

What Determines the Location of a Well?

Geology, leasing, permitting, technology, economics, and the environment

Introduction

Oil- and gas-rich rocks are only found in certain parts of the United States, so most of the country has no oil or gas wells. Where oil and gas production is commercially viable, many factors determine the exact location of each well, including leasing, permitting, competing land uses, environmental protection, economics, and drilling technology. These factors are strongly interlinked: the best well location for environmental protection may be on land that the owner will not lease for drilling, may be more expensive to drill on, or may be too close to a school for the state to issue a drilling permit. The most profitable location may endanger a local waterway or encroach on important agricultural land. The final location for most wells is usually chosen to balance the requirements of federal, state, and local regulators, landowners, oil and gas operators, and the local community.

Finding the Right Rocks

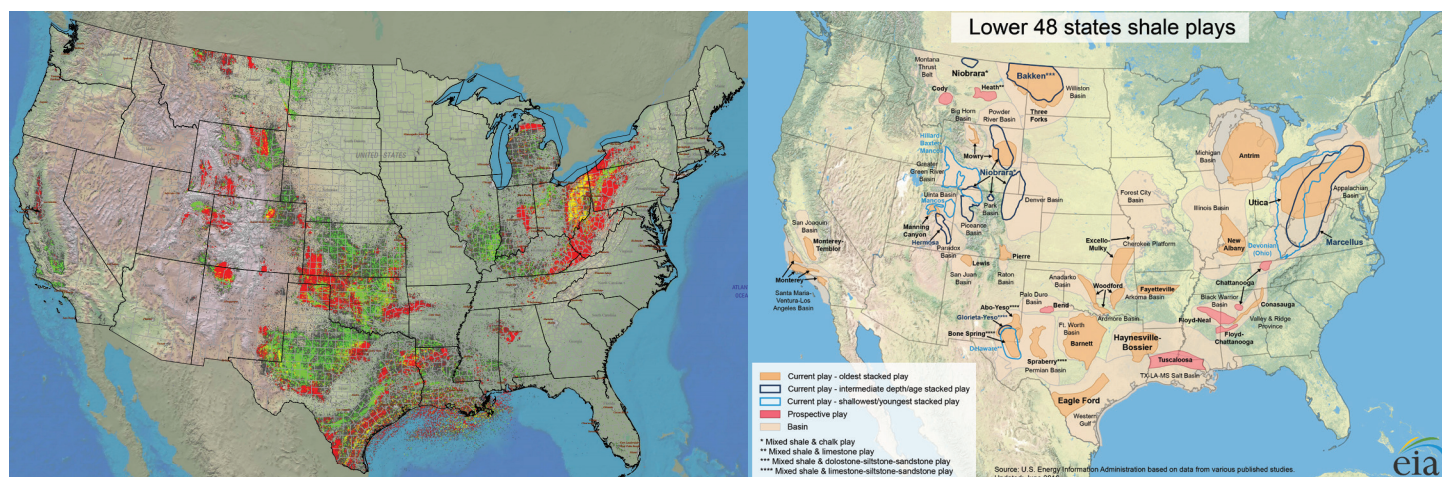
Oil and gas cannot form in all rocks; significant quantities can only form from organic matter (the remains of living organisms) trapped in thick layers of sediments. While peat and coal are formed from plant matter, oil and gas are mostly formed from large accumulations of tiny plankton that lived and died in

ancient lakes, seas, and oceans. As the organic-rich sediments accumulate over time, the deeper portions become buried. Once the sediments reach depths of 5,000 to 30,000 feet, heat and pressure are high enough to convert the organic matter to oil and gas. The buoyant oil and gas may rise toward the surface and become trapped by overlying impermeable rocks or may remain trapped in the rocks where they formed (typically shales). These processes have produced the large oil and gas fields in California, within and east of the Rocky Mountains, and in the Gulf of Mexico and the Appalachian Basin.

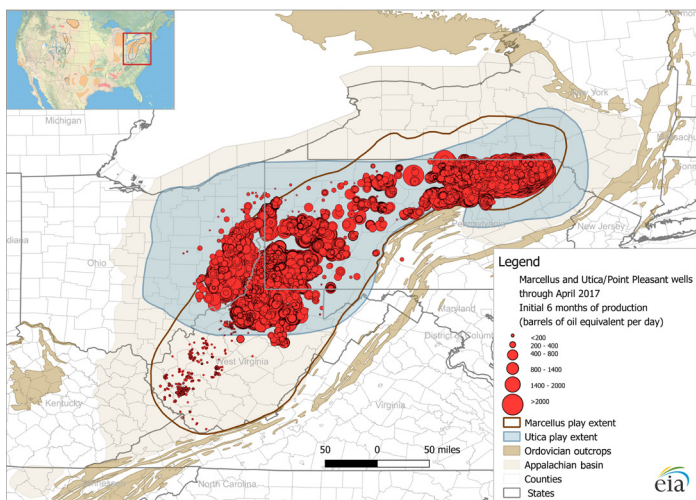
Within oil-rich areas, finer-scale variations in the geology of the area will produce regions of greater or lesser productivity, as shown on the next page for the Marcellus and Utica/Point Pleasant plays in the Appalachian Basin.³

Leasing: Permission from the Landowner

Mineral rights – the ownership of rocks, minerals, oil, and gas beneath an area of land – may belong to private individuals or local, state, or federal government. Before exploring for and producing oil and gas, operators must obtain a lease from the mineral rights owner. The mineral rights owner may be different



Left: Areas of historical oil (red), gas (green), or mixed (yellow) production in the contiguous United States as of 2005 (immediately prior to the shale boom). Right: Current (solid orange, plus blue and black outlines) and prospective (solid red) shales for oil/gas production, overlain on major sedimentary basins (tan), as of 2016. Image credits: Laura R.H. Biewick, U.S. Geological Survey;¹ U.S. Energy Information Administration.²



Map of wells in the Marcellus and Utica/Point Pleasant formations (Pennsylvania, Ohio, and West Virginia) through April 2017. Although potentially oil- and/or gas-bearing shales (brown outline and blue field) underlie almost the entire region, a wide variety of factors (discussed throughout the text) determine exactly where and in what concentration wells are drilled. Image credit: U.S. Energy Information Administration.⁴

from the surface landowner, and in some cases the owner of one mineral, such as coal, differs from the owner of oil and gas. These cases of “split estate,” where there are different owners of surface and underground resources, result from the fact that mineral ownership can be sold or transferred like other property.

Obtaining a lease does not mean that a well will be drilled. Typically, an operator acquires a large number of leases in an area to give them the flexibility to drill wells in a range of locations based on the results of exploration and early drilling.

Private mineral owners can choose to lease or not to lease their land for drilling, and can negotiate the terms of the lease, including an up-front “bonus” payment of less than one hundred to as much as several thousands of dollars per acre. The lease also sets the royalty payments (the proportion of the value of resources produced that will be paid to the mineral owner, often 12.5%). Lease terms may also include requirements to protect crops, livestock, or buildings, all of which may affect the location of the well.

The federal government restricts oil and gas activities in national parks, monuments, and areas where Congress or the President has suspended such activities. In other areas, the federal government leases public land for oil and gas development when it is deemed

to be compatible with other public uses and the protection of wildlife, scenery, water, and land.⁵ Federal leases are offered in regularly scheduled competitive lease sales. State lands may also be leased, usually in a competitive process. For example, the Marcellus and Utica shales underlie 1.5 million acres of Pennsylvania state forest land; in 2017, over 130,000 of these acres were under lease for shale gas production.⁶ In addition, Native American tribes, individual Native American mineral owners, and Alaska Native Corporations may lease their lands for oil and gas development.⁷

Drilling Permits

Regardless of leasing agreements, operators must obtain permission from the state to drill a well on any land within that state, whether it is private or owned by the local, state, or federal government.⁸ If the land is federally owned, federal approval is also required (see below). In some cases, the well will also require county or local government permission to drill. Although state drilling regulations vary widely, common regulations include:

- Restrictions on drilling in or near parks or historic sites
- Rules on how closely wells can be spaced, to prevent operators from extracting resources that belong to adjacent leases and mineral rights owners
- Minimum distances or setbacks between wells and homes, businesses, schools, roads or public areas – some local and county governments also set minimum distances within their jurisdictions

In some states, the application to drill a well may be open for public comments before being approved.

If the operator plans to hydraulically fracture a well, they may be subject to additional regulations such as taking groundwater measurements before drilling. This provides information about the pre-drilling composition of local groundwater, which allows potential groundwater contamination from hydraulic fracturing fluids to be identified.⁹ As of 2018, hydraulic fracturing has been banned in two states with resources that could be produced using the technology (New York¹⁰ and Maryland¹¹) and one state with no known oil or gas resources (Vermont¹²).

Drilling Restrictions on Federal Land

Drilling on public land is controlled by the federal government, which aims to balance a wide variety of land uses, including oil and gas exploration and production, livestock grazing, hunting and fishing, coal and mineral development, recreation, and natural or cultural conservation.¹³ Laws passed by Congress and signed by the President – or executive orders signed by the President – can restrict or ban leasing and/or drilling in federally controlled areas. Recent and historical restrictions and bans of this nature have been implemented in national parks and monuments, wilderness areas, the Great Lakes, and offshore (see “Offshore Oil and Gas” in this series for more information on offshore drilling).

Oil and gas development of onshore federal land is largely overseen by the Bureau of Land Management (BLM). There are roughly 100,000 active wells in areas managed by BLM; between 2000 and 2016, on average 3,000 new wells were drilled each year.^{13,14} The Forest Service, the National Park Service, the Army Corps of Engineers, the military, or the Bureau of Reclamation may impose additional restrictions on lands under their management. Regardless of land ownership, if operators intend to drill beneath a navigable waterway or add new material (e.g., for roads or well pads) that might affect a waterway or wetland, they must first obtain permission from the U.S. Army Corps of Engineers.¹⁵

The National Environmental Policy Act of 1970 (NEPA) requires federal agencies to assess the environmental effects of their proposed actions, including oil and gas leasing or drilling on federal land.¹⁶ For NEPA compliance and other requirements, BLM develops regional, long-term land-use plans, called Resource Management Plans, with input from other government agencies, individuals, organizations, and local governments (see “The Pinedale Gas Field, Wyoming” in this series for example elements of a Resource Management Plan).¹⁷

Drilling Technology

Early oil and gas wells were drilled straight downward, meaning that oil and gas resources could only be extracted if a well site could be installed directly above them. Over time, drilling technology continuously advanced, and by the first half of the 20th century, wells could be drilled at an angle, allowing the location of the wellhead to be placed away from sensitive areas or competing land

Protecting Forests while Producing Energy in Appalachia

Forests and streams in Appalachia support diverse plant and animal populations that may be threatened by habitat fragmentation caused by oil and gas activity. Environmental organizations in partnership with industry and academia are working to reduce the surface impact of oil and gas operations in this region by optimizing the placement of drilling and production sites, roads, and pipelines. For example:

- The Landscape Environmental Energy Planning tool (LEEP)¹⁸ was developed by The Nature Conservancy (TNC) in collaboration with the University of Tennessee at Knoxville, the Cadmus Group, and industry advisors. LEEP is an interactive, web-based GIS program that industry planners can use to assess the relative costs and environmental impacts of different configurations for wells, access roads, and gathering pipelines.
- A 2015 workshop hosted by TNC and Carnegie Mellon University brought together a group of over 70 organizations to develop siting recommendations for energy infrastructure to protect Appalachian biodiversity. The publication, “Advancing the Next Generation of Environmental Practices for Shale Development,”¹⁹ was a collaborative effort between the energy industry, non-governmental organizations, academic institutions, and federal, state, and local government.

uses. More recently, advances in horizontal drilling have allowed operators to drill horizontally underground for up to several miles.²⁰ This has the potential to provide increased flexibility in choosing the surface location of drill sites based on other factors, such as environmental protection (see sidebar).

Enhanced Recovery Wells and Pooling

Many advanced techniques for oil and gas production require operations to span more than one lease:

- Enhanced oil recovery techniques such as steamflooding, waterflooding, and carbon dioxide injection require

an operator to drill injection wells some distance from producing wells.²²

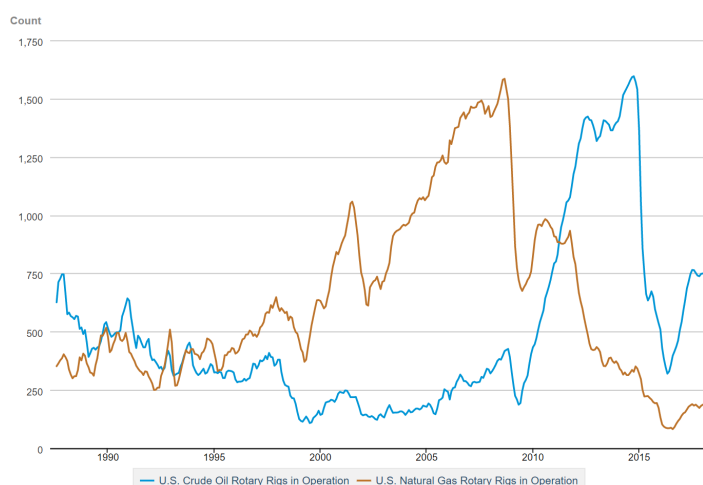
- Since the early 2000s, the proliferation of horizontal wells extending a mile or more away from the vertical portion of the well has required operators to work with mineral rights owners in leases adjacent to those where the producing well sites are located.

“Pooling” refers to the combining of leases and sharing of operational costs and production revenues within those leases by all parties involved. Mineral owners adjacent to an area leased for oil and gas development may be legally forced to lease their subsurface minerals if theirs are necessary for development of the first lease – this is referred to as “forced pooling”. All mineral rights owners in the pool share in the costs and revenues, even if there are no producing wells on their land.²³

Economic Considerations

For oil and gas operations to be financially viable, the expected cost to explore for, drill, and extract the resource must be less than the value of oil and gas expected to be produced over the life of the well. National and global demand and price for oil

Crude Oil and Natural Gas Drilling Activity



U.S. oil and natural gas drilling activity by number of drilling rigs in operation, 1988-2018. Natural gas drilling boomed with the use of horizontal drilling and hydraulic fracturing in the early 2000s, then fell in response to the 2008 recession and continued to fall due to excess gas production. Drilling in oil-rich shale areas picked up after the 2008 recession but fell with low oil prices in 2014-2015. Image credit: U.S. Energy Information Administration.²¹

and gas have major implications for the number and location of new wells that are drilled. For example, declining natural gas prices from 2008 to mid-2016 led operators to focus on more oil-rich areas. The drop in the price of oil in late 2014 reduced the total number of new wells being drilled and led the industry to focus operations in areas with highly productive wells and lower operating costs. Even with decreased drilling costs and improved drilling efficiency,²⁴ the number of new wells plummeted. For example, in Texas, the number of new wells drilled per year dropped from over 27,000 in 2014 to less than 9,000 in 2016.²⁵

References & More Resources

For a complete listing of references, see the “References” section of the full publication, *Petroleum and the Environment*, or visit the online version at: www.americangeosciences.org/critical-issues/petroleum-environment

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