North Dakota Water Resources Research Institute

Annual Technical Report
2018

General Information

Products

Peer-reviewed Journal Papers

Chu, X., Lin, Z., Tahmasebi Nasab, M., Zeng, L., Grimm, K., Bazrkar, M. H., Wang, N., Liu, X., Zhang, X., and Zheng, H. 2019. Macro-scale grid-based and subbasin-based hydrologic modeling: joint simulation and cross-calibration. Journal of Hydroinformatics, 21(1), 77-91, https://doi.org/10.2166/hydro.2018.026.

Fidantemiz, Y.F., Jia, X., Daigh, A.L.M, Hatterman-Valenti, H., Steele, D.D., Niaghi, A.R., and Simsek, H. 2019. Effect of water table depth on soybean water use, growth, and yield parameters. Water, 11(5), 931, https://doi.org/10.3390/w11050931.

Grimm, K. and Chu, X. 2018. Modeling of spatiotemporal variations in runoff contribution areas and analysis of hydrologic connectivity. Land Degradation & Development, 29(8), 2629-2643, https://doi.org/10.1002/ldr.3076.

Grimm, K., Tahmasebi Nasab, M., and Chu, X. 2018. TWI computations and topographic analysis of depression-dominated surfaces. Water, 10, 663, 1-12, https://doi.org/10.3390/w10050663.

Lackmann, A.R., Andrews, A.H., Butler, M.G., Bielak-Lackmann, E.S., and Clark, M.E. 2019. Bigmouth Buffalo Ictiobus cyprinellus sets freshwater teleost record as improved age analysis reveals centenarian longevity. Communications Biology, https://doi.org/10.1038/s42003-019-0452-0.

Lin, Z., Lin, T., Lim, S.H. Hove, M.H., and Schuh, W.M. 2018. Impacts of Bakken shale oil development on regional water resources. Journal of the American Water Resources Association, 54(1), 225-239, https://doi.org/10.1111/1752-1688.12605.

Niaghi, A.R., Jia, X., Scherer, T.F., and Steele, D.D. 2019. Measurement of non-irrigated turfgrass evapotranspiration rate in the Red River Valley. Vadose Zone Journal, https://doi.org/10.2136/vzj2018.11.0202.

O’Brien, P.L., Acharya, U., Alghamadi, R., Niaghi, A.R., Sanyal, D., Wirtz, J., Daigh, A.L.M., and DeSutter, T.M. 2018. Hydromulch application to bare soil: soil temperature dynamics and evaporative fluxes. Agricultural and Environmental Letters Abstract-Research Letters, 3(1), https://doi.org/10.2134/ael2018.03.0014.

Tahmasebi Nasab, M., Grimm, K., Bazrkar, M., Zeng, L., Shabani, A., Zhang, X., and Chu, X. 2018. SWAT modeling of non-point source pollution in depression-dominated basins under varying hydroclimatic conditions. International Journal of Environmental Research and Public Health, 15, 2492, 1-17, https://doi.org/10.3390/ijerph15112492.

Wang, N., Zhang, X., and Chu, X. 2019. New model for simulating hydrologic processes under influence of surface depressions. Journal of Hydrologic Engineering, 24(5), 04019008, 1-13, https://doi.org/10.1061/(ASCE)HE.1943-5584.0001772.

Waraniak, J.M., Fischer, J.D.L., Purcell, K., Mushet, D.M., and Stockwell, C.A. 2019. Landscape genetics reveal broad and fine scale population structure due to landscape features and climate history in the northern leopard frog (Rana pipiens) in North Dakota. Ecology and Evolution, 9(3):1041-1060, https://doi.org/10.1002/ece3.4745.

Conference Proceedings

Tahmasebi Nasab, M. and Chu, X. 2018. Topo-statistical analyses of ponding area versus ponding storage of depression-dominated regions for macro-scale hydrologic modeling, p415-424. In: Watershed Management, Irrigation and Drainage, and Water Resources Planning and Management, Proceedings of the 2018 ASCE World Environmental and Water Resources Congress, edited by Sri Kamojjala, American Society of Civil Engineers, https://doi.org/10.1061/9780784481400.

Theses and Dissertations

Guzel, Haci Osman. 2019. Prediction of Freshwater Harmful Algal Blooms in Western Lake Erie Using Artificial Neural Network Modeling Techniques. M.S. Thesis. Natural Resources Management, College of Graduate and Interdisciplinary Studies, North Dakota State University, Fargo, ND (available at: https://library.ndsu.edu/ir/handle/10365/29605).

Grimm, Kendall. 2018. Modeling of Dynamic Hydrologic Connectivity: How Do Depressions Affect the Modeling of Hydrologic Processes?" Ph.D. Dissertation. Civil Engineering, North Dakota State University, Fargo, ND (available at: https://library.ndsu.edu/ir/handle/10365/28983).

Fidantemiz, Yavuz F. 2018. Effect of Water Table Level on Soybean Water Use, Growth and Yield Parameters. M.S. Thesis. Agricultural & Biosystems Engineering, North Dakota State University, Fargo, ND (available at: https://library.ndsu.edu/ir/handle/10365/29277).

Shabani, Afshin. 2018. Mitigating Environmental Impacts of Terminal Lake Flooding: A Case Study of Devils Lake, North Dakota. Ph.D. Dissertation. Earth System Science & Policy, University of North Dakota, Grand Forks, ND (available at: https://commons.und.edu/theses/2429/).

Technical Reports

Fidantemiz, Yavuz Fatih and Simsek, Halis. 2019. Response of Soybean Growth, Yield and Some Quality Parameters to Different Water Table Depths. Technical Report No: ND19-01. North Dakota Water Resources Research Institute, Fargo, ND (available at: https://www.ndsu.edu/wrri/Publications/ND19-01.pdf).

Guzel, Haci Osman and Simsek, Halis. 2019. Estimation of Freshwater Harmful Algal Blooms Using Multilayer Perceptron Neural Network Model. Technical Report No: ND19-02. North Dakota Water Resources Research Institute, Fargo, ND (available at: https://www.ndsu.edu/wrri/Publications/ND19-02.pdf).

Leelaruban, Navaratnam, Padmanabhan, G., and Akuz, Adnan. 2018. A Study of the Spatial and Temporal Characteristics of Drought and Its Impact in North Dakota. Technical Report No: ND18-01. North Dakota Water Resources Research Institute, Fargo, ND (available at: https://www.ndsu.edu/wrri/Publications/ND18-01.pdf).

Information Transfer Program

Information dissemination is mainly done through an annual newsletter, and presentations and publications by the grant and fellowship recipients. The Institute's website (https://www.ndsu.edu/wrri/) also helped disseminate all Institute-related information. The latest newsletter and all past newsletters can be accessed through the Institute's website. The technical reports of the Fellowship projects authored by the Fellows and their advisors are also available at the Institute homepage. The major information transfer activities supported with the 104b annual base grants and required matching funds include: (1) maintaining the Institute website as an effective way communicating to the public, (2) publishing the annual Institute newsletter, (3) publishing the Fellowships and the related research funded through the Institute, (4) hosting the 1st NDWRRI Special Water Resources Seminar featured with four keynote talks by speakers from the USGS and ND State government agencies and nine project presentations by the NDWRRI Fellows, (5) presenting research findings by the NWRRI Fellows and affiliated faculty at various international/national, regional, and local conferences, and (6) sponsoring or co-sponsoring local or regional conferences. The website of the Institute was updated at least quarterly, providing the details on the Institute's activities, Fellows and affiliated faculty, funded research projects, and publications. The Institute continued its annual newsletter, which highlighted the graduate research fellowship program, the associated research grants, and general summaries of ongoing research. The newsletter also profiled the Institute researchers and their accomplishments, and published other water issues in the State.

Student Support

For the last 18 years, NDWRRI has offered competitive fellowships to graduate students at North Dakota State University (NDSU) and the University of North Dakota (UND) for research on water resources topics through a

Graduate Research Fellowship (GRF) program effectively using the 104b annual base and required matching funds. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984. In addition, North Dakota State Water Commission provided a supplemental fund for this GRF program. The fellowship program encourages entry of young university faculty and new research scientists and engineers into the water resources field; provides training and education to future water resource scientists and engineers; promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and engages university faculty in collaborative research programs seeking supports from entities concerned with water problems. The GRF program was administrated and managed by the Director. Applications were invited from the graduate students and their advisors of the two research universities of the State, NDSU and UND. The awards were determined based on a rigorous review by the State Advisory Committee and other water professionals in the State. Active participation of the academic advisors of the students in meeting the matching requirement and seeking co-funding from local, state, and other sources is another positive aspect of the GRF program. The research progress of the Fellows and their advisors in meeting the fellowship expectations was ensured by seeking their reports and by encouraging them to present their research results at local, regional, and national/international conferences and technical seminars.

In the 2018-2019 funding period, the NDWRRI fellowships were awarded to fifteen graduate students, including nine Ph.D. students and six M.S. students, who conducted water resources research at NDSU and UND. These fifteen graduate research projects were supported with the federal 104b annual base grant ($69,300) and required matching funds, as well as the supplemental fund ($25,000) from North Dakota State Water Commission. The Fellowships ranged from $2,250 to $11,000.

Notable Achievements and Awards

In the 2018-2019 funding period, fifteen projects were funded through the NDWRRI Fellowship program to address various water resources issues in North Dakota. Seventeen faculty/advisors, nine Ph.D. students, and six M.S. students have been involved in these projects. 11 peer-reviewed journal papers and 1 conference proceeding paper have been published; 2 Ph.D. dissertations and 2 M.S. theses have been published; and 3 Institute technical reports have been published. Numerous conference presentations have been presented at national/international, regional, and local conferences. The Institute successfully organized its 1st Special Water Resources Seminar. Particularly, four keynote speakers from the USGS and ND state agencies talked about the major water resources issues in ND, current state and federal efforts in ND, challenges, research needs and priorities, and potential collaboration opportunities. It helped the faculty and students at NDSU and UND better understand the water resources issues in North Dakota and improved the collaborations between the federal/state agencies and the two universities. For this funding year, one featured study, conducted by Alec Lackmann (Ph.D. student and NDWRRI Fellow) and Drs. Mark Clark and Malcolm Butler (his advisors), should be highlighted. Their research findings have been published in Communications Biology, showing that a Bigmouth Buffalo fish could live up to 112 years, which more than quadruples all previous age estimates for this species. The related work has been widely reported by national, regional, and local news media.

Projects

An Integrated Social and Ecological Model for Stream Flow Simulation

Project Type: Annual Base Grant **Project ID:** 2018ND348B

Project Impact: Unconventional oil production at the Bakken Shale of western North Dakota has increased nearly ten-fold from 2008 to 2014. During this period, Bakken Shale was drilled approximately 10,000 horizontal wells and the average water use was around 2.0 × 10^6 gal/well. The rapid expansion of unconventional oil and gas extraction and the cumulative water needs for hydraulic fracturing (HF) have raised concerns in surface water resources management in some local areas. The Little Muddy River, the second most frequently used surface water sources for HF, was chosen for this project. To address the potential HF water stress on the regional surface water resources, two steps were implemented. Firstly, a SWAT model was developed to simulate the hydrological processes of the Little Muddy River basin. Secondly, an agent-based model of HF water use was integrated with the SWAT model to simulate the changes in the river discharge. The results indicated that the streamflow was not influenced by the water use for hydraulic fracturing. Even when the total HF water use increased up to 100 times, this HF water use would still not have significant impact on the river in both wet and dry periods when streamflow is greater than 1.0 cms. This coupled human and nature system improves the understanding of the dynamics of the HF impact on local streams in the region. It also helps policy and decision makers devise appropriate policy tools to manage the regional water resources for long-term and sustainable use.

Application of Green Iron Nanoparticles Synthesized using Barley and other Plant-borne Polyphenols to Combat Lake Eutrophication

Project Type: Annual Base Grant **Project ID:** 2018ND343B

Project Impact: The extract of barley (Hordeum vulgare L.) was used for synthesizing iron nanoparticles (Fe-NPs) and the synthesized particles were used for phosphate removal. Green tea polyphenol based Fe-NPs were used in the control experiment. While the particle size of NPs synthesized with the green tea extract ranged from 3 to 11 nm, barley extract produced particles >3 nm. The barley-based Fe-NPs did not show metallic properties (based on XRD data) as the particles were coated with plant materials. However, the phosphate removal capacity of barley-based Fe-NPs was higher than that of the green tea based Fe-NPs. The nanoparticles (3 g/L) were also used to remove phosphate from municipal wastewater (5-7 mgP/L initial concentration), and up to 98% phosphate removal was achieved. The mechanism of nanoparticle formation was also examined. This study indicates that the barely-based nanoparticles are useful for phosphate recovery from waters. The next phase of experiments will look into the reuse of the nanoparticle-sorbed phosphate for agricultural applications.

Assessing Effect of Precise Evapotranspiration Measurement on Crop Coefficient and Water Use

Project Type: Annual Base Grant **Project ID:** 2018ND340B

Project Impact: It is crucial to accurately measure the ETc from dominant vegetation surfaces in agricultural land management. Among different methods used to measure the ETc, above ground energy balance method is superior, especially in areas with shallow groundwater. In this project, corn ETc was measured using the near-surface energy balance with EC and BREB systems in a tile drained field. After analyzing the data during the growing season, the measured H with EC and the calculated latent heat flux (LE) using the residual method decreased with increasing the crop ground coverage. The results showed that the residual method was useful for closing the energy balance equation if the data were screened properly and the system was maintained in an acceptable condition. The diurnal analysis of H showed that the H measured by the EC and BREB agreed well with each other in July and August and similar in June and September, which resulted in a better estimation of LE and ETc. The developed Kc values using the EC system with the residual method can be as accurate as the result obtained from the BREB system. Therefore, they can be used for agricultural water management in the Red River Valley.

Development of a New Depression-oriented Hydrologic Modeling System (HYDROL-D)

Project Type: Annual Base Grant **Project ID:** 2018NDSWC-02

Project Impact: This project focuses on the development of a new semi-distributed, physically-based modeling system (HYDROL-D) for continuously simulating hydrologic processes in depression-dominated areas. HYDROL-D has a unique model structure to handle surface runoff routing across depressional surfaces. In the HYDROL-D system, a watershed is delineated into a number of subbasins, each of which is further divided into a main channel and many puddle-based units (PBUs), off-stream channel-based units (CBUs), and on-stream CBUs. Surface runoff generated in all PBUs and off-stream CBUs flows into their associated downstream units and then into the on-stream CBUs. The runoff water in the on-stream CBUs of a subbasin eventually flows into the main channel, which is further routed in the model. HYDROL-D system has a unique model structure that facilitates the simulation of water movement along the vertical direction. Specifically, each modeling unit (e.g., a PBU) consists of four zones, including canopy zone, snow zone, surface zone, and soil zone. All units in a subbasin share a common shallow groundwater zone. The HYDROL-D system was applied to five upstream subbasins in the Devils Lake watershed in the Prairie Pothole Region (PPR) to analyze the impacts of depressions on hydrologic processes on a daily time scale. The model was calibrated and validated by comparing the simulated and observed discharges. This study demonstrated the improved applicability and capability of the HYDROL-D modeling system, especially for depression-dominated regions.

Development of the Macro-Scale Hydrologic Processes Simulator (Macro-HyProS) and Applications in the Red River Basin and North Dakota

Project Type: Annual Base Grant **Project ID:** 2018NDSWC-01

Project Impact: Micro-topographical characteristics and indices such as hierarchical relationships of depressions, ponding storage, ponding area, and topographic wetness index were utilized to establish a second-order multiple regression model, which provided a dynamic relationship between the ponding area and different topographic indices. The regression model was tested for several surfaces within the Red River basin. The results indicated that the model was statistically helpful for prediction of the ponding area. The results also suggested that the variations in the ponding area across the entire study area could be explained by using ponding storage and other topographic indices such as topographic wetness index. In this project, a new Macro-Scale Hydrologic Processes Simulator (Macro-HyProS) was developed. Particularly, it incorporated an improved physically-based representation of the snowmelt processes. The model was applied to the Missouri River basin for water years 2011 and 2012, which represented historic wet and dry years, respectively. The snowmelt simulations suggested that unlike monthly and annual snowmelt, the daily snowmelt simulations were profoundly affected by the sub-daily temperature fluctuations. The improved Macro-HyProS can be used to simulate a variety of hydrologic processes, especially in depression-dominated cold climate regions. It provides daily, monthly, and yearly simulations of hydrologic processes to assist management of agricultural activities. The topo-statistical analyses used to develop the regression model can also be used in other macro-scale hydrologic models to improve the modeling for depression-dominated regions.

Effect of Water Level on Soybean Growth and Quality Parameters with High Salinity Water

Project Type: Annual Base Grant **Project ID:** 2018ND349B

Project Impact: Water table contribution to plant water use is a significant element in improving water use efficiency (WUE) for agricultural water management. This project focused on determining groundwater contributions to soybean water use and the soybean response to different water table levels. The specific objectives of the study are: (1) to determine crop water of soybean from different water table depths (WTD) without irrigation, (2) to determine the effects of shallow groundwater on soybean growth and yield parameters, and (3) to determine the effect of groundwater depth on the root distribution of soybean. In this study, lysimeter experiments were conducted in a controlled environment to investigate the response of soybean water uptake and growth parameters under water table depths of 30, 50, 70, and 90 cm. Further analysis of the root mass and proportional distribution among different soil layers indicated that the lysimeters with WTD of 70 and 90 cm had greater root mass with higher root distribution at 40–75 cm of the soil layer. The results also indicated that the WTD of 70 and 90 cm yielded higher grain yield and biomasses with greater WUE and better root distribution than the irrigated or shallow WTD treatments. This research provides farmers with the valuable information about soybean tolerance on water depths, which helps minimize the risk of yield reduction in the field. The comprehensive data collected also help design field-scale tile drainage system.

Enhanced Removal of Heavy Metals from Stormwater by Bioretention Cells

Project Type: Annual Base Grant **Project ID:** 2018ND347B

Project Impact: The objective of this project was to determine what materials had the greatest ability at sequestering copper (II) ions from aqueous solution. Potential sorbent materials were selected. Batch-scale experiments were performed on the sorption of cupper ions (Cu(II)) by different materials, including flocs formed during coagulation/flocculation of surface water treatment, biochar, biomass materials, sand, and iron-modified sand. In addition, laboratory column tests packed with the materials selected for the batch-scale experiments, including flocs and iron-modified sand, were also performed. It was found that high modified iron-coated (MIC) sand was capable of retaining copper (II) ions passed through the column or removing the influent copper (II) ions. The primary discovery gained from the fixed-bed column experiments was that the majority of the sorbent materials were less efficient than the iron-modified sand. This was of particular interest because many of the materials such as tap water flocs had high maximum adsorption capacity values in the batch experiments, which could only be explained by the limited contact time and preferential contaminant flow paths. The major findings from this research include (1) the ranking of materials for maximum adsorption capacity and (2) the materials possessing the greatest retention capacity with contact time constraints.

Evaluating the Response of Diatoms and Cladocerans Communities to Climate Change over the Last Century in Lake P1, North Dakota

Project Type: Annual Base Grant **Project ID:** 2018ND345B

Project Impact: Prairie pothole wetlands play a significant role in providing important freshwater resources and vital ecosystem services in North Dakota, including habitat for waterfowl and other biodiversity, carbon sequestration and flood abatement. The climate in the Prairie Pothole Region (PPR) is highly variable, with multiyear periods of drought and periods of excess precipitation occurring over the past century, which have markedly influenced the wetland ecosystems. This study aims to evaluate the past climate change effects on biological assemblages (i.e., diatoms) in the prairie pothole wetland ecosystem by combining long-term historical meteorological datasets with sediment records from a prairie pothole lake. Initial results suggest that nutrient availability is the main factor that drives diatom assemblage changes over the past century. Diatoms in the sediment record show a shift from primarily benthic species to more planktonic taxa since 1966, which corresponds to the increased water levels in 1967-1972 (i.e., a relatively wetter period). These results imply that water level changes result in habitat changes due to climate change and can have important implications for biological community structure and wetland functioning. This research helps to test how the PPR’s primary producer communities have responded to changes in the frequency and duration of the wet and dry cycles. A clear understanding about the dynamics of the PPR wetland ecosystem in response to climate variability helps policy and decision makers propose appropriate management strategies to cope with the changing climate of the future.

Evidence of Recruitment Failure for 80 Years in Bigmouth Buffalo Fish (Ictiobus cyprinellus Valenciennes 1844) Populations of the Red River of the North basin: A Call for Further Study and Action

Project Type: Annual Base Grant **Project ID:** 2018ND338B

Project Impact: We found Bigmouth Buffalo Ictiobus cyprinellus can live beyond 110 years, surpassing all other freshwater teleosts (~12,000 species) by nearly 40 years. We conclusively validated these ages via bomb radiocarbon analysis, making Bigmouth Buffalo the oldest age-validated freshwater fish. These age-data alone have potential to transform the management of this species and change the perception of other closely-related taxa. For several endemic populations, spans of four and eight decades with no representative year classes suggest long-term recruitment failure on a regional level. This paradigm-shifting life history data comes at a crucial point in this species’ history. Our findings reveal Bigmouth Buffalo and other catostomids require urgent attention. We also report on novel, age-related external markings that accrue on Bigmouth Buffalo. These orange and black spots highly correlate with the age of the fish, providing a non-lethal means of age estimation as well as aid recognition of individual fish. We found that Bigmouth Buffalo reach asymptotic adult size around the age of 30-40 years, and there is a pronounced sexual dimorphism in their size structure (females are much larger than males at maturity). In addition, there is marked variation in adult size within each sex. In fact, the oldest specimen in our research paper (taken by a bowfisher in 2018) was 112 years old. Overall, little was known about this North American species. Careful examination has revealed discoveries overlooked and management dilemmas that can arise as a consequence of the ecological neglect underappreciated species.

Examining the Impact of Devils Lakes Outlets on Flood Risk and Water Quality of the Sheyenne River

Project Type: Annual Base Grant **Project ID:** 2018ND337B

Project Impact: Devils Lake is an endorheic lake in the Red River of the North basin in northeastern North Dakota. During the last two decades, the lake water level has risen by nearly 10 m, causing floods with a total cost of more than 1 billion USD. In this project, a SWAT model was developed for the Sheyenne River watershed to simulate daily streamflow and a coupled SWAT and CE-QUAL-W2 model was also developed to simulate Devils Lake water levels and sulfate distribution. The models for the Sheyenne River and Devils Lake were then linked to simulate the impact of the diverted water from the lake on the river discharge and sulfate concentration. The coupled SWAT and CE-QUAL-W2 model showed that the sulfate concentration in Devils Lake increased from west to east, which made the operation of the east outlet more of a concern for degrading the water quality in the Sheyenne River. The hydrologic and water quality modeling results showed that the impact of the outlet operation on the Sheyenne River discharge was within confines of two-year floods (36 m^3/s), while the river sulfate concentration increased from 125 mg/l to ? 750 mg/l. Using an optimization model and actual outlet schedule, an optimal management was determined, which mitigated the discharge and sulfate concentration of the Sheyenne River to ? 26 m^3/s and ? 650 mg/l, respectively.

Implications of Stormwater Control Measures on Hydrology of an Urban Watershed in the Fargo, ND Area

Project Type: Annual Base Grant **Project ID:** 2018ND341B

Project Impact: The goals of this study were to assess the performance between pre-retrofit concrete-lined channel and post-retrofit earthen channel with respect to flood frequency for small storms, and to estimate the ponding time, infiltration, and evaporation of the retrofit basin for various storm sizes/intensities. Monitoring was performed by using an Onset HOBO weather station and various in-channel Onset HOBO water level loggers. A drone flight and manual survey of the channel and sediment forebay were also conducted to estimate a DEM by the structure-from-motion technique within Pix4D. HEC-RAS was used to estimate and compare post- and pre-retrofit channel capacities of small storms. The ArcMap’s ModelBuilder was used to estimate hourly ponded volume and ponding time for each storm. Hydrus-1D was used to estimate infiltration and evaporation during ponding time of the selected storms. The northern-most post-retrofit channel behaved similarly to the pre-retrofit channel in terms of flood frequency due to increased erosion of the earthen channel. The southern post-retrofit channel flooded significantly more often than the pre-retrofit channel, leading to a potential increase in ponding time, infiltration, and evaporation. 50% of the storms had a ponding time equal to or greater than 9 hours, while 40% of the storms had a ponding time equal to or greater than 12 hours. It is apparent that sediment re-mobilization occurred, and the sediment was deposited at the outlet. It was found that evaporation was relatively negligible in comparison to infiltration.

Interdisciplinary Approach to Understanding Fluvial Geomorphology of Post-glaciolacustrine Meandering Rivers: A Case Study of the Red River

Project Type: Annual Base Grant **Project ID:** 2018ND350B

Project Impact: This project focuses on how rivers and their basins have changed since deglaciation and the draining of Lake Agassiz by (1) analyzing and interpreting landforms recorded in digital elevation data, (2) studying erosional processes of river ice at laboratory and field scales, and (3) using numerical simulations to reconstruct and erode landscapes of the Red River Basin 12,000 years ago. Interdisciplinary field, laboratory, and computer modeling methods were used to study how erosional processes led to the changes in the river or landscape. Although the Red River was established entirely on the bed of Lake Agassiz, there was evidence of glacial moraines influencing river incision and making meander cutoffs greater relief. It was demonstrated that the frozen/thawed conditions of the river banks were a product of the temperature conditions and timing/character of ice breakup. Floods in the Red River basin, because of the low relief landscape, occurred over multi-week time periods. Even if the river banks were frozen when flooding started and ice floe began, they were thawed only a few days after flooding began. This research revealed that the relative timing of the Grand Marais Creek/Red Lake River avulsion was about 500-600 years after Lake Agassiz receded from that area. This project also demonstrated the methods for running Landscape Evolution Modeling experiments on a real DEM-based landscape. This research showed that most of the significant landscape evolution and river path changes were taking place early in the Holocene.

Landscape Genetics of Northern Leopard Frog (Rana pipiens) to Evaluate Biotic Connectivity and Environmental Quality of North Dakota Wetland Resources

Project Type: Annual Base Grant **Project ID:** 2018ND344B

Project Impact: In this project, microsatellite genotypes of northern leopard frog populations around the state of North Dakota were analyzed. It was discovered that the population structure of R. pipiens was strongly associated with river basins and that the Missouri River acted as a major barrier restricting gene flow between populations on different sides of the river. It was estimated that the population division caused by the Missouri River occurred ~18,000 years ago as glaciers receded out of northeastern North Dakota. Population subdivisions by river basin were estimated to occur mostly between 8000 – 5000 years ago during the mid-Holocene. This was a period characterized by extreme droughts in the Northern Plains, which isolated R. pipiens in deep-water habitats causing the population sub-structuring by the river basin. This research forms an important baseline of knowledge to conduct more fine-scale genetic analyses of R. pipiens populations in North Dakota. Field sampling of R. pipiens in North Dakota was completed to examine the ecological and evolutionary impacts of intensive agriculture on populations. Tissue samples for genomic analysis were collected from 632 frogs at 36 sample sites across the state. DNA extractions from these samples were completed. The SNP markers were used to detect signatures of selection due to compromised water quality in areas with intensive agriculture, to estimate the rates of gene flow and identify habitats important for biotic connectivity in the Prairie Pothole Region, and to infer demographic history.

Mathematical Modeling of Freshwater Harmful Algal Blooms

Project Type: Annual Base Grant **Project ID:** 2018ND342B

Project Impact: Excess nutrients in a freshwater environment stimulate blue-green algae, which rapidly increase and accumulate in lakes and rivers when favorable environmental conditions are met. Blue-green algae produce toxins and cause a wide range of problems including oxygen depletion, fish kills, harm or death to other aquatic organisms, and subsequent habitat loss. Cyanobacteria are a type of prokaryotic blue-green algae that can form harmful algal blooms (HABs) in water ecosystems and sometimes called CyanoHABs. The development of a HAB early-warning system is highly dependent on reliable modeling methods that predict HAB occurrence with a high accuracy. In this study, artificial intelligence techniques, particularly multilayer perceptron (MLP) neural network model were used to estimate blue-green algae fluorescence for the year-round data collected in 2016 and 2017 from western Lake Erie, USA. Eight input parameters including phosphorous, nitrogen, chlorophyll-a, air temperature, water temperature, turbidity, wind speed, and pH were used to run the model. Five different learning algorithms were tested, and the Levenberg-Marquardt algorithm resulted in the highest R2 values of 0.98 and 0.72 for eight, and three (phosphorous, nitrogen, and chlorophyll-a) input parameters, respectively. The eight input parameters produced the best estimation.

Treatment of Produced Water for Discharge to Surface Waters and Non-potable Uses

Project Type: Annual Base Grant **Project ID:** 2018ND346B

Project Impact: Unconventional oil production from the Bakken region in North Dakota has been rising significantly since 2006 because of the development of the hydraulic fracturing and horizontal drilling technologies. The fracking produced water is typically injected back to underground disposal well, discharged to a nearby surface water body, discharged to municipal wastewater treatment/shallow groundwater, or reused for future fracking. The produced water is high in salinity and contains a number of toxic trace elements and naturally occurring radioactive material. Therefore, the direct discharge of the produced water to surface water/groundwater may cause the impairment of the water quality and be threatening to the local ecosystem and the public health. This project explored an alternative way of disposal of fracking-produced water. 38 elements in a couple of produced water samples collected from the North Dakota oilfield were measured by using a Thermo Scientific iCAP Qc ICP-MS equipped with a Teledyne CETAC ASX560 Autosampler. Nickel sampler and skimmer cones, a Microflow PFA-ST nebulizer, and a quartz cyclonic spray chamber were used for all experiments. Grade 5 helium was utilized as an inert gas in kinetic energy discrimination mode. It was found that the concentrations of certain elements were elevated in the produced water, especially some heavy metal ions. The concentrations of major elements were strongly correlated with each other, suggesting that these elements were from the same source(s). Caustic softening can efficiently reduce the concentrations of multivalent metal ions. The removal efficiency correlates well with the solubility product constants of metal hydroxides.