DEEP WATER

CASE STUDY

Integration Drives Performance and Accelerates Learning Curve in an Ultra-Deepwater Pre-Salt Exploration Drilling Project in Brazil

HALLIBURTON INTEGRATED SERVICES ACHIEVES NEW BENCHMARKS IN POST-SALT AND SALT SECTIONS

SANTOS BASIN, PRE-SALT BRAZIL

CHALLENGES

- Hole instability issues in 28-inch riserless section and high torque and drag
- Sidetrack occurrences in 28-inch section
- Hard rock intercalations in salt section
- Mitigate severe fluid losses
- Salt creep, stuck pipe
- Cementing salt zones and carbonates with high CO_2 concentration
- Cementing in severe lost circulation scenario
- Drill though hard carbonate formation in ultra-deepwater
- Reservoir characterization

SOLUTIONS

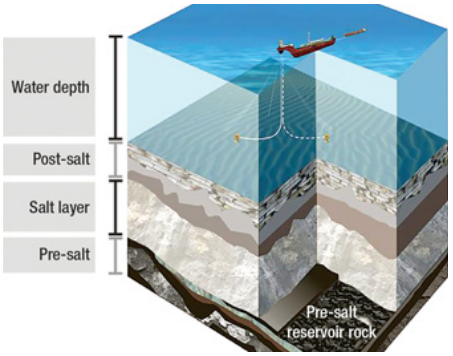
- Halliburton Project Management
- Drilling Engineering Solutions (DES)
- Customized bits via DatCi℠ Process
- Geo-Tech® PDC bits and EZ-Sleeve™ at-bit reamers
- Geo-Pilot® DURO™ rotary steerable system (RSS)
- ADT® drilling optimization service
- Geomechanics services
- ENCORE® drilling fluid
- BaraBlend®-665 and BaraLock®-666 lost circulation materials (LCMs)
- GeoBalance® Managed Pressure Drilling (MPD) service
- LOGIQ® logging platform

RESULTS

Reduced total well construction costs though:

- Increased ROP in 28-inch riserless section
- Reduced torque and drag, no need for back reaming
- Better hole quality, no spiraling
- Riserless sections and salt section done in a single run per section, with minimum bit wear
- Up to 60% drilling time reduction in salt section
- First well done in four sections
- Accelerated learning curve
- 56% improvement in productive drilling time

OVERVIEW



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In Brazil, the Halliburton Integrated Services (IS) technical team is continuously collaborating to optimize well construction and evaluation services in a giant pre-salt field for a major consortium. A new advanced integrated services contract model in a challenging offshore exploratory area with water depths of around 2,200m (7218 ft) has performance clauses based on minimum required rates of penetration (ROP) per section. The contract terms were comprised of a fixed component portion (cost per meter drilled with bit on bottom) and time and materials for other services, such as cementing, lost circulation materials, waste management, coring, wireline and well testing. Proper selection of these technologies to increase project performance and flawless execution were key aspects for the project´s success.

DRILLING IN ULTRA-DEEPWATER

The operator faced many challenges to build exploratory wells in this ultra-deepwater environment, with the main objectives to minimize the significant drilling risks and costs and reduce the total cost of well construction and evaluation. Other challenges included the long 28-inch riserless section in the post-salt formations facing hole instability issues and high torque and drag and vibration; the occurrence of hard rock intercalations in the salt and sometimes in the post-salt sections; very thick salt zones of around 2000m (6562 ft); geo-stopping at the top of the carbonate reservoir; low rate of penetration in hard and abrasive pre-salt carbonate reservoir with high carbon dioxide (CO_2) and hydrogen sulfide (H_2S) concentrations and severe fluid losses. Salt imaging, reservoir characterization, zonal isolation in salt zones and at the reservoir with high CO_2 concentrations and remote locations up to 200 km (124 mi) offshore also had to be addressed.

ENSURING A SMOOTH PROJECT IMPLEMENTATION

First, a Halliburton Project Management (PM) organization was nominated with a dedicated project manager, an IS coordinator, an operations manager, wellsite supervisors, a logistics coordinator, a senior well engineer and technical advisors from the segments involved, consultants for geomechanics, Drilling Engineering Solutions (DES) experts with DrillingXpert℠ advanced software package, Formation and Reservoir Solutions (FRS) and real-time monitoring services. A performance leader and health, safety and environment (HSE) coordinator are also members of this organization providing support in HSE, service quality, and review meetings on performance and lessons learned with the client for continuous improvement.

Early engagement of the PM team with the client and the creation of a communication protocol and an integrated execution plan were fundamental for a smooth project startup, helping to create a collaborative environment for risk identification and management, engineering support during well planning, proper selection of technology tools to enhance project performance, fostering synergies among Halliburton and stakeholders.

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CUSTOMIZED SOLUTIONS AND NEW TECHNOLOGIES

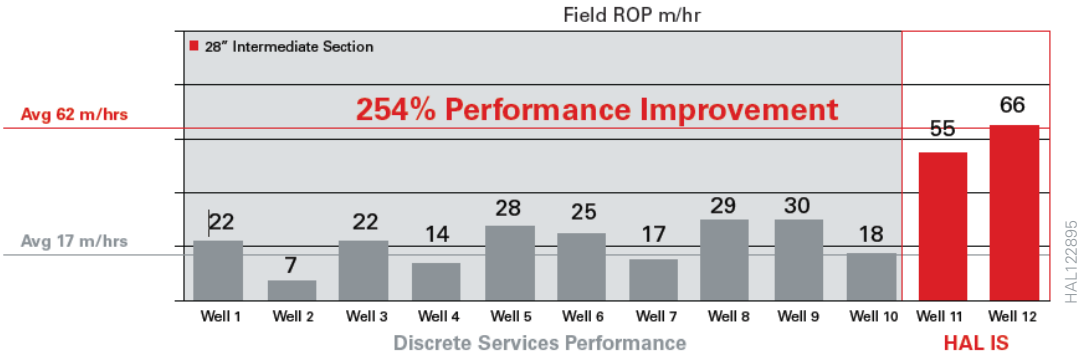
Next came the implementation of customized solutions and introduction of new technologies to boost project performance, thus reducing the total number of days to construct the well.

For the 28-inch riserless section, Halliburton designed new customized Geo-Tech® PDC bits and EZ- Sleeve™ at-bit reamer specific for the formation and used roller reamers, to reduce torque and drag, along with vibration; thereby increasing ROP in 254% in average in a single run, when compared to previous wells drilled in the field using discrete service contracts. In one of the wells, Halliburton drilled 1151 m (3776 ft) in 17.5 hours in a single run, establishing a new record for the field in 28-inch section with excellent hole quality and hole cleaning; achieving double trip-out speed; and avoiding spiraling and drilling jar activations. Minimum bit wear was also observed. High viscous pills were important for hole cleaning.

The optimized bottomhole assembly (BHA) allowed an extension of the 28-inch section to be drilled with seawater, eliminating the 18-1/8-inch x 22-inch hole enlargement section, saving around 17 days to the project; thus reducing the number of sections and casings from five to four. This was the first well completed with four casings in the northwest area of the field.

A pump-and-dump drilling technique was available for the lower portion of 28-inch section in case of difficulties in advancing drilling. This involves mixing seawater with a very viscous and high-density fluid using a Mix on the Fly® unit from Baroid, which creates a single, homogeneous, riserless drilling fluid stream. The equipment allows real-time adjustment of fluid weight, viscosity, flow rate and cuttings carrying capacity. The homogeneous fluid is then pumped down the drillstring, and the returns (fluid and drill cuttings) are discharged at the seafloor. The riserless drilling fluid is usually supplemented with high-viscosity sweeps to clean out the hole.

254% ROP increase in 28-inch riserless section



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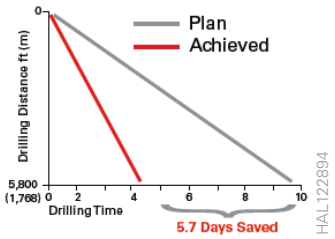
Graph showing ROP performance improvement in 28-in riserless section of the Halliburton IS project, over that of previous wells in the field

In the salt section, Halliburton introduced the latest and more robust Geo-Pilot® DURO™ rotary steerable system. Another optimized BHA configured with 16-inch PDC MegaForce™ bit, EZ-Sleeve® and Geo-Pilot® DURO™ RSS successfully drilled a 1741m (5712 ft) salt section in 4.1 days in a single run in the well. This represented a 60% drilling time reduction compared to the 9.8 days plan, while reducing the risk of getting stuck in salt and controlling hole verticalization. This BHA configuration is a unique solution due to the "point-the-bit" RSS concept. In addition, real-time monitoring played a very important role in anticipating and quickly addressing any downhole issues during drilling. Halliburton also provided geomechanics with mechanical specific energy (MSE) and salt-creep control services and ADT® drilling optimization service in real-time to observe wellbore stability, rock failure and BHA integrity conditions.

60% drilling time reduction in salt section



Graph showing Drilling Times in 16-inch Salt section

	Drilled	Time	ROP
Plan	5,791 ft (1,765 m)	9.8 days	24.6 ft/hr (7.5 m/hr)
Achieved	5,712 ft (1,741 m)	4.1 days	58.7 ft/hr (17.9 m/hr)

Sperry Drilling exceeded pre-job planning expectations by optimizing performance with zero NPT, thus saving 5.7 days of drilling time for the operator.

In some wells, GeoBalance® Managed Pressure Drilling (MPD) service was applied in the salt and carbonate reservoir zones. In salt, it helped to control salt creep. In carbonate, it minimized fluid losses and allowed to operate in a very narrow mud window.

In carbonate section, Halliburton used its Turbopower™ turbodrill with 12-1/4-inch impregnated bits and MRIL®-WD™ magnetic resonance imaging logging-while-drilling (LWD) tools for reservoir characterization and fluid identification.

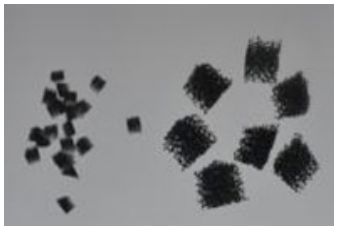
Baroid deployed lost circulation material (LCM) technologies, such as BaraBlend®-665 and BaraLock®-666 LCMs, to combat severe fluid losses. BaraBlend®-665 high-fluid-loss LCM, blended with fine and medium BaraLock®-666 reticulated foam, sealed the naturally fractured carbonate formation and helped save costs for the consortium by saving time related to cement plugs pumping and curing the losses of the expensive Encore® synthetic-oil-based fluid. The BaraLock® reticulated foam LCM system is capable of extending the fracture sealing capacity of the BaraBlend® single-sack solution up to 7,000 microns.

To characterize the reservoir, Halliburton deployed its LOGIQ® logging platform to acquire real-time data in an extensive logging program.

Loss rate dropped from 250 bbl /hr to ZERO

Severe Fluid Losses

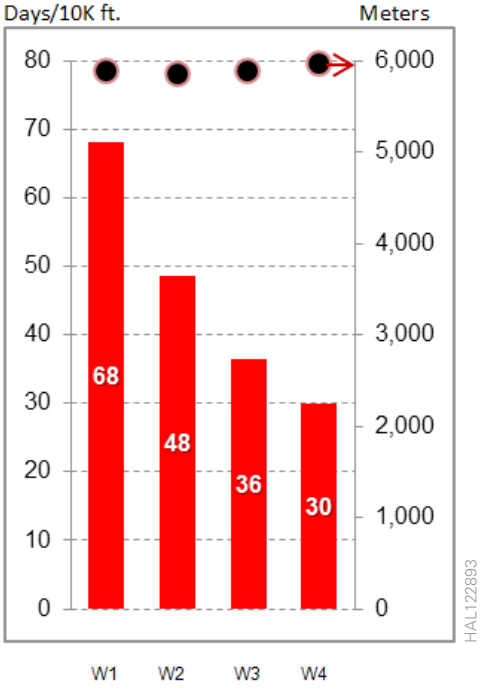
BaraBlend®-665



BaraLock®-666

SETTING A NEW BENCHMARK

To streamline the delivery of services, Halliburton Project Management provided collaborative leadership to manage risks, integrate stakeholders, boost project performance and reduce overall costs. This strategy ultimately delivered predictable well construction services, setting drilling records in the post-salt and salt sections and a new benchmark for the field, and resulted in the following positive outcomes:



Graph showing Fast Learning Curve

- A safer working environment with higher operating efficiency
- Integration among stakeholders/services and collaboration around risk management, well planning and technology
- Acceleration of learning curve by leveraging global lessons learned from similar projects
- A record-breaking in the field 254% ROP improvement in 28-inch riserless section
- First well drilled in 4 sections in the north west area of the field
- Up to 60% drilling time reduction in thick salt section
- Significantly reduced or stopped severe fluid losses though use of efficient LCMs
- Accelerated the project learning curve with integrated services
- 56% improvement in productive normalized drilling time per 10,000 ft (3,048 m)
- Fastest well drilled in the north west area of the field
- Reduced total well construction costs

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