Water Quality Data for Fall Creek, New York, USA: 1972-1995

D. R. Bouldin[1] and N. O'Leary[2*]

[1]Professor Emeritus of Crop and Soil Sciences, Cornell University, Ithaca, NY, USA
[2]Environmental Science, Wells College, Aurora, NY, USA

* Correspondence to: Niamh O'Leary, Environmental Science, Wells College, 170 Main St., Aurora, NY 13026, USA. E-mail: noleary@wells.edu

ABSTRACT
The 33,086 ha mixed land use Fall Creek watershed in upstate New York is part of the Great Lakes drainage system. Results from more than 3,500 water samples are available in a data set that compiles flow data and measurements of various water quality analytes collected between 1972 and 1995 in all seasons and under all flow regimes in Fall Creek and its tributaries. Data is freely accessible at https://ecommons.cornell.edu/handle/1813/8148 and includes measurements of suspended solids, pH, alkalinity, calcium, magnesium, potassium, sodium, chloride, nitrate nitrogen (NO3-N), sulfate sulfur (SO4-S), phosphorus (P) fractions molybdate reactive P (MRP) and total dissolved P (TDP), percent P in sediment, and ammonium nitrogen (NH4-N). Methods, sub-watershed areas, and coordinates for sampling sites are also included. The work represented in this data set has made important scientific contributions to understanding of hydrological and biogeochemical processes that influence loading in mixed use watersheds and that have an impact on algal productivity in receiving water bodies. In addition, the work has been foundational for important regulatory and management decisions in the region.

1 INTRODUCTION

Long-term data are valuable in the study of systems that are inherently variable over days, seasons, years, and decades. A data set of water quality parameters in the Fall Creek watershed in upstate New York, USA, has provided insights into hydrological processes for many decades, and is freely available to the scientific community to use for basic or applied research purposes. Data collection on multiple water quality analytes at numerous sampling sites began in the early 1970s and continued intermittently until the mid-1990s. Employment of consistent methodology throughout the sampling interval has generated a unique and valuable data set with applications in research, management, and watershed protection.

2 METHODS

2.1 Geographic setting

The 33,086 ha Fall Creek watershed is the largest sub-watershed of Cayuga Lake, which is part of the Seneca-Oneida-Oswego River drainage in New York State, northeastern United States (Figure 1). The center of Cayuga Lake is located at a latitude of 42.692^{o} N and longitude of 76.689^{o} W. Bedrock geology is predominantly shale, siltstone, and sandstone, and surficial geology is glacial till (Bloom, 2018). Land use in the 1970s was classified as 59% agricultural, 34% forest, and 1% urban (Bouldin, Johnson, & Lauer, 1975); by the 2000s land use was classified as 48% agricultural, 40% forest/brush, and 11% urban (Haith, Hollingshead, Bell, Kreszewski, & Morey, 2012).

2.2 Study sites

Data were collected from 43 sampling sites in the Fall Creek watershed. Approximately half of the data points were collected at the primary sampling site, location 1, which is about 100m upstream of USGS gaging station 04234000 and about 6 km upstream of the point where Fall Creek empties into Cayuga Lake. Three hundred or more samples were collected from two of the remaining sampling sites, locations 15 and 16, both of which were gaged and have flow data included for many samples (Bouldin et al., 1975). Location 16 is on the major tributary of Virgil Creek, upstream of where it converges with the main Fall Creek stem; location 15 is upstream of the convergence on Fall Creek (Figure 1). Fewer samples were collected from the remainder of the sites. Coordinates of all sampling sites and sub-watershed areas are included in the data set.

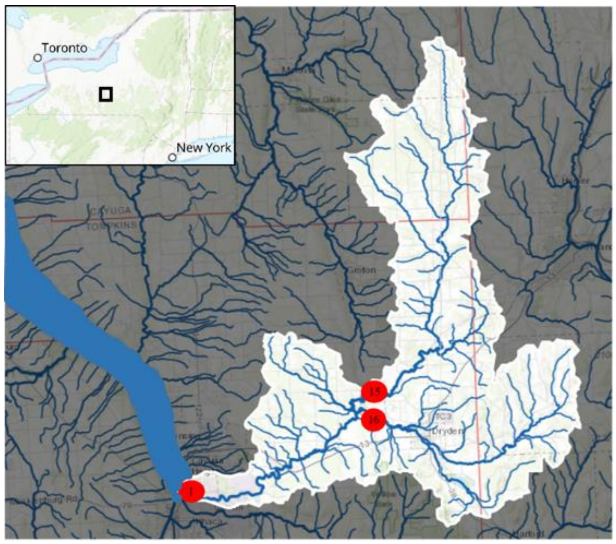

Figure 1. Boundary of the 33,086 ha Fall Creek watershed and approximate location of major sampling sites. Location 1 is close to the outlet to Cayuga Lake; locations 15 and 16 are upstream of the convergence of Fall Creek with its major tributary Virgil Creek. Map retrieved and modified from https://modelmywatershed.org. Inset map shows the approximate location of the Fall Creek watershed in New York State, USA.

2.3 Collection and analysis of stream samples

More than 3,500 water samples were collected between 1972 and 1995 in all seasons and under all flow regimes. About 80% of the samples were collected in the 1970s, with particularly intensive sampling between 1973 and 1975. This reflects the origin of the data set as part of early studies on the role of nutrient runoff as a driver of eutrophication in the Finger Lakes region of New York State. Samples were collected more intermittently at a subset of the sites after 1975 (Table 1). Sampling frequency was based on flow, with several samples taken per day during high flow periods and samples collected every 1 to 3 weeks during low flow periods. Samples were analyzed for suspended solids, pH, alkalinity, calcium, magnesium, potassium, sodium, chloride, nitrate nitrogen (NO3-N), sulfate sulfur (SO4-S), phosphorus (P) fractions molybdate reactive P (MRP) and total dissolved P (TDP), percent P in sediment, and ammonium nitrogen (NH4-N). Detailed methods for each analyte are described in the metadata that accompany the data set. Uncertainty in the data results from sample size limitations and measurement error. Uncertainty is greatest for those sites with the lowest numbers of samples. Quality assurance and control precautions limited measurement error, and the data set benefits from the consistency of a single scientist throughout its history. The precision value associated with each analytical method is included in the metadata.

Table 1. Forty-three sites in the Fall Creek Watershed were sampled intermittently between 1975 and 1995.

Site Number	Years Sampled
1	1972–1975, 1977–1981, 1987–1995
4, 5, 7, 8, 9, 10, 11, 12, 17, 18, 19, 21	1973–1974
6	1973–1981, 1992–1994
13, 14, 123	1975
15	1973–1975, 1977–1981
16	1972–1975, 1977–1981
20	1973
22	1973–1975, 1992–1994
101, 102, 103, 104, 105, 106, 111, 115, 116, 119, 120, 121, 122	1974–1975
107, 108, 109, 110, 112, 113, 114, 117, 118	1974

3 DATA SET

3.1 Contributors to the data set

D. R. Bouldin of Cornell University created the data set working with many research associates, graduate students, postdoctoral fellows, and faculty who contributed to the work including A.H. Johnson, A. M. Hedges, H. R. Capener, G. L. Casler, A. E. Durfee, R. C. Loehr, R. L. Oglesby, R. J. Young, P. R. Burkholder, P. J. Godfrey, E. A. Goyette, G. W. Hergert, G. E. Likens, D. Allee, W. R. Schaffner, B. J. Peterson, and K. S. Porter.

3.2 Ownership and use of the data

Cornell University has ownership of the data set, which can be used along with the accompanying metadata for non-commercial academic, research, and other professional purposes. Permission to use the data is granted to the data user subject to the following terms:
1) Data user will cite the data set owner in derivative works or publications that use the data set;
2) Data user will share any derivative works for non-commercial academic, research, and other

professional purposes; 3) Data user will notify users that such derivative work is a modified version and not the original data and documentation distributed by the data set owner.

3.3 Data availability

The data set is openly available in Cornell University's digital repository at https://ecommons.cornell.edu/handle/1813/8148. The data set is in a zipped file that includes a data folder and a metadata file. The data folder includes two files: one with the water quality data and one that has the coordinates for sampling sites as well as the sub-watershed areas. The two data files download as notepad files that can then be opened in Microsoft Excel. The official title of the data set is *Water Quality Data for Fall Creek (Tompkins County, NY) Sampling Sites: 1972-1995.*

4 IMPORTANCE OF THE FALL CREEK WORK

Major contributions that the Fall Creek work has made to improved understanding of hydrological processes, their study, and their application, are outlined below.

- Concentrations of P fractions in stream water vary seasonally and also vary with flow intensity, with much of the P being exported during high flow events (Johnson, Bouldin, Goyette, & Hedges, 1976a). Thus effective stream sampling can only be carried out in a regime that covers all seasons and all flow levels, with an emphasis on high flow periods.
- Johnson, Bouldin, and Hergert (1975) used Fall Creek samples to determine best practices for sample storage in order for subsequent phosphate analysis to be accurate.
- Porter, Lauer, Messinger, and Bouldin (1975) estimated that less than 3% of the P added to the watershed annually was leaving in Fall Creek as biologically available P, and concluded that export was unlikely to be significantly affected by changes in the levels of inputs of P.
- Johnson et al. (1976a) determined that the landscape was accumulating P, laying groundwork for the concept of legacy P as a complicating factor in watershed management.
- Bouldin et al. (1977) determined a cost estimate of per unit P reduction from different sources and concluded that on a per unit basis, reducing P from agricultural and unsewered sources is more expensive than reducing it from other sources.
- The actual impact of new regulatory measures was demonstrated when the data set was used to detect changes consistent with the expected response to a 1973 statewide phosphorus detergent ban (Bouldin et al., 1975).
- Schaffner and Oglesby (1978) examined P loading to lakes and used Fall Creek data to argue that the best calculations of loading reflect forms of P with the most biological significance.
- Bouldin et al. (1975) hypothesized on the relative bioavailability of different forms of P. Their hypothesis was later supported by Prestigiacomo et al. (2016) who demonstrated that biologically available P in the region is a composite of completely bioavailable soluble reactive P, mostly bioavailable soluble unreactive P, and less bioavailable particulate P.
- Haith et al. (2012) used work derived from the data set to develop and test a model of phosphorus loading in the Cayuga Lake watershed.
- The data set was augmented with the results of additional sampling in the 2000's, which led to the finding of no significant change in flow rate-adjusted soluble reactive P concentration in Fall Creek over many decades. As a result, inter-annual variation in soluble reactive P loading to Cayuga Lake was determined to be primarily a function of variation in discharge (O' Leary, Johnston, Gardner, Penningroth, & Bouldin, 2019).

- Seasonal variation in nitrate export was documented by Johnson, Bouldin, Goyette, and Hedges (1976b), and the Fall Creek data also contributed to a comprehensive study of long-term nitrate dynamics by Johnson, Woodbury, Pell, and Lehmann (2007).
- The data set was used to model the response of watersheds to chloride from road salt applications. Results of the model projected future changes in stream salt concentrations and offered insights into watershed dynamics (Shaw, Marjerison, Bouldin, Parlange, & Walter, 2012).
- Nagle, Fahey, Ritchie, and Woodbury (2007) used Fall Creek data as part of a study that demonstrated the major role of eroding streamside glacial deposits in sediment yield in many watersheds of the region.
- In addition to basic research that has improved understanding of underlying hydrological processes, the Fall Creek work has played an important role in management and regulatory decisions in the larger Cayuga Lake Watershed. It appears in a baseline characterization of P and nitrogen inputs into Cayuga Lake (Genesee-Finger Lakes Regional Planning Council, 2000). The work was fundamental to the environmental impact assessment necessary for the Cornell University Lake Source Cooling project, where it was chosen as the basis for an estimate of tributary P input (Cornell University Facilities and Campus Services, 1998). It has also been used as part of tributary analysis and in the validation of a loading model for the total maximum daily load calculation for Cayuga Lake (UFI et al*.,* 2014).

Scientific value continues to be extracted from this data set. It has already served as an important baseline, and will continue to do so in the future. Combined with additional data collected after 1995 it has demonstrated the stability of the Fall Creek watershed over long periods of time and under changing conditions, with implications for expected response to management decisions in the broader region (O'Leary et al., 2019). The motivation for the first work on this data set, where particular analytes were selected in collaboration with limnologists studying lake responses to tributary inputs in the early 1970s, is still relevant today as new concerns about the proliferation of harmful algal blooms drive additional watershed studies with the goal of developing predictive models and effective mitigation strategies. Supplemental and complementary data in future decades will help improve models and answer new questions about the impacts of changes in land use, climate, discharge, and inputs, including those attributable to atmospheric deposition and wastewater management.

This data set includes a large number of parameters measured in many sub-watersheds over a long timeframe making it versatile for a wide variety of applications. Usage statistics on the site indicate that the data is regularly accessed by interested parties around the world. It is freely accessible for any future use in the service of basic research or applied work on streams, watersheds, loading, or other applications.

ACKNOWLEDGEMENTS
We are grateful for a grant from the Rockefeller Foundation in 1970, and to Cornell University which continued to fund this work. We thank Roxy Johnston for her assistance in editing this manuscript.

REFERENCES

Bloom, A.L. 2018. *Gorges History: Landscapes and Geology of the Finger Lakes Region*. Palentological Research Institution, Ithaca NY.

Bouldin, D. R., Johnson, A. H., & Lauer, D. A. 1975. The influence of human activity on the export of phosphorus and nitrate from Fall Creek. In *Nitrogen and Phosphorus. Food Production, Waste and the Environment*; Porter, K., Ed.; Ann Arbor Science: Ann Arbor, MI, USA; pp. 59–120.

Bouldin, D. R., Capener, H. R., Casler, G. L., Durfee, A. E., Loehr, R. C., Oglesby, R. T. & Young, R. J. 1977. *Lakes and Phosphorus Inputs: A Focus on Management.* New York State College of Agriculture and Life Sciences, Cornell University, Ithaca NY. Information Bulletin 127.

Cornell University Facilities and Campus Services. 1998. Final Environmental Impact Statement, Lake Source Cooling, Cornell University. Available online: https://fcs.cornell.edu/departments/energy-sustainability/utilities/cooling-home/cooling-distribution/lake-source-cooling-home/lsc-environmental-impact-statement/lsc-eis-23-surface-water-cayuga-lake/lsc-eis-233-phosphorus-productivity

Genesee-Finger Lakes Regional Planning Council. 2000. Cayuga Lake Watershed Characterization. Available online: http://cayugawatershed.org/documents/CLW_characterization_2000.pdf

Haith, D. A., Hollingshead, N., Bell, M. L., Kreszewski, S. W., & Morey, S. J. 2012. Nutrient loads to Cayuga Lake, New York: Watershed modeling on a budget. *Journal of Water Resources Planning and Management* 138: 571–580.

Johnson, A. H. Bouldin, D. R., & Hergert, G. W. 1975. Some observations concerning preparation and storage of stream samples for dissolved inorganic phosphorus. *Water Resources Research* 11:559-562.

Johnson, A. H., Bouldin, D. R., Goyette, E. A. & Hedges, A. M. 1976a. Phosphorus loss by stream transport from a rural watershed: Quantities, processes and sources. *Journal of Environmental Quality* 5:148-157.

Johnson, A. H., Bouldin D. R., Goyette, E. A. & Hedges, A. M.1976b. Nitrate dynamics in Fall Creek New York. *Journal of Environmental Quality* 5: 386-391.

Johnson, M. S., Woodbury, P. B., Pell, A. N., Lehmann, J. 2007. Land-use change and stream water fluxes: Decadal dynamics in watershed nitrate exports. *Ecosystems* 10: 1182–1196.

Nagle, G. N., Fahey, T. J., Ritchie, J. C. & Woodbury, P. B. 2007. Variations in sediment sources and yields in the Finger Lakes and Catskills regions of New York. *Hydrological Processes* 21: 828–838.

O'Leary, N., Johnston, R., Gardner, E. L., Penningroth, S. M., & Bouldin, D. R. 2019. Long-term study of soluble reactive phosphorus concentration in Fall Creek and comparison to northeastern tributaries of Cayuga Lake, NY: Implications for watershed monitoring and management. *Water* 11(10): 2075.

Porter, K., Lauer, D., Messinger, J., Bouldin, D. 1975. Flows of nitrogen and phosphorus on land. In *Nitrogen and Phosphorus. Food Production, Waste and the Environment*; Porter, K., Ed.; Ann Arbor Science: Ann Arbor, MI, USA pp. 123–168.

Prestigiacomo, A. R., Effler, S. W., Gelda, R. K., Matthews, D. A., Auer, M. T., Downer, B. E., … & Walter, M. T. 2016. Apportionment of bioavailable phosphorus loads entering Cayuga Lake, New York. *Journal of the American Water Resources Association* 52: 31–47.

Schaffner, W. R. & Oglesby, R. T. 1978. Phosphorus loadings to lakes and some of their responses. Part 1. A new calculation of phosphorus loading and its application to 13 New York lakes. *Limnology and Oceanography* 23: 120-134.

Shaw, S. B., Marjerison, R. D., Bouldin, D. R., Parlange, J-Y, & Walter, M. T. 2012. Simple model of changes in stream chloride levels attributable to road salt applications. *Journal of Environmental Engineering* 138: 112-118.

Upstate Freshwater Institute, Department of Biological and Environmental Science, Cornell University; Cornell Biological Field Station, Department of Ecology and Evolutionary Biology, Cornell University. Final Phase I Report: Monitoring and Modeling Support for a Phosphorus/Eutrophication Model for Cayuga Lake. 2014. Available online: https://fcs.cornell.edu/sites/default/files/imce/site_contributor/Dept_Energy_and_Sustainability/documents/Phase_I_Cayuga_Lake_Final_Report_121914.pdf