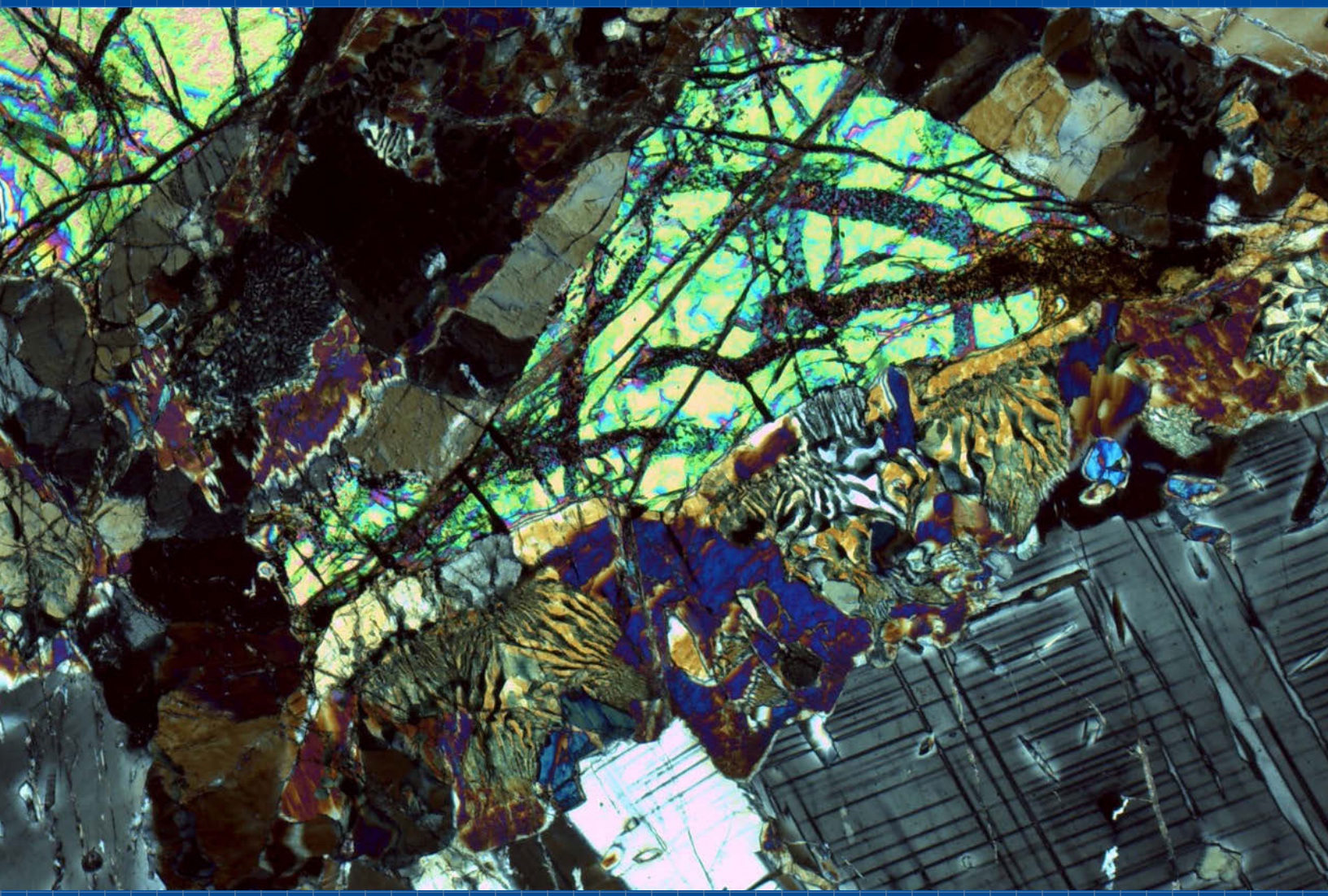
Delaware Geological Survey

Annual Report of Programs & Activities

2015 – 16



Photomicrograph of Bringhurst Gabbro, Bringhurst Woods, Wilmington, Delaware. Shown in the figure are olivine--plagioclase-- pyroxene gabbronorite with hornblende-spinel symplectites. This photomicrograph, by William "Sandy" Schenck, was chosen for the "Art in Science" exhibit at the University of Delaware Harker Laboratory. Thin section by Bernhard Dirska.

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

It has been said that the best geologists are the ones who have been exposed to the most exposures. And in some ways, fieldwork is the essence of geology. Many of us became geologists because of the promise of spending at least part of our careers in the field examining the geology, absorbing the scenery, collecting specimens or samples, and compiling field notes that record our observations. I have always been a person who has to visit and observe any field site that I am working on. Even when studying groundwater, which for the most part is hidden in the subsurface, I find that getting a lay of the land is important for letting your training and instincts inform your observations and hypotheses.

The DGS routinely collects field data to augment our efforts to map the state's surficial geology, characterize offshore sand and gravel resources, and to evaluate the hydraulic properties of aquifers. Fieldwork results in the need for sample collection and preservation, so over the past several years DGS has made several investments in improving the quality of our core repository and laboratories so we can better process and preserve samples. For example, we recently upgraded one of our labs to designate it as a core evaluation lab with ergonomic work tables, better lighting, and plumbing. We also improved ventilation and added dehumidifiers to reduce moisture. We are also currently working to construct an offsite storage facility to protect our steel drill rods and other ancillary field equipment. DGS also has several funded projects underway that are enabling us to improve the storage, organization, and cataloging of existing cores and cuttings.

In 2017, the DGS will be hosting our third biannual Delaware Geological Research Symposium. In an effort to highlight and celebrate the field components of our research, this symposium will consist of a daylong field trip. Participants will join DGS staff in reviewing new exposures and land forms in the crystalline Piedmont rocks, as well as observe the methods DGS scientists use to collect and characterize subsurface cores. You will also participate in discussions to help us address new geologic questions. More information on the field trip agenda and registration details will be forthcoming. So mark April 21, 2017, on your calendars and plan to attend our first field symposium—because geology is better observed in the field.

– David R. Wunsch
Director and State Geologist

SAVE THE DATE!

Delaware Geological Research Symposium

APRIL 2017

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

A DAYLONG
FIELD TRIP EXPLORING THE
PIEDMONT AND COASTAL PLAIN
OF DELAWARE

1. Water Resources

Photo credit: Thomas Needles.

Sharing Groundwater Expertise Internationally

Article courtesy of the University of Delaware, UDaily.

State Department taps UD's Wunsch to attend South Asia Groundwater Forum

David Wunsch (second from left), Director of the Delaware Geological Survey, at the South Asia Groundwater Forum, held June 1-3, 2016, in Jaipur, India. Photo courtesy of David Wunsch.

David Wunsch, the state geologist for Delaware and director of the Delaware Geological Survey, served as a special consultant for the U.S. State Department at the South Asia Groundwater Forum in Jaipur, India, June 1-3.

The meeting, hosted by the government of India, in partnership with the World Bank and the International Water Association, brought together regional government and non-government stakeholders and experts from water, agriculture, energy, and environmental sectors.

Wunsch gave an invited presentation on how Delaware regulates groundwater withdrawals within the state, and how scientific data and maps from the Delaware Geologic Survey, a state agency based at the University of Delaware and housed in the College of Earth, Ocean, and Environment (CEOE), helps advise the regulatory authorities on Delaware-specific groundwater issues.

The opportunity is part of a broader effort by the U.S. State Department and members of the U.S. Water Partnership to increase technical exchanges between scientists, academics and policymakers in order to address sustainable management of groundwater sources.

South Asia contains a vast treasure trove of groundwater, which historically has contributed to the region's domestic water security, food security and industrial water supply, as well as to the rural livelihood of over a billion people.

But over the past 60 years, largely unplanned and unregulated groundwater development has resulted in declining

water tables, contamination, land subsidence and saltwater intrusion in several parts of the region, which is comprised of Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka.

During breakout sessions, Wunsch and other Western specialists provided individual assistance to specific countries. Wunsch advised water ministers from Sri Lanka on issues surrounding high fluoride concentrations in groundwater, an area of expertise during his career.

"It was an amazing opportunity to share the knowledge I have gained throughout my career," said Wunsch, who is a founding member of the Federal Advisory Committee on Water Information's Subcommittee on Ground Water, which is charged with developing a framework for monitoring the nation's ground-water resources.

National Ground-Water Monitoring Network

Project Contact: A. Scott Andres

DGS participation in interstate data sharing consortium helps improve national and state groundwater data infrastructure

The DGS became a data provider for the National Ground-Water Monitoring Network (NGWMN) in early 2016. NGWMN is a consortium of state and local agencies and the U.S. Geological Survey (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. The network will ultimately allow users to view groundwater data across state lines to observe trends in groundwater quality and availability in a local, regional, or national context. NGWMN resources are managed by the USGS Center for Data Analytics and can be accessed at http://cida.usgs.gov/ngwmn/.

Project team members A. Scott Andres, David Wunsch, Changming He, John Callahan, and Thomas McKenna have identified nearly 40 monitoring wells in 13 aquifers to add to the network and have led the work to create the technology infrastructure that delivers data from internal DGS sources to the national data portal website operated by the USGS. This work takes advantage of data generated by existing DGS groundwater monitoring programs and expands accessibility to the information to a wider audience. DGS will be able to leverage the software and networking technology used by the national portal to improve data distribution capabilities on the Survey's web site.

The NGWMN is a product of the Subcommittee on Ground Water (SOGW), a subcommittee of the Federal Advisory Committee on Water Information (ACWI; http://acwi.gov). Joining the NGWMN is the culmination of hard work by the DGS. DGS scientists have participated since the beginning of this national effort, as well as contributed to the development of the Framework Report that outlines monitoring well network development, field practices, data management, and implementation. David Wunsch, Director of the DGS and State Geologist, is a member of ACWI and one of the founding members of the SOGW. A. Scott Andres was a co-leader of the group that developed data standards for NGWMN.

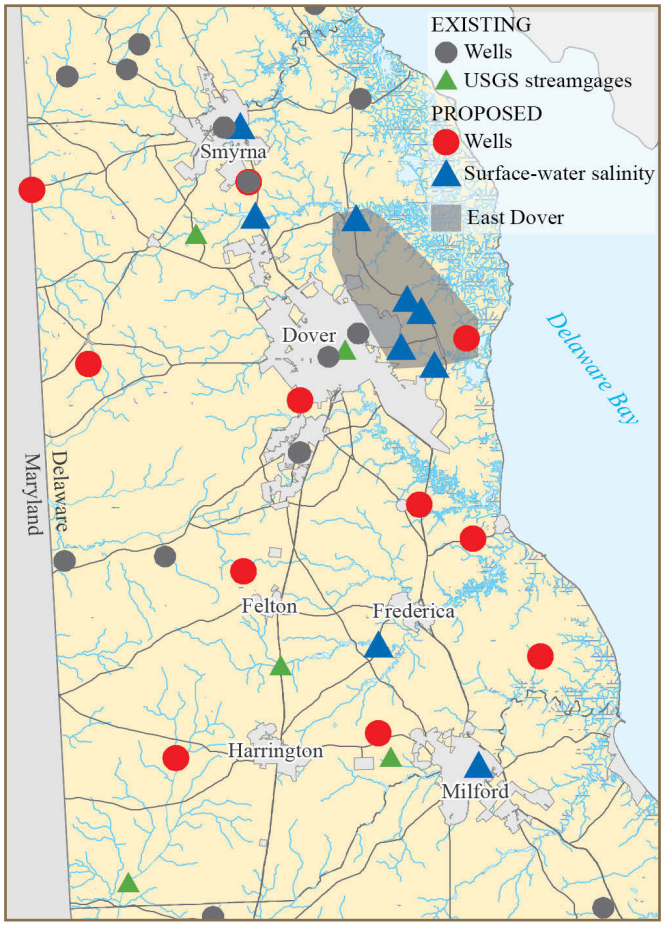
Groundwater and Saline Water Intrusion Monitoring Network Infrastructure Improvements: Kent County, Delaware

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

New monitoring well infrastructure will be installed to allow DGS and DNREC to track conditions in a part of Delaware that has significant development and water availability issues

The DGS will soon be undertaking a new three-year project to add new and necessary capabilities to our statewide network of observation wells and stream monitoring stations. The project resulted from issues raised by the DGS and the Delaware Department of Natural Resources and Environmental Control (DNREC) with the Delaware Water Supply Coordinating Council (WSCC) regarding the availability and sustainability of groundwater in Kent County; a growing area with critical water-supply and water-quality issues. The WSCC, with support from the DNREC, recommended a comprehensive examination of the groundwater and surface-water resources in this area, including construction of monitoring wells and installation of surface-water flow and salinity monitoring stations. The project has been funded by the FY2017 DNREC Bond Bill appropriation.

Ten sites spread across Kent County have been identified for installation of up to 35 monitoring wells at depths ranging from 20 to 550 feet. These wells will fill spatial gaps in our network. Additional monitoring wells ranging in depth from 10 to 80 feet will be installed in the east Dover area where supply wells operated by the City of Dover and irri-gation wells operated by multiple farmers are withdrawing water from the shallow Columbia aquifer. Surface-water salinity monitoring stations will be established near the head



Locations of existing and proposed sites for monitoring groundwater, surface water, and salinity in Kent County.

of tide in selected streams to track the duration, frequency, and magnitude of saline water incursion, and identify if nearby wells are at risk of contamination by salt water. Having adequate information on this issue will become more important as sea level continues to rise. Two historic streamflow monitoring stations operated by the USGS and located southwest of Smyrna and south of Felton will be reactivated to evaluate the impact of increasing groundwater development on streamflow in those areas. Groundwater and surface-water sites will be monitored with automated data collection instruments that both reduce data collection costs and vastly improve our ability to document and identify natural and human-caused trends.

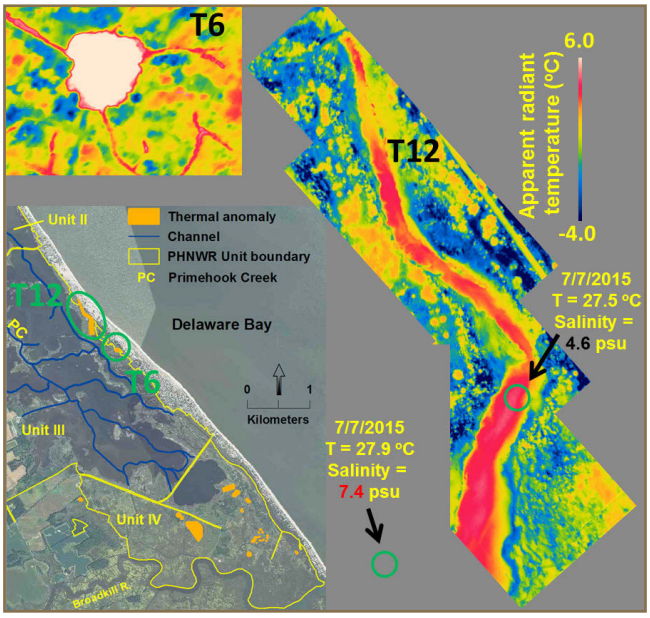
Identifying Groundwater Discharge Locations in Prime Hook National Wildlife Refuge

Project Contact: Thomas E. McKenna

Using thermal imaging technology to identify locations of groundwater discharge

Breaches in the estuarine barrier at Prime Hook National Wildlife Refuge (Refuge) resulted in significant increases in salinity in impoundments that were previously fresh water. A restoration effort at the Refuge was completed in October 2016. The design included cutting and modifying channels in the marsh to increase circulation and lower water levels in the Refuge. It also included closing the large breaches in the estuarine barrier in Unit II of the Refuge (~3 km north of the area shown in the image; south of Fowlers Beach Road). The sand and mud from these operations were spread onto the surrounding area for the added value of increased bed elevation conducive to increasing saltmarsh vegetation. Before the soil enhancement began, it was important to identify locations where fresh groundwater was entering channels and ponds in the marsh, where it was upwelled onto the marsh platform and/or entered locations along the upland/fringe boundary.

This DGS project used thermal-infrared imaging from ground and aerial platforms to identify locations of groundwater discharge. Ground-based thermal imaging and manual



Warm groundwater discharge locations (green circles, bottom left aerial photo, April 2015) appear as thermal anomalies in the two thermal images of sites T6 and T12. In-situ measurements near and in anomaly T12 shown as green circles with the southwestern site located just southwest of image.

measurements of salinity and temperature were made in July and October 2015 to identify major thermal anomalies. Pending funding, a new aerial thermal imaging survey will be done to identify any new groundwater discharge areas and flow patterns in the dredged channels. It is likely that some new areas will be identified as there were many channel reaches where the dredged material was sand-sized or coarser.

This project was funded by the U.S. Fish and Wildlife Service through an agreement with DNREC Coastal Programs and by the DGS. Aircraft time was supplied by volunteer John Chirtea, a Friend of the Prime Hook National Wildlife Refuge.

Temporal Imaging of the Intertidal Critical Zone

Project Contact: Thomas E. McKenna

Co-Principal Investigator: Jack Puleo (University of Delaware Center for Applied Coastal Research and Department of Civil and Environmental Engineering)

Potential for innovative ground-based imaging system to address environmental issues.

The extensive tidal wetlands and mudflats of the Delaware Estuary are complex environmental systems that provide critical hydrological, geochemical, and ecological functions for the State of Delaware (e.g. flood attenuation, water quality, nursery for marine life). Collecting the data needed to quantify processes in this critical zone while not altering its environment is extremely difficult due to soft sediment, shallow water, and the flooding and ebbing of tides. Remote sensing is a viable alternative, but the typical low-frequency acquisition of imagery from satellite and aerial platforms limits its applicability in process-based research in an environment where high-frequency variations are the norm (e.g. exposure/inundation, changes in moisture content, presence/absence of algal mats).

To overcome this limitation, we are developing an innovative ground-based imaging system to collect multi-spectral imagery (visible, near and thermal infrared bands) at time-scales (minutes/hours) below those of the dominant processes in intertidal environments (semi-diurnal tides, day/night). A modular system based on mature imaging technology is being assembled for science missions by foot, boat, truck, tower, and lift. This project includes critical laboratory studies to test our conceptual framework.

We are investigating the effects of viewing geometry and the relationships between imagery and sediment properties (lithology, moisture content) under simulated conditions of exposure/inundation and radiant heating. The work will catalyze an exciting new multidisciplinary collaboration that takes advantage of the Principal Investigators' expertise in thermography, ground-based imaging and coastal geology/hydrology/engineering. The imaging system and associated analytical techniques could have broad value for research in the critical zone, a major focus of the University of Delaware's Delaware Environmental Institute.

The proposed imaging system is a tool that helps scientists doing process-based research in dynamic and spatially heterogeneous environments. It could be used to quantify temporal changes in spatial patterns, quantify temporal changes at many points (every pixel can yield a time series), and to set varying spatial and temporal boundary conditions in numerical models of processes. We also easily see how the system could be used to address environmental issues relevant to Delaware including water quality, wetland loss, point and nonpoint source pollution, contaminated sites, habitat degradation, coastal erosion, oil spills, and deteriorating sewer and water infrastructure.

This project was partially funded by the Delaware EPSCoR program as part of a Research Infrastructure and Improvement grant from the National Science Foundation, the Delaware Space Grant Consortium as part of an EPSCOR Research Infrastructure Development grant from NASA, and the DGS. EPSCoR, the Experimental Program to Stimulate Competitive Research, is a federal grant program that helps states develop research capabilities and institutions.

The North East Water Resources Network

Project Contact: A. Scott Andres

Understanding how climate variations may influence water quality and quantity during extreme weather events

The DGS has been participating in the North East Water Resources (NEWRnet) consortium since August 2013. This research group, which includes the Experimental Program to Stimulate Competitive Research jurisdictions of Delaware, Rhode Island, and Vermont, was awarded funding to develop a comprehensive regional picture of how climate variations may play a role in water quality and quantity during extreme weather events using an advanced sensor network in streams. The sensors used in the project are the coming wave in the measurement and analysis of physical, chemical, and biological make up of streams, ponds, estuaries, and oceans.

In conjunction with the Delaware Environmental Observing System (DEOS), DGS installed a sensor array that includes nitrate-nitrogen, three classes of organic carbon, turbidity, pH, temperature, salinity, dissolved oxygen, two algal pigments, and stream discharge in summer 2014 in the Murderkill River watershed at Coursey Pond. These sensors collect data every 30 minutes and telemeter the data back to DEOS every hour, allowing project members to access the data and assess if the instruments may need to be serviced. To date, instruments have analyzed over 25,000 samples. In addition, DGS and scientists from the University of Delaware College of Earth, Ocean and Environment have collected and analyzed more than 120 traditional grab samples, and have been collaborating with the NEWRnet project team to interpret results.

One interesting outcome of the work has been the development of models that calculate the balance between nitrogen input, water flow, and algae growth. These findings will inform the Total Maximum Daily Load model for the Murderkill River, a tool used by managers, scientists, and engineers to prescribe the amount of nitrogen that the river can assimilate, plan and design wastewater treatment infrastructure, and improve agricultural practices to reduce nitrogen loss.

In Situ Measurements of Shear Stress, Erosion and Deposition in Man-Made Tidal Channels Within a Tidal Saltmarsh

Project Contact: Thomas E. McKenna

Co-Principal Investigator: Jack Puleo (University of Delaware Center for Applied Coastal Research and Department of Civil and Environmental Engineering)

Ph.D. Student: Aline Pieterse (University of Delaware Department of Geological Sciences)

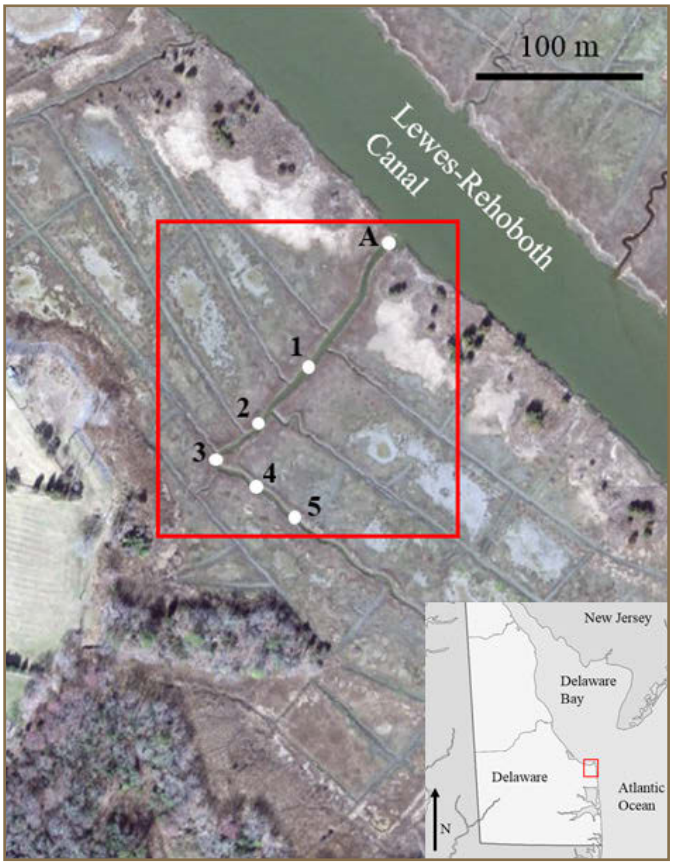
Understanding and modeling shallow water flows and sediment transport in tidal wetlands using novel in-situ sensors and a ground-based imaging system

Relative sea-level rise could have a large impact on tidal wetlands (salt marshes) in the Delaware Estuary because of the limited ability for natural landward migration due to anthropogenic land uses. Ditched marshes are ubiquitous features along the Delaware Bay coastline. These ditches impact the marshes by changing of tidal-water flow directions in natural channels and ditches on the marsh platform, lowering the water table, and changing the transport pathways and storage locations of sediment. Previous studies have shown that the ditches may provide a sink for sediment that could otherwise be transported onto the marsh platform. This would result in lower elevations of the marsh platform that would be even more susceptible to sea-level rise.

In this project, a three-week-long continuous experiment investigated flow in a ditched salt marsh adjacent to the Lewes and Rehoboth Canal in Lewes, Delaware. The experiment used an integrated network of over 30 sensors and 9 computers that time-synchronized logging of data and images. This and an earlier experiment at a marsh adjacent to Brockonbridge Gut in Kent County are the first to observe the variability of hydrologic processes in tidal wetlands at the high temporal and spatial resolution (submeter to meters; subsecond to minutes) obtainable with a novel suite of in-situ sensors and a ground-based imaging system.

The project ended in January 2016 and a final report was submitted to Delaware Sea Grant.

Funding was provided by Delaware Sea Grant, Delaware Geological Survey and the University of Delaware Center for Applied Coastal Research.



Study area (red box) in ditched salt marsh in Lewes, Delaware along the Lewes-Rehoboth Canal. The canal connects to Delaware Bay through Roosevelt Inlet in Lewes. Instrumented sites are labeled 1-5 and A.

Groundwater Response to Extreme Rainfall Event – Eastern Sussex County

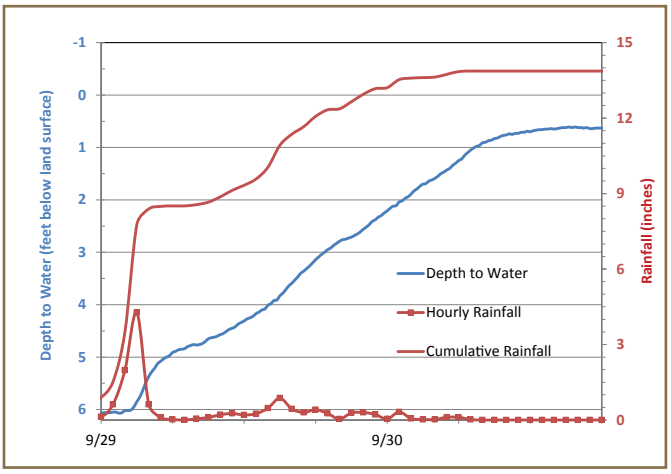
Project Contact: A. Scott Andres

Capturing real-time groundwater response to 500-year rain event

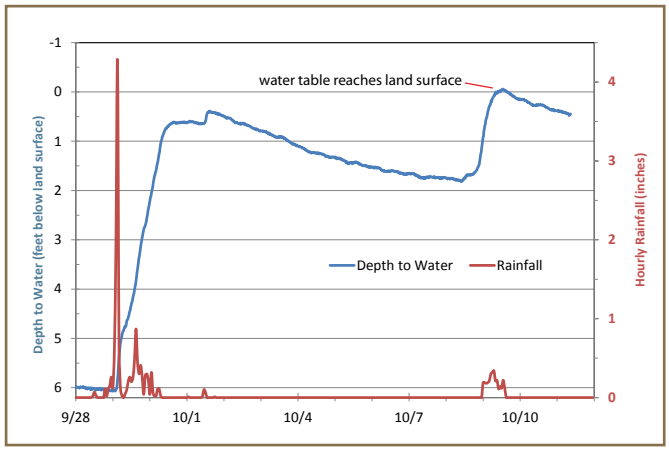
Unless you have a wet basement, chances are you do not think about what is happening beneath the ground during an intense rainstorm. DGS scientists are monitoring underground conditions 24 hours a day, 365 days a year, to document what is happening beneath the ground under all types of weather conditions.

On September 29-30, 2016, an extreme rainfall event occurred near Harbeson, Delaware. A DEOS meteorological station (DE-REC) recorded over 13 inches of rainfall. Just over 4 and a quarter inches of rain fell between 3:00 and 4:00 AM. The storm caused localized flooding and closed roads. The daily intensity was estimated to be just less than a 1 in 500 year event, and the maximum hourly intensity was a nearly 1 in 1000 year event.

The DGS operates a shallow monitoring well equipped with a water-level data recorder next to the DEOS station as part of a study that is examining water demands by plants (http://www.dgs.udel.edu/news/new-instrumentation-water-budget-evaluation). The well, open to the Columbia aquifer between 8 and 13 feet below land surface, monitors water-table fluctuations. The water-level record shows that the water table rose from about 6 feet bls to about 0.8 feet bls - just over 5 feet - in less than a day and a half.



Rainfall and water-table response, September 29 and 30, 2016. "0" on the chart is land surface at the well. DEOS Harbeson-REC, Well Oh51-09.



Rainfall and water-table response, September 29 through October 11, 2016. DEOS Harbeson REC, Well Oh51-09.

The water table receded almost 2 feet during the following week of dry weather. During a subsequent storm, October 8 - 9, an additional 3.6 inches of rainfall was recorded at the DEOS station. The water table rose nearly 2 feet in response and flooded the ground surface for a period of about 8 hours on October 9.

Flooding by groundwater has been previously observed in eastern Sussex County. In early March 2010, the water table rose several feet in response to melting of accumulated snow and ice and flooded a number of homes in the area. Evaluation of weather and groundwater conditions is part of the DGS's mission to advise the citizens of Delaware and government agencies about earth and water resources and flooding hazards caused by storms.

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.

The DGS, in concert with the Delaware Department of Natural Resources and Environmental Control Commissioner to the Delaware River Basin Commission, work diligently to represent Delaware's interest in maintaining equitable access to the, at times, limited water resources within the Delaware River Basin. This includes ensuring adequate flows of fresh water in the Delaware River to provide for water supply and ecological needs, as well as to prevent salt-water intrusion into aquifers, or the upstream advancement of the saltwater front in the Delaware Estuary.

The Delaware River Basin (outlined in red) contains 13,539 square miles with 1,004 square miles or 7.9% in Delaware. Over 15 million people (approximately 5% of the nation's population) rely on the waters of the Delaware River Basin for drinking, agricultural, and industrial use.

New Instrumentation for Water Budget Evaluation

Project Contacts: A. Scott Andres, Changming He, and Kevin Brinson (University of Delaware Department of Geography)

Understanding evapotranspiration will improve ability to manage water resources

The DGS and the Delaware Environmental Observing System (DEOS) have acquired and installed new instrumentation to measure evapotranspiration (ET). The instrumentation was purchased with support from the Delaware Department of Natural Resources and Environmental Control, which will improve the ability to quantify ET during agricultural and water supply drought periods and improve water availability estimates for resource managers.

The key to evaluating the sustainability of surface and groundwater resources is an accurate accounting of the water budget in which precipitation input is balanced by runoff and ET. Precipitation and runoff are adequately monitored; however, ET, which accounts for approximately two-thirds of the annual average water budget, is not directly measured in Delaware.

The new instrumentation is operating at an existing DEOS weather station located near Fairmount, Delaware. Research will be conducted during the next year to compare direct ET measurements from the new sensor to ET estimates derived by traditional methods and low-tech instrumentation.

Eddy covariance installed at the DEOS site located at the University of Delaware Warrington Farm Agricultural Experimental Station in Sussex County.

The DGS Support Team

Behind every program and activity is a fantastic support team

Steven Bertsche

Computing Support Specialist II

Steve has the challenging position as IT professional who provides network and desktop support, identifies technologies for future implementation, and provides technology budgeting, system security, and purchasing.

Karen L. D'Amato

Assistant to the Director

Karen 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 obtaining all permits from state and local governments, drilling the holes necessary to obtain the 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 obtaining 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 communications 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.

2. Geology & Mapping

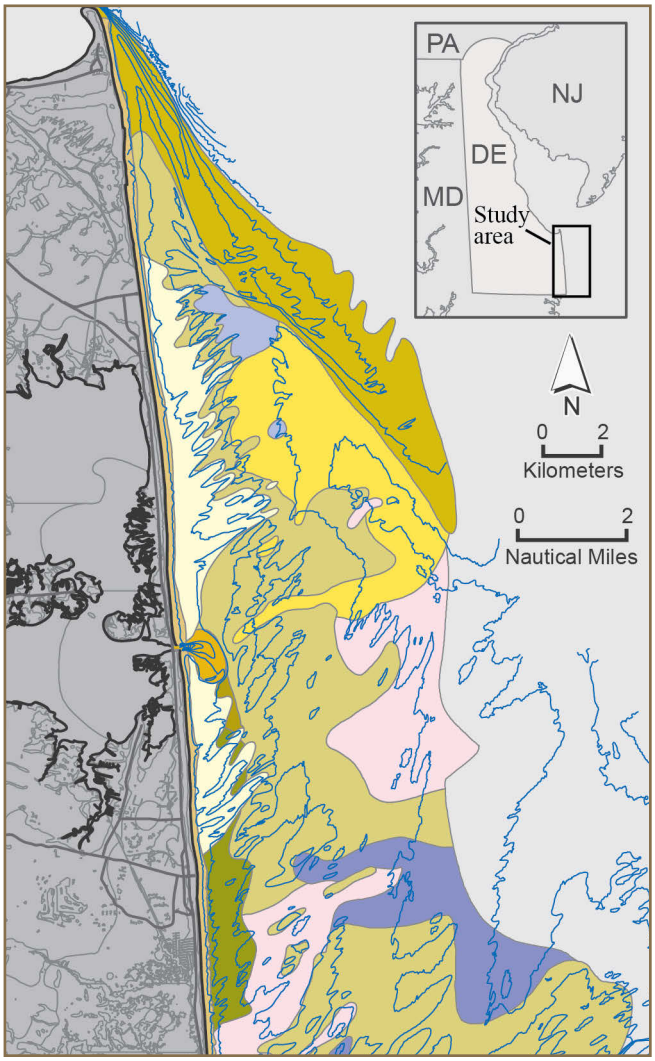
Delaware Offshore Sand Resources - Update

Project Contacts: Kelvin W. Ramsey and Trevor Metz

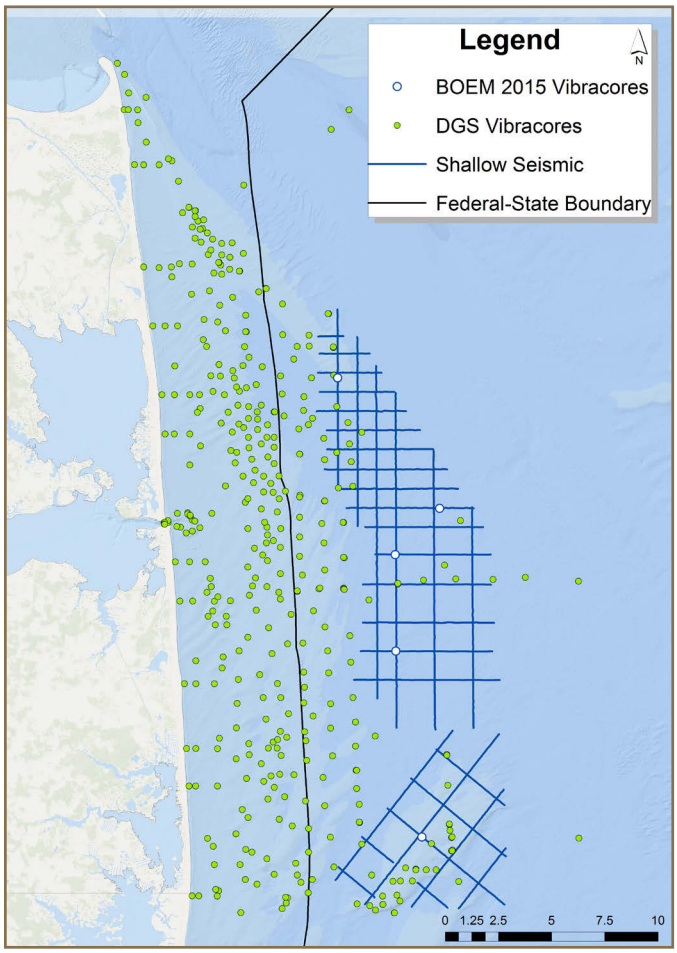
Identifying sand resources for coastal resiliency and restoration efforts

This year, DGS completed a two-year cooperative agreement between the Bureau of Ocean Energy Management (BOEM) and the state of Delaware as part of the Atlantic Sand Assessment Project (ASAP). The main focus of this project, which was renewed for an additional two years in July 2016, is to identify offshore sand resources for coastal resiliency and restoration efforts. To this end, the DGS developed a preliminary geologic map connecting the onshore geology with the offshore.

A better understanding of offshore geology will be valuable for offshore sand resource investigation and identification of target areas for beach replenishment material. Identifying the



A portion of preliminary geologic map of the Outer Continental Shelf offshore Delaware.



Location of existing (green) and recently collected (yellow circles inside blue grid) vibracores used for the BOEM project. Blue lines show recently collected shallow seismic data.

sediment characteristics of each geologic unit and the unit's geographic proximity to replenishment sites can significantly streamline the process of targeting sand resources, constraining their distribution, and determining volumes available for future nourishment projects. Onshore Delaware, mapping of surficial deposits is well established with published 1:24,000 geologic maps for the entire Delaware Atlantic Coast region. Surficial deposits onshore Delaware have been extended to five miles offshore through analysis of 415 offshore vibracore records, samples, and descriptions representing over 40 years of sediment surveys. Of the offshore units, Holocene sheet sands and shoal deposits, have the greatest potential for sand resources. The units offshore, however, are variable in thickness and distribution, and will require detailed, site-specific mapping for economic sand resource evaluation. Continuing efforts on this project over the next two years will include analysis of recently collected shallow seismic data, continued integration of geochronologic data, and collection of additional vibracores.

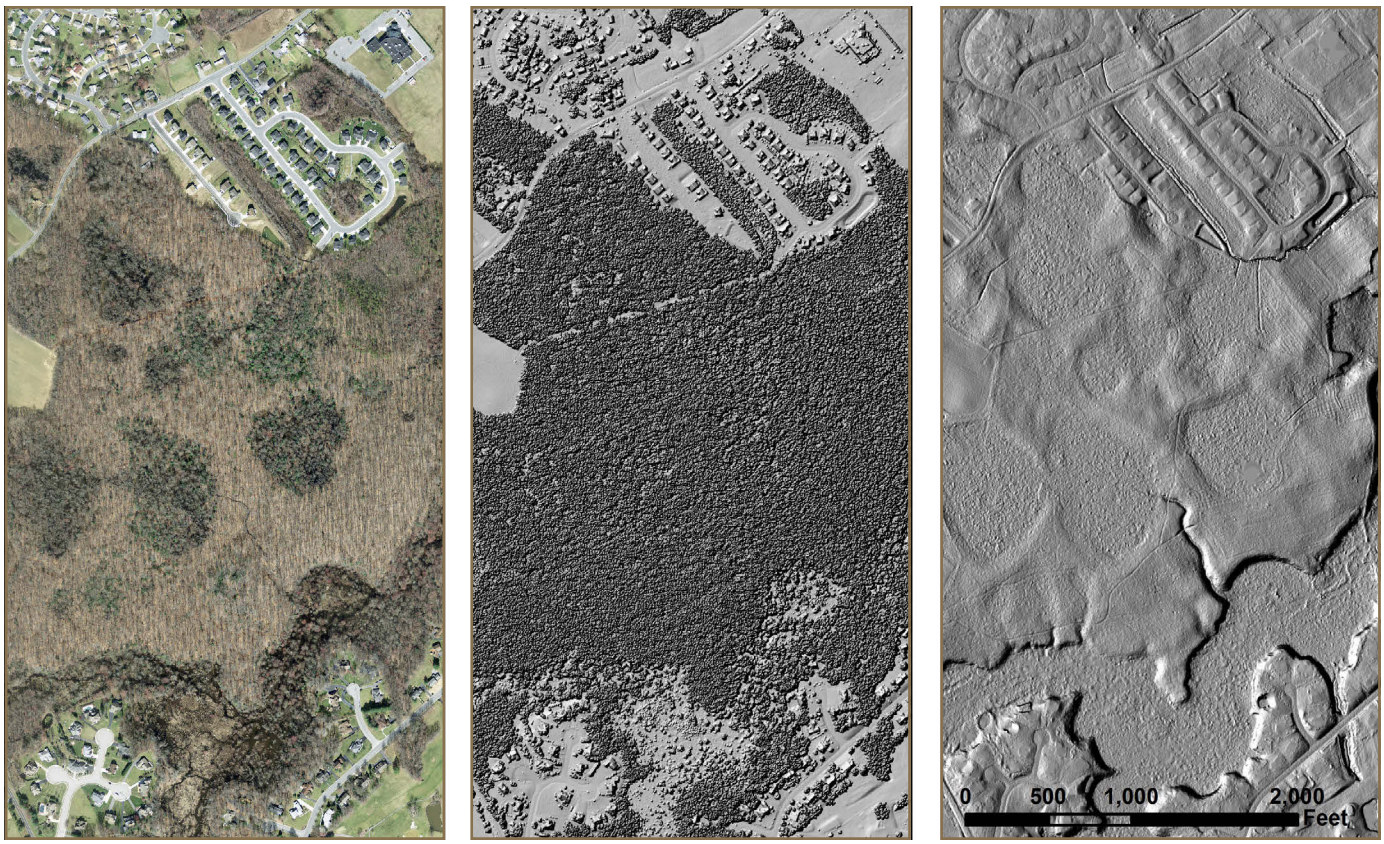
A concurrent project between DGS and BOEM began in 2015, entitled "BOEM Mid-Atlantic Cooperative ASAP Core Analysis and Characterization." The goal of this project is to increase the understanding of the sedimentation processes and geologic framework of the sediments in Outer Continental Shelf waters off the Delmarva Peninsula region from New Jersey to Virginia. This goal will be accomplished by a cooperative effort between the states to: 1) collect new data in the form of cores or other sediment samples and geophysical data, and 2) synthesize the new data with existing data to produce a regional, rather than a state-based framework. A broad undertaking, this project is collaborative with other state and federal agencies, including the state geologic surveys of New Jersey, Maryland, and Virginia, as well as the USGS. This extension of the ASAP work continue to focus on collecting new data. Additional work will focus on mapping paleochannels to determine their relationship to potential resource areas.

Statewide LiDAR Data for Delaware

Project Contacts: Naomi S. Bates, John A. Callahan, and William S. Schenck

New, high-resolution LiDAR and digital elevation data for Delaware

LiDAR, which stands for Light Detection and Ranging, is an active remote sensing method that uses a pulsed laser to measure distances from a source to a target object. Airborne LiDAR data for the entire state of Delaware was collected in 2014 as part of a multi-agency state and federal effort (including the DGS, Delaware Department of Transportation, DNREC, USGS, and NOAA) and funded by the Hurricane Sandy Relief appropriation. The LiDAR point data were used to produce a 1-meter resolution digital elevation model (DEM) for the State of Delaware. This high-resolution DEM is being used to update elevation contours for the state, model potential sea-level rise scenarios, enhance watershed modeling for stream flooding, update topographic maps, predict storm surge impacts, improve geologic and land use mapping, and aid in vegetation studies and habitat analysis. In addition, the LiDAR-derived DEM and hillshade allow excellent visualization of the land surface, even in heavily vegetated areas (see image), which can be used for landscape feature identification, site reconnaissance, and identification of historical features such as mill races, roads, building sites. The DGS will store and maintain the LiDAR dataset and derivatives as well as provide expertise for Delaware.



Aerial imagery from 2012 (left) shown alongside high-resolution hillshade of the LiDAR-derived digital surface model including vegetation and buildings (middle), and digital elevation model (right) showing the bare earth model of land surface elevations with vegetation and buildings removed. Note the prominence of such features as the Carolina Bays (circular depressions near the middle of the image), the wide stream valley bottom, trails, and low order stream channels.

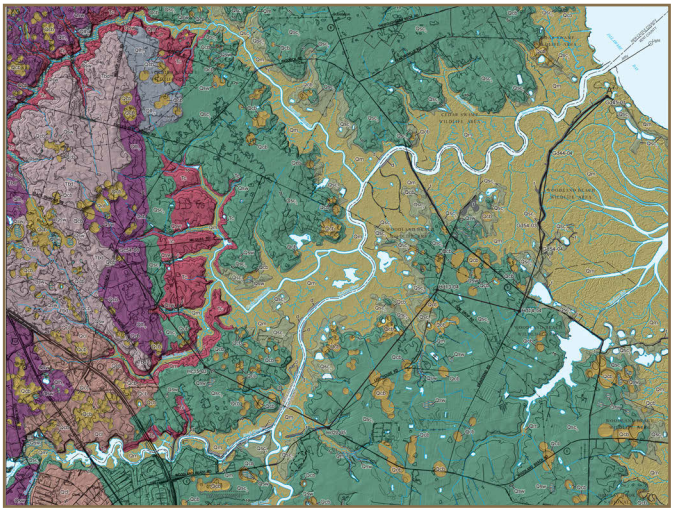
Delaware Geologic Mapping Program – Update

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

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 for 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 DGS geologic mapping efforts.

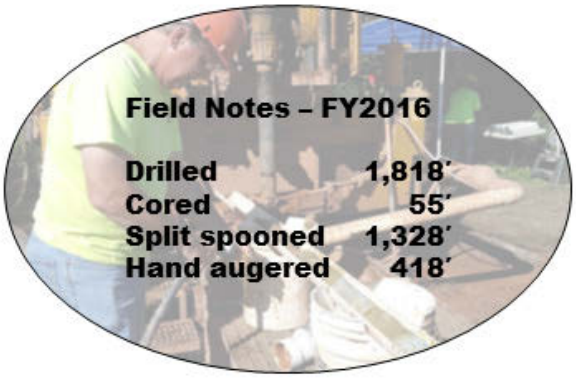
The current mapping project area is located in New Castle County near Saint Georges. Fieldwork for this project began in July 2016 and will be completed in June 2017. In August, a wireline core hole was drilled to basement rock in the Saint Georges Quadrangle. The 713.5' boring was a collaborative effort by several DGS scientists and is the deepest hole drilled to date using the DGS drill rig. The project took two and a half weeks to complete. The upper portion of the core

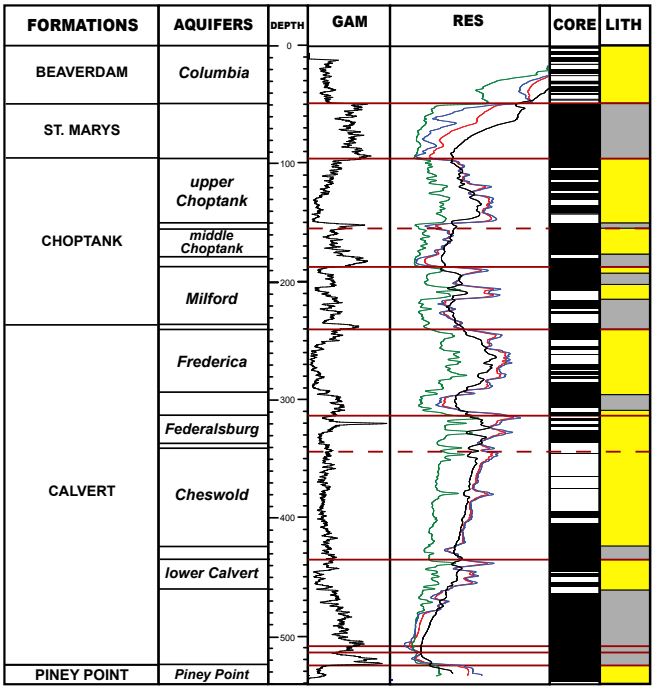


A portion of a preliminary geologic map of the Smyrna Quadrangle, which is being mapped by DGS.

hole provided high-quality continuous core for the Statemap geologists to make surficial and near-surface stratigraphic correlations with shallower Statemap split-spoon cores in the quadrangle.

Mapping for the Smyrna Quadrangle was completed in July 2016, and a draft map was submitted to the USGS in August. This mapping effort revealed that the Columbia Formation occurs further east than previously mapped.





Formations, aquifers, and well logs for the Marshy Hope test hole, northwestern Sussex County.

Geological Characterization of Aquifers and Depositional History of the Miocene Sediments of Northwest Sussex County, Marshy Hope Core Site

Project Contact: Peter P. McLaughlin, Jr.

An investigation of the subsurface geology of an agricultural area where the relationship of confined aquifers and intervening confining beds may be important to groundwater protection

The Miocene-age sediments of central and southern Delaware include four important confined aquifers: Cheswold, "Federalsburg," Frederica, and Milford. The DGS and two University of Delaware graduate students have completed a detailed, sample-based characterization of these aquifers and the confining beds that protect them in a research test hole at Marshy Hope Wildlife Area. The results allow us to better estimate trends in aquifer quality, recognize the decreasing thickness of confining beds between the aquifers, and understand issues with aquifer connectivity in nearby areas of Sussex County and the Eastern Shore of Maryland. The results of this work are being summarized in a forthcoming DGS report.

Stratigraphy and Geological Characterization of Aquifers in the Potomac Formation, New Castle County

Project Contact: Peter P. McLaughlin, Jr.

A multi-part research theme aimed at understanding the geological controls on aquifer connectivity in the subsurface of northern Delaware

The Potomac Formation of northern Delaware contains a complex network of aquifer sands that provide an important

DGS research team drills a research test hole in the Potomac aquifer near Red Lion, Delaware, 2016.

source of groundwater for household use and industry. The DGS has conducted a number of studies over the last fifteen years that have resulted in an increasingly detailed understanding of the geological characteristics of this complex aquifer framework. DGS staff are preparing reports for stakeholder use that document the results of several drilling campaigns targeting these aquifers, as well as a geophysical survey conducted in the Chesapeake and Delaware Canal area. These reports will provide detailed, sample-based data on the geological characteristics of the subterranean horizons in the Potomac Formation that store groundwater, as well as delineate their dimensions and connectivity.

Geological Carbon Sequestration Data Framework

Project Contact: Peter P. McLaughlin, Jr.

Compiling detailed inventory of DGS OCS repository for use on regional study

The DGS is participating in two multi-institution projects to compile data that enables characterization of the geological carbon sequestration potential of deep-subsurface formations in our region. These projects, funded through the U.S. Department of Energy and administered by Battelle Memorial Institute, include one project to compile data from the deep subsurface of the Northeast and Middle Atlantic U.S. Outer Continental Shelf (OCS) and second project to coordinate interpretations of the deep subsurface of the onshore Middle Atlantic Coastal Plain with neighboring states.

A core section from an offshore U.S. Outer Continental Shelf test hole with a bottom depth of 8,787.3 feet. White circles indicate where samples were taken for further analysis.

The DGS has a well-established reputation for regional expertise on the stratigraphy and hydrogeology of the Middle Atlantic region, focused on Delaware, and understanding the regional context in the area that extends from Virginia, through Maryland, into New Jersey, and to Long Island, New York. Additionally, the DGS has a long standing interest in understanding the geology of the Atlantic OCS of the United States dating back to petroleum exploration programs in that area in the 1970s and 1980s that found no commercial hydrocarbons. The DGS OCS Sample and Data Repository holds the entirety of remaining sample materials (core, cuttings, prepared samples) from the costly exploration wells drilled in that period.

The DGS is providing technical advice and support to the project team, assisting in the development of a regional framework for the study area, and providing access to and interpretive support for relevant geological samples, well logs, core data, and geophysical data. The project funding has enabled us to hire project personnel to make a detailed, item-by-item inventory of holdings in the DGS OCS Sample and Data Repository and to better preserve these irreplaceable materials for the long term. Moreover, the geologic characterization conducted as part of this project will advance our understanding of the deep geologic framework for the Delaware Coastal Plain, which may provide valuable insight into the thickness and extent of relatively deep geologic formations that may provide future sources of groundwater.

SAVE THE DATE!

Delaware Geological Research Symposium

APRIL 2017

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

A DAYLONG
FIELD TRIP EXPLORING THE
PIEDMONT AND COASTAL PLAIN
OF DELAWARE

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. For example, DGS staff attended 28 bridge calls with emergency managers in the last 12 months. 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 the Delaware Department of Natural Resources and Environmental Control, Delaware Department of Transportation, and other federal, state, and county groups on the Delaware Storm Reporter Advisory Group, an on-line program that enables the rapid delivery of coastal storm damage information. The DGS also serves on the Delaware Emergency Management Agency (DEMA) Emergency Response Task Force for flooding, northeasters, 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, which provides email and text alerts, as well as web–based inundation maps and elevation

Flooding at Kitts Hummock following Mother's Day Storm 2008.

profiles of evacuation routes, based on real-time forecasts to coastal communities along the Delaware Bay coast. In addition, DGS continuously maintains storm books for 16 USGS stream gages—13 in Delaware and 3 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.

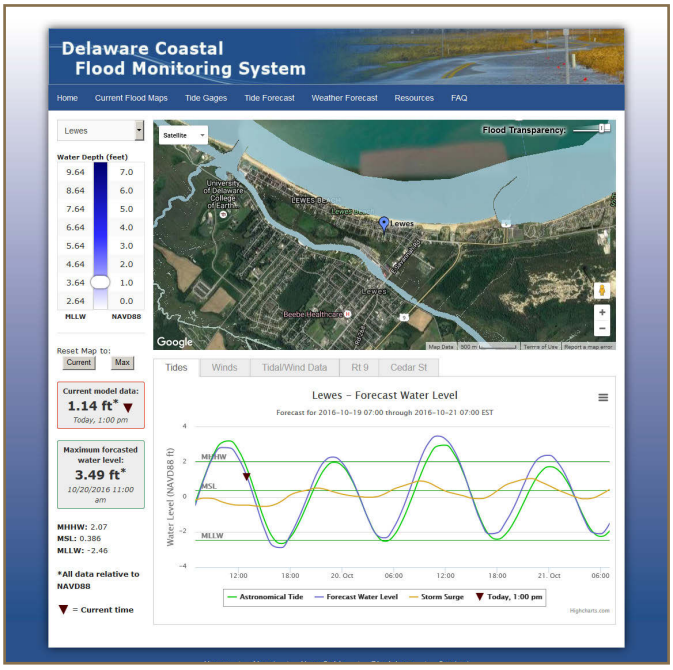
The Delaware Coastal Flood Monitoring System

Project Contact: John A. Callahan

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

In the last two decades, large storms such as Hurricanes Katrina and Sandy have resulted in significant loss of life, injuries, and property damage in the United States. Much of the damage was the result of severe coastal flooding. The Delaware coastline is extremely vulnerable to such events. The Mother's Day storm of May 2008 left at least one person dead and many people homeless causing evacuations in many communities within Kent County along the Delaware Bay coast. Sea-level rise, land subsidence, and the frequency and intensity of storms are a growing concern in regard to coastal flooding.

In response to these risks, the DGS has worked with the Delaware Department of Natural Resources and Environmental Control (DNREC) and the University of Delaware Delaware Environmental Observing System to develop the Delaware Coastal Flood Monitoring System (CFMS), a web-based early warning system designed to provide emergency managers, planners, and others information on the extent, timing, and severity of upcoming flood events. The CFMS covers the Delaware Bay coastline from the City of New Castle to Lewes (approximately 15 communities), and provides email or text alerts up to 48 hours in advance of high water conditions. Real-time flood inundation maps, road elevation profiles, forecasts of tides, storm surge and winds as well as current meteorological and hydrological conditions are also included on the website. This tool is currently used by the Delaware Emergency Management Agency, DNREC, and other organizations throughout the state during times leading up to coastal storm events. Recently, the CFMS has been highlighted at the Delaware National Estuarine Research Reserve Symposium, by the Delaware River Basin Commission Flood Advisory Committee, Army Reserve Force Policy Committee, the regional Mid-Atlantic Coastal Resiliency Institute, among other groups and events. The CFMS is constantly being improved with recent updates including



The Delaware Coastal Flood Monitoring System (CFMS) is a web-based tool and alert system designed to provide emergency managers, planners, and others the information needed regarding upcoming coastal flood events.

the development of a mobile-friendly version of the website, move to updated backend computing infrastructure, addition of forecasted wind data, and improved inundation maps based on recent lidar acquisition.

Evaluation of the DGS Seismic Network

Activity Contact: Stefanie J. Baxter and Tom Smith

Monitoring earthquake hazards in Delaware

In 1973, the DGS established its first seismic station and for decades maintained its own network of five seismic stations to detect local earthquake activity. In 2014, with funding from the Delaware Emergency Management Agency, the DGS took permanent ownership of two state-of-the-art, multi-channel, broadband seismometers bringing a significant upgrade to the network and the total number of seismic stations across Delaware to seven. These two new sensors provide significantly higher resolution seismic information for emergency managers, scientists, and engineers to evaluate seismic activity.

During the past year, equipment used to operate two of the older stations expired, making it apparent that we needed to re-evaluate the network and determine the most cost-effective measures to maintain the network yet keep seismic coverage over the entire state. Taking into consideration the age of the equipment and the

quality of the seismic signals at each of the stations, the most cost effective and efficient option is to reduce the total number of stations from seven to three – retaining two stations in New Castle County where the majority of historical events have occurred, and one station downstate.

The DGS is working with Lamont-Doherty Earth Observatory of Columbia University to determine the best downstate location to relocate one of the multi-channel, broadband stations. Our goal is to have the equipment installed and operating by the end of the year.

Tom Smith (left) and Steve McCreary (right) inspect the vault that will house the seismic equipment at a site in downstate Delaware.

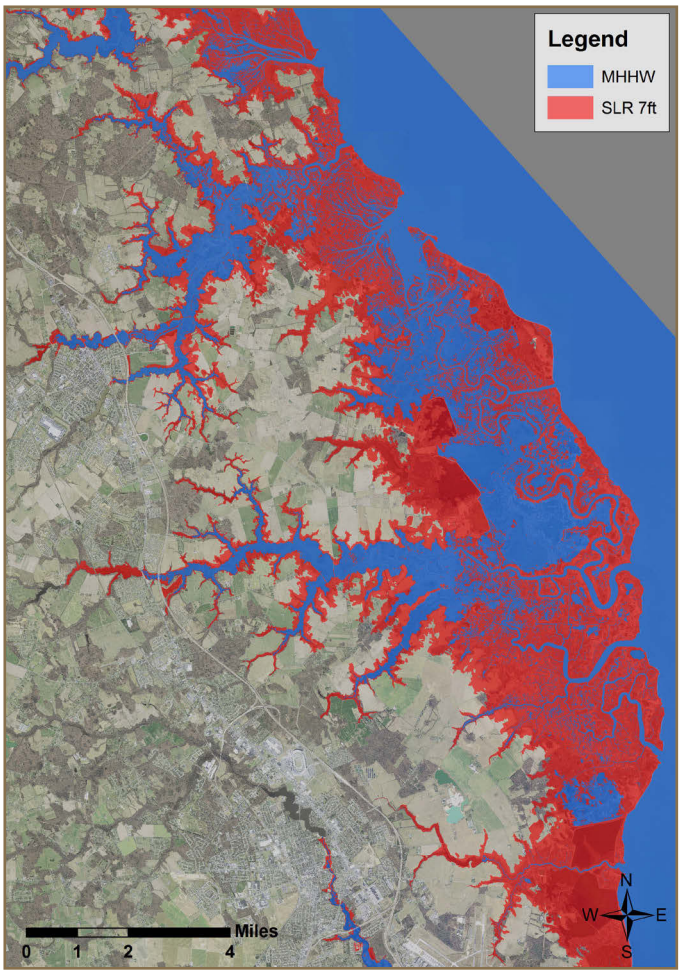
Sea-Level Rise Planning Scenarios for Delaware

Project Contacts: John A. Callahan and Naomi S. Bates

Updating determination of future sea-level rise planning scenarios and development of coastal inundation maps for the State of Delaware

Sea-Level Rise (SLR) is one of the most significant impacts of climate change. Delaware is especially vulnerable to the effects of SLR due to its flat topography, low mean elevation, frequency of coastal storm impacts, ongoing land subsidence, and increased development and population in coastal areas. The DGS is working with DNREC Delaware Coastal Programs to update the previous sea-level rise planning scenarios from 2009. At that time, the High, Intermediate, and Low SLR planning scenarios equated to 0.5, 1.0, and 1.5 meters, respectively, of increased base sea level by the year 2100 (relative to the year 1992.) In 2013 the Intergovernmental Panel on Climate Change released its Fifth Assessment Report, and in 2012 and 2014 the U.S. Global Change Research Program released its National Climate Assessments for the United States. These and other technical reports, as well as much peer-reviewed science-based literature, conclude that the rate of SLR has increased over recent years and will very likely continue to do so in the future.

The DGS is coordinating the activities of the 2016 SLR technical committee comprised of scientists representing both academia and state government, in Delaware and regionally, with knowledge and experience in coastal issues



Bathtub-model coastal inundation map corresponding the mean higher-high water (MHHW) level and sea-level rise scenario of 7 feet above MHHW.

relating to sea-level rise. The primary goals of this project are 1) to summarize the recent scientific peer-reviewed literature, technical reports, and international/national assessments regarding past/observed and future/projected sea-level change, globally and regionally, and 2) to project scenarios of future sea-level rise based on sound scientific methodologies that state, county, and local agencies in Delaware can use for incorporating SLR into their planning activities. The technical committee has worked together since November 2015 to review historical reconstructions and current tide gage observations of past and recent sea-level rise, and to identify the primary causes and their relative influences on relative SLR in the mid-Atlantic region. As a result of this work, the technical committee is developing a document that will summarize the relevant scientific literature and provide the basis for new SLR planning scenarios for Delaware. This document will be made publically available through DNREC and DGS.

In addition, the DGS is working with DNREC to develop a series of SLR coastal inundation maps corresponding to water surfaces from the mean higher-high water (MHHW) level to 7 feet above MHHW, in 1-foot increments. Development of the bathtub-model inundation maps was based on a high-quality, 1-meter Digital Elevation Model derived from the 2014 state-wide LiDAR acquisition funded jointly by DGS, DNREC, Delaware Department of Transportation and the USGS through Hurricane Sandy Supplemental Relief Funds. The final product of these analyses is a geodatabase containing eight layers (MHHW to MHHW + 7 ft) representing the bare-earth SLR inundation maps and eight layers showing the same regions with an accounting for elevated roadways and bridges. These maps and the updated SLR planning scenarios will help advise long-range planning of infrastructure, facilities, land management, land use, and capital spending.

Development of a High Water Mark Database and Display System for Coastal Flooding Events in Delaware

Project Contact: John A. Callahan

Improving collaboration for analyzing, monitoring, and documenting magnitude and extent of flooding

Delaware is susceptible to coastal storms, both tropical and extra-tropical (particularly Nor'easters) and has been hard hit in the past by Superstorm Sandy in 2012, Hurricane Irene (2011), the Mother's Day Storm (2008), and the Ash Wednesday Storm (1962).

Coastal flooding, Fowler Beach Road (DNREC file photo).

The DGS is currently compiling a database of high-water marks (HWMs) that will provide valuable data on flooding for multiple applications, including disaster recovery planning, allocation of insurance claims, validating hydrodynamic models, or assessing the severity and spatial extent of a storm. HWMs are arguably the best method for capturing the maximum depth and extent of a flood, which can occur as a result of overtopping of streams or rising water levels due to storm surge. They are typically observed as peak measurements on automated gages, as water stains on building walls, or as debris lines on the street or beach. Unfortunately, there has been no formal collaboration among Delaware organizations for collecting HWMs, or technical infrastructure in place for sharing HWMs or peak storm tide data. Thus, the DGS is filling a need for improved collaboration to better analyze, monitor, and document the magnitude and extent of flooding. Initial focus is on coastal flooding, but our efforts can expand to support stream flooding HWMs in the future.

Development of the database is being done in partnership with the Office of the Delaware State Climatologist, the Delaware Environmental Observing System (DEOS), and the Delaware Environmental Monitoring and Analysis Agency. Hydrologic data were compiled from approximately 50 water level tide gages and several post-event, surveyed HWMs from coastal flood events (i.e., from storms or strong winds) from 1960 through present, currently consisting of over 1,700 observations. Tide-gage data sources included USGS, NOAA, DNREC, DEOS, Delaware National Estuarine and Research Reserve, and U.S. Fish and Wildlife Service. HWM surveyed data were gathered from past reports and documentation from the Federal Emergency Management Agency, Delaware Emergency Management Agency, USGS, DGS,

and others. A corresponding website is also being developed to display the HWM database in map and list form.

Two workshops were held at the St. Jones Reserve Training Facility in Dover, Delaware to foster collaboration among federal and state agencies in regard to 1) tide and stream monitoring deployment before each event, 2) post-event surveys, 3) the specific type of HWM data that are most useful to collect and share, and 4) the possibilities for building a technical infrastructure to store, distribute, and share this information.

Analysis of Storm Surge and Tidal Data Relationships in the Delaware Inland Bays

Project Contact: John A. Callahan

Analyzing storm surge and tidal data relationships in the Delaware Inland Bays based on meteorological conditions

Coastal events bring many types of natural hazards (beach and dune erosion, winds, waves, precipitation) and public infrastructure damage (power loss, road damages) to Delaware; however, flooding from storm surge is often the greatest threat to life and property. The Delaware Inland Bays (DIB) are of primary concern due to their importance to Delaware's tourism, role in the state's overall economy and industry, the increasing population and development along the Bays' coasts, and its low elevation and direct connection to the ocean.

However, the Inland Bays represent a complex hydrodynamic system consisting of three shallow interconnected bays: Rehoboth Bay, Indian River Bay, and Little Assawoman Bay. These bays encompass approximately 32 square miles of water and 320 square miles of watershed. The Rehoboth and Indian River Bays drain solely to the Delaware Bay through the Indian River Bay Inlet whereas the Little Assawoman Bay drains southward to the larger Assawoman Bay. All of the bays are connected to each other via the Lewes-Rehoboth Canal and Assawoman Bay Canal. This complexity makes it difficult for operational hydrodynamic models in the Delaware Bay and coastal Atlantic Ocean to reliably provide estimates on the magnitude and timing of coastal flooding.

DGS, with support from the Delaware Department of Natural Resources and Environmental Control Delaware Coastal Programs, is analyzing the observational record from tide gages throughout the Inland Bays. Storm surge and astronomical high tides combine to raise water levels in many Inland Bay communities, with differing characteristics depending on the meteorological conditions, such as precipitation, prevailing wind speed and direction. Statistical analysis is being performed to compare the magnitude and timing of high tides and peak storm tides in the Delaware Bay at the Indian River Bay Inlet to the numerous monitoring locations within the DIB system.

The results of the project will allow for a better understanding of the influence of meteorological conditions on the propagation of storm surge and high tide through the DIB system. We will also include the DIB into the Delaware Coastal Flood Monitoring System, an online early warning system for Delaware (that is currently only available for the City of Lewes area and northward), that assists emergency managers and local officials with preparing for impending flooding events.

This project focuses on the behavior of storm surge and high tides in the Delaware Inland Bays.

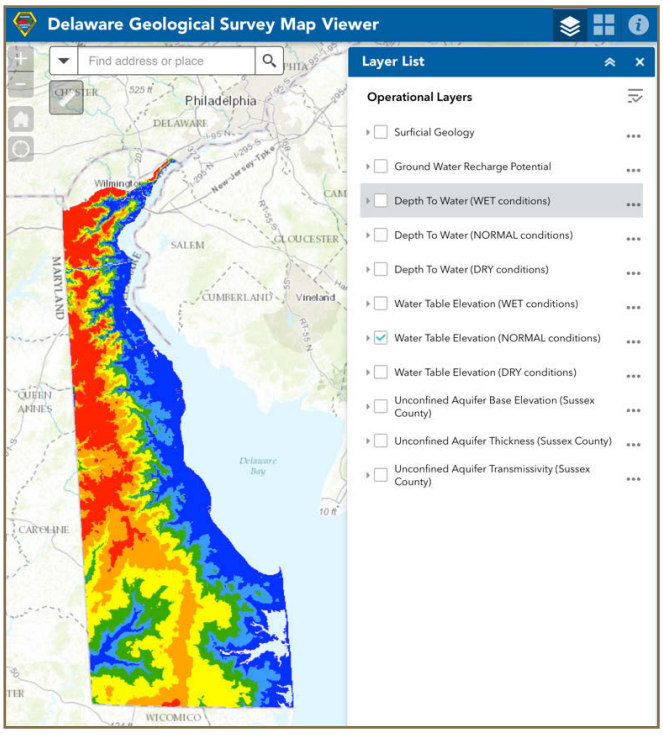
4. Information and Data Dissemination

Online Open Data Access

Project Contacts: John A. Callahan and Lillian T. Wang

DGS research data available online and via web mapping services

The Delaware Geological Survey strives to continually improve the way we make our hydrologic, geologic, and other research data available online. Most datasets are available through 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—providing easy access for state agencies, academic research groups, industry, and the public. Source datasets are updated at various time intervals, depending upon the nature of the data collection. For example, most groundwater-level data are updated on monthly and quarterly time periods (depending upon staff visits to each well) whereas additions to the subsurface geophysical and lithologic data are made on a well-by-well basis, usually soon after installation. DGS strives to distribute data and services via open, interoperable formats and



Screenshot of the Delaware Geological Survey Map Viewer application hosted on FirstMap. Several web map services of Delaware geologic and hydrogeologic data are made available through this free, publicly available map viewer.

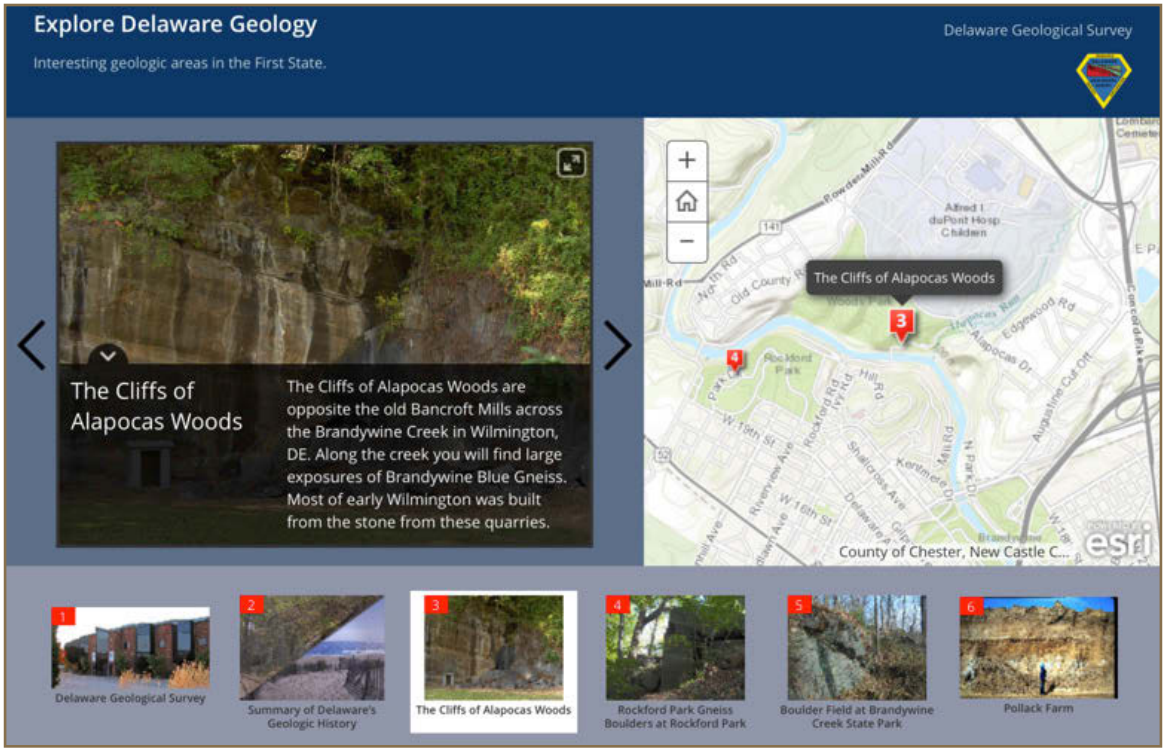
protocols compatible with both proprietary and open-source-GIS and programming packages, supporting as wide a user group as possible.

DGS also distributes its data through several large scale geoscience data networks, which helps standardize distribution formats and protocols, consistent with other states and federal agencies, and expands the accessible audience of DGS scientific information. Surface geologic maps published by the DGS since 1993 are available through the United States Geoscience Information Network (USGIN), developed through a partnership between the Association of American State Geologists and the USGS. The USGIN also includes metadata and links to additional DGS geoscience data. OneGeology, an international effort to make available digital geologic map data from around the world in a standardized way, links to statewide 1:100,000 surficial geologic maps of Delaware from DGS. DGS maintains a Four Star web service accreditation rating and is one of only a few states in the US that participate in OneGeology. During this past year, DGS has joined the National Ground-Water Monitoring Network (NGWMN), 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 though XML web data services.

During spring 2016, DGS contributed several of its published GIS data layers to FirstMap (http://firstmap.gis.delaware.gov/), Delaware's enterprise Geographic Information System (GIS). FirstMap is the result of the Delaware GIS community's need for a self-service, centralized GIS where data are shared among state organizations, local governments, academia, and the public. Web services are available for public users to view FirstMap data holdings in a web browser along with a variety of base maps to choose from. GIS professionals are able to use these web services in GIS desktop software, mobile applications, and online maps.

DGS data in FirstMap include surficial geology, ground-water recharge potential, depth to the water table and water-table elevations under normal, wet, and dry conditions, and elevation, thickness, and transmissivity of the unconfined portion of the Columbia aquifer in Sussex County.

Users can view these datasets in the Delaware Geological Survey Map Viewer which is accessed in the FirstMap ArcGIS Online Portal (http://delaware.maps.arcgis.com/). There is also an application called Explore Delaware Geology which takes users on a virtual tour and describes interesting geologic features throughout the state.



Screenshot of the front page of The Cliffs of Alapocas Woods, a virtual tour developed by Lillian Wang of the DGS. It can be accessed at the FirstMap ArcGIS Online Portal (http://delaware.maps.arcgis.com).

WATSYS2: A Shared Internal Data Service

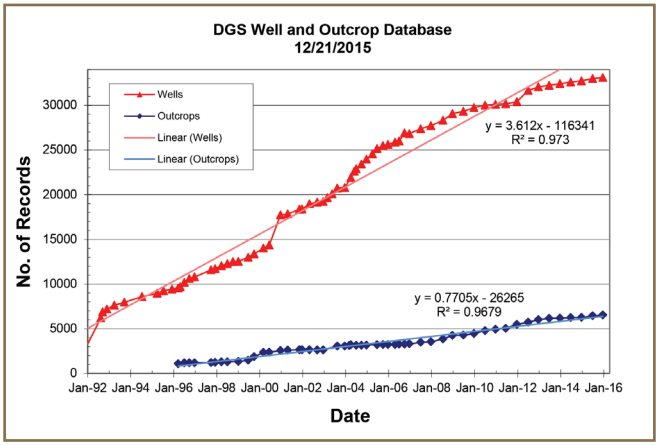
Project Contact: A. Scott Andres

The DGS geoscience data backbone

The Watsys2 data system is the backbone of the DGS geoscience data system. The shared database contains digital records for over 13.5 million individual pieces of data and associated metadata. This relational database system has served the DGS with limited interruption since 1981. The vast majority of data in Watsys2 are distributed to the public through the DGS web site.

Tables in the database contain data and metadata on wells, test borings, outcrops, rock and sediment samples, water samples, water levels, analytic chemistry, geophysical logs, lithologic logs, aquifer tests, groundwater recharge, and scientific instruments. It includes records of over 158,000 wells, 93,000 water samples, and 33,000 rock samples. Nearly 6,000 new well records were made in the last fiscal year.

DGS staff members have multiple methods to add, edit, view and extract data. An Oracle© software package handles most everyday data entry, editing, viewing, and quality control tasks for DGS staff members. More complex tabular and map-based data analyses tasks are done in spreadsheet and GIS software that use ODBC connections to Watsys2.



History of the DGS well and outcrop data holdings.

Delaware Geological Survey Data Preservation

Project Contacts: William S. Schenck, Peter P. McLaughlin, Jr., and Kelvin W. Ramsey

Preserving geological sample material is a part of an on-going project that ensures valuable information is available for future generations

The DGS has invested a major effort in sample and data preservation over the last year. The majority of this work has been sample preservation for two externally funded geology programs. One program has the goal of evaluating the potential for geologic carbon sequestration in deep geologic formations offshore the east coast of the United States and is funded by the U.S. Department of Energy. This project has supported a detailed itemized inventory of related sample and data holdings in the DGS Outer Continental Shelf Sample and Data Repository. This one of-a-kind collection holds all remaining sample material from east coast offshore drilling in the 1970s and 1980s, preserving irreplaceable geological samples obtained from multimillion dollar drilling programs for 51 wells. Since early 2016, more than 70,000 well cuttings samples, 3,000 core samples, and 80,000 processed sample preparations have been inventoried for this project. Inventory work is expected to continue into early 2017, with additional work on preservation of poorly packaged samples planned for later 2017 and 2018. The other part of this effort is a multi-project program, funded by the U.S. Bureau of Ocean Energy Management, to increase our knowledge of sand resources offshore and identify new sand resources to meet future needs. As part of this, the DGS has undertaken a major effort to inspect, inventory, and repackage 371 offshore sand cores. These samples provide an invaluable archive of data on sand resource types, quality, and distribution from the Atlantic sea bottom offshore Delaware and will be an essential resource for these projects as well as future studies.

PUBLICATIONS

PUBLICATIONS COMPLETED

Bulletins

Bulletin 21A Evaluation of Wastewater Treatment Options Used in Rapid Infiltration Basin Systems (RIBS)

Bulletin 21B Hydrogeology of a Rapid Infiltration Basin System at Cape Henlopen State Park, Delaware

Bulletin 21C Groundwater Quality and Monitoring of Rapid Infiltration Basis Systems, Theory and Field Experiments at Cape Henlopen State Park, Delaware

Bulletin 21D Using Numerical Models To Assess a Rapid Infiltration Basin System, Cape Henlopen State Park, Delaware

PUBLICATIONS IN PROGRESS

Open File Reports

OFR 51 Methods and Procedures for Collection, Processing, and Management of Groundwater Level Data

Geologic Maps

GM 24 Geologic Map of the Clayton and Millington Quadrangles, Delaware

GM 25 Geologic Map of the Cecilton and Middletown Quadrangles, Delaware

GM 26 Geologic Map of the Smyrna Quadrangle, Delaware

Report of Investigations

RI 80 Investigation of Submarine Groundwater Discharge at Holts Landing State Park, Delaware: Hydrogeologic Framework, Groundwater Level and Salinity Observations

RI 81 Characterization of Tidal Wetland Inundation in the Murderkill Estuary

RI 82 Results of Coring and Well Installation for the Southern New Castle-Northern Kent Counties Groundwater Monitoring Project

RI 83 Aquifers and Groundwater Withdrawals, Kent and Sussex Counties, Delaware

RI 84 Evaluating Impacts of Sea-Level Rise on Groundwater Resources

RI 85 Results of Physical Hydrogeologic Investigations of the Columbia, Rancocas, and Mt. Laurel Aquifers, and Magothy Formation, Southern New Castle and Northern Kent Counties, Delaware

RI 86 Results of Groundwater Quality Investigations of the Columbia, Rancocas, and Mt. Laurel Aquifers, and Magothy Formation, Southern New Castle and Northern Kent Counties, Delaware

RI 87 The Potomac Formation in Five Core Sites in New Castle County, Delaware

RI 88 Stratigraphic Geometry and Facies Characteristics of the Potomac Formation near the Chesapeake and Delaware Canal, Delaware, on the basis of a Reflection Seismic Survey and Well Data

Photo credit: Mike Ciosek, photographer for the Wilmington and Western Railroad.

DGS Service to Professional Societies, Boards, and Committees

American Association of Stratigraphic Palynologists

American Geosciences Institute

Association of American State Geologists

Center for the Inland Bays Executive Committee

Center for the Inland Bays Scientific and Technologic Advisory Committee

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

Delaware Emergency Management Agency Hazard Mitigation Council

Delaware Emergency Management Agency Technical Assessment Center Group

Delaware Geographic Data Committee

Delaware Geologic Mapping Advisory Committee

Delaware Resilient and Sustainable Communities League

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

Delaware Water Supply Coordinating Council

Delaware Water Well Licensing Board

DelDOT Hydrology Coordination Workgroup

Delmarva GIS Conference Committee

Federal Advisory Committee on Water Information

Federal Geologic Mapping Advisory Committee

Federal Subcommittee on Groundwater

Geological Society of America, Geology and Public Policy Committee

Mid-Atlantic Coastal Resilience Institute (MACRI) Working Group

Murderkill River Monitoring and Modeling Workgroup

National Association of State Boards of Geology

National Association of State Boards of Geology Council of Examiners

National Ground Water Association, Water Management Subcommittee

New Castle County Resource Protection Area Technical Advisory Committee

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

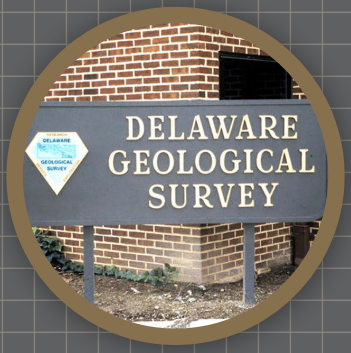
Regulated Flow Advisory Committee of the Delaware River Basin Commission

River Master Advisory Committee

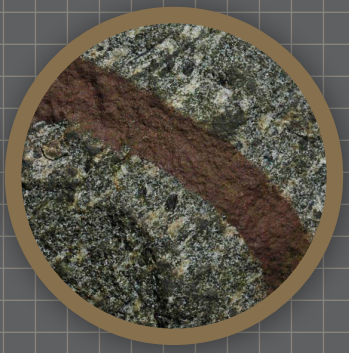
River Master Decree Party Workgroup

University of Delaware Public Engagement Committee

ANNUAL REPORT OF PROGRAMS AND ACTIVITIES | 2015-16







Delaware Geological Survey

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

www.dgs.udel.edu