

## Water in the Native World

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To Indigenous peoples, water is sacred. Water is the lifeline of Indigenous cultures, ceremonies, livelihood, and beliefs. Indigenous peoples have a repository of knowledge related to water, its use, and its spatial and temporal distribution. Hydrology and water resources can greatly benefit from Indigenous perspectives that includes place-based knowledge that helps us better understand complex natural and human systems. Sivapalan et al. (2012) termed “social-hydrology” as the science of people and water that is aimed at understanding the dynamics and co-evolution of coupled human-water systems. For Indigenous people, the study and observation of water were never separated from the people. For some Indigenous people, separating people and water is impossible as the origin, occurrence, form, and quality of water often define an Indigenous person, clan, people, and/or community.

Internationally, Indigenous people are known as “water protectors” and they have been fighting to protect their waters from overuse and contamination. However, the voices of Indigenous people are rarely heard in hydrological sciences. The representation of Indigenous scientists in hydrology is also very small and they are often asked to participate in water research on tribal lands to ensure ethical protocols, strong tribal partnerships, and cultural sensitivity. Indigenous hydroscintists not only produce scientific investigation and knowledge, but they also have a passion and a deep commitment to doing science for the purpose of helping their communities address water challenges. In a sense, Indigenous hydroscintists become “water protectors” by using science as a tool to address water challenges facing tribal communities. Indigenous water scientists play a key role in bridging Western science with

Indigenous knowledge and it is imperative to recruit and retain more Indigenous students in hydrological sciences. In this Special Issue, “Water in the Native World,” nearly all of the co-authors are Indigenous and two publications (Bulltail and Walter 2020; Conroy-Ben 2020) are led by an Indigenous lead author. With the need to consider the people in water research, Indigenous perspectives can also be gained through Indigenous scientists in health and social sciences. Indigenous health and social scientists have been present in health and social science research longer and in greater numbers than in hydrosiences. It is important to bridge hydrosiences with health and social sciences to critically examine health disparities and social dynamics. This Special Issue provides several examples of bridging hydrosiences with health and social sciences including Ellis and Perry (2020), Martin et al. (2020), and Kozich et al. (2020). This Special Issue is compiled by an Indigenous hydroscintist (Dr. Karletta Chief, Diné) and aims to bring to the forefront “Water in the Native World” where water challenges facing Indigenous communities are addressed and led by Indigenous hydroscintists; where Indigenous perspectives are not only included in the research but also *drive* the research questions; where Indigenous community members are co-authors; and where Indigenous students participate in data collection, analysis, synthesis and publication in the important research facing their communities.

In 2017, a group of Indigenous hydroscintists were awarded a National Science Foundation (NSF) Integrative and Collaborative Education and Research (ICER) Grant entitled “Water in the Native World: A Symposium on Indigenous Water Knowledge and Hydrologic Science.” This team of Indigenous hydroscintists and professors included

Dr. Karletta Chief (Diné), University of Arizona; Dr. Otakuye Conroy-Ben (Oglala Sioux), Arizona State University; Dr. Ryan Emanuel (Lumbee), North Carolina State University; Dr. Shandin Pete (Salish and Diné), Salish Kootenai College; and Dr. Raymond Torres (Chemhuevi), University of South Carolina. This collaborative team aimed to not only address research questions regarding water challenges facing tribes, but to also build a network of Indigenous water scientists and allies to work together. The Symposium (Chief et al. 2019), held at a tribal college, Salish Kootenai College, in Pablo, MT in August 2018, aimed to: 1) define research and education priorities in the hydrologic sciences that are relevant to Indigenous peoples in a rapidly changing world; 2) create a network of Indigenous hydrologists and traditional knowledge holders of water; and 3) identify educational needs and tools to support Indigenous perspectives in hydrology.

The Symposium began with a cultural welcoming ceremony by the Confederated Salish and Kootenai Tribes. This welcome acknowledged our relations with one another and the environment and blessed our thoughts so that the Symposium would be successful. This ceremony set the tone for discussions about water in both technical terms and as a source of Indigenous identity. Participants, who came from nine states and 15 tribal affiliations, presented and led technical discussions on topics ranging from water quality disparities (Conroy-Ben and Richard 2018), water contamination, and earth surface processes to public policy and resource management. Several presenters highlighted the negative effects of mining and reclamation measures on tribal communities (Bulltail and Walter 2020) and water insecurity among tribes in the Southwest (Ellis and Perry 2020) and beyond. A few presenters included the social context in water research such as Kozich et al. (2018). Presenters also demonstrated the success of hydrological research on tribal nations where university-tribal partnerships were honored, nurtured, and strengthened through the project (Tsinnajinnie et al. 2018; Tulley-Cordova et al. 2018). Presentations by elders placed technical work in the context of multiple tribal cultures (Ellis and Perry 2020). In addition to discussing ways to make hydrosience findings more

accessible and interpretable for the general public (e.g., to make our work operational), participants joined breakout groups and were challenged to bring Indigenous views and priorities concerning the interactions of land, air, and water into both scientific discourse and environmental decision-making. By asking questions such as, “how can the larger community of environmental scientists and practitioners benefit from Indigenous perspectives and experiences?,” participants looked beyond internal discussions among Indigenous scholars and practitioners toward establishing a greater presence of Indigenous knowledge in earth system science. Such a presence would help, for instance, reduce disparities in water quality and quantity on tribal lands (Conroy-Ben and Richard 2018; Conroy-Ben and Crowder 2020), which supply a disproportionately large share of freshwater supplies in the United States.

Toward this end, Symposium leaders authored papers in a Special Issue of the *Journal of Contemporary Water Research and Education* (JCWRE) published in April 2018 entitled “Emerging Voices of Tribal Perspectives in Water Resources” (<https://onlinelibrary.wiley.com/toc/1936704x/2018/163/1>). Authors also led sessions at national meetings, including the American Geophysical Union Fall Meeting in oral and poster sessions entitled “Native Science-Research to Action.” Symposium leaders challenged the scientific community to include Indigenous voices and perspectives in scholarly discourse regarding the environment.

This April 2020 Special Issue of *Journal of Contemporary Water Research & Education* entitled “Water in the Native World” was born through the 2018 NSF Symposium discussions and expanding network. This Special Issue sought out manuscript submissions that focus on water research on tribal lands and water challenges facing tribes including hydrology, water resources, water quality, climate change, water rights, traditional knowledge, cultural values, and environmental monitoring and analysis. The seven papers in this Special Issue cover surface and groundwater challenges facing tribes in the Southwestern United States, Montana, and Michigan. Topics include: 1) contaminants on tribal lands with examples from the Southwest and Montana; 2) cultural values of

water with examples from Hopi Tribe, Crow Tribe, and the Keweenaw Bay Indian Community (KBIC); and 3) climate change impacts on important tribal fishery. Four papers focused on water quality on tribal lands including Conroy-Ben and Crowder (2020) on emerging contaminants; Jones, Credo, Parnell, et al. (2020) on uranium and arsenic; Jones, Credo, Ingram, et al. (2020) on arsenic; and Bulltail and Walter (2020) on mine produced waters. Three papers focused on cultural values of water including Ellis and Perry (2020) who discuss a Hopi spring that is a sacred site; Martin et al. (2020) who write about the perspectives of Crow elders on water and climate change; and Kozich et al. (2020) who interviewed KBIC tribal members on their perspectives of tribal fisheries and combine these results with water temperature measured during a fish harvest to recommend fishery management policies.

The first paper in “Water in the Native World” is entitled “A confluence of anticolonial pathways for Indigenous sacred site protection” by Ellis and Perry (2020). This paper is a prime example of the need to have Indigenous perspectives in the discourse of water management and policy, particularly when Indigenous perspectives on water use, water rights, and water conservation are so different from Western perspectives. Ellis and Perry (2020) discuss the challenges facing the Hopi Tribe in advocating for the protection of a sacred site, *Sipapuni*, in the Western paradigms of water rights litigation and cultural resource management, particularly alongside the legacies of coal mining. *Sipapuni* is the place of emergence for the Hopi people and is a geologic dome created from the deposition of minerals at a spring along the Little Colorado River upstream from the Colorado River-Little Colorado River confluence. The Little Colorado River and *Sipapuni* are being impacted by water use from industrial and non-tribal interests within the Little Colorado River watershed. At this time, the Arizona court has denied Hopi rights to the Little Colorado River and to a water right for cultural waters because claims for *Sipapuni* were not quantified. The traditional cultural values of the Hopi do not fit into the Western water rights paradigm, but the Hopi are forced to operate within that system. The motivation for this research is driven by Black Mesa Trust whose Executive

Director, Vernon Masayesva, warns that *Sipapuni* is dying from decreasing water flows. Masayesva explains *Sipapuni* as the umbilical cord to the Colorado Plateau and the heartbeat of Mother Earth.

The second and third papers by Jones, Credo, Parnell, et al. (2020) and Jones, Credo, Ingram, et al. (2020) also focus on the Southwest and provide results on arsenic and uranium contaminants in water and its impact on tribal communities. On the Navajo Nation, approximately 30% of Navajo residents do not have access to running water and as a result, there is risk of Navajos resorting to non-potable water sources. In addition, the Navajo Nation has over 500 abandoned uranium mines and naturally occurring arsenic is found in water sources. Jones, Credo, Parnell, et al. (2020) published “Dissolved uranium and arsenic in unregulated groundwater sources - Western Navajo Nation.” Since 2003, they have sampled 82 unregulated wells on the western side of the Navajo Nation and tested for uranium and arsenic. The study area included seven of the 110 Navajo chapters. They compared uranium and arsenic concentrations to the Maximum Contaminant Level (MCL) for drinking water standards. Uranium and arsenic were primarily highest in the southwestern portion of the study area and corresponded to a region where there are many abandoned uranium mines. In addition, arsenic was also high in the Tuba City Chapter. They found that nine groundwater samples exceeded the uranium MCL and 14 exceeded the arsenic MCL. This study provided insight to areas on the Navajo Nation where groundwater sources may pose a health risk to Navajos as well as identified groundwater wells that could be considered for addition to the public drinking water systems. The authors demonstrated the importance of community engaged research in hydrological sciences where the Navajo community provided approvals for the authors to collect water samples and conduct research. Jones, Credo, Parnell, et al. (2020) also reported results back to the Navajo communities and engaged in data transparency.

The third paper entitled “Arsenic concentrations in ground and surface waters across Arizona including Native lands” by Jones, Credo, Ingram, et al. (2020) compiled online water quality databases

to understand visually arsenic concentrations in groundwater and surface water sources in Arizona, resulting in 33,000 water samples collected from 1990-2017. They found that 20.7% of water samples exceeded the arsenic MCL and in particular 40% exceeded arsenic MCL in Pinal and Yavapai counties. The public databases display a lack of water quality information on arsenic on tribal lands in Arizona particularly on Fort Apache, Navajo, Hopi, San Carlos Apache, and Tohono O'odham Nations. These maps are a tool for decision makers to address the water quality disparities and risks that exist across Arizona, particularly on tribal lands.

The fourth and fifth papers focus on water challenges facing a Montana tribe (the Crow Tribe). The fourth paper by Martin et al. (2020) entitled "Change rippling through our waters and culture" employs qualitative research to document traditional knowledge and observations of climate change impacts on the water, ecosystems, community health and well-being of the Crow Tribe in Montana. Crow Tribal elders were interviewed to identify key impacts based on life-long observations. The key determinants of health that Martin et al. (2020) found were cultural, social, economic, and environmental factors. The Crow elders described the deep impact of climate change on their community and despite these impacts, the resiliency of the tribe to maintain their culture and livelihood remains. Climate change is impacting tribes in unique ways due to their deep connection to water, land, and sacred places; therefore it is important to have tribal perspectives in studying climate change impacts to tribal waters.

The fifth paper by Bulltail and Walter (2020) focuses on investigating the impact of coal mining on surface water quality on and around the Crow Reservation. Their paper is entitled "Impacts of coal resource development on surface water quality in a multi-jurisdictional watershed in the western United States." At eight sites, 25 surface water samples were collected in September 2016 and cations and Sodium Adsorption Rates (SAR) were measured at a Montana commercial lab. The water quality results were compared to historical water quality data. Many tribes have an abundant source of natural resources and have been impacted by mining. Mining impacts exist today through legacy mining, and current mining and mining

exploration on tribal lands continue. Therefore, research such as that conducted by Bulltail and Walter (2020) is important to understand mining impacts on tribal waters and to protect tribal waters from contamination.

The sixth article by Conroy-Ben and Crowder (2020) is entitled "Unregulated and emerging contaminants in tribal water." Authors analyzed data from the Unregulated Contaminant Monitoring Rule (UCMR) for Tribal Public Water Systems (PWS). Emerging contaminants are contaminants of concern to health and the environment, but are not regulated. Endocrine disruptors found in wastewater treatment effluent have been found to change the sex of amphibians. However, emerging contaminants have not been widely studied on tribal lands until the Safe Drinking Water Act was amended with the UCMR requiring monitoring of 30 new contaminants every five years starting in 2001. As of 2019, four campaigns had been completed (UCMR1 to 4) and tribal lands were included. On tribal lands, metals, chlorate, and dioxane were detected in UCMR3 and some exceeded the Environmental Protection Agency's health reference limit (HRL). Considering that many tribal nations depend on water for their livelihood, and cultural and spiritual values, these emerging contaminants on tribal lands highlight emerging contaminants that should be considered for monitoring and water treatment on tribal lands. Less than 3% of tribal PWS were included in UCMR1-4. These results indicate the importance of including more tribes in the UCMR campaigns to assess the presence of emerging contaminants on tribal lands.

The final paper by Kozich et al. (2020) entitled "Walleye (*ogaawag*) spearing in the Portage Waterway, Michigan: Integrating mixed methodology for insight on an important tribal fishery" focuses on integrating science with tribal perspectives to recommend ways to improve the management of tribal fisheries in Michigan. For many federally recognized tribes, rights to hunting and fishing are protected through Indian treaties; however, different factors may impact the ability of tribes to protect their hunting and fishing rights such as climate change, pollution, drought, or off-reservation water use. In this paper, Kozich et al. combine water temperature measurements



made in the Portage Waterway in Michigan during walleye (*ogaawag*) harvest with a survey administered to the KBIC to recommend changes in fishery management for priority zones.

Community engagement and tribal driven research are critical and important in hydrological sciences. Research questions should be formulated by tribal communities and research is overseen by the tribe through designated tribal entities (Chief et al 2016). Helicopter research (Minasny et al. 2020), or research in which scientists dictate research with little to no engagement by tribal communities, is not welcomed by tribes. Research questions formulated by the tribes prevent reactive research where tribes are engaged as an afterthought or after scientists have obtained research grants. Engaging tribes from the beginning also ensures that the research being conducted is for the benefit of the tribe and not just conducted for research sake. Jones, Credo, Parnell, et al. (2020), Martin et al. (2020), and Kozich et al. (2020) are good examples of tribal engaged research where there is multi-lateral communication, reporting back, and oversight from the beginning of the research to dissemination of the results. The majority of Martin et al. (2020) are tribal members including tribal college and university partners, tribal community members, and tribal students. When research is conducted with tribes, it is important to acknowledge the contribution of tribal partners in co-authorship. The development and fostering of tribal partnerships are delicate and require the trust of tribes in the researchers. A strong university-tribal partnership not only involves transparency, on-going communication, and data sovereignty, but it also includes involving the tribe in the research either as co-authors or in the education and training of Indigenous students. Jones, Credo, Parnell, et al. (2020), Martin et al. (2020), and Kozich et al. (2020) demonstrated these aspects.

Indigenous hydroscintists play a key role in water research conducted on tribal lands. Jani C. Ingram, a Diné chemist and professor at Northern Arizona University in Flagstaff, AZ was a lead author in the first two papers (Jones, Credo, Parnell, et al. 2020; Jones, Credo, Ingram, et al. 2020). Dr. Ingram has conducted environmental health research on tribal lands for decades and has trained many Indigenous students in her lab, many

of whom have gone on to conduct environmental research on tribal lands. For example, one of her co-authors is Jonathan Credo, a Diné doctoral MD/PhD student in the Clinical Translational Sciences at the University of Arizona Medical School. Not only does Dr. Ingram's work have a profound impact on addressing water quality disparities on the Navajo Nation and other Southwestern tribes, but she has also forged a path for Indigenous youth and college students to be trained in her lab and do research related to their own tribal communities.

Another senior Indigenous scientist co-authoring a publication in this Special Issue is Dr. Julie A. Baldwin, a Regents' Professor in the Department of Health Sciences, the Director of the Center for Health Equity Research, and Lead Principal Investigator on the Southwest Health Equities Research Consortium at Northern Arizona University, in Flagstaff, AZ. As a citizen of the Cherokee Nation of Oklahoma, she has made a life-long commitment to serving diverse communities and to advocating for health promotion programs for children, adolescents, and families. Dr. Baldwin earned her doctorate in Behavioral Sciences and Health Education in 1991 from the Johns Hopkins University School of Hygiene and Public Health. For over 29 years, she has worked primarily with tribal communities throughout the U.S. to design culturally relevant health promotion programs for youth and families. Dr. Baldwin's research over the years has focused on both infectious and chronic disease prevention. Cross-cutting themes which have characterized her work include: utilizing community-based participatory research approaches, working with underserved and/or marginalized populations, and addressing health disparities by developing and implementing culturally-centered public health interventions.

In addition to senior Indigenous hydroscintists such as Dr. Jani Ingram, are up and coming Indigenous junior faculty. Two Indigenous assistant professors who contributed research on tribal water challenges in this Special Issue are Dr. Grace Bulltail (Crow) and Dr. Otakuye Conroy-Ben (Oglala Lakota). Dr. Bulltail recently joined the University of Wisconsin-Madison in 2019 as an assistant professor of Native American Environment, Health, and Community where she is interested in understanding the intersection of

watershed management and tribal sovereignty and has investigated oil and gas extraction on water quality and watershed management. Dr. Bulltail is a member of the Crow Tribe and a descendant of the Mandan, Hidatsa, and Arikara Tribes of Fort Berthold, North Dakota. In her new role at the University of Wisconsin-Madison, Bulltail hopes to continue researching water policy while focusing on transboundary watersheds and the land tenure challenges present in Wisconsin.

Dr. Conroy-Ben has been in academia for nearly 10 years, including as a post-doctorate at the University of Arizona in 2007 and as an assistant professor at the University of Utah. She is now at Arizona State University in the School of Sustainable Engineering and the Built Environment. Dr. Conroy-Ben is the only Native American professor in a tenure track position in environmental engineering. Her research focuses on the biological effects of polluted water, environmental endocrine disruption, metal and antibiotic resistance in bacteria, and wastewater epidemiology. Her work is important to tribes as her article Conroy-Ben and Crowder (2020) demonstrates that tribes manage their water and wastewater. In addition, tribes that rely on fish like KBIC may become more concerned with how wastewater effluent impacts their fish.

There is a great need to increase the number of Indigenous students in the hydrosociences. Therefore it is imperative to provide opportunities for Indigenous students to be involved in water-related research facing tribes and their communities (Jones, Credo, Ingram, et al. 2020; Jones, Credo, Parnell, et al. 2020). Martin et al. (2020) and Kozich et al. (2020) demonstrate the involvement of Indigenous students in tribal water research. Indigenous students are passionate about giving back to their communities and doing research in their communities hence providing valuable opportunities for them to participate in important water research.

With 573 federally recognized tribes in the United States with diverse cultural and spiritual water practices (Federal Register 2019), Indigenous perspectives contribute diverse knowledge and unique problem-solving approaches. With recent events like Dakota Access Pipeline (DAPL) at Standing Rock Indian Reservation, Gold King

Mine Spill impacting the Navajo Nation and Ute Mountain Ute Tribes, and the Intertribal Coalition to designate Bears Ears National Monument to protect sacred and cultural lands, and a range of other water and environmental challenges facing Indigenous peoples, it is even more critical to engage Indigenous perspectives in water topics and challenges using ethical protocols, mutual understanding, and respect.

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