Dewatering and Groundwater Control Systems Installation and Operation

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1. INSTALLATION OF DEWATERING AND GROUNDWATER CONTROL SYSTEMS

1.1 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.

1.2 DEEP-WELL SYSTEMS.

1.2.1 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.

1.2.2 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.

1.2.3 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) without tremieing if it is poured in around the screen in a heavy continuous stream to minimize segregation.

1.2.4 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.

1.2.5 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.

1.2.6 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, non-shrinking 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.

1.2.7 AFTER THE WELLS ARE DEVELOPED and satisfactorily tested by pumping, the pumps, power unite, and discharge piping may be installed.

1.2.8 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.

1.3 WELLPOINT SYSTEMS.

1.3.1 WELLPOINT SYSTEMS ARE installed by first laying the header at the location and elevation called for by the plans. 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 usually follows layout of the header pipe.

1.3.2 SELF-JETTING WELLPOINTS are installed by jetting them into the ground by forcing water out the tip of the wellpoint under high pressure. 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.

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

1.3.4 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.

1.3.5 WELLPOINT PUMPS 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.

1.3.6 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.

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

1.4 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.

1.5 CUTOFFS.

1.5.1 CEMENT AND CHEMICAL GROUT CURTAINS.

1.5.1.1 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.

1.5.1.2 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.

1.5.1.3 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.

1.5.2 SLURRY WALLS.

1.5.2.1 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.

1.5.2.2 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.

1.5.2.3 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 1.

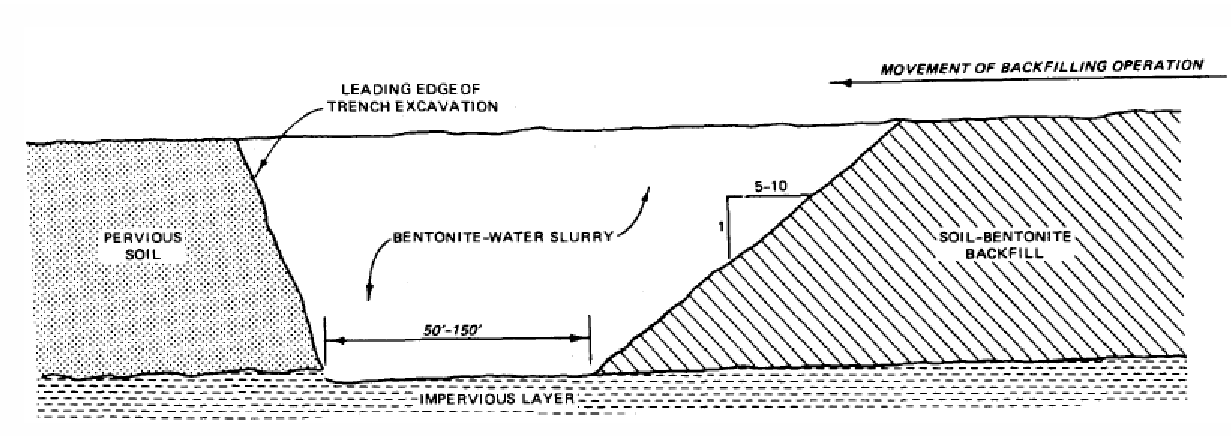

Figure 1

Installation of a slurry cutoff trench.

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

1.5.2.4 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.)

1.5.2.5 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.)

1.5.2.6 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.

1.5.3 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.

1.5.4 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.

1.6 PIEZOMETERS.

1.6.1 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 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 non-shrinking 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.

1.6.1.1 HOLLOW-STEM AUGER METHOD.

1.6.1.1.1 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.

1.6.1.1.2 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.

1.6.1.1.3 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 "sandlock" 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.

1.6.1.1.4 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.

1.6.2 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: 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.

Type of Soil in which Piezometer Screen is Set	Observation Period (Minutes)	Approx. Time of 50% Fall (Minutes)
Sandy Silt (>50% silt)	30	30
Silty Sand (>12% silt, < 50% silt)	10	5
Fine Sand	5	1

2. OPERATION AND PERFORMANCE CONTROL

2.1 GENERAL. The success of a dewatering operation finally hinges on the proper operation, maintenance, and control of the system. If the system is not operated and maintained properly, its effectiveness may soon be lost. After a dewatering or pressure relief system has been installed, a full-scale pumping test should be made and its performance evaluated for adequacy or need for any modification of the system. This test and analysis should include measurement of the initial water table, pump discharge, water table in excavation, water table in wells or vacuum in header system, and a comparison of the data with the original design.

2.2 OPERATION.

2.2.1 WELLPOINT SYSTEMS.

2.2.1.1 THE PROPER PERFORMANCE of a wellpoint system requires continuous maintenance of a steady, high vacuum. After the system is installed, the header line and all joints should be tested for leaks by closing all swing-joint and pump suction valves, filling the header with water under a pressure of 10 to 15 pounds per square inch, and checking the line for leaks. The next step is to start the wellpoint pump with the pump suction valve closed. The vacuum should rise to a steady 25 to 27 inches of mercury. If the vacuum on the pump is less than this height, there must be air leaks or worn parts in the pump itself. If the vacuum at the pump is satisfactory, the gate valve on the suction side of the pump may be opened and the vacuum applied to the header, with the wellpoint swing-joint valves still closed. If the pump creates a steady vacuum of 25 inches or more in the line, the header line may be considered tight. The swing-joint valves are then opened and the vacuum is applied to the wellpoints. If a low, unsteady vacuum develops, leaks may be present in the wellpoint riser pipes, or the water table has been lowered to the screen in some wellpoints so that air is entering the system through one or more wellpoint screens. One method of eliminating air entering the system through the wellpoints is to use a riser pipe 25 feet or more in length. If the soil formation requires the use of a shorter riser pipe, entry of air into the system can be prevented by partially closing the main valve between the pump and the header or by adjusting the valves in the swing connections until air entering the system is stopped. This method is commonly used for controlling air entry and is known as tuning the system; the pump operator should do this daily.

2.2.1.2 A WELLPOINT LEAKING air will frequently cause an audible throbbing or bumping in the swing-joint connection, which may be felt by placing the hand on the swing joint. The throbbing or bumping is caused by intermittent charges of water hitting the elbow at the top of the riser pipe, In warm weather, wellpoints that are functioning properly feel cool and will sweat due to condensation in a humid atmosphere. A wellpoint that is not sweating or that feels warm may be drawing air through the ground, or it may be clogged and not functioning. Likewise, in very cold weather, properly functioning wellpoints will feel warm to the touch of the hand compared with the temperature of the atmosphere, Vacuum wellpoints disconnected from the header pipe can admit air to the aquifer and may affect adjacent wellpoints. Disconnected vacuum wellpoints with riser pipes shorter than 25 feet should be capped.

2.2.1.3 WELLPOINT HEADERS, SWING CONNECTIONS, and riser pipes should be protected from damage by construction equipment. Access roads should cross header lines with bridges over the header to prevent damage to the headers or riser connections and to provide access for tuning and operating the system.

2.2.2 DEEP WELLS. Optimum performance of a deep-well system requires continuous uninterrupted operation of all wells. If the pumps produce excessive drawdowns in the wells, it is preferable to regulate the flow from all of the wells to match the flow to the system, rather than reduce the number of unite operating and thus create an uneven drawdown in the dewatered area. The discharge of the wells may be regulated by varying the pump speed (if other than electric power is used) or by varying the discharge pressure head by means of a gate valve installed in the discharge lines. Uncontrolled discharge of the wells may also produce excessive drawdowns within the well causing undesirable surging and uneven performance of the pumps.

2.2.3 PUMPS. Pumps, motors, and engines should always be operated and maintained in accordance with the manufacturer's directions. All equipment should be maintained in first-class operating condition at all times. Standby pumps and power units in operating conditions should be provided for the system. Standby equipment may be required to operate during breakdown of a pumping unit or during periods of routine maintenance and oil change of the regular dewatering equipment. All standby equipment should be periodically operated to ensure that it is ready to function in event of a breakdown of the regular equipment. Automatic starters, clutches, and valves may be included in the standby system if the dewatering requirements so dictate. Signal lights or warning buzzers may be desirable to indicate, respectively, the operation or breakdown of a pumping unit. If control of the groundwater is critical to safety of the excavation or foundation, appropriate operating personnel should be on duty at all times. Where gravity flow conditions exist that allow the water table to be lowered an appreciable amount below the bottom of the excavation and the recovery of the water table is slow, the system may be pumped only part time, but this procedure is rarely possible or desirable. Such an operating procedure should not be attempted without first carefully observing the rate of rise of the groundwater table at critical locations in the excavations and analyzing the data with regard to existing soil formations and the status of the excavation.

2.2.4 SURFACE WATER CONTROL. Ditches, dikes, sumps, and pumps for the control of surface water and the protection of dewatering pumps should be maintained throughout construction of the project. Maintenance of ditches and sumps is of particular importance. Silting of ditches may cause overtopping of dikes and serious erosion of slopes that may clog the sumps and sump pumps. Failure of sump pumps may result in flooding of the dewatering equipment and complete breakdown of the system. Dikes around the top of an excavation to prevent the entry of surface water should be maintained to their design section and grade at all times. Any breaks in slope protection should be promptly repaired.

2.3 CONTROL AND EVALUATION OF PERFORMANCE. After a dewatering or groundwater control system is installed, it should be pump-tested to check its performance and adequacy. This test should include measurement of initial groundwater or artesian water table, drawdown at critical locations in the excavation, flow from the system, elevation of the water level in the wells or vacuum at various points in the header, and distance to the "effective" source of seepage, if possible. These data should be analyzed, and if conditions at the time of test are different than those for which the system was designed, the data should be extrapolated to water levels and source of seepage assumed in design. It is important to evaluate the system as early as possible to determine its adequacy to meet full design requirements. Testing a dewatering system and monitoring its performance require the *installation of piezometers and the setting up of some means for measuring the flow from the system or wells. Pressure and vacuum gages should also be installed at the pumps and in the header lines. For multistage wellpoint systems, the installation and operation of the first stage of wellpoints may offer an opportunity to check the permeability of the pervious strata, radius of influence or distance to the source of seepage, and the head losses in the wellpoint system. Thus, from observations of the drawdown and discharge of the first stage of wellpoints, the adequacy of the design for lower stages may be checked to a degree.

2.3.1 PIEZOMETERS. The location of piezometers should be selected to produce a complete and reliable picture of the drawdown produced by the dewatering system. Piezometers should be located so they will clearly indicate whether water levels required by specifications are attained at significant locations. The number of piezometers depends on the size and configuration of the excavation and the dewatering system. Normally, three to eight piezometers are installed in large excavations and two or three in smaller excavations. If the pervious strata are stratified and artesian pressure exists beneath the excavation, piezometers should be located in each significant stratum. Piezometers should be installed at the edge of and outside the excavation area to determine the shape of the drawdown curve to the dewatering system and the effective source of seepage to be used in evaluating the adequacy of the system. If recharge of the aquifer near the dewatering system is required to prevent settlement of adjacent structures, control piezometers should be installed in these areas. Where the groundwater is likely to cause incrustation of well screens, piezometers may be installed at the outer edge of the filter and inside the well screen to monitor the head loss through the screen as time progresses. In this way, if a significant increase in head loss is noted, cleaning and reconditioning of the screens should be undertaken to improve the efficiency of the system. Provisions for measuring the drawdown in the wells or at the line of wellpoints are desirable from both an operation and evaluation standpoint.

2.3.2 FLOW MEASUREMENTS. Measurement of flow from a dewatering system is desirable to evaluate the performance of the system relative to design predictions. Flow measurements are also useful in recognizing any loss in efficiency of the system due to incrustation or clogging of the wellpoints or well screens.

2.4 OPERATIONAL RECORDS. Piezometers located within the excavated area should be observed at least once a day, or more frequently, if the situation demands, to ensure that the required drawdown is being maintained. Vacuum and gages (revolutions per minute) on pumps and engines should be checked at least every few hours by the operator as he makes his rounds. Piezometers located outside the excavated area, and discharge of the system, may be observed less frequently after the initial pumping test of the completed system is concluded. Piezometer readings, flow measurements, stages of nearby streams or the elevation of the surrounding groundwater, and the number of wells or wellpoints operating should be recorded and plotted throughout the operation of the dewatering system. The data on the performance of the dewatering system should be continually evaluated to detect any irregular functioning or loss of efficiency of the dewatering system before the construction operations are impeded, or the excavation or foundation is damaged.

3. CONTRACT SPECIFICATIONS

3.1 GENERAL. Good specifications are essential to ensure adequate dewatering and groundwater control. Specifications must be clear, concise, and complete with respect to the desired results, special conditions, inspection and control, payment, and responsibility. The extent to which specifications should specify procedures and methods is largely dependent upon the complexity and magnitude of the dewatering problem, criticality of the dewatering with respect to schedule and damage to the work, and the experience of the probable bidders. Regardless of the type of specification selected, the dewatering system(s) should be designed, installed, operated, and monitored in accordance with the principles and criteria set forth in this discussion.

3.2 TYPES OF SPECIFICATIONS.

3.2.1 TYPE A. Where dewatering of an excavation does not involve unusual or complex features and failure or inadequacy of the system would not adversely affect the safety of personnel, the schedule, performance of the work, foundation for the structure, or the completed work, the specifications should be one of the following types:

3.2.1.1 TYPE A-1. .A brief specification that requires the Contractor to assume full responsibility for design, installation, operation, and maintenance of an adequate system. (This type should not be used unless the Owner has considerable confidence in the Contractor's dewatering qualifications and has the time and capability to check the Contractor's proposal and work.)

3.2.1.2 TYPE A-2. A specification that is more detailed than type A-1 but still requires the Contractor to assume the responsibility for design, installation, operation, and maintenance. (This type conveys more information regarding requirements of design and construction than type A- 1 while retaining the limitations described in above.)

3.2.2 TYPE B. Where dewatering or relief of artesian pressure is complex and of a considerable magnitude and is critical with respect to schedule and damage to the work, the specifications should be of one of the following types:

3.2.2.1 TYPE B-1. A specification that sets forth in detail the design and installation of a "minimum" systern that will ensure a basically adequate degree of watering and pressure relief but still makes the Contractor fully responsible for obtaining the required dewatering and pressure relief as proven by a full-scale pumping test(s) on the system prior to start of excavation, and for all maintenance, repairs, and operations.

3.2.2.2 TYPE B-2. A specification that sets forth in detail the design and installation of a system that has been designed to achieve the desired control of groundwater wherein the Owner assumes full responsibility for its initial performance, based on a full-scale pumping test(s), but makes the Contractor responsible for maintenance and operation except for major repairs required over and beyond those appropriate to normal maintenance. (This type of specification eliminates claims and contingencies commonly added to bid prices for dewatering and also ensures that the Owner gets a dewatering system that it has paid for and a properly dewatered excavation if the system has been designed and its installation supervised by qualified and experienced personnel.)

3.2.2.3 TYPE B-3. A specification that sets forth the desired results making the Contractor solely responsible for design, equipment, installation procedures, maintenance, and performance, but requires that the Contractor employ or subcontract the dewatering and groundwater control to a recognized company with at least 5 years, and preferably 10 years, of experience in the management, design, installation, and operation of dewatering systems of equal complexity. The specification should also state that the system(s) must be designed by a registered professional engineer recognized as an expert in dewatering with a minimum of 5 to 10 years of responsible experience in the design and installation of dewatering systems. This type of specification should further require submittal of a brief but comprehensive report for review and approval including:

3.2.2.3.1 A DESCRIPTION AND PROFILE of the geology, soil, and groundwater conditions and characteristics at the site.

3.2.2.3.2 DESIGN VALUES, ANALYSES, and calculations.

3.2.2.3.3 DRAWINGS OF THE COMPLETE dewatering system(s) including a plan drawing, appropriate sections, pump and pipe capacities and sizes, power system(s), standby power and pumps, grades, filter gradation, surface water control, valving, and disposal of water.

3.2.2.3.4 A DESCRIPTION OF INSTALLATION and operational procedures.

3.2.2.3.5 A LAYOUT OF PIEZOMETERS and flow measuring devices for monitoring performance of the system(s).

3.2.2.3.6 A PLAN AND SCHEDULE for monitoring performance of the system(s).

3.2.2.3.7 A STATEMENT that the dewatering system(s) has been designed in accordance with the principles and criteria set forth in this manual.

3.2.2.3.8 THE SEAL OF THE DESIGNER. (This type of specification should not be used unless the Owner has or employs someone competent to evaluate the report and design submitted, and is prepared to insist on compliance with the above.)

3.3 DATA TO BE INCLUDED IN SPECIFICATIONS. All data obtained from field investigations relating to dewatering or control of groundwater made at the site of the project should be included with the specifications and drawings or appended thereto. These data should include logs of borings; soil profiles; results of laboratory tests including mechanical analyses, water content of silts and clays, and any chemical analyses of the groundwater; pumping tests; groundwater levels in each aquifer, if more than one, as measured by properly installed and tested piezometers, and its variation with the season or with river stages; and river stages and tides for previous years if available. Borings should not only be made in the immediate vicinity of the excavation, but some borings should be made on lines out to the source of groundwater flow or to the estimated “effective” radius of influence. Sufficient borings should be made to a depth that will delineate the full thickness of any substrata that would have a bearing on the control of groundwater or unbalanced uplift pressures. It is essential that all field or laboratory test data be included with the specifications, or referenced, and that the data be accurate. The availability, adequacy, and reliability of electric power, if known, should be included in the contract documents. The same is true for the disposal of water to be pumped from the dewatering systems. The location and ownership of water wells off the project site that might be effected by lowering the groundwater level should be shown on one of the contract drawings.

3.4 DEWATERING REQUIREMENTS AND SPECIFICATIONS. The section of the specifications relating to dewatering and the control of groundwater should be prepared by a geotechnical engineer experienced in dewatering and in the writing of specifications, in cooperation with the civil designer for the project. The dewatering specifications may be rather general or quite detailed depending upon the type of specification to be issued.

3.4.1 TYPE A SPECIFICATIONS.

3.4.1.1 IF THE SPECIFICATION IS to be of Types A-1 and A-2, the desired results should explicitly specify the level to which the groundwater and/or piezometric surface should be lowered; give recommended factors of safety; require that all permanent work be accomplished in the dry and on a stable subgrade; and advise the Contractor that he is responsible for designing, providing, installing, operating, monitoring, and removing the dewatering system by a plan approved by the Owner or the Engineer. This type of specification should note the limitations of groundwater information furnished since seepage conditions may exist that were not discovered during the field exploration program. It should be made clear that the Contractor is not relieved of responsibility of controlling and disposing of all water, even though the discharge of the dewatering system required to maintain satisfactory conditions in the excavation may be in excess of that indicated by tests or analyses performed by the Owner. This type of specification should not only specify the desired results but also require that the Contractor provide adequate methods for obtaining them by means of pumping from wells, wellpoint systems, cutoffs, grouting, freezing, or any other measures necessary for particular site conditions. The method of payment should also be clearly specified.

3.4.1.2 PRIOR TO THE START OF EXCAVATION the Contractor should be required to submit for review a proposed method for dewatering the excavation, disposing of the water, and removing the system, as well as a list of the equipment to be used, including standby equipment for emergency use. (This plan should be detailed and adapted to site conditions and should provide for around-the-clock dewatering operation.)

3.4.1.3 PERIMETER AND DIVERSION DITCHES and dikes should be required and maintained as necessary to prevent surface water from entering any excavation. The specifications should also provide for controlling the surface water that falls or flows into the excavation by adequate pumps and sumps. Seepage of any water from excavated slopes should be controlled to prevent sloughing, and ponding of water in the excavation should be prevented during construction operations. Any water encountered in an excavation for a shaft or tunnel shall be controlled, before advancing the excavation, to prevent sloughing of the walls or ‘boils" in the bottom of the excavation or blow-in of the tunnel face. If the flow of water into an excavation becomes excessive and cannot be controlled by the dewatering system that the Contractor has installed, excavation should be halted until satisfactory remedial measures have been taken. Dewatering of excavations for shafts, tunnels, and lagged open excavations should continue for the duration of the work to be performed in the excavations unless the tunnel or shaft has been securely lined and is safe from hydrostatic pressure and seepage.

3.4.1.4 THE SPECIFICATIONS should also require that the Contractor's plan provide for testing the adequacy of the system prior to start of excavation and for monitoring the performance of the system by installing piezometers and means for measuring the discharge from the system.

3.4.2 TYPE B SPECIFICATIONS.

3.4.2.1 TYPES B-1 AND B-2 SPECIFICATIONS should set forth not only the required results for dewatering, pressure relief, and surface water control, but also a detailed list of the materials, equipment, and procedures that are to be used in achieving the desired system(s). The degree of responsibility of the Contractor for dewatering should be clearly set forth for specification types B-1 and B-2. With either type of specification, the Contractor should be advised that he or she is responsible for operating and maintaining the system(s) in accordance with the manufacturer's recommendation relating to equipment and in accordance with good construction practice. The Contractor should also be advised that he or she is responsible for correcting any unanticipated seepage or pressure conditions and taking appropriate measures to control such, payment for which would depend upon the type of specification and terms of payment.

3.4.2.2 TYPE B-3 SPECIFICATIONS should include the basic requirements set forth above for types A-1 and A-2 specifications plus the additional requirements.

3.5 MEASUREMENT AND PAYMENT.

3.5.1 PAYMENT WHEN USING types A-1 and A-2 specifications is generally best handled by a 'lump sum" payment.

3.5.2 PAYMENT WHEN USING type B- 1 specifications may be based on a lump sum type, or unit prices may be set up for specific items that have been predesigned and specified with lump sum payment for operational and maintenance costs.

3.5.3 PAYMENT WHEN USING type B-2 specifications is generally on the basis of various unit prices of such items as wells, pumps, and piping, in keeping with normal payment practices for specified work. Operation for maintenance and repairs generally should be set up as a lump sum payment with partial payment in accordance with commonly accepted percentages of work completed.

3.5.4 PAYMENT WHEN USING type B-3 specifications would generally be based on a lump sum type of payment.

3.5.5 PAYMENT FOR MONITORING PIEZOMETERS and flow measuring devices is generally made in keeping with the method of payment for the various types of dewatering specifications described above.