MEASURING AND MAPPING GROUND-WATER LEVELS IN WELLS

REASONS FOR TAKING WATER LEVELS

- Determine flow directions
- Identify changes in gradients and (or) flow directions (temporal variance)
- Measurements for aquifer testing
- Measurements related to ground-water sampling

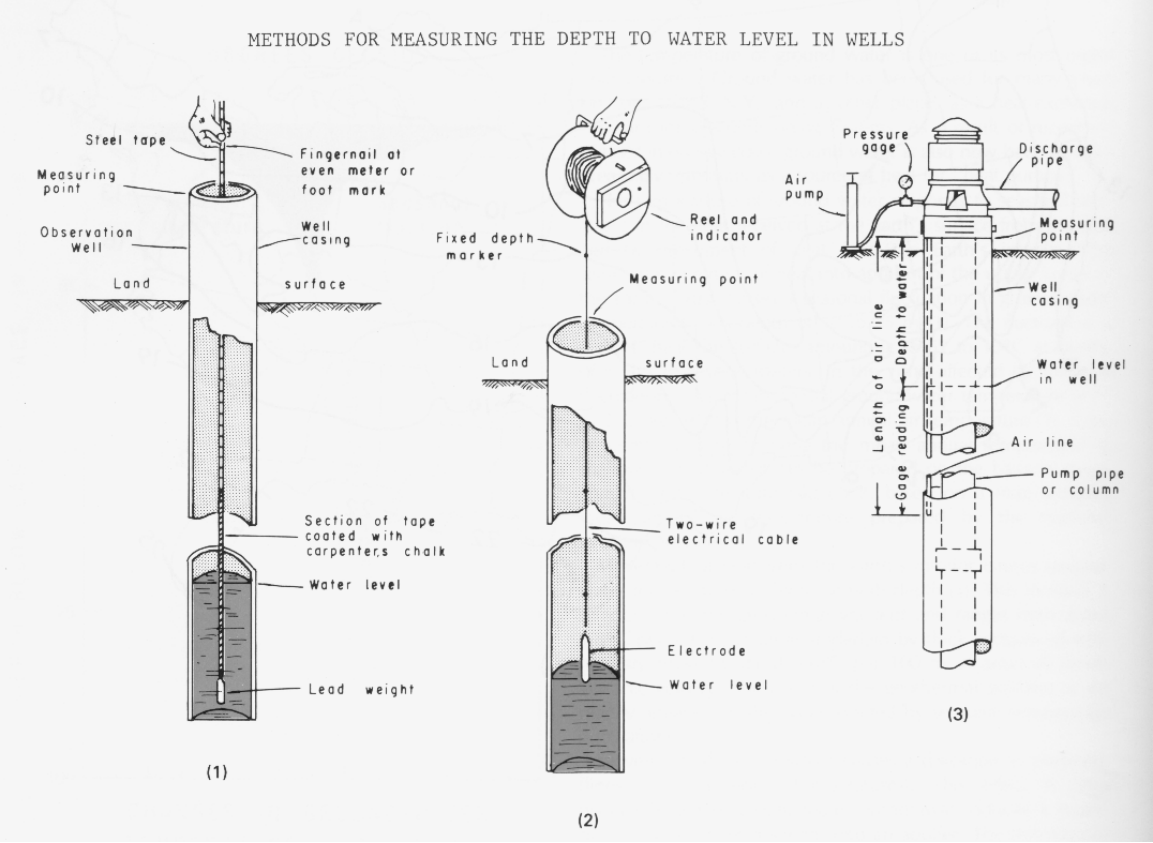


Figure --. Equipment and methods of manually measuring ground-water levels.

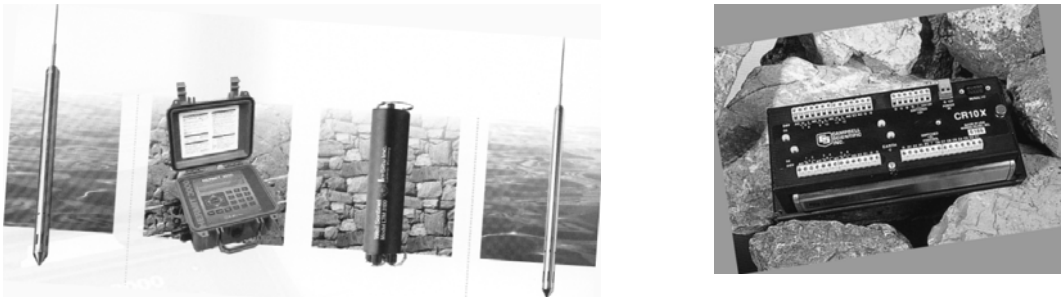


Figure --. Pressure transducers and data loggers for automatically measuring water levels.

A basic measurement in ground-water studies is that of water levels in wells. Measurements may be made with several types of equipment. The choice of equipment depends on several factors including the accuracy or ease of measurement required, water-quality concerns, type of well (monitoring or water supply), and pumping activity of well and (or) nearby wells.

For all measurements, a fixed reference point must be established at the well head. This point usually is the top of the casing or the access port in water-supply wells. The reference point typically is surveyed to establish its position above sea level, to an accuracy of 0.01 ft. To ensure the same reference points are used for all measurement, a notch or marking is made on the casing and the location of the point well documented in the site file. If the well cap is not vented, remove several minutes before measurement to allow water levels to equilibrate to atmospheric pressure.

The most accurate measurement (+- 0.01 feet (ft)) is obtained with a *chalked steel tape*. This method utilizes a graduated tape with a weight attached to its end. A quality steel tape has limited elasticity and with sufficient weight hangs vertically in the well. Older tapes may use a lead weight, but present concerns about water quality require that the weight be brass or stainless steel.

The lower 3-4 ft of the tape is coated with carpenter's chalk, and the tape is lowered into the water until the lower part of the tape (about 2 ft) is submerged. By lowering the tape at intervals of about 2-3 ft the contact of the weight with the water's surface can be heard. For wells with deep water levels, it may be necessary to approximately know the depth to water or to make several measurement attempts to ensure that the tape is not submerged below its chalked length. The tape is held at the reference point and the tape position recorded. The depth to the water level below the reference point is determined by subtracting the length of wet tape (indicated by wet chalk) from the total length of tape lowered into the well. To lessen the possibility of computation errors, the "hold" position should be either on even foot or --.99 ft. The measurement should be repeated to ensure its accuracy (two measurements of within 0.01 ft) and that the measured water level is static.

Steel tape measurements usually are required in studies where horizontal gradients are very low and, thus, are not accurately determined with less accurate measuring devices. For water-supply wells, particularly small-diameter (< 6 inches) domestic wells with pitless adapters, the tapes may be used without the weight to ensure against entanglement with the wiring and damage to the contained pump.

Electric measuring tapes typically consist of a pair of insulated wires whose exposed ends are separated by an air gap in an electrode and containing, in the circuit, a source of power such as flashlight batteries. When the electrode contacts the water surface, a current flows through the tape circuit and is indicated by an ammeter-needle deflection, light, and (or) audible signal. The "hold" depth against the reference point on the well is read directly from the tape as depth to water. Recent electric tapes are marked at 0.01 ft. Some tapes are marked at to 0.05 to 5 ft intervals, particularly tapes that are used in deep wells (> about 500 ft). For these tapes the unmarked interval must be estimated or measured with another device. Because the tape medium may be easily bent and the weight is often less than that used on steel tapes, the accuracy of electric tapes is considered to be +- 0.02, but may be as great as 0.1 ft. The tape can be calibrated against a steel tape and if several electric tapes are used in a study, they should all be calibrated against a reference steel tape. Calibration is especially important when electric tapes are used in studies of where horizontal gradients are small. If water levels are affected by nearby ground-water pumping or previous use of the well (not static), the measurement is more easily and accurately made with an electric tape.

Special sensing probes with an optical liquid sensor along and conducting electrodes is used to simultaneously measure the thickness of hydrocarbon layers floating on ground water and the depth to water.

Water levels in water-supply wells may not be measurable by steel or electric tapes if an access port is not present or the well cap is not easily removed. Such wells, particularly high-capacity industrial and municipal well use an air line for measurement. This method involves the installation of a small-diameter pipe or tube (the air line) from the top of the well to a point about 10 ft below the lowest anticipated water level and a pressure gage. The water level in this pipe is the same as that in the well. To determine the depth to water, an air pump with a sufficient pressure rating (1 PSI = 2.31 ft H20) are attached to the top of the air line (at a noted reference point and gage location). Air is pumped into the line until all the water is displaced. This occurs when the pressure indicated on the gage stabilizes. The gage reading indicates the length of submerged air line. The result of subtracting the submerged length of the air line from the total length of the air line is the depth to water below the measuring point. Air lines generally are accurate to about +- 1 ft.

Measurement of water levels often is intended to represent “static” levels. For water-supply wells, the well should generally not be used for a minimum of 30 minutes before measurements are made. Longer time periods generally are required for high-capacity wells.

Long term or near-continuous measurement of ground-water levels is generally done with the use of pressure transducers and automatic digital data loggers. Pressure transducers use silicon-based strain gages that generate an electric current. The current is calibrated to pressure (pounds per square inch) which can be related to water levels by the equation: 1 psi = 2.31 ft of water. Pressure transducers generally used vented cables to eliminate response to atmospheric pressure changes (thus measured changes do not include aquifer response to barometric pressure fluctuations). Pressure transducers are selected on the basis of expected water-level change. For example, 0-10 psi (up to 23 ft change in level); 0-30 psi. The smallest acceptable range provides the greatest measurement resolution. Accuracy generally is 0.01-0.1% of the full scale range. For example, for a 0-10 psi transducer with an accuracy of 0.01%, measurements will be to the nearest 0.02 ft. Data loggers are use to store measurements. Logger software allows measurement at various linear and logarithmic intervals, setting of sensitivity limits for data storage, and field calibration of the transducers.

Pressure transducers are temperature sensitive and cables are subject to stretching with time. Thus, the transducers must be both factory and field calibrated. To measure water levels, select appropriate psi-range transducer. Submerge to transducer to about mid-monitoring range (about 12 ft for 0-10 psi). Allow it to acclimate to ground-water temperature for about 20 minutes. Set factory-prescribed range, linearity, and offset for proper quadratic conversion of electric signal to psi/feet of water. Wrap a small piece of electrical tape on the transducer cable at the top of the well casing. Using a measuring tape position vertically on top of the well casing, raise the cable and transducer 1.00 ft; check water level change using the data logger. Raise cable another 1.00 ft. Check water level change again. Lower the cable 1.00 ft, check change and repeat. Each measurement should be within about 0.02 ft of the 1.00 ft raising increments. Secure the cable to the well head, so it will not slip and the reference tape can be used to monitor possible slippage. Measure the depth to water with a steel or electric tape and set reference depth in data logger (0.00 to record relative change or depth to water or water-level altitude. Periodically check the transducer reading with tape measurement to monitor electronic drift or slippage of the cable. If drift or slippage reset position and datum and adjust record accordingly (prorating change in position/depth reading?).

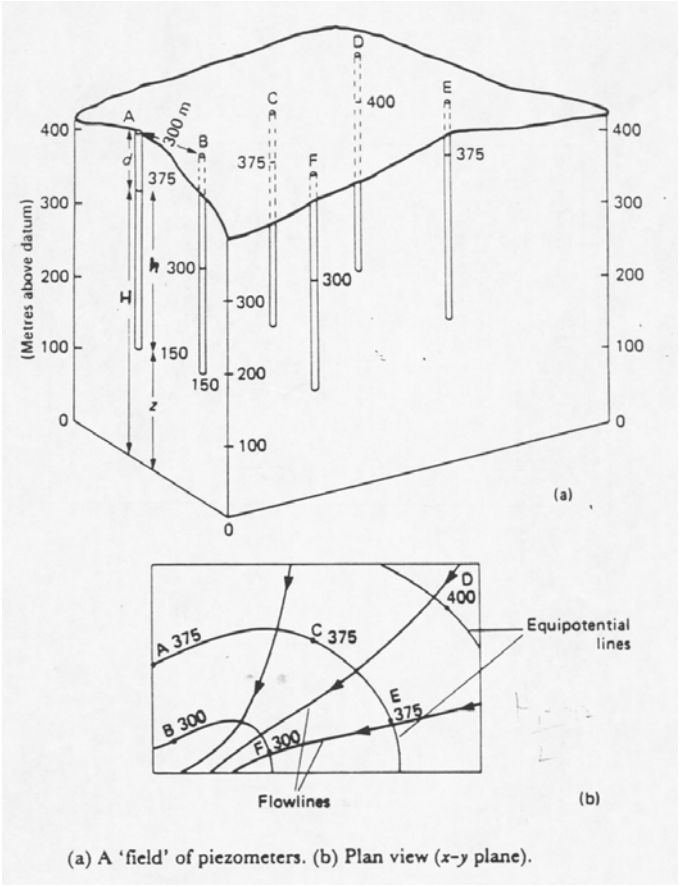
Major manufactures of pressure transducers include Druck and In-Situ, Inc. Major manufactures of data loggers include In-Situ, Inc. and Campbell Scientific, Inc. In-Situ's Hermit loggers are preprogrammed and easy to use. Campbell Scientific loggers are programmable and therefore very flexible in their application, but may be difficult to use because of the required programming language.

POTENTIAL INACCURACIES IN WATER-LEVEL MEASUREMENT AND MAPPING

- Faulty procedures and (or) equipment
- Incorrect measurement point used
- Long well screens intercept more than one aquifer unit
- Water levels not "static"
- Hydrocarbons (LNAPL's) in water (require special sensors, measured thickness in Well may be greater than mobile component in ground water)

Table -- Water-level measuring devices (Nielson, 1991)

Measurement method	Accuracy, in feet	Major interference or disadvantage
Non-flowing wells		
Steel tape and chalk	0.01	Cascading water
Electric tape	0.02-0.1	Cable wear; hydrocarbons on water
Pressure transducers	0.01-0.1	Temp. change; elect. drift; blocked capillary
Acoustic probe	0.02	Cascading water; hydrocarbons on water
Ultrasonics	0.02-0.01	Temperature change; well materials
Floats	0.02-0.05	Float or cable drag; float size or lag
Poppers	0.1	Well noise; well equipment; well depth
Air Lines	0.25-1.0	Air line or fitting leaks; gage inaccuracies
Flowing wells		
Transducers	0.02	Temperature changes; electronic drift
Casing extensions	0.1	Limited range; awkward
Manometer/ pressure gage	0.1-0.5	Gage inaccuracies; calibration required



(a) A 'field' of piezometers. (b) Plan view (x–y plane).

Figure – Mapping of potentiometric surface from measured ground-water levels

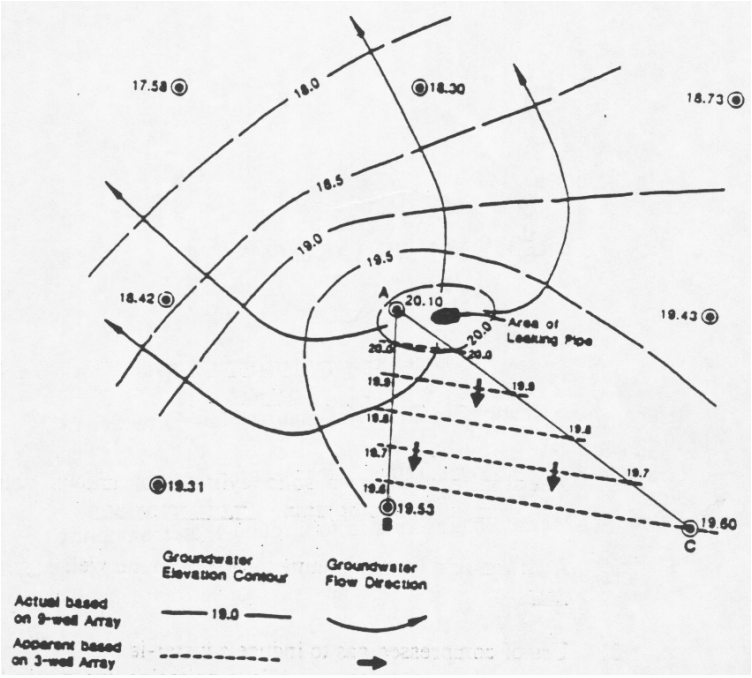


Figure .— Estimation of ground-water flow directions with 3- and 9-well array.

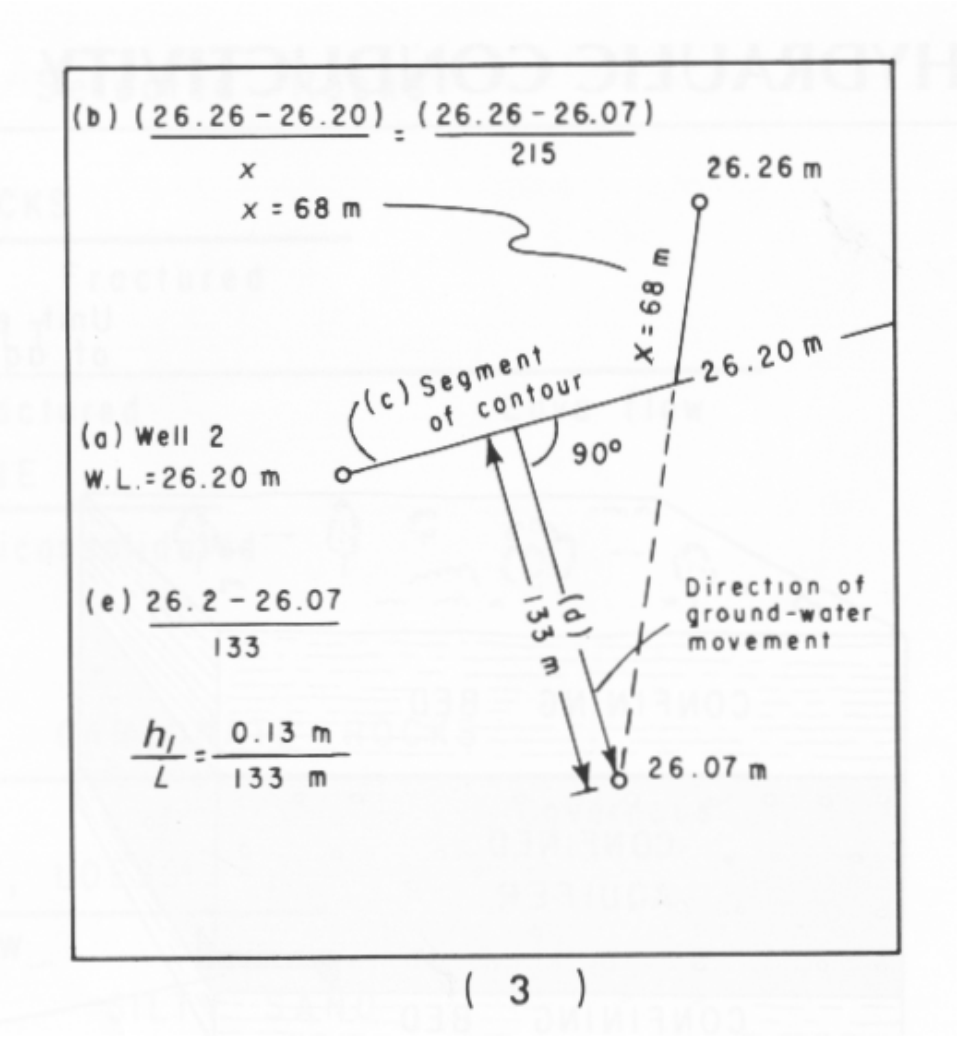


Figure – Method for determining direction of flow and hydraulic gradient from 3-well array . (Heath, 1983, p.11)

REFERENCE:

Garber, M.S. and Koopman, F.C., 1978, Methods of measuring water levels in deep wells: U.S. Geological Survey Techniques of Water-Resources Investigations of the United States Geological Survey, Book 8, Chapter A1, 23 p.