Paper ID #35690

McMillan Water Treatment Plant DC: embedding culture in civil engineering

Prof. W. M. Kim Roddis, The George Washington University

McMillan Water Treatment Plant DC:
Embedding Culture in Civil Engineering

The McMillan Water Treatment Plant (WTP) in Washington, DC is a case study I use in the course CE 1010 Introduction to Civil and Environmental Engineering taught at the George Washington University (GW). The course not only surveys 100 years of urban drinking water technology, but also includes multiple cultural aspects. My teaching philosophy is to approach engineering problem-solving in a broader societal context. Civil engineering inherently serves society. Selecting case studies that embed significant cultural content into the civil engineering problem statement allows me to emphasize to my students that solving the right problem is as important as solving the problem right.

This paper begins with a history of water treatment in DC. This material focuses on a single WTP location at the McMillan Reservoir, supplying most of the city's water. Square brackets and italics are used to highlight Next, the use of this case study in a course is described. Finally, an evaluation of the effectiveness of the case study use is presented, with suggestions for future work.

The McMillan WTP is a rich source of material exposing undergraduate engineering students to evolution of an engineering system to satisfy complex and at times conflicting societal goals. Technical content, such as using water quality measures to indicate the physical, chemical, and biological characteristics of the water suitable for drinking, is introduced in lecture format. Washington, DC has historically been plagued by poor drinking water quality. From its founding the city relied on wells, springs, and cisterns for drinking water [1]. Union troops stationed in Washington during the Civil War suffered from waterborne diseases. Abraham Lincoln's son, Willie, died at age 11 of typhoid fever [2]. By the mid-nineteenth century the quantity of the water supply was inadequate, as evidenced by the loss to fire of nearly two-thirds of the contents of the Library of Congress in 1851. This prompted Congress to allocate funds and task the Army Corps of Engineers with determining the means to provide abundant and wholesome water. Montgomery C. Meigs was the engineer heading this Washington Aqueduct project. The Great Falls on the Potomac River was chosen as the water source, providing both reliable quantity and hydraulic head for firefighting. A diversion dam at Great Falls fed the water into a 12 mile long, 9 ft diameter conduit to the Dalecarlia Receiving Reservoir for initial sediment settling. Another conduit took the water to the Georgetown Distributing Reservoir for additional settling. Originally, the city mains were fed from here. However, the turbidity of the Potomac water along with the occasional small fish, resulted in many continuing to use contaminated wells and springs [1]. The first stage of the Washington Aqueduct solved the quantity of water problem, but the water quality problem remained.

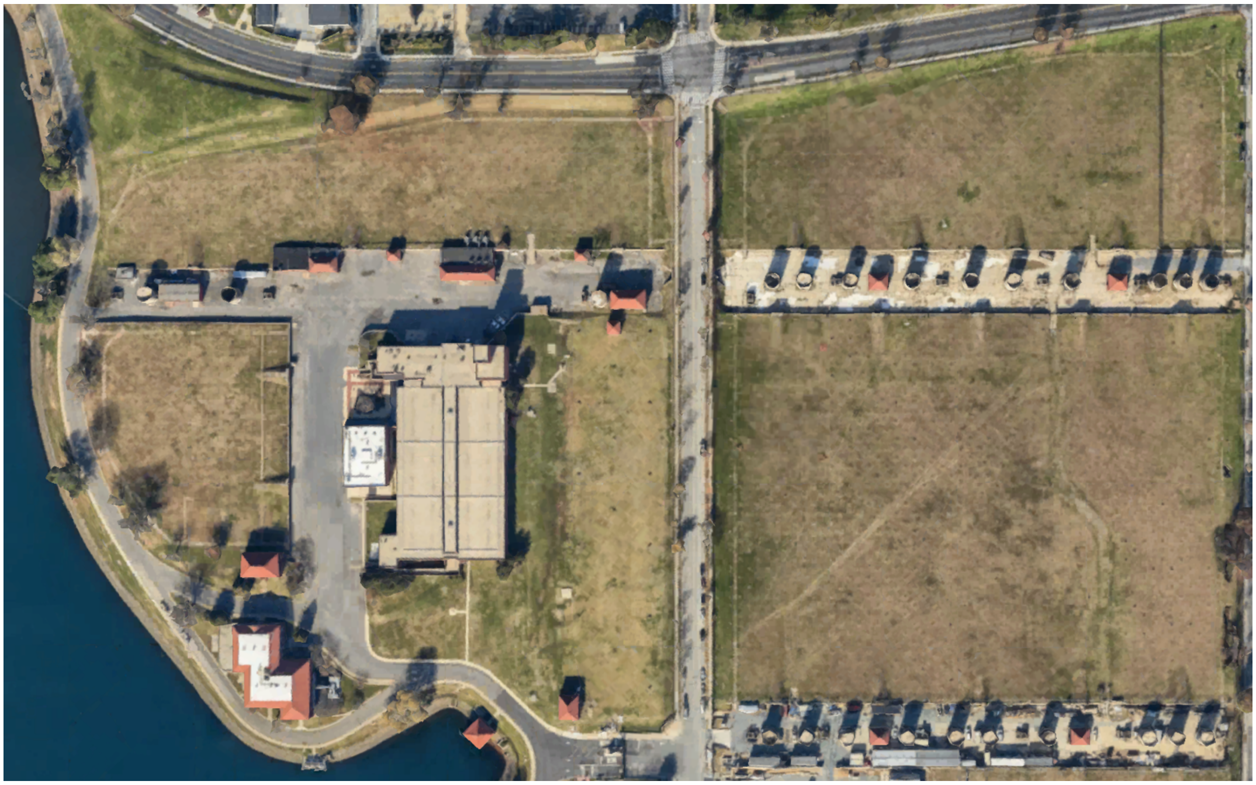
At the turn of the century, the 4-mile-long City Tunnel was built to take water from the Georgetown Reservoir to the new McMillan Reservoir next to Howard University. Public health improved with the opening of the original McMillan WTP in 1905. The original McMillan WTP used slow sand filter technology, purifying water using physical and biological filtration processes. This was due to the reluctance of Congress to accept chemical water treatment at that time, providing an opportunity for student discussion about societal willingness to adopt new technologies. Slow sand filters provide potable water without the use of chemicals but are land and labor intensive. The option of treating drinking water for a city without using chemicals is a novel idea to students. The possibility of building such a system using only locally available materials can be used to have students explore sustainable alternatives to conventional water treatment. A second WTP was completed at Dalecarlia in 1928 to add capacity. Unlike the McMillan WTP, the Dalecarlia uses chemical treatments and a rapid sand filter.

The McMillan slow sand filter cells covered many acres. Fredrick Law Olmsted designed a 25 acre public park over most of the grid of cells. McMillan Park, opening in 1912, was arguably the only de facto racially integrated park in DC at the time [3]. The park provided a rare opportunity to enjoy this public good for people in the surrounding communities. This illustrates multipurpose use of public land, an aspect of civil engineering of current interest with the green infrastructure approach to stormwater control. McMillan park was fenced off for security at the beginning of WWII and remained unused for more than 80 years. This history of early multi-racial access followed by long disuse provides an opportunity to directly discuss open spaces and 20th century race relations in the United States.

In 1986, the slow sand filter McMillan WTP was decommissioned with the opening of the adjacent new rapid sand filter McMillan WTP. This technology uses physical and chemical processes to provide potable water. To summarize the current process [4], the Potomac River water flows from the Great Falls raw water intake and the Little Falls raw water pumping station. Pre-sedimentation occurs at Dalecarlia Reservoir. Fluoride and the coagulant, alum, are added and the water enters the Georgetown Sedimentation Basins. The water flows underground through the Washington City Tunnel to the McMillan Reservoir. Power actuated carbon and chlorine are added and the water flows through the rapid sand filter. Lime, orthophosphate, and chlorine are added and primary disinfection takes place during dwell time in the clearwell. Ammonia is added and the water passes to the storage clearwell. DC WASA Bryant Street Pump Station drives the water to storage tanks from which the water is distributed to consumers in the District of Columbia, Arlington County, and the City of Falls Church.

The McMillan WTP is still in use today. It provides a tangible example of the importance and evolution of municipal drinking water. It has been and continues to be upgraded with modern advances in water treatment. One change, made before 2001, had dire unintended consequences. Chemical treatment was changed from chlorine to chloramine [5]. This provided longer term disinfection when water flowed through distribution pipes. Tragically, this also destabilized the pipe chemistry, resulting in harmful lead levels. The problem was fixed in 2004, but thousands of children suffered permanent damage [6].

With the less land intensive rapid sand filter in place, the 25 acre fenced and closed McMillan park was sold to the government of DC. In 2021, this space remains chained off and idle, with the neighborhoods continuing to protest the city's development plan [7]. This provides and example to discuss difficulties and failures in government attempts to redevelop public land.



McMillan WTP satellite view, Google Earth [8]

Curated case studies are used widely in the teaching of engineering ethics [9]. The efficacy of using case methods in civil engineering is established.

> The benefits of using this approach are improved retention of knowledge, better reasoning and analytical skills, development of higher-order skills, greater ability to identify relevant issues and recognize multiple perspectives, higher motivation and awareness of non-technical issues. Many of these outcomes are part of the expected attributes of civil engineers outlined by professional bodies [10].

The McMillan WTP case study is intended to bring similar benefits by integrating cultural content into civil engineering teaching. The chronological account above of the McMillan WTP shows it to be suitable for use in civil engineering courses to meet multiple learning objectives.

In the course CE 1010 Introduction to Civil and Environmental Engineering taught at the George Washington University, the McMillan WTP case study is used in a unit of material introducing environmental engineering. The unit delivery takes place over two calendar weeks and 5 hours of direct instruction and guided interaction with the instructor. The unit is organized into three components: 1) a lecture introducing the field of environmental engineering, 2) a hands-on laboratory team project on a gravity water filter, and 3) the McMillan WTP case study.

The first component of the unit is intended to provide an overview to first semester students of environmental engineering as one of the technical specialties within the broad field of civil engineering. The classroom delivery of this material is presented by an environmental engineering professor specializing in water treatment in the role of a guest lecturer. This not only covers required material but also provides an opportunity to have the students interact with another of the professors in their home department. The content begins with an overview of environmental engineering including air, water, and soil, but then focuses down onto issues of water quantity and water quality. Graphics, short video clips, and questions and answers, are each included. Following this presentation the students are assigned reading material to prepare them to engage in the next component of the unit.

The second component is a hands-on lab activity. Students work in groups of three to design, build, and test roughing filters for water. Each team is competing to obtain the lowest turbidity while maintaining a minimum required flow rate. The pre-reading introduced to the concept of turbidity, the idea of using granular materials to perform as a physical and biological filter for surface water, as well as describing the actual lab activity and its reporting requirements. The lab begins with measuring the turbidity of the "dirty" water (distilled water with bentonite clay and coarse black pepper). Each team gets a paper bag of materials including a granular materials ranging from fine aquarium sand to glass marbles. Cups, sticks, duct tape, and scissors are included. The students are free to use any of the materials provided to build their filters, including the bag. They get three opportunities to build and test a filter, with the best of the three results being used as their team entry. The results of the competition are recorded as the lab proceeds so all can follow the developments. The grand, and only, prize is "bragging rights."

The third component again includes pre-reading, this time on the McMillan WTP [1, 4, 7]. The students take a field trip to the McMillan WTP to tour both the operating rapid sand filter WTP and a cell of the retired slow sand filter WTP. The bus trip to the site provides time for discussing the pre-reading. The bus trip back from the site provides time to contextualize DC's history as a racially segregated city including on the Foggy Bottom campus of GW. The tour concludes with a return to the classroom and a student discussion of the current controversy over the development of McMillan site in light of their knowledge of the use of this piece of land over the past 100 years.

ABET Student Outcomes for the environmental engineering unit in which the McMillan WTP case study is embedded are as follows:

> Student Outcome 2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
>
> Student Outcome 4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

The Learning Objectives associated with these Student Outcomes are broken down with the design portion of Outcome 2 separated (Learning Objective A) and the diverse factors of Outcome 2 combined with Outcome 4 (both Learning Objective B).

Learning Objective A: Complete the design exercise for water filtration using the engineering problem-solving steps of identify, formulate, and solve to balance the competing demands of discharge rate versus clarity.

Learning Objective B: Write essay on engineering artifact or process.

The ABET Learning Outcomes bearing on the use of the McMillan WTP case study in CE 1010 may thus be reworded as:

An ability to recognize 1) that engineering design solutions should meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors and 2) ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

This is a suitable restatement since ABET Outcome 2 is merely introduced in this course, then used and refined in later courses when students are prepared to **apply** engineering design to produce solutions to meet the needs they have first learned to **recognize**. It is Learning Objective B, the engineering essay, that is used to evaluate the effectiveness of using the case study.

The assignment for this essay directs students to pick an individual topic by finding an object or process on or around the GW campus that is an example of one of the technical specialties of civil and environmental engineering. The student is to produce a two or three page document that has at least one illustration (photo or drawing by student) and paragraphs of text, with a word count in the range of about 500 to 600 words in the body of text, plus references. There is a sequence of submittals and feedback: 1) key references, 2) first draft, 3) second draft, 4) final essay. The prompts for this writing assignment do not specify a need to consider the broader societal context when designing an engineering artifact or process.

The assessment material was comprised of these individual essays, collected for two student groups, one having been exposed to the case study while the second having not seen the case study. Both groups participated in the first and second components of the environmental engineering unit. Only the group exposed to the case study participated in the third component. The other group did no part of the third component, not going on the field trip. Both groups had the same writing assignment prompts for composing their essays. The essays were assessed for inclusion or absence of content concerning “societal context”. Using the lists from ABET Outcomes 2 and 4, “societal content” was judged to be explicit content about public health, safety, and welfare, as well as global, cultural, social, and environmental factors. Mention of solely economic factors was not interpreted as “societal context”. The groups were small, each consisting of 16 students. For the group exposed to the case study, 9 essays included social context while 7 essays did not. For the group not exposed to the case study, 6 essays included social context while 10 essays did not. Expressed as percentages, for the group exposed to the case study, 56 percent included social context when the case study was used, while 44 percent did not. For the group not exposed to the case study, 38 percent included social context while 62 percent did not. Having an increase in unprompted demonstration of the targeted learning objective from 38 percent to 56 percent indicates success. However, the difference between each group was only 3 students given the small sample size, In addition, the groups were taught during two consecutive offerings of the course, rather than in a simultaneous offering. The presence or absence of the case study was the only change in syllabus between offerings. The outcome of this pilot evaluation is hopeful. A more robust and reliable assessment seems called for in the future. To continue this work, the case study could be used in a larger class with multiple sections with collection of evidence more directly assessing prior and post demonstration of student comprehension of the learning objectives. A suitable civil engineering course for continuing evaluation of the efficacy of using this case study to embed cultural content is being determined.

References

[1] A.S. Gorzalski, A. L. Spiesman, "Washington Aqueduct: Serving Our Nation's Capital for Over 150 Years," *Journal - American Water Works Association*, Volume 108, Issue 2 p. 40-47, 01 Feb 2016.
[2] J. Marszalek, H. Holzer, W. Rawls, W. Blair, "What is the greatest overlooked story of the Civil War for the period between the battles of Ball's Bluff and Shiloh?," *The Washington Post*; Washington, D.C. [Washington, D.C]. 09 Oct 2011.
[3] J. Carrano, DISSERTATION "Contested play and clean water: McMillan Park, race, and the built environment in Washington, D.C., 1900-1941," University of Maryland, College Park. 2016.
[4] US Army Corps of Engineers, Treatment Process, Baltimore District Website, https://www.nab.usace.army.mil/Missions/Washington-Aqueduct/, 14 Oct 2021.
[5] M. Edwards, A. Dudi, "role of chlorine and chloramine in corrosion of lead-bearing plumbing materials," *Journal - American Water Works Association*, Vol.96 (10), p.69-81. 01 Oct 2004.
[6] M. Edwards, S. Triantafyllidou, D. Best, "Elevated Blood Lead in Young Children Due to Lead-Contaminated Drinking Water: Washington, DC, 2001−2004," *Environmental science & technology,* Vol.43 (5), p.1618-1623, 01 Mar 2009.
[7] Rachel Kurzius, "McMillan, D.C.'s Most Cursed Development Project, Explained," *The DCist*, Jan 27, 2020, updated Oct 29, 2021. [Online] Available: https://dcist.com/story/20/01/27/mcmillan-d-c-s-most-cursed-development-project-explained/, [Accessed Nov 1, 2021].
[8] https://earth.google.com/web/search/district+of+columbia/, [Accessed Nov 1, 2021].
[9] C. Whitbeck, "Desirable attributes of public educational websites," *Science and engineering ethics*, Vol.11 (3), p.463-476, Sep 2005.
[10] T. Newson, N. J. Delatte, "Case methods in civil engineering teaching," *Canadian Journal of Civil Engineering*, Vol. 38 Issue 9, p1016-1030. 15p. Sep 2011.