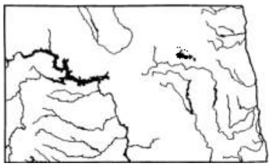
2020-2021

North Dakota Water Resources Research Institute

North Dakota State University, Fargo, ND 58108-6050



Newsletter

The National Institutes for Water Resources

https://www.ndsu.edu/wrri/

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From the Director

Welcome to the 2020-2021 issue of North Dakota Water Resources Research Institute (NDWRRI) Newsletter. This newsletter introduces the fourteen 2021-2022 NDWRRI Fellows and highlights the nineteen 2020-2021 graduate fellowship research projects and the related findings and accomplishments achieved by the Fellows and their advisors. This issue features one Institute affiliate faculty, Dr. Syeed Iskander, Assistant Professor in the Department of Civil, Construction and Environmental Engineering at NDSU, in the section of "Meet Our Faculty." Other sections include the information on the NDWRRI State Advisory Committee, 2022 North Dakota Water Quality Monitoring Conference, and the awards the Institute Fellows received. The last section lists the recent publications and presentations by the Institute Fellows and their advisors, the Fellows' theses and dissertations, as well as recent USGS ND-related publications and ND Department of Water Resources reports and publications.

As the Director of the Institute, I would like to gratefully acknowledge the supplemental support for the graduate research fellowship program from the ND Department of Water Resources, in addition to the federal 104b base funds. This is the last Newsletter in my 4-year term as the Director (2018-2022). Since 2018, NDWRRI has funded 60 research projects through its graduate research fellowship program. The NDWRRI Fellows and their faculty advisors from both NDSU and UND have been actively involved in their research projects, published their research findings in peer-reviewed journals, and presented at the international/national/regional conferences. I have had opportunities to work with them and observe their accomplishments in these NDWRRI-funded projects. Particularly, it has been my great pleasure to see that so many NDWWRI Fellows successfully received their Ph.D. and M.S degrees from a variety of graduate programs at NDSU and UND. I greatly appreciate the support for my NDWRRI work from both NDSU and UND, as well as USGS Dakota Water Science Center and state government agencies, ND Department of Water Resources (DWR) and ND Department of Environmental Quality (DEQ). Special thanks to our State Advisory Committee members, including Joel Galloway and Steve Robinson (USGS), Andrew Nygren (ND DWR), and Peter Wax (ND DEQ) for their guidance on the Institute's research priorities and graduate research fellowship program that contributes to the success of the Institute. Finally, thanks to Linda Charlton Gunderson for her contributions to the Institute throughout my 4-year period.

Best wishes to the future of NDWRRI.

Xuefeng (Michael) Chu, Ph.D.
Professor, Civil, Construction and Environmental Engineering
North Dakota State University

The Institute Awarded Fourteen Graduate Fellowships for Year 2021-2022

The North Dakota Water Resources Research Institute announced its Graduate Research Fellowship recipients for the year 2021-2022. The fellowships were awarded to fourteen graduate students, including twelve Ph.D. and two M.S. students, who will conduct water resources research at NDSU and UND. These fourteen graduate research projects are supported with the annual base (104b) federal grant and an additional fund from North Dakota State Water Commission. The 2021-2022 NDWRRI Fellows, and their faculty advisors, academic programs, and research projects are listed as follows:

Fellow: Ali Alinezhad (Ph.D. student) **Advisor:** Dr. Feng 'Frank' Xiao
Program: Civil Engineering, University of North Dakota
Title: Remediation of PFAS-contaminated Soils to Protect Groundwater

Fellow: Berkay Koyuncu (Ph.D. student) **Advisor:** Dr. Trung Bao Le
Program: Civil & Environmental Engineering, North Dakota State University
Title: Dynamics of flows under ice-coverage in the Red River

Fellow: Christine Cornish (Ph.D. student) **Advisor:** Dr. Jon Sweetman
Program: Biological Sciences/Environmental & Conservation Sciences, North Dakota State University
Title: Does wetland restoration affect the accumulation of glyphosate?

Fellow: Justin Waraniak (Ph.D. student) **Advisor:** Dr. Craig Stockwell
Program: Biological Sciences/Environmental & Conservation Sciences, North Dakota State University
Title: Assessment of agricultural impact on biotic components of North Dakota wetland resources using habitat suitability landscape genomics of amphibians

Fellow: David Khani (Ph.D. student) **Advisor:** Dr. Yeo Howe Lim
Program: Civil Engineering, University of North Dakota
Title: A novel numerical model for transient mixed flow analysis in sewer pipes

Fellow: Franklin Odili (M.S. student) **Advisor:** Dr. Halis Simsek
Program: Agricultural & Biosystems Engineering/Environmental & Conservation Science, North Dakota State University
Title: Impact of groundwater tables on the water use, yield, root growth distribution and quality of spring wheat (Triticum aestivum)

Fellow: James Sullivan (M.S. student) **Advisor:** Dr. Yeo Howe Lim
Program: Civil Engineering, University of North Dakota
Title: Use of LIDAR and synthetic bathymetry to develop stream cross sections for alternative modeling of streamflow in North Dakota using HEC-RAS: A case study on the Tongue River

Fellow: Kui Hu (Ph.D. student) **Advisor:** Dr. Jon Sweetman
Program: Biological Sciences/Environmental & Conservation Sciences, North Dakota State University
Title: Understanding the impacts of hydrology on seasonal and spatial water chemistry changes in two adjacent prairie potholes in North Dakota using stable isotopes

Fellow: Mansurat Golden Abdulmalik Ali (Ph.D. student) **Advisor:** Dr. Feng "Frank" Xiao
Program: Civil Engineering, University of North Dakota
Title: Fate and transport of microplastics in the natural environment

Fellow: Mohammad Hadi Bazrkar (Ph.D. student) **Advisor:** Dr. Xuefeng Chu
Program: Civil & Environmental Engineering, North Dakota State University
Title: Drought identification, categorization, and prediction in cold climate regions

Fellow: Pavankumar Challa Sasi (Ph.D. student) **Advisor:** Dr. Feng "Frank" Xiao
Program: Civil Engineering, University of North Dakota
Title: Thermal stability of per- and polyfluoroalkyl substances and the impact on the aquatic environment

Fellow: Shashi Bhushan (Ph.D. student) **Advisor:** Dr. Halis Simsek
Program: Agricultural and Biosystems Engineering, North Dakota State University
Title: Fabrication of a tailor-made surface for microalgal biofilm mediated nutrient removal from municipal wastewater

The Institute Awarded Fourteen Graduate Fellowships for Year 2021-2022

Fellow: Uday Bhanu Prakash Vaddevolu (Ph.D. student) **Advisor:** Dr. Xinhua Jia
Program: Agricultural & Biosystems Engineering, North Dakota State University
Title: Simulation of soil water dynamics for drip-mulch fields using Hydrus-2D

Fellow: Vida Atashi (Ph.D. student) **Advisor:** Dr. Yeo Howe Lim
Program: Civil Engineering, University of North Dakota
Title: Hydraulic and hydrologic routing parameters in natural channels in North Dakota under snowmelt-induced flooding conditions

2020 — 2021 NDWRRI Fellowship Research Highlights

Red Lake River and Red River Raw Water Quality Investigation

***Zachary Ranisate** (Fellow) & **Dr. Feng Xiao** (Advisor), University of North Dakota*

The City of Grand Forks, ND has built a new drinking-water treatment plant that treats surface water from the Red River and the Red Lake River by two systems. In one of the systems, conventional processes are used. Another system consists of membrane filtration technologies, including ultrafiltration and reverse osmosis. The pretreatment of membrane filtration is a coagulation/flocculation process. However, our preliminary data show that total organic carbon (TOC) after conventional/enhanced coagulation is still greater than 3.5 mg/L, which appears to be too high for membrane filtration. In addition, removal of TOC from water prior to chlorine disinfection is able to reduce the formation of cariogenic disinfection byproducts. In this project, we identified the major sources of TOC in the Red River and the Red Lake River in order to reduce the input of TOC to the drinking-water treatment plant, mitigate the organic fouling of membranes, and reduce the formation of disinfection byproducts. The results can potentially lead to the reduction of TOC and disinfection byproducts in drinking water of this city.

Imprinting and Hydromulch for Soil Erosion Reduction and Plant Establishment in Semi-arid Soils Disturbed from Oil and Gas Development

***Zachary Bartsch** (Fellow) & **Dr. Tom DeSutter and Dr. Miranda Meehan** (Advisors), North Dakota State University*

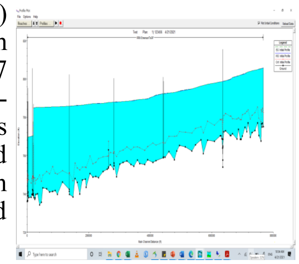
Energy development and construction, specifically construction of natural gas pipelines, has expanded across western North Dakota within the Williston Basin (Bakken and Three Forks formations). This expansion challenges reclamation when vegetative plant establishment is limited post-installation. Limited vegetation establishment increases soil erosion and water runoff, and provides an environment with the potential to allow invasive plant species to encroach, resulting in numerous, expensive attempts of reseeding right-of-ways. This study examines five seed-preparation methods near Williston, ND, and their effects on water runoff, sediment loss, and vegetation establishment under rainfall simulation during a severe drought in a semi-arid climate. The treatments used in this study were wood-fiber hydromulch, land imprinting, wheat-straw crimping, the combination of hydromulch and imprinting, and bare ground (control), all on 2% and 5% slopes within the same catena. Rainfall simulations were completed in September 2020, and again in June 2021 to examine the treatments over time. Crimping straw, one of the most economical options, was the only treatment that reduced runoff long-term with an equivalent depth of 0.7 cm of water, compared to 1.8 cm of water for the control. However, hydromulch and imprinting with hydromulch were the only treatments that reduced sediment load over both simulations, reducing erosion by over 58% when compared to the control. Plant establishment was not significant for any treatment, likely due to the severe drought conditions. Cover is necessary in times of drought when plants fail to establish, with straw crimping being the best option during an extended drought.

2020 — 2021 NDWRRI Fellowship Research Highlights

Hydraulic and Hydrologic Routing Parameters in Natural Channels in North Dakota under Spring Snowmelt Conditions

__Vida Atashi__ (Fellow) & __Dr. Yeo Howe Lim__ (Advisor), University of North Dakota

Hydrological processes related to snow occur in large regions on earth including North Dakota where runoff triggered by snowmelt is an important annual event. The Muskingum model is one of the most popular models for hydrologic channel flood routing. Despite the simplicity of the Muskingum equation, the parameters of this equation have not been calibrated for streams in North Dakota using actual flow hydrographs due to the lack of pair-wise gauging sites along streams. In this research, the parameters of the Muskingum model were identified by using the basin characteristics representing the inlet and outlet of the channel reach for two stations in the Pembina River, North Dakota (Walhalla and Neche) and two stations in the Red River (Grand Forks and Emerson). The Muskingum flood routing method was applied to three flood events in 2009, 2011, and 2017 for the Pembina River. Further work will be conducted to investigate other reaches in the region. To achieve the goal, the coefficients of x and K as outcomes from HEC-RAS were determined. The result showed that the coefficient of x of the Muskingum method had values close to zero for the Red River Basin during spring melting season, which was consistent with the results for streams with wide flood plains. The coefficient of K of the Muskingum method was found to be 24.26, 20.8, and 34.126 for the events in 2009, 2011, and 2017, respectively.



Automatic Sensor-controlled Drip Irrigation under Mulches for Tomato and Watermelon Productions

__Uday Bhanu Prakash Vaddevolu__ (Fellow) & __Dr. Xinhua Jia__ (Advisor), North Dakota State University

Irrigation is one of the most important factors in agriculture. Irrigation scheduling determines the time and the amount of water supply, which is based on crop water use or soil moisture status. Therefore, the irrigation water can be applied using an irrigation controller, which is a device to operate irrigation automatically. In this study, a soil water potential sensor based controller was used to manage the drip irrigation system automatically in a two-year field experiment. Watermelon and tomato productions using the automatic drip irrigation system under black plastic, clear plastic, and landscape fabric mulch along with no mulch were tested in Fargo, ND. During the field experiments, the irrigation system was tested at threshold 4 (approximately -25 centibars) under different mulches. The results showed that the tomato yield from irrigation under black plastic mulch had the highest yield compared to the other regimes, whereas the drip irrigation under clear plastic mulch for watermelons had the best yield and quality.

Impact of Subsurface Drainage and Subirrigation on Water Quality in Richland County, North Dakota

__Kristen Almen__ (Fellow) & __Dr. Xinhua Jia__ (Advisor), North Dakota State University

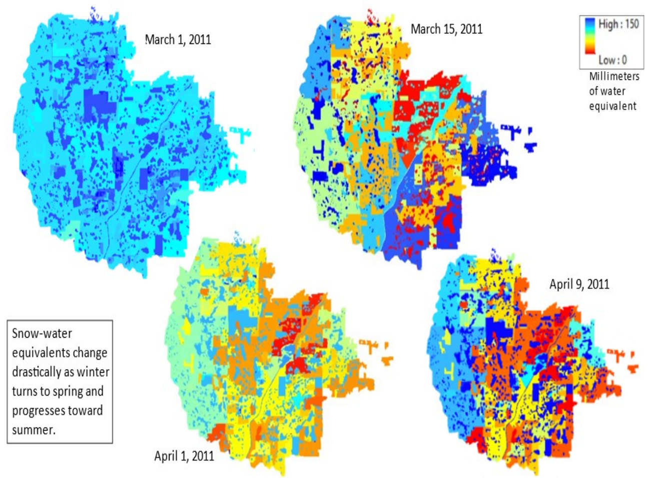
Drainage water management via controlled drainage (CD) and subirrigation (SI) has shown positive effects on water quality. To determine the impact of CD and SI in the Red River Valley (RRV), water samples from two fields, each with CD and SI, were analyzed. A decreasing trend in overall nutrient load loss was observed due to reduced drainage flow via drainage water management. However, few chemical concentrations (e.g. sulfate) were above the recommended surface water quality standards during spring free drainage (FD) period, which was caused by the soil chemistry in this region. The water quality during the SI periods was significantly different from that during the CD and FD periods, likely due to the SI water source of marginal quality, which also impacted soil quality near the drain tile. Overall, the CD and SI reduced the nutrient loss and benefited the agricultural fields.

2020 — 2021 NDWRRI Fellowship Research Highlights

Hydrological Changes Due to Recent Wetting in a Cold Region Riverine Headwaters Environment

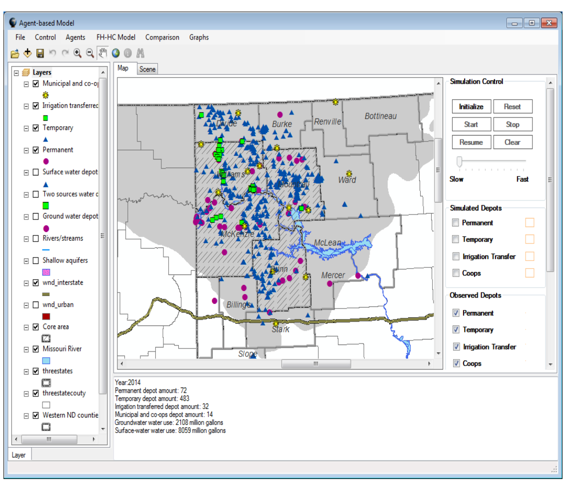
Stevie Holmes *(Fellow) &* ***Dr. Taufique Mehmood*** *(Advisor), University of North Dakota*

Gradual increases in precipitation in the headwaters of the Sheyenne River above Harvey, ND have led to changes in previously observed patterns of snow accumulation, timing of peak snow-water equivalent and melt, duration of snow cover period, snowmelt runoff, streamflow generation mechanism, frozen vs. unfrozen soil conditions, and infiltration capacity. The use of a physically-based model in the Cold Regions Hydrologic Model (CRHM) platform helps to understand the impacts of this climatic shift on hydrologic processes in space and time. Intensive data collection was conducted for the CRHM model, including weather and climate data, elevation, soil type, land use and land cover maps, and division of the entire watershed into over 1,000 hydrologic response units (HRUs). The model setup has also incorporated more robust sources of data, such as IMERG precipitation data and USGS streamflow data at hourly resolution. Verification of the model's initial conditions is ongoing, in particular to confirm the depressional storage within the basin so that fill-and-spill hydrology processes are accurately reflected in the model results. Periods of regional wet and dry cycles on the order of 3-4 years are generally well defined for the Red River of the North contributing area, and further refinement of the individual contributing watersheds appears possible with more vigorous analysis of higher-quality data sources. Preliminary results indicate a strong influence of fill-spill hydrology and variable contributing area on snowmelt streamflow generation during the deluge years.

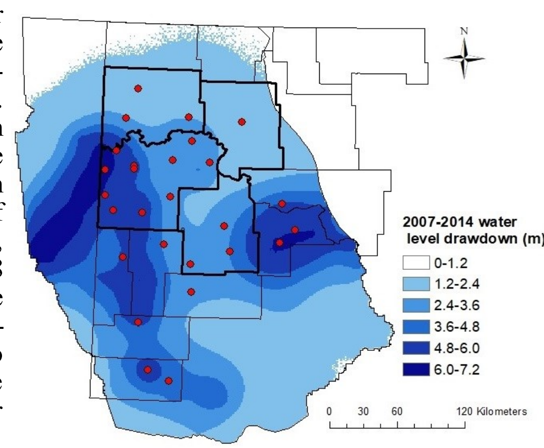


Using Coupled Human and Natural Systems for Water Resources Management in the Bakken Region of Western North Dakota

Tong Lin *(Fellow) &* ***Dr. Zhulu Lin*** *(Advisor), North Dakota State University*



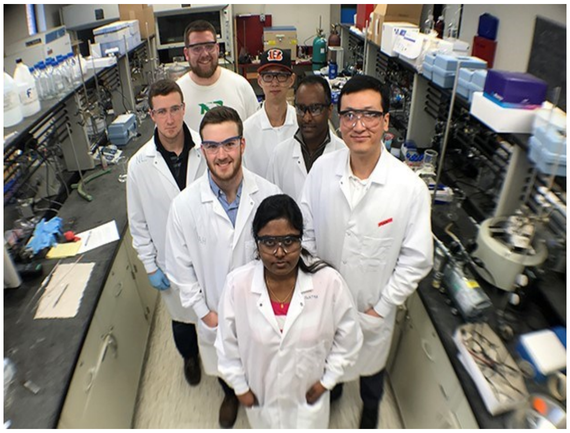
Previously, we developed a SWAT model for the Little Muddy River and coupled it with our agent-based model under different climate, population growth, water demand, and policy scenarios. To further investigate the impact of hydraulic fracturing (HF) water use on regional groundwater, we loosely coupled an agent-based model with a developed MODFLOW groundwater model. The coupled models were designed to simulate the groundwater level changes of the Fox Hill-Hell Creek aquifer under fourteen scenarios, including HF water demand increase, precipitation decrease, population increase, and policy change scenarios. The results showed that the hydraulic fracturing water demand scenarios, the population increase scenarios, the precipitation scenarios, and two policy change scenarios did not cause any changes in the groundwater drawdown because of the industrial water use restriction policy on the aquifer. However, had this restriction policy been removed, the average groundwater level in the Fox Hill-Hell Creek aquifer would have decreased by 65%. The number of agents withdrawing water from this aquifer would have increased from 5 to 27, and the amount of water use would have increased from 962 acre-feet to 14,358 acre-feet between 2007 and 2014. The largest water-level drawdown would have occurred in the western and southeastern regions, the outskirts of the core four-county area. The coupled agent-based SWAT and groundwater models are able to identify the HF water impact on regional water resources, and help understand the impact of the increasing hydraulic fracturing water use on regional sources under different conditions.



2020 — 2021 NDWRRI Fellowship Research Highlights

Soil Amendment for Reducing the Runoff of Nutrients from Agricultural Lands

Swetha Mallula *(Fellow) &* ***Dr. Feng Xiao*** *(Advisor), University of North Dakota*



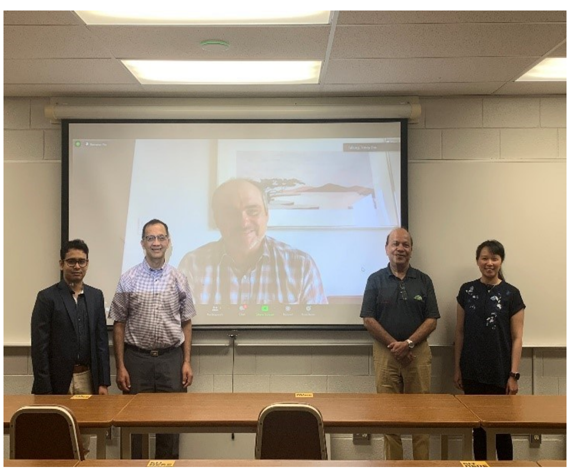
The runoff of nitrogen (N) and phosphorus (P) from agricultural lands is responsible for 40% of the impaired lake/river area in the U.S. Loss of N and P from agricultural lands applied with conventional fertilizers not only wastes the State billions of dollars every year, but also results in negative agronomic and environmental consequences including decreased crop profitability, water impairment, and potential impacts on climate change. In this project, we developed a novel carbonaceous bio-soil amendment (CSA) from biomass (renewable) resources to retain nutrients and act as a controlled-release form of N and P. The substrate is bio-char made by pyrolysis of biomass materials, such as crop residue and agricultural waste materials, at moderate temperature and under limited oxygen supply. The CSA was produced optimally binding phosphate, ammonium and metal cations (i.e., magnesium (Mg) or calcium (Ca)) on the surface of bio-char. Consistent with our hypotheses, we found that nano-crystallites of struvite ($MgNH_4PO_4$) and calcium ammonium phosphate ($CaNH_4PO_4$) precipitates are deposited on surfaces and in pores of char; and such precipitates were sparingly soluble and acted as controlled-release supplies of N and P. The results of this project may promote innovation and result in the development of the next-generation soil conditioner–fertilizer compost by sustainably utilizing the biomass materials that are abundant in the Midwest.

Muffle furnace

Corn waste materials

Fabrication of Point of Use Treatment Systems for Aqueous Arsenic and their Evaluation

Tonoy K Das *(Fellow) &* ***Dr. Achintya N Bezbaruah*** *(Advisor), North Dakota State University*



Drinking water arsenic contamination affects more than 250 million global population and turns into a significant public health concern due to arsenic carcinogenicity and genotoxicity. Low iron use efficiency and slow reaction kinetics of iron-based adsorbents make it ineffective for field application despite its low cost and easy availability. In this work, we developed a novel graphene-oxide iron-nanohybrid (GFeN) with high adsorption capacity (306/431 mg/g for As (III)/As(V)) and quick reaction kinetics for aqueous arsenic removal. The nanohybrids showed significantly better arsenic removal performances than the conventional iron nanoparticles in a wide range of pH, temperature, and presence of co-existing ions. The graphene oxide sheet in GFeN played an essential role in enhancing iron use efficiency and stabilizing the adsorbed arsenic through active electron transfer between the graphene oxide layer and iron nano interface. Our two-year batch desorption data indicates that adsorbed arsenic remains stable with a ~ 5.73% desorption of adsorbed phase arsenic. Powdered GFeN has some operational challenges in point-of-use treatment systems like the movement of nanomaterial through the filter bed and potential clogging. GFeN is entrapped into a polyether sulfone matrix for ease of field application. Cellulose nanofiber was also used in polymer bead formation to enhance the beads' internal porosity, which improved arsenic removal by 15-40%. Further, economic feasibility, application viability, and stakeholder acceptability of the technology should be evaluated. This research provides fundamental understanding of reliable and safe nano-based safe materials for aqueous arsenic removal and elucidates the mechanisms in the arsenic removal process.

2020 — 2021 NDWRRI Fellowship Research Highlights

Flood and Bathymetry Alteration Simulations Under Ice-Coverage in Red River

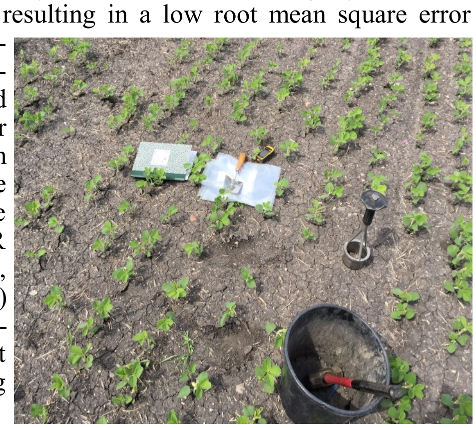
***Berkay Koyuncu** (Fellow) & **Trung Bao Le** (Advisor), North Dakota State University*

This study investigates the impacts of ice on hydrodynamics of meandering rivers. The existence of ice cover complicates the entire flow structure, including secondary flow patterns and shear velocity distribution. Many measurements are conducted throughout this study to examine the flow structures of the Red River in North Dakota. The digital terrain map is reconstructed by LiDAR and Acoustic Doppler Current Profiler data acquired using moving-vessel and stationary deployment technique. Stationary deployment technique is used to collect vertical velocity profiles at more than 120 fixed stations under open surface and ice-covered conditions. Datasets are processed to identify the logarithmic layers and shear velocity distribution by employing the best-fitting method. Extension of the logarithmic layer near the riverbed under ice-covered condition is found to be limited in comparison to the open surface case. Afterwards, secondary flow patterns are visualized and circulations are located accordingly. Results show that the secondary flow patterns under ice-covered condition are drastically different from those under the open surface condition. More significantly, it is observed that the position of the main circulations is shifted towards the outer bank, which weakens the circulation strength. This phenomenon is crucial in addressing sediment transport and erosion risks. The same vertical profiles are processed by using quartic solution to evaluate the shear velocity distributions in ice-covered case. Results suggest that the shear velocity is significantly low under ice coverage near the outer bank. The ice coverage contributes significantly to the transition of flow dynamics, which occur during fall-winter and winter-spring periods.

Soil Moisture Mapping Using Landsat Data in a Frigid Glaciolacustrine Landscape with Agricultural Production

***Umesh Acharya** (Fellow) & **Dr. Aaron L. M. Daigh** (Advisor), North Dakota State University*

Weather stations provide key information related to soil moisture and have been used by farmers to decide various field operations. We first evaluated the discrepancies in soil moisture between a weather station and nearby field due to soil texture, crop residue cover, crop type, growth stage and duration of temporal dependency to recent rainfall and evaporation rates using regression analysis. The analysis showed a strong relationship between soil moisture at the weather station and the nearby field at the late vegetative and early reproductive stages. The correlation thereafter declined at later growth stages for corn and wheat. The regression coefficient of soil moisture with four-day cumulative rainfall slightly increased with an increase in the crop residue resulting in a low root mean square error (RMSE). We compared different machine learning models and found Random Forest Regression and Boosted Regression Trees performed best over others (RMSE = 0.045 and 0.048 m^3 m^{-3}, respectively). We then evaluated the integration of weather station data, (RFR) machine learning, and remotely sensed satellite imagery to predict soil moisture in nearby fields. Soil moisture predicted with an RFR algorithm using OPtical TRApezoidal Model (OPTRAM) moisture values, rainfall, standardized precipitation index, and percent clay showed high goodness of fit ($r^2 = 0.69$) and low RMSE (0.053 m^3 m^{-3}). This research shows that the integration of weather station data, machine learning, and remote sensing tools can be used to effectively predict soil moisture in the Red River Valley of the North among a large diversity of cropping systems.



2020 — 2021 NDWRRI Fellowship Research Highlights

Rejuvenation of Urban Streams in Cold Climate Regions Using Hydroponic Systems: A Case Study on English Coulee in Grand Forks, North Dakota

Mike Rosati *(Fellow) &* ***Yeo Howe Lim*** *(Advisor), University of North Dakota*

The primary objective of this project was to determine the effectiveness of a Floating Treatment Wetland (FTW) system, specifically in the case of the English Coulee in Grand Forks, ND. Over the course of this experiment, two pilot scale FTW systems were set up in the coulee and monitored over the period from May to September in 2021. This study primarily examined nitrate and phosphate levels as a measure of performance by the FTWs. Data was also collected on how the plants responded to environmental conditions in the cold weather region of North Dakota. The data collected helped determine the optimal plant species for a theoretical full-scale system as well as the removal efficiency of that system. The study identified Juncus effusus and Leersia oryzoides as optimal candidates for full scale design showing the highest survival and growth rates. At this stage, little to no difference in upstream nutrient concentrations was observed, which is due to the small size and unestablished root systems. With each successive growing season, the roots become more established, and the plants can grow to larger sizes, improving the FTW efficiency. As these plants continue to grow in next season, growth rate and nutrient removal will continue to be monitored to help better understand the impact of this system and the potential for a full-scale design. Thus, more effort and data collection are needed.

Influence of Habitat Characteristics on Amphibian Stress and Reproductive Success in North Dakota

Rebecca Jones-Bradley *(Fellow) &* ***Dr. Matthew Smith*** *(Advisor), North Dakota State University*

Assessments of habitat suitability provide a necessary framework to guide conservation decisions. This is particularly true for amphibians, as they are experiencing unprecedented population declines and extinction events. Northern Leopard frogs (Lithobates pipiens) are no exception, as they have been observed declining in the central and eastern regions of North America. Large portions of diverse wetlands across the State of North Dakota are being lost to agriculture at unprecedented rates and as a result, habitat for anurans is declining. Larval and visual encounter surveys were conducted to distinguish the essential habitat characteristics that are crucial during each stage of amphibian reproduction. This study found that surrounding developed area impacts larval suitability of a habitat and stress levels. Additionally, there was a near significant positive relationship with variance in phosphate and corticosterone levels. It would be interesting to see if this relationship were to increase with a larger sample size. This research provides an updated suitability model, baseline levels of corticosterone and white cell profiles for a native anuran species, and reference wetland habitat/water characteristic data for Wildlife Management Areas (WMAs) in North Dakota.

Understanding Intra-lake Seasonal and Spatial Variability in Shallow Prairie Lake Diatom Communities: Implications for Paleolimnological Studies

Kui Hu *(Fellow) &* ***Dr. Jon N. Sweetman*** *(Advisor), North Dakota State University*

Prairie-pothole wetlands are an important freshwater resource in the Northern Great Plains and play a significant role in providing vital ecosystem services. However, the high variability of regional climate and complex hydrology can make it difficult to effectively manage these systems. To better understand the hydrologic influences on water chemistry of prairie-pothole wetlands, we examined the water chemistry of two adjacent, but hydrologically contrasting prairie-pothole wetlands in the Cottonwood Lake Study Area, North Dakota. Wetland P1, a closed-basin wetland, appeared to be more susceptible to precipitation-driven variability in water levels compared to Wetland P8, which had a natural outlet that limited the maximum water depths during periods of high precipitation. Our results showed that water isotopic signals ($\delta^{18}O$, $\delta^{2}H$) were depleted in both study wetlands during the wetter year, which likely resulted from increased snow melt or direct precipitation inputs. Nutrient concentrations in both wetlands responded mostly to precipitation amounts, while major ions concentrations were more closely related to topographic influences on hydrology; the closed-basin wetland possessed higher concentrations of major ions than the open-basin wetland. These differences were likely due to an increased pond periphery in the closed-basin wetland that provided more ionic movement from shallow groundwater into the wetland and losses of ions through the outlet of the open-basin wetland during the wet period. Our results highlight the importance of considering spatial variability, such as basin topographic features when managing prairie-pothole wetlands.

2020 — 2021 NDWRRI Fellowship Research Highlights

Assessment of Agricultural Impact on Biotic Components of North Dakota Wetland Resources Using Habitat Suitability and Landscape Genomics of Amphibians

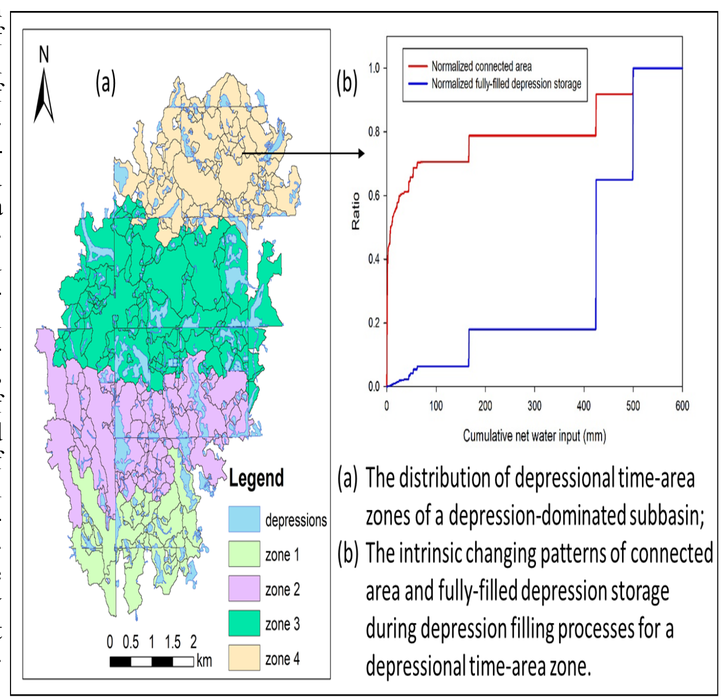
Justin Waraniak *(Fellow) &* ***Dr. Craig Stockwell and Dr. David Mushet*** *(Advisor), North Dakota State University*

Connectivity analyses using landscape genetic data from northern leopard frog (Rana pipiens) populations were completed, which provided insights into land use and other landscape feature impacts on the fragmentation of populations. The best landscape resistance models explaining genetic distance among R. pipiens populations sampled in the James River and Lake Oahe basins identified land use and topography as the most important variables influencing connectivity. Open water (primarily large lakes and the Missouri River), high intensity urban areas (Jamestown and Bismarck), and wetlands impeded gene flow, whereas cropland had moderately high resistance but was still somewhat permeable. Pasture and grassland consistently had the lowest resistances and were the most important land uses maintaining connectivity. Topographic roughness was also an important landscape variable; gene flow occurred primarily over flat land while areas with steep slope impeded movements. There were no apparent effects of habitat fragmentation on genetic diversity or population structure of R. pipiens in the study area. No inbreeding-coefficient estimates were significantly greater than 0 and measures of genetic diversity were not related to amount of nearby agriculture. There was weak spatial structure among the sample sites, suggesting high gene-flow levels historically throughout the study area. This research shows how land use is influencing functional biotic connectivity of wetlands in the Prairie Pothole Region. Conversion of grassland and pasture to cropland increases the risk of habitat fragmentation for amphibians. Additionally, output from the landscape resistance models can be used to help managers identify areas important for maintaining or restoring connectivity.

Development of a New Depression-oriented Watershed Hydrologic Model and Its Application in North Dakota

Lan Zeng *(Fellow) &* ***Dr. Xuefeng Chu*** *(Advisor), North Dakota State University*

In this project, a new depression-oriented watershed-scale hydrologic model was developed to simulate the influence of depressions on surface runoff generation and propagation processes. In the model, a subbasin is divided into many depressional time-area zones to quantify the spatially distributed depression storages. For each depressional time-area zone, the intrinsic changing patterns of depression storage and connected areas during the depression filling processes were identified, based on which the formation of connected areas and generation of surface runoff during real rainfall events were simulated. Then, based on the depressional time-area zone scheme, the outlet contributing area was determined and the surface runoff generated from each depressional time-area zone was routed to the subbasin outlet. The likelihood of occurrence of outlet CA and runoff contributions was also quantified by using a joint probability distribution associated with depression storages and their spatial distribution. The developed model was applied to the upper portion of the Sheyenne River Watershed in the Prairie Pothole Region of North Dakota. Results demonstrated the model capabilities in tracking the formation of outlet contributing area and simulating the depression-influenced surface runoff processes, which highlighted the important roles of depressions. Without considering depression storages, a model would overestimate outlet contributing area and runoff contribution to the subbasin outlet. Without considering the spatial distribution of depression storages, a model would fail to track the outlet contributing area and characterize the timing and quantity of runoff contributions. The new model developed in this project can also be used to estimate the probability of occurrence of outlet discharges under rainfall events with different return periods.

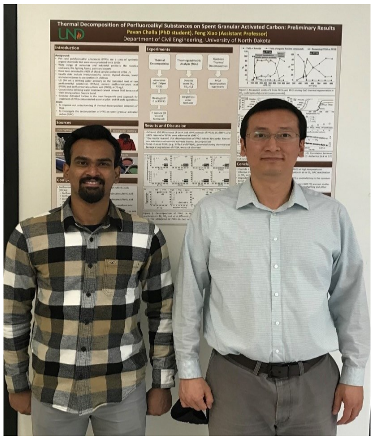


(a) The distribution of depressional time-area zones of a depression-dominated subbasin;
(b) The intrinsic changing patterns of connected area and fully-filled depression storage during depression filling processes for a depressional time-area zone.

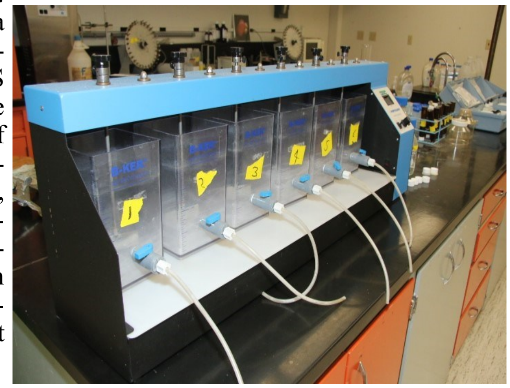
2020 — 2021 NDWRRI Fellowship Research Highlights

Effectively and Practically Remove Per- and Polyfluoroalkyl Substances from Landfill Leachate and Groundwater

Pavankumar Challa Sasi *(Fellow) &* ***Dr. Feng Xiao*** *(Advisor), University of North Dakota*



Poly- and perfluoroalkyl substances (PFAS) are a large group of organic contaminants that have been detected nationally in the aquatic environment. Two PFAS compounds, perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), have been observed in > 95% of the blood samples collected during multiple U.S. national surveys at health-relevant concentrations. Contaminated drinking water is a major source exposure to PFAS for the general public. The U.S. EPA has recently set a drinking water advisory on the combined level of PFOA and PFOS at 0.070 µg/L, making removal of PFAS from drinking-water sources a priority issue. The goal of this project is to develop an innovative treatment system that can effectively and practically remove PFAS from landfill leachate and groundwater.



The leachate samples were pretreated to simulate a typical wastewater treatment setup using flocculation/coagulation and ozonation. The fate of PFAS throughout the entire process was identified. We also performed experiments on the adsorption of PFAS using various commercially available granular activated carbon (GAC) samples using DI water, surface water, and leachate. We tested the decomposition of PFAS using thermal treatment techniques discussed in our previous publications on leachate samples. The results of this project have important implications for technological improvements in water purification. Water treatment plants, the water industry, water resources personnel, and the broader education and research communities who are concerned about PFAS contamination would benefit from the results of this project.

Does Wetland Restoration Affect the Accumulation of Glyphosate?

Christine Cornish *(Fellow) &* ***Dr. Jon Sweetman*** *(Advisor), North Dakota State University*

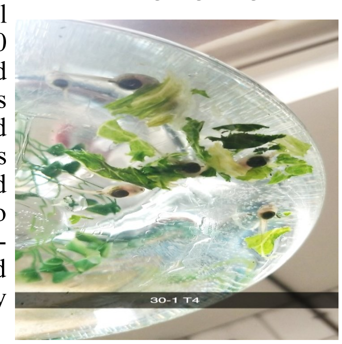
In the Prairie Pothole Region, wetland restoration is an important remediation tool. However, more information is needed on how its efforts impact agrochemicals and microbial succession, which play crucial roles in ecosystem functioning. This project is investigating relationships between wetland restoration, common use herbicides, and microorganisms. Having a better understanding on wetland succession post-restoration could broaden future conservation mechanisms. In July 2020, surface sediment (~1-2 cm) was sampled from 20 wetlands in North Dakota (5 replicates each wetland, n = 100), where 15 wetlands were restored and 5 were natural. Replicates were composited to yield one sediment sample per wetland (n = 20) for analyses. Microbial DNA was extracted and the extracts were stored in -20 ºC until 16S rRNA sequencing. Additionally, sediments were submitted to the University of Guelph Agriculture and Food Laboratory (Ontario, Canada) for herbicide residue analyses. They were analyzed for the top five most commonly used herbicides in North Dakota, including glyphosate, atrazine, 2,4-D, metolachlor, and acetochlor. Results showed no detections in any sample for all five herbicides tested with the maximum limit of quantifications as follows: glyphosate, AMPA (glyphosate metabolite), acetochlor, and desethyl-atrazine (atrazine metabolite) = 0.02 ppm, atrazine = 0.008 ppm, 2,4-D = 0.03 ppm, and metolachlor = 0.005 ppm. The results suggested that herbicide residues did not persist in benthic sediments of these wetlands. However, additional testing is needed to confirm these results and findings.

2020 — 2021 NDWRRI Fellowship Research Highlights

The Ecotoxicological Effects of Saline Water Characteristics on Amphibian Survival and Development

Alicia Schlarb *(Fellow) &* ***Dr. Matthew Smith*** *(Advisor), North Dakota State University*

Sodium Chloride production in the United States is at an all-time high. As weather patterns become harsher through climate change and demands on energy and agriculture increase, evidence of long-term NaCl exposure is emerging throughout environments. Salt loading practices affect sensitive inhabitants, such as amphibians that are dependent on freshwater resources. With a focus on Canadian toads (CT) exposed at multiple developmental time periods, this research fills existent gaps of NaCl effects on tadpole weight, survival, time to metamorphosis, and hatch success (eggs), while also highlighting urban wetland conductivity and chloride (Cl) fluctuations. Conductivity and Cl levels were monitored throughout the spring and summer of 2020 from 20 wetlands around the Fargo area. Concurrently, CT eggs were collected and exposed to the same environmentally observed salinity concentrations within a lab-controlled environment. It was found that conductivity spiked in May and June, with the lowest level recorded in August. Chloride levels were the highest at the beginning of the warm season, peaking in June, with the lowest levels recorded in August. Although weight, survival, and hatch success were not affected by NaCl, the time taken to complete metamorphosis was extended in tadpoles exposed to NaCl at an older age. These levels coincide with CT breeding as they tend to lay in early May. Eggs continue to hatch throughout May and larval development continues into June. Metamorphosis typically occurs at the end of June into July when the levels are at their highest, potentially impacting the time to complete metamorphosis.



Meet Our Faculty

Syeed Md Iskander is an Assistant Professor in the Department of Civil, Construction and Environmental Engineering. Before moving to NDSU in Aug 2020, Dr. Iskander worked as a postdoctoral research associate in the Civil and Environmental Engineering Department at the University of Southern California. Dr. Iskander's research exists in the interface of innovative waste management and environmental and public health. Dr. Iskander earned his Ph.D. in Civil Engineering from Virginia Tech (VT), MS in Environmental Engineering from Washington State University, and BS in Civil Engineering from Bangladesh University of Engineering and Technology.

Iskander Research Group at North Dakota State University works on advancing solid waste management processes. The group is dedicated to understanding and minimizing pollution from different solid waste management processes. The major interest of Iskander Group is understanding the degradation kinetics and fate of plastics in landfills and compost. Plastics in landfills break down into micro and nanoplastics through complex physicochemical interactions and end up in the environment. The movement of microplastics through compost in agricultural soil is a major environmental problem. Iskander Group works to understand plastics pollution from landfills and composting plants to develop possible control and remediation measures. As microplastics are not standalone pollutants but can be carriers of other harmful adsorbed contaminants, Iskander Group is also investigating the association of different micropollutants with solid waste plastics. Another focus of Iskander Group is to develop effective treatment technologies for landfill leachate. During his first two years at NDSU, Iskander has taught undergraduate courses on Introduction to Environmental Engineering and Environmental Microbiology, and a graduate course on Solid Waste Management. Moreover, he has developed a graduate-level course titled 'Plastics Pollution to Solution' focusing on the different aspects of plastics pollution and solution. With his group's research outcomes integrated into teaching and outreach activities, Iskander's goal is to help create a healthy world without pollution.

NDWRRI State Advisory Committee

Awards Received by Institute Fellows

Umesh Acharya received a Graduate Student Travel Award for oral presentation at the Soils and Crop Conference, University of Saskatchewan, Canada.

Pavankumar Challa Sasi received the 2nd prize at 3MT (3-minute Thesis) competition held at the University of North Dakota for a presentation on Destruction of "Forever Chemicals."

Tonoy K Das received 2021 Doctoral Dissertation Fellowship from the College of Graduate and Interdisciplinary Studies, North Dakota State University.

Justin Waraniak won a runner-up in the Northern Plains Biological Symposium Best Poster Competition.

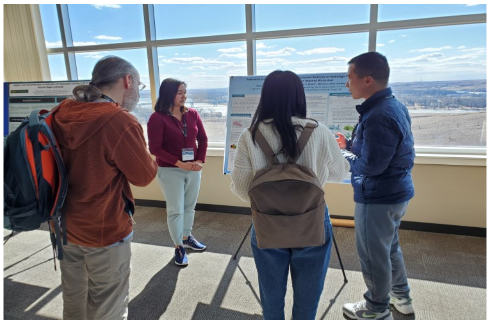
Kui Hu received 2021 Harvey K. Nelson Scholarship.

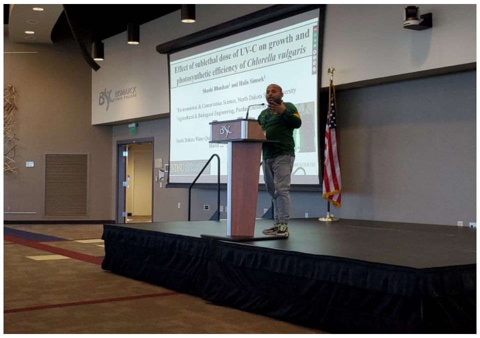
Jarrett Lardy won the 3rd Place Poster at the 65th Annual Manitoba Soil Science Society Conference and Annual General Meeting, February 3-4, 2021.

Berkay Koyuncu received a travel award from American Physical Society (APS) to present his research at 2021 APS Division of Fluid Dynamics (DFD) Meeting, November 21-23, 2021, Phoenix, AZ.

2022 North Dakota Water Quality Monitoring Conference

North Dakota Water Quality Monitoring Conference was held at the BSC National Energy Center of Excellence in Bismarck, North Dakota on March 21-23, 2022. The theme of the conference was Water Resources in an Expanding North Dakota Economy. The conference brought together professionals and students to discuss current water resources issues in North Dakota. The topics covered included: Agricultural Processes (Drain Tile Management), Nutrient Management, Energy Development, Wetland Ecosystems, Emerging Contaminants (PFAS, PCBs, Mercury, Microplastics, Neonics), Surface Water, Groundwater, Basin Issues (Red River, Upper & Lower Missouri River, Souris River, and James River), Data Sharing, Weather Extremes/Climate, Monitoring & Assessment, and Other Water Research.





Recent Publications and Presentations by Institute Fellows and PIs

Peer-reviewed Journal Papers

Acharya, U., Daigh, A.L.M., and Oduor, P.G. 2021. Factors affecting in the use of weather stations data in predicting surface soil moisture for agricultural applications. *Canadian Journal of Soil Science*. https://doi.org/10.1139/CJSS-2021-0034.

Acharya, U., Daigh, A.L.M., and Oduor, P.G. 2021. Machine learning for predicting field soil moisture using soil, crop, and nearby weather station data in the Red River Valley of the North. *Soil Syst.* 5(4), 57, https://doi.org/10.3390/soilsystems5040057.

Almen, K., Jia, X., DeSutter, T., Scherer, T., and Lin, M. 2021. Impact of controlled drainage and subirrigation on water quality in the Red River Valley. *Water*, *13*(3), 308. https://doi.org/10.3390/w13030308.

Das, T. K., Quentin, S, and Bezbaruah, A. N. 2021. Montmorillonite clay-iron crosslinked alginate beads for aqueous phosphate removal. *Chemosphere*. 281, 130837, https://doi.org/10.1016/j.chemosphere.2021.130837.

Das, T. K. and Bezbaruah, A. N. 2021. Comparative study of arsenic removal by iron-based nanomaterials: Potential candidates for field applications. *Science of the Total Environment*. 142914. https://doi.org/10.1016/j.scitotenv.2020.142914.

Das, T. K., Sakthivel, T. S., Jeyaranjan, A., Seal, S., and Bezbaruah, A. N. 2020. Ultra-high arsenic adsorption by graphene oxide iron nanohybrid: Removal mechanisms and potential applications. *Chemosphere*. 126702. https://doi.org/10.1016/j.chemosphere.2020.126702.

Lin, Z., Lim, S. H., Lin, T., and Borders, M. 2020. Using agent-based modeling for water resources management in the Bakken region. *Journal of Water Resources Planning and Management*, *146*(1), 05019020, https://doi.org/10.1061/(ASCE)WR.1943-5452.0001147.

Rashid, U. S., Das, T. K., Sakthivel, T. S., Seal, S., and Bezbaruah, A. N. 2021. Mechanisms of rapid fluoride removal by GO-CeO_2 nanohybrid. *Science of the Total Environment.* 148547. https://doi.org/10.1016/j.scitotenv.2021.148547.

Vaddevolu, U.B.P., Lester, J., Jia, X., Scherer, T.F., and Lee, C.W. 2021. Tomato and watermelon production with mulches and automatic drip irrigation in North Dakota. *Water*, 13(14): 1991. https://doi.org/10.3390/w13141991.

Zeng, L. and Chu, X. 2021. A new probability-embodied model for simulating variable contributing areas and hydrologic processes dominated by surface depressions. *Journal of Hydrology*, 602, 126762, 1-15. https://doi.org/10.1016/j.jhydrol.2021.126762.

Zeng, L., and Chu, X. 2021. Integrating depression storages and their spatial distribution in watershed-scale hydrologic modeling. *Advances in Water Resources*, 151, 103911, 1-14, https://doi.org/10.1016/j.advwatres.2021.103911.

Conference Proceeding Papers

Atashi, V. and Lim, Y. H. 2021. Investigation of Muskingum Routing parameters in natural channel in North Dakotan River under snowmelt-induced flooding conditions. In: Proceeding of 2021 Western South Dakota Hydrology Conference, APR 21-22, 2021, Rushmore Plaza Civic Center, Rapid City, SD.

Vaddevolu, U. B. P., Jia, X., Scherer, T. F., and Lee, C. 2020. Automatic sensor controlled drip irrigation under mulches for tomato and watermelon productions. In: Proceedings of the 2020 ASABE International Meeting, Omaha, NE, USA, 12–15 July 2020; p. 2001035.

Conference/Seminar Presentations

Acharya, U., A. L. M. Daigh, and P. G. Oduor. 2021. Use of Landsat 8 image and meteorological data to map soil moisture in the Red River Valley. ASA-CSSA-SSSA International Annual Meetings, November 9-13, 2020 (Virtual).

Almen, K., X. Jia, T. DeSutter, and T. Scherer. 2020. Impact of controlled drainage and subirrigation on water quality in Richland County, North Dakota. ASABE 2020 Annual International Meeting, July 13-15, 2020 (Virtual).

Atashi, V. and Y. H. Lim. 2021. Investigation of Muskingum routing parameters in natural channel in North Dakotan River under snowmelt-induced flooding conditions. 2021 Western South Dakota Hydrology Conference, April 21-22, 2021, Rapid City, SD.

Challa Sasi, P., A. Alinezhad, F. Xiao, Y. Bin, A. Kubatova, and S. Golovko. 2021. Thermal treatment of PFAS in aqueous media. Inaugural North Dakota Regional Environmental Conference, Air and Waste Management Association, Upper Midwest Section, October 7, 2021, Bismarck, North Dakota.

Recent Publications and Presentations by Institute Fellows and PIs

Conference/Seminar Presentations

Cornish, C., Y. Yuan, W. Sauskojus, M. Otte, and J. Sweetman. 2022. Comparing herbicide concentrations and microbial succession in natural and restored wetlands of North Dakota. NDWQM 2022, March 21-23, 2022, Bismarck, ND.

Cornish, C., S. Bansal, J. Meier, O. Johnson, T. Harris, B. Sturm, and J. Sweetman. 2021. Can herbicide loading increase methane emissions in freshwater ecosystems? Great Plains Limnology Conference 2021, October 23, 2021 (Virtual).

Das, T. K., R. S. Hazra, M. Quadir, L. Jiang, and A. N. Bezbaruah. 2020. Graphene oxide iron nanohybrids loaded polyethersulfone-cellulose nanofiber beads for arsenic removal. 8th Sustainable Nanotechnology Conference (Virtual), November 12-13, 2020.

Holmes, S., T. Mahmood, and M. Mann. 2020. Cold region hydrologic variability due to recent wetting in the Northern Great Plains. 2020 AGU Fall Meeting, December 1-17, 2020, San Francisco, CA.

Hu, K., D. M. Mushet, and J. N. Sweetman. 2021. Understanding the impacts of hydrology on seasonal and spatial water chemistry changes in two adjacent prairie potholes in North Dakota using stable isotopes. 13th Ontario-Quebec Paleolimnological Symposium (PALS) meeting, May 4-5, 2021 (Virtual).

Hu, K., D. M. Mushet, and J. N. Sweetman. 2021. Using stable isotopes to better understand hydrological impacts on water chemistry in prairie-pothole wetlands of the Northern Great Plains, USA. Great Plains Limnology Conference, October 23, 2021 (Virtual).

Koyuncu, B. and T. Le. 2021. Impact of ice coverage on velocity profiles in a bend. 2021 AGU Fall Meeting, December 13-17, 2021, New Orleans, LA.

Koyuncu, B. and T. Le. 2021. In the structures of the ice-covered flows in a bend. APS Division of Fluid Dynamics (DFD) Meeting, November 21-23, 2021, Phoenix, AZ.

Koyuncu, B. and T. Le. 2020. Secondary flow structures in natural channels under open and ice-coverage conditions. APS Division of Fluid Dynamics (DFD) Meeting, November 22-24, 2020 (Virtual).

Lardy, J., T. DeSutter, M. Meehan, N. Derby, K. Horsager, and A. Daigh. 2021. Methods to reduce runoff, erosion, and increase plant establishment for pipeline restoration. 2021 NDSU School of Natural Resources Graduate Symposium, November 1, 2021, Fargo, ND.

Lardy, J., T. DeSutter, M. Meehan, N. Derby, K. Horsager, and A. Daigh. 2021. An examination of pipeline site-preparation methods for improving plant establishment. 2021 Manitoba Soil Science Society Annual General Meeting, February 4-5, 2021, Winnipeg, Manitoba.

Le, T., B. Koyuncu, D. Arumugam, and R. Yellavajjala. 2021. Modal analysis of surface flows in river bend using autoencoder. 2021 AGU Fall Meeting, December 13-17, 2021, New Orleans, LA.

Le, T., A. Khosronejad, K. Flora, and B. Koyuncu. 2021. Hydrodynamics of meandering rivers: The role of simulation. 2021 AGU Fall Meeting, December 13-17, 2021, New Orleans, LA.

Le, T. and B. Koyuncu. 2021. Large-eddy simulation of ice-covered flows in a river bend. APS Division of Fluid Dynamics Meeting, November 21-23, 2021, Phoenix, AZ.

Le, T. and B. Koyuncu. 2020. Structures of icy flows in a river bend. 2020 AGU Fall Meeting, December 1-17, 2020 (Virtual).

Vaddevolu, U .B. P., X. Jia, T. F. Scherer, and C. Lee. 2020. Automatic sensor-controlled drip irrigation under mulches for tomato and watermelon productions. 2020 ASABE International Meeting, July 12-15, 2020. Omaha, NE.

Waraniak, J. M., D. M. Mushet, and C. A. Stockwell. 2021. Population connectivity in an agricultural landscape: Land use effects on gene flow in northern leopard frog (*Rana pipiens*) in the Prairie Pothole Region. American Genetics Association President's Symposium, October 17-20, 2021, Snowbird, UT.

Theses and Dissertations

Acharya, Umesh. 2021. Soil Moisture Prediction using Meteorological Data, Satellite Imagery, and Machine Learning in the Red River Valley of the North. Ph.D. Dissertation. Soil Science, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://www.proquest.com/docview/2572634490/54D8B495D0C44CD0PQ/1?accountid=6766)

Almen, Kristen Karen. 2020. Impacts of Controlled Drainage and Subirrigation in the Red River Valley. M.S. Thesis. Environmental and Conservation Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://www.proquest.com/docview/2477876026/13710E66E47447F6PQ/1?accountid=6766)

Das, Tonoy Kumar. 2021. Graphene Oxide Supported Metal Oxide Nanohybrids for Aqueous Arsenic Removal. Ph.D. Dissertation. Environmental and Conservation Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://www.proquest.com/docview/2572633759/6B7B4C4065224892PQ/1?accountid=6766)

Jones, Rebecca. 2021. Influence of Habitat Characteristics on Amphibian Stress and Reproductive Success in North Dakota. M.S. Thesis. Biological Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://www.proquest.com/docview/2543807471/947C1F2995FC4F5DPQ/1?accountid=6766)

Lin, Tong. 2021. An Agent-based Model for Water Allocation and Management at the Bakken Shale in Western North Dakota. Ph.D. Dissertation. Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND

Schlarb, Alicia Michelle. 2021. The Effects of Salinity on Canadian Toad (*Anaxyrus hemiophrys*) Larvae and Post-Metamorphic Juveniles. M.S. Thesis. Environmental and Conservation Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://www.proquest.com/docview/2544279966/A2DA49EFA47F43DAPQ/1?accountid=6766)

Zeng, Lan. 2020. Improved Hydrologic Modeling for Characterizing Variable Contributing Areas and Threshold-Controlled Overland Flow in Depression-Dominated Areas. Ph.D. Dissertation. Civil Engineering, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://www.proquest.com/docview/2478600088/E3C31B319BC74B5FPQ/1?accountid=6766)

Recent USGS Publications

Tatge, W. S., R. A. Nustad, and J. M. Galloway. 2022. Evaluation of Salinity and Nutrient Conditions in the Heart River Basin, North Dakota, 1970–2020. USGS Scientific Investigations Report 2022–5013, doi:10.3133/sir20225013.

Galloway, J. M. and B. R. Hanson. 2022. Measurements of Streamflow Gain and Loss on the Souris River between Lake Darling and Verendrye, North Dakota, August 31 and September 1, 2021. USGS Open-File Report, doi:10.3133/ofr20221005.

Galloway, J. M., W. S. Tatge, and S. L. Wheeling. 2021. Evaluation of Hydrologic Simulation Models for Fields with Subsurface Drainage to Mitigated Wetlands in Barnes, Dickey, and Sargent Counties, North Dakota. USGS Scientific Investigations Report 2021–5091, doi:10.3133/sir20215091.

Medler, C. J. and W. G. Eldridge. 2021. Spring Types and Contributing Aquifers from Water-Chemistry and Multivariate Statistical Analyses for Seeps and Springs in Theodore Roosevelt National Park, North Dakota, 2018. USGS Scientific Investigations Report 2020–5121, doi:10.3133/sir20205121.

Recent ND Department of Water Resources Reports and Publications

North Dakota Department of Water Resources, Reports and Publications
https://www.swc.nd.gov/info_edu/reports_and_publications/

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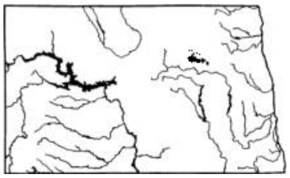

North Dakota Water Resources Research Institute
North Dakota State University, Dept. 2890
P.O. Box 6050
Fargo, ND 58108-6050

Phone: 701-231-9758
Fax: 701-231-6185
E-mail: xuefeng.chu@ndsu.edu
Website: https://www.ndsu.edu/wrri/

North Dakota Water Resources Research Institute (NDWRRI)

The Institute was founded in 1965 by authority of Congress as one of the 54 Institutes throughout the nation and is administered through the United States Geological Survey. The NDWRRI receives funding through section 104 of the Water Resources Research Act of 1984 and it applies its Federal allotment funds to research that fosters: A) the entry of new research scientists into the water resources field, B) training and education of future water resources scientists, engineers, and technicians; C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and D) the dissemination of research results to water managers and the public.