PRIORITIZING LOW-INCOME GROUPS AND THE ENVIRONMENT IN COMMUNITIES WITH POOR WATER QUALITY

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ABSTRACT

When a community has poor water quality, the U.S. Environmental Protection Agency (EPA) requires it to comply with federal standards in accordance with the Clean Water Act (CWA). The projects required to meet these standards can be very costly, so the EPA allows communities facing these regulations to evaluate their ability to afford them. If the EPA determines that ratepayers in the utility district would face an economic burden by meeting these standards, the community is allowed to extend the schedule for reaching compliance. This prolongs diminished environmental conditions beyond what is usually considered acceptable under the CWA. My research analyzes the benefits and costs when a community uses a schedule extension and I find that schedule extensions ultimately reduce the benefits of the improved water quality through delay. I offer an alternative payment structure based on economic principles that capture the benefits lost by extension and are sensitive to cost burden by income group.

EXECUTIVE SUMMARY

Hundreds of communities across the United States have poor water quality in their rivers and lakes. This is often due to having old infrastructure that conveys wastewater into water bodies during heavy storms. Communities with this issue are subject to the U.S. Environmental Protection Agency's Clean Water Act, which requires that it reduce the incidences of overflows. The projects necessary to accomplish this are often very expensive, as they require years of engineering and construction. When affordability becomes a concern, the EPA allows the community to assess the impact on ratepayers and, if costs cross a certain threshold, the schedule for meeting compliance may be extended in order to lessen the cost burden.

The EPA's method for assessing the affordability of ratepayers considers the cost per household of the projects as a percentage of median household income. However, using the median household income may not give an accurate estimate of the community's ability to afford the projects because income disparity is not considered and because the median is often overestimated in utility districts that do not lie within a single county. My research evaluates both of these considerations to determine how low-income groups are affected by the affordability criterion. Several professionals in the wastewater regulation industry have criticized this method for assessing affordability and my analysis of the rule supports their argument.

When a community is allowed to extend its schedule for meeting Clean Water Act compliance, which can result in up to 20 additional years of poor water quality, environmental and public health concerns are overlooked. Using a benefit cost analysis of the Washington D.C. Water and Sewer Authority's (WASA) plan for managing sewer system overflows as a case study, I have determined the loss of net benefits that the community would have experienced with its proposed scenarios for extending compliance. I have also found that the net benefit loss is greater for higher income levels because they tend to place a higher value on water quality.

Prior research has supported the notion that value of clean water increases with income. Using a study written by Carson and Mitchell titled “The Value of Clean Water: The Public’s Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water,” I propose a solution to the net benefit loss resulting from an extended compliance schedule that significantly reduces financial hardship on the poorest members of the community. This involves completing projects in the recommended timeframe by charging sewer rates that more closely match the willingness to pay of each income level in order to maximize net benefit for the community.

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ACRONYMS AND ABBREVIATIONS

CSO	combined sewer overflow
CWA	Clean Water Act
DOJ	U.S. Department of Justice
EPA	U.S. Environmental Protection Agency
MHI	median household income
RI	residential indicator
WASA	Water and Sewer Authority
WTP	willingness to pay

INTRODUCTION

Many communities across the United States do not meet U.S. Environmental Protection Agency water quality standards promulgated to implement the Clean Water Act. This can have numerous consequences, such as exposing the public to *E. coli* and harming wildlife in lakes and rivers. These issues are common where combined sewer systems are prevalent, which occur in more than 770 cities nationwide, mostly in the Northeast and Great Lakes regions of the United States (Downing and Warsmith). Though the EPA has set guidelines for achieving clean water in these cases, remediation measures are often expensive and some communities encounter financial hardship when undertaking the projects required to meet regulations. When affordability is a concern, the EPA will allow the community to extend its schedule for reaching compliance, reducing the yearly burden on ratepayers. The framework that the EPA has set for assessing affordability is very limited and has been criticized by several organizations and professionals in the industry. My research uses case studies to evaluate this affordability assessment and the burden it causes for low-income groups within the community.

In addition, I use the Washington D.C Water and Sewer Authority's 2002 CWA mandate as a case study to demonstrate the net benefit change resulting from a schedule extension. My results show that using a schedule extension would have caused a net benefit loss for the community. By also conducting a benefit cost analysis on individual household income levels, I found that the net benefit loss for the highest income groups, who typically have a higher value of water quality, is more than double the net benefit loss experienced by the lowest income groups. These results suggest that in order to reduce net benefit loss without imposing a financial burden on the poor, wealthier members of a community may be willing to pay a higher utility rate. The final part of my research proposes an alternative cost structure where each income level is charged a rate that more closely matches its willingness to pay in order to determine if value loss can be minimized.

BACKGROUND

The EPA issued the Clean Water Act in 1972 to present a standard for clean water, as well as federally mandated rules for addressing water that does not meet the standard. Many communities, like Washington D.C., are subject to the aspect of the CWA that regulates combined sewer overflows (CSOs), which occur when stormwater floods the sewer system and overflows into bodies of water. Originally designed to keep odorous wastes out of backyards by conveying them through storm drains, combined sewer systems have been a part of the country's infrastructure for centuries (Moffa). Figure 1 on the next page illustrates a combined sewer system that overflows into a local river during heavy wet weather events (The City of Portland Oregon). These overflows can limit recreational activity as well as harm wildlife and public health. The EPA requires that CSO-prone communities take actions to limit their occurrences. A few common methods for reducing CSOs are to separate the stormwater and wastewater sewer systems, increase the capacity of the combined sewer system, and build larger storage tanks that can manage excess capacity, all of which can be very expensive.

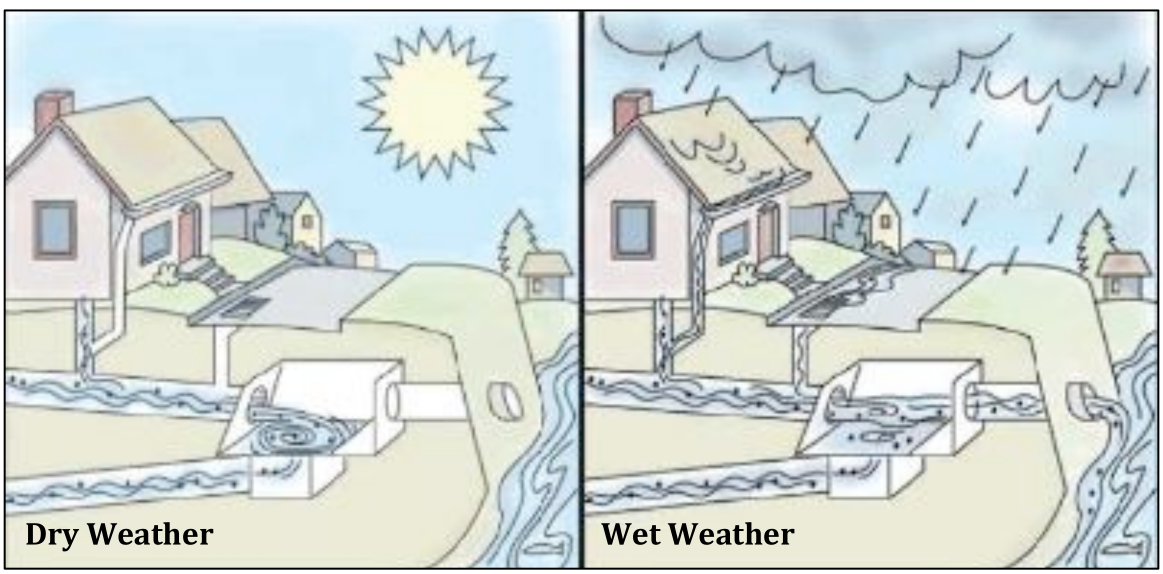

Figure 1 – Combined Sewer System During Dry and Wet Weather

In order to provide a solution for communities that would face an undue financial burden by achieving CWA compliance, the EPA issued the *Combined Sewer Overflows –*

Guidance for Financial Capability and Schedule Development document. The guidance has two phases to determine if the burden on ratepayers is high. The first phase calculates the cost per household of the projects required to meet the EPA's standard and divides this by the median household income (MHI) of the community. This calculation is called the residential indicator (RI). An RI of two percent or greater indicates a high financial impact (U.S. Environmental Protection Agency).

The second phase of the affordability assessment determines the municipality's financial capability based on various debt and socioeconomic indicators. Table 1 shows the EPA's financial capability matrix for determining a community's overall burden, using the residential indicator and financial capability assessment (U.S. Environmental Protection Agency).

	Residential Indicator		
Financial Capability Indicator Score	**Low (Below 1.0%)**	**Mid-Range (Between 1.0-2.0%)**	**High (Above 2.0%)**
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5-2.5)	Low Burden	Medium Burden	High Burden
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

Table 1 – EPA Financial Capability Matrix

Based on the level of burden determined by these two evaluations, the EPA may allow a compliance schedule extension up to 20 years after the recommended deadline. When a schedule extension is used, the intention is to complete the most important projects first in order to prevent furthering negative effects. By delaying full completion of the projects, however, the full benefits to the community of being in compliance with the CWA are delayed.

LITERATURE REVIEW

Criticisms of Affordability Criteria

Most of the criticisms of the EPA's financial capability measurements are targeted toward the residential indicator, either because of its limited scope or its uncertain foundations. The EPA's Environmental Financial Advisory Board, a group that provides input on costs of environmental projects, states "[MHI] does not completely capture all important dimensions of financial capability and is frequently an oversimplification of ratepayer affordability" (Environmental Financial Advisory Board). The National Association of Clean Water Agencies presents a similar argument in the 2005 *Financial Capability and Affordability in Wet Weather Negotiations White Paper*. The paper argues that MHI does not represent financial conditions across various sub-groups of a community and that using this measurement may result in negative impacts on poor populations (National Association of Clean Water Agencies).

Another issue with the EPA's affordability rule is the uncertainty about where the residential indicator originated and why two percent was chosen as the measure for a high financial burden. The EPA's 1997 guidance for financial capability stated that the measures for financial impact "reflect EPA's previous experience with water pollution control programs," but did not provide any additional information (U.S. Environmental Protection Agency). Other organizations have speculated what the EPA's previous experience is in reference to. The National Association of Clean Water Agencies' assessment of the EPA's criteria suggests that using MHI as an indicator of affordability originated with the Farm Home Loan program, which is dated before the Clean Water Act (National Association of Clean Water Agencies). A United States Conference of Mayors testimony states that, "there is serious confusion about the origins of the [two percent] of MHI as a 'standard' benchmark," and suggests that it came about at the time of the EPA's construction grants program and rural assistance in the early 1970s (United States Conference of Mayors). Very little information is available regarding affordability as it relates to the Farm Home Loan program, the construction grants program, or rural assistance in the early 1970s. As the testimony suggests, even industry experts and members of the EPA are unsure of the exact reason why two percent was chosen as a benchmark or if it is still relevant today.

Affordability Defined

Defining affordability in the context of public utilities is necessary for evaluating benchmarks of affordability, such as the Clean Water Act's RI threshold and benchmarks for other federal mandates. The National Drinking Water Advisory Council advised the EPA on its affordability criteria for the Safe Drinking Water Act, which has similar foundations as the Clean Water Act as well as a similar method for assessing affordability. The Work Group recommends that, for drinking water, affordability should be determined by evaluating willingness to pay for water quality (National Drinking Water Advisory Council). Carson and Mitchell's study of the public's value of water quality improvements determines that willingness to pay for water quality depends on several factors, an important one of which is income level (Carson and Mitchell). A journal article written by Raucher et al. defines affordability for water as household monthly water bills that do not result in an economic burden for low-income households in the utility's service area (Raucher et al.). The article goes on to say that affordability does not have a quantitative measurement and requires a hands-on evaluation rather than a subjective judgment, asking that the EPA use a more thorough approach to the issue of assessing community affordability. Neither willingness to pay nor a comprehensive evaluation of affordability are within the scope of the EPA's criteria at this time.

Alternative Affordability Assessments

Several organizations have recommended alternatives to the EPA's assessment of community affordability. A joint United States Conference of Mayors, American Water Works Association, and Water Environment Federation report proposes that affordability criteria consider income distribution, poverty rates, nondiscretionary spending, and other socioeconomic indicators in addition to income levels (United States Conference of Mayors, American Water Works Association, and Water Environment Federation). The report offers methods for collecting the necessary data, most of which is available online through the U.S. Census Bureau. In 2014, the Environmental Financial Advisory Board recommended that the EPA broaden their evaluation of community affordability beyond using only MHI to determine the residential indicator. They suggest considering cost of living for the area and including charges for other utilities in the burden analysis (Environmental Financial

Advisory Board). The industry is beginning to realize that MHI alone is not the best indicator of community affordability and that using a more comprehensive approach is easier than ever before because of data available online.

CASE STUDIES

My research uses three communities that have faced CWA mandates to evaluate the implications of the EPA's affordability benchmark. In this section, I describe the reason for each mandate as well as the cost and the approach used to solve the problem.

Washington D.C

In 2003, the U.S. Department of Justice (DOJ) and EPA reached a settlement with the Washington D.C. Water and Sewer Authority to reduce sewage overflows into local rivers. The overflows were a result of a combined sewage system, serving about one-third of the district (District of Columbia Water and Sewer Authority). The city tackled its CSO problem by creating the Clean Rivers Project to implement a Long Term Control Plan (LTCP). The total cost of the LTCP was projected to be $1.27 Billion (District of Columbia Water and Sewer Authority). The initial compliance schedule was 15 years, however the district requested an extended schedule and/or federal assistance. Washington D.C.'s LTCP provides detailed information about each schedule extension proposal, so I have used this as my primary case study to determine the benefits and costs of delaying compliance.

Baltimore, MD

In 2002, the DOJ, the EPA, the State of Maryland, and the City of Baltimore reached a settlement addressing the city's sanitary sewer overflows. Sanitary sewer overflows are different from combined sewer overflows because they are usually a result of poor infrastructure that causes leakages, resulting in unplanned sewage runoff. Because the city has also faced Safe Drinking Water Act mandates in addition to its $1 Billion Clean Water Act mandates, they opted for an integrated planning approach, which allows the city to integrate projects for both regulations at the same time, prioritizing the most important aspects of each (U.S. Environmental Protection Agency; Clean Water Baltimore). Using this approach may allow them to extend the compliance schedule for both mandates up to 13 years, which will result in more manageable yearly water and sewer rates.

Hartford, CT

In 2006, several organizations, including the DOJ, the EPA, and Hartford's Metropolitan District reached a settlement to reduce the city's combined sewer overflows and sanitary sewer overflows. The city created the Clean Water Project in order to implement its LTCP, with costs totaling $2.1 Billion. The proposed schedule takes place over 21 years, ending in 2026 (The Metropolitan District).

I use these communities to analyze how the EPA's affordability benchmark impacts the poor. It is important to note that the service areas for these utilities do not necessarily match the Census boundaries found in the data I used, so the numbers in the section below are representative of the utility district, but are not exact.

EPA'S AFFORDABILITY MEASUREMENT

Income Disparity

One reason that median household income is a poor indicator of residential affordability is that it does not consider the income disparity within a community. Using this measurement in a community with a high income disparity would cause low-income groups to be subject to a higher burden than in a community where the median household income is not much greater than lower income levels. For example, if the United States were a utility district, the MHI in 2014 was $53,657. This means that EPA-mandated projects costing $1,073 per household, two percent of MHI, would be considered at the high burden threshold. For the country's lowest income quintile of $21,909, this cost per household represents 4.9 percent of household income. As income disparity has increased nationwide, this burden has increased from 4.8 percent in 2006. In communities like Washington D.C., Baltimore, and Connecticut, however, greater income disparity means that the burden on low-income groups, represented by the lowest income quintile, is significantly higher than in the United States as a whole. This trend is shown in Figure 2.

The data used is from the U.S. Census Bureau 2006-2014 1-year estimates for median household income, income quintiles, and population.

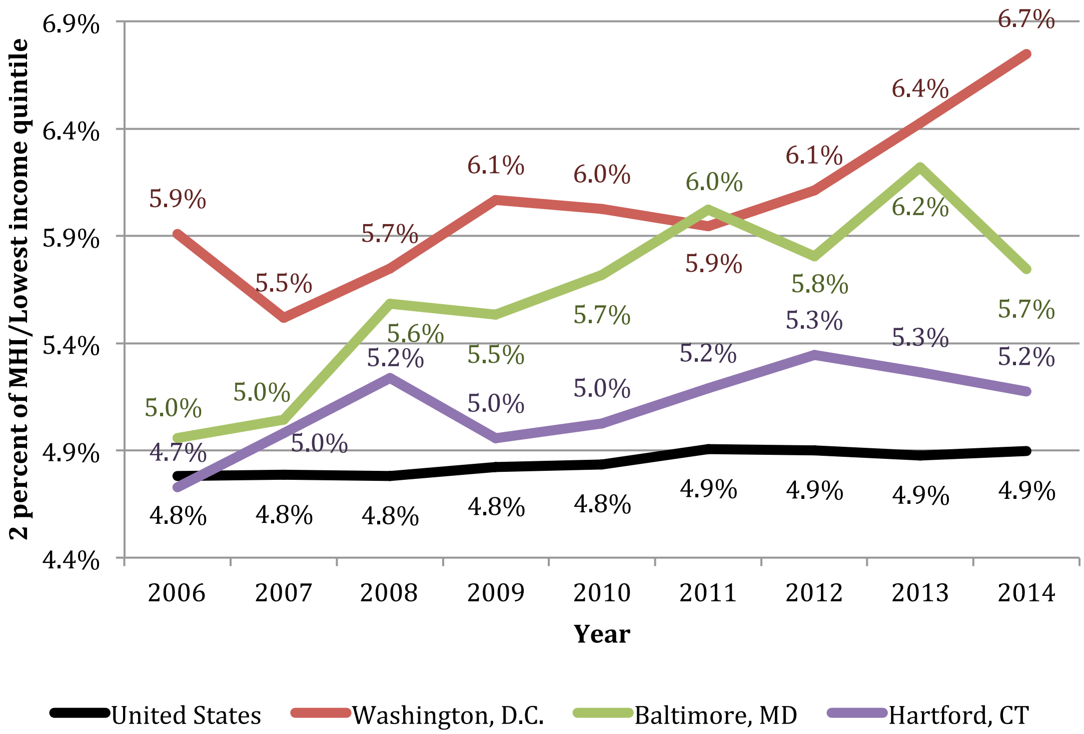

Figure 2 - Burden of Residential Indicator Benchmark on Low-Income Groups

If the EPA did consider income disparity when it decided to use MHI as the benchmark for community affordability, it did not account for the fact that this differs significantly across communities and over time. In order to properly assess a community's ability to afford projects required to reach CWA compliance, it is important to consider the impact that using a benchmark has on low-income groups.

EPA's MHI Calculation Method

Another challenge with the EPA's RI assessment is the inaccuracy of calculating MHI when the utility district does not lie within a single county. The 1997 guidance, *Combined Sewer Overflows – Guidance for Financial Capability Assessment and Schedule Development* suggests the use of a weighted MHI, calculated using the MHI and number of households in each Census tract within the district (U.S. Environmental Protection Agency). This approach may overestimate actual MHI, which could cause EPA-mandated projects to be considered affordable when they are not. Table 2 shows the actual MHI for Washington D.C., Baltimore, and Hartford as well as the EPA's would-be estimate of MHI if only Census tract-level data were available. Also shown is the percentage difference in cost that ratepayers could be expected to pay due to this calculation error and the percentage of median and low-income levels that this represents. This data is from the U.S. Census Bureau 2014 5-year estimates for median household income and income quintiles. More detail of these calculations is shown in Appendix B of this report.

	Actual MHI	EPA's Calculation of MHI	Difference	Impact on Median Income Level	Impact on Lowest Income Quintile
Washington D.C.	$69,235	$78,493	+13.4%	0.3%	0.8%
Baltimore, MD	$41,819	$46,237	+10.6%	0.2%	0.6%
Hartford, CT	$65,499	$71,330	+8.9%	0.2%	0.4%

Table 2 - Median Household Income Calculation Error

Because the RI calculation is considered high when cost per household is two percent of MHI, in Baltimore and Hartford, the cost would need to be ten percent higher to reach the same residential indicator threshold for a high burden because the community is assumed to be wealthier than it actually is. In Washington D.C., because the impact of this error on the median income level is 0.3 percent, the cost per household would need to be 15 percent higher to reach the same residential indicator threshold. Due to the fact that actual median household income is not possible to calculate when only Census tract-level data is available for a utility district, the EPA may not recognize a community as having affordability concerns due to miscalculation alone. In these communities, this error represents a significant portion of income for low-income groups, creating the potential for an even higher burden than these income levels would normally experience.

NET BENEFIT

Using the Washington D.C. Water and Sewer Authority as a case study, I have calculated the net benefit to ratepayers of reaching compliance. The original LTCP required the city to complete the necessary projects in 15 years, but the authority requested a schedule extension to instead reach compliance in either 20, 30, or 40 years. Although the LTCP is now well under way, my analysis determines which scenario would have been best for the city back in 2002 in order to encourage an economically desirable solution for communities that may face this issue in the future.

Methods

Present value net benefit is measured as the sum of benefits less costs for each year under each schedule scenario, divided by the discount rate.

$$NB_{ij} = \sum_{t=1}^{\infty} \frac{B_{ijt} - C_{ijt}}{(1+r)^t}$$

where B_{ijt} is the benefit in scenario *i* for income level *j* in year *t*, C_{ijt} is the cost in scenario *i* for income level *j* in year *t*, and *r* is a discount rate of two percent, as recommended by the Congressional Budget Office (Bellinger). To measure the net benefits for the community as a whole, I used the average benefits and costs for the community.

Benefits

Benefits are measured as the percentage of the project that is complete multiplied by the *WTP* of water quality for the respective income level. While actual project completion rates are unknown, I assumed that about the same amount of the projects would be completed each year within any given scenario. The assumed relationship between schedule duration and project completion is shown in Figure 3.

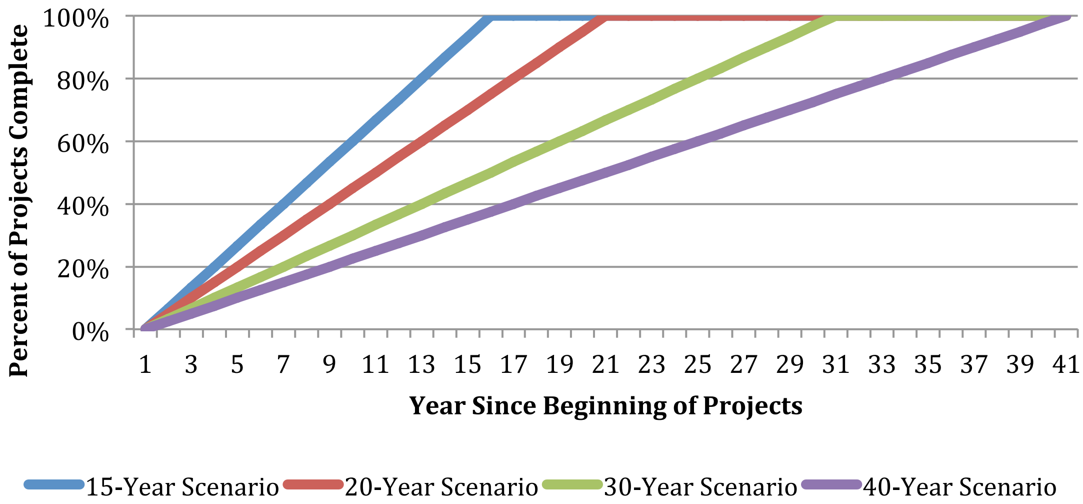

Figure 3 - Percentage of Project Completion by Year

Net benefit beyond year 41 is the same for all schedule scenarios and is calculated as the present value of *WTP* for improved water quality less the expected operations and maintenance costs, shown in Appendix C as the baseline scenario rate increase.

To determine *WTP* for improved water quality, I used results from a paper by Carson and Mitchell titled "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water." This study uses a contingent valuation method to determine participants' willingness to pay to reach these levels of water quality. There are several other studies that measure value of water quality, but I chose this one because it uses the most thorough approach and is generally considered the most complete study to date. Carson and Mitchell's study uses a national probability-based sample of U.S. households. Of the 813 households that responded to their survey, 564 households completed the entire survey including the valuation section. The valuation function models individual willingness to pay question responses by survey respondent characteristics.

This study assesses an individual's willingness to pay to reach boatable, fishable, or swimmable water quality for all United States water bodies. A paper by Richardson, Loomis, and Weiler shows that willingness to pay for environmental improvements is highly dependent on proximity to resources, implying that much of the Carson and Mitchell estimate is attributable to local water quality (Richardson, Loomis, and Weiler). Below is the valuation function for the highest level of water quality improvements estimated by the study.

$$TOTWTP_i = \exp[0.413 + 0.819\times \log(q_i) + 0.959\times \log(Y_0) + 0.207\times W_r + 0.460\times \log(A_e)]$$

where q_i is the numeric value on the water quality ladder being valued, Y_0 is the household income level in thousands of dollars, W_r is a dummy variable for whether or not a member of the household participated in boating, swimming, or fishing activities during the previous year, and A_e is a dummy variable for whether or not the correspondent regarded a national goal of environmental protection. Because not all of these variables were identified for the members of the Washington D.C. community, I worked backward from the mean willingness to pay given in the study to determine a coefficient that would allow me to tease out the income effect alone. Below is the equation I used to determine willingness to pay for each Washington D.C. income level.

$$WTP_j = \exp[4.289 + 0.959\times \log(Y_0)]$$

where WTP_j is the willingness to pay for income level *j* and Y_0 is the household income level in thousands of dollars.[1]

I expect that, by assuming the other variables used in the Carson and Mitchell study are constant across income levels, this may result in a negative bias. This is because higher income levels are more likely to have participated in boating, fishing, or swimming activities in the previous year and they may be more likely to regard environmental protection as a national goal than lower income groups. Not considering these correlations could have underestimated the willingness to pay of high-income groups and overestimated the willingness to pay of low-income groups. Ultimately, accounting for these factors would have increased the spread of net benefit loss between high- and low-income groups, but would not have had much of an impact on the spread of net benefit loss between schedule scenarios at the mean level of willingness to pay. It is important to note

[1] In order to determine the most accurate measurement of *WTP*, I first deflated the 2001 income levels given in the Washington D.C. LTCP, then calculated *WTP* in 1993 dollars using the formula, and then re-inflated back to 2001 dollars.

that my estimate of willingness to pay is for the purpose of revealing changes in net benefits between schedule scenarios and income levels rather than for pinpointing accurate valuation estimates.

Income level data for the Washington D.C. Water and Sewer Authority came from the below chart, Figure 4, in the 2002 Long Term Control Plan (District of Columbia Water and Sewer Authority). I estimated income deciles based on the chart, however the exact values are not available in the LTCP. To measure WTP_j using Carson and Mitchell's regression, I used the median income level within each income quintile to represent the respective quintile. For example, in the lowest income quintile, which is the lowest 20 percent of the income distribution, I used the 10 percent income level to represent the entire quintile. For the second lowest income quintile, which is 20 percent to 40 percent of the income distribution, I used the 30 percent income level to represent the entire quintile, and so on for each of the other three quintiles.

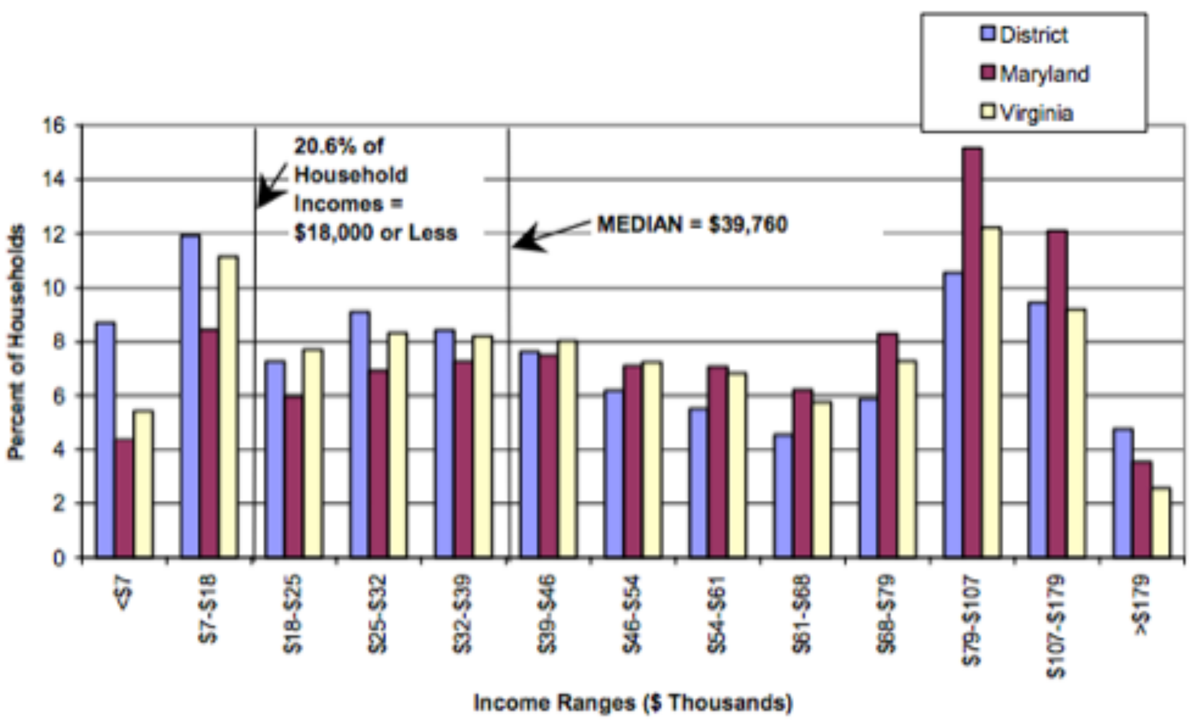

Figure 4 - Washington D.C. WASA Income Distribution

Figure 5, below, shows the *WTP* results for each Washington D.C. WASA income quintile as well as the mean willingness to pay of the community using the *WTP* results of each income quintile. These results are also summarized in Table 3 and Table 4.

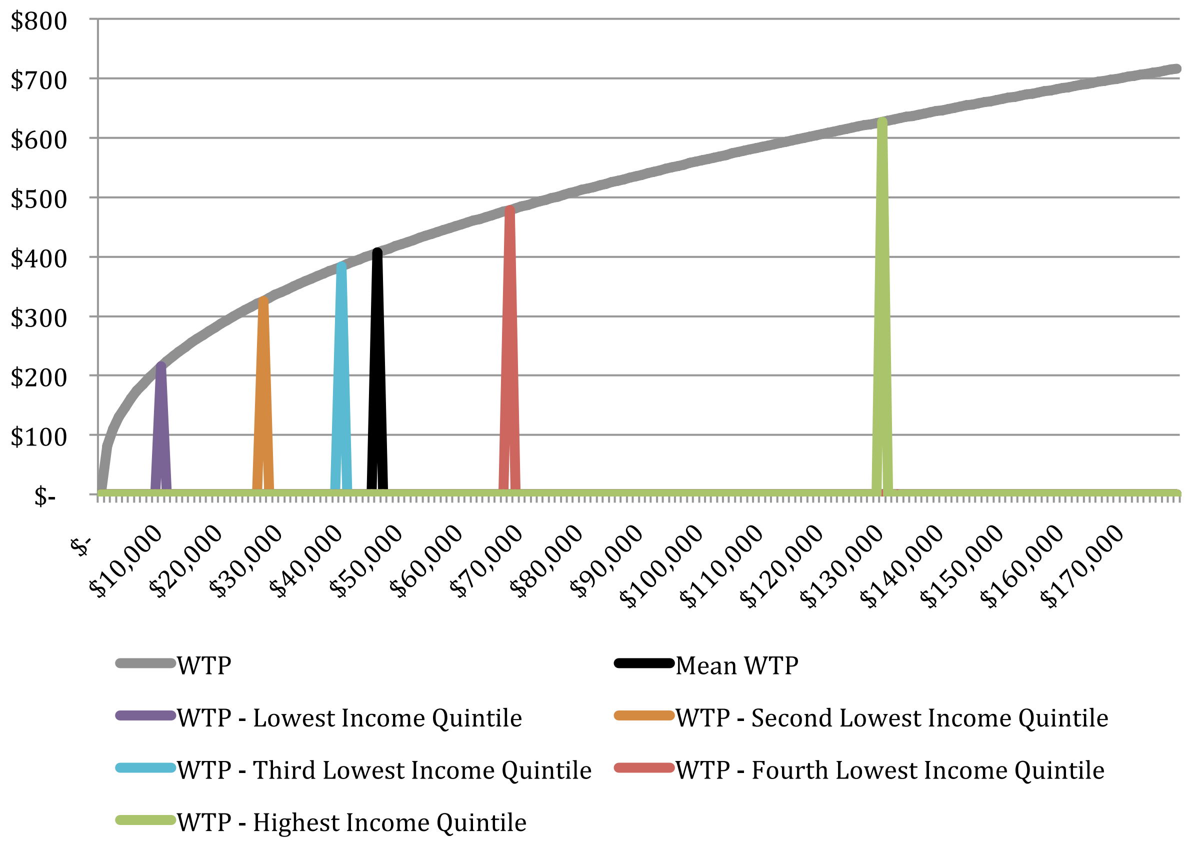

Figure 5 - *WTP* for Improved Water Quality

Income Quintile	Income Level (Median within Income Quintile)	*WTP* for Improved Water Quality
Lowest	$10,000	$215
Second Lowest	$27,000	$326
Third Lowest	$40,000	$384
Fourth Lowest	$68,000	$479
Highest	$130,000	$627

Table 3 - *WTP* for Improved Water Quality by Income Level

In order to calculate $\overline{WTP}$, I took the average WTP for each Washington D.C. income quintile. By using intervals of income distribution rather than income levels for each household in the community, which was not available, this estimate is approximate. [2] The result is shown in Table 4.

Income Level at $\overline{WTP}$	$\overline{WTP}$
$46,000	$406

Table 4 - $\overline{WTP}$ for Water Quality Improvements

The net benefit change resulting from a schedule extension is shown for the community as a whole using $\overline{WTP}$ as well as for each income quintile using WTP_j. Measuring the net benefit loss for each income quintile demonstrates how net benefit changes vary across income levels.

Another important consideration is that the benefits calculated in my analysis are only for ratepayers in the Washington D.C. Water and Sewer District. By considering local benefits only rather than regional benefits, which would include those downstream from the district's water bodies that will also experience a benefit from implementation of the Long Term Control Plan, the net benefit and net benefit loss are both underestimated.

[2] I calculated mean willingness to pay as the average of $WTP_{\text{j=lowest income quintile}}$, $WTP_{\text{j=second lowest income quintile}}$, $WTP_{\text{j=third lowest income quintile}}$, $WTP_{\text{j=fourth lowest income quintile}}$, $WTP_{\text{j=highest income quintile}}$. The median income level within the income quintile represents each income quintile.

Costs

Costs are measured by the yearly water rate in each scenario. Rate increases from the Washington D.C. Water and Sewer Authority's Long Term Control Plan are shown in Appendix C of this report. The costs beyond year 40 are assumed to be regular operations and maintenance costs, shown as the baseline scenario rates of the charts in Appendix C.

Net Benefit Change

To calculate an individual ratepayer's benefit loss of each scenario where the compliance schedule was extended beyond the recommended 15-year deadline, I subtracted the net benefit of the extended schedule scenario by the net benefit of the recommended schedule.

$$NB_{ij} - NB_{i=15-year\ scenario,j}$$

where NB_{ij} is the net benefit of the 20-, 30-, or 40-year scenario for an individual household within each income level.

Results

Table 5 shows the total net benefit and net benefit change at $\overline{WTP}$ for the 15-, 20-, 30-, and 40-year schedules. Using $\overline{WTP}$ is important for benefit cost analysis because I am able to estimate the net benefit for the community as a whole by multiplying the below values by the number of households in the utility district. The number of households is estimated to be about $233,000 because the population of the utility district at the time of their LTCP was 600,000 people and the Census estimates about 2.58 people per household (District of Columbia Water and Sewer Authority; U.S. Census Bureau).

	Net Benefit $\overline{WTP} = \$406$	Individual Household Net Benefit Change from 15-Year Scenario	Community Net Benefit Change from 15-Year Scenario
15-Year Scenario	$2,094		
20-Year Scenario	$1,294	$(800)	$(186,004,052)
30-Year Scenario	$(148)	$(2,241)	$(521,232,899)
40-Year Scenario	$(1,416)	$(3,509)	$(816,146,867)

Table 5 – Net Benefit and Net Benefit Change at $\overline{WTP} = \$406$

The net benefit loss is highest for the greatest schedule extension. This is because all costs are paid eventually, however present value benefits are less when the schedule is extended because the value realized from water quality improvements are delayed. Having a net benefit loss in each schedule extension scenario is economically inefficient and this community should attempt to avoid leaving benefits on the table by reaching compliance in the recommended 15-year timeframe.

Table 6 shows the net benefit and benefit change for each income level using WTP_j under each schedule scenario.

	Lowest Income Quintile		Second Lowest Income Quintile		Third Lowest Income Quintile		Fourth Lowest Income Quintile		Highest Income Quintile	
	Net Benefit	Δ	Net Benefit	Δ	Net Benefit	Δ	Net Benefit	Δ	Net Benefit	Δ
15-Year Scenario	\$(6,075)		\$(1,347)		\$1,135		\$5,201		\$11,553	
20-Year Scenario	\$(6,502)	\$(427)	\$(1,990)	\$(643)	\$379	\$(756)	\$4,259	\$(941)	\$10,322	\$(800)
30-Year Scenario	\$(7,266)	\$(1,192)	\$(3,146)	\$(1,799)	\$(983)	\$(2,118)	\$2,560	\$(2,641)	\$8,097	\$(2,241)
40-Year Scenario	\$(7,937)	\$(1,862)	\$(4,162)	\$(2,816)	\$(2,181)	\$(3,316)	\$1,065	\$(4,136)	\$6,136	\$(3,509)

Table 6 - Net Benefit and Net Benefit Change for Income Quintiles

The net benefit loss is greatest for households in higher income groups. According to the results of Carson and Mitchell's study, households in higher income levels place a higher value on improved water quality, so a schedule extension causing delayed water quality improvement results in a greater net benefit loss for those households than for households in low-income groups.

The analysis so far has been based on the Carson and Mitchell estimate for bringing all water bodies up to the swimmable standard. I now consider the percentage of the value for this estimate that would result in zero net benefits. In a community where $\overline{WTP}$ is \$357, which is 88% of the $\overline{WTP}$ in Washington D.C. according to the results from Carson and Mitchell's study, the net benefits under the 15-year scenario would be zero, indicating that the community as a whole would be indifferent to completing the projects. Table 7 shows the net benefit loss for each schedule extension where $\overline{WTP}$ is equal to \$357.

	Net Benefit $\overline{WTP} = \$357$	Individual Household Net Benefit Change from 15-Year Scenario	Community Net Benefit Change from 15-Year Scenario
15-Year Scenario	$0		
20-Year Scenario	$(704)	$(704)	$(163,810,700)
30-Year Scenario	$(1,972)	$(1,972)	$(458,670,603)
40-Year Scenario	$(3,087)	$(3,087)	$(717,968,294)

Table 7 - Net Benefit and Net Benefit Change at $\overline{WTP} = \$357$

Even when the benefits for meeting compliance are on the edge of passing or failing the benefit cost test, the loss of net benefits from delay are fairly consistent with that of a higher annual benefit estimate, such as what was experienced in Washington D.C. On average, the annual net benefit loss of delay is over $3,000 under the 40-year completion deadline and about $2,000 under the 30-year completion deadline. Aggregating these values up to the population suggests large economic losses exceeding $700 Million for the greatest extension. The analysis suggests that the most efficient solution would be to reach compliance as early as possible given communities are bound by the law to eventually comply.

ALTERNATIVE COST STRUCTURE

In order to maximize total community benefits without causing a high burden on the community's low-income ratepayers, Washington D.C. could have developed a rate structure that more closely matched its community members' willingness to pay for water quality based on income. A paper written by Paul A. Samuelson titled "The Pure Theory of Public Expenditure" suggests that, when it comes to collective consumption goods, each member of the collective should pay his or her willingness to pay, in this case for improved water quality (Samuelson).

Because some years require greater rate increases than others in order to fund specific projects, the yearly rate for each income level could not exactly match the yearly WTP_j. Instead, I have calculated the WTP for each income level as a percentage of $\overline{WTP}$ and applied the percentage to the yearly rate increases under the 15-year compliance schedule. Table 8 shows this proportional *WTP* factor for each income quintile within the district.

Income Quintile	Income Level (Median within Income Quintile)	*WTP* as % of $\overline{WTP} = \$406$
Lowest	$10,000	53%
Second Lowest	$27,000	80%
Third Lowest	$40,000	94%
Fourth Lowest	$68,000	118%
Highest	$130,000	154%

Table 8 - Income Quintile *WTP* as a Percentage of $\overline{WTP}$

By reallocating water rates to more closely match willingness to pay, low-income groups pay less than they would have paid in each year under the longest schedule extension. In addition, adding these factors to the yearly rate increases under the 15-year schedule shown in Appendix C allows the community to reach compliance within the recommended 15-year timeframe, which leads to the greatest net benefit for the community. Table 9 shows the net benefit for individual households within each income quintile under this funding scheme.

Income Quintile	Income Level (Median within Income Quintile)	Net Benefit	Net Benefit without Rate Adjustment
Lowest	$10,000	$1,114	$(6,075)
Second Lowest	$27,000	$1,695	$(1,347)
Third Lowest	$40,000	$2,012	$1,135
Fourth Lowest	$68,000	$2,458	$5,201
Highest	$130,000	$3,258	$11,553

Table 9 - Net Benefit by Income Level Under *WTP*-Adjusted Rate Structure

This rate structure allows each member of the community to realize a positive net benefit, unlike in the original structure where rates were the same across all income levels. Also, because the community would reach compliance in 15 years, there is no net benefit loss for the community as a whole due to a schedule extension.

CONCLUSION

The EPA attempts to protect communities from poor water quality through enforcement of the Clean Water Act. However, by allowing a compliance schedule extension for utility districts with affordability concerns, the objectives of the CWA are undermined. The results of my research suggest that when a community such as Washington D.C. takes advantage of a schedule extension, ratepayers experience a net benefit loss. Prior research has shown that willingness to pay for water quality improvements is related to income, so I have also shown that the net benefit loss is greatest for high-income groups. In order to reach a more economically desirable outcome – one that does not result in a net benefit loss – higher income groups may be willing to pay a utility rate that more closely matches their higher value of water quality improvements. This could allow the community to reach compliance within the recommended timeframe and may be possible through government subsidies or grant funding. For communities that face CWA regulations in the future, using this solution would allow for maximum environmental benefits without causing a burden on low-income groups.

APPENDIX A – U.S. CENSUS BURDEN ON POOR CALCULATION

	Median Household Income	Quintile Upper Limits: - Lowest Quintile	2% of Median Household Income	2% of Median Household Income/Lowest Income Quintile
2006	$48,451	$20,264	$969	4.8%
2007	$50,740	$21,204	$1,015	4.8%
2008	$52,029	$21,769	$1,041	4.8%
2009	$50,221	$20,826	$1,004	4.8%
2010	$50,046	$20,699	$1,001	4.8%
2011	$50,502	$20,585	$1,010	4.9%
2012	$51,371	$20,968	$1,027	4.9%
2013	$52,250	$21,433	$1,045	4.9%
2014	$53,657	$21,909	$1,073	4.9%

Table 10 - United States Calculation of Burden on Low-Income Groups Over Time

	Median Household Income	Quintile Upper Limits: - Lowest Quintile	2% of Median Household Income	2% of Median Household Income/Lowest Income Quintile
2006	$51,847	$17,546	$1,037	5.9%
2007	$54,317	$19,691	$1,086	5.5%
2008	$57,936	$20,159	$1,159	5.7%
2009	$59,290	$19,543	$1,186	6.1%
2010	$60,903	$20,216	$1,218	6.0%
2011	$63,124	$21,233	$1,262	5.9%
2012	$66,583	$21,782	$1,332	6.1%
2013	$67,572	$21,036	$1,351	6.4%
2014	$71,648	$21,230	$1,433	6.7%

Table 11 - Washington D.C. Calculation of Burden on Low-Income Groups Over Time

	Median Household Income	Quintile Upper Limits: - Lowest Quintile	2% of Median Household Income	2% of Median Household Income/Lowest Income Quintile
2006	$36,031	$14,535	$721	5.0%
2007	$36,949	$14,655	$739	5.0%
2008	$40,313	$14,438	$806	5.6%
2009	$38,772	$14,017	$775	5.5%
2010	$38,346	$13,414	$767	5.7%
2011	$38,721	$12,856	$774	6.0%
2012	$39,241	$13,522	$785	5.8%
2013	$42,266	$13,588	$845	6.2%
2014	$42,665	$14,856	$853	5.7%

Table 12 - Baltimore Calculation of Burden on Low-Income Groups Over Time

	Median Household Income	Quintile Upper Limits: - Lowest Quintile	2% of Median Household Income	2% of Median Household Income/Lowest Income Quintile
2006	$58,666	$24,816	$1,173	4.7%
2007	$61,096	$24,537	$1,222	5.0%
2008	$64,184	$24,509	$1,284	5.2%
2009	$62,030	$25,031	$1,241	5.0%
2010	$60,041	$23,888	$1,201	5.0%
2011	$60,965	$23,492	$1,219	5.2%
2012	$63,536	$23,780	$1,271	5.3%
2013	$63,603	$24,167	$1,272	5.3%
2014	$65,894	$25,472	$1,318	5.2%

Table 13 - Hartford Calculation of Burden on Low-Income Groups Over Time

APPENDIX B – U.S. CENSUS MEDIAN HOUSEHOLD INCOME ESTIMATIONS

	Actual MHI	EPA's Estimate of MHI	Quintile Upper Limits: - Lowest Quintile	No. of Households
Washington D.C.	$69,235	$78,493	$22,132	267,415
Baltimore, MD	$41,819	$46,237	$14,358	242,212
Hartford, CT	$65,499	$71,330	$25,121	348,204

	2% of Actual MHI	2% of EPA's Estimate of MHI	Difference ($)	Difference (%)	Impact on Lowest Quintile (% of Income)
Washington D.C.	$1,385	$1,570	$185	13.4%	0.8%
Baltimore, MD	$836	$925	$88	10.6%	0.6%
Hartford, CT	$1,310	$1,427	$117	8.9%	0.5%

Table 14 - EPA's Estimate of Median Household Income

APPENDIX C – WASHINGTON D.C. WATER AND SEWER AUTHORITY LONG TERM CONTROL PLAN ANNUAL RATE INCREASES

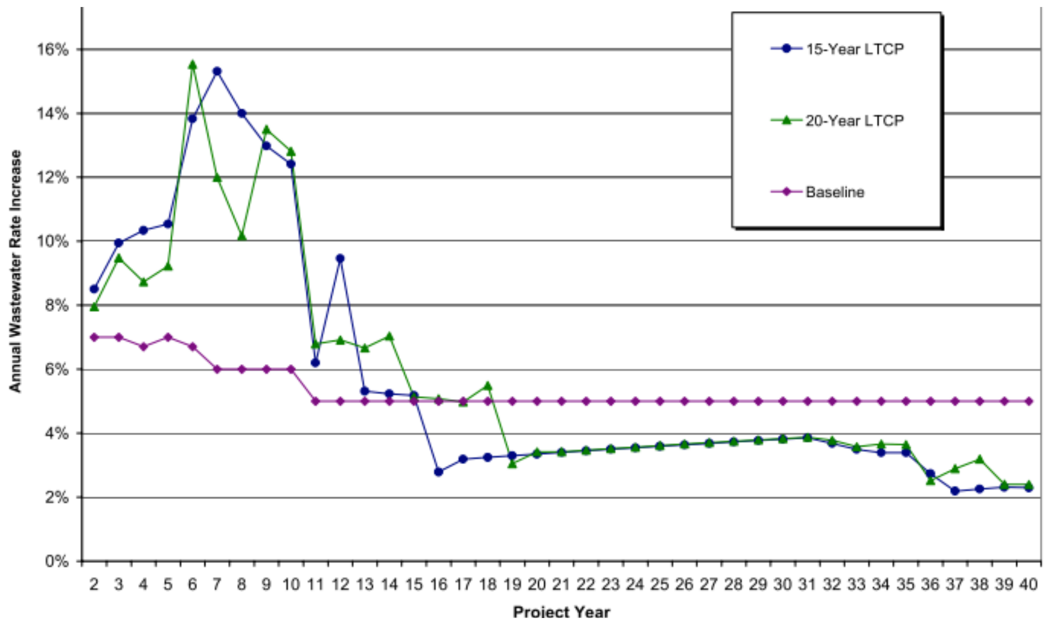

Figure 6 - WASA Long Term Control Plan Annual Rate Increases Required for 15- and 20-Year Plans

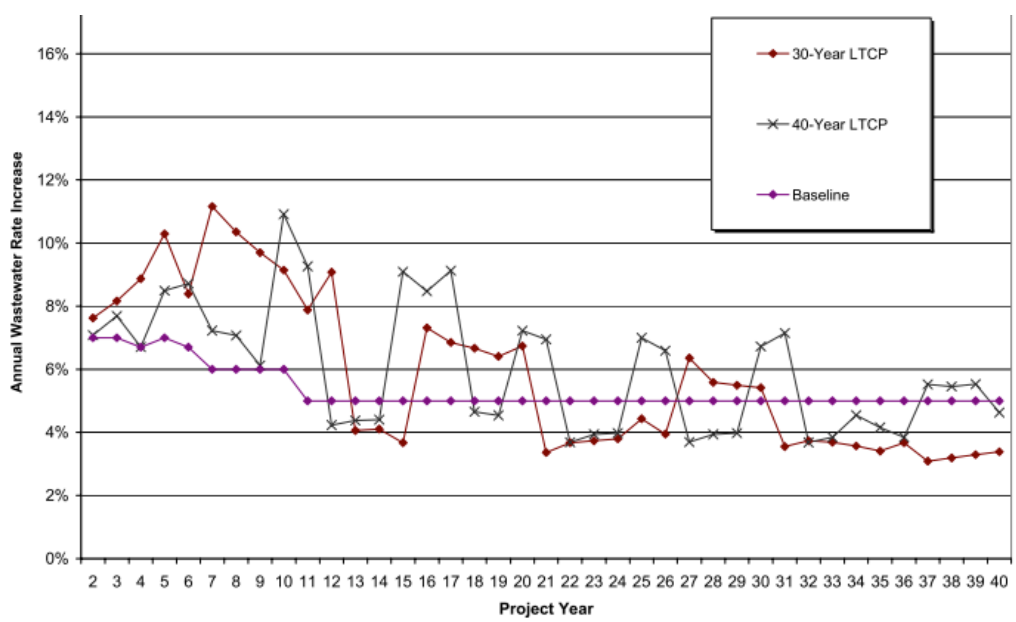

Figure 7 - WASA Long Term Control Plan Annual Rate Increases Required for 30- and 40-Year Plans

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