REQUEST FOR PROPOSALS

FROM THE

PIEDMONT WETLANDS RESEARCH PROGRAM

RFP #01 – WETLAND HYDROLOGY MONITORING

A PROGRAM FUNDED BY WETLAND CREDIT SALES

FROM

NORTH FORK WETLANDS BANK

CEDAR RUN WETLANDS BANK

BULL RUN WETLANDS BANK

ADMINISTERED BY

WETLAND STUDIES AND SOLUTIONS, INC.

FUNDING PAYMENTS FROM

THE PETERSON FAMILY FOUNDATION

Proposal Application Due Date: February 29, 2008

WSSI #25000.01E

5300 Wellington Branch Drive • Suite 100 • Gainesville, VA 20155 • Phone 703.679.5602 • Fax 703.679.5601
mrolband@wetlandstudies.com • www.wetlandstudies.com

CONTENTS

CONTENTS

Attachments:

A. Solicitation Offer and Award Form

B. Groundwater Observation Well Diagram - Wetland Studies and Solutions, Inc. Standard Plan Detail

C. *Soil Mechanics in Engineering Practice,* Second Edition, Karl Terzaghi and Ralph B. Peck, figure 68.5, page 672

D. *Technical Standard for Water-Table Monitoring of Potential Wetland Sites*, U.S. Army Corps of Engineers, ERDC TN-WRAP-05-2, June 2005, 18 pages

E. *Installing Monitoring Wells/Piezometers in Wetlands*, ERDC TN-WRAP-00-02, July 2000, 17 pages

I. Background

The U.S. Army Corps of Engineers (COE), Department of Environmental Quality (DEQ), and U.S. Fish and Wildlife Service (USFWS) have worked with Wetland Studies and Solutions, Inc. (WSSI) and their wetlands bank financial partner, The Peterson Companies and the Peterson Family Foundation (PFF), to establish a wetlands research funding mechanism from revenues resulting from certain credit sales in three mitigation banks (Bull Run, Cedar Run, and North Fork).

The general goal for all research projects funded by this program shall be to determine the overall effectiveness of compensatory mitigation efforts and specifically how design and construction practices should be modified to improve the performance, in terms of functions and values, of compensatory mitigation.

The mission of this program is to fund applied research that makes a real and measurable difference (in terms of how mitigation sites are designed and built) in wetland creation, restoration, and enhancement activities in the Virginia Piedmont.

This Request for Proposal (RFP) is issued to public and private universities in Virginia, accredited by the Commonwealth of Virginia and with established programs related to the research topic. Its goal is to support research that will advance the science and engineering and provide state of the art practices for non-tidal wetlands creation, restoration, and enhancement, in the Piedmont Physiographic Province of Virginia.

II. Research Topic

A. The Basic Issue

"How to effectively and accurately monitor wetland hydrology in surface water driven systems with clayey soils?" Presumptively, an accurate monitoring system or device would reliably allow the user to correctly and consistently differentiate between saturated and unsaturated zoned within the upper portion of a wetland soil's root zone.

The current Standard of Practice (in the industry) is to use one inch (1") or two inch (2") shallow open casing wells (see attached Groundwater Observation Well diagram (from WSSI plan standards), *Technical Standard for Water-Table Monitoring of Potential Wetland Sites*, and *Installing Monitoring Wells/Piezometers in Wetlands*). While the COE changed installation recommendations for clayey soils in surface hydrology driven systems underlain by impermeable soils – this does not account for the long response (or "lag") time in low permeability soils (see *Soil Mechanics in Engineering Practice*, Second Edition, Karl Terzaghi and Ralph B. Peck, figure 68.5, page 672 – excerpt attached). Thus, often the well readings are not consistent with adjacent observable conditions such as soil saturation, vegetation response, or ditch drainage.

A second related issue is how such readings can be obtained in a manner that minimizes the ability for fraudulent measurements to be submitted (elevation, location, and timing).

B. Scope of Work Requirements

1. The successful applicant will[1]:

    a. Determine and document current COE well installation requirements, as well as current industry practices.

    b. Determine and document all available technology for wetland hydrology monitoring, such as (but not limited to):
        i. Various types of water content reflectometers;
        ii. Groundwater wells with probe readers;
        iii. Capacitance and conductance measuring devices; and
        iv. Time-domain reflectometer (TDR) and related technologies.

    c. Review literature for other methodologies, such as coated steel, Fe-oxide coated PVC, or copper rods that can be used to determine wetland hydrology.

    d. Determine and document all available technology to collect the actual hydrology data – ranging from field books to electronic personal digital assistants (PDAs) to Global Positioning System (GPS) enabled devices (for location and time verification).

2. Technology Assessment

    The successful applicant will:

    a. Develop unique methodologies for research studies (i.e., new ways of measuring soil saturation status)[2].

    b. Conduct laboratory and/or field testing on all promising methods identified after completing the work in Section II. B. 1.

    c. Assess and evaluate all tested methods upon the following (at a minimum) criteria:

        i. Accuracy;

---

[1] After selection and funding (not for the proposal)

[2] It is understood that this is an open-ended type of task and may not be practicable for all researchers. Thus, it is suggested that a portion of this project's budget be allocated to this task with the understanding that it may or may not result in a viable methodology.

ii. Reliability of use (i.e., do they break due to vandals, lightning, animals, etc.);
iii. Audit capability (can we prevent fraudulent data from being presented);
iv. How often a given method could/should acquire data; and
v. Cost.

3. Recommendation

The successful applicant will:

a. Provide an analysis of the pros and cons of each tested device and make a recommendation based upon this analysis.

b. Document how to make, obtain, and/or install the recommended device(s).

III. Submission of Proposals

A. Deadline and Delivery

The proposal application must be received by **5:00 PM on January 30, 2008**. Each proposal should be submitted as six (6) bound paper copies and an electronic copy in PDF format on a CD. Send proposal applications to the following address:

Michael S. Rolband, P.E., P.W.S., P.W.D.
Wetland Studies and Solutions, Inc.
5300 Wellington Branch Drive, Suite 100
Gainesville, Virginia 20155
Telephone: 703 679 5602
E-mail: mrolband@wetlandstudies.com

Please note that misdirected proposal applications will be deemed late and returned to the applicant. All proposal applications must be complete at the time of submission. Later changes or addendums will not be accepted.

FAXED OR E-MAILED APPLICATIONS WILL NOT BE ACCEPTED

B. Questions

Questions that arise during the proposal preparation should be directed by e-mail or U.S. Mail or overnight service[3] to:

Laura A. B. Giese, PhD, CF, PWS, PWD, CSE
Wetland Studies and Solutions, Inc.

[3] Telephone calls are not preferred, as all registered proposers must be informed of all questions, answers, and clarifications.

5300 Wellington Branch Drive, Suite 100
Gainesville, Virginia 20155
Telephone: 703 679 5633
E-mail: lgiese@wetlandstudies.com

With a copy to:

Carol Novak
Wetland Studies and Solutions, Inc.
5300 Wellington Branch Drive, Suite 100
Gainesville, Virginia 20155
Telephone: 703 679 5607
E-mail: cnovak@wetlandstudies.com

All responses and related responses shall be distributed to all registered proposers.

C. Registration of Proposers

If you desire to be informed of all questions and answers addressed during the proposal preparation process, as well as any RFP amendments, you must notify (via e-mail or U.S. mail) the following for registration:

Laura A. B. Giese, PhD, CF, PWS, PWD, CSE
Wetland Studies and Solutions, Inc.
5300 Wellington Branch Drive, Suite 100
Gainesville, Virginia 20155
Telephone: 703 679 5633
E-mail: lgiese@wetlandstudies.com

With a copy to:

Carol Novak
Wetland Studies and Solutions, Inc.
5300 Wellington Branch Drive, Suite 100
Gainesville, Virginia 20155
Telephone: 703 679 5607
E-mail: cnovak@wetlandstudies.com

IV. Program Funding

A. The PFF shall fund 100% of the accepted proposal's budget pursuant to an agreed upon payment schedule based upon research progress.

B. Applicants are ***not*** expected to provide any cost-share towards the research budget, unless your institution requires such funding to offset the difference between the allowed Indirect Cost rate and your institution's Indirect Cost rate.

C. The Indirect Cost rate shall be limited to 35% of all Direct Costs. This is a maximum rate; proposers may offer a lower rate.

D. Tuition for graduate students ***is allowable*** as a Direct Cost on a proportionate basis to the percentage of their research time dedicated to the proposal work.

E. The estimated cost range for this project is $150,000 to $250,000, with 12-18 month duration. If you do not expect this budget or time frame to be adequate to perform the work, please notify us as soon as possible during your preparation of the proposal so we can consider an amendment.

V. Proposal Review Process

A. Submission of Response to the Piedmont Wetlands Research Program in care of WSSI.

B. Based upon peer review recommendations in each proposal, as well as suggestions from WSSI staff and Mitigation Bank Review Team (MBRT) members, WSSI shall solicit peer review participants.

C. WSSI shall convene a peer review panel at its office for a one-day review meeting (MBRT members shall be invited to participate).

D. WSSI shall provide a recommendation to the MBRT for an award based upon its staff and peer review discussions. WSSI staff, MBRT members, and external peer reviewers will not review proposals where a significant personal or organizational conflict of interest exists.

E. The MBRT Chair shall have ten (10) days to (based upon MBRT comments): (i) concur with the RFP Award Recommendation, (ii) select an alternative proposal, or (iii) reject all proposals. The MBRT Chair shall provide one (1) signed original “Solicitation Offer and Award” form confirming its decision to WSSI.

F. WSSI shall notify PFF of the decision and the research grant shall be awarded by PFF to the selected proposal (if any).

G. ***More than one (1) response may be selected*** if the reviewers determine that significantly different research approaches are proposed that separately have the strong possibility of yielding a different, yet practicable, solution.

H. Timing: We expect the review process to take 90-120 days.

VI. Subcontractors

One academic institution must be the prime research contractor and designate a Principal Investigator (PI) as both the point of contact and the party responsible for performing the work. Other entities may be subcontractors to the prime research contractor subject to the following conditions:

A. They are an academic institution or a federal government entity with research capabilities (such as USGS), and

B. No more than 30% of the work (measured in dollars of Direct Cost) shall be undertaken by academic personnel from a non-Virginian academic institution or federal government entity.

C. The Prime Research Contractor cannot apply any indirect rate markup to the subcontractor's total cost except if that subcontractor's indirect rate is lower than that allowed for the prime. In such case, the prime contractor may charge the difference. In no case can the subcontractor charge more than the indirect rate allowed by the prime.

VII. Review Criteria

The proposals will be reviewed and scored based upon the following criteria, with the weighting noted below showing the likely value of each criterion in the award decision:

	Criteria	**Weight**
1.	Viability of the proposed research program relative to solving the stated need	20%
2.	Level of interest and expertise of the Principal Investigator(s) in the research topic	20%
3.	Overall proposal quality, innovation, and viability	20%
4.	Unique methodologies proposed for investigation	20%
5.	Cost	20%

The reviewers and ultimate decision makers reserve the right to modify, at any time during the review process, the weighting of each criteria or simply make a unilateral decision to not follow said weighting in the extraordinary circumstance that the weighting does not result in a practicable outcome. For example, if one proposal was triple the cost of all others, even if it was deemed superior in every other manner, we may determine that it is not an economically viable approach and not select that proposal or contact the proposer to discuss a modification to its proposal to address the cost issue.

VIII. Submission Requirements

Your response to this RFP must not exceed ten (10) single-spaced, typed pages,[4] using 12-point font size and one-inch margins (all sides) and include the following sections:

A. Solicitation Offer and Award Form (referenced in Section XII and provided in Appendix A): You must complete all sections on this form and obtain signatures of the appropriate officials.

B. Table of Contents: Please include major sections and the corresponding page numbers.

C. Executive Summary (limit to one page single spaced): Explain what you plan to do and why your team should be selected.

D. Project Team: Describe which institutions and, specifically, the people who will be involved (and to what degree) in this project. Explain why this team is best suited for this project.

E. Project Description:

1. Objectives: List the specific objectives of the project.

2. Background: Explain the relevance of the project.

3. Preliminary Studies (if applicable): Describe any precursor research you have conducted or are aware of that applies to the project topic and what was determined from those preliminary results.

4. Experimental Procedures/Methodologies: Describe any laboratory or field testing to be performed referencing analytical methods used and commercial products planned to be used or assessed in this program. List and describe each type of device that you will test and evaluate.

5. Description of Resources (i.e., laboratory facilities and/or field sites): Describe the laboratory facilities, testing equipment, field sites, etc. available for conducting the tasks associated with this project. If WSSI field sites are desired for use, describe which ones and how large an area.

6. Literature Cited: List all sources used.

[4] Text Section (i.e., does not include resumes, budgets, cash flow projections, schedules, or SOAF)

F. Scope of Work:

1. Issue Identification: Identify and briefly describe the issue this project is addressing.

2. Work Tasks: Break the project into specific work tasks and describe each work task individually.

3. Time Allocation: Describe how much time (by months) is to be allotted for each work task and when each task is to begin and end.

4. Resource Allocation: For each work task, list the personnel who will be working on that task and specifically what each person will be doing.

5. Quality Assurance/Quality Control: List measures planned to ensure that high quality results are achieved, such as descriptions of statistics to be used to evaluate data and to compare data to controls; field and lab QA/QC, data handling and security, and how to deal with the potential that graduate student tenures may not coincide with the research schedule.

6. Determination of Goals: Identify the means to be used to determine that project goals are met.

G. Budget and cash flow requirements for requested funding (use similar format as provided in Sections X and XI). You propose duration and cost, within the general parameters established in Section IV.E.

H. Budget Narrative: The budget may include salaries, travel, equipment, materials, and services ***not including fees or profit***. It is imperative that you specify any overhead, Indirect Costs, or fringe benefits rates, as well as which budget categories are affected by those rates. (For example, Indirect Costs defined as "Facilities and Administration" = 10% of Total Direct Cost less tuition and equipment). In addition, salaries must include personnel descriptions (i.e., faculty, graduate student, hourly worker, etc.), the number of hours expended on the project, and the hourly rate. Supplies must be listed in general terms (i.e., field supplies, general office supplies, etc.). Travel must include a description (trips to field site, conference, etc.), estimated number of hours for travel, and estimated cost per trip. In addition, for travel to conferences, estimate proposed expenses in the budget. For travel to conferences, specific information on conference title, dates of conference, and purpose in attending (i.e., presenting paper, poster session, etc.) must be supplied to WSSI for approval prior to travel. Other Direct Costs must include a general description (i.e., chemical analysis) and include units and unit cost. As stated in Section IV. C., Indirect Costs are fixed at 35% of Direct Cost. No cost-share funding is required.

Major pieces of equipment (>$5,000 with lifetime >2 years) are not eligible for purchase with funding from this program unless (i) they are clearly essential to the conduct of the proposed work, (ii) their documented use will be primarily for the proposed work, and (iii) they will be made available for use by future consortium research programs after the funding program is completed.

I. Proprietary Information: No information provided in proposals responding to this RFP shall be deemed proprietary. All information in each proposal could be subject to public disclosure or disclosed to other parties.

J. Organizational Chart: Provide an organizational chart depicting the structure of your team.

K. Curriculum Vitae (CV): Provide CV for each senior investigator involved in the proposed project. Resumes should be no more than two pages with an attachment listing all relevant publications within the past 20 years. Senior investigators include the principal investigator and any other faculty or senior-level personnel involved in the project. CV of lower level researchers may be included at your option.

L. Peer Review: Provide the name and contact data (address, telephone, e-mail) for a minimum of three (3) researchers you feel would be qualified to provide a peer review of this proposal without personal or organizational conflict of interest.

M. Research Schedule: Provide a projected schedule for your research activities. This schedule should be logically related to the budget's cash flow projections.

IX. Payment and Reporting Requirements

A. Reporting Requirements Shall Include:

1. Quarterly (i.e., March 31, June 30, September 30, December 31) Progress Reports with reports submitted within thirty (30) days after the end of the quarter describing (one or two paragraphs) your progress relative to the Proposal Schedule, Budget, and Scope of Work tasks.

2. An invoice for the work completed in the previous quarter – provided with the related quarterly report and billed by Work Task item.

3. Draft Final Report for WSSI and MBRT review.

4. Final Report (six [6] hard copies and six [6] PDFs on CD).

5. One short article for Virginia Association of Wetlands Professional Scientists (VAWPS) newsletter.

6. One peer reviewed publication article shall be prepared and submitted to an appropriate journal, such as *Wetlands*.

7. One seminar at WSSI's office which will be open to VAWPS and academics, as well as the consulting and regulatory community at large.

B. Payment Requirements

1. WSSI and/or MBRT representatives may inspect research facilities and discuss progress with researchers to verify invoice amounts and research progress at their discretion.

2. Undisputed Invoices shall be paid by PFF within thirty (30) days of tender ***if and only if*** they are submitted in the mandated manner and schedule described above. Invoices submitted later than prescribed above shall be delayed for processing until all reporting submissions are made timely in the next quarter.

X. Budget Sheet

Your proposed budget shall be submitted in a spreadsheet in a format similar to the description depicted below (to assist you in completing this form, a sample is provided):

Budget Sheet

Project Title: ______________________________

Principal Investigator: ______________________________

Organization: ______________________________

Requested Duration in Months: ______________________________

Item	**Unit Rate**[5] (A)	**Units**[6] (B)	**Quantity** (C)	**Cost** (D = A x C)
Salaries (list each person or position separately)				
Benefits (list each benefits rate per person / position)				
Tuition				
Supplies[7]				
Equipment[8]				
Subcontracts (provide breakdown of salary, benefits, tuition, supplies, equipment, etc. unless it is a lump sum less than $5,000)				
Travel				
Other Direct Cost				
Total Direct Cost				
Indirect Cost	35%[9]	N/A	N/A	
Total Cost	N/A	N/A	N/A	

[5] i.e., $/hr; ¢/mile
[6] i.e., LS = lump sum; hr = hours
[7] Items costing <$2,000 with a useful life <2 years
[8] Items costing ≥$2,000 with a useful life ≥2 years
[9] This is the maximum rate. Proposer may offer a lower rate.

SAMPLE

Budget Sheet

Project Title:	**Wetland Hydrology Monitoring**
Principal Investigator:	**Sam Jones, Ph.D.**
Organization:	**University of Wetlands**
Requested Duration in Months:	**18 Months**

Item	**Unit Rate**[10] (A)	**Units**[11] (B)	**Quantity** (C)	**Cost** (D = A x C)
Salaries				
Sam Jones, P.I.	8,000/month	N/A	9[12]	72,000.00
Jane Waters, Research Associate	3,000/month	N/A	18	54,000.00
Benefits				
P.I.	20%	N/A	N/A	14,400.00
R.A.	16.5%	N/A	N/A	8,910.00
Tuition	5,000 / semester	semester	3	15,000.00
Supplies	10,000	L.S.	1	10,000.00
Equipment	5,000	L.S.	1	5,000.00
Subcontracts				
Mineralogy Lab	3,000	L.S.	1	3,000.00
VA Tech Soils Lab	2,000	L.S.	1	2,000.00
Travel	.50/mile	Miles	5,000	2,500.00
Other Direct Cost	N/A	N/A	N/A	N/A
Total Direct Cost	N/A	N/A	N/A	186,810.00
Indirect Cost	35%	N/A	N/A	65,383.50
Total Cost	N/A	N/A	N/A	252,193.50

[10] i.e., $/hr; ¢/mile
[11] i.e., LS = lump sum; hr = hours
[12] 50% of 18 months

XI. Cash Flow and Work Task Budget Projection

Your Scope of Work shall include a Work Task section. For each Work Task, provide a quarterly (calendar year basis) cash flow projection. Ideally, you should develop this by spreading out your man hours, and related costs (from your budget) by work task and quarter. Each Invoice and each Progress Report should relate to these projections.

In summary, the Cash Flow and Work Task Budget should be presented in a format similar to the spreadsheet titled, "Cash Flow Projection Form." To assist you in completing this form, a sample is also provided.

Note: Some researchers asked why cash flow projections are requested. The reasons are twofold:

1. It provides a management indicator as to whether or not the resources expected to be needed for the project are being utilized – minimizing the potential of the "last minute push."

2. It allows the PFF to invest these monies prior to payments to researches in vehicles that maximize the return on investment subject to the limitation that they be available for use when you need the money.

Cash Flow Projection Form

(You Select Duration, i.e., Number of Quarters)

Work Task	**Total Budget**	**Cash Flow Projection**			
		1st Quarter 2008	**2nd Quarter 2008**	**3rd Quarter 2008**	**4th Quarter 2008**
List Each Task from Scope of Work:					
Draft Final Report					
Final Report					
VAWPS Article					
Peer Article					
WSSI Seminar					
Total Costs					

SAMPLE

Cash Flow Projection Form

(You Select Duration, i.e., Number of Quarters)

Work Task	Total Budget	Cash Flow Projection			
		1st Quarter 2008	2nd Quarter 2008	3rd Quarter 2008	4th Quarter 2008
List Each Task from Scope of Work:					
A. Document Existing Technology	15,000.00	15,000.00			
B. Develop Black Box Technology	70,000.00	35,000.00	35,000.00		
C. Set Up Testing Cells	30,000.00	30,000.00			
D. Lab Testing	60,000.00		30,000.00	30,000.00	
E. Data Compilation	30,000.00		10,000.00	20,000.00	
Draft Final Report	20,000.00			10,000.00	10,000.00
Final Report	10,000.00				10,000.00
VAWPS Article	2,000.00				2,000.00
Peer Article	10,000.00				10,000.00
WSSI Seminar	5,000.00				5,000.00
Total Costs	252,000.00	80,000.00	75,000.00	60,000.00	37,000.00

XII. Solicitation Offer and Award Form (SOAF)

Include one (1) original of the SOAF, signed by the Principal Investigator and Organization's Certifying Representative, with each of the six (6) hard copy submissions, and a PDF of said signed document on the CD containing your proposal.

See Attachment A: Solicitation Offer and Award Form.

RFP #1

WETLAND HYDROLOGY MONITORING

ATTACHMENTS

RFP #1

Wetland Hydrology Monitoring

Attachment A

Solicitation Offer and Award Form

Piedmont Wetlands Research Program
SOLICITATION OFFER AND AWARD

Wetland Studies and Solutions, Inc. 5300 Wellington Branch Drive, Suite 100 Gainesville, Virginia 20155	1. FOR INFORMATION CONTACT Name: **Laura A. B. Giese, PhD, CF, PWS, PWD, CSE** Phone: **703 679 5633** E-mail: **lgiese@wetlandstudies.com**

2. SOLICITATION NUMBER	3. TYPE OF SOLICITATION	4. DATE ISSUED
RFP #01 - WETLAND HYDROLOGY MONITORING	REQUEST FOR PROPOSALS (RFP)	**____________________, 200____**

SOLICITATION

5. DESCRIPTION OF WORK

The Proposer shall furnish all necessary staff, materials, tools, equipment and supervision to provide the research program and deliverables as described in the referenced RFP for Wetland Hydrology Monitoring and Proposer's Response.

6. DEADLINE FOR SUBMISSION

All proposals must be delivered to the following address by **5:00 PM** on **January 30, 2008**:

Michael S. Rolband, P.E., P.W.S., P.W.D.
President
Wetland Studies and Solutions, Inc.
5300 Wellington Branch Drive, Suite 100
Gainesville, Virginia 20155

7. PROPOSED BUDGET

____ ($____________.00)

OFFER (Offeror must complete in its entirety)

8. PRINCIPAL INVESTIGATOR

Name and Title: ____________________
Organization: ____________________
Mailing Address: ____________________
Telephone: ____________________ **Fax:** ____________________
E-mail: ____________________

PI Assurance: I agree to accept responsibility for the scientific conduct of the project, to provide the required reports, to acknowledge Peterson Family Foundation (PFF) and Wetland Studies and Solutions, Inc. (WSSI) in any presentations and publications wherein the results of this project are used, and to provide copies of presentation abstracts and publications to PFF and WSSI. I also agree to allow this proposal to be reviewed by industry and/or academia and that there is no proprietary information in this proposal.

____________________ ____________________
Signature of Principal Investigator **Date**

9. PROPOSER'S ORGANIZATION

Name: ____________________
Address: ____________________
Federal Tax ID Number: ____________________
Certifying Representative: ____________________
Name and Title

Certification and Acceptance: I certify that to the best of my knowledge, the statements contained herein are complete and true and I accept the obligation to comply with PFF and WSSI terms and conditions provided an award is made as a result of this submission.

____________________ ____________________
Signature of Organization's Certifying Representative **Date**

AWARD (To be completed by Review Entities)

10. APPROVAL AMOUNT	11. DATE OF AWARD
12. APPROVED RESEARCH START DATE	13. APPROVED RESEARCH COMPLETION DATE

14. RECOMMENDATION BY WETLAND STUDIES AND SOLUTIONS, INC.

____________________ ____________ ☐ Approved ☐ Rejected
Michael S. Rolband, President Date ☐ Proposed with Conditions:

____
____

15. SELECTION APPROVAL BY MITIGATION BANK REVIEW TEAM – BY U.S. ARMY CORPS OF ENGINEERS AS CHAIR

____________________ ____________
Signature/Title Date

By: ____________________ ☐ Approved ☐ Rejected
(Print or type name) ☐ Proposed with Conditions:

____
____

16. AWARD APPROVAL BY THE PETERSON FAMILY FOUNDATION

____________________ ____________
Signature/Title Date

By: ____________________
(Print or type name)

RFP #1

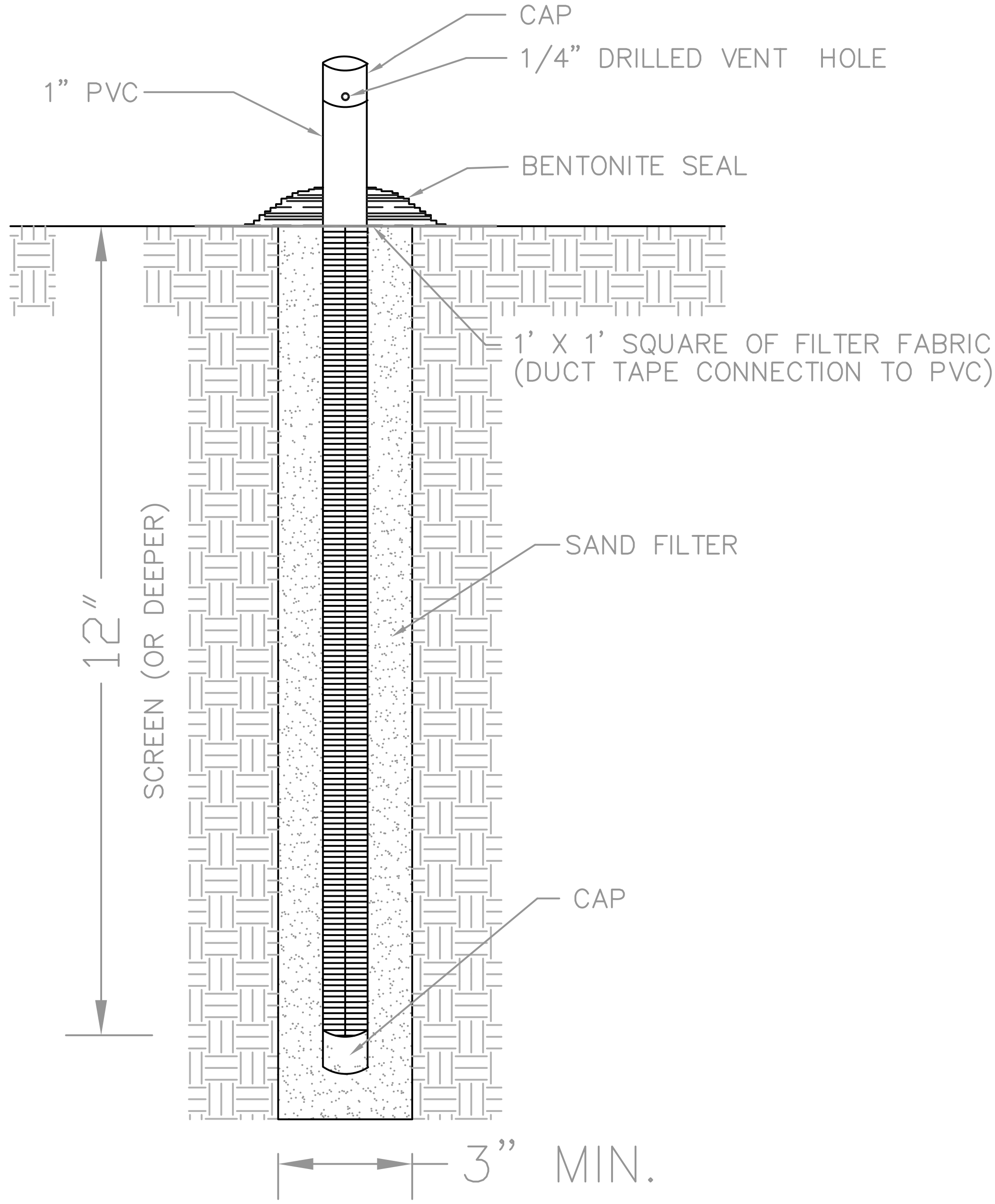
WETLAND HYDROLOGY MONITORING

ATTACHMENT B

GROUNDWATER OBSERVATION WELL DIAGRAM

WETLAND STUDIES AND SOLUTIONS, INC.

STANDARD PLAN DETAIL



GROUNDWATER OBSERVATION WELL
(SHALLOW MONITORING WELL)
(NOT TO SCALE)

1. Location depicted on Grading Plan.
2. Installation by WSSI under monitoring contract.
3. If larger PVC pipe used, maintain well diameter at least 2" greater than pipe diameter.

W

RFP #1

WETLAND HYDROLOGY MONITORING

ATTACHMENT C

SOIL MECHANICS IN ENGINEERING PRACTICE

SECOND EDITION

KARL TERZAGHI AND RALPH B. PECK

FIGURE 68.5, PAGE 672

Soil Mechanics in Engineering Practice

Karl Terzaghi

Late Professor of the Practice of Civil Engineering
Harvard University
Lecturer and Research Consultant in Civil Engineering
University of Illinois

Ralph B. Peck

Professor of Foundation Engineering
University of Illinois

Second Edition

JOHN WILEY & SONS, INC., New York, London, Sydney

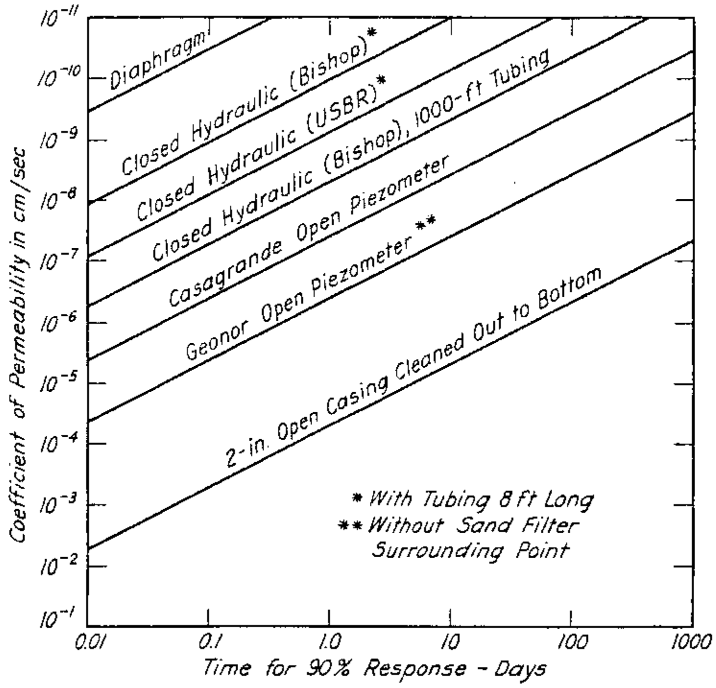


Fig. 68.5. Approximate response times for various types of piezometers (after Hvorslev 1951, Penman 1961, Brooker and Lindberg 1965, and others).

It is apparent that the requirements of each installation must be given careful consideration. A thorough knowledge of the subsurface conditions and of the fundamentals of groundwater flow is necessary for a proper choice of instrument. Moreover, unless the installation is made with the greatest care, and with intelligent consideration of field conditions rather than blind adherence to a set of rules, even the most refined instruments may lead to completely erroneous results or may cease to function altogether. Hence, the installation of piezometers, except in pervious, fairly homogeneous soils, cannot be delegated to the construction forces but must be done or supervised at every step by an experienced man who appreciates the significance of all the requirements for success.

Selected Reading

Detailed instructions concerning the installation and observation of piezometer tips of the USBR type are found in the *Earth Manual* (1963), 1st

They also avoid electrical circuitry. Their time lag is relatively small, but has not yet been fully evaluated.

Selection of Type of Piezometer

As a rule, the piezometer selected for a particular purpose should be the simplest that will satisfy the requirements. With increasing sophistication of the piezometer or of the measuring system, the probability of malfunction and of eventual failure increases, as does the cost.

The influence of the physical restrictions at the site on the type of piezometer that should be selected has already been mentioned. Not only is the type of instrument of concern, but so also are the relative ease or difficulty of providing an effective seal, and the extent to which the installation may interfere with the construction operations.

In all instances the hydrostatic time lag for the installation deserves careful consideration and may eliminate certain types of piezometers. The order of magnitude of the time required for 90% response of piezometers of several types, located in homogeneous soils, can be obtained from Fig. 68.5. The significance of the hydraulic time lag depends to a considerable extent on the nature of the anticipated fluctuations of the porewater pressure. For example, according to Fig. 68.5, the time lag for 90% response of a Geonor open standpipe in a soil having a coefficient of permeability of 10^{-7} cm/sec is about 5 days. If the purpose of the installation is to determine the porewater pressure in a natural deposit in which fluctuations of the pressure are not likely to be significant, and if the instrument can be left in position for several days, use of the Geonor piezometer would be appropriate. On the other hand, if the intention is to make a detailed survey of piezometric conditions over a wide area by inserting the instrument at a given location, waiting for equilibrium, and then withdrawing the instrument and moving to a new location, a time lag of more than a few minutes would not be tolerable and the instrument would not be suitable. Furthermore, if the water pressure at the point of measurement should be subject to daily fluctuations, as might occur in the reservoir above the dam for a power house, a hydrostatic time lag of three days would completely obscure the real variations of porewater pressure and the observations would have no value whatsoever. To obtain satisfactory results under these conditions, an installation with a time lag of no more than 30 to 60 minutes would be required. According to Fig. 68.5, a closed hydraulic piezometer would be needed.

RFP #1

WETLAND HYDROLOGY MONITORING

ATTACHMENT D

TECHNICAL STANDARD
FOR
WATER-TABLE MONITORING
OF
POTENTIAL WETLAND SITES

U.S. ARMY CORPS OF ENGINEERS

ERDC TN-WRAP-05-2

JUNE 2005, 18 PAGES

Technical Standard for Water-Table Monitoring of Potential Wetland Sites

by U.S. Army Corps of Engineers

PURPOSE: This technical note describes national standards for the collection, analysis, interpretation, and reporting of hydrologic data, which may be used to help determine whether wetlands are present on disturbed or problematic sites that may be subject to Clean Water Act regulatory jurisdiction. These standards may be supplemented or superseded by locally or regionally developed standards at the discretion of the appropriate Corps of Engineers District.

BACKGROUND: Wetland determinations in the majority of cases are based on the presence of readily observable field indicators of hydrophytic vegetation, hydric soils, and wetland hydrology, according to procedures given in the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987) (hereafter called the Corps Manual). These three characteristics are the best available evidence that an area has performed in the past, and continues to perform, the functions associated with wetland ecosystems.

The Corps Manual (Part IV, Section F, Atypical Situations) recognizes that wetland determinations on some sites may be difficult because of human disturbance that may have altered or destroyed wetland indicators. In addition, some naturally occurring wetland types may lack indicators or may have indicators present only at certain times of year or during certain years in a multi-year cycle (Part IV, Section G, Problem Areas). Wetland determinations in these atypical and problem situations increasingly involve the use of direct hydrologic monitoring to confirm the presence of wetlands in cases where soils or vegetation have been significantly disturbed or are naturally problematic, or where the hydrology of the site has been altered recently such that soil and vegetation indicators may give a misleading impression of the site's current wetland status.

The Corps Manual provides only a general discussion of wetland hydrology concepts and does not provide a suitable standard that can be used to design a hydrologic monitoring study or interpret hydrologic data, particularly in cases where groundwater is an important water source. Therefore, the purpose of this Technical Standard is to provide a minimum standard for the design, construction, and installation of water-table monitoring wells, and for the collection and interpretation of groundwater monitoring data, in cases where direct hydrologic measurements are needed to determine whether wetlands are present on highly disturbed or problematic sites.

USE OF THE TECHNICAL STANDARD: The Technical Standard is intended for use in atypical and problem situations as described in the Corps Manual. Atypical situations are broadly defined as any wetlands where indicators of hydrophytic vegetation, hydric soil, or wetland hydrology may be lacking due to recent human activities or natural events. Problem areas are wetlands that may lack wetland indicators at certain times due to normal variations in environmental conditions. This standard is designed to determine a site's current hydrologic status and may not be appropriate for evaluating past or pre-disturbance conditions.

This standard should not be used to overrule a wetland determination based on indicators of hydrophytic vegetation, hydric soil, and wetland hydrology on sites that are not significantly disturbed or problematic. Wetland indicators reflect natural processes that occur in wetlands and generally provide the best evidence that functioning wetlands are present on a site. The actual hydrologic regime required to produce and maintain a wetland may vary locally and regionally due to climate, landforms, geology, soils, and plant and animal adaptations. Therefore, any wetland hydrologic standard is necessarily an approximation and should be used only when an indicator-based wetland determination is not possible or would give misleading results.

In addition, this standard is not intended to overrule other scientific evidence that particular regional or local wetland types may be associated with hydrologic conditions different from those described here, including the seasonal timing, depth, duration, and frequency of saturation. Standards used to verify wetland hydrology in such cases should be based on the best available scientific information concerning a particular local or regional wetland type.

The Technical Standard is designed solely to determine the location of the water table for wetland jurisdictional purposes. It should not be used for water-quality monitoring or other purposes. This national standard may be supplemented or superseded by locally or regionally developed standards at the discretion of the District, and well-documented and justified deviations from the standard are acceptable with the approval of the District. It is always good practice to discuss the goals and design of the monitoring study with Corps regulatory personnel before initiating work. This may help to avoid disagreements and problems of interpretation later. This standard is subject to periodic review and revision as better scientific information becomes available.

SITE CHARACTERIZATION: A detailed site characterization should be completed before initiating the groundwater monitoring program. Site information is needed to determine appropriate well locations, installation depths, and other design features. The site characterization should begin with a review of all pertinent off-site information including county soil surveys, topographic maps, aerial photographs, and National Wetland Inventory (NWI) maps, if available. This review should be followed by a field investigation to verify the off-site information and gather additional data. At a minimum, the following site information should be collected (see Warne and Wakeley (2000) for detailed guidance):

- Detailed site map showing the location of property and project-area boundaries (determine coordinates of boundary points and landmarks, if possible).
- Topographic map showing the watershed boundary, water features (e.g., lakes, streams, minor drainages), and direction of water movement across the site.
- Current vegetation and land use.
- Detailed description of any modifications to site hydrology (e.g., water diversions or additions including ditches, subsurface drains, dams, berms, channelized streams, irrigation, modified surface topography, etc.).
- Soil profile descriptions including locations of soil test pits (indicate on site map and determine coordinates, if possible).

Soil profile descriptions are an important part of the site characterization because they may dictate appropriate depths for installation of water-table monitoring wells. Of critical importance is the identification of soil strata that can restrict downward water movement and create a perched water table. Examples of soil strata that may produce perched water tables include fragipans, spodic horizons, argillic horizons, and shallow bedrock. If a shallow restrictive soil layer is identified, care must be taken during well installation to ensure that the layer is not penetrated. Penetration of the restrictive layer may result in misleading water-level readings.

Soil profile descriptions should include horizon depths and (for each horizon) information about texture, color, induration (cementation), redoximorphic features, and roots, so that significant differences in permeability can be evaluated (Sprecher 2000). A blank Soil Characterization Data Form is provided for this purpose (Appendix A). Soil profiles must be described at least to the anticipated installation depth of the wells; profile descriptions to 24 in. or more are recommended. Several soil characteristics indicate that downward water flow may be impeded and that perched water tables may exist. Features to note include the following (Sprecher 2000):

- Abrupt change from many roots to few or no roots.
- Abrupt change in soil texture.
- Abrupt change in ease of excavation.
- Abrupt change in water content, such as presence of saturated soil horizons immediately above soil horizons that are dry or only moist.
- Redoximorphic features at any of the distinct boundaries listed above.

WELL PLACEMENT: A detailed discussion of monitoring well placement within the project site is beyond the scope of this Technical Standard. In general, well placement depends on the objectives of the investigation and characteristics of the site. If the objective is to determine whether wetland hydrology is present at a particular point, a single well may be sufficient. However, multiple wells may be necessary to determine if wetland hydrology occurs on a complex site where topography and human alterations (e.g., road construction, ditching) have produced considerable hydrologic variation. Well locations and depths are dictated by site conditions including topographic relief and the depth and continuity of restrictive soil layers. Portions of a site that are most likely to meet wetland hydrology standards (e.g., low-lying areas such as depressions, floodplain backwaters, swales and washes, fringes of lakes and ponds, toes of slopes, or other areas with shallow restrictive soil layers) should be identified during site characterization and considered for well placement.

If the objective is to confirm wetland boundaries based on groundwater measurements, then multiple wells installed along transects perpendicular to the expected wetland boundary are needed (Figure 1). The number and spacing of wells along each transect depend on the topographic gradient and the precision needed in defining the wetland boundary. Other site information that may help in placing wells and identifying boundaries includes changes in topographic gradient, proximity to hydrologic alterations (e.g., ditches), and changes in soil characteristics or vegetation.

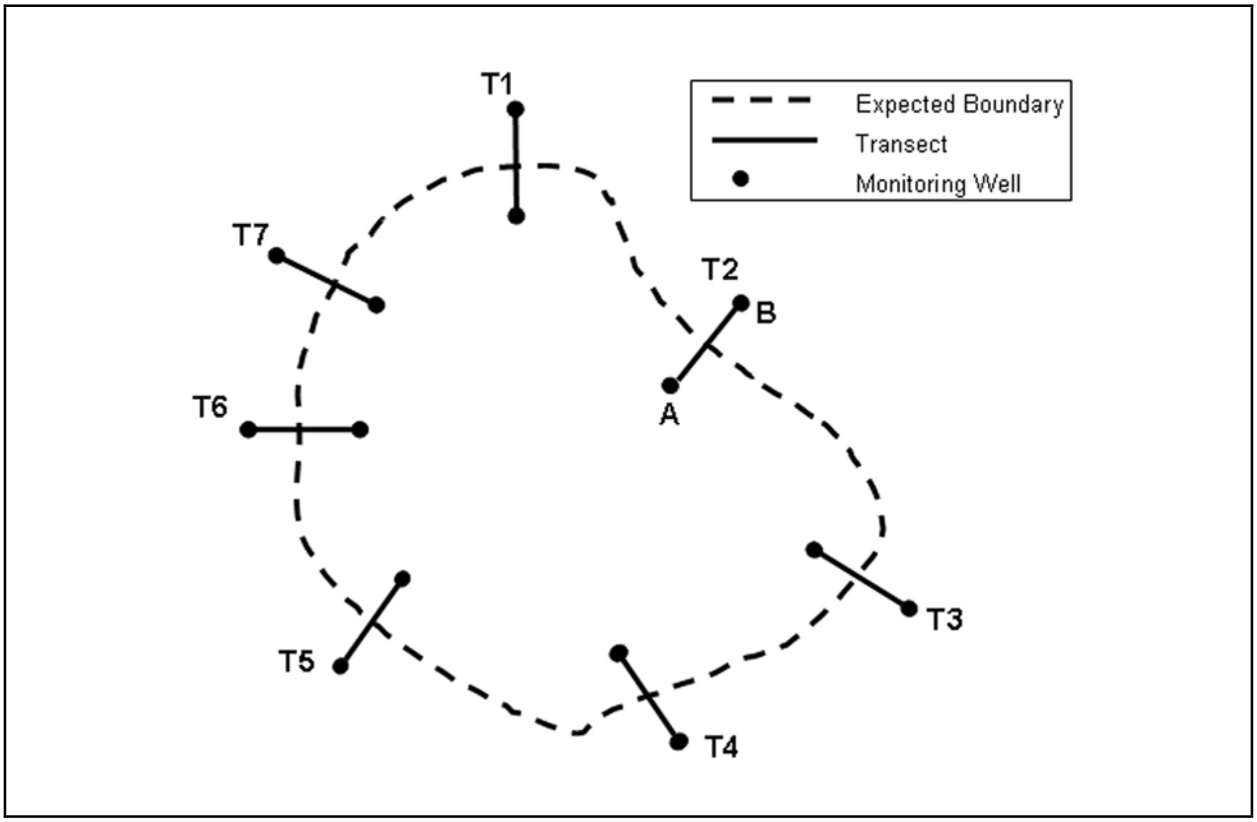


Figure 1. Example of monitoring wells located along transects across the expected wetland boundary. Transects extend from obvious upland to obvious wetland. Two or more wells are needed along each transect (e.g., at locations A and B).

MONITORING WELL CONSTRUCTION: In most cases, a standard monitoring well installed to a depth of 15 in. below the soil surface should be used to measure water-table depth on potential wetland sites. Shallower installation depths may be needed if restrictive soil layers exist within 15 in. of the surface. Monitoring wells must not penetrate any such restrictive layer. The standard design is for a well installed by augering. Depending upon site conditions, wells installed by driving may also be acceptable (see the section on Monitoring Well Installation). Installation of one or more additional deeper (4-5 ft) wells at each site is also encouraged to help in interpreting water-table fluctuations and warn of sudden changes in water-table depth. Deeper wells are not required but, if used, should not penetrate any restrictive soil layers. The performance of all wells must be tested and verified before use.

Monitoring Well Components. A standard monitoring well installed by augering is shown in Figure 2 and consists of the following main components: well screen, riser, well caps, sand filter pack, and bentonite sealant. Specifications for each of these components are given below.

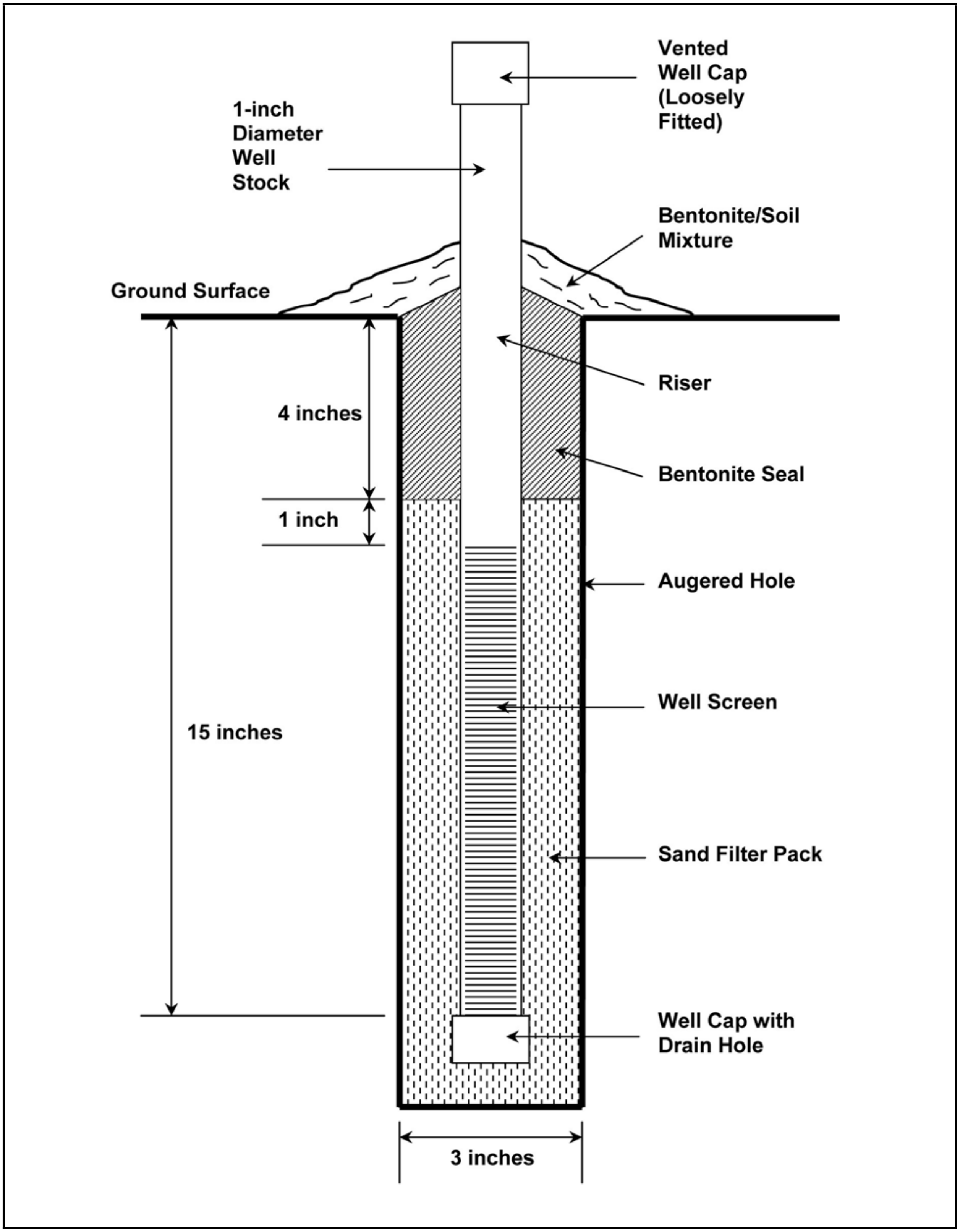


Figure 2. Standard 15-in. monitoring well installed by augering

Well Stock. Shallow monitoring wells should be made from commercially manufactured well stock. Schedule 40, 1-in. inside diameter PVC pipe is recommended. The diameter of the pipe allows sufficient room for hand measurement of water levels while minimizing well volume and maximizing responsiveness to water-table changes. The small diameter also minimizes auger hole diameter, volume of the filter pack, and the quantity of bentonite needed to seal the bore hole. However, if required by automated water-level recorders, then 2-in.-diam pipes can be substituted. Well stock larger than 2 in. in diameter should be avoided.

Well Screen and Bottom Cap. Recommended slot opening and slot spacing for the well screen are 0.010 in. and 0.125 in., respectively. The slotted screen should extend from approximately 5 in. below the ground surface down to the bottom of the well. Hand-slotted or drilled well screens should not be used.

One problem with the use of commercial well screen for very shallow monitoring wells is that there often is a length of unslotted pipe and joint or threads below the screen. In shallow monitoring situations, this extra length often must be inserted into underlying soil material that should be left undisturbed. In combination with a commercial well point, this extra length also provides a reservoir where water can remain trapped after the outside groundwater has dropped, resulting in the potential of misleading or incorrect readings during water-table drawdown. To avoid this problem, commercial well screen should be cut to the desired length within the slotted portion of the pipe. A PVC cap should be glued at the bottom of the screen and a small drain hole should be drilled in the bottom cap (Figure 2).

Riser. The riser is the unslotted PVC pipe that extends from the top of the well screen to above the ground surface (Figure 2). The riser should extend far enough above the ground to allow easy access but not so high that the leverage of normal handling will crack below-ground seals. In locations that do not pond or flood, 9 to 12 in. above the ground surface is usually sufficient. A longer riser may be needed on inundated sites or where automatic recording devices are used.

Well Top Cap. A well cap is required to protect the top of the well from contamination and rainfall. Caps should be attached loosely so they can be removed easily without jarring or dislodging the well, or cracking the bentonite seal. Tight-fitting caps, either threaded or unthreaded, should be avoided because they may seize to the riser and require rough handling to remove. A suitable well cap can be constructed from a short length of PVC pipe of a larger diameter than the riser, with a glued PVC cap at one end (Sprecher 2000). The constructed well cap can be attached loosely to the riser by drilling a hole through both the cap and the riser and connecting the two with a wire lock pin. The cap should be vented to allow equilibration of air pressure inside and outside of the well.

Filter Pack. A filter pack is placed around the well screen to remove fine particles and provide a zone of high hydraulic conductivity that promotes water movement toward the well (Figure 2). Filter packs can be classified into two major categories, natural and artificial. Natural packs are created by manually repacking any excavated soil around the well screen, ensuring that large voids are absent. Natural packs are recommended in coarse-textured, sandy soils. In fine-textured soils, an artificial pack should be used. See Table 1 for recommendations on the use of filter packs for soils of different textures.

Table 1
USDA Soil Texture Classes and Recommendations for Sand Filter Packs

USDA Soil Texture	Sand Pack
Muck, Mucky Peat, Peat	None
Coarse Sand	None
Medium Sand	None
Fine Sand	None
Loamy Sand	None
Sandy Loam	Recommended
Loam	Recommended
Silt Loam	Recommended
Silt	Recommended
Sandy Clay Loam	Required
Silty Clay Loam	Required
Clay Loam	Required
Sandy Clay	Required
Silty Clay	Required
Clay	Required

Commercially available silica sand is recommended for use as artificial pack material and is usually well-sorted, well-rounded, clean, chemically inert, and free of all fine-grained clays, particles, and organic material. Silica sand is available from water-well supply houses in uniformly graded sizes. Sand that passes a 20-mesh screen and is retained by a 40-mesh screen (20-40 sand) is recommended with a 0.010-in. well screen.

Bentonite Sealant. Bentonite is a type of clay that absorbs large quantities of water and swells when wetted. It is used in well installation to form a tight seal around the riser to prevent water from running down the outside of the pipe to the well screen. With this protective plug, only groundwater enters the slotted well screen.

When installing a monitoring well, 4 in. of bentonite should be placed around the riser immediately at and below the ground surface (Figure 2). This 4-in. ring of bentonite rests directly on top of the filter pack around the well screen. Above the bentonite ring, additional bentonite mixed with natural soil material should be mounded slightly and shaped to slope away from the riser so that surface water will run away from the pipe rather than pond around it at the ground surface.

Bentonite is available from well drilling supply companies in powder, chip, or pellet form. Chips are easiest to use in the field. They can be dropped directly down the annular space above the sand filter pack. If this zone is already saturated with water, the chips will absorb water in place, swell tight, and seal off the sand filter from above. If the bentonite chips are dropped into a dry annular space, they should be packed dry and then water should be added down the annular space so the clay can swell shut.

Modified Well Design for Clay Soils. In heavy clay soils, such as Vertisols, water movement occurs preferentially along cracks and interconnected large pores. These cracks may deliver water to a standard monitoring well through its vertical, slotted walls. Even when the surrounding soil is unsaturated, water may remain in the well for days due to impeded drainage into the slowly permeable clay. This problem can be reduced, but not eliminated, by using a well that is slotted or open only at the bottom. In addition, the sand filter pack should be installed only around the immediate well opening and should not extend up the riser. The annular space around the riser should be packed with the natural clay soil material or filled with bentonite.

Because Vertisols in wetland situations tend to be episaturated (i.e., they perch water at or near the surface but may remain unsaturated below), monitoring should focus on detection of surface ponding and saturation in the upper few inches of the soil. For this purpose, wells shorter than 15 in. may be needed.

MONITORING WELL INSTALLATION

Installation Methods. The recommended method for installing shallow monitoring wells involves the use of a bucket auger with an outside diameter 2 in. greater than the well diameter (e.g., 3 in. for a standard 1-in. well). As an alternative, wells may be installed by driving them into the ground. Driven wells may be preferred in areas with noncohesive coarse-grained (sandy) soils, rocky soils (e.g., glacial tills), or in saturated organic materials (i.e., mucks or peats). Procedures for both installation methods are given below. No matter which installation method is selected, wells must be tested for performance before being used. These procedures assume that the soil profile at the well location has already been described and that the appropriate well depth (i.e., 15 in. or less) has been determined based on the presence or absence of restrictive soil layers. A Monitoring Well Installation Data Form (Appendix B) should be completed to document the design and installation of each well (Sprecher 2000).

Augering. Recommended equipment includes a bucket auger 2 in. larger than the diameter of the well being installed, a tamping tool (e.g., wooden or metal rod), bentonite chips, silica sand, and the constructed monitoring well. A pump or bailer may be needed to test the well after installation. The following procedure is used to install the well:

1. Auger a hole in the ground to a depth approximately 2 in. deeper than the bottom of the well. Be sure the hole is vertical.

2. Scarify the sides of the hole if it was smeared during augering.

3. Place 2 to 3 in. of silica sand in the bottom of the hole.

4. For a 15-in. well with 10 in. of well screen, make a permanent mark on the well riser 5 in. above the top of the screen. Insert the well into the hole to the proper depth; the permanent mark on the riser should be even with the soil surface. Do not insert through the sand.

5. Pour and gently tamp more of the same sand in the annular space around the screen and 1 in. above the screen.

6. Pour and gently tamp 4 in. of bentonite chips above the sand to the ground surface. If necessary, add water to cause the bentonite sealant to expand.

7. Form a low mound of a soil/bentonite mixture on the ground surface around the base of the riser to prevent surface water from puddling around the pipe.

Driving. Well installation by driving is recommended when site conditions prevent augering (e.g., noncohesive sandy soils, soils with many coarse fragments, saturated organic soils). In addition, driven wells are acceptable whenever their performance can be shown to be equivalent to that of an augered well. Plans to use driven wells for regulatory purposes should be discussed in advance with the appropriate Corps of Engineers District office.

A driven well is similar in design and construction to the augered well described previously, with the addition of a well point in place of the bottom cap (Figure 3). Well points are commercially available and can be vented to permit draining by drilling a hole in the bottom. A special driving tool may be needed to install the well without damaging the PVC pipe.

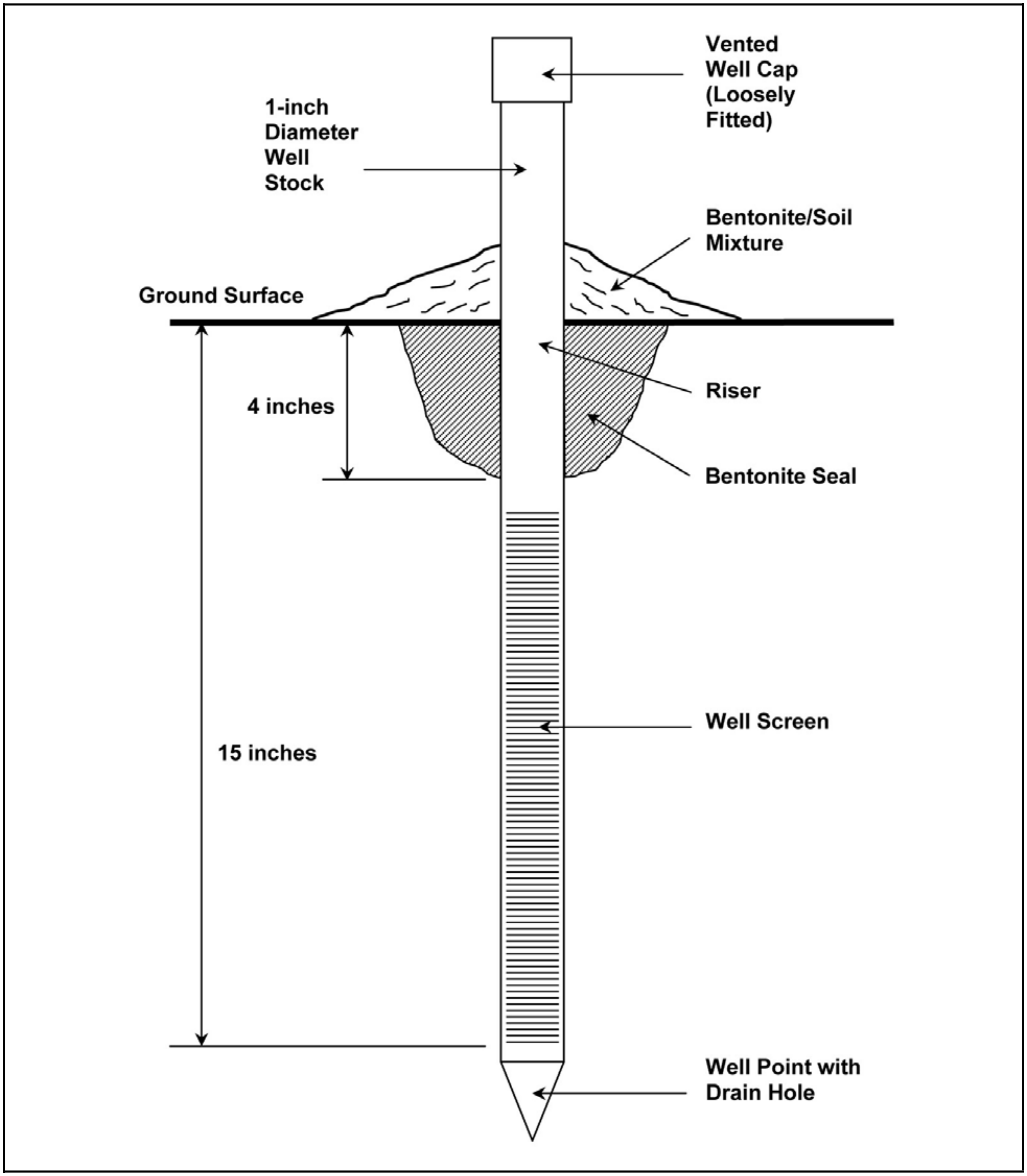


Figure 3. Standard 15-in. monitoring well installed by driving

Required materials include bentonite chips and the constructed monitoring well with vented well point. A pump or bailer may be needed to test the well after installation and, depending on site conditions, a driving device may be required. The following procedure is used to install the well:

1. For a standard 15-in. well, make a permanent mark on the riser 15 in. above the bottom of the well screen. With the well cap removed, use a driving device to drive the well vertically into the ground until the mark is at the ground surface. In organic soil materials, the well may simply be pushed into the ground.

2. Dig out a ring of soil around the well riser to a depth of 4 in. Fill this space with bentonite chips and add water, if necessary, to form a tight seal.

3. Form a low mound of a soil/bentonite mixture on the ground surface around the base of the riser to prevent surface water from puddling around the pipe.

Establishing Riser Height. Water-level measurements are typically recorded as the "depth to water" from the top of the well riser. The depth of the water table below the ground surface is determined by subtracting the riser height from the "depth to water" measurement. Therefore, after installing the well, measure and permanently record the height of the riser above the ground surface. If automated water-level recording devices are used, follow the manufacturer's instructions for calibration of water-level readings relative to the ground surface. Riser height should be checked after soils have thawed in spring, and should be re-checked periodically when water-table measurements are taken or electronic data are downloaded.

Surface Water. In areas subject to flooding or ponding, a separate staff gauge or automated device is required to measure the depth of surface water.

MONITORING WELL TESTING AND MAINTENANCE: During well installation, particularly with driven wells, fine soil particles may clog the well screen, impeding water flow and increasing the response time of the well. The performance of the well should be tested by (1) emptying the well by pumping or bailing and monitoring how quickly the water level returns to the initial level, or (2) if the well is dry, filling it with water and monitoring the rate of outflow. The water level in the well should reestablish itself at approximately the same rate as it would in a freshly dug hole without any pipe. In soils with a high percentage of clay, this could require several hours. If the water does not return to the initial level in a reasonable amount of time, pull the instrument out of the ground, clean it, reinstall it, and retest it. If water-table readings are questionable at any time during the monitoring period, one option is to move some distance away from the well location, auger to the depth in question, and determine whether the water level in the auger hole is the same as that indicated by the monitoring well.

Routine Maintenance. Monitoring well responsiveness should be tested at the beginning of the monitoring period and at least every 2-3 months thereafter by the procedure described above, because wells can plug over time due to bacterial growth and movement of fine soil particles. Well performance can also be affected by cracking of the bentonite seal, sediment deposition in the well, and movement of the ground surface and/or monitoring well due to frost heaving or shrink-swell action. To ensure accurate water-level readings, check for vertical displacement of the well after spring thaw and periodically during sampling by re-measuring the height of the riser above the ground surface and adjusting water-table measurements or resetting the well, as needed.

MAKING WATER-LEVEL MEASUREMENTS: Water levels in monitoring wells should be measured with an accuracy of ±0.25 in., if possible. Measurements may be made manually or with automated equipment. The use of automated water-level recorders is recommended unless an uninterrupted schedule of frequent site visits can be maintained. Automated recorders are also recommended in areas with highly variable or flashy hydrology. Whichever method is selected, it should be used consistently throughout the duration of the monitoring study.

Manual Readings. Water-level measurements can be made easily with a steel measuring tape marked with chalk or a water-soluble marker. Another approach is to use an electric device that sounds or flashes when the sensor, attached to the end of a graduated tape, makes contact with the water. Measurement devices that displace large amounts of water (e.g., dowel rods) should not be used.

Automated Readings. Automated recording devices record water levels with down-well transducers or capacitance-based sensors. An important consideration when purchasing automatic recording devices is the ability to compensate internally for variations in barometric pressure. These variations can be significant in wetland determinations. Automated equipment is more costly than hand measurement, but the devices can be used again in future studies. The credibility of monitoring results is enhanced with the high frequency of water-level readings that automated wells allow. Automated water-level recorders should be checked frequently for accuracy by comparison with manual readings. If automated readings are not within instrument specifications, the device should be recalibrated.

Required Timing, Frequency, and Duration of Readings. Water-level measurements must be taken at least once each day, beginning 5-7 days before the first day of the growing season and continuing until the end of the growing season or until the minimum standard for wetland hydrology is met that year. If automated recorders are used, readings four times per day are recommended (use the lowest reading each day). On sites subject to flooding or ponding, depth of surface water must be measured each day that water-table readings are made.

Growing season beginning and ending dates shall be based on the median dates (i.e., 5 years in 10, or 50 percent probability) of 28 °F air temperatures in spring and fall as reported in WETS tables provided by the USDA-NRCS National Water and Climate Center. WETS tables are based on long-term temperature data collected at National Weather Service (NWS) cooperative weather stations throughout the United States and are available on the Internet at http://www.wcc.nrcs.usda.gov/climate/wetlands.html. For a particular project site, growing season information from the nearest available weather station should be used unless, due to elevation or other factors, a more distant weather station is considered to be more representative of conditions at the project site. Alternative local or regional procedures for determining growing season dates may be used at the District's discretion.

Because hydrologic conditions are naturally variable, many years of groundwater monitoring data may be needed to establish what is typical for a given site. This is particularly true in the arid western United States where rainfall can be sparse, unpredictable, and highly localized. In general, ten or more years of water-table monitoring data may be needed to determine whether minimum standards for water-table depth, duration, and frequency in wetlands are met. However, because long-term monitoring is often impractical in a regulatory context, short-term studies may provide sufficient information if the normality of precipitation during the monitoring period is considered. Determining "normal" rainfall is addressed in the following section.

ANALYSIS AND INTERPRETATION OF MONITORING DATA

Technical Standard for Wetland Hydrology. Wetland hydrology is considered to be present on an atypical or problem site if the following standard is met:

> *The site is inundated (flooded or ponded) or the water table is ≤12 inches below the soil surface for ≥14 consecutive days during the growing season at a minimum frequency of 5 years in 10 (≥50% probability). Any combination of inundation or shallow water table is acceptable in meeting the 14-day minimum requirement. Short-term monitoring data may be used to address the frequency requirement if the normality of rainfall occurring prior to and during the monitoring period each year is considered.*

The Corps Manual discusses wetland hydrology in general, but does not provide a wetland hydrology criterion suitable for use in interpreting monitoring well data. The standard given above is based on recommendations by the National Academy of Sciences (National Research Council 1995). By requiring a water table within 12 in. of the surface, this standard ensures that saturation by free water or the capillary fringe occurs within the "major portion of the root zone" described in the Manual. A 14-day minimum duration standard is assumed to apply nationwide unless Corps Districts have adopted a different standard at the local or regional level. The Corps Manual addresses the need for long-term data (10 or more years) in analyses of stream-gauge data but does not consider the use of short-term data in wetland determinations, nor does it address the frequency issue in relation to water-table monitoring. This Technical Standard allows the use of short-term monitoring data to address the frequency requirement for wetland hydrology, if the normality of rainfall is considered.

The depth to saturation depends both on the position of the water table and the height of the tension-saturated capillary fringe (National Research Council 1995). While its presence has an influence on both plant growth and soil features, the upper limit of the capillary fringe is difficult to measure in the field and impractical as a basis for hydrologic monitoring. The Technical Standard for Wetland Hydrology is based on the depth of the water table because, in most cases, water-table depth can be monitored readily and consistently through the use of shallow wells with either manual or automated data collection. Water-table measurements should not be corrected for a capillary fringe unless other evidence, such as tensiometer readings, laboratory analysis of soil water content, or evidence of soil anoxia, indicates that the height of the saturated capillary fringe is greater than a few inches.

Determining Normal Precipitation. Short-term water-table monitoring data (i.e., <10 years) must be interpreted in relation to the amount of precipitation that fell during and for at least 3 months prior to the monitoring period each year. This is done by comparing the precipitation record for a given year with the normal range of precipitation based on long-term records collected at the nearest appropriate NWS cooperative weather station. The USDA-NRCS National Water and Climate Center calculates normal precipitation ranges for each month (defined as between the 30^{th} and 70^{th} percentiles of monthly precipitation totals) for NWS stations throughout the United States. The information is published in WETS tables available on the Internet (http://www.wcc.nrcs.usda.gov/climate/wetlands.html).

Sprecher and Warne (2000, Chapter 4) describe three methods for evaluating precipitation normality within a given year. The first method is taken from the NRCS Engineering Field Handbook (Natural Resources Conservation Service 1997) and involves the direct application of WETS tables in relation to monthly rainfall totals at the project site. At a minimum, this method shall be used to determine whether rainfall was normal immediately before and during a groundwater monitoring study. The analysis should focus on the period leading up to and during the time when water tables are usually high in that climatic region. In many parts of the country, this is at the beginning of the growing season, when precipitation is abundant and evapotranspiration is relatively low. The second method described by Sprecher and Warne (2000) evaluates daily precipitation data on the basis of 30-day rolling sums, and the third method combines the two procedures. If daily precipitation data are available, the combined method is recommended. The evaluation of precipitation normality should include the three months prior to the start of the growing season and extend throughout the entire monitoring period each year.

For many wetlands, water tables in a given year may be affected by precipitation that occurred in previous years, especially if monitoring occurs after an extended period of drought or precipitation excess. After a series of dry years, for example, it may take several years of normal or above-normal rainfall to recharge groundwater and return water tables to normal levels. Therefore, in evaluating wetland hydrology based on short-term monitoring, it is necessary to consider the normality of rainfall over a period of years prior to the groundwater study. Recent precipitation trends can be determined by comparing annual rainfall totals at the monitoring site with the normal range given in WETS tables for two or more years prior to the monitoring study, or by examining trends in drought indices, such as the Palmer Drought Severity Index (Sprecher and Warne 2000). This issue may not be important in soils with perched water tables that respond to the current year's rainfall and dry out seasonally.

Interpreting Results. If ten or more years of water-table monitoring data are available for a site, the long-term record probably includes years of normal, below normal, and above normal precipitation and thus reflects the average hydrologic conditions on the site. Therefore, wetland hydrology can be evaluated directly by the following procedure:

1. For each year, determine the maximum number of consecutive days that the site was either inundated or the water table was ≤12 in. from the ground surface during the growing season. Wetland hydrology occurred in a given year if the number of consecutive days of inundation or shallow water tables was ≥14 days.

2. The Technical Standard for Wetland Hydrology was met if wetland hydrology occurred in at least 50 percent of years (i.e., ≥5 years in 10).

This procedure may not be appropriate during extended periods of drought or precipitation excess. Furthermore, in some regions with highly variable precipitation patterns (e.g., the arid West) more than ten years of groundwater monitoring data may be needed to capture the typical hydrologic conditions on a site.

If fewer than ten years of water-table data are available, then the normality of precipitation preceding and during the monitoring period must be considered. One option is to apply the procedures described in the section on "Determining Normal Precipitation" for each year that water tables were monitored. In addition, annual precipitation or drought severity indices should be evaluated for two or more years prior to the monitoring period on any site that lacks a perched water table. Wetland hydrology can then be evaluated by the following procedure:

1. Select those years of monitoring data when precipitation was normal, or select an equal number of wetter-than-normal and drier-than-normal years.

2. If wetland hydrology (i.e., any combination of inundation or water table ≤12 in. from the surface for ≥14 consecutive days during the growing season) occurred in ≥50 percent of years (e.g., 3 years in 5), then the site most likely meets the Technical Standard for Wetland Hydrology.

It is important to remember that, even in normal rainfall years, many wetlands will lack wetland hydrology in some years due to annual differences in air temperatures (which affect evapotranspiration rates) and the daily distribution of rainfall that are not considered in this analysis. This is particularly true of borderline wetlands that may have shallow water tables in only 50-60 percent of years. Therefore, this procedure may fail to identify some marginal wetlands.

Another option, particularly for very short-duration monitoring studies (e.g., ≤3 years), is to evaluate water-table measurements in conjunction with groundwater modeling. Hunt et al. (2001) described one such approach, called the Threshold Wetland Simulation (TWS), which uses the DRAINMOD model. Actual water-table measurements in a given year are compared with those of a simulated, threshold wetland (i.e., one that meets wetland hydrology requirements in exactly 50 percent of years). The TWS approach requires detailed long-term precipitation and temperature data, soil characteristics, and considerable expertise with the DRAINMOD program.

No method to determine wetland hydrology based on short-term water-table measurements is entirely reliable or free of assumptions. Therefore, ultimate responsibility for the interpretation of water-table monitoring data rests with the appropriate Corps District.

REPORTING OF RESULTS: Warne and Wakeley (2000) provided a comprehensive checklist of information that should be included in the report of a groundwater monitoring study. The report should also include a justification for any deviations from procedures given in this Technical Standard.

The report should include a clear, graphical presentation of daily water-table levels at each well plotted over time and shown in relation to the soil surface and the 12-in. depth, the depth of the monitoring well, growing season starting and ending dates, local precipitation that year, and normal precipitation ranges based on WETS tables. Another useful feature is a diagram of the soil profile at the well location including depths and textures of each major horizon. An example graph with many of these features is shown in Figure 4 (Sprecher 2000).

ACKNOWLEDGMENTS: The initial outline for this Technical Standard was developed at a workshop in Decatur, GA, in September 2003. Participants (in alphabetical order) were Mr. William Ainslie, U. S. Environmental Protection Agency (USEPA), Region 4; Mr. Bradley Cook, Minnesota State University, Mankato; Mr. Jason Hill, Tennessee Tech University (TTU); Ms. Julie Kelley, Geotechnical and Structures Laboratory (GSL), U. S. Army Engineer Research and Development Center (ERDC); Dr. Barbara Kleiss, Environmental Laboratory (EL), ERDC; Dr. Vincent Neary, TTU; Mr. Chris Noble, EL-ERDC; Dr. Bruce Pruitt, Nutter and Associates, Inc.; Dr. Thomas Roberts, TTU; Mr. Paul Rodrigue, USDA Natural Resources Conservation Service (NRCS);

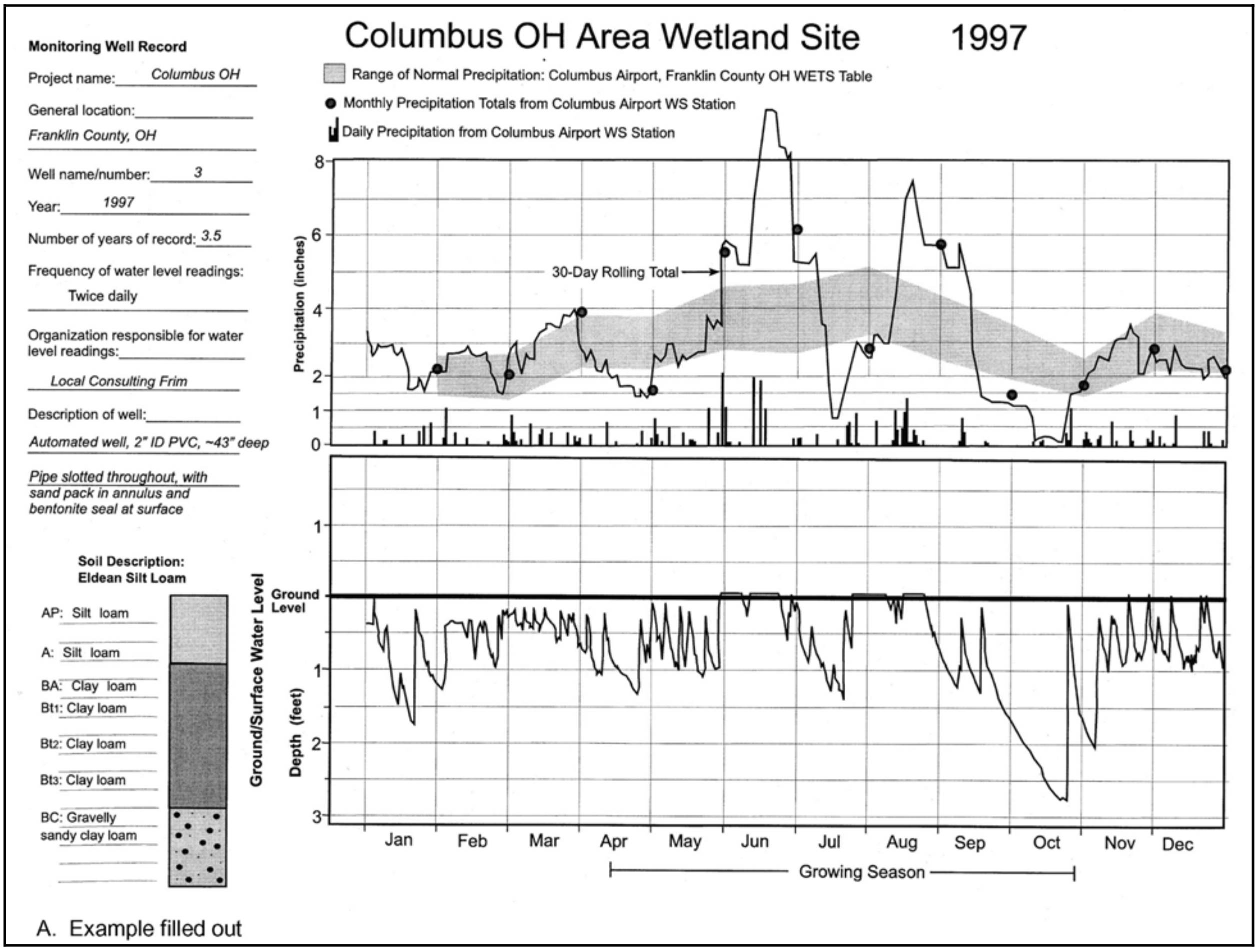


Figure 4. Example of graphical presentation of water-table monitoring data (Note that this example uses a deeper well than the 15 in. specified in this Technical Standard)

Dr. Steven Sprecher, U. S. Army Engineer (USAE) District, Detroit; and Dr. James Wakeley, EL-ERDC. The first draft was written by Drs. Neary and Wakeley and Messrs. Hill and Noble. Technical reviewers included Harry Baij, Jr., USAE District, Anchorage; Mark Clark, NRCS; David D'Amore, U. S. Forest Service (USFS); Jackie DeMontigny, USFS; Michiel Holley, USAE District, Anchorage; Wesley Miller, NRCS; James Miner, Illinois State Geological Survey; Joe Moore, NRCS; Dr. Chien-Lu Ping, University of Alaska, Fairbanks; Ann Puffer, USFS; and Ralph Rogers, USEPA Region 10. A subcommittee of the National Technical Committee for Hydric Soils (NTCHS) provided an independent peer review in accordance with Office of Management and Budget guidelines. The authors are grateful to NTCHS members Drs. Michael Vepraskas and R. Wayne Skaggs, North Carolina State University; and Mr. Ed Blake, Mr. P. Michael Whited, Ms. Lenore Vasilas, and Mr. G. Wade Hurt, NRCS, for their comments and suggestions. The work was supported by Headquarters, U. S. Army Corps of Engineers through the Wetlands Regulatory Assistance Program (WRAP).

POINTS OF CONTACT: For additional information, contact Dr. James S. Wakeley, U. S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, (601-634-3702, James.S.Wakeley@erdc.usace.army.mil) or the Program Manager of the Wetlands Regulatory

Assistance Program, Mr. Bob Lazor (601-634-2935, *Bob.L.Lazor@erdc.usace.army.mil*). This technical note should be cited as follows:

> U. S. Army Corps of Engineers. (2005). "Technical Standard for Water-Table Monitoring of Potential Wetland Sites," *WRAP Technical Notes Collection* (ERDC TN-WRAP-05-2), U. S. Army Engineer Research and Development Center, Vicksburg, MS.

REFERENCES

Environmental Laboratory. (1987). "Corps of Engineers Wetlands Delineation Manual," Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. (Annotated on-line version available at http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf)

Hunt, W. F., III, Skaggs, R. W, Chescheir, G. M., and Amatya, D. M. (2001). "Examination of the Wetland Hydrologic Criterion and its Application in the Determination of Wetland Hydrologic Status," Report No. 333, Water Resources Research Institute of the University of North Carolina, North Carolina State Univ., Raleigh.

National Research Council. (1995). "Wetlands: Characteristics and Boundaries," National Academy Press, Washington, DC.

Natural Resources Conservation Service. (1997). "Hydrology tools for wetland determination," Chapter 19, *Engineering field handbook*, Donald E. Woodward, ed., USDA-NRCS, Fort Worth, TX. (http://www.info.usda.gov/CED/ftp/CED/EFH-Ch19.pdf)

Sprecher, S. W. (2000). "Installing monitoring wells/piezometers in wetlands," WRAP Technical Notes Collection, ERDC TN-WRAP-00-02, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/tnwrap00-2.pdf)

Sprecher, S. W., and Warne, A. G. (2000). "Accessing and using meteorological data to evaluate wetland hydrology," Technical Report TR-WRAP-00-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/wrap00-1/wrap00-1.pdf)

Warne, A. G., and Wakeley, J. S. (2000). "Guidelines for conducting and reporting hydrologic assessments of potential wetland sites," *WRAP Technical Notes Collection*, ERDC TN-WRAP-00-01, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://el.erdc.usace.army.mil/elpubs/pdf/tnwrap00-1.pdf)

APPENDIX A. SOIL CHARACTERIZATION DATA FORM

Soil Characterization Data Form

Project Name________________________________ Date________________________
Personnel___________________________________ Soil Pit ID_____________________

Horizon Depths (inches)	Texture	Matrix Color (Munsell moist)	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		

Comments:

APPENDIX B. MONITORING WELL INSTALLATION DATA FORM

Monitoring Well Installation Data Form

Project Name ____________________ Date of Installation ______________
Project Location ____________________ Personnel ______________
Well Identification Code ____________________
Attach map of project, showing well locations and significant topographic and hydrologic features.

Characteristics of Instrument:
Source of instrument/well stock ________________________________
Material of well stock ____________________ Diameter of pipe ______________
Slot width ____________________ Slot spacing ______________
Kind of well cap ____________________ Kind of well point/end plug ______________
Installation:
Was well installed by augering or driving? ________________________________
Kind of filter sand ____________________ Kind of bentonite ______________
Depth to lowest screen slots ____________________ Riser height above ground ______________
Was bentonite wetted for expansion? ________________________________
Method of measuring water levels in instrument ________________________________
How was instrument checked for clogging after installation? ________________________________

Instrument Diagram[a]	Soil Characteristics					
	Texture	Matrix Color	Redoximorphic Features		Induration (none, weak, strong)	Roots
			Color	Abundance		

[a]Show depths (heights) of riser, well screen, sand pack, and bentonite in relation to soil horizons.

RFP #1

WETLAND HYDROLOGY MONITORING

ATTACHMENT E

INSTALLING MONITORING WELLS / PIEZOMETERS IN WETLANDS

ERDC TN-WRAP-00-02

JULY 2000, 17 PAGES

Installing Monitoring Wells/ Piezometers in Wetlands

PURPOSE: Wetland scientists frequently need quantitative information about shallow groundwater regimes near wetland boundaries and in adjacent uplands. Monitoring wells and piezometers are some of the easiest means of determining depth and movement of water tables within and immediately below the soil profile. Most of the literature on monitoring wells and piezometers, however, deals with installation to depths greater than needed for wetland regulatory purposes.

This revision of the original 1993 technical note reflects increased experience gained over several monitoring years from around the nation in the USDA-NRCS Wet Soils Monitoring project (*http://www.statlab.iastate.edu/soils/nssc/globhome.html#project9*) and other wetland research efforts.[1] Significant changes from the original version include:

- Recommending that 15-in. wells be used to test whether the hydrologic regime meets the criteria for wetland hydrology.
- Listing documentation needs.
- Eliminating well points except with commercially manufactured, automatic recording wells.
- Recommending that a bentonite be used rather than grout in the annular space around the riser and at the ground surface.
- Using filter fabric when installation under water prevents use of a sand pack.
- Stating explicitly that these procedures are not applicable to soils with low bulk strength and lateral water flow, such as mucks or peats. If the bentonite seal and sand pack might interfere with monitoring objectives, procedures described by Cherry et al. (1983) should be considered.

BACKGROUND: Monitoring wells and piezometers are perforated pipes set vertically in the ground to intercept the groundwater passively (Figure 1).

- **Monitoring wells** have perforations extending from just below the ground surface to the bottom of the pipe. Water levels inside the pipe result from the integrated water pressures along the entire length of perforations.
- **Piezometers** are perforated only at the bottom of the pipe. They are usually installed with an impermeable bentonite seal above the perforated zone so water cannot flow down the outside of the pipe. Water levels inside the pipe result from the water pressure over the narrow zone of perforation at the bottom of the pipe.

---

1 The methods described herein do not apply to water-sampling studies. Researchers needing to sample water from wells should refer to U.S. Army Corps of Engineers (1990); American Society for Testing and Materials (1990); and Cherry et al. (1983).

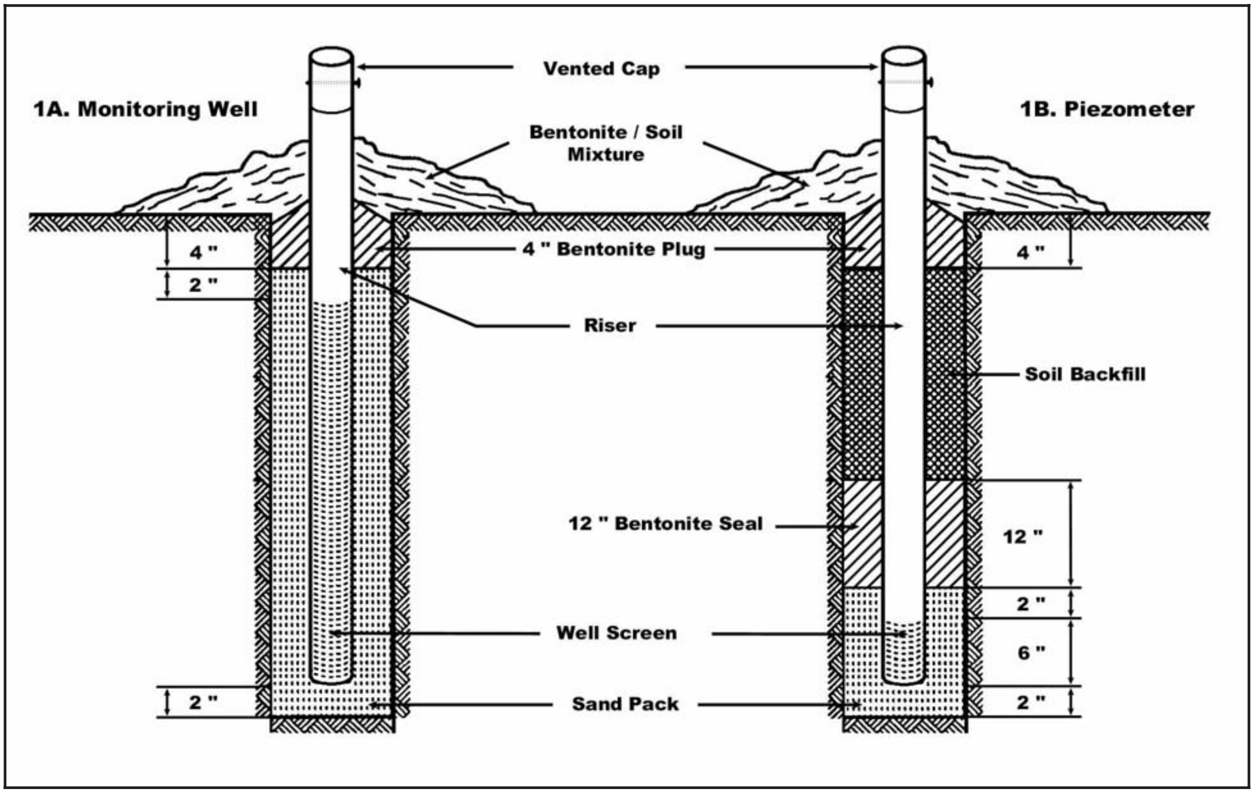


Figure 1. Schematic diagram of installed monitoring well and piezometer. A. Shallow monitoring well. B. Piezometer

Water levels in slotted pipes do not necessarily equate with the actual water table in the undisturbed soil. Instead, water levels in slotted pipes result from water pressures at the instrument:soil interface. Consequently, slotted pipes of different lengths can have differing water levels, despite the fact that they intercept the same body of groundwater. This distinction can be significant if the body of groundwater is moving upward or downward. If the body of water is moving upward, as in artesian flow, water pressures are greater at depth and decrease closer to the groundwater surface. Consequently, water levels will be higher in deep pipes than in shallow ones (Figure 2A). Conversely, in systems where water moves downward, water levels are lower in deep pipes and higher in shallow ones (Figure 2B).

Recent work in Illinois has shown that differences between water levels in 12- and 30-in.-long wells are on the order of centimeters rather than decimeters or millimeters,[1] and that these differences are more pronounced in soils that have been disturbed. Such differences can be significant for wetland delineation studies at the wetland boundary. See Table 1 for an example of water levels in 15- and 30-in. wells near the wetland boundary where water is flowing downwards.

1 Personal Communication, July 2000, James J. Miner, Geologist, Illinois State Geological Survey, Champaign, IL.

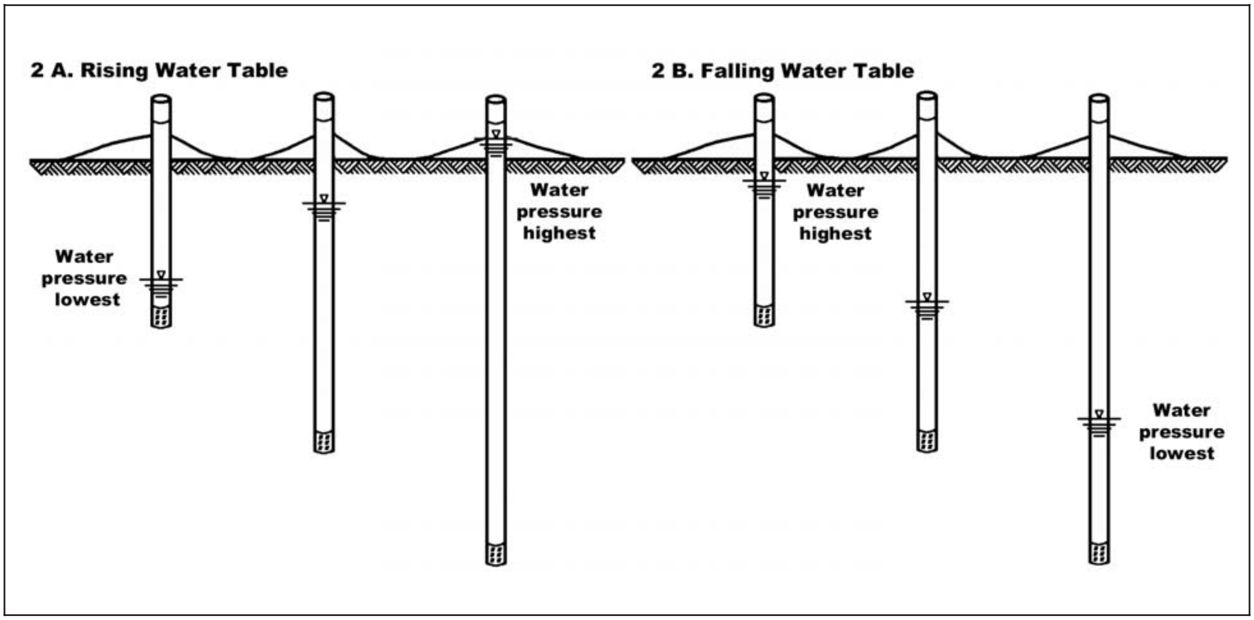


Figure 2. Example of water levels in piezometers. A. Water tables rising from below (artesian or discharge system). B. Water tables dropping from above (recharge system)

Table 1
Example of Water Well Readings in Shallow and Deep Wells with Downward Water Flow

Depth of Slotted Screen	Water Level Inside Instrument	Above Critical Depth for Wetland Hydrology?
15-in. well	11 in.	Yes
30-in. well	13 in.	No

These two wells are probably measuring hydrostatic pressures in the same body of groundwater. The net flow is downward. Assume that the data from either of these two wells were used alone to assess whether wetland hydrology criteria were met. Using the deep well, the evaluator would have to tally the data as being below the 12-in. threshold for wetland hydrology; using the shallow well, however, the evaluator would have to tally the data as being above the 12-in. threshold. The 2-in. (5-cm) difference is within the range of actual differences found in the field.

In borderline situations such as this, 15-in. wells should be included in the study design unless differences between readings in shallow and deep wells are smaller than the precision of data interpretation. In Table 1, the shallow wells are redundant to the deep wells if water levels are interpreted with a precision of ± 2 in. However, if water levels are interpreted with greater precision, the shallow wells provide important additional information.

SELECTING INSTRUMENTATION: It is vital to define study objectives before buying and installing instruments in order to avoid gathering unnecessary or meaningless data. Common study purposes are wetland determination, wetland delineation, determination of whether a wetland is a recharge or discharge system, and determination of water flow paths in the landscape.

Wetland Determination. When determining whether criteria for wetland hydrology or hydric soils are met at a point on the landscape, there are usually three objectives. Table 2 summarizes the instruments required for three different scenarios.

Table 2
Water Table Monitoring Objectives and Instrumentation for Three Scenarios of Perching

	Instrument		
Objective	**Scenario 1: Degree of Perching Uncertain; Discharge or Recharge Systems (e.g., most wetland fringes)**	**Scenario 2: Shallow Water Table Perched within Depth of Monitoring (e.g., soils w/clay textures throughout or clay-rich horizons)**	**Scenario 3: Shallow, Static Water Table or Water Flow is Lateral (e.g., tidal marsh or flow-through wetland)**
Objective 1: Determine timing, duration, and frequency that water tables are shallower than threshold depths for wetland criteria	15-in. well	15-in. well	Well to greatest depth of interest, usually less than 48 in.
Objective 2: Determine timing, duration, and frequency that water tables are near threshold depths for wetland criteria	Well to greatest depth of interest; install well to top of perching layer if perching is proven	Well to top of perching zone	Well to greatest depth of interest, usually less than 48 in.
Objective 3: Determine timing, duration, and frequency that water tables are considerably deeper than critical depths	Well to greatest depth of interest, usually less than 48 in.; per Scenario 2 if perching is proven	Piezometers within and below impermeable layer	Well to greatest depth of interest, usually less than 48 in.
Summary of Instruments	15-in. well and deep well	15-in. well and piezometers in and below perching zone	One deep well; if soil is unconsolidated, consider methods of Cherry et al. (1983)

For Scenario 1 (Table 2), both 15-in. and deep wells should be installed unless local experience indicates that the shallow ones provide no additional information. The financial stakes of most regulatory investigations will usually be much greater than the very small additional investment of time and money needed to install, read, and maintain the shorter wells. If it is documented that a single deep instrument will meet all three objectives (Table 2), the shallower instruments can be dispensed with. It may not be necessary to install both shallow and deep wells at every monitoring station around a wetland. The number and depths of deep and shallow wells should be determined beforehand by all parties involved in the project to avoid later contention.

When installing very shallow monitoring wells, be aware of their physical instability. Shallow wells may need to be reinstalled more frequently than deeper ones.

Wetland Delineation. To identify the location of the boundary between wetlands and non-wetlands, install sets of instruments along transects perpendicular to the expected wetland boundary. The same combinations of instruments that were recommended for wetland determination should be installed at each point along the transect. Shallow wells can be dispensed with in obvious wetlands and in obvious non-wetlands, but usually they are necessary close to the wetland boundary.

Recharge Versus Discharge Determination. Sets of piezometers at different depths are needed to determine direction of water flow (upward or downward) at any point in a wetland (Figure 2). The exact depths of piezometers will vary from site to site, depending on stratigraphy and topographic position. In soils with large differences in permeability, piezometers should be placed on top of, within, and below suspected perching layers to test whether the suspect layers actually impede water flow. Unusually permeable layers, such as sand lenses, should always be instrumented.

Determine Water Flow Paths in a Landscape. Sets of piezometers are located both up- and down-gradient along suspected water flow paths (Warne and Smith 1995).

CONSTRUCTION OF PIEZOMETERS AND SHALLOW MONITORING WELLS

Well Stock. Shallow monitoring instruments should be made from commercially manufactured well stock. Schedule 40, 1-in.-diam PVC pipe is recommended. This diameter pipe allows sufficient room for sampling while minimizing sampling volume and size of bentonite seal in the bore hole. Larger diameter pipes can be substituted when needed, as with automated samplers.

Well Screen. Use 0.010-in.-wide slots and 20-40 sand (see section on sand pack below). For shallow wells, the slotted screen should extend from approximately half a foot below the ground surface down to the bottom of the well (Figure 1A). For piezometers, the well screen is usually the bottom 6 in. of the pipe (Figure 1B).

One problem with use of commercial well screen for very shallow monitoring wells and piezometers is that there often is a length of unslotted pipe and joint or threads below the screen. In shallow monitoring situations this extra length often must be extended into an underlying soil horizon that should be left undisturbed. In combination with a commercial well point, this extra length also provides a reservoir where water can remain trapped after the outside groundwater has dropped, making readings difficult to interpret during water table drawdown. To avoid these problems, cut commercial well screen to the desired length within the slotted portion of the pipe (Miner and Simon 1997). Glue a PVC cap at the bottom of the screen and drill a small vent hole in the bottom cap (Figure 3).

Riser. The riser is the unslotted PVC pipe that extends from the top of the well screen to above the ground surface (Figure 1). The riser should extend far enough above ground to allow easy access but not so high that the leverage of normal handling will break below-ground seals. Nine to twelve inches is usually sufficient. A greater length of riser above the ground may be needed on sites that are inundated regularly or where automatic recording devices are used.

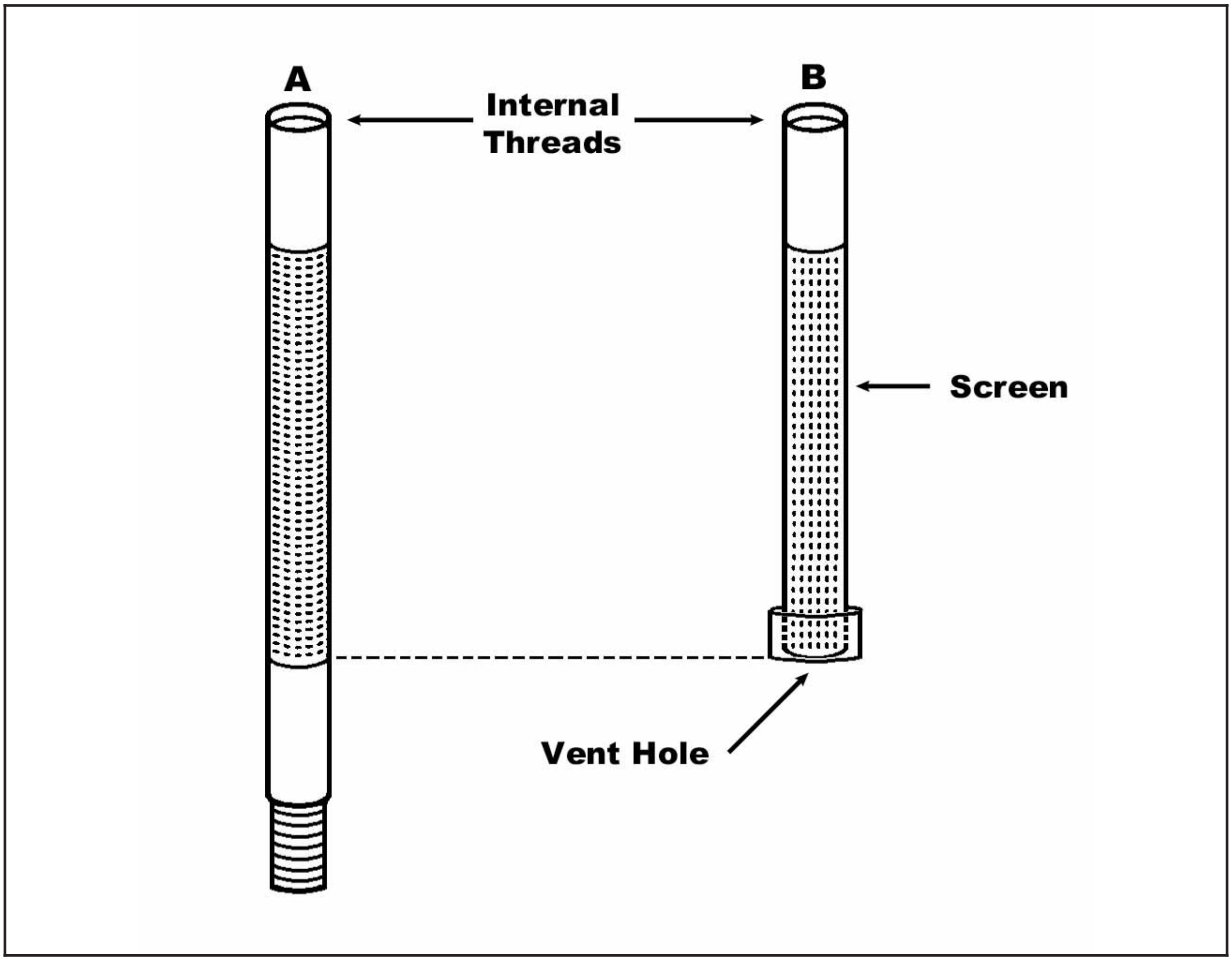


Figure 3. Modified commercial well screen. A. Commercial well screen with threads at both top and bottom. B. Screen after sawing lower threaded portion of pipe off and closing with vented PVC plug

Well Cap. Well caps protect wells from contamination and rainfall. Caps need to be attached loosely enough that they can be removed without jostling the riser. Well caps can be constructed from PVC pipe as shown in Figure 4. The homemade cap can be attached to the riser by drilling a hole through both the cap and the riser and connecting the two with a wire lock pin. Well caps should be made of materials that will not deteriorate in sunlight or frost.

A common problem with commercially made well caps (threaded or unthreaded) is that the cap may seize to the riser and require rough handling to remove. This is likely to break the seal between the riser and the ground, especially in shallow wells. If commercially made well caps are used, they should be modified to prevent such snug fits. All caps should be vented to allow equilibration of air pressure inside and outside of the riser.

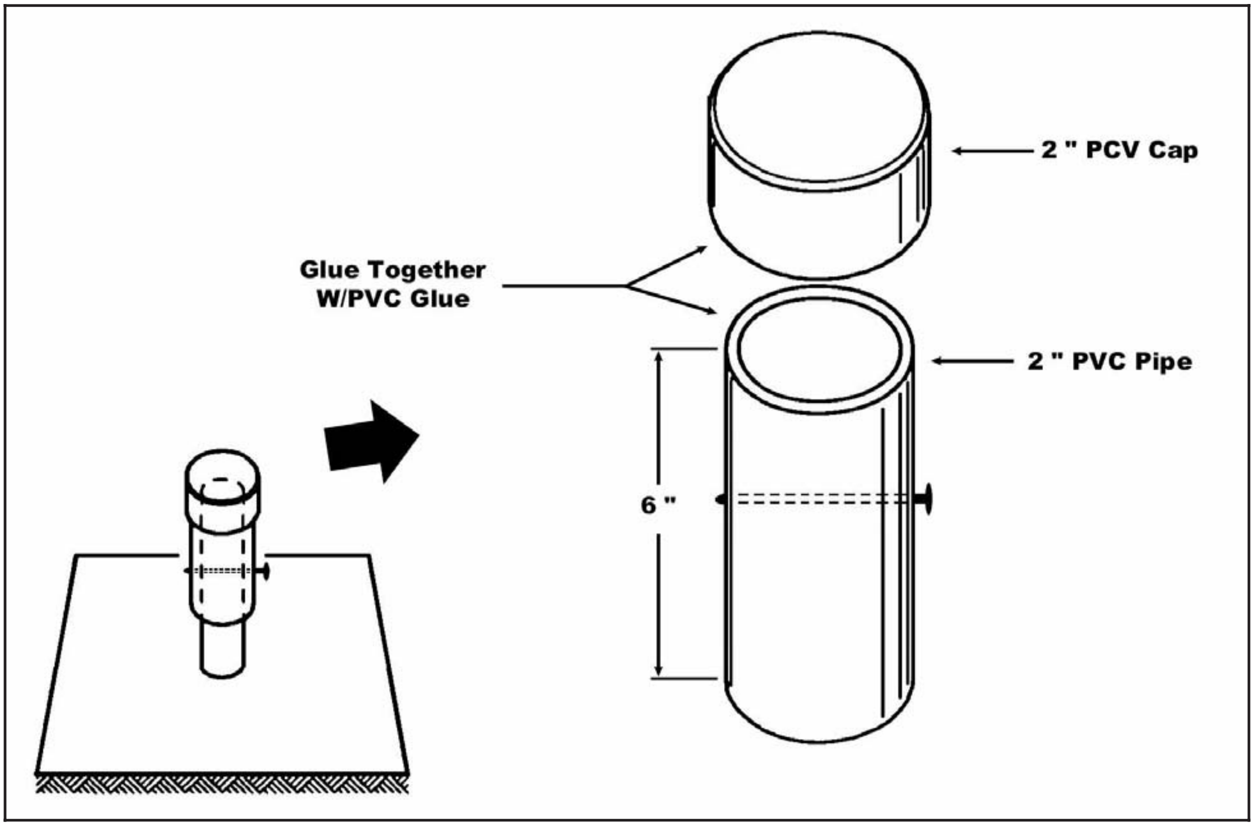


Figure 4. Homemade cap made from oversize PVC piping

Well Point. Commercial PVC well points are not needed if the bottom of the screen is capped. A PVC cap glued on the bottom of the slotted portion of the screen keeps out sand and has the advantage of being shorter than most commercial well points (Figure 3).

Sand Pack. Sand is placed around the slotted interval to filter out silts and clays (Figure 1). Silica sand is available from water-well supply houses in uniformly graded sizes. Sand that passes a 20-mesh screen and is retained by a 40-mesh screen (20-40 sand) is recommended with 0.010-in. well screen; finer sized 40-60 grade sand is appropriate for use with 0.006-in. screen. The finer sand and screen should be used to pack instruments in dispersive soils with silt and fine silt loam textures.

The sand pack may need to be dispensed with in permanently saturated soils that have little strength, such as peats or mucks. The methods of Cherry et al. (1983) should be used in such situations. Sand packs and bentonite simply slough down the sides of the pipe and into the surrounding muck in such soils.[1]

Bentonite Sealant. Bentonite is a clay that absorbs large quantities of water and swells when wetted. It is used in well installation to form a tight seal around the riser to prevent water from running down the pipe to the well screen. With this protective plug, only groundwater enters the slotted well screen.

1 Personnal Communication, 2000, D. L. Siegel, Syracuse University.

Four inches of bentonite are placed around the riser immediately below the ground surface when installing either monitoring wells or piezometers (Figures 1A and 1B). This 4-in. ring of bentonite rests directly on top of the sand pack around the well screen for monitoring wells, and rests on top of the backfill of soil tamped into the annular space of the auger hole for piezometers. The top of the bentonite plug should be shaped to slope away from the riser so that water will run away from the pipe rather than pond around it at the ground surface.

A minimum of 12 in. of bentonite clay is placed around piezometers above the sand filter as a sealant (Figure 1B). This prevents water flow along the sides of the pipe from the ground surface and through channels leading to the pipe. It is critical that piezometers have an effective bentonite seal above the sand pack in layered or structured soils.

Bentonite is available from well-drilling supply companies in either powder, chip, or pellet form. Chips or pellets are easier to use in the field than powder. They can be dropped directly down the annular space above the sand filter and gently tamped into place. If this zone is already saturated with water, the chips will absorb water in place, swell tight, and seal off the sand filter from the annular space above. If the bentonite chips are dropped into a dry annular space, they should be packed dry and water should be added down the annular space so the clay can swell shut.

Cracks are inevitable in clayey soils with high shrink-swell activity. In these soils three piezometers should be installed as replicates for each depth of instrumentation. If readings are questionable, move some yards away from the instrument site, auger to the depth in question, and evaluate whether free water is present at the depth of the well screen.

Filter Socks. Filter socks are tubes of finely meshed fabric that can be slipped over the screened end of a well to filter out silt and clay particles. They are not necessary if a sand pack is used and the pipe is capped at the bottom. Filter socks are recommended only when it is impractical to install a sand pack, such as in permanently saturated organic soils. Filter socks are available from engineering and water-well supply houses.

INSTALLATION OF SHALLOW MONITORING WELLS AND PIEZOMETERS

Soil Profile Description. The soil profile must be described and evaluated before installation of an instrument in order to identify strata that can alter vertical and horizontal water flows. Profile descriptions should include horizon depths and information about texture, induration, bulk density, redoximorphic features, and roots, so that significant differences in permeability can be inferred (Figure 5). Once potential aquitard horizons have been identified in the soil, appropriate lengths and depths of well screen can be determined. The importance of onsite soil characterization to determine the appropriate well depths cannot be overemphasized.

Several soil characteristics may indicate that vertical water flow is impeded and that perched water tables exist. Features to watch for include the following:

- Sudden change from many roots to few or no roots.
- Sudden change in sand or clay content.
- Sudden change in ease of excavation.

Soil Features[1] Used to Identify Horizons with Different Permeabilities							
Horizon Depths	Matrix Color	Texture	Redoximorphic Features	Structure	Consistence	Induration (none, weak, strong)	Roots
[1] Soil Survey Division Staff (1993).							

Figure 5. Sample soil characterization form

- Sudden change in water content, such as presence of saturated soil horizons immediately above soil horizons that are dry or barely moist.
- Redoximorphic features at any of the distinct boundaries listed above.

Installation of Shallow Monitoring Wells (Figure 1A).

1. Auger a hole in the ground with a 3-in. bucket auger to a depth approximately 2 in. deeper than the bottom of the well. Be sure the auger hole is vertical.

2. Scarify the sides of the auger hole if it was smeared during augering.

3. Place 2 in. of silica sand in the bottom of the hole.

4. Insert the well into the hole but not through the sand

5. Pour and gently tamp more of the same sand in the annular space around the screen and 2 in. above the screen.

6. Pour and gently tamp bentonite above the sand to the ground surface. Shape the surface of this plug so that water will not pond around the riser.

7. Form a mound of a soil/bentonite mixture at the top of the ground around the base of the riser to direct surface water flow away from the pipe.

Piezometers. Installation of a piezometer entails the same steps as above, with the modifications that 12 in. of bentonite are placed above the sand pack and water is added to expand the clay and form a seal (Figure 1B). Backfill and tamp soil into the auger hole from the top of the bentonite plug to within 4 in. of the soil surface. Place a second plug of bentonite at the ground surface per Instruction 6 immediately above.

Equipment. Equipment needs vary with depth and diameter of instruments to be installed. This list of equipment is sufficient to install monitoring wells and standard piezometers to 10 ft or shallower.

Bucket auger 2 in. wider than the OD of the pipe being installed
Auger extensions

Pipe wrenches for auger extensions
Color book and soil description forms
Piezometer or well
Water level reading device (see below)
Tamping tool (0.5-in.-thick lath works well to 4 ft; 0.5-in.-diam metal pipe for greater depths)
Bentonite chips
Commercial grade silica sand
Steel tape long enough to measure deepest hole
Paint marker to label pipes
Hand pump to pump water from well and check for clogging
Survey equipment of sufficient accuracy to measure elevations required for study purposes

Checking for Clogged Pipes. After the pipe has been installed, either pump the well dry and monitor how quickly water levels return to the pre-pumped level; or if the pipe is dry, fill it with water and monitor rate of outflow. Water levels in wells should return at approximately the same rate as they would in freshly dug holes without any pipe. If water levels do not return to pre-pumped levels, pull the instrument out and determine why it is plugged. This test should be performed every few months throughout the study, because wells can plug due to bacterial growth as well as slumping of dispersive soil.

Elevations. Most methods of determining water levels in pipes entail measurement from the top of the riser to the water surface in the pipe. Therefore, a correction must be made for the difference between riser elevation and ground elevation. If study objectives require comparing water levels in different pipes, then relative elevations of pipes also need to be surveyed in.

Record the height of the riser above the ground surface at the time of installation and every few months thereafter. Pipes tend to move upward during cycles of wetting and drying. If marking the side of the pipe for future reference, use a paint marker; paint lasts longer than permanent marking ink.

Foot Traffic from Study Personnel. Microtopography and shallow soil properties can be altered in wetlands when foot paths are worn into the ground during the wet season. This can even puddle the soil around a shallow well if it is visited numerous times when saturated. It may be necessary to install boardwalks between instruments at long-term study sites.

Concrete Pads. Some localities require that monitoring wells be installed with concrete pads to protect drinking water sources from surface runoff. Local regulations should be observed at all sites. Concrete pads should not be used with shallow monitoring wells because pads of the required size probably interfere with water infiltration into the soil immediately around the shallow well.

Vandalism. Vandalism often cannot be avoided. Three approaches to the problem are (1) to hide the wells, (2) to armor them, or (3) to post them with identifying signs. All three approaches have worked in different communities. Pipes cannot be protected in all situations. Extra wells, installation equipment, and accessories should be brought along on monitoring trips so that vandalized instruments can be replaced.

READING WATER LEVELS: Water levels can be read with a steel measuring tape marked with a water-soluble marker. The only equipment needed is the tape, marker, and a rag to wipe the tape dry after each reading. Height of riser above the ground surface should be noted every time the instrument is read because pipes may move as much as 3 in. in a season.

One commonly used device (pair of wires, battery, open electric junction, and light or meter) is an open electric circuit that is completed when the junction makes contact with water. If using such a device, be aware that flexible wire will give a less accurate measurement than a rigid tape. Do not read water levels with a dowel stick because of the large displacement of the volume of the dowel.

Frequency of reading will depend on study purposes and rate of water table fluctuation. Water levels should be checked weekly or more often during the season of high water tables. More frequent readings may be needed in flashy systems, such as sandy floodplains of small streams or tidal areas. For long-term studies it usually suffices to collect data every other week during most of the year and every week to every day during water table rise or drawdown.

Automatic recording devices record water levels with down-well transducers or capacitance-based sensors. These cost much more than manually read instruments but may be necessary for some studies. Because automatic devices may be reused for several projects, cost estimates should be prorated over their expected life rather than assigned only to one study. Automatic recorders may be less expensive than travel costs and salaries if study objectives require frequent readings at remote sites. The credibility of monitoring results is enhanced by the high frequency of readings allowed by automatic wells. Automatic water-level recorders should be checked every few months and recalibrated as necessary.

Documentation. The form in Figure 6 solicits information necessary to document study design in most wetland regulatory situations. Figure 7 can be used when reading water levels manually. Figure 8 provides one possible format for reporting water levels, soil profile, growing season dates, and precipitation data in one graph. An effort should be made to acquire precipitation data from nearby weather stations and interpret the data with respect to long-term ranges of normal (Sprecher and Warne 2000).

POINTS OF CONTACT: For additional information, contact Steven W. Sprecher, USACE Detroit District, South Bend Field Office, 2422 Viridian Drive, Suite 101, South Bend, IN 46628 (219-232-1952) or the Manager of the Wetlands Regulatory Assistance Program, Dr. Russell F. Theriot (601-634-2733, *therior@wes.army.mil*). This technical note should be cited as follows:

> Sprecher, S. W. (2000). "Installing monitoring wells/piezometers in wetlands," *WRAP Technical Notes Collection* (ERDC TN-WRAP-00-02), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/wrap*

Installation Data Sheet

Project Name ___Alpha Project___ Date of Installation ___9/9/99___

Project Location ___Beta Place___ Personnel ___J Doe___

Well Identification Code ___A-15___ ___J Bloe___

Attach map of project, showing well locations and significant topographic and hydrologic features.
As appropriate, attach map of well site, showing locations and ground elevations of all instruments and microtopographic features of significance, with respect to reference datum.

Type of Instrument

Source of instrument / well stock ___Acme Well Company___

Material of well stock ___Schedule 40 PVC___ Diameter of pipe ___1 inch___

Slot size ___0.010 inch___ Slot spacing ___0.5 inch___

Kind of well cap ___homemade PVC w/vent___ Kind of end plug ___1" plug, vented___

Nature of Installation Materials

Nature of packing sand ___20-40 silica___ Kind of bentonite ___chips___

Nature of backfill ___bentonite/soil mix___ Depth of backfill ___6 in to ground surface___

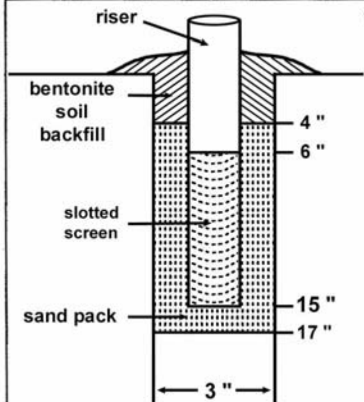
Was bentonite installed below groundwater depth at installation? ___NA___

Was water added to bentonite for expansion? ___NA___

Method of measuring water levels in instrument ___steel tape and soluble marker___

How was instrument checked for clogging after installation? ___Water poured down well and drainage monitored. No water standing in well after 20 minutes.___

Instrument Diagram



Soil Characteristics

Depth	Texture	Structure	Roots	Consis-tence	Redox Features
+ 9 " – 0 "					
0 " – 6 "	*silt loam*	*strong granular*	*many medium*	*very friable*	*none*
6 " – 18 "	*silt loam*	*weak sub-angular blocky*	*common*	*friable*	*2.5Y5/1 matrix common Fe-concentrations*
18 " – 36 "	*silty clay loam*	*moderate blocky*	*few fine*	*very firm*	*10YR 4/1 matrix many Fe-concentrations & depletions*
36 " –	*silty clay loam*	*weak sub-angular blocky*		*very firm*	*10YR 5/1 matrix common Fe-concentrations & depletions*

Show depths (heights) of soil horizons, riser, screen, sand pack, bentonite, backfill, mound, etc.

A. Example filled out

Figure 6. Sample installation data form (Continued)

Installation Data Sheet

Project Name ________________________________ Date of Installation______________
Project Location ______________________________ Personnel _____________________
Well Identification Code________________________ _____________________
Attach map of project, showing well locations and significant topographic and hydrologic features.
Attach map of well site, showing locations and ground elevations of all instruments and microtopographic features of significance, with respect to reference datum.

Type of Instrument
Source of instrument / well stock ____
Material of well stock __________________ Diameter of pipe _____________________
Slot size _____________________________ Slot spacing
____
Kind of well cap ______________________ Kind of well point / end plug ___________
Nature of Installation Materials
Nature of packing sand ___________________ Kind of bentonite ____________________
Nature of backfill ________________________ Depth of backfill _____________________
Was bentonite installed below groundwater depth at installation? ________
Was water added to bentonite for expansion? ________________________
Method of measuring water levels in instrument ____
How was instrument checked for clogging after installation? ___________________________________
____

Instrument Diagram	**Soil Characteristics**				
	Texture	**Structure**	**Roots**	**Consis-Tence**	**Redox Features**

Show depths (heights) of soil horizons, riser, screen, sand pack, bentonite, backfill, etc.

B. Blank master

Figure 6. (Concluded)

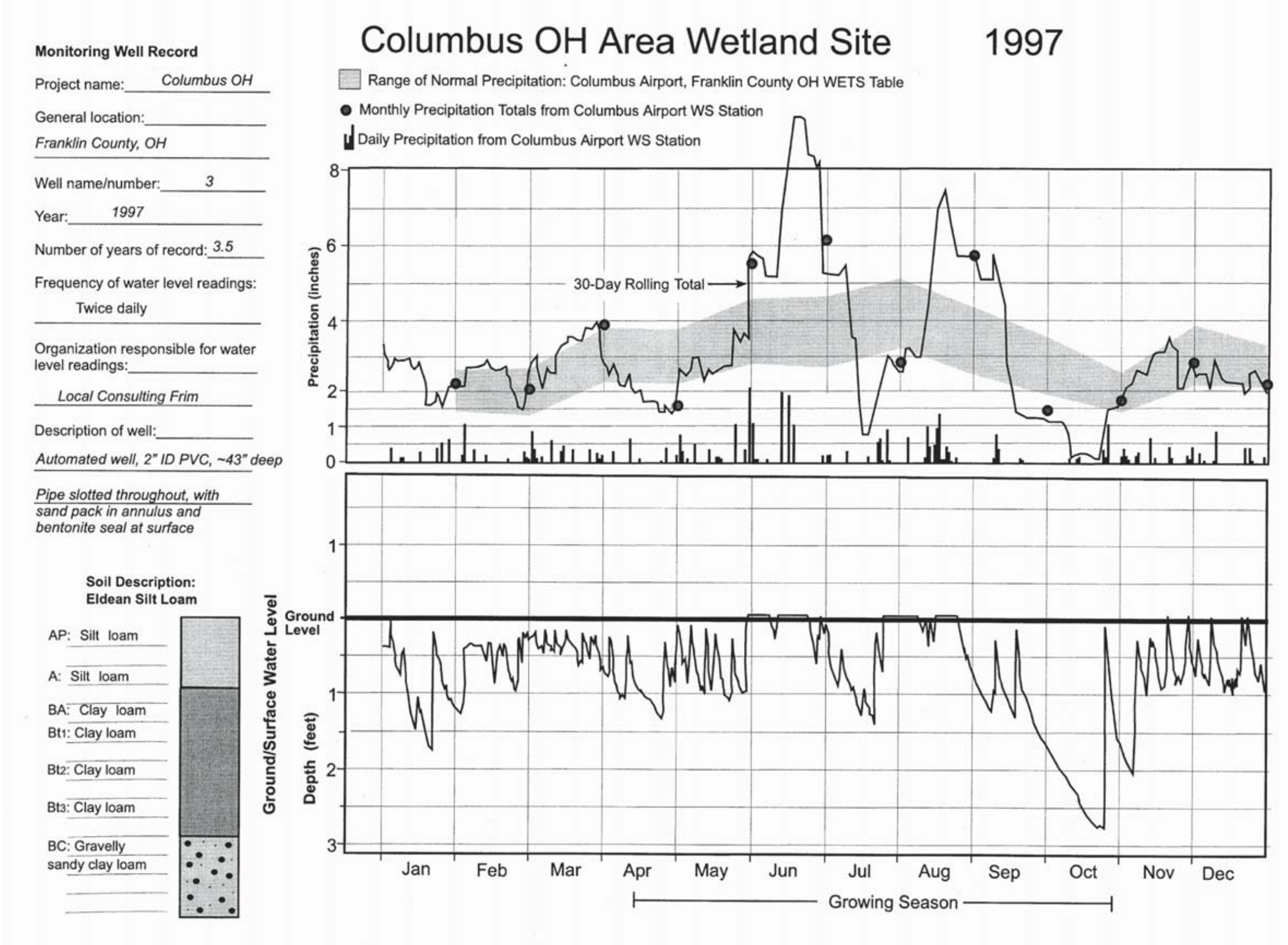
Water Level Record

Project Name ____________

Well ID Code ________

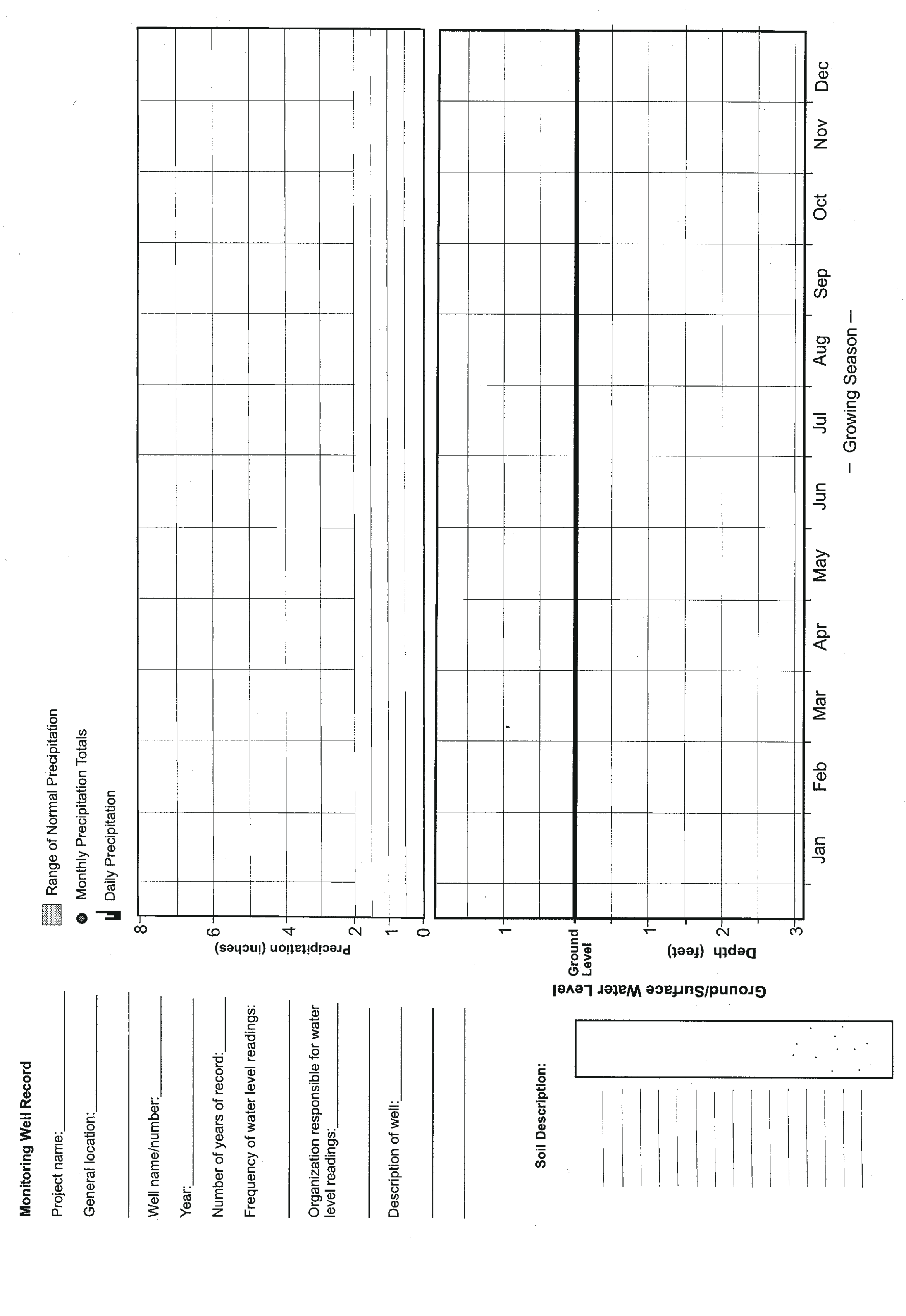
Date / Time	Height of Riser Above Ground	Depth to Water From Top of Riser	Water Level Below Ground	Comments (pipe checked for clogging? pipe checked for movement? vandalism? well cap missing? raining? etc.)

Figure 7. Sample water level record



A. Example filled out

Figure 8. Sample graph for reporting water levels (Continued)



B. Blank master

Figure 8. (Concluded)

REFERENCES

American Society for Testing and Materials. (1990). "Standard practice for design and installation of ground water monitoring wells in aquifers," Designation: D5092-90, Philadelphia, PA.

Cherry, J. A., Gillham, R. W., Anderson, E. G., and Johnson, P. E. (1983). "Migration of contaminants in groundwater at a landfill: A case study: 2. Groundwater monitoring devises," *J. of Hydrology* 63, 31-49.

Miner, J. J., and Simon, S. D. (1997). "A simplified soil-zone monitoring well," *Restoration and Management Notes* 15(2), 156-160.

Sprecher, S. W., and Warne, A. G. (2000). "Accessing and using meteorological data to evaluate wetland hydrology," ERDC/EL TR-WRAP-00-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Warne, A. G., and Smith, L. H. (1995). "Framework for wetland systems management. Earth resources perspective," WRP Technical Report WRP-SM-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers. (1990). "Monitor well installation at hazardous and toxic waste sites," Engineer Circular 1110-7-1(FR), Washington, DC.

BIBLIOGRAPHY

Aller, L., Bennett, T. W., Hackett, G., Petty, R. J., Lehr, J. H., Sedoris, H., and Nielsen, D. M. (1990). *Handbook of suggested practices for the design and installation of ground-water monitoring wells*. National Water Well Association, Dublin, OH.

Driscoll, F. (1986). *Ground water and wells.* Johnson Division, St. Paul, MN.

Gamble, E. E., and Calhoun, T. E. (1979). "Methods of installing piezometers for soil moisture investigations," U.S.D.A. Soil Conservation Service, unpublished technical note.

U.S. Environmental Protection Agency. (1975). "Manual of water well construction practices," Office of Water Supply, EPA-570/9-75-001.