CHAPTER 2

METHODS FOR DEWATERING, PRESSURE RELIEF, AND SEEPAGE CUTOFF

2-1. General.

a. Tempomry dewatering systems. Dewatering and control of groundwater during construction may be accomplished by one or a combination of methods described in the following paragraphs. The applicability of different methods to various types of excavations, groundwater lowering, and soil conditions is also discussed in these paragraphs. Analysis and design of dewatering pressure relief and groundwater control systems are described in chapter 4.

b. Permanent dminuge systems. The principles and methods of groundwater control for permanent structures are similar to those to be described for construction projects. A method often used for permanent groundwater control consists of relief wells (to be discussed subsequently in detail) installed beneath and adjacent to the structure, with drainage blankets beneath and surrounding the structure at locations below the water table as shown previously in figure 1-2. The water entering the wells and drainage blanket is carried through collector pipes to sumps, pits, or manholes, from which it is pumped or drained. Permanent groundwater control may include a combination of wells, cutoffs, and vertical sand drains. Additional information on the design of permanent drainage systems for buildings may be found in TM 5-818-1/AFM 88-3, Chapter 7; TM 5-818-4/AFM 88-5, Chapter 5; and TM 5-818-6/AFM 88-32. (See app. A for references.)

2-2. Types and source of seepage.

a. Types of seepage flow. Types of seepage flow are tabulated below:

Type of flow	*Flow characteristics*
Artesian	Seepage through the previous aquifer is confined between two or more impervious strata, and the piezometric head within the previous aquifer is above the top of the pervious aquifer (fig. 1-2).
Gravity	The surface of the water table is below the top of the pervious aquifer (fig. 1-2).

For some soil configurations and drawdowns, the flow may be artesian in some areas and gravity in other areas, such as near wells or sumps where drawdown occurs. The type of seepage flow to a dewatering system can be determined from a study of the groundwater table and soil formations in the area and the drawdown required to dewater the excavation.

b. Source of seepage flow. The source and distance L* to the source of seepage or radius of influence R must be estimated or determined prior to designing or evaluating a dewatering or drainage system.

(1) The source of seepage depends on the geological features of the area, the existence of adjacent streams or bodies of water, the perviousness of the sand formation, recharge, amount of drawdown, and duration of pumping. The source of seepage may be a nearby stream or lake, the aquifer being drained, or both an adjacent body of water and storage in the aquifer.

(2) Where the site is not adjacent to a river or lake, the source of seepage will be from storage in the formation being drained and recharged from rainfall over the area. Where this condition exists, flow to the area being dewatered can be computed on the assumption that the source of seepage is circular and at a distance R. The radius of influence R is defined as the radius of the circle beyond which pumping of a dewatering system has no significant effect on the original groundwater level or piezometric surface (see para 4-2*a*(3)).

(3) Where an excavation is located close to a river or shoreline in contact with the aquifer to be dewatered, the distance to the effective source of seepage L, if less than R/2, may be considered as being approximately the near bank of the river; if the distance to the riverbank or shoreline is equal to about R/2, or greater, the source of seepage can be considered a circle with a radius somewhat less than R.

(4) Where a line or two parallel lines of wells are installed in an area not close to a river, the source of seepage may be considered as a line paralleling the line of wells.

2-3. Sumps and ditches.

a. Open excavations, An elementary dewatering procedure involves installation of ditches, French drains, and sumps within an excavation, from which water entering the excavation can be pumped (fig. 2-1). This method of dewatering generally should not

*For convenience, symbols and unusual abbreviations are listed in the Notation (app B).

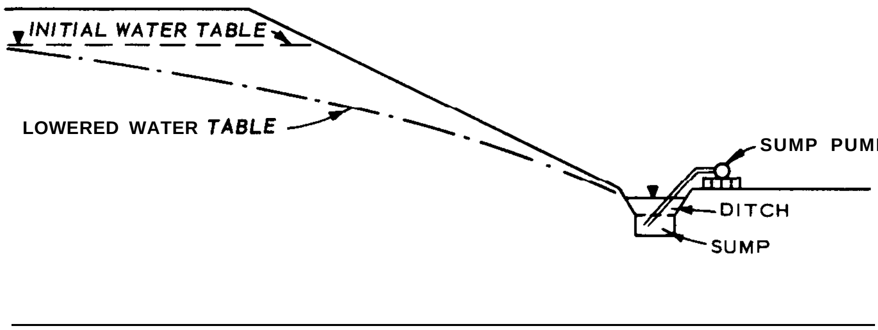

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Figure 2-1. Dewatering open excavation by ditch and sump.

be considered where the groundwater head must be lowered more than a few feet, as seepage into the excavation may impair the stability of excavation slopes or have a detrimental effect on the integrity of the foundation soils. Filter blankets or drains may be included in a sump and ditch system to overcome minor raveling and facilitate collection of seepage. Disadvantages of a sump dewatering system are slowness in drainage of the slopes; potentially wet conditions during excavation and backfilling, which may impede construction and adversely affect the subgrade soil; space required in the bottom of the excavation for drains, ditches, sumps, and pumps; and the frequent lack of workmen who are skilled in the proper construction or operation of sumps.

b. Cofferdams. A common method of excavating below the groundwater table in confined areas is to drive wood or steel sheet piling below subgrade elevation, install bracing, excavate the earth, and pump out any seepage that enters the cofferdammed area.

(1) Dewatering a sheeted excavation with sumps and ditches is subject to the same limitations and serious disadvantages as for open excavations. However, the danger of hydraulic heave in the bottom of an excavation in sand may be reduced where the sheeting can be driven into an underlying impermeable stratum, thereby reducing the seepage into the bottom of the excavation.

(2) Excavations below the water table can sometimes be successfully made using sheeting and sump pumping, However, the sheeting and bracing must be designed for hydrostatic pressures and reduced toe support caused by upward seepage forces. Covering the bottom of the excavation with an inverted sand and gravel filter blanket will facilitate construction and pumping out seepage water.

2-4. **Wellpoint systems.** Wellpoint systems are a commonly used dewatering method as they are applicable to a wide range of excavations and groundwater conditions.

a. *Conventional wellpoint systems.* A conventional wellpoint system consists of one or more stages of wellpoints having 1% or 2-inch-diameter riser pipes, installed in a line or ring at spacings between about 3 and 10 feet, with the risers connected to a common header pumped with one or more wellpoint pumps. Wellpoints are small well screens composed of either brass or stainless steel mesh, slotted brass or plastic pipe, or trapezoidal-shaped wire wrapped on rods to form a screen. They generally range in size from 2 to 4 inches in diameter and 2 to 5 feet in length and are constructed with either closed ends or self-jetting tips as shown in figure 2-2. They may or may not be surrounded with a filter depending upon the type of soil drained. Wellpoint screens and riser pipes may be as large as 6 inches and as long as 25 feet in certain situations. A wellpoint pump uses a combined vacuum and a centrifugal pump connected to the header to produce a vacuum in the system and to pump out the water that drains to the wellpoints. One or more supplementary vacuum pumps may be added to the main pumps where additional air handling capacity is required or desirable. Generally, a stage of wellpoints (wellpoints connected to a header at a common elevation) is capable of lowering the groundwater table about 15 feet; lowering the groundwater more than 15 feet generally requires a multistage installation of wellpoints as shown in figures 2-3 and 2-4. A wellpoint system is usually the most practical method for dewatering where the site is accessible and where the excavation and water-bearing strata to be drained are not too deep. For large or deep excavations where the depth of excavation is more than 30 or 40 feet, or where artesian pressure in a deep aquifer must be reduced, it may be more practical to use eductor-type wellpoints or deep wells (discussed subsequently) with turbine or submersible pumps, using wellpoints as a

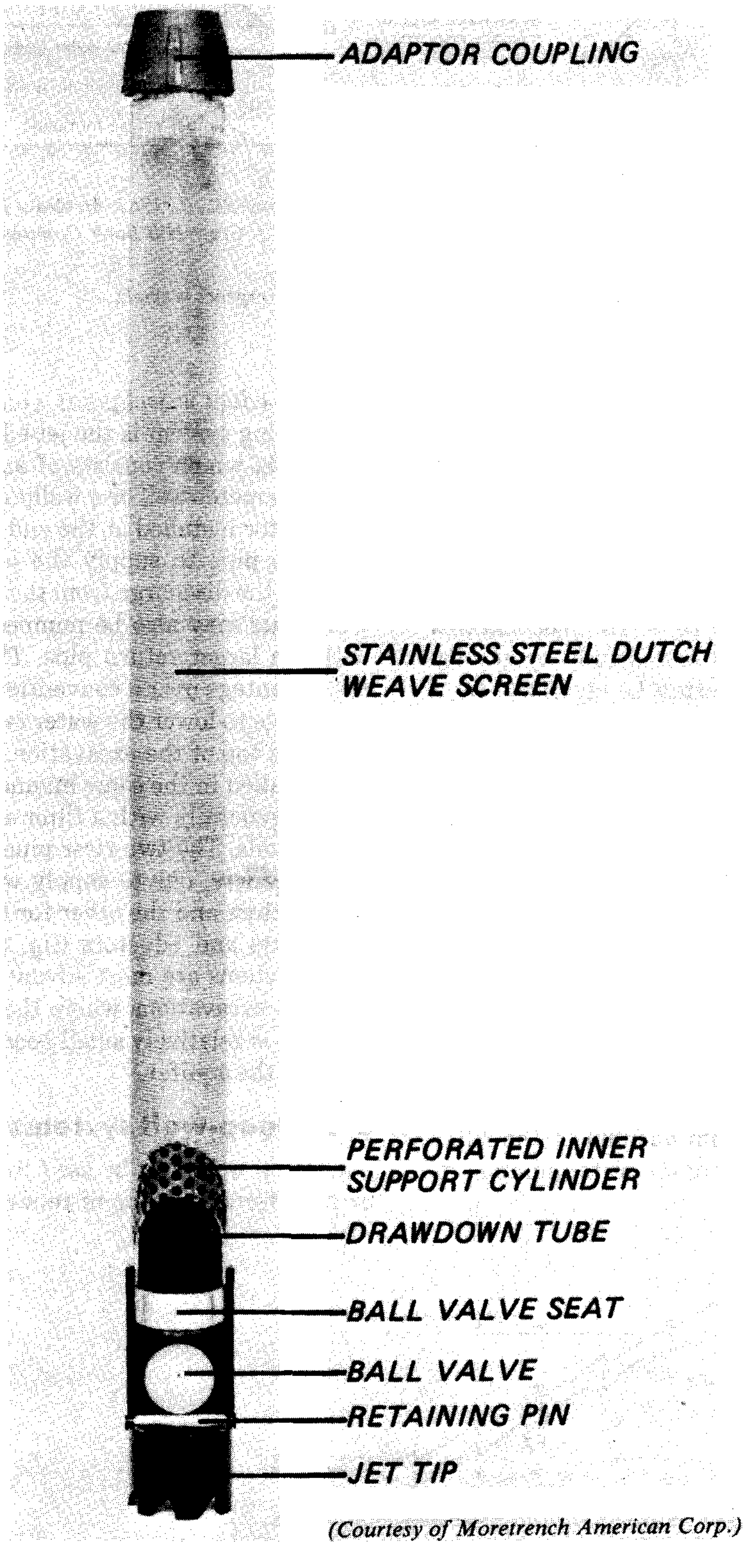

Figure 2-2. Self-jetting wellpoint.

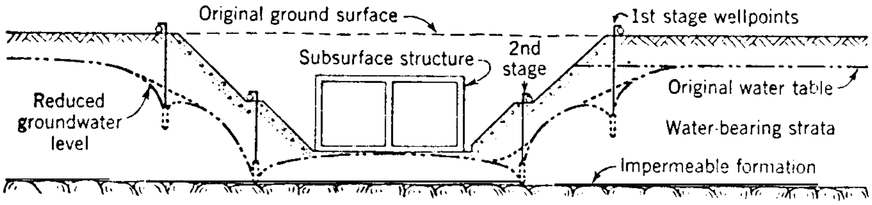

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Figure 2-3. Use of wellpoints where submergence is small

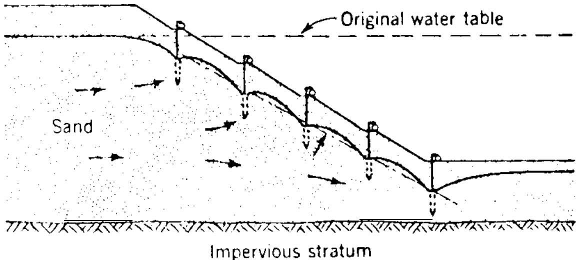
supplementary method of dewatering if needed. Wellpoints are more suitable than deep wells where the submergence available for the well screens is small (fig. 2-3) and close spacing is required to intercept seepage.

b. Vacuum wellpoint systems. Silts and sandy silts ($D_{10} \leq 0.05$ millimetre) with a low coefficient of permeability ($k = 0.1 \times 10^{-4}$ to 10×10^{-4} centimetres per second) cannot be drained successfully by gravity methods, but such soils can often be stabilized by a vacuum wellpoint system. A vacuum wellpoint system is essentially a conventional well system in which a partial vacuum is maintained in the sand filter around the wellpoint and riser pipe (fig 2-5). This vacuum will increase the hydraulic gradient producing flow to the wellpoints and will improve drainage and stabilization of the surrounding soil. For a wellpoint system, the net vacuum at the wellpoint and in the filter is the vacuum in the header pipe minus the lift or length of the riser pipe. Therefore, relatively little vacuum effect can be obtained with a wellpoint system if the lift is more than about 15 feet. If there is much air loss, it may be necessary to provide additional vacuum pumps to ensure maintaining the maximum vacuum in the filter column. The required capacity of the water pump is, of course, small,

c. Jet-eductor wellpoint systems. Another type of dewatering system is the jet-eductor wellpoint system (fig. 2-6), which consists of an eductor installed in a small diameter well or a wellpoint screen attached to a jet-eductor installed at the end of double riser pipes, a pressure pipe to supply the jet-eductor and another pipe for the discharge from the eductor pump. Eductor wellpoints may also be pumped with a pressure pipe within a larger return pipe. This type of system has the advantage over a conventional wellpoint system of being able to lower the water table as much as 100 feet from the top of the excavation. Jet-eductor wellpoints are installed in the same manner as conventional wellpoints, generally with a filter as required by the foundation soils. The two riser pipes are connected to separate headers, one to supply water under pressure to the eductors and the other for return of flow from the wellpoints and eductors (fig. 2-6). Jet-eductor wellpoint systems are most advantageously used to dewater deep excavations where the volume of water to be pumped is relatively small because of the low permeability of the aquifer.

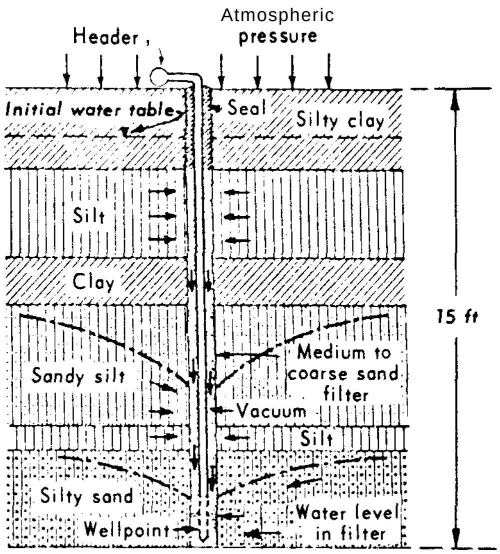
2-5. Deep-well systems.

a. Deep wells can be used to dewater pervious sand or rock formations or to relieve artesian pressure be-



(From "Soils Mechanics in Engineering Practice," by K. Terzaghi and R. B. Peck, 1948, Wiley & Sons, Inc. Used with permission of Wiley & Sons, Inc.)

Figure 2-4. Drainage of an open deep cut by means of a multistage wellpoint system.



Note: Vacuum in header = 25 ft; vacuum in filter and soil in vicinity of well point = approximately 10 ft.

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Figure 2-5. Vacuum wellpoin t system,

neath an excavation. They are particularly suited for dewatering large excavations requiring high rates of pumping, and for dewatering deep excavations for dams, tunnels, locks, powerhouses, and shafts. Excavations and shafts as deep as 300 feet can be dewatered by pumping from deep wells with turbine or submersible pumps. The principal advantages of deep wells are that they can be installed around the periphery of an excavation and thus leave the construction area unemcumbered by dewatering equipment, as shown in figure 2-7, and the excavation can be predrained for its full depth.

b. Deep wells for dewatering are similar in type and construction to commercial water wells. They commonly have a screen with a diameter of 6 to 24 inches with lengths up to 300 feet and are generally installed with a filter around the screen to prevent the infiltration of foundation materials into the well and to improve the yield of the well,

c. Deep wells may be used in conjunction with a vacuum system to dewater small, deep excavations for tunnels, shafts, or caissons sunk in relatively fine-grained or stratified pervious soils or rock below the groundwater table. The addition of a vacuum to the well screen and filter will increase the hydraulic gradient to the well and will create a vacuum within the surrounding soil that will prevent or minimize seepage from perched water into the excavation. Installations of this type, as shown in figure 2-8, require dequate vacuum capacity to ensure efficient operations of the system.

2-6. Vertical sand drains. Where a stratified semipervious stratum with a low vertical permeability overlies a pervious stratum and the groundwater table has to be lowered in both strata, the water table in the upper stratum can be lowered by means of sand drains as shown in figures 2-9. If properly designed and installed, sand drains will intercept seepage in the upper stratum and conduct it into the lower, more permeable stratum being dewatered with wells or wellpoints. Sand drains consist of a column of pervious sand placed in a cased hole, either driven or drilled through the soil, with the casing subsequently removed. The capacity of sand drains can be significantly increased by installation of a slotted 1% or 2-inch pipe inside the sand drain to conduct the water down to the more pervious stratum.

2-7. Electro-osmosis. Some soils, such as silts, clayey silts, and clayey silty sands, at times cannot be dewatered by pumping from wellpoints or wells. However, such soils can be drained by wells or wellpoints combined with a flow of direct electric current through the soil toward the wells. Creation of a hydraulic gradient by pumping from the wells or wellpoints with the passage of direct electrical current through the soil causes the water contained in the soil voids to migrate from the positive electrode (anode) to the negative electrode (cathode). By making the cathode a wellpoint, the water that migrates to the cathode can be removed by either vacuum or eductor pumping (fig. 2-10).

2-8. Cutoffs. Cutoff curtains can be used to stop or minimize seepage into an excavation where the cutoff can be installed down to an impervious formation. Such cutoffs can be constructed by driving steel sheet piling, grouting existing soil with cement or chemical grout, excavating by means of a slurry trench and backfilling with a plastic mix of bentonite and soil, installing a concrete wall, possibly consisting of overlapping shafts, or freezing, However, groundwater within the area enclosed by a cutoff curtain, or leakage through or under such a curtain, will have to be pumped out with a well or wellpoint system as shown in figue 2-11.

a. Cement and chemical grout curtains. A cutoff around an excavation in coarse sand and gravel or porous rock can be created by injecting cement or chemical grout into the voids of the soil. For grouting to be effective, the voids in the rock or soil must be large enough to accept the grout, and the holes must be close enough together so that a continuous grout curtain is obtained. The type of grout that can be used depends upon the size of voids in the sand and gravel or rock to

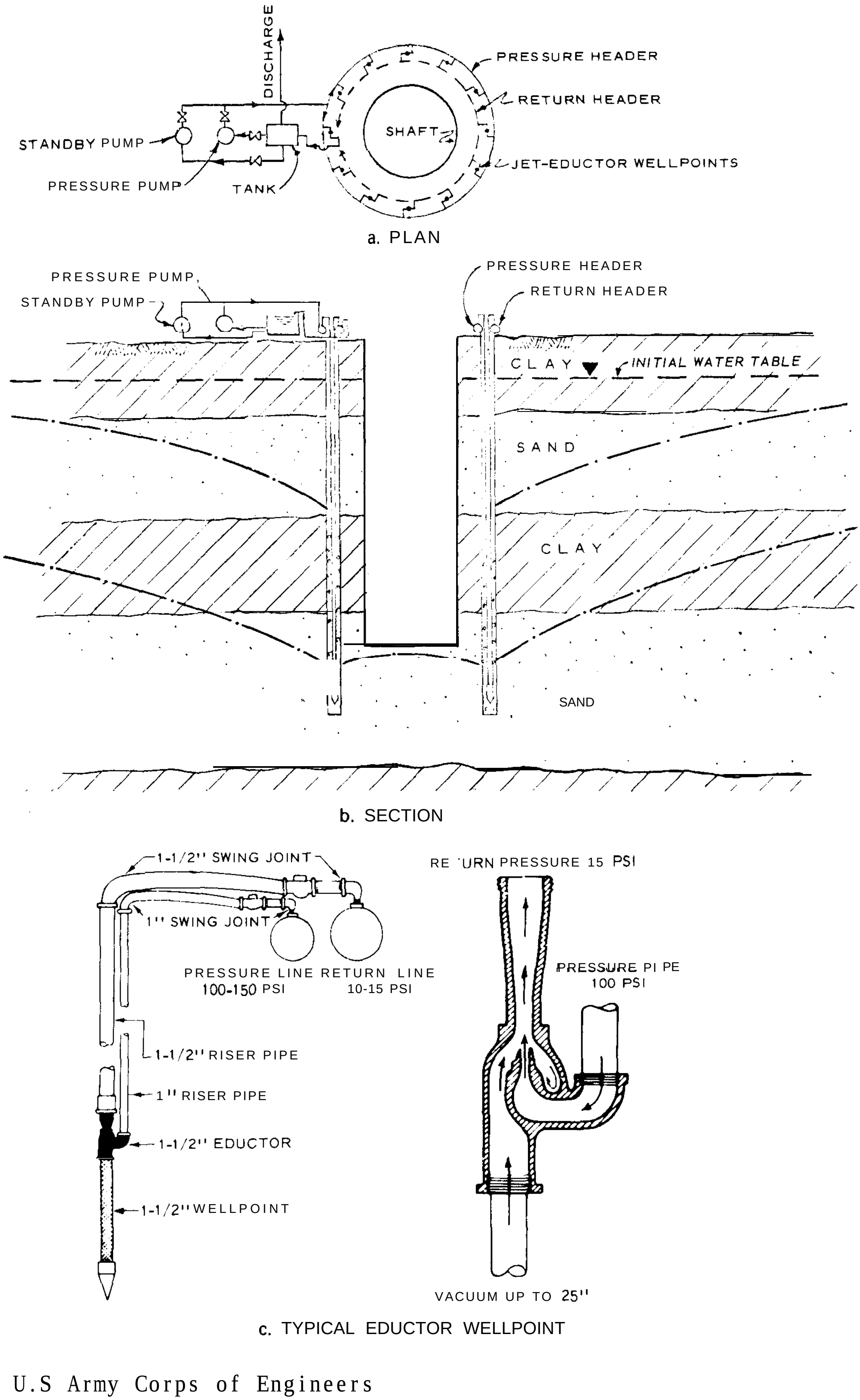

Figure 2-6. Jet-eductor wellpoint system for dewateringa shaft.

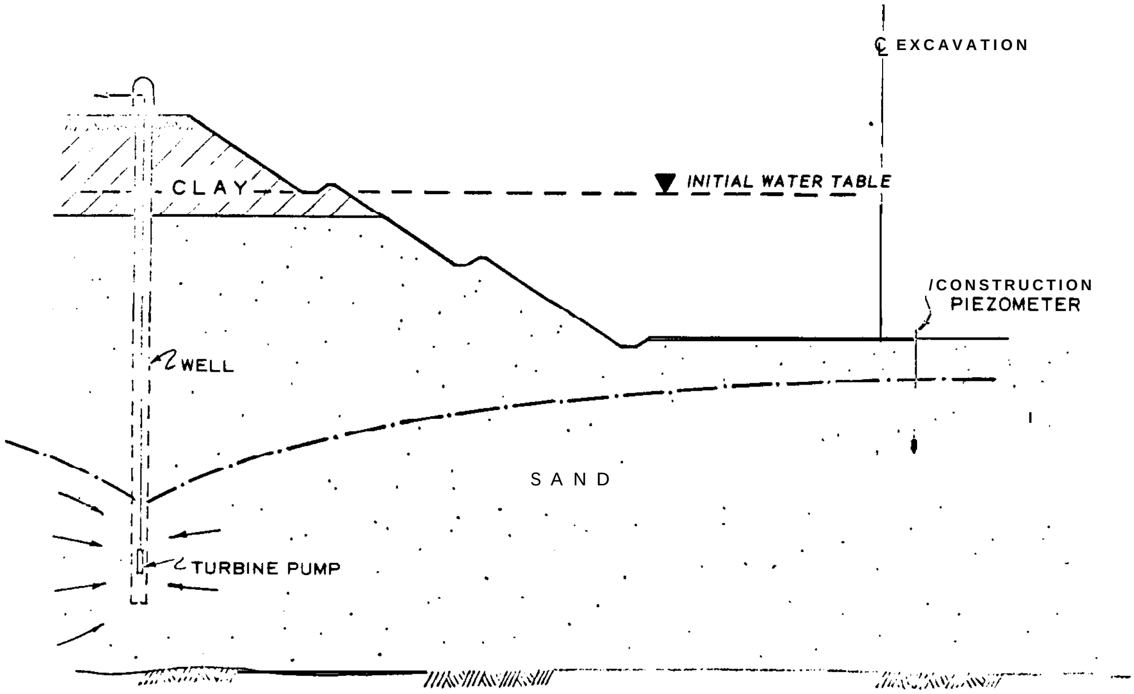

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Figure 2-7. Deep-well system for dewateringan excavation in sand.

be grouted. Grouts commonly used for this purpose are portland cement and water; cement, bentonite, an admixture to reduce surface tension, and water; silica gels; or a commercial product. Generally, grouting of fine or medium sand is not very effective for blocking seepage. Single lines of grout holes are also generally ineffective as seepage cutoffs; three or more lines are generally required Detailed information on chemical grouting and grouting methods is contained in TM 5-818-6/AFM 88-32 and NAVFAC DM 7.3.

b. Slurry walls. A cutoff to prevent or minimize seepage into an excavation can also be formed by digging a narrow trench around the area to be excavated and backfilling it with an impervious soil. Such a trench can be constructed in almost any soil, either above or below the water table, by keeping the trench filled with a bentonite mud slurry and backfilling it with a suitable impervious soil. Generally, the trench is backfilled with a well-graded clayey sand gravel mixed with bentonite slurry. Details regarding design and construction of a slurry cutoff wall are given in paragraphs 4-9g(2) and 5-5b.

c. Concrete walls. Techniques have been developed for constructing concrete cutoff walls by overlapping cylinders and also as continuous walls excavated and concreted in sections. These walls can be reinforced and are sometimes incorporated as a permanent part of a structure.

d. Steel sheet piling. The effectiveness of sheet piling driven around an excavation to reduce seepage depends upon the perviousness of the soil, the tightness of the interlocks, and the length of the seepage path. Some seepage through the interlocks should be expected. When constructing small structures in open water, it may be desirable to drive steel sheet piling around the structure, excavate the soil underwater, and then tremie in a concrete seal. The concrete tremie seal must withstand uplift pressures, or pressure relief measures must be used. In restricted areas, it may be necessary to use a combination of sheeting and bracing with wells or wellpoints installed just inside or outside of the sheeting. Sheet piling is not very effective in blocking seepage where boulders or other hard ob structions may be encountered because of driving out of interlock.

e. *Freezing.* Seepage into a excavation or shaft can be prevented by freezing the surrounding soil. However, freezing is expensive and requires expert design, installation, and operation. If the soil around the excavation is not completely frozen, seepage can cause rap-

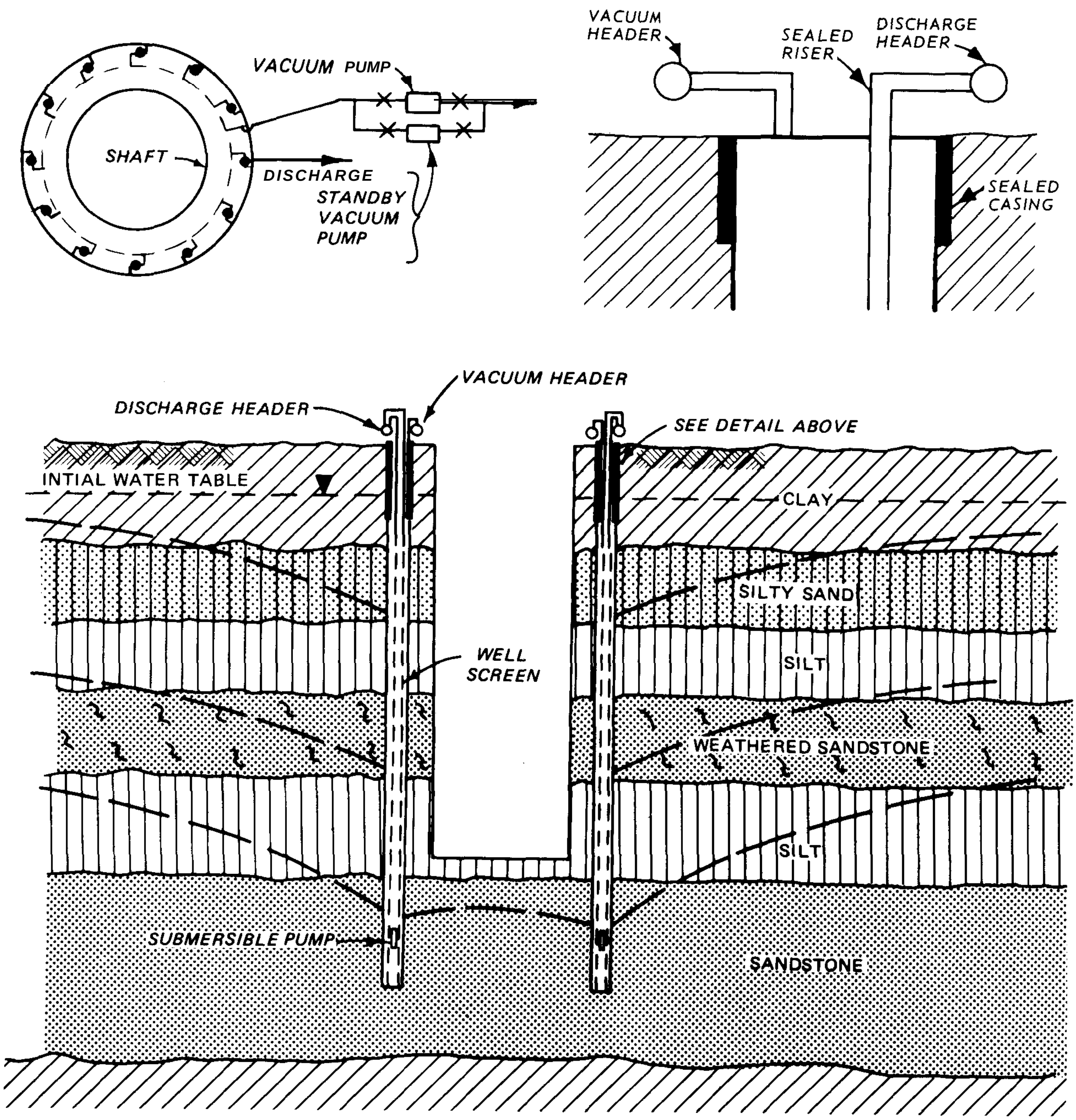

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Figure 2-8. Deep wells with auxiliary **vacuum** *system for dewateringa shaft in stratified materials.*

id enlargement of a fault (unfrozen zone) with consequent serious trouble, which is difficult to remedy.

2-9. Summary of groundwater control methods. A brief summary of groundwater control methods discussed in this section is given in table2-1.

2-10. Selection of dewatering system.

a. General. The method most suitable for dewatering an excavation depends upon the location, type, size, and depth of the excavation; thickness, stratification, and permeability of the foundation soils below the water table into which the excavation extends or is

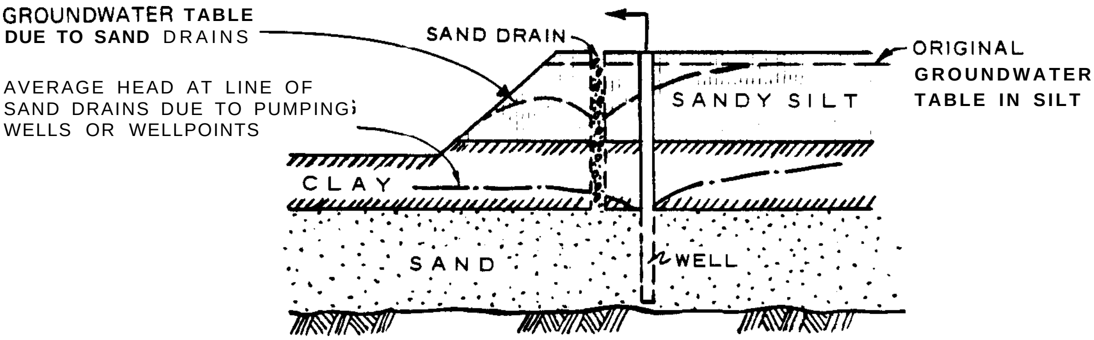

Figure 2-9. Sand drains for dewatering a slope.

underlain; potential damage resulting from failure of the dewatering system; and the cost of installation and operation of the system. The cost of a dewatering method or system will depend upon:

(1) Type, size, and pumping requirements of project.

(2) Type and availability of power.

(3) Labor requirements.

(4) Duration of required pumping.

The rapid development of slurry cutoff walls has made this method of groundwater control, combined with a certain amount of pumping, a practical and economical alternative for some projects, especially those where pumping costs would otherwise be great.

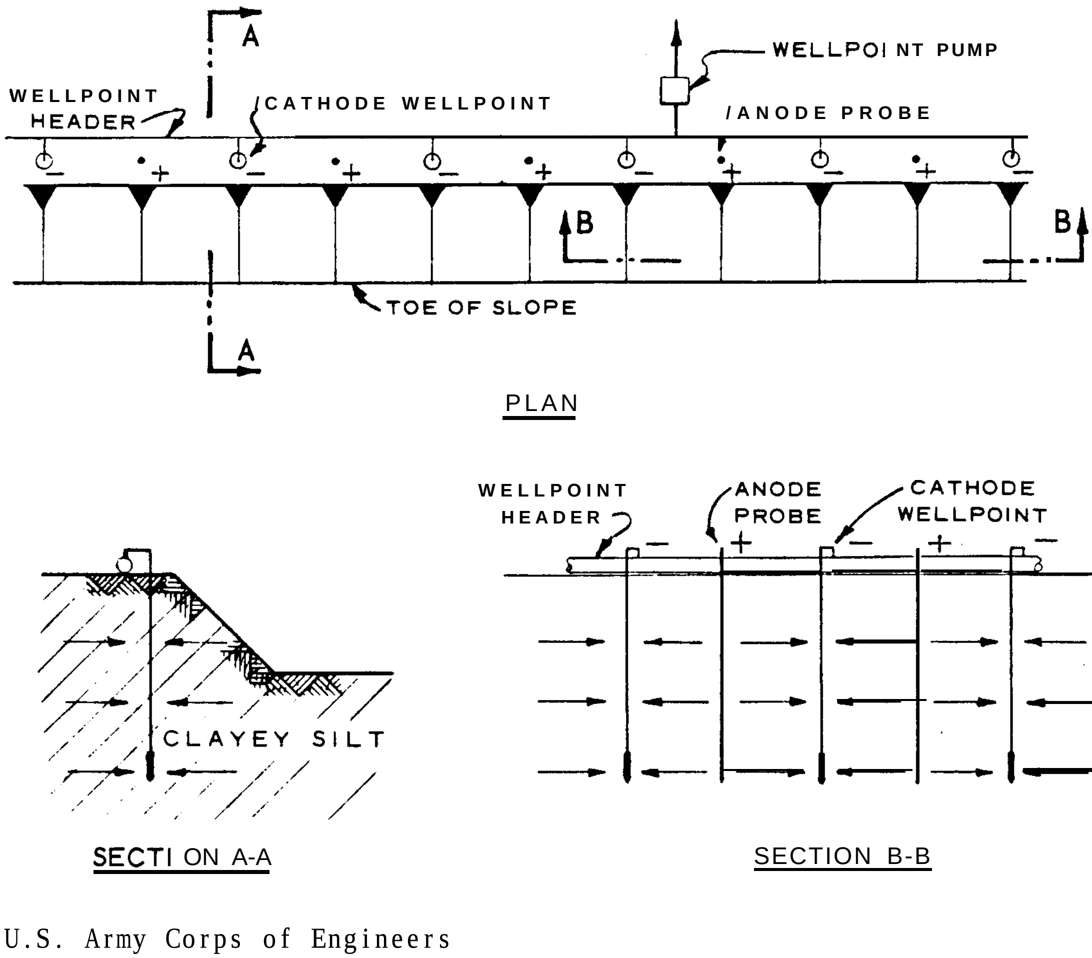

Figure 2-10. Electro-osmotic wellpoint system for stabilizing an excavation slope.

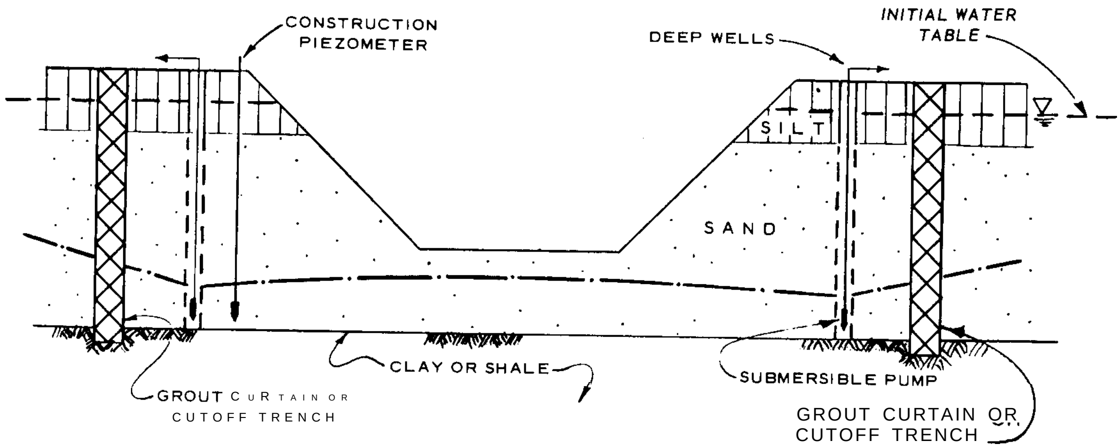

Figure 2-11. Grout curtain or cutoff trench around an excavation.

b. Factors controlling selection. Where foundations must be constructed on soils below the groundwater level, it will generally be necessary to dewater the excavation by means of a deep-well or wellpoint system rather than trenching and sump pumping, Dewatering is usually essential to prevent damage to foundation soils caused by equipment operations and sloughing or sliding in of the side slopes. Conventional deep-well and wellpoint systems designed and installed by companies specializing in this work are generally satisfactory, and detailed designs need not be prepared by the engineer. However, where unusual pressure relief or dewatering requirements must be achieved, the engineer should make detailed analyses and specify the dewatering system or detailed results to be achieved in the contract documents. Where unusual equipment and procedures are required to achieve desired results, they should be described in detail in the contract documents. The user of this manual is referred to paragraphs 6*b*, 14*b*, and 2*f* of Appendix III, TM 5-818-4/AFM 88-5, Chapter 5, for additional discussions of dewatering requirements and contract specifications. Major factors affecting selection of dewatering and groundwater control systems are discussed in the following paragraphs.

(1) *Type of excavation.* Small open excavations, or excavations where the depth of water table lowering is small, can generally be dewatering most economically and safely by means of a conventional wellpoint system. If the excavation requires that the water table or artesian pressure be lowered more than 20 or 30 feet, a system of jet-eductor type wellpoints or deep wells may be more suitable. Either wellpoints, deep wells, or a combination thereof can be used to dewater an excavation surrounded by a cofferdam. Excavations for deep shafts, caissons, or tunnels that penetrate stratified pervious soil or rock can generally best be dewatered with either a deep-well system (with or without an auxiliary vacuum) or a jet-eductor wellpoint system depending on the soil formation and required rate of pumping, but slurry cutoff walls and freezing should be evaluated as alternative procedures. Other factors relating to selection of a dewatering system are interference of the system with construction operations, space available for the system, sequence of construction operations, durations of dewatering, and cost of the installation and its operation. Where groundwater lowering is expensive and where cofferdams are required, caisson construction may be more economical. Caissons are being used more frequently, even for small structures.

(2) *Geologic and soil conditions.* The geologic and soil formations at a site may dictate the type of dewatering or drainage system. If the soil below the water table is a deep, more or less homogeneous, free-draining sand, it can be effectively dewatered with either a conventional well or wellpoint system. If, on the other hand, the formation is highly stratified, or the saturated soil to be dewatered is underlain by an impervious stratum of clay, shale, or rock, wellpoints or wells on relatively close centers may be required. Where soil and groundwater conditions require only the relief of artesian pressure beneath an excavation, this pressure relief can be accomplished by means of relatively few deep wells or jet-eductor wellpoints installed around and at the top of the excavation.

(*a*) If an aquifer is thick so that the penetration of a system of wellpoints is small, the small ratio of

Table 2-1. Summary of Groundwater Control Methods.

Method	Applicability	Remarks
Sumps and ditches	Collect water entering an excavation or structure.	Generally water level can be lowered only a few feet. Used to collect water within cofferdams and excavations. Sumping is usually only successful in relatively stable gravel or well-graded sandy gravel, partially cemented materials, or porous rock formations.
Conventional wellpoint system	Dewater soils that can be drained by gravity flow.	Most commonly used dewatering method. Drawdown limited to about 15 ft per stage; however, several stages may be used. Can be installed quickly.
Vacuum wellpoint system	Dewater or stabilize soils with low permeability. (Some silts, sandy silts).	Vacuum increases the hydraulic gradient causing flow. Little vacuum effect can be obtained if lift is more than 15 ft.
Jet-eductor wellpoint	Dewater soils that can be drained by gravity flow. Usually for deep excavations where small flows are required.	Can lower water table as much as 100 ft from top of excavation. Jet-eductors are particularly suitable for dewatering shafts and tunnels. Two header pipes and two riser pipes, or a pipe within a pipe, are required.
Deep-well systems	Dewater soils that can be drained by gravity flow. Usually for large, deep excavations where large flows are required.	Can be installed around periphery of excavation, thus removing dewatering equipment from within the excavation. Deep wells are particularly suitable for dewatering shafts and tunnels.
Vertical sand drains	Usually used to conduct water from an upper stratum to a lower more pervious stratum.	Not effective in highly pervious soils.
Electroosmosis	Dewater soils that cannot be drained by gravity. (Some silts, clayey silts, clayey silty sands),	Direct electrical current increases hydraulic gradient causing flow.
Cutoffs	Stop or minimize seepage into an excavation when installed down to an impervious stratum.	See paragraph 2-8 for materials used.

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screen length to aquifer thickness may result in relatively little drawdown within the excavation, even though the water table is lowered 15 to 20 feet at the line of wellpoints. For deep aquifers, a deep-well system will generally be more applicable, or the length of the wellpoints should be increased and the wellpoints set deep and surrounded with a high-capacity filter. On the other hand, if the aquifer is relatively thin or stratified wellpoints may be best suited to the situation.

(*b*) The perviousness and drainability of a soil or rock may dictate the general type of a dewatering system to be used for a project. A guide for the selection of a dewatering system related to the grain size of soils is presented in figure 2-12. Some gravels and rock formations may be so permeable that a barrier to flow, such as a slurry trench, grout curtain, sheet pile cutoff, or freezing, may be necessary to reduce the quantity of flow to the dewatering system to reasonable proportions. Clean, free-draining sands can be effectively dewatered by wells or wellpoints. Drainage of sandy silts and silts will usually require the application of additional vacuum to well or wellpoint dewatering systems, or possibly the use of the electroosmotic method of dewatering where soils are silty or clayey. However, where thin sand layers are present, special requirements may be unnecessary. Electroosmosis should never be used until a test of a conventional system of wellpoints, wells with vacuum, or jet-eductor wellpoints has been attempted.

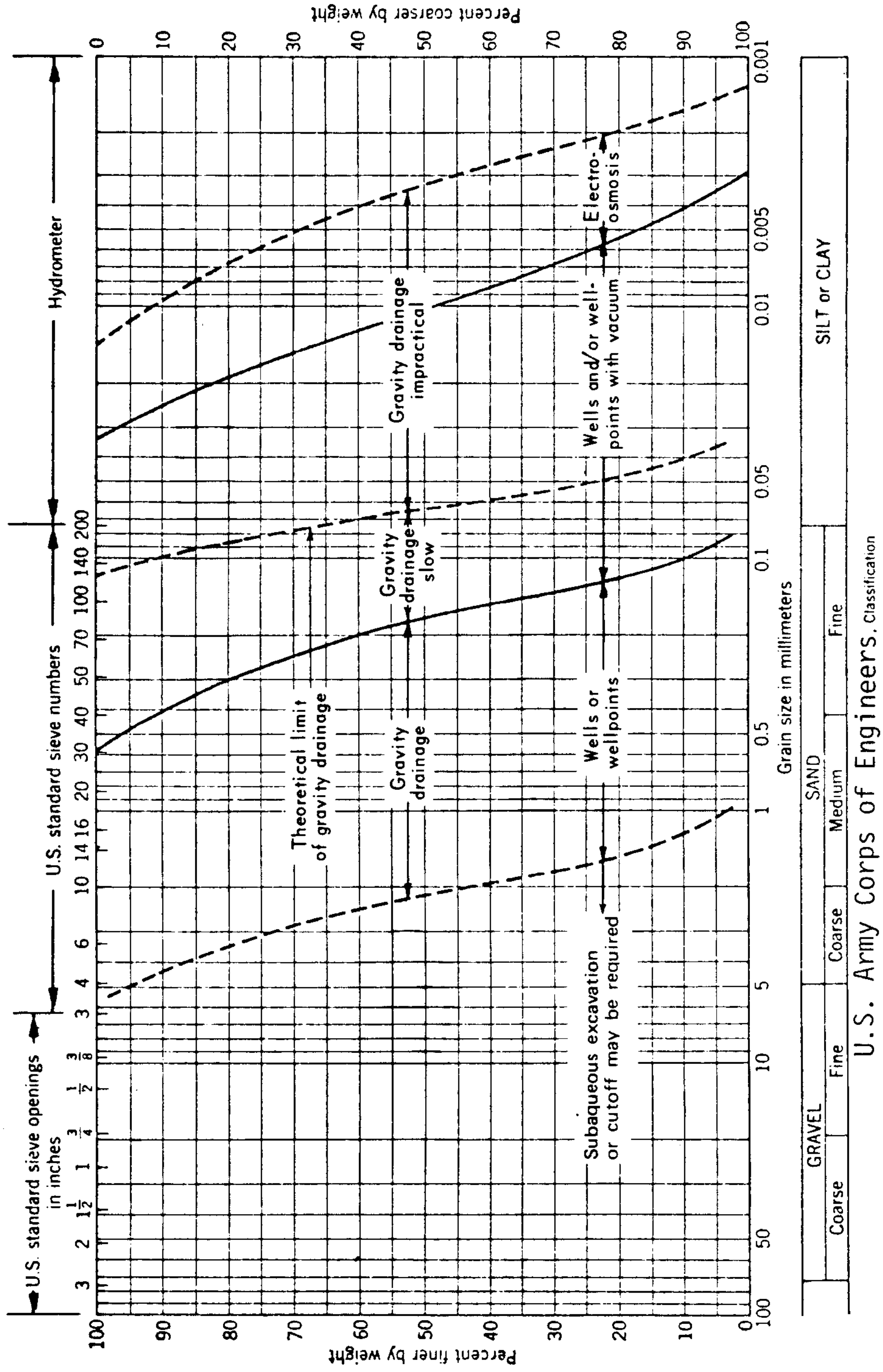
(3) *Depth of groundwater lowering.* The magnitude of the drawdown required is an important consideration in selecting a dewatering system. If the drawdown required is large, deep wells or jet-eductor wellpoints may be the best because of their ability to achieve large drawdowns from the top of an excavation, whereas many stages of wellpoints would be required to accomplish the same drawdown. Deep wells can be used for a wide range of flows by selecting pumps of appropriate size, but jet-eductor wellpoints are not as flexible. Since jet-eductor pumps are relatively inefficient, they are most applicable where well flows are small as in silty to fine sand formations.

(4) *Reliability requirements.* The reliability of groundwater control required for a project will have a significant bearing on the design of the dewatering pumps, power supply, and standby power and equipment. If the dewatering problem is one involving the relief of artesian pressure to prevent a "blowup" of the bottom of an excavation, the rate of water table rebound, in event of failure of the system, may be extremely rapid. Such a situation may influence the type of pressure relief system selected and require inclusion of standby equipment with automatic power transfer and starting equipment.

(5) *Required rate of pumping.* The rate of pumping required to dewater an excavation may vary from 5 to 50,000 gallons per minute or more. Thus, flow to a drainage system will have an important effect on the design and selection of the wells, pumps, and piping system. Turbine or submersible pumps for pumping deep wells are available in sizes from 3 to 14 inches with capacities ranging from 5 to 5000 gallons per minute at heads up to 500 feet. Wellpoint pumps are available in sizes from 6 to 12 inches with capacities ranging from 500 to 5000 gallons per minute depending upon vacuum and discharge heads. Jet-eductor pumps are available that will pump from 3 to 20 gallons per minute for lifts up to 100 feet. Where soil conditions dictate the use of vacuum or electroosmotic wellpoint systems, the rate of pumpage will be very small. The rate of pumpage will depend largely on the distance to the effective source of seepage, amount of drawdown or pressure relief required, and thickness and perviousness of the aquifer through which the flow is occurring.

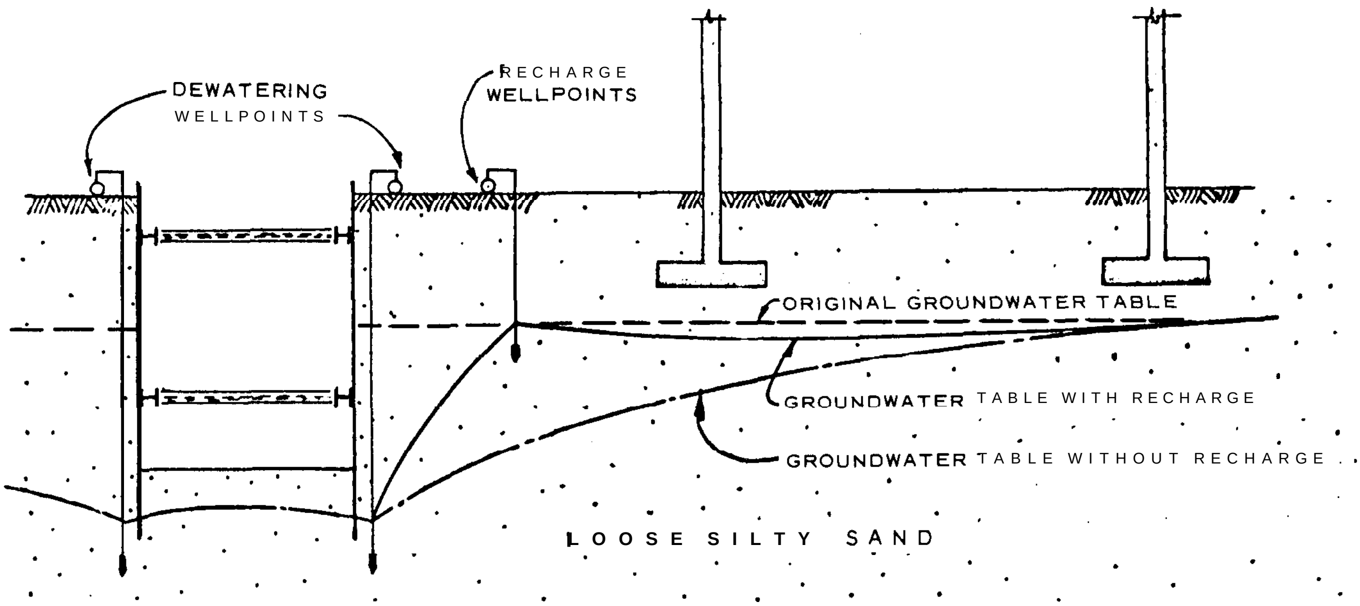
(6) *Intermittent pumping.* Pumping labor costs can occasionally be materially reduced by pumping a dewatering system only one or two shifts per day. While this operation is not generally possible, nor advantageous, it can be economical where the dewatered area is large; subsoils below subgrade elevation are deep, pervious, and homogeneous; and the pumping plant is oversize. Where these conditions exist, the pumping system can be operated to produce an abnormally large drawdown during one or two shifts. The recovery during nonpumping shifts raises the groundwater level, but not sufficiently to approach subgrade elevation. This type of pumping plant operation should be permitted only where adequate piezometers have been installed and are read frequently.

(7) *Effect of ground wa ter lowering on adjacent structures and wells.* Lowering the groundwater table increases the load on foundation soils below the original groundwater table. As most soils consolidate upon application of additional load, structures located within the radius of influence of a dewatering system may settle. The possibility of such settlement should be investigated before a dewatering system is designed. Establishing reference hubs on adjacent structures prior to the start of dewatering operations will permit measuring any settlement that occurs during dewatering, and provides a warning of possible distress or failure of a structure that might be affected. Recharge of the groundwater, as illustrated in figure 2-13, may be necessary to reduce or eliminate distress to adjacent structures, or it may be necessary to use positive cutoffs to avoid lowering the groundwater level outside of an excavation. Positive cutoffs include soil freezing and slurry cutoff techniques. Observations should be made of the water level in nearby wells before and during dewatering to determine any effect



(Courtesy of Moretrench American Corp.)

Figure 2-12. Dewatering systems applicable to different soils.



U.S. Army Corps of Engineers

Figure 2-13. Recharge of groundwater to prevent settlement of a building as a result of dewatering operations.

of dewatering. This information will provide a basis for evaluating any claims that may be made.

(8) *Dewatering versus cutoffs and other procedures.* While dewatering is generally the most expeditious and economical procedure for controlling water, it is sometimes possible to excavate more economically in the wet inside of a cofferdam or caisson and then seal the bottom of the excavation with a tremie seal, or use a combination of slurry wall or other type of cutoff and dewatering. Where subsurface construction extends to a considerable depth or where high uplift pressures or large flows are anticipated, it may occasionally be advantageous to: substitute a caisson for a conventional foundation and sink it to the design elevation without lowering the groundwater level; use a combination of'concrete cutoff walls constructed in slurry-supported trenches, and a tremied concrete foundation slab, in which case the cutoff walls may serve also as part of the completed structure; use large rotary drilling machines for excavating purposes, without lowering the groundwater level; or use freezing techniques. Cofferdams, caissons, and cutoff walls may have difficulty penetrating formations containing numerous boulders. Foundation designs requiring compressed air will rarely be needed, although compressed air may be economical or necessary for some tunnel construction work.