

The Super Lateral Campaign – Engineered Design Enables Drilling Beyond 30,000 Feet

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Abstract

In the Northeastern United States, a super lateral campaign continues to drill record-breaking horizontal wells in fewer than 20 days. To achieve this level of efficiency, engineering design must closely align with operational execution to eliminate potential non-productive time while anticipating drilling risk. This strategy has delivered over a dozen super lateral wells with horizontal intervals exceeding 15,000 feet throughout the Utica shale formation.

Engineering practices begin with an optimized well profile for maximum reservoir contact. This engineering optimization insures the casing program meets regulatory requirements and minimizes the potential for losses while drilling and cementing. The vertical section is drilled with air. For the curve and lateral sections, a rotary steerable tool aids in directional control while a tapered string design optimizes hydraulic efficiency for improved hole cleaning. A comprehensive drilling fluid program insures effective hole cleaning while minimizing excess cleanup cycles. This allows for trouble-free trips and casing runs while limiting non-productive time associated with excess precautionary measures. The super lateral design has become standard practice for the operator enabling deep Utica targets to be reached in fewer than 20 days.

A disciplined approach continues to prove the feasibility of extremely long horizontals as demonstrated in the Utica shale; however, potential applications from these lessons extend worldwide.

Introduction

The Eclipse Resources drilling program targets production of dry gas and condensate throughout the Utica and Marcellus formations across Ohio, West Virginia, and Pennsylvania (Figure 1).¹ Eclipse Resources defines a super lateral as having a lateral length of 15,000 feet or greater. This term has been adopted by others in the industry as they pursue extended reach drilling campaigns of their own. The proven drilling and completion methods developed in the super lateral campaign have been embraced by numerous operators targeting unconventional reservoirs in the United States. This is a strong indicator that the adoption of super laterals in other regions is likely to continue.^{2,3}

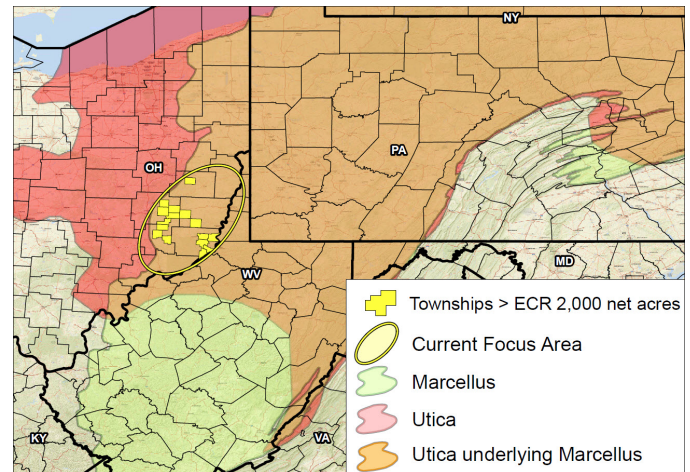


Figure 1: Key operating areas for the super lateral case histories presented in this paper.¹

Historically, early unconventional laterals in the region extended only about 2,000 feet. As adjacent leases consolidated and unconventional well technologies matured, lateral lengths continued to increase.³ Lateral lengths were gradually extended from 6,000 to 14,000 feet as production recovery did not appear to decline with increasing lateral length.

The engineering team recognized the potential to increase lateral length as costs dictated improved well efficiency and geographic conditions encouraged fewer well sites, particularly in the Northeastern United States. Pad site options in the Northeastern US are limited by rugged terrain and greater proximity to population centers.

While a longer horizontal aspect presents more potential for failure, well optimization and effective delivery provides critical cost reductions and greater ultimate recovery per foot.⁵

In the early days of extended reach laterals, such as the Wytch Farm project in the United Kingdom, it was clear that downhole equipment failures and difficulty with trips presented the greatest project risk to well delivery. Longer measured depths required greater reliability to address these risks. Proven equipment, practices, and techniques are essential to maximize well productivity and efficiency.⁶ As methods and technologies have matured, operations in the Utica Shale have resulted in longest known unconventional laterals in the world with total

measured depths regularly approaching 30,000 feet.^{7,8,9}

Super Lateral Well Profile

Super lateral wells are drilled where justified by technical and economic requirements – that is, not all wells are, or should be, super laterals. In 2017, eleven super laterals were drilled as part of a 24-well drilling plan in the Utica shale formation. Of the 11 super laterals, eight targeted condensate and three targeted dry gas. Pads usually feature between two and six wells, with an average of four wells.

The drilling program of a typical super lateral features a driven conductor plus three casing intervals (Figure 2). The pre-set conductor is set at around 120 ft. The 17½-in. surface interval is drilled with air/mist, then running and cementing 13⅜-in. casing to protect freshwater sands. The 12¼-in. intermediate section is also drilled with air/mist to the desired total depth then the well section is filled to surface for the 9⅝-in. casing run and cement. The 8¾-in. curve section and 8½-in. lateral sections are drilled with invert emulsion drilling fluid, with each section using a dedicated drilling assembly to achieve interval objectives. The 5½-in. casing is run across both sections and cemented to complete the drilling process of the well.

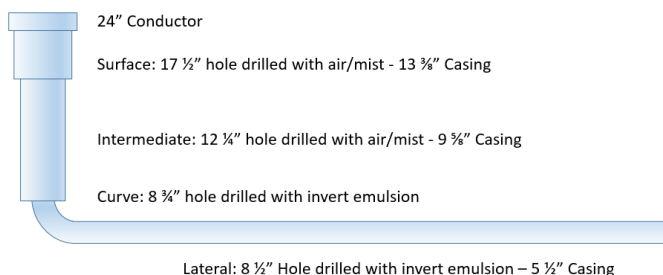


Figure 2: Typical casing profile of a super lateral well.

Rig Equipment

A properly equipped drilling rig is essential to achieve effective performance in a super lateral. The drilling rig must be designed for extended reach horizontals targeting unconventional reservoirs. It features a 750,000-lb mast and a top drive system rated to 37,500 ft•lb_f of continuous torque.

Three mud pumps support pump pressures rated to 7,500 psi, with typical pump pressures sustained around 6,500 psi. Properly powered mud pumps are required to insure sufficient circulating rates for cleaning across extended laterals as longer laterals result in greater friction pressure loss. A key learning from the introduction of 7,500-psi pumps was that thoughtful selection of key pump expendables combined with pump maintenance has been key to preventing/mitigating the common, constant occurrence of pump expendable failures at elevated pressures.

Surface and Intermediate Intervals

Surface and intermediate intervals are drilled with air/mist to minimize risk of losses and maximize drill rates. Drilling risks in the surface and intermediate sections include losses, water influxes, wellbore instability, and poor cement jobs. The

drilling program provides key steps to quickly recognize and act when signs of known issues become apparent.

17½-in. Hole Section

The 17½-in. hole section is drilled with a sealed bearing motor and insert drill bit using air/mist. Interval depth varies by county, but it is set right above the first commercially viable hydrocarbon zone and/or formation containing >10,000 ppm total dissolved solids incorporated into the air/mist system. In many cases, this is around 1,500 feet true vertical depth, although actual depth varies by county.

The air/mist is circulated at 50 to 70-bbl per hour while drilling, adjusting the misting rate for the maximum rate of penetration in line with drilling conditions. At total depth (TD) of the 17½-in. section, the hole is circulated clean before pulling out of the hole.

The 13⅜-in. casing follows, with washing down as needed and circulating with freshwater prior to cementing. The 17½-in. interval is typically trouble-free; however, it protects critically sensitive freshwater sands that require a flawless cement job to protect the surrounding environment.

12¼-in. Hole Section

The 12¼-in. hole section also uses a sealed bearing motor and insert drill bit similar to the 17½-in. section. Air/mist is used as the drilling fluid, although the fluid composition transitions to a 2% KCl/polymer blend prior to drilling reactive shale sections. Minimizing wellbore tortuosity is a top priority for the air/mist system in the 12¼-in. section in order to accomplish all the objectives of a very challenging well from a torque and drag standpoint.

Total depth targets are set at least 100 ft into the Reedsville formation to provide adequate formation integrity for drilling the production interval. The hole is circulated clean and tripping commences, displacing the well with up to 12.5-lb/gal invert emulsion drilling fluid. The 9⅝-in. casing is run and washed down, if needed. Casing is cemented via a two-stage operation, chasing the cement slurry with weighted invert emulsion drilling fluid in preparation for the curve section.

Curve Section

The curve assembly features a PDC bit and a rotary steerable assembly with a straight motor designed for building the curve section. Rotary steerable tools are preferred for their proven ability to provide a smooth directional wellbore with the ability to rotate and aid in hole cleaning.¹⁰

Surveys are taken at regular intervals to verify anti-collision requirements are met, building between 8 and 10 degrees per hundred feet. The target landing point inclination for the curve section is just over 90 degrees. The azimuth targets are 15 to 20 degrees of north-south to remain perpendicular to the maximum stress field for effective fracture placement.¹¹

Hole cleaning remains critical throughout the build section. All efforts are made to maximize pipe rotation and flow rate to efficiently convey cuttings to surface. Typical flow rates remain above 500 gal/min while the 6-rev/min reading is maintained between 6 to 8 degrees.

At total section depth, a cleanup cycle is performed, monitoring the shakers for cuttings accumulations while reciprocating the drillstring. When minimal cuttings are present, an additional cleanup cycle is performed prior to pulling out of the hole. Any indications of additional waves of cuttings extends cleanup cycles until conditions suggest a clean wellbore.

Lateral Section

The lateral section maximizes drilling efficiency through a combination of best practices, engineering, and wellsite execution. The average daily footage drilled exceeds 1,600 feet, with some days reaching or exceeding 3,000 feet. Many lateral sections exceeding 15,000 ft are drilled in less than 7 days.

Drilling Assembly

Another rotary steerable system with a straight motor is utilized featuring an 8½-in. five-blade PDC bit. The ability to rotate is essential for hole cleaning while maintaining directional control. Reliability is another key concern due to the extended trip lengths to change failed downhole equipment. All efforts are made to drill the horizontal section in a single run to avoid costly downtime.⁹

The final 10,000 to 13,000 feet of drill pipe is 5⅞ inches, tapering outwards from the 5-in. drillpipe below. This increases annular velocity⁸ and aids in applying weight at the drilling assembly. A proper balance of string diameter, flow regime, and equivalent circulating density is required to prevent excess ECD from causing a flow restriction¹² while insuring good annular velocity for hole-cleaning.

Drilling Practices

Drilling practices balance performance with critical observations of any changes in conditions. Every 500 feet standpipe pressure is measured to calibrate it with changes in drilling fluid properties and increased friction pressures from the additional well length. Should values deviate from expected standards, specific steps are prescribed to quickly return to normal operating parameters.

Fluid Properties

Fluid properties focus upon optimal parameters for performance while minimizing ECD. While ECD is a function of many factors, careful monitoring and maintenance is necessary to prevent losses and track hole-cleaning performance.⁹

A diesel-based invert emulsion drilling fluid provides the necessary properties with adjustments as needed to maintain programmed values. Table 1 shows typical properties of the diesel-based drilling fluid followed by a specific discussion of the properties.

Mud weights range from about 11.2 to 12.0 lb_m/gal, with a typical mud weight at TD of 11.8 lb_m/gal. Oil:water ratios usually range from 80:20 to 90:10 to minimize plastic viscosity and associated friction. In conjunction with the oil:water ratio, low gravity solids are maintained below 13% to keep the plastic

viscosity below 28 cP. In most cases, the plastic viscosity values range between 18 to 22 cP.

Property	Typical Values
Mud Weight, lb _m /gal	11.2 – 12.0
6 rev/min, degrees at 150°F	6 – 10
Plastic Viscosity, cP	18 – 22
HPHT Fluid Loss, mL/30-min @ 250°F	9 - 18
Electrical Stability, volts @ 150°F	400 - 600
Water Phase Salinity, mg/L	180,000 – 220,000
Low Gravity Solids, %	8 - 12

For cuttings suspension, the 6-rev/min reading is monitored and maintained between 6 and 10 degrees. Gels are monitored to avoid their becoming excessively progressive.

The HPHT fluid loss is programmed between 10 and 20 mL/30 minutes, but seldom exceeds 15 mL/30. As recognized by API standards, the electrical stability is monitored for trends as opposed to a specific value,¹³ but at the standard oil:water ratios seen while drilling, values trend between 400 and 600 volts, increasing with higher oil content and bit shear.

Solids Control

The Utica Formation is known for its fine, coffee-ground sized cuttings which are particularly challenging to separate from drilling fluid. A comprehensive solids-control package is essential to maintain drilling fluid properties at the lowest possible cost.

Three conventional shakers are complemented by a set of drying shakers. Shaker screens require the balance of effective drill-solids removal and retention of barite, using 200-mesh API screens throughout the interval.

The centrifuge package allows for conventional or barite recovery mode to help minimize low-gravity solids. Output is regularly monitored to verify centrifuge performance meets expectations.

Hole Cleaning

Hydraulic optimization throughout the horizontal is key to effective hole cleaning. Flow rates usually exceed 600 gal/min while rotating at more than 150 rev/min.^{14,15} No sweeps of any kind are required to convey cuttings to surface.

Cleanup cycles are pumped as dictated by the drilling program – specifically, when parameters indicate hole cleaning is compromised or during downtime. Maximum flow rate and pipe rotation is maintained during cleanup cycles.

Typical indicators that require adjustments for hole cleaning include excess standpipe pressure, excess weight on bit, insufficient cuttings at the shakers, or drilling with parameters that have drifted out of specification. This attention to detail prevents complications during trips and minimizes the risk of incurring conditions requiring backreaming.^{16,17}

Torque and Drag

Torque and drag management is a constant challenge in

extended reach wells. Directional control with a smooth well profile is essential to avoiding excess torque.^{7,16,18,19} The drilling rig top drive must be sufficiently powered to manage torque without the addition of additional torque reduction measures.

The quality invert emulsion drilling fluid provides lubricity without the assistance of fluid additives. While lower torque is desired whenever possible, there are significant shortcomings with chemical additives.

Many chemical lubricants for invert emulsion systems fail to sustain torque reduction^{6,20} because their chemistry is very similar to that of surfactants used as wetting agents, meaning the lubricant is incorporated into the solution of the drilling fluid over time. Other lubricants fail to meet expectations because they were developed in pristine lab environments, failing to account for the complex nature of a solids-laden drilling fluid.²¹

Lost circulation materials, such as nut shells, graphite, and fibrous materials, are known to provide some relief, but these products have not been proven effective in controlling torque and drag.¹⁷

When necessary, many operators choose to utilize mechanical methods to control torque and drag. Proven options include non-rotating drillpipe protectors, hard banding, and altering the cutting structure of the drill bit.²¹ In scenarios with drag while running casing, beads have been used, bypassing the shakers while washing down and rotating.

Total Depth

As with at other sections, cleanup cycles feature maximum flow rate and pipe rotation at TD. Pipe is reciprocated and a stand is pulled every bottoms up. Once the shakers appear clear of cuttings, an additional two bottoms up are circulated before pulling out of the hole. Any significant appearance of cuttings at the shakers requires additional cleanup cycles.

All efforts are made to pull out of the hole on elevators. Backreaming is limited whenever possible, using drilling parameters to insure freed cuttings are circulated away from the BHA. Torque is carefully monitored to help determine if the overpull is from cuttings, tortuosity, or even a flowing well. Specific steps are included in the drilling program to identify and address each scenario. Recognizing and working tight spots before running casing can save time and help to identify the issue when running back in the hole.²²

Once the drilling assembly reaches the landing point, a flow check and cleanup cycle are performed, monitoring the shakers for additional cuttings. As the drilling assembly approaches less than 60 degrees in the curve section, practices shift to vertical hole conditions.

Running and Cementing Casing

Extended casing lengths can require additional tools to reach total depth. In some cases, this involves floatation to reduce the overall casing string weight however the operator usually runs production casing conventionally and fills the pipe from surface as it is being run to bottom. Other methods include a liner and tieback, which significantly increases cost.¹⁶

For the super-laterals, premium casing threads allow for sufficient torque to rotate the casing through ledges. This also allows for circulation to wash down the casing, if necessary, which is not an option using casing floatation.

The 5½-in. casing features several test/frac valves along with associated float equipment. Slack-off weight is carefully monitored to determine if rotation is required. Once casing is on bottom, cementing operations commence and the well is handed over for future completion operations.

Case Histories

Through the efficiencies of the super-lateral campaign, more than ten super lateral wells have been drilled with an average lateral length of 18,000 feet and an average time of 16 days to drill from spud to TD.²³ Records continue to break as methods are enhanced and completion techniques continue to verify the economic advantages of the super-lateral.^{7,8,9} Table 2 compares the performance and characteristics of the four super laterals reviewed below.

Well	Lateral Length (ft)	Measured Depth (ft)	Time (Days)
Purple Hayes 1H	18,500	27,048	18
Great Scott 3H	19,300	27401	17
Outlaw C 11H	19,600	27,339	17
Mercury B 5H	20,800	28,775	13

Purple Hayes 1H

Purple Hayes 1H was the first super lateral attempted after an intensive pre-planning phase to confirm the feasibility of the super-lateral. The 18,500-foot lateral was drilled in under 18 days with a total measured depth of 27,048 feet. Prior to drilling the well, there was a strong belief that laterals could go even further, but as the first super lateral well, the desire was to prove key concepts for even longer wells.

Great Scott 3H

Great Scott 3H was drilled in Guernsey County, Ohio. Total measured depth reached 27,401 feet with a final true vertical depth of 7,595 ft. Drilling time from spud to TD took less than 17 days, even with an MWD failure in the curve section. Casing was run to about 25,000 feet before needing to wash and rotate to reach bottom.

The lateral length was approximately 19,300 feet, breaking the previous record set by the Purple Hayes 1H well and further validating the engineering concepts of the super lateral.

Outlaw C 11H

The Outlaw C11H well was drilled to a measured depth of

27,739 feet with a 19,600-foot lateral length in 17 days from spud to TD. Casing was run to about 18,000 feet before spotting beads to aid in reaching bottom. Beads were added at regular intervals while circulating to reach total depth. Otherwise, operations were trouble-free.

Mercury B 5H

The Mercury B 5H well currently holds the record for lateral length at 20,800 ft with a total measured depth of 28,775 feet and a true vertical depth of 7,561 feet. Also drilled in Guernsey County, drilling time from spud to TD was 13 days with only 5 days required to drill the lateral. There were no issues running casing to bottom.

Conclusions

The drilling challenges of various formations may vary, but the approach discussed provides a roadmap to longer lateral lengths with a disciplined approach:

- Super-lateral wells are a trend that is expected to continue.
- Completion technology that maximizes the production efficiency of longer laterals justifies the practicality of extended reach drilling methods.
- Practices continue to evolve over time; however, the success of the super-laterals begins with planning, comprehensive engineering, and a commitment to best practices at all phases.
- A carefully crafted drilling program that includes contingency actions minimizes the potential for downtime to continue drilling record-breaking wells.

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Nomenclature

BHA	= Bottomhole assembly
ECD	= Equivalent circulating density
HPHT	= High-Pressure, High-Temperature
TD	= Total depth

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