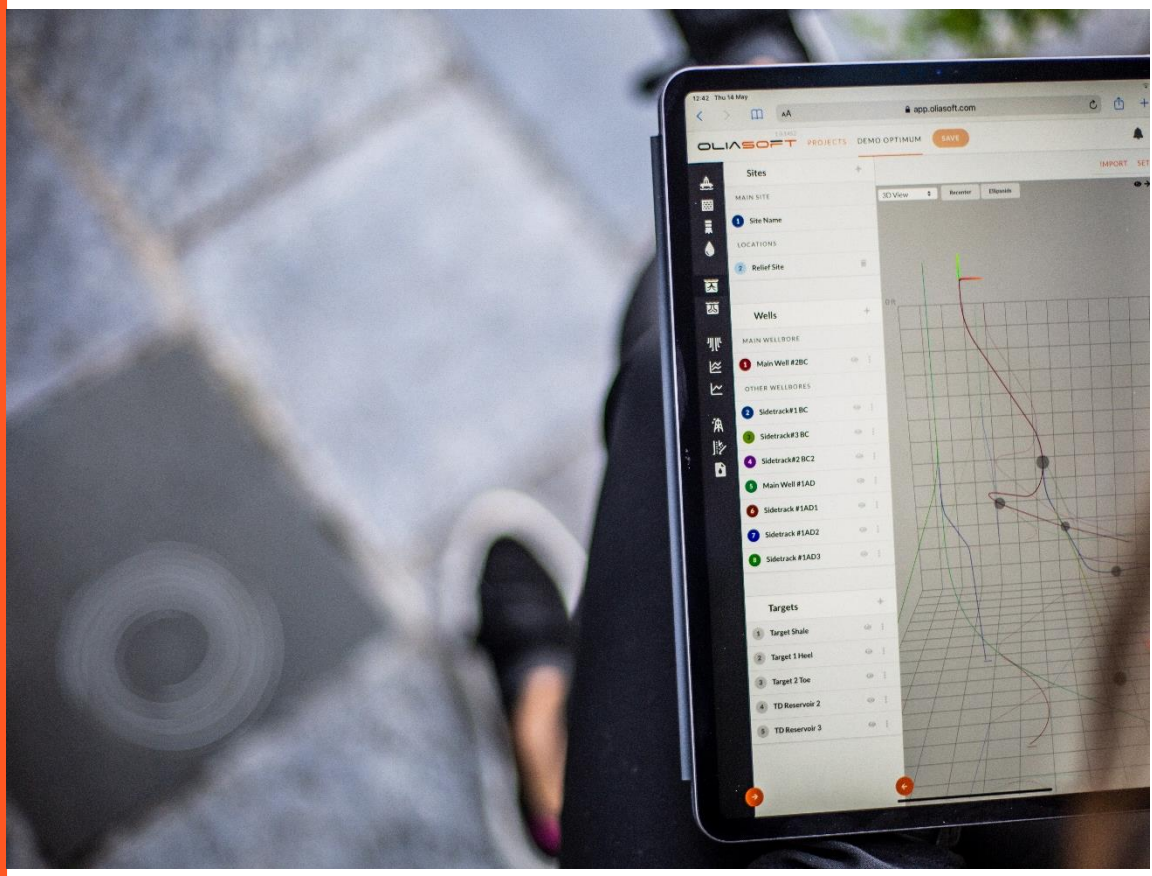
OLIASOFT



Oliasoft WellDesign®

Technical Validation Report Torque & Drag

Oct 2020

Content

1 Introduction

This report is part of the technical validation of Oliasoft WellDesign Torque & Drag engine.

The results calculated in the report have been simulated in Oliasoft WellDesign (OWD) and compared with planning and real time data provided by a major global operator.

The data provided includes Wellplan reports and realtime data from the operation. The bottom hole assemblies, casing strings and general conditions used in the WellPlan simulations are sometimes different from the realtime data.

In order to perform a thorough validation of the T&D simulations from OWD, simulations have therefore been performed in two steps.

1. Comparison of OWD and real time data, by reconstructing "As run" operational parameters and compared with real time data and input parameters found in "as run" BHA´s, casing tallies and daily drilling reports

2. Reconstruction of WellPlan simulation parameters, simulated in OWD and compared with provided WellPlan reports

The second step has been included in the validation to be able to validate results such as effective tension, stretch and torque results.

The report includes comparison results from the following sections/operations:

- Drilling 26" open hole
- Running 22" casing
- Drilling 18.125 x21" open hole
- Running 16" casing
- Drilling 14 x 16.5 open hole
- Running 14 liner
- Drilling 12 ¼"open hole

All simulations except effective tension plots have been run with true tension and piston effects activated.

Note: Data provided has not always been clear or precise on what type of input parameters and equipment that was used for the both real time and WellPlan results. As T&D simulations are sensitive to weights, densities etc. we have tried our best to replicate scenarios, but results may not always match 100% based on the ambiguity of input and running parameters in real life.

2 Summary

2.1 Oliasoft Vs. Real Time Data

“As run“ parameters have been reconstructed in Oliasoft WellDesign (OWD) to simulate the different operations run for this well. This comparison has been done for all drilling and tripping in of casing/liner operations.

In general, simulated loads have good to very good correlation with measured realtime data.

For the drilling operations (26”, 18.125 x 21”, 14.5 x 16.5” and 12.25”) the simulated results are matching well compared to reported hookload, with around 5% or less deviation from realtime data.

For the casing running operations (22”, 16”, 14” liner), the simulated results are matching well compared to reported hookload. Some overestimations on the hookload can likely be addressed to inaccuracies in input data. Average deviation around 5% or less in the deeper sections and up to 10% in the shallow sections.

2.2 OWD Vs. WellPlan

Based on WellPlan reports and result spreadsheets, Oliasoft has reproduced the same input and running parameters used in WellPlan (as far as possible) for all sections in the well.

There are some discrepancies between the Wellplan reports and spreadsheets. This has caused some room for error in a direct comparison between the two systems. The discrepancies relate to which weights were used for different components, drill pipe configuration and running parameters.

However, the comparison between OWD and Wellplan gives a good indication of consistency of trends and magnitude of results between the two simulation engines.

Comparisons with WellPlan shows a clear correlation between the results simulated in the two programs for most sections, but some sections seem to have a different slope. This is likely due to some difference in weights or mud weight used in input parameters that we have been unable to identify, in particular the 26” section.

In general, Oliasoft simulations seems to deviate less compared to realtime data than the WellPlan reports, especially for deeper sections.

2.3 Abbreviations

- BHA – Bottom Hole Assembly
- OWD – Oliasoft WellDesign
- ROB – Rotating On Bottom
- ROP – Rate Of Penetration

- TIH – Tripping Into Hole
- TOH – Tripping Out of Hole
- WOB – Weight On Bit

3 Results

The results in the chapter below are split into two sections as explained in the introduction. The different sections of the well are presented in a chronological order starting with drilling of the 26" section. The results for each section are split into two parts

1. Comparison of OWD "as run" simulations and real time data.

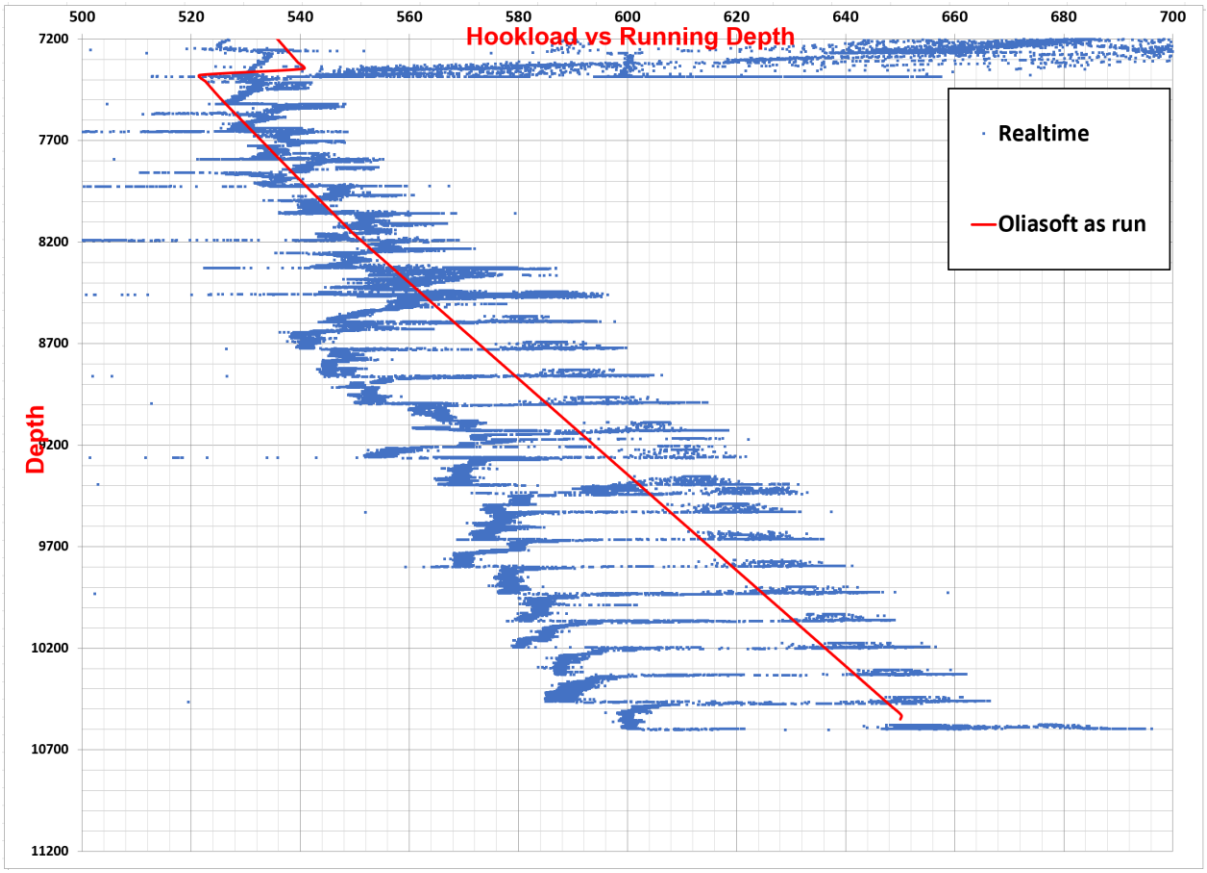
2. Comparison of simulations run in OWD and Wellplan results.

The simulation input parameters used for each section are presented in a table at the start of each subchapter. The files used as a source for input and results are presented below this table for each section.

3.1 Drilling 26" open hole

3.1.1 OWD Vs. Real Time Data

Drilling 26" Open hole				
BHA	26" As run			
Block Weight [kip]	185			
Mud weight [ppg]	10.1			
Friction factors	Riser	Casing	Open hole	
	Riserless	0.18	0.18	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit [lbf·ft]	WOB [kip]
	32	100	1400	40



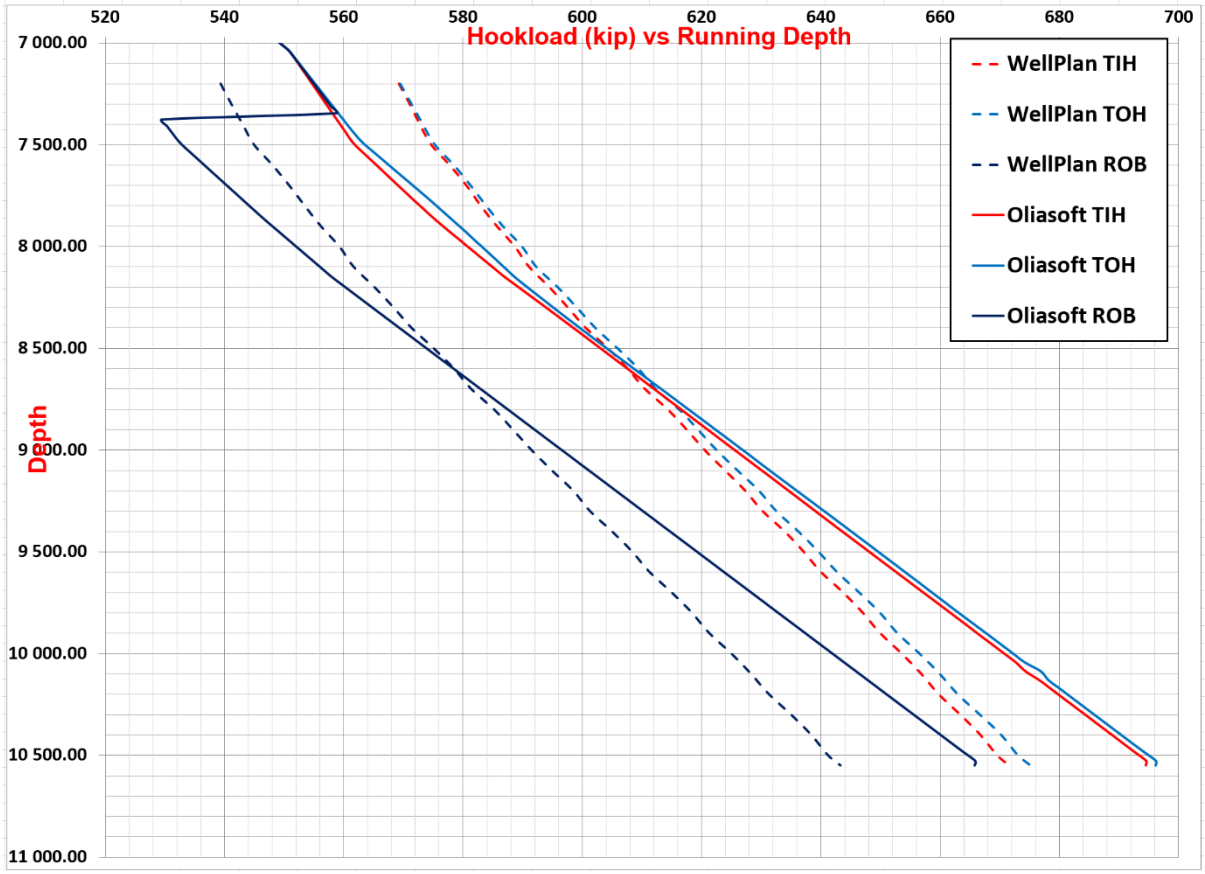
Plot 1: Simulated hookload plotted against real time hookload.

The plot clearly shows how OWD simulation follows the real time hookload data. The plot only shows depths from the drilling operation. The sudden decrease in hookload, starting at 8500ft might be due to an increase in WOB or mud density related as there is cuttings in the annulus here. This has not been included in the analysis.

3.1.2 OWD Vs. WellPlan

Only hookload results from WellPlan was available so only this simulation is evaluated below.

Drilling 26" Open hole				
BHA	26" Wellplan			
Block Weight [kip]	185			
Mud weight [pgg]	10.1			
Friction factors	Riser	Casing	Open hole	
	Riserless	0.18	0.18	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit [lbf·ft]	WOB [kip]
	32	100	1400	30



Plot 2: Simulated hookload with OWD and WellPlan. All operations from OWD follow a slightly different slope than the same operations in WellPlan.

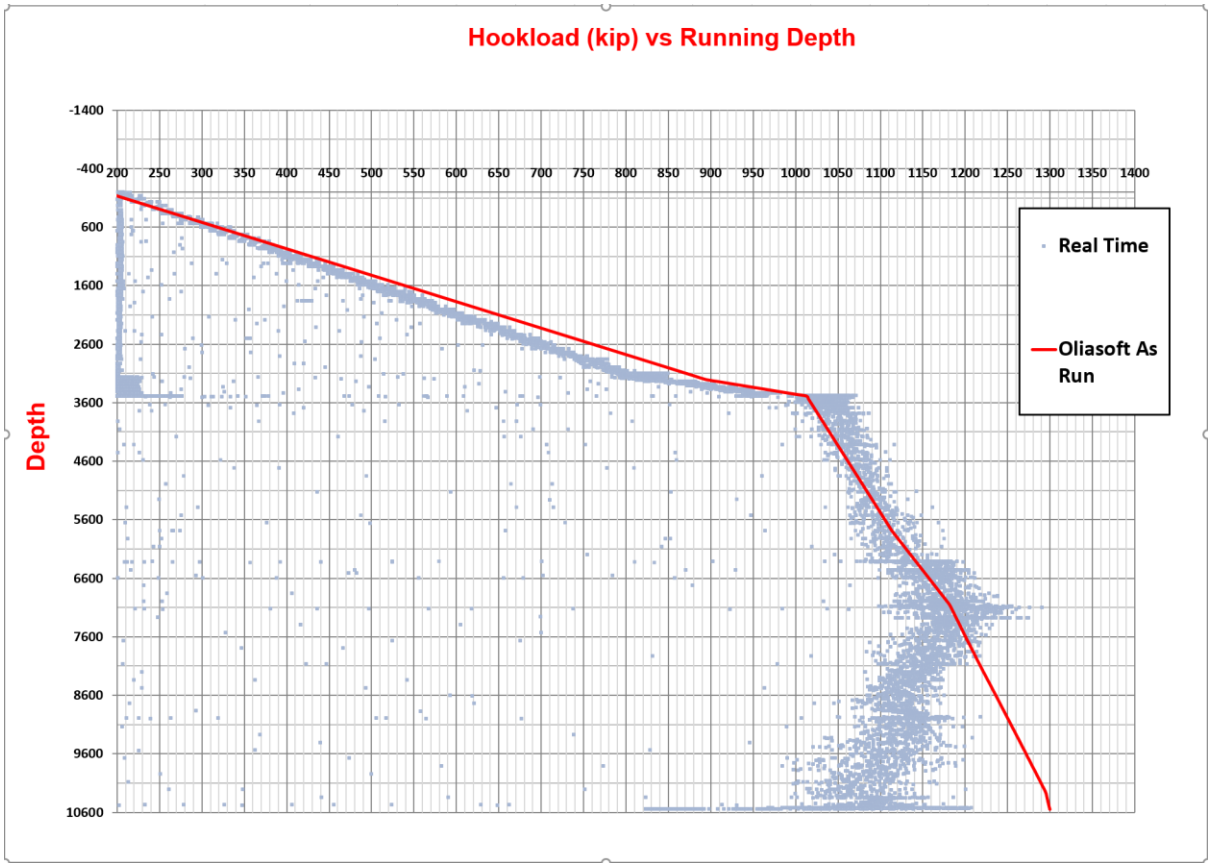
In the plot you can see that lines for trip in/out follow each other similarly in both programs. The different slopes can be due to different component weights. From “Oliasoft ROB '' you can see how Oliasoft simulates drilling operation without WOB until drilling of the open hole starts, indicated by the clear shift in weight at 7400 ft. The WOB used was 30 kip.

3.2 Running 22” Casing

3.2.1 OWD Vs. Real Time

Running 22" Casing				
BHA	22" Casing As run w/Centralizers			
Block Weight [kip]	185			
Mud weight [ppg]	10.1			
Friction factors	Riser	Casing	Open hole	
	Riserless	0.2	0.1	

The 22" casing was run with an inner string that was added to the weight of the casing string in order to simulate the effects of the pipe inside the casing.



Plot 3: Simulated hookload from OWD plotted against real time hookload.

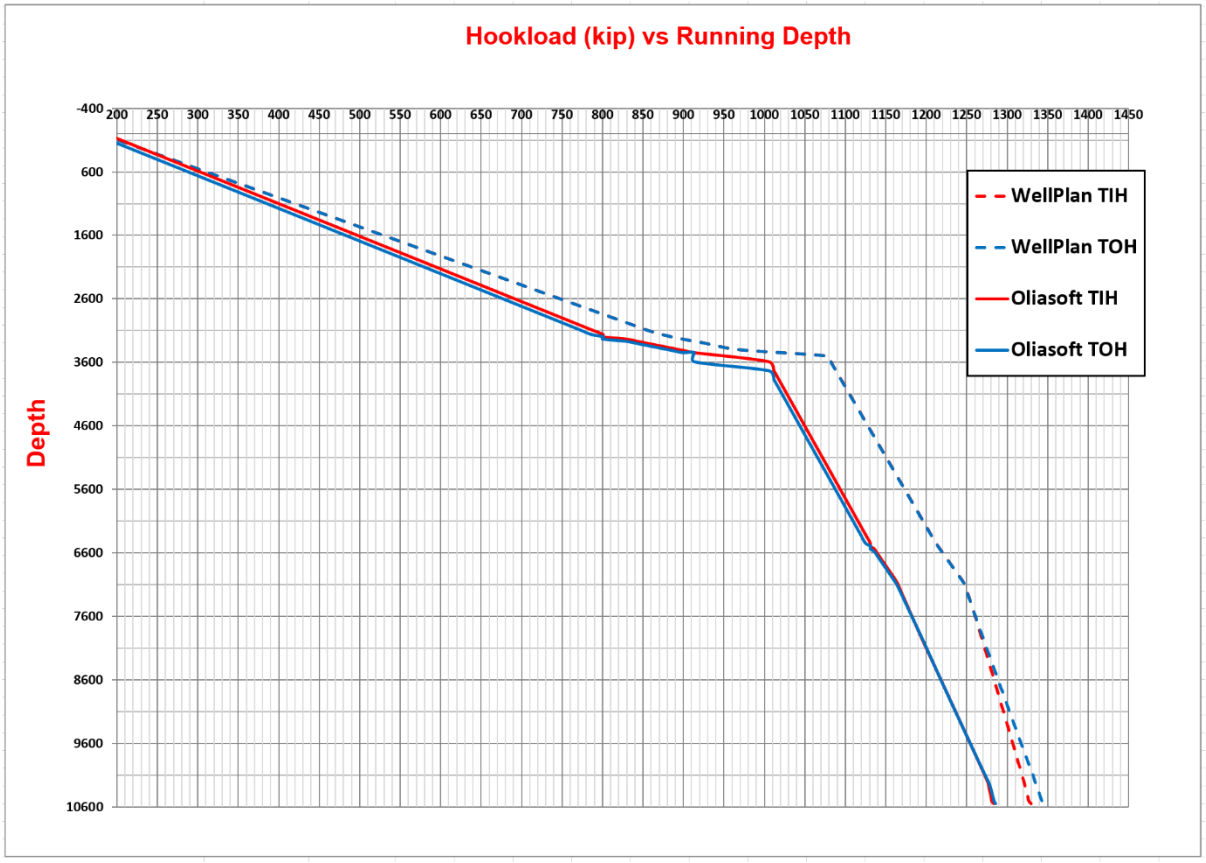
The plot shows how the simulated operation follows the real time hookload until entering the open hole. The simulation has not been able to mimic the increased drag (reduced hookload) in the open hole section. This is suspected to be due to some operation parameter not reproduced in the simulation. When the casing reached the well head the seawater inside the casing was replaced with a heavier mud (same as in hole), though no apparent increase in hookload is seen, thus the actual operation conditions parameters were likely not the same as the ones used in the simulation

The difference in slope seen in the first part of the water column (only casing being lowered) indicates some discrepancy in either weight or steel volume of the casing compared to the as

built casing. The casing also has centralizers. The same friction factors were used for the casing without bow springs as was used for the casing with bow springs

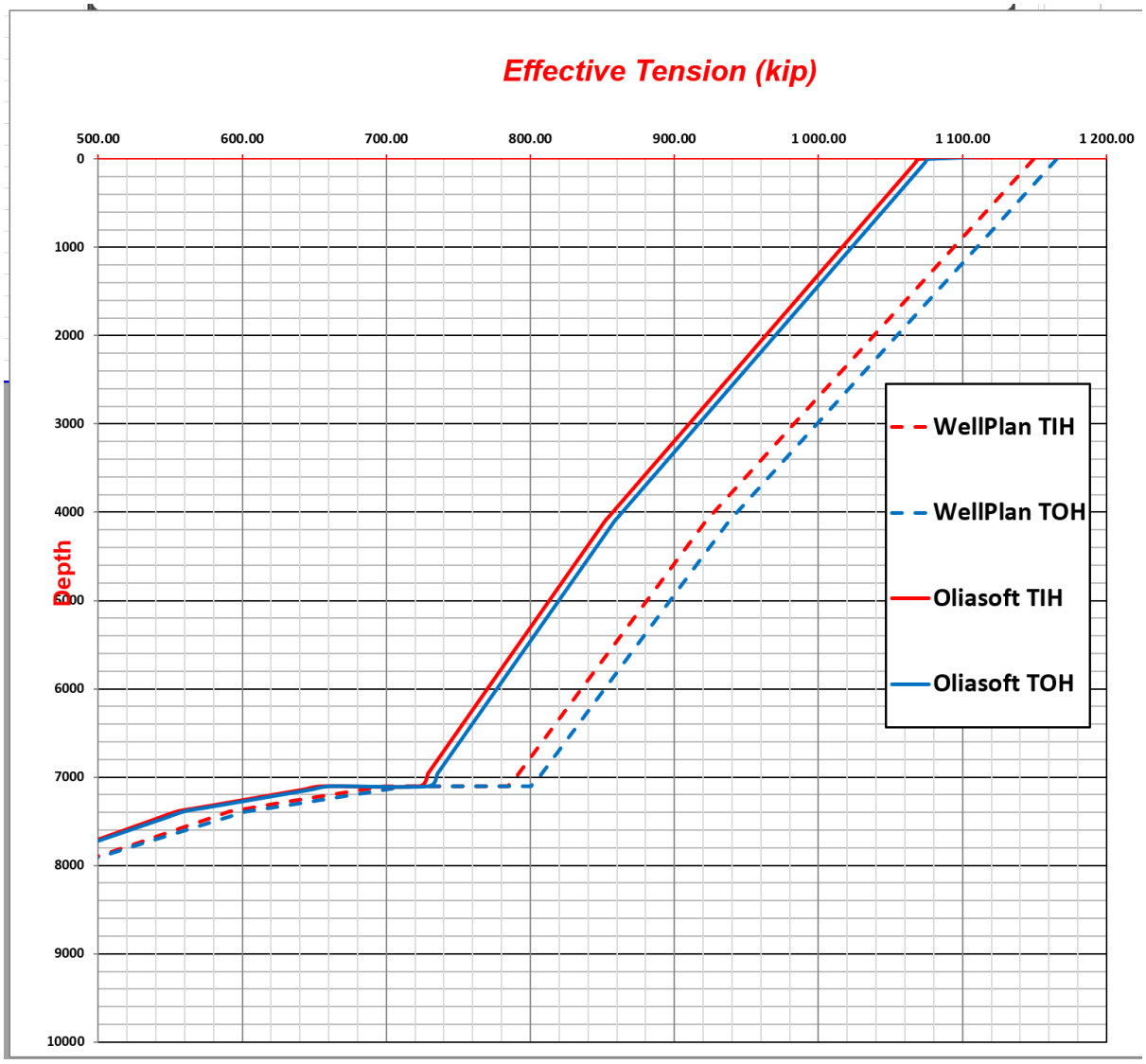
3.2.2 OWD Vs. WellPlan

Running 22" Casing				
BHA	22" Casing WellPlan			
Block Weight [kip]	185			
Mud weight [ppg]	10.1			
Friction factors	Riser	Casing	Open hole	
	Riserless	0.2	0.1	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit [lbf·ft]	WOB [kip]
	32	100	0	0



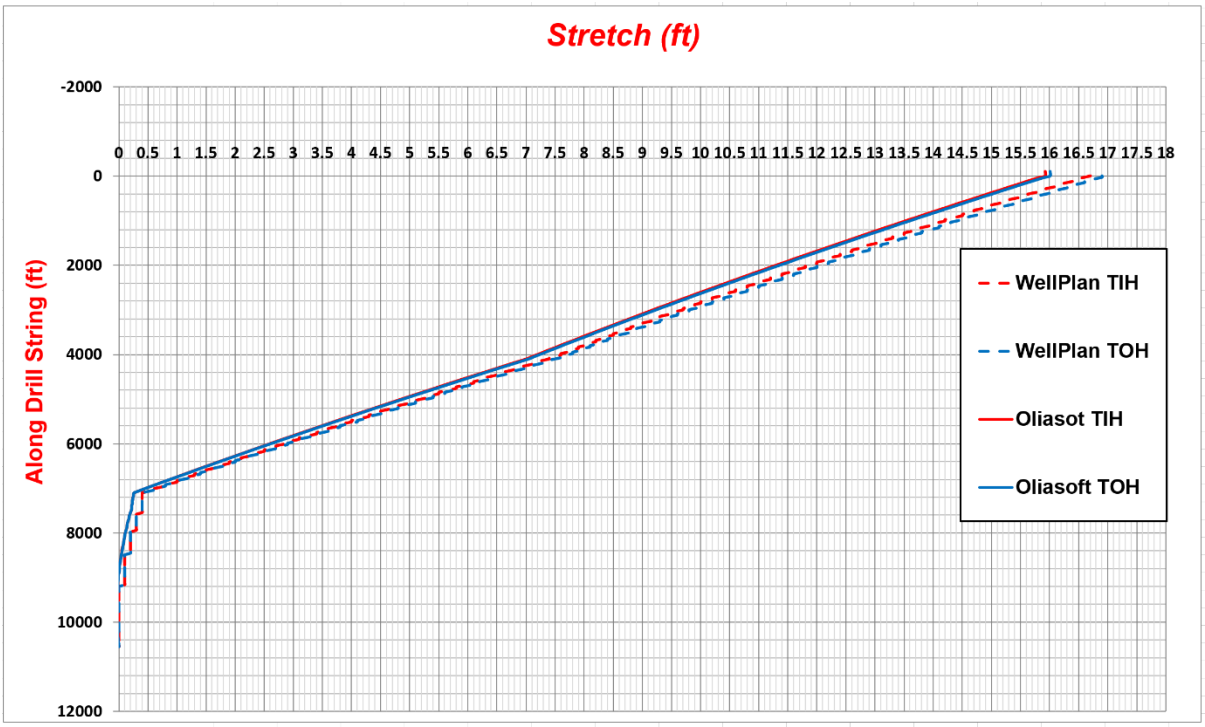
Plot 4: Simulated hookload with OWD and WellPlan.

The differences in the hookload plot are small, but the vertical section in the first 7000ft, where a different slope is seen indicates different weights pr component, different mud densities or different treatment of seawater compressibility.



Plot 5: Simulated effective tension from OWD and WellPlan.

The differences in effective tension are small, but they correspond with the hookload plot, less tension results in lower hookload.

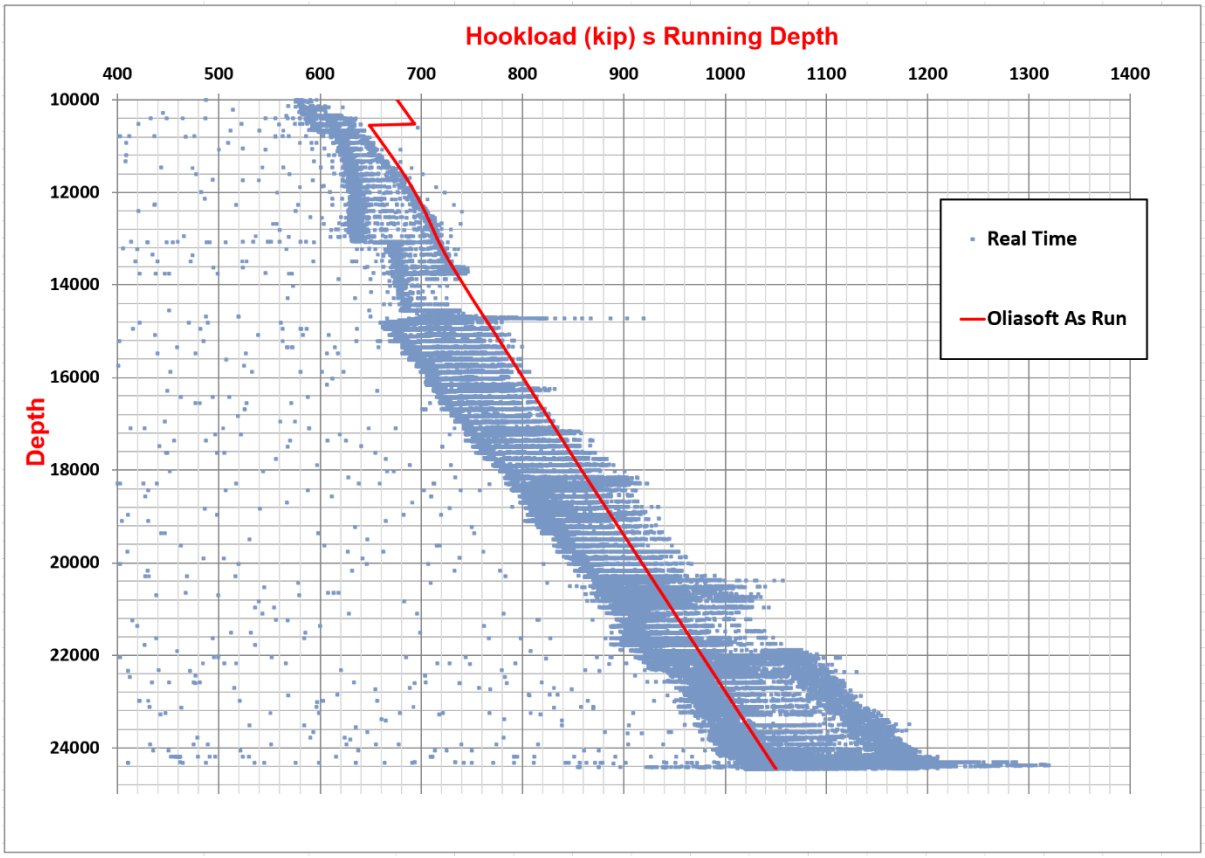


Plot 6: Accumulated stretch simulated in OWD and WellPlan simulations. The results follow the same trend as in the previous plots.

3.3 Drilling 18.125 x 21 Open Hole

3.3.1 OWD Vs. Real Time

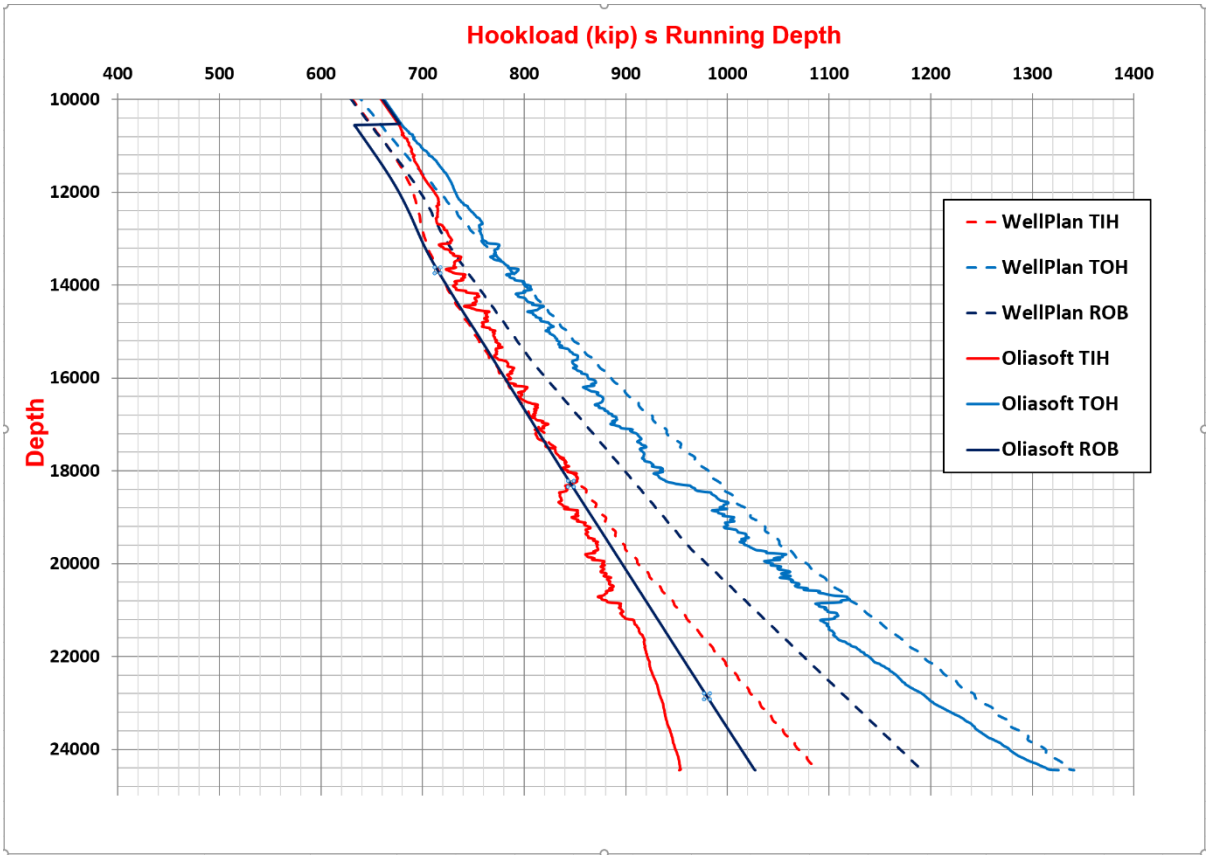
Drilling 18.125 x 21				
BHA	18.125 x 21			
Block Weight [kip]	185			
Mud weight [ppg]	11.2			
Friction factors	Riser	Casing	Open hole	
	0.1	0.2	0.2	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit [ft/lbf]	WOB [kip]
	30	100	14000	30



Plot 7 : Simulated hookload (OWD) plotted against real time hookload. The simulated hookload lies within the reported hookload for the entire drilling operation.

3.3.2 OWD Vs. WellPlan

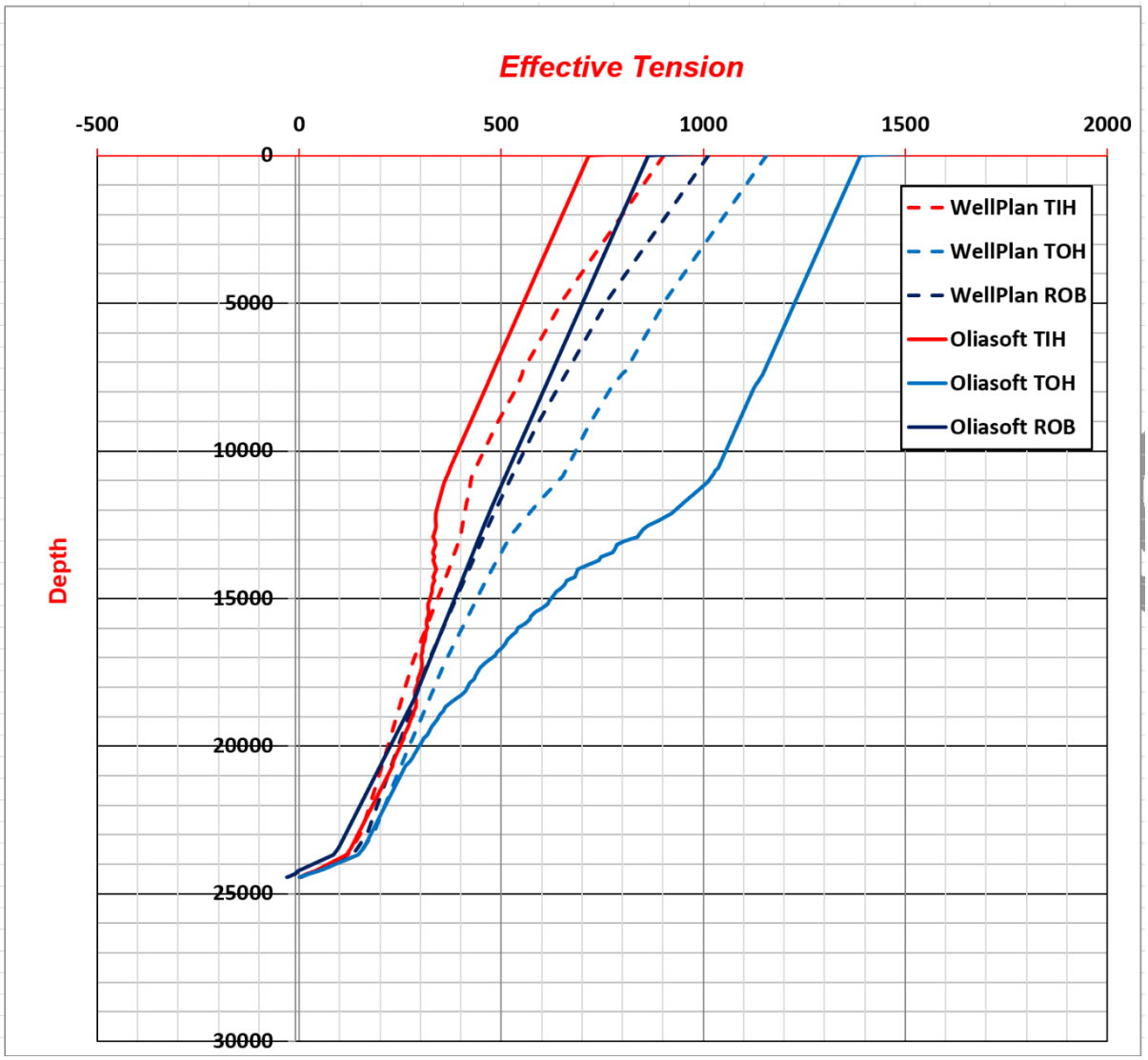
Drilling 18.125 x 21				
BHA	18.125 x 21 WellPlan			
Block Weight [kip]	185			
Mud weight [ppg]	12.1			
Friction factors	Riser	Casing	Open hole	
	0.1	0.2	0.2	
Running parameters	ROP [ft/hr]	[RPM}	Torque at Bit [lbf·ft]	WOB [kip]
	30	100	14000	30



Plot 8: Simulated hookload in OWD and WellPlan.

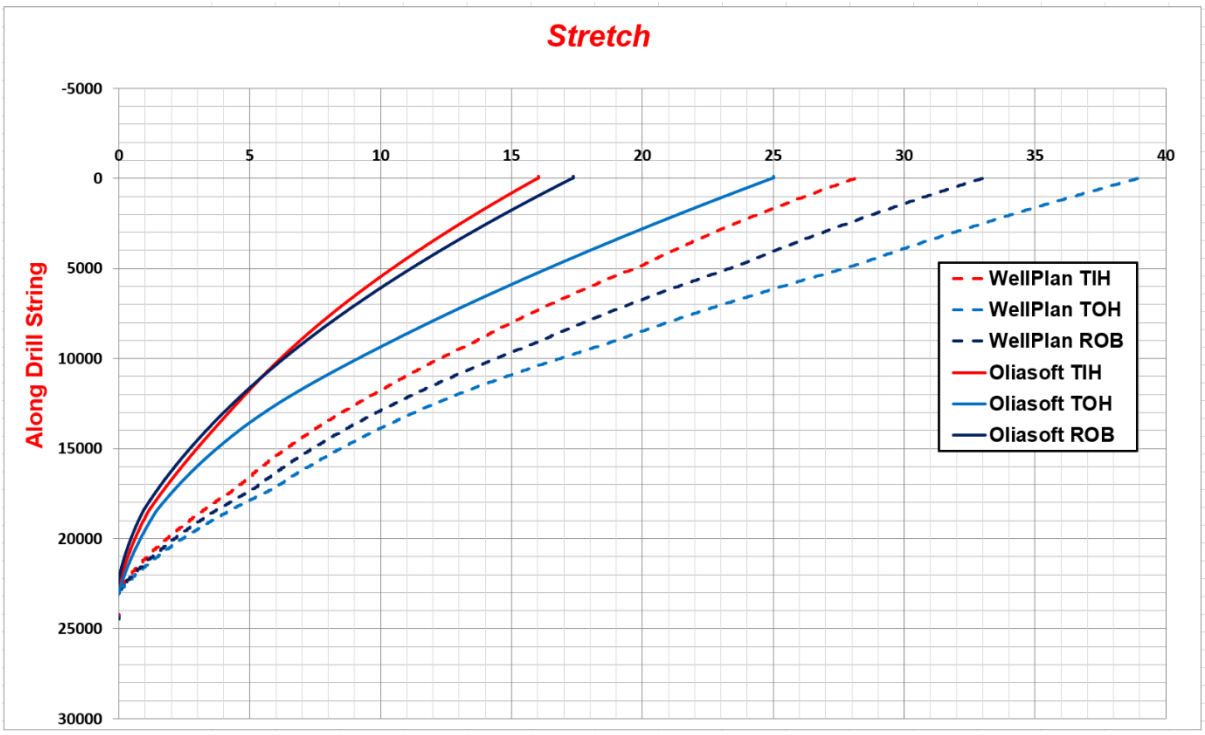
The WellPlan results have lowest hookload when tripping in, then ROB and tripping out giving the highest hookload. OWD shows the same behavior. There are minor differences down to 18000ft for the tripping operations, but the drilling operations shows a more significant difference, with OWD giving lower hookloads throughout the operation.

Oliasoft follows the trend from WellPlan closely. The uneven lines representing trip in/out from Oliasoft reflects the varying DLS from the survey listing.



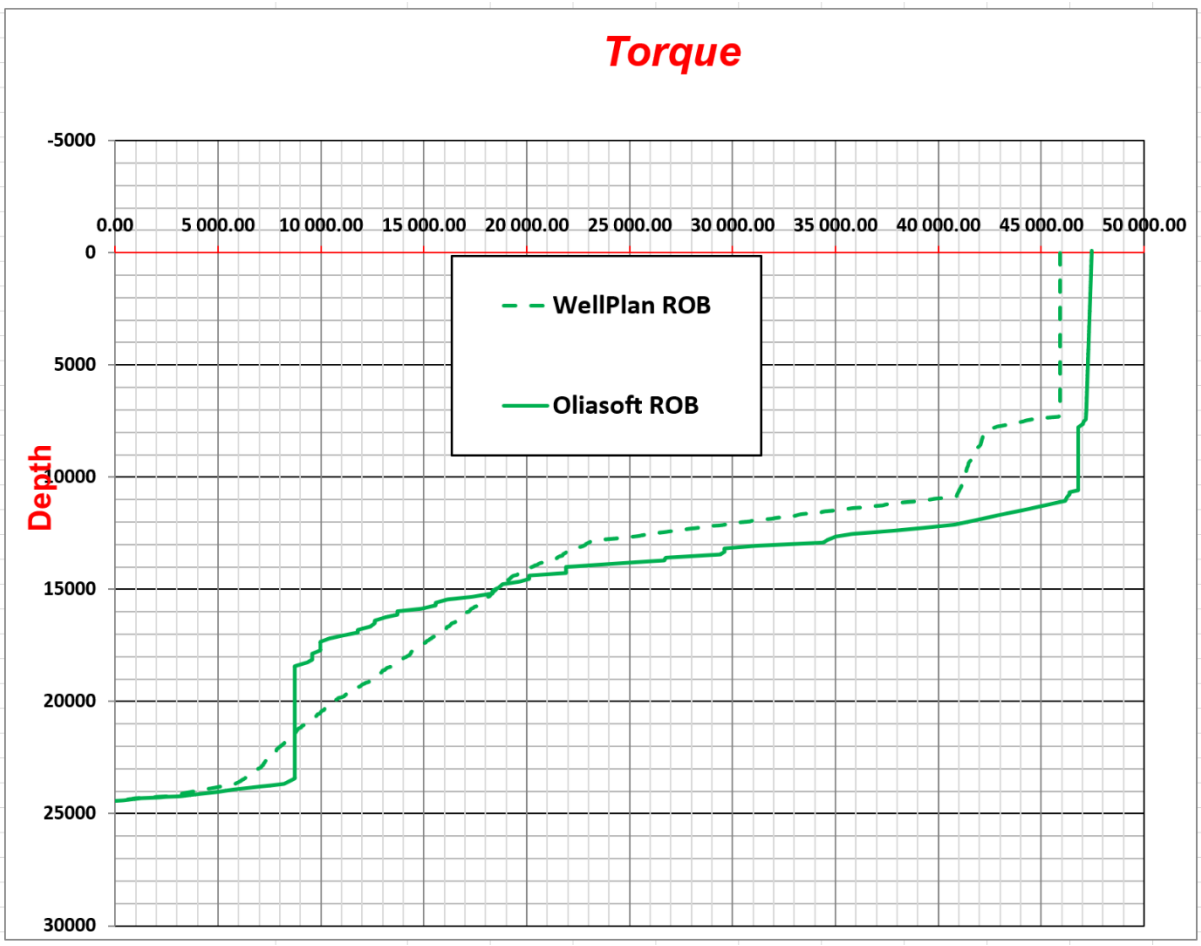
Plot 9: Simulated effective tension from OWD and WellPlan.

The lines correspond with the hookload plot, where the effective tension for trip in and ROB are on the lower side than WellPlan. The trip out plot from Oliasoft is higher for Oliasoft than WellPlan.



Plot 10: Accumulated stretch simulated with OWD and WellPlan.

In general, there is lower calculated stretch with OWD, but this reflects the previous tension plot where tension is lower in OWD than WellPlan. Stretch depends on the tension and the cross section of the pipe, thus it is an anticipated difference in the result.



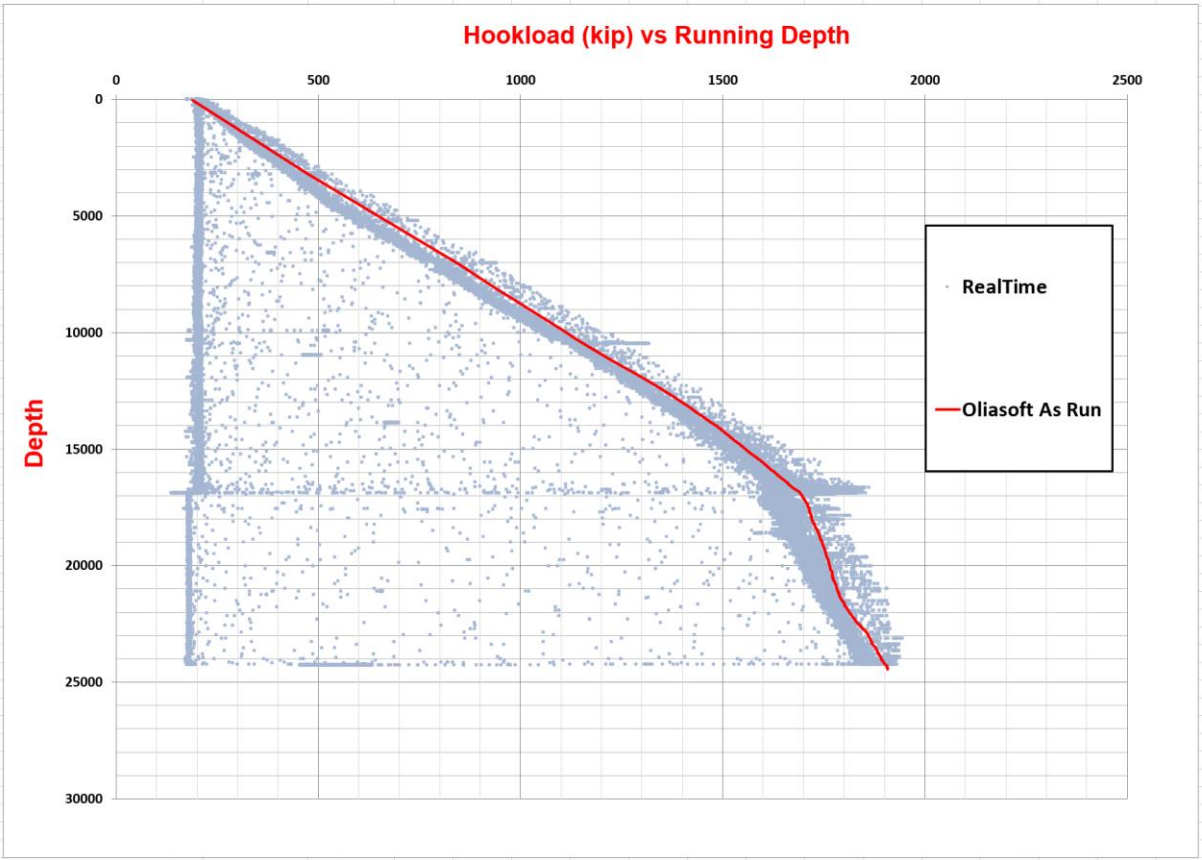
Plot 11: Simulated torque along drill string from OWD and WellPlan.

The torque plot above shows a close match between the two softwares. Oliasoft has slightly higher torque in the top section, and a different slope in the lowest section.

3.4 Running 16” Casing

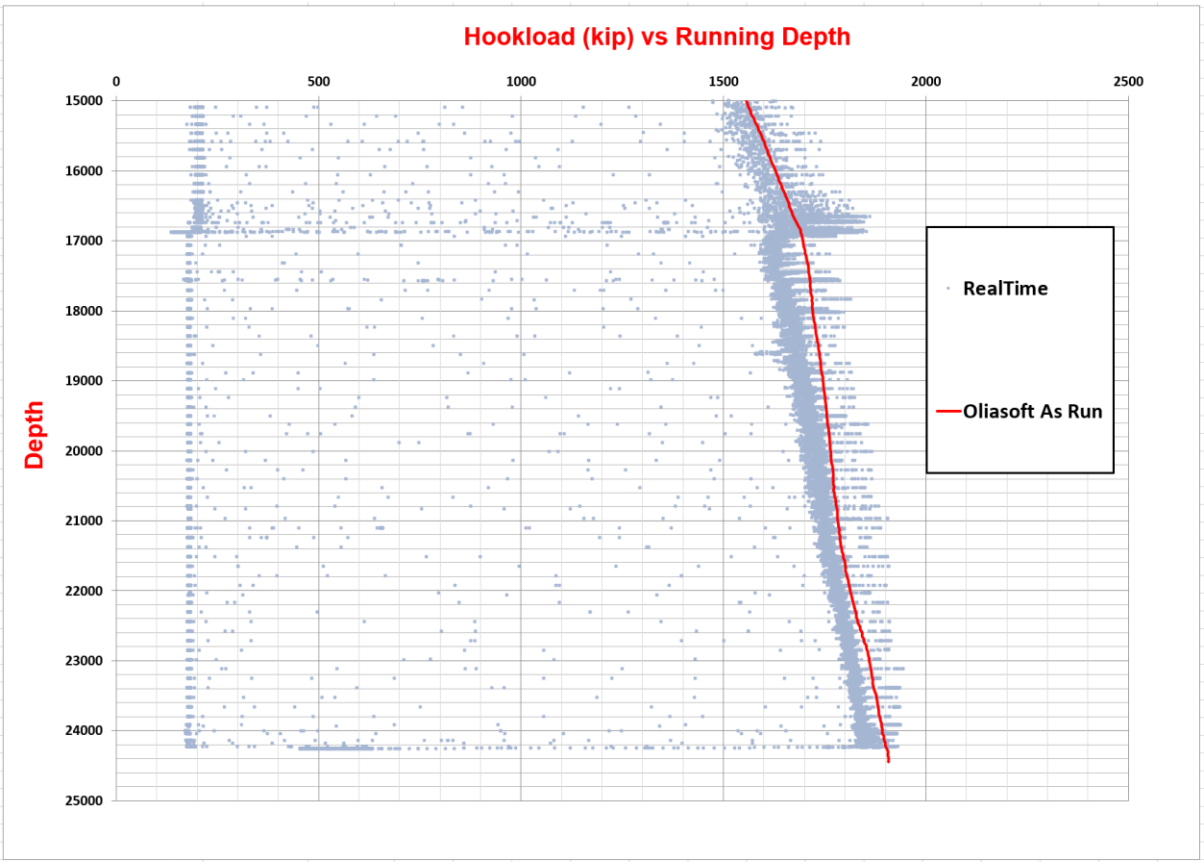
3.4.1 OWD Vs. Real Time

Running 16" Casing			
BHA	16" Casing w/Centralizers		
Block Weight [kip]	185		
Mud weight [ppg]	12.1		
Friction factors	Riser	Casing	Open hole
	0.1	0.2	0.2



Plot 12: Simulated hookload (OWD) plotted against real time hookload.

There is overall good agreement with real time data, indicating that the analysis parameters were relatively correct when the simulation was run.

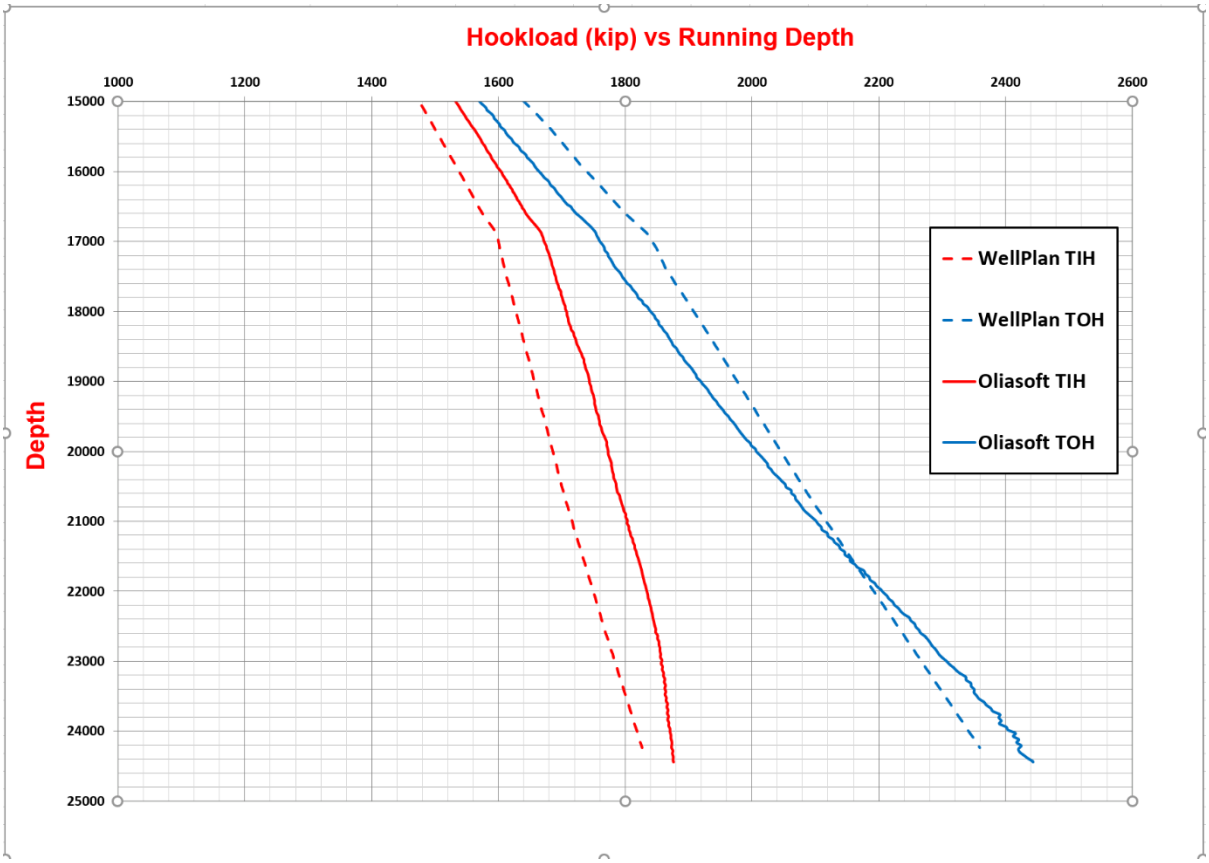


Plot 13: Simulated hookload (OWD) plotted against real time hookload, from 15 000 ft to TD.

The plot shows how Oliasoft simulations follow the reported real time hookload.

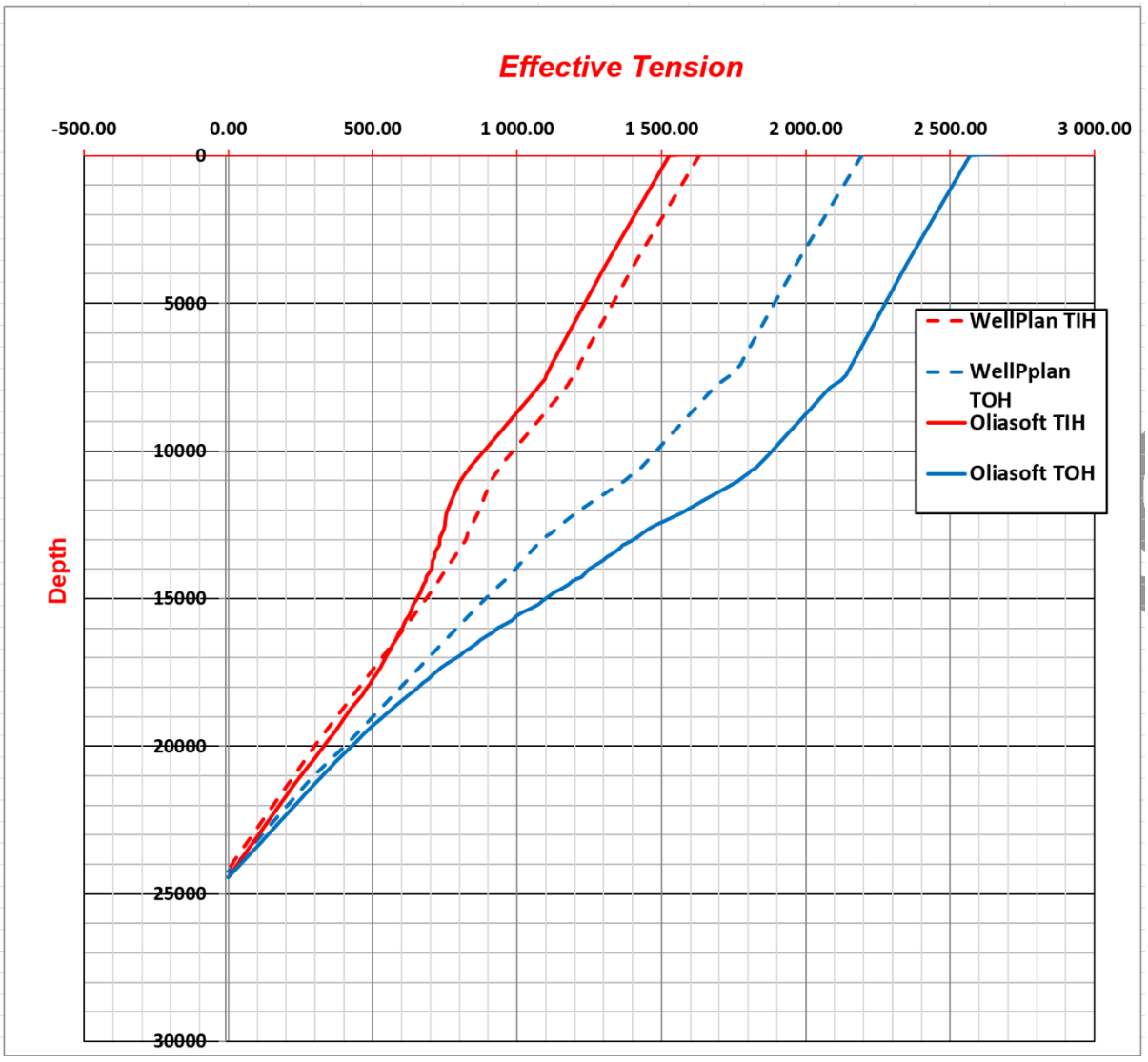
3.4.2 OWD Vs. WellPlan

Running 16" Casing			
BHA	16" Casing WellPlan		
Block Weight [kip]	185		
Mud weight [ppg]	12.1		
Friction factors	Riser	Casing	Open hole
	0.1	0.2	0.2

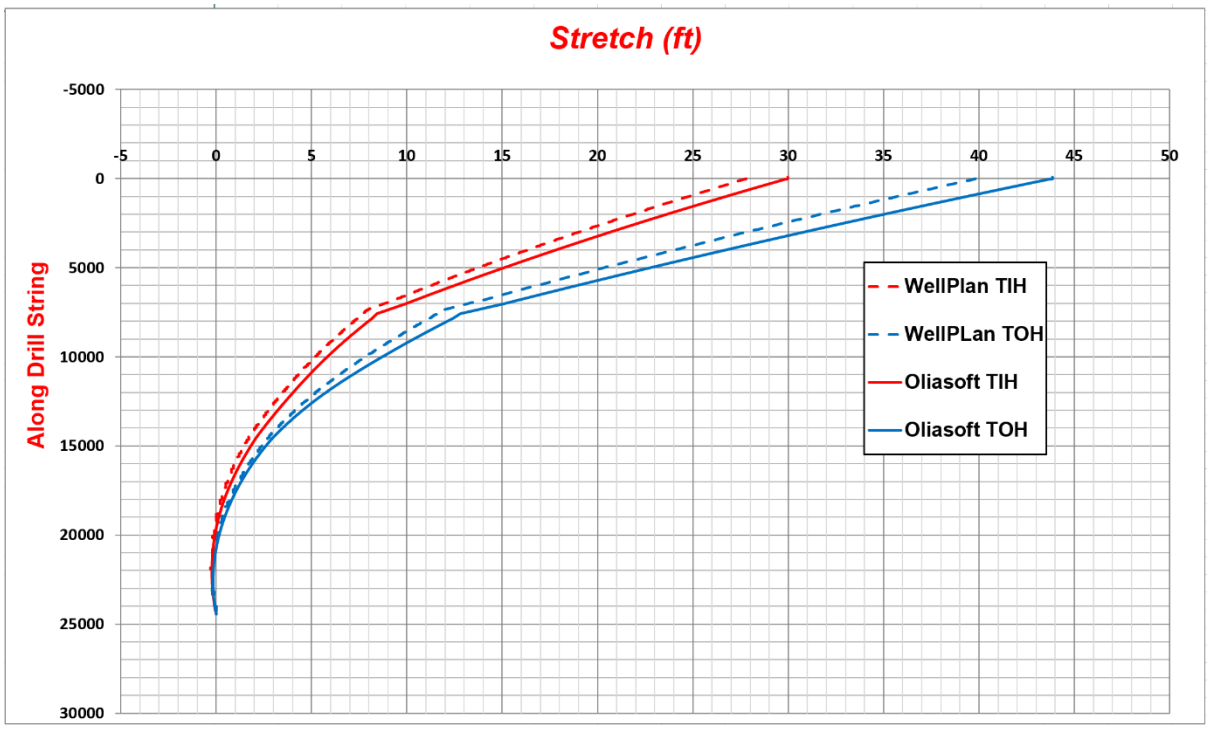


Plot 14: Simulated hookload in OWD and WellPlan.

Good agreement between the results are seen for both operations.



Plot 15: Simulated effective tension from OWD and WellPlan



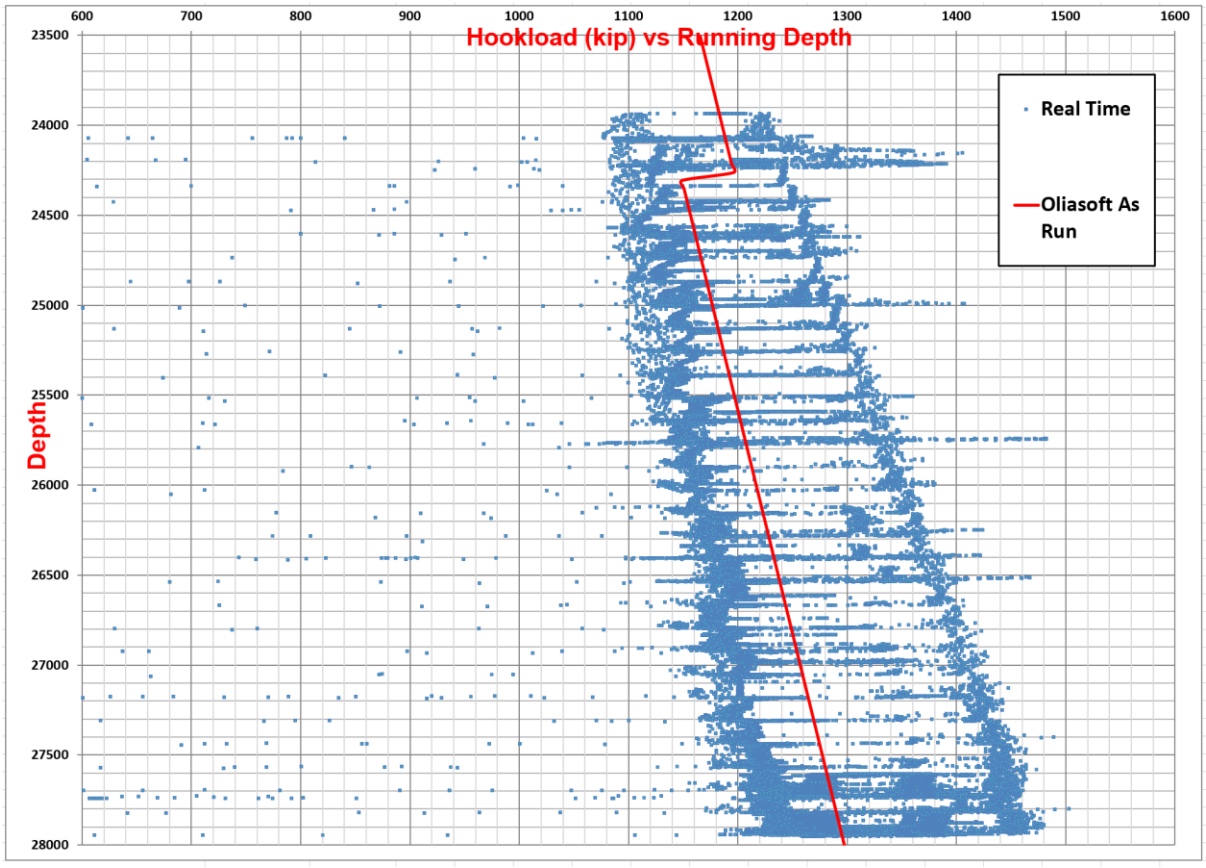
Plot 16: Accumulated stretch simulated with OWD and WellPlan.

The stretch plot shows how OWD and WellPlan results follow each other very closely. The slightly higher hookload from Oliasoft can also be seen in the form of Oliasoft having slightly higher stretch for all the simulated operations in the plot above. The lines follow each other but are shifted slightly to the left for each operation.

3.5 Drilling 14.5 x16.5 Open Hole

3.5.1 OWD Vs. Real Time

Drilling 14.5 x 16.5				
BHA	Drill String 14 x 16			
Block Weight [kip]	185			
Mud weight [ppg]	12.1			
Friction factors	Riser	Casing	Open hole	
	0.1	0.17	0.2	
Running parameters	ROP [ft/hr}	[RPM]	Torque at Bit [lbf·ft]	WOB [kip]
	30	100	14000	40

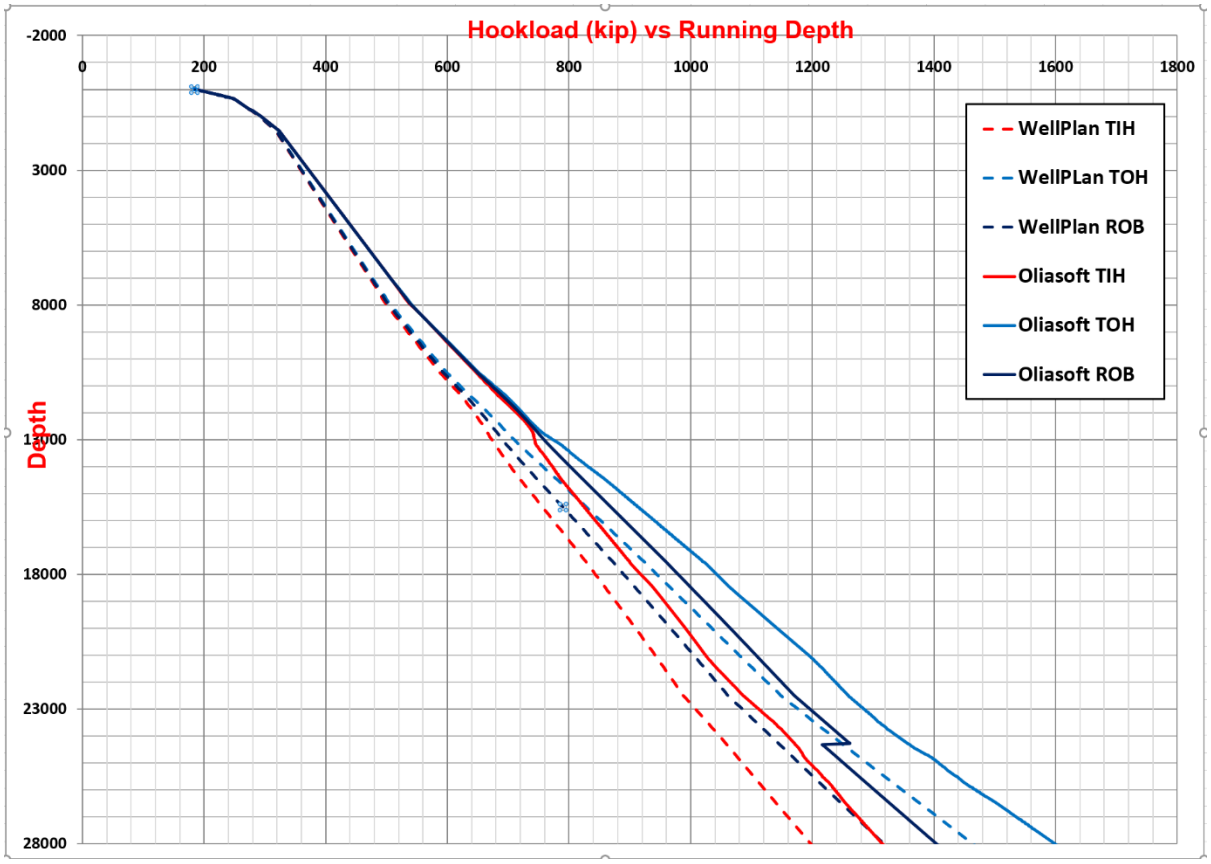


Plot 17: Simulated hookload in OWD plotted against WellPlan simulations.

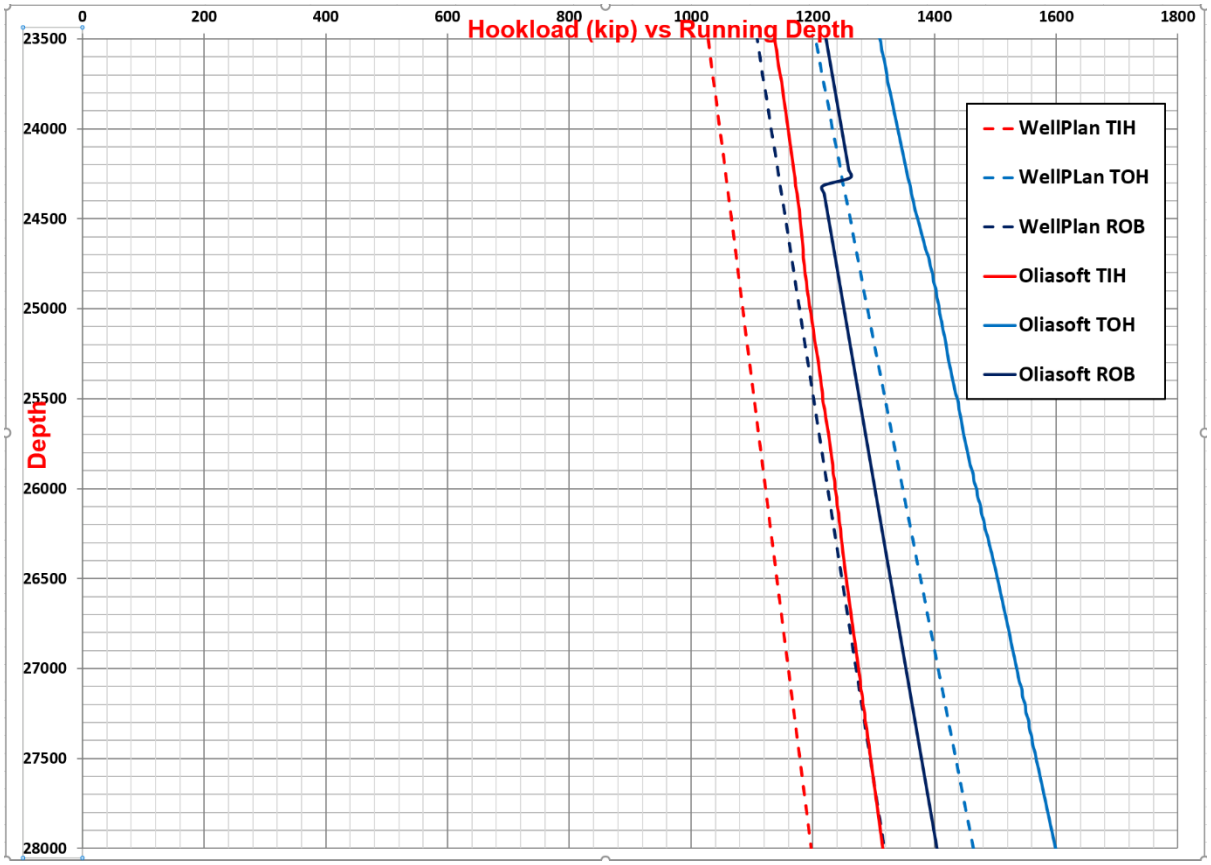
The plot shows how the simulated hookload from drilling operation follows the real time data very closely.

3.5.2 OWDVs. WellPlan

Drilling 14.5 x 16.5				
BHA	Excel Drill String 14 x16 WellPlan			
Block Weight [kip]	185			
Mud weight [ppg]	12.1			
Friction factors	Riser	Casing	Open hole	
	0.1	0.17	0.2	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit [lbf·ft]	WOB [kip]
	30	100	14000	40

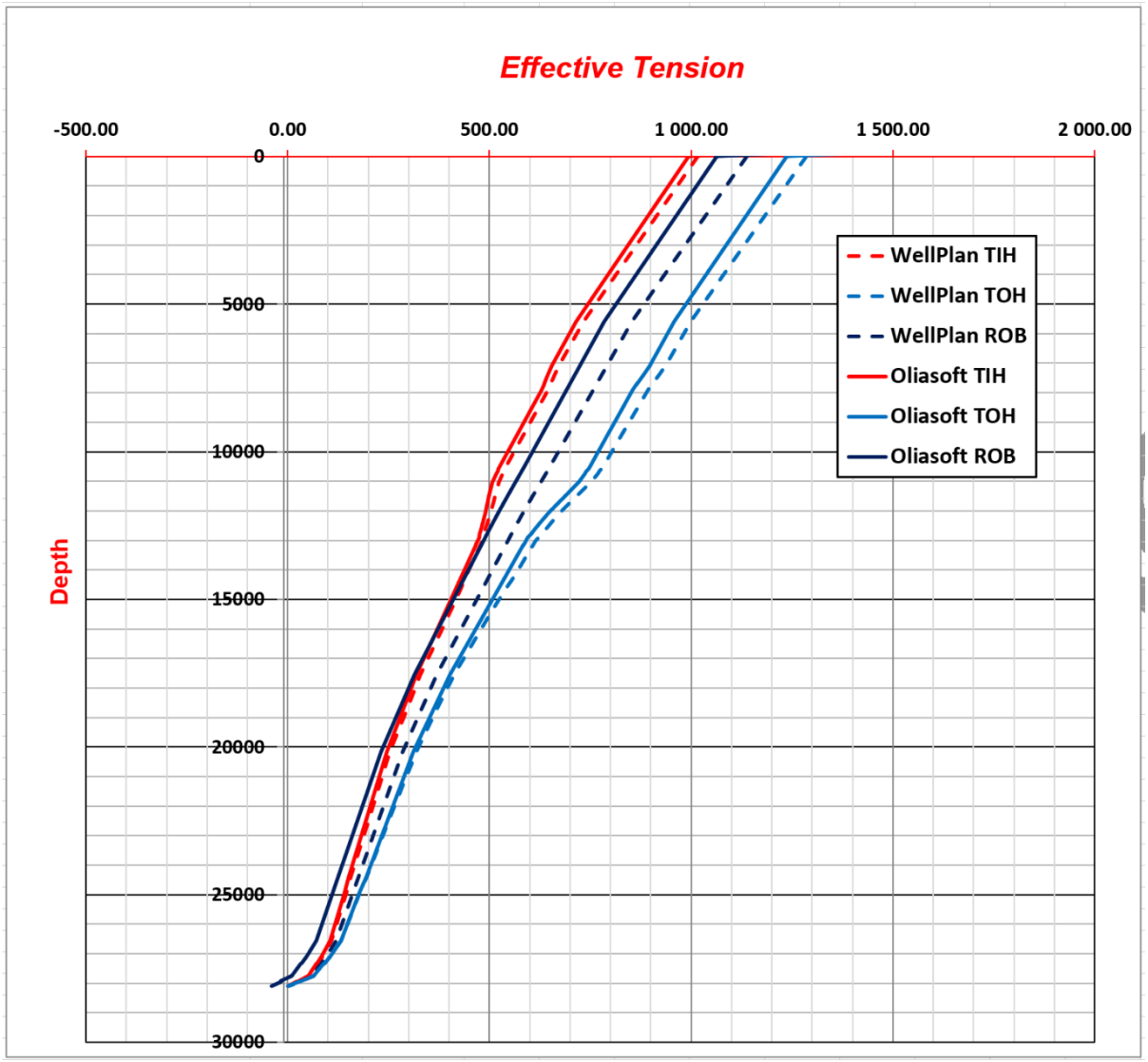


Plot 18: Simulated hookload from OWD and WellPlan.

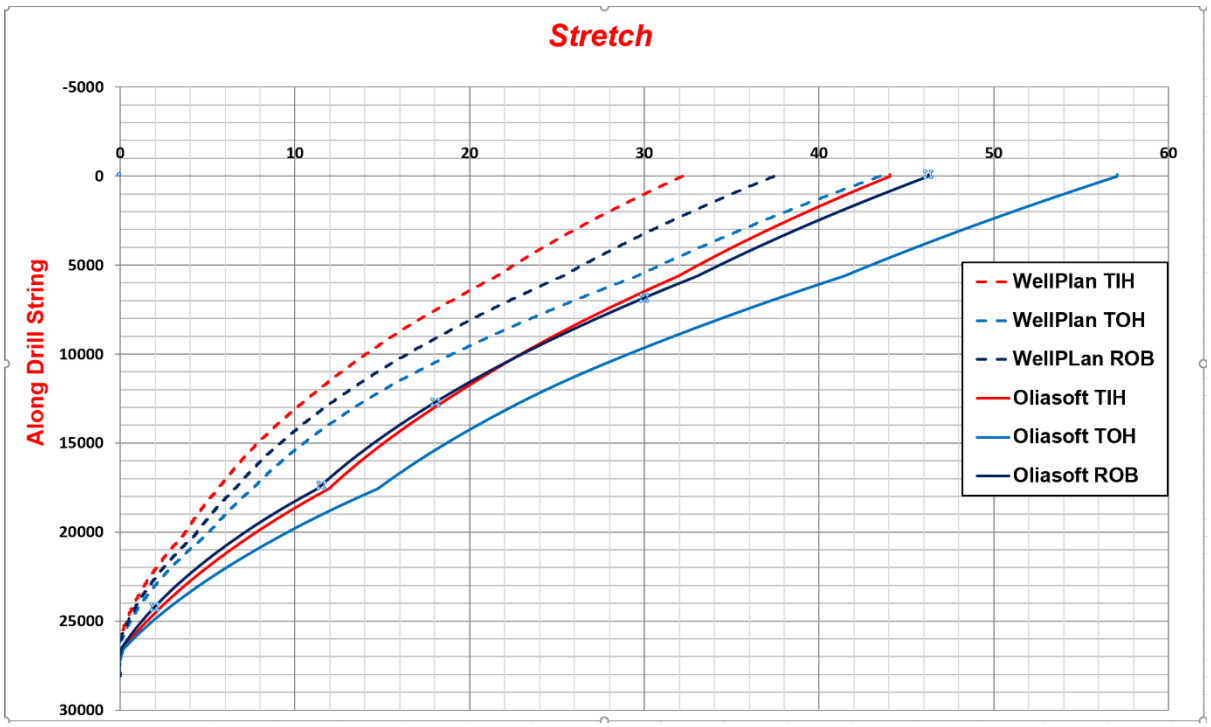


Plot 19: Simulated hookload from OWD and WellPlan, from 23 500 ft to TD.

The trends of each operation are similar, however the result from Oliasoft looks to follow a higher hookload from the start, indicating different weights being used. The Oliasoft results follows this parallel shift all the way to TD.

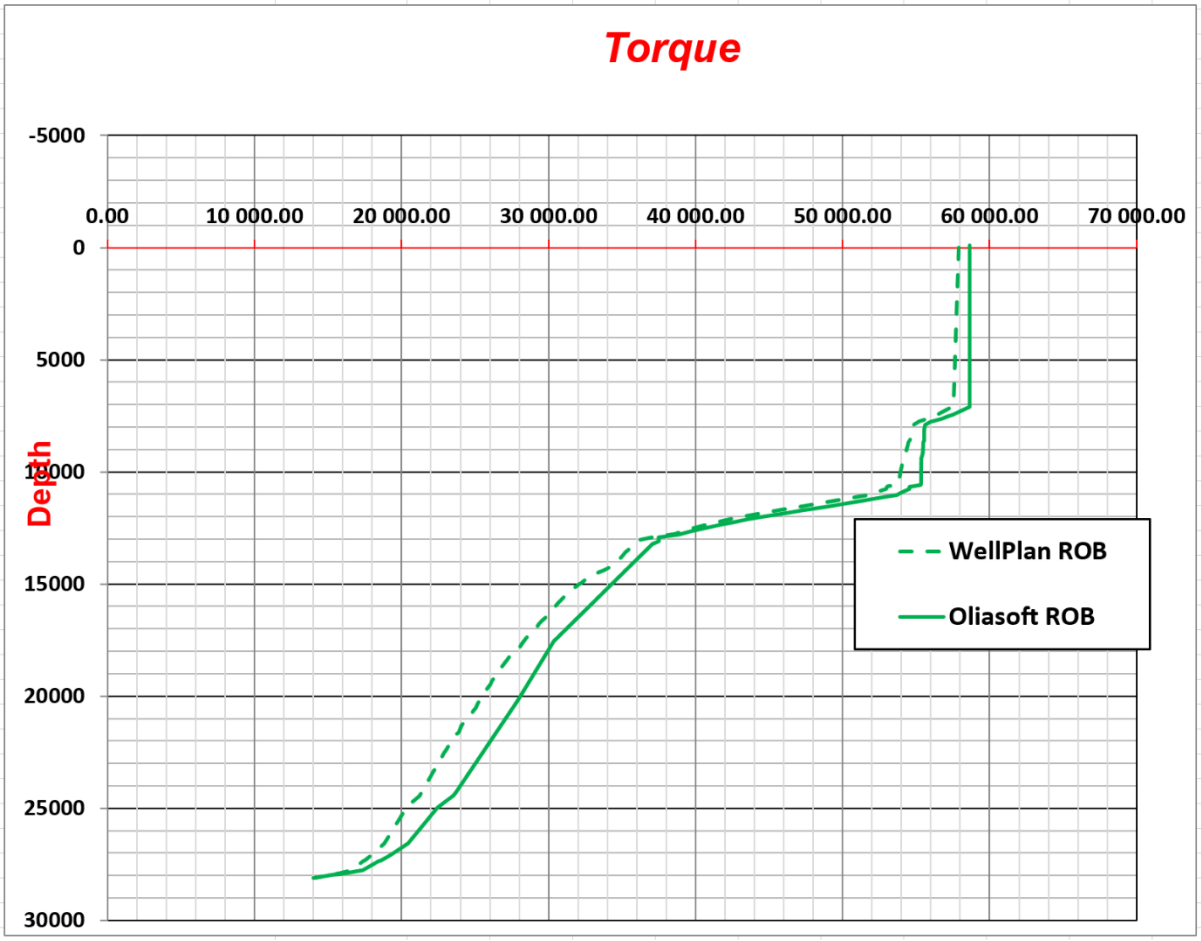


Plot 20: Simulated effective tension from OWD and WellPlan.



Plot 21: Accumulated stretch simulated with OWD and WellPlan.

The stretch plot shows the same effect seen in the hookload plot. The three first plot lines (from right) show stretch from WellPlan.



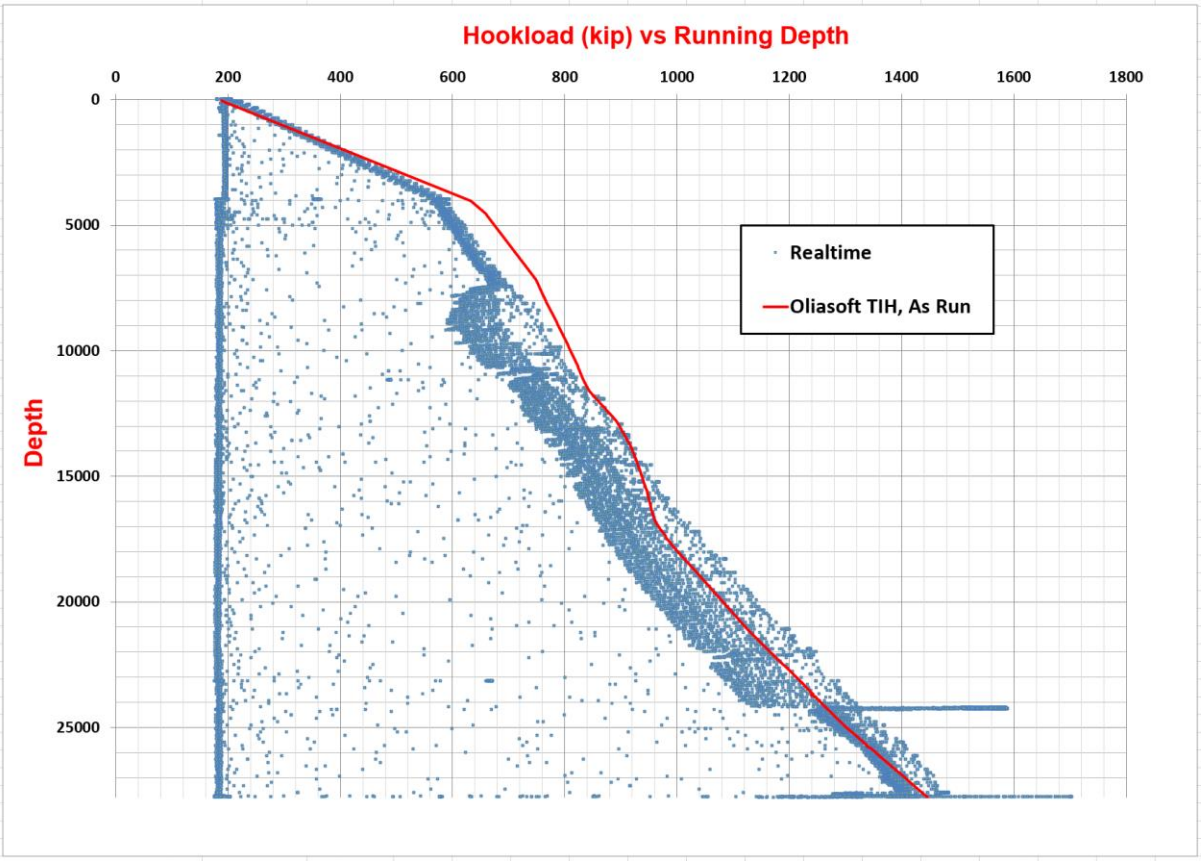
Plot 22: Simulated torque along drill string from OWD and WellPlan.

The torque plot shows a similar torque trend, where Oliasoft torque follows the torque simulated in WellPlan but with a slightly higher value. Torque is a function of the side forces which is a function of the tension, so the difference seen here is anticipated.

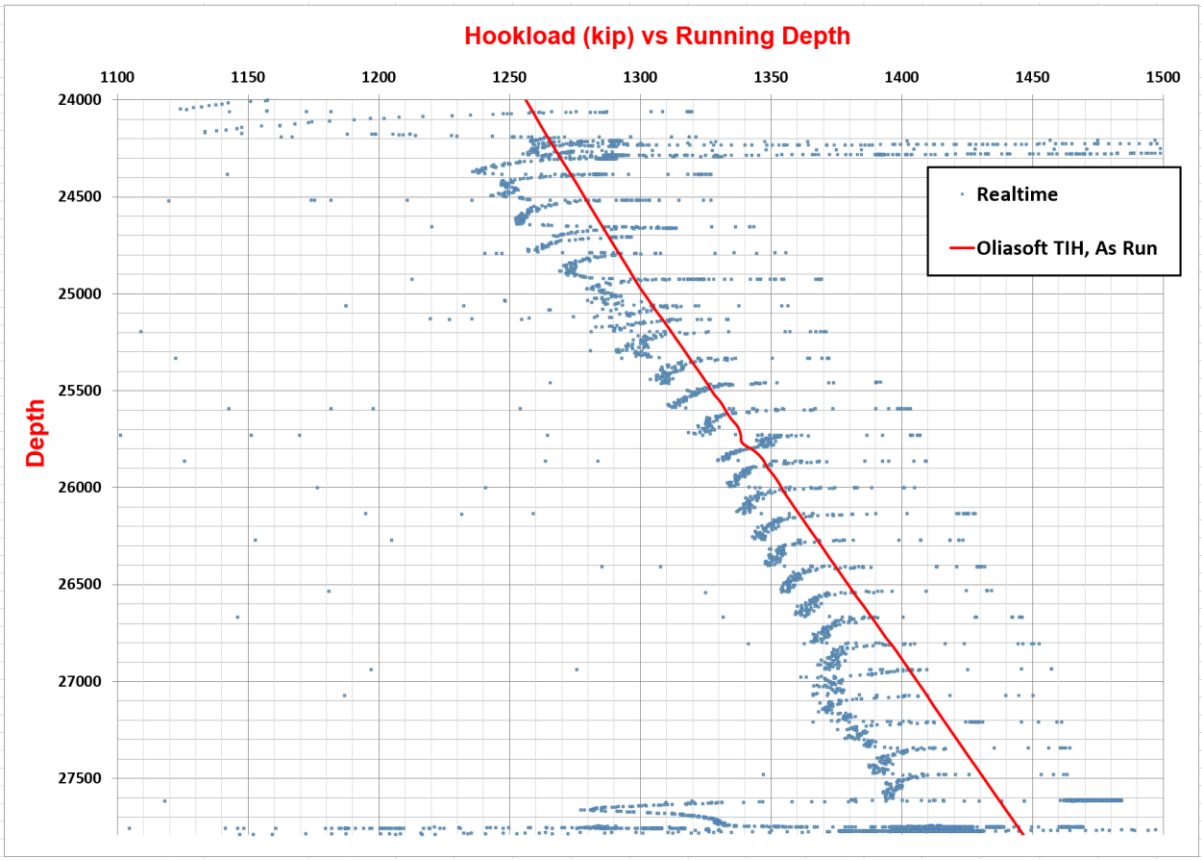
3.6 Running 14” Liner

3.6.1 OWDVs. Real Time

Running 14" Liner			
BHA	14" Liner As run w/Centralizers		
Block Weight [kip]	185		
Mud weight [ppg]	13.5		
Friction factors	Riser	Casing	Open hole
	0.1	0.17	0.2



Plot 23: Simulated hookload from OWD plotted against real time hookload.

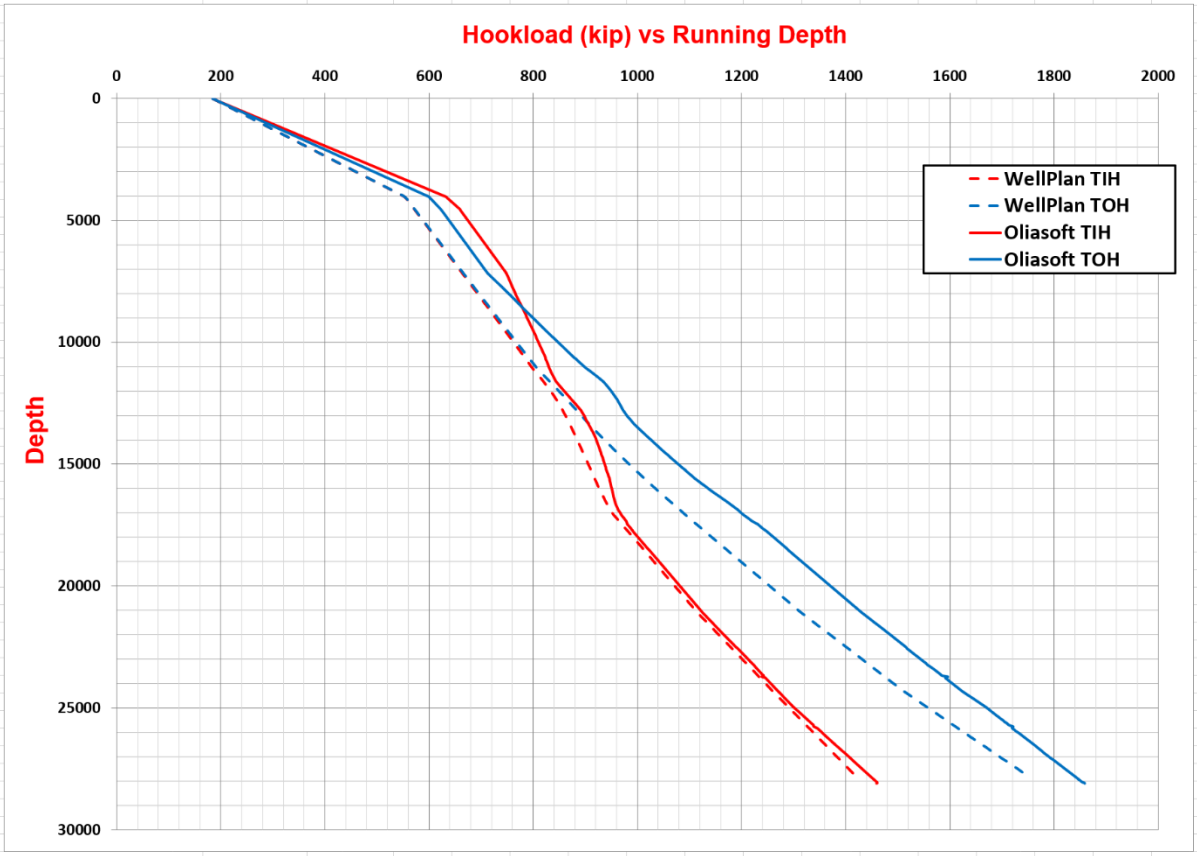


Plot 24: Simulated hookload (OWD) plotted against real time hookload between 24000ft and 28000ft.

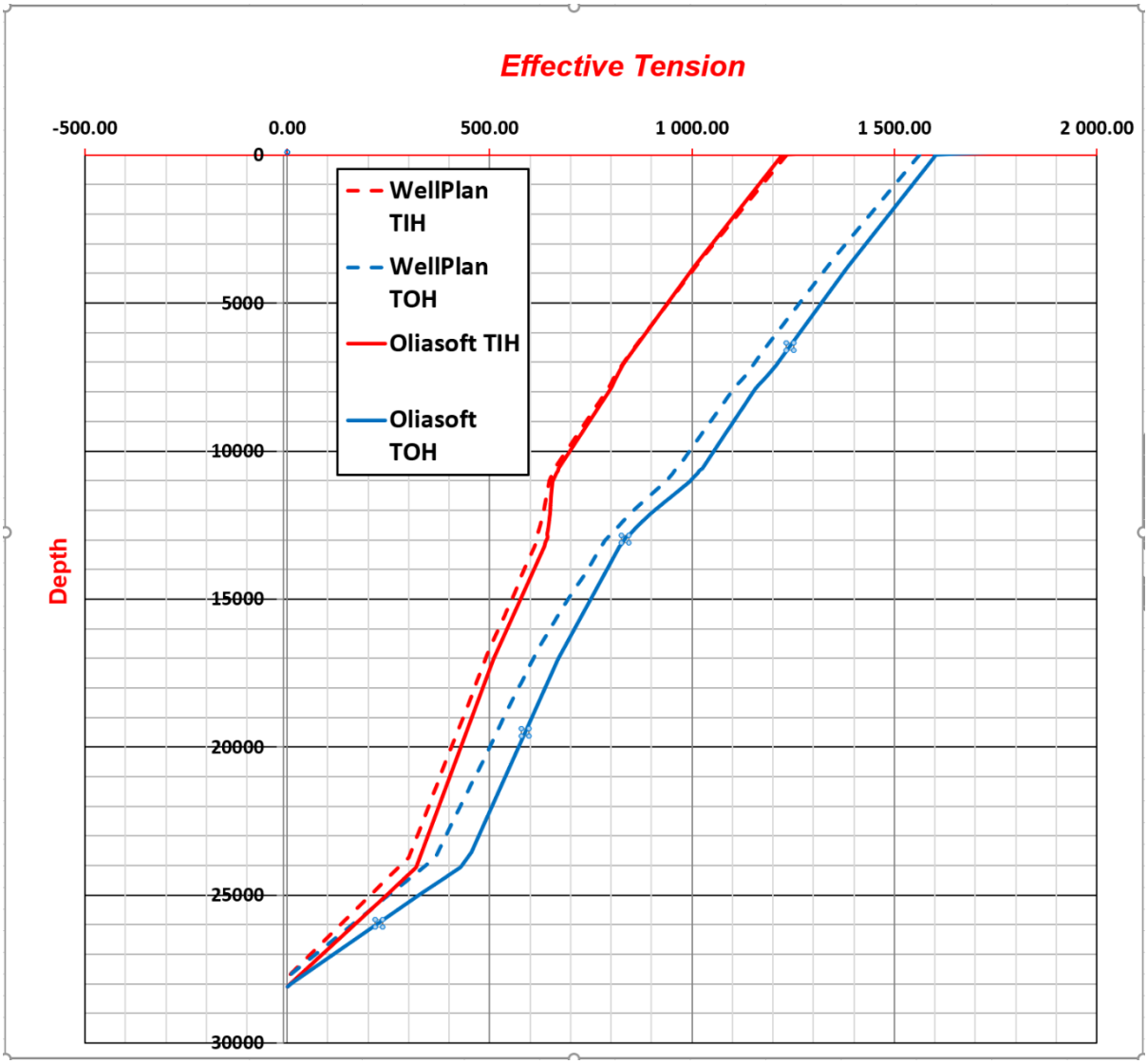
The simulated results follow the real time data points closely in this region, which is the open hole part of the well for this operation.

3.6.2 OWDVs. WellPlan

Running 14" Liner				
BHA	14" Liner As run			
Block Weight [kip]	185			
Mud weight [ppg]	13.5			
Friction factors	Riser	Casing	Open hole	
	0.1	0.17	0.2	

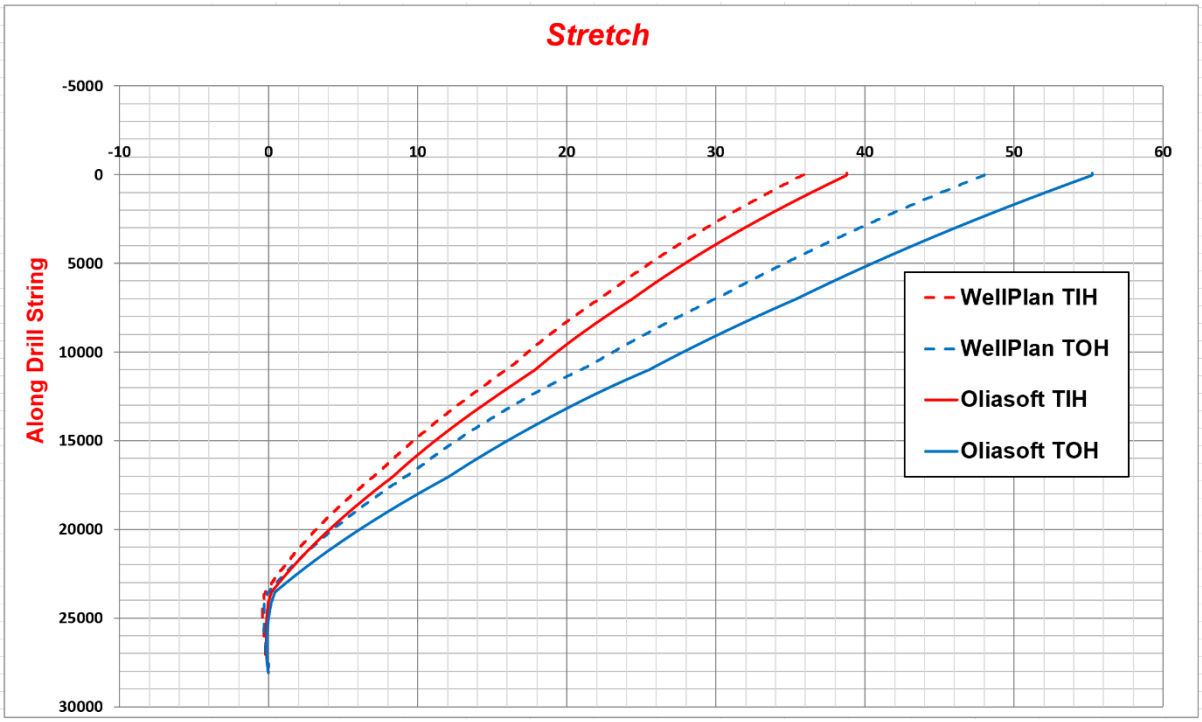


Plot 25: Simulated hookload from OWD and WellPlan. There is a difference in slope in riser.



Plot 26: Simulated effective tension with OWD and WellPlan.

The effective tension lines follow each other closely with effective tension for the trip out operation from Oliasoft giving small differences also seen in the hookload plot.



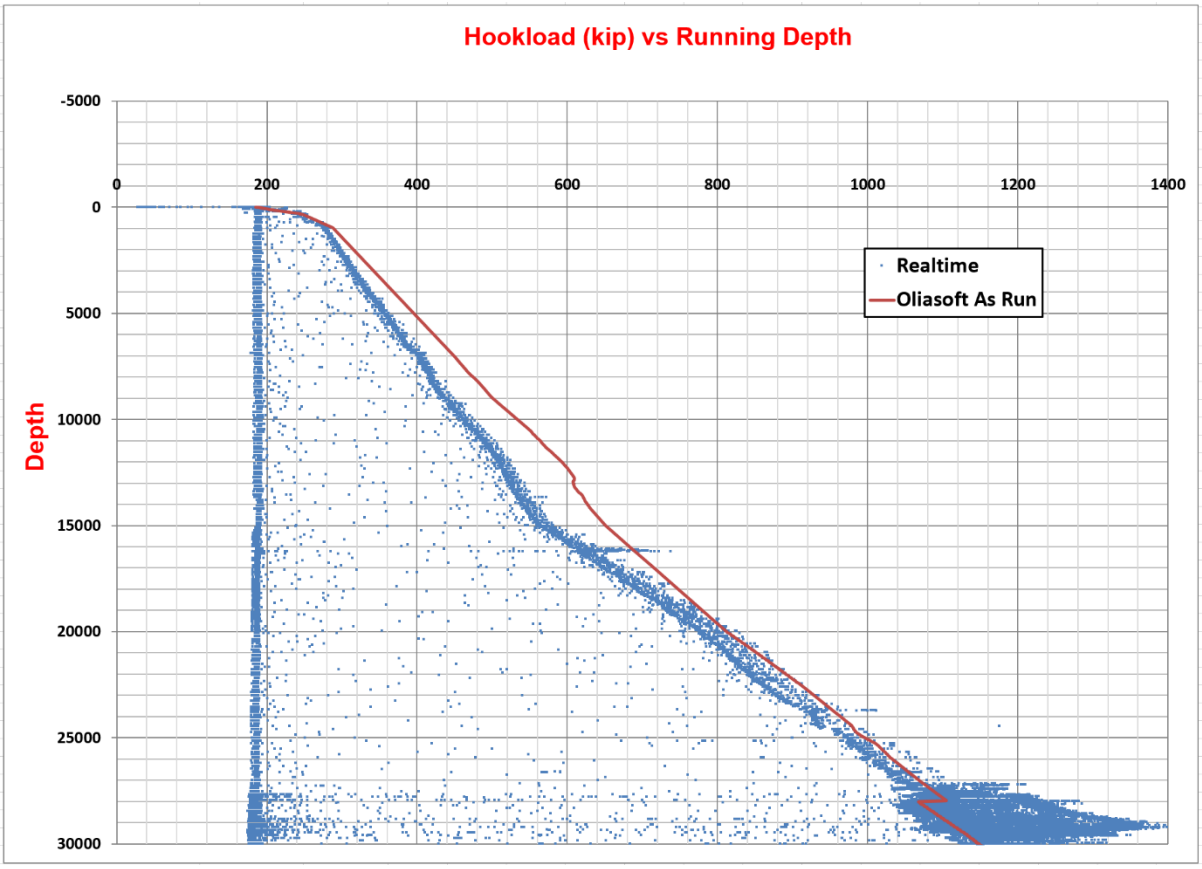
Plot 27: Simulated accumulated stretch with OWD and WellPlan.

The same effects as in the hookload plot can be seen in the stretch plot where OWD simulates higher stretch for both operations.

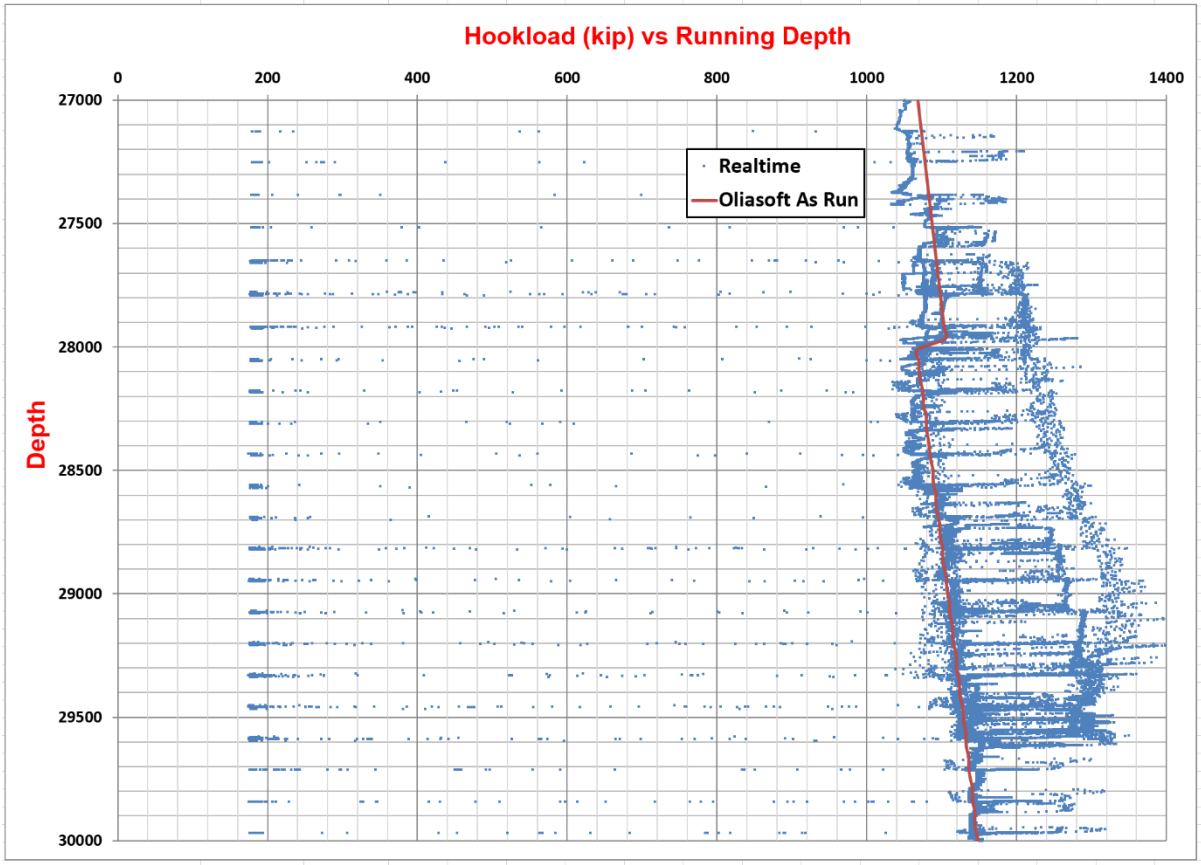
3.7 Drilling 12 ¼ Open Hole Section

3.7.1 Oliasoft Vs. Real Time

Drilling 12 1/4 "				
BHA	12 1/4 As run			
Block Weight [kip]	185			
Mud weight [ppg]	13.5			
Friction factors	Riser	Casing	Open hole	
	0	0.17	0.2	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit [ft/lbf]	WOB [kip]
	30	150	27000	45



Plot 28: Simulated hookload (OWD) plotted against real time hookload.

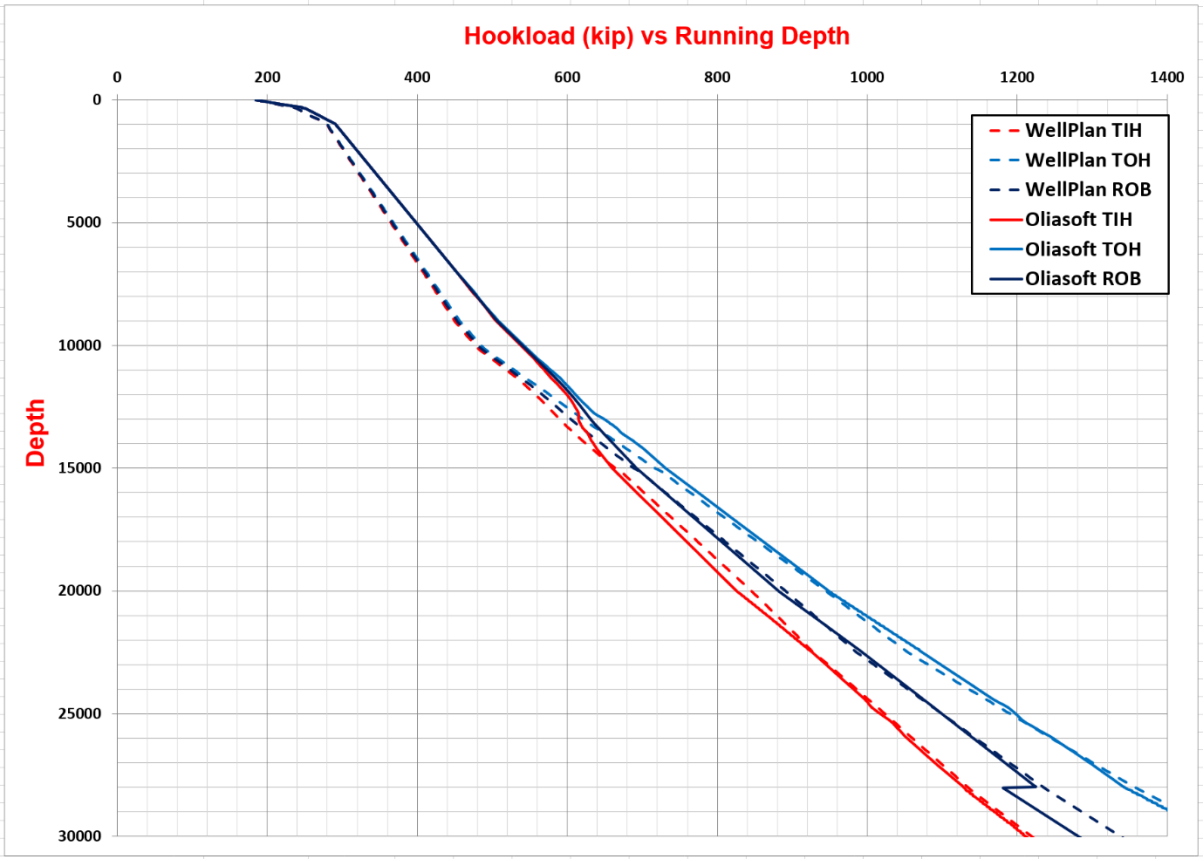


Plot 29: Simulated hookload (OWD) plotted against real time hookload, from 27 000 ft to TD.

In the focus area, which is the open hole section, Oliasoft drilling simulation shows good correspondence with the reported hookload. A larger WOB might have been used during this section in real life. The simulation was run with a constant WOB of 45 kip. The topmost plot shows that there are some unknowns wrt. the as built string, as its buoyant weight seems to be a lot less than the string used in the simulation.

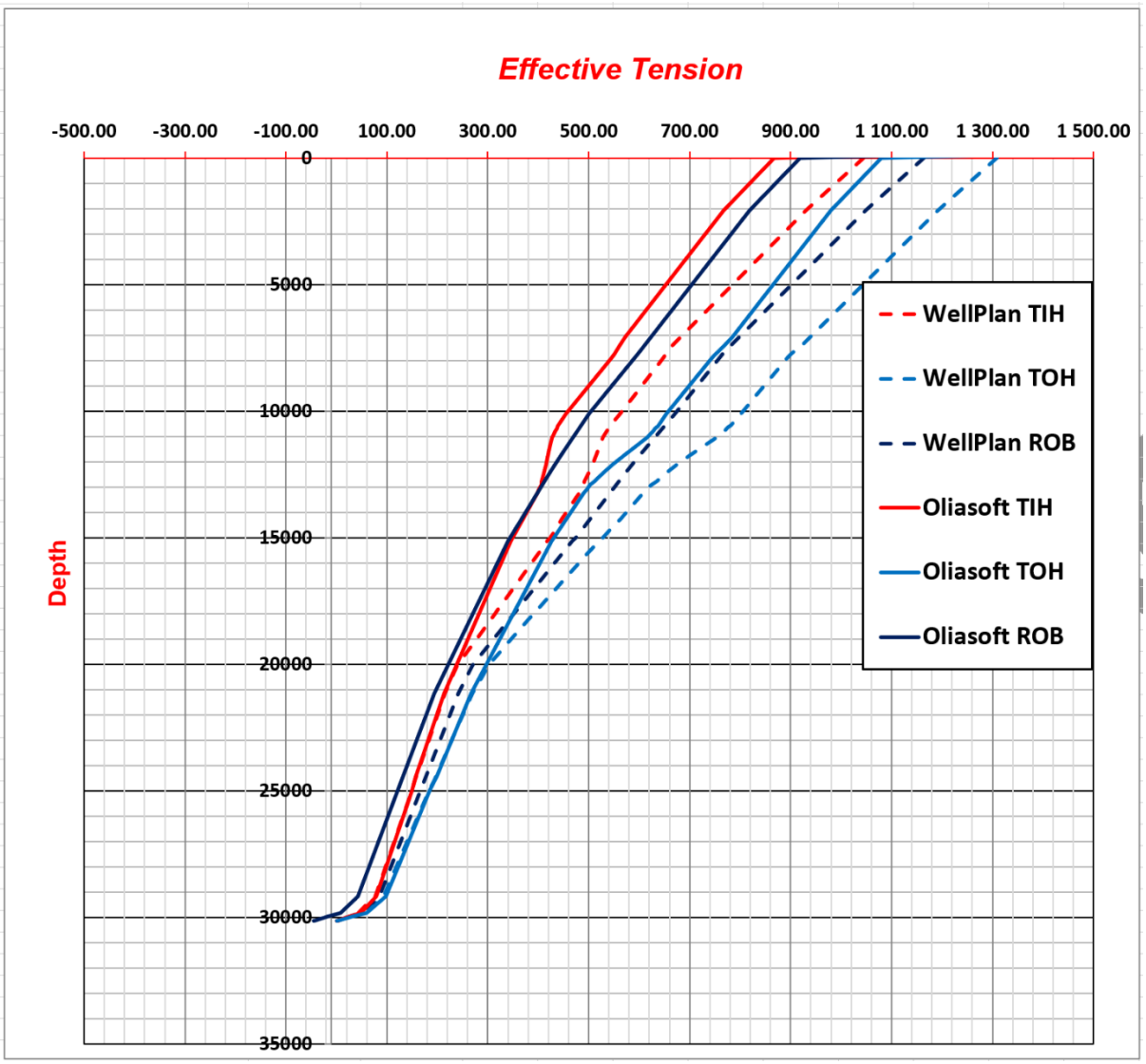
3.7.2 OWDVs. WellPlan

Drilling 12 1/4 "				
BHA	12 1/4 WellPlan			
Block Weight [kip]	185			
Mud weight [ppg]	13.5			
Friction factors	Riser	Casing	Open hole	
	0	0.17	0.2	
Running parameters	ROP [ft/hr]	[RPM]	Torque at Bit l[bf·ft]	WOB [kip]
	30	150	27000	45

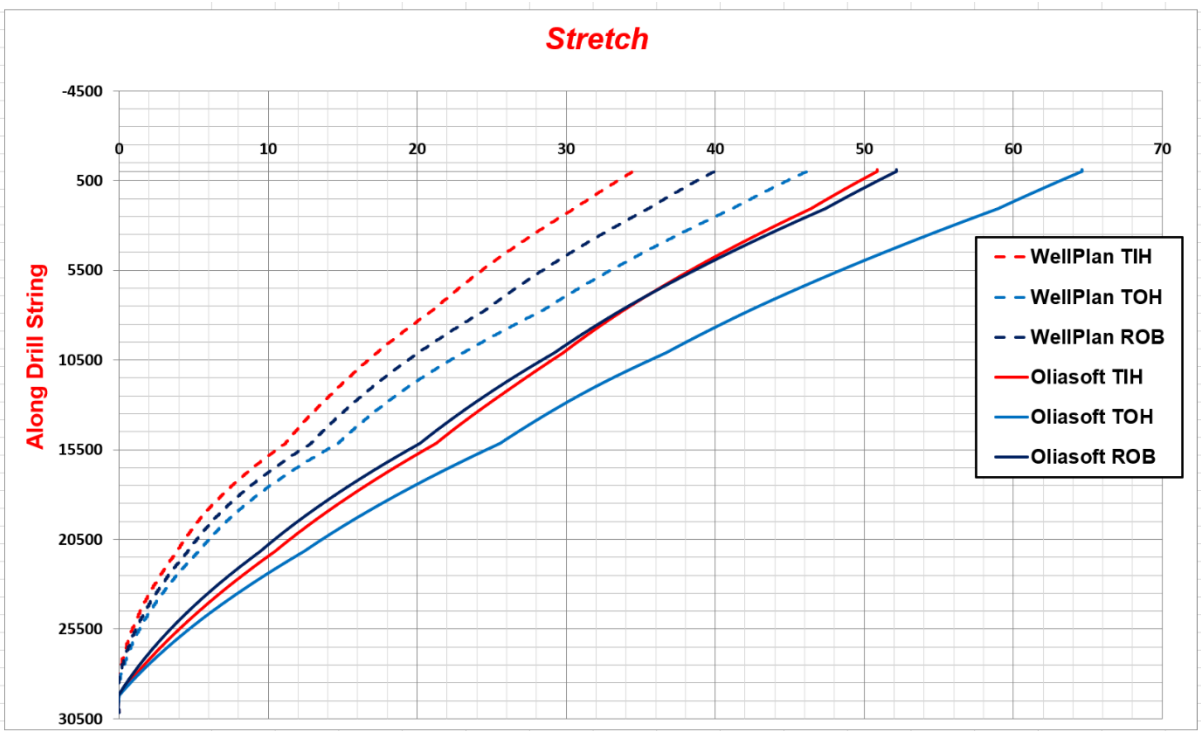


Plot 30: Simulated hookload with OWD and WellPlan.

The simulated values follow each other closely, but a small differences can be seen in the top part of this section.

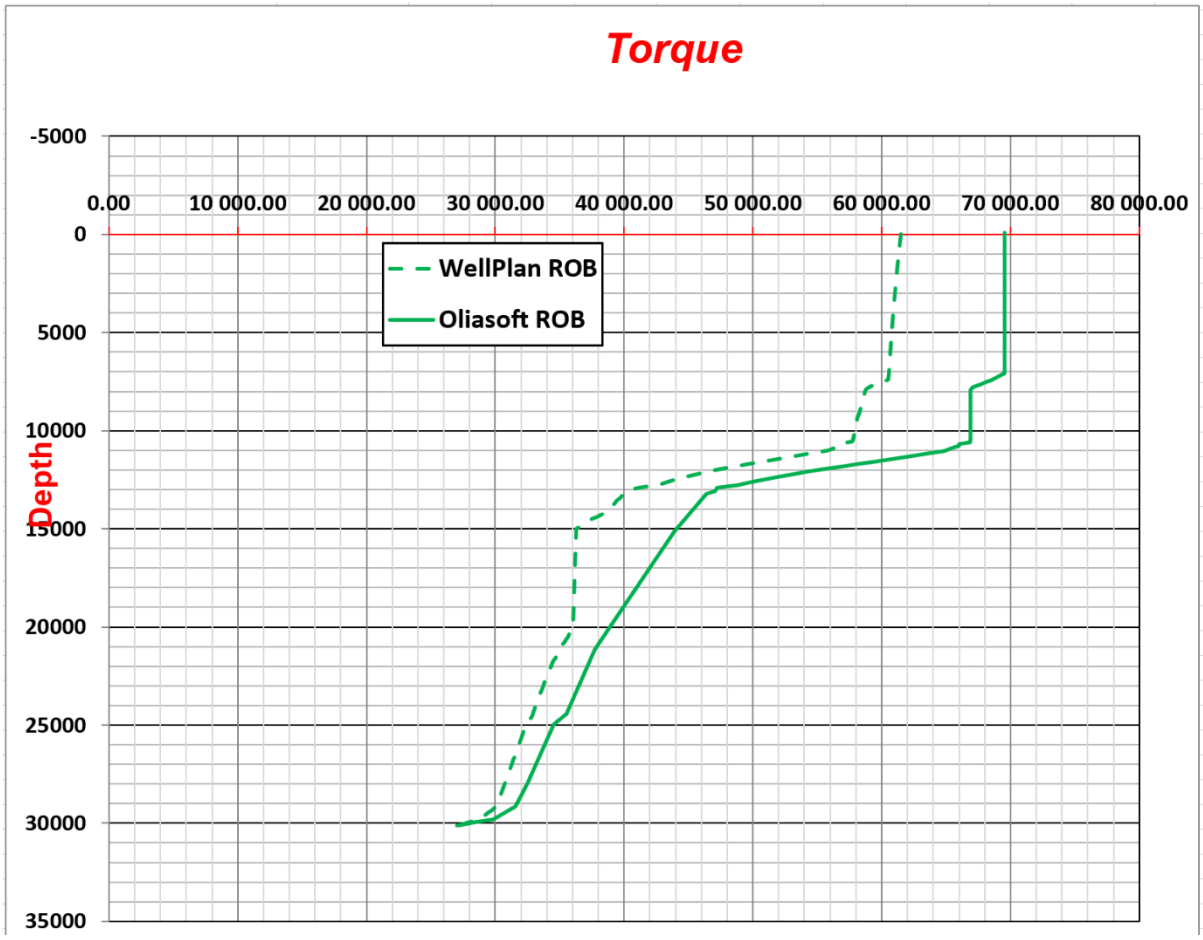


Plot 31: Simulated effective tension with OWD and WellPlan.



Plot 32: Accumulated stretch simulated with OWD and WellPlan.

OWD stretch illustrated in the plot as the three first plot lines from the left. The lines show an anticipated difference, since the hookloads are different.



Plot 33: Simulated torque along drill string with OWD and WellPlan.

The torque plot shows a higher torque simulation than from WellPlan. The major deviation with WellPlan is between 15000 ft and 20000 ft where the trajectory holds a steady 25 degree angle. It is unreasonable that the torque does not increase during this part of the section.