NDSU NORTH DAKOTA STATE UNIVERSITY

Letter of Intent

Jun 30, 2020

North Dakota State University is pleased to submit an application to:
Earth Science Information Partners

Title:
Auto-reconstruction of Inundation map using Deep Leaming: Benchmarking with UDAR data

Proposed Performance Period:	12/01/2020 - 05/15/2021
NDSU Proposal Reference #:	NOV0003425
NDSU Principal Investigator:	Dr. Trung Bao Le
Department:	Civil & Environmental Eng.
PI email address:	trung.le@ndsu.edu
Direct Cost:	$7,000.00
Indirect Cost:	$0.00
Total Requested US Dollars	$7,000.00
Committed Cost Share in US Dollars:	$0.00

This proposal has been institutionally reviewed and approved by the appropriate administrative and programmatic officials. Should this proposal be selected for funding, NDSU reserves the right to negotiate an award with terms and conditions that are appropriate for a public institution of higher education and consistent with NDSU's policies.

NDSU's institutional administrative information is available at https://www.ndsu.edu/research/for_researchers/proposal_development/institutional_information/ NDSU DUNS: 80-3882299 NDSU EIN #: 45-6002439

Any award that results from this application should be in the legal name of the North Dakota State University emailed to ndsu.research@ndsu.edu or sent to the address below. Please call 701.231.8045 if further assistance is required. For technical questions, please contact NDSU's PI.

Sincerely,

Award and Program Officer

SPONSORED PROGRAMS ADMINISTRATION
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8045 | Fax 701.231.8098 | ndsu.research@ndsu.edu

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102

United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Dakota Water Science Center

ND Programs Office
821 E. Interstate Avenue
Bismarck, ND 58503

SD Programs Office
1608 Mountain View Road
Rapid City, SD 57702

Memorandum

To: Earth Science Information Partners (ESIP) Lab

From: Karen R. Ryberg, Ph.D., Dakota Water Science Center

Subject: Support for proposal "Auto-reconstruction of inundation map using Deep Learning: Bench-marking with LiDAR data" by Trung Bao Le for the 2020 Spring ESIP Lab Request for Proposals

The U.S. Geological Survey (USGS) Dakota Water Science Center has already begun collaboration with Dr. Trung Bao Le at North Dakota State University (NDSU) on methodology for making a streamflow measurements under ice using an Acoustic Doppler Current Profiler, https://www.facebook.com/USGSDakotas/posts/2561586340765762. In addition, I am serving on the dissertation committee of one of his graduate students. This proposed work will continue our collaboration as the combination of detailed streamflow measurements, remote sensing, LiDaR data, and the use of machine learning is where the USGS wants to move in terms of advanced flood analysis. This modernization of flood science fits well with the goals of the ESIP Lab.

This work will be shared throughout the hydrologic community through publications, presentations, webinars, and the distribution of the code on publicly available code repositories. Therefore, I am supportive of and endorse this proposed work and feel that both the USGS and NDSU will learn from each other's expertise and innovative ideas.

PROJECT DETAILS

Name of project: *Auto-reconstruction of inundation map using Deep Learning: Bench-marking with LiDAR data*

Project lead and contact details: *Trung Bao Le (PhD), Assistant Professor, Department of Civil and Environmental Engineering, North Dakota State University, trung.le@ndsu.edu*

Project partners and contact details: *Karen R Ryberg (PhD), Dakota Water Science Center, United States Geological Survey, kryberg@usgs.gov*

Proposed start and end date: 12/01/2020 – 05/15/2021

*Budget Requested: $7,000

* PhD Student: Berkay Koyuncu

Task 1: Collect bathymetry data (Dec 2020) ($1,000),

Personnel: Berkay Koyuncu, Trung Le

Task 2: Reconstruction of inundation map using DeepWaterMap (Jan-March 2021) ($5,000),

Personnel: Berkay Koyuncu, Trung Le, Karen Ryberg

Task 3: Validating and finetuning deep learning algorithms of DeepWaterMap for constructing inundation map (March-May 2021) ($1,000),

Personnel: Berkay Koyuncu, Trung Le, Karen Ryberg

** Funds are requested to support one half-time graduate research assistant (Berkay Koyuncu, who will devote 100% time to this project. The graduate student will be supervised by the PI (Trung Bao Le) to work on the field works and the image classification, respectively. A monthly salary of $1,200 will be provided with annual raises of 3% thereafter (total $6,000). Fringe benefits ($180) are calculated at 3% for the graduate research assistant. Funds ($820) are requested to cover the cost of regular lab and field work supplies, including seeding particles for field works, shop materials for measuring (ropes, steel frames), 3D-printing materials, and computer accessories for temporary data storage and transfer.*

PROJECT OUTLINE

Project description:

Flooding is one of the main disasters in the United States with the annual damages totaling approximately 1.5 billion USD. In North Dakota, spring flood events are frequent because of flat topography and rapid snow melt. Damages from the 1997 Red River flood along the North Dakota–Minnesota border alone were estimated at approximately 2 billion USD [1]. Under changing climate conditions, extreme flood events are expected to continue to be a societal challenge [2]. Thus, a better understanding of flooding and inundation is relevant to many applications including: (i) flood mitigation measures; and (ii) infrastructures planning and management.

One of the key challenges in assessing flooding is the ability to estimate inundated areas, which are important for understanding the hydrodynamic interaction between the floodplain and the main channel. Recent availability of high-resolution topographic data such as Light Detection and Ranging (LiDAR) has enabled the derivation of inundation maps with useful accuracy. However, the inundation maps derived from LiDAR do not reflect the actual areas covered by flood waters because such maps are purely based on geometry. So, it is important to rely on a different mode of data acquisition to confirm this coverage, especially in areas without at-site water-level measurement.

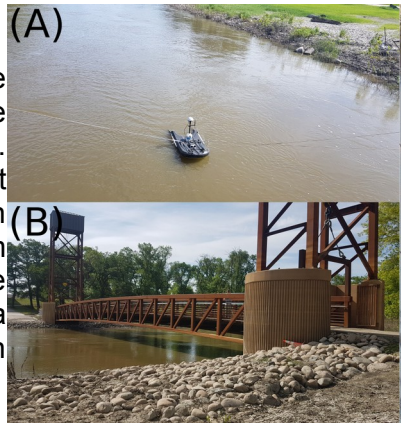

***Figure 1**: Field measurements using ADCP to measure: (A) Bathymetry; and (B) Flow distribution across one cross-section*

The European Space Agency has recently launched a series of satellites (Sentinel 1 and 2) to provide high-resolution images for land monitoring. These satellites provide high resolution images (10-meter resolution) every 5 days. In the event of flooding, the utilization of these satellites to derive inundation maps is important, especially to evaluate flood damage. One key task of developing inundation maps from satellite images is to differentiate areas occupied by land or water. Traditionally, this task is carried out

by masking the areas of interest with a predefined wavelength band. This approach is time-consuming and requires subjective band selection of band. Recently, machine learning techniques have been applied widely in image classification to deal with this type of task. One of those tools is the open-source DeepWaterMap (DWM) [3] (https://github.com/isikdogan/deepwatermap). This tool works by constructing a neural network, which successively filters the original image into different spatial resolutions. The neural network is then trained by being fed with previously classified images. Using the reconstructed images at different resolutions, a deep learning (DL) algorithm is applied to identify the neural network parameters by comparing its output with the classified image in the input library. When complete, this process leads to an automated classification without subjectively biasing the inundation map.

The main challenge for automated processes is validation, especially at high spatial resolution since studies of urban flooding require high accuracy in identifying the land-water interface [4,5]. With the current 10-meter spatial resolution, it is unclear if DWM can provide an accurate description of inundated areas in the case of flooding. Therefore, it is critical to test the validity of DWM in urban settings. In this proposal, we plan to investigate and improve the performance of DWM with a pilot project in a well-controlled area.

Project objectives, significance, and impact:

The main goal of the proposed project is to validate the usability of the DL algorithm in classifying inundation during flooding in urban settings. The objectives of the proposed project are:

G1: Carry out field measurements to construct topobathy of an urban area from surveyed bathymetry (Acoustic Doppler Current Profiler) and topography (LiDAR) data,

G2: Classify the water-land interface using satellite images and the DL algorithm during flooding, and normal conditions

G3: Validate the accuracy of DL algorithm by comparing DWM results with inundated areas calculated from the topobathy data (USGS on-site measurements)

Description of key project steps and timeline:

We propose to carry out field measurement and remote sensing data analysis to investigate the ability of DL in classifying inundated areas during flooding. We will demonstrate a multi-modality approach to evaluate data sources comprehensively and to analyze flooding in Fargo, North Dakota. The study area is chosen to be Lindenwood Park since there is an on-site United State Geological Survey (USGS) station. Temperature, gage height and other parameters (USGS station 09020104) are monitored continuously. The following steps will be taken.

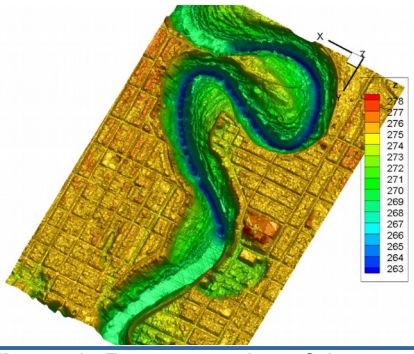

Figure 2*: Reconstruction of three-dimensional topobathy by combining LiDAR and ADCP data [5]*

Task 1: Measurements to collect bathymetry data (Nov-Dec 2020)

To construct the topobathy of the study area, we will measure flow and bathymetry during the fall of 2020 along the Red River in Fargo, North Dakota, using an Acoustic Doppler Current Profiler (ADCP) SonTek M9 attached to a kayak as shown in Figure 1. Since we have carried out similar measurements in the same study area in the past (in coordination with the USGS) [5], this task will provide additional bathymetry data to reconstruct three-dimensional topobathy as shown in Figure 2. Our preliminary effort to generate the topobathy is shown in Figure 3 indicating that our method is valid for this area. Our preliminary data in Figure 3 indicates that a minimum spacing of 10 meters for measured points is required to provide accurate description of the riverbed.

Task 2: Reconstruction of inundation map using DeepWaterMap (Jan-March 2021) The raw satellite images from Sentinel-2 will be first processed with the open-source software QGIS3 during flooding

periods. Since spring floods have occurred annually in Fargo, North Dakota, in the last few decades, there will be sufficient data (at least 5 years since the launch of Sentinel-1 & 2) to provide a basis for the classification. To automate the data processing, MATLAB and Python scripts will be used to convert and interpolate the raster dataset into numeric forms. Finally, the dataset will be compared with the inundation map derived from LiDAR. Our preliminary result is shown in Figure 4 indicating that DWM performs reasonably well with the image resolution of Sentinel-2.

Task 3: Validating and finetuning deep learning algorithms of DeepWaterMap for constructing inundation map (March-May 2021)

The DWM TensorFlow neural net has been trained in advance specifically to classify land and inundated areas using a global database. Our preliminary work is shown in Figure 4 demonstrating the comparison between LiDAR data and DWM based results for 04/26/2019. We use water-level data from the USGS streamgage to create a water surface and overlay it on the LiDAR data. Our preliminary results show that DWM can provide accurate delineation of the inundated areas as shown in Figure 4. To calculate differences in between LiDAR and DWM data, a comparison in every single raster pixel is carried out. The challenge is that the DWM output is a probability distribution, not a binary separation of land-water areas. Thus, a threshold value (p = 0.5 – 50%) must be used to delineate the water-land interface. After that, the inundation area comparison can be completed to obtain the difference/error between DWM output and LiDAR. We will investigate the sensitivity of the choice for threshold value by changing the value for p. To improve the DWM performance, we will retrain its neural net by adding our high-resolution LiDAR data to the training dataset. We expect that the retraining will improve the delineation process by providing a more accurate value of the probability distribution function.

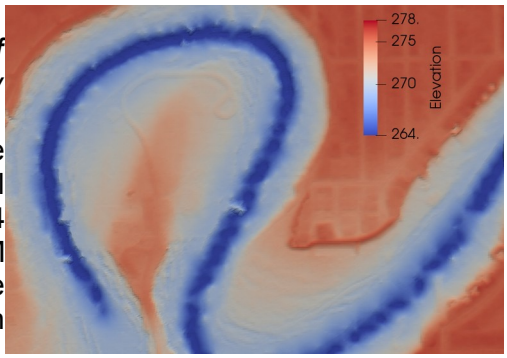

Figure 3: *Topobathy data for the study area reconstructed using our preliminary data*

Description of additional funding currently supporting this work:

The project has been funded using the start-up package of Trung Bao Le, Assistant Professor at the Department of Civil and Environmental Engineering, North Dakota State University. The PI also has been funded by the USGS through the Water Resources Research Institute in the form of a pre-doctoral fellowship for Berkay Koyuncu to initiate this project as described in the preliminary work.

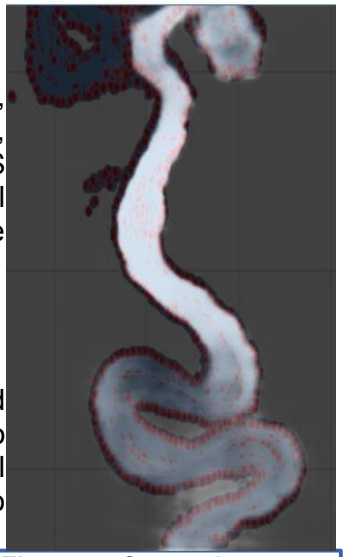

Figure 4: *Comparison between LiDAR (Red points) and DWM results (Shade)*

OUTREACH

What groups/audiences will be engaged in the project?

The PI will collaborate with River Keepers (a non-profit organization dedicated to advocate for safe and sustainable use of the Red River of the North) to engage K-12 students in exploring winter hydraulics and flooding. The PI will utilize the capabilities of the River Keepers in creating stream tables to introduce hands-on experience for students on how ice-jams and ice dams form. The students will have opportunities to observe and interact with the ice models floating on a river during the River Keepers' annual events of Race the Red (May) and Water Festival (September). Students are expected to learn and explore characteristics of Fargo flooding. We will also take part in regular sampling water quality of the Red River, a monthly program of River Keepers to engage the community in an effort to sustain the river biodiversity.

How will you judge the project's impact?
We plan to upload the new version of DeepWaterMap to GitHub and Bitbucket websites. Therefore, we can measure the number of downloads of our code to evaluate the impacts of our proposed method. In addition, the impacts of our educational program can be measured through feedback from River Keepers.

How will you share the knowledge generated by the project?
The PI plans to give guest lectures in two existing courses at NDSU (Applied Hydrology and Introduction to GIS) to demonstrate the usability and utilization of our proposed methods in Hydrology. We plan to write up a journal article to submit to American Geophysical Union. In addition, the PI will prepare online presentation and tutorials so that our new code will be accessible to many more in the hydrologic community. In addition, the field data collected in this project will be shared publicly using the portals such as the NSF-funded CUASHI program (https://www.cuahsi.org/). The data will be kept there at least 3 years for maintenance. The USGS project partner will arrange for a webinar to the USGS Dakota Water Science Center (WSC) and the Upper Midwest WSC, as well as interested staff in the USGS Water Mission Area.

Description of who should be aware of this project, i.e. potential outreach targets:
We have been working closely with the USGS Dakota WSC in this project while performing the field measurements. We will continue to work with the USGS and the National Weather Service (NWS Forecast Office and NWS River Forecast Center) as this work integrates detailed streamflow field measurements, remote sensing, and a multi-dimensional hydrodynamic model. These are three aspects of flood monitoring that the USGS is interested in combining in order to better understand flood risk. We have also worked with the engineers of the City of Fargo to obtain historical flooding data. We have contacted River Keepers to take part in their regular measurement activities to provide more technical support for their citizen scientists program.

PROJECT PARTNER
Description of project partners (agencies/individuals) and their involvement:
The USGS Dakota WSC (Karen Ryberg, PhD) will collaborate with us in this project. The role of Dr. Ryberg is to provide us guidance in understanding the hydrological characteristics of flooding in Fargo during spring. Since Dr. Ryberg has expertise in surface-water statistics, she will identify the factors and components that might provide critical combinations for 100-year and 500-year floods.

How will this project engage members of the ESIP community:
Since the technological advancement in this project is applicable for other watersheds, our proposed project will provide significant benefits to other members of the ESIP community. By developing an efficient tool for determining the inundation areas during urban flooding, many organizations in the ESIP community can use our code to further their work. The PI plans to develop and release the new version of DeepWaterMap to better reflect advancements made through this proposed work.

REFERENCES
[1] Roger A Pielke. "Who decides? Forecasts and responsibilities in the 1997 Red River Flood". In: Applied Behavioral Science Review (1999). doi: 10.1016/S1068-8595(00)80012-4.
[2] Francesco Serinaldi and Chris G. Kilsby. "Stationarity is undead: Uncertainty dominates the distribution of extremes". In: Advances in Water Resources (2015). doi: 10.1016/j.advwatres.2014.12.013.
[3] Alan Bovik, Leo F. Isikdogan, and Paola Passalacqua. "Seeing through the clouds with DeepWaterMap". In: IEEE Geoscience and Remote Sensing Letters (2019). Print ISSN: 1545-598X, Electronic ISSN: 1558-0571. doi: 10.1109/LGRS.2019. 2953261.
[4] Ali Khosronejad et al. "High-fidelity numerical modeling of the Upper Mississippi River under extreme flood condition". In: Advances in Water Resources (2016). ISSN: 03091708. doi: 10.1016/j.advwatres.2016.10.018.
[5] Trung B. Le et al. "Large-eddy simulation of the Mississippi River under base-flow condition: hydrodynamics of a natural diffluence-conuence region". In: Journal of Hydraulic Research (2019). doi: 10.1080/00221686.2018.1534282.

NSF BIOGRAPHICAL SKETCH

NAME: Le, Trung

ORCID: 0000-0002-4692-5469

POSITION TITLE & INSTITUTION: ASSISTANT PROFESSOR, NORTH DAKOTA STATE UNIVERSITY

(a) PROFESSIONAL PREPARATION

INSTITUTION	LOCATION	MAJOR / AREA OF STUDY	DEGREE (if applicable)	YEAR YYYY
THUY LOI UNIVERSITY	HANOI, HANOI	CIVIL ENGINEERING	BCE	2003
ASIAN INSTITUTE OF TECHNOLOGY	BANGKOK, BANGKOK	CIVIL ENGINEERING	MCE	2005
UNIVERSITY OF MINNESOTA	MINNEAPOLIS, MINNESOTA	CIVIL ENGINEERING	PHD	2011

(b) APPOINTMENTS

2018 - present ASSISTANT PROFESSOR, NORTH DAKOTA STATE UNIVERSITY, FARGO, ND

2016 - 2018 RESEARCH SCIENTIST, MEDICAL COLLEGE OF WISCONSIN, WAUWATOSA, WI

2013 - 2016 LECTURER, THUY LOI UNIVERSITY, HANOI

2011 - 2013 POSTDOCTORAL ASSOCIATE, UNIVERSITY OF MINNESOTA, MINNEAPOLIS, MN

(c) PRODUCTS

Products Most Closely Related to the Proposed Project

1. Khosronejad A, Le T, DeWall P, Bartelt N, Woldeamlak S, Yang X, Sotiropoulos F. High-fidelity numerical modeling of the Upper Mississippi River under extreme flood condition. Advances in Water Resources. 2016 December; 98:97-113. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0309170816305899 DOI: 10.1016/j.advwatres.2016.10.018
2. Borazjani I, Ge L, Le T, Sotiropoulos F. A parallel overset-curvilinear-immersed boundary framework for simulating complex 3D incompressible flows. Computers & Fluids. 2013; 77:76-96. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0045793013000790 DOI: 10.1016/j.compfluid.2013.02.017
3. Le T, Borazjani I, Kang S, Sotiropoulos F. On the structure of vortex rings from inclined nozzles. Journal of Fluid Mechanics. 2011 September 26; 686:451-483. Available from: https://www.cambridge.org/core/product/identifier/S0022112011003405/type/journal_article DOI: 10.1017/jfm.2011.340
4. Le T, Khosronejad A, Sotiropoulos F, Bartelt N, Woldeamlak S, Dewall P. Large-eddy simulation of the Mississippi River under base-flow condition: hydrodynamics of a natural diffluence-confluence region. Journal of Hydraulic Research. 2018 December 07; 57(6):836-851. Available from:

https://www.tandfonline.com/doi/full/10.1080/00221686.2018.1534282 DOI: 10.1080/00221686.2018.1534282

5. Coffey D, Malbraaten N, Le T, Borazjani I, Sotiropoulos F, Keefe D. Slice WIM. Symposium on Interactive 3D Graphics and Games on - I3D '11. Symposium on Interactive 3D Graphics and Games; ; San Francisco, California. New York, New York, USA: ACM Press; c2011. Available from: http://portal.acm.org/citation.cfm?doid=1944745.1944777 DOI: 10.1145/1944745.1944777

Other Significant Products, Whether or Not Related to the Proposed Project

1. Le T, Sotiropoulos F. On the three-dimensional vortical structure of early diastolic flow in a patient-specific left ventricle. European Journal of Mechanics - B/Fluids. 2012; 35:20-24. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0997754612000143 DOI: 10.1016/j.euromechflu.2012.01.013
2. Le TB, Sotiropoulos F. Fluid-structure interaction of an aortic heart valve prosthesis driven by an animated anatomic left ventricle. J Comput Phys. 2013 Jul 1;244:41-62. PubMed PMID: 23729841; PubMed Central PMCID: PMC3667163.
3. Le TB, Sotiropoulos F, Coffey D, Keefe D. Vortex formation and instability in the left ventricle. Phys Fluids (1994). 2012 Sep;24(9):91110. PubMed PMID: 23112565; PubMed Central PMCID: PMC3465351.
4. Sotiropoulos F, Le T, Gilmanov A. Fluid Mechanics of Heart Valves and Their Replacements. Annual Review of Fluid Mechanics. 2016 January 03; 48(1):259-283. Available from: http://www.annualreviews.org/doi/10.1146/annurev-fluid-122414-034314 DOI: 10.1146/annurev-fluid-122414-034314

(d) SYNERGISTIC ACTIVITIES

1. Reviewer for 20 academic journals including Biomechanics and Modeling in Mechanobiology, Journal of Computational Physics, PLOS ONE, Annals of Biomedical Engineering (ABME), Cardiovascular Engineering and Technology (CVET), Journal of Biomechanical Engineering, Computers in Biology and Medicine, Medical Engineering & Physics (MEP), Medical & Biological Engineering & Computing (MBEC), Nature Scientific Reports, Bioinspiration & Biomimetics and others

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Dakota Water Science Center
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Karen R. Ryberg, Ph.D.

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Cell: (701) 226-0973
kryberg@usgs.gov
usgs.gov/staff-profiles/karen-r-ryberg

Professional Experience

July 2016–present

Research Statistician
U.S. Geological Survey, Bismarck, North Dakota

Duties

- Project management
- Statistical analysis of hydrologic data
- Hydrologic analysis software development in R
- Publication and peer review of scientific journal articles and reports
- Course coordinator for Statistical Methods for Environmental Data Analysis class at the USGS National Training Center (2017–present), member of teaching team (2011–present)

Teams/Committees

- Lead for Surface Water and Statistics Theme Team, Dakota Water Science Center (2019–present)
- Lead for Climate Effects Team of the NAWQA Cycle 3 Surface-Water Status and Trends Team (2017–19)
- Stakeholder Advisory Team member for the NOAA Sectoral Applications Research Program focused on agriculture in the James River Basin of North and South Dakota (2017–18)
- USGS Nonstationarity Workgroup (2016–17)
- Lead Ancillary Data Causal Analysis Workgroup NAWQA Cycle 3 Surface-Water Status and Trends Team (lead, 2013–17)
- Member of National Water Quality Assessment (NAWQA) Cycle 3 Surface-Water Status and Trends Team (2013–present)

July 2003–July 2016

Statistician
U.S. Geological Survey, Bismarck, North Dakota

Duties

- Statistical analysis of hydrologic data, including parametric and non-parametric methods
- Hydrologic analysis software development in R
- Analysis of trends in pesticide concentrations for the NAWQA National Pesticide Synthesis Team (2009–13)
- Publication and peer review of scientific journal articles and reports
- Part of team teaching Statistical Methods for Environmental Data Analysis class at the USGS National Training Center (2011–present)
- Data mining to find patterns, trends, and outliers in large data sets
- Web access log analysis and web usage analysis
- North Dakota Water Science Center Webmaster (ended in 2008)

April 2002–July 2003 | **Student Trainee (Information Technology)**
U.S. Geological Survey, Bismarck, North Dakota

- Perl and Visual Basic programming
- Database creation, manipulation, and retrieval
- North Dakota Water Science Center Webmaster
- USGS Lewis & Clark Bicentennial Committee

March 2001–April 2002 | **Computer Clerk**
U.S. Geological Survey, Bismarck, North Dakota

- Computer programming
- Database creation, manipulation, and retrieval
- Creation of new content for and maintenance of North Dakota Water Science Center website

Previous employment in Information Technology and Telecommunications Outside Plant Engineering and Right-of-Way Acquisition. Previous employers include Finley Engineering, Inc.; West River Telecommunications Cooperative; Bismarck State College; Sykes Enterprises, Inc.; and University of Mary.

Education

Doctorate of Philosophy in Environmental and Conservation Sciences, 2015
Environmental Science Track
North Dakota State University, Fargo, North Dakota
Dissertation: *Impact of Climate Variability on Streamflow and Water Quality in the North Central United States*
Advisor: Prof. Wei Lin

Master of Science in Statistics, 2006
Colorado State University, Fort Collins, Colorado
Masters Project: *Water-Quality Trend Analysis for the Devils Lake Basin, North Dakota, January 1965 through September 2003*
Advisors: Prof. F. Jay Breidt and Faculty Affiliate Aldo V. Vecchia

Associate of Applied Science Computer Support Specialist, 2001
Bismarck State College, Bismarck, North Dakota

Bachelor of Arts in Mathematics, Minor in Latin, 1995
Luther College, Decorah, Iowa
Senior Paper: *Music for the Mind, Mathematics for the Soul—Abstract Algebra and Musical Composition*

Certificates

Mathematics for Machine Learning Specialization Certificate, 2020
Imperial College London, on Coursera
Three courses on advanced mathematics for applications in data science and machine learning

Executive Data Science, a 5-course specialization, 2018
Johns Hopkins University, on Coursera
Five courses in assembling the right team, asking the right questions, and avoiding the mistakes that derail data science projects

Data Mining and Applications, Graduate Certificate , 2008
Stanford University, Stanford, California

Management Certificate, 1996
University of Mary, Bismarck, North Dakota

Publications in the Last Ten Years—Peer Reviewed

Journal Articles

Stets, E.G., Sprague, L.A., Oelsner, G.P., Johnson, H.M., Murphy, J.C., Ryberg, K., Vecchia, A.V., Zuellig, R.E., Falcone, J.A., and Riskin, M.L., 2020, Landscape drivers of dynamic change in water quality of U.S. rivers: *Environmental Science & Technology*, v. 54, no. 7, p. 4336–4343, https://doi.org/10.1021/acs.est.9b05344.

Blum, A.G., Ferraro, P.J., Archfield, S.A., and Ryberg, K.R., 2020, Causal effect of impervious cover on annual flood magnitude for the United States: *Geophysical Research Letters*, v. 47, no. 5, article no. e2019GL086480, https://doi.org/10.1029/2019GL086480.

Ryberg, K.R., Stone, S., Wesley W., and Baker, N.T., 2020, Causal factors for pesticide trends in streams of the United States?Atrazine and deethylatrazine: *Journal of Environmental Quality*, v. 49, no. 1, p. 152–162, https://doi.org/10.1002/jeq2.20045.

Ryberg, K.R., Hodgkins, G.A., and Dudley, R.W., 2020, Change points in annual peak streamflows—Method comparisons and historical change points in the United States: *Journal of Hydrology*, v. 583, article no. 124307, https://doi.org/10.1016/j.jhydrol.2019.124307.

Ryberg, K.R., Blomquist, J.D., Sprague, L.A., Sekellick, A.J., and Keisman, J., 2018, Modeling drivers of phosphorus loads in Chesapeake Bay tributaries and inferences about long-term change: *Science of The Total Environment*, v. 616–617, p. 1423–1430,
https://doi.org/10.1016/j.scitotenv.2017.10.173.

Ryberg, K. R., 2017, Structural equation model of total phosphorus loads in the Red River of the North Basin, USA and Canada: *Journal of Environmental Quality*, v. 46, no. 5, p. 1072–1080,
http://doi.org/10.2134/jeq2017.04.0131.

Ryberg, K.R., Akyüz, F.A., Wiche, G.J. Lin, W., 2016, Changes in seasonality and timing of peak streamflow in snow and semi-arid climates of the north central United States, 1910–2012: *Hydrologic Processes*, v. 30, p. 1208–1218, http://doi.org/10.1002/hyp.10693.

Ryberg, K.R., Vecchia, A.V., Akyüz, F.A., Lin, W., 2016, Tree-ring based estimates of long-term seasonal precipitation in the Souris River Region of Saskatchewan, North Dakota, and Manitoba: *Canadian Water Resources Journal / Revue canadienne des ressources hydriques*, v. 41, no. 3, 412–428,
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Ryberg, K.R. and Gilliom, R.J., 2015, Pesticide concentration and use trends in major rivers of the United States: *Science of the Total Environment*, v. 538, p. 431–444, http://doi.org/10.1016/j.scitotenv.2015.06.095.

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Invited Presentations and Panels in the Last Ten Years

Presentations

Ryberg, K.R., Chanat, J.G., February 27, 2020, *Trends in water quality in relation to predicted climate effects*, Seminar for Environmental and Conservation Sciences Program, North Dakota State University, Fargo, N. Dak.

Harden, T.M. (presenter), Ryberg, K.R. (presenter), O'Connor, J.E., Friedman, J.M., and Kiang, J.E., February 21, 2020, *Paleoflood analyses for probabilistic flood hazard assessments—Approaches and review guidelines*: U.S. Nuclear Regulatory Commission Fifth Annual Probabilistic Flood Hazard Assessment Research Workshop, February 19–21, 2020, Rockville, Md.

Ryberg, K.R., Archfield, S.A., Asquith, W.H., Barth, N.A., Chase, K.J., Dickinson, J.E., Dudley, R.W., Gregory, A.E., Harden, T.M., Hodgkins, G.A., Holtschlag, D.J., Humberson, D., Konrad, C.P., Levin, S.B., Restivo, D.E., Sando, R., Sando, S.K., Swain, E.D., Tillery, A.C., York, B.C., and Kiang, J.E., February 20, 2020, *Attribution of flood nonstationarity across the United States—Climate-related analyses*: U.S. Nuclear Regulatory Commission Fifth Annual Probabilistic Flood Hazard Assessment Research Workshop, February 19–21, 2020, Rockville, Md.

Ryberg, K.R., February 4, 2020, *Flood regime changes across the US—Detection, attribution, and adjustment of flood-frequency analysis methods*: 2019-2020 Annual Quad Agency Meeting, February 4–6, 2020, Kansas City, Mo. (delivered remotely)

Archfield, S.A., Ryberg, K.R., Blum, A.G., Barth, N.A., Awashti, C., Li, H., Abeshu, G.W., Arumugam, S., December 9, 2019, *What defines a flood? Building shared understanding across differing attributes and definitions of flooding*: AGU Fall Meeting, December 9–13, 2019, San Francisco, Calif.

Ryberg, K.R., Archfield, S.A., Kiang, J.E., Barth, N.A., and Gregory, A.E., March, 20, 2019, *National flood trends—Detection and attribution and adjustment for flood-frequency analysis*, Seminar for Civil and Environmental Engineering Department, North Dakota State University, Fargo, N. Dak.

Ryberg, K.R., January 29, 2019, *Trend analysis, Mark Twain, and Idaho water quality*, Idaho Water Quality Workshop, January 29–31, 2019, Boise, Idaho. **KEYNOTE**

Blum, A.G., Ferraro, P., Ryberg, K.R., and Archfield, S.A., December 12, 2018, *Econometric panel approaches to isolating the causal impact of impervious cover on annual peak floods*, AGU Fall Meeting, December 10–14, 2018, Washington, D.C.

Ryberg, K.R., Blomquist, Sprague, L.A., Sekellick, A. and Keisman, J., December 11, 2018, *Modeling causal drivers of phosphorus loads in Chesapeake Bay tributaries using structural equation models*, AGU Fall Meeting, December 10–14, 2018, Washington, D.C.

Ryberg, K.R., June 7, 2018, *The Story of Devils Lake*, Visiting Scientists Series Lightning Talks, Bismarck Veterans Memorial Public Library, Bismarck, N. Dak.

Ryberg, K.R., Kolars, K.A., and Kiang, J.E., December 4, 2017, *Flood-frequency estimation for very low annual exceedance probabilities using historical and paleoflood data, with considerations for nonstationary systems*, U.S. Nuclear Regulatory Commission Third Annual Probabilistic Flood Hazard Assessment Research Workshop, December 4–5, 2017, Rockville, Md.

Ryberg, K.R., November 29, 2017, *Multivariate statistical analysis in water quality*: National Water Quality Monitoring Council webinar

Ryberg, K.R., April 4, 2017, *Earth as Art*, Public lecture, Visiting Scientists Series and ArtsQuest, Bismarck State College, N.Dak.

Ryberg, K.R., March 8, 2017, *Climate, runoff, and flooding in the north central United States*, Seminar for Department of Soil, Water, and Climate, University of Minnesota, St. Paul, Minn.

Ryberg, K.R., Kolars, K.A., and Vecchia, A.V., November 17, 2016, *Climate and streamflow modeling and future flood risk—Souris River Basin, Saskatchewan, North Dakota, and Manitoba*, Minnesota Association of Floodplain Managers Annual Conference, November 16-18, 2016, St. Cloud, Minn. **PLENARY**

Ryberg, K.R., and Blomquist, J., May 5, 2016, *Assessing the causes of changes in nutrient loading from major tributaries of Chesapeake Bay*, 10th National Monitoring Conference, May 2–6, 2016, Tampa, Fla.

Ryberg, K.R., Kolars, K.A., and Vecchia, A.V., February 24, 2016, *Stochastic model for simulating Souris River Basin precipitation, evapotranspiration, and natural streamflow*, International Souris River Board Winter Meeting, Bismarck, N. Dak.

Ryberg, K.R., November 12, 2015, *Climate variability in the northern Great Plains*, Climate Change Scenario Planning Workshop for Resource Management and Operations in Central North Dakota, November 12–13, 2015, Bismarck, N. Dak.

Ryberg, K. R., Vecchia, A.V., Akyüz, F.A., and Lin, W., June 19, 2015, *Tree-ring based estimates of long-term seasonal precipitation in the Souris River Region, of Saskatchewan, North Dakota, and Manitoba*, International Souris River Board Meeting, June 19, 2015, Estevan, Saskatchewan, Canada.

Ryberg, K. R., Vecchia, A.V., Akyüz, F.A., and Lin, W., February 10, 2015, *Tree-ring based estimates of long-term seasonal precipitation Souris River Region, Saskatchewan, North Dakota, and Manitoba*, Water Mission Area Investigations Chiefs Meeting, February 10–12, 2015, Reston, Va.

Ryberg, K.R., June 24, 2014, *Climate, flooding, and the Souris River Basin*, International Souris River Board Public Meeting, Minot, N. Dak.

Ryberg, K.R. (presenter) and Vecchia, A.V. (presenter), March 5, 2014, *Modeling pesticide concentrations in surface water, with special emphasis on results for the corn-belt region of the United States and the Missouri and Red River Basins*, 2014 ND Water Quality Monitoring Conference, March 4–6, 2014, Bismarck, N. Dak. **PLENARY**

Ryberg, K.R., October 18, 2012, *Web site and social media usage during flooding—communicating science*, US-Russia Bi-Presidential Commission Science and Technology Working Group Sub-Working Group on Climate Change and the Working Group on Emergency Situations Workshop on Flood Frequency and Flood Inundation Mapping, October 17–19, 2012, Hydrometeorological Center of Russia, Moscow, Russian Federation.

Ryberg, K.R., Lin, W., and Vecchia, A.V., October 15, 2012, *Impact of climate variability on runoff in the North Central United States*, US-Russia Bi-Presidential Commission Science and Technology Working Group Sub-Working Group on Climate Change and the Working Group on Emergency Situations Workshop on The Impact of Climate Variability on Streamflow in the United States and Russia, October 15–16, 2012, State Hydrologic Institute, St. Petersburg, Russian Federation.

Ryberg, K.R., September 27, 2012, *Web usage and social media during flooding—communicating science*, USGS National Data Conference, September 24–27, 2012, Portland, Oreg.

Ryberg, K.R., June 9, 2011, *NWISWeb tips & tricks*, USGS National Data Conference, June 6–9, 2011, Pittsburgh, Pa.

Ryberg, K.R., June 8, 2011, *Web usage and social media during flooding*, USGS National Data Conference, June 6–9, 2011, Pittsburgh, Pa.

Wiche, G.J. and Ryberg, K.R. (presenter), June 2, 2011, *Challenges and opportunities in the hydrologic sciences*, 2011 International Student Prairie Conference on Environmental Issues, June 2–4, 2011, North Dakota State University, Fargo, N. Dak.

Panel Moderator

Invited co-presider of AGRO-SETAC Joint Symposium titled *Role of monitoring data in advancing regulatory risk assessment* on August 22, 2018, at the American Chemical Society Fall Meeting, August 19–23, 2019, Boston, Mass. AGRO is a division of the American Chemical Society that brings together a worldwide community of scientists and stakeholders to advance knowledge and promote innovative solutions for the protection of agricultural productivity, public health, and environment. SETAC is the Society of Environmental Toxicology and Chemistry.

Panel Member

March 28, 2019, *Exploring causal hypotheses—What's driving environmental trends and conditions?*, National Monitoring Conference, March 25–29, 2019, Denver, Colo.

August 26, 2017, *Women in Science, Technology, Engineering, and Math*, Women's Equality Day, Former Governor's Mansion State Historic Site, Bismarck, N. Dak.

August 21, 2015, *Innovation in the U.S. Geological Survey*, Panel of scientists from Northern Prairie Wildlife Research Center (NPWRC) and North Dakota Water Science Center (NDWSC)—Moderated by Suzette Kimball, Acting Director USGS, Jamestown, N. Dak.

November 14, 2014, *Long-term climate and hydrology trends in the region*, Balancing the Issues Panel Discussion, Assiniboine River Basin Initiative Conference–3 River Watersheds 1 Basin—Shaping our Future—Qu'Appelle, Souris, Assiniboine Rivers, November 12–14, 2014, Regina, Saskatchewan, Canada.

August 28, 2014, *Flooding and climate in the Red River Basin and surrounding region*, Flooding on the Red River Panel Discussion, U.S. Geological Survey 2014 Congressional Field Trip—Exploring USGS Science in the Dakotas, August 24–29, 2014, Fargo, N. Dak.

Selected Service to Profession

Workshops Organized or Co-organized

- **Flood-Frequency Analysis Workshop using Bulletin 17C Methods**, Ryberg, K.R., Barth, N.A., and Williams-Sether, T., May 19, 2020, North Dakota State Water Commission, Bismarck, N.Dak.
- **Development of a Framework for Technical Review of Paleoflood Information**, Ryberg, K.R., Harden, T.M., O'Connor, J.E., and Friedman, J.M., May 27–28, 2019, U.S. Nuclear Regulatory Commission, Rockville, Md.
- **Multivariate Statistics in Water Quality**, Ryberg, K.R., November 8, 2018, SETAC (Society of Environmental Toxicology and Chemistry) North America 39th Annual Meeting, November 4–8, 2018, Sacramento, Calif.
- **Statistical Analysis Methods for Water-Quality Data**, Ryberg, K.R. and Vecchia, A.V., March 8, 2018, North Dakota Water Quality Monitoring Conference, March 7–8, 2018, Bismarck, N. Dak.
- **Site-Specific Peak-Streamflow Frequency Analysis**, Asquith, W.H., Ryberg, K.R., and Kiang, J.E., October 18–19, 2017, Nuclear Regulatory Commission, Rockville, Md.
- **Scientific Communication**, Ryberg, K.R., Vecchia, A.V., Christensen, V.G., March 20, 2014, a one-day workshop for the Environmental and Conservation Science Program at North Dakota State University, Fargo, N. Dak.
- **Introduction to R**, Ryberg, K.R. and Vecchia, A.V., December 11–12, 2013, a workshop on using statistical software for the U.S. Geological Survey North Dakota Water Science Center, Bismarck, N. Dak.