SESYNC Case Study

The Maumee River Watershed and Algal Blooms in Lake Erie[1] [2]

Ramiro Berardo[3] & Ajay Singh[4].

Summary:

The decay of Lake Erie's environmental health and its impacts on local communities, including public health and the environment, was one of the focal events motivating the passage of the Clean Water Act in 1972. Despite the considerable improvement in water quality in the 1970s and 1980s because of implementation of agricultural best management practices to address soil erosion, seasonal algal blooms returned to Western Lake Erie. Potential causes of algal blooms may be a mixture of agricultural and urban practices that threaten ecological stability and public health for millions dependent on the lake for drinking water, tourism, and fisheries. For instance, in fall, 2014, national attention turned to the city of Toledo, Ohio as the city's residents experienced disruption to city services such as access to potable water and certain medical services including child birth and surgery. For this case study we will study the relationship between human behavior and water quality impairments which lead to toxic algal blooms in the Western Lake Erie Basin, and in particular, the Maumee River Watershed. We will also review prior management and policy efforts of different stakeholders to improve water quality as well as issues surrounding the development of proposed policy and management changes. Multiple stakeholders from multiple states and Canadian provinces are involved in seeking solutions to the ongoing pollution problems. This case study will be ideal to examine how cooperation unfolds in the presence of collective action problems, and the interrelationships between human behavior and environmental outcomes. The case is designed to be taught in 8 sessions to an audience of upper level undergraduate students, though an audience of graduate students is also possible provided that instructors design additional assignments.

What course(s) might this case be appropriate for?

The materials and activities herein are ideally applicable to courses in interdisciplinary programs where students are trained in both the natural and the social sciences. The case study is suggested for courses with no more than 30 students.

What level is this case appropriate for?

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This case study can be used with upper division undergraduate students who have had introductory courses in both the natural and social sciences. This case study and associated assignments are developed for courses of no more than 30 students. This case can be altered to be taught to graduate students but it is suggested that additional assignments such as an annotated bibliography or data analysis project should be added.

Social-Ecological Systems (SES) Learning Goals

SES Goal 1. Describe the social ecological system in the Maumee River Watershed and the Western Lake Erie Basin by identifying their constituent elements and their interactions

Related activity: Create a mental model at the beginning of the study and refine throughout the duration of the case study.

SES Goal 2. Identify relevant stakeholders involved in the issue of land use in the Maumee River watershed and harmful algal blooms in Lake Erie.

Related activity: The student will write a stakeholder analysis that includes a mental model of interactions between human behavior and development of algal blooms.

SES Goal 3. Identify the main variables that drive farmers' behavior in the adoption of best management practices.

Related activity: The student will integrate understanding of farmer behavior and adoption of BMPs in the stakeholder analysis and policy brief.

SES Goal 4. Communicate the basics of the bio-geochemical process leading to the algal blooms in the lake.

Related activity: The description of this process should be added to the policy brief.

SES Goal 5. Examine the effectiveness of current policy responses to the problem

Related activity: The examination will be contained in the policy brief

SES Goal 6. Suggest policy alternatives leading to a potential reduction of the magnitude of algal blooms and associated impacts

Related activity: the final policy brief will contain a section where policy alternatives will be discussed.

Case Study Learning Objectives Students will…	SES Learning Goals			
	Understand structure & behavior of S-E systems	**Consider importance of scale & context in S-E problems**	**Develop res. Questions & models in inter or trans-disciplinary teams**	**Find, analyze, and synthesize existing data and ideas**
Describe the social ecological system in the Maumee River Watershed and Lake Erie by identifying their constituent elements and their interactions	Directly related	Directly related	Indirectly related	
Identify relevant stakeholders involved in the issue of land use in the Maumee River watershed and harmful algal blooms in Lake Erie	Indirectly related	Directly related		
Identify the main variables that drive farmers' behavior in the adoption of best management practices.	Directly related		Indirectly related	Directly related
Communicate the basics of the bio-geochemical process leading to the algal blooms in the lake.	Directly related			
Examine the effectiveness of current policy responses to the problem	Directly related	Directly related		Directly related
Design policy alternatives leading to a potential reduction of the magnitude of algal blooms and associated impacts	Directly related	Directly related		

Case Study Introduction[5]

Charter boat captain Jim Cook looked down over the side of his small fishing boat into a lake of what looked like pea soup. “We need to do something about this algae,” Captain Jim sighed in resignation, “I used to take 5-6 people out for day trips on the lake 7 days a week all summer long. Now, people are calling me up to ask how bad the water looks before they book a trip. They talk about the news stories they hear and read about. And when they hear it’s bad, they don’t come. I can’t blame them because who wants to pull a fish out of the water with green slime covering it?”

Paul Pachowski, president of the Lake Erie Charter Boat Captain Association, believes that algal blooms are devastating the fishing industry on the lake.[6] When algal blooms are reported in the news people call up and cancel boat reservations. If too many people cancel boat owners can’t make a living. If boat captains can’t make a living, they go out of business. If boat owners go out of business even less people can go out on the lake. If even less people visit the lake, less people stay in hotels, eat in restaurants, buy t-shirts in gift shops. In other words, the environmental dead zone in the lake could create an economic dead-zone on shore.

Photo credit: Dr. Jeff Reutter, Ohio Sea Grant

To find the causes of the algal blooms one has to look towards the mouth of rivers and streams entering in to the lake. In particular, researchers have identified the Maumee River, which enters the lake near Toledo, OH, as a source of much of the nutrients that help grow algae. Nutrients are by-products of intensive agricultural production in the watershed.

“We need to stop agricultural run-off. Period. Farmers are killing my business,” Jim Cook laments, “Boat owners can complain to politicians in Columbus or Washington all we want but farmers are the ones

[5] Jim Cook is a fictional character that the authors of the case deem as representative of the large number of cases portrayed in the media of individuals whose enjoyment of clean water in Lake Erie is hampered by the presence of algal blooms.

[6] Paul Pachowski is a real person.

who have the ability to do something about the problem. The more they wait to do something the closer I am to closing my doors."

BACKGROUND

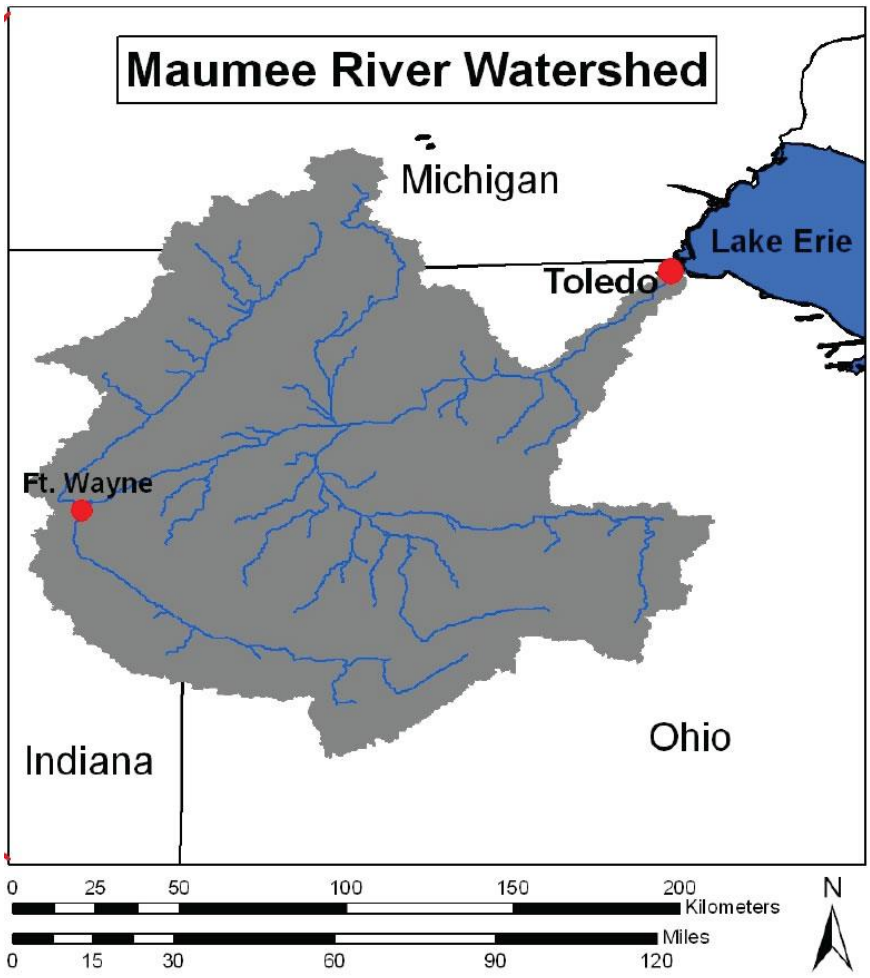
Lake Erie is the shallowest and warmest of the Great Lakes and is one of the most productive fisheries in the Great Lakes region. Lake Erie is the source of drinking water for more than 12 million people in the U.S. and Canada, including large metropolitan areas of Toledo and Cleveland, OH. The lake is a source of income for tourism and provides fishing and recreational opportunities to multiple states and provinces. The main land-use surrounding Lake Erie consists of agriculture, mainly corn and soybeans and mid-sized dairy farms. Lake Erie Basin drains more than 58,000 km^2 and retains water for an average of 2.7 years before draining into Lake Ontario through Niagara Falls. Lake Erie is considered to be an indicator for future environmental and social conditions for the Great Lake Ecosystem because of possible changes to climate conditions.

Source: Michigan Sea Grant

Figure 1. Map of the Lake Erie Basin

The Maumee River Watershed drains 21,000 km^2 of southeastern Michigan, Eastern Indiana, and North-Western Ohio and enters Western Lake Erie Basin near Toledo, Ohio. The watershed comprised of clay soils with little elevation change. Historically, 65% of the watershed consisted of wetlands. Today however, there are nearly 650,000 acres in agriculture, 42,000 forested acres, 20,000 urban and

suburban acres, and 12,000 acres in wetland and natural areas. The watershed also has mid-sized urban areas of Ft. Wayne, Indiana and Toledo, Ohio.



Source: University of Toledo

Figure 2. Map of Maumee River Watershed

PROBLEM STATEMENT

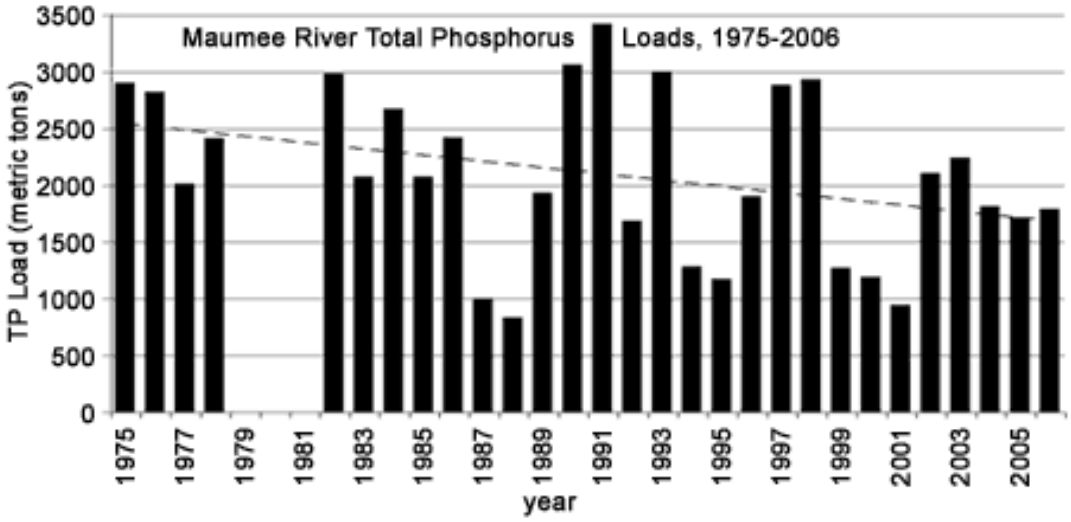
Eutrophication, the result from the development and decay of large algal blooms due to increased nutrient loads which leads to a reduction of dissolved oxygen in large bodies of water, has occurred in Lake Erie before. After years of phosphorus, nitrogen, and potassium runoff from agricultural lands Lake Erie was declared "dead" in the 1970's. Fertilizer inputs used by farmers to grow crops also help other plants in the larger ecosystem grow- the most apparent are the large algal blooms we see today. The algal blooms we see today have contributed to reduced water quality, hypoxia leading to large fish kills, and impacts to water treatment plants.

Photo credit: NASA Earth Observatory

Figure 3. Aerial Photography of Lake Erie in 2012

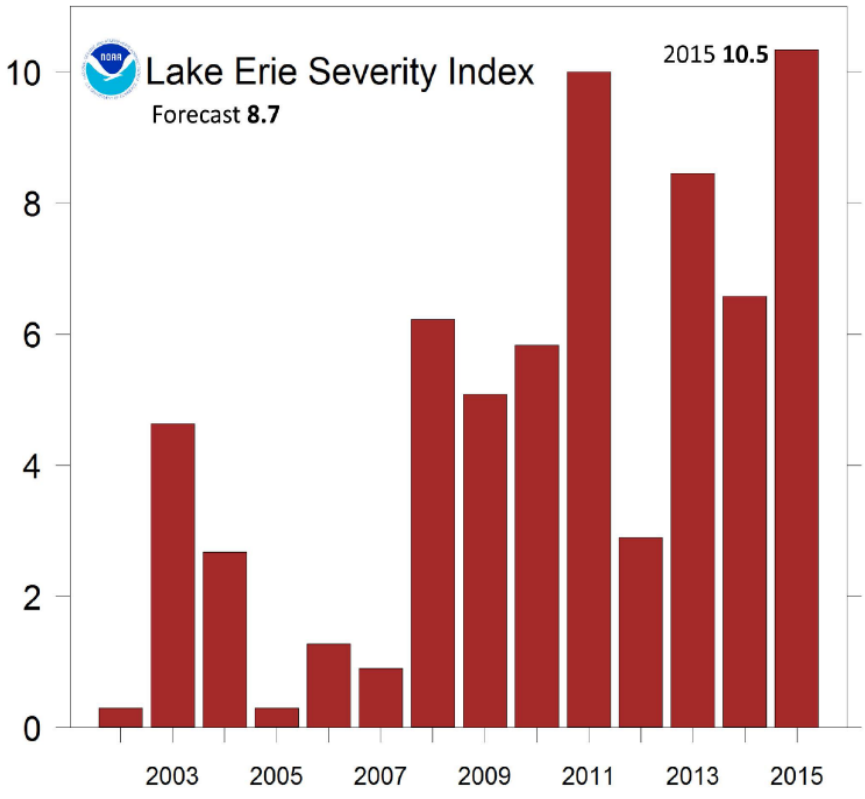
Starting in the 1970s, federal programs targeting point sources led to steady reductions in harmful algal blooms and improved water clarity. Between 1975 and late 2000's total phosphorous loads into Lake Erie decreased (Figure 4); however, in recent years, the frequency and magnitude of algal blooms has increased (Figure 5). Dissolved particulate phosphorus inputs to the lake and agricultural runoff was identified as the dominant factor leading to the large toxic algal blooms that occurred prior to 1980. In fact, dissolved particulate phosphorous decreased between 1975 and 2006 due to the implementation of agricultural best management practices addressing soil erosion. However, the Maumee River Watershed has been identified as one of the major contributors of dissolved reactive phosphorous (DRP) into the Western Lake Erie Basin. Figure 6 below shows average concentration of DRP in the Maumee River Watershed beginning in 1975. The figure shows that although concentrations of dissolved reactive phosphorus decreased in the 1970's through the 1990's, concentrations have begun to rise again; leading to an increase in frequency and magnitude of algal blooms in Lake Erie.

The increase in algal blooms has led to conflicts between downstream water users and fishing interests in Lake Erie. Most recently the City of Toledo issued a warning against use of tap water for drinking, bathing, and washing and recommended use of bottled water and also disrupted medical services; impacting more than 400,000 people in the region. Because of the impacts of algal blooms there is renewed need to address abatement of agricultural runoff and a focus on DRP.



Source: EPA

Figure 4. Total Dissolved Phosphorous Loads



Source: NOAA

Figure 5. Severity of Algal Blooms 2002-2014

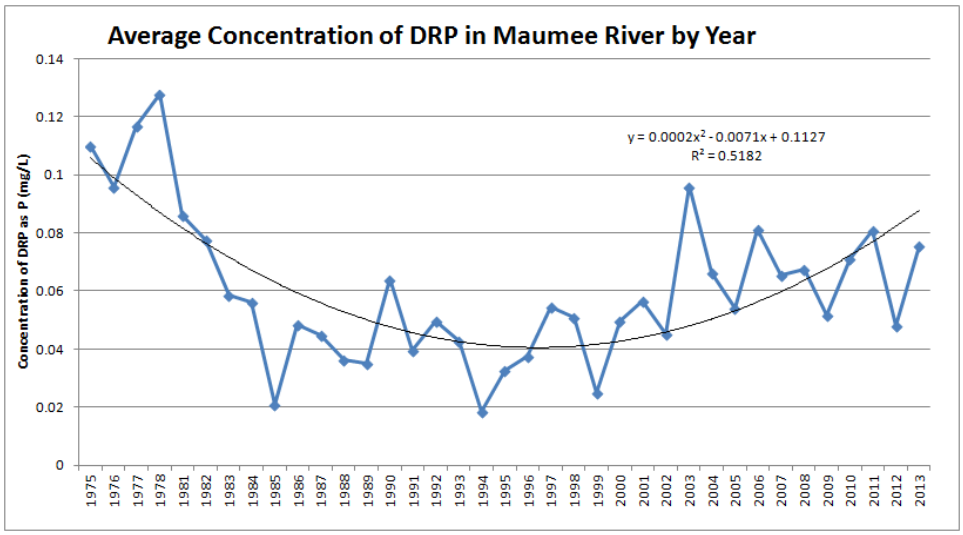


Figure 6. Dissolved Reactive Phosphorous

Class Schedule

Summary: There are 8 meetings, each for 75 minutes. The total amount of class time is 600 minutes, or 10 hours.

Week 1. An introduction to the topic of algal blooms in Lake Erie

Class 1. Introduction to the topic

(75-minute class)

Pre-class activities:

1. Complete the following activities:
1.1. Background information provided by the instructor (The "hook")

Class Preparation:

1. Before class instructor should have PBS Newshour video (http://www.pbs.org/newshour/bb/drones-limit-fertilizer-flow-lake-erie/) loaded on internet browser on computer with access to projector
2. Have posterboard and markers available for the initial development of mental models

Class activities:

1. The instructor will start the meeting with a 40-minute lecture. The first 20 minutes will be devoted to the history of corn production in northwestern Ohio and how farming and other human activities are linked to algal blooms. The second half of the lecture will describe the value of studying complex environmental problems through a social-ecological systems lens. See slides 1 through 19 in the supplemental Powerpoint presentation.
2. The students will then watch the following PBS Newshour short video (7 minutes, 53 seconds): http://www.pbs.org/newshour/bb/drones-limit-fertilizer-flow-lake-erie/
3. Discuss the background information provided by the instructor (The "hook")
4. Students will grouped in teams of two or three. They will devise an initial mental model identifying social and environmental factors that affect the occurrence of algal blooms in Lake Erie. This outcome of this exercise is to have students begin to think about the problem as a system wherein both social and environmental conditions need to be taken into consideration. The models will be further developed in subsequent activities. For examples of mental models, see supplemental file or visit http://cmap.ihmc.us/publications/ResearchPapers/TheoryCmaps/TheoryUnderlyingConceptMaps.htm or https://www.youtube.com/watch?v=H4Rcj_JYTeo
5. At the end of the period, students will tape models to walls and make short presentation on their initial model and the instructor will provide discussion questions to guide further development of the mental model.
6. The instructor should outline the remainder of the case including the expectations of students for each assignment.

Class 2. How do algal blooms happen?

(75-minute class)

Pre-class activities:

1. Complete the following readings:
   1.1. Kane, D. D., Conroy, J. D., Richards, R. P., Baker, D. B., & Culver, D. A. (2014). Re-eutrophication of Lake Erie: Correlations between tributary nutrient loads and phytoplankton biomass. *Journal of Great Lakes Research*, *40*(3), 496-501
   1.2. Conroy, J.D., Kane, D.D., Briland, R.D., Culver, D.A. (2014). Systemic, early-season Microcystis blooms in western Lake Erie and two of its major agricultural tributaries (Maumee and Sandusky rivers). *Journal of Great Lakes Research*, *40*(3), 518-523
   1.3. Michalak, Anna et al. 2013. "Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions." *Proceedings of the National Academy of Sciences* 110(16): 6448-6452.

Class Preparation:

1. Before class instructor should have the YouTube video (https://www.youtube.com/watch?v=G-aGMbdHDIU) loaded on internet browser on computer with access to projector.

Class activities:

2. The students will watch the YouTube video "Ohio EPA introduces new harmful algal bloom advisory system". The video is 2 and a half minutes long.
3. The instructor will then give a 20-minute lecture discussing human contributions to algal blooms and the natural conditions that lead to algal blooms. See slides 20 through 31 in the supplemental Powerpoint presentation.
4. Following the lecture, there will be a 15-minute discussion on the content of the lecture, and the state of the Maumee River Watershed.
5. Finally, in the remaining 30 to 35 minutes, the students will visit NOAA's Great Lake Environmental Research Laboratory at http://www.glerl.noaa.gov/res/HABs_and_Hypoxia/, where they can track harmful algal blooms (HABs) in Lake Erie, and review data about the presence of microcystin, and hypoxia conditions in the lake. The instructor will provide the following leading questions for this activity:
   5.1. What's the current overall state of water quality in western Lake Erie?
   5.2. Are HABs currently a problem in the western portion of the lake?
   5.3. Given current data for hypoxia in the lake, are water managers in cities and towns on the southwestern shores of the lake more or less likely to run into management problems in the near future?

   For this activity, students should work in groups of 2 or 3 and write down their responses to the questions, which will then be turned in to the instructor, who will randomly choose answers and share them with the rest of the class. A discussion should ensue about the responses.

Week 2. Understanding who is involved

Class 3. Farmer behavior and adoption of best management practices

(75-minute class)

Pre-class activities:

1. For both students and instructors: Download mental model software (available at http://www.mentalmodeler.org/) and bring laptop to class. The instructor should also familiarize herself/himself with the software to be able to explain its basic features to students. When opened, Mental Modeler provides a very easy set of instructions of use, which the instructor should review prior to coming to class.
2. Complete the following readings:
   2.1. Baumgart-Getz, A., Prokopy, L.S., and Floress, K.. (2012). "Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature." *Journal of environmental management* 96(1): 17-25.
   2.2. Knowler, D., andBradshaw, B. (2007). "Farmers' adoption of conservation agriculture: A review and synthesis of recent research." *Food policy* 32(1): 25-48.
   2.3. Prokopy, L. S., Floress, K., Klotthor-Weinkauf, D., & Baumgart-Getz, A. (2008). "Determinants of agricultural best management practice adoption: Evidence from the literature." *Journal of Soil and Water Conservation 63*(5):300-311.

Class Preparation:

1. Instructor will need to have downloaded the mental model software to class computer or laptop which has access to projector.
2. Before class instructor should have the YouTube video, "Identifying practices to best manage phosphorus", https://www.youtube.com/watch?v=pVfN28w6vvg loaded on internet browser on computer with access to projector.

Class activities:

1. The students will watch the video "Identifying practices to best manage phosphorus", available at https://www.youtube.com/watch?v=pVfN28w6vvg. The video is 4 minutes long.
2. The instructor will open this class period with a 30-minute lecture discussing farming behavior and the adoption of best management practices. See slides 32 through 42 in the supplemental Powerpoint presentation.
   3. Students will then be grouped in teams of 2 or 3, and discuss the obstacles to the adoption of best management practices for about 10 to 15 minutes. The instructor will provide the following leading questions for this activity:
      3.1. What individual variables make farmers more likely to adopt best management practices that reduce the likelihood of harmful algal blooms in Lake Erie?
      3.2. What sort of influence do social ties have in the adoption of best management practices?
      3.3. What types of social ties have a greater effect on the adoption of best management practices?
   4. Following the discussion, the instructor will provide tutorial on how to use the mental model software. This activity should not take longer than 10 minutes.

5. Students will use the final 15 minutes of class to refine the mental model produced during the first class period. They will do so using "mental modeler". The mental model should include both stakeholders and bio-physical components.

Class 4. Broadening the Stakeholders analysis

(75-minute class)

Pre-class activities:

1. Complete the following readings:
   1.1. Yeager-Kozacek, Cody. 2014. "Great Lakes Drinking Water Fouled by Toxic Algae." Available at Circle of Blue: http://www.circleofblue.org/waternews/2014/world/choke-point-index-great-lakes-drinking-water-fouled-by-toxic-algae/
   1.2. Yeager-Kozacek, Cody. 2014. "Cities Tackle Sewer Overflows to Reduce Phosphorus." Available at Circle of Blue: http://www.circleofblue.org/waternews/2014/world/cities-tackle-sewer-overflows-reduce-phosphorus/
   1.3. Yeager-Kozacek, Cody. 2014. Consolidation of Livestock Farms Creates a Big Manure—and Nutrient–Challenge. Available at http://www.circleofblue.org/waternews/2014/world/consolidation-livestock-farms-creates-big-manure-nutrient-challenge%E2%80%A8%E2%80%A8/
   1.4. Reed, Mark S., Anil Graves, Norman Dandy, Helena Posthumus, Klaus Hubacek, Joe Morris, Christina Prell, Claire H. Quinn, and Lindsay C. Stringer. 2009. "Who's in and why? A typology of stakeholder analysis methods for natural resource management." Journal of environmental management 90(5): 1933-1949

Class Preparation:

1. Before class instructor should have the YouTube video, video "Toledoans recall the water crisis". Available at https://www.youtube.com/watch?v=efAuWDuCspI loaded on internet browser on computer with access to projector
2. Have students bring laptop to class for development of mental model and stakeholder analysis

Class activities:

1. The students will watch the video "Toledoans recall the water crisis". The video is 4 minutes long.
2. The instructor will lecture on the components of a stakeholder analysis for a period of approximately 20 minutes. The instructor will also explain how mental modeler can be used to explain interactions between stakeholders and the environment and organize the stakeholder analysis.
3. Working in groups of 2 or 3, students will utilize one of the typologies of stakeholder analysis described in Reed et al. (2009) and identify the relevant stakeholders for the case. This activity will last 25 to 30 minutes. At the end of the activity, students will tape their stakeholder analysis diagram to the walls of the classroom.

4. For the remainder of the meeting, the instructor will pair teams. Each team in a pair will be asked to review the other team's stakeholder analysis. This exercise will be followed by a discussion wherein members of each group will criticize the other team's performance.

Week 3. Policy Alternatives

Class 5. Policy instruments and tools

(75-minute class)

Pre-class activities:

1. Complete the following readings:
   1.1. Bearden, David M., Claudia Copeland, Linda Luther, James E. McCarthy, Mary Tiemann, Robert Esworthy, and Jerry H. Yen. 2013. "Environmental Laws: Summaries of Major Statutes Administered by the Environmental Protection Agency." Available at http://www.fas.org/sgp/crs/misc/RL30798.pdf. Read pp. 25-33.
   1.2. Jaffe, Adam B., and Robert N. Stavins. "Dynamic incentives of environmental regulations: The effects of alternative policy instruments on technology diffusion." *Journal of environmental economics and management* 29, no. 3 (1995): S43-S63.
   1.3. Poe, Gregory L., William D. Schulze, Kathleen Segerson, Jordan F. Suter, and Christian A. Vossler. "Exploring the performance of ambient-based policy instruments when nonpoint source polluters can cooperate." *American Journal of Agricultural Economics* 86, no. 5 (2004): 1203-1210.
   1.4. Ohio SB-1: "Agricultural Pollution Abatement Program-transfer to Department of Agriculture/applicators of fertilizer or manure-regulate/algae management and response." Available at https://www.legislature.ohio.gov/legislation/legislation-summary?id=GA131-SB-1.

Class activities:

1. The instructor will open the meeting with a 30 minute lecture that will cover a typology of policy instruments that can be used to tackle environmental problems. The lecture should also introduce students to the basics of the Clean Water Act and the 2015 Clean Water Rule enacted by the Obama administration. Both of these legal instruments affect water quality and the effectiveness with which the EPA and state agencies can address non-point source pollution.
2. The next activity will be a group discussion that will take the remainder of the time for this meeting. Groups will be formed by 2 or 3 students. The discussion will revolve around the following questions provided by the instructor.
   2.1. Given what you have learned about how algal blooms occur in Lake Erie, what are the best types of policy instruments to tackle the problem of HABs? Rank them in order of importance.
   2.2. What are the strengths and limitations of current policy instruments used by the federal and state governments to tackle the problem of HABs in Lake Erie?
   2.3. What are the best ways in which the issue of policy fragmentation can be addressed?
3. The final 20 minutes of the meeting should be devoted to an open discussion of the ranking that each team produced.

Class 6. Designing a policy brief

(75-minute class)

Pre-class activities:

1. Students will read examples of policy briefs provided by the instructor (included in the Student Handout).

Class activities:

1. The class will begin with a 30-minute presentation by the instructor on the main component of policy briefs.
2. Students will then use the "policy brief grading sheet" to grade one of the sample policy briefs, which will be selected by the instructor. The policy brief grading sheet is provided in the Student Handouts. This activity should take approximately 10 minutes.
3. Two students will then be picked randomly to share their grading with the rest of the class. After these presentations, the instructor will open the floor for a broader discussion on the strengths and weaknesses of the selected policy brief. The activity will take approximately 15 minutes.
4. The students will take the remainder of the time to fill the "beginning your policy brief" form, which is contained in the Student Handouts.

Week 4. Presentation of results

Class 7. Policy brief workshop

(75-minute class)

Pre-class activities:

1. Each student will be asked to complete a draft of their policy brief before coming to class. The draft should contain the basic layout of the brief, and content in the main sections as described in the lecture given in class 6.

Class activities:

1. In the first 50 minutes of the meeting, students will be grouped in teams of 4. Each student will then read their teammates' drafts, and grade them using the "policy brief grading sheet", which they will be familiar with from the previous meeting. After grading each other's drafts, the students will discuss:
   1.1. Their level of agreement on the strengths and weaknesses of each of the drafts, and
   1.2. How to improve the final versions of their policy briefs.
2. Next, the instructor will identify the draft that obtained the highest average score from each team, and randomly select two or three of them. Then, the instructor will ask members of the team to share with the rest of the class the reasons why they evaluated the draft positively. This exercise is designed to provide the class with a sense of what is it that makes a policy brief a valuable and effective communication tool.

Class 8 – Policy Brief presentations

(75-minute class)

Pre-class activities:

1. The students will submit their final policy brief to the instructor.
2. Students will also print a color-copy of their policy brief, and bring it to the classroom, where they will be asked to tape it to the wall.

Class activities:

1. Each student will be asked to walk around the classroom reviewing the different policy briefs. The student will choose the best three policy briefs using the "final policy briefs ranking sheet" (see student handouts).
2. The second half of the class will be used to tally the results and proclaim a "Policy Brief Champion".