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A Water Conservation Scenario for the Residential and Industrial Sectors in California: Potential Saveings of Water and Related Energy




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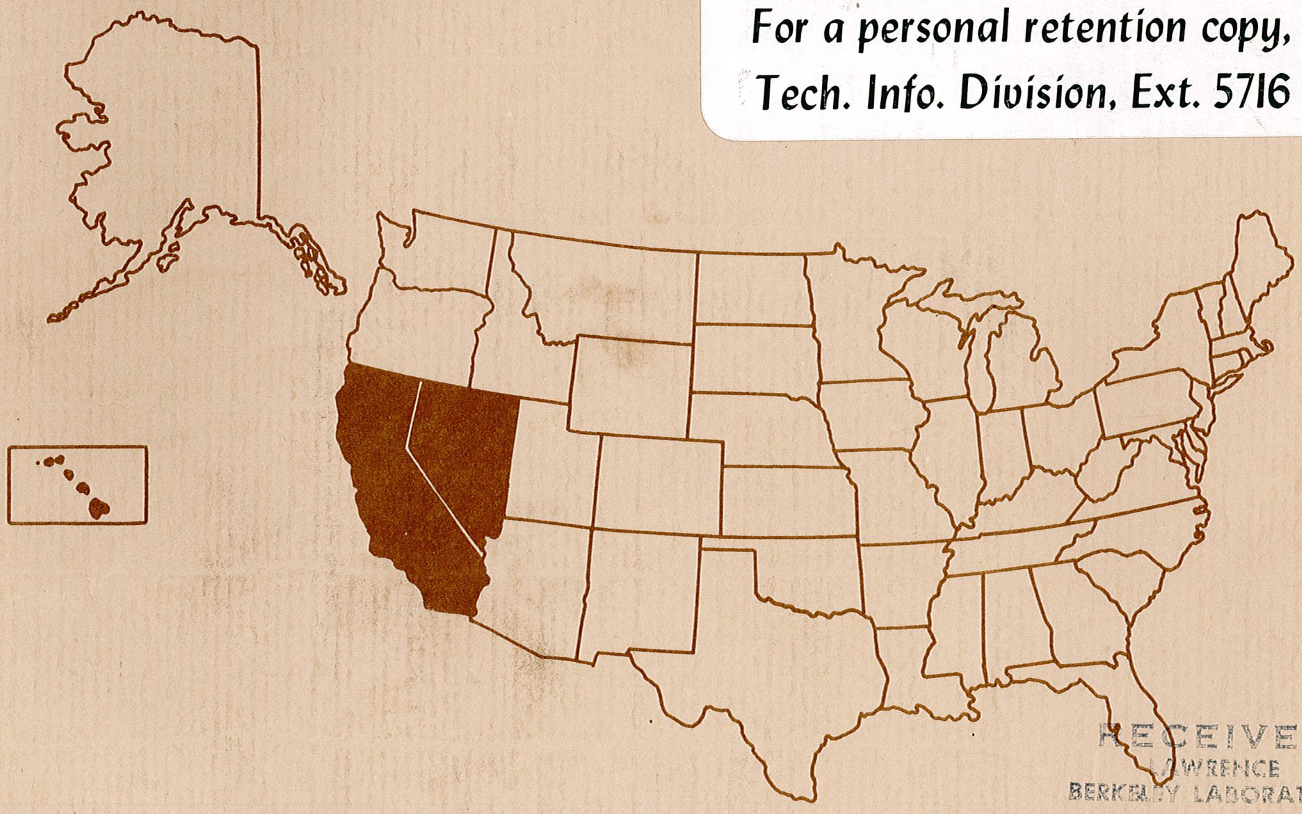
Peter Benenson

Energy Analysis Program
August 1977









Lawrence
Berkeley
Laboratory

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# A WATER CONSERVATION SCENARIO FOR THE RESIDENTIAL AND INDUSTRIAL SECTORS IN CALIFORNIA: POTENTIAL SAVINGS OF WATER AND RELATED ENERGY

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August 1977

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## GUIDE TO THE READER

This study is written in three levels of detail: the summary, the main report, and the appendices. The summary highlights what was accomplished and presents the major results and policy implications. It is designed to provide an overview in a fifteen minute reading. The main body of the report contains the major components of the study, but the detailed data and calculations that may not interest every reader have been extracted. The main report includes the study scope placed in the context of the total California water situation, the study objectives, a description of the approach, a detailed report of the findings, and a discussion of the policy implications. The most detailed material is presented in the appendices. These are designed only for the reader who wishes either to use the data collected or to see the detailed derivations of the estimates.

## ACKNOWLEDGMENTS

Several people contributed to the research for this study. Lauran Vincent compiled the industry conservation measures and most of the data for the industrial sector. Betsy Krieg estimated the energy requirements for surface water deliveries, groundwater pumping, and water distribution. Barbara Greene researched the interior and exterior residential water use estimates and, with Robert Clear, computed the energy requirements for water heating. Henry Ruderman wrote the computer programs for the water conservation scenarios. Yvonne Howell edited the text and made helpful suggestions to improve the clarity and continuity of the presentation.

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# SUMMARY

A residential and industrial water conservation scenario for California has been constructed in which water consumption has been disaggregated by residential end-use, industrial sector, and hydrologic study area. The energy use associated with this water use was estimated for surface and groundwater delivery, distribution, heating, and wastewater treatment. For each end-use and sector, water conservation measures have been delineated and their potential savings in terms of both water and attendant energy use have been estimated. This material has been combined to estimate the total water and energy savings potential by end-use, sector, and HSA. This potential is then compared with the reported water savings to date, and finally, some conclusions and policy implications are drawn from the results. The general findings are discussed first, followed by a listing of the more important detailed results.

There are several important links between water and energy. In California, water is a major source of energy supply: in 1975, 25% of total electric energy was supplied by hydroelectric power. Water is also needed for power plant cooling and fossil fuel extraction and refining. Energy is required to extract, convey, purify, and heat water prior to use, and to treat wastewater. Thus water conservation results in water and energy savings. The estimates from this study indicate that approximately 1.8 million acre feet of water, 2.6 billion kWh of electricity, and 0.5 billion therms of natural gas could be saved this year from implementing the water conservation measures presented in Tables 3 and 4. This constitutes 38% of the estimated residential and industrial water use (approximately 5% of Statewide water use), 2% of Statewide electricity consumption, and 3% of Statewide natural gas consumption. The electricity savings would lead to a decreased consumption of nonrenewable fuels and to decreased pollution emissions.

The estimated savings potential is thought to be conservative because several water districts and industries have already reported far greater savings. However, the lack of data for the industrial sector prevented any further estimates. A comparison of the estimated water savings potential with the savings actually reported shows that while the estimated potential is attainable, and in some cases has been exceeded, overall only 1/3 of the conservation potential derived in this study has been reached. Moreover, the actual gap is probably even greater due to the conservative nature of our estimates.

This significant conservation potential can be regarded as an alternative to constructing water supply systems for protection against water scarcity. For example, in the San Francisco HSA the estimated annual water savings potential of 410,000 acre feet exceeds the estimated deliveries from the major proposed water supply projects there. In the South Coastal HSA the estimated potential savings of 820,000 acre feet annually is more than twice as large as the current short run overdraft in the Owens Valley. Statewide, the estimated potential savings is approximately 40% of urban fresh water use in 1972.

Therefore, for optimal water supply planning, the pros and cons of both dams and water conservation should be considered. Dams regulate the water supply and provide flood control, hydroelectric power, and lakes for recreation. But they are costly, employ few people relative to other projects of comparable costs, and have many negative environmental impacts (e.g., they destroy natural habitats and accelerate eutrophication). Water conservation eases the water scarcity and has none of the environmental impacts associated with dams. Many measures can be implemented cheaply and quickly.

One of the main difficulties to relying on water conservation is the potential for sustained consumer resistance to behavioral change. The residential and industrial consumer directly perceives the inconvenience of water conservation, but not of dam construction. In the latter case, local residents absorb most of the inconvenience and the financial cost is borne by the taxpayers. Generally, the costs of these two alternatives are not equally apparent; this hinders the process of evaluation of the alternatives, and hence of rational water supply planning.

The objection of potential consumer resistance to behavioral change applies mainly to conservation measures that require continuous attention to the resource in question. But large savings are possible from conservation measures that require a one-time installment of a technological device. As savings accrue from these types of measures, the likelihood of reaching full conservation potential will be easier to assess because we will have more experience with conservation. The possibilities include such diverse outcomes as rejection of any effort to conserve and complete integration of water conserving behavior into daily routines.

Presently, although conservation cannot be relied upon with certainty as an option equivalent to its full potential for protection against water scarcity, it cannot be ignored as often has been the case in the past. Although surplus capacity for water supply has large economic and social value, to plan for water supply based on historic water consumption patterns would result in suboptimal water supply planning. Given the advantages and disadvantages of dam construction and water conservation, a rational water supply planning process requires reassessment of plans for construction of additional water supply systems that were made prior to the availability of recent evidence on water conservation potential.

The more detailed results upon which these general conclusions are based are summarized below:

- Overall residential water consumption can be reduced by 44% of average use by implementing the measures in Table 3. Electricity and natural gas consumption associated with this water use could be reduced by about the same percentage.
- Exterior water use, toilet flushing, and bathing are the largest residential water uses. Conservation efforts applied to these end uses will result in the largest reductions in residential water consumption.
- The highest per capita electricity consumption associated with water use occurs in the South Coastal HSA where 57% of the State's population resides.

- Of the four energy components considered, energy for water heating dominates the energy uses associated with water consumption. Potential natural gas savings are greater than potential electricity savings because gas hot water heaters are more prevalent than electric water heaters in California.
- Bathing and laundry rank first and second for energy consumption among residential water uses because of the high volume of hot water used.
- Accordingly, water conservation measures that reduce water for bathing and laundry, and all measures that reduce water consumption in the South Coastal and San Francisco HSAs (where the energy required for water delivery is relatively high) would have the largest impacts in water-related energy savings.
- Industrial water consumption and the associated energy requirements for water delivery and distribution can be reduced by at least 19% and 23%, respectively. This is thought to be a conservative estimate.
- The conservation measures that can be applied most immediately are housekeeping measures, some closed cycle cooling water reductions, and reuse of process water where extensive retrofitting of equipment is not required.
- The centers of industrial water consumption are the South Coastal and San Francisco HSAs. Water-related energy use also is highest here because of the energy requirements for delivery and distribution. So relatively large and immediate water and energy savings can be made by implementing the above mentioned water conservation measures in these areas.
- So far the largest savings potentials reported are in the paper and petroleum sectors. Food processing should be given special attention because it is the largest industrial water user.

## INTRODUCTION

This study of the use and conservation of water and water-related energy was made in conjunction with a broader examination of the effects of the drought on energy consumption and peak electrical generating capacity in California [17]. The initial work focused on the water, energy, and power situation during the summer of 1977.

The link between drought, energy consumption, and peak electrical capacity involves both water and energy supply demand. Water is a major source of energy supply in California; in 1975, 25% of total electrical energy supply for the State was generated by hydroelectric power. Water is also needed for power plant cooling.

On the demand side, energy is required to extract, convey, purify, and heat fresh water, as well as to treat waste water. There is also a direct relationship between water demand and peak power demand since some water use always occurs during periods of peak electrical demand. Moreover, during a drought, the energy requirements for groundwater pumping increase, because the supply of surface water is reduced and because the water table is lower. In agriculture, this increase in the energy needed for pumping water may be reduced either by a decrease in the acreage planted or by water conservation; and in urban areas, by water conservation.

## OBJECTIVES OF THE STUDY

The total California water demand in 1972 (a typical water year) was apportioned as follows:

residential sector - 9%
industrial sector - 2% (excluding brackish water use)
agricultural sector - 85%[6, p. 89; 8, p. 14]*

The annual electricity consumption associated with water use in the residential and industrial sectors is about 6.5 billion kWh; for agriculture, it is about 4 billion kWh. These energy requirements for

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*Numbers in square brackets [ ] refer to items in the bibliography.

water use are comparatively small when viewed in the context of the total electricity consumption in California — 4% and 3% of the total, respectively. However, if these percentages are significantly altered, they could impact both the electrical capacity reserve margins and fuel use required for electricity generation. The impact of changes in water consumption is relatively larger than for electricity consumption, owing to the larger percentages of total water use attributable to these sectors.

Accordingly, the objectives in this study are to determine the impact of current and potential water conservation efforts for reducing both water consumption and the attendant energy and peak power demand, to pinpoint the water conservation strategies that are likely to have the largest impacts on energy and water demand, and to highlight some of the complementarities between water and energy use.

## APPROACH

To accomplish these objectives, it is first necessary to determine present water use in major geographic regions of California by residential end-use and by industrial sector, and to trace the energy use associated with this water, from its extraction and delivery to wastewater treatment.

In developing the scenarios for this study, the data have been disaggregated by residential end-use, industrial sector, and hydrologic study area (HSA). The sector and end-use disaggregations are used to determine the potential for energy and water savings from specific water conservation measures. The geographic disaggregation helps capture the variability across the State in energy requirements for water delivery. These energy requirements vary because, in general, the major sources of water in the State are not located near the major points of use. The map of water storage and conveyance facilities (Fig. 1) clearly illustrates this situation. Water is conveyed from northern California to southern California, from the Sierra to the Central Valley and San Francisco, from the Owens Valley to Los Angeles, and from the


Figure 1
Water Storage and Conveyance Facilities in California

Source: [18]

Colorado River to San Diego and Los Angeles. Also, there are regional differences in the energy required for groundwater pumping. The HSA boundaries are shown in Fig. 2.

Once the water and associated energy use are determined, the next steps are to find how water can be saved in each end-use and industrial sector, and to estimate how much can be saved. Finally, this information is combined to construct a scenario of water and attendant energy use before and after water conservation. The details of this approach are described separately for each sector in the text below and in Appendix B.

Residential Scenario Construction

The scenario for the residential sector begins with an estimate of interior and exterior water use; interior use is broken down into detailed end-uses such as toilet flushing, bathing, etc. (Table 1).

Table 1

RESIDENTIAL INTERIOR WATER USE

| End Use | Temperature °F | Gallons/ Person/ Year | Comments |
|---|---|---|---|
| Toilet | 60 | 9125 | 5-gallon toilet flushed 5 times per day |
| Bathing | 105 | 7300 | 5 showers per person per week, 5 gallons per minute, 5-6 minutes per shower |
| Laundry | 130 | 3194 | 62 gallons per person per week |
| Dishwashing | 105-140 | 1369 | |
| Cooking, Drinking | 60 | 1095 | |
| Bathroom Sink | 105 | 730 | |
| Utility Sink | 105 | 456 | |
| TOTAL | | 23,269 | |

Sources: [28, 30, 33, 34]

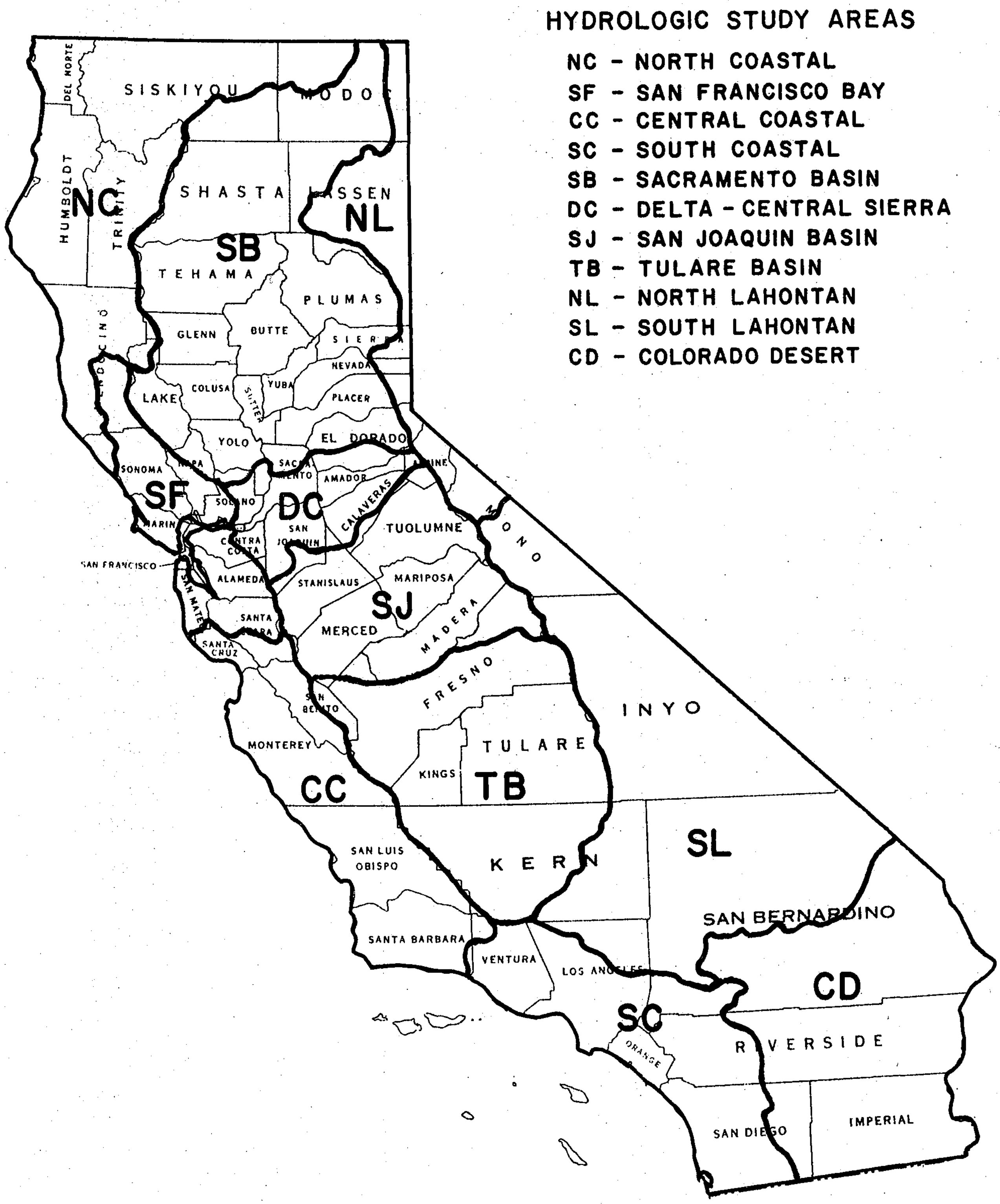


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FIGURE 2
HYDROLOGIC STUDY AREA BOUNDARIES

TABLE 3

RESIDENTIAL WATER CONSERVATION BY END USE

| End Use | Overall Savings from Water Conservation | Derivation and Sources |
|---|---|---|
| Toilet | 28% | Two quart plastic bottles in 5-gallon tank (10%). Reduce number of flushes per day from 5 to 4 (20%). |
| Bathing[a] | 57% | Flow control restrictors (40%). Reduce showering time from 5.6 to 4.6 minutes (18%). |
| Laundry[b] | 14% | Existing stock: Wash full loads, check for leaks, and save and reuse cleanest rinse water (5%). Wash on shortest cycle and eliminate prewash (10%). New machines: Buy the most water-efficient. |
| Dishwashing[b,c] | 41% | Existing stock: By machine: plug leaks and wash only full loads (5%). By hand: aerators (50%), plug leaks and shut off water when not in use (5%). Dishwasher saturation assumed to be 24% [8,p.18]. |
| | 50% | New stock: Buy the most water-efficient. |
| Cooking, drinking | 5% | Reuse boiling water in soups or other cooking and save unused drinking water (5%). |
| Bathroom sink[c] | 50% | Collect running water while waiting for water to get hot; turn off water while not in use, e.g. while lathering hands and face or brushing teeth; use cup for brushing teeth; install aerator. |
| Utility sink | 50% | Install aerators and apply all relevant measures give for bathroom sink. |
| Exterior use | 50% | Landscape watering: Use household grey-water. Water with soak hose or drip irrigators. Eliminate use of sprinklers. Water during low wind periods. Do not overwater plants. Plant drought-resistant varieties. Collect rainwater in barrels. Sidewalks: Sweep, don't wash. Swimming pools: Cover to reduce evaporation loss. Empty pool. Car wash: Wash and rinse with bucket, not hose. |

[a] [75]    [b] [8]    [c] [32]

Industrial Scenario Construction

The industrial sector scenario begins with the selection of the largest industrial water users. In decreasing order of fresh water use in 1970 these are:

- Food and kindred products
- Paper and allied products
- Petroleum and coal products
- Chemical and allied products
- Lumber and wood products
- Stone, clay, and glass products
- Primary metals

These users account for 86% of the industrial water consumption in California [40, Table 6]. The rest of the industries are aggregated into a category called "Other industries."

For each industrial category, estimates are made of the water use, both fresh and brackish, as well as the energy needed for water delivery in each HSA and for delivery plus distribution in the San Francisco and South Coastal HSAs. After energy and water use per employee are calculated, total water and associated energy use for 1977 are estimated from an extrapolation of employment in each industry [41,62].

Then the water conservation potential in each industrial sector is estimated. The water conservation measures for the industrial sectors are broken down by industry and by three generic categories — housekeeping, cooling, and effluent reduction for reuse. These categories, defined in Table 4 and Appendix A, correspond to the three ways that industry can conserve water: for the water that is now being wasted, the housekeeping measures apply; where the water temperature is being increased, it can be cooled for reuse; where its quality is decreased, it can be used in processes that tolerate lower quality water or it can be purified and reused. Table 4 summarizes the applicability of these water conserving measures to the seven largest water-consuming industries and also shows the estimated potential for water conservation in each industry; the industry-specific conservation measures from which this generic compilation was made are presented in Appendix A.

TABLE 4

WATER CONSERVATION MEASURES APPLICABLE TO INDUSTRY[a]

| | Food and kindred products | Paper and allied products | Petroleum and coal products | Chemicals and allied products | Lumber and wood products | Stone, clay and glass | Primary metals |
|---|---|---|---|---|---|---|---|
| Water consumption[b] ($10^6$ gallons fresh water in 1970) | 83852 | 55646 | 55043 | 26185 | 22013 | 15167 | 10335 |
| Percentage of total industrial water use | 27 | 18 | 18 | 8 | 7 | 5 | 3 |
| Type of Conservation Measure[c] | | | | | | | |
| 1. Housekeeping | | | | | | | |
| Leak plugging | x | x | x | | x | | x |
| Waste reduction | x | x | x | | x | x | |
| 2. Cooling | | | | | | | |
| Dry | | | x | | | x | |
| Wet | x | x | x | x | x | x | x |
| Spray ponds | | | | | | | x |
| 3. Effluent reduction for re-use | | | | | | | |
| Filter | x | | x | | x | x | x |
| Reverse osmosis | | | | | | | x |
| Flocculent | | | | | | x | x |
| Counter flow | x | | | | x | | x |
| Re-use as is | x | x | | x | x | | x |
| Wetting agents | | | | | | | x |
| Closed systems | | | x | x | x | | x |
| High pressure steam | x | | | | x | | x |
| Savings of water and energy from water conservation (%)[d] | 5 – 7 | 10 – 50 | 24 – 48 | † | † | † | † |

[a] x denotes applicability as indicated in the source document listed in c below.

[b] [40]

[c] [45]

[d] [47]

† Five percent water and energy savings from water conservation is assumed in these industries.

Because the conditions in each firm within an industry vary greatly with respect to the age and quality of capital stock, water conservation measures previously implemented, geographical locations, and quality of water available, a range rather than a point estimate was obtained for the savings potential due to water conservation. For some industries, data on potential savings were unavailable. In these cases, it was assumed that a minimum of 5% savings of water and associated energy is obtainable simply by improving housekeeping practices, reusing process water to a limited extent, and reducing blowdown and evaporation losses in cooling towers through regular tower maintenance, installation of extra filters, increasing concentration in the cooling water where conditions permit, and installing automatic control of cooling water temperatures. The potential savings in cooling towers alone can be substantial, ranging between 10% and 50% of the cooling water intake normally used. Presently, these savings are not quantified because of the lack of data on water used for closed-cycle cooling in each industry. For these reasons the savings estimates are conservative.

Once the savings potential is estimated, calculations are made (as for the residential sector) of the water and associated energy consumption expected this year without water conservation, and the consumption that would result with full conservation implementation.

## FINDINGS AND POLICY IMPLICATIONS

The results of the above calculations yield estimates of the residential and industrial water and associated energy consumption, by end-use and sector, respectively, and by HSA before and after water conservation. These detailed estimates are presented in Appendix D. The summary totals, aggregated over residential end-uses and industrial sectors or across HSAs, are given in Tables 5-7.

The total estimated consumption for 1977 without water conservation is 1568 billion gallons of water, 6.5 billion kWh of electricity, and 1.4 billion therms of natural gas. This represents approximately 13%, 4%, and 8%, respectively, of the Statewide consumption of these resources (including brackish water use in industry).

TABLE 5

WATER AND ASSOCIATED ENERGY CONSUMPTION BY HYDROLOGIC STUDY AREA

| Hydrologic study area (HSA) | Without Water Conservation | | | | | With 100% Water Conservation Implementation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | Industrial | | Residential | | | Industrial | |
| | Water $10^9$ gal | Electricity $10^6$ kWh | Natural gas $10^6$ therms | Water $10^9$ gal | Electricity $10^6$ kWh | Water $10^9$ gal | Electricity $10^6$ kWh | Natural gas $10^6$ therms | Water $10^9$ gal | Electricity $10^6$ kWh |
| 1. North Coastal | 11 | 63 | 20 | 30 | 7 | 6 | 38 | 13 | 19 | 4 |
| 2. San Francisco Bay | 219 | 1216 | 321 | 140 | 138 | 125 | 716 | 191 | 99 | 104 |
| 3. Central Coastal | 44 | 211 | 61 | 18 | 4 | 25 | 126 | 36 | 14 | 3 |
| 4. South Coastal | 553 | 3648 | 786 | 132 | 242 | 315 | 2148 | 468 | 103 | 198 |
| 5. Sacramento Basin | 105 | 284 | 84 | 30 | 7 | 57 | 169 | 50 | 25 | 6 |
| 6. Delta-Central Sierra | 31 | 109 | 33 | 46 | 15 | 17 | 64 | 20 | 35 | 13 |
| 7. San Joaquin Basin | 42 | 114 | 32 | 24 | 15 | 22 | 67 | 19 | 22 | 14 |
| 8. Tulare Basin | 78 | 234 | 55 | 19 | 20 | 42 | 134 | 33 | 18 | 19 |
| 9. North Lahontan | 3 | 10 | 3 | 2 | 1 | 2 | 6 | 2 | 2 | 1 |
| 10. South Lahontan | 20 | 85 | 21 | 8 | 7 | 11 | 50 | 13 | 7 | 7 |
| 11. Colorado Desert | 13 | 43 | 11 | 1 | 1 | 7 | 25 | 7 | 1 | 1 |
| 12. Total California | 1119 | 6017 | 1427 | 449 | 457 | 629 | 3542 | 850 | 345 | 368 |

TABLE 6

RESIDENTIAL WATER AND ASSOCIATED ENERGY CONSUMPTION BY END USE

| End Use | Without Water Conservation | | | With 100% Water Conservation Implementation | | |
|---|---|---|---|---|---|---|
| | Water $10^9$ gal | Electricity $10^6$ kWh | Natural Gas $10^6$ therms | Water $10^9$ gal | Electricity $10^6$ kWh | Natural Gas $10^6$ therms |
| Toilet | 194 | 482 | 0 | 140 | 347 | 0 |
| Bathing | 155 | 2271 | 699 | 67 | 977 | 301 |
| Laundry | 68 | 1451 | 481 | 58 | 1248 | 414 |
| Dishwashing | 29 | 424 | 132 | 17 | 250 | 78 |
| Cooking and drinking | 23 | 59 | 0 | 22 | 56 | 0 |
| Bathroom sink | 16 | 228 | 70 | 8 | 114 | 35 |
| Utility sink | 10 | 141 | 45 | 5 | 71 | 22 |
| Exterior | 624 | 960 | 0 | 312 | 480 | 0 |
| TOTAL | 1119 | 6017 | 1427 | 629 | 3542 | 850 |

TABLE 7

INDUSTRIAL WATER AND ASSOCIATED ENERGY USE BY SECTOR

| Sector | Without Water Conservation | | With 100% Water Conservation Implementation | |
|---|---|---|---|---|
| | Water $10^9$ gal | Electricity $10^6$ kWh | Water $10^9$ gal | Electricity $10^6$ kWh |
| Food and kindred products | 115 | 124 | 107 | 115 |
| Lumber and wood products | 30 | 14 | 28 | 13 |
| Paper and allied products | 84 | 61 | 42 | 31 |
| Chemicals and allied products | 53 | 43 | 50 | 41 |
| Petroleum and coal products | 98 | 83 | 51 | 43 |
| Stone, clay and glass products | 16 | 26 | 15 | 25 |
| Primary metals | 10 | 19 | 9 | 18 |
| Other industries | 44 | 87 | 41 | 83 |
| TOTAL | 449 | 457 | 345 | 368 |

A comparison of water consumption during the first four months of 1977 in major urban areas with information for the same time period in 1976 yields an estimate of water conservation that is presently being implemented [55]. The Statewide reduction is 13%; application of this figure to the 1977 estimates yields a savings of 204 billion gallons of water, 0.9 billion kWh of electricity, and 0.2 billion therms of natural gas (2%, 0.6%, and 1%, respectively, of Statewide resource consumption).

If the water conservation measures listed in Tables 3 and 4 were fully implemented, water consumption would be reduced by 38% with concomitant energy savings of 40%. The energy use reductions imply water use reductions in accordance with the distribution of conservation measures given in Tables 3 and 4. This is one of many possible distributions. Consumers may place a different emphasis on particular measures e.g., greater cutbacks of exterior use and less of interior use. Hot water use may or may not be among the reductions emphasized. The estimated savings are 1.8 million acre feet of water, 2.6 billion kWh of electricity, and 0.5 billion therms of natural gas. This amounts to 2% of the State's total electricity use, 5% of its water use, and 3% of its natural gas use. These figures are within the range of savings estimated by the Department of Water Resources [8]. How attainable are these savings? To answer this, the estimated conservation potential can be compared with three sets of water consumption data presently available:

1. A survey conducted by LBL of major municipal water agencies throughout the State. The data pertain to water consumption for selected months of 1976 and 1977 as available.
2. Four-month cumulative totals for water consumption in 1976 and 1977 in selected metropolitan water agencies throughout the State [55].
3. A record of the water consumption at the Lawrence Berkeley Laboratory in 1976 and 1977, which includes residential, commercial, and industrial type uses.

A summary by HSA of the first two sets of data is presented in Table 8; the data for the water districts from which these summary statistics are derived are included in Appendix E. These figures show

Table 8

SUMMARY OF ESTIMATED CHANGE IN MUNICIPAL WATER CONSUMPTION: 1976 TO 1977

| HSA | Percentage Change January - May* Cumulative Total | Percentage Change Selected† Months |
|---|---|---|
| North Coastal | -18 | NA |
| San Francisco Bay | -25 | -40 |
| Central Coastal | -19 | -20 |
| South Coastal | -3 | -2 |
| Sacramento Basin | -0.6 | -18 |
| Delta-Central Sierra | -18 | -17 |
| San Joaquin Basin | -5 | -7 |
| Tulare Basin | -11 | +7 |
| North Lahontan | NA | NA |
| South Lahontan | NA | NA |
| Colorado Desert | NA | NA |

Source

*[55].

†[LBL Survey].

NA [Not available].

that in a few areas of northern California the estimated savings potential has been reached and in some cases surpassed. The latter cases occur, for example, in the Marin Municipal Water District and the East Bay Municipal Utility District, where savings of more than 50% of 1976 consumption have been achieved. Statewide, however, present water savings are far below the potential estimated, as the reported water consumption in the South Coastal and Tulare Basin HSA's indicate.

The 1977 water consumption at the Lawrence Berkeley Laboratory is 50% of what it was in 1976 (Table 9). Significant inroads were made in end-uses that span most sectors of the economy. Water use for toilets and sinks has been reduced by 27%, for cooling tower blowdown by 87%, for photographic processing by 73%, and for landscape irrigation by 87%.

The reported consumption of the Marin and East Bay water districts and the experience at LBL point to the feasibility of the water conservation potential estimated above (38% with full conservation implementation). But the Statewide savings indicate that the level of conservation currently being achieved is only about one-third of this potential. Moreover, this potential is believed to be conservative, primarily because the data for the industrial sector are inadequate to assess the full conservation potential there, and because greater savings than those estimated in this study have already been reported by the water districts mentioned above and by several industries (Table 10). Therefore, although the water saving potential is quite large and attainable, the gap between actual and potential water savings is even greater than the results of this study indicate.

This finding bears on the policy decisions for water supply planning, as it means that water conservation can be considered an alternative to construction of additional water supply systems for protection against future water scarcity. In the San Francisco HSA, for example, the estimated potential savings are 410,000 acre-feet per year. This exceeds the estimated deliveries from the major proposed urban water supply projects in this area (San Felipe - 143,000 acre-feet per year, the EBMUD portion of the Auburn Dam deliveries - 150,000 acre-feet per year, and the fourth San Joaquin pipeline to convey Tuolomne River water, 110,000 acre-feet per year). In the South Coastal HSA the potential savings are 820,000 acre feet per year, which is more than twice the present rate of short-run overdraft from the Owens Valley. Statewide, the estimated savings potential through conservation is 1.8 million acre-feet, roughly 40% of total urban fresh water use in 1972.

Table 9

PRELIMINARY RESULTS FROM THE WATER CONSERVATION PROGRAM AT THE LAWRENCE BERKELEY LABORATORY†
(ALL UNITS IN GALLONS PER MINUTE UNLESS OTHERWISE NOTED)

| Use | Pre-conservation Summer Rate 1976 | Use to Date After Water Conserved |
|---|---|---|
| Toilets, Sinks | 30 | 22 |
| Cooling Towers | | |
| Blowdown | 15 | 2 |
| Evaporation | 80 | 68 |
| Photographic Processes | 15 | 4 |
| Dilution and Cleaning | 10 | 7 |
| Once through Cooling | 65 | 15 |
| Roof Soaker Cooling | 10 | 0 |
| Landscape Irrigation | 15* | 2* |
| TOTAL | 240 | 120 |

† Source: [71]

* [Yearly Use ÷ Minutes Per Year].

Table 10

WATER SAVINGS REPORTED BY SELECTED CALIFORNIA FIRMS*

| Industry | Savings (%) |
|---|---|
| Fibreboard | 77 [a] |
| Canning | 20-40 [b] |
| Electronics | 45 [c] |
| Petroleum Refining | 25 [d] |

* All findings reported at the Drought Conference on Industrial Water Allocation and Conservation, Sheraton Inn-Airport. Concord, July 25, 1977.

a. (64)
b. (79)
c. (69)
d. (88)

Thus for optimal water supply planning, the pros and cons of both dams and aqueduct construction and water conservation should be clearly set out and evaluated.

Dams regulate water supply for agricultural and urban use and provide flood control, hydroelectric power, and lakes for recreation. But they are costly to build, they employ few people for construction and operation compared with other projects of comparable cost, and the construction time is long. They also have numerous negative environmental impacts: they submerge natural habitats upstream and decrease the water supply to those below; they block movement of fish; they accelerate eutrophication by raising water temperature and trapping nutrients; they upset the salt-water-freshwater balance in estuaries by diminishing the flow rate; they change the evaporative pattern of the water system and increase its evaporation losses; they may contribute to earthquakes by lubricating faults near the dam; they sometimes break, which causes loss of life and property damage; and they eventually fill up with silt which renders them useless.

Water conservation eases the water scarcity and has none of the negative environmental impacts that are associated with dams. Reduced water flow causes problems in wastewater treatment such as clogging of sewer lines and increased concentration of wastewater effluent. The latter may in turn increase the wastewater treatment energy requirements. Also, reduced exterior residential water use negatively impacts landscape vegetation. But generally, there appear to be no negative environmental impacts from water conservation comparable to those from dam construction. In the residential sector, conservation is relatively inexpensive and can be implemented almost immediately. In the industrial sector, the cost is relatively low for housekeeping, for selected measures for cooling towers, and, in some cases, for recycling by matching water quality with water needs. These measures also can be implemented quickly. Other measures in the industrial sector have significant water and attendant energy savings but are more costly and require long lead times for installation. Implemented correctly, none of the measures in Table 4 or Appendix A result in decreased product quality or volume. To the extent that materials are needed to implement water conservation, while these represent costs to the firm or household, they result in water and energy savings that are reflected in decreased payments for these resources. They also generate income and employment for the sectors that produce and install the materials, so that the net economic impacts may be positive or negative depending on the conservation measure in question.

One of the main objections to relying on water conservation as an alternative to constructing water supply systems for protection against water scarcity is the potential for sustained consumer resistance to behavioral change. To implement some water conservation measures, the consumer, residential or industrial, perceives some inconvenience — e.g., reducing showering time from 10 minutes to 5, or sweeping rather than washing work areas. The burden of conservation is borne by each individual. In dam and aqueduct construction this is not the case. Local residents absorb most of the inconvenience, and the financial cost is borne by the taxpayers. It is usually impossible to determine what portion of one's taxes is assignable to a particular project; besides, the water user does not pay for water at the marginal cost of new supply, but at a lesser rate that is subsidized by tax revenues. So the actions of individuals or firms to conserve water are not rewarded by the price mechanism to the full extent of the savings achieved, and the economic incentive to conserve is dampered. In sum, the costs of dam construction and water conservation are not equally apparent, which hinders the process of evaluation of the alternatives, and hence, of rational water supply planning.

In the context of this problem of potential sustained consumer resistance to water conservation, it is important to distinguish between conservation measures that require continuous attention to the resource being used (such as decreasing showering time and shutting off unused faucets), and those measures that require a one-time installation of a technological improvement (such as installing a shower flow control restrictor or a cooling tower filter). Significant savings can be made from both types of conservation measures, but the objection discussed above applies mainly to the former. The latter approach appears less inconvenient to consumers and employees; flow control restrictors, toilet dams, spring loaded faucets, pressure control valves, footpedals (instead of handles), aerators for faucets, automatic timers, filters, and recycling systems can be installed with only an initial inconvenience. (Even these measures involve some behavioral change, though not a continuous one.)

As water savings accrue, the likelihood of reaching the full potential of water conservation will be easier to assess because our experience with water conservation will accumulate. Many outcomes are possible, several of which are discussed here. Consumers and producers could become disgusted with conservation and refuse to cooperate regardless of the cost of new water supply projects or the severity of the drought. Or they could implement technological measures to conserve water and become lax on their management of water consumption, thereby partially or fully offsetting the water savings achieved.

A third possibility is that consumer and producer awareness of present resource waste and conservation potential may increase. This awareness could serve as a stimulus for overcoming the initial inertia connected with changing a behavior pattern, such as collecting shower and sink water while waiting for it to get hot, or shutting off unused faucets in production processes. Once integrated into a daily routine, these new tasks could become no more inconvenient than the myriad of others performed each day.

More information over a long period of time is needed regarding actual water use reductions and consumer and producer attitudes toward the water situation. Some of the data on recent water consumption were discussed above. One survey is available regarding consumer attitudes toward the water problem and the consumers' willingness to conserve water [29]. The survey was conducted throughout California in March 1977. Forty-eight percent of the sample of 962 people surveyed thought the water shortage for the State as a whole was "extremely serious" and an additional 37% thought it was "somewhat serious." Fifty-two percent think there is a serious water shortage in their county, and 72% believe there may be one in the foreseeable future. Seventy percent think the State should have a Statewide water plan. Regarding personal cooperation, 87% indicated they could cut water use by 25%; about half this group said they could do it without any problem while the other half indicated it would be inconvenient but they could do it. Forty-eight percent said they could make a cutback of 50%, but most said it would be inconvenient. Fifty-one percent of the people surveyed thought a 50% reduction would be a severe problem. Ninety-three percent claimed practicing some form of water conservation: less water for bathing, 70%; less frequent car washing, 58%; reduced watering of lawns and gardens, 67%. It is interesting to note, however, that two relatively large residential water saving measures that require a one-time installation (toilet dams or plastic bottles, and shower flow control restrictors) had been installed by only 24% and 16%, respectively, of the sample interviewed. Thus the potential for large water savings easily achieved is far from exhausted.

Presently, although conservation cannot be relied upon with certainty as a water supply option equivalent to its full potential, it cannot be ignored as it often has been in past water supply planning. While it is recognized that surplus capacity for water supply, especially in times of low rainfall, has large social and economic value, to plan for water supply on the basis of past water consumption (per capita residential and per unit output industrial) would result in suboptimal water supply planning. Because of the significant potential of water conservation, its lower cost, shorter implementation time, and more benign environmental impact relative to dam construction, a rational water supply planning process requires that those plans for water supply construction made prior to the availability of recent evidence on water conservation potential should be reassessed.

An itemization of the more detailed results for each sector upon which these general conclusions are based is given below:

- Overall residential water consumption can be reduced by 44% of average use by implementing the specific water conservation measures in Table 3. The electricity and natural gas consumption associated with this water use could be reduced by approximately the same percentage. The conservation measures can be implemented immediately at minimal financial outlay per person.

- The largest residential water use occurs outside the house (landscape irrigation, car washing, etc.). Toilet flushing and bathing are the largest interior water uses. Accordingly, the largest reductions in residential water consumption can be obtained by concentrating conservation efforts on these end uses.
- The highest per capita electricity consumption associated with water use occurs in the South Coastal HSA where 57% of the State's population resides. The South Coastal and Tulare Basin HSAs have the highest energy requirements for water deliveries — the former because of the long distance and predominance of surface water conveyance, the latter because of the importance and depth of groundwater pumping.
- Of the four energy components considered (delivery, distribution, heating, and wastewater treatment) energy for water heating dominates the energy uses associated with water consumption. Potential natural gas savings are significantly greater than potential electricity savings due to the more extensive use of gas hot water heaters in California.
- Bathing, the second highest interior residential water use, requires the most energy of all residential water end uses because of the high volume of hot water used; laundry ranks second for the same reason. Accordingly, water conservation measures aimed at reducing water use for bathing (e.g., flow control restrictors and shorter showers) and for laundry (washing only full loads on the shortest cycle) and all measures that reduce water use in the South Coastal and San Francisco HSAs (where the delivery energy requirements are relatively high) would have the largest impacts on water-related energy use. The exception is the Tulare Basin HSA where, due to the high energy requirements for groundwater pumping, substantial reductions in energy use could be achieved by reducing exterior water use.
- Overall industrial water consumption and the associated energy requirements for delivery and distribution can be reduced by at least 23% and 19%, respectively. This estimate is thought to be conservative for two reasons: some industries have already reported greater savings, and lack of data prevented estimates of the full savings potential for various conservation measures and industries. The conservation measures that can be applied most immediately are:

    a. housekeeping measures such as leak plugging, waste reduction, elimination of unnecessary cleaning, turning off pumps and spigots not in use, installing spring loaded faucets and footpedals, etc.;

    b. closed-cycle cooling water reductions such as reduction or elimination of blowdown, installation of basin filters, automatic conductivity sensing units, automatic fan control, reduction of drift losses by installing better eliminators;

c. reuse of process water where extensive retrofitting of equipment is not required.

Because some conservation measures for water recycling require retrofitting or new equipment, not all the savings estimated in this study could be realized in the short run.

- The centers of industrial water consumption are the San Francisco and South Coastal HSA s. Due to the high energy requirements for delivery and distribution, the greatest water-related energy use also occurs in these regions. Accordingly, relatively large and immediate water savings can be made by implementing the conservation measures listed above in these areas. From the data gathered thus far, the greatest savings potential among the large industrial water users occurs in the Paper and Petroleum sectors. Therefore, a tentative conclusion is that large savings could be effected by concentrating water-conservation efforts in these sectors. This bears further investigation and does not imply that significant savings are not achievable in other sectors. Special attention should be given to food processing because it is the largest industrial water user.

# APPENDIX A

## INDUSTRY CONSERVATION MEASURES

The following industry-specific water conservation measures were compiled from the EPA Development Documents for Proposed Effluent Limitations Guidelines [45] and from [43]. They are the basis for Table 4, Water Conservation Measures Applicable to Industry. They are included to provide an indication of the possibilities for industrial water conservation; however, it is important to keep in mind that each firm is a specific case with its own water quality, atmospheric, capital equipment, and quality control problems that require individual examination and application of the water conservation principles listed.

A section at the end of this appendix is devoted to water conservation in closed-cycle cooling towers. This material is derived from the water conservation measures implemented at the Lawrence Berkeley Laboratory cooling towers.

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
| --- | --- | --- | --- |
| 1) Food | | | |
| | A) Canned, cured, frozen | | [45a, pp 83-91] |
| | | 1) <u>Housekeeping/Waste</u> | |
| | | a) Automatic shut-off valves in evaporators, boilers, cookers | |
| | | 2) <u>Cooling</u> | |
| | | a) Cooling towers | |
| | | b) Using cooling tower blowdown | |
| | | 3) <u>Effluent Reduction</u> | |
| | | a) Bulk unloaders to reuse conveyance & rinsewaters | |
| | | b) Cleaning of plants with a high pressure steam cleaning system. | |
| | | c) "Counter-current" flow system | |
| | B) Sugar Refining | | [45b, pp 77-81] |
| | | 1) <u>Housekeeping/Waste</u> | |
| | | a) Recover spilled sugar by sweeping instead of washing | |
| | | b) Recover all floor, wash drains, sweet water | |
| | | c) Recovery of waste water with lower sucrose concentration | |
| | | d) Reduction in volume of wash water used to sweeten off bone char & carbon columns | |
| | | 2) <u>Cooling</u> | |
| | | a) Cooling towers to recycle barometric condenser cooling water | |
| | | 3) <u>Effluent Reduction</u> | |
| | | a) Elimination or reduction in use of ion exchange as an organic color remover | |
| | | b) Minimum contact time between sugar beets & flume water | [45c, pp 62-65] |
| | | c) Dry handling procedures | |
| | | d) Flume water recycling | |
| | | e) Dry pulp conveyor system | |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| 1) Food | B) Sugar Refining | 3) Effluent Reduction (continued) | |
| | | f) Handling of lime muds: | |
| | | 1) Low water dilution/air pump conveyance | |
| | | 2) Recovered, recalcinated for reuse | |
| | C) Dairy | | [45d] |
| | | 1) Housekeeping/Waste | pg 75 |
| | | a) Water shut off valves | |
| | | 2) Cooling | |
| | | None | |
| | | 3) Effluent Reduction | pg 75 |
| | | a) Cone-type silo tank | " |
| | | b) Filler drip shield | " |
| | | c) Interlock control | " |
| | | d) Ice cream filler drip shields | pg 76 |
| | | e) Novelty collection system | " |
| | | f) Product recovery can system | " |
| | | g) Non-leak portable damage package unit | " |
| | | h) Case washer control | pg 77 |
| | | i) C.I.P. systems-reuse type | " |
| | | j) Automated continuous processing | " |
| | | k) H.T.S.T. recovery system | " |
| | | l) Product rinse recovery | " |
| | | m) Post-rinse utilization | " |
| | | n) Air blowdown | pg 78 |
| | | o) Ice cream rerun system | " |
| | D) Meat | | [50f] |
| | | 1) Housekeeping/Waste | pg 72 |
| | | a) Replace all wash water valves with squeeze or press-to-open valves | |
| | | b) Install foot-pedal hand-washing and drinking fountain water valves | |
| | | c) Replace all drilled spray pipe systems with spray nozzles | |
| | | d) Install automatic control for sprays | |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| | | 2) Cooling | |
| | | a) Replace product chillers with chillers using a cryogenic liquid | pg 72 |
| | | b) High pressure water spray systems | " |
| | | 3) Effluent Reduction | |
| | | a) Reuse boiler blowdown | " |
| | | b) Automatic I. P. system | " |
| | | c) Use lowest quality of water satisfactory for the process | " |
| 2) Petroleum and Coal Product | | | |
| | A) Petroleum Refining | | |
| | | 1) Housekeeping/Waste | [43] |
| | | a) Substitute broom, shovel, and dry chemical for wash down water | Pg 97 |
| | | 2) Cooling | |
| | | a) Substituting an air exchanger in place of cooling water sprays | pg 95 |
| | | b) Substitution of air in place of water coolers | pg 98 |
| | | c) Blowing down from a high pressure level of steam generation to a lower level | pg 96 |
| | | d) Use of vacuum pumps in place of steam jet ejectors | " |
| | | e) Reuse of process condensate | " |
| | | f) Install level gauge on water blowdown points | pg 97 |
| | | g) Replace water seal on a flarestack with a molecular seal | " |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| | | 3) Effluent Reduction | [43] |
| | | a) Vessels containing heavy oils should be flushed with a lighter oil before cleaning | pg 97 |
| | | b) Separate water and oil drains on pump and compressor pads | " |
| | | c) Cleaning water drained to a sump with skimming device | pg 98 |
| 3) Pulp and Paper | | | |
| | A) Pulp and Paper | | |
| | | 1) Housekeeping/Waste | [45h] |
| | | a) Self cleaning showers | pg 103 |
| | | 2) Cooling | |
| | | a) Utilize vacuum water for cooling of heat exchanger | pg 102 |
| | | 3) Effluent Reduction | |
| | | a) Recycle white water | pg 100 |
| | | b) Reuse of clarified effluent | pg 101 |
| | | c) Reduction of seal water | pg 102 |
| 4) Chemical and Allied Products | | | |
| | A) Chemicals | 1) Housekeeping/ Waste | |
| | | a) None listed | |
| | | 2) Cooling | [40] |
| | | a) Cooling towers | pg 79 |
| | | 3) Effluent Reduction | |
| | | a) Recycle direct contact process water | pg 81 |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| | B) Soaps and Detergents | | |
| | | 1) <u>Housekeeping/Waste</u><br>None listed | |
| | | 2) <u>Cooling</u><br>a) Change operating techniques associated with barometric condensors or replace them with surface condeners | [45k] pg 93 |
| | | 3) <u>Effluent Reduction</u><br>a) Installation of additional water recycling piping and tankage | " |
| | | b) Identify and untangle waste water lines which lead to sewers | " |
| 5) Lumber and Wood Product | | | |
| | A) Millwork, Plywood and Related Products | | |
| | | 1) <u>Housekeeping/Waste</u><br>None listed | |
| | | 2) <u>Cooling</u><br>None listed | |
| | | 3) <u>Effluent Reduction</u><br>a) Process water recycle with blowdown to control suspended solids and dissolved organics | [45m] pg 174 |
| | | b) Process water recycle through a primary clarifier with blowdown of some clarifier effluent & recycle sludge | " |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| 5) Lumber and Wood Products | | | |
| | A) Millwork, Plywood & Related Products | | |
| | | 3) Effluent Reduction (continued) | |
| | | c) Process water recycle through primary clarifier with blowdown being evaporated and some evaporator condensate being utilized for makeup. | [45m] pg 174 |
| | | d) Process water recycle with blowdown passing through chemical coagulation system | " |
| | B) Sawmills & Planing Mills | | |
| | | 1) Housekeeping/Waste | [451] |
| | | a) Reducing flow to minimum volume | pg 242 |
| | | b) All mill clean-up without use of water | " |
| | | c) Store unprocessed wood on land, sprinkle with water | pg 240 |
| | | d) Install special flow control systems | pg 242 |
| | | 2) Cooling | " |
| | | a) Cooling water discharged in cooling pumps, turbines, or condensers by way of closed conduits | |
| | | b) Saw cooling water usage and chain belt lubricating water usage should be minimized | pg 243 |
| | | 3) Effluent Reduction | |
| | | a) Dip vats covered to keep out precipitation and equipped with an apron to catch all dripage | pg 242 |
| | | b) Clean up water used for make up | " |
| | | c) High pressure steam hoses | pg 243 |
| | | d) Scraping mixing tanks & other surfaces to remove glue residue | " |
| | | e) Wash water recycle | " |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| 5) Lumber and Wood Products | | | |
| | B) Sawmills & Planing Mills | 3) Effluent Reduction (continued) | |
| | | f) Split-Recycle System (for single-product plants) | pg 266 |
| | | g) Use of primary clarifier | pg 268 |
| | | h) Use of diatomaceous earth filter | " |
| | | i) Use of spray nozzles to keep logs moist | " |
| 6) Stone, Clay, Glass | A) Flat Glass | 1) Housekeeping/Waste | |
| | | None listed | |
| | | 2) Cooling | [45p] |
| | | a) Air cooling water rather than quenching | pg 79 |
| | | 3) Effluent Reduction | |
| | | a) Recycling washers | " |
| | | b) Diatomaceous earth filters | " |
| | B) Cement | 1) Housekeeping/Waste | [45o] |
| | | a) Removing accumulation of dust from roofs & buildings for return to process | pg 53 |
| | | b) Paving areas for vehicles to minimize solid spillage | " |
| | | 2) Cooling | |
| | | a) Cooling Towers | pg 52 |
| | | b) Spray Ponds | " |
| | | 3) Effluent Reduction | |
| | | a) Use slurry water to handle some waste water generated | pg 53 |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
|---|---|---|---|
| 7) Primary Metals | A) Blast Furnace & Basic Steel Products | | |
| | | 1) Housekeeping/Waste | [45q] |
| | | a) Use of steam to remove volatile compounds | pg 174 |
| | | 2) Cooling | |
| | | a) Cooling Towers | pg 175 |
| | | b) Spray Ponds | pg 175,200,246 |
| | | c) Recycle quench wastes | pg 175 |
| | | d) Reuse blowdown water in a non-sensitive process | pg 204,217,218,226 |
| | | e) Add make-up water and recycling water into spark-box spray system | " |
| | | f) Demineralize blowdown and return condensate to system | pg 200,203 |
| | | 3) Effluent Reduction | |
| | | a) Distillation & incineration of coke plant waste loads in controlled combustion system | pg 175 |
| | | b) Carbon absorption | " |
| | | c) Waste water recycle system | pg 200 |
| | | d) Gas scrubber water on a tight recycle system | pg 194 |
| | B) Primary Metals (Non-Ferrous) | | |
| | | 1) Housekeeping/Waste | [45r] |
| | | a) Flow Restrictors in Waste Water Feed Lines | pg 77 |
| | | 2) Cooling | |
| | | a) Freezing | pg 100 |
| | | b) Add wetting agent to rinse water | pg 82 |
| | | c) Install air or ultrasonic agitation | " |
| | | 3) Effluent Reduction | |
| | | a) Installing counter flow rinse tanks & ion exchange | pg 77 |
| | | b) Evaporation recovery | pg 88 |
| | | c) Reverse osmosis | pg 100 |

| SECTOR | INDUSTRY | CONSERVATION MEASURE | REFERENCE |
| --- | --- | --- | --- |
| 7) Primary Metals | b) Primary Metals (non-ferrous) | 3) Effluent Reduction (continued) | |
| | | d) Electrodialysis | pg 101 |
| | | e) Electrolytic Stripping | pg 104 |
| | | f) Carbon Adsorption | pg 107 |
| | | g) Liquid-Liquid Extraction | pg 107 |
| | | h) Drag-Out Reduction | pg 82 |
| | | i) Use of Conductivity Meters in Final Rinse | pg 82 |

Water Conservation Potential for Closed Cycle Cooling Towers

Water losses from closed-cycle cooling towers occur from blowdown, evaporation and drift loss. Blowdown is the deliberate expulsion of water from the basin to prevent excessive buildup of salt concentration in the tower water. Evaporation occurs as the water falls through the cooling tower. The rate of evaporation depends upon the heat load imposed upon the tower and upon the atmospheric conditions. Drift losses consist of the tiny droplets of water which are thrown out of the tower stack by the action of the tower fan.

The conservation measures listed below are designed to reduce blowdown, evaporation and drift losses to a minimum. They have been implemented on 37 cooling towers at LBL. Most of these towers have a cooling capacity of approximately four megawatts.

It should be pointed out that each facility has its own particular cooling requirements, types of equipment, makeup water quality, atmospheric conditions, etc. so that it is difficult to generalize about conservation procedures. The following is to illustrate what measures can be explored. Specific procedures must be developed on a case by case basis.

1. Reduce blowdown to a minimum.

   The quality of the makeup water at LBL is quite good so that the blowdown can be reduced to a very low value. One effective method to accomplish this is to control the rate of blowdown with a solenoid valve actuated automatically when the salt concentration of the basin water exceeds a predetermined value. This value of salt concentration (conductivity) can be set as high as is practicable without causing undue scaling or otherwise adversely affecting the tower operation. This reduction in blowdown has resulted in savings at LBL of approximately 1700 gallons per day per tower. In addition to salt concentration, dust, weedseeds, debris etc. also adversely affect the water in the tower basin. The following procedures were implemented at LBL to alleviate this situation:

a. Screens and side stream filters (progressively 50, 10 and 1 micron) were installed to remove suspended solids.
b. These screens and filters were monitored, cleaned, maintained and replaced at regular intervals.
c. The tower basins are drained and cleaned yearly. It is highly recommended that new basins be constructed with sloping sides to facilitate cleaning.
d. The tower water is checked daily for concentration of calcium and magnesium, for conductivity and for pH. The tower is also examined for the presence of algae.
e. Chemical treatment for prevention of corrosion and scale formation and for pH control is being controlled automatically in some towers. Algae control may also be automatic if chlorine is used.
f. Dispersing agents are added to the tower water to keep solids in suspension so that they may be removed during the slip-stream filtration.
g. Sludge from the cleaning of the tower basins or from the filters are collected in barrels and disposed of in a controlled dump.

Consideration has been given to eliminating blowdown altogether and simply recycling the basin water through ion exchange or reverse osmosis units to remove the undesirable constituents. It may be difficult at this time to justify this procedure in terms of the monetary cost.

2. Reduce water losses by controlling the speed of the tower water fan.

Install automatic water controls such that the temperature of the tower basin water (tower water supply to equipment) will determine the speed of the cooling tower fan.

By determining the highest tower water supply temperature which can be used to cool the particular equipment, and using this as the basin water set temperature for the fan controls, one can avoid running the fan unnecessarily or at excessive speeds. This will save electricity, will reduce the drift loss (which is caused by the air movement from the fan) and will probably reduce evaporation.

If this procedure is used, heaters should be installed in the fan motors to prevent condensation when the motors are not running.

3. Drift losses can also be reduced by improving the efficiency of the drift eliminators. The Cooling Tower Institute Code limits drift loss to 0.2% of the circulation rate of water over the tower.

# APPENDIX B

## METHODOLOGY AND DATA FLOW

### Residential Sector Scenario Construction

The calculation of residential water and energy use and water conservation potential entails the following steps:

- Present interior and exterior water use per person is estimated for each HSA. Interior use per person is assumed to remain constant over geographical regions of the State, but exterior use is calculated separately for each HSA because water use for landscape irrigation and swimming pools differs widely across the State. Interior use is then broken down into major end uses: toilet flushing, bathing, laundry, dishwashing, cooking, bathroom sink, utility sink.

- For each water end use the associated energy use is estimated on an HSA basis for the following categories: delivery from surface and groundwater, distribution, heating, and wastewater treatment. For exterior use, only delivery and distribution energy use apply. Distribution requirements were calculated only for the two most populated HSA's (San Francisco and South Coast) because of the paucity of data. Energy use for delivery for each HSA was calculated separately because of differences in the distances over which surface water is conveyed, the depth of groundwater, and the proportion of ground-to-surface water use. Energy use for waste water treatment was also estimated for each HSA based on the estimated degree of treatment in each HSA and the size of the treatment plant. The derivation of the estimates for the energy requirements associated with water use are given in Appendix C.

- Next, water conservation measures for each end use were listed and the approximate reductions in water use from their implementation were estimated. Per Capita water and energy consumption for each end use were extrapolated to 1977. The 1977 population for each HSA was estimated by aggregating 1975 county population figures [22, p. 7] to HSA's [19], then projecting these figures at the average annual statewide population growth rate for the period 1970-1975. This rate is 1.06 per cent per year [22, p. 7]. Estimated 1977 population by HSA is presented in Table 11.

- The savings of water and energy due to the water conservation measures were calculated and a revised estimate was made of water and energy consumption with water conservation factored in. These estimates scale with the rate of conservation implementation; i.e. the savings at 100% implementation are twice those realized at 50% implementation.

  The steps outlined above are displayed in the following flow chart (Figure 3). The chart also denotes the source of data for each component in the calculation.

## Industrial Sector Scenario Construction

The estimation of water and associated energy use in the industrial sector proceeds on the basis of sectoral rather than end use categories.

- First the industries that account for most of the industrial water consumption in California are determined and examined individually.
- Fresh and brackish water use by industry and HSA are estimated for 1970, the most recent year that data are available [40].

Table 11

Estimated 1977 Population by Hydrologic Study Area

| HYDROLOGIC STUDY AREA | | POPULATION |
|---|---|---|
| 1. | NORTH COASTAL | 291,705 |
| 2. | SAN FRANCISCO BAY | 4,788,974 |
| 3. | CENTRAL COASTAL | 909,065 |
| 4. | SOUTH COASTAL | 11,723,888 |
| 5. | SACRAMENTO BASIN | 1,257,227 |
| 6. | DELTA-CENTRAL SIERRA | 499,634 |
| 7. | SAN JOAQUIN BASIN | 471,286 |
| 8. | TULARE BASIN | 820,302 |
| 9. | NORTH LAHONTAN | 44,525 |
| 10. | SOUTH LAHONTAN | 318,723 |
| 11. | COLORADO DESERT | 165,507 |
| | TOTAL | 21,290,836 |

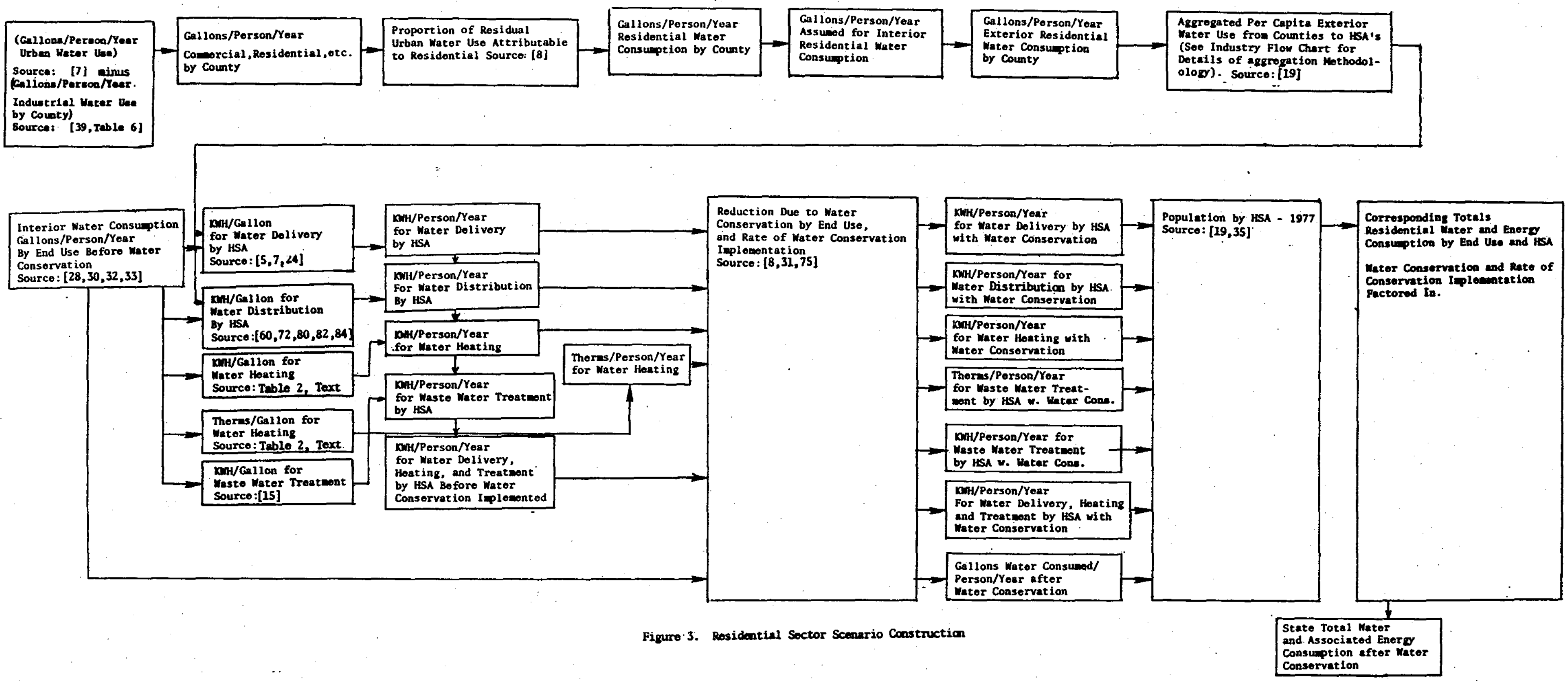


Figure 3. Residential Sector Scenario Construction

- Next, the energy cost for the delivery and distribution of this water are calculated. The breakdown between surface and groundwater is assumed to be the same for industry as for the rest of urban use. All brackish water is assumed to be pumped from rivers with an average required lift of five feet. The energy cost for industrial wastewater treatment has not yet been estimated because of data limitations. On-site treatment varies with each firm and location as does the proportion subsequently discharged to municipal treatment plants. This information is not available through published sources.
- Water conserving measures are then indicated, and wherever possible, quantitative estimates of the savings potential are obtained. Water and the associated energy use by industry and HSA are then extrapolated to the summer of 1977. The extrapolation is based on seasonally adjusted employment figures in each industry [62].
- Finally, an estimate is made of the potential reductions of water and energy consumption as water conserving measures are applied.

These calculations are presented in the following flow chart. (Figure 4) The source for each component is also indicated.

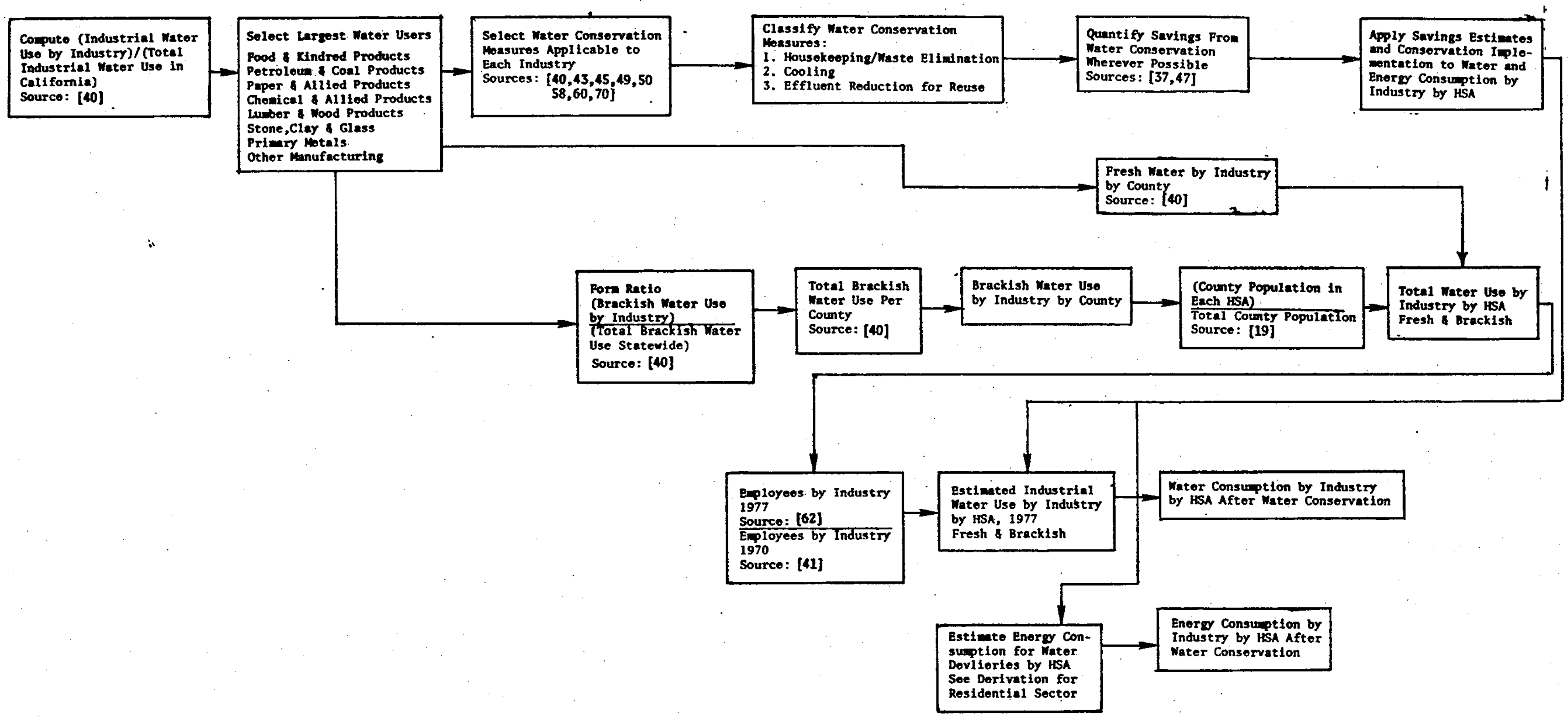


**Figure 4. Industrial Sector Scenario Construction**

# APPENDIX C

## DERIVATION OF ENERGY REQUIREMENTS FOR WATER DELIVERY, DISTRIBUTION, HEATING, AND WASTEWATER TREATMENT

### Water Delivery

Calculation of the energy requirements for water deliveries requires three types of information:

(1) the water sources for each area, both ground and surface;
(2) the energy requirements for delivery from each source; and
(3) the fraction that each source constitutes of total urban water deliveries in each area.

The major sources of urban water in California are the Central Valley Project(CVP), the State Water Project (SWP), local surface supplies, imports from out of state, and groundwater. The deliveries are estimated by HSA s. These are shown in Figure 2. For each HSA, water deliveries and the associated energy requirements by the CVP and SWP are estimated. The estimates are based partially on published sources [5, pp. 24, 32; 23, pp. 4,7] and partially on discussions with personnel connected with operation or use of the projects [48, 52, 60, 68, 72, 78, 89]. Since the SWP does not break out urban water deliveries by HSA, total deliveries were distributed to the appropriate HSA and split between urban and agricultural use based on the location and name of the agencies to which water was delivered. Water delivered to irrigation districts was assumed to be entirely for agricultural use, and water to municipal water districts entirely for urban use. The resulting distribution was compared with the totals for agricultural and urban water use in Ref. 5 p. 36. The distribution was adjusted based on probable water use and population density in each geographic location.

Local surface water supplies and imports with the attendant energy requirements were included where data are readily available—the Hetch Hetchy and Mokelumne Aqueducts in the San Francisco HSA [60, 65] and the Los Angeles and Colorado River Aqueducts in the South Coastal HSA [3, 14, 15]. These were added to the estimates for the CVP and SWP to obtain total estimated surface water deliveries by HSA and the associated energy requirements (see Table 12). Water deliveries and the attendant energy requirements from the California Aqueduct to the South Coastal HSA were excluded from the calculation because these deliveries were stopped on March 1, 1977.

To calculate groundwater use in each HSA, the surface water deliveries estimated above were subtracted from total urban water use in each HSA [7, p. 7]. It is assumed that the entire residual is attributable to groundwater supply; the amount attributable to local surface water supplies, aside from the four major aqueducts discussed above, was not estimated due to the lack of data. The surface water deliveries used for groundwater recharge that is subsequently pumped again for urban use is ignored, but the control total for urban water use agrees with the published figure in [7]. Estimates of the energy required for groundwater pumping are based on the average groundwater depth in each HSA [16, p.7], and on an assumed pump efficiency of 59.5% [16, p. 5]. The average well depth in each area pertains to agricultural wells. The average depth for urban use may vary from this estimate. The data on groundwater depth are reported by Hydrologic Planning Basin rather than by HSA. The correspondence between the two is shown in Table 12. Also shown for each HSA are the estimated energy requirements for groundwater pumping, average groundwater depth, and total urban water use. The estimated energy requirements for groundwater pumping weighted by the estimated fraction of total urban water use supplied from groundwater, are combined with the energy requirements for surface water deliveries, weighted by the corresponding fraction for surface water use. This yields an overall energy requirement for urban water delivery in each HSA (Table 12).

An additional energy requirement is included for the industrial sector to account for pumping of brackish water. A five foot lift and a pumping efficiency of 79% is assumed for all brackish water consumption; the resulting energy requirement is .02 Wh per gallon.

TABLE 12

ENERGY REQUIREMENTS FOR URBAN WATER DELIVERIES

| Notes | | North Coastal | San Francisco | Central Coastal | South Coastal | Sacramento Basin | Delta Central Sierra | San Joaquin Basin | Tulare Basin | North Lahontan | South Lahontan | Colorado Desert | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <u>Surface</u> | | | | | | | | | | | | |
| | Water deliveries (AF) | 954 | 685,990 | 0 | 1,674,000 | 1,545 | 54,743 | 9,454 | 47,108 | 0 | 0 | 0 | 2,473,794 |
| | Energy required (kWh × $10^6$) | 0.39 | 179 | 0 | 1,326 | (2.45) | 13.24 | 2.47 | 25.80 | 0 | 0 | 0 | -- |
| a,b | Energy per gallon (Wh/gal) | (1.26) | 0.80 | 0 | 1.94 | (4.86) | 0.74 | 0.80 | 1.68 | 0 | 0 | 0 | -- |
| | <u>Ground</u> | | | | | | | | | | | | |
| c | Estimated ground water use (AF) | 103,171 | 268,706 | 175,279 | 575,508 | 472,993 | 97,922 | 199,307 | 345,947 | 23,605 | 82,117 | 97,337 | 2,441,892 |
| | Average depth (ft) | 43 | 86 | 103 | 105 | 53 | 89 | 123 | 181 | 54 | 181 | 124 | -- |
| | Energy per gallon (Wh/gal) | 0.23 | 0.45 | 0.54 | 0.54 | 0.28 | 0.47 | 0.65 | 0.96 | 0.29 | 0.96 | 0.66 | -- |
| | Portion of urban water use from groundwater (%) | 99 | 26 | 100 | 26 | 99 | 64 | 95 | 88 | 100 | 100 | 100 | -- |
| | Overall energy requirement for delivery (Wh/gal) | 0.22 | 0.71 | 0.54 | 1.97 | 0.23 | 0.57 | 0.66 | 1.05 | 0.29 | 0.96 | 0.66 | -- |
| | <u>Other data required for calculations</u> | | | | | | | | | | | | |
| d | Estimated 1972 population (people) | 178,296 | 4,628,250 | 807,738 | 11,247,540 | 1,207,746 | 432,280 | 427,788 | 965,736 | 42,840 | 240,108 | 230,112 | 20,408,434 |
| e | Urban water use (AF) | 104,125 | 925,650 | 175,279 | 2,249,508 | 474,538 | 152,665 | 208,761 | 393,055 | 23,605 | 82,117 | 97,337 | 4,886,640 |
| | Hydrologic planning basin | 1A,1B | 2 | 3 | 4A,4B,8,9 | 5A | 5B | 5C | 5D | 6A | 6B | 7A,7B | -- |

Notes:
- a 325,851 gallons per acre foot.
- b ( ) energy generated.
- c Urban water use minus surface water deliveries.
- d 1970 population from [7,p.7] increased by 2%.
- e Based on annual per capita urban water use from [7,p.7]

Distribution

The unit energy requirements for water distribution within urban areas are calculated from estimates of both water deliveries by municipal water departments and the attendant energy expenditures. As there appear to be no published sources for the energy data, personal communications with water department personnel were relied upon. The lack of published data prevented estimation of the distribution energy requirements for all urban areas in the time alloted for this study. Estimates were made for the San Francisco and South Coastal HSAs where three-quarters of the State's population resides. The data are shown in Table 13. The unit energy requirement is obtained by dividing total electricity requirements for each HSA by the corresponding urban water deliveries.

Water Heating

A statewide saturation of 85% gas hot water heaters and 11% electric water heaters is assumed (based on [2]). The calculation of the energy consumption for heating water is based on assumptions of 70% efficiency for gas hot water heaters, 99.5% efficiency for electric hot water heaters, and 8.32 Btus per gallon per degree fahrenheit to heat water from 60°F to 140°F (source: [27], Tables for Heat Capacity of Water). The estimates are for the incremental energy requirements only and do not include standby losses from the water heater. The calculation is made as follows:

$$((8.32 \text{ Btu/G/°F} \times 80\text{°F})/.7)/100{,}000 \text{ Btu/Th} = .00952 \text{ Th/G/°F}$$

$$((8.32 \text{ Btu/G/°F} \times 80\text{°F})/.995)3413 \text{ Btu/kWh} = .196 \text{ KWh/G/°F}$$

Wastewater Treatment

Estimates of the energy consumption per gallon of wastewater treated are taken from reference [15], Table 5. The figures do not include energy recovered from digester gas, offsite energy for chemical production, or energy for construction of the plant. Exfiltration from

TABLE 13

ENERGY REQUIREMENTS FOR WATER DISTRIBUTION
WITHIN THE SAN FRANCISCO AND SOUTH COASTAL HYDROLOGIC STUDY AREAS

| HSA | Water Department | Water Deliveries (acre-feet) | Total Energy Required $10^6$ kWh | Unit Energy Required Wh/gal |
|---|---|---|---|---|
| San Francisco | San Francisco City Water Dept. | 105,852[a] | 49[b] | |
| | East Bay Municipal Utility District | 250,000[c] | 48[c] | |
| | TOTAL | 355,852 | 97 | .84[d] |
| South Coastal | Los Angeles Aqueduct | 480,000 | 199[e] | |
| | Colorado Aqueduct | 1,212,000 | 0[f] | |
| | San Diego City Water Dept. | 180,700 | 13.6[g] | |
| | TOTAL | 1,872,700 | 212.6 | .35 |

a. [83].

b. [84].

c. [60].

d. 325,851 gallons per acre foot .

e. [72].

f. [76].

g. [82].

interior residential use is ignored. All water used inside the house is assumed treated. The pairing of HSAs with the type of wastewater treatment is based on conversations with Professor William Oswald [54] and Dr. David Spath [53]. The estimates reflect the present type of treatment, or the type expected when construction in progress is complete. The size of the plants was estimated from inspection of the average daily flow data for municipal waste water treatment facilities in each HSA [39, Table 1]. The size and type of treatment assumed for each HSA are summarized in Table 14.

Table 14

WASTEWATER TREATMENT FACILITIES:
ASSUMED PLANT SIZE AND LEVEL OF TREATMENT

| HSA | Size $10^6$ Gallons per Day | Level of Treatment |
|---|---|---|
| North Coastal | 1 | Secondary |
| San Francisco Bay | 100 | Primary |
| Central Coastal | 1 | Secondary |
| South Coastal | 100 | Secondary |
| Sacramento Basin | 1 | Secondary |
| Delta-Central Sierra | 100 | Primary |
| San Joaquin Basin | 1 | Primary |
| Tulare Basin | 1 | Primary |
| North Lahontan | 1 | Secondary |
| South Lahontan | 1 | Secondary |
| Colorado Desert | 1 | Secondary |

# APPENDIX D

## RESIDENTIAL AND INDUSTRIAL WATER AND RELATED ENERGY CONSUMPTION BY RESIDENTIAL END USE, INDUSTRIAL SECTOR, AND HYDROLOGIC STUDY AREA

## RESIDENTIAL WATER CONSUMPTION DURING 1977
(MILLIONS OF GALLONS)

| | | TOILET | BATHING | LAUNDRY | DISH WASHING | COOKING | BATHROOM SINK | UTILITY SINK | EXTERIOR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 2662 | 2129 | 932 | 399 | 319 | 213 | 133 | 4146 | 10934 |
| 2 | SAN FRANCISCO BAY | 43699 | 34960 | 15296 | 6556 | 5244 | 3496 | 2184 | 107852 | 219287 |
| 3 | CENTRAL COASTAL | 8295 | 6636 | 2904 | 1245 | 995 | 664 | 415 | 22962 | 44115 |
| 4 | SOUTH COASTAL | 106980 | 85584 | 37446 | 16050 | 12838 | 8558 | 5346 | 280693 | 553496 |
| 5 | SACRAMENTO BASIN | 11472 | 9178 | 4016 | 1721 | 1377 | 918 | 573 | 76060 | 105314 |
| 6 | DELTA-CENTRAL SIERRA | 4559 | 3647 | 1596 | 684 | 547 | 365 | 228 | 19370 | 30996 |
| 7 | SAN JOAQUIN BASIN | 4300 | 3440 | 1505 | 645 | 516 | 344 | 215 | 30610 | 41576 |
| 8 | TULARE BASIN | 7485 | 5988 | 2620 | 1123 | 898 | 599 | 374 | 59114 | 78202 |
| 9 | NORTH LAHONTAN | 406 | 325 | 142 | 61 | 49 | 33 | 20 | 1713 | 2749 |
| 10 | SOUTH LAHONTAN | 2908 | 2327 | 1018 | 436 | 349 | 233 | 145 | 12447 | 19864 |
| 11 | COLORADO DESERT | 1510 | 1208 | 529 | 227 | 181 | 121 | 75 | 8866 | 12717 |
| 12 | TOTAL CALIFORNIA | 194279 | 155423 | 68003 | 29147 | 23313 | 15542 | 9709 | 623834 | 1119250 |

## RESIDENTIAL WATER CONSUMPTION AT 100 PERCENT IMPLEMENTATION
(MILLIONS OF GALLONS)

| | | TOILET | BATHING | LAUNDRY | DISH WASHING | COOKING | BATHROOM SINK | UTILITY SINK | EXTERIOR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 1917 | 916 | 801 | 236 | 303 | 136 | 67 | 2073 | 6419 |
| 2 | SAN FRANCISCO BAY | 31464 | 15033 | 13155 | 3868 | 4982 | 1748 | 1092 | 53926 | 125267 |
| 3 | CENTRAL COASTAL | 5973 | 2854 | 2497 | 734 | 946 | 332 | 207 | 11481 | 25023 |
| 4 | SOUTH COASTAL | 77026 | 36801 | 32204 | 9470 | 12196 | 4279 | 2673 | 140347 | 314995 |
| 5 | SACRAMENTO BASIN | 8260 | 3946 | 3453 | 1015 | 1308 | 459 | 287 | 38030 | 56759 |
| 6 | DELTA-CENTRAL SIERRA | 3283 | 1568 | 1372 | 404 | 526 | 132 | 114 | 9685 | 17128 |
| 7 | SAN JOAQUIN BASIN | 3096 | 1479 | 1295 | 381 | 490 | 172 | 107 | 15305 | 22325 |
| 8 | TULARE BASIN | 5389 | 2575 | 2253 | 663 | 853 | 299 | 187 | 29557 | 41777 |
| 9 | NORTH LAHONTAN | 293 | 140 | 122 | 36 | 46 | 16 | 10 | 857 | 1520 |
| 10 | SOUTH LAHONTAN | 2094 | 1000 | 875 | 257 | 332 | 116 | 73 | 6224 | 10972 |
| 11 | COLORADO DESERT | 1087 | 520 | 455 | 134 | 172 | 60 | 38 | 4433 | 6898 |
| 12 | TOTAL CALIFORNIA | 139881 | 66832 | 58483 | 17197 | 22148 | 7771 | 4854 | 311917 | 629082 |

ELECTRICITY CONSUMPTION FOR RESIDENTAIL WATER USE
(MILLIONS OF KILOWATT-HOURS)

| | | TOILET | BATHING | LAUNDRY | DISH WASHING | COOKING | BATHROOM SINK | UTILITY SINK | EXTERIOR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 4 | 29 | 19 | 5 | 0 | 3 | 2 | 1 | 63 |
| 2 | SAN FRANCISCO BAY | 73 | 483 | 315 | 90 | 9 | 48 | 30 | 167 | 1216 |
| 3 | CENTRAL COASTAL | 14 | 92 | 60 | 17 | 2 | 9 | 6 | 12 | 211 |
| 4 | SOUTH COASTAL | 349 | 1318 | 828 | 246 | 42 | 132 | 82 | 651 | 3648 |
| 5 | SACRAMENTO BASIN | 16 | 124 | 81 | 23 | 2 | 12 | 8 | 17 | 284 |
| 6 | DELTA-CENTRAL SIERRA | 3 | 47 | 31 | 9 | 0 | 5 | 3 | 11 | 109 |
| 7 | SAN JOAQUIN BASIN | 4 | 45 | 30 | 8 | 0 | 5 | 3 | 20 | 114 |
| 8 | TULARE BASIN | 10 | 80 | 53 | 15 | 1 | 8 | 5 | 62 | 234 |
| 9 | NORTH LAHONTAN | 1 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 10 |
| 10 | SOUTH LAHONTAN | 6 | 33 | 21 | 6 | 1 | 3 | 2 | 12 | 85 |
| 11 | COLORADO DESERT | 3 | 17 | 11 | 3 | 0 | 2 | 1 | 6 | 43 |
| 12 | TOTAL CALIFORNIA | 482 | 2271 | 1451 | 424 | 59 | 228 | 141 | 960 | 6017 |



ELECTRICITY CONSUMPTION AT 100 PERCENT IMPLEMENTATION
(MILLIONS OF KILOWATT-HOURS)

| | | TOILET | BATHING | LAUNDRY | DISH WASHING | COOKING | BATHROOM SINK | UTILITY SINK | EXTERIOR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 3 | 12 | 16 | 3 | 0 | 1 | 1 | 0 | 38 |
| 2 | SAN FRANCISCO BAY | 53 | 208 | 271 | 53 | 9 | 24 | 15 | 84 | 716 |
| 3 | CENTRAL COASTAL | 10 | 39 | 51 | 10 | 2 | 5 | 3 | 6 | 126 |
| 4 | SOUTH COASTAL | 252 | 567 | 712 | 145 | 40 | 56 | 41 | 325 | 2148 |
| 5 | SACRAMENTO BASIN | 11 | 53 | 70 | 14 | 2 | 6 | 4 | 9 | 169 |
| 6 | DELTA-CENTRAL SIERRA | 2 | 20 | 27 | 5 | 0 | 2 | 1 | 6 | 64 |
| 7 | SAN JOAQUIN BASIN | 3 | 19 | 26 | 5 | 0 | 2 | 1 | 10 | 67 |
| 8 | TULARE BASIN | 7 | 34 | 45 | 9 | 1 | 4 | 3 | 31 | 134 |
| 9 | NORTH LAHONTAN | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 6 |
| 10 | SOUTH LAHONTAN | 4 | 14 | 18 | 4 | 1 | 2 | 1 | 6 | 50 |
| 11 | COLORADO DESERT | 2 | 7 | 9 | 2 | 0 | 1 | 1 | 3 | 25 |
| 12 | TOTAL CALIFORNIA | 347 | 977 | 1248 | 250 | 56 | 114 | 71 | 480 | 3542 |

NATURAL GAS CONSUMPTION FOR RESIDENTIAL WATER USE
(MILLIONS OF THERMS)

| | | TOILET | BATHING | LAUNDRY | DISH WASHING | COOKING | BATHROOM SINK | UTILITY SINK | EXTERIOR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 0 | 10 | 7 | 2 | 0 | 1 | 1 | 0 | 20 |
| 2 | SAN FRANCISCO BAY | 0 | 157 | 108 | 30 | 0 | 16 | 10 | 0 | 321 |
| 3 | CENTRAL COASTAL | 0 | 30 | 21 | 6 | 0 | 3 | 2 | 0 | 61 |
| 4 | SOUTH COASTAL | 0 | 385 | 265 | 73 | 0 | 39 | 25 | 0 | 786 |
| 5 | SACRAMENTO BASIN | 0 | 41 | 28 | 8 | 0 | 4 | 3 | 0 | 84 |
| 6 | DELTA-CENTRAL SIERRA | 0 | 16 | 11 | 3 | 0 | 2 | 1 | 0 | 33 |
| 7 | SAN JOAQUIN BASIN | 0 | 15 | 11 | 3 | 0 | 2 | 1 | 0 | 32 |
| 8 | TULARE BASIN | 0 | 27 | 19 | 5 | 0 | 3 | 2 | 0 | 55 |
| 9 | NORTH LAHONTAN | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| 10 | SOUTH LAHONTAN | 0 | 10 | 7 | 2 | 0 | 1 | 1 | 0 | 21 |
| 11 | COLORADO DESERT | 0 | 5 | 4 | 1 | 0 | 1 | 0 | 0 | 11 |
| 12 | TOTAL CALIFORNIA | 0 | 699 | 481 | 132 | 0 | 70 | 45 | 0 | 1427 |

NATURAL GAS CONSUMPTION AT 100 PERCENT IMPLEMENTATION
(MILLIONS OF THERMS)

| | | TOILET | BATHING | LAUNDRY | DISH WASHING | COOKING | BATHROOM SINK | UTILITY SINK | EXTERIOR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 0 | 4 | 6 | 1 | 0 | 0 | 0 | 0 | 12 |
| 2 | SAN FRANCISCO BAY | 0 | 68 | 93 | 18 | 0 | 8 | 5 | 0 | 191 |
| 3 | CENTRAL COASTAL | 0 | 13 | 18 | 3 | 0 | 1 | 1 | 0 | 36 |
| 4 | SOUTH COASTAL | 0 | 166 | 228 | 43 | 0 | 19 | 12 | 0 | 468 |
| 5 | SACRAMENTO BASIN | 0 | 18 | 24 | 5 | 0 | 2 | 1 | 0 | 50 |
| 6 | DELTA-CENTRAL SIERRA | 0 | 7 | 10 | 2 | 0 | 1 | 1 | 0 | 20 |
| 7 | SAN JOAQUIN BASIN | 0 | 7 | 9 | 2 | 0 | 1 | 0 | 0 | 19 |
| 8 | TULARE BASIN | 0 | 12 | 16 | 3 | 0 | 1 | 1 | 0 | 33 |
| 9 | NORTH LAHONTAN | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| 10 | SOUTH LAHONTAN | 0 | 5 | 6 | 1 | 0 | 1 | 0 | 0 | 13 |
| 11 | COLORADO DESERT | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 7 |
| 12 | TOTAL CALIFORNIA | 0 | 301 | 414 | 78 | 0 | 33 | 22 | 0 | 850 |

## INDUSTRIAL TOTAL WATER CONSUMPTION DURING 1977
(MILLIONS OF GALLONS)

| | | FOOD AND KINDRED PRODUCTS | LUMBER AND WOOD PRODUCTS | PAPER AND ALLIED PRODUCTS | CHEMICAL AND ALLIED PRODUCTS | PETROLEUM AND COAL PRODUCTS | STONE CLAY AND GLASS PRODUCTS | PRIMARY METALS | OTHER INDUSTRIES | TOTAL INDUSTRIES |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 316 | 7759 | 22104 | 4 | 17 | 18 | 0 | 14 | 30232 |
| 2 | SAN FRANCISCO BAY | 26410 | 2014 | 27766 | 21171 | 47516 | 3080 | 2374 | 9303 | 139634 |
| 3 | CENTRAL COASTAL | 5539 | 13 | 4503 | 4589 | 798 | 1504 | 97 | 821 | 17864 |
| 4 | SOUTH COASTAL | 24182 | 348 | 15958 | 13056 | 34243 | 7811 | 6312 | 29665 | 131576 |
| 5 | SACRAMENTO BASIN | 9670 | 12566 | 5509 | 1075 | 44 | 308 | 31 | 376 | 29580 |
| 6 | DELTA-CENTRAL SIERRA | 16054 | 1004 | 6743 | 7347 | 13134 | 842 | 70 | 641 | 45834 |
| 7 | SAN JOAQUIN BASIN | 20248 | 817 | 623 | 1122 | 118 | 602 | 10 | 142 | 23680 |
| 8 | TULARE BASIN | 10750 | 3334 | 29 | 2781 | 1021 | 669 | 65 | 571 | 19321 |
| 9 | NORTH LAHONTAN | 4 | 1859 | 0 | 1 | 0 | 10 | 1 | 6 | 1880 |
| 10 | SOUTH LAHONTAN | 1998 | 89 | 255 | 1712 | 762 | 942 | 478 | 2027 | 8263 |
| 11 | COLORADO DESERT | 277 | 11 | 36 | 148 | 74 | 280 | 218 | 105 | 1148 |
| 12 | TOTAL CALIFORNIA | 115447 | 29815 | 83527 | 53005 | 97727 | 16065 | 9656 | 43770 | 449013 |

## MINIMUM INDUSTRIAL TOTAL WATER USEAGE 100 PERCENT IMPLEMENTATION
(MILLIONS OF GALLONS)

| | | FOOD AND KINDRED PRODUCTS | LUMBER AND WOOD PRODUCTS | PAPER AND ALLIED PRODUCTS | CHEMICAL AND ALLIED PRODUCTS | PETROLEUM AND COAL PRODUCTS | STONE CLAY AND GLASS PRODUCTS | PRIMARY METALS | OTHER INDUSTRIES | TOTAL INDUSTRIES |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 293 | 7371 | 11052 | 4 | 9 | 17 | 0 | 13 | 18760 |
| 2 | SAN FRANCISCO BAY | 24561 | 1913 | 13883 | 20112 | 24708 | 2926 | 2255 | 8837 | 99197 |
| 3 | CENTRAL COASTAL | 5152 | 13 | 2252 | 4359 | 415 | 1429 | 92 | 780 | 14490 |
| 4 | SOUTH COASTAL | 22489 | 331 | 7979 | 12404 | 17807 | 7420 | 5997 | 28181 | 102607 |
| 5 | SACRAMENTO BASIN | 8993 | 11938 | 2755 | 1021 | 23 | 293 | 30 | 358 | 25409 |
| 6 | DELTA-CENTRAL SIERRA | 14930 | 954 | 3372 | 6979 | 6830 | 800 | 66 | 609 | 34540 |
| 7 | SAN JOAQUIN BASIN | 18831 | 776 | 311 | 1066 | 61 | 572 | 9 | 135 | 21761 |
| 8 | TULARE BASIN | 9997 | 3168 | 14 | 2642 | 531 | 636 | 62 | 638 | 17688 |
| 9 | NORTH LAHONTAN | 3 | 1766 | 0 | 1 | 0 | 9 | 1 | 5 | 1786 |
| 10 | SOUTH LAHONTAN | 1858 | 85 | 128 | 1626 | 396 | 895 | 454 | 1926 | 7367 |
| 11 | COLORADO DESERT | 258 | 10 | 18 | 140 | 38 | 266 | 207 | 100 | 1038 |
| 12 | TOTAL CALIFORNIA | 107365 | 28324 | 41764 | 50355 | 50818 | 15262 | 9173 | 41582 | 344643 |

ENERGY REQUIREMENTS FOR TOTAL WATER DEL+DIST DURING 1977
(THOUSANDS OF KILOWATT-HOURS)

| | | FOOD AND KINDRED PRODUCTS | LUMBER AND WOOD PRODUCTS | PAPER AND ALLIED PRODUCTS | CHEMICAL AND ALLIED PRODUCTS | PETROLEUM AND COAL PRODUCTS | STONE CLAY AND GLASS PRODUCTS | PRIMARY METALS | OTHER INDUSTRIES | TOTAL INDUSTRIES |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 69 | 1707 | 4863 | 1 | 4 | 4 | 0 | 3 | 6651 |
| 2 | SAN FRANCISCO BAY | 34021 | 3122 | 27927 | 17464 | 32951 | 4721 | 3656 | 14419 | 138282 |
| 3 | CENTRAL COASTAL | 1933 | 7 | 122 | 132 | 310 | 804 | 49 | 443 | 3800 |
| 4 | SOUTH COASTAL | 50843 | 808 | 24820 | 17895 | 46600 | 18078 | 14626 | 68822 | 242492 |
| 5 | SACRAMENTO BASIN | 2224 | 2890 | 1267 | 247 | 10 | 71 | 7 | 87 | 6803 |
| 6 | DELTA-CENTRAL SIERRA | 8199 | 573 | 1680 | 1989 | 1658 | 472 | 36 | 365 | 14972 |
| 7 | SAN JOAQUIN BASIN | 13250 | 539 | 148 | 473 | 7 | 396 | 6 | 94 | 14913 |
| 8 | TULARE BASIN | 11287 | 3501 | 30 | 2920 | 1072 | 703 | 69 | 705 | 20287 |
| 9 | NORTH LAHONTAN | 1 | 539 | 0 | 0 | 0 | 3 | 0 | 2 | 545 |
| 10 | SOUTH LAHONTAN | 1872 | 86 | 140 | 1536 | 448 | 904 | 459 | 1946 | 7390 |
| 11 | COLORADO DESERT | 178 | 7 | 12 | 86 | 18 | 184 | 144 | 69 | 699 |
| 12 | TOTAL CALIFORNIA | 123879 | 13779 | 61009 | 42744 | 83077 | 26340 | 19052 | 86954 | 456835 |

MINIMUM ENERGY USEAGE FOR TOTAL WATER DEL+DIST 100 PERCENT IMPLEMENTATION
(THOUSANDS OF KILOWATT-HOURS)

| | | FOOD AND KINDRED PRODUCTS | LUMBER AND WOOD PRODUCTS | PAPER AND ALLIED PRODUCTS | CHEMICAL AND ALLIED PRODUCTS | PETROLEUM AND COAL PRODUCTS | STONE CLAY AND GLASS PRODUCTS | PRIMARY METALS | OTHER INDUSTRIES | TOTAL INDUSTRIES |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NORTH COASTAL | 65 | 1622 | 2431 | 1 | 2 | 4 | 0 | 3 | 4127 |
| 2 | SAN FRANCISCO BAY | 31639 | 2966 | 13964 | 16591 | 17135 | 4485 | 3473 | 13698 | 103951 |
| 3 | CENTRAL COASTAL | 1798 | 7 | 61 | 125 | 161 | 763 | 46 | 421 | 3383 |
| 4 | SOUTH COASTAL | 47284 | 768 | 12410 | 17000 | 24232 | 17174 | 13895 | 65381 | 198144 |
| 5 | SACRAMENTO BASIN | 2068 | 2746 | 634 | 235 | 5 | 67 | 7 | 82 | 5844 |
| 6 | DELTA-CENTRAL SIERRA | 7625 | 544 | 840 | 1890 | 862 | 449 | 35 | 347 | 12591 |
| 7 | SAN JOAQUIN BASIN | 12323 | 512 | 74 | 449 | 3 | 376 | 6 | 89 | 13833 |
| 8 | TULARE BASIN | 10497 | 3326 | 15 | 2774 | 557 | 668 | 65 | 669 | 18573 |
| 9 | NORTH LAHONTAN | 1 | 512 | 0 | 0 | 0 | 3 | 0 | 2 | 518 |
| 10 | SOUTH LAHONTAN | 1741 | 81 | 70 | 1459 | 233 | 859 | 436 | 1849 | 6727 |
| 11 | COLORADO DESERT | 166 | 7 | 6 | 82 | 9 | 175 | 137 | 66 | 648 |
| 12 | TOTAL CALIFORNIA | 115207 | 13090 | 30505 | 40607 | 43200 | 25023 | 18100 | 82606 | 368339 |

# APPENDIX E

## WATER CONSUMPTION IN 1976 AND 1977
## FOR SELECTED MONTHS AND WATER DISTRICTS

# APPENDIX E

## COMPARISON OF 1976 TO 1977 WATER CONSUMPTION BY DISTRICT*

| Hydrologic Study Area | Water District | Period | Water Consumption ($10^6$ Gallons) 1976 | 1977 | Percent Change |
|---|---|---|---|---|---|
| (1) North Coastal | Eureka | | 537 | 439 | |
| Total | | | 537 | 439 | -18 |
| (2) San Francisco | San Francisco | 1/1-5/20 | 14067 | 10803 | |
| | San Jose | 1/1-5/19 | 13967 | 10757 | |
| | East Bay MUD | 1/1-5/19 | 27702 | 19342 | |
| | Alameda Co. WD | 1/1-5/19 | 3339 | 2530 | |
| | Santa Clara | 1/1-5/3 | 2173 | 1893 | |
| | San Mateo | 1/1-4/30 | 1286 | 968 | |
| | Daly City | 1/1-5/21 | 1061 | 811 | |
| | Hayward | 1/1-4/30 | 1487 | 1081 | |
| | Sunnyvale | 1/1-4/30 | 2172 | 1779 | |
| | Marin MWD | 1/1-5/22 | 2967 | 1452 | |
| | No. Marin MWD | 1/1-5/30 | 754 | 513 | |
| | Santa Rosa | 1/1-4/30 | 1194 | 934 | |
| | Contra Costa Co. WD | | 10559 | 9315 | |
| Total | | | 82728 | 62,178 | -25 |
| (3) Central Coastal | Monterey Bay | 1/1-4/30 | 1535 | 988 | |
| | Santa Barbara | 1/1-5/1 | 1417 | 1250 | |
| | San Luis Obispo | 1/1-5/1 | 602 | 605 | |
| | Santa Maria | 1/1-5/1 | 746 | 656 | |
| Total | | | 4300 | 3499 | -19 |

APPENDIX E
(cont'd)

| Hydrologic Study Area | | Water District | Period | Water Consumption ($10^6$ Gallons) 1976 | 1977 | Percent Change |
|---|---|---|---|---|---|---|
| (4) | South Coastal | Los Angeles | 1/1-5/1 | 56894 | 55389 | |
| | | San Diego | 1/1-5/1 | 15203 | 14678 | |
| | | Long Beach | 1/1-5/1 | 11542 | 5976 | |
| | | Anaheim | 1/1-5/1 | 5009 | 4774 | |
| | | Riverside | 1/1-3/31 | 2724 | 2412 | |
| | | Oxnard | 1/1-5/1 | 1686 | 1680 | |
| | | Ventura | 1/1-5/1 | 2105 | 1789 | |
| | Total | | | 90,163 | 86,698 | -3 |
| (5) | Sacramento Basin | Redding | 1/1-2/5 | 184 | 221 | |
| | | Chico | 1/1-4/30 | 1076 | 1018 | |
| | | Alturas | 1/1-4/30 | 64 | 76 | |
| | Total | | | 1324 | 1315 | -.6 |
| (6) | Delta-Central Sierra | Stockton | 1/1-4/30 | 2457 | 2012 | -18 |
| | Total | | | 2457 | 2012 | |
| (7) | San Joaquin Basin | Sacramento | 1/1-4/30 | 6263 | 6065 | |
| | | Modesto | 1/1-4/30 | 2445 | 2181 | |
| | | Merced | 1/1-4/30 | 844 | 771 | |
| | | Sonora Jamestown | 1/1-4/30 | 133 | 129 | |
| | Total | | | 9685 | 9146 | -6 |

APPENDIX E
(cont'd)

| Hydrologic Study Area | Water District | Period | Water Consumption ($10^6$ Gallons) 1976 | 1977 | Percent Change |
|---|---|---|---|---|---|
| (8) Tulare Basin | Fresno | 1/1-4/30 | 4684 | 4040 | |
| | Bakersfield | 1/1-4/30 | 3636 | 3355 | |
| Total | | | 8320 | 7395 | -11 |
| STATE TOTAL | | | 199514 | 172652 | -13 |

* Source: [55]

COMPARISON OF 1976 TO 1977 WATER CONSUMPTION

BY DISTRICT: SELECTED MONTHS*

| HSA | Water district | Water Consumption 1976 (×10^6 gal per month) | Water Consumption 1977 (×10^6 gal per month) | Month | Percent change |
|---|---|---|---|---|---|
| San Francisco | EBMUD | 7950.0 | 3630.0 | 5 | |
| | SFWD | 7868.0 | 5726.0 | 4 | |
| | So. SF | 227.4 | 155.2 | 4 | |
| | San Mateo | 361.2 | 248.2 | 4 | |
| | Los Altos | 337.2 | 255.2 | 4 | |
| | San Carlos | 124.8 | 82.5 | 4 | |
| | Total | 16868.6 | 10097.1 | | -40 |
| Central Coastal | Santa Cruz | 404.2 | 172.0 | 5 | |
| | Santa Barbara | 358.4 | 376.0 | 4 | |
| | Salinas | 251.0 | 242.4 | | |
| | King City | 85.1 | 94.0 | | |
| | Total | 1098.7 | 884.4 | | -20 |
| South Coastal | LADWP | 191.5 | 186.7 | 3 | |
| | LADWP | 199.9 | 192.9 | 4 | |
| | E. LA | 520.7 | 501.7 | 4 | |
| | Hermosa/Redondo | 380.6 | 343.6 | 4 | |
| | Palos Verdes | 403.2 | 430.9 | 4 | |
| | Total | 1695.9 | 1655.8 | | -2 |
| Sacramento Basin | Sacramento | 6707.0 | 5365.0 | 4 | |
| | Willows | 118.1 | 108.7 | 4 | |
| | Chico | 369.6 | 379.8 | 4 | |
| | Marysville | 65.2 | 61.7 | 4 | |
| | Oroville | 74.9 | 80.2 | 4 | |
| | Total | 7334.8 | 5995.4 | | -18 |

continued . . .

TABLE 15 (continued)

| HSA | Water district | Water Consumption 1976 (×10$^6$ gal per month) | Water Consumption 1977 (×10$^6$ gal per month) | Month | Percent change |
|---|---|---|---|---|---|
| Delta Central Sierra | Stockton | 761.4 | 639.2 | 5 | |
| | Dixon | 33.9 | 29.3 | 5 | |
| | Livermore | 164.1 | 126.2 | 1-4 | |
| | Total | 959.4 | 794.7 | | -17 |
| Tulare Basin | Fresno | 25.2 | 30.8 | 1 | |
| | Fresno | 25.9 | 26.9 | 2 | |
| | Fresno | 29.6 | 37.1 | 3 | |
| | Fresno | 42.8 | 44.9 | 4 | |
| | Selma | 85.6 | 81.3 | 4 | |
| | Bakersfield | 1133.8 | 1210.0 | 4 | |
| | Visalia | 313.7 | 340.3 | | |
| | Total | 1656.6 | 1771.3 | | +7 |
| San Joaquin | Modesto | 540.0 | 457.0 | 1 | |
| | Modesto | 467.0 | 437.0 | 2 | |
| | Modesto | 659.0 | 507.0 | 3 | |
| | Modesto | 791.0 | 783.0 | 4 | |
| | Merced | 166.2 | 247.3 | 3 | |
| | Merced | 301.8 | 301.6 | 4 | |
| | Turlock | 271.0 | 238.6 | 4 | |
| | Total | 3196.0 | 2971.5 | | -7 |

*Sources: LBL survey of above water district offices.

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B. Cane Sugar
C. Beet Sugar
D. Dairy Product Processing
E. Poultry
F. Red Meat Processing
G. Petroleum Refining
H. Unbleached Kraft and Semi-Chemical Pulp
I. Organic Chemicals
J. Inorganic Chemicals
K. Soaps and Detergents
L. Wet Storage, Sawmills, Particleboard and Insulation Board
M. Plywood, Hardboard and Wood Preserving
N. Wood Furniture and Fixture Manufacturing
O. Cement Processing
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