Use of Watersheds and The TMDL Process as Tools for Curriculum Development and the Introduction of Research Concepts in an Undergraduate Environmental Engineering Course

Dr. Bruce W. Berdanier, PE, PS
Ohio Northern University, Ada, Ohio

Abstract

CE 426, Environmental Engineering II, has been developed as an Environmental Engineering analysis course at Ohio Northern University (ONU). This course is offered in the spring quarter and is typically the final Environmental Engineering course taken by senior Civil Engineering students as an elective course. Environmental Studies students in the Biology program also took the course last spring in its first offering. The course is designed to give students sufficient background information in the design and implementation of a surface water quality Total Maximum Daily Load (TMDL) study along with information on designing and implementing a "graduate level" research project. The intent of the course is to have students implement this project on an actual 13 square mile watershed near the university. The stream is impacted by nutrients, and a formal TMDL will be developed by environmental professionals and stakeholders in the near future in accordance with Clean Water Act (CWA) requirements. Student teams sample and analyze for multiple chemical constituents and flow at multiple stream stations according to their project design for distribution of sampling site and time intervals. Students design the study based on the watershed characteristics they study in the course: land use, topography, point and non-point sources, stream accessibility, etc. A complete report of the sampling, analysis, and quantification of the TMDL is prepared by each student by the end of the quarter. An introduction to QUAL2E water quality modeling was included in the Spring 2001 offering. Future course offerings will be modified to better address water quality computer modeling along with establishment of indices used by the state environmental protection agency such as the Qualitative Habitat Evaluation Index (QHEI).

Introduction

CE 426 was designed and implemented in Spring 2001 as an environmental engineering analysis course at the undergraduate level. Environmental engineering courses in Civil engineering programs at the undergraduate level are typically focused around engineering design concepts and focused closed-end design and laboratory experiences. The objectives of this new course were:

- To provide the students with an open-ended field laboratory experience that they would have to design and implement themselves,
- To have the students focus the independent lecture and laboratory experiences that they had accumulated throughout their program of study to determine the information that they would need to characterize a watershed and conduct a TMDL study,

- To have the students synthesize and analyze the data collected in the field studies and from available data bases into a defensible TMDL conclusion, and
- To familiarize the students with surface water quality modeling using QUAL2E software.[1]

The Field Laboratory

The "field laboratory" for this course is the Grass Run watershed near the Village of Ada, Hardin County, Ohio. The Grass Run watershed is approximately thirteen square miles in size and predominately agricultural. The Ohio Northern University (ONU) is located in the Village of Ada. The village has approximately 3,000 permanent residents. ONU is primarily a residential campus and adds approximately 3,200 students to the village's population. The delineation of the Grass Run watershed with the location of the Village of Ada and Ohio Northern University is shown in Figure 1.

The Village of Ada's municipal wastewater treatment plant (WWTP) is the major point source pollutant of concern in the watershed. The WWTP is an advanced secondary treatment plant that relies on activated sludge for carbonaceous biochemical oxygen demand (BOD) removal and trickling filters for nitrification. The plant is currently undergoing renovation to upgrade is sludge handling facilities and secondary clarification processes. There is no specific treatment process to address phosphorus removal at the WWTP.

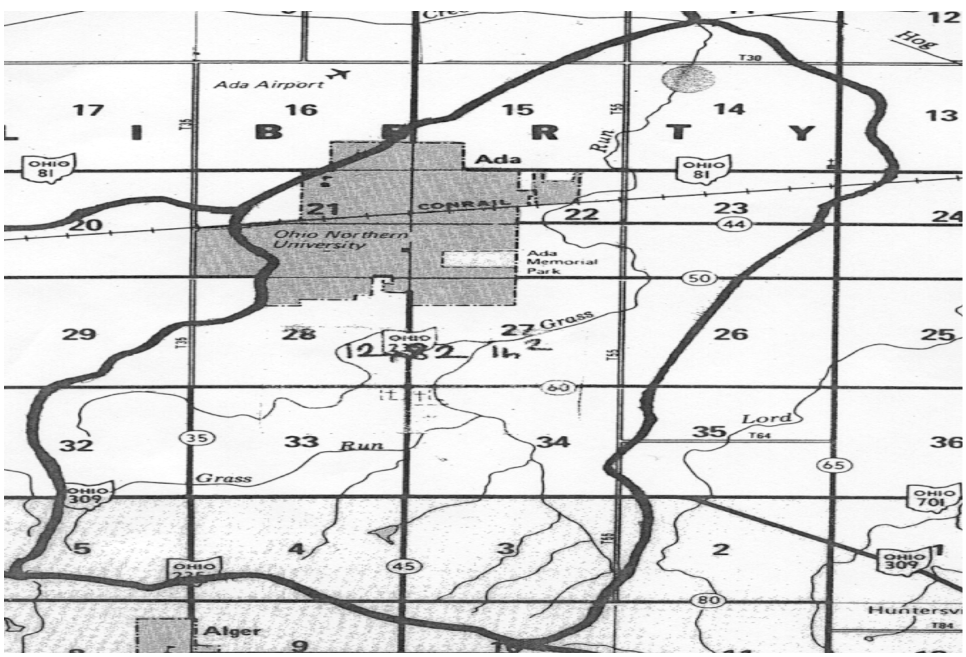

Figure 1. The Grass Run Watershed

The Grass Run is tributary to Hog Creek, which runs into the Ottawa River east of the City of Lima. The Ottawa River flows to the Maumee River and ultimately to Lake Erie (Figure 2). The Grass Run watershed is a sub watershed of the Ottawa River watershed. The Grass Run has a use designation of Warm Water Habitat, Agricultural and Industrial Water Supply, and Primary

Contact Recreation. The Ohio 303D list[2] of impacted waters states that nutrients is one of the main parameters of concern for the Hog Creek which the Grass Run is directly tributary to.

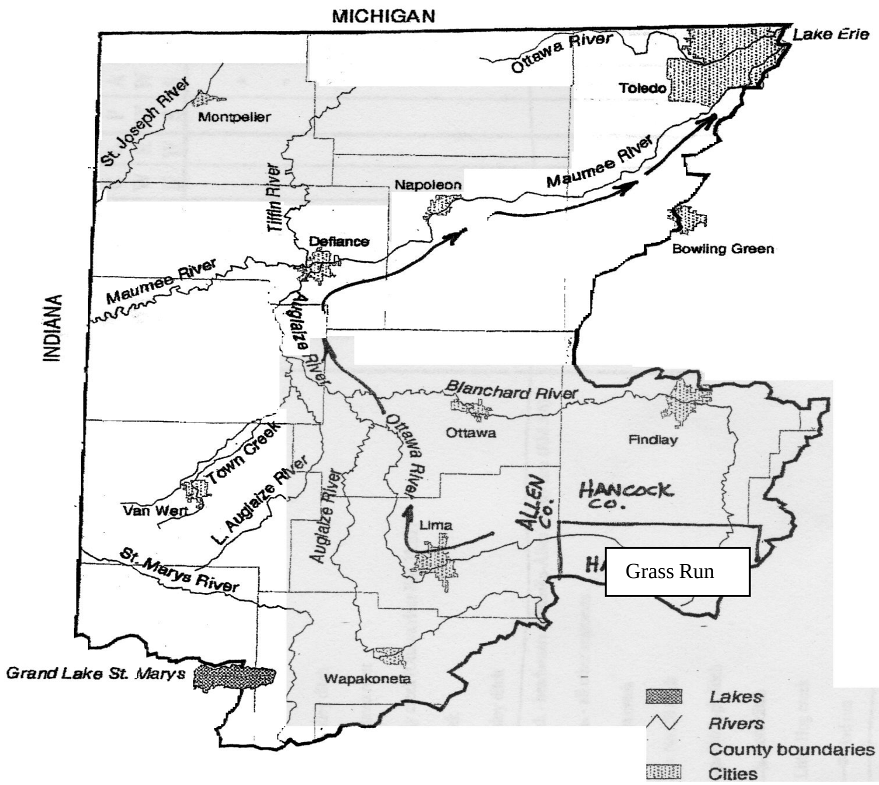

Figure 2. Grass Run Watershed Tributary to Lake Erie

The Ottawa River Coalition is a non-profit organization that was formed in 1993 to bring watershed stakeholders together to promote public education, improved water quality, and balanced use in the watershed. The organization has seven committees, one of which is the Water Quality committee, which seeks to address the development of a Total Maximum Daily Load (TMDL) for the Grass Run watershed. The Ottawa River Coalition is currently partially supported through an Environmental Protection Agency (EPA) 319 grant for the TMDL development. Acquisition of existing data has been ongoing for the past few years. Additionally, sampling and analysis for phosphorus and flow measurement have recently been initiated.

Determining the Information Needed and Developing the Context

CE 426 is designed to provide the students approximately 4-5 weeks of structured lectures covering a broad range of topics designed to help them organize their thoughts in designing the watershed study. A considerable amount of time is spent describing the "watershed-mass balance -point/non-point source-TMDL" study theory. Although all of these students have spent copious time in environmental science, chemistry, and environmental engineering design classes applying mass balance concepts, many or most of them have not considered or applied such concepts to quantifying inputs to a watershed. The definitions of TMDL terminology using waste load allocation (WLA) for point sources, load allocations (LA) for non-point sources, background loads (BL) for baseline loads occurring in the watershed, and margin of safety (MOS) is explained for the students to use in their analysis of the watershed. A history of the TMDL program's evolution since the inception of the CWA along with the current legislative developments and EPA guidance of record is presented to the students. The seven component of the TMDL program[3] are also presented to the students as an "outline" for organizing their plan of study.

The lecture series also reviews the fundamental analytical concepts for modeling dissolved oxygen in a stream that were developed earlier in the 1900's by Streeter and Phelps.[4] The expanded and updated formulation of these ideas are the foundation of the complex water quality computer models of today such as QUAL2E. The students performed analytical homework assignments using Streeter-Phelps equations and ran sample input data on the QUAL2E program and analyzed the resultant output.

Lecture material is also presented on low flow concepts used in water quality determinations, and students learn how to do a historic analysis and quantitatively determine a low flow condition for a stream using on-line United States Geologic Service (USGS) stream flow data. Several lectures are used to expose students to the wide array of electronic data bases that are available for their use in developing watershed background data such as the following: water quality data, topography, land use, soil classification, toxic release inventory (TRI), hazardous waste (RCRA), superfund (CERCLA), and other discharges impacting surface water quality. Students complete a homework assignment to collect such information for the Grass Run Watershed.

Designing the Field Study

Students are given a midterm examination over all of the theory presented in the first half of the quarter. The class is then divided into project teams, and the students are instructed to walk and drive through the watershed to conduct a "windshield survey." The students make use of all of the theory and background information that they have developed to date and "see" the watershed from the knowledgeable context that they have developed. The teams return to class and propose the design of the field study, i.e. the water quality parameters that should be sampled and analyzed for along with the sampling stations that they feel are necessary to quantify point and non-point sources in the watershed. Additionally, the student teams propose a sampling/analysis schedule along with standard procedures and quality control specifications.

The team proposals are discussed and integrated in class, and a final study plan is agreed upon. For our study in 2001 we determined seven sampling stations and nine water quality parameters (phosphorus, BOD, DO, pH, temperature, ammonia, turbidity, total dissolved solids, and flow). The teams agreed to complete one complete sampling/analysis cycle in the watershed each week for four weeks to develop their field data.

Report Preparation

At the halfway point in the quarter, the students have accomplished the following tasks:

- Defined the problem,
- Developed a fundamental theoretical context to operate from,
- Gathered and organized existing background data, and
- Designed an approach to solving the problem

The remainder of the quarter is spent in sampling, analysis, and final report preparation. The students are provided with a suggested format guidance document to use in writing their report. Although field sampling and analysis is performed as a team activity, each student is required to prepare his/her own TMDL report. All field data results are entered on a class computer as soon as they are available after each sampling event so that students can work on developing their report analysis concurrent with sampling.

In the report preparation, students are heartily encouraged to "take a chance" and try to perform "rough, first-cut" modeling of the oxygen deficit in the watershed. Students are reluctant to take this step, feeling that they have inadequate knowledge and experience to develop even a simple model of surface water quality. Additionally, students are instructed to develop an equation to model changes in one of the main water quality parameters chosen as it progresses through the watershed.

Conclusions, Successes, Failures

Initially, I would like to conclude this paper by stating how pleased I was with the success of the first offering of this course. I am very excited about offering the course again in 2002. I also believe that the course will be more focused in the second year as I now have a more quantitative grasp on some of the possibilities and limitations of conducting this type of study within the ten-week time frame available. As the Ottawa River Coalition Water Quality committee develops their TMDL planning, the course can also be tailored toward supporting and validating their process and results. However, I don't want the course to become a close-ended process. The open-ended problem solving aspect of this class is very important to introduce the undergraduate students to participating in solving "real-life" problems. Further, I believe this is a good introduction for the advanced undergrads to the type of process they enter into in graduate level research. If the course becomes too predictable, I will be motivated to search for a new watershed to characterize.

I was impressed with about 80% of the students' final products that came out of this study. Some of the students really were "brave" and took a risk in trying to model and predict changes in the surface water quality parameters. I estimate that 20% of the students got to the end of the project and didn't make a strong effort on the final project report at the end of the quarter. It is very important in this type of project class to keep the students focused on the end goal. The open-ended nature of the course project frustrates some of the students. This is not the type of class project that a student can finish in a week or study for overnight.

There were problems, near failures, and failures in the course. The physical field sampling/analysis goals need to be more finite. Seven sampling stations and nine water quality parameters produced too much work for the students to reasonably accomplish in the last half of the quarter. There were also problems with organizing the sampling events within the students' available time and under the limitation of the field sampling equipment resources of the university. Some of the students complained about these problems. I could have controlled the process and forced the students to set and follow a rigid sampling schedule. However, I am a firm believer in the students learning to manage time and resources while communicating between teams. Some more time needs to be spent in the course to focus the students on this aspect of project management. Unless the project progress breaks down, I am reluctant to take control of the process.

The expectations for computer modeling in the initial course offering were too high for the time limitations of the course. The QUAL2E model is too large and complex for the students to grasp in a short time period in addition to the theory and fieldwork. A more simplified computer model will be evaluated for the second course offering.

One of the largest failures in the course that I perceived was that only one of the students properly analyzed the TMDL using mass loading concepts. This outcome was surprising to me. After several courses in environmental science, chemistry, environmental engineering, and this course's lecture series stressing the mass loading concepts, 90% of the students based their analysis on contaminant concentrations rather than loads. This aspect must be strongly addressed in the next course offering.

References

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Biographical Information

BRUCE W. BERDANIER, PhD, PE, PS is an Assistant Professor of Civil Engineering at Ohio Northern University in Ada, Ohio. He has worked in the fields of municipal and environmental engineering since 1974 and has taught at the university level since receiving his PhD in 1995. His research interests are in ground and surface water quality and in treatment processes for water and wastewater.