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Lost-in-hole preventive initiative to successfully drill deep geothermal project in Continental Europe

Mateusz Bedzyk, Davide Di Tommaso and Michael Phillips
Weatherford

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Abstract

In 2023, a major energy provider and operator of an extensive district heating network announced the development of a deep geothermal power plant. By the end of 2024, drilling operations commenced, and by May 2025, the third and final well successfully reached its planned total depth, targeting a naturally occurring hot water reservoir approximately 3,000 meters below the surface.
As of now, production testing—intended to assess formation water temperature, chemical composition, and flow rates—has not been conducted. Therefore, this paper focuses on the planning and execution phases of the drilling campaign.
We will present an application of the Weatherford’s Lost-in-Hole (LIH) Preventive Initiative as a continuous improvement strategy, highlighting lessons learned from the first to the third well. Emphasis is placed on the joint efforts of Weatherford’s Drilling Engineering and Interpretation and Evaluation teams in accurately interpreting downhole and surface data to assess risks and inform our client on mitigation strategies and drilling practices. It incorporates a two-phased assessment approach: an initial risk screening for early identification of high-risk well sections, followed by an in-depth assessment to develop targeted mitigation strategies. A Well Management System was developed and used to store and share Drilling Engineering studies, data and lessons learned from offset wells and LIH risk based on the Well Complexity Index (WCI).
The Initiative serves as a replicable example, crucial for minimizing wellbore stability issues, preventing lost-in-hole incidents and tool damage, reducing Non-Productive Time (NPT), and ultimately enhancing drilling performance across the project.

1. Introduction

The drilling processes involved in accessing hydrocarbon and geothermal resources, particularly in the complex geologies of Continental Europe, pose significant technical challenges. One of the prominent issues encountered is the “lost-in-hole” (LIH) phenomenon, where drilling tools become trapped or lost within the borehole, leading to costly delays and operational setbacks. This article delves into a pioneering initiative designed to manage and mitigate such risks, enhancing the efficiency and success rate of drilling projects. This initiative aims to establish a framework that not only addresses the specific geological conditions of Europe or geothermal wells specifically but also sets a precedent for drilling operations worldwide.
Figure 1 shows the LIH event trend of 2024 versus 2025 activity, normalized for the Well Complexity Index: considering that the well complexity has increased from 2024 to 2025, the LIH trend without prevention should have increased, indeed we are seeing a large decrease of events compared with 2024.

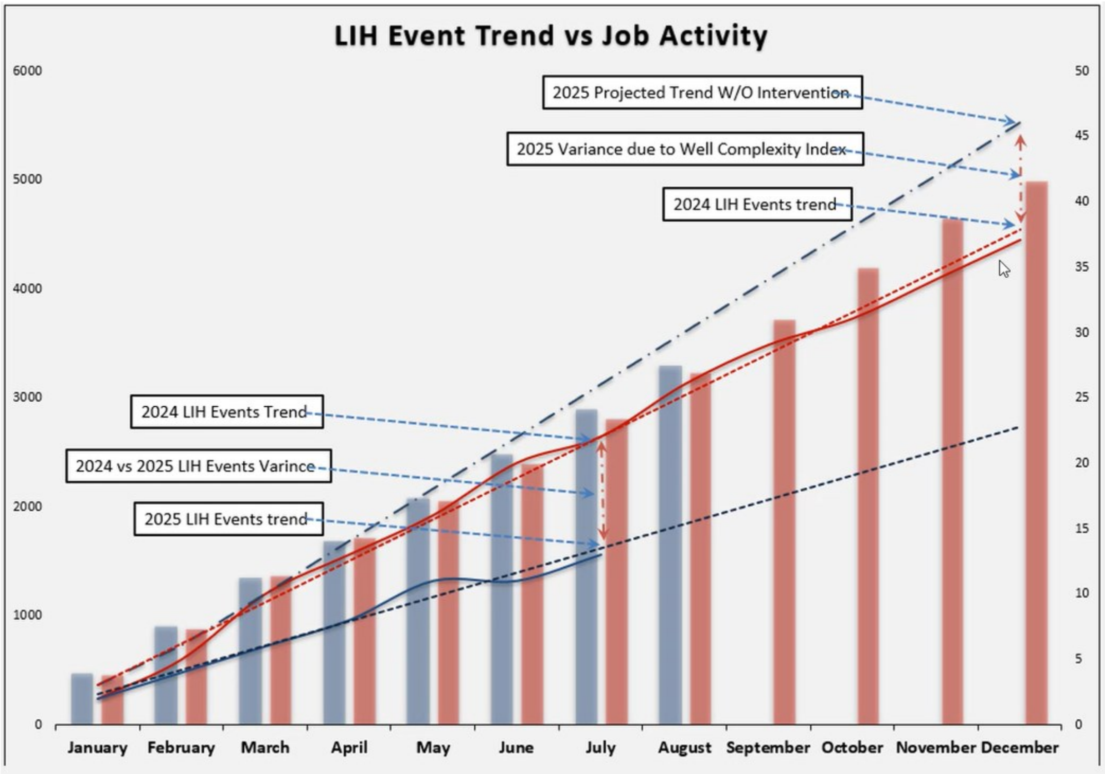

Fig. 1: LIH event trend of 2024 versus 2025 activity normalized for the Well Complexity Index.

2. Lost-in hole (LIH) Prevention Initiative

Since end of 2024, following a period of development and implementation, the Drilling Services (DS) and Interpretation and Evaluation Services (IES) departments of Weatherford have been collaborating to apply a Lost in Hole (LIH) Prevention Initiative procedure. The scope of that is to provide a structured, step-by-step approach for assessing and mitigating LIH risks throughout the well-drilling process. This workflow emphasizes a proactive approach, integrating real-time data, historical analysis, and domain expertise to enhance safety and efficiency in high-risk well sections.
This workflow is applicable to all well-drilling jobs where LIH risks are anticipated or have been historically significant. It incorporates a two-phased assessment approach: an initial risk screening for early identification of high-risk well sections, followed by an in-depth assessment to develop targeted mitigation strategies. The goal is to prevent LIH incidents by identifying potential risks early and establishing actionable, field-specific plans to address them.
The LIH Prevention Workflow is divided into two main phases:

- Phase 1: Preliminary Risk Assessment
  This phase involves a rapid risk screening to identify well sections with elevated LIH risks. The DS team completes the risk matrix, based on available data, with each well section receiving a risk score. Sections scoring above a predetermined threshold are flagged for further assessment. A new tool called Well Management System was implemented to store and share data analysis, drill engineering and anti-collision studies, risk assessment, lessons learned, and events occurred in offset wells, and calculate Well Complexity Index (WCI) based on planned BHA, wellbore design and geological challenges.

- Phase 2: Detailed Risk Assessment and Mitigation Planning
  For high-risk sections identified in Phase 1, the IES team performs an in-depth assessment. This includes gathering additional data and applying advanced analyses to understand the root causes of potential LIH risks. Based on these insights, the IES/DS team develops customized mitigation strategies, which are documented and shared with all stakeholders prior to execution.
  The workflow chart (Figure 3 - Figure 7) illustrates the sequential steps and decision points within each phase, providing a clear roadmap for identifying, analyzing, and mitigating LIH risks. This structured approach allows teams to follow a standardized process, promoting consistency, communication, and effective risk management across all stages of the workflow.

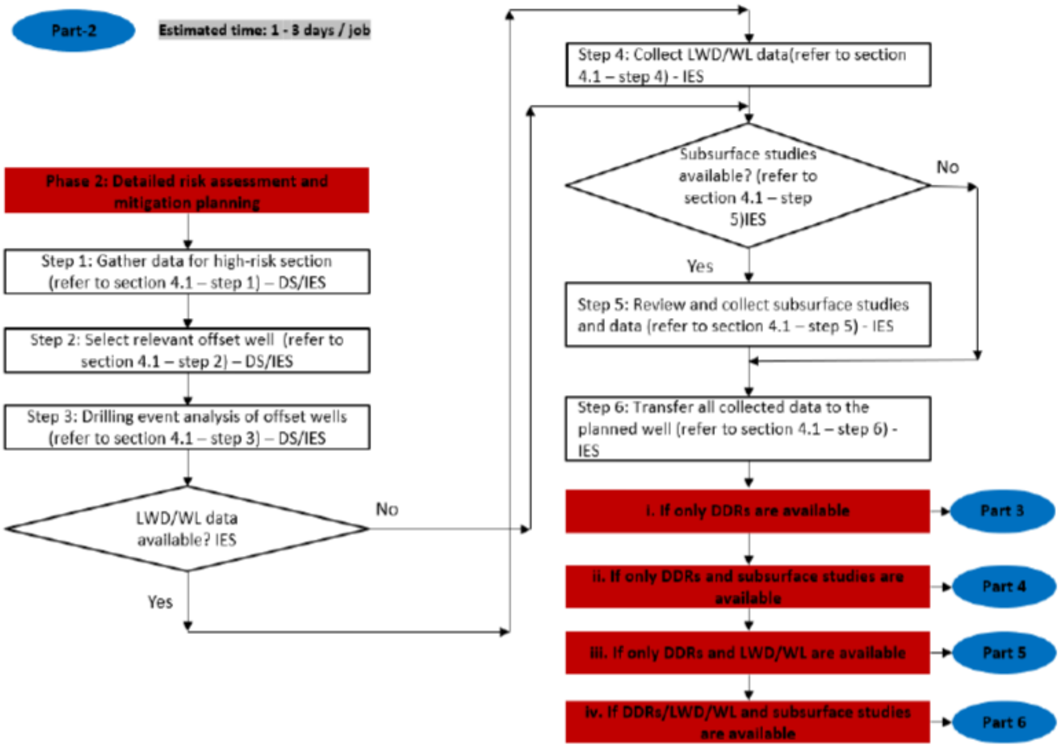

Fig. 2: The Figure illustrates the steps of a Phase 2 detailed risk assessment. It instructs on which specific workflow chart must be used, depending on the available data.

3 Case Study: Deep Geothermal Well in Continental Europe

In 2024 a major energy provider and operator of an extensive district heating network hired Weatherford to drill three wells to develop a deep geothermal power plant. In parallel with the usual drilling plan and engineering study, the brand new LIH prevention initiative procedure and tools, involving multiple product lines and departments, were used for the risk analysis and mitigation strategy. This was done in the planning stage and, to enhance the efficiency and success rate of drilling projects, during the execution stage after the first of the three planned wells.

3.1 Well #1

As a starting point of the planning stage the Well Management System was fed with data analysis, drill engineering and anti-collision studies, risk assessment, lessons learned, and events occurred in offset wells, and the Well Complexity Index (WCI) was calculated based on planned BHA, wellbore design and geological challenges returning a level GEM-I (Figure 3) meaning only phase 1, preliminary risk assessment, was required.

Fig. 3: Well Complexity Index (WCI) evaluation within Well Management System. In this case the well is classified as a GEM-I, which means that will undergo to phase 1 for a preliminary risk assessment.

A risk analysis was performed at each specific formation and interval of the 12 ¼" and 8 ½" sections to be drilled, which identified risk of hole cleaning issue causing tight spots, hole instability, due to presence of fractures, and possible losses. Using mitigation strategies those risks were removed or strongly limited, but the first of the three planned wells, drilled with a Motorized Rotary-Steerable-System (RSS), encountered some unpredicted issues mainly related to poor performance and to vibrations while transitioning gravel layers. Because of the vibrations, once on surface, severe damage to downhole equipment was reported. To investigate it all the surface and downhole data from sensors were gathered and analyzed (see Fig.4), also taking advantage of the new LIH prevention initiative procedure and digital tools.

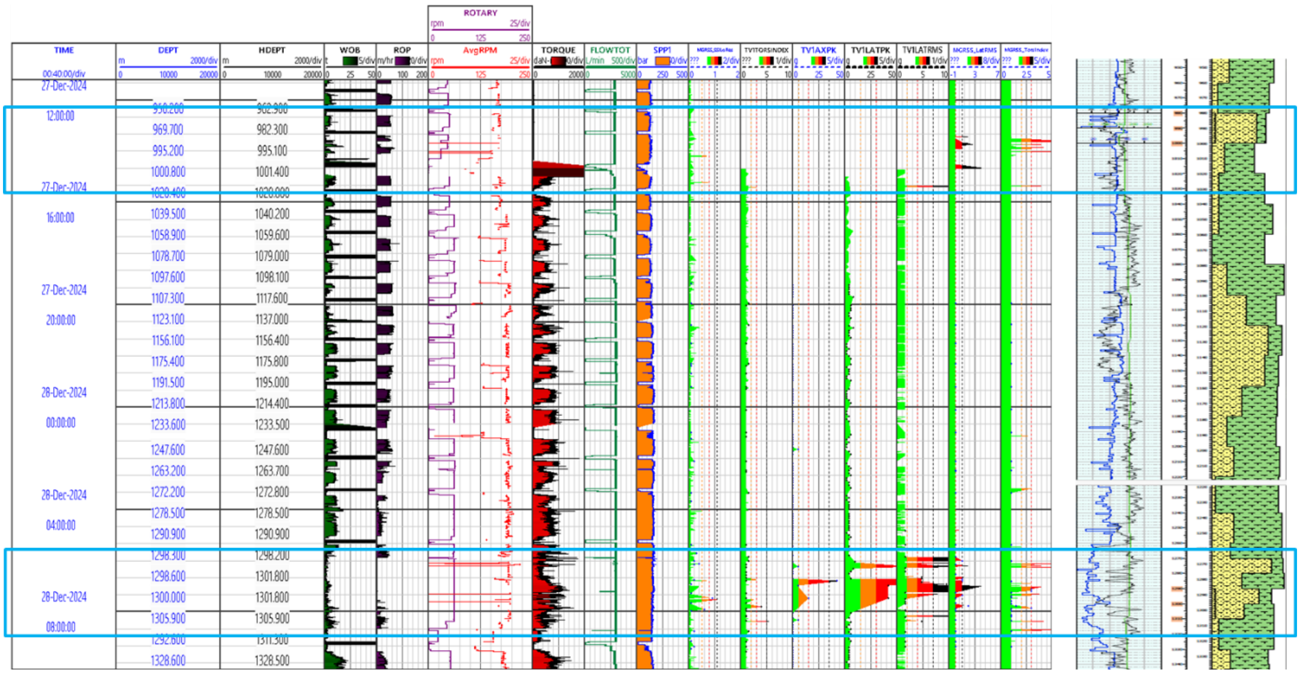

Fig. 4: Vibration spikes, with high levels in black, and stick-slip (SSI) occurring while reaming in the gravel intervals mostly related to formation washout.

The result of the investigation was that the vibration spikes occurred in the gravel intervals and could be explained with BHA loosing proper stabilization in an enlarged borehole. The enlargement was later verified by the two wireline passes. Also, comparing LWD with wireline data, it was clear that in the problematic area the washout was already there soon after drilling and did no occurred in the time between drilling and wireline logs (see Fig.5). In the problematic intervals some cavings were reported and primarily blocky with few fresh surfaces, which indicates shear failure, as an effect of a tensile stress, in the wellbore.

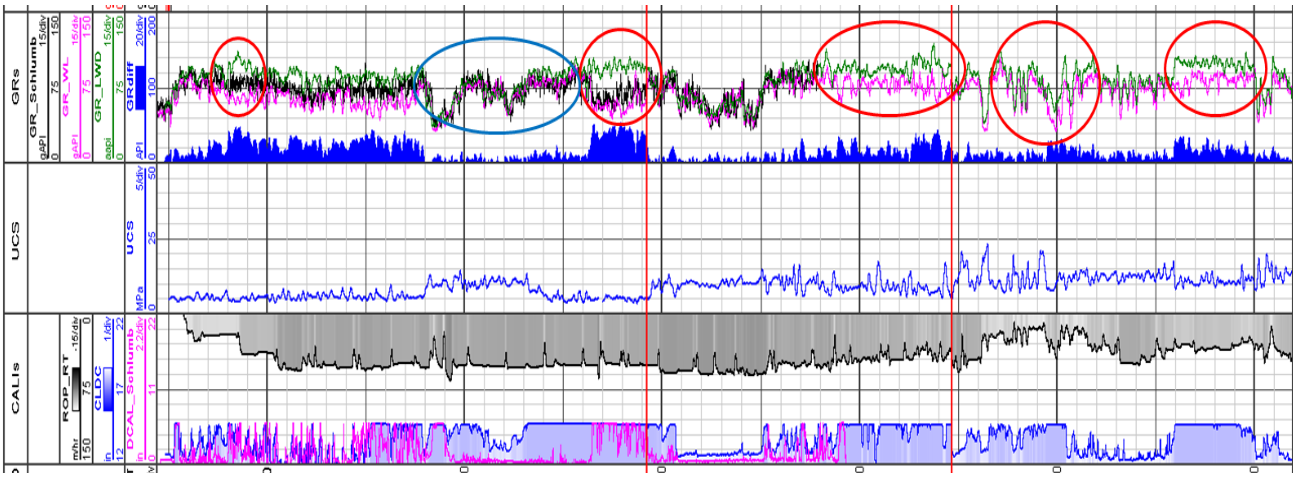

Fig. 5: difference between calliper curves of two wireline passes indicates that hole conditions changed meanwhile. Gamma ray (GR) from wireline and LWD was also compared: it is a good indicator of the borehole status, as it is attenuated by the excess of mud due to borehole enlargement. Difference between LWD and Wireline GR indicates the washout occurred after drilling (red circles), while matching GR in washed intervals indicates that enlarged hole was already there during drilling (blue circles).

3.2 Wells #2 and #3

As a follow up of the analysis, a new risk of washout and high vibration in those intervals was added to the matrix to be taken into consideration for the 12 ¼" and 8 ½" sections of the two following wells. As lessons learned, some remedial actions were proposed to the operator to avoid tool damage and lost-in-hole, which are listed below:

- Monitor vibration while drilling and mitigate when identified.
- Avoid back reaming unless necessary (with Low RPM meaning Low flow rate in motorized RSS) to do not damage the filter cake.
- Avoid surge and swab while tripping.
- Employ good hole cleaning practice in the interval (High vis pills).
- Monitor cavings.
- Keep Mud Weight (MW) steady, as raising MW without proper filter cake can cause further destabilization.
- Confirm the required type and concentration of inhibitors to minimize mud rock chemical interaction.

Some points of the mitigation plan above were put in place by the operator with a specific plan for the wiper trips and back ream, as shown in figure 6.

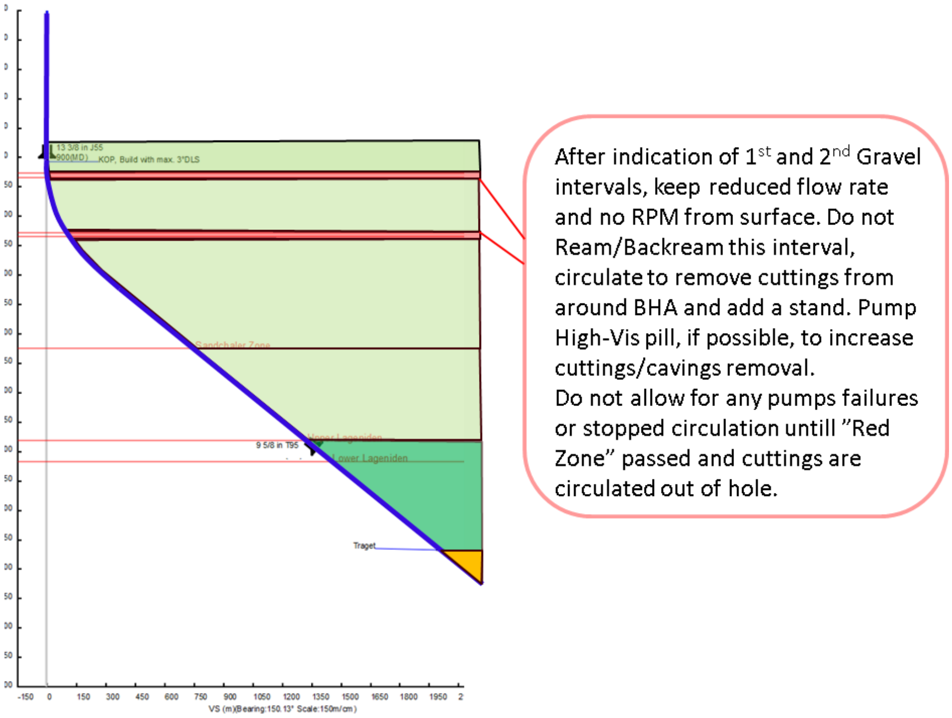

Fig. 6: In this picture we are highlighting the best practice for the two main problematic zones ("Red Zone") corresponding to the gravel intervals. But it is only a piece of a wider "driller's roadmap" that provided drilling and reaming practice for each specific interval of the wells #2 and #3, following the analysis and lessons learned on the well #1.

The mitigation strategies successfully reduced the lateral and torsional vibrations from high level in the well #1 to medium and low in the following wells #2 and #3, allowing to complete the project without damages to downhole equipment, thus reducing LIH risk and improving drilling performance, while achieving a dog-leg-severity (DLS) up to 5 degrees per 30 meters in the 12.25" section.

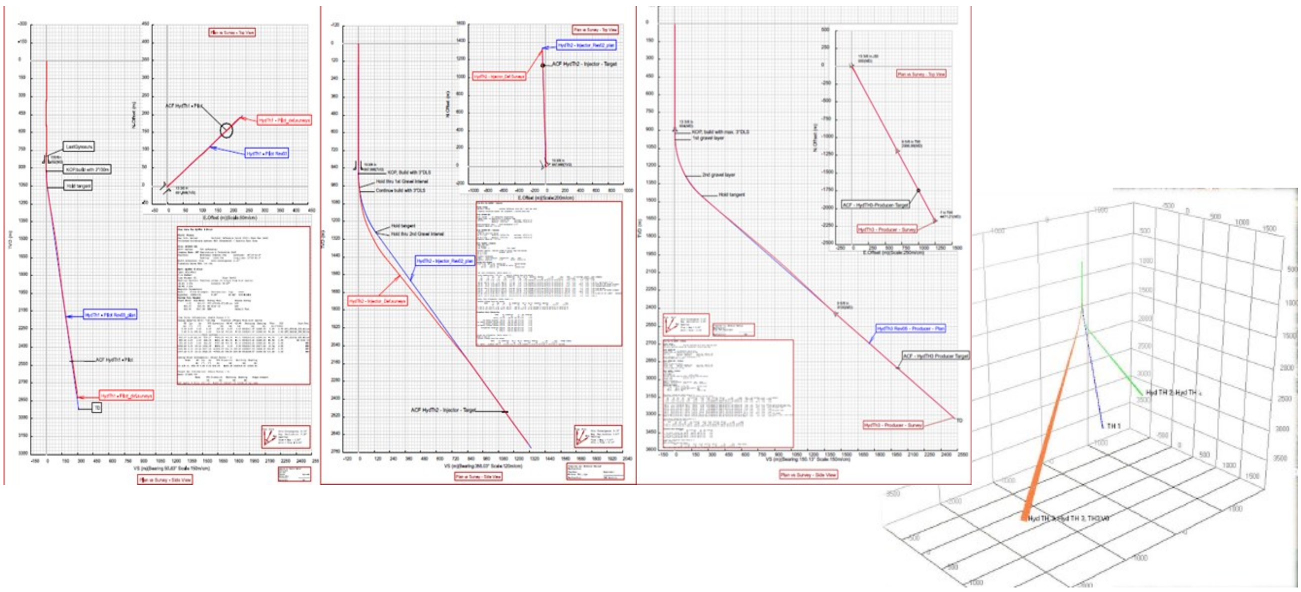

Fig. 7: In this picture are represented the three wells of the geothermal project which were drilled using lessons learned and mitigation strategies.

4. Conclusions

The Lost-in-Hole (LIH) Prevention Initiative presented in this paper demonstrates a proactive and structured approach to mitigating the risks associated with drilling in complex geological environments, particularly within the context of Continental Europe. By integrating real-time data analysis, historical insights, and domain expertise, the initiative provides a comprehensive framework for identifying and addressing potential LIH events. The successful application of this initiative in the case study of deep geothermal wells highlights its effectiveness in enhancing drilling efficiency and reducing operational setbacks. The lessons learned and mitigation strategies developed from Well #1 were effectively applied to Wells #2 and #3, showcasing the adaptability and robustness of the LIH prevention framework. This initiative not only holds promise for geothermal projects but also sets a benchmark for drilling operations globally, emphasizing the importance of early risk identification and tailored mitigation planning.

Sources

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Weatherford, Via Nino Pace, 23, Ortona (CH), Italy, 66026

davide.ditommaso@weatherford.com