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MANUAL METHODS FOR MEASUREMENT OF GROUND WATER LEVEL IN A WELL

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FOREWORD

(Formal clauses of the foreword will be added later)

This standard deals with the measurement of a water level in a well which constitutes a data-collection process that provides fundamental information about the status of a groundwater system. Accordingly, measured water levels should be sufficiently accurate and reproducible to meet the needs of most data-collection and monitoring programs. Several manual methods commonly used to collect water level data in wells employ relatively simple measuring devices such as graduated steel tapes, electric tapes, and air lines. In some cases, water level measurements are required in flowing wells. The procedures associated with each of these methods are intrinsically different and subject to varying limitations and accuracies. Standardization of these methods would ensure that the procedures and associated equipment used by the international community to collect water level data in a well are consistent, and that the results can be compared with minimal concern about the relative accuracies.

It has been assumed in the formulation of this standard that the execution of its provisions is entrusted to appropriately qualified and experienced people, for whose guidance it has been prepared.

In reporting the results of a test or analysis made in accordance with this standard, if the final value observed or calculated, is to be rounded off, it shall be done in accordance with IS 2.

Draft Indian Standard

MANUAL METHODS FOR MEASUREMENT OF GROUND WATER LEVEL IN A WELL

1 SCOPE

1.1 This standard describes procedures and prescribes the accuracy required of water level measurements made in wells using graduated steel tapes, electric tapes, and air lines. Procedures and accuracy requirements for measuring water levels in a flowing well are also included, as are procedures required to establish a permanent measuring point. The standard discusses the advantages and limitations of each method and requirements for recording the data.

1.2 Excluded in this standard are methods that use automated electrical or mechanical means to record water levels.

2 TERMINOLOGY

For the purposes of this standard, the following terms and definitions apply:

2.1 Air Line

A water level measuring device consisting of a small diameter open-ended tube fixed in position that is accessible from the top of the casing and extends to below the water level in a well where pressurized air measurements can be used to determine the depth to water

2.2 Casing (Well Casing)

Tubular retaining structure, which is installed in a drilled borehole or excavated well, to maintain the borehole opening. Plain casing prevents the entry of water

2.3 Electric Tape

A water-level measuring device that uses an electrical signal sent through a cable with permanently fixed distance marks to indicate the water level that can be wound on a reel

2.4 Flowing Well (or Overflowing Well)

Well from which groundwater is discharged at the ground surface without the aid of pumping.

Note: A deprecated term for this definition is an artesian well

2.5 Graduated Steel Tape

A water level measuring device consisting of a flat measuring tape with permanently fixed distance marks that can be wound on a reel.

2.6 Groundwater

Sub-surface water occupying the zone of saturation and which is free to move under gravity. In a strict sense the term applies only to water below the water table.

2.7 Land Surface Datum

The point altitude of land surface at a reference well .

2.8 Measuring Point

Permanently reference mark on well casing or well parapet, as the case may be .

2.9 Static Water Level

The water level in a non-pumping well outside the area of influence of any pumping well. This level registers one point on the water table in a water-table well or one point on the pressure surface in a confined water well.

2.10 Static Head

The height, relative to an arbitrary reference level, or a column of water that can be supported by the static pressure at a given point.

2.11 Well

An artificial excavation (pit, hole, shaft) generally cylindrical in form and often walled in sunk (drilled, dug, driven, bored or jetted) into the ground to such a depth as to penetrate water yielding rock or soil and allow the water to flow or to be pumped to the surface.

3 WATER-LEVEL MEASUREMENT USING A GRADUATED STEEL TAPE

3.1 Purpose

To measure the depth to the water surface (level) below a measuring point using the graduated steel tape (wetted-tape) method.

3.2 Materials and Instruments

The following materials and instruments are required:

(a) a steel tape graduated in meters and centimeters. A black tape is preferred to a chromium-plated tape because the wetted chalk mark is easier to read against a black tape. A break-away weight should be attached to the ring on the end of the tape with wire strong enough to hold the weight, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free. The weight should be made of brass, stainless steel, or iron.

(b) colored chalk;

(c) a clean cloth;

(d) a pencil and eraser;

(e) a steel tape calibration and maintenance equipment log book;

(f) a water level measurement field form (Table 1);

(g) two wrenches with adjustable jaws for removing well cap; and

(h) common household chlorine bleach.

3.3 Data Accuracy and Limitations

The following data accuracy and limitations apply:

(a) Independent graduated steel tape measurements of static water levels should agree within + or – 10 mm for depths of less than 60 meters.

(b) For depths of 60 -150 meters, independent measurements using the same tape should agree within + or - 20 mm. An example of correcting a deep water level for thermal expansion and stretch of a steel tape is given in Annex A. However, because the equipment required to measure temperatures at land surface and down the well may not always be readily available, the corrections described in Annex A are not required for the purposes of this standard, though the practitioner shall note on the water-level field form (Table 1) whether or not any such corrections were applied. While measuring deeper water level (>60mts), there is always a possibility of overestimation of depth to water level, which arises due to drying up of the chalked portion on steel tape while pulling it out of the well. Hence on the spot correction needs to be incorporated accordingly. Manual measurement of water level using tap should be restricted upto 100m depth. In certain situation where chalked portion of the tap gets wet due to seeping water in the uncased well, alternative methods of water level measurement may be adopted.

(c) The steel tape should be calibrated against another steel tape conforming to IS 7068 'Specification for 6.25 mm calibration tape'.

(d) If the well casing is angled, instead of vertical, the depth to water will have to be corrected. If the casing angle is unknown and a correction is not feasible, this should be noted in water level measurement field form (Table 1).

3.4 Advantages and Disadvantages

The graduated steel tape method is easy to use and is considered to be the most acceptable method for measuring the water level in nonflowing wells of moderate depth. However, it may be impossible to get reliable results if water is dripping into the well or condensing on the well casing. Also, the method is not recommended for measuring pumping levels in wells.

3.5 Assumptions

The following assumptions apply in the use of the graduated steel tape method:

(a) an established measuring point (MP) exists and the vertical distance from the MP to land-surface datum (LSD) is known (Table 1). See the technical procedure for establishing a permanent MP.

(b) the results from previous water-level measurements made at the well are available for estimating the length of tape that is required;

(c) the steel tape will retain the chalk; and

(d) the well is free of obstructions. Well obstructions, if present, could cause errors in the measurement if the obstructions affect the plumbness of the steel tape.

3.6 Measurement Procedures

The following procedures for measuring water levels in a well with graduated steel tape shall be observed:

(a) Apply the colored chalk to the lower few centimeters of the tape by pulling the tape across the chalk. The wetted chalk mark will identify that part of the tape that was submerged.

(b) Lower the weight and tape into the well until the lower end of the tape is submerged below the water (more than one attempted measurement may be needed to determine the length of tape required to submerge the weight). Once the tape is submerged , hold the tape and extend it up to MP and read the measurements on tape opposite to MP. This reading on the tape shall be recorded as the “ MP HOLD (Fig 1).

(c) Pull the tape back to the surface before the wetted chalk mark dries and becomes difficult to read. Record the number of the wetted chalk mark (sometimes referred to as the cut) shall be recorded in the ‘WETTED CHALK MARK' (Fig 1) column of the water level measurements field form (Table 1).

(d) Subtract the wetted chalk mark number from the number held to the MP, and record this number in the ‘DEPTH TO WATER FROM MP' (Fig 1) column of the water level measurements field form (Table 1). The difference between these two readings is the depth to water below the MP.

(e) Apply the MP correction to get the depth to water below or above land-surface datum (LSD). If the MP is above land surface (Table 1), the distance between the MP and land surface datum is subtracted from the depth to water from the MP (Table 1) to obtain the depth to water below land surface. If the MP is below land surface, precede the MP correction value with a minus (-) sign and subtract the distance between the MP and land surface datum from the depth to water from the MP to obtain the depth to water below land surface. Record this number in the 'DEPTH TO WATER FROM LSD' (Fig 1) column of the water level measurements field form (Table 1). If the water level is above LSD, record the depth to water in metre above land surface as a negative number.

(f) After completing the well measurement(s), disinfect the steel tape by pouring a small amount of common household chlorine bleach on a clean cloth and wiping down the part of the tape that was submerged below the water surface. This will avoid possible contamination of other wells.

(g) The tape shall be maintained in good working condition by periodically checking the tape for rust, breaks, kinks and possible stretch due to the suspended weight of the tape and the tape weight.

All calibration and maintenance data associated with the steel tape being used shall be recorded in its calibration and maintenance equipment log book. All water-level data shall be recorded on the water level measurements field form (Table 1) to the nearest centimeter.

In some contaminated or pumped wells, a layer of oil may be floating on the surface of the water. In such cases, the tape reading made at the top of the oil mark can be used as the water-level measurement. The associated error in this case should be relatively small because the level of the oil surface would differ only slightly from the level of the water surface that would be measured if no oil were present. If a meter of more of oil is present, or if it is deemed necessary to ascertain the thickness of the oil layer, a commercially-available water-detection paste, originally developed to detect water in gasoline storage tanks, is available to do so. The paste can be applied to the end of the measuring tape that is lowered into the well. The top of the oil layer will be reflected as a wet line on the tape, while the top of the water will be shown by a distinct color change. In either event, whether the oil layer is greater than or less than a few millimeters in thickness, its presence should be noted on the water level measurements field form (Table 1).

4 WATER-LEVEL MEASUREMENT USING AN ELECTRIC TAPE

4.1 Purpose

To measure the depth to the water surface below a measuring point using the electric tape method.

Electric tapes fall into two categories:

Type 1 **:** Partially graduated tapes – Those with fixed graduations spaced at length not equal to or larger than the accuracy required for the reading to be made at sufficient accuracy with the use of additional graduated measures.

Type 2 **:** Fully graduated tapes – Those with fixed graduations which are spaced at lengths equal to or smaller than the accuracy required for the readings.

In general, fully graduated tapes are preferred to partially graduated tapes. Fully graduated tapes are easier to use and there are fewer opportunities for errors in measurement when the time intervals between measurements is small such as during pumping tests.

4.2 Materials and Instruments

The following materials and instruments are required:

(a) an electric tape of various wiring arrangements or configurations that would include flat parallel or co-axial conductive wires, graduated in meters and centimeters. Electric tapes are commonly mounted on a hand-cranked supply reel that contains space for the batteries and some device for signaling when the circuit is closed (Fig 2).

(b) an electric tape calibration and maintenance equipment log book;

(c) a pencil and eraser;

(d) a water level measurement field form (Table 2 and 2a);

(e) two wrenches with adjustable jaws for removing the well cap; and

(f) common household chlorine bleach.

(g) a steel tape graduated in meters and centimeters.

4.3 Data Accuracy and Limitations

The following data accuracy and limitations apply:

(a) independent electric tape measurements of static water levels using the same tape should agree within + or – 10 mm for depths of less than 60 meters;

(b) for depths of about 150 meters, the maximum difference of independent measurements using the same tape should agree within + or – 30 mm;

(c) for depths in the 500 meter range, the repeatability of measurements using the same tape should agree within + or – 150 mm .

4.4 Advantages and Disadvantages

The electric tape method is preferred to the graduated steel tape method when (a) water is dripping into the well or condensing on the inside of casing walls which may make it very difficult to get a good water mark on the chalked tape; (b) wells are being pumped and the splashing of the water surface makes chalked measurements virtually impossible; and (c) a series of measurements are needed in quick succession, such as in aquifer tests, because the electric tape does not have to be removed from the well for each reading. Also, the electric tape method is safer to use in pumping wells because the water is sensed as soon as the probe reaches the water surface and there is less danger of lowering the tape into the pump impellers.

Graduated steel tapes provide better measurements than the measurements provided by Electric tape. Electric tapes are also harder to keep calibrated than are steel tapes and electric connections need to be maintained in good order. Also, the insulation around the conductor cables may be severed when being drawn across sharp edges of metal pipes at the top of a borehole. In addition, the presence of hydrocarbons on the water surface that may result from oil leaks during drilling operations may coat the sonde, resulting in a failure to complete the electrical circuit. Finally, a stilling pipe may be required to avoid inaccurate readings where water is cascading down the borehole during pumping (aquifer) tests.

4.5 Instructions

The following procedures for measuring water levels in a well with an electric tape shall be observed:

(a) Prior to using an electric tape in the field, calibrate it by comparing the total length of the electric tape against the length of an acceptable steel tape. An acceptable steel tape is one that is maintained in the office for the sole purpose of calibrating electric tapes. Also, check the accuracy of the position of each 1 meter interval metal band to make sure that the bands have not moved. This is especially important if the electric tape has been used for a long time or after it has been pulled hard in attempting to free the line.

(b) Check the circuitry of the electric tape before lowering the probe into the well by dipping the probe into water and observe if the indicator operates (needle, light, or buzzer), indicating that the circuit is closing. Note the position the indicator needle deflects during the circuitry check.

(c) Make all readings using the same deflection point on the indicator scale so that water levels will be consistent between measurements.

(d) Lower the electrode probe slowly into the well until contact with the water surface (Fig 2) causes the circuit to close. Then place the nail of the index finger on the insulated wire at the MP once the indicator needle deflects to the point chosen during the circuitry check.

(e) For fully graduated tapes, partly withdraw the electric tape from the well and record the depth to water to the nearest centimeter. Record in the 'DEPTH TO WATER FROM MP' column of the water level measurements field form (Table 2).

For partially graduated tapes, partly withdraw the electric tape from the well and record the meter mark of the nearest 1-meter tape band below the MP in the 'NEAREST 1-meter TAPE BAND BELOW MP' column of the water level measurements field form (Table 2a). Then measure the distance from the MP mark on the insulated wire to the nearest 1-meter tape band that is below the MP mark with a graduated steel tape and record that distance, to the nearest centimeter, in the 'DIFFERENCE BETWEEN MP MARK AND NEAREST 1-meter TAPE BAND BELOW MP' column of the water level measurements field form (Table 2a). The depth to water below MP is then obtained by adding the distance between the MP mark and the next lowest 1-meter tape band to the value of the next lowest tape band. Record this number in the 'DEPTH TO WATER FROM MP' column of the water level measurements field form (Table 2a).

(f) Apply the MP correction to get the depth to water below or above LSD. If the MP is above land surface, its height is subtracted from the water level to obtain the depth to water below land surface. If the MP is below land surface, precede the MP correction value with a minus (-) sign and subtract its height from the water level to obtain the depth to water below land surface. Subtract the MP correction (Table 2 or 2a) from the depth to water from MP (Table 2 or 2a) and record this number in the 'DEPTH TO WATER CORRECTED FOR LSD' column of the water level measurements field form (Table 2 or 2a). If the water level is above LSD, enter the water level in metres above land surface preceded by a minus sign (-).

(g) Make a check measurement by repeating steps (d) through (f). If the check measurement does not agree within the accuracy given in 4.3 under 'Data accuracy and limitations' continue to make check measurements until the reason for the lack of agreement is determined or until the accuracy requirement is met.

(h) After completing the well measurement, disinfect the electric tape by pouring a small amount of common household chlorine bleach on a clean cloth and wiping down the part of the tape that was submerged below the water surface; this will avoid possible contamination of other wells.

(i) Maintain the tape in good working condition by periodically checking the tape for breaks, kinks, and possible stretch due to the suspended weight of the tape and the tape weight. Do not let the tape rub across the top of the casing because the 1-meter metal bands can become displaced; consequently, placement of the bands should be checked frequently with a steel tape.

All calibration and maintenance data associated with the electric tape being used shall be recorded in its calibration and maintenance equipment log book. All data shall be recorded in the water level measurements field form (Table 1) to the appropriate accuracy for the depth being measured. See data accuracy and limitations.

Because an electric tape will not respond to oil floating on water in a well, the liquid level determined by an electric tape will be different than that determined by a steel tape, with the difference depending on the thickness of the oil layer. In cases where this is of concern, a miniature float-driven switch can be put on a two-conductor electric tape that will allow detection of the oil surface.

5 WATER-LEVEL MEASUREMENT USING AN AIR LINE

5.1 Purpose

To measure the depth to the water surface below a measuring point using a submerged air line.

5.2 Materials and Instruments

The following materials and instruments are required:

(a) Seamless copper tubing, brass tubing, or galvanized pipe, preferably 3 mm to 6 mm in diameter, with a suitable pipe tee for connecting an altitude or pressure gauge. Flexible plastic tubing can also be used, but is less desirable;

(b) An altitude or pressure gage;

(c) A tire valve stem and tire pump;

(d) A small open end wrench;

(e) Wire or electrician's tape;

(f) A steel tape graduated in meters and centimeters, blue carpenters chalk, and a clean rag;

(g) A field notebook, pencil and eraser; and

(h) A water level measurement field form (Table 3).

5.3 Data Accuracy and Limitations

The following data accuracy and limitations apply:

(a) Water-level measurements using an altitude gauge should be accurate to 30 mm.

(b) Water-level measurements using a pressure gauge are more approximate and should not be considered accurate to more than 300 mm;

(c) As in all pressure-dependent methods, fluid density should be considered when measuring water levels by the air-line method because the conversion constant of 0.102 meters of water per kilopascal is valid only for distilled water at 20 C. An example of correcting a water level measured by an air line for temperature and dissolved solids content is given in Annex B. However, because the equipment required to measure the temperature and/or dissolved solids content of the ground water is not always readily available, the corrections described in Annex B are not required for the purposes of this standard, though the practitioner shall note on the water-level field form (Table 4) whether or not any such corrections were applied.

5.4 Advantages and Disadvantages

The air-line method is especially useful in pumped wells where water turbulence may preclude using a more precise method. The method can be used while the well is being pumped, when splashing of water makes the wetted tape method useless. Bends or spirals in the air line do not influence the accuracy of this method as long as the position of the tubing is not appreciably changed. However, the air-line method is less accurate than the wetted tape or the electric tape methods and requires time to install the air line and equipment.

5.5 Assumptions

The following assumptions apply in the use of the air line method:

(a) An established measuring point (MP) exists. See technical procedure for establishing an MP.

(b) The MP is clearly marked and described so that all measurements will be taken from the same point.

5.6 Instructions

Fig. 3 shows a typical installation for measuring water levels by the air-line method.

The following procedures for measuring water levels in a well with an air line shall be observed:

(a) Install an air-line pipe or tube in the well. The air line can be installed by either lowering it into the annular space between the pump column and casing after the pump has been installed in the well, or by securing it to sections of the pump and pump column with wire or tape as it is lowered into the well.

(b) The air line shall be extended far enough below the water level such that the lower end remains submerged during pumping of the well;

(c) Attach a pipe tee to the top end of the air line. On the opposite end of the pipe tee, attach a tire valve stem;

(d) Connect an altitude gauge that reads in meters, or a pressure gauge that reads pressure in kiloPascals (kPa), to the fitting on top of the pipe tee with a wrench. If an altitude gauge is used, read the gauge to the nearest centimeter. For pressure gauges with kilopascal (kPa) units, read the gauge to the nearest kPa and multiply by 0.104 to convert to meters of water.

(e) Connect a tire pump to the tire valve stem fitting on the pipe tee;

(f) As the water level in the well changes, h and d (Fig. 3) must change in a manner such that their sum remains the same. Their sum is a constant (k), which is determined at the same time as a simultaneous wetted-steel tape and air gauge measurement is made;

(g) To calibrate the air line and gage, make an initial depth to water level measurement (d) with a wetted-steel tape, and an initial air gauge reading (h). Add d and h to determine the constant value for k. Use a tire pump to pump compressed air into the air line until all the water is expelled from the line. Once all water is displaced from the air line, record the maximum gauge reading;

Calibrate the air line and gauge as indicated in (g) above;

Example 1. -- Using an altitude gauge. The initial measured depth to the water level, d, is 7.88 m; the initial altitude gauge reading, h, is 23.02 m. Then the constant k = 7.88 m + 23.02 m = 30.90 m (table 3).

Example 2. -- Using a pressure gauge. The initial measured depth to the water level, d, is 26.17 m; the initial pressure gauge reading, h, is 190 kPa. Then the constant k = 26.17 m + (190 kPa x 0.102 m/kPa) = 26.17 m + 19.38 m = 45.55 m (table 4).

(h) to measure the water level depth in a well with an air line, subsequent air line readings are subtracted from the constant k to determine the depth to the water level below the MP. Use a tire pump to pump compressed air into the air line until all the water is expelled from the line, and record the maximum gauge reading;

Example 1. -- Depth to the water level in a well using an altitude gauge with a constant k of 30.90 m. During a later pumping period, the maximum altitude gauge h reads 15.24 m; therefore, the water level, d = 30.90 m – 15.24 m = 15.66 m (Table 3).

Example 2. -- Depth to the water level in a well using a pressure gauge with a constant k of 45.55 m. During a later pumping period, the maximum pressure gauge h reads 122 kPa; therefore, the water level, d = 45.55 m - (122 kPa x 0.102 m/kPa) = 45.55 m – 12.44 m = 33.11 m (Table 4).

(i) measure the water level depth as indicated in (i) above;

(j) apply the MP correction to get the depth to water below or above land-surface datum; and

(k) record water level data in the field notebook and on the water level measurement field form (Table 3 or 4).

6 WATER-LEVEL MEASUREMENT IN A FLOWING WELL

6.1 Purpose

To measure Piezometric heads in flowing wells “. It is classified into two categories-

1) Low pressure heads.

2) High pressure heads.

6.1.1 Advantages and Disadvantages

Low-pressure head measurements are simpler, faster, safer, and are more accurate than high-pressure head measurements, but are impractical for wells with heads greater than 2 meters above land surface.

High-pressure head measurements can be made at wells with heads greater than 2 meters above land surface, but the altitude/pressure gauges required for such measurements are delicate, easily broken, and subject to erroneous readings if dropped or mistreated.

6.2 Materials and Instruments

The following materials and instruments are required:

6.2.1 Low-pressure head measurements

(a) transparent plastic tubing of suitable length and diameter;

(b) ladder if pressure head is more than 1 to 2 meters;

(c) hose clamps;

(d) a measuring scale;

(e) a pencil and eraser;

(f) a calibration and maintenance log book; and

(g) a water level measurement field form (Table 5).

6.2.2 High-pressure head measurements

(a) flexible hose with a 3-way valve;

(b) hose clamps;

(c) an altitude or pressure gauge, and spare gauges;

(d) a small open end wrench;

(e) a soil-pipe test plug, also known as a sanitary seal, available from most plumbing-supply stores in sizes that will fit 50 to 250 mm diameter pipes. Soil-pipe test plugs consist of a length of small-diameter pipe, generally less than 30 mm, surrounded by a rubber packer. The packer can be expanded by an attached wing nut to fit tightly against the inside of the well casing or discharge pipe. The small-diameter pipe is threaded so that it can be attached to a valve, hose, or altitude/pressure gauge.

(f) a pencil and eraser;

(g) a calibration and maintenance log book; and

(h) a water level measurement field form (Table 5).

(i) Ladder.

6.3 Data accuracy and Limitations

The following data accuracy and limitations apply:

(a) low-pressure head measurements can be measured to an accuracy of 30 mm;

(b) high-pressure head measurements using a pressure-gauge are probably not accurate to within less than 30 mm, although the measurements themselves can be read at finer resolutions;

(c) the pressure in the well shall not exceed the limit of the altitude/pressure gauge. Pressure gauges are generally most accurate in the middle third of the gauge range;

(d) the measuring gauge shall not be connected to a well that uses a booster pump in the system, because the pump could start automatically and the resulting pressure surge may ruin the gauge;

(e) when a flowing well is closed or opened by a valve or test plug, it should be done gradually. If pressure is applied or released suddenly, the well could be permanently damaged by the "water-hammer effect" with subsequent caving of the aquifer material, breakage of the well casing, or damage to the distribution lines or gauges. To reduce the possibility of a water-hammer effect, a pressure-snubber should be installed ahead of the altitude/pressure gauge;

(f) ideally, all flow from the well should be shut down so that a static water-level measurement can be made. However, because of well owner objections or system leaks, this is not always possible. If the well does not have a shut down valve, it can be shut-in by installing a soil-pipe test plug on the well or discharge line; and

(g) if a well has to be shut down, the time required to reach static pressure after shut-in may range from hours to days. Since it may be impractical or impossible to reach true static conditions, record the shut-in time for each gauge reading. During return visits to a particular well, it is desirable to duplicate the previously used shut-in time before making a altitude/pressure gauge reading.

6.4 Advantages and Disadvantages

Low-pressure head measurements are simpler, faster, safer, and are more accurate than high-pressure head measurements, but are impractical for wells with heads greater than 2 meters above land surface.

High-pressure head measurements can be made at wells with heads greater than 2 meters above land surface, but the altitude/pressure gauges required for such measurements are delicate, easily broken, and subject to erroneous readings if dropped or mistreated.

6.5 Assumptions

The following assumptions apply when measuring water levels in a flowing well:

(a) an established measuring point (MP) exists. See technical procedure establishing an MP;

(b) the altitude/pressure gauges have been calibrated with a dead-weight tester; and

(c) a log book containing all calibration and maintenance records is available for each altitude/pressure gauge.

6.6 Instructions

Fig. 4 shows water level measurement in a flowing well.

6.6.1 Low-pressure head measurement (direct measurement).

(a) connect a short length of transparent plastic tubing tightly to the well with hose clamps;

(b) raise the free end of the tubing until the flow stops;

(c) rest the measuring scale on the measuring point (MP);

(d) read the water level directly by placing the hose against the measuring scale;

(e) apply the MP correction to get the depth to water above land-surface datum (LSD); and

(f) repeat steps (b) through (e) for a second check reading.

6.6.2 High-pressure head measurement (indirect measurement).

(a) make sure that all well valves are closed except the one to the altitude/pressure gage. This will prevent use of the well during the measurement period and assure an accurate water-level reading. Record the original position of each valve that is closed (full open, half open, closed, etc.), so that the well can be restored to its original operating condition;

(b) connect a flexible hose with a 3-way valve to the well with hose clamps using the soil-pipe test plug or appropriate plumbing fittings;

(c) select a gauge where the water pressure in the well will fall in the middle third of the gauge range. It is suggested that, if in doubt, use a pressure gauge with at least a 500 kiloPascal (kPa) range to make an initial measurement, then select the gauge with the proper range for more accurate measurements;

(d) attach the altitude/pressure gauge to one of the two "open" valve positions using a wrench. Do not tighten or loosen the gauge by twisting the case because the strain will disturb the calibration and give erroneous readings;

(e) bleed air from the hose, using the other "open" valve position;

(f) open the altitude/pressure gage valve slowly to reduce the risk of damage by the "water-hammer effect" to the well, distribution lines and gauges. Once the needle stops moving, tap the glass face of the gauge lightly with a finger to make sure that the needle is not stuck;

(g) make sure that the well is not being used by checking to see that there are no fluctuations in pressure;

(h) hold the altitude/pressure gauge in a vertical position, with the center of the gauge at the exact height of the MP. If using an altitude gauge, read the gauge to the nearest centimeter. For pressure gauges with kPa units, read the gauge to the nearest kPa and multiply by 0.102 to convert to meters of water;

(i) apply the MP correction to get the depth to water above LSD;

(j) shut off the well pressure and repeat steps e-i for a second check reading; and

(k) record the identification number of the altitude/pressure gauge with each water-level measurement so that the reading can be back referenced to the calibration record, if necessary.

All calibration and maintenance data for the well shall be recorded in the log book. All water-level data shall be recorded on the water level measurements field form (table 5).

7 ESTABLISHING A PERMANENT MEASURING POINT

A permanent Measuring Point (MP) is to be established and marked prominently on the observation well.

7.1 Purpose

To establish a permanent reference point from which all water levels are measured in a particular well. This is to ensure that no error is committed in recording the repeated observation particularly where previous readings are used for comparison of water level.

Altitude of MP shall be considered as the altitude of the observation well. MP should be described with respect to direction also.

7.2 Materials and Instruments

The following materials and instruments are required:

(a) a ground-water site inventory form;

(b) a steel tape graduated in meters and centimeters;

(c) a steel tape calibration and maintenance equipment log book;

(d) a field notebook;

(e) a pencil and eraser;

(f) spray paint, bright color; and

(g) two wrenches with adjustable jaws for removing well cap.

7.3 Data accuracy and Limitations

The accuracy with which the Measuring Point (MP) measurement is established should be the same as that established for the water-level measurement; that is, if water levels are measured to the nearest centimeter, then the MP should be established to an accuracy of 0.01 meters.

7.4 Assumptions

For comparability, water-level measurements shall be referenced to the same datum (elevation). Land surface datum (LSD) at the well is an arbitrary plane chosen to be approximately equivalent to the average altitude of the ground around the well. Because LSD around a well may change over time, the distance between the MP and LSD should be checked periodically. Also, measuring points change from time to time, especially on private wells.

7.5 Instructions

(a) the MP must be as permanent as possible, clearly defined, marked, and easily located;

(b) The measuring point should preferably be the top of the well casing in the case of piezometers and top of the parapet wall in the case of dug wells.

(c) the MP should be measured in reference to land surface datum (LSD) and at a point on the well convenient for measuring water levels (most often at the top of the well casing);

(d) clearly mark the MP with an arrow sprayed with a bright colored paint;

(e) measure the height of the MP in meters above or below LSD (Fig. 5) and record it on the ground water site inventory form. Values for measuring points below land surface (Fig. 5B) shall be preceded by a minus sign (-). Also record the date the MP was established and a detailed description of the MP. Depending on the purpose of a study, it may be desirable to "survey-in" the LSD and the MP to a national geodesic reference point. If so, then the accuracy of the surveyed altitude should be estimated and recorded in the well file.

(f) establish at least one clearly marked reference point (RP) somewhere near the well. The RP is an arbitrary datum established by permanent marks, and is used to check the MP or to re-establish a measuring point should the original MP be destroyed or changed; and

(g) make a detailed sketch of the MP and the RP on the groundwater site inventory form . If possible, take a photograph and clearly identify the MP and RP on the developed photograph.

All calibration and maintenance data associated with the steel tape being used are recorded in its calibration and maintenance equipment log book. MP data are recorded in a field notebook and on the groundwater site inventory form.

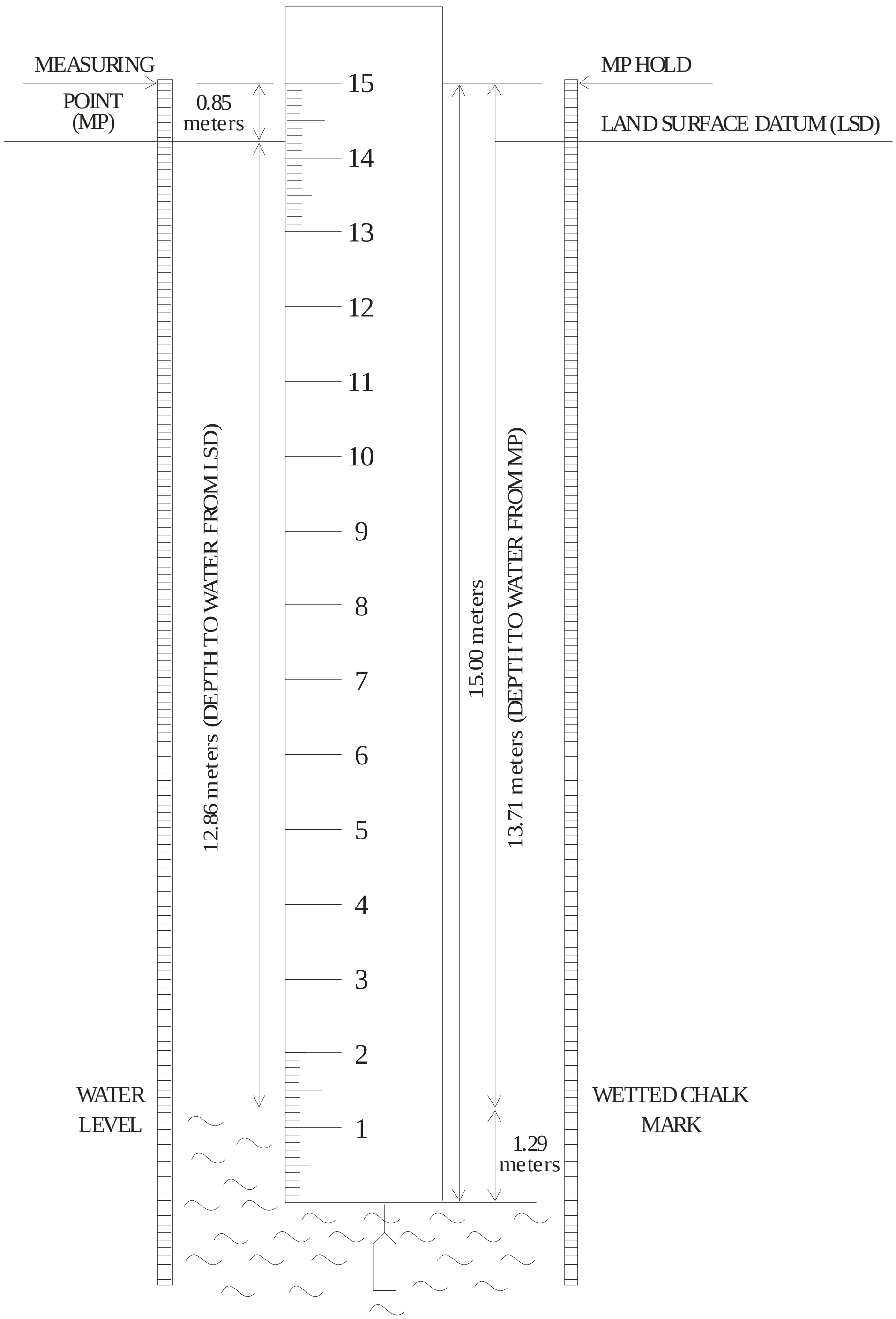

Figure 1 -- Water-level measurements using a graduated steel tape.

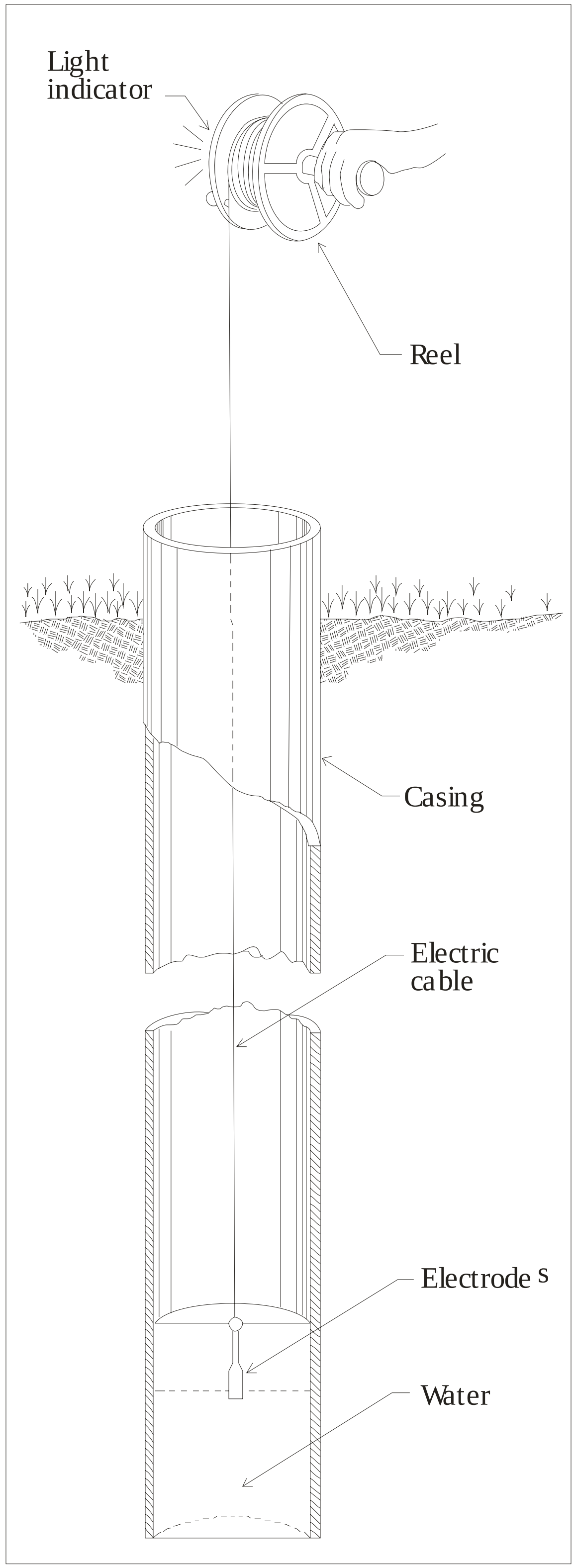

Figure 2 -- Water-level measurements using an electric tape (Driscoll, 1986, fig.16.12)

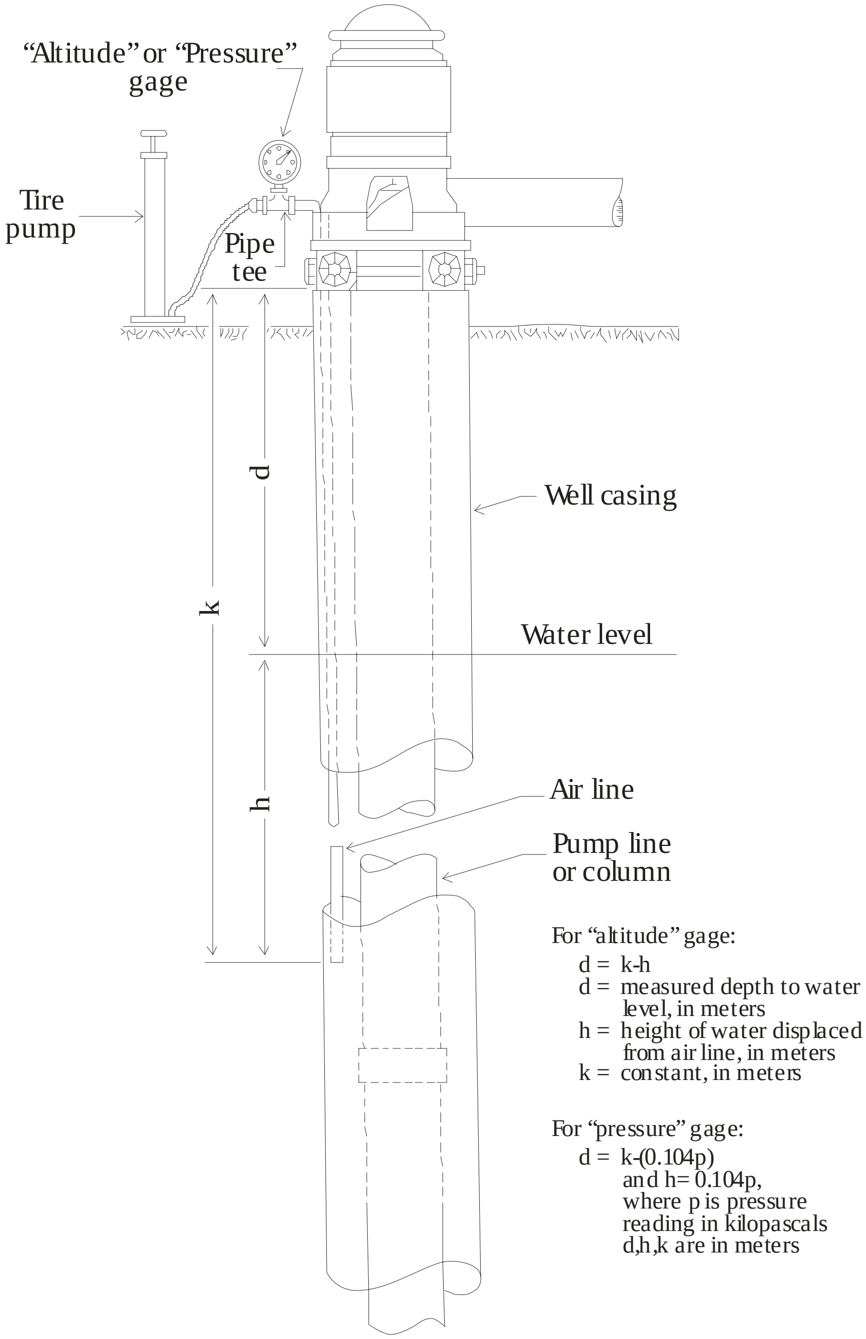

Figure 3 –Typical installation for measuring water levels by the air-line method and relation of measured depth to water level, height of water displaced from air line, and depth to bottom of air line

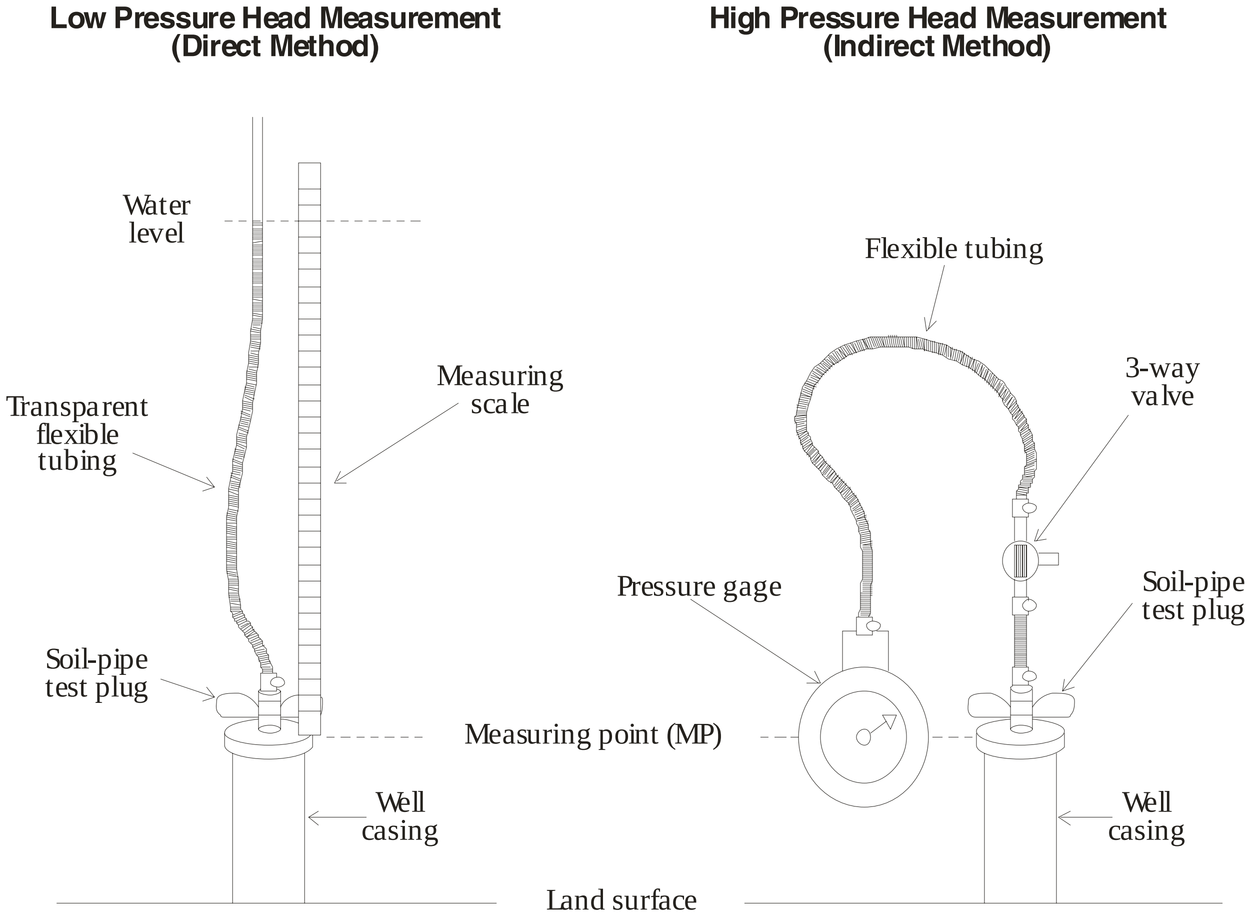

Figure 4 -- Water level measurement in a flowing well.

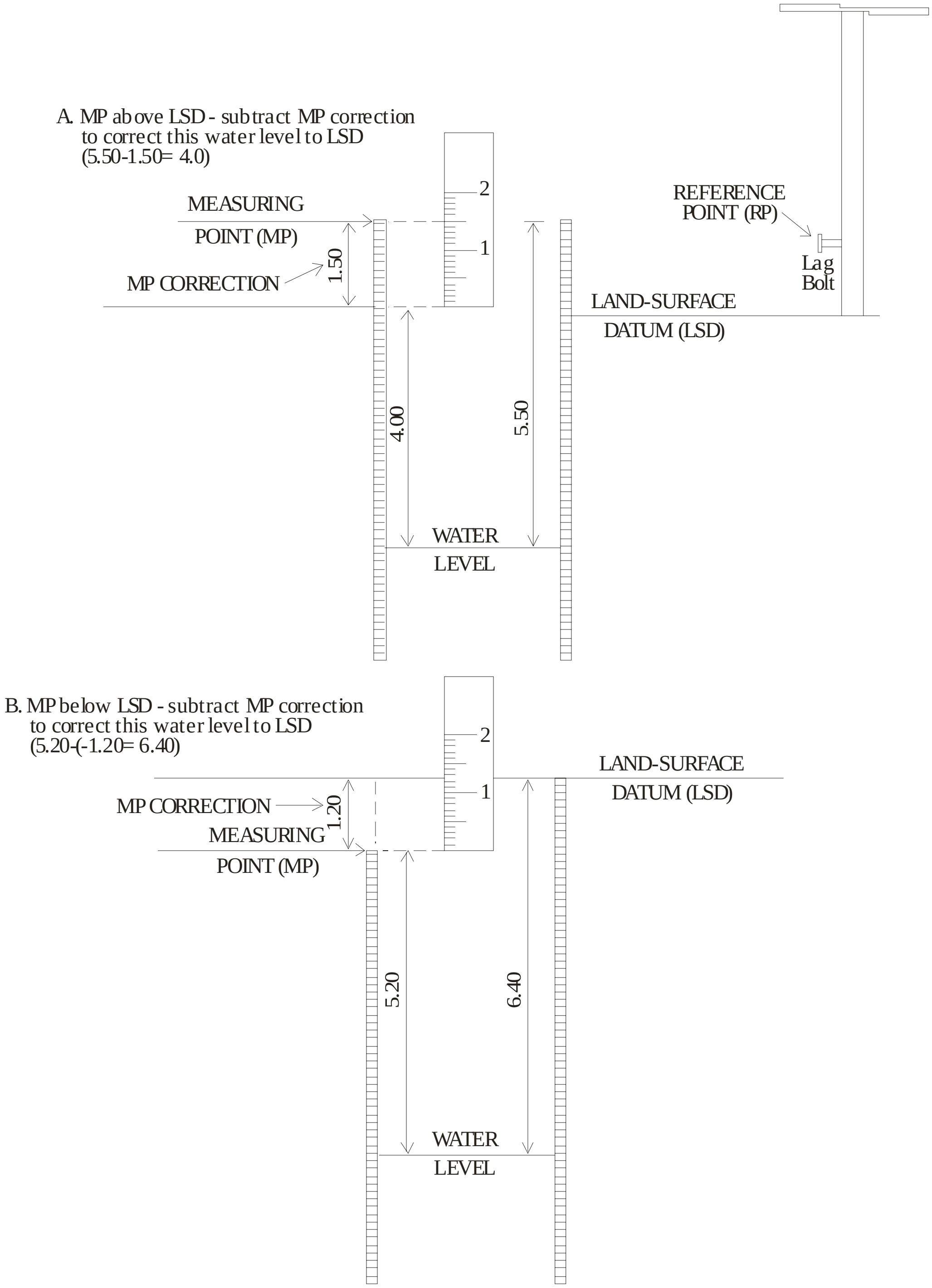

Figure 5 – Relation of measuring point, (A.) above or (B.) below land surface datum, reference point, and the water level.

Table 1 - Example of field data sheet for measurement of water levels with a graduated steel tape

WATER LEVEL MEASUREMENTS (Field)

WELL NO.

LOCATION OF WELL

MP DESCRIPTION

DATE	HOUR	MP HOLD, IN METERS	WETTED CHALK MARK, IN METERS	DEPTH TO WATER FROM MP, IN METERS	DEPTH TO WATER FROM LSD, IN METERS	REMARKS

Note:

1) Withdrawal structure to be located at a distance of y metres due to pre-monsoon rainfall affected from external water bodies, etc.

2) In case of pumping, well is measured after x hours of stoppage of pumping.

Table 2 - Example of field data sheet for measurement of water levels with a fully graduated electric tape.

WATER LEVEL MEASUREMENTS (Field)

LOCATION OF WELL WELL NO. ______

MP DESCRIPTION

DATE	HOUR	DEPTH TO WATER FROM MP, IN METERS	DEPTH TO WATER FROM LSD, IN METERS	REMARKS

Table 2a - Example of field data sheet for measurement of water levels with a partially graduated electric tape.

WATER LEVEL MEASUREMENTS (Field)

WELL NO. ______

LOCATION OF WELL

MP
DESCRIPTION

DATE	HOUR	NEAREST 1-METER TAPE BAND BELOW MP, IN METERS	DIFFERENCE BETWEEN MP MARK AND NEAREST 1-METER TAPE BAND BELOW MP, IN METERS	DEPTH TO WATER FROM MP, IN METERS	DEPTH TO WATER FROM LSD, IN METERS	REMARKS

Table 3 - Example of field data sheet for measurement of water levels with an air line using an altitude gauge.

WATER LEVEL MEASUREMENTS (Field)

WELL NO. ______

LOCATION OF WELL

MP DESCRIPTION

DATE	HOUR	ALTITUDE GAUGE CONSTANT, IN METERS (k)	ALTITUDE GAUGE READING, IN METERS (h)	DEPTH TO WATER FROM MP,IN METER (d)	DEPTH TO WATER FROM LSD, IN METERS (d-MP)	REMARKS

Table 4 - Example of field data sheet for measurement of water levels with an air line using a pressure gauge.

WATER LEVEL MEASUREMENTS (Field)

WELL NO. _____

LOCATION OF WELL

MP DESCRIPTION

DATE	HOUR	PRESSURE GAUGE CONSTANT, IN METERS (k)	PRESSURE GAUGE READING, IN METERS (h)	DEPTH TO WATER FROM MP, IN METERS (d)	DEPTH TO WATER FROM LSD, IN METERS (d-MP)	REMARKS

Table 5 - Example of field data sheet for measurement of pressure head (water level) in a flowing well

WATER LEVEL MEASUREMENTS (Field)

WELL NO.________

LOCATION OF WELL

MP DESCRIPTION

DATE	HOUR	PRESSURE HEAD (WATER LEVEL) ABOVE MP, IN METERS	PRESSURE HEAD (WATER LEVEL) ABOVE LSD, IN METERS	REMARKS

Annex A

(Clause 3.3(b))

Corrections for water levels measured in deep wells by steel tapes subject to temperature changes and tape stretch

In measuring water level in deep wells, practitioners may wish to consider errors introduced from the effects of thermal expansion and/or stretch of the metal tape produced by the suspended weight of the tape and attached plumb bob. While such errors are negligible for many water-level measurements, they may become appreciable for measurements in deep wells, that is, for wells exceeding 300 meters in depth. The corrections described below are not required for the purposes of this standard, but rather to provide the practitioner a means of evaluating the potential magnitude of such errors.

The equations used to estimate the changes in length of a metal tape resulting from thermal expansion and stretch are given by Garber and Koopman (1968) in Eqs.(1) and (2), respectively, as

$$\mathbf{C_T=LE(T_a-20)} \qquad (1)$$

and

$$\mathbf{C_S=(L_e^2WS/2)+PL_eS} \qquad (2)$$

where

C_T = thermal correction, m

C_S = stretch correction, m

L = measured depth to water, m

E = coefficient of thermal expansion of the steel tape, m/m per degree C

(difference between the average temperature in the well and 20 C)

T_a = average temperature in the well from land surface to water level, C

L_e = length of suspended tape corrected for thermal expansion, m

W = weight of tape per meter

S = coefficient of stretch, m per m per kg, and

P = weight of plumb bob, in kg (usually 0.10 to 0.30 kg)

The following example illustrates the effects of thermal expansion and stretch on a steel tape used to measure water levels in a deep well:

Given: L = 515.00 meters

E = 1.13×10^{-5} m/m per degree C

T_a = 30 C

W = 0.0036 kg

S = 3.85×10^{-5} m/m per kg

P = 0.20 kg

<u>a. correction for thermal expansion:</u>

$C_T = LE(T_a – 20 \text{ degrees C}) = 515(1.13x10^{-5})(30-20) = 0.06$ meters

then

$L_e = 515.00 - 0.06 = 514.94$ meters

b. correction for stretch:

$C_S = (L_e^2 WS/2) + PL_eS = ((514.94)^2(.0036)(3.85x10^{-5})/2)) + (0.20)(514.94)(3.85x10^{-5})$

$= 0.02$ meters

then corrected depth = L_e – stretch correction = 514.94 – 0.02 = 514.92 meters

Annex B

(clause 5.3(c))

Corrections for water levels measured in wells with the air-line method

As in all pressure-dependent methods, fluid density should be considered when measuring water levels by the air-line method. Fluid density is affected primarily by temperature and, to a lesser extent, by the concentration of dissolved solids. The density of water at 20 C is 0.99823 gm/ml. At this density, 0.102 meters of water can be associated with each kilopascal of measured pressure. However, water with temperatures greater than or less than 20 C would have proportionately smaller or greater densities, respectively, with proportionately greater or smaller conversion factors. A table quantifying the change in density of distilled water over a wide temperature range is shown below.

Density of pure water, free from air [a]

t, degrees C	density, gm/ml	t, degrees C	density, gm/ml
0	0.99987	45	0.99025
3.98	1.00000	50	0.98807
5	0.99999	55	0.98573
10	0.99973	60	0.98324
15	0.99913	65	0.98059
18	0.99862	70	0.97781
20	0.99823	75	0.97489
25	0.99707	80	0.97183
30	0.99567	85	0.96865
35	0.99406	90	0.96534
38	0.99299	95	0.96192
40	0.99224	100	0.95838

To illustrate the use of the above table in correcting water-level measurements for temperature in air lines, consider Example #2 previously described in Section 5.6 (Instructions) and shown in Table 4. If, in that example, the water in the air line had some temperature other than 20 C, say 60 C, then the conversion factor, C_c, used to convert the pressure reading in kilopascals to meters of water would be recalculated as

$$C_c = 0.102 \text{ m/kPa} \times (0.99823 \text{ gm/ml})/(0.98324 \text{ gm/ml}) = 0.1036 \text{ m/kPa}$$

and

initial h = 0.1036 m/kPa x 190 kPa = 19.68 m, and (from Table 4), k = 19.68 + 26.17 = 45.85 m

then the corrected depth to water would be calculated as d = k – h = 45.85 – (0.1036)(122 kPa) = 33.21 m (versus an uncorrected depth of 33.11 m from Table 4)

In moderate concentrations, the effect of dissolved solids on fluid density is at least one order of magnitude less than that of temperature. For example, for dissolved solids having a specific gravity of 2.5 (water taken as unity), calculations show that the density of water having a dissolved solids concentration of 100 mg/l would be 1.00006; water having a dissolved solids concentration of 200 mg/l would have a density of 1.00012; and water having a dissolved solids concentration of 1,000 mg/l would have a density of 1.0006.