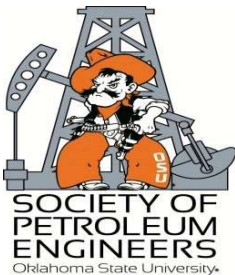


# ***PETE 5313***

## ***Advanced Drilling***

### ***Handout #7&8***

***Parametric Study of Single PDC Bit Run with Wear  
and  
Optimization of Single PDC Bit Run Using the Optimizer***



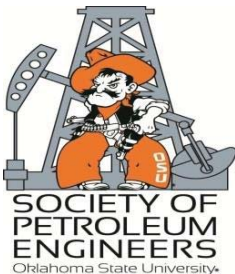
## Handout#7&8

- ◆ Handout#7 Parametric Study of a PDC bit run with wear using the “Optimizer”
- ◆ Handout#8 Optimization of Single PDC Bit Run (Using Only Existing ARSL Bit) using the “Optimizer”
- ◆ Project #3 from both Handout #7&8

# Handout #7

## I. Parametric Study: Single PDC Bit Run with Wear

- ◆ This section we will focus on one single PDC bit run
- ◆ The effect of bit wear on ROP
- ◆ The integrated effect of bit wear and operating conditions on ROP
- ◆ Cutter PDC layer thickness
- ◆ Bit with backup cutters
- ◆ Single Bit Run Optimization
- ◆ Using Existing ARSL Bit



# **I. Parametric Study Single PDC Bit Run**

## **Procedure for Study**

- ◆ Study the effect of constant operating parameters on overall ROP
- ◆ Try multiple combinations for operating conditions on ROP
- ◆ Study the effect of varying operating parameters throughout the bit run
- ◆ Study the effect of bit design parameters on ROP
- ◆ Input new bit designs
- ◆ Compare performance of different bit designs.
- ◆ Discuss limits on operating parameters

# **I. Parametric Study Single PDC Bit Run**

## **Parametric Study**

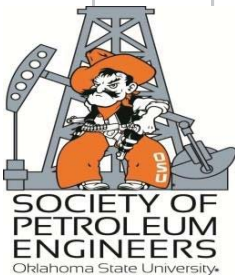
- ◆ The parametric study is performed with a ARSL from 2859-3600m to illustrate the effect of different parameters on ROP
- ◆ The ARSL will have constant input operational parameters for one bit run from 2859-3600m.
- ◆ The bit has a wear of 2.0
- ◆ The ARSL is created from three input files that is vertical and the input parameters are constant as in the "LongPDC"
- ◆ The PDC bit sensitivity study will include wear, operating and bit design parameters



# I. Parametric Study Single PDC Bit Run

## The GDL Input File - figeo1.lith

MD	TD	SAND	SHAL	LIME	DOLO	SILI	CONG	COAL	NULL	NULL	NULL	P.P.	PERM
-----													
2859	2859	0	1	0	0	0	0	0	0	0	0	1.45	1
2860	2860	0	1	0	0	0	0	0	0	0	0	1.45	1
2861	2861	0	1	0	0	0	0	0	0	0	0	1.45	1
2862	2862	0	1	0	0	0	0	0	0	0	0	1.45	1
2863	2863	0	1	0	0	0	0	0	0	0	0	1.45	1
2864	2864	0	1	0	0	0	0	0	0	0	0	1.45	1
2865	2865	0	1	0	0	0	0	0	0	0	0	1.45	1
2866	2866	0	1	0	0	0	0	0	0	0	0	1.45	1
2867	2867	0	1	0	0	0	0	0	0	0	0	1.45	1
2868	2868	0	1	0	0	0	0	0	0	0	0	1.45	1
2869	2869	0	1	0	0	0	0	0	0	0	0	1.45	1
2870	2870	0	1	0	0	0	0	0	0	0	0	1.45	1
2871	2871	0	1	0	0	0	0	0	0	0	0	1.45	1



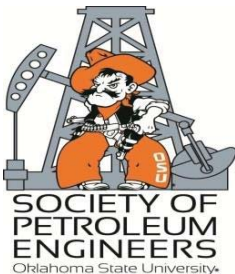
# I. Parametric Study Single PDC Bit Run

## The GDL Input File - fidri1.drill

MD	TD	ROP	WOB	RPM	GPM	PV	MW	MUDTYPE
-----								
2859	2859	20	10	150	2400	44	1.65	1
2860	2860	20	10	150	2400	44	1.65	1
2861	2861	20	10	150	2400	44	1.65	1
2862	2862	20	10	150	2400	44	1.65	1
2863	2863	20	10	150	2400	44	1.65	1
2864	2864	20	10	150	2400	44	1.65	1
2865	2865	20	10	150	2400	44	1.65	1
2866	2866	20	10	150	2400	44	1.65	1
2867	2867	20	10	150	2400	44	1.65	1
2868	2868	20	10	150	2400	44	1.65	1
2869	2869	20	10	150	2400	44	1.65	1
2870	2870	20	10	150	2400	44	1.65	1
2871	2871	20	10	150	2400	44	1.65	1

# The ARSL Input File - fibit.bit

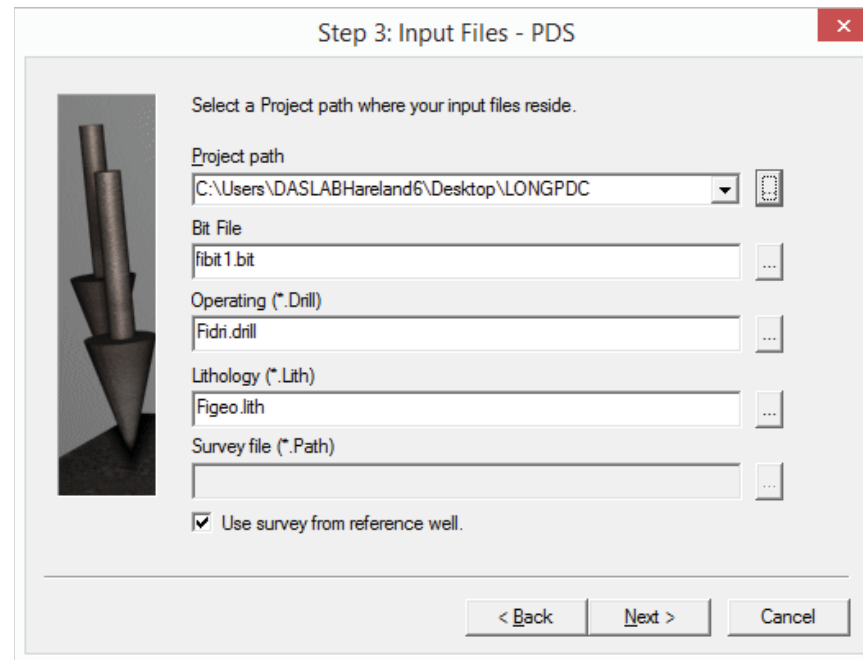
[Info]					
Version = 1.1					
Well = N/A (converted file)					
Prepared By = N/A (converted file)					
Comment = Converted file, no additional info available					
[123456]					
Bit Type = pdc					
IADC Code = 999					
Bit Diameter = 12.25					
TVD In = 2859.00					
TVD Out = 3600.00					
MD In = 2859.00					
MD Out = 3600.00					
Wear In = 0.0					
Wear Out = 2.0					
Cost = 48062					
DHM Cost = 0					
Manufacturer = N/A (converted file)					
Bit Description = N/A (converted file)					
Nozzle1 = 14					
Nozzle2 = 14					
Nozzle3 = 14					
Nozzle4 = 14					
Nozzle5 = 14					
Nozzle6 = 14					
Nozzle7 = 0					
Nozzle8 = 0					
Primary Number of Cutters = 69					
Backup Number of Cutters = 0					
Primary Cutter Size = 0.5					
Backup Cutter Size = 0.0					
Primary Backrake = 20					
Backup Backrake = 0					
Primary Siderake = 15					
Backup Siderake = 0					
Number of Blades = 6					
Junk Slot Area = 28					
Thickness = .08					
Exposure = 0					
Distance = 0					



# I. Parametric Study Single PDC Bit Run

## Parametric Study with “LongPDC”

- ◆ Start “Optimizer” and use default rig rate, times and parameter bounds
- ◆ Locate the “LongPDC” project at: LongPDC



# I. Parametric Study Single PDC Bit Run

## “Simulation Window - Sim000”

- ◆ The first simulation indicates the parameters and costs related to the reference well
- ◆ The drilling parameters are now averaged for the section

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	10.0	150.0	2400.0	44.0	1.65	2.0	2.0	20.00	630.49	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.0
001	New							

Average ROP for entire well: 20.00

Simulation completed :

# I. Parametric Study Single PDC Bit Run

## “Simulation Window - Sim001”

- ◆ Click on “Run” and the drilling is simulated with the same parameters and the ROP and the \$/m is calculated for the bit run
- ◆ We are now ready to simulate any combinations of parameters and bits

The screenshot shows the 'Simulation Control Sheet' window. It contains a table of simulation parameters for a single PDC bit run. Below the table are various control buttons like 'View Plot', 'Run', and 'Parameters'. At the bottom, there is a 'Simulation results summary' table and a section for 'Average ROP for entire well'.

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	10.0	150.0	2400.0	44.0	1.65	2.0	2.0	20.00	630.49	Rotary	Oil

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.0
001	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
002	New							

Average ROP for entire well: 0.00

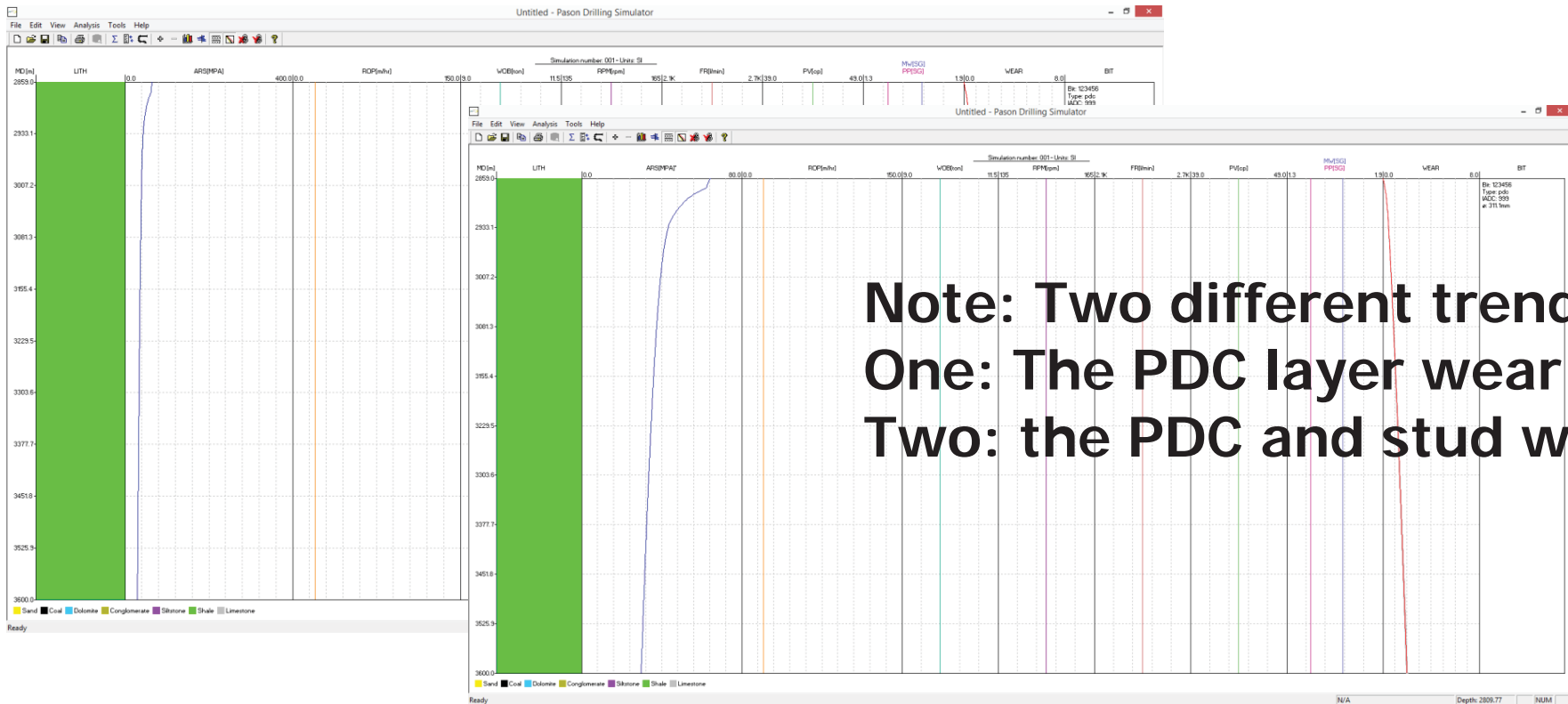
Lowest cost/m: sim001

Simulation completed :

# I. Parametric Study Single PDC Bit Run

## Sensitivity Study with “LongPDC”

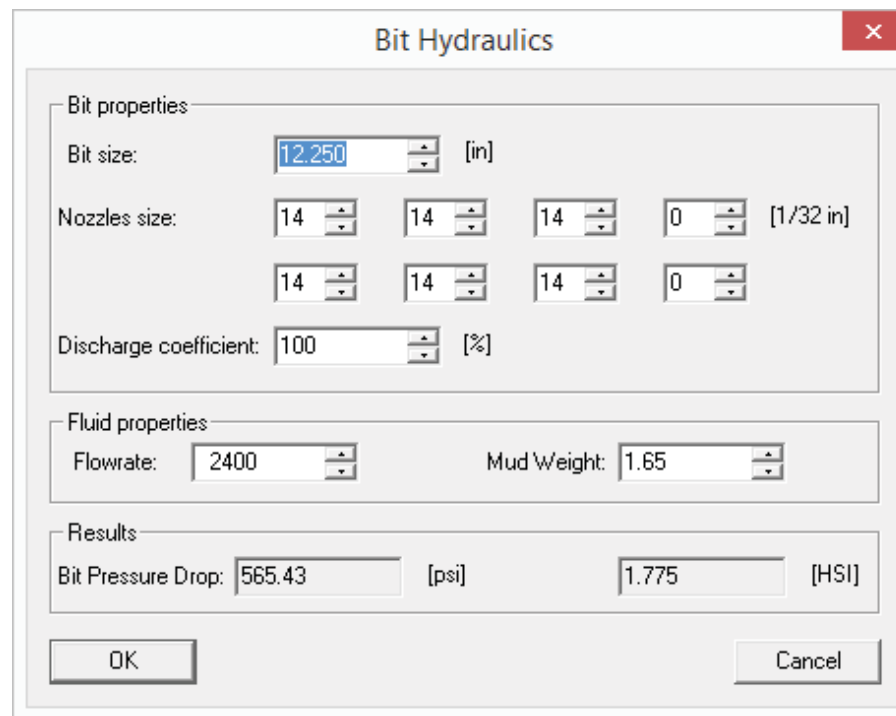
- ◆ The Plot screen is now displayed
- ◆ Note the change in ARSL - due to difference in wear and confining pressure
- ◆ Right Click – select “Plotting Options” and set ARS from 0 to 80



# I. Parametric Study Single PDC Bit Run

## Sensitivity Study with “LongPDC”

- ◆ To evaluate the bit hydraulics click on the hydraulics box
- ◆ You can evaluate different nozzle configurations but not change them



The screenshot shows a software dialog box titled "Bit Hydraulics" with a close button (X) in the top right corner. The dialog is organized into three sections: "Bit properties", "Fluid properties", and "Results".

**Bit properties:**

- Bit size: 12.250 [in]
- Nozzles size: A 2x4 grid of spinners. The top row has values 14, 14, 14, and 0. The bottom row has values 14, 14, 14, and 0. The unit [1/32 in] is shown to the right.
- Discharge coefficient: 100 [%]

**Fluid properties:**

- Flowrate: 2400
- Mud Weight: 1.65

**Results:**

- Bit Pressure Drop: 565.43 [psi] and 1.775 [HSI]

At the bottom are "OK" and "Cancel" buttons.



# I. Parametric Study Single PDC Bit Run

## Sensitivity Study with “LongPDC”

- ◆ To change the bit nozzles click on the “Bitinfo” box
- ◆ This will display the bit details and to change the bit parameters click on “Edit”
- ◆ Same as before!!

Bit details

Bit details:

ID	Detail
Bit ID	001
Used in section	001
Type	pdc
IADC Code	999
Serial Number	123456
Diameter	12.250
Wear In	0.00
Cost	48062.00 USD
DHM Cost	0.00 USD
Wear constant	2.416874e-005
Primary cutters	69.000
Backup cutters	0.000
Primary Cutter size	0.500
Backup Cutter size	0.000
Primary Back rake	20.000
Backup Back rake	0.000
Primary Side rake	15.000
Backup Side rake	0.000
Thickness	0.080000
Junk Slot Area	28.000
Number of blades	6.0
Exposure	0.000000
Distance	0.000
Nozzle Size 1	14.00 (32th inch)
Nozzle Size 2	14.00 (32th inch)
Nozzle Size 3	14.00 (32th inch)
Nozzle Size 4	14.00 (32th inch)
Nozzle Size 5	14.00 (32th inch)
Nozzle Size 6	14.00 (32th inch)
Nozzle Size 7	0.00 (32th inch)

Exit

Bit database

Export Bit

Import Bit

Edit

New

Triroller

PDC

NDB

IMP

1/1 - Serial #: 123456

# I. Parametric Study Single PDC Bit Run

## Sensitivity Study with “LongPDC”

- ◆ Here you change the nozzles the click “OK” then “OK” on the bit details

The screenshot shows the 'Bit Details PDC' dialog box with the following fields and values:

General		Cutters				Hydraulics (32th inch)	
IADC Code	999	#	Backrake (Deg)	Siderake (Deg)	Diameter (inch)	Nozzle 1	Nozzle 5
Serial Number	123456	Primary Cutters	69	20	15	0.5	14
Diameter	12.25	Backup Cutters	0	0	0	0	14
Wear In	0					Nozzle 3	Nozzle 7
Cost	48062					14	0
DHM Cost	0	Number Of Blades	6	Exposure(inch)	0	Nozzle 4	Nozzle 8
Wear Constant	2.417e-005	Junk Slot Area(inch^2)	28	Distance(inch)	0	14	0
		Thickness(inch)	0.08			Total Flow Area(in.^2) 0.90	

Buttons: OK, Cancel

- ◆ The nozzles have then been changed for this bit!!

# Sensitivity Study with “LongPDC” (study the effects of bit wear)

Operating Parameter			Base Case		
WOB	3	7	10	14	20
ROP			20		31
Bit Wear			2		
RPM	50	100	150	200	250
ROP			20		26.88
Bit Wear			2		
HP/Inch**2	0.436	1.18	1.775	2.5	3.3
ROP	16.4		20		20.3
Bit Wear			2		
Nozzle Size	6*12	6*13	6*14	6*15	6*16
ROP	20.3		20		
Bit Wear			2		
Flowrate	2000	2200	2400	2600	2800
ROP		19.7	20		
Bit Wear			2		
Mud Weight	1.55	1.6	1.65	1.7	1.75
ROP			20		
Bit Wear			2		
Plastic Viscosity	24	34	44	54	64
ROP	21.77		20		
Bit Wear			2		
Oil VS Water			Oil		WTR
ROP			20		15.06
Bit Wear			2		

Hmm? Why does bit wear change as it does?

# I. Parametric Study Single PDC Bit Run

## “Hydraulics Effect”

- ◆ Click on “Split Section” and split the drilling interval at 2900m.
- ◆ Input WOB=25 ton only in the first interval from 2859-2900m.

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	2900.0	41.0	25.0	150.0	2400.0	44.0	1.65	0.6	0.6	34.03	0.00	Rotary	Oil
002	001	001 - pdc	2900.0	3600.0	700.0	10.0	150.0	2400.0	44.0	1.65	1.6	2.2	18.73	646.17	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
005	48.1	81.7	52.1	0.0	172.3	354.1	477.3	22.3
006	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
007	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
008	48.1	81.7	52.1	0.0	297.6	479.5	646.2	38.6
009	New							

Average ROP for entire well: 0.00

Lowest cost/m: sim002

Simulation completed :

Now - ROP is higher initially but slower after 2900m – wear?

# I. Parametric Study Single PDC Bit Run

## “Hydraulics Effect”

◆ Focus only on the first section and change the HP/in\*\*2 as in table.

Operating Parameter				Base Case		
HP/Inch**2		0.427	1.18	1.775	2.5	3.3
ROP		23.37		34.04		48.65

Can you think about why the HSI effect is now much larger then the previous base case?

# I. Parametric Study Single PDC Bit Run

## “Optimizer - WOB and RPM Optimization”

- ◆ Merge the two sections back to Base Case
- ◆ Click on “Merge with Next” then “Run” and make sure you have one section and that the ROP is 20.0 m/hr
- ◆ We will next have the “Optimizer” find the optimum combination of WOB and RPM
- ◆ This is done using the “AI” feature
- ◆ Click on “AI” and the following window will appear

Input parameters for AI

Min WOB: 1 Max WOB: 70 Steps: 2  
Min RPM: 50 Max RPM: 2000 Steps: 2  
Depth In: 2859 Depth Out: 3600 Sections: 1

Average wear should not exceed 6.

Section	Depth In	Depth Out
1	2859.00	3600.00

Depth In:   
Depth Out:   
WOB steps: 1.00 70.00  
RPM steps: 50.00 2000.00

# of combinations: 4  
Aprox time: Below 1(one) second

# I. Parametric Study Single PDC Bit Run

## "AI" Feature

- ◆ Input the range of operating conditions you would like to simulate as below
- ◆ Input 20 Steps for each parameters and leave max wear at 3.0.

Input parameters for AI

Min WOB: 5 Max WOB: 20 Steps: 20

Min RPM: 50 Max RPM: 200 Steps: 20

Depth In: 2859 Depth Out: 3600 Sections: 1

Average wear should not exceed 3.

Section	Depth In	Depth Out
1	2859.00	3600.00

Depth In: [dropdown] Depth Out: [dropdown]

WOB steps: 5.00 5.79 6.58 7.37 8.16 8.95 9.74 10.53 11.32 12.11 12.89 13.68

RPM steps: 50.00 57.89 65.79 73.68 81.58 89.47 97.37 105.26 113.16 121.05 128.95 136.84

# of combinations: 400

Aprox time: Below 1(one) second

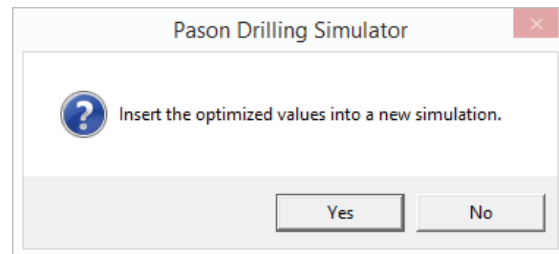
**Note: 400 simulations  
From 20x20!**

- ◆ The Optimizer will then estimate the number of simulations and the rough amount of time to simulate these.
- ◆ Then click on OK.

# I. Parametric Study Single PDC Bit Run

## "AI" Feature

- ◆ The PDS will now run through these combinations and report the best one (All simulations where bit wear is more than 3.0 before reaching TD (Total Depth) are 17%)
- ◆ WOB-14.47
- ◆ RPM-176.32
- ◆ After the PDS is finished it will ask if you would like to insert the best result
- ◆ Click "Yes " and it will be inserted into the simulation window - then click run



# I. Parametric Study Single PDC Bit Run

## "AI" Feature

- ◆ The result is shown below.

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	14.5	176.3	2400.0	44.0	1.65	3.0	3.0	28.70	513.70	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
007	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
008	48.1	81.7	52.1	0.0	297.6	479.5	646.2	38.6
009	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
010	48.1	81.7	52.1	0.0	199.3	381.2	513.7	25.9
011	New							

Average ROP for entire well: 0.00

Lowest cost/m: sim002

Simulation completed :

- ◆ The average ROP is now 28.7 m/hr or 25.9 hours

# I. Parametric Study Single PDC Bit Run

## "AI" Feature – Two Sections

- ◆ Input the range of operating conditions you would like to simulate as below
- ◆ Input Steps as below for each parameters, split depth at 3229m and leave max wear at 3.0.

Input parameters for AI

Min WOB: 5 Max WOB: 25 Steps: 6 OK  
Min RPM: 50 Max RPM: 250 Steps: 9 Cancel  
Depth In: 2859 Depth Out: 3600 Sections: 2

Average wear should not exceed 3.

Section	Depth In	Depth Out
1	2859.00	3229.00
2	3229.00	3600.00

# of combinations: 2916  
Approx time: Below 1(one) second

Depth In:   
Depth Out:   
WOB steps: 5.00 9.00 13.00 17.00 21.00 25.00  
RPM steps: 50.00 75.00 100.00 125.00 150.00 175.00 200.00 225.00 250.00

- ◆ Then click on OK



# I. Parametric Study Single PDC Bit Run

## "AI" Feature – Two Sections

- ◆ The result is indicated below (38% of more then 3 wear reported)
- ◆ Insert the simulations into the new simulation

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3229.0	370.0	13.0	200.0	2400.0	44.0	1.65	1.7	1.7	28.62	0.00	Rotary	Oil
002	001	001 - pdc	3229.0	3600.0	371.0	13.0	225.0	2400.0	44.0	1.65	1.3	3.0	28.97	512.81	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
008	48.1	81.7	52.1	0.0	297.6	479.5	646.2	38.6
009	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
010	48.1	81.7	52.1	0.0	199.3	381.2	513.7	25.9
011	48.1	81.7	52.1	0.0	198.7	380.5	512.8	25.8
012	New							

Average ROP for entire well: 28.75

Lowest cost/m: sim002

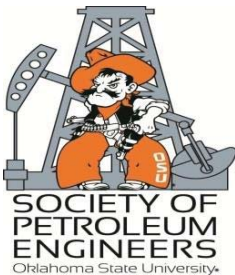
Simulation completed :

- ◆ The average ROP is now 28.75 m/hr or 25.8 hours – little less then with one section. (did we split at the wrong depth?)

# I. Parametric Study Single PDC Bit Run

## After "AI" Feature – we all simulate with max wear of 3.0!

- ◆ YOU do next!
- ◆ Input 10 values for WOB and RPM, split depth at 3450m and leave max wear at 3.0 (10,000 simulations)
- ◆ Now use these results to manually fine tune
- ◆ Split into 3 sections and try to increase overall ROP
- ◆ Run at least 10 more simulations – (think about what you are doing when selecting the next parameters!)
- ◆ Who can get the best result?



Did you learn anything from this?



# I. Parametric Study Single PDC Bit Run

## **"AI" Feature**

- ◆ Use common sense with AI
- ◆ Use cushion on wear - make sure you are not pushing it in too far on your operating parameters recommendations
- ◆ When running "AI" with multiple depth splits be aware of time too run simulations
- ◆ It will give a good indicator on WOB and RPM, but multiple depth splits is often done better manually
- ◆ Remember hydraulics must be done separately

# I. Parametric Study Single PDC Bit Run

## “PDS - Bit Design Parameters”

- ◆ Go Back to base case
- ◆ Click on “Split Section” and split the drilling interval at 3450m
- ◆ Input WOB=25 ton only in the first interval from 2859-3450m
- ◆ Focus only on the first section and change the **Junk Slot Area** as in table on the next page

**Simulation Control Sheet**

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3450.0	591.0	25.0	150.0	2400.0	44.0	1.65	3.8	3.8	33.75	0.00	Rotary	Oil
002	001	001 - pdc	3450.0	3600.0	150.0	10.0	150.0	2400.0	44.0	1.65	0.3	4.1	12.35	553.46	Rotary	Oil

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DH Moto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
010	48.1	81.7	52.1	0.0	199.3	381.2	513.7	25.9
011	48.1	81.7	52.1	0.0	198.7	380.5	512.8	25.8
012	48.1	81.7	52.1	0.0	286.0	467.8	630.5	37.1
013	48.1	81.7	52.1	0.0	228.8	410.7	553.5	29.7
014	New							

Average ROP for entire well: 0.00

Lowest cost/m: sim002

Simulation completed :

# I. Parametric Study Single PDC Bit Run

## “Optimizer - Bit Design Parameters”

- ◆ Use the “Bitinfo” box to change the bit parameters.
- ◆ Make sure that you get back to the base case between changing the different parameters.

The screenshot shows a software dialog box titled "Bit Details PDC" with a close button (X) in the top right corner. The dialog is organized into several sections for inputting bit parameters:

- General Information:** IADC Code (999), Serial Number (123456), Diameter (12.25), Wear In (0) and Out (2), Cost (48062), DHM Cost (0), and Wear Constant (2.417e-005).
- Cutter Configuration:** A table for Primary and Backup Cutters with columns for count (#), Backrake (Deg), Siderake (Deg), and Diameter (inch).

	#	Backrake (Deg)	Siderake (Deg)	Diameter (inch)
Primary Cutters	69	20	15	0.5
Backup Cutters	0	0	0	0
- Blade and Slot Parameters:** Number Of Blades (6), Exposure(inch) (0), Junk Slot Area(inch^2) (28), Distance(inch) (0), and Thickness(inch) (0.08).
- Hydraulics (32th inch):** Eight nozzle size inputs (Nozzle 1-8, all set to 14) and a Total Flow Area(in.^2) input (0.90).

At the bottom right, there are "OK" and "Cancel" buttons.

# I. Parametric Study Single PDC Bit Run

## “Bit Design - Junk Slot Area Effect”

Operating Parameter				Base Case		
Junk Slot Area		20	25	28	38	50
ROP				33.75		49.67

Observe the large difference in the effect compared to the earlier case.

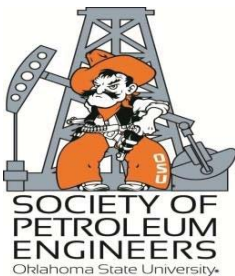
The larger JSA (Junk Slot Area) faster the ROP!



# I. Parametric Study Single PDC Bit Run

## **“PDS - Bit Design Parameters”**

- ◆ Merge the two sections back to Base Case
- ◆ Click on “Merge with Next” then “Run” and make sure you have one section and that the ROP is 20.0 m/hr
- ◆ We will next study the effect of different bit design parameters on ROP
- ◆ All the design parameters that will change later are listed on slide 34
- ◆ First we will just see and discuss some effects of bit design parameters on ROP

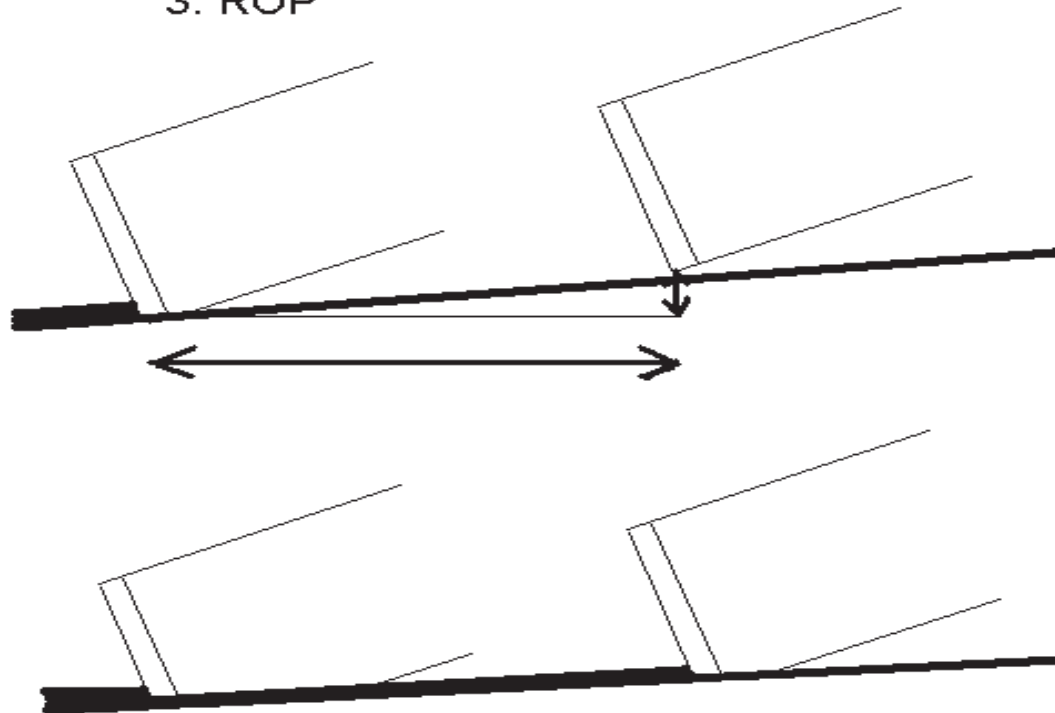


# I. Parametric Study Single PDC Bit Run

## “Back-Up Cutters”

Parameters

1. Distance Between Cutters
2. Exposure
3. ROP



# I. Parametric Study Single PDC Bit Run

## “Optimizer - Bit Design Parameters”

- ◆ Go back to base case - 20m/hr
- ◆ Go to “Bitinfo” menu and select a new PDC bit
- ◆ Input a bit with backup cutters as seen below

The screenshot shows the 'Bit Details PDC' dialog box with the following fields and values:

IADC Code		999	
Serial Number		123456	
Diameter		12.25	
Wear In	Out	0	2
Cost		48062	
DHM Cost		0	
Wear Constant		2.417e-005	

	#	Backrake (Deg)	Siderake (Deg)	Diameter (inch)
Primary Cutters	69	20	15	0.5
Backup Cutters	36	20	15	.5

Number Of Blades		6
Junk Slot Area(inch^2)		28
Thickness(inch)		0.08
Exposure(inch)		.05
Distance(inch)		1.5

Hydraulics (32th inch)		
Nozzle 1	14	
Nozzle 2	14	
Nozzle 3	14	
Nozzle 4	14	
Nozzle 5	14	
Nozzle 6	14	
Nozzle 7	0	
Nozzle 8	0	
Total Flow Area(in.^2)		0.90

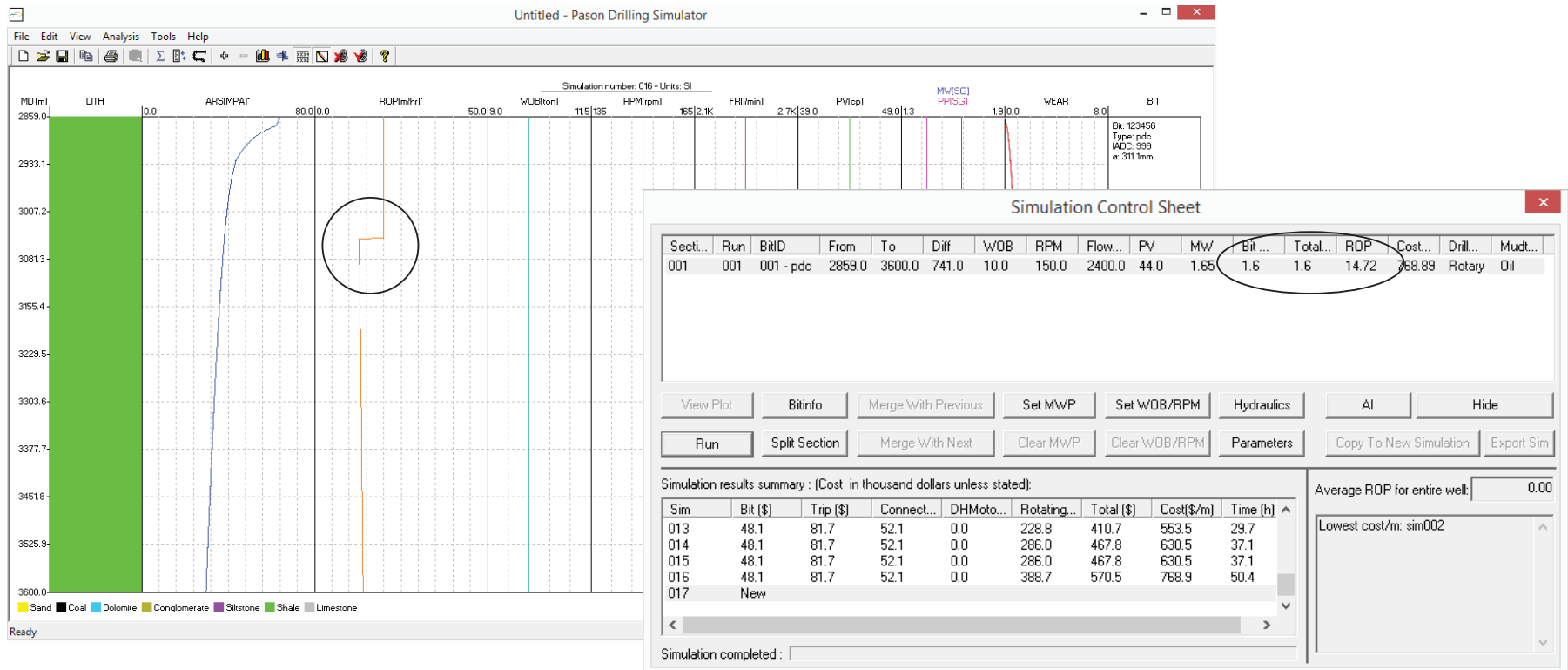
OK Cancel

- ◆ Modify bit design
- ◆ Then run the simulation and you should get an ROP of 14.72 m/hr
- ◆ This is the base case for the next parametric study

# I. Parametric Study Single PDC Bit Run

## “Optimizer - Bit Design Parameters”

- ◆ Note: Bit wear is 1.6 less then 2.0.
- ◆ Note: When the backup cutters kick in.



# I. Parametric Study Single PDC Bit Run

## “Optimizer - Bit Design Parameters”

Bit Design Parameters			Base Case		
Number of Backup Cutters	12	24	36	48	60
ROP			14.72		
Wear			1.6		
Backup Cutters Backrake	10	15	20	30	40
ROP			14.72		
Wear			1.6		
Backup Cutters Siderake	0	5	15	20	25
ROP			14.72		
Wear			1.6		
Backup Cutters Exposure	0.02	0.05	0.1	0.15	0.2
ROP			14.72		
Wear			1.6		
Backup Cutters Distance from Primary Blade	0.5	1	1.5	2	
ROP			14.72		
Wear			1.6		
PDC Cutter Layer Thickness	0.04	0.06	0.08	0.1	0.12
ROP			14.72		
Wear			1.6		

Ops Shift!?



# I. Parametric Study Single PDC Bit Run

## Section Summary

- ◆ Learned some new functionality's of the Optimizer
- ◆ The effect of operating parameters on ROP
- ◆ Tried multiple combinations of operating conditions on ROP (used AI)
- ◆ The effect of varying operating parameters through out the bit run
- ◆ Evaluated the effect of bit designs on performance
- ◆ Compared performance of different bit designs

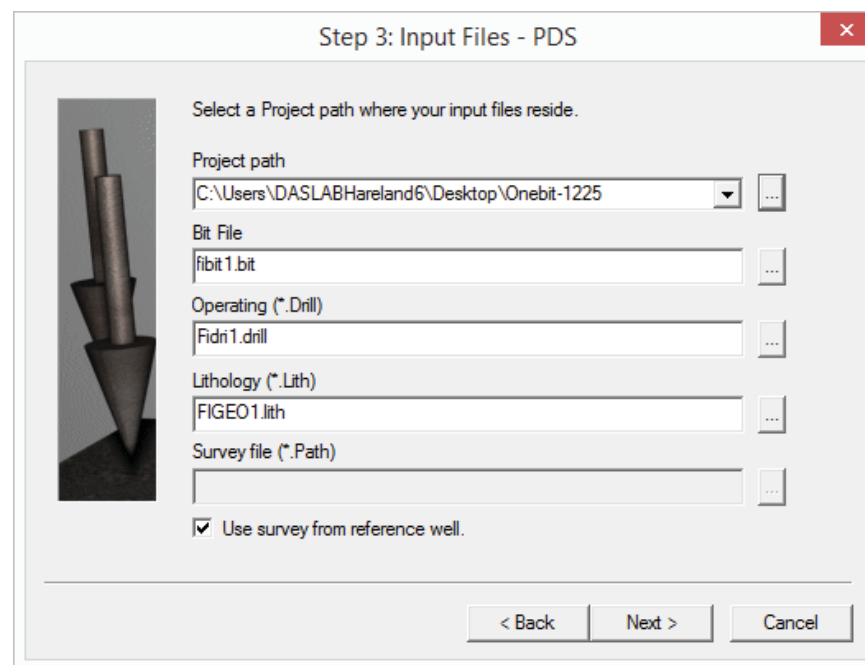
# Handout#8

## II. Optimization of Single PDC Bit Run

- ◆ The ARSL is created from an actual well with one bit run from 2859-3600m
- ◆ The bit has wear out of 4.4. (Actual 2.5-6.0)
  - ◆ Older bit design with max wear of 6-7!!
- ◆ The ARSL is created from three input files in the Onebit-1225 folder
- ◆ This study will involve optimizing the hydraulics and recommend a set of operating parameters for the bit used
- ◆ Initially you will follow 5 simulations
- ◆ Thereafter you will simulate on your own individually to see who obtains the best results

## II. Optimization of Single PDC Bit Run

- ◆ Locate the “Onebit-1225” project at:
- ◆ Onebit-1225
- ◆ Then click “OK”



# II. Optimization of Single PDC Bit Run

## Simulation 000

- ◆ The first simulation window gives an average ROP of 18.64 m/hr
- ◆ The average operating conditions are displayed but they are actually used with variations as in the plot

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	5.6	210.1	2404.5	45.9	1.55	4.4	4.4	18.74	656.33	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

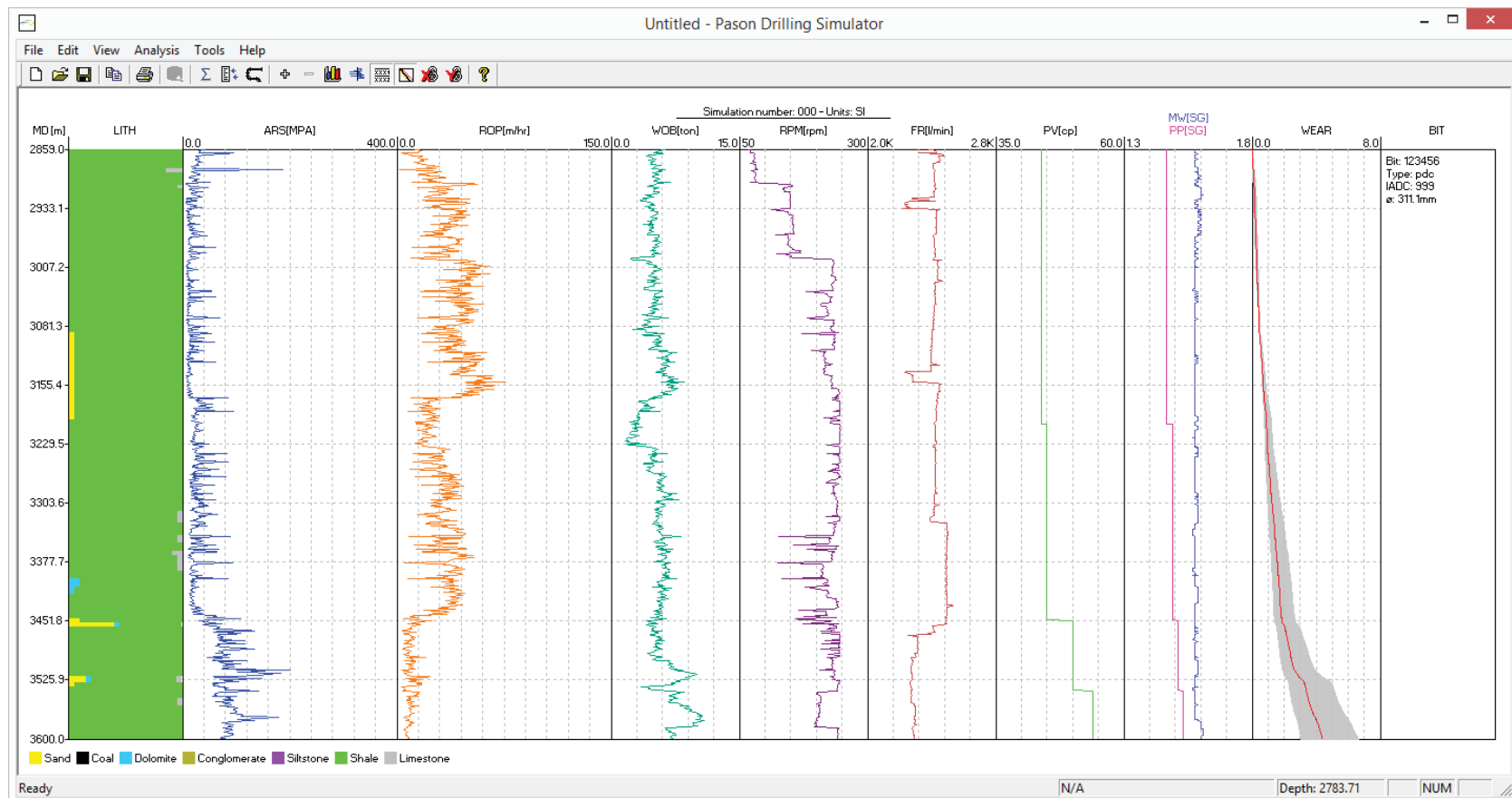
Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	305.2	487.0	656.3	39.5
001	New							

Average ROP for entire well: 18.74

Simulation completed :

## II. Optimization of Single PDC Bit Run

- ◆ The plot window is shown below for sim000 which is used to generate the ARSL (and uses the actual field data)
- ◆ Note the variations in the ARSL and operating parameters
- ◆ Note the bit wear distribution



# II. Optimization of Single PDC Bit Run

## Simulation 001

- ◆ Next you run with the average parameters (much easier!)
- ◆ The first simulation window gives an average ROP of 16.49 m/hr, bit wear 3.9 and 45 hours .
- ◆ Now you have a starting point, but there are a few things you generally have to do before optimization starts

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	5.6	210.1	2404.5	45.9	1.55	3.9	3.9	16.49	712.60	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DHMoto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	305.2	487.0	656.3	39.5
001	48.1	81.7	52.1	0.0	346.9	528.7	712.6	45.0
002	New							

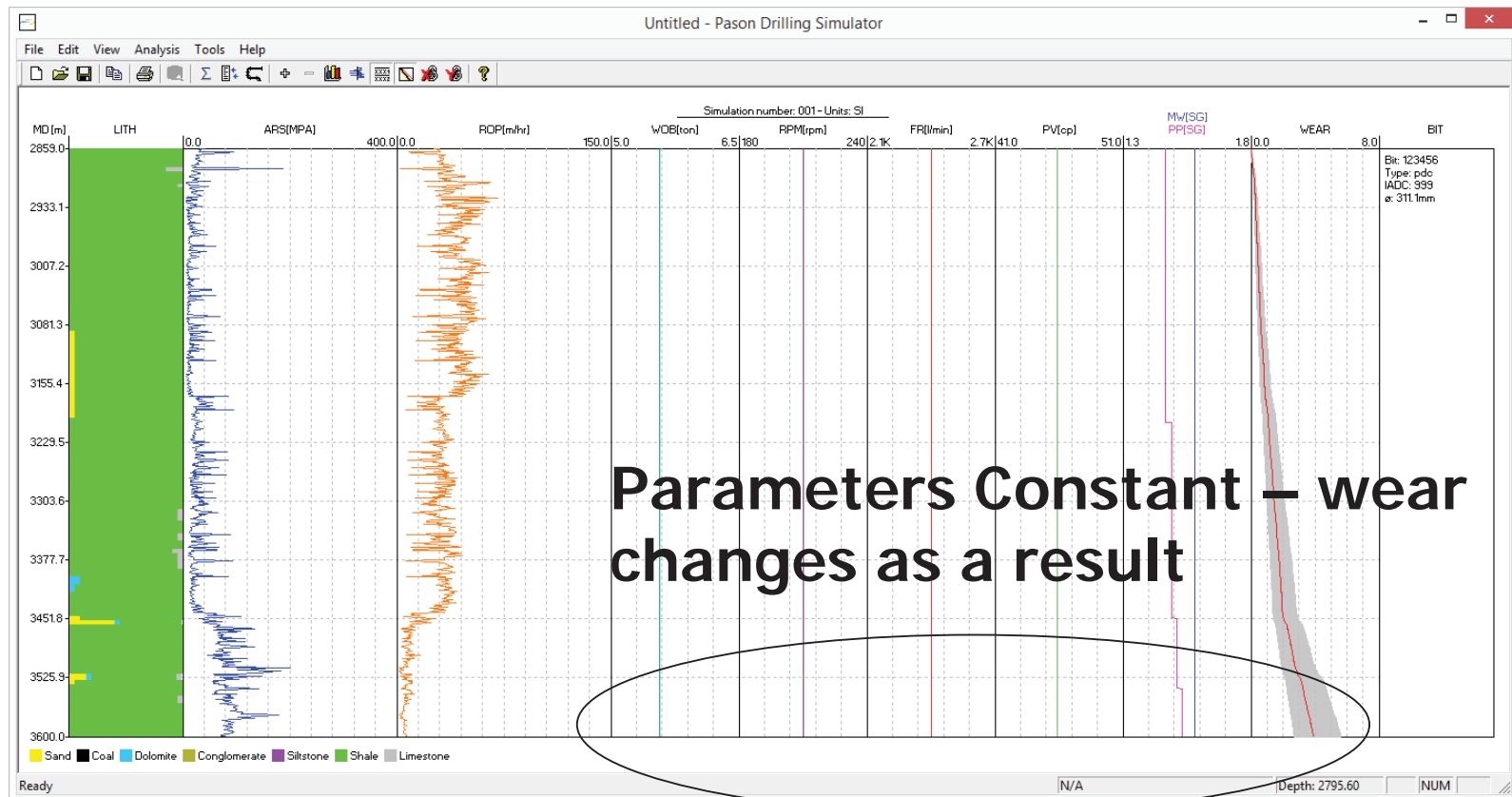
Average ROP for entire well: 0.00

Lowest cost/m: sim000

Simulation completed :

## II. Optimization of Single PDC Bit Run

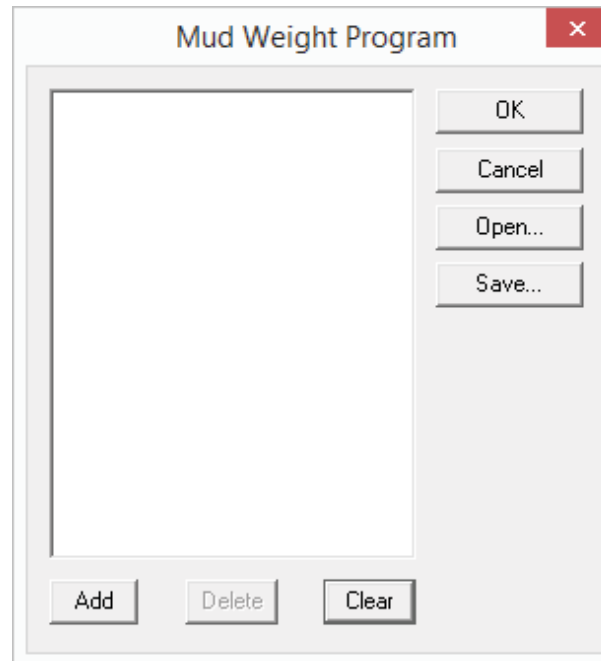
- ◆ The plot window is shown below
- ◆ Note the correlation with variations in the ARSL and the bit wear distribution (wear slope)



## II. Optimization of Single PDC Bit Run

### Simulation 002

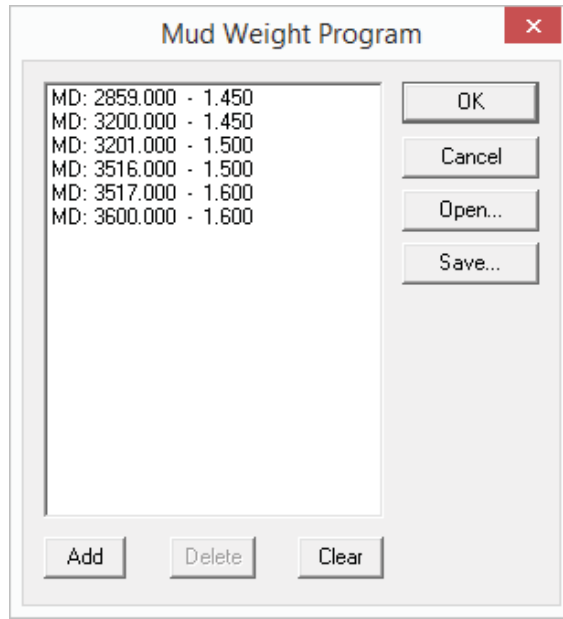
- ◆ The average MW is 1.55, but there are actually variations throughout the bit run
- ◆ To set the new MW program click on “SetMWP” and the following menu will appear



# II. Optimization of Single PDC Bit Run

## Simulation 002

- ◆ The actual MW program is shown below



**This is the mud weight program planned for the next well!**

- ◆ You can generate the mud weight program by adding each of the above listed sections – (then save it to your file folder as MY-MWP.mwp so you can use it later)
- ◆ Next click OK
- ◆ Back at the simulation window click run and you see that the MW indicate MWP, which means that the MW is read from the input file.

# II. Optimization of Single PDC Bit Run

## Simulation 002

- ◆ Run the Optimizer!
- ◆ The average ROP is now 19.13 m/hr

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW/	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	5.6	210.1	2404.5	45.9	MWP	3.3	3.3	19.13	648.09	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DH Moto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	305.2	487.0	656.3	39.5
001	48.1	81.7	52.1	0.0	346.9	528.7	712.6	45.0
002	48.1	81.7	52.1	0.0	299.0	480.9	648.1	38.8
003	New							

Average ROP for entire well: 0.00

Lowest cost/m: sim002

Simulation completed :

- ◆ The next step is to evaluate the bit hydraulics.



# II. Optimization of Single PDC Bit Run

## Simulation 003

- ◆ The hydraulics ran on the bit was only 1.675 HSI, with MW of 1.55
- ◆ The MW program has 1.6 at the end of the section- insert 1.6
- ◆ The available bit pressure drop given is 863 psi. Assume flowrate of 2404 l/min. Find the nozzles sizes.

Bit Hydraulics

Bit properties

Bit size: 12.250 [in]

Nozzles size: 14 14 14 0 [1/32 in]

Discharge coefficient: 100 [%]

Fluid properties

Flowrate: 2404 Mud Weight: 1.55

Results

Bit Pressure Drop: 532.94 [psi] 1.675 [HSI]

OK Cancel

Bit Hydraulics

Bit properties

Bit size: 12.250 [in]

Nozzles size: 14 14 14 0 [1/32 in]

Discharge coefficient: 100 [%]

Fluid properties

Flowrate: 2404 Mud Weight: 1.60

Results

Bit Pressure Drop: 550.13 [psi] 1.729 [HSI]

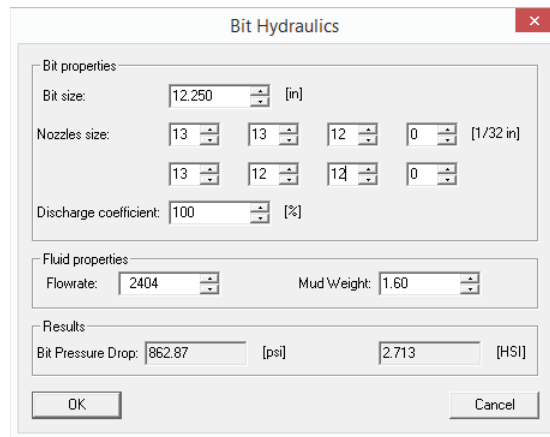
OK Cancel



# II. Optimization of Single PDC Bit Run

## Simulation 003

- ◆ The nozzle selection found was 3\*12 and 3\*13.
- ◆ This indicates a HSI of 2.713.



Bit Hydraulics

Bit properties

Bit size: 12.250 [in]

Nozzles size: 13 13 12 0 [1/32 in]

Discharge coefficient: 100 [%]

Fluid properties

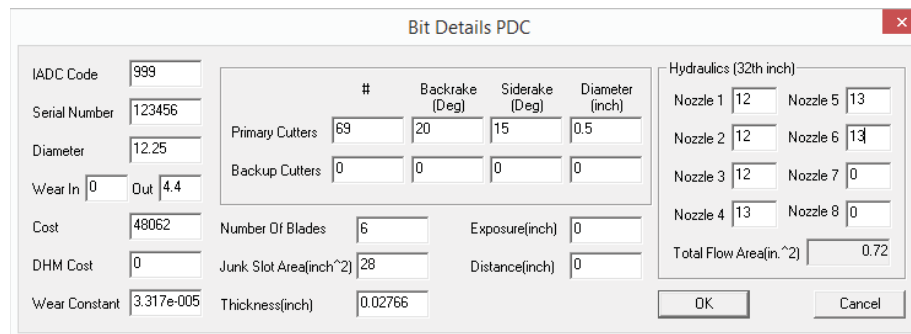
Flowrate: 2404 Mud Weight: 1.60

Results

Bit Pressure Drop: 862.87 [psi] 2.713 [HSI]

OK Cancel

- ◆ Go to the bit Info menu and change the nozzles, the OK the bit and run a simulation with new bit hydraulics.



Bit Details PDC

IADC Code: 999

Serial Number: 123456

Diameter: 12.25

Wear In: 0 Out: 4.4

Cost: 48062

DHM Cost: 0

Wear Constant: 3.317e-005

Primary Cutters: 69 Backrake (Deg): 20 Siderake (Deg): 15 Diameter (inch): 0.5

Backup Cutters: 0 0 0 0

Number Of Blades: 6 Exposure (inch): 0

Junk Slot Area (inch^2): 28 Distance (inch): 0

Thickness (inch): 0.02766

Hydraulics (32th inch)

Nozzle 1: 12 Nozzle 5: 13

Nozzle 2: 12 Nozzle 6: 13

Nozzle 3: 12 Nozzle 7: 0

Nozzle 4: 13 Nozzle 8: 0

Total Flow Area (in.^2): 0.72

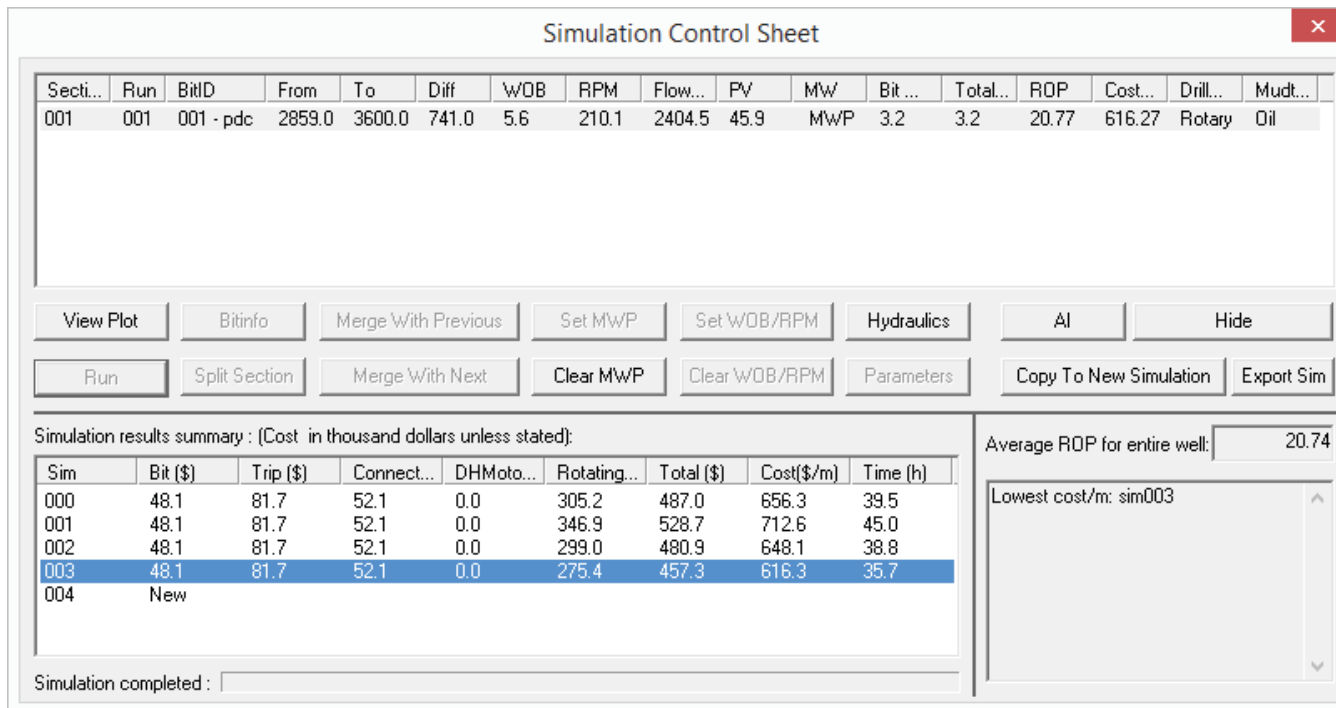
OK Cancel



# II. Optimization of Single PDC Bit Run

## Simulation 003

- ◆ The simulated ROP is now 20.77 m/hr



- ◆ The nozzle change gave an increase in ROP from 19.13 to 20.77 m/hr. This is an increase of 8.5 percent
- ◆ Bit wear also changed from 3.3 to 3.2

# II. Optimization of Single PDC Bit Run

## Simulation 004

- ◆ The next change is to increase the WOB from 5.6 to 14 tons

The screenshot shows two windows from a drilling simulation software. The 'Operating Parameters' dialog box is open, showing the following values: WOB: 14, MW: 1.55, RPM: 210.07, PV: 45.87, Flowrate: 2404.47, Bit: [No Change], Mud Type: Oil, and Drilling Mode: Rotary. The 'Simulation Control Sheet' window displays a table of simulation results for section 001, showing an average ROP of 14.72 m/hr. Below the table is a 'Simulation results summary' table and a text box with simulation details.

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	14.0	210.1	2404.5	45.9	MwP	8.0	8.0	14.72	768.76	Rotary	Oil

Sim	Bit (\$)	Trip (\$)	Connect...	DH Moto...	Rotating...	Total (\$)	Cost (\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	305.2	487.0	656.3	39.5
001	48.1	81.7	52.1	0.0	346.9	528.7	712.6	45.0
002	48.1	81.7	52.1	0.0	299.0	480.9	648.1	38.8
003	48.1	81.7	52.1	0.0	275.4	457.3	616.3	35.7
004	48.1	81.7	52.1	0.0	388.6	570.4	768.8	50.4
005	New							

Simulation results summary : (Cost in thousand dollars unless stated):

Average ROP for entire well: 0.00

Lowest cost/m: sim003  
AvgWear > 8 in section 001

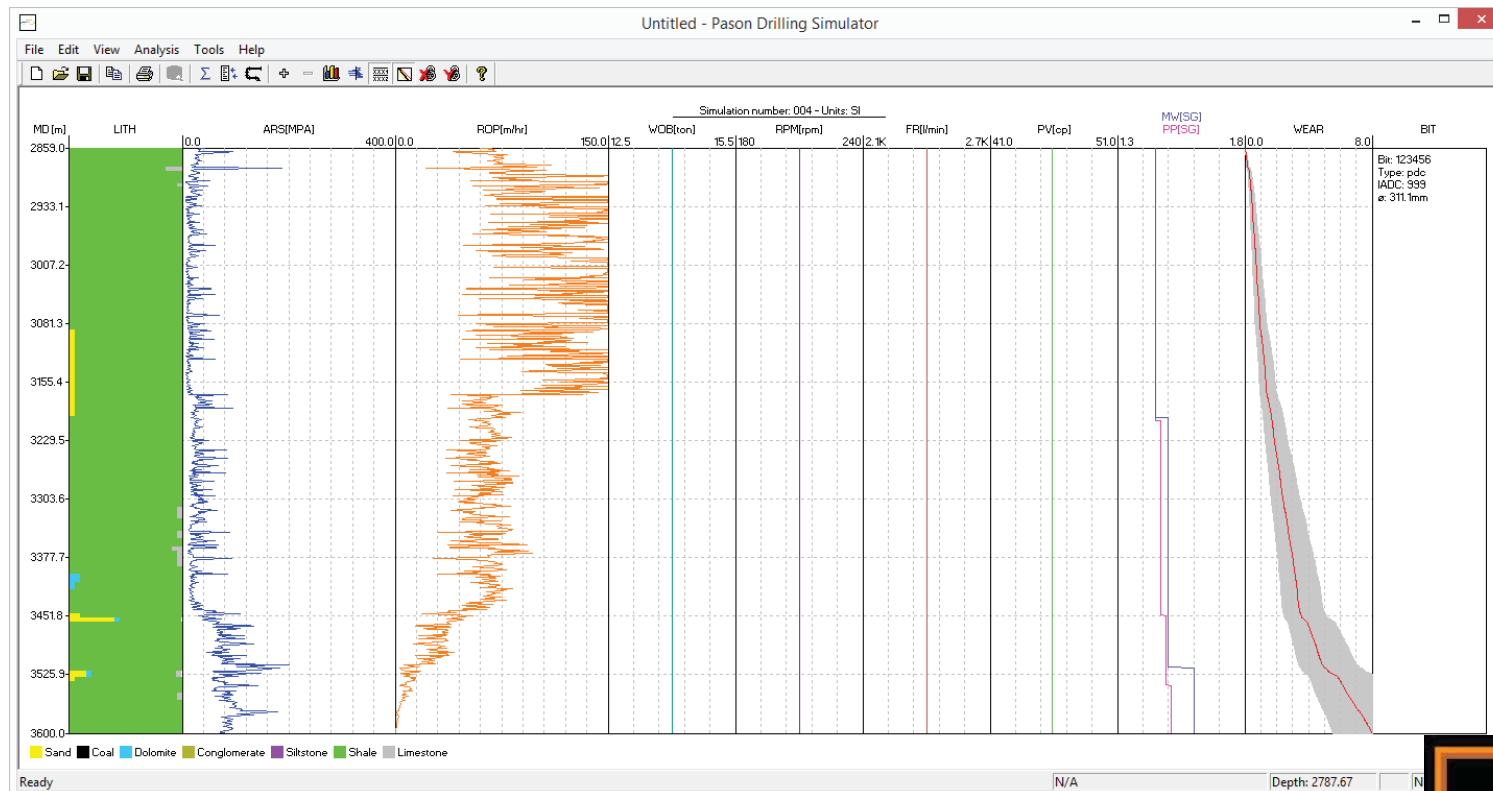
Simulation completed :

- ◆ The average ROP is now 14.72 m/hr.
- ◆ The reason for this is that the bit makes it but with a wear of 8.0 at TD.

# II. Optimization of Single PDC Bit Run

## Simulation 004

- ◆ If we evaluate the plots we see that the ROP is decreasing rapidly in the harder section towards the end
- ◆ The outer/gage cutters are wearing out - This is only an experience indicator



# II. Optimization of Single PDC Bit Run

## Simulation 005

- ◆ The next change is to decrease the RPM to 100 while maintaining the WOB at 14 tons

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3600.0	741.0	14.0	100.0	2404.5	45.9	MWP	5.1	5.1	28.47	515.85	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : [Cost in thousand dollars unless stated]:

Sim	Bit (\$)	Trip (\$)	Connect...	DH Moto...	Rotating...	Total (\$)	Cost (\$/m)	Time (h)
000	48.1	81.7	52.1	0.0	305.2	487.0	656.3	39.5
001	48.1	81.7	52.1	0.0	346.9	528.7	712.6	45.0
002	48.1	81.7	52.1	0.0	299.0	480.9	648.1	38.8
003	48.1	81.7	52.1	0.0	275.4	457.3	616.3	35.7
004	48.1	81.7	52.1	0.0	388.6	570.4	768.8	50.4
005	48.1	81.7	52.1	0.0	200.9	382.8	515.9	26.1
006	New							

Simulation completed :

Average ROP for entire well: 0.00

Lowest cost/m: sim005

Operating Parameters

WOB: 14 MW: 1.55 OK

RPM: 100 PV: 45.87 Cancel

Flowrate: 2404.47 Bit: [No Change]

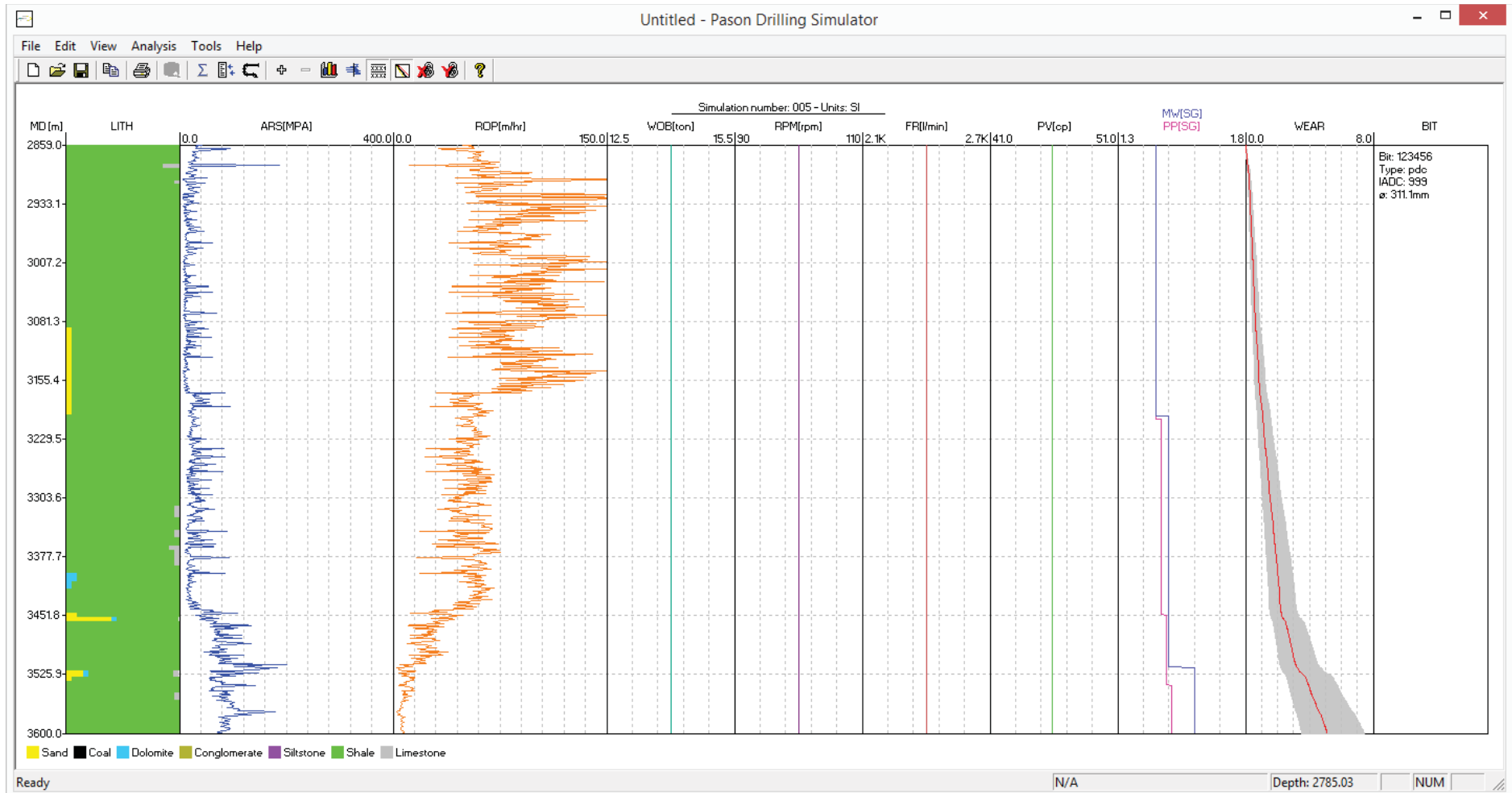
Mud Type: Oil Drilling Mode: Rotary

- ◆ The average ROP is now 28.47 m/hr or 26.1 hours drilling
- ◆ Bit wear is 5.1!

# II. Optimization of Single PDC Bit Run

## Simulation 005

- ◆ The bit now comes out with a wear of 5.1



# II. Optimization of Single PDC Bit Run

## Simulation 006

- ◆ When evaluating the ARSL we see that there is an increase in rock strength at 3450
- ◆ It would be logic to change the drilling parameters at this depth?
- ◆ Generate a split at 3450m, do not change the parameters, then run

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3450.0	591.0	14.0	100.0	2404.5	45.9	MWP	2.3	2.3	61.36	0.00	Rotary	Oil
002	001	001 - pdc	3450.0	3600.0	150.0	14.0	100.0	2404.5	45.9	MWP	2.9	5.1	9.14	515.85	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DH Moto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
003	48.1	81.7	52.1	0.0	275.4	457.3	616.3	35.7
004	48.1	81.7	52.1	0.0	388.6	570.4	768.8	50.4
005	48.1	81.7	52.1	0.0	200.9	382.8	515.9	26.1
006	48.1	81.7	52.1	0.0	200.9	382.8	515.9	26.1
007	New							

Average ROP for entire well: 0.00

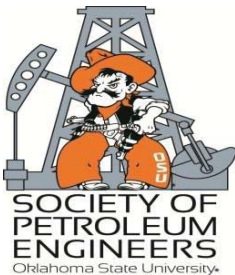
Lowest cost/m: sim005

Simulation completed :

## II. Optimization of Single PDC Bit Run

### Simulation 006

- ◆ The ROP of the first section is 61.36 m/hr with a wear of 2.3
- ◆ The ROP of the second section is 9.14 m/hr with a wear of 2.9
- ◆ The total wear is 5.1, the total hours is 26.1 and the average ROP 28.47 m/hr as before.



# II. Optimization of Single PDC Bit Run

## Simulation 007

- ◆ Now, change the WOB=8 tons and RPM=160 in the first section from 2859-3450m only, then run
- ◆ The ROP of the first section is 52.48 m/hr with a wear of 1.7
- ◆ The ROP of the second section is 10.54 m/hr with a wear of 2.9
- ◆ The total wear is 4.6, the total hours is 25.5 with the average ROP 29.05 m/hr.

Simulation Control Sheet

Secti...	Run	BitID	From	To	Diff	WOB	RPM	Flow...	PV	MW	Bit ...	Total...	ROP	Cost...	Drill...	Mudt...
001	001	001 - pdc	2859.0	3450.0	591.0	8.0	160.0	2404.5	45.9	MwP	1.7	1.7	52.48	0.00	Rotary	Oil
002	001	001 - pdc	3450.0	3600.0	150.0	14.0	100.0	2404.5	45.9	MwP	2.9	4.6	10.54	510.09	Rotary	Oil

View Plot Bitinfo Merge With Previous Set MWP Set WOB/RPM Hydraulics AI Hide

Run Split Section Merge With Next Clear MWP Clear WOB/RPM Parameters Copy To New Simulation Export Sim

Simulation results summary : (Cost in thousand dollars unless stated):

Sim	Bit (\$)	Trip (\$)	Connect...	DH Moto...	Rotating...	Total (\$)	Cost(\$/m)	Time (h)
004	48.1	81.7	52.1	0.0	388.6	570.4	768.8	50.4
005	48.1	81.7	52.1	0.0	200.9	382.8	515.9	26.1
006	48.1	81.7	52.1	0.0	200.9	382.8	515.9	26.1
007	48.1	81.7	52.1	0.0	196.6	378.5	510.1	25.5
008	New							

Average ROP for entire well: 29.05

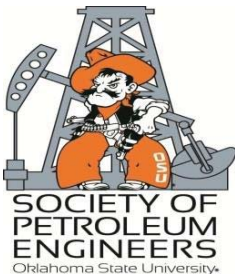
Lowest cost/m: sim007

Simulation completed :

## II. Optimization of Single PDC Bit Run

### Simulation 008 and on to 030+

- ◆ Next you manually simulate by fine tuning from your last simulation you can split into max of 5 sections (max bit wear of 5.0)
- ◆ Fine tuning is done by manual change of WOB and RPM in the individual sections
- ◆ Try to reduce the time and cost until you have 030 simulations at least



# Optimization of Single PDC Bit Run

## Conclusions

- ◆ It is the overall ROP that counts, not instantaneous or in some sections
- ◆ The MW program should be set initially
- ◆ The hydraulics should be optimized and the improvements is a function of available HSI and pump pressure
- ◆ The more you split the better fine tuning you get on the operating conditions for maximum average ROP
- ◆ 4 to 5 manual splits is usually close to optimum
- ◆ Be careful about the wear out you allow - safety cushion (max of 5)
- ◆ Next we will evaluate an entire hole section with multiple bit runs!

# **Project#2**

## **“Parametric Study and Optimization of a Single PDC Bit Run”**

### **Generate a 21 slide PPT**

Slide 1 Title/name

Slide 2 Outline,

Slide 3 Objective Part1. Long PDC Run with Constant Input Parameters – Parametric Evaluation of ROP and Bit Wear

Slide 4 Fill in Table with Operating Parameters (slide 16)

Slide 5 Discuss your Observations from Table in Slide 16 – all the parameters and their effect on ROP and bit wear

Slide 6 Study the effect of HSI on ROP when WOB is 25 tons in the section from 2859m-2900m and show the Table with comments on your observation (Slide 18)

Slide 7 Fill in Table with the effect of JSA in Slide 29 and discuss results.

Slide 8 Fill in Table with Bit Design Parameters with backup cutter bit base case Slide 34

Slide 9 Discuss your Observations from Table in Slide 34 – all the parameters and their effect on ROP and bit wear

Slide 10 Explain the functionality of the AI window and what it can do

Slide 11 Show a table with the 10 AI simulations you did and explain the results

Slide 12 Discuss all the results and functionalities you have learned in Part 1

Slide 13 Objective Part2. Offset PDC Bit Run with Variable Bit Parameters and the Optimization Procedure of the Next Similar Run

Slide 14 Show the plot of simulation000 and explain the correlation between the ARSL, ROP and operating parameters

Slide 15 Generate a table that explains the first 7 simulations you did

Slide 16 Plot your learning curve for these 7 simulations

Slide 17 Explain in general what you did in the next 23+ simulations and what your objective was for these simulations

Slide 18 Generate a table for your 23+ simulations (after simulation 7) and include reasoning in each simulation with the resultant \$/ft

Slide 19 Plot your \$/ft for all your 30+ simulations on a scale from 300-1000 \$/ft on the y-axis

Slide 20 Discuss your results and learnings of Part2

Slide 21 What was the most important learning you did on in this exercise?