



Production Logging: Conventional Tool vs Array Tool Interpretation

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Agenda

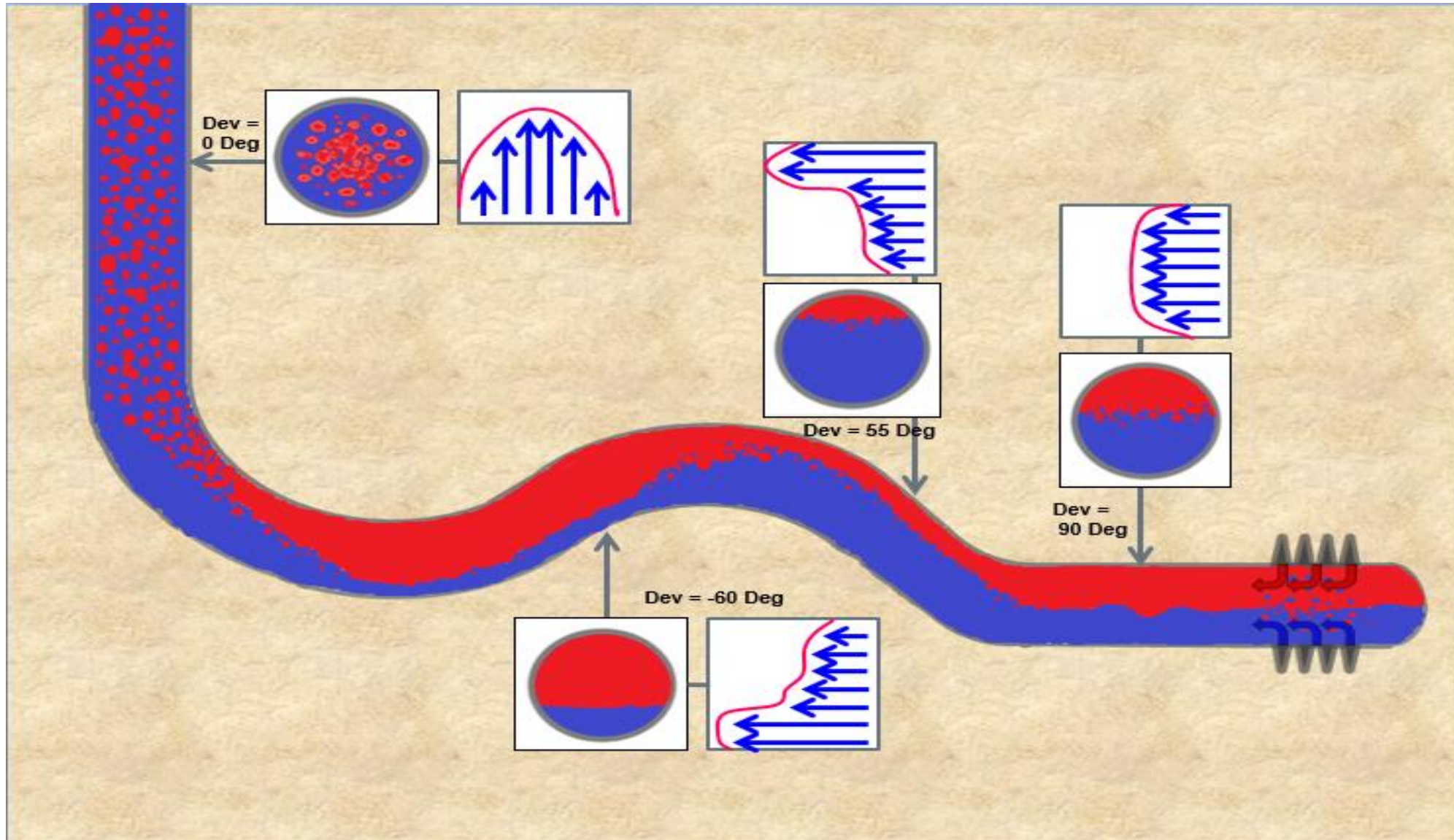
- Background
- Brief Overview of PL Array Tools
- Typical PL Workflow
- Comparison of Conventional Vs Array Tool Workflows
- Conclusions/Key Lessons

Background

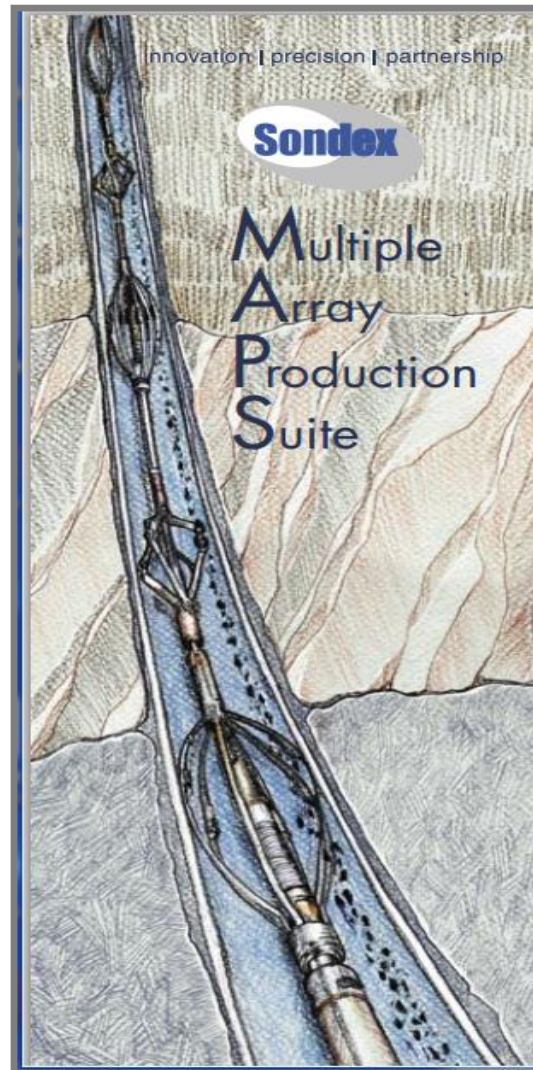
- IP is a complete well data interpretation package with around 2000 licenses worldwide
- A wide range of interpretation modules include a Production Logging analysis (PL) module
- PL module recently upgraded to accommodate Array Tools (initially MAPS)



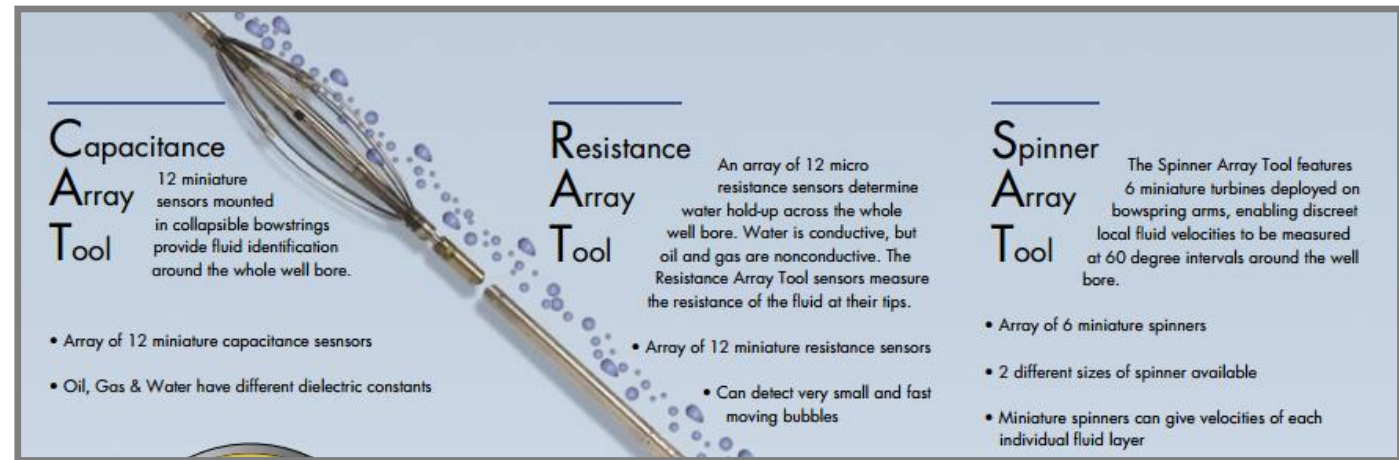
Deviated/Horizontal Production



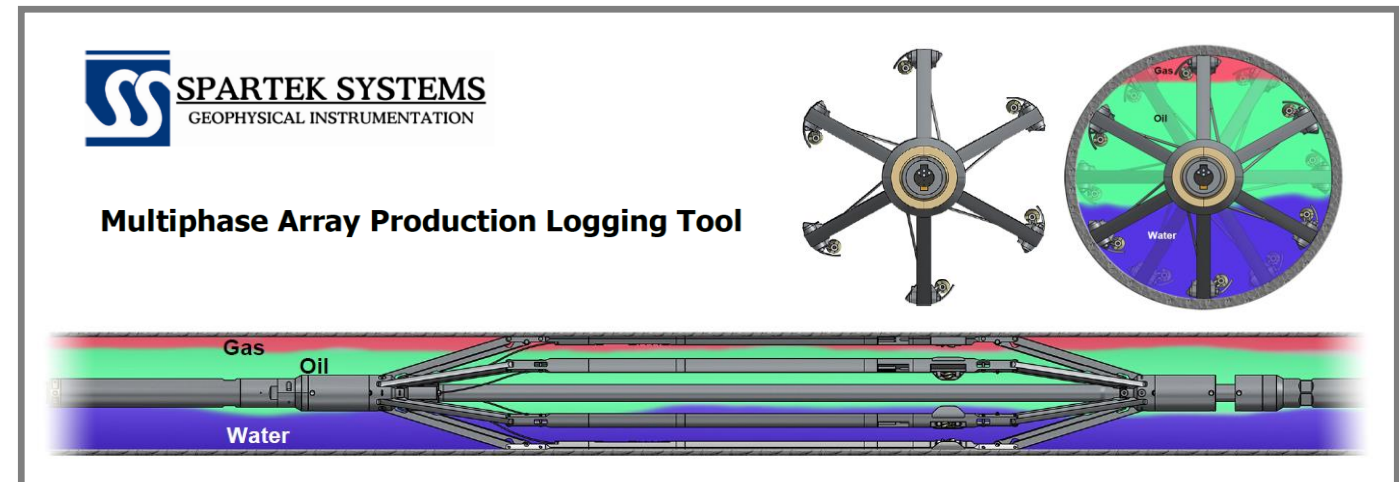
Overview of Array Tools



MAPS - Courtesy GE Oil & Gas



MAPS - Courtesy GE Oil & Gas



Multiphase Array Production Tool - Courtesy Spartek Systems

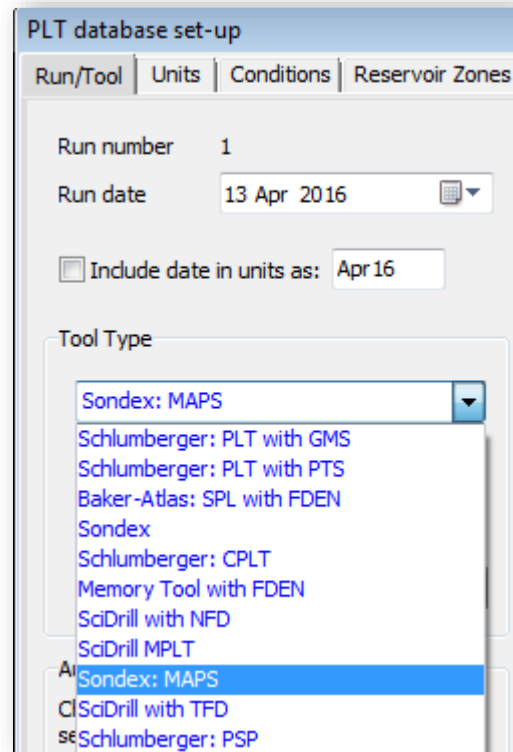
Typical PL Interpretation Workflow

- 1) Interpretation Setup
- 2) Data Import
- 3) Data QC/Edit
- 4) Holdup (Fluid Types) Determination
- 5) Fluid Velocity Calculation
- 6) PVT Calculations
- 7) Flow Rate Calculation
- 8) Reporting and Presenting

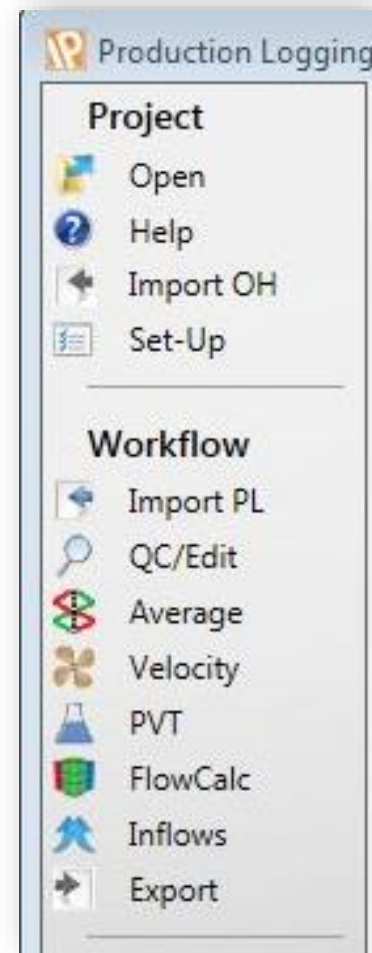


Set Up

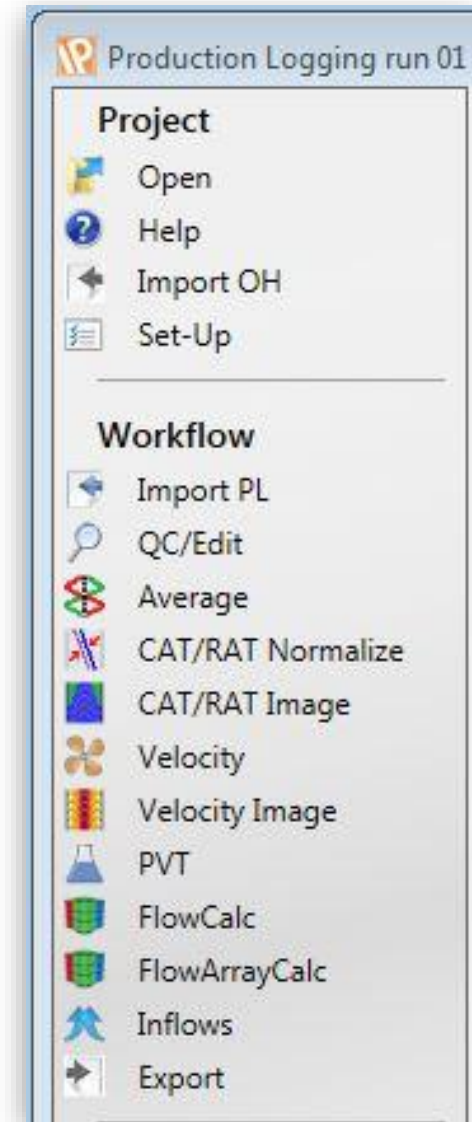
- Tool Selection Updates Workflow



PL Tool List



Conventional
PL Workflow



MAPS
Workflow

Set Up

- Tool Geometry Setup

Baker-Atlas: SPL with FDEN

Tool diameter 1.6900 inches

Spinner diameter
0.70 inches

Pipe inside diameter 6.184 inches

Conventional PL Tool
Geometry

Array Flow Calculations - MAP531

Inputs Tool Parameters Output Curves Zones Results Surface Match Slippage

Tool Parameters

Number of Segments	5
Casing ID	6.184
Tool OD	1.6875
Mini-Spinner OD	0.6
Mini-Spinner standoff	0.5
RAT Sensor OD	0.25
RAT Sensor standoff	0.5
CAT Sensor OD	0.25
CAT Sensor standoff	0.5

SAT CAT RAT

Dimensions in inches

Array Tool Geometry Setup

Data Import

- Typical Conv PL pass = @15 curves
- Typical Array PL Pass = @ 80 curves

Easy Loading of multiple LAS/ASCII files

- Switch on/off required curves
- Rename Groups of incoming curves
- Load multiple passes simultaneously
- Settings only required on first incoming file

The screenshot displays the 'LAS import' window for the file 'C:\Users\rbrackenridge\Documents\Data\Raw Data\MAPS\Read Example\Flow Passes Cat Rat\P1D1_45_CATRAT.LAS'. The window title is 'LAS import from C:\Users\rbrackenridge\Documents\Data\Raw Data\MAPS\Read Example\Flow Passes Cat Rat\P1D1_45_CATRAT.LAS'. The 'Well details read from input file' section shows 'Well name: 11497.25 to 16599.00 @ 4.00 sample(s) per ft'.

Name	Description	PL Name	Units	Sensor	Load
TEMP	Downhole Temperature	TEMP	degC	Temperature	Yes
CWH	Capacitance Water Holdup	CWH_	Hz	Capacitance	Yes
RATMN01	RAT Mean 01	RA01		RAT 1 to 12	Yes
RATMN02	RAT Mean 02	RA02		RAT 1 to 12	Yes
RATMN03	RAT Mean 03	RA03		RAT 1 to 12	Yes
RATMN04	RAT Mean 04	RA04		RAT 1 to 12	Yes
RATMN05	RAT Mean 05	RA05		RAT 1 to 12	Yes
RATMN06	RAT Mean 06	RA06		RAT 1 to 12	Yes
RATMN07	RAT Mean 07	RA07		RAT 1 to 12	Yes
RATMN08	RAT Mean 08	RA08		RAT 1 to 12	Yes
RATMN09	RAT Mean 09	RA09		RAT 1 to 12	Yes
RATMN10	RAT Mean 10	RA10		RAT 1 to 12	Yes

On the right, there are checkboxes for 'Fill data gaps : Maximum gap length 3 ft', 'Don't prompt to overwrite existing curves', and 'Don't overwrite data with absent data from LAS file'. A 'Reset the PL Names from the input file' button is also present. Below these is a 'Sensor' table with columns 'Sensor', 'Input name', and 'Map to'.

Sensor	Input name	Map to
Spinners 1 to 6	SPIN	SPI
CAT 1 to 12	NCAP	CA
RAT 1 to 12	RATMN	RA

An 'Apply mapping' button is located below the sensor table. At the bottom of the main window, a text area shows the following text:

```
1 ~Version Information
2 VERS.
3 WRAP.
4 #Non standard L
5 ~Well Informati
6 STRT.FT
7 STOP.FT
8 STEP.FT
9 NULL.
10 COMP.
11 WELL.
12 FLD.
13 LOC.
14 CNTY.
15 SRVC.
16 DATE.
17 UWI.
18 STAT.
```

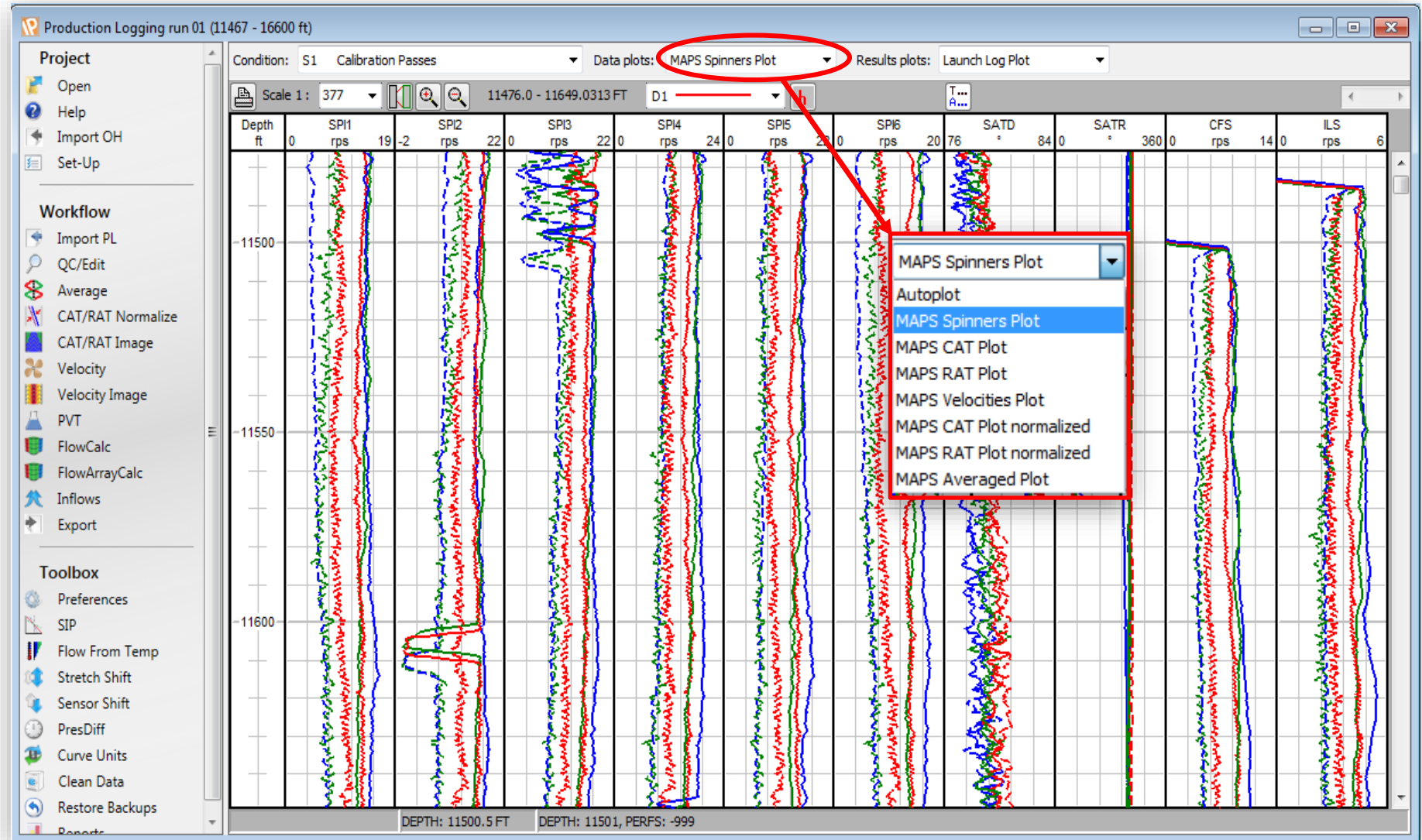
An 'Input File / pass definition' dialog box is open in the foreground. It has a 'Build extensions from the input filename' button and a table with columns 'Input file name', 'Condition', 'Direction', 'Pass', and 'Extension'.

Input file name	Condition	Direction	Pass	Extension
SCD1_30.LAS	S1	DOWN	1	S1D1
SCD2_45.LAS	S1	DOWN	2	S1D2
SCD3_60.LAS	S1	DOWN	3	S1D3
SCU1_30.LAS	S1	UP	1	S1U1
SCU2_45.LAS	S1	UP	2	S1U2
SCU3_60.LAS	S1	UP	3	S1U3

The dialog box has 'Load' and 'Cancel' buttons at the bottom.

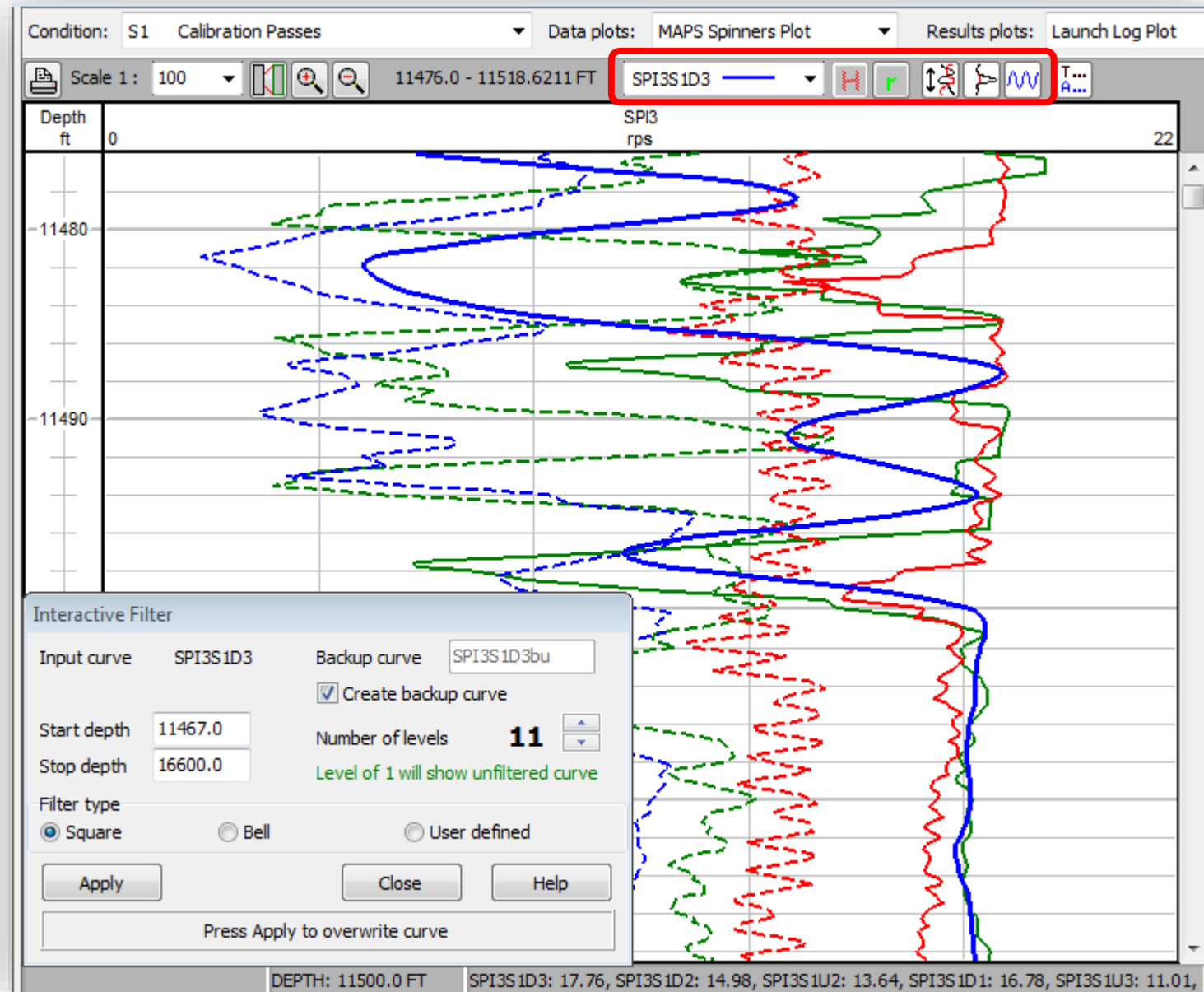
Data QC/Edit

- Autoplot all data from all passes
- Conv. PL QC can fit on one screen
- Array PL requires multiple auto-plots
- Easy Switch between plots



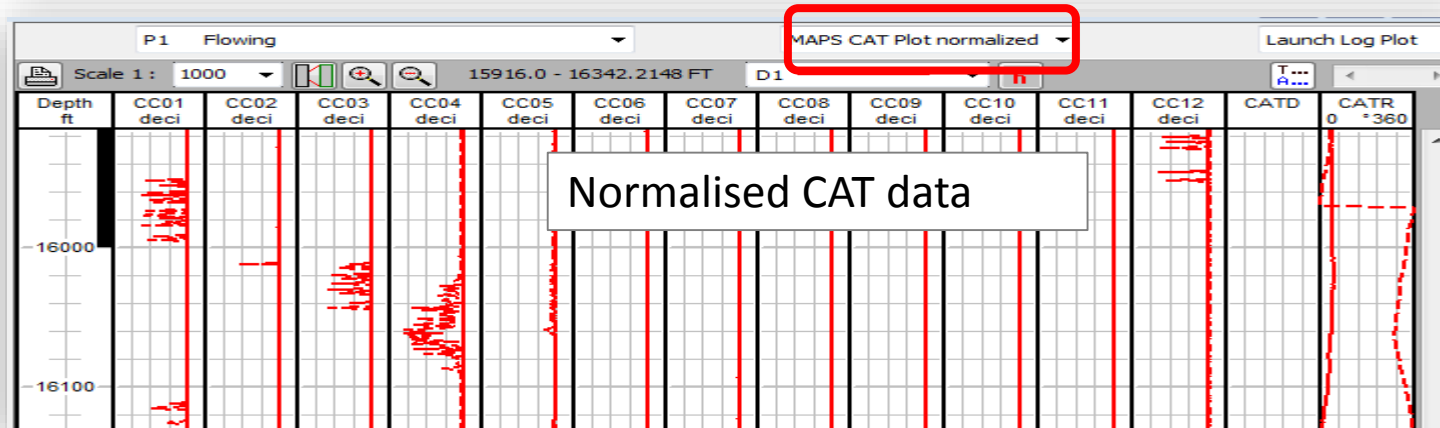
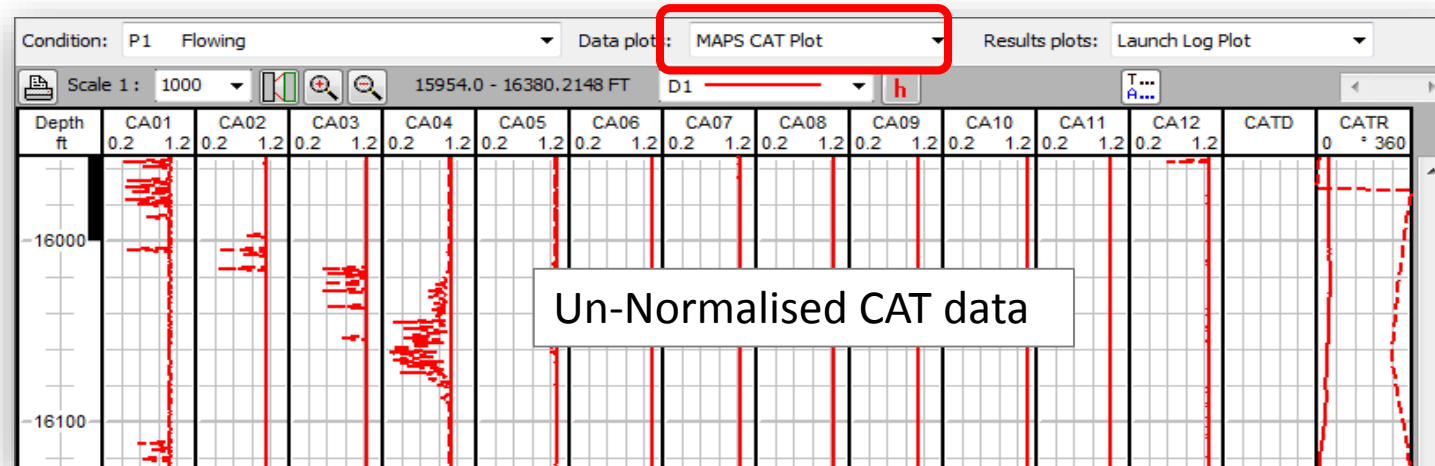
Data QC/Edit

- Shifting, Editing, and Filtering
- Array tool data typically of lower quality than conventional sensors
- May require more filtering and edit than Conv PL data
- New Normalization Tools created for CAT/RAT



Data QC/Edit

- New Normalization Tools created for CAT/RAT



CAT/RAT Normalize

Select sensor type: ☒ CAT ☐ RAT

Select input curves: ☒ CA01P1D1 ☒ CA01P1U1

Select sensor: CA01, CA02, CA03, CA04, CA05, CA06, CA07, CA08, CA09, CA10, CA11, CA12

All CAnnxxxx curves for all conditions will be normalized and the results written to CCnnxxxx curves.

Normalization options: ☐ No normalization - copy input curves, ☐ Apply shut-in normalization only, ☒ Apply flowing normalization only, ☐ Apply shut-in and then flowing normalization

Expected readings: Gas, Oil 0.400, Water 1.000

Normalise raw input data: Interval, Top depth, Bottom depth, Fluid. Sump, 16300.0, 16500.0, Water

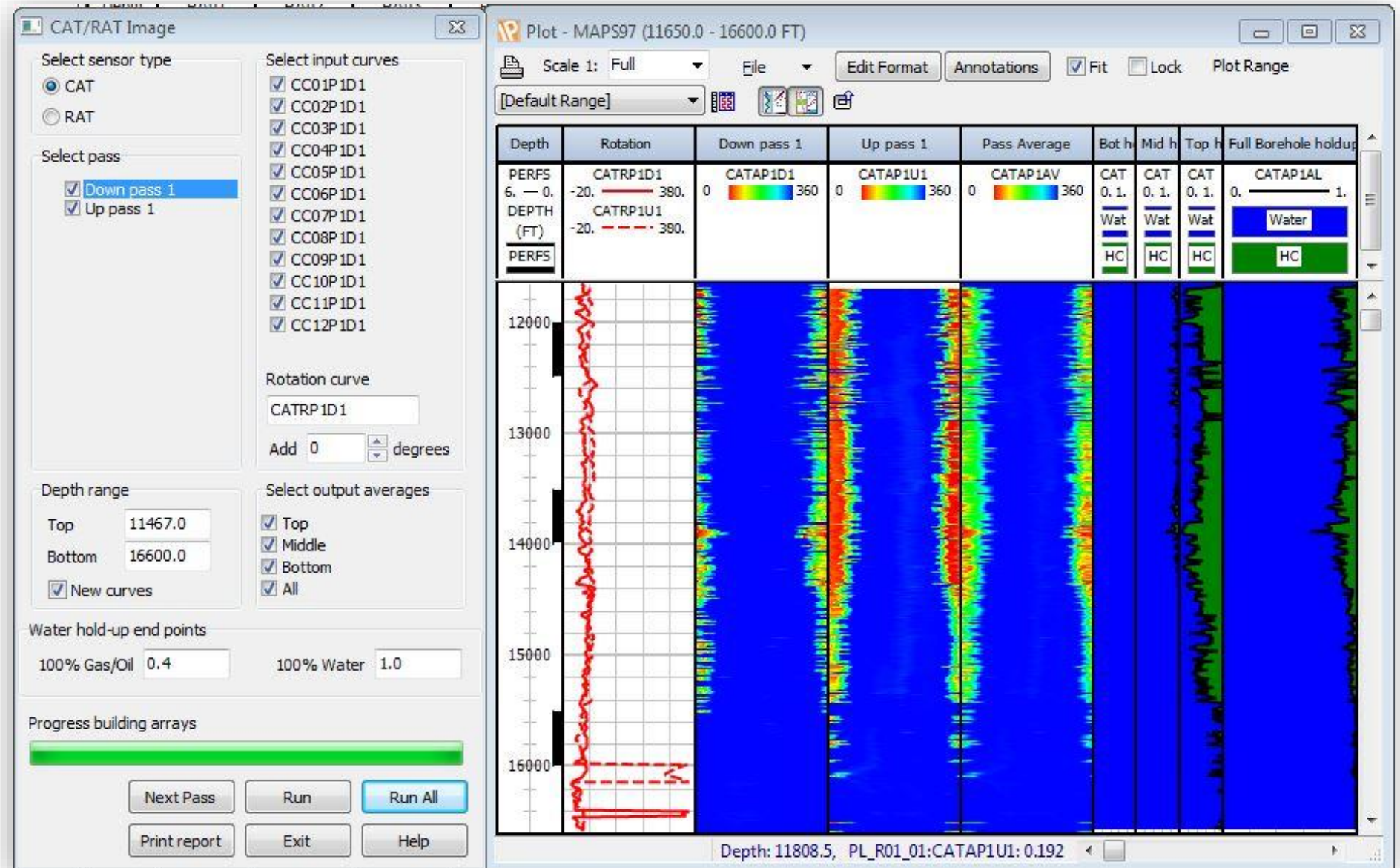
Filters: ☐ Exclude bad data outside -0.100 and 1.100, ☐ Limit output curves between 0.000 and 1.000

Next sensor, Run, Run All, Print report, Exit, Help

Holdup (Fluid Type) Determination

New Array Holdup Calculation Tool

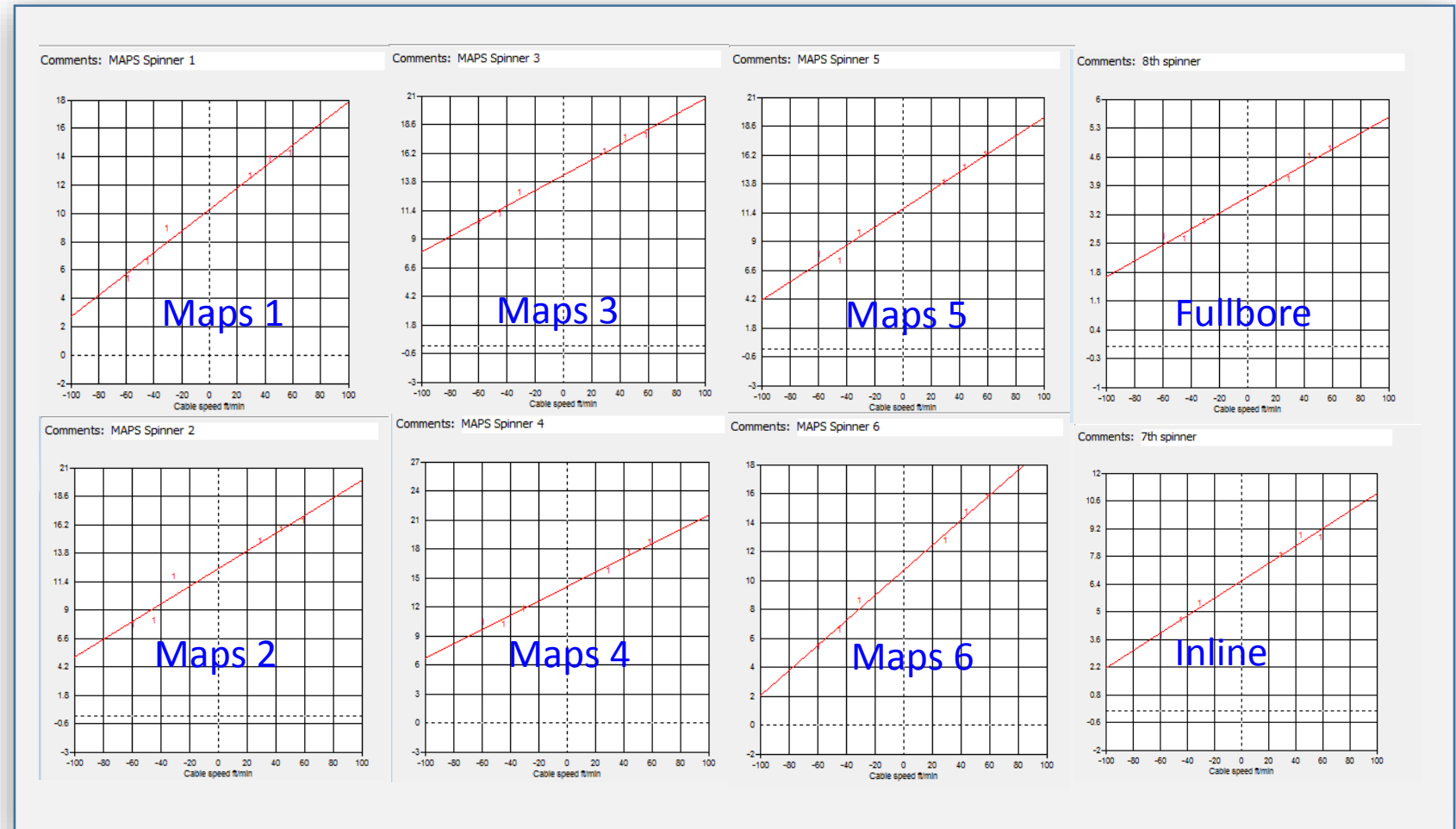
- Applied to CAT and RAT data
- Images corrected for tool rotations
- Enter Holdup End Points
- De-select any bad sensors
- Select Passes to be used
- Holdup Array for each Pass
- Averaged Hold Up Array
- Top/Mid/Bot Hold ups
- BH Volume weighted Holdup



Fluid Velocity Calculation

Spinner X-plots

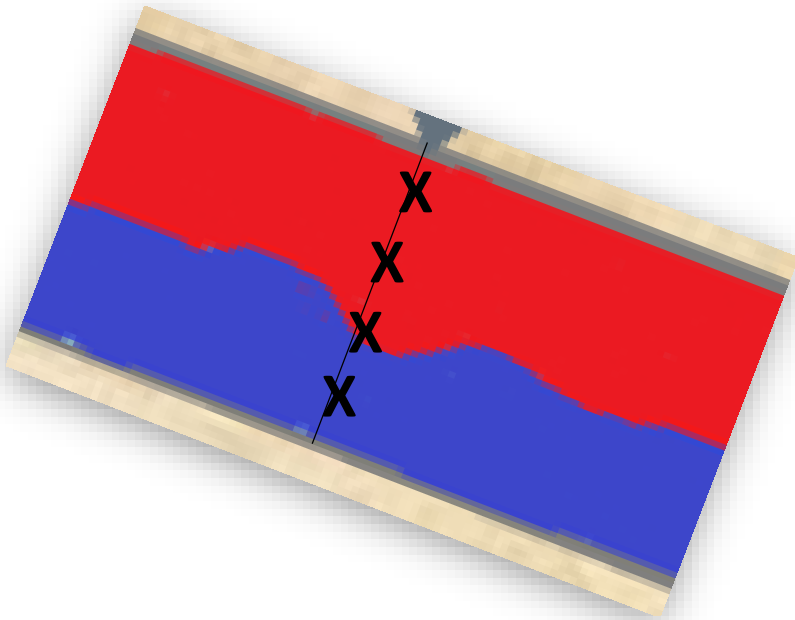
- Used to calculate Slope and Threshold (Sensitivity) of each individual spinner
- Conv PL Workflow = 2 x-plots, Array PL workflow = * plots
- Spinners must be calibrated independently and cannot be averaged first
- New version of module will use holdup array to discriminate for fluids
- Additional tools will be required to calibrate MAPS spinners to each fluid



Fluid Velocity Calculation

- Conventional PL workflow can calculate continuous Spinner sensitivity at every depth during flowing, Two reasons this cannot be done with Array data -

1) At each depth each spinner could be in different mix of fluid

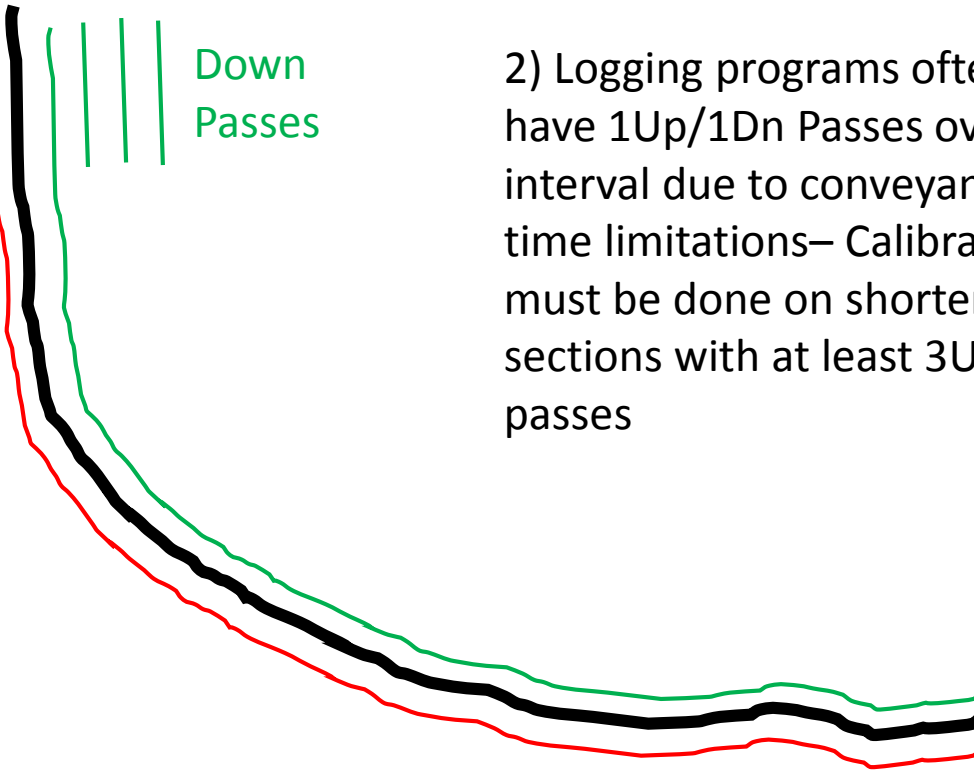


Well
Trajectory

Up
Passes

Down
Passes

2) Logging programs often only have 1Up/1Dn Passes over full interval due to conveyance and time limitations– Calibration must be done on shorter sections with at least 3Up/3Dn passes



Fluid Velocity Calculation

- New Array Velocity Images Tool

Velocity Image

Select pass

☒ Down pass 1
☒ Up pass 1

Select input curves

☒ VA01P1D1
☒ VA02P1D1
☒ VA03P1D1
☒ VA04P1D1
☒ VA05P1D1
☒ VA06P1D1

Rotation curve

SATRP1D1

Add 0 degrees

Depth range

Top 11467.0
Bottom 16600.0

☒ New curves

Select output averages

☒ Top
☒ Middle
☒ Bottom
☒ All

Plot limits

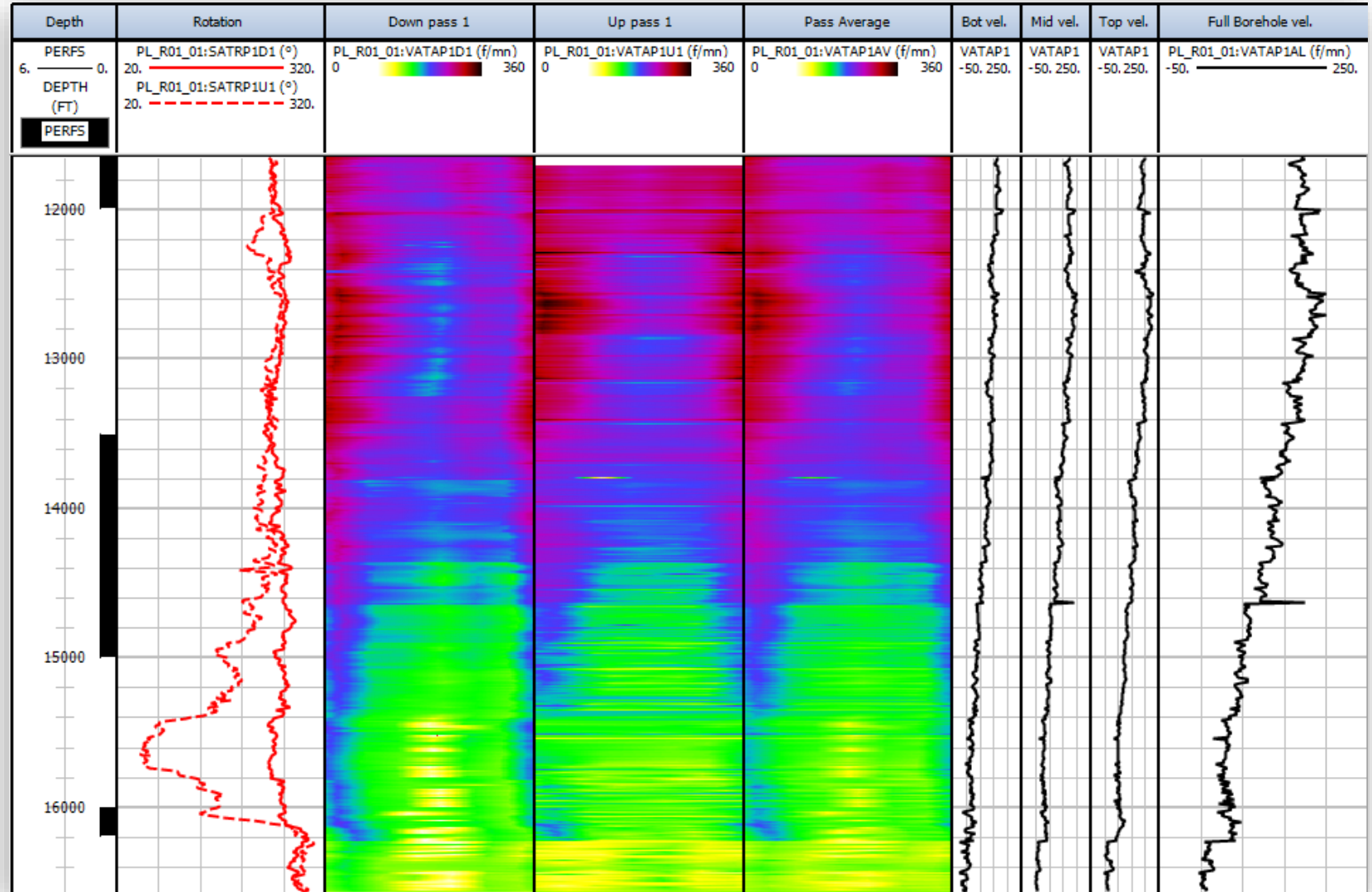
Left -50 Right 250

Apply

Progress building arrays

Next Pass Run Run All

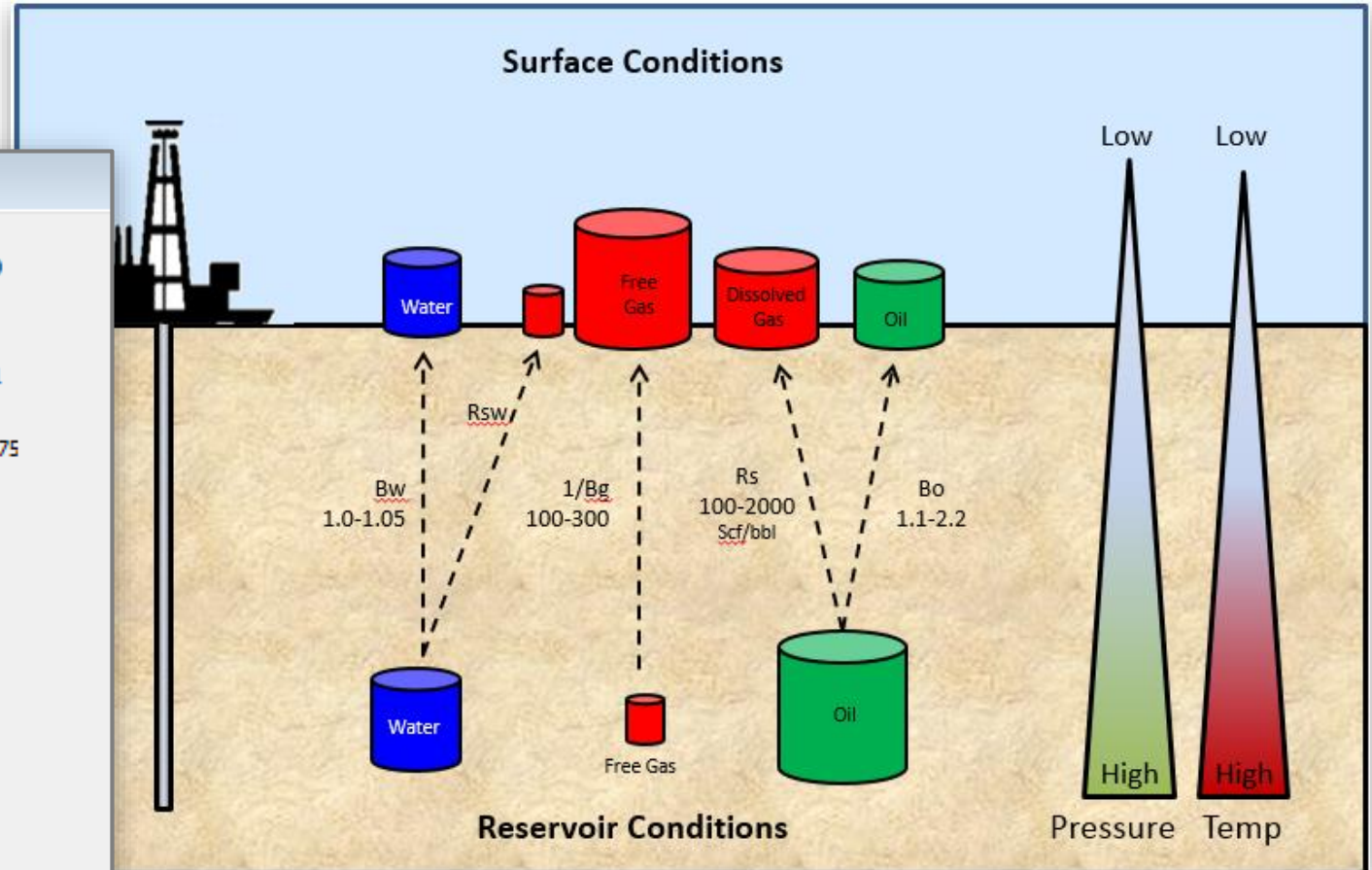
Print report Exit Help



PVT

- No significant change to PVT calculations

PVT properties for field: VASQUEZ BEGGS				
		A	B	C
Top depth		12000.0	13500.0	15500.0
Temperature	(deg F)	75.64	77.10	77.95
Pressure	(psia)	1883.50	1925.91	1952.11
Gas FVF	(cuft/scf)	0.005809	0.011865	-0.243175
Gas density	(g/cc)	0.1474	0.0722	0.0000
Gas viscosity	(cp)	0.0172	0.0130	0.0108
Oil FVF	(rb/stb)	1.201	1.206	1.210
Dis. gas/oil	(scf/stb)	408.8	418.0	423.7
Oil density	(g/cc)	0.7595	0.7573	0.7560
Oil viscosity	(cp)	3.2216	3.0136	2.9000
Water FVF	(rbw/stbw)	0.996	0.996	0.996
Dis. gas/Water	(scf/stb)	0.0	0.0	0.0
Water density	(g/cc)	1.0418	1.0416	1.0415
Water viscosity	(cp)	0.9815	0.9640	0.9541



Flowrate Calculation

- Conventional Analysis uses Single holdup and velocity values to calculate flowrates
- Using Array Holdups and Array Velocity required a brand new module

Array Flow Calculations - MAPS97

Inputs | Tool Parameters | Output Curves | Zones | Results | Surface Match | Slippage

Options

Tool type: MAPS

Model: ☒ Oil / Water ☐ Gas / Water

Water Holdup: ☐ Capacitance array tool (CAT) ☒ Resistivity array tool (RAT)

Flow Shading: ☒ Gas Red / Oil Green ☐ Gas Green / Oil Red

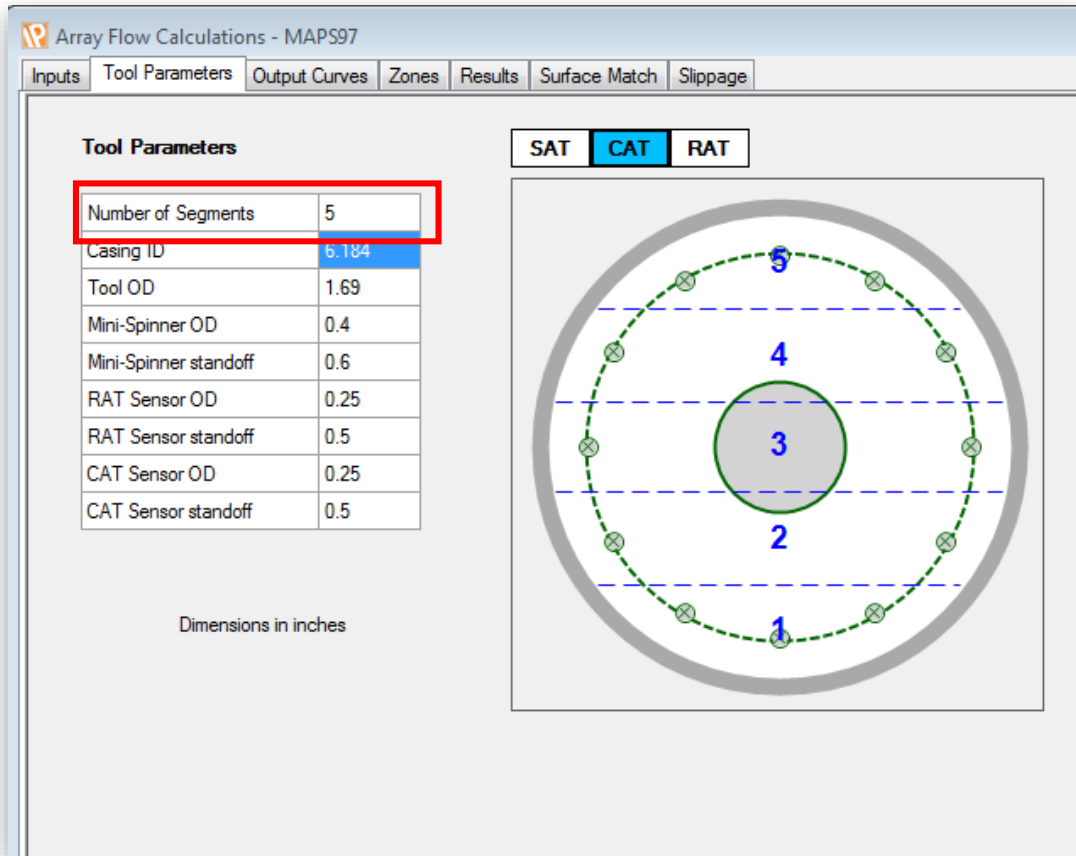
Input Curves

Gamma Ray	PL_R01_01:GR_P1U1
SAT Velocity Image	PL_R01_01:VATAP1AV
CAT Holdup Image	PL_R01_01:CATAP1AV
RAT Holdup Image	PL_R01_01:RATAP1AV
Deviation	
Perforations	PL_R01_01:PERFS
Temperature	PL_R01_01:TEMPP1R1
Pressure	PL_R01_01:QP_P1R1
Water FVF	PL_R01_01:FVFWP1R1
Oil FVF	PL_R01_01:FVFP1R1
Gas FVF	PL_R01_01:FVFGP1R1
GOR	PL_R01_01:GOR_P1R1
GWR	PL_R01_01:GWR_P1R1
Gas Density	PL_R01_01:DENGP1R1
Oil Density	PL_R01_01:DENOP1R1
Water Density	PL_R01_01:DENWP1R1
Oil/Water Surface Tension	PL_R01_01:STOWP1R1

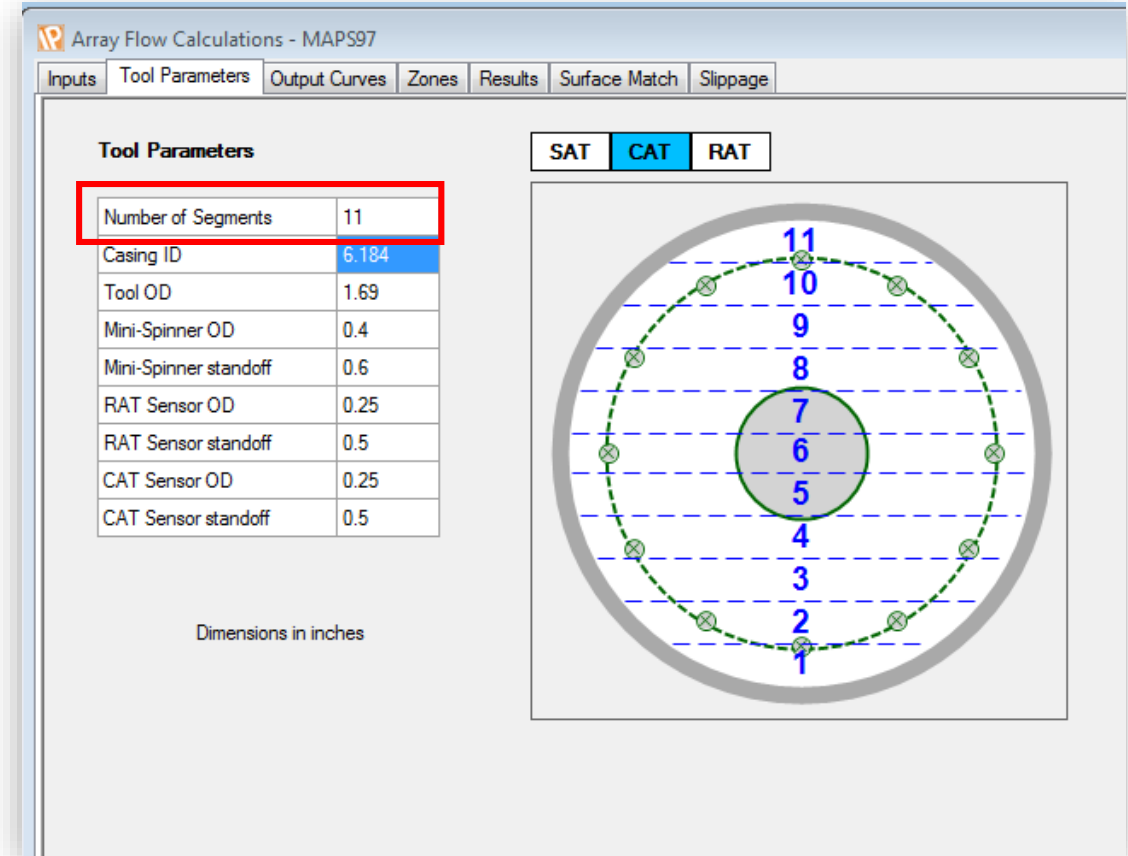
SM Curve Set - Condition PL_R01_01 - P1 Plot All Report Close Help

Flowrate Calculation

Select number of vertical borehole segments, A balance is required..



Low number allows more 'real' data in each segment average but can also increase influence of slippage

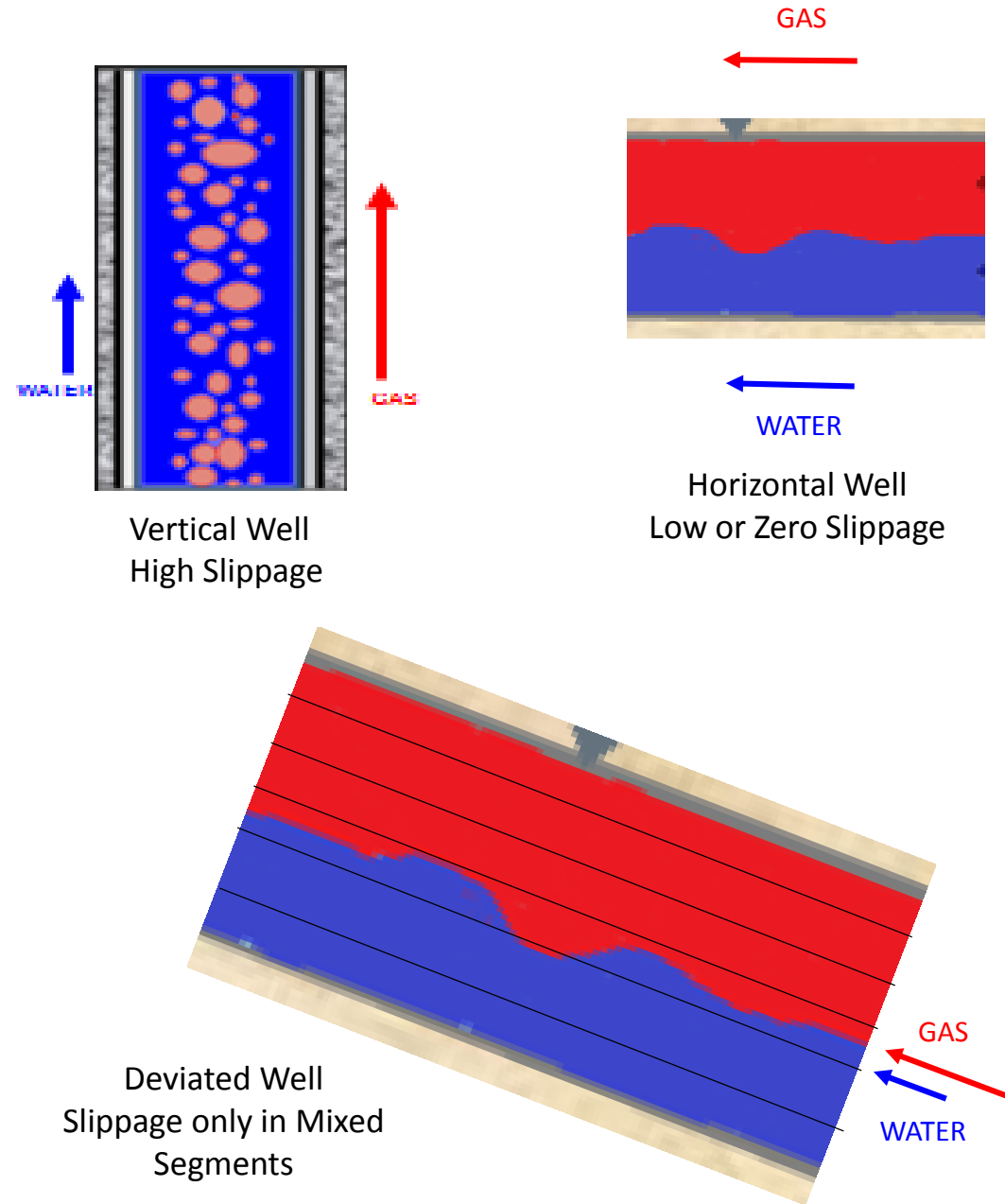


High number creates smoother results and reduces affects of slippage but can result in heavily interpolated segments

Flowrate Calculation

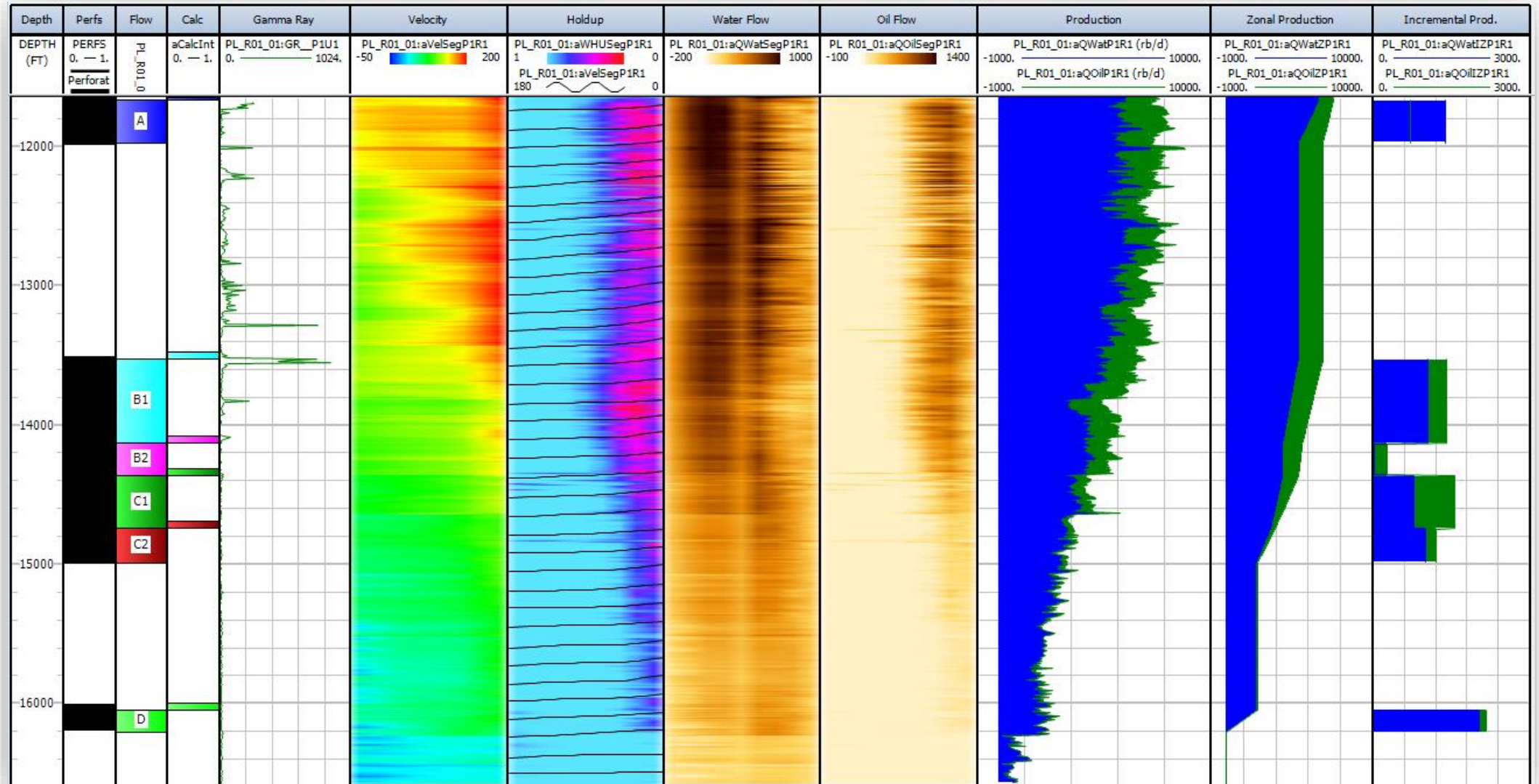
Slippage

- The option to apply slippage correction has been retained in the Array workflow but required modification
- Traditional slippage correction applies to whole borehole, Array workflow slippage only required in Mixed fluid Segments
- Weighting of Dominant Fluid must be considered
- Slippage Corrected fluid velocities of each fluid must add up to measured average
- New correction is generally small but could be more significant if large segments used in a gas/water well.



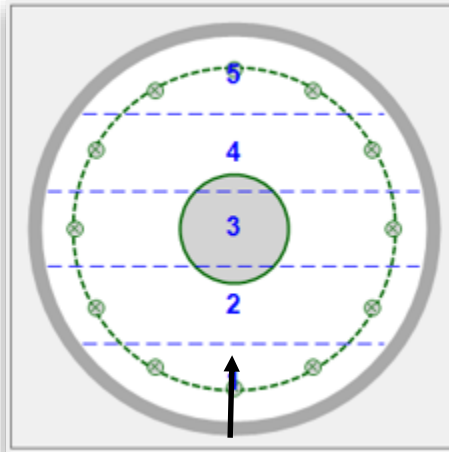
Flowrate Calculation

- Results Plot



Flowrate Calculation

- Comparing results to surface
- Fine Tuning Options:



Increase or
Decrease Number
of Horizontal
Segments

Depth	Perfs	Flow	Calc
DEPTH (FT)	PERFS 0. — 1. Perforat	PL_R01_0	aCalcInt 0. — 1.
12000		A	
13000			
14000		B2	
15000		C1	
16000		D	

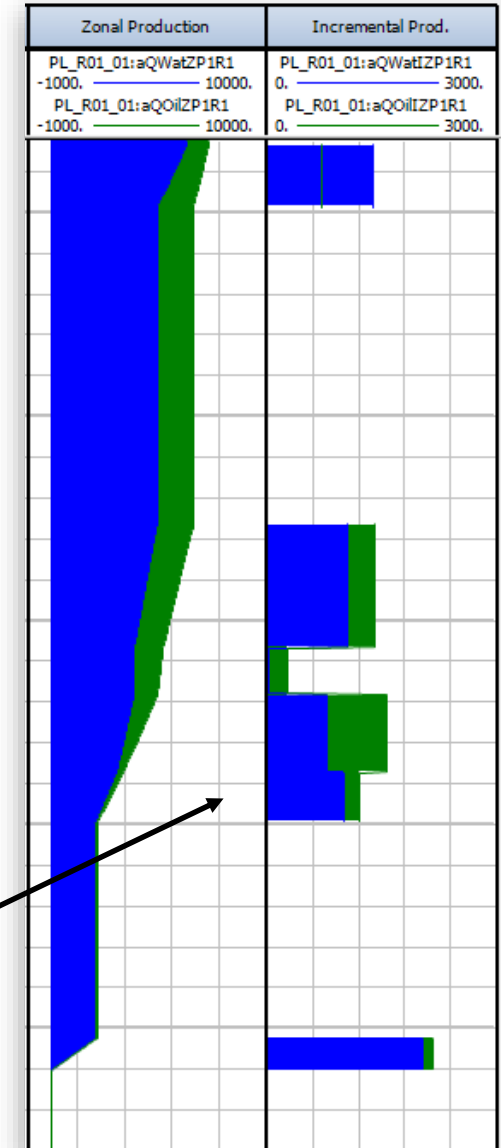
	Measured	Calculated
Surface		
S.T. Gas Rate (Mmscf/d)	1.5	1.2
S.T. Oil Rate (stb/d)	1000	803.0
S.T. Water Rate (stbw/d)	1203.3	1536
Down Hole		
Total Rate (rb/d)	2697.0	2736
Gas Rate (rb/d)	0	0
Oil Rate (rb/d)	1203.3	974
Water Rate (rb/d)	1493.8	1807.1

☒ Use
 Velocity multiplier
 Holdup multiplier
 Slippage multiplier

- Velocity Multiplier
- Holdup Adjustments
- Slippage Adjustment

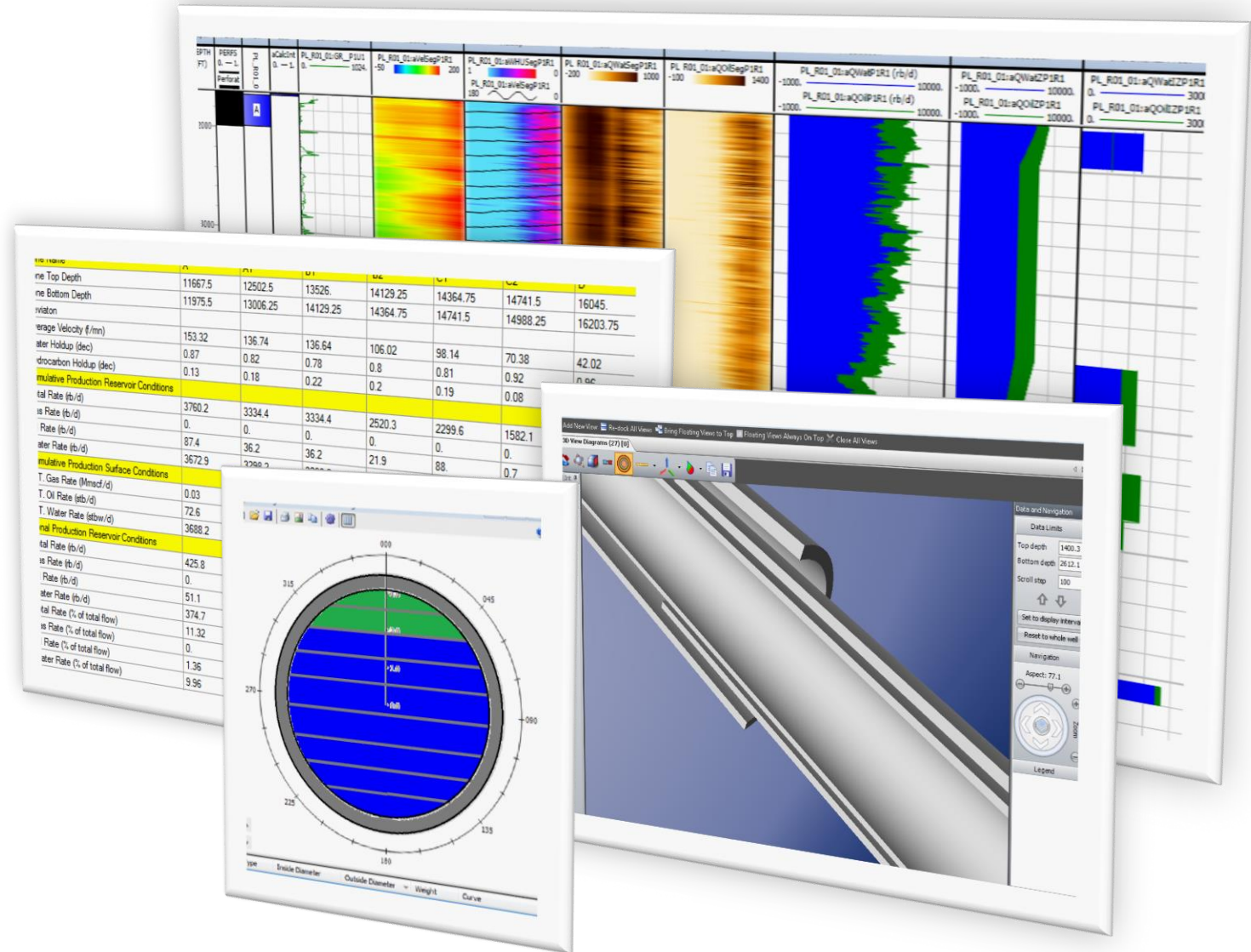
Interactively
Move, Add or Split
Calculations

Instant Update
of Results



Reporting and Presenting

- Auto-Reporting
- Automated Log Plots
- Borehole cross sections
- 3D Viewer
- Collaborate with other data types



Conclusions/Key Lessons?

Key Lessons will creating the PL Array workflow

- Logging program is key to a good dataset and successful interpretation
- Large amount of data requires higher level of data management and functionality – Usability must be maintained!
- Array Workflow has more emphasis on real data rather than models/charts
- Understanding Sensor Position and Tool rotation throughout is key to a successful interpretation
- Use of averages whenever possible (between passes, across borehole segments and over depth) improves data quality and result accuracy
- Completely new method for holdup calculation – weighted holdup dependant on sensor position
- Tools need to improve on distributed gas holdup measurements to allow accurate 3-phase analysis
- Updated method required for Spinner Calibration/Velocity calculation to account for spinner position/holdup
- Completely new sub-module was required for calculating Flowrates based on segments of the borehole rather than the centred data



IP Production Logging Software



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<http://www.lr-senergy.com/software>

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