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STANDARD OPERATING PROCEDURES FOR GROUNDWATER RESEARCH STATIONS

NORTH CAROLINA PIEDMONT AND MOUNTAINS GROUNDWATER RESOURCE EVALUATION PROGRAM

NORTH CAROLINA DEPT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WATER QUALITY, GROUNDWATER SCIENCES UNIT

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Note: This manual of Standard Operating Procedures was written by a joint North Carolina Department of Environment and Natural Resources, Division of Water Quality (NCDENR, DWQ) and United States Geological Survey (USGS) workgroup, specifically for the Piedmont and Mountains Groundwater Resource Evaluation Project (REP). Recommended practices should be followed during all phases of work to the extent practical.

Table of Contents

DWQ AND USGS COOPERATION 4
RESEARCH SITE SELECTION – 7
MINIMUM SET OF DATA ELEMENTS (MSDE) 13
OPERATIONS SITE SAFETY 14
SOIL AND ROCK LOGGING: 33
GEOPHYSICAL LOGGING 38
WELL CONSTRUCTION - WELLS COMPLETED IN BEDROCK 41
WELL CONSTRUCTION – WELLS COMPLETED IN REGOLITH 44
MONITORING WELL DEVELOPMENT 47
MEASURING WATER LEVELS IN MONITORING WELLS: 54
MONITORING WELL SAMPLING 58
INSTANTANEOUS CHANGE IN HEAD (SLUG) TESTING 64
AQUIFER TESTING 70
PUBLICATIONS: 88

DWQ AND USGS COOPERATION

PURPOSE: To establish clear protocols of cooperation between DWQ and USGS management, scientists, engineers, and technicians to help ensure high standards of program implementation.

NOTES

The Piedmont/Mountains Groundwater Resource Evaluation Program is primarily funded through DWQ, with equivalent or less than equivalent cooperative matching funds from the USGS. The success of this program depends on mutual scheduling of work tasks, effective and timely data interpretation, and coordination between DWQ and USGS personnel.

FIELDWORK

1. Regional Office (RO) and USGS staff will mutually develop schedules for all field activities. They will also coordinate personnel and resources between themselves and with DWQ Central Office (CO) staff.

2. The RO representative will serve as overall site/project manager, as all site activities will be coordinated through him/her. The USGS will provide scientists, technicians, and equipment, as appropriate to conduct monitoring and applied research such as automated water-level, surface-water stage, and water-quality recordings, water-quality sampling, aquifer testing, geophysical logging and surveys, and other related fieldwork. The RO representative will provide the USGS with geologic mapping data, well construction records, lithologic descriptions of core and cuttings, DWQ laboratory analytical results for water-quality samples, and other pertinent site information. The CO will provide personnel and equipment, as available, to support these activities.

3. The USGS will provide borehole geophysical logging support in coordination with the CO. Equipment will be shared between the USGS and CO. The USGS will be responsible for providing geophysical logging of the bedrock wells, including applied research methods such as heat-pulse flowmeter and optical tele-viewer imaging. Surface geophysical equipment also is available for loan to USGS personnel from the USGS Office of Geophysics, Branch of Geophysics. RO and CO staff may be asked to assist in these surface geophysical surveys and have the opportunity for training in the use of this equipment. CO staff may also conduct surface EM-31 geophysical profiling in addition to borehole services, such as gamma; SP; SPR; caliper; and temperature logging.

4. All fieldwork will be performed in accordance with schedules mutually developed by the RO and USGS. Activities may be performed outside of established schedules, when needed, but must be coordinated between the RO and USGS, via written justification, before being implemented.

5. Unless otherwise requested by DWQ, the Kinston Office (KO) drilling staff will perform all drilling operations.

LOGISTICS

1. The CO will provide annual funding for the Piedmont/Mountains Resource Evaluation Program, with equivalent or nearly equivalent matching funds from the USGS.

2. The CO will develop an annual scope of Work for DWQ and USGS Piedmont/Mountain Resource Evaluation collaboration. The USGS will provide the CO with the annual Joint Funding agreement for USGS cooperative funding.

3. The CO will schedule periodic Piedmont/Mountains Resource Evaluation Program meetings, involving relevant staff. These meetings will allow for discussion and communication between RO, CO, and USGS personnel. At least one of these meetings will be held as close to the beginning of the calendar year as possible, to establish overall schedules and fieldwork goals for each research station for that respective year. The USGS will host a meeting at the beginning of the federal fiscal year in October.

4. USGS will provide a complete copy of all raw research station data collected by the USGS along with a brief interpretive summary of the results of any geophysical surveys or special investigations performed by the USGS on the REP sites. All continuous and periodic water level and water quality data are published in the USGS Annual Data reports for each water year (October 1st through September 30th). Written interpretations provided by the USGS will be collated throughout the duration of the project and used by the RO and the USGS for report development. Copies of reader versions of interpretation software will be provided to RO and CO personnel, or the licensed software can be made available for use in the USGS District Office in Raleigh.

5. Publication deadlines and media type will be established by the respective RO, in coordination with the USGS and the CO. Data may be promulgated as articles, posters/abstracts, formal USGS or DWQ reports, (circular, etc.), and/or WebPages.

COMMUNICATIONS

1. The following requests, if originating from an RO, must be routed through the CO:

    a. Equipment procurement.
    b. Use of CO equipment and/or personnel.
    c. Professional or technical training, external to respective RO.
    d. Professional or technical conference attendance.
    e. Contracts and/or contract amendments.
    f. Standard Operating Procedure (SOP) establishment or change.
    g. Program amendments.
    h. Publishing or otherwise promulgating data.

2. The following requests, regardless of origination, must be routed through the Aquifer Protection Section's Central Office Hydrogeologist and the KO:

   a. Use of KO equipment and/or personnel.
   b. Drilling operations

3. The following requests, if originating from an RO, must be scheduled in coordination with the USGS:

   a. Use of USGS equipment and personnel.
   b. Scheduling and support of all research station fieldwork.
   c. Specialized USGS laboratory work (i.e. age-dating methods/isotopes).

4. RO personnel are obligated to notify the CO of the following:

   a. Site/project progress.
   b. Sampling results.
   c. Construction details for monitoring wells, piezometers, and core holes.
   d. Location information for monitoring wells, piezometers, and core holes.
   e. Non-contractual work/outreach with other organizations.
   f. Software requests, which are routed through a respective RO supervisor.

5. CO personnel are obligated to notify ROs of the following:

   a. Upcoming Resource Evaluation Program (REP) meetings.
   b. SOP change or establishment
   c. REP amendments
   d. Equipment purchasing/availability
   e. Training availability

RESEARCH SITE SELECTION –

THE RESEARCH PROPOSAL, REQUEST FOR INVESTIGATION, AND LAND USE AGREEMENT

PURPOSE: The Division of Water Quality is the only agency responsible for developing groundwater classifications and standards and for regulating water quality issues associated with permitted facilities and naturally occurring contaminants. In order to fulfill these responsibilities, DWQ needs knowledge about groundwater impacts of permitted discharges, groundwater-surface water interaction, ambient water quality, and naturally occurring contaminants such as arsenic and radon. REP studies should be developed to serve these needs.
If a study meets DWQ's needs, then Division support services such as drilling, analytical laboratory, and aquifer testing should be provided as needed. Once a decision is made that DWQ should proceed with a study, the RFI review process becomes a matter of resources.
If the drilling operations and other DWQ services are supporting work that is obviously linked to DWQ's core mission and responsibilities, it will be much easier to justify continued or expanded funding for those operations. This document is intended to establish guidelines to assist the reader in the procedures to locate and identify a Research Site, and to instruct the reader on the procedures for the following tasks:

- **I. Research Station Site Selection.**
- **II. Writing a Research Proposal, Request For Investigation (RFI), and obtaining a Land Use agreement.**
- **III. The Checklist**

I. RESEARCH STATION SITE SELECTION

A. RESEARCHING THE SITE. Attempting to select a site that meets Program research objectives can be difficult, especially if you are not familiar with the local geologic or hydrogeologic terrane. To understand the local geology and hydrogeology, obtain for yourself the following items:

1. USGS 7.5 minute topographic quadrangles of the area in consideration.
2. USGS published documents of the area.
3. Aerial photographs of area. NCDOT's photogrammetry unit, in Raleigh, N.C. is the best source. Photos should be obtained to allow for both two-dimensional and stereo viewing.
4. State Geologic Survey documents and maps of the area.
5. State Groundwater Reports, or any other available and relevant State Open File Reports.
6. Reprints or copies of papers published in or near the area of interest from any available source such as graduate student thesis or dissertations from nearby

universities and colleges (check with universities or state and federal geologic surveys for availability of these), and related journal articles.
7. Existing well logs and well location data. These may be available in hard copy or electronic format. Check central and regional office files. Some sources are: NCDENR Groundwater Section, the USGS, NCDENR Division of Water Resources, Public Water Supply, Underground Storage Tank Section, just to name a few.
8. Water Quality data. Again, check availability of data from the Aquifer Protection Section, then branch out to other organizations.
9. Geophysical logs (as above).
10. Previous aquifer test data (as above).
11. Start organizing your data. Make notebooks or files for your reprints, journal articles, maps, and notes. You will need ready access to all this data later as references, so organize it in a meaningful way such as by Subject, Author, or Title (and always in alphabetical order).

Note: It is always a good idea to find someone you can contact in the State or Federal US Geologic Survey who can answer questions about potential research areas, data availability, and relevance of the project.

B. SELECTION CRITERIA 'What are we going to learn here, and how will that knowledge benefit all of us?' How will the information collected from a site help to protect the groundwater resources of North Carolina? These are the first, and most important, questions to be answered when considering a research site.

The following criteria are to be considered when selecting a groundwater research station for inclusion in the Resource Evaluation Program Piedmont & Mountains Project:

1. *Data Value & Transferability.* Research data and insight gathered from the site should provide scientific data that will benefit not only the DWQ, but also provide information that will benefit the citizens of the state. Scientific questions and objectives of this program are:

a. What is the aqueous geochemical signature of the groundwater in this area?
b. What is the relationship between land use and groundwater quality?
c. How can a selected site help to further our understanding of fracture flow hydrology?
d. What is the groundwater recharge rate in this environment?
e. What are the local ages of groundwater and how long is the travel time from recharge to discharge?
f. How are shallow, intermediate, and deep groundwater storage and transport affected by groundwater recharge?
g. What is the expected capture zone for a bedrock water supply well constructed in the piedmont and mountains regions?
h. What is a typical groundwater flow path from ridge to stream?

i. What is the relationship between groundwater quality & surface water quality?
j. Does groundwater quality affect aquatic fauna?
k. Are there long-term climatic effects on groundwater resources in the watershed?
l. Is there a correlation between regolith and bedrock to aqueous geochemistry and geophysical signatures?

2. Representativeness. To meet the objectives of the Program, sites chosen for groundwater research projects should be representative of a hydrogeologic terrane within the North Carolina Piedmont or Appalachian Mountain physical provinces. A selected site should fall into a defined hydrogeologic terrane if possible (leaving open the possibility that not all terranes have been named and mapped that are "common" to these regions), located within a given geologic terrane. The identified geologic terranes (or Belts) of the North Carolina Piedmont and Mountain Regions are:

a. Blue Ridge Belt
b. Murphy Belt
c. Chauga Belt
d. Inner Piedmont Belt
e. Kings Mountain Belt
f. Milton Belt
g. Charlotte Belt
h. Carolina Slate Belt
i. Raleigh Belt
j. Eastern Slate Belt
k. Triassic Basins

Two generalized types of hydrogeologic terranes that are of interest to this study are:

1. Massive or foliated crystalline rock under thick regolith
2. Massive or foliated crystalline rock under thin regolith

These hydrogeologic terranes have common feature sets, namely, massive or foliated crystalline rock under (thick or thin) regolith. However, a research site with unique features and the applicability of the research gained from that site can also be a factor in research site determination.

3. Station Access. Research stations should be accessible. An ideal site will generally be university, state, or federal agency lands with long-term access. After you have selected a potential site from a topographic map and evaluated the known geologic and hydrologic literature and you still think the site is a good choice:

a. Plan a site visit
b. Contact the property owners.
c. Contact DWQ, USGS, and any other necessary, workgroup members.
d. Take pictures.
e. Take GPS readings to accurately locate the site.
f. During your site visits, ask questions and take notes. Here are a few suggestions:

1. Who was present at the site, his/her position, and his/her Agency affiliation (get a business card if possible)?
2. Note the geomorphology or topography of the site and any accessibility concerns or favorable well site locations. Are there areas that are off limits or sensitive?
3. Will potential well locations require tree cutting, roadwork, or site leveling?
4. Where is the nearest potable water source for the drilling rigs? Is water easily accessible or will it have to be transported to the site?
5. Are there restroom facilities or will portable facilities be needed?
6. Are there any paper work tasks associated with the site such as Federal NEPA reports that require extra time to prepare?

Note: You can do this step before you do #2 (Representativeness) if you prefer.

4. Educational Outreach. This is strongly encouraged and considered an integral part of this program. Educational outreach can take many forms, from fieldtrips with local students, to building displays for the general public. Cooperative studies with other governmental or private non-profit organizations are also desirable.

C. Optional Criteria. In addition to meeting the three main selection criteria of Data Value and Transferability, Representativeness, and Station Access, here are some additional criteria that can be used in site selection:

1. Previous work done at the site.
2. Site used for land application of sludge, pesticides, or other potential groundwater contaminants.

II. THE RESEARCH PROPOSAL, REQUEST FOR INVESTIGATION (RFI), & LAND USE AGREEMENT

Step 1. The Research Proposal. Now that you have gone through the Site Selection Criteria, gathered sufficient data, visited the site, and determined that the site you chose meets the criteria to be included in the Resource Evaluation Program, you will need to put together a Research Proposal.

The Research Proposal is a synopsis of the data that you gathered about the site, plus any other data gathered about the site that is relevant to your proposal. The research proposal should include the goals to be achieved by drilling a research station at the site, the processes, or steps to be taken to meet the goals, all relevant maps, including a site map, and a time schedule for the project. It is your responsibility to produce the Research Proposal and to send it out for comments. At a minimum, this document should be provided to the following personnel:

1	Respective Land Owner
2	Drilling Supervisor (Currently Billy Casper) NCDENR/DWQ/Aquifer Protection Section Kinston Field Office, 1766 HWY 258 S. Kinston NC 28504
3	USGS REP Member (Currently Melinda Chapman) USGS Water Resources Division 3916 Sunset Ridge Road Raleigh, NC 27607
4	Senior Hydrogeologist (Currently Rick Bolich) NCDENR/DWQ/Aquifer Protection Section 1636 Mail Service Center Raleigh NC 27699-1636
5	Other REP workgroup members
6	Your Supervisor

REP workgroup members, USGS, and the APS Central Office should respond with any comments on the proposal within 30 days of receipt.

<u>Step 2. The Request for Investigation (RFI).</u> The RFI is an in-house DWQ document that is used to notify the CO that you have need of their services. While the proposal is out for comments, start the RFI and Land Use agreement processes. No drilling can begin on your proposed Research Station until the Central Office (CO) Hydrogeologist, located in the NCDENR/Aquifer Protection Section (APS) has accepted an RFI.

After the proposal comment period, submit the proposal and RFI to both the Senior hydrogeologist and the APS drilling supervisor. The Senior Hydrogeologist will review and may ask for revisions to your RFI. Once he/she has approved the RFI, and scheduled the work you have requested, the Senior Hydrogeologist will notify you.

The RFI contains the following information:

1. RFI Checklist
2. General Information (Project Name, Requestor, etc)
3. Site Location, Map, Address, Lat/Lon, etc.
4. Explicit driving directions to the site
5. Drilling Information (Proposed drilling methods, Estimated depth, etc.)
6. Property Owner (Name, address, etc.)
7. Health & Safety Plan
8. Additional Information
9. Lodging (if necessary) for you and the drillers. Addresses and maps to nearest hotels. Ask the Drilling Supervisor for suggestions.

Blank copies of the RFI are included in Appendix II.

Step 3. The Land Use Agreement. The drilling crew cannot begin work on the proposed research site until you have a signed Land Use Agreement (LUA) on file. As soon as the landowner signs a final LUA, it must be sent to CO to be reviewed by the Aquifer Protection Section Chief. When you get the signed copy back from CO, send a copy to the CO Hydrogeologist and the Drilling Supervisor.

It is your responsibility to provide the owner/agent of the proposed research area with a copy of the standard LUA for his/her comments and revisions. Use the standard Land Use Agreement provided in Appendix II and modify it to indicate the details of the research station you are proposing. Once you have a draft, send the land use agreement along to the owner as soon as possible in order to have time to deal with last minute additions that may arise.

All regional offices participating in the Resource Evaluation Program should have a complete set of identical originals, or copies, of the Research Proposal, the RFI, and the Land Use Agreement for their records. Be sure to mark all copies as such. Keep the original in a file or folder in your office.

Now that you have completed the Research Proposal, RFI, obtained an LUA, and have sent these documents to all the appropriate personnel; it is time for you to develop a Work Plan. Using the anticipated schedule from your Research Proposal, create a draft Work Plan that details a phased approach for completing specific tasks.

MINIMUM SET OF DATA ELEMENTS (MSDE)

PURPOSE: To establish a minimum set of data elements to be collected for Research Stations.

Data should be recorded in the field (where possible) on appropriate forms and in field notebooks. All forms used for Resource Evaluation Projects can be found in Appendix III. The table below lists data elements and the appropriate methods of recording respective information.

Data Element	Minimum Data Recording Method
Well and/or Borehole Construction	Form GW-1 (Well Construction Record)
Well and /or Borehole Abandonment	Form GW-30 (Well Abandonment Record)
GPS, Leveling, and Surveying	Field Notebook; GIS
Aquifer (Pump) and Slug Tests	Form GW- 40 (or equivalent)
Lithologic Descriptions	Field Notebook
Geophysical Surveys	Electronic files (i.e. spreadsheet or text)
Water, Soil, and Other Sampling	LIMS Database; Form GW-54; Field Notebook

The following published references provide guidance concerning Minimum Data Set elements.

U.S. EPA, Definitions For The Minimum Set of Data Elements For Ground Water Quality, EPA 813/B-92-002, July 1992.

USGS, Guidelines and Standard Procedures for Studies of Ground-Water Quality: Selection and Installation of Wells, and Supporting Documentation, Water-Resources Investigations Report 96-4233, 1997.

USGS, Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Selection, Installation, and Documentation of Wells, and Collection of Related Data, Open-File Report 95-398.

USGS, Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of Water Quality Samples and Related Data, Open-File Report 95-399.

ASTM, Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers, D 5092-90, 1990.

OPERATIONS SITE SAFETY

PURPOSE: To establish acceptable methods for maintaining the safety and health of all persons on a drilling operations site. This document addresses the following topics:

- **I. OSHA Training**
- **II. Equipment Handling**
- **III. Personal Safety Equipment**
- **IV. First Aid**
- **V. Site Safety Plans**
- **VI. NCDENR DWQ Safety Memorandum**

I. OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) TRAINING

All personnel who are actively involved with work on-site, or who must remain in close proximity to on-site operations should be OSHA trained and certified in proper equipment and materials handling. The Drilling Crew in the Field Investigation Group are trained and certified by OSHA by DWQ annually. If you have any questions about their certification and training for their equipment, you should ask the Lead Driller on-site, or the Drilling Supervisor.

II. EQUIPMENT HANDLING

NCDENR DWQ Groundwater Section Certified Well Drillers are the only persons authorized to handle or operate drilling equipment and machinery on Resource Evaluation Program research sites. Unauthorized personnel or visitors are never allowed to handle or operate drilling equipment unless an authorized person has approved and an authorized person is on-site to supervise such activities. The Lead Driller and Project Hydrogeologist on-site are responsible for daily operations around the drill site and are considered the authorized on-site persons. The Lead Driller on-site is responsible for making decisions concerning all equipment handling associated with the drill rig and its equipment and personnel. No one but the Lead Driller on-site and the DWQ Drilling Supervisor are allowed to give permission to handle, operate, or otherwise participate in on-site drilling activities. The drill crew also has on-site safety procedures and documents. You should ask about these and become familiar with them so that you know the appropriate ways to handle yourself around a drilling rig.

III. SAFETY EQUIPMENT

All persons within the immediate operations area or area designated as being within a operation hazards area must wear the minimum required safety equipment as indicated in the following list:

A. Hard hats. These must be worn at all times during drilling, when the mast is raised or when the potential for falling debris is present.

B. Safety glasses. These must be worn when the potential for flying debris is present, such as during air rotary drilling or when hammering on equipment or rock core.
C. Steel toe shoes or boots. These must be worn at all times when in the immediate operations area or when in an operation hazards area.
D. Ear plugs. These must be worn at all times if air rotary drilling or wire line coring in consolidated material, or any time an air compressor is operating or other loud noise is present.
E. High-Visibility Vest. This must be worn at all times, if working in or near high vehicle traffic areas or while on property being used for hunting.
F. Working Gloves. These must be worn at all times, while actively conducting or assisting with drilling operations.
G. Flashing/Revolving Yellow Light. This must be operated on the roof of all DWQ vehicles, operating in or near high vehicle traffic areas.

Drill crew safety equipment and requirements may be different from those listed here. You should ask the Lead Driller on-site what those are. If you help the drill crew with operations, you should follow their safety requirements for wearing safety equipment.

IV. FIRST AID

A. First Aid Kit. A complete first aid kit is an on-site requirement. A first aid kit should be kept on-site and inventoried for completeness on a regular basis. Everyone on site should know exactly where to find a first aid kit. If you don't have one, check with the drill crew and note the location of theirs. Ask your Supervisor, building Safety Officer, or Division Safety Consultant (currently Steve Kaasa) how to obtain one for your vehicle.

B. First Aid Manual. A First Aid reference should be kept on-site at all times. This reference should contain instructions for expected injuries as well as contain CPR, wound dressing, and basic assessment and care of life threatening injuries. You should be given a first aid manual during safety training for your section or your building. If you don't have one, request one from the DWQ Safety Consultant (currently Steve Kaasa), or from your building Safety Officer. Read the manual and become familiar with first aid methods you might encounter. If you are unsure what these might be, review the on-site hazards from the RFI and ask the drill crew.

C. CPR. All of the on-site personnel involved in daily operations should be trained and certified in proper Cardio-Pulmonary Resuscitation (CPR) methods. A good first aid manual will include instructions for CPR that can be kept on site as a refresher. Unless you have had specific training in injury treatment, or have worked in the medical field, the first time you deal with on-site work-related injuries can be very nerve rattling. Have your first aid kit and manual in a well-thought out place in your gear or vehicle.

D. Injuries. Everyone on-site and involved with daily operations should be trained on how to treat non-life threatening injuries and how to assess life threatening injuries until medical help arrives or can be obtained. Go through the first aid manual and check your first aid kit to see if you have the basic materials for treating the most common injuries you could expect while working on-site.

E. Practice & Review. You may want to practice or simulate injuries and response on-site to ensure that you have all the required pieces for your first aid kit and know how to cope. You may want to designate duties and alternate duties in emergency situations. You may also want to enlist the help of the local 911 services to assist with a practice drill. This may be helpful, especially while working in remote areas where time may be a critical factor.

V. SITE HEALTH AND SAFETY PLANS

A. Health and Safety Plan. Each Health and Safety Plan should delineate potential site hazards and emergency facility locations. Each Plan should include the following:

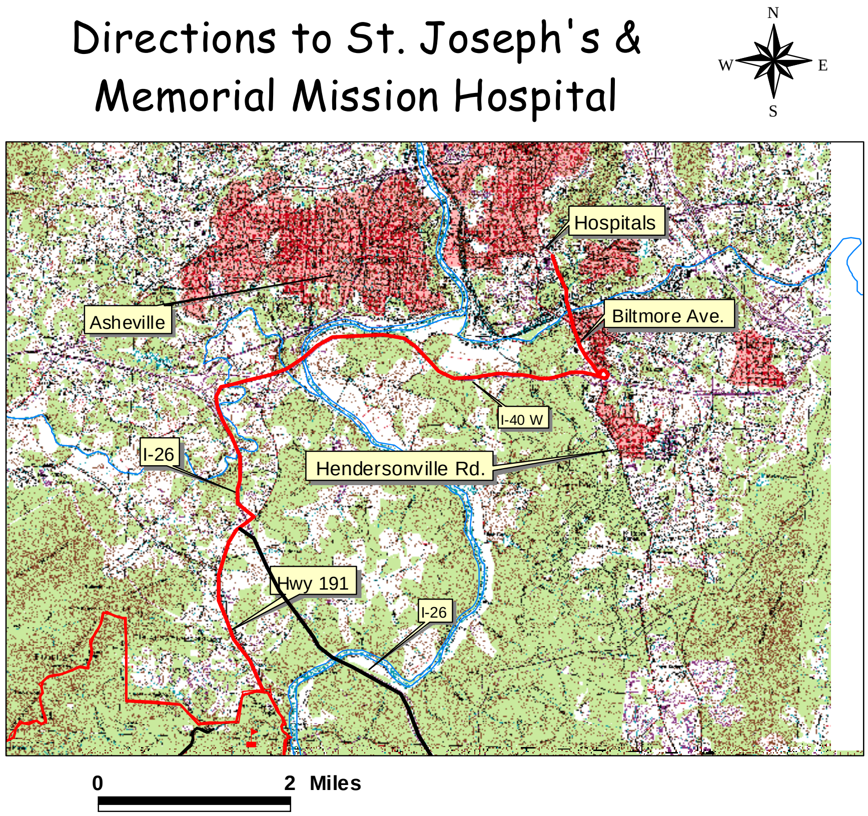
1. Hazards and the Hospital. As the Project Hydrogeologist, it is your responsibility to research and complete the RFI (Request For Investigation) Form Health and Safety Information portion of the request before sending it to the CO. An example is shown below. From your visits to the site you should be able to list any potential natural hazards like snakes, poison ivy, etc. Ask the landowner or caretaker if there are any other on-site hazards of which you should be aware.

HEALTH AND SAFETY INFORMATION
(Please provide only site-specific information)

Chemical Exposure Potential (on-site chemical storage, drums, pesticides, fuel tanks, etc.): ***Unknown – Nothing on-site.***
Biological Exposure Potential (on-site poisonous plants and animals, other wild animals, etc.): ***Possible venomous snakes, poison oak & ivy, stinging insects.***
Physical/Electrical/Radiological Exposure Potential (on-site power lines, open ditches or trenches, heavy traffic, farm machinery, etc.): ***Minor vehicular traffic along access road.***
Name and Location of Nearest Emergency Facility (mark location on attached map): ***Park Ridge Hospital, Naples Rd., Fletcher 828.684.8501*** ***St. Joseph's Hospital, Asheville 428 Biltmore Ave. 828.213.1111*** **Memorial Mission Hospital, Asheville 509 Biltmore Ave. 828.213.1111**
Emergency Facility Phone Number: ☒ 911 Service Available? ***(Note: 911 service is not enhanced-must be able to give directions to site) 911 Dispatch = 828.697.4911 (Henderson County Sheriff's Department)***

2. A Map The RFI must also include a map showing directions to the nearest emergency care facility from the drill-site. An example is shown below.

Directions to St. Joseph's & Memorial Mission Hospital



Take Hwy 191 to I-26W
Then take I-40W to Biltmore Ave. exit
Turn right onto Biltmore Ave. at bottom of exit ramp
Go ~ 1.5 miles to Memorial Mission Hospital on left
and St. Joseph's Hospital on right.
(Approx. 9.5 miles)

Created by: Tina Parsons
Date: 12 January 2001
Sources: USGS 7.5 Minute Quadrangles

<u>B. Environmental Stressors (Hyperthermia & Hypothermia.</u> Working outside in extreme temperatures can be challenging and even dangerous. The most common work related injuries are related to environmental stressors, like heat and cold. When temperatures rise, heat and humidity can create nearly unbearable conditions, especially if you and the drill crew are working with no shade. When temperatures fall below 50^{o}F with wind and rain, frostbite can occur. Know your limits, take breaks, and let your crew know when you have reached your tolerance or limit of heat (Hyperthermia) or cold (Hypothermia). Conversely, keep an eye on your crew members and don't let them work if they are showing signs of heat or cold exhaustion or shock.

1. Heat Exhaustion (Hyperthermia). Heat exhaustion, shock, and stroke can be of major concern while working outside all day. Depending on your metabolism's ability to regulate heat, you may be susceptible to heat exhaustion, shock, and in the last stage, heat stroke. This type of exhaustion, shock, or stroke is brought about by fluid and salt loss from the body. You do not have to be overweight to experience heat exhaustion or shock.

Prolonged exposure to excessive heat can create an emergency in which an individual perspires heavily and drinks large quantities of water. Perspiration causes a loss of salt from the body, and without adequate replacement, the victim will suffer painful muscle cramps. This loss of body fluid and salt causes a medical condition that can range from exhaustion to extreme shock. This can occur more easily to individuals who are not accustomed to working in hot weather.

a. Heat Exhaustion – Symptoms

- Muscle cramps in the legs or abdomen.
- Rapid, shallow breathing.
- Weak pulse.
- Moist pale skin, which may feel normal to cool.
- Weakness or exhaustion, dizziness or faintness.
- Heavy perspiration.
- Loss of consciousness.

b. Heat Exhaustion – First Aid

- Place individual in cool environment (air conditioning if possible).
- Loosen or remove clothing and fan individual without chilling him/her.
- Give sips of water if individual is responsive and not nauseated or vomiting. If individual is unresponsive or vomiting, transport on his/her left side.
- Keep individual at rest (elevate foot end of stretcher).
- Apply moist towels over cramped muscles.
- Transport to a medical facility.

2. Heat Stroke (Hyperthermia). This happens when a person's body cannot rid itself of excess heat. This is a true emergency. It is a sudden onset of illness from exposure to the direct rays of the sun or too high temperature without exposure to the sun. Physical exertion and high humidity definitely contribute to the incidence of heat stroke.

The most important characteristic of heat stroke is high body temperature, which is caused by a disturbance in the heat-regulating mechanism. The person can no longer sweat, and this causes a rise in body temperature.

a. Heat Stroke – Symptoms

- Hot, dry, or possibly moist skin.
- Little or no perspiration.
- Rapid, shallow breathing.
- Strong and rapid pulse, but may become weak and rapid as the individual's conditions worsens.
- Loss of consciousness and seizures.

b. Heat Stroke – First Aid

- Ensure an open airway.
- Move to a cool environment (air conditioning if possible).
- Remove restrictive clothing.
- Apply cool pack to neck, groin, and armpits, or keep the skin wet by applying water by sponge or wet towels. Fan the individual.
- Transport the individual to the hospital as rapidly as possible, continuing to cool en route.
- If transportation is delayed and the above treatment is not feasible, immerse the patient in cool water.

3. Some tips for dealing with the heat

a. Wear lightweight and light colored clothing on hot days.
b. Know your limits. Take breaks to cool down. Better to take a break than to lose consciousness.
c. Take your boots and socks off. Loosen tight clothing. Fan yourself.
d. Sit someplace cool. Get in your vehicle and turn on the air conditioner. Sit in the creek, or put your feet in the creek. Never drink untreated creek water, and do watch out for creatures (like snakes and spiders) and plants (like poison ivy and oak) that can be harmful.
e. Keep some water and towels or sponges on hand so you can use them to bring your body temperature down. Make a turban of a wet or damp towel. Keep a spray bottle of water handy and spray yourself frequently. Put ice in a towel or plastic bag and use it as a compress.
f. DWQ should provide you with bottled water on request to take out in the field. Alternatively, you may want to apply for reimbursement for heat-related supplies, like water and sunscreen. Check with your Supervisor or your workgroup on the procedure.
g. In addition to keeping plenty of water on hand, ask for or purchase electrolyte-replacing fluids like Gatorade. The drill crew generally has packets of Gatorade you can mix in one of the coolers.
h. In a heat emergency where you need to a person's temperature down, you can immerse yourself in creek water or the drilling rig water tub. You can put ice from coolers into the tub to bring the water temperature down if necessary.

4. Cold Stress (Hypothermia). When you have to work outside, effective measures against cold are fewer than for heat. Layer clothing, starting with light insulating clothing next to the skin, then progressively add heavier insulating outer layers. The Section should provide you with insulating outer layers such as boots, gloves, and outerwear when you are required to work outside during cold weather. Ask your workgroup or Supervisor how to obtain these items when necessary.

Hypothermia is a general cooling of the entire body. The inner core of the body is chilled so the body cannot generate heat to stay warm. This condition can be produced by exposure to low temperatures or to temperatures between 30 and 50 degrees Fahrenheit with wind and rain. Hypothermia is more likely to occur when the wind is blowing, taking heat away from the body. Fatigue, hunger, and physical condition can also be a contributing factor.

The nose, cheeks, ears, toes, and fingers are the body parts most frequently injured as a result of blood vessel constriction during cold exposure. Hypothermia goes through the stages of frostnip, superficial frostbite, and deep frostbite. Since hypothermia is a numbing effect, the affected individual may not be aware of showing frostbite signs on extremities until told.

a. Hypothermia – Symptoms

- Shivering (an involuntary response of the body to try to preserve internal temperature for organs).
- Apathy, listlessness, indifference, sleepiness.
- Loss of judgment, reasoning.
- Loss of muscle coordination.
- Very slow pulse, very slow respirations, and coma.
- Death.

b. Hypothermia – First Aid

- Get individual out of elements (rain, snow, cold, wind).
- Remove all wet clothing.
- Wrap individual in blankets, both over and under the body.
- Maintain individuals body temperature. Build a fire, use heat packs, electric heating pads, and hot water bottles.
- Do not warm the individual too quickly.
- If individual is conscious, give warm liquids and try to keep him/her awake.
- Perform CPR if individual stops breathing or his/her heart stops beating.
- Get individual to medical facility as quickly as possible.
- Handle gently. Rough handling of the individual can result in death.

c. Local Cold Injuries – Frostbite

- Early or Superficial frostbite (cold injury) indicated by change in skin color:
- Light skin → Red → White
- Dark skin → Light → White
- Area feels frozen on surface and soft below surface. Area will also be numb.

d. Frostbite – First Aid

- Move individual out of cold.
- Warm affected area. Use bare hands, warm air (blow on affected area), hold fingers under armpits, etc.
- DO NOT RUB or massage area (may peel skin off).
- DO NOT RE-EXPOSE to cold.
- Dress, pad, or splint injury. Pad between fingers and toes if affected.

e. Late Frostbite – Symptoms

- Skin turns white and waxy.
- Skin feels frozen to the touch.
- Skin turns mottled or blotchy, and then turns from white to grayish yellow, to grayish blue.
- Swelling and blisters may appear.

f. Late Frostbite – First Aid

- DO NOT TRY TO RE-WARM FROZEN PARTS. Do not try to warm individual or affected area in this stage.
- Dress, pad, or splint individual or affected area. Always pad between toes and fingers.
- Leave affected area frozen and take individual to hospital.
- DO NOT RUB or MASSAGE. Skin may come off.
- DO NOT BREAK BLISTERS.

g. Late Frostbite - If transport to hospital is delayed

- DO NOT re-warm if there is possibility of re-freezing.
- Do not rub, chafe, or manipulate person or parts. If feet, do not let person walk.
- Do not use hot water bottles, heat lamps, or place patient near stove. Excess heat will cause more tissue damage.
- Do not allow patient to smoke, drink coffee, tea, or hot chocolate. These cause blood vessels to constrict.
- DO Place in water bath of 100-105 degrees. Use warm cloths on non-submerged parts. Re-warming is complete when area is warm and red or blue in color and remains so after removal from bath.
- Do place sterile dressings between fingers and toes before wrapping hands or feet.

- Do cover individual lightly. No pressure on injury.
- Do cover individual’s head to prevent heat loss.
- Do elevate affected limbs if possible.

Heat and cold are two of the most common environmental stressors that you’ll encounter when working outside installing research stations. Cuts, scratches, and bruises are also common. You may want to check to see if you need a tetanus booster to protect yourself against infection from open cuts from equipment or old debris you may encounter on-site.

5. Environmental Stressors – Insects. Ticks and Mosquitoes are also very common antagonists for 6-8 months a year. Chances are you’ll encounter these on a regular basis when working outside and especially when working in wooded areas near water.

a. Ticks. Ticks can carry Lyme disease, which is an infection that can cause skin, arthritic, heart and nervous system problems. Lyme disease is caused by a bacterium spread by the bite of the deer tick. In the summer, deer ticks are about the size of a poppy seed.

Warning signs of a tick bite vary greatly for individuals. Some common symptoms include a red rash surrounding the tick bite, Flu-like symptoms, stiff neck, and muscle and joint pain. There is a Lyme disease vaccination available to you either through DWQ or your Insurance.

b. Mosquitoes. Mosquitoes can carry encephalitis and meningitis bacteria and viruses, as well as many other viruses, including the West Nile Virus. The bacterial forms can be deadly. DWQ will provide Insect-Repellent to you or you may apply for re-imbursement for your supplies. If you are susceptible to mosquito bites, you should take precautions to protect yourself, like wearing long-sleeved shirts and insect repellent.

REFERENCES

U.S. Department of Labor, Mine Safety and Health Administration. 1998. First Aid Book.

North Carolina Office of State Personnel. 1999. North Carolina State Employee Safety & Health Handbook.

VI. The NCDENR Division of Water Quality Drill Site Visitors Safety Policy

The following memorandum is from Steve Kaasa, the Division Safety Consultant. Steve indicates how visitors and site visits to all Resource Evaluation Program research sites should be handled.

March, 2005

MEMORANDUM

TO: **Ted Bush, Aquifer Protection Section Chief**
Tim Hill, Drilling Supervisor

FROM: Stephen J. Kaasa
DWQ Safety Consultant

SUBJECT: Visitors to Groundwater Section Drill Sites

Recently the mission of the Groundwater Drilling Team has expanded to include the drilling of research wells for various outside agencies and for internal DWQ research initiatives. This type of drilling activity may increase the level of visitors to any particular drill site. The current practices at the drill sites may not accommodate this potential increase in visitors, This memo provides some guidance to include in future drill site planning and operation. Based on the visits I have made to past drill sites, I know the majority of the items included in this memo are currently being employed at the on-going research drill sites.

In regards to site accessibility, personnel at a particular site can be grouped into three distinct groups. The first group is made up those personnel who have a direct bearing on the work being accomplished at a drill site, with the second and third groups being made up of those persons who do not have a direct bearing on the work being accomplished and would by necessity be considered visitors to the site.

Group 1 should include the Drilling Team members, the DWQ Hydrogeologist(s) in charge of the research and other Division employees having a direct impact on the location, setup, and/or operation of a particular site. Extra-Division employees would most likely include N.C. Geological Survey or U.S. Geological Survey personnel who are assisting with the project.

The second group would include Division personnel who do not have an impact on the work being accomplished at the project site. Personnel in this category would include DWQ employees regardless of rank or supervisory level, who do not have occasion to regularly visit a drilling project.

Group 3 would consist of any other state employee or non-state employee visitors. There is the possibility that a fourth group might exist, which would include the landowner where the research site is located. Persons in this category might need to be treated slightly differently, but in essence should be considered to be in Group 2.

Personnel in Group 1 should have near unlimited access to the research site. These personnel affect progress at the site and should have nearly unimpeded accessibility and proximity to the drilling equipment. When questions of direct personnel safety are involved, the lead project driller and/or the Drilling Supervisor (if on site) should have final authority to direct any other person's activities or accessibility.

For Division employees in Category 2 who may have occasion to visit a drill site, the visit should be approved through the Drilling Supervisor and the lead driller on the site. The visit should also be coordinated with the site hydrogeologist.

Access to a site by Group 3 visitors should be approved by the Drilling Supervisor and the hydrogeologist in charge of the site. The visit should remain under the supervision of the site hydrogeologist with any communication from the visitors being coordinated through him or her. The site hydrogeologist should handle all Group 3 visitations, so as not to distract the drilling crews, while they are working.

The most important aspect of providing a safe research site is communication between all personnel. It is essential that all parties know the operational steps undertaken at the site, and are aware of one another's presence and activities. The drilling teams normally have site safety meetings on a regular basis. The site hydrogeologist and any others who may be working on the site should be included in these meetings. A log of these activities should be maintained. Therefore all those in attendance should be required to sign the log.

During the initial investigation phase at a particular site, a visitor viewing area sufficiently distant from the actual drilling operations should be selected and identified. Selection and siting of this area will be the responsibility of the lead driller and the site hydrogeologist.

This viewing area should be far enough from the actual operations so that hazards associated with drilling are virtually non-existent. Potential hazards would include, but not be limited to, noise and dust created by equipment operation, as well as potential hazards of equipment failure and/or rig tip over. It will be in this area where all visitors in Groups 2 and 3 will be permitted, unescorted. Once operations at the site commence, the visitor viewing area perimeter should be physically identified with the use of barricade tape, rope or some by other visible means.

The site hydrogeologist should be the primary contact for the visitors arriving on scene. It is his/her responsibility to manage the activities of visitors. Additionally, personnel in Groups 2, or 3, or 4 should never be allowed into the actual drill area, unescorted.

III. RESEARCH PROPOSAL AND REQUEST FOR INVESTIGATION (RFI) APPROVAL AND SCHEDULING PROCESS

The completed Request for Investigation (RFI) package, including the Research Proposal, signed Land Use Agreement(s), and Site Health and Safety Plan will be evaluated by the Central Office Hydrogeologist, the Groundwater Planning Unit Supervisor, and the Aquifer Protection Section Chief. If all of the elements in the RFI are complete, and the proposed project has technical merit, the RFI will be assigned a Priority Number for scheduling purposes. A Priority Number will be assigned by a consensus of the Central Office Hydrogeologist and the Groundwater Planning Unit Supervisor. The priority number will determine where the proposed project fits in with the existing field investigation services schedule. A priority number will only be assigned upon receipt of a COMPLETE RFI package. The objectives of prioritization are to: (1) encourage proposals that support Division goals and objectives, (2) ensure that projects that support Division goals and objectives are given priority access to limited drilling resources and (3) help ensure a steady flow of investigations (4) provide all APS staff with an understanding of how drilling services will be allocated in the event of schedule conflicts.

The Priority Number will be assigned based on the following criteria:

<u>Priority Level One (1)</u> = Projects that clearly support the goals and mission of the Division of Water Quality and provide data that cannot be obtained in any other way and that must be completed as soon as possible.

<u>Priority Level Two (2)</u> = Projects that support the goals and missions of the Division and provide data that cannot be obtained without field investigation services, but are not time-sensitive.

<u>Priority Level Three (3)</u> = Projects that may or may not directly support the goals and missions of the Division and are not time-sensitive.

In the event that two or more RFI's with the same priority level are in the schedule queue, the APS Section Chief will determine which drilling project is initiated first after consulting with the APS Drilling Unit Supervisor. The actual drilling schedule will be determined by the APS Drilling Unit Supervisor based on equipment and personnel availability. "Emergency" situations may occur at any time, which could require the drilling crew to temporarily suspend work at any site in order to accommodate an urgent situation. Normal fieldwork scheduling will resume after any "emergency" situation has been addressed.

WIRELINE CORING

PURPOSE: To establish acceptable methods for collecting and handling and storing unconsolidated and consolidated cores collected using the wireline method in the Piedmont and Mountains of North Carolina.

MATERIALS:

1. Core Boxes
2. Small Sledgehammer and Chisel
3. Trowel or Spatula
4. Small Wooden Spacers
5. Measuring Tape or Ruler
6. Camera
7. Log Sheets or PDA/Field Notebook Computer loaded with the Log Sheet File
8. Clean water
9. Water-filled Spray Bottle or clean brush and 2-gallon bucket

CORE REMOVAL AND LOGGING:

1. Consolidated and unconsolidated cores should be carefully removed from the core barrel in order to keep them as intact as possible. A split 5' section of well screen may be used to cradle the core as it is removed from the barrel and transported to a suitable logging location. The well screen should be marked in such a way that the top and bottom of the core can be readily determined after transport. Any material remaining in the core barrel shoe should be removed and placed at the bottom of the section of recovered core.

2. Core should be examined for evidence of moisture immediately after removal and transport to the logging location. Water bearing fractures in consolidated core may only remain moist for a few minutes, particularly on a hot or dry day. Observed moisture content and the location of water bearing fractures should be recorded on the log sheet.

3. Core should be reassembled if necessary and measured using a ruler or tape. The length of the recovered core should be estimated to the nearest tenth of a foot and recorded on the log sheet.

4. Consolidated core should be cleaned, if necessary, using water from a clean source prior to being logged.

5. As much as ¼ of an unconsolidated core should be carefully removed lengthwise using a trowel or spatula, if necessary, to reveal the internal structure of the core.

6. The core should be logged according to the standard operating procedure "Soil and Bedrock Description, Identification and Logging." Clean water from a spray bottle may

be used when logging consolidated core in order to better observe texture, structure, and mineralogy.

7. In addition to the standard information collected during logging, information related to the drilling time in minutes per foot, bit pressure, and change or loss in the return of drilling fluid should be noted.

8. In some instances it will be necessary to log or complete logging of the core at a later time. If so, it is especially important to keep the core as intact as possible during storage and transport.

PLACEMENT OF CORE INTO BOXES:

1. When all logging is completed, the core should be transferred to a core box. The core box and lid should be adequately labeled prior to receiving the core. At a minimum the label should include the site name, core hole ID, depth interval, and box number. The top and bottom of the box should also be marked.

2. The core box should contain separators that allow for the core to be placed into individual columns or rows. If the core is particularly wet and cardboard core boxes are being used, plastic sheeting should be used to keep the core separate from the box.

3. According to ASTM D 2113 – 83, Core should be placed into the core box as a book would read, from left to right in each row and from top row to bottom row. The beginning point of storage in each core box is the upper left-hand corner. The upper left hand corner of a hinged core box is the uppermost left corner when the hinge is on the far side of the box and the box is right-side up. An unhinged core box should be clearly marked so that the orientation and direction of the core is obvious.

4. Wooden or plastic spacers should be inserted at the beginning/end of each core run or where a significant gap in the core is present. These spacers should be clearly labeled with an appropriate depth on at least two sides. The use of pressure treated wood for spacers is preferred.

5. It may be necessary to separate or break core in order to fit it into the core box. A trowel or spatula should be sufficient to separate unconsolidated core. A small sledgehammer and chisel may be necessary to break consolidated core. Care should be taken to avoid separating or breaking the core along lithologic contacts or other significant features.

6. If a section of core does not completely fill a row, the separation or breaking of the next section of intact core may be necessary. In general, if the remaining space is more than 0.5 feet, an appropriate length of the next section of core should be used to fill the remaining space. If the remaining space is less than 0.5 feet, the beginning of the next section of core should be placed into the following row.

7. Breaks made in consolidated core during handling should be marked with a permanent marker so that they may be readily distinguished from naturally occurring fractures.

8. When a core box has been filled, it will be beneficial to photograph the open box. All boxes in a core hole should be photographed under similar light conditions. A readable sign indicating the box number, depth interval, and orientation of the core should be included in the photograph.

CORE BOX STORAGE AND TRANSPORT:

1. During transport, core boxes should be firmly secured.

2. Temporary and permanent storage of core boxes should be in a dry, secure location that is protected from the elements.

3. All boxes from individual core holes should be stored separately and in numerical order.

4. Heavier boxes containing consolidated core should not be placed on top of boxes containing unconsolidated core.

5. The final disposition of core boxes should be noted both on the log sheet and in the permanent site file.

SOIL AND BEDROCK SAMPLE COLLECTION

PURPOSE: To establish acceptable methods for the collection of soil and rock samples in the Piedmont and Mountains of North Carolina.

MATERIALS:

1. Latex, nitrile, or vinyl gloves
2. Stainless steel trowel
3. Stainless steel shovel
4. Stainless steel hand auger
5. Rock hammer
6. Clean water
7. De-ionized water
8. Clean brush
9. Non-phosphate detergent

SAMPLING METHODS:

1. Soil and rock samples will generally be collected from cores. Cores can be produced using a hand auger, Geoprobe with continuous sampling tube, split barrel sampler, Shelby tube, or wire line coring device. Cores produced with a hand auger or split barrel sampler are considered to be representative but disturbed. They are suitable for descriptive purposes and for the testing of most chemical parameters, but are not suitable for the testing of physical or hydraulic properties. Samples collected using the Geoprobe, Shelby tube, or the wireline-coring device may be undisturbed and representative. If so, they are suitable for all purposes.

2. The suitability of soil and rock samples that are not collected from cores must be determined on an individual basis. In general, outcrop samples and samples collected from banks or road cuts can be considered to be undisturbed and representative. The potential effects of chemical weathering and exposure to contaminants should be considered, however, when collecting surficial samples. In general, samples collected from drill cuttings are considered to be disturbed and non-representative. They can be used for descriptive purposes, but should not be used for testing purposes.

SAMPLE COLLECTION:

1. Samples collected for descriptive purposes or for testing should be representative.

2. Samples collected for testing purposes should be taken from the middle portion of the core or from an undisturbed area for non-core samples.

3. Soil samples should be collected using a clean trowel or hand shovel to minimize disturbance to the sample. For hand auger samples, the careful removal of the core by hand is acceptable.

4. In general, core samples should be collected from a discrete interval and should not be taken in composite from different locations within a core. Non-core samples should be collected from a specific location and not taken in composite from several locations at a site.

5. Samples collected for chemical testing should be of sufficient volume. These samples should be placed immediately into DWQ Chemistry Laboratory (lab) approved containers. Care should be taken to avoid disturbing samples when placing them in containers. Any required preservatives should be added at the time when the sample is placed into the container.

6. Sample containers should be stored in the field in accordance with lab guidelines, generally in an ice-filled cooler.

QA/QC AND EQUIPMENT DECONTAMINATION:

1. All soil and rock samples collected for testing purposes will be collected using clean sampling equipment. At a minimum, the standard cleaning procedure prior to and after sample collection will consist of washing the outside and inside of all equipment with a low-lathering, non-phosphate detergent (e.g., Alconox, Liquinox, etc.) using clean water and a clean brush followed by rinsing with organic-free de-ionized water or high-pressure steam cleaning (large equipment).

2. Latex, nitrile, or vinyl gloves will be worn at the discretion of the project hydrogeologist.

3. In general, trip blanks will not be required for soil sampling activities.

SAMPLE SHIPMENT:

1. Samples collected for testing will generally be taken to the DWQ Chemistry Laboratory, either by courier or by direct transport from the field.

2. Samples shipped via courier should be properly sealed. Lab sheets must be completely filled out and placed in a watertight bag inside the cooler.

3. The lab must receive samples within the specified holding time for the analyses that are to be performed.

DOCUMENTATION:

1. A unique identification code must be established for each sample, consistent with requirements for the DWQ Laboratory Information Management System (LIMS). This code should be clearly identifiable on the sample container at the time of sample collection. In addition to the LIMS numbering requirement, samples may be also identified in accordance with a numbering scheme (i.e. MW-01D, SB-01, etc.) devised by the project hydrogeologist.

2. The sample identification code, a description of the sample location and depth, and the site name should be clearly marked on the sampling sheet and the lab sheet, if applicable.

3. The location of all samples collected should be recorded on a scaled site map. All sample locations should be surveyed with a differentially corrected GPS receiver whenever possible.

SOIL AND BEDROCK DESCRIPTION, IDENTIFICATION AND LOGGING

PURPOSE: To establish acceptable methods for describing, identifying and logging soil and bedrock in the Piedmont and Mountains of North Carolina.

MATERIALS:

1. Unified Soil Classification Flow Chart
2. Grain Size Classification Chart
3. Munsell Soil and/or Rock Color Charts
4. Hand Lens
5. Rock Hammer
6. Small Knife or Spatula
7. Dilute hydrochloric acid (to identify carbonates)
8. Log Sheets PDA or Field Notebook Computer Loaded with the Log Sheet File

SOIL AND ROCK DESCRIPTION:

1. All soil should be described in accordance with the ASTM Standard Practice for the Description and Identification of Soil, Visual-Manual Procedure (ASTM 2488-90).

2. Written soil descriptions will include the following information: consistency, structure, moisture content (note only if notably dry or wet), color, minor size fraction, major size fraction, and other notable observations (organic material, accessory minerals, quartz fragments, relict rock textures, odor, staining along fractures, etc.)

3. If the soil contains coarse sand, gravel, cobbles or boulders, the angularity or range of angularity of the particles should be noted.

4. If the soil contains gravel or sand, the description should include whether the gravel is coarse or fine, or whether the sand is coarse, medium, or fine.

5. The color description should include the color name and color notation as identified using the Munsell Soil Color Charts.

6. An example of a soil description would be: *stiff, blocky, dry, reddish brown (5YR/5/3), silty clay containing a few blocky angular quartz fragments up to 1 cm in diameter and a trace of white mica.*

7. Competent rock samples should be described using conventional geologic terminology. At a minimum, rock descriptions should include: degree of weathering, color, grain size, type and intensity and condition (i.e. staining or mineralization) of planar and linear

fabrics, and identifiable mineralogy. If the rock described is in place, measurements of planar and linear fabrics should also be included in the description.

8. An example of a rock description would be: *fresh, silver to dark-gray, fine- to medium-grained, moderately well- to well-foliated, garnet-muscovite schist.*

SOIL AND ROCK IDENTIFICATION:

1. Soil will generally be identified in accordance with the ASTM Standard Practice for the Description and Identification of Soil, Visual-Manual Procedure (ASTM 2488-90). In some cases soil identification will be made by laboratory analysis in accordance with ASTM 2487-92.

2. Determine the percentages of gravel, sand, and fines to the nearest 5%.

3. Identify a coarse grained soil (<50% fines) using the Unified Soil Classification System flow chart.

4. Identify a fine grained soil (>50% fines) by:
   A. performing field tests for dry strength, dilatancy, and toughness.
   B. deciding whether the soil is inorganic or organic.
   C. using the Unified Soil Classification System flow chart.

5. Rock samples should generally be identified in the field using conventional geologic terminology. In some cases, geochemical or thin section analysis may be used to provide a more accurate or specific rock name. An effort should be made to correlate rock names to names established in published geologic maps and literature.

SOIL AND ROCK LOGGING:

1. A log sheet will be completed at the time that a soil boring or monitoring well is installed. At a minimum, the log sheet should indicate the type, location and name of the boring, the date the boring was completed, the person who logged the boring, and the location and description of any samples collected from the boring.

2. Complete soil and rock descriptions and identifications should be recorded directly on the log sheet. The depth range of each type of soil and rock should be recorded to the nearest 0.5 foot. The nature of contacts separating different rock and soil types should be determined if possible.

3. Rock structures and relict structures in saprolite should be identified on the boring log sheet. An indication of the general orientation of foliation and fractures (ie. vertical, horizontal, moderately dipping) should be included. Descriptions of fractures, including spacing (if part of a set) and relation of fracture orientation to foliation, should be noted.

4. Gradational changes in composition or structure within a single rock or soil type should be indicated on the boring log sheet (i.e. manganese oxide coated fractures increasing with depth).

5. An indication of the approximate depth of the contact between soil and saprolite, saprolite and the transition zone, and the transition zone and bedrock should be made on the log sheet.

6. Descriptions of fractures in the bedrock should include: drilling induced versus natural, open versus sealed, mineralization, spacing (if part of a set), relative orientation compared with foliation, and any evidence of chemical weathering.

DOCUMENTATION:

1. Soil and bedrock descriptions that are unrelated to a boring or a monitoring well should be recorded in a field notebook that is dedicated to the site where work is being performed. The sample and/or sample location should be assigned a number and/or letter code designation that is consistent with the sample numbering scheme devised at the beginning of the project.

2. Soil and bedrock descriptions that are related to a boring or a monitoring well should be recorded on the log sheet. The log sheet should be copied as soon as possible after it is filled out. The original sheet should be stored in the site file at the Regional Office. If an electronic device is used for logging, the logging file should be transferred to the computer used in office and printed out for site physical file as soon as possible.

3. The location of all soil and bedrock described and identified during a project should be determined using a transit or a GPS instrument with sub-meter accuracy.

REGOLITH LOG SHEET

PROJECT: ____________ **DRILLING METHOD:** wireline coring

BORING ID: ____________ **CORE DIAMETER:** 2.1"

LOGGED BY: ____________

BEGIN DATE: ____________

END DATE: ____________

INTERVAL	RECOVERY	SOIL HORIZON	DRY/WET	COLOR	DRY STRENGTH	DILATANCY	TOUGHNESS	PLASTICITY	UNIFIED CLASS	DESCRIPTION
TO										
TO										
TO										
TO										
TO										

BEDROCK LOG SHEET

PROJECT:
BORING ID:
LOGGED BY:
BEGIN DATE:
END DATE:

DRILLING METHOD: WIRELINE CORING

CORE DIAMETER: 2.1"

LITHOLOGIC DESCRIPTION				FRACTURE INFO			
INTERVAL	RECOVERY	DESCRIPTION		# ANNEALED	# OPEN	H20 BEARING	MINERALS
			V				
TO			SV				
			M				
			SH				
			H				
			V				
TO			SV				
			M				
			SH				
			H				
			V				
TO			SV				
			M				
			SH				
			H				
			V				
TO			SV				
			M				
			SH				
			H				
			V				

TO			SV					
			M					
			SH					
			H					

4.

GEOPHYSICAL LOGGING

PURPOSE: To characterize fracture zones and lithologies in open-hole bedrock wells as part of the hydrogeologic framework of bedrock aquifers. These data can be used to: interpret depth of fracture zones and lithologic contacts, orientations of fractures and rock fabric, qualitative comparison of fracture zones with regard to relative permeability, quantitative measurement of flow into or out of the well near fracture zones, and relative comparison of specific conductance of groundwater in fracture zones.

NOTES: Both USGS and DWQ maintain and use geophysical equipment. Thus, various borehole geophysical logging systems may be used as part of this project, including:

1. USGS North Carolina District Century logging system;
2. USGS Office of Ground Water (OGW) logging systems (various);
3. DWQ Mount Sopris logging system.

TECHNIQUES AND EQUIPMENT:

Borehole Geophysical Logging. This method of data collection involves the lowering of one or multiple probes into a well or borehole to collect geophysical information. Typical tools that will be used in the REP for research station work include the following:

a. Caliper – measures borehole diameter; allows interpretation of depth of fracture zones and magnitude of borehole breakout.
b. Gamma - measures naturally occurring gamma emissions from surrounding geologic material. Abrupt changes in gamma emissions typically indicate a change in borehole lithology.
c. Electrical - measures electrical properties of open-hole rock and/or fluids. Parameters include Spontaneous Potential (SP), Spontaneous Potential Resistance (SPR), Fluid Conductivity, and Fluid Resistivity. Abrupt changes in any of these parameters typically indicate a change in lithology, water chemistry, and/or water suspended solids.
d. Temperature - measures the temperature of fluid within a borehole, which may be influenced by the presence, or lack, of groundwater discharge.
e. Acoustic Televiewer – measures reflected acoustic signal velocity and amplitude, and borehole deviation, and allows interpretation of fracture and rock fabric (foliation – schists), magnitude, and direction of borehole deviation with depth.
f. Optical Televiewer – records digital, visual, oriented image of borehole wall and allows interpretation of orientations of fractures and rock fabric, spacing between fracture planes and compositional layers, and thickness of lithologies penetrated by the borehole.
g. Well Camera - records qualitative, depth-integrated, visual data of borehole/well characteristics, and allows assessment of rock fabric, rock fractures, and well/borehole construction quality.

h. RADAR – measures reflected radar signal velocity and amplitude in both directional, omni-directional, and tomography modes, and allows interpretation of fracture depths, relative extent of fracture planes, fracture orientation (both within and outside of the borehole). When areal signal penetration into the rock is significant (generally more than 100 feet in resistive rocks) imaging of fracture zones connecting wells is possible.

Surface Geophysical Logging. This method of data collection involves the transiting of underground sensing equipment along the land surface to measure subsurface profiles. Although various surface geophysical techniques may be used at a research station, two common methods are Ground-Penetrating RADAR (GPR) and Electromagnetic (EM) profiling. GPR emits high-frequency radio waves, which reflect off subsurface contacts, allowing the user to develop a subsurface profile. EM measures the electrical conductivity of soil, rock, and groundwater and is also used for subsurface profiling.

FIELD PROCEDURES:

All borehole geophysical logging equipment, including tools and cable, must be decontaminated prior to use on research wells. This will include:

- Initial rinsing using tap water;
- Cleaning – using Alconox or similar soap product, use scrub brushes and clean paper towels;
- A second tap water rinse to remove soap film;
- A final de-ionized water rinse. *Note: In most instances organic solvent rinses (methanol, ethanol, hexane) should be avoided at research sites due to the possible introduction of contamination.

Prior to logging, the water level in the well will be recorded in a field notebook. This data will be entered into the log header included in the borehole geophysical data acquisition software.

Header information – Basic well information needs to be recorded within the log header as part of the geophysical data acquisition software requirements. This information should include, as available:

- Local well number,
- Water level,
- Measuring point (land surface estimation, or from top of casing),
- Latitude and longitude of well location,
- Well elevation,
- Total depth of well,
- Depth of casing, casing materials

DATA STORAGE AND INTERPRETATION:

Geophysical data is typically collected and stored in an on-site laptop computer. Therefore, data backup, using flash drive or compact disks is prudent. Data interpretation is best accomplished by comparing all sources of field data, such as geophysical information, driller's logs, geologist's logs, etc. These data, when evaluated collectively, allow for the best interpretation of fracture zones and orientation, lithologic contacts, rock fabric, structural features, and other useful geologic controls affecting groundwater vulnerability and flow.

REFERENCES:

Benson, R., Glaccum, R.A., Noel, M.R., Geophysical techniques for sensing buried wastes and waste migration, 1988: National Water Well Association, Dublin, OH, 236 p.

Keys, W.S., Borehole geophysics applied to ground-water investigations, 1989: National Water Well Association, Dublin, OH, 313 p.

WELL CONSTRUCTION - WELLS COMPLETED IN BEDROCK

PURPOSE: To establish acceptable methods for construction of monitoring wells completed in bedrock of the Piedmont and Mountains of North Carolina.

NOTE: Well construction will adhere to standards described in North Carolina Administrative Code Title 15A, Department of Environment and Natural Resources, Division of Water Quality, Subchapter 2C, Section .0100 Well Construction Standards. A variance must be obtained if well construction deviates from these standards.

MATERIALS:

1. Monitoring wells completed in bedrock will generally be constructed of six and one quarter inch (outside diameter) steel casing. However, other casing material may also be used, such as six and one quarter inch (inside diameter), schedule 80 "Certalok" PVC casing, or four inch (inside diameter), Certalok PVC casing. Choice of casing material will be determined by the site hydrogeologist and the DWQ Drilling Supervisor. Regardless of materials used, casing will be seated into the bedrock, with open borehole completion in the bedrock.

2. No glues or solvents will be used in well construction.

3. A twelve-inch bit must be used to drill through the regolith and into bedrock. A smaller diameter bit may be used to extend the hole deeper into bedrock and to provide a better seat for the bottom of the casing.

4. Bentonite grout will generally be used as an annular sealant.

5. All well construction materials (well casing and other materials permanently installed, and annular sealant injection equipment) should be decontaminated prior to well installation, with water from a clean source. Standard decontamination procedures consist of washing the outside and inside (if possible) of equipment with a low-lathering, non-phosphate detergent. This should be followed by high-pressure steam cleaning, when practical.

INSTALLATION:

1. Drill the well using air-rotary technology with a 12 inch bit, while continuously injecting mud/foam through the bit to prevent hole collapse. In some instances it may be possible to safely advance the bit without injecting mud/foam and without hole collapse, thereby reducing or eliminating the introduction of drilling mud to the subsurface. This method

must be agreed to by both the site hydrogeologist and the drilling supervisor prior to its use.

2. If possible, run any necessary borehole geophysical tools through the open borehole after drilling into the first few feet of bedrock and prior to casing installation.

3. Set casing from land surface to a minimum of 5’ into competent bedrock using stainless-steel centralizers on the casing: one just above the bedrock, and one at each casing joint.

4. Using the tremie method, grout from the bottom of the casing up to a minimum of 20’ using a cement/bentonite mixture.

5. Allow the grout to cure using the manufacturers’ recommended cure times, then use 3/8” hole plug to seal the remainder of the annular space around the casing. Advance the borehole by drilling within this casing and into the bedrock beneath.

6. When drilling is complete, the well will consist of casing from above ground surface into the bedrock, sealing off the regolith. Open borehole will extend from the bottom of the casing to the bottom of the well. Geophysical logs will be run on the open borehole portion of the well after well completion.

7. Establish a permanent measuring point from which water levels will be consistently measured. The measuring point must be clearly identified and thoroughly documented.

8. Attach a hinged, locking lid to the PVC casing to restrict unauthorized access to the well. Or, place a steel protective casing with a hinged, locking lid over the well. If steel protective casing is used, it will be at least 2-inch in diameter larger than the PVC casing, and will be seated in wet concrete. Attach a long-neck field-grade lock to secure the lid; lock should be keyed to accept standard REP well keys.

9. Each well shall have a permanently affixed identification plate containing the following information:

    a. Drilling contractor and registration number
    b. Well completion date
    c. Total well depth
    d. Warning that the well is not a water-supply well and that groundwater may contain contaminants
    e. Screened interval, if applicable
    f. Casing depth, if applicable
    g. LIMS location identification number

10. In high traffic areas or other places of potential damage to the well, it may be necessary to install additional protection such as bumper posts, markers, and signs.

11. Additional monitoring wells will be located at the discretion of the site hydrogeologist. He or she should consider the potential for cross contamination from drilling mud, when placing one well near another.

12. Changes to these procedures may be made if warranted by site conditions, if technically defensible, and if agreed to by both the site hydrogeologist and the drilling supervisor.

DOCUMENTATION:

1. Thoroughly document the materials and methods used for well construction. Complete a well-construction diagram on-site showing the borehole depth and diameter; type and length of well casing; location and length of open interval; materials and length of annular seals; and description of measuring point.

2. Record well construction details on a Form GW-1 and submit to the CO for processing.

3. Record well location with GPS unit and/or leveling/surveying equipment.

SPECIAL CONSIDERATION: *Wells constructed in the 100-yr floodplain must be protected by water-sealing the well or by extending the casing above the 100-yr floodplain level.*

WELL CONSTRUCTION – WELLS COMPLETED IN REGOLITH

PURPOSE: To establish methods for construction of monitoring wells completed in the regolith of the Piedmont and Mountains of North Carolina.

NOTE: Well construction will adhere to standards described in North Carolina Administrative Code Title 15A, Department of Environment and Natural Resources, Division of Water Quality, Subchapter 2C, Section .0100 Well Construction Standards. A variance must be obtained if well construction deviates from these standards.

MATERIALS:

1. Monitoring wells completed in the regolith generally will be constructed of 4-inch, inside diameter, schedule 40 PVC casing to allow greatest flexibility for various uses (sampling, geophysics, water-level monitoring, etc).

2. Threaded, flush joint casing is required. No glues or solvents will be used in well construction.

3. Screens generally will be 10-feet long, 4-inch diameter PVC, with 0.010-inch slot size, unless otherwise dictated by the site hydrogeologist. Screens will be flush-threaded with a bottom plug.

4. Filter pack will consist of chemically inert fine-to medium grained uniform sand.

5. Annular sealants will consist of bentonite grout, bentonite pellets or chips, or neat cement grout.

6. Protective casings will be steel, and will have a hinged, locking lid. The protective casing will be at least 2-inches in diameter larger than the diameter of the monitoring well. If the well is flush mounted, an appropriate housing must be used. The cover to this housing must be watertight and securely bolted. The top of the casing should extend at least 2-inches above the bottom of the housing.

7. All well construction materials should be decontaminated immediately prior to well installation, with water from a clean source. Standard decontamination procedures consist of washing the outside and inside (if possible) of equipment with a low-lathering, non-phosphate detergent. This should be followed by high-pressure steam cleaning, when practical.

INSTALLATION:

1. After drilling to the desired depth, place two to six inches of filter pack at the bottom of the borehole to provide a firm footing for the well. Following decontamination of well materials, assemble the well screen and riser pipe and place a stainless steel centralizer just above the top of the well screen. Lower the assembly to the bottom of the borehole, center it, and hold it in position. Cap the riser to deter entrance of foreign materials during well completion.

2. Carefully pour or tremie pipe a filter pack in the annular space around the screened interval, and extending two to three feet above the top of the screen. Gradually remove the drill pipe, hollow stem augers, or temporary casing (depending on drilling method used) in small increments as the filter pack is emplaced. Periodically measure the location and height of the filter pack in the borehole as it is placed. Take care to prevent bridging of the filter pack material between the drill pipe, augers or temporary casing and the well screen and riser pipe.

3. Place bentonite in the annular space between the borehole and riser pipe on top of the filter pack. The bentonite seal will consist of bentonite pellets, chips or grout, and will extend from the top of the filter pack to approximately three feet below land surface. If pellets or chips are used and extend above the water table, pour water into the annular space to ensure that the bentonite hydrates. If bentonite grout is used, it will be emplaced using the tremie method.

4. Place a steel protective casing at least 2-inch larger in diameter than the monitoring well over the well on completion of grouting to protect the well from damage and to restrict unauthorized access to the well. Seat the protective casing in wet concrete that extends from approximately three feet below land surface to slightly above land surface. Install a temporary centering device between the monitoring well and protective casing until the concrete dries. Maintain sufficient clearance between the lid of the protective casing and the top of the monitoring well to accommodate a well cap, and sampling or other monitoring equipment.

5. Construct a square concrete pad (about two feet by two feet and four feet thick) around the well at the surface, sloping to direct water drainage away from the well. Drill a ¼" weep hole in the protective casing above the cement collar for drainage of water which may enter the protective casing annulus. Coarse sand or pea gravel may be placed in the annular space of the protective casing.

6. Each monitoring well will be covered with a cap. If practical, drill a vent hole in the riser pipe below the well cap to allow for venting of gases and to maintain atmospheric pressure as water level rises and falls in the well.

7. Establish a permanent measuring point from which water levels will be consistently measured. The measuring point must be clearly identified and thoroughly documented.

8. Each well shall have a permanently fixed identification plate containing the following information:
    a. drilling contractor and registration number
    b. date well completed
    c. total depth of well
    d. a warning that the well is not a water-supply well and that groundwater may contain contaminants
    e. screened interval(s)
    f. LIMS location identification number

9. In high traffic areas or other areas where there is high probability of damage to the well, it may be necessary to install additional protection such as bumper posts, markers, signs, etc.

10. Secure the well by locking the protective casing with a Master lock (2640 keyed).

DOCUMENTATION:

1. Thoroughly document the materials and methods used for well construction. Complete a well-construction diagram on-site showing the borehole depth and diameter, type and length of well casing and screen; location and length of screened interval; materials and length of filter packs, annular and surface seals; description of measuring point; and characteristics of protective casing.

2. Record the well construction details on a computer spreadsheet.

SPECIAL CONSIDERATION:

1. Wells constructed in the 100-yr floodplain must be protected by sealing the well or by extending the well and protective casings above the floodplain. Do not drill a vent hole in the well casing for wells constructed in a floodplain or for flush mount wells.

MONITORING WELL DEVELOPMENT

PURPOSE: To establish acceptable methods for well development in the Piedmont and Mountains of North Carolina.

NOTES:

1. Well development restores the area of the aquifer adjacent to the well to its pre-drilling condition in order to provide water representative of the formation being sampled. Well development attempts to mitigate artifacts associated with drilling and improve hydraulic communication between the well and the aquifer by removing fine-grained sediments and drilling fluid residue from the filter pack and natural formation in the vicinity of the screened interval or open borehole.

2. Well development will be accomplished by actively agitating (surging) the water column in a well, forcing water back and forth through the well screen and filter pack (or natural formation) to loosen fine-grained material and bring them into the well. The fine-grained material will then be removed from the well, along with drilling and well installation fluids, until pre-drilling conditions in the aquifer are restored.

3. Three methods of well development might be used during this project: bailing, mechanical surging, and pumping with backwashing. These methods may be used individually or in combination, depending on the characteristics of the well being developed.

4. Following well installation, allow the grout to cure and settle a minimum of 48 hours before beginning well development.

5. Do not introduce air, foreign water or chemicals (i.e., dispersing agents, acids, surfactants, disinfectants) into the well during well development.

6. Initiate well development gently for each method used to avoid damage to the well screen or borehole. Increase the degree of agitation slowly as flow is established through the intake portions of the well.

MATERIALS:

1. Any equipment introduced into the well during development must be decontaminated prior to well development. Standard decontamination procedures consist of washing the inside and outside of equipment with a low-lathering, non-phosphate detergent, followed by rinsing with copious amounts of deionized water.

2. Bailers used for well development will be bottom filling and constructed of stainless steel, polyethylene, or Teflon. Diameter of the bailer will be slightly smaller than the inside diameter of the well (i.e., use a 3-inch bailer for a 4-inch well, and a 4-inch bailer for a 3-inch well), to achieve the maximum surging effect. Bailers used for well development will not be used for groundwater sampling. Clean, non-fraying rope or cable will be used on the bailer for each well.

3. Stainless steel submersible pumps will be used for well development. Diameter of the pump used will depend on the diameter and capacity of the respective well. Typically, a 2-inch submersible pump will be used to develop the 4-inch regolith wells, while a 4-inch submersible pump will be used to develop the 3-inch bedrock wells. Pumps will not be equipped with a backflow prevention valve. Pumps used for well development will not be used for groundwater sampling, if possible.

DEVELOPMENT PROCEDURES: The methodology below delineates typical steps for monitoring well development. However, based on local geology or other factors, the site hydrogeologist may elect to modify these procedures.

1. Before beginning well development, complete the following tasks:
    a. Decontaminate the equipment to be used for development.
    b. Measure the water level in the well ($\pm$ 0.01 feet).
    c. Measure the total depth of the well ($\pm$ .1 feet).

2. For regolith wells, initiate well development by bailing gently. Lower the bailer into the well to just above the screened interval. Remove the bailer from the well. Repeat the procedure, lowering the bailer to various positions throughout the screened interval. Insertion and removal of the bailer causes a surging effect. This forces water from the well into the aquifer on the downward motion, and induces water to flow from the aquifer back into the well on the upward motion.

3. Continued repetition of procedure #2 loosens and removes fine-grained material from the aquifer adjacent to the screened interval and removes suspended sediment from the well itself. Increase the degree of agitation as bailing proceeds.

4. To enhance removal of particulate matter from the well, move the bailer up and down with short rapid strokes near the bottom of the well.

5. Continue (regolith wells) or initiate (bedrock wells) the well development process by repetitive cycles of pumping, with backwashing, if yield of the well allows. Lower the pump into the well until it enters the water column. Begin pumping at a low rate, and then slowly lower the pump to the top of the screened interval (or bedrock open borehole). Pumping induces water, fine-grained material, and drilling fluid to flow from the aquifer into the well. Backwashing consists of shutting the pump off (no backflow prevention valve) and allowing water in the pump and discharge line to fall back into the well, causing outward surging of water into the aquifer.

6. The pump also can be used as a surge block. Alternately, a specially constructed surge block can be used. To surge, repeatedly raise and lower the pump (or surge block) 1-2 feet within the interval to be developed, forcing water back and forth through the well screen or bedrock fractures. Pump or bail to remove the turbid water, fines and drilling/well installation fluids drawn into the well. Repeatedly surge, pump, and backwash while lowering the pump at intervals of 5 feet or less to the bottom of the well and back up to the top of the saturated portion of the well screen or bedrock open borehole zone, as many times as necessary, until the discharge water appears to be clear during surging. Increase pumping rate as development proceeds to a rate greater than that typically maintained for purging/sampling activities.

7. Rinse the well casing or open bedrock borehole above the water table using only water from the well to remove extraneous materials (grout, bentonite, sand) that might have dropped into the well or has remain on the well/borehole wall from well installation.

8. Water removed from the well during development typically will be discharged onto the ground, away from the well to prevent pooling around the casing. If the well being developed is known to contain contaminants, the water may need to be stored in drums or tanks for future, appropriate disposal.

9. Measure water quality field parameters (i.e. pH, specific conductance, temperature, turbidity, dissolved oxygen, etc.) periodically during well development.

10. Measure water level periodically during well development, if possible. Water-level response during well development can be used to evaluate well purging flow rates prior to sampling.

11. Continue well development until (1) visibly clear water is discharged during the active portion of well development; and (2) the total volume of water removed from the well is at least equal to the estimated volume of fluid added to the borehole during drilling and well installation, and (3) water quality field parameters are stable. Field parameters are considered stable when five consecutive measurements, each separated by five minutes, have pH values within ± 0.2 units, temperature within ± 0.5 degrees Celsius, and specific conductance within ± 5% for values < 100 (± 3% for values > 100).

12. Allow the well to stabilize for at least one week (preferably longer) after well development before collection of groundwater samples.

DOCUMENTATION:

Thoroughly document the method(s) used and time required for development; equipment used; static water level; estimate of volume of water removed; pumping rate(s); visual appearance of the discharge water; well characteristics (depth of well, well diameter, and depth to screened or open interval); and measurement of turbidity and other field parameters. An example of a well development record is attached, and illustrates the information to be recorded in the field notebook.

DIFFERENTIAL LEVELING SURVEYS

PURPOSE: To establish acceptable methods for obtaining elevation data using the differential leveling survey method in the Piedmont and Mountains of North Carolina.

NOTES:

1. This document will serve as a general guide to leveling procedures, but hands-on training by someone familiar with leveling is required to actually train staff in the methodology.

2. Two people are generally required to perform a leveling survey.

3. Elevations should be calculated to the nearest hundredth (0.01) foot.

4. Although the vertical accuracy of GPS units are continually being developed and improved, is it wise to verify GPS elevations with a leveling survey.

5. If a measuring point (MP) for water level measurements was not established during well construction (see sections on Well Construction), is must be established when the well is being surveyed for the first time. The MP is typically located at the top of the PVC casing, but can also be at the top of the protective outer casing if necessary. The standard method of establishing an MP is to file a small notch on the top of the casing. The MP should be clearly marked and described by the surveyors so it can be located by anyone collecting water level measurements. The distance from the MP to the land surface datum (LSD) should also be measured during the initial survey and noted for future MP corrections.

MATERIALS:

1. Surveyor's telescopic level with tripod. However, a transit or total station may also be used. The level should occasionally be calibrated or checked by a professional.

2. Level rod graduated in feet, tenths and hundredths of feet.

3. Field notebook or Leveling Form.

4. Calculator.

INSTRUCTIONS:

1. Locate a benchmark in the area in which you will be surveying and determine its elevation by contacting the NC Geodetic Survey. Alternatively, establish a temporary benchmark (TBM) at a semi-permanent object on the site to be surveyed (e.g., a nail in a concrete pad, a lag bolt in a telephone pole, one corner of a concrete pad, etc.). Assign an arbitrary elevation to the TBM (such as 100' or 1000') to be used to determine the relative elevations of all other survey points. Be sure to describe the location of the TBM accurately so that future surveyors can find it. The TBM will also need to be located by GPS as part of the GPS survey of the site and located on any maps or figures of the site.

2. Position the leveling instrument on its tripod in a location where you can see the level rod (through the telescope) placed on the benchmark and also on the objects to be surveyed. The instrument should be leveled according to the device it uses (bubble level, etc.). The instrument should be higher than the benchmark and survey points so that the numbers on the rod can be read through the telescope (see Fig. 1 on how to read the graduations on the rod). The more objects on site that can be surveyed from the first instrument position, the less error will be introduced.

3. The first task is to determine the height of the leveling instrument (HI). Record the elevation of the benchmark in the "Elevation" column (see Fig. 2). Position the rod on the benchmark and hold it vertical and as still as possible. The rodperson should check often that it is vertical and the levelperson should signal the rodperson as to the direction it needs to be moved to make it vertical. The vertical line in the telescopic sight can be used for this. The levelperson then sights through the telescope, focuses the rod into view, and uses the middle horizontal line to take a reading to the nearest 0.01 foot (see Fig. 1). This reading is known as a *backsight* (BS) and is added to the elevation of the benchmark to determine the HI. (BS is also called a *plus sight* because it is always added to the known elevation.) Record the BS in the appropriate column, add it to the benchmark elevation, and record this number in the HI column (see Fig. 2).

4. The HI is now used to determine the relative elevation of additional survey points. While the level remains in place, move the rod to the next object and hold it vertical and steady on the MP. Focus the view through the level and take a reading (see Fig. 1). This reading is known as a *foresight* (FS) and is subtracted from the HI to determine the elevation of the object. (FS is also called a *minus sight* because it is always subtracted from the known HI.) Record the FS in the appropriate column, subtract it from the HI, and record this number in the "Elevation" column (see Fig. 2) as the elevation of the object.

5. Repeat step 4 for all objects that can be seen from the instrument's position.

6. If additional objects need to be surveyed and cannot be seen from the current instrument position, or if the objects are too far away to get an accurate reading to 0.01 foot, the instrument needs to be moved to a new position. This is accomplished by using Turning Points (TPs). A TP can be the last object surveyed before moving the instrument, or it

can be a new arbitrary location. The fewer TPs you have in a given leveling survey, the less error you will introduce into your data. To use the last surveyed object as your TP, the rodperson continues to hold the rod while the level is moved to a new location, from where other unsurveyed objects can be seen. The levelperson then makes a BS reading to determine the new HI, adds this reading to the elevation of the object (now serving as a TP) and records the data in the appropriate columns (see Fig. 2). Additional FS readings can now be made from the new instrument position to other objects using the new HI (following step 4). To use an arbitrary location as a TP, the level remains stationary and the rodperson moves to a new point. This point should be chosen so that the levelperson can see it (as well as other objects to be surveyed) from a new instrument location. The levelperson takes a FS reading to determine the elevation of the arbitrary TP subtracts this from the HI and records the data in the appropriate columns (see Fig. 2). The rod must remain stationary at this point, while the instrument is then moved forward to a new location from where the levelperson can view the TP as well as other survey objects. After the instrument is set up at the new location, a BS is taken to determine the new HI. After recording this data, the rod can be moved on to other objects for additional FS readings in order to calculate additional elevations.

7. After elevations have been determined for all objects, the leveling survey should be “closed” to ensure the highest possible data accuracy and to determine any potential sources of error. This is accomplished through a series of one or more TPs, ultimately tying in to the original benchmark. The final elevation of the benchmark determined by the survey closure should be no more than 0.05 feet different than the original elevation.

REFERENCE:

Harbin, A. L., 1985, Land Surveyor Reference Manual, Professional Publications, Inc., San Carlos, CA, pages 21-6 through 21-9.

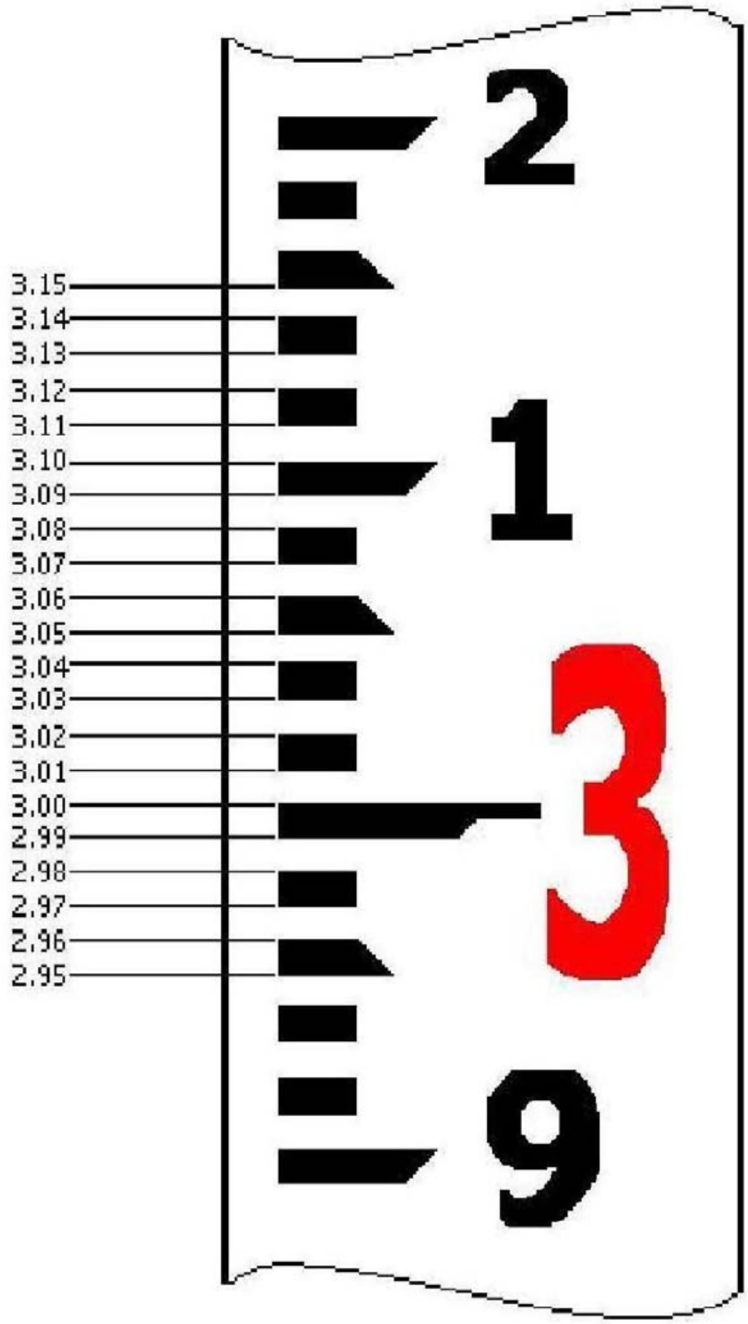


Figure 1. Diagram of a portion of a typical leveling rod showing how to read graduation marks. Each black bar and each white space between the bars is equal to 0.01 feet thick.

MEASURING WATER LEVELS IN MONITORING WELLS:

GRADUATED ELECTRIC TAPE METHOD

(This is the preferred method for groundwater sampling and for aquifer tests.)

PURPOSE: To establish an acceptable method for measuring water levels with an electric measuring tape in the Piedmont and Mountains of North Carolina.

MATERIALS:

1. Electric water level measuring tape graduated in feet, tenths and hundredths of feet. The tape should have charged batteries and a working indicator signal, verified before leaving the office.

2. Water Level Measurements Form.

3. Master Lock keys, wrenches, sockets and bolt cutters to open monitoring wells.

4. Deionized water in a squirt bottle and a clean cloth or paper towels.

ASSUMPTIONS:

1. All wells to be measured have an established measuring point (MP), and the distance from the MP to the land surface datum (LSD) is known. The MP should have been established shortly after well construction or during the leveling survey and is typically a small notch filed on the top of the casing.

2. The MP is clearly marked and described so anyone unfamiliar with the well will know from which point to measure. If an MP has not been established, review the SOP sections on Well Construction or Differential Leveling Surveys.

INSTRUCTIONS:

1. Check the circuitry of the electric tape before lowering the probe into the well by dipping the probe into a container of clean tap water. (Distilled or deionized water may not work for this purpose.) Make sure the audible indicator sounds or the indicator needle deflects, indicating that the circuit closes properly.

2. Lower the electrode probe slowly into the well until the audio or needle indicator signifies contact with the water surface.

3. Read the depth to water with the tape directly against the MP on the well casing. If this is impractical, grasp the measuring tape at the well's MP with two fingers and pull the tape partly out of the well to read the depth to water (to the nearest 0.01 foot). Record the measurement.

4. Apply the MP "correction" (distance of measuring point above land surface) to this measurement to get the depth to water below or above Land Surface Datum (LSD).

5. Check the original measurement by repeating steps 2 through 4. If the measurements do not agree to within +/- 0.02 feet, continue to check measurements until the results are shown to be reliable.

6. When measurement is completed, clean the part of the tape and probe that came in contact with water by rinsing thoroughly with deionized water or, if the probe or tape has become dirty, by soaking a cloth or paper towel with deionized water and wiping down the equipment. The probe and tape will need to be decontaminated with Alconox, Liquinox or methanol and deionized water if the water is known to contain contaminants.

7. Record any necessary remarks on the form.

REFERENCE:

Draft internal USGS-OGW Stand-Alone Procedure Document GWPD 4, "Water-Level Measurement Using an Electric Tape".

MEASURING WATER LEVELS IN MONITORING WELLS:
GRADUATED STEEL TAPE METHOD

PURPOSE: To establish an acceptable method for measuring water levels with a steel measuring tape in the Piedmont and Mountains of North Carolina.

MATERIALS:

1. Steel measuring tape graduated in feet, tenths, and hundredths of feet. A breakaway weight should be attached to the bottom of the tape with wire strong enough to hold the weight but weak enough to be severed if not as strong as the weight becomes lodged in the well. The weight should be made of brass, stainless steel, or some other non-reactive material.

2. Chalk for coating tape.

3. Water-level measurement taken during the previous field visit, to estimate depth to water.

4. Water Level Measurements Form.

5. Lock keys, wrenches, sockets and bolt cutters to open monitoring wells.

6. Deionized water in a squirt bottle and a clean cloth or paper towels.

ASSUMPTIONS:

1. All wells to be measured have an established measuring point (MP), and the distance from the MP to the land surface datum (LSD) is known and recorded on the Water Level Measurement Form. The MP should have been established shortly after well construction or during the leveling survey and is typically a small notch filed on the top of the casing.

2. The MP is clearly marked and described so anyone unfamiliar with the well will know from where to measure. If an MP has not been established yet, review the SOP sections on Well Construction or Differential Leveling Surveys.

INSTRUCTIONS:

1. Thoroughly cover the lower few feet of tape with chalk. When the tape is submerged, the wetted chalk mark will identify the part of tape that was lowered beneath the water surface.

2. Lower the weighted tape into the well until the lower end of the chalked tape is submerged. Lower the tape slowly to avoid splashing. Continue to lower the tape until the next whole foot gradation is opposite the MP. Record this number.

3. Pull the end of the tape rapidly to the surface before the wetted chalk mark dries. Record the measurement of the wetted chalk mark.

4. Subtract the "Wetted Chalk Mark" number from the "MP Hold" number.

5. Apply the MP correction to this measurement to get the depth to water below or above Land Surface Datum (LSD).

6. Check the original measurement by repeating steps 1 through 5. If the measurements do not agree to within +/- 0.02 feet, continue to make check measurements until the results are shown to be reliable.

7. When measurement is completed, clean the part of the tape that came in contact with water by rinsing thoroughly with deionized water or, if the probe or tape has become dirty, by soaking a cloth or paper towel with deionized water and wiping down the equipment. The probe and tape will need to be decontaminated with Alconox, Liquinox or methanol and deionized water if the water is known to contain contaminants.

MONITORING WELL SAMPLING

PURPOSE: To establish acceptable methods of collecting representative groundwater samples in the Piedmont and Mountains of North Carolina.

MATERIALS:

1. Monitoring wells will be purged, and, if possible, sampled using a Grundfos Redi-Flo II variable flow rate submersible pump constructed primarily of type "316" stainless steel and Teflon. The pump will be equipped with an anti-back siphon device. For bedrock wells having fracture-sampling zones deeper than 300 feet (the general limit of the Redi-Flo II pump), an alternate type of submersible pump (piston-type) may be used. Parameter stabilization will be used as criteria for sampling.

2. Pumps used for initial well development will not be used for the collection of groundwater samples.

3. The pump used for purging the well will also be used for sample collection.

4. Individual or multi-parameter water-quality meters will be used for measurement of field parameters. Discharge from the pump will be directed to an in-line flow-through chamber, where the field parameters will be measured.

5. All sampling personnel will wear vinyl, nitrile or latex gloves during equipment cleaning and during the collection and processing of samples. Gloves will be changed frequently and at the site hydrogeologist's discretion to reduce the potential for sample contamination.

6. All equipment used for purging and sample collection will be cleaned prior to use at each monitoring well. Standard cleaning procedures consist of scrubbing the outside of pumps, discharge lines, and other equipment with a low-lathering non-phosphate detergent solution, followed by multiple rinses with deionized water. The detergent solution and rinse water also should be circulated through the inside of the pump and discharge lines. Additional cleaning procedures may be required depending on the specific constituents to be analyzed.

PRE-SAMPLING PREPARATIONS:

1. Thoroughly clean all sampling equipment before use at a well.

2. Assemble all equipment and supplies, and ensure that they are clean and in working order. Load vehicle(s) with equipment and supplies needed for planned sampling event.

3. Prepare and organize the sample containers for each well site before going in the field. Pre-label sample bottles to the extent possible prior to the sampling event. Labels should be waterproof, and should contain the following information:

    a. sample identification,
    b. sampling site name,
    c. date and time of collection,
    d. types of analyses,
    e. sample type,
    f. preservative,
    g. name of individual collecting the sample.

4. At the sampling site, park sampling vehicle in a location suitable to prevent sample contamination from the vehicle, based on the prevailing wind direction. Do not store or transport gasoline, generators, heavily soiled tools, etc in the vehicle used for water-quality sampling.

5. Calibrate the field meters.

6. Measure the static water level in the well with an electronic water-level meter before purging the well.

7. Measure total depth of the well prior to initiation of purging.

8. If necessary, place plastic sheeting on the ground around the well to keep the sampling equipment clean.

9. Position sampling equipment and field instruments. Keep the discharge line shaded from direct sunlight to minimize changes in the temperature of the sampled water.

PURGING:

1. Purging the well replaces stagnant water in the well with fresh groundwater from the adjacent water-bearing formation.

2. Lower the pump intake into the well to the desired location (usually two to four feet below the water surface or, in the case of deep bed rock wells, to a depth adjacent to a major water-bearing fracture set), so that the entire static volume (or an equivalent volume) is removed during purging. Move the equipment slowly and smoothly through the water column to the desired depth to minimize suspension of sediments.

3. Place the water level meter to a depth near the water surface.

4. Start the pump at about 500 ml/min initially. Adjust the flow rate if necessary. The goal is to limit water level drawdown to a maximum of 0.5 – 1 foot, while completing the purge

within a reasonable amount of time. The purge should not overly stress the aquifer, mobilize particulates, or cause cascading or excessive agitation within the well. If the purge volume is small and can be completed within an hour, leave the flow rate at 500 ml/min for the entire purge. If not, slowly increase the flow rate to an acceptable rate while monitoring the water level. Adjust the flow rate at the pump with the pump control box, not with a flow-splitting valve.

5. After the flow rate is established, re-route the flow through the flow-through chamber of the water-quality meter(s) and continue the purge. Discharge the purge water on the ground far enough away from the well so as not to affect water quality. If the well being sampled is known to contain contaminants, the water may need to be stored in drums or tanks for future appropriate disposal.

6. Begin periodically monitoring and recording water level and field parameters (including, for example, pH, temperature, SpC, dissolved oxygen, ORP, turbidity, etc.). Record the start time of pumping, the flow rate, and depth of pump intake.

7. Avoid sudden change the flow rate during the purging process. Do not move the depth of the pump intake during purging, if possible.

8. If the purging flow rate was greater than 500 ml/min, reduce it to 500 ml/min for the last 15 to 25 minutes of the purge. Take the final 5 sets of field measurements about 5 minutes apart. The final pumping rate (established once the stability of 5 or more sets of field measurements are consistent) must be the same as the pumping rate during sample collection.

9. Monitor the field measurements against the stability criteria. Field parameters are considered stable when five consecutive measurements, each separated by at least five minutes, have pH values ± 0.2 units, temperature within ± 0.5^{o}C, specific conductance within ±5 percent for values greater than or equal to 100 or ± 3 percent for values greater than 100. Dissolved oxygen should be ± 0.3 mg/L.

10. Well purging is considered complete when field parameters are stable. If field parameters are not stable after 5 well volumes have been removed, the project hydrogeologist will decide whether or not to collect the sample.

11. For low-yielding wells with slow recovery, the well might be purged completely dry before the parameters stabilize. In this case, lower the pump intake slowly during the purging process and pump at a rate that minimizes suspension of sediments. Obtain field measurements and groundwater samples after the water level has recovered to at least 90 percent of the level measured before beginning the purge, provided recovery occurs within 24 hours of evacuation. If sampling with a Grundfos pump is not practical, alternative sampling methods (bailers, other types of pumps) may need to be considered.

SAMPLE COLLECTION:

1. The well should be sampled immediately after completion of the purging process. Do not stop the pump or adjust the flow rate between completion of purging and initiation of sample collection.

2. Change gloves prior to collecting groundwater samples.

3. Collect samples in sample containers appropriate for the constituent to be analyzed. The NCDENR-DWQ Chemistry Lab's current standard operating procedures for container type, minimum required sample volume, preservation and maximum holding time for various types of chemical constituents that may be collected in this study are available at the following website: http://h2o.enr.state.nc.us/lab/qa/sampsubguide.htm. Samples collected for analysis by the USGS National Water Quality Lab and other USGS laboratories will follow internal guidelines for bottles and container type.

4. Disconnect the discharge line from the flow-through cell and rinse the sample bottles (if required) with sample water from the discharge line. Then fill the sample bottles directly from the discharge line of the pump, in order of decreasing compound volatility from most volatile to least volatile.

5. Leave one-half inch of air space in all sample bottles except volatile analytes (volatile organics, hydrogen sulfide, radon, and others).

6. Record the field measurements made immediately prior to sample collection on the groundwater sample form.

7. Analyses of some chemical constituents (chlorofluorocarbons, tritium, and others, for example) may require modifications to the above sample collection procedures.

SAMPLE PRESERVATION:

1. Sample preservation is an attempt to minimize physical, biological, or chemical degradation of the sample between time of collection and analysis. Sample preservation generally consists of sample chilling and (or) chemical treatment.

   Preservation of samples should follow the current standard operating procedures of the NCDENR-DWQ Chemistry Lab or other laboratories used in the project. The DWQ laboratory website, http://h2o.enr.state.nc.us/lab/qa/sampsubguide.htm, indicates the appropriate treatment for various types of chemical constituents that may be collected in this study. Samples collected for analysis by the USGS National Water Quality Lab and other USGS laboratories will follow internal guidelines for sample preservation.

2. Temporarily place all samples not requiring chemical treatment in a cooler with ice, immediately after sample collection.

3. Preserve all samples requiring chemical treatment with the appropriate preservative as soon as possible after sample collection. Change gloves between additions of each type of preservative.

PACKING AND SHIPPING:

1. Prior to packing and shipping the samples, verify that all sample types required from the well are present, and that all the information required on sample labels and field forms is complete.

2. Samples must be transported to the laboratory in a manner that meets holding times of individual samples, as referenced at http://h2o.enr.state.nc.us/lab/qa/sampsubguide.htm.

3. Although some analytes do not require chilling, it is generally easier to ship all the samples in the same iced cooler.

4. Double-line all coolers with plastic garbage bags to prevent leakage during shipping. Seal the sample bottles in plastic "zip lock" bags and place the bottles in coolers so they do not tip, spill or break. If necessary, wrap the sample bottles in "bubble wrap" to prevent bottle breakage.

5. Place sufficient ice in the cooler around the sample bottles to maintain a sample temperature of $4^{o}C$ or less. To verify that low sample temperatures are maintained, place a temperature blank in the middle of the bottles being shipped. The temperature blank consists of a small (250 mL) bottle of tap or deionized water labeled "temperature blank", which the laboratory personnel will use to measure temperature upon sample arrival. Seal the plastic garbage bags around the ice.

6. Transport sample coolers to the DWQ Chemistry Lab in Raleigh. Samples should arrive within 24 hours of collection.

DOCUMENTATION:

1. Thoroughly document the equipment and methods used for collection of groundwater quality data. Document calibration of water-quality meter(s) used for measurement of field parameters. Complete a groundwater sampling form during purging and sample collection recording information such as sampling personnel, weather, well identification, pump type, water level, total depth of well, purge information (pump depth, pumping rate, volume pumped, appearance of water, periodic water level and field parameter measurements), and sample collection information. An example of a groundwater sampling form is attached.

2. All groundwater samples and respective data should be recorded in the LIMS database.

3. Record the groundwater sampling information on a computer spreadsheet and ensure that backup copies of the file are maintained.

INSTANTANEOUS CHANGE IN HEAD (SLUG) TESTING

PURPOSE: This section addresses field procedures for performing an in-situ, instantaneous change in head (slug) test. The slug test field procedure is used in conjunction with a slug test analytical procedure, such as Bouwer and Rice (1976), to provide quick and relatively inexpensive estimates of aquifer horizontal transmissivity.

The most reliable type of aquifer test usually conducted is a pumping test. However, a pumping test is generally expensive to conduct. An alternative to a pumping test is a slug or bail-down test that can be a performed in a small-diameter monitoring well. A slug test is used to determine to the hydraulic properties of the formation in the immediate vicinity of the well. It should be emphasized that slug tests provide very limited information on the hydraulic properties of the aquifer and often produce estimates that are only accurate to within an order of magnitude. Many experts believe that slug tests are relied on much too heavily in site characterization and contamination studies. Slug testing is still useful during the initial site studies to assist in developing a site conceptual model and in aquifer pumping test design.

The slug test provides an advantage over pumping tests in than it does not require the disposal of the large quantities of water that may be produced during an aquifer-pumping test. This is especially advantageous when testing a potentially contaminated aquifer. Another advantage of a slug test is that it may be performed in aquifer materials with lower hydraulic conductivity than generally considered suitable for hydraulic testing with pumping tests. A slug test may be the only practical methodology available for assessing in-situ horizontal hydraulic conductivity in aquifers with ‘K’ values below 1×10^{-5} cm/sec. However, slug tests reflect conditions near the well, and are therefore influenced by near-well conditions such as improper gravel pack, poor well development, and "skin" effects (Seeve, 1991). Therefore, wells subjected to slug tests must be properly developed prior to testing.

The method of data analysis (analytical procedure) should be known prior to the field-testing to ensure that all appropriate dimensions and measurements are properly recorded.

EQUIPMENT:

1. Water level indicator (electric and/or metal tape)
2. Solid slug or gas injection manifold
3. Pressure transducer 4. Electronic data logger
5. Braided nylon line – 1/8” diameter or larger
6. Field notebook
7. Key to well
8. Tool box
9. Watch
10. Laptop computer with required software for transducers/data loggers.

TERMINOLOGY:

Control well - well by which the aquifer is stressed, for example, by pumping, injection, or imposing a constant change of head.

Head – Water level within well referenced to a specified datum. Head measurements during slug testing usually are referenced to pre-test (static) water level

Hydraulic conductivity (K) - the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

observation well - a well open to all or part of an aquifer.

overdamped-well response - characterized by the water level returning to the static level in an approximately exponential manner following a sudden change in level. (See for comparison *underdamped well.)*

slug - a volume of water or solid object used to induce a sudden change of head in a well.

storage coefficient - the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. For a confined aquifer, it is equal to the product of specific storage and aquifer thickness. For an unconfined aquifer, the storage coefficient is approximately equal to the specific yield.

transmissivity - the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer.

underdamped well response – characterized by the water level oscillating about the static water level following a sudden change in water level. (See for comparison see *overdamped well.)*

SUMMARY:

This test method describes the field procedures involved in conducting an instantaneous head (slug) test. The slug test method involves causing a sudden change in head in a control well and measuring the water level response within that control well. Head change may be induced by suddenly injecting or removing a known quantity or "slug" of water into the well, rapid insertion or removal of a mechanical "slug" from below the water level, or increasing or decreasing the air pressure in the well casing.

The water-level response in the well is a function of the mass of water in the well, the transmissivity, and the storage coefficient of the aquifer. Slug test data can be analyzed and interpreted using many different techniques, the most common of which are the Bouwer and Rice method, the Hvorslev method, and the Cooper-Papadapolous method. The method of data reduction selected must take into account the type of aquifer (confined vs. unconfined) and well construction issues.

APPARATUS:

Slug-Inducing Equipment – Solid slug or compressed gas-injection device is the preferred equipment to induce a change in water level. Solid slugs should be constructed of a material that is compatible with the tested well construction and which will not potentially interfere with water quality analysis. PVC slugs are commonly used for this purpose due to their low cost and ease of use. The diameter of a solid slug should be sufficient to allow the slug to move freely inside the well in the presence of a pressure transducer cable, but also wide enough to generate a 'significant' change in the water level on insertion and withdrawal. Similarly, the length of a solid slug should be sufficient to generate a significant change in water level, but should still be capable of inducing an "instantaneous" change in head. For practical purposes, solid slug should be no longer than five feet for ease of use in the field.

Water-Level Measurement Equipment - The method of water level measurement may depend on the method of slug injection and the well response. When a solid slug is used, water levels may be monitored with an electric water level tape and/or a pressure transducer attached to an electronic data logger. Whenever possible, a pressure transducer and an electronic data logger should be used to collect water level data at logarithmic time intervals. Wells with very low water level recovery periods may be monitored using only an electric water level tape. Care must be taken to ensure that the correct pressure-rated transducer is selected; a low p.s.i. transducer (10 – 15 p.s.i.) is preferable for high precision data, but these transducers must not be placed at a depth greater than 80% of their rated range. If compressed gas is used to induce the slug, ensure that the combination of the gas pressure and water pressure does not exceed the range rating of the transducer.

TYPICAL PROCEDURE:

***Step 1. Decontaminate Down-hole Equipment**.* Ensure that all equipment that will come in contact with the inside of a well has been thoroughly cleaned and decontaminated in accordance with program established equipment decontamination procedures before use.

Step 2. Measuring Pre-Test Water Levels and Well Depth. - Measure the water level in the control well before beginning the test for a period of at least 10 minutes to determine the pre-test water level fluctuations and to determine a reference static water level. Determine and record the total depth of the well and check to see if the depth agrees with well construction records. Examine the measuring apparatus to check for the presence of silt that could block the openings of the pressure transducer. If silt is present in the bottom of the well, verify that the well has been properly developed before beginning the test and ensure that the pressure transducer is suspended above the silt layer. Silt can block the sensor openings in the pressure transducer, resulting in erroneous data.

Step 3. Insert Pressure Transducer. Carefully lower the pressure transducer inside the well and suspend it no more than ten feet below the static water level. Avoid allowing the transducer to rest on the bottom of the well unless there is no appreciable silt present. Prior to establishing the reference level, secure the pressure transducer to the well casing. One should also allow the probe to hang in the well for around 30 minutes, to allow for transducer cable stretching. The pressure transducer must not be moved during the test once the reference level has been established.

Step 4. Check Water Level. If a pressure transducer is used to monitor water level changes, ensure that the water level has recovered to the level established before the pressure transducer was lowered into place.

Step 5. Alter Water Level. Cause a change in water level, either a rise or decline, by one of the following methods:

- *Mechanical Slug* - Inject or withdraw a mechanical slug below or above the water level. The water within the control well will then rise or decline an amount equal to the volume of the mechanical slug.

- *Release Vacuum or Pressure*- A method of simulating the injection or withdrawal of a slug of water is by the release of a vacuum or pressure on a tightly capped (shut-in) control well. After the release, the vacuum or pressure is held constant.

NOTE - There is no fixed requirement for the magnitude of the change in water level. Generally, an induced head change from one-half to one meter is adequate. Some considerations include a magnitude of change that can be readily measured with the apparatus selected, for example the head change should be such that the method of measurement should be accurate to 1% of the maximum head change. The mechanical model for the test assumes the head change is induced instantaneously. Practically, a finite time is required to effect a head change. Selection of time zero can be performed using the test data. Refer to the method of analysis to determine time zero and to evaluate the suitability of the change effected in the well.

Step 6. Measure Water Level Response. Measure water-level response to the slug. The frequency of water-level measurement during the test is dependent on the hydraulic conductivity of the material being tested. During the early portions of the test (first two minutes), measure water levels as quickly as possible but no longer than 30 seconds between measurements until the water level has recovered to about 80% of the pre-test (static) level. Increase the length of time between measurements with increasing duration of the test. Since most methods of data analysis are curve-fitting techniques, it is essential that water levels be measured frequently enough to define the water-level response curve.

In aquifer-well systems where water-level changes are rapid, it will be necessary to use a pressure transducer linked to an electronic data logger to measure and record the water levels frequently enough to adequately define the water level response. Select a logarithmic time sampling interval on electronic data loggers. The use of transducers and data loggers generally provides a greater than adequate frequency of measurements, ranging from several measurements per second in the early part of the test to a specified frequency in the later portions of a test. Frequent measurements of water level using an electric water level indicator tape are required during the test in order to assess the degree of accuracy of the electronic data. In general, water level readings obtained using a pressure transducer should be within +/- 0.05 foot of readings obtained from an electric water level indicator tape.

Step 7. Post-Test Procedure. Make preliminary analysis of the data before leaving the field and evaluate the test regarding the criteria given in this test method and the method of analysis to determine if the test should be rerun.

RECORDS:

Include the information listed below in the report of the field procedure:

1. Date, time, and well identification
2. Method of slug withdrawal or injection, as well as whether the test is a falling head (injection) or a rising head (withdrawal) test
3. Inside diameter of well screen and well casing above screen
4. Depth of well
5. Length and depth setting of screen
6. Volume of mechanical slug or pressure change imposed on water level
7. Establish and record the measurement point from which all measurements of water level are made
8. Record date, time, and depth to water level below measurement point of all water levels
9. If the water levels are measured with a pressure transducer and recorded with an electronic data logger, record the name of the data file on the data logger

REFERENCES:

ASTM Committee D-18 on Soil and Rock, D4044-1991. Standard Test Method for (Field Procedure) Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers. American Society of Testing Materials.

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Dawson, K. J., and J. D. Istok, 1991. Aquifer Testing: Design and Analysis of Pumping and Slug Tests. Lewis Publishers, Chelsea, MI, 344 pp.

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Staliman, R. W., 1971 (Reprinted 1983). Aquifer-Test Design, Observation and Data Analysis. U.S. Geological Survey, Techniques of Water Resources Investigations, Book 3, Chapter 8l; U.S. Government Printing Office, Denver, CO, 26 pages.

AQUIFER TESTING

PURPOSE: To present the basic elements of aquifer (pumping) test design and implementation, and describe the procedure to perform an aquifer test. The determination of accurate estimates of aquifer hydraulic characteristics depends on the availability of reliable data from an aquifer test. If an accurate conceptual model of the site is developed and the proper equipment, wells, and procedures are selected during the design phase, the resulting data should be reliable. This document is not intended to be an overview of aquifer test analysis. The analysis and evaluation of pumping test data is adequately covered by numerous texts (Dawson and Istok, 1991; Kruseman and de Ridder, 1991; and Walton, 1987). However, information on the methods for analyzing test data should be reviewed during the planning phase since the aquifer estimates obtained from analyzing the data will depend on the method of analysis. This is important for determining the number, location, and construction details for all wells involved in the test.

Specific Capacity Testing: A specific capacity test involves the pumping of a single well with no associated observation wells. The purpose of a specific capacity test is to obtain information on well yield, observed drawdown, pump efficiency, and calculated specific capacity. The information is used mainly for developing the final design of the pump facility and water delivery system. The specific capacity test usually extends from 2 to 12 hours with periodic water level and discharge measurements. The pump is generally allowed to run at maximum capacity with little or no attempt to maintain constant discharge. Discharge variations are often as high as 50 percent. Short-term specific capacity tests with poor control of discharge are not suitable for estimating parameters needed for adequate aquifer characterization. If the specific capacity test is, however, run in such a way that the discharge rate varies less than 5 percent and water levels are measured frequently, the test data can also be used to obtain some estimates of aquifer performance. It should be emphasized that an estimate of aquifer transmissivity obtained in this manner will not be as accurate as that obtained using an aquifer test including observation wells. Also, this method does not normally provide information on boundaries, storativity, leaky aquifers, and other information needed to adequately characterize the hydrology of an aquifer. The objectives of an aquifer pumping test should clearly indicate the aquifer parameters that are to be investigated. A step-drawdown test with one or more observation wells may be adequate to determine basic site hydraulic characteristics.

Aquifer Testing (Pump Test): For the purpose of this document, an aquifer test is defined as a controlled field experiment using a discharging (control) well and at least one observation well. The aquifer test involves the application of a known stress to an aquifer and observation of water level response. Hydraulic characteristics that may be estimated if the test is designed and implemented properly include, but are not limited to, the storage coefficient, specific yield, transmissivity, hydraulic conductivity, and confining layer leakage. Depending on the location of observation wells, it may be possible to determine the location of aquifer boundaries. It may also be possible to determine the impact of pumping on surface-water features, if measurements are made on nearby springs or ponds.

EQUIPMENT:

1. Water level indicators (electric and/or metal tape – one per well if possible)
2. Pressure transducers/data loggers
3. Clipboards (one per well)
4. Pens (one per clipboard)
5. Field notebook
6. Keys to wells
7. Tool box
8. Graduated 5 gallon bucket
9. Stop watch
10. Submersible pump (and controller if electric pump is used)
11. Check valve for pump
12. Generator
13. Extra fuel for generator
14. Lights
15. Discharge pipe or tubing and couplings
16. Flow meter
17. Connection fittings for discharge line and gauges
18. Lap-top PC with data analysis software and/or type curves
19. Steel measuring tape
20. Wrist or pocket watch for every member of field team
21. Data collection forms
22. Barometer
23. Floodlights
24. Flashlights
25. Extension cords
26. Surge protectors
27. Optional – chairs and conveniences for field team
28. Optional - small television, VCR/DVD, and movies

TEST DESIGN:

Proper planning and design of the aquifer pumping tests will assure that the respective time and monetary expense will produce useful results. Individuals involved in designing an aquifer test should review the relevant ASTM Standards relating to: 1) appropriate field procedures for determining aquifer hydraulic properties (D4050 and D4106); 2) selection of aquifer test method (D4043); and 3) design and installation of monitoring wells (D5092). The relevant portions of these standards should be incorporated into the design.

All available information regarding the aquifer and the site should be collected and reviewed at the commencement of the test design phase. This information will provide the basis for development of a conceptual model of the site and for selecting the final design. It is important that the geometry of the site, location and depth of observation wells and piezometers, and the pumping period agree with the mathematical model to be used in the analysis of the data. A test should be designed for the most important parameters to be determined, while other parameters may have to be de-emphasized.

Aquifer Data Needs

The initial element of test design, formulating a conceptual model of the site, involves the collection and analysis of existing data regarding the aquifer and related geologic and hydrologic units. This includes saturated thickness, locations of aquifer boundaries, locations of springs, information on all on-site and all nearby wells (construction, well logs, pumping schedules, etc.), estimates of regional transmissivities, and other pertinent data. Detailed information relating to the geology and hydrology is needed to formulate the conceptual model and to determine which mathematical model should be utilized to estimate the most important parameters. It is also important to review various methods for the analyses and evaluation of pumping test data (Kruseman and De Ridder, 1991; and Walton, 1987). Then, determine which analytical method should be utilized to estimate the most important parameters. Information relating to the various analytical methods and associated data needs will assist the hydrologist in reviewing the existing data, identifying gaps in information, and formulating a program for filling any gaps that exist.

The conceptual model of the site should be prepared after carrying out a detailed site visit and an evaluation of the assembled information. The review of available records should include files available from the U. S. Geological Survey, other state agencies, and information from local drillers with experience in the area. Formulation of a conceptual model should include a brief analysis of how the local hydrology/geology fits into the regional hydrogeologic setting.

Aquifer Location

The depth to, thickness of, aerial extent of, and lithology of the aquifer to be tested should be delineated, if possible.

Aquifer Boundaries

Nearby aquifer discontinuities caused by changes in lithology, topography, or by incised streams and lakes should be mapped. All known and suspected boundaries should be mapped such that observation wells can be placed where they will provide the best opportunity to measure the aquifer's response to the pumping and the boundary effects during testing.

Hydraulic Properties

Estimates of all pertinent hydraulic properties of the aquifers and pertinent geologic units must be made by any means feasible. Estimates of transmissivity and the storage coefficient should be made, and if leaky confining beds are detected, leakage coefficients should be estimated. The estimation of transmissivity and the storage coefficient should be carried out by making a close examination of existing well logs and core data in the area or by gathering information from nearby aquifer tests, slug tests, or drill stem tests conducted on the aquifer(s) in question.

It may also be feasible to run a slug test on the wells near the site to get preliminary values. It should be noted that slug tests often produce results that are as much as an order of magnitude low. Slug test results can be as much as two orders of magnitude high if the well sand pack dominates the test and the investigators failed to notice this effect. Such tests will, however, provide a starting point for the design. If no core analyses are available, the well log review should form a basis for utilizing an available table that correlates the type of aquifer material with the hydraulic conductivity. If detailed sample results from drill holes are available and they have grain size analyses, there are empirical formulas for estimation of transmissivity. Estimation of storage coefficient is more difficult, but can be based on the expected porosity of the material or the expected confinement of the aquifer. It is recommended that a range of values be chosen to provide a worst-case and best case scenario. Trial calculations of well drawdown using these estimated values should be made to finalize the design, location, and operation of test and observation wells.

If local perched aquifers are of a significant size and location to impact the pump test, this impact should be estimated if possible. The final test design should include adequate monitoring of any perched aquifers and leaky confining beds. This might involve the placing of piezometers into and/or above the leaky confining zone or into the perched aquifer.

Evaluation of Existing Well Information

Because the drilling of new production wells and observation wells expressly for an aquifer test can be time consuming and expensive, it is advisable to use existing wells for conducting an aquifer test when possible. However, many existing wells are not suitable for aquifer testing. They may be unsuitably constructed (such as a well which is not completed in the same aquifer zone as the pumping well) or may be inappropriately located. It is also important to note that well logs and well completion data for existing facilities are not always reliable. Existing data should always be verified. The design of each well, whether existing or to be drilled, must be carefully considered to determine if it will meet the needs of the proposed test plan and analytical methods. Special attention must be paid to well location, the depth and interval of the well screen, and the present condition of existing well screens. Proposed pumping wells that have not been utilized over a period of a few months may be subject to fouling due to iron bacteria. Pumping wells with improperly constructed and/or fouled well screens will result in inaccurate estimates of aquifer parameters.

After the process of developing the site model and determining which analytical methods should be used, it is possible to move to the final design stage. The final stage of the design involves development of the key elements of the aquifer test: 1) number and location of observation wells; 2) design of observation wells; 3) approximate duration of the test; and 4) discharge rate.

Design of Pumping Facility

There are seven principal elements to be considered during the pumping facility design phase: 1) well construction; 2) the well development procedure; 3) well access for water level measurements; 4) a reliable power source; 5) the type of pump; 6) the discharge-control and measurement equipment; and 7) the method of water disposal. These elements are discussed in the following sections.

1) Well Construction

The diameter, depth and thickness of all intervals open to the aquifer in the pumping well should be known, as should total depth. The diameter must be large enough to accommodate a test pump and allow for water level measurements. If the pumping well has to be drilled, the depth, diameter, and well screen size should be established using data from existing well logs and from the information obtained during the drilling of the new well itself. The screen interval should be designed to have sufficient open area to minimize well losses caused by fluid entry into the well, but still be able to prevent sediment from entering into the well. In general, a minimum four-inch diameter well should be used for a pumping well, and at least a one-inch diameter well should be used for observation wells and piezometers. Refer to Section _?_ of this document for additional details on well construction.

2) Well Development

Information on how the pumping well was constructed and developed should be collected during the review of existing site information. <u>It is crucial that the pumping well and the observation wells are properly developed prior to beginning an aquifer pumping test</u>. If the well has not been adequately developed, the data collected from the well may not be representative of the aquifer. For instance, the efficiency of the well may be reduced; thereby causing increased drawdown in the pumping well.

When a well is pumped, there are two components of drawdown: 1) the head losses in the aquifer; and 2) the head losses associated with entry into the well. A well that is poorly constructed or has a plugged well screen will have a high head loss associated with entry into the well. These losses will affect the accuracy of the estimates of aquifer hydraulic parameters made using data from that well. If the well is suspected to have been poorly developed, or nothing is known, it is advisable to develop the well prior to running any type of aquifer tests. See the section on well development in this document for more detail on how to properly develop a well.

3) Water Level Measurement

It must be possible to measure depth to the water level in the pumping well before, during, and after pumping. The quickest and generally the most accurate means of measuring the water levels in the pumped well during an aquifer test is to use an electric sounder or pressure transducer system. The transducer system may be expensive and may be difficult to install in an existing well. If a pressure transducer is used in the pumping well, it should be placed at least a foot below the intake of the pump and should not rest on the bottom of the well. In larger diameter pumping wells, a small diameter (1-inch) PVC stilling well can be installed to physically protect the pressure transducer and to ensure accurate water-level measurements. Note the pressure range of the transducer and assure that it is capable of accurate, precise measurement of water levels over the anticipated range of water level fluctuations.

Lower p.s.i. transducers may be appropriate for more precise water level measurements in the observation wells. Care must still be exercised in the placement of pressure transducers in observation wells to avoid over-ranging. Once a transducer has been set inside a well, it is essential that the transducer not be moved during the duration of the test. To avoid accidental movement of a transducer, secure the cable to the well, but avoid contact with sharp surfaces on the well casing that could cut the transducer cable. An electronic water level tape should be used to verify pressure transducer readings before, during, and after the aquifer test. A steel tape may be used for water level measurements, but in general, the use of a steel tape is usually confined to the later stages of the pump test where rapid changes in water levels are not occurring.

In cases where the pump is isolated by a packer to allow production from a particular zone, a transducer system should be used to monitor pumping hydraulic heads. It is important, however, to calibrate the transducers before and after the test. In addition, reference checks with an electric sounder or steel tape should be made before, during, and after the test. The ASTM Standard Test Method for determining subsurface liquid levels in a borehole or monitoring well (D4750) should be reviewed as part of the design process.

4) Reliable Power Source

Having power continuously available to the pump, for the duration of the test, is crucial to the success of the test. If power is interrupted during the test, it may be necessary to terminate the test and allow for sufficient recovery so that pre-pumping water levels are reached. At that point, a new test would be run. If, however, brief interruptions in power occur late in the test, pumping at a calculated higher rate for some period so that the average rate remains unchanged can eliminate the affect of the interruption. The increased rate must be calculated such that the final portion of the test compensates for the pumpage that would have occurred during the interruption of pumping.

Some submersible pumps, such as the Grundfos™ Redi-Flo2, require a relatively “clean” and consistent power source. Many gasoline-powered generators are unable to deliver this type of power. Honda gasoline powered generators seem to work satisfactorily with these pumps. Verify that the generator and the pump are compatible before beginning the aquifer test.

Many power failures occur as a result of the generator running out of fuel. Establish a regular fuel capacity inspection schedule for the generator at the beginning of the test. Ensure there is sufficient lighting around the generator to facilitate safe re-fueling during nighttime operation.

5) Pump Selection

A reliable pump is a necessity during an aquifer test. The pump must operate continuously during the test. Should a pump fail during the pumping period of the test, the time, effort, and expense of conducting the test could be wasted. For this reason, it is advisable to have a functioning spare pump that can be used in case the primary pump fails. Electrically powered pumps produce the most constant discharge and are often recommended for use during an aquifer test. However, electric motors are nearly constant-load devices, so that as the lift increases (water level declines), the pumping rate decreases. This is a particular problem for inefficient wells or low transmissivity aquifers. The pump discharge rate needs to be monitored frequently during the early stages of a pumping test, and adjustments to the pump speed should be made as necessary to maintain a constant discharge rate. The use of pneumatic (bladder) pumps should be avoided due to their intermittent pumping cycles.

A small, variable speed submersible pump such as a Grundfos™ Redi-Flo2 pump is a good choice for low discharge rate pumping tests (less than 5 gallons per minute). These pumps are subject to premature wear if used in turbid water due to their relatively soft construction materials. If pumping rates exceed 5 gallons per minute, a four-inch submersible pump may be an optimal choice. Avoid over-stressing a low horsepower pump. Conversely, it is inadvisable to significantly restrict the discharge of many electric submersible pumps by valves, etc. to achieve a low pumping rate. Restricting the output of some pumps can over-stress the mechanical and electrical components, leading to pump failure.

In order to obtain good data during the period of recovery at the end of pumping, it is necessary to have a check valve installed at the base of the pump column pipe in the discharging well. This will prevent the back flow of water from the column pipe into the well when the pumping portion of the test is terminated and the recovery begins. Any back flow into the well will interfere with or totally mask the water level recovery of the aquifer and this would make any aquifer analysis based on recovery data useless.

6) Discharge-Control and Measurement Equipment

Control of the pumping rate during the test requires an accurate means for measuring the discharge of the pump and a convenient means of adjusting the rate to keep it as nearly constant as possible. Common methods of measuring well discharge include the use of an orifice plate and manometer, an inline flow meter, an inline calibrated Pitot tube, a calibrated weir or flume. Regardless of the type of discharge rate measurement, the instrument should be calibrated before use and checked periodically during the test by observing the length of time taken for the discharging water to fill a container of known volume (e.g. 5 gallon bucket; 55 gallon drum). Redundant instrumentation for discharge flow rates is also advisable to minimize the potential problems associated with instrument failure.

In addition to the potentially large variation in discharge associated with the pump motor, the discharge rate is also related to the drop in water level near the pumping well during the aquifer test. As the pumping lift increases, the rate of discharge at a given level of power (such as engine rpm) will decrease. The pump should not be operated at its maximum rate. Generally, the pumping unit should be designed so that the maximum pumping rate is at least 20 percent more than the estimated long-term sustainable yield of the aquifer. The long-term yield of the aquifer should be determined by collecting data on pumping rates in nearby wells. If possible, a short-term test of one to two hours should be run when the pump is installed. This test data should be compared to the historic data as part of the estimation process.

The pumping rate can be controlled by placing valves on the discharge line and/or by placing controls on the pump power source. A rheostat control on an electric pump will allow accurate control of the discharge rate without creating potentially damaging back pressure.

7) Water Disposal

Discharging water immediately adjacent to the pumping well can cause problems with the aquifer test, especially in tests of permeable unconfined alluvial aquifers. The water becomes a source of recharge that will affect the results of the test. <u>The produced water from the test well must be transported away from the control well and observation wells so it cannot return to the aquifer during the test.</u> This may necessitate the laying of a temporary pipeline (sprinkler irrigation line is often used) to convey the discharge water a sufficient distance from the test site. In some cases, it may be necessary to have on-site storage, such as steel storage tanks or lined ponds. This is especially critical when testing contaminated zones where water treatment capacity is not available. The test designer should carefully review applicable requirements of the RCRA hazardous waste program if the pump discharge may contain hazardous chemicals.

Design of Observation Well(s)

Total Depth

In general, observation wells should penetrate the tested aquifer to the same stratigraphic horizon as the well screen of the pumping well. This assumes the observation well is to be used for monitoring response in the same aquifer from which the discharging well is pumping. Actual screen design will depend on aquifer geometry and site-specific lithology as well as test objectives. Having observation wells screened at the same depth intervals as the pumping well makes data reduction easier since the effects of partial penetration are eliminated. If the aquifer test is designed to detect hydraulic connection between aquifers, at least one observation well should be screened in the strata for which hydraulic inter-connection is suspected. Depending on how much information is needed, additional wells screened in other strata may be needed.

Well Diameter

In general, observation well casing should have a diameter just large enough to allow for accurate, rapid water level measurements. A two-inch well casing is usually adequate for use as an observation well in shallow aquifers that are less than 100 feet in depth. The difficulties in drilling a straight hole usually dictate that a well over 200 feet deep be at least four inches in diameter. If pressure transducers or other instrumentation is to be installed in the well, ensure that there is sufficient space to accommodate both the instrumentation and a water level probe.

Well Construction

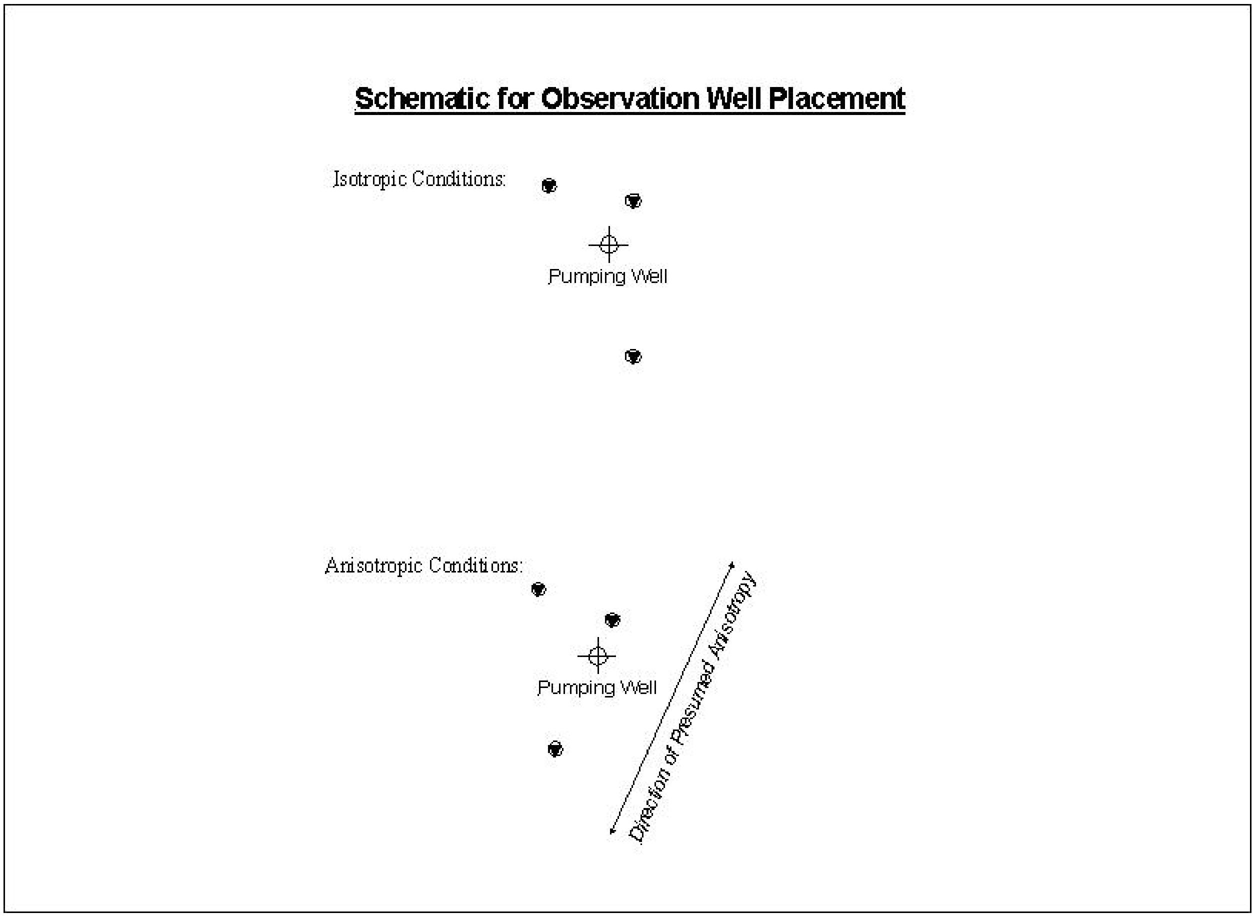
Ideally, the observation well(s) should have five to twenty feet of well screen near the bottom of the well. The final well screen interval(s) will depend on the nature of geologic conditions at the site and the types of parameters to be estimated as well as any additional uses planned for the well. Any openings that allow water to enter the well from aquifers that are not to be tested should be sealed or closed off for the duration of the test.

Radial Distance and Location Relative to the Pumped Well

The number and position of observation wells is an important factor affecting the validity of the aquifer test results. In general, the more observation wells used in a test, the more reliable the results will be. Observation wells are usually located 10 to 300 feet from the pumped well. However, each test situation should be evaluated individually, because certain hydraulic conditions may exist which warrant the use of a closer or more distant observation well. If the pumping well has a low yield (<5 gpm), the observation wells should generally be located fairly close to the pumping well (20 to 100 feet), but if the well yield is high, observation wells may be needed at distances from 50 to 300 feet or more from the pumping well.

In the case of multiple boundaries or leaky aquifers, the observation wells need to be located in a manner that will identify the location and effect of the boundaries. If the location of the boundary is suspected before the test, it is desirable to locate most of the wells along a line parallel to the boundary and running through the pumping well.

If aquifer anisotropy is expected, the observation wells should be located in a pattern based on the suspected or known anisotropic conditions. Observation wells should be installed on rays extending from the pumping well parallel with the suspected direction(s) of anisotropy. Other observation wells should be installed at high angles (nearly perpendicular) to the direction of suspected anisotropy. Refer to the following figure for an illustration of the suggested observation well placement schemes.



PRE-PUMPING TEST PROCEDURES:

Well thought out field procedures and accurate monitoring equipment are the key to a successful aquifer test. The following sections provide an overview of the methods and equipment for establishing a pre-test baseline condition and running the test itself.

Establish Baseline Trend

Collecting data on pre-test water levels is essential if the analysis of the test data is to be completely successful. The baseline data provides a basis for correcting the test data to account for on-going regional water level changes. Although the wells on-site are the main target for baseline measurements, it is important to measure key wells adjacent to the site and to account for off-site pumping which may affect the test results.
Baseline water levelsPrior to beginning the test, it will be necessary to establish a baseline trend in the water levels in the pumping and all observation wells. As a general rule, the period of observation before the start of the test should be at least five days. Baseline measurements must be made for a period that is sufficient to establish the pre-pumping water level trends on site. The baseline data must be sufficient to explain any differences between individual observation wells. If the water levels in on-site wells were declining or rising prior to the test, the drawdown during the test may need to be corrected to account for the pre-pumping trend. This data may

also show water level responses to previously unknown conditions such as unidentified pumping wells or recharge phenomena.

Baseline measurements should be recorded with transducers and a data logger if these instruments are to be used during the pumping test. This procedure will also provide time for the transducers to equilibrate with the pressure and temperature before the test, and will provide for a quality assurance check for the accuracy of the readings. The data logger should be programmed to record water levels at a minimum interval of 15 minutes during baseline measurements. Verify the data periodically with a water level meter or steel tape.

Nearby pumping activities

During the baseline measurements, the on-off times should be recorded for any nearby wells in use. The well discharge rates should be noted, as should any observed changes in the proposed on-site control well and observation wells. Baseline water level measurements should be made in all off-site wells within the anticipated area of influence.

Significant effects due to nearby pumping wells can often be removed from the test data if the on-off times of the wells are monitored before and during the test. Interference effects may not always be observable, however. In any case, changes associated with nearby pumping wells will make analysis more difficult. If possible, the cooperation of nearby well owners should be obtained to either cease pumping prior to and during the test period or to control the discharge of these wells during the baseline and test period. The underlying principle is to recognize and minimize changes in regional effects during the baseline, test and recovery periods.

Barometric pressure changes

During the baseline trend observation period, it is desirable to monitor and record the barometric pressure to a sensitivity of plus or minus 0.01 inches of mercury. The monitoring should continue throughout the test and for at least one day to a week after the completion of the recovery measurement period. This data, when combined with the water level trends measured during the baseline period, can be used to correct for the effects of barometric changes that may occur during the test.

Earth tides
In some confined aquifers, including fractured bedrock wells, semidiurnal fluctuations in groundwater levels, described as “earth tides” (caused by the attraction exerted on the earth’s crust by the moon), may be observed. Earth tides generally are small in magnitude, a few tenths of a foot, but may need to be considered for correction during aquifer tests. Baseline, continuous groundwater-level data allows accurate interpretation of these cyclic variations in the water level in a well.

Local activities which may affect test

Changes in depth to water level observed during the test may be due to several variables such as recharge (local rainfall and other precipitation), barometric response, or "noise" resulting from operation of nearby water supply wells, blasting activities, or loading of the aquifer by trains or other surface disturbances. It is important to identify major activities (especially cyclic activities) that may impact the test data.

PUMPING TEST PROCEDURES:

Initial water level measurements

Static water levels in all test wells should be recorded just prior to starting the pump. Measurements of drawdown in the pumping well can be simplified by taping a calibrated steel tape to the electric sounder wire. The zero point of the tape may be taped at the point representing static water level. This will enable the drawdown to be measured directly rather than by depth to water.

Measuring water levels during test

All personnel involved in the test should synchronize their watches immediately prior to beginning the test. If drawdown is expected in the observation well(s) soon after testing begins and continuous water level recorders are not installed, an observer should be stationed at each observation well to record water levels during the first two to three hours of testing. Subsequently (after 3-4 hours), a single observer is usually able to record water levels in all wells because simultaneous measurements are unnecessary. If there are numerous observation wells, a pressure transducer data-logging system should be considered to improve data accuracy and help reduce manpower needs.

Time frame for measuring water levels

Table 1 shows the recommended maximum time intervals for recording water levels in the pumped well. NOTE: the times provided in Table 1 are only the maximum recommended time intervals--more frequent measurements may be taken if test conditions warrant. For instance, it is recommended that water level measurements be taken at least every 30 seconds for the first several minutes of the test. Frequent measurements during early times are needed to define the drawdown curve. The use of a logarithmic sampling interval on the data logger allows water levels to be collected about every 0.6 seconds initially and less frequently as the test progresses. Measurements in the observation well(s) should occur often enough and soon enough after testing begins to avoid missing the initial drawdown values. Actual timing will depend on the aquifer and well conditions that vary from test area to test area. Estimates for timing should be made during the planning stages of aquifer testing using estimated aquifer parameters based on the conceptual model of the site.

Table 1. Recommended Time Intervals for Aquifer Test Water Level Measurements

0 to 3 minutes	Every 30 seconds
3 to 15 minutes	Every minute
5 to 60 minutes	Every 5 minutes

60 to 120 minutes	Every 10 minutes
120 min. to 10 hours	Every 30 minutes
10 hours to shut down	Every hour

Monitoring discharge rate

During the initial hour of the aquifer test, well discharge in the pumping well should be monitored and recorded as frequently as practical. Ideally, the pretest discharge will equal zero. If it does not, the discharge should be measured for the first time within a minute or two after the pump is started. It is important when starting a test to bring the discharge up to the chosen rate as quickly as possible. The discharge rate should be checked at the same logarithmic intervals as the water level measurements shown in Table 1. <u>The discharge should</u> <u>never be allowed to vary more than plus or minus 5 percent</u>. The lower the discharge rate, the more important it is to minimize variations. The variation of discharge rate has a large effect on permeability estimates calculated using data collected during a test. The importance of controlling the discharge rate can be demonstrated using a sensitivity analysis of pumping test data. An analysis of this type indicates that a 10 percent variation in discharge can result in a 100 percent variation in the estimate of aquifer transmissivity. How frequently the discharge needs to be measured and adjusted for a test depends on the pump, well, aquifer, and power characteristics as well as test objectives. Output from electrically driven equipment requires less frequent adjustments than from all other pumping equipment. Engine-driven pumps generally require adjustments several times a day because of variation that occurs in the motor performance due to a number of factors, including air temperature effects.

It should be emphasized, however, that some random, short-term variations in discharge may be acceptable, if the average discharge does not vary by more than plus or minus 5 percent. A systematic or monotonic change in discharge (usually, a decrease in discharge with increasing time) is, however, unacceptable.

Length of test

The amount of time the aquifer should be pumped depends on the objectives of the test, the type of aquifer, location of suspected boundaries, the degree of accuracy needed to establish the storage coefficient and transmissivity, and the rate of pumping. The test should continue until the data are adequate to define the shape of the type curve sufficiently so that the parameters required are defined. This may require pumping for a significant period after the rate of water level change becomes small (so-called water level 'stabilization"). This is especially the case when the locations of boundaries or the effects of delayed drainage are of interest. Their influence may occur a few hours after pumping starts, or it may be days or weeks. Some aquifer tests may never achieve equilibrium, or exhibit boundary effects.

Although it is not necessary for the pumping to continue until equilibrium is approached, it is recommended that pumping be continued for as long as possible and at least for 24 hours. The costs of running the pump a few extra hours are low compared with the total costs of the test, and the improvement in additional information gained could be the difference between a conclusive and an inconclusive aquifer test. A portable PC with appropriate software may be used to provide type curves for observation wells based on the conceptual model for the aquifer and the analytical model for data analysis. This will allow for decisions on pumping duration to be based on comparing the empirical data with the model predicted data. Recovery measurements should be made for a similar period or until the projected pre-pumping water level trend has been attained.

Water disposal

As discussed previously, the water being pumped must be disposed of legally within applicable local, State, and Federal rules and regulations. This is especially true if the groundwater is contaminated or is of poor quality compared to that at the point of disposal. During the pumping test, the individuals carrying out the test should carry out water quality monitoring as required by the test plan and any necessary disposal permits. This monitoring should include periodic checks to assure that the water disposal procedures are following the test design and are not recharging the aquifer in a manner that would adversely affect the test results. The field notes for the test should document when and how monitoring was performed.

Water level recovery

Recovery measurements should be made in the same manner as the drawdown measurements. After pumping is terminated, recovery measurements should be taken at the same frequency as the drawdown measurements listed above in Table 1.

Record keeping

All data should be recorded on the forms prepared prior to testing. An accurate recording of the time, water level, and discharge measurements and comments during the test will prove valuable and necessary during the data analysis stage following the test.

Plotting data

During the test, a plot of drawdown versus time on semi-log paper should always be prepared and updated as new data is collected for each observation well. A plot of the data prepared during the actual test is essential for monitoring the status and effectiveness of the test. The plot of drawdown versus time will reveal the effects of boundaries or other hydraulic features if they are encountered during the test, and will indicate when enough data for a solution have been recorded. A semi-log or log-log mass plot of water level data from all observation wells should be prepared as time allows. Such a plot can be used to show when aquifer conditions are beginning to affect individual wells. More importantly, it enables the observer to identify erroneous data. This is especially important if transducers are being used for data collection. The utilization of a portable PC with a graphics package is an option for use in carrying out additional field manipulation of the data. It should not be a substitute for a manual plot of the data.

Precautions

(a) Care should be taken for all observers to use the same measuring point on the top of the well casing for each well. If it is necessary to change the measuring point during the test, the time at which the point was changed should be noted and the new measuring point described in detail including the elevation of the new point. Whenever possible, use the same water level indicating device at all times for a given well in order to avoid slight differences in measurements that are possible between different devices.

(b) Regardless of the prescribed time interval, the actual time of measurement should be recorded for all measurements. It is recognized that the measurements will not be taken at the exact time intervals suggested.

(c) If measurements in observation well(s) are taken by several individuals during the early stages of testing, synchronize stop watches to standardize testing time.

(d) It is important to remember to start all stopwatches at the time pumping is started (or stopped if performing a recovery test).

(e) Comments can be valuable in analyzing the data. It is important to note any problems, or situations that may alter the test data or the accuracy with which the observer is working. If several water level indicators are to be used, they should be compared before the start of the test to assure that constant readings can be made. If the water level indicator in use is changed, the change should be noted and the new indicator identified in the notes.

PUMPING TEST DATA REDUCTION AND PRESENTATION:

All forms required for recording the test data should be prepared prior to the start of the test and should be attached to a clipboard for ease of use in the field. It is an option to have a portable PC located on-site with appropriate spreadsheets and graphics package to allow for easier manipulation of the data during the test. The hard copy of the forms should be maintained for the files.

Tabular Data

All raw data in tabular form should be submitted along with the analysis and computations. The data should clearly indicate the well location(s), and date of test and type of test. All data corrections, for pre-pumping trends, barometric pressure fluctuations and other corrections should be given individually and clearly labeled. All graphs used for corrections should be referenced on the specific table. These graphs should be attached to the data package.

Graphs

All graphs or plots should be drafted carefully so that the individual points that reflect the measured data can be retrieved. Semi-logarithmic and logarithmic data plots should be on paper scaled appropriately for the anticipated length of the test and the anticipated drawdown. All X-Y coordinates shall be carefully labeled on each plot. All plots must include the well location, date of test, and an explanation of any points plotted or symbols used.

ANALYSIS OF TEST RESULTS:

Data analysis involves using the raw field data to calculate estimated values of hydraulic properties. If the design and field-observation phases of the aquifer test are conducted successfully, data analyses should be routine and successful. The method(s) of analysis utilized will depend, of course, on particular aquifer conditions in the area (known or assumed) and the parameters to be estimated.

Calculations

All calculations and data analyses must accompany the final report. All calculations should clearly show the data used for input, the equations used and the results achieved. Any assumptions made as part of the analysis should be noted in the calculation section. This is especially important if the data were corrected to account for barometric pressure changes, off-site pumping changes, or other activities that have affected the test. The calculations should reference the appropriate tables and graphs used for a particular calculation.

SUMMARY

An aquifer test should be extensively planned and properly designed for the most important hydrogeologic parameters to be determined. The test design should consist of a conceptual model of the site based on available geologic and hydrogeologic data and existing well information. The conceptual model should include the aquifer location and boundaries and pertinent (available) hydraulic data of the aquifer. Slug tests provide good, preliminary estimates of the aquifer properties and provide a starting point for the aquifer test design. An appropriate analytical method to determine the target parameters should also be chosen

The pumping facility design should include details of well construction, selection of a suitable pump, discharge control and water level measuring devices, and a reliable power source. The number and position of observation wells are to be chosen based on the study objectives. It is crucial that pumping well and the observation wells are properly developed before an aquifer test. Establish baseline water level trends by measuring water levels in the wells for at least five days before the test.

The procedure for a pumping test should include: a) measurement of initial water levels; b) periodic measurement of water levels according the recommended time intervals provided in Table 1 of this section, or a reasonably similar time intervals; c) maintenance of a constant discharge rate (within 5 percent) through periodic monitoring of discharge rate; and d) proper disposal of the pumped water. The aquifer test should continue until there is sufficient data to define the shape of the type curve so that the target parameters are determined with reasonable accuracy. The pumping should continue through the period of water level stabilization, longer but not necessarily until equilibrium, but at least for 24 hours. Recovery measurements should be made for a similar period or until the projected water level trend is attained. Field plotting of data using data analysis software is valuable for decision on pumping duration and determination of effectiveness of the test. All manual data measurements should be recorded on appropriate forms, while the transducer data should be stored on digital discs. Data analysis and interpretation should be based on appropriate spreadsheets and graphics.

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PUBLICATIONS

PURPOSE: The REP has a need to make the scientific community, regulatory agencies, and the general public aware of the work we are performing and to provide all interested parties with the data that we have collected on the groundwater systems in the North Carolina piedmont and mountain regions. It is important that all publications are checked for accuracy and that they are consistent with applicable policies established by NCDENR and the Division of Water Quality. There are four basic venues available for publication of REP documents and data; USGS reports, scientific journals, Groundwater circulars, and the worldwide web. The following sections describe the procedures that are to be employed for each of the four basic publications venues. Please note that all publications (except USGS reports) are required to comply with the policies and procedures established by the NCDENR Public Affairs Office. The NCDENR publication guidelines and procedures may be found at the following website: http://www.enr.state.nc.us/creativeservicesfolder/creativeservices/cs_pages/Guidelines%20PAGE%202.html If it is determined that your publication or website requires review by the NCDENR Public Affairs Office (see the guidelines on the website above), complete the following form and forward it to the NCDENR Public Affairs Office:
http://www.enr.state.nc.us/files/publicationreview.pdf

USGS Publications: The primary outlet for publication of data for REP studies is USGS publications. USGS personnel will be the primary authors of these publications. The regional REP hydrogeologist will be responsible for writing report sections on the regional and local geology, core boring logs, well construction logs, and any other report section that the REP hydrogeologist and the USGS personnel agree upon. USGS reports on REP studies may be in the form of Open-File Reports, Scientific Investigations Reports, Water-Resources Investigations Reports, and Water-Data Reports.

Scientific Journals (including abstracts for symposiums): Articles for publication in scientific or technical journals tend to be focused on a specific topic or finding and are generally peer-reviewed by other technical specialists prior to publication. Therefore, a broad review by other members of the REP is not necessary. However, individual authors may desire to have journal publications reviewed by other REP members in an effort to improve the quality of the publication prior to submittal. The REP regional office supervisor and the DWQ Public Information Officer (PIO) must review journal articles and abstracts prior to submittal for publication. Most journal articles will not require review by the NCDENR Public Affairs Office unless they contain policy or position statements.

The REP hydrogeologist will provide the reviewers with adequate time to review and comment on the proposed publication, typically at least three business days for abstracts and five business days for articles. The due date for the submission should be clearly stated to the reviewers by the REP hydrogeologist.

Groundwater Circulars: Groundwater Circulars are publications produced by the Aquifer Protection Section and generally are used to publicize the results of special studies and projects that APS personnel have worked on and are the primary investigators. The REP regional supervisor, each of the REP regional hydrogeologists, and the senior hydrogeologist in the APS central office will review Groundwater Circulars. After all of the internal reviews have been completed and any necessary changes have been made, the final document will be sent to the DWQ Public Information Officer for final review. After the final review has been completed and any revisions have been completed, the Groundwater Circular document will be sent to the APS senior hydrogeologist, who will assign a document number and contract any required publication and binding services. A copy of all new Groundwater Circulars will be sent to the NCDENR library and each regional office. The final Groundwater Circular will also be sent to the REP web site manager for publication on the REP website.

Web Pages: The REP will maintain a web page that will contain data and reports on all research station sites. The REP web page will be maintained by a web site manager will be maintained by APS Central Office staff authorized to manage the APS web pages. The REP web page will be stored on a server located in either the APS central office (Parker-Lincoln building) or on a DWQ server located in the Archdale building. Each REP site will have a separate web page or pages. Each REP site web page will contain data on the groundwater chemistry, water levels, core boring logs, well construction diagrams, geophysical surveys, and aquifer tests. Links to publications related to the REP sites will be shown on the site web pages and/or on the REP site main page.

_________ REGIONAL OFFICE
DIVISION OF WATER QUALITY
AQUIFER PROTECTION SECTION

{Date}

Resource Evaluation Program Study Proposal

TO: Ted Bush; Aquifer Protection Section Chief
Evan Kane; Groundwater Planning Unit Supervisor

THROUGH: {Regional Supervisor}

FROM: {REP Regional Hydrogeologist}

SUBJECT: {Hydrogeologic Research Station}
_____________, NC

{General Site Description}

{List Cooperators and Their Roles and Responsibilities}

{Brief Description (1 paragraph) of the Major Elements of the Research Station (# of borings, wells, surface water stations, etc.)}

GOALS

- {Bullet List of Investigation Goals and Relevance to Section's Priorities}

Attachments: RFI, completed access agreement, site maps

REQUEST FOR INVESTIGATION (RFI)

[1] Incident/Project name:	[2] Incident Number (if applicable):
[3] Region/County:	[4] Site Priority Ranking (from Central Office):
[5] Address/Location:	[6] USGS 7.5' Quadrangle Name and Site Latitude & Longitude:
[7] Regional Office Contact:	[8] Date submitted:

[9] RFI Planning Meeting(s)*: Prior to submittal of the RFI package, the Regional Office will organize a planning meeting. The meeting shall include appropriate Regional Office and Central Office personnel. The meeting format will be flexible and may be held via telecommunication, on-site or in-office. The broad purpose of the meeting is the discussion of the Project Objectives and Scope of Work. Typical discussion topics may include the following:

- division of responsibilities
- existing publications
- site location and information
- topography and inferred hydrogeologic characteristics
- existing site conditions that may affect contaminant transport, migration & fate
- potential or suspected sources of contamination and type(s) of contamination
- other topics as deemed necessary to develop the initial Site Conceptual Model, Project Objectives and the Scope of Work

[10] What event(s) or groundwater issue(s) necessitated this Request for Investigation?

REQUEST FOR INVESTIGATION (RFI)

11 How will implementation of the proposed Investigation help resolve the issue(s) listed in #10 above?

12 Attach a Site Location Map (combine with other map(s) if appropriate).

13 DRILLING INFORMATION

13a Proposed drilling method(s):	13b Estimated depth to bedrock or first confining unit:
13c Proposed decontamination location:	13d Estimated depth to groundwater:
13e Proposed temporary storage location for drilling equipment:	
13f Proposed disposal facility for contaminated water and soils:	13g Source of clean drilling/decon. water*: *Up to 2,000 gallons/day.

13h Proposed Well Number	13i Proposed Depth	13j Proposed Diameter	13k Construction and Completion

13l Attach a map showing proposed drilling locations. (combine with other map(s) where appropriate)

14 PROPERTY OWNERS

14a Name:	14b Address:	14c Phone Number:	14d LUA?

14e Attach a map identifying property owners. (combine with other map(s) where appropriate)

REQUEST FOR INVESTIGATION

15 HEALTH AND SAFETY INFORMATION (please provide only site-specific information)

15a Chemical exposure potential (on-site chemical storage, drums, pesticides, fuel tanks, etc.):
15b Type of Contamination Expected (list substances or compounds, if known):
15c Site Specific Issues or Concerns (access, noise, general hazards, utilities, traffic, etc.):
15d Biological exposure potential (on-site poisonous plants and animals, other wild animals, etc.):
15e Required safety equipment: ☐ Hard hat ☐ Gloves _____________ (type) ☐ Steel toe boots ☐ PID/OVA ☐ Hearing Protection ☐ Other (specify)
15f Physical/electrical/radiological exposure potential (on-site power lines, open ditches or trenches, water bodies, heavy traffic, farm machinery, temperature extremes, etc.):
15g Name and address of nearest hospital:
15h Emergency facility phone number: 911 service available: yes no
15i Attach a map indicating location and route to nearest hospital (combine with other map(s) where appropriate)

REQUEST FOR INVESTIGATION

15j **Health and Safety Plan Site Meeting Sign-Off Sheet.** **"By my signature on this form, I hereby certify that I have read and understand the information contained in the "Health and Safety Information" section in this document."**	
Signature	**Date**

REQUEST FOR INVESTIGATION (RFI)

Check List for Request for Investigation Submission:
Verify that the RFI package contains all of the following applicable items. Incomplete submittals will cause delays in processing of RFI package.

Forms:

☐ Transmittal memo from/through Regional Supervisor or Agency requesting the investigation to Central Office

☐ Completed Request for Investigation form and checklist

☐ Pollution Incident Reporting Form (PIRF)

☐ Site Health and Safety Planning Form

☐ Source for Drilling Water Identified and Tested

☐ Signed Land Use Agreements (LUA) for all properties to be included in the investigation

☐ Documentation of RFI Planning Meeting (brief summary, time, date, personnel present, etc.)

Division of Responsibility:

Develop Scope of Work	☐ Region	☐ Central
Secure Land Use Agreements	☐ Region	☐ Central
Coordinate with Driller	☐ Region	☐ Central
Perform Preliminary Site Visits	☐ Region	☐ Central
GPS and/or Survey	☐ Region	☐ Central
Evaluate Data	☐ Region	☐ Central
Perform Draft Project Report	☐ Region	☐ Central
Review Project Report	☐ Region	☐ Central
Finalize Project Report	☐ Region	☐ Central

Maps*:

☐ Local site/area map showing affected properties with owner's name(s), location of existing well(s), and proposed drilling locations (county tax map or an aerial photo are preferred, although a neatly hand drawn map is acceptable).

☐ Include written directions to site from a nearby well known landmark or primary road intersection.

☐ Regional map showing directions to site from main highway or other major artery (please use one of the following: USGS 7.5' quad, DOT county road map, NC Atlas & Gazetteer 1:150,000 scale map)

☐ Directions, phone number, and location map for the nearest hospital
* Combine maps where possible and appropriate

Supporting Information (if Applicable):

☐ Laboratory report(s) of previous sampling and testing

☐ Well construction records of existing monitoring wells

☐ Well construction data for affected private supply wells (type, installation date, total depth, casing depth, screened interval(s), well logs, etc.)

☐ References to existing investigations, reports, etc,

☐ Other supporting information available in the Regional Office but not included in this RFI package (please list): ____

Signature of person verifying review and completeness of attached RFI package:

Signature____Date________________

North Carolina Groundwater Section/U.S. Geological Survey
Resource Evaluation Program

Water Level Measurements Form
(Electronic Water Level Meter)

Project Name: ____________________

Location: ____________________

Well Number or Name: ____________________

MP Description: ____________________

MP Correction (+/-): ____________________

Date	Time	Depth to Water From MP, in Ft.	Depth to Water Corrected for LSD	Remarks (e.g., technician, weather, well condition)

NOTES:

Project Name:

Location:

Well Number or Name:

MP Description:

MP Correction (+/-):

Date	Time	MP Hold, in Ft.	Wetted Chalk Mark, in Ft.	Depth to Water From MP, in Ft.	Depth to Water Corrected for LSD	Remarks (e.g., technician, weather, well condition)

NOTES:

DWQ-GW SECTION PIEDMONT/MOUNTAINS PROJECT

Chemistry Laboratory Report / Ground Water Quality

Lab Number :
Date Received :
Time Received :
Received By :

Released By :
Date reported :

PROJECT:
COUNTY:

REPORT TO : Regional Office
COLLECTOR(S) :
DATE:
TIME:

Sample ID:
Sample Location:
Sample Depth:
Sample Type:
Sample Method:

LABORATORY ANALYSIS

	BOD 310	mg/L		Diss. Solids 70300	mg/L		Ag-Silver 46566	ug/L		Organochlorine Pesticides
	COD High 340	mg/L		Fluoride 951	mg/L		Al-Aluminum 46557	ug/L		Organophosphorus Pesticides
	COD Low 335	mg/L		Hardness: total 900	mg/L		As-Arsenic 46551	ug/L		Nitrogen Pesticides
	Coliform: MF Fecal 31616	/100ml		Hardness: (non-carb) 902	mg/L		Ba-Barium 46558	ug/L		
	Coliform: MF Total 31504	/100ml		Phenols 32730	ug/L		Ca-Calcium 46552	mg/L		Acid Herbicides
	TOC	mg/l		Specific Cond. 95	umhos/cm2		Cd-Cadium 46559	ug/L		
	Turbitity	NTU		Sulfate	mg/L		Cr-Chromium 46560	ug/L		Semivolatiles
	Residue., Suspended 530	mg/L		Sulfide 745	mg/L		Cu- Copper 1042	ug/L		TPH-Diesel Range
	Total Suspended solids	mg/L		MBAS	mg/L		Fe- Iron 1045	ug/L		
				Oil and Grease	mg/L		Hg- Mercury 71900	ug/L		Volatile Organics (VOA bottle)
	pH	units		Silica	mg/L		K-Potassium 46555	mg/L		
	Alkalinity to pH 4.5	mg/L		Boron			Mg- Magnesium 927	mg/L		TPH-Gasoline Range
	Alkalinity to pH 8.3	mg/L		Formaldehyde	mg/L		Mn-Manganese 1055	ug/L		TPH-BTEX Gasoline Range
	Carbonate	mg/L		NH3 as N 610	mg/L		Na- Sodium 929	mg/L		
	Bicarbonate	mg/L		TKN as N 625	mg/L		Ni-Nickel	ug/L		
	Carbon dioxide	mg/L		NO2 +NO3 as n 630	mg/L		Pb-Lead 46564	ug/L		
	Chloride	mg/L		P: Total as P 665	mg/L		Se-Selenium	ug/L		
	Chromium: Hex 1032	ug/L		PO4	mg/L		Zn_Zinc 46567	ug/L		
	Color: True 80	c.u.								
	Cyanide 720	mg/L								

COMMENTS :

AQUIFER PUMPING TEST FIELD DATA COLLECTION FORM

Site ______________________________

Well ID ______________

Pumping Well ID ______________________

Distance to Pumping Well ______________________ feet

Recorded By ______________________

Measuring Point ______________________

Date	Time	Depth to Water	Pumping Rate (gpm)	Comments:

AQUIFER PUMPING TEST FIELD DATA COLLECTION FORM

Site ____

Well ID ________

Pumping Well ID ______________________________

Distance to Pumping Well ______________________________ feet

Recorded By ______________________________

Measuring Point ______________________________

Date	Time	Depth to Water	Pumping Rate (gpm)	Comments:

Project Name:

Date(s) of Survey:

Point Name	Latitude	Longitude	Latdecimal	Londecimal	Elevation

NOTES:

Project Name:

Date(s) of Survey:

Point Name	(+) Backsight (BS)	(-) Foresight (FS)	Height of Instrument (HI)	Elevation

NOTES:

Page __ of___

SLUG TEST FIELD DATA COLLECTION FORM

Site ____

Well ID __________

Recorded By __________________________

Measuring Point __________________________

Slug Type __________________________

Date	Time	Depth to Water	Comments: