C. APPENDIX C - OIL AND GAS EXPLORATION, DEVELOPMENT, AND PRODUCTION

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C. OIL AND GAS EXPLORATION, DEVELOPMENT, AND PRODUCTION

C.1 INTRODUCTION

Once an oil and gas lease is issued, the lessee or operator may enter upon the leasehold to conduct oil and gas operations unless otherwise limited by special stipulations. The following depicts what can be expected to occur and, therefore, assumed will occur for the purposes of this analysis when oil and gas is discovered and development of a lease is undertaken. It also is assumed that the technology of oil and gas exploration and development will not change significantly during the life of this document.

This section (Appendix C), the Reasonably Foreseeable Development Scenario (Appendix D), and the assumptions made for the various development activities, are the basis for the levels of activity on which the environmental effects listed in Chapter 3 of this document have been estimated.

Successful oil and gas exploration and development generally progresses through five basic operational phases. These include (1) preliminary investigation (includes geophysical exploration), (2) exploratory drilling, (3) field development, (4) production, and (5) plugging and reclamation. Several operational phases can occur in the same area at the same time. One company may drill an exploratory well on a lease, while nearby another company conducts preliminary investigations. However, if only one company is conducting operations in an area, normally only one phase of the operation will take place at a time. A lapse of several months or perhaps years may occur between the preliminary investigation and exploratory drilling phases. A lapse of several weeks or months also may occur between the exploratory drilling and development phases. The development and production phases may occur simultaneously, especially if a large field has been discovered. Only a small percentage of the wildcat (exploratory) wells drilled in the United States are successful.

It may take several years to determine whether an exploratory well is a financial success. If it is a success, the operations progress through the three remaining phases over a time span ranging up to 50 years.

The lapsed time between the production and abandonment phases of a field may be 20 to 50 years. If exploratory drilling is unsuccessful in the discovery of a commercial deposit of oil and gas, operations are terminated and plugging and reclamation is initiated. The operation also may go directly from development to abandonment if one or more of the development wells are unsuccessful.

C.2 PRELIMINARY INVESTIGATIONS (PHASE 1)

Exploration methods such as remote sensing and the mapping of rock outcrops and seeps can obtain indications of the presence of oil and gas. In many cases indirect methods, such as seismic, gravity, and magnetic surveys are used to delineate subsurface features that may contain oil and gas.

C.2.1 Permitting Process

Geophysical exploration (seismic reflection surveys) on National Forest System (NFS) lands is authorized under a prospecting permit issued by the Forest Service. Proposals for geophysical operations on and off oil and gas leases are examined by the Forest Service prior to being approved or authorized. Most casual-use investigation methods, such as geological, gravity, geomagnetic, and geochemical surveys, do not require a permit since no surface disturbance occurs and only a "casual" presence on the land surface is required to conduct the operations.

In order to secure a permit for non-casual operations on NFS lands, the geophysical operator is required to file, in person or by mail, an application for a prospecting permit. The application must describe the proposed activities in detail and include a map showing access routes and location of exploration activities. Upon receipt of the application, the Forest Service reviews the proposed activities, determines and conducts the appropriate NEPA analysis, and determines the requirements or conditions necessary to protect surface uses and resources. After the Forest Service reviews the application, a permit is prepared. The operator is sent the prospecting permit indicating the stipulations, fee to be paid (if applicable), and amount of bond required. The operator must sign and return the permit with the fee and bond required prior to receiving a permit.

The operator must receive approval of a prospecting permit prior to initiating operations. The operator must also notify the Forest Service of the scheduled entry onto the land, must comply with all permit conditions, and receive prior approval of any changes in the original plans. A pre-work conference and a cultural resources survey may be required prior to undertaking surface disturbing activities. The Forest Service conducts compliance inspections during exploration operations to ensure compliance with the permit and to prevent unnecessary damage to the surface resources.

The geophysical operator is required to notify the Forest Service when operations and required reclamation are completed. The Forest Service conducts a final inspection prior to approval of termination of the permit and release of the bond.

C.2.2 Geologic and Remote Investigations (Surveys)

Geologic investigation begins with a review of geologic and technical data available for the area of interest. If the data indicates a potential for oil and gas, information for specific areas or trends are evaluated. If the area does not have a history of producing oil, and no previous wildcat wells have been drilled, an extensive geophysical exploration program covering a large area may be undertaken to collect the subsurface data necessary to evaluate the oil and gas producing potential.

Remote investigations may be conducted either from the air or on the ground. These are preliminary investigations that involve only casual use and no permits are required. However, the investigators must comply with the Forest Service rules and regulations. The oil and gas lease does not grant an exclusive right to conduct remote investigations and geophysical exploration. These activities may be conducted prior to, or after, leasing by either the lessee or someone other than the lessee. These investigations may result in an expression of interest to lease specific areas.

Geological Surveys—Geological surveys normally are a casual use. Rock outcrops and topography are examined to determine the structural attitude and age of the surface formations, and surface maps are prepared. In some areas, sufficient information may be obtained to enable the geologist to recommend a drilling location without conducting additional exploration work.

Geochemical and Soil-Gas Surveys—Geochemical and soil-gas surveys involve casual use of the land. In geochemical surveys, the chemical contents of water, soil, or vegetative samples are analyzed for the minute presence of oil or gas.

Gravity Surveys—Gravitational prospecting is a casual use to detect small variations in gravity caused by the differences in the density of various rock types. The instrument used for gravity surveys is a small portable device called a gravimeter, which can be carried by an individual. There is little surface disturbance associated with gravity prospecting except that which may be caused by off-highway vehicle (OHV) use to transport equipment.

Geomagnetic Surveys—Magnetic prospecting is used to a limited extent in oil and gas exploration. Magnetic surveyors use an instrument called a magnetometer to detect small magnetic anomalies in the earth's crust. Most magnetic surveys are conducted from the air by suspending a magnetometer under an airplane. This is a casual use. There is no surface disturbance from magnetic survey operations.

C.2.3 Seismic Reflection Surveys (Geophysical Exploration)

Seismic prospecting is the most common indirect method used for locating subsurface structures that may contain oil and gas. Shock waves are induced into the earth using one of several methods. These waves travel downward and outward encountering various strata, each having a different seismic velocity. Sensing devices called geophones are placed on the surface to detect these reflections. The geophones are connected to a data recorder, which stores the data. The time required for the shock waves to travel from the seismic energy source down to a given reflector (a change in rock strata) and back to the geophone can be correlated to the depth of the reflector. Shock waves can be generated by truck-mounted thumpers or vibrators (vibroseis), drilling/explosives, surface charges, or explosive cord (primacord). At the present time, vibroseis and drilling/explosives are the two most commonly used geophysical exploration methods.

Vibroseis Surveys—The thumper and vibrator methods pound or vibrate the earth to create the shock wave. Usually large trucks, each equipped with vibrator pads (about four feet square), are used. The pads are lowered to the ground and vibrators on all trucks are turned on simultaneously. Information is recorded, the trucks are moved forward a short distance, and the process is repeated. Except where an access trail may need to be constructed or where cross-country travel is necessary, surface disturbance is usually minimal since little surface area or disturbance is required to operate the equipment at each test site.

Drilling/Explosives—In this method, small-diameter holes are drilled to depths of 100 to 200 feet. Four to twelve holes are drilled per mile of line. Drills can be truck-mounted, portable by helicopter or off-road vehicle, or in some instances portable by pack animals. A charge of explosives is placed in the hole, covered, and detonated. The explosion sends energy waves that are reflected back to the surface from subsurface rock layers. Holes are drilled along a line that can be miles in length. In rugged topography, inaccessible to wheeled vehicles, a portable drill may be transported by helicopter. A typical seismic drilling operation may use 10 to 15 workers operating multiple drills. Under normal conditions, three to five miles of line can be surveyed each day using the explosive method. The vehicles used for a typical drilling program include several truck-mounted drill rigs, water trucks, a computer recording truck, and several light pickups for the surveyors, shot-hole crew, geophone crew, permit man, and party chief. Public roads and existing private roads and trails are used. Off-road, cross-country travel may also be necessary. Helicopters may support activities in remote areas or difficult terrain. Shot holes may be drilled with either air or water. Drilling water, when needed, is usually obtained locally.

In some cases, seismic exploration is conducted using small portable drills that are transported by helicopter from site to site to drill the "shot holes". The recording equipment and crews also are transported by helicopter from a staging area or landing zone. Generally, the shot holes are shallower than when drilled with truck-mounted drills and the size of the explosive charge used is smaller.

Surface Charges—Another portable technique eliminates the drill holes by placing the charges on wooden sticks, or lath, three feet above the ground. Charges used are either 2.5 or 5 pounds. Usually, 10 charges in a line are detonated at once. In remote areas, a series of short seismic lines may be used to determine the regional dip and strike of subsurface formations. Seismic lines then may be aligned in relationship to the regional structures to facilitate more accurate seismic data and interpretations. The seismic sensors and energy source are located along lines on a one- to two-mile grid. Although alignment may be critical, spacing of the lines can often be changed up to one-quarter mile on a one-mile grid before the investigation is significantly affected. This type of charge results in destruction of above ground vegetation, but this damage is usually undetectable after several growing seasons. The disadvantage of this type charge is its limited depth of shock wave penetration.

Primacord—Another seismic technique involves the use of explosive cord. The cord is buried in a 2.5-foot-deep furrow, plowed by a specially designed mechanical plow mounted on a tractor. Multiple sets of cord, often in a pattern, are buried at the same time. This method offers efficiency advantages over the shot-hole seismic method in that it is faster, less costly, and the quality of the data is often improved. However, surface disturbance may be considerably greater than with the shot hole seismic method.

C.2.4 Post-Lease Preliminary Investigations

If the preliminary investigations indicate that an oil or gas trap may exist in an area, the company may secure leases either directly through the federal leasing system or from existing leaseholders through assignment (lease is purchased and ownership is assigned). Additional preliminary investigations may be carried out after a lease is acquired. Post-leasing investigations may include airborne and surface operations similar to those of the pre-leasing phase. The lessee may intensify the seismic studies by extending lines on 0.5-mile grids and laying out a criss-cross pattern of lines tying to the previous seismic lines. Other preliminary investigations may also be initiated prior to drilling.

C.3 EXPLORATORY DRILLING (PHASE 2)

C.3.1 Permitting Process

Where preliminary investigations are favorable and information warrants further exploration, exploratory drilling is conducted. The presence of suspected oil and gas deposits may be confirmed by exploratory (wildcat) drilling of deep holes. Exploratory drilling on NFS lands is authorized only by a federal oil and gas lease, and cannot be conducted unless a Surface Use Plan of Operations (SUPO), drilling program, and Application for Permit to Drill (APD) are approved.

The Forest Service must approve proposed construction and other operations that involve surface disturbance conducted under the terms of a lease before such activities are conducted. Proposed drilling, development, and production operations must be approved by the BLM. Operations must be approved and conducted in accordance with (1) lease terms and conditions; (2) 43 CFR 3160; (3) 36 CFR 228, Subpart E; (4) Onshore Oil and Gas Order No. 1; (5) other onshore oil and gas orders; (6) applicable Notices to Lessees (NTLs); (7) conditions of approval; and (8) subsequent orders of the authorized officers of the BLM and Forest Service.

No drilling operations or related surface disturbance can be conducted without an approved APD. An APD includes a drilling plan, which consists of (1) a surface use program, and (2) a drilling program. The detailed information required to be submitted under each program is identified in Onshore Oil and Gas Order No. 1 and 36 CFR 228, Subpart E. An on-site inspection of the proposed wellsite, road location, and other areas of proposed surface use is conducted prior to approval. The inspection team includes BLM and Forest Service representatives, the lessee or operator, and the operator's principal drilling and construction contractors. The purpose of the on-site inspection is to identify problems and potential environmental impacts associated with the proposal, and methods for mitigating those impacts. These may include making adjustments to the proposed well site and road locations, identifying the construction methods to be employed, and identifying reclamation standards for the lands after drilling.

The Forest Service is responsible for conducting the environmental analysis, preparing the documentation, and identifying conditions of approval for the SUPO to protect surface resource values on NFS lands. The BLM is responsible for approval of the drilling program, protection of groundwater resources, and final approval of the APD. On split estate lands with federal minerals, the BLM is solely responsible. The BLM and/or the operator coordinate with the private surface owner while analyzing an APD for split estate lands

Other proposals to occupy the surface that involve surface disturbance, but are not associated with drilling a well, must also receive advance approval under the procedures described above.

There are two options available to the oil and gas operator when applying for approval of an APD. These are (1) the Notice of Staking (NOS) option, and (2) the APD option.

NOS Option—The NOS consists of an outline of what the company intends to do, including a location map and sketched site plan. BLM and FS staff review the NOS document to identify any conflicts with known resource values and also use it for the on-site inspection and to provide the preliminary data to assess what items are needed to complete an acceptable surface use plan and drilling program.

Application for Permit to Drill (APD) Option—The operator or lessee may submit a completed APD, in lieu of the NOS, to the BLM. An APD consists of two main parts: the 13-point surface plan that describes all proposed surface disturbances, and the 8-point plan that details the drilling program.

The BLM holds a field inspection with the operator and the Forest Service. The drilling plan may be revised or site-specific mitigation added as conditions of approval to the APD for protection of surface and/or subsurface resource values in the vicinity of the proposed activity. The APD is valid for one year from the approval date.

Special use permits are issued by the Forest Service for facilities, tank batteries, pipelines, powerlines, and access roads that occupy NFS lands outside the leasehold or unit boundary, whether constructed by the lessee/operator or a third party.

C.3.2 Oil and Gas Exploratory Units

Surface use in an oil or gas prospect may be affected by unitization (consolidation) of the leaseholds. In areas of federally owned minerals, an exploratory unit may be formed before a wildcat exploratory well is drilled. The boundary of the unit is based on geologic data. The leaseholders of the unit can enter into an agreement to explore and/or develop and operate a unit, without regard to separate lease ownerships (43 CFR 3180). Costs and benefits of the exploration are allocated according to agreed-upon terms. Unitization has the potential to extend the terms of leases within the unit by two years or more.

C.3.3 Exploratory/Wildcat Wells

Wildcat wells are deeper test wells, drilled in areas having no known oil or gas deposits. Construction of access roads and drill pads are typically required to conduct these exploratory drilling operations.

The well site is selected on the basis of prior surface investigations, seismic surveys, data from other wells that have been drilled in the area, topography, accessibility, and requirements of lease stipulations and protection of surface resources.

C.3.4 Surface Requirements and Construction

Upon approval of the APD, construction equipment may enter the leasehold. Construction usually begins with the access road to the well site. The types of construction equipment used include dozers (track-mounted and rubber-tired), scrapers, and motor-graders. Moving equipment to the construction site requires several semi-trucks. Roads must be constructed to handle tractor-trailer size vehicles and must be capable of being used year-round unless only seasonal drilling is anticipated. Existing roads and trails often require improvement in places, and occasionally culverts or cattle guards are installed. The operator moves construction equipment to the point where the access road begins. Generally, the shortest feasible route consistent with the topography is selected to reduce the haul distance and construction costs. In some cases, potential environmental impacts or existing transportation plans dictate a longer route. Roads are usually constructed to a 14-foot-wide travel surface (in relatively level terrain). In rough terrain, road construction uses a method where the material taken from the cut portion of the road is used to construct the fill portion. Road surfacing may be required in some cases because of adverse soil conditions, steepness of grade, and moisture conditions. Helicopter-supported construction and drilling operations can be used in some instances. When this occurs, the need for construction of some, or all, access routes is eliminated.

Well sites are selected and constructed with consideration for the amount of level surface required for safe assembly and operation of a drilling rig. The area required varies with the drilling depth and the type of rig used. An average well site on the Custer National Forest is approximately 200 feet square, not counting cuts and fills, and occupies approximately one acre. The substructure of the drilling derrick must be located on solid ground, because settling of uncompacted fill material under the drill rig may cause the substructure and mast to lean or even fall.

All soil material suitable for plant growth is first removed from areas to be disturbed, and stockpiled in a designated area. Well sites located on flat terrain usually require little more than removing the topsoil material and vegetation. Well sites on ridge tops and hillsides are constructed by cutting and filling portions of the location to provide a level area (drill pad) to accommodate the drill rig, ancillary facilities, and drilling operations. The majority of the excess cut material is stockpiled in an area that will allow easy recovery for reclamation. Extra cut material may need to be stockpiled to avoid casting the excess material down hillsides and drainages where it cannot be recovered for rehabilitation.

Depending on the relation of the drill site to natural drainages, it may be necessary to construct water bars or diversions. The size of the area disturbed for construction and the potential for successful revegetation often depends on the steepness of the slope, as well as soil type and climate.

The drilling rig and its attendant facilities such as pumps, mud tanks, generators, pipe racks, tool house, etc., are located on the drill pad. Other facilities such as storage tanks for water and fuel may be located on or near the drill pad.

C.3.5 Drilling Operations

Drilling activities usually begin shortly after the well site and access road have been constructed. The drilling rig and associated equipment are moved to the site and erected. Moving a drilling rig may require 30 to 40 truckloads of equipment over public highways and private roads.

The most commonly used drilling equipment is the rotary rig, which consists of (1) a power system, normally diesel-engine-powered electric generators; (2) a hoisting system, which consists of a derrick ("mast"), crown block, and traveling block used to lift and lower the drill; (3) the rotary system, which consists of the drill bit attached to a length of tubular high tensile steel drill pipe (collectively called the "drill stem"), which is turned by a rotary table; and (4) the mud circulating system (i.e., drilling fluid) consisting of mud tanks, mud pumps, and reserve pit. Depending on the height of the substructures, the mast may rise to over 160 feet above the ground surface and is the most visible and noticeable feature of a drill rig.

The start of drilling is commonly referred to as "spudding." The actual drilling is accomplished by passing the drill string through the rotary table, which turns the drill string and bit, which in turn performs the actual drilling. The weight of the drill string provides downward pressure on the drill bit, which chips and pulverizes the rock as it rotates in the bottom of the hole. By continually adding more drill-stem pipe to the drill string, the hole is steadily deepened.

The initial hole is drilled to a depth of 80 to 100 or more feet, depending on the surface geology of the area. The hole then is lined with conductor pipe (casing). The space between the conductor pipe and the drilled hole (borehole) is filled with cement. This prevents unconsolidated surface formations from sloughing into the hole. The pipe must be set in rock that is capable of withstanding the maximum anticipated pressure to which it may be exposed.

After the conductor pipe is in place, a series of blowout preventer (BOP) valves are attached to the well. The valves will close down the well in the event the drill bit penetrates rock formations exhibiting extreme pressure zones that could cause unexpected changes in pressure and a well blowout. Blowouts are extremely dangerous and may result in uncontrolled fire, escape of toxic gases, loss of lives, extensive environmental damage, and loss of resources and equipment. It is usually very difficult and expensive to bring a well back under control. Therefore, special attention is given to the prevention of well blowouts and most of the equipment used to support the actual drilling operations is for controlling excess pressure that may be encountered. Blowout prevention equipment is tested and inspected by both the rig personnel and the BLM. The drill rig crew must be trained in safety and blowout prevention.

After installation of casing and BOP equipment, drilling is resumed using a smaller bit. After the borehole has penetrated all of the surface formations, which may contain fresh water, the bit and drill string are hoisted out of the well and another length of pipe (surface casing) is lowered into the borehole and cemented in place. The depth of the conductor pipe is an important part of blowout prevention. The casing also protects the quality of water-bearing strata (aquifers) from being contaminated by the drilling mud.

Drilling mud (fluid) is circulated through the drill pipe and bit to the bottom of the hole, then up the bore of the well, through a screen that separates the cuttings, and into holding tanks from which it is pumped back into the well. The mud is maintained at a specific weight and thickness to cool the drill bit, lubricate the drill string, seal porous rock zones, prevent blowout or loss of drilling fluid, and transport the cuttings resulting from the drilling to the surface for disposal. Various additives are used to maintain the drill mud at the desired viscosities and weights. Some additives that may be used are caustic, toxic, or acidic. The drilling mud and rock chips are stored in lined pits or tanks for later reuse or disposal at an approved facility.

A self-contained mud system is used to contain the drilling mud, fluids and additives. The drilling fluids, mud, and cuttings are stored in metal tanks and later transported to approved off-site disposal areas.

Water for drilling is hauled by truck to the rig storage tanks or transported by surface pipeline. Water sources are usually rivers, wells, or reservoirs. Occasionally, water supply wells are drilled on or close to the drill site. The operator must obtain a permit from the County for the use of

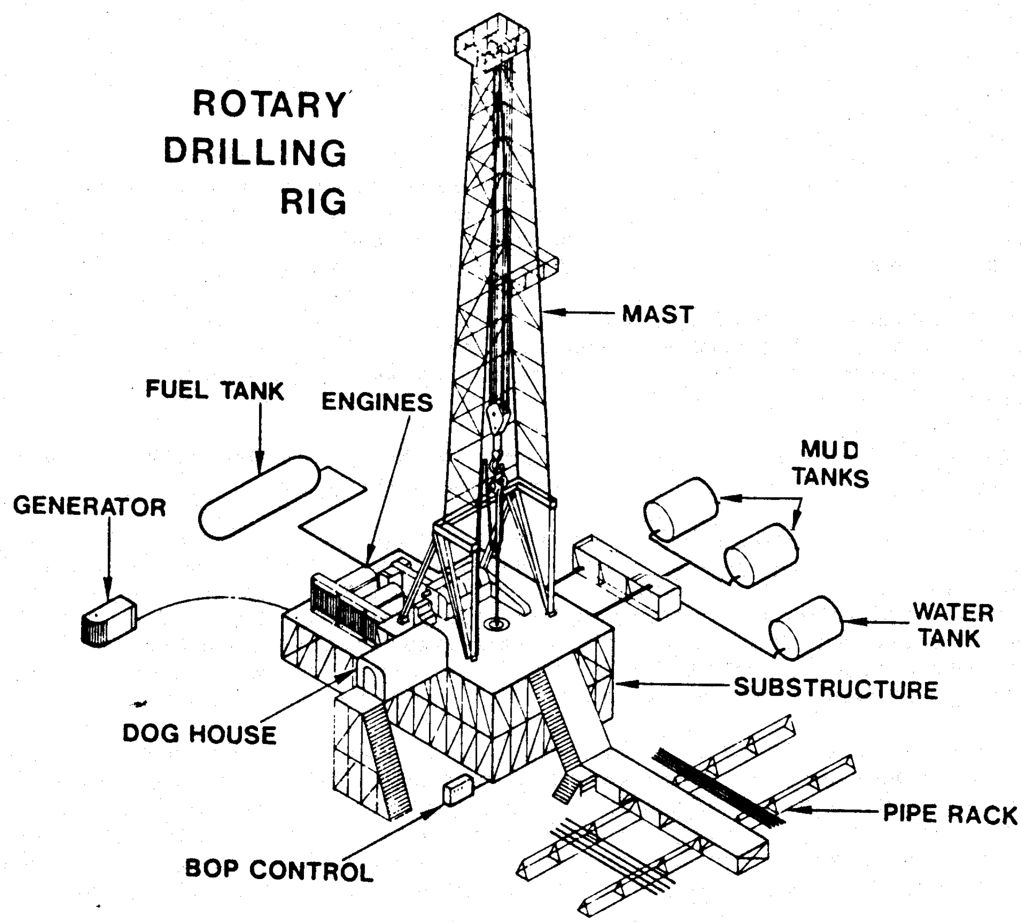

Figure C-1. Typical Drill Site Materials And Equipment.

surface or subsurface water for drilling. When the Forest Service holds the water permits for surface water (stock ponds), it must also approve such use. Water is continually being transported to the well site during drilling operations. Although it will vary significantly from well to well, approximately 40,000 barrels or up to 1,700,000 gallons of water may be required to drill an oil or gas well to the depth of 9,000 feet. If water is hauled by truck, a significant amount of traffic will be generated by transporting water to and from the drill site. More water is required if the underground rocks are fractured and drilling fluids are lost into the formation (lost circulation zone). Uncontrollable loss of drilling fluids may cause drilling to be terminated.

In some areas where drilling must penetrate clay or shale layers, oil-base drilling muds are often used instead of water-base muds after the surface casing has been installed and cemented. The oil-base muds prevent the clays or shales from swelling and caving into the borehole, which can result in the collapse of the borehole making it impossible to pull the bit out of the hole. High-pressure air is sometimes used in place of mud. The use of mud or air is largely dependent upon the target formation, drilling depth, and type of completion desired.

As the drilling proceeds, additional casings of concentrically smaller diameter are lowered into the well and cemented in place until the final depth (target zone) is reached. During the drilling process, the drill string must be pulled from the well periodically to change the drill bit, install casing, or remove core samples from the wellbore. Core samples are analyzed to determine the type of rocks penetrated and their porosity, permeability, chemical properties, and hydrocarbon content. At periodic intervals, BLM personnel will conduct inspections of the drilling rig and operations to ensure compliance with the approved plans in the APD. Forest Service staff will also conduct periodic inspections to ensure compliance with surface construction requirements.

Drilling operations continue 24 hours a day, seven days a week. The crews usually work three eight-hour shifts or two 12-hour shifts a day. The greatest amount of human, vehicular, and equipment activity and accompanying noise, etc., occurs during construction and drilling activities. Traffic is generated by trucks hauling equipment and water, service companies delivering supplies and equipment and performing specialized work on the drill, drilling crew shift changes, well treatment, and testing equipment, etc. There is a high level of human activity and use of heavy construction and drilling equipment during drilling operations, which is accompanied by considerable noise and highly visible activity.

Upon completion of drilling, the well is "logged" and tested to obtain information about the rock formation and production of fluids. After completion of the tests, the drill rig and other equipment are removed. If oil or gas is not discovered in commercial quantities, the well is considered dry. The operator must comply with state and federal procedures for plugging a dry hole and reclaiming the site. If the well is capable of producing hydrocarbons it will likely be tested to determine if production is economic. Gas well testing generally requires flaring of test gas for up to 30 days. Oil is produced into test tanks and the associated gas may be vented to the atmosphere or flared. If oil or gas is found in commercial quantities the well is completed as a producer.

C.3.6 Directional Drilling or Horizontal Drilling

Directional drilling may be used where the drill site cannot be placed directly over the reservoir, as might be the case where a river or mountain is involved, where no surface occupancy is permitted on the leasehold, or where land use restrictions require centrally located drill sites.

There are limits both to (1) the degree that the wellbore can be deviated from the vertical, and (2) the horizontal distance the well can be drilled from the well site to the target zone. The limit of horizontal distance is affected by depth of the target zone, characteristics of the rock formation to be penetrated, and the additional costs of directional drilling. These factors all are considered before applying this technology. This analysis assumes that it is not economical to drill directionally from outside an area where surface occupancy is denied and reach a target zone at a horizontal distance of more than one-half mile from the drill site.

Horizontal Drilling is a common practice in South Dakota.

Oil and Gas Discovery

At the completion of drilling, the well is evaluated to determine if hydrocarbons can be commercially produced. A "drill-stem test" is conducted to directly measure the fluid content (water, oil, or gas) of the formation and the amount of flow and shut-in pressure of the well. The well is logged by measuring the electric resistivity that provides information as to the porosity of the rock, the kind of fluids present, and fluid saturation level of the rocks. These physical characteristics of the rock formations and associated fluids are measured and recorded. If it is determined, based on the tests, that the well can be economically developed for production, the well is readied for production, and connected to a gathering system (refer to Field Development Phase 3 and Production Phase 4).

The subsurface (geological) information required to be submitted includes:

a) Occurrence and anticipated depths of fresh water aquifers
b) Expected depths of possible oil or gas productive zones above or below the zone already discovered
c) Other mineral-bearing formations
d) The potential for entering highly permeable formations in which the drilling mud might be lost
e) The anticipated pressures in the formations to be drilled
f) The potential for encountering other geologic conditions that could cause drilling problems.

This information is obtained to determine whether the proposed drilling program is adequate, and to ensure the drilling mud, pressure control, casing, cementing, testing, well logging, and completion programs adequately protect the surface and subsurface environments, protect other subsurface resources, and provide safe working conditions.

C.4 FIELD DEVELOPMENT (PHASE 3)

The completion of a wildcat well as a commercial producer marks the beginning of the development of an oil and gas field.

C.4.1 Approval of Field Development Plans

After discovery of oil and gas and prior to development of a field, the lessee/operator must receive approval of the Applications for Permits to Drill (APDs) including the Drilling and Surface Use programs. A Field Development Plan consists of a coordinated collection of site-specific drilling and surface use proposals for individual wells as required by Onshore Oil and Gas Order No. 1. The lessee/operator may be required to submit the plan when sufficient information is available to project a reasonably foreseeable development of the field. Sufficient information may not be available until one or more confirmation wells have been drilled to delineate the characteristics of the reservoir. The limits of a field located on a structural trap can be determined more easily than a stratigraphic field based on the information obtained from drilled wells and geophysical data.

The surface plan includes information on existing roads, the proposed location of the access roads, the proposed and existing wells, and the tank battery; the proposed location and type of water supply; the proposed waste disposal methods; plans for reclamation of the surface; and other information deemed necessary.

C.4.2 Well-Spacing Pattern

Before development of an oil and gas field begins, a well-spacing pattern is established to allot a spacing unit for each well that will be drilled in the discovery area. Oil well spacing patterns in the United States range from less than one acre per well to 640 acres per well. Spacing units established for oil production are usually closer than gas well spacing and are generally in multiples of 40 acres (i.e., 40, 80, 160, 320, 640 acres per well). Gas well spacing patterns in the United States range from 40 to 1440 acres per well. Most spacing patterns established at the present time for production of gas are 160, 320, or 640 acres per well.

The well-spacing pattern established for an oil and gas field is the primary factor that determines the amount and intensity of human presence and associated activity during the development and operation of an oil and gas field and the amount of surface disturbance and land area required to accommodate surface facilities. The wider the well-spacing pattern, the lower the intensity and concentration of human activity and the less overall surface disturbance occurs within the oil and gas field. Well spacing is determined by how much of the reserves can be produced by any one well; the producer will attempt to maximize production using the fewest number of wells possible.

Currently, the oil field adjacent to the South Cave Hills has a spacing pattern of one well per 640 acres. The oil field nearest the North Cave Hills has a spacing pattern of one well per 320 acres.

C.4.3 Unitization

Surface use in an oil and gas field is affected by unitization (consolidation of leases) of the leaseholds. In areas involving federal lands, any exploratory unit would be formed pursuant to 43 CFR, Subpart 3180 through Subpart 3186. The area enclosed within a production unit is based on available geologic data.

A unit agreement provides for (a) development and operation of the field as a single, consolidated unit without regard to separate lease ownerships; and (b) the allocation of costs and benefits according to terms of the agreement. Unit agreements involving federal leases require BLM approval.

Leases that are committed to a producing unit are considered producing leases and will not terminate as long as production continues within the unit. As the limits of the productive area are defined by additional drilling, some leases may be dropped from the unit. If a lease is dropped from a unit, the term of the lease may be extended for a period of two years if less than two years remain in the primary term of the lease.

Field development under a unit agreement reduces the surface use requirements because all wells within the unit boundaries are operated as though they are located on a single lease. Development and operations of the field are planned and conducted by a single unit operator and, therefore, duplication of field processing equipment and facilities is minimized. Oil or gas field development under a unitization plan also may involve a wider well-spacing pattern and fewer wells than fields developed on a lease-by-lease basis.

C.4.4 Drilling Procedures

The drilling of development wells is essentially the same as the drilling of a wildcat well. Roads and other facilities are planned and constructed for long-term use.

C.4.5 Surface Use Requirements

Surface uses associated with oil and gas field development wells include access roads, well sites, flowlines, storage tank batteries, and facilities to separate oil, gas, and water. Access roads are planned, located, and constructed for long-term use as opposed to roads built for short-term use to drill wildcat wells.

C.4.6 Surface Use and Construction Standards

The minimum standards for design, construction, and oil and gas operations are set forth in the *Surface Operating Standards for Oil and Gas Exploration and Development, Third Edition – U.S. Forest Service and Bureau of Land Management.* The publication prescribes the minimum operating standards for oil and gas operations on federal lands. The objective of the standards is to minimize surface disturbance, effects on other resources, and retain the reclamation potential of the disturbed area. Additional site-specific construction and design standards may be required depending on the proposed activities and conditions encountered at the construction site.

The locations for well sites, tank batteries, production facility sites, pumping stations, roads, and pipelines are selected to minimize to the extent possible the long-term impacts to other resources and disruption of other land uses. Ideal locations for oil and gas activities are seldom available and avoidance of damage to surface resources is not always possible. Well sites are constrained by the geologic target to be drilled and pipelines, because of their linear nature, cannot always be located to avoid all areas exhibiting environmental sensitivity to impacts. In the selection of sites, special attention is given to avoiding construction on steep topography and unstable soils, near streams and other open water areas, on cultural resource sites, and in threatened, endangered, or sensitive species habitats. It is not possible or practical to avoid all situations, and special construction techniques may need to be employed to minimize the impacts. In some cases, occupancy of the surface is not allowed.

Well sites are usually located on the most level location available that accommodates the intended use consistent with reaching the geologic target. The drill site layout also can be oriented to conform to or fit into the topographic conditions at the drill site. However, safety considerations in a hydrogen sulfide (H_2S) area may be an overruling factor when determining the topographic setting and providing adequate escape routes for the drill crew. In general, steeply sloping locations, which require deep, nearly vertical cuts and steep fill slopes, are avoided. The well site also is reviewed to determine its effect in conjunction with the location of the access road. Adverse effects resulting from the location of the access road may negate advantages gained on a good well site or tank battery location.

Well-site Construction Standards must conform to the approved well site and layout plan in the Surface Use Plan of Operations (SUPO), and excavation of the cut-and-fill slopes of the well site are guided by information on the surveyed construction stakes. Generally, all surface soil materials (topsoil) are removed from the entire construction area and stockpiled. The depth of topsoil to be removed and stockpiled is determined at the pre-drill inspection and stated either in the proposed SUPO or specified as a condition of approval. In order to avoid mixing topsoil with subsurface materials during construction and reclamation, topsoil stockpiles are located at specified locations, out of the way of construction activities.

Fill materials are compacted to minimize the chance of slope failure. Terracing may be used on both cut-and-fill slopes to reduce the land area occupied by the well site and to prevent excessive water accumulation, slope failure, and erosion. If excess material needs to be excavated, the excess material is to be disposed of or stockpiled at approved locations.

The area of the well pad that actually supports the drilling rig substructure must be level and capable of supporting the weight of the rig. The drilling rig, tanks, heater-treater, etc., are not placed on uncompacted fill material. The area used for mud tanks, generators, mud storage, and fuel tanks, etc., is usually slightly sloping to provide surface drainage from the work area. Runoff water from offsite areas is diverted away from the well site by ditches, water bars, or terraces up-slope from the drilling and well site.

C.4.7 Roads and Access Ways

It is Forest Service policy that existing roads be used for access when they are available, when they meet Forest Service standards for the intended use, and when there are no significant conflicts with other uses. When access involves use of existing roads, the oil and gas operator may be required to contribute to the road's maintenance. Usually this use is authorized by a joint use agreement in which each user's *pro rata* share of the road maintenance costs is assessed.

New road construction, or reconstruction, by the operator must be consistent with the goals of the Forest's transportation plan and must meet Forest Service standards established for the intended road use.

Proper road location is critical for the engineering success and mitigation of the environmental effects of road construction. The surface and subsurface conditions of a proposed road location also determine the cost to survey, design, construct, and maintain a road. The following factors are considered when determining road locations:

- Intended use of the road, planned season of use, and type of vehicles to be used
- Forest's transportation plan, which may already identify feasible routes for the area
- *Existing data including maps and aerial photos, of administrative, biological, physical, and cultural conditions of the area.*

A field reconnaissance during the pre-drill inspection of the proposed and alternative routes is made to determine type of excavation, landslide areas, and subgrade conditions, the need for surfacing, potential cut or fill slope problems, surface or subsurface water problem areas, and potential borrow and waste sites.

When steep slope areas, erosion hazard areas, visually sensitive areas, stream crossings, and other areas of high environmental sensitivity cannot be avoided, special road design and construction techniques may be required. Best Management Practices (BMPs) are used to prevent or minimize soil erosion and other adverse effects on soils and water quality.

Both the BLM and the Forest Service require that all permanent roads constructed by non-government entities across public or NFS lands be designed by, or constructed under the direction of, a licensed professional engineer. The design and construction requirements depend on the site conditions, planned use of the road, seasons of use, amount and type of traffic, and whether use will be short- or long-term. These factors also are used to determine the class of road built to accommodate the intended use(s).

Other factors used in road location and design that are unique and directly applicable to the oil and gas industry include:

- The prevailing wind direction in relation to the potential for encountering sour gas (H_2S) and the need for a clear escape route from the drill site.
- The potential for year-round operation (drill sites and producing locations may require all-weather access and special maintenance considerations for snow removal).
- The potential for exploratory drilling to result in a producing operation (the initial road alignments will be such as to allow upgrading to a permanent road if a discovery is made).

When the road location information is submitted to the Forest Service in the Surface Use Plan, the proposed route, and if applicable, alternative routes, road design standards, and construction methods, are evaluated. Final approval of the road location, road design standards, and construction standards are made during processing of the Surface Use Plan of Operations.

C.4.8 Pipeline Standards

General pipeline construction standards were established to minimize surface disturbance, provide soil stability, and preserve reclamation potential. Pipeline construction usually involves clearing vegetation and leveling a strip of land wide enough to accommodate a pipeline trench, excavated material, and pipeline construction equipment and transport trucks. The width of the area cleared and leveled is kept to a minimum consistent with access and construction requirements. The width of the disturbed area varies depending on the number of lines within a corridor, size of the pipeline, equipment, and topographic setting.

Pipelines located on gentle topography usually require less construction and surface disturbance and are, therefore, inherently more stable and retain greater reclamation potential. Locating pipeline routes on steep hillsides or adjacent to live watercourses is avoided to the extent possible. However, because of the extended linear nature of a pipeline, these situations cannot be entirely eliminated. Extensive cuts and fills that destabilize steep slopes are avoided. In steep country, pipelines are often buried in or adjacent to access roads or located above ground to minimize erosion problems.

It is a standard practice to stockpile topsoil to the side of the pipeline right-of-way prior to construction and leveling the pipeline bed. The topsoil is segregated and not mixed or covered by excavated material during construction.

Upon completion of construction, the pipeline is graded to conform to the adjoining terrain, the surface soil material returned to the right-of-way, and the pipeline right-of-way water barred and revegetated to avoid erosion and minimize the visual intrusion.

C.4.9 Rate of Development

The rate at which development wells are drilled in a newly discovered field depends on the following factors:

- Whether the field is developed on a lease basis or unitized basis
- The probability of profitable production
- The availability of drilling equipment
- Protective drilling requirements
- The degree to which limits of the field are known
- Size of field.

The development of a field that is based on a stratigraphic reservoir may proceed more slowly and yield more dry holes than development of a field located on a structural trap reservoir.

The most important factor when determining how fast field development occurs is indicated production potential. If large productive capacity and substantial reserves are indicated, development drilling proceeds at a rapid pace. If there is a question as to whether indicated reserves are sufficient to warrant additional wells, the development drilling occurs at a slower pace. An evaluation period to observe production performance may follow the drilling of each well.

Development on an individual lease basis proceeds more rapidly than development in a unitized area. When development drilling is undertaken on a lease basis, each lessee drills his own well(s) to obtain production from the field. This creates a competitive situation where the first wells drilled produce the greatest share of oil or gas from the reservoir and the quickest and greatest return on the investment. When unitized, all owners within the "participating area" share in a well's production regardless of whose lease on which the well is located. The development of the reservoir then can proceed in a more orderly manner and pace.

C.4.10 Protective Drilling

The drilling of a well to prevent drainage of petroleum to a producing well on an adjoining lease may be required in fields that contain a mixture of federal lands and patented or fee lands. The terms of federal leases require the drilling of a protective well on the leased tract if an "offset" well is located on adjacent non-federal lands or on federal lands leased at a lower royalty rate. An "offset" well is a well drilled at the next location in accordance with the established spacing rule to prevent the drainage of oil and gas to an adjoining tract where a well is being drilled or is already producing.

C.4.11 Pool Discoveries

Discovery of a "new pay zone" within an existing field is a "pool" discovery, as distinguished from a new field discovery. A pool discovery may result in the drilling of additional wells -- often on the same well pads as existing wells, or often sharing the same boreholes or separated only by a few feet. Existing wells also may be drilled deeper to the new pay zone. Some fields contain as many as seven or more pay zones all sharing a geologic structure that created the conditions for the accumulation of oil and gas. Each new pay zone developed requires additional flowlines, storage, and treatment facilities if the fluids from the various pools are to be kept separate. Commingling (mixing) of fluids from the different pay zones may eliminate the need for additional surface production facilities, but approval of commingling depends on the specific oil or gas characteristics.

C.5 PRODUCTION (PHASE 4)

Production is a combination of operations that includes:

- Bringing the fluids (oil, gas, and water) to the surface
- Maintaining and/or enhancing the productive capacity of the wells
- Treating and separating the fluids
- Purifying, testing, measuring, and otherwise preparing the fluids for market
- Disposing of produced water
- Transporting oil and gas to market.

The production of oil and gas from a single well is usually initiated as soon as drilling is completed and the well is developed for production. In the meantime, other wells may be in production, being drilled, or exist only in the field development plans. Sometimes there is usually little time between the activities associated with exploratory drilling, oil and gas field development, and actual production of oil or gas. Other times it may take a few months to several years before a field is fully developed. Therefore, field development activities and those activities normally associated with oil and gas production occur simultaneously during the early life of a field. Drilling of new wells may be undertaken periodically throughout the life of a producing field to increase or maintain production from the reservoir.

C.5.1 Pipeline Standards

General pipeline construction standards were established to minimize surface disturbance, provide soil stability, and preserve reclamation potential. Pipeline construction usually involves clearing vegetation and leveling a strip of land wide enough to accommodate a pipeline trench, excavated material, and pipeline construction equipment and transport trucks. The width of the area cleared and leveled is kept to a minimum consistent with access and construction requirements. The width of the disturbed area varies depending on the number of lines within a corridor, size of the pipeline, equipment, and topographic setting.

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However, because of the extended linear nature of a pipeline, these situations cannot be entirely eliminated. Extensive cuts and fills that destabilize steep slopes are avoided. In steep country, pipelines are often buried in or adjacent to access roads or located above ground to minimize erosion problems.

It is a standard practice to stockpile topsoil to the side of the pipeline right-of-way prior to construction and leveling the pipeline bed. The topsoil is segregated and not mixed or covered by excavated material during construction.

Upon completion of construction, the pipeline is graded to conform to the adjoining terrain, the surface soil material returned to the right-of-way, and the pipeline right-of-way water barred and revegetated to avoid erosion and minimize the visual intrusion.

C.5.2 Oil Field Production Development

Production operations in an oil field begin soon after the discovery well is completed. Portable and temporary facilities located on the drill pad are used to initiate the production of oil from the reservoir. As further drilling proceeds and reservoir limits are established, permanent production facilities are designed and installed at centralized locations. The type, size, and number of the facilities are determined by the number of producing wells, expected production rates, volumes of gas and water expected to be produced with the oil, the number of separate leases involved, and whether or not the field is being developed on a unitized or individual lease basis. Development of production on a lease basis requires that handling and processing facilities be installed on or near each lease. Unitization reduces the number of facilities needed to produce, process, and store the oil prior to marketing. However these facilities are often larger than those used on an individual lease. Since field development has occurred near the North and South Cave Hills, new wells may be able to use existing production facilities.

C.5.3 Gas Field Production Development

Production operations in a gas field begin when a pipeline to a market outlet is constructed. Market pipelines are not economical unless sufficient gas reserves have been proven to exist by drilling operations. Gas wells are sometimes shut-in after completion for periods of several months or years until a pipeline connection becomes available.

C.5.4 Well Completion Report

A "Well Completion or Recompletion Report and Log" must be filed with the BLM within 30 days after completion of a well for production. The completion report reflects the mechanical and physical condition of the well. Geologic data and, when applicable, information on the completed interval and production, is required. Operators must notify the BLM no later than the fifth business day after a well begins production. The information in these reports may be withheld from the public as proprietary information for a limited amount of time.

C.5.5 Well Completions

After a well has been drilled and evaluated for its economic worth and profit, work to set the casing and prepare the well for completion and production begins. The decision to complete an individual well for production is based on the type of oil or gas accumulations involved, the expected future development that may be undertaken during the life of the well, and the economic circumstances at the time.

Well completion involves installation of steel casing between the surface casing and the oil and gas producing zone. The casing is cemented between the wellbore and casing wall to provide stability and to protect specific zones (i.e., fresh water aquifers). The casing is perforated at the level of the "pay zone" to allow entry of oil or gas into the well bore. The "pay zone" may later be "stimulated" or "treated" to increase productivity.

The drilling rig and most of the support equipment are moved from the well site after the casing is cemented and the pay zone is stimulated. Small diameter "production" tubing is then placed inside the casing down to the producing zone. The tubing is connected to the surface equipment and transports the oil and gas from the bottom of the well to the surface. If the pressure is sufficient to raise a column of oil to the surface, the well is completed as a flowing well. When pressure is not sufficient, a pumping system is installed. After the well is completed, the well may be tested for a period of days or months before another well is drilled.

Temporary storage tanks are normally used to hold the produced oil during testing. A "separator" is required to separate the gas from the oil. The gas separated from the oil may be burned off as waste until a pipeline connection is available. This flaring requires prior approval from the BLM in accordance with NTL-4A, Beneficial Use. If water is produced with the oil, a "treater" may be needed to separate emulsified oil and water.

C.5.6 Well Stimulation

"Well stimulation" is employed to enlarge channels or to create new ones in the producing formation rock to enhance oil and gas production. Since oil is usually contained in the pores or cracks of sand or limestone formations, enlarging or creating new channels allows the oil or gas to accumulate and move more freely to a wellbore. A well may be restimulated several times during its lifetime to maintain or increase production. There is a short-term increase in activity at the well site during this process. Generally, no new surface disturbance is required to perform these operations. Three basic well stimulation methods have been developed: explosive fracturing, acid treatment and hydraulic fracturing.

Explosive fracturing is used to enlarge the wellbore, eliminate nearby plugging of the rock pores, and force fluids into the formation, thereby fracturing the rock in the proximity of the well bore to stimulate increased production.

Acid treatment dissolves rock with weak hydrochloric acid, thereby enlarging existing channels and opening new ones for oil to flow to the wellbore. Reservoir rocks most commonly acidized are limestone (calcium carbonate) and dolomite that exhibit low permeability. Well servicing rigs are used to prepare both new and old wells for acid treatment.

Hydraulic fracturing is used to create or enlarge cracks in sandstone reservoirs in the same manner as acid treatment is used in limestone or dolomite reservoirs. Hydraulic pressure is applied against the formation by pumping fluid, either gelled water or diesel fuel, under high pressure into the well. This pressure splits and cracks the rocks in the production formation to improve the productivity of the well, or increase the rate fluids can be injected into disposal wells. Most well pads are of sufficient size to accommodate the trucks and other equipment needed to complete a "frac" job.

C.5.7 Oil Wells - Wellhead Facilities

The "wellhead" is the equipment installed to maintain control of the well at the surface and to prevent well fluids from "blowing" or "leaking" at the surface. The pressures encountered in the well determine the type of wellhead equipment needed. This varies from a simple assembly to support the weight of the production tubing in the well to a high-pressure wellhead to control reservoir pressures. Pressures in these reservoirs are usually great enough to result in a "flowing" well. However, after reservoir pressures are depleted, some type of artificial lift is usually required to bring the oil to the surface.

C.5.8 Flowing Wells

The surface equipment at the head of a flowing well is limited to a series of valves, or "Christmas tree," and a service area ranging from 15 feet x 15 feet to 50 feet x 50 feet around the wellhead. A service area also may contain a small (1 ft x 2 ft x 3 ft) gas powered chemical pump and "guy line" anchors for servicing units brought in for well repairs. Chemical pumps used to inject emulsion breakers, corrosion inhibitors, or paraffin solvents into the well or flow line may be present.

C.5.9 Artificial Lift (Pumping)

When a well is completed, the natural reservoir pressure drives the fluid to the surface. At some time during the life of an oil well, the pressure is depleted and some form of artificial lift is used to raise the fluid to the surface. The most common methods of artificial lift are sucker rod pumps, centrifugal pumps, hydraulic pumps, and gas lift. All of the pump systems require some type of surface equipment and a power system. All power systems generate noise; however, this ranges from almost none for electric motors to high noise levels for single-cylinder gas engines.

Sucker Rod (Beam) Pumps—The pumping unit is the most visible and recognizable piece of equipment within oil fields. Pumping units vary in size from 4 feet to over 25 feet in height depending on the depth of the well. The principle of the sucker rod pump is the same as that of the common hand pump used to lift water. A series of rods and a valve move up and down through a "stuffing box" in the well to bring the oil to the surface. The stuffing box is regularly maintained to prevent oil leaks from the wellhead. Failed packing in stuffing boxes is a common cause of oil spills. The rod is connected to a reciprocating pumping unit or "pump jack." Surface pumping units are usually powered by electric motors; however, internal combustion engines are used when electric power is not available. Single-cylinder engines may operate at high noise levels, whereas multi-cylinder engines operate at lower noise levels and electric motors at a low noise level.

Centrifugal Pumps—Centrifugal submersible oil well pumps consist of a stack of 25 to 300 electric-powered small pumps located inside the well casing. Centrifugal pumps require little equipment above the ground and generate minimal noise at the surface. Surface equipment requirements include a switch or control cabinet, the wellhead, a spool for the cable used to transmit electricity to the pumps, and an electric power line.

Hydraulic Pumps—The pumping unit of a hydraulic system is located inside the well and is powered by oil under high pressure. The equipment required on the surface includes a storage tank for the power oil, a pump to pressurize the oil, an electric motor or internal combustion engine to power the oil pump, power oil regulating valves and pressure gauges, hydraulic pump, and the oil wells. The total surface area used for this type of facility may be greater than for other pumping systems if a centralized power system and additional oil pressure lines are used to carry the power oil from the pump to the wellheads. The noise level created at the wellhead depends on whether an electric motor or internal combustion engine is used to power the oil pump.

Gas Lift—Gas lift is commonly used where low-cost, high-pressure natural gas is available and where pressure in the petroleum reservoir is sufficient to force the petroleum part of the way up the well. In this system, natural gas is injected into well casing under pressure. The gas forces the fluids up the production tubing to the surface. The gas pressure maintained inside the casing creates a flowing well. The surface equipment used for gas lift includes a gas compressor, oil storage tank, and separator. The system is quiet if the compressor is powered by electric motor and little physical space is required at the wellhead.

C.5.10 Gas Wells

Most gas wells produce by natural flow and, in most cases, do not require pumping. Surface use at a flowing gas well usually is limited to a 20-foot x 20-foot fenced area. Water may enter a gas well and choke off the gas flow. A pump then is installed to pump off the column of water. Some gas wells may require from periodic to almost continual water pumping. The typical gas wellhead facilities are similar to those of a flowing oil well, consisting of a relatively unobtrusive wellhead "Christmas tree." Other equipment may be required depending on the gas quality and location of the measurement facilities. Additional equipment may include a separator, dehydrator, gas meter house, and a compressor.

C.5.11 Oil Field Gathering Systems

Crude oil is transferred in small diameter pipelines called "flowlines" from the wells to treatment facilities and a central tank storage battery before it is transported from the lease. The flow lines usually are constructed with 2- to 4-inch-diameter steel pipes.

Flow lines may be buried or may be located above the ground. Buried flow lines are the routine practice on the Sioux District. The installation of flowlines is similar to small-scale pipeline construction. Generally, a level bed is constructed to provide for vehicle access, trenching, and burial of the flow line. Flow lines are often installed in, or adjacent to, a roadbed to reduce surface disturbance and facilitate its installation. In very steep country, flow lines may be located on the surface to reduce erosion problems.

After the oil is gathered from the field and is treated, measured, and tested, it will be transported from the lease by pipeline or trucked to market.

Natural gas is often sold at the wellhead and transported directly off the lease. If processing and conditioning are required to remove liquid hydrocarbons, "associated gases", and water, the gas may be transferred to a central collection point and treating facility through flowlines prior to sale. Gas-gathering systems may include equipment for (1) conditioning and upgrading the gas; (2) compressing the gas so that it flows through the pipelines; and (3) controlling, measuring, and recording its flow.

C.5.12 Oil and Gas Separating, Treating, and Storage Facilities

Fluids produced from a well normally contain oil, gas, and water. The oil, gas, and water are separated or treated before the oil is stored in the tank battery. The treating facilities may be located at the wellhead, but in a fully developed field, they are usually located at the tank battery site. If enough "natural gas" is produced with the oil to warrant separation, it will be separated from the fluids, compressed, and pipelined directly to market.

Enough "casinghead gasoline" or "drip gas" may be produced in the field to make it economical to process it for marketing. A "gasoline" plant may then be built in the area to remove natural gasoline, butane, and propane. Some of the residue gas may be used to fuel gas compressors, pump engines, and heat the separating and treating vessels. The remainder of the gas is marketed as “natural gas.”

The oil and water produced from a well are usually in the form of an emulsion. Water is separated and removed after the gas is removed. The type of treatment facilities used depends on the amount of emulsification. If emulsification is high, chemical and/or heat treatment is used to separate the oil and water. Heat is applied in a facility called a "heater-treater," which breaks the oil in water emulsification. The heat is supplemented in most cases by chemical emulsion breakers. The oil and water, when not highly emulsified, may be separated by gravity in a tall settling tank called a "gun barrel." Conditioning equipment such as separators, heaters, dehydrators, and compressors may be located at the wellhead where the oil and gas first reach the surface or at the tank batteries and/or gas compressor stations in the field.

After the oil and water are separated, the oil is piped to storage tanks (tank batteries). The tank batteries are usually located on, or in the vicinity of, the lease. Tank batteries usually contain at least two tanks. The number and size of tanks vary with the rate of petroleum production from the field. Small leases may contain only one tank battery; large leases or units may contain several, each with its own separating, treating, and storage facilities. Tank battery sites may occupy from one to five acres depending on associated facilities and number and size of tanks.

Although natural gas is produced in varying quantities with the crude oil, in many fields the primary or sole production is the natural gas itself. The field processing to upgrade the gas for transportation and marketing consists of two primary treatments. The first is to separate the natural gas from crude oil and/or other liquid condensates including free water. In this process, the gas is run through "separators" and "heaters" to separate the liquids from the gas. The gas then is run through a "dehydration unit" to remove the remaining water vapor.

Saltwater Disposal

Although not a secondary recovery process, *per se*, saltwater disposal is a common form of fluid injection. Its primary purpose is simply to dispose of the saltwater produced with crude oil. A typical system is composed of collection centers in which saltwater from several wells is gathered, a central treating plant in which corrosion-forming substances are removed, and a disposal well. The saltwater is injected into the originating zone and used to pressurize and drive the oil towards the borehole of a producing well. (See Disposal of Produced Water.)

Gas Injection

Gas injection is a secondary recovery technique that is generally used only in oil and gas reservoirs that have an existing gas cap. Natural gas is injected under pressure to restore and maintain reservoir pressures to displace and move oil to the producing wells.

Enhanced Recovery Methods (Tertiary Recovery)

Enhanced recovery methods increase the amount of oil produced and recovered from an oil reservoir beyond that obtained from primary and secondary methods. Enhanced oil recovery techniques employ chemicals, water, gases, and heat, either singly or in combination, to reduce the factors that inhibit oil recovery. Considerable technical and financial risk is involved because of the large investment in equipment and the unknown factors or characteristics of the oil reservoir that may affect the success of an enhanced recovery method. There are three broad categories of enhanced recovery methods currently used:

- Thermal enhancement, which primarily involves injecting high-pressure steam into the oil reservoir to reduce oil viscosity and increase its ability to flow.
- Miscible flood, in which propane, butane, natural gas, CO2, or other gases are injected into the reservoir to dissolve and displace the oil.
- Chemical enhancement, which includes injecting polymers to thicken injected waters to increase uniformity of oil displacement in the reservoir or injecting detergents ("surfactants") that essentially "wash" the oil from the reservoir rocks.

As with secondary recovery systems, additional land surface is required to accommodate the injection and oil recovery systems. This includes additional wells, injection lines and flowlines, roads, storage, and treatment facilities, pumps, and injection equipment. There also is an increase in construction and drilling activities during the installation of all enhanced recovery systems.

C.5.13 Well Servicing and Oil and Gas Field Maintenance

Producing wells in active oil and gas fields periodically require repair and workover operations. Operations involving no new surface disturbance to redrill, deepen, and plug-back require prior approval of the authorized officer of the BLM.

The BLM requires immediate reporting of all major undesirable events (more than 100 barrels of fluid/500 MCF of gas released or fatalities involved). Any spill, venting of gas, or fire, regardless of volume must be reported within 24 hours if the event is located in an environmentally sensitive area. Notification is not required if it is contained within the facility's containment dike.

C.5.14 Inspection and Enforcement

The BLM and Forest Service have developed procedures to ensure that leaseholds that are producing or expected to produce significant quantities of oil or gas in any year, or have a history of noncompliance, are inspected at least once a year. Other factors such as health, safety, and environmental concerns, and potential conflict with other resources, also determine inspection priority. Inspections of leasehold operations ensure compliance with applicable laws, regulations, lease terms, Onshore Oil and Gas Orders, NTLs, other written orders of the authorized officer, and the approved plans of operation. The administration of oil and gas operations on NFS lands is conducted in accordance with 36 CFR 228.111 - 228.114, and BLM oil and gas regulations 43 CFR 3160.

C.6 PLUGGING AND RECLAMATION (PHASE 5)

All abandonment, whether it involves one wildcat well, a well no longer productive, or an entire leasehold, require the approval and acceptance of the abandonment of the individual well(s) by the BLM and the Forest Service. An acceptable abandonment includes (1) the plugging of the wellbore, and (2) reclamation of the land surface to a stable and productive use.

C.6.1 Approval of Plugging and Abandonment

Well abandonment operations may not be started without prior approval of a "Sundry Notices and Reports on Wells" by the authorized officer of the BLM. The Sundry Notice serves as the operator's Notice of Intent to Abandon (NIA). In the case of newly drilled dry holes, failures, and in emergency situations, oral approval may be obtained from the authorized officer followed by written confirmation. In such cases, the surface reclamation requirements will have been discussed with the operator and stipulated in the approved APD. Additional surface reclamation measures may be required by the Forest Service. For older existing wells, not having an approved SUPO, a reclamation plan must be submitted with the NIA. Reclamation requirements are part of the approval of the NIA. The operator must contact the BLM prior to plugging a well to allow for approval and witnessing of the plugging operations.

C.6.2 Plugging of Wells

The purpose of plugging a well is to prevent fluid migration between zones within the wellbore in order to protect aquifers of useable quality water and to protect other minerals from damage. Well plugging requirements vary with the characteristics of the rock, geologic strata, well design, and reclamation requirements. For wells no longer capable of production, all perforations must be isolated so as not to allow fluid to migrate up hole to the surface. The perforations may be isolated by:

1. Placing a cement plug across the perforations that extends 50 feet above and below the perforations.
2. Setting a cement retainer (cement tool that acts like a plug except that cement can be pumped below the tool but no fluid can pass above the tool) +/- 100 feet above the perforations and pumping a sufficient volume of cement into the perforations.

3. Setting a bridge plug (a tool similar to a cement retainer except that no fluid can pass in either direction) +/- 100 feet above the perforations and placing 50 feet of cement on top of the bridge plug.

The production casing may be removed. If the casing is cut and removed, the casing stub (the top of the casing remaining in the hole) must be plugged with a 100-foot cement plug to extend 50 feet inside the casing stub and 50 feet outside the casing stub (open hole). If the casing is not removed, the surface casing shoe must be isolated by perforating the production casing near the surface casing shoe. A cement retainer must be set about 100 feet above the perforations and a sufficient volume of cement is pumped below the retainer, through the perforations, and between the outside of the production casing and the inside of the surface casing for a distance of 100 feet. All cement plugs must have sufficient volume to fill 100 feet of hole plus an additional volume of 10 percent per 1000 feet of depth (e.g., a 100 foot plug at 5000 feet would be required to have an additional 50 feet of cement). At the surface, the casing and all annular spaces must be plugged with at least 50 feet of cement.

The operator's plan for plugging and abandonment is submitted with the Notice of Intent to Abandon and is reviewed for completeness and adequacy. Although the plugging of each well must be designed individually, the minimum requirements are described below.

In open hole situations, cement plugs must extend at least 50 feet above and below zones with fluid that has the potential to migrate, zones of lost circulation (this type of zone may require an alternate method to isolate), and zones of potentially valuable minerals. Thick zones may be isolated using 100-foot plugs across the top and bottom of the zone. In the absence of productive zones and minerals, long sections of open hole may be plugged by placing plugs every 3,000 feet. In cased holes, cement plugs must be placed opposite perforations and extending 50 feet above and below except where limited by plug back depth. (See Onshore Oil and Gas Order No. 2.)

Wells are normally plugged when they are no longer capable of production. However, if a well has potential for use in a secondary recovery program, it may be allowed to stand idle until it is converted to other uses. Dry wildcat and development wells are normally plugged before the drill rig is removed form the wellsite. This allows the drill rig to plug the hole and avoid the necessity of bringing in other plugging equipment. Truck-mounted equipment is used to plug former producing wells.

A permanent abandonment marker is required on all wells unless the Forest Service waives this requirement. This marker pipe is usually four feet above the ground and embedded in cement at the borehole site. The pipe is capped and the well's identity and location permanently inscribed.

C.6.3 Surface Reclamation

A reclamation plan is a part of the Surface Use Plan of Operations (SUPO). Reclamation may be required of any surface previously disturbed that is not necessary for continued well or other oil/gas related operations. When abandoning a well and other facilities that do not have a previously approved reclamation plan, a plan must be submitted with a NIA. Additional reclamation measures may be required based on the conditions existing at the time of abandonment. Any additional reclamation requirements are made part of the conditions of approval of the NIA. The general standards and guidelines for reclamation and abandonment of oil and gas operations are set forth in the third edition of the *Surface Operating Standards for Oil and Gas Exploration and Development*. Additional standards and requirements may be applied to accommodate the site-specific and geographic conditions of the reclamation site.

Prior to the start of reclamation, all equipment and debris must be removed from the area to be reclaimed. When an entire lease is abandoned, the separators, heater treaters, tanks, and other processing and handling equipment are removed and the surface restored. Flowlines and injection lines installed on the surface are removed, but buried lines are cleaned out and usually are left in place.

Well Site Reclamation—Well site reclamation must be planned on both producing and abandoned well sites. The entire site, or portion not required for the continued operation of the well, is reclaimed.

When they are dry, all excavations and mud pits must be closed by backfilling and graded to conform to the surrounding terrain as much as possible. Water bars and terracing may be installed to prevent erosion of fill material.

Cut and fill slopes must be reduced and graded to blend the site to the adjacent terrain. The well site may be recontoured by bringing the construction material back onto the well pad and reestablishing the natural contours.. Areas surfaced with gravel are buried deep in the recontoured area to prevent possible surface exposure.

The topsoil is replaced on the reclamation area and prepared to provide a seedbed for reestablishment of desirable vegetation. Standard reclamation practices may include contouring, terracing, gouging, scarifying, mulching, fertilizing, seeding, and/or planting.