Estimating Financial Sustainability for Developed Land Water Utility Supply

By

DAKARI ADE' BARKSDALE B.S.
(California Polytechnic State
University, San Luis Obispo) 2010

MS PLAN II

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Civil and Environmental

Engineering in the

OFFICE OF GRADUATE STUDIES

of the UNIVERSITY OF

CALIFORNIA DAVIS

Approved:

Dr. Jay R. Lund, Chair

Dr. Debbie Niemeier

Dr. Frank Loge

Committee in
Charge

2015

Dakari Ade' Barksdale
September 2015
Civil and Environmental Engineering

Estimating Financial Sustainability for Developed Land Water Utility Supply

Abstract

Much of our underground infrastructure is in grave need of repair. The American Water Works Association estimates that it will cost at least $1 trillion to repair existing water systems and expand to meet population growth. Many municipalities are waiting and hoping to receive funds to repair or expand their water systems. Water systems that are not financially sustainable must be subsidized and depend upon government funding for repairs. When government funds are unavailable, the repairs for financially unsustainable water systems are delayed, increasing the risk of pipe failure and increasing future costs. A spreadsheet model developed in this paper helps determine if a community is financially sustainable and therefore helps reduce dependence on government subsidies. Hiddenbrooke, a community in the City of Vallejo, is analyzed as a case study, and it is found that the costs of the water system in Hiddenbrooke exceed the current revenues.

Acknowledgements

I would like to first thank my family and friends for their support throughout this project. Second I would like to thank Mr. Querin of Vallejo and Dr. Lund from UC Davis for their guidance and mentorship. Finally I would like to thank West Yost Associates employee Mr. Vera for his help finding and using cost estimates.

Contents

List of Figures

List of Tables

List of Equations

Chapter 1 - Introduction

1 Sustainability

Sustainability is receiving increased public attention. As defined by dictionary.com, the environmental aspect of sustainability is, “the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance”. Sustainability can also be defined from a business standpoint. According to BussinessDictionary.com, it is defined as, “Continued development or growth, without significant deterioration of the environment and depletion of natural resources on which human well-being depends. This definition measures income as flow of goods and services that an economy can generate indefinitely without reducing its natural productive capacity”. Many civil and environmental engineers have a profound understanding of environmental sustainability. However, the dependence on loans, the minimal economics courses studied by engineers, and the lack of long term financial analysis of engineering projects suggests that civil/environmental engineers may not have a firm grasp of economics. Luckily for the design engineer, they do not have to reach into their own pockets to make up for funding gaps that occur down the road. However, the financial burden falls on the general public. A spreadsheet model described in this paper seeks reduce the risk of developing financially unsustainable water systems.

Over time many engineers have tried to save money by putting off maintenance costs, or they have expanded services rather than maintaining the quality of current services. This has allowed the overall quality of above ground and underground infrastructure to degrade. The American Society of Civil Engineers (ASCE) has graded the drinking water infrastructure as a D. ASCE states that, “Delaying the investment can result in degrading water service, increasing water service disruptions, and increasing expenditures for emergency repairs. Ultimately we will have to face the need to ‘catch up’ with past deferred investments, and the more we delay the harder the job will be when the day of reckoning comes” (ASCE, 2013). Investment in sustainable projects would reduce the reliance on bonds and loans. Instead, many unsustainable projects are funded, and municipalities hope to receive a grant or other low-cost funding to pay for repairs (Duffy, 2010).

Providing water for a new low density community not adjacent to an existing water service can be financially unsustainable. By providing water to a new remote community, funding is directed away from maintaining current infrastructure and toward building new infrastructure. “People move out of one community, leaving behind a pipe network of fixed size but with fewer customers to support it. They move into a new community, requiring that the water system there be expanded to serve the new customers” (AWWA, 2010). This paper helps analyze the cost of providing water to a remote community. A community that is isolated from other communities requires a distribution main that will only service that one community. Figure 1 depicts Hiddenbrooke, a community that is removed from the rest of the city of Vallejo.

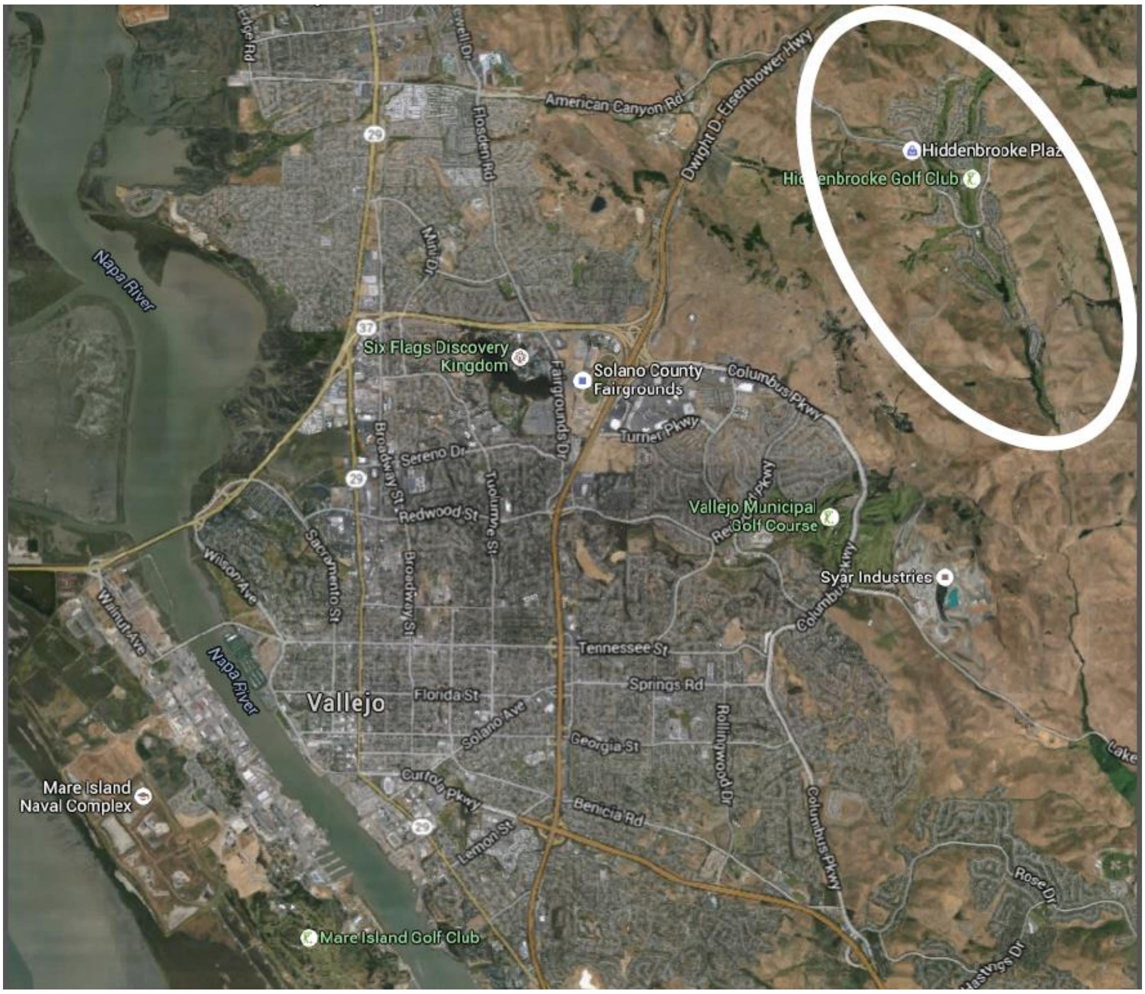


Figure 1 The Hiddenbrooke community located within the city of Vallejo (Google Maps, 2015)

2 Sprawl

This paper can be used as a tool to help determine the financial sustainability of providing water to a new community. A case study was conducted on Hiddenbrooke, to determine if the benefits of providing water to the community outweigh the costs. Hiddenbrooke is a community of over 1200 homes built around an Arnold Palmer designed golf course on the outskirts of Vallejo. Hiddenbrooke also has a small restaurant, a small grocery store, and a few other small businesses. Hiddenbrooke is less than 40 miles from San Francisco and about 10 miles from Napa Valley, making it a rather desirable place to live. Although homes in Hiddenbrooke may be less expensive than similar homes in larger nearby cities, they are often much larger due to the effect of sprawl. Sprawl refers to spread-out low density housing (Speir and Stephenson, 2002). The Hiddenbrooke community better fits the definition of sprawl than many communities in Vallejo or Oakland. Sprawl provides the benefit of cheaper housing and the potential of homeownership (Burchell et al, 2002). In comparison, the Hiddenbrooke home seen in Figures 2 and 3 is likely to be more appealing to people than the Oakland home seen in Figures 4 and 5. Both are 3 bedroom and 2 bath homes. However, the home in Hiddenbrooke was built in 2001 on a 15,246 square foot lot, and the Oakland home was built in 1889 on a 2,613 square foot lot. Even with more amenities, a larger lot size, and increased floor space the Hiddenbrooke home is being sold for $65,000 less than the Oakland home (Zillow.com, 2015).

The home in Oakland is much closer to San Francisco, where there is great economic opportunity. Since Oakland is more compact, its residents often spend less of their household income on the combined cost of housing and transportation (Ewing et al, 2014). Increased economic opportunity and decreased housing and transportations costs are part of the reason why people move to or stay in large cities. Many commuters consider paying more to live closer to the city they work in or paying less to commute to work. Although a sprawling neighborhood may be preferred by individuals, it increases the expense of public services (Burchell et al, 2002). School buses, police officers, and firefighters must make longer trips to provide their services. Infrastructure and land conversion costs are also increased due to sprawl. The results of a study done by Speir and Stephenson shows that low density housing is more costly to supply with water and sewer services (2002).

Figure 2 A home located within Hiddenbrooke (Google Maps, 2015)

Figure 3 An aerial view of the home in Hiddenbrooke (Google Maps, 2015)

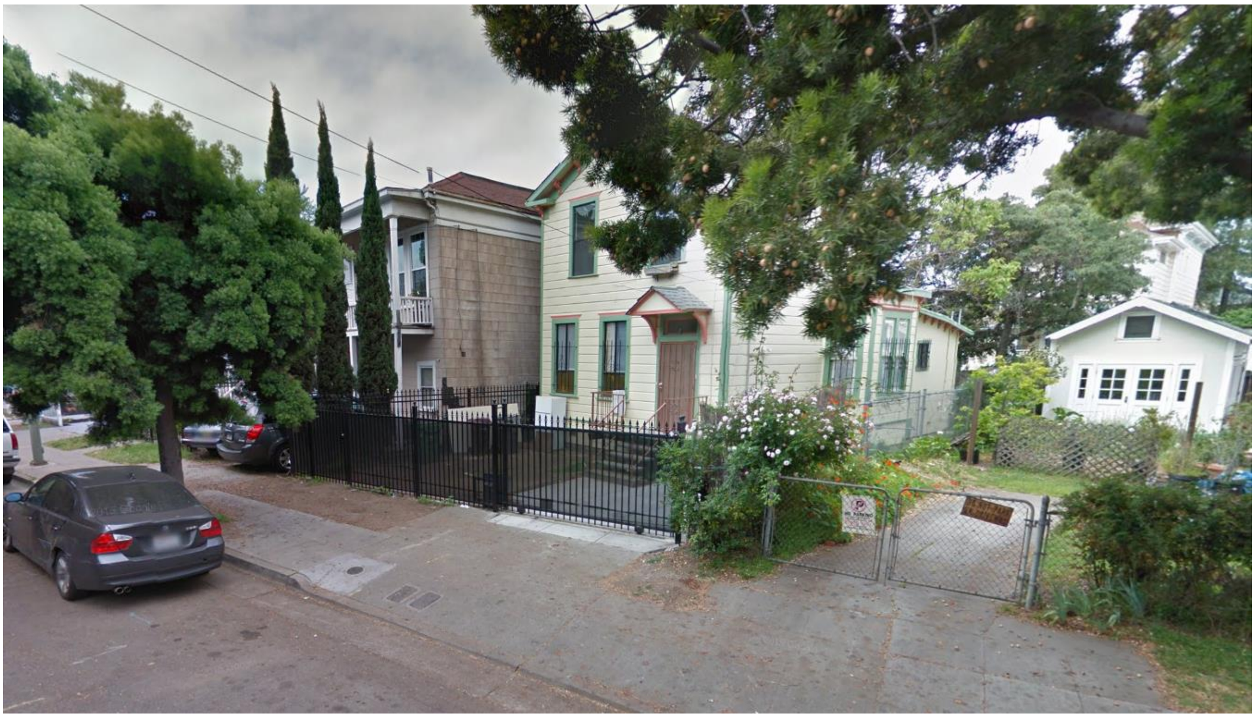


Figure 4 A home located within Oakland (Google Maps, 2015)

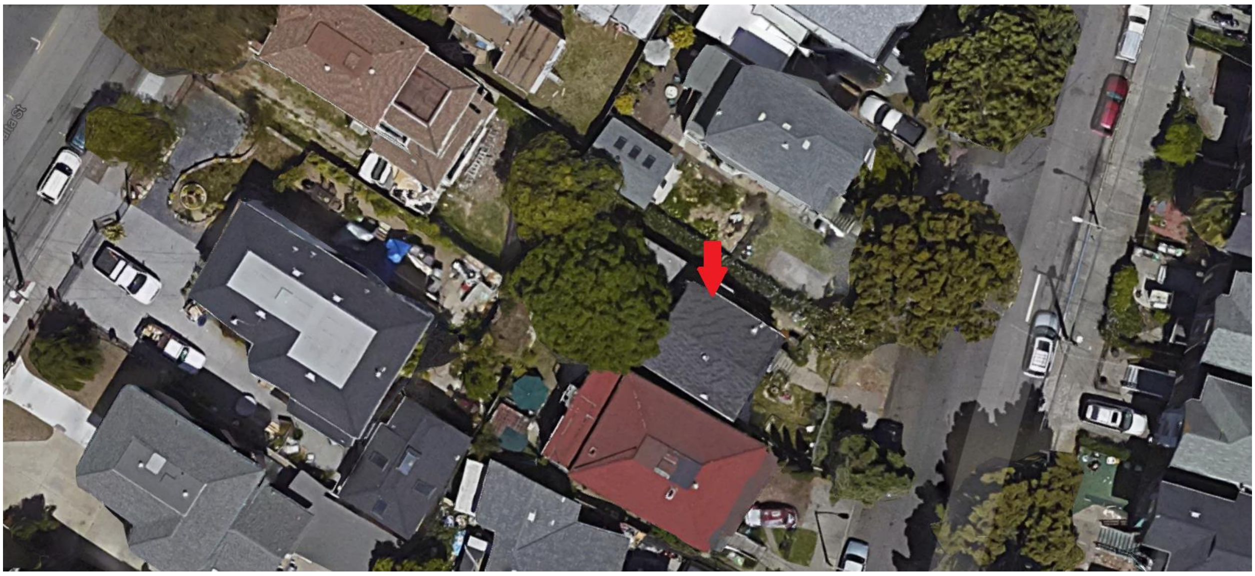


Figure 5 An aerial view of the home in Oakland

The literature on sprawl does not provide a precise definition for sprawl. The attributes of sprawl are often described, but they are rarely quantified (Speir and Stephenson, 2002). Also, the detriments and benefits of sprawl are not weighted by the same scale (Burchell et al, 2002). Therefore, this paper does not attempt to portray sprawl in its entirety as a negative or a positive for city development; instead this paper analyses the costs and benefits of providing water to a new community. Specifically, this paper estimates the cost of providing water to Hiddenbrooke in Vallejo, California. The following chapters in this paper are the methods, case study results, sensitivity analysis, and conclusions. The methods chapter explains all the values and formulas used in the spreadsheet model. The third chapter provides a cost analysis of the Hiddenbrooke development drinking water system. The sensitivity analysis chapter expands on the affect each variable has on the cost of the Hiddenbrooke water system. The final chapter provides a summary of the findings of this paper.

Chapter 2 - Methods

Many components must be considered in estimating the cost of providing water to a community. These components include the following:

- Pipe material cost
- Pipe installation cost
    - Trenching
    - Shoring
    - Pipe Laying
    - Boring
    - Dewatering
    - Erosion Protection
- Pumping cost
- Pump initial cost
- Valve cost
    - Gate Valves
    - Blow-off Valves
    - Air/Vacuum Valves
    - Zones Valves
- Flow Meter Cost
- Treatment Plant cost
- Annual Treatment cost
- Tank cost
- Replacement costs
- Maintenance costs

The aforementioned cost components are only the construction, maintenance, and replacement costs related to providing drinking water. Additional infrastructure components that could be included are road repair, sewage, design costs, and the cost of right-of-way easements. All costs for any project can vary greatly from location to location, due to different soil conditions, flow rates, available construction/engineering firms, etc. In this case study, the components such as road repair, sewage, design, and right of way easement costs are neglected.

1 Pipe Cost

Pipe costs can be estimated by two methods in this model. The simpler method solely uses a unit cost that includes the material cost and installation cost. In this model, the values for pipe material and installation cost were gathered from All Cost Data, a website devoted to providing free construction cost estimates. The total pipe material and installation unit cost is provided in dollars per linear foot and multiplied by the total linear feet to provide the total cost. The second, more advanced method of cost estimating includes individual values for the materials, excavation, and backfill.

Pipe material unit costs were estimated using Table 1 created by Engineering News-Record. Table 1 lists the price per linear foot based on the pipe diameter and material. Unit price estimates for San Francisco were used in this paper. Since this list is not exhaustive, some prices were estimated using linear regression lines seen in Figure 6. The linear regression line for PVC is negative when the diameter is less than 4 inches. This is handled in two ways. One, the price of PVC rated for use in sanitary sewer pipes can be used as a lower limit value, since sewer pipes are cheaper than drinking water pipes, as seen in the Engineering News-Record table. Two, in the Hiddenbrooke case study, the smallest diameter PVC pipe is 4 inches. The cost of purchasing drinking water pipes was calculated by multiplying the cost per linear foot by the corresponding length of pipe. For example, if there is 100 linear feet of 6 inch ductile iron pipe it would cost $1298, because each linear foot of 6 inch ductile iron costs $12.98.

Table 1 Engineering News-Record Pipe Material Unit Costs (Engineering News-Record, 2015)

ITEM	UNIT	KANSAS CITY	LOS ANGELES	MINNEAPOLIS	NEW ORLEANS	NEW YORK	PHILADELPHIA	PITTSBURGH	ST. LOUIS	SAN FRANCISCO	SEATTLE
REINFORCED-CONCRETE PIPE (RCP)											
12"	FT	+16.02	12.39	+17.28	15.25	16.15	16.59	13.05	+17.00	12.68	14.97
24"	FT	+29.33	25.26	+30.80	28.90	27.80	31.20	23.09	+23.10	26.32	27.35
36"	FT	+58.42	51.38	+50.62	57.88	50.53	59.07	50.11	+45.30	54.75	54.88
48"	FT	+99.10	87.86	−92.10	94.02	90.61	97.48	79.36	+82.10	88.49	91.20
CORRUGATED-STEEL PIPE											
12"	FT	9.94	8.20	10.36	9.98	+10.09	10.02	9.68	10.25	8.29	−9.87
36"	FT	29.55	25.69	35.10	30.85	−33.00	34.30	34.10	26.18	26.65	−31.05
60"	FT	72.85	64.80	92.18	−70.30	−77.19	69.45	68.26	57.90	67.87	−72.78
POLYETHYLENE PIPE (PE): UNDERDRAIN											
4"	FT	0.94	0.95	+0.94	+1.03	1.05	1.02	0.92	0.98	1.00	1.15
POLYVINYL-CHLORIDE PIPE (PVC)											
SEWER 4"	FT	1.34	1.73	1.48	−1.65	1.80	1.69	1.42	1.48	1.87	1.58
8"	FT	5.60	5.83	4.70	−5.15	5.83	5.98	5.27	4.33	5.83	5.32
WATER 6"	FT	3.60	6.07	7.10	5.74	6.18	6.00	5.43	4.76	6.07	6.10
8"	FT	5.55	9.42	12.40	8.95	8.50	9.15	7.55	8.60	9.42	9.00
12"	FT	12.10	19.56	19.32	16.62	17.49	18.23	17.69	14.05	19.56	17.98
DUCTILE-IRON PIPE (DIP)											
6"	FT	+14.05	12.82	13.10	17.09	−19.95	21.71	20.07	16.73	12.98	18.09
8"	FT	+17.00	19.05	22.72	25.23	29.88	31.55	34.13	22.95	19.61	25.60
12"	FT	+31.78	30.13	38.65	35.78	43.56	42.05	42.18	37.95	32.98	37.25
COPPER WATER TUBING: TYPE L											
½"	FT	1.78	1.92	2.00	1.97	1.98	+2.10	1.84	2.26	1.92	1.90
1½"	FT	4.50	4.84	5.75	5.10	5.45	+5.49	6.00	5.38	4.48	4.88

+ OR – DENOTES PRICE HAS RISEN OR FALLEN SINCE PREVIOUS REPORT; QUOTES ARE DELIVERED PRICES. SOME PRICES MAY INCLUDE TAXES OR DISCOUNTS. PRODUCT SPECIFICATION MAY VARY, DEPENDING ON WHAT IS MOST COMMONLY USED OR MOST ACCESSIBLE IN A CITY. QUANTITIES ARE GENERALLY TRUCKLOADS. RCP PIPE IS ASTM C76; 12 IN. AND 24 IN. ARE RUBBER-GASKET JOINTED, OTHERS ARE NON-CORRUGATED. CORRUGATED STEEL PIPE IS PLAIN GALVANIZED; 12 IN. IS 16 GAUGE, 36 IN. IS 14 GAUGE, 60 IN. IS 12 GAUGE. PE PIPE IS M252, PERFORATED AND CORRUGATED. PVC SEWER PIPE IS ASTM D-3034, SDR-35. PVC WATER PIPE IS C900, CL 150. DIP PIPE IS CL 150 WITH A PUSH-ON JOINT. COPPER WATER TUBING PIPE IS HARD AND INTERIOR DIAMETER, TYPE L.

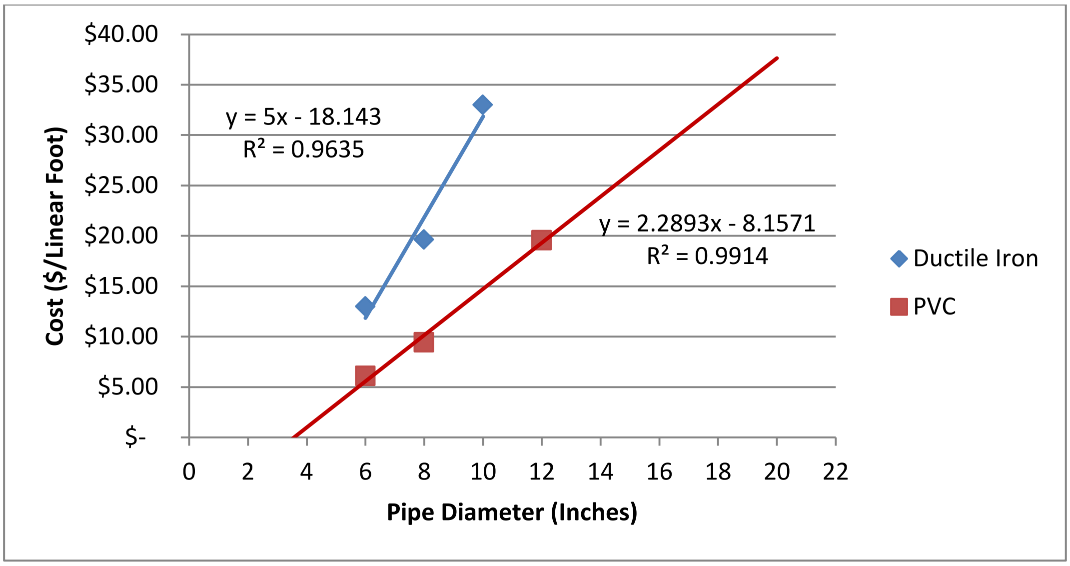


Figure 6 Ductile Iron and PVC material unit cost linear regression

The pipe installation cost was estimated utilizing data from the United States Department of Agriculture Natural Resources Conservation Service and data from JM Eagle. Labor and equipment costs were calculated using cost per linear foot estimates provided by JM Eagle. The labor and equipment cost per linear foot estimates can be seen in Table 2.

Table 2 Labor and Equipment Costs ($/LF)		
Dia	DI	PVC
4	6.59	4.39
6	6.59	5.27
8	6.59	5.73
10	7.32	6.59
12	7.75	6.59
14	9.41	8.23
16	11.36	10.29
18	13.17	11.76
20	14.64	13.17
22	18.82	16.47

The cost of backfill and excavation was estimated using United States Department of Agriculture Natural Resources Conservation Service (NRCS) data. The excavation volume was estimated by assuming the trench width needed to be at least 8 inches larger than the diameter, see Equation 1, of the pipe and that the cover was 24 inches. It was assumed that it cost $4.82 per cubic yard for excavation (USDA NRCS, 2000). The backfill cost is comprised of two separate costs. One part of the backfill cost is the bedding cost which is the cost of the soil backfilled to the top of the diameter of the pipe. The calculation of the bedding backfill volume can be seen in Equation 2 and explained in Figure 7. The other part of the backfill cost is the common backfill, see Equation 3. This is the cost of filling in the remainder of the trench. The calculation of the common backfill volume can be seen in Figure 7. It was assumed to cost $11.24 per cubic yard of bedding backfill and $3.21 per cubic yard of common backfill (USDA NRC, 2000). The values used for excavation and backfill are all in 2015 dollars, the USDA NRCS data gave the following 2000 dollar values, $3.00 for excavation, $7.00 for bedding backfill, and $2.00 for common backfill. The 2000 dollar values were converted to 2015 dollars using the Engineering News-Record Construction Cost Index, see Appendix A.

$$Trench\ Width = 8" + Pipe\ Diameter \qquad \text{Equation 1}$$

$$Bedding\ Backfill = Trench\ Width * Pipe\ Diameter * 1\ linear\ foot \qquad \text{Equation 2}$$

$$Common\ Backfill = 24"\ Cover * Trench\ Width * 1\ linear\ foot \qquad \text{Equation 3}$$

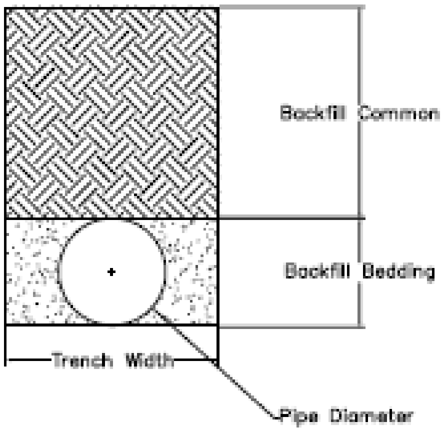


Figure 7 Backfill Calculation

2 Pump Cost

The pumping cost was calculated using Equation 1. In this equation Q is the flow rate in gallons per minute, h is the head in feet, and c is the cost rate per kilowatt hour in dollars per kilowatt hour (Engineering Toolbox, 2015). The cost per kilowatt hour depends on the time of day and any special rates that may apply for the water provider. A range of typical values in the Pacific Gas and Electric (PG&E) Service area can be found on the PG&E website. The cost rates per kilowatt hour found on the PG&E website ranged from $0.15 per kilowatt hour to $0.25 per kilowatt hour.

In the denominator, μ_p is the pump efficiency and μ_p is the motor efficiency. These values were assumed to be 0.9 and 0.85 respectively. For new pumps these values are a good assumption, but as pumps age this assumption may be too high. Reducing these values would increase the pumping cost.

$$\frac{\$}{hr} = \frac{0.746 * Q * h * c}{3960 * \mu_p * \mu_m} \qquad \text{Equation 4}$$

The cost of the pump and pump station is estimated based on the required horsepower. According to the United States Bureau of Reclamation (USBR), pumps cost anywhere between $1,300/horsepower to $1,500/horsepower in 2005 dollars. The spreadsheet model uses $1,805/horsepower in 2015 dollars. This estimate includes the cost of controls and structures (USBR, 2006). The cost excluding structures is $440/horsepower to $500/horsepower in 2005 dollars ($632/horsepower in 2015 dollars is used in the model). To calculate the horsepower required by the pump, the water horsepower must first be calculated. The water horsepower is the horsepower that would be required if the motor and pump were 100% efficient. Water horsepower can be calculated by multiplying the specific gravity, S.G., by the flow rate and the head. The specific gravity of water is 1 for practical purposes. When the flow rate is given in gallons per minute and the head is given in feet the product of them divided by 3690 results in the water horsepower, see Equation 5. As seen in Equation 6, the water horsepower is then divided by the product of the motor efficiency and the pump efficiency, referred to as the pumping plant efficiency.

$$WHP = \frac{S.G.*Q*H}{3690} \quad \text{Equation 5}$$

$$HP = \frac{WHP}{Pumping\ Plant\ Efficiency} \quad \text{Equation 6}$$

3 Valve and Hydrant Cost

Fire hydrant, gate valve, and blow off valve costs were estimated using construction bids received by West Yost Associates. Multiple projects were analyzed to estimate the unit costs of fire hydrants, gate valves, and blow of valves. The estimate from the lowest bidder was recorded from each project, and then all recorded estimates were averaged. The averaged values, seen in Table 3, were then used as the unit cost for the fire hydrants, gate valves, and blow off valves.

Table 3 Vale and Hydrant Unit Costs

Variable	Unit Cost
Fire Hydrants	$7,000
Gate Valves	$1,500
Blowoffs	$2,750

4 Treatment Plant Cost

Treatment plant costs are estimated using a United States Bureau of Reclamation appendix on cost estimates (2006). Assuming that a treatment plant is to be expanded to provide water to the community being studied, building costs are $0.40 per gallon per day ($400,000 per million gallons per day), and water treatment plant expansion costs are $0.90 per gallon per day ($900,000 per million gallons per day). In 2015 dollars, the building cost is $0.54 per gallon per day, and the treatment plant expansion cost is $1.21 per gallon per day.

5 Annual Treatment Cost

The EPA has estimated that the production of tap water costs slightly more than $2 per 1,000 gallons; about 15% of that cost is the treatment cost (2004). The other 85% of the cost is from the treatment plant equipment, the distribution system, and the operation and maintenance of the system. The annual treatment cost was estimated in this model using the unit cost of $0.30 per thousand gallons of water, since 15% of $2 is $030. In 2015 dollars, the treatment cost is $0.42 per thousand gallons of water.

6 Tank Cost

Tank costs were estimated using values from an Engineering News-Record cost index. Table 4 shows the cost of installing a welded steel water tank based on the capacity of the tank. A linear regression was used in the model to determine the estimated cost in millions of dollars. The R^2 value for the linear regression line is 0.9997, as seen in Figure 8. The tank storage is calculated using the flow rate and the amount of time the supply would last without pumping.

Table 4 Welded Steel Storage Reservoirs

Capacity (MG)	Estimated Cost (Million $)
0.5	1.47
1	1.83
2	2.48
3	3.21
4	3.94
5	4.59
6	5.32

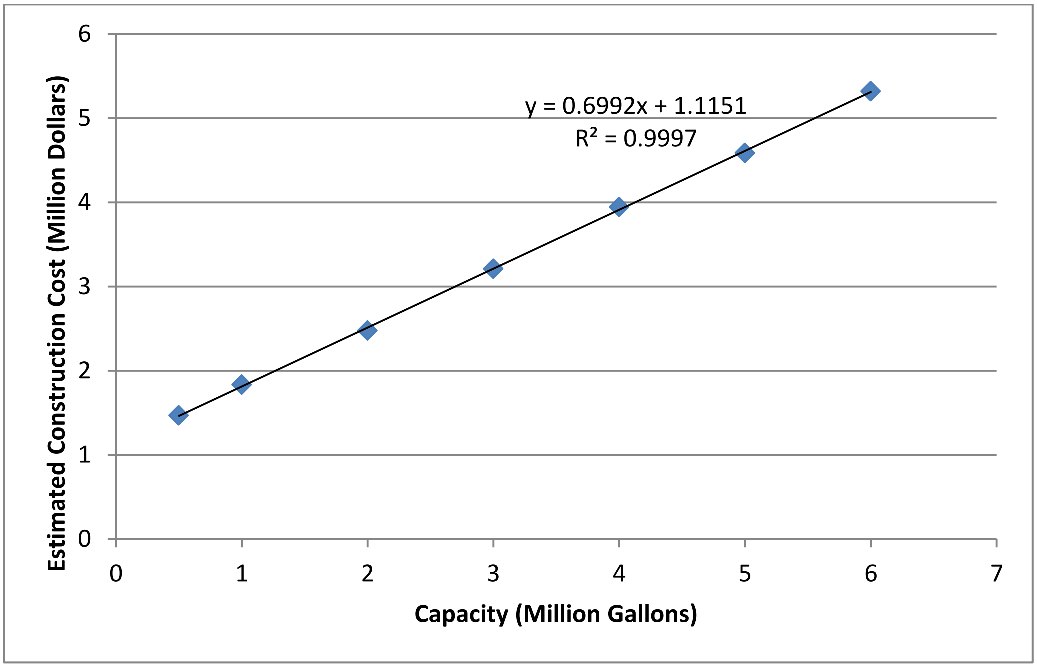


Figure 8 Welded Steel Tank Construction Costs Linear Regression

7 Maintenance Cost

Maintenance costs were estimated for the pipes, the treatment plant, the pumps and controls, and the pump structure, based on data from the United State Bureau of Reclamation (2006). The annual pipe maintenance cost is estimated to be 0.75% of the initial pipeline cost. The annual maintenance cost of the treatment plant is estimated to be 5% of the initial cost. Annual maintenance of the pumps and controls is estimated to be 5% of the initial cost of the pumps and controls (not including the pump structure). The annual pump structure maintenance cost is estimated to be 1% of the structure initial cost. Maintenance costs for the hydrants, valves, meters and tanks were not included.

8 Replacement Cost

Replacement costs were estimated by utilizing useful lifespan data procured from the American Water Works Association. The American Water Works Association has determined long service lives (LSL) and short service lives (SSL) for some pipe materials. Long service lives occur when a pipeline is placed in benign ground conditions and/or the pipe laying practice is well performed. A short service live occurs when the ground conditions are harsh and/or the laying of the pipe is not well executed (AWWA, 2010). The American Water Works Association estimates of pipe lifespan can be seen in Table 5.

California falls in the West categories of the Table 5. See Table 6 for the system size determination.

Here, it was assumed that the pipe lifespan is the average of the long and short service life. The average lifespan of ductile iron used in this paper is 85 years. The American Water Works Association estimates the lifespan of PVC to be 70 years. The AWWA table does not provide a service life expectancy for HDPE, so it was assumed to have the same life expectancy as PVC, 70 years. This seems to be a reasonable value since the Plastic Pipe Institute (PPI) gives HDPE a life expectancy range of 50 to 100 years (PPI, 2006). Steel pipe is expected to have a service life of 95 years. The United States Bureau of Reclamation appendix on cost estimates states that pumps should be replaced every 10 to 20 years (USBR, 2006). An average value of 15 years has been chosen for this paper. Once the lifespan of each asset was determined, the lifespan and initial payment was then used to estimate an annualized payment. This is described further in the following section.

Table 5 Pipeline Service Life (AWWA, 2010)

Derived Current Service Lives (Years)	CI	CICL (LSL)	CICL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	Steel	Conc & PCCP
Northeast Large	130	120	100	110	50	80	80	100	100	100
Midwest Large	125	120	85	110	50	100	85	55	80	105
South Large	110	100	100	105	55	100	80	55	70	105
West Large	115	100	75	110	60	105	75	70	95	75
Northeast Medium & Small	115	120	100	110	55	100	85	100	100	100
Midwest Medium & Small	125	120	85	110	50	70	70	55	80	105
South Medium & Small	105	100	100	105	55	100	80	55	70	105
West Medium & Small	105	100	75	110	60	105	75	70	95	75
Northeast Very Small	115	120	100	120	60	100	85	100	100	100
Midwest Very Small	135	120	85	110	60	80	75	55	80	105
South Very Small	130	110	100	105	55	100	80	55	70	105
West Very Small	130	100	75	110	60	105	65	70	95	75

LSL indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices etc.
SSL indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices, etc.

Table 6 AWWA Water System Size Determination (AWWA, 2010)	
Very Small	<3,300 people
Small	3,300 - 9,999 people
Medium	10,000 - 49,999 people
Large	>50,000 people

9 Present and Future Value of Money

"A dollar today is worth more than a dollar tomorrow". Due to the time value of money it is not exactly correct to assume that a $100,000 loan can be paid off in 20 payments of $5,000. For this reason, the spreadsheet model has been set up to calculate the annual payments required to pay off a loan after a specified number of years. The present value and future value of money can be equated using Equation 7. In this equation, P represents the present value of money, A is the future amount of money, r is the real interest rate, and n is the number of periods. Equation 8, which is derived from Equation 7, can be used to determine the monthly or annual payment required to pay off the initial loan in m periods. The required payment can be solved for algebraically, iteratively, or with the Excel formula "=pmt()". A 100,000 dollar loan with a real interest rate of 2.5% can be paid off in 5 years with 60 payments of $1,774.74, as seen in Figure 9. This can also be calculated through the use of websites such as bankrate.com, see Figure 10. In the model, once the initial costs are annualized they are then added to the annual pumping, maintenance, and the treatment costs. This summation provides the Annual Cost required for paying off the loan and paying for maintenance, pumping, and treatment. However, this annual cost does not incorporate the cost of replacing pipes, pumps, hydrants, valves, meters, etc. Annual costs in this model are calculated as 12 monthly payments rather than one payment each year.

The replacement cost for each asset is determined using Excel, see Equation 5. The number of periods is set to be the lifespan of the asset, and the present value is set to be the initial cost of the asset. The interest and inflation values can be set in the "Inputs" worksheet of the model.

$$P = \frac{A}{(1+r)^n} \qquad \text{Equation 7}$$

$$P = \frac{Payment}{(1+r)^1} + \frac{Payment}{(1+r)^2} + \cdots \frac{Payment}{(1+r)^{m-1}} + \frac{Payment}{(1+r)^m} \qquad \text{Equation 8}$$

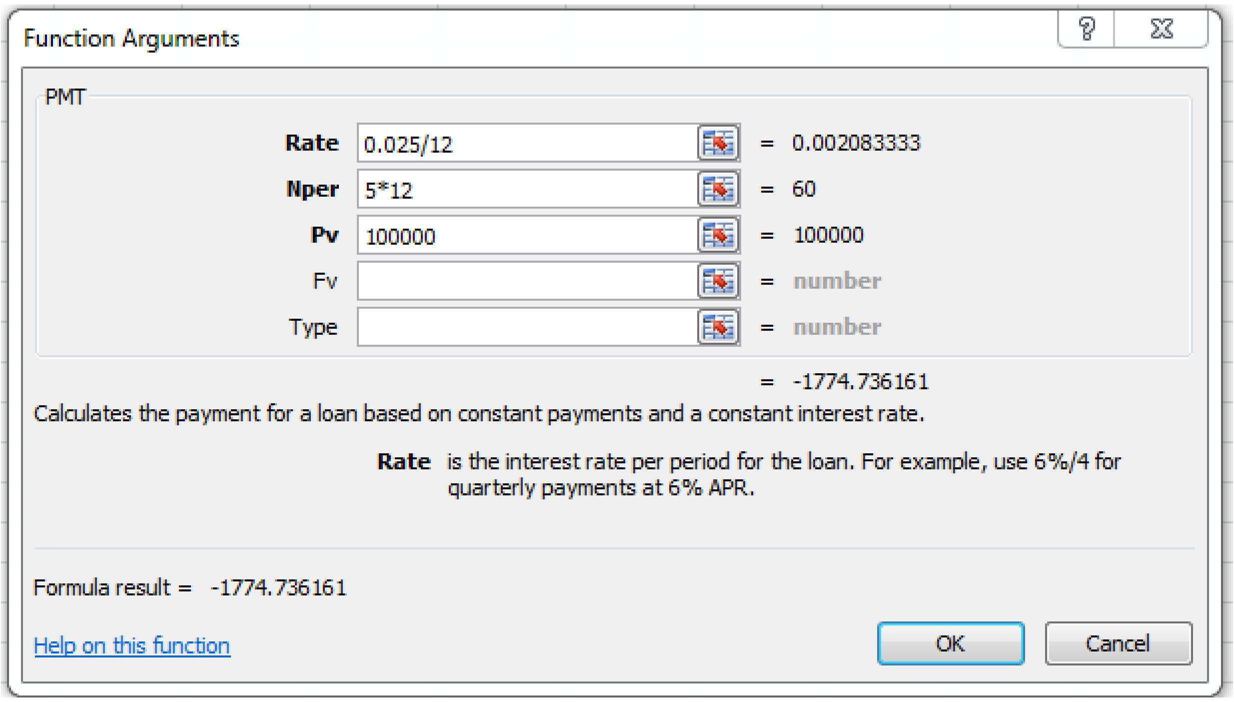


Figure 9 Excel Payment Function Output

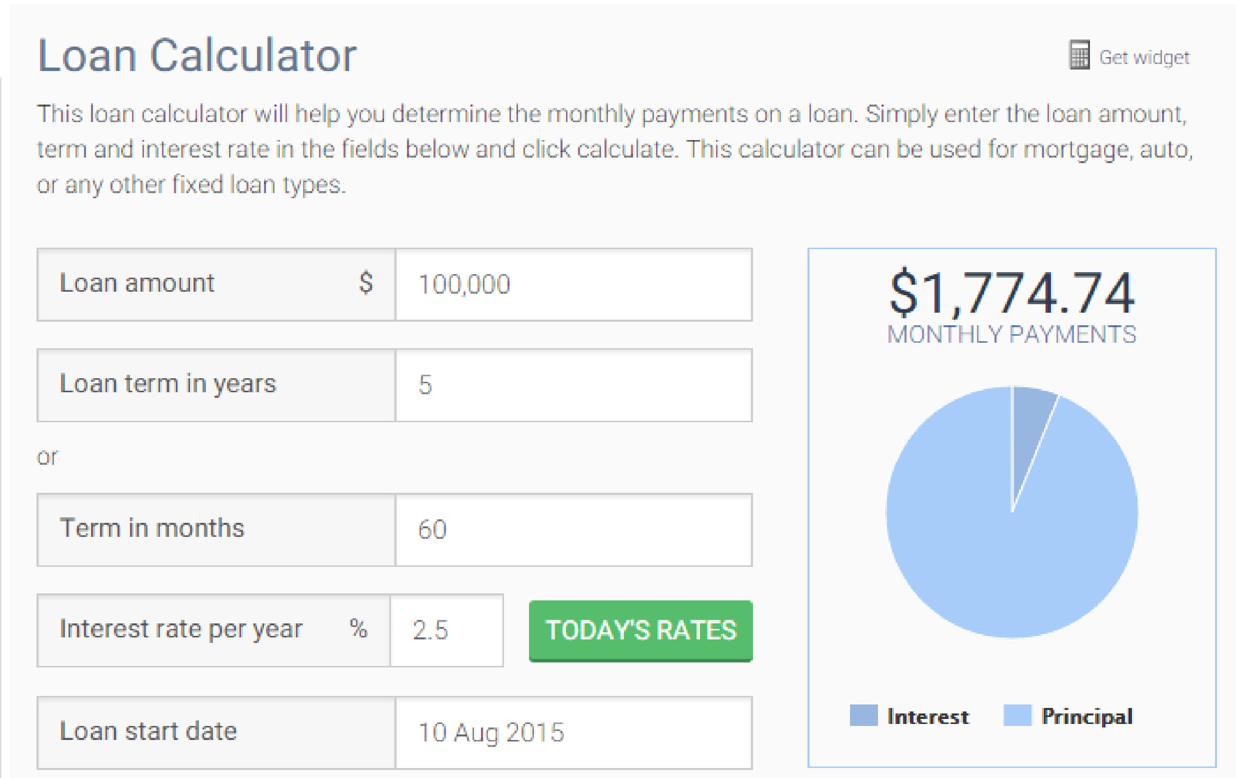


Figure 10 Bankrate.com Payment Calculator (Bankrate.com, 2015)

10 Using the Model

The model consists of 8 worksheets. The first sheet is the "Inputs" worksheet. Table 7 can be found in the "Inputs" sheet. The values in this table are used for most calculations in the model. All values and unit costs in this sheet can be edited and updated. A drop down list on the "Inputs" sheet allows the user to calculate the cost of pipes by one of two methods. The simple method allows the user to enter only one value for the total price per linear foot, which includes the material, excavation, backfill, and fitting cost. In the advanced method of pipeline cost estimation, the excavation, backfill and pipe laying costs are calculated individually and summed to be the total price per linear foot. The "Cost Summary" and "Annual Costs" sheets are designed so that only the cost estimate corresponding to the selected method will be calculated.

Table 7 Model Inputs

Value	Variable	Unit Cost	Description/Units
0.00%	Inflation Rate		(Used for the Annual Costs)
2.00%	Real Interest Rate		(Used for the Cost Summary)
20	Loan payback period	Years	
297	Flow rate		gallons per minute
500	Head		feet
0.15	Cost rate per kWh		($0.15-$0.25 is a typical range)
156	Fire Hydrants	$7,000	each
383	Gate Valves	$1,500	each
0	Butterfly Valves	$0	each
56	Blowoffs	$2,750	each
3	Zone Valves	$0	each
1220	Homes		(for water meters and service lines)
1220	Water Meters	$0	each
1220	1-1/2 inch Services	$82.40	each
285	Hundred ft3/month	$2.88	each

The second sheet, the "Inputs – Pipes" sheet is used for inputting pipes based on their diameter, material, and length, as seen in Table 8. Up to 100,000 pipe assets can be entered without needing to alter the model. Pipe diameters and materials are entered in the "Pipe Lengths" sheet which is used to filter all of the pipes. Any orange cell, like the material cells and the diameter cells seen in Table 9, is an input cell. The material name must match exactly with the material names in the “Inputs – Pipes” sheet to be included in the pipe lengths sheet. This helps filter unwanted and incorrect pipe diameters and materials. The “Pipe Lengths” sheet will only include pipes that match the material and diameters entered in the input cells. For example, neither a concrete nor a 36 inch pipe would be included in the calculations if the “Pipe Lengths” worksheet was set up like Table 9.

Table 8 Pipe Inputs Table

Pipe Diameter	Pipe Material	Pipe Length
4	DI	4.041806
4	DI	5.000522
4	PVC	69.854947
4	PVC	1.759959
4	PVC	3.373962
6	DI	4.140861
6	DI	29.690134
6	DI	10.55922
6	DI	17.162536
6	DI	10.692169
6	DI	17.029587
6	DI	17.41136
6	DI	10.310396
6	DI	7.284107

Table 9 Pipe Lengths By Diameter and Material

	DI	HDPE	PVC	STL	UNK	Total
Dia	Length	Length	Length	Length	Length	Length
Inches	LF	LF	LF	LF	LF	LF
2	0	0	0	0	0	0
4	9	0	75	0	0	84
6	7,869	0	73	0	1,057	8,999
8	37,258	891	1,851	0	35	40,034
10	12,299	0	0	0	7	12,307
12	12,710	0	7,138	0	0	19,848
14	8,493	0	0	0	0	8,493
16	2,039	0	0	0	0	2,039
18	1,980	0	0	0	0	1,980
20	1,231	0	0	0	0	1,231
22	0	0	0	0	0	0
24	7,920	0	0	79	0	7,999
Total	91,809	891	9,136	79	1,099	103,014

The fourth and fifth sheets both calculate the cost of the distribution piping; sheet four uses the simple method while sheet five uses the advanced method. The simple method of calculating the cost of the distribution piping uses only one unit value to estimate cost, while the advanced method uses multiple values to estimate the cost. The sixth sheet has two inputs, one that determines the horsepower of the pump and one that determines the capacity of the tank. The seventh and eighth sheets do not require any inputs; these sheets are cost summaries.

Chapter 3 – Hiddenbrooke Case Study Results

1 Asset Costs

Costs of providing water to Hiddenbrooke, a neighborhood in Vallejo, California, have been analyzed using this model. The Hiddenbrooke community uses about 427 thousand gallons per day, assuming that the 1220 homes use an average of 350 gallons per day. Using the Cordelia Quadrangle United States Geographical Studies topographic map, the head was estimated to be 500 feet from the water treatment plant to the tank, see Appendix B. Using 0.9 as the pump efficiency and 0.85 as the motor efficiency, the annual pumping cost is estimated to be $48 thousand dollars a year. The water horsepower estimate is 37.4 horsepower. The product of the pump efficiency and motor efficiency provide the pumping plant efficiency used to estimate a minimum required pump horsepower of 48.9. For safety the minimum required horsepower was increased by 20%, to 58.7 horsepower. As the pump and motor efficiency decrease, the pump horsepower would need to be increased. The safety factor helps accommodate for decreased efficiencies and fiction in the pipes. Using the United States Bureau of Reclamation estimate of $1,879 per horsepower, the pumping plant for Hiddenbrooke would cost about $110 thousand dollars. Treatment plant upgrades are estimated to cost $1.21 per gallon per day (EPA, 2004). Since Hiddenbrooke uses about 427 thousand gallons per day, the initial cost required to upgrade the treatment plant is $516 thousand dollars. Assuming the tank in Hiddenbrooke can provide 1.5 days' worth of water, the tank size is 0.64 million gallons. A tank of this size would cost 1.6 million dollars based on estimates from the Engineering New Record.

According to the City of Vallejo, within Hiddenbrooke there are 156 fire hydrants, 383 gate valves, and 56 blowoffs; in total the estimated cost for these assets is 1.8 million dollars. According to the Vallejo asset list, no butterfly valves are installed in Hiddenbrooke. However, there are 3 zone valves in Hiddenbrooke, but the information found regarding the unit price of zone valves is very vague. Since there are only three zone valves, the zone valves price has not been included.

There are 83,889 feet of ductile iron pipe, 891 feet of HDPE pipe, 9,136 feet of PVC pipe, and 1,099 feet of unknown pipe of known diameter within Hiddenbrooke. There is an additional 1600 feet of pipe of unknown diameter. Nearly all of the unknown diameter pipes are also of unknown material; these completely unknown pipes are not included in the cost estimate. However, the unknown pipes have the potential to increase the initial cost by $100,000, if they are 24 inch ductile iron pipes, or to only increase the initial cost by $6,000, if they are 4 inch PVC pipes. The 1,099 feet of unknown pipe of known diameter has been assumed to be ductile iron pipe, since it is the most common pipe material in Hiddenbrooke. The water tank within Hiddenbrooke must receive water from a pipeline that starts in the main part of Vallejo. The closest part of the rest of Vallejo is about 1.5 miles from Hiddenbrooke. This means that the pipeline that transports water from the main part of Vallejo to Hiddenbrooke must be at least 1.5 miles in length. The largest diameter pipe in Hiddenbrooke is 24 inch ductile iron pipe. The 1.5 mile long pipe should be at least 24 inches, but it could be much larger to reduce the friction along the 1.5 miles of pipe. The initial cost of the 1.5 mile pipeline increases the initial cost of all pipes by 28%.

The initial cost of all the pipes is estimated to be $3.9 million when using the simple method that includes the excavation, backfill and fitting costs in one unit cost. The unit costs used for the simple method were mostly taken from All Cost Data, a database of free construction cost data. The advanced method of pipeline cost estimation includes many assumptions for the Hiddenbrooke case study, so it is used only to estimate the cost of the PVC pipes. All Cost Data unfortunately does not provide unit costs on PVC that include trenching and backfill, so the advanced method was used to provide a cost estimate for the PVC pipe. When the advanced method is used for all the pipes, the total pipeline cost is estimated to be $4.7 million. The ductile iron pipe cost and the PVC pipe cost make up most of the pipeline cost, while the HDPE and steel pipes account for less than $30,000. The ductile iron and PVC pipe costs can be seen in Table 10. Ductile iron prices are for cement lined ductile iron pipe. PVC prices are for schedule 40 PVC pipe. See Appendix D for HDPE , steel, and unknown pipe unit costs and prices.

Table 10 Ductile Iron and PVC Pipe Prices

Pipe Diameter	DI				PVC			
Inches	$/LF*	LF		$	$/LF**	LF		$
2		0	$	-		0	$	-
4	17.38	9	$	157	7.47	75	$	560
6	20.00	7,869	$	157,378	12.84	73	$	932
8	24.53	37,258	$	913,935	16.91	1,851	$	31,287
10	34.18	12,299	$	420,383	23.40	0	$	-
12	39.78	12,710	$	505,605	28.47	7,138	$	203,235
14	50.59	8,493	$	429,677	34.88	0	$	-
16	59.22	2,039	$	120,751	42.01	0	$	-
18	69.52	1,980	$	137,684	48.50	0	$	-
20	81.50	1,231	$	100,309	54.94	0	$	-
22		0	$	-	63.47	0	$	-
24	107.89	7,920	$	854,489		0	$	-
Total		91,809	$	3,640,368		9,136	$	236,014

2 Annualized Cost (Excluding Replacement)

Many costs are included in distributing water to Hiddenbrooke. A summary of these costs can be seen in Figure 11. The costs are broken down into multiple sections. The first section is the initial costs; these costs can be paid off with a loan or in cash. It is assumed in this case study that the original materials are all paid for with a 20 year loan at 2% interest. These seem to be reasonable numbers when compared to information provided by the Inland Empire Utilities Agency on the California Drinking Water State Revolving Fund (Gu and Valencia, 2014). An Inland Empire Utilities Agency example shows the SRF interest rate to be 1.787% and a bond rate to be 3.575%.

The second section of the “Cost Summary” worksheet is the Annualized cost section. The pumping cost, treatment cost, and maintenance cost are all annual costs assumed to be unchanging, ignoring inflation and increasing power costs. Annual loan payments are calculated using the payment function in Excel, and supported by a Bank Rate loan calculator. The $7.91 million loan used to pay the initial cost would require $480,234 payments each year for 20 years. The annual cost of $650,307 includes the annual loan payments, annual pumping cost, annual treatment cost, and the maintenance cost, but excludes the replacement cost.

		Initial Costs		
$	**3,925,921**	**Pipe Material and Installation Cost**		
		$	3,640,368	DI
		$	16,566	HDPE
		$	236,014	PVC
		$	10,723	STL
		$	22,250	Unkown
$	**110,347**	**Initial Pump Price (including controls and structures)**		
		$	37,102	Pump and Control Cost
		$	73,245	Pump Structure Cost
$	**515,755**	**Treatment Plant Upgrade Cost**		
$	**1,092,000**	**Hydrants Cost**		
$	**574,500**	**Gate Valves Cost**		
$	**-**	**Butterfly Valves Cost**		
$	**154,000**	**Blowoffs Cost**		
$	**-**	**Zone Valves Cost**		
$	**-**	**Water Meters Cost**		
$	**1,562,938**	**Tank Cost**		
$	**7,935,461**	**Total Initial Cost (Loan Cost)**		
		Annual Costs (Excluding replacement)		
$	**481,730**	**Annual Loan Payments for a 20 year period**		
$	**47,975**	**Annual Pumping Cost**		
$	**65,669**	**Annual Treatment Cost**		
$	**57,820**	**Maintenance Cost**		
		$	29,444	Pipeline Maintenance
		$	25,788	Treatment Plant Maintenance
		$	1,855	Pump and Control Maintenance
		$	732	Pump Structure Maintenance
$	**653,194**	**Annual Cost (Excluding replacement cost)**		
		Annual Costs (Including replacement)		
$	**749,213**	**Total Annual Cost (Including replacement cost)**		
		$	653,194	Annual Cost (Excluding replacement cost)
			$96,019	Annualized Replacement cost

Figure 11 Hiddenbrooke Cost Summary

3 Replacement Cost

Annual replacement costs are assumed to be a portion of the initial cost. Inflation rates can be incorporated to alter the amount of money required to replace an asset, but they are not included in this model. For simplicity, if an asset must be replaced every 5 years the model calculates that one-fifth of the initial cost must be saved every year. Since lifespans of the pipes are all very long (70 years or longer for all materials), only $46,811 dollars would need to be saved each year to be able to replace the pipes at the end of their useful life.

The required savings to replace each pipe at the end of its lifespan is only about 8% of the fees paid by Hiddenbrooke residents. All the annual costs that must be paid even after the loan is paid off can be seen in Table 11. The replacement costs of the assets other than pipes, such as the fire hydrants, gate valves, etc., can be seen in Table 12. Individual pipe replacement costs can be seen in Appendix E. The replacement costs could be paid for by a government subsidy or by saving money each year to pay the replacement cost in cash. Each year Hiddenbrooke should save at least $46,811 for the pipes and $49,208 for all the other water supply assets.

Table 11 Annual Costs Excluding Loan Repayment

Item	Annual Costs
Pipes	$46,811
Maintenance, Treatment, and Pumping Costs	$171,464
Other Assets	$49,208
Total	$267,483

Table 12 Annual Costs of Assets Other Than Pipes

Other Assets	Lifespan	Initial Cost	Annualized Cost
Pump and Controls	15	$ 37,102	$2,473
Pump Structure	85	$ 73,245	$862
Treatment Plant	85	$ 515,755	$6,068
Hydrant	85	$ 1,092,000	$12,847
Gate Valve	85	$ 574,500	$6,759
Blow-off Valve	85	$ 154,000	$1,812
Zone Valve	85	$ -	$0
Water Meter	85	$ -	$0
Tank	85	$ 1,562,938	$18,388
Total		$ 4,009,539	$49,208

4 Revenues & Sustainability

The costs of providing water to Hiddenbrooke cannot be evaluated without comparing them to the revenues from its customers to Vallejo's water division. The estimates for the money received by Vallejo from Hiddenbrooke residents were calculated using the estimated flow rate required for Hiddenbrooke and the 2013 Vallejo Water rates seen in Table 13. The annual customer fee for 1220 homes, assuming all homes have a 1 ½-inch service line and use a total of 285 hundred cubic feet per month, is $613,032. The cost of providing water to Hiddenbrooke is estimated to be at least 640 thousand dollars per year; thus it would seem that the revenues of providing water to this community are outweighed by the costs. There are more revenues that are not accounted for such as the rates paid by the Hiddenbrooke golf course and other small businesses. However, the costs seen in Figure 11 do not include any contingencies or design costs, so it still may be that the costs outweigh overall revenues.

Table 13 Vallejo Water Rates (Vallejo, 2009)

Customer Class and Rate Type	Vallejo Service Area Rates (Effective on Dates Listed)				
	7/1/2009	7/1/2010	7/1/2011	7/1/2012	7/1/2013
SINGLE FAMILY RESIDENTIAL					
Bi-Monthly Service Charge					
5/8-inch or 3/4-inch	$26.80	$28.70	$29.60	$31.20	$32.90
1-inch	$40.30	$43.00	$44.50	$46.90	$49.40
1 1/2-inch	$67.10	$71.80	$74.30	$78.20	$82.40
2-inch	$99.40	$106.20	$110.10	$115.80	$122.00
Bi-Monthly Water Rates (Per Ccf)					
0-2,600 Cubic Feet	N/A	N/A	N/A	N/A	N/A
OVER 2,600 Cubic Feet	N/A	N/A	N/A	N/A	N/A
0-2,200 Cubic Feet	$2.25	$2.37	$2.55	$2.71	$2.88
OVER 2,200 Cubic Feet	$4.05	$4.31	$4.68	$5.03	$5.40
Bi-Monthly Surcharge Fee Per Residential Unit	N/A	N/A	N/A	N/A	N/A
MULTI-FAMILY RESIDENTIAL					
Monthly Service Charge					
5/8-inch or 3/4-inch	$18.70	$19.10	$20.00	$21.10	$22.20
1-inch	$25.40	$26.90	$28.00	$29.60	$31.10
1 1/2-inch	$39.90	$42.50	$44.20	$46.50	$49.00
2-inch	$57.50	$61.10	$63.60	$66.90	$70.50
3-inch	$98.30	$104.70	$108.90	$114.50	$120.60
4-inch	$158.30	$166.90	$173.60	$182.40	$192.20
6-inch	$313.60	$322.40	$335.20	$352.30	$371.10
8-inch	$500.00	$509.00	$529.30	$556.20	$585.80
10-inch	$717.40	$726.70	$755.60	$794.00	$836.30
12-inch	$1,338.60	$1,348.70	$1,402.30	$1,473.50	$1,552.10
Monthly Water Rates (Per Ccf)					
ALL CONSUMPTION	$2.76	$2.91	$3.13	$3.33	$3.53
Monthly Surcharge Fee Per Residential Unit	N/A	N/A	N/A	N/A	N/A

5 Hiddenbrooke Net Financial Contributions

Investing in water utilities for a community is financially sustainable if the revenue is equals or exceeds the costs. The revenue generated by Hiddenbrooke water users is estimated to be $613,032. The annual cost including the replacement cost of the water system in Hiddenbrooke is estimated to be $749,213. This is an annual discrepancy of $136,180 each year. The annual Hiddenbrooke water system cost estimate of $750 thousand dollars does not include design or contingency costs. The United States Bureau of Reclamation uses a 20% contingency cost and a 12% engineering design and construction oversight cost. Increasing the initial cost by 32% yields an annual cost estimate of $903 thousand dollars per year.

Even if the replacement costs were ignored for the low cost estimate, the $653,194 annual cost, for loan payments, treatment, pumping and maintenance, would exceed the revenues. Therefore a water utility investment in this community is probably not financially sustainable and must be subsidized. However, it could have been possible to make the investment financially sustainable by changing the interest rate, loan payback period, flow rate, head, cost per kWh, pipe lengths, and/or the water rates. The effects of changing each of these variables can be seen in the sensitivity analysis.

Chapter 4 - Sensitivity Analysis

Many variables could be changed to make Hiddenbrooke a better utility investment. The interest rates on loans are changing constantly and can vary greatly depending on the lender. Even with the same lender, the payback period can differ based on the municipality receiving the loan. Of course the flow rate and head would also be different throughout a municipality and between different municipalities. Also, energy cost rates can differ and the number of homes in a neighborhood could differ. The effects of altering each variable listed above will be assessed against the “standard” values used in the case study. The “standard” values are 2% real interest rate, 20 year loan payback period, 297 gallons per minute, 500 feet of head and an energy cost rate of $0.20 per kilowatt hour. Of these values the loan repayment period has the most effect on the annual cost of providing water to Hiddenbrooke. The values with the greatest effect on the cost of water services are the values with the greatest slope seen in Figure 12. Changing the loan repayment period by only 11%, from 20 years to 22 years, reduces the costs to the break-even point. The percent each variable must be changed to reduce the cost to be equal to revenues can be seen in Figures 13 through 18. The percent each variable needed to be changed was calculated by iterating to find the value that would equate the cost to the benefit, see Table 14. For all but the flow rate, the cost was reduced to the value of the benefit. Altering the flow rate alters both the cost and the benefit. (The flow rate influences the infrastructure, such as the treatment plant and tank sizes, not just the cost of treating the water. This is why the costs decrease as the flow rate decreases.) Changing all the other variables reduces the cost to $613,032, but changing the flow rate reduced both the cost and the benefit to be $611,142. All values examined in the sensitivity analysis can be seen in Appendix C.

Once a water system is in place it would be difficult to decrease costs by changing the interest rate on loans, the repayment period, the flow rate, head, energy cost, or pipe length. Since it would be difficult to decrease capital costs, revenues would need to be increased. To equate the revenues and costs in Hiddenbrooke, the variable water rate would need to increase by 387% (from $2.88 to $13.76 per hundred cubic feet of water). This is probably infeasible due to the public reaction to fee increases. Instead of increasing the variable cost, the fixed cost could be increased by only 6% (from $82.40 to $87.49 per month). The required changes in the water rates were calculated using Excel's goal seek to set the cost equal to the benefit while ranging the water rates.

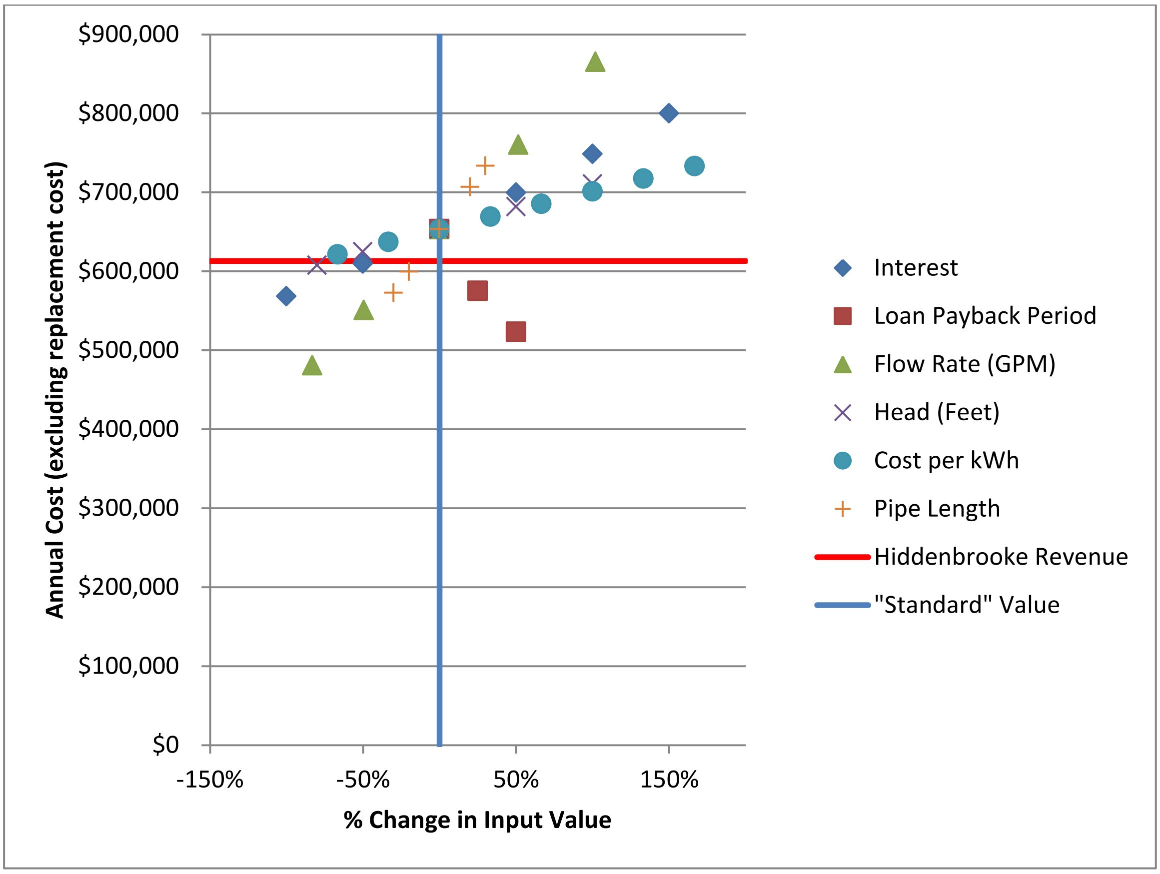


Figure 12 Sensitivity Analysis

Table 14 Sensitivity Analysis - Values Required to Break Even

Variable	Base Case Value	Value Required to Break-even	Percent Change in Variable
Interest	2%	1.09%	-46%
Loan Payback Period (years)	20	22.29	11.44%
Flow Rate (gpm)	297	236	-21%
Head (feet)	500	149.3	-70%
Cost per kWh ($/kWh)	0.15	0.024	-88%
Pipe Length (feet)	103,014	87,563	-15%
Fixed Water Service Cost ($/house)	$82.40	$87.89	7%
Variable Water Cost ($/100 ft3)	$2.88	$14.61	407%
Homes in Hiddenbrooke	1220		

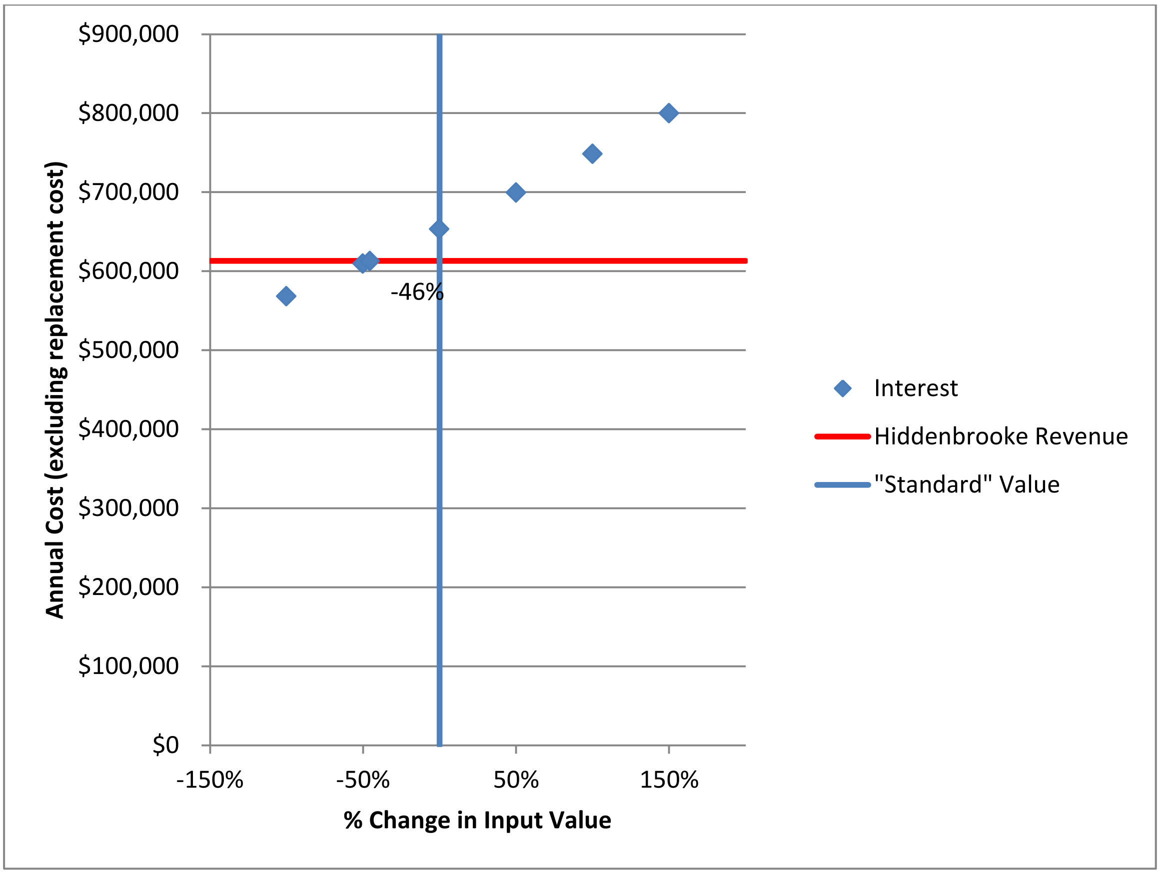


Figure 13 Sensitivity Analysis - Interest

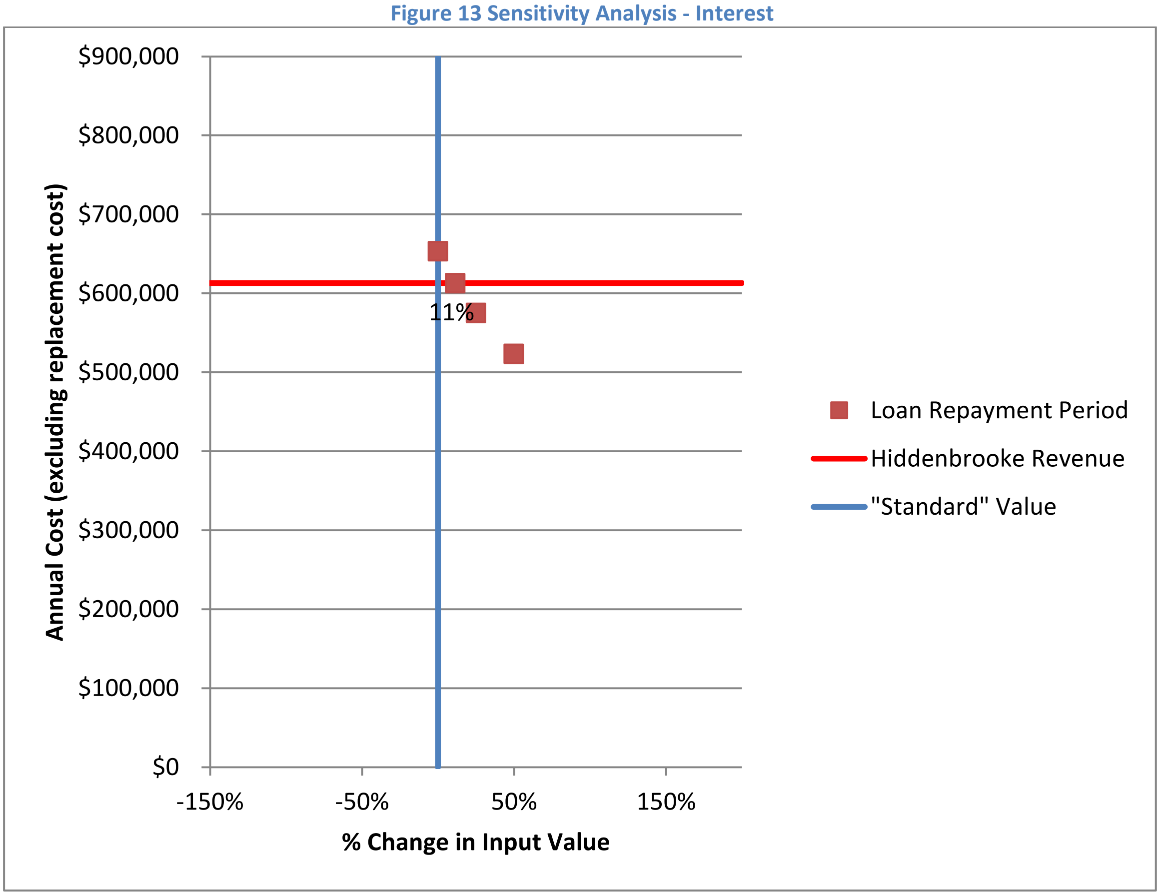


Figure 14 Sensitivity Analysis – Loan Repayment Period

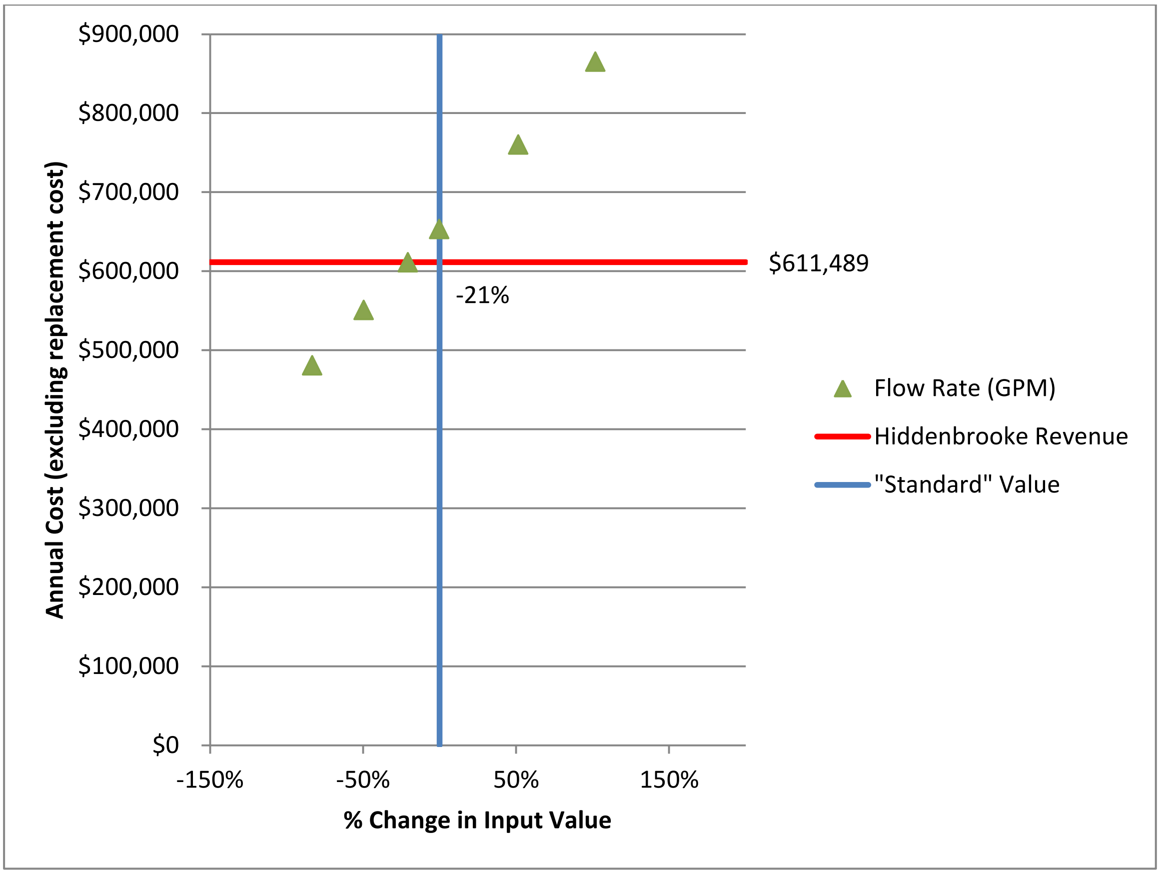


Figure 15 Sensitivity Analysis - Flow Rate

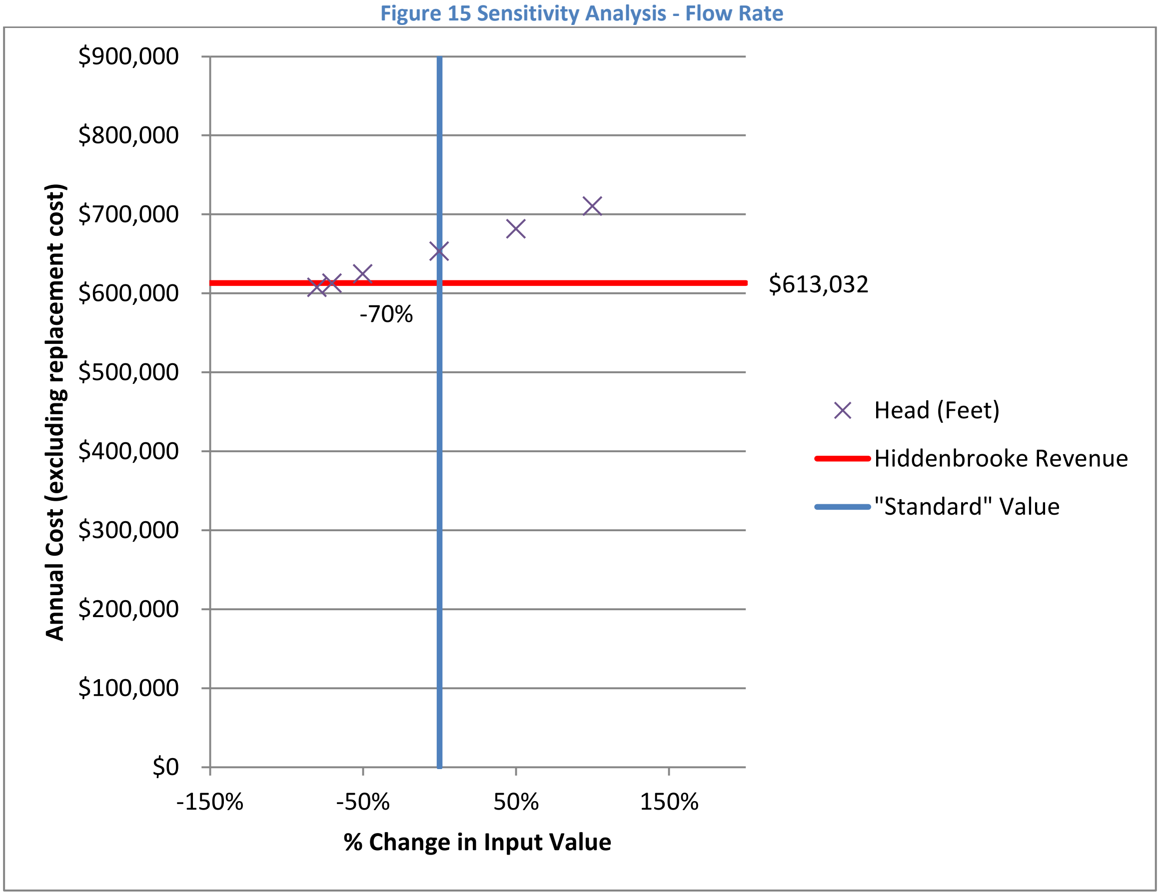


Figure 16 Sensitivity Analysis - Head

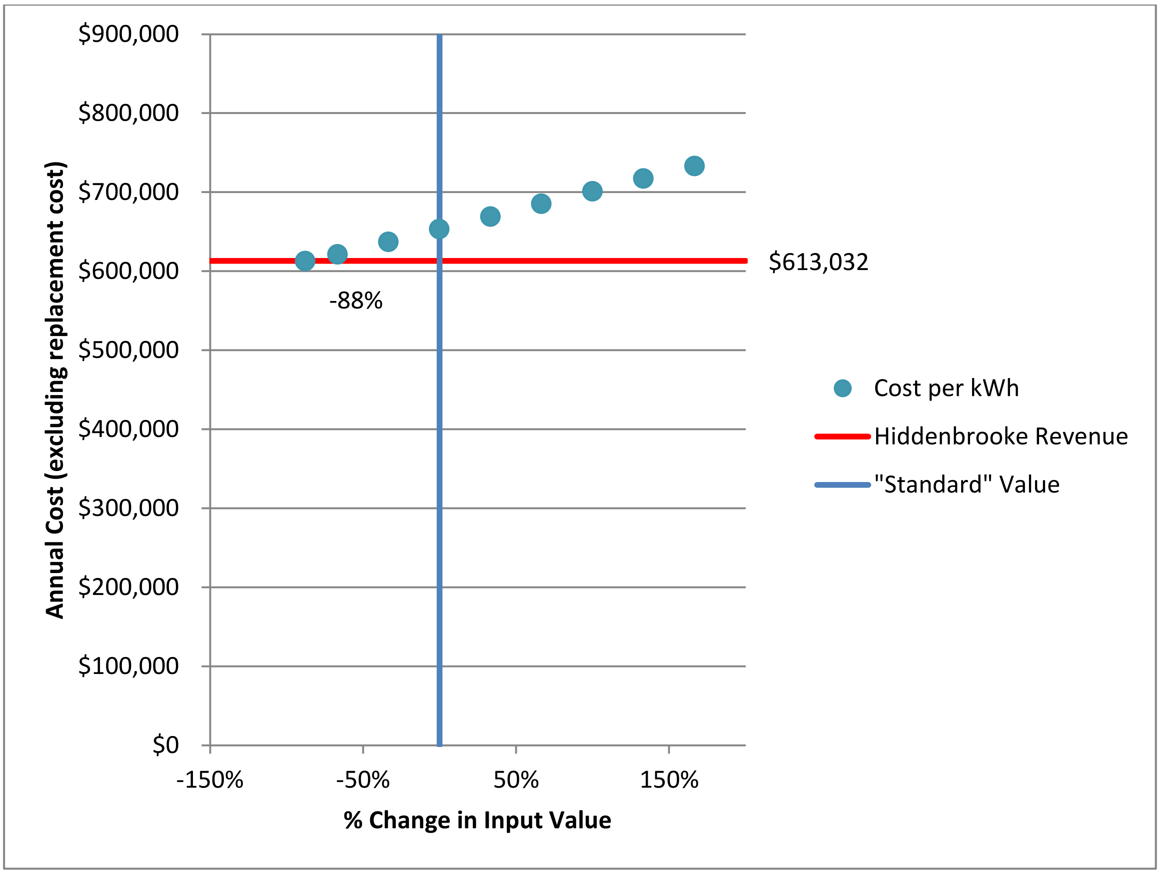


Figure 17 Sensitivity Analysis - Cost per kWh

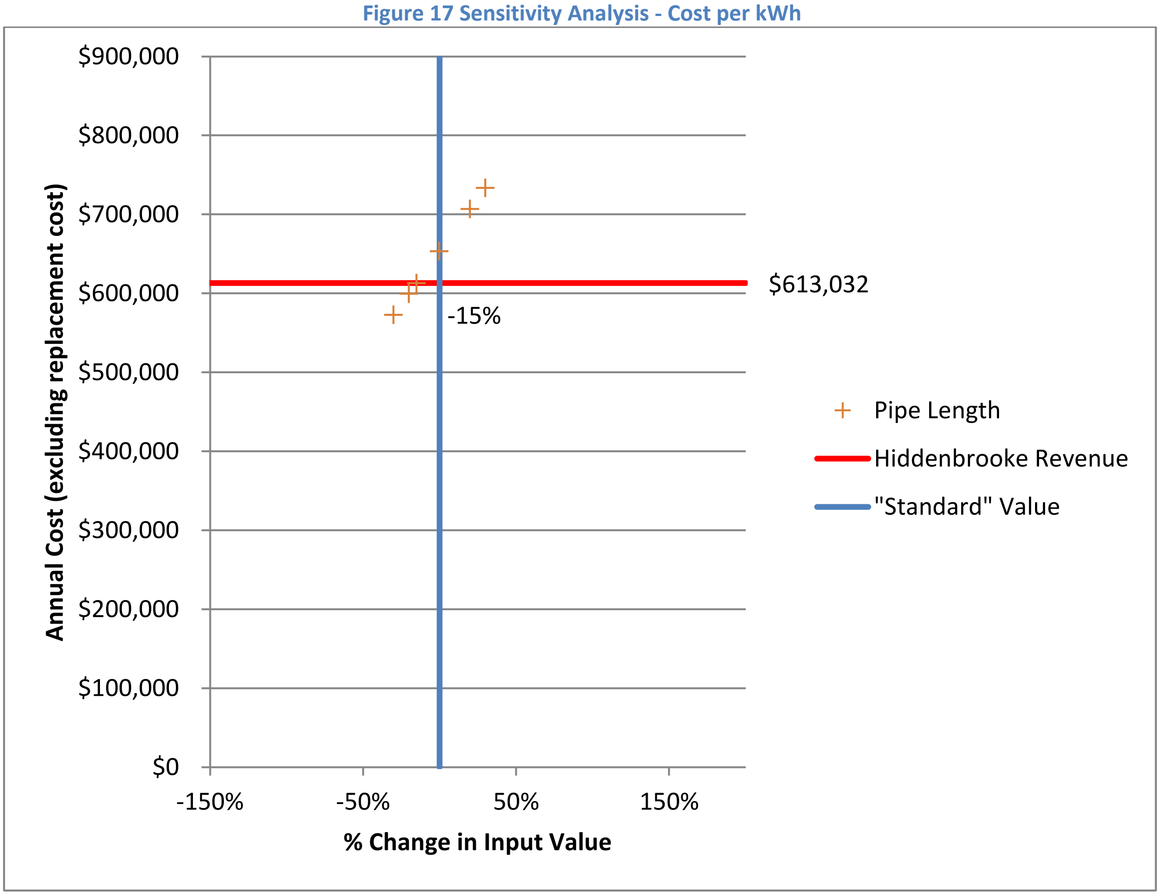


Figure 18 Sensitivity Analysis - Pipe Length

Chapter 5 - Conclusion

Many municipalities depend on loans and grants to fund their infrastructure replacement costs (Duffy, 2010). These municipalities are often not financially sustainable. Around 240 million people are served by water systems in America, and over the next 20 years it is estimated that $355 billion is needed to replace the infrastructure (Duffy, 2010). If the federal and state governments cannot subsidize all these repairs and local governments require subsidies to make repairs, then repairs are delayed. Engineers place the general public at risk by developing financially unsustainable water systems in hopes that the state or federal government will pay for the repairs. When repairs are delayed, degraded pipes can compromise tap water quality and firefighting flows and leaking or burst pipes can cause flooding or sinkholes which could disrupt business, waste water, and potentially harm lives. Water systems in communities with low density housing have greater costs. The wider lots increase pipe lengths which increases costs.

The initial cost for all water supply assets within Hiddenbrooke in the City of Vallejo, California is nearly $8 million. The initial cost of the pipes is about $3.9 million. Annual maintenance cost is about $59 thousand per year, and pipeline maintenance cost is over $29 thousand per year. The pipes are a large portion of the cost, so it is understandable why the cost is so sensitive to a change in pipe length. Decreasing the length of all the pipes by 20% reduces the annual cost (excluding replacement) by 8%. Pipe lengths could be reduced if the neighborhood was closer to the rest of Vallejo or if the houses were closer together. In either case, if the pipe lengths were reduced by 20% the benefits would outweigh the costs of providing water to Hiddenbrooke. By increasing the density of the housing and thus decreasing the length of pipe, a financially unsustainable community could have been avoided or made more sustainable. By delaying replacements we increase future costs. Action must be taken now to reduce the burden on future generations. Financially sustainable investments must be made.

References

All Cost Data(2015). "Free Construction Cost Data." 2015, from http://www.allcostdata.info/index.html.

American Society of Civil Engineers(2013). "Report Card for America's Intfrastructure." Drinking Water. 2015, from http://www.infrastructurereportcard.org/drinking-water/.

American Water Works Association (2010). "Buried No Longer: Confronting America's Water Infrastructure Challenge."

Burchell et al (2002). "Costs of Sprawl-2000." TCRP 74

BusinessDictionary.com(2015). "Sustainability." 2015, from http://www.businessdictionary.com/definition/sustainability.html.

City-Data.com(2015). "Hiddenbrooke Neighbothood in Vallejo, California." 2015, from http://www.city-data.com/neighborhood/Hiddenbrooke-Vallejo-CA.html.

Dictionary.com(2015). "Sustainability." 2015, from http://dictionary.reference.com/browse/sustainability.

Duffy, Maureen(2010). "Challenges in the Water Industry: Infrastructure and its Role in Water Supply." American Water

Ewing et al (2014). "Measuring Sprawl 2014." Smart Growth America

Greg R. Card (2000). "Pipe Cost Estimator." United States Department of Agriculture

Gu, Jason and C. Valencia (2014). "I Didn't Know the SRFs Did That!" Paying for Water Infrastructure'from'https://drive.google.com/folderview?id=0B47xBRY3FZ3NMWRiVXBiMURqMmM&usp=sharing.

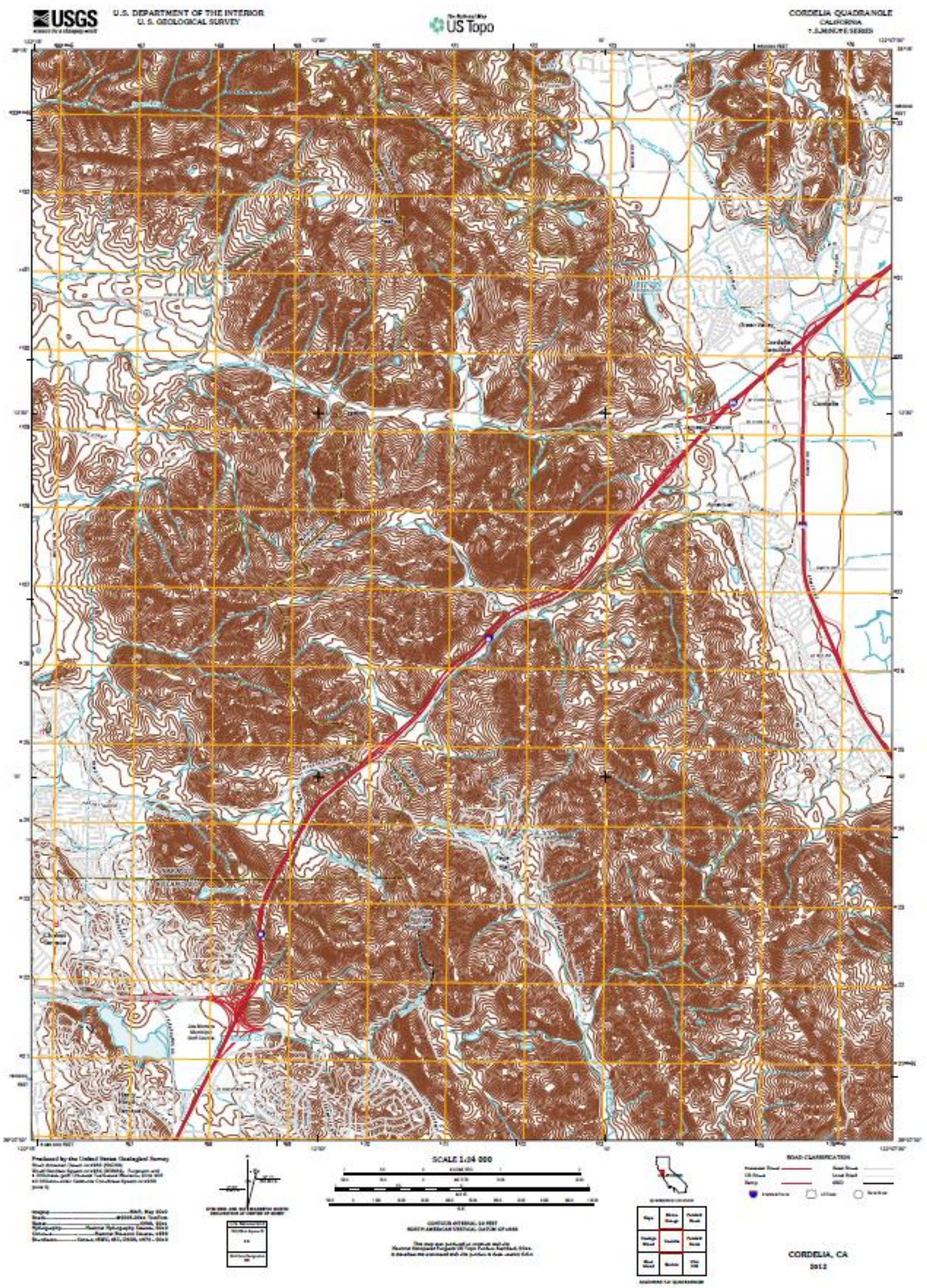
Pacific Gas and Electric(2015). 2015, from http://www.pge.com/en/mybusiness/rates/tvp/toupricing.page?WT.mc_id=TOU%20Summer%20Readiness_SMB%20TVP_banner_20150401_Steps%20-%20BEC_image?WT.mc_id=SMB%20TVP_banner_20150401_Steps%20-%20BEC_image http://www.pge.com/en/mybusiness/rates/tvp/toupricing.pag.

Plastic Pipe Institute(2009). "HDPE Pipe for Water Distribution and Transmission Applications." 2015, from https://plasticpipe.org/pdf/tn-27-faq-hdpe-water-transmission.pdf.

Appendix A – Engineering News-Record Construction Cost Indices

ENR'S CONSTRUCTION COST INDEX HISTORY (1908-2015)													
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG.
2015	9972	9962	9972	9992	9979	10039	10037						
2014	9664	9681	9702	9750	9796	9800	9835	9846	9870	9886	9912	9936	9806
2013	9437	9453	9456	9484	9516	9542	9552	9545	9552	9689	9666	9668	9547
2012	9176	9198	9268	9273	9290	9291	9324	9351	9341	9376	9398	9412	9308
2011	8938	8998	9011	9027	9035	9053	9080	9088	9116	9147	9173	9172	9070
2010	8660	8672	8671	8677	8761	8805	8844	8837	8836	8921	8951	8952	8799
2009	8549	8533	8534	8528	8574	8578	8566	8564	8586	8596	8592	8641	8570
2008	8090	8094	8109	8112	8141	8185	8293	8362	8557	8623	8602	8551	8310
2007	7880	7880	7856	7865	7942	7939	7959	8007	8050	8045	8092	8089	7966
2006	7660	7689	7692	7695	7691	7700	7721	7722	7763	7883	7911	7888	7751
2005	7297	7298	7309	7355	7398	7415	7422	7479	7540	7563	7630	7647	7446
2004	6825	6862	6957	7017	7065	7109	7126	7188	7298	7314	7312	7308	7115
2003	6581	6640	6627	6635	6642	6694	6695	6733	6741	6771	6794	6782	6694
2002	6462	6462	6502	6480	6512	6532	6605	6592	6589	6579	6578	6563	6538
2001	6281	6272	6279	6286	6288	6318	6404	6389	6391	6397	6410	6390	6343
2000	6130	6160	6202	6201	6233	6238	6225	6233	6224	6259	6266	6283	6221
1999	6000	5992	5986	6008	6006	6039	6076	6091	6128	6134	6127	6127	6059
1998	5852	5874	5875	5883	5881	5895	5921	5929	5963	5986	5995	5991	5920
1997	5765	5769	5759	5799	5837	5860	5863	5854	5851	5848	5838	5858	5826
1996	5523	5532	5537	5550	5572	5597	5617	5652	5683	5719	5740	5744	5620
1995	5443	5444	5435	5432	5433	5432	5484	5506	5491	5511	5519	5524	5471
1994	5336	5371	5381	5405	5405	5408	5409	5424	5437	5437	5439	5439	5408
1993	5071	5070	5106	5167	5262	5260	5252	5230	5255	5264	5278	5310	5210
1992	4888	4884	4927	4946	4965	4973	4992	5032	5042	5052	5058	5059	4985
1991	4777	4773	4772	4766	4801	4818	4854	4892	4891	4892	4896	4889	4835
1990	4680	4685	4691	4693	4707	4732	4734	4752	4774	4771	4787	4777	4732

Appendix B - Vallejo Topographic Map



Appendix C – Sensitivity Analysis Data

Value	% Change in Value	Annual Cost Excluding Replacement	% Change in Cost
Interest			
0%	-100%	$568,237	-13.0%
1%	-50%	$609,401	-6.7%
2%	0%	$653,194	0.0%
3%	50%	$699,582	7.1%
4%	100%	$748,512	14.6%
5%	150%	$799,910	22.5%
1.09%	-46%	$613,032	
Loan Repayment Period			
20	0%	$653,194	0.0%
25	25%	$575,081	-12.0%
30	50%	$523,436	-19.9%
22.3	11%	$613,032	
Flow Rate (GPM)			
50	-83%	$480,920	-26.4%
150	-49%	$550,800	-15.7%
297	0%	$653,194	0.0%
450	52%	$760,441	16.4%
600	102%	$865,261	32.5%
1200	304%	$1,284,542	96.7%
1800	506%	$1,703,822	160.8%
236	-21%	$611,025	
Head (Feet)			
100	-80%	$607,385	-7.0%
250	-50%	$624,563	-4.4%
500	0%	$653,194	0.0%

750	50%	$681,824	4.4%
1000	100%	$710,455	8.8%
149.3	-70%	$613,032	
Cost per kWh			
0.05	-67%	$621,211	-7.2%
0.10	-33%	$637,202	-4.8%
0.15	0%	$653,194	-2.4%
0.20	33%	$669,186	0.0%
0.25	67%	$685,177	2.4%
0.30	100%	$701,169	4.8%
0.35	133%	$717,160	7.2%
0.40	167%	$733,152	9.6%
0.024	-88%	$613,032	
Pipe Length			
72,110	-30%	$572,863	-12.3%
82,411	-20%	$599,640	-8.2%
103,014	0%	$653,194	0.0%
123,617	20%	$706,748	8.2%
133,918	30%	$733,525	12.3%
87,563	-15%	$613,032	-6.1%
User Fee Variable Rate			% Change in Revenue
$2.88	0%	$613,032	0.0%
$14.61	407%	$653,194	6.6%
USer Fee Fixed Rate			
$82.40	0%	$613,032	0.0%
$87.89	7%	$653,194	6.6%
Homes in Hiddenbrooke			
1,220	0%	$613,032	0.0%
1,301	7%	$653,194	6.6%

Appendix D – Pipe Material and Installation Costs

Pipe & Installation Cost (Using $/LF estimates)											
Pipe Diameter	HDPE			STL			UNK			Total	
Inches	$/LF	LF	$	$/LF	LF	$	$/LF	LF	$	LF	$
2	7.81	0	$ -		0	$ -		0	$ -	0	$ -
4	9.27	0	$ -		0	$ -	17.38	0	$ -	84	$ 717
6	14.13	0	$ -		0	$ -	20.00	1,057	$ 21,141	8,999	$ 179,451
8	18.59	891	$ 16,566	33.48	0	$ -	24.53	35	$ 853	40,034	$ 962,642
10	26.72	0	$ -	39.93	0	$ -	34.18	7	$ 255	12,307	$ 420,639
12	32.83	0	$ -	48.00	0	$ -	39.78	0	$ -	19,848	$ 708,840
14	41.90	0	$ -	67.85	0	$ -	50.59	0	$ -	8,493	$ 429,677
16	53.21	0	$ -	74.60	0	$ -	59.22	0	$ -	2,039	$ 120,751
18	69.57	0	$ -	95.24	0	$ -	69.52	0	$ -	1,980	$ 137,684
20	75.17	0	$ -		0	$ -	81.50	0	$ -	1,231	$ 100,309
22	85.86	0	$ -		0	$ -		0	$ -	0	$ -
24	101.94	0	$ -	135.55	79	$ 10,723	107.89	0	$ -	7,999	$ 865,212
Total		891	$ 16,566		79	$ 10,723		1,099	$ 22,250	103,014	$ 3,925,921

Appendix E – Pipe Lifespan and Replacement Costs

Pipe Replacement Costs based on Lifespan												
	DI		HDPE		PVC		STL		UNK		Total	
Lifespan	85		70		70		95		85			
	Total Initial Cost	Annualized Cost	Total Initial Cost	Annualized Cost	Total Initial Cost	Annualized Cost	Total Initial Cost	Annualized Cost	Total Initial Cost	Annualized Cost	Total Initial Cost	Annualized Cost
2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
4	$ 157	$ 2	$ -	$ -	$ 560	$ 8	$ -	$ -	$ -	$ -	$ 717	$ 10
6	$ 157,378	$ 1,852	$ -	$ -	$ 932	$ 13	$ -	$ -	$ 21,141	$ 249	$ 179,451	$ 2,114
8	$ 913,935	$ 10,752	$ 16,566	$ 237	$ 31,287	$ 447	$ -	$ -	$ 853	$ 10	$ 962,642	$ 11,446
10	$ 420,383	$ 4,946	$ -	$ -	$ -	$ -	$ -	$ -	$ 255	$ 3	$ 420,639	$ 4,949
12	$ 505,605	$ 5,948	$ -	$ -	$ 203,235	$ 2,903	$ -	$ -	$ -	$ -	$ 708,840	$ 8,852
14	$ 429,677	$ 5,055	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 429,677	$ 5,055
16	$ 120,751	$ 1,421	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 120,751	$ 1,421
18	$ 137,684	$ 1,620	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 137,684	$ 1,620
20	$ 100,309	$ 1,180	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 100,309	$ 1,180
22	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
24	$ 854,489	$ 10,053	$ -	$ -	$ -	$ -	$ 10,723	$ 113	$ -	$ -	$ 865,212	$ 10,166
	$ 3,640,368	$ 42,828	$ 16,566	$ 237	$ 236,014	$ 3,372	$ 10,723	$ 113	$ 22,250	$ 262	$ 3,925,921	$ 46,811