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Groundwater Investigations

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Module 6: Groundwater Investigations

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the two primary types of groundwater investigations and their role in geotechnical design.
- **Select** appropriate field methods for determining groundwater levels and measuring subsurface permeability.
- **Evaluate** the reliability and technical constraints of various permeability tests, including pumping, slug, and dissipation tests.

Executive Summary: Groundwater conditions and seepage potential are fundamental factors in nearly all geotechnical analyses. Investigations must determine water levels and pressures while measuring subsurface permeability to inform designs for dewatering, seepage control, and contaminant migration.

Design Fundamentals

Groundwater evaluation is a basic element of almost all geotechnical programs. These investigations are divided into two primary types:

- **Determination of groundwater levels and pressures.**
- **Measurement of the permeability** of subsurface materials.

These investigations identify the elevation of the water table, perched water tables, aquifers, and artesian pressures. Data is critical for studying seepage through earth dams, well yields, infiltration, and construction dewatering.

Determination of Groundwater Levels and Pressures

Groundwater identification requires the same level of care as soil descriptions. At a minimum, engineers should measure water entry during drilling and record levels at least once following drilling completion.

Information on Existing Wells

Existing water well logs are excellent sources for identifying materials and historical water levels. Public and private records may provide extensive data on seasonal fluctuations. This information is often regulated by state agencies such as the Department of Transportation or Division of Water Resources.

Open Borings

In open borings, measure water levels after prolonged drilling interruptions, at boring completion, and again 12 to 24 hours later.

- **Recording:** Always record the date and time of each observation.
- **Caving:** If a borehole caves, record the depth of the collapsed region as it may indicate specific groundwater conditions.

⚠ Safety Constraint: Drilling mud can obscure groundwater observations due to filter cake action. If drilling fluids are used, the drill crew must **baile the hole** prior to making measurements.

Observation Wells

Observation wells and piezometers are the fundamental means for measuring water head in an aquifer.

- **Piezometers:** Measure pressure in a confined aquifer or at a specific horizon.
- **Observation Wells:** Measure the level in a water table aquifer.

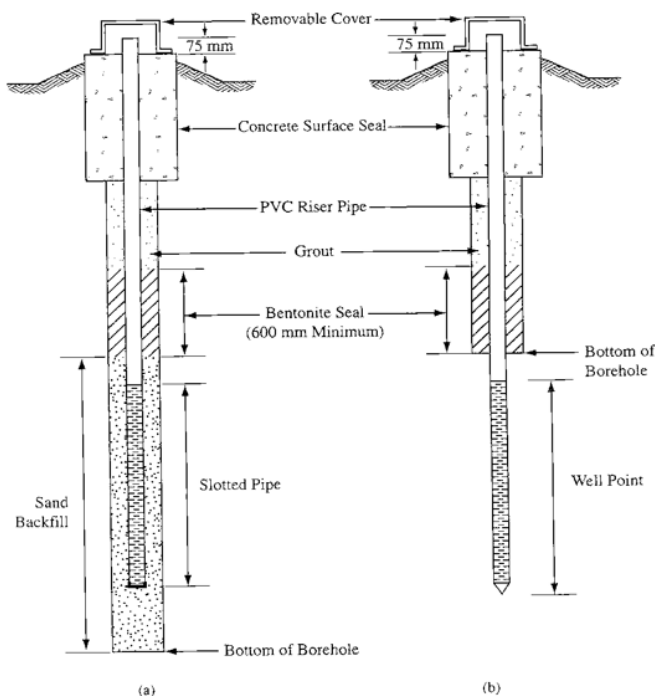


Figure 6-1. Representative Details of Observation Well Installations. (a) Drilled-in-place Stand- Pipe Piezometer, (b) Driven Well Point.

💡 Design Tip: Minimum pipe diameters should allow the introduction of a bailer or pumping apparatus to remove fine-grained materials and improve response time.

Water Level Measurements

Standard practice uses the top of the casing as a reference point for depth measurements.

- **Chalked Tape:** A metal tape is chalked at the lower end and lowered until it passes the water surface. This is the most accurate method, especially for pump tests.
- **Tape with a Float:** A float is lowered until it hits the water and the tape goes slack. While common, accuracy is poor.
- **Electric Water-Level Indicator:** A battery-operated probe triggers a light or horn upon contacting water. It is advantageous for extremely small holes.
- **Data Loggers:** Useful for frequent measurements during pump or slug tests. They utilize electric transducers to sense pressure changes.

Field Measurement of Permeability

Permeability (k), or hydraulic conductivity, represents a flow property of the geomaterial. It is closely related to the coefficient of consolidation (c_v), which controls the time rate of settlement.

Equation 6-1:

$$q = k \cdot i \cdot A$$

Where:

- q = flow (cm^3 / sec)
- k = coefficient of permeability (cm/sec)
- i = hydraulic gradient
- A = cross-sectional area of flow

Table 6-1. Field Methods For Measurement of Permeability

Test Method	Applicable Soils	Reference
Various Field Methods	Soil & Rock Aquifers	ASTM D 4043
Pumping tests	Drawdown in soils	ASTM D 4050
Double-ring infiltrometer	Surface fill soils	ASTM D 3385
Infiltrator with sealed ring	Surface soils	ASTM D 5093
Various field methods	Soils in vadose zone	ASTM D 5126
Slug tests.	Soils at depth	ASTM D 4044
Hydraulic fracturing	Rock in-situ	ASTM D 4645
Constant head injection	Low-permeability rocks	ASTM D 4630
Pressure pulse technique	Low-permeability rocks	ASTM D 4630
Piezocone dissipation	Low to medium k soils	Houlsby & Teh (1988)
Dilatometer dissipation	Low to medium k soils	Robertson et al. (1988)
Falling head tests	Cased borehole in soils	Lambe & Whitman (1979)

Seepage Tests

Seepage tests are valuable for sands or gravels where undisturbed laboratory samples are difficult to obtain.

- **Rising Level Test:** This is the preferred method. It avoids pore clogging but requires sounding the hole base to ensure heaving has not occurred.
- **Falling Level Test:** Water flows from the hole to the soil; sediment in the test water may clog soil pores.
- **Constant Level Test:** Used when permeability is too high for accurate rising or falling measurements.

Pressure ("Packer") Test

This test determines the apparent permeability and soundness of rock by forcing water under pressure through borehole walls.

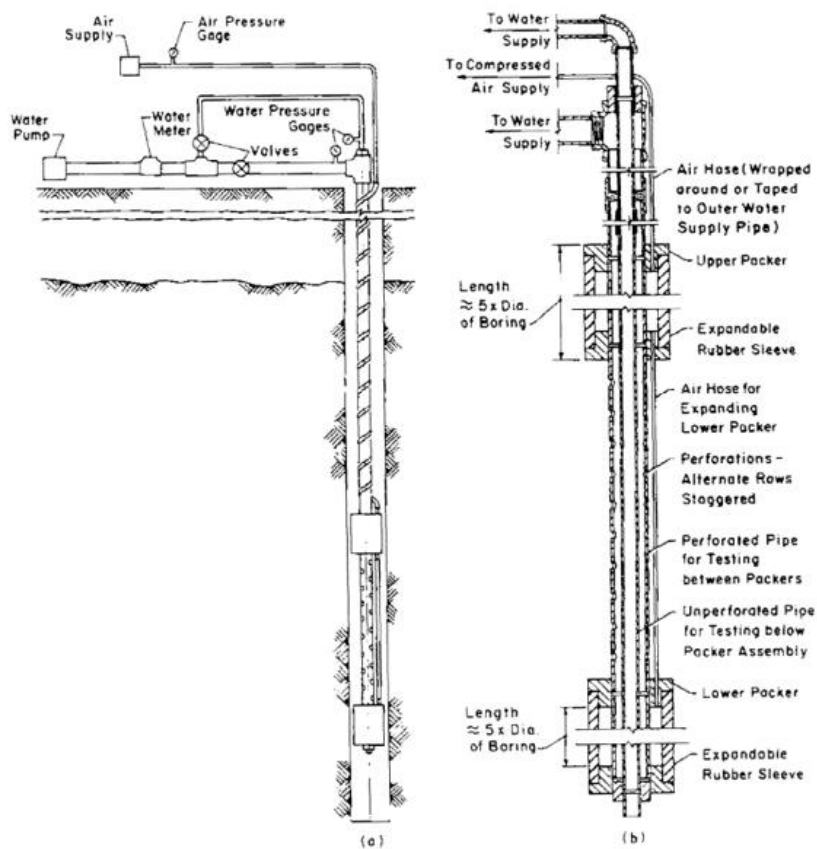


Figure 6-2. Packer-Type Pressure-Test Apparatus for Determining the Permeability of Rock. (a) Schematic Diagram; (b) Detail of Packer Unit. (Lowe and Zaccheo, 1991)

⚠ **Safety Constraint:** Excess test pressure above the natural piezometric level must **never exceed 23 kPa per meter** of soil and rock overburden above the upper packer to prevent foundation damage.

Equation 6a (for $L \geq 10r$):

$$k = \left[\frac{Q}{2\pi LH} \right] \cdot \ln\left(\frac{L}{r}\right)$$

Where:

- **k** = apparent permeability
- **Q** = constant rate of flow
- **L** = length of test section
- **H** = differential head
- **r** = radius of borehole

Pumping Tests

Continuous pumping tests determine well yield and the permeability of subsurface materials in situ. They involve pumping from a central well and observing drawdown in an array of observation wells.

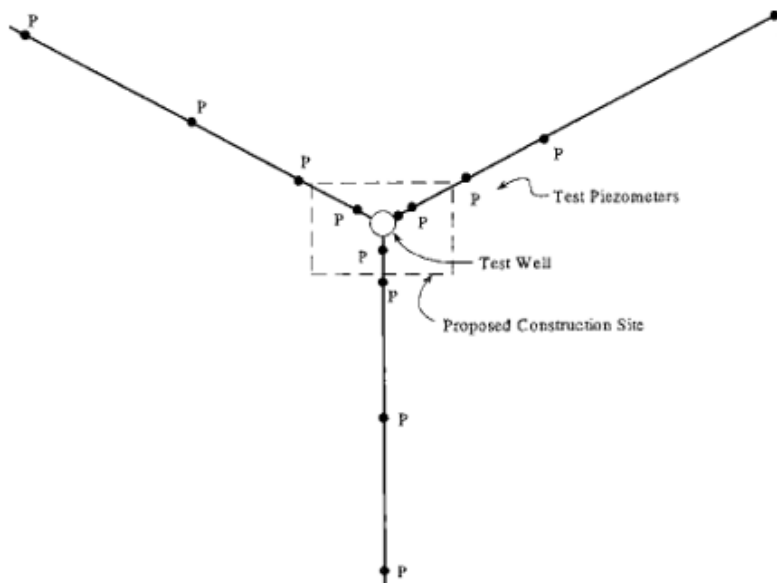


Figure 6-3. A General Configuration and Layout of Piezometers for a Pumping Test.



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