

UNIVERSITY OF CALIFORNIA
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"Analysis of Water Demand, Supply, and Pricing: 1987-1992 Drought
in Santa Barbara, California"

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by

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ABSTRACT

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This paper analyzes the progression of average water use, water revenue, and the average cost of water supply for a moderately-sized municipality, the City of Santa Barbara, California, during an extreme drought event from 1987 to 1992. The 1987-1992 drought was one of the most severe to strike the State of California this century. The study area was struck particularly hard. Prior to the drought, the City of Santa Barbara was solely dependent on local water sources to supply its water users. This made it particularly vulnerable to the recurrent droughts which are part of the regional climate. The 1987-1992 drought provided a rare opportunity to observe the sensitivity of municipal water use to pricing, conservation, and other water system management measures during extreme drought conditions. The analysis indicates that the average cost of supplying water rose more than three-fold in real terms from 1986 to 1996. During the same period, the average price of a unit of water being paid by the water user was at all times below the average cost to the water supplier to produce a unit of water. Per-capita water use during the height of the drought dropped to 48% that of pre-drought per-capita water use. In 1996, per-capita water use had only risen to 64% of the pre-drought level.

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1. Introduction

During the water years 1986-87 to 1991-92 (a water year runs from October 1 through September 30), California endured the longest and most severe drought of the twentieth century, since the “great” drought of 1928-29 to 1933-34. The 1928-29 to 1933-34 drought is the worst drought on record to strike the State of California. Over its six-year duration, estimated average stream runoff for the Sacramento River Basin, which is used as an indicator of statewide water supply conditions, was 9.8 million acre feet per year (MAFY) ($1.20834 \times 10^{10} \text{ m}^3/\text{year}$) (State of California Department of Water Resources, 1993). One acre foot is equivalent to one level acre of land ($43,560 \text{ ft}^2$, or $4,046 \text{ m}^2$) covered by 1 foot (30.48 cm) of water, or approximately 326,000 gallons ($1 \text{ AF} = 1,233 \text{ m}^3$). This same region fared only slightly better during the 1986-87 to 1991-92 drought, with an estimated average runoff of 10.0 MAFY ($1.233 \times 10^{10} \text{ m}^3/\text{year}$) (State of California Department of Water Resources, 1993).

During the six-year duration of the 1986-87 to 1991-92 drought, five of the six years were labeled “critically dry” by the State of California Department of Water Resources, while water year 1988-89 was labeled as a less severe “dry” (State of California Department of Water Resources, 1993). For water years 1986-87 to 1991-92, statewide annual stream runoff was, given as a percent of average: 48%,

48%, 72%, 45%, 43%, and 43%, respectively (State of California Department of Water Resources, 1993). Of the ten hydrologic regions into which the state is divided (see figure 1), the Central Coast Hydrologic Region suffered particularly strong hydrologic, environmental, political, and economic impacts due to the 1986-87 to 1991-92 drought. This region roughly includes the counties of Santa Cruz, San Benito, Monterey, San Luis Obispo, and Santa Barbara. Within this region, annual stream runoff was far below average for the duration of the drought. For water years 1986-1987 to 1991-1992 annual stream runoff in the Central Coast Hydrologic Region was, given as a percent of average: 19%, 20%, 19%, 9%, 43%, and 53%, respectively (State of California Department of Water Resources, 1993). During the summer of 1990, Cachuma Reservoir, which is located in the southernmost part of the Central Coast Hydrologic Region, and serves a large portion of Santa Barbara County's south coast population, contained only enough water to endure another 12 months of continued drought (State of California Department of Water Resources, October 1994).

These impacts were aggravated in part due to the fact that the Central Coast Hydrologic Region was, at the time, not a participant in any of three major water transfer projects within the state: the Central Valley Project, the State Water Project, and diversions of water from the Colorado River. Lacking connection to these outside water supplies prior to the drought, the Central Coast Hydrologic Region was forced to subsist on local surface water supplies, and to a lesser extent,

local groundwater supplies. One reason for the lack of these outside water supplies was the prohibitively high cost of transporting the water from the central portions of the state over the coastal mountain ranges. Other reasons included independently-minded agricultural concerns relying on private groundwater resources whenever possible, and a prevalent anti-growth sentiment in many areas of the Central Coast Hydrologic Region, which associated the presence of state water with massive development.

This self-imposed isolation was stable, both economically and politically, until the arrival of the drought. The drought occurred at a time when the demand for urban water was at its highest level to date. With the arrival of the drought, water purveyors had to resort to extreme measures to temper its impact. Strict conservation programs were enacted, including water rationing, in an effort to control water demand. New pricing structures were put in place, with some water rates climbing over 300%. Innovative ways to stabilize water supply were introduced, including the construction of the first municipal ocean water desalination facility in the contiguous United States. Water customers were forced to adopt conservation conscious approaches to water use to avoid the steep financial penalties associated with wasting water. The 1986-87 to 1991-92 drought showed just how vulnerable the Central Coast Hydrologic Region was to severe and sustained drought. All of these events combined to reveal the inter-relationships

between water supply, demand, and pricing which are not readily observable during average hydrologic conditions.

2. Objectives of the study

The central hypothesis of this research project is that in areas with uncertain water supplies and slow growth, such as in the Central Coast Hydrologic Region of California, water supply sources, conservation, and pricing structure are determined by a convergence of economic and social factors that occur only during conditions of extreme (both severe and sustained) drought. During average hydrologic conditions, such as those that have prevailed in the Central Coast Hydrologic Region ever since the 1940's with typical periodic oscillations, water pricing is set to recover capital and operational costs of (monopolistic) water purveyors. This method for financial operation is required by law for public water purveyors in the State of California. Section 71616 of the *California Water Code* (State of California, 1977) states that:

"A district, so far as practicable, shall fix rates for water in the district, and in each improvement district therein, as will result in revenues which will:

- (a) Pay the operating expenses of the district and the improvement district.
- (b) Provide for repairs and depreciation of works
- (c) Provide a reasonable surplus for improvements, extensions, and enlargement.
- (d) Pay the interest on any bonded debt.
- (e) Provide a sinking or other fund for the payment of the principal of such bonded debt as it becomes due.
- (f) Repay advances, together with interest at a rate not to exceed the interest value of money to

the district, made from the district to an improvement district.”

When extreme drought occurs, water prices and demand can vary greatly, and they will adjust themselves to whatever level secures a perceived level of reliable water supply for a risk-averse and broad-based constituency of water customers. In essence, it is proposed that in the absence of strong growth caused by either internal or external factors, water supply, demand, and pricing policy is set to satisfy local growth with pricing set to recover costs of developing the water supplies. Dramatic departures from this pricing policy can be caused by extreme hydrologic drought. Then, political and economic factors combine to change water policy as needed to reduce perceived water uncertainty as much as possible.

To investigate this hypothesis and understand the progression of water supply, demand, and pricing relationships during periods of hydrologic stress, the City of Santa Barbara, Santa Barbara County, California (see figure 2) was selected as the case from which data was analyzed to determine the impact of the 1986-87 to 1991-92 drought. This research investigation consists of five parts: (1) analysis of the long-term hydrology of the Santa Ynez River, which is a major source of water for the City of Santa Barbara. This analysis is based on an already developed 428-year long tree-ring reconstruction of annual streamflows of the Santa Ynez River to establish the historical context of the 1986-87 to 1991-92 drought as measured by the volume of runoff, duration of the drought, and the time distribution of runoff

during the drought; (2) study of the changes in water demand, and its progression from pre-drought conditions, throughout the drought, and into the post-drought period; (3) study of water pricing mechanisms and their progression through pre-drought, drought, and post-drought conditions; (4) analysis of water supply development as a result of the drought, including ocean-water desalination, groundwater management, state water importation, water conservation, and water reclamation. This part of the research will examine volumes, costs, environmental impacts, and time-to-implementation of new water alternatives; and (5) analysis of demand/price and supply/cost relationships.

3. Hydrologic droughts and the 1986-87 to 1991-92 drought in the study area

3.1 Historic rainfall record

The historical record for annual rainfall in the City of Santa Barbara begins in water year 1867-68. The State of California Department of Water Resources records a water year as beginning on October 1, and ending on September 30, the following calendar year. The annual rainfall totals for Santa Barbara are shown in figure 3, and given in appendix A. The median amount of rainfall for the 128-year record is 15.85 inches (40.26 cm, 1 in. = 2.54 cm). Figure 4 shows a histogram of drought frequency and duration for Santa Barbara within the historic record. Here, "drought" is defined as a year with below median rainfall. The longest below median rainfall period for Santa Barbara was seven years, which occurred from water years 1944-45 to 1950-51. There was also one instance of a five year below median rainfall period, water years 1869-70 to 1873-74. Two instances of a four year below median rainfall period are evident. These are water years 1927-28 to 1930-31 and 1986-87 to 1989-90. From figure 4, it can be seen that even within the historic record, the 1986-87 to 1991-92 drought does not represent the worst case drought scenario, in terms of temporal extent, for the City of Santa Barbara.

Even more important than the rainfall which falls upon the city, is the rainfall which falls upon the watershed of the Santa Ynez River. The two reservoirs which

supply water to the city, Gibraltar and Cachuma, are located on the Santa Ynez River (see figure 2). The historic rainfall record for Gibraltar Dam, dating back to water year 1919-20 is shown in figure 5, and given in appendix D. The median annual rainfall for this period is 21.52 inches (55.66 cm). The increase over precipitation amounts in Santa Barbara is due to the dam's elevation of 1,399 feet (426.4 m) in the upper reaches of the Santa Ynez Valley. At this elevation, the orographic effect of the surrounding mountains, causes the increase in precipitation. The historic rainfall record for Bradbury Dam (at Cachuma Reservoir), dating back to water year 1951-52 is shown in figure 6, and given in appendix E. The median annual rainfall for this period was 16.84 inches (42.77 cm). The median rainfall amounts during the same 1951-52 to 1995-96 period at Santa Barbara and Gibraltar Dam were 16.71 inches (42.44 cm) and 21.83 inches (55.70 cm), respectively.

3.2 Dendroclimatic runoff record

A reconstruction of the flows on the Santa Ynez River at Bradbury Dam based on tree rings was produced by Michaelisen and Haston (1988). This is shown in figure 7, and given in appendix B. The median amount of runoff for the 428-year period from 1537-1964 is 29,586 AFY ($36,479,538 \text{ m}^3$). Figure 8 shows a histogram of drought frequency and duration for the period. Here, "drought" is defined as a year with below median runoff. The longest reconstructed below median runoff period was nine years, which was from 1626-1634. There was one

instance of a six year period of below median runoff, 1946-1951. There were four periods of below median annual runoff lasting five years: 1544-1548, 1653-1657, 1733-1737, 1896-1900. There were also six periods of below median annual runoff lasting four years: 1573-1576, 1621-1624, 1663-1666, 1856-1859, 1928-1931, and 1953-1956. As with the historic rainfall record, the reconstructed runoff record would suggest, that the 1986-87 to 1991-92 drought was not the most severe, again in terms of temporal extent, which could be expected to occur within the study area.

3.3 The Santa Ynez River Model

Another reconstruction was produced by the *Santa Ynez River Model*, which was created the Santa Barbara County Flood Control and Water Conservation District. This model produced unimpaired flows of the Santa Ynez River (in AFY) for the water years 1917-18 to 1991-92. In this context, “unimpaired flows” refer to the theoretical volume of water that would be contained in the river, given known precipitation amounts, if the three dams (Bradbury, Gibraltar, and Juncal) along its run were to be removed. In addition, the model also assumes that there is no extraction of groundwater along the river. The calculated unimpaired flows at Bradbury Dam are shown in figure 9, and given in appendix C. The calculated unimpaired flows superimposed over annual rainfall for Cachuma Reservoir are shown in figure 10.

The median unimpaired flow at Bradbury Dam was 22,918 AFY (28,257,894 m³), as compared to the 29,586 AFY (36,479,538 m³) as determined by examination of the tree cores from the study area. A comparison between the dendroclimatic record and the Santa Ynez River Model for all droughts lasting four years or longer is given in table 1. These two different methods are compared on the basis of total annual runoff. When compared volumetrically, it is again seen that the 1986-87 to 1991-92 drought does not represent a worst case scenario for the study area. In addition, the dendroclimatic record would suggest that droughts of greater severity (duration and intensity) than those indicated by the historic record are possible within the study area.

3.4 Temporal distribution of rainfall/runoff during the drought

The temporal distribution of rainfall for the City of Santa Barbara during the drought is shown in figure 11. During the height of the drought, for twenty-two months from March of 1989 to December of 1990, Santa Barbara received a total of 8.78 inches (22.30 cm) of rainfall. Only two of the twenty-two months received greater than 0.90 inches (2.29 cm) of rainfall, and fourteen of the twenty-two months received less than 0.15 inches (0.38 cm) of rainfall. The median monthly rainfall for Santa Barbara for this period was only 0.06 inches (0.15 cm).

The time distribution of rainfall and runoff along the Santa Ynez River at Bradbury Dam during the drought is shown in figure 12. The runoff amounts are the unimpaired flows at Bradbury Dam, as calculated by the Santa Ynez River Model. For the four years and nine months spanning from June 1987 to February 1992, the model calculated a total 28,628 AF (35,298,324 m³) of runoff. Out of these fifty-seven months, only two exceeded 2,500 AF (3,082,500 m³) of runoff. For purposes of comparison, 2,500 AF is only about one sixth of the city of Santa Barbara's pre-drought annual demand of approximately 16,000 AFY (19,728,000 m³). Forty-eight of the fifty-seven months had 500 AF (616,500 m³) or less of runoff. The median monthly runoff for the Santa Ynez River at Bradbury Dam for this period was 199.5 AF (245,984 m³).

The lack of rainfall, and subsequent runoff had a dramatic impact on the city's water supply reservoirs. The monthly distribution of storage in Gibraltar Reservoir is shown in figure 13. The total storage capacity of Gibraltar Reservoir has decreased over time due to the continuous influx of silt. The *Long-Term Water Supply Alternatives Analysis & Urban Water Management Plan* (City of Santa Barbara Department of Public Works et al., 1991) gives the estimated average siltation rate for Gibraltar Reservoir as 216 AFY (266,328 m³). This rate can vary greatly, depending on the annual amount of rainfall, and the loss of vegetative cover in the watershed area due to wildfire. The total storage capacity as of October 1979 was 8,940 AF (11,023,020 m³) (Bowers et al., 1988). Total capacity as of

September 1986 was 8,240 AF (10,159,920 m³) (Bowers et al., 1990). As of February 1989, total capacity was 8,440 AF (10,406,520 m³) (Bowers et al., 1991). The increase in storage capacity was due to the removal of silt from the reservoir by dredging. The project was a joint venture between the City of Santa Barbara and the Environmental Protection Agency (City of Santa Barbara Department of Public Works et al., 1991). The most recent survey, which was completed in December of 1995, estimated total capacity at 7,635 AF (9,413,955 m³) (City of Santa Barbara Department of Public Works, 1996). This survey estimated that approximately 1000 AF of storage capacity had been lost since the last survey had been done in 1992. A large portion of this loss is assumed to be the result of the heavy rainfall during the 1994-95 winter.

During the winter of 1987-88, storage in Gibraltar Reservoir dropped to 2,050 AF (3,082,500 m³) in December 1987, or 25% of total capacity (see figure 13). Storage recovered somewhat the following April, rising to 7,060 AF (8,704,980 m³), or 85% of total capacity. After that, a declining trend began, with storage dropping to 26% of total capacity in May of 1989. Gibraltar Reservoir went completely dry on November 17, 1989 (City of Santa Barbara Department of Public Works et al., 1991). Storage remained at 0% of total capacity for sixteen months. Storage finally reached 100% of total capacity in March of 1991, after the arrival of a particularly wet month. Santa Barbara received 11.05 inches (28.07 cm) of rainfall during the month of March, while Gibraltar Reservoir received 23.12 inches

(58.72 cm) of rainfall. From March of 1991 to the present (1996), winter rains were sufficient to maintain Gibraltar reservoir at close to total capacity.

The monthly distribution of storage in Cachuma Reservoir is shown in figure 14. The total storage capacity for Cachuma Reservoir has also decreased over time due to siltation. As of water year 1985, total storage capacity was 204,874 AF (252,609,642 m³) (Bowers et al., 1987). By water year 1990, total capacity had dropped to 190,409 AF (234,774,297 m³) (Bowers et al., 1991) due to siltation. The winter rains of 1985-86 were enough to fill Cachuma Reservoir to 98% of total capacity. As the drought began, water levels gradually declined, reaching 50% of total capacity in September of 1988, 24% in June of 1990, and bottoming out at 15% in March of 1991. The spring rains of 1991 that filled Gibraltar Reservoir were only sufficient to fill Cachuma Reservoir to 40% of total capacity. By the following winter of 1991-92 storage had again dropped, lowering to 27% of total capacity in January of 1992. However, due to the spring rains of 1991-92, storage eventually reached 94% of total capacity in June of 1992 (Bowers et al., 1993). Since the winter of 1991-92, runoff has been sufficient to maintain an adequate water supply in the reservoir. The decrease in volume in 1995, evident in figure 14, was due to releases of water to maintain the reservoir at a lower level, until repairs to Bradbury Dam could be made to make it more resistant to seismic damage (City of Santa Barbara Department of Public Works, 1996).

4. Evolution of water demand in the study area

4.1 Water demand by water year, calendar year, and fiscal year

The two ways in which the City of Santa Barbara records annual water demand are total potable production, and total metered sales. Total potable production refers to the total amount of water produced and sent into the system for delivery to all water customers. This would include water which can not be accounted for due to leaks in the delivery system, water meter error, fire fighting, customer theft, etc. Total metered sales refers to water that is actually delivered, and recorded on the customer's water meter. The metered sales ratio is the total metered sales divided by the total potable production. From the pre-drought era (1986) through the post-drought era in Santa Barbara, the metered sales ratio has ranged from 91% to 96% (City of Santa Barbara Department of Public Works, 1996).

Prior to the 1986-87 to 1991-92 drought, demand had been relatively stable for several years. Table 2 shows annual total potable production by water year going back to 1969. From water year 1968-69 to water year 1982-83, total production varied between 12,636 AFY (15,580,188 m³) and 15,141 AFY (18,668,853 m³), with a median of 13,874 AFY (17,106,642 m³). By the pre-drought water year 1985-86, total potable production had been close to or above 16,000 AFY (19,728,000 m³) for three consecutive years. By water year 1989-90, total potable

production dropped to 10,518 AF (12,968,694 m³), or only 66% of pre-drought levels. Water year 1990-91 saw the lowest level of total potable production: 9,149 AF (11,280,717 m³), or 57% of pre-drought levels. By water year 1994-95, three years after the end of the drought, total potable production was still only 11,724 AF (14,455,692 m³), or 73% of pre-drought levels.

The demand for water on a per-capita basis is shown in tables 3,4, and 5. Table 3 gives per-capita demand for Santa Barbara by water year. Tables 4 and 5 give demand by calendar year and fiscal year, respectively, and are included for comparison. From table 3, it can be seen that during water year 1990-91, per-capita water demand had dropped to 48% of the pre-drought level of 82.7 HCF/capita in water year 1986-87. By water year 1994-95, even though Santa Barbara had returned to "normal" hydrologic conditions and there was a secure water supply, per-capita demand was still only 60% of pre-drought levels.

Residential (both single and multi-family units) water use accounts for about 70% of the water used in Santa Barbara (City of Santa Barbara Department of Public Works, 1995). Given that, demand for water was also calculated for single family units, on a per-residential unit basis. This is shown in tables 6 and 7. Table 6 gives demand by water year. Table 7 gives demand by calendar year. From table 7, it is seen that during calendar year 1990, single family residential demand was only 1,551,819 HCF (4,391,648 m³), or 56% of the pre-drought level of 2,768,717 HCF

(7,835,469 m³) in 1986. By calendar year 1995, single family residential demand had only climbed back up to 2,074,078 HCF (5,869,641 m³), or 75% of pre-drought levels.

The discrepancy between the pre- and post-drought demand on tables 3 and 7 can be explained two ways. First, table 3 gives the demand for the entire population of Santa Barbara. This would include all classes of water customers, such as industrial and commercial, not just single-family residential, as is the case with table 7. It would not be expected that single-family residential units would have the same demand as all other classes of water customers. Second, table 3 is based on state water years (October 1 through September 30), while table 7 is based on calendar years. The periods defining pre- and post-drought in these two tables are not identical, so it reasonable not to expect that these tables contain identical information. What is noteworthy, is that fact that in neither case did post-drought water consumption approach pre-drought levels.

4.2 Distribution of water consumption

Variations in single-family residential water demand were also analyzed via water consumption distribution curves. Consumption is measured in increments of one hundred cubic feet (HCF, 1 HCF = 748 gallons = 2.83 m³). These curves show, for each level of consumption, what percentage of the single-family residential units

are using a certain number or less of HCF/month. Figure 15 shows water consumption distribution curves for different periods from before the drought to after the drought. Each curve represents a one-year time period. The periods of record do not all cover the same months of the year. These periods were selected on the basis of (limited) data availability. For pre-drought conditions, in calendar year 1986, the median use was 9 HCF/month ($25.47 \text{ m}^3/\text{month}$) per unit. For the next period of record, December 1988 - November 1989, the median use increased to 10.0 HCF/month ($28.3 \text{ m}^3/\text{month}$). Median use dropped to its lowest during the period September 1989 - August 1990, reaching 6.1 HCF/month ($17.26 \text{ m}^3/\text{month}$). By 1991, median use rose to 6.3 HCF/month ($17.83 \text{ m}^3/\text{month}$). For the most recent period of record, fiscal year 1993-94 (a fiscal year runs from July 1 of one year to June 30 the following year), median use had only risen to 7.4 HCF/month ($20.94 \text{ m}^3/\text{month}$). This represents 82.2% of the pre-drought median use for single-family residential units.

The effects of the drought on the distribution patterns of consumption are also clearly visible in figure 15. Out of all five years displayed, the pre-drought calendar year, 1986, displays a curve which is the least steep. This would imply that in 1986, the distribution of water consumption was the most evenly divided over the range of consumption levels. During the period December 1988 - November 1989, it is seen that the median use actually went up. However, for approximately 25% of users with the largest consumption, median use dropped. This overall lowering of

water demand is evident by the leftward shift in the upper 25% of the curve. The curve is steeper than the curve for 1986. This means that the distribution of consumption is divided over a smaller range of consumption levels than the curve for 1986. There is an increase in low-end users and a decrease in high end users compared to the consumption distribution curve for 1986.

The next period of record in figure 15, September 1989 - August 1990, shows another decrease in median use. Again, the steepness of the curve is indicative of the uneven distribution of consumption. The curve for calendar year 1991 is the steepest out of all five years. Although the median use of 6.3 HCF/month (17.83 m³/month) is slightly higher than that of the previous period of record, September 1989 - August 1990 at 6.1 HCF/month (17.26 m³/month), the distribution shows a decrease in the number of high-end users, and an increase in the number of low-end users.

With the most recent period of record in figure 15, July 1993 - June 1994, the distribution shows an increase in overall median use. By this time, the median use had risen to 7.4 HCF/month (20.94 m³/month). It is interesting to note that even though this consumption distribution curve represents the post-drought era, the shape of the curve appears to be closer to those of the drought years, than it is to the pre-drought calendar year 1986. This effect shown in figure 15, the slight growth in median use while maintaining pre-drought consumption distribution patterns, is one

of the most important effects of the drought. It would suggest that the conservation-minded water use patterns that were established during the drought are having a lasting impact on water demand in the post-drought era. Even though the period from July 1993 - June 1994 shows a slight increase in the median use, it is important to note that this is still only 82.2% of the pre-drought median use.

The drought's effect on post-drought consumption distribution patterns is dramatically evident in figure 16. This figure shows the consumption distribution curve for calendar years 1991 (a drought year), 1992 (a transitional year), and the curves for three different post-drought one-year periods. What is immediately evident is that all three post-drought curves are extremely similar in shape, and median use. In the two years represented by the three post-drought curves, the consumption distribution has changed very little. In addition, the shape of the curves closely resembles that of calendar year 1991, a drought year with the narrowest overall range of consumption distribution. If the conservation patterns which were a response to the drought do in fact remain in place for several years, resulting in similar consumption distribution patterns, then it appears that demand will approach its pre-drought level only through an increase in the population size of Santa Barbara. The individual consumption distribution curves for each of the one-year periods displayed in figures 15 and 16 are given for reference in figures 19-26.

5. Evolution of water pricing in the study area

5.1 Different types of water rate structures

There are four basic methods used for charging customers for water. These are a fixed charge with unmeasured consumption, an increasing block rate, a uniform rate, and a decreasing block rate. Any of the last three methods could also be combined with a fixed monthly service charge. The different pricing structures are shown in figure 17. Case (A) in figure 17 shows a fixed charge with unmeasured consumption. Here the customer is charged a flat fee, and the level of consumption does not determine the size of the water bill.

Cases (B), (C), and (D) show the addition of a fixed monthly service charge (F). The introduction of the service charge serves to reduce revenue vulnerability. Revenue vulnerability is defined as the percentage of the water purveyor's revenue which comes from the metered sales of water as opposed to monthly service charges. If a high percentage of revenue comes from metered sales, then the water purveyor is subject to the repercussions of fluctuations in water demand, which may result in financial instability.

Case (B) shows an increasing block rate (with a fixed monthly service charge). With this pricing structure, the unit price per HCF increases as the customer's total

consumption increases. In case (B), the range of consumption, (Q), is broken into four blocks. These blocks do not necessarily have to be of equal size. A typical breakdown of the range of consumption could be: block 1 = 0 - 4 HCF, block 2 = 5 - 12 HCF, block 3 = 13 - 20 HCF, and block 4 = over 21 HCF. For each unit HCF purchased within one of the blocks, the corresponding unit price, $(P_n)/\text{HCF}$, would apply ($n=1,2,3,4$). For the sample breakdown over the range mentioned here, for the first 4 HCF, the unit price would be P_1/HCF . Once the 4th HCF had been consumed, the unit price would then be P_2/HCF . This unit price/HCF would continue until the 12th HCF had been consumed, at which point the unit price would become P_3/HCF , etc. The total monthly bill for water purchased would therefore be equal to:

$$F + (P_1 * R_1) + (P_2 * R_2) + (P_3 * R_3) + (P_4 * R_4),$$

where R_n would be the number of HCF purchased within each block.

According to the 1994 water rate survey (Ernst & Young's Consulting Services, 1994), only 22% of water purveyors surveyed nationwide were using the increasing block rate pricing structure. Among the western states, the percentage was 32%. The main reason for using an increasing block rate price structure is to encourage water conservation. The higher rates which are applied to the blocks of higher water

usage are intended as an incentive for customers to remain in the lower usage blocks.

Case (C) shows a uniform rate (with a fixed monthly service charge). Here the customer is charged the same rate per HCF for any level of consumption. A 1994 national water rate survey showed that 37% of 159 surveyed water utilities were using the uniform rate (Ernst & Young's Consulting Services, 1994). Among the western states, this number was 56%. Some problems with the uniform rate and the unmeasured consumption pricing structures are that they can imply that all levels of water production cost the same to produce, and that there is an ample water supply. Although the uniform rate and the unmeasured consumption pricing structures do occur in areas where water is scarce, they can hinder a water purveyor who is trying to induce water conservation among its customers.

Case (D) shows a decreasing block rate (with a fixed monthly service charge). This pricing structure is similar to the increasing block rate pricing structure, except that the unit price per HCF decreases with the customer's increasing total consumption. As a result, the lower water rates at higher rates of consumption give no incentive for the customer to conserve water. Not surprisingly, according to the 1994 survey (Ernst & Young's Consulting Services, 1994), only 4% of surveyed water purveyors in the western states were using the decreasing block rate pricing structure in 1994. The decreasing block rate pricing structure was much more

common in the rest of the country. It was being used by 40% of water purveyors in the Northeast, 36% in the South, and 71% in the Midwest. It is interesting to note that in 1986, prior to the 1986-87 to 1991-92 drought in California, the number of surveyed water purveyors in the western states which were using the decreasing block rate pricing structure was much higher, at 30%. This is not to say that the drought in California caused these changes, but it is worth noting.

5.2 Pre-drought to post-drought water rate structures

In Santa Barbara, prior to the 1986-87 to 1991-92 drought, the pricing structure which had been in use for several years was the uniform rate with fixed monthly service charge. Beginning in July of 1989, the pricing structure was changed to an increasing block rate with a fixed monthly service charge. This method of billing water customers has remained until the present day. Figure 18 shows all the different pricing structures, with their corresponding service charges, that have been in effect since April of 1976. Prior to the drought, in 1986, the price for water was a uniform rate of \$0.89/HCF, with a service charge of \$4.10/month. This pricing structure remained in effect for two years. In July of 1988, the uniform rate was raised to \$1.02/HCF, and the service charge was raised to \$4.72/month. This pricing structure was in effect for one year. It was during March of 1989, that a Stage I Drought Condition was declared by the Santa Barbara City Council. This established a water conservation goal of 10%.

In July of 1989, the first increasing block rate pricing structure was put into effect. Within this pricing structure, there were four different unit price blocks. The unit price blocks for this pricing structure ranged from \$1.09 to \$3.01/HCF, and the service charge was lowered to \$1.47/month. This pricing structure was in effect for eight months. It was during this time, in January of 1990, that a Stage II Drought Condition was declared by the City Council. This established a water conservation goal of 15%. Also during the time period while this pricing structure was in effect, in February of 1990, the City Council decided to upgrade to a Stage III Drought Condition. This established a water conservation goal of 45%. Also, as part of the Stage III Drought Condition, prohibitions on landscape irrigation were imposed.

In March of 1990, new water rates were put into effect. These were the most expensive rates of any period before, during, or after the drought. These rates ranged from \$1.09 to \$29.43/HCF, with a service charge of \$1.47/month. The block 4 rate of \$29.43/HCF was an increase of over 3,300% of the pre-drought uniform rate of \$0.89/HCF. In April of 1990, there was actually a one month deferral of the new rates to allow customers to adjust their water consuming behavior to these new rates. In July of 1990, there was a one month reduction of the block 4 rates down to the level of the block 3 rates due to the Painted Cave fire of June, 1990. This pricing structure remained in effect for eight months.

Water rates were lowered in November of 1990. The new rates ranged from \$1.09 to \$16.50/HCF, with a service charge of \$1.47/month. The block 4 rate of \$16.50/HCF was still an increase of over 1,850% of the pre-drought uniform rate of \$0.89/HCF. The water conservation goal of 45% was lowered to 32%. In March of 1991, Santa Barbara received 11.05 inches (28.07 cm) of rainfall. The following May, water rates were again lowered. The new rates ranged from \$1.85 to \$12.00/HCF, with an increase in the service charge to \$3.70/month. This pricing structure was in effect for five months. Although the customers with higher monthly water usage saw sizable decreases in their water bills, the customers in the lower end of the consumption spectrum actually had an increase in their water bills. Table 8 shows the water bills that would accrue with various levels of water consumption, for all the different pricing structures that were in effect in Santa Barbara before, during, and after the drought.

In September of 1991, the Santa Barbara City Council cancelled the Stage III Drought Condition, and the city reverted back to a Stage II Drought Condition. In October of 1991, the water rates were again lowered. The new rates ranged from \$1.85 to \$7.40/HCF, with a service charge of \$3.70/month. It was during the time period for which this pricing structure was in effect, in March of 1992, that the City Council cancelled the Stage II Drought Condition, thus officially terminating the drought. For the next nineteen months, from October of 1991 until April of 1993, water rates were dynamic in that the number of HCF required to move from one

unit price to the next changed. However, the range of the rates did not change during this period. The rates remained from \$1.85 to \$7.40/HCF, with a service charge of \$3.70/month. Rates were again lowered in May of 1993. The new rates ranged from \$1.85 to \$5.10/HCF, with a service charge of \$3.70/month. This pricing structure remained in effect for twenty-seven months. It is noteworthy that in the 51 months from May of 1991 to July of 1995, even though there were four different pricing structures in effect, the actual amount paid by water customers using 10 HCF/month ($28.30 \text{ m}^3/\text{month}$) or less did not change at all (see table 8).

The last change in water rates went into effect in August of 1995. The new rates ranged from \$2.10 to \$3.70/HCF, with an increase in the service charge to \$5.50/month. These rates will have the effect of raising water bills for almost all water users, except for the those with the highest consumption (see table 8). This new pricing structure was agreed upon after the city embarked upon a six month water rate study. The objectives of this study were to obtain public input for the rate-making process, assess revenue requirements, derive costs of service, and recommend some alternative water rate structures which would ensure that Santa Barbara's water utility would be financially stable in the future (Kennedy/Jenks Consultants, 1995).

The water rate study concluded that the rates in effect at the time of the study (\$1.85 to \$5.10/HCF and \$3.70/month service charge) would be adequate to meet

the Water Department's minimum financial needs for the next five years (Kennedy/Jenks Consultants, 1995). However, this would be dependent upon a continuing increase in water demand. The consultants assumed that demand will grow by approximately three percent per year for the next five years. The financial stability of the Water Department is also dependent on an adequate water supply and normal hydrologic conditions. If any of these conditions are not met, the revenue stream may be jeopardized, forcing increased water rates, most likely in the form of a larger service charge.

6. Evolution of water supply in the study area

6.1 Structural Measures

Prior to the 1986-87 to 1991-92 drought, local surface water was the primary source of water supply for the City of Santa Barbara. A secondary, smaller supply was obtained through the limited extraction of local ground water. In the search for new and more reliable water supplies, several sources were considered. These were both structural and non-structural. Structural measures included the State Water Project (SWP), a desalination plant, a water reclamation plant, and increased groundwater extraction. Non-structural measures consisted of water conservation programs such as the distribution of low-flow showerheads, rebates for the installation of low-flow toilets and the encouragement of xeriscaping.

6.1.1 The State Water Project

On June 4th, 1991, the voters of the City of Santa Barbara approved two new structural water supply measures (City of Santa Barbara Department of Public Works, July 1994). One was for the construction of a permanent facility to extract potable water from the ocean by means of desalination, and the other was for the linking of Santa Barbara to the State Water Project via a pipeline from Kern County to Lake Cachuma, the primary water source for the City of Santa Barbara.

The approval of the measure regarding state water required that the City of Santa Barbara participate in the State Water Project, and take its full allotment of 3,000 AFY (36,990,000 m³) (City of Santa Barbara Department of Public Works, July 1994). This is out of an nominal yield of 45,486 AFY (56,084,238 m³) which will be delivered to Santa Barbara County (City of Santa Barbara Department of Public Works et al., 1991). The water will be delivered by a 142-mile (228 km) long buried pipeline. The first segment of the pipeline, the "Coastal Branch", will begin at Devil's Den, in western Kern County. The pipeline will be 60 inches (1.52 m) in diameter, and run for 87 miles (140 km) to the Santa Barbara - San Luis Obispo County line near the City of Santa Maria. This segment will include a regional water treatment facility, three pumping plants, a hydroelectric power plant, and four water storage tanks. The second segment of the pipeline, the "Mission Hills Extension", will run from Santa Maria for 23 miles (37 km) to Mission Hills, near Lompoc. This segment will include one pumping plant, and two storage tanks. The third and final segment of the pipeline, the "Santa Ynez Extension", will run from Mission Hills for 32 miles (51 km) to Lake Cachuma.

The total cost for all three segments of the project is estimated at \$367,000,000 (City of Santa Barbara Department of Public Works et al., 1991). The City of Santa Barbara's share of the cost of the Coastal Branch of the project will be approximately \$1,300,000 per year for 35 years. The city's share of the costs for the Mission Hills and Santa Ynez extensions will be approximately \$2,000,000 per

year for 35 years. The total cost to the City of Santa Barbara will be approximately \$115,500,000. This will make the cost for state water approximately \$1,100/AF (assuming the city does indeed receive an annual allocation of 3,000 AF). The first deliveries from the State Water Project have yet to arrive as of March of 1997.

The Draft Environmental Impact Report for the Coastal Branch and Mission Hills Extension (State of California Department of Water Resources, 1990) portions of the project concluded that most of the potentially significant impacts associated with the construction phase of the project could be reduced to levels that are less than significant, or within current allowable limits. There are two impacts associated with the operation of the completed project which can not be mitigated. These are energy consumption and aesthetics. The delivery of water from the central portions of the state to Lake Cachuma requires that the water be transported over the coastal mountain ranges. This route is very energy intensive. The delivery of SWP water from the Sacramento Delta to Lake Cachuma is estimated to use approximately 3,200 kilowatt hours of electricity per acre foot of water delivered (City of Santa Barbara Department of Public Works et al., 1991). The environmental impact report concluded that most of this energy can be produced by five hydroelectric power plants run by the Metropolitan Water District of Southern California, and therefore is renewable (State of California Department of Water Resources, 1990). When combined with wind driven generators that are available for use by the State Water Project, renewable energy sources will provide over 70%

of the energy required to transport the water from the Sacramento Delta to Lake Cachuma. The problems with aesthetics are associated with the visual blight of the construction process of the project.

In the *Long-Term Water Supply Alternatives Analysis and Urban Water Management Plan* (City of Santa Barbara Department of Public Works et al., 1991), it is pointed out that in some respects, the quality of SWP water will be an improvement over local sources. One common test to determine the purity of water, and hence its potential for human consumption, is to determine the amount of total dissolved solids which the water contains. Particulates are considered dissolved if they are smaller than about 1.2 micrometers. The standard set by the state for maximum allowable total dissolved solids is 1000 parts per million (ppm) (EIP Associates, 1994). The local surface water and ground water used in the City of Santa Barbara are relatively high in total dissolved solids. Local surface waters average 635 ppm, while local groundwater averages 735 ppm (EIP Associates, 1994). The *State Water Project Coastal Branch, Phase II And Mission Hills Extension Draft Environmental Impact Report* (State of California Department of Water Resources, 1990) stated that the Berrenda Mesa Water District, in Santa Barbara County, was currently receiving SWP water from an already existing portion of the Coastal Branch. Tests of this water showed it to have a total dissolved solids content of 258 ppm. SWP water will also contain some contaminants, such as pesticides from agricultural runoff, not currently encountered in local water

supplies. The quality of SWP water will be continuously monitored to ensure that it complies with set guidelines to make it suitable for human consumption.

6.1.2 The desalination facility

The election of June 4th, 1991, also resulted in the approval of the construction of a permanent desalination facility in Santa Barbara. The plant went on-line on March 4th, 1992. The plant has a total capacity of 7,500 AFY (9,247,500 m³). Out of this amount, the City of Santa Barbara is entitled to 3,181 AFY (3,922,173 m³). The remaining 4,319 AFY (5,103,387 m³) is allotted for purchase by the neighboring communities of Montecito and Goleta. The plant ceased operation in June of 1992, and was placed in standby mode (State of California Department of Water Resources, October 1994).

Seawater for desalination is acquired through an intake pipeline, located 2,500 feet (762 m) from shore. The desalination process uses reverse osmosis to produce potable water. The process of reverse osmosis involves forcing the seawater, under high pressure, through membranes which remove particulate matter. After chemical treatment to ensure the water's suitability for human consumption, the desalinated water is introduced into the city's distribution system. The waste product, or brine, is a highly concentrated saline solution. This is mixed with the waste product of an

adjacent sewage treatment plant so as to lower its initial concentration. The mixture is disposed of through an offshore pipeline.

The Long-Term Water Supply Program Final Environmental Impact Report (EIP Associates, 1994) reported several environmental concerns associated with the operation of the desalination facility. The greatest concern is that of the effect of the brine on marine water quality. The brine is, on average, 70% saltier than seawater, with total dissolved solids ranging from 57,400 - 58,900 milligrams per liter. The brine is discharged through an outfall pipeline, four feet in diameter. Beginning at 8,000 feet (2,438 m) offshore, and continuing to the outfall at 8,700 feet (2,662 m) offshore, the pipeline is perforated with holes 3.5 - 4 inches (8.89 - 10.16 cm) wide. The brine is discharged at a rate of 0.24 - 0.33 ft³ (0.0068 - 0.0093 m³) per second per hole. It will be from 0 - 3 °C (0 - 5.4 °F) warmer than the surrounding seawater. As long as the brine is mixed with an adequate amount of waste from the sewage treatment plant, which is 7 - 9 °C (12.6 - 16.2 °F) warmer than seawater, it should be less dense than the surrounding seawater, which would cause the plume from the outfall pipe to rise with an initial dilution of 80 to 1. If the treatment plant does not produce enough wastewater, then the brine-sewage mixture might be denser than the surrounding seawater, which would result in the discharge plume sinking. This would result in a longer amount of time being required to dilute the wastewater and brine mixture. The environmental impact report found that all impacts on marine

water quality were less than significant, and did not require any mitigation measures (EIP Associates, 1994).

No significant impacts are expected on marine life. When the desalination plant was still in the planning stages, it was calculated that if it were to operate at 10,000 AFY (12,330,000 m³) the intake pipe would only be pulling in seawater at 0.1 ft³ (0.00028 m³) per second, or about one third the strength of the natural current. According to the environmental impact report, this weak intake current, in addition to the presence of a blocking screen, will prevent the intake of marine life into the system in numbers that would constitute a significant environmental impact (EIP Associates, 1994).

The quality of the desalinated water is better than that of city water in many respects. However, desalinated water has 170 mg/L of chloride, while local surface and groundwater have only 36 mg/L and 95 mg/L, respectively. Sodium levels in desalinated water are 102 mg/L, while local surface and groundwater have only 45 mg/L and 53 mg/L, respectively. These two ions can have an adverse effect upon the growth of vegetation. While the desalination plant will be operating, certain areas of the city will receive 100% desalinated water. Therefore, the vegetation in these areas will have to be monitored to ensure that they are not damaged by the desalinated water.

The desalination process will produce about 0.4 ft^3 (0.01 m^3) of sludge for every 1 AF ($1,233 \text{ m}^3$) of water that is produced. This would consist of the particulate matter removed from the seawater, as well as residue cleaned from the membranes in the pipes. The sludge produced by the desalination process will require disposal in a landfill.

6.1.3 The water reclamation facility

The City of Santa Barbara has a water reclamation plant which can produce usable water from treated sewage wastewater. Although it is not suitable for human consumption, it can be used for the irrigation of landscaping. Adjacent to the reclamation plant is El Estero Wastewater Treatment Plant. The plant produces between 7 and 9 million gallons ($27,125$ and $34,875 \text{ m}^3$) of wastewater per day. It is possible to reclaim a maximum of 4 million gallons ($15,500 \text{ m}^3$) per day of this wastewater, or up to 4,479 AFY ($5,522,607 \text{ m}^3$). Currently, the plant has the capability to reclaim about 1,302 AFY ($16,053,366 \text{ m}^3$). This is distributed to 521 acres (2.11 km^2), consisting mainly of parks, schools, and golf courses. Phase I of the plant was completed in July of 1989. It has the capacity to reclaim 670 AFY ($826,110 \text{ m}^3$) of water which is delivered to 268 acres (1.08 km^2), mainly in the eastern portions of the city. Phase I cost \$6,000,000. Phase II of the plant was completed in March of 1992. It has the capacity to reclaim 632 AFY ($779,256 \text{ m}^3$) which is delivered to 253 acres (1.02 km^2), mainly in the western portions of the

city. Phase II cost \$8,000,000. The price for reclaimed water is approximately \$1,300/AF (City of Santa Barbara Department of Public Works et al. 1991).

The process of reclaiming water is the result of three different stages of treatment of the wastewater. Primary treatment involves the removal of solid waste and floating debris. This is accomplished through the use of screens, and allowing the heavier material to sink. This material can then be collected from the bottom of the wastewater storage containers. During secondary treatment, suspended solids and organic matter are removed from the wastewater. During the last stage of the process, tertiary treatment, the effluent from the secondary treatment is disinfected, making it usable as reclaimed water.

The greatest concern with reclaimed water is the high concentration of total dissolved solids, especially salts (Cl, B, Na). Irrigation water with a high level of total dissolved solids can have a detrimental effect on plant life and soils. High levels of salts in the soil can impair the plants ability to extract water from the soil. High salt levels also reduce the soils overall permeability, reducing the amount of water that can infiltrate the soil. The more sensitive plants can tolerate total dissolved solids levels of 1,000 to 1,200 ppm. The less sensitive plants can tolerate total dissolved solids levels of 1,500 ppm. Total dissolved solids levels of 2,000 ppm can cause severe damage (Golf Ventures International, 1992). From January, 1990 to June, 1992, total dissolved solids for the reclaimed water ranged from 1,096

to 1,567 ppm. Water with these high levels of total dissolved solids can cause leaf burn if applied directly to plant foliage. To counter the effects of high concentrations of total dissolved solids, irrigation water should be applied in a manner such that it does not come in contact with plant foliage. In addition, the amount of (reclaimed) irrigation water applied should be increased to leach salts from the soil. It was determined that those customers using the city's reclaimed water for irrigation purposes should increase the amount of water used by 10.8% (Golf Ventures International, 1992). This added amount of water will allow the salts contained in the reclaimed water to be carried down below the root zone, where they will not affect the growth of overlying vegetation. The reclaimed water can also be diluted through the addition of potable water. Cited examples of the damage which can be caused to vegetation by the use of reclaimed water can be found in Swancar (1996).

There are some benefits to using reclaimed water for irrigation purposes. Nitrogen, phosphorus, potassium, and sulfur will be added to the soil in small, but steady quantities by the use of reclaimed water. Due to the addition of these elements, it is possible to reduce the application of nitrogen and phosphorous by up to 25%.

6.1.4 Ground water management

The City of Santa Barbara extracts ground water from three different basins that make up the Santa Barbara ground water basin. These are Storage Unit I, which underlies most of the downtown area, Storage Unit II, which is northwest of the city, and Storage Unit III, which underlies the western portions of the city. The pumping capacity for Storage Unit I is 3,300 AFY (4,068,900 m³). Storage Unit II has a pumping capacity of 1,900 AFY (2,342,700 m³). Storage Unit III, with only one well, has a pumping capacity of only 350 AFY (431,550 m³) (EIP Associates, 1994).

The Santa Barbara ground water basin has an estimated total storage capacity of 108,800 AF (134,150,400 m³) (EIP Associates, 1994). The estimated annual recharge rate is between 2,000 and 2,500 AFY (2,466,000 and 3,082,500 m³) (EIP Associates, 1994). The city's *Long-Term Water Supply Program* estimates the perennial safe yield at 1,400 AFY (1,726,200 m³) (City of Santa Barbara Department of Public Works, July 1994). It calls for an average ground water extraction of 1,304 AFY (1,607,832 m³). Therefore it is not expected that long-term overdraft of the basin, or land subsidence will occur. At the present time (1996), the ground water basin is at full capacity, and will remain so until another drought strikes. This will prevent seawater from intruding into the basin due to pumping of the coastal aquifer.

Storage Unit I, the main water-producing unit, is divided into five separate zones. The zone closest to the surface, known as the shallow zone, is composed of alluvium. The zone below it, the upper producing zone, consists mainly of medium to coarse sand. The next three zones, in descending order, are the middle zone, the lower producing zone, and the deep zone. The middle zone consists mainly of fine-grained deposits with occasional coarse-grained water-bearing deposits interlaced. The lower producing zone consists of medium to coarse sand. The deep zone consists of fine-grained deposits.

The upper and lower producing zones are the two main zones from which ground water is extracted in the Santa Barbara ground water basin. Both the shallow and middle zones yield little water to wells, due to their composition mainly of fine-grained deposits. The water in the deep zone is of an inferior quality. As such, this water is not suitable for human consumption. The water from the deep zone was tested, and found to have a total dissolved solids concentration of 2,260 mg/L (Martin, 1984). It also has high levels of both sodium and chloride. Although the deep zone is in contact with seawater, it is believed that the poor quality of the water in the deep zone is the result more of geochemical reactions within the deep zone than of seawater intrusion (Martin, 1984).

Between August 1978 and January 1980, ground water extraction levels were increased in the Santa Barbara ground water basin as part of a study by the United

States Geological Survey to determine the usable amount of ground water within the basin (see Martin, 1984). For the six-month period prior to the study, pumping rates averaged 1 AF (1,233 m³)/day. During the study pumping rates were increased approximately 700%, and averaged 7 AF (8,631 m³)/day. There were six active wells in this area, less than one mile from the ocean. These were municipal wells 4N/27W-14Q1, 4N/27W-15J2, 4N/27W-15Q10, 4N/27W-22B6, 4N/27W-22C1, and 4N/27W-E1 (solely a monitoring well) (Martin, 1984).

During 1979, the total amount of ground water extracted from the Santa Barbara basin was 2,760 AF (3,403,080 m³). This resulted in large declines in ground water levels in some portions of the basin near the ocean. Ground water levels dropped over 100 ft (30.48 m) in the southern portion of the basin. This resulted in the ground water levels in this portion of the basin dropping below sea level. Prior to this period, the direction of ground water flow was basically from the northwest, down the coastal plain, to the ocean. However, by January 1980, the ground water flow between this portion of Storage Unit I and the Pacific Ocean had been reversed. This resulted in seawater intrusion into the southern portion of the basin. The six active wells that were within one mile of the ocean all exceeded the Environmental Protection Agency's standard for chloride concentrations. The approximate rate of ground water flow from the coastline in an inland direction was calculated to be 0.37 feet (0.113 m) per day (Martin, 1984). Given this rate of flow, ground water contaminated by seawater intrusion would have reached the first city

pumping well in about twenty-two years, if the more intensive pumping levels had been maintained.

Seawater intrusion was not the only negative impact due to increased pumping. The increased pumping during the testing period caused the hydraulic head in the lower producing zone to drop to a level which was less than that of the deep zone immediately below it. This created a situation where it would be likely for the poor quality water in the deep zone to rise, and contaminate the lower producing zone. Fortunately, the presence of a clay layer between the deep zone and the lower producing zone precludes the large scale movement of water from the deep zone upward into the lower producing zone.

As a result of the study from August 1978 through January 1980, several recommendations were made to raise the ground water levels and prevent the intrusion of seawater into the Santa Barbara ground water basin (Martin, 1984). These were to decrease pumpage within the basin, increase the recharge to the basin through Mission Creek, recharge the basin through injection wells, and to move the city wells further inland, away from the ocean.

All of these recommendations were adopted by the city. Future pumping levels are expected to be below the annual safe yield of 1,400 AFY (1,726,200 m³). According to the city's *Long-Term Water Supply Program*, future ground water extractions should average 1,304 AFY (currently (1996) they are 0 AFY), except

during periods when surface water supplies are not able to keep up with demand (City of Santa Barbara Department of Public Works, July 1994). The average annual natural recharge from Mission Creek into Storage Unit I is estimated at 235 AFY (289,755 m³) (EIP Associates, 1994). Controlled releases directly into Mission Creek from Mission Tunnel, the tunnel used to transport water from Gibraltar Reservoir to Santa Barbara, could increase the recharge through Mission Creek by approximately 1,200 AFY (EIP Associates, 1994). However, artificial releases into the creek have been halted to avoid the development of artificial habitats. If these habitats were to become established, then the city could be required to maintain discharges into the creek. Artificial recharge wells have been installed, and are in use. With the addition of new pumping wells farther from the coastline, the need for pumping in the lower portions of the basin has been lessened, thus reducing the chance of seawater intrusion into the Santa Barbara ground water basin. As of summer of 1996, ground water levels in the Santa Barbara ground water basin had returned to full capacity. This would indicated that the effect of the increased pumping that had occurred during the 1986-87 to 1991-92 drought had been erased.

6.2 Non-structural measures

6.2.1 City conservation programs

Prior to the 1986-87 to 1991-92 drought, the City of Santa Barbara had very little in the way of conservation programs. With the onset of the drought, a wide array of different approaches to water conservation were undertaken by the city. Most of the measures were recommended in the city's *Five-Year Water Policy Action Plan*. The plan was completed in 1988, and was intended to balance supply with demand in the then near future (City of Santa Barbara Department of Public Works et al., 1991). Beginning in August of 1988, the city began issuing an \$80 rebate for each standard toilet which was replaced with a "low-flow" toilet. A low-flow toilet is defined as using 1.6 or less gallons (6.06 liters) of water per flush. This would result in a savings of between 2 and 4 gallons (7.57 and 15.14 liters) per flush over a standard toilet. Since the beginning of the program, 22,000 rebates have been issued. This has resulted in an estimated annual savings of 314 AFY (387,162 m³). It is the stated goal of the city to retrofit 75% of the city's toilets over a 20-year period (City of Santa Barbara Department of Public Works et al., 1991). The initial annual cost would be \$238,000 (in 1991 dollars). The estimated annual savings would be 660 AFY (813,780 m³), at a cost of approximately \$780/AF (City of Santa Barbara Department of Public Works et al., 1991).

Also beginning in August of 1988, the city began giving away low-flow showerheads. These use only 2 gallons (7.57 liters) of water per minute (gpm), compared to between 3 and 4 gpm (11.36 and 15.14 liters per minute) for a standard showerhead. If a person takes one 8-minute shower per day, the use of a low-flow showerhead instead of a 4 gpm showerhead would result in the saving of 5,840 gallons (22,104 liters) per year, or 7.8 HCF. The showerheads cost the city \$2.80 each. Since the beginning of the program, the city has given away 40,000 showerheads, for a total cost of \$112,000. If each showerhead were used for one 8-minute shower per day, the annual water savings compared with the use of a 4 gpm showerhead would be over 700 AFY (863,100 m³) (City of Santa Barbara Department of Public Works et al., 1991).

If a water customer wanted help with their conservation efforts, it was possible for them to contact the Public Works Department directly. A member of the staff would inspect their property, both inside and outside, to determine what the homeowner could do to reduce their water consumption. The cost to the city to perform an individual audit is \$60. The program estimates that approximately 1,000 audits per year will be performed. Over a 20-year period, the water savings would be 400 AFY (493,200 m³), at a cost of \$424/AF

The city also made use of several other less drastic water conservation measures. A water hotline was created. Water customers could call in with their questions

regarding water conservation. In addition, the hotline could be used to inform city officials of customers who were wasting water. The city provided free literature to water customers on a wide range of topics such as drip irrigation systems, how to read water meters, water rates, how to find and repair leaks, greywater use, and xeriscaping. Seminars were held to provide customers with information on xeriscaping and landscape management to aid in both fire and erosion control. Customers were kept up-to-date of current water supply situations through inserts that were included with their water bills. Lastly, during a "Stage III Drought Condition", the discharge from laundry washing machines is allowed to be released into the soil, to recharge the groundwater basin.

6.2.2 Xeriscaping

The use of water for landscape irrigation can consume up to 60% of a residential unit's water demand (City of Santa Barbara Department of Public Works et al., 1991). Through the use of xeriscaping, a residence can reduce its total water consumption by up to 50%. The *Long-Term Water Supply Alternatives Analysis and Urban Water Management Plan* states seven xeriscape concepts to achieve these savings (City of Santa Barbara Department of Public Works et al., 1991). These are good landscape planning and design, limiting the size of turf areas, the use of plants which require little water, efficient irrigation systems (such as drip irrigation),

addition of soil improvements, the use of mulches (to conserve soil moisture), and the appropriate maintenance.

6.2.3 The Comprehensive Water Conservation Program

The city has a developed plan for courses of action to implement during periods when available water supplies are adequate to meet water demand. The *Comprehensive Water Conservation Program* was completed in April of 1988 (City of Santa Department of Public Works, 1992). It contains seven objectives. First, to investigate new water supply options, and have them developed where possible. Second, whenever possible, at city facilities: install water efficient fixtures, convert turf areas to drought tolerant landscaping, and prioritize distribution system leaks. Third, to promote long-term water conservation goals and ideas. Fourth, to promote the use of reclaimed water, and increase the distribution system for such water. Fifth, to encourage all water conservation techniques which require only minimal lifestyle changes. Sixth, to implement water use efficiency standards for plumbing fixtures, landscape design, and water use practices. Seventh, to encourage conservation through the creation of an increasing block rate structure for the sale of water. At this stage customer compliance is voluntary, although repeated complaints about a customer's wasting of water can result in their water being shut off.

6.2.4 The Drought Contingency Plan

The City of Santa Barbara has developed another plan of action, to deal with periods when the available water supplies are not adequate to meet demand. The *Drought Contingency Plan* was completed in November of 1988 (City of Santa Barbara Department of Public Works et al., 1991). This plan assigns three levels of severity to a drought. The first level of drought severity is the Stage I Drought Condition, or "Drought Watch". Next is the Stage II Drought Condition, or "Drought Alert". Lastly, the most serious drought condition is the Stage III Drought Condition, or "Drought Emergency".

The *Drought Contingency Plan* has five objectives. First, to identify the required steps to insure an adequate water supply for the city. Second, to establish the city's authority to implement regulations and restrictions concerning water. Third, to maximize the public benefit of water and minimize the impacts of water shortages. Fourth, to distinguish between short-term conservation efforts and long-term supply and efficiency improvements. Fifth, to prevent penalizing efficient water users by basing water use restrictions on standard allotments, instead of as a percent of historical water use (City of Santa Barbara Department of Public Works et al., 1991).

The Drought Contingency Plan defines a Stage I Drought Condition as a situation in which the water supply for the current or impending water year is 10% less than the anticipated demand. The Stage I Drought Condition was declared on March 9th, 1989. The strategies for a Stage I Drought Condition are as follows: the city staff publicize the declaration of a "Drought Watch" and provide the media and the public with information about current water supplies; public education efforts encourage temporary and voluntary lifestyle changes to reduce water consumption by 10% ; encourage neighborhood watches to inform the city of water waste; the city's allotment of Cachuma water is reviewed to determine if a reduction in all allocations to Cachuma customers is in order; and make public the results of progress towards water conservation goals. At this stage, customer compliance is voluntary, with the same conditions applying as with the case of the adequate supply situation.

A Stage II Drought Condition is defined as when the available water supply is 15% below the anticipated demand. The Stage II Drought Condition was declared on January 9th, 1990. In addition to the strategies implemented for a Stage I Drought Condition, the Stage II Drought Condition adds several more, such as: city staff publicize the declaration of a "Drought Alert" and provide the media and public with information about current water supplies; institute a block rate billing structure (which to date, remains in place); ask customers for voluntary reduction of 15-25% in water use; city staff directed to reduce use by 15% through reducing

irrigation, turning off fountains, and reduced cleaning of city vehicles; activate water use regulations such as prohibiting hosing off of paved surfaces, prohibiting landscape irrigation between the hours of 8 am and 6 pm, and lowering the water supply system pressure; establish a "hotline" telephone number for customers to report violations of these regulations. At this stage, customer compliance with these water conservation measures is encouraged through the use of the block rate billing structure. "Drought Enforcement Officers" will be hired to patrol the water utility's service area. They will have the authority to issue citations for water waste. The fine for the first offense is \$25, and for the second is \$50. A third violation can result in the installation of a water flow restrictor, or even the complete discontinuation of water service.

A Stage III Drought Condition is defined as a situation in which the available water supply is 20% or more below the anticipated water demand. After little winter rain fell, a Stage III Drought Condition was declared on February 28th, 1990, and then downgraded back to a Stage II Drought Condition on September 24th, 1991. The Stage III Drought Condition implements the most severe strategies on top of those already in place with Stages I and II, including: the declaration of a "Drought Emergency" and informing the media and public of such condition; city facilities attempt to reduce consumption by 20% through the elimination of washing of city vehicles and filling of city pools, flushing of sewers and storm drains done on an emergency basis only, and the repairing of leaky water pipes; more severe

restrictions on customer water use, such as prohibiting landscape irrigation, washing of vehicles, and filling of pools. Water meters which are served solely under irrigation water rates will be shut off. Water prices under the block rate billing structure could be increased in order to encourage conservation. More "Drought Enforcement Officers" will be hired. The citations that they issue will carry a fine of up to \$250 for each offense. In addition, a water flow restrictor may be installed after the second offense, instead of after the third offense as with the Stage II Drought Condition.

7. Analysis of demand/price and supply/cost relationships

Revenue vulnerability for the water supplier will be defined herein as the percentage of the total revenue which comes from metered water sales, as opposed to service charges. A water provider which does not have a service charge would have a revenue vulnerability of 100%. This would not be a financially advisable situation for the water purveyor, since revenue would be entirely dependent upon the potentially volatile water demand. If water demand were to fall below projections, then the water purveyor would run the risk that the revenue collected from water sales might not be sufficient to meet its fixed financial requirements. Having a service charge increases the financial stability of the water purveyor by guaranteeing an incoming revenue stream of minimum size. For the purposes of water supply planning, a larger service charge is advantageous. However, acquiring acceptance for a larger service charge from a public wishing to minimize all of its fixed costs can be problematic for the water purveyor.

The estimated revenue vulnerability for Santa Barbara is shown in table 9. For fiscal years 1986-87 and 1987-88 (a fiscal year runs from July 1st of one year to June 30th the following year), revenue vulnerability was about 80%. This meant that approximately 80% of the incoming revenue was directly controlled by the demand of the water customers, with only 20% coming from fixed service charges.

It was during this period that the uniform rate billing system was still in effect (see figure 18). After the uniform rates were replaced with the first block rate billing system during fiscal year 1989-90, the service charge was lowered from \$4.72 to \$1.47. This combined with the higher water rates under the block billing system, had the effect of raising the revenue vulnerability to 94.2%. The peak was in fiscal year 1990-91, with a revenue vulnerability of 95.3%. For the three fiscal years from 1992-93 through 1994-95, revenue vulnerability remained above 90%. In August of 1995, new water rates were put into effect. Along with these new rates, the service charge was raised to \$5.50. This resulted in a decrease in revenue vulnerability to 85.2% for fiscal year 1995-96. Although this is an improvement over the last three previous years, it is still higher than the pre-drought revenue vulnerability of 80.3%, when there was a uniform rate of \$0.89/hcf for water and a service charge of \$4.10. The 1995 water rate setting process in the Santa Barbara clearly showed that it was politically infeasible to decrease the burden of revenue uncertainty by increasing the service charge. This happened even though the previous and new water rates were such that they supposedly preserved "revenue" neutrality, i.e. they both yielded the same total revenue for a given demand.

The average price (AP) of water, by fiscal year, charged to the customer can be determined by dividing the total amount of revenue (TR) collected from water sales during a fiscal year by the total amount of water sold during the same period (Q),

$(AP = \frac{TR}{Q})$. This price is shown in table 10. The average price for each fiscal

year has been adjusted for inflation to fiscal year 1995-96 dollars (using the consumer price index for all urban customers), and for population growth to fiscal year 1995-96 population levels. The growth in metered sales due to increases in city population was estimated as follows: the population for a given fiscal year was estimated as the average population for the two calendar years of which it was comprised. The 1995-96 population was divided by the population of a given fiscal year; the resultant number was multiplied by the metered sales for the given fiscal year to estimate the adjusted metered sales for that year.

The average cost (AC) to the city to produce water, by fiscal year, can also be calculated. The total operating cost (TC) for the water department for a fiscal year is divided by the total amount of water sold during the fiscal year (Q),

$(AC = \frac{TC}{Q})$. This average cost is shown in table 11, and has also been adjusted to

fiscal year 1995-96 dollars and population levels. In pre-drought fiscal year 1986-87 the average price/HCF charged for water was 89.5% of the average cost to the city to produce that unit of water. In post-drought fiscal year 1995-96 this ratio was 83.2%

The change in the adjusted average price (adjusted for inflation to fiscal year 1995-96 dollars) plotted against the demand for water (total metered sales, adjusted to fiscal year 1995-96 population levels) from the pre-drought period through the post-drought period is shown in figure 27. There is a rather large shift in the plot of adjusted average price versus total metered sales between fiscal years 1988-89 and 1990-91. This change was not caused by price increases alone. Other factors which could control demand in addition to price increases could have begun to come into play, such as public education campaigns, conservation, and an extremely dry climate. It was during fiscal year 1988-89 that the Stage I Drought Condition was put into effect by the Santa Barbara City Council (March 1989). And it was during fiscal year 1989-90 that the Stage II and Stage III Drought Conditions were put into effect by the City Council (January 1990, and February 1990, respectively). During fiscal year 1991-92, the Stage III Drought Condition was reverted to a Stage II Drought Condition (September 1991), and the drought was declared to be officially terminated by the City Council (March 1992). In the post-drought fiscal years (1992-93 to 1995-96), the price vs. total metered sales plot in figure 27 shows a slightly stabilizing pattern, possibly caused by a changed climatic situation, and a desire by segments of the public to return, if only partly, to past habits of water use.

The change of the adjusted average cost (adjusted for inflation to fiscal year 1995-95 dollars) plotted against the demand for water (total metered sales, adjusted to fiscal year 1995-96 dollars) is plotted in figure 28. Figures 27 and 28 display the

same general pattern. Between fiscal years 1987-88 and 1991-92 dramatic upward shifts in the plot of average cost versus total metered sales are evident. In the post drought fiscal years 1992-93 to 1995-96, again a slightly stabilizing trend is evident, although not as pronounced as in the plot of average price versus total metered sales. It would appear that water demand (adjusted for population growth) and the average water price and cost (adjusted to fiscal year 1995-96 dollars) are approaching a post-drought equilibrium. The fiscal year 1995-96 water demand is significantly lower than the fiscal year 1986-87 level (see table 10), while the average price and cost for water is significantly higher than their pre-drought predecessors (see tables 10 and 11). In figure 29, the adjusted average price and cost for water are plotted as a function of fiscal year. Figure 29 shows that, prior to the drought, the average cost of water for the city to produce was close to or exceeded the average price charged to the consumer. It is seen however, that at no time during, or after the drought did the average price for water exceed or even equal the average cost for water. This is not to say that Santa Barbara's water utility operates at a financial loss. Rather, the financial difference between revenue and cost is made up through other means, such as utility taxes, and interest generated by the city's invested water fund. The invested water fund is a contingency fund saved to accrue interest and weather out unforeseen financial demands, including those from natural hazards. If indeed a major natural disaster, such as a wildfire, flood, or earthquake, were to effect the City of Santa Barbara, then the water fund could be

expended rather quickly. This could make the discrepancy between average cost and average price a matter of great concern.

In figure 30, is shown the average cost curve and the average price curve, both derived from a linear least squares fit. From these curves it can be seen that for almost all but the highest level of demand for water, the average cost to the water purveyor to secure that level of water production is higher than the average price that was being charged for it. From these interpolated cost and price curves, it is possible to derive total cost, marginal cost, total revenue, and marginal revenue, to further investigate the trends in price/demand and cost/supply relationships.

Total cost (TC) is defined as the cost to the water purveyor to produce a given quantity (Q) of water ($TC = AC * Q$). Marginal cost (MC) is the incremental cost to the water purveyor to produce one more unit of water, beyond the current level of production ($MC = \frac{d TC}{d Q}$). Total revenue (TR) is the total monetary gain taken in

by the water purveyor for the sale of a given quantity of water ($TR = AP * Q$).

Marginal revenue (MR) is the incremental monetary gain to the water purveyor for the sale of one more unit of water, beyond the current level of production

$$(MR = \frac{d TR}{d Q}).$$

Figure 31 shows the average price and average cost curves, as well as the marginal price and marginal cost curves. From the equations for the marginal cost and marginal revenue curves, it can be calculated that the marginal cost to the water purveyor is above the marginal revenue until more than 3,915,750 HCF (11,081,573 m³) of water are demanded by the public. The discrepancy between cost and price is further portrayed in figure 32. Here it is seen that, for any given level of demand, the total monetary cost to the water purveyor is greater than the total amount of revenue taken in due to water sales until more than 7,831,500 HCF (22,163,145 m³) are sold.

8. Conclusions

This research has focused on the hydrologic and economic effects of a severe and sustained drought upon the City of Santa Barbara, California. The conditions in the city were followed from a period several years prior to the onset of the drought, until 1996, a few years after the drought's termination. From the empirical evidence presented here, several important points can be made:

1. From the dendroclimatic record, the historic record, and the output of the Santa Ynez River Model, it can be seen that the 1986-87 to 1991-92 drought had neither the greatest temporal extent, nor the most severe impact (in terms of runoff), which can be expected to occur in the Santa Barbara area.
2. During the drought, total water production dropped to 57% of the pre-drought production levels. Three years after the end of the drought, in water year 1994-95, total water production had only risen to 73% of the pre-drought production level. Four years after the drought's termination, in water year 1995-96, total production had only risen to 78% of pre-drought levels. When calculated on a per-capita basis, the drought's impact on water demand is even more clearly visible. During the drought, per-capita demand dropped to 48% of pre-drought per-capita demand. By water year 1994-95, a "drought shadow" was still being cast upon the city, as per-

capita demand had only risen to 60% of the level of pre-drought demand. By water year 1995-96, per-capita demand had risen to 64% of the pre-drought level.

3. In addition, the post-drought consumption distribution patterns closely mimic those which were occurring during the height of the drought much more so than the patterns associated with the pre-drought era, or those patterns of the early years of the drought. These post-drought patterns were distinguished by a much more narrow range of consumption distribution than those of their pre-drought predecessors. It is evident from these post-drought patterns that a significant portion of the customers continue to practice the stringent water conservation measures which were recommended during the drought. Some of these measures are, for all practical purposes, irreversible. These would include such actions as installing low-flow toilets and drought-resistant landscaping.

4. In July of 1989, the billing structure was changed from a uniform rate to an increasing block rate. This was an effort to curb water demand through the introduction of punitive water rates for higher levels of consumption. In addition, although the monthly service charge was initially lowered with the introduction of the block rate billing structure, it has been occasionally increased, in an effort to stabilize incoming revenue. Although the price of water, as well as the size of the rate-blocks was very dynamic all throughout the drought, the increasing block rate

and the larger service charge have remained in place during the post-drought era as a means to ensure continuing water conservation and financial stability.

5. In order to help reduce the risk of a future water shortage, the 1986-87 to 1991-92 drought resulted in the development of several new water supply sources, including: a desalination facility to extract potable water from the ocean, connection to the State Water Project, artificial recharge of the city's ground water basin, a water reclamation facility, and an aggressive water conservation plan.

6. Before the drought, revenue vulnerability, the variable amount of revenue coming from metered sales as opposed to the fixed amount of revenue coming from monthly service charges, was approximately 80%. During the drought, this amount climbed to 95.3%. For three years after the drought's termination, revenue vulnerability has remained above 90%. The most recent period of record, fiscal year 1995-96, had a revenue vulnerability of 85.2%. Therefore, it has been shown that although attempts have been made to control and stabilize water demand and revenues, the incoming revenue stream is still highly susceptible to subtle changes in water demand.

7. At all times throughout the period during, and after the drought, the average price of a unit of water being charged to the water customers was below the average cost to the city to produce that water. At times during the drought, the average cost to

the city to produce a unit of water more than tripled. In the post-drought era, the cost to the city to produce a unit of water is still nearly triple that of the pre-drought era.

The central hypothesis of this research was that in areas with uncertain water supplies and slow growth, such as in the Central Coast Hydrologic Region of which the City of Santa Barbara is a part, water supply sources, water conservation measures, and water pricing structure are determined by a convergence of economic and social factors that occur only during condition of extreme (severe and sustained) drought. For the past several decades, with periodic disturbances, water pricing has been set to recover capital and operational costs of water purveyors. When an extreme drought does occur, water prices and demand will vary greatly, and will settle at levels that produce a reliable water supply with a minimum of accepted risk. In this instance, the fact that the present (four years after the drought's termination) water demand is closer to that of drought levels than to pre-drought "normal" levels, that present water pricing structure and rates are dictated by the effects of, and actions taken during the drought (and are to remain so for the foreseeable future), that the addition of several present water supplies (desalination, reclamation, state water, ground water management, and conservation measures) were the direct result of the drought, all point to an affirmation of the hypothesis.

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Figure 12. Monthly distribution of rainfall at, and runoff into Lake Cachuma, water years 1985-86 to 1994-95 (Source: Santa Barbara County Water Agency, 1988, Santa Barbara County Flood Control and Water Conservation District, 1995, and Cachuma Operation and Maintenance Board, 1996). (1 in. = 2.54 cm, 1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)

Figure 13. Monthly distribution of storage capacity for Gibraltar Reservoir, water years 1984-85 to 1994-95 (Source: Agajanian et al., 1994, 1995, Bowers et al., 1987, 1988, 1989, 1990, 1991, 1992, 1993, and City of Santa Barbara Department of Public Works, 1995). (1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)

Figure 14. Monthly distribution of storage capacity for Lake Cachuma, water years 1984-85 to 1994-95 (Source: Agajanian et al., 1994, 1995, Bowers et al., 1987, 1988, 1989, 1990, 1991, 1992, 1993, and Cachuma Operation and Maintenance Board, 1995). (1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)

Figure 15. Single-family residential consumption distribution curves for the City of Santa Barbara, 1986 - 1994 (Source: City of Santa Barbara Department of Public Works, 1987, 1990, June 1993, and Kennedy/Jenks Consultants, 1995). (1 HCF = 100 ft³ = 2.83 m³)

Figure 16. Single-family residential consumption distribution curves for the City of Santa Barbara, 1991 - 1994 (Source: City of Santa Barbara Department of Public Works, June 1993, June 1994, and Kennedy/Jenks Consultants, 1995). (1 HCF = 100 ft³ = 2.83 m³)

Figure 17. The different of water rate structures: (A) fixed charge with unmeasured consumption; (B) increasing block rate with service charge(F); (C) uniform rate with service charge(F); (D) decreasing block rate with service charge(F) (Source: Loaiciga, 1995).

Figure 18. Pricing structures for single-family residential units which were in effect in Santa Barbara before, during, and after the drought in the City of Santa Barbara (Source: City of Santa Barbara Department of Public Works, 1995). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 19. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1986 (Source: City of Santa Barbara Department of Public Works, 1987). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 20. Single-family residential consumption distribution curve for the City of Santa Barbara, December 1988 - November 1989 (Source: City of Santa Barbara Department of Public Works, January 1990). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 21. Single-family residential consumption distribution curve for the City of Santa Barbara, September 1989 - August 1990 (Source: City of Santa Barbara Department of Public Works, September 1990). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 22. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1991 (Source: City of Santa Barbara Department of Public Works, June 1993). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 23. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1992 (Source: City of Santa Barbara Department of Public Works, June 1993). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 24. Single-family residential consumption distribution curve for the City of Santa Barbara, June 1992 - May 1993 (Source: City of Santa Barbara Department of Public Works, June 1993). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 25. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1993 (Source: City of Santa Barbara Department of Public Works, June 1994). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 26. Single-family residential consumption distribution curve for the City of Santa Barbara, July 1993 - June 1994 (Source: Kennedy/Jenks consultants, 1995). (1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$)

Figure 27. Average price charged for water for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$, fiscal year = July 1 through June 30)

Figure 28. Average cost to produce water for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$, fiscal year = July 1 through June 30)

Figure 29. Average price and average cost of water for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$, fiscal year = July 1 through June 30)

Figure 30. Generalized demand/price and supply/cost curves for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$, fiscal year = July 1 through June 30)

Figure 31. Average cost(AC), average price(AP), marginal cost(MC), and marginal revenue(MR) for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$, fiscal year = July 1 through June 30)

Figure 32. Total cost(TC) and total revenue(TR) for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 HCF = $100 \text{ ft}^3 = 2.83 \text{ m}^3$, fiscal year = July 1 through June 30)

Appendix A: Annual rainfall totals for the City of Santa Barbara, water years 1867-68 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

<u>water year</u>	<u>rainfall</u>	<u>water year</u>	<u>rainfall</u>	<u>water year</u>	<u>rainfall</u>
1867-68	25.19 in.	1905-06	22.51 in.	1943-44	17.95 in.
1868-69	15.77	1906-07	27.73	1944-45	15.23
1869-70	10.47	1907-08	20.16	1945-46	11.33
1870-71	8.94	1908-09	34.80	1946-47	13.41
1871-72	15.01	1909-10	22.02	1947-48	9.28
1872-73	10.45	1910-11	29.48	1948-49	10.43
1873-74	14.44	1911-12	16.23	1949-50	14.39
1874-75	18.71	1912-13	13.11	1950-51	10.11
1875-76	23.07	1913-14	31.24	1951-52	31.22
1876-77	4.49	1914-15	21.46	1952-53	12.91
1877-78	28.51	1915-16	27.84	1953-54	15.33
1878-79	13.61	1916-17	19.91	1954-55	17.06
1879-80	25.64	1917-18	24.43	1955-56	19.58
1880-81	15.67	1918-19	10.33	1956-57	13.89
1881-82	13.83	1919-20	13.84	1957-58	32.21
1882-83	13.41	1920-21	14.55	1958-59	8.80
1883-84	34.66	1921-22	19.01	1959-60	10.81
1884-85	13.10	1922-23	17.40	1960-61	10.04
1885-86	24.24	1923-24	6.20	1961-62	26.17
1886-87	13.34	1924-25	12.31	1962-63	16.71
1887-88	21.39	1925-26	16.93	1963-64	9.22
1888-89	21.00	1926-27	22.84	1964-65	18.52
1889-90	33.97	1927-28	13.32	1965-66	14.39
1890-91	15.96	1928-29	14.54	1966-67	25.14
1891-92	10.66	1929-30	13.92	1967-68	13.46
1892-93	26.97	1930-31	15.22	1968-69	30.52
1893-94	8.50	1931-32	22.00	1969-70	11.98
1894-95	14.86	1932-33	8.53	1970-71	14.00
1895-96	13.72	1933-34	13.47	1971-72	8.66
1896-97	18.10	1934-35	21.39	1972-73	23.35
1897-98	7.74	1935-36	18.61	1973-74	17.34
1898-99	9.18	1936-37	24.80	1974-75	18.85
1899-00	12.71	1937-38	26.29	1975-76	12.83
1900-01	15.85	1938-39	13.42	1976-77	11.96
1901-02	13.70	1939-40	14.68	1977-78	42.43
1902-03	20.74	1940-41	45.25	1978-79	21.59
1903-04	18.83	1941-42	12.86		
1904-05	22.60	1942-43	24.34		

Appendix A: continued

<u>water year</u>	<u>rainfall</u>
1979-80	23.93 in.
1980-81	14.63
1981-82	17.15
1982-83	41.35
1983-84	11.40
1984-85	12.25
1985-86	23.48
1986-87	10.13
1987-88	15.37
1988-89	9.24
1989-90	6.53
1990-91	18.44
1991-92	24.90
1993-94	16.35
1994-95	33.91
1995-96	18.91

**Appendix B: Reconstructed flows of the Santa Ynez River at Bradbury Dam,
1537 - 1964 (Source: Michaelsen and Haston, 1988). (1 AF = 1,233 m³)**

<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>
1537	14,112	1574	15,672	1611	362,917
1538	112,691	1575	1,415	1612	3,351
1539	287,956	1576	9,461	1613	1,158
1540	29,115	1577	59,016	1614	47,419
1541	3,089	1578	45,042	1615	51,670
1542	2,754	1579	1,950	1616	111,998
1543	267,022	1580	2,372	1617	79,984
1544	5,371	1581	163,179	1618	10,902
1545	17,395	1582	26,769	1619	11,820
1546	11,848	1583	30,002	1620	129,270
1547	2,485	1584	41,911	1621	8,799
1548	6,179	1585	1,457	1622	20,982
1549	142,795	1586	107,194	1623	9,546
1550	40,873	1587	146,928	1624	8,353
1551	135,766	1588	44,002	1625	44,027
1552	3,775	1589	481,113	1626	850
1553	116,883	1590	529	1627	29,467
1554	16,390	1591	41,250	1628	6,931
1555	114,824	1592	15,224	1629	25,471
1556	49,640	1593	64,894	1630	22,957
1557	765,602	1594	56,399	1631	6,768
1558	17,057	1595	17,538	1632	6,484
1559	99,463	1596	88,964	1633	2,178
1560	60,803	1597	8,042	1634	23,150
1561	11,810	1598	714,504	1635	69,704
1562	308,521	1599	261,370	1636	16,679
1563	31,848	1600	6,456	1637	2,741
1564	82,896	1601	522,139	1638	34,833
1565	3,276,524	1602	109,385	1639	33,492
1566	78,463	1603	15,683	1640	66,218
1567	392,796	1604	443,338	1641	75,430
1568	12,325,621	1605	19,321	1642	585,198
1569	3,040	1606	278,572	1643	23,493
1570	8,078	1607	8,766	1644	75,594
1571	157	1608	98,474	1645	3,897
1572	75,606	1609	84,867	1646	7,921
1573	27,020	1610	137,072	1647	40,093

Appendix B: continued

<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>
1648	6,779	1687	78,616	1726	38,309
1649	65,061	1688	64,872	1727	44,162
1650	3,227	1689	19,236	1728	955
1651	553,101	1690	2,584	1729	24,686
1652	97,575	1691	11,273	1730	27,688
1653	3,558	1692	59,751	1731	57,583
1654	824	1693	38,115	1732	43,339
1655	7,535	1694	68,699	1733	20,645
1656	14,013	1695	12,281	1734	19,864
1657	23,225	1696	29,286	1735	6,828
1658	148,278	1697	25,763	1736	17,787
1659	55,642	1698	4,129	1737	5,769
1660	31,037	1699	146,243	1738	84,414
1661	324,335	1700	30,284	1739	645
1662	30,637	1701	7,267	1740	38,756
1663	1,644	1702	65,890	1741	111,875
1664	24,829	1703	2,428	1742	3,886
1665	4,195	1704	22,089	1743	18,934
1666	10,543	1705	33,216	1744	13,543
1667	38,810	1706	2,181	1745	88,840
1668	3,246	1707	2,717	1746	299,116
1669	4,472	1708	31,710	1747	178,052
1670	859	1709	46,505	1748	1,385
1671	42,096	1710	86,874	1749	176,643
1672	28,835	1711	11,745	1750	54,848
1673	17,729	1712	23,186	1751	68,774
1674	96,801	1713	14,728	1752	314
1675	9,699	1714	42,715	1753	41,971
1676	5,920	1715	14,714	1754	878
1677	22,492	1716	17,661	1755	21,371
1678	51,783	1717	20,899	1756	12,070
1679	51,911	1718	39,491	1757	38,864
1680	235,561	1719	45,450	1758	18,697
1681	38,429	1720	29,586	1759	28,201
1682	136,521	1721	6,906	1760	33,303
1683	51,685	1722	44,606	1761	17,854
1684	39,639	1723	146,043	1762	48,048
1685	120,840	1724	11,136	1763	9,011
1686	5,129	1725	16,961	1764	31,269

Appendix B: continued

<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>
1765	2,209	1804	331,711	1843	1,463
1766	130,835	1805	55,256	1844	14,830
1767	94,622	1806	6,311	1845	2,412
1768	66,390	1807	790	1846	101,207
1769	25,248	1808	33,814	1847	20,484
1770	8,612	1809	210	1848	46,890
1771	204,629	1810	93,636	1849	11,290
1772	55,432	1811	36,873	1850	29,680
1773	20,042	1812	1,616	1851	41,947
1774	36,247	1813	4,519	1852	171,475
1775	27,836	1814	56,551	1853	333,233
1776	44,831	1815	11,069	1854	54,297
1777	1,614	1816	143,626	1855	41,178
1778	18,344	1817	17,890	1856	1,598
1779	30,146	1818	113,849	1857	594
1780	52,901	1819	21,774	1858	27,333
1781	174,645	1820	884	1859	9,907
1782	197	1821	43,364	1860	30,163
1783	211,538	1822	16,886	1861	74,383
1784	111,508	1823	541	1862	75,364
1785	105,233	1824	11,050	1863	2,102
1786	65,340	1825	121,427	1864	1,632
1787	84,513	1826	98,878	1865	122,072
1788	4,284	1827	17,522	1866	60,627
1789	75,201	1828	67,719	1867	38,741
1790	21,088	1829	426	1868	3,192,916
1791	52,392	1830	561,543	1869	58,946
1792	177,905	1831	56,033	1870	2,860
1793	140,905	1832	209,897	1871	3,287
1794	2,455	1833	77,676	1872	30,672
1795	1,719	1834	17,715	1873	14,401
1796	23,912	1835	47,914	1874	24,364
1797	33,926	1836	2,447	1875	6,606
1798	53,265	1837	48,273	1876	50,021
1799	260,579	1838	43,088	1877	3,914
1800	17,718	1839	210,429	1878	160,849
1801	87,948	1840	235,914	1879	20,334
1802	32,027	1841	105	1880	30,275
1803	9,041	1842	41,579	1881	4,241

Appendix B: continued

<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>	<u>year</u>	<u>runoff (AF)</u>
1882	12,996	1921	19,537	1960	5,732
1883	8,179	1922	122,649	1961	997
1884	76,071	1923	15,010	1962	134,591
1885	21,436	1924	3,459	1963	17,431
1886	405,605	1925	7,427	1964	2,481
1887	30,084	1926	94,359		
1888	30,308	1927	174,864		
1889	62,453	1928	12,659		
1890	107,304	1929	4,286		
1891	48,633	1930	17,590		
1892	11,978	1931	8,396		
1893	29,400	1932	56,744		
1894	488	1933	24,398		
1895	84,521	1934	3,844		
1896	8,039	1935	96,140		
1897	2,489	1936	26,942		
1898	1,803	1937	108,567		
1899	9,985	1938	131,319		
1900	3,024	1939	38,990		
1901	41,916	1940	17,306		
1902	13,312	1941	254,868		
1903	28,274	1942	61,661		
1904	2,618	1943	35,864		
1905	614,404	1944	104,417		
1906	207,385	1945	33,392		
1907	669,420	1946	18,167		
1908	49,456	1947	15,276		
1909	20,844	1948	1,745		
1910	19,842	1949	6,181		
1911	134,366	1950	8,473		
1912	10,064	1951	1,972		
1913	5,152	1952	113,790		
1914	461,479	1953	8,471		
1915	204,545	1954	21,600		
1916	113,422	1955	18,433		
1917	42,908	1956	24,583		
1918	5,096	1957	85,238		
1919	12,312	1958	184,742		
1920	56,063	1959	9,962		

Appendix C: Unimpaired flows of the Santa Ynez River at Bradbury Dam, water years 1917-18 to 1991-92 (Source: Santa Barbara County Flood Control and Water Conservation District, 1995). (1 AF = 1,233 m³, water year = Oct. 1 to Sept. 30)

<u>water year</u>	<u>runoff</u>	<u>water year</u>	<u>runoff</u>
1917-18	237,395 AF	1955-56	30,446 AF
1918-19	6,306	1956-57	8,806
1919-20	21,512	1957-58	202,693
1920-21	11,510	1958-59	19,511
1921-22	143,456	1959-60	2,406
1922-23	16,110	1960-61	406
1923-24	4,306	1961-62	115,315
1924-25	5,508	1962-63	5,406
1925-26	77,330	1963-64	2,504
1926-27	117,116	1964-65	20,553
1927-28	16,008	1965-66	87,114
1928-29	7,609	1966-67	214,598
1929-30	6,308	1967-68	12,702
1930-31	1,205	1968-69	485,212
1931-32	121,016	1969-70	27,608
1932-33	17,104	1970-71	31,309
1933-34	22,826	1971-72	16,403
1934-35	47,615	1972-73	120,789
1935-36	34,906	1973-74	37,312
1936-37	160,664	1974-75	54,117
1937-38	273,793	1975-76	8,609
1938-39	22,310	1976-77	3,206
1939-40	15,110	1977-78	313,802
1940-41	474,723	1978-79	62,516
1941-42	33,912	1979-80	156,371
1942-43	185,163	1980-81	26,311
1943-44	94,332	1981-82	30,808
1944-45	43,412	1982-83	430,416
1945-46	40,311	1983-84	40,508
1946-47	16,107	1984-85	7,305
1947-48	400	1985-86	83,613
1948-49	1,900	1986-87	2,103
1949-50	4,605	1987-88	14,814
1950-51	99	1988-89	5,104
1951-52	200,478	1989-90	1,804
1952-53	17,907	1990-91	65,213
1953-54	23,010	1991-92	137,444
1954-55	6,607		

Appendix D: Annual rainfall totals for Gibraltar Reservoir, water years 1919-20 to 1995-96 (Source: Santa Barbara County Water Agency, 1988, and City of Santa Barbara Department of Public Works, 1996).

(1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

<u>water year</u>	<u>rainfall</u>	<u>water year</u>	<u>rainfall</u>	<u>water year</u>	<u>rainfall</u>
1919-20	20.81 in.	1955-56	23.82 in.	1991-92	39.09 in.
1920-21	22.61	1956-57	18.85	1992-93	49.61
1921-22	41.46	1957-58	52.69	1993-94	19.59
1922-23	22.36	1958-59	17.16	1994-95	58.96
1923-24	10.40	1959-60	14.97	1995-96	19.86
1924-25	17.41	1960-61	12.10		
1925-26	27.14	1961-62	36.14		
1926-27	28.26	1962-63	20.04		
1927-28	20.07	1963-64	14.78		
1928-29	19.65	1964-65	22.72		
1929-30	18.02	1965-66	29.70		
1930-31	17.34	1966-67	39.31		
1931-32	33.28	1967-68	14.93		
1932-33	16.43	1968-69	58.37		
1933-34	19.72	1969-70	17.39		
1934-35	29.70	1970-71	22.48		
1935-36	21.63	1971-72	15.62		
1936-37	36.14	1972-73	38.25		
1937-38	41.30	1973-74	25.25		
1938-39	20.76	1974-75	27.63		
1939-40	18.13	1975-76	19.42		
1940-41	66.71	1976-77	15.66		
1941-42	18.95	1977-78	59.88		
1942-43	37.49	1978-79	28.11		
1943-44	29.41	1979-80	35.11		
1944-45	21.07	1980-81	21.93		
1945-46	22.67	1981-82	24.81		
1946-47	16.10	1982-83	63.67		
1947-48	12.39	1983-84	18.37		
1948-49	15.10	1984-85	16.25		
1949-50	16.84	1985-86	31.64		
1950-51	11.07	1986-87	10.71		
1951-52	49.42	1987-88	24.95		
1952-53	16.38	1988-89	14.71		
1953-54	20.54	1989-90	11.80		
1954-55	21.52	1990-91	30.62		

Appendix E: Annual rainfall totals for Bradbury Dam, water years 1951-52 to 1995-96 (Source: Santa Barbara County Water Agency, 1988, and Cachuma Operation and Maintenance Board, 1996).

(1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

<u>water year</u>	<u>rainfall</u>	<u>water year</u>	<u>rainfall</u>
1951-52	11.27 in.	1987-88	21.92 in.
1952-53	13.80	1988-89	9.68
1953-54	16.92	1989-90	7.93
1954-55	16.96	1990-91	24.39
1955-56	21.48	1991-92	29.13
1956-57	14.23	1992-93	36.71
1957-58	35.25	1993-94	17.38
1958-59	14.58	1994-95	45.57
1959-60	11.26	1995-96	13.44
1960-61	10.88		
1961-62	24.14		
1962-63	15.91		
1963-64	10.57		
1964-65	15.34		
1965-66	18.57		
1966-67	23.24		
1967-68	9.99		
1968-69	39.44		
1969-70	11.67		
1970-71	15.06		
1971-72	10.43		
1972-73	29.20		
1973-74	16.84		
1974-75	24.50		
1975-76	14.22		
1976-77	13.05		
1977-78	42.53		
1978-79	21.00		
1979-80	24.25		
1980-81	16.43		
1981-82	17.37		
1982-83	44.31		
1983-84	12.54		
1984-85	12.28		
1985-86	23.33		
1986-87	8.63		

Table 1. Comparison of drought duration and severity, taken at Bradbury Dam 1537 - 1992 (Source: Michaelsen and Haston, 1988, and Santa Barbara County Flood Control and Water Conservation District, 1995).
(1 AF = 1,233 m³)

period	duration in years	total runoff, in acre feet (AF) per year, as estimated by: dendroclimatic record	Santa Ynez River Model
1544-1548	5	43,278 AF	not available
1573-1576	4	53,568	not available
1621-1624	4	47,680	not available
1626-1634	9	124,256	not available
1653-1657	5	49,155	not available
1663-1666	4	41,211	not available
1733-1737	5	70,893	not available
1856-1859	4	39,432	not available
1896-1900	5	25,340	not available
1929-1934	6	115,258	176,068 AF
1946-1951	6	51,814	63,422
1953-1956	4	73,087	77,970
1987-1992	6	not available	226,482

Table 2. Total potable production for the City of Santa Barbara, water years 1968-69 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)

water year ending September 30	total potable production	water year ending September 30	total potable production
1968-69	12,683 AF	1987-88	16,228 AF
1969-70	14,565	1988-89	15,287
1970-71	14,232	1989-90	10,518
1971-72	15,141	1990-91	9,149
1972-73	13,577	1991-92	10,184
1973-74	13,796	1992-93	10,587
1974-75	14,189	1993-94	11,387
1975-76	14,916	1994-95	11,724
1976-77	12,791	1995-96	12,567
1977-78	12,636		
1978-79	13,525		
1979-80	13,952		
1980-81	14,663		
1981-82	13,529		
1982-83	14,216		
1983-84	16,621		
1984-85	16,169		
1985-86	15,958		
1986-87	16,641		

Table 3. Per-capita annual consumption of water for the City of Santa Barbara, water years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997).

(1 HCF = 100 ft³ = 2.83 m³, water year = Oct. 1 through Sept. 30)

water year ending September 30	city ^a population	metered sales ^b (in HCF)	HCF/capita
1977-78	72,238	6,164,439 HCF	85.3 HCF/capita
1978-79	73,866	6,082,439	82.3
1979-80	74,414	5,855,615	78.7
1980-81	74,414	6,088,235	81.8
1981-82	74,845	not available	
1982-83	75,688	not available	
1983-84	76,848	6,196,524	80.6
1984-85	78,105	not available	
1985-86	79,395	not available	
1986-87	80,695	6,676,890	82.7
1987-88	81,995	6,526,009	79.6
1988-89	83,295	6,405,080	76.9
1989-90	87,831	4,315,194	49.1
1990-91	89,991	3,602,345	40.0
1991-92	90,760	4,145,724	45.7
1992-93	91,019	4,350,638	47.8
1993-94	91,260	4,625,222	50.7
1994-95	91,917	4,559,444	49.6
1995-96	92,884	4,952,727	53.3

^a 1977-78: From "Comprehensive Annual Financial Report for the City of Santa Barbara" fiscal year 1986-87.

1978-79 to 1995-96: Estimated from calendar year population numbers (see table 4).

Oct. 1 - Dec. 31 = 25.2% of calendar year

Jan. 1 - Sept. 30 = 74.8% of calendar year

e.g. 1986-87 water year population = 0.252*(1986 calendar year population) +
0.748*(1987 calendar year population)

^b 1977-78 - Dec. 1986: From "Water Utility Statistics Report".

Jan. 1987 - Dec. 1987: Estimated by multiplying the percent of the total annual potable production for any one month times the total annual metered sales.

e.g. Jan. 1987 = (percent of total potable production for 1987 which occurred in Jan. 1987) *
(total metered sales for 1987) = 0.0695 * 6,458,206 HCF = 448,845 HCF

Jan. 1988 - Sept. 1996: From "Metered Sales by Customer Class" reports.

Table 4. Per-capita annual consumption of water for the City of Santa Barbara, calendar years 1974, 1978 - 1996 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³)

calendar year	city ^a population	metered sales ^b (in HCF)	HCF/capita
1974	70,215	5,998,212 HCF	85.4 HCF/capita
1978	72,238	6,171,123	85.4
1979	74,414	5,962,567	80.1
1980	74,414	6,260,695	84.1
1981	74,414	5,573,529	74.9
1982	74,990	not available	
1983	75,923	not available	
1984	77,160	6,475,936	83.9
1985	78,423	not available	
1986	79,723	6,592,246	82.7
1987	81,023	6,458,206	79.7
1988	82,323	7,119,513	86.5
1989	83,623	6,203,209	74.2
1990	89,249	3,385,548	37.9
1991	90,241	3,651,480	40.5
1992	90,935	4,262,013	46.9
1993	91,047	4,387,246	48.2
1994	91,332	4,629,031	50.7
1995	92,114	4,659,308	50.6
1996	93,144	4,930,703	52.9

^a 1974, 1978 - 1981: From "Comprehensive Annual Financial Report for the City of Santa Barbara", fiscal years 1977-78 to 1982-83.

1982 - 1989: Estimated from city water year (May 15 - May 14) population numbers as reported in "Long-Term Water Supply Program".

Jan. 1 - May 14 = 36.7% of city water year

May 15 - Dec. 31 = 63.3% of city water year

e.g. 1986 cal. year population = 0.367(1985-1986 city water year population) + 0.633(1986-87 city water year population)

1990 - 1990: Population estimates from Department of Public Works Staff.

^b 1974: From Lawrance, Fisk, & McFarland Inc., 1985

1978 - 1986: From "Water Utility Statistics Report".

1987: From "Water Usage by Category" (pie chart).

1988 - 1996: From "Metered Sales by Customer Class" report.

Table 5. Per-capita annual consumption of water for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997).

(1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)

fiscal year ending June 30	city ^a population	metered sales ^b (in HCF)	HCF/capita
1977-78	72,238	6,298,128 HCF	87.2 HCF/capita
1978-79	73,326	5,800,802	79.1
1979-80	74,414	6,004,011	80.7
1980-81	74,414	5,961,230	80.1
1981-82	74,702	5,585,561	74.8
1982-83	75,457	6,222,100	82.5
1983-84	76,542	5,941,176	77.6
1984-85	77,792	7,052,139	90.7
1985-86	79,073	7,051,100	89.2
1986-87	80,373	6,645,981	82.7
1987-88	81,673	6,897,094	84.4
1988-89	82,973	6,863,636	82.7
1989-90	86,436	5,092,897	58.9
1990-91	89,732	3,566,380	39.7
1991-92	90,588	3,806,591	42.0
1992-93	90,991	4,376,425	48.0
1993-94	91,190	4,470,600	49.0
1994-95	91,723	4,600,635	50.2
1995-96	92,629	4,845,328	52.3

^a 1977-78: From "Comprehensive Annual Financial Report for the City of Santa Barbara", fiscal year 1986-87.

1978-79 to 1995-96: Estimated by averaging two calendar year population numbers (see table 4).

^b 1977-78 to 1981-82, 1983-84 to 1984-85, July 1986 - Dec. 1986: From "Water Utility Statistics Report".

1982-83, 1985-86: From Black and Veatch Consultants, 1986.

Jan. - Dec. 1987: Estimated by multiplying the percent of the total annual potable production for any one month times the total annual metered sales.

e.g. Jan. 1987 = (percent of total potable production for 1987 which occurred in Jan. 1987) * (total metered sales for 1987) = 0.0695 * 6,458,206 HCF = 448,845 HCF.

Jan. 1988 - Sept. 1996: From "Metered Sales by Customer Class" reports.

Table 6. Single-family residential water consumption for the City of Santa Barbara, water years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1996).
(1 HCF = 100 ft³ = 2.83 m³, water year = Oct. 1 through Sept. 30)

water year ending September 30	metered sales ^a (in HCF)	demand ^b (in HCF)	SF residential demand as a % of metered sales
1986-87	6,676,890	not available	
1987-88	6,526,009	not available	
1988-89	6,405,080	2,897,708	45.2
1989-90	4,315,194	1,850,684	42.9
1990-91	3,602,345	1,511,630	42.0
1991-92	4,145,724	1,768,448	42.7
1992-93	4,350,638	1,899,778	43.7
1993-94	4,625,222	2,073,034	44.8
1994-95	4,559,444	2,014,399	44.2
1995-96	4,952,727	2,232,195	45.1

^a Oct. - Dec. 1986; From "Water Utility Statistics Report".

Jan. 1987 - Dec. 1987: Estimated by multiplying the percent of the total potable production for any one month times the total annual metered sales.

e.g. Jan. 1987 = (percent of the total potable production for 1987 which occurred in Jan. 1987) * (total metered sales for 1987)
= 0.0695 * 6,458,206 HCF = 448,845 HCF

Jan. 1988 - Sept. 1996; From "Metered Sales by Customer Class" reports.

^b Oct. - Nov. 1988; estimated by multiplying the percent of the total potable production for any one month times the total residential metered sales for calendar year 1988 (3,176,395 HCF) as reported in "Residential Water Consumption (Acre Feet)", 7/6/93.

Dec. 1988 - Sept. 1989; From range report, 1/27/90.

Oct. - Dec. 1989; from range report, 9/5/90.

Jan. 1990 - Sept. 1996; From "Metered Sales by Customer Class" reports.

Table 7. Single-family residential water consumption for the City of Santa Barbara, calendar years 1974 - 1996 (Source: City of Santa Barbara Department of Public Works, 1995, 1997).

(1 HCF = 100 ft³ = 2.83 m³)

calendar year	metered sales ^a (in HCF)	SF residential demand ^b (in HCF)	SF residential demand as a % of metered sales
1974	5,998,212 HCF	2,379,944 HCF	39.7
1975	not available		
1976	not available		
1977	not available		
1978	6,171,123	2,053,593	33.3
1979	5,962,567	not available	
1980	6,260,695	2,462,839	39.3
1981	5,573,529		
1982	not available		
1983	not available		
1984	6,475,936	2,516,113	38.9
1985	not available		
1986	6,592,246	2,768,717	42.0
1987	6,458,206	not available	
1988	7,119,513	3,176,395	44.6
1989	6,203,209	2,875,831	46.4
1990	3,835,548	1,551,819	40.5
1991	3,651,480	1,558,494	42.7
1992	4,262,013	1,818,703	42.7
1993	4,387,246	1,936,136	44.1
1994	4,629,031	2,070,368	44.7
1995	4,659,308	2,074,078	44.5
1996	4,930,703	2,206,983	44.8

^a 1974: From Lawrance, Fisk & McFarland Inc., 1985.

1978 - 1986: From "Water Utility Statistics Report".

1987: From "Water Usage by Category" (pie chart).

1988 - 1996: From "Metered Sales by Customer Class" reports.

^b 1974 - 1984: From Lawrance, Fisk & McFarland Inc., 1985.

1986: From "Water Utility Statistics Report".

1988 - 1989: From "Residential Water Consumption (Acre Feet)" 7/6/93.

1990 - 1996 From "Metered Sales by Customer Class" reports.

Table 8. Comparison of water bills before, during, and after the drought for the City of Santa Barbara (Source: City of Santa Barbara Department of Public Works, 1995).
(1 HCF = 100 ft³ = 2.83 m³)

period	water bill for monthly consumption					
	0 HCF	5	10	15	20	25
4/76 - 6/80	\$2.00	\$3.67	\$5.33	\$7.00	\$8.66	\$10.33
7/80 - 6/81	2.67	5.67	8.47	11.37	14.27	17.17
7/81 - 7/82	2.85	5.95	9.05	12.15	15.25	18.35
8/82 - 5/86	3.42	7.12	10.82	14.52	18.22	21.92
6/86 - 6/88	4.10	8.55	13.00	17.45	21.90	26.35
7/88 - 6/89	4.72	9.82	14.92	20.02	25.12	30.22
7/89 - 2/90	1.47	6.92	13.35	18.09	29.15	39.00
3/90 - 10/90	1.47	9.10	38.53	107.20	254.35	401.50
11/90 - 4/91	1.47	9.33	26.83	66.83	140.83	223.33
5/91 - 9/91	3.70	14.80	33.30	60.20	92.70	125.20
10/91 - 4/92	3.70	14.80	33.30	57.35	85.10	112.85
5/92 - 4/93	3.70	14.80	33.30	51.80	70.30	98.05
5/93 - 7/95	3.70	14.80	33.30	51.80	70.30	88.80
8/95 - present	5.50	17.40	34.90	52.40	69.90	88.40

Table 9. Estimated revenue vulnerability for the City of Santa Barbara, fiscal years 1986-87 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1996).
(fiscal year = July 1 through June 30)

fiscal year ending June 30	approximate service ^a charge revenue(\$)	total ^b revenue(\$)	percent of revenue from metered sales
1986-87	1,484,000	7,514,899	80.3
1987-88	1,572,000	7,849,727	80.0
1988-89	1,845,000	8,516,467	78.3
1989-90	573,000	9,864,983	94.2
1990-91	582,000	12,328,522	95.3
1991-92	1,432,000	13,883,662	89.7
1992-93	1,452,000	15,701,997	90.8
1993-94	1,452,000	15,771,912	90.8
1994-95	1,457,000	16,382,600	91.1
1995-96	2,642,640	17,797,681	85.2

^a 1986-87 to 1994-95: From city Public Works Department staff.

1995-96: From Kennedy/Jenks Consultants (1995), assuming 40,040 equivalent meters.

^b Total revenue = service charge + metered-water revenues.

1986-87 to 1987-88: From "Comprehensive Annual Financial Report".

1988-89 to 1995-96: From "Analysis of Water Fund Budgets July 1988 to June 1998".

Table 10. Average price of water for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997).
(1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)

fiscal year ending June 30	total ^a revenue (\$)	metered ^b sales (HCF)	average ^c price (\$/HCF)	adjusted ^d total revenue(\$)	adjusted ^e metered sales (HCF)	adjusted ^f average price (\$/HCF)
1977-78	\$2,515,000	6,298,128 HCF	\$0.40/HCF	\$6,207,149	8,075,934 HCF	\$0.76/HCF
1978-79	2,875,000	5,800,802	0.50	6,484,489	7,327,858	0.88
1979-80	3,924,000	6,004,011	0.65	7,812,603	7,473,668	1.05
1980-81	4,075,563	5,961,230	0.68	7,271,068	7,420,415	0.97
1981-82	4,523,985	5,585,561	0.81	7,427,797	6,925,985	1.07
1982-83	5,178,823	6,222,100	0.83	8,147,945	7,662,822	1.06
1983-84	6,273,188	5,941,176	1.06	9,520,703	7,189,846	1.32
1984-85	6,740,686	7,052,139	0.96	9,843,440	8,397,169	1.17
1985-86	6,697,259	7,051,100	0.95	9,510,354	8,259,916	1.15
1986-87	7,514,899	6,645,981	1.13	10,441,114	7,659,420	1.36
1987-88	7,849,727	6,897,094	1.14	10,473,081	7,822,303	1.34
1988-89	8,516,467	6,863,636	1.24	10,856,387	7,662,393	1.42
1989-90	9,854,983	5,092,897	1.94	11,988,936	5,457,795	2.20
1990-91	12,328,522	3,566,380	3.46	14,225,218	3,681,521	3.86
1991-92	13,883,662	3,806,591	3.65	15,521,171	3,892,356	3.99
1992-93	15,701,997	4,376,425	3.59	17,100,165	4,455,208	3.84
1993-94	15,771,912	4,470,600	3.53	16,677,308	4,541,147	3.67
1994-95	16,382,600	4,600,635	3.56	16,829,200	4,646,078	3.62
1995-96	17,797,681	4,845,328	3.67	17,797,681	4,845,328	3.67

^a Total revenue = meter charge + metered-water revenues.

1977-78 to 1980-81: From "City of Santa Barbara Annual Operating Budget", fiscal years 1977-78 to 1982-83.

1981-82 to 1987-88: From "City of Santa Barbara Comprehensive Annual Financial Report".

1988-89 to 1995-96: From Public Works Department staff.

^b Fiscal years 1977-78 - 1981-82, 1983-84 - 1984-85, Jan. - Dec. 1986: From "Water Utility Statistics Report".

Fiscal years 1982-83, 1985-86: from Black and Veatch Consultants, 1986.

1987: Estimated by multiplying the percent of total annual potable production for any one month times the total annual metered sales. E.g. Jan. 1987 = (percent of total potable production which occurred in Jan. 1987) * (total metered sales for 1987).

Jan. 1988 - June 1996: From "Metered Sales by Customer Class" report.

^c Average price = total revenue / metered sales.

^d Adjusted to 1995-96 dollars, using the Consumer Price Index (for all urban customers).

^e Adjusted to fiscal year 1995-96 population levels. E.g. 1980-81 = (1995-96 population/1980-81 population) * 1980-81 metered sales.

^f Adjusted average price = adjusted total revenue / adjusted metered sales.

Table 11. Average cost of water for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)

fiscal year ending June 30	total ^a operating cost(\$)	metered sales (HCF)	^b average ^c cost (\$/HCF)	adjusted ^d total operating cost(\$)	adjusted ^e metered sales (HCF)	adjusted ^f average cost (\$/HCF)
1977-78	\$2,734,345	6,298,128	HCF \$0.43/HCF	\$6,748,503	8,075,934	HCF \$0.84/HCF
1978-79	2,787,901	5,800,802	0.48	6,288,039	7,327,858	0.86
1979-80	3,028,548	6,004,011	0.50	6,029,777	7,473,668	0.81
1980-81	4,028,329	5,961,230	0.68	7,186,799	7,420,415	0.97
1981-82	5,343,002	5,585,561	0.96	8,772,517	6,925,985	1.27
1982-83	4,756,695	6,222,100	0.76	7,483,802	7,662,822	0.98
1983-84	5,678,216	5,941,176	0.96	8,617,725	7,189,846	1.20
1984-85	5,639,451	7,052,139	0.80	8,235,304	8,397,169	0.98
1985-86	5,678,884	7,051,100	0.81	8,064,224	8,259,916	0.98
1986-87	8,400,000	6,645,981	1.26	11,670,863	7,659,420	1.52
1987-88	8,600,000	6,897,094	1.25	11,474,093	7,822,303	1.47
1988-89	13,719,748	6,863,636	2.00	17,489,283	7,662,393	2.28
1989-90	13,279,446	5,092,897	2.61	16,154,917	5,457,795	2.96
1990-91	13,361,575	3,566,380	3.75	15,417,202	3,681,521	4.19
1991-92	16,385,516	3,806,591	4.30	18,318,106	3,892,356	4.71
1992-93	20,106,575	4,376,425	4.59	21,799,760	4,455,208	4.89
1993-94	19,767,753	4,470,600	4.42	20,889,999	4,541,147	4.60
1994-95	19,057,344	4,600,635	4.14	19,576,859	4,646,078	4.21
1995-96	21,372,070	4,845,328	4.41	21,372,070	4,845,328	4.41

^a 1977-78 to 1980-81: From "City of Santa Barbara Annual Operating Budget", fiscal years 1977-78 to 1982-83.

1981-82 to 1985-86: From "City of Santa Barbara Comprehensive Annual Financial Report".

1986-87 to 1995-96: From Public Works Department staff.

^b Fiscal years 1977-78 - 1981-82, 1983-84 - 1984-85, Jan. 1986 - Dec. 1986: From "Water Utility Statistics Report".

1987: Estimated by multiplying the percent of the total annual potable production for any one month times the total annual metered sales. e.g. Jan. 1987 = (percent of total potable production which occurred in Jan. 1987) * (total metered sales for 1987)

Jan. 1988 - June 1996: From "Metered Sales by Customer Class" reports.

^c Average cost = total operating cost / metered sales.

^d Adjusted to fiscal year 1995-96 dollars, using the Consumer Price Index (for all urban customers).

^e Adjusted to fiscal year 1995-96 population levels. E.g. 1980-81 = (1995-96 population/1980-81 population) * 1980-81 metered sales.

^f Adjusted average cost = adjusted total operating cost / adjusted metered sales.

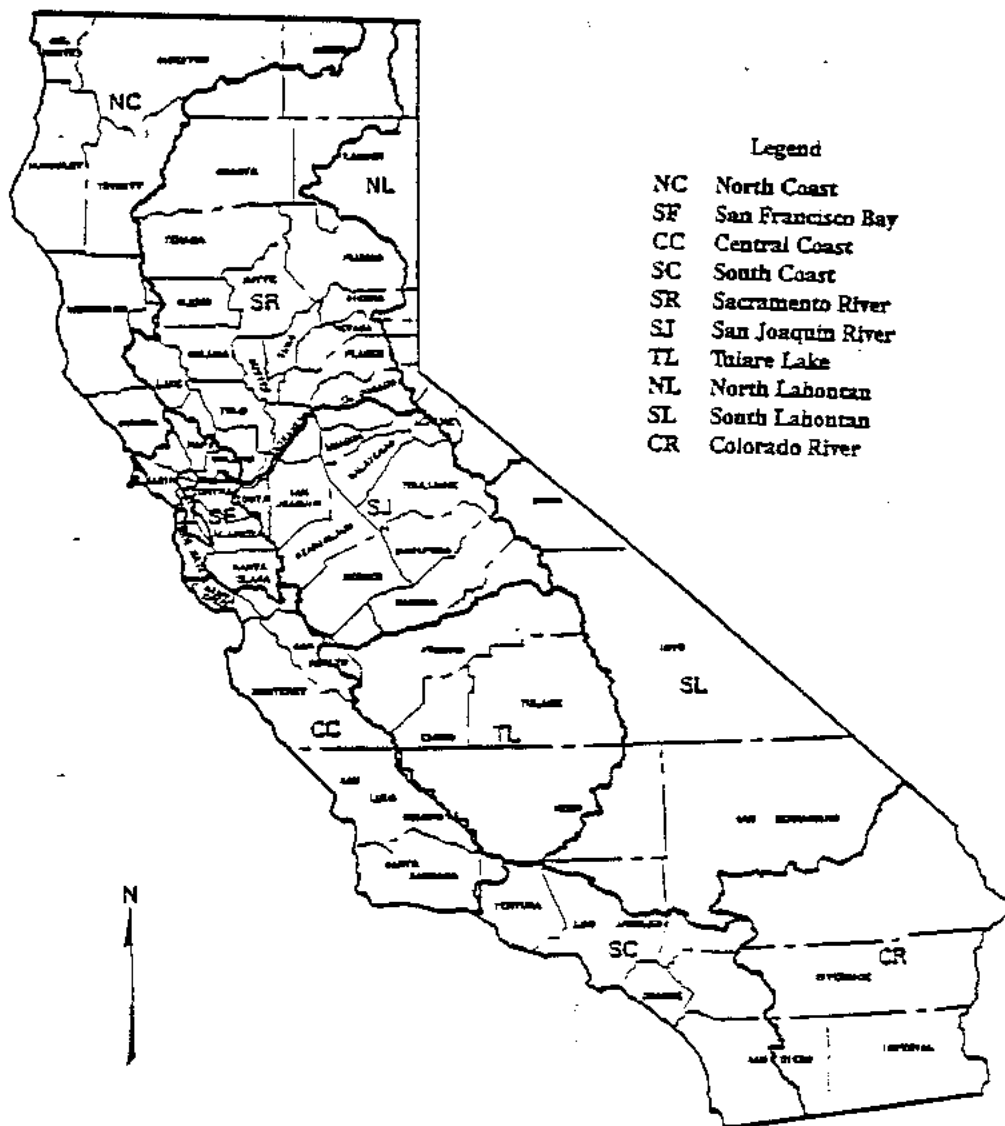


Figure 1. The hydologic regions of California (Source: State of California Department of Water Resources, August 1994).

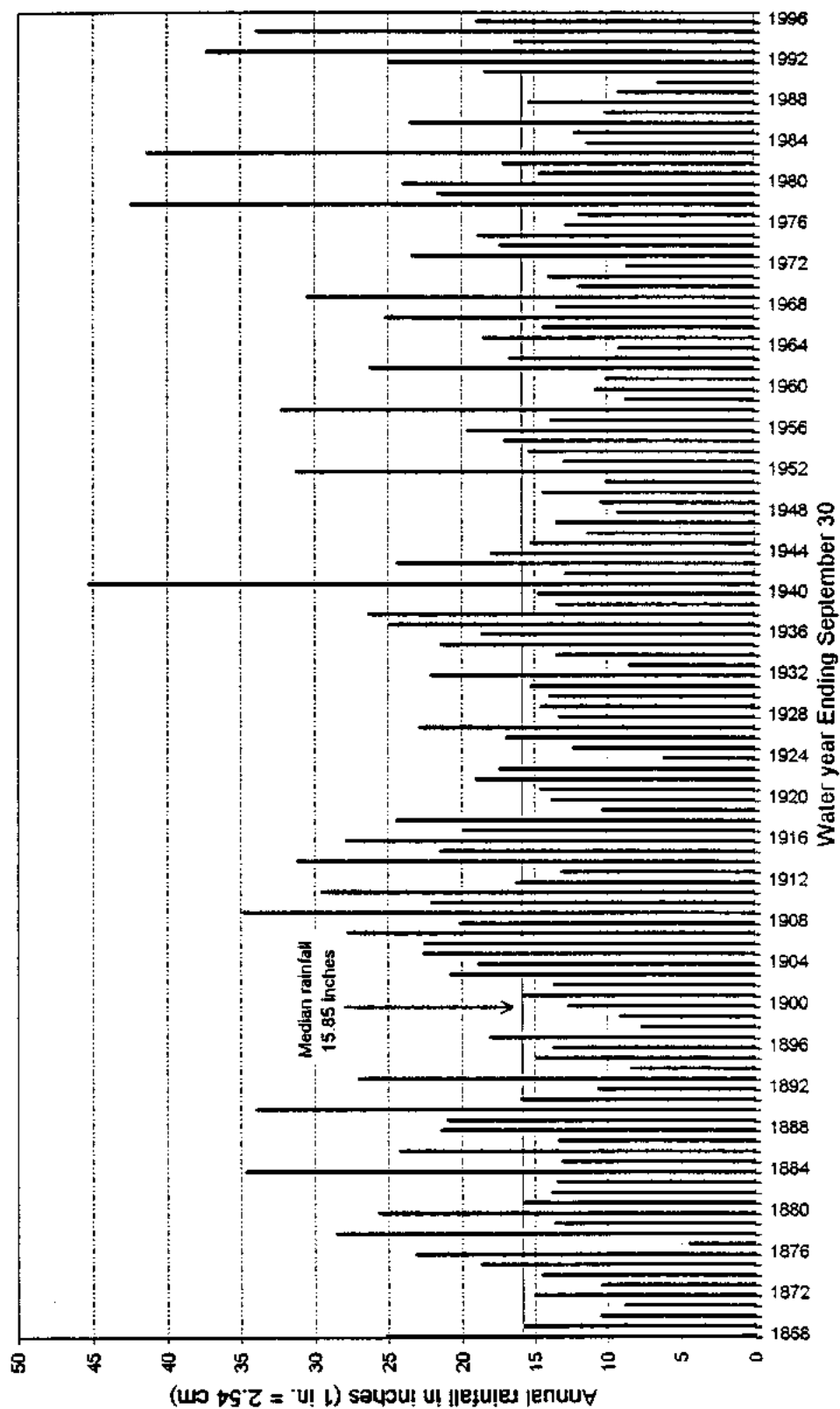


Figure 3. Annual rainfall totals for the City of Santa Barbara, water years 1867-68 to 1995-96
 (Source: City of Santa Barbara Department of Public Works, 1995, 1997).
 (1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

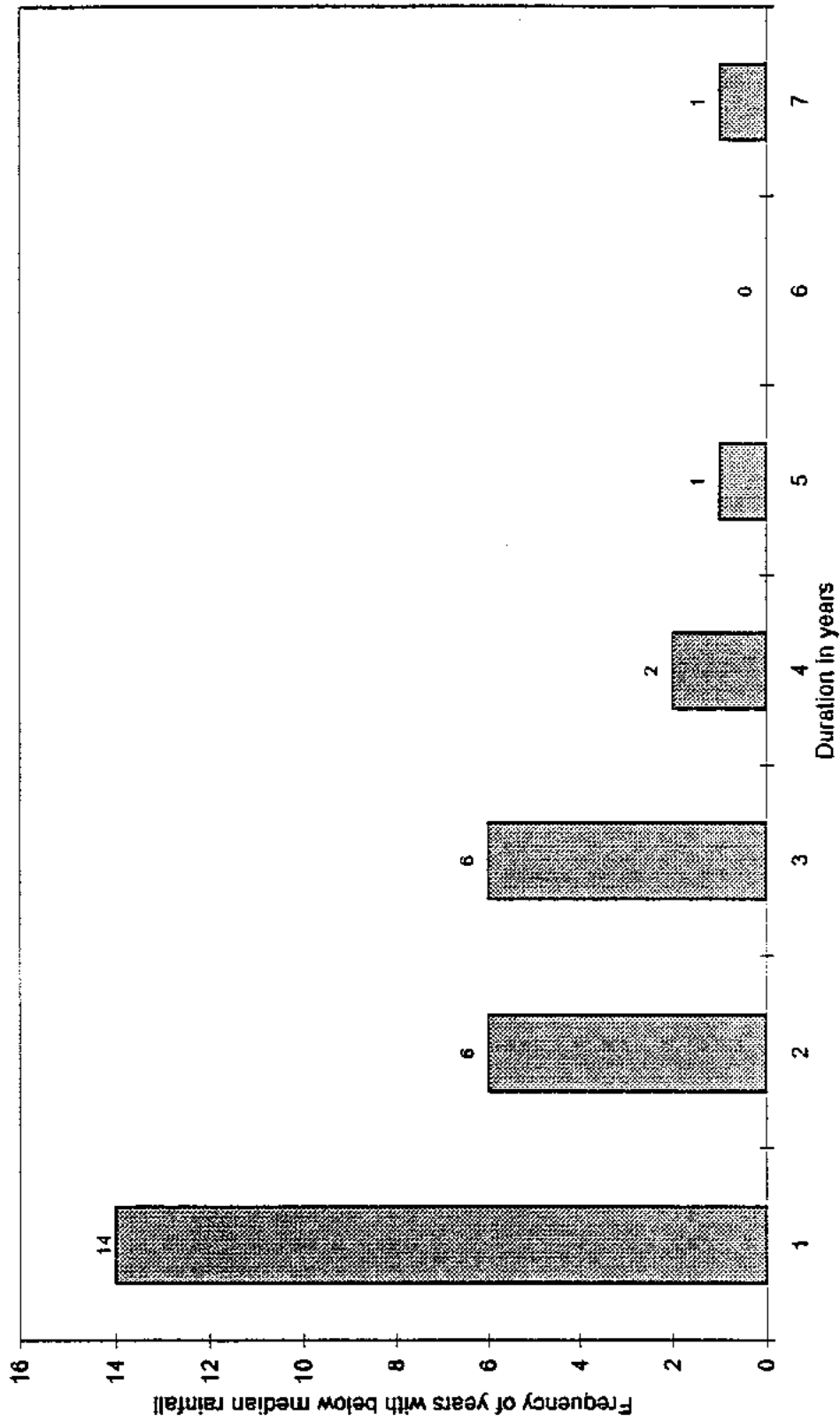


Figure 4. Frequency and duration of years with below median rainfall for the City of Santa Barbara, water years 1867-68 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (water year = Oct. 1 through Sept. 30)

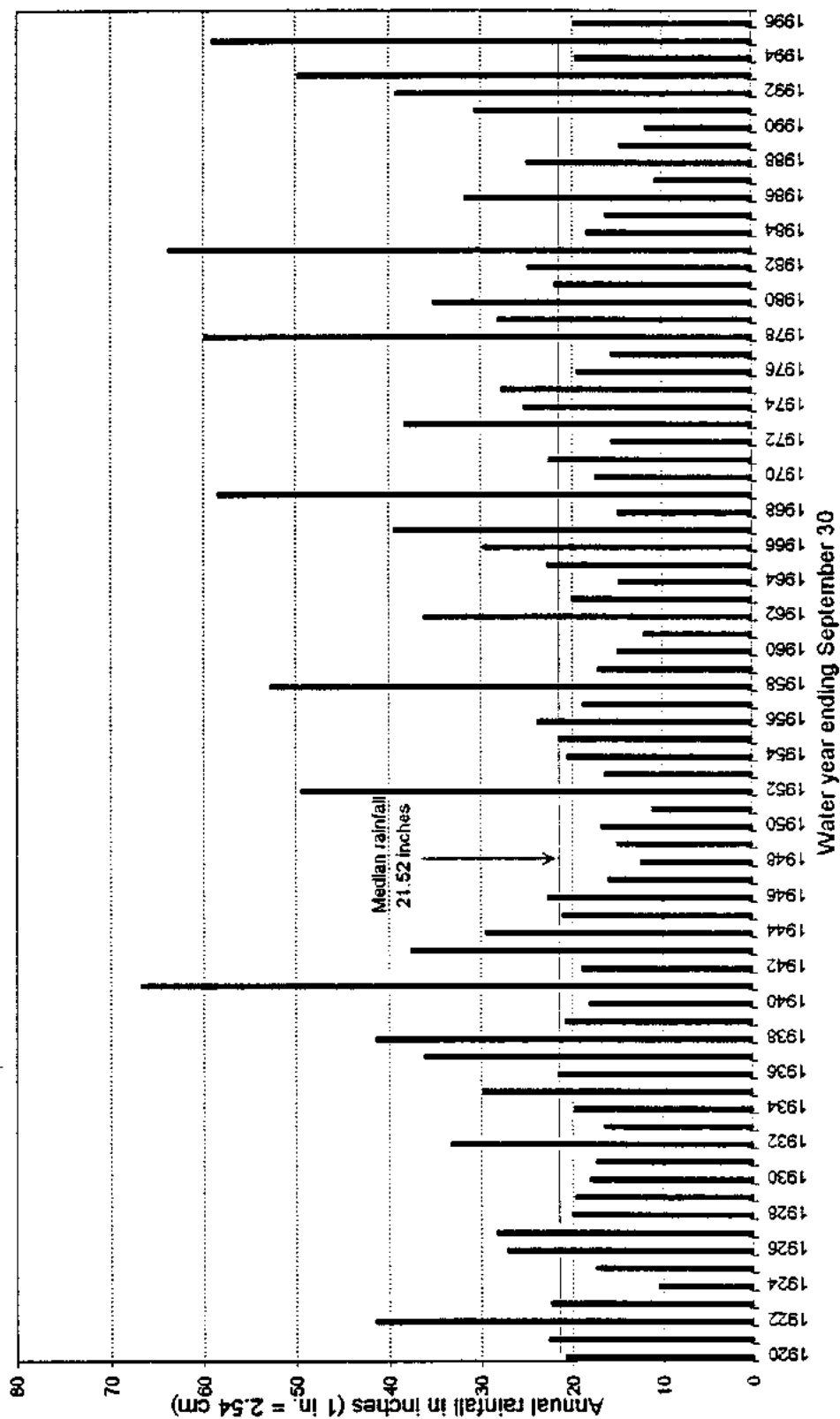


Figure 5. Annual rainfall totals for Gibraltar Reservoir, water years 1919-20 to 1995-96
 (Source: County of Santa Barbara Water Agency, 1988, and City of Santa Barbara
 Department of Public Works, 1996). (1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

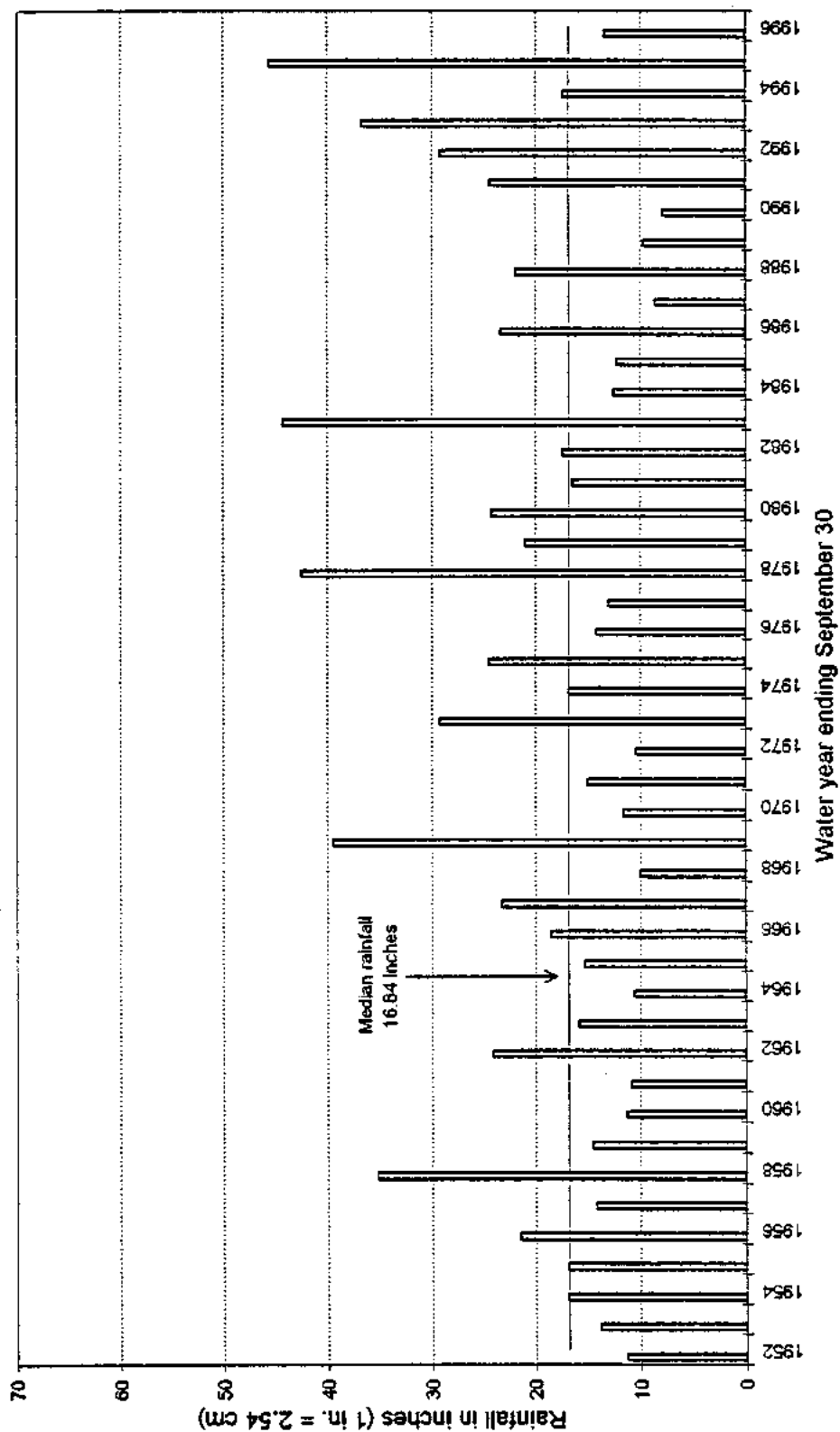


Figure 6. Annual rainfall for Bradbury Dam, water years 1951-52 to 1995-96 (Source: Santa Barbara County Water Agency, 1988, and Cachuma Operations and Maintenance Board, 1996). (1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

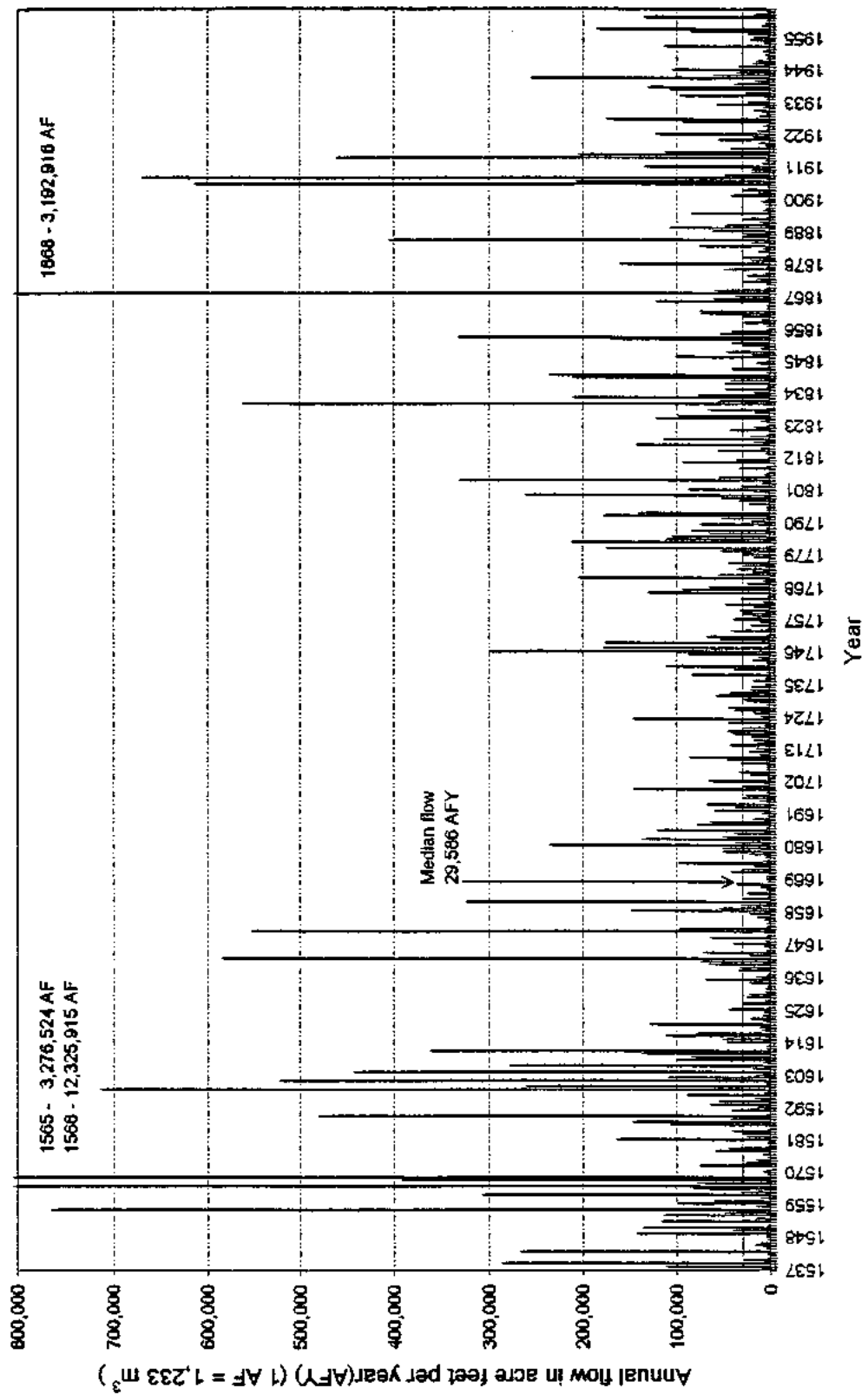


Figure 7. Reconstructed flows of the Santa Ynez River at Bradbury Dam, 1537 - 1964 (Source: Michaelensen and Haston, 1988). (1 AF = 1,233 m³)

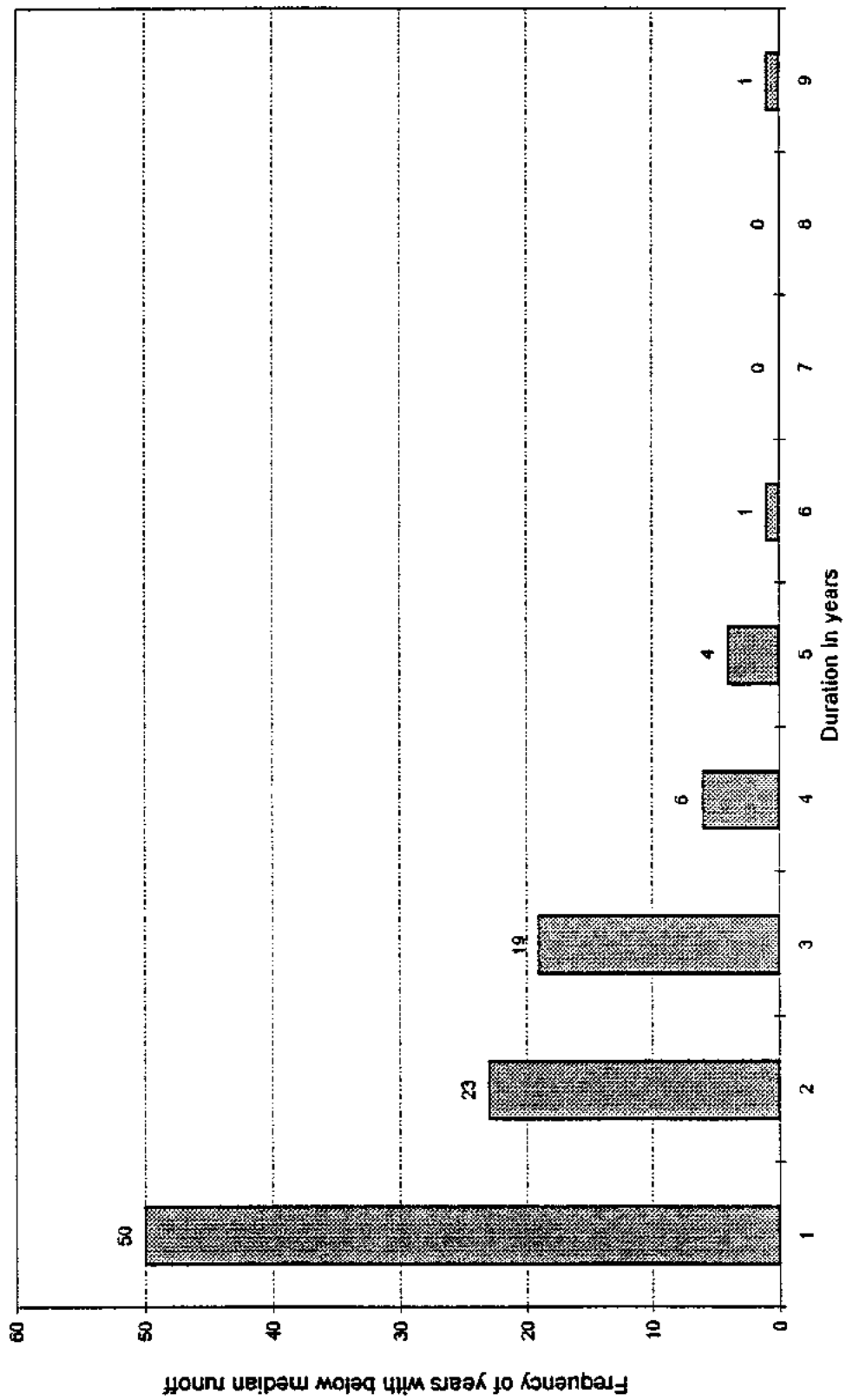


Figure 8. Frequency and duration of years with below median runoff for the Santa Ynez River at Bradbury Dam, 1537 - 1964 (Source: Michaelson and Haston, 1988).

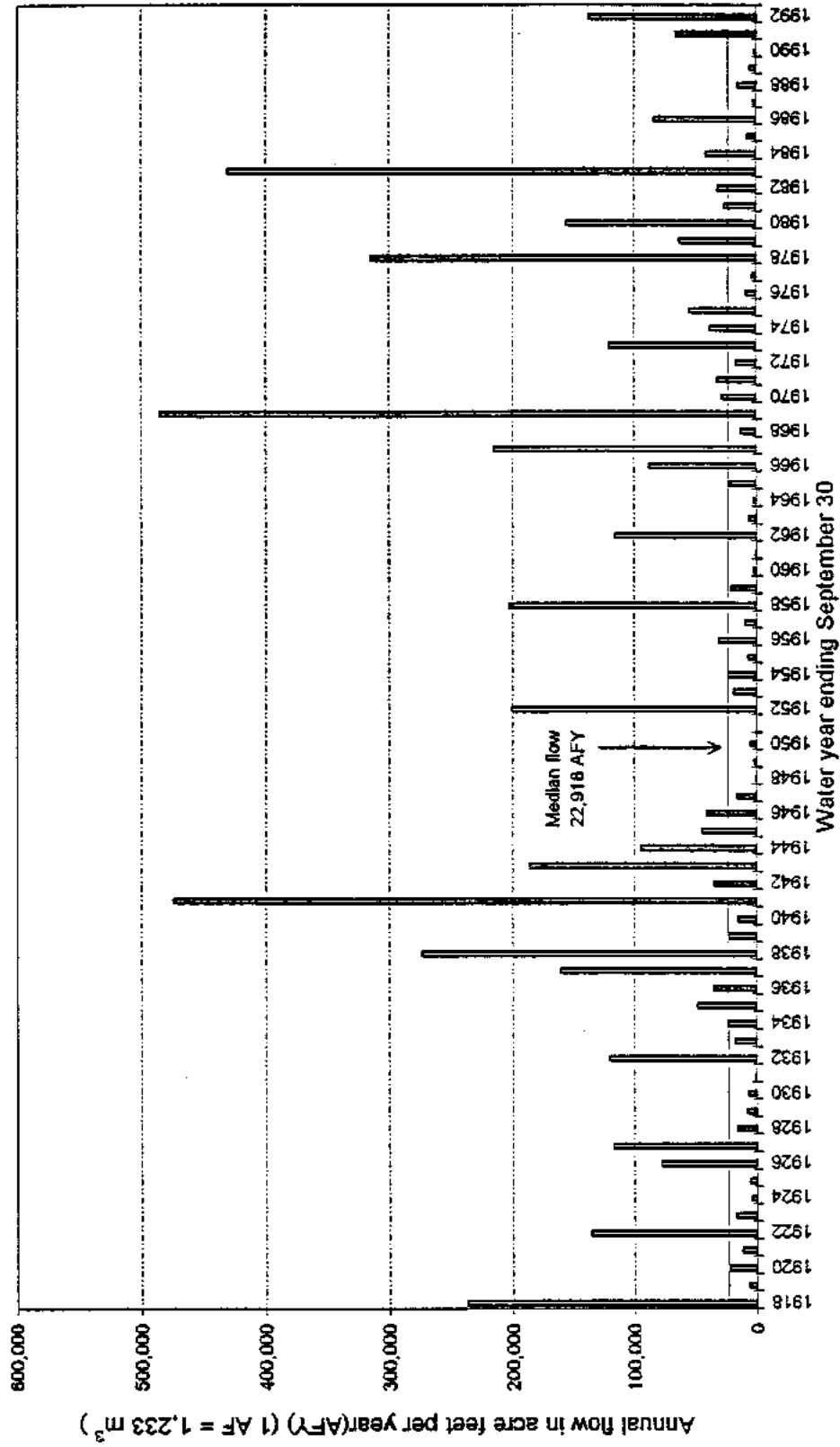


Figure 9. Unimpaired flows of the Santa Ynez River at Bradbury Dam, water years 1917-18 to 1991-92 (Source: Santa Barbara County Flood Control and Water Conservation District, 1995). (1 AF = 1,233 m³)

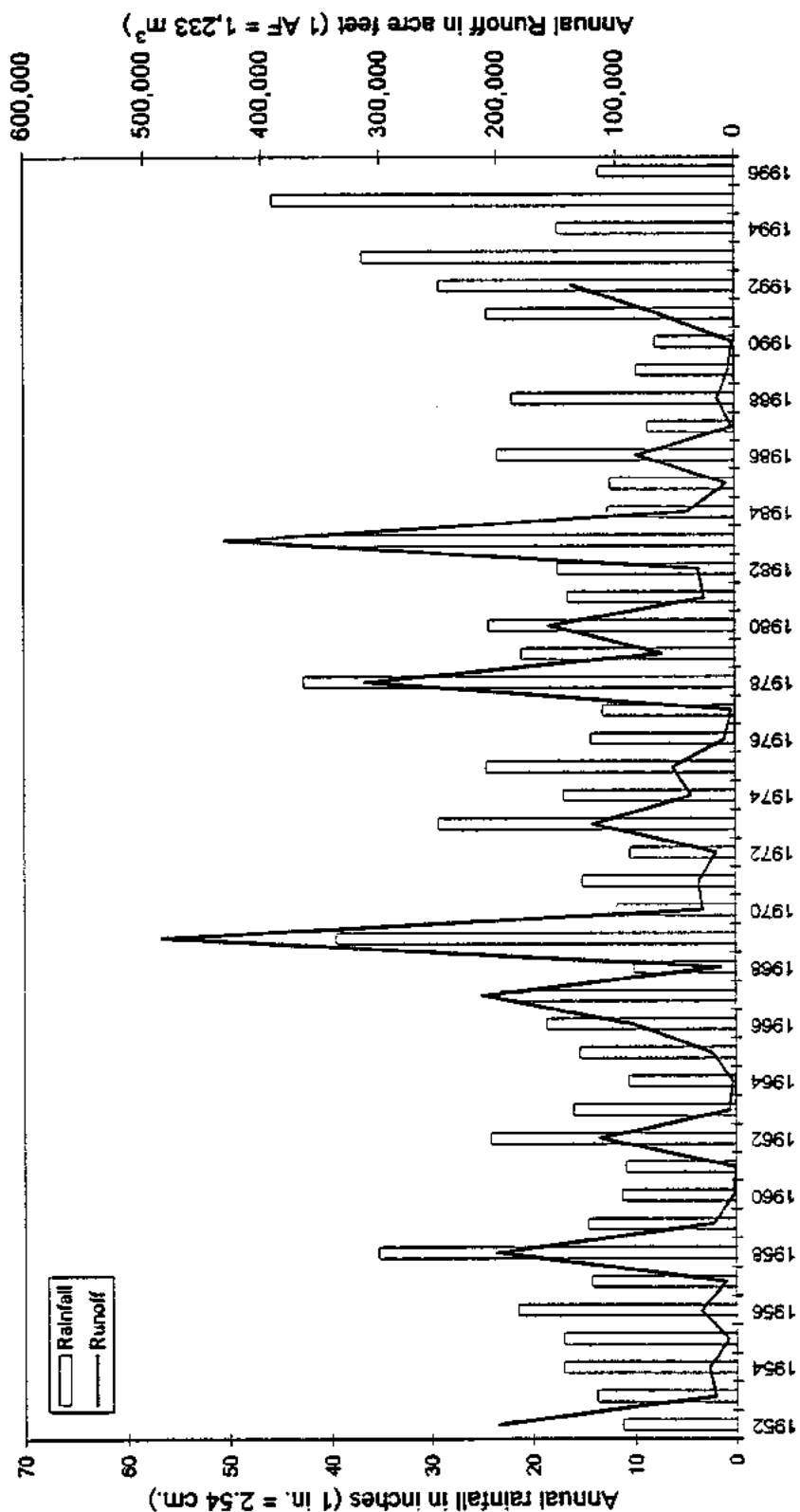


Figure 10. Annual rainfall totals at, and runoff into Lake Cachuma, water years 1951-52 to 1995-96 (Source: Santa Barbara County Water Agency, 1988, Santa Barbara County Flood Control and Water Conservation District, 1995, and Cachuma Operation and Maintenance Board, 1996).
 (1 in. = 2.54 cm, 1 AF = 1,233 m³, water year = Oct.1 through Sept. 30)

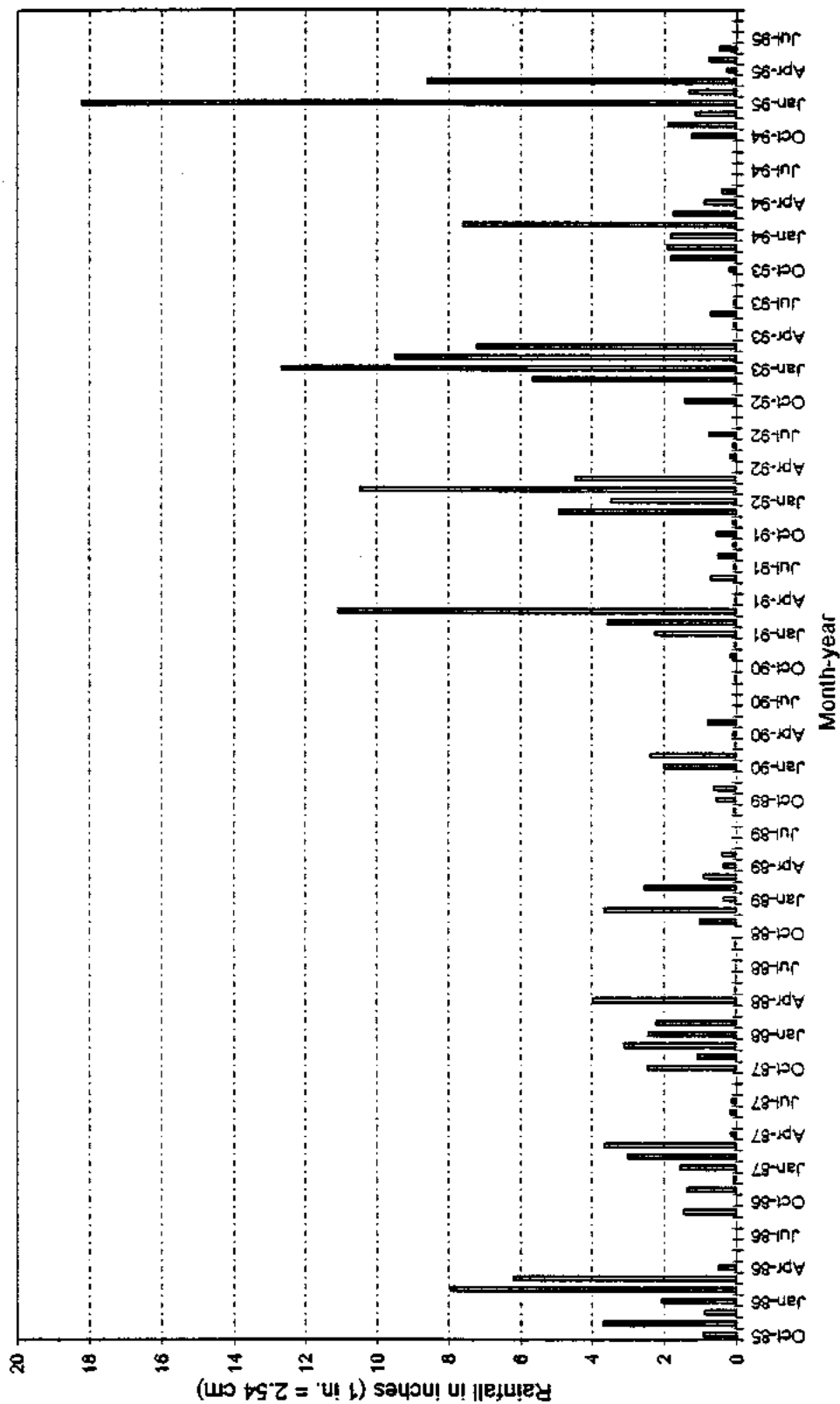


Figure 11. Monthly distribution of rainfall for the City of Santa Barbara, water years 1985-86 to 1994-95 (Source: City of Santa Barbara Department of Public Works, 1995). (1 in. = 2.54 cm, water year = Oct. 1 through Sept. 30)

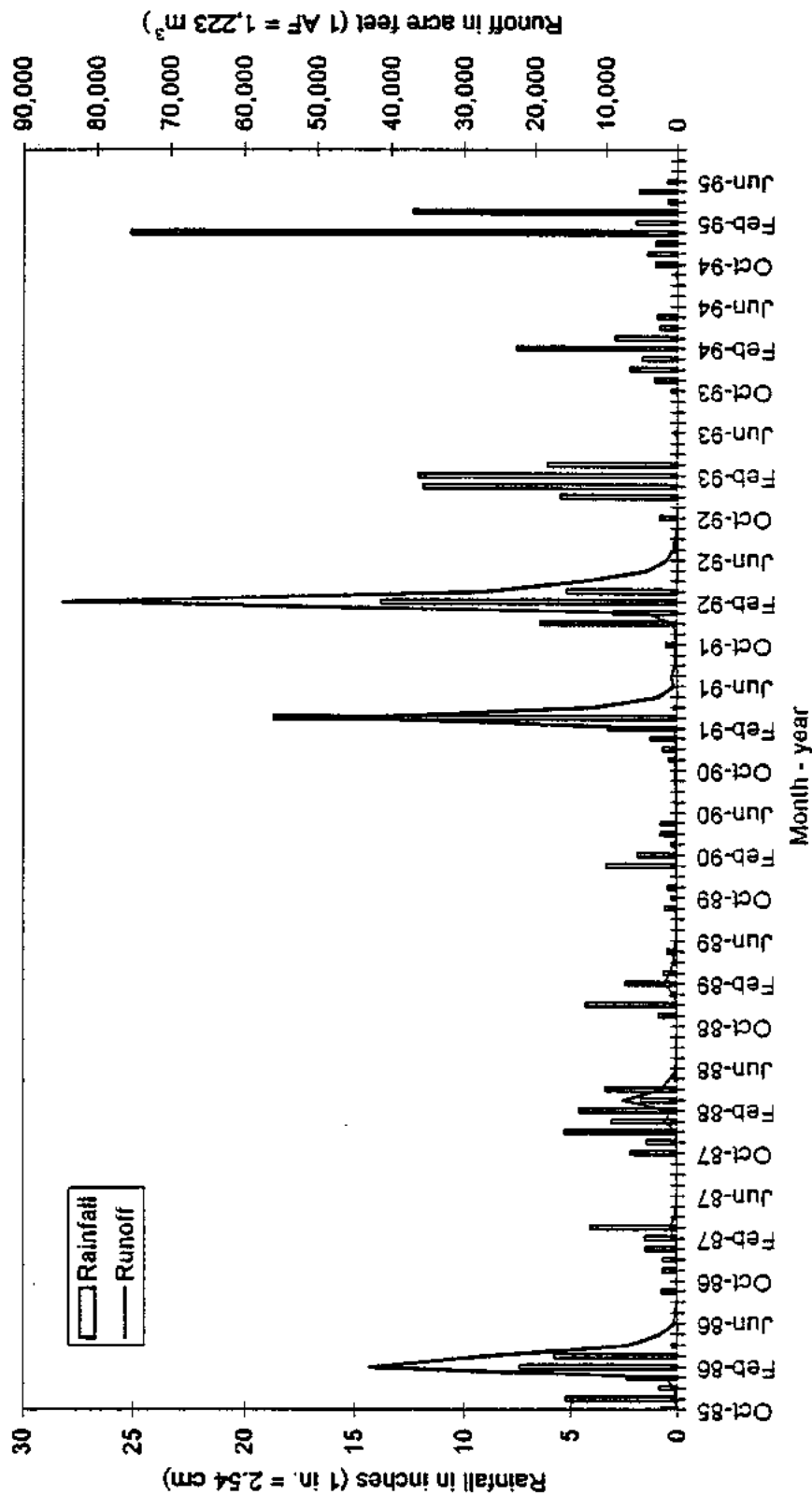


Figure 12. Monthly distribution of rainfall at, and runoff into Lake Cachuma, water years 1985-86 to 1994-95 (Source: Santa Barbara County Water Agency, 1988, Santa Barbara County Flood Control and Water Conservation District, 1995, and Cachuma Operation and Maintenance board, 1996).
(1 in. = 2.54 cm, 1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)

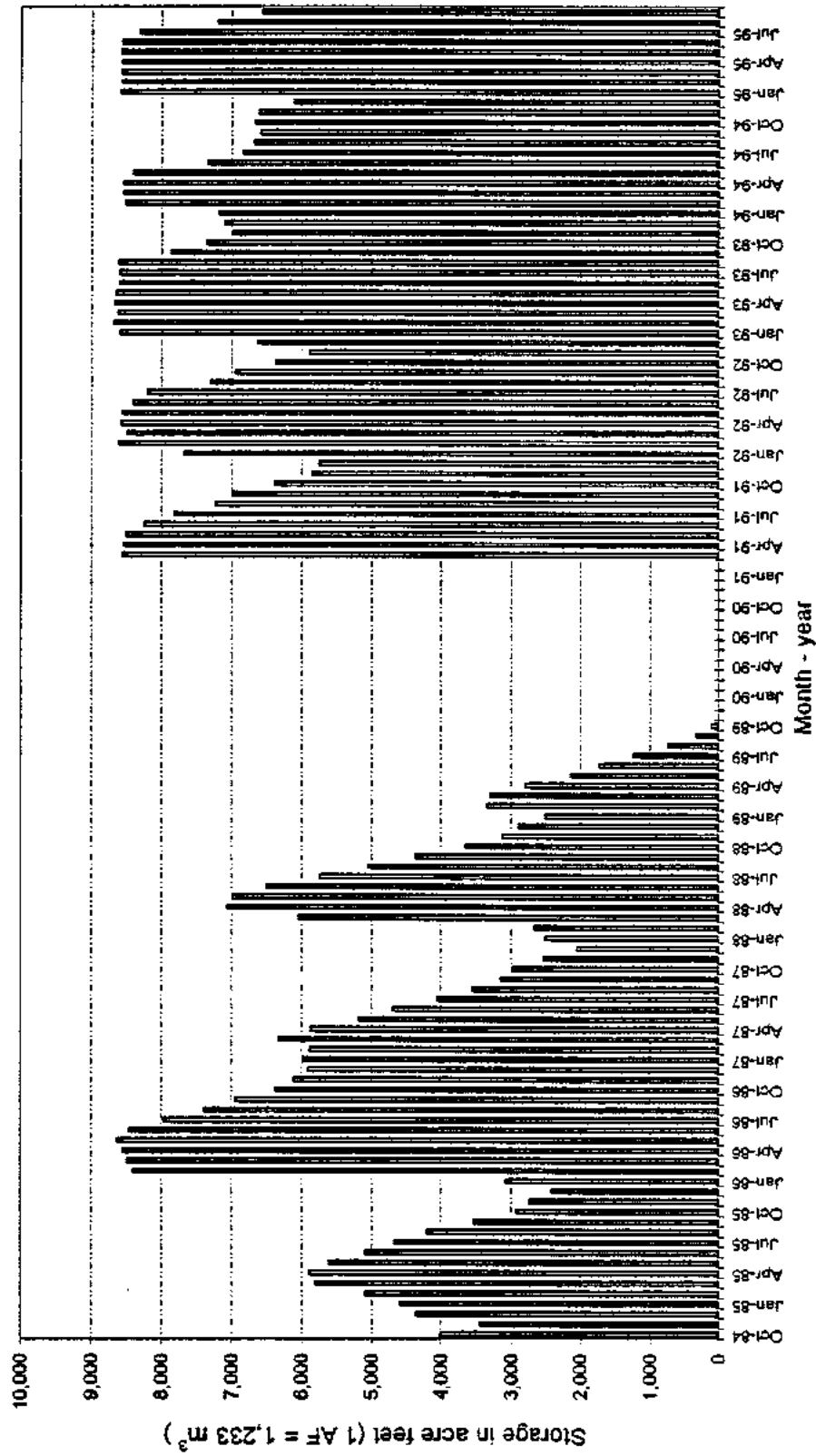


Figure 13. Monthly distribution of storage capacity for Gibraltar Reservoir, water years 1984-85 to 1994-95 (Source: Agajanian et al., 1994, 1995, Bowers et al., 1987, 1988, 1989, 1990, 1991, 1992, 1993, and City of Santa Barbara Department of Public Works, 1995). (1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)



Figure 14. Monthly distribution of storage capacity for Lake Cachuma, water years 1985-86 to 1994-95 (Source: Agajanian et al., 1994, 1995, Bowers et al., 1987, 1988, 1989, 1990, 1991, 1992, 1993, and Cachuma Operation & Maintenance Board, 1995). (1 AF = 1,233 m³, water year = Oct. 1 through Sept. 30)

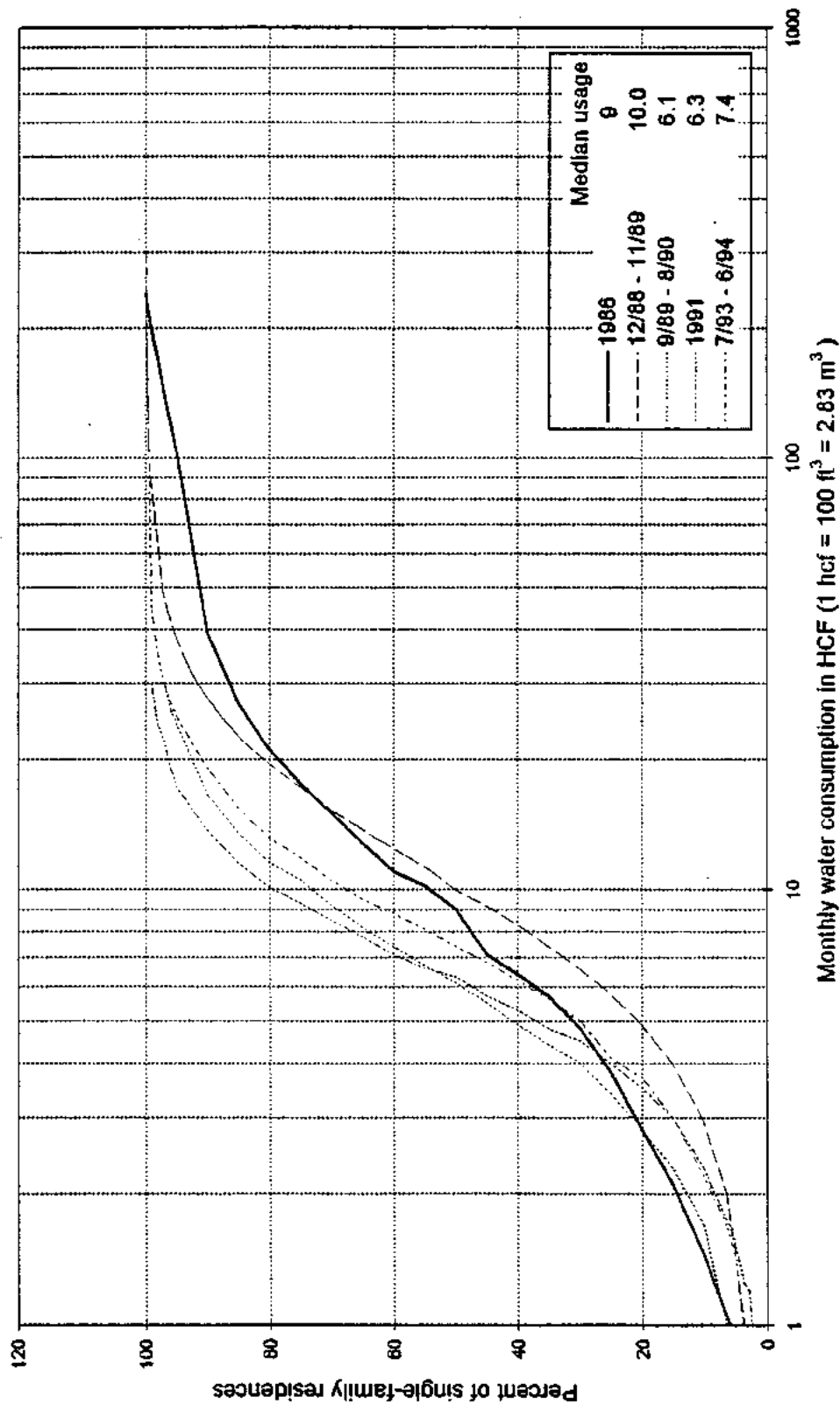


Figure 15. Single-family residential consumption distribution curves for the City of Santa Barbara, 1986 - 1994 (Source: City of Santa Barbara Department of Public Works, 1987, 1990, June 1993, and Kennedy/Jenks Consultants, 1995). (1 HCF = 100 ft³ = 2.83 m³)

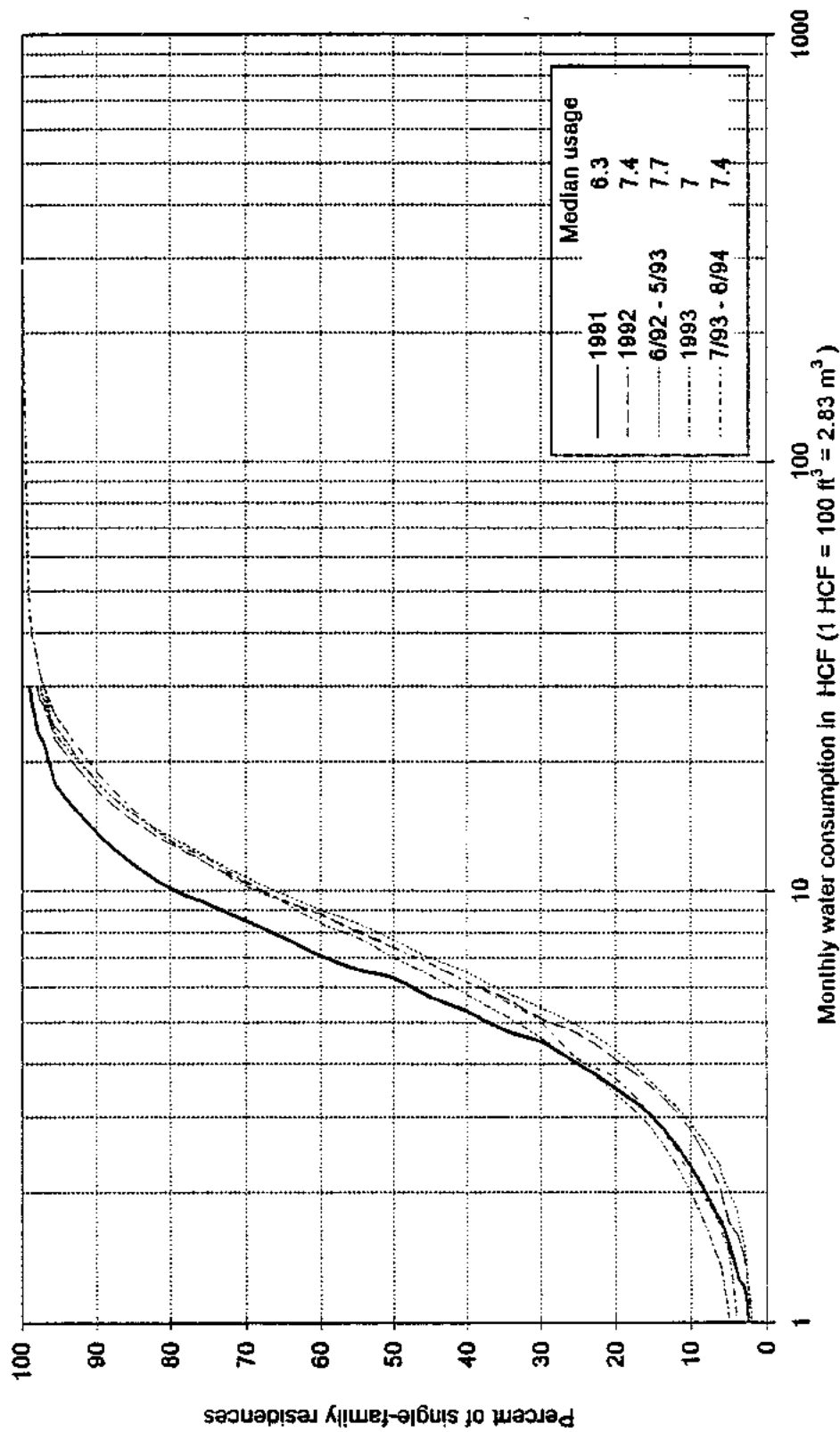


Figure 16. Single family residential consumption distribution curves for the City of Santa Barbara, 1991 - 1994 (Source: City of Santa Barbara Department of Public Works, June 1993, June 1994, and Kennedy/Jenks Consultants, 1995). (1 HCF = 100 ft³ = 2.83 m³)

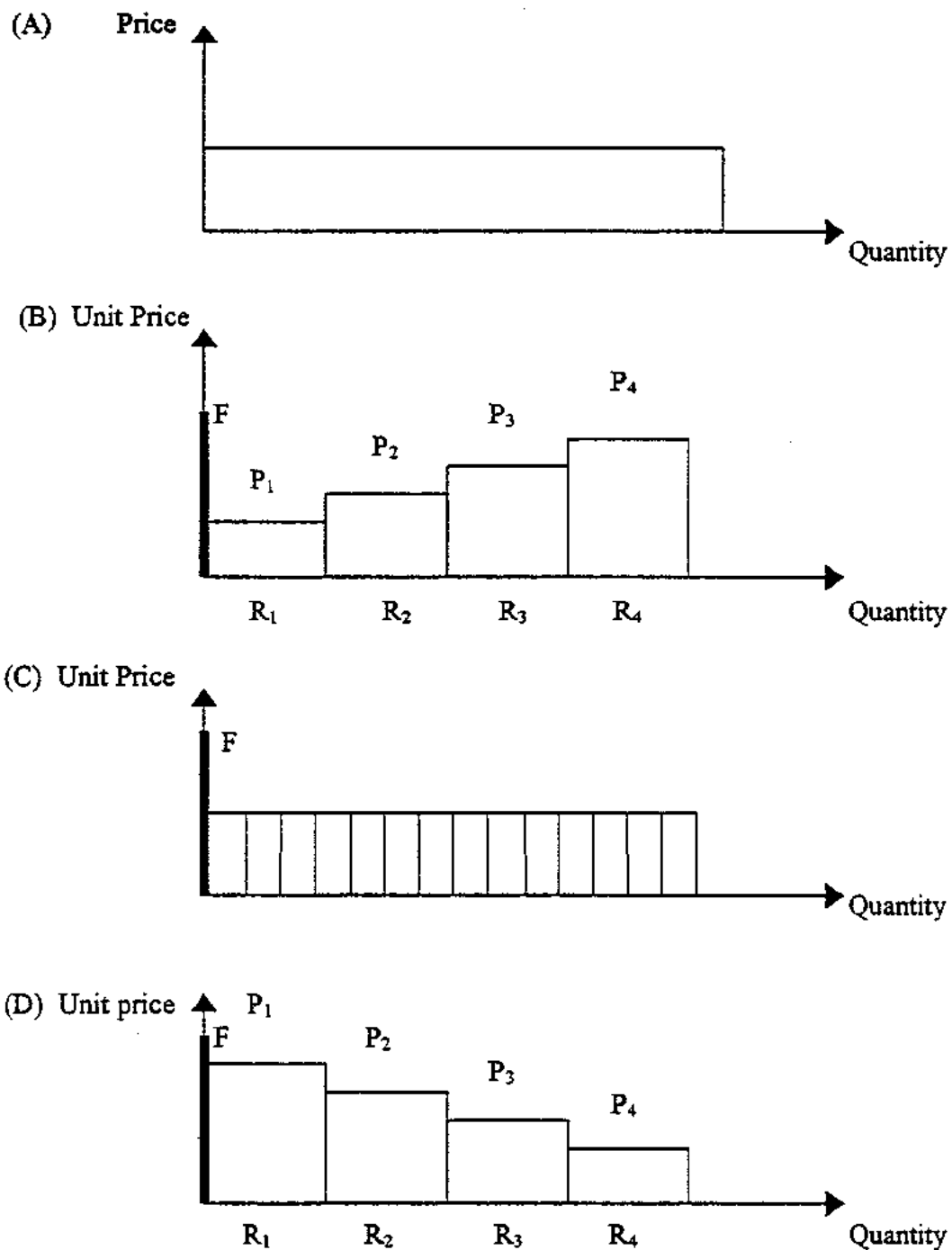


Figure 17. The different types of water-rate structures. (A) fixed charge with unmeasured consumption; (B) increasing block rate with service charge(F); (C) uniform flat rate with service charge(F); (D) decreasing block rate with service charge(F) (Source: Loaiciga, 1995).

Date of price structure	Level of usage (HCF/month) and corresponding price per unit (\$/HCF)						Service charge (\$)
	0	10	20	30	40	50	
4/76 - 6/80			\$ 0.333/HCF				2.00
7/80 - 6/81			0.58				2.67
7/81 - 7/82			0.62				2.85
8/82 - 5/86			0.74				3.42
6/86 - 6/88			0.89				4.10
7/88 - 6/89			1.02				4.72
7/89 - 2/90	1.09	1.58		1.97		3.01	1.47
3/90 - 10/90	1.09	3.27	9.81	29.43			1.47
11/90 - 4/91	1.09	3.50	8.00	16.50			1.47
5/91 - 9/91	1.85	3.70	6.50		12.00		3.70
10/91 - 4/92	1.85	3.70	5.55		7.40		3.70
5/92 - 4/93	1.85	3.70	5.55		7.40		3.70
5/93 - 7/95	1.85	3.70			5.10		3.70
8/95 - present	2.10	3.50		3.70			5.50

Figure 18. Pricing structure for single-family residential units which were in effect before, during, and after the drought in the City of Santa Barbara (Source: City of Santa Barbara Department of Public Works, 1995). (1 HCF = 100 ft³ = 2.83 m³)

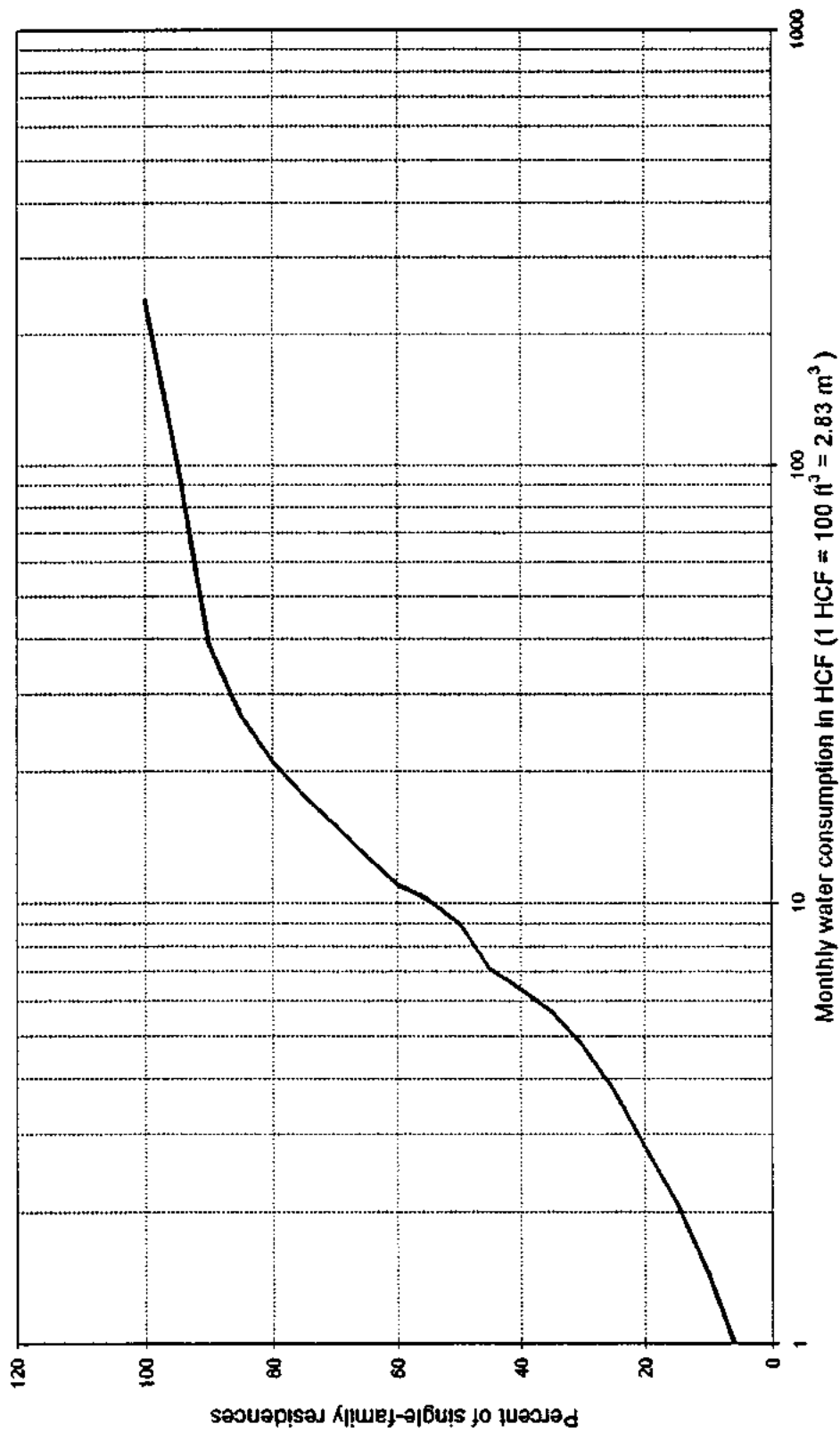


Figure 19. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1986 (Source: City of Santa Barbara Department of Public Works, 1987). (1 HCF = 100 ft³ = 2.83 m³)

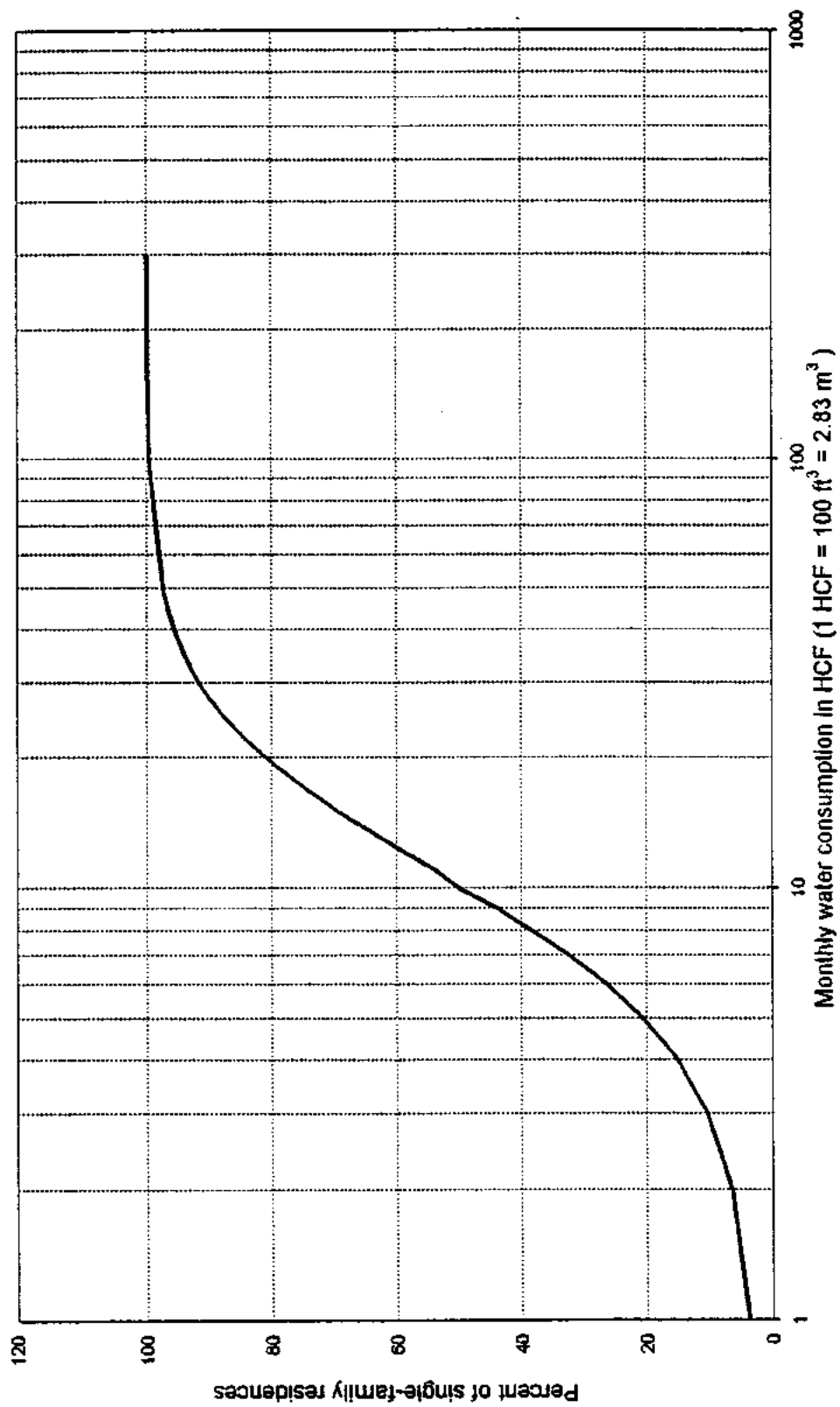


Figure 20. Single-family residential consumption distribution curve for the City of Santa Barbara, December 1988 - November 1989 (Source: City of Santa Barbara Department of Public Works, January 1990). (1 HCF = 100 ft³ = 2.83 m³)

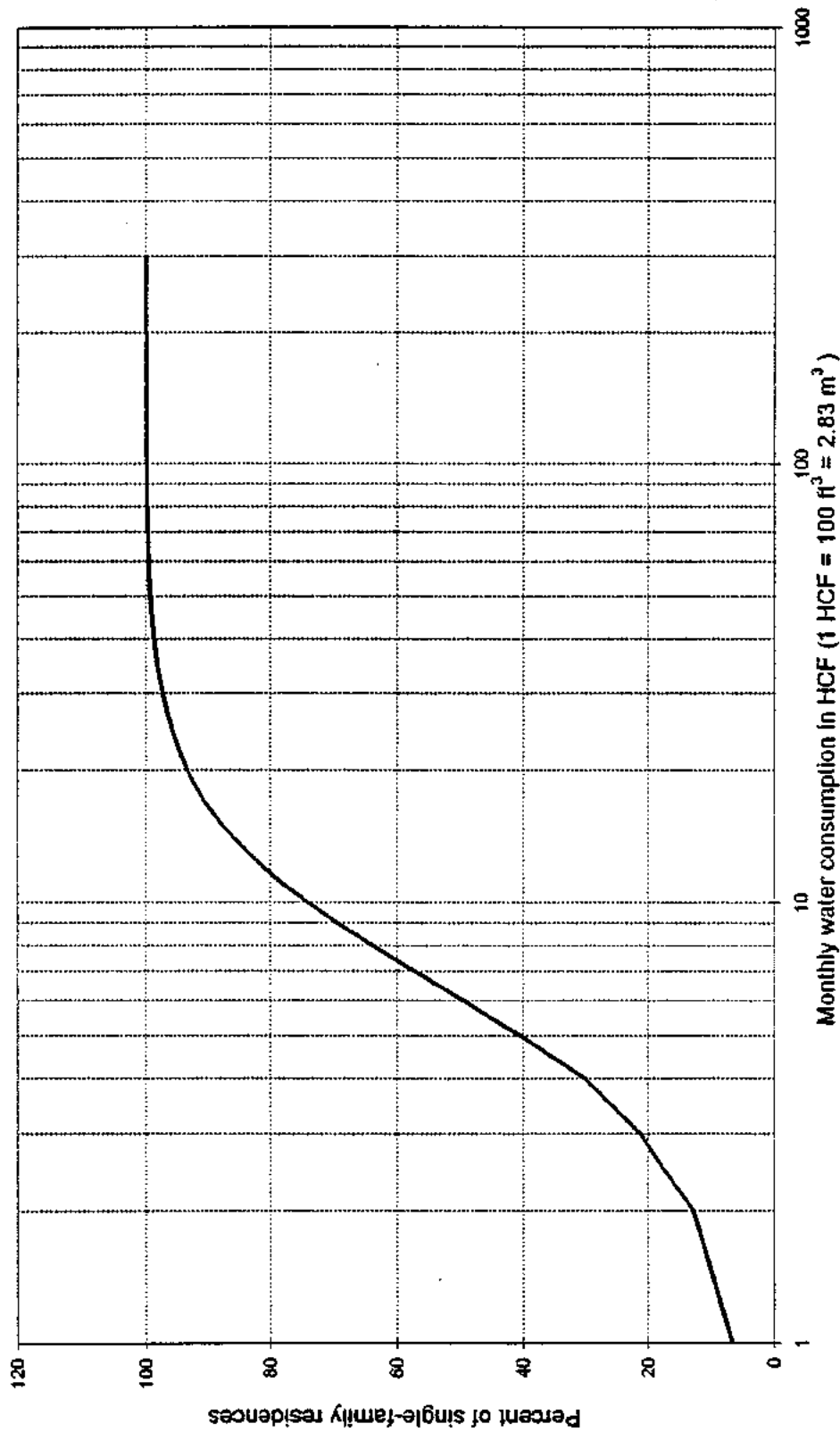


Figure 21. Single-family residential consumption distribution curve for the City of Santa Barbara, September 1989 - August 1990 (Source: City of Santa Barbara Department of Public Works, September 1990). (1 HCF = 100 ft³ ≈ 2.83 m³)

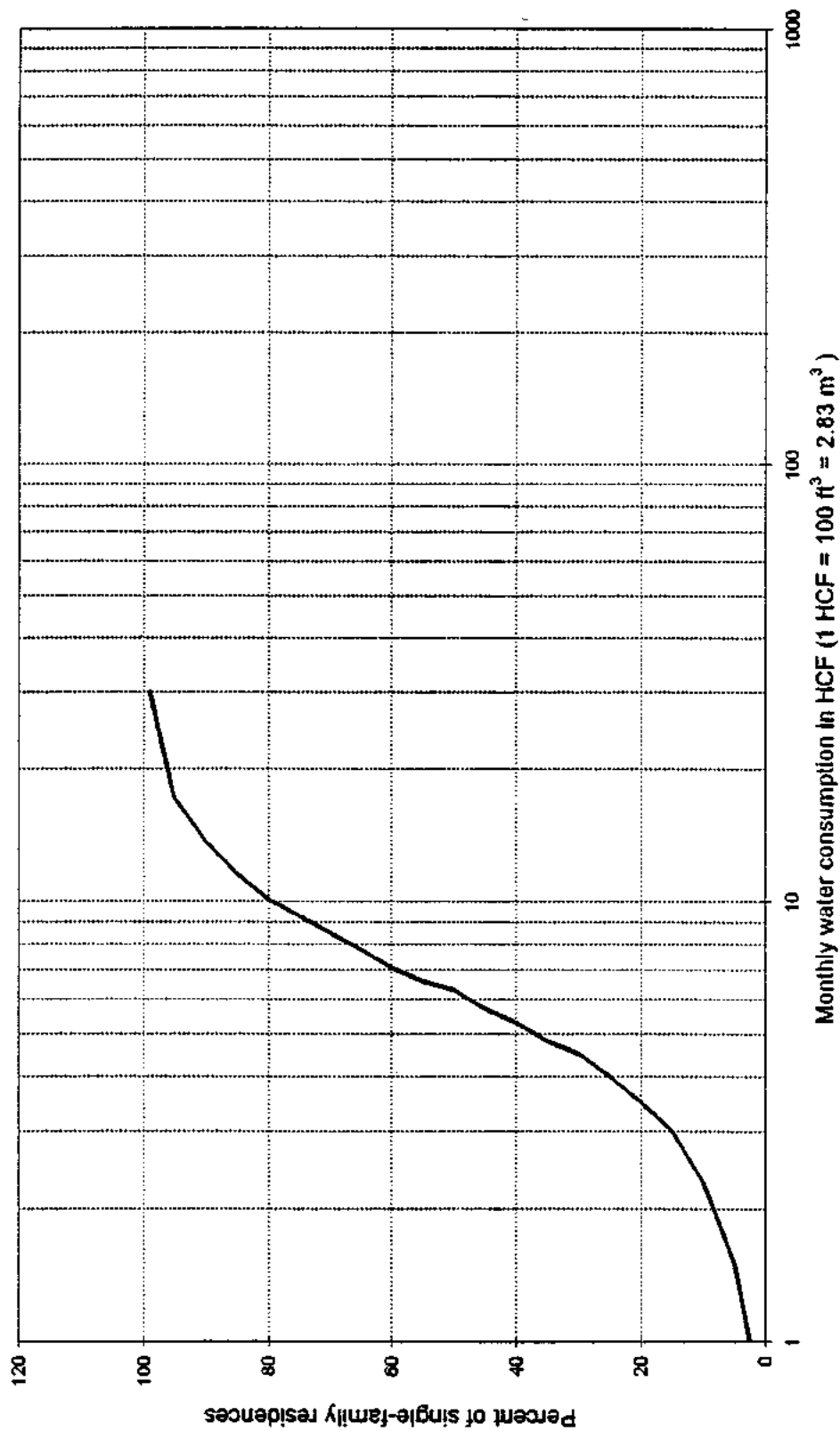


Figure 22. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1991 (Source: City of Santa Barbara Department of Public Works, June 1993). (1 HCF = 100 ft³ ≈ 2.83 m³)

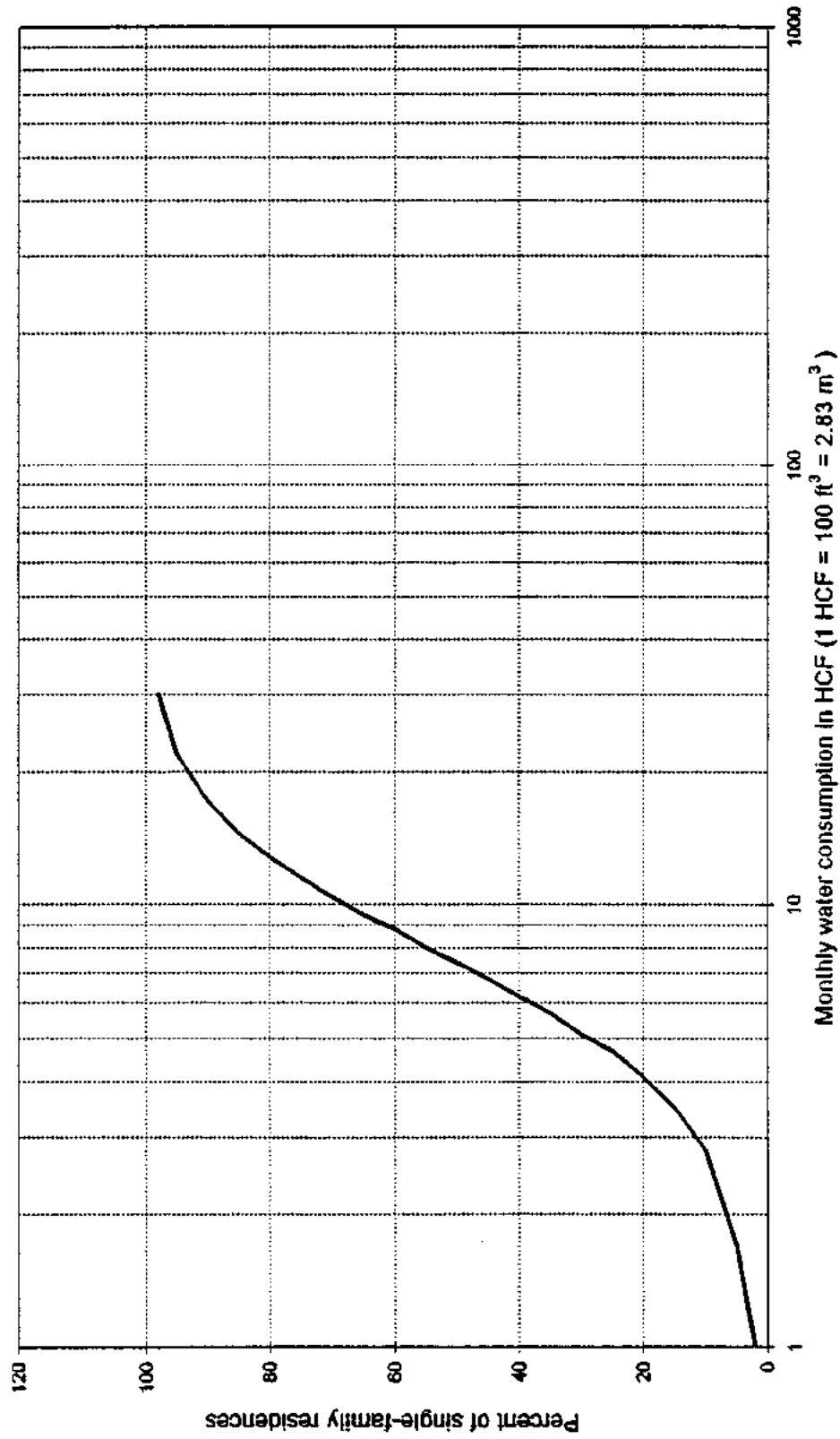


Figure 23. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1992 (Source: City of Santa Barbara Department of Public Works, June 1993). (1 HCF = 100 ft³ = 2.83 m³)

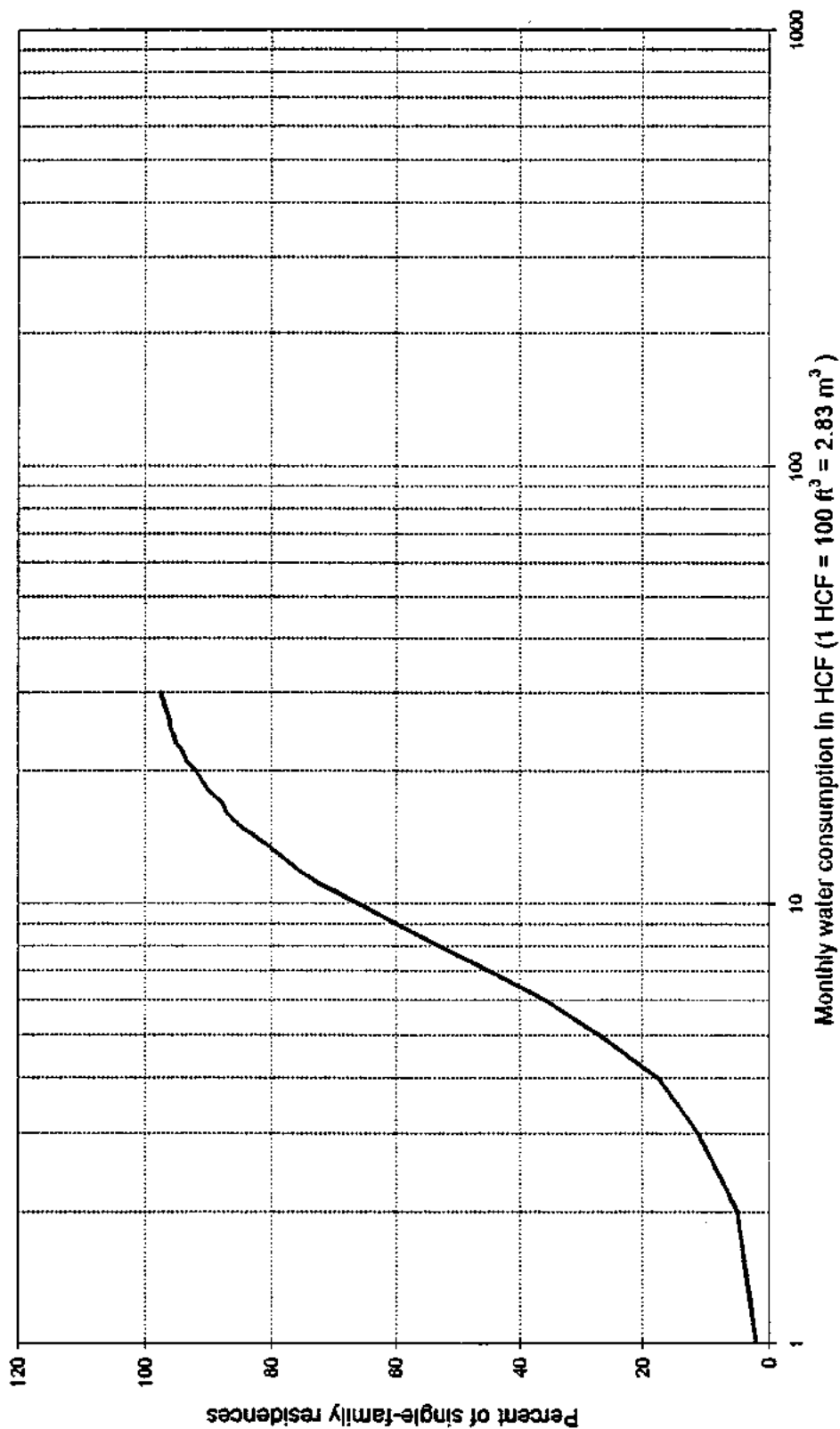


Figure 24. Single-family residential consumption distribution curve for the City of Santa Barbara, June 1992 - May 1993 (Source: City of Santa Barbara Department of Public Works, June 1993). (1 HCF = 100 ft³ = 2.83 m³)

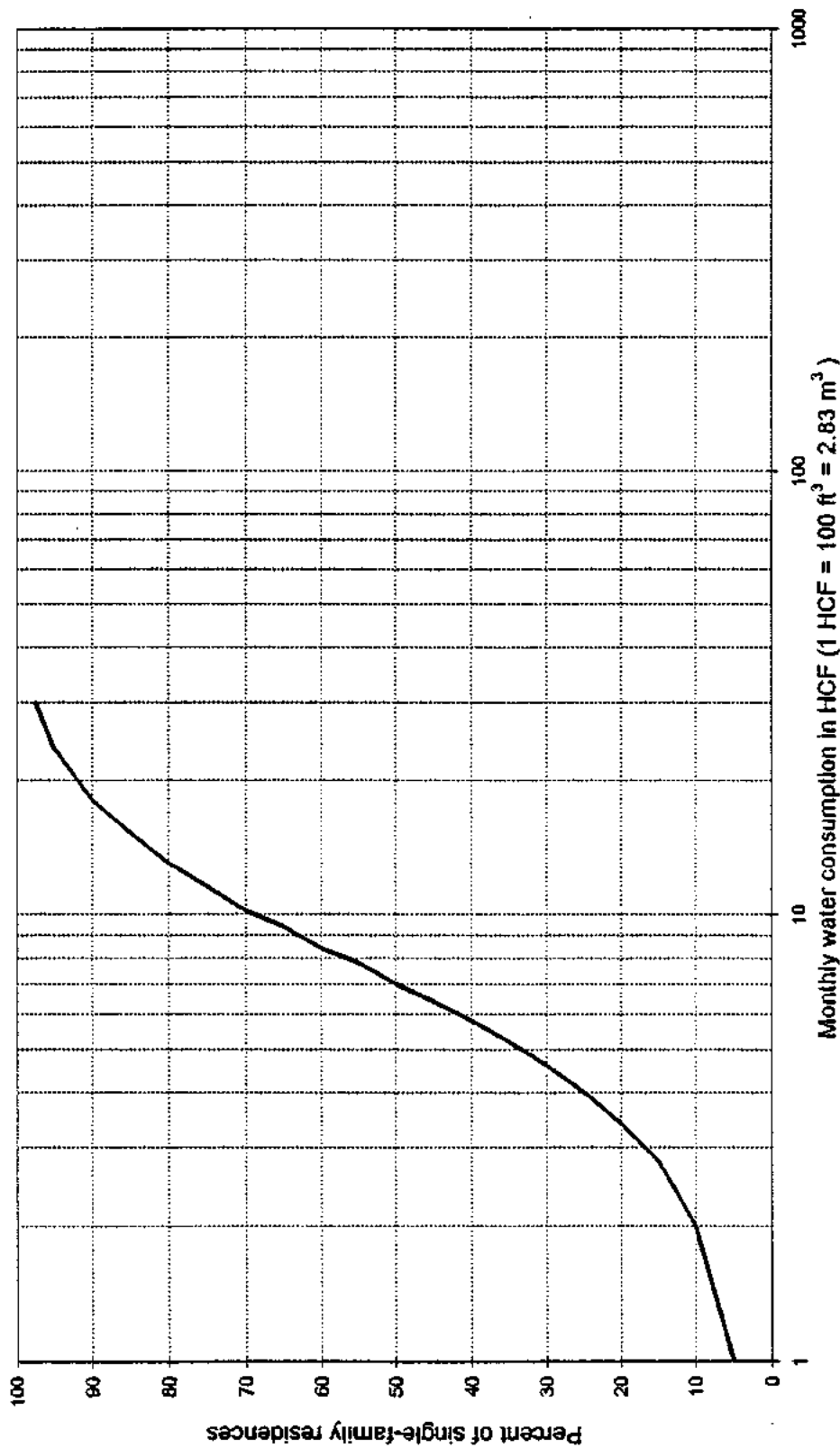


Figure 25. Single-family residential consumption distribution curve for the City of Santa Barbara, calendar year 1993 (Source: City of Santa Barbara Department of Public Works, June 1994). (1 HCF = 100 ft³ = 2.83 m³)

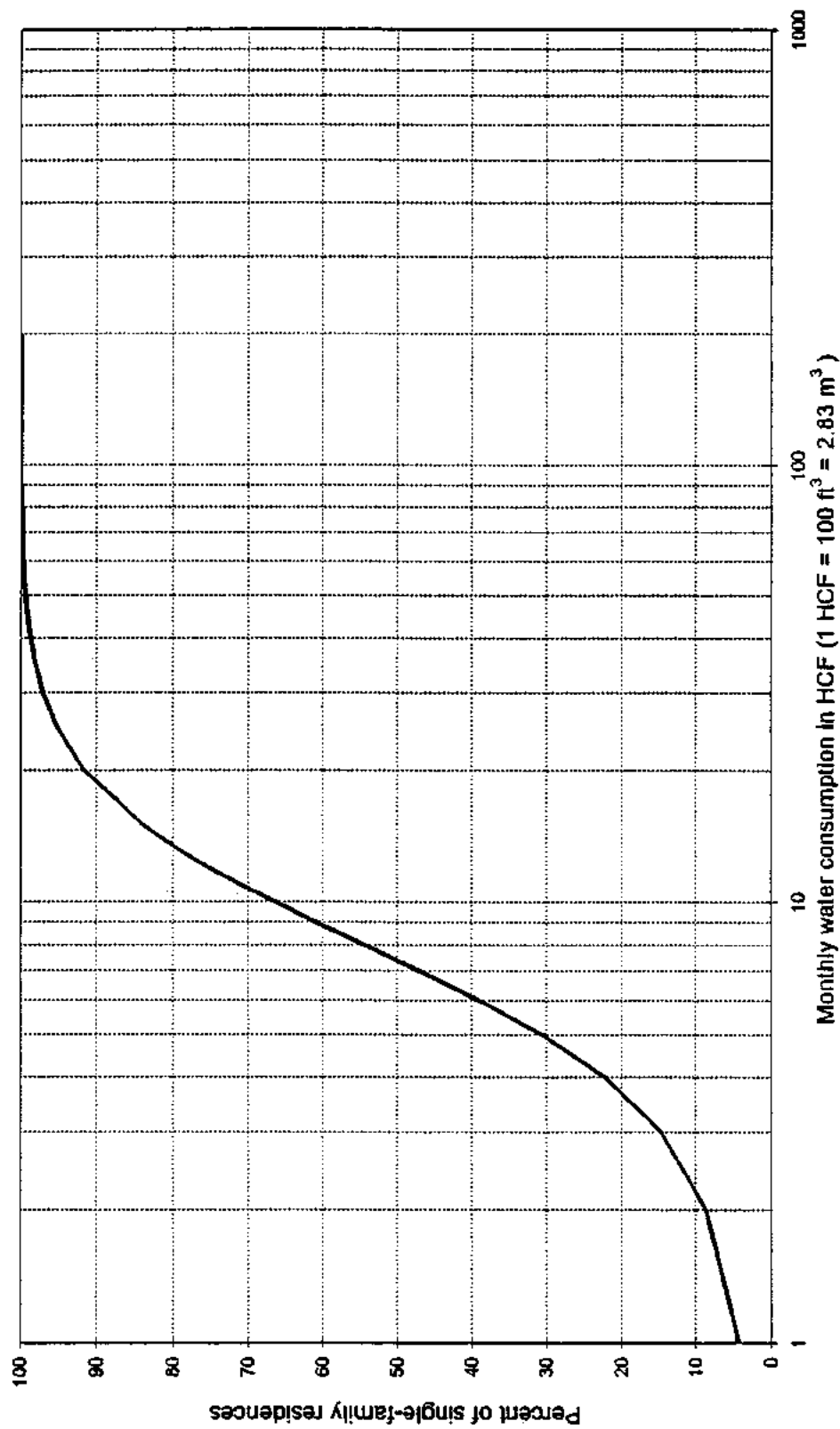


**Figure 26. Single-family residential consumption distribution curve for the City of Santa Barbara, July 1993 - June 1994 (Source: Kennedy/Jenks Consultants, 1995).
(1 HCF = 100 ft³ = 2.83 m³)**

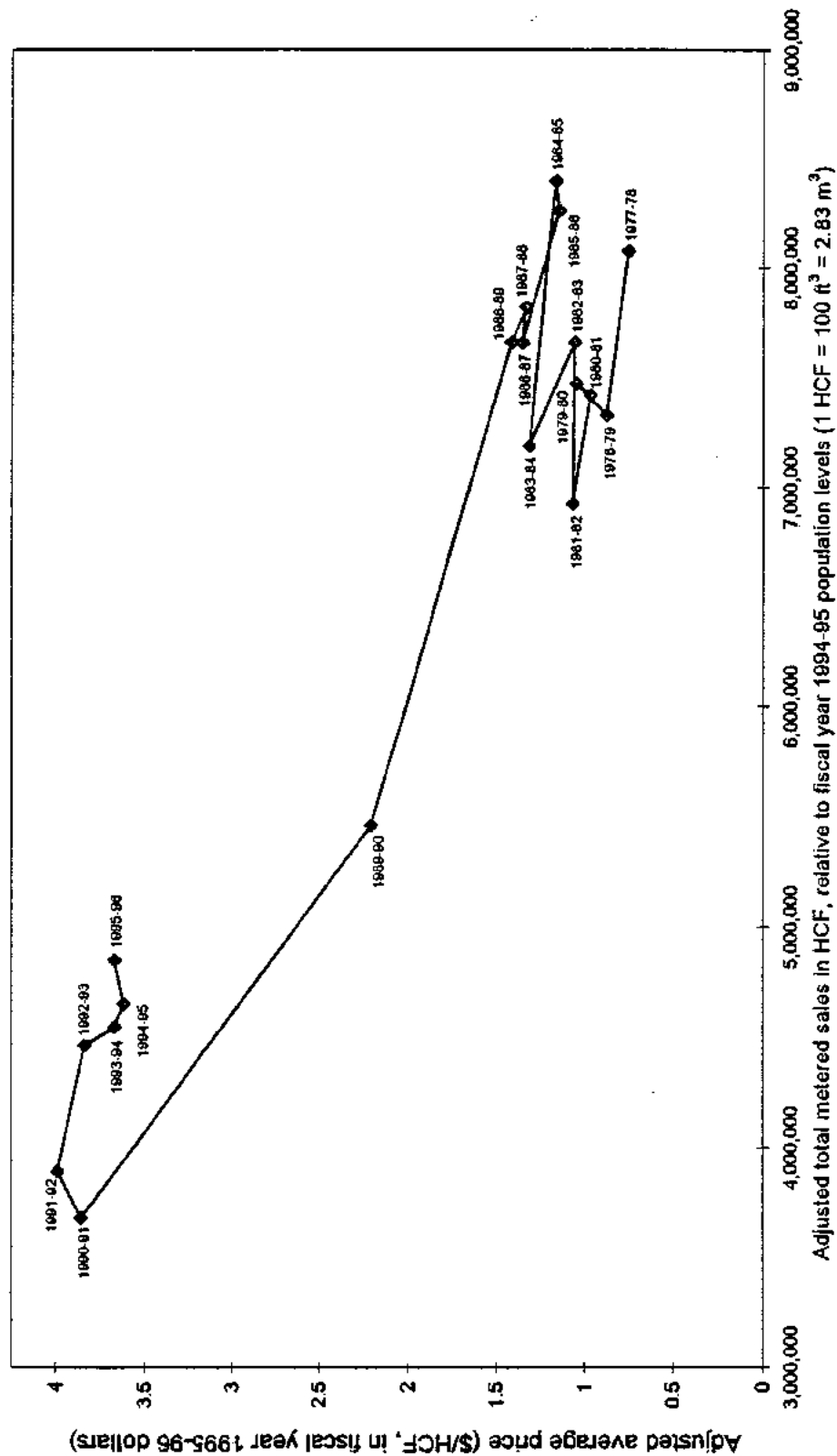


Figure 27. Average price charged for water for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)

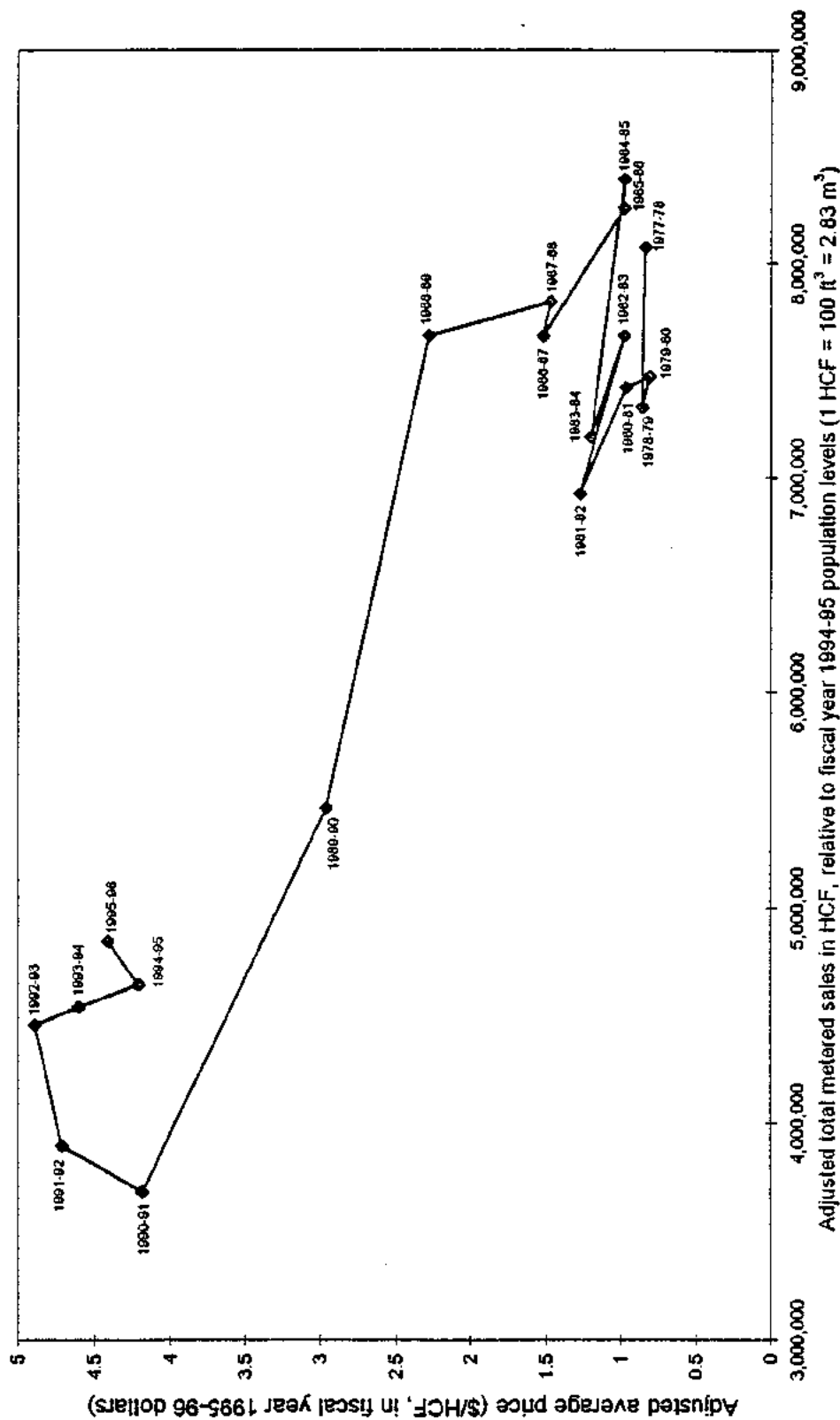


Figure 28. Average cost to produce water for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)

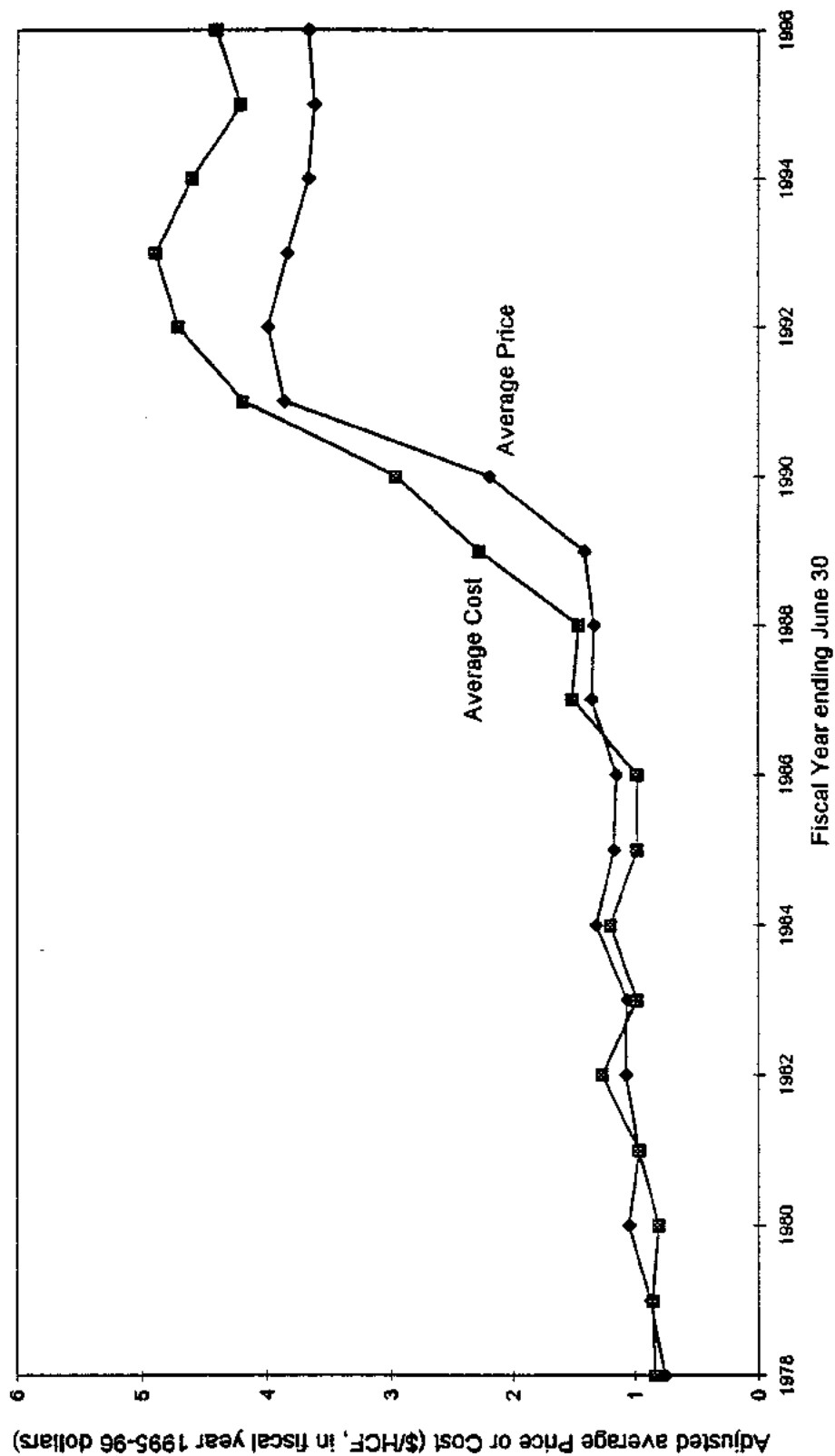


Figure 29. Average price and average cost of water for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)

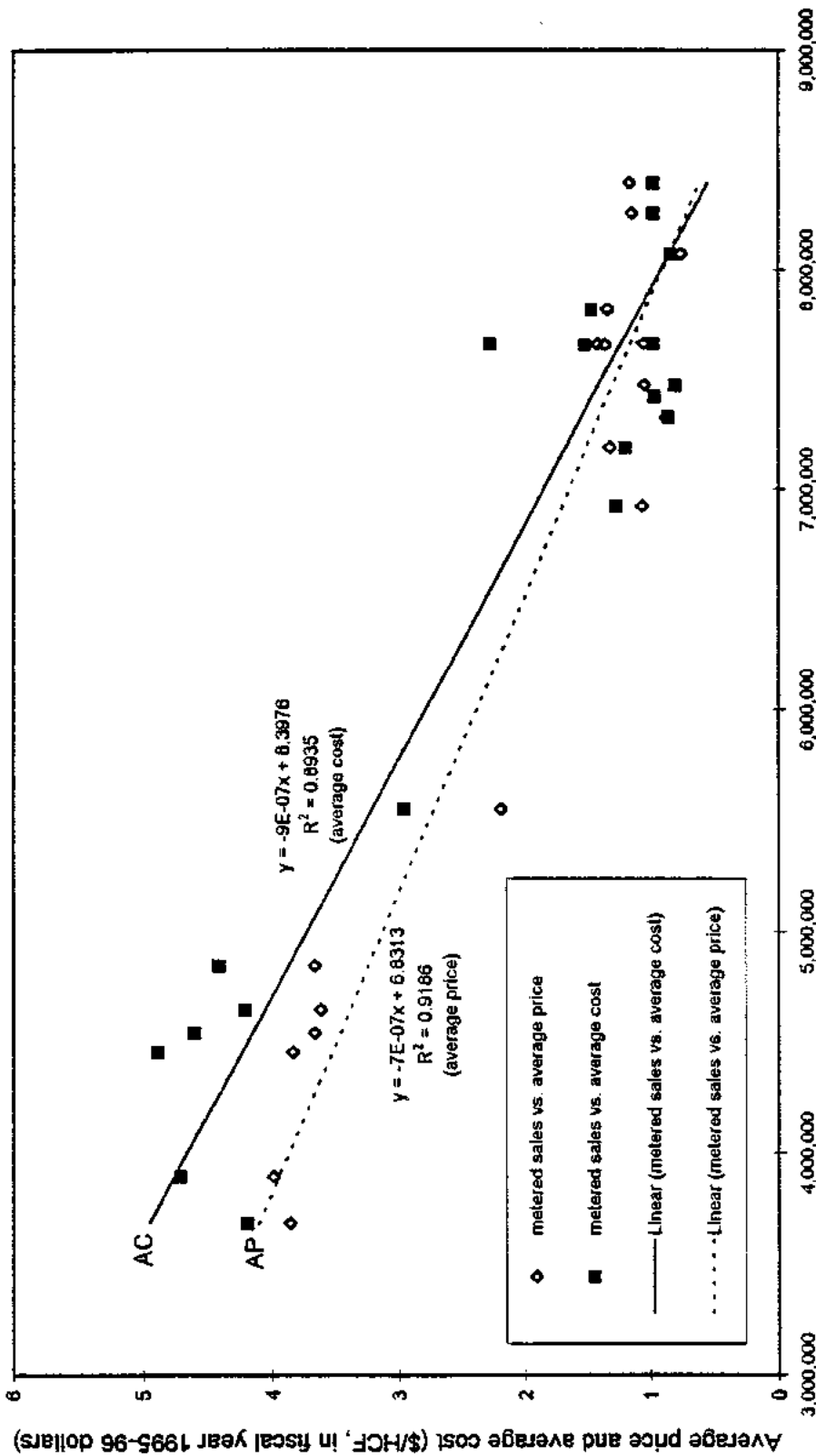
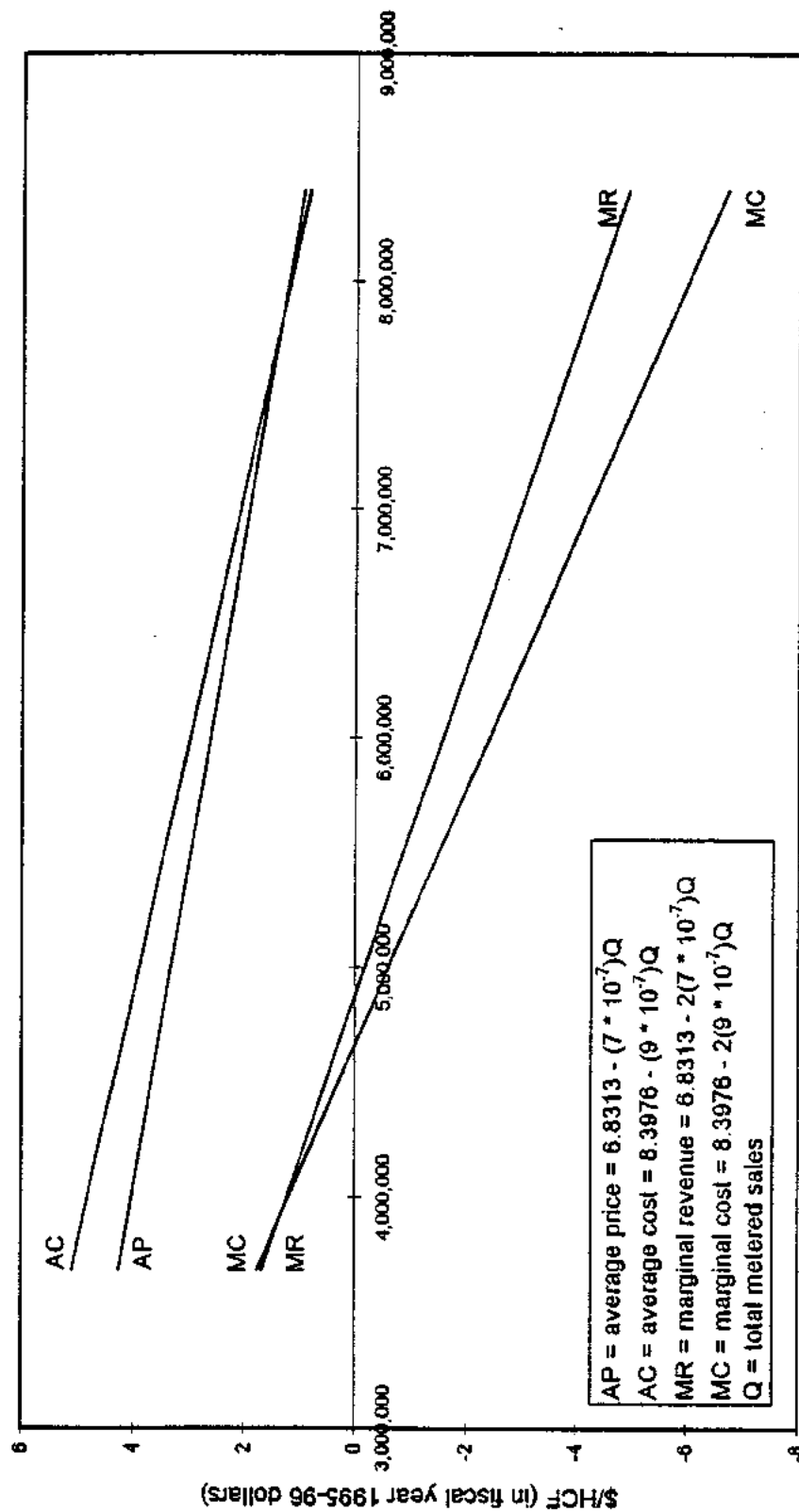


Figure 30. Average price (AP) and average cost (AC) curves for the city of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through June 30)



Total metered sales in HCF (adjusted to fiscal year 1995-96 population levels, 1 HCF = 100 ft³ = 2.83 m³)

Figure 31. Average price (AP) and average cost (AC), marginal revenue (MR), and marginal cost (MC) for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through Sept. 30)

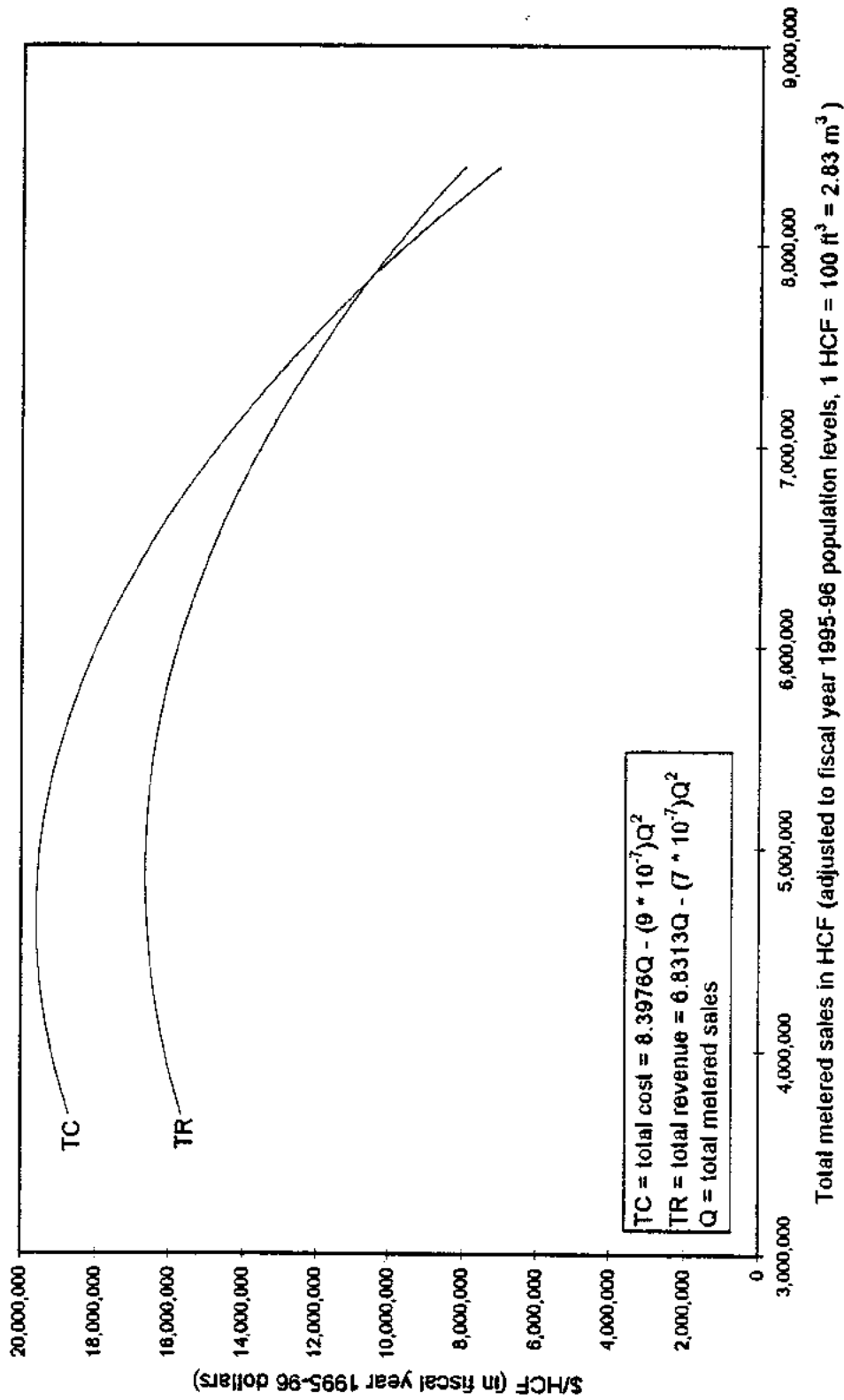


Figure 32. Total cost (TC) and total revenue (TR) for the City of Santa Barbara, fiscal years 1977-78 to 1995-96 (Source: City of Santa Barbara Department of Public Works, 1995, 1997). (1 HCF = 100 ft³ = 2.83 m³, fiscal year = July 1 through Sept. 30)