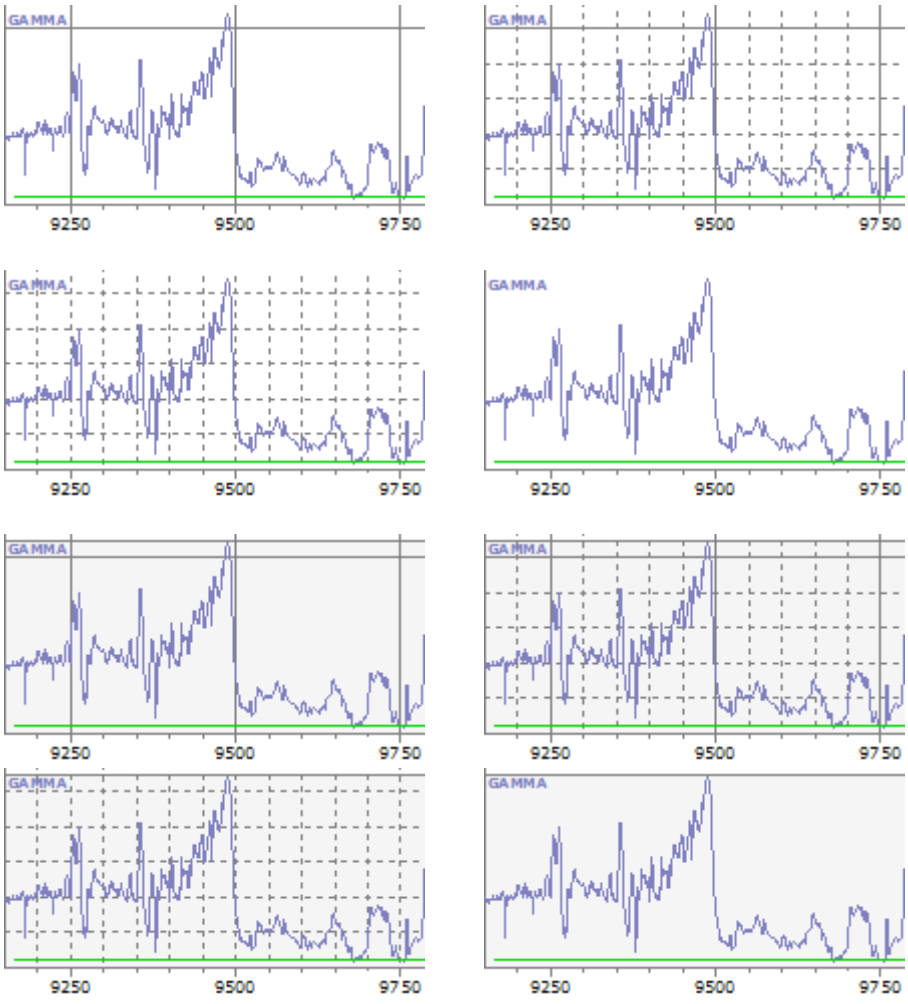
Data from two LWD datasets may be plotted on a cross section; thus, up to 2x8=16 curves. Select the desired LWD dataset from the dropdown box to list its data curves. Check the box just left of the curve name to display it; select the track from the dropdown box to control where the respective curve is plotted.

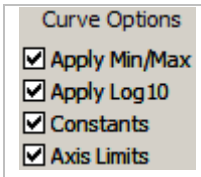


"**Track(s) Setup**": four tracks are available on which to graph LWD data on the cross section. Track 1 ("bottom") runs along the bottom of the main plot. Track 2 ("above") is stacked above Track 1 (or above where Track 1 would exist if something was being posted on it). Track 3 ("top") runs along the top of the main plot. Track 4 ("below") is stacked below Track 3 (or below where Track 3 would exist if something was being posted on it). Only tracks currently in-use are enabled.



Two display options accompany each track: "show gridlines through track" and "show gray background behind track". If "show gridlines through track" is checked and if major gridlines and/or minor gridlines are checked under **13.4.1 General Main Plot Settings**, then the respective track will essentially share gridlines with the main plot. If "show gray background behind track" is checked, then a border around the track is displayed and the area filled with a gray background. Examples of the eight possible combinations are provided below.



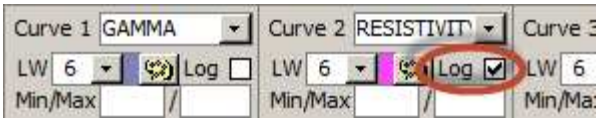


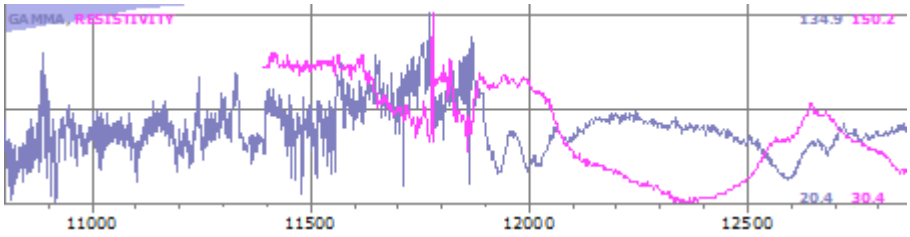
"**Curve Options**": multiple display options are available to control various attributes of the LWD curve data presentation.

"**Apply Min/Max**" – check this option to truncate curve data to its minimum and/or maximum values as configured for the respective curve from LWD screen. If unchecked, axis limits are auto-scaled to display all curve data without margin and axis limits are single curve dependent. This option also accordingly affects image log generation.

If data from focused/azimuthal tool measurements are being graphed as standard curves, "Apply Min/Max" should be checked AND identical Min/Max preferred values should be entered for each respective LWD data curve from LWD screen to ensure apples-to-apples comparison of like signal.

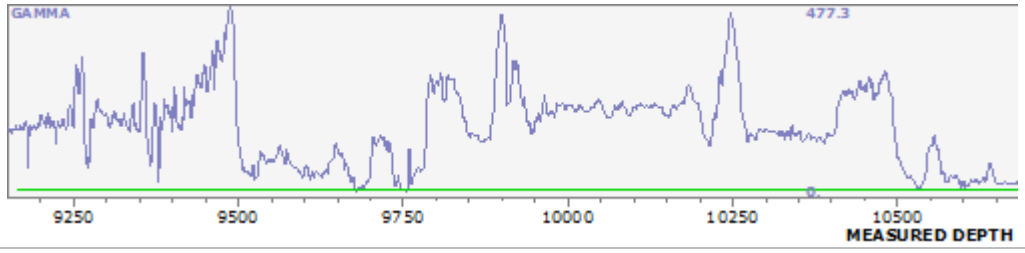
"**Apply Log10**" – check this option to enforce a Log10 scale format if the LWD data curve is configured for such from LWD screen. If unchecked, all curve data are plotted on a linear scale. Log10 and linear LWD data curves may be displayed on the same track. Gridlines are not affected by this setting. In the example below, Gamma is plotted on a linear scale and Resistivity is plotted on a Log10 scale, and no Min/Max values are set.



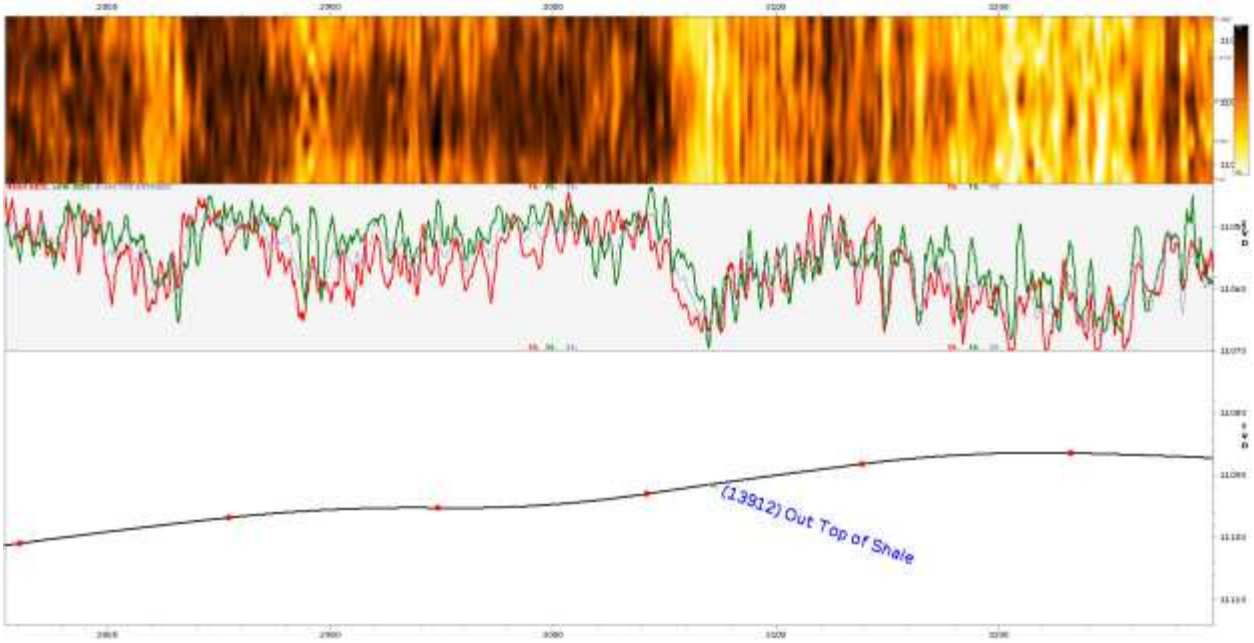


"**Constants**" – check this option to post a horizontal line at constant values entered for the respective LWD data curve from LWD screen. See green line in picture below.

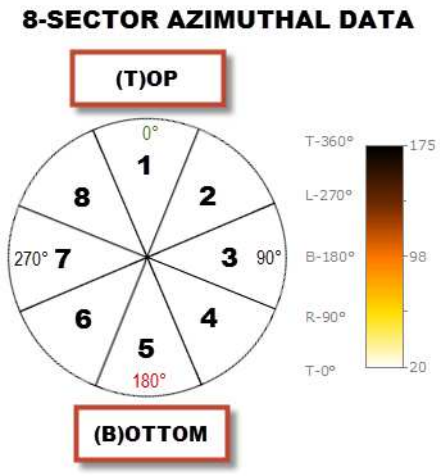
"**Axis Limits**" – check this option to post labels of the respective LWD curve axis min/max limits at the top and base of the respective track. See "477.3" and "0." in picture below.



13.4.5 LWD Data along Cross Section (Azimuthal Image Logs)



LWD data from azimuthal signal measurements—of gamma ray, resistivity, etc.—may be presented in image log format on one or two tracks of the main cross section plot. A borehole image log is a representation of scalar data in a special format that provides insight about how measurements vary circumferentially about the wellbore and along the wellbore.

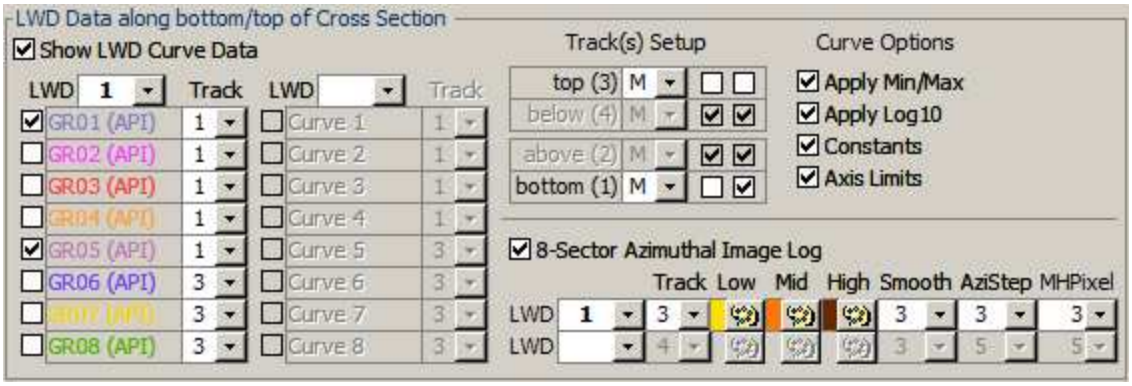


As shown in the adjacent sketch, typical convention for 8-sector data is sector one is wellbore high-side ("top") and sector 5 is wellbore low-side ("bottom"). Image log pixels corresponding to MD and azimuthal location about the wellbore are colored in proportion to signal magnitude, thereby enabling the analyst to observe contrast differences between—most importantly—high-side and low-side readings. On the above image log where MD increases from left to right, the upper and lower edges of the image log correspond to the top of the wellbore and the center of the image log corresponds to the bottom of the wellbore.

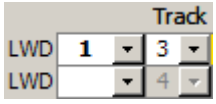
Azimuthal LWD borehole measurements may help discern and/or confirm wellbore stratigraphic location at MD, for example, when high-side and low-side values significantly differ near a suspected stratigraphic bed boundary. This type of clarity is possible to obtain through an image log or through direct graphing of high-side and low-side measurement values. However, an image log makes for an entirely different visual experience and has other attributes of value. To learn more about general borehole imaging technology, please see Atefeh Shahinpour's September 2013 thesis.

If only 4-sector (up/down and left/right) azimuthal data are available, make sectors 2=8=1 (high-side) and sectors 4=6=5 (low-side) to produce a *similar* image as would 8-sector azimuthal data. This data manipulation can be performed within SES when importing LWD data from LWD screen or through column copy/paste from LWD screen.

In SES, data smoothing in three dimensions is performed in order to generate an image log for specific display from "raw" numeric sector-at-depth data. The smoothing dimensions include MD, azimuthal binning at which to interpolate to produce data between known sector values, and then with respect to horizontal pixilation control on the canvas. The analyst has control of three smoothing parameters and color spectrum characteristics.



8-Sector Azimuthal Image Log Check "8-Sector Azimuthal Image Log" option to display an image log on the main plot of the cross section.



Select the LWD dataset from the dropdown box that contains LWD 8-sector azimuthal signal data from which to generate an image log. One or two image logs may be generated on the cross section using the same or different datasets. Select the respective track on which to post the image log. Using the same LWD dataset on two different tracks allows for faster experimentation with altering display options described below. To clear/remove an LWD dataset selection, delete its number from inside the text box.

LWD Curve 1 should contain sector 1 (high-side) data, Curve 3 should contain sector 3 (right-side) data, Curve 5 should contain sector 5 (low-side) data, and so forth. **LWD Curve 1 Min/Max** overrides control of all sector curve data during image log generation and the color spectrum extents, when curve option "Apply Min/Max" is checked.

The image log color spectrum varies from white (0%; minimum) to black (100%; maximum). "Primary" colors within the color spectrum may be set using the respective color palette button for "Low" (25%), "Mid" (50%), and "High" (75%). An SES algorithm then colors pixels accordingly.

Select a "Smooth" value to control data smoothing in the MD domain. This value represents the window size—number of data points—for central moving average smoothing. Select 1 for no smoothing.

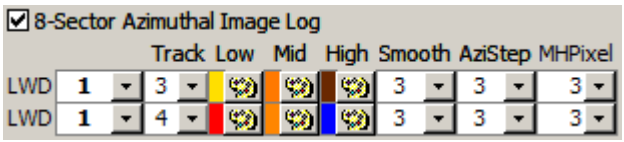
AziStep

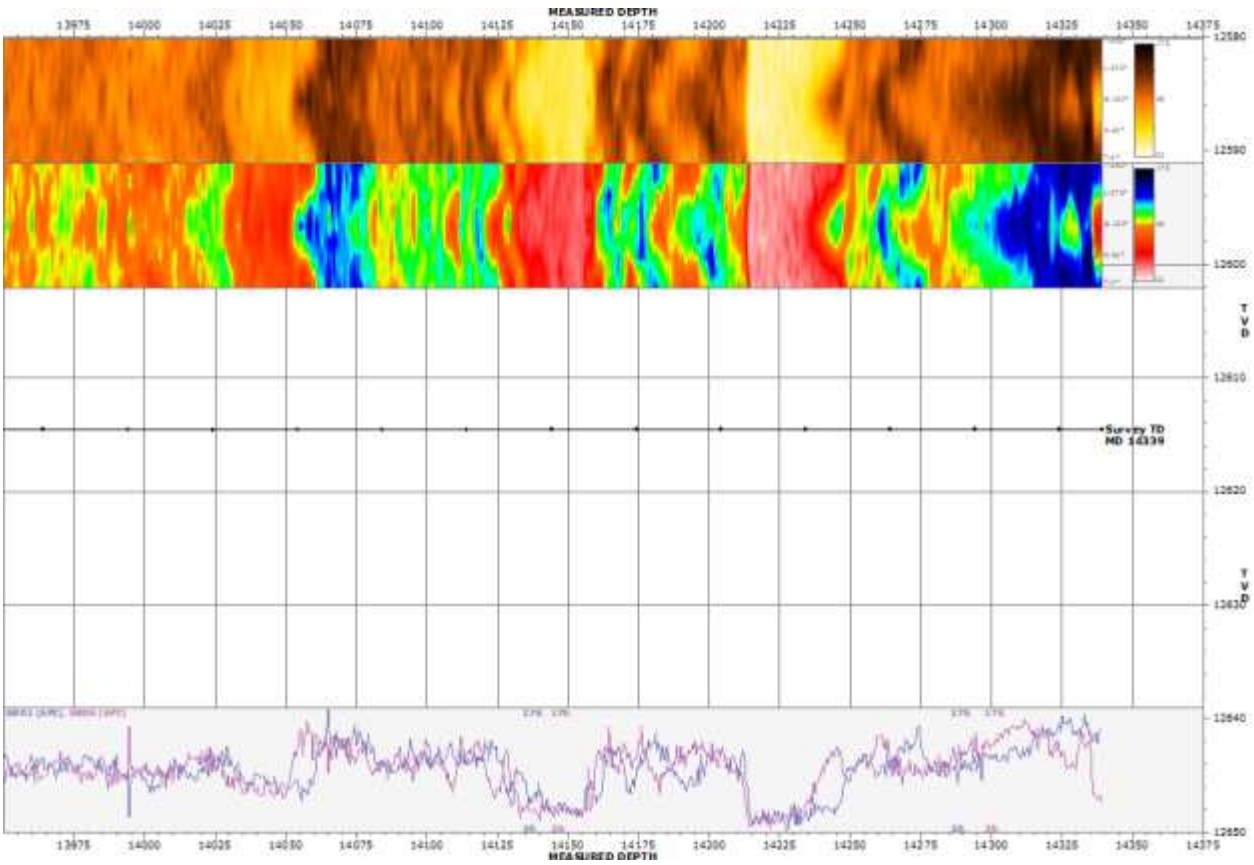
3 Select an "AziStep" value to set the azimuthal bin size in degrees. For example, 8-sector azimuthal data has known values at every 45 degrees. If azimuthal bin size of 15 degrees is selected, there will be 360/15=24 bins about the wellbore of which 8 are inputs and 16 are calculated with interpolation. This parameter affects the image "pixel" in the "vertical" direction.

MHPixel

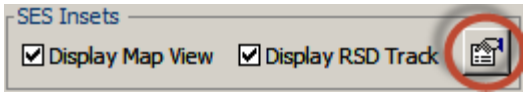
3 Select an "MHPixel" value to set the minimum horizontal "pixel" width in inch 1000ths. Discussion: MD and azimuthal binning generate "raw pixels", "horizontally" and "vertically", which are then again "lumped" horizontally to be displayed on the cross section. This final lumping step depends on the total MD range of displayed wellbore and essentially the physical length on which the image log is printed, in order to create a reasonable display memory-size-wise. Large total MD range and a small MHPixel setting value may require significant on-screen video resources and generate relatively large cross section PDF file sizes when printed.

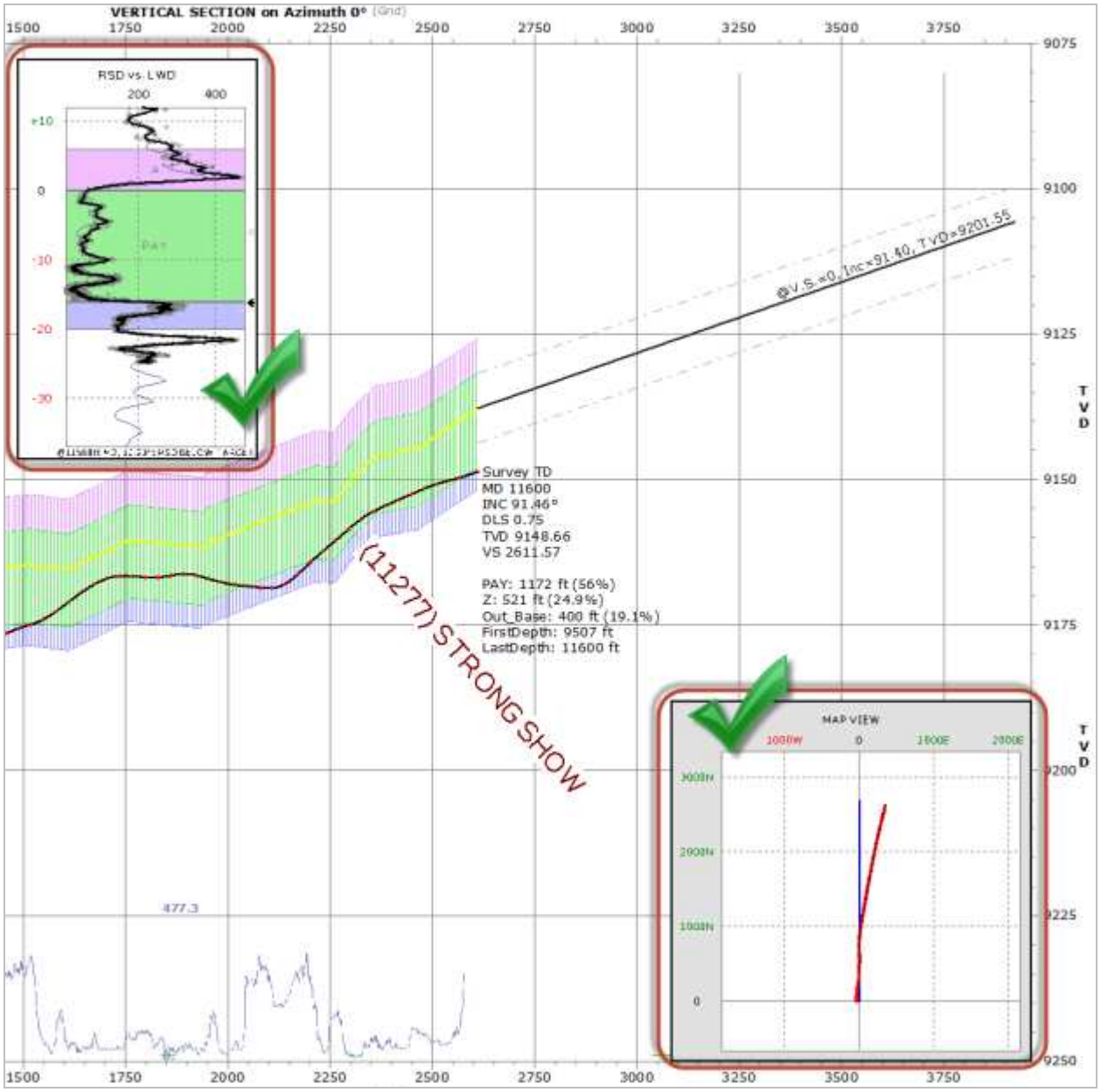
Over roughly 400 feet of wellbore, two example color setups (with identical gamma ray data and smoothing settings) follow.





13.4.6 SES Insets

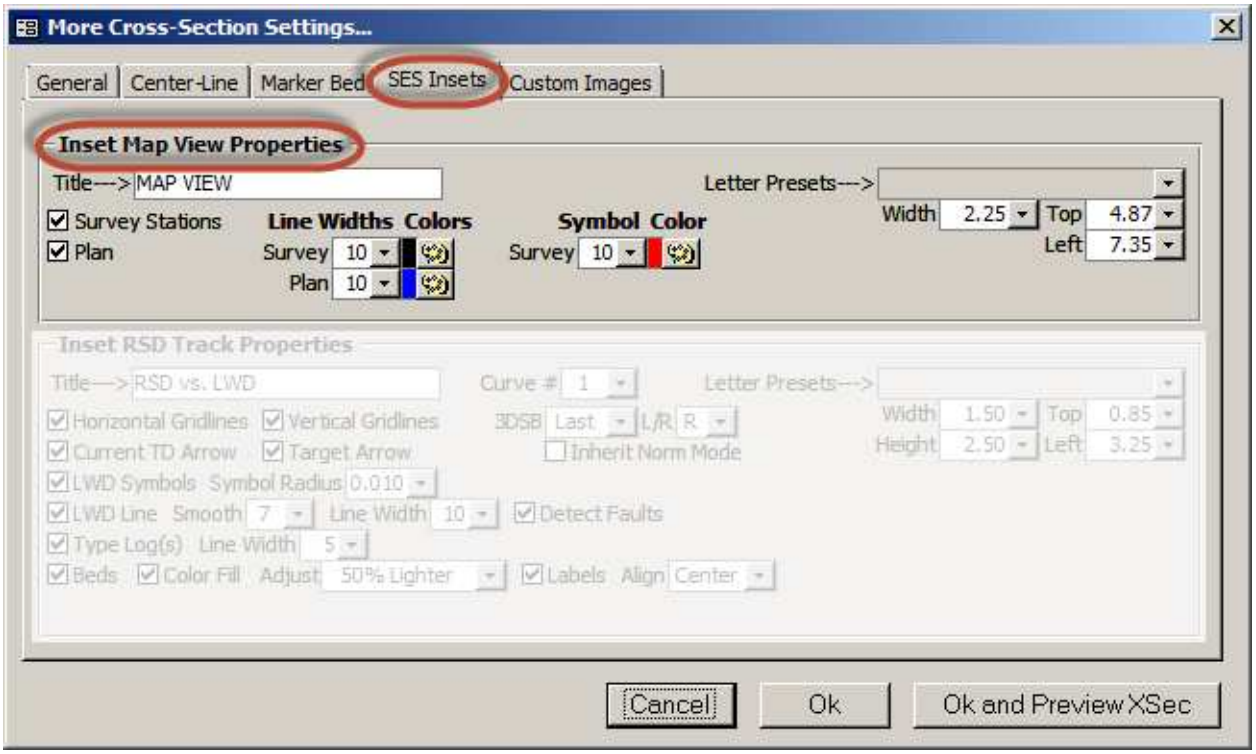




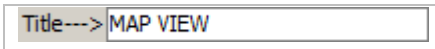
An "SES Inset" is a free-standing graph of information with coordinate axes that are independent from the main plot of the cross section. The inset may be aligned to overlay the main plot or it may be configured to reside along the right side of the canvas (by reducing the width of the main plot).

All SES Insets configuration settings are accessible through the "properties" button () circle above from Cross-Sections screen. Two insets are currently available: a map view of directional surveys and well plans, and a log strip that presents a look at the geologic interpretation in the relative stratigraphic depth (RSD) domain. Their display settings are described in the following sub-sections.

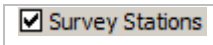
13.4.6.1 Inset Map View Properties



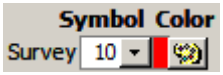
Inset Map View provides a top-down horizontal view of the Survey and Plan. The inset may be arbitrarily sized (width equal height) and the top/left corner coordinates may be set for inset placement on the canvas. Inset Map View properties are described below.



Enter text into "Title" to set the main title on the inset map view.



Check "Survey Stations" option to post unfilled circular symbols at directional survey station locations.

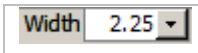


Select the circle's radius in inch 1000ths from the "Survey" "Symbol" dropdown box and use the color palette button to control its color.

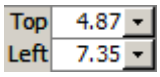
A line is posted along the path of the directional survey. Use the dropdown box to set the Survey line width in pixels. Use the color palette button to set Survey line color.

Check "Plan" option to post a line along the planned path.

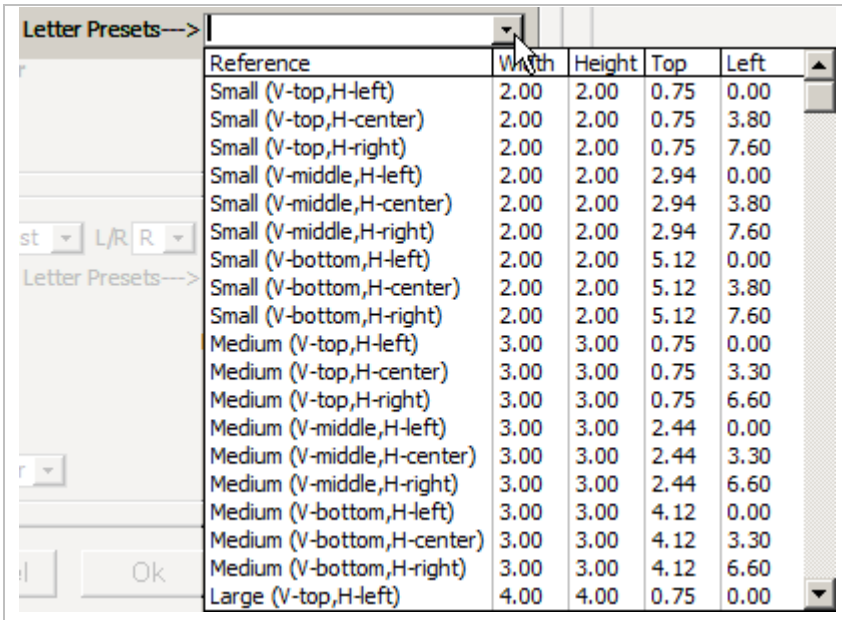
Use the dropdown box to set the Plan line width in pixels. Use the color palette button to set the Plan line color.



Enter or select the inset width ("Width") in inches. Inset height is made equal to inset width. See "Letter Presets" below.

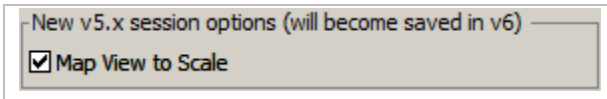


Enter or select the top ("Top") and left ("Left") inset corner coordinates in inches to control the placement of the inset on the canvas. See "Letter Presets" below.

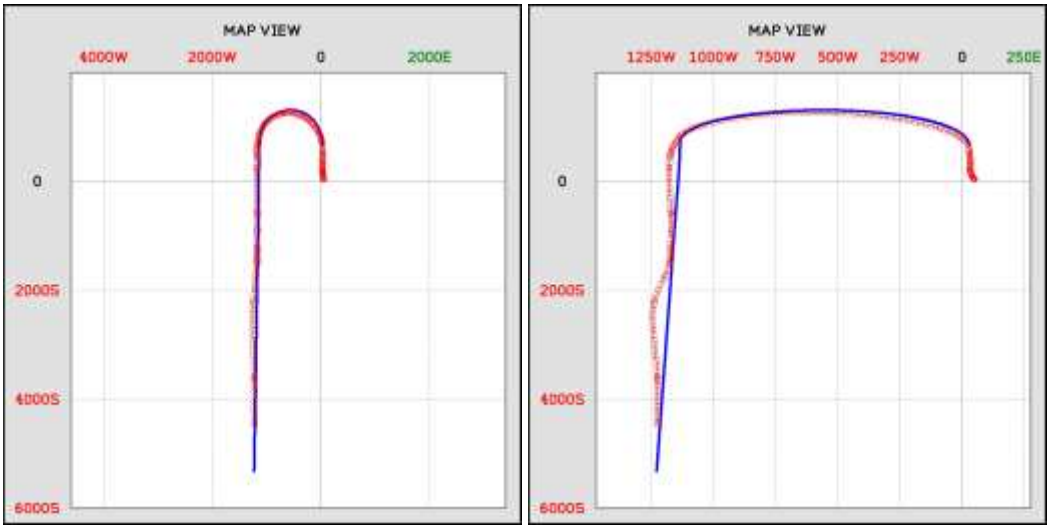


Reference	Width	Height	Top	Left
Small (V-top,H-left)	2.00	2.00	0.75	0.00
Small (V-top,H-center)	2.00	2.00	0.75	3.80
Small (V-top,H-right)	2.00	2.00	0.75	7.60
Small (V-middle,H-left)	2.00	2.00	2.94	0.00
Small (V-middle,H-center)	2.00	2.00	2.94	3.80
Small (V-middle,H-right)	2.00	2.00	2.94	7.60
Small (V-bottom,H-left)	2.00	2.00	5.12	0.00
Small (V-bottom,H-center)	2.00	2.00	5.12	3.80
Small (V-bottom,H-right)	2.00	2.00	5.12	7.60
Medium (V-top,H-left)	3.00	3.00	0.75	0.00
Medium (V-top,H-center)	3.00	3.00	0.75	3.30
Medium (V-top,H-right)	3.00	3.00	0.75	6.60
Medium (V-middle,H-left)	3.00	3.00	2.44	0.00
Medium (V-middle,H-center)	3.00	3.00	2.44	3.30
Medium (V-middle,H-right)	3.00	3.00	2.44	6.60
Medium (V-bottom,H-left)	3.00	3.00	4.12	0.00
Medium (V-bottom,H-center)	3.00	3.00	4.12	3.30
Medium (V-bottom,H-right)	3.00	3.00	4.12	6.60
Large (V-top,H-left)	4.00	4.00	0.75	0.00

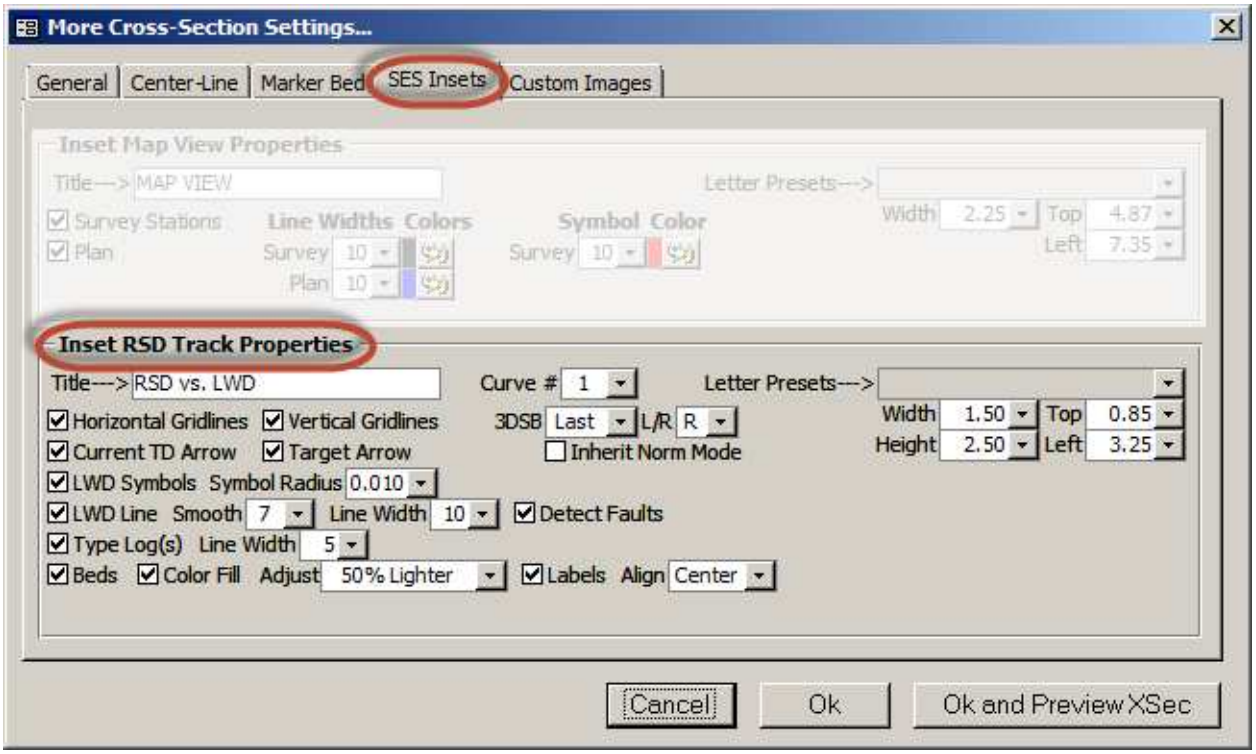
"Letter Presets" (or "Legal Presets" or "A4 Presets") lists a number of automatic placement options to more quickly spot the location of the inset. The list depends on the cross section Paper Size in use. There are three general size options ("Small", "Medium", "Large"), three vertical alignment options ("top", "middle", "bottom"), and three horizontal alignment options ("left", "middle", "right").



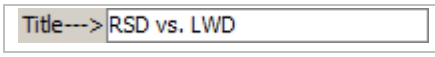
Cross-Sections screen contains a session setting for the Inset Map View feature called "Map View to Scale". An example of its effect is shown below.



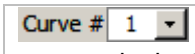
13.4.6.2 Inset RSD Track Properties



Inset RSD (Relative Stratigraphic Depth) Track provides a look into the underlying details of the geologic interpretation (Marker Bed), as interpreted with ParamTuner. The inset may be arbitrarily sized and the top/left corner coordinates may be set for inset placement on the canvas. Inset RSD Track properties are described below.

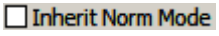


Enter text into "Title" to set the main title on the inset RSD track.



Similar to Geosteer screen and how ParamTuner is loaded, select the data curve to process in the Relative Stratigraphic Depth (RSD) domain. In other words, set which Type Log & LWD curve to graph on the inset RSD track. Curve 1 is most common but in some situations (for example, where both gamma ray and resistivity are being measured downhole) something other than curve 1 may be applicable.

The RSD axis min/max range is inherited from a 3DSB of the Marker Bed, and its corresponding ParamTuner settings. The default 3DSB's min/max range is from the last 3DSB. However, option "3DSB" shown here will also accept entering a specific 3DSB number (for example, 8), or selection "First", which means 3DSB #0. Option "3DSB" is further clarified with either the left ("L") RSD track or right ("R") RSD track since ParamTuner displays two such tracks with different values.



Check "Inherit Norm Mode" option to apply the normalization settings in use for the 3DSB whose settings are being copied to determine RSD axis min/max range on the inset RSD track. If this option is unchecked, "raw" (non-normalized) LWD and Type Log data are plotted on the inset RSD track. See **11.6 Rescale LWD on RSD Tracks (Normalize Mode)** for information about signal normalization.

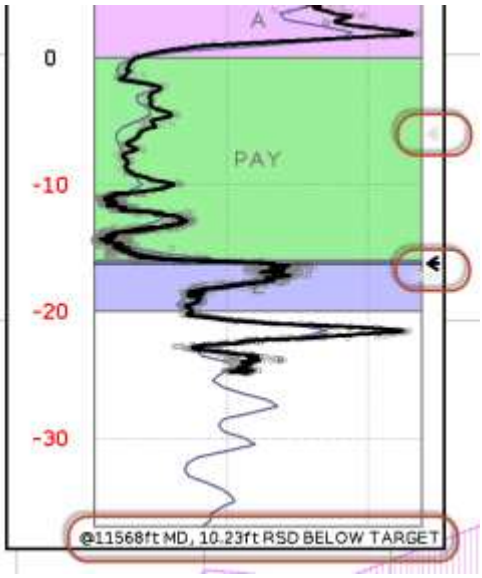
☑ Horizontal Gridlines ☑ Vertical Gridlines Check "Horizontal Gridlines" option to display horizontal gridlines on the inset RSD track. Check "Vertical Gridlines" option to display vertical gridlines on the inset RSD track.

☑ Current TD Arrow Check "Current TD Arrow" option to post:

1) small black arrow in the right margin of the inset RSD track at the RSD corresponding to the current deepest interpreted depth with LWD data ("TD").

2) numeric text reporting the RSD distance from RSD at "TD" to target RSD.

3) text summary of conditions at "TD" (for example, "@11568ft MD, 10.23ft RSD BELOW TARGET") in the bottom margin of the inset RSD track.

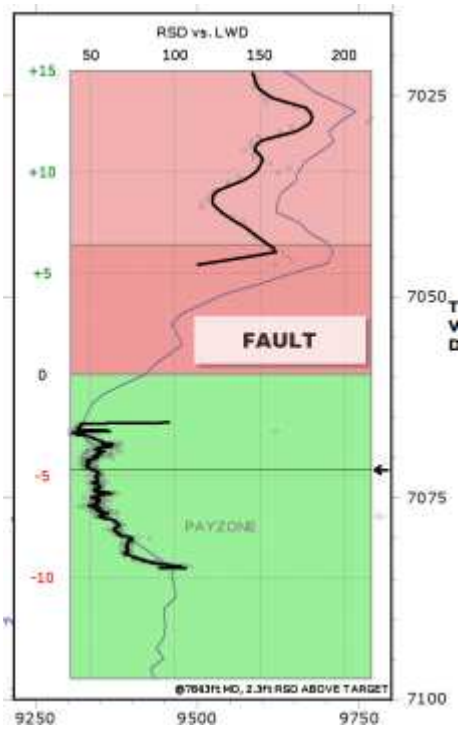


☑ Target Arrow Check "Target Arrow" option to post a small gray arrow in the right margin of the inset RSD track at the RSD corresponding to the target line as set for the Marker Bed (see "Stratigraphic Depth Offset to Target" feature at **10.3 Other Functions/Features** for more information).

The arrows and text described above are intended to be subtle features that normally require zooming to generally expose legible access to these details.

☑ LWD Symbols Symbol Radius 0.010 Check "LWD Symbols" option to post unfilled gray circular symbols of LWD|RSD data being plotted. Select the circle's radius in inches from the "Symbol Radius" dropdown box.

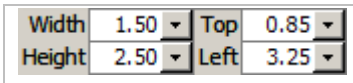
☑ LWD Line Smooth 7 Line Width 10 ☑ Detect Faults Check "LWD Line" option to calculate and post a black smoothed line through the LWD data using a central moving average window. The "Smooth" value from the dropdown box represents the window size—number of data points—for central moving average smoothing. Select 1 for no smoothing. Use "Line Width" dropdown box to set its line width in pixels. Check "Detect Faults" option to apply an algorithm that looks for significant discontinuities in the RSD domain and if found, a respective break in the LWD line is drawn.



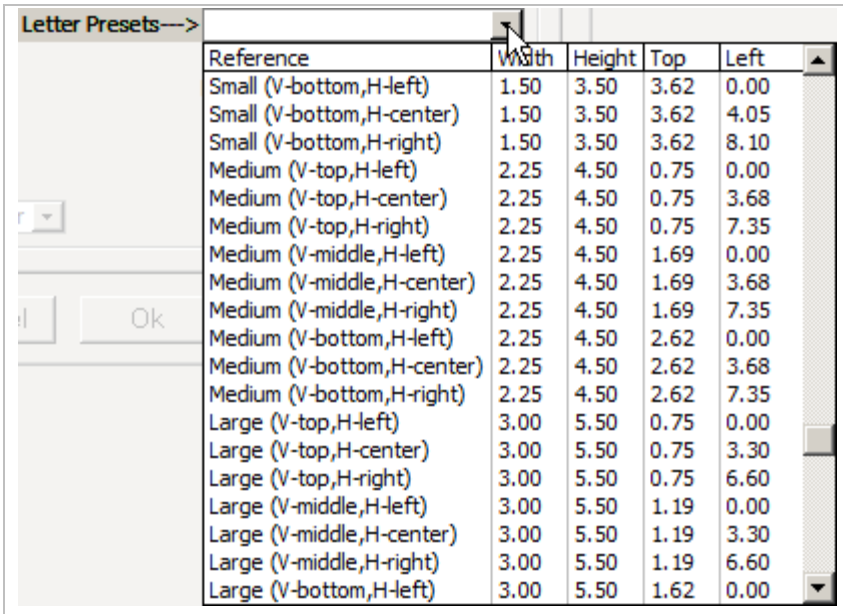
☑ Type Log(s) Line Width 5 Check "Type Log(s)" option to post type log data from Type Log datasets currently checked "Use in ParamTuner" from Type Log screen (see "Use in ParamTuner" feature at **8.3 Other Functions/Features** for more information). Use "Line Width" dropdown box to set its line width in pixels. Type Log line colors are inherited from the respective Type Log dataset.

☑ Beds ☑ Color Fill Adjust 50% Lighter ☑ Labels Align Center Check "Beds" option to draw payzone and offset bed layers within view on the inset RSD track. Check "Color Fill" option to fill the layers with their respective colors as set for the 3DSB. Select "Adjust" option to lighten or darken the fill color as may be desired. Check "Labels" option to include the

respective bed/layer name on the inset RSD track and set the preferred text alignment using "Align" dropdown box. For more information about bed thicknesses/names/colors see **10.3 Other Functions/Features**).



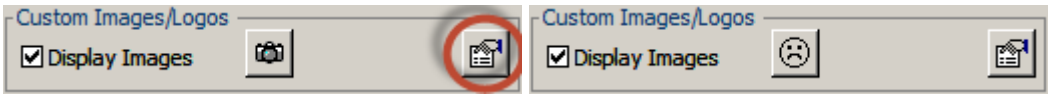
Enter or select the inset width ("Width") and height ("Height") in inches. Enter or select the top ("Top") and left ("Left") inset corner coordinates in inches to control the placement of the inset on the canvas. See "Letter Presets" below.



Reference	Width	Height	Top	Left
Small (V-bottom,H-left)	1.50	3.50	3.62	0.00
Small (V-bottom,H-center)	1.50	3.50	3.62	4.05
Small (V-bottom,H-right)	1.50	3.50	3.62	8.10
Medium (V-top,H-left)	2.25	4.50	0.75	0.00
Medium (V-top,H-center)	2.25	4.50	0.75	3.68
Medium (V-top,H-right)	2.25	4.50	0.75	7.35
Medium (V-middle,H-left)	2.25	4.50	1.69	0.00
Medium (V-middle,H-center)	2.25	4.50	1.69	3.68
Medium (V-middle,H-right)	2.25	4.50	1.69	7.35
Medium (V-bottom,H-left)	2.25	4.50	2.62	0.00
Medium (V-bottom,H-center)	2.25	4.50	2.62	3.68
Medium (V-bottom,H-right)	2.25	4.50	2.62	7.35
Large (V-top,H-left)	3.00	5.50	0.75	0.00
Large (V-top,H-center)	3.00	5.50	0.75	3.30
Large (V-top,H-right)	3.00	5.50	0.75	6.60
Large (V-middle,H-left)	3.00	5.50	1.19	0.00
Large (V-middle,H-center)	3.00	5.50	1.19	3.30
Large (V-middle,H-right)	3.00	5.50	1.19	6.60
Large (V-bottom,H-left)	3.00	5.50	1.62	0.00

"Letter Presets" (or "Legal Presets" or "A4 Presets") lists a number of automatic placement options to more quickly spot the location of the inset. The list depends on the cross section Paper Size in use. There are three general size options ("Small", "Medium", "Large"), three vertical alignment options ("top", "middle", "bottom"), and three horizontal alignment options ("left", "middle", "right"). Making a selection here updates "Width", "Height", "Top", and "Left" setting values.

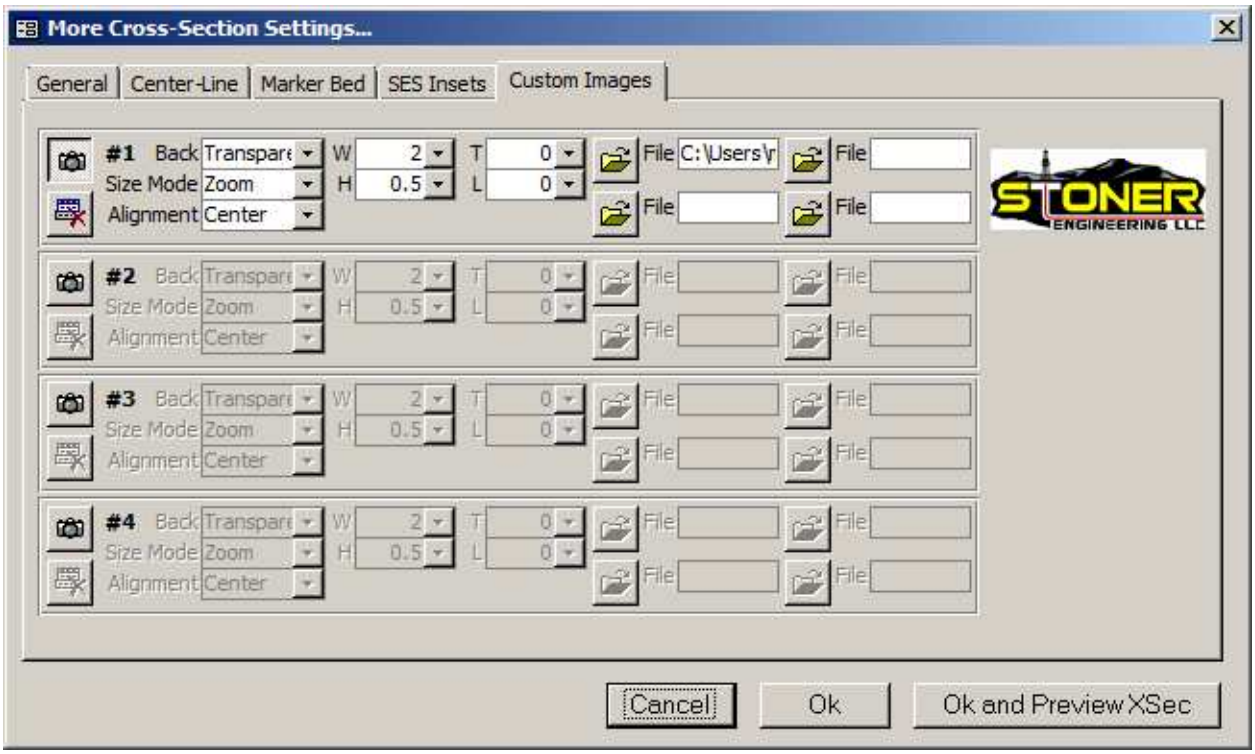
13.4.7 Custom Images/Logos



"Custom Images/Logos" are external graphics files (pictures) that may be posted on the cross section. Custom images overlay any portion of the cross section printable area including the header section. Custom images—can be just that, anything—have included pictures of cuttings samples, 3D views, snips from field maps, proprietary report summaries/content, and operator/service company branding.

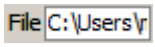
Up to four pictures may be displayed, and, SES will look at up to four different locations on computer systems for the respective picture file. For example, a company logo file may reside at different places to which users have current access. In the displays above, an icon means there is a graphics file set to be displayed—camera icon means the file is currently available while a frown icon means file not found or file not entered correctly.

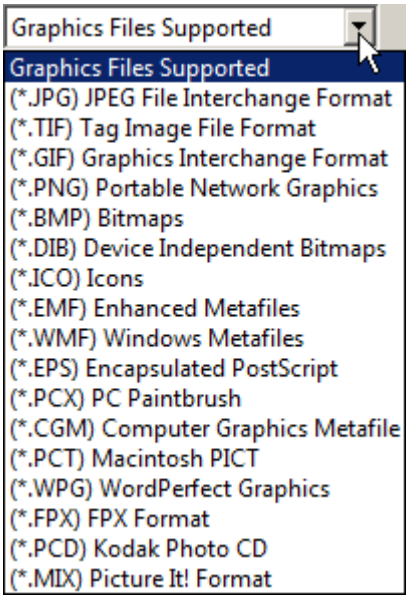
All Custom Images/Logos configuration settings are accessible through the "properties" button () circled above from Cross-Sections screen. The display settings are described next.

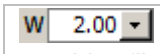


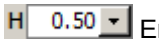

Click this camera icon toggle button to enable/disable the display of a graphics file within an image frame.

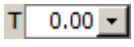

Click this open icon to browse for a graphics file to display within an image frame. Supported file formats are displayed in the adjacent picture.

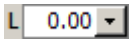

The textbox contains the actual path and file name to a possible location of the graphics file. Its content may also be manually edited. Up to four different computer locations may be searched to look for a specific graphics file. SES uses the first such file that is found. Mouse-over the "File" text box to see a basic preview of the file.

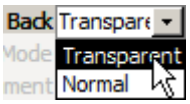



Enter or select the image frame width in inches. The graphics file is displayed within the image frame.

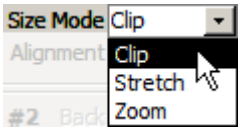

Enter or select the image frame height in inches. The graphics file is displayed within the image frame.


Enter or select the distance in inches from the top edge of the printable area to the top side of the image frame.

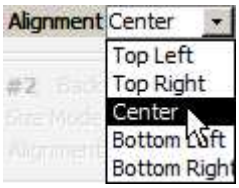

Enter or select the distance in inches from the left edge of the printable area to the left side of the image frame.



Select "Back" option to set the image frame back style. Options include: transparent ("Transparent") or normal ("Normal"). With normal option, any space between the image frame boundary and the picture boundary is white.



Select "Size Mode" option to set the image frame size mode. Options include: clip ("Clip"), stretch ("Stretch"), or zoom ("Zoom"). With clip option, the picture is displayed at its actual size and if the picture is larger than the image frame then the picture is truncated. With stretch option, the picture is sized to fill the image frame so if the picture size and image size are significantly unequal the picture will appear distorted. With Zoom option, the entire picture is displayed and only resized as necessary to prevent distortion.

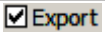


Select "Alignment" option to set the image frame alignment. Options include: top left ("Top Left"), top right ("Top Right"), center, ("Center"), bottom left ("Bottom Left"), or bottom right ("Bottom Right").


Click this icon to reset all properties to default settings and to delete all currently saved file paths for the respective image.

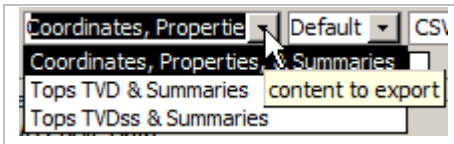
13.5 Export Cross Section Data for 3rd Party Software

Geologic interpretation and related data processing in SES creates new knowledge of the drilling area and wellbore/rock completion and this information is often fed while drilling or post drilling into other industry G&G software or proprietary systems. Cross-Sections screen "Export" feature provides a versatile way to extract the desired digits of interest. When "Export" option is checked, export preferences may be set, and then when the cross section is previewed a corresponding data file is generated for use in 3rd party software. This section details current data export capabilities.



Click "Export" option to enable controls to make preference settings; then preview or print the cross section to generate the corresponding data file.

13.5.1 Data Content



Three data content options are currently available for export.

"**Coordinates, Properties, & Summaries**" – export all (full directional survey via minimum curvature interpolation, 3DSB calibration properties, RSD, local coordinates (TVD) of top/base all layers, wellbore completion layer/zone ID, gridX|Y, global coordinates (TVDss) of top/base all layers, well ID, wellbore ID; payzone summary; gross zone summary; and completion summary).

Main table default columns include: MD, INC, AZI, TVD, N, E, DLS, VS, 3DSB#, 3DSBDip, 3DSBDipAzi, AppDip, AppDipAzi, RSD, Top_Up10, Top_Up9, Top_Up8, Top_Up7, Top_Up6, Top_Up5, Top_Up4, Top_Up3, Top_Up2, Top_Up1, Top_PAYZONE, Target, Base_PAYZONE, Top_Dn1, Base_Dn1, Top_Dn2, Base_Dn2, Top_Dn3, Base_Dn3, Top_Dn4, Base_Dn4, Top_Dn5, Base_Dn5, ZoneID, GridX, GridY, Z_Top_Up10, Z_Top_Up9, Z_Top_Up8, Z_Top_Up7, Z_Top_Up6, Z_Top_Up5, Z_Top_Up4, Z_Top_Up3, Z_Top_Up2, Z_Top_Up1, Z_Top_PAYZONE, Target, Z_Base_PAYZONE, Z_Top_Dn1, Z_Base_Dn1, Z_Top_Dn2, Z_Base_Dn2, Z_Top_Dn3, Z_Base_Dn3, Z_Top_Dn4, Z_Base_Dn4, Z_Top_Dn5, Z_Base_Dn5, WellID, WellboreID.

Payzone Summary table default columns include: ZoneID, ZoneName, LengthInZone, InZonePct, WellID, WellboreID.

Gross Zone Summary table default columns include: ZoneID, ZoneName, LengthInZone, WellID, WellboreID.

Completion Summary table default columns include: MDStart, MDEnd, ZoneID, ZoneName, LengthInZone, WellID, WellboreID.

"**Tops TVD & Summaries**" – export non-null tops & summaries in generally database friendly column format (in-use layer tops (TVD) in **local** coordinates; payzone summary; gross zone summary; and completion summary).

Main table default columns include: WellboreID, MD, 1stTop, 2ndTop, ..., LastTop, Count

Payzone Summary table default columns include: ZoneID, ZoneName, LengthInZone, InZonePct, WellID, WellboreID.

Gross Zone Summary table default columns include: ZoneID, ZoneName, LengthInZone, WellID, WellboreID.

Completion Summary table default columns include: MDStart, MDEnd, ZoneID, ZoneName, LengthInZone, WellID, WellboreID.

"**Tops TVDss & Summaries**" – export non-null tops & summaries in generally database friendly column format (in-use layer tops (TVDss) in **global** coordinates; payzone summary; gross zone summary; and completion summary).

Main table default columns include: WellboreID, MD, 1stTop, 2ndTop, ..., LastTop, Count

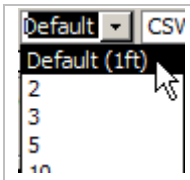
Payzone Summary table default columns include: ZoneID, ZoneName, LengthInZone, InZonePct, WellID, WellboreID.

Gross Zone Summary table default columns include: ZoneID, ZoneName, LengthInZone, WellID, WellboreID.

Completion Summary table default columns include: MDStart, MDEnd, ZoneID, ZoneName, LengthInZone, WellID, WellboreID.

When source directional survey data are referenced to true north, SES correctly transforms coordinates when converting to global/grid coordinates (GridX, GridY). Please see "Azimuths are Relative to" at **6.3 Other Functions/Features** for more information.

13.5.2 MD Frequency



Select the preferred export frequency (MD-step). High-resolution (1 ft or 0.25 m) is the default export measured depth frequency, but sometimes a sampling (for example, coordinates every 200 ft MD) is desired. Note: summaries are always computed from high-resolution depth frequency even when selected MD-step isn't.

If "Default" MD-step is selected and file format is CSV, the output file will normally contain duplicate MDs at 3DSB boundaries (fault boundaries for example will have two different TVDs at one MD's value on two rows). If duplicate MDs create a problem for the subsequent export file's use, choose a non-default MD frequency or select any file format besides CSV. However, a high-resolution dataset is always thinned to produce a sampled unique-MD dataset and during the process first MD survives.

13.5.3 File Format

Five file format options are available for export. File formats LAS, XLS, TXT, and PRN always create a unique-MD dataset. File format CSV and "Default" MD frequency may produce duplicate MD rows at 3DSB boundaries.

"CSV" – comma separated value text; unique-MD and duplicate MD datasets possible.

"LAS" – Canadian Well Logging Society Log ASCII Standard version 3.0 text; unique-MD dataset.

"XLS" – Microsoft Excel binary; unique-MD dataset.

"TXT" – tab delimited text; unique-MD dataset.

"PRN" – fixed-width text; unique-MD dataset.

13.5.4 Options

Additional export options are available to further customize the export content and/or logistics. For example, the file SaveAs dialog may be hidden and file content may be placed onto the clipboard for subsequent paste. The export options make for a plethora of possible output combinations to efficiently meet the needs of many other systems that operate on SES data. Additional data export options are handled with checkboxes on the row below "Export" option and are discussed next.

[1] "close preview after export" – check this option to automatically close the cross section window after the data file has been created.

[2] "auto-name export file (no SaveAs prompt; overwrite; last export folder)" – check this option to automatically name the export file and save it to the last folder to which was exported. If unchecked, the analyst is prompted to verify or enter the file name and folder each time an export is performed.

[3] "include footer summaries" – check this option to include "Payzone", "Gross Zone", and "Completion" summaries in the created file; if unchecked, only the respective main table is present.

[4] "include header comment (first line)" – check this option to include the header comment in the created file; header comment includes meta data about the file and is printed on the first row (for example, "SES v5.11 www.makinhole.com & WellID=555555550 & SURVEY=1 & MARKERBED=1 - Coordinates and Properties (Length Units are ft; Azimuths to GRID North)").

[5] "include column labels" – check this option to include column labels in the main table of the created file; does not affect summaries.

[6] "include N,E| X,Y in Tops export" – check this option to insert into the main table of the created file after MD column—North and East into Tops TVD export or GridX and GridY into Tops TVDss export.

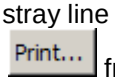
[7] "include target *surface* in Tops export" – check this option to insert into the main table of the created file the target surface, which is normally between the payzone top and payzone base layers.

[8] "copy to clipboard" – check this option to place an exact copy of the file content onto the clipboard for immediate paste capability.

13.6 Critical

1.) "preview cross section" toolbar button  draws the cross section on the screen and uses the Windows default printer driver. The system default printer should support Letter, Legal, or A4 size paper.

2.) "send cross section to *default* printer" toolbar button  prints to the system default printer (including Adobe/PDF). To change your system default printer, use Windows Control Panel.

3.) Right-clicking the actual cross section preview also provides options such as printing, including printer selection. If a stray line appears to connect first and last survey stations on a print-out, use "Print... " toolbar button 

from Cross-Sections screen to print instead.

4.) If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

13.7 Hot Keys

- Double-click Center-Line Dip Azimuth to flip it 180°

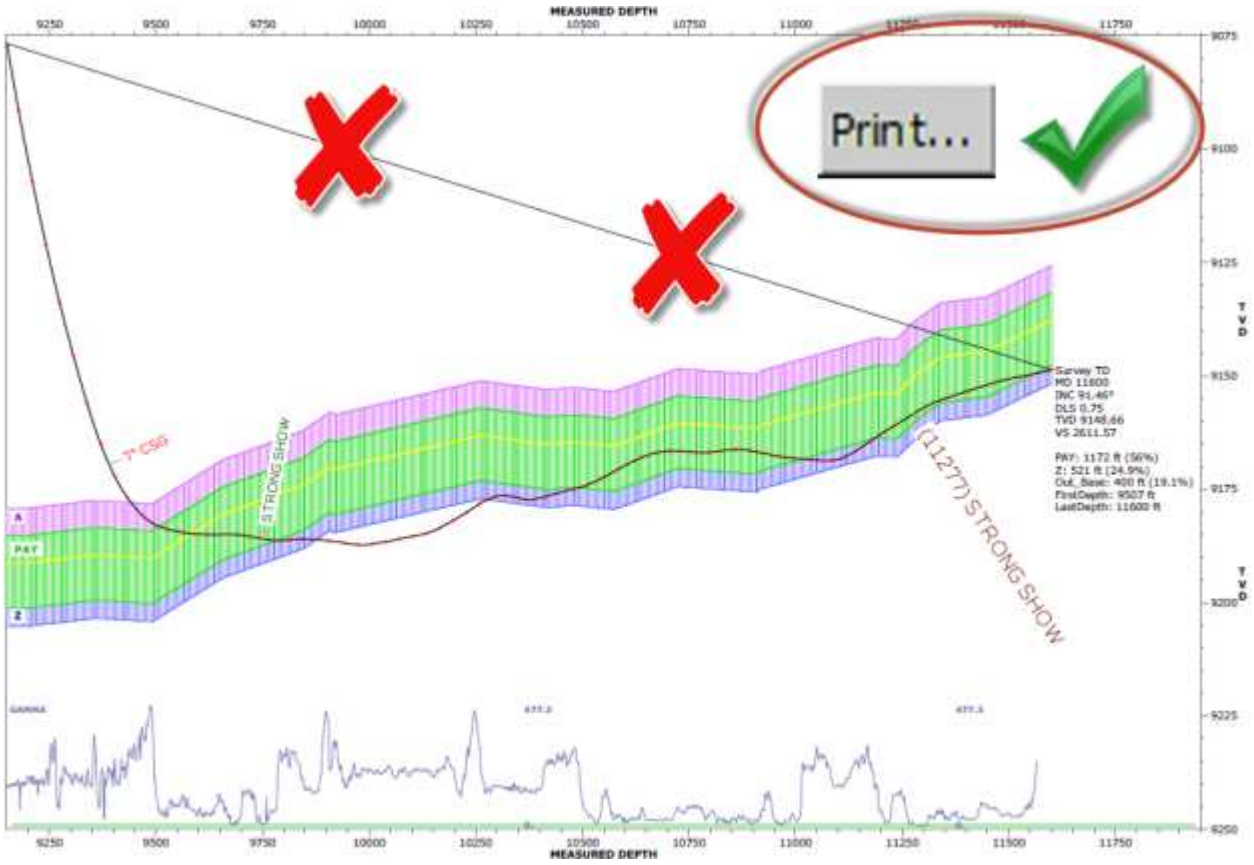
- Esc – close cross section preview (some Office versions first require clicking on side gray area before Esc key functions in this manner)

13.8 Tips

TIPS

- Even if planning to display a cross section in vertical section mode, it is recommended to first setup the cross section to look ideal in MD mode. Typically, the cross section starting MD ("MD MIN") will exceed MDStart of 3DSB #0. If right-side space/padding is desired (i.e., room out-front of the bit showing section yet to be drilled and interpreted) and it normally is, set cross section ending MD ("MD MAX") much greater than current survey TD...perhaps 100s greater than planned TD.

- Sometimes, printing directly from Print Preview (using right-click shortcut menu or ribbon toolbar in some Microsoft Office versions) will generate a cross section with aberrant connecting lines, for example a line may display that connects the wellbore survey from its start to TD as if to close a polygon (see picture below). This is a Microsoft bug present in Access 2000, 2002, 2003, 2007, 2010, 2013, and 2016! The workaround is to use Print... from Cross-Sections screen to generate a cross section without any such connecting lines.



- SES uses your Windows default printer driver to preview the cross section on-screen. If an "unexplained" or "strange" error message (e.g., Error 6 Overflow) is all-of-sudden being displayed when any cross section is previewed, check that your Windows default printer is still the correct one (some other application may have changed it; or a brand new computer may need to have a

legitimate printer added) and that it supports letter/legal/A4 paper size. If it's correct, remove the printer and then add it back again, as the printer driver may have become corrupt.

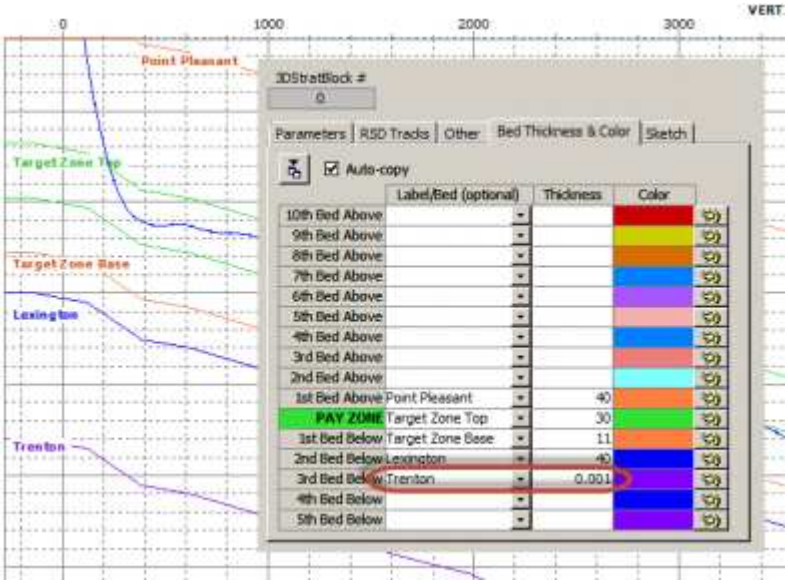
- If all-of-sudden the cross section looks goofy from normal (all lines are really thick; portions of the plot are truncated; text appears exceedingly bold; etc.) when any cross section is previewed, check that your Windows default printer is still the correct one. If it's correct, remove the printer and then add it back again, as the printer driver may have become corrupt.

- To post a well plan—or extrapolate a Center-Line, or interpolate Grid data—BEYOND current Survey TD, the cross section must be generated using Vertical Section mode ("V.S. Mode").

- To post a well plan in MD mode, THD must have been calculated for the corresponding survey/plan pair (see **12. SES Screen – THD**). To post a well plan in Vertical Section mode, THD need not be calculated.

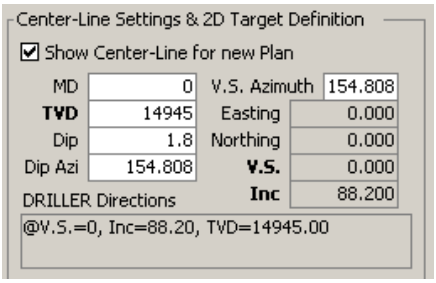
- To export numeric cross section data, please see **13.5 Export Cross Section Data for 3rd Party Software**.

- To post zone tops without color fill and when the bottom-most top is desired to be posted without its base, a very small thickness (e.g., 0.001) should be entered for its thickness (see adjacent picture).



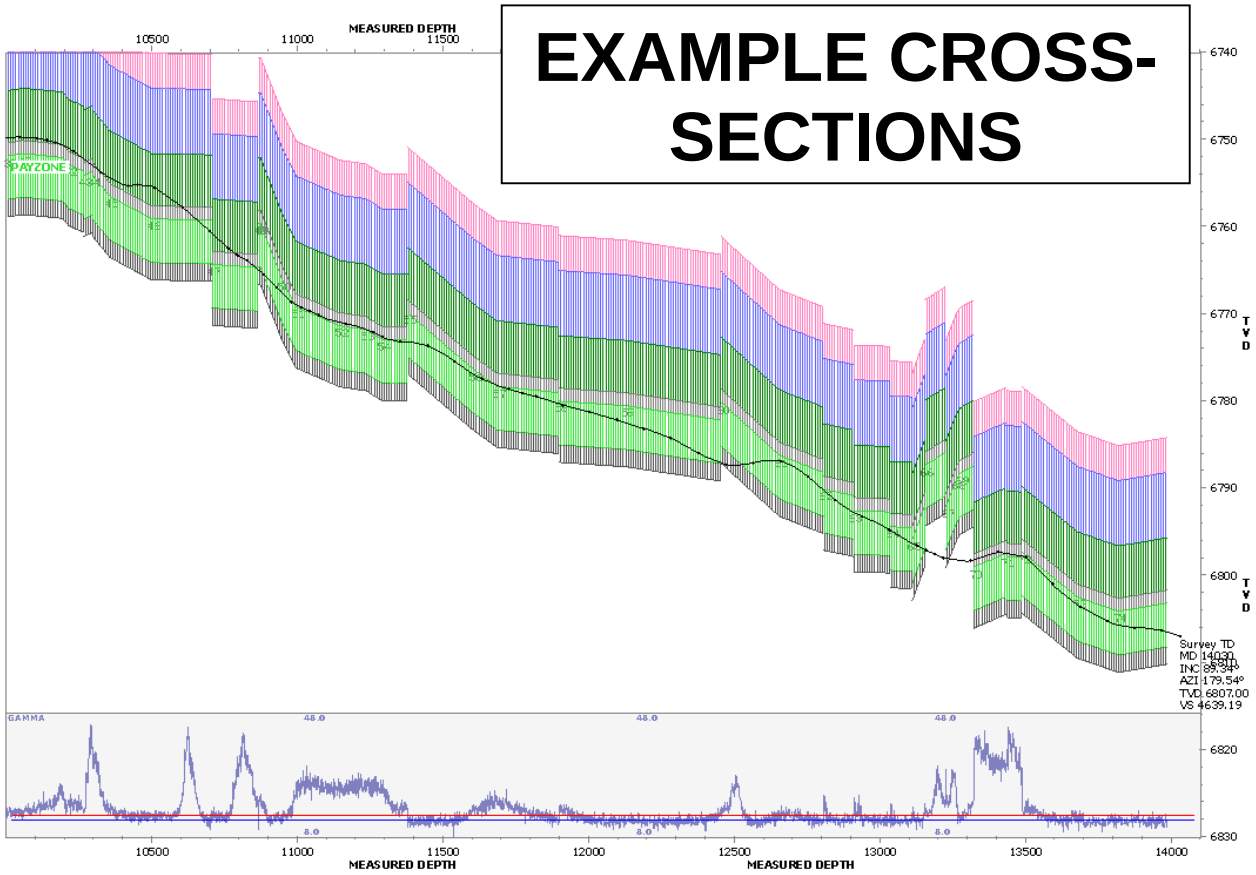
- The **13.4.2 Center-Line Settings for Revised Planned Path** feature of Cross-Sections screen provides a way to create a revised linear planned well path definition based on the analyst's interpretation that can easily be communicated to directional drilling personnel during live drilling operations. The line is determined by the intersection of a 3D dipping plane and a vertical plane defined by the vertical section azimuth of the associated Survey.

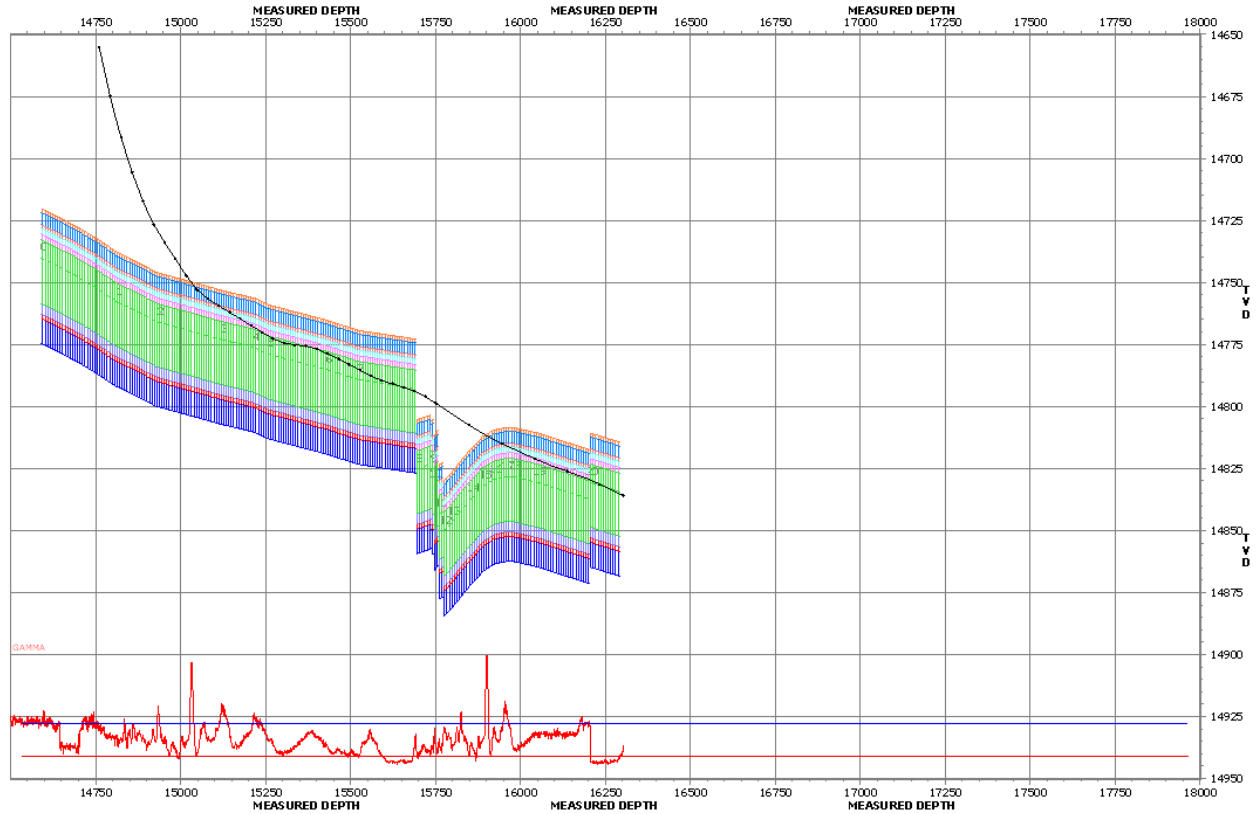
    - To make a Center-Line "plan" available from THD and Geosteer/ParamTuner screens, define and calculate it using Planner screen. See below for an example Center-Line followed by its equivalent Planner screen well plan input where total vertical section at TD is set to 4300.

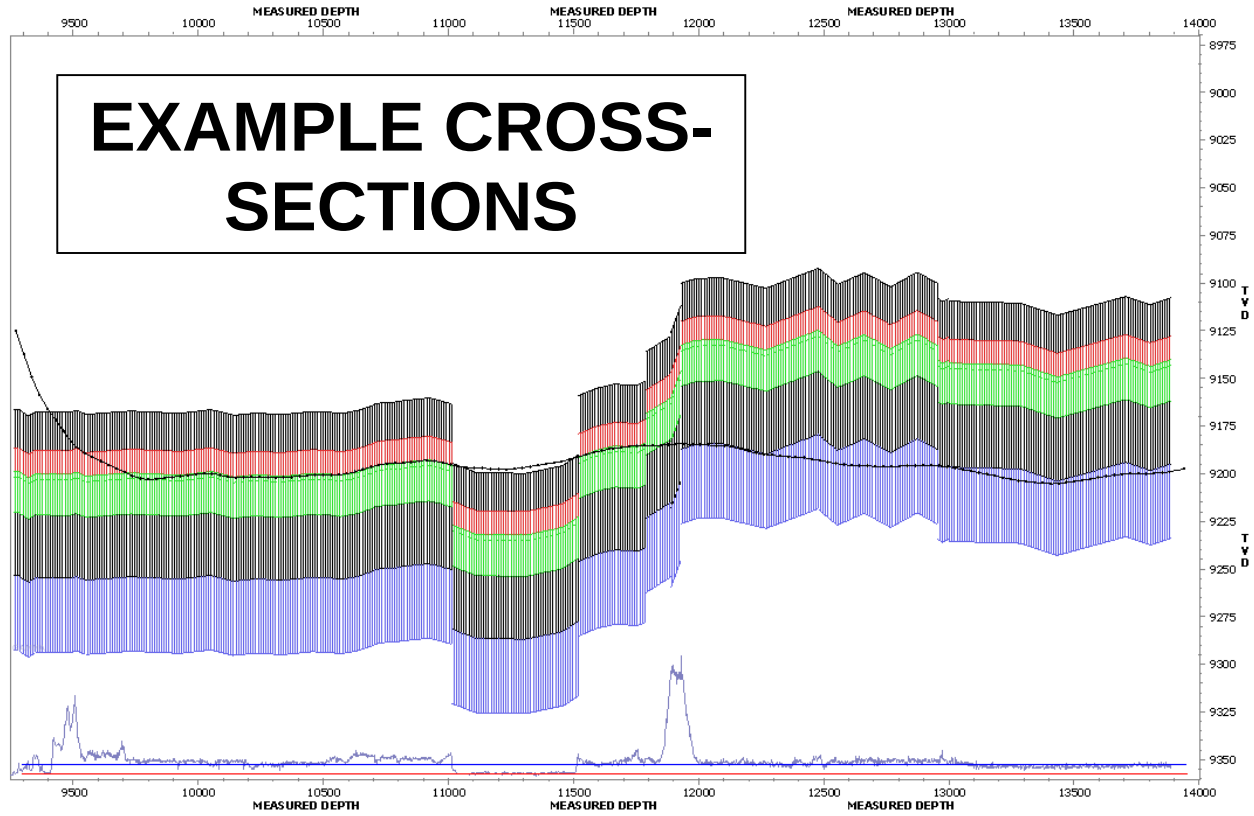


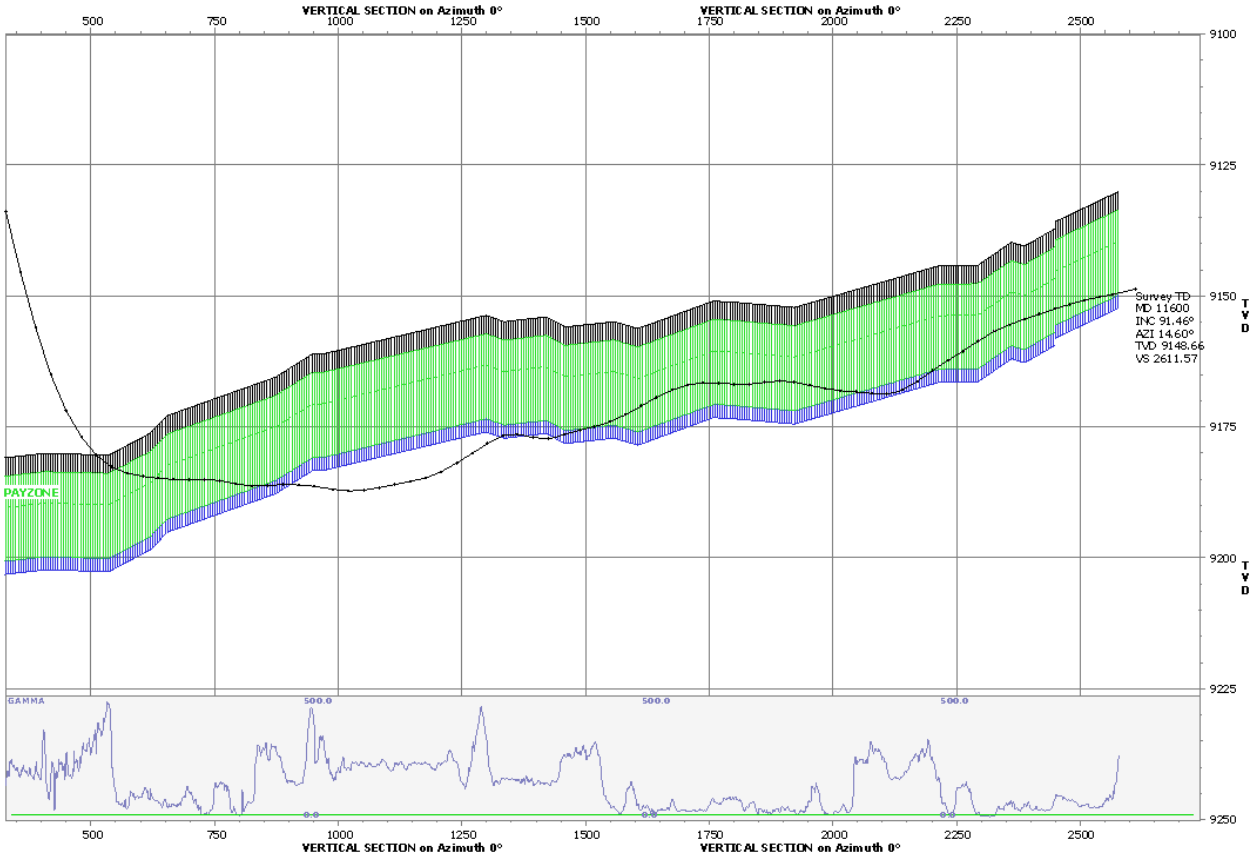
dMD	Inc	Azi	TVD	N	E	DLS	Reference	ID
14945	88.2	154.81	14945	0	0		TVDKB	0
4300	88.2	154.81					TD	1
								2

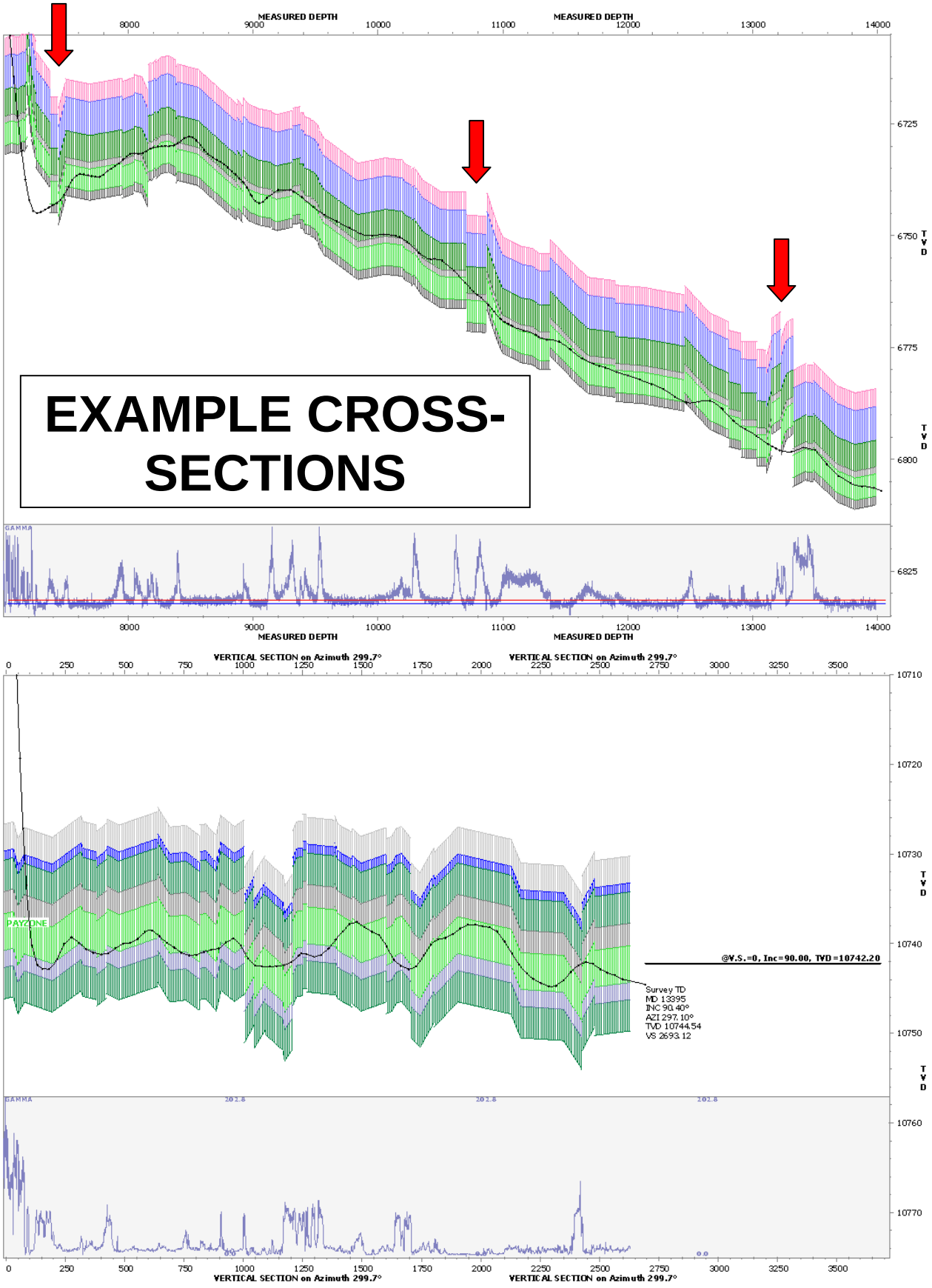
EXAMPLE CROSS-SECTIONS

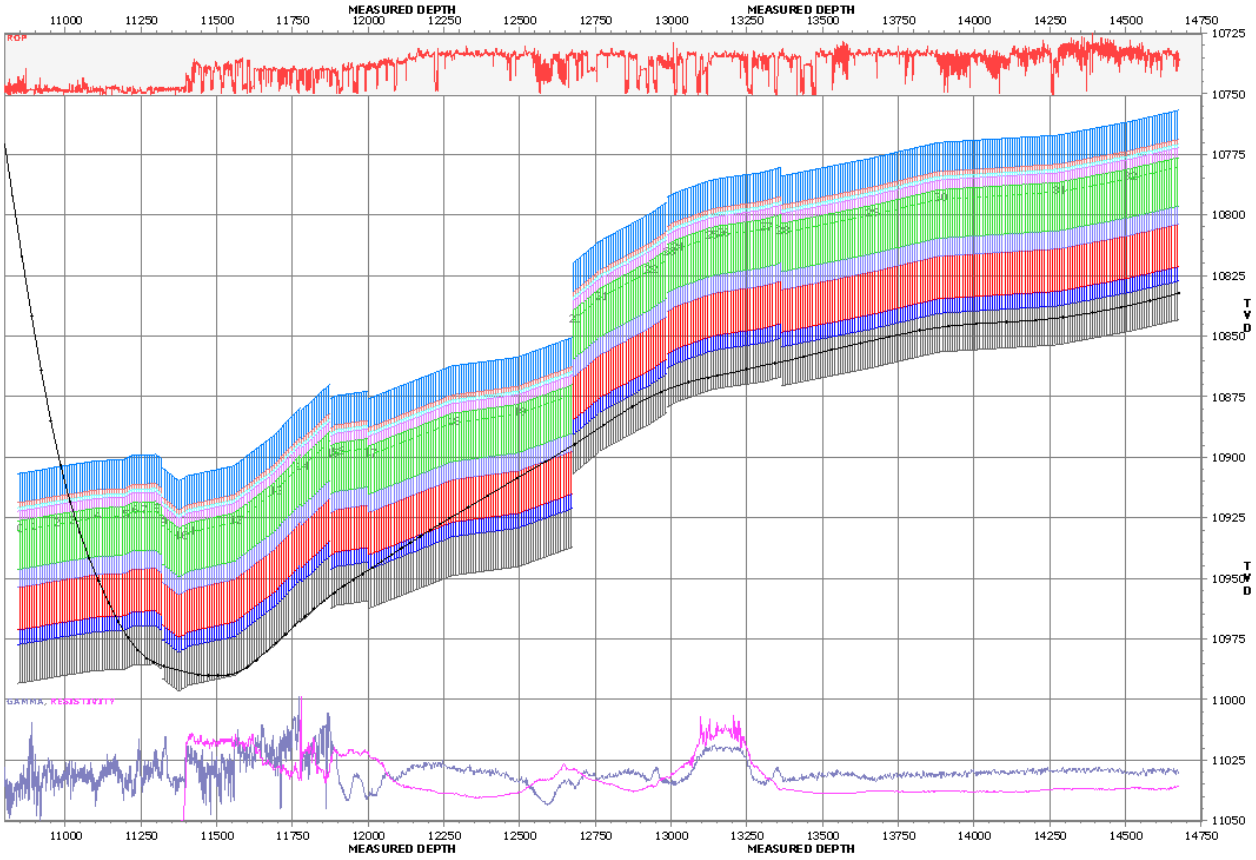


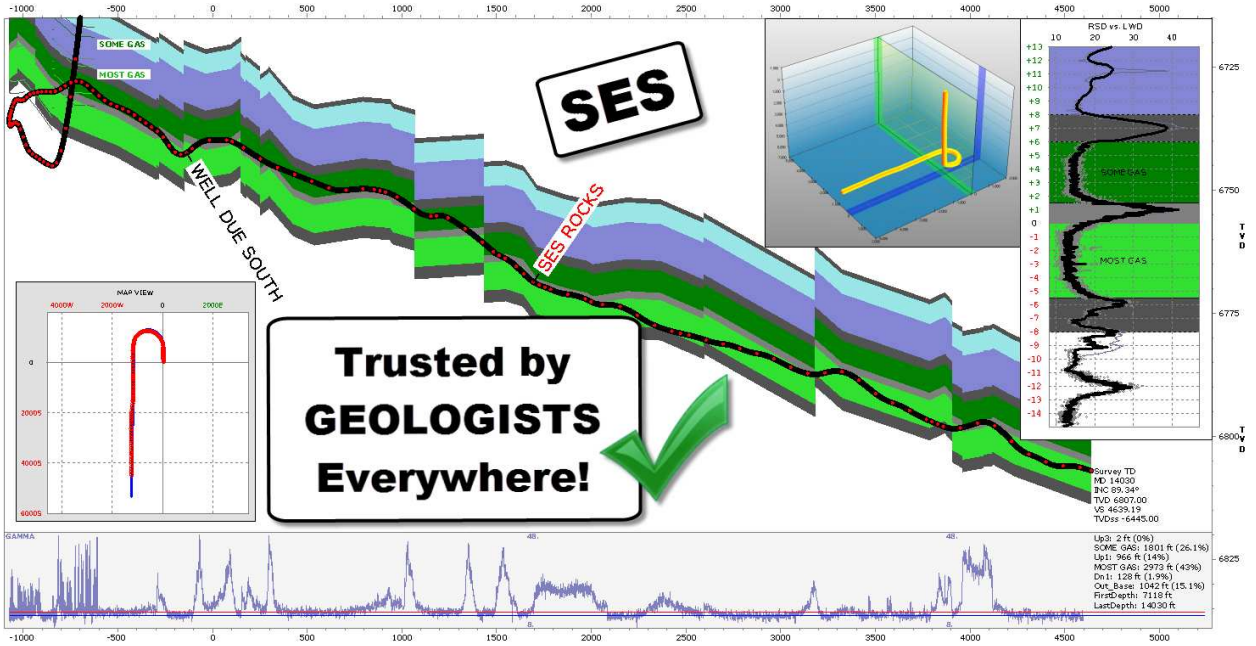



EXAMPLE CROSS-SECTIONS
MEASURED DEPTH
TVD


VERTICAL SECTION on Azimuth 0°
Survey TD
MD 11600
INC 91.46°
AZI 14.60°
TVD 9148.66
VS 2611.57
PAYZONE
GAMMA
TVD


MEASURED DEPTH
8000
9000
10000
11000
12000
13000
14000
6725
6750
6775
6800
6825
TVD
GAMMA
EXAMPLE CROSS-SECTIONS
VERTICAL SECTION on Azimuth 299.7°
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
10710
10720
10730
10740
10750
10760
10770
PAYZONE
@V.S.=0, Inc=90.00, TVD=10742.20
Survey TD
MD 13395
INC 90.40°
AZI 297.10°
TVD 10744.54
VS 2693.12


MEASURED DEPTH
ROP
GAMMA, RESISTIVITY
TVD


SOME GAS
MOST GAS
WELL DUE SOUTH
SES
SES ROCKS
Trusted by
GEOLOGISTS
Everywhere!
MAP VIEW
RSD vs. LWD
GAMMA
TVD

14. TECHNICAL HOLE DEVIATION & THD WELLS LOGS

Technical Hole Deviation (THD) mathematically quantifies spatial differences between actual and planned well paths. THD provides unique insight regarding three important directional drilling issues: control, monitoring, and post-evaluation.

More specifically, THD provides:

- **support information for real-time rationalization of directional tool settings.** A THD well log significantly augments the visual tools available to the directional driller to rationalize control decisions, especially for 3D/complex wellbores and non-linear hole sections.

- **information for daily progress monitoring of directional control performance.** Many relevant wellbore details cannot be determined from directional vertical section and plan view plots. For example from these standard plots alone, it is impossible to determine dogleg-severity (DLS), wellbore inclination, and wellbore azimuth, and (more importantly) how they are changing relative to the planned trajectory. THD logs present all of this information and much more. A glance at the THD logs for a well, quickly conveys how directional control is progressing, on a scale that doesn't mask the true details.

- **a basis upon which to evaluate overall directional control performance of a directional driller, service company, or directional drilling system.** With THD, directional control performance can be quantified with various metrics. Three such examples are Average Absolute Vertical Deviation, Average Absolute Inclinational Deviation, and Excess Measured Depth.

THD is calculated at each survey station. THD may be fully presented with two well logs. Computing THD only requires a mathematical understanding of the "current" planned well path, and directional survey data. Employing THD technology doesn't require more "steering"; rather, it's an enhanced use of standard information to make more-informed directional control decisions at the same or less steering frequency.

Technical Hole Deviation (THD) is:

- **directly applicable to all types of directional drilling** (ultra-short, short, medium, and long radii of curvature; slant; horizontal, etc.)

- **relevant to every type of directional drilling system** (rotary, PDM, rotary steerable) and all related industries (oil & gas, utilities/HDD, in-seam coal bed methane (CBM), in-seam coal mine methane degasification)

- **mathematically valid as defined, with any planned well path profile** (2D/3D circular arc, line, catenary, double circle, spline-in-tension, 3D StratBlock, earth model marker bed grid, "plan" defined by survey of offset well for relief well drilling, etc.)

Of critical importance to almost any system is how its state is changing. Actual directional well paths are "noisy". From an engineering/mathematical point of view, differentiating "noisy" data is useless. In effect, THD smoothes the data by associating the actual well path to the planned well path. The smoothed profile is then differentiated (differenced) to determine how it is changing relative to lineal and angular target path properties. This process provides the foundation for projecting future well path deviations, without explicitly assuming a model of directional drilling.

14.1 Technical Hole Deviation Components

THD Component	Description	Deviation "Sense"	Unit	Order	Lineal Deviation	Angular Deviation	Verbal Descriptor
ms**VD**	**vertical deviation**	Vertical	ft or m	1st	X		High/Low
RCVD	relative change in vertical deviation	Vertical	ft/1000ft or m/304.8m	2nd	X		+ | –
ms**ID**	**inclinational deviation**	Vertical	deg	1st		X	High/Low
RCID	relative change in inclinational deviation	Vertical	deg/100ft or deg/30.48m	2nd		X	+ | –
ms**HD**	**horizontal deviation**	Horizontal	ft or m	1st	X		Left/Right
RCHD	relative change in horizontal deviation	Horizontal	ft/1000ft or m/304.8m	2nd	X		+ | –
ms**AD**	**azimuthal deviation**	Horizontal	deg	1st		X	High/Low
RCAD	relative change in azimuthal deviation	Horizontal	deg/100ft or deg/30.48m	2nd		X	+ | –

The planned well path defines the preferred location of the wellbore in 3D space. Every directional well has a planned path. In some cases as information is acquired while drilling, the planned path changes via geosteering. However, there is always a planned path in force at each survey station.

Technical hole deviation is defined with properties of the nearest point between "current TD" and the "current" planned path. Given the current actual location of the wellbore, there is one point along the planned path that minimizes the 3D distance between where the bottomhole location actually is, and where it is preferred.

This point along the planned path is called MD* ("measured depth star"). Associated with MD* is N*, E*, TVD*, Inc*, and Azi*, respectively, planned values North, East, True Vertical Depth, Inclination, and Azimuth. With a directional survey and a mathematical understanding of the planned path, MD* is found iteratively.

Eight components collectively define technical hole deviation and are presented in the above table. They are based on lineal and angular differences—and the relative changes thereof—between the actual and planned well paths. Four THD components address hole deviation in the "vertical" sense, and four THD components address hole deviation in the "horizontal" sense. Other variables of interest include:

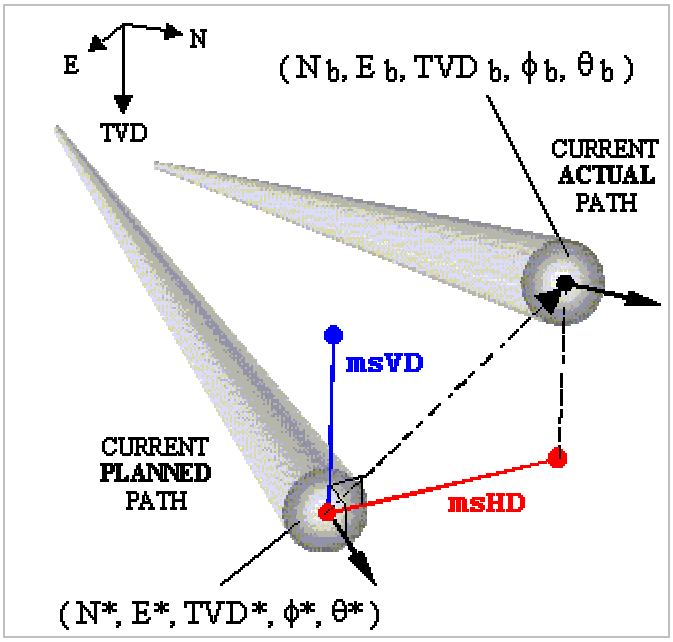
- INC (ϕ) - actual wellbore inclination angle; (deg)
- INC* (ϕ^*) - planned wellbore inclination angle; (deg)
- DLS - actual wellbore dogleg-severity; (deg/100ft or deg/30m)
- DLS* - planned wellbore dogleg-severity; (deg/100ft or deg/30m)

- AZI (θ) - actual wellbore azimuth; (deg)
- AZI* (θ^*) - planned wellbore azimuth; (deg)
- ΔL - difference in MD* between two consecutive survey stations
- b - subscript with reference to current wellbore total depth
- n - superscript with reference to a survey station
- * - denotes a planned value

A description and mathematical definition of each THD component follows.

14.1.1 msVD|msHD (1st Order, Lineal Deviation)

Vertical Deviation, **msVD**, and Horizontal Deviation, **msHD**, are the two most easily-visualized components of technical hole deviation. They convey where the wellbore exists in space, relative to the (current) preferred location.



$$msVD = \cos(\theta^*)\cos(\phi^*)(N_b - N^*) + \sin(\theta^*)\cos(\phi^*)(E_b - E^*) - \sin(\phi^*)(TVD_b - TVD^*)$$

$$msHD = \cos(\theta^*)(E_b - E^*) - \sin(\theta^*)(N_b - N^*)$$

By design, their definitions are such that being High or Low, and Left or Right, match common directional-driller sense. The terminology and equations apply to ALL curvilinear and linear well plans (i.e., not just circular-arc). In the mind's eye, if you were to "walk" along the planned path at MD* as the well is drilled and point to the current wellbore TD, the components of that pointing vector, relative to the high side of the planned hole, would be msVD and msHD.

The relevancy of industry's "vertical section" deteriorates when the current planned azimuth is different from the vertical section azimuth. In other words, projecting well path departure onto a single vertical plane (i.e., to compute vertical section) can sometimes have little meaning over thousands of feet of hole. EVERY well with "turn" built into the plan, to some degree, suffers from this fact. It's not an issue with msVD and msHD.

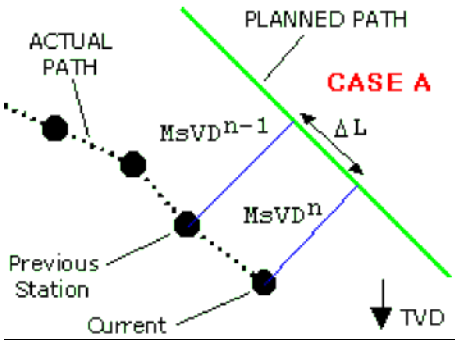
14.1.2 RCVD|RCHD (2nd Order, Lineal Deviation)

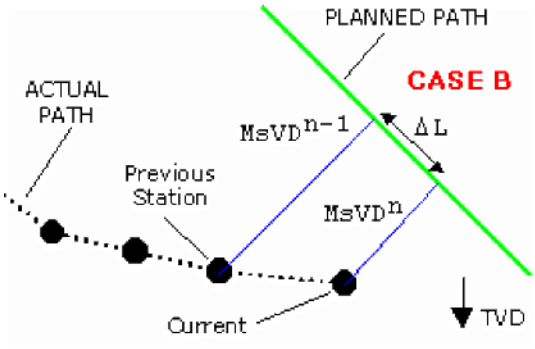
The Relative Change in Vertical Deviation, **RCVD**, and the Relative Change in Horizontal Deviation, **RCHD**, are less visually intuitive than are msVD and msHD. However, they contain much information, including "predictive" qualities because, for example, RCVD leads msVD (or similarly msVD lags RCVD).

$$RCVD = 1000\frac{msVD^{n} - msVD^{n-1}}{\Delta L^{n}} \qquad RCHD = 1000\frac{msHD^{n} - msHD^{n-1}}{\Delta L^{n}}$$

*Note: For metric, use 304.8 in place of 1000 in the equations above.

Consider two THD examples in the vertical sense, as sketched below.





Current msVD is identical in both cases, that is, the wellbore is low of the plan by the same amount. Current RCVD is positive in both cases but the magnitude of RCVD for Case B is clearly higher. Thus, the plan is being approached more quickly in Case B than in Case A, which may have significant influence on the next directional tool setting decision.

RCVD provides insight as to how msVD is changing. RCHD provides insight as to how msHD is changing. The signs and magnitudes of RCVD and RCHD are important for real-time tool-setting purposes. For example, if the wellbore is high, then RCVD must be made negative before the wellbore will begin to approach the plan. Typically, this will happen long before the planned path is approached or intersected, hence, the "predictive" quality as mentioned above. RCVD and RCHD are also used for projecting msVD and msHD.

14.1.3 msID|msAD (1st Order, Angular Deviation)

Inclinational Deviation, **msID**, and Azimuthal Deviation, **msAD**, are differences in actual and preferred wellbore angles. For example, if the current wellbore inclination is 91.6 degrees while the plan is horizontal, msID = 1.6 degrees.

$$msID = \phi_b - \phi^* \qquad msAD = \theta_b - \theta^*$$

Visualizing msID or msAD in space is not simple. Nevertheless, both their signs and magnitudes contain important directional control information, especially when combined with other THD components and while considering the task at hand. In all cases, controlling msID (or msAD) is easier to accomplish than controlling msVD (or msHD), because sooner or later msVD depends on msID.

While drilling the upper hole section of a directional well, maintaining msID and msAD close to zero is usually more important than minimizing msVD and msHD. Why? Because it means the wellbore is headed in the planned directions and drilling is taking place at the planned DLS. For example, you may be drilling that 45 degree tangent section 15 feet low, but you're drilling it at 45 degrees, which may be perfect in the practical sense.

However, landing and drilling the payzone "perfectly" requires minimization of all 8 components of technical hole deviation. In the vertical sense, this includes msVD, RCVD, msID, and RCID. In the horizontal sense, this includes msHD, RCHD, msAD, and RCAD. Typically, "being on depth", that is, minimizing hole deviation in the vertical sense is most important.

It is entirely possible for msVD ≅ 0, RCVD ≅ 0, and msID to be significantly greater-than or less-than 0. In other words, even though the wellbore is *currently* on-depth, msVD won't stay zero for long and the wellbore will soon be either high or low. Collectively analyzing technical hole deviation in the vertical sense can help eliminate the foregoing situation.

14.1.4 RCID|RCAD (2nd Order, Angular Deviation)

The Relative Change in Inclinational Deviation, **RCID**, and the Relative Change in Azimuthal Deviation, **RCAD**, are similar in design to RCVD and RCHD. They quantify how msID and msAD are changing as the hole is drilled.

$$RCID = 100\frac{msID^{n} - msID^{n-1}}{\Delta L^{n}} \qquad RCAD = 100\frac{msAD^{n} - msAD^{n-1}}{\Delta L^{n}}$$

*Note: For metric, use 30.48 in place of 100 in the equations above.

As was the case with 2nd order lineal deviation, both the signs and magnitudes of RCID (or RCAD) have relevancy and insight into controlling msID and msVD (or msAD and msHD). In fact, the directional driller may directly control these THD components more-easily than any of the preceding THD components.

14.1.5 THD Summary

Dr. Michael Stoner patented a Fuzzy-Logic-based controller for auto/guided directional drilling and for general steering guidance at surface. In its infancy in 1996, the project began with identifying the system observables of directional drilling trajectory control. This work led to what is now called Technical Hole Deviation (THD). Since THD is essential "input" to an auto/guided directional drilling control system, THD may assist the directional drilling industry in general by directly assisting directional drillers and conveying information to operators. A more-informed human (or system) is more likely to make better decisions.

Discovering new technology from "standard data" is a welcomed occurrence. Numerically defining geometric hole deviation extracts an abundance of information, simply from directional survey data and a planned well path. The details of directional control performance are no longer hidden. THD well logs convey the actual and planned well path properties in a manner far superior than path projections onto static vertical and horizontal planes and tables of numbers alone.

Directional drilling trajectory control requires minimization in at least 4 x 2 = 8 dimensions. This helps to convey its complexity! Minimizing 8 variables is not simple for man or machine. Much value exists in simply identifying what needs minimized. It is our opinion that the THD state variables msVD, msID, msHD, msAD, and the respective THD state-transition variables RCVD, RCID, RCHD, and RCAD, collectively and sufficiently quantify how a directional well path differs from its planned trajectory.

14.2 THD Well Logs

A visual way in which to present Technical Hole Deviation (THD) is with a well log. A "THD Log" is a well log that conveys the directional well plan and the actual associated geometric deviations. THD logs equip the operator with a superior mechanism for monitoring and/or "grading" directional control performance, and they provide directional drillers with critical information for rationalizing tool settings while drilling.

As would be expected, THD values are plotted versus actual measured depth. The Vertical Technical Hole Deviation Log addresses deviations in the "vertical" sense. It presents planned and actual values of well bore inclination and dogleg-severity, and THD components msVD, RCVD, msID, and RCID. The Horizontal Technical Hole Deviation Log addresses deviations in the "horizontal" sense. It presents

planned and actual values of well bore azimuth and dogleg-severity, and THD components msHD, RCHD, msAD, and RCAD.

THD logs can be created prior to drilling in order to present the plan, just like standard directional plots. Then, as drilling commences, the "actual part" of the THD logs are plotted and the directional control performance unfolds. The footer section of a THD log also contains standard vertical section and plan view directional plots!

Regardless of the planned well path linear/curved 3D/2D complexity, the target path is always a single vertical green zero line on the two right Technical Hole Deviation log tracks.

14.2.1 THD Well Log Headers

Besides Measured Depth, the commonality between the Vertical THD Log and the Horizontal THD Log is the inner left track. Here, planned and actual dogleg-severities (DLS) are graphed. Circular unfilled markers on the actual DLS curve convey depths with directional surveys. Circular filled markers on the planned DLS curve convey critical-point changes in the well plan (e.g., curved to straight).

14.2.1.1 Vertical THD Log Header

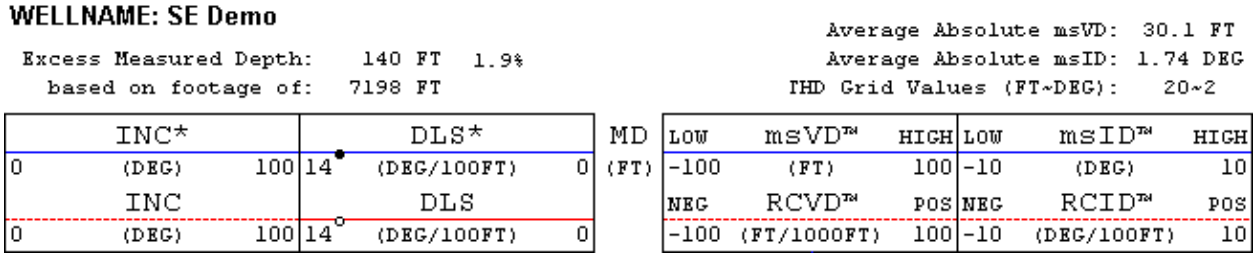
The upper THD log header section contains basic summary statistics. These include:

- **Excess Measured Depth** - amount of actual hole drilled subtracted by the corresponding planned measured length of drill hole. This value typically indicates the "cost" of oscillating about the planned path. However, in special cases this value can be negative. Such may be observed, for example, when dropping a well bore to vertical with actual dogleg-severities exceeding planned dogleg-severities.

- **Average Absolute msVD** - average absolute value of vertical deviation (msVD) associated with real survey stations over the length of drill hole for which the THD log was created. A smaller value usually indicates better directional control performance.

- **Average Absolute msID** - average absolute value of inclinational deviation (msID) associated with real survey stations over the length of drill hole for which the THD log was created. A smaller value usually indicates better directional control performance.

- **THD Grid Values** - conveys the grid values of the THD tracks, as a result of auto-scaling. For the example header below, the "20~2" means the grid value for the msVD track is 20 feet, and the grid value for the msID track is 2 degrees.



The outer left track graphs planned and actual wellbore inclination. Hole deviation in the "vertical" sense is displayed on the two right tracks. The inner right track displays vertical deviation (msVD-blue) and the relative change in vertical deviation (RCVD-red). The outer right track displays inclinational deviation (msID-blue) and the relative change in inclinational deviation (RCID-red).

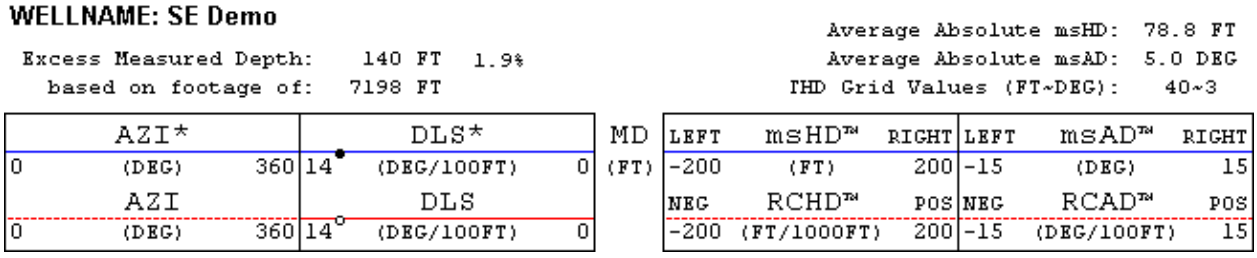
A zero line (green) centers each of the two THD tracks. For the actual drill path to follow the planned path in the vertical sense, msVD, RCVD, msID, and RCID must trace their respective zero lines.

14.2.1.2 Horizontal THD Log Header

The upper header section of the Horizontal THD Log contains the same Excess Measured Depth values and other basic summary statistics including:

- **Average Absolute msHD** - average absolute value of horizontal deviation (msHD) associated with real survey stations over the length of drill hole for which the THD log was created. A smaller value usually indicates better directional control performance.

- **Average Absolute msAD** - average absolute value of azimuthal deviation (msAD) associated with real survey stations over the length of drill hole for which the THD log was created. A smaller value usually indicates better directional control performance.



The outer left track graphs planned and actual wellbore azimuth. Hole deviation in the "horizontal sense" is displayed on the two right tracks. The inner right track displays horizontal deviation (msHD-blue) and the relative change in horizontal deviation (RCHD-red). The outer right track displays azimuthal deviation (msAD-blue) and the relative change in azimuthal deviation (RCAD-red).

A zero line (green) centers each of the two THD tracks. For the actual drill path to follow the planned path in the horizontal sense, msHD, RCHD, msAD, and RCAD must trace their respective zero lines.

14.2.2 THD Projections

Forecasts of msVD and msHD are shown on THD logs as thick black lines that extend from the last survey station depth. These THD projections are helpful for directional drillers while they rationalize directional tool setting adjustments during drilling operations.

The equations for projecting THD in the vertical sense (msVD) and in the horizontal sense (msHD) are provided below. In either case, ΔMD represents a projection length (e.g., 100 feet measured depth) beyond the current known values at the deepest survey station "n".

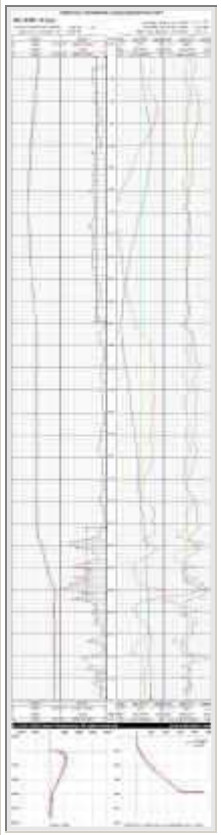
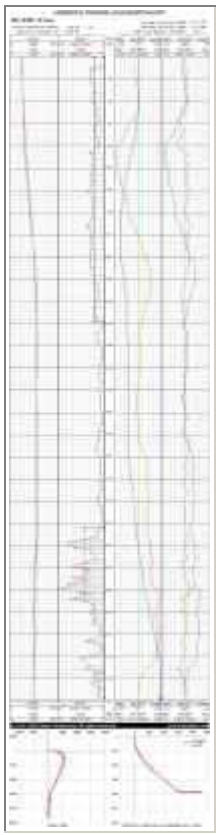
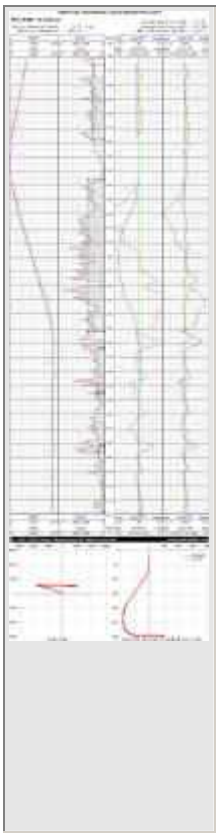
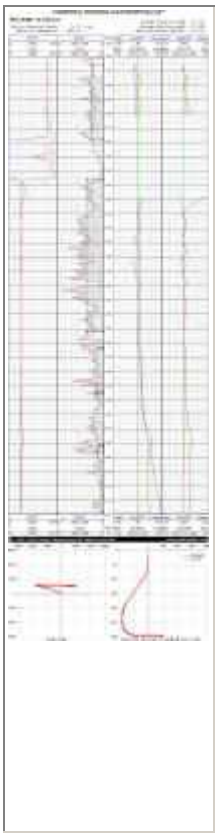
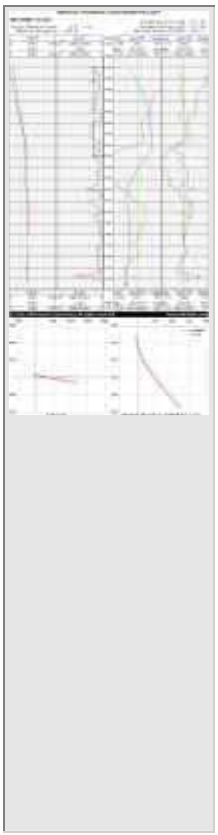
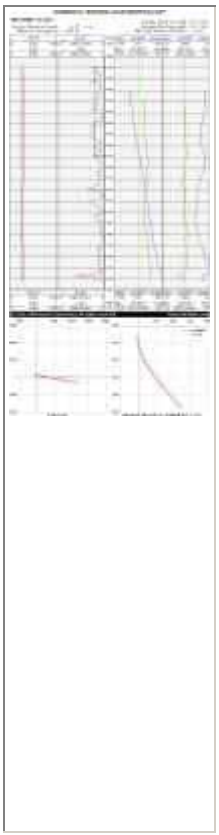
$$msVD^{n+1} = msVD^{n} + \frac{RCVD^{n}}{1000}\Delta MD \qquad msHD^{n+1} = msHD^{n} + \frac{RCHD^{n}}{1000}\Delta MD$$

*Note: For metric, use 304.8 in place of 1000 in the equations above.

Although the THD projection equations are linear, it does not mean the planned or actual well paths are assumed linear, circular, or of any specific shape. What is assumed is that the relative change in deviation is constant over delMD. Over short distances this assumption is often completely valid. Obviously, forecasting and subsequent visual interpretation influences the tool-setting control actions taken by the directional driller, which will affect the actual well path and thus the actual THD profiles that unfold.

14.3 Example THD Well Logs

Vertical and Horizontal THD well logs for three wells are presented below. These logs were created with SES and then converted to JPEG graphics files. Click a thumbnail to enlarge. All data are from actual wells.

3D Sidetrack Horizontal	3D Sidetrack Horizontal	2D Sidetrack Directional
3 in. / 1000 ft	5 cm / 300 m	1.5 in. / 1000 ft
 	 	 

14.4 THD and Directional Steering Guidance

A technical article about THD was published in 1999 (click here). A similar paper may be found here.

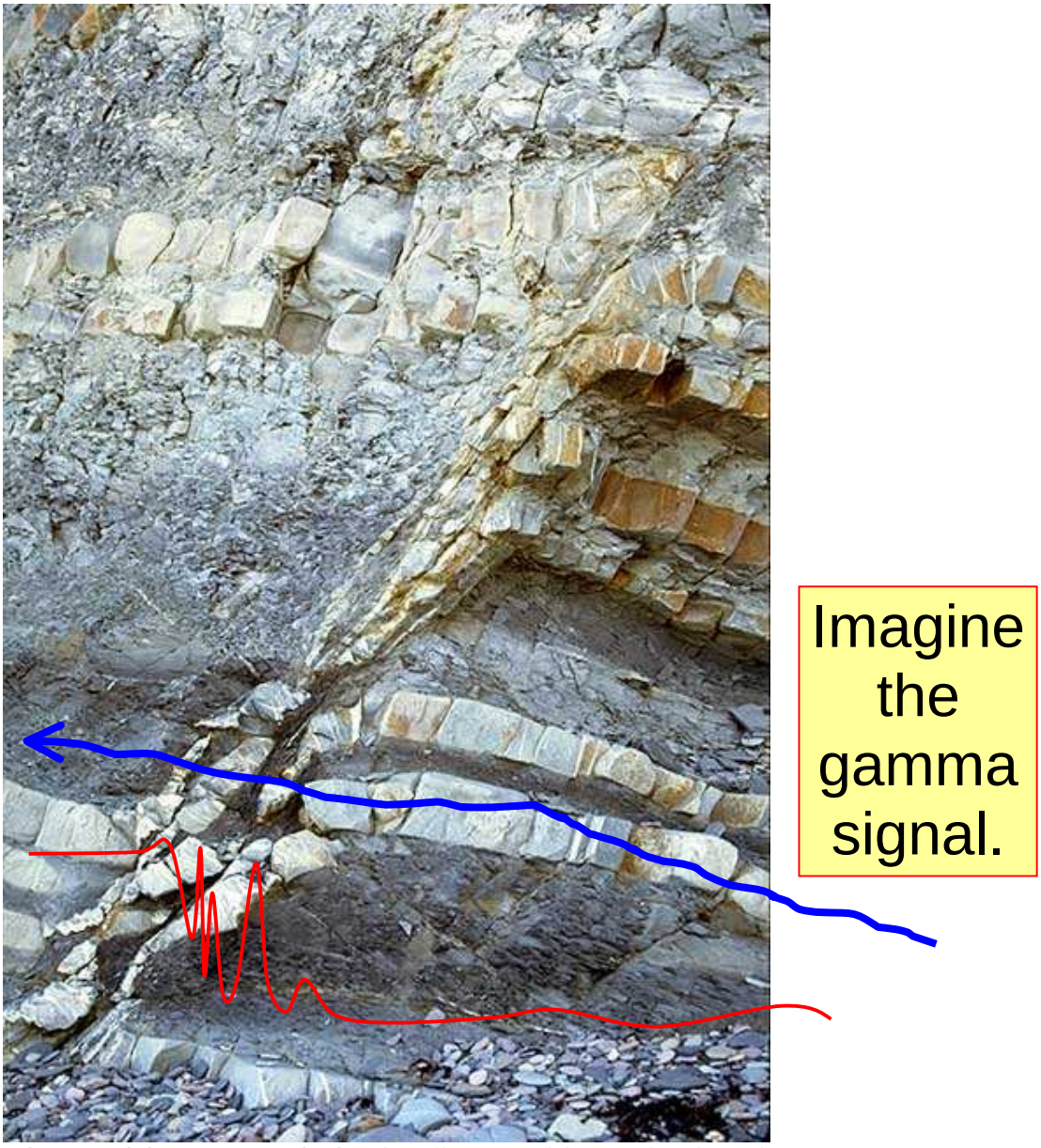
SES directional steering guidance is calculated using THD and a Fuzzy Logic control system that was patented in the United States in 2000 (click here). A technical article about SES directional steering guidance was published in 2003 (click here). A similar paper may be found here.

Please see **12.4 SES Steering Guidance** for more discussion about SES steering guidance.

15. FAULT PICTURES for ENGINEERS

This chapter is primarily for engineers. ☺ We all know the cliché about pictures and words. Enough said.

Jurassic Limestone-Shale Sequence (1)

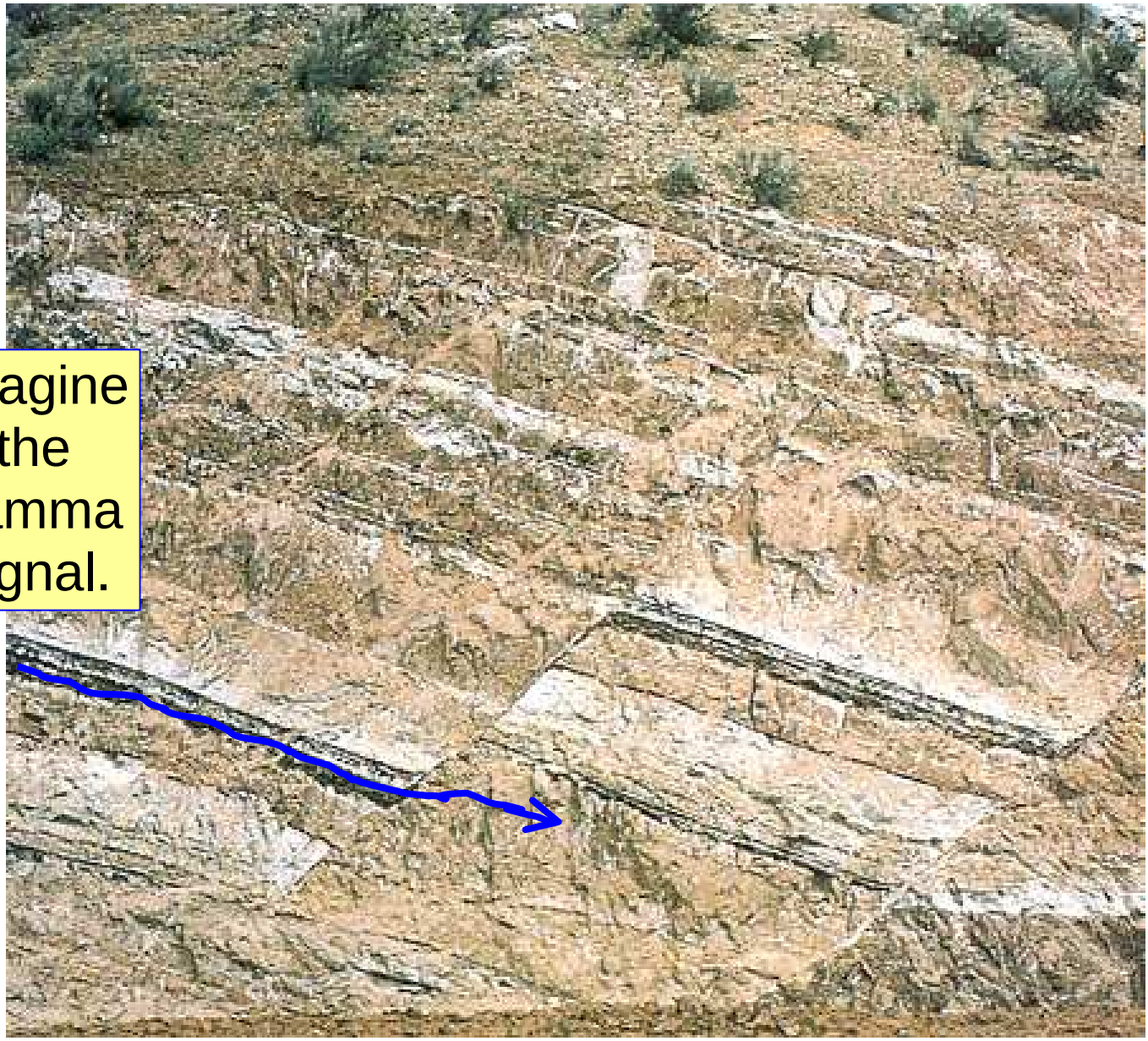


Photograph by Grant M. Skerlec, http://www.sealsinternational.com/

Jurassic Limestone-Shale Sequence (2)

Photograph by Grant M. Skerlec, http://www.sealsinternational.com/

Faults (1)



http://www.northseattle.edu/

Faults (2)

"Local" can be opposite "Regional."

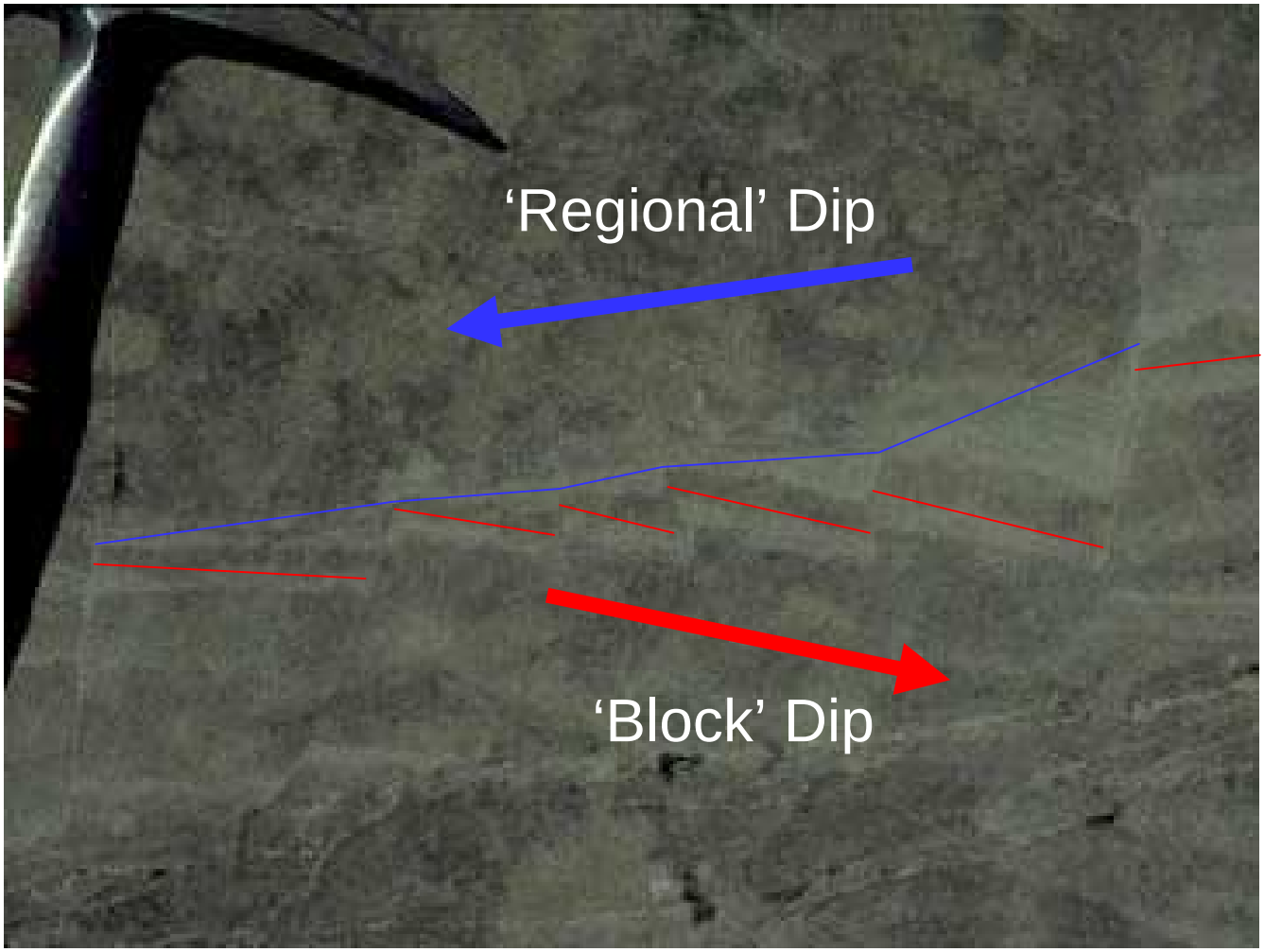


Photo by T.N. Diggs, http://www.glossary.oilfield.slb.com/en/Terms/f/fault.aspx

Faults (3)

First fault would go undetected.

Imagine the gamma signal.

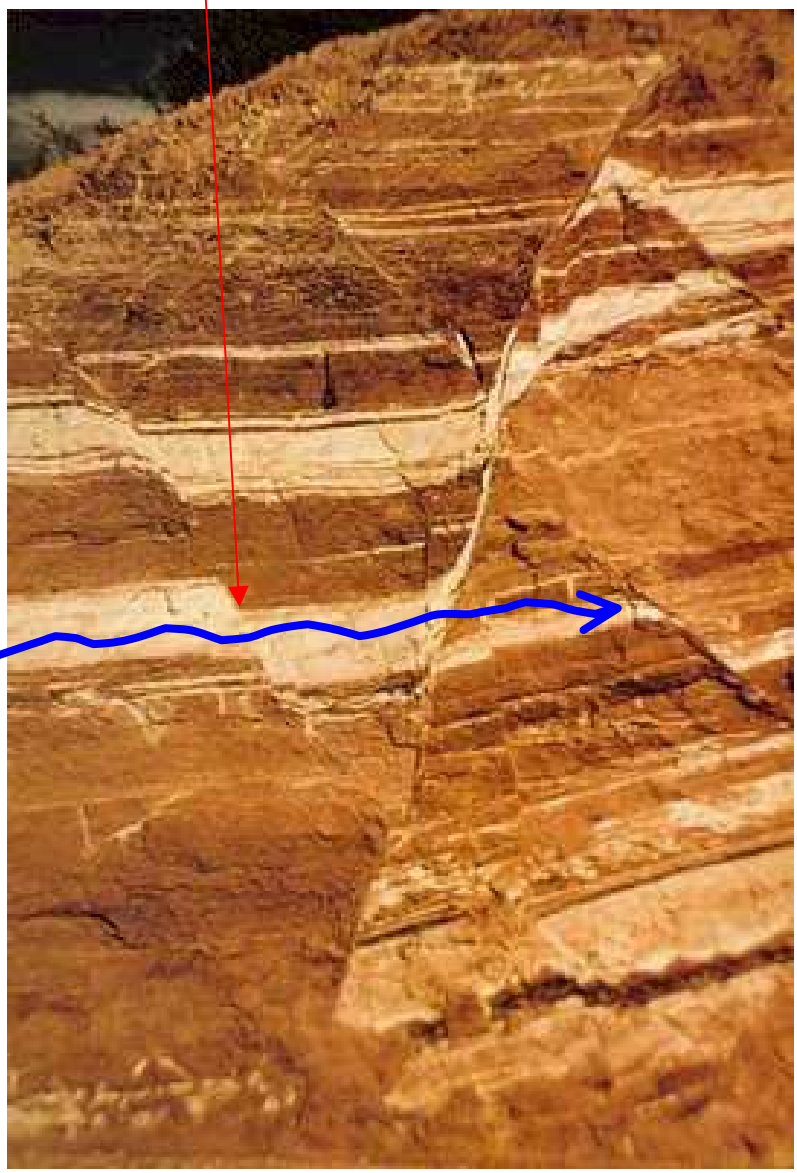
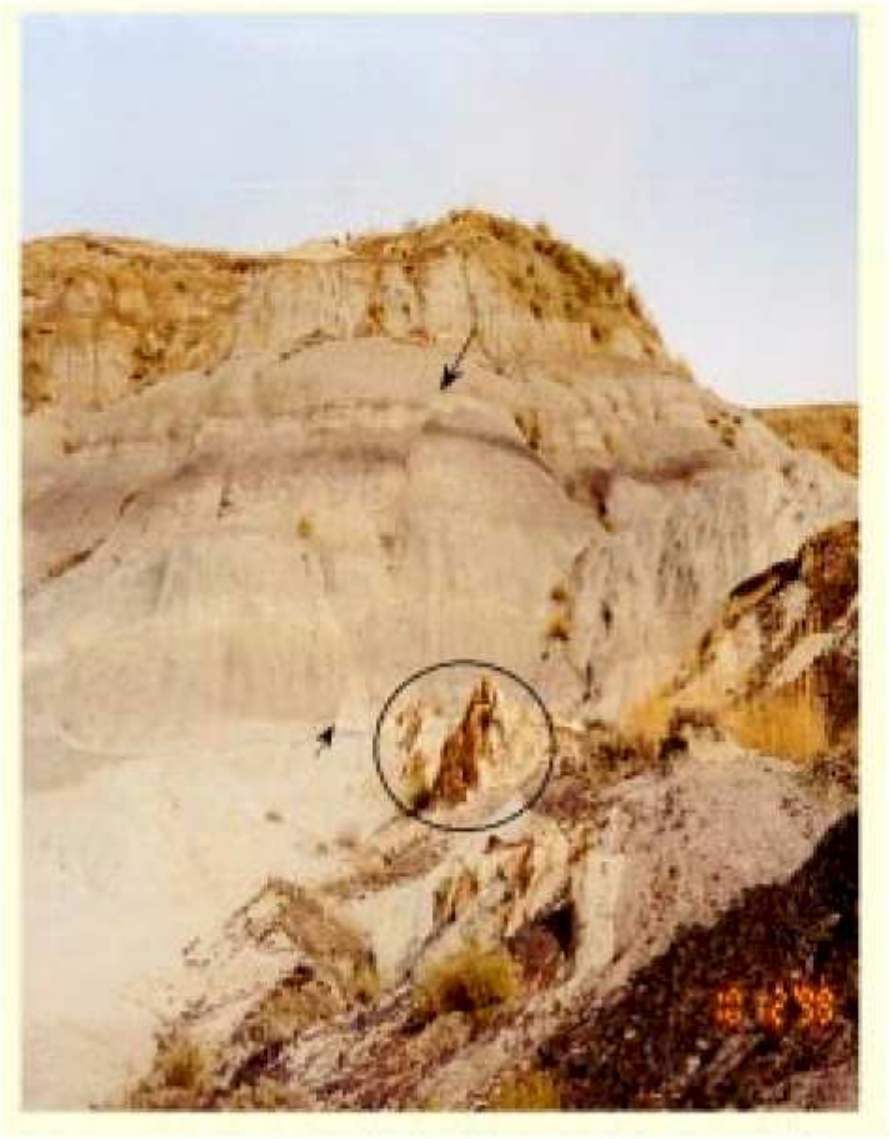


Photo by Gordon Pirie, http://www.glossary.oilfield.slb.com/en/Terms/f/fault.aspx

Faults (4)

"Photograph of faulting in Cretaceous strata southwest of Marmarth, North Dakota. Sectional view of the fault trace is exposed on the side of the bluff (between arrows)."



NDGS Newsletter, by Paul E. Diehl
https://www.dmr.nd.gov/ndgs/documents/newsletter/2001Winter/PDF/smlsclW01.pdf

Faults (5)

One "brave" geologist, or too close to the details?

http://folk.uib.no/nglhe/StructuralGeoBook.html

More pictures and information about rock faulting can be found here.

16. GEOSTEERING TRADE SECRETS

This chapter features a variety of critically important topics related to horizontal drilling and technical geosteering. Some content is specific to SES and other is general.

16.1 Geosteering 101

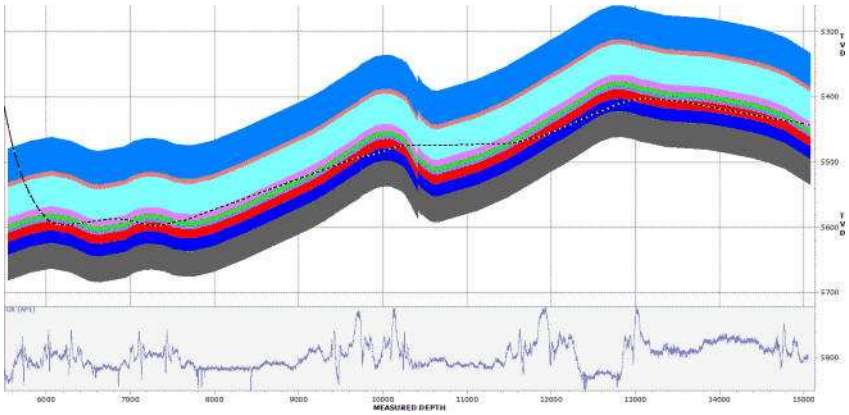
Geosteering is drilling a horizontal wellbore that ideally is located within or near preferred rock layers. As interpretive analysis performed while or after drilling, geosteering determines and communicates a wellbore's stratigraphic depth location in part by estimating local geometric bedding structure. Early geosteering was performed mostly with interpretation from cuttings samples, paper well logs, maps, and rough sketches/calculations. **Modern geosteering** normally incorporates more dimensions of information, including insight from downhole data and quantitative correlation methods.

Ultimately, today's geosteering provides explicit approximation of the location of nearby geologic beds in relation to a wellbore and coordinate system, and helps to explain wellbore/rock completion and subsequent oil/gas/water/frac fluid-flow observations from and into rock. What happens structurally between vertical wells is uncertain. Horizontal drilling is lateral geologic **exploration**.

16.2 Quantitative Geosteering

Quantitative geosteering analyses often follow one of **two fundamental technical approaches**. Along the actual wellbore path, one approach effectively assumes the **vertical** formation-evaluation (FE) well log profile is known while the other approach effectively assumes that the **stratigraphic** FE well log profile is known. Regardless of approach, normally one or very few sparsely-distributed control well logs from non-horizontal wellbores exist in the direct drilling vicinity.

In most commercial oil and gas horizontal well geologic settings, **stratigraphic thickness is relatively more stable than vertical thickness** along a horizontal wellbore path because bedding dips change and faults are crossed. By definition, bed vertical thickness depends on dip AND stratigraphic thickness at the map location of interest, and furthermore is complicated when considering attributes of true dip versus apparent dip and the fact that—incidentally and/or purposely—real 3D wellbore paths turn left and turn right in map view. In numerous structurally-complex (i.e., dip-varying) geologic settings over typical horizontal wellbore lengths, stratigraphic thickness may actually be effectively constant or its thickening/thinning tendencies known with sufficient certainty. In the below cross section the wellbore turns right about 40 degrees azimuth **after** landing and true stratigraphic thickness (TST) throughout is fully constant for all layers while true vertical thickness (TVT) is of course dip-dependent and thus varies. Bottom line...TVT will always vary because dip always varies; but the same is not necessarily true for TST.



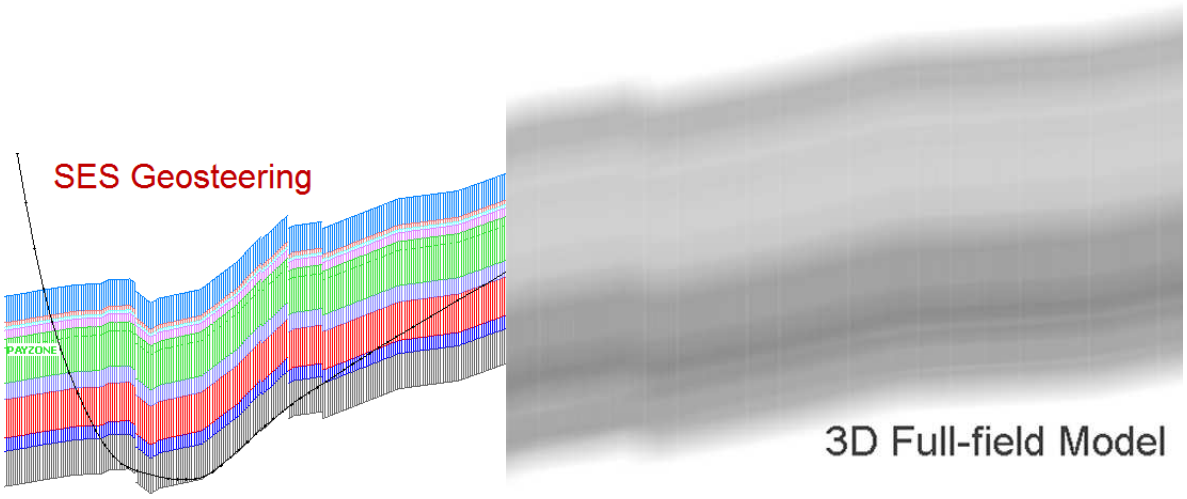
Therefore, in general when trying to approximate structure/dip, analyzing FE data at the local horizontal well level in the **stratigraphic** depth domain is **superior** than in the **vertical** depth domain (ΔVerticalDepth ≠ ΔStratigraphicDepth) and performing 3D-math geosteering logic is better than projecting into a 2D vertical plane (ΔMeasuredDepth ≠ ΔVerticalSection).

16.3 Vertical Scale Uncertainty

Think about vertical scale: seismic, vertical well log, and core. The vertical scale of SES technical geosteering—approaching the landing and within significant lengths of lateral—is *between vertical well log and core.* It is not surprising to repeatedly discover structural features and tendencies at **near-core scale** that are not observable at seismic or full-field 3D model scale and that can only be discovered through drilling horizontally.

Seismic analyses and structure contour maps are calibrated with picks from vertical, directional, and even horizontal wells. All such picks are subject to **ellipsoids of uncertainty** regarding their true global 3D locations, and these uncertainties are blended within a gridding process that creates a model of surfaces with wrinkles of unknowable errors. The aerially-sparse sampling of control points (picks)—especially within an environment of low regional bed dip—**clouds structural tendency certainties at near-core scale** along a brand new horizontal wellbore.

In other words, pre-spud drilling area dip accuracies from full-field 3D models are X°±Y°, and Y (one standard deviation) could easily be 0.5° to 2° whether X is 0° or 20°! Furthermore, "instantaneous dip"—3DSB dip; what is calibrated with SES over 10s to 100s of ft—can often be X ± 2-5 times Y! For a real example, "From seismic we fully expected to see 3° down-dip, but mostly what we saw was 2° up-dip."



The **advantage of SES technical geosteering** is that the analysis is **disconnected from absolute** 3D accuracy, which is inherently impractical because of relatively large modeling uncertainty at near-core scale. The effective SES ellipsoid sizes are much smaller because the interpretation is calibrated **relative** to local geologic markers deep in the landing; a bad KB or absolute survey errors or a busted contour map from a miss-spotted nearby well or a more complex world than seismic or contouring can honor at near-core scale, all matter not. In this "relative, small-scale world" we keep our "eye on the prize" and let others address absolute 3D modeling accuracy later. There is no better estimate of lateral small-scale geologic reality—which horizontal drilling sees—than what evolves from technical geosteering.

16.4 Interpreting the Early Landing

An offset-well type log provides *guidance* for stratigraphic correlation when drilling through the landing portion and the payzone portion of a horizontal well. However, as different horizons are traversed from the near-vertical to near-horizontal wellbore states, the wellbore penetration is a unique sample of rock

and measured signal. Therefore, "think like a geologist" instead of an engineering curve fitter when interpreting signal coming into the landing. ☺

The calibrated structural picture is true to the same degree that the RSD signal mapping is true. In other words, if the RSD signal mapping ("curve match") fits well but is in fact not representative of reality, then the resulting structural picture will not reflect reality. ☹

Consulting/displaying multiple offset type logs may help to communicate the level of thickness and signal character variability to be expected, coming into the landing (drilling the curve) and within the payzone (drilling the lateral). Quite often though, the nearest vertical reservoir penetration well log is used as the single type log to guide all expectations. With either case—single or multiple type log use—differences between "actual" and type log must be handled. In areas of low general geologic heterogeneity, there is little issue; but in many plays that luxury is unavailable.

How do geosteering analysts deal with thickness variability between "evidenced" and type log when drilling the curve? The answer depends on multiple possible factors but the solution set of choices includes the application of one or more combinations of the following techniques:

- "**Fake fault**" (regional or zero 3DSB dip is maintained, but what appears as a fault in RSD and structural domains is introduced between two adjacent 3DSBs to handle thickness variability while constraining dip variability)
- "**Unrealistic dip**" (some 3DSB dips are exceedingly different/large in magnitude from what is most likely actually present, however, RSD mapping "matches" the type log and stratigraphic depth is therefore generally tracked)
- "**Tie-on**" (current deepest signal is matched/snapped-to; "poor" uphole RSD mapping differences are ignored; final tie-on ~100 ft RSD or wellbore inclination ~60°, using regional average dip before then)

With the "Tie-on" method, only 3DSB control point TVD is adjusted while dip and dip direction azimuth are left constant at a regional average value over the drilling area.

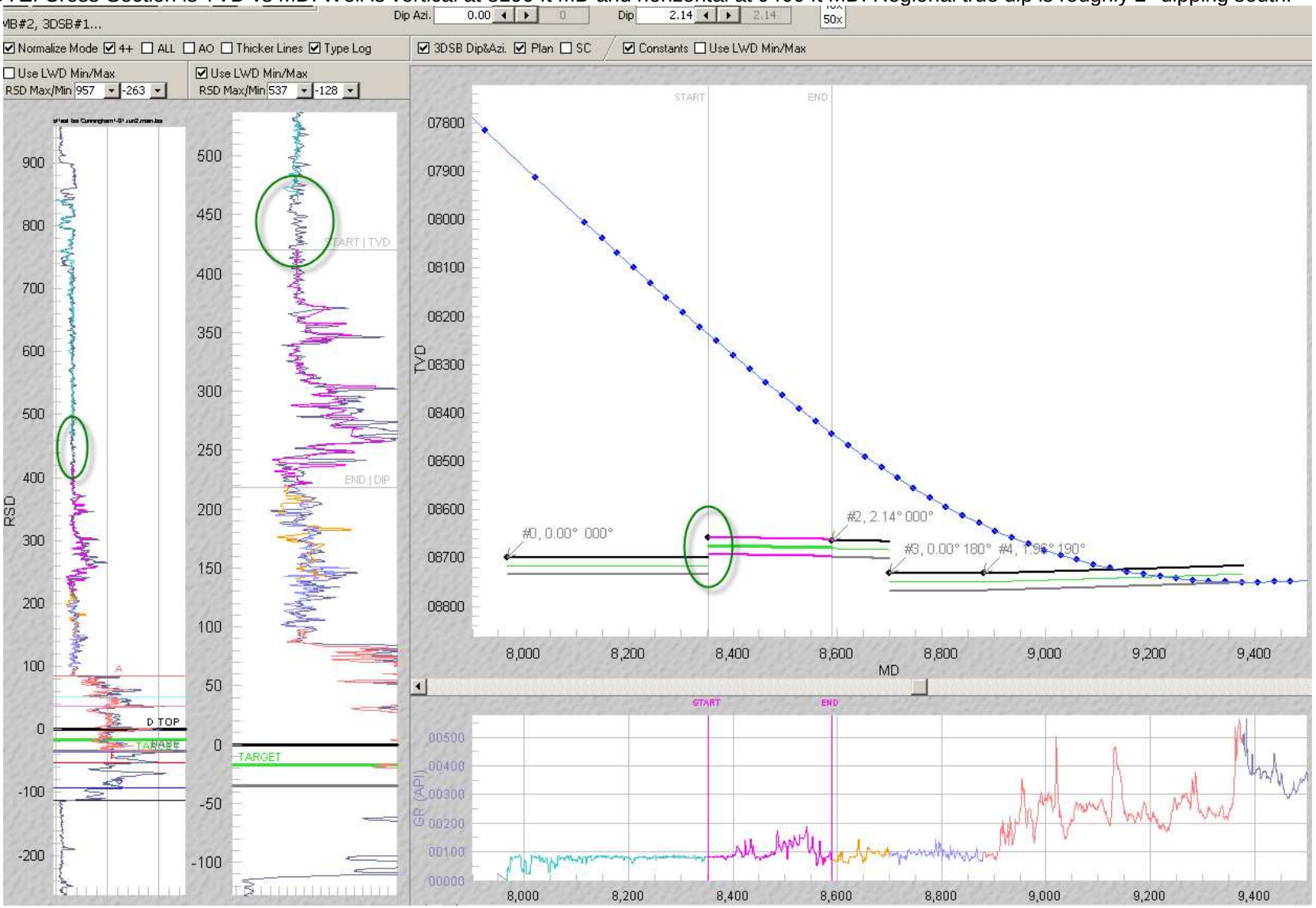
The "**Tie-on**" method may actually be the **most accurate and operationally usable technique**, but it isn't necessarily the most pleasing curve fit appearance in the RSD domain. The provided ball-park numbers (~100 ft RSD or wellbore inclination ~60°) depend on wellbore build gradient in the curve and geologic variability. Displaying/using multiple type logs during the landing may also help to remind the geosteering analyst or analyst's client of uphole thickness variations in the area.

Drawing definitive conclusions **too early** (and acting upon it with the directional driller) regarding "where the payzone is coming-in" can be **counterproductive** if significant thickness variability is present. Zones above the payzone may have quite different thickness variation characteristics than the payzone. Fortunately, as signal characteristics understanding, local/small-scale structural tendencies understanding, and geosteering experience within a particular field all evolve, trained personnel know what is normal and what isn't and how best to act.

Three early-landing interpretation examples follow to demonstrate the three aforementioned techniques of addressing uphole thickness variations in geosteering interpretation. Please note the following interpretations are identical from 8880 ft MD forward! The latter part of the landing phase is most critical and usually more stable. Fortunately, when wellbore inclination becomes significantly high, the **very-early-landing** estimate becomes effectively trivial and in most cases will purposefully **not be displayed in distributed cross sections**.

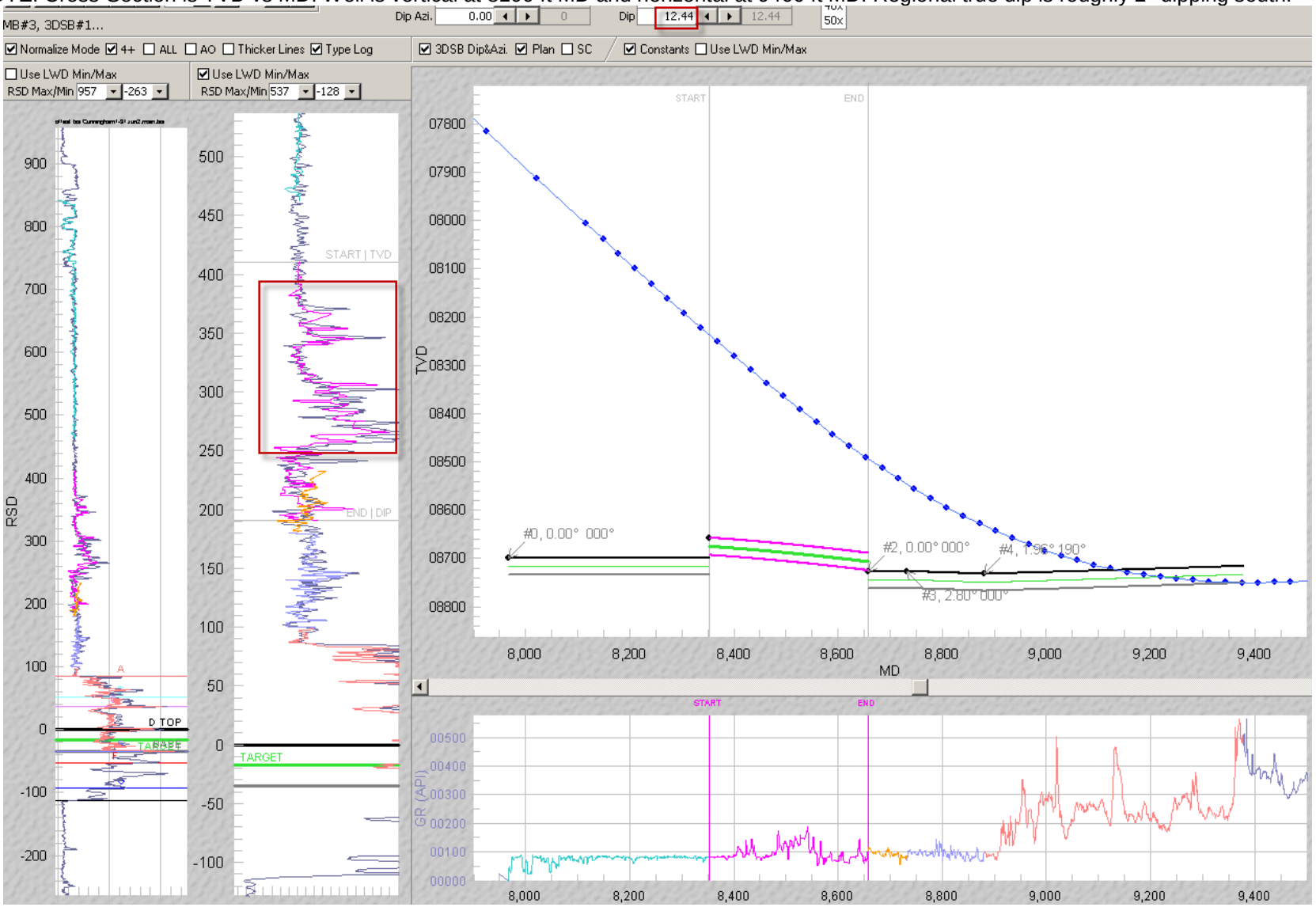
"Fake Fault" Landing Interpretation Example

NOTE: Cross-Section is TVD vs MD. Well is vertical at 8100 ft MD and horizontal at 9400 ft MD. Regional true dip is roughly 2° dipping south.

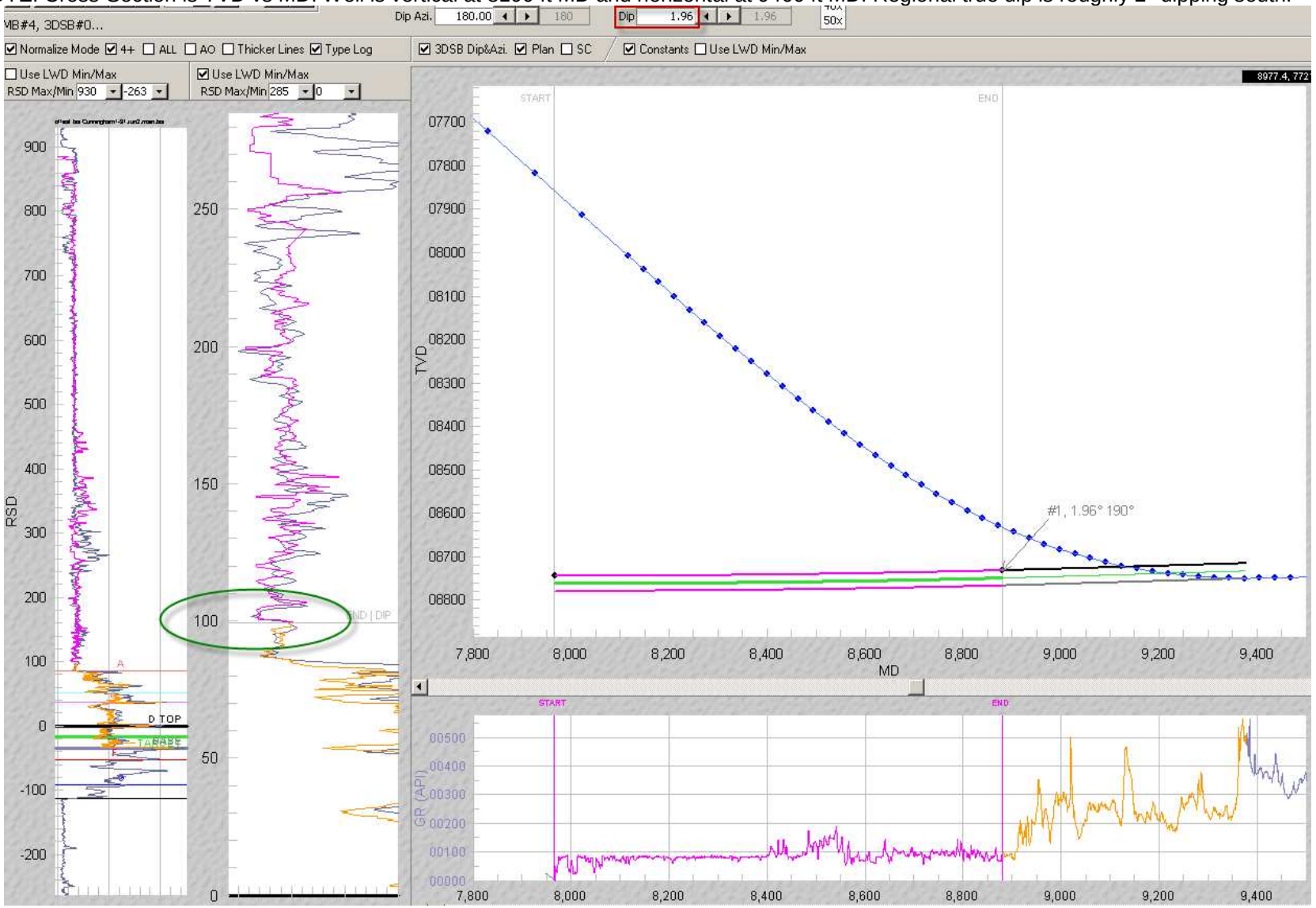


"Unrealistic Dip" Landing Interpretation Example

NOTE: Cross-Section is TVD vs MD. Well is vertical at 8100 ft MD and horizontal at 9400 ft MD. Regional true dip is roughly 2° dipping south.



"Tie-on" Landing Interpretation Example (ignore uphole differences; final tie-on is about 100 ft RSD or wellbore inclination ~60°)
NOTE: Cross-Section is TVD vs MD. Well is vertical at 8100 ft MD and horizontal at 9400 ft MD. Regional true dip is roughly 2° dipping south.



16.5 Dip vs. Thickness

After the well is landed...by drilling horizontal hole and analyzing LWD signal, **payzone properties** true stratigraphic thickness (TST) AND true bed dip (and direction) over tens to hundreds of feet are mathematically indeterminate, i.e., their quantities are not known and cannot for which be solved. They are coupled properties. Therefore, we assume to know one (usually stratigraphic thickness) and calibrate/solve-for the other (dip) because this usually makes the most sense based on commercial O&G expected payzone variabilities and because this process yields a solution—albeit non-unique—sufficient to make definitive, confident, and defendable decisions.

Be that as it may, with SES, the geosteering analyst **may impose a variable thickness interpretation** along the horizontal wellbore. 3DSB thickness, which is TST, is set by 3DSB and therefore different 3DSBs may have different thicknesses. When variable TST logic of interpretation is performed, much offset vertical well control is normally available to defend its application, especially if more than general and minimal payzone thickening or thinning is being portrayed. **Constant 3DSB and offset layer thicknesses is most common**.

16.6 Novice Curve Mistake: Calibrating Dip Too Early

Until significant wellbore inclination is attained in the curve (perhaps greater than 45°, but there is no magic inclination), 3DStratBlock calibration may primarily be based on control point TVD adjustments, with 3DSB dip set to zero or the regional average value as determined from a contour map over the drilling area. This is known as the "Tie-on" method (see **16.4 Interpreting the Early Landing**).

An empirical manifestation of "it's too early to calibrate dip" is overly sensitive and/or erratic RSD signal response to dip adjustments made via dragging the "End|Dip" horizontal line on the inner/right RSD track on ParamTuner screen. Erratic RSD signal response would include the "Start|TVD" line significantly moving. The fundamental reason for this behavior is that the mathematics of SES technical geosteering are not generally applicable to vertical or near-vertical wellbores. Viewing the wellbore on TVD vs. MD axes can mask the present inclination state of the wellbore, but ParamTuner always displays inclination at TD.


Recall, the calibrated structural bedding picture is only true to the same degree that the RSD signal mapping is true. If RSD signal mapping "fits" well but is in fact not reality, then the resulting structural picture will also not reflect reality. If "forcing" a signal match in the RSD domain requires unrealistic dip and there isn't the situation discussed in the next section, then wellbore inclination may still be too low to effectively calibrate dip or the type log may not be very representative at the current stage of progression towards the payzone. The math is such that the general sensitivity to "forcing" an erroneous thickness match and observing erratic RSD signal response is exacerbated in a non-horizontal wellbore.

16.7 Novice Lateral Mistake: Over-fitting/Under-fitting

Repeatedly making 3DSBs too short can give the geosteering analyst a *false* sense of stratigraphic location certainty and it can obscure the opportunity to observe the sought-after good estimate of reality. At the other end of the spectrum, 3DSBs that are too long—with overly-repeated signal retracing in the RSD domain—can mask important structural information that is clearly present but hidden by the smearing of the puzzle pieces. Too much of anything is not helpful! ☺

The rule-of-thumb is to **calibrate a 3DSB to be as long as possible, without burying important signal**. This frequently requires interpretation exploration with temporary interpretation gaps or even overlaps, and fitting different length 3DSBs together. At other times during live drilling operations, multiple possible interpretations are necessary to be maintained until sufficiently definitive signal is acquired after drilling more wellbore and analyzing its data. In other cases, formerly numerous 3DSBs may be replaced with one or fewer 3DSBs as interpretation certainty unfolds with the help of new stratigraphically informative data, such as a boundary crossing or scrape.

There is no uniform 3DSB length that governs best geosteering practices. How nature is curving with respect to the vertical and horizontal scales of interest is a variable, governing factor of ideal 3DSB length, as is analyst preference with respect to appearances of type log curve matching.

16.8 "Block of Clarity" – the Calm Feeling of Certainty

Stratigraphic location certainty changes along the horizontal wellbore. In other words, the confidence in the interpretation of *some* 3DStratBlocks will be much greater than others. This is normal and inescapable. For example, the signal signature when "scraping" an offset bed may be more recognizable than drilling somewhere in the "middle" of a relatively thick, clean (or dirty) gamma ray portion of a bed.

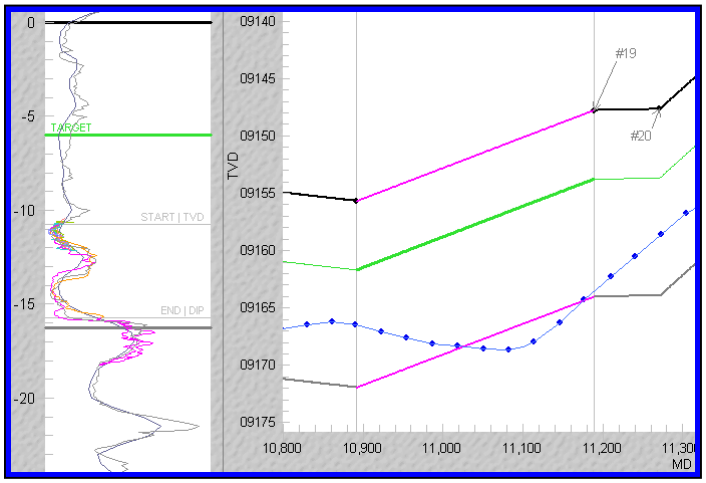
SES by design is setup to enable quick isolation of wellbore signal portions to help find where interpretation confidence could be high. In this process a MD gap—interval of wellbore with no current interpretation of payzone location—may be introduced as the user changes MD_Start of a 3DSB (or MD_End of an internal 3DSB) and focuses on a portion of recognized signal. Subsequently, the gap is typically filled-in with one or more 3DSBs and calibrated with "Occam's razor" in mind…the simplest geologic interpretation is best.

A "**block of clarity**" corresponds to an interval of wellbore where **stratigraphic location is highly certain based on** great signal matching in the RSD domain, the structural domain making unmitigated sense, and the general **passing** of **all "sniff tests"** from all possible data sources. In many cases a block of clarity will provide guidance to geosteer towards. *In fact, the case can be made that technical geosteering analysis is in-effect the process of identifying as many blocks of clarity as possible, such that when fully "connected" over the entire wellbore length, reality is well portrayed and closely approximated*.

Pinpointing reality confidently well should usually precede any planned well path change, and **changing the planned well path always includes *speculation*** about rock structural behavior in front of the drill bit. Indeed, solidifying with high certainty what has occurred behind the drill bit is step one of geosteering. Repeated observations of geologic reality in a given commercial play increase the speculator's odds of making steering decisions that turn-out good, because geologic realities often repeat.

16.9 "TraceBack" – a GeoSteerer's Best Friend

A geosteering analyst is sometimes called a geosteerer. *"Traceback"* is the name given to a portion of RSD signal mapping that captures a stratigraphic down-up or up-down traverse over a continuous wellbore interval. The signal "traces back" over itself at a specific dip. When accurate, this observation is an excellent estimate of 3DSB dip. With subsequent 3DSB TVD adjustment usually then necessary to vertically align the signal against the type log, the final result provides a "block of clarity" that serves as a local anchor about which to geosteer (towards and/or from). The adjacent picture displays in magenta traceback in the RSD domain and its block of clarity in the structural domain.



If true bed dip in reality is steady and nearly flat, then traceback will be evidenced with sufficient alternating wellbore TVD increase and then decrease (or decrease and then increase) against a backdrop of sufficient signal character contrast. However, traceback need not necessarily coincide with absolute

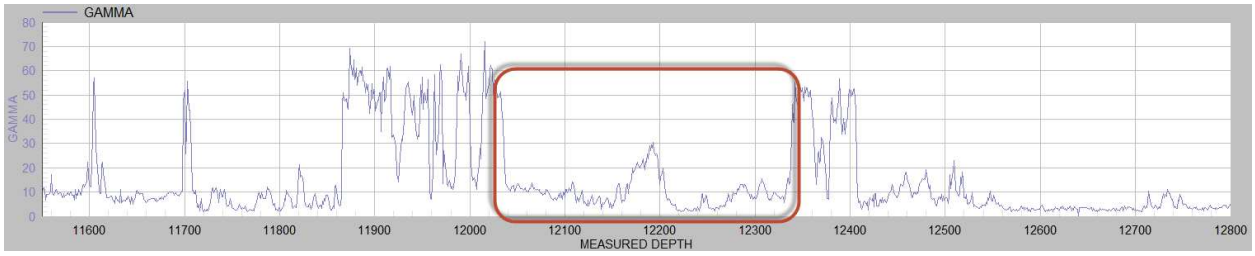
TVD increase/decrease! **Traceback is evidenced by means of definitive changing wellbore stratigraphic location relative to a *chance* intersection of payzone with constant dip.** Therefore, traceback may be evidenced while wellbore TVD is increasing but at varying rates (or is decreasing at varying rates) relative to a portion of geologic reality that happens to possess constant dip over the same interval. This means **traceback can technically be evidenced anywhere along a lateral**. ☺

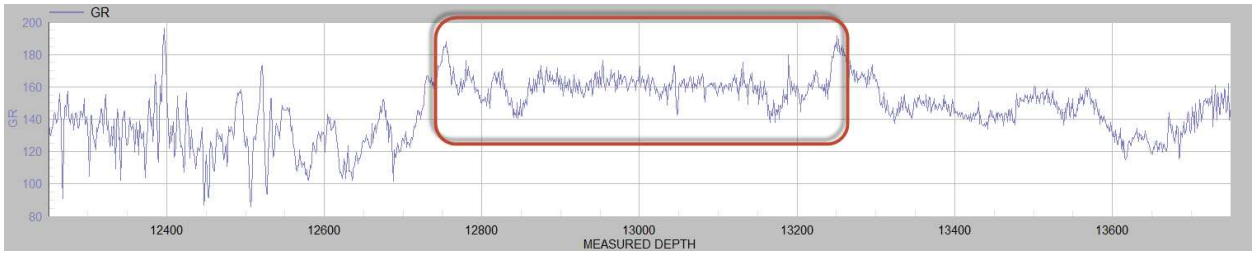
The heart of the landing may provide an opportunity to observe traceback, and some operators in some payzones purposefully plan the landing to observe it. Such a landing may immediately supply a landing-derived type log for subsequent drilling of the lateral. At other times while geosteering, directional steering action may intentionally be performed to look for traceback by increasing or decreasing wellbore inclination to help reduce uncertainty about the wellbore's current stratigraphic location. In other more structurally complex situations, "traceback" may effectively be assembled but with multiple contiguous 3DSBs, in particular when nature significantly curved while true stratigraphic down-up or up-down traverse over a wellbore interval in fact occurred or if it occurred over a relatively long section of wellbore.

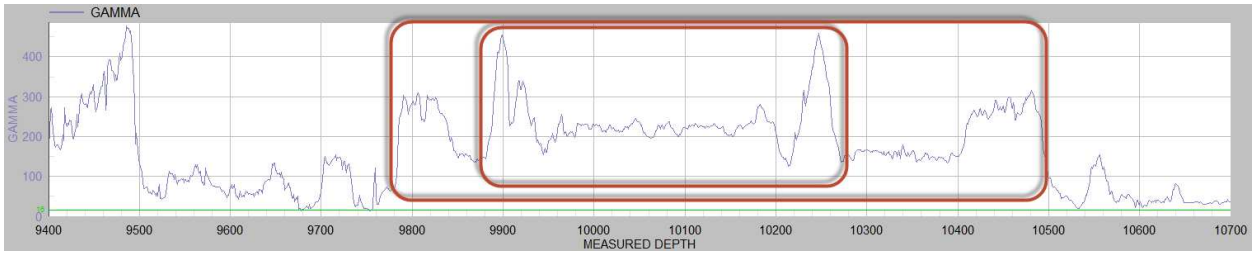
16.10 Watch for Mirrors

Sometimes it's helpful to isolate the extents of a 3DSB to a particular portion of LWD signal character, such as a "signal mirror" portion of wellbore that potentially suggests up-and-then-down or down-and-then-up stratigraphic movement ("traceback"). After such data isolation, experiments with 3DSB dip and control point TVD often follow. If valid traceback is found, it is a welcomed observation as explained in **16.9 "TraceBack" – a GeoSteerer's Best Friend**. Therefore, always be on the lookout for signal mirrors.

"Signal mirror" gamma ray data from what indeed turns out to be traceback from three different wells are shown below. Notice how the boxed data portion somewhat appears to repeat or "mirror" the measurement signal after roughly midway through the boxed area. It's never perfect and working in ParamTuner and the RSD domain will significantly help, but even at the raw data level a "signal mirror" may scream to the analyst what's happening or for what and where to look.







16.11 3DSB Dip Azimuth...What should I use?

3DStratBlock (3DSB) control point coordinates, plus dip and dip direction azimuth define a unique 3D plane that is an estimate of the payzone top location and therefore technically is independent of wellbore location (including wellbore direction/azimuth). If regional true dip direction azimuth **is confidently known** over the horizontal well area or certainly if true dip magnitude is large, then **regional true dip direction azimuth** (or its 180° counterpart) may be and **should be applied while geosteering with ParamTuner**. The reason for this is due to the inherent 3D mathematics underlying RSD and signal calibration from independent 3D objects (wellbore and zones).

An **alternative option** is to strictly use **vertical section azimuth** (or its 180° counterpart) for 3DSB dip direction azimuth. In this case, the 3DSB dip being calibrated is of an apparent (instead of true) nature. This is a common practice in drilling areas of low regional dip (e.g., **less than two degrees**) and a 2D well plan (**no** appreciable wellbore **turn** in map view).

A third option is to use "current" wellbore azimuth (or its 180° counterpart). In this case, the 3DSB dip being calibrated is also of an apparent nature.

Because of the non-unique nature of coupled dip and dip direction azimuth, and the RSD calculation, different pairs of dip/dip_azimuth can produce near-identical mapping of signal onto the type log and thus a near-identical interpretation of where the payzone is located over the respective finite interval of wellbore; but a different number of 3DSBs may be required to produce the "same" mappings. In general this is a positive attribute because if 3DSB dip azimuth is different than nature's true dip direction azimuth, a similar interpretation can still be found.

The 3DSB/RSD concept is superior to vertical section projection analyses because in practice the ability of transforming all related data to use wellbore-interval-dependent "projection azimuth" is entirely impractical with current industry protocols. Also, with **3D objects** (wellbore and zones) truly **being modeled as 3D objects** instead of projected-into-2D objects, "things" often **fall into place more easily** and naturally, and **distortions related to projections are largely altogether avoided**. Such distortions are exacerbated with thin payzones or "3D wellbores" (appreciable wellbore turn in map view).

16.12 High Dip Artifacts in Low Dip Environments

A condition can arise related somewhat to general numeric "instability" within the 3D math from having calibration parameters "out of sync" in a particular geologic/geometric setting. IF true dips are actually quite low (e.g. <1 degree) AND the 3DSB dip direction azimuth set in ParamTuner is roughly 90 degrees different than the wellbore azimuth, then larger calibrated 3DSB dip magnitudes in ParamTuner may be evidenced and are an artifact of being very-much out of phase in the low-dip environment. Dip and dip direction azimuth are coupled. In this situation, it would be better to set 3DSB dip direction azimuth to either be a better estimate of true dip direction azimuth (from a contour map) or set it to either the vertical section azimuth or the wellbore azimuth at TD and recognize that dips being calibrated in ParamTuner are of an apparent (instead of true) nature.


In general, as true dip magnitude gets smaller, the concept of dip direction azimuth becomes less significant/absolute, and in fact dip direction azimuth is undefined/meaningless at true dip equal zero. The larger true dip magnitude is, the more influential dip direction azimuth becomes on RSD calculations.

For example, if nature is truly dipping at 0.68 degrees at dip azimuth of 325 degrees, and if 3DSB dip azimuth is set to 68/248 degrees and therefore 325-248=77—which is approaching 90 degrees—this condition may lead to the situation of calibrated 3DSB dip magnitude being larger than expected, for the reasons explained above. Again, dip and dip direction azimuth are coupled parameters, which model reality. In this example it may be better to change 3DSB dip azimuth to 325, or to vertical section azimuth or wellbore azimuth at current TD and realize 3DSB dip is of an apparent nature.

16.13 Truths & Tips

Geosteering professionals embrace the following realities:

- Wellbore/stratigraphic certainties are limited and sporadically located along a wellbore path.
- Wellbore/stratigraphic certainties near current TD and beyond are unknowable.
- Making steering decisions that turn-out to be incorrect by some measure are inevitable for all.
- Geosteering purpose attempts to maximize wellbore/payzone exposure and avoid troublesome drilling/completion/production conditions.
- Geosteering purpose attempts to add economic value, geologic knowledge, and reservoir knowledge.
- Geosteering analysis combines creative geologic knowledge and imagination ("art") with systematic and intellectual reasoning ("science").
- Geosteering expertise is a craft that takes time, experience, and thought to acquire.
- It's best to carefully consider the full drilling/completion/production risks and tradeoffs before making planned well path changes while drilling.
- A strong working knowledge of the area's geology/drilling/production leads to better geosteering/steering decisions and increased odds of favorable results.
- The drilled/analyzed wellbore and beds are 3D objects. Think 3D.
- Fault certainties aren't known until perhaps 100s of feet past the fault. Drill ahead and speculate and get more data, but also remember it's easier to sidetrack on hole low side.
- It's easier with hindsight (also known here as...more data)! The best estimates of wellbore/rock-layer certainties over the entire lateral are obtained after TD is reached and full datasets are analyzed by trained personnel; and later re-analyzed after significant numbers of new datasets and area experience have been acquired.

Final tips:

- When geologically lost, carry multiple working hypotheses until new data resolves ambiguity.
- When geologically lost, get others' opinions/input. Geologic truth does exist!
- Respect the full-field structure model and type logs but don't blindly anchor to them, as realities along portions of your wellbore may be quite different than thought prior.

If it were easy, many more folks would do it—as well. ☺ GOOD LUCK!

THANKS for using SES!

IMPORTANT

SES evolves and changes and the program behavior reported in this user manual may be different in the version of SES you are running today. See SES Release Notes documentation for detailed updates to the changes and new-feature additions!

If your computer does not respond to keyboard typing, make all graphs NOT have the focus (magenta outline) by "clicking-elsewhere". This is a Microsoft bust (http://support.microsoft.com/kb/210608/en-us).

There are several screen tips. Just place your mouse over a control and if available the tip will appear. Clicking into a text box usually provides more information in the status bar.

The status bar at the far bottom of the application window is used extensively to inform you of various information. If SES is working OR if the mouse cursor shows "busy", please let processing complete before clicking or typing.

Several example wells accompany SES. Seeing examples is a great way to start learning new software!

Need a feature added to SES? Send FEEDBACK to us now using menu Help, Online/Download, and click 'Email Technical Support.'

THANKS for using SES!