Spring 2021

the FOREFRONT

A Review of ERDC Publications

Modeling COVID-19

Ensuring bridge safety

Making research more accessible

A half century of snow research

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

ITL
INFORMATION TECHNOLOGY LABORATORY

About *The Forefront*

The Engineer Research and Development Center (ERDC) is the premier civil works engineering and environmental sciences research and development arm of the U.S. Army Corps of Engineers (USACE). As such, it partners with the Army, Department of Defense (DoD), federal agencies, and civilian organizations to help solve our Nation's most challenging problems in civil and military engineering, geospatial sciences, water resources, and environmental sciences.

A special government knowledge center, ERDC Information Technology Laboratory's Information Science and Knowledge Management (ISKM) Branch is critical to ERDC's mission, fulfilling research requirements by offering a variety of editing and library services to advance the creation, dissemination, and curation of ERDC and USACE research knowledge.

Serving as the publishing authority for the ERDC, ISKM publishes all ERDC technical publications to the Digital Repository Knowledge Core, sends a copy to the Defense Technical Information Center (DTIC) and creates a press release about each publication on the ERDC website. *The Forefront* seeks to provide an additional mechanism for highlighting some of our technical publications to the ERDC, USACE, Army, and DoD communities. This publication also encourages those outside ERDC to contact us about using ERDC editing services.

For more information regarding the reports highlighted in this publications or others that ERDC researchers' have created, please contact the ISKM virtual reference desk at erdclibrary@ask-a-librarian.info or visit the ISKM's online repository, Knowledge Core, at https://erdc-library.erdc.dren.mil/.

—Jennefer Beyl
Librarian and Editing Team Code 4
ITL Information Science and
Knowledge Management Branch

The Forefront Staff

Managing Editor: Karen Taylor

Art Director: Emily Moynihan

Contributing Writers: Emily Moynihan, Karen Taylor, James Dolan, Kathleen Miles, Vicki Reinhart, and Jennefer Beyl

Publication Supervisor: Jennefer Beyl

Branch Chief: Molly McManus

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Cover Photo: ERDC's DIVE.lab on display. (U.S. Army photo by Jake Pope.)

Your ISKM Writer-Editors

Coastal Hydraulics Laboratory (CHL)
Tony Tullos
Tony.L.Tullos@usace.army.mil
(601) 634-2572

Cold Regions Research Laboratory (CRREL)
Emily Moynihan
Emily.B.Moynihan@usace.army.mil
(603) 646-4404

Construction Engineering Research Laboratory (CERL)
On-Site Editor
erdclibrary@ask-a-librarian.info
(601) 634-2355

Environmental Laboratory (EL)
On-Site Editor
erdclibrary@ask-a-librarian.info
(601) 634-2355

Geospatial Research Laboratory (GRL)
Karen Taylor
Karen.J.Taylor@usace.army.mil
(601) 634-3419

Geotechnical and Structures Laboratory (GSL)
Kathleen Miles
Kathleen.K.Miles@usace.army.mil
(601) 634-7234

Information Technology Laboratory (ITL)
Karen Taylor
Karen.J.Taylor@usace.army.mil
(601) 634-3419

Editorial Assistant for all labs
Vicki Reinhart
Vicki.A.Reinhart@usace.army.mil
(217) 373-5824

ERDC Library
https://erdc-library.erdc.dren.mil/ | erdclibrary@ask-a-librarian.info
Vicksburg: (601) 634-2355 | Hanover: (603) 646-4779 | Champaign: (217) 373-2717

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ERDC/ITL SR-17-1

Publications of the U.S. Army Engineer Research and Development Center

Appendix E: FY20 (October 2019–September 2020)

Compiled by James A. Dolan

Abstract: Publications issued October 2019 through September 2020 by the U.S. Army Engineer Research and Development Center (ERDC) are listed. The publications are grouped according to the technical laboratories or technical program for which they were prepared. Procedures for obtaining ERDC reports are included in the Preface.

http://dx.doi.org/10.21079/11681/39201

Previous publications

ERDC/ITL SR-17-1	http://dx.doi.org/10.21079/11681/21022
ERDC/ITL SR-17-1 App. A	http://dx.doi.org/10.21079/11681/22581
ERDC/ITL SR-17-1 App. B	http://dx.doi.org/10.21079/11681/27267
ERDC/ITL SR-17-1 App. C	http://dx.doi.org/10.21079/11681/31406
ERDC/ITL SR-17-1 App. D	http://dx.doi.org/10.21079/11681/34897

Continued work . . .

This compilation is the fifth appendix to the original special report, *Publications of the U.S. Army Engineer Research and Development Center: October 1999–December 2015*. The report contains approximately 277 works published by ERDC with links to those reports and technical notes approved for public release. Publications are listed by laboratory or program and contain, when available, Defense Technical Information Center accession document (AD) numbers for ordering purposes. Both the original report and all subsequent appendices are available from the ERDC Library's Knowledge Core.

This collection is an important resource for ERDC, providing an easy yet comprehensive listing of all of its publications. Not only is it an important reference for confirming the status of various projects and programs, but it also provides a high-level overview of the diversity of research happening across ERDC in a given year. It is an opportunity to see the many capabilities and resources available at ERDC in terms of both facilities and expertise. This in turn can lead to otherwise unknown collaboration opportunities within and across laboratories. Further, by better understanding the work ERDC has done in the past, we can better prepare for the future.☐

Article contributed by James A. Dolan, Librarian for the ITL Information Science and Knowledge Management Branch.

Left: The ERDC-Hanover Library holds over 25,000 books and over 75,000 reports, an excellent resource for ERDC researchers.

Bottom: The ERDC-Hanover Library's collection provides a broad range of modern and historical materials to inspire new research. The oldest book in the collection is from 1745—a description of Greenland by Hans Egede.

ERDC/CRREL SR-20-1

Site-Specific Case Studies for Determining Ground Snow Loads in the United States

By James Buska, Alan Greatorex, and Wayne Tobiasson

Abstract: The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has mapped ground snow loads for much of the United States. In some areas where extreme local variations preclude mapping on a national scale, instead of loads, "CS" is used to indicate that Case Studies are needed. This report and the accompanying spreadsheet, which contains the 15,104-station CRREL ground snow load database, provide the information needed to conduct Case Studies. When the latitude, longitude, and elevation of a site of interest are provided, the spreadsheet tabulates data available in the vicinity and generates plots that relate ground snow loads nearby to elevation. With this information, the ground snow load at the site of interest can be determined. This report uses 10 examples to illustrate the methodology and provides our answer and the comments we generate for each of these Case Studies and for 16 additional sites of interest, 8 of which have their answers "disguised" for practice purposes. CRREL has conducted over 1000 Case Studies upon request. Practicing structural engineers were involved in over 250 of them to verify that this methodology is ready to transfer to the design profession.

http://dx.doi.org/10.21079/11681/37574

Ensuring safety . . .

One of the most important outcomes of research is the data, methods, and results; but ensuring that others have access to it is critical. On top of this is the challenge of transferring a lifetime of experience to the next generation of researchers and engineers. This report and the accompanying *Case Study Spreadsheet* aim to accomplish all of these.

"The report and its companion spreadsheet document almost half a century of CRREL research on ground snow loads using the 50-year mean recurrence interval extreme-value approach," described authors James "Jim" Buska and Alan Greatorex. Being able to determine a ground snow load (which is necessary for calculating the roof snow load) is essential when designing structures in cold climates. In some parts of the country, snow is often the largest load these buildings undergo, but local data for ground snow loads are rare. Typically, the only measurement available is snow depth. So, the challenge is reliably converting these snow depths to loads. "We provide the dataset and guidance on how to conduct ground snow load case studies. During this time of transition, having decades-old baselines to refer to can be quite beneficial."

To complete this report, Jim, Alan, and Wayne Tobiasson (retired from CRREL in 2015, 2004, and 1997, respectively) continued to meet in CRREL conference rooms to discuss their work on snow loads—and to enjoy coffee breaks with cookies provided by Wayne's wife, Elizabeth. Their belief in the value of their snow load work drove them to keep developing and revising the Case Study methodology they had spent the last 38 years on. As they explained, "Snow and ice studies are basic research at ERDC-CRREL. This report and other reports by us and our colleagues, have resulted in national snow load and ice load design guidance (e.g., ASCE [American Society of Civil Engineers] Standard 7) that meets an essential need to provide safe facilities for the nation and our families."

Wayne Nils Tobiasson
1939–2020

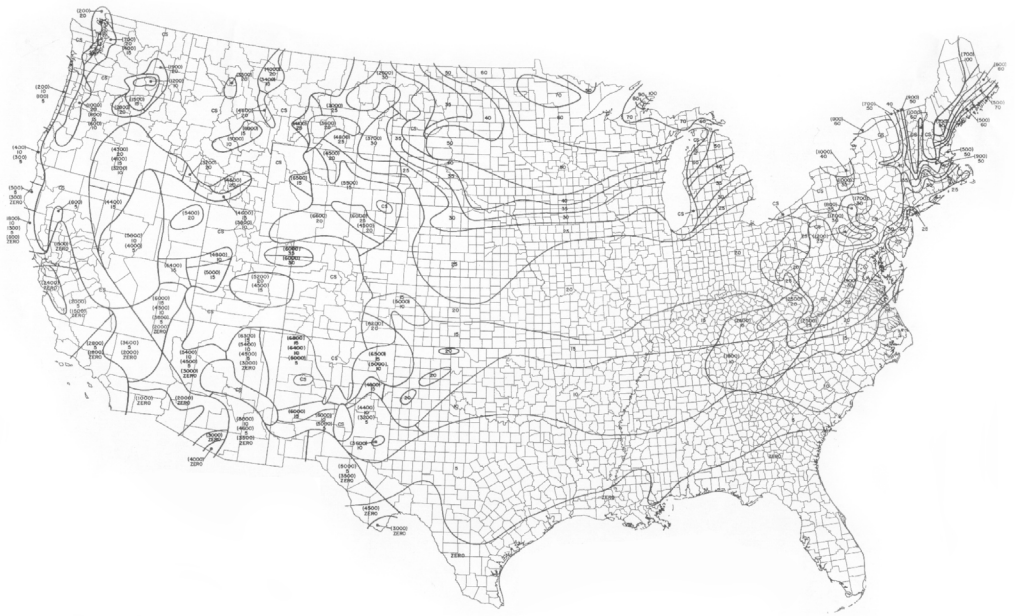
With Wayne's death in August 2020, this team and the CRREL community lost a "Distinguished Employee" and friend. Visit the following sites for more about Wayne's legacy:

https://www.vnews.com/wayne-tobiasson-obit-vn-082020-35816000

https://source.asce.org/army-corps-of-engineers-cold-regions-expert-dies-at-81-2/

In addition to work on this report, the team has been active in ASCE projects. The ASCE Subcommittee on Snow and Rain Loads invited them to contribute to efforts to update ground snow load data and to produce a more reliable load map for the U.S., which the next version of ASCE Standard 7-22 will likely incorporate. Their ERDC-CRREL report informs much of this update, once again proving CRREL's adeptness at addressing nationwide concerns. ☐

Article contributed by Emily B. Moynihan, Writer-Editor for the ITL Information Science and Knowledge Management Branch.



Opposite: Mt. Hood Meadows, Oregon, one of the Case Study locations.

Right: Ground snow load for the United States (psf). For the full-size version, see the Case Study Spreadsheet available with the report.

ERDC/CHL CHETN-IV-121

Vessel Wake Prediction Tool

By Michael A. Hartman and Richard Styles

Abstract: The purpose of this Coastal and Hydraulics Engineering Technical Note (CHETN) is to introduce a desktop application that can be used as a screening tool to assess the relative contribution of vessel wake energy to erosion as compared to that from currents and tides. The application uses simplified algorithms reported in the literature that predict wake height as a function of vessel speed and other parameters. The tool also estimates the maximum shear stress and energy dissipation, which are used as a proxy for erosion potential. This CHETN presents a brief description of the vessel wake algorithms and then describes the desktop application software to help familiarize the user with the layout and other features. The CHETN concludes with conditional limitations that should be considered before using the application.

http://dx.doi.org/10.21079/11681/35153

Protecting our shorelines . . .

When a vessel travels through the water, the energy from its motion dissipates in part through the water in the form of waves. That wave energy affects shoreline erosion in addition to the wave energy from naturally occurring currents, tides, and coastal storms. Shoreline erosion contributes to turbidity in the water, a result of suspended sediment particles, that inhibit light penetration and therefore photosynthesis of submerged aquatic vegetation. With the development of Michael Hartman and Richard Styles's Vessel Wake Prediction Tool, or VWPT, researchers can analyze the relative contribution of each of these wave energy types to shoreline erosion.

The tool combines a number of previously developed USACE models, which are composed of simplified vessel-wake algorithms, and then calculates the relative contribution of vessel wake energy dissipation to the overall tidal system. It also calculates the bottom shear stress. Finally, the VWPT predicts the decay in wave height away from the vessel. The resulting analysis gives researchers concrete data on the level of shoreline erosion likely occurring because of vessel wakes.

As a desktop application, the VWPT allows rapid computation, which helps researchers quickly run a number of scenarios for a given coastal system and see immediate results. These data give researchers the ability to analyze optimum vessel speeds and distances from shore to minimize harmful or excessive shoreline erosion potential. And while the tool requires supplementary field data and higher-order models, such as three-dimensional morphodynamic models, to independently assess the VWPT's accuracy for a given system, Hartman and Styles's work gives researchers an easy-to-use, powerful way to provide a dependable baseline for further investigation. ☐

Article contributed by a staff writer for the ITL Information Science and Knowledge Management Branch.

Bottom: Too much kinetic energy from passing vessels can overwhelm local aquatic systems.

ERDC/CRREL TR-19-24

Frost-Depth Penetration and Frost Heave in Frost-Susceptible Soils

By Wade A. Lein, Scott Michael L. Slone, Charles E. Smith Jr., Andrew P. Bernier, and Jared I. Oren

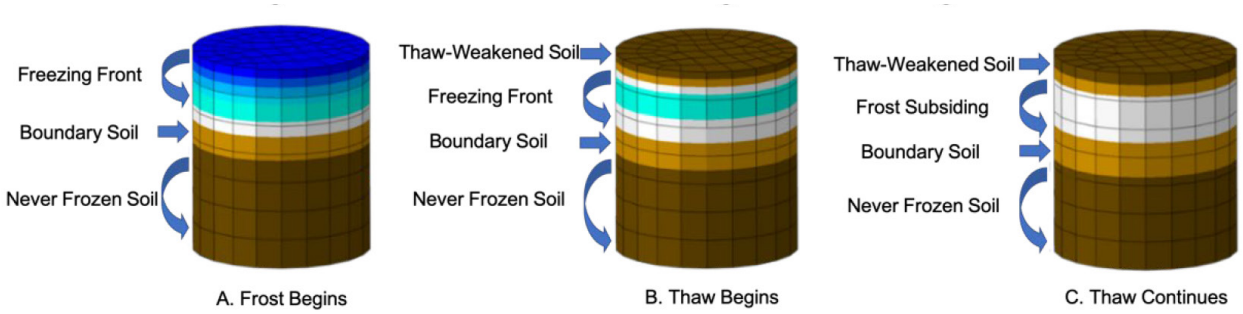
Abstract: The natural freezing and thawing of soils dramatically affects their thermal and mechanical properties. This can have destructive effects on structures built on those soils.

This study developed a thermodynamic finite element model using multiple frost-susceptible soil types. It measured thermal conductivity and temperature through several freeze–thaw cycles. We identified moisture migration as likely the most significant factor in frost heave and frost penetration. Additionally, the thermal conductivity increased near the freezing front across all samples. For example, the thermal conductivity for ML (low-plasticity silt) soils rose from 301 to 357 milliBtu/(hr*ft*°F), which appeared to correspond to where the moisture concentrated and ice formation was highest.

Our experimental results guided model development, where thermal parameters changed with respect to temperature, ice, and moisture during freeze–thaw cycles. Using dynamic thermal parameters improved frost-depth prediction compared to the standard Modified Berggren equation. For our tested conditions, the equation had an error of 2.2 in. for a frost depth of 8 in. while our model had an error of 1.4 in.

These developments are important to airfield runway and general pavements design and maintenance in frost-affected regions. The findings will allow more accurate predictions of frost depth and deflection.

http://dx.doi.org/10.21079/11681/34893.21079/11681/29508



Know more . . .

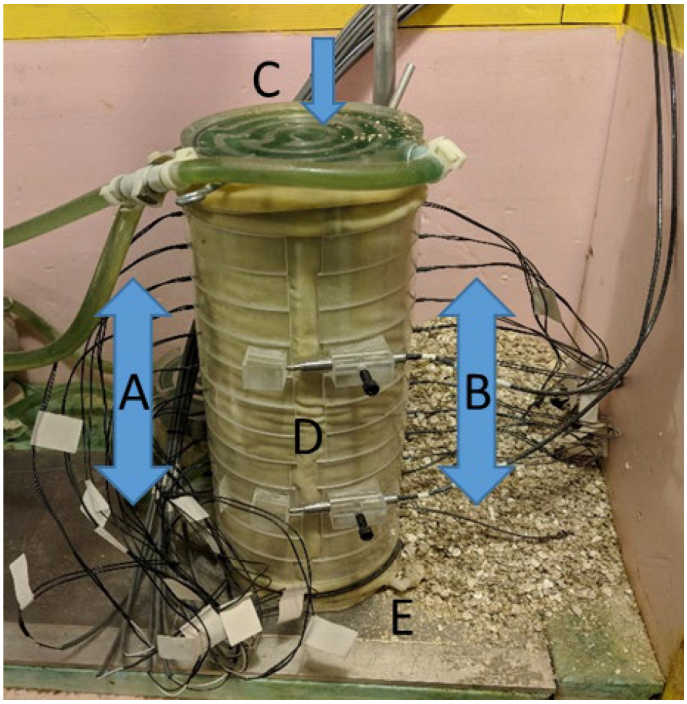
While it is common knowledge that freezing and thawing cycles have deteriorating effects on soils, the challenge is predicting those effects. Current procedures for physically studying soil composition and the potential detrimental effects of these cycles include excavating the material and testing it in the lab, but it is challenging to precisely remanufacture the soil's structure and to apply a realistic freezing curve to it.

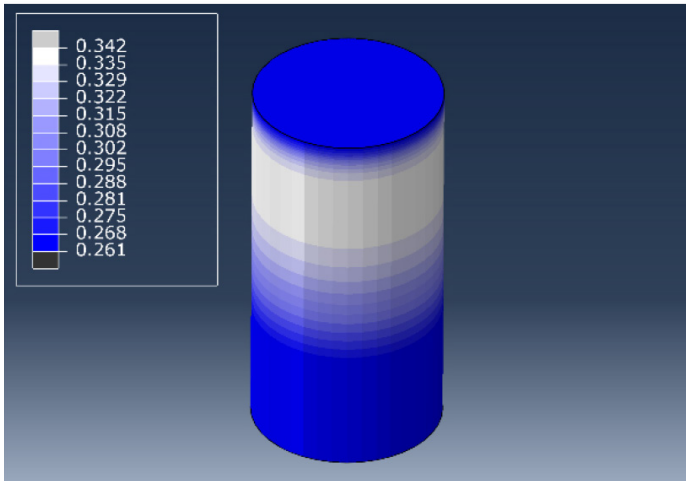
Therefore, this team, lead by Dr. Wade Lein, aimed to find a better way to understand and anticipate soil behavior. Luckily, Dr. Lein enjoys creating new equipment and getting out in the field to test it. With a background in electrical and geotechnical engineering, Dr. Lein combined both fields in this project, working with the team to devise a method to test the material in situ and then creating a model to more accurately capture expected behavior.

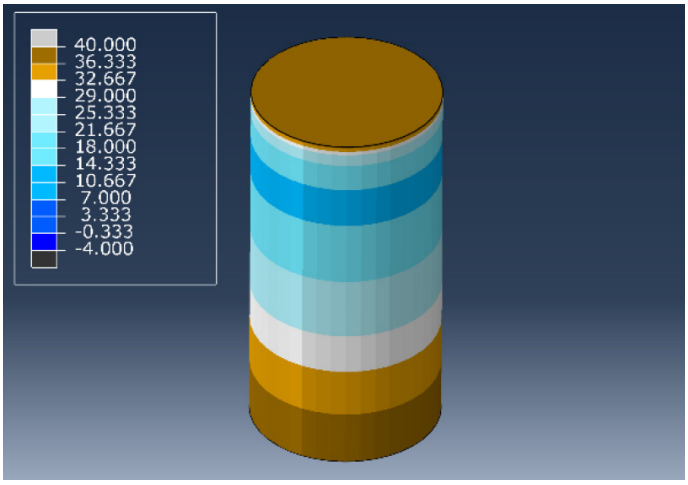
As with all new challenges, issues are bound to arise, from melted probes to broken samples. "That's why you have test samples so you can get comfortable," explained Dr. Lein. "Bounce off some walls, and you eventually go straight."

Future work on the model looks to include climatic data to allow real-time prediction of when certain areas will freeze and have frost loads. Both the current and future work could have significant benefits by preventing the additional costs associated with infrastructure failure. The team is currently in talks with the Air Force as precise models could provide additional flexibility for runway managers, who could adjust runways loads for specific conditions rather than for an entire season. Overall, models such as the ones by Dr. Lein and his team are creating a foundation for a safer and more efficient DoD. ☐

Article contributed by Emily B. Moynihan, Writer-Editor for the ITL Information Science and Knowledge Management Branch.







Opposite: FROST model initial design at various stages.

Top: Testing setup for the modified frost-heave test: (A) the thermal probes; (B) the thermal conductivity thermistors; (C) the cooling and heating glycol plate and the location of the vertical linear variable differential transformer (LVDT) for measuring frost heave; (D) the location of the radial LVDTs; and (E) the bottom plate, which was held at a constant 40°F.

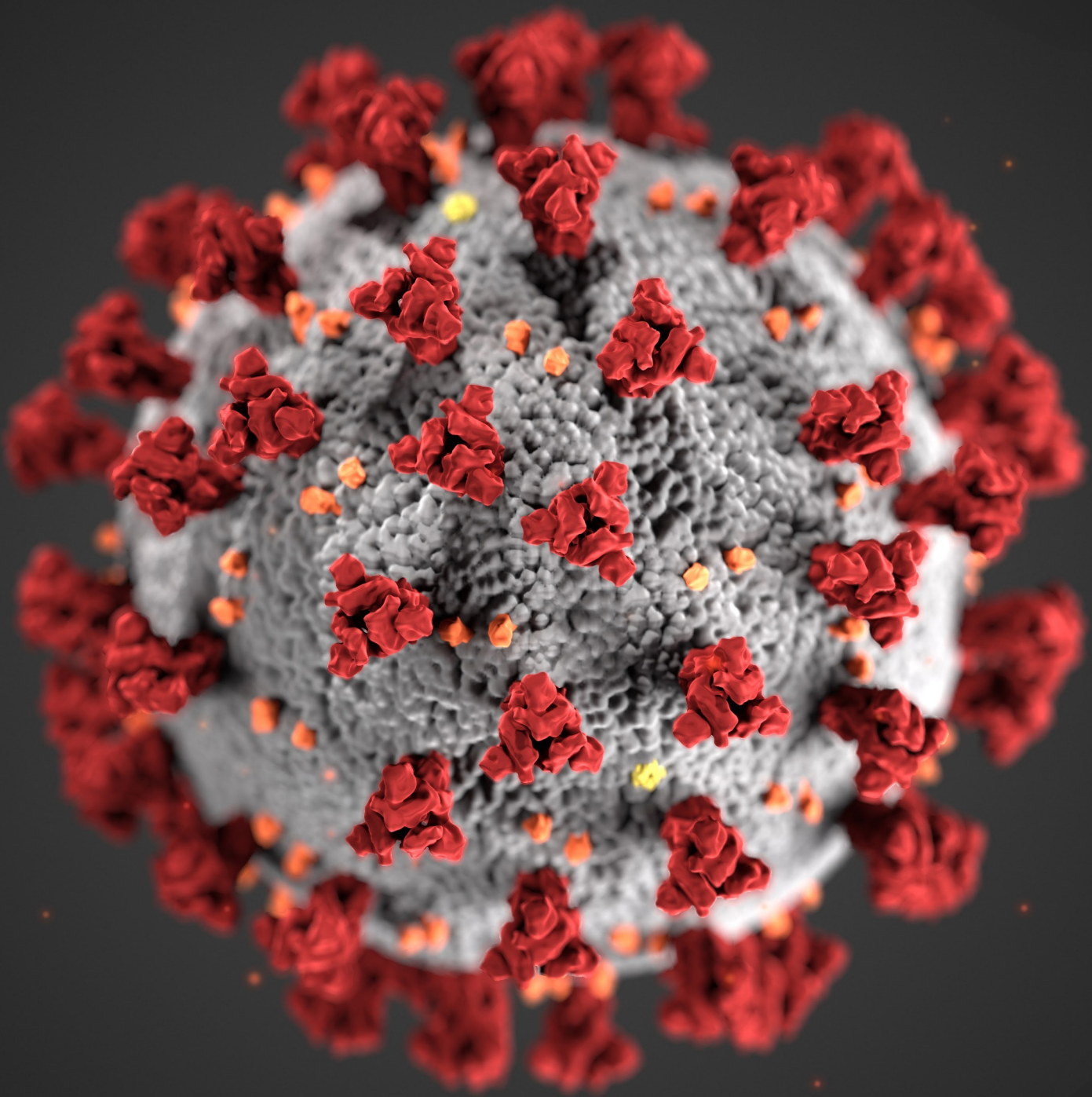
Middle: FROST model current design, soil temperature in degrees Fahrenheit.

Bottom: FROST model current design, ice/moisture content in volume fraction.

Modeling COVID-19 Infections

An Interlaboratory Collaboration

For Michael Mayo, a research physical scientist at ERDC's Environmental Laboratory (EL), the search for a COVID-19 model that could support the Department of Defense's response efforts began in earnest on a Friday night. What followed was a massive team effort, long hours, multiple not-quite-right models, and finally a huge success: the ERDC's Susceptible, Exposed, Infectious, Recovered, or ERDC-SEIR, model.



Securing our public health

Brandon Lafferty, acting division chief for EL's Environmental Processes and Engineering Division, asked Mayo, along with Michael Rowland, acting chief of the Environmental Processes Branch, to take the Columbia University COVID-19 model and adapt it for the center's high-performance computers, such as Onyx (below). But the Columbia model lacked any county-level prediction capabilities, the crucial metric Mayo and the rest of the team were after. So Mayo turned next to a model developed in China for the city level and that weekend rewrote the entire code. He sent it to his team members at the Information Technology Laboratory (ITL) that Sunday night.

> "I never got to a point where I was questioning whether or not we could do it. It was a question of when."
>
> —Michael Mayo, ERDC-EL

Using Department of Transportation data to account for commuters moving from county to county, the team created a single model that provided predictive output for all of the more than 3000 counties in the United States. Unfortunately, the model still could not provide the data they were after, so Mayo changed tactics. Rather than create one model for all counties, he decided to make the model fit each county individually. The change in tactics worked.

With some reasonable predictions in hand, Mayo next turned to EL public health experts Igor Linkov and Ben Trump. Linkov and Trump provided crucial feedback—namely, whether its forecasts actually made sense from a public health perspective. Throughout this time, Mayo's team member Matt Parno, research physical scientist at the Cold Regions Research and Engineering Laboratory, worked on optimizing the model as the team's resident optimization expert. And while the model was working better, it wasn't performing well enough at the county level to meet the response efforts' needs.

So Mayo changed tactics again. Up until that point, the team had been trying to make the cumulative infections data, the most common data available, work in the model; but these data didn't provide enough information for the model to pick which of its many potential curves fit the historical data. Mayo decided

instead to use the number of new cases per day; and at last he and the team had the data point they needed to narrow it down to a single, predictive curve.

This breakthrough led to a clearing of the path for the project, and from then on there were no major technical or developmental issues. "Looking back on it," Mayo recalled, "it feels like we transitioned into a new phase. That kind of was the turning point." He credits the realization as his biggest success. "I never got to a point where I was questioning whether or not we could do it. It was a question of when." But he admitted that "after we got things working, it was a huge relief."

The ERDC-SEIR model provides predictions already incorporating the approximately nine-day lag in reported cases due to natural delays caused by time between infection and onset of symptoms as well as time between testing, results, and reports. As Mayo put it, "you can only do so many [tests] in a day." With the ERDC-SEIR model, researchers and policymakers know what the state of COVID-19 infections is right now. There is no need to wait for the trailing nine days of reports to roll in. One of many models used by the Centers for Disease Control, FiveThirtyEight, and other model aggregators, ERDC-SEIR is now helping policy makers at all levels make informed, data-driven decisions.

Through the long hours and communication challenges inherent in the current teleworking situation, and the difficult and complex technical challenges to craft the ERDC-SEIR model, Mayo credits the cohesiveness of the team for the project's success. When asked what he was most proud of, he was unequivocal. "The thing I'm most proud of isn't technical," Mayo said, but rather "the way we all worked together as a team." Mayo is certain the SEIR project would not have succeeded without it. ☐

Article contributed by a staff writer for the ITL Information Science and Knowledge Management Branch.

Previous: A CDC rendering of the COVID-19 virus.

Bottom: ITL's ONYX supercomputer

ERDC/CERL TR-20-5

Enhancing Army Energy Culture with Behavioral Approaches

By Eileen T. Westervelt, Paul M. Loechl, Sarah A. Clark, and Courtney E. DuPont

Abstract: Facility energy efficiency efforts too often underperform because of people's choices and actions in their use of technology. Recognizing this challenge, Army energy guidance calls for establishing an informed energy-conscious culture of stewardship to meet mission resilience requirements. However, the details for implementing that guidance have not been established. This report provides two primary products to address these needs: (1) a Human-Centered Efficiency Process (HCEP), which is a coordinated nine-step process to use best practices in energy behavior, and (2) an outline of a strategy to build a culture of efficiency. The practical HCEP is synthesized from energy management, change management, and Army processes (After Action Report [AAR] and Commander's Intent), as well as insights from federal personnel. It is built around an organizational framework and a continuous improvement process that systematically enables people to use technology effectively and efficiently. The culture strategy consists of a method of assessing the current status of the Army's energy culture; a vision of a desired end state; and a path toward change.

http://dx.doi.org/10.21079/11681/37945

A proven path to change . . .

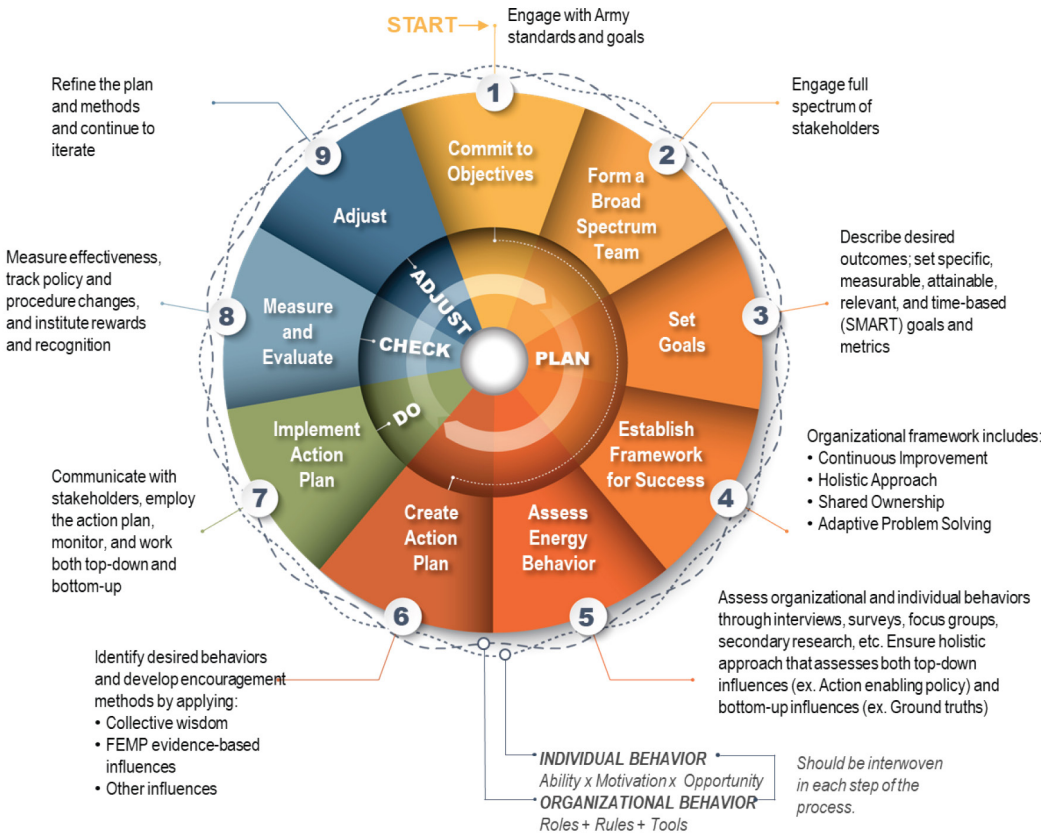
The most energy-efficient heating and cooling system in the world cannot compete with a human who opens the window for some fresh air. But culture shifts require top-down and bottom-up participation to succeed. The Human-Centered Efficiency Process, or HCEP, developed by Construction Engineering Research Laboratory researchers Eileen Westervelt, Paul Loechl, Sarah Clark, and Courtney DuPont addresses the human factor when it comes to creating and maintaining energy-efficient installations.

The nine-step process gives U.S. Army personnel a framework to plan, carry out, check, and adjust energy efficiency–related objectives while addressing cognitive biases and resistance in the installation's community. Important to the HCEP is forming partnerships between stakeholders—especially between the organization's leadership and individual members. The HCEP uses the models of Individual Behavior = Ability × Motivation × Opportunity and Organizational Behavior = Rules + Roles + Tools to identify desired behaviors and develop support tactics that encourage and reward those behaviors. In that way, the HCEP uses a positive and affirmative approach to behavioral change instead of a negative and punitive approach.

Using a baseline of 80% of the population adopting the new behavior as a target, the CERL researchers also developed a strategy outline to help individual installations build a culture of efficiency. Their multidisciplinary strategy advocates for continuous improvement, shared ownership, adaptive problem solving, and a holistic systems approach as a framework conducive to organizational success that also incorporates energy stewardship into the definition of effective leadership. As a result, the HCEP does not delegate all the energy efficiency responsibility (and blame) onto individual and low-ranking members of the community. Instead, the method shares responsibility for behavior and behavioral change between those with the most power and the least.

The work of Westervelt, Loechl, Clark, and DuPont gives facility managers, installation leadership, and the entire US Army a concrete, step-by-step approach to analyzing current energy culture and creating a plan to change that culture. Implementing it will increase installation readiness and resilience, protecting personnel and saving time and money at home and abroad. ☐

Article contributed by a staff writer for the ITL Information Science and Knowledge Management Branch.



Opposite: Human actions such as leaving high-performance windows open undermine their energy efficiency.

Right: The new approach weaves together individual and organizational behaviors in a positive feedback loop.

ERDC/GSL TR-21-1

Estimating Bridge Reliability by Using Bayesian Networks

By Andrew B. Groeneveld, Stephanie G. Wood, Edgardo Ruiz, and Jeffery M. Roberts

Abstract: As part of an inspection, bridge inspectors assign condition ratings to the main components of a bridge's structural system and identify any defects that they observe. Condition ratings are necessarily somewhat subjective, as they are influenced by the experience of the inspectors. In the current work, procedures were developed for making inferences on the reliability of reinforced concrete girders with defects at both the cross section and the girder level. The Bayesian network (BN) tools constructed in this work use simple structural mechanics to model the capacity of girders. By using expert elicitation, defects observed during inspection are correlated with underlying deterioration mechanisms. By linking these deterioration mechanisms with reductions in mechanical properties, inferences on the reliability of a bridge can be made based on visual observation of defects. With more development, this BN tool can be used to compare conditions of bridges relative to one another and aid in the prioritization of repairs. However, an extensive survey of bridges affected by deterioration mechanisms is needed to confidently establish valid relationships between deterioration severity and mechanical properties.

http://dx.doi.org/10.21079/11681/39601

Helping to keep bridges safe . . .

Bridge inspection is an integral part of geotechnical and structural research, and assessments can vary from inspector to inspector. Condition ratings and observation of defects are major players in determining bridge reliability. One team of structural engineering collaborators was tasked with finding a quantitative way to interpret bridge inspection results and the impact of potential defects in bridge elements, including bridge decks, superstructures, and substructures.

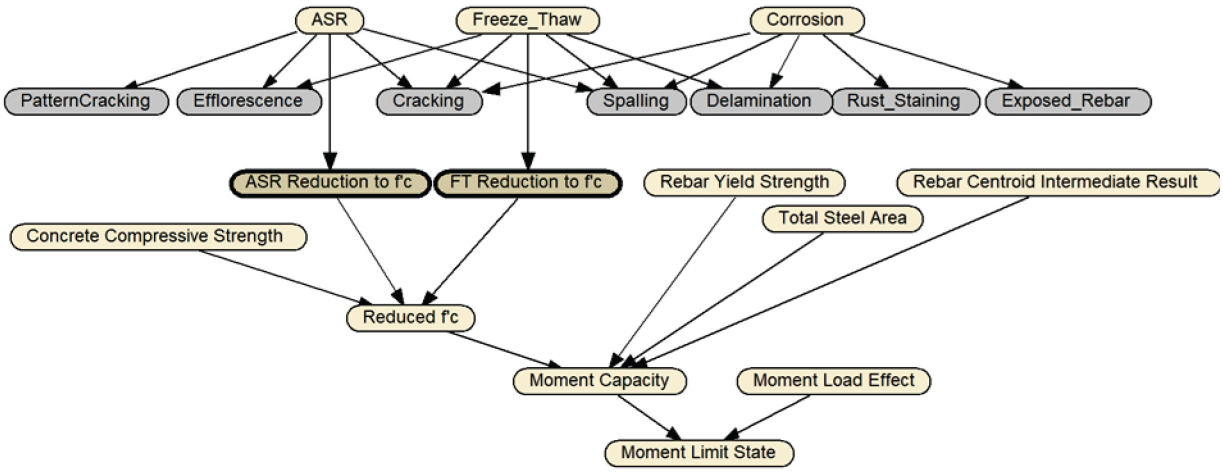
As part of its effort, the team explored the use of a Bayesian network, which is a type of probabilistic graphical model that expresses the causal relationships between variables. Team members researched a process for using such a network to make inferences on reinforced concrete bridge reliability.

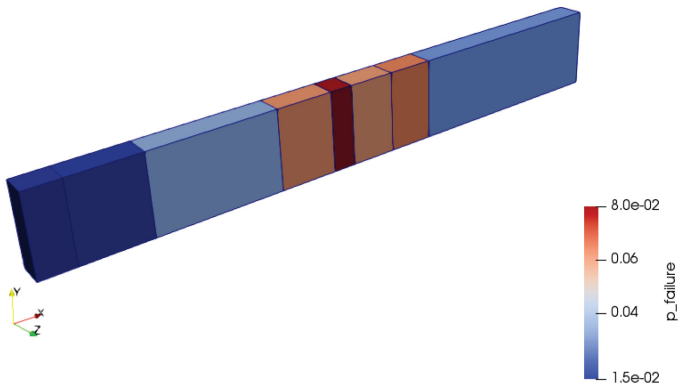
Their initial effort included assembling a list of common and less-obvious bridge defects—damage from overloading or impact, deterioration from abrasion, steel corrosion, freeze–thaw cycling, etc. The team followed up with determining how defects can affect mechanical properties. By examining reliability theories and establishing conditional probabilities for material defects, the collaborators were able to put together Bayesian network tools that allowed for making inferences on the reliability of a reinforced concrete girder section with defects.

Applying processes and results of single-girder research, the team performed model development using Netica 6.04 and Python API for Netica to establish a framework and create a prototype graphical user interface for both bridge reliability and girder condition. Team members broke a girder with multiple defects into segments and, by conducting sectional analysis, determined girder reliability. Their findings can be used to eventually assess the probability of failure of an entire bridge.

Following their extensive research, team members concluded that their Bayesian network tool can be further developed to compare conditions of bridges relative to one another and allow for the prioritization of repairs. As a result of their findings, the team was able to establish relationships between defects and deterioration mechanisms, develop a Bayesian network for inferences on girder reliability, and write two prototype programs for automating a reliability inference procedure. ☐

Article contributed by Kathleen Miles, Writer-Editor for the ITL Information Science and Knowledge Management Branch.





Opposite: The Williamsburg Bridge, maintained by the New York City Department of Transportation, spent 21 years as the longest suspension bridge span in the world.

Top: Full Bayesian network for analysis of a reinforced concrete girder at a single section.

Right: Rendering of probability of failure for girder segments.

ERDC/ITL SR-19-2

Google Search Appliance End of Life and Replacement Recommendations

By Byron M. Garton, Jonathan S. Broderick, and Brandon K. Randle

Abstract: The Engineering Research and Development Center (ERDC) Knowledge Management relies on a search technology provided by Google. Known as the Google Search Appliance (GSA), it indexes and searches ERDC's accumulation of knowledge stored on various web connected systems. The GSA provides a familiar and simple to use interface to facilitate quick location and retrieval of ERDC knowledge stored on these systems that are located on ERDC's internal and extra-net websites. In 2016, Google announced the discontinuation of the GSA product at the end of March 2019.

This document details the investigation into potential GSA replacement options and the recommended actions to be taken to minimize the impact of the March 2019 sunset. Emphasis is placed on equivalent or enhanced feature sets, ease of installation and migration, and the costs associated with installation, migration, and maintenance.

http://dx.doi.org/10.21079/11681/33410

Connecting the dots . . .

With the abundance of world-class knowledge and resources that ERDC produces each year, researchers need an easy way to sort through all this information. Previously, ERDC used Google Search Appliance, or GSA, for this purpose. A physical device that provided Google's searching and indexing power to enterprise data sets, the GSA's capability helped researchers quickly and accurately find the information they needed. But with the discontinuation of GSA, ERDC needed a replacement. And so, Byron Garton, Jonathan Broderick, and Brandon Randle of the Information Technology Laboratory set out to find one.

Finding a replacement for the GSA first required finding the GSAs themselves, which proved to be quite the adventure. After an extensive search from office to office, the team found them in a pile on someone's floor. As Garton noted, "That was an interesting discovery." With the GSAs in hand, the team analyzed the devices' full capabilities to find a suitable replacement. After completing the research, the team chose Mindbreeze.

With Mindbreeze now in place, all the information ERDC houses is discoverable once again, enabling our world-class researchers to stay at the forefront of discovery, building on the vast amount of knowledge that already exists within the organization. The information obtained and stored through the research at ERDC is scattered across several platforms, so having Mindbreeze's search capability, which compiles the information in a central location, provides researchers access to all this information quickly, easily, and cheaply.

When asked how this research could benefit ERDC's researchers in the future, Garton stated that Mindbreeze gives ERDC "the fundamental features that an enterprise search appliance" should have. It gives researchers "a starting point when analyzing current capabilities that are available on a future market."

This search appliance has now successfully replaced the GSA and is working effectively. Reflecting on what he would change if he could do the research over, Garton responded, "I would probably have put more effort into discovering what technologies were being used across DoD. The research focused on what technologies were available on the commercial market." Not certain whether it would have changed the team's results, Garton still believes it would have given them more information to work with. □

Article contributed by Karen Taylor, Writer-Editor for the ITL Information Science and Knowledge Management Branch.

Opposite: Mindbreeze InSpire search appliance. (Reproduced by permission from Mindbreeze.)

Top: The Discover ERDC landing page search box performs searches on the GSA.

ERDC/EL TR-20-7

Evaluation of Unmanned Aircraft System Coastal Data Collection and Horizontal Accuracy

A Case Study at Garden City Beach, South Carolina

By Molly Reif, Scott Bourne, Jennifer Laird, Thomas Berry, Justin Wilkens, Kevin Philley, and Kenneth Matheson

Abstract: The U.S. Army Corps of Engineers (USACE) aims to evaluate unmanned aircraft system (UAS) technology to support flood risk management applications, examining data collection and processing methods and exploring potential for coastal capabilities. Foundational evaluation of the technology is critical for understanding data application and determining best practices for data collection and processing. This study demonstrated UAS Multispectral (MS) and Red Green Blue (RGB) image efficacy for coastal monitoring using Garden City Beach, South Carolina, as a case study. Relative impacts to horizontal accuracy were evaluated under varying field scenarios (flying altitude, viewing angle, and use of onboard Real-Time Kinematic–Global Positioning System), level of commercial off-the-shelf software processing precision (default optimal versus high or low levels) and processing time, and number of ground control points applied during postprocessing (default number versus additional points). Many data sets met the minimum horizontal accuracy requirements designated by USACE Engineering Manual 2015. Data collection and processing methods highlight procedures resulting in high resolution UAS MS and RGB imagery that meets a variety of USACE project monitoring needs for site plans, beach renourishment and hurricane protection projects, project conditions, planning and feasibility studies, floodplain mapping, water quality analysis, flood control studies, emergency management, and ecosystem restoration.

http://dx.doi.org/10.21079/11681/38281

Leading the way . . .

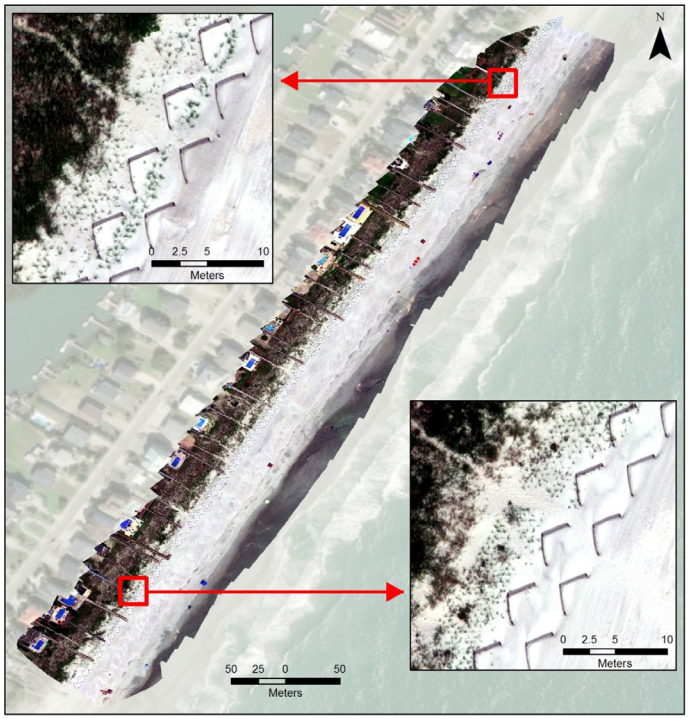
Molly Reif and her team of researchers from the Environmental Laboratory—Scott Bourne, Jennifer Laird, Thomas Berry, Justin Wilkens, Kevin Philley, and Kenneth Matheson—worked with USACE–Charleston District to evaluate unmanned aircraft system, or UAS, technology to support flood-risk management. They chose Garden City Beach, South Carolina, to use as a case study and demonstrated the efficacy of UAS for coastal monitoring. The team evaluated a variety of field scenarios using commercially available image processing software, analyzed processing time and postprocessing data accuracy needs, and demonstrated UAS multispectral and red-green-blue image efficacy for coastal monitoring. Most importantly, the majority of the data collected via UAS exceeded the minimum horizontal accuracy requirements designated by the 2015 USACE engineering manual. Reif and her team's technique applies to site planning, beach renourishment and hurricane protection projects, feasibility studies, floodplain mapping, water-quality analysis, flood-control studies, emergency management, and ecosystem restoration.

Collecting UAS data always presents a challenge. As Reif explained, "You can have the best flight planning, field sample design, and logistical coordination, but weather and people are unpredictable." At the Garden City site, the late-summer fieldwork meant that a lot of people were out on the beach. Fortunately, through early and consistent communication, Reif and her team built a strong relationship with Charleston District from the start of the project, so that district personnel were able to connect Reif's team with the right county officials. The local officials ensured the team collected the data they needed while also prioritizing public safety, a huge part of making this case study a success.

Across ERDC and USACE, tremendous potential exists to use UAS technology to address a variety of research needs. Asked for advice for other researchers looking to make their UAS projects a success, Reif recommended first finding the right remote-sensing platform and sensor combination, whether airborne or spaceborne, for a particular project's goals. Even though UAS is a new technology growing in popularity, sometimes a different remote-sensing technology will be the best tool for the task. She advised researchers to "expect the unexpected" and "have a team of experienced, creative, hard-working people" who can adapt quickly to unanticipated obstacles and difficulties.

This project serves as an excellent example for how ERDC laboratories and USACE districts can work together in flood-risk management, coastal monitoring, and developing best practices for emerging technologies. The work Reif and her team completed in partnership with Charleston District stands as yet one more instance of ERDC leading the way coastal systems research. ☐

Article contributed by a staff writer for the ITL Information Science and Knowledge Management Branch.



Top: BirdsEyeView FireFly6 Pro UAS used to survey the study area at Garden City Beach.

Bottom: Multispectral image example (Flight F6) from 8 August 2018, with insets showing examples of dune vegetation restoration (fencing and planting matrix).

The DIVE.lab

Dynamic, Immersive Virtual Environments


UNCLASSIFIED
Digital Twins– Keeping Your Data Connected
3D
4D
5D
6D
7D
Power of BIM
Reality Capture
AR and VR
INTERNET OF THINGS
IoT Sensor Connectivity
AI/ML on Facility Data
Predictive Analytics
ERDC
ITL
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UNCLASSIFIED

True-scale, three-dimensional immersion

In the words of Jonathan Boone, program manager at the Dynamic, Immersive Virtual Environment Laboratory, "we're creating a center of expertise." And that is exactly what the researchers at the Information Technology Laboratory's newest facility are doing.

The DIVE.lab, as it's known, represents a tremendous achievement for research capabilities at ERDC. It gives researchers the ability to apply interactive technologies to real-world engineering problems through the use of artificial reality, or AR, and virtual reality, or VR. The laboratory provides opportunities for data visualization and exploration that ERDC has never had before, they're doing it with a collaborative space available to all ERDC researchers.

The laboratory provides opportunities for data visualization and exploration that ERDC has never had before, they're doing it with a collaborative space available to all ERDC researchers.

Nowhere is this collaborative potential better highlighted than the DIVE.lab team's work this past year on COVID-19 remote facility assessments. Working with seven USACE districts from across the country, the team developed an AR technology for conducting assessments of potential locations for new field hospitals. Combining livestream and mixed-reality overlays, the lab allows engineers who cannot physically visit a site to now offer virtual support and expertise.

The DIVE.lab also makes possible "synthetic training environments" that allow soldiers the ability to practice what would otherwise be dangerous real-world situations in safety and security. Instead of expensive physical environments that would require soldiers to travel, AR and VR trainings give soldiers those same repetitions while keeping them at home for longer—with the added benefit of advanced data collection and analysis to improve learning. Any number of scenarios can run in a virtual environment, a feature that would prove prohibitively expensive to reproduce as a physical training exercise, and not just soldiers benefit. Any U.S. Army personnel who would benefit from practical experience can use VR for training.

The DIVE.lab is also leading the way in developing virtual models of real-world structures and other physical spaces. These models can then store data on their physical counterparts, giving researchers, asset managers, inspectors, maintenance technicians, and other personnel instant access to it. A security officer could virtually walk the proposed plans for a new facility and point out a blind corner, or a facilities manger could note a boiler room that's technically to code but in reality just a bit too small for easy, efficient repairs—both things an architect might not otherwise realize, it not being the architect's primary expertise.

And if there's one thing the DIVE.lab is set up for, it's collaboration. Multimodal, interdisciplinary collaboration from experts in a variety of fields who can get together and combine their expertise to solve the most difficult challenges in the most innovative ways. Coastal hydraulics engineers can walk through their own models, and structural engineers can watch an airfield repair kit crack

under strain in real time at real-world scale. Combining field tests with the infinite number of computer simulations possible with the DIVE.lab, researchers can refine, retest, and recalculate.

Further, the DIVE.lab is perfectly positioned to show nonexperts why ERDC results are so compelling. A data table or a line graph certainly tells a story, but showing a decision maker, sponsor, or stakeholder how the reconstructed wetland absorbs water during a coastal storm—diverting it from the nearby community, preventing flooding, saving lives—is convincing in a way that no single set of numbers ever can be. And with no requirement to know how to code, the DIVE.lab's facilities and capabilities are open to everyone.

Now that the laboratory is up and running, what Boone wants most is to "start connecting the dots." He wants to turn this tremendous capability into concrete actions. His hope is that ERDC researchers will start to think about their projects and their data sets in conjunction with DIVE.lab's AR and VR capacities from the beginning, asking themselves how showing someone, walking with someone, through the visualized results of the project will help researchers tell the story of their success. Boone noted that there's a real need for other laboratories to come to the DIVE.lab and ask about how to leverage their data because Boone and his team are happy to help. Working with other researchers, bouncing ideas off each other, coming up with new ways to highlight important findings and results in the data—all of these are what Boone and the team want most for DIVE.

In the future, Boone wants collaborations with DIVE and other ERDC laboratories to be common. He wants these collaborations to lead to partnerships around the DoD and to partnerships with other state and federal agencies. Asked to sum up why the DIVE.lab is such a critical asset to ERDC, Boone responded, "The DIVE.lab gives our team the infrastructure space and technology to address specific stakeholder challenges. . . . In a virtual world, our stakeholders can practice, fail, learn, and improve through repetition in a safe environment." ☐

Article contributed by a staff writer for the ITL Information Science and Knowledge Management Branch.

Previous: With multiple work stations, monitors, and a variety of tools, the DIVE.lab makes interdisciplinary collaboration easy.

Opposite: Researchers work in the team space at DIVE (pre-COVID).

Above: Virtual renders provide previews of proposed construction.

The DIVE.lab has received much attention for its capabilities, especially in the fight against COVID-19.

https://www.defensemedianetwork.com/stories/engineer-research-development-center-answers-covid-19-call-building-strong-2020-2021/

ERDC/ITL TR-20-2 highlights use of the DIVE.lab as the platform for a Synthetic Training Environment.

http://dx.doi.org/10.21079/11681/38201

ERDC/GRL TR-20-6

Optimized Low Size, Weight, Power and Cost (SWaP-C) Payload for Mapping Interiors and Subterranean on an Unmanned Ground Vehicle

By Garry Glaspell, Steven Lessard, Benjamin Christie, Kyle Jannak-Huang, Noah Wilde, Weiyu He, Osama Ennasr, Daniel Pham, Daniel Hasemann, Phil Devine, and John Kiene

Abstract: Section 3 of the FY15 Force 2025 Maneuvers Annual Report indicates that in Dense Urban Areas (DUA), specifically in a subsurface, surface, or super-surface structure, the ability to identify threats will be diminished. Most commercially available LIght Detection And Ranging (LIDAR) systems are specifically designed for high-resolution aerial imaging and mapping applications. As a result, they tend to be large, heavy, power-hungry, data bandwidth intensive, and expensive. They also employ lasers that are not typically eye-safe, which limits their overall effectiveness in subterranean and the interiors of subsurface or super-surface structures. However, due to recent advances in the automotive industry, there are new generations of Size, Weight, Power, and Cost (SWaP-C) sensors that are eye-safe, making them suitable for use indoors and in subterranean environments. While these tradeoffs limit their effective use to hundreds of meters (compared to kilometers for their more expensive counterparts), they are ideal candidates for use in subterranean and building interiors. While cameras fill this niche to some extent, the volumetric calculations provided by these sensors provide additional intelligence to shape the security of the environment and offer more precision when maneuvering troops. These sensors would provide the warfighter with situational understanding in previously inaccessible locations. Therefore, to aid in the Army's need to obtain and maintain situational understanding in DUAs, the authors propose utilizing low size, weight, power, and cost (SWaP-C) sensors, on a robot platform, for surveying and mapping underground structures and building interiors. Rapid/near real-time data processing is possible by utilizing open-source software and commercial off the shelf (COTS) components. Using the preferred sensor payload autonomously was also explored.

http://dx.doi.org/10.21079/11681/35878

A chat with the author . . .

Working with robots, game controllers, and mobile devices is becoming increasingly popular when it comes to mapping. This report proved that the SWaP-C was a reliable asset for this process. I was able to throw a few questions by author Garry Glaspell about the process of this research and what its future potential could be.

Q: Was there anything out of the ordinary that happened during this research that did not make it into the report?

A: The robot can be teleoperated with a game controller. One of the buttons on the controller initiates the front flippers. On more than one occasion, we have accidentally hit this button and the flippers start making the robot do its version of a push-up. At this point, we usually are in full-blown panic mode. So rather than press the "e-stop" button on the controller, we usually "Ctrl+C" the joy stick node on the computer or rip the battery from the controller. Neither of these actions interrupt the robots workout routine. When we are finally cognizant to hit the "e-stop" button, the robot has already finished its set of "10."

Q: What do you think this research/report could be used for in the future?

A: For those that are new to using the Robot Operating System (ROS) this report gives a good breakdown on what low Size, Weight, Power and Cost (SWaP-C) sensors will meet their needs. It also covers a number of popular Simultaneous Localization And Mapping (SLAM) techniques, which should help narrow down their choices. It also has sufficient code in the appendices to get them up and running quickly.

Q: Is this research still ongoing?

A: Yes, the research is still ongoing. We are still using the sensor payload and SLAM method used in this report, but have extended our capabilities to include object recognition as well as waypoint navigation and frontier exploration.

Q: If you could do it over, would there be anything you would do differently to get your results?

A: I don't think so; even when we made mistakes, we learned something new. Where we are right now is a culmination of both the successes and failures (mostly failures) we have made to date.

Q: How do you envision this research and report keeping ERDC ahead of the game?

A: As this research matures, I envision a robotic payload that will autonomously map previously unexplored GPS-denied areas and provide real time situational awareness to the soldier.

Q: What was your favorite part of doing this research?

A: I really enjoy delving into the code and seeing how things work "under the hood." I also particularly enjoy when new code is pushed or a new sensor hits the market. Experimenting with the parameters and pushing the limits of what is possible is what makes my job fun.

Q: Why is this research so important?

A: This is an exciting time to be working in robotics. It is constantly in flux; both software and hardware are evolving at a tremendous rate. Being able to have a pulse on what is currently possible and matching that with the needs of the soldier is paramount. ☐

Article contributed by Karen Taylor, Writer-Editor for the ITL Information Science and Knowledge Management Branch.

Top: High-density point cloud collected using Elast cFusion.

What Is 508 Compliance?

Making Federal Research Accessible

In January 2018, new requirements, called Section 508 requirements, came into effect to ensure everyone can access the federal government's electronic documents. These requirements affect internal and external documents, and they update the U.S. standards to bring them in line with the European Commission and the Web Content Accessibility Guidelines 2.0. Visiting section508.gov provides a wealth of resources to anyone who needs to create electronic documents at ERDC, but below are some of the basic requirements most technical report authors should keep in mind:

1. Use self-explanatory document titles
Make sure the purpose and content of the document is clear from the file name.

2. Add alternative text for figures and tables
Describe these succinctly to someone who cannot see them, but make sure not to just repeat what information is already in the caption and the main text. Contact your laboratory's editor for guidance on writing compliant alternative text for all your figures and tables.

3. Format lists with Word's list function
This one is simple. Use the automated bulleted or numbered list function in your word processor. A screen reader uses the XML data behind the scenes to read the list in the correct order in the correct way to the person using it.

4. Use text and shape to supplement color
Not everyone can distinguish all colors! So use text or shapes to convey any information you convey with color a second way. For county and other maps, colorbrewer2.org has a number of color schemes you can choose from to take the guesswork out of picking a compliant color scheme. For line graphs, use dotted and other line types for different data. For bar graphs, use different fill shapes or label them along the x-axis. A simple test for the color in your document is to print it out in gray scale. Can you still easily understand what's what? For very complicated presentation of data, contact your laboratory's editor for advice.

5. Tables have repeating header rows and are free of merged or splits cells
We know: sometimes a merged cell above your column stubs just makes the table look nicer! But merged cells and screen readers do not mix very well, and it can turn the ordered presentation of your data into an illogical mess. (On the editing side of things, merged cells are also a nightmare to tag.) If you're not sure how to present a complicated data table that's also 508 compliant, contact your laboratory's editor. They can offer suggestions to either change the table or offer the information in an accessible format as an appendix to your report.

Making our publications more accessible to everyone will increase the reach and dissemination of ERDC's world-class research. And since 26% of Americans[1] have some type of disability and 41% of post-9/11 veterans have a service-related disability,[2] inaccessibility is not an option. Accessibility in the creation and dissemination of research results in a more inclusive environment, which benefits us all.

Article contributed by a staff writer for the ITL Information Science and Knowledge Management Branch.

1 https://www.cdc.gov/ncbddd/disabilityandhealth/infographic-disability-impacts-all.html#:~:text=61%20million%20adults%20in%20the,have%20some%20type%20of%20disability.

2 https://www.bls.gov/news.release/pdf/vet.pdf.

Top left, braille computer display for visually impaired users; top right, accessible research benefits everyone; bottom, researchers collaborate on a project. (Credit: Jordan Nicholson, Disability: IN. CC BY-ND 4.0.)

No Cost to Publish a Miscellaneous Paper

An ISKM Service

A Miscellaneous Paper (MP) is an official ERDC publication and is published online to the ERDC Digital Repository and sent to the Defense Technical Information Center (DTIC). This series is used to recognize work by ERDC authors that has been published or presented outside of an official federal government publishing program. Examples include articles published in journals, conference proceedings, book chapters, and technical reports prepared by ERDC researchers for other agencies.

Updated technical reporting requirements from ERDC (issued 1 May 2019) for Army-sponsored Research, Development, Test, and Evaluation (RDTE) 6.1–6.3 projects are to provide technical reporting guidance and an established process for the review, reference, and transfer of ERDC's Army RDTE technologies and data. This also allows us to better maintain accurate records for data calls, track publication statistics, and to increase the visibility of ERDC authors and their research.

ERDC authors should submit all final submitted journal articles and conference proceedings resulting from Army sponsored RDTE 6.1–6.3 projects to ERDC Editing to be documented as ERDC MPs. The process is uncomplicated; and for FY21, it is also done at NO COST to the author.

Preparing a digital publication for the online repositories includes adding an ERDC MP cover, title page, preface, and SF 298 and issuing an MP number. ISKM editing staff will not edit the article. The text will be formatted to remove all copyrighted markings. The following items should be submitted to ERDC Editing:

1. A digital copy of the final accepted manuscript including all modifications from the peer-review process or a PDF copy of the article.
2. A completed and signed ERDC Form 7.
3. A copy of the final laboratory approval (for the journal article).
4. The journal citation metadata and DOI (journal article citation metadata will be stated in the MP preface and SF 298).
5. A copy of the signed ERDC Security Office clearance form, if required.

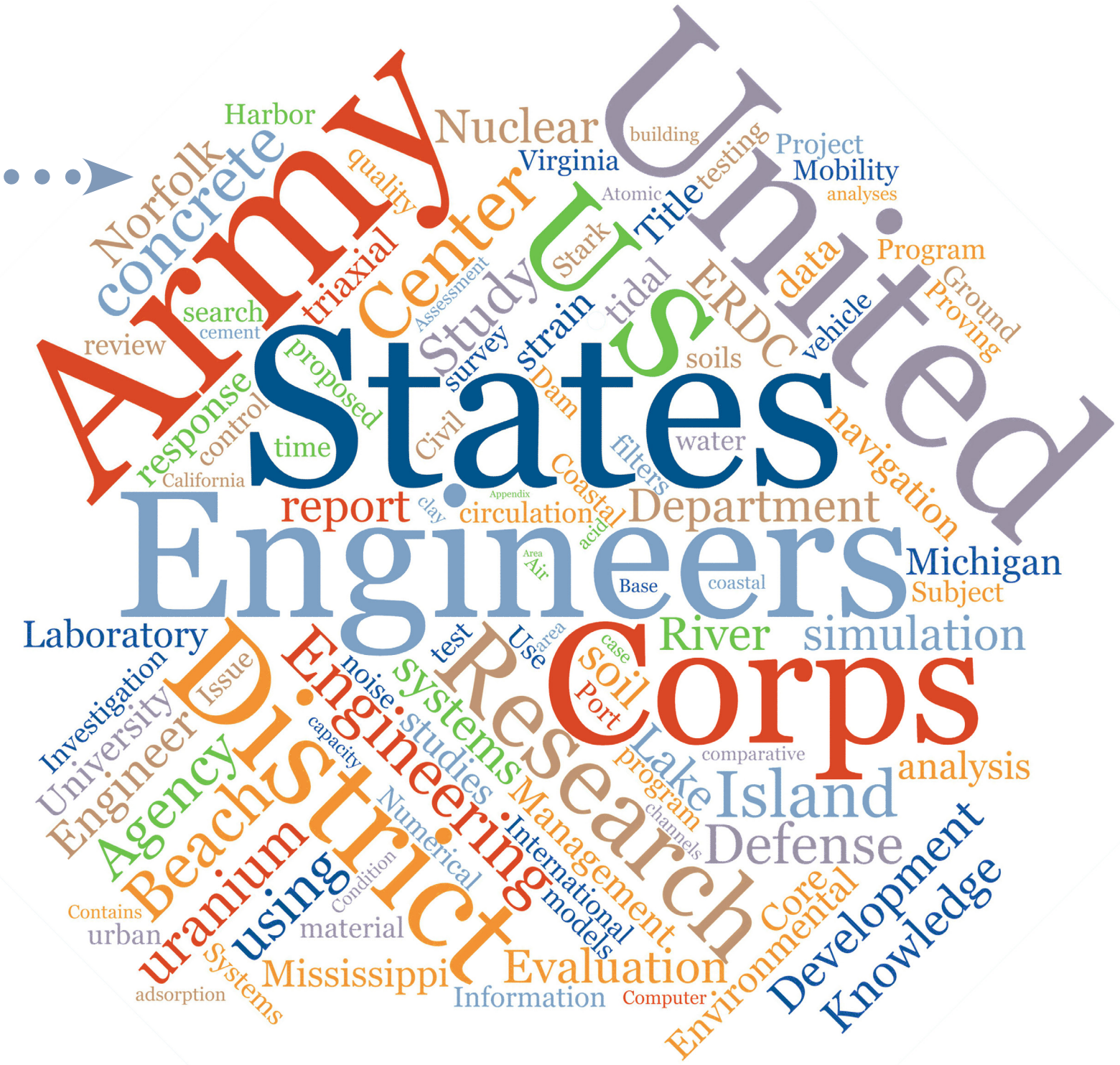
To honor the journal publisher's copyrights, DTIC ensures a 12-month embargo before posting the manuscript on the public site. The ERDC library also ensures a 12-month embargo before posting the manuscript in Knowledge Core, our online Digital Repository.

If you are an ERDC researcher who has published a journal article, conference paper, presentation, or abstract, please submit the accepted manuscript to erdclibrary@ask-a-librarian.info. ISKM editing staff will make sure your research is properly cataloged and recorded.

Article contributed by Vicki Reinhart, Editorial Assistant for the ITL Information Science and Knowledge Management Branch.

For those who would like more details concerning this publishing requirement, refer to the following documents:

- Department of Defense DoDI 3200.12, *DoD Scientific and Technical Information Program (STIP),* issued 22 August 2013, aims to maximize public access to publicly funded research.
- DoD Grants and Agreements Regulations (DoDGARS), 2 CFR Section 1134.140, updated 19 August 2020, requires depositing all significant scientific or technological findings and results derived from DoD endeavors, including final performance reports, and also mandates the submission of final manuscripts of journal articles accepted for publication to DTIC via a Component's defined submission process.
- ERDC issued updated requirements on 1 May 2019 for technical reporting of all Army sponsored RDTE 6.1–6.3 projects to comply with DoD changes. This policy requires ERDC researchers to document Army RDTE 6.1–6.3 project research findings and includes ERDC Technical Reports, Special Reports, journal articles, and proceedings from Army-sponsored technical meetings, conferences, and symposia.



Above: Miscellaneous Papers cover a wide range of topics from across ERDC's seven laboratories.

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14. ABSTRACT

The Engineer Research and Development Center (ERDC) is the premier civil works engineering and environmental sciences research and development arm of the U.S. Army Corps of Engineers (USACE). As such, it partners with the Army, Department of Defense (DoD), federal agencies, and civilian organizations to help solve our Nation's most challenging problems in civil and military engineering, geospatial sciences, water resources, and environmental sciences.

A special government knowledge center, ERDC Information Technology Laboratory's Information Science and Knowledge Management (ISKM) Branch is critical to ERDC's mission, fulfilling research requirements by offering a variety of editing and library services to advance the creation, dissemination, and curation of ERDC and USACE research knowledge.

Serving as the publishing authority for the ERDC, ISKM publishes all ERDC technical publications to the Digital Repository Knowledge Core, sends a copy to the Defense Technical Information Center (DTIC) and creates a press release about each publication on the ERDC website. *The Forefront* seeks to provide an additional mechanism for highlighting some of our technical publications to the ERDC, USACE, Army, and DoD communities. This publication also encourages those outside ERDC to contact us about using ERDC editing services.

For more information regarding the reports highlighted in this publications or others that ERDC researchers' have created, please contact the ISKM virtual reference desk at erdclibrary@ask-a-librarian.info or visit the ISKM's online repository, Knowledge Core, at https://erdc-library.erdc.dren.mil/.

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The reports highlighted here are just a few of the 200+ publications that the ERDC Information Technology Laboratory's Information Science and Knowledge Management (ISKM) Branch publishes for ERDC, USACE, Army, and DoD communities each year.

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ERDC/ITL SR-20-1; Issue 2

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