U.S. Department of the Interior

Annual Report on Technology Transfer

FY 2019 Activities

July 2020

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I. Introduction

Technology transfer for the Department of the Interior (Department) includes a range of activities designed to disseminate scientific and technical information and knowledge between the Department, other Federal agencies, and non-Federal entities. It includes, but is not limited to, publishing and exchanging scientific and technical information, protecting and licensing intellectual property rights, and sharing—or otherwise making available—for scientific or technical purposes the expertise and specialized scientific material and resources that the Department manages. The technology transfer activities within the Department are consistent with its mission to protect and manage the Nation's natural resources and cultural heritage, to make available scientific and other information about those resources, to honor trust responsibilities to Tribes, and to supply energy for the future.

This report describes the actions that the Department took in FY 2019 to advance technology transfer. These range from developing new technologies that would help identify various substances in water to improved methods to measure water quality in high biofouling environments. These activities demonstrate the innovation, expertise, and dedication of the Department's employees, including its many scientists and engineers, to help reduce risks to public health, safety, and the environment from natural and man-made hazards. The Data Appendix provides cumulative data tables requested by the Office of Management and Budget and the National Institute of Standards and Technology for the Department for FYs 2012–2019. These tables include updates to previous years' data where appropriate.

This report is the result of a cooperative effort by the Departmental Working Group on Technology Transfer, coordinated by the Department's Office of Policy Analysis.

II. Advancing Technology Transfer in the Department of the Interior

The FY 2019 enacted budget for the Department of the Interior included $942.6 million for research and development (R&D). The majority of the funding was for applied research ($707.8 million), while basic research and basic development received $76.5 million and $158.4 million, respectively.[1] The programs supported through these funds generate new and improved knowledge, information, and technology, which help the Department meet its mission objectives and are transferred to resource managers, stakeholders, and the general public.

The Department's bureaus have varying levels of involvement with scientific and technical research and innovation and technology transfer. In FY 2019, as in previous years, the majority of technology transfer activities reported by the Department under the Federal Technology Transfer Act of 1986 (FTTA) were undertaken by the U.S. Geological Survey (USGS), which is the largest R&D organization in the Department, in terms of both budget and personnel. Typically, USGS accounts for more than 60 percent of the Department's R&D budget.

[1] Estimates furnished by the Office of Budget, Department of the Interior, December 2019.

The Department's scientists, engineers, and other technical personnel advance the state of knowledge related to the resources it manages and ensure that this information is accessible to resource managers, private industry, and the general public. The vast majority of the Department's technology transfer activities use traditional technology transfer mechanisms, such as publications of peer-reviewed papers and reports, webpage postings, fact sheets, and presentations at meetings and conferences. In 2019, DOI personnel authored or co-authored more than 9,800 reports, books, fact sheets, and other publications, including more than 3,200 articles in scientific journals and 4,800 abstracts and data releases.

Bureaus also use other conventional approaches to share scientific and technical resources and expertise, with universities and other entities to address resource management issues. For example, seven DOI bureaus are active participants in the network of 17 Cooperative Ecosystem Studies Units (CESUs), a collaboration among 15 Federal agencies and more than 400 non-Federal partners (including universities, Tribes and Tribal organizations, State agencies, museums, aquariums, arboretums, and conservation organizations). Each CESU is hosted by a university.

In addition, some bureaus and/or offices have offered prizes to help develop new or improve existing technologies. The bulk of the prize competition activities at DOI are undertaken by the Bureau of Reclamation's Water Prize Competition Center (WPCC). From FYs 2017–2018, DOI bureaus completed, had underway, or launched 15 prize competitions, which included 14 from the WPCC and one jointly offered by the National Invasive Species Council, DOI's Office of Hawaiian Affairs, and other DOI bureaus. Reclamation alone plans to launch 17 more competitions over the next few years.[2]

Bureaus that are active in research and development or have research capabilities that complement U.S. commercial interests may also utilize technology transfer agreements authorized by the FTTA to join forces with non-Federal partners. Such agreements allow the Department's bureaus and private-sector industries to pool their expertise and resources to jointly create and advance technologies that could help fulfill agency missions while helping U.S. industries innovate and commercialize technologies, which can strengthen our national economy and create jobs. This report focuses primarily on, but is not limited to, aspects of technology transfer related to the FTTA.

FY 2019 Accomplishments

During FY 2019, the Department's scientific, technical, and engineering personnel continued to engage in a broad range of cooperative activities to develop and disseminate innovative technologies, including—

- Publishing more than 9,800 reports, books, fact sheets, and other publications, including more than 3,200 articles in scientific journals and 4,800 abstracts and data releases.

[2] *U.S. Department of the Interior Report on Prize Competitions FY 2017–18*. Available at https://www.doi.gov/sites/doi.gov/files/uploads/doi-prize-report-fy-2017-2018.pdf.

- Collaborating on 470 Cooperative Research and Development Agreements (CRADAs), of which 352 were initiated in FY 2019. In addition, the Department engaged in at least 269 other collaborative R&D relationships.
- Engaging in 425 nontraditional CRADAs, such as material use and facility use agreements, under the FTTA.
- Disclosing eight (8) new inventions. Three (3) new patent applications were filed. One (1) new patent was awarded.
- Managing eighteen (18) active patent licenses for inventions and other intellectual property, earning about $42,000 collectively.

III. Overview of Technology Transfer Activities

Table 1 shows that the Department's bureaus use or are contemplating using a variety of mechanisms to transfer information, knowledge, and technology within and outside their agencies.

Table 1: Principal Technology Transfer Mechanisms Identified by Each Bureau

	USGS	FWS	OSMRE	NPS	BSEE	BOR	BOEM	BLM
Technical/Scientific Publications	X	X	X	X	X	X	X	X
Workshops/Seminars	X	X	X	X	X	X	X	X
Educational Courses & Other Outreach	X	X	X		X	X	X	X
Cooperative Research and Development Agreements (CRADAs)	X	X		X		X		
Technical Assistance Agreements (TAAs)	X							
Facility Use/Service Agreements (FUSAs)	X					X		
Material Transfer Agreements	X			X		X		
Demonstration/Joint Projects					X	X		X
Patents	X	X		X		X		
Licenses	X	X		X		X		
Other Cooperative Ventures & Agreement Types	X	X	X	X	X	X		
Web and Other Mechanisms	X	X	X	X	X	X	X	X

IV. Technology Transfer Agreements

Table 2 provides a summary of new and active technology transfer agreements undertaken within the Department in FY 2019. There was a total of 470 active CRADAs in FY 2019, of which 352 were newly executed. In FY 2018, there were a total of 740 CRADAS (including 422 new ones).

Table 2: Collaborative Relationships for Research & Development (FY 2019)

	USGS	BOR	BOEM	FWS	NPS	Total
CRADAs						
Active CRADAs[1]	457	9	1	2	2	470[5]
New CRADAs	350	2	0	0	0	352
Active CRADAs with Small Business Involvement					2	2[6]
Number of Small Businesses Involved in Active CRADAs					2	2[6]
Traditional CRADAs[2]						
Active CRADAs	42	0	0	0	1	43[5]
New CRADAs	9	0	0	0	0	9
Nontraditional CRADAs[3]						
Active	415	9	0	0	1	425
New	341	2	0	0	0	343
Other Collaborative R&D Relationships[4]						
(Collaborative Agreements) Total Active in the FY	269	0	0	0	0	269
New in the FY	149	0	0	0	0	149

(1) "Active" = legally in force at any time during the FY. "Total active" is comprehensive of all agreements under CRADA authority (15 U.S.C. § 3710a).
(2) CRADAs involving collaborative research and development by a Federal laboratory and non-Federal partner.
(3) CRADAs used for special purposes, such as material transfer or technical assistance that may result in protected information. For USGS, Technical Assistance Agreements (TAAs) and Facility Use/Service Agreements (FUSAs) fit in this category.
(4) Based on available data. These figures do not account for the majority of collaborative agreements that bureaus engage in under authorities other than the FTTA.
(5) This number is one less than the sum of the preceding columns because one CRADA is counted in both the USGS and BOEM tallies.
(6) Only NPS has collected data on small business participation.

Table 3 summarizes invention and patenting activity within the Department during FY 2019, broken out by bureau. The table indicates that eight new inventions were disclosed, three new patent applications were filed, and two new patents were issued.

Table 3: Invention Disclosure and Patent Activity (FY 2019)

	USGS	BOR	FWS	Total
Invention Disclosures				
New Inventions Disclosed	5	2	1	8
Patents				
New Applications Filed	3	0	0	3
Patents Received	1	0	0	1

Table 4 provides a summary of the number of active licenses managed by the Department's bureaus.

Table 4: License Activity (FY 2019)

	USGS	BOR	Total
Licenses, Total Active	14	4	18
New Licenses	2	0	2
Invention Licenses, Total Active	14	2	16
New Invention Licenses	2	0	2
Income-Bearing Licenses, Total Active	14	2	16
Income-Bearing Exclusive Licenses	7	0	7

Total income in FY 2019 from all licenses amounted to about $42,000 (from 16 income-bearing licenses), compared with $50,000 (from 13 income-bearing licenses) in the previous fiscal year.

Table 5 provides a summary of the scope and nature of technology transfer activities and mechanisms that the various bureaus implement currently or might implement in the future.

Table 5: Scope of Activities and Plans Related to the FTTA, by Bureau

Mission	Technology Transfer
U.S. Geological Survey (USGS). The mission of USGS is to serve the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.	USGS serves the Nation as an independent fact-finding agency that collects, monitors, and analyzes scientific and technical information to provide scientific understanding about natural resource conditions, issues, and problems. USGS makes this information and knowledge readily available to decision makers and the public. Thus, one of USGS's main thrusts is broad and open dissemination of its knowledge and information. USGS also pursues technology transfer opportunities under the FTTA and the Stevenson-Wydler Act in a variety of ways.
U.S. Fish & Wildlife Service (FWS). The mission of FWS is working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.	FWS's Research and Development (R&D) is primarily focused on providing the basis for effective conservation to meet its mission. For example, the FWS Fish Technology Centers were established in 1965 to develop and improve fish culture technology and to provide assistance to Federal and State agencies, Tribes, and other nations interested in aquaculture research and solutions. They have worked with industry and government to improve aquaculture opportunities.
Office of Surface Mining Reclamation and Enforcement (OSMRE). OSMRE is responsible for ensuring, through a nationwide regulatory program, that coal mining is conducted in a manner that protects communities and the environment, restores the land to beneficial use following mining, and mitigates the effects of past mining by aggressively pursuing reclamation of abandoned mine lands.	OSMRE advances its mission by providing technical assistance, based on sound science and training, to its State and Tribal partners to enhance their ability to maintain effective programs. Although OSMRE has no formal research and development activities, its Technology Development and Transfer program promotes and disseminates information on technological innovations to better protect the environment during mining and in reclaiming and restoring active and abandoned mines. The program also provides training to ensure that States, Tribes, and OSMRE's other partners continue to administer their surface mining programs efficiently and effectively.
National Park Service (NPS). The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of current and future generations. NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.	Technology transfer and employee inventions are addressed under the NPS benefits-sharing policy and procedural guidance (available at http://www.nps.gov/applications/npspolicy/DOrders.cfm). Benefits sharing occurs when NPS receives monetary or nonmonetary benefits from the commercial use of a discovery or invention resulting from research originating under an NPS Scientific Research and Collecting Permit or other NPS permit or authorization. Authorities under the FTTA are essential to the NPS benefits-sharing program.
Bureau of Safety and Environmental Enforcement (BSEE). BSEE works to promote safety, protect the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement.	The BSEE R&D program operates through the Emerging Technologies Branch (ETB) and the Oil Spill Response Research program (OSRR) in the Response Research Branch. BSEE research is associated with operational safety, pollution prevention, and oil spill cleanup techniques and technologies. BSEE research results are used to inform

Table 5: Scope of Activities and Plans Related to the FTTA, by Bureau

Mission	Technology Transfer
	regulatory decision making and to promote the use of Best Available and Safest Technology on the U.S. Outer Continental Shelf.
Bureau of Reclamation (Reclamation). The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.	Reclamation has the lead Federal responsibility for water management and hydropower in the 17 Western States. Its research program is applied toward the development of solutions that increase efficiency, reduce maintenance costs, improve work safety, enhance infrastructure reliability, and increase the effectiveness of using desalination and other water treatment technologies to expand water supplies. The research programs use technology transfer fundamentals to help speed field deployment of new innovations.
Bureau of Ocean Energy Management (BOEM). BOEM manages the exploration and development of the Nation's offshore energy and mineral resources in an environmentally and economically responsible way. It seeks to appropriately balance economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development, and environmental reviews and studies.	BOEM's Environmental Studies Program (ESP) develops, conducts, and oversees scientific research specifically to inform policy decisions regarding development of Outer Continental Shelf (OCS) energy and mineral resources. The research covers physical oceanography, atmospheric sciences, biology, protected species, social sciences, economics, submerged cultural resources, and environmental fates and effects. BOEM also funds research into offshore renewable energy technology.
Bureau of Land Management (BLM). The BLM mission is to sustain the health, diversity, and productivity of America's public lands for the use and enjoyment of present and future generations. The Federal Land Policy and Management Act of 1976 (FLPMA) mandates that BLM manages public land resources for a combination of balanced and diverse resource uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources, including, but not limited to, recreation, range, timber, minerals, watershed, wildlife and fish, and natural scenic, scientific, and historical values.	BLM's scientific and technical focus has been on place-based applications to improve the management of public lands, in accordance with FLPMA's multiple-use mandate. Accordingly, it focuses on traditional technological transfer activities to help advance its multiple-use mandate.

Subsequent sections briefly describe each bureau's technology transfer program and provide a sample of their activities in FY 2019. The tabular data requested by OMB Circular A-11 are reported in the Data Appendix, to the extent data are available.

V. U.S. Geological Survey

The United States Geological Survey (USGS) is a science bureau within the Department of the Interior whose mission is to serve the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life. USGS focuses on the following interdisciplinary mission areas: Ecosystems; Land Resources; Energy and Minerals; Environmental Health; Natural Hazards; Water Resources; and Core Science Systems. The combined expertise from several Earth Science disciplines (e.g., hydrology, geology, biology) addresses relevant issues of concern to people and other living things on the planet. Organization around these mission areas allows USGS to better address the needs of the Nation, customers, and partners.

Delivery of science information is a primary purpose of the bureau. Technology transfer activities with the public and private sectors, including academia and nonprofits, are integral to fulfilling this purpose. They typically support knowledge dissemination, including the collection and transfer of scientific data. In FY 2019, for example, USGS personnel authored or coauthored 9,314 reports, books, fact sheets, and other publications and information products, including more than 2,409 scientific journal articles, 766 USGS Series scientific publications, 622 data releases, and 4,134 abstracts. USGS also cooperates with its public and private collaborators to help them maintain essential and necessary services, better understand the environmental consequences of their commercial and noncommercial activities, and develop new products and services. USGS has 361 major laboratories and several hundred field offices around the country.

Within USGS, technology transfer that extends beyond traditional publications, meetings, and conferences and is related to the Stevenson-Wydler Innovation Act and the FTTA is managed through the USGS Office of Policy and Analysis (OPA). OPA staff service USGS Science Centers and offices throughout the country.

OPA, on behalf of USGS, negotiates and drafts Cooperative Research and Development Agreements (CRADAs) (including Technical Assistance Agreements, Facility Use Service Agreements, Material Transfer Agreements, and Data Use Licenses) and Patent Licenses. OPA also manages the USGS intellectual property and inventions program; markets USGS technology opportunities; and facilitates partnerships with industry, nonprofits, academic institutions, Tribal nations, and State agencies. OPA also provides training to USGS personnel on technology transfer and intellectual property matters.

In 2019, USGS had 872 active traditional and nontraditional CRADAs, the majority of which (415) were technical assistance and facility use agreements. By contrast, in FY 2018, it had 1,403 active CRADAs, including 677 nontraditional CRADAs. In addition, in FY 2019, USGS executed 269 other collaborative agreements and managed a total of fourteen (14) active licenses. USGS also filed three (3) new patent applications and received one (1) patent.

USGS science and research contributes to a broad range of collaborative projects in the private and academic sector. USGS provides unique analytical laboratory services to domestic, foreign, and academic partners through the USGS Facility Use program. Examples include—

Sea Lamprey Control Program. Sea lamprey, a parasitic fish species that is nonnative to the Great Lakes, preys on a wide variety of large Great Lakes fish, such as lake trout, brown trout, lake sturgeon, lake whitefish, Chinook and coho salmon, and steelhead (rainbow) trout. The USGS Upper Midwest Environmental Sciences Center (UMESC) in La Crosse, Wisconsin, established a CRADA with the Coating Place, Inc. (CPI) in Verona, Wisconsin, and the Great Lakes Fisheries Commission (GLFC). UMESC has a long-standing established program to provide technical assistance, lampricide formulation development, and regulatory support to the GLFC Sea Lamprey Control Program. The GLFC provides financial and directional support for the UMESC program as part of its responsibility to administer the binational Sea Lamprey Control Program. CPI is an established producer of multiple lampricide formulation used in the Sea Lamprey Control Program and has expertise in formulation and coating development.

Under the CRADA, UMESC staff are working with CPI to develop a water-based formulation of liquid Bayluscide as a replacement to the current Bayluscide 20% Emulsifiable Concentrate lampricide (Figure 1). Numerous issues have been noted by the control agents when applying the current formulation, including clogging of spreader tubing, erosion of pump seals, and problematic cleaning of application equipment. These problems prompted research for a replacement formulation. Preliminary analysis of the water-based formulation of Bayluscide (Bayluscide LF), developed by CPI, showed promise in eliminating application and cleanup issues. UMESC worked with the U.S. Environmental Protection Agency and Michigan's Department of Environment, Great Lakes, and Energy to obtain an Experimental Use Permit (EUP) waiver for an experimental field application. An experimental field application of the water-based formulation was conducted on the Indian River on September 24, 2019. Approximately 55 L of the experimental Bayluscide formulation was successfully applied; however, settling of the Bayluscide formulation in the containers was observed. UMESC met with CPI to discuss formulation modifications that could resolve product settling issues, and a path forward for the formulation is expected in early 2020.

In a similar effort, UMESC staff are working with CPI to develop an improved surfactant-based trifluoromethyl nitrophenol (TFM) lampricide bar formulation as a replacement to the current bar formulation to treat small feeder streams (Figure 2). Lampricide bars are placed in feeder streams to prevent sea lamprey from seeking refuge in untreated waters as the main treatment block passes. The current bar formulation dissolves too quickly and can require reapplication to prevent sea lamprey larvae escape. UMESC prepared and provided TFM Crystalized Extract for CPI to use in experimental bar formulations, and during FY 2019, UMESC conducted 27 dissolution trials with nine (9) experimental TFM bar prototypes. Experimental TFM bar formulations show promise for improved performance characteristics. Additional formulation development work scheduled for 2020 will include evaluating increased active ingredient concentrations and carrier surfactant modifications and/or substitutions.

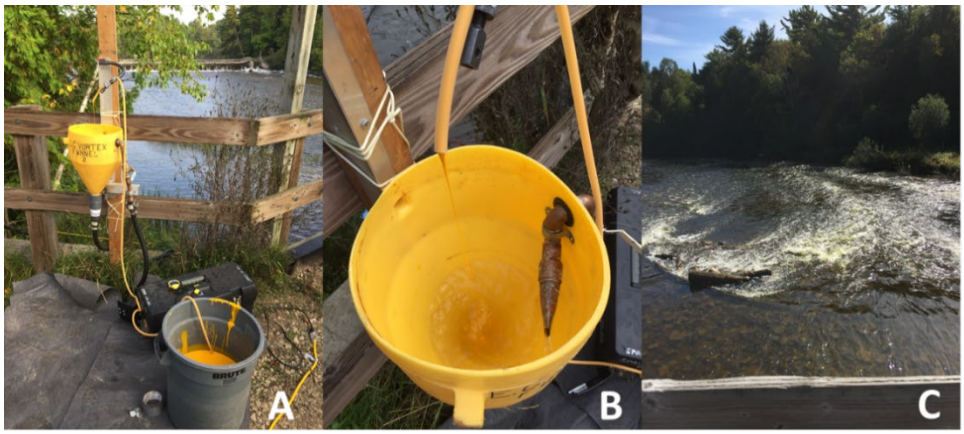


Figure 1. Experimental Bayluscide liquid flowable lampricide application (A, B) in the Indian River, Manistique, MI (C) in September 2019. USGS photos.

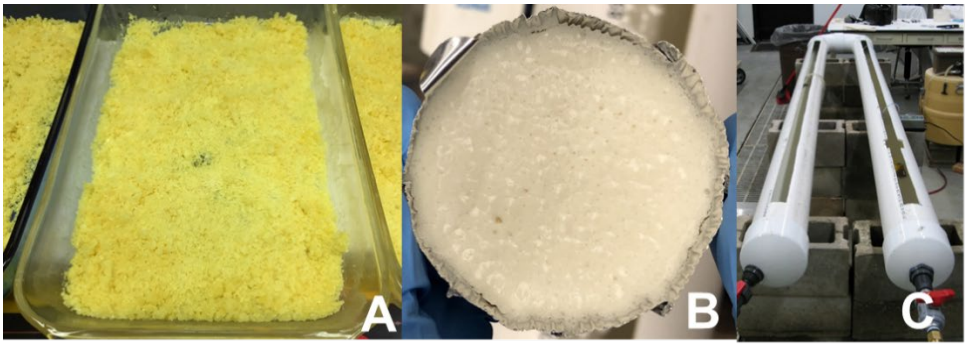
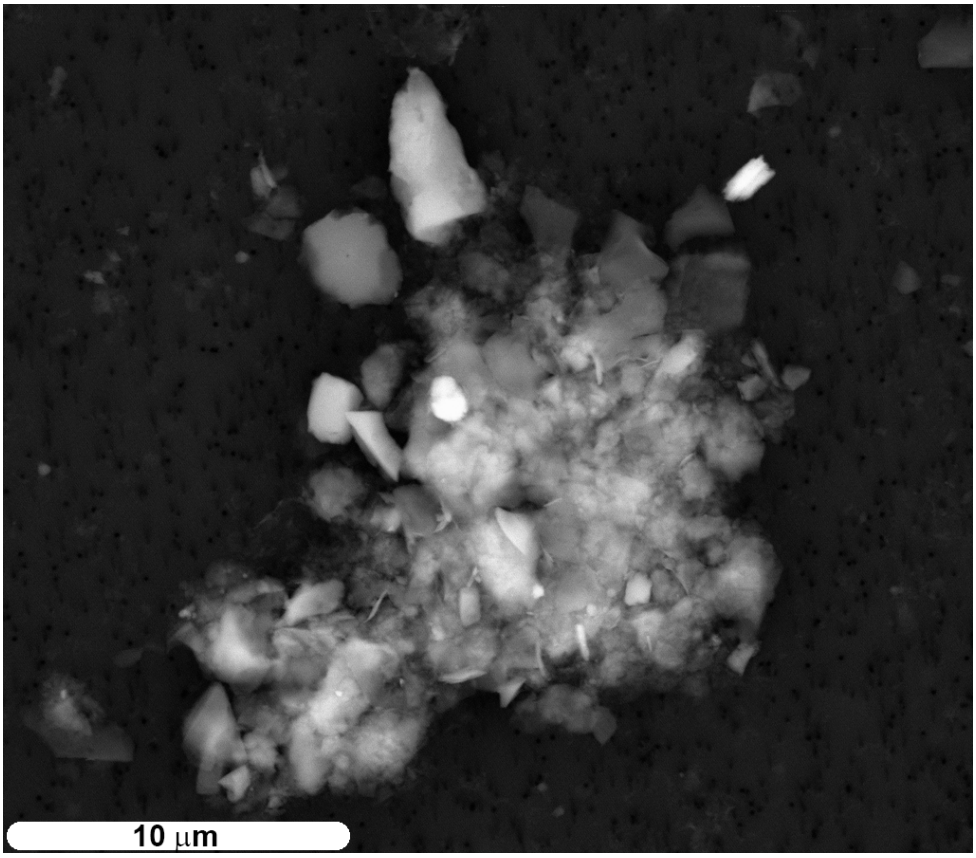


Figure 2. Crystalline TFM extract (A), experimental TFM lampricide bar formulation (B), and experimental apparatus used to evaluate the dissolution of experimental TFM lampricide bar formulations (C). USGS photos.

Characteristics of Dust and Risk Factors Associated with the Development of Rapidly Progressive Pneumoconiosis and Progressive Massive Fibrosis. Since the mid-1990s, research studies and surveillance reports have documented a significant increase in coal workers' pneumoconiosis (CWP)—including the most severe forms of progressive massive fibrosis (PMF) and rapidly progressive pneumoconiosis (RPP)—in U.S. coal miners, with many cases occurring in younger miners. The Appalachian coalfields appear to be particularly affected. There are several possible explanations for these observations, including excessive exposure to respirable dust and increased exposure to particulate dust constituents (e.g., freshly fractured silica and silicates or smaller particles) that may be the result of changing mining practices. To date, however, the causal links between specific exposure characteristics and the increase in cases of RPP and PMF have not been elucidated; therefore, current protections for active mine workers may not be adequate. As part of its mission, USGS studies how geologic materials influence human health. Under this CRADA, USGS will collaborate with the University of Illinois at Chicago (UIC) to explore the link between the inhalation of respirable airborne geologic particulate matter released during coal mining processes and the documented significant increase in coal workers' pneumoconiosis (CWP) and progressive massive fibrosis (PMF). The UIC seeks USGS expertise in providing field emission scanning electron microscopy analyses of

particulate matter in situ of lung tissue samples and from bleach-digested lung tissue. It also requires USGS knowledge and expertise to develop a method for bulk chemical analysis of the bleach digestion solution to determine possible bleach-soluble phases within the lung tissue.



Backscattered electron image of filtered particulate matter (PM) from a case of rapidly progressive pneumoconiosis. PM includes silica, silicates, and carbonaceous particles. USGS photo.

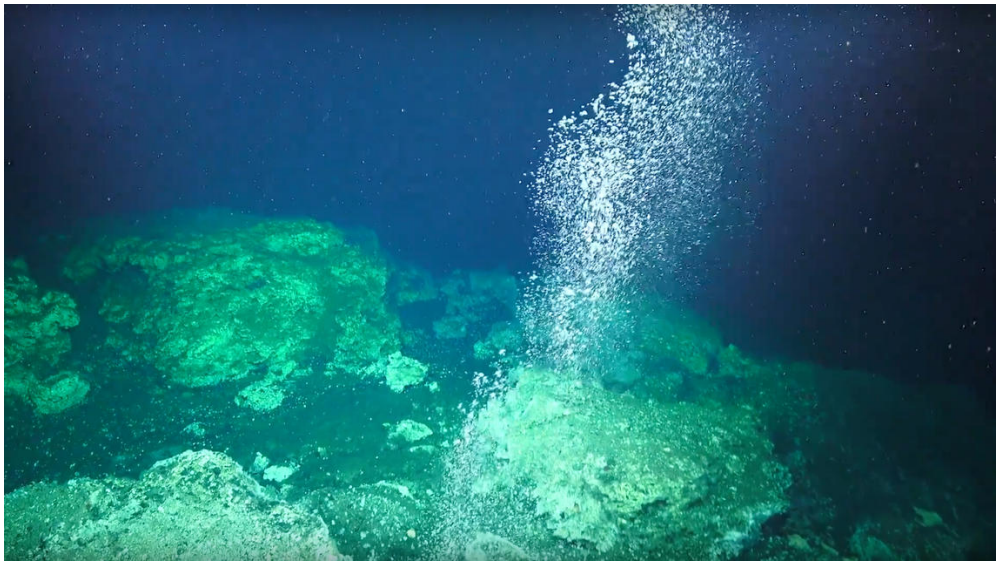
This CRADA benefits both USGS and collaborators by providing funding that will support the USGS scientists for scientifically and societally important research, enhance transdisciplinary research collaborations with the public health community, and lead to the development of new methods for the study of mineral matter in tissue that can then, in turn, be applied to future projects.

In addition, the anticipated outcomes of the collaboration could benefit the American people by providing guidance to mitigate risk factors to coal miners exposed to particulate matter.

To date, USGS has digested and acquired automated particle size and classification analysis from 30 samples. Data are currently being reviewed for consistency and accuracy. The work conducted by USGS and collaborators was summarized and presented at the American Thoracic Society Meetings.

Methane Seeps. USGS collaborated with Schmidt Ocean Institute to discover and study methane bubbles, specifically, gas hydrates—frozen crystals of ice and methane—that have

been well-documented off the Oregon coast.[3] This effort provided a snapshot of Cascadia margin seep dynamics and processes at different locations and on several timescales. The project included physical measurements of methane bubble emission rates and sizes; chemical measurements of dissolved gas concentrations in the water column, water column pH, sediment pore water compositions, and various isotopes; and biological measurements to constrain the rate of methane oxidation at the seafloor in seep settings. The project also included seabed and seabed feature mapping, quantitative surveying, and sampling of seafloor benthic communities, associated fauna inhabiting the sediment, and motile organisms near seeps; characterization of the physics and chemistry of sediments at seep locations and in the far field; and geochronologic studies of authigenic carbonates to constrain the timing of methane seepage events.



Methane bubbles up from a seep on the seafloor off the coast of Oregon. Photo: Schmidt Ocean Institute, used with permission.

This collaboration included a 21-day scientific expedition onboard the Schmidt Ocean Institute Research Vessel (R/V) *Falkor* into the Pacific off the coast of Oregon. Additional details are available in a USGS news release: https://www.usgs.gov/news/seeking-seeps. The Schmidt Ocean Institute also released the highlights reel for week 1 of the R/V *Falkor* cruise involving USGS personnel across several mission areas: https://www.youtube.com/watch?v=8mAJoxXaKFo

[3] Riedel, M., P.E. Long, and T.S. Collett, "Estimates of in situ gas hydrate concentration from resistivity monitoring of gas hydrate bearing sediments during temperature equilibration," *Marine Geology* 227, Nos. 3–4 pp. 215–225 (March 30, 2006).

Patents

In FY 2019, USGS was awarded one patent, U.S. Patent No.10,180,360, for a temperature sensor probe that enables a person to take continuous temperature measurements in soils and riverbed sediments at multiple depths. The probe contained multiple sensors placed at various locations, independently powered throughout the probe for prolonged usage and continuous monitoring that allows for the study of groundwater movement near streams.

VI. U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) is dedicated to the conservation, protection, and enhancement of fish, wildlife, and plants and their habitats. FWS is the only agency in the Federal Government whose primary responsibility is managing fish and wildlife resources for the American public. It manages more than 855 million acres of lands and waters in the National Wildlife Refuge System, including seven national monuments, 568 National Wildlife Refuges, and 211 Waterfowl Production Areas. FWS also operates National Fish Hatcheries, which, in conjunction with its Fish Health Centers and Fish Technology Centers (including the Conservation Genetics Lab in Alaska), restore native aquatic populations, mitigate for fish lost as a result of Federal water projects, and support recreational fisheries throughout the United States.

Research and Development (R&D) within FWS is primarily focused on applying the latest scientific and technical information to fulfill its mission of working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. Transferring FWS's technology and knowledge to the public and collaborators accelerates the adoption and use of agency research while improving the economic and societal benefit from its R&D investments to help solve natural resource problems.

The technology transfer function of FWS is shared among several programs, including Science Applications; Fish and Aquatic Conservation (FAC); and Policy, Economics, Risk Assessment, and Analytics. The majority of FWS's technology transfer is done via dissemination to the public and scientific community through traditional avenues such as peer-reviewed papers, reports, and fact sheets.

FWS employees are actively involved in the larger scientific community and participate in scientific societies, meetings, and conferences and publish scientific research. Sharing scientific and technical information via public outreach and partnerships is a high priority for FWS. For example, FWS is a partner to all units within the 17 Cooperative Ecosystem Studies Units (CESU) Network, allowing FWS to be involved in interdisciplinary and multiagency research projects with the host university and other non-Federal partners. Each year, FWS pursues dozens of projects through the CESU network, including surveying and monitoring efforts, climate change vulnerability assessments, streamflow projections, and many others.

Scientists within the agency published 400 scholarly articles, papers, or book chapters in publications focused on diverse topics such as ecology, biodiversity conservation, fisheries, zoology, ornithology, environmental sciences, and evolutionary biology. FWS also manages two

online peer-reviewed publications focused on the practical application and integration of applied science to wildlife conservation and management—the *Journal of Fish and Wildlife Management* and the *North American Fauna Monograph Series*. These electronic journals are in the public domain. FWS also uses its research to help inform a wide range of wildlife management decisions in the interest of the general public. For example, the National Wildlife Refuge Inventory and Monitoring Program systematically obtains a range of biological data about the status, trends, and management responses of species and habitats within the Refuge System. Those data inform and improve the conservation of fish, wildlife, and plant natural resources. In 2019, the two scientific journals were queried more than 238,924 times in scholarly searches.

Patents. FWS received a disclosure in FY 2019 from an employee for a fipronil-treated pellet to control fleas on prairie dogs, which would indirectly benefit black-footed ferrets (*Mustela nigripe*s) The black-footed ferret, once believed to be extinct but now rediscovered, is one of the most endangered mammals in the United States. After researching prior art and marketability, FWS determined that pursuing a patent on this invention would not be in the best interest of FWS or the Department.

CRADAs. In FY 2019, FWS maintained two CRADAs it has in place through the Aquatic Animal Drug Approval Program (AADAP) within FAC. FWS also maintains a joint CRADA involving USGS and BOEM (on behalf of DOI) and Bird Studies Canada, which was signed in FY 2017.[4]

Following is a brief description of FWS programs and entities engaged in technology development and transfer activities.

National Conservation Training Center. The FWS Conservation Library at the National Conservation Training Center (NCTC) in Shepherdstown, West Virginia, provides a searchable collection of selected documents, images, historical artifacts, audio clips, publications, and videos, most of which are in the public domain. FWS also makes internal publications, reports, and other information available to the public through the FWS website. Collections of current and legacy publications (including biological and technical publications) are available online from the NCTC library catalog and websites. NCTC also maintains links to biological and technical publications, as well as additional publications regarding birds, wetlands, fish hatcheries, and National Wildlife Refuges.

NCTC also hosts publicly accessible webinars dealing with a variety of scientific and technical issues that affect the nation's fish and wildlife resources. During FY 2019, NCTC hosted 85 online science, technology, and educational webinars; 13 e-courses; and 4 podcasts related to managing the Nation's fish, wildlife, and plant resources. These are an important component of FWS's traditional technology transfer activities.

Fish and Aquatic Conservation Program. FWS's primary research nexus with the private sector centers on programs and facilities within the Fish and Aquatic Conservation (FAC) Program. The program includes a network of Fish Hatcheries, Fish and Wildlife Conservation

[4] Because the FWS/USGS/BOEM/Bird Studies CRADA is already accounted for in the USGS tally of CRADAs, it is not included in the tallies for the other bureaus in Section IV and the data tables in the Appendix.

Offices, Fish Health Centers, Fish Technology Centers, the Conservation Genetics Laboratory in Anchorage, Alaska, and the Aquatic Animal Drug Approval Partnership (AADAP). These centers and programs provide assistance and support to conservation partners of FWS—including Federal, State, Tribal, and nongovernmental organizations (NGOs)—that cover a broad range of disciplines, including biostatistics, population ecology, genetics, nutrition, and fish health and pathology. FWS's Fish Health Centers, Fish Technology Centers, and AADAP play an integral role in applied science and technology transfer.

FWS Aquatic Animal Drug Approval Partnership. AADAP is the only program in the United States singularly dedicated to obtaining U.S. Food and Drug Administration (FDA) approval of new medications needed for use in fish culture and fisheries management. Since the late 1990s, AADAP has contributed to virtually every new fish medication approved by the FDA. Ultimately, the AADAP program allows fisheries professionals to more effectively and efficiently rear and manage a variety of fish species to meet production goals, stock healthy fish, and maintain a healthy environment.

Fish Technology Centers. Most of the Fish Technology Centers (FTCs) were established in 1965 to develop and improve fish culture technology and provide assistance and advice on fish culture to National Fish Hatcheries, other Federal and State agencies, Tribes, other Nations, and the aquaculture industry. The FTCs provide applied science products and transfer technology related to fish and fisheries for the Nation. The FTCs have developed culture techniques and fish diets now used around the world, including dehydrated long-lasting feeds that revolutionized the fish-culture industry. Results of studies conducted by FWS scientists are published in peer-reviewed journals, and management recommendations are communicated within the Service and to our partners through conservation science partnerships.

- **Nutrition and Diet Development Laboratories.** These facilities allow for the manufacture of experimental larval, fingerling, and broodstock fish feeds and the testing of many different kinds of ingredients to improve fish nutrition, performance, and quality. This program also develops specialized diets for use in captive rearing of endangered fish species.

- **Physiology Laboratories.** These laboratories support conservation- and management-related needs of FWS and its partners, including, but not limited to, understanding the physiological needs of fish to support conservation and/or commercial opportunities.

- **Conservation Genetics Laboratories.** These laboratories support conservation- and management-related needs of FWS and its partners, including, but not limited to (a) using genetic DNA methods to meet real-time fishery needs to conserve and manage species; (b) assisting with Endangered Species Act status reviews and recovery planning via baseline data on genetic population structures and genetic monitoring and evaluation of listed populations and species; (c) establishing and maintaining genetic tissue/DNA repositories for imperiled species; and (d) characterizing diversity within and among wild populations.

- **Ecology Laboratories.** These laboratories focus on understanding the physiological requirements and tolerances of threatened and endangered species. Less invasive or noninvasive tools, such as measurement of plasma sex steroids and ultrasound, are used

to determine gender, stage of sexual maturity, and spawn readiness of individual fish in wild and captive populations of threatened and endangered species. These laboratories also provide contract services to Federal and State agencies, universities, and NGOs for a variety of analyses employing these less invasive tools, as well as blood chemistry analysis, histology, proximate analysis, and radio-immunoassays.

- **Fish Health Centers.** FWS's Fish Health Centers play an integral role in applied science and technology transfer. Their scientists are leaders both nationally and internationally in the diagnosis of wildlife diseases and in the science of aquatic animal health, developing and validating tests that benefit—and are adopted by—the aquaculture industry. Fish Health Centers work closely with Federal, State, Tribal, academic, and NGO partners to promote the scientific management of fisheries and aquaculture by reducing the effects of wildlife pathogens.

Aquatic Invasive Species. The FWS Aquatic Invasive Species program works to prevent the transfer and introduction of exotic, introduced, nonnative, and other potentially harmful species and to develop early detection and rapid response capabilities. For example, the program worked with numerous partners to develop methods for detecting minuscule amounts of free-floating DNA (environmental DNA or eDNA) in water samples to confirm the presence (or absence) of species at levels undetectable by traditional sampling methods. This innovative technology is now being applied widely in monitoring programs and, as it continues to be further developed and refined, will significantly benefit both FWS programs and partners by allowing earlier detections of invasive species.

The FAC program is also applying rapid screening tools it has developed to help determine a species' risk for invasion. Knowledge of both low- and high-risk species will help industry, States, and consumers make more responsible choices about which species to acquire and use. Also, these tools will help State agencies make decisions on potentially invasive species and work with industry to manage risky species in their jurisdictions. For example, Michigan's Public Act 537 established new protections to minimize the risk of invasive species that require, among other things, the use of FWS's risk assessment protocol.

VII. Office of Surface Mining Reclamation and Enforcement

The Office of Surface Mining Reclamation and Enforcement (OSMRE), established by the Surface Mining Control and Reclamation Act of 1977 (SMCRA), is responsible for ensuring that coal mining is conducted in a manner that protects communities and the environment, restores the land to beneficial use following mining, and mitigates the effects of past mining by aggressively pursuing reclamation of abandoned mine lands. OSMRE achieves this in part by providing technical assistance based on sound science and by providing training to its State and Tribal partners to enhance their ability to maintain effective programs.

The goals that underlie OSMRE's Technology Development and Transfer program include (a) increasing the technical knowledge of the reclamation of active and abandoned coal mines; (b) developing and enhancing working relationships among the bureau's partners in Federal, State,

and Tribal governments and in industry and academia; and (c) leveraging its resources through partnerships. OSMRE accomplishes these goals via the Technical Innovation and Professional Services (TIPS) program, the National Technical Training Program (NTTP), and the National Technology Transfer Team (NTTT).

Technical Innovation and Professional Services (TIPS). TIPS is a national program that continues to research and apply emerging technologies to SMCRA workflows. Currently, TIPS assistance includes providing commercial software applications and hardware to State, Tribal, and OSMRE offices at considerable cost savings by sharing the commercial licenses for 28 commercially available software applications via the Internet and OSMRE wide area network. These software applications cover a wide range of regulatory and abandoned mine lands subjects. The customer base covers more than 90 State, Tribal, and OSMRE office locations throughout the country—about 2,000 users.

One goal of TIPS is to provide State, Tribal, and OSMRE personnel with a comprehensive set of analytical tools to aid in technical decision making related to regulatory and reclamation processes. The services provided are centered on off-the-shelf scientific and engineering computer software and technical hardware supported by OSMRE in partnership with the States and Tribes. TIPS hardware is available to States and Tribes that regulate coal mining to advance reclamation projects nationwide.

The TIPS suite of scientific, hydrologic, and mapping core software aids the technical decision making associated with a wide variety of tasks that surface mining agencies have to perform regularly: (1) conducting reviews of permits, (2) performing cumulative hydrologic impact assessments, (3) quantifying potential effects of coal mining, (4) preventing acid mine drainage, (5) quantifying subsidence impacts, (6) measuring revegetation success, (7) assisting in the design of abandoned mine lands projects, and (8) providing the scientific basis for environmental assessments and environmental impact statements.

Demand for TIPS tools and support continues to increase, especially in geospatial data and mobile computing tools for field use. TIPS is offering more onsite training to accommodate the use of mobile computing devices by inspectors. Mobile computing increases efficiency in resolving issues with primacy State staff and industry.

The TIPS program continues to develop and enhance the GeoMine Web Application, an interactive web-based mapping application of coal mining and reclamation activities within the United States. The TIPS program also trains State, Tribal, and Federal personnel to ensure that all agencies with SMCRA responsibilities are using the same advanced software and hardware tools to conduct the business required by the Act. These activities include—

- GeoMine Web Application: It is designed to provide the best available data for surface coal mining operations across the country, merging data from numerous sources to create standardized, seamless layers that cross State boundaries. OSMRE updated the GeoMine Web Application in 2019 to improve functionality and make the data more accessible on mobile devices. In addition, satellite imagery is included with a live data feed to provide the most current imagery available. The data, which are updated as they are made available to OSMRE, are also linked to the national Geoplatform, making data easily

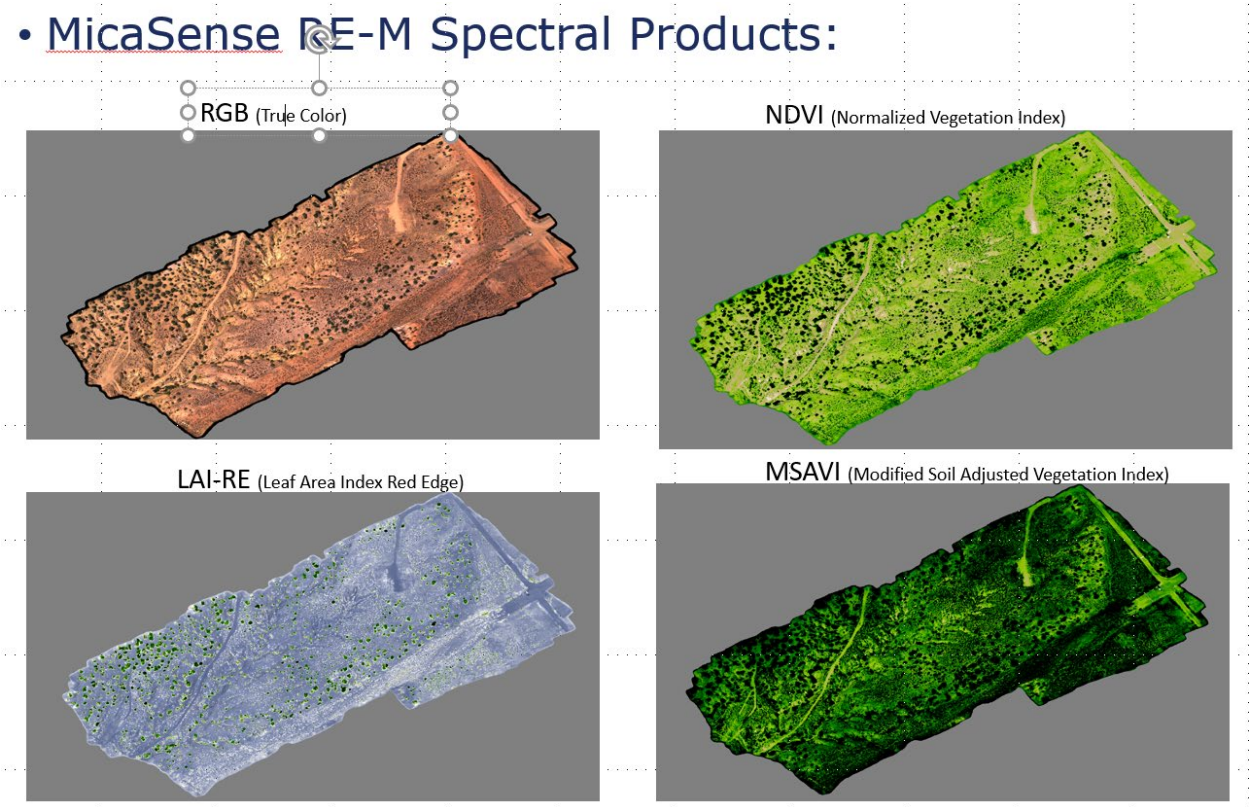
searchable and integrated with data published by other agencies. This transparency allows the public to better understand the impacts of both coal mining and reclamation activities.

- TIPS Training Program: The TIPS Training Program is a collaborative effort among OSMRE, States, and Tribes. Course developers and instructors are reclamation experts who use TIPS software to solve a wide range of complex permitting, enforcement and abandoned mine land problems. Although most of the TIPS tools are off-the-shelf applications, TIPS training is tailored exclusively to mining and reclamation uses. TIPS courses are delivered onsite at the customer's request and in training centers in OSMRE's Regional Offices: Denver, Colorado; Alton, Illinois; and Pittsburgh, Pennsylvania.

  In FY 2019, the TIPS training program received a customer satisfaction rating of 98 percent, meeting the annual Government Performance and Results Act goal. Eleven instructor-led classes were held in FY 2019, with 118 students completing class sessions. Additionally, 32 students attended three online self-study training classes sponsored by TIPS, bringing the FY 2019 total to 150 students. Two of the 11 onsite training classes were conducted at Kentucky State University and at a commercial training center in Albuquerque, New Mexico, to meet the specific training needs of particular groups of students throughout the SMCRA community. Also, in FY 2019, there was course development for a combined NTTP/TIPS class: Mine Pool Predictions Using Global Mapper.

  Although many TIPS courses are facilitated by an instructor in a traditional classroom, the TIPS Training Program continues to actively expand online opportunities and provide "just-in-time" training resources for its customers. More than 100 online courses are available on DOI Talent and ESRI for Geographic Information System modeling and mapping. TIPS utilizes the DOI Talent eLearning environment and continues to educate instructors on eLearning techniques for online instruction.

- OSMRE Unmanned Aircraft Systems (UAS) Program: In FY 2019, OSMRE continued using the UAS to enhance assessment of active and abandoned mine sites, especially on large land areas with diverse and complicated topography and over areas where dangerous conditions exist, thus allowing surveillance of an area without endangering people on the ground. OSMRE has new multispectral sensors that can be mounted on the aircraft to collect data that are invisible to the naked eye. The data can be used, among other things, to evaluate vegetation health before release of bond posted to ensure reclamation. The following panels provide examples of such products. OSMRE is finding that, as it develops its expertise, many States are seeking OSMRE assistance in using this technology for data collection and processing on sites that require quick action and accurate digital terrain modeling.



Four different multispectral products produced from the same flight over the La Plata Haul Road bond release inspection to evaluate vegetation health at the La Plata coal mine. The first RGB image is like a standard color photograph from the air. The NDVI image uses near-infrared and red band wavelengths to highlight areas of active photosynthesis, indicating healthy vegetation. The LAI-RE image includes the Red Edge band to calculate the amount of green leaf foliage compared to the ground. The final MSAVI image is similar to the NDVI image but compensates for the soil brightness found in arid areas to provide a more accurate measurement of vegetation cover. [Photo: Carrie Middleton, OSMRE, 2019]

OSMRE drone pilots provided technical assistance to our customers to help them develop, maintain, and grow their UAS programs to fulfill their mission. OSMRE does this through technical transfer roadshows, office visits, presentations at various conferences, and field visits, which include flights over reclaimed and abandoned coal mine sites to showcase UAS applications and provide hands-on demonstrations. OSMRE also conducts frequent phone calls (including bimonthly UAS tech chats), emails, and UAS workshops. In addition, policy documents, standard operating procedures, and UAS workflows are shared and discussed with its customers.

OSMRE drone pilot goes over preflight checklist with employees from Illinois Department of Natural Resources Office of Mines and Minerals before a subsidence investigation. [Photo: Chris Kiser, OSMRE, 2019]

National Technical Training Program (NTTP). Established in 1985, NTTP is an ongoing training program designed to aid the bureau's mission by increasing the technical competence and professionalism of State, Tribal, and OSMRE regulatory and reclamation staff. The NTTP provides comprehensive training in the skills needed to carry out the mandates of SMCRA. The entire program, from the identification of training needs through course development and presentation, is a cooperative effort between State, Tribal, and OSMRE offices. The NTTP utilized 127 subject matter expert instructors from State, Tribal, and OSMRE offices in FY 2019 to teach classes. The instructors are experts in mining regulatory and reclamation practices who keep abreast of changing technologies, evolving methodologies, and policies to ensure the training reflects the best protection and land restoration practices.

In FY 2019, NTTP trained 601 students from State, Tribal, and OSMRE programs. It offered 36 training sessions covering technical, legal, and programmatic subjects ranging from best practices and technologies to protect society and the environment from the adverse effects of surface and underground mining to methods to restore land use capabilities. The course subjects are, where possible, tailored to conditions and characteristics specific to each mining region and are offered in or near those regions. Course subjects include a wide variety of technical areas for a variety of practical applications, including the design of abandoned mine land restoration, proper inspection tools and techniques, soils and revegetation, identification and handling of toxic/acid-forming materials, water quality assessment, legal aspects of enforcement procedures, and preparation of evidence and testimony. In FY 2019, the program achieved an overall effectiveness rating of 90 percent, based on student and supervisor responses regarding the value of the training in their current positions.

National Technology Transfer Team (NTTT). The OSMRE NTTT brings together members of OSMRE, State, and Tribal SMCRA programs, as well as representatives from the Interstate

Mining Compact Commission and the National Association of Abandoned Mine Land Programs to coordinate understanding of mining-related issues across the country. The team manages and promotes the Applied Science Program, whose goal is to develop and demonstrate improved technologies to address environmental issues related to the mining of coal and subsequent reclamation of the land. The program has accomplished this by funding studies by universities, nonprofit organizations, and SMCRA Regulatory Authorities covering topics such as coal mine reclamation, revegetation, blasting, hydrology, coal mine voids and fires, soil productivity, acid mine drainage, and other topics relevant to environmentally responsible mining and reclamation. The Applied Science Program had 15 ongoing projects at the beginning of FY 2019, of which 11 were completed during that fiscal year. Also, six Technical Investigations funded in FY 2015 have been completed; the remaining project is continuing under an approved no-cost time extension. Three of 12 Applied Science projects funded in FY 2016 were completed during FY 2019, and six have been completed during the first quarter of FY 2020. The remaining three projects are continuing under approved no-cost time extensions. Reports of findings of completed projects and investigations are available at https://www.osmre.gov/programs/tdt/appliedscience/projects.shtm.

The NTTT also hosts and participates in technology transfer activities such as workshops, forums, and symposia to collaborate with partners outside the SMCRA community. This aspect of the team's activities is currently being expanded to take advantage of newer, web-based options, such as webinars, YouTube, and social media, including Twitter, Facebook, Instagram, and Snapchat. The team has created an interactive map on its webpage by which interested parties can access information on completed projects by selecting the location of the institution that conducted the project work. The map can be accessed at https://www.osmre.gov/programs/tdt/appliedScience.shtm.

Another program that OSMRE uses to award cooperative agreements is the Acid Drainage Technology Initiative (ADTI), created in 1995 and renamed the Mine Drainage Technology Initiative (MDTI) in FY 2017 to reflect the need to address mine drainage (MD) issues beyond acidity. The guiding principle of the initiative was to build consensus among industry, Federal, and State regulatory agencies on acidic and toxic drainage technology development and technology transfer issues. MDTI cooperative agreements, which are established under authorities other than the Federal Technology Transfer Act, provide a forum for collaboration and information exchange with the following goals: (1) develop an understanding of MD to better predict, avoid, monitor, and remediate MD; (2) develop innovative solutions to MD water quality problems; (3) identify, evaluate, and develop "best science" practices to predict MD before mining; and (4) identify successful remediation practices for existing MD sources, and describe the best preventive technologies. In FY 2019, there was one ongoing MDTI cooperative agreement that was on track to be completed in FY 2020.

VIII. National Park Service

As part of its mission, the National Park Service (NPS) actively manages the natural, cultural, and historical resources entrusted to it. This management includes preserving and maintaining these resources and, where necessary, preventing impairment, mitigating adverse impacts, or restoring these resources. Most of these activities are undertaken at the level of each individual park unit, but servicewide networks, programs, and centers make related scientific contributions in areas such as inventory and monitoring and preservation technology.

Scientific activities within NPS focus on improving the understanding and management of park natural and cultural resources. In cooperation with partners, NPS also works to preserve and interpret similar resources outside parks. The information generated by these activities is shared with park managers and stakeholders—including public and private land managers, as well as the broader public—largely through interpretive programs, exhibits, conferences, meetings, training, and standard publication media, such as reports, newspapers, journals, magazines, fact sheets, and webpage postings.

To expand the range of expertise and tools available to it, NPS participates in many collaborative ventures with universities and other governmental and nongovernmental organizations, including the Cooperative Ecosystem Studies Units Network.

NPS Cultural Programs include the National Center for Preservation Technology and Training (NCPTT), which Congress created to fill a fundamental need for research and technology transfer among Federal, State, and local historic preservation programs. The NCPTT serves as a research and development laboratory for historic preservation and advances the application of science and technology to preservation problems. The NCPTT also supports applied research, partners with professional and scientific organizations, publishes technical guidance for preservation professionals, and trains students and practitioners in the latest preservation techniques.

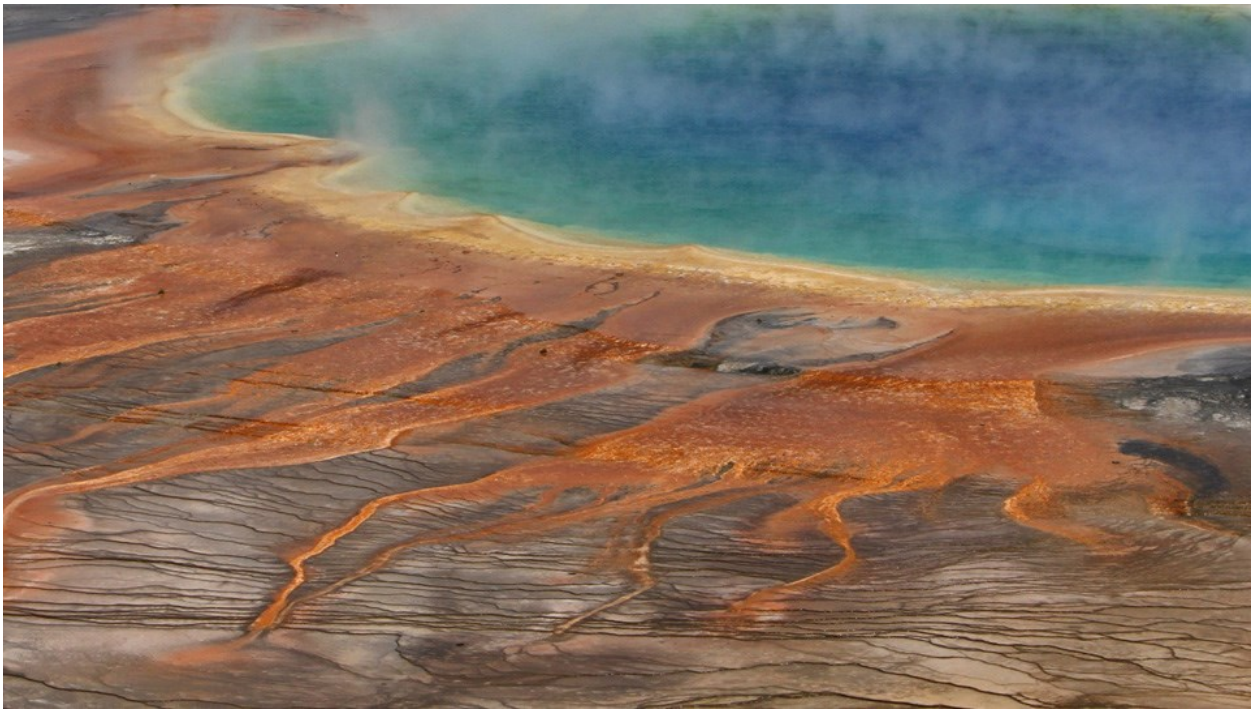
NPS also encourages qualified scientists to undertake research on parks' physical, biological, and other resources under the aegis of park Scientific Research and Collecting Permits and other permits. Such permits are issued for scientific and educational purposes only. The collected specimens and other materials and components of such specimens and materials may not be used for commercial or other revenue-generating purposes. Parties proposing commercial use of research results must enter into an agreement to share benefits with NPS or an agreement in which NPS explicitly declines to share benefits. In accordance with the National Parks Omnibus Management Act of 1998, which authorizes the Secretary of the Interior to enter into negotiations with the research community and private industry for equitable, efficient benefits-sharing arrangements, NPS has developed policies and procedures to implement benefits sharing. For each benefits-sharing agreement, NPS proposes to choose an applicable agreement type from among several available authorities. The CRADA, authorized by the FTTA, is one such option. For further information on NPS benefits sharing, see http://www.nps.gov/applications/npspolicy/DOrders.cfm.

Device to Facilitate Water Quality Measurement in High Biofouling Environments. The Gulf Coast Inventory and Monitoring Network, one of 32 NPS Inventory and Monitoring Networks, has a CRADA with In-Situ, Inc., to develop and test an NPS employee's invention and evaluate its potential for commercial manufacture and sale. The device enables currently available datasondes—which are used to measure water quality—to greatly increase the length of unmanned or continuous monitoring deployments in biofouling environments. It may also increase accuracy under turbulent flow conditions. The device modifies the calibration chamber of the sondes so that instrument/sensor drift—rather than water quality conditions—drives recalibration frequency requirements.

Two water quality instruments deployed side by side at Padre Island National Seashore showing the extent of biofouling without the invention (above) and with the invention (below). [Photo: Joe Meiman, NPS]

In FY 2019, the Gulf Coast Inventory and Monitoring Network continued operating two of the modified instruments at Padre Island National Seashore (PAIS). Before the deployment of the invention at PAIS, instruments needed to be cleaned and maintained every 2 weeks to maintain data quality. These same instruments can now be deployed for more than 45 days without maintenance, resulting in significant savings to the Network. The goal is to make the invention available on the open market so others can benefit from using the device.

Benefits-Sharing Agreement. Yellowstone National Park has a nontraditional CRADA with a small business that plans to commercialize research results from a study of microbial mats collected from thermal areas in the park. The company is providing nonmonetary benefits related to a genetic monitoring program for the purpose of conserving genetic diversity of park wildlife. The company will provide monetary benefits upon successful commercialization of its discoveries.



Grand Prismatic Spring, Yellowstone National Park. Research on microorganisms found in the extreme environments created by Yellowstone thermal features have led to some significant discoveries, including making the polymerase chain reaction (PCR) economically viable for DNA replication. [Photo: NPS/Jim Peaco]

IX. Bureau of Reclamation

The Bureau of Reclamation (Reclamation or BOR) is a water management agency whose mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Reclamation is the largest supplier and manager of water in the 17 Western States and the Nation's second-largest producer of hydroelectric power. Reclamation manages water for agricultural, municipal, and industrial uses and provides flood risk reduction and recreation for millions of people.

Ririe Dam, Ririe, Idaho. [Photo: Kirsten Strough]

According to the Department of the Interior's Economic Report Fiscal Year 2018, Reclamation's activities, including recreation, contribute more than $64.9 billion to the economy and support 462,000 jobs.[5] Reclamation owns 76 power plants and operates and maintains 53 of those plants. The 53 hydroelectric power plants account for 19 percent of the hydroelectric generating capacity in the United States. Annually, Reclamation generates 44 billion kilowatt hours of electricity—enough to supply more than 3.4 million U.S. households—and adds $1.8 billion in value to economic output.

Reclamation Research and Development (R&D). Reclamation's R&D is primarily focused on applications to identify and develop solutions related to the broad spectrum of water- and hydropower-related issues. Reclamation's R&D Office manages two appropriated R&D programs: the Science and Technology (S&T) Program and the Desalination and Water Purification Research (DWPR) Program. The S&T Program is the primary R&D program for Reclamation and funds intramural research that spans the spectrum of water- and water-related-resources challenges. The program also enlists crowdsourced innovation via technology prize competitions addressing some of Reclamation's most difficult challenges in infrastructure, water availability, and environmental compliance. S&T Program goals are to identify and develop cost-effective solutions to the technical and scientific problems affecting the accomplishment of Reclamation's mission and to communicate those solutions to Reclamation offices, its stakeholders, other water and power management officials, and the general public. The DWPR

[5] https://doi.sciencebase.gov/doidv/doi-bureau.html?bureau=Bureau%20of%20Reclamation.

Program invests in extramural R&D that advances the capabilities of water treatment technologies to enable them to be used more broadly for the creation of new water supplies. Such new supplies can relieve water stress on Western communities, Tribes, Western river basins supporting Reclamation projects, and the Nation as a whole. The program also supports the operation and maintenance of the Brackish Groundwater National Desalination Research Facility, which hosts Federal and non-Federal R&D clients conducting bench-scale studies to pilot-scale demonstrations.

Reclamation Technology Transfer. Although Reclamation's R&D focuses on water and power issues specific to the arid and variable climates characteristic of the western United States, the new solutions, tools, and information developed can have broad applicability regardless of location or jurisdiction. The transfer of Reclamation's technology and knowledge across the national and international communities of practice maximizes public benefits of Reclamation's R&D investments.

Most of Reclamation's technology advancements are transferred through public dissemination via the R&D office website (www.usbr.gov/research/), while others require the capabilities and know-how of the private sector to mature, mass-produce, and otherwise commercialize the technology into market-ready products. Reclamation's research nexus with industry is typically in the area of hydroelectric power generation, water infrastructure, water conservation, and desalination/water purification technologies. Reclamation's R&D Office produced more than 47 research reports in FY 2019.

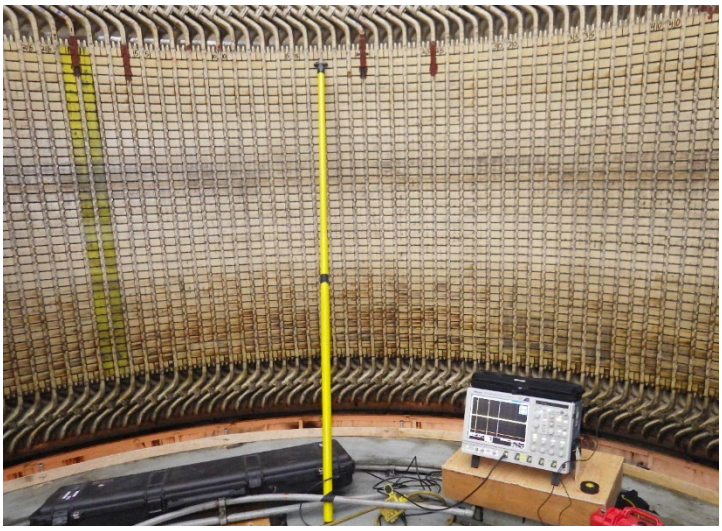
If an industry partner is needed to ultimately transfer the technology into a market-ready product, Reclamation utilizes the authorities available under Federal technology transfer legislation to protect intellectual property, as needed, and form research and licensing partnerships with U.S. manufacturing industries. Reclamation's R&D Office implements these authorities on behalf of the bureau and serves as the Bureau's Office of Research and Technology Applications (ORTA), as required by 15 U.S.C. § 3710(b).

Reclamation also works to increase awareness across U.S. industries and other nongovernmental organizations of the specialized research resources (people, lands, and facilities) that they can access through technology transfer agreements authorized by 15 U.S.C. § 3710a. In addition to physical research laboratories, Reclamation's R&D assets include engineering and scientific expertise, extensive water storage, water delivery, and hydropower facilities that offer unsurpassed, real-world laboratories for field tests, evaluations, and demonstrations of new technologies and processes related to water and hydropower. Although many of its R&D activities do not involve the development of patents or industry involvement to mature technologies into viable products, the technology transfer activities that Reclamation conducts under the authorities of the Federal technology transfer legislation are an important subset of its technology transfer responsibilities.

Highlights of activities conducted under the Federal Technology Transfer Act during FY 2019 include the following.

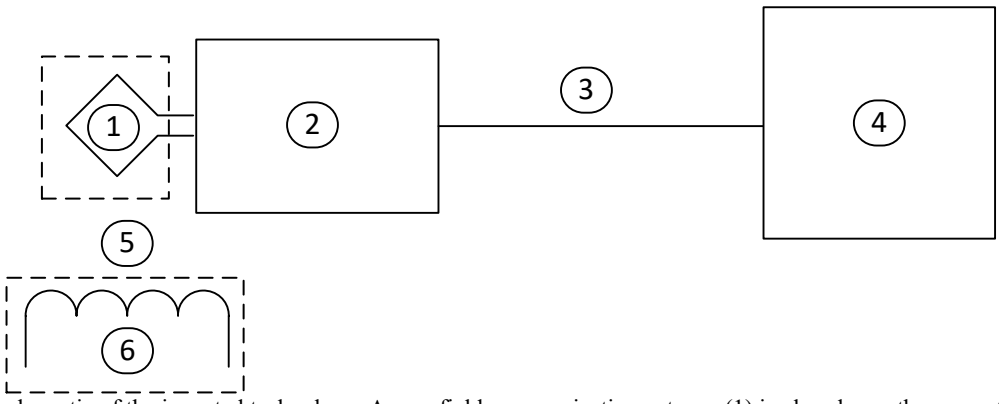
Patch Antennas: New Technology to Map Corona and Detect Other Partial Electrical Discharges in High Voltage Environments. Reclamation's Technical Service Center, Hydropower Diagnostics and Supervisory Control and Data Acquisition (SCADA) Group developed a detection device that uses patch antennas to measure partial electrical discharge within small spaces. Potential use cases would include mapping partial discharge activity throughout a hydropower generator from within the air gap without removing the rotor. Reclamation has filed a provisional patent for this technology and is currently seeking research partners to develop a potential commercial device.

Current methods to measure partial discharge in a rotating machine's stator winding involve removing the rotor, exciting the stator to operating voltages, and physically probing the stator winding with an iron core antenna, as illustrated in the following photograph. This typically involves using many personnel hours to remove the rotor, which increases the potential for maintenance-induced failures due to the mechanical complexity of rotor removal, exposes personnel to high-voltage safety risks, and results in lost revenue.



This photograph shows the current method to map partial discharge within a hydropower generator. The rotor must first be removed exposing the winding, as shown. To complete the test of mapping partial discharge, an engineer would need to manually hold and press the antenna at the end of the yellow stick against each vertical slot in the winding shown while the winding is energized to 8 kV, which can expose the engineer to high safety risks.

Despite the high risks inherent to current testing methods, the data obtained from the test procedure are extremely valuable. With this new device, a schematic of which is shown below, the downsides of the patch antenna could be significantly mitigated. This new device may allow diagnostic tests to be performed routinely, and data could be used to anticipate and forestall future machine failures and reduce unplanned machine failures and associated outages. Such savings in operational and maintenance costs would directly benefit Reclamation by continuing to advance toward a more economically competitive posture within power generation.



Generalized schematic of the invented technology. A near field communication antenna (1) is placed near the generator winding (6), with a small gap between the antenna and winding (5). The antenna's signal is captured through means of impedance matching (2) and is routed to the data recorder and/or analyzer (4) via coaxial or fiber-optic cabling (3). This technology can be used to detect partial discharge within a variety of power assets without major disassembly or the need to expose personnel to hazardous environments, which could greatly reduce operational and maintenance costs within a power asset fleet. [Photo: Jacob Lapenna, Bureau of Reclamation]

Implementing a Novel Application of Forward Osmosis for Ion Exchange Waste Brine Management. Ion exchange (IX) is among the best available technologies to treat and purify water to meet potable water regulatory requirements. It can be used to remove nitrate, chromium, arsenic, uranium, and other inorganic constituents, including calcium and magnesium, which reduces the "hardness" of water. In addition, it has the capability of removing constituents that can cause water to be aesthetically displeasing—specifically color, which is derived from dissolved organic matter.

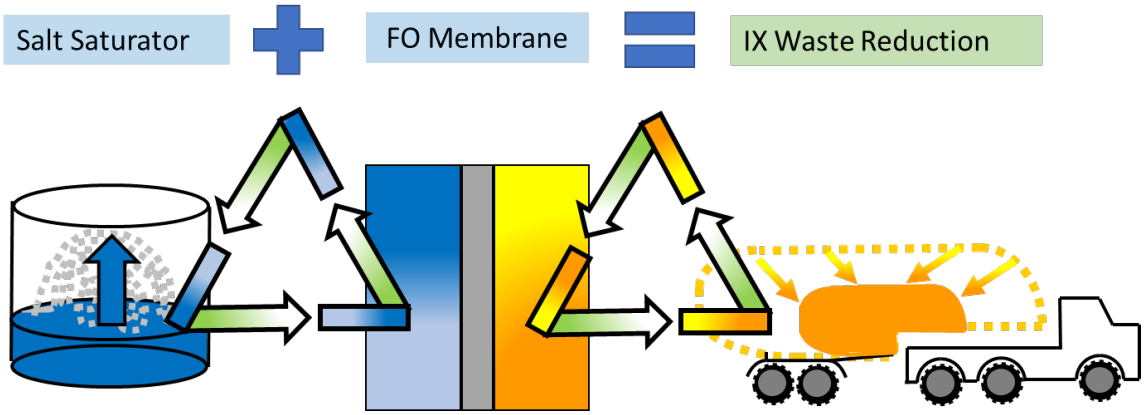
IX is enabled by running the contaminated water over a medium (usually a solid resin) where the IX occurs. Once the medium's capacity to clean the water has been exhausted, it is regenerated, usually by using a brine solution. For many systems, the principal economic, environmental, and operational considerations relate to waste disposal of the brine used to regenerate the medium. Reducing the volume of IX waste brine would provide cost savings for utilities because transportation costs associated with brine disposal would be significantly reduced.

Forward osmosis (FO) uses a semi-permeable membrane to extract freshwater from waste brine using a "draw" solution with a higher osmotic pressure than the brine. The osmotic gradient between solutions drives the passage of water through the membrane. The FO process therefore uses minimal energy because the entire process can be accomplished with low-pressure recirculation pumps. The energy-intensive component of FO is extracting water from the draw solution.

An invention developed by Reclamation's Technical Services Center Water Treatment Group involved coupling FO and IX processes to minimize the waste brine volume. In the case of IX waste brine management, existing IX salt saturators provide a natural and untapped chemical energy source to reduce waste brine volume using the FO process. The water extracted from the waste brine can be directly reused in a subsequent regeneration, for which freshwater extraction from the draw solution is not required. IX systems in either the design phase or existing

installations can benefit from this technology, where space requirements are minimal and if implementation is amenable to process retrofitting.

This invention could reduce waste brine disposal costs by 60 to 80 percent, depending on the application. This new process can also be applied to other fields that use IX processes to remove minerals in water and reduce the volume of IX waste brine, including metallurgy, industrial waste treatment, and pharmaceutical manufacturing.



Miguel S. Arias-Paić and Julie A. Korak, "Forward Osmosis for Ion Exchange Waste Brine Management," *Environmental Science Technology Letters* 7, No. 2, pp. 111–117 (2020), The American Chemical Society.

X. Bureau of Safety and Environmental Enforcement

The Bureau of Safety and Environmental Enforcement (BSEE) works to promote safety, protect the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement. BSEE's R&D focus is on offshore operational oil, gas, and renewable energy issues.

Within BSEE, the Office of Offshore Regulatory Programs (OORP) develops standards and regulations to enhance operational safety and environmental protection for the exploration, development, and production of offshore oil and natural gas on the U.S. Outer Continental Shelf (OCS). OORP conducts standards research, inspection policy evaluations, technology risk analysis, and data interpretations to manage compliance programs governing oil, gas, and mineral operations on the OCS.

The Oil Spill Preparedness Division (OSPD) is responsible for developing standards and guidelines to ensure that offshore operators are prepared to respond to oil spills. OSPD also ensures that operators' Oil Spill Response Plans comply with regulatory requirements. OSPD plays a critical role in the review and creation of policy, guidance, direction, and oversight of activities related to the agency's role in ensuring the industry's preparedness for oil spill response. The Division oversees the Oil Spill Response Research (OSRR) program and works closely with sister agencies, such as the U.S. Coast Guard, the National Oceanic and

Atmospheric Administration, and the Environmental Protection Agency to continually enhance response technologies and capabilities.

BSEE R&D programs operate through OORP's Emerging Technologies Branch (ETB) and OSPD's Response Research Branch (RRB). The ETB is the agency's focal point on operational safety and pollution prevention research. OSPD's Oil Spill Response Research (OSRR) program was established through the Oil Pollution Act of 1990 to research oil spill response technologies and operational techniques. OSPD also operates the Ohmsett Facility in Leonardo, New Jersey, which serves as the National Oil Spill Response Research and Renewable Energy Test Facility. The Ohmsett facility is available to provide independent and objective performance testing of full-scale oil spill response equipment and marine renewable energy devices. In addition, the facility is available to help improve existing technologies through research and development.

The majority of BSEE's technology advances are transferred through public dissemination. In addition to making the final reports of research projects publicly available on its website, BSEE also makes its research results available via conferences, such as the annual Clean Gulf Conference, and other fora, such as the Pacific States-British Columbia Oil Spill Task Force Annual Meeting and the Ocean Energy Safety Institute's Public Research Forum.

BSEE's primary research synergy is with the State, Federal, and international government organizations; the oil/gas and renewable energy industries; and oil spill removal organizations. Research is typically in areas pertaining to critical equipment and technology, environmental impact, and risk reduction and assessment tools and techniques applicable to the U.S. OCS to ensure that the best available science is utilized in regulatory decision making. Additional information and research deliverables are available at https://www.bsee.gov/what-we-do/research/tap and https://www.bsee.gov/what-we-do/oil-spill-preparedness/oil-spill-response-research.

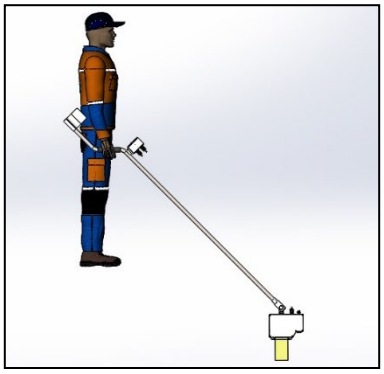
BSEE is a member of the International Committee on Regulatory Authority Research and Development (ICRARD), which focuses on transferring knowledge worldwide among governmental entities in the area of health, safety, and the environment in the petroleum sector. Although membership is available only to government entities, ICRARD cooperates with industry to coordinate and transfer technology.

BSEE is also a member of the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR). Comprising 15 Federal agencies, ICCOPR was established as part of the Oil Pollution Act of 1990 to "coordinate a comprehensive program of oil pollution research, technology development, and demonstration among the Federal agencies, in cooperation and coordination with industry, universities, research institutions, state governments, and other nations, as appropriate."

BSEE is a member of the International Regulators' Forum (IRF). This organization consists of 10 members from countries whose goal is to provide leadership on safety and safety-related regulatory matters for offshore oil and gas activities. Other members include Norway, Canada, Brazil, and the United Kingdom.

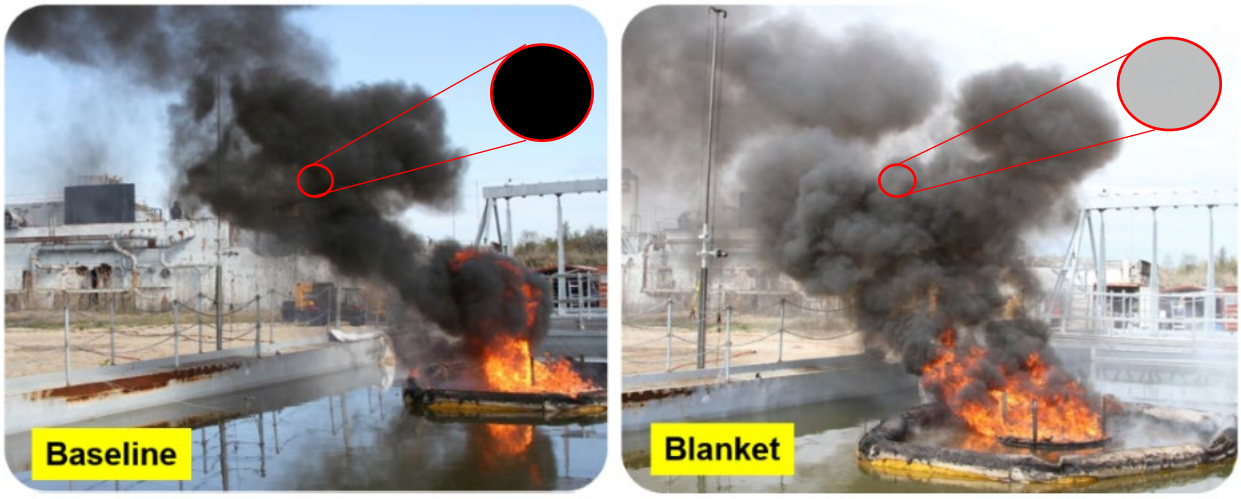
The following are examples of FY 2019 completed or ongoing research projects that would, among other things, advance technological options and transfer knowledge about best technological practices to industries and regulators operating on the OCS.

Advancing the Oil Thickness Sensor. Accurate measurement of oil slick thickness is essential for oil skimmer equipment testing, field data collection, and oil spill response operations. The contractor has applied for an international patent under the Patent Cooperation Treaty (PCT) and a U.S. patent, application no. 20190242689. The Oil Thickness Sensor is currently in Phase II development to produce specific measurement tools for testing and field operations. A handheld sensor (shown conceptually) will accurately measure floating oil thicknesses from 3 mm to 10 cm and display the measurement in real-time on the tool's handle. This tool is extendable to 3 m to measure oil thickness in a test basin or from a field vessel. A remote thickness sensor can be mounted to an oil skimmer, a buoy, or an oil collection boom to wirelessly transmit thickness data for 100 m in real-time to a user. This thickness data can be used by a responder to adjust skimming operations to maximize recovery efficiency. The remote sensor could also be used in the future for an autonomous application to control a skimmer's automated recovery. These tools will be tested at Ohmsett in 2020, and potentially be made available to Oil Spill Removal Organizations for further evaluation and feedback.



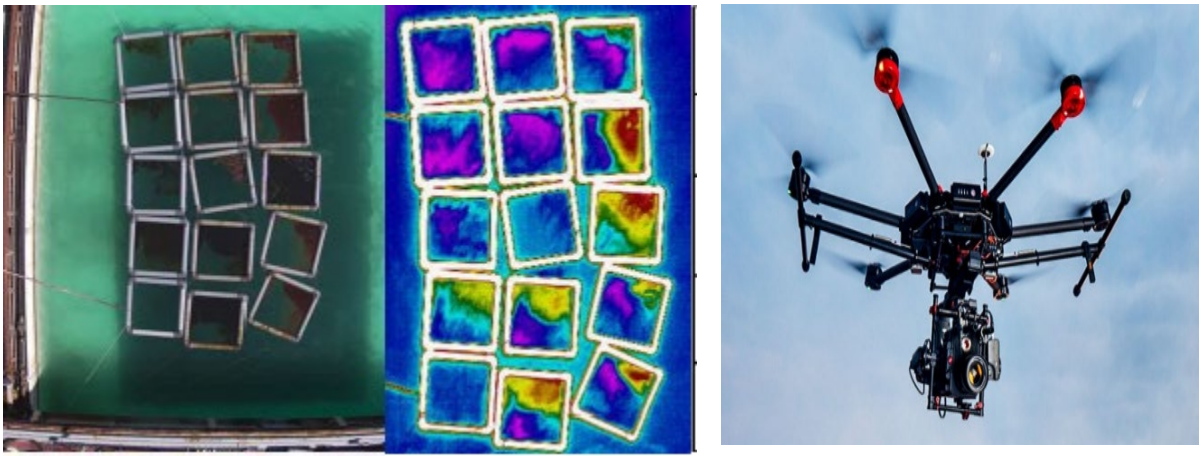
Conceptual View of Handheld Sensor. [Photo: American University of Beirut]

Advancing Flame Refluxer™ Technology. The Flame Refluxer™ technology is a heat feedback system being developed to enhance in situ burn (ISB) operations of crude oil on water to reduce oil contamination of surface waters. Worcester Polytechnic Institute holds U.S. patent no. US20160123582A1 on this technology. During ISB pool fires, approximately 95 to 97 percent of the heat generated dissipates into the atmosphere. The Flame Refluxer™ collects the heat in the flames and transfers it back to the oil slick, resulting in hotter, more efficient burns. Testing of the prototype technology resulted in greatly reduced plume emissions and burn residues. The following pictures of test burns show the significant decrease in black carbon soot with the Flame Refluxer,™ as indicated by the change in the plume from a dark black to a steel gray. Researchers were pleasantly surprised by the almost complete absence of burn residue with the Flame Refluxer™ technology. Current research efforts focus on the optimum materials and geometries for easy storage and deployment of the technology. Maturation efforts are expected to result in tenfold increases in burning efficiency through scale-up effects.



Flame Refluxer™ technology results in faster and cleaner burns with reduced emissions and decreased burn residues, as may be seen by the reduced opacity of the smoke in the right-hand panel, magnified in the circular insets on the top right of each panel. Photo credit: BSEE.

Drone System to Estimate Oil Thickness and Emulsification. The focus of this project was the design and implementation of two components: the unmanned aircraft system (UAS) and the algorithms for the image processing used on the system. The project was carried out in two phases: Phase 1—Development/Implementation of the UAS platform/sensors and its algorithms for oil classification and image processing based on Ohmsett testing. Phase 2—Assessment of the integrated system. An image-processing algorithm can be used to process data collected from aerial platforms operating a combination of multispectral and thermal sensors. This algorithm/sensor system demonstrated its capacity for identifying areas and locations of actionable oils to response units. The information generated from the system allows improved oil mitigation and control actions by responder vessels and for assessment of the impact and magnitude of the oil spill.



Left: RGB image of square setup containing different volume of Hoover Offshore Oil Pipeline System (HOOPS) oil emulsions, crude oil, and Sargassum; Middle: thermal infrared images; Right: Unmanned Aircraft Systems (UAS). [Photo: BSEE]

XI. Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) manages the Nation's offshore energy and mineral resources in an environmentally and economically responsible way. It ensures access to and the fair return for conventional and renewable energy and mineral resources of the U.S. Outer Continental Shelf (OCS) to help meet the energy demands and mineral needs of the Nation while also balancing such access with the protection of the human, marine, and coastal environments.

As the Nation's offshore energy and mineral resource manager, BOEM is committed to using the best available science across a range of relevant disciplines that provide the scientific and technical foundation and the human capital needed to make sound decisions at all levels of the organization. Management of the energy and mineral resources of the OCS is governed by the Outer Continental Shelf Lands Act, which establishes procedures for leasing, exploration, and development and production of those resources, including oil, gas, offshore renewable energy, and marine minerals such as sand and gravel used for coastal restoration projects.

BOEM's Office of Environmental Programs (http://www.boem.gov/Environmental-Stewardship/) conducts environmental reviews, including National Environmental Policy Act (NEPA) analyses and compliance documents for each major stage of energy development and planning. These analyses inform BOEM's decisions on its National OCS Oil and Gas Leasing Program, as well as a variety of other conventional and renewable energy leasing and development activities. In addition, BOEM's scientists conduct and oversee environmental studies to help make the best policy decisions relating to the management of energy and marine mineral resources on the OCS through its Environmental Studies Program (ESP).

BOEM's three regional offices—strategically located in New Orleans, Louisiana; Camarillo, California; and Anchorage, Alaska—manage oil and gas resource evaluations; environmental studies and assessments; leasing activities, including the review of plans for exploration, development, and production; fair market value determinations; and geological and geophysical permitting.

BOEM Environmental Studies Program

BOEM's Environmental Studies Program strives to apply the best science available for informed decision making. It plans, conducts, and oversees world-class scientific research to inform policy decisions regarding leasing and developing OCS energy and mineral resources. BOEM works to manage the exploration and development of the Nation's offshore resources in a way that appropriately balances economic growth, energy development, and environmental protection through oil and gas leases, renewable energy development, and environmental reviews and studies. BOEM's environmental studies cover a broad range of disciplines, including archaeological resource protection, physical oceanography, meteorology and air sciences, biology, protected species, social sciences and economics, submerged cultural resources evaluation, and the overall environmental effects of energy development. BOEM continues to be a leading contributor to the growing body of scientific knowledge about the Nation's marine and coastal environment.

BOEM oversees scientific research conducted through contracts, partnerships with other governmental bureaus, cooperative agreements with State institutions or universities, and interagency agreements. These arrangements enable the bureau to leverage resources, meet national priorities, and satisfy common needs for robust scientific information. Many of the bureau's studies are collaborations with partners under the umbrella of the National Oceanographic Partnership Program.

BOEM Technology Transfer

BOEM's technology transfer activities include disseminating information, knowledge, and technologies to the various regions and to commercial entities and other stakeholders with interests in or about the OCS. Virtually all these activities are undertaken using authorities provided to BOEM other than the Federal Technology Transfer Act of 1986 (FTTA). Studies undertaken by or through funding from BOEM are available to the public through the Environmental Studies Program Information System (ESPIS), which summarizes more than 1,800 ongoing and completed BOEM-sponsored environmental research projects and provides online access to more than 3,600 research reports (http://www.boem.gov/studies). In 2019, ESP completed 45 studies that accounted for approximately $35.5 million in BOEM-funded ocean research.

BOEM also partners with BSEE to select and fund research into renewable energy to facilitate industry development and promote operational safety and pollution prevention through BSEE's Technology Assessment Program. More information on this research is available at https://www.boem.gov/Technology-Assessment/.

Many large interdisciplinary projects with funding from BOEM have included partnerships with other Federal agencies and academic institutions, as well as private companies directed toward offshore ecosystem studies that utilize state-of-the-art technologies, such as autonomous underwater vehicle surveys, deep-water human-occupied submersibles, and remotely operated vehicles. Many projects have developed innovative imaging technologies and digital analysis techniques for establishing long-term biological monitoring stations in deep water. These partnership studies have leveraged expertise and technologies to meet common management goals.

The following are a few examples of BOEM's ongoing scientific research and development activities, including some conducted in cooperation with other parties.

Marine Arctic Ecosystem Study (MARES). BOEM is leading the Marine Arctic Ecosystem Study (MARES)—a partnership of Federal, State, Tribal, industry, academic, and nongovernmental organizations—to advance our understanding of ecosystem structure and function in the Chukchi and Beaufort shelves. This research included testing new technology to assess whether it can better associate marine mammal presence to environmental conditions.

DEEP SEARCH. Launched in July 2017, Deep Sea Exploration to Advance Research on Coral/Canyon/Cold seep Habitats (DEEP SEARCH) is a multiyear, multiagency study conducted to characterize the deep-sea ecosystems of the U.S. mid- and south Atlantic. DEEP SEARCH is

an ongoing study that seeks to explore and characterize the biological communities of the study area; examine their sensitivity to natural and human disturbance; and describe the oceanographic, geological, geochemical, and acoustic conditions associated with each habitat type. The National Oceanic and Atmospheric Administration's (NOAA's) Office of Ocean Exploration and Research provided the assets (ship and submersible), as well as expedition coordination, data management, and engagement support for four research cruises that took place from August 2017 to April 2019. The DEEP SEARCH team has collected more than 2,800 biological and geological samples and mapped more than 14,966 square kilometers of seafloor. Recently, while exploring methane cold seeps 36 miles off the shore of North Carolina, scientists discovered 85 linear miles of Lophelia coral off the shore of South Carolina and chemosynthetic vestimentiferan tubeworms, marking the first time that tubeworms have been observed in this part of the Atlantic.

Atlantic Deepwater Ecosystem Observatory Network (ADEON). In collaboration with NOAA and the Office of Naval Research (ONR), BOEM is investigating connections between the ocean's soundscape and its ecosystems. The ultimate goal of the Atlantic Deepwater Ecosystem Observatory Network (ADEON) is to generate multiyear measurements of the natural and human factors that describe the ecology and soundscape of the U.S. East Coast Outer Continental Shelf (OCS). To fully comprehend how human, biological, and natural abiotic components create the soundscape and influence ecosystem dynamics of the OCS, ADEON combines acoustic information with contextual data from space-based remote sensing, hydrographic sensors, and mobile platforms. The project has advanced the technology and hardware needed for establishing directional, passive acoustic recordings. The directional recording capability on landers has proven reliable for measuring the simultaneous direction of arrival of sounds from vessels and marine mammals.

Developing the Next Generation of Animal Telemetry Study—BOEM is partnering with the National Aeronautics and Space Administration (NASA) to leverage space-based transceivers aboard small satellites, called CubeSats, as a low-cost method to improve animal tracking. This method will better track marine mammal movement, using an innovative, low-cost, and open-source solution that could increase receiving options, expand the number of data providers, and lead to more affordable data acquisition. Several initial experiments in 2017–2018 included a high-altitude balloon flight test to simulate conditions of a small low-Earth-orbit satellite. A second flight will test the capability of an open-source software-defined radio, which could be integrated into the payload. The team recently conducted an "Ideation Challenge," which sought ideas on incorporating small satellite technology—along with other space, stratosphere, land, and water surface systems—to improve the current system of data reception for tracking animal position and path. More than 430 competitors from 24 countries, including 20 from the United States, entered the challenge; two winners each received $15,000 for their winning entries.

Use of Satellite Data for Offshore Air Quality Applications—Conducted through an interagency agreement between BOEM and NASA, this scoping study assesses the applicability of existing satellite datasets to support BOEM's air quality regulations and NEPA analysis. Specifically, this scoping study will determine the feasibility of using satellite data in the offshore environment in the Gulf of Mexico region for estimating and monitoring long-term trends of the ground-level concentrations of criteria pollutants for which there are National

Ambient Air Quality Standard (NAAQS), precursors, and visibility pollutants. An offshore monitoring field campaign commenced in May 2019 with a NASA/BOEM cruise to validate the satellite data that sampled nitrogen dioxide (NO_2), ozone (O_3), and methane (CH_4), along with other pollutants and meteorological data. Using the TROPOspheric Monitoring Instrument (TROPOMI) satellite NO_2 data, the Visible Infrared Imaging Radiometer Suite (VIIRS), and a HYSPLIT back trajectory model, researchers observed a flaring event from the Olympus oil rig platform in the Mars field in the Gulf of Mexico. These data, along with other Pandora NO_2 observations on the cruise, indicate that TROPOMI is useful for measuring the Gulf of Mexico and coastal pollution and that there is an excellent correlation between the NO_2 measurement systems on NASA's Pandora Project and TROPOMI for the offshore environment.

Smithsonian Barcoding Study—Over the past 35 years, the Smithsonian's National Museum of Natural History, Department of Invertebrate Zoology (NMNH-IZ) has partnered with BOEM to provide professional collection management services for the long-term curation of marine invertebrate specimens. During the last decade of this partnership, NMNH-IZ's biorepository facility has brought BOEM's specimen collections into the 21st century and enhanced BOEM's long-term collections by complementing voucher specimens with corresponding viable, cryogenically preserved tissue samples that are barcoded for CO1 gene sequence and preserved for future genomic research. Work over the past 3 years has focused on developing a genomic sampling strategy, which can demonstrate the utility of this partnership in becoming a voucher-based reference facility for OCS ocean biodiversity.

XII. Bureau of Land Management

The Bureau of Land Management (BLM) manages approximately 245 million surface acres and 700 million subsurface acres, which amounts to more than 1-in-10 acres of the surface land and about 1-in-3 acres of the subsurface land in the United States. BLM's multiple-use and sustained yield mandate, set forth in the Federal Land Policy and Management Act of 1976, directs the management of America's public land resources for a variety of uses, such as energy and minerals development, livestock grazing, recreation, and timber harvesting, while also protecting a wide array of natural, cultural, and historical resources for the use and enjoyment of present and future generations. BLM works with partners to promote multiple uses of those lands through shared conservation stewardship and facilitates opportunities for energy development that create jobs, help support local communities, and establish America's energy dominance.

In FY 2018, the latest year for which data have been compiled, the diverse activities authorized on BLM-managed lands generated $105 billion in economic output throughout the country—more than any other bureau within the Department of the Interior and a substantial increase from $95.6 billion in 2017.[6] In FY 2018, this economic activity supported approximately 471,000 full- and part-time jobs, up from 468,000 jobs in 2017, and also provided $51 billion in direct—and $66 billion in indirect— contributions to the U.S. economy. This activity also generated

[6] U.S. Department of the Interior Economic Report, FY 2018, Table 3, https://www.doi.gov/sites/doi.gov/files/uploads/fy-2018-econ-report-final-9-30-19-v2.pdf.

substantial revenue for the U.S. Treasury and State governments, mostly through royalties on minerals, and through taxes on economic activities.[7]

BLM regularly gathers, maintains, and publishes various types of data to inform stakeholders and the general public about its stewardship responsibilities. Those data include detailed information on the commercial uses of the public lands (e.g., energy development, livestock grazing, mining, and timber harvesting); recreational activities (e.g., hunting, fishing, wildlife viewing, hiking, and camping); revenues from these activities; wild horse and burro management; cadastral (mapping) surveys; and the extent and quality of rangeland resources for more than 870 special units, such as wilderness areas, that are part of the BLM's 32-million-acre National Conservation Lands system. The data also include information on the socioeconomic impacts of public land management.

Examples of FY 2019 technology transfer activities include the following bureauwide and program-specific efforts.

Maintaining and Publishing Quality Land Management Data—BLM compiles, maintains, and publishes approximately 20 sets of national data, including the Public Land Survey System (PLSS), which is a detailed, nationwide information system on BLM Administrative Unit Boundaries, the Surface Management Agency, Grazing Allotments, and Wild Horse and Burro Herd Areas, among others. The PLSS dataset is used, maintained, and published in partnership with other Federal agencies, as well as Tribal, State, and local governments. The Western Governors' Association (WGA) recognizes the published PLSS dataset (also referred to as Cadastral National Spatial Data Infrastructure [CadNSDI]), land record modernization, and cadastral data as "critical for maintaining livable communities, encouraging economic development and developing tools that give community leaders the ability to manage both."[8] The States of Utah and Montana host PLSS data on their websites for publication and distribution, and the data are used by the Bureau of Census to standardize the mapping of State, county, and other jurisdictional boundaries. This PLSS dataset also serves as the basis for automating the mapping of land transactions such as oil and gas leasing, permitting, timber sales, and the withdrawal of lands for military use or preservation.

Increased Access to and Use of Data and Information—BLM increased public access to data and information through a variety of technologies and applications, including BLM's geographic information system (GIS) transformation project; Landscape Approach Data Portal; BLM Navigator, a one-stop shop for keyword and geospatial search of BLM data; and the BLM Library. The BLM Library, located at the National Operations Center in Denver, exists to serve BLM employees and to assist members of the general public. It provides access to BLM's extensive library catalog, publications, journals, databases, and subject guides. In FY 2019, the library website had 32,684 page views.

BLM provides data to clearinghouses maintained by the Federal Government, such as data.gov, recreation.gov, and data.doi.gov. These tools make it easier for the public to view, explore, and

[7] Ibid.
[8] Western Governors' Association (WGA), Policy Resolution 00 – 005, reprinted as Appendix B, in WGA, Western Cadastral Data and Policy Forum Final Report, http://nationalcad.org/download/2000-WGA-Final-Report.pdf.

acquire data that the BLM uses to help manage public lands for multiple, diverse, and seemingly conflicting uses, such as energy development, livestock grazing, recreation, and cultural resources.

BLM is providing all of its historic and newly acquired imagery to the public via the U.S. Geological Survey's Earth Resources Observation and Science Center (USGS-EROS). To assist people in using this information, BLM also initiated a learning outreach effort to its State and field offices regarding the use of Google Earth Engine for scientific resource management. Google Earth Engine is an online architecture that allows the processing, analysis, and derivation of management products from remotely sensed imagery and other geospatial information about BLM lands across the United States. In addition, BLM provided photogrammetric training for terrestrial and unmanned aerial systems projects to a variety of constituencies, including Federal agencies, nonprofit organizations, universities, and K–12 student groups. These classes focus on the proper capture, processing, analysis, and use of imagery for natural and cultural resource management.

Assessment, Inventory, and Monitoring (AIM): BLM's Assessment, Inventory, and Monitoring (AIM) strategy provides a standardized process for BLM to collect quantitative information on the status, condition, trend, amount, location, and spatial pattern of resources on the Nation's public lands. BLM uses AIM data to make necessary management adjustments to meet resource management objectives described at the project, activity plan, resource management plan, and National program levels.

The AIM approach is based on five key elements: (1) a standardized set of core and contingent indicators for both terrestrial and aquatic ecosystems, (2) an appropriate sampling design, (3) a structured implementation process, (4) electronic data capture, and (5) integration with remote sensing.

Core terrestrial and aquatic indicators were selected because they are known to be both ecologically relevant and clearly tied to rangeland health and to State and Federal clean water standards. Both the development of indicators and the collection of data to track the indicators are standardized. The use of standardized methods helps ensure that the AIM data collected at different locations by various observers are comparable.

AIM data are available through the public-facing versions of the Terrestrial AIM Database (TerrADat) and the Aquatic AIM Database (AquADat). Various State Government agencies—such as the Nevada Department of Wildlife, Wyoming Game and Fish, and the Alaska Department of Environmental Conservation—are engaged in data collection that is compatible with AIM. AIM data are used by a wide variety of Federal and State agencies, universities, nongovernmental organizations, private industry, and the public. BLM partners with other Federal agencies (e.g., NPS, USFS, USFWS) and Utah State University to support the National Aquatic Monitoring Center (NAMC). NAMC encourages and fosters scientifically sound aquatic monitoring activities on public lands. NAMC's primary foci are the use of aquatic macroinvertebrates as bioindicators of freshwater biological integrity under the Clean Water Act and the development of scientifically defensible aquatic monitoring and assessment tools. NAMC processed more than 1,300 macroinvertebrate and water samples in FY 2019 for more

than a dozen State and Federal agencies and supported web-based interfaces to publicly serve all monitoring data. NAMC also identifies and documents the distribution of aquatic invasive invertebrates to help ultimately prevent their spread to uninhabited water bodies.

BLM's National Conservation Lands: BLM's National Conservation Lands Division works with scientific partners and local communities to address BLM's management-focused research needs. BLM encourages scientists to perform research on National Monuments and Conservation Areas and communicate their findings to the public. All research projects performed on BLM's National Conservation Lands have a public outreach component, including presentations, reports, and publications. In FY 2019, projects performed on National Conservation Lands with local partners included pollinator habitat studies, paleontological and archaeological resource inventories, wetland condition assessments, and rare species surveys.

Cultural Heritage and Paleontology—The BLM Cultural Heritage and Paleontology programs partner with museums, universities, and others to conduct research, inventory the public lands, learn about the location and significance of cultural and paleontological resources, manage important cultural and scientific collections of artifacts and specimens from the public lands, and share research results with the public and across research communities. In addition, BLM partners with State historic preservation offices, State geologic surveys, Indian Tribes, museums, and universities, as appropriate, to facilitate research and better manage cultural and paleontological sites and locality information. The relationship is often reciprocal, with scientific data shared by BLM and partners. These partnerships address requirements of the National Historic Preservation Act of 1966, the Archaeological Resources Protection Act of 1979, and the Paleontological Resources Preservation Act of 2009.

XIII. Conclusion

During FY 2019, the Department's technology transfer activities included—

- Publishing more than 9,800 reports, books, papers, fact sheets, and other publications.
- Engaging in 470 Cooperative Research and Development Agreements (CRADAs) and at least 269 other collaborative R&D relationships.
- Executing 425 nontraditional CRADAs, such as technical assistance, material use, and facility use agreements.
- Disclosing eight (8) new inventions, filing three (3) new patents, and receiving one (1) patent.
- Managing eighteen (18) active licenses for inventions and other intellectual property, which collectively earned about $42,000.

DATA APPENDIX

The following tables provide cumulative data for the Department from FY 2015 through FY 2019. Data for individual bureaus are available online at this link.

Data are provided if they are collected and readily available. Note that a blank cell or N/A indicates either zero, the data are not collected, or the data are otherwise unavailable. These tables include updates to previous years' data, where appropriate. Also, note that only NPS has data on small business participation (lines 23 and 24).

Table 1: Invention Disclosures and Patents

		FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
	Invention Disclosures					
1	Number of new inventions disclosed	7	8	13	9	8
	Patents					
2	Number of patent applications filed	8	4	6	7	3
3	Number of patents received	3	1	3	6	1

Table 2: Income Bearing Licenses

		FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
	Income Bearing Licenses					
4	Number of income bearing licenses	18	17	13	15	16
5	Exclusive licenses	7	8	7	8	7
6	Partially exclusive licenses	0	0	0	0	0
7	Nonexclusive licenses	11	9	6	8	9

Table 3: Licensing Income

		FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
	Total income (all licenses active in FY)	$105,580	$82,997	$50,090	$50,925	$42,168
	Total income distributed	$97,198	$81,559	$49,990	$43,190	$33,588
	Total income from patent licenses	$105,580	$82,997	$50,090	$50,925	$42,168
	Total income distributed	$97,198	$81,559	$32,557	$50,925	$27,211
	Disposition of Earned Royalty Income (ERI)					
	Total ERI	$105,580	$82,997	$50,090	$50,925	$42,168
	Total ERI distributed	$97,198	$81,559	$32,557	$50,925	$27,211

Table 4: CRADAs

		FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
	CRADAs					
21	Number of active CRADAs	826	873	841	742	470
22	Number of newly executed CRADAs	586	511	477	422	352
23	Active CRADAs with small business involvement				2	2
24	Number of small businesses involved in active CRADAs				2	2
	Traditional CRADAs					
25	Active traditional CRADAs	38	37	58	54	43
26	Newly executed traditional CRADAs	12	9	13	5	9
	Nontraditional CRADAs					
27	Active nontraditional CRADAs	787	836	783	687	425
28	Newly executed nontraditional CRADAs	574	505	466	418	343
	Other collaborative R&D relationships					
	Total active in the FY	318	319	247	249	269
	New, executed in the FY	121	126	89	117	149

Table 3A: License Activity

	Metric	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
	Licenses, Total Active	20	22	15	17	18
-	New Licenses	3	0	0	2	2
	Invention Licenses, Total Active	18	20	13	15	16
	New Invention Licenses	3	0	0	2	2
	Income Bearing Licenses, Total Active	18	17	13	13	16
-	Income Bearing Exclusive Licenses	7	8	7	8	7

Frequently Used Acronyms

AADAP	Aquatic Animal Drug Approval Program
ARS	Agricultural Research Service (within USDA)
BAST	Best Available and Safest Technologies
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BOR	Bureau of Reclamation
BSEE	Bureau of Safety and Environmental Enforcement
CESU	Cooperative Ecosystem Studies Units
CRADA	Cooperative Research and Development Agreements
CWA	Clean Water Act
DHS	Department of Homeland Security
eDNA	environmental DNA
EPA	Environmental Protection Agency
EPM	electron microprobe
ESA	Endangered Species Act
ETB	Emerging Technologies Branch
FAC	Division of Fisheries and Aquatic Conservation
FEMA	Federal Emergency Management Agency
FTC	Fish Technology Center
FTTA	Federal Technology Transfer Act of 1986
FUSA	Facility Use/Service Agreement
FWS	Fish and Wildlife Service
GSA	General Services Administration
GSS	Global Security Systems
MHEP	Minority Higher Education Program
MTA	Material Transfer Agreement
NASA	National Aeronautics and Space Administration
NCPTT	National Center for Preservation Technology and Training
NCR	Natural and Cultural Resources
NCTC	National Conservation Training Center
NDRF	National Disaster Recovery Framework

NEPA	National Environmental Policy Act
NFPP	National Fish Passage Program
NGA	National Geospatial-Intelligence Agency
NGO	nongovernmental organization
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRF	National Response Framework
NTTP	National Technical Training Program
NTTT	National Technology Transfer Team
OCS	Outer Continental Shelf
OEPC	Office of Environmental Policy and Compliance
OPA	Office of Policy and Analysis (within USGS)
ORTA	Office of Research and Technology Applications
OSMRE	Office of Surface Mining Reclamation and Enforcement
OSPD	Oil Spill Preparedness Division
PHMSA	Pipeline and Hazardous Materials Safety Administration
R&D	Research & Development
READ	Resource Advisor
RSF	Recovery Support Function
SEM	scanning electron microscope
SMCRA	Surface Mining Control and Reclamation Act of 1977
TAA	Technical Assistance Agreement
TIPS	Technical Innovation and Professional Services
UAS	Unmanned Aircraft System (also known as a drone)
USACE	U.S. Army Corps of Engineers
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey