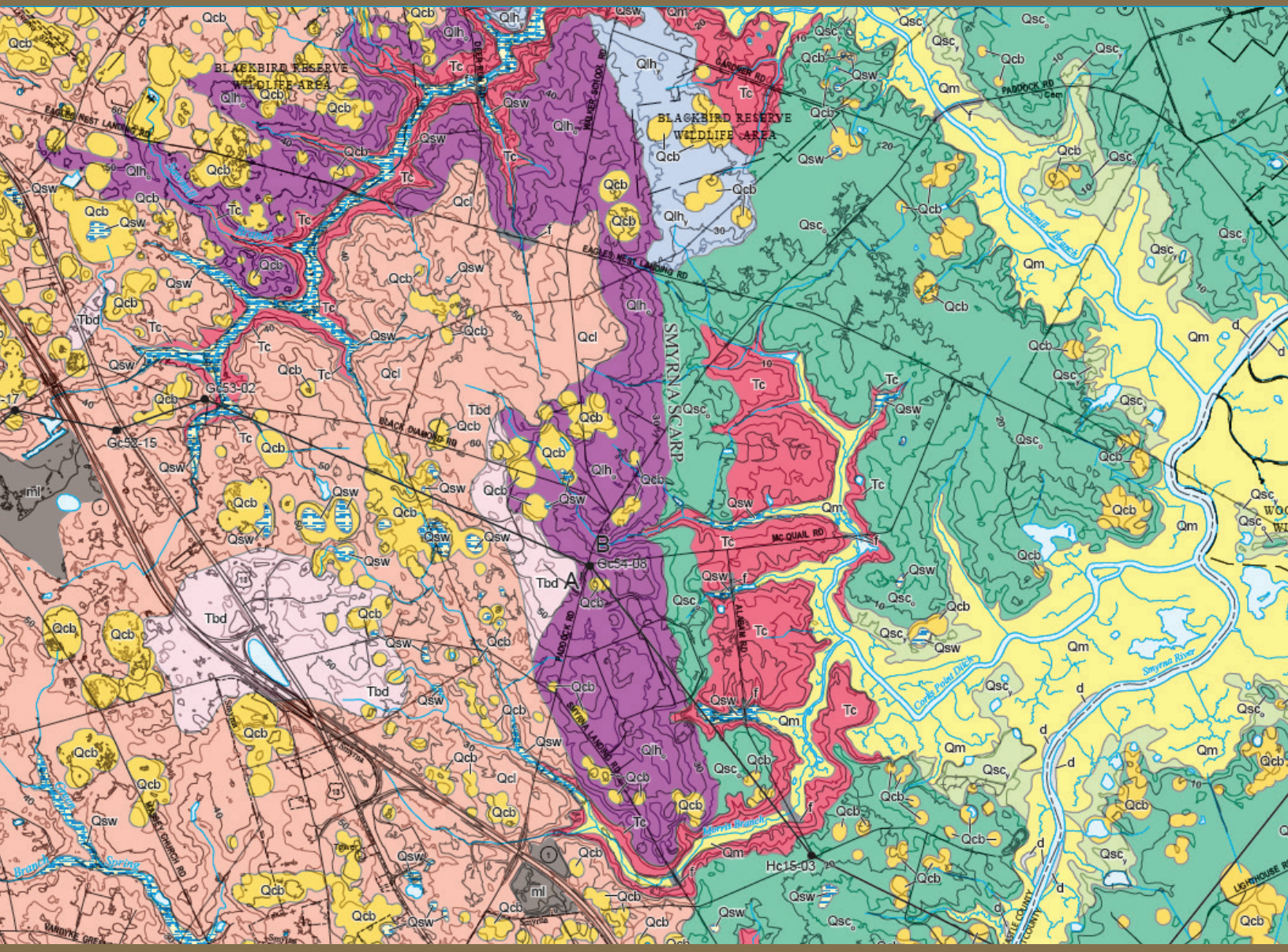
Delaware Geological Survey

ANNUAL REPORT OF PROGRAMS & ACTIVITIES



2021-2022

Above photo: University of Delaware geology students participate in DGS drilling exercise to map subsurface geology at the University of Delaware farm in Newark, Delaware.
Front cover photo: Snip of DGS GM24: Geologic Map of Millington, Clayton and Smyrna Quadrangles.
Credit for above photo: Staff of the Delaware Geological Survey.

OUR MISSION

The Delaware Geological Survey's mission is, by statute, geologic and hydrologic research and exploration, and dissemination of information through publication and public service.

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Message from the Director

Wind-blown rain is pounding against my office window as I am sitting here composing my Message from the Director. The remnant of Hurricane Ian is now in the Mid-Atlantic region, and it has been throwing moderate to heavy rain upon Delaware for several days, causing some minor coastal flooding in flood-prone areas, mainly in Sussex County. But luckily, the hurricane that pounded Florida is now just a small fragment of its former self, and Delaware emergency officials have breathed a sigh of relief.

Hurricane forecasters at NOAA predicted we would have 14-20 named storms in the 2022 season. As of this writing, there have been 13 named storms, with seven that strengthened into hurricanes. However, few have made landfall on the U.S. Nevertheless, this lack of hurricane or tropical storm landfalls does not mean that we should let our guard down, as there is a month to go in the Atlantic hurricane season, and we need to remain prepared. In addition to hurricanes, Delaware is also subject to nor'easter's, cyclonic snow and ice storms that approach from the west, and severe weather outbreaks that can produce intense, short-lived rain events, as well as damaging winds.

DGS works closely with the Delaware Department of Emergency Management (DEMA) by serving on the State Hazard Mitigation Council. Whenever severe weather is approaching, DEMA will host bridge calls that bring together first responders, state and local planners, emergency managers, and academic units to share information about the upcoming storm event, coordinate resources, and discuss preparations for each individual storm. A storm's dimension, direction, and duration all come into play for emergency planning, as each event is unique. DGS representatives typically attend 10 to 20 bridge calls per year. Moreover, during long duration or severe events, DGS staff have been detailed to the DEMA Emergency Operations Center (EOC) to monitor hydrologic conditions and provide first-hand advice in real-time. The last event necessitating DGS staff participation at the EOC was Superstorm Sandy in 2012.

Many of DGS's programs and activities feed into our Natural Hazards Emergency Response Program. For example, DGS manages the state's stream and tide gages through a cooperative program with the U.S. Geological Survey, which provides critical data when trying to predict flooding risks and hazards during major flooding events. Additionally, our groundwater monitoring network provides critical information with regard to drought, which is also a natural hazard. And when you consider that Delaware is a low-lying state with a shallow water table, monitoring wells can help predict "groundwater flooding," which is becoming a more common occurrence where a quickly rising water table can flood home basements, and create chronic high water table conditions that ordinary sump pumps can't manage. DGS also partners with DNREC and the Bureau of Ocean Energy Management (BOEM) with conducting sand resource characterizations that are used to evaluate sand resources for beach replenishment after storms leave their mark on Delaware's beaches. We also work closely with the UD Center for Environmental Monitoring and Analysis (CEMA), which manages the Delaware Environmental Observing System (DEOS) that consists of 80 environmental monitoring platforms that collect comprehensive climate and weather information. When the DEOS network information is combined with the stream, groundwater, and tide monitoring stations that DGS manages, it provides Delaware with one of the most comprehensive monitoring programs of any state in the nation, with most of the data—real-time or archival—available with the click of a mouse.

Currently DGS is working with the Delaware Office of State Planning Coordination and the Department of Technology & Information to acquire new statewide LiDAR data, which is critical for determining land-use changes, and for creating extremely accurate land elevation models that are critical for watershed management, along with flood prediction and planning. In essence, every project and program within the DGS provides some measure of information that cumulatively provides a wide information base for Delaware with regard to emergency planning, preparation, and readiness for natural hazards. This is one of the most important services the DGS provides for the state of Delaware.

David R. Wunsch

David R. Wunsch
Director and State Geologist

1. Water Resources

Delaware Groundwater Monitoring Network

Project Contacts: Changming He and Rachel W. McQuiggan

DGS currently monitors groundwater levels and groundwater quality in a network of wells that support multiple uses by the environmental management, engineering, water supply, and science communities

Groundwater is the backbone of Delaware's water resources, serving the water needs of the public, the economy, and our natural environment. As such, groundwater monitoring is a necessary and resource-intensive program of the DGS. The Delaware Groundwater Monitoring Network is the umbrella program used by DGS to coordinate monitoring activities and leverage institutional resources and staff expertise.

Since the 1960s, the DGS has maintained a network of wells that are used for groundwater-level and groundwater-quality observations. The goals of maintaining this network are to characterize and increase knowledge about the State's groundwater resources, to identify trends and changes in groundwater quality, and to guide the development of best management practices to avoid future groundwater impacts. Currently, the network consists of more than 120 wells covering 17 aquifers. Most of these wells are equipped with automatic data loggers that record water levels at 15-minute intervals, while the remaining wells are measured manually four times per year. A small number of wells are equipped with automated conductivity sensors to help track any developing saltwater issues.

In 2021, in response to the challenge of potential degradation of water quality due to ever-growing human activities as well as saltwater intrusion induced by sea-level rise, the DGS added a new water-quality component to the existing Delaware groundwater monitoring network. The groundwater-quality monitoring network consists of 60 wells covering 13 aquifers that are used for water supply across Delaware. Each well will be sampled every five years and analyzed for basic groundwater geochemical constituents (major ions and select metals) and stable isotopes (^{2}H and ^{18}O). Monitoring methods are adapted from protocols from the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA), programs in other states, and our own experience and expertise. This project is under contract with the Source Water Protection Program in the Delaware Department of Natural Resources and Environmental Control (DNREC) and is funded through a grant from the USEPA.

Rachel McQuiggan, DGS research associate, measuring water quality for the Delaware groundwater monitoring network.

As of July 2022, our data resource holds nearly 470,000 records of manually measured water levels and daily average water levels derived from almost 4,800 wells, and 5,930 groundwater samples from 645 wells. We currently manage nearly 34.6 million water-level records collected by automated pressure sensors and are adding over 2.8 million new records to this dataset every year. More than 11.1 million groundwater temperature and 6.4 million salinity records measured by automated sensors are included in our water-quality dataset.

Data that meet QA/QC requirements are stored in an Oracle database and shared with stakeholders and the public through multiple channels. Water-level data, including manual measurements and daily averaged logger data are accessible through the DGS public website (https://www.dgs.udel.edu) and the Delaware Geologic Information Resource (DGIR, http://data.dgs.udel.edu/). More comprehensive digital logger data collected at 15-minute intervals, and water-quality data can be provided electronically per request. In addition, DGS works cooperatively with the Delaware Solid Waste Authority and the Delaware Environmental Observing System (http://www.deos.udel.edu/) to provide telemetered real-time data from four wells. We also provide groundwater-level and groundwater-quality data from more than 50 Delaware wells to the National Ground Water Monitoring Network (www.cida.usgs.gov/ngwmn), a network of over 30 state and regionally operated groundwater monitoring programs.

Project WiCCED

Project Contact: Rachel W. McQuiggan

Project leverages other DGS monitoring to investigate groundwater salinization and eutrophication

DGS staff members Rachel McQuiggan and Scott Andres (retired) are participants in an ongoing National Science Foundation EPSCoR-funded effort, Water in the Changing Coastal Environment of Delaware (Project WiCCED). Project WiCCED is a consortium of scientists and educators from the University of Delaware (UD), Delaware State University, Wesley College, and Delaware Technical and Community College. Working with Dr. Holly Michael and doctoral student, Mary Hingst of the UD Department of Earth Sciences, one of the project goals is to investigate the dynamics and drivers of groundwater salinization in the east Dover area through direct monitoring and numerical simulation. DGS scientist, Changming He, is advising Ms. Hingst's work.

Helicopter towing an antenna for an Airborne Electromagnetic (AEM) survey will aid scientists in determining the distribution of subsurface saline groundwater.

An intensive field study was conducted in ponds, streams, and groundwater-sourced water supplies, and included existing infrastructure that is part of DGS's statewide groundwater monitoring network. Newly acquired geophysical data from an aerial survey that the USGS performed over the Delaware Bay and Delaware and New Jersey coastlines will allow scientists to visualize the salinity distribution in the subsurface. Project WiCCED and DGS are working with the USGS team to provide ground-based data calibration points for the survey.

DGS and the Delaware Center for the Inland Bays (CIB) jointly operate five water-quality stations in the Inland Bays, with two on the upper Indian River, one on Vines Creek, one on Guinea Creek, and one near Dewey Beach. Every half-hour the stations measure tide height, temperature, salinity, dissolved oxygen, turbidity, pH, and plant pigments chlorophyll *a* and phycoerythrin. Over the past three summers, the instruments have collected nearly 99,000 measurements. The work has allowed the team to quantify the frequency and duration of hypoxic events and their relationships to other water-quality and flow variables. The measurements provide critical data for Delaware's Clean Water Act programs, and the CIB's prioritization and targeting of management and mitigation practices.

More information can be accessed on the project website: www.projectwicced.org.

Delaware Stream and Tide Gage Program

Project Contacts: Stefanie J. Baxter and Kelvin W. Ramsey

Ongoing DGS program to advise state and local agencies on stream conditions and flooding on the basis of a cooperative DGS-USGS program to operate stream and tide gages

The USGS, in cooperation with the DGS, has been operating and maintaining continuous-record stream and tide gages throughout Delaware for decades. This year, ten streamgages and seven tide gages were operated for the program. The data are used for water-resource planning and management, evaluation of drought conditions, and flood forecasting, warning, and response, including early warning systems. The warning systems are used by the DGS, Delaware Emergency Management Agency (DEMA), all three county emergency management offices, most municipalities, and the National Weather Service.

The DGS also assists other Delaware government agencies by coordinating USGS resources through the DGS-USGS cooperative program related to water resources. This includes coordinating the continued operation and maintenance of real-time streamflow gages for the DNREC Watershed Assesment Section at Millsboro Pond Outlet at Millsboro, Beaverdam Ditch near Millville, and Silver Lake Tributary at Middletown; tide gages at Indian River at Rosedale Beach and Indian River near Bethany Beach, and one tide and discharge gage on the Murderkill River at Bowers. Also included in the DGS-USGS cooperative program is the operation and maintenance of water-quality monitoring stations for DNREC Watershed Assesment Section on the Brandywine Creek at Wilmington, Christina River at Newport, Appoquinimink River near Odessa, Millsboro Pond Outlet at Millsboro, and Massey Ditch at Massey Landing; intensive water-quality monitoring on the Murderkill River near Frederica for Kent County; and a five-year project with the Delaware Department of Transportation (DelDOT) to integrate USGS and DelDOT real-time data streams through testing and use of data-logger technology. The DGS adds significant value to projects undertaken for Delaware agencies by the USGS by ensuring appropriate coordination and scoping of work and technical review of products before contract payments are released.

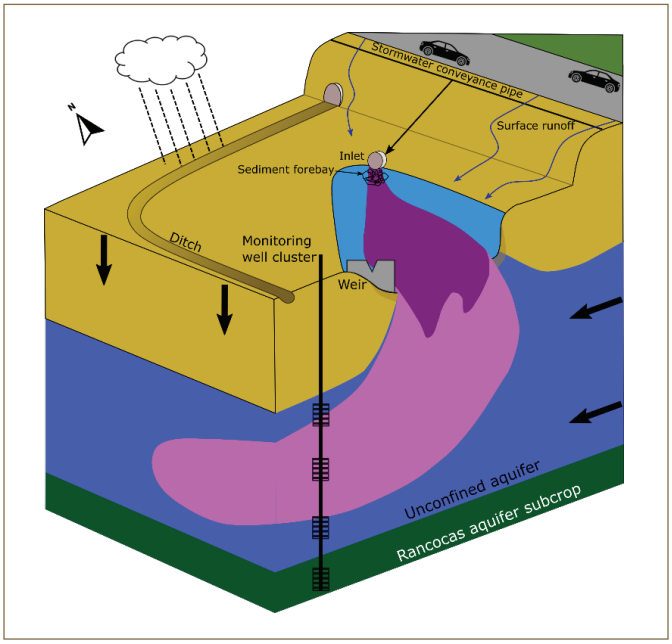
Stormwater Infiltration BMP Impacts on Groundwater Quality

Project Contact: Rachel W. McQuiggan

Monitoring and evaluating the impacts of winter deicing salt transport to groundwater

In cooperation with DelDOT, the DGS has been monitoring groundwater and stormwater at a roadside site and a DelDOT-managed stormwater infiltration basin to characterize the impacts of deicing salt on groundwater. We have been operating and maintaining automated, high-frequency stormwater flow and salinity, as well as groundwater pressure, temperature, and electrical conductivity/salinity systems at both sites for over two years. This project was prompted by increasing chloride concentrations in a number of groundwater-supplied public water systems in New Castle County and occurrences of radium in several of the impacted water sources.

Data from groundwater samples, stormwater and groundwater sensors, and subsurface geophysical surveys allowed us to develop and test conceptual models of the movement of water and salt from drainage networks into groundwater. We have collected over 5 million water-level and electrical conductivity/salinity records,



Conceptual sketch of deicer-impacted stormwater coming into an infiltration basin.

600,000 stormwater inflow measurements, five rounds of groundwater samples at project wells, and 42 stormwater and surface-water samples.

Extensive use of in-situ measurements of electrical conductivity/salinity made by automated sensors has greatly improved data resolution and our ability to develop and test conceptual models, while reducing the time and money needed for collection and laboratory testing of samples. Empirical relationships between sensor and laboratory measured data from this study are very well correlated showing that sensors are reliable and cost effective for monitoring movement of road-salt brines. Using sensors and geophysical logging, we observed saltwater migrating through different layers within the aquifer and found that speed and pathways of saltwater movement depend on hydraulic properties of geologic units.

Groundwater chemistry shows two mixing processes occur beneath the infiltration basin—one that occurs as salty stormwater infiltrates to the water table and moves downgradient from the basin, and the other as dilute stormwater flushes through during late summer and fall. Increasing salt concentration correlates with radium mobilization in groundwater due to competitive cation exchange. Monitoring will continue at the infiltration basin through another year and will include soil chemistry and infiltration testing. Data from this work will support development of statistical and simulations tools to evaluate the risks of deicing on groundwater.

The Coastal Critical Zone

Project Contact: Rachel W. McQuiggan

Studying coastal processes to understand critical feedbacks related to climate change

The critical zone includes all Earth processes from the tree canopy down to bedrock. In Delaware, coastal marshes play an important role in the critical zone by storing carbon, nutrients, and other contaminants. Sea-level rise is expanding the marshes, but also salinizing soil and shallow groundwater, which can damage adjacent forests and farm crop fields.

DGS researcher Rachel McQuiggan joined a NSF-funded project investigating the hydrological, biogeochemical, ecological, and geomorphological processes in the coastal Mid-Atlantic region. UD's Department of Earth Sciences professor, Dr. Holly Michael, is the lead primary investigator (PI) for the research, which is called The Coastal Critical Zone: Processes that transform landscapes and fluxes between land and sea. The cluster group of additional researchers includes other UD staff and faculty as co-PIs, as well as collaborators at Wesley College, University of Maryland, George Washington University, Virginia Institute of Marine Science, and Boston University. McQuiggan will act as data manager for the coastal group, assisting with processing, management, storage, and dissemination of field and experimental data.

Six project study sites have been instrumented with long-term water, soil, air, vegetation, and land surveying monitoring equipment. Study sites are located in Delaware, Maryland, and Virginia, and focus on the transition zones between marsh, forest, and agriculture. This project will share monitoring resources with the NSF-funded EPSCoR Project WiCCED, which is also investigating groundwater salinization in the east Dover area.

Over 6 million records of hydrological and ecological data collected from in-situ sensors have been processed and stored. Monitoring sites and descriptions are displayed on an interactive web mapper (https://czn.coastal.udel.edu/resources/) and sampling metadata are being made available to the public through online data repositories such as the Environmental Data Initiative and HydroShare.

Retirement Tribute to A. Scott Andres - 37 Years of Service to the DGS

Scott Andres retired after 37 years of service to the DGS. His contributions to DGS are significant, and range from outstanding scientific research to data-base design and management. Below is an abridged version of remarks presented by DGS Director, David R. Wunsch, upon Scott's retirement

We would like to recognize Scott Andres for thirty-seven years of dedicated service to the DGS, the University, and the State of Delaware. Scott began his career in hydrogeology in 1980 with the New Jersey Department of Environmental Protection and joined the DGS in 1984. In that time, he has grown to be one of Delaware's preeminent experts on groundwater and surface-water issues. Scott stands out among his peers for his extraordinary commitment to science-grounded public service that has ensured the citizens of Delaware benefit from high-quality technical input for the management of water resources and the environment. The scope of this work has been broad, but always focused on public needs, ranging from the effects of agriculture and land-based disposal of wastewater on soils, groundwater, and surface-water bodies to the use of automated sensors for high-frequency monitoring water quality in wells and watersheds, submarine groundwater discharge, and mapping and characterization of aquifer hydrology.

Scott is an outspoken advocate for the application of science to unbiased decision-making about our water resources, especially in coastal areas where groundwater faces multidimensional threats. Scott frequently was asked to contribute expert commentary to state citizen's technical advisor councils on groundwater issues, such as the DNREC's Source Water Protection Citizen's Technical Advisory Committee and the Governor's Water Supply Coordinating Council. He has been a leader in conducting research on aquifers in areas with competing groundwater demands in coordination with state and local governments. He has played a key role in developing a modern groundwater monitoring well network for the state, and overseeing the planning, installation, and instrumentation of the majority of these wells. This infrastructure—the legacy of his work—will last for decades.

His work has contributed to sound environmental decision making. In his long-time role as Chair of the Scientific and Technical Advisory Committee and Board Member at the Center for Inland Bays, Scott helped with the Center's scientific assessments on a number of important issues, including pollution from the Mountaire Farms poultry plant. His work on a wide variety of environmental threats to the Inland Bays has been of real benefit to Delaware's citizens and marine life. This includes work on environmental risks related to land-based wastewater discharge in rapid infiltration basins (RIBS), understanding pathways for submarine discharge of groundwater that may be sources of estuarine pollution, and new infrastructure for monitoring water quality in the Inland Bays.

Personally, I relied on Scott's institutional knowledge significantly for water-related issues, and I always appreciated that he kept me abreast of political or regulatory winds as they affected the state's water and environmental issues.

Scott has collaborated on a regular basis with many other UD researchers on topics such as groundwater/surface-water interaction and salt-water intrusion.

Scott has an outstanding publication record of both DGS and external peer-reviewed publications. Additionally, his early interests in computers and database development led to Scott becoming the director of information technology for the DGS. His genuine interest and continuing education allowed him to develop advanced IT skills, which led to the development of computer hardware and software systems for data and interpretive products. During his tenure at DGS he developed and refined an in-house networked Oracle database and ESRI-SDE geodatabase with associated reporting and analytical applications that manage more than 8 million records in numerous data tables. This infrastructure allows our raw and value-added data resources to port directly to the DGS website, making them available to the public on a routine basis. Scott has also been a leader in linking Delaware to national water resource database initiatives, including the Subcommittee on Ground Water and the National Ground-Water Monitoring Network.

Through more than three and one-half decades of doing science in the public interest at the DGS, Scott has made a long-lasting, positive impact on the people, lands, and waters of Delaware. He has exemplified science in public service. His expertise, articulate promotion of science, commitment to public needs, and dedication to our university and state will be very much missed at the DGS.

2. Geology & Mapping

Middle Atlantic Coastal Plain Stratigraphic Reconciliation Initiative

Project Contacts: Peter P. McLaughlin and Kelvin W. Ramsey

USGS-funded multistate initiative to establish equivalency of geologic units

The DGS continues to lead a multi-state, multi-organization initiative aimed at establishing a regional understanding of the equivalencies of formation names across state lines in the Middle Atlantic Coastal Plain. This project, the Middle Atlantic Coastal Plain Stratigraphic Reconciliation Initiative or "MAtStrat", was developed as a cooperative effort of regional experts from state and federal geological survey organizations, water resource agencies, and universities and is focused on the stratigraphic nomenclature in four states: Virginia, Maryland, Delaware, and New Jersey.

The MAtStrat Project was funded by the U.S. Geological Survey's National Geologic Map Database Project (NGMDB) as the first of a handful of regional stratigraphic equivalency initiatives across the nation. The results of the project are expected to clarify the definition of geological formations in the four states, which will help NGMDB resolve longstanding problems of stratigraphic name equivalencies at state boundaries where surficial geological maps created by different systems can appear to conflict. In addition, the equivalency of naming systems for aquifers between states requires clarification to ensure that the connectivity of aquifer systems beneath these states can be clearly delineated.

MAtStrat project efforts have compiled a large volume of documentation on lithologies and ages at key reference sections in each state, particularly wireline core sites. This has allowed us to assemble tables documenting each formation recognized in the project area and defining criteria from key localities. Preliminary cross sections and stratigraphic charts have also been constructed. As the project wraps up, we will share our inventory of stratigraphic data on the core sites and outcrops in the project area. The results are expected to better reconcile stratigraphic frameworks across the Mid-Atlantic region, benefitting geological map and aquifer work within each state geological survey as well as positively impacting the mission of USGS National Geological Map efforts.

Middle Atlantic Coastal Plain Stratigraphic Reconciliation Initiative, Part II

Project Contacts: Kelvin W. Ramsey and Peter P. McLaughlin

Focusing on heavily used aquifers in the Mid-Atlantic region

As an outgrowth of the MAtStrat Project, a second phase of study, designated MAtStrat II, was undertaken with USGS funding to focus on stratigraphic problems in the late Miocene to early Pleistocene sediments along the coastal parts of the MAtStrat area from southeastern Virginia to Cape May, New Jersey. These strata contain important aquifers that are used by public water systems, agriculture, industry, and household consumers in the region, including growing municipalities with large summer tourist populations located along the Atlantic Coast.

The goal of MAtStrat II is to examine in detail all available core and sample material (especially wireline core) in the area of interest to develop a regional stratigraphic framework of the units. This will be accomplished by 1) collection of all available stratigraphic data both published and unpublished, 2) identification of available core material, 3) construction of regional cross sections, 4) a multi-state workshop to refine the cross sections and correlations, and 5) identification of additional work needed.

While examining the corehole data available to address important late Miocene to early Pleistocene stratigraphic issues, a data gap was identified in the Atlantic Coastal area of Maryland between Ocean City and the area near the Virginia border. With the cooperation of the Maryland Geological Survey (MGS), the DGS drilled a 470-foot continuous wireline corehole at the Maryland State Highway Administration work yard east of Berlin, Maryland. The corehole allowed a detailed description of the late Miocene to early Pleistocene sediments in the data gap, clarifying the nature of the north-to-south stratigraphic changes in this part of the study area.

In addition, the project served as an excellent opportunity for education and professional collaboration. DGS staff trained four college students in methods to describe sediment in detail and familiarized them with drilling techniques. Helpful onsite discussions of geology were made possible by the presence of local geological experts from the MGS, USGS, and the Virginia Department of Environmental Quality's Groundwater Characterization Program.

Pete McLaughlin, DGS senior scientist, instructing students how to perform a detailed core description.

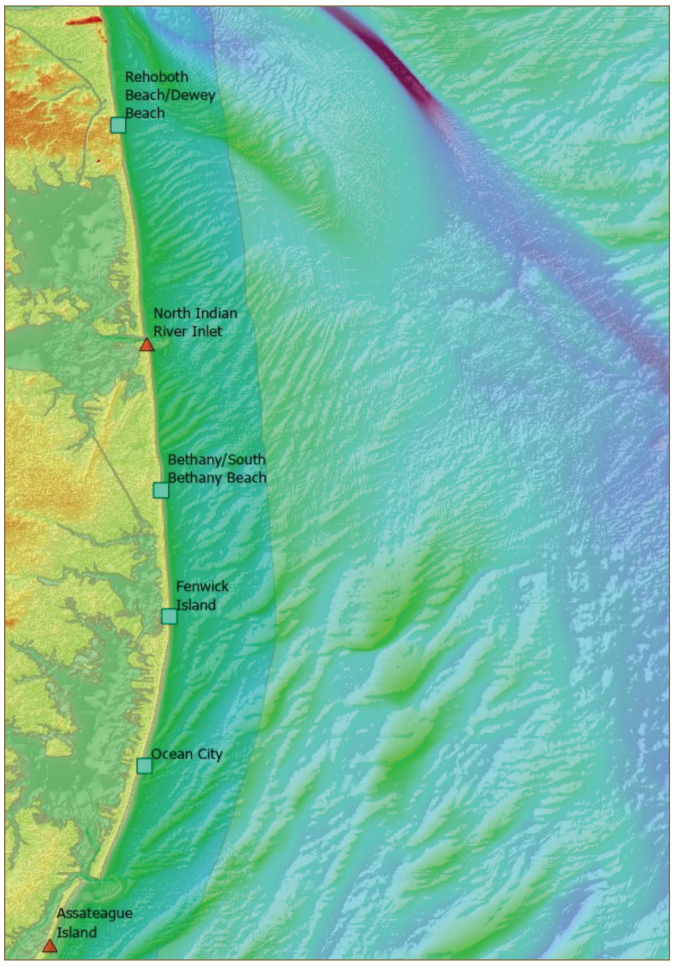
Delaware Offshore Sand Resources

Project Contacts: Daniel L. Warner, Kelvin W. Ramsey, and David R. Wunsch

Evaluating sand resource needs and supply along the Delaware coast

The Atlantic beaches of Delaware and Maryland are major drivers of the tourism and recreation economy in this region. These areas have been extensively developed over the past century. However, rising sea levels coupled with the constant natural erosion of the shoreline reduces the ability of the beach and dune systems to absorb major storm surges, threatening the infrastructure and intrinsic economic value of these coastal areas. Over the past several decades, Delaware and Maryland have adopted beach nourishment, the periodic placement of sand from the seafloor onto the beach, as a means of protecting coastal infrastructure from storm surges and flooding. This approach requires large quantities of sand to be dredged from offshore areas every few years.

In cooperation with the Bureau of Ocean Energy Management (BOEM), DGS researchers are investigating historical sand usage rates to better estimate regional sand resource demand over the 21st century. By coupling the sand needs of different beach communities with the sand availability in known offshore deposits, the team hopes to establish a timeline of when new sand deposits, likely in federal waters, may need to be utilized. This work will help guide coastal resilience planning and BOEM's decision making pertaining to offshore leasing activities along this stretch of coastline.



Coastal topography and bathymetry along the Delaware and Maryland Atlantic Coastline. Key communities where beach nourishment activities occur are indicated. The shaded region represents the three-mile limit where state-managed waters end and federally managed waters begin.

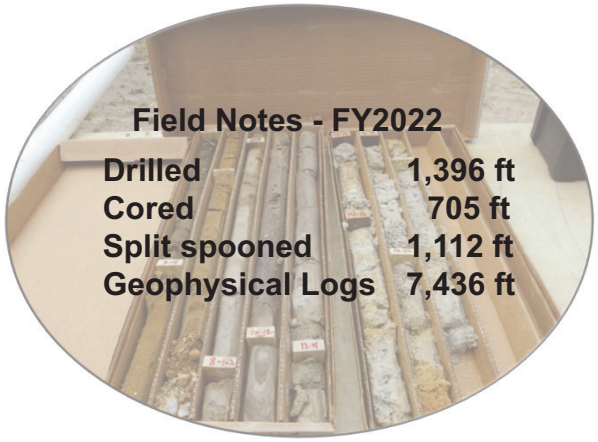
Delaware Geologic Mapping Program

Project Contacts: Jaime L. Tomlinson and Kelvin W. Ramsey

Mapping the surficial geology of Delaware through the STATEMAP federal cost-share program

The primary goal of the DGS geological mapping program is to map surficial geology of the First State at the detailed scale of 1:24,000. Geologic maps provide an understanding of the earth materials beneath our feet, benefiting Delawareans by defining the subsurface geologic framework that has applications characterizing groundwater, land-use planning, natural hazards, environmental geology, soils/agriculture, and geotechnical engineering. The USGS STATEMAP Program provides federal dollar-for-dollar matching funds for most of DGS's geologic mapping efforts. Products from the mapping efforts include PDF map publications as well as digital data (shape and data point files) that can be downloaded and imported into GIS software.

The current map area is located in the Wyoming Quadrangle. This quadrangle was chosen, in part, with the guidance of the Delaware Geologic Mapping Advisory Committee (DGMAC). The DGMAC is comprised of Survey stakeholders from diverse backgrounds including federal, state, and county government, environmental consulting, academia, and the non-profit sector. The committee prioritized this area over five other possible project locations due to the high population density, the large number of environmentally compromised sites, and the proposed redevelopment of a state park. Fieldwork for this project will be completed in June 2023.



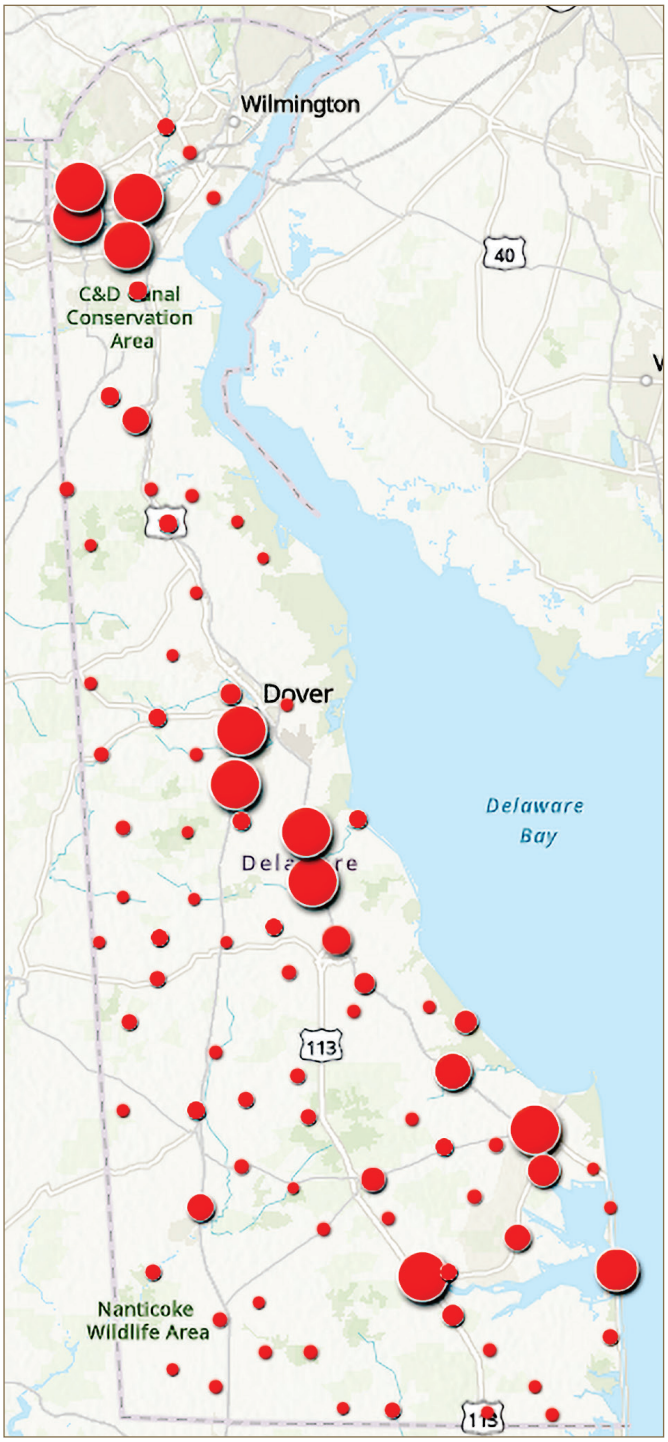
Borehole Lithology Log Data Preservation Project

Project Contacts: Peter P. McLaughlin and Mojisola A. KunleDare

NGGDPP-funded project preserves borehole lithology logs for future studies

The Delaware Geological Survey completed a project to preserve and index a large volume of uncatalogued borehole lithology logs and to improve public access to these logs. This project continues DGS participation in the National Geological and Geophysical Data Preservation Program (NGGDPP), a federal program created in the Energy Policy Act of 2005 and administered by the USGS. The program provides assistance to state geological surveys for the preservation of geologic and geophysical data, maps, and samples, and to make them available for use.

The project preserved geologically valuable borehole lithology log data from highway construction projects and enhanced public access to these data via the internet. We worked on cataloguing, extracting from geotechnical reports, and storing in institutional archives, PDF-format images of lithologic logs



Screenshot of web application temporarily being used to serve preserved PDF logs to the public. The size of the circle indicates the number of features at each location, which range from >70 (largest circles) to 1 (smallest circles).

from Delaware Department of Transportation (DelDOT) construction projects. Digital preservation of lithologic log data in the DGS in-house relational database system (WATSYS) was achieved through transcription of lithologies from borehole logs. We have provided public access to the preserved logs by making the PDF images available through

STATE OF DELAWARE
DEPARTMENT OF TRANSPORTATION
MATERIALS AND RESEARCH

BORING C-51

Project Name: NEWARK TRANSPORTATION CENTER **Location:** Newark, DE
State Contract #: T201251601 **Federal Contract #:**
Station/Offset: **Northing:** 607152.50 **Easting:** 607152.50
Boring Surface Elev.: **Reference:**
Date Started: 8/15/16 **Date Completed:** 8/15/16

Wt. of Sample Hammer: 140 Lbs. **Average Fall:** 30 IN.
Type of: D-Sampler: Split Barrel O.D. O.D. of Sampler: 2 IN.
S-Sampler: O.D. O.D. of Samp. Tube: IN.
U-Sampler: O.D. O.D. of Samp. Tube: IN.
Core Bit: O.D. O.D. of Rock Core: IN.

Hollow Stem Auger Diameter: 3 1/4" Inches **From Depth of:** 0.0 **To:** 50.0
Mud Rotary: **From Depth of:** **To:**

Water Level Readings

Date	Depth to Water (ft)	Caved Depth (ft)
8/15/16	11.0	
8/15/16	Dry	4.0

Boring Contractor: Walton Corporation **Equipment/Rig Type:** CME 45 Trailer Rig
Driller: Billy Holden **Logged By:** Randy Ferguson

Depth (ft.)	Water Level	No.	Sample Depth	Blows/6"	Sample Description	AASHTO Class.	Remarks
		1	0.0' – 2.0'	2 3 2 2	No Recovery — NR" RECOVERY		
2.53		2	2.0' – 4.0'	8 12 11 11	Wet very stiff gray clayey silt w/some coarse to fine sand, trace of fine gravel. — 16" RECOVERY	A-4(3)	
5.06		3	4.0' – 6.0'	5 4 4 6	Wet firm gray clayey silt w/some fine to coarse sand and fine gravel. — 16" RECOVERY	A-4(4)	
7.59		4	6.0' – 8.0'	7 11 9 11	Wet very stiff brown clayey silt w/some fine to coarse sand, trace of fine gravel. — 15" RECOVERY	A-4(3)	
10.12		5	8.0' – 10.0'	5 11 13 9	Wet medium dense brown fine to coarse sand and fine gravel w/some silt. — 15" RECOVERY	A-1-b	
	■	6	10.0' – 12.0'	7 9 9 11	Wet medium dense brown fine gravelly fine sand w/trace coarse sand and silt. — 18" RECOVERY	A-3	
12.65		7	12.0'	12 14 11 10	Wet medium dense brown coarse to fine sandy fine gravel w/trace silt.	A-1-b	

Example of borehole log from DelDOT transportation infrastructure project.

a new public-facing DGS online mapping application and to the associated transcribed digital data through the Delaware Geological Information Resource (DGIR) web application accessible via the DGS website. Significant results were achieved on all project objectives. The objective for capture of borehole lithology PDF files was exceeded nearly two-fold, with 2,244 PDF images of logs added to DGS inventory and preserved, of which 1,727 are available now to the public via an ArcGIS Online web application. Lithology data for each of the 1,727 boreholes has been transcribed digitally and made available via the DGIR application, where they are provided in tabular form or as standardized graphical logs.

Borehole lithology descriptions are fundamental to DGS geologic and hydrologic research and so must be preserved and retrievable for use by our researchers and stakeholders. Support from the NGGDPP has allowed the DGS to preserve valuable logs and data from road and infrastructure projects that would otherwise be unavailable for geological studies, providing real value to stakeholders for future scientific studies and policy decisions. As this project progresses in the coming year, we expect to add borehole geophysical logs to the current lithologic data offerings and to create a single permanent web portal for borehole data delivery as part of our NGGDPP funded FY2022 project.

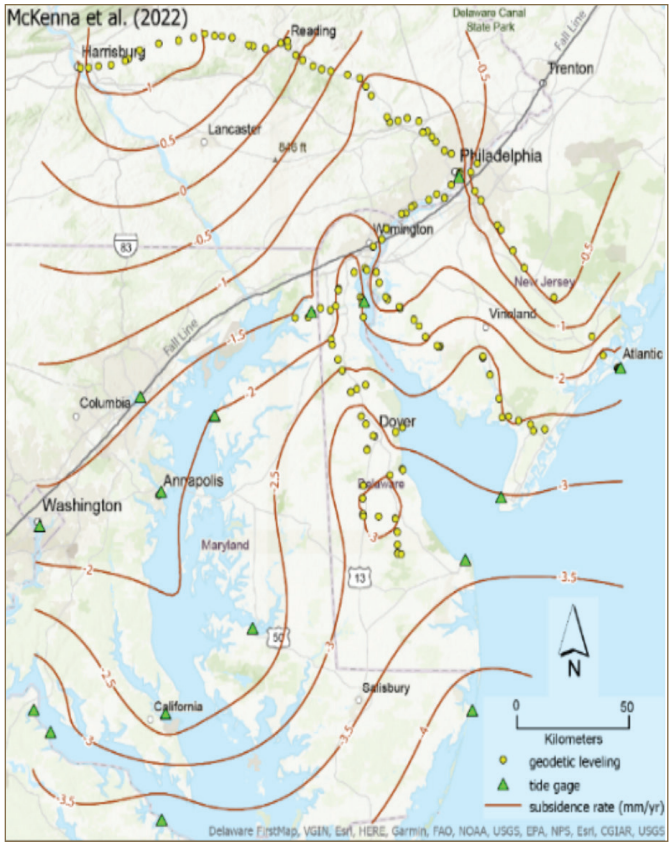
Contribution of Land Subsidence to Relative Sea-Level Rise along the Delaware Bay Coastline

Project Contacts: Thomas E. McKenna, Changming He, Daniel L. Warner, and David R. Wunsch

Quantifying and mapping land subsidence along Delaware Bay

Delaware's land is subsiding (decreasing in elevation) while sea level is rising. Together these factors represent a net rise in relative sea-level rise along our coasts. What do we mean when we talk about relative sea-level rise? People often think it is the level of the ocean all around the globe (global sea-level rise). But that is not the whole picture. We also need to add on any decreases in land surface elevation (subsidence). The term relative sea-level rise is the relevant value to use when determining impacts on Delaware's coastline. Relative sea-level rise is the sum of global sea-level rise and land subsidence. In parts of the state, land subsidence is greater than global sea-level rise.

DGS conducted a study to map the land subsidence in the Delmarva region by analyzing National Geodetic Survey (NGS) historical high-accuracy geodetic-leveling data and NOAA long-term tide-gage data. The study results suggest that the subsidence rates are -1 to -3.5 mm/year while current global sea-level rise is 2 mm/year. These numbers appear small but are significant over decadal time scales. For example, with a subsidence rate of 3 mm/year (1/8 in/year) and global sea-level rise of 2 mm/year (5/64 in/year), relative sea-level rise is 10 cm (4 in) in 20 years, 25 cm (10 in) in 50 years, and 50 cm (19.7 in) in 100 years. Global sea level is predicted to increase over the next century, so the impact on the coast will be even larger. Subsidence generally increases from northern to southern Delaware. The most prominent feature is a linear trend of high subsidence oriented approximately north-south from southern Sussex County to north of Philadelphia. It is most prominent between Dover and Delaware's northern boundary. The primary cause of land subsidence in Delaware is likely to be glacial isostatic rebound, a process where the earth recovers from the melting of glacial ice 14,000 years ago. The weight of the glaciers pressing on our tectonic plate lowered elevations in areas that were under the ice. In unglaciated areas, like Delaware, the pressure on the tectonic plate under the ice caused the plate to flex resulting in uplift. We are now experiencing the lowering of that flexed area. Groundwater pumping has been recognized worldwide as a major cause of human-induced subsidence, especially in coastal plain sediments. However, while speculated about in the past, the pattern of subsidence suggests groundwater pumping is not a leading cause of subsidence in Delaware. The ridge of high subsidence is too small to be caused by glacial isostatic adjustment, but, speculatively, it could be due to faulting deep in the earth. We recommend creating a subsidence monitoring network of periodic and synchronous static GPS observations coupled with satellite data (InSAR).



Contours of land subsidence rates (mm/yr).

As a jump-start towards a permanent monitoring network, DGS is participating in a regional evaluation of subsidence focused on greater Chesapeake Bay. The project is led by investigators from Virginia Tech, USGS, and NGS and includes many cooperators. The project consists of annual campaigns of static GPS observations at over 80 survey marks during the month of October. We observe eight stations in Delaware. Preliminary results for Delaware indicate subsidence is occurring at most of the locations, but it is not statistically significant because the amount of subsidence is not much more than the margin of error what GPS can measure. Results should be significant after 5-10 years. A subsidence monitoring network would enable Delaware's government agencies and commnities to optimize actions that focus on global sea-level rise accentuated by localized subsidence.

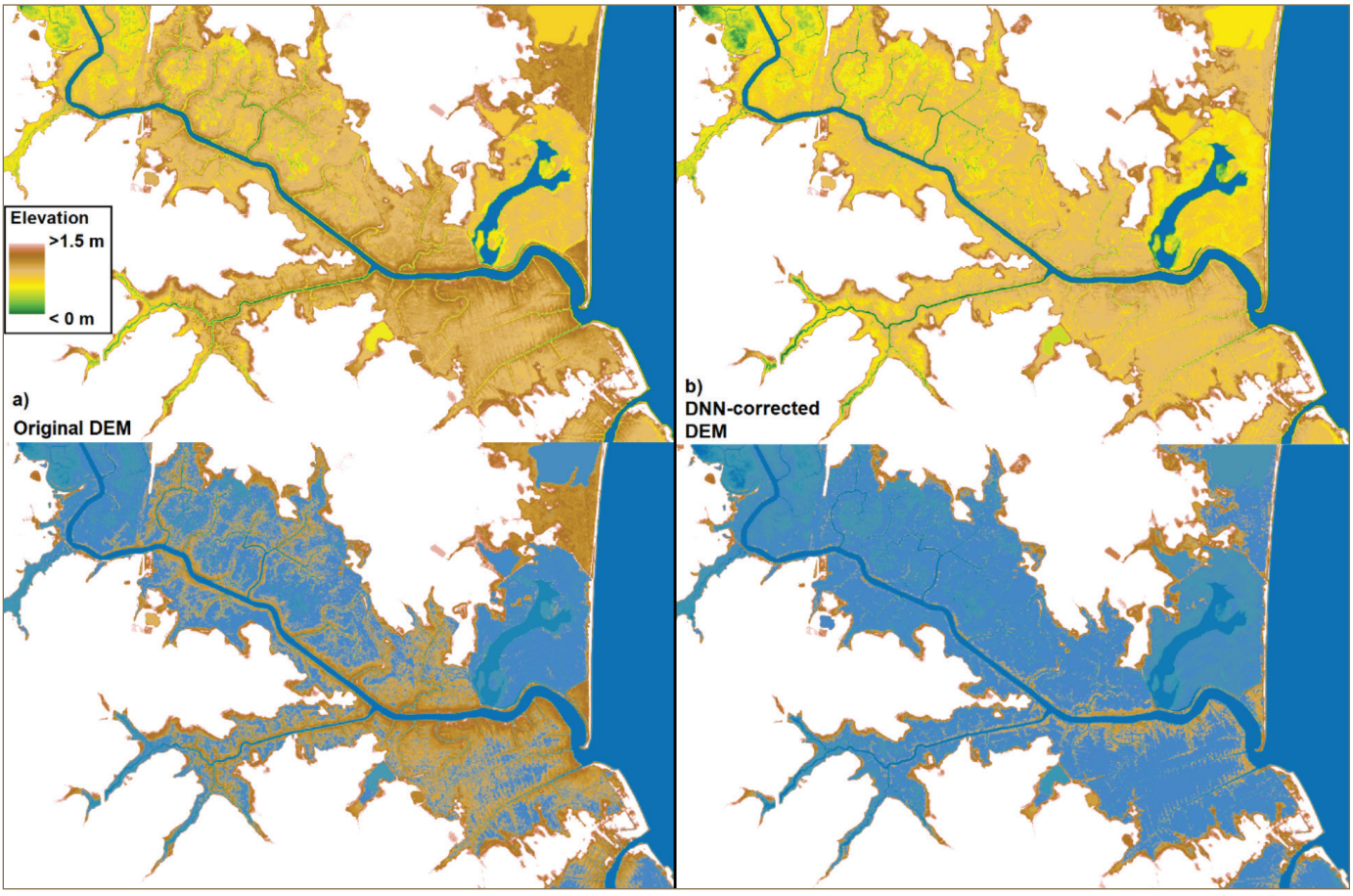
Reducing Vertical Bias and Uncertainty in Tidal Marsh Digital Elevation Models

Project Contacts: Daniel L. Warner and Thomas E. McKenna

Reducing vertical bias is crucial for those living in coastal areas

Tidal marshes provide a wide array of ecosystem services that benefit both human society and natural ecosystems. A key determinant of the ability of marsh systems to provide these services is the spatial and temporal patterns of marsh inundation, or flooding. Marsh inundation affects where different species may live or spawn, how the marsh can grow and accumulate carbon, and the ability of the marsh to attenuate storm surges. Researchers need high quality elevation data to study marsh inundation, as differences of only a few centimeters can have major implications on flooding patterns in these flat, low-lying systems. However, much of the elevation data available in Delaware is derived from airborne light detection and ranging (LiDAR) surveys, which struggle to separate dense marsh grasses from the actual marsh platform below. This results in noisy elevation data with a positive vertical bias that hinders marsh research efforts.

Researchers at DGS sought to reduce the vertical bias and noise of the available digital elevation models (DEM) in tidal marshes along Delaware Bay. First, we collected and compiled field observations of actual marsh platform elevations from high accuracy GPS units and calculated the error of these observations relative to the DEM. Then we investigated various statistical and machine learning techniques for modeling DEM error based on secondary LiDAR and elevation derivatives, such as LiDAR point skewness and variance or DEM curvature. The best performing technique, a deep neural network ensemble, was extrapolated to produce a corrected DEM surface that removed, on average, approximately 11 cm (4.3 in) of vertical bias and reduced the mean error (noise) of the DEM from 13 cm (5.1 in) to 3.5 cm (1.4 in). Additionally, the DGS team developed an ArcGIS tool to facilitate rapid overland



Example comparison of the original elevation data (left) and neural network corrected elevations (right). The bottom panels illustrate how estimates of inundation extent at mean higher high water (about 0.93 m (3.0 ft) in this example) can be substantially different between the original and corrected elevation surface.

flow modeling in coastal marshes. This project provides a data product and tool that will support ongoing Delaware coastal zone research in a time when sea-level rise and coastal inundation represent major concerns for the state.

Integrated Stratigraphic Studies of the Paleocene-Eocene Deposits and Rancocas Aquifer in Central Delaware

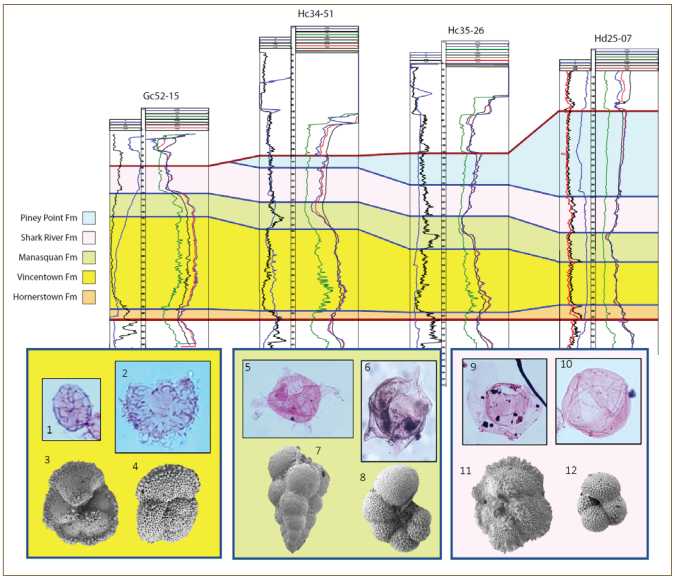
Project Contact: Peter P. McLaughlin

Microscopic fossils help to understand hidden geological characteristics of sediments in the subsurface of Delaware

The DGS is conducting several projects that use microscopic fossils to improve our understanding of the regional variations in the character of two important aquifers and to establish an accurate determination of their underground connectivity.

Two projects are examining the nature of the Rancocas aquifer near the border of New Castle and Kent Counties. The Rancocas aquifer is a thick interval of clean, permeable aquifer sands that provide groundwater in southern New Castle County but change southward into a zone of sandy muds and muddy sands south and east of Smyrna where they are not suitable for groundwater withdrawals. Details of this change in the groundwater system have not been well constrained by previous studies. Microfossils examined for this study help to better understand the equivalency of aquifer zones between wells and the geological history that affects their use as groundwater sources. The Rancocas projects use samples from previous coring projects, including material from the Vincentown Formation (in which the Rancocas aquifer occurs) and two formations above it that serve as confining beds, the Manasquan and Shark River Formations. Study of fossil dinoflagellate cysts and pollen with graduate student Kristina Gardner has allowed us to revise the correlation of the formations associated with the Rancocas aquifer between New Castle and Kent Counties. Study of fossil foraminifera with graduate student William Vincett appears to indicate that the change in aquifer quality corresponds to a southward increase in the depth of water in which the Vincentown Formation was deposited.

A new, third project examines the Magothy aquifer, an important groundwater source in central New Castle County that occurs as far north as the Chesapeake and Delaware Canal area. Clear delineation of the geographical extent of the Magothy aquifer is a challenge because of significant variations in its thickness; in the Canal area, it is present in some locations and very thin or absent in others. Graduate student Caleb Norville has joined in our work on the fossil pollen of the Magothy Formation, examining fossil pollen occurrences in previously collected samples from New Castle and Kent Counties as well as new samples collected during a recent drilling project at Port Penn. The hope is that the pollen characteristic of four subdivisions of the Magothy Formation will contribute to more detailed correlation of Magothy aquifer sands within Delaware and into nearby areas of Maryland and New Jersey.



Subsurface correlation of core sites in the Smyrna area. Geophysical log curves include gamma-ray (left side of each plot, black and red), spontaneous potential (left side, blue), and resistivity (right side, red 16-inch, black 64-inch, blue lateral, and green point resistance). Microfossil names: 1. Cladopyxidium saeptum (D); 2. Areoligera gippingensis (D); 3. Morozovella aequa (F); 4. Morozovella acuta (F); 5. Dracodinium samlandicum (D); 6. Deflandrea oebisfeldensis (D); 7. Jenkinsonia triseriata (F); 8. Pseudohastigerina wilcoxensis (F); 9. Thalassiphora delicata (D); 10. Cribroperidinium giuseppei (D); 11. Morozovella marginodentata (F); 12. Turborotalita bassriverensis (F). Dinocysts (D) by K. Gardner; foraminifera (F) by W. Vincett.

Atlantic Outer Continental Shelf Sample and Data Repository

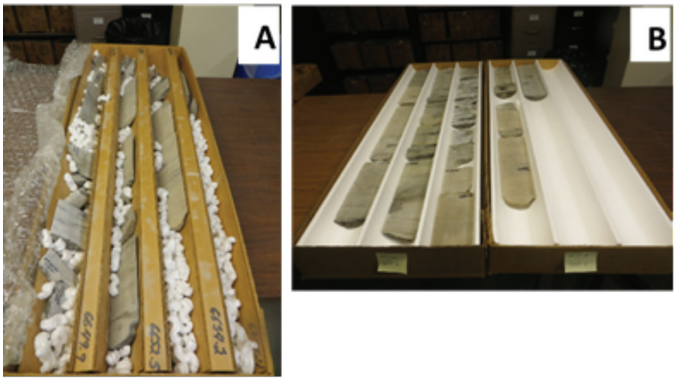
Project Contacts: Mojisola A. KunleDare and Peter P. McLaughlin

DGS repository preserves valuable cores and samples

The DGS Atlantic Outer Continental Shelf Sample and Data Repository is a unique collection of irreplaceable sample

materials from offshore oil exploration wells, stratigraphic test wells, and deep research boreholes drilled on the U.S. Atlantic Outer Continental Shelf in the 1970s and 1980s. This collection holds all of the remaining geological samples and associated prepared materials from those multimillion-dollar offshore drilling projects. The repository is an important resource for stakeholders from government agencies, universities, consultancies, and industry interests seeking to understand the geology below the continental shelf.

During the last year, we have continued our ongoing work to reorganize and repackage cores from the five Continental Offshore Stratigraphic Test (COST) wells, making substantial improvements for several wells. Archival sets in display-ready boxes fitted with custom foam inserts have been created for long-term preservation, and working sets of boxes of ordered and repackaged leftover items have been created for project sampling use. The DGS also works with collection users to access data products such as petrographic slide scanned images, cuttings photographs, and raw analyses results. These submitted data from collection use and loans are made available to all stakeholders and enhance the collection offerings. The results of these ongoing efforts ensure that irreplaceable, geologically significant samples and data are securely preserved for future research projects.



Section of COST GE-1 Core 2 showing cores before (A) and after (B) preservation work.

IN MEMORIAM: NENAD SPOLJARIC

Article by UDaily staff

Community remembers senior scientist in Delaware Geological Survey

Nenad Spoljaric, senior scientist in the Delaware Geological Survey (DGS) for nearly 34 years, passed away on April 20, 2022, at his home in Boca Raton, Florida, surrounded by his family. He was 87.

Born in Zagreb, Croatia, he earned a bachelor's degree in geology from the University of Ljubljana and worked at the Petroleum Institute in Zagreb for several years. In 1963, he immigrated to the United States to marry his high school sweetheart, Barbara Simunovic. He earned his master's degree from Harvard University and his doctorate in geology from Bryn Mawr University.

Dr. Spoljaric joined the Survey as senior scientist in 1965. He retired in 1999. Widely respected by his colleagues and members of the scientific community for his research and contributions to the field of geology, he was the author or coauthor of more than 20 DGS publications.

3. Natural Hazards

DGS Natural Hazards Emergency Response Program

Project Contacts: Stefanie J. Baxter, Kelvin W. Ramsey, and David R. Wunsch

Coordination of DGS activities related to assessing natural hazards and risks associated with earthquakes, floods, and storms, and providing support to emergency managers

A major responsibility of the DGS is to understand natural hazards in the First State that present risks to human life and property. Our Natural Hazards program includes scientific initiatives as well as event-driven advisement to emergency management agencies. DGS is a designated participant in the Delaware Emergency Operations Plan, and provides service to the State Hazard Mitigation Council.

Our most frequent emergency operations activity is storm response. The DGS serves on the DEMA Emergency Response Task Force for flooding, nor'easters, and hurricanes. When storm threats require, DGS staff participate in response efforts at DEMA headquarters to monitor stream and tide gages as well as provide as-needed, real-time advice to New Castle, Kent, and Sussex County emergency managers. A key resource is the Delaware Coastal Flood Monitoring System (CFMS), which provides email and text alerts, as well as web-based inundation maps and elevation profiles of evacuation routes, based on real-time forecasts to communities along the Delaware Bay coast. In addition, DGS continuously maintains storm books for 16 USGS stream gages—13 in Delaware and three in neighboring Pennsylvania—that record the date, time, and flow stage for all significant storms in the region so estimates can be made regarding the severity of flooding based on predicted precipitation amounts from approaching storms.

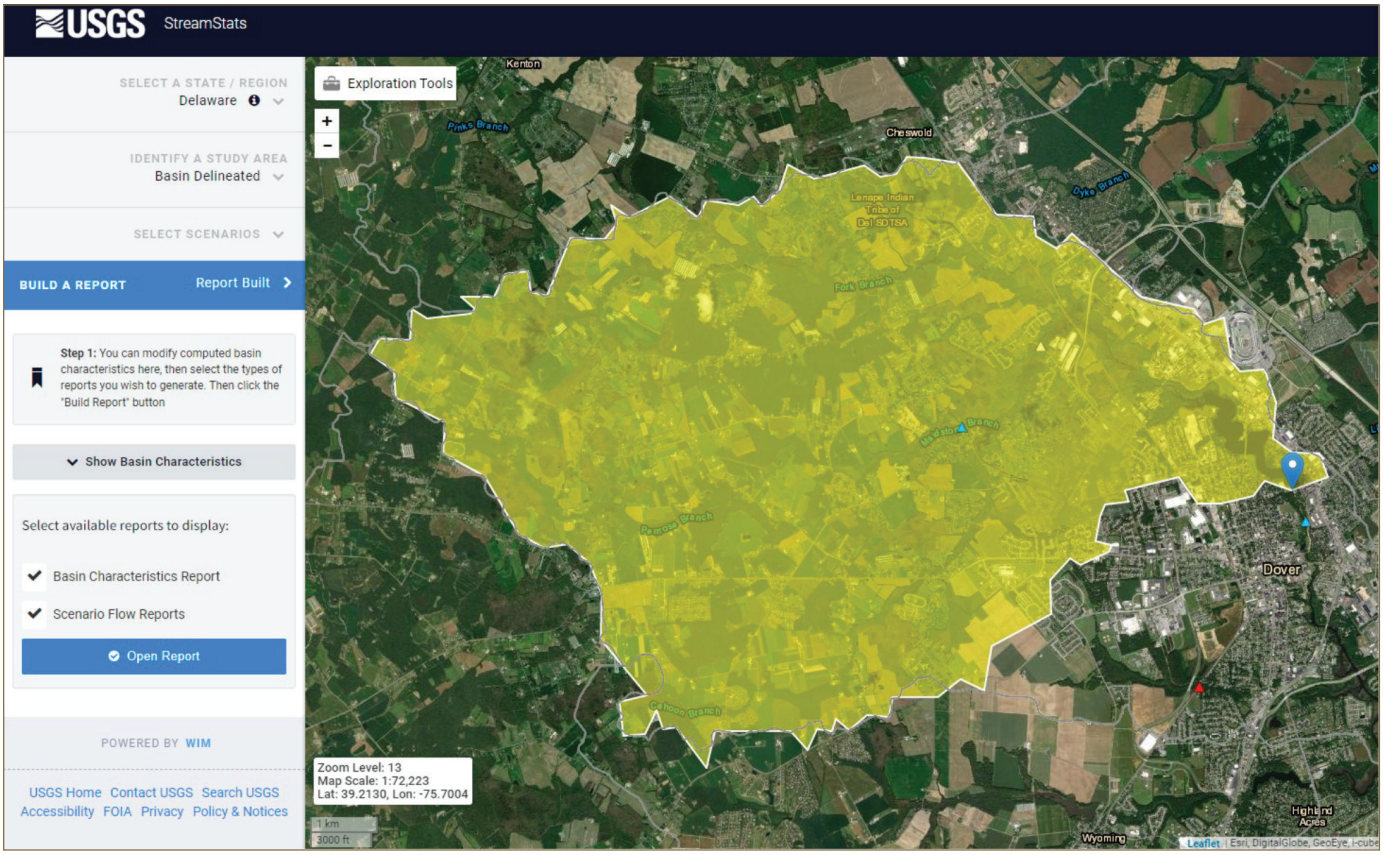
Delaware StreamStats

Project Contacts: Daniel L. Warner and David R. Wunsch

Digital Elevation Model, GIS, and Watershed Analysis to Support Update of USGS StreamStats

The USGS StreamStats program is an online platform for rapidly delineating and characterizing watersheds for any point on any stream in the United States. The program provides end users with estimates on peak and low flows of target streams or rivers, which helps hydrologists, ecologists, and engineers address an array of scientific questions.

StreamStats relies on a set of geospatial data layers for performing its calculations. Over time, these layers may become outdated, or newer, higher-quality layers may



Screenshot of the StreamStats online interface. Pictured is the watershed of Silver Lake in Dover, Delaware. Small triangles on the map indicate current or historical stream gages that were used in building the StreamStats predictive equations.

become available. In Delaware, for example, major changes in land cover have occurred in the past two decades and new elevation data were collected. For the past several years, researchers at the DGS worked in cooperation with the USGS StreamStats team to update these data layers, as well as the equations that StreamStats uses to predict peak and low flows. As of spring 2022, the updated Delaware StreamStats is now active and available for public use. Interested users can visit: https://streamstats.usgs.gov/ss/ and select "Delaware" as their region of interest to use the platform. The associated datasets and reports can be found at: https://www.usgs.gov/search?keywords=delaware+streamstats.

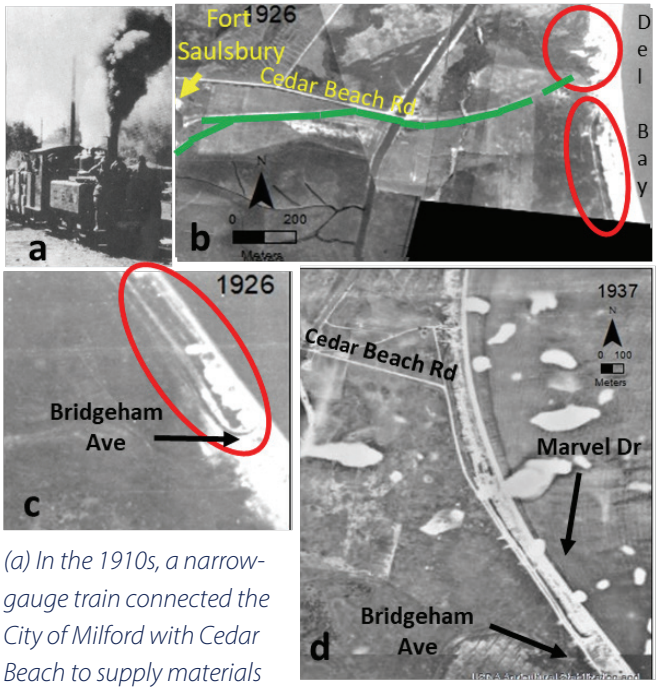
Back-Barrier Flooding in Slaughter Beach, Delaware

Project Contact: Thomas E. McKenna

Providing hydrologic information to develop and implement strategies for a bayside community

Low-lying coastal towns in the eastern U.S. are experiencing an uptick in flooding. Floods result from elevated tides caused by tropical storms, hurricanes, northeasters, precipitation, and, increasingly, nuisance flooding from high spring tides and blow-in tides (also called high-tide flooding or sunny-day flooding). The Town of Slaughter Beach, Delaware, on the Delaware Bay is no exception. Slaughter Beach is on a sandy barrier with an extensive salt marsh separating it from the upland that is about 2 km (1.2 mi) to the west. Key hydrologic features are Cedar Creek, Slaughter Creek, Mispillion River, Delaware Bay, and a dense set of man-made mosquito ditches in the salt marsh. Water from Delaware Bay directly floods the barrier when storm surge and waves breach protective dunes. From the marsh side of the barrier, tidal water from Cedar Creek and Slaughter Creek flow in channels and ditches, then on the marsh platform towards the barrier. A lack of drainage during and after large precipitation events is another cause of nuisance flooding in the northern part of Slaughter Beach. Nuisance tidal flooding is expected to increase in frequency due to sea-level rise (the combination of global sea level rise and land subsidence) and due to increased precipitation.

The hydrology of the area changed drastically after 1849. Modifications included rerouting Cedar and Slaughter Creeks to discharge to the Mispillion River instead of Delaware Bay, digging numerous ditches in the salt marsh adjacent to the town, and mining of sand from the barrier to construct Fort Saulsbury in 1918. The latter is of interest because, in the northern part of Slaughter



(a) In the 1910s, a narrow-gauge train connected the City of Milford with Cedar Beach to supply materials for construction of Fort Saulsbury. (b) and (c) The circled areas shown in these 1926 aerial photographs are interpreted as sand mines that served in construction of the fort. Mining exposed dark-colored mud under light-colored sand. (d) The strip mine is still evident in a 1937 aerial photograph.

Beach, the sand mine was filled with material that has a lower permeability than the beach and dune sand originally on the barrier. Rainwater does not infiltrate as quickly in this lower permeability fill. This explains the ponding after rain events. This is a classic problem in hydrogeology at reclaimed surface mines. It is not unusual for workers to mix construction materials, shrubs, and trees in with the sediment as they place the fill.

As a result of this study, we concluded 1) that the primary tidal forcing that pushes water towards the back barrier comes from Delaware Bay at the mouth of Cedar Creek, 2) a minor component of tidal forcing emanates from Slaughter Creek in the south, 3) tidal water from Cedar and Slaughter Creeks first reaches the back-barrier via tidal channels, first Clarks Gut (north), then Sheps Gut (central), then Todds Gut (south) and old Cedar Creek (central), 4) the time lag for high tide from Cedar Beach Road to the barrier is 1.6 hours at Clarks Gut near Beach Plum Drive, 3.8 hours at Bridgeham Avenue, and 5.4 hours at North Delaware Avenue, and that 5) nuisance flooding occurs after precipitation events greater than 23 millimeters (0.91 inches).

The DGS Support Team

Behind every program and activity is a fantastic support team

June A. Hazewski

Research Technician

June joined the DGS in 2021. One of her major laboratory responsibilities is the processing of sediment samples to isolate fossil pollen and other microscopic fossils. June also performs other standard laboratory operations including sediment analysis and helps manage DGS sample collections. She supports DGS field operations for collection of water levels in monitoring wells and obtaining geophysical logs from recently drilled wells.

Denise T. Heldorfer

Assistant to the Director

Denise is responsible for establishing, managing, and coordinating the integrated fiscal and administrative operations of the Survey. She assists the DGS Director with fiscal management, monitors and reconciles all accounting revenue and expenditures, and administers all DGS grant proposals.

Paul "Steve" McCreary

DGS Well Driller

Steve is a licensed well driller in Delaware whose responsibilities include acquiring all permits from state and local governments, drilling the holes necessary to obtain geologic and hydrologic data, abandoning holes or installing wells in accordance with state laws, and maintaining all DGS heavy equipment, including a CME drill rig. Steve is also responsible for taking and recording water levels for the DGS monitoring well network.

Laura K. Wisk

Administrative Assistant

Laura is the first contact when people call or visit our office, and responds to requests for information. She is responsible for managing DGS mailing lists, distributing publications and newsletters, and managing the inventory of DGS publications. Laura is also in charge of processing payroll records for the DGS student work force and ordering supplies.

Sheng Yao

Computing Support Specialist II

Sheng is the DGS IT specialist who provides network and desktop support, identifies technologies for future implementation, and guides technology cost analysis, system security, and purchasing.

4. Information and Data Dissemination

Online Open Data Access

Project Contact: Lillian T. Wang

DGS research data available online and via web mapping services

The DGS strives to continually improve the way we make our hydrologic, geologic, and other research data available online. Most datasets are available through Delaware First Map (https://firstmap.delaware.gov) as web map services or the DGS website in tabular or GIS data formats. Downloadable data files are distributed in industry standard formats (e.g., zipped, comma-delimited, Excel) while the web mapping services allow for direct access to DGS data via GIS software (e.g., ESRI ArcGIS, Quantum GIS) or website applications (e.g., Google Maps) without the need for downloading data files. Map products are available as Adobe PDF files with source data downloadable separately in GIS format. Published map products in recent years are available as interactive PDFs, allowing the user to switch on/off each map layer embedded in the document. The variety of data sharing methods employed by DGS provides easy access for state agencies, academic research groups, industry, and the public.

Online XML and Mapping Applications

Project Contacts: Changming He and Daniel L. Warner

Delivering DGS data to state agencies and the public using web-based technologies

The DGS participates in the National Groundwater Monitoring Network (NGWMN), a product of the Subcommittee on Ground Water of the Federal Advisory Committee on Water Information. The NGWMN is a consortium of state and local agencies and the USGS that was established in 2013 to create a single point of access for scientists, engineers, policy makers, and the public to view and acquire important physical and chemical data on the nation's groundwater resources.

DGS contributes groundwater levels, lithologic data, and water-quality information from a selected set of wells to the national portal (https://cida.usgs.gov/ngwmn). Data are continuously evaluated for consistency and quality, converted to the national standard formats, and distributed through XML web data services. Existing wells and supporting infrastructure are regularly maintained and new wells are evaluated for possible inclusion in the network. Participation in the network allows users to view Delaware's current status and trends in groundwater quality and availability in a local, regional or national context.

Additionally, DGS distributes many types of data through the Delaware Geologic Information Resource (DGIR), an online application (http://maps.dgs.udel.edu/dgir/draft/) designed to deliver the most commonly available and requested geologic and hydrologic information. The application provides an intuitive and comprehensive toolset for locating, quickly viewing, and downloading geologic and hydrogeologic information. DGIR includes a rich variety of DGS data and products, including point data such as well lithologic logs, geophysical logs, and groundwater levels as well as areal data such as geologic maps, water table depth, and aquifer thickness. DGIR also allows a user to combine DGS-published datasets alongside other external Delaware datasets (e.g., town boundaries, hydrology, roads, watersheds, orthophotography) into a single web-based map interface, with direct access to metadata, data files, and map services. Although the project is currently focused on providing information to DNREC and the Delaware professional geosciences community, the application is open for public use.

PUBLICATIONS

DGS PUBLICATIONS IN PROGRESS

BULLETINS

B 22 Aquifers and Groundwater Withdrawals, Kent and Sussex Counties, Delaware *(in press)*

REPORT OF INVESTIGATIONS

RI 83 Evaluating Impacts of Sea-Level Rise on Groundwater Resources in the Delaware Coastal Plain *(in press)*

RI 84 Mapping Evapotranspiration for 2016 Growing Season Using Landsat 8 Images and Metric Model, Sussex County, Delaware *(in press)*

RI 85 Kent County Groundwater Monitoring Project: Results of Subsurface Exploration and Hydrogeological Studies *(in press)*

RI 86 Kent County Groundwater Monitoring Project: Hydrogeology and Salinization Dynamics of Eastern Kent County *(in press)*

OPEN FILE REPORTS

OFR 56 Early Mesozoic Rift Basins in Delaware: A Review of their Occurrence and an Assessment of their Carbon Potential *(in press)*

GEOLOGIC MAPS

GM 27 Geologic Map of the Elkton, St. Georges, and Delaware City Quadrangles, Delaware

EXTERNAL PUBLICATIONS BY DGS STAFF

Arends, H., Dahl, D., Dejarnett, B.B., Harrison, W.B., III, Honey, J., Johnson, M.R., and **KunleDare, M.,** 2021, Directory of Public Repositories of Geological Materials: U.S. Geological Survey data release, https://doi.org/10.5066/P9JMGRB3. (ArcGIS Online Web Service derived from 10.5066/P9JMGRB3 - Johnson, M.R., 2021, Public Geological Materials Repository Directory: U.S. Geological Survey - National Geological and Geophysical Data Preservation Program (NGGDPP), https://doi.org/10.48637/YQ3S-FD26.

Peters, C.N., Kimsal, C., Frederiks, R.S., Paldor, A., **McQuiggan, R.,** and Michael, H.A., 2022, Groundwater pumping causes salinization of coastal streams due to baseflow depletion: Analytical framework and application to Savannah River: Journal of Hydrology, v. 604, 127238, 12 p., https://doi.org/10.1016/j.jhydrol.2021.127238.

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Troia, Gabrielle, Stamps, D. Sarah, Hensel, Philippe, Lotspeich, Robert R., McCoy, Kurt, Moore, William B., Nash, Jonathan, Layton, Janelle, Hippenstiel, Ryan, **McKenna, Thomas,** Andreasen, David, Lokken, Scott, Geoghegan, Charles, Covington, Scott, Winn, Neil, Quinn, Heather, Staley, Andrew, Ulizio, Thomas P., Williams, Karen, 2020, Chesapeake Bay Vertical Land Motions 2019, The GAGE Facility operated by UNAVCO, Inc., GPS/GNSS Observations Dataset, https://doi.org/10.7283/M6D3-T837.

Troia, Gabrielle, Stamps, D. Sarah, Hensel, Philippe, Lotspeich, Robert R., McCoy, Kurt, Moore, William B., Nash, Jonathan, Hippenstiel, Ryan, **McKenna, Thomas,** Andreasen, David, Lokken, Scott, Geoghegan, Charles, Covington, Scott, Winn, Neil, Quinn, Heather, Staley, Andrew, Ulizio, Thomas P., Carr, Joel, Walters, David, Kronebusch, Madeline, 2022, Chesapeake Bay Vertical Land Motions 2020, UNAVCO, GPS/GNSS Observations Dataset, https://doi.org/10.7283/98DG-AJ14

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DGS Service to Professional Societies, Boards, and Committees

American Association of Petroleum Geologists Committee on Preservation of Geoscience Data

American Geophysical Union

American Geosciences Institute, Executive Committee

Association of American State Geologists

Association of American State Geologists Foundation

Center for the Inland Bays, Board of Directors

Center for the Inland Bays Scientific and Technical Advisory Committee

Cushman Foundation for Foraminiferal Research, Board of Directors

Cushman Foundation for Foraminiferal Research, Chairperson for Student Awards Committee

Delaware Department of Natural Resources Source Water Protection Program Citizen and Technical Advisory Committee

Delaware Emergency Management Agency State Hazard Mitigation Council

Delaware Emergency Management Agency Technical Assessment Center Group

Delaware Geographic Data Committee

Delaware Geologic Mapping Advisory Committee

Delaware Leaking Underground Storage Tank Committee

Delaware River Basin Commission Regulated Flow Advisory Committee

Delaware State Board of Geologists

Delaware State Names Authority

Delaware Water Infrastructure Advisory Council, Wastewater Subcommittee

Delaware Water Resources Center Advisory Panel

Delaware Water Supply Coordinating Council

Delaware Water Well Licensing Board

Directory of Public Repositories of Geological Materials Working Group

Federal Geologic Mapping Advisory Committee

Geological Society of America, Academic and Applied Geoscience Relations Committee

Geological Society of America, Hydrogeology Division, Liaison to AGI

International Continental Scientific Drilling Program

Murderkill River Monitoring and Modeling Workgroup

National Association of State Boards of Geology

National Association of State Boards of Geology Council of Examiners

National Geologic Map Database, Geologic Map Schema Working Group

National Ground Water Association, Water Management Subcommittee

National Index of Borehole Information Working Group

National Petroleum Council

New Castle County Resource Protection Area Technical Advisory Committee

River Master Advisory Committee

River Master Decree Party Workgroup

Sussex County Source Water Protection Technical Advisory Committee

University of Delaware Engagement Council of Public Engagement

University of Delaware Ph.D. and M.S. Student Committees

University of Delaware Department of Earth Sciences Chairperson Search Committee

ANNUAL REPORT OF PROGRAMS AND ACTIVITIES | 2021-22

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