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Recommended Procedures and Standards for Conducting a Water Table Study

Submitted to the Virginia Department of Health Office of Environmental Health Services

Submitted By
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Preface

Depth to water table or soil wetness features is a major factor in determining soil-site suitability for an onsite wastewater treatment and disposal system. Depth to water table or soil wetness features not only determines if a soil-site is suitable, but also is a critical factor in how well and for how long a wastewater system will function. This document serves to develop and provide consistent and uniform methods and terminology to observe, describe, measure, and report water table levels for soils and *sites that potentially may be used for onsite wastewater treatment and disposal. Successful water table studies do not by themselves mean that a permit for an onsite wastewater treatment system will be issued since there are other site and soil conditions that must be considered.* Protection of public health and groundwater is the ultimate goal of this document.

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Introduction to Water Table Levels and Soil Wetness Indicators

Water Table Defined

The water table is that portion of the soil-geologic continuum where redoximorphic features have formed by reduction, oxidation, and translocation of iron and manganese compounds. Or that portion of the soil-geologic continuum that is saturated with groundwater year-after-year in the wettest seasons that may or may not exhibit redoximorphic features, and the saturation can be observed and measured over defined space and time.

Types of Water Tables

Two basic kinds of water tables found in Virginia (Soil Survey Staff, 2006.) are:
(i) apparent water table which is the level of stabilized water in a fresh, unlined borehole; and (ii) perched water table is water that lies above an unsaturated zone for at least 3 days and will fall if the borehole is extended. Sources of these water tables include but are not limited to seasonal high-water table, perched water table, tidal water, and seasonally saturated soil by lateral water movement.

Redoximorphic Features

Historically, soil wetness indicators were known as 'mottles'. However, **redoximorphic** (redox) **features** is the recommended term to indicate evidence of soil wetness conditions and is defined as: "**Soil properties associated with wetness that result from the reduction and oxidation of iron and manganese compounds in the soil after saturation with water and desaturation, respectively" (Glossary of Soil Science Terms, 1996).** Redox features have color patterns including shades of gray, red, yellow, and pale brown and a reduced matrix, where an entire horizon is reduced.

Reduction and oxidation are complex processes in the soil. All parameters have to be present and probably optimal in the soil for redox features to be formed. Where redox features are present in a soil, the only conclusion that can be made with certainty is that conditions were right for redox features to form. One of these conditions is the presence of stagnant water persisting for up to several weeks. **Therefore the presence of redox features is a reasonable approximation of the seasonal water table in lieu of actual water table data when hydrology has not been altered.** A more detailed discussion on the formation and field identification of redoximorphic features is presented in another document.

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Justification for Conducting Water Table Studies

Virginia's Sewage Handling and Disposal Regulations (2000) require a vertical separation distance from the bottom of the trenches to the top of a water table. Soil color (redox features) is commonly used to determine the depth of water table levels. Using redox features to predict depth to seasonal saturation is generally reliable, but it does not tell us the exact duration or frequency of saturation at a given depth. The standard duration of saturation for redox features ranges from 14 to 21 consecutive days (Vepraskas, 1999). A water table study can be used to assess the exact frequency, depth, and duration of soil wetness conditions.

There are several reasons to conduct a water table study:

1) The owner (or their consultant) proposes to use an onsite wastewater system requiring a deeper depth to a soil wetness condition than the depth observed in the soil by field evaluation procedures.

2) Soil features and conditions that may need to be measured and interpreted during site suitability determinations include: relict or historic redox features; lithochromic soil colors inherited from parent rock; wet soils that have minimal to no redoximorphic features, and anomalous bright and loamy soils. These features are candidates for further study because of their inconclusive morphologies with respect to the depth, frequency, and duration of saturation.

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Soil and Site Features That May Elicit Water Table Studies

Relict Redox Features

Redox features in soils allow the site evaluator to reliably predict the level of seasonal saturation and reduction in the soil if the site has not been hydrologically altered by natural or artificial processes. Soil Taxonomy (Soil Survey Staff, 1999) indicates that there have been significant climatic changes during geologic time and soil features present today may have formed under different climatic regimes; and "such soils have relict features that reflect the former moisture regime...."

One obvious setting for relict redox features in the field is where extensive down cutting and dissection has taken place across former level and nearly level landforms. These former subdued landforms may have had water table and redox processes close to the soil surface. As down-cutting proceeded over geologic and pedologic time, the area or regional water table was lowered in the wet soils and relict redox features were left "high and dry." This is best observed in the Virginia Coastal Plain in areas where a major river such as the Rappahannock meets the tidal estuaries along the Chesapeake Bay.

Today, some of these highly dissected areas have gray colors in soils that are on steep and very steep sideslopes. These gray colors were probably formed when the area was flatter and wetter. Many of these relict colors are in fine-textured soil materials and horizons that have current-day slow or restrictive permeability. It may be necessary to conduct Ksat tests as well as a water table study to determine ultimate suitability for a drainfield in these fine-textured soil materials.

Morphologic features observed at hydrologically altered sites may be relict redox features. Drainage ditches and subsurface tile drains alter site hydrology, and redox features may no longer be reliable indicators of the saturation and anaerobic conditions (Lindbo et. al., 1997, Hayes, 1998). Relict features are commonly distinguished in the field by having sharp, distinct boundaries. Current day wetness features typically have diffuse boundaries (Vepraskas, 1999).

Soils with Lithochromic (Parent Material) Colors

Lithochromic is a term used to describe colors and features that are derived from and retain characteristics of the parent material (formerly described as parent material mottles), formed from geological processes rather than soil forming processes. Soils that are the same color throughout the profile as the underlying parent rocks are generally called lithochromic soils. These soils are commonly red, gray, or black. Low chroma lithochromic mottles are not normally indicative of wetness. However, lithochromic soils need careful evaluation for determining drainfield suitability because water table and soil wetness features may be masked or "lost" in the overall soil colors. The color of the soil may not be reflective of the current day drainage and permeability. Two examples of this are the Triassic reddish brown soils weathered from sedimentary red beds, and the Piedmont soils weathered from graphite schist.

In the Triassic soils, it is typical to have only the A or Ap horizon be slightly different in color than the underlying Bt, C, Cr, and R horizons, which are usually reddish brown. Reddish brown soils are generally considered to be well drained because of the oxidized colors in the Bt horizons. However, the red bed soils have inherited their reddish brown colors from the underlying parent rocks. Soil wetness features in these reddish brown soils may consist only of chroma 3 and 4 redox depletions, high chroma redox concentrations, and manganese oxide coatings on rock faces.

Graphite schist in the crystalline rocks of the Piedmont commonly weathers to gray and black soils. The profile may be gray or black from top to bottom. These dark colors can easily mask redox features and minimize other soil wetness features that may be present in the soil, especially on low relief and slightly concave landforms. Because soil wetness may be masked, it is critical that drainfields be sited only on suitable upland landforms. It is recommended to avoid marginal landforms and landscape positions

Eluvial Horizons

Eluvial (E) horizons typically possess low chroma matrix colors due to their low Fe content. Some coarser textured soils have a gray-colored E horizon directly below the topsoil. Incomplete breakdown of soil organic matter in the topsoil results in the formation of organic acids, which causes extensive leaching in underlying soil layers unrelated to anaerobic soil conditions (Veneman et. al., 1998). The iron is stripped from the sand gains by the process of chemical complexation (podzolization) resulting in gray colors. Typically, the presence of redox concentrations in the E horizon is a soil wetness indicator (Vepraskas, 1999).

Minimal Redox Features

Many studies have demonstrated the existence of soils with significant wetness periods that do not exhibit low chroma redox features (Simonson and Boersma, 1972; Pickering and Veneman, 1984; Evans and Franzmeier,1986; Griffin et al., 1992; James and Fenton, 1993; Vepraskas et al., 1999;). These soils are typically wet during some part of the winter and spring, but have minimal redox features. Typically, free water seeps into an auger boring or backhoe pit. The soils can be any texture, but often the free water in a profile is perched on a restrictive soil horizon. The soils are often on lower or “dependent” landforms such as long toeslopes or footslopes.

Chroma 3 and 4 Redox Depletions

In many transported soils, the presence of chroma 3 and 4 depletions, and/or higher chroma concentrations, without the presence of chroma 2 or less redox depletions is a wetness indicaror. Chroma 3 and 4 depletions are formed by the same processes as low chroma <2 depletions. Chroma 3 colors can indicate the presence of remaining Fe oxides on the particle surfaces (Vepraskas 1999), natural mineral color, low amounts (<1%) of soluble carbon, or oxygenated water. These soils can be reduced for short periods, but may be waterlogged for long periods (Franzmeier, et. al. 1983; Vepraskas and Wilding, 1983; Daniels, et. al. 1987).

Anomalous Bright and Loamy Soils

These are newly recognized hydric soils in the Mid-Atlantic Coastal Plain, located adjacent to estuarine marshes or waters (USDA, 2006). They are problem soils because they meet saturation and reduction requirements for hydric soils but do not exhibit the typical morphological features of hydric soils. These soils occur on the Lower Coastal Plain and Eastern Shore on linear or convex landforms that are: a) within 656 lateral feet of estuarine marshes or waters; b) within 3.28 feet vertical distance of the mean high water level; c) contain a mineral layer at least 4 inches thick starting within 8 inches of the soil surface; and d) have a matrix (60% or more of the volume) chroma of 4 or less and 10 % or more distinct or prominent redox concentrations occurring as soft masses or pore linings and/or depletions. The concept in part (d) can be applied to non-hydric situations in the same geomorphic setting. For instance, the depth to the water table could be the depth to the soil horizon with 10% or more redox concentrations with a matrix color of chroma 4 or less.

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Methods and Procedures for Planning and Conducting Water Table Studies

A detailed plan for conducting a water table study should be developed by the interested party and ultimately reviewed by the appropriate county or district health department. Justifications for conducting the water table study, construction and installation standards, and minimum requirements for site approval should be agreed to by all parties in a mandatory premonitoring conference. Plans shall be submitted to the district or county VDH office at least 30 days prior to initiation of the study. Ample time shall be allowed beyond the 30-day review period for well installation prior to the beginning of water table observations. Provisions shall be in place prior to the start of the water table study that allow VDH personnel to check water table levels at any time during the study period, including written permission from the owner to visit the site.

Site Location and Map Standards

The water table study plan should include a site location on a surveyed plat with contour intervals, if available. In addition the overall study site and individual well locations should be delineated on a paper or digital USGS 1:24,000 topographic map.
The required survey plat or scale drawing (1 inch equals not more than 60 feet) of the study site and adjacent property shall contain at a minimum the following:

1. *Fixed horizontal distance and elevation reference points or benchmarks.*
2. *Property corners and property lines with dimensions.*
3. *Location of water supply wells, water lines, and/or public water lines.*
4. *Surface waters (e.g., stream, pond, lake, canal or marsh).*
5. *Structures (both present and proposed future), including buildings, pools, garages, driveways, decks, etc.*
6. *Appurtenances such as easements (i.e. utility, access, etc.), right-of- ways (street, Department of Transportation, Army Corps of Engineers, etc.), quarries, Resource Protection Area, etc.*
7. *Drainage features (present and proposed) and location of drain outfall(s).*
8. *Location of borings/pits used to describe soil profiles.*
9. *Location of proposed water level monitoring wells and rain gauges.*
10. *Contour map of the lot consistent with GMP 126.*
11. *Relative elevations of the monitoring wells referenced to a semi-permanent or permanent reference points.*

Soil and Site Descriptions

The study plan should provide detailed soil descriptions that conform to the standards of the National Cooperative Soil Survey and/or approved standards set forth by VDH. Soils should be classified to the series or series-like level (i.e. Munden-like) using existing soil survey information, or rough field classifications. The soil descriptions should be taken from the hole the in which the wells will be installed so that water table data can be correlated with soil morphological features. Soil profile descriptions can be made using a hand auger or a more detailed description with backhoe pit, as long as the pit does not affect the local water table hydrology associated with the monitoring well. Data shall be invalid if pits are deemed to disturb the local hydrology.

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Water Table Study Components and Standards for Manual and Automated Monitoring Wells

1. Number of Monitoring Wells

a. Individual Lot or Site:

A minimum of three (3) monitoring wells shall be located in any proposed onsite wastewater treatment and disposal area. The three (3) wells may be comprised of any combination of automated and/or manual wells. The three monitoring wells may be all automated or all manual. If three (3) automated wells are used to monitor the site, at least one (1) manual well will be required for data verification. Manual wells are adequate substitutes for malfunctioned data loggers if read with a frequency detailed in 5 (a) and length outlined in section 7. If more than one data logger fail simultaneously and the study area is not adequately covered by manual wells, the entire study may be invalidated. To ensure contiguous coverage of the study area more than three wells may be necessary.

The consultant shall provide a minimum of one (1) soil profile description at each monitoring well location. Complex and/or variable soils/ sites shall require additional soil documentation. If a reserve area is required and is contiguous to the proposed onsite area, one of the three wells shall be in the reserve area. If a required reserve area is not contiguous to the proposed onsite area, three (3) additional monitoring wells shall be located in the reserve area.

Three (3) wells shall be required for gravel pad systems to fully assess the water table dynamic at the site. However, only two (2) wells must be located within the drainfield and reserve area while one (1) well can be located on identical landscape positions immediately adjacent to the drainfield and reserve areas.

b. Subdivisions and Mass Drainfields:

A plan shall be submitted showing the location of wells with justification for the number and location of wells. If agreed to by VDH, monitoring wells may be placed in selected soil areas that represent the wettest soil morphologic features and local hydrology throughout the subdivision or mass drainfield areas. Additional wells shall be required for sites handling systems with a design flow greater than 600 gallons per day (minimum of one additional well per 600 gallons per day increment).

c. Use of Soil and Site Conditions for Well Locations:

For all water table studies including individual lots, subdivisions, or mass drainfields, one or more monitoring wells must be located in what is considered to be the wettest portion of any proposed onsite wastewater area, based on landform and soil morphologic features.

2. Well Construction Standards for Automated and Manual Wells

a. The monitoring well shall be bored using a soil auger with efforts made to minimize smearing and compaction of the sidewall soil materials (especially the bottom 18 inches) and basal area of the hole. The well should be installed when the soil is slightly moist or dry to prevent smearing and compaction of the sidewalls. Erratic or unreasonable data from a monitoring well will result in it being eliminated from the water table study, and may require the installation and monitoring of a replacement well.

b. For manual wells, the well should be cased with schedule 40 PCV pipe with an inside diameter of 1.5 to 3.0 inches. The top of the pipe should be covered with a threaded PCV cap that allows for easy observation, but also can be tightened to minimize vandalism or tampering. The lower twelve inches of the pipe that are in contact with a presumed water table should have narrow slits 1/8 to 1/4 inch wide, or drilled holes 1/8 to 1/4 inch in diameter.

c. The borehole shall have a minimum annular spacing of 1.0 to 3.0 inches. Adequate annular spacing is necessary to pour pea gravel and grout between the PCV pipe and the surrounding undisturbed soil.

d. The annular space should be backfilled with clean pea gravel so that all the slits and drilled holes in the PVC pipe are encased in the porous pea gravel. Then, six (6) more inches of pea gravel should be added above the encasing depth. The remaining annular space should be grouted almost to the surface with neat cement or bentonite. It is recommended that only a few inches of bentonite be added in the annular space at a time, and then water should be added uniformly around the PVC pipe; then repeat the process. It is best to have the bentonite grout stop at 2 to 4 inches below the ground surface, and then backfill to the surface with fine textured soil material that does not excessively shrink, crack, or swell during moisture flux. The soil material should be lightly tamped after backfilling. Avoid having bentonite on the soil surface; it is very messy and adhesive. A collar should be made at the surface around the monitoring well to minimize surface water collecting and entering around the well. Careful installation and grouting is critical to the collection of meaningful data. The site may appear wetter than it actually is due to improper grouting or installation.

e. A reference level should be established from which all measurements are made. The reference level and measurement technique must allow for accurate measurement of the depth from the surface to the water level within plus or minus one inch. Reference levels greater than one inch below ground surface may result in erroneous data.

f. Depending upon the type of automated water table recording device (data logger) used, follow the manufacturers additional installation procedures.

3. Depths of Wells

a. For sites without soil restrictions:
The bottom of the well shall be placed a minimum of eighteen (18) inches below the proposed drainfield trench installation depth.

b. For sites with soil restrictions where the drainfield trench bottom is proposed to be placed:

1) Above a restrictive horizon: all wells shall be anchored into the top of the restrictive horizon.
2) Below a restrictive horizon: all wells should be placed a minimum of eighteen (18) inches below the proposed depth of the drainfield trenches. All other regulatory requirements for installing a drainfield beneath a restriction shall be met.

c. A schematic diagram showing well construction components and materials, and sizes and dimensions and depths, shall be provided.

4. Annual Observation Periods

For the purpose of determining minimum depth of a seasonal water table, it is not necessary to observe water table levels on a year round basis. Evaluation of existing water table data along with climatic and anecdotal information shows that sustained high water table levels are far more likely to occur during mid-winter to mid-spring that at any other time of the year. Periods of high water tables can occur at other times of the year (usually associated with tropical storms and hurricanes) but are sufficiently anomalous and infrequent that it would be impractical to be considered in siting a drainfield. Consequently, the annual observation period for water table studies is December through May, inclusive.

5. Frequency of Observation

a. Manual Wells:

During the annual observation period, manual monitoring wells should be observed a minimum of two (2) times per week at an interval of two (2) to four (4) days, not to exceed four (4) days between observations. The interval between observations will be used as the time periods represented by each observation in determining the duration of a seasonally high water table. For example, with a four (4) day interval, each time a water table is measured within the minimum separation distance as specified by the regulation, a period of four (4) days of unacceptably high water table levels would be recorded toward the maximum consecutive or cumulative totals allowed in 8 (a) and (b) noted below. In soils suspected to have rapidly fluctuating water tables, a one (1) to two (2) day observation interval may be advantageous in determining the actual time an unacceptably high water table is present.

The frequency of monitoring in water table studies may be changed during the study when there is mutual agreement between the client and VDH.

b. Automated Wells:

During the annual observation period, automated wells must be set to read at least daily. It is recommended to set the reading interval to two or four times daily for soils with rapidly fluctuating water tables.

6. Precipitation

Precipitation monitoring may be evaluated on a case-by-case basis. Onsite precipitation data must be correlated with one of the acceptable precipitation reference sources mentioned later. The source of long-term precipitation data to be utilized for a study must be reviewed and approved by VDH prior to the start of monitoring.

Precipitation information may be obtained from a manual or automated rain (precipitation) gauge within one-half mile of the site, beginning no later than December 1 through March 15. Automated rain gauges shall record at least daily rainfall and must be supplanted with data from a manual rain gauge to ensure data validity. Manual rain gauges must be recorded at least biweekly. Rain gauges must be situated such that there is at least a 75-foot radius clear of trees and other vegetation. If the site is in a heavily wooded tract, a portion of land should be cleared to maintain the 75-foot lateral standoff distance of the gauges to the vegetation.

Data from the following acceptable sources may be substituted for onsite data if the data station is within 10 miles of the study site and reflects the general climatic conditions at the water table sites. Other sources of acceptable precipitation data may include the closest National Oceanic and Atmospheric Administration (NOAA) approved weather station or other technically valid sources such as university research stations, media weather stations, U.S. Geologic Survey stations, municipal water and sewer stations, and Virginia climatologic stations.

7. Length of Study

The duration of the water table study depends on how measured precipitation data for the year(s) in consideration compare with long-term (30+ yr) precipitation data obtained from a source mentioned in section 6. The comparisons must be evaluated in the 2 month period leading up to the study in addition to the observation period. Excessively low precipitation levels (<80% of long-term average precipitation) in the two (2) month period leading up to the monitoring period, or during the monitoring period, will result in that years monitoring being invalid. The water table study shall be conducted for:

One (1) annual observation period when there is >80% of normal, long term average precipitation in the 2 month period preceding the study and >95% of normal, long term average precipitation in the annual observation period. *OR*

Two (2) annual observation periods when there is >80% of normal, long term average precipitation in the 2 month period preceding the study and >80% of normal, long term average precipitation in each annual observation periods.

The observation study may be ended at any time after the maximum cumulative or consecutive time period of higher than allowed water table levels as specified in 8 (a) and (b) has been exceeded.

The study period must be of adequate length to show a trend into and out of the wet season. This is to ensure a proper evaluation of high water table levels that may be found in the months prior to and after the conventional “wet season”. If the seasonal water table has not trended downward by May 15, then monitoring must continue until it does.

8. Acceptable Water Table Levels

a. Annual Cumulative Days

The seasonal high water table should not be above the minimum required depth as specified by the Sewage Handling and Disposal Regulations and agreed to in the study proposal for more than thirty (30) cumulative days during any one annual monitoring period.

b. Annual Consecutive Days

The seasonal high water table should not be above the minimum required depth as specified in the Regulations and agreed to in the study proposal for more than twenty (20) consecutive days. This should be calculated by adding the number of consecutive days when water table levels were present. When two consecutive readings show the water table was shallower than the minimum required depth, the day before the first reading and the day after the second reading and all intervening days shall be counted as days where the water table levels were above the required minimum depth. A single high reading is considered as three (3) days where the water table levels were above the required minimum depth of high readings.

Criteria for acceptable water table levels are the same requirements for oxyaquic conditions found in the Keys to Soil Taxonomy (Soil Survey Staff, 2006). In addition, an average of 21 days of continuous saturation is needed for iron reduction (He, et al., 2003).

9. Failure and Termination of Testing and Monitoring

a. Termination of Testing

There shall be no site modifications (e.g., cut and fill, tile drainage, ditching, timber harvesting, etc.) during the study period. Site modification(s) conducted before, during, or after the installation of monitoring wells will invalidate monitoring of the site (s) and any submitted data, and will be considered prima facia evidence of site failure of the water table monitoring test. Site modifications will result in immediate termination of water table monitoring.

b. Failure of Test

When the seasonal high water table exceeds the annual consecutive days or cumulative days specified in 8 (a) or (b).

10. Reporting and Notification

a. Reporting

(1) Copies of the water table observation data and the precipitation data shall be submitted to the local health department within fourteen (14) days of the end of each month of observation.

(2) Within thirty (30) days of the end of each annual observation period, a report shall be submitted to the local health department summarizing the water table monitoring. The report shall relate data to the water table observation and precipitation data to maximize cumulative and consecutive days above the minimum depth required by the Regulations. In addition, the report shall state the percent of normal precipitation that occurred from December through May.

(3) A final report shall be submitted to the local health department within sixty (60) days of completion of the study. The report should include all water table and precipitation data and appropriate data summaries. The report shall clearly indicate the depth the water table for design purposes. The report should also discuss the overall results of the study with respect to required minimum depths to water table levels, percent of normal precipitation, and cumulative and consecutive days observed above the minimum 8 (a) and (b). The preferred water table data is in a line hydrograph format, showing horizontal lines where the water table criteria set in section 8 is met. A request for technical review of the report shall include digital copies of monitoring data.

b. Notification

The owner or his consultant shall notify the local health district within fourteen (14) working days when the observed water table level in any monitoring well has remained above the minimum required depth in excess of the consecutive or cumulative time limits specified in 8 (a) or (b).

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c. Authorization to Conduct Monitoring Tests

Water table monitoring may only be conducted by third-party consultant(s) and VDH staff. Virginia Certified Professional Soil Scientists (CPSS), Authorized Onsite Evaluators (AOSE) or Professional Engineers (PE) may conduct monitoring tests, with prior review and approval of VDH through a pre-monitoring conference.

d. Certifying Reports, Results and Interpretations

The third-party consultant(s) conducting the monitoring tests (see 10.c.) must certify that the reports, results, interpretations and conclusions submitted are accurate and complete, and represent an analysis of all available data for the site(s). Certifying the results will require a written statement and signed professional stamp on the written statement. When a PE works in conjunction with an CPSS and/or an AOSE on a monitoring project, both must sign and stamp the certification statement.

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Further technical information regarding the installation of water table monitoring wells can be found within these other documents:

Sprecher, S.W. 2008. Installing Monitoring wells in soils (Version 1.0) National Soil Survey Center, Natural Resources Conservation Service, USDA, Lincoln, NE. ftp://ftp-fc.sc.egov.udsa.gov/NSSC/wells/monitoring_wells.pdf

U. S. Army Corps of Engineers. 2005. Technical standard for water-table monitoring of potential wetland sites. ERDC TN-WRAP-05-2. US Army Engineer Research and Development Center, Vicksburg, MS. http://el.erdc.usace.army.mil/wrap/pdf/tnwrap05-2.pdf (accessed May 29, 2008).