WSRC-RP-2001-00614
Rev. 0

Use of Sonic Technology for Drilling through and Installing Wells Below "Competent" Confining Units (U)

May 23, 2001

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Prepared for the United States Department of Energy Under Contract No. DE-AC09-96-SR18500

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U.S. Department of Energy.

DISCLAIMER

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Drilling through "competent" confining units for characterization purposes is an activity of concern in the environmental industry. The scenario of concern is when the aquifer above the confining unit is contaminated and the underlying aquifer is uncontaminated or contaminant levels are unknown. In these cases, standard practice when using mud rotary drilling methods is to install either temporary or permanent surface casing. This is dependent on whether samples are being collected on a one time basis or if a permanent well is being installed, respectively. With the development of sonic drilling methods and their use of a multiple casing system, the need for setting surface casing is not necessary. The outer casing used with the sonic system provides the same function as the traditional surface casing.

Purpose of Surface Casing at SRS

Surface casing is used at SRS for one or more of the following reasons as identified in the SRS Procedure Manual 3Q5:

1. To reduce the potential for downward migration of contaminants (surface casing may be placed either before or after drilling to total depth, depending on the potential for contamination)
2. To seal off zones in which drilling fluid is lost at an excessive rate. (surface casing is usually placed immediately after encountering problem zone)
3. To seal off zones of unconsolidated sand or other materials where caving or bridging of the hole occurs. (surface casing is usually placed immediately after encountering problem zone)
4. To stabilize surface soils in the vicinity of the drilling rig, providing support during drilling. (this surface casing does not necessarily require grout injection or reach deep enough to contact saturated sediments) (WSRC, 1997)

To install surface casing to mitigate reason one, the following must apply: The overlying aquifer is known to be contaminated, and the underlying aquifer is known to be uncontaminated with the constituents present in the overlying aquifer. In the instance of aqueous phase contaminants there also must be appreciable downward potential for water flow between the two aquifers.

Sonic Drilling Method

The sonic drilling technology combines harmonics (vibration) and rotation as the basis for tool advancement. Sonic drilling uses water as the fluid medium as opposed to mud rotary which uses mud. Sonic drilling reduces Investigation Derived Waste by approximately 70%, in most formations, as compared to mud rotary methods. Core recovery from sonic drilling conducted at SRS over the past 4 years is greater than 90% on average. Sonic drilling saves approximately 4 days times versus mud rotary methods for installing a 200 ft well through a confining unit.

Drilling is conducted using an inner casing (core barrel) followed by an outer casing. Standard casing sizes are 3 inch core barrel by 5 inch outer casing when only core is being collected and 4 inch core barrel by 6 inch outer casing for installation of 2 inch wells. The core barrel advances 10 feet into the subsurface, followed by the outer casing. The core barrel is then removed from the borehole and the soil either sampled and bagged for preservation or for disposal according to SRS requirements. The core barrel is put back into the borehole and pushed another 10 feet. An additional 10 foot length of outer casing is added to the outer casing that is in the ground and it is drilled to meet the bottom of the core barrel. This process continues until total depth is reached. A sketch of the drilling setup is shown in Figure 1.

For installation of a well, upon reaching total depth the core barrel is removed followed by placement of the monitoring well. The outer casing remains in place when the well materials (casing, screen, plug, centralizers, etc.) are installed. The outer casing is pulled back slowly in stages as the gravel pack is installed. The gravel pack is tremied in using the outer casing and gravel pack materials are installed dry.

The outer casing is vibrated up the hole a few feet and the top of the filter pack is tagged. This process is repeated until sufficient filter pack is placed in the borehole. The bentonite pellet seal is then installed in the same manner and hydrated for 2 hours. The grout is placed into the borehole using a side discharge tremie pipe. Grout installed below the water table follows this same protocol of pulling the outer casing back in short stages. Once above the water table the outer casing is pulled back in longer stages (20 to 30 ft). The standard protocol of staging the grout lifts based on height is followed. The outer casing is vibrated out of the hole, eliminating the potential for bridging of the annular materials. A sketch of the well installation process is shown in Figure 2.

Installation of wells with diameters greater than 2-inches requires use of additional larger diameter (> 6-inch diameter) override casings. These are drilled over the core barrel and outer casing (6-inch diameter) until the required borehole diameter is reached.

Sonic Outer Casing As Alternative to Permanent Surface Casing

Installation of a well below a competent confining unit follows the same protocol as the process described in the preceding section with one addition. Upon reaching the top of the confining unit (this is determined by reviewing the core removed from the borehole with the inner barrel), an override casing is drilled into the top 1 to 2 feet of the confining unit. This casing is pressurized with air or water and tested to ensure a seal will hold. This pressure testing can only be successful if the confining unit is impermeable (no sands are present in the confining unit). Upon successful placement of this override casing, drilling continues into the underlying aquifer with the two casing system. Figure 3 is a sketch of the use of the override casing. The well and filter pack are then installed. Grout is installed by tremie until the grout column reaches several feet above the bottom depth of the override casing. At this point the outer casing (not override casing) that penetrated both aquifers is pulled from the ground. Grouting then continues inside the override casing. Upon placing a stage of grout in the override casing, the casing is extracted several feet and the process continues until grout reaches ground surface and the override casing has been extracted from the ground.

When penetrating several confining units requiring surface casing, the process can be repeated. For example, if two confining units are to be penetrated, an 8-inch temporary casing will be advanced over the 7-inch temporary protective casing set into the upper confining unit. The 7-inch temporary protective casing would then be removed and a seal established in the 8-inch temporary protective casing, as described above. The 7-inch temporary protective casing would then be advanced inside the 8-inch temporary protective casing to the base of the lower confining unit and a seal established. Drilling below this lower confining unit would then continue with the 6-inch casing with 4-inch core barrel.

The outer casing acts as a surface casing during drilling of the borehole and installation of the well. The installation processes are the same. Once the well has been installed and the annular material is in place, the grout prevents the downward migration of the contaminants.

Use of Sonic Drilling at SRS

As with all drilling methods, sonic methods have an appropriate place in the drilling toolbox. The following are instances where sonic drilling is the appropriate method of choice:

1. Collecting water and/or soil samples and/or installing wells below confining units. (The outer casing provides the same protection as surface casing.)
2. High percentage of core recovery is needed. Core recovery rates are consistently high without loss of time. The core is collected in 5 to20 foot sections.
3. In zones where drilling fluid is being lost at an excessive rate. (The outer casing blocks off these zones.)

4. In zones of unconsolidated sand or other materials where caving or bridging of the hole occurs. (The outer casing blocks off these zones.)
5. Installation of wells that have multiple zones where some zones are below the water table and others are above the water table. (i.e. A well is installed with pressure monitors below the water table and a well screen is installed above the water table. Depending on the depth below the water table, an auger drill will more than likely have problems with locking of the augers. A mud rotary rig will produce a mud pack around the screen in the vadose zone, making that screen unusable as you will not be able to develop the zone and remove the mud.)
6. Below the water table in contaminated zones when soil samples are to be collected and there is the potential for flushing the contaminants from the sampling zone.

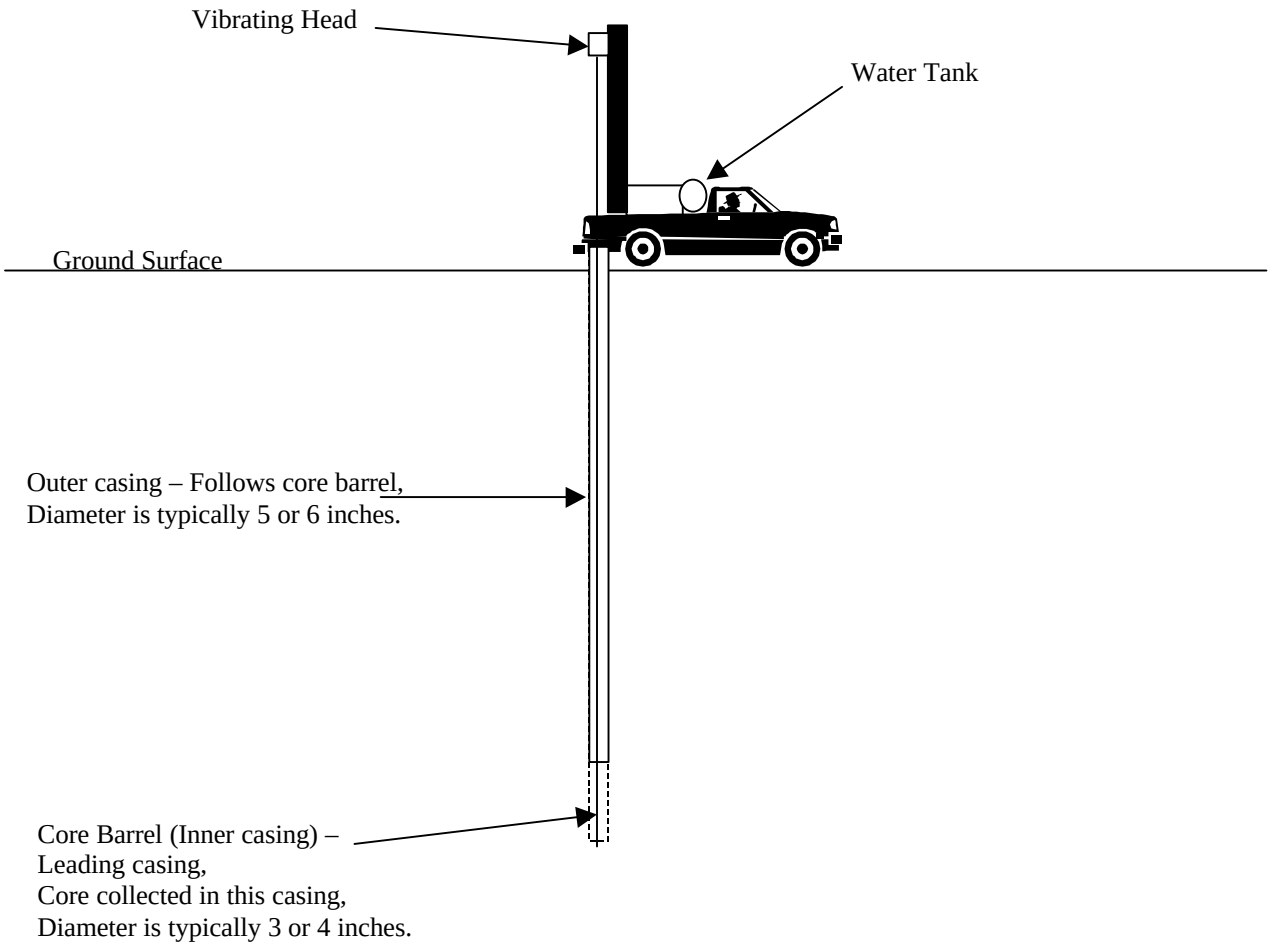
Other drilling methods may be more appropriate than sonic under the conditions described below:

Drilling in the vadose zone is more economical and provides equal or better quality samples depending on the constituents of interest. For example, when sampling for volatile organic contaminants in the vadose zone, it is best to drill without using any fluids, as the fluids may flush some of the contaminants from the sampling zone. Cone penetrometer technology, direct push and auger drilling are excellent options in this circumstance.

Great depth is needed. Based on the experience we have at SRS to date, drilling over 350 ft at SRS is beyond the present capabilities of the sonic system. Depth is further limited by the size of the well to be installed. The larger the well diameter, the shallower the limits of penetration. A part of this limitation is the weight of the drilling casings versus the stress on the sonic heads.

A full suite of geophysical logs are needed. One drawback to sonic drilling is that a full suite of geophysical logs is not possible because of the steel outer casing that lines the wall of the borehole to keep it open. Gamma logs can be run inside the casing used in sonic drilling.

Reference:
WSRC, 3Q5, Hydrogeologic Data Collection Procedures and Specifications, Rev. 2, 6/3/97.



Standard lengths of both inner and outer casing as 10 ft.

Figure 1. Sketch of Casing Emplacement with Sonic Drilling

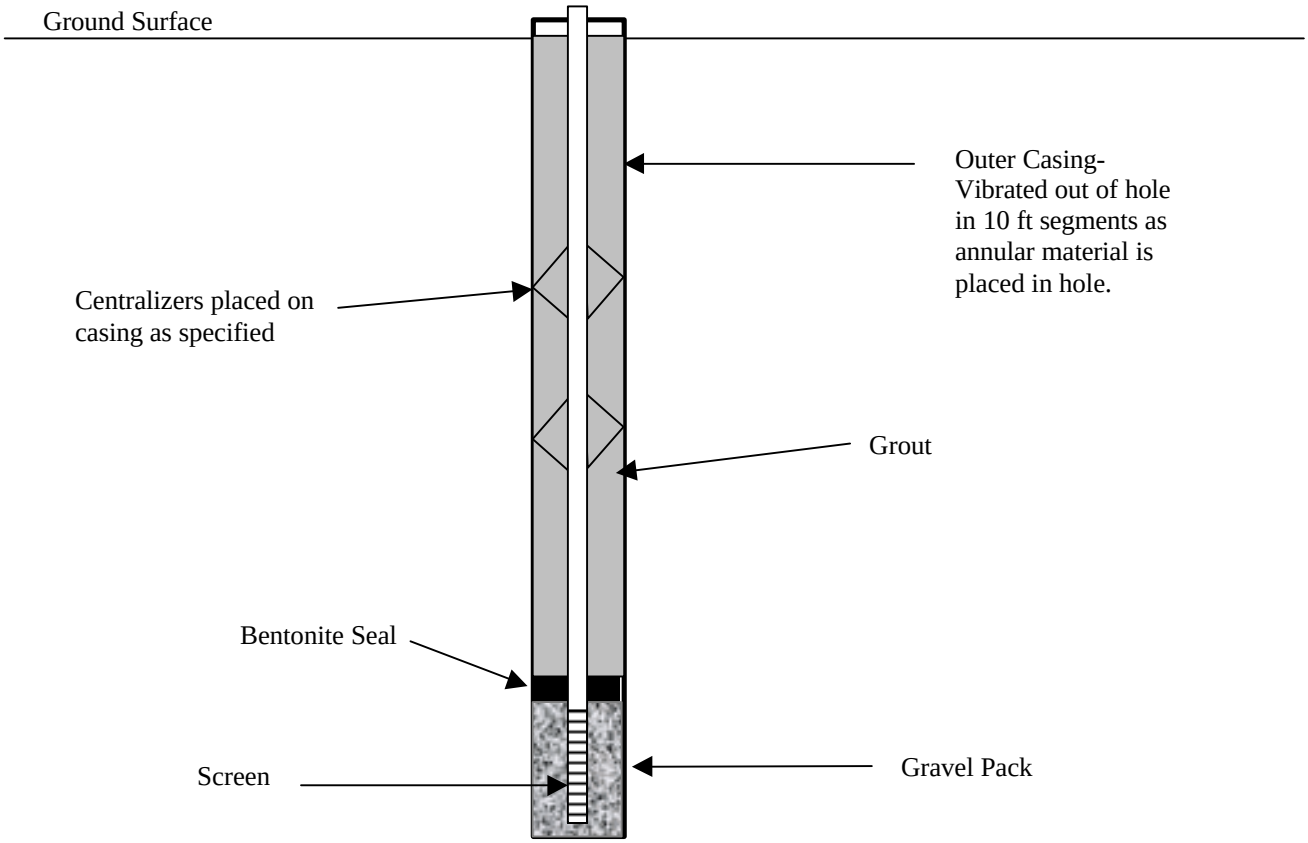


Figure 2: Sketch of Well Installed with Sonic Drilling Method

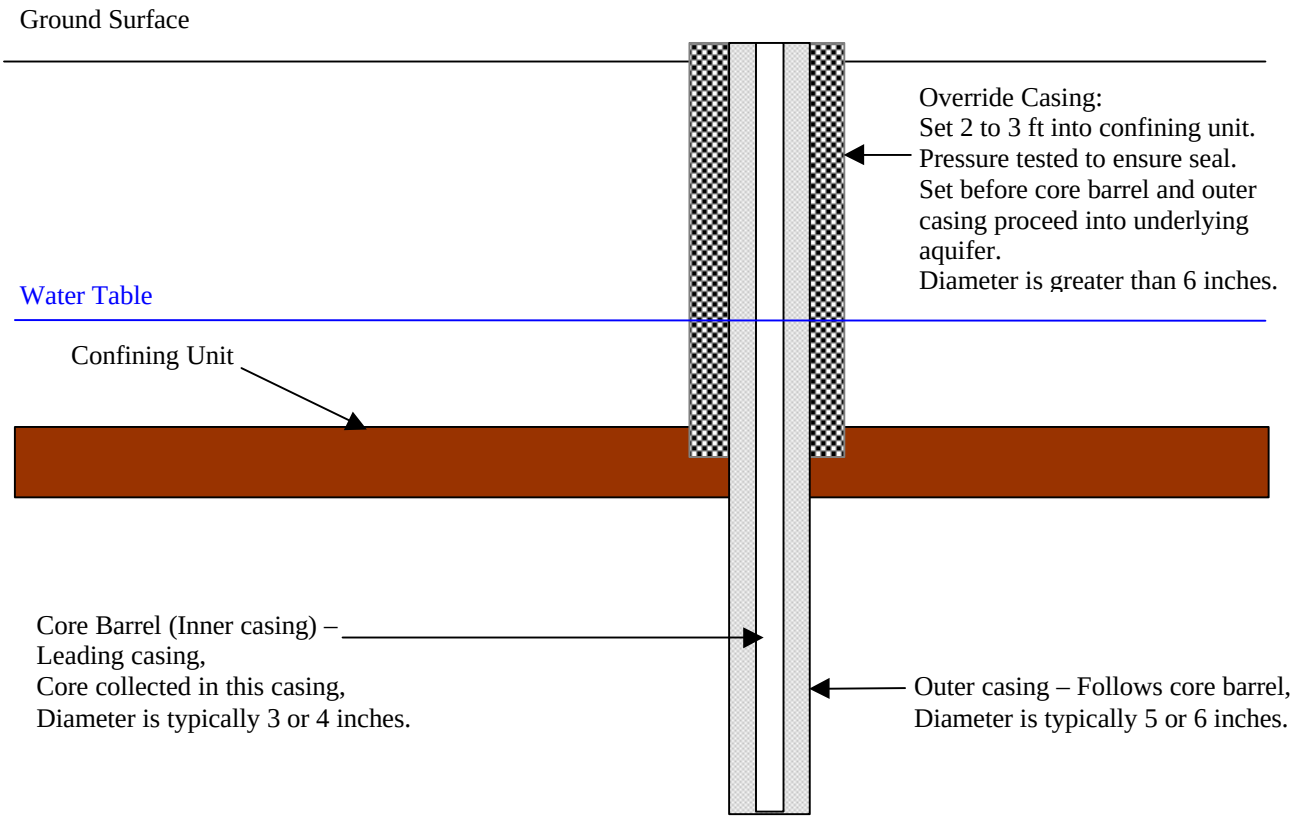


Figure 3: Sketch of OverrideCasing Emplacement Across a Confining Unit Using Sonic Drilling Method