ANNUAL REPORT & RESEARCH HIGHLIGHTS

2018
2019

60th DRI
Desert Research Institute

PHOTO: Nathan Chellman, graduate student researcher, talks with visitors at the Ice Core Lab during the May Science Be With You open house in Reno. **Credit:** Cathleen Allison/Nevada Momentum.

COVER PHOTO: Tim Minor flies an unmanned aircraft system (UAS) to collect images of soil and vegetation in California's Central Valley. This is just one of many ways that drone technology is applied in environmental sciences research at DRI—learn more about DRI's UAS research on page 13. **Credit:** DRI's Dave Page.

DRI AT A GLANCE | JULY 2018 – JUNE 2019

$31 MILLION IN SPONSORED RESEARCH

31,590 NEVADA STUDENTS REACHED IN 2018–2019 BY K-12 PROGRAMS

758 K-12 SCIENCE TEACHERS TRAINED

OVER **400** SCIENTISTS, ENGINEERS, STUDENTS, AND STAFF

OVER **300** PROJECTS ON ALL **7** CONTINENTS

100 PH.D. FACULTY

RESEARCH IN OVER **40** SCIENTIFIC DISCIPLINES

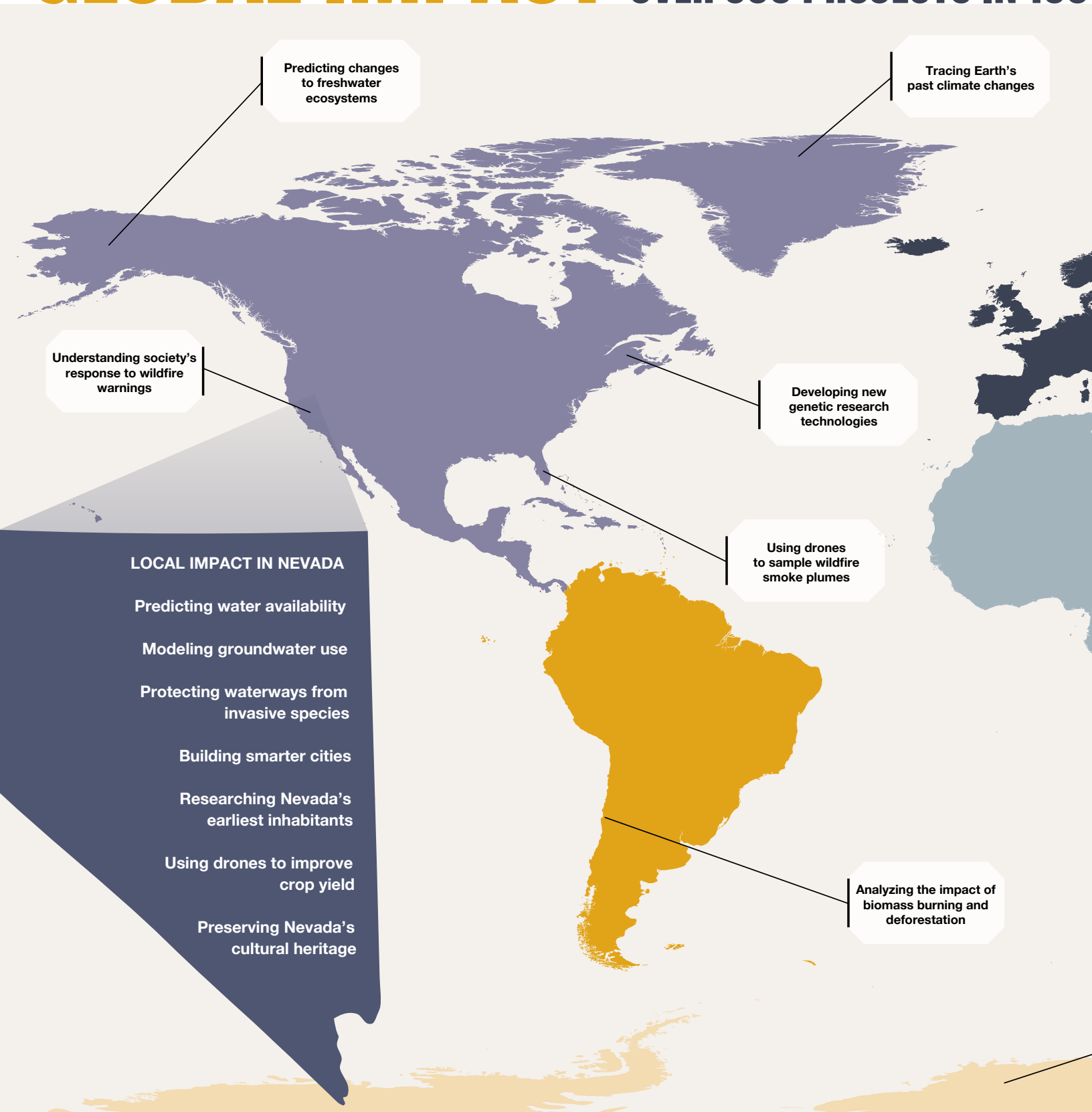
40 SPECIALIZED LABS

OVER **$9** IN TOTAL ECONOMIC BENEFIT TO NEVADA FOR EVERY **$1** IN STATE APPROPRIATIONS

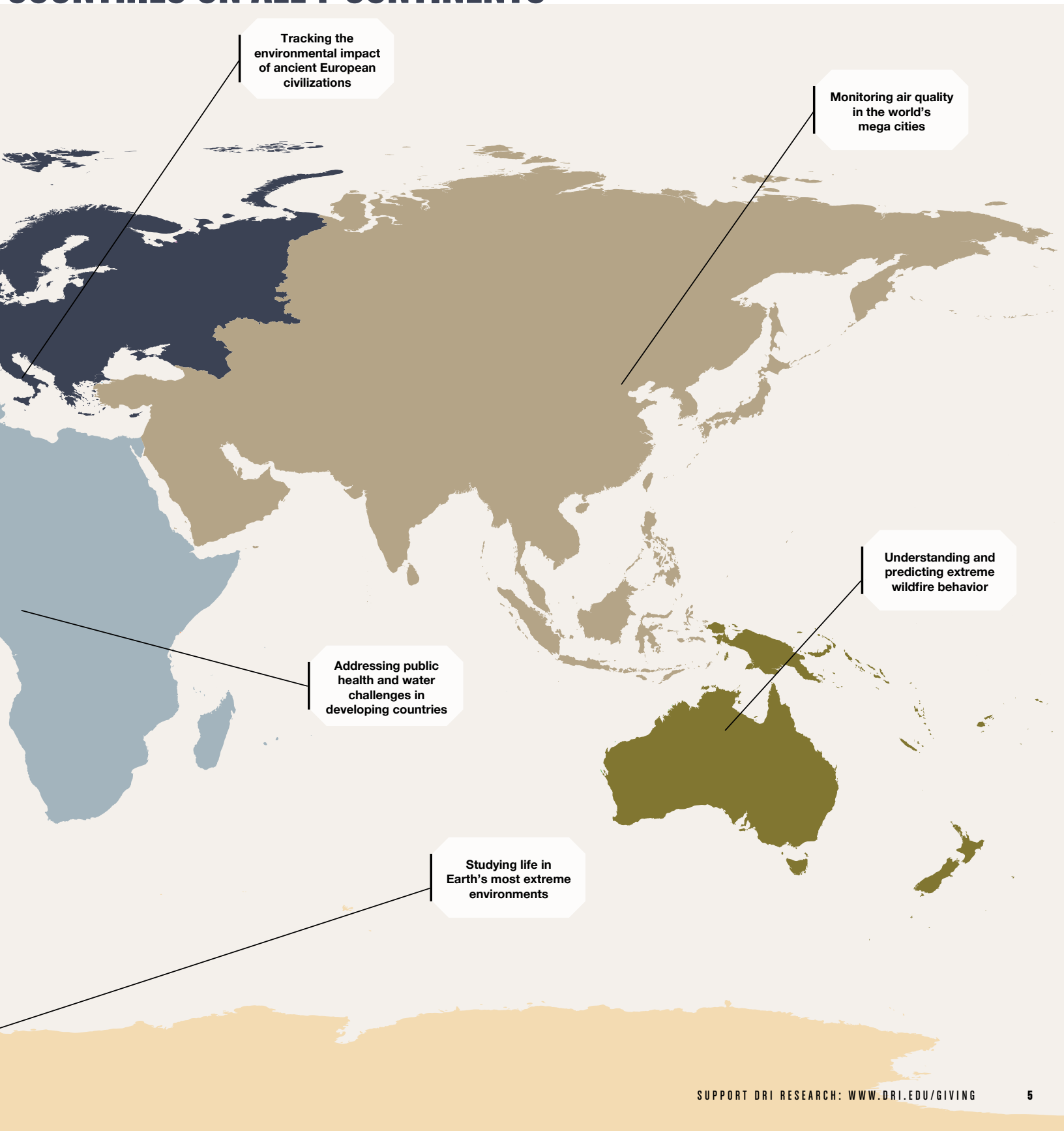
2 RESEARCH CAMPUSES

GLOBAL IMPACT

OVER 300 PROJECTS IN 100



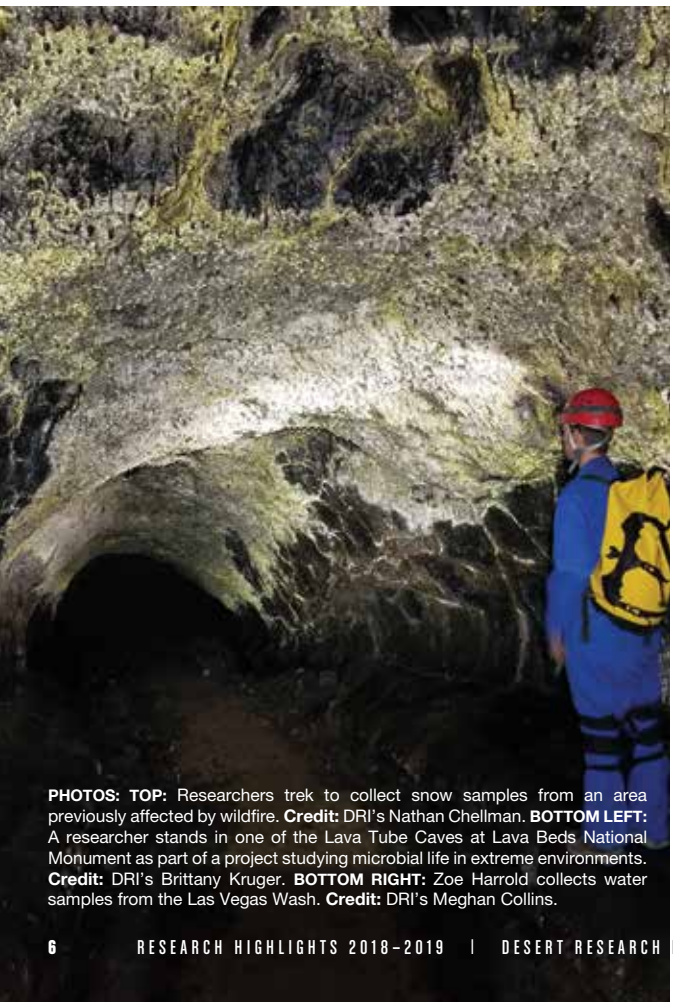
COUNTRIES ON ALL 7 CONTINENTS



SCIENCE FOR A SMARTER NEVADA & A SMARTER WORLD.

The Desert Research Institute (DRI) is a recognized world leader in basic and applied interdisciplinary research. Committed to scientific excellence and integrity, DRI faculty, students, and staff have developed scientific knowledge and innovative technologies in research projects around the globe. Since 1959, DRI's research has advanced scientific knowledge, supported Nevada's diversifying economy, provided science-based educational opportunities, and informed policy makers, business leaders, and community members. With campuses in Reno and Las Vegas, DRI is one of eight institutions in the Nevada System of Higher Education.

DRI's faculty members are nontenured and responsible for their own salaries through external grants and contracts. Through this blend of academic rigor and private-sector pragmatism, DRI has earned a reputation for delivering high-quality scientific information in an efficient, transparent, and accountable fashion.



PHOTOS: TOP: Researchers trek to collect snow samples from an area previously affected by wildfire. **Credit:** DRI's Nathan Chellman. **BOTTOM LEFT:** A researcher stands in one of the Lava Tube Caves at Lava Beds National Monument as part of a project studying microbial life in extreme environments. **Credit:** DRI's Brittany Kruger. **BOTTOM RIGHT:** Zoe Harrold collects water samples from the Las Vegas Wash. **Credit:** DRI's Meghan Collins.

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THE DESERT RESEARCH INSTITUTE IS PART OF THE NEVADA SYSTEM OF HIGHER EDUCATION.

DRI
Desert Research Institute

Over the last year, we have seen both the depth of our research expertise and the breadth of our community outreach grow in remarkable ways.

For 60 years, the vision for DRI has been to be one of the top environmental research institutions in the country. Emerging dialogues questioning the value of science, coupled with the national need to train the next generation of STEM professionals, both point to the need to improve the connection between science and society. We must go further than being just great scientists, and this year we did just that.

We illustrated the public health hazards of e-cigarettes, uncovered clues about the genetic ancestry of early Great Basin inhabitants, traced the rise and fall of ancient European economies through lead deposits in ice cores, and so much more.

Our faculty, students, and research support staff also shared their work, and their passion, with more people than ever before.

Scientists shared their research with Nevada legislators at DRI's first-ever Day at the Nevada State Legislature in March in honor of the Institute's 60th anniversary. This spring, DRI's Science Alive K-12 program led Girl's Day of STEM events in Reno and Las Vegas with the Girl Scouts. Researchers hit the airwaves with the launch of the Science Distilled podcast in May. Both campuses hosted open house events this year, bringing thousands of community members to join us for lab tours and science activities—this marked the first time that the Reno campus was open to the public in a decade.

Each of these milestones build on our history of scientific excellence and aim to broaden the reach of that science, sharing not only the results of our research but also their significance and impact to our communities.

As we look ahead to our next 60 years, we're eager to carry on and expand our legacy, advancing scientific knowledge and developing new technologies for the good of our state, our nation, and our planet.

KUMUD ACHARYA, Ph.D.
INTERIM PRESIDENT

PHOTOS: PAGE 8–9 CENTER: Chiranjivi Bhattarai works on an instrument in the Organic Analytical Lab. **PAGE 9 LEFT (L–R):** Vera Samburova, Andrey Khylstov, Chiranjivi Bhattarai, and Yeongkwon Son in the Organic Analytical Lab. **PAGE 9 RIGHT:** E-cigarettes and flavoring liquids.

E-cigarettes pose health risks to both users and bystanders

DRI RESEARCH TEAM: Andrey Khlystov, Vera Samburova, Chiranjivi Bhattarai, Yeongkwon Son

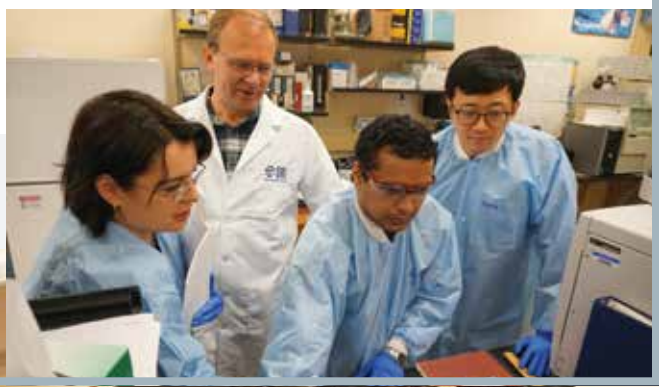
E-cigarettes have become increasingly popular as a "safer" alternative to conventional tobacco cigarettes, but the health effects of "vaping" on humans have been debated in the scientific and tobacco manufacturing communities. While aldehydes—chemicals like formaldehyde that are known to cause cancer in humans—have been identified in e-cigarette emissions by numerous laboratory studies, questions remained whether the observed dangerous concentrations of such toxins also occur during real-life e-cigarette use.

In August 2018, a team of researchers from DRI's Organic Analytical Lab (OAL) and the University of Nevada, Reno published a pilot study in the journal *Toxics* showing that significant amounts of cancer-causing chemicals such as formaldehyde are indeed produced during a typical vaping session. The researchers also found that while a major part of toxic aldehydes is retained by the user, the exhaled amounts of these chemicals are also substantial, underscoring the potential health risks posed by vaping to both users and bystanders.

"Until now, the only research on the respiratory uptake of aldehydes during smoking has been done on conventional cigarette users," said Vera Samburova, Ph.D., associate research professor in DRI's Division of Atmospheric Sciences and lead author of the study. "Little is known about this process for e-cigarette use, and understanding the unique risks vaping poses to users is critical in determining toxicological significance."

Samburova and fellow DRI research professor Andrey Khlystov, Ph.D., have been investigating the health risks associated with e-cigarettes for several years. In a study published in 2016, they were the first to demonstrate that the heating of flavorings during e-cigarette use is responsible for the dangerous levels of aldehydes found in e-cigarette aerosols.

In this study, the OAL team estimated e-cigarette users' exposure to these hazardous chemicals by analyzing the breath of twelve users before and after vaping. Through this process, they determined how much the concentration of aldehydes in the breath increased during vaping. Researchers then subtracted the concentration of chemicals in exhaled breath from the amount found in the vapors that come directly from the e-cigarette.



The difference, Samburova explains, is absorbed into the user's lungs.

"We saw that the concentration of some chemicals, like formaldehyde, in the breath after vaping was about a hundred times lower than what is found in the direct e-cigarette vapors, which suggests that a significant amount is being retained in the user's respiratory tract," Samburova said. "However, we also found that the average concentration of aldehydes in the breath after vaping sessions was about ten and a half times higher than before vaping." The exhaled aldehydes can be inhaled by bystanders or deposit to surfaces leading to exposure through skin contact.

The research team took care to ensure that the test conditions of the study mirrored real-life vaping sessions as much as possible. Most participants used their own e-cigarette devices during the study, used e-liquid flavors that were familiar to them, and inhaled for the amount of time that they ordinarily would. Because they tested "normal" vaping experiences, researchers confirmed that the high concentrations of aldehydes found in other studies aren't limited to laboratory conditions.

"Our new pilot study underlines the potential health risk associated with the aldehydes generated by e-cigarettes," said Samburova. "In the future, e-cigarette aldehyde exposure absolutely needs to be studied with a larger set of participants."

> "...a significant amount [of formaldehyde] is being retained in the user's respiratory tract."
>
> –VERA SAMBUROVA

Study identifies atmospheric conditions that increase likelihood of wildfires in Southwest, helping fire managers

DRI RESEARCH TEAM: Nick Nauslar, Tim Brown, Benjamin Hatchett, Michael Kaplan, John Mejia

To protect communities in arid landscapes from devastating wildfires, preparation is key. In January 2019, a team of DRI scientists published new research that may aid in the prevention of large fires by helping meteorologists and fire managers in the Southwestern U.S. to forecast periods of likely wildfire activity.

Each summer, from June through September, a weather pattern called the North American monsoon brings thunderstorms to the Southwestern U.S., with lightning that often sparks wildfires.

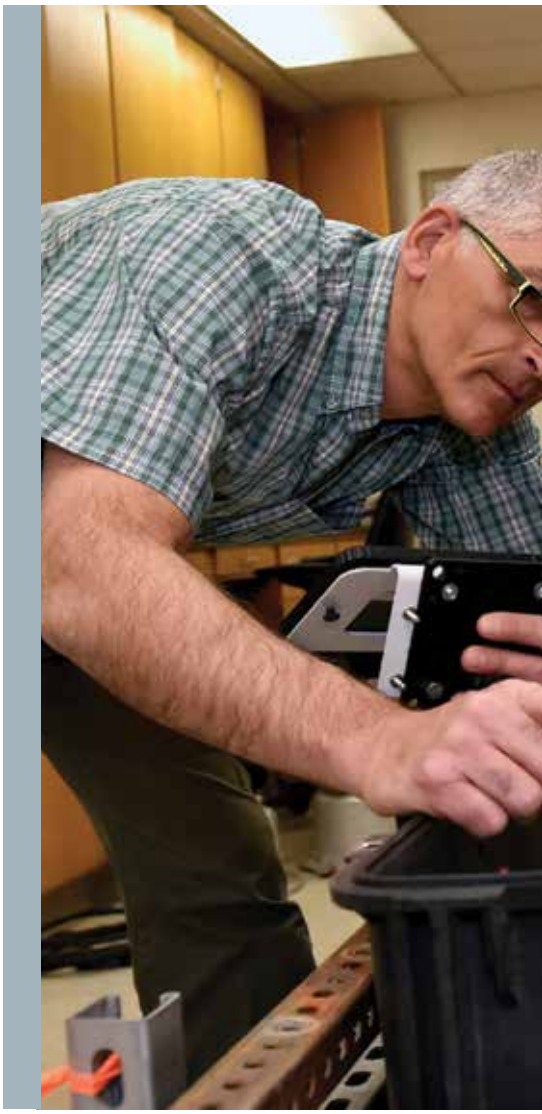
The study, published in the *International Journal of Climatology*, examined twenty common weather patterns that occur during the North American monsoon season and identified relationships between certain weather patterns and times of increased fire activity.

One of the most problematic weather patterns, the team learned, was when dry and windy conditions gave way to lightning storms in May and June—a time when fuels tended to be at their driest and monsoon rains had not yet soaked the region with added moisture. When lightning storms were followed by another hot, dry, windy period, increased fire activity was even more likely.

"A lot of fire meteorologists know from experience that this is how things happen, but our study actually quantified it and showed how the patterns unfold," said lead author Nick Nauslar, Ph.D., who completed this research while working as a graduate student at DRI under Tim Brown, Ph.D. "No one had ever really looked at large fire occurrence in the Southwest and how it related to atmospheric patterns."

In addition to identifying relationships between specific weather patterns and fire activity, researchers also looked for patterns in wildfire occurrence and fire size throughout the season. Analysis of more than 84,000 wildfires showed that although July was the month that the most wildfires occurred, wildfires that occurred during the month of June (prior to the arrival of much monsoonal moisture) were more likely to develop into large fires. In July and August, when the heaviest monsoonal precipitation typically occurs, the percentage of fires that developed into large fires decreased.

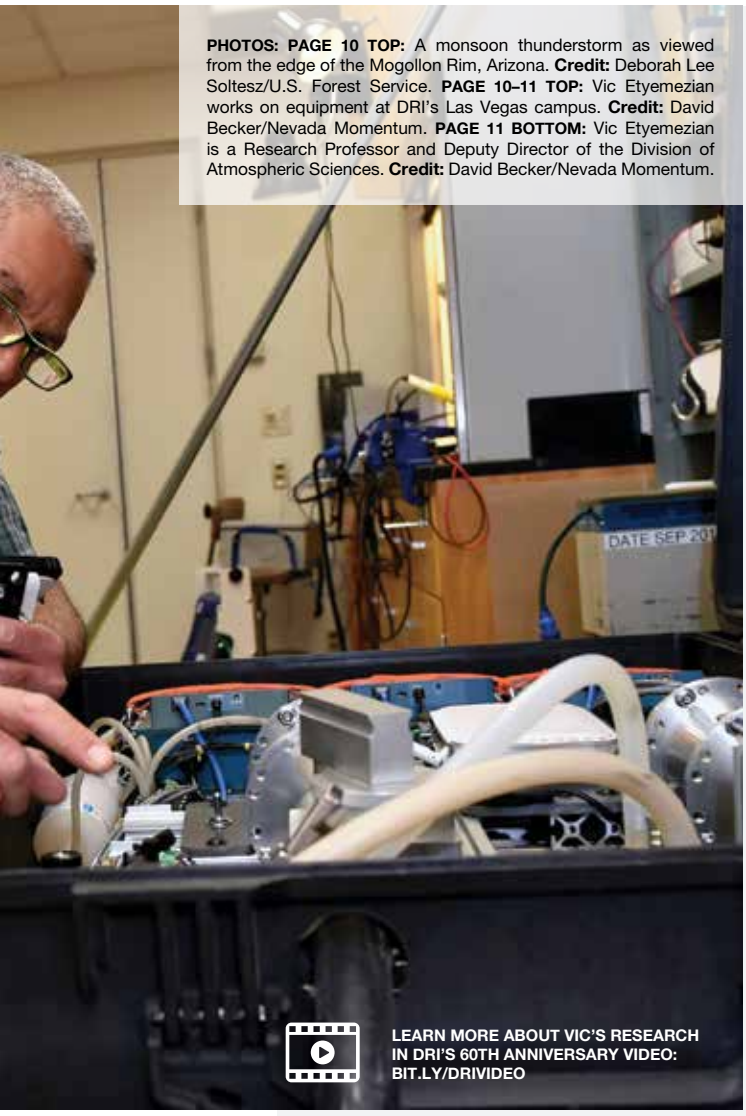
The study team hopes that their findings will help fire managers in the Southwest to proactively identify periods when wildfires are more likely to occur and to allocate firefighting resources accordingly.



"No one had ever really looked at large fire occurrence in the Southwest and how it related to atmospheric patterns."

–NICK NAUSLAR

PHOTOS: PAGE 10 TOP: A monsoon thunderstorm as viewed from the edge of the Mogollon Rim, Arizona. **Credit:** Deborah Lee Soltesz/U.S. Forest Service. **PAGE 10–11 TOP:** Vic Etyemezian works on equipment at DRI's Las Vegas campus. **Credit:** David Becker/Nevada Momentum. **PAGE 11 BOTTOM:** Vic Etyemezian is a Research Professor and Deputy Director of the Division of Atmospheric Sciences. **Credit:** David Becker/Nevada Momentum.



LEARN MORE ABOUT VIC'S RESEARCH IN DRI'S 60TH ANNIVERSARY VIDEO: BIT.LY/DRIVIDEO

Q&A: Meet Vic Etyemezian

What do you do here at DRI?
I'm a Research Professor in the Division of Atmospheric Sciences. I work in the field of air quality, and I specifically focus on issues related to dust in the air. I also develop instrumentation for studying and measuring dust, such as a portable device called the PI-SWERL, which we use to test and measure the potential for wind erosion and dust emissions from land surfaces.

> "I want to help supply the research community with better tools to make better decisions."
>
> –VIC ETYEMEZIAN

We understand that much of your work involves fugitive dust. What is fugitive dust?
A lot of air pollutants come out of tubes or pipes or some kind of effluent stream—something like a factory smokestack or a tailpipe from a car. Fugitive emissions are pollutants that don't come out of a stack; they're derived from across a broad area. Dust falls into that category because it's pretty much everywhere, especially in arid regions.

What kinds of new tools and technology are you developing to measure fugitive dust?
One of the things that we're working on right now is to develop a sensor that can be used in arid regions. It can essentially take measurements of wind and the movement of sand that results from that wind, and also the movement of dust that is suspended resulting from that wind. What you can do with these sensors, if they're inexpensive enough, is to deploy them by the hundreds or the thousands in places that might be too remote to have humans visit regularly or that may pose other difficulties for installation of standard instrumentation.

How will you use these sensors?
We think these sensors will be useful if you're trying to identify hotspots for blowing dust near highways, for example. There are a lot of places in New Mexico and Arizona and parts of Nevada where strong winds lead to brownout conditions that sometimes cause accidents on highways and even fatalities. So, we'd like to use these instruments to help identify where a lot of the dust comes from. The second thing we'd like to do, if possible, is to give is an early warning of a dust event that's about to happen.

What do you hope to accomplish in your career?
I want to help supply the research community with better tools to make better decisions and help increase the amount of useful information that is out there. As a scientist, what you'd like to do is of course discover new things, but as an environmental scientist, what you'd like to do is make contributions that help improve our understanding of the environment and ultimately improve the quality of life.

Teaching water, sanitation, hygiene and environmental issues in eSwatini

DRI RESEARCH TEAM: Braimah Apambire, Rosemary Carroll, Alan Heyvaert, Seshadri Rajagopal

In August and early September 2018, several DRI faculty members found themselves far from home—teaching courses in water, sanitation, and hygiene (WASH) and environmental issues in the Kingdom of eSwatini, formerly known as Swaziland, a small country nestled along South Africa's eastern border with Mozambique.

The courses—all focused on a set of interconnected environmental issues and public health challenges referred to by the acronym "WASH"—are part of an ongoing WASH Capacity Building Program operated by DRI's Center for International Water and Sustainability (CIWAS). This program received a five-year funding award from humanitarian non-governmental organization World Vision earlier in 2018 and provides technical capacity training to field staff who work in the WASH sector in developing countries.

> "DRI is helping to build women leaders in this sector."
>
> –BRAIMAH APAMBIRE

"The WASH Capacity Building Program is a partnership between DRI, the University of Nevada, Reno, Drexel University, and World Vision," explained Braimah Apambire, Ph.D., Director of CIWAS. "We've developed six courses which we teach partly online and partly face-to-face, and the students take four of those courses to complete our post-graduate certificate program. In April, we taught two courses in Ghana, and the two courses that we taught in eSwatini were the next in the series."

The 2018 cohort—the third since the program's pilot season in 2016—consisted of 30 students from 18 African countries. In eSwatini, their coursework focused on water supplies and environmental management in developing countries and on cross-cutting issues in WASH.

PHOTOS: PAGE 12 TOP: Students visit World Vision and eSwatini Water Services Corporation Program site in Matsanjeni, southeastern eSwatini. **PAGE 12 BOTTOM:** Courses were taught by instructors Braimah Apambire (DRI), Emmanuel Opong (World Vision), Rosemary Carroll (DRI), and Alan Heyvaert (DRI). **Credit:** World Vision eSwatini Communications. **PAGE 13 TOP:** Adam Watts explains the air quality sampling equipment he uses aboard UAS. **Credit:** Cathleen Allison/Nevada Momentum. **PAGE 13 BOTTOM:** Jayne Boehmler and Kellen Nelson, researchers formerly in the ASTER Lab, work on the UAS at the Sycan Marsh Preserve in October 2018. **Credit:** Craig Bienz/The Nature Conservancy.

Classroom time was interspersed with field trips to rural areas, dams, water and sanitation facilities, wastewater treatment plants, and more. CIWAS collaborators from the University of eSwatini gave guest lectures and organized field trips for the students during face-to-face teaching in the country.

Apambire is pleased to report that, for the first time, five of the students in this year's cohort are female. For women and girls in many African nations, challenges related to WASH impact everything from their ability to go to school each day to the survival and well-being of their children and families.

"DRI is helping to build women leaders in this sector," Apambire said. "Having women become trained as WASH professionals and go back to their villages really empowers them to become a part of the implementation and management of these projects."

Studying wildfire smoke with advanced airborne systems

Visit DRI's Northern Nevada campus on a clear afternoon, and you may hear a near-deafening buzzing. A massive swarm of bees? Thankfully, no—it's an unmanned aircraft system (UAS), or drone, being flown by researchers from DRI's Airborne Systems Testing and Environmental Research (ASTER) Laboratory.

Adam Watts, Ph.D., Associate Research Professor of Fire Ecology and Director of the ASTER Lab, has worked over the last several years to apply UAS technology in a variety of research projects in dangerous or hard-to-access environments. In 2017, for example, Watts led a 32-mile UAS flight at 1,500 feet above ground, the longest commercial UAS flight in American aviation history as part of a project to determine the feasibility of UAS for aerial cloud-seeding operations during winter storms.

More recently, Watts and his team in the ASTER lab have been working in entirely different environmental conditions: above prescribed burns.

"One of the big questions in land management, and in public health, is how smoke from prescribed fires versus wildfires differ, and what the effects are," said Watts.

> "One of the big questions in land management, and in public health, is how smoke from prescribed fires versus wildfires differ, and what the effects are."
>
> –ADAM WATTS

His team is looking to UAS technology to explore this question and learn more about the differences between prescribed fire emissions and those from wildfire. In 2018, they developed an innovative air sampling payload—a set of sensors and sampling equipment installed aboard the UAS—used to collect samples of wildland fire smoke. This payload allows the research team to collect samples directly from plumes and to move with a fire as its behavior changes, taking real-time measurements of CO_2, CO, particulate matter, temperature, humidity, and pressure.

To do this work, the ASTER lab team has worked collaboratively with the researchers in DRI's Organic Analytical Laboratory (OAL) to install sampling canisters on a UAS. While in flight, the canisters are opened remotely to suck in the surrounding air, all using a handheld touchscreen controller. Once the UAS is back on ground, the canisters are removed and returned to the OAL for analysis. Researchers hope these air quality data will improve understanding of smoke emissions from different fuel types.

"Smoke is really ephemeral," explained Watts. "You'll have a smoke plume moving around, or a little column of smoke coming up from a patch of vegetation that's burning. Our custom payload on an unmanned aircraft is a powerful tool to make targeted measurements."

Over the last year, Watts and his team have tested the equipment in the lab and in the field, and this summer, they hope to test the payload in the field over a live research burn to better understand live wildfire conditions.

Lead pollution in Greenland ice shows rise and fall of ancient European civilizations

DRI RESEARCH TEAM: Joe McConnell, Monica Arienzo, Nathan Chellman

To learn about the rise and fall of ancient European civilizations, researchers sometimes find clues in unlikely places: deep inside of the Greenland ice sheet, for example.

Thousands of years ago, during the height of the ancient Greek and Roman empires, lead emissions from sources such as the mining and smelting of lead-silver ores in Europe drifted with the winds over the ocean to Greenland—a distance of more than 2800 miles (4600 km)—and settled onto the ice. Year after year, as fallen snow added layers to the ice sheet, lead emissions were captured along with dust and other airborne particles and became part of the ice-core record that scientists use today to learn about conditions of the past.

In a study published in the *Proceedings of the National Academy of Sciences* in May 2018, researchers from DRI, the University of Oxford, NILU–Norwegian Institute for Air Research, and the University of Copenhagen used ice samples from the North Greenland Ice Core Project to measure, date and analyze European lead emissions that were captured in Greenland ice between 1100 BC and AD 800. Their results provide new insights for historians about how European civilizations and their economies fared over time.

"Our record of sub-annually resolved, accurately dated measurements in the ice core starts in 1100 BC during the late Iron Age and extends through antiquity and late antiquity to the early Middle Ages in Europe – a period that included the rise and fall of the Greek and Roman civilizations," said the study's lead author Joe McConnell, Ph.D., Research Professor of Hydrology at DRI. "We found that lead pollution in Greenland very closely tracked known plagues, wars, social unrest and imperial expansions during European antiquity."

A previous study from the mid-1990s examined lead levels in Greenland ice using only 18 measurements between 1100 BC and AD 800; the new study provides a much more complete record that included more than 21,000 precise measurements of lead and other chemicals to develop an accurately dated, continuous record for the same 1900-year period. Most of the lead emissions from this time period are believed to have been linked to the production of silver, which was a key component of currency.

"Because most of the emissions during these periods resulted from mining and smelting of lead-silver ores, lead emissions can be seen as a proxy or indicator of overall economic activity," McConnell explained.

Using their detailed ice-core chronology, the research team looked for linkages between lead emissions and significant historical events. Their results show that lead pollution emissions began to rise as early as 900 BC, as Phoenicians expanded their trading routes into the western Mediterranean. Lead emissions accelerated during a period of increased mining activity by the Carthaginians and Romans primarily in the Iberian Peninsula and reached a maximum under the Roman Empire.

The team's extensive measurements provide a different picture of ancient economic activity than previous research had provided. The team also found that lead emissions rose and fell along with wars and political instability, particularly during the Roman Republic, and took sharp dives when two major plagues struck the Roman Empire in the 2nd and 3rd centuries. The first, called the Antonine Plague, was probably smallpox. The second, called the Plague of Cyprian, struck during a period of political instability called the third-century crisis.

The research team for this study included ice-core specialists, atmospheric scientists, archaeologists, and economic historians—an unusual combination of expertise.

"Working with such a diverse team was a unique experience in my career as a scientist," McConnell said.

PHOTOS: PAGE 14–15 BACKGROUND: Meltwater canyon on the Greenland ice sheet. **Credit:** Sarah Das/Woods Hole Oceanographic Institution. **PAGE 15 TOP:** Monica Arienzo inspects an ice core sample in the DRI Ice Core Lab in Reno. **PAGE 15 CENTER:** An ice core sample. **PAGE 15 BOTTOM:** Joe McConnell and Nathan Chellman inspect an ice core sample in the Ice Core Lab in Reno. **All credits:** Cathleen Allison/Nevada Momentum.

NAMED AMONG TOP DISCOVERIES IN 2018

The work of DRI's Ice Core Lab on lead pollution in Greenland ice was recognized In the January/February 2019 issue of *Discover* magazine as one of the biggest scientific discoveries of 2018. Stories on these important research findings also appeared in publications such as the *Economist*, *New York Times*, *Science Magazine*, *Newsweek*, and the *Smithsonian*.

MORE ICE CORE LAB RESEARCH NEWS

The team in the Ice Core Lab has been busy this year. Here's a list of research highlights out of the Ice Core Lab in the last year:

- DRI ice core data provides insight into how dust and precipitation reach Earth's poles
- First non-polar historical iodine record shows impact of fossil fuel emissions
- DRI ice core data illustrates climate "teleconnection" between Earth's poles during climate changes in the last Ice Age
- Data from DRI ice core lab shows rapid melting of Greenland ice sheet
- Monica Arienzo receives Board of Regents 2019 Rising Researcher Award
- Forest fires accelerating snowmelt across western U.S., new study finds
- North Atlantic Ocean productivity has dropped 10 percent during Industrial era
- Traces of Roman-era pollution stored in the ice of Mont Blanc

Low severity fires impact soils more than previously believed, driving erosion risk

DRI RESEARCH TEAM: Markus Berli, Rose Shillito

Low-severity wildland fires and prescribed burns have long been presumed by scientists and resource managers to be harmless to soils, but this may not be the case, according to two studies published in 2018 by a team from DRI and the University of California, Merced (UCM). The studies show that low-severity burns—in which fire moves quickly and soil temperature does not exceed 250°C (482°F)—cause damage to soil structure and organic matter in ways that are not immediately apparent after a fire.

"...prescribed burns and other fires that occur during wetter times of year may be more harmful to soils than fires that occur during dry times."

–MARKUS BERLI

"In a low-severity fire, the organic matter doesn't burn off, and there is no visible destruction right away," said Teamrat Ghezzehei, Ph.D., principal investigator of the two studies and Associate Professor of Environmental Soil Physics at UCM. "But the burning weakens the soil structure, and unless you come back at a later time and carefully look at the soil, you wouldn't notice the damage."

In a study published in the journal *AGU Geophysical Research Letters* in May 2018, the research team, which included DRI's Markus Berli, Ph.D., Associate Research Professor of Environmental Science, used soil samples from two unburned forest areas in California and Nevada to analyze the impacts of low-severity fires on soil structure.

"Our results show that the heat produced by low-severity fires is actually enough to do damage to soil structure, and that the damage is worse if the soils are wet," Berli explained. "This is important information for resource managers because it implies that prescribed burns and other fires that occur during wetter times of year may be more harmful to soils than fires that occur during dry times."

In a second study that was published in *Frontiers in Environmental Science* in July 2018, the team conducted simulated burn experiments to weaken the structure of the soil aggregates, then tested the soils for changes over a 70-day period. They found that heating of soils led to the release of organic carbon into the atmosphere as CO_2 during the weeks and months after the fire, and again found that the highest levels of degradation occurred in soils that were moist.

Although their findings showed several detrimental effects of fire on soils, low-severity wildfires and prescribed burns are known to benefit ecosystems in other ways. It is not yet clear whether the negative impacts associated with these low-severity fires outweigh the positives, Berli says, but he hopes that their research results will help to inform land managers as they manage wildfires and plan prescribed burns.

PHOTOS: PAGE 16 UPPER LEFT: A burned area in the Humboldt-Toiyabe National Forest near Las Vegas shows lasting impacts of a fire that occurred in 2013. **Credit:** Teamrat Ghezzehei/ UCM. **PAGE 16 UPPER RIGHT:** Markus Berli is a research professor of Environmental Science at DRI in Las Vegas. **PAGE 17 UPPER:** Brittany Kruger collects samples at an underground mine site. **PAGE 17 LOWER RIGHT:** Brittany Kruger is a Staff Research Scientist in Geobiology.

LEARN MORE ABOUT BRITTANY'S RESEARCH IN DRI'S 60TH ANNIVERSARY VIDEO: BIT.LY/DRIVIDEO

Q&A: Meet Brittany Kruger

What do you do here at DRI?
I am a Staff Research Scientist in Geobiology with the Division of Hydrologic Sciences here at DRI. I support a number of different projects that focus on deep biosphere life, which essentially means we try and examine life as deep as we can access it underground. Specifically, we look for microbial life and try and understand how those organisms are functioning given the stresses that they encounter deep underground.

How do you access deep underground environments?
There are a couple different ways you can access the deep biosphere. One way is to actually go there—you can go down in deep mines, for example. In that scenario we can actually bring instruments and equipment down with us. One of our most recently active field sites is an old gold mine in South Dakota, where we are able to go about a mile underground. Another option to access subsurface life is to use deeply drilled wells that access water or aquifers that are very far underground. This is the approach that we use at active field sites in the Death Valley and Armargosa Valley areas.

Some of your research has implications for life on other planets. Can you tell us about that?
One of the projects that I've been focusing on since I started here at DRI is the NASA Astrobiology Life Underground Project, where I serve as continental fieldwork coordinator. We try to access the deep biosphere in multiple locations to install experimentation and collect samples, and we use what we learn about the way microbes are metabolizing and surviving in those locations to help us understand how life might be functioning on other planets that experience the same or similar stressors, like extreme heat, temperature, pressure, radiation, lack of sunlight, etc.

What is it like to work deep underground?
It's great. I love it. I'm always excited to go down. It's absolute pitch black, and it gets hotter the deeper you go. At our hottest underground site, it is something like 90 degrees and 90 percent humidity. It is uncomfortable to be there for a long time, for sure. But the facility we work in does a really good job of trying to mitigate air flow while we're there to keep that a little more comfortable. One of the best parts is spending time with the old miners. We get to see some really exciting things and some really awesome old history. It's fun.

> "We use what we learn about the way microbes are metabolizing and surviving in those locations to help us understand how life might be functioning on other planets."
>
> –BRITTANY KRUGER

COMMUNITY ENGAGEMENT

Vera Samburova (center), Girl's Day of STEM at DRI Reno, January 2019

Meghan Collins (left), The Science Behind Smarter Communities, April 2019

Girl's Day of STEM at DRI Reno, January 2019

DRI Day at the Nevada State Legislature, March 2019

Science Distilled, February 2019

May Science Be With You at DRI Las Vegas, May 2019

Teresa Wriston (right), May Science

Maureen King (left), May Science Be With You at DRI Las Vegas, May 2019

Meghan Collins, Native Waters Youth Day, October 2018

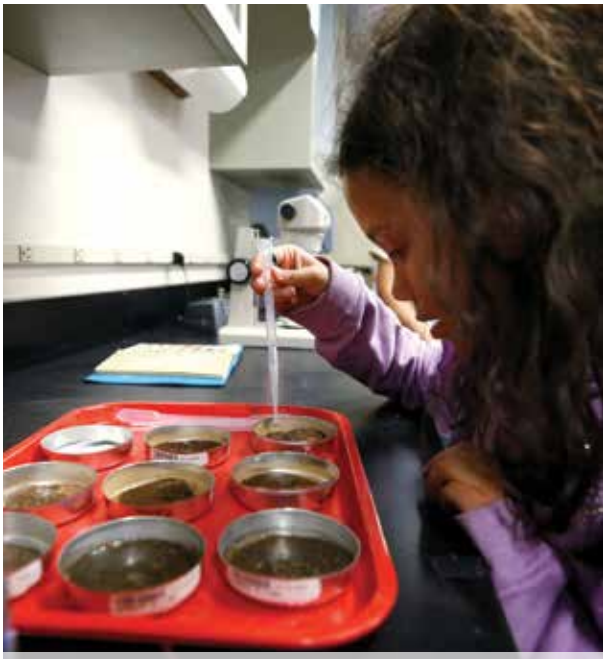
May Scien

Adam Watts (right), Tahoe Summit, August 2018

Tatianna Menocal (right), Girl's Day of STEM at DRI Las Vegas, March 2019

May Science Be With You at DRI Reno, May 2019

Be With You at DRI Reno, May 2019



May Science Be With You at DRI Reno, May 2019

Tim Minor (left), May Science Be With You at DRI Reno, May 2019

nce Be With You at DRI Las Vegas, May 2019

Richard Jasoni (right), May Science Be With You at DRI Reno, May 2019

Adam Watts (left), The Science Behind Smarter Communities, April 2019

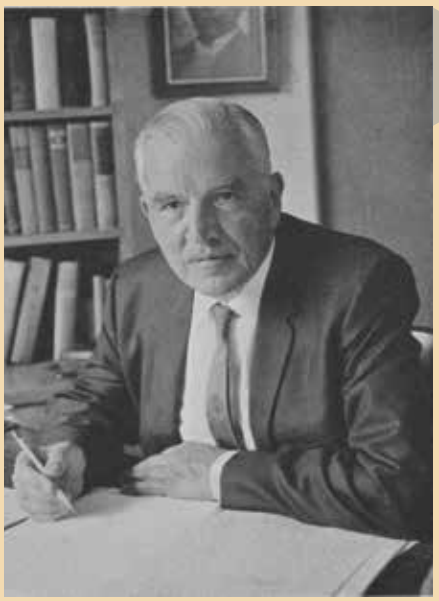
60th DRI
Desert Research Institute

CELEBRATING 60 YEARS OF SCIENTIFIC DISCOVERY AND INNOVATION, IN NEVADA AND AROUND THE WORLD.

1959–1968

1959 The Nevada State Legislature passed NRS396.7951, creating a division of the University of Nevada system specifically devoted to conducting research. From this legislative action, a small group of farsighted scientists created the Desert Research Institute.

1961 DRI began groundwater studies to support the Atomic Energy Commission's (now the Department of Energy) underground nuclear tests at locations in Nevada and across the United States, leading to decades of research providing valuable insight into groundwater systems and migration of radionuclides.



1965 Dr. Frits Went, head of DRI's Laboratory of Desert Biology, designed the first greenhouses in Nevada capable of conducting climate-controlled experiments. These structures, known as phytotrons, were precursors to the EcoCELLs now in the Gallagher Great Basin Environmental Research Laboratory on DRI's Reno campus.

1967 Dr. William Douglass directed the DRI Basque Studies Program, the only such program in the United States. DRI's Basque projects would eventually be assimilated into the Basque Studies Program at the University of Nevada, Reno, but DRI is proud to have established Nevada's unique Basque Studies Program and to have contributed to the preservation of Basque culture and history.

1969–1978

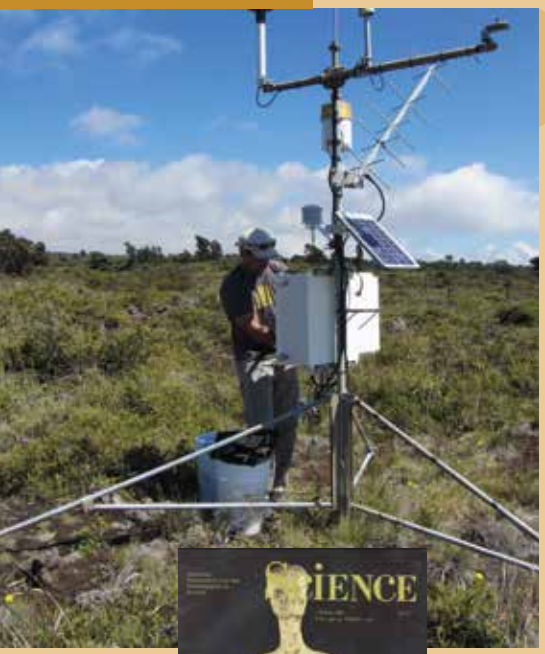
1969 DRI became an autonomous branch of what was then the University of Nevada System. Today, DRI is one of eight independent institutions in the Nevada System of Higher Education.

1975 DRI participated in the first Greenland Ice Sheet Project, sponsored by the National Science Foundation, which aimed to collect a continuous core of Greenland ice and study it for clues about Earth's past climate. DRI continued work in this project throughout the 80s and 90s and has since become a world leader in ice core research and analysis.

1977 Drought conditions prompted Governor Mike O'Callaghan to authorize the first Emergency Cloud Seeding Project, led by DRI. This project leveraged DRI's years of research in cloud seeding and has since evolved into the State of Nevada Cloud Seeding Project which seeds Nevada watersheds every winter to enhance snowpack.

1977 DRI began cultural resources management for the Department of Energy in the area now known as the Nevada National Security Site. This landscape holds a range of cultural resources from the earliest known prehistoric societies in North America circa 13,000 years ago to historic times, including Native American occupations, early Euro-American exploration, mining booms, ranching, and Cold War-era nuclear testing.

1979–1988



1986 DRI became home to the Western Regional Climate Center, one of six such centers run by the National Oceanic and Atmospheric Administration (NOAA). The WRCC stores climate and weather data, coordinates climate services across 11 Western states, and conducts applied research on weather and climate topics.

1986 DRI scientists pioneered the use of chemical fingerprinting, a technique to identify the relative contributions of different pollutants to overall pollution mass and the movement of pollutants to their eventual points of impact. This work has become the basis of air quality management in Nevada's urban areas and has been applied to mitigate haze in some of the world's most scenic places like the Rocky Mountains.

1988 The DRI Research Foundation presented the first ever Nevada Medal, an annual national award designed to enhance Nevada's prestige in the scientific community and recognize outstanding scientific achievement. The first Nevada Medalist was Verner E. Suomi, Ph.D., the father of satellite meteorology.

1988 DRI archaeologist Alan Simmons, Ph.D., made the cover of Science magazine for his work at the site of Ain Ghazal in Jordan. His team's excavation at this site, which dates back to the Neolithic period, helped shed light on early peoples' adoption of domestic plants and animals as primary subsistence sources.

1989–1998

1992 DRI's Las Vegas faculty moved into the Southern Nevada Science Center, the first facility in the city designed specifically for scientific research. DRI operations in Southern Nevada continue to operate from this campus.

1994 DRI became one of only a handful of institutions in the country equipped with luminescence dating capabilities, which allow researchers to determine the ages of materials too old for carbon dating and learn about past climate shifts, earthquakes, and volcanic eruptions. This work continues at DRI in what is now the E.L. Cord Luminescence Lab.

1995 DRI scientists successfully used satellite-based and airborne remote sensing to find suitable drinking water wells for communities in Ghana, improving water supplies and reducing the exposure to water-borne diseases.

1997 DRI launched the Science Box Traveling Kits Program, which provided portable instruction modules to Nevada educators. These kits, now called Green Boxes, have become ubiquitous in Nevada schools, reaching more than 23,000 Nevada students annually.

1999–2008

1999 DRI took over technical operations of the DOE-funded Community Environmental Monitoring Program after participating in the program since 1981, running a network of monitoring stations located in communities surrounding and downwind of the Nevada National Security Site. The CEMP is still active today: a strong contingent of local citizens continues to work with DRI scientists to maintain the stations and educate the community.

2001 DRI scientists began demonstrating the effectiveness of "TRAKER"—a vehicle outfitted with state of the art air sampling equipment—to urban air quality officials. This new technology, invented by DRI researchers, allowed resource managers to pinpoint sources of dust pollution and target key areas with dust abatement efforts in rapidly growing Las Vegas, improving the city's air quality.

2005 DRI researchers successfully used wildlife detection dogs to track and locate threatened desert tortoises in the Mojave Desert to allow for improved monitoring and protection of the population.

2005 DRI air quality experts collaborated with Chinese researchers to help preserve the Terra Cotta army, artifacts dating from 221 BC from the Qin Dynasty that were deteriorating due to poor air quality.

2009–2018

2013 A team of scientists led by DRI completed a multi-year project to evaluate the nearshore ecology of Lake Tahoe, forging a coordinated monitoring and evaluation effort between scientists and resource managers across the Tahoe Basin.

2016 In collaboration with the Terry Lee Wells Nevada Discovery Museum, DRI launched Science Distilled, a lecture series that makes cutting-edge research approachable and provides community members with an opportunity to talk with local scientists. The series features six talks annually, on topics ranging from cybersecurity to the ecology of snow.

2017 The Desert Research Corporation, the commercialization arm of DRI, successfully raised venture capital funding for Tu Biomics Inc. In conjunction with DRI's soil and molecular biology scientists, Tu Biomics is driving the development of organic antifungal chemicals as a cost-effective alternative to currently available options.

2018 Using ice core records from Greenland, DRI researchers identified a connection between lead pollution and the rise and fall of ancient European civilizations including the Roman Empire. Their findings were listed among the top 100 science stories of the year by Discover magazine.

DRI and collaborators awarded $6 million grant for innovative genetic research project

In November 2018, DRI, the Bigelow Laboratory for Ocean Sciences, and University of New Hampshire, received a $6 million National Science Foundation grant to fund the development of new genetic research technologies.

This four-year project will develop and apply new tools and techniques in genetic analysis to learn about links between the genomes (DNA, or genetic material) and phenomes (observable characteristics) expressed by single-celled organisms in diverse marine and continental environments.

The team will gather microbes from coastal ocean habitat in the Gulf of Maine, deep ocean and marine subsurface habitat along the Juan de Fuca Ridge of the northwestern Pacific Ocean, and terrestrial deep subsurface habitat in boreholes that intersect geological fault zones associated with Death Valley, Calif. Duane Moser, Ph.D., head of DRI's Environmental Microbiology and Astrobiology Labs in Las Vegas, will lead portions of the project related to the continental subsurface.

Floating evaporation stations deployed at Lake Powell

A new collaboration between DRI and the Technical Service Center of the Department of Interior's Bureau of Reclamation aims to improve our understanding of evaporation from Lake Powell and other major reservoirs of the western United States through the deployment of floating evaporation stations.

The two stations, which began collecting data during November 2018, monitor meteorological conditions over the water and estimate evaporation using four different primary methods. By collecting data from multiple sites in the reservoir, the research team will learn about how evaporation rates vary both spatially and temporally throughout the year.

The goal of this project, says principal investigator Chris Pearson, Assistant Research Scientist of Hydrology, is to help scientists and water managers make accurate evaporation estimates using best available science—both at Lake Powell and elsewhere in the world. Other members of the DRI project team include Justin Huntington, Brad Lyles, and Richard Jasoni.

Regional research institutions receive $4.5 million to continue applied climate research

In November 2018, the Southwest Climate Adaptation Science Center (SW CASC), a collaborative partnership between DRI, five other regional research institutions, and the United States Geological Survey (USGS), received a five-year, $4.5 million grant from the USGS to renew support for the center's research on climate science and adaption throughout the region.

With its renewed funding, the SW CASC will build on its almost seven years of collaborative research and outreach. Over the next five years, SW CASC researchers are aiming to produce new scientific information alongside decision makers and managers to help make more informed planning decisions about the region's highest priority issues, including the allocation of resources.

PHOTOS: PAGE 24 UPPER LEFT: Wellhead for the project's main continental deep biosphere site, shown here during a hydrologic pumping test. Death Valley's Funeral Mountains can be seen in the background. **PAGE 25 UPPER RIGHT:** Evaporation monitoring platform located in Padre Bay at Lake Powell. **PAGE 24–25 BOTTOM CENTER:** A firefighter hauls a hose near the front line of the Ferguson Fire in 2018. **Credit:** Kari Greer/U.S. Forest Service.

Research findings push back date of earliest North Americans by at least 2,500 years

For decades, researchers believed the Western Hemisphere was settled by humans roughly 13,500 years ago, a theory based largely upon the widespread distribution of Clovis artifacts dated to that time. Clovis artifacts are distinctive prehistoric stone tools so named because they were initially found near Clovis, New Mexico, in the 1920s but have since been identified throughout North and South America.

In recent years, though, archaeological evidence has increasingly called into question the idea of "Clovis First." In July 2018, a study published in the journal *Science Advances* by a team including DRI graduate student Kathleen Rodrigues and Amanda Keen-Zebert, Ph.D., Associate Research Professor and Director of the E.L. Cord Luminescence Lab, dated a significant assemblage of stone artifacts to 16-20,000 years of age, pushing back the timeline of the first human inhabitants of North America before Clovis by at least 2,500 years.

Significantly, this research identifies a previously unknown, early projectile point technology unrelated to Clovis, which suggests that Clovis technology spread across an already well-established, indigenous population.

"These projectile points are unique. We haven't found anything else like them," said Tom Williams, Ph.D., Postdoctoral Research Associate in the Department of Anthropology at Texas State University and lead author of the study. "Combine that with the ages and the fact that it underlies a Clovis component, and the Gault site provides a fantastic opportunity to study the earliest human occupants in the Americas."

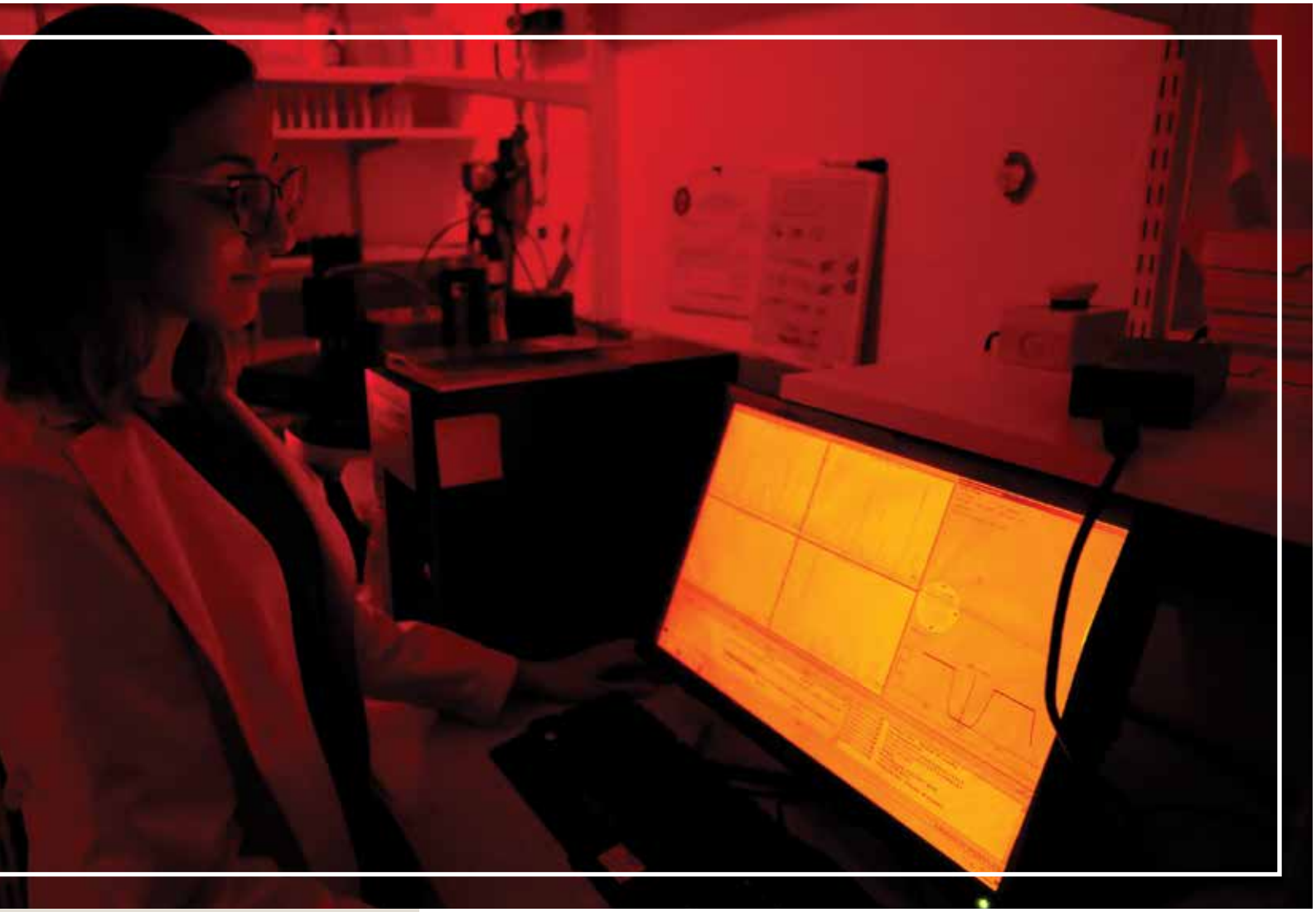
The research team identified the artifacts at the Gault Site in Central Texas, an extensive archaeological site with evidence of continuous human occupation. The presence of Clovis technology at the site is well-documented, but excavations below the deposits containing Clovis artifacts revealed well-stratified sediments containing artifacts distinctly different from Clovis.

To determine the ages of these artifacts, Rodrigues, Keen-Zebert, and colleagues used a process called optically stimulated luminescence (OSL) dating on the sediments surrounding them. In OSL, researchers expose minerals that have long been buried under sediment layers to light or heat, which causes the minerals to release trapped potassium, uranium, and thorium electrons that have accumulated over time due to exposure to ambient, naturally occurring radiation. When the trapped electrons are released, they emit photons of light which can be measured to determine the amount of time that has elapsed since the materials were last exposed to heat or sunlight.

"The fluvial nature of the sediments deposited at the Gault Site have created a poor environment for preservation of organic materials, so radiocarbon dating has not been a useful technique to apply in this region," said Kathleen Rodrigues, graduate research assistant in DRI's Division of Earth and Ecosystem Sciences. "This made luminescence dating a natural choice for dating the archaeological materials here. We are really pleased with the quality of the results that we have achieved."

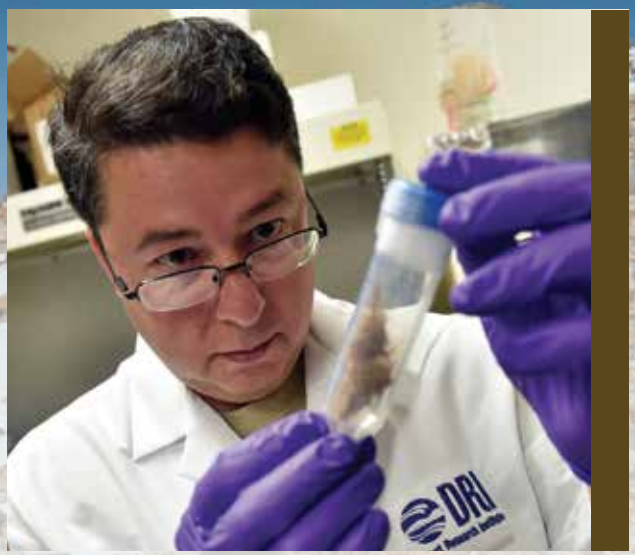
Jayme Blaschke of the Texas State University Office of Media Relations contributed to this release.

PHOTOS: PAGE 27 UPPER: Kathleen Rodrigues analyzes data in the E.L. Cord Luminescence Lab in Reno, which can only be lit in red to preserve the integrity of samples in the lab. **Credit:** Cathleen Allison/Nevada Momentum. **PAGE 27 LOWER:** Stone tool assemblage recovered from the Gault Site. **Credit:** N Velchoff, The Gault School of Archaeological Research.



"We are really pleased with the quality of the results that we have achieved."

–KATHLEEN RODRIGUES



Ancient 'quids' reveal genetic information, clues about migration patterns of early Great Basin inhabitants

DRI RESEARCH TEAM: Scott Hamilton-Brehm, Lidia Hristova, Susan Edwards, Jeffrey Wedding, Brittany Kruger, Duane Moser

If you want to know about your ancestors today, you can send a little saliva to a company where—for a fee—they will analyze your DNA and tell you where you come from. For scientists trying to find out about ancient peoples, however, the challenge is more complex.

Research published in 2018 in the journal *PLOS ONE* by a team of archaeologists and microbiologists from DRI and Southern Illinois University (SIU) Carbondale showcased the use of modern research methods to uncover clues about the genetic ancestry of Native Americans who inhabited the Desert Southwest during the last thousand years.

During the Late Holocene Epoch, which began 12,000 to 11,500 years ago and continues through the present, occupants of the Mule Spring Rockshelter in the foothills of the Spring Mountains of southern Nevada commonly gathered agave and yucca plants for food. The artichoke-like hearts and inner leaves of the plants were roasted then chewed to consume the sweet fleshy pulp. All that's spit out and left behind of the plant are wads of stringy fibers called "quids."

"The quid's coarse texture is excellent for capturing skin cells from the mouth, making them the equivalent of the modern-day cheek swab," explained Susan Edwards, an Associate Research Archaeologist at DRI and co-principal investigator who first thought of applying DNA extraction techniques to the quid samples.

The research team used laboratory and computational resources at DRI's Southern Nevada Science Center in Las Vegas, and later at SIU, to identify changes in the mitochondrial DNA sequences that are maintained in ancestrally related populations called haplogroups. The study showed that the Mule Spring Rockshelter quid specimens ranged in age from about 350 to 980 years old. Because Mule Spring Rockshelter sits at a crossroads between the southern Great Basin, the Mojave Desert, and the Southwest Puebloan cultures, these results may provide a better timeline for an important but contentiously debated event in human history known as the Numic Spread.

> "...these results may provide a better timeline for an important but contentiously debated event in human history known as the Numic spread."

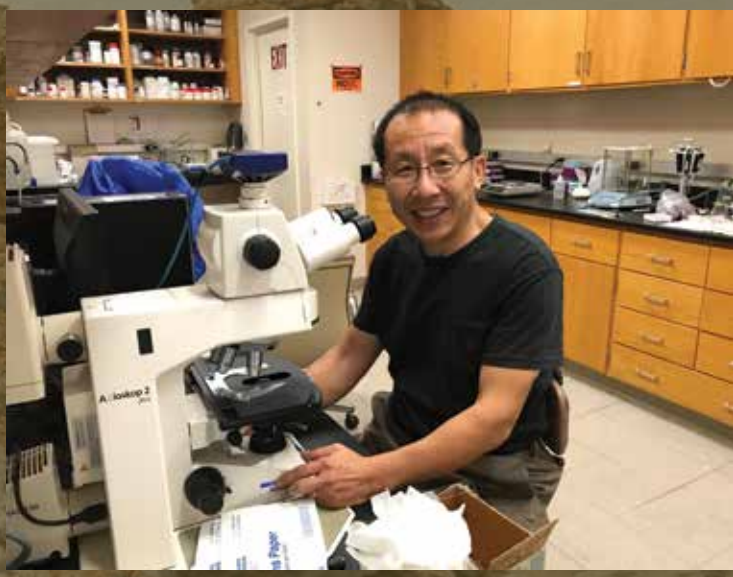
This research marks only the second time that scientists have been able to sequence human DNA from plant-based artifacts, expanding upon an approach utilized by Steven LeBlanc of Harvard University. As an added benefit of utilizing DNA from quid samples (rather than from more traditional sources such as bones or teeth), the research team found that they were able to obtain the information they needed while being respectful of cultural sensitivities.

Tim Crosby, Communications and Marketing Strategist at SIU Carbondale contributed to this story.

Q&A: Meet Henry Sun

What do you do here at DRI?

I am an Associate Research Professor of Microbiology with the Division of Earth and Ecosystem Sciences at DRI in Las Vegas. I do quite a few things, all centered around the study of life in extreme environments – places that are in one way or another similar to Mars. We are studying what we call analogue environments, trying to understand whether there's life in these places that are comparable to Mars, learning how to go about detecting life and organisms, and developing ideas for reliable instruments that we can send to Mars to look for life there.



How did you become interested in this line of work?

It started in graduate school, when I was given the opportunity to go to Antarctica, to a place called the Dry Valleys, to do my dissertation work. Until 1976, this was a place thought to be devoid of all life. But my former adviser, Imre Friedmann, discovered thriving communities of microalgae and cyanobacteria in the pore spaces in the Antarctic sandstone. I fell in love with these organisms on my very first trip there.

> "The first human mission to Mars may happen as early as the 2030s, but the scientists who go to Mars are still in school today. To me, there is no greater reward than to see children inspired by the work we do."
>
> –HENRY SUN

What did you learn from studying those organisms?

Probably the most remarkable thing we have learned about these organisms is that they have a very slow growth rate. We have monitored a few rocks closely over the last 50 years and never saw any appreciable signs of growth. In fact, they are so long-lived that their age can be determined by radiocarbon decay. In other words, if you look at their radiocarbon content, you would think they are dead, fossilized organisms. But we know they are alive because as soon as we thaw them to a normal temperature they start to breathe, taking up carbon dioxide and releasing oxygen. And because they start to grow and reproduce.

What do you like best about what you do?

I feel most rewarded when we engage school teachers and their students in what we do. We do this through a program called Spaceward Bound, which was created by Chris McKay, DRI's Nevada Medalist in 2015. The goal is to train the next generation of space explorers in remote but scientifically interesting places that are analogous to the moon or Mars. The first human mission to Mars may happen as early as the 2030s, but the scientists who will go to Mars are still in school today. To me, there is no greater reward than to see children get inspired by the work we do so that one day they may become scientists themselves and continue to push back the frontier of knowledge.

PHOTOS: PAGE 28–29 BACKGROUND: An outcrop of Antarctic sandstone at one of Henry Sun's field sites. **PAGE 28 LEFT:** Duane Moser examines a quid sample. **Credit:** David Becker/Nevada Momentum. **PAGE 28 RIGHT:** A quid sample in a vial. **Credit:** David Becker/Nevada Momentum. **PAGE 29 UPPER:** Henry Sun, Ph.D., is an Associate Research Professor of Microbiology with the Division of Earth and Ecosystem Sciences at the Desert Research Institute in Las Vegas. **PAGE 29 LOWER:** Closeup of one of Henry Sun's Antarctic rock samples, home to unknown species of microorganisms.

DESERT RESEARCH CORPORATION

Commercializing DRI research

The Desert Research Corporation (DRC) serves as the technology commercialization partner to DRI. DRC aligns nearly 60 years of world-renown scientific resources, specialized laboratories and facilities, and subject matter expertise with market-based solutions targeting some of the most complex sustainability challenges of our era. The innovation business process applied through the DRC positions it as a financial and transactional platform, enabling business to business interactions familiar to investors and industrial partners. In particular, the DRC serves as a holding/parent company, creating subsidiaries with preferred capital structures, investor incentives, and uniquely branded vehicles for the licensing and monetization of DRI IP. To date, four subsidiaries have been spun out of the DRC based on DRI innovation. These diverse entities are pointed towards large commercial markets such as agriculture, the microbiome, smarter communities and IoT, and nicotine replacement.

DRI launches field-scale trials of organic anti-fungal crop treatments

In 2019, a group of DRI scientists teamed up with one of California's largest agricultural producers to begin testing innovative solutions to combat harmful fungal pathogens impacting onion and garlic crops. Funded through a successful venture-capital round, the researchers formed a startup company called Tu Biomics, focused on industrial scale farming and its significant soil health challenges.

WaterStart Australia

A subsidiary of the Nevada-based organization, WaterStart, announced in 2019 the addition of Nick Shewring as its new General Manager in Queensland, Australia. After working as a startup founder for nearly 15 years, Shewring joined the WaterStart Australia team to further water innovation efforts and help attract more international technology companies to Queensland by working with major water utilities and water consumers across the state. WaterStart Australia was created as a result of Queensland and Nevada becoming Sister States in early 2018, committing to work collaboratively across key industries and opportunities including advancement in water technology. In May 2018, Queensland Urban Utilities (QUU) became WaterStart's first international member.

"We are motivated to help innovative tech companies scale up their operations and create more regional jobs across the state in the growing water sector."

–NICK SHEWRING

WaterStart is a cluster of global leaders in the implementation of water innovation. WaterStart leverages the strategic resources and expertise of its network to evaluate and demonstrate the performance of water innovation. As a channel for innovation, WaterStart accelerates the rate of adoption of new solutions to real challenges facing water management agencies and large consumers.

waterstart

Science Alive receives Tesla funding for teacher training in robotics and STEM

DRI Science Alive K-12 Outreach Program was selected as one of several recipients of the first round of funding through Tesla's new Nevada K-12 Education Investment Fund, through which Tesla will contribute over $37.5 million over five years to K-12 education in Nevada.

With this funding, Science Alive staff is developing a statewide teacher professional development curriculum and onboarding process for new robotics programs in partnership with FIRST, the REC Foundation (VEX), Solar Roller, the University of Nevada, Reno, and the University of Nevada, Las Vegas. In addition to coordinating teacher trainings, DRI will also be evaluating the effectiveness of robotics programs in student achievement and attitudes toward STEM.

DRI Desert Research Institute | science alive

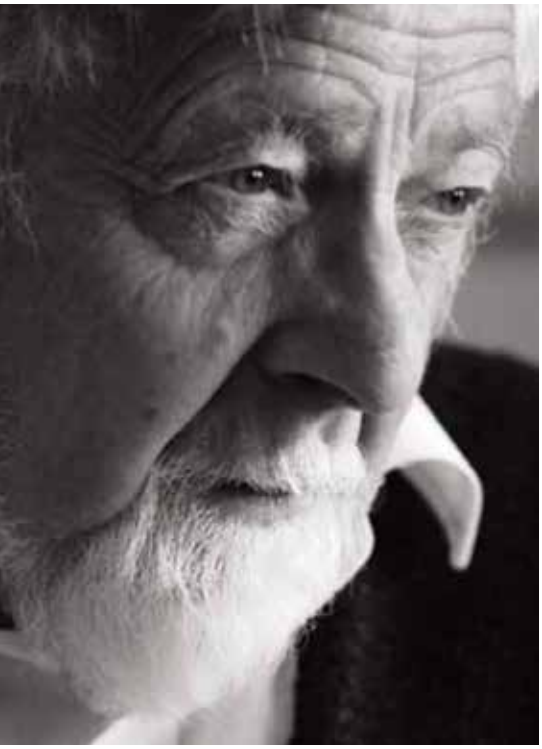
PHOTOS: PAGE 30: A garlic plant grown in DRI's greenhouses as part of a study on fungal pathogens affecting garlic and onion crops. **Credit:** Cathleen Allison/Nevada Momentum. **PAGE 31 BOTTOM:** Teachers work on an activity during the Robotics Academy of Nevada at UNLV in May 2019.

IN MEMORIAM

Dr. John Hallett

Dr. John Hallett, Research Professor of Atmospheric Physics in DRI's Division of Atmospheric Sciences, passed away on Monday, November 5, 2018, at his home in Reno.

John began his career at DRI in 1966 when his research and acquaintance with Dr. Wendell Mordy first drew him to Nevada. As the Institute's longest-serving scientist, Dr. Hallett helped start the Desert Research Institute and establish DRI as a leader in atmospheric physics research. He also played a central role in the development of the University of Nevada, Reno's atmospheric sciences graduate program, which he directed for over a decade.



Dr. Hallett was the only child of Stanley and Nellie (Veale) Hallett, and was born in Bristol, England, on December 2, 1929. As a child, he survived the Bristol Blitz during World War II, sleeping in his backyard bunker and scavenging for metal after the air raids to help in the war effort. Always an astute student, he dedicated himself to academics and began working as a lab tech at age 14. Inspired by a terrifying ice storm, he chose to study atmospheric physics in college. He earned his bachelor's degree in physics from the University of Bristol, then a Ph.D. in meteorology, at Imperial College, University of London. His research interests included cloud physics, cloud electrification, atmospheric chemistry, climate dynamics and physical meteorology.

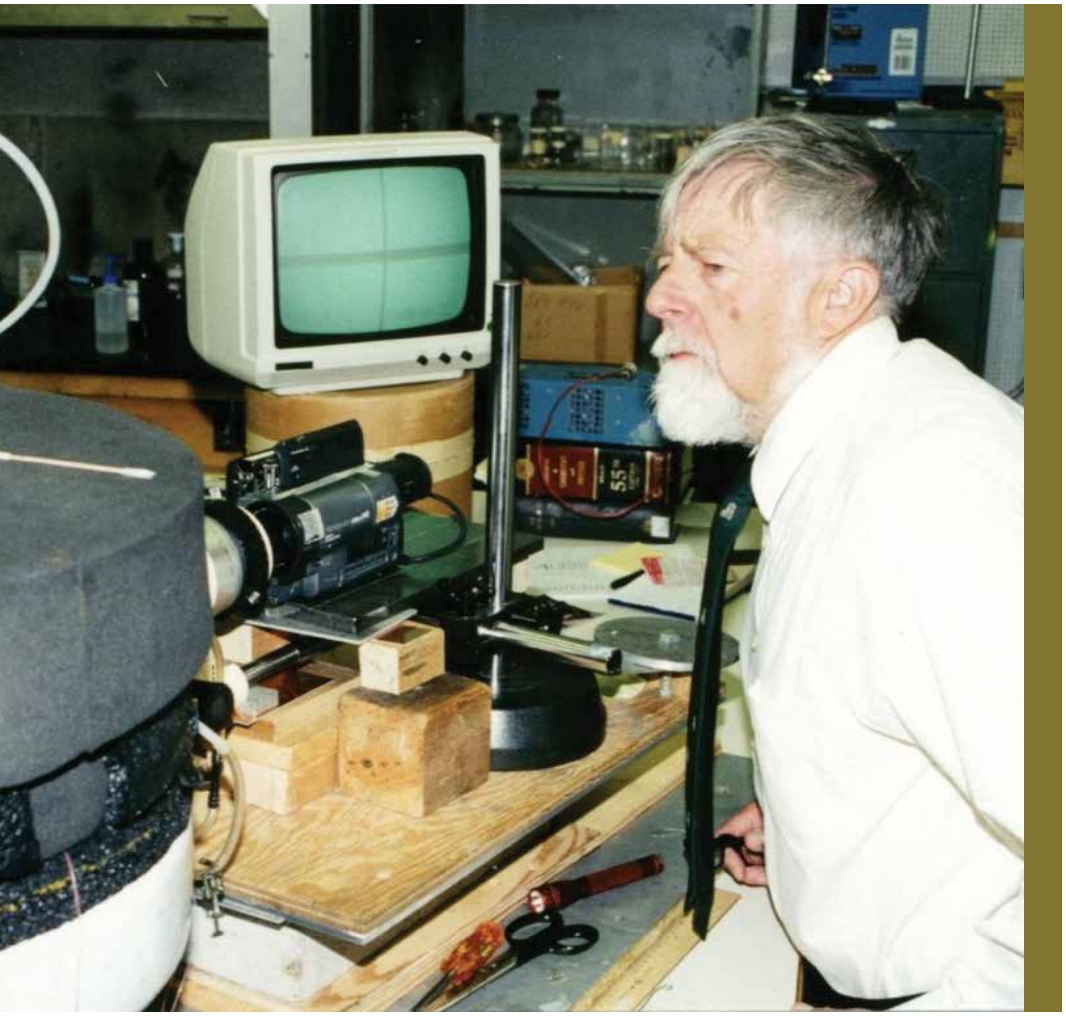
At Imperial College he met and married Dr. Joan Terry (Collar) Hallett and together they pursued a life of science, exploration, and inquiry. Dr. John Hallett collaborated with numerous researchers throughout the United States and internationally. They were first drawn to the U.S. in 1960 when they acquired teaching positions at the University of California, Los Angeles.

In 1966, Dr. Hallett was recruited to help start the Desert Research Institute (DRI), in Reno, Nevada. With their three daughters, the Halletts moved permanently to America where they had a fourth daughter. In addition to being a research scientist at DRI and the Director of the DRI Ice Physics Laboratory, Dr. Hallett also taught physics at the University of Nevada, Reno.

DRI was the perfect environment where Dr. Hallett could do research on how ice forms in clouds and how ice behaves in the atmosphere. He actively worked with NASA, the National Science Foundation, the Department of Defense, and other agencies to help understand the earth's atmosphere. Upon his retirement in 2011, Dr. John Hallett was the longest standing DRI scientist at 45 years.

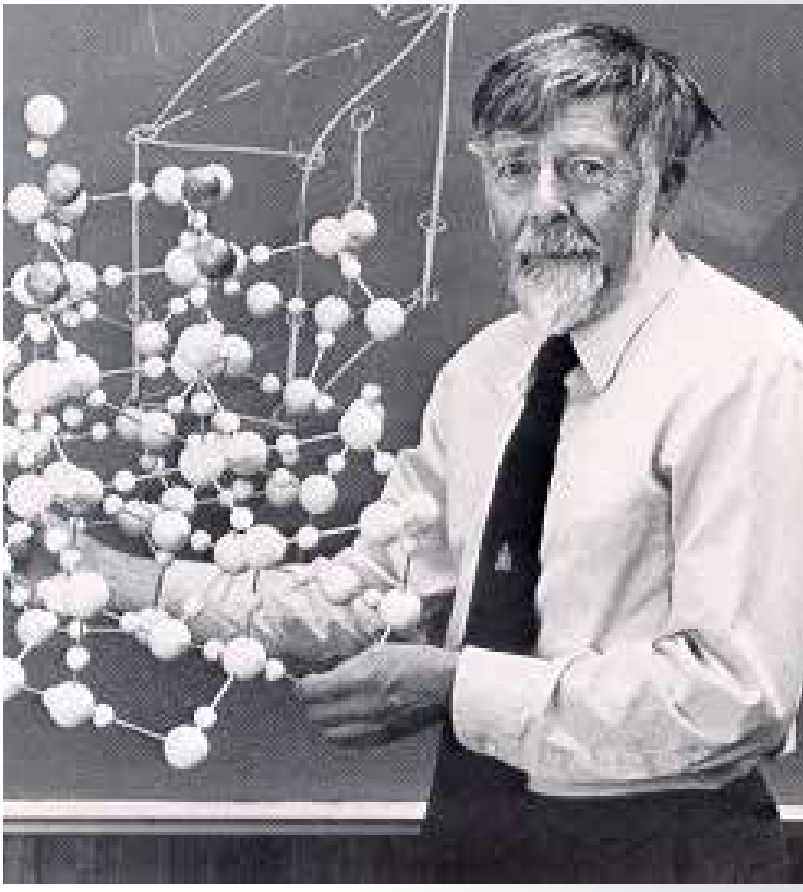
Although he was a brilliant scientist, he may be best remembered for his mentoring of the younger generation of scientists. He challenged his students and peers. During his time at DRI, Dr. Hallett earned the Edgar J. Marston chair of Atmospheric Sciences, authored over 140 scientific articles, and received numerous national and international awards including the DRI Dandini Medal of Science, the Nevada Regents' Researcher of the Year award, and a lifetime achievement award from the American Institute for Aeronautics and Astronautics. He was elected to be a Fellow of the American Meteorological Society for his many years of outstanding contributions to atmospheric sciences.

He was an avid conservationist, outdoorsman, photographer, and critical observer of the natural world, all passions that he passed down to his daughters and grandchildren. Dr. Hallett was preceded in death by his wife, Joan Terry Hallett. He will be thoughtfully remembered by his daughters, Jennifer (Chris), Joyce, Elaine, and Rosemary (Rafi), and grandchildren, Morgan, Gillian, Ceilidh, Colin, Alexander, Miles, Cora, Graham, Alison, and Liam.



"There are lots of things that we don't understand out there. There are still major problems out there to be investigated that have great scientific and practical applications."

–DR. JOHN HALLETT



DRI FOUNDATION

It is an honor to Chair the DRI Research Foundation Board and work with this group of dedicated friends of DRI. We are building on many years of Foundation support to move into FY2020 with exciting plans to secure DRI's future.

DRI's 60th Anniversary year began in March 2019. The Foundation and generous community partners supported kick-off celebrations taking DRI into the community with a special event, The Science Behind Smarter Communities, and bringing the community onto DRI campuses with open house events in Reno and Las Vegas.

I am so proud of the scientific achievements made possible by Foundation fundraising for the Innovation Research Program. An open selection process provided seed grants to eight teams of scientists in the fields described in the preceding pages of this Annual Report. Follow-up events brought the research teams and donors together to learn more about the amazing work of these gifted DRI scientists.

During the remainder of 2019 the Trustees will work closely with the DRI leadership team to launch the 60th Anniversary Fundraising Campaign to scale the Innovation Research Program across DRI. We will seek your support for the work of DRI's environmental scientists to address the responsibilities facing our generation for Planet Earth.

On behalf of the Foundation, thank you for your support to DRI.

TINA QUIGLEY
CHAIR, DESERT RESEARCH INSTITUTE FOUNDATION

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Supporting DRI Advancement

The DRI Foundation is working closely with the DRI Advancement Department to expand the capacities for identifying private foundation grants and assisting faculty in applying for grants.

During FY2019 nearly **$420,000** of new grants are supporting three projects:

- **$100,000** matching grant for the Science Alive K-12 Green Box Program within Nevada school districts
- **$29,739** for hydrological decontamination research in Las Vegas
- **$290,000** for development of the cloud seeding program over the Little Truckee River

The Science Behind Smarter Communities

Held in April 2019, this special event featured a thought-provoking panel discussion about the potential and cautions that surround the integration of autonomous technologies in smart cities and our daily lives. KNPR's Joe Schoenmann moderated a panel discussion with former DRI President Kristen Averyt, Foundation Chair and CEO of the RTC of Southern Nevada Tina Quigley, Nevada Medalist and Director of Duke University's Humans and Autonomy Lab Missy Cummings, and Nevada's Senior United States Senator Catherine Cortez Masto. During the evening, DRI scientists shared exhibits and hands-on opportunities for guests to explore the capabilities new technology brings to environmental science research.

PHOTOS: PAGE 35 TOP LEFT: Tim Minor talks with Senator Cortez Masto about using drones for terrain mapping. **PAGE 35 TOP RIGHT:** Meghan Collins talks with guests about citizen science projects at DRI. **PAGE 35 BOTTOM LEFT:** Guests learn to fly drones on a UAS flight simulator. **PAGE 35 BOTTOM RIGHT:** Senator Cortez Masto, Missy Cummings, Tina Quigley, Kristen Averyt pose after the panel.

FUNDING THE FUTURE

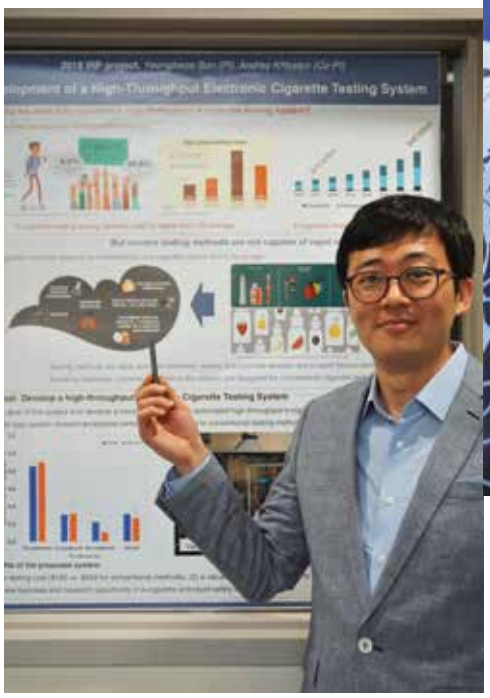
The Foundation Board is finalizing a fundraising initiative to enable a major expansion of the Innovation Research Program in support of embryonic, breakout research in environmental sciences at DRI. The funds will provide grants in an open selection process for new projects and the hiring of new Faculty, Postdoctoral Scholars and Graduate Student Fellows over the next two to three years.

INNOVATION RESEARCH PROGRAM PROJECTS & EVENTS

The DRI Foundation created the Innovation Research Program (IRP) to increase the opportunities for DRI's faculty and technical staff to succeed in their research by financially supporting their very best ideas. This financial support enhances DRI's reputation as a world leader in critical environmental research and attracts talented scientists to the Institute.

In October 2018, the DRI Foundation announced the first round of seed grants awarded by the IRP. Thanks to the support of generous donors, $257,000 was awarded to eight teams of researchers that are exploring innovative ideas related not only to human health and welfare but also to the well-being of the natural systems we depend on. The research teams will complete these projects over the course of one year.

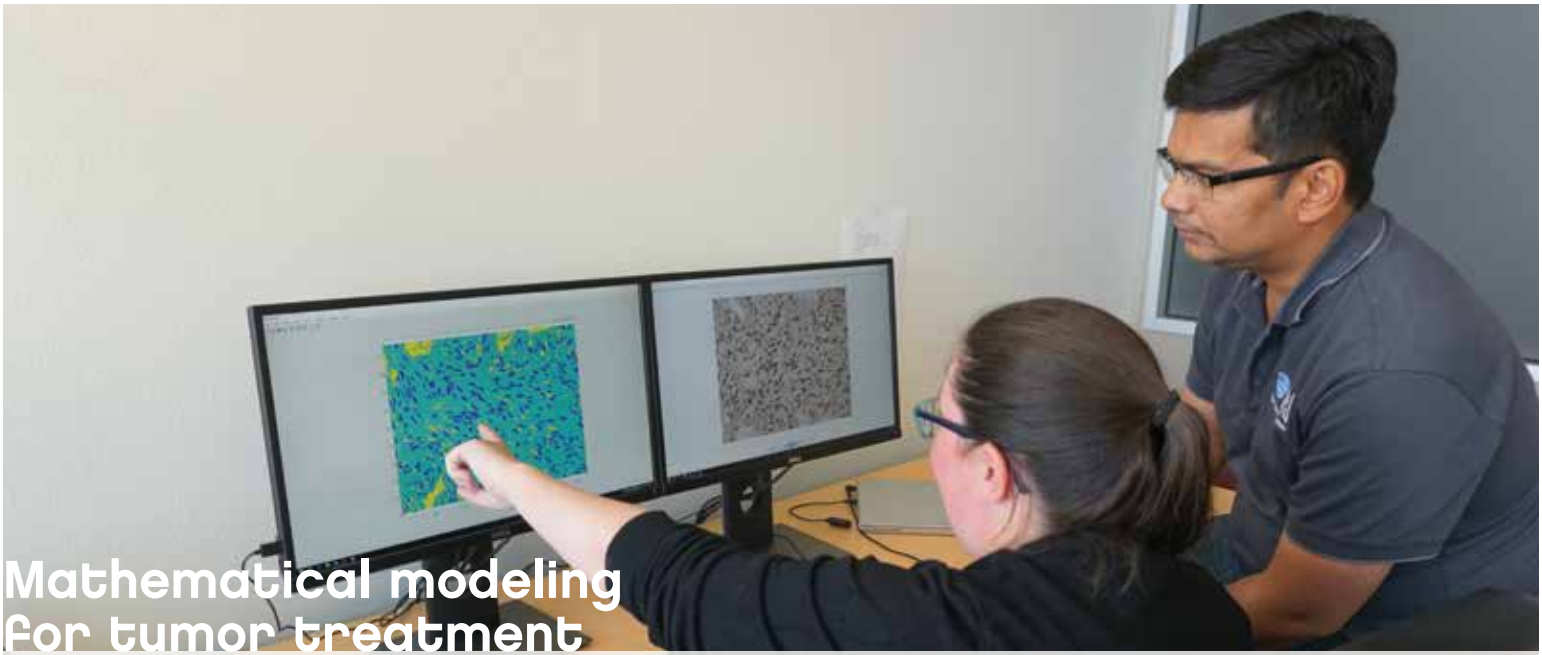
The first group of IRP seed grant recipients presented the progress of their projects to supporters of the IRP initiative at events in Las Vegas and Reno in May and June 2019.



PHOTOS: PAGE 38 LEFT: Yeongkwon Son presents his IRP funded research on e-cigarette use to members of the DRI Foundation in May 2019. **PAGE 38 RIGHT:** Xuelian Bai shows Mary Gallagher microplastics through a microscope at an event for donors in May 2019.

PROJECTS FUNDED IN 2018

1. Dan McEvoy, Ben Hatchett, & Justin Chambers are developing new tools to track snow drought throughout the western United States.
2. Eric Wilcox & Marco Giardano are designing novel sky-imaging tools to forecast fluctuations in solar power production based on cloud cover.
3. Vera Samburova & Andrey Khlystov are creating new ways to analyze human breath in order to learn about exposure to pollutants.
4. Hai Pham & Markus Berli are examining the relationship between wildfire and groundwater resources.
5. Rishi Parashar & Nicole Sund are mapping the distribution of anti-cancer drugs through the bloodstream for the effective treatment of tumors (learn more on the next page).
6. Yeongkwon Son & Andrey Khlystov are crafting tools to measure the harmful emissions of electronic cigarettes.
7. Monica Arienzo, Zoe Harrold, Meghan Collins, & Xuelian Bai are investigating the impact of microplastics on the aquatic ecosystems in Lake Tahoe and the Las Vegas Wash (learn more on the next page).
8. Vic Etyemezian & George Nikolich are building new instruments to simulate erosion of soils by wind.



Mathematical modeling for tumor treatment

To treat a tumor, doctors deliver chemotherapeutic agents and other drugs through the bloodstream so that they may travel to and treat the cancerous cells. The tissue in solid tumors, however, is deformed, with twisted blood vessels and increased cell variability. This means that drugs traveling through the vessels may not be able to reach all the affected cells, making the treatment ineffective.

With IRP funding, Rishi Parashar, Ph.D. (right), and Nicole Sund, Ph.D. (left), are using their expertise in hydrological modeling to better understand the movement of anti-cancer drugs through cancerous tumors. Collaborating with a molecular cancer virologist, Subhash Verma, Ph.D., at University of Nevada, Reno's School of Medicine, Parashar and Sund hope that the mathematical models they create will allow them to determine the effective concentration of drugs for treatment of solid tumors.

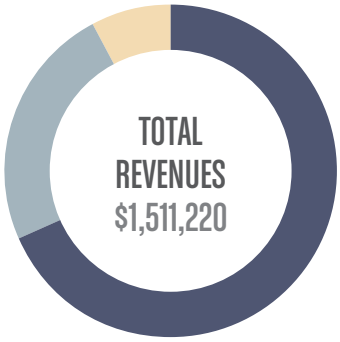
Microplastics in Nevada's waterways

Microplastics, pieces of plastic debris about the size of a pencil's eraser or smaller, come from the breakdown of products like fishing lines, synthetic clothing, and single-use plastic goods. These tiny pollutants are durable, insoluble, and potentially toxic. More and more, though, they're ending up in waterways, which could threaten aquatic environments and the organisms that live there.

With IRP funding, DRI researchers Monica Arienzo, Ph.D. (right), Zoe Harrold, Ph.D. (left), Meghan Collins, M.S., and Xuelian Bai, Ph.D., are investigating the presence of microplastics in Lake Tahoe and the Las Vegas Wash to learn more about how much microplastic exists in these waterways. In subsequent studies, the research team hopes to identify the sources of such pollution, the potential accumulation and negative health effects of microplastics in freshwater organisms, and ways to reduce the amount of microplastic in freshwater ecosystems.

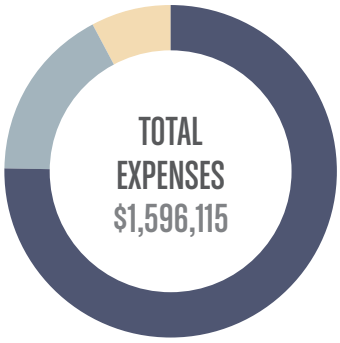
DRI FOUNDATION FINANCIALS

DRI FOUNDATION FY 2018 REVENUES



Gifts & Contributions	$1,036,878
Special Events & Other Revenues	$356,625
Desert Research Institute Support	$117,717

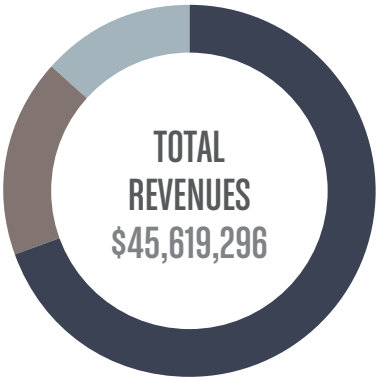
DRI FOUNDATION FY 2018 EXPENSES



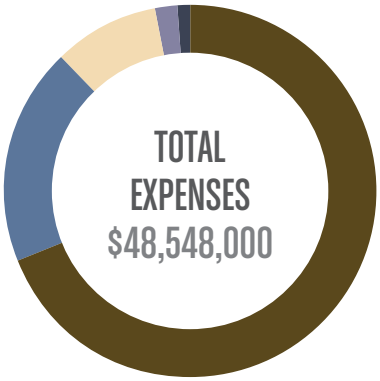
Gifts to DRI	$1,189,656
Supplies & Services	$294,587
Contributed Salaries & Benefits	$111,872

DRI INSTITUTION FINANCIALS

DRI FISCAL YEAR 2018 FINANCIALS (JULY 2018–JUNE 2019)

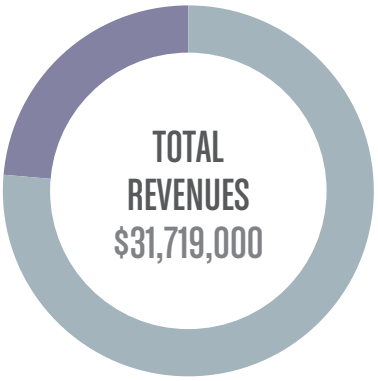


Total Grants & Contracts	$31,719,000
Federal	$24,235,000
Private & Foreign	$4,661,000
State & Local	$2,823,000
Total State Appropriations	$7,817,296
State General Fund	$7,393,000
State Appropriations for Capital	$424,296
Other Revenue	$6,083,000



Employee Compensation & Benefits	$33,577,000
Supplies & Services	$9,103,000
Depreciation	$4,539,000
Utilities	$862,000
Other Non-Operating Expenses	$467,000

DRI FY 2018 GRANT AND CONTRACTS FUNDING SOURCES



FEDERAL	$24,235,000
Dept. of Energy (DOE)	21.0%
Dept. of Defense (DOD)	15.6%
Dept. of Interior (DOI)	9.3%
Environmental Protection Agency (EPA)	8.6%
National Science Foundation (NSF)	6.4%
Dept. of Commerce (DOC)	5.6%
NASA	5.0%
USDA	4.1%
Other	0.8%
Total	**76.4%**

NON-FEDERAL	$7,484,000
Private	14.7%
State Government	7.6%
Local Government	1.3%
Total	**23.6%**

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DRI
Desert Research Institute

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& A SMARTER WORLD.

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