Appendix B
Drilling Methods

B-1. Introduction

A brief discussion of available drilling methods is included below. It is not the intent of this manual to include a detailed description of these methods. Neither is it intended to list all the methods available to the drilling industry. Most of the methods listed below may be good options for drilling in native soil or rock. When drilling in embankments extreme care must be taken to avoid damage to the core, as discussed in paragraph 6-5.

B-2. Hollow Stem Auger Drilling

The hole is advanced by turning sections of auger casing, called auger flights, into the subsurface (see Figure B-1). Rotating of the auger flights carries the soil to the surface. Soil samples can be taken off the flights of the augers as the soil comes to the surface. For accurate locations of samples, the auger pilot bit can be removed and split-spoon sampling can be performed through the augers ahead of the auger cutter head. This method is most effective when used in stable soil conditions which are generally free from cobbles and boulders. A detailed description of soil sampling procedures can be found in EM 1110-2-1907. The advantages of this method are that the hole is drilled and cased simultaneously, and the hole can be advanced without the introduction of fluids. Some of the disadvantages are that drilling difficulty significantly increases with depth and the auger flights must be removed from the hole without rotating to avoid damaging the installed instrument.

B-3. Cable Tool Drilling

a. The cable tool (churn drill or percussion drill) method of drilling involves the use of percussion by repeatedly lifting and dropping a heavy string of drilling tools or weight into a borehole (see Figure B-2). The material is pulverized at the bottom of the hole forming a slurry which is then removed with a bailer (see Figure B-3) when the penetration rate becomes unacceptable. The sides of the borehole can be supported with drill casing as needed. This method is useful for deep holes when a hydrostatic head from drilling mud is unacceptable. The main drawback is that it is relatively slow.

b. Continuous sampling may be accomplished with a cable tool if the chopping bit is replaced by a steel barrel or open-drive sampler and the short-stroke drilling jars attached between the sampler and drill bar are replaced by long-stroke fishing jars. The long jars facilitate driving without any upward motion. The hole is advanced by the sampling operation itself and is cleaned out by bailing each time the casing is advanced. Samples must be taken below the bottom of the casings. It is difficult, however, and often impossible to advance the borehole ahead of the casing when sampling in soft or cohesionless soils.

B-4. Direct Mud (Water) Rotary Drilling

Mud rotary drilling is a commonly used method of drilling that is suitable in rock as well as overburden but cannot be used in situations where excess hydrostatic heads cannot be tolerated such as in some earth embankment dams. As the name describes, a drill bit on the bottom of a string of drill rods is rotated in a borehole. Drilling fluid is circulated in the borehole by pumping down through the string of rods, where it picks up the drill cuttings and carries them to the surface of the borehole (see Figure B-4). As discussed in paragraph 6-6, selection of the proper drilling fluid is essential for the proper installation of some instruments. For most instrumentation installations the sides of the borehole should be supported with drill casing. The casing also prevents the drilling fluid from contacting the sidewalls of the borehole. The disadvantage of using drilling mud is that the fluid can seal the sides of the borehole where an instrument may be installed.

B-5. Air Drilling Systems

Air rotary drilling is similar to direct mud rotary drilling except that compressed air is used to transport the cuttings to the surface. An air-operated downhole casing advancement system is sometimes used. This casing advancement system consists of an air-operated down-the-hole hammer drill that is fitted with a specialized bit that has an eccentric reamer that cuts the hole large enough for the casing to follow. The hammer drill is designed to be used inside and at the bottom of the drill casing so that the bit and eccentric reamer are below the casing. Using compressed air, the hammer pulverizes the material below the casing, then blows it back through the casing to the top of the hole. As the hammer drives through material it also reacts against an interior shoulder bevelled on the drill casing shoe, which pulls the casing down the hole as the hammer drill is advanced. This method is well suited for drilling through difficult material such as rock fill. The major drawback is the high air pressure and large air volume required for operation and it is prohibited on embankment dams (see paragraph 6-5).

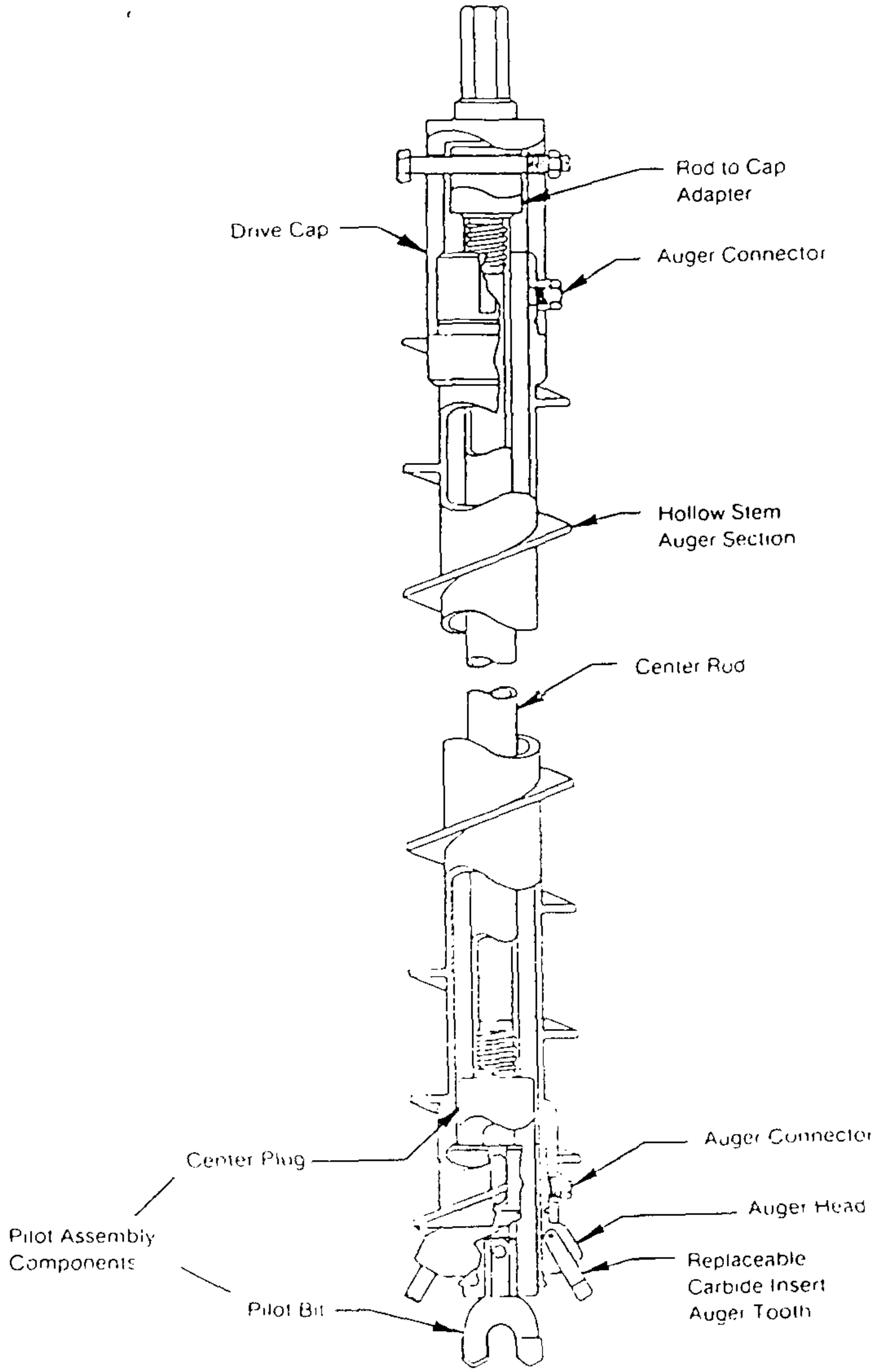

Figure B-1. Typical components of a hollow-stem auger. (Courtesy of National Ground Water Association)

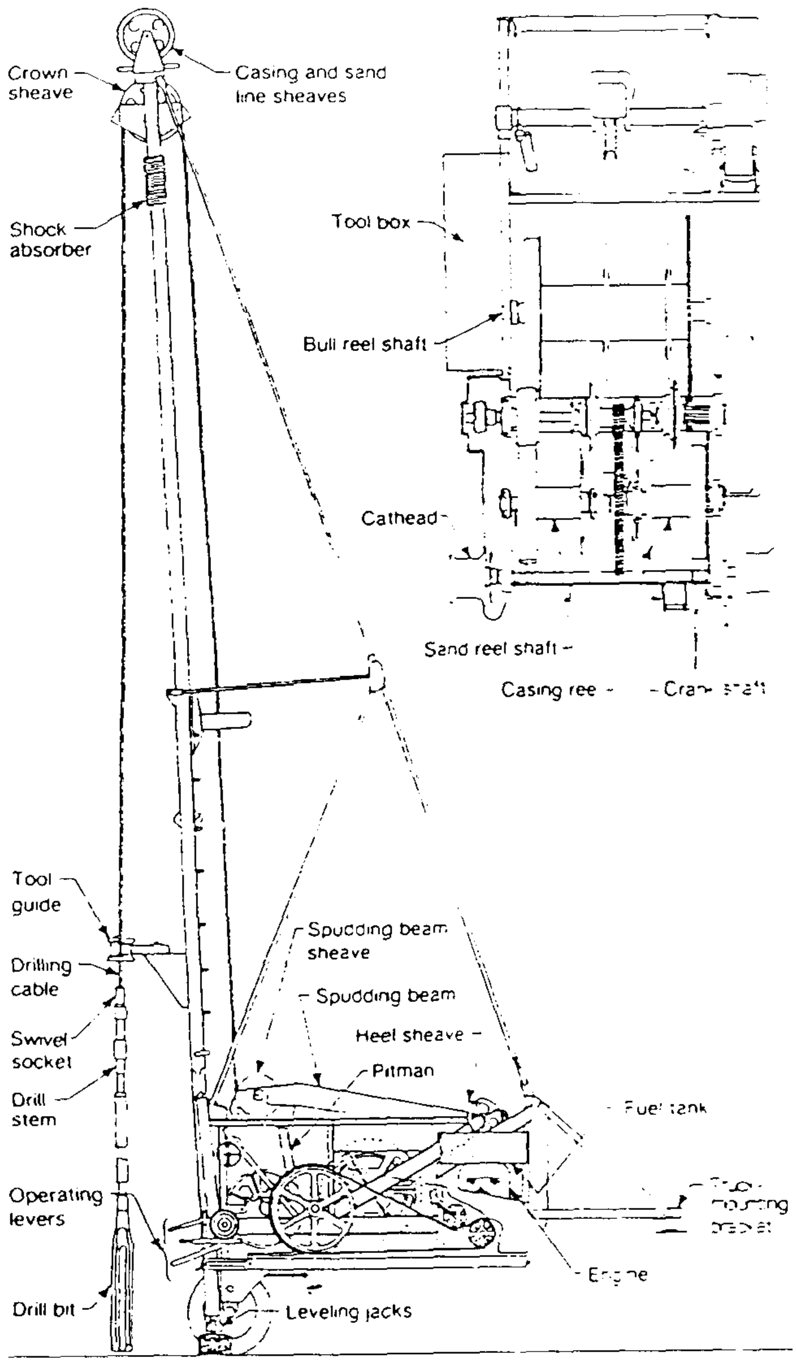

Figure B-2. Diagram of a cable tool drilling system. (Courtesy of National Ground Water Association)

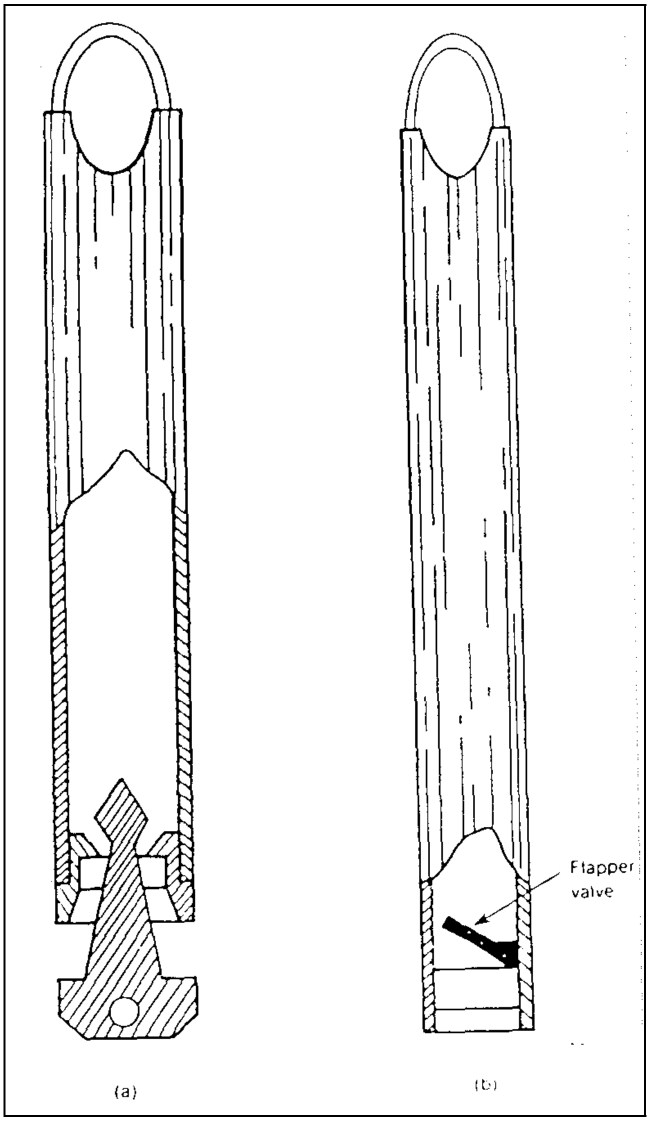

Figure B-3. Diagrams of two types of bailers: (a) dart valve and (b) flat bottom. (Courtesy of National Ground Water Association)

B-6. Core Drilling

Core drilling involves use of a core barrel, attached at the bottom of a string of rods, which is rotated and advanced through soil or rock to obtain a core sample of the material. Water or drill fluid is used to cool the cutting bit and to carry cuttings to the surface. The cutting bits are usually constructed of steel with carbide inserts or with impregnated diamonds. There are two types of core barrels: conventional (Figure B-5) and wire line (Figure B-6). To retrieve a core cut with a conventional core barrel, the entire string of drill rods must be removed from the hole. The wire line core barrel has an inner barrel which holds the core, that can be pulled up through the drill rods thereby eliminating the need to remove the entire string of drill rods.

B-7. Dual-Wall Reverse Circulation Drilling

Dual-wall reverse circulation drilling (see Figure B-7) can be used with either mud or air rotary drilling. The direction of flow is reversed and the transport medium is pumped down between the outer casing and the inner drill rods, through the drill bit, and up through the drill rods. This allows for rapid drilling through both unconsolidated and consolidated formations, and allows for continuous collection of the cuttings.

B-8. Wash Boring

The wash boring method is frequently used in sands and silts to either advance a casing or collect soil samples. Water is pumped down the drill rods under pressure and discharges through ports in the drill bit and carries the soil up to the surface in the annulus between the rod and the boring wall or casing. A washing or wedge-shaped chopping bit is normally used.

B-9. Other Drilling Methods

Other drilling methods include hand augers, driven wells (wellpoint) (see Figure B-8), and sonic (see Figure B-9). The major limitation of hand augers and driven wells is that they are normally restricted to shallow depths, although in sandy material wellpoints have been driven in excess of 15.24 m (50 ft). Solid-flight auger holes are difficult to instrument in most unconsolidated aquifers because of borehole caving upon auger removal. Sonic drilling uses a hydraulically activated unit that imparts high frequency sinusoidal wave vibrations into a drill string to achieve a cutting action at the bit face. The resultant cutting action forces a circular continuous core of the formation up into the drill rods. No cuttings are generated in the drilling process since excess material, generated by the cutting face of the bit, is redistributed into the borehole wall. For this reason sonic drilling should be evaluated before it is used as a drilling method for the purpose of installing instrumentation.

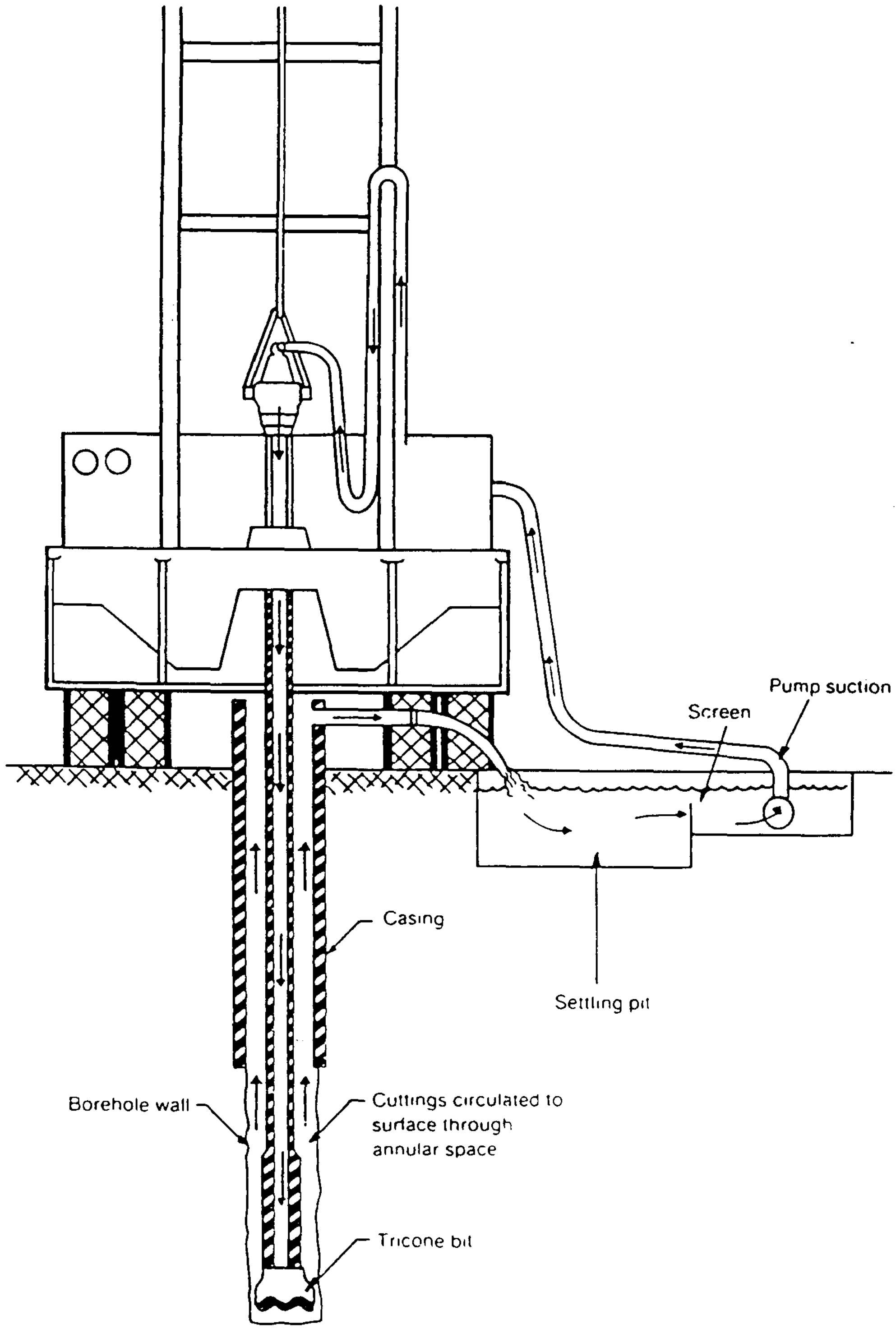

Figure B-4. Diagram of a direct rotary circulation system. (Courtesy of National Ground Water Association)

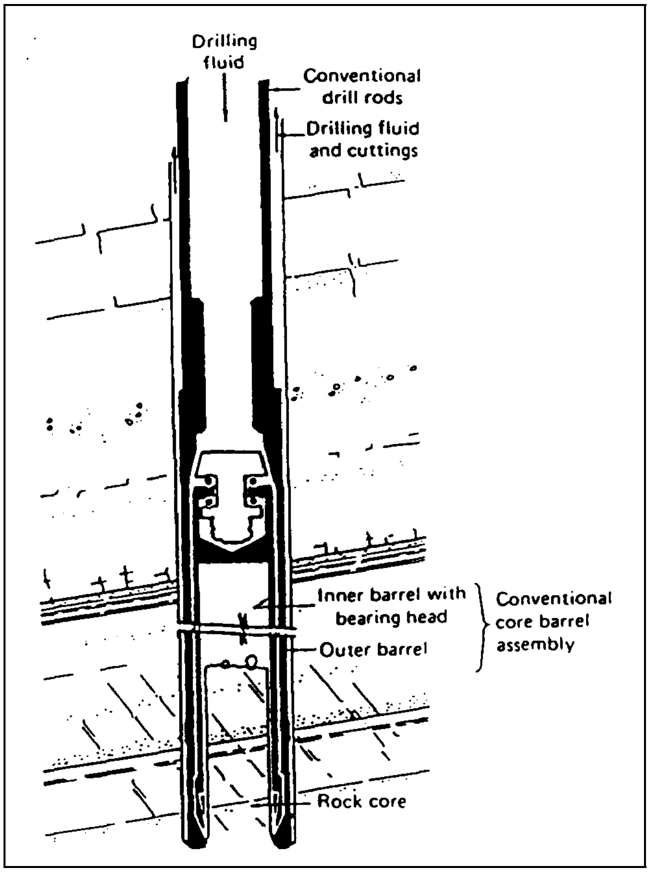

Figure B-5. Conventional core drilling (Dunnicliff 1988)

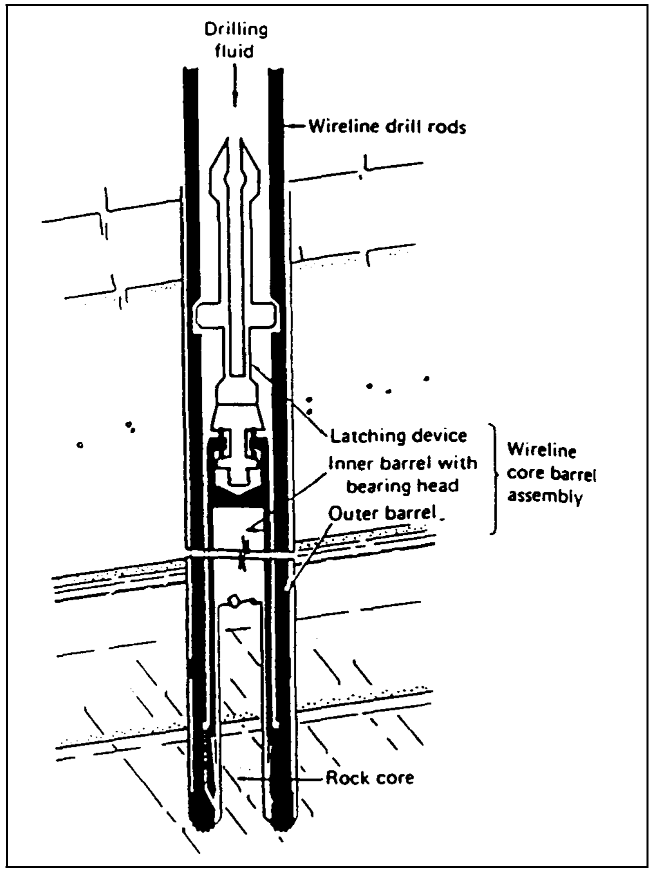

Figure B-6. Wireline core drilling (Dunnicliff, 1988)

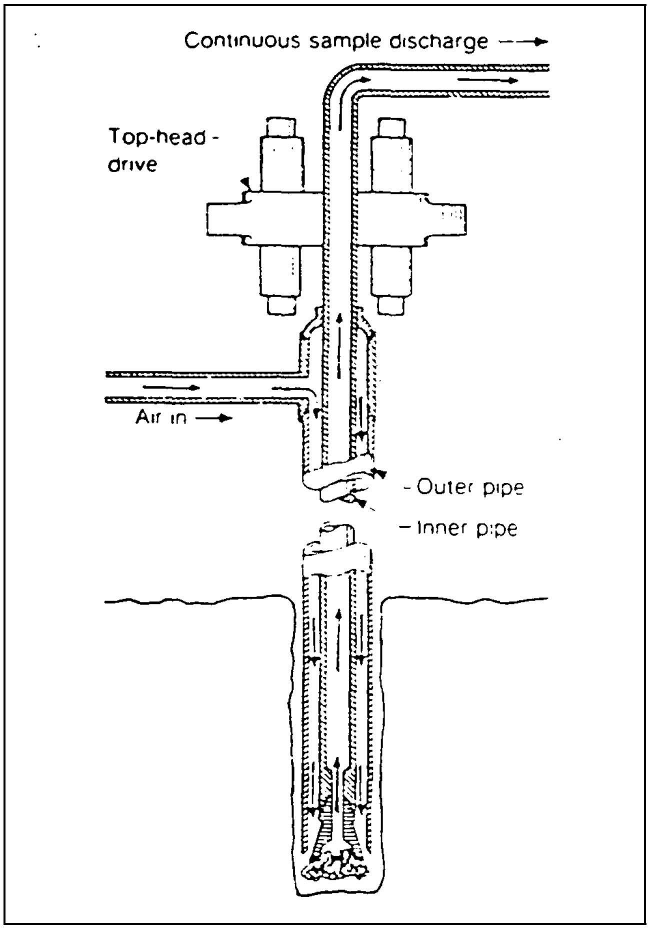

Figure B-7. Diagram of dual-wall reverse-circulation rotary method (Driscoll 1986)

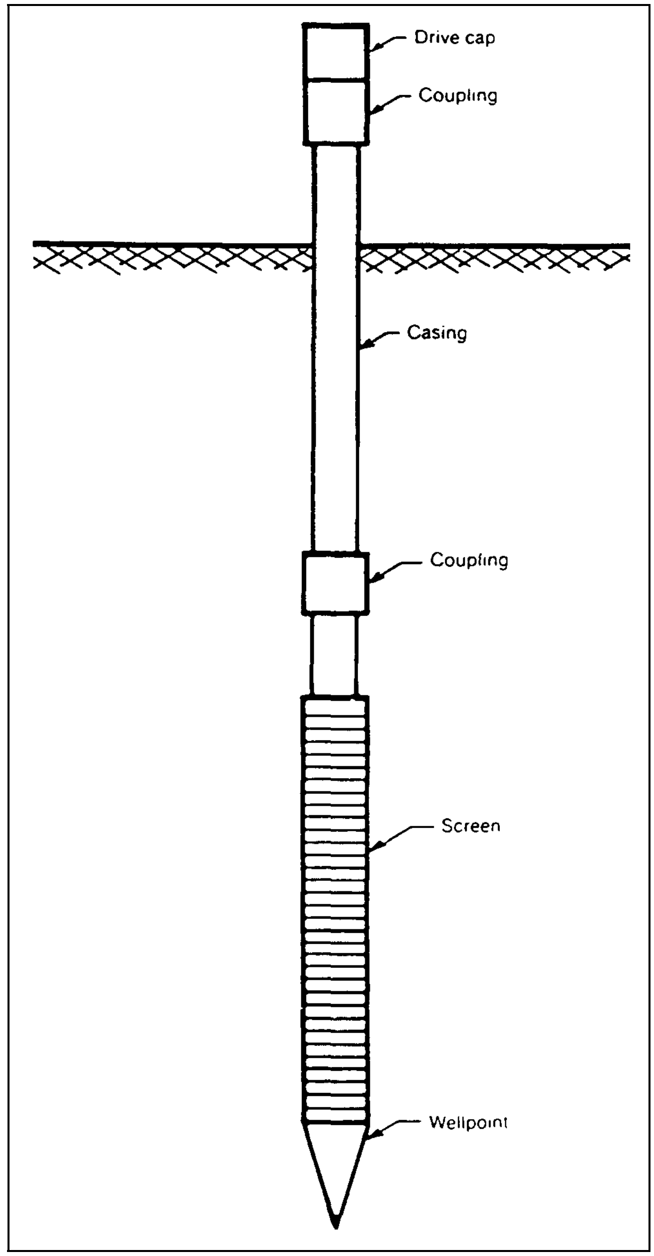

Figure B-8. Diagram of a wellpoint. (Courtesy of National Ground Water Association)

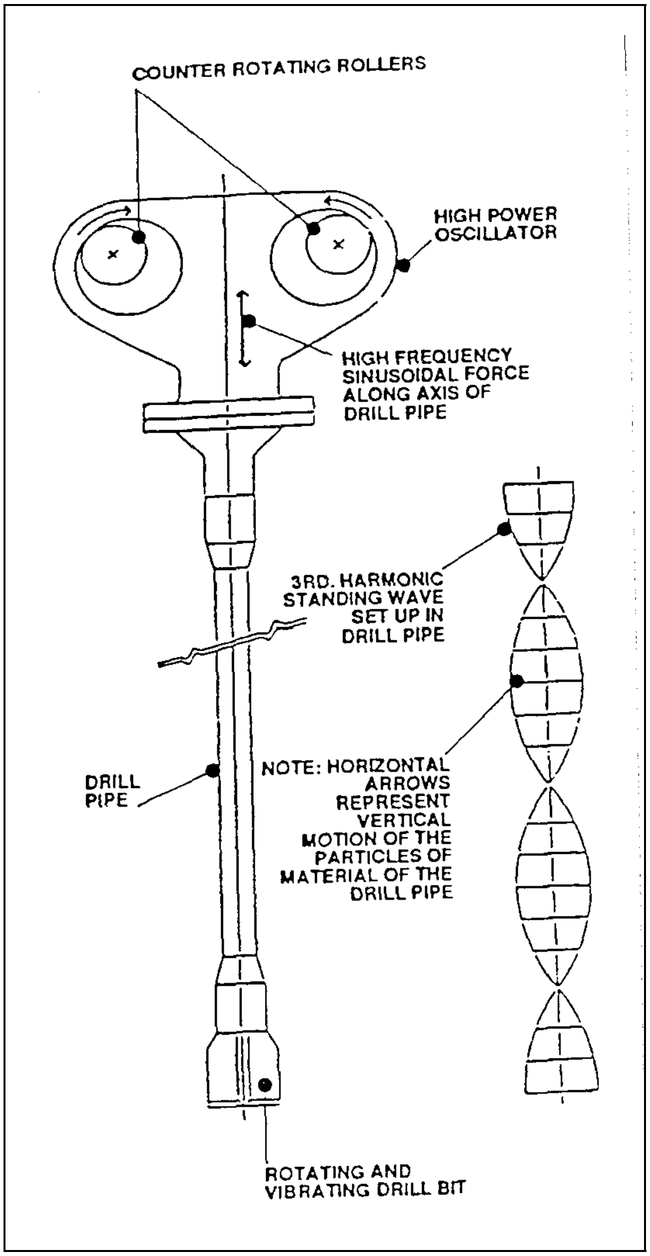

Figure B-9. Sonic drilling. (Courtesy of National Ground Water Association)