Sub. 107

Pages 1–31

Environmental
Protection Agency
28 AUG 2007

Hand's Lane
Rush
Co Dublin
23/08/07

Waste Licensing Section
EPA
Johnstown Castle Estate
Co Wexford

Dear Ms O'Keefe,

Please replace my submission dated 09/08/07 with the attached amended document as discussed on phone today,

Yours truly,

Patrick Boyle, BE

Hand's Lane
Rush
Co Dublin
09/08/07

Dr Ian Marnane
EPA
Johnstown Castle Estate
Co Wexford

Ref: Application by Fingal County Council for a Waste Licence at Nevitt, Co.Dublin

Dear Dr. Marnane,

I refer to the reply by the applicant to Article 13 Compliance Requirements in the matter of "Base and Slope Stability and Dewatering Requirements" – see attached page 12.

This is a single paragraph reply to a complex geotechnical problem, inadequate in it's scientific data "to permit a complete evaluation of the risk"- see attached article Europa>summaries of legislation> the precautionary principle.

The Nevitt /Lusk Action Group therefore wish to invoke the EU Precautionary Principle and request the EPA to require the applicant to

- Submit a full and detailed account of all relevant scientific data,
- Indicate precisely how these matters are to be addressed
- List and analyse all options available
- Provide detailed technical drawings where required.

We also wish to draw the EPA's attention to the provisions of Bullet Point 3, Guidelines for the use of the Precautionary Principle, and consequently respectfully request the EPA to give the Nevitt/Lusk Action Group adequate opportunity to study Fingal County Council's proposals on these matters, as provided for in the legislation, before any decision on this application is taken.

May we also draw the attention of the EPA to the contents of US ARMY Manual TM 5-818-5, Dewatering and Groundwater Control, and in particular Chapters 1 and 2 (attached). (The complete document is available on the Internet).

Yours truly,

Patrick Boyle, BE.

Submission P. Boyle, 9/8/07

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ARTICLE 13 COMPLIANCE REQUIREMENTS

BASE AND SLOPE STABILITY AND DEWATERING REQUIREMENTS

Respond to the points raised in Submission 74 (electronic copy attached) with regard to stability and dewatering requirements during the construction, operation and aftercare phase of the landfill. Ensure that a geotechnical engineer is consulted in preparing a response. Take into account all such concerns raised in the submission and also in Submission No. 77 (Point No. 4, 2nd and 3rd bullet point, electronic copy attached).

Undertaking cuttings of 10m depth and greater within glacial till and similar soil conditions with high water tables is a common practice and has been undertaken on numerous motorway and landfill projects throughout Ireland (including Gortadroma Landfill WL0017-3)). Groundwater control is typically undertaken on road projects using herring-bone or counterfort drainage systems with toe drains as permanent drainage systems. In the design of landfills, where groundwater inflow is anticipated, a drainage blanket is placed below the liner system to allow groundwater to be collected and diverted away from the base of the landfill. In this instance the groundwater will need to be controlled until such time that the waste above the liner system offers sufficient pressure to resist uplift forces both from the base and from side slopes. Large scale dewatering in the form of a perimeter deep well point or multi-stage system is not anticipated and neither is the need for a cut-off system as the clays are low permeability and groundwater inflow is controllable during construction through measures inserted on the cut-face such as those used on road cuttings.

DEPTH OF CLAY

2D Resistivity Profile 9long indicates areas across the southern area of the site where depth to gravel of less than 10 metres are present. The area covered by this profile is within the 10 metre cut contour of the landfill. Boreholes GS4 and GS5, adjacent to the profile line do not provide any evidence to indicate a greater depth of clay in this area. Discuss the above with regard to the requirement to maintain 10 metres of clay beneath the landfill footprint. Outline methods proposed to be employed during construction to ensure that 10metres of clay remains beneath the base of the landfill.

2D Resistivity Profile 9 Long is located in the north-west quarter of the investigated area at grid reference 317130E, 257421N. 2D Resistivity Profile 19 Long is located in the vicinity of boreholes GS4 and GS5 at grid reference 317552E, 256728N. Unfortunately the name of the resistivity profile '19 Long' is not clear on the plan drawings provided, Map 1a, Map 1b.

Both boreholes GS4 and GS5 terminate at depths of 9.6m and 10.5m in clay. They were terminated at this level because of the stiffness of the clay and the methods of drilling used for GS4 and GS5 were not adequate to penetrate in those conditions to a deeper level. Different drilling methods were employed at different locations so that different information could be provided. For example the drilling method employed at GS4 and GS5 was cable percussion drilling which can retrieve bulk samples in a relatively short space of time whereas borehole GR5 was drilled using rotary drilling methods and proved clay depths of 25.95m+. GR5 is located approximately midway between GS4 and GS5. Resistivity Profile 19 Long lies close to boreholes GS4, GR5 and GS5 where depths of clay were recorded at 9.6m (cable percussive), 25.95m (rotary), and 10.5 (cable percussive) respectively. The resistivity profile indicates an average depth of clay of 30m+ across the middle of the profile. Resistivity profile 18 Long (to the south of 19 Long) is reflective of clay depths in the location of GR6 and proves clay to 13.9m deep which is why this area remains outside the landfill footprint.

As with all construction projects of this nature, additional site investigation may be necessary to further classify the materials being excavated in order to establish construction methods, and to complete the detailed design. The final detailed design of all of the cells will take the depths already recorded into

Europa Activities of the European Union
Summaries of legislation

EUROPA > Summaries of legislation > The precautionary principle

Submission P. Boyle
9/8/07

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The precautionary principle

The precautionary principle may be invoked where urgent measures are needed in the face of a possible danger to human, animal or plant health, or to protect the environment where scientific data do not permit a complete evaluation of the risk. It may not be used as a pretext for protectionist measures. This principle is applied mainly where there is a danger to public health. For example, it may be used to stop distribution or order withdrawal from the market of products likely to constitute a health hazard.

ACT

Communication from the Commission of 2 February 2000 on the precautionary principle [COM(2000) 1 final - Not published in the Official Journal].

SUMMARY

The EC Treaty contains only one explicit reference to the precautionary principle, namely in the title on environmental protection. However, in practice, the scope of this principle is far wider and also covers consumer policy and human, animal and plant health.

Since the precautionary principle is not defined in the Treaty or in other Community instruments, the Council in its Resolution of 13 April 1999 requested the Commission to develop clear and effective guidelines for the application of the principle. The Commission's Communication is a response to this request.

The establishment of common guidelines on the application of the precautionary principle will also have positive repercussions at international level.
The principle has been recognised in various international agreements, notably in the Sanitary and Phytosanitary Agreement (SPS) concluded in the framework of the World Trade Organisation (WTO).
A clear definition as to how the Community intends to use the precautionary principle with a view to ensuring an appropriate level of environmental and health protection can contribute to the discussions already launched in these international arenas.

In its Communication, the Commission analyses the factors that trigger use of the precautionary principle and the associated measures. It then proposes guidelines for applying the principle.

The factors triggering use of the precautionary principle

According to the Commission the precautionary principle may be invoked when the potentially dangerous effects of a phenomenon, product or process have been identified by a scientific and objective evaluation, and this evaluation does not allow the risk to be determined with sufficient certainty. Hence use of the principle belongs in the general framework of risk analysis (which, besides risk evaluation, includes risk management and risk communication), and more particularly in the context of risk management which corresponds to decision-making.

The Commission stresses that the precautionary principle may only be invoked in the event of a potential risk and that it can never justify arbitrary decisions. Hence the precautionary principle may only be invoked when the three preliminary conditions are met - identification of potentially adverse effects, evaluation of the scientific data available and the extent of scientific uncertainty.

The measures resulting from use of the precautionary principle

As regards the measures resulting from use of the precautionary principle, they may take the form of a decision to act or not to act.
The response depends on a political decision and is a function of the level of risk considered "acceptable" by the society on which the risk is imposed.

When action without awaiting further scientific information seems to be the appropriate response to the risk in application of the precautionary principle, a decision still has to be taken as to the nature of this action. Besides the adoption of legal instruments subject to review by the courts, there are a whole raft of measures for decision-makers to choose from (funding of a research programme, informing the public as to the adverse effects of a product or procedure, etc.).
Under no circumstances may the measure be selected on the basis of an arbitrary decision.

Guidelines for use of the precautionary principle

The precautionary principle should be informed by three specific principles:

- implementation of the principle should be based on the fullest possible scientific evaluation. As far as possible this evaluation should determine the degree of scientific uncertainty at each stage;
- any decision to act or not to act pursuant to the precautionary principle must be preceded by a risk evaluation and an evaluation of the potential consequences of inaction;
- once the results of the scientific evaluation and/or the risk evaluation are available, all the interested parties must be given the opportunity to study of the various options available, while ensuring the greatest possible transparency.

Besides these specific principles, the general principles of good risk management remain applicable when the precautionary principle is invoked. These are the following five principles:

- proportionality between the measures taken and the chosen level of protection;
- non-discrimination in application of the measures;
- consistency of the measures with similar measures already taken in similar situations or using similar approaches;
- examination of the benefits and costs of action or lack of action;
- review of the measures in the light of scientific developments.
- The burden of proof

Apart from the rules applicable to products such as drugs, pesticides or food additives, Community legislation does not prescribe a prior authorisation system for placing products on the market. Thus in most cases it is for the users, the citizens or consumer associations to demonstrate the danger associated with a procedure or a product after it has been placed on the market.

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According to the Commission, an action taken under the precautionary principle may in certain cases include a clause shifting the burden of proof to the producer, manufacturer or importer. This possibility should be examined on a case-by-case basis; the Commission does not recommend the general extension of such an obligation to all products.

RELATED ACTS

Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety [Official Journal L 031 of 01.02.2002].
The precautionary principle may be invoked where a food might have harmful effects on health (Article 7), in order to be able to react quickly and take appropriate measures. This principle is implemented in particular where there is uncertainty or where comprehensive scientific information on the potential risk is not available.
Measures must be proportionate to the risk and must be reviewed within a reasonable period of time.

For more information on the precautionary principle, please consult the website of the Directorate-General for Health and Consumer Protection

Last updated: 02.11.2005

ATTACHMENT TO SUBMISSION OF NEVITT/LUSK ACTION GROUP, DATED 09/08/07- AUTHOR P. BOYLE, BE

REF: US ARMY TECHNICA MANUAL TM 5-818-5 DEWATERING AND GROUNDWATER CONTROL CHAPTERS 1 AND 2

Notes on Text.

1. Need for Groundwater Control (1.3. a)
   - The proposed lined landfill is "a subsurface structure founded in previous soil strata below the water table".
   - There is a requirement "to intercept seepage" and "increase the stability" of excavated and constructed slopes.
   - Groundwater control is needed to control "hydrostatic pressure, seepage, piping, heave and reduced stability of slopes".
2. "Excavation characteristics" of the site requires
   - The **lowering of the groundwater table** "by at least 2 to 3 feet below the slopes and bottom of the excavation during construction"
   - **The calculation and implementation of "a factor of safety"** due to the presence of clay underlain by gravel "under artesian pressure".
   - The design of the dewatering system should take into account "**the risk of damage**" to the environment "should the dewatering system fail." **In the case of the Nevitt site potential receptors include residents, school children, traffic on the M1, the groundwater supply to horticultural wells, the Corduff River and Rogerstown Estuary ecologies, and future groundwater resources.**
3. The groundwater control methods which would be necessary at the Nevitt site are
   - Removal of groundwater from the site
   - Reduction of artesian pressure from beneath the bottom of the excavation. (Figures 1-1 and 1-2).

   This would entail the design and installation of a system of pumped and pressure relief wells and control systems of some complexity, the details of which we require for inspection.

4. **It is our considered opinion that the Nevitt site would require a permanent dewatering system which would inevitably become a source of pollution to the aquatic environment (Figure 1-2.) for the following reasons**

- Dewatering a landfill site is **not** the same as a road cutting in that landfill runoff must be considered as a potential source of pollution.
- Connectivity in the gravel beneath the site would require at minimum the relief of groundwater pressure from the confined aquifer underlying the entire site for the full working life of the landfill i.e. 30 years. This can be considered as **RUNOFF WATER TYPE "A"**, – deep water from below 10 meters of clay. This water will have to be controlled by system of deep "relief wells".
- The Applicant proposes to control the shallower groundwater, seeping in from the sides and down from the surface, by using a drainage blanket of stones constructed at a depth of one meter below the landfill liner. The runoff from the drainage blanket can be considered as **RUNOFF WATER TYPE "B"- much more prone to contamination than runoff "A" as it has but one meter of clay protection.**
- The Applicant proposes, on closure, to allow the shallow groundwater to rise above the level of the liner bottom, presumably to a level above that of the leachate, in order to create an inward pressure on the liner and minimize the escape of leachate. Again this level will have to be controlled, thus creating TYPE "B" runoff **but now in contact with the liner itself, i.e. no clay barrier – RUNOFF WATER TYPE "C".**
- In the absence of more detailed information it is presumed that **RUNOFF TYPE "A" because of the large volumes involved will be directly into the Corduff River.** The volume could reasonably be expected to be in the region of 2/3 million litres per day, based on site trial well results.
- **Presumably it is planned to re-circulate RUNOFF TYPES "B" and "C" into the leachate,** although this detail again is not provided by the Applicant.

- **No allowance is made by the Applicant for the known presence of wells and new springs. This is the major difficulty inherent in the Nevitt site which in our opinion will prevent the implementation and successful working of the above dewatering system.** If the pressure in the confined aquifer is allowed to reassert itself, either after the closure of a cell or on completion of the project, then seepage of RUNOFF WATER TYPE "A" into RUNOFF "B" and /or "C" will occur through numerous wells and springs, at a piezometric head of up to 11meters. The resultant volume of leakage into the drainage blanket on such a large site is likely to be too large to be recycled into the leachate without creating unacceptable pore pressures within the waste, with the consequent danger of slope failure. An emergency situation is thus likely to occur which would necessitate the discharge of large volumes of toxic RUNOFF "B" or "C" into the Corduff River, resulting in catastrophic environmental pollution of ground and surface water.

- The inevitable breakdown of the liner system over a longer period of time in such a sensitive environment would also lead to a similar sudden and irreversible catastrophic scenario.

The proposal is thus unsustainable in the short and long-term, constitutes a serious potential danger to public health and the environment, and consequently the Nevitt/Lusk Action Group request full disclosure and a right to reply to all slope stability and dewatering plans as per EU Legislation.

P. S. Le. BE.

9/8/07

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This copy is a reprint which includes current pages from Change 1.

ARMY TM 5-818-5
NAVY NAVFAC P-418
AIR FORCE AFM 88-5, Chap 6

DEWATERING
AND
GROUNDWATER CONTROL

DEPARTMENTS OF THE ARMY, THE NAVY, AND THE AIR FORCE
NOVEMBER 1983

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TM5–818–5
AFM 88-5, Chap. 6
NAVFAC P-4 18
C-1

Change
No. 1

HEADQUARTERS
DEPARTMENTS OF THE ARMY,
AIR FORCE, AND NAVY
WASHINGTON, DC 27 June 1985

DEWATERING AND GROUNDWATER CONTROL

TM 5–818–5/AFM 88–5, Chapter 6/NAVFAC P–418, 15 November 1983 is changed as follows:

1. Remove old pages and insert new pages as indicated below. New or changed material is indicated by a vertical bar in the margin of the page.

Remove pages	Insert *pages*
i and ii	i and iii
A-1	A-1

2. File this change sheet in front of the publication for reference purposes.

By Order of the Secretaries of the Army, the Air Force, and the Marine Corps:

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General, United States Army
Chief of Staff

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Brigadier General, United States Army
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Logistics Command

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TECHNICAL MANUAL
No. 5-818-5
AIR FORCE MANUAL
No. 88-5, Chapter 6
NAVY MANUAL
No. P-418

HEADQUARTERS
DEPARTMENT OF THE ARMY,
THE AIR FORCE,
AND THE NAVY

WASHINGTON, DC *15 November 1983*

DEWATERING AND GROUNDWATER CONTROL

Paragraph *Page*

CHAPTER 1. INTRODUCTION

2. METHODS FOR DEWATERING, PRESSURE RELIEF, AND SEEPAGE CUTOFF

3. GEOLOGIC, SOIL, AND GROUNDWATER INVESTIGATIONS

4. DESIGN OF DEWATERING, PRESSURE RELIEF, AND GROUNDWATER CONTROL SYSTEMS

5. INSTALLATION OF DEWATERING AND GROUNDWATER CONTROL SYSTEMS

6 OPERATION AND PERFORMANCE CONTROL

7. CONTRACT SPECIFICATIONS

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*This manual supersedes TM 5-818-5/AFM 88-5, Chap 6/NAVFAC P-418, April 1971.

LIST OF FIGURES

19

15

Points marked and underlined.

9/8/07

CHAPTER 1

INTRODUCTION

1-1. Purpose and scope. This manual provides guidance for the planning, design, supervision, construction, and operation of dewatering and pressure relief systems and of seepage cutoffs for deep excavations for structures. It presents: description of various methods of dewatering and pressure relief; techniques for determining groundwater conditions, characteristics of pervious aquifers, and dewatering requirements; guidance for specifying requirements for dewatering and seepage control measures; guidance for determining the adequacy of designs and plans prepared by contractors; procedures for designing, installing, operating, and checking the performance of dewatering systems for various types of excavations; and descriptions and design of various types of cutoffs for controlling groundwater.

1-2. General.

a. It will generally be the responsibility of the contractor to design, install, and operate dewatering and groundwater control systems. The principal usefulness of this manual to design personnel will be those portions devoted to selecting and specifying dewatering and groundwater control systems. The portions of the manual dealing with design considerations should facilitate review of the contractor's plans for achieving the desired results.

b. Most of the analytical procedures set forth in this manual for groundwater flow are for "steady-state" flow and not for "unsteady-state" flow, which occurs during the initial phase of dewatering.

c. Some subsurface construction may require dewatering and groundwater control procedures that are not commonly encountered by construction contractors, or the dewatering may be sufficiently critical as to affect the competency of the foundation and design of the substructure. In these cases, it may be desirable to design and specify the equipment and procedures to be used and to accept responsibility for results obtained. This manual should assist design personnel in this work.

1

1-3. Construction dewatering.

a. Need for groundwater control. Proper control of groundwater can greatly facilitate construction of subsurface structures founded in, or underlain by, pervious soil strata below the water table by:

(1) Intercepting seepage that would otherwise emerge from the slopes or bottom of an excavation.

(2) Increasing the stability of excavated slopes and preventing the loss of material from the slopes or bottom of the excavation.

(3) Reducing lateral loads on cofferdams.

(4) Eliminating the need for, or reducing, air pressure in tunneling.

(5) Improving the excavation and backfill characteristics of sandy soils.

Uncontrolled or improperly controlled groundwater can, by hydrostatic pressure and seepage, cause piping, heave, or reduce the stability of excavation slopes or foundation soils so as to make them unsuitable for supporting the structure. For these reasons, subsurface construction should not be attempted or permitted without appropriate control of the groundwater and (subsurface) hydrostatic pressure.

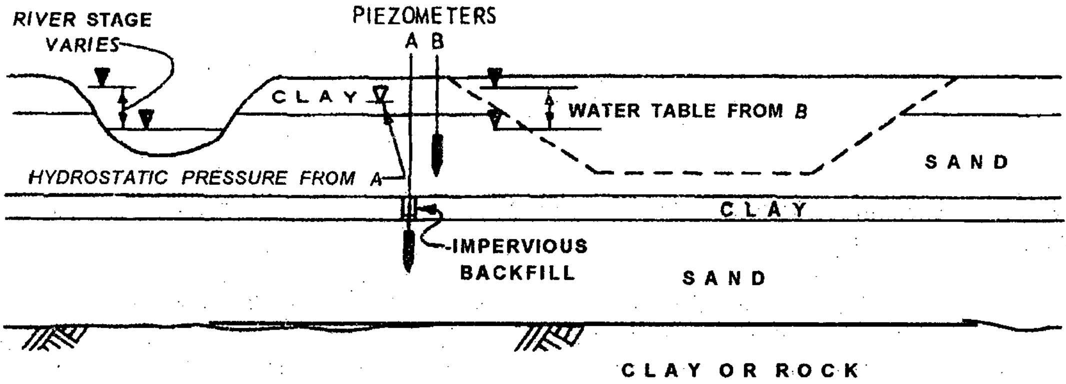
2

b. Influence of excavation characteristics. The location of an excavation, its size, depth, and type, such as open cut, shaft, or tunnel, and the type of soil to be excavated are important considerations in the selection and design of a dewatering system. For most granular soils, the groundwater table during construction should be maintained at least 2 to 3 feet below the slopes and bottom of an excavation in order to ensure "dry" working conditions. It may need to be maintained at lower depths for silts (5 to 10 feet below sub grade) to prevent water pumping to the surface and making the bottom of the excavation wet and spongy. Where such deep dewatering provisions are necessary, they should be explicitly required by the specifications as they greatly exceed normal requirements and would not otherwise be anticipated by contractors.

(1) Where the bottom of an excavation is underlain by a clay, silt, or shale stratum that is underlain by a pervious formation under artesian pressure (fig. 1-1), the upward pressure or seepage may rupture the bottom of the excavation or keep it wet even though the slopes have been dewatered. Factor of safety considerations with regard to artesian pressure are discussed in paragraph 4-8.

(2) Special measures may be required for excavations extending into weathered rock or shale where substantial water inflow can be accommodated without severe erosion. If the groundwater has not been controlled by dewatering and there is appreciable flow

(1



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

Figure 1-1. Installation of piezometers for determining water table and artesian hydrostatic pressure.

or significant hydrostatic pressures within the rock or shale deposit, rock anchors, tiebacks, and lagging or bracing may be required to prevent heave or to support exposed excavation slopes.

(3) An important facet of dewatering an excavation is the relative risk of damage that may occur to the excavation, cofferdam, or foundation for a structure in event of failure of the dewatering system. The method of excavation and reuse of the excavated soil may also have a bearing on the need for dewatering. These factors, as well as the construction schedule, must be determined and evaluated before proceeding with the design of a dewatering system.

c. Groundwater control methods. Methods for controlling groundwater may be divided into three categories:

3 (1) Interception and removal of groundwater from the site by pumping from sumps, wells, wellpoints, or drains. This type of control must include consideration of a filter to prevent migration of fines and possible development of piping in the soil being drained.

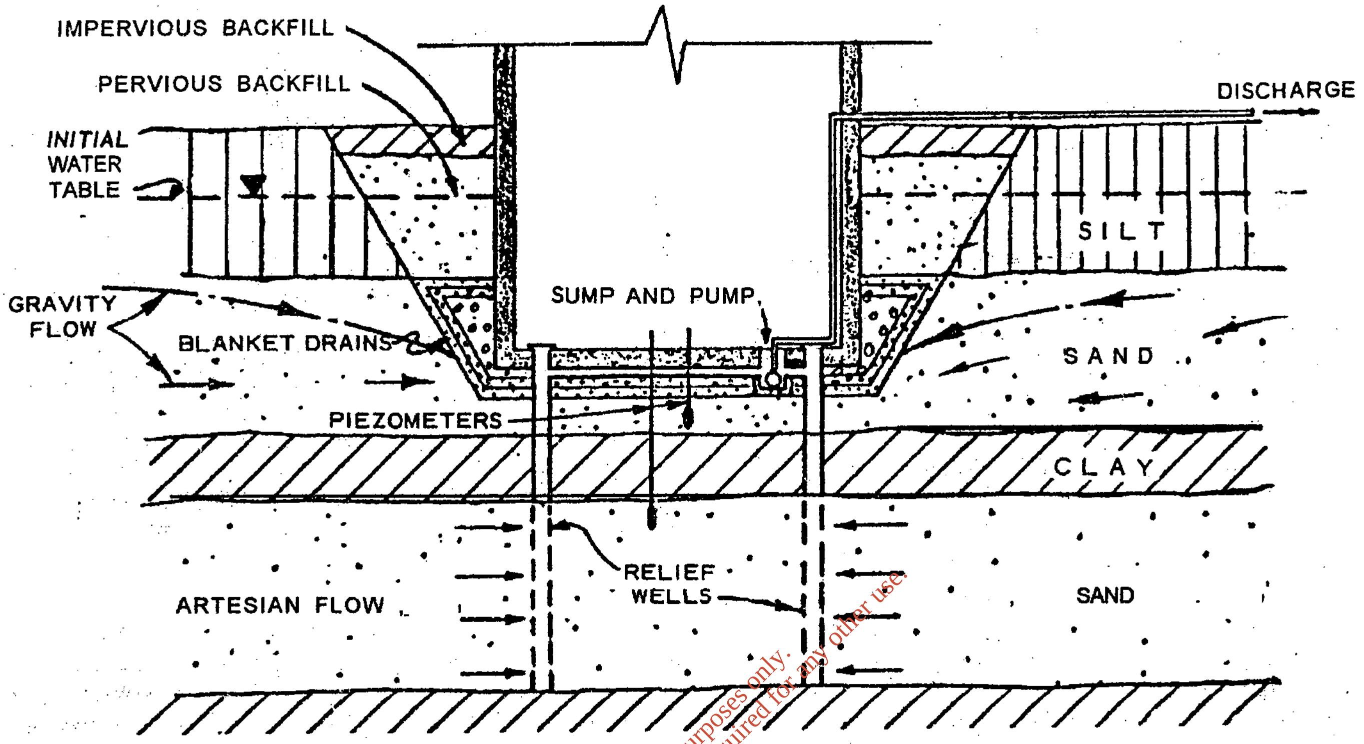
(2) Reduction of artesian pressure beneath the bottom of an excavation.

(3) Isolation of the excavation from the inflow of groundwater by a sheet-pile cutoff, grout curtain, slurry cutoff wall, or by freezing.

4

1-4. Permanent groundwater control.

Many factors relating to the design of a temporary dewatering or pressure relief system are equally applicable to the design of permanent groundwater control systems. The principal differences are the requirements for permanency and the need for continuous operation. The requirements for permanent drainage systems depend largely on the structural design and operational requirements of the facility. Since permanent groundwater control systems must operate continuously without interruption, they should be conservatively designed and mechanically simple to avoid the need for complicated control equipment subject to failure and the need for operating personnel. Permanent drainage systems should include provisions for inspection, maintenance, and monitoring the behavior of the system in more detail than is usually required for construction dewatering systems. Permanent systems should be conservatively designed so that satisfactory results are achieved even if there is a rise in the groundwater level in the surrounding area, which may occur if water supply wells are shut down or if the efficiency of the dewatering system decreases, as may happen if bacteria growth develops in the filter system. An example of a permanent groundwater control system is shown in figure 1-2.



(Fruco & Associates, Inc.)

U.S. Army Corps of Engineers

Figure 1-2. Permanent groundwater control system.

CHAPTER 2

METHODS FOR DEWATERING, PRESSURE RELIEF, AND SEEPAGE CUTOFF

2-1. General.

a. Temporary 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 drainage 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

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

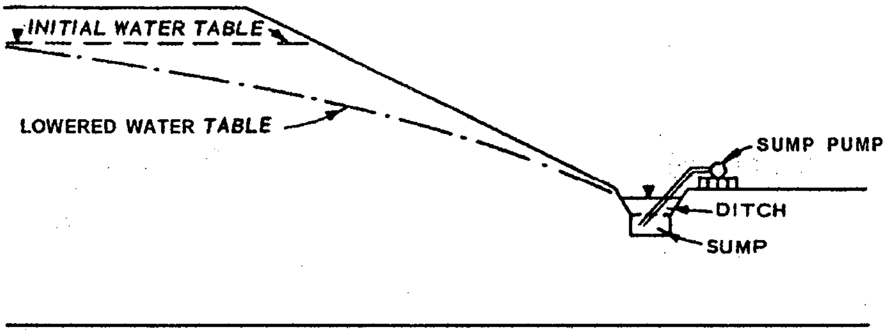

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Figure 2-1. Dewatering open excavation by ditch and sump.

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

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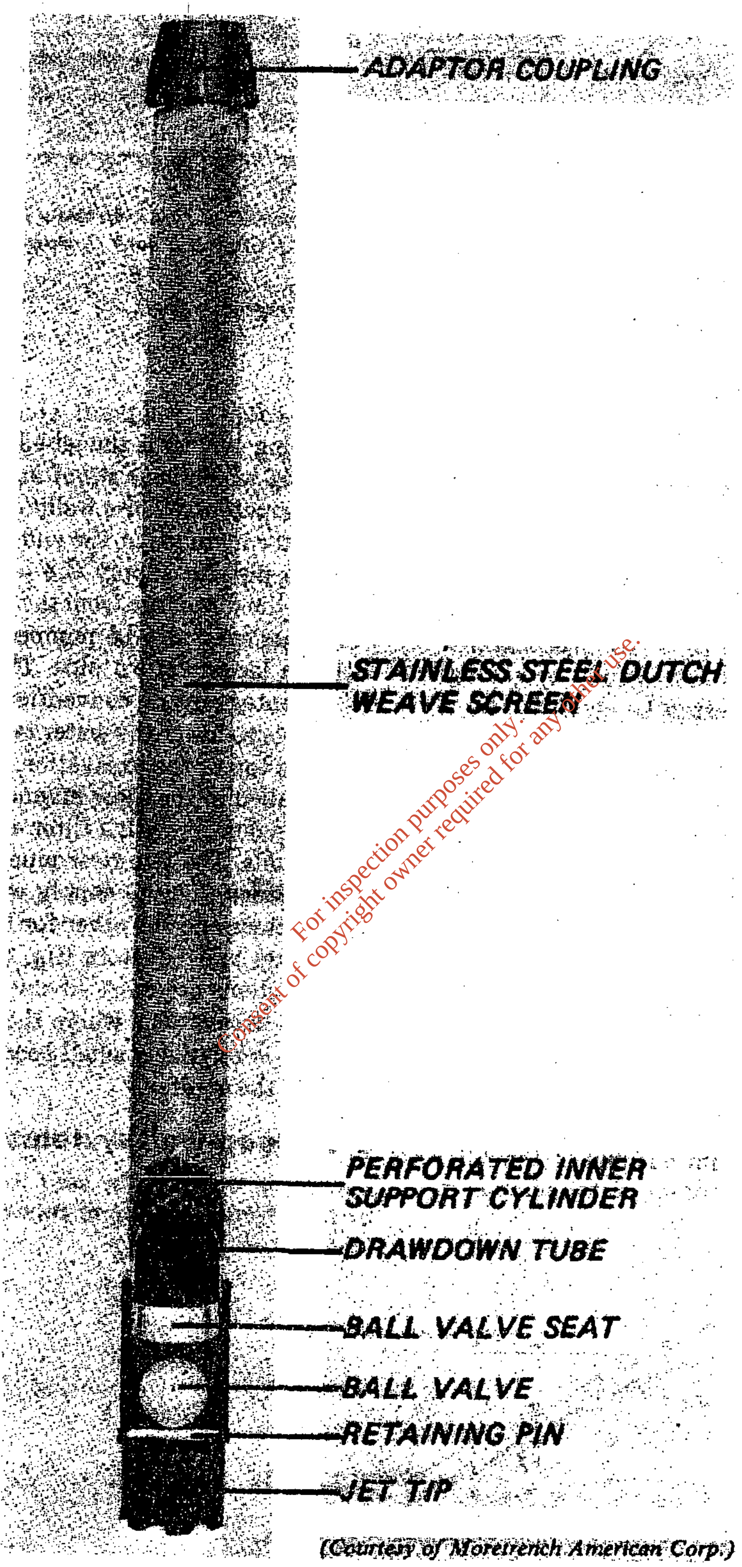

(Courtesy of Moretrench American Corp.)

Figure 2-2. Self-jetting wellpoint.

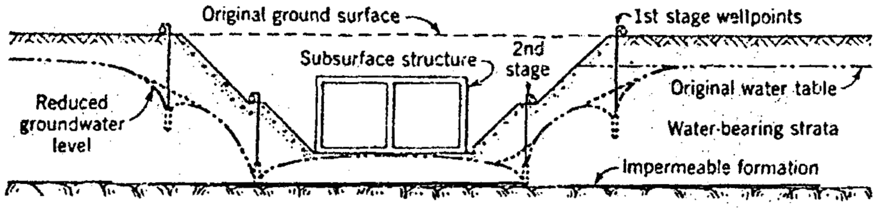

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Figure 2-3. Use of wellpoints where submergence is small

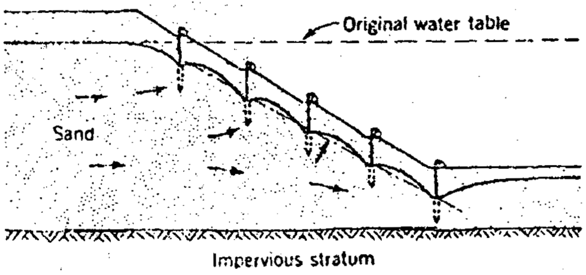
supplementary method of dewatering if needed. Wellpoints are more suitable than deep wells where the submergence available for the well screens is small (fig. 2-3) and close spacing is required to intercept seepage.

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.

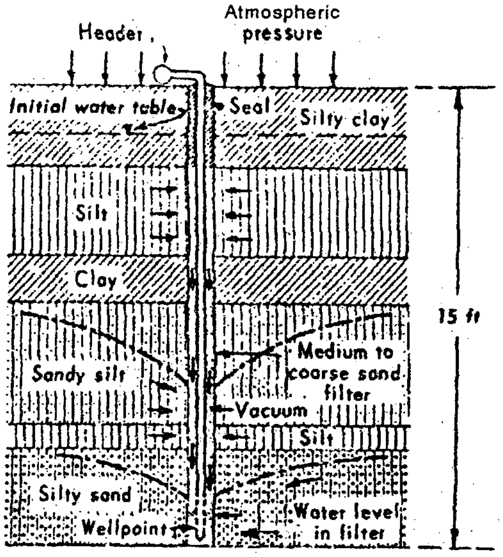
2-5. Deep-well systems.

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 wellpoint 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 unencumbered 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

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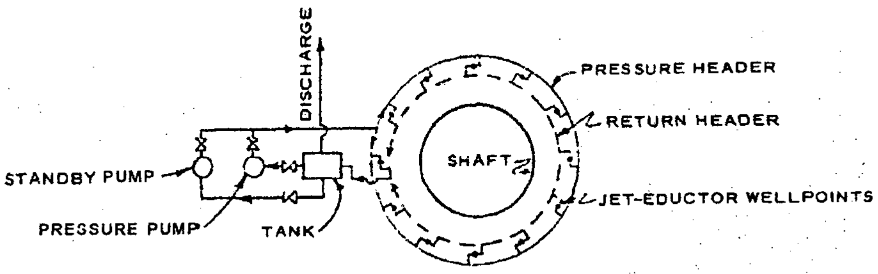
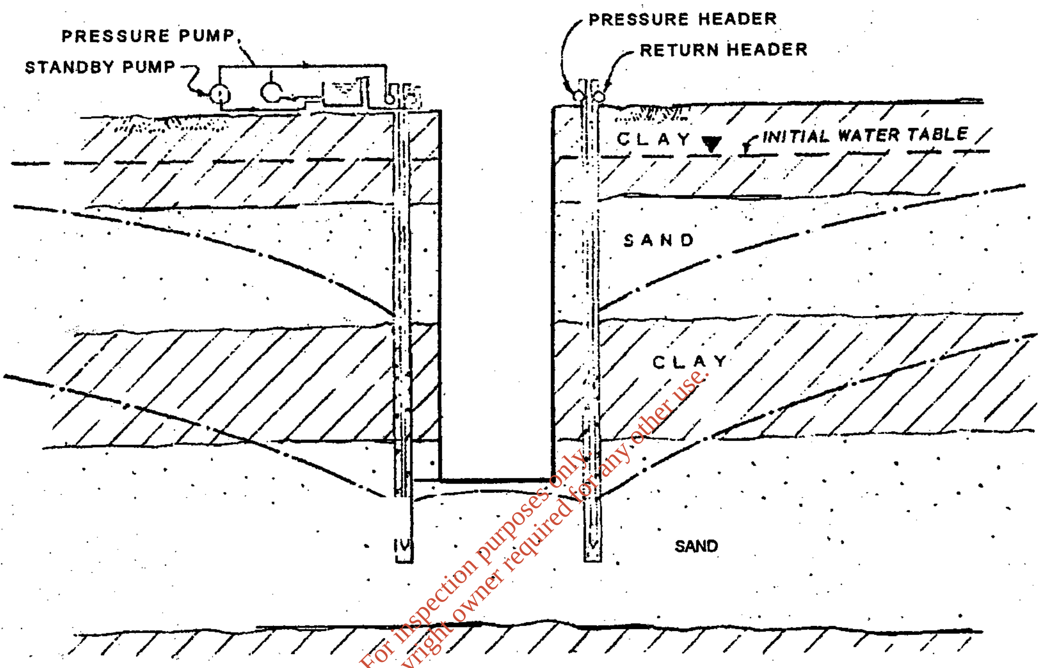
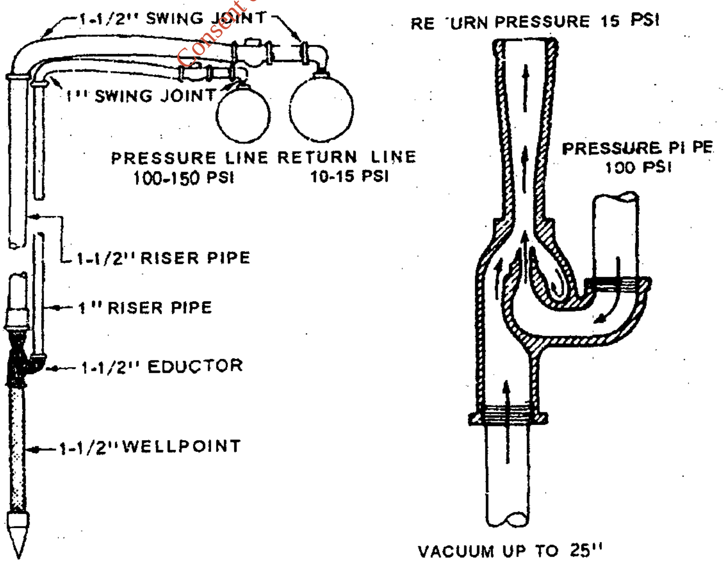


a. PLAN



b. SECTION



c. TYPICAL EDUCTOR WELLPOINT

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Figure 2-6. Jet-eductor wellpoint system for dewatering a shaft.

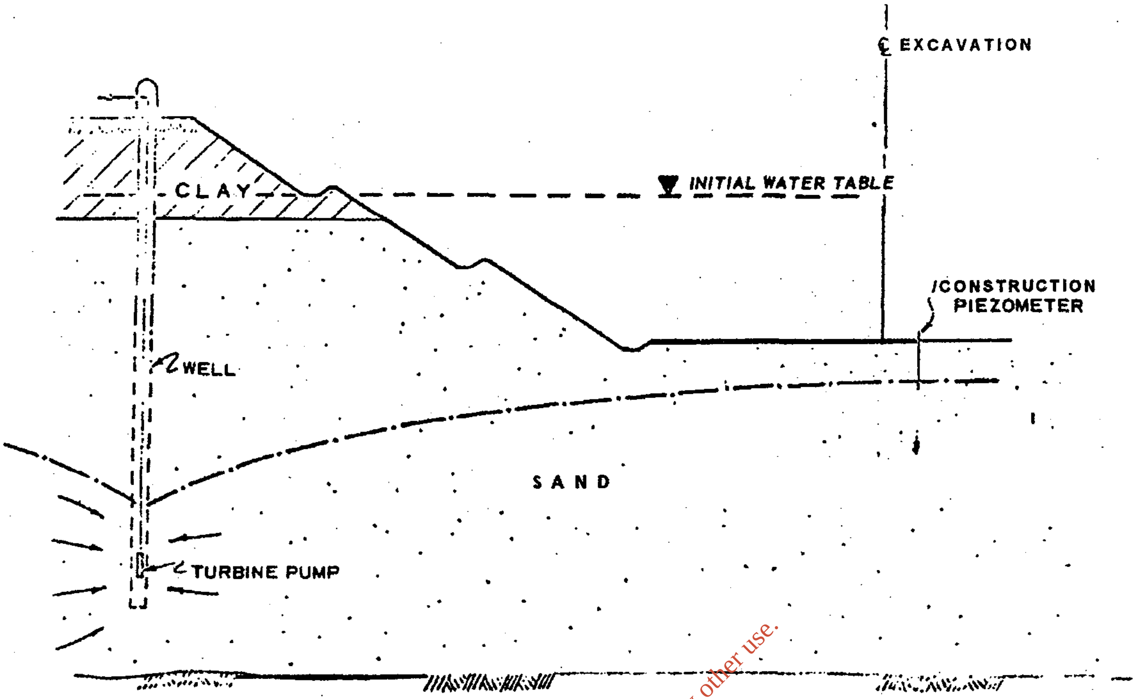

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Figure 2-7. Deep-well system for dewatering an excavation in sand.

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 4-9*g*(2) and 5-5*b*.

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 obstructions 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-

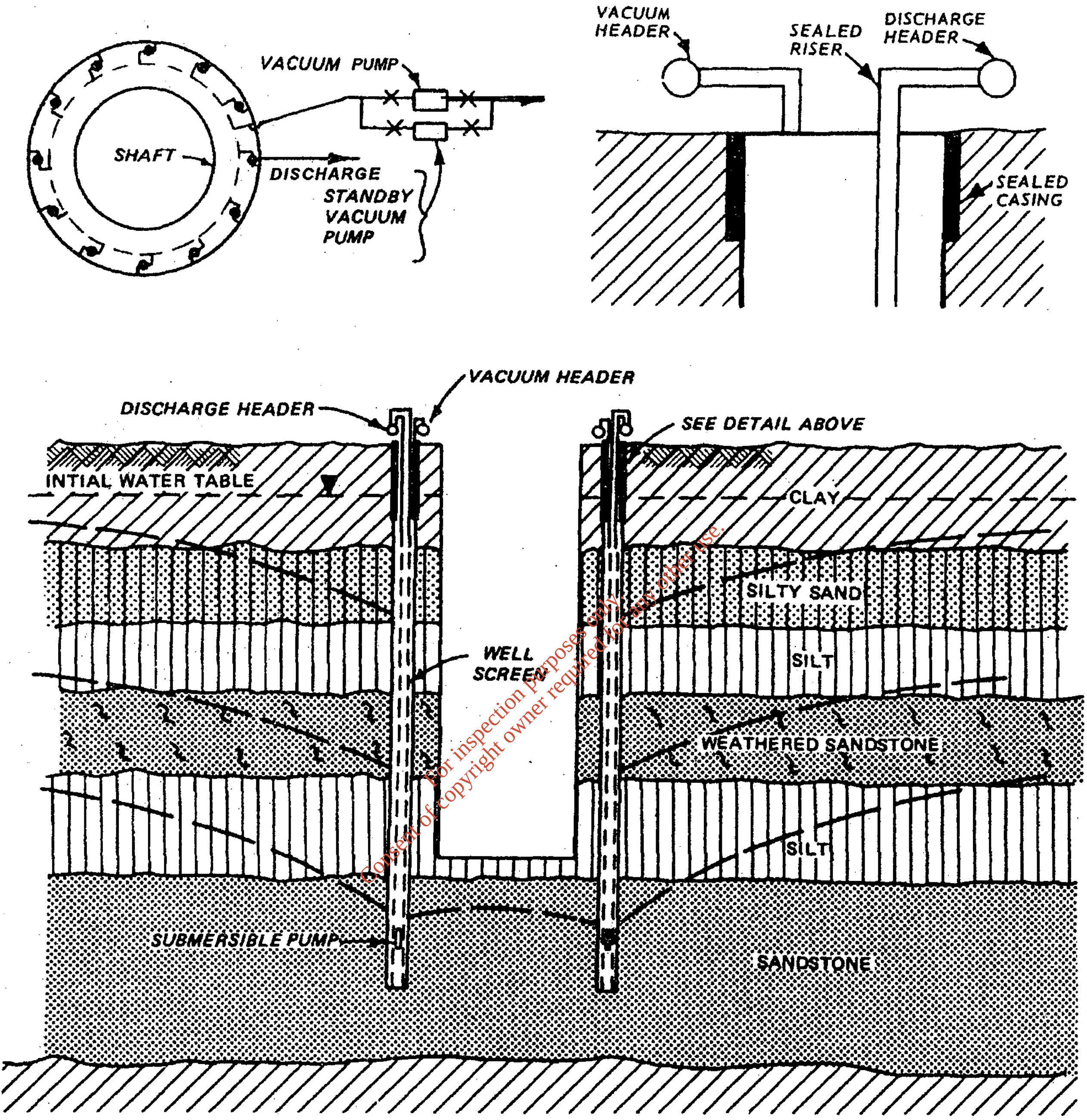

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Figure 2-8. Deep wells with auxiliary **vacuum** *system for dewateringa shaft in stratified materials.*

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

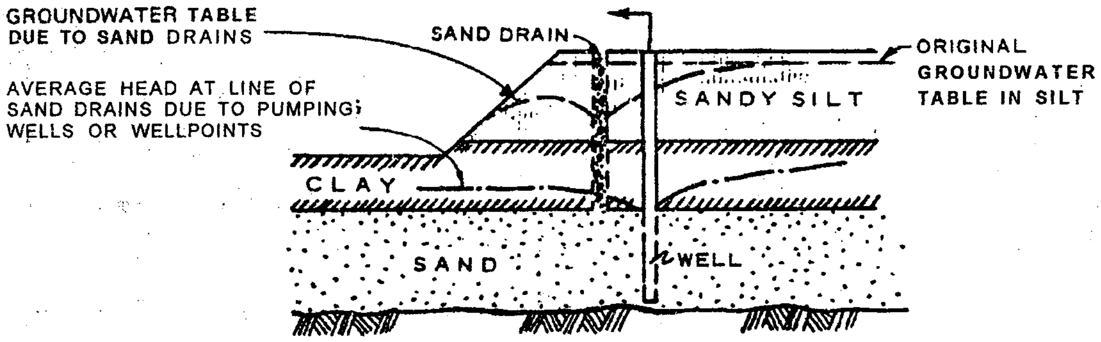

Figure 2-9. Sand drains for dewatering a slope.

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.

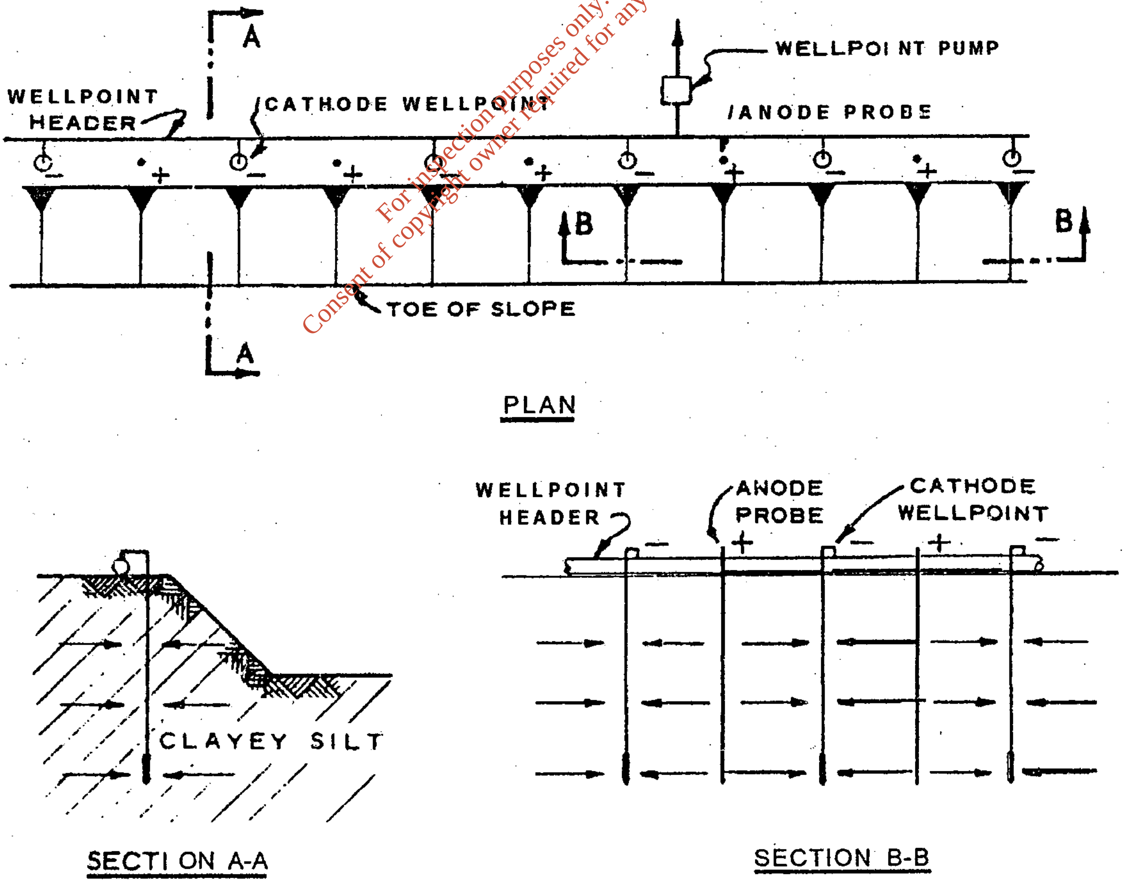

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Figure 2-10. Electro-osmotic wellpoint system for stabilizing an excavation slope.

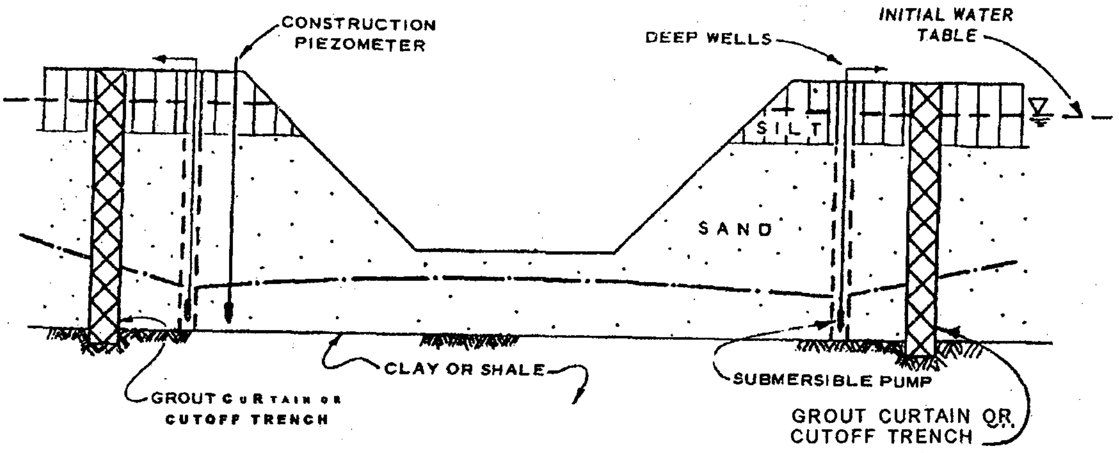

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Figure 2-11. Grout curtain or *cutoff trench* around an *excavation.*

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.

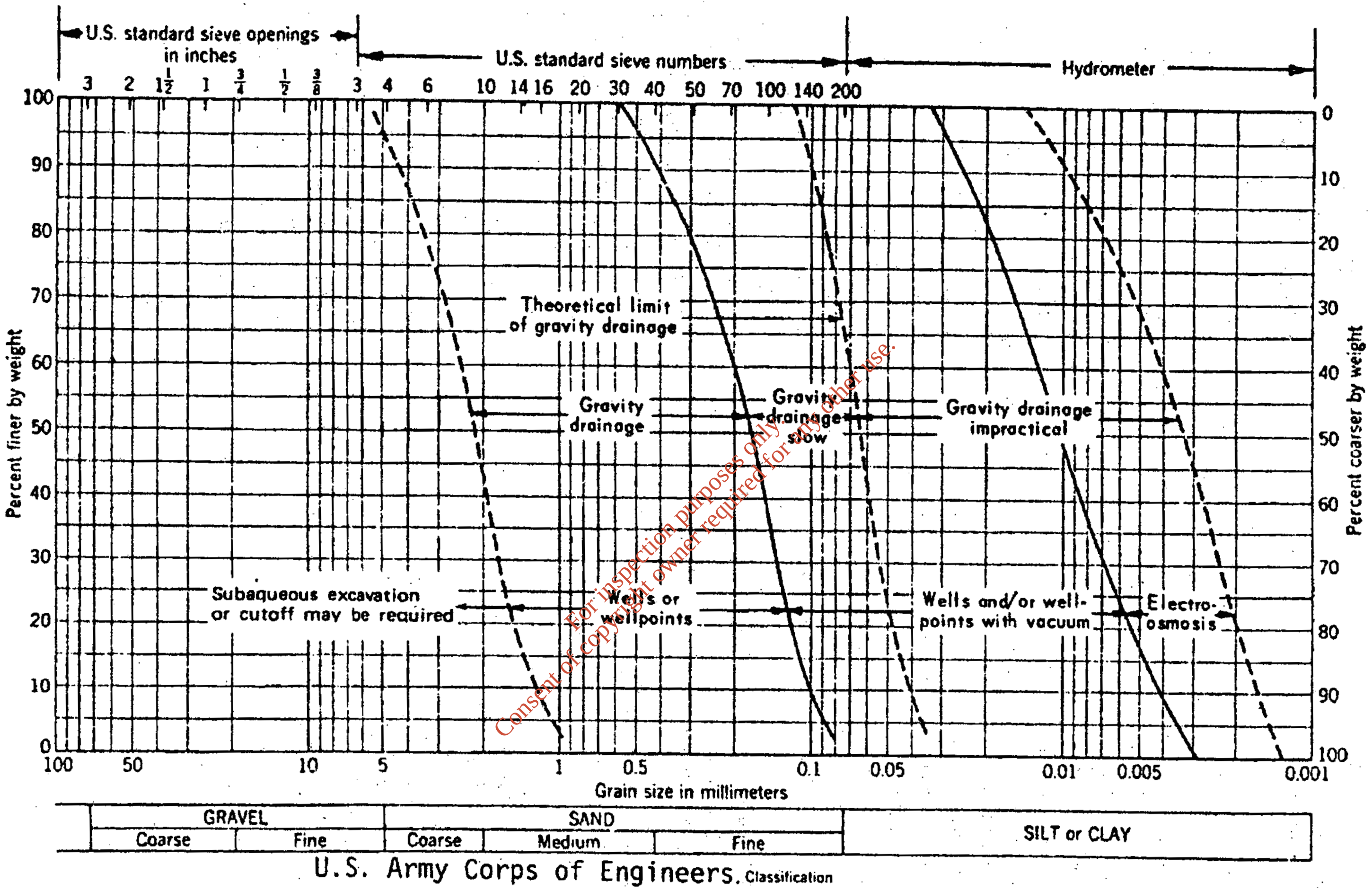
(3) *Depth of groundwater lowering.* The magnitude of the drawdown required is an important consideration in selecting a dewatering system. If the drawdown required is large, deep wells or jet-eductor wellpoints may be the best because of their ability to achieve large drawdowns from the top of an excavation, 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 groundwater 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.

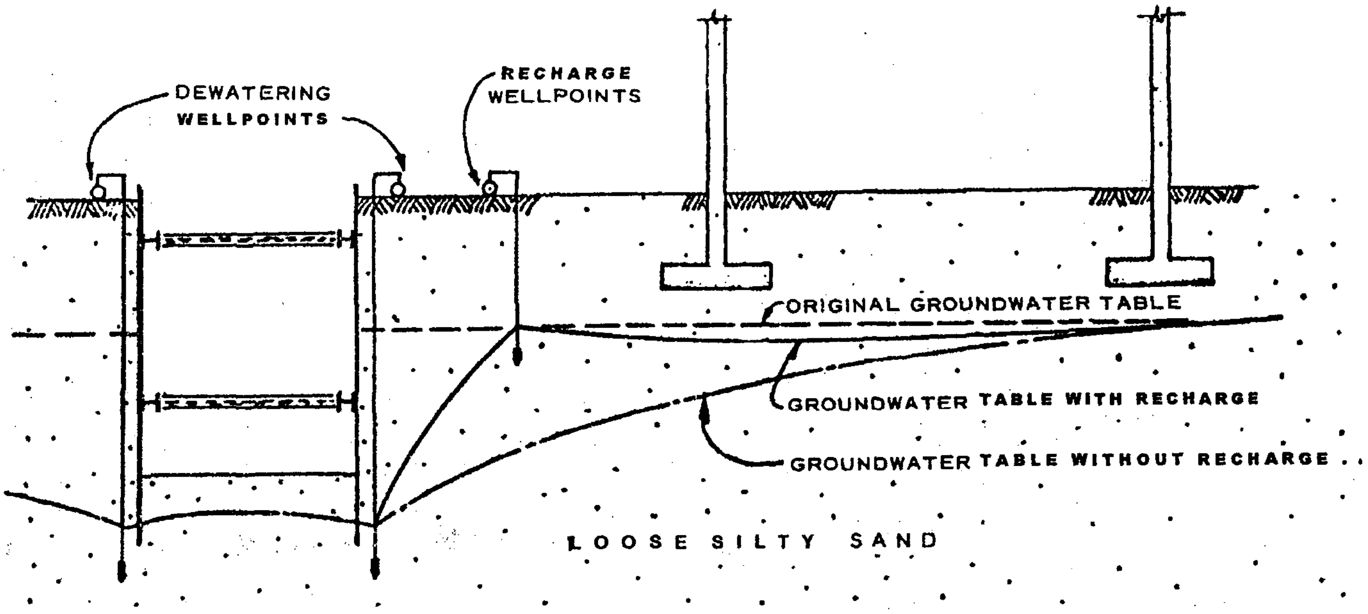


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Figure 2-13. Recharge of groundwater *to prevent settlement of a building* as *a result of dewatering operations.*

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.