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DELAWARE 2018-2020 NGWMN PARTICIPATION REPORT

Delaware Geological Survey (DGS) staff have completed the tasks necessary for Delaware's participation in the National Ground Water Monitoring Network (NGWMN) under the terms of the competitive program and our agreement #G18AC00068 with the U.S. Geological Survey (USGS). This work was dominated by evaluation of new wells for addition to the water-level and water-quality networks, maintenance of the IT and web services infrastructure, maintenance of data provided to the NGWMN portal, and included minor components consisting of well maintenance and filling data gaps. This final report documents the work. Figure 1 shows locations of Delaware sites in the NGWMN as of the date of this report. Readers are referred to the NGWMN portal for the latest data and metadata on DGS sites in NGWMN.

Objective 1: Expand Number of Sites

Site and Well Selection Methods

DGS selected new wells (Fig. 1, Table 1) for the water-level and water-quality networks from monitoring infrastructure installed at multiple sites between 2017 and 2018 as part of a State of Delaware funded infrastructure project. This same project funded level and quality data-collection efforts that are filling the baseline data needs of these wells. Selection criteria followed framework (SOGW, 2013) and USGS tip sheet guidance.

All of the wells evaluated in this project are in the North Atlantic Coastal Plain (NACP) principle aquifer (Trapp and Horn, 1997). The NACP principal aquifer occurs within a southeasterly dipping and thickening wedge of unconsolidated to weakly consolidated sediments (example shown in Fig. 1). In Delaware, the NACP includes four Major Aquifers – the Surficial (SAS), Chesapeake (CAS), Castle Hayne-Aquia (CHS), and Potomac-Raritan-Magothy (PRM) aquifer systems. The major aquifers host local aquifers, for example, the Piney Point (CHS), Cheswold, Federalsburg, Frederica, Milford (CAS), and Columbia (SAS). Wells proposed for evaluation span hydrologic settings that include unconfined to confined, updip to downdip, layered heterogeneous systems, and human impacted to background portions of major aquifers. New wells evaluated in this project were installed in multiple local aquifers at each site to generate data on vertical head differences between aquifers and on vertical differences in geochemistry that were expected from different flow paths and time-of-travel in the aquifers.

Decisions to add a particular well to the NGWMN or not were supported by evaluation of spatial data gaps within local aquifers, visual examination of hydrographs, evaluation of hydraulic testing data, consideration of in-state pumping and contamination stresses, and assessment of vertical head and water quality differences in our layered heterogeneous system. For example, for cases where NGWMN had spatial gaps in well distribution, and new wells were monitoring multiple local aquifers in a layered heterogeneous system, we added only the wells that had vertical head differences that were greater than 0.5 feet and dissimilar hydrographs. Conversely, we would not add multiple wells from a site where vertical head differences were small or hydrographs were similar.

Subnetworks and Monitoring Categories

Level Monitoring

Because of Delaware's small size, intensive agricultural and urban development, and reliance on groundwater for water supply, most new candidate wells evaluated for level monitoring fall into the known or suspected change subnetworks. A few water-table monitoring wells located in remote areas of state lands have been assigned to the background subnetwork. The master copy of sub-network metadata is maintained in the NGWMN well registry.

Water levels in all new level monitoring wells are manually measured at least quarterly and are equipped with automated water-level instruments that measure and record at 15-minute intervals. As such, these wells qualify as trend category wells. None of these wells have five years of data and are assigned a baseline status until such time that five years of data have been collected. We note that Delaware meets or exceeds the recommended level well density for principal and major aquifers but also note that nearly all wells are in the known or suspected change subnetworks. Multiple major and local aquifers are being pumped in neighboring New Jersey and Maryland and are showing significant drawdown across multiple states. As such, the increased density of level wells will inform regional water supply sustainability research and management issues.

Quality Monitoring

Even though water-level data from many new water quality wells show evidence of regional pumping impacts, many of these wells are finished in confined aquifers far from any sources of contamination. As a result, they are assigned to the background subnetwork. Several new unconfined wells located in state-owned forest or wildlife management lands also are assigned to the background subnetwork. Remaining new unconfined wells are located in agricultural areas and assigned to the known or suspected change sub-network. Sampling of these new wells will be every five years and as a result these wells are assigned to the surveillance category. We note that the number of trend and surveillance QW wells in Delaware is far less than the maximum number in the well density workbook and we will propose adding additional wells to the QW network in future years when funding is adequate.

Objective 2 Support Persistent Data Services

During the project period, DGS maintained a set of web services, corresponding to the four types of data categories (i.e., water levels, water quality, lithology, and well construction) and multiple databases that house this data. An Oracle database stores the primary data collection of well metadata and associated data variables. This database is secured behind an IT firewall and optimized to support DGS in-house daily operations and data editing. Another database, running the Postgres database system with the PostGIS addon, is located in a web-accessible environment and optimized to support distribution of data and web services to the NGWMN and other institutional users. Table records from the Oracle database are migrated to the Postgres database on a daily basis or can be run anytime as needed through a set of automated scripts. Both databases and all web service code are backed up regularly, with regular daily scheduled backups for data and approximately monthly backups for code.

The four web services operated with minimal interruption during the project period. Minor improvements in the code and in the XML responses were performed throughout the time period as needed. DGS staff responded to several service requests from USGS

NGWMN staff during the project period and proactively fixed problems that we found during our QA efforts.

One of the primary issues that stopped the web services from returning valid information was changes in the field definition of columns in the Oracle database needed to accommodate DGS staff needs for our internal database. Scripts that migrate tables from the Oracle database to the Postgres database then encountered errors with mismatched column specifications. This in turn resulted in numerous empty records that were not migrated, ultimately resulting in empty xml records to the query from the portal. All tables and fields within both databases were reviewed and aligned accordingly. Database administrators are aware of this issue and have new guidance for altering table and field definitions. Additional automated procedures continue to be developed to recognize these issues before they result in misinformation being reported in the XML responses.

The Postgres database now resides on recently installed Windows Server 2016 operating system and new hardware. Updates and security patches were performed on the operating systems on both database server machines as well as the application software (e.g., Apache, PHP) on the web server virtual machine.

Additionally, DGS worked with a contractor (Greenwing Solutions, Inc.) on three tasks: 1) maintain the Postgres database at the latest version of the software and management interface, 2) review and modify, as needed, the Oracle to Postgres database table migration script and the web services code in order to align with the move to new hardware; and, 3) develop a web-based display for the web service request log file so DGS staff can evaluate daily numbers of requests made and requesting IP address for each of the four types of web service. The product of task 3 makes it easier to assess server load timing and to identify XML response errors and synching information with the NGWMN portal.

DGS staff uploaded metadata for all new wells to the well registry and conducted quarterly reviews of the contents of the NGWMN well registry. No significant issues were found during these reviews. DGS maintained the same water level and water quality monitoring SOPs during the project period as were used in the first year. All of the metadata elements required by NGWMN are included in DGS web services.

DGS continues to use the same standard operating procedures (SOPs) that were documented in our first year's participation in the NGWMN. Water-level measurement SOPs are those from Andres et al. (2018) and data management SOPs are summarized in Appendix A. Water-quality SOPs for wells sampled by DGS are those from Andres et al. (in press), those for wells sampled by the Delaware Solid Waste Authority are included in Appendix B.

Table 1. New DGS sites in NGWMN water level and water quality networks

Site ID	National Aquifer Code	Local Aquifer Code	Local Aquifer Name
Fb23-70	S100NATLCP	211MLRL	Mount Laurel
Fb23-71	S100NATLCP	211MGTY	Magothy
Gb55-05	S100NATLCP	211MLRL	Mount Laurel
Gb55-06	S100NATLCP	125AQRC	Aquia-Rancocas
Gb55-08	S100NATLCP	112CLMB	Columbia
Hd25-10	S100NATLCP	211MLRL	Mount Laurel
Hd25-11	S100NATLCP	112CLMB	Columbia
Jb22-10	S100NATLCP	112CLMB	Columbia
Jb22-12	S100NATLCP	122CSLD	Cheswold
Ke25-09	S100NATLCP	112CLMB	Columbia
Ke25-10	S100NATLCP	122FRDC	Frederica
Ke25-11	S100NATLCP	122FDBG	Federalsburg
Ke25-12	S100NATLCP	122CSLD	Cheswold
Ke25-13	S100NATLCP	124PNPN	Piney Point
Lf23-03	S100NATLCP	112CLMB	Columbia
Lf23-04	S100NATLCP	122CSLD	Cheswold
Lf23-05	S100NATLCP	122FDBG	Federalsburg
Lf23-06	S100NATLCP	122FRDC	Frederica
Lf23-07	S100NATLCP	122MLFD	Milford
Mb33-05	S100NATLCP	112CLMB	Columbia
Mb33-06	S100NATLCP	122CSLD	Cheswold
Mb33-07	S100NATLCP	122FDBG	Federalsburg
Mb33-08	S100NATLCP	122FRDC	Frederica

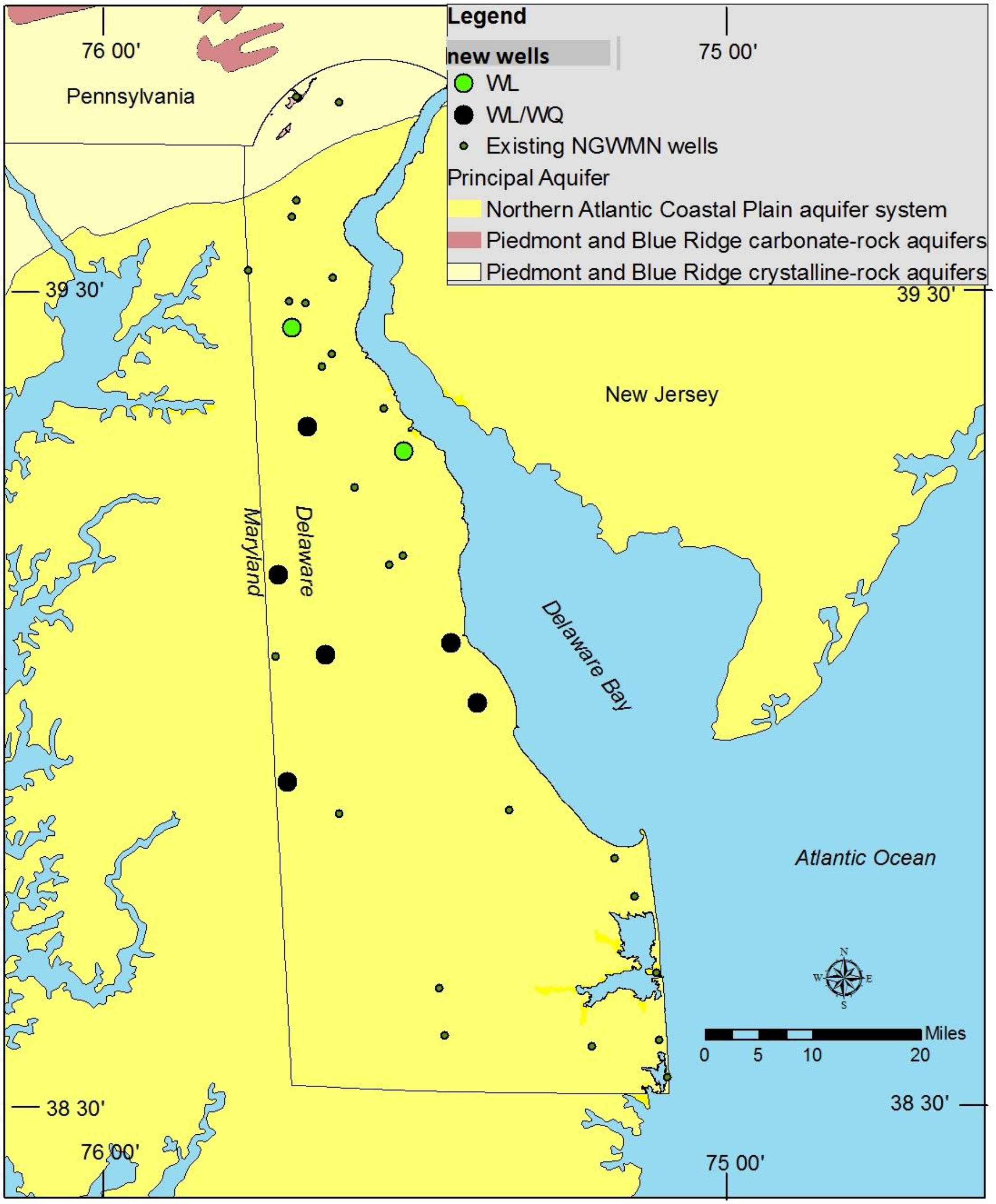

Figure 1. Map showing locations of existing and newly added wells in Delaware selected by the DGS for NGWMN. The wells monitor three principal aquifers and 13 local aquifers and cover unconfined and confined conditions. Many sites have multiple wells that are screened in different aquifers.

Objective 3 Filling Gaps in Information at Existing Sites

Lithology data and metadata for site DGS:Nc13-03 were added to our internal database and made available to our web services. These data are visible in the NGWMN portal.

Horizontal and vertical coordinates were collected for sites DGS:Nc13-03, DGS:Ng11-37, DGS:Oi24-06, DGS:Qe44-01, DGS:Qh54-05, and DGS:Qh54-06 by a combination of RTK GPS and autolevel methods. Some of the field work was delayed for six months by the recent COVID shutdown and as a result the post-processing and well registry update tasks have not been completed for sites DGS:Oi24-06, DGS:Qh54-05, and DGS:Qh54-06. The NGWMN registry entries were updated for the remaining sites.

Objective 4 Well Maintenance

The following sites were pumped and video inspected - DGS:Qh54-05, DGS:Qh54-06 DGS:Qe44-01, DGS:Db24-18, and DGS:Oi24-06. Site DGS:Qe44-01, a roughly 35 year old shallow well (roughly 20 foot deep) requires follow up work to repair a broken joint between the casing and screen. Slug testing shows this well is still hydraulically connected to the aquifer and the video shows only minor amounts of sediment had accumulated in the well. Should the well not be repairable, we are searching for an appropriate location for a replacement well. Wells at all other sites are intact and hydraulically connected to the adjacent aquifers. These wells pumped sediment free water.

The following sites were successfully pumped for a minimum of 30 minutes - DGS:Fb23-71, DGS:Gb55-05, DGS:Gb55-06, and DGS:Gb55-08. All sites yielded clear, sediment free water and similar pre- and post-pumping water level measurements showed the wells are hydraulically connected to their aquifers. Pumping of site DGS:Fb23-70 was not successful due to pump failure. This site has a static water level in excess of 120 feet and will be pumped when we acquire a suitable replacement pump.

Our experiences found that the costs of the administrative work needed to prepare the proposal and then schedule, accomplish, and bill direct and match expenses for these tasks far exceeded the compensation received from the NGWMN. As a result, we will judiciously evaluate including work under this objective in future proposals.

References Cited

Andres, A.S., He, C., and McKenna, T.E., 2018, Groundwater monitoring procedures part 1: equipment and procedures for manual and automated field measurement of groundwater levels in dedicated monitoring wells: Delaware Geological Survey Open File Report No. 51.

Andres, A.S., McQuiggan, R.W., He, C., and McKenna, T.E., in press, Kent County groundwater monitoring project: results of subsurface exploration and hydrogeological studies: Delaware Geological Survey Report of Investigations No. 85.

Masterson, J.P., Pope, J.P., Fienen, M.N., Monti, J., Jr., Nardi, M.R., and Finkelstein, J.S., 2016, Assessment of Groundwater Availability in the Northern Atlantic Coastal Plain Aquifer System From Long Island, New York, to North Carolina: U.S. Geological Survey Professional Paper 1829.

SOGW, 2013, A national framework for ground-water monitoring in the United States: Advisory Committee on Water Information.

Trapp Jr., H., and Horn, M.A., 1997, Ground water atlas of the United States, segment 11, Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia: U.S. Geological Survey Hydrologic Investigations Atlas 730-L.

Appendix A. Groundwater Level Data Collection and Processing

1. Introduction

This document outlines the processing of manually and electronically collected groundwater level data from field data collection to final data approval and publishing online.

2. Field data collection

DGS staff members collect groundwater level data using widely accepted procedures and practices (Andres et al., 2018), which were adapted to Delaware conditions from published methods (Holmes, et al., 2001; Cunningham and Schalk, 2011), interactions with staff of the USGS, consulting firms, and other state agencies. The standard operating procedure (SOP), which covers manual measurements and deployment and operation of dataloggers, and in-field data management tasks, has been documented and governs our program.

3. Data Management and Security

All data were entered into the DGS master database through an in-house groundwater database management tool (GWDBM). The GWDBM tool integrates entry, visualization and approval of data into one user-friendly interface. Built-in security and quality control processes significantly facilitate efficiency and reduces potential errors. This tool incorporates a password protected three-level authority scheme to protect the database from unintended or improper modifications. At Level 0, a "*Visitor*" can only display/query existing data. At Level 1, a "*User"* can input field and electronically logged data and edit provisional data. At Level 2, an "*Administrator"* can edit and approve any data.

3.1 Field measurement processing

The depth to water (DTW, feet), date and time (Eastern Standard Time) of measurement, as well as staff name, measuring point datum (top of casing, ground surface or other), and measuring device are entered into GWDBM by the staff. When prompted by the user, GWDBM uploads the data to the master water level data table and assigns a status of “P” (provisional), and displays new and existing data in a graph.

3.2 Electronic data processing

Upon returning from the field, electronically collected (e.g., transducer/datalogger instruments) groundwater level data needs to be processed before loading into database. Figure 1 shows the major steps of data processing within GWDBM. GWDBM plots new and historic data in one hydrograph, helping the user visually check and correct for offset and gaps in the record, and to identify instrument malfunction. GWDBM also compares manual and electronic measurements to calculate and correct for instrument drift over time and data are provisionally accepted when there is less than 0.5 feet difference between manually and electronically measured data. Daily averaged groundwater level will be calculated for days having more than 72 provisionally accepted 15-minute interval measurements and uploaded to the master database as along with associated metadata. All the original files of electronically collected data are archived for future referral.

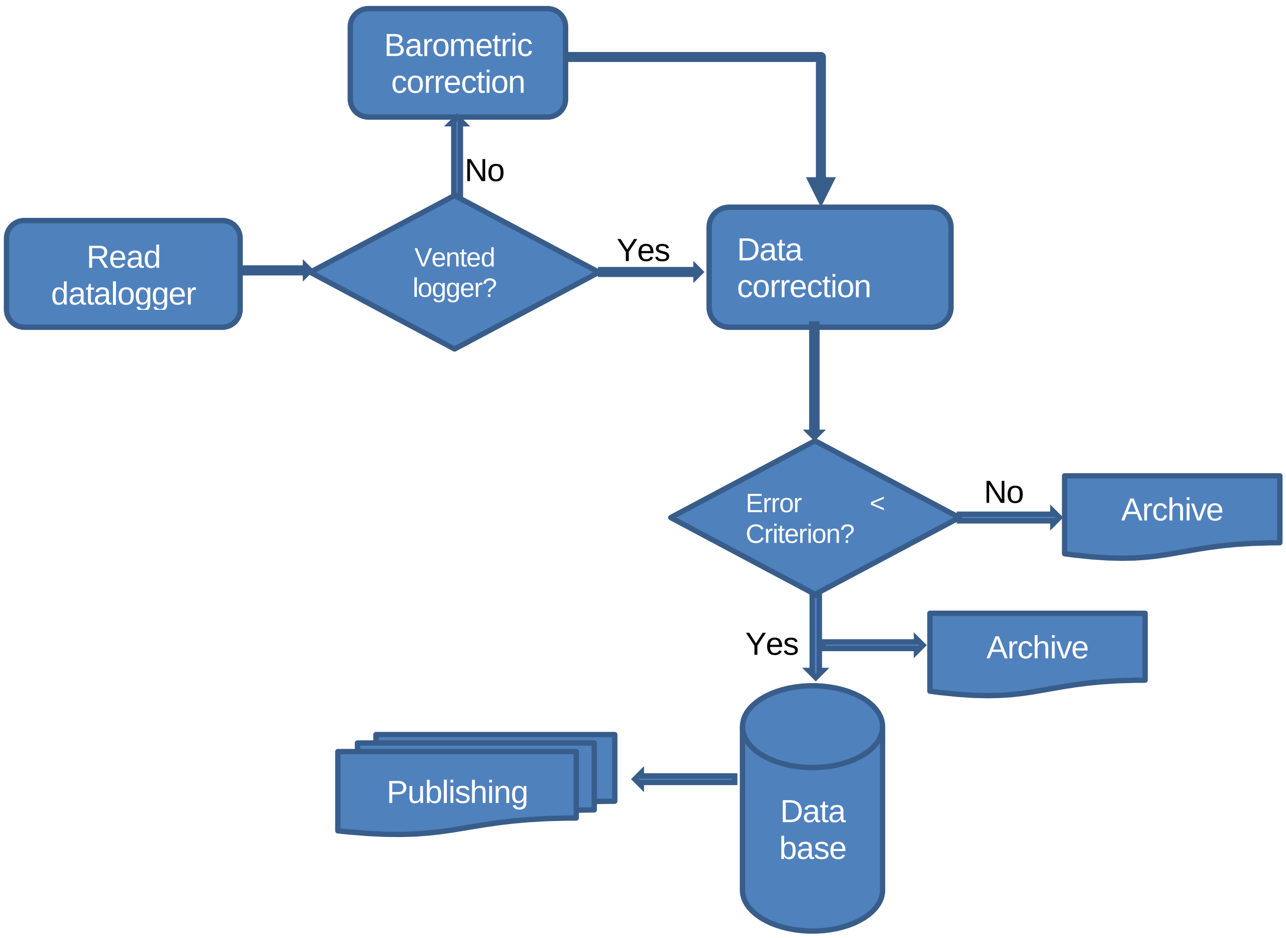

Figure 1. Flow chart of electronic data processing at DGS.

4. Data approval and publishing

Provisional data are evaluated and assigned a status of accepted or estimated within six months of being uploaded to the master database. The waiting period allows the data to be compared with subsequently collected data. For electronically collected data, the primary criteria for assigning the status are presence or absence of gaps in the electronic or manual measurement records, evidence of instrument malfunction, and the magnitude of the difference between manual and electronic measurements.

Manually measured data are assigned a status of accepted when they fit expected trends and agree with coeval electronically measured data and a status of estimated if there may be questions about the measurement but no clear evidence to reject the data. The criteria for evaluating the accuracy of electronically measured data may differ depending on whether they are collected by vented (gauge) or non-vented (absolute) instruments. For both types of instruments, data are assigned a status of estimated when a manual measurement was not recorded at the beginning or the end of the instrument deployment period.

From vented instruments - Data are accepted when there is less than 0.05 feet difference between manually and electronically measured water levels. Data are assigned a status of estimated when the difference is between 0.05 and 0.5 feet.

From non-vented instruments – Data are accepted when there is less than 0.1 feet difference between manually and electronically measured water levels. Data are assigned a status of estimated when the difference is between 0.1 and 0.5 feet.

Groundwater levels, including provisional data, from wells having 100 or more water level observations can be accessed through the DGS public website http://www.dgs.udel.edu.

References Cited

Andres, A.S., He, C., and McKenna, T.E., 2018, Groundwater monitoring procedures part 1: equipment and procedures for manual and automated field measurement of groundwater levels in dedicated monitoring wells: Delaware Geological Survey Open File Report No. 51.

Cunningham, W.L., and Schalk, C.W., compilers, 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151

Holmes Jr, R.R., Terrio, P.J., Harris, M.A., and Mills, P.C. 2001, Introduction to field methods for hydrologic and environmental studies: U.S. Geological Survey Open-File Report 2001-50.

Appendix B. Delaware Solid Waste Authority groundwater level and sample collection procedures (DSWA, written communication)

Groundwater Sample Collection Procedures

Background	Implementation of the Slow Purge Method
Section I	Monitoring
Section II	Analytical Methodology
Section III	Well Head Protection/Security

Section IV	Well Construction
Section V	Well Locations
Section VI	Well Modifications for Current Sampling Protocols
Section VII	Sample Collection Procedures
Section VIII	Groundwater Sample Collection
Section IX	Groundwater Monitoring Well Sampling
Section X	Quality Assurance/Quality Control
Section XI	Supply Disposal
Section XII	Reporting

Background: Implementation of Slow Purge Method

In October of 1991, the United States Environmental Protection Agency (USEPA) promulgated new regulations under RCRA called the "Solid Waste Disposal Facility Criteria - 40 CFR-258". These regulations present the minimum criteria that owners and operators of municipal solid waste landfill units must meet for protection of the surrounding environment. Some of the criteria covered in this document include:

1. Design
2. Operation
3. Closure
4. Post closure care
5. Monitoring
6. Record keeping
7. Financial Assurance

Although this document explains what criteria owners and operators have to meet to be in compliance with these regulations, the document does not present details concerning the selection and implementation of methodologies to meet compliance.

In 1992, a draft of the "Technical Manual for Solid Waste Disposal Facility Criteria - 40 CFR-258" was released to the State Governments for comment. This DRAFT technical manual discusses methods for selection of sites, materials, testing requirements, acceptance testing, sampling protocols, and monitoring requirements.

Review of this DRAFT technical manual, by the Delaware Department of Natural Resources and Environmental Control (DNREC) and the Delaware Solid Waste Authority (DSWA), raised questions concerning the benefits of implementing certain sampling protocols put forth within the document. Both Agencies felt that upgrading the current groundwater monitoring systems with dedicated equipment necessary to comply with these protocols would:

1. Add excessive and unnecessary costs to the current Environmental Monitoring Program.
2. Increase the time necessary for sample collection.
3. Not yield fully representative samples.

Due to the presence of fine sands, silts, and clays in the aquifers being monitored at all Delaware Solid Waste Authority solid waste management centers, DSWA has implemented a "Common Sense" approach for the collection and preparation of groundwater samples for analysis. Using guidance provided by DNREC, in 1993, DSWA began using slow-purge or micro-purge techniques to collect groundwater samples. These techniques or sampling protocols were implemented to accomplish the following:

1. Reduce the heavy pieces of field equipment, purge pumps, steam cleaners, and generators needed to purge wells and decontaminate equipment;
2. Reduce the number of wells being sampled;
3. Eliminate hand bailing;
4. Significantly reduce time spent purging wells;
5. Reduce or eliminate field filtering as required by 40 CFR-258;

Both the DNREC and the DSWA understand that these methods may vary significantly from many of the currently accepted methods. However, the hydrogeologic conditions that exist on the Delmarva Peninsula (and many other locations where the primary aquifers were formed by weathering and tidal deposition) make certain requirements of 40 CFR-258 difficult to meet without modification.

I. Monitoring

Groundwater samples shall be analyzed in accordance with the schedules set forth in DSWA's Monitoring Plans. Sample collection, preservation, Chain-of-Custody, labeling, shipment, and equipment decontamination, shall follow the same procedures as outlined in this Plan.

II. Analytical Methodology

All samples shall be collected and analyzed using the methods provided in the following publications:

1. SW-846 (Most Recent Edition) to be used first;
2. 40 CFR-136 (Most Recent Edition) to be used only if methods are not available in A above;
3. Standard Methods (Most Recent Edition) to be used only if methods are not available in A or B above;
4. Other methods as jointly approved by DSWA and DNREC to be used only if methods are not available in A, B, or C above.

III. Well Head Protection/Security

Well heads at all DSWA facilities meet or exceed the standards set forth in *DNREC's* *Delaware* *Regulations Governing the Construction and Use of Wells*. All monitoring wells are constructed of PVC or stainless steel with protective outer steel casings and locking caps. Additionally, most DSWA wells have additional outer protective casings made of concrete or steel, or concrete pads enclosed by bollards as shown in Figure 2 on Page 12 of this Plan. All protective steel casings have been outfitted with a locking cap, are kept locked using tamper resistant, hardened steel or brass locks. All locks at the major landfill facilities are keyed alike.

IV. Well Construction

All DSWA wells have been constructed and installed in a manner consistent with the existing specifications required by DNREC at the time of construction.

V. Well Locations

The inner well casings of all GMWs being monitored at DSWA facilities have been surveyed by a land surveyor licensed in the State of Delaware. All groundwater monitoring wells have been tied in to the National Geodetic Vertical Datum and Delaware State Coordinate plane using standard land surveying practices. At the time of this plan the coordinate systems being used are the 1927 Delaware State Plane coordinate system and 1929 National Geodetic Vertical Datum.

VI. Well Modifications for Current Sampling Protocols

A. No modifications have been made to groundwater monitoring wells with average DTWs greater than 25 feet.

B. All wells with an average DTW of 25 feet or less have been modified through the installation of a 3/16” Teflon™ tube extending the entire length of the casing and screen. The tube is plugged at the lower end to prevent uptake of solids during sampling, and is solid except for a liberally perforated 2-3 foot section located at mid screen of the well casing. The tube is secured to the outer steel casing by way of nylon cord and straps as shown in Figure 3 on Page 13 of this Plan.

VII. Sample Collection Procedures

The following presents the methods by which DSWA collects or has its Environmental Monitoring Contractors collect groundwater samples from DSWA solid waste management centers. It is believed that these methods allow for uniform sampling of the aquifers without drawing in fine sediments from the surrounding aquifer, or disturbing sediments present in the well casings.

A. Field Preparation: Mobilization/Demobilization

The following outlines those procedures DSWA requires of its environmental monitoring contractors for preparation for the sampling of groundwater at the DSWA facilities:

1. Standard QA/QC required by the monitoring contractor include:
    a. External audits through certification programs;
    b. External audits through acceptance of blind samples and round robin testing;
    c. Internal audits through splitting samples and shipping samples to other local and regional laboratories;
    d. Performance audits of all laboratory personnel and stations.

2. Many times, the bottles used by a contractor for sample collection, shipment, and storage are purchased pre-cleaned and (some with preservatives added) by an independent company. However, all sampling and field equipment is usually cleaned and maintained by the contractor. Therefore, as a part of standard quality checks, all bottle shipments should be tested by the contracted monitoring company on a routine basis for contamination. If the monitoring company elects to clean their own bottles, quality checks should be standard protocol, and should be run on every lot washed. As a minimum, the following should be done prior to any bottles going into the field:
   a. Fresh disposable Nitrile gloves should be worn whenever handling the glassware (prior to and after cleaning);
   b. All labels should be affixed to the bottles prior to issuance to field crews;
   c. All sample preservatives that can be placed in bottles prior to sample collection should be done so before the bottles are issued to the field crews. The type and amount of preservative should be placed on the label immediately prior to or after addition to the bottle;
   d. Specific analytes and sample locations should be placed on the labels in indelible ink prior to the bottles leaving the laboratory. Note that all caps for volatile organic samples should be screwed down tightly prior to labeling to eliminate any airborne volatile contaminants from the label glues or ink from indelible markers, pens, or type.

3. Preparation of field equipment should include the following:
   a. Cleaning of all manual sampling equipment should include the following procedures:
      1. A general rinse with water to remove debris and solids.
      2. An Alconox Wash.
      3. Sterile rinses with deionized/distilled water.
      4. Acid Wash.
      5. Sterile rinses with Deionized/distilled water.
      6. Hexane Wash.
      7. 3 sterile rinses with deionized/distilled water.

      All acids and chemical rinses used should be GCMS grade or better. The field sampling crew is required to carry the necessary chemicals and deionized/distilled water into the field in order to clean any materials that may become contaminated during sampling.

   b. All pumps and field meters should be cleaned and calibrated prior to each monitoring event using chemicals and standard procedures recommended by the manufacturer. The equipment should undergo the same protocols when it is returned to the lab.
   c. Maintenance and parts replacement should be performed as required by the manufacturers suggested schedule.
   d. The monitoring company is required to retain records of maintenance and calibration certification. These records are periodically checked by the DSWA.

e. All field equipment should be inspected and tested for proper operation prior to being sent into the field.
f. The sampling crew is required to carry duplicates of all major pieces of sampling equipment.

VIII. Groundwater Sample Collection

A. General

During all phases of groundwater monitoring at DSWA facilities, field sampling crews are required to:

1. Sign the Visitor's Log and enter their time of arrival at the Administration Building or Weigh Station. If needed, request an escort to the location where the samples are to be collected.
2. The Contractor shall be responsible for the health of its employees. The Contractor shall designate an individual in their organization as the "Safety Coordinator" for the site.
The Safety Coordinator shall evaluate the sites to determine what safety equipment is required, and shall what measures of procedures should be followed by the field crew. The Safety Coordinator shall develop a Health and Safety Plan (HASP) delineating these. The Contractor shall be responsible for ensuring compliance with the HASP. The Contractor shall submit the HASP to DSWA within two (2) weeks prior to commencement of monitoring activities.

3. A **minimum of** one pair of Nitrile gloves (two are recommended) are to be used while handling equipment and all phases of the collection, preparation, and shipment of samples. Gloves are changed between monitoring locations. (e.g. gloves are changed prior to sample collections and after equipment decontamination.) This insures minimal opportunity for contamination through handling of samples and equipment by operators.

4. At least one member of the sampling crew collecting samples at DSWA facilities shall carry the following valid certifications:
   a. 40 hour OSHA Emergency Response Program
   b. First Aid and CPR.
5. All monitoring events must be overseen by an individual with a minimum of three years field experience in the collection, preparation, and shipping of groundwater samples.
6. The monitoring company shall conduct annual audits of the procedures and equipment being used by their field crews.
7. DSWA shall conduct random inspections of the field crews sampling protocols during each monitoring event.

B. Gauging

Prior to the collection of any groundwater samples from a DSWA facility, the field sampling crew is required to measure the static groundwater levels to 1/100 of a foot in all groundwater monitoring wells on site. The contractor is required to use an electronic water level indicator dedicated specifically for this purpose. The inner well casings of all groundwater monitoring wells being monitored at DSWA facilities have been surveyed by a land surveyor licensed in the State of Delaware. Each is marked with a reference point that is tied into the National Geodetic Vertical Datum (NGVD). All depth to water readings are to be measured from these reference points.

The following procedures are used by environmental monitoring contractor's field sampling crews for gauging the groundwater monitoring wells prior to collection of samples from DSWA facilities:

1. The following protocols are to be used by the field sampling crew whenever groundwater elevations are taken:

   a. All measurements at a DSWA site are to be taken on the same day.
   b. All GMWs are to be inspected externally and internally for damage, and notations of physical well inspection entered in the field log prior to and after opening the well casing.
   c. Well casings are to be re-locked after measurements have been completed on the well.
   d. Measurements are to be taken from a reference point marked on the inner casing.
   e. A minimum of three measurements are to taken from each well. The location of the well and the three measurements are to be recorded in a field log along with the time and date. These readings are to be averaged. The average of these measurements will be used for:

      1. Mapping the potentiometric head elevations of each aquifer.
      2. Tracking groundwater elevation fluctuations in the aquifers.
      3. Calculating the flow directions and hydraulic gradients of the aquifers.
      4. Entry into a data base for engineering applications as well as possible fate-transport modeling.

2. Between each well being sampled, the field sampling crew is required to rinse the electronic water level indicator thoroughly with deionized-distilled water. If any procedural or well contamination is suspected, the field sampling crew is required to use the following protocols to decontaminate the water level indicator:

   a. A general rinse with water to remove debris and solids.
   b. An Alconox Wash.
   c. Sterile rinses with deionized/distilled water.
   d. Acid Wash.
   e. Sterile rinses with deionized/distilled water.

f. Hexane Wash.
g. 3 sterile rinses with deionized/distilled water.

C. Purging

After all wells have been gauged, the field sampling crew is to use the following procedures to collect the groundwater samples:

1. For wells with depth to water measurements (DTWs) equal to or less than 25 feet:

   The field sampling crew attaches a sterile piece of silicone tubing to the Teflon™ tube installed in the well. The sample crew attaches a fresh piece of dedicated Teflon™ tubing between the outflow of the peristaltic pump and a decontaminated flow-through sample chamber. The sample chamber contains the following probes and meters:

   a. pH
   b. Dissolved Oxygen
   c. Temperature
   d. Specific Conductance
   e. Oxidation/Reduction Potential
   f. Turbidity (measured initially at the outflow from the sample cell.)

2. For wells with DTWs greater than 25 feet:

   The field sampling crew lowers the pump head of an adjustable speed low flow pump down to the middle of the GMW screen and ties off, clips off, or sets the brake on the hose spool to maintain the preferred depth. The sample crew affixes a piece of Teflon™ tubing between the outlet of the pump and a decontaminated flow-through sample chamber. The sample chamber contains the following probes and meters:

   a. pH
   b. Dissolved Oxygen
   c. Temperature
   d. Specific Conductance
   e. Oxidation/Reduction Potential
   f. Turbidity is also measured initially at the outflow from the sample cell.

3. The field sampling crew begins the purge by recording the following:

   a. Date
   b. Start Time
   c. Location
   d. Location Description:

1. Well Diameter
2. Casing Type
3. Top of Casing
4. Depth of Well
5. Depth to Water
6. Standing Water in Casing
7. Land Surface Elevation (if necessary)
8. Sample Methods (Grab, Bailer, Pump, etc...)

4. The field sampling crew starts the purge at a flow rate of 1L/Min or less, and records the following in the field log:

   a. The flow rate setting of the peristaltic pump.
   b. Initial pH
   c. Initial Dissolved Oxygen
   d. Initial Temperature
   e. Initial Specific Conductance
   f. Initial Oxidation/Reduction Potential
   g. Initial Turbidity

   Stabilization of these indicator analytes (except Turbidity) is indicative of uniform water being drawn in from the aquifer. Therefore, the well is considered purged after stabilization has occurred. The field sampling crew is required to purge at least 5 minutes, and no longer than 10 minutes at each sampling point.

5. After purging is complete, the field sampling crew records the following in the field log.

   a. Final pH
   b. Final Dissolved Oxygen
   c. Final Temperature
   d. Final Specific Conductance
   e. Final Oxidation/Reduction Potential
   f. Final Turbidity
   g. Stop time of purge
   h. Total amount of water purged (Gallons), and the number of well volumes removed
   i. Any problems encountered during purging including:

      1. Mechanical problems/calibration problems.
      2. Any strange color, clarity, or odor problems with the samples.
      3. Any notes on problems with the wells such as the presence of roots, or gravel pack in the wells, or damage to the well and casing.

D. <u>Well Closeout</u>

1. Upon completion of sampling, the field crew is to rinse off the well plug or

expansion cap prior to replacement in the inner casing, replace or close the outer protective well lid, and re-lock the well.

2. The field crew shall use decontamination procedures recommended by the equipment manufacturer.

3. Readings from all equipment are verified 3X before final acceptance. If readings cannot be verified, re-calibration is required. If re-calibration does not result in verification, the monitoring company is required to switch to the back-up meter. Although they are generally done more frequently, calibration checks are required every three samples for most field meters.

Note: If the monitoring event only requires field analytes, instruments, sample cells, and sample tubes may be decontaminated between GMWs by flushing thoroughly with deionized- distilled water. All pump heads, and hosing of the variable speed pump must be thoroughly rinsed with deionized-distilled water between monitoring points.

IX. <u>Groundwater Monitoring Well Sampling</u>

If the monitoring event requires indicators or indicators/DNREC Supplemental Analysis for Groundwater Samples to be collected, the sample crew is required to use fresh or decontaminated/dedicated sample tubing in the peristaltic pump. Low flow variable speed pumps must undergo decontamination procedures recommended by the manufacturer. All sample cells are to be decontaminated using the procedures described in VII.A.3.a. above.

The following procedures are to be used by the field sampling crew to collect samples from DSWA GMW wells during a monitoring event that requires indicators or indicator/DNREC Supplemental Analysis for Groundwater Samples analysis to be run on GMW samples:

A. After purging is completed, the field sampling crew shall collect Volatile and Semi-Volatile Organic samples using the peristaltic pump or variable speed pump at a flow rate of 100 mL/Min or less. This is done to insure that: Volatile Organic Compounds (VOCs) are not stripped from the samples.

B. Samples can be collected directly into the bottles, however no contact is allowed between sample bottle or tubing from the pump. VOC vials are to be checked for air entrainment. If air entrainment occurs, the sample shall be retaken. After the VOC and Semi-Volatile Organic samples have been collected, the field crew can increase the flow rate of the pump to expedite the sampling of the remaining sample types which could include:

1. Heavy Metals and Indicator Metals
2. Cyanide
3. Sulfate and Chloride
4. Nitrate and Ammonia

5. Radionuclides
6. All other analytes of interest

The Metals fraction of the samples is to be collected after the Volatile and Semi volatile samples have been collected. Metals samples are the only type of sample that will be considered for filtration. Filtration of Metal samples is to be used as a last resort, and will only be allowed under the following conditions:

1. The turbidity of the sample is >10 NTU's.
2. Reduction in flow rates fail to decrease the Turbidity below 10 NTU's.

If filtration is necessary, the field crew are required to filter the samples through a 0.45 micron mesh cellulose or glass fiber filter.

C. After the sample is collected, the field crew is to record the flow rate of the peristaltic pump in the field logs.
D. After collection of each type of sample is completed, the field crew is required to add any preservatives not added during the bottle prep.
E. Labels affixed to any extra bottles that were not prepared in the laboratory, shall be filled out in indelible ink. Each label is to include the following information:

1. Customer Name or Identification
2. Facility Location
3. Sample Collection Location
4. Time
5. Date
6. Analysis Required
7. Preservatives Used
8. Flow rates used for sample collection.
9. Name of Person that collected the sample.
10. Analytes being analyzed for.

F. After the labels are completed, all samples are to be wrapped in bubble wrap, and placed in shipping boxes containing ice, dry ice, or freezer packs, and preserved at 4° C for shipment.
G. Chain of Custody forms (COC's) are to be filled out with the same information listed above. Each time the sample is transferred, the sample must have a signature of the individual who releases the sample, and one for the individual who receives the sample.
H. The field sampling crew then packages the samples and hand delivers, or ships by overnight express to the contracted analytical laboratory for testing.
I. As the samples arrive at the laboratory, they are to be logged into a laboratory information system where:

1. They are given sample identification numbers (This number is to be noted on the COC).
2. Their pH and Specific conductance is measured and noted on the COC.
3. They are stored or dispersed to the various laboratory stations for analysis.

J. After the samples are logged in, copies of all completed Field Data Sheets and Field logs are to be e-mailed to the DSWA via internet in upon completion of the monitoring event.

X. Quality Assurance/Quality Control

As a minimum, during each monitoring event, the following QA/QC samples are collected, or prepared and analyzed for the analytes required by State Permits/Regulatory Requirements and Federal Requirements under 40 CFR-258.

- Trip Blanks: One per sampling day per facility
- Field Blanks: One per sampling day per facility
- Laboratory Duplicates: One per 10 samples analyzed
- Surrogate Standards: One per sample set
- Surrogate Spike: One per 20 samples
- Lab Method Blanks: One per sample set This analysis is done to insure:

1. Procedures or equipment being used in the sampling, preparation, and shipment train do not cause degradation of the samples.
2. Procedures or equipment being used in the analysis train do not cause degradation of the samples.
3. Samples are not contaminated through outside sources.
4. Methods being used for analysis are conducive to the sample matrix.

XI. Supply Disposal

Non-hazardous expendable supplies and equipment used in the collection of samples can be disposed of at the small load collection station prior to the sampling team leaving the site. Unused or excess sample that has not contacted sample preservatives can be disposed of at the sample location. Disposal of hazardous expendable supplies such as excess preservatives are to be taken back to the laboratory by the sampling team for proper disposal.

XII. Prior to leaving the facility, the field sampling crew will sign out of the facility by entering their exit time in the “Visitor’s Log” at the Administration Building or Weigh Station, after which they must leave the facility.

XIII. Reporting

Results of analysis and discussion of the groundwater monitoring activities shall be included and discussed in the first quarterly groundwater monitoring report generated following reception of the groundwater monitoring data. The CIL historical groundwater monitoring database will be transferred to the Solid and Hazardous Waste Section of the Delaware Department of Natural Resources and Environmental Control by way of electronic media or direct file transfer on a quarterly basis.

As a final note, the environmental monitoring contractor and contracted laboratory providing analysis of samples is/are required to retain all field and laboratory records in hard copy format for a minimum of five years, with magnetic media storage for thirty years.