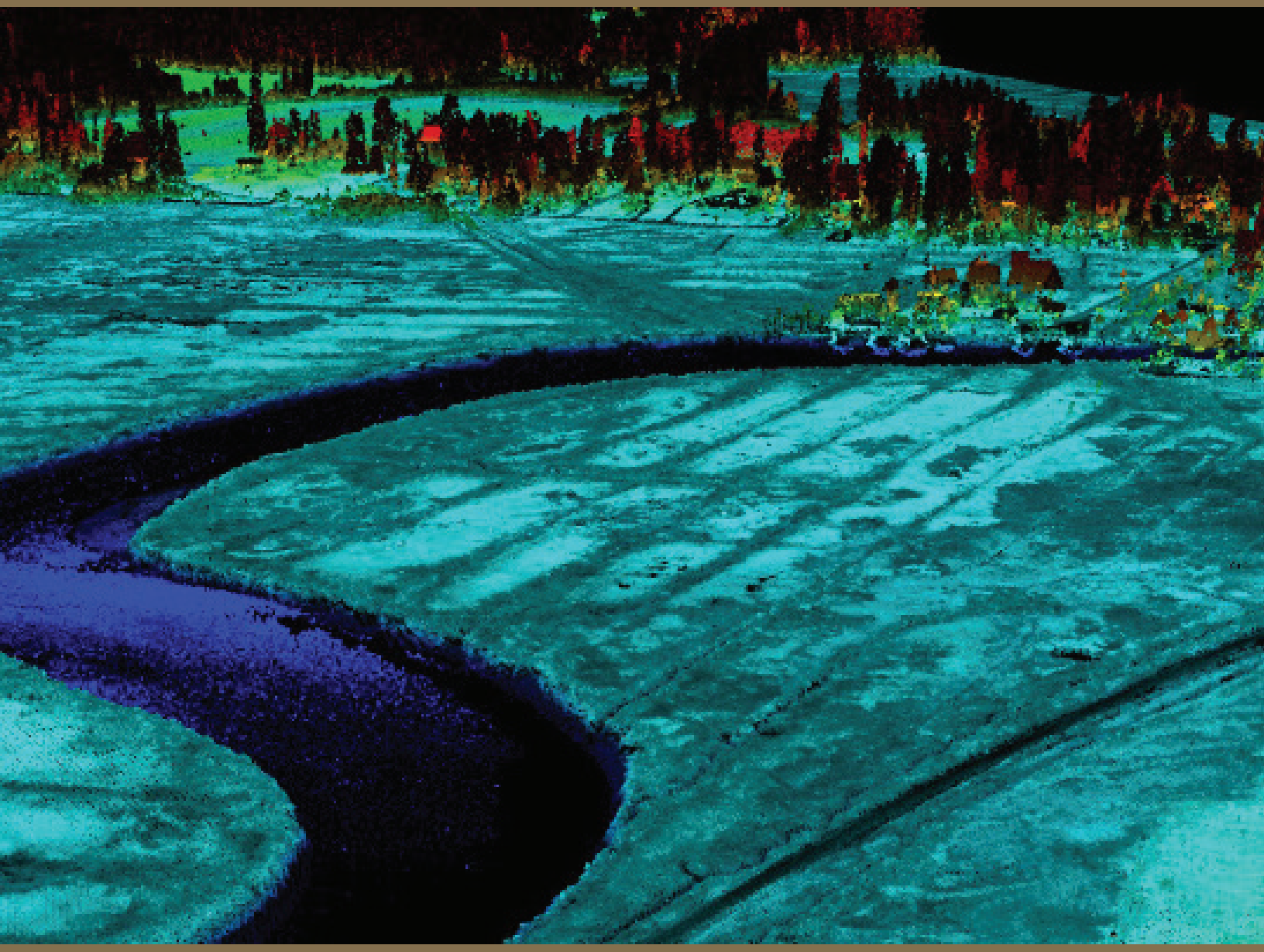
Delaware Geological Survey

ANNUAL REPORT OF PROGRAMS & ACTIVITIES



2019-2020

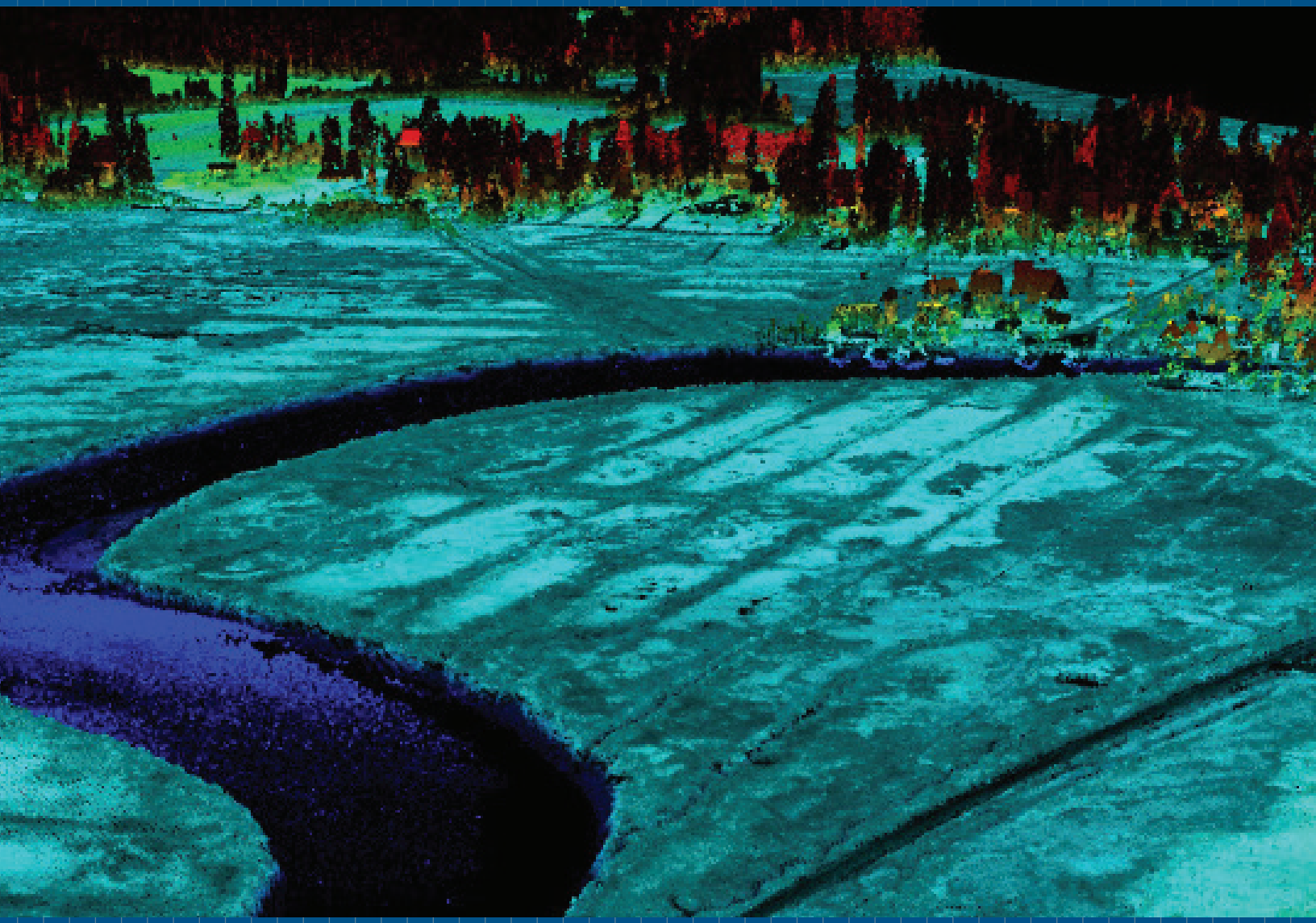


Image created from a LiDAR point cloud of Bowers Beach, Delaware, colorized based on elevation and return intensity, which is related to the surface reflecting the laser pulse from the LiDAR instrument.

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.

Delaware Geological Survey

DGS Building
257 Academy Street
University of Delaware
Newark, DE 19716-7501

www.dgs.udel.edu

Message from the Director

What a difference a year makes. Last year, as I composed this section of our Annual Report of Programs & Activities, I reported on the progress and improvements we had made at DGS over the previous five years since publishing our first issue of the Annual Report. I also highlighted our forthcoming plans for strategic planning to steer the DGS forward over the coming years. Then, in March, COVID-19 arrived on the UD campus, reminding us that the best laid plans can be disrupted by events out of our control. Delaware's first documented cases of the viral infection were identified with researchers who worked at UD's Integrated Science and Engineering (ISE) Lab, which is adjacent to the DGS building. So in essence, we were situated near Delaware's "ground zero." Soon after this discovery, the University sequentially closed down residence halls and classrooms, thereby sending all students home, and directing all faculty and non-critical staff to work remotely. With DGS being in the shadow of ground zero, we anticipated UD's closure in advance, so we immediately focused our attention on maintaining continuity of operations, and mitigating our critical IT needs, including scrambling to find enough portable computers to enable staff to connect remotely with high-speed access to DGS systems, if needed. Our proactive steps proved to be prudent and effective when the University formally closed down, as we only suffered a minimum loss of continuity with regard to maintaining communications among staff, and access to DGS in-house databases, shared drives, and other relevant systems.

However, DGS research depends on collecting geologic and hydrologic field data, and limited access to our labs, field sites, and equipment became a major impediment. Within weeks of the shutdown, we successfully petitioned the University to allow select staff to continue to maintain field equipment and collect data. It is important to highlight that the safety and well-being of staff was our highest priority, and we had to develop safety procedures and protocols that needed approval from the University before we could proceed. In addition, no DGS staff were required to perform field activities or perform work that risked human contact if they were uncomfortable, or had health conditions that could expose them to elevated risk.

In early June, the University announced its Phase 1 reopening, which allowed DGS staff to conduct limited lab and field activities that included drilling, coring, and the installation of monitoring wells. As of this writing, careful planning and project management has allowed DGS to maintain our work flow and meet our responsibilities for grants and contracts, as well as provide the data and information that our stakeholders have come to rely on. I have to commend the resiliency, creativity, and dedication of DGS employees who carefully worked around cumbersome protocols, social distancing measures, and operational inefficiencies (such as taking separate vehicles to accomplish field work) in order to minimize impacts to our ongoing projects and operations.

So what does the future hold? That is a challenging question, as we are now entering the flu season, which is when most experts expect a concomitant increase in COVID-19 cases. So again, we may need to adjust operations to meet protocols that constrain our ability to conduct our work, or limit our stakeholders' access to the DGS building to view hard files, geologic cores, and samples. We certainly appreciate your patience as we try to maneuver through these strange and challenging times. We are all hopeful that science will again come to society's rescue by creating a safe and viable vaccine in a timely manner—which may be the only remedy that gets us back to normalcy. In the interim, please check the DGS website regularly for information and updates related to our activities, and access to our resources. And you can always reach out to individual staff, or contact DGS through our general email address: delgeosurvey@udel.edu if you have specific questions or needs. And please, stay healthy out there!

David R. Wunsch

David R. Wunsch
Director and State Geologist

1. Water Resources

Delaware Groundwater Monitoring Network

Project Contacts: Changming He, A. Scott Andres, Rachel W. McQuiggan, and Thomas E. McKenna

DGS currently monitors groundwater levels 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, but 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. The DGS has operated a network of observations wells for more than 50 years, which allows us to monitor groundwater throughout the state. We have been working for nearly 20 years to replace wells, often poorly located and not constructed for monitoring purposes, with strategically located, designed, and instrumented monitoring wells. A modern database-management and data-distribution system serves the DGS and stakeholders.

Long time-series of water levels in major aquifers inform water-resource management through analyses of aquifer responses to pumping, climatic variability, drought, seawater intrusion, and interaction with streams and their ecosystems. The number and placement of wells and data-recording instruments that constitute the network are routinely reassessed in order to be responsive to changing water demands and environmental issues. Automated instrumentation that measures salinity has been incorporated into the network to monitor the effects of sea-level rise on water resources.

Our database contains over 34 million water level, temperature, and salinity records, and recent upgrades to our monitoring equipment now allow us to add more than 1.3 million new records per year. A web interface that provides self-service access to over 440,000 manually measured and daily-average data has been in operation for the past decade. These data serve groundwater flow models used to answer resource sustainability questions, evaluations of water supply conditions for public and agricultural water users, and assessments of groundwater-limited habitats and land uses.

The infrastructure and funding from DGS and the Delaware Department of Natural Resources and Environmental Control (DNREC) has allowed DGS to leverage additional federal funds. For example, we have received five

grants from the U.S. Geological Survey (USGS) to participate in the National Ground-Water Monitoring Network (NGWMN), a consortium of 35 state and local agencies that contribute expertise and data to a national program that distributes data from an Internet portal. Monitoring infrastructure has brought collaboration and additional resources from Project WiCCED (see below). These extra resources have permitted DGS to expand our services into collecting and testing samples for water quality and distributing those data to stakeholders, as well as improving our monitoring instrumentation and data analysis capability.

Project WiCCED

Project Contacts: A. Scott Andres and Rachel W. McQuiggan

Project leverages other DGS monitoring to investigate groundwater salinization and eutrophication

DGS staff members Rachel McQuiggan and Scott Andres 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.

Andres is a project co-leader in two research experiments. One, with Dr. Holly Michael and doctoral student Mary Hingst of the UD Department of Earth Sciences, involves studying salinization of groundwater through direct monitoring and numerical simulation. The focus of this project is on the area east of Dover along Route 9 and overlaps with both the Groundwater and Saline Water Intrusion Monitoring Network Infrastructure Improvements: Kent County, Delaware, and the Delaware Groundwater Monitoring Network projects. Dr. Changming He of the DGS is advising Ms. Hingst's work.

The second experiment, with Dr. Deb Jaisi of the UD Department of Plant and Soil Science and the Delaware Center for the Inland Bays (CIB), involves studying impacts of plant nutrients on the Murderkill River, the Indian River, and associated estuaries. Data from automated high-frequency sensor observations at the Indian River site will assist DNREC and CIB address critical eutrophication and resource management problems. Both of these experiments build upon the success of multiple previous studies.

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

Groundwater and Saline Water Intrusion Monitoring Network Infrastructure Improvements: Kent County, Delaware

Project Contacts: A. Scott Andres, Rachel W. McQuiggan, Changming He, and Thomas E. McKenna

Evaluating long-term monitoring data and tracking groundwater and surface-water conditions in an area that has significant water availability issues

The DGS is nearing the end of a multi-year project in Kent County where new water-monitoring infrastructure was installed and baseline data are currently being collected. The project was recommended in 2015 by the Delaware Water Supply Coordinating Council and funded in FY2017 with a DNREC Bond Bill appropriation. To date, more than 8,700 linear feet of monitoring wells have been installed at 15 sites, over 6,000 linear feet of geophysical logs, 420 hydraulic tests, more than 7 million water pressure observations, over 1 million salinity observations, and more than 90 groundwater-quality samples have been collected, cataloged, evaluated, and interpreted. The project is being conducted in cooperation with the Water Supply Section of DNREC. Our partners at the USGS are providing streamgaging services.

Expansion of water-monitoring infrastructure in Kent County has filled critical gaps in the resources needed to manage water in an area experiencing new pressures from a growing population and changing economic and environmental conditions. Significantly, irrigation practices have changed how we use water since regional studies were completed in the 1960s and 1970s. Through this project, we have developed detailed quantitative information on aquifers and confining beds, which has vastly improved the computer methods used to simulate, analyze, and predict the availability of groundwater and the impacts of increased groundwater use. Computer simulation of the major water-supply aquifers in Kent County is underway, and project data have informed identification of links between tides, storms, water use practices, and saline water intrusion.

The first two reports from this project are available as DGS Open File Reports 52 and 53 with associated DGS digital data products. A third report, DGS Report of Investigations No. 85, is in the final stages of publication.

Delaware Stream and Tide Gage Program

Project Contacts: Stefanie J. Baxter, Kelvin W. Ramsey, and John A. Callahan

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.

USGS tide gage on Jefferson Creek at South Bethany, Delaware. Photo credit: DGS staff.

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 three-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 Contacts: Rachel W. McQuiggan and A. Scott Andres

Monitoring transport of salt in groundwater to evaluate the risks of winter deicing practices on groundwater

In cooperation with DelDOT, the DGS is conducting a study to characterize the fate and transport of deicing salt in groundwater. In particular, we are characterizing the impacts of deicing on groundwater at a roadside site and a DelDOT-managed stormwater infiltration basin. 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.

The DGS has been operating and maintaining automated, high-frequency stormwater flow and salinity, as well as groundwater pressure, temperature, and electrical conductivity/salinity systems at two sites. A roadside site is located near Summit Bridge and is co-located with a pavement runoff and soil amendment project established by Dr. Paul Imhoff of the University of Delaware Department of Civil and Environmental Engineering. The other

Member of the DGS staff downloading information from an automated data collection system.

DGS staff measures water levels and accesses automated data loggers at a monitoring well cluster in the middle of a stormwater infiltration basin along Route 301.

site is a stormwater infiltration basin adjacent to the recently constructed Route 301.

Data from testing groundwater samples, stormwater and groundwater sensors, and subsurface geophysical surveys allow us to develop and test conceptual models of the movement of water and salt from drainage networks into groundwater. Key to the effort has been the establishment of empirical relationships between inexpensive field measurements of electrical conductivity/salinity and more time consuming and expensive laboratory-measured chloride concentrations.

Monitoring at the two sites will continue through another winter season and an additional round of post-winter groundwater sampling will help refine our conceptual model to account for salt movement and flow that spans multiple seasons. Data from this work will support development of statistical and simulations tools to evaluate the risks of deicing on groundwater.

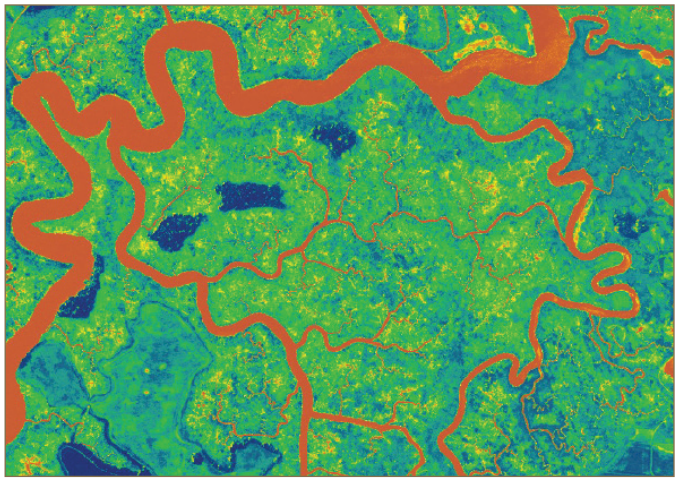
Morphology and Tidal Inundation of Tidal Wetlands in the Delaware Estuary

Project Contacts: Thomas E. McKenna, Daniel L. Warner, and John A. Callahan

Improving our understanding of Delaware tidal salt marshes with respect to coastal flooding and sea-level rise

An expanse of tidal wetlands fringes the Delaware Estuary and provides Delaware, Pennsylvania, and New Jersey with abundant habitat for indigenous and migrating plants and wildlife, biogeochemical cycling of nutrients, preservation of water quality, flood hazard mitigation, and recreational services. However, the tidal wetlands, in particular the saltmarshes, can only survive in a narrow band of elevation relative to the tidal water levels and are continuously degraded due to land use practices, coastal development, waves and inundation from coastal storms, and sea-level rise. Understanding the dynamic system of marsh hydrology is critical to assessing the current health of the marsh and modeling its behavior under future conditions.

The primary goal of this study is to improve our understanding of the hydrodynamic behavior of the tidal saltmarshes in the Delaware Estuary. Marsh elevation exerts a primary control on marsh hydrology. Marsh platform elevations were determined by correcting for the positive LiDAR-bias present in the bare-earth digital elevation models (DEMs) of densely vegetated areas such as saltmarshes. The resulting set of mini-DEMs for each marsh will be available publicly from the DGS website. Using modeled tidal water surfaces and the "corrected" mini-DEMs, we will compute the inundation frequency, extent, and spatial metrics related to the vulnerability of Delaware Bay saltmarshes in Delaware.



Normalized Difference Vegetation Index (NDVI) of Blackbird Creek estuary used as a variable to develop correction factors for the DEM elevations in the marsh.

Results from this work will help coastal communities prepare in real-time for upcoming storm events and long-term resiliency planning for sea-level rise. This project was funded by Delaware Sea Grant and the DGS. Land access was graciously provided by Delaware Wild Lands, DNREC Division of Fish and Wildlife, U.S. Fish and Wildlife Service, and Isaac Burrows.

Blue Carbon Storage in Delaware Coastal Wetlands

Project Contacts: Daniel L. Warner, John A. Callahan, and Thomas E. McKenna

Studying blue carbon storage in coastal wetlands to help inform state policy regarding sustainability targets

Coastal wetlands play a major role in the global carbon cycle because they are highly effective at removing carbon from the atmosphere and trapping it in biomass and soil. Wetland vegetation grows rapidly but decomposes slowly in anoxic and saline soil layers, which leads to an accumulation of stored organic carbon known as "blue" carbon. However, estimating the blue carbon storage of coastal ecosystems is challenging, and the fate of this stored carbon is uncertain due to sea-level rise and increases in tropical storm activity.

The objective of this study is to model spatial patterns of soil organic carbon in two coastal wetlands in Delaware using techniques in the emerging fields of digital soil mapping and machine learning. These techniques use statistical models to relate in situ point observations to spatially continuous remote sensing and vegetation cover datasets, allowing researchers to scale point observations to larger spatial domains.

A one-meter core of coastal wetland soil with tall marsh grasses in the background.

Point observations consist of loss-on-ignition and elemental analysis data from soil samples distributed across different marsh vegetation types, microtopographic features, and positions along a hydrologic network. Once data are collected, a variety of statistical models will be evaluated for their predictive ability to extrapolate point data of carbon density to the entire marsh. Model uncertainty will be propagated to constrain estimates of carbon storage. This work will build upon current projects designed to investigate inundation patterns of Delaware's coastal marshes to help identify areas that are highly vulnerable to carbon loss. This work may help inform state policy on meeting sustainability targets and guide future research into coastal blue carbon dynamics.

Impact of Channel Dredging on the Climate-Growth Relationship in an Atlantic White Cedar Freshwater Tidal Wetland

Project Contact: John A. Callahan

Utilizing channel dredging to provide insight into forested wetland response to sea-level rise

Coastal storms, sea-level rise, and land development and degradation threaten the health and services of many ecosystems along the Delaware Bay coast. Forested wetlands along coastal tributaries are particularly vulnerable as increases in salinity, high water tables, or changes in hydrology can cause significant tree die-off or suppressed growth. From 1992 to 2007, palustrine forests experienced the largest decrease in area coverage of any wetland type in the state. Researchers from the DGS and Wesley College investigated a swamp forest of Atlantic White Cedar (AWC) off Cypress Branch, a tributary of the St. Jones River, that died in the mid-1900s shortly after a major straightening and dredging project was completed in the 1920s. Freshwater wetlands with AWC, once prominent up the eastern coast of the United States of America, are now vanishing due to salinity intrusion and anthropogenic landscape alterations.

Annual tree ring width and growth suppression event chronologies were developed from the dead AWC trees and compared to annual and seasonal temperature, precipitation, and other climate variables during the periods before (1895-1920) and after (1928-1957) the dredging disturbance. The AWC trees died prematurely at an average age of 50.7 years. Although this research is ongoing, preliminary results show differences in the climate-growth relationship between the pre- and post-disturbance period, indicating a shift in climatic drivers of growth and growth suppression after the dredging and subsequent salinization. This project is important for an area such as Delaware that is experienc-

ing high rates of relative sea-level rise as it utilizes an anthropogenic disturbance event to provide insight about forested wetland response to potential future salinization.

DGS Service to the Delaware River Master Advisory Committee

Activity Contacts: David R. Wunsch and Stefanie J. Baxter

Ensuring Delaware is represented in Decree Party discussions and negotiations

A U.S. Supreme Court decree in 1954 settled an interstate water conflict between New York City (NYC) and the states of New York, New Jersey, Pennsylvania, and Delaware. The decree allows NYC to transfer up to 800 million gallons of water per day out of the Delaware River Basin to provide water supply to the city. The decree also created a body for governance, the River Master Advisory Committee, that consists of five Decree Party Principals (one from each of the states that are party to the decree, and NYC) who must be unanimous in their votes for all decisions related to water allocations, release quantity schedules, and agreements. By state statute, the Delaware State Geologist is the state's designee and represents the Governor on the Delaware River Master Advisory Committee. The State Geologist, with support from DGS staff, deals with the complexities of interstate water management issues regarding one of the largest and most complex water-supply systems in the world. The Decree Party Principals often address issues involving conflicting water needs, such as reducing releases to potentially mitigate flood risks, while near simultaneously being asked to increase release quantities to provide thermal relief for cold-water fisheries and recreational opportunities.

In October 2017, the Decree Parties committed to a long-term agreement that balances the myriad interests connected to the Delaware River. The 10-year program protects public health for millions of Americans by sustaining their supplies of high-quality drinking water. The agreement also expands efforts to enhance flood attenuation and support the outdoor recreation economy of the upper Delaware River through the protection of its natural ecology and wild trout fishery. The new agreement also requires the Decree Parties to pursue a number of scientific studies related to salinity intrusion in the lower Delaware River, the calculation of water available to be released downstream of New York City's reservoirs, and other topics related to water management in the basin.

Each year the Advisory Committee strives to hold an in-person Annual Meeting, where the principals have an opportunity to discuss business in an informal atmosphere, as well as conduct field visits to view infrastructure that is germane to water management issues in the meeting host's region of the Delaware River Basin. The DGS hosted the Annual Meeting for the first time on October 11-12, 2019, which was held at the DGS building on UD's campus. The meeting also included a field trip that incorporated excursions to an inflatable bladder dam on the White Clay Creek operated by Suez Water Delaware, which is used to control pool levels and protect their source-water intakes from salt-water infiltration during high tides. The group also visited the City of Newark's water supply reservoir, which is a prime example of the investments made in northern Delaware to ensure viable water supplies during times of drought. Meeting attendees included the Decree Party Principals and support staff from the four basin states and New York City, the Delaware River Master from the U.S. Geological Survey, and DGS staff. This meeting was a resounding success, and provided DGS a prime opportunity to showcase water management issues in the lower Delaware River Basin, such as ensuring adequate flows of fresh water in the Delaware River to provide for water supply and ecological needs, the prevention of saltwater intrusion into aquifers and the upstream advancement of the saltwater front in the Delaware Estuary.

An inflatable dam helps to control salinity near the intake of SUEZ Water Delaware.

Attendees of the Advisory Committee Annual Meeting enjoyed a tour of the City of Newark Reservoir, hosted by Water Operations Superintendent, Mark Neimeister.

2. Geology & Mapping

Early Mesozoic Buried Rift Basins in Delaware and Their Carbon Storage Potential

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

Study suggests buried rift basins may occur in Delaware with adequate potential resources for carbon storage

A study was concluded this year that re-examined the evidence for buried rift basins under the Delaware Coastal Plain. These basins, which are projected to occur thousands of feet below the land surface, represent ancient rift valleys formed approximately 140 to 250 million years ago as North American and north Africa were torn apart by global tectonic forces. We re-examined the idea of these basins as part of our work for a regional assessment of geological carbon storage potential by the Midwest Regional Carbon Sequestration Partnership.

Using geophysical surveys of the Middle Atlantic region, previous studies postulated that Delaware lies along the trend of a series of buried rift basins. Some rift basins, such as the Newark Basin of Pennsylvania, New Jersey, and New York, can be studied at the land surface. Other basins are deeply buried but known from geophysics and deep drilling, such as the Taylorsville Basin of Virginia and Maryland. Although seismic, gravity, and magnetics data suggest that rift basins extend beneath Delaware, no wells have been drilled deeply enough to reach them.

This project has re-evaluated buried rift basins by integrating newer geophysical data with older geophysical and geological data, previously published interpretations, and comparisons with similar exposed and buried rift basins. The findings support the plausibility of such basins under southern Delaware and provide new insights into their extent, tectonic evolution, and geometries. Updated delineation of the largest of these basins, the Queen Anne Basin, traces it from Maryland to southern New Jersey and suggests it is larger than previously recognized. The data also support the existing concept of two nearby smaller basins, the Greenwood and Bridgeville basins. Comparisons to other rift basins in the region suggest that the Delaware basins contain fluvial and lacustrine conglomerates, sands, and silts well suited to carbon storage, as well as interbedded shales that could act as seals. Although more deep subsurface data are required for complete characterization, this preliminary reassessment suggests that deep rift basins hold promise for carbon storage in Delaware.

Delaware Critical Minerals Data Inventory Project

Contacts: Mojisola A. KunleDare, Peter P. McLaughlin, William S. Schenck, and Kelvin W. Ramsey

NGGDPP-funded project mines, compiles, and preserves data on possible occurrences of critical minerals in Delaware

With the support of the USGS National Geological and Geophysical Data Preservation Program (NGGDPP), the DGS completed a project to mine and preserve data on known occurrences, extraction, and future potential of critical minerals in Delaware. Data products and maps were compiled for this project and provided to the NGGDPP, documenting the findings and providing the USGS with data on critical minerals derived from outside their organization. The compilation of the data holdings supports the USGS "process of identification and prioritization of focus areas for critical minerals in the U.S. by the Earth Mapping Resources Initiative (Earth MRI) Program."

The DGS also participated in a USGS eastern regional workshop to define focus areas for Earth MRI data acquisition. An initial assessment of the list of critical minerals suggested that at least a dozen are geologically likely or possible to occur in Delaware, with most occurrences expected to be in pegmatites and ultramafic rocks in the Piedmont region of northern Delaware and as a component of sands in the Coastal Plain region south of the Interstate 95 corridor. The results of the project provide up-to-date documentation of available data and information related to the geology, occurrence, location, composition and accessibility of possible resources and deposits of any of the identified critical minerals present in Delaware.

Products include spreadsheets and GIS dataset compilations of specific localities and broader areas of known critical mineral occurrence, borehole data documenting the depth to basement rocks, and references for sources of the information. This ensures that these data and information are available to inform the nationwide effort to secure the supply of critical minerals.

Atlantic Outer Continental Shelf Sample and Data Repository

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

NGGDPP-funded project preserves valuable cores and data and helps maintain and enhance stakeholder access

The DGS Atlantic Outer Continental Shelf (OCS) Sample and Data Repository is a valuable collection of all the remaining geological samples from the stratigraphic test and exploration

Core 9 from COST G-2 showing an example of reorganization work. Cores laid out in the original box (left) then reassembled and reboxed (right).

wells drilled offshore of the U.S. East Coast between 1977 and 1984. The repository is an important resource for stakeholders from government agencies, universities, consultants, industry, and the general public. A review of holdings at the start of the 2015-2018 multi-organization Middle Atlantic Offshore Carbon Storage Resource Assessment Project (MAOSCRAP) revealed that the core collection was in poor condition and in need of preservation.

Systematic inventory, reorganization, and preservation of the collection was begun as part of MAOSCRAP and continued as part of projects supported by the National Geological and Geophysical Data Preservation Program (NGGDPP). This work prioritized cores from the Continental Offshore Stratigraphic Test (COST) wells because of their value in representing the most complete stratigraphic records of the subsurface geology of the Atlantic OCS.

Last year, archival and sampling sets of cores were created for the COST G-2 well in display-ready boxes fitted with custom foam inserts, representing the fourth COST well preserved by the DGS. Identification of archive material and initial reorganization for a fifth COST well, GE-1, was also completed. The resulting preserved collections now comprise an archival set of 90 boxes of the most complete core section and a working set of 62 boxes of ordered and repackaged leftover items.

In addition, a set of poorly documented sample materials found within the collection were researched and determined to come from offshore research boreholes drilled in 1967 for the Atlantic Slope Project by the M/V Caldrill. Eighteen boxes of core materials, 11 boxes of microscope slides, and 1 box of microfossil residues were inventoried and integrated into the repository. The results of this project ensure that irreplaceable, geologically significant samples and data are securely preserved for the future.

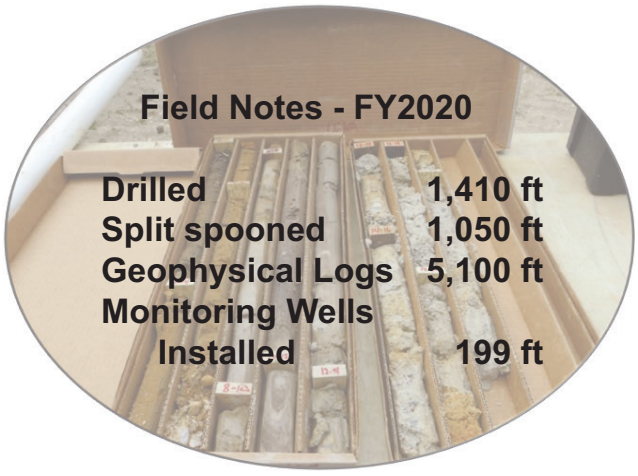
Delaware Geologic Mapping Program

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 Wilmington South and Delaware City Quadrangles. These quadrangles were 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 2021



Delaware Offshore Sand Resources

Project Contacts: Kelvin W. Ramsey and C. Robin Mattheus

Identifying sand resources for coastal resiliency and restoration projects

The DGS partnered with the Bureau of Ocean Energy Management (BOEM) in the exploration and identification of offshore sand resources for beach replenishment projects. This endeavor was prompted by the ongoing demand for sand resources and the depletion of resource areas in state waters off Delaware. Targeted areas of exploration funded by BOEM are situated in federal waters. The DGS has taken the lead in identifying which geologic units have the greatest potential for sand suitable for beach replenishment. This research led to a new, offshore geologic map, which utilized sediment-core information and geophysical data to map surface geology across the inner continental shelf. Efforts to organize more localized coring activities, designed to fill data gaps and refine sand-volume estimates, are currently underway, with potential collaboration with the U.S. Army Corps of Engineers (Philadelphia District), the DNREC Division of Watershed Stewardship, and BOEM.

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

A number of processes change sea-surface and local land-surface elevations in coastal Delaware. The rise in the sea-surface elevation is relatively well known, but the land subsidence component is still poorly constrained. Relative sea-level rise along the coastlines of the northern Delmarva Peninsula is about two times higher than the global rise of 1.7 mm/year over the last century. This higher rate is primarily due to the land subsidence component of relative sea-level rise. In the early 1970s, the National Geodetic Survey (NGS) estimated land subsidence in Delaware based on a regional high-precision releveling survey (the most accurate way to determine subsidence). More recently, in 2016, land subsidence was estimated using data from GPS Continuously Observed Reference Station (CORS) sites. For unknown reasons, the 2016 subsidence estimates are much less than the NGS reported rates. This project investigates land subsidence using geodetic-leveling data available from NGS for the period 1932 to 2016. We are also developing a plan for monitoring

DGS staff teaching a lesson on GPS to future geologists at Bombay Hook National Wildlife Refuge in Delaware.

subsidence based on GPS techniques and searching for corroborative evidence of subsidence via visual changes and/or detailed elevation surveys of old infrastructure. This project is funded by DNREC Coastal Programs and DGS.

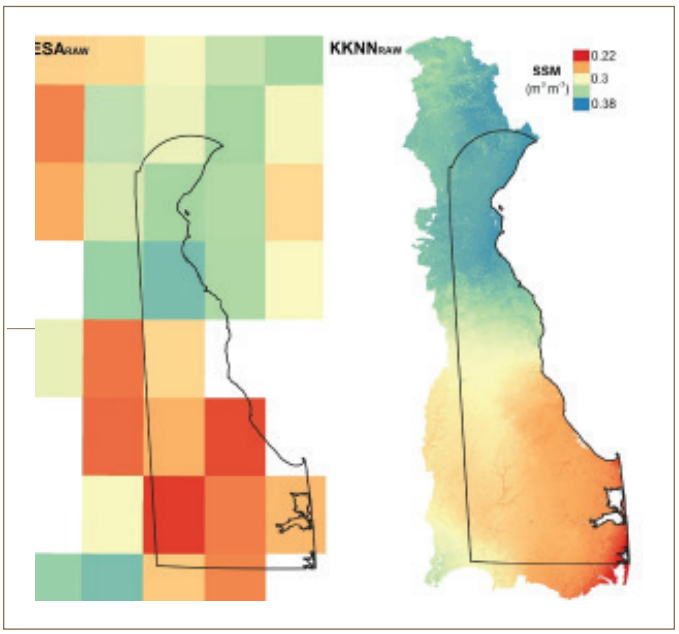
Downscaling Satellite-Derived Soil Moisture Datasets Based on Landscape Features

Project Contacts: Daniel L. Warner, John A. Callahan, Mario Guevara (external), Rodrigo Vargas (external)

Researching soil moisture predictions may yield useful daily datasets for agricultural communities

Moisture content in the surface layers of the soil is a critical environmental variable that influences plant health, soil-atmosphere greenhouse gas exchange, and surface-water hydrology. The importance of surface soil moisture and the need for reliable datasets over large areas has driven advances in the use of satellite microwave imagery for estimating soil moisture at regional to global scales. However, surface soil moisture is highly variable both in space and in time due to numerous factors, such as land use, soil type, elevation slope, and precipitation. Unfortunately, current remote sensing technology limits our ability to measure surface soil moisture at the high temporal (i.e., daily) and spatial resolution (i.e., < 1 km) needed for many accurate water and natural resource applications.

Researchers from DGS and the University of Delaware Department of Plant and Soil Science are investigating a potential methodology for downscaling a remotely sensed soil moisture dataset published by the European Space Agency's (ESA) Climate Change Initiative. The dataset consists of daily soil moisture maps with global coverage but very low spatial resolution (27 km). Using the ESA datasets, terrain data, and daily meteorological information, the DGS team built a machine learning model to predict soil moisture at 100-meter resolution across Delaware and its neighboring watersheds. The predictions of both the statistical model and ESA datasets were independently validated against a ground network of soil moisture sensors. Across the study region, the model performed better matching ground observations with errors 8 to 27 percent less than the ESA dataset, while providing surface soil moisture predictions at a resolution relevant to the landscape scale. Future efforts may yield useful daily datasets of surface soil moisture for agricultural and scientific communities.



An example of the raw ESA soil moisture dataset (left) and a dataset generated by the DGS model (right) using a bootstrapped kernel K-nearest neighbors algorithm.

3. Natural Hazards

DGS Natural Hazards Emergency Response Program

Project Contacts: Stefanie J. Baxter, Kelvin W. Ramsey, John A. Callahan, 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 or 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.

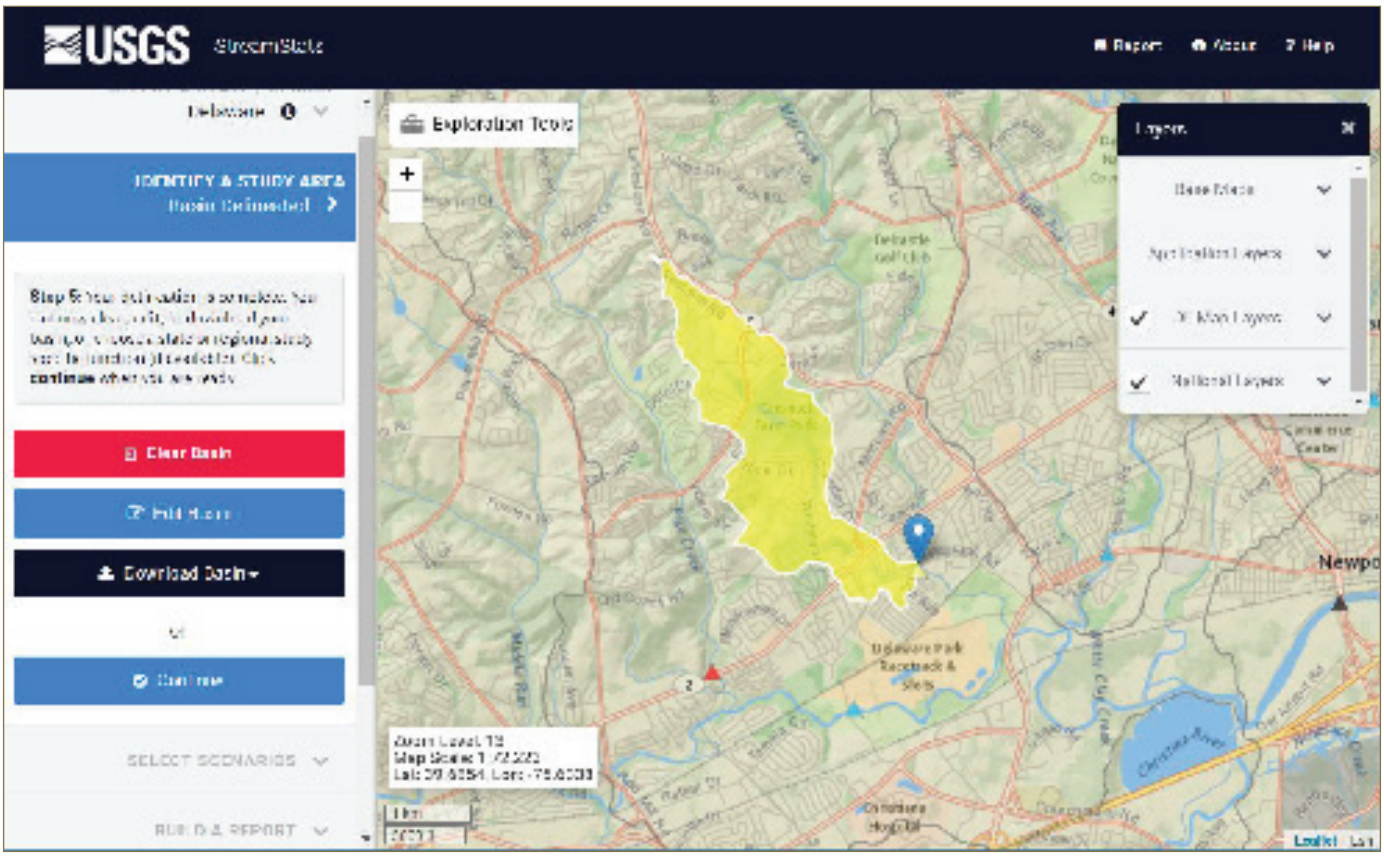
Our most frequent emergency operations activity is storm response. DGS staff works with DNREC, DelDOT, and other federal, state, and county groups on the Delaware Storm Reporter Advisory Group, an online program that enables the rapid delivery of coastal storm damage information. The DGS also serves 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, John A. Callahan, and David R. Wunsch

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

The USGS StreamStats program is a web-based platform allowing users to delineate their own local watersheds and estimate peak flood levels at gaged and ungaged sections of stream networks across the U.S. Peak flood statistics are extrapolated from empirical regression equations fit to observed peak flow curves at USGS stream gages using a set of basin



Example of online user interface for the USGS StreamStats website. Users can click any point along a stream (blue arrow) and the StreamStats program will delineate a watershed (yellow area), extract relevant basin characteristics for this watershed, and use these characteristics to estimate peak flood statistics based on empirical regression equations.

characteristics as predictors, derived from soil, terrain, meteorological, census, and land use data sets. StreamStats provides critical information for transportation engineers by predicting peak flood conditions at proposed roads, bridges, and railways, and is used by water quality modelers and urban planners to map potential inundation patterns across the landscape.

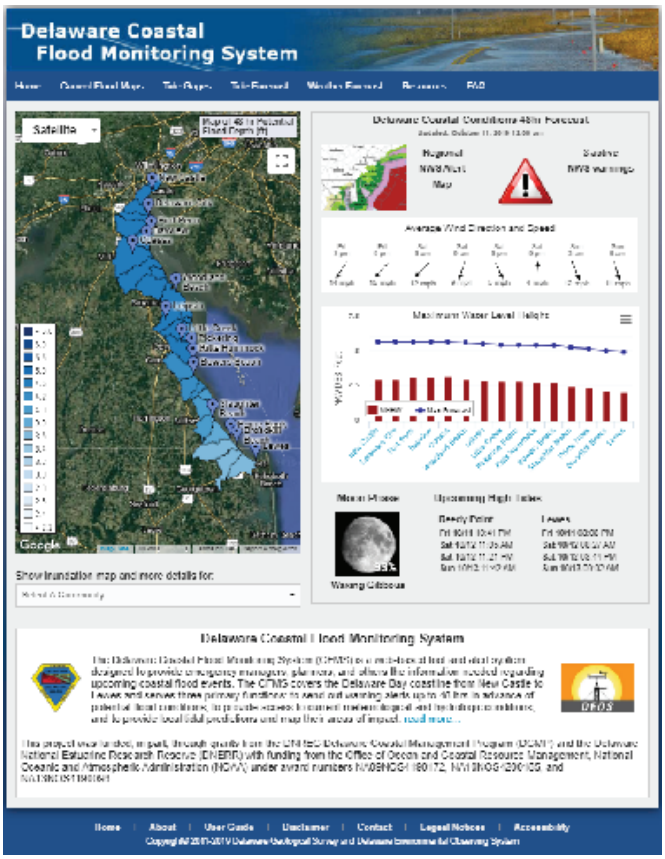
For StreamStats to remain a useful hydrologic tool, it must be periodically updated to account for changes in land use, demography, and digital elevation models (DEMs). The last such update for Delaware occurred in 2006. In partnership with the USGS, the DGS team produced updated versions of the core datasets and statistics required for StreamStats using more recent, higher-resolution spatial datasets. This required extensive data analysis and processing to produce hydrologically "enforced" DEMs necessary for rapid watershed delineation through the StreamStats program. The updated version includes data from the 2016 National Land Cover Dataset, a high resolution LiDAR DEM from 2014, and demographic data from the 2010 census. These newer sources of data, coupled with new streamgage records, will help improve the accuracy of predicted peak flows and hydrologic statistics generated by the StreamStats program for years to come.

The Delaware Coastal Flood Monitoring System

Project Contact: John A. Callahan

A real-time coastal flood monitoring and early warning system for Delaware coastal communities

In the last few decades, large tropical storms such as Hurricanes Irene and Sandy, as well as numerous strong nor'easters, have resulted in significant loss of life, injuries, and property damage along the Mid-Atlantic coast, with much of the damage the result of severe coastal flooding. The Delaware Coastal Flood Monitoring System (CFMS) is a online early warning system designed to provide emergency managers, planners, and other information on the extent, timing, and severity of upcoming flood events. The system is currently operated jointly by the DGS and the UD Center for Environmental Monitoring and Analysis (CEMA) and was developed in partnership with the Delaware Emergency Management Agency and DNREC Delaware Coastal Programs in response



Screenshot of the home page of the Delaware Coastal Flood Monitoring System, which is a web-based tool and alert system designed to provide emergency managers, planners, and others the information needed regarding upcoming coastal flood events.

to the significant damage caused by the Mothers' Day Storm of 2008, which left at least one person dead. The storm caused evacuations in communities along the Delaware Bay coast and left many residents homeless.

The CFMS covers the Delaware Bay coastline from the City of New Castle to Lewes (15 communities), and has been in use since 2013 by Delaware state agencies, the public, and the National Weather Service in preparation for upcoming storms. Email or text alerts are provided up to 48 hours in advance of potential coastal flooding. For each community, the CFMS includes real-time forecasted flood levels and wind speed/direction, flood inundation maps, road elevation profiles, and current meteorological and hydrological conditions, updated every six hours from the NOAA hydrodynamic Delaware Bay Operational Forecast System. Sea-level rise, a flat open coastal terrain, significant development, and recreational activities leave the Delaware coastline extremely vulnerable to coastal storms. The CFMS plays an important role in the planning, preparedness, and emergency response for many coastal communities in Delaware.

Determining Flow Paths for Flooding and Draining in Slaughter Beach, Delaware

Project Contact: Thomas E. McKenna

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

The Town of Slaughter Beach is a bayside community impacted by the effects of climate change, particularly sea-level rise. Flooding from storms can inundate streets and property in the area. Flooding is primarily on the roads entering Slaughter Beach and in the back-barrier area. This project provides hydrologic information needed to develop and implement strategies for flood mitigation related to the back-barrier salt marsh. The project is a direct follow up to a Resilient Community Partnership project by the DNREC Coastal Program. Results of this study will identify the flow paths for flooding and draining in Slaughter Beach, which will be used in future flood mitigation projects. This project seeks to confirm and/or identify the locations prone to flooding using both existing data and field-based hydrological evaluations. Marsh platform elevations are estimated by a digital elevation model that is corrected for the bias in LiDAR data caused by dense marsh vegetation. Multiple data loggers are recording water levels, temperature, and salinity in tidal channels and on the back-barrier upland. We are using temperature as a tracer of tidal water flow by collecting data with remote-controlled thermal infrared and visual cameras mounted on a small inflatable tethered blimp. This allows for observing the marsh over extended periods to capture both spacial and temporal dynamics of flow on the marsh platform.

This project is funded by DEMA, DNREC, and DGS. Land access graciously provided by Delaware Nature Society, DNREC Division of Fish and Wildlife, and the Town Council of Slaughter Beach.

Extreme Water Levels in the Delaware Bay and Inland Bays

Project Contact: John A. Callahan

Analysis of the maximum coastal flood events at NOAA and USGS tidal stations in the Delaware Bay and Inland Bays

The Delaware coastline is extremely vulnerable to floods, winds, waves, and heavy precipitation caused by coastal storms, such as the Great March Storm of 1962 and Hurricane Sandy in 2012. Delaware is especially vulnerable due to its low mean elevation, susceptibility to the occurrence of both extratropical and tropical cyclones, and increased development of public and private infrastructure (e.g., trans-

portation, residential housing, industrial and commercial development, tourism activities) along its coasts. Additionally, impacts of coastal storms are projected to be amplified by global warming and sea-level rise, of which long-term rates in Delaware are approximately twice the global mean rate. Understanding the magnitude and frequency of the largest coastal flooding events plays an important role in assessing risks and improving resiliency in coastal communities.

Water level data were gathered along the Delaware Bay and Delaware Inland Bays shorelines from 10 monitoring sites maintained by NOAA and the USGS with 19 or more years of hourly observations. Top coastal flooding events were identified and ranked at each site, a large majority of which were produced by extratropical weather patterns rather than directly by tropical cyclones. Hourly data were aggregated to monthly mean, maximum, and minimum to identify temporal and spatial patterns. Daily maximum water levels at each site were then used to analyze exceedance thresholds for 2, 5, 10, 25, 50, and 100-year return levels following a Generalized Pareto Distribution/Points-over-Threshold (GPD/POT) approach. This ongoing project is part of a larger effort to identify trends and drivers of regional coastal flooding, to help improve existing early warning systems, and to provide emergency managers with guidance on emergency preparedness.

Coastal Flooding from Tropical Storms

Project Contact: John A. Callahan

Storm tides and surges from tropical storm systems in the Delaware and Chesapeake Bays

Coastal flooding poses the greatest threat to human life and is often the most common source of damage from coastal storms. From 1980 to 2020, the top 6, and 17 of the top 25, costliest natural disasters in the United States were coastal storms, most of these tropical systems. The Delaware and Chesapeake Bays, two of the largest and most densely populated estuaries in the United States, have been significantly impacted by major hurricanes in recent decades, notably Hurricanes Isabel (2003), Irene (2011), and Sandy (2012). Future climate projections include more intense hurricanes with stronger winds and increased precipitation. Additionally, rates of sea-level rise in the region are approximately twice the global mean rate and expected to increase into the future. Due to the natural and built-up environments and growing population along the East Coast, it is critical that we understand the severity and variability of coastal storm hazards to properly assess the risk and aid in overall preparedness.

The goal of this ongoing study is to better quantify the magnitude and frequency of coastal flooding caused by tropical cyclones (TCs) in the Mid-Atlantic. Researchers at the DGS and UD Center for Environmental Monitoring and Analysis (CEMA) investigated all North Atlantic TCs that came within 750 km of the Delmarva Peninsula over the past 40 years (1980 – 2019). Water level data were obtained from 12 NOAA tidal stations in and around the Delaware and Chesapeake Bays. Harmonic analysis was performed to separate the astronomically-forced predicted tide and the non-tidal residual. Storm tide and skew surge (defined as the difference between the maximum water level and the maximum predicted tide within 3 hours of each tidal peak) were then extracted for each tropical cyclone nearby the Delmarva Peninsula. Tidal stations were grouped based on cross-correlation analysis of detrended and standardized surge values and TCs with the largest surges ranked for each geographic region.

Hurricanes Sandy and Isabel had the largest storm surge in the Delaware and Chesapeake Bay, respectively. Tropical cyclone storm surges in the upper regions of each bay more closely related to each other than to storm surges in the lower bay regions. Spatial variability of surge from coastal storms should be taken into account when devising mitigation or planning strategies. The current study is part of a larger effort to quantify trends and variability in coastal flooding from all types of meteorological influences in the Mid-Atlantic region.

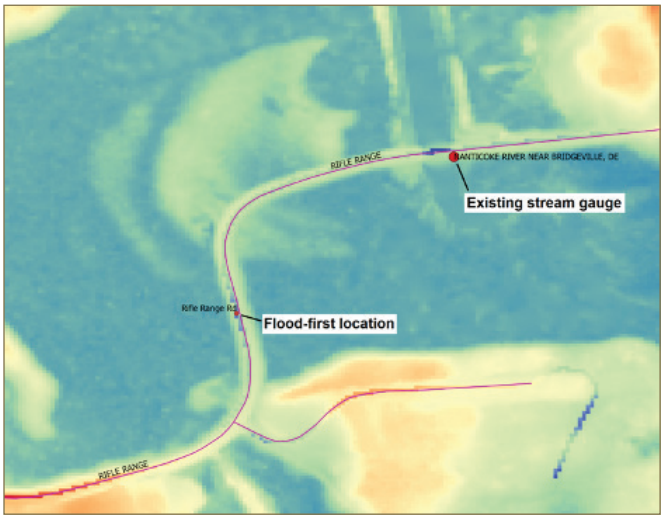
Identifying Flood-First Locations on Delaware Roadways

Project Contacts: Daniel L. Warner and John A. Callahan

Identifying locations which may be monitored to help improve flood forecasting capabilities

Delaware has many roadways prone to flooding by both upland streams and coastal waters. Flooded roads are a safety hazard for drivers and can damage or cut off important infrastructure when it is needed most. The Delaware Department of Transportation uses tide and stream gauges to help determine when and where roads may be impacted, allowing crews to close roads or place warnings in hazardous conditions. However, relationships between observed water levels and specific roadway elevations where flooding occurs, here referred to as "flood-first locations", are only known for a handful of roads within the state. A team from DGS has partnered with CEMA to identify flood-first locations across the state and link these locations to nearby water bodies which may be monitored in the future to improve flood forecasting capabilities.

This project has employed GIS, terrain analysis, and GPS field surveys to identify over 200 flood-first locations both near and far from existing hydrologic monitoring sites. Points are identified based on roadways and generalized areas known to be a flood risk. Potential flood-first locations are then identified based on focal elevation statistics, hydrologic indices, and 100-year flood plain maps. The team is also investigating potential locations where additional monitoring stations would potentially capture many flood-first locations that are distant or hydrologically disconnected from the existing monitoring network. This project will improve current understanding and guide future investigations of roadway flooding in the state.



Example of a flood-first location with an associated stream gage overlaid on a digital elevation model. The nearby gage may be used to identify when hazardous flood conditions may develop, while the flood-first location identifies where it will likely happen.

A portion of Sharpless Road in New Castle County made impassable from flooding on the Red Clay Creek.

The DGS Support Team

Behind every program and activity is a fantastic support team

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.

Charles "Tom" Smith

Senior Research Technician II

Tom is responsible for installing, maintaining, modifying, and repairing the various field instruments and communication links which are used to monitor Delaware's seismology, streams, aquifers, and rainfall. Tom is also responsible for obtaining 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 Contacts: John A. Callahan and 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.

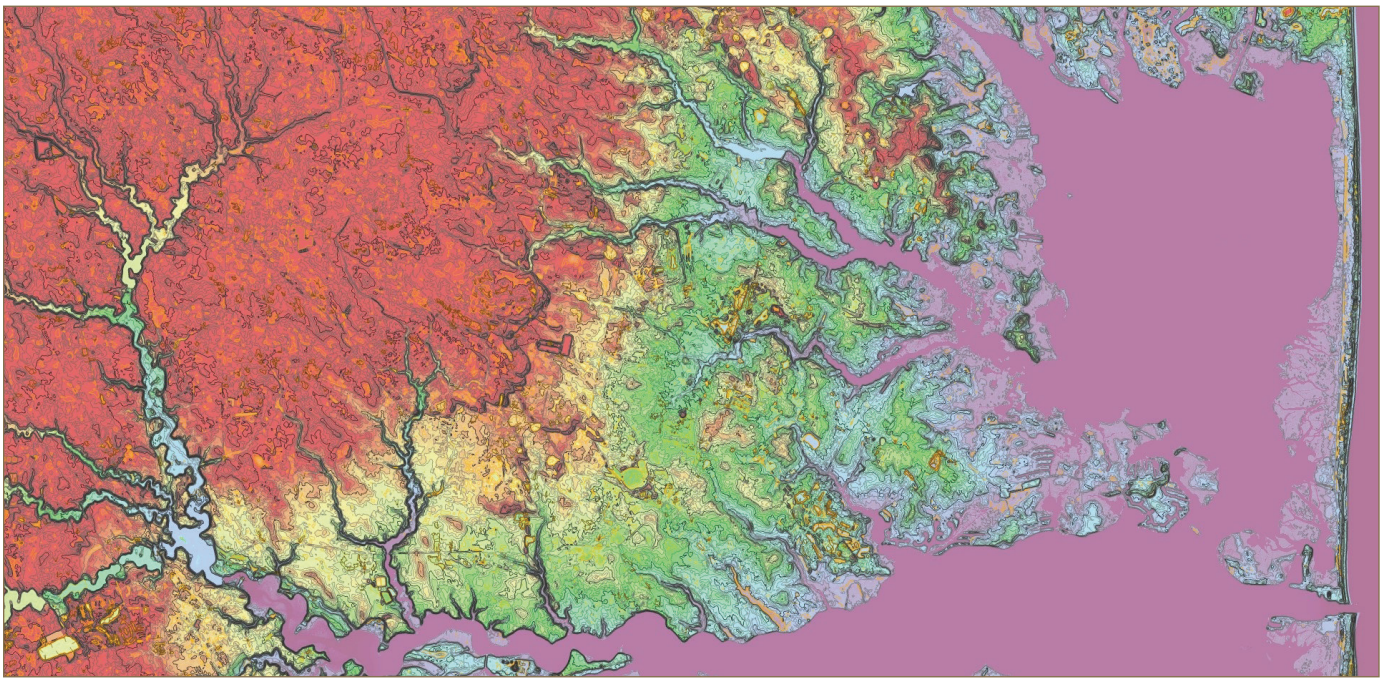
Statewide LiDAR Program for Delaware

Project Contacts: John A. Callahan and Daniel L. Warner

Distribution of topographic contours and LiDAR products for Delaware

LiDAR is an active remote sensing method that utilizes a pulsed laser to measure distances at high resolution. Airborne LiDAR was used to measure the elevation of the ground surface for the entire state of Delaware in 2014 as part of a multi-agency state and federal effort (including the DelDOT, DNREC, USGS, and NOAA) and funded by the Hurricane Sandy Relief appropriation. Acquisition of the 2014 LiDAR data met Quality Level 2 technical specifications with a sampling density of greater than 2 points per square meter and an open terrain accuracy of 6.3 cm.

The DGS analyzed the 2014 LiDAR datasets to generate topographic elevation contours (i.e., lines of equal elevation that form the basis of many topographic maps) for the entire state of Delaware at one-foot intervals. The DGS stores and makes available the elevation contours, a hydro-flattened and other LiDAR-based data products as well as provide expertise for Delaware state and local agencies and its citizens. Additionally, these LiDAR data are



Elevation map of Rehobeth Bay, Delaware, using both a digital elevation model and topographic contours. Both datasets were derived from LiDAR data collected from low flying aircraft in 2014. Cool purple and blue colors represent elevations near sea level with increasingly warm colors representing higher elevations. Solid black contour lines show elevations at five-foot intervals.

being integrated into several DGS studies including modeling coastal inundation scenarios, geologic mapping, salt marsh elevation studies, examination of potential bacterial and nutrient source areas, and habitat analysis.

Online XML and Mapping Applications

Project Contacts: John A. Callahan and A. Scott Andres

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 (ACWI). 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 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 COMPLETED

GEOLOGIC MAPS

GM 25 Geologic Map of Offshore Delaware

DGS PUBLICATIONS IN PROGRESS

BULLETINS

B22 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 Geological Characterization of Miocene Sediments at the Marshy Hope Core Site (Nb53-08), Northwest Sussex County, Delaware

OPEN FILE REPORTS

OFR 54 Early Mesozoic Rift Basins in Delaware: A Review of their Occurrence and an Assessment of their Carbon Potential

GEOLOGIC MAPS

GM 26 Geologic Map of the Cecilton and Middletown Quadrangles, Delaware

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

EXTERNAL PUBLICATIONS BY DGS STAFF

Andres, A.S., McQuiggan, R.W., and He, C., 2019, Challenges of characterizing impacts of de-icing salt in a heterogeneous aquifer: presented at 2019 American Geophysical Union Fall Meeting, San Francisco, California, Dec. 10, abstract H23L-2060.

Callahan, J.A., 2020, Total water levels, storm surge, and inundation frequency along Delaware's coasts: Abstract p. 8 presented at 2020 Delaware Wetlands Conference, Wilmington, Delaware, 29-30 Jan.

Gardner, K.F., and **McLaughlin, P.P.,** 2019, Paleocene-Eocene palynology and stratigraphic correlation across a nearshore-to-offshore transition in the subsurface of central Delaware (U.S. Mid-Atlantic Coastal Plain): A preliminary study: *Geological Society of America Abstracts with Programs,* vol. 51, no. 5, doi: 10.1130/abs/2019AM-340154.

Hingst, M., **McQuiggan, R.W., Peters, C., Andres, A.S.,** and Michael, H.A., "A-Salt" on Delaware farmland: Investigation of pathways and dynamics of saltwater intrusion near Dover: presented at 2019 American Geophysical Union Fall Meeting, San Francisco, California, Dec. 10, abstract H53I-1852.

McKenna, T.E., 2020, Flow paths for flooding on the back-barrier of Slaughter Beach, Delaware: Abstract p.15 presented at 2020 Delaware Wetlands Conference, Wilmington, Delaware, 29-30 Jan.

Medlock, C.L., **McKenna, T.E., Callahan, J.A., and Warner, D.L.,** 2020, LiDAR vertical bias assessment and digital elevation model correction of tidal salt marshes in Delaware: presented at 2020 Delaware Wetlands Conference, Wilmington, Delaware (awarded best student poster).

Robinson, J., Slater, L., Buda, A., Shober, A., and **Andres, A.S.,** 2020, Electrical monitoring of saline tracers to reveal subsurface flow pathways in a flat ditch-drained field: *Journal of Hydrology,* v. 586, doi: /10.1016/j.jhydrol.2020.124862.

Stotts, S., Gulledge, O., and **Callahan, J.A.,** Impact of channel dredging on the climate-growth relationship in a Mid-Atlantic white cedar (Chamaecyparis thyoides L. (B.S.P.) freshwater tidal wetland: *Journal of Coastal Research* (in press).

Warner, D.L., Callahan, J.A., and McKenna, T.E., 2020, Vulnerability of stored soil carbon in Delaware's coastal wetlands: Abstract p. 9 presented at 2020 Delaware Wetlands Conference, Wilmington, Delaware, 29-30 Jan.

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 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 Resilient and Sustainable Communities League

Delaware River Basin Commission Advisory Committee on Climate Change

Delaware River Basin Commission Regulated Flow Advisory Committee

Delaware Sea Level Rise Technical Workgroup

Delaware State Board of Geologists

Delaware State Names Authority

DelawareView (Delaware Chapter of AmericaView)

Delaware Water Infrastructure Advisory Council, Wastewater Subcommittee

Delaware Water Resources Center Advisory Panel

Delaware Water Supply Coordinating Council

Delaware Water Well Licensing Board

Federal Advisory Committee on Water Information

Federal Geologic Mapping Advisory Committee

Federal Subcommittee on Groundwater

Geological Society of America, Academic and Applied Geoscience Relations Committee

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 Petroleum Council

New Castle County Resource Protection Area Technical Advisory Committee

River Master Advisory Committee

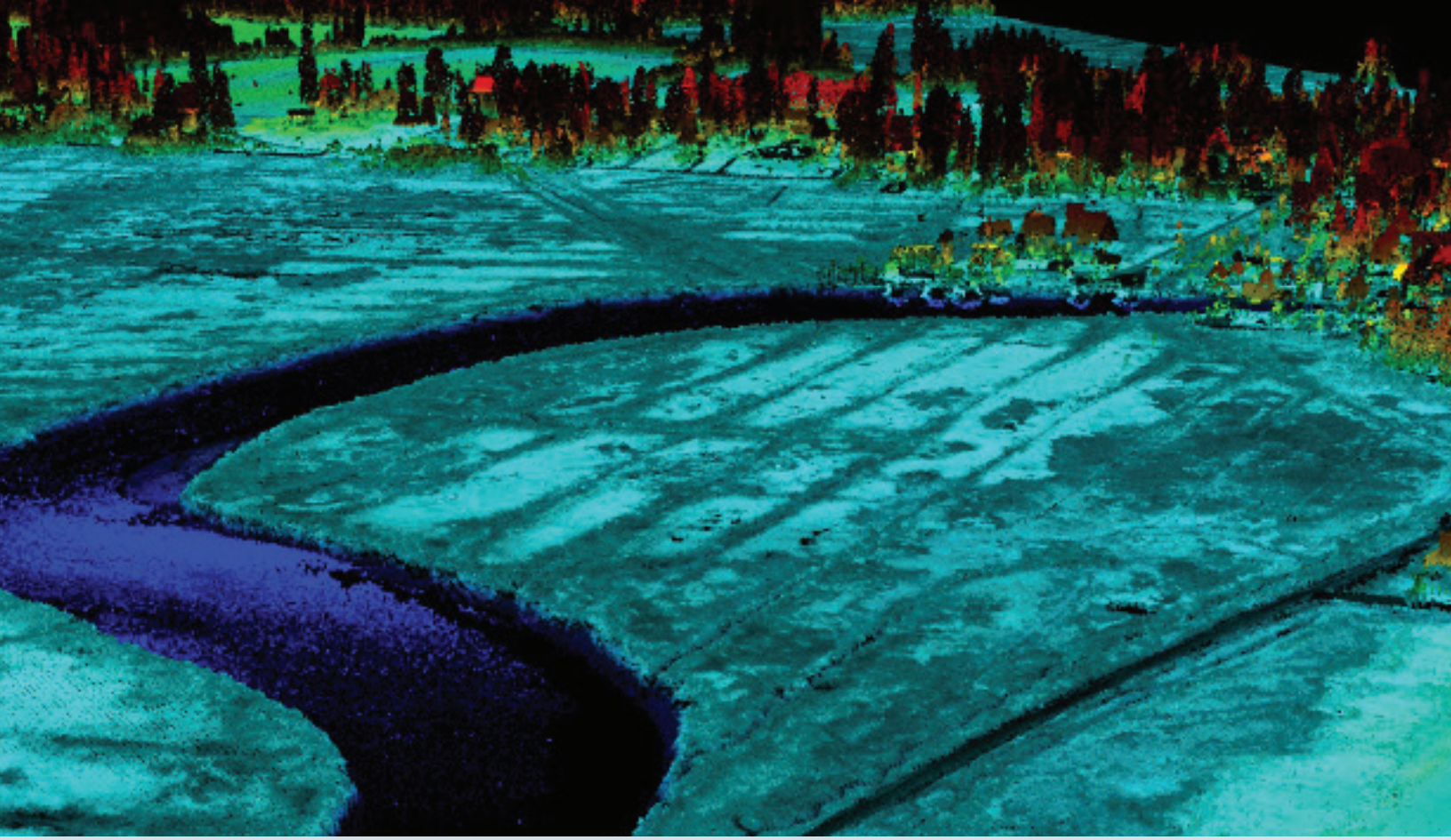
River Master Decree Party Workgroup

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 | 2019-20

Delaware Geological Survey

DGS Building
257 Academy Street
University of Delaware
Newark, DE 19716-7501
Phone: 302-831-2833

www.dgs.udel.edu