TGT

Product True Flow

Horizontal Flow

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Flow diagnostics perfected for horizontal wells

#KnowYourFlow

Product True Flow

Horizontal Flow

The new Horizontal Flow product powered by Cascade3 overcomes the drawbacks of conventional production surveys, delivering a continuous flow profile in a wide range of completion and reservoir scenarios, including fractured formations. Horizontal Flow profiles reflect activity in and out of the reservoir, delivering the truest picture possible of inflow and outflow downhole.

Hydrocarbon reservoirs are generally more horizontal in shape than vertical, so it makes sense that horizontal wells drilled through them provide more contact and productivity than vertical wells. However, the economic and efficiency gains of horizontal wells is matched by the complexity of managing them and the reservoirs they drain. This hefty task rests with the asset teams that must recover the maximum quantity of hydrocarbons in the safest, cleanest, and most economical way possible.

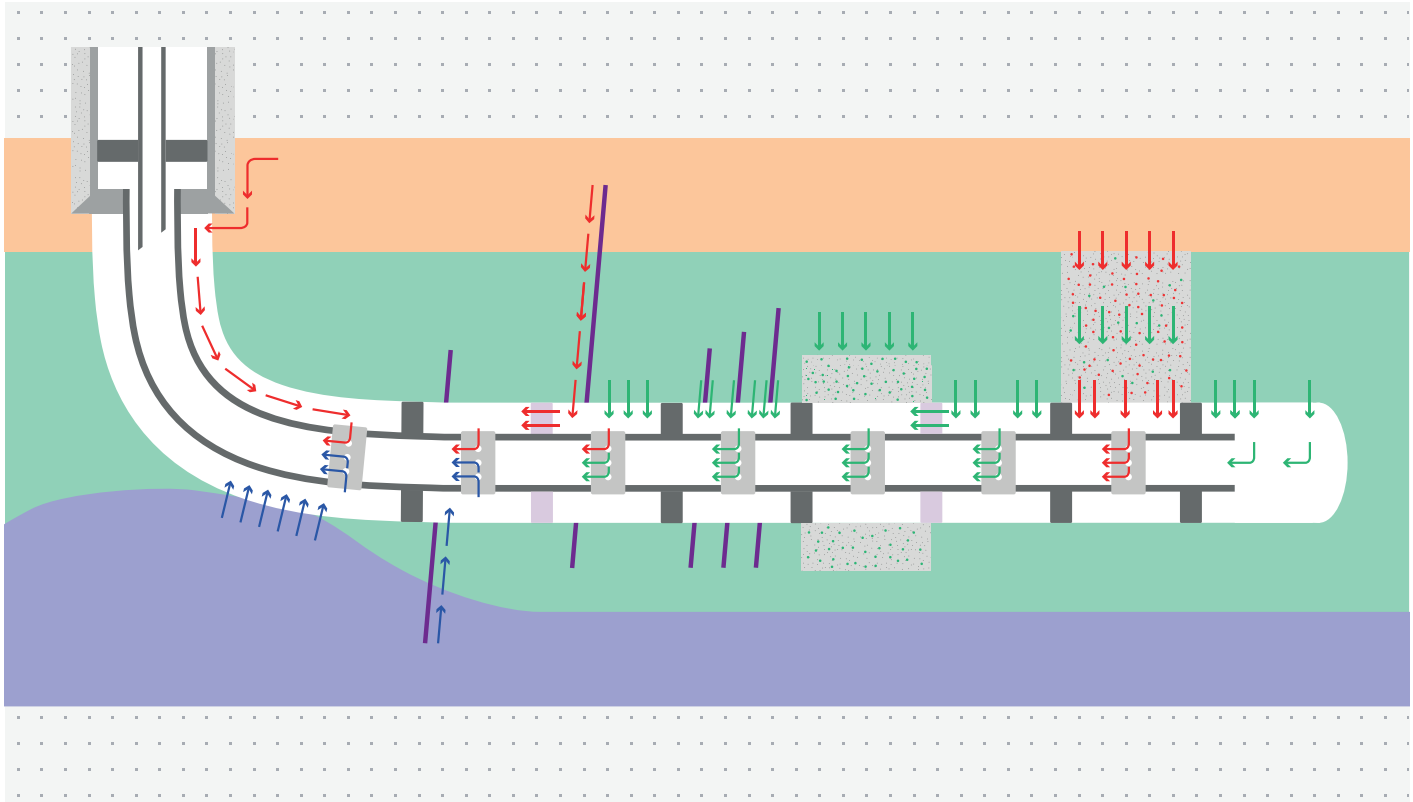
TGT's new Horizontal Flow diagnostics with Cascade3 technology has been created to provide asset teams with the flow insights they need to manage horizontal well and reservoir performance more effectively.

Underpinning Horizontal Flow is the all-new Cascade3 flow analysis platform. Cascade3 is purpose-built for horizontal wells and incorporates the industry's most advanced thermodynamic and hydrodynamic modelling codes to transform temperature, pressure and other well system data into accurate and continuous reservoir flow profiles. Cascade3 combines with three other proprietary platforms to make Horizontal Flow the perfect choice for diagnosing flow in horizontal wells.

Equipped with the right information, asset teams can take direct action to keep well and reservoir performance on track.

Flow inside the wellbore of a horizontal well can be challenging to decipher, but flow outside the wellbore is even more complex, and way beyond the reach of conventional surveys.

Horizontal Flow leverages Cascade3 and the True Flow system to deliver the truest picture possible of inflow and outflow downhole, even in the most challenging wells.



Decoding flow dynamics

Understanding flow dynamics in the well system is the key to unlocking better well and reservoir performance, and this is especially true for horizontal wells. Flow inside the wellbore of a horizontal well can be challenging to decipher, but flow outside is even more complex, and way beyond the reach of conventional production (PL) surveys. Horizontal Flow powered by Cascade3 and the True Flow system can decode the complex scenarios that are typical in horizontal wells, revealing flow where it matters most—at the reservoir.

Zone #1
Gas is channelling through the casing shoe and liner hanger entering the well at Zone #2. And water is coning at the heel.

Horizontal Flow locates the fluid inflow at the shoe and the heel and tracks it to the ICD in Zone #2.

Zone #2
Gas is entering the well from the shoe/hanger integrity failure in Zone #1 and water due to coning.

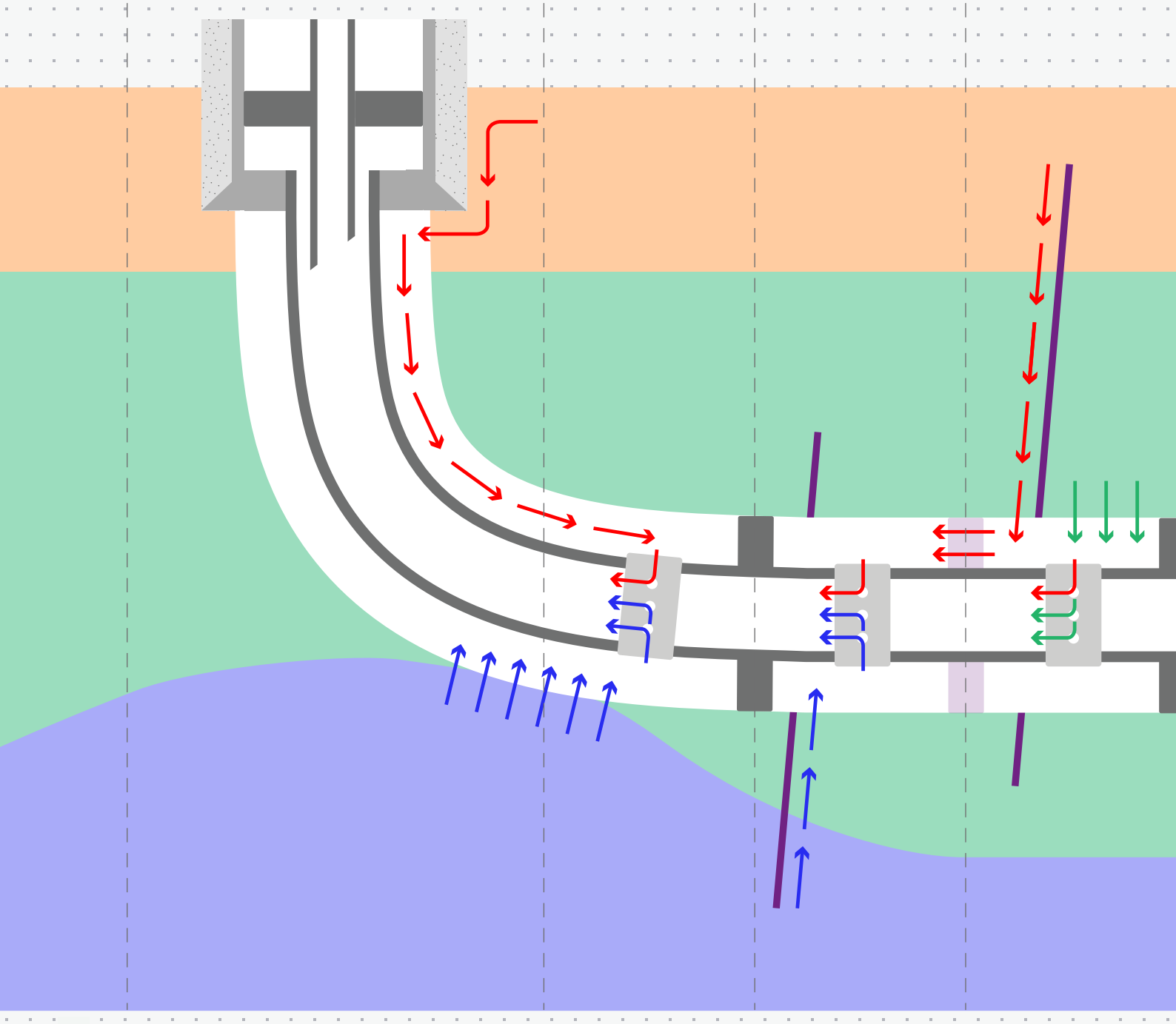
Horizontal Flow provides the insights necessary to track the gas and its origin, as well as providing a flow profile for the water entry.

Zone #3
Fractured zone with main fracture connecting to the water layer. Gas is also entering the well from Zone #4 via a failed packer.

Horizontal Flow diagnoses both scenarios.

Zone #4
Fractured zone with the main fracture connecting to the gas layer, providing a conduit for gas to enter the well, alongside the oil.

Horizontal Flow locates the fracture and delivers a continuous flow profile across the zone.



Zone #5
Fractured zone providing high permeability for oil flow.

Horizontal Flow measures relative contribution of each fracture.

Zone #6
Low permeability zone restricts oil flow into the completion. However, oil from Zone #7 enters the ICD via the failed packer.

Conventional PLT would assume Zone #6 was producing, whereas Horizontal Flow reveals that the true flow is sourced from Zone #7.

Zone #7
Normal zone with oil producing naturally from the reservoir, entering the ICD but also entering Zone #6 via a failed swell packer.

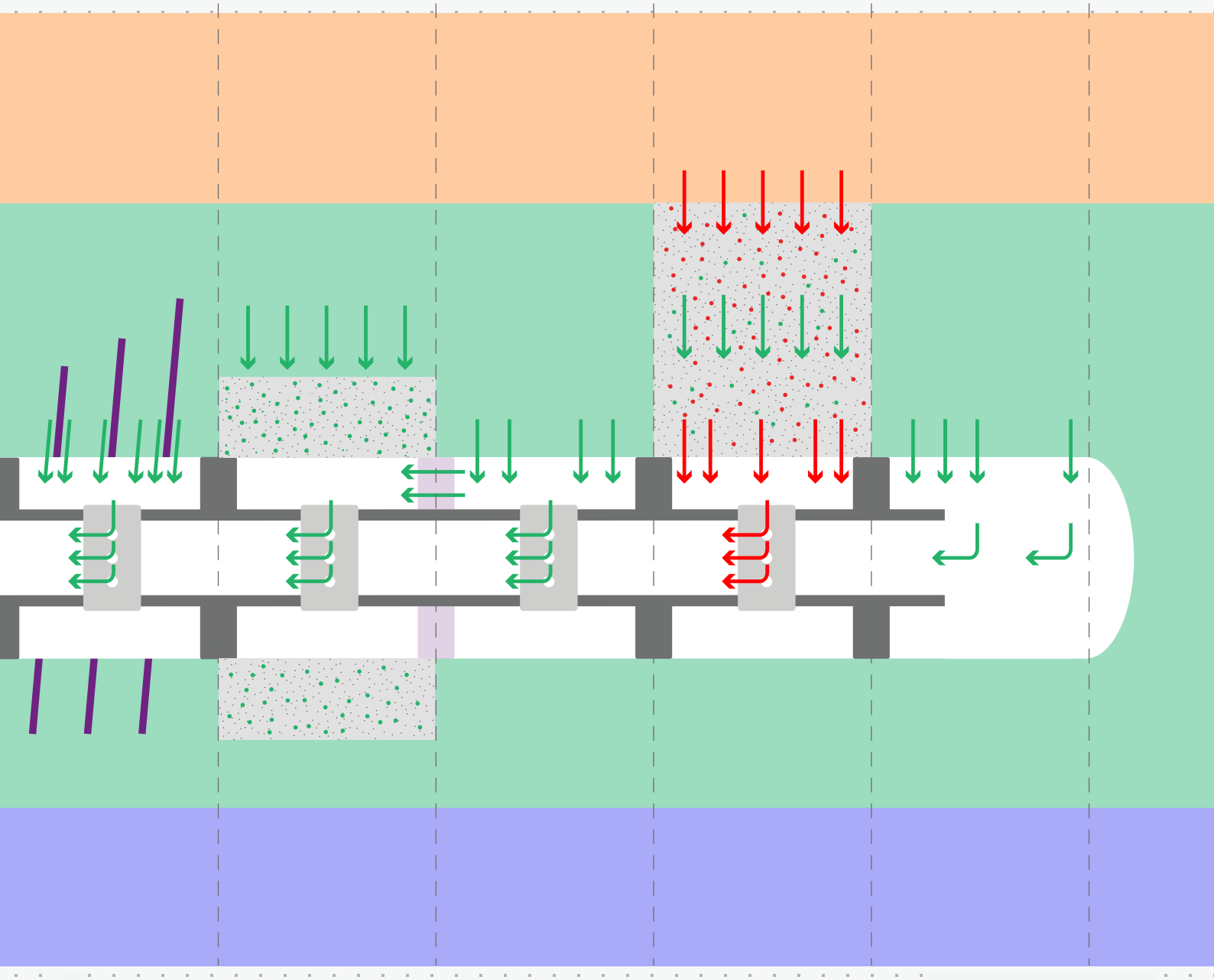
Horizontal Flow delivers reservoir flow profile that reveals non-uniform production across the zone.

Zone #8
Low permeability zone is conductive to gas with higher mobility that bypasses the oil.

Horizontal Flow deliver the gas flow profile across the zone.

Zone #9
Open hole section producing at the toe.

Horizontal Flow delivers a continuous flow profile in open hole as well as cased sections.



Reservoir performance

The hydrocarbon 'reservoir' is probably the most valuable and challenging asset managed by the operating company. Complex at the outset, reservoir complexity is amplified tenfold when wells are drilled and fluids are extracted or injected, disturbing a balance that existed for millennia. As a result, Reservoir Engineers must deal with tremendous uncertainty to maximise hydrocarbon recovery, reduce operating costs, and extend economic life.

At the heart of reservoir management is the 'dynamic reservoir model'. Used as a basis for field development decisions, investments, and reserves estimations, the robustness and accuracy of the model is critical to success. Inaccuracies can ultimately lead to poor decisions and huge losses.

The model is regularly updated by Reservoir Engineers by 'history matching' as more data is collected. Insights from Horizontal Flow and Cascade3 can play a vital role in history matching, reducing the uncertainty envelope and helping to improve the model.

The continuous flow profiles from Horizontal Flow provide a clear quantification of reservoir performance as it feeds the well system. Unlike standard wellbore surveys [PLTs] that can be corrupted by completion or reservoir integrity issues, Horizontal Flow delivers a reliable reservoir flow profile in a wide range of completion scenarios.

In particular, the continuous profile and its sensitivity to low rates provides a more accurate measurement of 'effective pay length', a key metric in making production forecasts and reserves estimates.

Horizontal Flow with Cascade3 also comes into its own with fractures. Natural or hydraulically induced fractures can transform the performance of a well or reservoir, and provide an unwanted pathway for water or gas breakthrough. Chorus acoustics can identify fractures along the wellbore and Cascade3 incorporates code that caters for the linear flow that occurs within them, providing an assessment of fracture contribution.

One of the most challenging and important tasks faced by Reservoir Engineers is preventing water or gas breakthrough. The deeper understanding of downhole flow dynamics provided by Horizontal Flow can provide an early warning of precisely where water or unwanted gas is reaching the well.

In addition to reservoir flow profiles, Cascade3 will output several parameters that Reservoir Engineers can use to validate existing reservoir assumptions. For example, effective pay length will impact production forecasts and reserves estimates. Other parameters such as reservoir pressure, permeability, and skin factor can be qualitatively corroborated.

Reservoir Engineers must deal with tremendous uncertainty to maximise hydrocarbon recovery, reduce operating costs, and extend economic life. The continuous flow profiles from Horizontal Flow provide a clear quantification of reservoir performance as it feeds the well system, enabling Reservoir Engineers to solve daily challenges with confidence and certainty.

Well performance

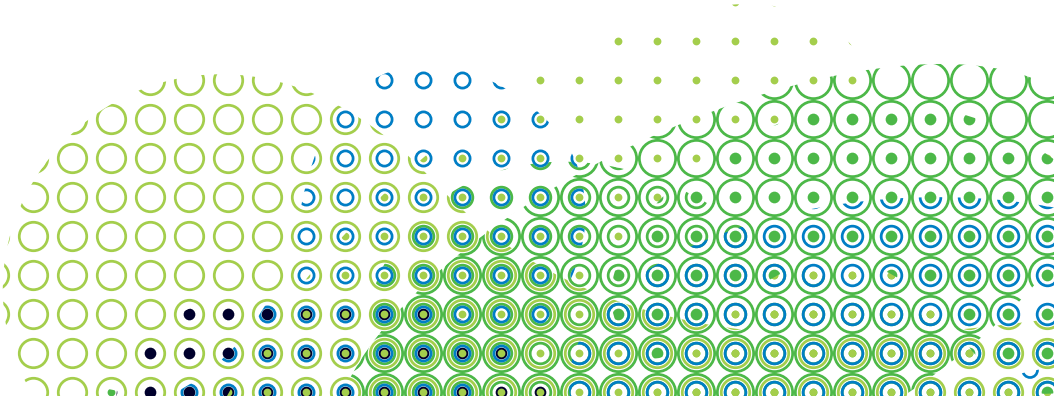
Horizontal wells are impressive feats of engineering, made possible by the ingenuity of the engineers and ground-breaking technology used to drill and complete them. Each well represents a significant resource investment and is designed to provide optimum contact with the reservoir, tapping hydrocarbon reserves with maximum efficiency. Production Engineers and the wider asset team are responsible to ensure that each well system performs to expectations, maintaining production targets and maximising recovery.

The performance of each well depends on the dynamic relationship between the well completion and the reservoir that surrounds it, and this in turn depends on the behaviour of completion components and the reservoir. To manage the well system effectively, Production Engineers need full visibility of fluids and flows downhole from the reservoir sandface to the wellbore and all points in between. The continuous flow profile from Horizontal Flow with Cascade3 delivers that visibility in a wide variety of completion and reservoir scenarios.

One of the key challenges faced by Production Engineers when surveying flow downhole is measuring real production or injection performance in the presence of complex completions. Integrity issues and zonal isolation or component failures can lead to scenarios where the profile of fluids in the wellbore is not the same as the profile at the reservoir. In these cases, standard production logs (PL) will give false or misleading results. Horizontal Flow diagnostics overcomes these issues by providing a definitive flow profile irrespective of completion, integrity, or zonal isolation issues. Furthermore, it can identify these issues and guide successful workover interventions.

Viscous fluids, fluid segregation and low flow rates can also confuse standard PL sensors, leading to a false picture of flow downhole. Horizontal Flow incorporates temperature and acoustic measurements that respond to all types of meaningful flow, overcoming the limitation of PL sensors and delivering a more accurate and continuous flow profile that asset teams can depend on. Equipped with a reliable flow profile, Production Engineers can measure ‘effective pay length’, which is fundamental to managing production, optimising completion designs and making reserves estimations.

Another key benefit is identifying early water or gas breakthrough and guiding remediation measures to maintain production targets. Assessing injection compliance is another advantage, and Horizontal Flow’s ability to expose the performance of completion elements such as inflow control devices and swell packers can be used to target repairs and inform future completion designs.



Asset performance

A key objective of Petroleum Engineers and asset teams is to maximise ultimate recovery whilst minimising operating costs, thereby lowering overall cost per barrel. Horizontal Flow diagnostics can help on both sides of the equation.

Developing fields with horizontal wells represents a significant investment in time, energy, and resources. Diagnostics play a key role in tracking well and reservoir performance and steering confident asset team decisions.

Horizontal Flow will expose well system inefficiencies and guide asset teams to problem areas in the completion or the reservoir. Equipped with a clear diagnosis of the entire well system, asset teams can act with greater certainty of a positive outcome.

Horizontal well interventions can be costly and time consuming, often requiring specialised equipment such as coiled tubing, composite rod, or tractors for well access. Horizontal Flow with Cascade3 provides a more complete and accurate downhole assessment, which means that diagnostic deployments will provide a wealth of information from a single programme, providing maximum insights and avoiding the need for subsequent deployments.

And when workovers are deemed necessary, the ability to plan and target workovers with greater precision means that they are also more efficient and effective, saving time and cost, and delivering better outcomes.

A key objective of Petroleum Engineers and asset teams is to maximise ultimate recovery whilst minimising operating costs, thereby lowering overall cost per barrel. Horizontal Flow diagnostics can help on both sides of the equation. And when workovers are deemed necessary, the ability to plan and target them with greater precision means that they are more efficient and effective, saving time and cost, and delivering better outcomes.

Environment

Horizontal Flow diagnostics can help operators reduce the environmental impact of oil and gas production in several ways, ultimately reducing their emissions and 'carbon per barrel' overhead.

Developing and producing oil and gas consumes an enormous amount of energy from diesel engines or gas turbines that produce carbon dioxide. Flaring of unwanted associated gas is also a major source of emissions. Combined carbon dioxide emissions from global upstream operations are estimated to be 1 GtCO2 each year, and methane emissions are even higher, at 1.9 GtCO2e. Horizontal Flow diagnostics help operators reduce emissions by revealing inefficiencies in energy-intensive operations, reducing the need to flare, and improving the efficiency of intervention operations that consume energy.

Water injection is responsible for roughly 40%† of total CO2 emissions in a typical oilfield. Horizontal Flow can assess whether all injected water is reaching the target and reveal thief zones. In many cases, diagnostics lead to a reduction in pumped volumes and emissions, and increased field production. Water production is another source of emissions. Produced water needs to be managed and treated at surface, consuming energy; and more water typically means less oil, reducing ultimate recovery and increasing carbon per barrel.

Gas flaring is estimated to release 310 MtCO2 each year or 30% of all upstream CO2 emissions. Horizontal Flow can identify sources of unwanted gas downhole and guide remediation plans, reducing the need to flare and the resulting emissions.

Workovers and diagnostic interventions in horizontal wells can also have a significant carbon overhead due to the energy-hungry equipment involved. Horizontal Flow can minimise this overhead in two ways compared to a conventional approach.

Firstly, the Horizontal Flow programme will provide a more accurate and far-reaching flow profile than a conventional PL survey, and in a wider range of well system settings. Crossflow, fractures, and integrity failures can confuse PL surveys, whereas Horizontal Flow will enable analysts to handle these issues with ease. This reduces the risk of an incomplete assessment and the need for subsequent surveys, and improves the efficiency of decision making. Complementing the survey programme with array sensors will provide the most complete multiphase flow analysis possible.

Secondly, once equipped with reliable information, asset teams can plan and target workovers with greater certainty and precision. This means that equipment and operations can be optimised to execute with higher efficiency and success rates, leading to better outcomes and lower emissions.

Developing and producing oil and gas consumes an enormous amount of energy from diesel engines or gas turbines that produce carbon dioxide. Flaring of unwanted associated gas is also a major source of emissions. Horizontal Flow diagnostics can help operators reduce the environmental impact of oil and gas production in several ways, ultimately reducing their emissions and 'carbon per barrel' overhead.

† Source Rystad Energy, EnergyCube, 2021

Applications and benefits
Horizontal Flow diagnostics are designed to help asset teams solve daily challenges with confidence and certainty. Whether its locating water or gas breakthrough, understanding fractures, or maintaining an accurate reservoir model, Horizontal Flow delivers the insights needed by asset teams to keep well and reservoir performance on track.

The range of applications and benefits delivered by Horizontal Flow are perfectly aligned with the needs of Reservoir Engineers in managing reservoir performance, and Production Engineers in managing well performance. The accurate reservoir flow profiles from Horizontal Flow are fundamental to driving both.

Asset performance / Asset teams

Applications
Accessing reliable flow profiles
Locating water/gas breakthrough
Maintaining an accurate reservoir model
Measuring effective pay length
Making accurate reserves assessments
Revealing crossflow
Assessing ICD's and packers
Locating and assessing fractures
Maintaining well integrity
Understanding well system dynamics
Making production forecasts
History matching

Benefits
Increase ultimate recovery
Reduce opex and cost per barrel
Reduce CO2 emissions
Optimise life-of-asset production
Extend economic asset life
Minimise water or unwanted gas
Maintain or increase production capacity
Maintain well integrity
Improve dynamic reservoir model
Improve sweep efficiency
Optimise reservoir and well completion strategies
Understand and optimise drive mechanisms
Optimise fracture programmes
Identify thief zones and reduce injected water
Better asset management decisions
Better asset performance

Economic benefits
Reduce opex and unit cost per barrel
Increase cashflow, NPV, PIR and IRR
Accurate reserves assessment

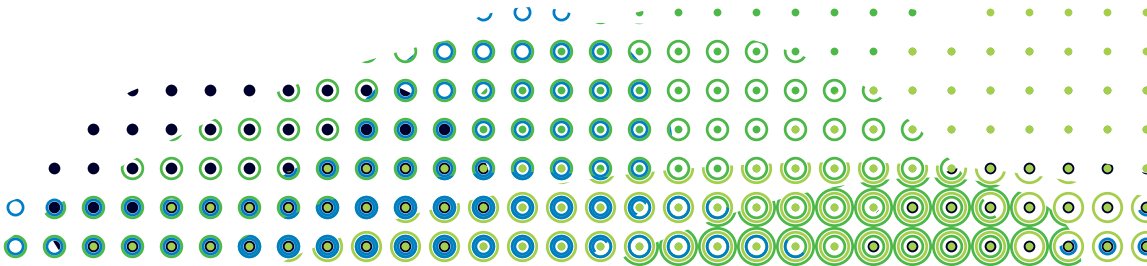
Environmental benefits
Reduce CO2 emissions
Reduce water injection
Reduce water production
Reduce unwanted gas production and flaring
Minimise energy consumption

Reservoir performance / Reservoir Engineers

Applications	Benefits
Locating water/gas breakthrough	Increase ultimate recovery
Maintaining an accurate reservoir model	Maintain or increase production capacity
Accessing reliable flow profiles	Reduce CO2 emissions
Locating and assessing fractures	Reduce opex and cost per barrel
Making accurate reserves assessments	Minimise water or unwanted gas
Revealing crossflow	Improve sweep efficiency
Making production forecasts	Accurate continuous flow profiles
Measuring effective pay length	Improve dynamic reservoir model
Understanding reservoir dynamics	Reduce uncertainty envelope
History matching	Validate dynamic reservoir model parameters
Locating and assessing fractures	Make accurate reserves assessments

Well performance / Production Engineers

Applications	Benefits
Accessing reliable flow profiles	Maintain or increase production capacity
Locating water/gas breakthrough	Optimise life-of-well production
Measuring effective pay length	Reduce CO2 emissions
Assessing ICD's and packers	Minimise water or unwanted gas
Locating and assessing fractures	Reduce opex and cost per barrel
Maintaining well integrity	Maintain well integrity
Making production forecasts	Increase ultimate recovery
Revealing crossflow	Extend economic well life
Assessing injection compliance	Accurate continuous flow profiles
Diagnosing flow in open hole	Optimise fracture programmes
Diagnosing flow in smart completions	Identify thief zones and reduce injected water
Understanding well system dynamics	Optimise completion designs
	Make accurate well production forecasts



Case study#1
Accurate flow diagnostics for a horizontal gas well used to optimise development of a low-permeability reservoir

Challenge

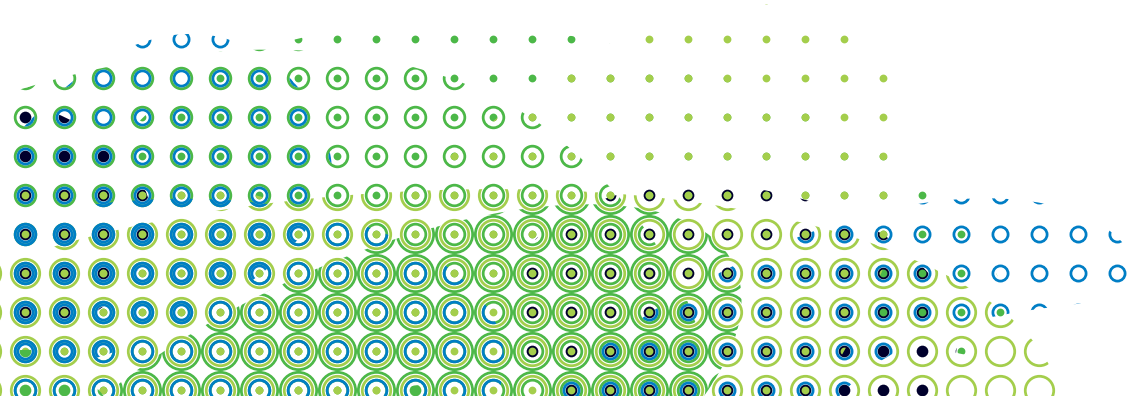
Producing gas from low-permeability reservoirs is always challenging, and making the correct field development decisions is crucial to success. Operators have to consider issues such as well type and configuration, and wellbore length for each geological or reservoir setting. Accurate gas production profiles from early wells help operators make the right field development choices.

Decisions made in the early stages of field development can have a huge impact on asset economics and longevity. In this case, the operators faced a particular challenge, as obtaining accurate production profiles in horizontal wells with uncemented slotted liners is extremely challenging for conventional PLT spinners. This is because of the complex gas flow regimes in the wellbore and the potential for the reservoir flow to be substantially different from the wellbore flow.

Solution

TGT's new Horizontal Flow diagnostics, powered by Cascade3, overcomes many of the challenges that hamper conventional production logs. It delivers a more reliable and complete assessment of flow dynamics in horizontal wells across a wide range of completion scenarios, thereby enabling petroleum engineers and asset managers to keep well and reservoir performance on track.

The Cascade3 flow analysis platform is purpose-built for horizontal wells and incorporates the industry's most advanced thermodynamic and hydrodynamic modelling codes. These enable Horizontal Flow to transform temperature and other well-system data into continuous reservoir flow profiles. These reflect flow activity both into and out of the reservoir, thereby delivering the most accurate picture of reservoir behaviour and downhole inflow and outflow. In this case, Horizontal Flow diagnostics enabled the field operator to evaluate the production profile and verify that it was consistent with the expected permeability distribution, that is, it matched the known reservoir properties and the current dynamic reservoir model.



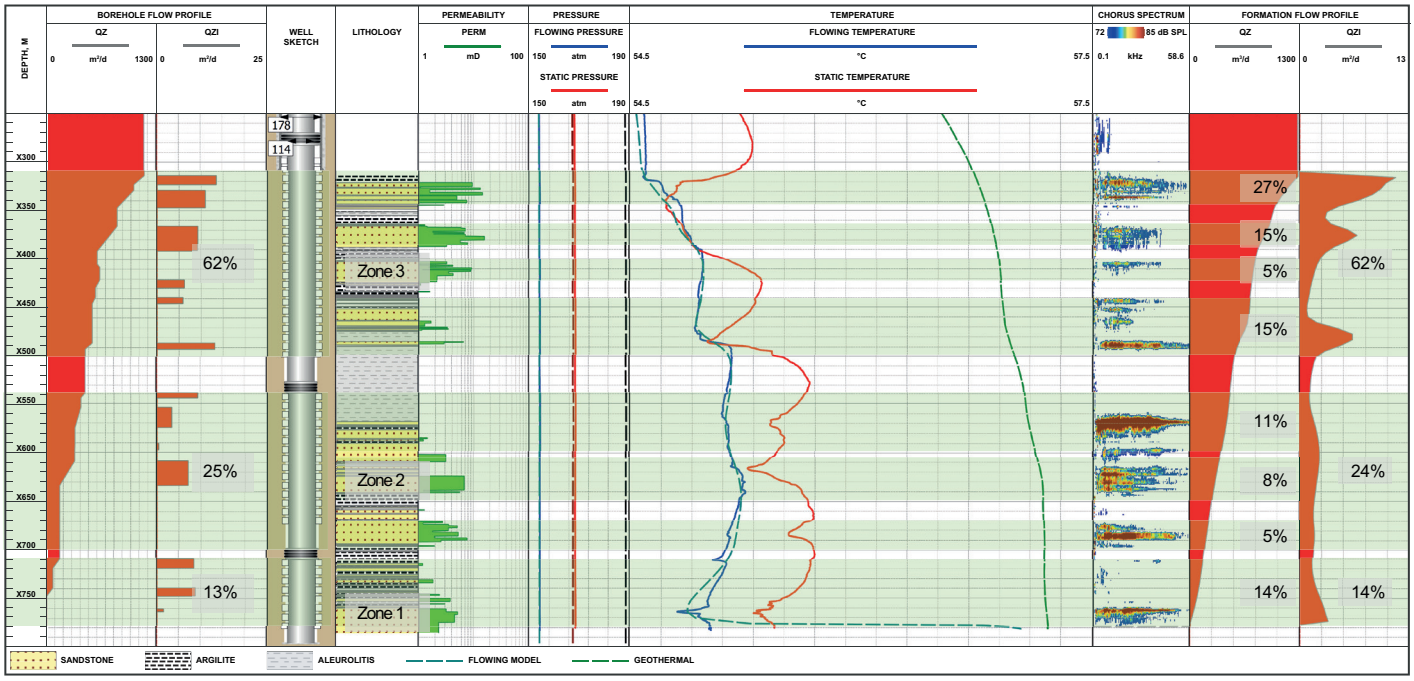
The Horizontal Flow survey confirmed that the production profile in this gas producer was consistent with the expected permeability distribution. In terms of total flow contribution from each zone, there is good agreement between Horizontal Flow with Cascade3 (14%, 24%, 62%) and standard PLT results (13%, 25%, 62%), but only Horizontal Flow showed the true reservoir flow profile from each layer. Relying on PLT results alone could have led to suboptimal field development decisions.

Result

Horizontal Flow diagnostics with Cascade3 and Chorus delivered an accurate gas-production profile for a horizontal well that had been drilled in a low-permeability, gas-bearing formation. The subject well was completed using a slotted liner across three zones separated by swellable packers. The contribution of each active permeable unit was accurately quantified with a continuous flow profile. The survey defined production contributions from each of the reservoir subunits, thereby improving the hydrodynamic reservoir model and making it possible to optimise subsequent wells in the ongoing field-development programme.

The Horizontal Flow survey confirmed that the target formations and the toe of the well would make economically viable contributions to production. The toe of the well is the main zone of concern for horizontal gas producers, and operators need to know whether production from that zone will overcome pressure drop and friction to contribute as effectively as the heel part of the well. The results of this survey showed no significant production loss for the well towards the toe. This supported expectations based on reservoir properties and confirmed that horizontal wells are a good option for developing this field.

Horizontal Flow diagnostics with Cascade3 justified the drilling of horizontal wellbores in this low-permeability clastic reservoir and gave the operator confidence to proceed with the existing field development plan. Building on the results of this survey, the operator is planning further horizontal gas producers in this and similar fields.



Case study#2
Identifying gas breakthrough in a horizontal oil producer with multistage fractures helps to optimise fracture design

Challenge
Low-permeability oil rim reservoirs can be developed using horizontal wells and multistage fractures. The challenge for operators is to find a hydraulic fracture design that improves production while minimising the risk of gas or water breakthrough from adjacent formations. Fluid breakthrough harms well economics and can lead to significant environmental impacts, for example, through the need for gas flaring.

Predicting and preventing water or gas breakthrough is one of the most important tasks faced by reservoir engineers. Operators will typically use pressure-transient analysis to assess fracture sweep efficiency, but this provides only average fracture parameters. A deeper understanding of downhole flow dynamics can provide an early warning of the locations where water or unwanted gas is reaching the well.

A horizontal well had been drilled into the oil rim of a low-permeability reservoir formation and hydraulically fractured in 12 stages. The gas/oil ratio for the well was high, indicating a potential issue with the fracture design that would need to be addressed before delivering or completing further wells in the field.

Solution
TGT's new Horizontal Flow diagnostics with Cascade3 technology has been created to provide asset teams with the flow insights they need to manage horizontal well and reservoir performance more effectively. This technology can locate fracture entry points and accurately quantify flow in horizontal well systems. This enables operators to assess the fluid contributions from various fractures and porous matrix zones across a wide range of completion designs.

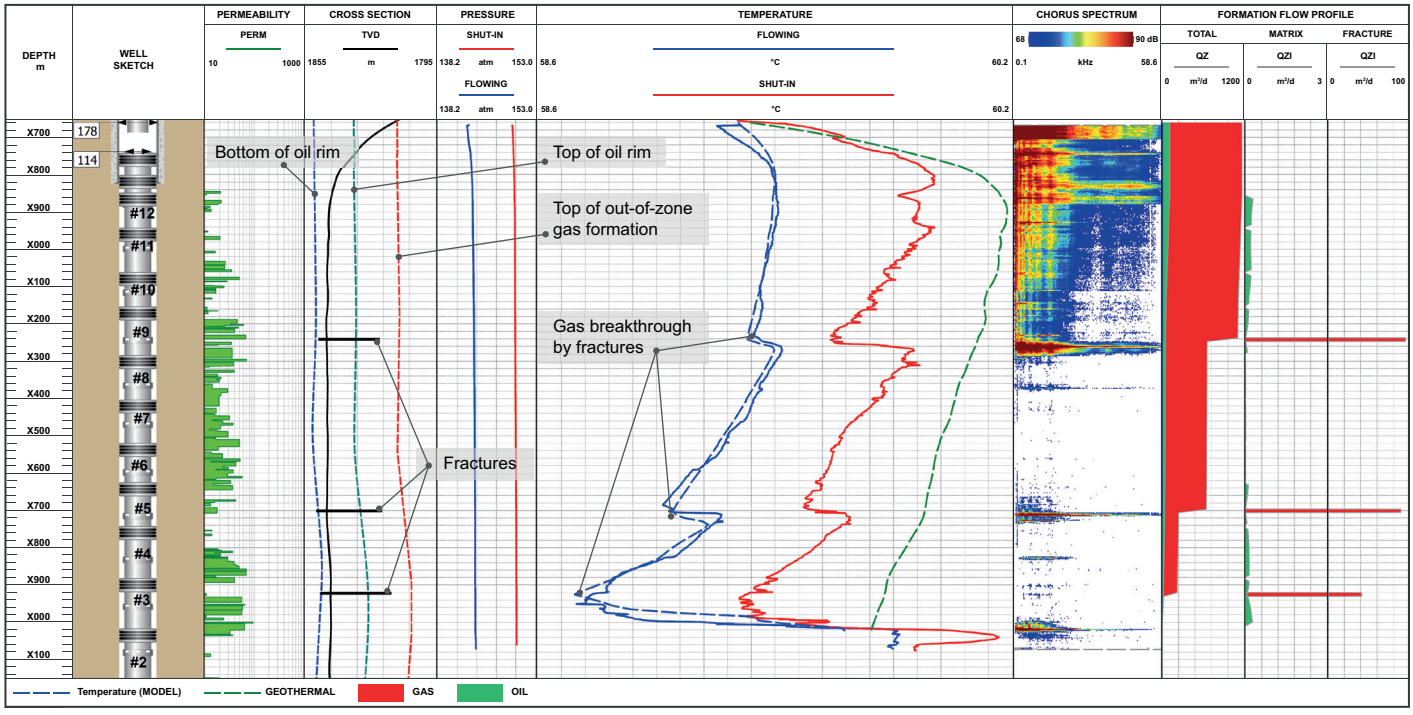
In this case, combining Cascade3 flow modelling and Chorus acoustic sensing would enable TGT analysts to locate and quantify the gas breakthrough zones present in the well, assess current 'out-of-target' fracture size and potential fracture growth, and confirm the source(s) of gas inflow.

Horizontal Flow diagnostics with Cascade3 and Chorus technology identified three gas breakthough zones and estimated potential fracture growth for these fractures. Estimated fracture size is shown in 'cross section' track. The results confirmed fracture propagation to an out-of-zone gas bearing formation. The QZI track shows three zones contributing to the gas inflow. There is minor oil contribution from the target formation. The higher formation pressure of the gas-bearing zone reduces the oil contribution from the target formation.

Result

The Horizontal Flow survey identified three gas breakthrough zones responsible for the well's high gas/oil ratio and estimated potential fracture growth, thereby indicating how far the fractures penetrated into the overlying gas-bearing formation. Fracture entry points behind the liner were assessed using the Chorus platform. This also revealed fractures in the target oil-bearing formation that were idle or non-productive owing to the gas breakthrough.

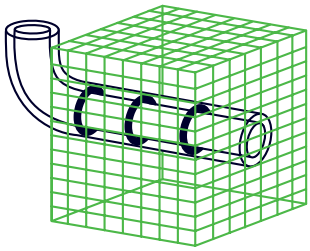
In this well, the completion contained swellable packers, which meant that gas-producing zones could be mechanically shut off. For future wells, the operator has redesigned the fracture programme so that production from the low-permeability oil rim can be maximised while preventing gas breakthroughs caused by out-of-zone fractures. Reducing the fracture pressure was identified as the most effective way to achieve this.



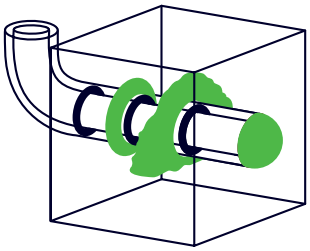
Cascade3 features
Many features combine to make Horizontal Flow with Cascade3 the most powerful flow diagnostic resource ever created for horizontal well systems.

At the heart of Cascade3 is Torrent – a remarkable modelling and simulation engine that predicts the hydrodynamic and thermodynamic behaviour of fluids and their surroundings as they flow through the well-reservoir system.

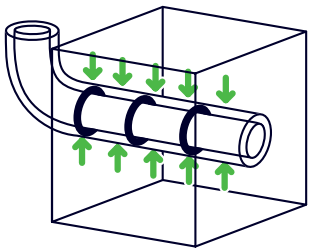
Torrent features a unique 3D fine-grid modelling framework and can simultaneously solve three distinct flow patterns – radial, spherical, and linear flow in fractures – reflecting the three main types of flow that occur in a horizontal well system. Apart from providing a more realistic flow modelling environment, these features mean that Horizontal Flow with Cascade3 delivers accurate continuous flow profiles in a variety of typical completion and reservoir settings, including fractured formations.



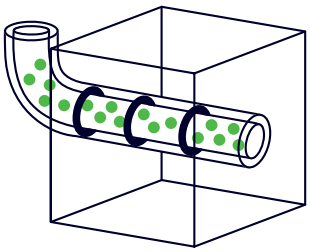
3D Fine grid
Flow moves in all directions through and around the well system. The 3D fine-grid modelling framework of Cascade3 provides a detailed workspace for accurate simulations that deliver clear and reliable flow modelling results.



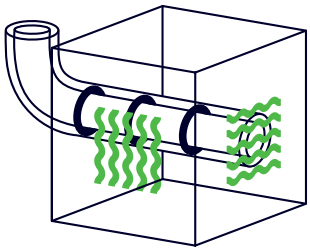
3x flow patterns
Flow moves in all directions through and around horizontal well systems has three main patterns: radial, spherical, and linear flow in fractures. Cascade3 is coded to handle all three to provide a robust computation of the real flow downhole, at all points along the well.



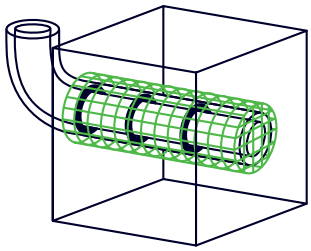
Actual reservoir flow
Conventional production surveys can only measure flow inside the liner, but flow in and out of the reservoir is what matters most. Horizontal Flow diagnostics delivers both, providing the most complete assessment possible of flow downhole.



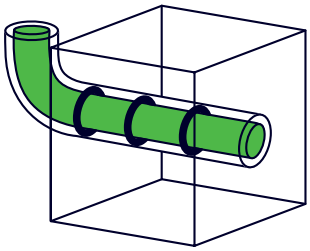
Continuous flow profile
Gaps or blind spots in the flow profile can lead to an incorrect assessment of well and reservoir performance. Horizontal Flow delivers a continuous flow profile to ensure that each zone is continuously assessed, without the gaps.



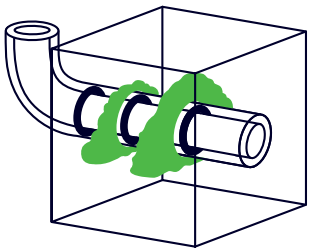
Hydrodynamics & Thermodynamics
Fluids in motion downhole are governed by the laws of hydrodynamics and thermodynamics. Cascade3 uniquely combines both, to decipher and quantify flow dynamics throughout the well system.



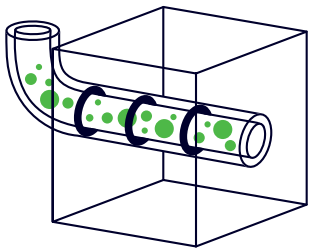
80 parameters
Horizontal well systems are impressively complex and dynamic. Cascade3 captures more than 80 input parameters, including well history, reservoir, and completion parameters to provide an immersive modelling environment for the well and the reservoir.



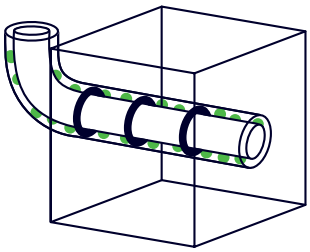
All completion types
Petroleum engineers design the well completion in harmony with the reservoir to maximise recovery. Cascade3 caters for all completion types, including uncemented liner, fracture ports, and barefoot, providing reliable flow profiles in all scenarios.



Fractures
Natural or induced fractures are a common feature in horizontal wells, and understanding how they affect performance is critical. Horizontal Flow reveals fracture locations and measures their flow performance.



Varied fluids & flows
Low flow rates and viscous fluids can confound conventional production surveys, causing gaps or 'blind spots' in the flow profile. Horizontal Flow cleverly combines temperature and acoustic measurements that work in all types of fluids and flow.



Flow behind liner
Conventional surveys are not equipped to locate or measure flow behind the liner, a common feature of horizontal wells. Horizontal Flow uses acoustics and Cascade3 to map and measure flow throughout the well system, even behind the liner.

A systematic workflow

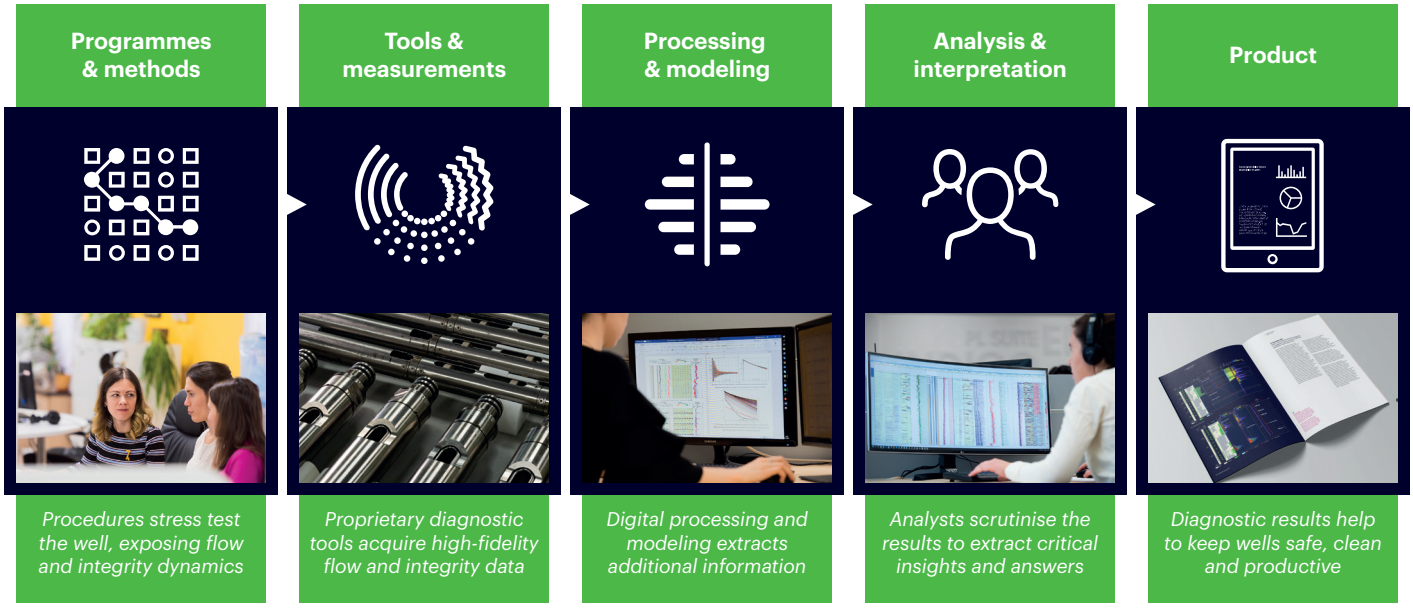
Analysts delivering Horizontal Flow follow a systematic workflow that starts with defining a survey programme to meet customer objectives. This 'programmes and methods' stage includes collecting information about the well and the reservoir. Up to 80 parameters are gathered, including well production/injection history, completion details, reservoir and PVT properties, pressure, and geothermal gradients. This data is used to build the hydrodynamic and thermodynamic models in Torrent and inform the survey programme.

The survey programme is designed to capture critical well and reservoir performance data as the well system is activated in various flowing and non-flowing states over specific time periods. The survey is the second stage of the workflow where proprietary 'tools and measurements' are deployed into the well. Principal measurements include high-precision temperature and advanced spectral acoustics with the Chorus platform. This stage can last several days depending on the complexity of the well system and the customer objectives.

'Processing and modelling' is the next stage where the analyst integrates all data into the model and begins refining it, comparing simulated outputs with actual measurements. Torrent computes several key outputs according to model parameters, including simulated temperature and pressure profiles and a continuous reservoir flow profile. Then crucially, the analyst adjusts key model parameters until there is a robust match between the measured and simulated temperatures and pressures. Parameters that are known with great certainty are not adjusted, and when a realistic match is achieved, the flow profile output becomes the definitive answer.

This stage overlaps with the next 'analysis and interpretation' stage, as the analyst balances observations, experience, and expert judgement to iterate the model until a coherent and robust answer is delivered. Their insights, answers and commentary are then packaged into the final Horizontal Flow answer product for personal delivery to the customer's asset team.

A systematic workflow
Analysts delivering Horizontal Flow follow a systematic workflow to ensure delivery of an accurate and comprehensive answer that meets customer objectives.



Platform partners

Analysts delivering Horizontal Flow use Cascade3 alongside three other technology platforms—Chorus, Indigo and Maxim, that together constitute the 'True Flow' system.

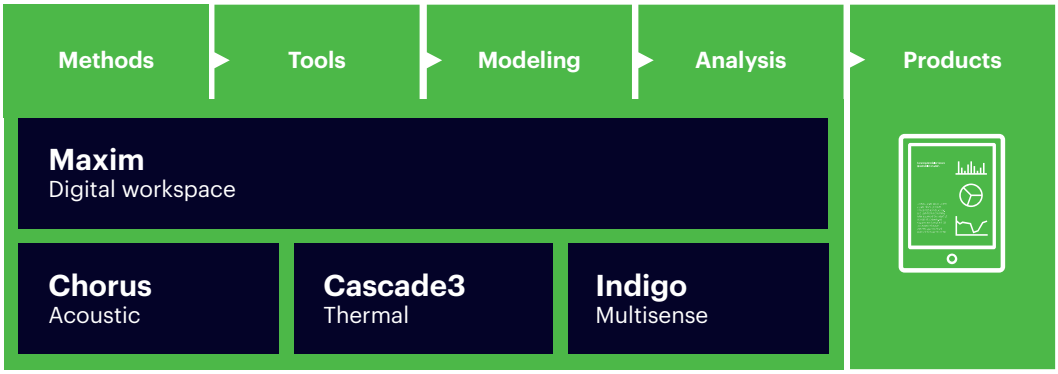
Each platform has a specific role in providing Horizontal Flow insights. Whereas Cascade3 quantifies flow activity by modelling and simulating temperature and pressure changes in the well system, Chorus locates and characterises flow activity by sensing and imaging acoustic energy. For example, Chorus data can help the analyst distinguish between wellbore flow, reservoir or matrix flow and fracture flow, and provide a clear indication of active zones. And both temperature and acoustic data can help distinguish between liquids and gas.

Multisensory Indigo provides a host of wellbore measurements, including high-precision temperature that feeds into Cascade3, pressure, and a range of standard and unique production sensors, as well as real-time data transmission to surface. High-precision temperature by itself is a powerful indicator of flow events in the well system, as changes in flow activity along the well often manifest as tell-tale temperature changes.

Maxim is the digital workspace where analysts plan the diagnostic programme, integrate, and process the acquired data, and perform the modelling and in-depth analysis delivered in the final Horizontal Flow answer product.

If additional fluid phase information is required from the wellbore, array sensors can be combined with the True Flow system to evaluate multiphase flow and map fluid segregation.

Overall, Cascade3 and the Horizontal Flow answer product represent one of the most important advances in well-reservoir diagnostics for decades. Equipped with a more accurate and complete understanding of flow dynamics downhole, asset teams can deliver effective well and reservoir management decisions, maximise hydrocarbon recovery and reduce operating costs.



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