Optimization of Columbia River Basin Usage
(Technical Paper)

Socio-Technical Relationships of Water Access among New Jersey, Michigan, and West Virginia
(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

Samantha Garcia
Fall, 2020

Technical Project Team Members
Hong Liang
Cam Bailey
Kenneth Ross

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction

Why is access to clean drinking water not universally accessible across the United States? A question that non-American citizens would ask since many are under the impression that since the United States is a developed country and known for being more technologically advanced, its citizens would have easy access to clean water. However, this is not the case for some parts of the country depending on the water sources and treatments available. Lower income and more rural areas of the United States such as Pretty Prairie, Kansas and certain areas of Delaware tend to struggle with getting access to clean drinking water (Langin 2018). These water policy violations were more likely to occur in rural areas, where communities often have trouble finding the funds to maintain their systems (Condon, 2019). Some citizens have issues with water quality relating to the aging infrastructure while others just do not have the resources available to properly treat their water.

The topic for this STS paper will focus on the socio-technical relationships between water quality and access within the United States. To expand on this topic, three case studies will be discussed and analyzed; Flint, Michigan, Newark, New Jersey, and the state of West Virginia. These three case studies are selected due to their water quality problems as a result of infrastructure issues, water resourcing, chemical spills, and government involvement. The analysis will utilize the STS framework of wicked problem framing to look into the water access and quality issues among the three case studies chosen. Wicked problem framing is utilized to analyze problems that have no solutions in sight and use methods to look into the problem and try to relieve some stress from the affected citizens.

The research for the capstone project also deals with water quality and access but in a different context. The Columbia River Basin consists of a multitude of rivers that run into the

Pacific Ocean and provides electricity, water, navigation, habitats and other resources to a wide swath of land. The river system has multiple uses that range from using the dams to prevent flooding to protecting the wildlife within the system thus the capstone group is trying to optimize multiple different uses of the system to keep it running smoothly, safely, and efficiently. The project will attempt to target the Columbia River basin's uses to maximize the systems productivity, functionality, and more. The four objectives will be to generate and store enough electricity to meet the region's demands, water supply must be maintained to keep several facilities operating, protect wildlife in particular the salmon population, and keep a level of robustness to deal with changes in public or private ownership and operations, demographic changes, and the effects of climate change. The research team will utilize these objectives to investigate reservoir operating policies to optimize for historical conditions and re-simulate them under possible changes in climate and energy market conditions to evaluate their potential consequences in the future on the reservoir.

Technical Topic

The Columbia River Basin, a tributary of 1,243 miles of rivers running into the Pacific Ocean, is a system that provides electricity, water, navigation, habitats and other resources to a large portion of the United States. The system itself stretches across six US states (Washington, Oregon, Idaho, Montana, Nevada, and Wyoming) and two Canadian provinces (British Columbia and Alberta) with over 400 dams (*The Columbia River system: inside story* 2001). The natural resources it offers are used in the aforementioned states and across other western states, namely in California. A system of this size affects a large number and variety of people and wildlife, lending the authoritative bodies over the basin to consider multiple objectives. Also, in

consideration of the multi-objective nature of this system are the large degrees of uncertainty in natural fluctuations of rain and human usage and also climate change.

The Columbia River Basin has lots of different uses among the affected area as the system contributes electric supply to many of its residents and the dams within the system, which are considered the foundation of the Northwest's power supply. The system is also used to control flooding within the area, the dams are used to store water since the river's flow widely varies. The system supplies water to many different industries although not all of the water supply is for human consumption. Water quality must also be considered because some of the water supply is used for drinking purposes. The basin also is home to many different types of aquatic life that need to be protected specifically the salmon population. Although the economic aspects of the basin are difficult to predict, the system needs to take into consideration how the system receives funding to run smoothly. Some effects of the basin to think about would be private/ public interest, indigenous lands, demographic and population shifts and more.

A common finding throughout the available literature was that the compounding effects of climate change are currently poorly understood. Renewables and combustible turbine energy accounted for 56% of electricity in the Western US in 2015 (Bartos and Chester, 2015), and climate change can impact the availability of these resources. Streamflow, air temperature, water temperature, humidity, and air density will all be affected by climate change, and therefore the overall energy production capacity of the region, calling into question the viability of the region's power grid. However, another source of uncertainty is the energy efficiency of future technology, that could impact the generating power of the system and the amount demanded.

The objective of our project is to design robust reservoir operating policies that can balance the Columbia River Basin's many conflicting objectives both now and in the future. We

will achieve this by stress-testing alternative operating policies designed for historical conditions over possible changes in climatic and market conditions to inform the choice of a robust design.

The optimization function will seek to accomplish multiple objectives as to minimize 100-year floods, minimize violations of reservoir spill requirements for salmon, maximize energy generation from renewables, and maximize expected economic benefits for Bonneville Power Administration (BPA). BPA is the company that markets energy from the Bonneville Dam to the facilities that need energy to meet power demands. The function will come up with possible future scenarios that encompass different climate conditions, energy demands, and energy supplies. To analyze the effects on the system, the operating policies and historical conditions within the scenarios selected will be evaluated to see the robustness of the potential policies.

STS Topic

The problem that motivates this sociotechnical project is the issue of water quality and access across the United States. Not only do certain states have issues with access to clean water but also some infrastructure does not support current water quality standards. The government also has regulations that states must obey to provide their citizens with clean water, but the states still must stay within their limits with available budgets and resources. The population within the United States is set to increase over the next few years and the growth will have a negative impact on water quality (Derrington, 2011) The research will focus on three cases within the United States that deal with lead contaminated water and other chemical spills. Pollutants are seeping into the drinking water supply and causing dangerous levels of chemicals into the water. One example of a pollutant in drinking water is lead. Exposure to lead in drinking water is very dangerous to women and children, leading to developmental problems and birth defects (Clauser,

2019). Neurological effects and intellectual disabilities have been found to be caused by lead exposure in children and can cause miscarriage, stillbirth, and infertility for women. Lead is not the only pollutant causing detrimental health issues to its citizens and the United States needs to reevaluate their water regulation choices to decide the best options for the safety of the nation.

The human and social aspects of this topic deal with how poor water quality can lead to health issues, the differences among demographics and social classes can affect people's access to clean water, and how government neglect has led to changes in water regulation laws across the nation. This research topic will compare the terms of socio-technical relationships between Flint, Newark, and West Virginia. The first case discussed will be Flint, Michigan; the lead exposure began in 2014 when the city of Flint changed their water supply from Detroit's system to the Flint River to save money (Denchak, 2018). "Within a few months of the water switch, Flint experienced an outbreak of Legionnaires' disease. Legionella bacteria thrived in the conditions created in Flint's corroded water pipes" (Gable 2017). Legionnaire's disease was one of the illnesses to affect Flint and caused the death of 12 people. Legionnaires' disease is not the only illness spread from the water supply switch such as learning disabilities, development issues among children, and more. Several lawsuits have been filed regarding the water crises in Flint, providing some preliminary insight into the potential for using health impact data to legally secure water for all (Gaber, 2019). The city had to provide data to prove the lead levels were causing negative health issues and this one of the many actions that Flint had to go through to prove they needed help. Luckily, Flint was heavily publicized around the world and when the government did not step up, the citizens of Flint decided to act and get justice for their people.

The next case study is about Newark, New Jersey. Newark is found to be in violation of the Safe Water Drinking Act starting in 2016 (Anselm, 2020). The city got in trouble with

National Resources Defense Council Inc, New Caucas, and the EPA for failing to treat their water supply after they became aware of lead flaking out of the pipes and neglecting to notify the citizens. The lead within the pipes has sowed anger, anxiety and confusion among residents, who question whether the city's negligence has endangered its youngest citizens (Corasaniti 2019). These organizations decided to take the city of Newark to court for the unsafe lead levels in the water to fight for the people of Newark with unsafe drinking water. To this day Newark is still working on getting safe drinking water, but the lead levels have decreased drastically but still present. The last case study will focus on West Virginia. The citizens of West Virginia in 2014 endured a large industrial chemical spill that leaked large amounts of MHCM into the Elk River. The Elk River provides water to many residents of the capital of West Virginia and more (Schmidt, 2018). This chemical, MCHM, deemed to be a non-hazardous waste proved to be affecting the health of many West Virginia residents. "MCHM is harmful if swallowed, causes skin and eye irritation, and at elevated temperatures can cause irritation of the eyes and respiratory tract" (Savoia 2015). After the chemical spill was deemed dangerous, the states advised citizens not to use the water for drinking, bathing, cooking, or clothes washing (Cooper 2014). The state had to take action to clean up the Elk River since this problem was in violation of the EPA and posing to be a threat to people's health.

These cases will be analyzed using wicked problem framing. Wicked problem framing analyzes an issue by recognizing multiple intricacies with no easily obtainable solution. Wicked problems are considered "doomed to failure" in the complex area of social planning (Seager, 2011) due to its complexity thus the framework works to analyze the issue under the specific constraints and determine the best way to handle the situation at hand. This framework looks at addressing the issue from an adaptive standpoint and be willing to accommodate to unexpected

circumstances along the way. The "solution" will be compiled of ways to be able to get all stances of the issues to cooperate with each other and be able to slightly improve the situation but not solve. Wicked problem framing also investigates the ethics of the problem by "ethical considerations must be considered at the scale of the collective, which we refer to here as macroethics" (Seager, 2011). To be able to formulate practical solutions to the complex problem, you must use professional ethics within skills and reasoning domain to come to the best option among the multiple objectives.

Research Question and Methods

Water quality and access are affected by lots of different aspects that correlate in many ways. The procedure for making sure all US states receive clean water access go through infrastructure, laws, government, technology, social class/demographics, and more. This paper will explore all of these facets to ensure all states get their basic right to clean water since water is a necessity for survival. The research question for the STS topic will be what are the socio-technical relationships among water quality and access among Flint, Michigan, Newark, New Jersey, and West Virginia? Several different methods will be employed to ensure the paper will be thorough and discuss all relationships among water access and quality. The method of documentary research methods will be used to gather information on the three case studies, so the case studies are understood completely by the reader and author. This method will also provide evidence for the existing socio-technical relationships of water quality and access. Auto-ethnography will be utilized to reflect on the author's personal experiences with lead exposure in their drinking water supply. This information will be used towards the New Jersey case study and how this issue affects people mentally and physically. Since three case studies are being studied, historical case studies will be on the methods used to gather primary and secondary

sources on the places and their impacts. Wicked problem framing will also be used as both a method and framework to organize and answer the research question. This method will be employed to show how the issue has connections in many different aspects, but all of these connections help arrive to a root of the issue. Also, the problem will never be solved completely due to the complexity of the issue. The last method will be policy analysis due to the government involvement in this issue, the current policies in place must be analyzed to ensure the laws are sufficient or need revisions.

Conclusion

This paper will investigate the socio-technical relationships around water quality and access. The deliverable for the STS topic will consist of a plan to revise the regulations, improve infrastructure, better budget, and make resources available to all people within the United States. This plan will be an outline for the case studies to follow to try to improve their water access problem and hopefully the steps are efficient and effective while also still being able to make changes since things can be unpredictable. The plan will be intended for use among Flint, Newark, and West Virginia specifically, but the plan can be utilized by multiple cities and towns to see how effective the method really is. The technical topic deliverable will involve a final solution to optimizing the future of the reservoir with estimating climate change and energy market conditions with test simulations. The simulations will also involve the reservoir operating policies with historical conditions to determine the proper condition to simulate. The end result will show the best conditions to use and how to maximize the efficiency and profits of the reservoir.

References

Anselm, B. (2020, April 28). Newark Drinking Water Crisis. Retrieved October 01, 2020, from https://www.nrdc.org/newark-drinking-water-crisis

Bartos, M. D., & Chester, M. V. (2015). Impacts of climate change on electric power supply in the Western United States. *Nature Climate Change*, *5*(8), 748–752. https://doi.org/10.1038/nclimate2648

B., U., & U. (2001). *The Columbia River system: Inside story* (Second ed.). Portland, OR: Bonneville Power Administration. Retrieved October 12, 2020, from https://app.luminpdf.com/viewer/5f643137bd672d0012f9a73b

Clauser, Morgan (2019) "Following the Newark, NJ Drinking Water Lead Crisis," *Gettysburg Social Sciences Review*: Vol. 3: Iss. 2, Article 3. Retrieved October 10, 2020, from https://cupola.gettysburg.edu/gssr/vol3/iss2/3

Condon, M. (2019, October 9). *Rural America's Drinking Water Crisis*. American Bar Association. Retrieved from https://www.americanbar.org/groups/crsj/publications/human_rights_magazine_home/vol--44--no-2--housing/rural-america-s-drinking-water-crisis/

Cooper, W. J. (2014). Responding to Crisis: The West Virginia Chemical Spill. *Environmental Science & Technology*, *48*(6), 3095. https://doi.org/10.1021/es500949g

Corasaniti, N. (2019, September 23). *Tainted Water, Ignored Warnings and a Boss With a Criminal Past*. Https://Www.Nytimes.Com/#publisher. https://www.nytimes.com/2019/08/24/nyregion/newark-lead-water-crisis.html#:%7E:text=Tainted%20Water%2C%20Ignored%20Warnings%20and%20a%20Boss%20With%20a%20Criminal%20Past,-Newark%20told%20residents&text=NEWARK%20%E2%80%94%20In%20the%20year%20after,a%20number%20of%20unexpected%20decisions.

Denchak, M. (2018, November 08). Flint Water Crisis: Everything You Need to Know. Retrieved October 01, 2020, from https://www.nrdc.org/stories/flint-water-crisis-everything-you-need-know

Derrington, E. (2011). Drinking Water in the United States: Are We Planning For a Sustainable Future? *Consilience,* (6), 63-90. Retrieved October 16, 2020, from http://www.jstor.org/stable/26167817

Gaber, N. (2019). Mobilizing Health Metrics for the Human Right to Water in Flint and Detroit, Michigan. *Health and Human Rights, 21*(1), 179-190. Retrieved October 16, 2020, from https://www.jstor.org/stable/26727083

Gable, L., & Buehler, J. (2017). Criticized, Fired, Sued, or Prosecuted: Hindsight and Public Health Accountability. *Public Health Reports (1974-), 132*(6), 676-678. doi:10.2307/26374188

Keiser, D., & Shapiro, J. (2019). US Water Pollution Regulation over the Past Half Century: Burning Waters to Crystal Springs? *The Journal of Economic Perspectives, 33*(4), 51-75. doi:10.2307/26796836

Langin. K. (2018, February 12). Millions of Americans drink potentially unsafe tap water. How does your country stack up? Retrieved from Science Magazine: https://www.sciencemag.org/news/2018/02/millions-americans-drink-potentially-unsafe-tap-water-how-does-your-county-stack

Savoia, E., Stoto, M.A., Gupta, R. (2015) Public response to the 2014 chemical spill in West Virginia: knowledge, opinions and behaviours. BMC Public Health **15,** 790 https://doi.org/10.1186/s12889-015-2134-2

Schmidt, S. (2018, April 28). Documentary uncovers contaminated truths behind water crisis in West Virginia, other locations. Retrieved October 02, 2020, from https://www.pri.org/stories/2018-04-28/documentary-uncovers-contaminated-truths-behind-water-crisis-west-virginia-other

Seager, T., Selinger, E., & Wiek, A. (2011). Sustainable Engineering Science for Resolving Wicked Problems. *Journal of Agricultural and Environmental Ethics*, *25*(4), 467–484. https://doi.org/10.1007/s10806-011-9342-2