

Wellbore Plugging and Abandonment

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Foreword

This document was prepared with input from oil and gas operators, drilling contractors, service companies, and consultants. Guidance is provided to accomplish the following:

- permanently abandon wells;
- place wells on inactive status (temporary abandonment).

Permanent abandonment is performed when there is no further utility for a wellbore by sealing the wellbore against fluid migration.

A well is placed on inactive status when there are plans for future utility of the wellbore. Temporary abandonment is performed by sealing the wellbore for the anticipated time of inactivity.

The purpose of this document is to address wellbore plugging and abandonment practices. The primary goals are protection of useable water sources, isolation of hydrocarbon bearing or water injection intervals, prevent any leakage to the surface, and prevention of unintended cross flow. Topics discussed include cementing practices and the placement of well barriers. This document does not address regulatory requirements nor surface reclamation.

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Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the standard.

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Wellbore Plugging and Abandonment

1 Scope

1.1 General Considerations

This document provides guidance for the design, placement, and verification of cement plugs in wells to be temporarily or permanently abandoned, as well as remediation and verification of annular barriers. Wells temporarily abandoned (suspended) are intended to be re-entered in the future. The placement of barriers may depend on whether the well is to be temporarily or permanently abandoned.

The information in this document is general in nature. Wellbore plugging and abandonment practices will vary with regulatory requirements, well type, and purpose. Sound engineering and operational practices should be applied to each wellbore plugging operation. Cement plug lengths are not considered in this document.

1.2 Well Construction and Abandonment Practices

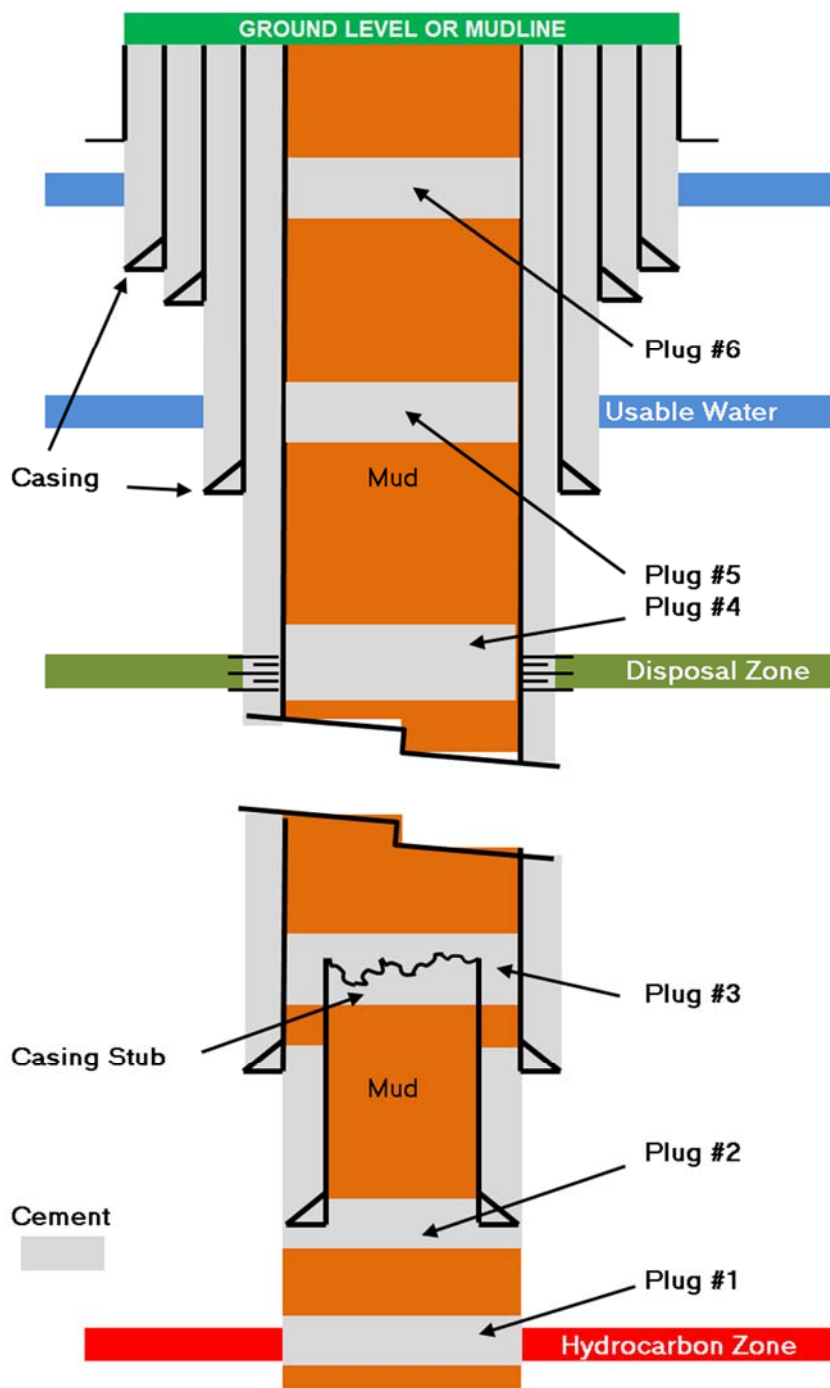
This document assumes that generally accepted well construction practices were followed during the installation of the cemented casings.

As specified in API 65-2, properly designed casing strings cemented in place provide multiple barriers during well operations.

Abandonment barriers may include those placed:

- across any exposed casing/liner shoe;
- in open hole;
- above perforated intervals in cased hole;
- at points where casing has been removed;
- across liner tops;
- above and below usable water sources;
- above or below hydrocarbon bearing zones or other potential flow zones;
- at the surface or mudline.

See Figure 1 for an example of a permanent well abandonment.



- NOTE 1 Plug #1 may cover all open hole length in several cases.
- NOTE 2 Plug #3 is commonly called a casing stub plug or "T" plug.
- NOTE 3 Plug #6 is commonly called a surface or environmental plug.
- NOTE 4 Top of cement in casing strings can vary depending on well construction.

Figure 1—Example Schematic of a Permanent Well Abandonment

2 Normative References

The following referenced document is indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any amendments/addenda/errata).

API Standard 65-2, *Isolating Potential Flow Zones During Well Construction*

For a listing of other documents associated with this publication, refer to the Bibliography.

2.1 Use of SI and U.S. Customary Units

This document contains derived metric units (SI) and U.S. customary oilfield units. For the purposes of this document, the conversion between the systems is not exact and has been intentionally rounded to allow for ease of use in calibration and measurement.

3 Terms and Definitions, Symbols, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

barrier

A component or practice that, if properly installed, contributes to the total system reliability by preventing liquid or gas flow.

3.1.2

bridge plug

A mechanical device, usually equipped with elastomer elements, that acts as a temporary barrier.

NOTE 1 A pumpable sealant may be placed below it before being placed in the wellbore, or above it after being activated.

NOTE 2 It can be placed in the wellbore using a workstring, coiled tubing, or wireline.

3.1.3

cement

Any material or combination of materials fluidized and pumped into the well to provide a seal.

NOTE This includes pumpable sealants containing Portland cement, pozzolan blends, blast furnace slag blends, phosphate cement, hardening ceramics, resins, geo-polymers or other appropriate materials.

3.1.4

coiled tubing

A long, continuous length of pipe wound on a spool.

NOTE The pipe is straightened prior to pushing into a wellbore and rewound to coil the pipe back onto the storage spool pulling out of the wellbore.

3.1.5

dump bailer

A wireline or slickline tool used to place small volumes of cement in a wellbore.

3.1.6
inside blowout preventer
IBOP

A tool used as a check valve inside the workstring.

3.1.7
mud

Any wellbore fluid, including drilling fluids and completion fluids, containing organic or inorganic salts.

3.1.8
packer

A mechanical device, usually equipped with elastomer elements, placed in the well using a workstring, coiled tubing, or wireline to act as a barrier.

NOTE It may be either permanent or temporary/retrievable type.

3.1.9
plug

A verifiable barrier located within the wellbore that may be mechanical or cement.

3.1.10
retainer

A mechanical device, usually equipped with elastomer elements, that allows passage of fluid through a valve that can then be closed.

NOTE It can be placed in the wellbore using a workstring, coiled tubing, or wireline.

3.1.11
through-tubing

An intervention technique of running through an existing tubing string in the wellbore.

NOTE 1 Normally, a packer is deployed using this technique, enabling placement in a larger-diameter open hole or casing located below the existing tubing string.

NOTE 2 The packer is typically run on coiled tubing, wireline, or slickline.

3.1.12
workstring

A generic term used to describe a tubular that is used to convey a treatment or for well service activities.

NOTE Examples include jointed tubing, coiled tubing, or drill pipe.

3.2 Symbols and Abbreviations

3.2.1 Symbols

For the purpose of this document, symbols are only used for balanced plug calculations, they are provided under Annex A.

3.2.2 Abbreviations

For the purpose of this document, the following acronyms or abbreviations are used.

BHA bottom hole assembly

ECD equivalent circulating density

IBOP inside blowout preventer

NAF	non-aqueous fluid
PWC	perforation, wash, and cement
psi	pound-force per square inch (lbf/in. ²)
SCP	sustained casing pressure
VRP	viscous reactive pill
WOC	waiting-on-cement

4 Applications and Operating Environment

4.1 Formation Types

4.1.1 Potential Flow Zones

Potential flow zones are any formations in a well where flow is possible when the wellbore pressure is less than the pore pressure (e.g., hydrocarbon zones, shallow gas, or overpressurized water zones that may be natural or induced). Isolation of these zones shall be the primary objective of wellbore plugging and abandonment unless cross flow is deemed acceptable. Prior to permanent abandonment operations, all potential flow zones in the wellbore shall be identified.

4.1.2 Usable Water Sources

Subsurface waters (aquifers) suitable for consumption by humans or animals with or without treatment are classified as usable water sources. These formation types shall be protected from contamination by fluid migration or surface water runoff.

4.1.3 Injection and Depleted Zones

Injection or disposal zones are geological formations whose strata are isolated from overlying usable water sources by an impermeable layer into which fluids are injected for disposal or charging. These formations may or may not be classified as depleted zones. Depleted zones are formations whose reservoir pressures are less than the adjacent formation pressures as a result of production operations. These zones may prevent plug stability during placement. Both injection and depleted zones shall be isolated during abandonment unless cross flow is deemed acceptable.

4.2 Positions

4.2.1 Barrier Installation

During the drilling of a well, the natural geologic seals to overpressured formations are penetrated by the wellbore. During well abandonment, the placement of a barrier prevents the flow of formation fluids to surface or seabed, cross flow between permeable formations, and contamination of usable water sources.

Since the initial geologic state was a continuous seal, well abandonment is typically performed by creating a continuous barrier across the wellbore at the natural seal location.

See Figure 2 for an illustration of a continuous barrier across the wellbore at the natural seal location.

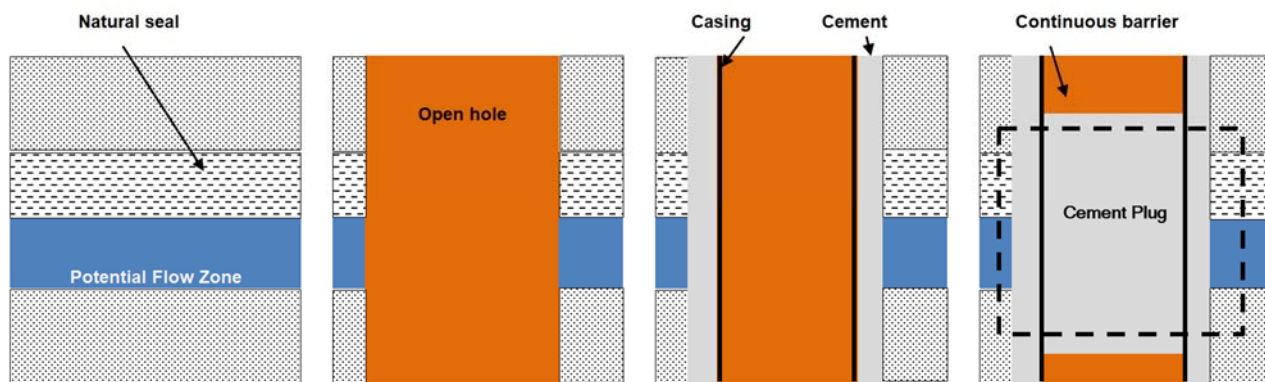


Figure 2—Illustration of a Continuous Barrier across the Wellbore at the Natural Seal Location

Permanent annular barriers set adjacent to the natural seal during the well construction phase can increase the efficiency of the permanent abandonment operations. During the construction of the well, considering field operational life can aide in the placement of barriers (e.g., conversion of a well to an injector, disposal).

During planning for permanent abandonment operations, potential flow zones identified during the well construction are reviewed and redefined if applicable. Local regulatory authorities may define zones that require permanent abandonment barriers.

The inclusion of a draft well abandonment plan or schematic showing the proposed locations of permanent barriers can aide in optimizing well construction activities in preparation for well abandonment.

4.2.2 Formation Pressures and Strengths

The location of a permanent abandonment barrier is typically at a depth where formation integrity can withstand the pressure from the potential flow zones being isolated. A natural seal for a potential flow zone typically starts immediately above the top of the potential flow zone. An understanding of individual seals to potential flow zones, and seals, which can contain all the pressures from above and below, can help plan the placement of permanent abandonment barriers.

The fluid gradient from each potential flow zone can be used in the determination of permanent abandonment barrier locations.

See Figure 3 for an example of the location of a permanent abandonment barrier placed at a depth where formation integrity (natural seal) can withstand the pressure from the potential flow zone being isolated.

Considerations for the placement of permanent abandonment barriers can include:

- location of potential flow zones and pore pressures;
- location of usable water sources;
- formation fracture pressure of natural seals;
- cross flow potential; direction and resultant equalized pressures;
- future field plans (e.g., injection activities);
- compaction, subsidence, and recharged formations;
- corrosion risks;
- field reservoir management requirements;

- regulatory requirements;
- location of natural faults and their ability to transmit fluids and/or pressure;
- ability to verify barrier;
- failure of a previous, temporary, or secondary barrier;
- operating environment.

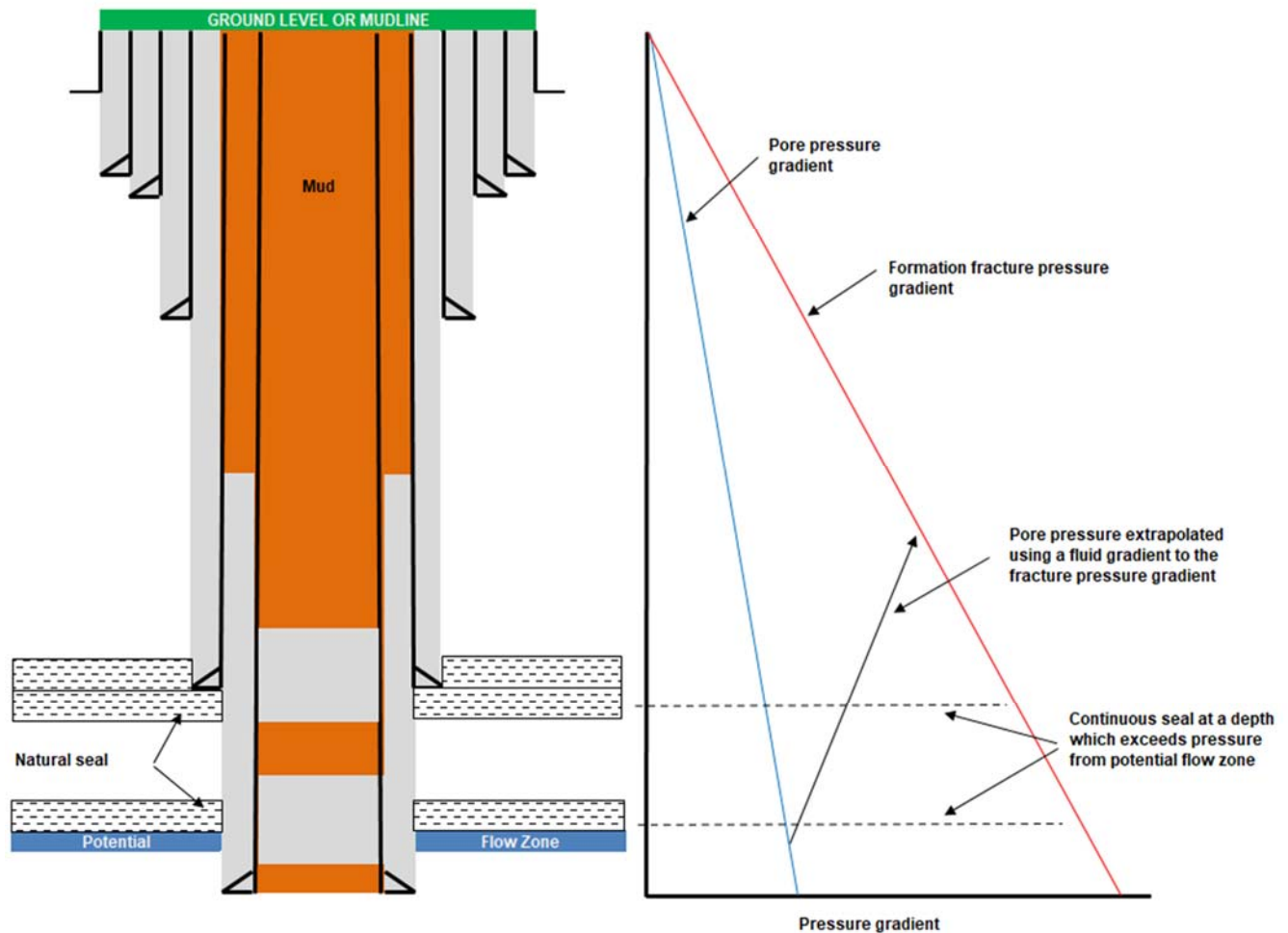


Figure 3—Two Continuous Barriers Adjacent to Natural Seals where Formation Integrity Exceeds Pressure from Potential Flow Zone

4.2.3 Open Hole

Methods used to place open hole abandonment plugs may include displacement, squeeze, coiled tubing, and through-tubing open hole inflatable packers.

Figure 4 shows a typical open hole abandonment using balanced plugs. Figure 5 shows a typical open hole abandonment using a cement retainer.

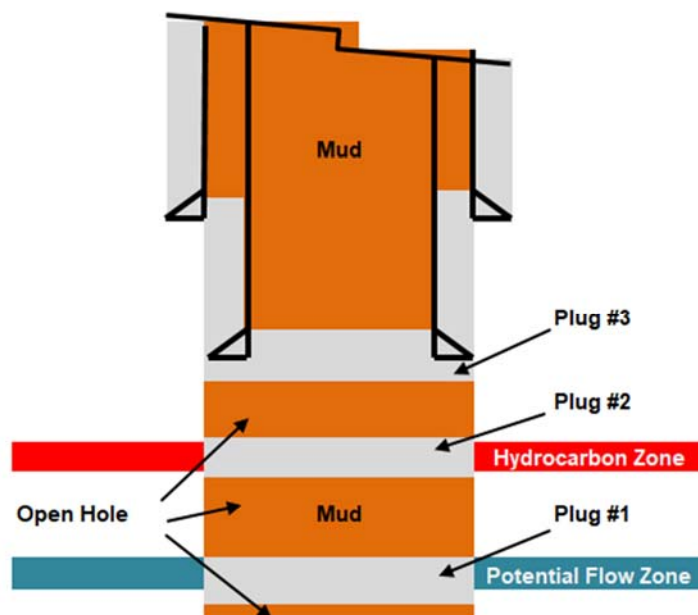


Figure 4—Open Hole Abandonment by Balanced Plugs

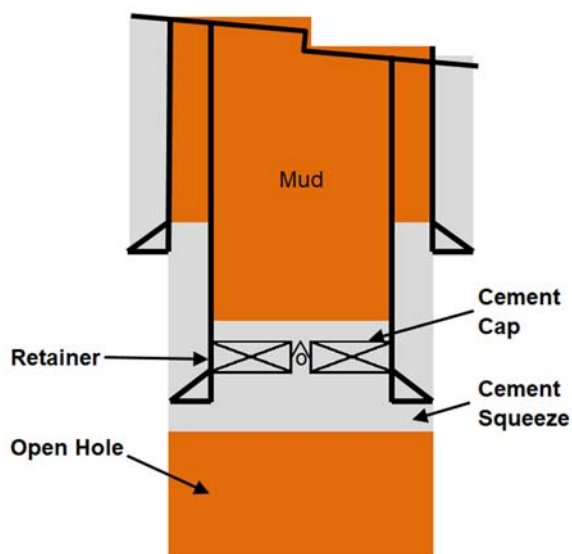


Figure 5—Open Hole Abandonment with a Cement Retainer Set at Casing Shoe

4.2.4 Cased Hole

Cased hole abandonments typically involve squeeze cementing and/or a cement plug to seal potential flow zone pathways, such as perforations, as well as placing cement plugs in the cased wellbore.

Figure 6 shows a typical cased hole abandonment using a perforation squeeze and a balanced plug. Figure 7 shows an example of a cased hole abandonment using a cement retainer for the same purpose.

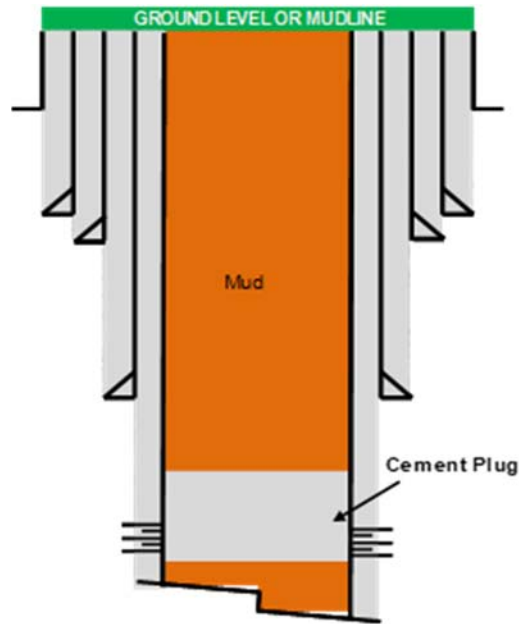


Figure 6—Cased Hole Abandonment with a Perforation Squeeze and a Balanced Plug

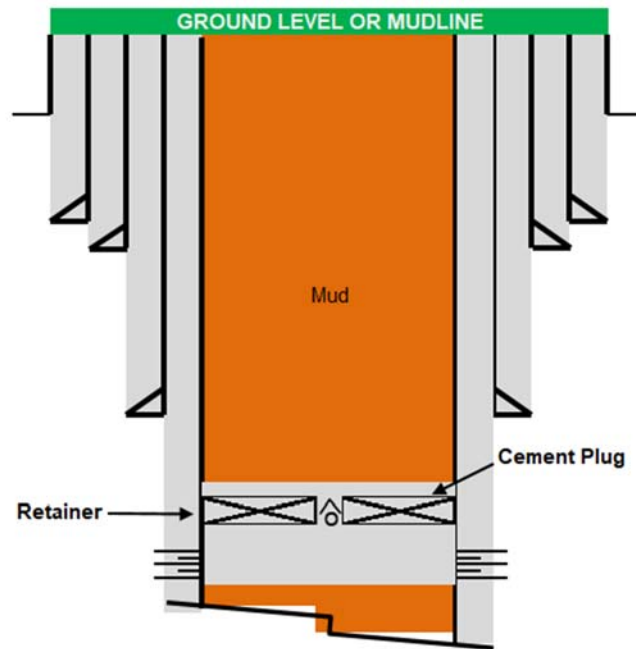


Figure 7—Cased Hole Abandonment with a Cement Retainer

4.2.5 Casing Shoe

The abandonment operations performed at the casing shoe provide a barrier to isolate the open hole below, and the open hole from the upper sections of the wellbore. Methods used to abandon a casing shoe may include displacement, squeeze, coiled tubing, and mechanical plugging.

Figure 8 shows an example of a cement plug used to isolate the open hole from the upper sections of the wellbore. Figure 9 shows an example of using a cement retainer to set a cement plug for the same purpose.