POSSIBLE ENERGY SAVINGS IN THE EAST BAY MUNICIPAL UTILITY DISTRICT'S WATER SUPPLY SYSTEM AS A RESULT OF WATER CONSERVATION BY CONSUMERS

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For many people, the consumption of water begins as the liquid flows from the faucet, and ends immediately after the flow is extinguished. The complex process by which water is processed and delivered often remains a mystery to the consumer, to be questioned only when the monthly bill for service arrives. The majority of today's water consumers fail to realize that large amounts of energy are required to pump and treat a municipal water supply, and that energy requirements represent the bulk of the costs of supplying water.

In the past, because of relatively inexpensive energy costs--largely owing to California's abundant hydroelectric resources and the low cost of fuel oil--there has been a lack of concern regarding the process by which water is distrituted. Thus, the low cost of electricity, coupled with a consistent and plentiful rate of precipitation, has helped to keep demand for water, and hence for electricity, high. Recently, however, rising energy costs and a drought (1976-77) have caused local municipalities such as the East Bay Municipal Utility District (EBMUD) to reconsider the importance of energy consumption within the water distribution system. EBMUD has responded to these events by implementing energy conserving practices (Mizuno, 1982).

Although the rise in oil prices that accompanied the recent political instability in the Middle East has for the present subsided, and even though the amount of rainfall received in the last two years has been more than adequate, the water available for use in California and the cost of distributing the supply remains subject to two unpredictable phenomena--political unrest in the Middle East and changes in climatic patterns. Furthermore, EBMUD's 1980 consumer population of 1,058,000 customers is expected to reach 1,214,000 by the year 2000. The gross water demand for the year 2000 has been estimated at 246 MGD (million gallons per day) compared to 193.5 MGD in 1980 (EBMUD, 1982b). Given these projected increases, EBMUD will be required to supply greater volumes of water in the future. In order to meet the future increase in demand, greater amounts of energy will be required throughout the system. Therefore, if EBMUD hopes to continue the reliable and cost-effective service it has given in the past, an energy-efficient water supply system relying on efficient end use of water should be established.

Objectives

In order to assess the possibilities of energy conservation as a result of water conservation within the EBMUD system, one must first uncover which components of the system contribute most to energy consumption, and then consider how water conservation might affect energy use. An analysis of EBMUD's entire operating structure is beyond the scope of this study, which will focus on that portion of the system serving the City of Berkeley. The results determined for Berkeley will then be used to make a rough estimate of the potential savings within the entire EBMUD system.

As a result of the topography of Berkeley, as well as the city's water consumption patterns, practically all of today's state-of-the-art methods for water distribution and treatment must be used in order to accommodate the relatively large demand for water. The City of Berkeley represents approximately 8% of the total water supplied by EBMUD in calendar year 1982 (EBMUD, January 1983). The majority of Berkeley's water consumers--approximately 60%--fall under the category of "Residential Users", as do most of EBMUD's total customers. (The entirety of EBMUD's residential sector represents approximately 60% of the total water consumed within the EBMUD system.) The topography of Berkeley is in many respects similar to that found in the majority of areas served by EBMUD. Water must be distributed to flat, low-lying areas as is the case in the Berkeley flatlands, as well as to the higher elevations in the Berkeley Hills. Berkeley is therefore representative of the "average" city depending on EBMUD for its water supply and provides a suitable area to examine concerning the methods of water distribution used.

The EBMUD System

Water for the EBMUD system comes mostly from the Pardee Reservoir, located approximately ninety mi s east of Walnut Creek on the Mokelumne River in the foothills of the Sierra Nevada. The water is transported via three aqueducts, primarily by means of gravity flow, across the San Joaquin Valley to three large pumping plants in Walnut Creek. From there the water is distributed through a system of just over 100 pumping plants, 200 storage facilities, 9 filter plants, 5 major reservoirs and a large number of flow controls, rate control stations, pressure regulators, check valves and other components too numerous to mention here (Figure 1). After the water has been used, or degraded, it is transported by the various cities served by the system to a central "interceptor" through which the water is relayed to EBMUD's treatment plant, Special District No. 1 (SDL), for final treatment before being released into San Francisco Bay.

Two portions of the system contribute most to energy consumption. Distribution and waste water treatment accounted for 89% to 85% of the total dollars spent on energy during fiscal year 1981-82 (Table 1). "Distribution" consumes energy in the treatment of water at the filter plants

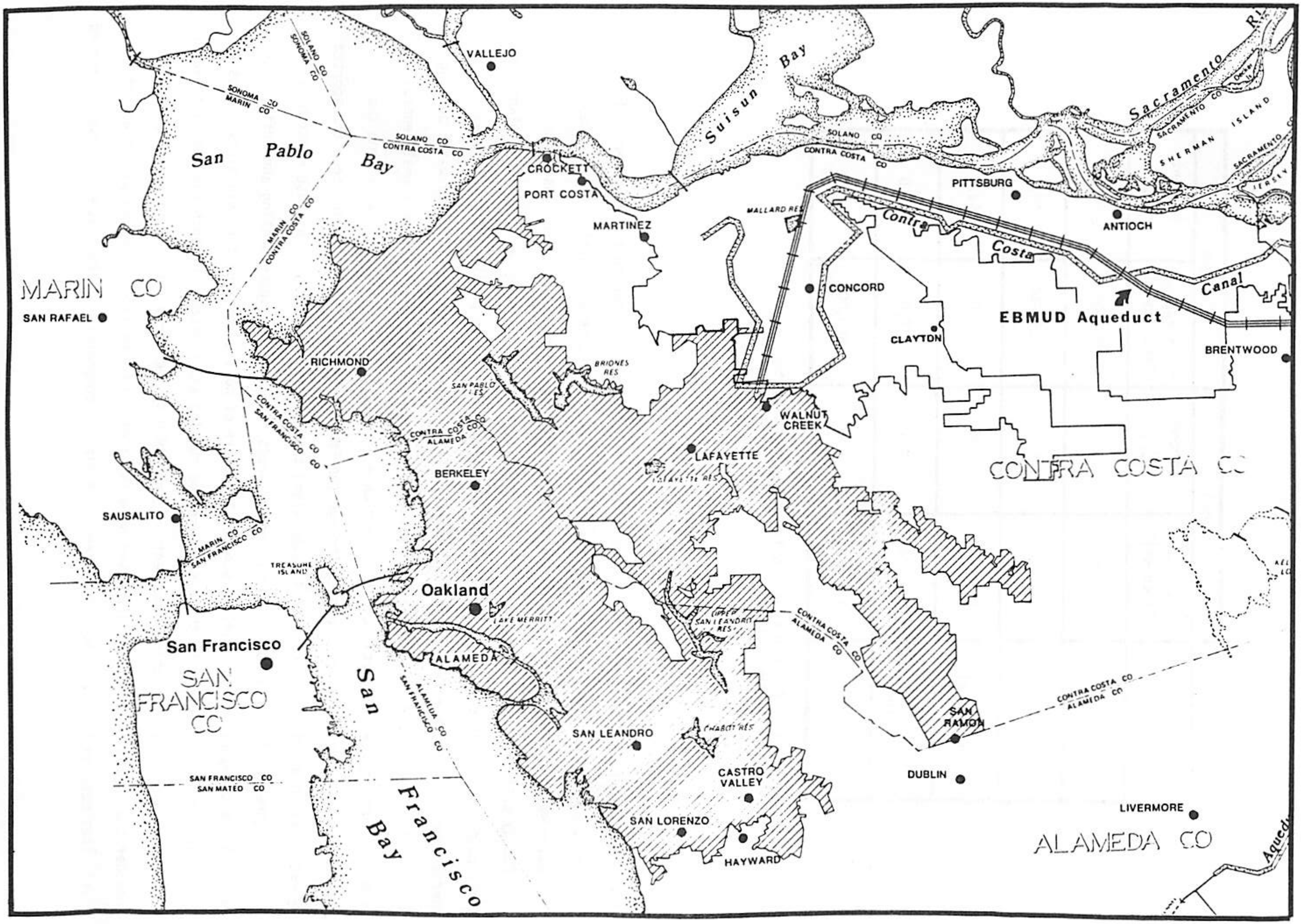

Figure 1. East Bay Municipal Utility District Service Area (shaded).

Sector	1980 Total Energy Expenses($)	1980 Percent of Total	1981 Total Energy Expenses($)	1981 Percent of Total
Raw Water Pumping	552,000	10.2	361,000	6.0
Distribution	2,231,000	41.3	2,725,000	43.0
Special District #1	2,186,000	40.4	2,724,000	43.0
Wastewater Pumping	109,000	2.0	118,000	2.0
Audited Support	319,000	5.9	360,000	6.0

Table 1: Gas and Power Costs in the EBMUD System.
Source: EBMUD, 1983.

prior to delivery, and includes energy used in pumping the treated water to the consumer. (For further insight into water treatment see Steve Shankland's paper, this report). SD1 is EBMUD's sole waste water treatment plant and accounts for 40% to 45% of the total energy costs.

Energy costs for pumping water other than that which has been treated at the filter plants are small owing to the large role played by gravity in transporting this portion of the supply. The energy required to pump water to the filter plants falls under the category of "raw water pumping," which in 1982, accounted for only 6% of total energy costs. Again, the relatively small energy needs for pumping raw water reflects the importance of gravity in transporting water from the Mokelumne River. Waste water is pumped through the EBMUD system only after having been transported by each city to a main "interceptor" located along the margins of the bay. This use contributed only 2% to the total energy costs. Minor energy needs for lighting, space heating and coffee pots fall under a category called "audited support," and are of no significance for this study. Thus, the major end uses of energy in the system are the pumping and treatment of both raw and waste water.

In order to determine which components of the EBMUD system serve the City of Berkeley, one must consider the complex and highly integrated network of distribution lines, pumping plants and filter plants that make up the distribution system. The various components of the system are not restricted to a specific region. For example, in the case of malfunction or maintenance requirements, a filter or pumping plant that normally serves Berkeley, might be required to serve Alameda as well. For this reason difficulties arise in the attempt to pinpoint exactly which components serve Berkeley. Therefore, any component that offers the potential to serve Berkeley has been included in the study.

In order to determine the total amount of energy required to process, and subsequently distribute, a given volume of water to and from the City of Berkeley, it is first necessary to calculate the energy requirements within each of the various components. To facilitate this task, the system has been divided into three separate components, which include the various pumping plants, the filter plants, and the waste water treatment plant, SD1. In the sections that follow, each component is examined separately.

Filter Plants

San Pablo and Orinda FIlter PLants are the two facilities that serve Berkeley with potable water. Their energy use ranges from 21 kilowatt-hours per million gallons (KWH/MG) at the Orinda Plant to 123 KWH/MG at the San Pablo Plant (Figure 2). These amounts of energy consumed, described in equation 1, were calculated using available data for monthly flows of both water and electricity at the two filter plants (EBMUD, 1983a).

$$\text{Equation 1: } \frac{\text{Total flow of energy through system (KWH/month)}}{\text{Total flow of water through system (MG/month)}} = \frac{\text{KWH}}{\text{MG}}$$

The energy requirements for the two plants differ greatly because although the Orinda Plant treats a larger volume of water, both plants must be in constant operation whenever possible. Therefore, the ratio of energy to unit volume of water used by the San Pablo Plant is much greater than that used by the Orinda Plant. As might be expected, the rate of energy used varies greatly from month to month, depending upon demand.

Special District No. 1

The energy requirements for treating waste water at SD1 vary, as a function of time, to an even greater extent than those at the Orinda and San Pablo Plants. The average energy used is 1545 KWH/MG-- a substantial quantity. Because monthly flows for electricity and water are available, Equation 1 was also used to determine the energy requirement at SD1. The energy use at SD1 has a more cyclical pattern than does that of either the San Pablo or Orinda Filter Plants (Figure 3).

Figure 3 shows that more energy is required per unit volume in the dry, summer months than in the winter months when rainfall is frequent. During the rainy season, SD1 treats as much of the run-off as possible, with capacity constrained by thedesign capacity of 290 MGD. In the winter months wastewater flow to SD1 often reaches this maximum capacity. Because it is economically and technically not feasible to shut down equipment regardless of fluctuations in flow, and since flows of water are significantly

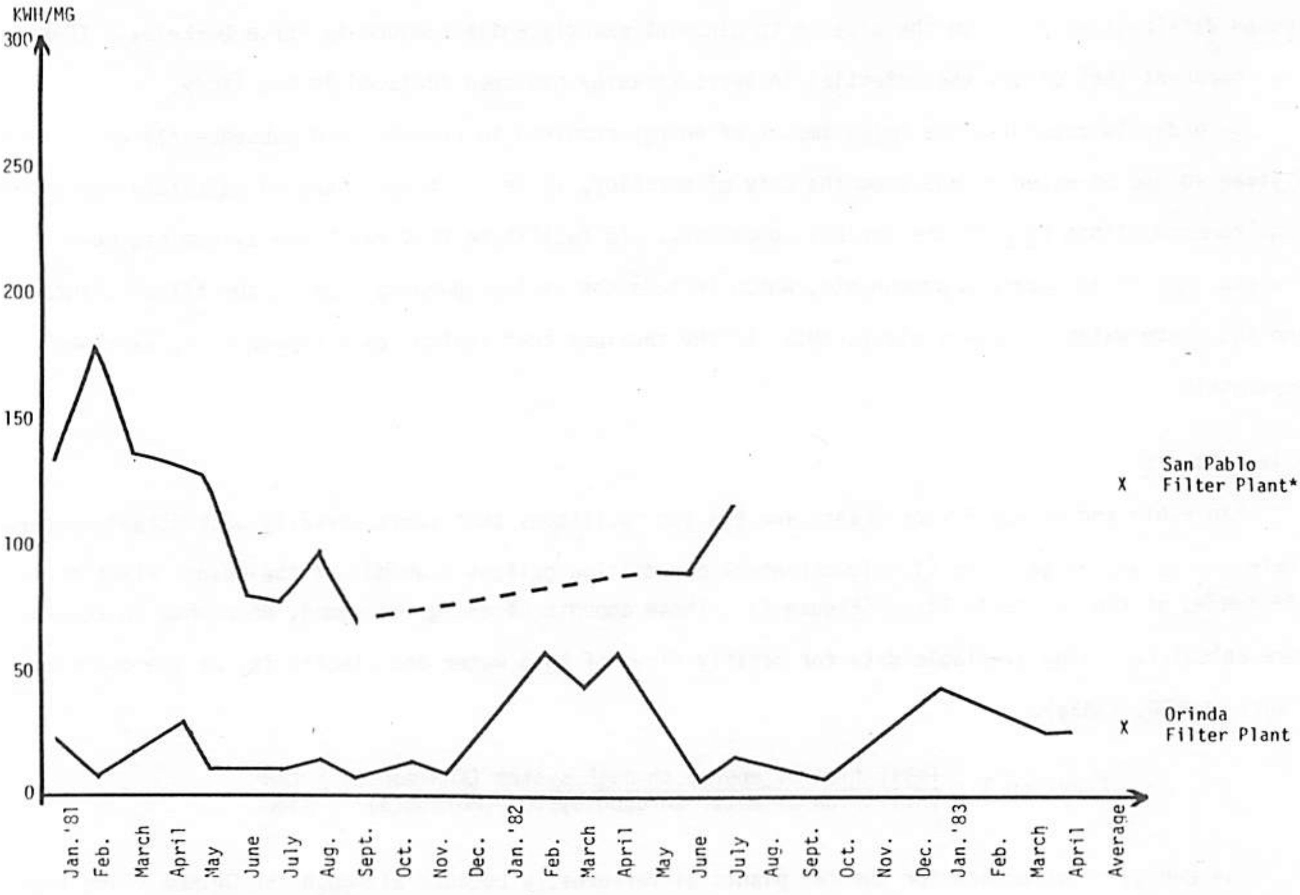

Figure 2: Energy Consumption at the Orinda and San Pablo Filter Plants.

Source: EBMUD, February 1983.

*Dashed portion of curve represents those periods when the plant was not operating and should not be taken as a projection of energy requirements under operation.

greater during the winter, the ratio of energy to unit volume of water processed is greater in the summer months. The large variation in flows treated at SD1 arises due to differences in end use of water by consumers during the two seasons. There is an increase in demand during the summer of approximately 20% owing to lawn and garden watering. Therefore, because a large portion of the increased demand absorbs into the soil rather than being treated at SD1, the proportion of energy used during the summer increases.

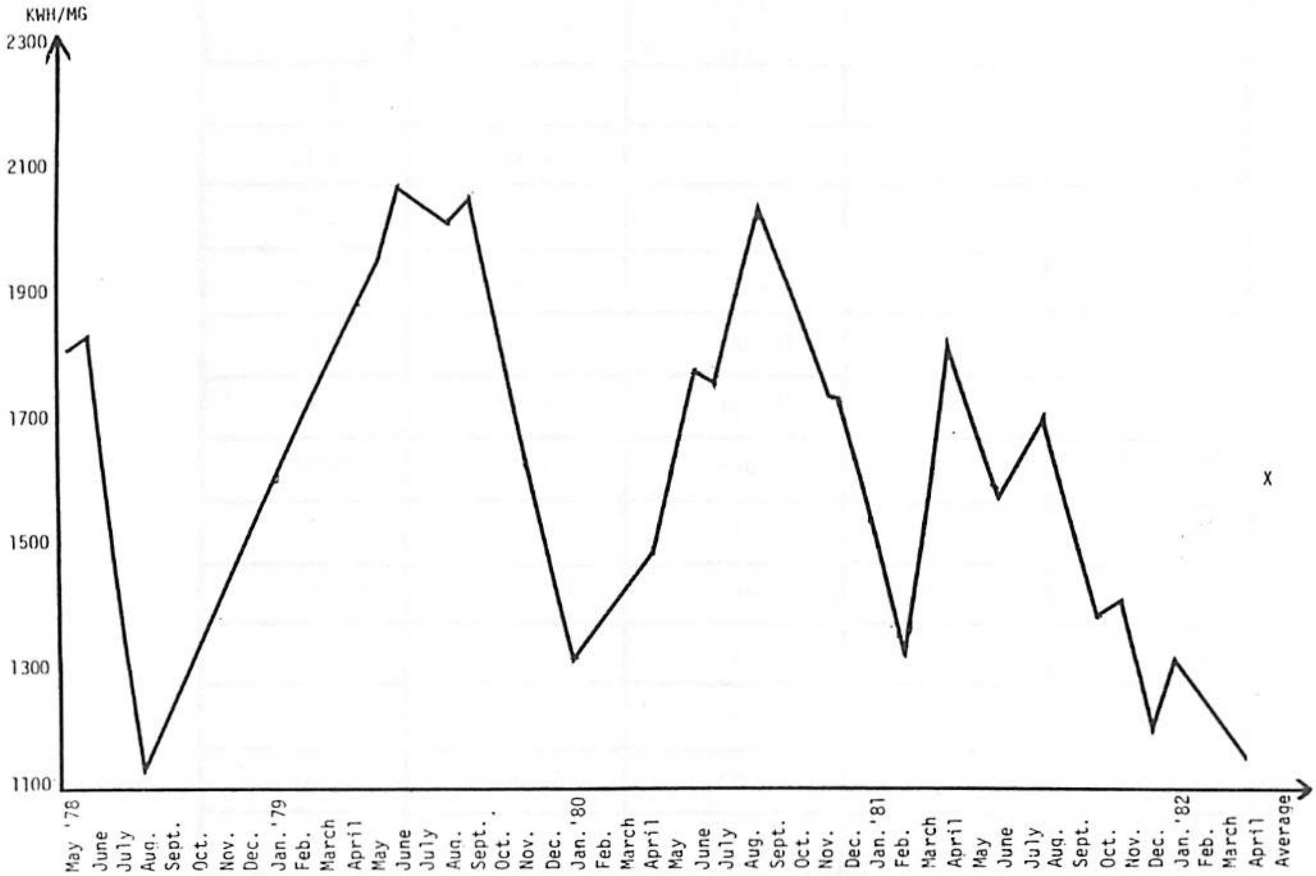

Figure 3: Energy Consumption at Special District No. 1.

Source: EBMUD, May 1978-April 1982.

Pumping Plants

Seventeen pumping plants serve the City of Berkeley (Table 2). Their average energy use ranges from 1525 KWH/MG to 8765 KWH/MG (Table 2). Energy use per unit volume of water for the pumping plants can be calculated from data on average cost per kilowatt-hour paid by EBMUD to Pacific Gas and Electric Co., the total number of dollars spent on electricity, and the total flow of water through the system as follows:

Pumping Plant	Total Volume Pumped (MG)[a]	Total Cost of Electricity[b] ($)	Total Energy Consumed (KWH)	KWH/MG
Amito	114.91	8846	121,178	1054
Arlington	141.91	10,851	148,643	1048
Berkeley Hills	0.04	286	3917	97,945
Berkeley View	118.85	12,636	3095	1456
Berryman	378.05	44,325	607,191	1606
Berryman North	178.03	11,741	160,835	903
Berryman South	723.90	57,068	781,753	1079
Berryman West	c	c	c	c
Gwin	43.49	43,490	595,753	13,698
Shasta	316.60	44,497	609,547	1925
Strathmoore	48.93	5916	81,041	1656
Summit East	d	1203	16,479	d
Summit North	140.23	17,319	237,246	1691
Summit South	797.04	137,592	1,884,821	232
Summit West	547.98	153,340	2,100,547	3833
University	8.26	1092	14,958	1811
Woods	226.02	25,297	346,534	1533
Average KWH/MG consumed:		1525*-8765		

Table 2: Pumping Plants Serving the City of Berkeley

Source: EBMUD, 1982a.

a) Figures are for June 30, 1981-June 30, 1982.
b) Figures are for June 30, 1981-June 30, 1982.
c) Plant not in service during this time.
d) Pumping to maintain water pressure, but no flow of water.

* Does not include Berkeley Hills and Gwin Pumping Plants.

Equation 2: $$\frac{\text{Total dollars spent for electricity}}{\text{Average cost per KWH}} \times \frac{1}{\text{Total flow of water through system}} = \frac{\text{KWH}}{\text{MG}}$$

It is interesting to note that the major contributors to energy consumption are those pumps that must overcome a substantial static lift in order to deliver their supply of water, specifically the Berkeley Hills and Gwin Pumping Plants. These two plants required approximately 100,000 KWH/MG and 1400 KWH/MG respectively, whereas plants located in the flatlands, such as the Berryman plants, required only 903 to 1606 KWH/MG. This raises the interesting question of whether rates for water consumption should vary depending upon elevation--an issue that is currently being debated by EBMUD, under pressure from various public interest groups.

Although differences in elevation set the Gwin and Berkeley Hills Pumping Plants apart from the other pumping plants, there are other factors that might explain the dissimilarities in energy consumption for pumping plants located at the same, or nearly the same, elevation. The most obvious is variations in pumping requirements. Those pumps that are needed to transport larger volumes of water consume greater amounts of energy. In addition, EBMUD has recently begun to replace the older pumps with more efficient pumps at a substantial savings. Thus, an equivalent volume of water is pumped, consuming significantly less energy.

But to what extent do the pumps located in other hilly locations outside of Berkeley account for energy consumption, and do they consume the same proportion of energy within their sectors as the Gwin and Berkeley Hills pumps? Since it is difficult to calculate the exact proportion, and because the Gwin and Berkeley Hills Pumping Plants differ so greatly from the remainder of the pumps serving Berkeley, a range of values is cited rather than an average for the total energy consumed. The lower limit of 1525 KWG/MG excludes Gwin and Berkeley Hills, and is representative of those pumps serving the flat, low-lying areas. The upper limit of 8765 KWH/MG includes the two and reflects the greater amounts of energy needed to pump water to the higher elevations. This range, rather than the average, is more precise in describing the energy consumed by the pumping plants; and in the attempt to estimate the energy used by the entire EBMUD system, these figures will give a more accurate determination of the energy consumed.

The range for the <u>total</u> energy required to pump, filter and treat one million gallons of water for the City of Berkeley is the summation of the various components analyzed above and equals 3215 KWH/MG-10,455 KWH/MG (Table 3). For comparison, 10,455 KWH is approximately equivalent to the energy contained in six barrels of crude petroleum. One barrel of crude is equal to 0.137 metric tonnes, or approximately 300 lb of oil.

San Pablo Filter Plant[a]	Orinda Filter Plant[a]	Special District No.1[b]	Pumping Plants[c]	Total
123	22	1545	1525-8766	3215-10,455

Table 3: Total Average Energy Needed to Process One Million Gallons of Water in the EBMUD System Serving Berkeley.

Source: a) EBMUD, 1982a.
b) EBMUD, May 1978-April 1982.
c) EBMUD, Jan. 1982-Dec. 1982.

Effects of Water Conservation on Energy Conservation

Given the above results, one can now proceed to determine the effect that water conservation might have on energy consumption within EBMUD's distribution-waste water treatment system, the extent to which water conservation could be realized within the EBMUD system, and whether the possible energy savings resulting from water conservation are significant. Fortunately, water conservation data are available as a result of the 1976-77 drought in California.

The year before the drought (1975) marked the highest annual gross water consumption on record at EBMUD--222 MGD (EBMUD, January 1, 1982). During the drought, EBMUD hoped to attain a 25% reduction in consumption (McCrea, March 1983). This level of conservation requires very few behavioral modifications in patterns of water consumption. The actual reduction was approximately 35% (McCrea, March 1983). As the situation worsened, and EBMUD was forced to regulate consumption within the various sectors, an additional 3% conservation was achieved for a total of 38%.

For the purposes of this report, two levels of water conservation, 25% and 38%, are used to calculate energy conservation. A 25% level is easily attainable without severe behavioral changes. At a rate of 38%, customers must dramatically alter their patterns of water consumption. The higher rate provides a theoretical calculation of possible energy savings--a result that is not at all unrealistic if intelligent decisions are made to curb the wasteful manner in which water, and hence energy, is utilized (see Lincoln Castro's and Eric Schaefer's reports, this paper, on water conservation).

In 1982, EBMUD supplied a total of approximately 7310 MG of water to the City of Berkeley (EBMUD, January 1982 - December 1982). At conservation rates of 25% and 38%, the savings can be substantial (Table 4). Although a range of 1525 KWH/MG to 10,455 KWH/MG is cited, this range could not be directly applied to the corresponding water savings within each component. Even though the total volume of water conserved can be thought of as water that would fail to pass through the filter and pumping plants, this is not the case for SD1.

Region	AT 25% WATER CONSERVATION				
	Volume of Water Saved[a] (MG X 10^3)	Revenue Saved From Electric Sources[a,b] (\$ X 10^3)	Revenue Lost From Treatment Charges[a,c] (\$ X 10^3)	Revenue Lost From Water Rates[a,d] (\$ X 10^3)	Net (\$ X 10^3)
Berkeley	1.8	130-560	960	1000	-(1400-1800)
Entire EBMUD System	16	1200-4800	8000	9200	-(13,000--16,000)
Region	AT 38% WATER CONSERVATION				
	Volume of Water Saved[a] (MG X 10^3)	Revenue Saved From Electric Sources[a,b] (\$ X 10^3)	Revenue Lost From Treatment Charges[a,c] (\$ X 10^3)	Revenue Lost From Water Rates[a,d] (\$ X 10^3)	Net
Berkeley	2.8	200-870	1500	2500	-(3100-3800)
Entire EBMUD System	24	1800-7400	13,00	14,000	-(19,000--25,000)

Table 4: Effects on Revenue at EBMUD as a Result of Water Conservation by Customers.

Source: a) EBMUD, January 1982-December 1982.
b) Derived using Schedule No. A-23: General Service-Time Metered, PG&E, Feb. 6,1983.
c) EBMUD, November 1, 1982.
d) EBMUD, May 1, 1979.

A substantial portion of water delivered to the consumer does not reach SD1. Much is lost to gardens, lawns, car washing and other water-related activities. For this reason one must determine the proportion of water treated at SD1, relative to that delivered by EBMUD to consumers. The average daily gross consumption during 1982 was 189/MGD (EBMUD, January 1983), and the average daily, dry weather, domestic and industrial waste water flow through SD1 for the same year was 82/MGD (EBMUD, January 1982). (The dry weather data are used here so as not to confound the flow of run-off during storms with flow due to consumption.) Thus, 43% of the total consumption in 1982 was treated at SD1. Accordingly, only 43% of the 25% and 38% of water conserved is reflected in energy savings at SDL. Although this percentage is derived from data for the entire EBMUD system, it will be assumed that it applies to Berkeley as well.

Conserving 25% in 1982 would have resulted in a savings of 3,980,000 KWH to 17,000,000 KWH of electricity in Berkeley. The savings at a rate of 38% water conservation approaches 6,100,000 KWH to 26,700,000 KWH. These are substantial savings. At an average cost of $0.03261/KWH paid by EBMUD (Pacific Gas & Electric Co., February 1983), these levels of conservation correspond to a savings of approximately $130,000 to $560,000 and $200,000 to $870,000 respectively. Going one step farther, one can now apply the energy savings calculated for Berkeley to the entire EBMUD system (Table 4).

At 25% water conservation, the entire system might save 16,000 MG of water per/year, 36,800,000 KWH to 147,000,000 KWH of electricity, and a corresponding dollar value of $1,200,000 to $4,800,000. A 38% water conservation level would result in a savings of 24,000 MG, 55,000,000 KWH to 230,000,000 KWH of electricity and 19,000,000 to 25,000,000 dollars.

Implementation and Feasibility

Although the savings in energy costs would seem to warrant immediate conservation practices, one must realize that the net savings to EBMUD would be sharply reduced if demand were actually reduced to such an extent. EBMUD customers are charged a fee for water delivered depending on the volume of water consumed. If water consumption is reduced, revenue received by EBMUD would be reduced as well.

In order to calculate the loss in revenue attributed to conservation, the average rate charged to the consumer must be derived. Rates charged to the Industrial, Commercial and Public Authority sectors tend to be extremely variable, and since the Residential sector accounted for approximately 60% of total consumption in 1982 (January 1983), the average rate charged to these customers is used.

The average "charge for water delivered" to the Residential consumer based on the monthly meter readings if $0.44 per 100 ft^3 (EBMUD, May 1, 1979). It is interesting to note that the consumer is charged less for monthly consumption over 50,000 cubic feet than for consumption of 49,500 cubic feet. This decreasing rate scale structure could, and probably does, provide incentive for increased demand, thus discouraging conservation (Table 5).

Volume(cubic feet)	Price($)
First 500	.38/100cu.ft.
Next 49,500	.50/100cu.ft.
Over 50,000	.43/100cu.ft.
Average	.44/100cu.ft.

Table 5: "Charge for Water Delivered".
Source: EBMUD, May 1, 1979.

As consumption in the City of Berkeley is reduced by 25%, the loss in revenue from rate charges is equivalent to:

$$(1{,}800\ \text{MG}) \times \left(\frac{100\ \text{ft}^3}{784.05\ \text{gals.}}\right) \times \left(\frac{\$0.44}{100\ \text{ft}^3}\right) = \$1{,}000{,}000.00$$

Table 4 gives the reduction in revenue from rate charges due to conservation by Berkeley, as well as the entire EBMUD system.

Because rates charged to the consumer for water treatment are also based on the volume of water delivered, the amount of revenue foregone as a result of water conservation can also be calculated. On the average, EBMUD customers are charged $.40/100 ft^3 for waste water treatment (EBMUD, November 1, 1982). Table 4 also shows the amount of revenue lost from water treatment rates. Although the above calculations are somewhat crude, they illustrate the fact that although substantial energy savings do exist, water conservation could very well result in a net loss in revenue, or at least a need to restructure the rate-making policy in order to offset these losses. All of the above losses in revenue might lead to some reluctance on the part of EBMUD to implement extensive conservation practices. EBMUD might also be allowed to sell the water rights for the conserved water to other interested parties and thus reduces its losses.

Aside from the fact that EBMUD may find itself on the losing end of a water conservation proposal, there are other equally relevant issues which should be mentioned, although their analysis is not the object of this report. One such issue concerns the economies of scale present within any large operation such as EBMUD. In order to realize the calculated energy savings, the equipment contained within the system must operate less. But to what extent does consumption have to be reduced before operating time can be reduced as well? This question is very difficult to answer, and there is much room for research in the area of operating efficiencies as a function of time. The problem is further complicated by the fact that EBMUD must supply water when demand increases. Although trends in consumption patterns are quite well established, it remains difficult to derive a reliable, efficient and economic solution concerning when and where to shut down a specific component in the system. Thus, a situation might occur in which water consumption is sufficiently reduced but energy consumption within the system remains constant.

There also exists the potential for increased unemployment if extensive water conservation practices are implemented. A large decrease in gross water consumption is likely to result in the eventual layoff of employees, who, owing to a decrease in plant capacity, are no longer needed. (Plant capacity refers to the amount of time a plant operates during a given period, and is defined as the total number of hours a plant operates in one year/total number of hours in one year). In periods of economic hardship, this result would prove highly unfavorable within the work force. However, the decrease in demand for water might be offset by the increases in population growth that have been projected for the future.

And finally, the most difficult problem that could severely hinder the implementation of a conservation effort is encouraging the public to modify its end-use patterns for water consumption. 1975, the year prior to the drought, marked the largest recorded year of water consumption in EBMUD's history. Although the public was willing to conserve, this trend has not continued. Table 6 compares billed consumption for the years 1975 and 1982, and shows that the only consistent decreases in demand have been in the Industrial and Public Authority sectors. These decreases are largely due to permanent,

	Residential	Commercial	Industrial	Public Authority	Total
Dec. 1975	2544	624	1253	428	4849
Dec. 1982	2670(105.1)[a]	625(100.1)[a]	845(67.5)[a]	345(80.5)[a]	4485(92.5)[a]

Table 6: Billed Gross Consumption in 1975 and 1982(MG).

Source: Walsh, W.C., Senior Accountant, EBMUD, 1983.

[a]Percent of 1975 Consumption.

retro-fitting of equipment during the drought years. The demand by the Residential and Commercial sectors has slightly surpassed 1975 levels, implying that these sectors are creatures of the "all or nothing" school of water consumption. Unfortunately, EBMUD customers, and the American public in general, have taken the attitude that any available resource, whether it be water or oil, should be exploited without restraint. As a result, the U.S. dependence on exhaustible resources has led to near catastrophes during a series of oil embargoes in the early 70's, not to mention the countless problems attributed to the drought. The policy of "consumption at will" prevailed prior to both of these crises.

Conclusions

Although there is little incentive for conservation of water or energy in the Bay Area--water, because of two seasons of greater than average rainfall, and energy, due to a recent drop in oil prices--it is the goal of this study to bring to light the great potential for energy conservation through the conservation of water. One can only hope that more work will be done in this much neglected area of energy conservation--a field that often focuses on a technical fix rather than the real problem of inefficient end use.

Although EBMUD could very well find itself in a state of economic hardship if heavy conservation practices are implemented, this is not to say that EBMUD has not already initiated energy conserving devices within its system. For example, a $5 million contract for generators to produce electricity from digesting gas, a by-product of sewage treatment, has recently been approved by the EBMUD Board of Directors, and the equipment is expected to be on-line sometime in 1985 (EBMUD, 1983). Many other projects are also under way to improve the efficiency of pumps and other machinery; and as oil prices begin to rise again (which they most certainly will do), many more projects will be researched. Moreover, EBMUD is constantly circulating information in the form of brochures and many other clever devices in an attempt to render the consumer more aware of the problems of supplying large amounts of potable water. Given the results of this report, any project concerned with water conservation and hence energy conservation is a welcome ally to those interested in the future of our natural resources.

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