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CHAPTER 5

INSTALLATION OF DEWATERING AND GROUNDWATER CONTROL SYSTEMS

5-1. General. The successful performance of any dewatering system requires that it be properly installed. Principal installation features of various types of dewatering or groundwater control systems are presented in the following paragraphs.

5-2. Deep-well systems.

a. Deep wells may be installed by the *reverse-rotary* drilling method, by driving and jetting a casing into the ground and cleaning it with a bailer or jet, or with a bucket auger.

b. In the reverse-rotary method, the hole for the well is made by rotary drilling, using a bit of a size required by the screen diameter and thickness of filter. Soil from the drilling is removed from the hole by the flow of water circulating from the ground surface down the hole and back up the (hollow) drill stem from the bit. The drill water is circulated by a centrifugal or jet-eductor pump that pumps the flow from the drill stem into a sump pit. As the hole is advanced, the soil particles settle out in the sump pit, and the muddy water flows back into the drill hole through a ditch cut from the sump to the hole. The sides of the drill hole are stabilized by seepage forces acting against a thin film of fine-grained soil that forms on the wall of the hole. A sufficient seepage force to stabilize the hole is produced by maintaining the water level in the hole at least 7 feet above the natural water table. No *bentonite drilling mud* should be used because of gelling in the filter and aquifer adjacent to the well. If the hole is drilled in clean sands, some silt soil may need to be added to the drilling water to attain the desired degree of muddiness (approximately 3000 parts per million). (Organic drilling material, e.g., Johnson's Revert or equivalent, may also be added to the drilling water to reduce water loss.) The sump pit should be large enough to allow the sand to settle out but small enough so that the silt is kept in suspension.

c. Holes for deep wells should be vertical so that the screen and riser may be installed straight and plumb; appropriate guides should be used to center and keep the screen plumb and straight in the hole. The hole should be some deeper than the well screen and riser. (The additional depth of the hole is to provide space for wasting filter material first put in the tremie pipe if used.) After the screen is in place. the filter is tremied in. The tremie pipe should be 4 to 5 inches in diameter, be perforated with slots 1/16 to 3/32 inch wide and about 6 inches long, and have flush screw joints. The slots will allow the filter material to become saturated, thereby breaking the surface tension and "bulking" of the filter in the tremie. One or two slots per linear foot of tremie is generally sufficient. After the tremie pipe has been lowered to the bottom of the hole, it should be filled with filter material, and then slowly raised, keeping it full of filter material at all times, until the filter material is 5 to 10 feet above the top of the screen, The filter material initially poured in the tremie should be wasted in the bottom of the hole. The level of drilling fluid or water in a reverse-rotary drilled hole must be maintained at least 7 feet above the natural groundwater level until all the filter material is placed. If a casing is used, it should be pulled as the filter material is placed, keeping the bottom of the casing 2 to 10 feet below the top of the filter material as the filter is placed. A properly designed, uniform ($D_{90}/D_{10} \leq 3$ to 4) filter sand may be placed without tremieing if it is poured in around the screen in a heavy continuous stream to minimize segregation.

d. After the filter is placed, the well should be developed to obtain the maximum yield and efficiency of the well. The purpose of the development is to remove any film of silt from the walls of the drilled hole and to develop the filter immediately adjacent to the screen to permit an easy flow of water into the well. Development of a well should be accomplished as soon after the hole has been drilled as practicable. Delay in doing this may prevent a well being developed to the efficiency assumed in design. A well may be developed by surge pumping or surging it with a loosely fitting surge block that is raised and lowered through the well screen at a speed of about 2 feet per second. The surge block should be slightly flexible and have a diameter 1 to 2 inches smaller than the inside diameter of the well screen. The amount of material deposited in the bottom of the well should be determined after each cycle (about 15 trips per cycle). Surging should continue until the accumulation of material pulled through the well screen in any one cycle becomes less than about 0.2 foot deep. The well screen should be bailed clean if the accumulation of material in the bottom of the screen becomes more than 1 to 2 feet at any time during surging, and recleaned after surging is completed. Material bailed from a well should be inspected to see if any foundation sand is being removed. It is possible to oversurge a well, which may breach the filter with resulting infiltration of foundation sand when the well is pumped.

e. After a well has been developed, it should be pumped to clear it of muddy water and sand and to check it for yield and infiltration. The well should be pumped at approximately the design discharge from 30 minutes to several hours, with periodic measurement of the well flow, drawdown in the well, depth of sand in the bottom of the well, and amount of sand in the discharge. Measurements of well discharge and drawdown may be used to determine the efficiency and degree of development of the well. The performance of the well filter may be evaluated by measuring the accumulation of sand in the bottom of the well and in the discharge. A well should be developed and pumped until the amount of sand infiltration is less than 5 to 10 parts per million.

f. Deep wells, in which a vacuum is to be maintained, require an airtight seal around the well riser pipe from the ground surface down for a distance of 10 to 50 feet. The seal may be made with compacted clay, nonshrinking grout or concrete, bentonitic mud, or a short length of surface casing capped at the top. Improper or careless placement of this seal will make it impossible to attain a sufficient vacuum in the system to cause the dewatering system to operate as designed. The top of the well must also be sealed airtight.

g. After the wells are developed and satisfactorily tested by pumping, the pumps, power unite, and discharge piping may be installed.

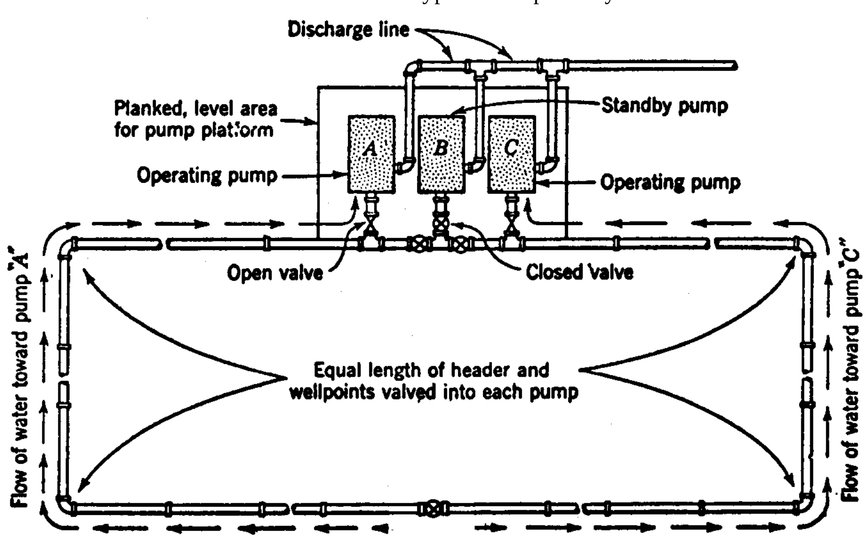
h. Where drawdown or vacuum requirements in deep wells demand that the water level be lowered and maintained near the bottom of the wells, the pumps will have to handle a mixture of water and air. If such a requirement exists, the pump bowls should be designed to allow increasing amounts of air to enter the bowl, which will reduce the efficiency of the pump until the pump capacity just equals the inflow of water, without cavitation of the impellers. The impellers of deep-well turbine pumps should be set according to the manufacturer's recommendations. Improper impeller settings can significantly reduce the performance of a deep-well pump.

5-3. Wellpoint systems.

a. Wellpoint systems are installed by first laying the header at the location and elevation called for by the plans as illustrated in figure 5-1. After the header pipe is laid, the stopcock portion of the swing connection should be connected to the header on the spacing called for by the design, and all fittings and plugs in the header made airtight using a pipe joint compound to prevent leakage. Installation of the wellpoints generally follows layout of the header pipe.

b. Self-jetting wellpoints are installed by jetting them into the ground by forcing water out the tip of the wellpoint under high pressure. The jetting action of a typical self-jetting wellpoint is illustrated in fig-

Plan of a typical wellpoint system.

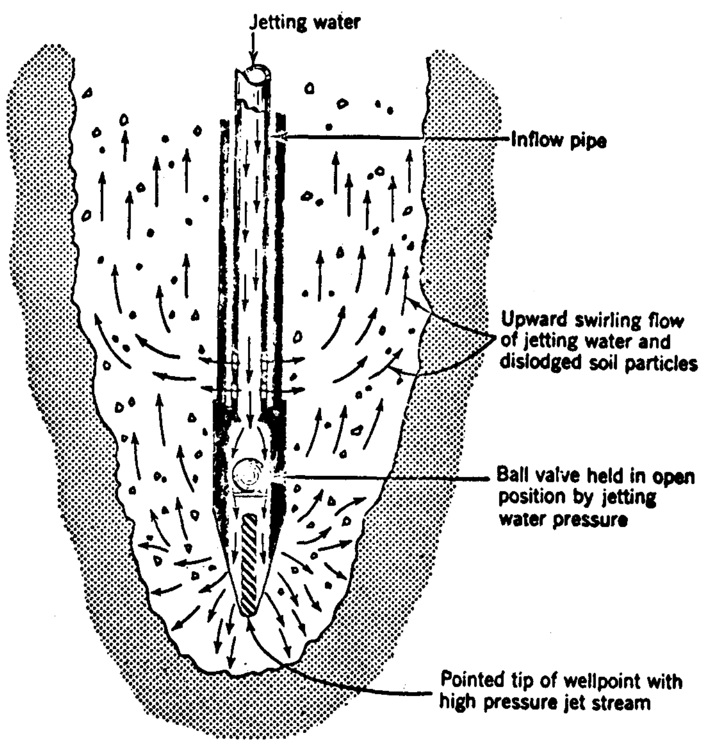


(From "Foundation Engineering," G. A. Leonards, ed., 1962, McGraw-Hill Book Company. Used with permission of McGraw-Hill Book Company.)

Figure 5-1. Plan** of a **typical wellpoint system.

ure 5-2. Self-jetting wellpoints can be installed in medium and fine sand with water pressures of about 50 pounds per square inch. Wellpoints jetted into coarse sand and gravel require considerably more water and higher water pressures (about 125 pounds per square inch) to carry out the heavier particles; either a hydrant or a jetting pump of appropriate size for the pressures and quantities of jetting water required can be used. The jetting hose, usually 2 to 3 inches in diameter, is attached to the wellpoint riser, which is picked up either by a crane or by hand and held in a vertical position as the jet water is turned on. The wellpoint is allowed to sink slowly into the ground and is slowly raised and lowered during sinking to ensure that all fine sand and dirt are washed out of the hole. Care should be taken to ensure that a return of jet water to the surface is maintained; otherwise, the point may "freeze" before it reaches grade. If the return of jet water disappears, the point should be quickly raised until circulation is restored and then slowly relowered. In gravelly soils, it may be necessary to supplement the jet water with a separate air supply at about 125 pounds per square inch to lift the gravel to the surface. If filter sand is required around the wellpoint to increase its efficiency or prevent infiltration of foundation soils, the wellpoints generally should be installed using a hole puncher and a jet casing to form the hole for the wellpoint and filter. When the wellpoint reaches grade and before the water is turned off, the two halves of a swing connection, if used, should be lined up for easy connection when the jet water is turned off and the jetting hose disconnected.

c. Where a wellpoint is to be installed with a filter (i.e. "sanded"), generally the wellpoint should be installed in a hole formed by jetting down a 10- to 12-inch heavy steel casing. The casing may be fitted with a removable cap at the top through which air and water may be introduced. The casing is jetted into the ground with a return of air and water along the outside of the casing. Jetting pressures of 125 pounds per square inch are commonly used; where resistant strata are encountered, the casing may have to be raised and dropped with a crane to chop through and penetrate to the required depth. A casing may also be installed using a combination jetting and driving tool, equipped with both water and air lines, which fits inside the casing and extends to the bottom of the casing. Most of the return water from a 'hole puncher" rises inside the casing, causing considerably less disturbance of the adjacent foundation soils. After the casing is installed to a depth of 1 to 3 feet greater than the length of the as-



(Courtesy of Griffin Wellpoint Corp.)

Figure 5-2. Self-jetting wellpoint.

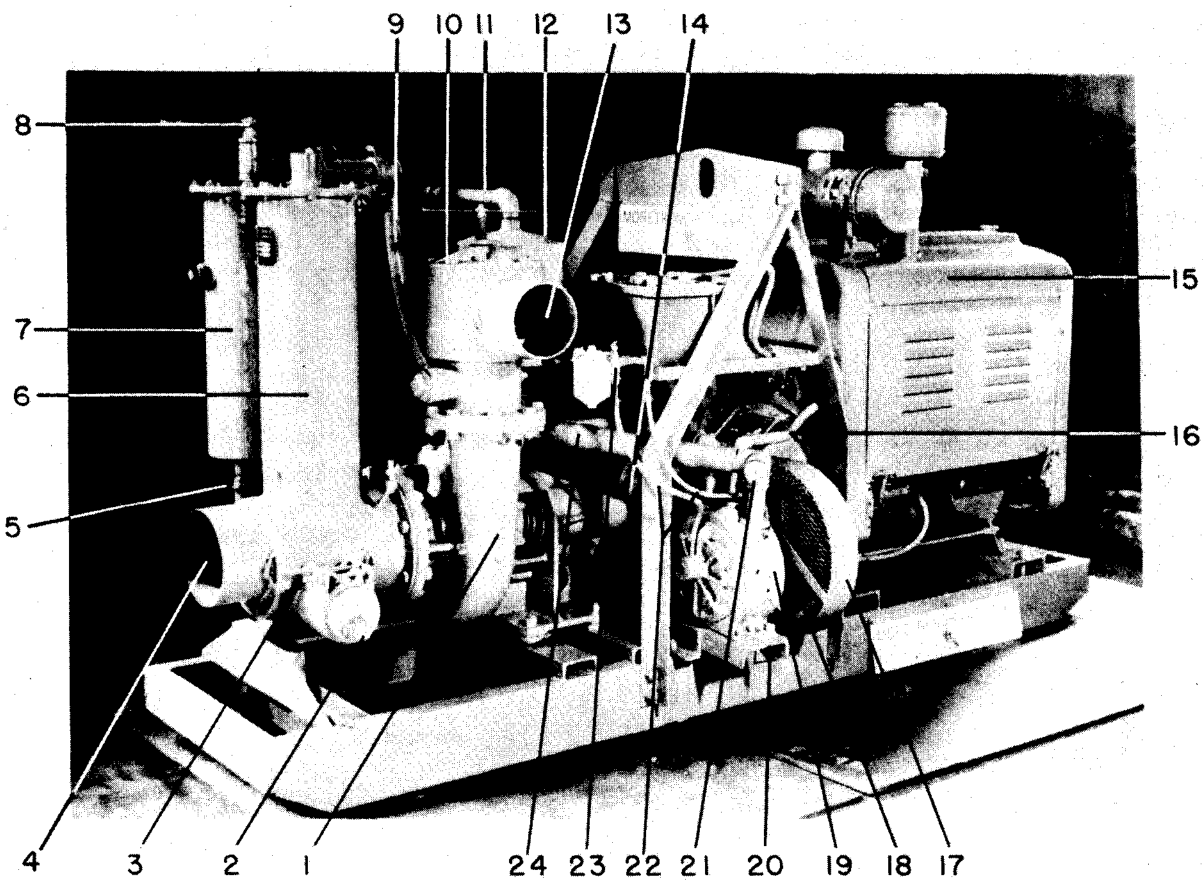
sembled wellpoint, the jet is allowed to run until the casing is flushed clean with clear water.

d. The wellpoint is placed in the casing, the sand filter tremied or poured in, and the casing pulled. Care should be taken to center the wellpoint in the casing so that it is completely surrounded with filter material. Before the wellpoint is connected to the header, it should be pumped to flush it and the filter and to check it for "sanding." All joints connecting wellpoints to the header should be made airtight to obtain the maximum needed vacuum.

e. Wellpoint pumps, similar to that shown in figure 5-3, are used to provide the vacuum and to remove water flowing to the system. To obtain the maximum possible vacuum, the suction intake of the pump should be set level with the header pipe. Wellpoint pumps should be protected from the weather by a shelter and from surface water or sloughing slopes by ditches and dikes. The discharge pipe should be watertight and supported independently of the pump.

f. Vacuum wellpoint systems are installed in the same manner as ordinary wellpoint systems using a jet casing and filter, except the upper 5 feet of the riser is sealed airtight to maintain the vacuum in the filter.

g. Jet-eductor wellpoints are usually installed using a hole puncher and surrounding the wellpoint and riser pipe with filter sand. Jet eductors are connected to two headers-one for pressure to the eductors and



1. Centrifugal Pump Volute
2. Cleanout
3. Screenbox
4. Suction or Header Connection
5. Wiper Float Drain Line
6. Scrubber Float Chamber
7. Wiper Float Chamber
8. Air Vent Valve
9. Air Suction Line Wiper Float Chamber to Vacuum Pump
10. Discharge Check Valve
11. Vacuum Pump Exhaust
12. Oil Reclaimer for Vacuum Pump
13. Discharge Connection
14. Flexible Coupling
15. Engine
16. Cooling Water Line for Vacuum Pump
17. Belt Guard
18. Vacuum Pump Pulley
19. MT71-4 Rotary-Type Vacuum Pump
20. Vacuum Pump Rocker-Type Base
21. Vacuum Pump Exhaust Thermometer
22. Vacuum Pump Oil Supply Lines
23. Oil Dripper/Lubricator for Vacuum Pump

(Courtesy of Moretrench American Corp.)

Figure 5-3. Characteristic parts of a wellpoint pump.

another for return flow from the eductors and the wellpoints back to the recirculation tank and pressure pump.

5-4. Vertical sand drains. Vertical sand drains can be installed by jetting a 12- to 18-inch casing into the soil to be drained; thoroughly flushing the casing with clear water; filling it with clean, properly graded filter sand; and pulling the casing similar to installing "sanded" wellpoints. It is preferable to place the filter sand through a tremie to prevent segregation, which may result in portions of the filter being too coarse to filter fine-grained soils and too fine to permit vertical drainage. Sand drains should penetrate into the underlying pervious aquifer to be drained by means of wells or wellpoints.

5-5. Cutoffs.

a. Cement and chemical grout curtains.

(1) Cement or chemical grouts are injected through pipes installed in the soil or rock. Generally, pervious soil or rock formations are grouted from the top of the formation downward. When this procedure is followed, the hole for the grout pipe is first cored or drilled down to the first depth to be grouted, the grout pipe and packer set, and the first zone grouted. After the grout is allowed to set, the hole is redrilled and advanced for the second stage of grouting, and the above procedure repeated. This process is repeated until the entire depth of the formation has been grouted. No drilling mud should be used in drilling holes for grout pipes because the sides of the hole will be plastered with the mud and little, if any, penetration of grout will be achieved.

(2) Mixing tanks and pump equipment for pressure injection of cement or chemical grouts vary depending upon the materials being handled. Ingredients for a grout mix are loaded into a mixing tank equipped with an agitator and, from there, are pumped to a storage tank also equipped with an agitator. Pumps for grouting with cement are generally duplex, positive displacement, reciprocating pumps similar to slush pumps used in oil fields. Cement grouts are highly abrasive, so the cylinder liners and valves should be of case-hardened steel. Chemical grouts, because of their low viscosity and nonabrasive nature, can be pumped with any type of pump that produces a satisfactory pressure. Grout pump capacities commonly range from 20 to 100 gallons per minute at pressures ranging from 0 to 500 pounds per square inch. The maximum grout pressure used should not exceed about 1 pound per square inch times the depth at which the grout is being injected.

(3) The distribution system for grouting may be either of two types: a single-line system or a recirculating system. Because of segregation that may develop in the pressure supply line from the pump to the grout injection pipe, the line must occasionally be flushed to ensure that the grout being pumped into the formation is homogeneous and has the correct viscosity. The grout in a single-line system is flushed through a blowoff valve onto the ground surface and wasted. A recirculating system has a return line to the grout storage tank so that the grout is constantly being circulated through the supply line, with a tap off to the injection pipe where desired.

(4) Additional information on grouting is contained in TM 5-818-6.

b. Slurry walls.

(1) Slurry cutoff trenches can be dug with a trenching machine, backhoe, dragline, or a clam bucket, typically 2 to 5 feet wide, The walls of the trench are stabilized with a thick bentonitic slurry until the trench can be backfilled. The bentonitic slurry is best mixed at a central plant and delivered to the trench in trucks or pumped from slurry ponds. The trench is carried to full depth by excavation through the slurry, with the trench being maintained full of slurry by the addition of slurry as the trench is deepened and extended.

(2) With the trench open over a limited length and to full depth, cleaning of the slurry is commenced in order to remove gravelly or sandy soil particles that have collected in the slurry, especially near the bottom of the trench. Fair cleanup can be obtained using a clamshell bucket; more thorough cleaning can be obtained by airlifting the slurry to the surface for circulation through desanding units. Cleaning of the slurry makes it less viscous and ensures that the slurry will be displaced by the soil-bentonite backfill. After cleaning the "in-trench" slurry, the trench is generally backfilled with a well-graded mix of sand-clay-gravel and bentonite slurry with a slump of about 4 to 6 inches. The backfill material and slurry may be mixed either along and adjacent to the trench or in a central mixing plant and delivered to the trench in trucks.

(3) The backfill is introduced at the beginning of the trench so as to displace the slurry toward the advancing end of the trench. In the initial stages of backfill, special precautions should be taken to ensure that the backfill reaches the bottom of the trench and that it assumes a proper slope (generally 1V on 5H to 1V on 10H). In order to achieve this slope, the first backfill should be placed by clamshell or allowed to flow down an inclined ramp, dug at the beginning end of the trench. As the surface of the backfill is built up to the top of the trench, digging the trench resumes as shown in figure 5-4. As the backfill is bulldozed into the back of the trench, it flows down the sloped face of the already placed backfill, displacing slurry as it advances. Proper control of the properties of the slurry and back-

fill is required to ensure that the slurry is not trapped within the backfill.

(4) The backfill should be placed continuously as the trench is advanced. By so doing, sloughing of the trench walls will be minimized, and the amount of bentonitic slurry required kept to a minimum. The level of the slurry in the trench should be maintained at least 5 feet above the groundwater table. Care should be taken to control the density and viscosity of the bentonitic slurry as required by the design. To minimize wastage of bentonitic slurry, it may be necessary to screen out sand and gravel in order to reuse the slurry. (Construction techniques are still being developed.)

(5) The toe of the backfill slope should be kept within 50 to 150 feet of the leading edge of the trench to minimize the open length of the slurry-supported trench. During placement operations, excavation and cleaning operations proceed simultaneously ahead of the advancing backfill. (It should be noted that because of the geometric constraints set by the backfill slope, the amount of open trench length supported by slurry is a function of the depth of the trench. For example, if the trench is 100 feet deep and the backfill slope is 1V on 8H, the open length will be about 900 to 950 feet-800 feet along the slope of the backfill face plus 100 to 150 feet from the backfill toe to the leading edge of the trench.)

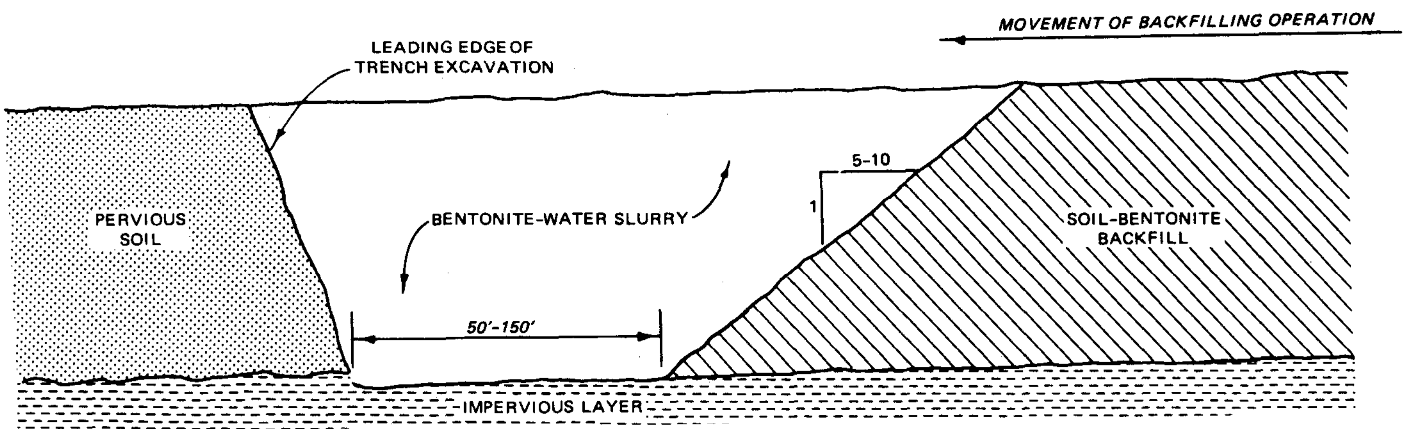
(6) When the trench is complete and the backfill occupies the entire trench, a compacted clay cap is normally placed over the trench. Key steps in this construction sequence involve the mixing of the bentonite-water slurry, excavation and stabilization of the trench, cleaning of the slurry, mixing of the soil-bentonite backfill, displacement of the slurry by the backfill, and treatment of the top of the trench. Each of these items must be covered in the specifications.

c. Steel sheet piling. Steel sheet pile cutoffs are constructed employing the same general techniques as those used for driving steel sheet piles. However, precautions should be taken in handling and driving sheet piling to ensure that the interlocks are tight for the full depth of the piling and that all of the sheets are driven into the underlying impermeable stratum at all locations along the sheet pile cutoff. Methods and techniques for driving steel sheet piling are described in numerous references on this subject.

d. Freezing. Freezing the soil around a shaft or tunnel requires the installation of pipes into the soil and circulating chilled brine through them. These pipes generally consist of a 2-inch inflow pipe placed in a 6-inch closed-end "freezing" pipe installed in the ground by any convenient drilling means. Two headers are required for a freezing installation: one to carry chilled brine from the refrigeration plant and the other to carry the return flow of refrigerant. The refrigeration plant should be of adequate capacity and should include standby or auxiliary equipment to maintain a continuous operation.

5-6. Piezometers.

a. Installation. Piezometers are installed to determine the elevation of the groundwater table (gravity or artesian) for designing and evaluating the performance of a dewatering system. For most dewatering applications, commercial wellpoints or small screens are satisfactory as piezometers. The selection of wellpoint or screen, slot size, need for filter, and method of installation is the same for piezometers as for dewatering wellpoints. Holes for the installation of piezometers can be advanced using continuous flight auger with a hollow stem plugged at the bottom with a removable



U.S. Army Corps of Engineers

Figure 5-4. Installation of a slurry cutoff trench.

plug, augering with more or less simultaneous installation of a casing, or using rotary wash-boring methods. The hole for a piezometer should be kept filled with water or approved drilling fluid at all times. Bentonitic drilling mud should not be used; however, an organic type of drilling fluid, such as Johnson's Revert or equivalent, may be used if necessary to keep the drilled hole open. Any auger used in advancing the hole should be withdrawn slowly from the hole so as to minimize any suction effect caused by its removal. When assembling piezometers, all fittings should be tight and sealed with joint compound so that water levels measured are those actually existing at the location of the wellpoint screen. Where the water table in different pervious formations is to be measured, the riser pipe from the piezometer tip must be sealed from the top of the screen to the ground surface to preserve the isolation of one stratum from another and to obtain the true water level in the stratum in which the piezometer is set. Such piezometers may be sealed by grouting the hole around the riser with a nonshrinking grout of bentonite, cement, and fly ash or other suitable admixture. Proportions of 1 sack of cement and 1 gallon of bentonite to 10 gallons of water have been found to be a suitable grout mix for this purpose. Fly ash can be used to replace part of the cement to reduce heat of hydration, but it does reduce the strength of the grout. The tops of piezometer riser pipes should be threaded and fitted with a vented cap to keep dirt and debris from entering the piezometer and to permit the water level in the piezometer to adjust to any changes in the natural water table.

(1) *Hollow-stem auger method.*

(a) After the hole for the piezometer is advanced to grade, 1 to 2 feet below the piezometer tip, or after the last sample is taken in a hole to receive a piezometer, the hollow-stem auger should be flushed clean with water and the plug reinserted at the bottom of the auger. The auger should then be slowly raised to the elevation that the piezometer tip is to be installed. At this elevation, the hollow stem should be filled with clean water and the plug removed. Water should be added to keep the stem full of water during withdrawal of the plug. The hole should then be sounded to determine whether or not the hollow stem is open to the bottom of the auger. If material has entered the hollow stem of the auger, the hollow stem should be cleaned by flushing with clear water, or fresh Johnson's Revert or equivalent drilling fluid if necessary to stabilize the bottom of the hole, through a bit designed to deflect the flow of water upward, until the discharge is free of soil particles. The piezometer screen and riser should then be lowered to the proper depth inside the hollow stem and the filter sand placed. A wire spider should be attached to the bottom of the piezometer screen to center the piezometer screen in the hole in which it is to be placed.

(b) The filter sand should be poured down the hollow stem around the riser at a rate (to be determined in the field) which will ensure a continuous flow of filter sand that will keep the hole below the auger filled as the auger is withdrawn. Withdrawal of the auger and filling the space around the piezometer tip and riser with filter sand should continue until the hole is filled to a point 2 to 5 feet above the top of the piezometer screen. Above this elevation, the space around the riser pipe may be filled with any clean uniform sand up to the top of the particular sand stratum in which the piezometer is being installed but not closer than 10 feet of the ground surface. An impervious grout seal should then be placed from the top of the sand backfill to the ground surface.

(2) Casing method. The hole for a piezometer may be formed by setting the casing to an elevation 1 to 2 feet deeper than the elevation of the piezometer tip. The casing may be set by a combination of rotary drilling and driving the casing. The casing should be kept filled with water, or organic drilling fluid, if necessary, to keep the bottom of the hole from "blowing." After the casing has been set to grade, it should be flushed with water or fresh drilling fluid until clear of any sand. The piezometer tip and riser pipe should then be installed and a filter sand, conforming to that specified previously, poured in around the riser at a rate (to be determined in the field) which will ensure a continuous flow of filter sand that will keep the space around the riser pipe and below the casing filled as the casing is withdrawn without "sand-locking" the casing and the riser pipe. Placement of the filter sand and withdrawal of the casing may be accomplished in steps as long as the top of the filter sand is maintained above the bottom of the casing but not so much as to "sand-lock" the riser pipe and casing. Filling the space around the piezometer tip and riser with filter and should continue until the hole is filled to a point 2 to 5 feet above the top of the piezometer screen. An impervious grout seal should then be placed from the top of the sand backfill to the ground surface.

(3) Rotary method. The hole for a piezometer may be advanced by the hydraulic rotary method using water or an organic drilling fluid. After the hole has been advanced to a depth of 1 or 2 feet below the piezometer tip elevation, it should be flushed with clear water or clean drilling fluid, and the piezometer, filter sand, sand backfill, and grout placed as specified above for the casing method, except there will be no casing to pull.

b. Development and testing. The piezometer should be flushed with clear water and pumped after installation and then checked to determine if it is functioning properly by filling with water and observing the rate of fall. A lo-foot minimum positive head should be maintained in the piezometer following breakdown of the drilling fluid. After at least 30 minutes have elapsed, the piezometer should be flushed with clear water and pumped. For the piezometer to be considered acceptable, it should pump at a rate of at least 2 gallons per minute, or when the piezometer is filled with water, the water level should fall approximately half the distance to the groundwater table in a time slightly less than the time given below for various types of soil:

Type of Soil in Which Piezometer Screen Is Set	*Period of Observation minutes*	*Approximate Time of 50 Percent Fall minutes*
Sandy silt (>50% silt)	30	30
Silty sand (<50% silt, >12% silt)	10	5
Fine sand	5	1

If the piezometer does not function properly, it will be developed by air surging or pumping with air if necessary to make it perform properly.