USGS National Groundwater Monitoring Network
Final Technical Report
Mississippi

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Overview

The Office of Land and Water Resources (OLWR), a division of the Mississippi Department of Environmental Quality (MDEQ), manages and maintains a network of observation wells across the state of Mississippi. Static water levels are recorded for 174 wells across 67 of Mississippi's 82 counties. The observation network was originally managed by the United States Geological Survey (USGS) and was picked up by the OLWR in 1993. Because of this, the network has water level data dating back to the 1930s.

All wells in the network are part of the Coastal Plains Aquifer System, as classified by the USGS. This aquifer system is further divided into five smaller systems. Three of the five are found in Mississippi. The subdivisions found in Mississippi are the Coastal Lowlands Aquifer System, the Mississippi Embayment Aquifer System, and the Southeastern Coastal Plain Aquifer System. The OLWR's current monitoring network measures various smaller aquifers within these aquifer systems.

The OLWR applied for funding to become a data provider to the National Groundwater Monitoring Network (NGWMN) in 2015. The OLWR submitted a Scope of Work to the USGS outlining steps the OLWR would take to integrate its current monitoring well network into the NGWMN database. In the Scope of Work document, the OLWR divided this process into seven tasks with a detailed description of how each task would be executed.

This document is being submitted to the USGS to explain in detail the processes and techniques used to complete the seven objectives listed in the Scope of Work document. For each task the OLWR will provide a general overview of steps taken along with problems encountered and possible solutions. This document will also present objectives for future funding years.

The Scope of Work document originally submitted to the USGS contained estimates of time to be spent on each task. The OLWR has updated those estimates to be more in line with actual time spent on each task.

Task	Original Allocation of Time	Final Allocation of Time
1: Evaluate monitoring sites	**25%**	**25%**
2: Classify selected sites	**25%**	**20%**
3: Populate Well Registry	**10%**	**30%**
4: Set up Web Services	**10%**	**5%**
5: Map fields to portal	**10%**	**10%**
6: Document data-collection	**5%**	**5%**
7: Produce Summary Document	**15%**	**5%**

Task 1: Evaluate monitoring sites and select sites for Network

The initial Scope of Work submitted by the OLWR included 193 existing monitoring wells. Most wells in the network are non-pumping wells where static water levels can be recorded. In the OLWR's Scope of Work document, parameters were set forth to determine ideal candidate sites. These sites needed to meet criteria set forth by the NGWMN and produce quality reproducible water-level measurements. It is also important that the wells be easily accessible and well maintained. Of the original 193 wells, it was determined that 174 were viable candidates for the network.

The first step to evaluate the OLWR's monitoring sites required field verification that the wells fit all parameters set forth in the Scope of Work document. Accessibility is an important aspect of field verification. Landowner changes presented problems for some wells. Due to staffing constraints, some wells had not been measured in several years. Overgrown vegetation, flooded or washed out access roads, and storm damage (a tornado in Smithville for example) presented challenges as well. Some wells were removed from the network for these reasons.

The next step required analysis of historical measurement records to determine if water level measurements were consistent. Variable water levels can be caused by a variety of factors, including degradation of the well, such as is seen with casing shifts or collapse. Same day fluctuations can also be indicative of influence from nearby wells. This analysis allowed OLWR staff to determine historical water level trends. Sudden changes that were not consistent with historical trends were investigated on a well by well basis. This was also a very important tool for dividing the wells into subnetworks.

Task 2: Classify selected sites into subnetworks and monitoring categories

OLWR staff considered several factors to determine subnetworks and monitoring categories. First, wells were divided into subnetworks. The OLWR used the geodatabase ArcGIS to plot wells over population density maps. OLWR staff then generated a GIS layer of total permitted volume by county. After comparing these values, employees with experience measuring this set of wells were consulted to expand on areas where there might be suspected changes in water levels.

Background Subnetwork: The "Background" subnetwork consists of wells that are in areas with the lowest population density and lowest permitted volumes. The OLWR used existing ArcGIS data layers to narrow the list for the "Background" subnetwork. Further, the historical water level data was analyzed to verify that permitted volumes were consistent with

historical trends. Wells outside of the area of influence of pumping wells were chosen so that ambient water levels would be represented. Generally, these wells are in rural areas with very little industry.

Suspected Changes Subnetwork: The "Suspected Changes" subnetwork consists of wells in areas that either have a high population density or an uncharacteristically high permitted volume (usually due to an increased industrial presence). The OLWR staff also consulted Geologists and Engineers within the department for areas that may be experiencing changes in water withdrawal volumes that were not consistent with the historical record. These wells are generally in areas with new growth or decline. These could also be in areas where aquifers are under stress.

Documented Changes Subnetwork: The "Documented Changes" subnetwork was not determined using the same methods as the "Background" or "Suspected Changes" subnetwork. The wells in this group were decided based solely on existing water level data.

The USGS suggests a minimum of quarterly monitoring for monitoring wells to be considered "Trend" Wells. Due to staffing constraints, quarterly monitoring of sites is not possible at this time. Thus, all wells in the current network will be considered "Surveillance" wells. Efforts have been made to prioritize wells to be considered for increased monitoring so that these wells can be recategorized as "Trend" wells at a later date. The OLWR is currently evaluating 103 wells in the existing network for suitability.

Task 3: Populate NGWMN Well Registry

The first step to populate the Well Registry required OLWR staff to compile all known information for each well. The OLWR used the Well Registry Tip Sheets to determine what information would be needed. This information includes, but is not limited to: locational information, lithology and well construction information, historical water level measurements, accuracy of information, and units of measure. All information was pulled from either a USGS well schedule, an electric log, or a driller's log. Not all fields have been populated due to missing information. For these fields the term UNKNOWN has been entered. It is the intention of OLWR to use future funding from the USGS to fill in these data gaps.

Once the fields were populated they were reviewed for sensitive information such as personally identifying landowner information. This information was then replaced with new but equivalent information. For example: if an individual's name had previously been used to identify a well, that information was exchanged for other well-specific information (such as Plant Well #2).

Task 4: Set up web services to allow connection to agency databases

Originally, all web services were populated to one master spreadsheet. This master spreadsheet was divided into three separate files for each web service, titled: Lithology, Water Level, and Well Construction. Pertinent information was then added according to the USGS tip sheets. The lithology web service currently only specifies the water-bearing strata being measured. The well construction web service currently represents all well casings as one continuous unit of uniform size. The OLWR is working to collect in house records to fill in this information. It may be necessary to run new geophysical logs on some wells to address data gaps.

A Windows 2012 Server running a dedicated service has been utilized to meet obligations of the NGWMN grant. As designed, a map service created by an ArcGIS Server Manager is used to connect to the NGWMN data portal. This REST service is configured for web mapping and web feature services. The operations made available by the service are map-query and tabular data access. Shapefiles, added to a geodatabase (.gdb), are used in creating a map document (.mxd) published as a map service. Once published, a REST service exists through which the data can be accessed and queried. The OLWR REST service has been tested with the USGS for preliminary connectivity and data transfer. The OLWR is still working with USGS staff to bring web services fully online.

Task 5: Map fields in web services to NGWMN Data Portal

The process of mapping fields from the web services to the Data Portal began in December of 2016. OLWR staff worked with USGS staff to determine and address problems during this process. Most of the problems encountered were formatting issues. For example, use of the IS8601 format for time stamps. There was also a problem with the representation of significant figures. Overall, the process took much less time than expected.

Task 6: Document data-collection and data-management procedures

The OLWR has established guidelines for the manual measurement of water levels. Those guidelines can be found in Appendix A. There are also established guidelines for data entry within the OLWR database. These have not been included in the Final Report because they contain sensitive information (including screengrabs) of the database. They are available at the request of the USGS.

Upon reviewing the Framework document for the NGWMN, the OLWR noticed that some changes need to be made to our field practices. The most important change needed is the development of a quality-assurance plan. MDEQ hopes to address this issue in future

funding years. Other concerns include equipment decontamination, measurement accuracy, and additional site notations while in the field.

Task 7: Produce Summary Document

This document shall serve as the Final Technical Report requested by the USGS. This document was formatted to mimic the original request for funding to streamline the review. It includes a detailed overview of activities proposed and achieved throughout the project. As requested, the OLWR has included a copy of the Standard Operating Procedures (SOP's) for water level measurement and data entry. This document can be found in Appendix A.

Overall, the experience of becoming a data provider has been a positive one. The funding provided has allowed for dedicated staff time to assess the OLWR's current network, evaluate training methods, and consider a broader scope for the agency's current monitoring activities. It has also helped staff identify gaps in information and address deficiencies in data collection and management protocols. One of the biggest advantages of participating in the program has been the ability to meet with other professionals in the field of groundwater monitoring to work on a common goal. Working as a collective group to determine best practices and to address shortfalls of current monitoring programs has allowed OLWR staff to work with greater efficiency to address information needs within our own agency.

APPENDIX A

OLWR's Standard Operating Procedures for Water Level Measurement and Data Entry

DEFINITIONS

Observation Well—a water well used to gain information about current groundwater levels. These wells can be active or inactive, and may look very different. Some observation wells will have pumps on them, but some are simply a hole in the ground with a cover.

Measuring Point (MP)– Most observation wells have been measured repeatedly. Try to use the same MP (top of open hole, edge of vent pipe, lowest crack in casing, etc). Measure the height of the MP (in tenths of a foot) from average ground height. Take into account concrete slabs or other man-made change to elevation. Record the MP on the field sheet (description and height). If the same MP is used each time, the height should not change unless the land or the well itself is altered. If land elevation has changed, then the database elevation will need to be adjusted. Unless using a different MP, avoid changing MP number even if you think your measurement is more accurate by 2 hundredths of a foot. An unnecessary change in MP will make it appear that the water level has changed even if it has not.

Steel Tape—a surveyor's tool similar to a tape measure, made of steel, that is marked in increments of .1 foot used to take water level measurements. We have a 100', 300', and 500' version.

Electric Tape—a water level measurement device which has a steel probe that senses contact with water

Chalk—a piece of chalk used to mark a steel tape in order to show where the steel tape makes contact with water.

Field Sheet—a form printed from a database with information about the well including well number, location, owner, pictures, and previous water level measurements.

BEFORE YOU GO INTO THE FIELD

1. Print out field sheets for all of the wells that you intend to measure and gather supplies, including regional notebooks.
2. Sign out a vehicle and check to make sure that it has a full tank of gas, a Fuelman card, and a completed monthly checklist. If the list has not been completed, do so before you return the vehicle. It is also policy to return the vehicle with a full tank of gas and thoroughly cleaned out (including a car wash if the vehicle is muddy). You will also need to know your Fuelman pin in

order to purchase gas. Fuelman has an app and a website with lists of their participating stations, but locations change frequently. Always keep an eye on your gas tank.

3. Alert your supervisor that you will be out of the office and sign out on the board. It isn't always possible to pre-plan direct routes, but it's best to let your supervisor know where you will be. It is also advisable to set up an out of office message for your voicemail and email. It is preferable to have at least two people performing water level measurements together, with at least one person experienced at taking water level measurements.
4. If you are staying overnight, be sure to make hotel reservations. Some hotels provide direct bill to MDEQ. The direct bill list changes regularly. You should always check that a hotel is still on the list when making a reservation. Otherwise, you will have to pay out of pocket.
5. Be sure to check the weather and wear appropriate clothing. Field boots and pants are your best bet. These older wells tend to have a lot of oil, so wear something you don't mind getting dirty.
6. Once field work is complete be sure to bring all supplies back to their storage closet and to promptly return the vehicle.

OBSERVATION WELL SUPPLY CHECKLIST

- Regional Notebooks
- Field Sheets
- Atlas/Maps
- Contact Lists
- Steel Tape (100', 300', and 500')
- Electric Tape
- Chalk
- Measuring Tape
- Keys
- Gloves
- Shop Towels/Wipes
- Tool boxes
- WD40
- Flowing Well Supplies
- Camera/charger
- GPS/charger
- State Phone/charger
- Extra batteries
- Bug Spray and Wasp Spray
- Machete
- Kaiser Blade
- Loppers
- First Aid Kit (including poison ivy treatment)
- Trash can

Well Measurement Protocol

Important note: When measuring public supply or other *active* wells, permission should be obtained from the owner, operator, or another responsible party. This is especially important in light of current heightened concerns about water supply security.

1. Check the well schedule, field sheet (with picture), or gps to make sure you are at the correct well. Check the health department tag on the well, but do not consider it the definitive check for whether you are at the correct well.

2. Note any significant changes to the site with special attention to any changes in elevation (due to earth moving, etc.)

3. Take a GPS reading at every well, even if it has already been done before. This takes little time and provides us with invaluable assistance if there is any question about which well has been measured.

4. Take a picture of the well if one is not available on the field sheet. Also, take a picture of each well if the well or surrounding well yard appears to have changed since that last picture was taken.

5. If the pump is running on arrival, turn it off and let the well recover a minimum of 15 minutes. If the well is not running, check to see if the pump is cold; if it is not, then allow well to recover as above. **For submersible pumps, make sure the well is off and the electricity running to the pump is off!** If this is not possible, do NOT measure a submersible pump. It has power lines running directly to it. Ask that any nearby (within sight) pumping wells also be turned off. If they cannot be turned off, please note this and give an estimate of distance between the wells.

6. Get a minimum of two water levels within 0.2 feet of each other with sufficient time (i.e. 4-5 minutes) between them to make sure the well has recovered. Please note how long the pump was off for each level.

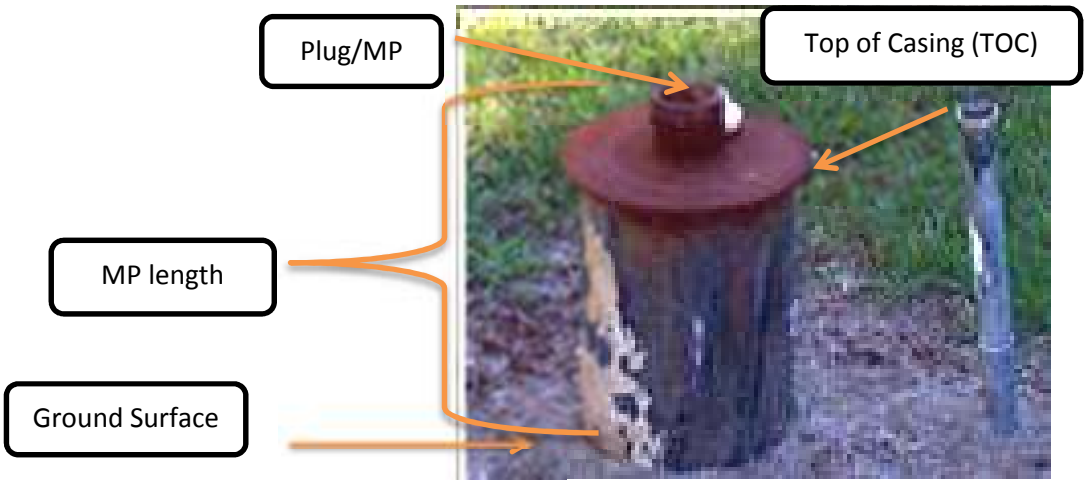
7. Record measuring point, height of measuring point, any difficulties in measuring, and quality of measurements. Was the cut good, clean and clear? Oil/water cut? Good weight? Any places where tape tends to hang?

8. If you were accompanied by someone with the system, make a note of it. If not, return the pump to the setting you found it on (usually 'auto') and re-lock the gate if you unlocked it or were asked to re-lock it after obtaining the measurements. If anything is being left different than it was at arrival, make a note of it. It is a good idea to note the time of departure from each well site in case any problems arise. If requested, and they usually will, notify the well operator that well(s) have been measured and well yards are back to same conditions as on arrival.

Establishing a Measuring Point (adapted from USGS)

In order to establish a measuring point you must locate an opening on the well that has direct access to the well casing. You must also establish the surface elevation and then measure the distance from the ground surface to the Measuring Point (MP). Generally, this is done in the field with a handheld GPS unit and a measuring tape.

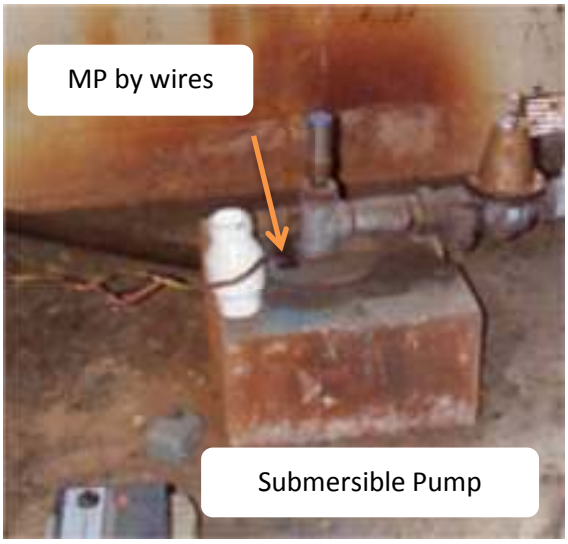
For many wells in our network, the pumps have been removed. For these wells, one should simply measure the distance from the ground surface to the lip of the casing.



For wells with a pump still attached, most wells on the observation well list will fall into one of three categories: a turbine pump, a submersible pump, or a flowing well.

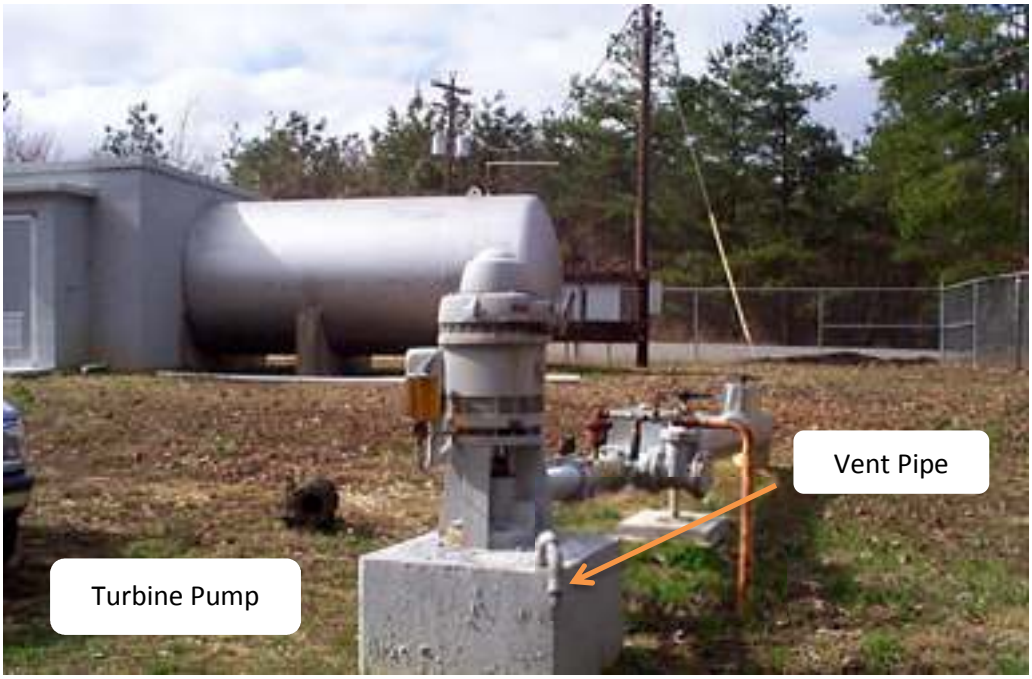
SUBMERSIBLE PUMP WELLS

A submersible well has a pump not visible above ground. The plumbing, however, will be visible on the ground surface. Measurements are usually taken from the vent pipe or by the wires supplying power to the pump.



TURBINE PUMP WELLS

A turbine pump is visible above ground. These wells are generally easily spotted on an aerial and can have multiple entry points. Usually the measurement is taken from the vent pipe, but can also be taken from a plug on the base plate or a hole in the casing.



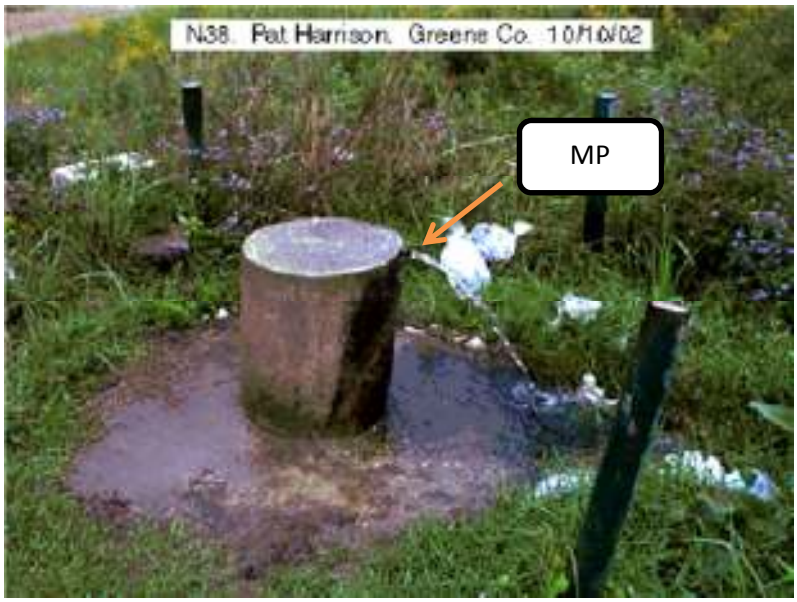
When establishing an MP for a well, one should consider a stable (preferably flat) location that is as permanent as possible and can be clearly defined and easily located. It should be a place where access to the casing is most convenient. When possible, the MP should be marked with a reference mark. The MP should be measured to the nearest 0.01ft for our purposes.

Once an MP has been designated, an elevation should be determined and a measurement should be taken to establish the amount of correction needed. When able, the MP should be measured vertically

from the ground. If the tape must make a path that is not verticle (such as through a discharge pipe) the entire measurement path of the tape should be included in the MP adjustment. To ensure that the same MP is used, it is best to document with a picture as well.

FLOWING WELLS

Flowing wells occur when a well site has a pressure head that is above ground surface. The MP should be established at the point where water exits, or flows, from the pipe.



USGS WELLS

The USGS has an established well network, and allows MDEQ to use these wells as observation wells. The wells are equipped with a box on top of the casing to protect the well. If measuring a USGS well, you will need to make sure that you have a key to unlock the box.

MEASURING WITH STEEL TAPE

We have steel surveyor tapes in lengths of 100, 300 and 500 feet. Choose a tape based on the most recent water level or a best guess of water level. Water levels drop an average of 1 – 2 feet per year. If the last water level was 25 feet to water and that was 5 years ago, you should lower at least 35 feet of tape into the well.

Chalking – Steel tape must be marked with blue carpenter's chalk to be able to see when the tape enters water. We typically chalk the lower 30 feet of tape. You can repeat measurements without re-chalking if you increase the length of tape lowered into the casing. Oil or high condensation may force you to clean and re-chalk the tape between each measurement.

Lowering the tape – Feed the tip of the tape through the chosen MP opening. It may take a few attempts and wiggling to get past bends in vent pipe necks or unevenness in casing. Once a fair bit of tape has entered the well casing, you'll begin to feel weight or a tug. You can slowly let the tape continue to feed itself, keeping your fingers loosely around it. When approaching target depth, slow the tape advance and stop about five feet above target. Hold the target number at your thumb and lower it to the edge of the MP. Back away from the well and begin reeling the tape up. You'll see the blue chalk at 30'. When you see the color change that indicates wet tape, measure the distance above the next lower foot marker with the engineering measuring tape (feet measured in tenths). Subtract the number of feet wet (cut) from the length lowered into the well (held). Subtract the MP from this. After recording this information, continue reeling the tape to make sure that this is the actual cut.

Repeat the measurement. The water level should be within 2 tenths of a foot from the first measurement. If not, repeat until you have two matching numbers.

The tape is not permanently attached to the reel. If a tape gets completely out of your control, the entire tape may fly off the reel and drop into the casing. If you must, drop the reel and step on it to stop the tape.

**Measuring with the 500' tape: Avoid using this tape unless depth absolutely requires it. The tape is thinner, narrower, and quite brittle compared to the 300' tape and hangs significantly more. It's also much more expensive to replace.

MEASURING WITH ELECTRIC TAPE

Before each trip, check the batteries in the tape. Turn the dial to 'on' and push the red button. If it doesn't beep, replace the batteries. At the well site, turn the dial to 'on' and recheck the battery. Leave the tape on and set to mid-sensitivity. If set too high, the tape will beep for condensation. There is a plastic screw on the side which works as a brake. Loosen the screw enough to easily pull the tape. Avoid using e-tape in situations where the path isn't completely clear to water level. The probe could be snagged and pulled off. Never use in a well which still has a submersible pump and preferably not with any pump. Also, don't use in an oily well. Oil depresses the natural water level.

Lower the probe until it beeps. Raise and lower a couple of times to confirm the probe isn't stuck in condensation. Record the water level from the chosen MP (lip of casing).

It's not necessary to re-measure with e-tape. One measurement is sufficient.

MEASURING FLOWING WELLS

Before attempting a measurement, verify that well has been shut off. A flowing well requires the use of a pressure gauge in place of a steel tape or electric tape. The choice of pressure gauge range should be based on the last known measurement of head. Since connections vary, there is no standard process for connecting a pressure gauge to a well. Generally, you should choose an appropriate fitting to connect the gauge hose to the well. Be sure that the valve of the gauge is open before you attach it to the well. Once connected, close valve SLOWLY (this is to prevent what is known as water hammer, which can permanently damage the well). Place the gauge on the ground and wait for pressure to normalize before recording the measurement. Once finished SLOWLY reopen the valve and remove gauge and equipment.

HINTS AND POINTERS

Access – Most of the observation wells are no longer in use. For the few which are still in use, ask the landowner/operator if they will allow the pump to be turned off for a measurement. It's a good idea to double check that power is off (even for unused wells). When finished, turn power back on or ask operator to do so.

There will be a vent pipe, plug, gap next to wires (submersible pump) or sometimes just an open casing. If the well has previously been measured, the field sheet should have notes about the measuring point. The access and type of pump (or lack thereof) will determine which type of tape can be used. Electric tape should not be used in a well that still has a pump. It should also not be used in an oily well. (Oil will likely be present if a turbine pump was used).

Remove vent cap, plug or other covering. If you hear a hiss or feel air coming from under a cap, stop turning the cap. Changes in barometric pressure can create a vacuum or high pressure in the well. Caps have been known to fly off wells with enough force to injure a person in the path. Let the air escape slowly until the hissing has stopped. Resume turning the cap.

Condensation – early morning or high humidity days will create condensation that collects on the inside of casings. This will sometimes cause false positives if an electric tape hits the side of the casing. It can also make a steel tape cling to the casing. But the most common problem is that it will wet the chalk on steel tape before it reaches water. Try to avoid measurements with condensation. If it's unavoidable, try to minimize the number of times the tape touches the casing. Change positions, don't bounce the tape unnecessarily, chalk heavily, or take more levels when in doubt.

Wasps/insects/snakes/chickens – Wells may be covered with 55-gallon drums, buckets, or metal plates. The USGS made protective boxes with hinged doors to cover their observation wells. Use caution when opening doors or removing covers. At least one well was known to house a black widow, and one USGS box was home to a chicken.

POST FIELD WORK

We will have multiple people taking water level measurements, and communication between coworkers will be important. It is also important that everyone has access to the supplies needed for water level

measurements. When you return from the field, promptly return all items on the checklist to their designated area. If you have reserved a vehicle for an extended period and have chosen to keep the equipment in said vehicle, be sure to let someone know.

DATA ENTRY

Water level measurement data must be entered in both Access and WRIMS for the time being. Preferably, there will be one person in charge of data entry for all wells to limit confusion. Be sure to return observation well notebooks and field sheets to the person designated. If you perform water level measurements in the field, but are not the designated person to enter that data into the computer, it is your responsibility to turn over that information in a timely manner to the person responsible for entering data. If changes need to be made to the master list of observation wells, please be sure to make note of changes that need to be made. This could include, but is not limited to:

1. Change in owner/contact information.
2. Corrected location information, including whether the well is still there and accessible.
3. Changes in Measuring Point (MP) or special notes to assist the next water level measurement.

In addition to Water Level information, we also track observation wells in a separate database. We have a master list of all current wells that needs to be kept up to date.

DELETING OBSERVATION WELLS

Each year, we find wells destroyed or they become unmeasurable. There are many reasons for dropping a well from the network. Many reasons, such as a hostile landowner or an unsafe measuring environment are simply not negotiable. No water level measurement is worth endangering your life.

But sometimes a well may seem unmeasurable and it may simply be a matter of technique or weather. Before removing it from the network, be certain it is really beyond hope. Have at least two different people try to measure it. Try in different times of the day or in different weather. For example, wells that are prone to condensation are more difficult to measure in the summer.

If the tape hangs at a certain point above water level, try a different tape. We have 300’ tapes with and without a loop at the end. We also have a 500’ which is thinner than the 300’. It may be able to get through tighter places.

If the water level has raised or dropped at a rate dissimilar to other wells in the same aquifer, try slugging the well. Carry water with you to pour into the well (if you have access). The water level should temporarily rise and then start dropping back to the pre-slugged level. If not, the casing is probably clogged.

MP is blocked. Look for an alternate entrance. Wiggle wires, look for gaps around casing.

If you must give up and remove the well from the network, record the date it was removed and the reason for removing it.