B04 – Guided Interpretation #4

This example illustrates the following options:
- Apparent Downflow
- SIP (selective inflow performance)
- Temperature
- Standing water column

B04.1 • Example data

➢ Open the file B04.ke2 located in the Examples directory, Fig. B04.1.

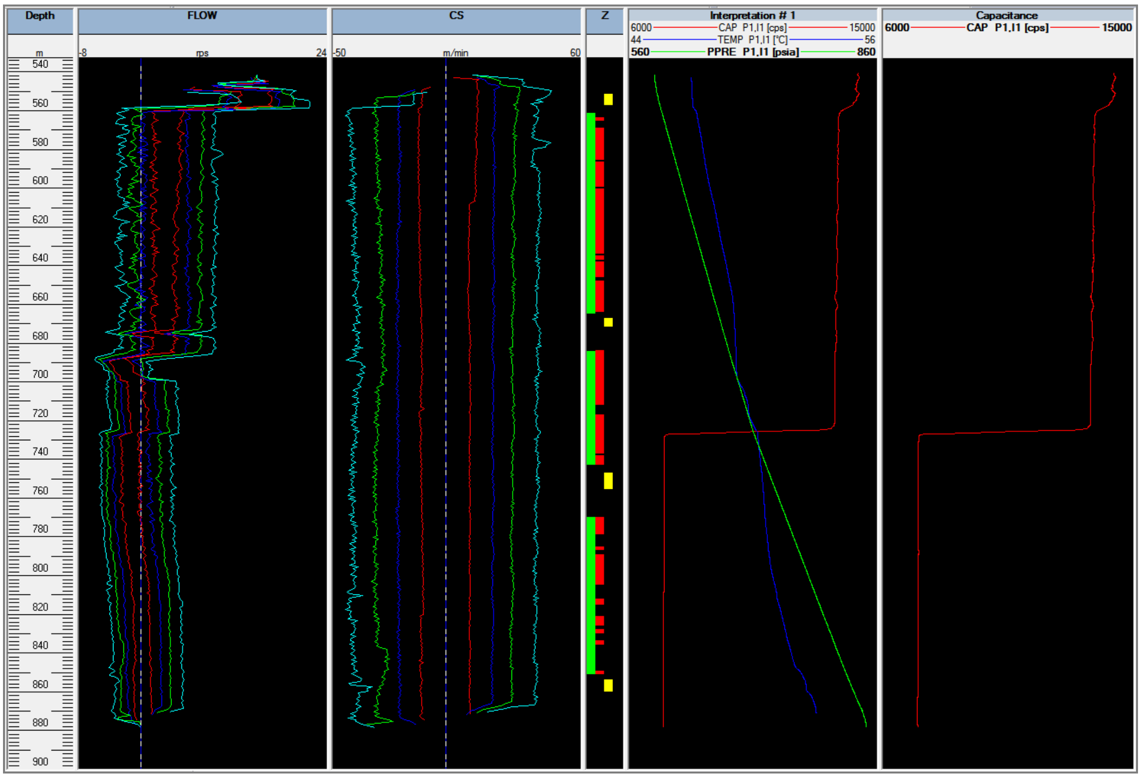


Fig. B04.1 • Main interpretation screen

This file contains 4 different surveys/interpretations. There are 1 shut-in and 3 productions. The tool string includes the following: Spinner, Gradio, and Capacitance. The gradio failed in some surveys: Shut-in #1, Production #1, Production #3. All surveys have been interpreted except for Production #1 which is considered in the sections below. The well is around 50° deviated. The tubing shoe is set at 725 meters, after which there is 9 5/8 casing. There are 3 reservoirs, the uppermost producing through a sliding sleeve around 560 m. There is no water production at surface.

Production #2 illustrates the profile obtained in this well (you can activate this survey to see the interpretation). The combination of the well deviation, the large casing diameter, and the large water holdup at the bottom of the well creates favourable conditions for phase re-circulation inside the casing. It can be seen that the complete log, everywhere faithful to the data, exhibits only downflow of water inside the casing. The schematic however, is showing upflow of oil in that zone. This result was obtained using the Apparent Downflow option of Emeraude, which is illustrated in the section below.

An alternative, described in section B04.4, is to use the temperature quantitatively. In any case, a proper interpretation of the data inside the casing can only be obtained by disregarding the spinner in that section.

B04.1.1 • Production#1 Interpretation

Reference channels for pressure, temperature, and capacitance have already been produced. We will first create a pseudo-density channel from the pressure.

- Make sure you return to Production #1.
- Open the data browser; then the nodes Production #1, Interpretation #1, Input. Select the Pressure channel and then the icon **f'** (or the 'Derivative' option in the popup menu).
- Enter smoothing = 2m.

2 new tracks appear at the right: one titled 'DPDZ' and the match track labelled 'Density'. The density is also added to the Interpretation #1 view.

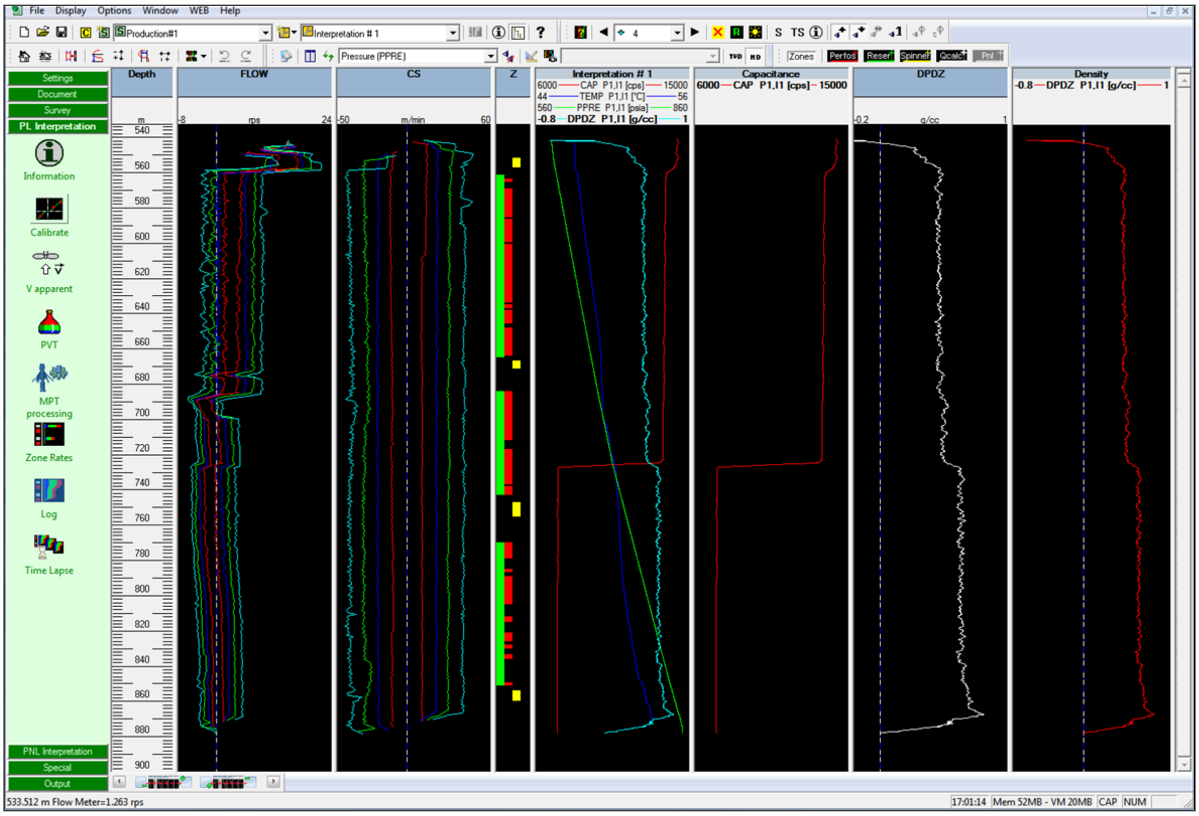


Fig B04.2 • Pseudo-density channel created

In shut-in #1, the DPDZ was checked against the PVT data. It was decided to offset the channel by –0.027 g/cc (this can be viewed inside the data browser).

➢ The same shift must be applied here (y -> a.y + b inside the data browser).

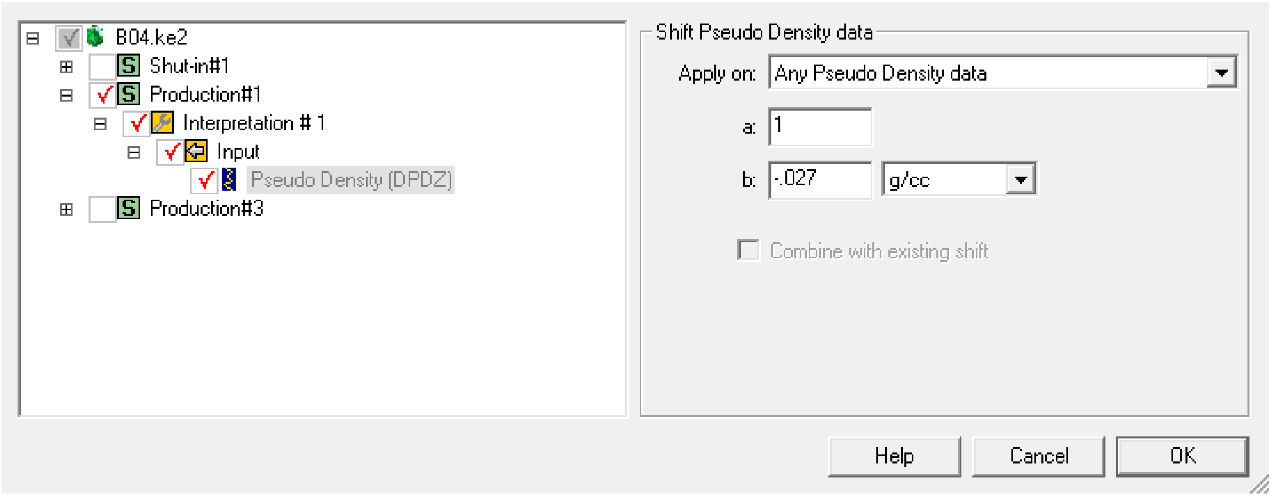


Fig B04.3 • Shifting the density channel

Calibration / Vapparent

Spinner calibration zones were already defined.

➢ Click on the 'Calibrate' icon to view the calibration. Accept all defaults and generate VAFLOW.

➢ Hide the cable speed, density (DPDZ), velocity (VAFLOW) and spinner views. Tile.

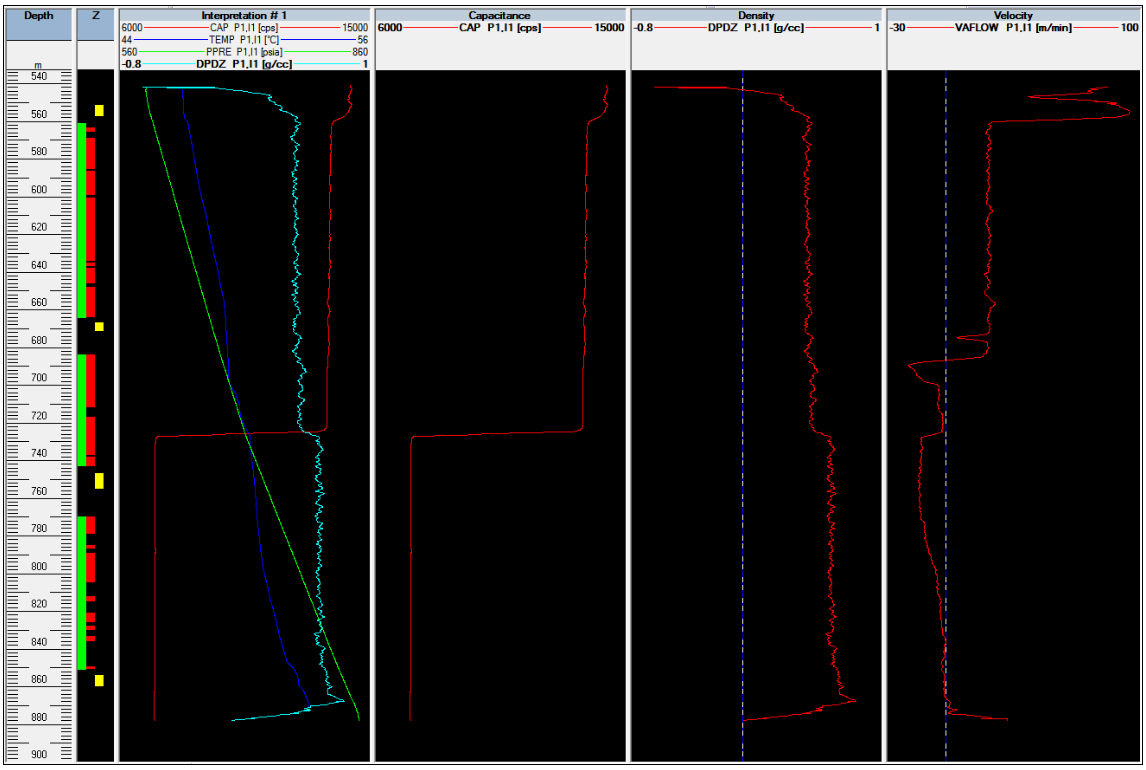


Fig B04.4 • Apparent velocity created

Below 686 meters the VAFLOW is negative. From 726 down it is the 9”5/8 casing. It can be seen on the density and capacitance that most of this section is occupied by water and the spinner is telling us that this water is going down. We will assume that what is actually happening is only an apparent down flow and that water falls back only as a result of being dragged upward by an up flowing light phase, oil.

In this session, we will run two interpretations to substantiate this fact: one using the specific Apparent Downflow option, the other one using the Temperature.

- Click on the ‘Calculation zones’ button and create zones ’Same as Spinner calibration zones’.

B04.2 • Interpretation with Apparent Downflow

- Select ‘Zone Rates’ and choose:

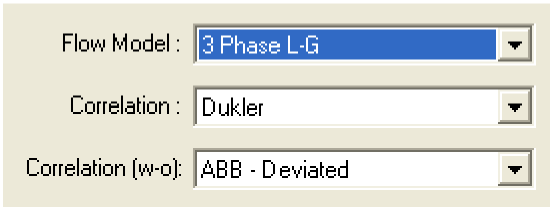


Fig B04.5 • Flow model and Correlation selection

- Click on the ‘Rate Calculation’ tab; select the ‘Plot’ display:

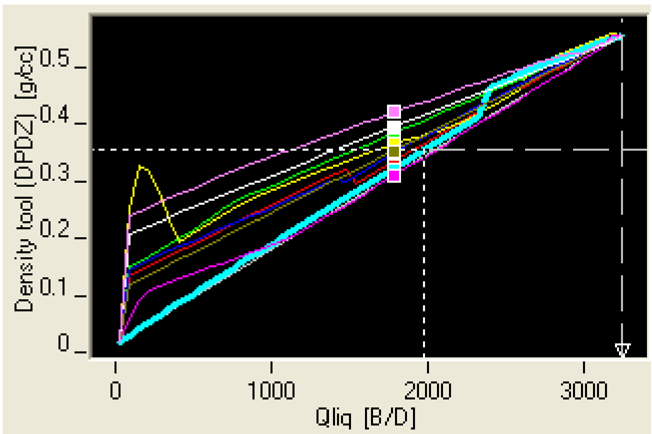


Fig B04.6 • Rate Calculation - Plot Display

It can be seen that there is fairly good agreement between the surface rates, the model, and the measurements.

- Move to Zone 3 (Rate Calculation Tab).

The rates are all negative. Checking the pressure/PVT, we know that we are above bubble point so we toggle the model to Water-Hydrocarbon(L).

- Change the Model to ‘Water-Hydrocarbon (L)’.

The ‘Apparent Downflow’ option (ADF) is now enabled.

- Check ‘ADF’.

'Apparent Downflow' can occur in deviated wells with a high heavy phase holdup. In a deviated well with a high water holdup, the water may be dragged upwards by the oil flowing up on the high side of the pipe, and fall back on the low side of the pipe. This circulation of water may be 'seen' by the spinner as only downward flow when it is in fact due to upwards oil flow. Deciding that the flow is up when the spinners says it is down, can be done if additional information is available (zone pressure, temperature, etc).

An 'Apparent downflow' option in the Zone Rate dialog can be used for quantitative interpretation. The option is available in both Liquid-Liquid and Liquid-Gas cases and is offered regardless of the sign of the apparent velocity VAFLOW. In this option, the rate of the light phase Qlight (Qhc in our case) is assumed to be a function of the slip velocity, Vs and the holdup of the heavy phase: $Q_{light} = C_{ADF} \times (Vs+V_{ADF}) \times (1 - Y_{heavy}) \times A_{pipe}$ where C_{ADF} and V_{ADF} are editable parameters (accessed in the 'Edit' dialog, respectively set to 1 and 0 by default).

The spinner measurement is disregarded and the superficial velocity of the heavy phase is set to 0. The match is preferentially on water holdup. Yet because of the larger water holdup the density is certainly more reliable here.

- ➢ Select the 'Table', 'Unfit' the capacitance (Zone 3 only).
- ➢ Select the 'Plot' and click 'Improve':

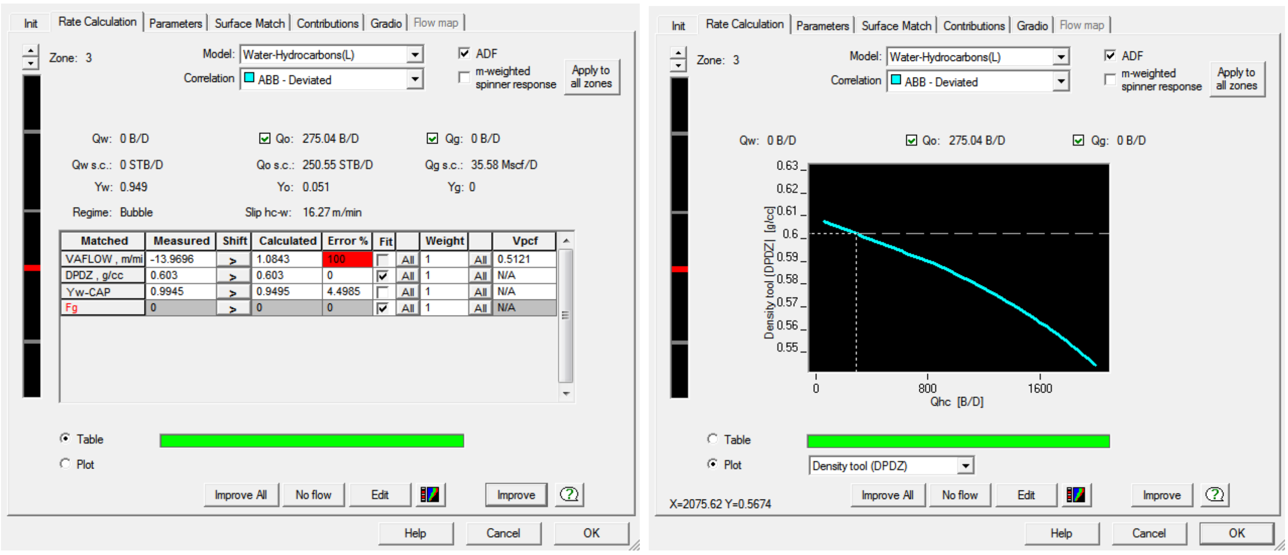


Fig B04.7 • Rate Calculation tab

- ➢ Select the bottom zone and set it to 'No Flow'.
- ➢ Validate with OK and generate the schematic logs, Fig B04.8.

The simulated channels change value linearly across the inflow zones. The simulated apparent velocity data are not relevant wherever Apparent Downflow applies. This is because the VAFLOW model disregards VAFLOW completely and uses holdup/density measurements only.

Also, for the top reservoir, the contribution shown on the schematic is assigned linearly to the corresponding inflow zone. This of course, is different from what the spinner 'sees' since the top reservoir contribution is entering only at the level of the sliding sleeve. Since we are using the 'Zoned' interpretation method this is not an issue.

Also, note that all other interpretations inside this document have been carried out in the exact same manner:

1. Set/Reset All Zones with 3-Phase L-G (Dukler + ABB-Deviated).
2. Zone 3, change to Water-Hydrocarbon, Check ADF, Disallow Yw, Improve.
3. Zone 4, Set Vm = 0, clicking on the 'No Flow' button.

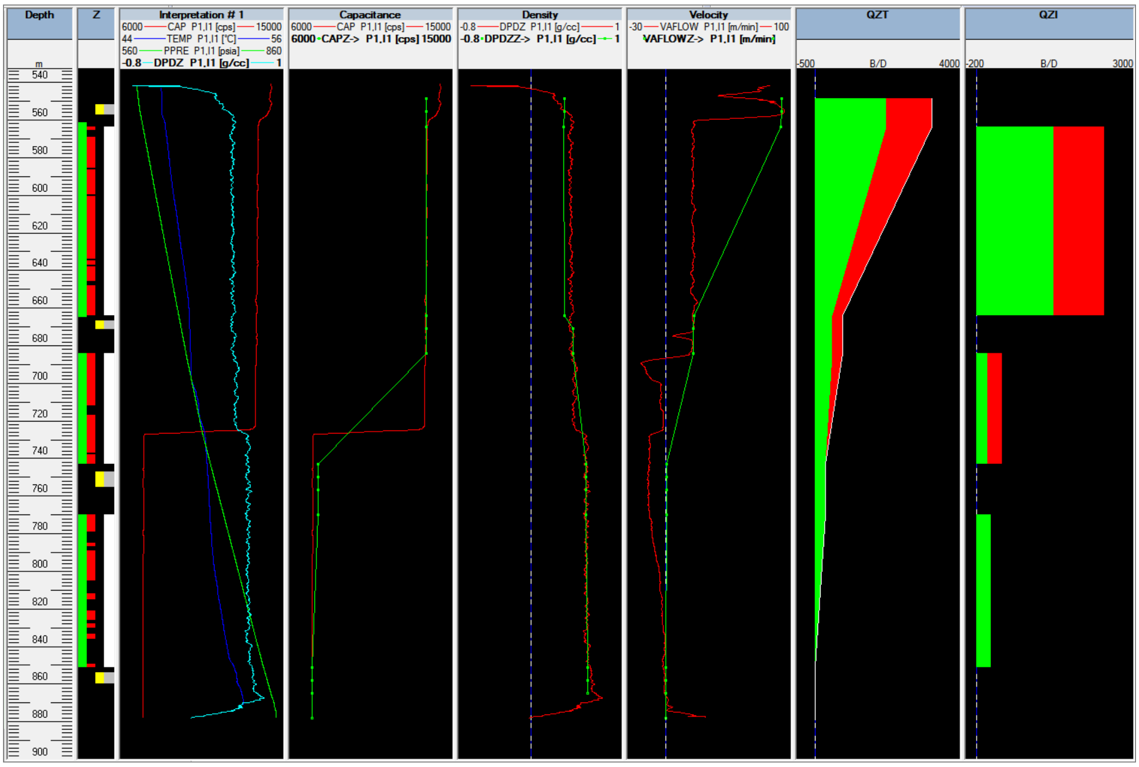


Fig B04.8 • Schematic logs

B04.3 • S.I.P.

➢ Move to the 'Special' page and select SIP. The following IPR options are given:
- Straight line, Fetkovitch, LIT relations.
- Surface/reservoir conditions.
- P or m(p) for gas production.
- Composite IPR (sum of all zones).

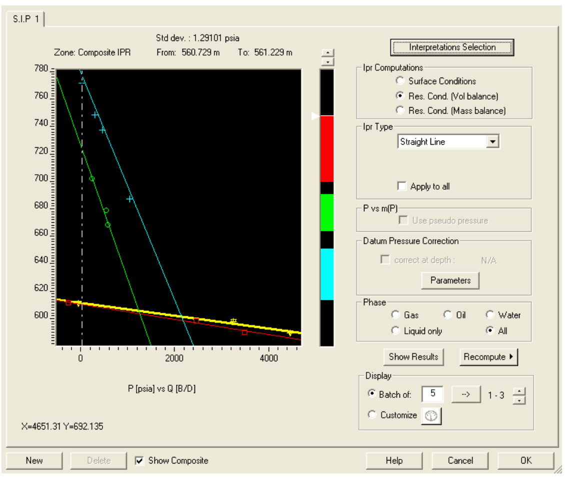


Fig B04.9 • S.I.P

➢ Click on 'Parameters' and define the reference depth at 560 m.

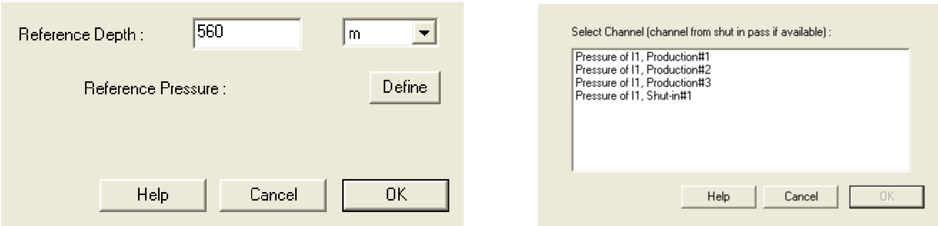


Fig B04.10a&b • S.I.P. parameters

➢ Click the 'Define' button in the dialog to select Shut-In #1 for the reference pressure.

After validating your inputs, click the box 'correct at depth:'… When all pressures are corrected to a common datum, all the inflow curves (here the lines) should cross the Y axis at the same location. A discrepancy is representative of cross-flow. In the Shut-in #1 survey the spinner is certainly not stable causing the difference.

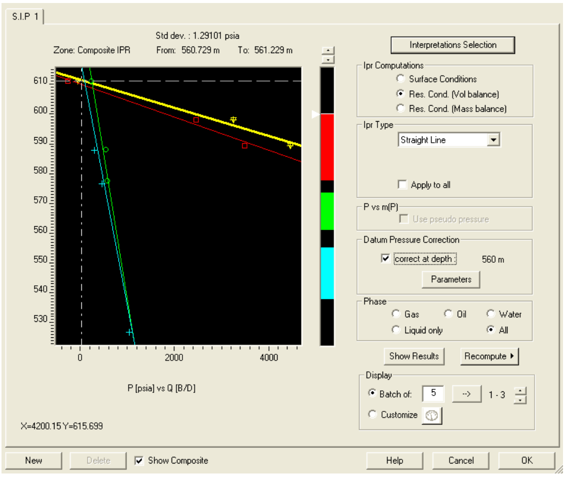


Fig B04.11 • S.I.P.

B04.4 • Temperature

On Production #1, we will redo the interpretation but instead of using the Apparent Downflow model inside the casing we will use the temperature.

➢ In survey Production #1, create a new interpretation #2 from Interpretation #1. Select the PVT, the spinner calibration and the input channels for copy. Do not copy the calculation zones.

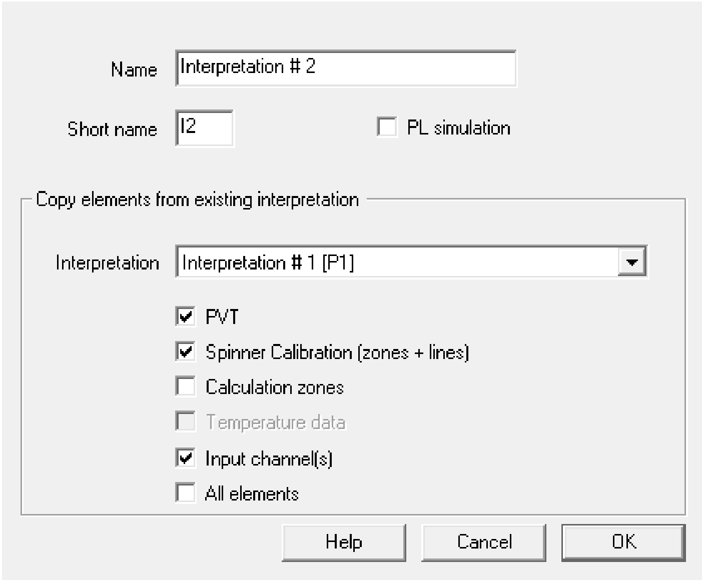


Fig B04.12 • New interpretation

Change method, Init, and enable the Standing water option

- Change to 'Continuous' method and Init based on 'Surface rates and inflow types'.

When matching the temperature those two choices should be the norm. The Continuous method will seek an agreement between the simulated and measured temperature everywhere. If we used the 'Zoned method' each calculation zone would consider 2 residual points for the regression, one at the bottom of the inflow above, the other at the top of the inflow below. Usually working only on those discrete points is not sufficient, unless there is a very large number of inflow zones.

For Init, i.e. finding an initial solution, the 'Zone local values' option amounts to running a local regression on each zone focused for the temperature on the two residuals mentioned above. Because those regressions are run in isolation, and because they use only those 2 control points, the result is sometimes erratic. With the 'Surface rates and inflow type' option, on the other hand, the starting point is obtained by splitting the overall production evenly among the inflow zones.

- In the 'Reference channels' tab check the 'Flow through standing water up to' and enter 726 m.

We know that the water present inside the casing is not flowing to surface. However, by default, Emeraude will only come up with a water holdup if this water is mobile. This means that we will either have a water production at surface or else, end up with solution showing water production and a water thief zone. One way of dealing with such a situation is to use the 'Standing water option', which will allow a water holdup to be calculated with no water flowing.

Activating the Temperature calculation

- Go to the 'Temperature' tab.
- Click 'Simulate Temperature' and 'Match temperature'.
- Select 'Segmented model'.
- Answer yes 'Convert the HLC' (Heat Loss Coefficient).
- Enter delta P (Joule Thomson) = 30 psia.

The geothermal profile could be defined by a point and a gradient, but this will be done interactively instead.

- Validate with OK. A warning indicates that the geothermal profile is undefined. We are going to define it now.

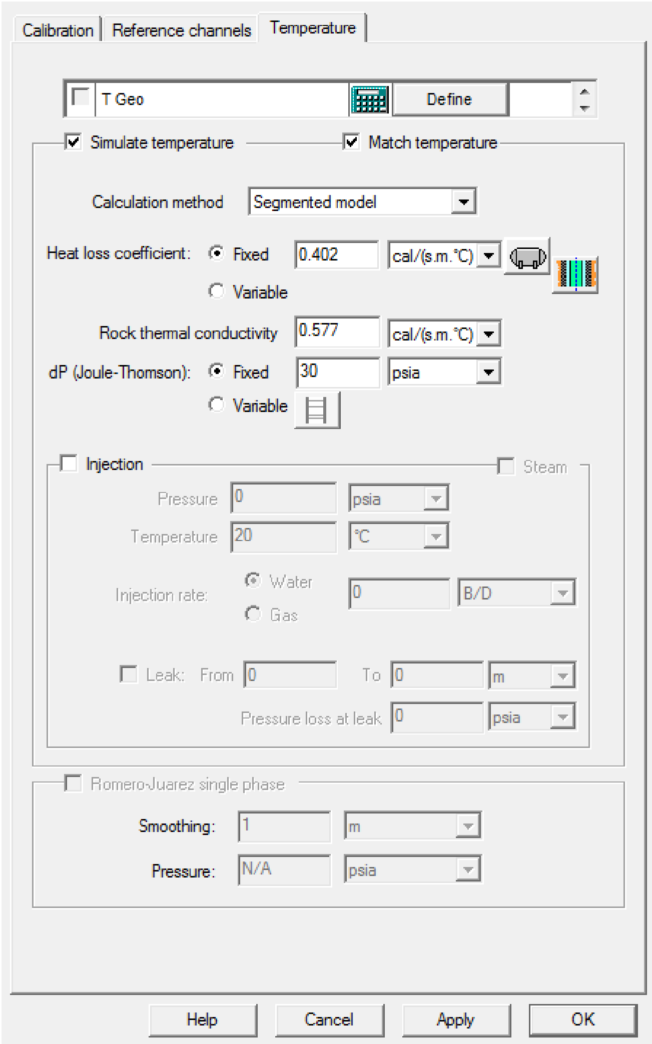


Fig. B04.13 • Interpretation settings

Definition of the geothermal profile

After the previous step, Emeraude added a Temperature match view on the screen.

- Maximize this view, with a double click on its title bar.
- Open the data browser and select the interpretation temperature in Interpretation#2.
- Click on the geothermal profile definition button (or right click and select this option in the browser popup menu).
- Click the mouse around 833 and drag to about 847 m. While dragging, the defined geothermal profile appears alongside the temperature channel, Fig B04.14.

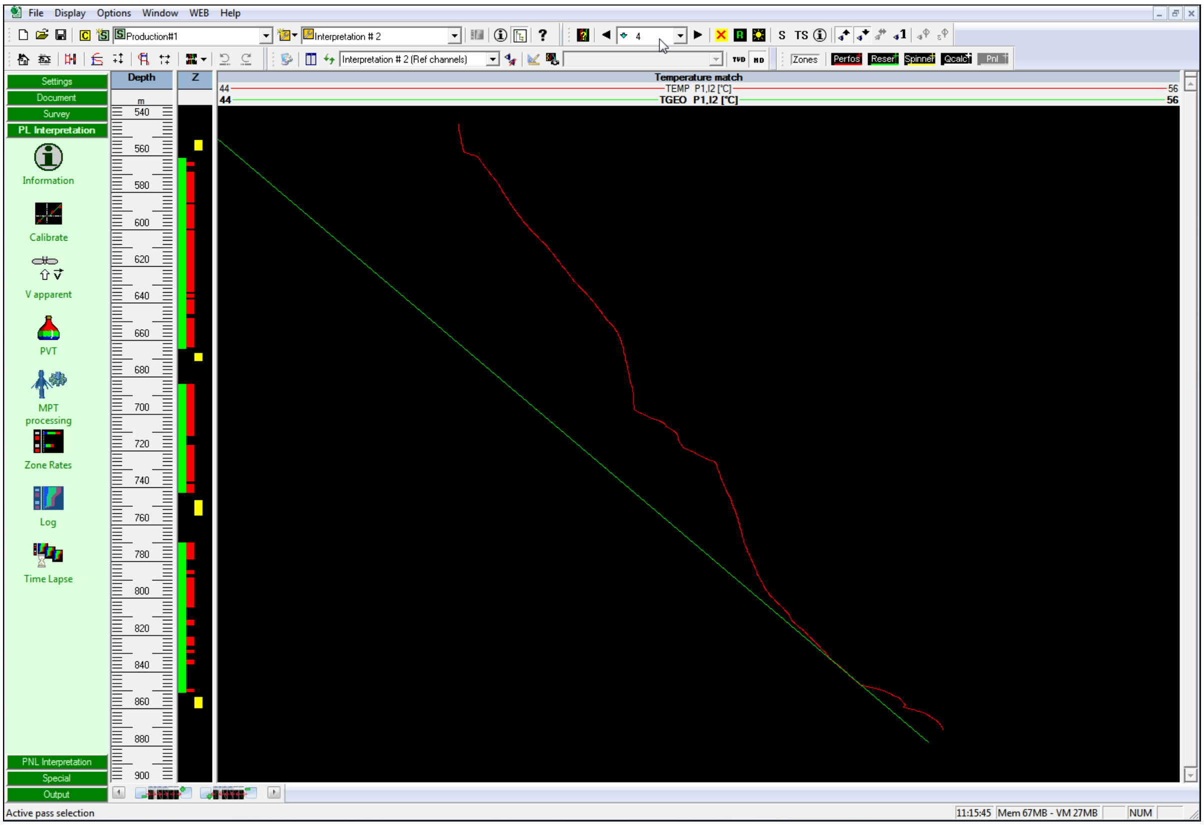


Fig. B04.14 • Defining the geothermal profile

- Go back to the ‘Temperature’ tab of the ‘Information’ dialog.
- Click on the calculator button to access the geothermal gradient parameters. Ensure that the values are 833m for the reference depth, 51.65°C for the reference temperature and 0.025°C/m for the temperature gradient and enable the ‘Correction for varying deviation’, Fig B04.15.

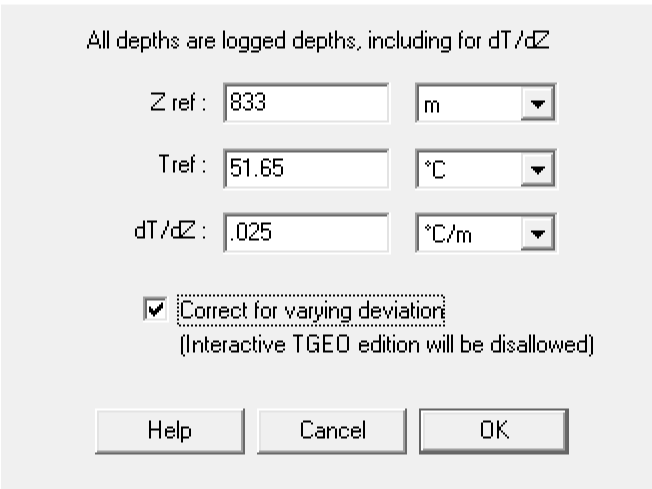


Fig. B04.15 • Geothermal profile parameters

- Restore the match view size and the previous screen layout.

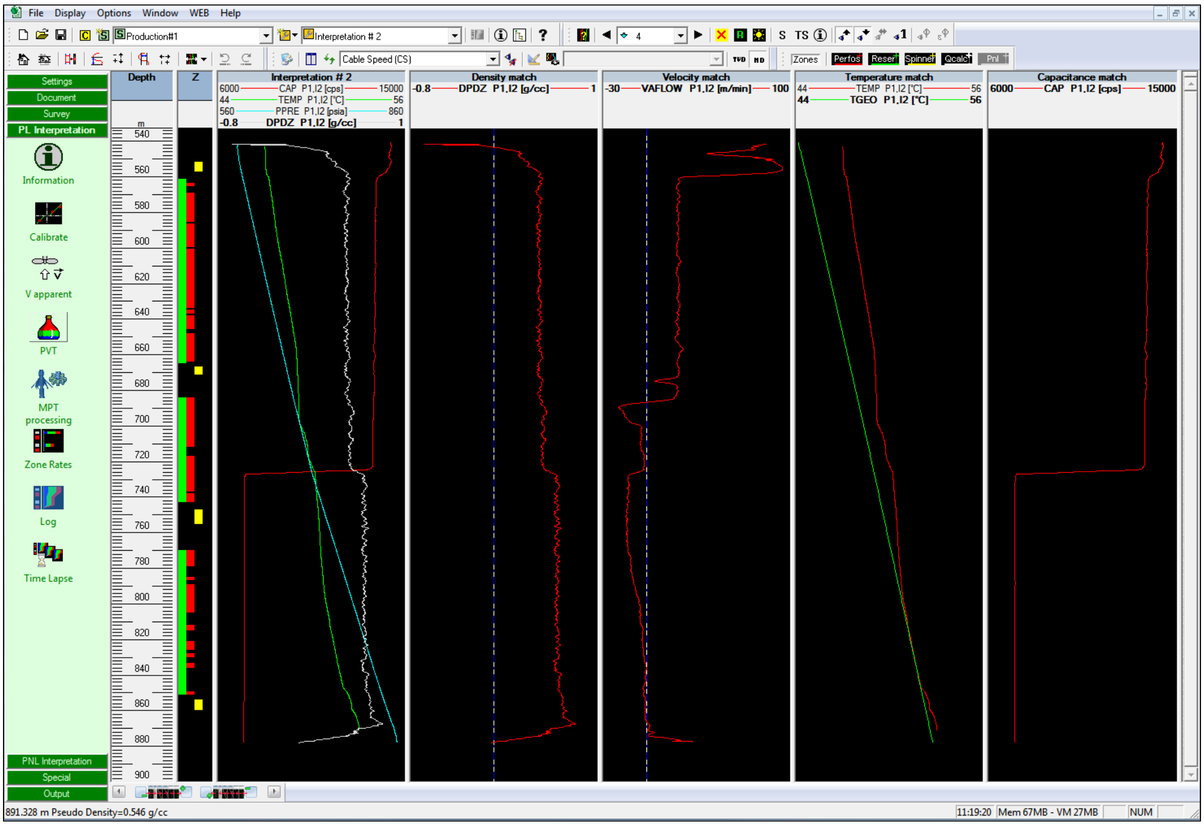


Fig. B04.16 • Geothermal profile

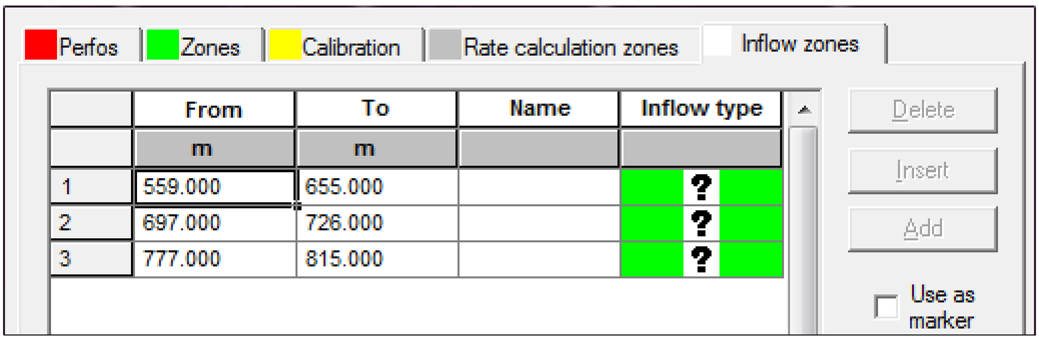
Refining the inflow zones

- ➢ Click on the 'Qcalc' zones button of the toolbar and create zones 'Same as Spinner' calibration zones.

By maximizing the Temperature match views, you can pinpoint the fluid entries and it is clear that the default inflow zones (in white in the Z-track) need to be resized. This can be done interactively, on the basis of the temperature profile alone. Note that you could also generate and use a temperature derivative channel as an additional guide.

For the sake of this session we will define the inflow zones by keyboard input.

- ➢ Select the Zones option (or double-click in the Z track) to access the grid where the inflow zone limits can be edited. Enter the values: 559 - 655; 697 - 726; 777 – 815 m.



	From	To	Name	Inflow type
	m	m		
1	559.000	655.000		?
2	697.000	726.000		?
3	777.000	815.000		?

Fig. B04.17 • Inflow zones

Hiding the irrelevant section of the data

With the Continuous method the goal is to match all the supplied data everywhere and it is critical that we hide the sections where our model will not reproduce the measurements. There are 2 such sections: (1) the part where re-circulation occurs and (2) the part between the bottom of the top inflow and the sliding sleeve. The reason why we need to hide this second section is that the temperature reacts to the flow as the fluid comes out of the formation. In other words, for the top zone, the temperature sees behind the tubing. On the other hand, the spinner, the density and the capacitance, only see the fluid when it enters the tubing through the sliding sleeve. If we do not hide the top section on those curves, there will be no way to match simultaneously all data and the regression will end up with an erroneous 'in-between' solution. We use the browser 'Hide parts' option to edit the VAFLOW curve first.

- Hide the data between 681 and 840 m (recirculation part).

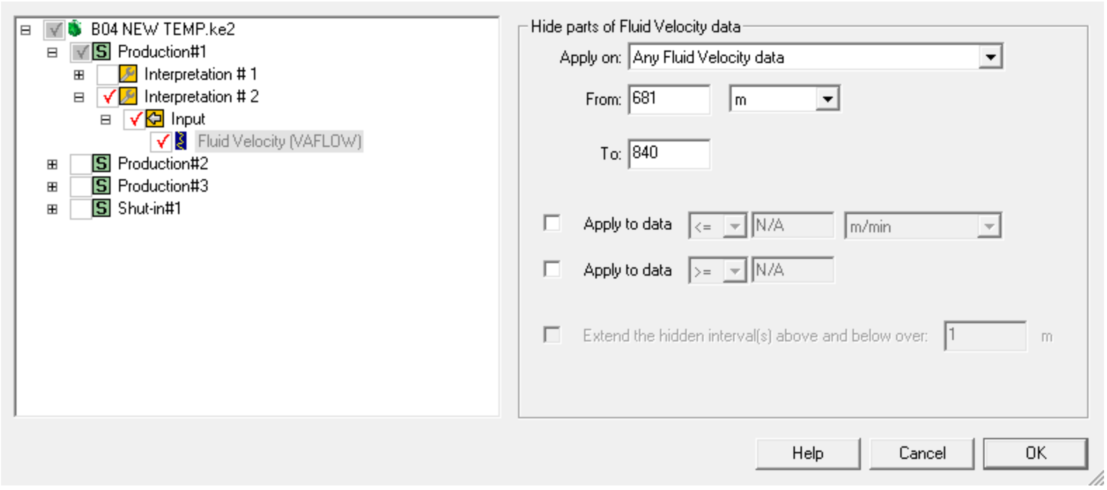


Fig. B04.18a • Recirculation zone; hiding VAFLOW

- Repeat this operation on the range 555 – 655 m (top zone production below the sliding sleeve).
- Choose to 'Apply on': 'Any type of data' and inside the Interpretation #2 Input, tick the DPDZ and CAP channels as shown below:

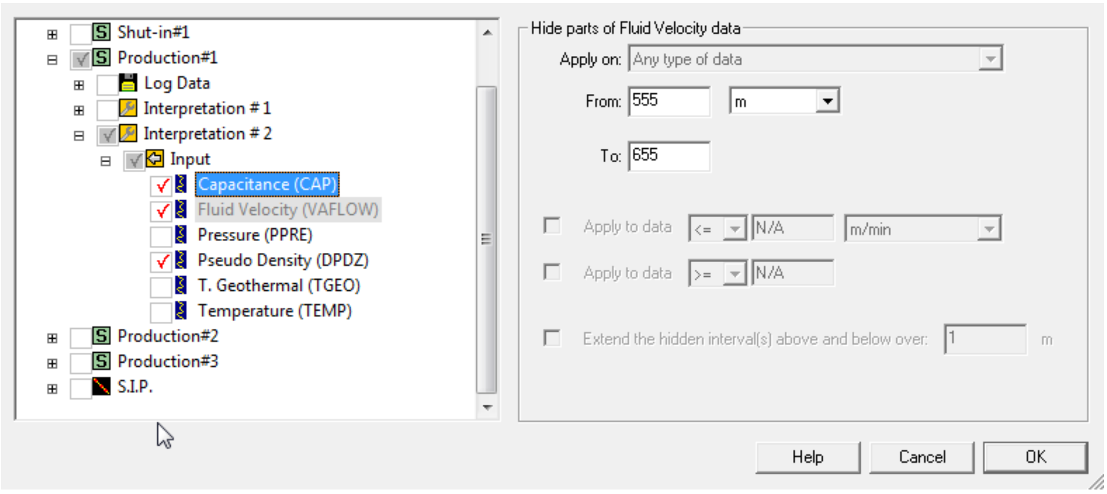


Fig. B04.18b • Top zone; hiding VAFLOW, DPDZ, and CAP

The top of those 3 curves shows large variations and would probably deserve more editing but we will leave them unchanged in our case.

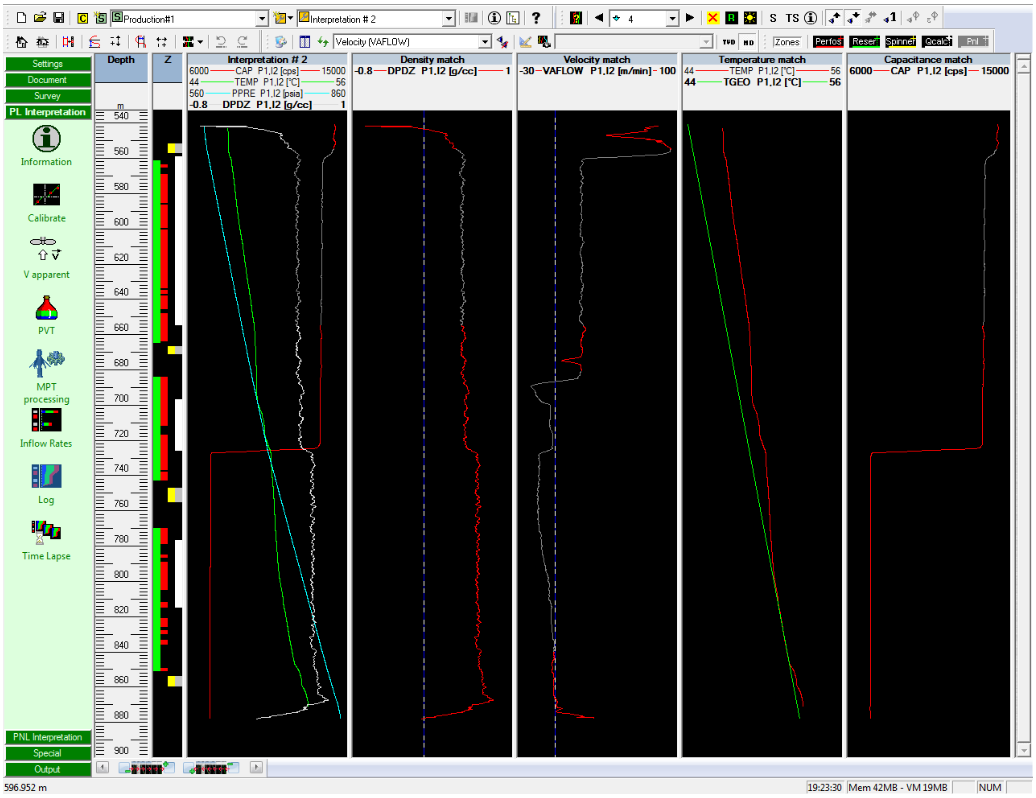


Fig B04.19 • After hiding parts on VAFLOW, DPDZ, CAP

Inflow Rates

- Select 'Inflow Rates'.
- Select 3-Phase L-G; accept the defaults (Dukler and ABB-deviated) with OK.

You are driven to the 'Contributions' tab, because the Continuous method was selected. It can be seen that the bottom zone has been set to 'No Flow' automatically.

- Check 'Match surface conditions'.
- dQw is 0 for all zones; lock those values (you can click on the 'Lock' header button to lock all of them at once).
- Set dQg= 0 for inflow 3 and lock.
- Check 'Heat loss coefficient as a variable'.
- Uncheck 'Constrain slippage sign'
- Select 'Global Improve'. You can see the schematics updated during the nonlinear regression.
- Exit 'Zone Rates', Fig B04.21.

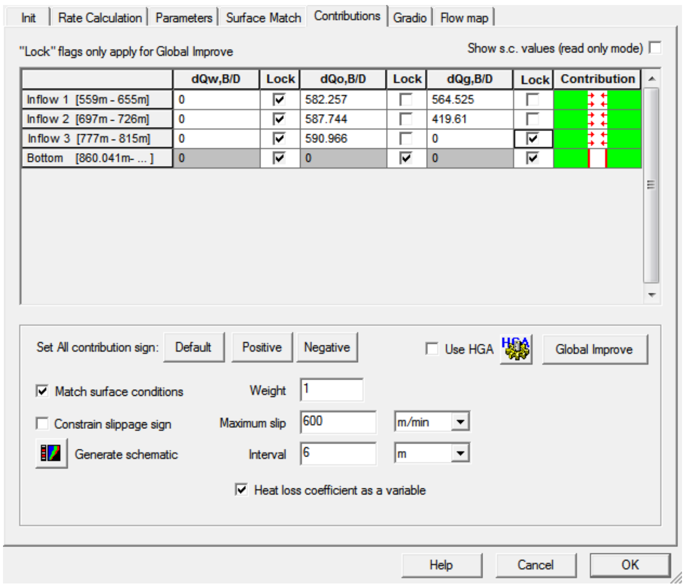


Fig B04.20 • Contributions tab

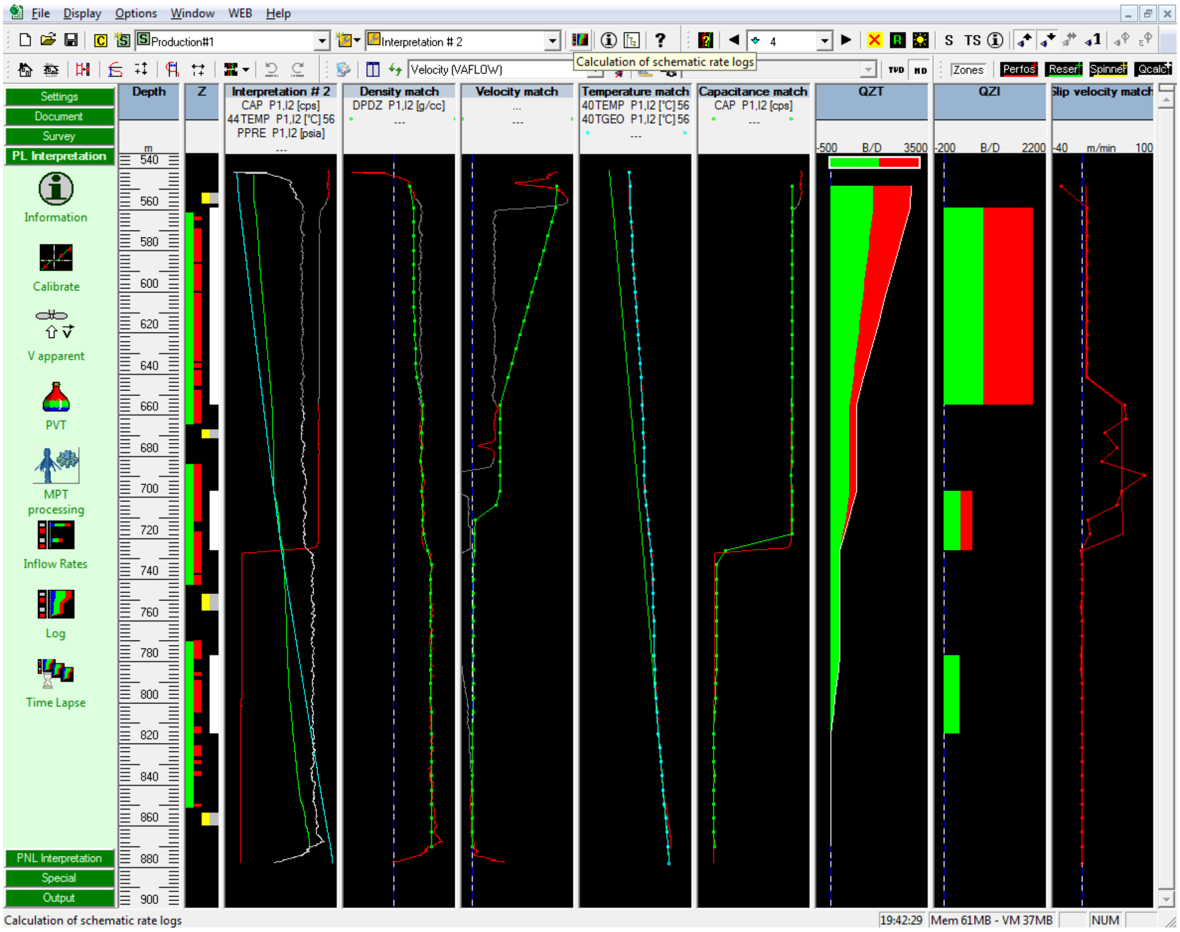


Fig B04.21 • Schematic logs

The final match shows an agreement with the overall behavior of the data. The match with temperature is fairly close everywhere and the temperature is the one mostly driving the solution here. The match on VAFLOW is slightly poorer and we could change the weight to have a better match on the tubing section between the top two reservoirs. Perhaps the capacitance calibration end points should be revised as well, as we see on the top a lack of agreement between the DPDZ and CAP curves. Any of those changes could be made easily and the Global Improve re-run.

As the Continuous model was used, some freedom was given to the holdups compared to the slip model predictions. The slip velocity match track displays the slip model predictions (solid lines) and the deviations to obtain the match, which is very small.

This concludes Guided Interpretation #4.