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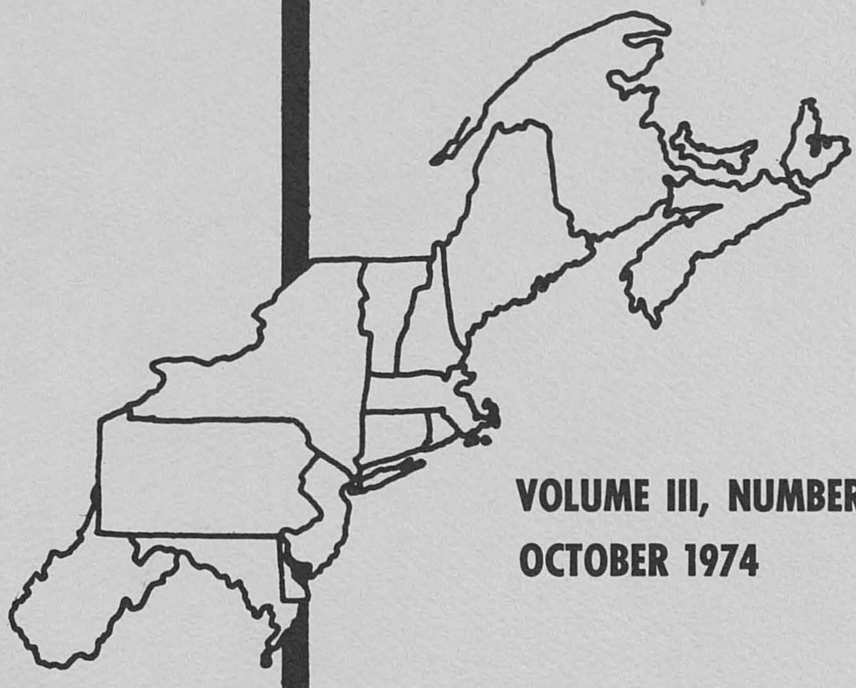

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THE INCIDENCE OF THE COST OF INCREASING THE CAPACITY OF AN URBAN WATER SYSTEM*

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Introduction

Rural and urban communities alike are adopting, formally or informally, "no-growth" policies. The residents of these communities share a set of beliefs concerning the impact of economic growth and development on their community. These residents also share a set of values concerning what constitutes the good life for them. The "no-growth" policies result because of a conflict between the values held by the residents and their beliefs concerning the impacts of economic growth and development. One of the beliefs shared by many of these residents is that economic growth and development will require an expansion of various public service systems such as water and sewer. In addition, these residents believe that they will be required to pay much of the cost involved in expanding the systems even though they will receive few, if any, of the benefits. In essence, the residents of these communities are concerned with the incidence of the cost of system expansion.

The incidence of the cost of system expansion is highly related to the institutional arrangement used to finance system expansion. In some systems, expansion is financed by special assessments on undeveloped land. If this arrangement is used then the cost of system expansion falls primarily on the new users in the system. In other cases, system expansion is financed from general system revenues or from tax revenues. If this arrangement is used, then existing users or taxpayers bear a large part of the cost of system expansion. The objective of this study is to determine the incidence of the cost of system expansion in the State College Borough Water Authority.

The State College, Pennsylvania, Area Water System

The State College Borough Water Authority (hereafter, the Authority) serves the borough of State College and five surrounding townships. In

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1972, the number of customers served by the Authority was approximately 5,300. In that year, these customers purchased approximately one billion gallons of water. The Authority does not provide water for The Pennsylvania State University.

The Authority has grown substantially in the recent past. For example, during the period 1966-1972, the number of customers receiving water increased by about 16 percent. During that same period of time, the quantity of water purchased increased by about 37 percent. Approximately 75 percent of the new customers were single family dwellings and about 10 percent of the new customers were apartment complexes.

The Authority has made substantial investments in the water system in order to meet the increased demand for service. In 1962, the Authority floated a bond issue for $1,493,000 to extend the system's distribution mains to some of the developing areas of the communities. In 1967, the Authority floated another bond issue for $1,300,000 to develop and operationalize a set of new well fields. In 1972, a bond issue totaling $1,625,000 was floated to develop yet additional sources of water. In addition, substantial amounts of capital improvements have been financed from current revenues.

Financing the expansion of this water system is handled as follows. The Authority uses the proceeds of the bond issues to construct the transmission mains required in the system and to develop the wells necessary to supply the water. These bond issues are repaid from current revenues rather than from special assessments. The Authority requires that developers construct the distribution mains and laterals required to make the service available to the residents of developing areas.

Within the context of this growing water system, the specific objective of this study was to determine the extent to which the customers who utilized a new supply of water actually pay for the cost of constructing the facilities to provide that water. Specifically, we determined if the customers who utilized the water provided by the wells financed with the 1967 bond issue actually payed for the principle and interest cost associated with that bond issue.

Procedures for Determining the Incidence of the Cost of System Expansion

In general terms, the procedures were as follows.

1. Identify the set of customers who benefited from the water supplied by the new wells financed by the 1967 bond issue. Benefited customers were defined as those customers whose water use increased between the point in time at which the capacity of the old wells was completely utilized and the point in time at which the capacity of the new wells will be fully utilized.

2. Determine the amount that the water payments by the benefited customers exceeded the operation and maintenance cost associated with providing water to these customers. This difference is defined as the annual capital payments balance.

3. Compare the present value of the annual capital payments balance stream to the present value of the principle and interest payments of the 1967 bond issue. If the present value of the annual capital payments stream is the larger, then this indicates that the benefited customers do in fact pay the cost of constructing the new wells.

During the mid-1960's, there was a rather severe drought in the State College area, and for a time there was a serious question concerning whether or not the existing water supply was adequate to service the customers in the system at that time. This experience was largely responsible for the Authority's decision to float a bond issue and to develop new sources of water. Accordingly, for purposes of this study, a benefited customer is defined as one whose water use increased after the first quarter of 1966.

An analysis of the water used over time indicates that the customers in the system as of the first quarter of 1966 do not change their water use significantly. That is, any increase in the quantity of water demanded appears to come primarily from new customers entering the system. Therefore, for purposes of this study, benefited customers were those customers entering the system after the first quarter of 1966.

In essence then, what was required to satisfy the objectives of this study was to develop a model that would estimate the capital payments balances generated by new users entering the system after the first quarter of 1966. This model must project future system operation because the new wells will not be utilized until some future date. The basic elements of this model are described below.

A customer classification scheme was developed such that the water use over time was similar for the customers in a particular class. The classification scheme included 144 classes of customers. These 144 classes were the result of a cross tabulation of two geographic classes (inside or outside the borough), eight customer types (residential, commercial, and so forth) and nine user-size classes (the size classes are those used in the Authority's rate structure). The classes were called geographic-type-size classes (GTS classes). For example, the customers in GTS Class 1 were customers who were located in the borough, who were residential customers, and who belonged to the smallest size class.

The model that was developed to estimate the capital payments balance stream generated by new customers was based on a set of 144 Dummy Accounts such as the one shown in Table 1. Based on the water use information for the period 1966-1972, it was possible to estimate the average quarterly water use by customers in each of the GTS classes.

Table 1
Dummy Account for GTS Class 1

			Year t		
Quarter	Water Use	Water Bill	Number of Customers	Class Water Use	Class Payments
1	q_{11}	b_{11}	X_{1t}	Q_{11t}	B_{11t}
2	q_{12}	b_{12}	$X_{1t} + \Delta U_1$	Q_{12t}	B_{12t}
3	q_{13}	b_{13}	$X_{1t} + 2\Delta U_1$	Q_{13t}	B_{13t}
4	q_{14}	b_{14}	$X_{1t} + 3\Delta U_1$	Q_{14t}	B_{14t}
Total			$4X_{1t} + 6\Delta U_1$	$Q_{1 \cdot t}$	$B_{1 \cdot t}$

Where:

q_{ij} = water purchased by representative customer in the i^{th} GTS class in the j^{th} quarter.

b_{ij} = water bill of a representative customer in the i^{th} GTS class in the j^{th} quarter.

X_{it} = number of users in the i^{th} GTS class in the first quarter of year t.

U_i = number of new users each quarter in the i^{th} GTS class.

Q_{ijt} = $(q_{ij}) \times [X_{it} + (j-1)(\Delta U_i)]$ = total water purchased by customers in the i^{th} GTS class in the j^{th} quarter of year t.

B_{ijt} = $b_{ij}\ [X_{it} + (j-1)(\Delta U_i)]$ = total water payments by customers in the i^{th} GTS class in the j^{th} quarter of year t.

$Q_{i \cdot t}$ = annual water used by customers in the i^{th} GTS class in year t.

$B_{i \cdot t}$ = annual payments by customers in the i^{th} GTS class in year t.

This average used was taken to be the water purchases by the representative user in each of the GTS classes. The second column in the Dummy Account is obtained by applying the Authority's water rate schedule to the water used by the representative customer in each class. The Authority provided information concerning the average number of users entering a particular GTS class per quarter for the period 1966-1972. Assuming that this number enters the system each quarter it is possible to generate the third column of the Dummy Account found in Table 1, namely the number of customers in each class during each quarter. The fourth column in the Dummy Account is derived from multiplying the entry in the first column by the entry in the third column to determine the total quarterly water use by a particular GTS class. Likewise, the total payments by customers in a GTS class are found in column five and are obtained by multiplying the bill for the representative customer in column two by the total number of customers receiving water in that particular quarter. The total of the fifth column provides the annual water payments by customers in that GTS class. Summing that total for all GTS classes provides an estimate of the total water payments by customers who entered the system after the first quarter of 1966. In order to develop estimates of the annual capital payments balance, it is necessary to estimate the operation and maintenance cost associated with providing water to these new customers.

A regression equation was estimated which had total operation and maintenance cost as the dependent variable and the number of customers and quantity of water purchased as independent variables. This equation was used to estimate the total operation and maintenance cost in the system for future years. That is, the model described above provided estimates of the total quantity of water used in each year and of the average number of customers receiving water in each of the future years. (This assumes that the number of customers in the system in the first quarter of 1966 and their use remains constant.) These two estimates were substituted into the regression equation to provide the estimates of total operation and maintenance cost in future years. Total operation and maintenance cost was divided into total operation cost and total maintenance cost by assuming that the proportion in each of these categories was the same as it was during the period 1966-1972. Total operating costs were assigned to users in the system before 1966 and those entering the system after 1966 in proportion to the quantity of water consumed by these two groups. Also, total maintenance costs were allocated to these two groups in proportion to the number of customers in each of these two groups. That part of total operation costs that was allocated to users entering the system since 1966 were then allocated among GTS classes in proportion to the water used by each GTS class. Also that part of total maintenance costs that was allocated to users entering the system since 1966 was allocated among GTS classes in proportion to the number of users in each class. The operation and maintenance cost assigned to a particular GTS class was subtracted from the total water payments by that class to get the capital payments balance for that class. Summing the capital payments balance for all classes provided the estimate of the annual capital payments balance generated by the new customers in the system. The results obtained by empirically implementing this model are discussed in the following section.

Findings

The capital payments stream generated by the model under three alternative growth rates is presented in Table 2. The three growth rates referred to the number of new users that are assumed to enter each of the GTS classes per quarter. Growth factor 1 is the growth rate that was realized during the period 1966-1972, growth factor .75 is 75 percent of that historical growth rate, and growth rate 1.25 is 125 percent of the historical growth rate.

To calculate the present value of the capital payments stream requires that the information in Table 2 be modified somewhat. Namely, the capital payments balance stream has to be modified by the capacity of the new wells. For example, if the capacity of the new wells is 500 million gallons of water per year, then assuming growth factor .75, this quantity of water will be consumed by the new customers entering the system during the period 1966-1972. Therefore, the capital payments stream will be as shown in Table 2 up to and including 1982 but then each capital payments balance for years thereafter will also be $89,000 because the capital payments by this group of users cannot increase. On the other hand, if the capacity of the system is 750 million gallons of water per year, then the capital payments balance will be as shown in Table 1 up until the year 1991 and for years thereafter it will become $128,000 per year.

Obviously, the capital payments stream is very sensitive to the capacity of the new wells and to the growth rates assumed in the model. These two issues are pointed out because there is some indication that the historical growth rate is not likely to apply in the future and because an accurate estimate of the capacity of the new wells was not forthcoming.

The area serviced by the Authority is highly affected by the expansion of The Pennsylvania State University. The University grew fairly rapidly during the 1966-1972 time period, but there is uncertainty concerning the future growth rate of this University as well as other institutions of higher learning. Therefore, it is appropriate that the results of the model be provided for a growth rate somewhat less than that experienced during the period 1966-1972.

Accurate estimates of the capacity of the new wells were impossible to obtain because of uncertainty concerning certain factors that affect this capacity. The uncertainty concerning the capacity of the new well results from:

(1) the potential pollution of the new well field;

Table 2
Simulated System Growth Under Alternative Growth Rates

	Growth Factor = .75			Growth Factor = 1.0			Growth Factor = 1.25			Actual	
Year	New Users[1]	New Use[2] (Millions)	Capital Balance (000)	New Users[1]	New Use[2] (Millions)	Capital Balance (000)	New Users[1]	New Use[2] (Millions)	Capital Balance (000)	New Users[1]	Use
1966	64	19	$ 4	85	25	$ 5	107	31	$ 6	160	20
1967	167	49	10	223	65	13	279	82	16	279	40
1968	270	79	16	360	105	21	450	132	26	404	109
1969	373	109	22	498	146	29	622	182	36	573	178
1970	476	139	28	635	186	36	794	232	45	712	231
1971	579	169	33	773	226	43	966	281	53	795	242
1972	682	200	39	910	266	51	1,138	333	62	879	295
1973	785	230	44	1,047	306	57	1,309	383	70		
1974	888	260	49	1,185	347	64	1,481	434	78		
1975	992	290	55	1,322	387	71	1,653	484	86		
1976	1,095	320	60	1,460	427	77	1,825	534	94		
1977	1,198	350	65	1,597	467	83	1,996	584	101		
1978	1,301	381	70	1,734	508	90	2,168	635	108		
1979	1,404	411	75	1,872	548	96	2,340	685	115		
1980	1,507	441	79	2,009	588	102	2,512	735	123		

1/ Total number of customers who have entered the system since the first quarter of 1966.

2/ Total quantity of water used by those customers entering the system since the first quarter of 1966.

Table 2 (continued)

Year	Growth Factor = .75 New Users[1]	Growth Factor = .75 New Use[2] (Millions)	Growth Factor = .75 Capital Balance (000)	Growth Factor = 1.0 New Users[1]	Growth Factor = 1.0 New Use[2] (Millions)	Growth Factor = 1.0 Capital Balance (000)	Growth Factor = 1.25 New Users[1]	Growth Factor = 1.25 New Use[2] (Millions)	Growth Factor = 1.25 Capital Balance (000)	Actual New Users[1]	Actual Use
1981	1,610	471	$ 84	2,147	628	$107	2,684	785	$129		
1982	1,713	501	89	2,284	669	113	2,855	836	136		
1983	1,816	531	93	2,422	709	119	3,027	886	143		
1984	1,919	562	98	2,559	749	124	3,199	936	150		
1985	2,022	592	102	2,696	789	130	3,371	987	156		
1986	2,125	622	106	2,834	829	135	3,542	1,038	163		
1987	2,228	652	111	2,971	870	141					
1988	2,331	682	115	3,109	910	146					
1989	2,434	712	119	3,246	950	151					
1990	2,538	743	124	3,384	990	157					
1991	2,641	773	128	3,521	1,031	162					
1992	2,744	803	132								
1993	2,847	833	136								
1994	2,950	863	140								
1995	3,053	893	144								
1996	3,156	924	148								
1997	3,259	954	152								
1998	3,362	984	156								
1999	3,465	1,014	160								

1/ Total number of customers who have entered the system since the first quarter of 1966.

2/ Total quantity of water used by those customers entering the system since the first quarter of 1966.

(2) the inability of the transmission and distributions system to handle the capacity of the new wells;

(3) the production interdependence between the new and old wells; and

(4) the capacity of the new wells may have been overestimated because it may not be possible to drill the wells as deeply as had been planned.

The growth rate and capacity estimates affect the composition of the capital payments stream, but the present value of those streams are obviously dependent upon the interest rate used to calculate that present value. Accordingly, the present value of the alternative capital payment streams was calculated using two discount rates. A discount rate of 4.8 percent was used because that is the interest rate that was charged on the long-term bonds in the 1967 issue. An alternative rate of seven percent was used to calculate the present value because it was believed that this rate more accurately reflected the rate of time preference of the customers in the water system. The present value of the alternative capital payments streams using different interest rates are provided in Table 3.

As indicated above, there is no way to determine exactly what the growth of the system will be, what the capacity of the new wells will eventually be, nor what is the appropriate social rate of time preference to discount the time streams. However, the author is inclined to suggest that the appropriate growth rate is .75, that the capacity of the new wells is about 750 million gallons of water per year, and the appropriate discount rate is seven percent. If so, the present value of the capital payment stream would be $826,000 as compared to the present value of the principle and interest payments on the 1967 bond issues of $721,425.

Conclusions

The analysis presented above indicates that the payments by new customers entering the water system are just sufficient to cover the operation and maintenance cost associated with providing their water and the principle and interest payments from the bond issue required to develop the water supplies necessary to serve them. However, it is important to recall that providing water to these new customers also requires transmission mains and storage facilities. In essence, then, one can conclude that the new customers do pay part of the capital construction costs required to provide them service but they do not pay nearly all of the cost of providing capital for system expansion.

Caution is required in generalizing the results of this study to other water systems. However, the Authority is not atypical of the water systems in many growing areas. The key factors to take into account when attempting to generalize from this study are:

Table 3
Present Value of Annual Capital Payments
Using 4.8 Percent Discount Rate

		Growth Rate[1]		
		.75	1.00	1.25
Annual[2] Capacity	500	$1,078,000	$1,199,000	$1,237,000
	750	1,262,000	1,455,000	1,624,000
	1,000	1,356,000	1,631,000	1,829,000

Present Value of Principle and Interest Payments
on the 1967 Bond Issue in $1,035,000

Present Value of Annual Capital Payments
Using Seven Percent Discount Rate

		Growth Rate[1]		
		.75	1.00	1.25
Annual[2] Capacity	500	$726,000	$ 825,000	$ 865,000
	750	826,000	974,000	1,101,000
	1,000	871,000	1,066,000	1,216,154

Present Value of Required Principle and
Interest Payments = $721,425

1/ Growth rate 1.00 represents the growth rate of the Authority of the years 1967-1972. The growth rates .75 and 1.25 are 75 percent and 125 percent of the 1967-1972 growth rate.

2/ The three capacity classes are 500, 750, and 1,000 million gallons per year.

(1) does the water system require developers or new users to make lump sum payments in addition to the regular water bills or do water rates discriminate between old and new users;

(2) is the growth rate of the system as compared to the capacity similar to the situation studied here? If the growth rate is less, the subsidy is likely to be greater.

The basic model provided in this study can easily be altered to fit the operations of varying types of water systems. It was demonstrated above how the alternative growth rates and the alternative capacities could be used in this particular model. In addition, it would be relatively easy to modify the model to take account of alternative institutional arrangements for financing system growth. The point is, the model is reasonably flexible, but the specific parameters that apply to the State College Borough Water Authority are unlikely to be applicable to other water systems.