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Groundwater
and
Wells

Second Edition

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at selected points in an often irregular field. This generally involves the installation of multiple wells that are mutually interfering, and therefore the specific capacity is less than optimal. This contrasts with the conventional water well approach, where the number of wells is limited for a certain yield, interference is minimized or avoided altogether, and maximum well efficiency is of paramount importance. Well efficiency is usually of secondary importance in the design of well-point dewatering systems, because most of these systems are installed in highly heterogeneous sediments and are usually pumped for only brief periods. Ease of installation, ruggedness, and flexibility in design are generally more important factors than well efficiency. On the other hand, efficiency is quite important for deep wells which individually are much more expensive to construct and are usually pumped for long periods. High efficiency minimizes the number of deep wells required for a dewatering system.

If pumping test data are not available to provide estimates for transmissivity and storage, the hydraulic conductivity of the surficial material can be estimated from the graphs in Figure 22.1, provided the density of the material is known. Density is obtained from a standard penetration test (ASTM D1586) in which the number of blows per foot are recorded as a split-spoon sampler is driven by a 140-lb (63.5-kg) hammer falling 30 in (762 mm) (see Table 22.1). Transmissivity is then calculated by multiplying the hydraulic conductivity by the estimated thickness of the material to be dewatered.

Storage coefficients can also be estimated if pumping test data are not available. Storage coefficients for unconfined aquifers range from 0.01 to 0.3, and for confined aquifers they range from 10^{-5} to 10^{-3}. For coarse-grained material in an unconfined aquifer, a storage coefficient of 0.2 is generally used. If finer material is present (clays or silts), there may be more water in the pores, but the actual volume of water removed from clays and silts during dewatering may be quite small as compared to coarser grained material. For confined conditions, a storage coefficient of 10^{-5} is assumed for fine-grained sandstone/siltstone formations, whereas 10^{-3} is a good value for clean, coarse-grained sandstone.

Effective dewatering of fine sediments will require much more time and considerably closer well spacings because of significantly lower transmissivity. In practice, only enough water is removed from these fine sediments to increase the density to the point where the material is stable. Some capillary water is needed in the pore spaces to bond or hold the small grains together. Sand drains, electro-osmosis techniques, and well-point systems put under vacuum are methods used to dewater fine-grained materials. Firms familiar with these and other techniques should be consulted when fine-grained materials are to be dewatered.

Table 22.1. Soil Density from Standard Penetration Test (ASTM D1586)*

Granular Soils	Cohesive Soils
0 – 10 Loose	0 – 4 Soft
10 – 30 Medium dense	4 – 8 Medium stiff
30 – 50 Dense	8 – 15 Stiff
Over 50 Very dense	15 – 30 Very stiff

*Blows per foot of a 140-lb hammer falling 30 inches on a standard split-spoon sampler.
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Table 5.1 Porosities for Common Consolidated and Unconsolidated Materials

Unconsolidated Sediments	η (%)	Consolidated Rocks	η (%)
Clay	45–55	Sandstone	5–30
Silt	35–50	Limestone/dolomite (original & secondary porosity	1–20
Sand	25–40	Shale	0–10
Gravel	25–40	Fractured crystalline rock	0–10
Sand & gravel mixes	10–35	Vesicular basalt	10–50
Glacial till	10–25	Dense, solid rock	< 1

volume of water an aquifer can hold, it does not indicate how much water the aquifer will yield.

When water is drained from a saturated material under the force of gravity, the material releases only part of the total volume stored in its pores. The quantity of water that a unit volume of unconfined aquifer gives up by gravity is called its specific yield (Figure 5.5). Specific yields for certain rocks and sediment types are presented in Table 5.2. Some water is retained in the pores by molecular attraction and capillarity. The amount of water that a unit volume of aquifer retains after gravity drainage is called its specific retention. The smaller the average grain size, the greater is the percent of retention; the coarser the sediment, the greater will be the specific yield when compared to the porosity. The surface area for different-size sand grains is shown in Table 5.3. Note the large increase in surface area for the finest sediment. As the surface area increases, a larger percentage of the water in the pores is held by surface tension or other adhesive forces. Therefore, finer sediments have lower specific yields compared to coarser sediments, even if they both have the same porosity.

Specific yield plus specific retention equals the porosity of an aquifer. Both specific yield and specific retention are expressed as decimal fractions or percentages. Specific yields of unconfined aquifers (equivalent to their storage coefficients*) range from 0.01 to 0.30. Specific yields cannot be determined for confined aquifers because the aquifer materials are not dewatered during pumping.

Storage coefficients are much lower in confined aquifers because they are not drained during pumping, and any water released from storage is obtained primarily by compression of the aquifer and expansion of the water when pumped. During

Table 5.2. Representative Specific Yield Ranges for Selected Earth Materials

Sediment	Specific Yield, %
Clay	1–10
Sand	10–30
Gravel	15–30
Sand and Gravel	15–25
Sandstone	5–15
Shale	0.5– 5
Limestone	0.5– 5

(Walton, 1970)

*The coefficient of storage is fully defined in Chapter 9. Briefly, it is the volume of water taken into or released from storage per unit change in head per unit area.

Clastic. Pertaining to a rock or sediment composed principally of broken fragments that are derived from pre-existing rocks or minerals and that have been transported some distance from their places of origin.

Coefficient of permeability. An obsolete term that has been replaced by the term hydraulic conductivity.

Coefficient of storage. The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Coefficient of transmissivity. See Transmissivity.

Colloid. Extremely small solid particles, 0.0001 to 1 micron in size, which will not settle out of a solution; intermediate between a true dissolved particle and a suspended solid which will settle out of solution.

Cone of depression. A depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn. It defines the area of influence of a well.

Confined aquifer. A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.

Contamination. The degradation of natural water quality as a result of man's activities. There is no implication of any specific limits, since the degree of permissible contamination depends upon the intended end use, or uses, of the water.

Corrosion. The act or process of dissolving or wearing away metals.

Darcy's law. A derived equation for the flow of fluids on the assumption that the flow is laminar and that inertia can be neglected.

Deflocculation. Breakup of flocs of gel structures by use of a thinner.

Density. Matter measured as mass per unit volume expressed in pounds per gallon (lb/gal), pounds per cubic ft (lb/ft^3), and kilogram per cubic m (kg/m^3).

Desalination. To remove salt and other chemicals from sea water or saline water.

Development. The act of repairing damage to the formation caused by drilling procedures and increasing the porosity and permeability of the materials surrounding the intake portion of the well.

Diatomaceous earth. A light-colored, soft, siliceous earth composed of the shells of diatoms, a form of algae. Some deposits are of lake origin but the largest are marine.

Dispersion. The spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

Dissociation. A chemical process that causes a molecule to split into simpler groups of atoms, single atoms, or ions. For example, the water molecule (H_2O) breaks down spontaneously into H^+ and OH^- ions.

Drainage basin. The land area from which surface runoff drains into a stream channel or system of channels, or to a lake, reservoir, or other body of water.

Drawdown. The distance between the static water level and the surface of the cone of depression.

Drill collar. A length of extremely heavy steel tube. It is placed in the drill string immediately above the drill bit to minimize bending caused by the weight of the drill pipe.

Drill pipe. Special pipe used to transmit rotation from the rotating mechanism to the bit. The pipe also transmits weight to the bit and conveys air or fluid which removes cuttings from the hole and cools the bit.

Drilling fluid. A water- or air-based fluid used in the water-well drilling operation to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill string and the sides of the hole, and to seal the borehole.

Drive point. See Well point.

Effective size. The 90-percent-retained size of a sediment as determined from a grain-size analysis; therefore, 10 percent of the sediment is finer and 90 percent is coarser.

Effluent. A waste liquid discharge from a manufacturing or treatment process, in its natural state or partially or completely treated, that discharges into the environment.

Electrical conductance. A measure of the ease with which a conducting current can be caused to flow through a material under the influence of an applied electric field. It is the reciprocal of resistivity and is measured in mhos per foot (meter).

Electrical resistivity. The property of a material which resists the flow of electrical current measured per unit length through a unit cross-sectional area.

Electrolyte. A chemical which dissociates into positive and negative ions when dissolved in water, increasing the electrical conductivity.