Production Logging: Conventional Tool vs Array Tool Interpretation

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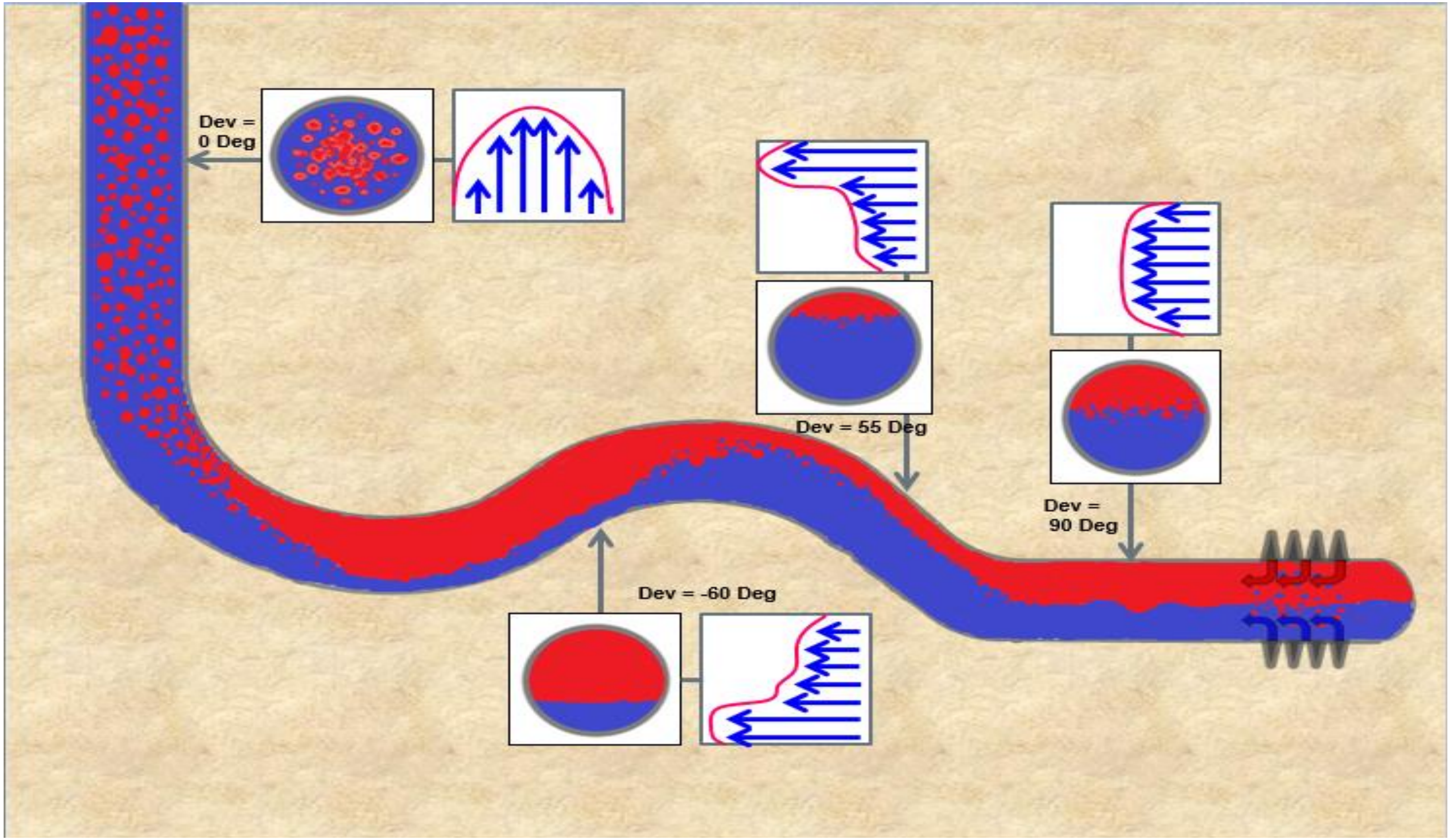
Agenda

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

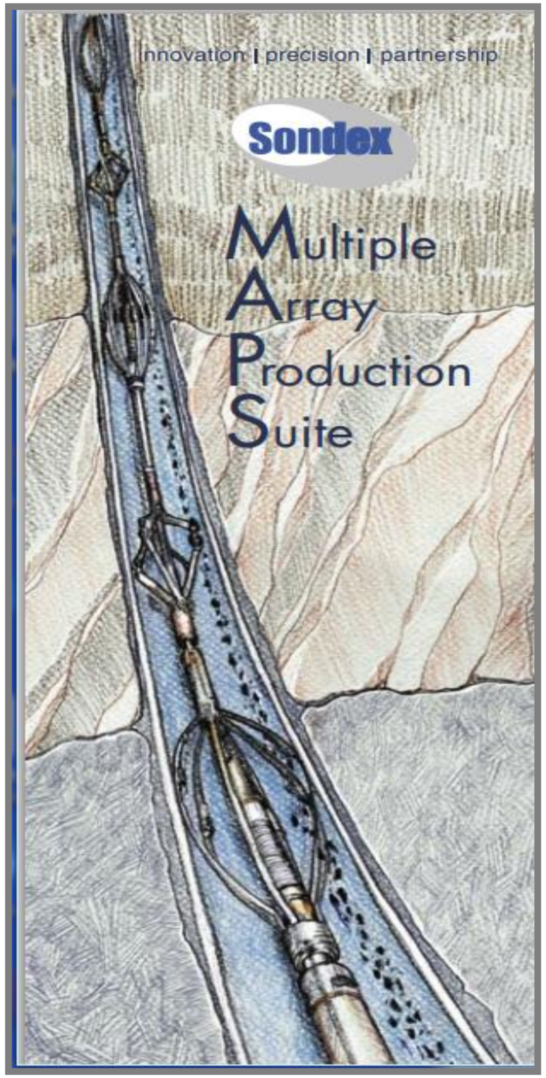
Background

- 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*

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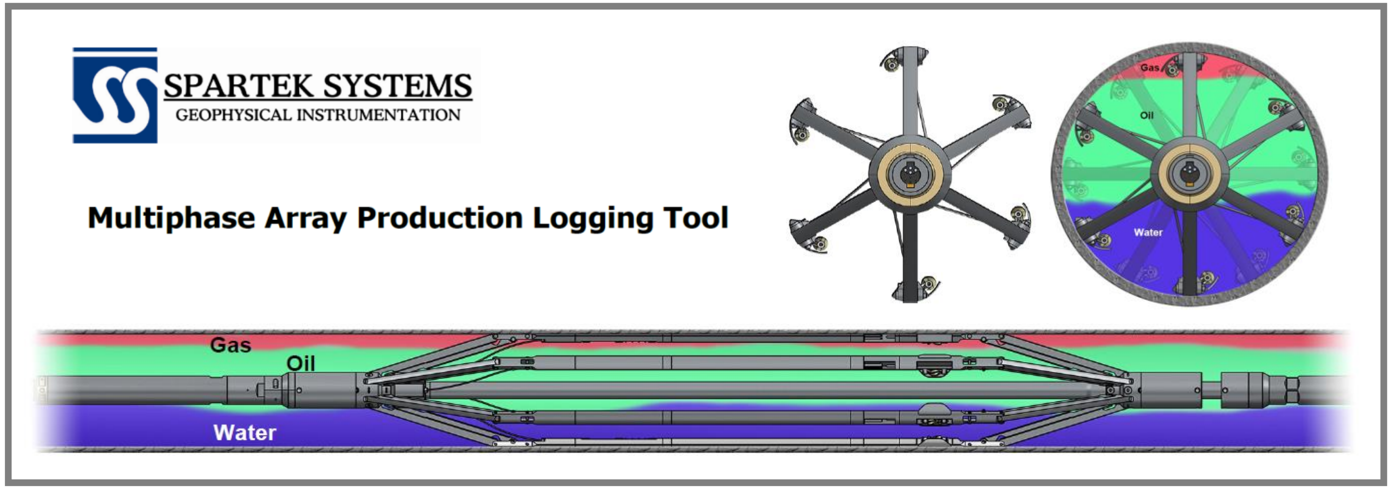


***Multiphase Array Production Tool** - Courtesy Spartek Systems*

Typical PL Interpretation Workflow

1) Interpretation Setup

2) Data Import

3)Data QC/Edit

4)Holdup (Fluid Types) Determination

5) Fluid Velocity Calculation

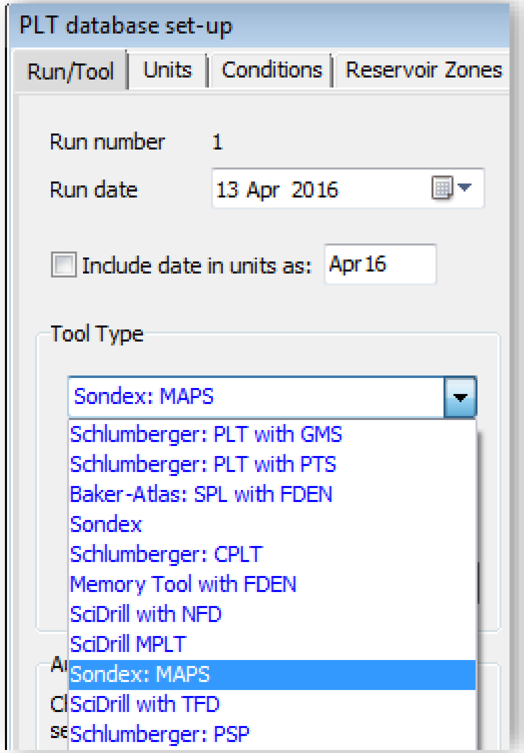
6) PVT Calculations

7) Flow Rate Calculation

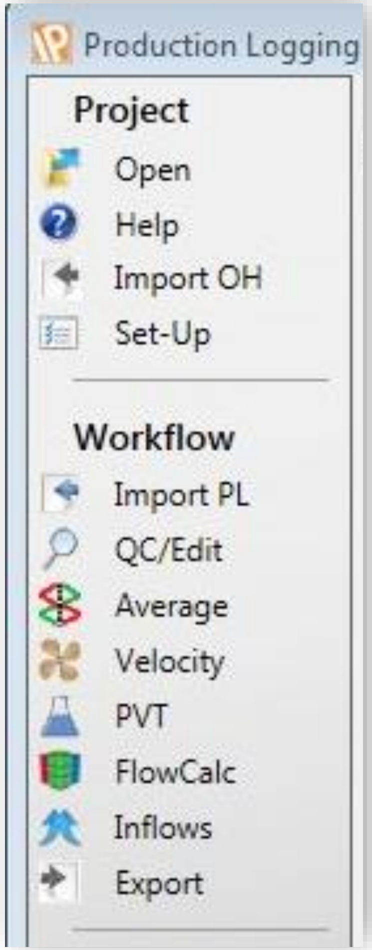
8) Reporting and Presenting

Set Up

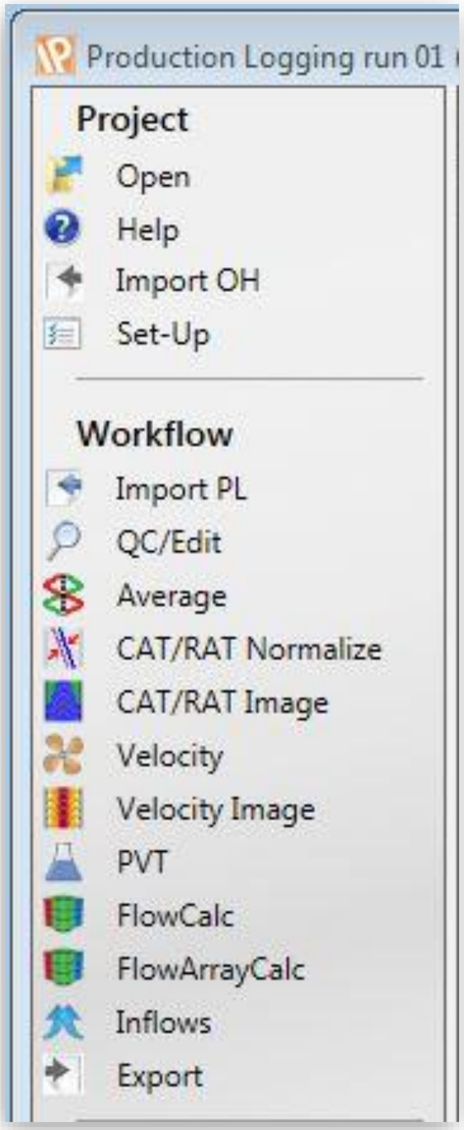
- Tool Selection Updates Workflow



PL Tool List



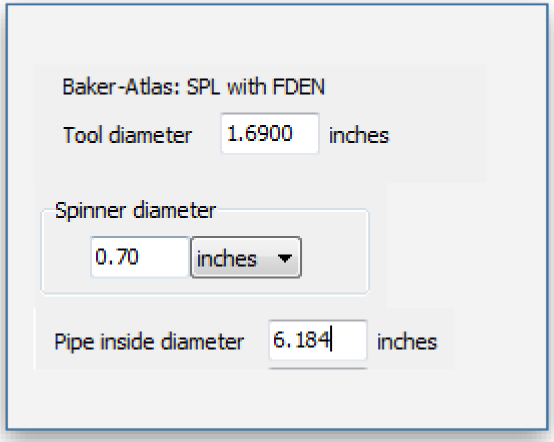
Conventional PL Workflow



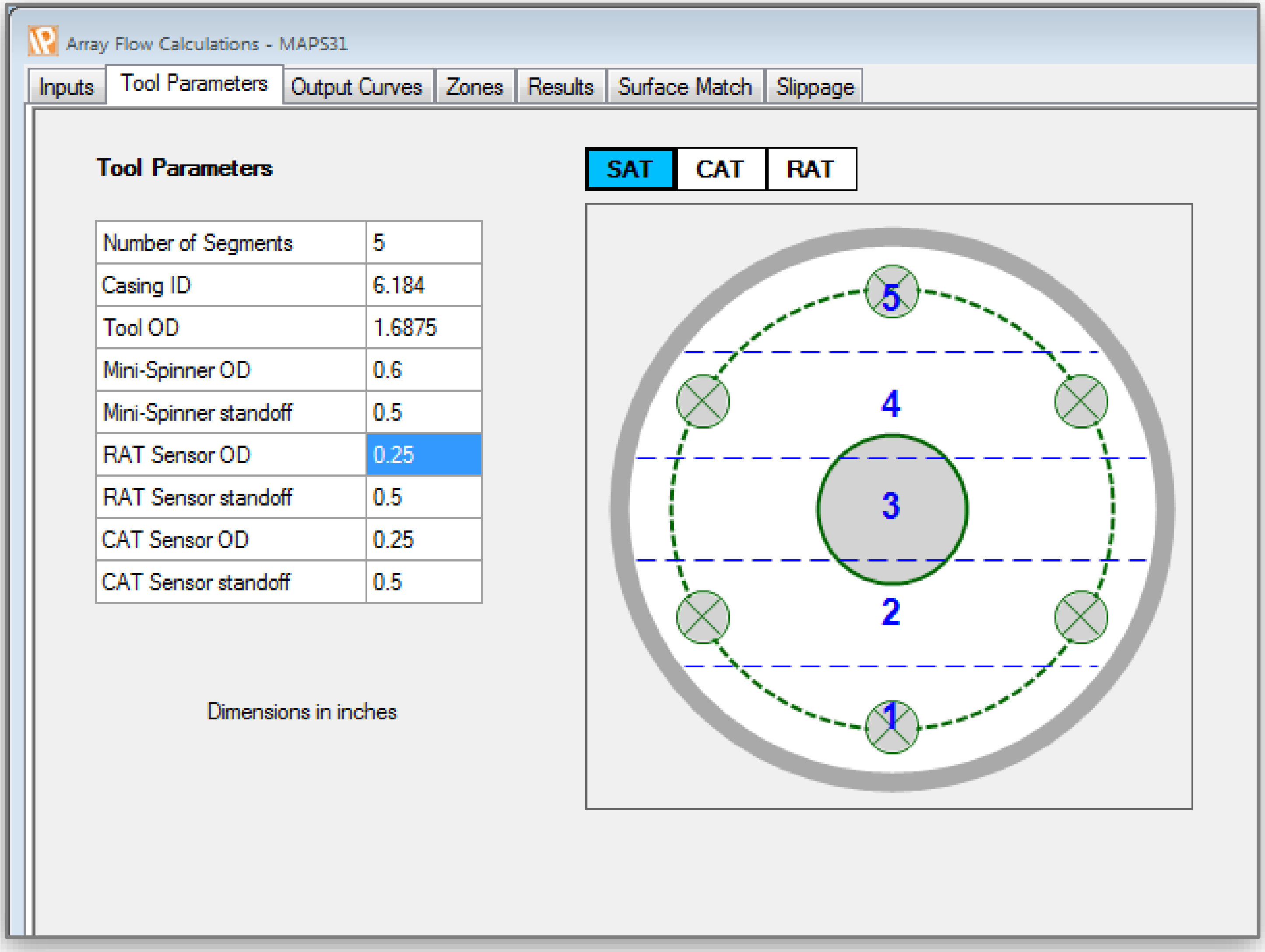
MAPS Workflow

Set Up

- Tool Geometry Setup



Conventional PL Tool Geometry



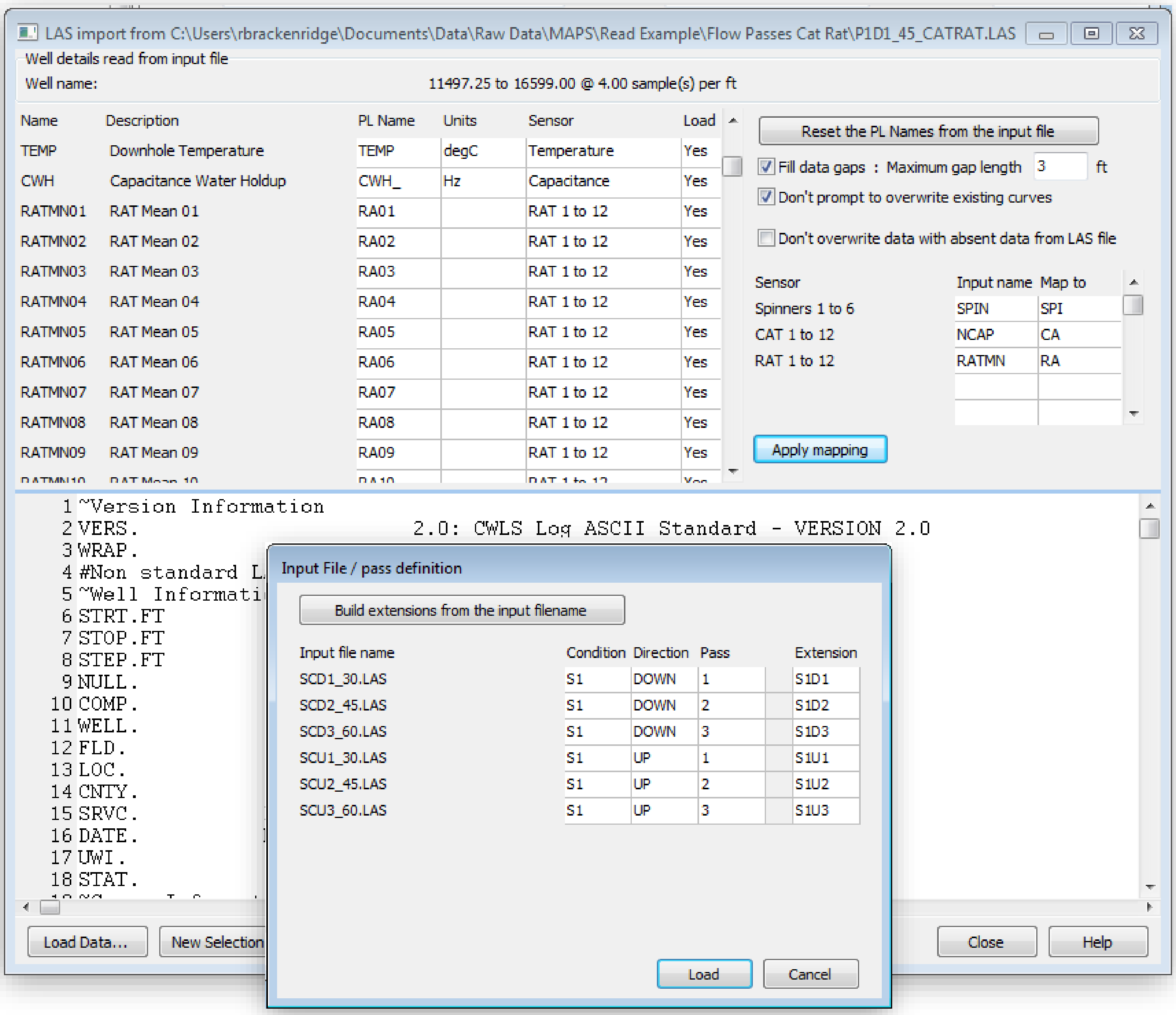
Array Tool Geometry Setup

Data Import

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

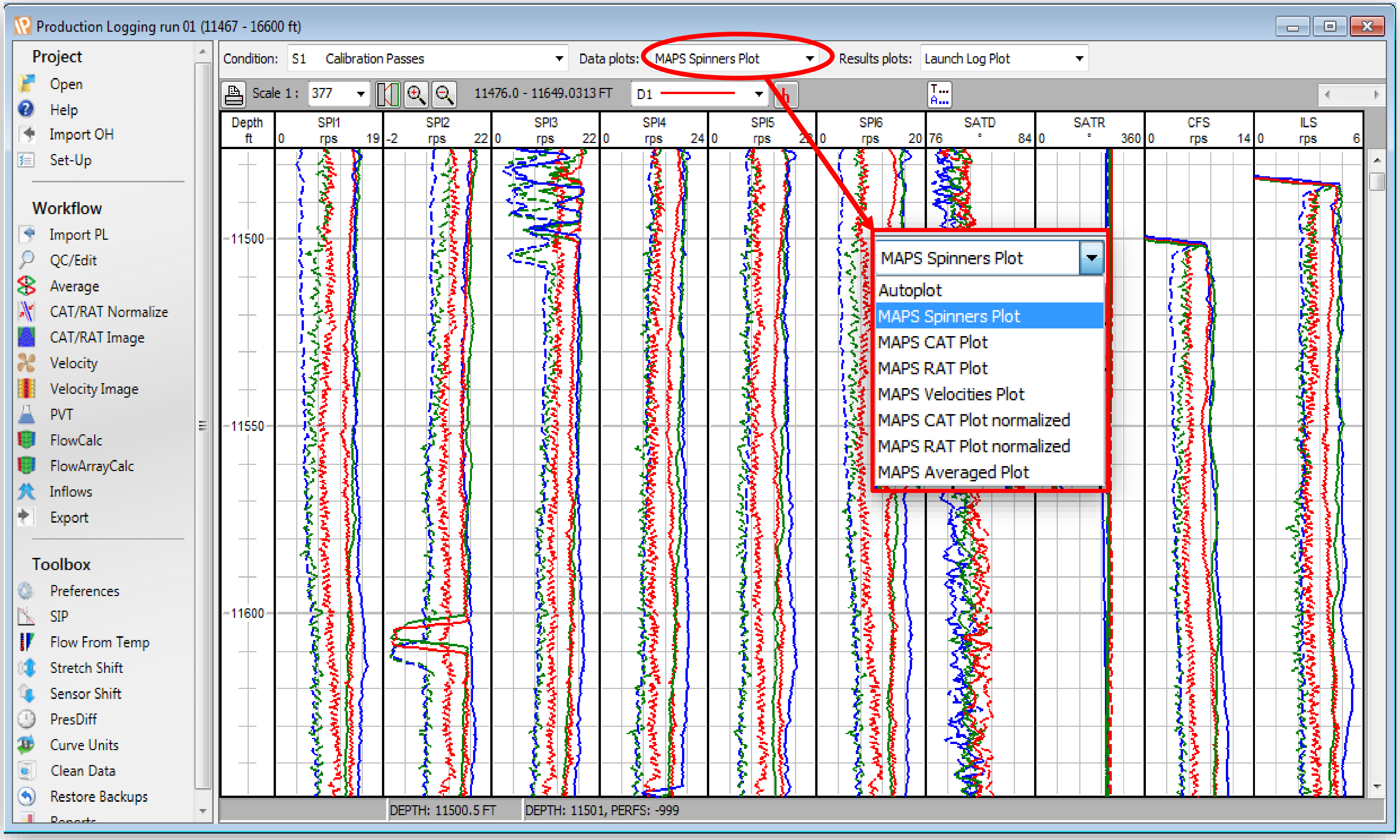
Easy Loading of multiple LAS/ASCII files

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



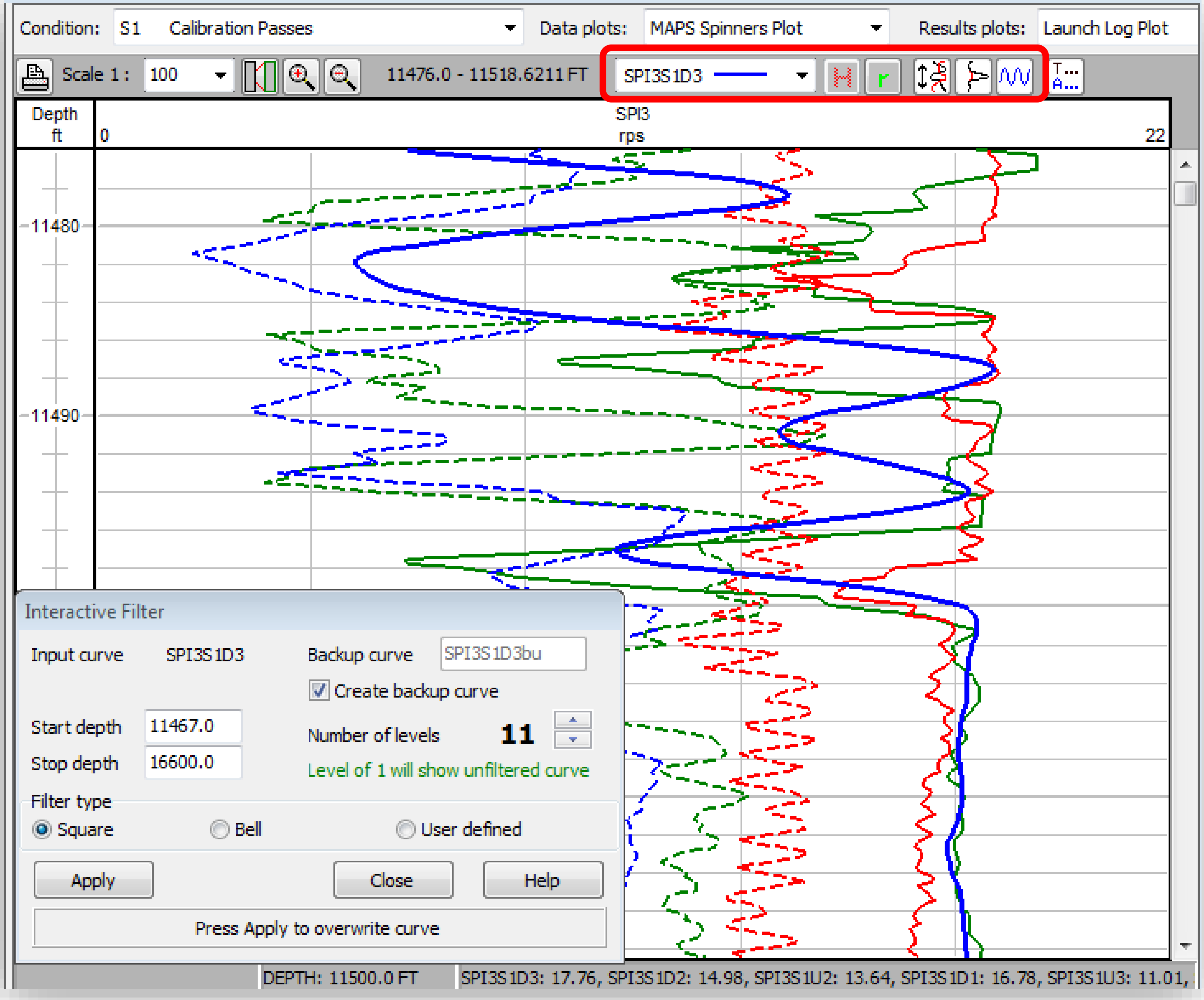
Data QC/Edit

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



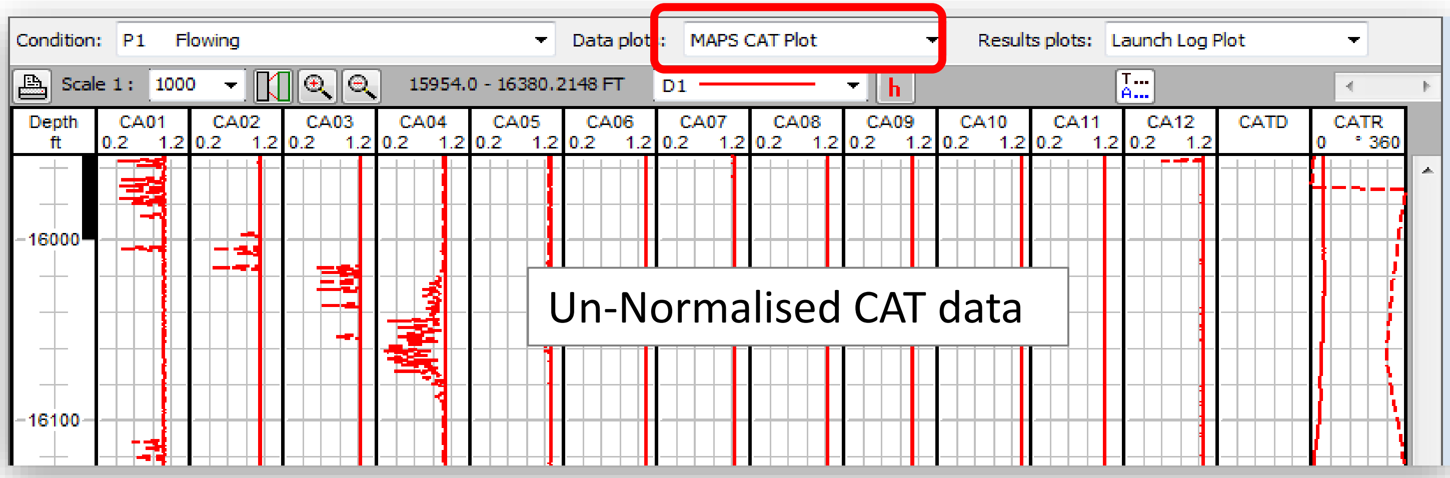
Data QC/Edit

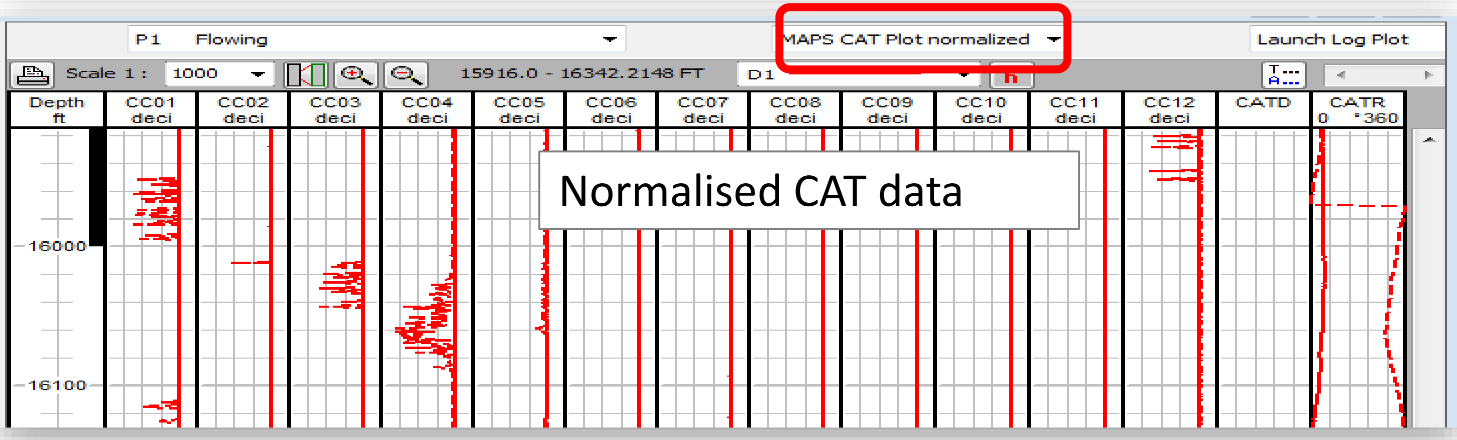
- Shifting, Editing, and Filtering
- Array tool data typically of lower quality than conventional sensors
- May require more filtering and edit than Conv PL data
- New Normalization Tools created for CAT/RAT

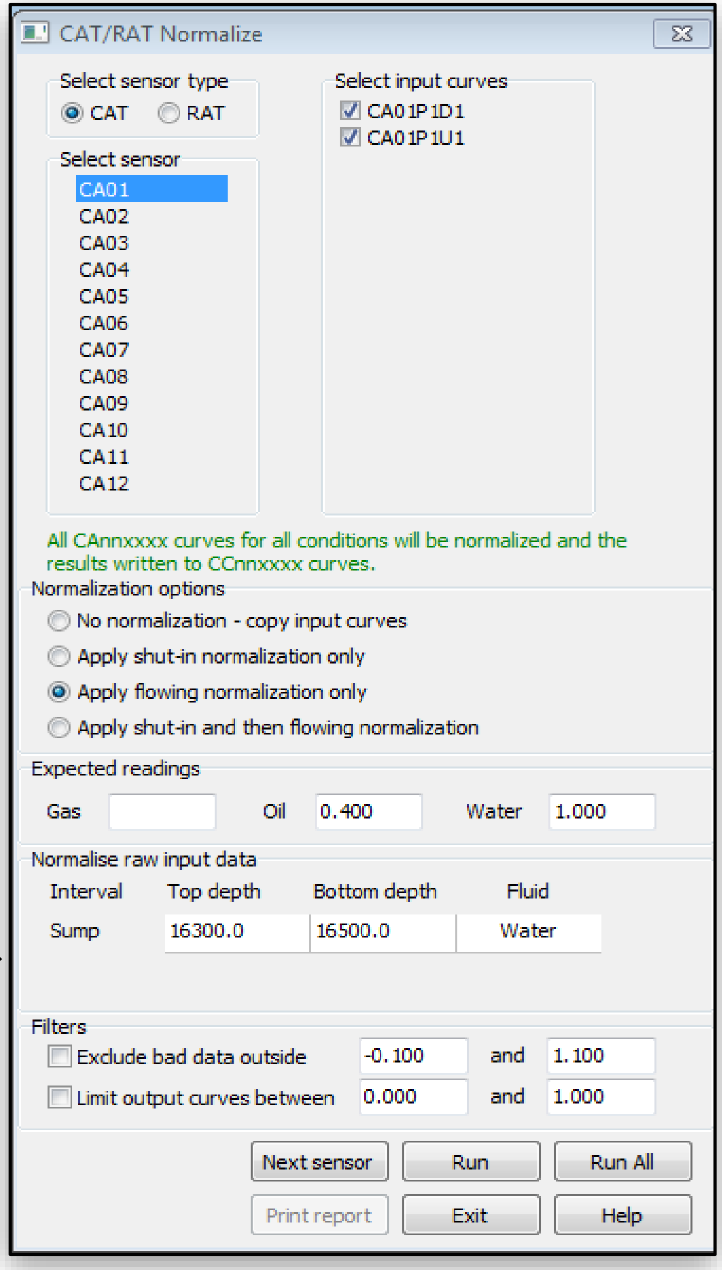


Data QC/Edit

- New Normalization Tools created for CAT/RAT



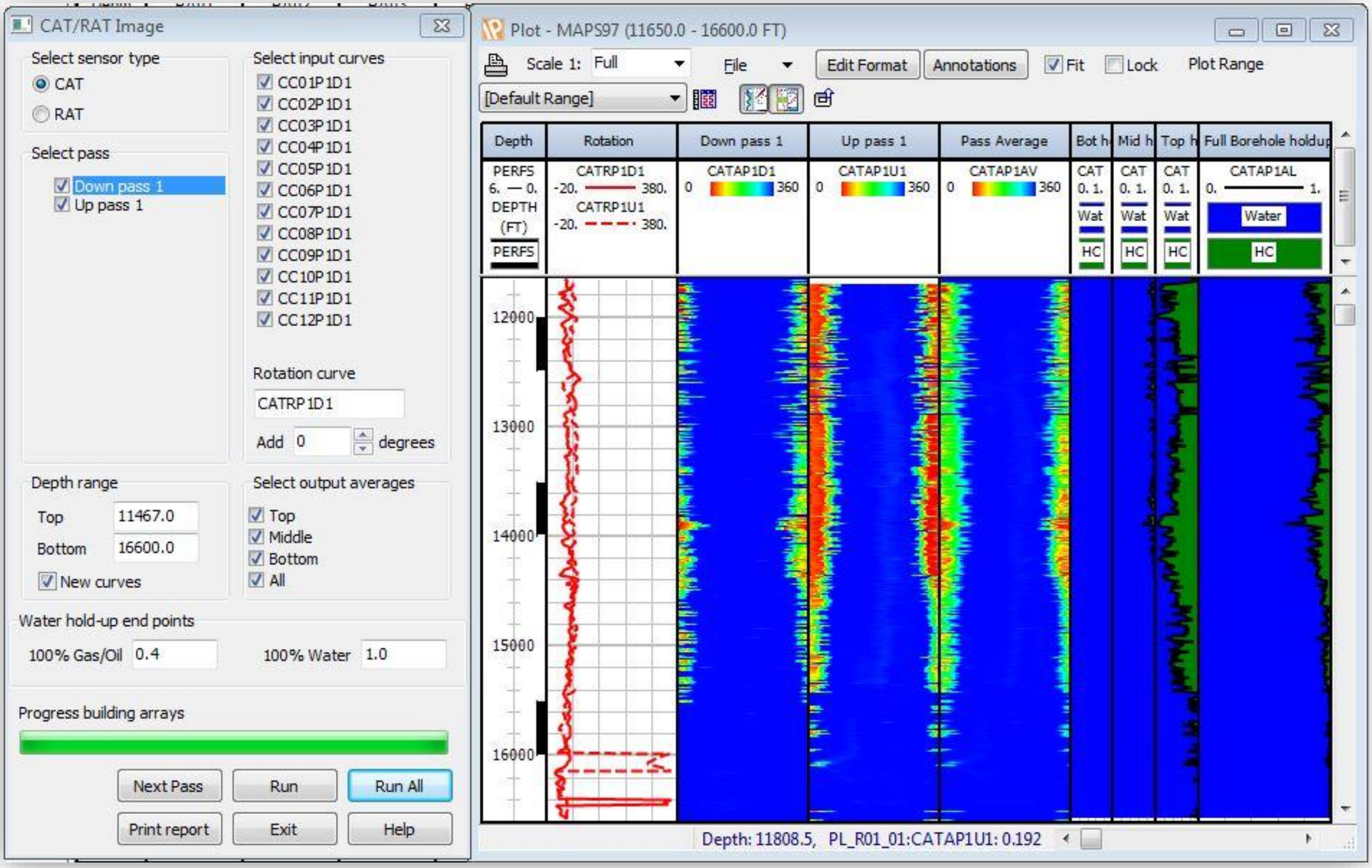




Holdup (Fluid Type) Determination

New Array Holdup Calculation Tool

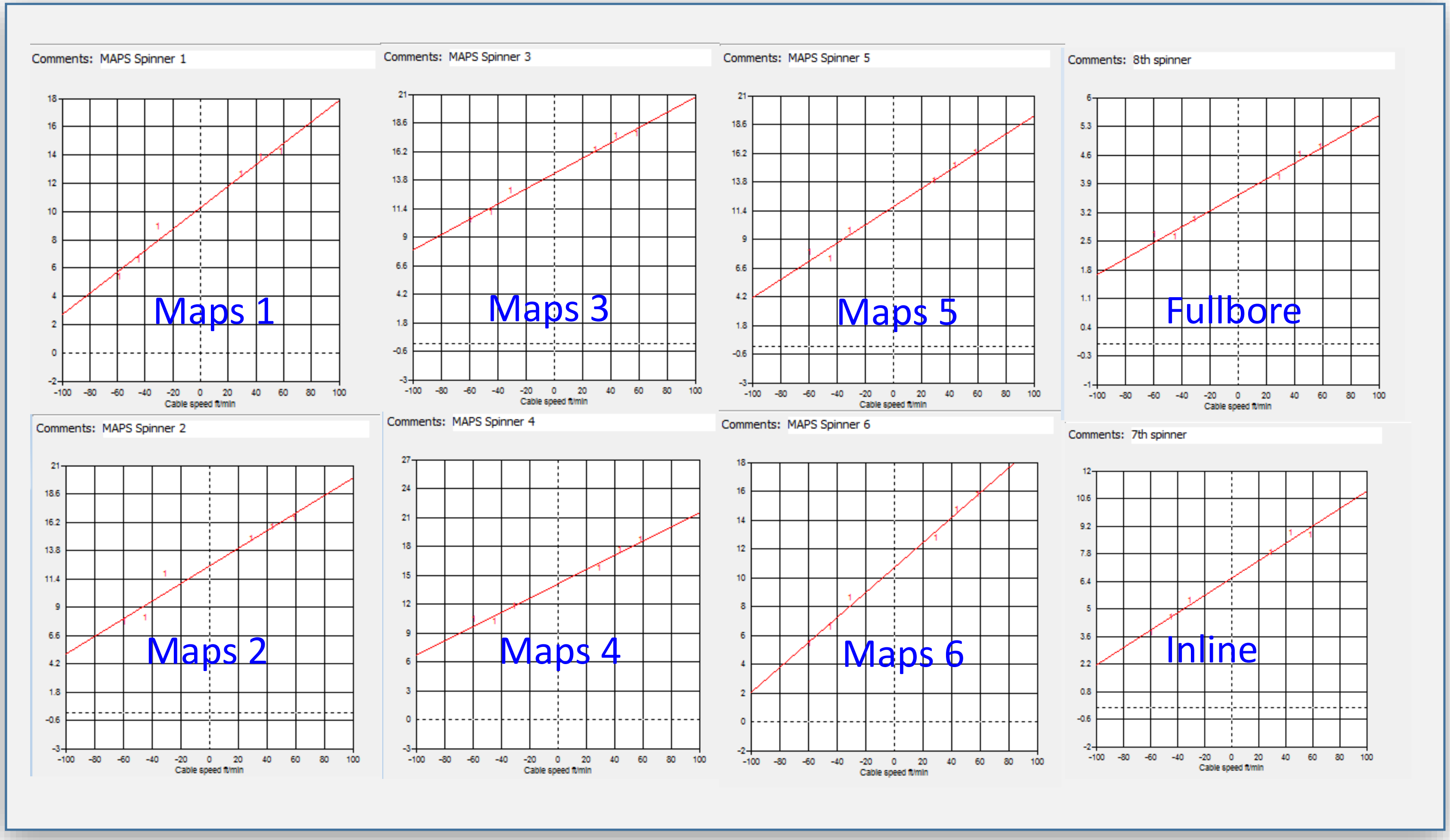
- Applied to CAT and RAT data
- Images corrected for tool rotations
- Enter Holdup End Points
- De-select any bad sensors
- Select Passes to be used
- Holdup Array for each Pass
- Averaged Hold Up Array
- Top/Mid/Bot Hold ups
- BH Volume weighted Holdup



Fluid Velocity Calculation

Spinner X-plots

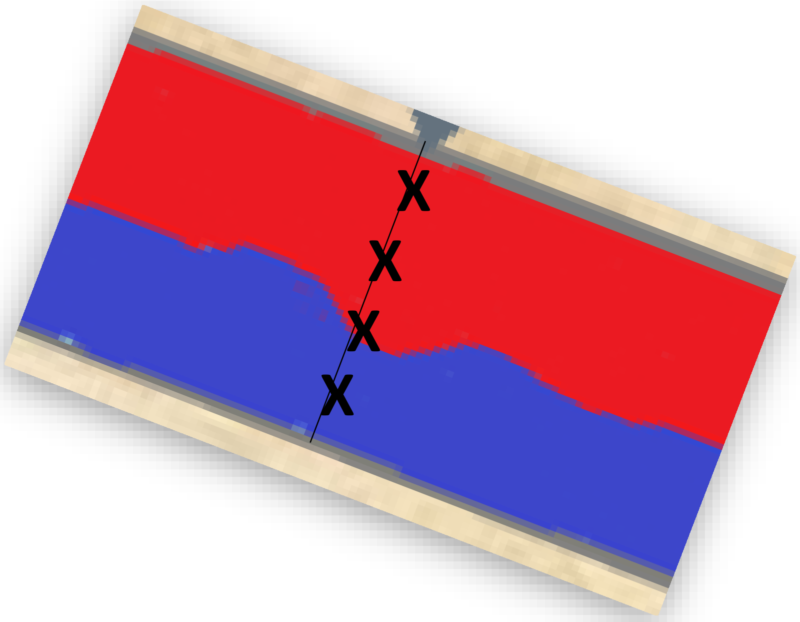
- Used to calculate Slope and Threshold (Sensitivity) of each individual spinner
- Conv PL Workflow = 2 x-plots, Array PL workflow = * plots
- Spinners must be calibrated independently and cannot be averaged first
- New version of module will use holdup array to discriminate for fluids
- Additional tools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

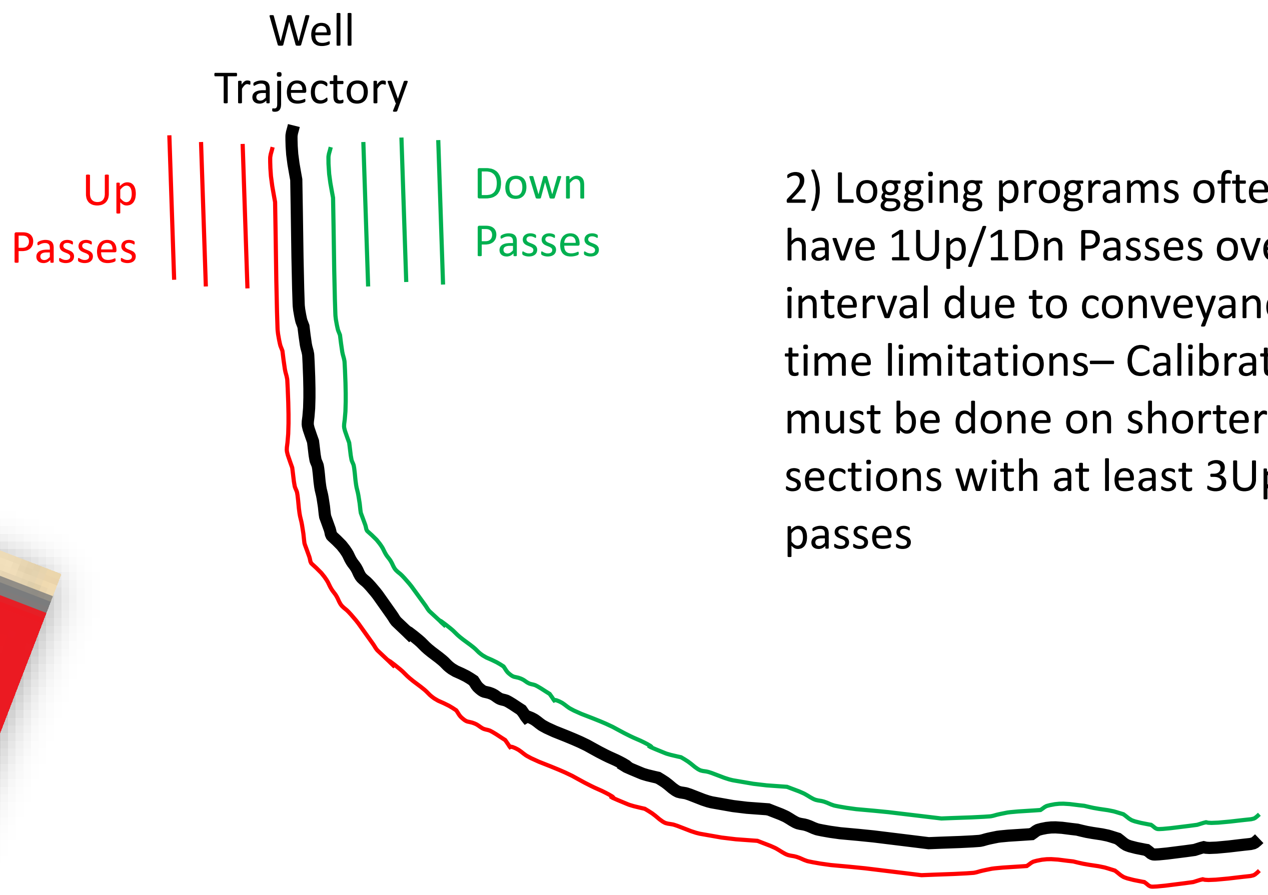


Fluid Velocity Calculation

- 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

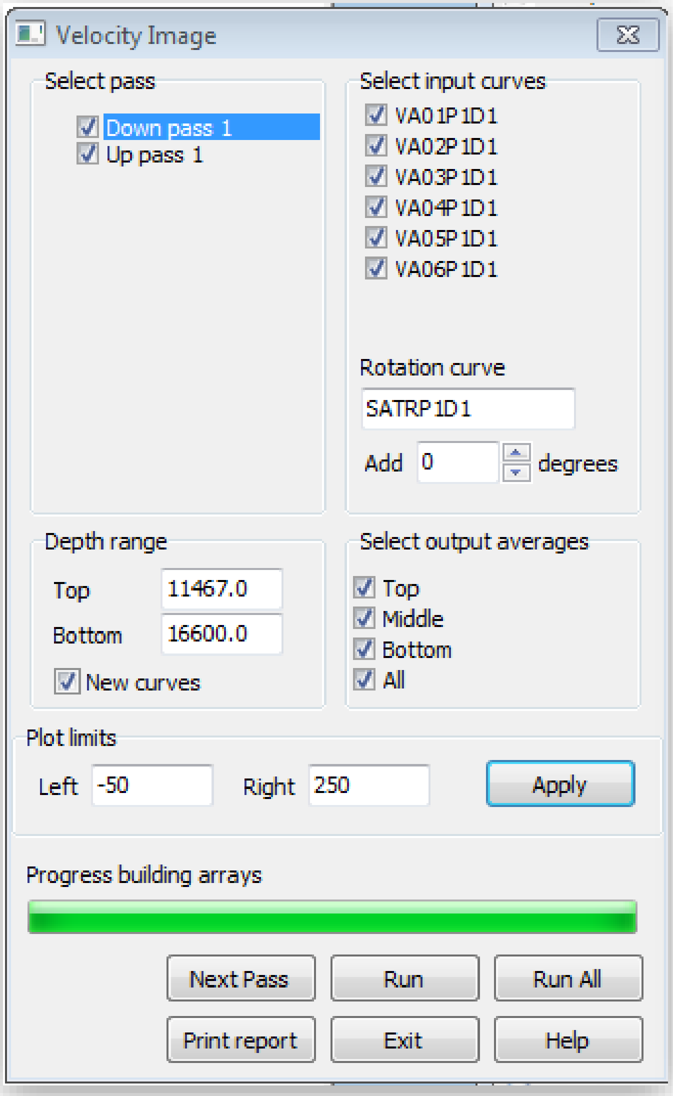


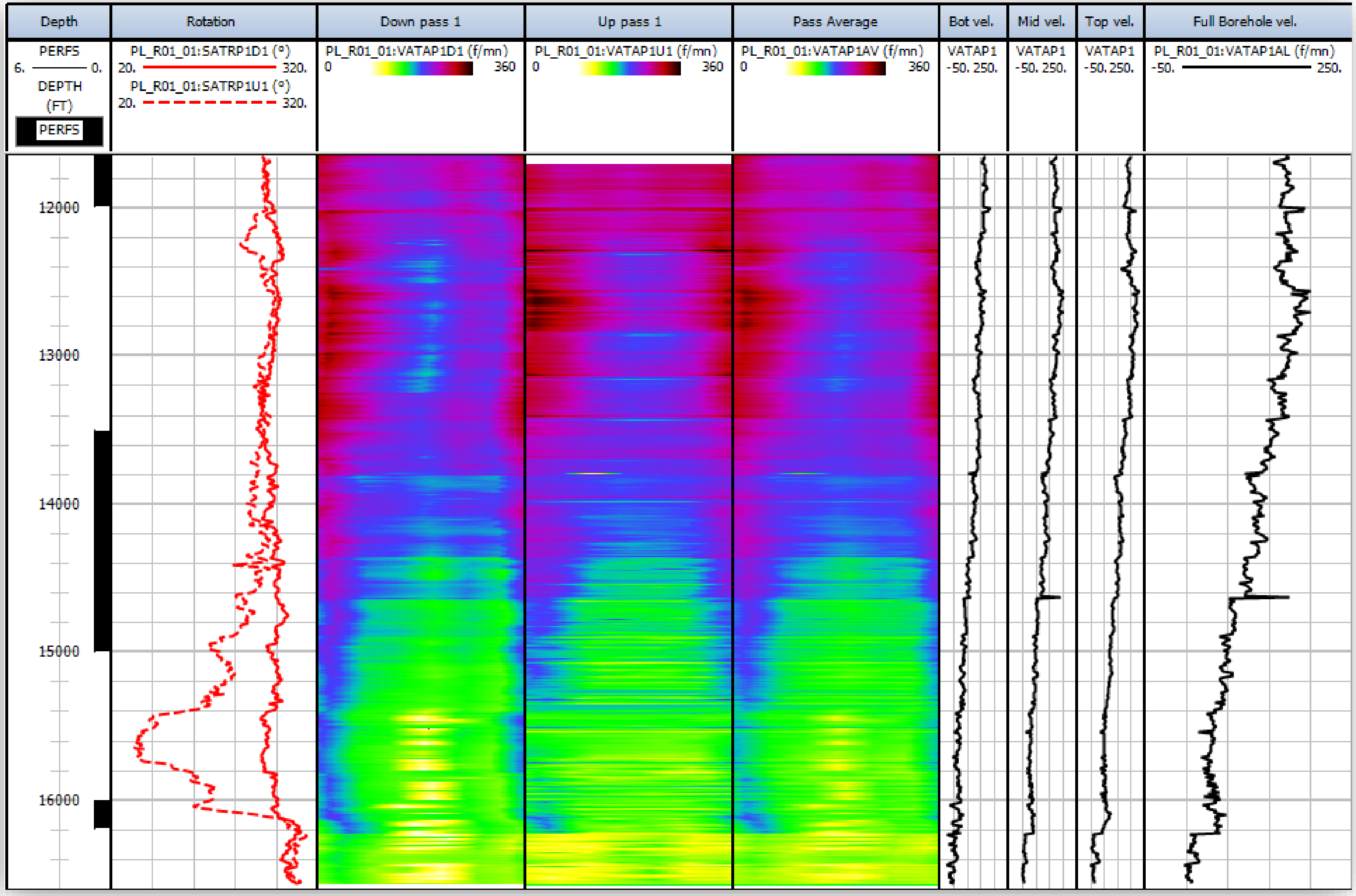


2) Logging programs often only have 1Up/1Dn Passes over full interval due to conveyance and time limitations– Calibration must be done on shorter sections with at least 3Up/3Dn passes

Fluid Velocity Calculation

- New Array Velocity Images Tool



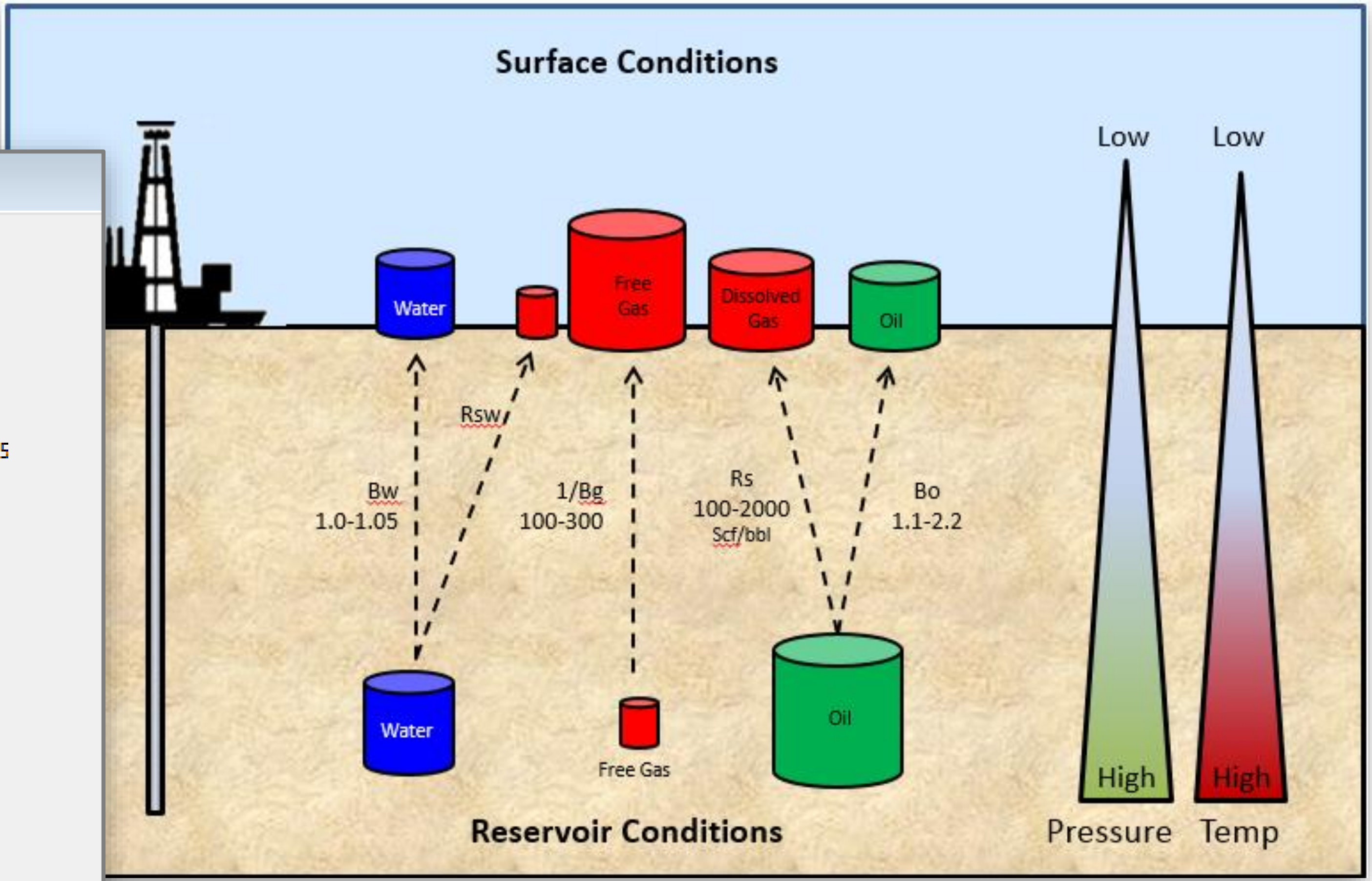


PVT

- No significant change to PVT calculations

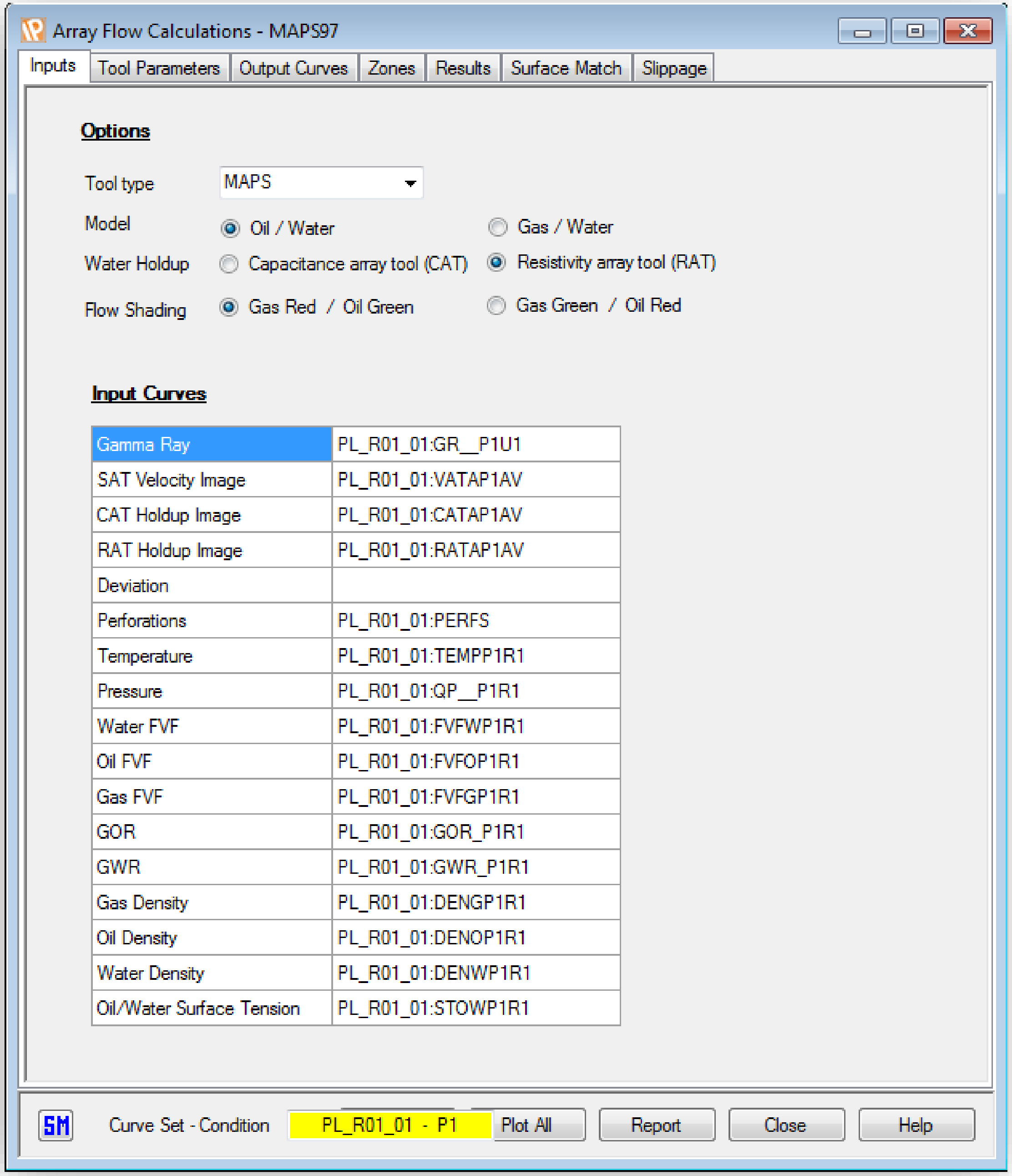
PVT properties for field: VASQUEZ BEGGS

		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



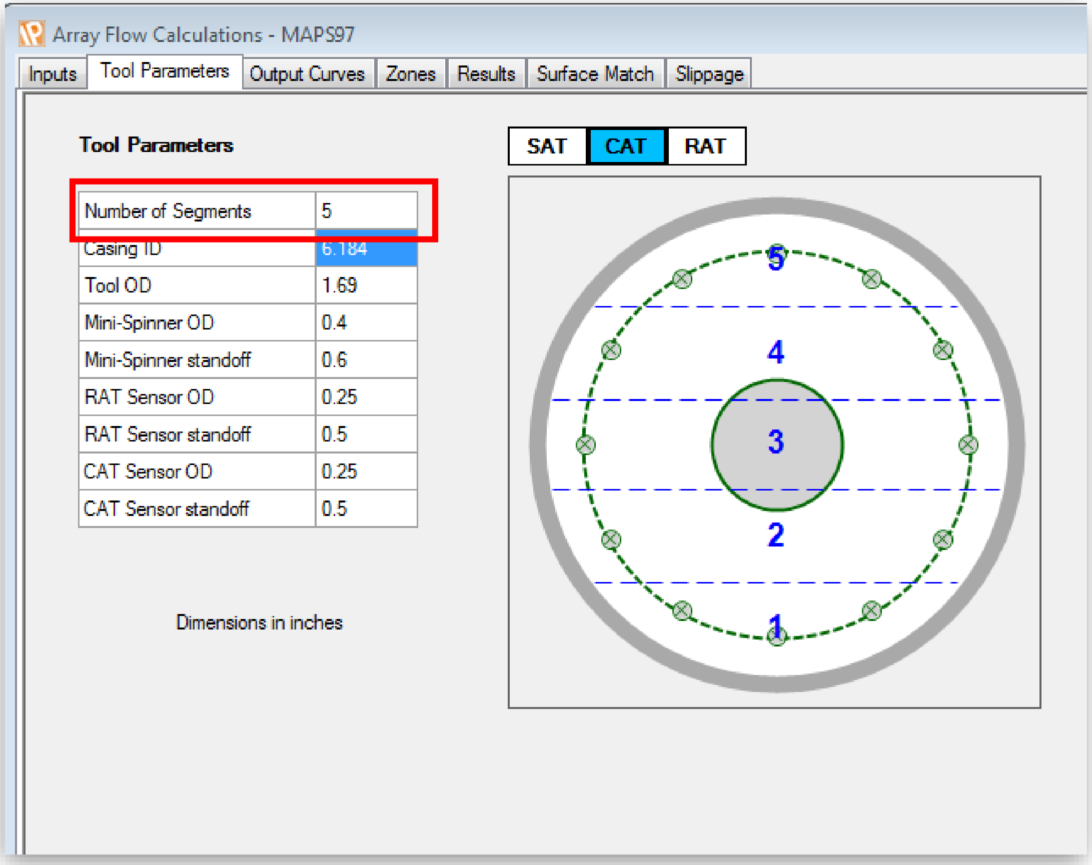
Flowrate Calculation

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

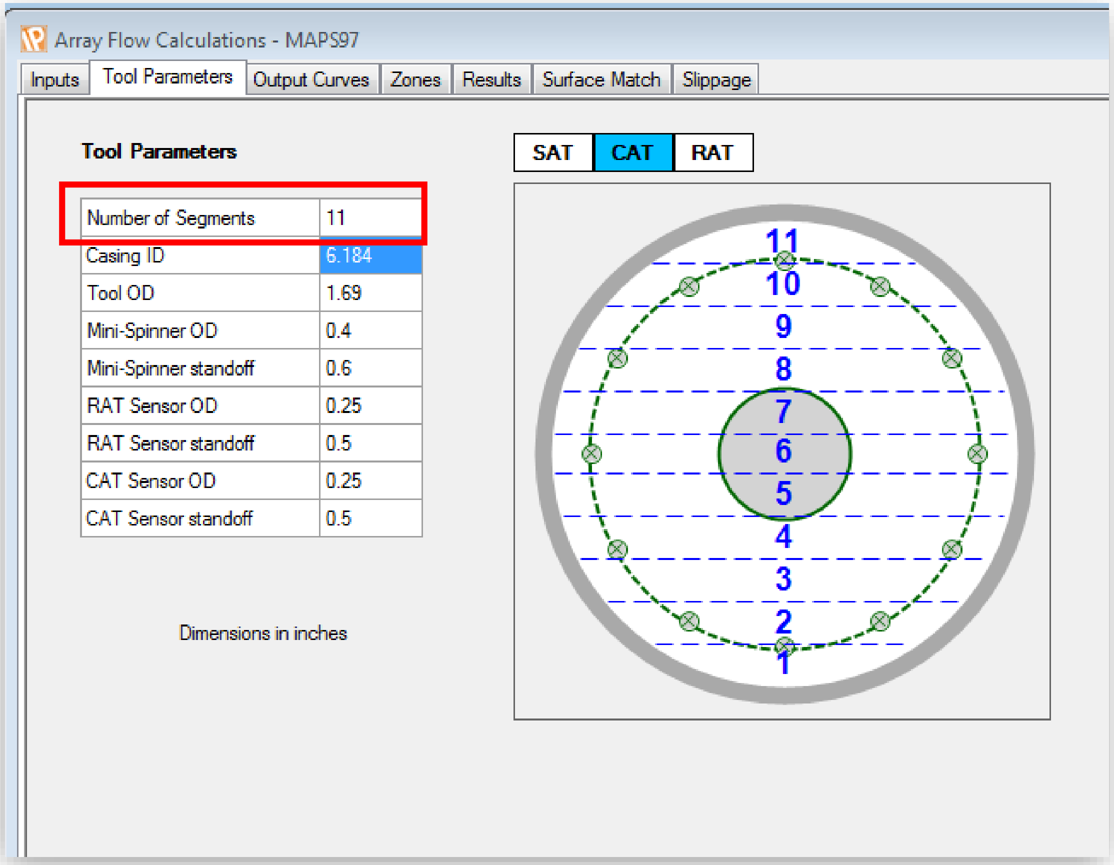


Flowrate Calculation

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

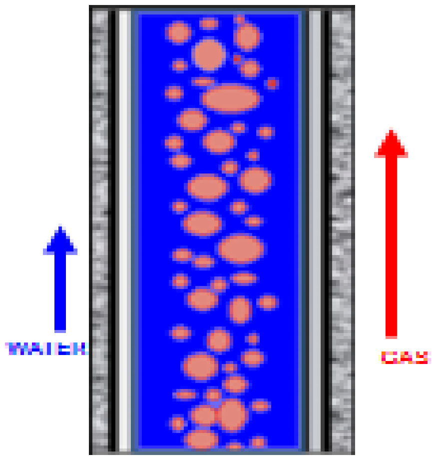


High number creates smoother results and reduces affects of slippage but can result in heavily interpolated segments

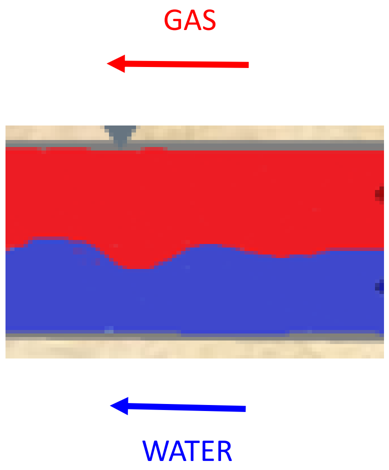
Flowrate Calculation

Slippage

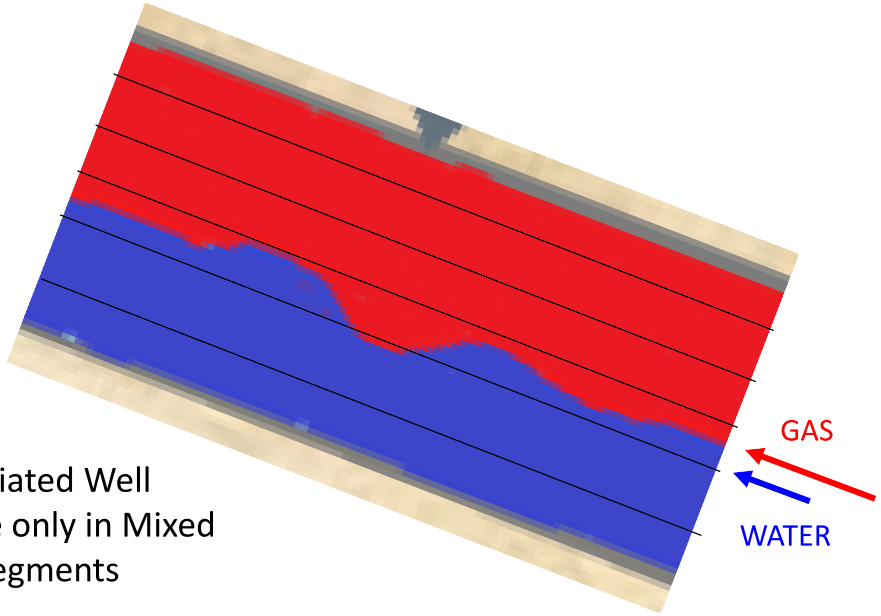
- The option to apply slippage correction has been retained in the Array workflow but required modification
- Traditional slippage correction applies to whole borehole, Array workflow slippage only required in Mixed fluid Segments
- Weighting of Dominant Fluid must be considered
- Slippage Corrected 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.



Vertical Well
High Slippage



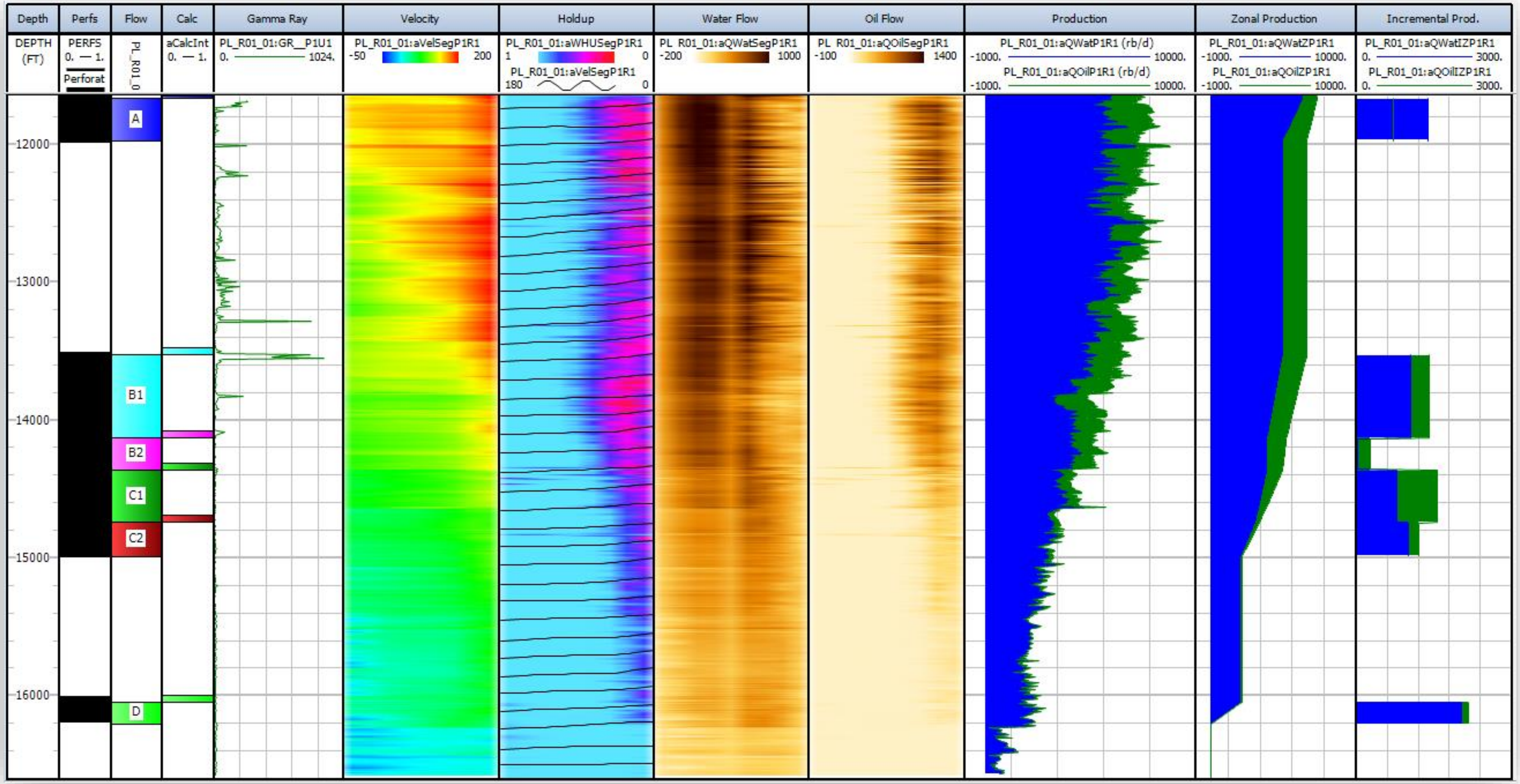
Horizontal Well
Low or Zero Slippage



Deviated Well
Slippage only in Mixed Segments

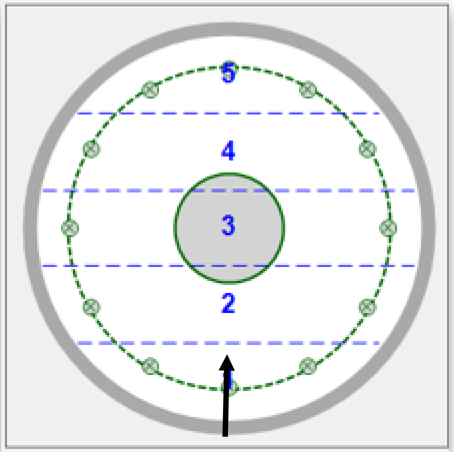
Flowrate Calculation

- Results Plot

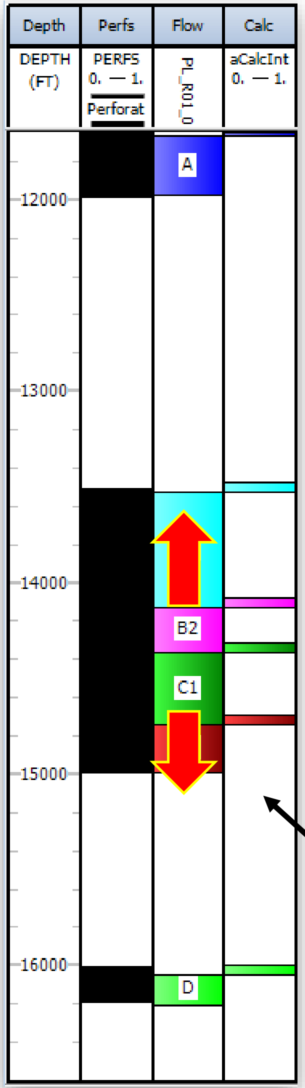


Flowrate Calculation

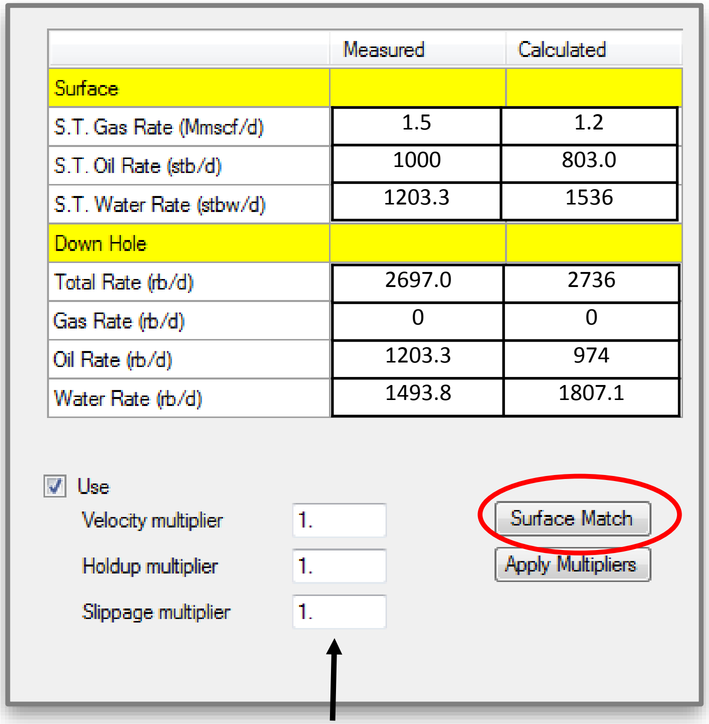
- Comparing results to surface
- Fine Tuning Options:



Increase or Decrease Number of Horizontal Segments

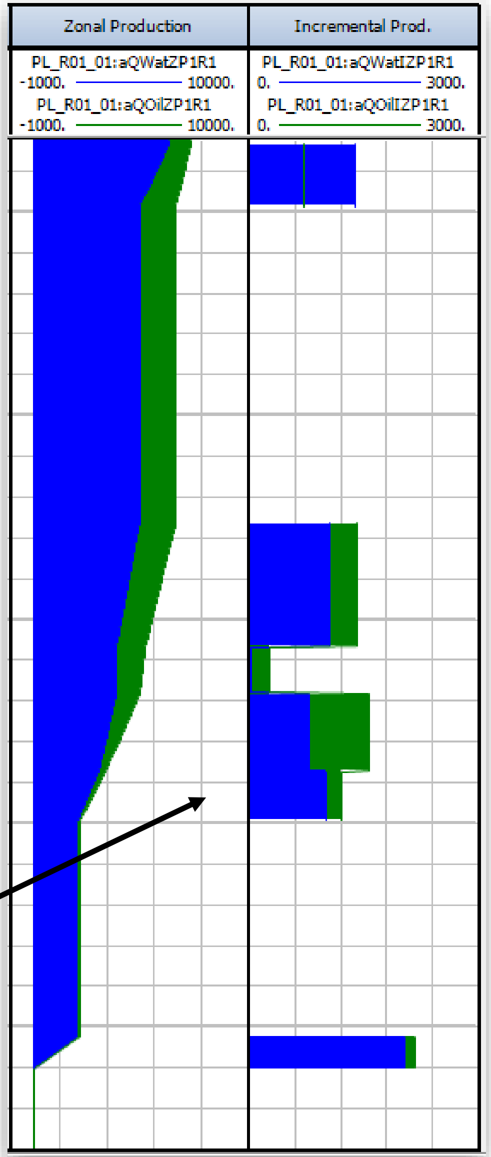


Interactively Move, Add or Split Calculations



	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

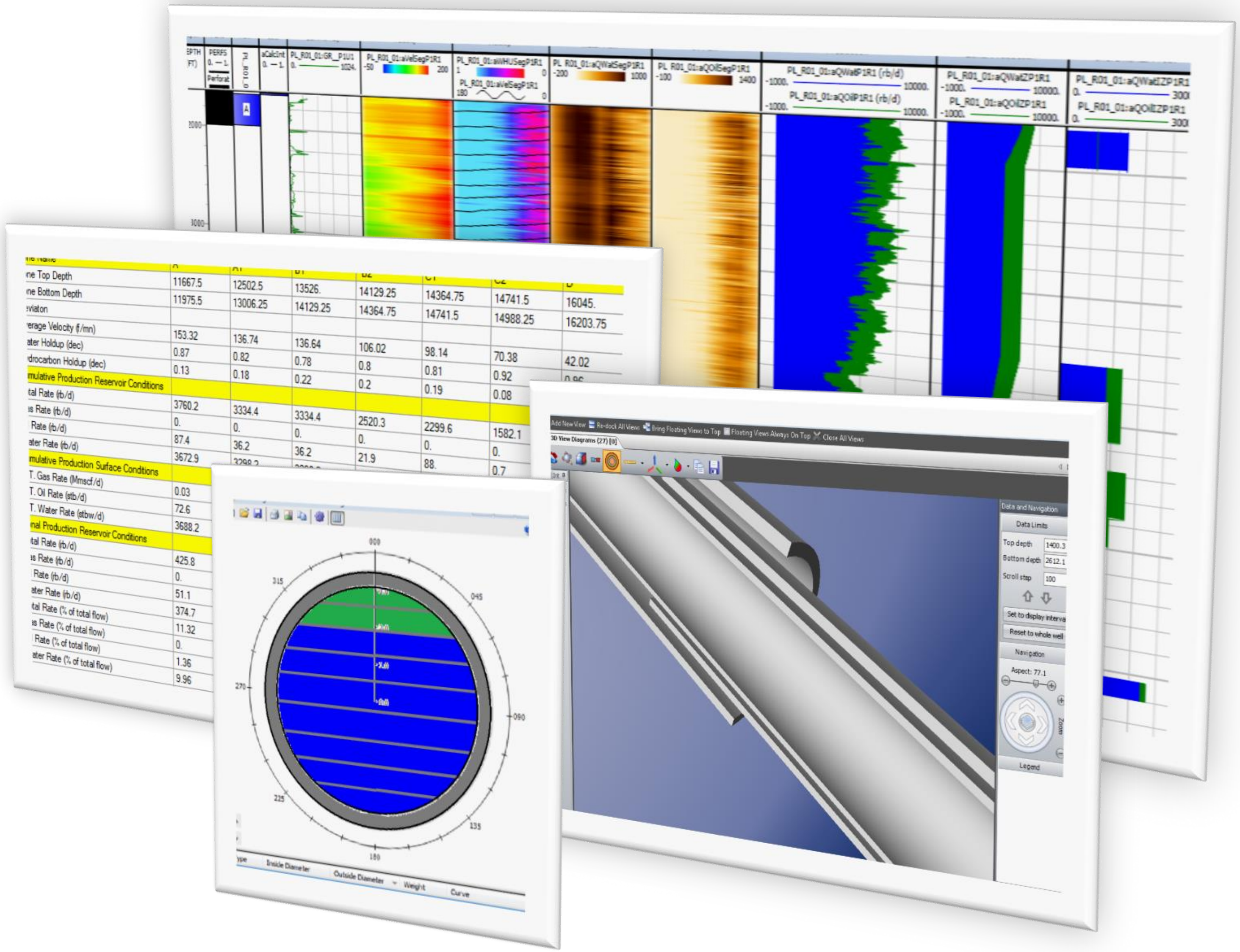
- Velocity Multiplier
- Holdup Adjustments
- Slippage Adjustment



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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