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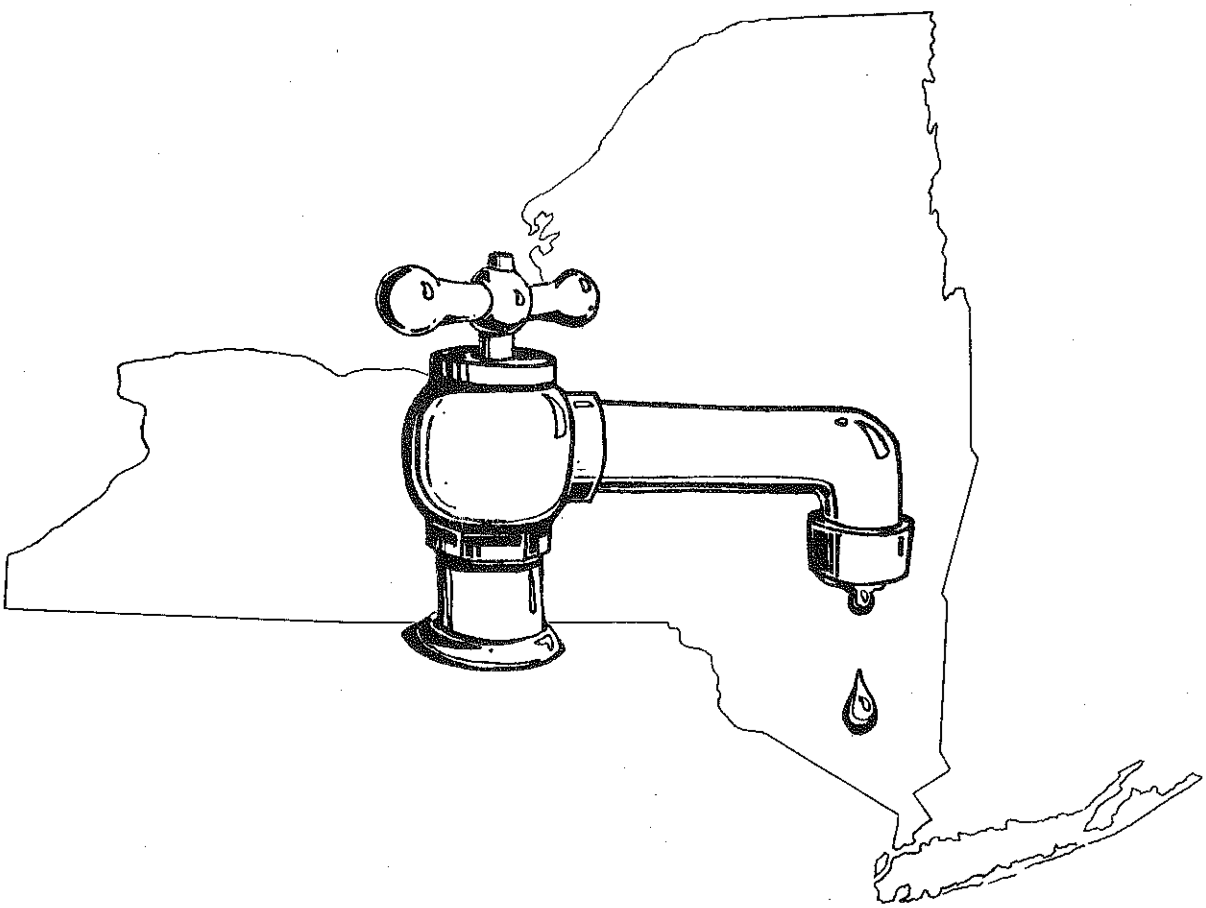

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* Excerpted by A. E. Johnson from Merkens, Paul W. "Risk Acceptance in Public Water Supply: A New York City Case Study." Ph.D. Thesis, Cornell University, 1974.

Foreword by D. J. Allee, Professor of Resource Economics, Cornell University.

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Foreword

There are two basic ways to increase the capacity of a water supply system: store more water to use in dry years, but not in others, and, learn to use less water in dry years. Both are costly in terms of what society must give up and both are demanding of public decision-making capacity. There is no free water at lunch or any other time.

The cheap dam sites have dams in them, or are full of other things. Dams have become a symbol of the impact of human activity on the other elements of the biological system. If the dedication of opponents is any measure, the psychic costs of dams may be their largest contribution to the classic "no free lunch", i.e., the dilemma of social decision making.

Doing without part of the water supply is the cost explored in this study, which examines the great drought of the 1960s, by systematically identifying what the people served by the New York City water system actually gave up. It seeks to put dollar measures on many directly enjoyed values to which prices are not usually applied. Car washing, swimming pool filling, lawn watering, showering without a friend and confidence in government all represent values to people served by a water system. They are affected by a drought. This study goes much further in producing dollar measures of such values than others in the literature, yet it stops short of full coverage. It provides a significant start, if only because most discussions of the cost of expanding water service deal only with the supply side and do not deal with demand management at all.

The measures applied are for the period of the drought studied - not for current values. for the 1980s the dollar measures would have to be more than doubled and some would have to be changed more than that because the change in the value of money (inflation) is only an average measure of shifts in relative value over time.

Moreover, these values are for a use reduction of only about 20 percent. Many adjustments are possible which reduce the impact of a water shortage. In other words, the first 20 percent reduction is much less costly than the next 20 percent. Remember that last 20 percent can kill and thus asking "what is the total value of water" is irrelevant. Cutting the last increment is too costly to allow.

On November 25, 1980 the New York Times announced that the City's supply of stored water was at 36.9 percent of capacity, the lowest since 1966. The significance of this was enhanced by the fact that fewer people were using more water. In the 60s 1.2 billion gallons per day were released and in the early 80s the rate was 1.5 billion per day. The yield in a very dry year, i.e., the safe yield, is now rated at 1.29 billion gallons per day. In the dry months since the Times article, usage has been cut to levels comparable with those achieved in the 1960s. Interest in water service capacity and particularly in ability to manage risk has prompted the release of this study.

Paul Merkens wrote the thesis from which this report was extracted. Readers will find many details of concept and method presented there. He also developed improvements in the analytical methods for balancing withdrawals from reservoirs as a drought progresses. He estimated the value of metering as well as the management of groundwater in conjunction with surface water. Much of this was used by the Southeast New York Water Supply Commission, on whose staff he served under the intrepid Bob Hennigan. He went on to work as a consultant and as a policy analyst for the U.S. Secretary of the Interior. He was a part of the staff of the Assistant Secretary for Water Resources when a stroke prematurely ended his career.

David J. Allee
August 31, 1981

THE NEW YORK CITY WATER SYSTEM AND THE 1960s DROUGHT

Introductory Summary

The traditional approach to water supply planning is to make certain safe yield is always equal to or greater than forecasted water requirements. Safe yield is the minimum amount of water a system will produce in a repetition of the most severe drought of record and is a very conservative estimate of supply capability. Usually no attempt is made to estimate economic benefits associated with supply at different levels and thus at different costs. This methodology has been used to develop no-risk plans for expansion of water supply capacity for the New York metropolitan area.

The dissertation from which this paper was excerpted developed a probability distribution of supply capabilities from the New York City water supply system. A Markov-chain, reservoir-storage-probability model which preserves the serial correlation of inflows simplified the supply problem by assuming two six-month periods per year and one large reservoir. The model output showed that the safe yield of the New York system would be equaled or exceeded 99.9 percent of the time.

Economic benefits lost in a water shortage were estimated by counting losses of economic welfare to producers and consumers during the severe Northeast drought of the 1960s. Shortage loss functions were then developed for the New York area.

The shortage loss functions and probability distribution of supply were combined in a capacity expansion analysis which explicitly accepted risk. The analysis determined the combination and timing of projects which minimizes the total present value of expected annual shortage losses and the annual cost of projects. The analysis was constrained to limit the maximum shortage in any year to levels previously experienced and to limit the frequency of large shortages. By accepting risk, project timing could be delayed by six years, capital costs were reduced, required storage volume was reduced and the total present value of costs was reduced by 38 percent.

Demand management through universal metering in New York City was explored as a means of reducing consumption and shortage risks. A linear regression analysis of per capita consumption of residences directly metered, indicated universal metering would reduce consumption in the City by 15 percent. With universal metering in the constrained-risk, capacity-expansion analysis, timing of projects is delayed by 20 years from the original no-risk plan, and the total present value of annual costs is reduced by 60 percent.

This study demonstrates that by accepting some risk in public water supply planning, it is possible to delay required projects and to reduce the present value of costs. This allows greater flexibility and time to refine project plans and to develop alternative technologies.

Responses to Water Shortages

There have been recent droughts which have caused significant water shortages for the New York City water supply system. The Northeast drought of 1961-67 was an extremely rare and severe event. This review of the City's response to that shortage will indicate responses to be expected and types of information necessary to estimate the costs of future water supply shortages.

From 1961-1967, there was a severe drought which affected the New York City water supply system more critically than the previous one of 1949-50. At the beginning of the dry season in June, 1961, the City reservoirs were full. In the next two years precipitation was 77 percent of the average and consequently, at the beginning of the dry season in 1963 the reservoirs had a void of 35 percent (Groopman 1968). By November 1, 1963, storage was down to 26 percent of capacity, further signaling a shortage. At this time the City initiated a conservation campaign designed to gain voluntary cooperation. No mandatory restrictions were imposed.

In the Spring of 1964, runoffs into the reservoirs were near normal, storage was at 89 percent capacity by May 1 and the conservation campaign was suspended. After May, however, the drought intensified. Precipitation was 44 percent of normal and runoff was at record low levels. With such low runoffs, high releases were required to maintain low-flow requirements in the Delaware River. In 1965, the Mayor declared a water shortage, appealed for voluntary cooperation and instituted restrictive measures which included (NYC Bureau of Water Supply 1965):

April 7, 1965 - watering of municipal parks and golf courses restricted

- use of water for street cleaning banned
- fire hydrant harnesses installed and laws governing illegal hydrant openings more rigidly enforced
- water for cleaning subway cars and buses reduced.

April 19, 1965 - watering lawns and gardens curtailed

May 19, 1965 - use of City water for ornamental fountains banned

- car washings restricted

June 16, 1965 - watering lawns or gardens banned

August 5, 1965 - washing fleet vehicles with City water banned

- air conditioning limited to 12 hours a day.

These restrictions were also imposed on water utilities outside the City which were supplied from the City system. Survey teams inspected apartment buildings for plumbing which could be repaired to conserve water. An intensive publicity campaign through the press, radio, TV and posters was aimed at domestic consumers and appeals for cooperation were also addressed to heavy water-using industries and commercial operations such as bottling plants, laundries, breweries, hotels and commercial car wash establishments. Other than for commercial car washes and air-conditioning installations, however, there were no mandated restrictions on commercial or industrial water users. Commercial car wash establishments were required to install water-recyling equipment and a survey of air-conditioning installations was undertaken to determine noncompliance with recycling.

The City, moving to develop emergency supplies, petitioned the State to allow the reinstallation of the Hudson River emergency pumping plant at Chelsea. This plant started pumping on March 21, 1966 and continued through January 13, 1967. In this period 22 billion gallons (75 million gallons per day) was pumped from the river. The City groundwater field in Long Island's Nassau County had not been pumped since the mid-fifties because of the rather poor water quality of this source. However, during a 12-month period in 1965 and 1966, this well field was reactivated and 6.5 billion gallons (18 MGD) were pumped into the City and blended with upstate water. Also, water from the Cannonsville Reservoir in the Delaware Basin complex was diverted to New York City.

Because of the record low flows in the Delaware Basin, releases required to maintain the Delaware streamflow target placed an enormous burden on the City water supply system. By mid-June of 1965 it was necessary to release 600 MGD to maintain the target. Continued releases at such levels would have emptied the Delaware reservoirs by mid-August. The City, therefore, unilaterally reduced downstream releases to a level equal to natural inflows (Groopman 1968).

On July 7, 1965, the Delaware River Basin Commission declared that the drought constituted a state of emergency. In the interest of the City and the downstream states, temporary diversion rates and release requirements were established. Under the temporary specification the target was reduced by 21 percent. New York was not permitted to store water in Cannonsville Reservoir unless the flow at Montague was 1200 cubic feet per second without releases from any storage. The modified release requirements gave an extra 160 MGD to the City for the period of June, 1965 through May, 1966.

In 1967, the drought conditions ended and streamflows began to approach average levels. By the end of the year, normal water use again predominated and consumption rose to near predrought levels. On March 2, 1967, the Delaware River Basin Commission declared the end of the state of emergency and releases, as stipulated by the Court decree, were again required. On March 30, 1967, the Cannonsville Reservoir was full enough to be considered officially on line. Because of its severity, the 1960s drought has had a long-term effect on water-supply thinking for New York City. First, the severity of the drought caused a reevaluation of the existing system. As stated by Abraham Groopman, the Chief Engineer of the New York City water supply system (1968):

> The current drought has demonstrated most vividly that the New York City system can no longer be depended upon during a protracted dry period to produce the quantities of water

for which it was designed. In fact, the loss of close to 1-1/2 years of precipitation in the past 6 years has drastically reduced the yield capability of the watersheds.

Prior to this, the most severe drought of record was that of 1930. Based on the inflows of that experience the safe yield for the New York City reservoir system was set at 1800 MGD, a figure used by the Supreme Court in allocating the water of the Delaware. Based on the drought of the sixties, however, the safe yield of the system was set at 1297 MGD, a reduction of 28 percent. Although its basis was an extremely rare event, the reduced safe yield is now being used to demonstrate the need for additional water supply projects.

Because of the apparent need, the drought of the sixties has inspired several studies of the metropolitan water situation. The US Congress, in the Rivers and Harbors Act of 1968, commissioned the Northeastern United States Water Supply Study. This was the first major involvement of the Federal government in municipal water supply planning, an activity usually undertaken by local and state governments. The State of New York responded to the apparent inadequacy of supply by establishing the Temporary State Commission on the Water Supply Needs of Southeastern New York. This commission determined on the basis of the sixties drought that an additional source of supply would be required by 1985.

Another response to the drought was an increase in the price of water to consumers. At the time of the 60s drought, both metered and flat rates in NYC were the same as in 1934. On July 1, 1966, the frontage rate was increased by 100 percent, and on January 1, 1971, by 75 percent. The metered rate was increased by 100 percent on September 1, 1968, and by 75 percent on August 1, 1970, to the present rate of $700 per million gallons: that is, after the drought, water rates were increased by a factor of 3.5 times the original rates.

Conservation campaigns and emergency sources are the only drought responses now available to the City. Were Cannonsville Reservoir on line during the 60s drought, the City would probably have been able to meet the required Delaware releases and it is doubtful that the Delaware River Basin Commission would have relaxed the requirements. Therefore, with the present facilities it is assumed that the Delaware target will be met and that a reduction in releases is a less possible response for future shortages. In the water shortages of both 1949-50 and 1965-66, conservation campaigns were able to effect reductions of about 17 percent of anticipated needs. In both cases the reductions followed rather intensive campaigns, indicating a probable upper limit to such reductions prompted by water shortages.

Both the 1950s and 1960s campaigns resulted in similar reductions of water needs. However, the reductions came from different sectors. In 1950, commercial and industrial users reduced water use by approximately 20 percent. All others including municipal and residential users effected reductions of about 17 percent. In absolute terms, the residential users were responsible for most of the reduction. In 1965 and 1966, there was no significant reduction in water use by industrial/commercial accounts. Residential and municipal water use, on the other hand, dropped by about 18 percent.

This difference in response between the two consumption campaigns follows the different emphases of the two campaigns. The 50s campaign included restrictions for commercial users. The most important was the requirement for recirculating equipment on air-conditioning installations of three tons and over, a requirement made permanent after the drought. The only restrictions for residential and municipal uses were bans on lawn sprinkling, car washing and swimming pools. Recognizing that residential reductions had accounted for the greatest absolute drop in water use, the conservation campaign of the 60s was directed essentially at municipal and residential users. Other than the requirement for recyling equipment in commercial car wash establishments and the reduced hours of air-conditioning operation, no restrictions were placed on commercial/industrial uses. Rather, voluntary cooperation was expected in this sector.

Municipal water use restrictions were placed on such operations as street cleaning, park and golf course uses, subway car washing and ornamental fountains. Curtailment of these municipal uses accounted for a very small reduction in use, but were important, for in conjunction with the educational campaign, they helped promote a crisis psychology necessary to gain the fuller cooperation of residential users.

New York City's responses to the droughts are rather typical of drought responses in other water utility systems. According to a survey done in Massachusetts, a typical response to a water shortage is the introduction of use restrictions. This is quite often followed by emergency supplies (Russel et al. 1970). An interesting finding was the apparent order in which different sectors were restrained in their water use: if the potential shortage facing a community was less than 10 percent, the community attempted to meet it by restricting residential and possibly municipal uses, and only when the potential shortage was significantly greater than 10 percent did communities move to restrain industrial use.

The hierarchy of response is even more applicable in New York City because industrial usage amounts to a very small portion of the City's needs. There is no large water-using industry in the City, although there is a large intake by the commercial sector. The most significant commercial use is make-up water for air conditioning. With a permanent requirement for recirculating equipment in air conditioners, there is small opportunity for reduction in this sector.

Thus, New York City is limited in its drought response to restrictions on municipal uses, outside residential uses such as lawn sprinkling and car washing, and voluntary restraint on in-house domestic uses. The most important of these possible responses are voluntary reductions by apartment tenants and by homeowners.

Economic Costs of the Drought

Economic loss estimates center on the costs of use restraints and substitutes. These estimates can then be used to develop shortage loss functions for the New York City water supply system.

The loss estimates were based on a partial equilibrium rather than on a general equilibrium. That is, the general economy within the region was held constant and only the firms and consumers affected by water shortage were identified and analyzed. Full employment was assumed for the region and economic inputs used to mitigate the effects of the shortage would have been diverted from some other activity, thus resulting in a net loss to the region.

A regional accounting stance was taken and extraregional externalities due to the shortage responses in the New York region were ignored. This is reasonable if the possibility of a reduced streamflow target in the Delaware River is not considered viable and if there is no loss of industrial output from the region.

Economic Welfare Accounting Model

There are three levels of interrelationship in the production and consumption of water supply: first level supplier, intermediate producers and ultimate consumers (figure 1). The first level in this case is the New York City Bureau of Water Supply. This utility faced a shortage of water because of the drought and responded with emergency supplies (substitutes), curtailed output and mandated use restrictions. The utility, taken as a separate producing firm, had reduced producer surplus because of the costs of the emergency supplies and reduced revenues. Estimating the loss of economic welfare at this first level necessitates an accounting of these costs.

The water utility supplies water to the second level of the interrelationship, the intermediate producers, who are not ultimate consumers but use water in the production of goods consumed by others. The intermediate level includes industrial and commercial firms, certain municipal functions and water utilities outside the City supplied from the City system. During the drought, some of the intermediate producers reduced output, saved on their water costs and passed the loss of economic welfare to consumers. Others kept their output at the normal level but used substitutes or alternate technology and absorbed the loss of economic welfare associated with the shortage. To account for the loss of economic welfare at this level it is necessary to determine which producers used substitutes and absorbed the cost of the water shortage and which reduced output.

The third level of the interrelationship is the ultimate consumers. At this level, economic welfare is measured by consumer surplus utility. To account for the loss of consumer surplus, it is necessary to isolate which water supply goods and other goods were in short supply to consumers. Then the demand curve for these goods can be used to estimate the reduced consumer surplus.

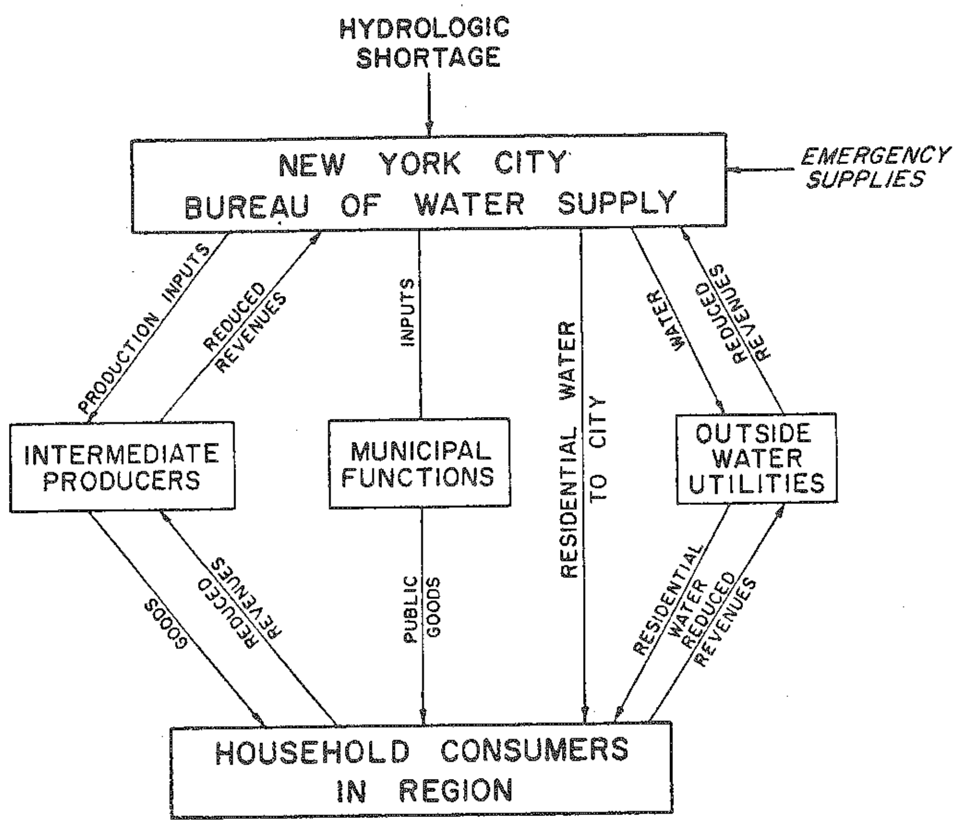

Figure 1. Water Shortage Welfare Schematic.

Two exceptions to the use of consumer surplus must be made. These exceptions are for residential water in New York City and for some public goods. First, the water supplied residential consumers in New York City is not metered but is paid on a flat-rate formula. Nonmetered consumers pay the same water cost no matter how much water they actually consume. When nonmetered consumers reduce consumption below normal levels, they lose the full utility associated with this reduction. There is no reduction in water costs and no loss of revenues to the utility. The loss of economic welfare is, therefore, equal to the total area under the demand curve not just the consumer surplus portion.

The second special case for estimating lost economic welfare is related to those goods having no readily defined demand curve. This includes goods such as air conditioning and public goods from municipal functions such as clean streets and ornamental fountains. A public good is defined as a good which can be used by one consumer without diminishing its availability to others. To determine the demand curve for a public good, it is necessary to sum the payments which various members of society are willing to contribute to assure its supply. Determining each individual's true willingness to pay is difficult because regardless of payment size, each still retains equal use (Baumol 1965). Lacking demand curves to define consumer surplus for these public goods, this study will use the less precise concept of benefits. For those goods in short supply from intermediate producers, it will be determined if there was a loss of benefits. For those goods in short supply from intermediate producers, it will be determined if there was a loss of benefits and their value will be measured by using the surrogate of the costs of ordinarily supplying the benefits.

Summary of Welfare Losses: 1965-67 Drought

Costs in terms of lost economic welfare in NYC were estimated for the drought of 1965-67. The first step was to estimate the costs for the June, 1965 thru May, 1966 period. This was the first period of drought response and included the most intense one-year period of shortage. The estimated losses of producers surplus to the water supplier and intermediate producers and the estimated losses of economic welfare to the ultimate consumers are summarized in table 1.

The 1965-66 base data was also extrapolated to include the 1965-67 period. The water supply shortage became particularly acute in the early part of 1965 and the water conservation campaign was initiated in April of that year. The most pronounced water use reductions were achieved in the 1965-66 period, although the campaign continued for almost a year more. In the one-year period from June, 1966 through May, 1967, average daily consumption from the New York City water supply system was reduced by 123 MGD or 10 percent below the normally anticipated consumption level. The costs of these continued water reductions must be included in the total drought costs. Not all of the costs of the water shortage incurred in the June, 1965- May, 1966 period were repeated in the following year. The capital costs of developing substitute sources, installing recycling equipment or repairing plumbing leaks were assumed in the first period and were not repeated in the second. The economic costs which continued were estimated by prorating the losses from June, 1965 to May, 1966, assuming that consumers continued the same water conservation practices beyond the 1965-66 period but did so for less than a full year. It is estimated that the total loss of economic welfare amounted to $73 million (table 2). The losses of producer surplus amounted to $15 million, one-fifth the total, while losses of consumer surplus amounted to $58 million.

Consumers in the residential sector of New York City and the upstate service area contributed 77 percent of the water reduction and suffered 80 percent of the economic losses. The domestic users in New York City alone contributed 69 percent of the reduction and accepted 65 percent of the losses. Under normal conditions, domestic consumption in the City amounts to 43 percent of the total usage from the New York City water supply system. The commercial/industrial sector, excluding apartment buildings, generally uses 23 percent of the total supplied. This sector contributed less than 5 percent to the total reduction. The New York City Bureau of Water Supply sustained 10.6 percent of the drought costs through the costs of emergency supplies and lost revenues. The upstate service area normally uses 6-7

Table 1. New York City Water Supply System. Costs of Drought Responses to Producers and Consumers, June 1965 - May 1966.

Affected Activity	Reduction in Water Intake	Cost of Reduction (Net loss of Producer Surplus)	Water Costs Saved
FIRST LEVEL SUPPLY			
New York City - Bureau of Water Supply[1]	--	$6,582,000	0
Emergency Supplies	--	5,100,000	--
Reduced Revenues	--	1,482,000	--
INTERMEDIATE PRODUCERS	40 MGD	6,666,000	--
Municipal Functions		5,000	
Public Golf Courses	0.2 MGD	0	--
Street Cleaning	1 MGD	5,000	--
Fire Hydrants[1]	5 MGD	0	--
Ornamental Fountains[1]	0.5 MGD	0	--
Commercial Sector		5,316,000	
Washing Subway Cars	0.05 MGD	($4,000)[3]	$ 44,000[2]
Air Conditioning	6 MGD	0	438,000
Car Wash Establishments	2.1 MGD	2,320,000	551,000[2]
Apartment Buildings	25 MGD	3,000,000	0
Upstate Service Area			
Water Utilities			
Reduced Revenues	125 MGD	1,345,000	449,000
Apartment Buildings	0		327,000
CONSUMERS	175 MGD	37,973,000	--
New York City Residential Sector	162.5 MGD	36,124,000	0
Lawn Sprinkling	3.5 MGD	1,680,000	0
Car Washing	1.0 MGD	2,254,000	0
Domestic Consumption	158 MGD		
Apartments		25,900,000	0
Single Family Homes		6,290,000	0
Upstate Service Area Residential Sector	12.5 MGD	1,813,000	
Lawn Sprinkling	5 MGD	430,000	725,000
Car Washing	0.5 MGD	914,000	75,000
Domestic Consumption	7 MGD		
Apartments		100,000	0
Single Family Homes		369,000	666,000
Consumption of Other Goods		128,000	
Ornamental Fountains	*	128,000	0
Air Conditioning	*	0	0
Public Golf Courses	*	0	0
TOTAL FOR PRODUCERS AND CONSUMERS	215	51,221,000	

[1]Activities which reduced production or output.

[2]Present value of water costs saved over lifetime of water substitutes.

[3]( ) indicates cost saving.

* See text for discussion.

Table 2. New York City Water Supply System. Total Costs of Drought Responses, 1965-1967

Level and Affected Activity	Net Reduction in Economic Welfare	Share of Total Costs	Contribution to Total Reduction	
		(%)	B.G.	(%)
FIRST LEVEL SUPPLY	$ 7,736,000	10.6		
NYC Bureau of Water Supply				
Emergency Supplies	5,700,000	7.8		
Lost Revenues	2,036,000	2.8		
INTERMEDIATE PRODUCERS	7,253,000	9.9	28.7	23.2
Municipal Functions	9,000	Neg.	4.9	4.0
Public Golf Courses	0	0	0.1	0.1
Street Cleaning	9,000	Neg.	0.7	0.6
Illegal Fire Hydrant Openings	0	0	3.7	3.0
Ornamental Fountains			0.4	0.3
Commercial Sector	5,316,000	7.3	23.8	19.2
Washing Subway Cars	($4,000)	0	Neg.	
Air Conditioning	0	0	4.0	3.2
Car Wash Establishments	2,320,000	3.2	1.5	1.2
Apartment Buildings	3,000,000	4.1	18.3	14.8
Upstate Water Utilities				
Lost Producer Surplus	1,928,000	2.6		
CONSUMERS	58,144,000	79.5	94.7	76.9
Public Goods				
Ornamental Fountains	235,000	0.3	-	-
New York City Residential Sector	54,962,000	75.2	88.3	71.7
Lawn Sprinkling	3,360,000	4.6	2.6	2.1
Car Washing	4,131,000	5.7	0.7	0.6
Domestic Consumption	47,471,000	64.9	85.0	69.0
Apartments	38,195,000	52.2		
Single Family Homes	9,276,000	12.7		
Upstate Service Area	2,947,000	4.0	6.4	5.2
Lawn Sprinkling	602,000	0.8	2.5	2.0
Car Washing	1,675,000	2.3	0.3	0.2
Domestic Consumption	670,000	0.9	3.6	3.0
Apartments	143,000	0.2		
Single Family Homes	527,000	0.7		
TOTAL FOR PRODUCERS AND CONSUMERS	$73,133,000	100.0	123.4	100.0

B.G. = Billion Gallons.

percent of the water supplied by the New York City water system and, proportionately, suffered nearly 7 percent of the lost economic welfare.

Commentary on the Cost Estimate

The very nature of nonmarket goods makes them difficult to quantify in an economic evaluation. In many instances, the values are intangible and consumers find it difficult to express what about the good gives satisfaction. Where it is possible to develop an agreed-upon measure of the good, the measure is often not comparable with other goods and economic costs.

Public and social goods are generally indivisible, making it difficult to exclude a consumer even though he or she is unable to make known the degree of willingness to pay. In addition, much of the value of social goods is involved in consumer's option demand. That is, an individual may not actually consume a public good but takes satisfaction in its availability and in the option to use it when desired (Davidson, Adams and Seneco 1965).

This lack of total refinement in evaluating nonmarket goods is not a serious constraint to the basic purpose of this study. The economic welfare costs of the drought responses were estimated in order to develop water shortage loss functions. These were used in combination with water supply project costs, which, while easier to define, are also subject to variation. Thus, refining the value estimate of nonmarket goods may not improve the accuracy of the final output. Finally, a sensitivity analysis will determine the full significance of the nonmarket goods that are imperfectly quantified.

Estimates of Drought Costs

The costs associated with the drought were estimated for producers that developed substitute sources or reduced production of goods and for consumers when shortages of water or other goods resulted in loss to that sector.[2/]

Losses to Producers

The New York City Bureau of Water Supply - The Bureau passed on a shortage equal to 17 percent of normal water usage to intermediate producers and consumers. In addition, the Bureau developed emergency sources. Both responses reduced the Bureau's producer surplus. In 1965, the City reactivated the Hudson River emergency pumping plant which had been inactive since 1955. The intake and discharge lines were still in place, so the only expense was for pumping equipment, chlorine and alum feeds. These cost an estimated $4.9 million (Metcalf and Eddy 1966). The Chelsea pumping plant was completed and went on line March 21, 1966. From that date until January 13, 1967, a total of 22 billion gallons were pumped from the Hudson with operation and maintenance costs of $800,000. The share of the operation and maintenance costs assigned to the June, 1965 through May, 1966 period was $190,000 for a total cost in that period of $5.1 million dollars.

The New York City Bureau of Water Supply also drew emergency water from the Long Island groundwater field, in disuse since 1955. They drew 6.5 billion gallons over a 12-month period in 1965-66, at an estimated cost of $1,000 for the year.

The loss of revenues to the Bureau was due to reduced wholesale water sales upstate and reduced sales to the commercial sector. These totaled $1,482,000, including the present value of the stream of reduced revenues

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[2/]For references and details of these calculations see Merkens, 1974.

from the Transit Authority and commercial car washes. These two industries developed substitute sources of water which also reduced revenues to the City.

Municipal Functions - Water use restrictions were imposed on municipal golf courses and parks, street-flushing operations and ornamental fountains (NYC Parks, Recreation, and Cultural Affairs Administration). In addition, there was increased emphasis on preventing illegal fire hydrant openings. In New York City, all municipal operations are exempt from water use charges. Thus, there was no reduction of water costs for those services which reduced consumption.

There are 13 municipally owned golf courses and numerous parks in the City. In a normal year approximately 63 million gallons of water from municipal sources is used to maintain the golf courses. During the drought, this use was curtailed and annual consumption was reduced by 20 million gallons. Water use was not banned altogether in order to protect the City's substantial investment in its golf courses. Watering of greens was continued. Trees and fairways were reconditioned after the drought through normal maintenance operations and there were no extraordinary expenses for repair.

The lawns in the City-owned parks are dependent on rain and were thus unaffected by water use restraints. Formalized areas in the parks including shrub beds and ornamental trees and gardens are in some cases irrigated with City water. When sprinkling water was banned, these areas were watered from trucks. There were negligible cost increases associated with this maintenance procedure.

Prior to the drought of the 1950s, City water from free-flowing hydrants was used for street flushing and snow removal. This use amounted to 20 MGD (WPA). After that drought, the prohibitions on such water uses were continued. Presently, only water from trucks and other street-cleaning equipment may be used for street-cleaning operations. The City's Department of Sanitation has 50 trucks which each use approximately 15,000 gallons per day for street cleaning. During the drought of the sixties, use of City water was again banned for street-cleaning operations. River water was substituted and was heavily chlorinated. This substitute water and the chlorination requirement caused some corrosion of equipment and a figure of $100 per truck was assigned as a cost. There were no effects on the sewer system from the brackish river water because of the high dilution of the relatively small amount used (NYC Dept. of Sanitation).

The City issues fire hydrant caps which can be used to spray water for recreational purposes. In addition, children often illegally open the hydrants on their own using considerably more water than with the caps. During the drought, the use of the caps was continued but illegal fire hydrant openings were curtailed. On very hot days, it has been estimated that as much as 500 MGD are lost through free-flowing hydrants. The Engineering Panel on Water Supply (1951) estimated that 5 MGD on an annual average was saved during the drought of 1949-50 through surveillance for illegal hydrant openings, and this figure was assumed for this study. No direct cost was associated with this curtailment; it was part of the general public cooperation.

During the sixties drought, water for ornamental fountains was banned, saving an estimated 0.5 MGD. There was no reduction in water costs because the fountains, as a municipal function, were exempt from water costs. The loss of economic welfare associated with the fountains was passed to consumers.

Commercial Sector - The industrial use of publicly supplied water in New York City is minor and was not restricted during the drought. There were, however, minor restraints on the commercial sector. Air-conditioning operators reduced production, and other restrained activities in the commercial sector used water substitutes which affected their producer surplus.

The New York City Transit Authority uses about 50,000 gallons per day to wash its subway cars. During the drought, this use of City water was restricted and the Authority developed substitute sources for its five maintenance centers. Five wells of 100 gallons per minute capacity were drilled at an approximate cost of $5,000 per well, with an annual operating cost of $250 each. Assuming a forty-year life for wells and an eight percent discount rate, the present worth of the cost of the wells is $40,000.

Using City water at a cost of 20¢ per 1,000 gallons would cost the Transit Authority $3,650 each year. This has a present worth, over 40 years at eight percent, of $44,000. Therefore, in using wells to supply water, there was actually a net savings in terms of present worth of $4,000 (New York City Transit Authority).

There are a total of 1.2 million tons of water-cooled air conditioning in New York City. In 1965, 85 percent of this tonnage recycled cooling water and used an annual average of 22 MGD for makeup water. The remaining non-recycling units used an annual average of 49 MGD. During the drought, all units were limited to 12 hours a day of operation and those units not recycling were limited to the amount of water they would have used if they recycled.

The effect of the 12-hour limit was a reduction in water use of 6 MGD, annually. This reduced water costs to producers by $438,000 and translated into reduced revenues to the Bureau of Water Supply. The loss of economic welfare was passed to consumers of air-conditioning benefits. About 15 percent of the tonnage was not recycled. These were small units with an average capacity of 4 tons. Through the drought campaign, the City was able to gain compliance from 70 percent of these small units. Although the sixties drought promoted greater compliance of the restriction carried through from the drought of the fifties, the cost of compliance should be charged against the fifties drought, since equipment was not installed and operating until the summer of 1967 when the shortage was considered past.

If 70 percent of the tonnage not recycling cooling water were to install recycling equipment, there would be a reduction in water use of 32 MGD, annually. The average water use for industrial/commercial purposes was 282 MGD for the years of 1960-66. Only in 1967 did industrial/commercial consumption drop to 253 MGD, apparently accounted for by the installation of recycling equipment.

In 1965, 145 of the estimated 160 commercial car wash establishments in New York City used 2.1 MGD of City water. During the drought, the City required car washes to either install recycling equipment or reduce their water intake by 50 percent. Recycling equipment costs an average of $10,000 and reduces water used per car from 100 down to 50 gallons. The annual cost with recycling equipment would be:

Depreciation (Straight line, 5 years) --	$2,000
Operation and Maintenance	500
Annual Water Costs	50
Total annual costs	$2,550

These annual costs, combined with the initial capital investment would have a present worth of $20,000 (8 percent over 5 years).

Without recycling equipment the annual cost for water would be $1000 for the average car wash. With a five-year stream and a discount rate of 8 percent, this would have a present worth of $4000. Thus, the net cost of recyling equipment in terms of present worth would be $16,000 for the average car wash. For those supplied by New York City, this represents a loss of producers surplus of $2,320,000 for their use of water substitutes. There would be a loss of water revenues to the City of $138,000 per year with a present worth of $551,000.

In New York City, assuming recycling equipment, the cost for water accounts for between 3 and 4 percent of variable costs. Fixed costs would be increased by about 4 percent. The average capital investment for a new car wash would be about $200,000 without and $210,000 with recycling equipment. Labor cost would continue to be the largest share of costs. The estimates assumed 100 percent compliance and are thus probably high.

It is assumed that apartment building owners and managers cooperated with the drought campaign by repairing leaky fixtures and plumbing at a total estimated cost of $3,000,000. Because apartment buildings are unmetered, there was no reduction in water costs so the owners had a $3,000,000 reduction in producer surplus. A survey done in New york City in 1947 found 9,142 leaks in 2,832 dwelling units for an estimated waste of 2,237 gallons per day. This extrapolates to a total waste inside residential buildings of 200 MGD (Beame 1959). During the drought of 1949-50, many repairs were made and waste dropped to an estimated 100 MGD (D'Angelo 1964).

In 1965, Fire Department teams inspected 69,500 dwellings and found 200,000 breaks or 3 leaks per building (Pitometer Associates 1968). With the same incidence of leaks as in the 1947 sample, it is probable that waste inside buildings was as high as 200 MGD. In extrapolating the 1965 Fire Department sample, there would have been as many as 1,500,000 leaky fixtures or plumbing leaks in the City in 1965. It is assumed that the drought campaign inspired the repair of one-third of these leaks at a cost of $6.00 each. The total cost of the repairs would have been $3,000,000 and water intake would have been reduced by 25-50 MGD. Although the tenants in apartment buildings reduced consumption an estimated 30 percent, there was no reduction in water costs to apartment owners, as they pay a fixed rate for service.

Upstate Service Area - New York City does not retail water to consumers in the upstate service area. Rather, the City wholesales to other utilities who then retail the water. On the basis of predrought records, it is estimated that the upstate service area would have used 80 MGD in 1965. Because of the drought the utilities actually supplied 68 MGD. The reduced demand lowered their water revenues by $1,794,000. However, their wholesale water costs were concurrently reduced by $449,000, leaving a net loss of producer surplus of $1,345,000. Tenants in upstate apartment buildings reduced water consumption an estimated 17 percent, resulting in a reduction of costs to apartment owners of $327,000.

Losses to Consumers

During the drought, consumers faced shortages in water supply as well as the supply of goods from some intermediate producers. There were reductions or diminished quality in the supply of fire hydrant openings, ornamental fountains, air conditioning and public golf courses.

Lawn sprinkling - New York City's lawn watering is limited to the Boroughs of Richmond and Queens, the only areas having a high percentage of single-family dwelling units with lawns to be watered. It was necessary to impute a demand function for lawn watering, and the demand curve derived by Howe and Linaweaver (1967) was assumed. The willingness to pay for the water not used was taken as the consumer utility lost by the ban on sprinkling.

The willingness to pay, V_t, is the area under the demand curve $P = f(Q)$ shown by the integral:

$$V_t = \int_{Q_1}^{Q_2} P\,dq$$

where Q_1 and Q_2 are points on the demand curve. For this study, Q_2 is the household water use including sprinkling and Q_1 is household use without sprinkling.

If the price elasticity of demand, E, is a constant between Q_1 and Q_2 and if a point on the demand curve can be specified (P_b, Q_b) then the above integral can be expressed as

$$V_t = \frac{P_b Q_b^{1/E}}{1-\frac{1}{E}} \left[\frac{Q_2}{Q_2^{\frac{1}{E}}} - \frac{Q_1}{Q_1^{\frac{1}{E}}} \right]$$

(Young & Gray 1972)

Estimates of P_b, Q_b, and E were taken from Howe and Linaweaver. According to their study, the average price for water in the eastern United States is 40 cents per 1000 gallons. At this price an urban household uses 80 gallons per day per dwelling unit (gpud) for lawn sprinkling during the summer season (90 days). These two pieces of information are taken as P_b and Q_b.

The price elasticity of demand for sprinkling water in the East was -1.6 according to Howe and Linaweaver. They also derived an elasticity of demand for the nation as a whole equal to -1.1. The less elastic measure of demand was used in this study for several reasons. First, the lawns in Richmond and Queens are rather small and do not require much water. The small amount used will be less sensitive to price than will a large demand. Second, in the drought of the 1960s there was very little precipitation and without sprinkling water households were concerned not just with greenness but with the possibility of permanent lawn damage. In other words, the drought situation in the East was analogous to normal conditions in the West. The demand for sprinkling water in the West is inelastic and when included in the national average, makes the national elasticity of demand inelastic.

In Richmond Q_1 = 270 gpud and Q_2 = 350 gpud. This yields a willingness to pay for sprinkling water of 11 cents a day per household or $445,500 per sprinkling season of 90 days for the 45,000 single-family dwellings in Richmond.

In the borough of Queens, Q_1 was 260 gpud and Q_2 was 340 gpud. This gave a consumer utility for sprinkling water of 10.7 cents per day or $1,233,000 per season for the 128,000 single-family homes in Queens. Not all the single-family homes in Queens were included in this estimate because 30 percent of the borough was served by a private water company which did not impose water use restrictions during the drought.

<u>Car Washing</u> - In 1965 an estimated 1,220,000 of the 1,340,000 private cars in New York City were owned by people in areas supplied by the City Water Supply (Census of Housing). Assuming an average of 10 washes each year, there would be 12.2 million car washings. Commercial car washes accounted for 7.6 million so there would be a potential of 4.6 million private car washings in 1965. During the drought, these were banned.

A surrogate for the consumer surplus from a private car washing is estimated to be 49 cents. This was estimated as follows:

Total utility of a clean car (surrogate from commercial car washes		$1.00
Costs of a private car wash (from National Car Wash Council)	Cents	
water	2.4	
detergent	2.1	
heating the water	2.4	
labor	43.9	
Total		$ .51
Consumer Surplus		$ .49

This consumer surplus lost because of the ban on car washing represents a total of $2,254,000 for New York City. It takes about 80 gallons of water to wash a car so approximately 1 MGD was saved through the car wash ban.

Domestic consumption - This is water used inside residences for cooking, drinking, laundering and personal hygiene. During the drought, domestic consumers in New York City reduced consumption by 158 MGD or 30 percent below the normal level of 525 MGD. The resulting reduction in consumer utility amounted to $25,900,000 for apartment dwellers and $6,290,000 for single-family homeowners. This represents the full willingness to pay as there were no water costs saved by the nonmetered domestic consumers (table 3).

Table 3. Lost Consumer Surplus, New York City and Upstate New York Apartments and Single-Family Homes, 1965-66.

	New York City Lost Consumer Surplus		Upstate New York Lost Consumer Surplus	
	Apartments	Single-family Units	Apartments	Single-family Homes
Number of Units	2,541,173	346,426	71,200	91,300
Market Value (avg.)	$12,400	$27,300	$15,200	$40,700
Occupants (avg. no.)	2.6	3.3	2.6	3.5
Water Use (gpd)	171	260	183	295
Total Use (MGD)	435	90	13	27
Drought Reduction (%)	30	30	17	17
Price per 1000 gal.	$ 0.40	$ 0.40	$ 0.40	$ 0.40
Lost Consumer Surplus (¢/unit/day)	3.07	5.41	1.618	1.106 (3.106)
Total Annual Loss ($ million)	25.9	6.3	1.0	0.369
Reduced Water Cost (¢/unit/day)			1.24	2.00
Total Reduced Costs ($ thousand)			327.0	666.0

Upstate Consumer Losses

In addition to supplying the City, the Bureau of Water Supply also wholesales water to the upstate counties of Ulster, Orange, Putnam and Westchester. In 1965, an estimated 628,000 upstate people were supplied 72.2 MGD from the New York City system. Most of this water (94 percent) went to Westchester County which was used as the data base to estimate the economic costs of the drought in the upstate service area. Water use in the county is predominantly for residential purposes. Industrial and commercial water use is only about 10 percent of the total supplied.

For metered service areas on public sewers, such as Westchester County, the demand function for lawn sprinkling water is (Howe & Linaweaver 1967):

$$q_s = C(W_s - 0.6r_s)^{2.07} P_s^{-1.12} V^{0.662}$$

where q_s = average summer sprinkling demand in gpud

C = constant to fit the function to a specific area

P_s = water cost (cents/1000 gal)

V = market value of the dwelling unit

r_s = inches of precipitation for June, July and August, and

W_s = inches of potential evapotranspiration for June, July and August estimated by the method of Thornthwaite and Mather. For Westchester County P_s = 40, and V = $40,700. The constant C is 6.79.

According to this, in the summer of 1965 the demand for sprinkling water would normally have been 317 gpud or 28.9 MGD for the upstate service area. This defines the demand function

$$P_w = 6854q_s^{-0.893}$$

In 1965, the actual sprinkling use was 96 gpud or 8.8 MGD. The willingness to pay for the water use foregone is estimated at 14.1 cents per day per dwelling unit. The loss of consumer surplus was 5.2 cents per day per dwelling unit and the reduction in water costs was 8.8 cents a day. The reduction in the cost of water to consumers was absorbed by the water utilities as a loss of revenues.

In Westchester County in 1965 there were an estimated 221,000 cars which were washed an average of 10 times each year. The ten commercial car washes in the county accounted for 345,000 car washings. (There were no restrictions on water use by commercial car washes in upstate counties. This leaves a potential of 1,856,010 private car washings which were banned. The lost consumer surplus is estimated at $914,000. The reduction in water use of 1.5 MGD resulted in reduced cost to consumers or a loss of revenues to the water utilities of $75,000.

During the drought, the domestic consumption in the City-supplied upstate service area was reduced by 7 MGD or 17 percent. This resulted in a loss of consumer surplus of $100,000 for apartment dwellers and $369,000 for private homeowners. There was a saving in water costs to private homeowners of $666,000.

Other Goods in Short Supply

Fire Hydrants - Although illegal fire hydrant openings were curtailed during the drought, hydrant spray caps were still available. Therefore, there was no loss of public good.

Ornamental Fountains - The loss of benefits associated with dry ornamental fountains is difficult to measure. The utility of a fountain is aesthetic and a function of fountain design and the number of people who draw pleasure from it each day, parameters not easily measured. The minimum benefit of water used for an ornamental fountain would be the cost of supplying that water. The meter rate for water in New York City was $700 per million gallons. This yields a minimum value of $350 a day or $128,000 a year for the water used in ornamental fountains, and is the assumed surrogate for the loss of benefits associated with the ban on water for the fountains.

Air Conditioning - There was a reduction in the air-conditioning good, although no significant loss of comfort. For ambient temperatures below 95°F, the systems are overdesigned and will provide adequate comfort even if limited to 12 hours a day of operation. The average temperature for the summer of 1965 was about 2°F below normal and only one day exceeded 95°F. Electrical shortages on extremely hot days have a more pronounced effect on air-conditioning efficiency than water use limits.

Public Golf Courses - During the drought, the use of water for sprinkling municipal golf courses was curtailed and consequently the greens and fairways became browned. This diminished quality but did not reduce the supply of the golf course good. In an average year, about 900,000 golfers use municipal courses. During the drought in 1965, the number of golfers was about 892,000. Thus, the poorer quality did not appear to have affected benefits.

Unaccounted Costs

There were several drought responses for which no cost estimates were made. These were the public education campaign and the reduced flows in the Delaware River. The success of the conservation campaign on residential consumption was a result of the intense public education effort of the city. Leaflets were distributed to consumers, and the press, radio and television were enlisted to publicize the crisis. With the exception of the leaflets, however, there was no incremental cost to the mass media for broadcasting the drought story. They would have had the same costs for broadcasting news, whether or not the water shortage was included. Therefore, there is no cost assigned to the public education campaign. Certain water uses were curtailed not only to save water but also to help promote the idea of crisis. These were highly visible uses such as ornamental fountains and watering golf courses.

One of the responses made to the drought of the sixties was a temporary reduction in downstream releases to the Delaware River. No attempt has been made to estimate any economic losses related to the lower streamflows. However, there were no significant economic costs which could be directly assigned to the low streamflow. There were two extensive fishkills in the lower Delaware River in mid-May of 1965 due to the depressed levels of dissolved oxygen. This was, however, apparently an isolated occurrence. The low streamflows allowed the saltwater wedge of the Delaware estuary to move seriously close to the Philadelphia water intake. But the chloride content at that point remained within water supply standards of the US Public Health Service. These drought experiences indicate that conditions approached significant losses either to fish life or to the water supply of Philadelphia and demonstrate the need for the downstream releases from the New York City reservoirs.

Other costs not measured are even more elusive. They include the psychic value to community members gained when they have helped alleviate a crisis or the psychological unrest when a basic human need is in short supply. These and other such costs are important to the welfare of individuals and no doubt influence decision makers, although they are beyond the scope of this study.

Summary and Implications

Many formally organized activities are directed toward avoiding risk and gaining at least the appearance of certainty and security. Such activities as the national defense establishment, social security, insurance companies and pension funds account for a large percentage of our productive capabilities. They are efforts to establish a minimum framework of certainty and represent a desire to cope with an uncertain and a rapidly changing world. Only infrequently, however, is any attempt made to measure how much is sacrificed to gain the security these efforts attempt to guarantee.

Attempts to gain certainty and avoid risk are also evidenced in water resources planning. Such concepts as safety factors in design, the maximum probable precipitation in flood control studies and safe yield in water supply planning are common practices to cope with uncertainty.

This particular study has made an effort to more closely analyze risk aversion in public water supply. The intention has been to disclose the economic implications of a water supply policy tightly constrained by risk aversion. It is felt that the singular policy of risk aversion has resulted in water supply plans for New York City with insurance premiums which are out of proportion to the possible costs of natural catastrophies. The study, by actually estimating the economic costs and probabilities of a water supply crisis in New York City, offers an alternative policy which gives a closer balance between the costs of avoiding risk and the costs suffered if a water supply shortage occurs. This alternate policy, while it does require risk acceptance, does not completely ignore risk aversion. The probability of an inordinately severe water supply crisis in New York City is still avoided.

The amount of water naturally available for water supply varies over a considerable range from year to year and season to season. Storage facilities reduce some of the variation but transpose the remaining variation into uncertainty about supply from the storage system. One approach for coping with this range is to ignore the possible variation and to concentrate on the minimum amount the system would yield under the worst of natural hydrological conditions. This leads to the current definition of safe yield which is the maximum defendable quantity of water which could be produced by a system with a repetition of the severest drought of record.

While this definition gives adequate information for planning and management, it gives rather incomplete information. It only tells how much water is available under the worst conditions. It does not tell how much water may be available 99 percent of the time.

Information is available about how much water can be expected from the New York reservoir system all of the time, not just one percent of the time. This information can be displayed as a probability distribution of supply and gives the percentage of time a given level of supply will be equaled or exceeded. One probability analysis indicated, for example, that the New York City reservoir system will supply the safe yield or more 99.9 percent of the time (see Merkens 1974).

Information other than about natural hydrology and storage-yield relationships is required for water supply planning. Much of this must be estimated or assumed: the populations to be served, the amount of water they will consume, and the benefits associated with that consumption. This study went well beyond previous studies and estimated the level of benefits associated with given consumption levels, present or forecast.

It is very difficult to measure the economic benefits flowing from a given level of water usage. There are many singular and interrelated uses for public water supply and many secondary benefits. This study has avoided the definition of fixed requirements and has developed information about water supply benefits. No attempt was made to measure the total of water supply benefits. Only those lost during a water supply shortage were identified and estimated.

By avoiding the use of inviolable requirements and using benefits instead, a study can explicitly allow for water supply shortages which will shrink consumption and benefits. There are several facts which suggest that the normal level of consumption and benefits can be reduced, at least on occasion. The most basic is that New York City and other water supply systems have experienced water supply shortages with consequences considerably less than catastrophic.

A second fact which allows shortages recognizes the many uses of water supply. Some, such as fire fighting must be supplied without question. Others are normally inefficient, have available substitutes for public water or can be sacrificed for short periods. Previous research has given estimates of demand curves for some uses of public water supply. The estimated elasticities of demand indicate that these uses are not totally inelastic; their consumption level can be contracted in response to price or to shortage.

Using an accounting methodology, it was estimated that the cost of the drought (loss of benefits) in the June, 1965 through May, 1967 drought period in the New York metropolitan area was $73 million. Of this, 10 percent was absorbed by the Bureau of Water Supply, 10 percent by the intermediate producers and 80 percent by residential consumers. The cost for the drought for the one year duration, June, 1965 through May, 1966, was $51 million. This loss of benefits may seem costly, but in comparison to the cost of proposed projects to avoid future losses, it is not great.

Risk Acceptance[1/]

With the greater information made available about the supply capabilities from the New York City reservoir system and the loss of benefits resulting from a water shortage, it is possible to develop a plan which accepts risk. Such a plan is important of itself and to make known the economic implications of risk aversion. The intention in developing such a plan is to demonstrate that by accepting some risk, it is possible to delay the required timing of projects and reduce the present worth of project costs.

Merkens, for example, developed a capacity expansion model which allows for water supply shortages for the New York metropolitan area. This model sought to find the project timing which minimizes the total present value of annual project costs and expected annual shortage costs. Each year a given project is delayed, the present worth of annual project costs is reduced. However, each year the consumption levels increase with a given level of supply, the expected costs of water shortage are increased. The expected loss of benefits in any given year, T, is $E_T(L_T)$ which is approximated by

$$E_T(L_T) = \sum_{s_T=0}^{98} \text{Prob}\ (s_T \leq S_T \leq s_T + 2) \cdot L_T(s_T + 1)$$

where s_T is a shortage of s percent, and $L_T(s_T + 1)$ is the loss of benefits or the costs of a shortage of between s and s + 2 percent. Prob $(s_T < S_T < s_T + 2)$ is the probability of a shortage of between s_T and $s_T + 2$ percent with the existing facilities. This information comes from the probability distribution of supply for the New York City reservoir system.

The timing which resulted from the initial capacity expansion analysis was found unacceptable. The magnitude of a possible shortage in some years was greater than the shortage experienced in the sixties drought. Moreover, the frequency of possible shortages was unacceptable. The resulting solution gave a proper balance between expected drought losses and project costs. However, because the costs of projects to expand the New York City system are so great, the expected losses, the associated probability of shortages and the possible magnitude of shortages were great.

Therefore, two constraints were introduced. One limited the maximum percent shortage which can occur to about 20 percent or the level of shortage experienced in the 1965-66 drought. The second limited the frequency of

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1/See also P. W. Merkens, "Risk Acceptance," pp. 149-76.

large shortages by constraining the probability of a shortage greater than 1.5 percent to 0.1 in any year. This constraint was designed to give assurances to system managers. The constraint gives 90 percent reliability that no shortage greater than 1.5 percent of normal consumption will occur in any year.

The results with the two added constraints showed that the required timing of the first project in the risk-acceptance plan is 1991, versus 1985 for the no-risk policy. More importantly, the long-range plan based on risk acceptance does not require as much reservoir storage capacity. The total present value of expected shortage costs and annual project costs in the risk acceptance plan is $196 million and the capital costs, $885 million. The no-risk plan has a present value of project costs of $314 million and capital costs of $1.1 billion.

Demand Management and Universal Metering[1]

In public water supply, the most significant approach to reducing risk is demand management. Metering is essential for any form of rational pricing arrangement and to properly allocate the costs of water supply. In New York City, only the industrial and commercial accounts or 25 percent of the water supplied is metered. The rest of the accounts pay on a flat-rate basis. This situation exists even though universal metering in New York continues to be recommended by many studies by both state and federal agencies.

The City has apparently felt that the large number of apartment dwellers who would not be metered directly would make metering only marginally effective in reducing consumption. However, Merkens demonstrated that metering would be effective and that other large cities with universal metering have considerably lower consumption per capita. Also water waste in buildings and leakage from distribution lines would be detectable with metering.

Universal metering in New York City would reduce total consumption by 15 percent. This was determined from a linear regression analysis which related per capita consumption of water to the percent of residential consumers directly metered. This regression gave a high degree of statistical significance to the reductions possible.

The consumption levels forecast for the New York metropolitan area were adjusted to reflect the assumed effect of universal metering. The capacity expansion model was then rerun with some adjustments in the shortage loss functions. It was found that the loss of benefits from a given shortage were greater when metering was assumed. This is to be expected as metering reduces the inefficient uses of water which can be easily abated in response to a shortage.

The resulting capacity expansion plan with metering included the same combination of projects as the risk-acceptance, no-metering plan. However, the timing of the first project is delayed from 1991 until 2006. The total present value of the risk-acceptance metering plan, project costs, metering

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[1]/See also P. W. Merkens, "Risk Acceptance," pp. 177-221.

costs and expected shortage losses is $128 million. This compares with $196 million for the risk, no-metering plan and with $314 million for the no-risk, no-metering plan.

In order to determine which of the assumed parameters has the greatest effect on the capacity expansion plan with metering, a sensitivity analysis was performed. This showed that a 10-percent increase in forecast consumption would require the first project by 1995. This is still 10 years later than the no-risk, no-metering plan. It was also found that the analysis is not particularly sensitive to the shortage loss functions derived from the estimated costs of the 1965-66 drought. A 10-percent increase in the shortage costs would not change the timing of required projects and the total present value would only be increased by 1.1 percent.

Conclusions

The obvious conclusion which can be drawn from this study is that a plan which accepts risk delays the required timing of projects without incurring unacceptable losses. This reduces the urgency often associated with water supply in New York City. Further implications of risk acceptance are displayed in the following table:

Table 4. Summary of Risk Policy Costs and Water Project Timing With and Without Metering, New York City.

Risk/Metering Policy	Timing First Project	Present Value of Costs 1/	Annual Premiums No-Risk
		($ Million)	
Averse/No metering	1985	314	9.7
Averse/Metering	1985	316	15.5
Accept/No metering	1991	196	-
Accept/Metering	2006	128	-

1/Includes present value of water projects and present value of expected shortage costs.

The annual premiums of the risk-aversion policy attempt to display the economic implications of risk aversion in one number. The difference in present value between the no-risk and risk-acceptance policies is viewed as the implied premium that risk averters are willing to pay to avoid shortages. This difference was spread out over the planning horizon through the use of equivalent annual costs to determine the annual premiums.

With the risk-acceptance, no-metering policy, the maximum possible annual shortage losses are $73 million. In other words, the risk aversion policy (no metering) requires annual premiums of about $10 million for a 46-year period to avoid a maximum possible damage in any year of $73 million.

Comparing the risk-aversion and risk-acceptance policies which include metering, the implied annual premiums are nearly $16 million to avoid a maximum possible damage in any year of $83 million.

When it is realized that the New York City water supply system serves more than 8 million people, a $16 million annual premium does not appear significant, amounting to less than $2 per person per year. Yet, the loss of consumer benefits for a one-year period during the sixties drought (a very rare event) was only about $5.10 per person.

The risk-acceptance metering policy has a total present value 60 percent less than the risk-aversion metering policy. In terms of benefit cost analysis, it is difficult to justify the risk-aversion policy. A policy which explicitly recognizes and accepts risk has greater economic efficiency because it makes extended use of the existing facilities. A risk-acceptance policy delays new projects and allows the probability of shortages to increase, but also increases the percent of time an existing level of development will be used at near its hydrologic capacity.

The risk-acceptance policy developed does not obviate the need for further water supply investments in the New York area. It does, however, delay the required timing of projects, makes more efficient use of existing facilities and reduces the present value of project costs. By delaying the required timing of projects, new options are opened to planners and managers.

The greater time available can be used to refine the elements of imperfect information, particularly information about water consumption forecasts and benefits. It also gives further time for the advancement of water supply technology. Presently, there are some emerging technologies such as waste water recycling which are on the threshold of becoming technically and economically practical.

The delay in project timing and required fixed investments will avoid a self-fulfilling prophecy. The National Water Commission has stated that there is no inexorable reason why per capita water consumption should continue to rise. Yet, historical consumption patterns in New York City exhibit a fairly constant increase in consumption even though population levels in the City have stabilized. Much of this increase is no doubt due to economic improvement and growth.

Yet, there remains the possibility that assured levels of supply have contributed to increased consumption. New York City does not have a formal distribution-leak detection program and cannot do a thorough job of leak detection without universal metering. Seventy-five percent of the water delivered to the City is paid for on a flat-rate basis. The price of water service in the City remained the same for thirty years until the mid-sixties drought. The City has resisted universal metering since 1860. All of these factors betray a management orientation which relies on continued levels of assured supply. A risk-acceptance policy which explicitly fixes the level of supply should inspire a serious reevaluation of this orientation.

Requirements of a Risk-Acceptance Policy

If a policy of risk acceptance in public water supply is to be implemented, some planning and management changes will have to be made. These changes will make risk acceptance more palatable and limit the risk to advertised levels.

Criticism should be expected in any future shortage. A risk-acceptance policy will not be viable if limited criticism forces premature construction of projects. Managers should be able to understand criticism and write it off as another cost of a shortage. Criticisms from a shortage could be minimized through public education. The probability of shortages should be made known along with information about the possible magnitude and the required shortage responses. The economic and efficiency advantages and the allowed delay in projects should be advertised.

The concept of rigid requirements might well be relaxed and replaced with the concept of consumer benefits. Managers should view public water supply as an industry which supplies many goods, some rather basic and some not totally inelastic. It is easier to accept the possibility of a shortage if it is seen as a temporary sacrifice in benefits rather than an inability to meet requirements. The potential of universal metering to this end has already been demonstrated. Leak detection programs and pricing directed toward demand management would further improve efficiency and reduce risk. Drought forecasting could be used to signal when further conservation measures are warranted. In other words, the risk policy being advocated should include action to make risk acceptable, not inevitable.

The process of project implementation must be streamlined to make risk acceptance viable. It has been argued that the apparently inevitable delays in project construction are really a form of risk policy. However, this is not an explicit pattern of risk acceptance. There is no true programming for risk, the probabilities of shortage are unknown and required shortage responses have not been developed. Rather, when faced with delay there is a real temptation to propose oversized projects to be sure they are adequate when finally available.

The essence of a risk-acceptance plan is a series of measured responses to keep risk within certain limits. The responses must be available when planned. This requires a reduction in the expected time lag for project implementation.

Risk acceptance and the associated implications will be better appreciated if water supply planners and managers expand their perceived sphere of influence and responsibility. The region affected by water supply facilities is not just the supply service area, it includes the source and potential source areas. In this greater region there are many valid uses for water and other natural resources. Water supply should be taken as a high priority but not preemptive use. Risk acceptance is a trend in this direction.

The required investments for public water supply are allocated from a fixed public budget. A matrix of other public functions must also be financed from this budget. A recognition and understanding of the total demands made on the fixed budget will promote the possibility of delaying water supply investments.

Water supply planners and managers should also expand their sphere of responsibility to foster relations with ecology and conservation groups. There is a growing suspicion in society that unfettered development may not be the most sensible avenue to continued well-being. A public investment policy which includes conservation measures such as metering and which delays major developments through risk acceptance will be consistent with this thinking.

More importantly, a policy which delays development will give needed time for the discussion of possible alternative futures. A public decision for risk acceptance which recognizes, allows and solicits possibilities is to be encouraged.

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