



Understanding Well Construction and Surface Footprint



INFORMATION ABOUT CANADA'S
EMERGING ENERGY RESOURCES

Well Construction Timeline



Well Site Planning & Preparation

Stage 1: Planning and Preparation

- Acquire Surface Lease Agreement
- Determination of multi-well pad or single well pad requirements
- Inform stakeholders of the proposed well construction
- Evaluation of sour gas probability; this will influence equipment location, etc.
- Acquire Well license(s)
- Obtain Operation(s) permits
- Site Excavation and Preparation
- The preparation of the location would include the drilling of initial “rat hole/mouse hole” and placement of conductor string/ pipe
- Identify safety procedures, environmental and regulatory requirements
- Outline the emergency response plans/procedures

Drilling

Stage 2: Drilling

- Drilling rig and equipment mobilization (if not used for Surface Hole drilling)
- Drilling fluids/mud – testing and recycling
- Blow Out Preventer (BOP) installation
- Surface, and intermediate (in some cases) casing cemented into the wellbore
- Drill cutting samples taken and analyzed (ongoing throughout the drilling process)
- Wellbore drilled to total depth(vertical, directional or horizontal)
- Potential reservoir(s) identified and evaluated using geophysical logging techniques

Most stages of well construction include stakeholder dialogue. Consultation with stakeholders is the responsibility of the individual project proponent.

Casing & Cement

Completion & Stimulation

Site Maintenance

Stage 3: Casing and Cement

- Production casing lowered into the well and cemented into place
- Diagnostic tools are utilized to ensure wellbore integrity

Stage 4: Completion & Stimulation

- Drilling rig is moved offsite and permanent wellhead installed
- Stimulation equipment is moved into place
- Reservoir horizons are perforated and then stimulated
- Stimulation equipment is moved offsite
- Producing zones are tested
- With the drilling and completion equipment demobilized, the surface footprint is dramatically reduced.

After casing, cementing and well stimulation activities are completed, and assuming the well is successful, there will be additional construction activity on site to install surface facilities if required, tie the well into the pipeline infrastructure, and contour and reclaim part of the lease site.

This information booklet discusses well construction practices only. For more information about the completions process, including Hydraulic Fracturing or other stimulation techniques, please reference *Understanding Hydraulic Fracturing* or *Understanding Water and Unconventional Resources* at www.csur.com

Well Site Planning & Preparation

Single vs. Multi-well pad

A standard single well lease site for conventional oil or gas will typically affect a surface area measuring 100 metres by 100 metres. The lease site will typically hold the drilling rig and additional equipment along with supervisory accommodation and material storage. If multiple wells from a single pad are planned, the surface area of the lease site would be larger; in some cases as much as double the size. (100 metres by 200 metres.) While a multi-well pad site will have a larger surface area, the cumulative surface impact of the total number of wells drilled in the project area will be smaller. Pad sites allow multiple wells to be drilled from one surface lease, thereby reducing the total surface area required for oil and gas development. Once drilling is completed and the well(s) is/are connected/tied-in to the pipeline, a portion of the lease area can be reclaimed to minimize surface disturbance.

Surface Lease Site Agreement

A surface lease site agreement grants a company access to drill a well(s) on land that is held either privately, by the crown or by a First Nation. The agreement also specifies any conditions relating to the commitments and responsibilities of both the company and the landowner, including the payment of compensation by the company to the landowner.

License & Permit

Federal and/or Provincial and Municipal licenses and permits are required for lease site construction; project specific requirements will vary depending on the location of the well.

Excavation & Leveling

To prepare for initial drilling, the lease site is leveled, if necessary, with a bulldozer and/or grader, with careful consideration given to buried pipelines and utilities, as well as proximity to surface water features. The scale and duration of lease site preparation is site-specific. On some drilling sites, a **cellar** may be excavated. This is where the main borehole is to be drilled. A reserve pit and settling pits may be excavated and are used for water or **drilling fluid** (mud) discharges. Often the soil layers are separated for better soil conservation. Upon completion of the drilling, the soils can then be restored to their original location.



Excavated lease site

Drilling of the “Surface Hole”, etc.

As part of any oil or gas well, a conductor hole and surface hole are required as part of the entire wellbore. Commonly, a rathole and/or a mousehole are drilled prior to the actual drilling of the well to reservoir depth. A conductor hole, also referred to as a “starter hole” is a large diameter hole, lined with pipe which varies in depth, and is used to house the BOP (Blow Out Preventer). A rathole is a hole lying below the rig floor, 30 to 35 feet deep, lined with **casing** into which the **kelly** is placed when hoisting operations are in progress. A mousehole is a shallow bore hole under the rig floor, usually lined with pipe, into which joints of drill pipe are temporarily placed during drilling operations. These are either done by the portable rig that drills the conductor hole, or can be done by the primary rig after **rigging-up**. The surface hole is drilled and cased to isolate potential shallow groundwater **aquifers** from the wellbore.

Safety Procedures & Emergency Response Plans

All drilling sites are typically classified according to areas of potential and/or actual exposure to **Hydrogen Sulfide (H₂S)**. H₂S is an extremely toxic and poisonous gas. Employers will take special precautions when choosing equipment. Well site employees are trained to respond accordingly should they encounter H₂S. Under these circumstances, all employees are required to wear specially

approved masks and air supply equipment. The recommendations and employee instruction will vary depending on the type of area, as will the emergency response plans (ERPs) that are in place

Environmental and Regulatory Considerations

Provincial and federal regulations, which govern the oil and gas industry, have been in place for many years. They have been established to ensure that both the public and the environment are protected throughout exploration, development and production of hydrocarbon resources. Regulations are also continually reviewed and revised, as required, in response to advancements in industry technologies and the techniques employed to extract the resource.

The fundamental regulatory basics of surface and groundwater protection, wellbore integrity, lease construction, for example, apply to all types of hydrocarbon developments; including unconventional resources. Similarly, the use of water for drilling and completion activities require approvals or permits from appropriate authorities.

Prior to acquisition of the surface lease site, a number of different steps are required. Requirements will vary depending on the location of the proposed development and jurisdictional prerequisites.

Drilling

Equipment Assembly and Placement

A site, and its access road, must accommodate a large number of temporary and semi-permanent structures and tanks, all brought in by truck. At a newly-prepared drill site, the stability of the well pad is necessary to support the drilling rig and auxiliary equipment required onsite. In some localities where the ground is unstable rig mats are commonly used. After the well pad is properly prepared the drilling rig is then unloaded and assembled.

There are many rig designs, and this booklet does not cover each type individually. During assembly of the rig, some equipment may be handled and set with crane, rig up trucks, or forklift, depending on the size of the rig.

The substructure is assembled, pinned together, leveled, and tied into other rig components. Once the substructure is set in place, installing the power system and raising the derrick begins. Most drilling rigs are powered by electricity that is delivered by onsite diesel powered generators.

While one crew finishes preparing the rig floor, another crew might be rigging up the circulating system. The mud tanks and mud pumps are set into the predetermined location.

Once all additional drilling and auxiliary equipment are set into place a final inspection can be done. The entire process of rigging-up can take one or two days. Where multiple wells are drilled from a single pad, commonly the drilling rig will have the ability to move to the next location on the lease with minimal disassembly/reassembly.

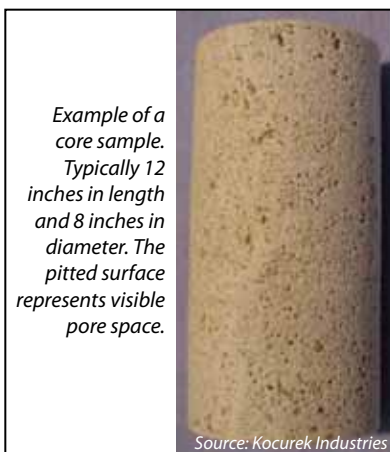


Source: Shale Exploration

Drilling boreholes deep into the ground and preparing them to produce oil and gas is a highly technical and specialized process. Throughout the operation, custom-designed fluids fulfill many different roles. While drilling, these include: lubricating the **drill bit**; circulating drilled-up rock out of the hole; containing **formation fluids** within the hole; and facilitating operation of sophisticated **formation evaluation tools**. Fluids may be water-based, oil-based, or synthetic.

Core Samples

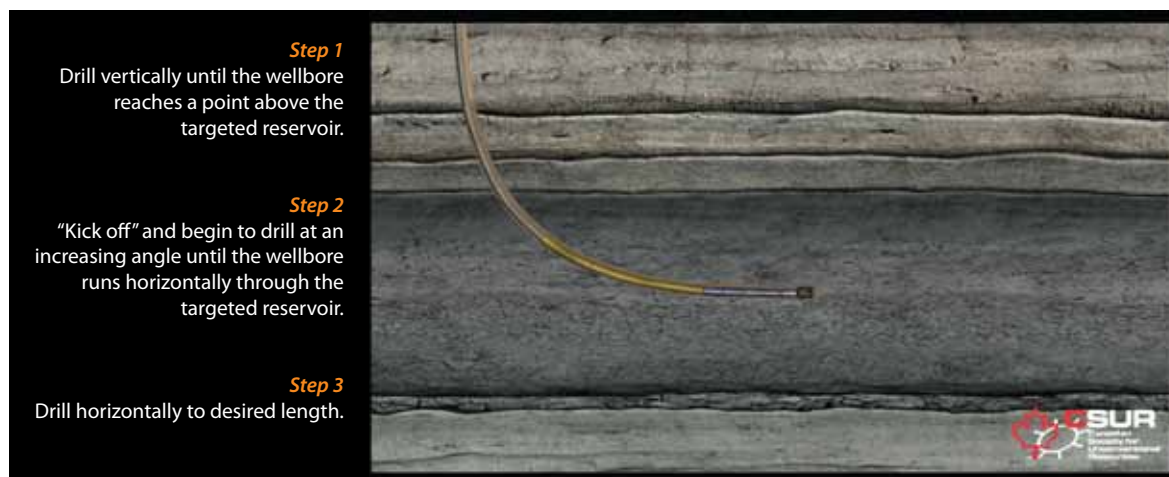
In some cases, a core sample of the formation is taken for testing. A special core barrel is lowered to the bottom on the **drill string** and is rotated to cut a core from the formation. This core is brought to the surface and examined in a laboratory. Some core or chip analysis may occur at the temporary on-site lab while other core samples are sealed and shipped to specialized labs for in-depth reservoir characteristic and core analysis.



Vertical vs. Horizontal

Although historically oil and gas wells have been drilled vertically, new technologies have made it possible for wells to be drilled horizontally. The purpose of drilling a horizontal well is to increase amount of reservoir rock that is intersected from the wellbore. Horizontal drilling first entails drilling a vertical well to a predetermined depth above the reservoir. The well is then drilled at an increasing angle until it intersects the reservoir interval in a horizontal plane. Once horizontal, the well is then drilled to a selected length, which could extend to as much as 3500m. This portion of the well, called the horizontal leg, allows significantly increased contact of the wellbore with the reservoir compared to a vertical well. Upon completion of drilling, **production casing** is commonly placed into the wellbore. A **perforating**

gun is lowered into the wellbore and placed in a selected interval within the horizontal leg. It is then activated to create a series of holes in the casing to allow communication between the reservoir and the wellbore



Casing and Cement

Well construction activities are engineered to ensure that groundwater bearing horizons are isolated from the wellbore. This process eliminates the potential for communications and possible contamination during subsequent drilling, completion and final production operations. To provide the protection necessary, usually a number of steps are completed to isolate the wellbore from the surrounding rock intervals that have been penetrated during the drilling process.

Step 1 Once the conductor pipe has been put in place the surface hole is drilled to the base of groundwater protection, as defined by the regulatory body. Surface casing is lowered into the hole and cemented in place. At this stage, a barrier of steel AND cement is created to prevent the contamination of potential shallow groundwater aquifers as well provide wellbore stability for the remaining drill hole.

Step 2 The cement is allowed to set prior to continuation of drilling and in some jurisdictions, a “cement bond” **geophysical log** is run to determine the integrity of the cement that surrounds the surface casing.

Step 3 The wellbore is then drilled to its total depth. In some cases, depending on the total depth of the well or the orientation (horizontal or

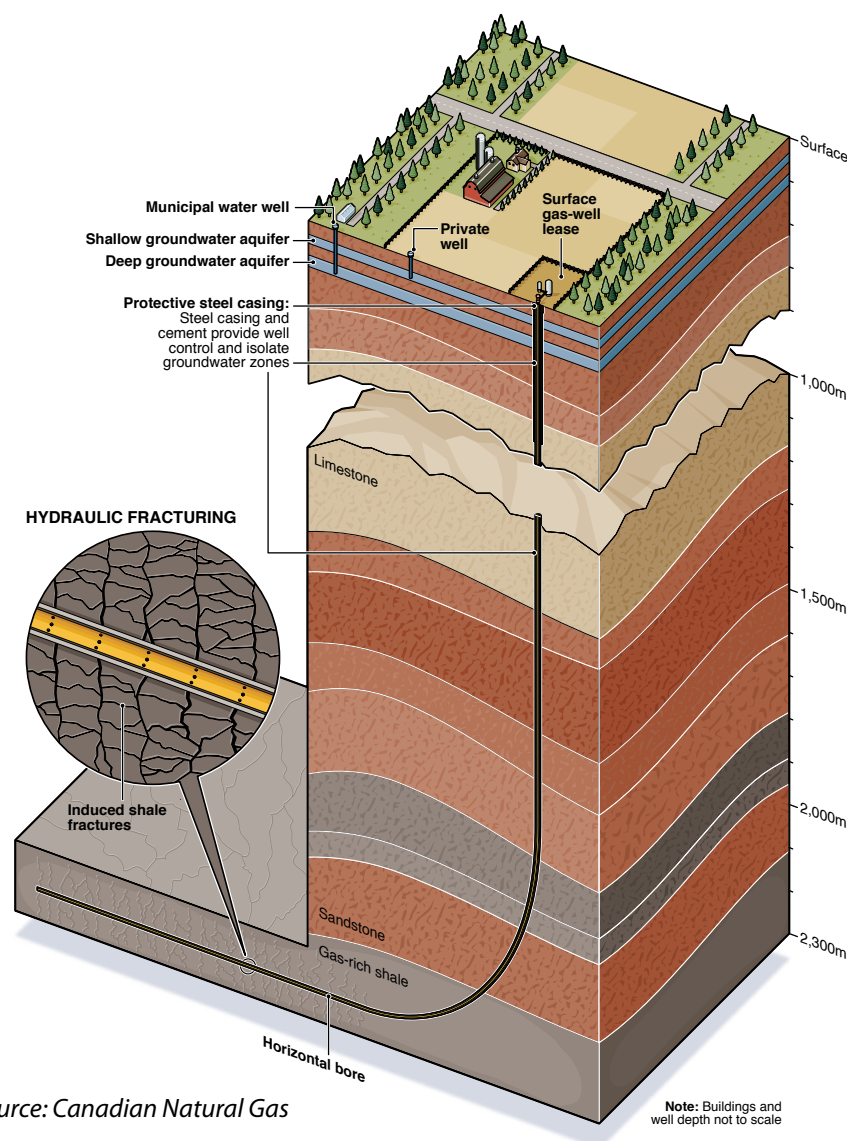
vertical) an intermediate set of casing may be inserted into the wellbore and cemented in place. The process of installation and cementing of intermediate and production casing is similar to surface casing. The decision to install additional casing is based upon expected reservoir conditions as well as completion and stimulation techniques that are to be used. This second (or third) set of steel casing provides additional isolation of the hydrocarbon zone from potential shallow aquifers.



CSUR Casing Model

It is important to recognize that the oil and gas industry uses technologically advanced cement to construct the wellbore. Concrete used for sidewalks is very different than the cement used to secure surface, intermediate and production casing in place. Cements are tailored to formation, temperature, depth, completion technique and other factors.

It is important to ensure that groundwater is protected, not only in the first few stages of wellbore construction, but also during the full life cycle of the well. This is a regulated process whereby the owner of the well is required to ensure that conditions downhole do not degrade the wellbore integrity over time. Possible well integrity concerns could arise as a result of poor cement bond, casing shift, corrosion of casing over time, etc. There are several diagnostic tools utilized in industry to help promote wellbore integrity such as **cathodic protection**, chemical treatment and production packers. There are also several tools to identify wellbore integrity issues after they've occurred, for example, corrosion logs, cement bond logs, production logs and casing patches.



Source: Canadian Natural Gas

Completions and Stimulation

Once the well has been drilled and cased it is now ready to be stimulated. There are a variety of stimulation processes, the most common of which being hydraulic fracturing. Following the stimulation of the potential zone(s) the well is ready to be equipped for production.

When the well is ready, hydrocarbons can be produced either through the production casing or through tubing inserted down the production casing. The type of hydrocarbons produced (oil or gas) will determine the type of production string used.

If tubing is to be used, the joints are linked together with couplings to make up a tubing string. Tubing is run into the well much the same as casing, but tubing is smaller in diameter and is removable. Coiled tubing can also be used thus eliminating the need for tongs, slips, or elevators, which makes it easier to install. Prior to production flow, downhole isolation equipment such as **packers** or plugs are removed and drilling fluid is flushed from the wellbore. Hydrocarbons can now flow freely to the wellhead.

If the well does not flow on its own, artificial lift systems may need to be considered, such as a **beam pumping unit**.



Coil Tubing Unit

Source: Schlumberger



Beam Pumping Units.

Source: United States Department of Labour

Key Personnel

The drilling of an oil or gas well requires a number of highly trained professionals, both in the office as well as in the field. Key personnel may include but are not limited to:

Drilling Engineers design and implement procedures to drill wells as safely and economically as possible, while at the same time protecting the health and safety of workers and other personnel in accordance with established regulations.

Surface Land Men ensure the timely and accurate acquisition of surface rights; coordinating the efforts of Surveyors and Brokers. They represent the drilling company and interact extensively with internal Business Units, public and regulatory stakeholders. They also make sure surface acquisition and consultation compliance meet Regulatory requirements.

Surveyors determine the precise location of the planned well the surrounding lease site. He or she is licensed by the province and work on behalf of the oil and gas company



A **Construction Engineer** performs engineering work in the field to support well construction and helps in the planning and execution of construction work in the field.

Contractors or **Sub-Contractors** are employed by the oil and gas company to perform work onsite throughout various stages during well construction. The drilling crew, cementers, well testers, water haulers and welders are all examples of contractors that work on the construction site.

Well site geologists monitor the progress of the well as it is drilled to identify the presence of oil and gas in the sub surface. They also inform the rest of the drill team when the well has reached the reservoir target.



Site Maintenance

Footprint

Commercial production of unconventional resources often requires numerous wells to intersect the oil and gas bearing formation(s) in order to be economic. The technologies of horizontal drilling and multi-stage fracture stimulation coupled with multiple wells from a single pad have enabled the cumulative surface footprint to be minimized.

Companies can drill multiple wells from a single-pad location and extract the hydrocarbons from as much as 10 sq km. While the size of a multi-well pad is slightly larger than a regular oil and gas lease the cumulative footprint for a development is much smaller than it would be with conventional development using vertical wells. Fewer access roads and the concentration of facilities and pipelines within the pad footprint minimize the surface disturbance of a development.

During the actual drilling and hydraulic stimulation procedures for unconventional resource development, there is a concentration of heavy equipment on site. Water requirements for both drilling and fracturing can be large and commonly a lined reservoir pit or tanks are used for storage. In some cases, if the water source is nearby, temporary pipelines are constructed to transport the water rather than using tanker trucks. Upon completion of the drilling activities, all of the heavy equipment is removed and permanent surface facilities are constructed. In most cases, the footprint of the wells and surface facilities is much smaller than the original drilling footprint

Construction vs. Production

Once the well is completed and fully moved through to production, the footprint of the lease site is greatly reduced.



Multi-well pad during construction and completions activity



Horizontal multi-well pad in production

Source: Trident Exploration

Well Control

Properly trained personnel are essential for well control activities. Well control consists of two basic components: an active component consisting of specialized drilling fluids and pressure control to minimize the potential inflow of hydrocarbons or groundwater fluids and a passive component that consists of monitoring equipment that responds if a inflow or pressure kick occurs. The Blowout Preventer (BOP) is an integral part of the monitoring and well control equipment.

The first line of defense in well control is to have sufficient drilling fluid pressure in the wellbore. In the subsurface, underground fluids such as gas, water or oil are under pressure (**formation pressure**). The column of drilling fluid in the well creates a pressure (**mud pressure**) that counteracts the formation pressure. If the formation pressure is greater than the mud pressure, there is the possibility of a **blowout**.

The **blowout preventer (BOP)**, **accumulator** and **choke manifold** are installed by the rig crew after the surface casing is set and cemented. The choke line valve is used to redirect the mud from the well bore to the choke manifold should a pressure event occur. If an event does occur, the BOP is activated, containing the pressure and avoiding a blowout.

The BOPs, accumulators, and choke manifold need to be properly maintained and are tested on a regular basis



Blowout Preventer (BOP)



Choke Manifold

Glossary and Terminology

Accumulator: A device used in a hydraulic system to store energy or, in some applications, dampen pressure fluctuations. Well pressure-control systems typically incorporate sufficient accumulator capacity to enable the blowout preventer to be operated with all other power shut down.

Aquifers: Any water-bearing formation encountered while drilling. Drillers often are concerned about aquifers and are required to take special precautions in the design and execution of the well plan to protect fresh water aquifers from contamination by wellbore fluids.

Beam Pumping Unit: An artificial-lift pumping system using a surface power source to drive a downhole pump assembly.

BOP (Blow Out Preventer): A large valve at the top of a well that may be closed if the drilling crew loses control of formation fluids. By closing this valve (usually operated remotely via hydraulic actuators), the drilling crew can regain control of the reservoir.

Casing: Large-diameter pipe lowered into an openhole and cemented in place. The well designer must design casing to withstand a variety of forces, such as collapse, burst, and tensile failure, as well as chemically aggressive brines.

Cathodic Protection: A technique used to minimize the rate of corrosion of a structure. It does not eliminate corrosion, it transfers corrosion from the structure under protection to a known location where artificial anodes (plates or metal bars) are placed and could be replaced easily.

Cellar: A dug-out area, possibly lined with wood, cement or very large diameter pipe, located below the rig. The cellar serves as a cavity in which the casing spool and casing head reside. On smaller rigs, the cellar also serves as the place where the lower part of the BOP stack resides.

Cement Bond Logs: A representation of the integrity of the cement, used in casing of the well.

Choke Manifold: A set of high-pressure valves and associated piping that usually includes at least two adjustable chokes, arranged such that one adjustable choke may be isolated and taken out of service for repair and refurbishment while well flow is directed through the other one.

Drill Bit: The tool used to crush or cut rock. Everything on a drilling rig directly or indirectly assists the bit in crushing or cutting the rock.

Drilling Fluid: Any of a number of liquid and gaseous fluids and mixtures of fluids and solids (as solid suspensions, mixtures and emulsions of liquids, gases and solids) used in operations to drill boreholes into the earth.

Drill String: A pipe made of lengths of steel tubing that is attached to the drilling tool and rotates during drilling. The drilling fluid passes through the centre of the drill string through the bit which is attached at the end.

Formation Evaluation Tools: The tools used for the measurement and analysis of formation and fluid properties. Formation evaluation is performed to assess the quantity and producibility of fluids from a reservoir. Formation evaluation guides wellsite decisions, such as placement of perforations and hydraulic fracture stages, and reservoir development and production planning.

Formation Fluids: Any fluid that occurs in the pores of a rock. Strata containing different fluids, such as various saturations of oil, gas and water, may be encountered in the process of drilling an oil or gas well. Fluids found in the target reservoir formation are referred to as reservoir fluids.

Formation Pressure: The pressure of fluids within the pores of a reservoir, normally hydrostatic pressure, or the pressure exerted by a column of water from the formation's depth to sea level.

Geophysical Logs: A log of elemental concentrations from which the geochemistry of the formation may be derived.

Hydrogen Sulfide (H₂S): An extraordinarily poisonous gas with a molecular formula of H₂S. At low concentrations, H₂S has the odor of rotten eggs, but at higher, lethal concentrations, it is odorless. H₂S is hazardous to workers and a few seconds of exposure at relatively low concentrations can be lethal, but exposure to lower concentrations can also be harmful. The effect of H₂S depends on duration, frequency and intensity of exposure as well as the susceptibility of the individual.

Kelly: A long square or hexagonal steel bar with a hole drilled through the middle for a fluid path. The kelly is used to transmit rotary motion from the rotary table or kelly bushing to the drillstring, while allowing the drillstring to be lowered or raised during rotation.

Mud Pressure: The pressure of the column of drilling fluid in the wellbore.

Packer: A device that can be run into a wellbore with a smaller initial outside diameter that then expands externally to seal the wellbore.

Perforating Gun: A device used to perforate oil and gas wells in preparation for production.

Rigging-up: To make ready for use. Equipment must typically be moved onto the rig floor, assembled and connected to power sources or pressurized piping systems.

Rig Mat: A portable platform used to support equipment for construction and resource-based activities including drilling rigs, camps, tanks, helipads, etc. It also includes a structural roadway to provide passage over unstable ground, pipelines and more.

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