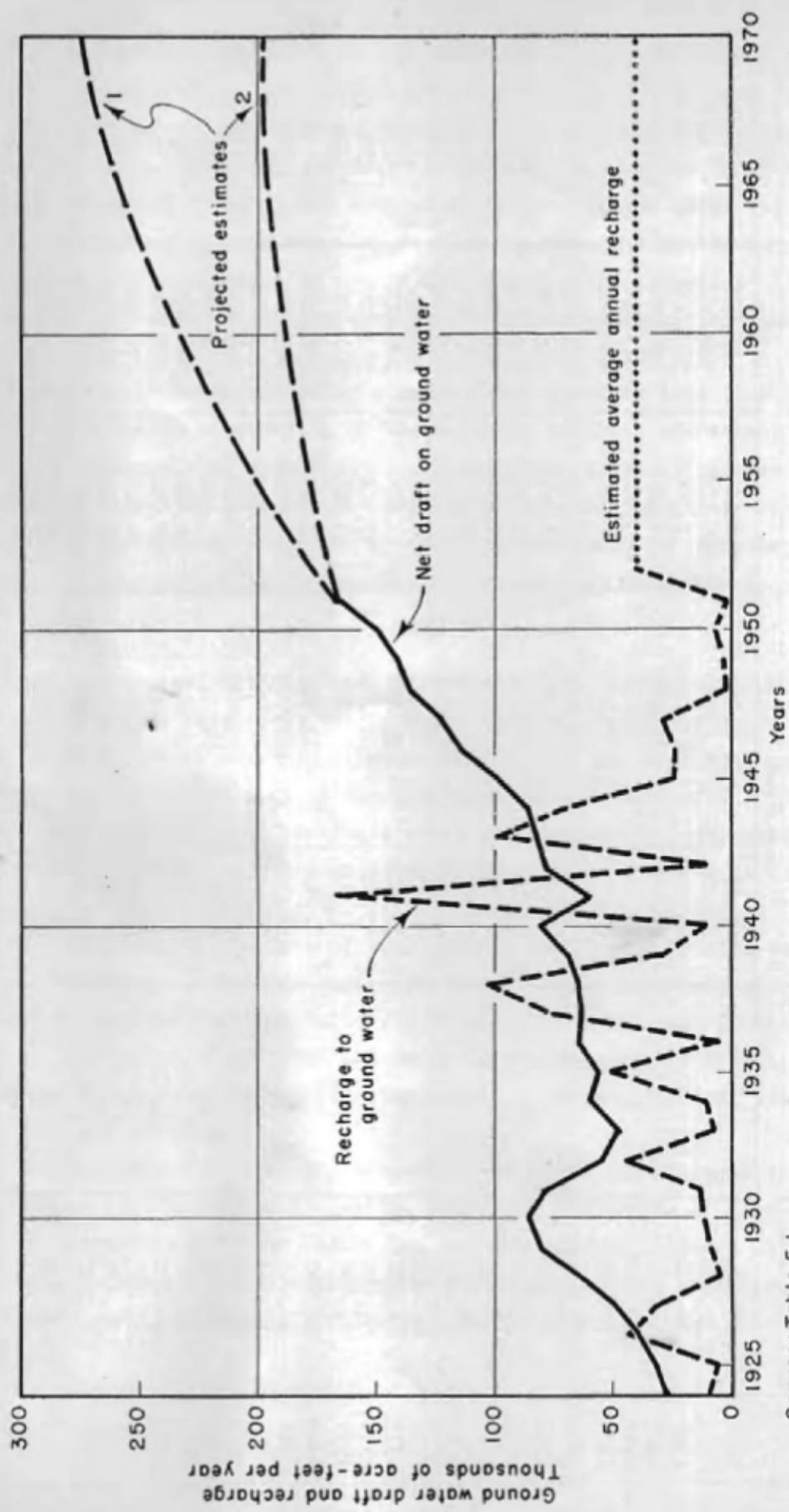
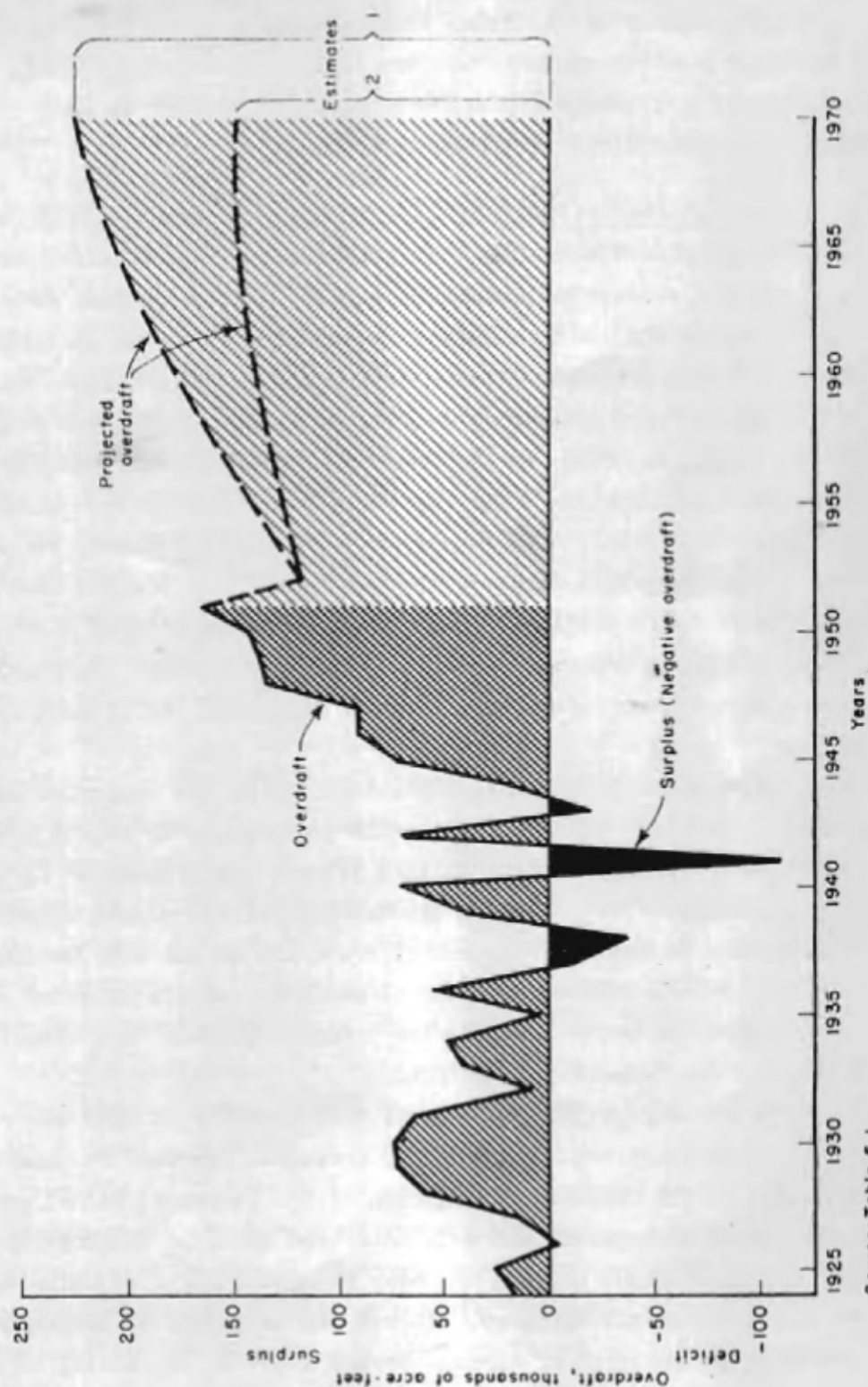


Figure 5.1
HISTORIC AND PROJECTED NET DRAFT AND RECHARGE
ANTELOPE VALLEY 1924 - 1970



Source: Table 5.1

Figure 5.2
HISTORIC AND PROJECTED OVERDRAFT
ANTELOPE VALLEY 1924 - 1970



Source: Table 5.1

Inherent problems in the measurement of overdraft have been fully covered in the earlier discussion of problems of measurement for recharge and draft. These difficulties should be borne in mind during the present discussion, but there is no need to restate them at this time. Unless otherwise specifically stated, when the term "draft" is used in the following discussion, net draft is implied.

Developmental Overdraft

Developmental overdraft involves removal of sufficient water from ground-water storage to permit the entire (average) annual recharge to enter storage and not be rejected as discharge. For an unconfined ground-water basin before development this would mean, depending on the extent of the basin, that relatively large volumes of ground water would need to be extracted. Prior to 1925, crop acreages and consequently ground-water draft in Antelope Valley were not sufficient to accomplish this necessary extraction. Yet many artesian wells had already ceased to flow, drops in ground-water levels had caused some concern about a possible future scarcity of ground water, and the natural discharge of ground water had decreased to a negligible proportion. Symptoms of developmental overdraft were clearly in evidence, but without apparent cause.

The explanation of this condition lies in the extensive artesian system in Antelope Valley. Most wells penetrating to depths greater than 80-100 feet are more or less subject to artesian pressure. Agricultural draft, combined with a wastage discussed earlier, reduced artesian pressure sufficiently to cause developmental overdraft in the area by about 1925. Thus, it is seen that either removal of large amounts of water or relatively small amounts of water coupled with pressure release from artesian aquifers can induce developmental overdraft.

For Antelope Valley this meant that as early as 1925 the volume of ground water in storage and artesian pressures had been reduced sufficiently to permit nearly complete utilization of the (average) annual recharge. It should be emphasized that this condition occurred at about the same time that sufficient acreage had been brought under irrigation to consume the (average) annual recharge. It was not necessary to induce developmental overdraft by expansion of acreage beyond a level that would, on the average, consume the safe yield of the ground-water reservoir: The condition of developmental overdraft had been created merely by pressure release from

artesian aquifers. At this stage of utilization of the Antelope Valley ground-water resources (1926-1927), the ground-water economy could have been maintained at a relatively stable level with only relatively unimportant types of overdraft occurring--if the farmers had (1) been able to retain the irrigated acreage structure that existed and (2) wished to do so.

Seasonal (Annual) and Cyclical (Periodic) Overdraft

Little can be said about seasonal overdraft in Antelope Valley that has not already been said earlier, in the general discussion. Recharge normally occurs during November-March and draft during April-October. Draft will deplete water in the area of draft and cause an inflow of water from the area of recharge. The major replenishment of the recharge area occurs six months or so after the draft period, causing a seasonal lag in replenishment. Although hydrostatic pressures may be transmitted at a rapid rate from the recharge to the draft areas, there will be relatively slow flow of water between the two areas, due to low transmissibility of the aquifers. These factors produce seasonal overdraft, other things being equal, and ground-water levels fall during the pumping season and rise during the recharge season.

Cyclical overdraft may be noted for the period 1924-1940, when irrigated crop acreage fluctuated at a level that consumed the safe yield of the ground-water reservoir, or slightly above. During 1924 and 1925, draft exceeded recharge; in 1926, the reverse occurred. During 1928-1931, large expansions in irrigated acreage and low recharge levels resulted each year in a greater magnitude of overdraft than would have occurred with a stable crop acreage. During the relatively stable period of 1932-1943, overdraft occurred seven times and annual surplus (or negative annual overdraft) occurred four times. A rapid and consistent acreage expansion since 1943 has eliminated this rather stable oscillation, and annual overdraft appears to have merged into a more serious type.

It is possible to discern a tendency toward cyclical or periodic overdraft for the period 1923-1951 if certain assumptions are made. During 1923-1934 an extensive overdraft occurred, because of low recharge to ground water and expansions in irrigated crop acreage. Average annual ground-water draft during this period was only slightly above the physically determined safe yield value. This dominant recurrence of overdraft for a period of twelve years is called the deficit phase of cyclical overdraft. The reverse

tendency during the next ten years (1935-1944) is called the surplus phase (or negative overdraft phase) of cyclical overdraft.

By comparing Figures 5.1 and 5.2 with Figure 3.4, it is evident that this tendency towards cyclical overdraft has been caused primarily by climatic fluctuations. From 1945 to 1951, assuming a constant acreage at or near the safe yield level, another deficit phase of cyclical overdraft would be observed. In fact, however, an increase in irrigated crop acreage induced a more serious type of overdraft.

Long-Run Overdraft--Past and Future

Since 1945, expansions in irrigated acreage in Antelope Valley have practically eliminated the possibility that annual recharge will ever again exceed annual draft. Even if this should happen occasionally, on the average the annual draft will exceed the annual recharge. Rejecting, for the moment at least, the possibilities of drastic reductions in future water consumption or large-scale importation of additional water, it can be stated that long-run overdraft has become the most important feature of the Antelope Valley ground-water economy.

Table 5.1 presented historical estimates of overdraft in Antelope Valley. Table 5.2 shows four hypothetical projections for the period 1952-1979, showing overdraft and the anticipated effect of this overdraft on the ground-water stock in terms of cumulative overdraft and pumping lift. From the beginning of agricultural development in the area up to 1951, it is estimated that overdraft (and waste) has been sufficient to remove nearly two million acre-feet from ground-water storage.^{7/} This would be equivalent to a drop in ground-water levels of nearly 100 feet (see Table 3.1). Actually, the drop in water levels has been nearly double this amount, once again demonstrating the importance of artesian pressures in maintaining ground-water levels.

The first projection in Table 5.2 is based on an assumed continued growth in both agricultural and nonagricultural water use at about the rate observed during 1945-1951, with a gradual leveling off around 1965-1970 and relative stability achieved by 1975-1979. Population increase is assumed to reach about 135,000 people in Antelope Valley by 1975-1979 and remain

^{7/} Estimated cumulative overdraft of 1,360,000 acre-feet plus estimated waste and pressure loss equivalent to 500,000 acre-feet.

TABLE 5.2

Hypothetical Draft, Overdraft, and Pumping Lift Projections for Antelope Valley, 1952-1979

	Net draft on ground water			Net recharge to ground water ^a / acre-feet	Overdraft on ground water		Increase in pumping lift ^b / feet	Total pumping lift at end of period
	Agricultural	Non-agricultural	Total		For the period	Cumulative		
1951 base	166,000	2,000	168,000	40,000	126,000	1,860,000	7	197
Projection No.1								
1952-1959	1,480,000	32,000	1,512,000	320,000	1,192,000	3,052,000	55	252
1960-1969	2,100,000	80,000	2,180,000	400,000	1,780,000	4,832,000	83	335
1970-1979	2,400,000	120,000	2,520,000	400,000	2,120,000	6,952,000	99	434
Projection No.2								
1952-1959	1,320,000	32,000	1,352,000	320,000	1,052,000	2,912,000	49	246
1960-1969	1,700,000	80,000	1,780,000	400,000	1,380,000	4,292,000	64	310
1970-1979	1,850,000	120,000	1,970,000	400,000	1,520,000	5,812,000	71	381
Projection No.3								
1952-1959	1,320,000	32,000	1,352,000	320,000	1,052,000	2,912,000	49	246
1960-1969	1,650,000	80,000	1,730,000	400,000	1,330,000	4,242,000	62	308
1970-1979	1,650,000	120,000	1,770,000	400,000	1,370,000	5,612,000	64	372
Projection No.4								
1952-1959	1,320,000	32,000	1,352,000	320,000	1,052,000	2,912,000	49	246
1960-1969	1,170,000	80,000	1,250,000	400,000	850,000	3,762,000	40	286
1970-1979	560,000	120,000	680,000	400,000	280,000	4,042,000	13	299

Average annual recharge equals 40,000 acre-feet.

It is estimated that permanent removal of ground water from storage in Antelope Valley will lower ground-water levels, on the average, at the rate of 100 feet per 2,150,000 acre-feet. See Table 3.1

TABLE 5.3

Hypothetical Annual Irrigated Acreage Projections
Antelope Valley, 1952-1979

	Alfalfa and irrigated pasture	Trees and vines	Vegetable crops	Hay and grain	Other field and miscellaneous crops	Total irrigated acreage
	acres					
<u>Projection No. 1</u>						
1952-1959	49,000	4,000	1,000	13,000	5,000	72,000
1960-1969	58,000	4,000	1,000	14,000	5,000	83,000
1970-1979	65,000	5,000	2,000	17,000	6,000	95,000
<u>Projection No. 2</u>						
1952-1959	45,000	3,000	1,000	10,000	4,000	63,000
1960-1969	47,000	3,000	1,000	11,000	4,000	65,000
1970-1979	49,000	4,000	2,000	13,000	4,000	72,000
<u>Projection No. 3</u>						
1952-1959	45,000	3,000	1,000	10,000	4,000	63,000
1960-1969	45,000	3,000	1,000	10,000	4,000	63,000
1970-1979	45,000	3,000	1,000	10,000	4,000	63,000
<u>Projection No. 4</u>						
1952-1959	45,000	3,000	2,000	10,000	3,000	63,000
1960-1969	20,000	1,000	20,000	1,000	9,000	51,000
1970-1979	5,000	--	14,000	1,000	6,000	26,000

relatively constant after that time. Gross per-capita water consumption is assumed to average 160 gallons per capita per day, with consumptive use one-half this amount.

Estimates of military-industrial water use are included in estimated nonagricultural draft.

Net ground-water draft by agriculture is assumed to reach a maximum of 240,000 acre-feet per year by 1970-1979. A projection of agricultural water use can be made by hypothesizing various combinations of acreages in irrigated crops by 1970-1979 and their relative growth to that time. One such set of estimates is given in Table 5.3 for the several projections of draft and overdraft. These acreage projections represent several possible alternatives for crop expansion and contraction. They represent possible developments and are formulated to demonstrate the effect that variations in irrigated acreage would have on the character of the ground-water stock figures shown in Table 5.2.

Projection No. 2 estimates net ground-water draft at 252,000 acre-feet per year by 1970-1979. Subtracting an average annual net recharge to ground water of 40,000 acre-feet per year, the average yearly overdraft will stand at 212,000 acre-feet per year. A cumulative overdraft of nearly 7,000,000 acre-feet would increase typical pumping lifts to 434 feet. All four physical projections of long-run overdraft assume that the economic limits of pumping will not have been reached by 1979; pumping could not otherwise continue at the rates projected. The economic forces that determine the economic limits of pumping will be considered at length in Chapters 6 and 7.

The second projection shown in Table 5.2 is based on a slightly different set of assumptions: The assumed nonagricultural use of water is the same, but agricultural use of water is assumed to expand at only about one-half the rate established during 1946-1951. A maximum net draft of 185,000 acre-feet per year will be reached by 1970-1979. This level of draft would create a cumulative overdraft of nearly 6,000,000 acre-feet and raise typical pumping lifts to a total of 381 feet by 1979.

Both projections assume increases in irrigated acreage that would not alter existing crop patterns in the Valley, while Projection No. 3 assumes relative stability in land and water use at about 1951 levels for agricultural purposes. The increases in nonagricultural draft assumed in the earlier projections are retained. In spite of the hypothesis of a static

irrigated acreage, cumulative overdraft by 1979 would amount to over 5,600,000 acre-feet and typical pumping lifts would be about 372 feet.

The only methods by which the severity of long-run overdraft could be lessened, without large-scale importation of water, would be to curtail total irrigated acreage or meter pumpage volumes for the wells. Projection No. 4 assumes a marked decrease in net draft resulting from decreases in total acreage as well as in alfalfa acreage. In addition, large-scale shifts from alfalfa to vegetable crops and corn (which require less water) are a part of this projection (see pp. 123-126 for a discussion of economic factors associated with such shifts). Although cumulative overdraft and typical pumping lifts are raised above 1951 base conditions, the rate of increase is reduced significantly. Cumulative overdraft would total 4,000,000 acre-feet and typical pumping lifts would reach nearly 300 feet. It is obvious that long-run overdraft is present and probably will continue in Antelope Valley.

One way by which long-run overdraft could be eliminated in the Valley would be to curtail water use until annual net draft is in approximate balance with average annual recharge. This means drastic reduction in irrigated crop acreage, extensive shifts from crops that require large amounts of water to those with smaller requirements, and increased efficiency in the use of ground water for irrigation, or a combination of all of these. For example, approximate balance could be reached with a cut from the 1951 level of about 46,000 acres in alfalfa and irrigated pasture to about 13,250 acres in these same crops, or to 20,000 acres in field and vegetable crops, assuming maximum irrigation efficiency. Such reductions are highly unlikely.

A second theoretical solution to long-run overdraft in the Valley involves water importation from some other watershed area. Such a solution is perhaps likely for Antelope Valley and other deficit water areas, by importing Feather River or other water from northern California. Social and political institutions backed by engineering know-how and available capital have usually combined to solve this type of water shortage problem by transferring water from surplus to deficit areas. Regardless of the origin of imported water and regardless of whether it would be used for gravity diversion irrigation or diverted to underground storage for pumping at a later date, water importation to the Valley sufficient to curtail

long-run overdraft is a definite possibility. Continued use of water at relatively high rates of consumption would be possible.

A third theoretical solution involves allowing economic and technological forces to impose severe reductions in pumping. Increase in pumping costs could, under appropriate conditions or assumptions, force farmers to abandon pumping when total lift exceeds, say, 500 feet. This process could gradually force farmers out of production until only a few of the most efficient operators were able to maintain their enterprises. In order to maintain an average total lift fluctuating around the 500-foot level, it would be necessary for average annual recharge to be in approximate balance with average annual draft. Thus, economic forces could create a condition where ground-water draft would equal the physically determined safe yield value, or draft and recharge would balance. The economic and technologic factors that influence the use of ground water in Antelope Valley will be considered in the following chapters.

Chapter 6

Pumping Costs and the Ground-Water Resource

It has been established that Antelope Valley agriculture is largely dependent upon the ground-water stock resource. Furthermore, annual draft rate in excess of annual recharge rate--ground-water mining--has created long-run overdraft. The next three chapters of the discussion examine the economic factors affecting ground-water resource use: chapter 6, a description and analysis of pumping costs; chapter 7, the influence of pumping costs on the selection of farm enterprises; and chapter 8, a discussion of the attempts made to combat overdraft in the Antelope Valley.

Determination of Pumping Costs

The annual water costs associated with ground-water utilization may be divided into two categories: (1) fixed annual charges--taxes and interest and depreciation on the original investment; (2) variable annual costs (operating costs)--determined by power (or fuel) consumption, lubricants, repairs, and attendance. The latter vary with the amount of water pumped. Pumping costs are also affected by the source of power or fuel used. The dominance of electricity in pumping ground water in the Valley permits the major emphasis to be placed on pumping costs using electricity as the power source; costs associated with other power sources will be introduced from time to time for purposes of comparison.

Fixed annual charges arise from the cost of well drilling, the cost of the pumping plant, and taxes. Appendix Table 9 shows, for several different installations in Antelope Valley in 1925 and 1951, the typical costs that determine fixed annual charges.^{1/} These charges are "fixed" in that, regardless of the amount of water pumped each year, the total annual cost remains constant.

Variable annual costs vary with the number of hours of operation and reflect the number of acre-feet pumped during the year. The principal factor determining these costs is the cost of power or fuel. Table 6.1 summarizes estimated pumping costs from various lifts in Antelope Valley using electrical power.

^{1/} These costs have not been corrected for changes in purchasing power.

TABLE 6.1
Cost of Pumping Water Per Acre-Foot, Antelope Valley^{a/}

Year	Range of total lift					
	25 to 75 feet		75 to 150 feet		150 to 300 feet	
	Minimum ^{b/}	Maximum ^{c/}	Minimum ^{b/}	Maximum ^{c/}	Minimum ^{b/}	Maximum ^{c/}
	dollars					
1925	0.73	4.10	1.98	7.40		
1935 and 1945	0.41	2.35	1.24	4.42	2.27	8.35
1951	0.41	2.31	1.15	4.36	2.26	8.22

a/ A 45% over-all efficiency is assumed for 1925, and 60% for 1935-1951. If 60% efficiency is assumed for 1925 the calculated costs of pumping per acre-foot are:

25 to 75 feet, \$0.58 to \$3.58
75 to 150 feet, \$1.59 to \$6.54

b/ The minimum cost is associated with the smallest lift within the range and a gross pumpage of 2,000 acre-feet per year.

c/ The maximum cost is associated with the greatest lift within the range and a gross pumpage of 100 acre-feet per year.

Source: Snyder, J. Herbert. op. cit., pp. 396-403.

Because of lack of information, it is not possible to determine the costs of pumping ground water before 1920. As has been indicated, electrical power for pumping has been of dominant importance in the area since 1920. The costs of pumping water using electrical power are divided into three time periods, beginning with 1920 and continuing to the present (1953). The power schedule for agricultural use that was in effect in 1920 continued in substantially the same form until 1933, when a large reduction was made in both service charge and power charge. The second schedule continued in effect virtually unchanged until 1946, when a further, slight reduction in service charge was made.^{2/} Costs of pumping water with the use of other

2/ The power schedules selected were obtained from the Public Utilities Commission office in San Francisco. Only one agricultural schedule (PA-31) was selected for the 1951 rates although at least two are available for use by the farmer, depending upon the rated horsepower of the pumping installation he uses. For horsepower installations in excess of 100, a separate rate (PA-P2) is available, which, when large quantities of water are pumped, results in a substantial reduction of the cost of pumping per acre-foot. This seems to put a premium on pumping more water than may actually be necessary. The average rate charged for installations of less than 100 h.p. is about \$0.01 per kilowatt-hour, while the average rate for installations over 100 h.p. is about \$0.0085 per kilowatt-hour. See also Appendix Tables C.9 to C.12 inclusive. Snyder, J. Herbert, op. cit.

fuels may be determined on the basis of theoretical comparative efficiencies of different fuels.^{3/} Specific discussion of the factors affecting pumping costs is undertaken below (pp. 101-112).

Similar to power or fuel costs, expenditures for lubricants, repairs, and plant attendance depend upon the number of hours of operation or volume of water pumped. Table 6.2 shows typical costs for these items for both motor-driven (electric) and engine-driven pumping plants.

TABLE 6.2
Typical Unit Costs of Lubricants, Repairs, and Attendance

Item	Motor-driven plant per acre-foot	Engine-driven plant per acre-foot
	dollars	
Lubricants	0.05	0.15
Repairs	0.20	0.35
Attendance ^{a/}	0.00	0.40

^{a/} Electrically powered (motor-driven) plants require a negligible amount of attendance; engine-driven plants require a large amount. Attendance is the amount of labor involved in repairs and supervision necessary to provide continuous operation of the unit.

Source: Molenaar, A. op. cit., p. 4.

The most noticeable feature of these data is the increase in costs that has occurred over the period of record. Several factors--such as the increasing pumping lifts, the increasing sizes of wells, the changes in types of wells, and increasing depths of wells drilled--have been responsible for these increasing costs. These factors are discussed in later sections.

Previous to a discussion of the factors that influence pumping costs, one point must be made clear: For the most part, the costs presented above are theoretically determined; they are based on estimates of typical installations and typical plant operation. Because they have been worked out in cooperation with farmers, dealers, manufacturers, and ground water specialists, they are believed to be fairly representative. Specific research into pumping costs for various areas and types of installations would be useful in ground-water analyses such as this, and would strengthen the results.

^{3/} "Brake horsepower tests on new tractor engines at the Nebraska Tractor Test Station indicate the following comparative efficiencies of liquid fuels:
Engines burning gasoline develop 9.72 H.P. hours per gallon.
Engines burning distillate develop 10.46 H.P. hours per gallon.
Engines burning diesel fuel develop 15.00 H.P. hours per gallon.

"By determining H.P. requirements for pumping an acre-foot of water, the gallons of fuel necessary can be computed from the above values for the different fuels. The fuel cost per acre-foot can then be calculated on the basis of prevailing fuel prices." Molenaar, A. Costs of Pumping Water for Irrigation, Davis, Univ. of Calif., Dept. of Irrigation, January, 1947. p. 3. Mimeographed.

Factors Affecting Water Costs

The important task in analyzing the factors that affect water costs is to separate them and examine each independently, insofar as possible. Among the more important variables are falling water table, number and size of pumping installations, power sources for pumping, volume of water pumped, and technological changes. As will be seen in the following discussion, these factors are not easily separated from each other: Water level declines have brought forth or been associated with changes in depth of well drilling, size of pumps used, type of pump used, etc.; each factor influences the cost of obtaining water, but seldom independently of other factors. In order to eliminate unnecessary confusion, each factor is discussed separately and its influence evaluated separately. Thus, although it is not possible to discuss the specific influence on water costs of multiple changes in multiple factors, the reader is cautioned to remember that a complicated relationship exists among the several factors.

Falling Water Table

A falling water table affects water costs by raising both the fixed annual charges and the variable pumping costs: Larger pumps and motors are required as pumping lifts increase; depth and size of well drilled may also be increased, as in Antelope Valley. The influence of these factors on total annual fixed charges is summarized in Table 6.1 for typical Valley pumping installations in 1925 and 1951. The increase in fixed charges for installations capable of supplying typical 40- and 80-acre alfalfa farms has been nearly fourfold.^{4/}

Although the falling water table helped increase these costs, other factors were also important: Most irrigation wells drilled in the Valley since World War II have been gravel packed, a feature not prevalent in the interwar period, and well size has changed with respect to diameter as well as depth. Associated with these changes, a larger pumping unit (pump, motor, and accessories) has been necessitated both by increased lifts and the size of acreage typically irrigated from each well.

^{4/} No comprehensive deflation of cost and price data has been undertaken in this study. As an illustrative example, however, components of the above-mentioned increase were deflated by both the "Purchasing Power of the Dollar" (U. S. Department of Commerce) and the "Index of Prices Paid by Farmers for Machinery" (U. S. Department of Agriculture). The results indicate a twofold increase, slightly less than one-half the above-indicated apparent increase.

Variable pumping costs may be calculated from two approaches: In the first method, cost estimates per acre-foot for various total pumping lifts may be based on the assumption of a uniform power rate per kilowatt-hour used.^{5/} This method does not take into account the influence of such factors as variation in total volume of water pumped, and--as pumping lifts increase--the slight decrease in efficiency and the larger motors or engines required, which consume relatively greater amounts of kilowatt-hours per acre-foot of water pumped. This method of calculating variable pumping costs from estimates of pumping cost per acre-foot reduces to a straight-line formula of very limited value.

The second method of estimating pumping costs is based on the power schedule for electricity in the area, the volume of water pumped, and the rate of pumping. This method uses the procedure for determining kilowatt-hour requirements outlined above, but corrects the cost calculation to reflect both the volume of water pumped and the variations in power rates for different sizes of electrical motors. Table 6.3 presents typical pumping costs per acre-foot of water associated with three different sizes of pumping plants and four different amounts of water applied.

Either method of estimating pumping costs indicates an increase in pumping costs as water tables fall. But there are compensating variables: changes in efficiency, changes in electrical power rates over time, and a preferential bias in power charges for large (over 100 h.p.) pumping units. An improvement in efficiency of 10 per cent permits pumping at the same cost from a depth of 35 to 45 feet greater than before. It may be seen in Table 6.2 that changes in power rates and in efficiencies permit pumping from greater depths at no change in cost of pumping. Table 6.3 shows that a change from power schedule PA-31 to PA-P2 (permissible when demand horsepower exceeds 100 h.p.) permits pumping at the same cost from depths 100 to 250 feet greater than before.

Effect of Number and Size of Pumping Units

One feature of the Valley's ground-water stock resource (stressed in Chapter 3) is the large number of thin aquifers characteristically encountered

^{5/} The number of kilowatt-hours theoretically required to lift one acre-foot of water may be calculated from the formula:

$$\text{Kilowatt-hours} = 1.024 \frac{\text{Total lift in feet}}{\text{Over-all efficiency of the pumping plant}}$$

Average billing rates per kilowatt-hour are available for most areas.

TABLE 6.3

Typical Pumping Costs Per Acre-Foot for Variable Rate
and Volume of Pumpage, Using Electrical Power ^{a/}

Rate and volume of water pumped	Total pumping lift									
	100 feet	150 feet	200 feet	250 feet	300 feet	350 feet	400 feet	450 feet	500 feet	600 feet
dollars										
450 gallons per minute on a 40-acre farm										
100 acre-feet (2.5 acre-feet per acre)	3.33	4.61	6.41	7.36	8.47	9.11	10.41	12.52	13.20	15.15
200 acre-feet (5.0 acre-feet per acre)	2.54	3.44	4.82	5.48	6.39	6.95	7.96	9.43	10.01	11.31
250 acre-feet (6.25 acre-feet per acre)	2.35	3.17	4.43	5.20	5.96	6.44	7.71	8.65	9.97	10.46
300 acre-feet (7.5 acre-feet per acre)	2.19	2.98	4.03	4.73	5.52	5.77	7.03	8.14	8.69	9.84
900 gallons per minute on an 80-acre farm										
200 acre-feet (2.5 acre-feet per acre)	3.34	4.36	5.95	7.03	7.97	8.61	5.08 ^{b/}	5.74	6.25	6.91
400 acre-feet (5.0 acre-feet per acre)	2.54	3.32	4.52	5.48	6.15	6.70	4.69 ^{b/}	5.28	5.75	6.37
500 acre-feet (6.25 acre-feet per acre)	2.35	3.08	4.18	5.09	5.69	6.30	4.61 ^{b/}	5.18	5.69	6.26
600 acre-feet (7.5 acre-feet per acre)	2.19	2.90	3.92	4.78	5.38	5.93	4.56 ^{b/}	5.12	5.63	6.19
1,800 gallons per minute on a 160-acre farm										
400 acre-feet (2.5 acre-feet per acre)	3.10	4.11	2.68 ^{b/}	3.28	3.94	4.49	4.99	5.63	6.14	6.79
800 acre-feet (5.0 acre-feet per acre)	2.39	3.20	2.49 ^{b/}	3.04	3.63	4.15	4.65	5.21	5.73	6.39
1,000 acre-feet (6.25 acre-feet per acre)	2.22	2.97	2.45 ^{b/}	3.00	3.57	4.08	4.58	5.14	5.65	6.21
1,200 acre-feet (7.5 acre-feet per acre)	2.09	2.81	2.42 ^{b/}	2.96	3.53	4.03	4.53	5.09	5.59	6.15

^{a/} Includes lubricant and repair charge of \$0.25 per acre-foot. Assumes 60 per cent over-all efficiency of the pumping plant. Based on Power Rate Schedule PA-31 and PA-F1 of the Southern California Edison Company.

^{b/} At these lifts a change in Power Rate Schedules takes place because demand horsepower exceeds 100 h.p. at the pumping plant.

Source: Appendix Tables C.9 to C.12. Snyder, J. Herbert. op. cit.

in any single vertical section of the alluvial fill. It has also been stated that in Antelope Valley deep wells of large diameter have become necessary to assure that adequate amounts of water can be withdrawn as needed. It is true that large, deep wells satisfy this requirement, but so will several smaller, relatively shallow wells. Would not four wells pumping at rates of 450 gallons per minute supply the water for 160 acres of alfalfa more economically than one well pumping at a rate of 1,800 gallons per minute? The thin aquifers could certainly supply the smaller draft, and the initial cost of well drilling and the cost of a smaller pumping unit is much less. But, referring to Appendix Table 9, a comparison of the 450-gallon-per-minute unit with the 1,800-gallon-per-minute unit reveals a substantial saving in initial cost by using the larger unit. Four small units would cost \$33,600 as compared with the cost of one large unit of \$21,500. Furthermore, the cost of pumping per acre-foot of water would be less with the large unit than with the several small units. Referring to Table 6.3, it will be seen that, for a 450-gallon-per-minute unit pumping 5 acre-feet per acre from a 250-foot lift, the cost is \$5.48 per acre-foot. For similar conditions, using the 1,800-gallon-per-minute unit, the cost per acre-foot is \$3.04. Thus, both fixed and variable costs have influenced the shift from a large number of small pumps to a relatively smaller number of large pumps.^{6/}

It is not easy to assess the influence on ground-water utilization of changes in the number and size of pumps. Theoretically, removal of a given volume of ground water from a specified volume of aquifer in a given period of time may be accomplished equally well by one large pump or several small pumps so long as the aquifer can supply the draft requirement of the large pump. Where many thin aquifers are present, as in Antelope Valley, large pumps may draw ground water from some of the aquifers more rapidly than the rate of replenishment within the aquifer, thus interrupting hydraulic continuity. This may, therefore, dry up, temporarily at least, the small, more shallow wells in the immediate vicinity. At the least the ground-water level (or the pressure surface) will show sudden and rapid declines during each pumping season.

^{6/} An examination of available statistics for Antelope Valley indicates an average of 35 acres per pump unit in 1930, 40 acres per pump unit in 1940, and 50 acres per pump unit in 1950. The increase in average acreage per pump substantiates the statement of a shift from small pumps to larger pumps.

From a practical economic standpoint, the use of larger pumps and deeper wells not only allows a farmer to contend with rapidly and widely fluctuating water levels but also permits pumping from greater depths than when using small pumps and shallow wells. To pump 5 acre-feet from a depth of 200 feet at a rate of 450 gallons per minute costs \$4.82 per acre-foot (Table 6.3). At the same cost, 5 acre-feet can be pumped from about 400 feet at a rate of 1,800 gallons per minute, based on power schedule PAP-1.

Differences in Power and Fuel Costs

Although electrically powered pumping units account for nearly all of the total annual draft on ground water in Antelope Valley, other energy sources are used to a small degree: A few diesel engines and a few gasoline engines still pump ground water for irrigation. At present, diesel-powered units do not compete favorably with electrically powered units. Gasoline-powered units compete even less favorably. In the period from 1920 to 1930, diesel- and gasoline-powered units were on a more favorable level of competition, but a general reduction in electrical power rates at the end of this period shifted the balance farther in favor of electrically powered units.

Electrically powered units possess at least two advantages: First, substantial economies of scale accrue to users of large amounts of electrical energy. The "block system" of decreasing charges per kilowatt-hour as larger amounts are used is not duplicated for users of diesel and gasoline fuels. Some saving may be obtained from volume purchases of these fuels, but nothing like that offered by the electrical block system. With diesel or gasoline fuels, the variable cost per acre-foot of water pumped remains relatively constant as volume increases; with electrical power, this cost goes down.

Second, the costs of repairs, lubricants, and attendance are higher for engine-driven units than for motor-driven units: The attendance cost is negligible for motor-driven units, but about \$0.40 per acre-foot of water pumped for engine-driven units. Totals for the three items average about \$0.25 per acre-foot for motor-driven units and about \$0.90 per acre-foot for engine-driven units (Table 6.3). Storage facilities and timing of fuel deliveries present further problems for these units.

The possibility of using energy sources not currently used in the Valley should not be overlooked: Natural gas power and electrical energy derived from atomic fission or fusion may both be potential energy sources for pumping ground water.

A recent study at the University of Arizona compared the costs of using electrical energy with the costs of using natural gas in pumping ground water.^{7/} A cost advantage of natural gas over electric power was observed, varying from about \$1.25 per acre-foot at 150-foot lifts to \$4.25 per acre-foot at 300-foot lifts. This permits pumping--at a given cost--from lifts 100 to 150 feet greater with natural gas than with electrical power. The cost advantage of gas over electricity increased as the total pumping lift increased, within the range of pumping lifts studied.

Prior to December 1, 1951, natural gas was not available in Antelope Valley. On that date the Southern California Gas Company, by arrangement with the Pacific Gas and Electric Company, tied into the latter's 34-inch Texas line near Mojave, some 25 miles north of Lancaster. This made natural gas available to Lancaster and vicinity. Two factors prevent a major shift from electrically powered to natural-gas powered pumps by the agricultural sector, however. Not only would the cost of laying new gas mains to the various farms be prohibitive but the amount of natural gas permitted to any one customer is limited. It does not seem likely that natural gas will be appreciably used for pumping ground water in Antelope Valley in the near future. Furthermore, the cost differential between electrical power and natural gas is not so favorable in California as that observed in Arizona.

Although still in the pilot plant stage, the generation of electricity from atomic reactors has taken place.^{8/} Two major studies of economic and social aspects of atomic power have been undertaken and an extensive bibliography is accumulating in this field of study.^{9/} On the basis of varied

^{7/} Rehnberg, Rex D. "Costs of Pumping Water Compared." Progressive Agriculture in Arizona. University of Arizona, vol. 4, no. 3, October, November, and December, 1952, pp. 3 and 12.

 "The Cost of Pumping Irrigation Water, Pinal County, 1951." Bulletin 246. Agricultural Experiment Station, Univ. of Arizona, Tucson. January, 1953. 27pp.

^{8/} The first known use of electric power generated from atomic energy took place at the Reactor Testing Station at Arco, Idaho, on December 20, 21, and 22, 1951. Power was generated at a rate in excess of 100 kw. U. S. Atomic Energy Commission. Eleventh Semiannual Report of the Atomic Energy Commission. Washington, Govt. Print. Off., January, 1952. p. 21.

^{9/} Schurr, S. H., and J. Marschak. Economic Aspects of Atomic Power. Cowles Commission and Princeton University Press. 1950. 289pp.

Isard, W., and V. Whitney. Atomic Power. New York, The Blakiston Co., 1952. 235pp.

Both of these books contain extensive bibliography lists.

assumptions, estimates of the cost of generating electrical energy vary from 4 to 14.5 mills per kilowatt-hour, as compared with existing costs for hydro-, oil-, and coal-powered electricity generation varying from 1+ (hydro) to 11 (coal) mills per kilowatt-hour.^{10/} Generation of electrical energy from atomic energy at costs below coal- and oil-powered generation and at a comparable or slightly lower cost than hydro-powered generation would result in a decreased cost of electrical power to consumers. With respect to ground-water utilization, reductions in electrical power rates would permit pumping from increasingly greater depths.

The Volume of Pumpage

As pumpage volume increases, cost of pumping per acre-foot for a given lift and at a given rate will decrease when the energy source is electrical power. Table 6.4 presents typical pumping cost data for three rates of pumping and four volumes of pumpage with pumping lifts of 250 feet. The cost differential affects the marginal (added) cost of water significantly, though not enough to bring the total cost of pumping 6.25 acre-feet below the total cost of 5.0 acre-feet.

One of the unknown factors in plant-water relationships in Antelope Valley is the yield variation that may be expected when the amount of water applied to crops is varied. Sufficient investigation has taken place to enable the specification of minimum consumptive-use requirements (pp. 70 to 73). No satisfactory data are available on the quantitative variation in yield in arid areas if this minimum volume is increased.^{11/} An investigation in the Salt River Valley of Arizona reveals an increase in alfalfa

^{10/} Within the United States, existing costs vary from 1+ to 8 mills per kilowatt-hour, with an average of 5-6. Cf. footnote 9. See also:

Isard W., and J. B. Lansing. "Comparisons of Power Cost for Atomic and Conventional Steam Stations." The Review of Economics and Statistics, vol. XXXI, no. 3. August, 1949. pp. 217-228.

Shannon, R. H., J. D. Selby, and M. B. Dagan. "A study of electric power generation utilizing heat energy from power breeder reactors." AECD-3444. Oak Ridge, Tennessee, November 19, 1951. (U. S. Atomic Energy Commission, Tech. Inf. Service.) Photostatic copy. 21 p. Declassified, August 27, 1952.

^{11/} Some experimental studies in semi-arid areas indicate no significant total yield increase as soil moisture is increased above the permanent wilting percentage. An extensive review of the literature is contained in Soil Moisture in Relation to Plant Growth, Veihmeyer, F. J., and A. H. Hendrickson, Univ. of California, November, 1949. Mimeographed. 40 pp.

yield of about 1 ton per acre (from 7 to 8 tons) as the volume of water applied is increased from 5 to 6.25 acre-feet per acre.^{12/}

TABLE 6.4

Influence of Volume of Pumpage
on Cost of Pumping Ground Water ^{a/}

Rate of pumping	Volume of pumpage ^{b/}	Pumping cost	Overhead expense	Total
gallons per minute	acre-feet	(variable cost)	(fixed cost)	cost
		dollars per acre-foot		
450	100	7.36	6.77	14.13
450	200	5.48	3.38	8.86
450	250	5.20	2.70	7.90
450	300	4.73	2.26	6.99
900	200	7.03	5.85	12.88
900	400	5.48	2.93	8.42
900	500	5.09	2.34	7.43
900	600	4.78	1.95	6.73
1,800	400	3.28	4.33	7.61
1,800	800	3.04	2.17	5.21
1,800	1,000	3.00	1.73	4.73
1,800	1,200	2.96	1.44	4.40

^{a/} Figures presented are for electrically powered units with a total pumping lift of 250 feet. Power rate schedule is PA-31, except for the 1,800 g.p.m. unit, which is based on power rate schedule PA-P1

^{b/} The four volumes listed for each rate of pumping are equivalent to 2.5, 5.0, 6.25, and 7.5 acre-feet per acre. See Table 6.3, the column headed "Rate and volume of water pumped."

Sources: Appendix Table 9 and Table 6.3

If a similar situation exists in Antelope Valley, then decreased unit cost per acre-foot as pumpage volume is increased will result in an increased volume of pumpage by the individual farmer. For example, increasing alfalfa hay yield from 6.2 to 7.2 tons per acre would increase total production costs by \$10.81 while total receipts would be increased by \$23.75 (see Table 6.5)^{13/}—a \$12.94 excess of total returns over total cost that is attributable

^{12/} The Salt River Valley is climatically similar to Antelope Valley. Marr, J. C. "The use and duty of water in the Salt River Valley." Tucson, July 1, 1927. pp. 63-97. Cf. especially Figure 4, p. 78. (Ariz. Agr. Exp. Sta. Bul. 120.)

^{13/} This is applicable to a total pumping lift of 250 feet. It is assumed that increasing the amount of water applied from 5.0 to 6.25 acre-feet per acre would produce this increase in yield.

TABLE 6.5
Variations in Yield and Net Returns as Influenced by Increasing
the Volume of Water Applied to Alfalfa in Antelope Valley^a

	Case I: Water cost b/ variable per acre-foot		Case II: Water cost c/ fixed per acre-foot	
	Original level of application	Increased level of application	Original level of application	Increased level of application
Volume of water applied	5.0	6.25	5.0	6.25
Alfalfa yield ^d	6.2	7.2	6.2	7.2
	tons per acre		dollars per acre	
Cost of production, excluding variable water cost	113.92	121.22	113.92	121.22
Variable water cost (pumping cost)	26.05	29.56	26.05	32.56
Total cost of production	139.97	150.78	139.97	153.78
Marginal cost of increasing production from 6.2 to 7.2 tons per acre	--	10.81	--	13.81
Total revenue at \$23.75 per ton	147.25	171.00	147.25	171.00
Marginal revenue from increasing production from 6.2 to 7.2 tons per acre	--	23.75	--	23.75
Net revenue	7.28	20.22	7.28	17.22
Excess of marginal revenue over marginal cost with increased yield	--	12.94	--	9.94

a/ Hypothetical data, 160 acres in alfalfa.

b/ Based on Table 6.4.

c/ Assume \$5.21 per acre-foot.

d/ The yield increase, as pumpage volume increases, is an assumption of this study.

Sources: Table 6.3 and text, pp. 107-110.

to irrigating for increased yield.^{14/} If no reduction in cost occurred as the volume of pumpage increased, the incentive to increase volume of pumpage would not be so great: The excess of total returns over total cost associated with the increased yield would be \$9.94.

Controlled irrigation experiments in the Valley would reveal to what extent this yield-irrigation relationship exists and would also indicate points at which it would no longer be profitable to increase the volume of irrigation water applied. If the relationship is substantiated for arid areas, a clear conflict between conservation of water resources and economic utilization of the same resources will be established. Although minimum crop requirements (consumptive use plus application losses) may be less than 5 acre-feet per acre for alfalfa (Appendix Table 6), increased returns may easily predicate using larger volumes of irrigation water than the minimum.

This general cost-price-yield relationship further emphasizes the benefits gained by using electrically powered pumping units instead of diesel or gasoline units: Increasing the pumpage volume reduces water cost per acre-foot when using electrical energy, but similar economies do not result when using gasoline or diesel units. Such pumping cost reductions serve to extend the depth from which ground water may be pumped. This, in turn, increases the ability of ground-water users to deplete the ground-water stock resource.

Technology and Pumping Costs

In spite of the presence of overdraft, Antelope Valley water users have expanded agricultural production and intensified overdraft. The several factors discussed have combined to encourage this. So long as it remains profitable to pump ground water for irrigation of crops that consume large amounts of water, pumping will continue despite the declining water level.^{15/} The result has been the mining of a stock resource--the ground-water resource of Antelope Valley.

An element of technological change may be observed in the several factors influencing pumping costs (technology, as applied to the pumping

^{14/} This is equivalent to saying that net profit per acre is \$12.40 greater if 7.2 tons per acre are produced as compared with 6.2 tons per acre. Technically, it may be stated that the excess of marginal returns over marginal reserve is \$12.40 per acre as the yield is increased from 6.2 to 7.2 tons per acre.

^{15/} The relationship of crops (and their water requirements) to the cost of pumping ground water will be discussed in the next chapter.

units, implies several features--such as pumping efficiency, size and number of pumps, and type of pumps):

The influence of pumping efficiency on water costs has been pointed out. Pumping efficiency arises from two sources: (1) the power unit, which may be a direct-connected unit (electric motor) or an indirect-connected unit (engines), with belt drive or gear head; and (2) the pump itself.^{16/} The greater the number of steps between power input and water output, other things being equal, the less efficient the pumping unit. Thus, direct-drive units have a higher efficiency than indirect-drive units. During the twenties, the majority of Antelope Valley pumping plants were indirect-drive units, and the majority of these were belt-driven plants. High speeds of operation resulted in belt slippage and further efficiency loss. The average over-all efficiency of belt-driven plants in Antelope Valley during this period was less than 40 per cent, with a maximum of about 50 per cent. A few gear-head units of slightly greater efficiency raised the average for all plants in the area to about 45 per cent. Belt-driven and gear-head plants are nearly extinct in the Valley. It is now estimated by Southern California Edison Power Company that a typical over-all efficiency for newly-installed large pumping plants is about 60 per cent, with 65-70 per cent efficiencies not uncommon.

The size of pumping unit (pump and motor) typical for a given installation has undergone a pronounced change in the period 1920-1950: Larger motors have become necessitated by the declining water table.

The type of pumping unit has also changed: In the early twenties, pit pumps were a common sight in Antelope Valley.^{17/} Simple centrifugal units were placed in pits dug to depths of 25 feet or more. As water levels continued to drop and the pits could not be economically deepened, a change was necessary. Fortunately, the deep-well turbine pump had become popular by then, and an easy shift from single-stage centrifugal pit pumps was possible.^{18/} Though the early deep-well turbine pumps were excessively heavy and not much more efficient than the pumps they replaced, pumping costs

^{16/} Over-all pumping efficiency is the product of pump efficiency multiplied by motor (engine) efficiency.

^{17/} Personal interview, William Keller, Lancaster.

^{18/} Bennison, E. W. Ground Water. St. Paul, Minnesota, Edward E. Johnson, Inc., 1947. pp. 381-382.

were nevertheless reduced--and additional unit-cost reductions have resulted as improvements have been made.

Technological innovations in pumping have so far been able to keep slightly ahead of the pumping limits forecast from time to time. Several types of improvement in the pumping units themselves have combined with reductions in electrical energy rates to permit pumping from increasingly great depths. The ground-water stock resource is being "mined," and continued overdraft is the result. The cost of pumping is small enough relative to total cost of production that it is profitable and rational for the farmers to act as they have.

The biggest and most important question raised is: "How long will it continue to be profitable to mine the ground water?" The answer to this question is related to what may be called the economic limit of pumping, which is considered at length in the next chapter.

Chapter 7

Pumping Costs and the Selection of Farm Enterprises

The next step in considering the economic aspects of ground-water utilization is to relate various types of farm enterprises to the costs of ground-water utilization. Ideally, such a step would include detailed information, from farms in the area under study, covering the costs and returns associated with the most typical farm enterprises and detailed information on their pumping unit and ground-water setting. Such detailed field work was beyond the scope of this ground-water study. It has, therefore, been necessary to synthesize cost and return data for several farm enterprises and relate this to available information concerning the ground-water economy of Antelope Valley. Research providing such basic data would strengthen future ground-water studies.

Enterprise Selection

Research and experimentation in the selection of crops for the Valley have begun only in the last few years, at the Antelope Valley Field Station of the University of California. Various crops have been grown in an effort to discover those readily adaptable to the area. It has been found that with reliable irrigation nearly all major field and vegetable crops can be grown.^{1/} Extended studies have not been made on the economic suitability of various crops to the area, but preliminary indications tend to substantiate the trial and error process of early farmers that made alfalfa the primary crop grown in the Valley.

Not all crops grown at the Field Station are ideally adapted to the area: Watermelons and other melons are easily grown there, but are subject to serious competition from other major producing areas of the state. To meet this competition effectively, the timing of harvest operations should be so governed that Antelope Valley production arrives on the market between arrivals from other areas. This would be difficult to achieve.

Early potatoes are in a similar economic situation, with production from the Valley in direct competition with the potato producing area of the

^{1/} A partial list of the crops successfully grown at the Field Station includes alfalfa, irrigated pasture, field corn, sweet corn, wheat, milo maize, broomcorn, melons, watermelons, squash, onions, carrots, sugar beets, cotton, strawberries, lettuce seed, clover seed, alfalfa seed, bush berries, castor beans, Lima beans, field beans, sweet potatoes, and potatoes.

southern San Joaquin Valley. Between 1941 and 1951, California state annual average prices have varied from \$1.06 to \$2.67 per hundredweight, with even greater fluctuations within a single season. An inelastic demand for this commodity leads to early market saturation.^{2/} Because of its perishable nature, the commodity cannot be stored and marked declines in market price therefore occur. High management incomes result if the product reaches the market at an appropriate time; otherwise substantial losses are incurred.

Castor beans appear to return a more than satisfactory management income, but two serious problems are found with this crop: First, the plant has a great tendency to shatter in harvest, which with a 30 per cent loss will reduce management income nearly to zero for most pumping lifts. Second, toxicity of castor beans to livestock constitutes a risk hazard.

For these reasons, the above three crops are not emphasized in the subsequent analysis. Few of the other crops grown at the Field Station have been included, because of a lack of appropriate technological knowledge on the part of the farmer or because of lack of suitable harvesting, processing, or marketing facilities.^{3/} Tree fruit crops have been omitted because of their relative unimportance in the Valley. Most of the land available for future agricultural development is not suitable for tree fruit production. Except for irrigated pasture for beef production, livestock enterprises have been omitted because of the insignificant consumption of water by livestock in the area. The enterprises selected represent single enterprise studies. That is, no intrafarm rotations or complementary-supplementary relationships are included. It is believed that such intrafarm combinations of enterprises would not materially affect the results obtained in the later sections of this chapter.

2/ In 1950, so much "cotton land" in the southern San Joaquin Valley went into early potato production that the potato market "broke," because of the relatively low demand elasticity for this crop. "The heavy shipments [of early potatoes from Kern County] practically demoralized the market." U. S. Production Marketing Administration and California Department of Agriculture, Bureau of Market News. Marketing Kern District Early White Long Potatoes. Summary of 1950 Season. April, 1951. p. 1.

3/ Two examples to illustrate the point may be cited: The specialty truck crops, such as lettuce, lettuce seed, carrots, table beets, etc., require adequate technological knowledge on the part of the farmer and an adequate supply of stooped labor to provide cultural labor for the crops. Sugar beets have been grown but delays in harvesting due to lack of equipment have caused farmers to suffer losses, because of post-maturity decline in the sugar content of the beets. Furthermore, sugar beets have suffered from "scalding" as a result of improper irrigation.

Economic Norms

Economic norms used in this portion of the study have been synthesized in the form of typical crop yields, prices received for crops, and costs of production. Table 7.1 summarizes this information.

Yield estimates are assumed to be the typical yields under average-to-good management that would be consistent with a minimum application of irrigation water--except for the alfalfa yield of 7.2 tons per acre, which is based on a typical irrigation application. The prices received for the various crops have been estimated by using 1946-1951 averages of the prices received by California producers. The prices received by farmers in Antelope Valley for alfalfa hay have traditionally averaged \$1 to \$2 per ton above the annual state average because of the higher quality of hay grown in the area.^{4/} Because of lack of information on prices received by Antelope Valley growers for the other crops being considered, this differential was not included, making possible a more direct comparison between the prices received and resulting incomes from the several crops.

Costs of production are based on 1946-1951 average costs for materials and labor, and represent typical operations of 160-acre enterprises for that period in Antelope Valley.^{5/} This period has been selected for use in this discussion because the cost-price relationships reflect the most recent methods of culture and the rather unstable but high-priced economy in which the farmer operates. The final entry in Table 7.1, management income plus fund for paying cost of pumping water, was derived by subtracting the total cost of production (excluding variable water costs) from the total receipts, on a per-acre basis.^{6/} This sum includes return available to spend on pumping water for application to the crop, return to the operator for his managerial abilities, and payment for the risk and uncertainties incurred in agricultural production.

Income and the Falling Water Table: Alfalfa, 1920-1951

Historical variation in management income for Antelope Valley alfalfa enterprises is shown in Table 7.2 for four different periods. The periods

^{4/} Alfalfa hay prices for Antelope Valley are available from the California Market News Service.

^{5/} Except for the dry-farmed wheat, which is based on an operation of 1,500 to 2,000 acres.

^{6/} Management income by itself is the payment allowed to the operator (manager) for his over-all farm investment, managerial activities, and risks and uncertainties incurred in agricultural production.

TABLE 7.1
Typical Yields, Costs, and Returns for Various Crops in Antelope Valley, Per-Acre Basis^{a/}

	Alfalfa		Alfalfa (Contract baled)	Alfalfa		Castor beans	Field corn	Cotton lint	Milo maize	Irrig- ated pasture	Potatoes	Water- melons	Irrig- ated wheat (double cropped)	Dry- farm wheat									
	Alfalfa	Water application		Alfalfa	Alfalfa																		
															5.0 acre-feet	6.25 acre- feet ^{b/}	600 lb.	40 cwt.	600 lb. gain in weight	250 cwt.	10 ton	42 cwt.	5 cwt.
Crop yield per acre	6.2 ton	6.2 ton	7.2 ton	1.0 ton	50 cwt.	600 lb. lint	40 cwt.	600 lb. gain in weight	250 cwt.	10 ton	42 cwt.	5 cwt.											
dollars																							
Returns per unit of production	23.75	23.75	23.75	180.00	2.75	0.295	2.55	0.20	2.05	20.00	3.16	3.16											
Total returns	147.25	147.25	171.00	180.00	137.50	204.00 ^{c/}	102.00	120.00	520.00 ^{d/}	200.00	132.72	15.80											
Costs of produc- tion																							
Cash cost, excluding water	62.11	69.86	69.41	64.95	66.90	138.39	39.58	31.15	428.50	105.16	58.46	10.37											
Non-cash cost	49.69	49.69	49.69	44.11	43.97	44.42	43.97	56.94	63.49	43.97	45.90	2.65											
Total cost, excluding cost of water (vari- able pumping cost only)	111.80	119.55	119.10	109.06	110.87	182.81	83.55	88.09	491.97	149.13	104.36	13.02											
Management income plus fund for pay- ing cost of pump- ing water	35.45	27.70	51.90	70.94	26.63	21.19	18.45	31.91	28.03	50.87	28.36	2.78 ^{e/}											

a/ 160 acre units assumed for all crops except dry-farmed wheat, which is for 1,500-2,000 acre operation.

b/ See Table

c/ This includes \$27.00 from the sale of 900 pounds of cottonseed.

d/ This includes \$7.50 from the sale of 50 sacks of cull potatoes.

e/ Because no irrigation water is used, this entire amount is management income.

have been selected rather arbitrarily to conform with information available on costs of production and electrical power costs for pumping irrigation water. Two sets of factors have been averaged in developing these sets of information, one temporal, the other managerial. The entries for each of the four periods are assumed to be typical for the period under consideration, with some incomes above and others below the stated level. Furthermore, managerial abilities represented by the given costs of production are assumed to be typical for Antelope Valley during the specified periods. The word typical is used in a median sense: It is assumed that approximately 50 per cent of the operators in the Valley would have greater costs of production than those herein specified, and 50 per cent would have lower costs of production.

TABLE 7.2

Typical Costs, Returns, and Management Income for
Alfalfa Hay, Antelope Valley, 1925-1952 ^{a/}
(per acre basis)

	1920- 1929 ^{b/}	1930- 1939 ^{b/}	1940- 1949 ^{c/}	1946- 1952 ^{c/}
	feet			
Assumed total pumping lift ^{d/}	90	130	165	200
	dollars			
Cash costs of production, excluding pumping costs	36.60	29.15	35.25	62.11
Noncash costs and repair costs ^{e/}	14.00	15.00	28.50	49.69
Pumping cost	15.25	13.00	16.75	20.50
Total cost of production	65.85	57.15	80.50	132.60
Returns per ton alfalfa	15.00	10.50	19.75	23.75
Total returns (6.2 T/acre)	93.00	65.10	122.45	147.25
Management income	27.15	7.95	41.95	15.05

^{a/} Assume water application of 5 acre-feet per acre.

^{b/} Typical for 40- and 80-acre alfalfa units.

^{c/} Typical for 120- and 160-acre alfalfa units.

^{d/} Typical for the period indicated.

^{e/} Depreciation and interest on pump, well, and distribution system constitute more than one-half of the non-cash costs.

Study of this information reveals that pumping costs have increased as the water table has fallen. Closer study indicates that the importance of pumping cost relative to total production cost has decreased from an average high of 23 per cent in the period 1920-1929 to an average low of

15.5 per cent in the period 1946-1951. This indicates that despite long-run overdraft on the ground-water stock resource of Antelope Valley the effect of increased costs of pumping ground water has been more than compensated by other factors. Some of these factors have already been discussed, others are to follow.

The period from 1920-1929 was one of general prosperity, with development moving steadily forward in Antelope Valley. The major economic depression of the thirties fell hard upon the Valley alfalfa farmer and caused much acreage to be abandoned. The decade of the forties, except for one or two years, brought with it a time of war-induced prosperity and an opportunity for the Antelope Valley alfalfa farmer to erase his debts and strengthen the financial structure of his farm.

Postwar increases in labor and materials costs and declines in water levels have combined to decrease the management income received by the alfalfa farmer in Antelope Valley. But the price received for alfalfa hay has risen measurably during this period absorbing some of the increased costs of production. A sharp and prolonged decline in alfalfa hay prices similar to the short decline experienced in California in late 1949 and early 1950 could lead to abandonment of some alfalfa acreage in the area.

Alfalfa and Other Crops: Present and Future

A variation in operator's earnings as pumping lifts increase has been synthesized for alfalfa and other crops, as shown in Table 7.3. Assumptions underlying this table are several: (1) Size of enterprise is approximately 160 acres. (2) Average 1946-1952 cost-price relations. (3) The pump, motor, and assembly are capable of handling an increase in pumping lift of about 100 feet before replacement is necessary. (4) Replacement of the old pump and motor is a capital expenditure incurred about every 100 feet, making only a small addition to total annual fixed charges and resulting change in operator's earnings. This permits the problem to be considered as one of change in pumping costs, not of change in fixed plus variable costs.

Until total pumping lift exceeds 450 feet, all listed enterprises yield positive returns. The farmer receives greater returns per acre from alfalfa than from the other crops, with the exception of watermelons and castor beans. Because of the greater volume of water used for the several alfalfa enterprises and irrigated pasture than for the field crops, the rate of decrease in returns as pumping lift increases is greater with the alfalfa and pasture enterprises.

TABLE 7.3

Typical Management Income Associated with Variable
Pumping Lifts for Several Crops in Antelope Valley ^{a/}

Crop	Water appli- cation acre-feet per acre	Yield per acre	Total pumping lift, feet					
			100	200	300	400	500	600
			dollars per acre					
Alfalfa	5.0	6.2T	23.50	23.00 ^{b/}	17.30	12.20	6.80	1.20
Alfalfa	6.25	7.2T	38.02	36.59 ^{b/}	29.59	23.27	16.59	9.77
Alfalfa (contract baled) c/	5.0	6.2T	15.75	15.25 ^{b/}	9.55	4.45 ^{b/}	- 0.95	--
Castor beans	2.5	2,000 pounds	64.59	59.64	55.56	59.21 ^{b/}	56.56	53.56
Field corn	2.5	5,000 pounds	20.28	15.33	11.25	14.90 ^{b/}	12.25	9.25
Cotton	2.5	600 pounds	14.84	9.89	5.81	9.46 ^{b/}	6.81	3.81
Milo maize	2.5	4,000 pounds	12.10	7.15	3.07	6.72 ^{b/}	4.07	1.07
Irrigated pasture	5.0	600 pounds gain	19.96	19.46 ^{b/}	13.76	8.66	3.26	--
Potatoes	2.5	2,500 pounds	21.68	16.73	12.65	16.30 ^{b/}	13.65	10.65
Watermelons	2.5	10T	44.52	39.57	35.49	39.14 ^{b/}	36.49	33.49
Irrigated wheat (double cropped)	2.5	4,200 pounds	22.01	17.06	12.98	16.63 ^{b/}	13.98	10.98

^{a/} 1946-1951 average cost-price relationships assumed.

^{b/} Discontinuities occur as demand horsepower reaches a level of 100 H.P., which permits shifting to a more favorable power rate schedule.

^{c/} Two enterprises assume a water application of 5 acre-feet per acre per year; one of these is contract baled while the operator performs his own baling on the other. The third alfalfa enterprise assumes a water application of 6.25 acre-feet per acre per year, operator-performed baling, and a higher yield than the other two. This yield increase is based on an investigation in the Salt River Valley of Arizona in which a 1-ton increase in alfalfa yield occurred (from 7 to 8 tons) as the volume of water applied was increased from 5 to 6.25 acre-feet per acre. Marr, J. C. "The Use and Duty of Water in the Salt River Valley." Tucson, July, 1927. pp. 63-97. (Ariz. Agr. Exp. Sta. Bul. 120.)

On the basis of these relationships, it follows that rigid conservation of the ground-water stock resource--i.e., the exclusion of mining by restricting draft to the safe-yield volume--and maximization of individual farm incomes are not necessarily consistent long-run objectives.^{7/} Furthermore, maximum

^{7/} As used herein, conservation is defined in terms of "... changes in the intertemporal distribution of use. In conservation, the redistribution of use is in the direction of the future; ..." Ciriacy-Wantrup, S. V. Resource Conservation, op. cit., pp. 51-53.

net social income over the long run is not necessarily consistent with rigid resource conservation.

Two factors bear directly upon this issue for Antelope Valley:

First, the hypothesis has been put forward that Valley farmers apply too much irrigation water to their alfalfa crops. That is, they exceed minimum theoretical requirements based on consumptive use (see Appendix Table 6). The corollary states that it will "soon" be uneconomic to pump irrigation water. Projecting the relationships and assumptions of Table 7.3 indicates that water levels can decline to a 400-600-foot level before negative returns are incurred, assuming no change in cost-price or technological relationships.

Second, the possible contradiction between rigid water conservation and maximization of farm income brought forth suggestions for shifts from alfalfa to crops that consume less water.^{8/} Excluding for the moment such specialty crops as watermelons and castor beans, theoretical transfers from alfalfa are not indicated until total pumping lift approaches 400 to 450 feet. Current experiments with field corn indicate a possible transfer at more shallow depths, especially for small farms with pumps discharging relatively small volumes of water.^{9/}

In the Valley there is little incentive to transfer to crops that consume less water so long as alfalfa remains more profitable than most other crops currently grown there. Should transfer occur, the annual draft on ground-water stock resources that would be required to supply an estimated 65,000 acres^{10/} of low water-consuming crops would still exceed by three-fold the average annual recharge. The resource would be conserved by shifting the rate of use into the future, but overdraft would not be eliminated. The rates of overdraft and decline of ground-water levels would decrease, but favorable operator's earnings--decreasing differently for the several alternative crops--would continue to stimulate overdraft.

^{8/} The term "duty of water" is not used in this discussion, for this reason: "The term duty of water . . . represents the relation between the area of land served and the quantity of water used. However, the term is somewhat confusing in its applications as a high duty of water represents a small amount of use and a low duty represents a large use." Etcheverry, B. A. and S. T. Harding. Irrigation Practice and Engineering. Vol. 1. Use of Irrigation Water and Irrigation Practice. p. 65.

^{9/} Experimental corn yields have exceeded 150 bushels per acre, but commercial yields approximate those indicated in Table 7.3.

^{10/} Estimated current total irrigated acreage in the Valley.

Price Variation and Enterprise Selection

A comparison of product-price variations and management incomes may be used to determine the price relationships necessary to make it profitable for a farmer to shift from alfalfa to crops that consume less water.^{11/} Figure 7.1 has been constructed for alfalfa and four low-water-consuming enterprises--corn, potatoes, cotton, and double-cropped, irrigated wheat. In each comparison the diagonal line represents the positions of equal management returns per acre associated with the respective commodity prices. For example, a corn price of \$3 per hundredweight will return to the operator the same management income as will an alfalfa price of \$25 per ton for the standard alfalfa enterprise. The dots in each figure represent paired observations of average annual prices received by farmers for the crops.^{12/} A dot falling below the line indicates that alfalfa was more profitable than the alternative enterprise; and above the line, vice versa. The dots plotted are for 1942-1951, inclusive. Figure 7.1 indicates that corn would have been more profitable than alfalfa two out of ten times, cotton and irrigated wheat three out of ten times, and potatoes eight out of ten times. The promise indicated for potatoes has already been discounted (see p. 114) because of unstable within-season demand and the perishable nature of the product.

Cotton, although not indicated as being more favorable than alfalfa for Antelope Valley, is an important factor in affecting the alfalfa situation in Antelope Valley. More important to Valley alfalfa growers than cotton grown in the area is the influence of cotton acreage allotments in other areas of California. In many areas of the San Joaquin Valley, cotton has replaced alfalfa because of the high price supports of the last two years (1951, 1952). Competition from San Joaquin and Imperial alfalfa in 1950, a year under cotton acreage allotments, accounted in large part for the severe drop in alfalfa prices received by Antelope Valley growers for that year. Alfalfa can be trucked to Los Angeles from southern San Joaquin Valley at approximately the same price it costs to truck from Antelope Valley.

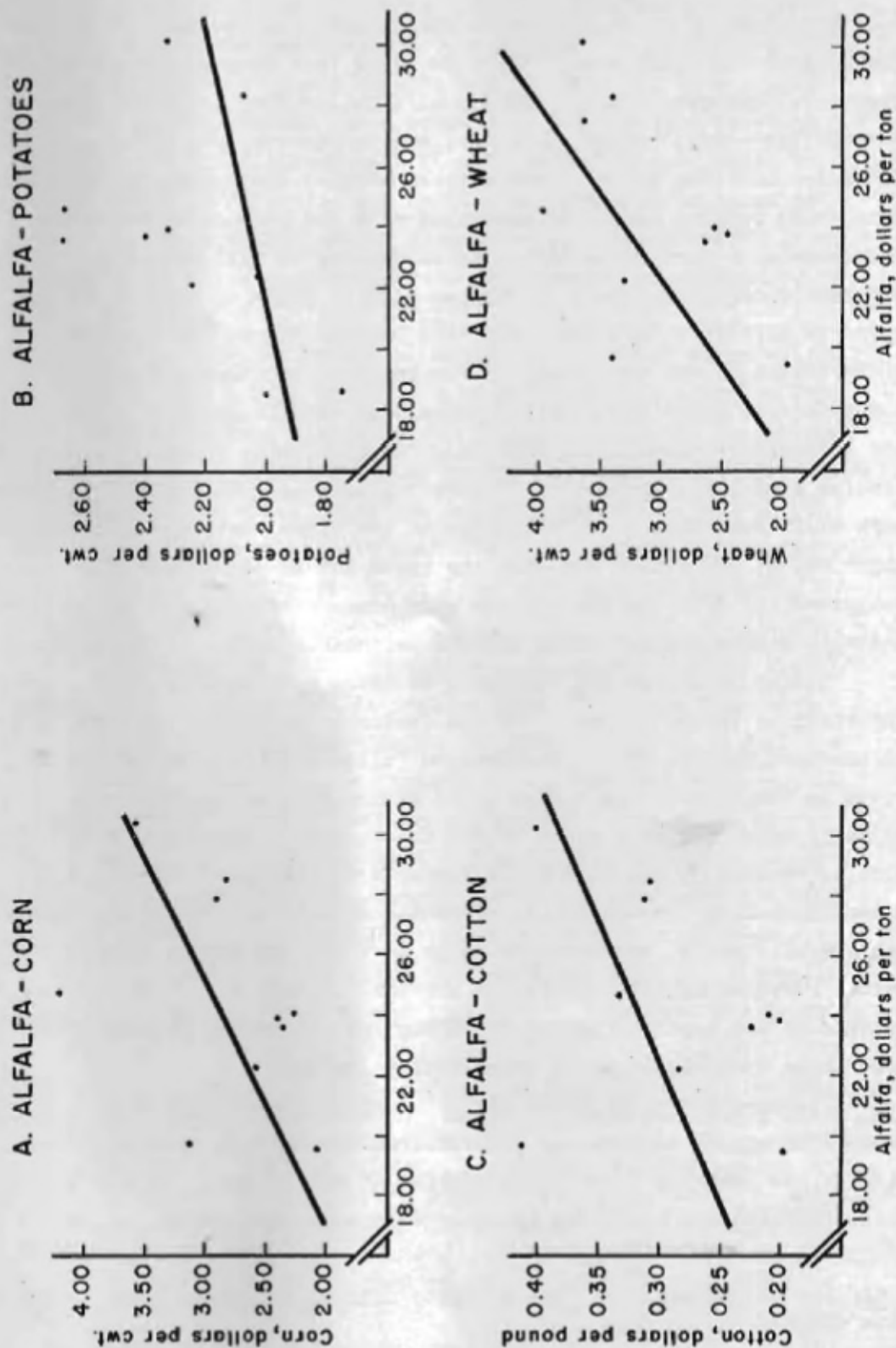
Assuming the above-described price situation to have prevailed in Antelope Valley throughout most of its agricultural history, it is little wonder that alfalfa has been the favorite enterprise of the farmer. Even on an annual crop basis, alfalfa has consistently returned greater management income to farmers

^{11/} The statements that follow relate only to the enterprises synthesized in this study.

^{12/} California state average annual prices received by farmer. See Appendix Table 10 .

Figure 7.1

MANAGEMENT INCOME AND COMMODITY PRICE VARIATION
ANTELOPE VALLEY 1942-1951^{g/}



^{g/} The line in each diagram represents prices of the crops which yield equal management income per acre.
Source: Table 7.5 Snyder, J. Herbert, *op. cit.*

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than the low-water-consuming crops. Add to this the fact that alfalfa is a perennial crop that can be grown for five years or more without replanting and the already strong price advantage is improved.^{13/}

Acreage Variation and Overdraft

Changes in cost-price relationships may affect on-farm overdraft by bringing forth enterprise changes. If all farms in the Valley were to change, the total effect on overdraft would vary depending upon the type and extent of change. Shifts in enterprise acreage for the Valley could reduce overdraft and, under very strict circumstances, eliminate it.

Hypothetical shifts in crop acreage are assumed to evolve gradually from present acreages. In four cases, no change in total irrigated acreage (of approximately 65,000 acres) is anticipated for the Valley, while in one case reductions to 30,000 and 20,000 acres are assumed. The cost-price-yield relationships developed above are assumed for the period of projection, as are the relationships between management income and the water table, which declines from a 200-foot level in the several cases. Pumping plants in existence at the beginning of the period are assumed to be able to adjust to the increased pumping lifts. The only increase in cost, that will occur is assumed to be in the variable pumping costs, as the pumping lift increases. Nonirrigated land use and incomes are assumed constant for the period. The projections are summarized in Table 7.4.

Case 1--No major changes in crop acreages. No major changes are assumed in crop acreages, and alfalfa remains the dominant crop. By 1963 the pumping lift will have increased about 69 feet beyond 1953 lift, as a result of a cumulative overdraft of 1,480,000 acre-feet for the period. Aggregate management income is estimated at \$1,150,000 for 1963, a decrease of \$110,000 from 1953 levels. The change is brought about entirely by increased costs of pumping, as the ground-water levels continue their decline. If the acreage under irrigation increases, overdraft and pumping lifts will increase and total earnings decrease.

Case 2-- Major shift from alfalfa to field corn. Major shifts from alfalfa to corn may occur because many small farms in the Valley are not equipped with pumping plants that can supply enough water to plant the entire farm to alfalfa. Large scale poultry enterprises in the Valley provide a

^{13/} The individual farmer would hesitate to plow under a mature alfalfa stand in anticipation of a one-year price advantage for another crop, and then replant alfalfa.

TABLE 7.4

Projections of Antelope Valley Irrigated Agriculture for 1963

Case Num- ber	Alfalfa	Field corn	Irri- gated pasture	Miscel- laneous fruit, field, and vegetable acres	Specialty vegetable	Total irri- gated acreage	Esti- mated increase in pump- ing lift for 1954-1963 feet	Total management income from all crops dollars	Change in total management income compared with 1953
1	44,000	1,000	5,000	15,000		65,000	69	1,150,000	- 110,000
2	20,000	25,000	5,000	15,000		65,000	56	1,120,000	- 140,000
3A	20,000	20,000	5,000	10,000	10,000	65,000	56	1,450,000	+ 190,000
3B	5,000	20,000	5,000	10,000	25,000	65,000	47	1,950,000	+ 690,000
4		20,000		10,000	35,000	65,000	42	2,300,000	+1,040,000
5A		10,000			20,000	30,000	33	1,200,000	- 60,000
5B		5,000			15,000	20,000	24	860,000	- 400,000

local demand for feed that would be conveniently suppliable by local corn producers.^{14/}

It is assumed here that 25,000 acres are shifted from alfalfa to field corn. By 1963, the pumping lift will have increased only 56 feet and cumulative overdraft will be 1,200,000 acre-feet. Annual on-farm water savings will have amounted to about 1.2 acre-feet per acre. Total management income is estimated at \$1,120,000, or \$140,000 below 1953 levels. The difference is due to lower pumping costs resulting from a smaller increase in pumping lift, and lower earnings from corn than from alfalfa. The two factors act in opposite directions, but losses resulting from the shift will more than offset the gain from decreased pumping lifts.

Case 3--Major shifts from alfalfa to field corn and special vegetable crops. Two levels of shift are demonstrated, depending upon the degree of shift to specialty vegetable crops. Two factors combine to permit a supposition of shift to vegetable crops: First, rapid urbanization around Los Angeles is removing substantial acreage from commercial vegetable production. Second, the smog problem around Los Angeles area is hastening this abandonment of commercial vegetable crop acreage. Experiments at the Antelope Valley Field Station of the University of California indicate that such commercial vegetable crops as sweet corn, melons, watermelons, squash, bush berries, sweet potatoes, onions, carrots, beets, lima beans, and cucumbers can be grown successfully in Antelope Valley.

Case 3A assumes a shift of 10,000 acres to commercial vegetable crops of this type. By 1963, the pumping lift will have increased 56 feet beyond 1953 lift, as a result of a cumulative overdraft of 1,200,000 acre-feet. Total management income is estimated at \$1,450,000 for 1963, or \$190,000 above 1953 levels. This increase is primarily attributable to increased earnings associated with specialty vegetable crops. A slight contribution will also be made by decreased pumping costs associated with smaller increases in pumping lifts.

Case 3B assumes a shift to specialty vegetable crops of 25,000 acres and a corresponding reduction in alfalfa acreage. By 1963 the pumping lift will have increased 47 feet over 1953 lift, as a result of a cumulative overdraft of 1,020,000 acre-feet. Earnings are estimated at \$1,950,000, or \$690,000 above 1953 levels. This increase results from the increased earnings associated with specialty vegetable crops and smaller increases in pumping lift.

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^{14/} In 1953, Antelope Valley field corn production from 1,500 acres supplied less than 7 per cent of the annual feed-grain requirement of local poultry enterprises.

Case 4--Abandonment of alfalfa enterprises. If the volume of water that can be applied per acre is regulated by law and set at a level below the amount necessary to irrigate alfalfa, abandonment of alfalfa and irrigated pastures in Antelope Valley could result.^{15/} It is assumed that specialty vegetable crops would absorb such acreage.

By 1963 the pumping lift will have increased 42 feet beyond 1953 lift, as a result of cumulative overdraft of 900,000 acre-feet. Total management income is estimated at \$2,300,000, or \$1,040,000 above 1953 levels. Greater earnings associated with specialty vegetable crops and lesser pumping costs associated with smaller increase in lifts combine to bring about aggregate earnings greater than those postulated in cases 1 to 3.

Case 5--Major reductions in irrigated crop acreage. Maintaining irrigated crop acreage in Antelope Valley at 65,000 acres will not reduce draft sufficiently to eliminate long-run overdraft at present levels of ground-water recharge. Case 5A assumes a reduction to 30,000 acres, all planted to field corn or specialty vegetable crops. By 1963 the pumping lift will have increased 33 feet beyond 1953 lift, as a result of a cumulative overdraft of 700,000 acre-feet. Total management income is estimated at \$1,200,000, or \$60,000 below 1953 levels. The severe reduction in acreage more than offsets the gains from shifting to specialty vegetable crops and pumping with more slowly declining levels.

Case 5B assumes a reduction to 20,000 irrigated acres, all planted to field corn or specialty vegetable crops. By 1963 the pumping lift will have increased only 24 feet beyond 1953 lift, as a result of cumulative overdraft of 510,000 acre-feet. Average annual draft and average annual recharge will finally be in balance, terminating the condition of long-run overdraft. Total earnings are estimated at \$860,000, or a decrease of \$400,000 from 1953 levels. For comparison, if all acreage is in alfalfa and the total acreage reduced until recharge equals draft, only 12,500 acres can be irrigated, reducing aggregate management income \$1,030,000 below the 1953 levels--to \$230,000 annually.

Any of the assumed shifts in crop patterns could occur in the Valley. It is unlikely, however, that acreage reductions sufficient to bring average annual recharge into balance with average annual draft will occur within the next ten years. Past experience indicates the profitability of mining the

^{15/} A suggestion has been made to limit pumpage volume to 5 acre-feet per acre per year in Antelope Valley. This limitation would not cause major abandonment of alfalfa acreage. No official action has ever been taken on this recommendation, see p. 138.

ground-water resource. For example, using the ground-water stock at a safe yield rate (draft = recharge) and devoting the entire amount to alfalfa production, it is estimated that operators' earnings from alfalfa for the period 1927-1950 would have totaled less than \$5,000,000. Actually, for only the period 1947-1950, alfalfa operators' earnings alone totaled \$4,500,000. Thus income generated by mining the ground-water stock resource may easily exceed a perpetuity income resulting from maintaining balance between recharge and draft. Technologic and price changes have stimulated long-run overdraft through continued expansion of irrigated acreage.

Examination of historic price variation shows that, relative to many alternative crop possibilities, alfalfa has retained an advantage. Major shifts out of alfalfa would depend on satisfactory net returns from other crops, or restrictions on water use. One method by which the Valley can attain such an advantageous shift is to become a major producing area for specialty vegetable crops instead of a minor producing area competing with major areas. Thus, although major shifts in particular crops grown in the area may occur to conserve the ground-water stock resource and reduce overdraft, elimination of long-run overdraft is not a strong probability within the next ten years.

Economic Limits for Pumping Ground Water

Theoretical maximum expenditures for water can be forecast quite precisely, but the practical limit is less tangible. To specify the maximum water cost, all that needs to be done is to specify the minimum desired management income per acre, hold all other factors constant, and allow pumping costs to increase until the management income limit is reached: If it is assumed that the average present value of a 160-acre farm producing the irrigated crops analyzed in this chapter is \$80,000 and that wages of management can be stipulated at 2 per cent of the value of the enterprise being managed, the necessary management income to produce this would be \$10 per acre. Projecting 1946-1951 cost-price-yield relationships, this management income is associated with pumping lifts ranging from 200 to 600 feet and costs of pumping ranging from \$13 to \$43 per acre (or \$7 to \$15 per acre-foot of water), depending upon the crop.

This is not to say that Antelope Valley would cease to produce crops when the total pumping lift approached 600 feet, or that water costs in excess of \$43 per acre would cause production to stop. Zero or even negative management incomes are frequently received by some enterprises. Management

income is essentially a payment for encountering the risks and uncertainties of agricultural production. If the operator (who pays himself a variable labor wage, depending on the crop) is willing to forego this payment for risk and uncertainty, then total pumping lifts can be extended beyond the 600-foot limit.^{16/} Furthermore, in periods of unfavorable prices, payments for depreciation and interest may be deferred and this money used to cover current cash costs. So long as cash costs in the short run are covered by enterprise returns, the operator will continue to produce.

Thus, the economic limit of pumping, or the limiting water cost, is a result of several factors--pumping cost per acre-foot, intensity of water application and crop grown, government acreage allotments, and supply-demand-generated price relationships among the several enterprises. The economic limit of pumping does not exist as a fixed concept: It is a changing concept over time, depending on actual and anticipated cost-price-technology relationships facing individual farmers and groups of farmers in a particular area.

With such complex situations, no simple statement of economic limits of pumping can be made. As a first approximation, and projecting the particular assumptions and findings of this paper, it appears that "mining" the ground-water stock resource will continue to be stimulated by economic pressures until total pumping lifts approximate 500 feet. Depending upon the rate of expansion or contraction in ground-water draft, these limits could be reached within 35 to 65 years. Periodic reexamination of the rate of depletion by "mining" and the level of revenues realized will be necessary because of changes in cost-price relations and technology.

^{16/} In all probability, however, repair and maintenance costs, which increase very rapidly as pumping lifts exceed 300 feet, may serve to set economic pumping limits before even a 500-foot lift is reached.

Chapter 8

Action Programs for Combating Overdraft

Having concluded that economic forces have induced and perpetuated a condition of long-run overdraft in Antelope Valley, the discussion turns to a consideration of attempts to alleviate overdraft. Some activities discussed are not action programs but only investigations that may lead to positive action programs. All have influenced the battle against overdraft in the Valley.

In 1909 Johnson concluded that the area had not reached the limit of development of its underground waters, but he warned that all who had the interests of the region at heart must recognize its water limitations. He particularly warned about the abuse of artesian resources. In 1920 Thompson estimated that annual withdrawals had approached within 20 per cent of annual recharge (his estimate) and warned that future economic development might be limited. His advice was to keep average annual removal from ground water no more than average annual recharge. Since these early dates, local inhabitants have gradually recognized the presence of ground-water overdraft. This chapter presents the investigations and action programs undertaken in efforts to combat overdraft in Antelope Valley. Insofar as practical, chronological order is followed.

Investigational Programs and Activities

Activities of the Agricultural Extension Service and University of California relevant to combating overdraft have taken two forms: (1) sponsoring the Agricultural Program Building Conferences in 1940 and 1941, and (2) investigating suitable crops as alternatives to alfalfa. These were in response to requests for help by local farmers, as is the normal and logical procedure in State institutions.

The Antelope Valley Agricultural Program Building Conference

Meetings were called by the Agricultural Extension Service, one in 1940 and the second in 1941.^{1/} The purpose was to plan for the best future development of Antelope Valley agriculture in cooperation with farmers presenting their

^{1/} Most of the information on these meetings is from mimeographed reports issued by the Agricultural Extension Service, one at the conclusion of each conference: "Recommendations for the Agricultural Development of Antelope Valley by the Antelope Valley Agricultural Program Building Conference," Lancaster, March 20, 1940, and "Report of the Second Antelope Valley Agricultural Program Building Conference," Lancaster, April 16, 1941.

opinions as to the major agricultural problems affecting them. Representative farmers and businessmen attended the conferences together with representatives from the Soil Conservation Service, Agricultural Conservation Service, Farm Security Administration, Forest Service, and other agencies serving agriculture in the Valley. At all meetings the constantly lowering water table was considered of major importance.

At the conclusion of each conference, recommendations were adopted that the conferees believed would stimulate action in solving overdraft and other agricultural problems of the area. Three recommendations directly affected the overdraft problem:

- "(1) As a means of securing greater efficiency in irrigation, we recommend that a study be made of water use of all crops for maximum production, such study to take into account soil type, irrigation layout, and particularly the advantages and disadvantages of reservoirs.
- "(2) Since soil and water conservation is essential to permanent prosperity in the valley, we recommend that studies and demonstrations of soil and water conservation be continued, with the establishment of soil conservation demonstration farms, soil conservation districts, and that a special study of water spreading possibilities be made . . .
- "(6) Since the obtaining of long-term credit is often dependent upon water supplies, we recommend the keeping out of, or removing from irrigation, undeveloped or sub-marginal land by a program of acquisition by district formation or otherwise. . ."

In addition, search for an experimentation with new cash crops were recommended for the area, to provide more diversity in agriculture as well as the possibility of less water consumption. Recommendations (1) and (2) were adopted at both conferences, but recommendation (6) was not adopted at the second conference. No meetings have been held since 1941.

Activities growing out of these conferences have had only small influence in combating overdraft in the Valley. Farmers have become aware of their tendency to over-irrigate, but have not been satisfactorily informed as to the amount of over-irrigation.^{2/} The possibility is discussed above (pp.107-110) that the crop-yield increases that result from applying more water than the minimum level may make rigid water conservation incompatible with profit maximization.

A direct outgrowth of recommendation (2) was the establishment, on July 22, 1941, of the Portal Ridge Soil Conservation District, comprising some

^{2/} Recommendation (1) called for study to determine "water use of all crops for maximum production, . . ." As yet no comprehensive investigation to determine minimum water requirements has been made in Antelope Valley. Consumptive use requirements have been estimated from comparison with other areas.

40,000 acres. Experience gained led to organization of the Antelope Valley Soil Conservation District, on June 20, 1944, including nearly the entire remaining area of Antelope Valley in Kern and Los Angeles counties. The Portal Ridge and Antelope Valley districts were consolidated in June, 1947, so that almost the entire Valley is now covered by one soil conservation district. District activities are discussed below.

The recommendations designed to encourage search for and experimentation with new cash crops for the area led to establishment of the Antelope Valley Field Station, of the University of California. Studies there have provided new crop possibilities by demonstrating the wide variety of crops physically suited to the area. However, more study is needed to determine economic crop suitability.

Recommendation (6), which called for the removal of land from irrigation, was abandoned after the first conference. Such action would reduce water consumption, but this means of attaining the objective was more offensive to many residents of the community than could be offset by the gains obtained. Even greater objection came from persons residing outside the Valley who owned land in the area and were (and still are) hopeful of speculative gains to be made in real estate sales.

The net benefit from these conferences is difficult to assess: Resulting awareness of overdraft in most portions of the Valley has increased local desire to combat the problem; but the rapid rate of agricultural development in the Valley has more than offset any gains provided by local farmers in combating overdraft.

Experimental Crop Investigations

Studies by the Antelope Valley Field Station have covered a large number of crops--primarily those with lower water requirements than those of alfalfa. Whether stimulated by Field Station studies or some other factor, noticeable acreage increases in irrigated grains and field corn have occurred since 1946. Some of this acreage was transferred from alfalfa enterprises, thus permitting the saving of water for the farms involved of about 1.2 acre-feet per acre per year. No saving of water for the entire Valley has occurred, however, because expansion of total irrigated acreage has increased annual net draft every year since 1942.

The net effect of recommendations to transfer from alfalfa to crops that consume less water has been insignificant so far as reducing overdraft is concerned. It is suggested that these crops may not be so financially profitable as alfalfa until total pumping lifts reach the range of 350 to 600 feet--unless other factors stimulate earlier transfer. (pp. 118-120).

Soil Conservation Service

Activities of the Soil Conservation Service were confined to a few demonstration farms prior to organization of the districts. Primary district activity has aimed at soil conservation problems, but some investigational projects have been undertaken in water-spreading and sprinkler irrigation.

Geological investigations in Antelope Valley have indicated that alluvial formations on the southern flank of the Valley would lend themselves to water spreading, done to recharge ground water.^{3/} The problem of water-spreading resolved itself into one of economic feasibility, depending upon the water supply available. A study based on runoff of Big Rock Creek (the only major stream adaptable to spreading operations) from 1923-24 to 1941-42 revealed that in only six of the eighteen years would spreading have been of benefit. Because of the rareness of flood runoff from this stream, the spreading systems considered were designed for water spreading primarily, and for flood control only incidentally.

The estimated costs of constructing spreading facilities on Big Rock Creek did not differ significantly from the known costs for constructing other spreading grounds in southern California. However, the average annual runoff to be spread from this stream was so small that the cost of putting one acre-foot of water into underground storage ranged from \$1 to \$2.75--from two- to ten-fold greater than for similar spreading grounds. The study concluded that construction of such facilities would not be economically sound. The geological structure of Antelope Valley is such that natural spreading and percolation of runoff from streams debouching into the Valley take place nearly as well as if from man-made spreading grounds (pp. 4-5, and 46-48).^{4/}

^{3/} Muckel, Dean C. Feasibility of Spreading Water at Mouth of Rock Creek in Antelope Valley, California. September 12, 1944. Typed Manuscript. This study is summarized in Ewing, P. A. The Irrigation Development of Antelope Valley, California. Soil Conservation Service, Berkeley, California. 1945. 57 p. Mimeographed.

^{4/} This is further substantiated by the fact that runoff from Big Rock Creek and Little Rock Creek during the recently concluded wet water-year of 1951-52 at no time came closer than eight to ten miles to the dry lakes in the center of the Valley. The runoff was absorbed into the alluvial fans rapidly and at the cost of only minor flood damage.

Sprinkler Irrigation Trials

The effectiveness and efficiency of sprinkler irrigation in Antelope Valley were studied on several small plots of alfalfa by the Division of Irrigation and Water Conservation of the Soil Conservation Service.^{5/} One significant result of this study concerned the small evaporation loss between the time the water left the sprinkler and fell on the ground. This was in spite of the windy conditions under which most of the tests were performed. Loss due to interception and evaporation was estimated by the Soil Conservation Service to be less than 2 per cent (for 6-inch applications) and within the experimental error of measurement.

Evaporation losses from flooding, on the other hand, may exceed 10 per cent of the total water applied. In the irrigation of alfalfa an annual application of 5 acre-feet applied by flooding could result in evaporation waste of .5 acre-feet. The same amount of water applied by sprinkler would evaporate about .1 of an acre-foot--a saving of .4 acre-feet per acre per year. If like savings could have been accomplished on each acre irrigated from ground water in Antelope Valley in 1951, over 21,000 acre-feet would have been saved, cutting estimated overdraft in that year by nearly 13 per cent.

It was nevertheless concluded that sprinkler irrigation cannot yet be definitely recommended in the Valley, because strong and unpredictable winds distort the water distribution pattern, making uniform irrigation difficult. Some sprinkling units are in use in the Valley at the present time. A longer history of experience with this wind problem is necessary before sprinkling can be recommended in the Valley as a means of saving water.

Zoning, Water Law, and Overdraft

Zoning ordinances utilize the police powers of the state to protect and promote certain types of land use and restrict others. Zoning regulations

^{5/} Litz, G. M., C. F. Bond, and W. W. Donnan. Sprinkler Irrigation Trials Antelope Valley Soil Conservation District. March, 1952. Typed Manuscript. A provisional report on irrigation investigations conducted by the Division of Irrigation and Water Conservation in cooperation with the Operations Division, Soil Conserveice, and the Antelope Valley Soil Conservation District.

do not call for the performance of specific acts but keep individual initiative in the use of land and improvements in predetermined channels.^{6/} Before discussing zoning in Antelope Valley, it is necessary to consider how zoning affects and is affected by water rights and conservation.

Ground-Water Law

Laws applying to ground water tend to be less definite and have developed more slowly than those applying to surface waters.^{7/} Court decisions have classified ground waters as (1) definite underground streams and (2) percolating waters. Most cases dealing with ground water in California have involved percolating waters, including waters of artesian areas not shown to be parts of definite underground streams.^{8/} No definite underground streams exist in Antelope Valley (except in the relatively small underflow areas of the major streams before they emerge into the Valley) so that only laws applying to percolating water are considered. California law presumes all ground waters to be percolating unless proven otherwise.^{9/}

Three general doctrines cover percolating water laws. The English or Common Law Rule of absolute ownership by the owner of the overlying land, applicable in California prior to 1903. But then the decision in *Katz vs. Walkinshaw* departed from this rule and adopted a modified form of the American Rule of Reasonable Use, which has come to be known as the California doctrine of correlative rights.^{10/} Court decisions since 1903 and noninterference by the legislature established the correlative rights doctrine as the

^{6/} Solberg, E. D. "Rural Zoning in the United States." Agricultural Information Bulletin No. 59. Washington, D. C., U. S. Bureau of Agricultural Economics, 1952. p. 4.

Solberg differentiates between land-use regulations and zoning. Land-use regulations "may be either positive or negative. That is, they may prohibit using land in a specified way, or they may order the proprietor to carry out certain practices." Zoning, on the other hand, does "not affirmatively call for the performance of specific acts." Land-use regulations, as defined by Solberg, are characteristic regulatory powers of soil conservation districts.

^{7/} U. S. National Resources Planning Board. State Water Law in the Development of the West. Washington, Govt. Print. Off., 1943. p. 69. Some of the reasons given for slowness in this area: (1) lack of knowledge of the physical conditions under the surface of the earth where ground water occurs; (2) the more ready availability of surface water; and (3) the expense involved in digging wells and pumping water.

^{8/} The President's Water Resources Policy Commission. Water Resources Law Vol. 3. Washington, Govt. Print. Off., 1950. pp. 717-718.

^{9/} Legal citations given in Wells A Hutchins, "Selected Problems in the Law of Water Rights in the West." Misc. Pub. No. 418. U. S. Department of Agriculture. Washington, Govt. Print. Off., 1942. p. 192.

^{10/} Ibid.

law of percolating water in California.^{11/} This rule accords to owners of land overlying a common ground-water supply equal rights for use on or in connection with their overlying lands, each to have a fair and just proportion where the supply is not sufficient for all. The landowner's right extends only to the quantity of water necessary for use on his land; any surplus may be appropriated for distant use.^{12/} Rights associated with proper overlying use (reasonable needs for beneficial purposes) are paramount. "The right of an appropriator, being limited to the surplus, must yield to that of the overlying owner in the event of a shortage."^{13/}

The third doctrine applicable to percolating waters under California law is the Appropriation Doctrine. No statutory procedures govern appropriation of surplus percolating water, although definite underground streams are covered by statute.^{14/} Appropriation of surplus percolating water is effected by diversion and beneficial use.

Antelope Valley Zoning Experience: Prohibition of Well Drilling

During 1944 property owners in Antelope Valley, particularly those active in the Portal Ridge and Antelope Valley Soil Conservation districts, became alarmed at the receding water levels and requested the Los Angeles County Board of Supervisors to take action. The intention of the request was to prevent drilling of wells for purposes other than what might be termed "very essential" needs, and also to prevent any property owner from drilling more wells on his property than was "absolutely necessary for the maintenance and development of his ordinary crops." New water development and new plantings to crops were to be stopped, temporarily at least. Los Angeles County Ordinance 4457 N.S., adopted by the Board of Supervisors on February 20, 1945 and effective thirty days later, zoned the area against further

^{11/} The President's Water Resources Policy Commission, op. cit., p. 718.

^{12/} For a summary of legal citations applicable to the California doctrine of correlative rights, see Ibid., footnotes 40 and 41, and Wells A Hutchins, "Selected Problems in the Law of Water Rights in the West," op. cit., pp. 192-204.

^{13/} "... unless the appropriator has gained prescriptive rights through the taking of nonsurplus waters." Pasadena vs. Alhambra, cited in the President's Water Resources Policy Commission, op. cit. The factors leading up to and associated with this decision are the subject of a special ground-water study (Raymond Basin) currently in progress by the Giannini Foundation of Agricultural Economics.

^{14/} State of California. Water Code, 1951. California Printing Division, Sacramento. See especially Division 2, Part 2, Chapter 1.

ground-water development unless specific exception is granted.

The main sections of the ordinance are as follows:

"Section 1. A person shall not drill any water well in . . . defined area of Los Angeles County portion of Antelope Valley until he first obtains a permit to do so from the Regional Planning Commission.

"Section 2. The Chief Engineer of the Regional Planning Commission shall grant a permit to drill a water well if:

- (a) He finds that such well is to be used exclusively for domestic purposes or for watering livestock, including poultry or both, or
- (b) He finds that such drilling of a water well is for the repair or replacement of existing wells and the water is to be used on land already under irrigation, or
- (c) An exception has been granted

"Section 4. The provisions of this ordinance do not apply to any municipality, district, governmental agency, or other public body in existence on the effective date of this ordinance, but do apply to all such public agencies formed after such effective date

"Section 6. This ordinance is enacted in contemplation of the preparation of a precise plan of the Master Plan of Land Use or the preparation of a Master Conservation Plan and precise plans thereof, or both, which plans are to be adopted in conformity with the Planning Act The Board of Supervisors . . . finds that the water table in . . . Antelope Valley is now so low and continuing to drop so rapidly that if restrictions upon the drilling of further water wells are not effective within the next thirty days the whole of such . . . area will be rendered unfit for agricultural use" ^{15/}

The ordinance as adopted was designed to preserve the status quo in Antelope Valley until a Master Plan of Land Use or Master Conservation Plan was prepared and adopted. The Los Angeles Regional Planning Commission had been conducting studies of Antelope Valley soil conditions with a view to working up a soil conservation plan. These studies were dropped, however, and "have not been resumed due to pressure of more urgent work." ^{16/}

Even before adoption of the ordinance, the Los Angeles County Counsel had warned the Board of Supervisors that such an ordinance would probably not be valid. ^{17/} After the ordinance had been in effect for several months, it

^{15/} Complete text of ordinance published in the Antelope Valley Ledger-Gazette, March 1, 1945.

^{16/} Communication from A. H. Adams, Director of Planning, the Regional Planning Commission to Victor W. Bruce, formerly Research Assistant, September 26, 1950.

^{17/} Letter dated November 15, 1944. A copy of this letter was procured for the present study by Mr. Bruce. The citation summarizing current legal opinion on this matter stated, ". . . if conservation be the end sought, it is not promoted by selecting a particular class of persons on an arbitrary basis and conferring special privileges on them and denying the same privileges to all others . . ." State ex rel. Bacich vs. Huse, 187 Wash. 75, 59 Pac.(2d) 1101, at 1105.

became evident that its constitutionality was being questioned. An action--Superior Court Case No. 506889 entitled Los Angeles County Farm Lands Company, a Corporation, Plaintiff vs. County of Los Angeles--was instituted for the purpose of testing the constitutionality of the ordinance.^{18/} In view of the impending suit and the opinion of the Los Angeles County Counsel, the Board of Supervisors repealed the ordinance on April 16, 1946, and the suit was withdrawn.^{19/} This ordinance was in effect slightly over a year during which time "many applications were made to the Regional Planning Commission for [well drilling] permits, most of which were granted." A few were denied, "on the grounds that the proposed use did not justify the drilling of an additional well."^{20/}

Because the ordinance was short lived and most applications for new wells were approved, it had little effect in lessening overdraft in Antelope Valley. No reduction in the trend of estimated draft was observed for 1945 (Appendix Table 7 and Figure 4.1). Any effect in subsequent years (had it remained in force) would have depended entirely upon the policy of the Regional Planning Commission in granting permits to drill new wells.

This attempt to combat overdraft by restricting irrigation development was not successful, even on a pro tem basis. The existing legal framework will not permit enforcement of an ordinance discriminatory between those who have already begun to farm and those who wish to begin in the future.^{21/}

^{18/} Over 100 plaintiffs, all owners of farm land in Antelope Valley, participated in this suit. The Los Angeles County Farm Lands Company, which held a "considerable amount of property," was nominal plaintiff. "All of the plaintiffs were farmers in the valley or were workers whose livelihood was directly affected by the proposed ordinance"--Communication from Loyd Wright, attorney for the plaintiff, May 16, 1952.

The Los Angeles County Farm Lands Company was organized in 1913, at which time 25,000 acres of land near Lancaster and Palmdale were purchased for "speculative purposes." No improvements were ever made to the land, and none was ever rented. Land has been sold in large (farm sized) and small (lot sized) parcels until only 160 acres remain. When this last holding is sold, the company will, for all practical purposes, cease to exist. Communication from P. E. Neuschaefer, Los Angeles County Farm Lands Company, July, 1953.

^{19/} Ordinance No. 4659 N.S., which repealed Ordinance No. 4457 N.S., was adopted April 16, 1946, and became effective thirty days later. South Antelope Valley Press, Palmdale, California. April 25, 1946.

^{20/} Personal communication from A. H. Adams, Director of Planning, The Regional Planning Commission, to Victor W. Bruce, formerly Research Assistant, August 23, 1950.

^{21/} For the reader interested in the complexities of ground-water law, a summary of source materials and citations may be found in Barta, P. M. Ground Water in California, op. cit., pp. 51-62.

A suggestion that land be retired from production so that a select area could be irrigated with the available ground water is not legally feasible, because it interferes with the property rights of land owners. Only if such land was owned by the state or some organization determined not to engage in irrigated agriculture but to sell ground water pumped from beneath the property for use on other lands would transfer of ground water from one area to another be possible. Presently existing patterns of ownership in Antelope Valley and the speculative interest in this land for future development make this possibility seem very unlikely.

Unless some change is made in the legal framework, it will remain impossible to bring all new developments in an area to a halt while methodical investigations of, and proposed solutions for, existing problems are determined. Comprehensive land and water surveys before an area is developed would permit regulated development (by zoning) at a pace and to such an extent that over-draft might be prevented entirely, or at least minimized.^{22/}

Following the repeal of Ordinance No. 4457 N.S., residents of Antelope Valley, through the Board of Directors of the Antelope Valley Soil Conservation District, made to the Board of Supervisors a new proposal, consistent with the opinions of the County Counsel. The proposal was that a county ordinance be adopted that would restrict the amount of water that could be pumped in any one season to a maximum of 5 acre-feet per acre per year. No action was ever taken on this proposal, probably because of the difficulties of enforcement and that "pressure of more urgent work" referred to earlier.

The major portion of zoning activity in Antelope Valley since the repeal of the short lived, discriminatory ordinance has focused on land use, without direct concern or interest in water-use problems. This may imply that the Regional Planning Commission would rather let nature take its course as far as the use of ground water for agriculture is concerned. As yet, the Master Plan of Land Use applying to Antelope Valley applies only to a relatively narrow strip across the Valley from, and including, Palmdale to, and including, Lancaster. This is the strip within which residential, commercial, and industrial expansions are anticipated; it includes very little of the area in the Valley devoted to irrigated crop production. Zoning that has as its focus point the water problems of irrigated agriculture has, at least temporarily, been moved into the background.

^{22/} Each area investigated, however, could present different situations, depending on the quantitative relationships existing between the flow and stock components of the ground-water resource and irrigable acreage.

Zoning to Eliminate Overdraft?

Zoning to combat overdraft would necessarily be based on the amount of water available for apportionment on a per-acre basis. It has been estimated that the average annual recharge for this area is approximately 40,000 acre-feet per year (p. 49). If zoning should be based on this volume of water, it would mean that at ultimate development each acre of irrigable land (approximately 600,000 acres) would receive less than one inch of water per year. No intensive agricultural crop enterprise could be supported by this amount of water established by zoning for ultimate development. But that would be the effect of proposed zoning in Antelope Valley to lead toward a "balance between the acres of irrigated land and the average water supply available in the Valley."^{23/}

One other method by which average annual recharge might be apportioned would be to reduce irrigated acreage in the Valley to a level that could be supported by this volume of water. The acreage that could be irrigated would, of course, depend upon the crop grown. Zoning could not dictate the crop to be grown.

As a first approximation, the high water-consuming crop of alfalfa may be used as a standard. Allowing 5 acre-feet per acre per year, average annual recharge would support 8,000 acres of alfalfa. This is less than one-quarter of the present alfalfa acreage in the Valley and means that ownership of nearly 600,000 acres of irrigable land would have to reside in the hands of the public in the form of governmental (state, county, etc.) or quasi-governmental (district) ownership; or if in private ownership, zoned against agricultural use. The volume of annual pumpage accorded to this large holding by its water rights could then be sold to the farmers operating the 8,000 acres of alfalfa.

Conversion to crops that consume small volumes of water might be brought about indirectly, by expanding the amount of land to be privately owned and cutting the amount of water sold (per-acre basis) to each farmer. For example, expanding the acreage from 8,000 to 16,000 would cut the amount of water sold annually to private holdings from 5 acre-feet per acre to about 2.5 acre-feet per acre. Such measures could make zoning effective in eliminating long-run overdraft in Antelope Valley, but associated

^{23/} Letter from Los Angeles County Counsel, op. cit., p. 1.

difficulties appear to preclude it: Water available each year--the ground-water flow resource--is not sufficient to support a valley full of intensive agricultural enterprises dependent on irrigation; necessary supervision and metering to guarantee that draft on ground water would not exceed 40,000 acre-feet per year would be a barrier.

An alternate suggestion--cutting total irrigated acreage perhaps to less than 20,000 acres--is probably not feasible from a political point of view. It would be necessary to acquire public ownership of nearly 600,000 acres, which would entail enormous expenditures.^{24/} Public ownership would be necessary to acquire the overlying water rights so that pumpage could be controlled effectively. If such acquisition could be accomplished, this plan would be feasible from a legal viewpoint. But economic infeasibility arising from a basic resource imbalance between water and land apparently preclude the adoption of government proprietorship as a tool of resource conservation.

It is concluded that zoning to eliminate long-run overdraft is not probable. The relation between irrigable acreage and recharge would not permit annual pumping at a volume approximately equal to average annual recharge. Thus, proposals to limit draft to the physically determined safe yield of this area (average annual recharge of 40,000 acre-feet) must be discounted if intensive irrigated agriculture is to remain in the Valley.

Zoning to Conserve Ground Water

Conservation is defined as "... changes in the intertemporal distribution of use. In conservation, the redistribution of use is in the direction of the future; in depletion, in the direction of the present."^{25/}

A differentiation was made between the flow and the stock components of the Antelope Valley ground-water resource (Chapter 3). It has been suggested that relatively little can be done to affect the magnitude of the flow resource, which fluctuates according to climatic fluctuation. For the most part, it serves to recharge the stock component as efficiently as possible (pp. 41-44). It would seem that conservation measures must be directed at the stock component of the ground-water resources.

^{24/} Private land is currently selling for \$500 to \$1,500 per acre, depending upon location and conditions and purpose of the sale.

^{25/} Ciriacy-Wantrup, S. V. Resource Conservation, Economics and Policies. Univ. of California Press, Berkeley, 1952. pp. 51-53.

Any measure to effect a redistribution of ground-water use rates of the stock resource in the direction of the future would be a conservation measure. This purpose could be served to a greater or lesser degree by several courses of action: reducing the volume of irrigation applied each year, changing to crops that use smaller volumes of water per acre, etc. In Antelope Valley none of these measures would have been sufficient of themselves to eliminate long-run overdraft; they would have been only conservation measures, shifting long-run overdraft into the future.

Zoning to conserve the ground-water stock resource is feasible within the existing legal framework. Zoning that specifies the amount of water to be used per unit area of land is possible, but the type of crop to be grown could not be regulated directly. A restriction as to the amount that each owner may pump would probably be justified under the police power as ". . . an adjustment of conflicting private rights and the apportionment of a common property right among the several owners. . . ." ^{26/} Furthermore, a court has said, in upholding the constitutionality of an Orange County ordinance regulating the use of water from pumping wells and prohibiting the waste of water therefrom:

"Legislation with respect to water affects the public welfare and the right to legislate in regard to its use and conservation is referable to the police power of the state. . . . [The ordinance] has for its purpose the conservation of subterranean waters, a legitimate field for the exercise of police power . . . it seeks to prevent the undue waste of the percolating waters within the County of Orange, thereby conserving said water and materially benefiting the public welfare. . . ." ^{27/}

Assuming that intensive irrigated agriculture will remain in the Valley, zoning could specify a maximum volume of pumpage on a per-acre basis, thus giving all property owners an equitable share in the ground-water stock. The level could be set to control--indirectly--the crop grown (i.e., high water user or low water user). Such zoning would tend to cut down annual draft rates, shift the rate of use of the resource into the future, and thus be a conserving action.

Such zoning would have problems of enforcement. Maintaining pumpage volumes at the specified level would require adequate supervision and metering of volume of draft for each irrigation pump in the Valley. This would be expensive, both in terms of money and time.

26/ *People vs. New York Carbonic Acid Co.*, 196 N. Y. 421, 90 N. E. 441, at 448.

27/ *In re Maas*, 219 Cal. 422, 27 Pac. (2d) 373, at 424 and 425 of 219 Cal.

As a possible alternative to actual metering of pump draft, an enforcement agency could approximate the results by keeping crop acreage records for each property holding. If water allotments were set at 2.5 acre-feet per acre per year, a farmer operating 160 acres could grow one-third of this acreage in alfalfa, fallow the remainder, and be assumed to be within his permissible volume of pumpage.^{28/} If the entire acreage were devoted to irrigated cereals or vegetable crops, it could be assumed the farmer was not pumping more than his allotted volume. This would not be as accurate as metering pump draft, but it could be operated at lower cost to the enforcement agency and would presumably not be greatly in error.

This type of zoning ordinance would probably not be instituted without some opposition, but it appears to be legally and technically feasible. Furthermore, it would serve to conserve the ground-water stock resource of Antelope Valley.

"Pay as You Pump"

Overdraft experience in Orange County, California,^{29/} has centered around a localized problem similar to that of Antelope Valley: During the period of early settlement an abundant artesian ground-water resource was exploited until pressure was reduced to the point where pumping became necessary. As early as 1920 it became evident that more water was being extracted from the ground-water reservoir than was being replenished by natural recharge. By 1951 estimated annual net draft on ground water amounted to 203,000 acre-feet, while average recharge is 136,000 acre-feet per year.

Salt water from the ocean has infiltrated the ground water until nearly 5,000 acres of land along the coast are now underlain by ocean water. It has

^{28/} In this situation, the farmer could apply as much as 7.5 acre-feet to each acre in alfalfa and still not exceed his allotment. If he were to apply only 5 acre-feet per acre to alfalfa, he could devote one-half of his acreage to this crop and fallow the remainder. Such situations, however, would not necessarily constitute economic units of operations.

^{29/} Information on Orange County ground-water problems is from the following reports: Browning, C. R. "Contribution of the Flow of Santa Ana River to Coastal Basin Replenishment or Beneficial Use in Acre-Feet." Tustin, Calif., August, 1952, 7 p. Processed. (Report by C. R. Browning, Consulting Civil Engineer.)

Miller, W. D. "To the Citizens Water Conservation Committee." Santa Ana, California, August, 1952. 8 p. Processed. (Report by W. D. Miller, Secretary of the Orange County Water District.)

Shafer, Ross A. "Statement to Joint Legislative Interim Committee on Water Problems, Re: The Proposed Plan for the Replenishment of the Coastal Basin of Orange County, California." Orange County Water District, Santa Ana, October, 1952. 8 p. Processed.

been estimated that restoration of 1920 water (and pressure) levels would halt further salt water encroachment. Restoring those levels would require a recharge volume to ground-water storage of about 375,000 acre-feet. Annual recharge importations must overcome this accumulated deficit (cumulative overdraft) as well as average annual overdraft. Geologic conditions are such that recharge can be accomplished without large-scale construction of spreading basins.

Two major problems were involved in this solution: (1) where to get the necessary volumes of water, and (2) how to pay for it? The first question was answered by obtaining water from the Metropolitan water district, which controls Colorado River water delivered to the Los Angeles and San Diego areas. A Metropolitan feeder line is conveniently located to discharge water into a natural percolation area. A new feeder line can be constructed to route water to an area where spreading grounds may be necessary.

Although the second question has defied answer for many years, the recent passage of Senate Bill 91, an amendment to the Orange County Water District Act, may not only solve the overdraft problem of Orange County but also set a pattern for solving some types of localized overdraft problems in other areas.^{30/} The act sets forth its major purpose as the replenishment of the underground water supplies of the Orange County Water District.

Two methods are specified to provide payment for the water necessary to fulfill this objective:

The first method allows the district to levy a general tax not to exceed eight cents per \$100 of assessed valuation of real property including improvements. The funds will be used to buy the necessary recharge volume of 375,000 acre-feet. Assessed valuations vary from less than \$300 per acre for ordinary cropland to a top of about \$1,300 for the best orange groves. Estimated total annual income to the district from the tax levy (agricultural and nonagricultural) would be about \$280,000 per year. Water purchases from this tax fund may be used to overcome cumulative overdraft only, and are to be limited to 25,000 acre-feet in any one year and 375,000 acre-feet in aggregate. This will protect non-farm property owners from subsidizing payments for water necessitated by overdraft induced by farmers.

The second method allows the district to make a pumping assessment not to exceed \$5.50 per acre-foot on ground water pumped within the district. This

^{30/} California, Statutes of 1953, Chapter 770. Deering's California General Laws, No. 5683.

money will be used to import the water necessary to offset a continuing annual overdraft. Computing at the maximum pumping levy for an estimated annual pump draft of nearly 200,000 acre-feet, the district income from the pumping levy would exceed one million dollars. For the individual farmer, assumed to be pumping ground water at an average cost of \$4.50 per acre-foot, total cost of pumping plus the levy would be \$10.00 per acre-foot--or less if the pumping assessment is less than the maximum. The total water cost paid by the farmer will vary with crop, irrigation practice, soil type, cost-price and climatic variations, etc. But for most crops and "average" situations the figures of \$8.50 to \$10.00 per acre-foot are not unreasonable. Every well in the district must be registered on or before January 15, 1954. Water meters will be installed on all wells sometime after that date. It is hoped that the plan will be in full operation by 1955, when the first extraction tax will be available.^{31/}

District income from both the land tax and pumping levy may exceed one and one-quarter million dollars per year, which will be enough to wipe out accumulated overdraft in the Orange County Water District and to balance out continuing annual overdraft. One of the major advantages of this plan is that it does not, insofar as can be determined at the present, interfere with the water rights of individual property owners any more than does any ordinary property tax. Furthermore, it dictates payment in proportion to the amount of ground water used by each pumper. Each individual pays to overcome local overdraft to the extent that he contributes to it.

Can the Orange County Plan Work in Antelope Valley?

Many points of similarity exist between the Orange County ground-water economy and that of Antelope Valley. The major point of difference is the magnitude of overdraft: Current annual overdraft in Orange County is approximately one-half that in Antelope Valley. Restoring 1920 water levels would require 375,000 acre-feet in Orange County, but about 2,000,000 acre-feet in Antelope Valley.

The first problem to be solved would be to organize a district for Antelope Valley that would have the powers necessary to levy both an ad valorem land tax and a use-charge pumping assessment. The Antelope Valley Soil Conservation District does not possess such powers, but two county water districts (in the Los Angeles County and Kern County portions of Antelope Valley) could be organized with sufficient powers. They would have to work

^{31/} Personal communication. W. D. Miller, Secretary, Orange County Water District. July 13, 1953.

closely in order to administer the activities involved in combating overdraft in the Valley. Perhaps a better district form would be a Water Storage and Conservation District that would encompass the entire Antelope Valley, thus minimizing administrative problems. If it is assumed that such a district can be formed in the Valley, are the other problems soluble?

What sources of water could be used to recharge the Antelope Valley ground-water stock resource?

The Owens Valley-Los Angeles Aqueduct crosses the western end of the Valley, transporting slightly more than 300,000 acre-feet per year. Water could be spilled into dry stream beds for natural recharge, or delivered by gravity through conduits to most areas of the Valley for direct irrigation. But the Los Angeles Department of Water and Power cannot provide water to Antelope Valley, for legal, physical, and economic reasons.^{32/}

Los Angeles' water rights in Inyo and Mono counties are appropriative and limited to the use of the City and its inhabitants unless surplus water exists--and none does. The exchange or sale of aqueduct water for use in the Valley would require the assent of two-thirds of the qualified voters of the City. Costs associated with the purchase and distribution of Metropolitan water, plus loss of revenue from power generation by aqueduct water below Antelope Valley, raise impassible economic barriers, even if the legal and physical obstacles could be overcome. Supplying water to Antelope Valley from the Los Angeles Aqueduct is not feasible.

Direct supply of water to the Valley from the Metropolitan Aqueduct (Colorado River water) is not technically feasible, because of differences in elevation--Antelope Valley being much higher than the Metropolitan outlets. The cost of lifting the water into the Valley, plus prior water rights by other areas of metropolitan Los Angeles, tends to exclude this water as a possible source of water for Antelope Valley agriculture.

Feather River Water is priced too high (\$50.00 per acre-foot) for Valley farmers (pp. 51-52 and 127-128). Unless the cost to farmers is at least partially subsidized, Feather River water does not present a probable water supply for Antelope Valley agriculture.

If a firm water supply could be provided at prices Valley farmers could afford, a plan similar to the Orange County Water District Plan could stem long-run overdraft in the Valley. The only alternative is for Valley farmers to conserve their limited stock resource as efficiently as possible.

^{32/} Communication, S. B. Morris, General Manager, Department of Water and Power, the City of Los Angeles. December 30, 1953.

State-wide Activity

The state of California has watched the water situation for many years. The Division of Water Resources has engaged in irrigation, drainage, and water-development investigations and programs, and is currently conducting cooperative investigations in Antelope Valley with the Los Angeles County Flood Control District and the U. S. Geological Survey.

The State Water Resources Board has been created to make state-wide investigations of water resources, their use, and their development. Recent land-utilization surveys made by the Division of Water Resources have been directed by the State Water Resources Board. The proposed Feather River Aqueduct, one of several developments from these investigations, appears to be one possible means of combating and perhaps eliminating overdraft in Antelope Valley and in other ground-water areas along its route that may be suffering from water shortages.

The California Division of Water Resources

Requested by House Resolution No. 101, adopted February 16, 1946, to survey the water supply of Antelope Valley and recommend means of assuring adequate water supply and underground water table conditions in Antelope Valley, the Division of Water Resources conducted a study and made recommendations as follows:

- "1. Every effort should be made to reduce consumptive use in the Valley through the substitution of higher duty crops. ^{33/} Studies with this end in view are now being carried out by the Soil Conservation Service, County Farm Advisors and others, and the efforts of influential local organizations should be continued.
- "2. Studies by the Soil Conservation Service and the University of California relative to improved irrigation practices and possible salvage of waste should be encouraged. The fact that this waste may be small does not justify neglecting it if it can be salvaged at a cost commensurate with the benefits derived.
- "3. Measurements of depth to ground water made by the United States Geological Survey and Los Angeles County Flood Control District, and analysis by the Division of Water Resources based on these measurements should be continued, to augment crop data presented annually by the County Agricultural Commissioner in a periodic appraisal of the situation.

^{33/} As used here, the term "higher duty" is synonymous with the term "lower water consuming."

- "4. As lands go out of production because of economic pressure or from other causes, they should be acquired and held by a properly constituted public agency. Lands sold to the State for taxes should not again be put on the open market. If publicly owned, these lands could still be used under lease or permit, but with cropping and water use restricted."^{34/}

Direct benefits from these recommendations have been small. The first three merely recommended the continuation of existing experimentation and research. The fourth recommendation is a synthesis of a recommendation arising from the 1940 Building Conference and certain legal opinions discussed previously. As far as can be determined, no specific action has ever been taken on recommendation 4.

The State Water Resources Board

This Board was organized in 1945 to investigate California's water resources. In 1947 the Board was authorized to make, and funds were appropriated for, a thorough state-wide water investigation.^{35/} The investigation continues to be conducted by the Division of Water Resources as requested and directed by the Board.^{36/} Antelope Valley is included as one of several areas in the state faced with the problem of a water supply inadequate to the needs of ultimate development.^{37/} The proposed Feather River Project is another State Water Resources Board activity. As a result of State Water Resources Board activities, actions have been taken that may ultimately alleviate southern California's water shortage in general and Antelope Valley's in particular.

In August, 1951, two applications were filed to appropriate 5,000,000 acre-feet of water annually and divert it from Feather River, Italian Slough, and Old River for use in "Areas south of Tehachapi Mountains" (i.e., southern California) and other areas south of the Sacramento-San Joaquin Delta area. The applications were filed on behalf of the Department of Finance of the

^{34/} State of California, Department of Public Works, Division of Water Resources. Report to the Assembly of the State Legislature on Water Supply of Antelope Valley in Los Angeles and Kern Counties. Pursuant to House Resolution 101 of February 16, 1946. Sacramento, Calif. State Print. Off., May, 1947. 22 p. Mimeographed.

^{35/} State Water Resources Board. "Water Resources of California." Bulletin No. 1. Sacramento, California, 1951.

^{36/} The Division of Water Resources conducts these investigations as requested and directed by the State Water Resources Board.

^{37/} Bulletin 2 of the State Water Resources Board will describe the relative imbalance between available water and water requirements when the various areas have expanded irrigated acreage to their maximum potential.

state of California by James S. Dean, Director of Finance, pursuant to Section 10500 of the Water Code of California.^{38/} No specific amount of water has as yet been allocated to Antelope Valley under either of these applications or to other areas in the category covered by "Areas south of Tehachapi Mountains." The Feather River Project has not yet been authorized for construction; only preliminary investigations have been launched.

It has been suggested above (p. 145) that the initially listed sale price for Feather River Project water of \$50.00 per acre-foot in areas south of the Tehachapi Mountains is more than agricultural users in Antelope Valley can pay. Thus far, water importations into southern California have been stimulated primarily by nonagricultural pressures. Urban users (residential, commercial, and industrial) have exhausted local water supplies, and can afford to pay the costs associated with water importations. For example, in the city of Los Angeles--during the period 1946-1949, inclusive--payments by residential water users amounted to \$66.38 per acre-foot. Commercial water users during the same period made payments averaging \$53.64 per acre-foot, while the few sales for agricultural irrigation averaged only \$6.78 per acre-foot. The average billing for all classes of water users averaged \$46.16 per acre-foot. These rates of payment for nonagricultural use are not out of line with the suggested sale price of \$50.00 per acre-foot for Feather River water in areas south of the Tehachapi Mountains. The question that requires an answer in such situations is to what extent agricultural water-users should be subsidized by nonagricultural water-users--if at all.

Technology, ability to pay, need for water, and other institutional factors tend to favor solving water-shortage problems by transferring water from surplus to deficit areas. But the possibility is serious in some areas that such a solution may be temporary--even if economically, physically, and legally feasible.

Notwithstanding the obstacles to water importation, it became increasingly apparent during this study that in Antelope Valley the only permanent method whereby long-run overdraft can be materially reduced involves the importation of outside water. Sufficient acreage reduction to eliminate or even materially reduce long-run overdraft in the Valley cannot be attained unless economic pressures force out marginal producers as the economic limits of pumping are reached. Even then, political pressures might be brought to bear to force some other solution.

^{38/} Communication, A. E. Edmonston, State Engineer.

Combating Overdraft

Investigations and action programs launched in Antelope Valley have, for the most part, led to only slight gains in the battle against overdraft, although data on water use have been accumulated that are of value in analyzing overdraft. Agricultural development of the area has proceeded at such a rapid rate that individual on-the-farm gains have been more than offset by water use of new development. Zoning attempts have been either legally unsound or too difficult to enforce.

Specific actions and measures against long-run overdraft are seriously affected by two sets of conditions: First, the physical resources available and their potential balance or imbalance can easily make it extremely difficult to control or limit overdraft. Second, economic factors that dictate resource utilization may be so strong as to offset measures designed to combat overdraft.

If, as in Antelope Valley, the local economy is developed far beyond the capacity of the flow component of the ground-water resource, with consequent "mining," no simple solution to overdraft is in sight. If some form of a "pay as you pump" plan, similar to that of the Orange County Water District, could be developed for Antelope Valley, it is possible that overdraft might be controlled and eliminated. The enactment and enforcement of zoning measures to eliminate overdraft in the Valley is not probable. Unless a "pay as you pump" plan can be put into effect early, the best that can be done is to act so as to conserve the ground-water stock resource as long as possible.

Economic pressures will eventually bring about a more or less gradual shift out of agriculture as the economic limit of pumping is approached. Urbanization may soften the harshness of such a transfer and also act to subsidize the importation of water to the area. Such importation would increase the flow component either directly (water stored underground) or indirectly (importations substituting for ground-water draft). The magnitude of importation and the extent of urbanization would determine the degree to which overdraft would be decreased.

Chapter 9

ANTELOPE VALLEY--The Lessons Learned

The physical and historic backgrounds to overdraft in Antelope Valley have been presented, as well as the physical and economic aspects that have caused this problem and influenced its growth. Investigations and action programs developed in efforts to combat overdraft have been discussed and their effectiveness evaluated. This final chapter concludes the present study with a consideration of the implications of the experience in Antelope Valley--the lessons learned.

The earliest settlers in the Valley attempted large-scale developments of the surface streams and discovered that the water supply was inadequate to support proposed developments. Dry farming is dependent upon a variable and unpredictable rainfall. Extended dry spells forced abandonment of both dry-farmed and surface-irrigated developments. Pumping lifts around the border of the Valley were too great to permit irrigation of crops.

The discovery and development of flowing artesian wells prompted a rebirth of agriculture. After the warning from earlier failures, growth of the irrigated area in the center of the Valley proceeded slowly but steadily. The coincident location of artesian wells and alkali-infested soils restricted the area that could be developed initially. Although the ground-water stock resource was used at a rate less than the annual flow volume, wasteful (unrestricted) flow from the artesian wells brought about a gradual decline in artesian pressures and a shift to pumps in order to supply sufficient water to irrigate the crops. In spite of the falling water table, improved technology and favorable cost-price structures stimulated continuity of agricultural growth. Wells ceased to flow and the water table dropped. The more the area was developed, the more rapid was the decline in ground-water levels.

Residents of the Valley began to be concerned with the declining water table and requested that something be done to help them. Investigations and action programs have evolved, over the past twenty years, in various attempts to combat overdraft. These have added to stores of knowledge but have not materially affected overdraft. Long-run overdraft, continuing at an increasing rate, is the ever-present problem of Antelope Valley.

The Ground-Water Flow Resource

In studying ground-water problems on a regional basis, one of the first duties of the investigator is to inventory the resource. A complete inventory will take into account all elements contributing and affecting recharge and discharge (including draft). Early in this study a differentiation was made between the stock and flow components of the ground-water resource--a differentiation that made easier the subsequent analysis.

Early settlers in the Valley discovered that the flow resource or recharge component of the ground-water inventory was, in the form of stream flow for surface diversion, inadequate to maintain large agricultural development. Measurement of this component through the years has proven the settlers to be correct.

The measurements for Antelope Valley as discussed in this paper indicate that an easier and just as accurate form of measurement as those currently in use may be found in simple correlations between precipitation and runoff. These correlations presuppose hydrologic similarity between observation stations (precipitation and runoff), but do not seem to require geographic proximity. Thus, preliminary investigations for areas with scant precipitation and runoff data can be expected to yield reasonably accurate estimates of runoff by relating available data in the one area with long-run, reliable precipitation data in hydrologically similar areas. Only seasonal (yearly) data have been investigated in this study. Further refinement, involving shorter periods of time in order to determine flood-flow runoff characteristics in relation to precipitation, will be necessary before this relationship may be used for any period less than seasonal data.

The Ground-Water Stock Resource

The ground-water stock of an area (volume of ground water in storage) may be estimated, but not with great accuracy. One needs to determine the volume of alluvial fill that holds ground water, and then the percentage of pore space in this fill that is--or can be--occupied by water (specific yield measurements). The magnitude of the stock resource, as estimated in this paper, was found to be very large compared to the magnitude of the flow resource, and relatively large compared with the irrigated acreage in Antelope Valley. The situation becomes more complex if artesian pressures mislead the investigator. In some other areas, precise discrimination between artesian and nonartesian aquifers is possible, but not in Antelope Valley: All the aquifers at depths below eighty feet are subject to artesian pressure more or less,

because of the pervasive interconnections between aquifers throughout the Valley alluvium. In attempting to estimate changes in volume of ground-water storage for the Antelope Valley, and thus estimate net draft on ground water, these artesian pressures and the scarcity of data combined to invalidate the computations.

Comparing characteristics and magnitudes of the flow and stock component of the ground-water resource, a most important physical fact is revealed: a small, highly variable flow resource has created a large stock resource that can be mined to provide water for agricultural and other uses.

Ground-Water Draft

The estimates of draft on ground water developed in this paper indicate that, although all estimates are more or less subject to error, those based on electrical power consumption are the most reliable. Not only do these estimates reflect acreage variation in an area, as do consumptive-use estimates of net draft, but they also reflect climatic and price-of-product variations, which consumptive-use estimates do not. In areas where the accounting zone for electrical power consumption coincides with the ground-water basin, this form of estimate may be made with relative reliability. The degree of reliability will depend upon the importance as a power source of electric energy relative to other forms of energy, and the availability of supplementary information in terms of pumping lift and efficiency of pumping.

If data are available on return recharge or irrigation efficiency in the area, then estimates of gross draft may be converted to estimates of net draft, the latter form of estimate being necessary in order to quantify and differentiate the several types of overdraft. Estimates of net draft are particularly difficult because of the problem of obtaining this information.

Types of Overdraft

A better understanding of the problem of overdraft is afforded by a logical, analytical differentiation of different types of overdraft. Overdraft per se may not be a "bad" element in ground-water utilization. Initial development of an area may necessitate developmental overdraft in order that ground-water storage space will be available to absorb recharge to ground water in years (or periods) of greater than normal runoff and recharge. By analogy, a farmer who observes a decline in water levels in his well during the course of the pumping season and a recovery during the season of nonuse

will not be much concerned, although he is observing the manifestation of seasonal overdraft.

In an area where long-run average annual recharge and draft are in approximate balance, the occurrence of a declining water-table level over several years' time indicates only the presence of a cyclical overdraft. Cyclical overdraft is not cause for alarm, as water-table levels will rise again during the wet phase of the cycle. Thus, declining water levels in themselves are not necessarily an indication of long-run overdraft.

If, however, it is observed that water levels continue their recession during wet periods as well as dry, indicating that the acreage under irrigation consumes more water each year than is supplied to the stock under draft, then concern over the utilization of the resource is proper, because long-run overdraft is a feature of the ground-water economy. Long-run overdraft, as well as the other types differentiated, is present in Antelope Valley. It may well be that other areas, both in and out of California, are likewise suffering from long-run overdraft, but only careful consideration of the entire physical make-up of an area will prove this supposition. Declining water levels alone may be misleading.

Physical Factors and Economic Forces

No matter how exhaustive the study, a purely physical description and inventory of a ground-water problem-area is not apt to lead to action that will stem overdraft. For that matter, coupling intensive study of economic facts and factors with the physical study will not necessarily lead to elimination of overdraft. Antelope Valley has been the scene of both physical and economic studies, yet long-run overdraft appeared and is continuing at increasing rates. Overdraft has been stimulated and perpetuated by economic forces; and only their reversal or their cessation will eliminate overdraft in the Valley without some other intervention.

Pumping Costs and Overdraft

The factors that determine pumping costs have been pointed out as the prime reasons for continued agricultural development in Antelope Valley. A large stock of ground water served as the supply of irrigation water as soon as pumping became physically and economically possible. Removal of the stock has brought about declining water levels and increased pumping lift, which tend toward increased pumping costs, other things being equal.

But other things have not been equal. The average costs of pumping ground water have decreased relative to total costs of production for alfalfa,

the leading crop in the Valley. Substantial decreases in the unit cost of electrical energy have permitted pumping from greater depths than initially, but an increase in electrical energy rates will reverse this trend. Shifts from gasoline and diesel fuels to electrical energy as power source have lowered the cost of pumping per acre-foot, thus permitting pumping from greater depths. The use of large motors (over 100-H.P. demand-horsepower rating), stimulated by a falling water table and large pumping volumes, permits pumping at lower cost than with small motors. Increasing the volume of pumpage per unit of land area may also lead to increased monetary returns, thus stimulating the application of greater than minimal amounts (consumptive use plus minimum allowance for wastage) of irrigation water.

Technological advancement is the phrase summarizing the factors that have served to offset the rising pumping costs associated with declining water levels. Changes in size, type, and efficiency of pumps, and changes in energy source and cost of the energy, have kept pumping costs down relative to total production cost. These factors serving to decrease relative pumping costs have also served to stimulate long-run overdraft. So long as technological innovation can keep ahead of the increasing costs associated with a declining water table, overdraft in this and similar ground-water economies will continue.

Under the conditions described in this study, the management income generated by mining the ground-water stock for only four or five years has exceeded the perpetuity income value that would be generated by maintaining a balance between recharge and draft. Income generated since initial development as a result of mining the stock probably exceeds the sustained income by many times. Economic forces have stimulated and perpetuated long-run overdraft in Antelope Valley. It is to be anticipated that these forces, as in the past, will similarly stimulate overdraft in other areas where an imbalance of resources permits overdraft to occur.

Economic Limits to Pumping

One solution to long-run overdraft in Antelope Valley may be the gradual elimination of irrigated farming enterprises as the limit of pumping (maximum economic total pumping lift) is approached. Under the set of assumptions used in this paper, a total pumping lift of about 500 feet represents the present limit. The economic pumping lift is not a static concept, however, and will change over time. It has been suggested that irrigation at or above current levels for the entire area may result in such an overdraft rate that these limits will be attained sometime after the year 2000. As this limit is

approached, less-efficient operators will gradually be forced to abandon irrigation enterprises, leaving only the most efficient to maintain their activity, unless political pressures are brought to bear to subsidize the less-efficient operator. Such abandonment would tend toward a balance between recharge and draft, eliminating overdraft.

Predictions of the consequences of observed and postulated actions, and possible dates of the occurrence of these consequences, have been made. Such predictions are not as accurate as desirable, because of the necessity of using a series of static conditions to predict the outcome of a dynamic situation. Changing economic factors governing ground-water utilization have been pointed out in this paper. It is hoped that future developments and trends, as they are observed, will permit refinement of the prediction. It is possible that a changing environment (rural to urban) may solve the problem of overdraft because of a greater financial ability to import water to the Valley from areas with a water surplus. Regardless of how the features of the Antelope Valley ground utilization may change in future years, some change will occur. Only close and continued contact with a ground-water region will permit accurate appraisals of the ground-water problems. It is unlikely that a single, simple proposed solution to a given problem will stand for all time, because of the changing character of the problem and the factors that determine it. Determining the economic limits of pumping is a continuous research activity rather than an isolated observation in the flow of time.

Combating Overdraft

Specific actions and measures effective in eliminating long-run overdraft are affected by two sets of conditions: First, the physical resources available and their potential balance or imbalance can, as in Antelope Valley, make control of overdraft extremely difficult. Second, economic factors dictating resource use may be so strong as to offset any actions designed to combat overdraft.

If a ground-water flow resource is, or can be, modified to support an economically desirable agricultural economy, then the existing legal framework governing ground-water use can be effective in controlling overdraft. Some changes in type of farming may be necessary, but no great imposition would be placed upon an individual farm or farmer. No large-scale or sudden changes would occur that could necessitate an equally large-scale transfer of workers

out of agriculture into other occupations, or an exodus from the area. Annual and cyclical variations in recharge would be absorbed by the ground-water stock and pumping lifts could be maintained at a relatively stable level.

If, as exists in Antelope Valley, a local economy is already developed far beyond the capacity of the ground-water flow resource, no simple solution is in sight. If a firm supply of imported water can be provided at a price that Valley agriculture can pay, some form of plan similar to the Orange County Water District Plan may reduce and eventually eliminate long-run overdraft. Enforcement of zoning measures necessary to eliminate overdraft in Antelope Valley is not feasible, unless imported water could be provided at a price Valley farmers could afford. Without a firm supply of inexpensive imported water the best that can be done--legally, economically, or politically--is to conserve the ground-water stock, allowing long-run overdraft to continue, though delayed.

Economic forces will bring about a more or less gradual shift out of agriculture as the economic limit of pumping is approached. Urbanization may not only soften the harshness of such a transfer but also act to subsidize, in part at least, the importation of water to the area. Importation from surplus to deficit areas--which is favored by technologic, economic, and political factors--would increase the ground-water flow-resource through direct addition to the stock each year or through use in direct surface diversion.

Further experience and research with a firm water import plan is necessary to determine what levels of water use would result in a balance of ground-water flow-resource (recharge plus imported water) and draft. Barring imported water, long-run overdraft in Antelope Valley and similarly characterized areas will continue until economic forces bring a balance between recharge and draft.

APPENDIX TABLE 1
Precipitation Summary^{a/}

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual average
<u>Backus Ranch^{b/}</u>													
Greatest monthly	3.90	5.63	5.19	1.74	0.72	0.54	0.47	0.63	1.62	1.26	2.67	6.14	
Mean monthly	0.91	1.57	1.51	0.28	0.10	0.06	0.03	0.11	0.27	0.28	0.40	1.63	7.15
Least monthly	0	0.17	0.22	0	0	0	0	0	0	0	0	0	
Greatest daily	1.74	2.03	1.68	0.57	0.43	0.54	0.47	0.63	1.60	0.75	1.18	2.81	
<u>Fairmont^{d/}</u>													
Greatest monthly	13.77	11.10	9.50	5.69	2.10	0.53	0.28	1.30	2.63	2.30	6.41	12.06	
Mean monthly	3.17	3.36	2.52	0.89	0.32	0.05	0.02	0.12	0.24	0.49	0.88	2.93	14.99
Least monthly	T	0	T	0	0	0	0	0	0	0	0	0	
Greatest daily	7.60	4.50	4.00	2.10	1.00	0.36	0.28	1.07	1.37	1.85	3.36	5.30	
<u>Llano^{e/}</u>													
Greatest monthly	7.45	8.06	5.06	4.31	1.44	1.50	1.50	1.60	1.86	3.01	3.40	7.78	
Mean monthly	1.26	1.47	1.26	0.54	0.16	0.07	0.12	0.25	0.20	0.38	0.46	1.44	7.61
Least monthly	0	0	0	0	0	0	0	0	0	0	0	0	
Greatest daily	6.45	4.15	2.27	1.24	1.00	1.05	1.50	1.13	1.58	1.21	2.05	2.75	
<u>Palmdale^{f/}</u>													
Greatest monthly	5.59	7.24	4.92	2.37	0.40	0.21	0.22	1.38	1.89	1.63	3.37	7.55	
Mean monthly	1.36	1.89	1.69	0.46	0.12	0.03	0.02	0.32	0.22	0.38	0.48	2.15	9.12
Least monthly	0	0	T	0	0	0	0	0	0	0	0	0	
Greatest daily	2.40	2.43	2.39	0.68	0.40	0.15	0.22	1.05	1.02	1.63	1.63	3.43	

a/ Data in inches of precipitation.

b/ Length of record--14 years.

c/ Trace.

d/ Length of record--42 years.

e/ Length of record--35 years.

f/ Length of record--19 years.

Source: U. S. Dept. of Commerce Weather Bureau. "Climatological Summary." San Francisco. Mimeographed data supplied for each station.

APPENDIX TABLE 2
Temperature Summary^{a/}

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Backus Ranch^{b/}													
Highest	82	79	83	97	102	108	111	110	110	97	86	77	76.1
Mean daily maximum	56.5	58.8	63.7	73.6	81.1	89.4	97.8	96.8	91.1	77.9	67.4	59.5	61.5
Mean daily	42.6	45.7	50.5	59.0	67.1	75.1	82.7	81.3	74.5	62.2	51.4	45.7	46.9
Mean daily minimum	28.7	32.5	37.3	45.3	53.0	60.8	67.6	65.8	58.0	46.4	35.5	32.0	32.0
Lowest	7	14	20	25	36	35	50	47	34	28	16	14	14
Fairmont^{c/}													
Highest	78	80	87	92	98	108	109	109	106	96	86	87	70.4
Mean daily maximum	52.3	55.0	59.8	66.2	72.8	81.5	90.7	90.2	84.9	73.7	63.7	54.5	60.3
Mean daily	43.7	46.3	50.5	56.3	62.7	71.0	79.7	78.8	73.2	62.7	52.8	45.9	50.2
Mean daily minimum	35.1	37.6	41.2	46.4	52.6	60.4	68.6	67.4	61.5	51.8	42.6	37.3	37.3
Lowest	11	16	19	26	32	39	48	48	42	31	18	19	19
Ilano^{d/}													
Highest	77	75	90	93	100	108	112	109	105	96	89	78	74.1
Mean daily maximum	54.2	58.1	63.7	71.0	79.2	88.3	95.4	94.4	88.0	76.2	64.3	56.1	59.9
Mean daily	43.1	46.4	50.5	56.5	63.6	71.5	79.0	77.9	71.9	61.8	51.7	45.0	46.5
Mean daily minimum	32.1	34.6	37.3	42.0	48.0	54.8	62.7	61.3	55.8	47.4	39.2	34.0	34.0
Lowest	8	14	20	22	28	35	39	38	36	25	15	13	13
Palmdale^{e/}													
Highest	81	78	89	97	107	109	112	112	111	100	86	83	76.0
Mean daily maximum	56.3	59.2	65.6	73.3	80.3	88.1	97.2	96.4	90.7	78.9	67.6	58.6	61.2
Mean daily	43.6	46.8	52.0	58.6	65.1	72.3	81.1	79.9	73.6	63.2	52.3	45.9	46.4
Mean daily minimum	30.8	34.3	38.5	43.9	49.9	56.4	65.0	63.5	56.6	47.5	37.0	33.1	33.1
Lowest	9	16	21	28	31	40	43	44	36	27	19	14	14

a/ Data in °F.

b/ Length of record, 14 years.

c/ Length of record, 29 years.

d/ Length of record, 32 years.

e/ Length of record, 19 years.

Source: U. S. Dept. of Commerce.
supplied for each station.

Weather Bureau. "Climatological Summary." San Francisco.

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Mimeographed data

APPENDIX TABLE 3

Histories of Irrigation Districts in Antelope Valley

Name of district and subsequent organizations	Date of organization	Area in district acres	Purpose of original organization	Extent of operations	Date of dis-organization
Palmdale Irrigation District	February 3, 1890	50,000	Nonspeculative	Organization held null and void by the courts before construction started.	July 10, 1891
Southern Antelope Valley Land Company	1895	--	Nonspeculative	Negligible, because of prolonged drought period and lack of storage facilities.	1912
Palmdale Water Company	1912	3,000	Nonspeculative	Negligible, because of prolonged drought period and lack of storage facilities.	1918
Palmdale Irrigation District	July 9, 1918	4,756	Nonspeculative	Lined and unlined ditches; concrete distribution lines for irrigation water, iron pipe lines for domestic water. Little Rock and Harold reservoirs to store irrigation water, wells to supply domestic water.	Very strong and active at present.
Big Rock Creek Irrigation District	July 14, 1890	30,000	Speculative	Some small ditches constructed.	1897
Mescal Land and Water Company	1900	--	--	Some ditches constructed, and a half-mile tunnel into bed of Big Rock Creek.	1902-03
Ilano del Río Company	1914	--	Socialistic colonization	Ditches constructed and some storage developed; small community constructed, designed to be self-supporting.	1917

(Continued on next page.)

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Appendix
Table 3 continued.

Name of district and subsequent organizations	Date of organization	Area in district acres	Purpose of original organization	Extent of operations	Date of dis-organization
Manzana Irrigation District	December 5, 1891	3,000	Speculative	Negligible, because of surface water lack.	1896
Little Rock Creek Irrigation District	March 28, 1892	4,200	Speculative	Ditches, flumes, and orchards; pumping plant installed during drought. District weakly active from 1895 to 1909. Abortive attempt to form a mutual water company in 1909. Since then, a gradual expansion of facilities and service, including construction of Little Rock Dam jointly with Palmdale District.	Strong and active at present.
Neenach Irrigation District	May 5, 1893	3,840	Nonspeculative	None.	1894
Armagoza Irrigation District	January 31, 1895	5,000	Nonspeculative	None.	1896

Source: Snyder, op. cit. Appendix A. Based on information contained in:

Adams, F. Histories of Irrigation Districts in California Organized Under Wright Act of 1887, 1887-1893. Irrigation Investigations, Office of Experiment Stations, USDA. Berkeley, 1915. 160p. Typewritten manuscript.

Adams, F. "Irrigation Districts in California, 1887-1915." Bulletin No. 2. State of California Dept. of Engineering. Sacramento, California, 1915.

Adams, F. Irrigation Districts in California. 1929 42lp. (Calif. Dept. Pub. Works, Bul. 21). Palmdale Irrigation District. "Open Letter to all Members of the Palmdale Irrigation District." Palmdale, 1950. Unpaged. Processed.

Personal interviews with secretaries of the Palmdale and Little Rock Creek Irrigation Districts, 1952.

APPENDIX TABLE 4

Irrigated Crop Acreage in Antelope Valley

Year	Alfalfa	Tree fruits and vines	Irrigated grain and pasture	Miscellaneous crops	Gravity irrigated crops	All crops irrigated from ground water	Total irrigated crop acreage
1910	2,500						4,629
1912							10,000
1916							11,960
1919	7,155	4,655 ^a			3,100	8,710	12,300
1920	7,400	4,900 ^a			2,950	9,350	
1922	7,000	4,700 ^a				10,000	
1924	12,000	4,780 ^a			2,600	14,180	16,780
1925	14,000						
1927	20,250						
1929	25,000				2,996 ^c		31,420
1930	22,000				2,509 ^c		
1931	21,700				1,708 ^c		
1932					1,736 ^c		
1933	15,317 ^b				1,810		23,800
1934	16,000				1,765		
1935							
1937	23,000				1,750		
1938	20,000				2,047		
1939	24,202 ^b				2,027		
1940		1,950	1,113	1,023			
1941	25,500 ^b						
1942							

(Continued on next page.)

Appendix
Table 4 continued.

Year	Alfalfa	Tree fruits and vines	Irrigated grain and pasture	Miscel- laneous crops	Gravity irrigated crops	All crops irrigated from ground water	Total irrigated crop acreage
1943	26,000 ^{b/}				2,052		
1944	29,600	1,870 ^{b/}	5,850 ^{b/}	475 ^{b/}	2,200	35,559 ^{d/}	37,795
1945	31,500	1,902 ^{b/}	5,590 ^{b/}	1,035 ^{b/}	2,236	37,634 ^{d/}	40,027
1946	34,700	2,067 ^{b/}	8,612 ^{b/}	971 ^{b/}	2,393		
1947	37,700	2,027	10,011 ^{b/}	1,312 ^{b/}			
1948	38,900	2,382	10,460 ^{b/}	755 ^{b/}	1,567	50,930 ^{d/}	52,497
1949	38,525	2,375	13,022 ^{b/}	744 ^{b/}	1,158	53,508 ^{d/}	54,666
1950	39,845	2,376	11,291 ^{b/}	943 ^{b/}	1,061	53,394 ^{d/}	54,455
1951							

a/ These acreages include some private stream diversions of unknown amount as well as acreage prepared for irrigation but never irrigated.

b/ Los Angeles County only. No information available for Kern County. Potato and melon acreage in Kern County estimated to average 675 acres for period 1945-1951. Other acreages small.

c/ These are acreages served by Palmdale and Little Rock Creek Irrigation districts. Individual diversions unimportant.

d/ Total Irrigated Crop Acreage less Gravity Irrigated Crop acreage.

e/ Includes 1,126 acres of cotton in Los Angeles and Kern Counties. This is the first major introduction of cotton into the area.

Source: Compiled from:

Adams, F., et al. Reports on the Irrigation Resources of California. Irrigation Investigation Off. of Exp. Sta., USDA, California State Printing Office, Sacramento. 1912.

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Appendix Table 5
Precipitation and Stream Flow; Antelope Valley, 1923-1951

	Seasonal precipitation		Precipitation as percent of mean annual rainfall		Seasonal stream flow discharge or runoff/		Stream flow as percent of mean annual runoff
	Fairmont	Llano	San Gabriel Mts. Watershed area, square miles	Fairmont percent	Llano	Rock Creek Drainage area: 23.0 square miles	Little Rock Creek Drainage area: 49.0 square miles
	inches per season					acre-feet	percent
1923-24	6.35	5.66	55.1	46.9	72.7	4,180	
1924-25	5.76	4.72	65.4	42.5	60.6	2,860	
1925-26	14.71	7.36	119.3	108.6	94.5	12,200	
1926-27	13.60	8.62	110.9	100.4	110.7	16,000	
1927-28	7.84	6.86	63.0	57.9	88.1	5,470	
1928-29	8.95	4.11	69.3	65.4	52.8	3,870	
1929-30	9.20	7.94	76.5	67.9	101.9	6,160	
1930-31	10.54	6.99	78.9	77.8	91.8	4,270	
1931-32	17.41	12.08	119.4	128.6	158.7	15,700	
1932-33	10.69	5.23	67.5	78.9	68.7	5,950	
1933-34	9.73	2.12	75.8	71.9	27.9	4,760	
1934-35	18.38	8.50	125.7	135.7	111.7	17,800	
1935-36	11.39	4.11	72.7	84.1	54.0	5,000	
1936-37	21.97	8.95	145.4	162.3	117.6	22,630	
1937-38	22.34	8.95	161.0	165.0	117.6	25,000 ^{c/}	
1938-39	15.92	9.89	104.9	117.6	130.0	10,660	
1939-40	12.77	8.95	75.8	94.3	117.6	8,660	
1940-41	29.13	15.39	190.1	215.1	202.4	36,420	
1941-42	9.98	5.65	72.7	73.7	74.3	7,000	
1942-43	22.76	15.61	160.0	168.1	205.1	30,740	
1943-44	24.24	19.02	142.3	179.0	249.9	24,120	
1944-45	12.77	6.36	96.6	94.3	83.6	10,450	
1945-46	17.87	7.48	94.5	132.0	98.3	14,560	
1946-47	14.44	9.08	101.8	106.6	119.3	16,040	
1947-48	9.02	5.73	53.0	66.6	75.3	4,640	
1948-49	8.54	5.80	59.2	63.1	76.2	4,180	
1949-50	8.75	3.56	57.1	64.6	46.8	3,390	
1950-51	4.17	3.51	45.7	30.8	46.1	1,380	
							52.5
							123.5
							31.0
							27.9
							131.0
							24.6
							163.0
							163.4
							50.5
							52.0
							382.3
							38.2
							266.4
							266.4
							68.7
							89.9
							117.7
							18.2
							23.6
							18.1
							3.2

(Continued on next page.)

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Appendix Table 5 continued.

- a/ Adapted from Seasonal Rainfall Index for San Gabriel Mountains contained in Los Angeles County Flood Control District. Biennial Report on Hydrologic Data, Seasons of 1949-50 and 1950-51.
- b/ Seasonal figures are for October 1-September 30, inclusive; for example, seasonal runoff for Rock Creek, October 1, 1923-September 30, 1924, was 4,180 acre-feet.
- c/ Estimated by Los Angeles County Flood Control District.

APPENDIX TABLE 6

Water Requirements of Crops in Antelope Valley

Crop	Growing season	Consumptive use		Minimum amount of irrigation water necessary to supply consumptive use ^a	Estimates of typical irrigation applications in Antelope Valley
		Total Annual	Supplied by precipitation	Supplied by irrigation	
			acre-foot per acre		
Alfalfa	April 1-October 31	3.37 ^b	0.35	3.02	5.75-7.5
Permanent pasture	April 1-October 31	3.18 ^b	0.35	2.83	5.75-7.5
Orchard (deciduous)	April 1-October 31	2.60	0.35	2.25 ^c	2.25-2.75
Hay and grain (irrigated)	December 1-June 1	1.33	0.35	0.98	1.75-2.25
Field crops (miscellaneous)	May 1-August 31	1.95	0.35	1.60	3.0-3.5
Cotton ^d	April 1-October 31	2.46	0.35	2.11	4.0-4.5
Truck crops (miscellaneous)	April 1-July 31	1.92	0.35	1.57	3.0-3.5
Sugar beets	April 1-September 30	2.54	0.35	2.19	4.0-4.5

a/ Assuming 70 per cent irrigation efficiency (cf. footnote 16, p.). Information obtained from R. L. Forsyth, Antelope Valley Field Station, University of California, tends to substantiate this column. The 30 per cent not used consumptively represented water evaporating from free water surfaces (either in storage reservoirs on the farm or as water floods over the checks) plus an amount required as necessary return flow.

b/ Estimates by Farm Advisors and Antelope Valley Experiment Station indicate that permanent pasture will use as much water as alfalfa, and possibly more.

c/ These values are in excess of current irrigation practice in the area.

d/ Adapted from State Department of Public Works, Division of Water Resources. "Irrigation Requirements of California Crops." Sacramento, Calif. State Print. Off., 1945. (Bul. 51) p. 79.

Sources: State Department of Public Works, Division of Water Resources. "Water Utilization and Requirements, Antelope Valley Basin." Bryce, California, June 1, 1951. (Mss. by T. C. Mackey. Preliminary information subject to revision.) California Agricultural Extension Service and U. S. Dept. of Agric. Alfalfa Cost and Management Study, Antelope Valley, 1950. Office of the Farm Advisor, Los Angeles, Calif. 1950 and earlier issues⁷. Mimeo. variable paging. California Agricultural Extension Service and U. S. Dept. of Agric. 1947 and 1948 Sugar Beet Production, Cost and Management Study, Antelope Valley. Office of the Farm Advisor, Los Angeles, Calif. 1948. 7pp. Mimeo. California Agricultural Extension Service. Information leaflets on growing corn, mild maize, irrigated wheat, and castor beans in Antelope Valley. Personal interviews.

APPENDIX TABLE 7
Annual Draft on Ground Water Antelope Valley
Based on Electrical Power Consumption

Year	Estimated average depth to static ground water level	Estimated average drawdown, friction, loss, etc.	Estimated total pumping head	Estimated over-all efficiency of pumping plants	Estimated KWH necessary to pump one acre-foot of water	Total annual power sales to agriculture, Lancaster District ^a	Estimated annual gross draft on ground water by electric pumping plants	Estimated annual net draft on ground water by electric pumping plants
		feet		per cent		KWH	acre-feet	
1924	59	30	89	45.0	202.6	11,100,000	54,788	27,000
1925	62	30	92	45.5	207.1	13,413,229	64,767	32,000
1926	66	30	96	46.0	213.7	17,389,599	81,374	41,000
1927	70	30	100	46.5	220.2	21,575,387	97,981	49,000
1928	72	30	102	47.0	222.3	28,804,011	128,673	64,000
1929	75	30	105	47.5	226.4	36,545,046	161,418	81,000
1930	79	30	109	48.0	232.5	40,127,057	172,590	86,000
1931	83	30	113	48.5	238.5	37,574,421	157,545	79,000
1932	86	30	116	49.0	242.4	26,452,939	109,129	55,000
1933	88	30	118	49.5	244.1	23,342,419	96,627	48,000
1934	92	35	127	50.0	260.1	31,029,494	119,298	60,000
1935	95	35	130	50.5	263.6	29,766,145	112,884	56,000
1936	98	35	133	51.0	267.1	35,033,084	131,161	66,000
1937	102	35	137	51.5	272.4	34,693,969	127,364	64,000
1938	105	35	140	52.0	275.7	36,103,543	130,952	65,000
1939	110	35	145	52.5	282.9	38,807,103	137,176	69,000
1940	111	35	146	53.0	282.2	39,804,883	141,052	82,000
1941	112	35	147	53.5	281.5	31,937,315	113,454	58,000
1942	117	35	152	54.0	288.2	44,790,903	155,416	79,000
1943	120	35	155	54.5	291.4	47,412,334	162,705	82,000
1944	121	40	161	55.0	300.1	50,813,056	169,320	86,000
1945	127	40	167	55.5	308.4	59,363,778	192,490	97,000
1946	129	40	169	56.0	309.1	69,746,931	225,645	114,000
1947	136	40	176	56.5	319.1	82,537,667	258,658	122,000
1948	140	40	180	57.0	323.3	99,760,942	308,571	136,000
1949	145	40	185	57.5	329.5	109,857,984	333,408	141,000
1950	150	40	190	58.0	335.5	121,624,753	362,518	149,000
1951	157	40	197	58.5	344.9	138,249,080	400,838	166,000

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^a Southern California Edison Company. Unpublished annual reports filed with California Public Utilities Commission, State Office Building, San Francisco, California, 1934-1951 inclusive.

APPENDIX TABLE 8

Net Draft on Ground Water in Antelope Valley
(Consumptive Use)

Water use category	1919	1920	1925	1927	1929	1930	1935	1940	1945
Agricultural use									
Crops	21,600	22,300	42,300	61,200	75,500	66,400	48,300	76,100	89,400
Alfalfa									
Permanent pasture								1,400	5,900
Irrigated grain								700	3,800
Miscellaneous field and truck	10,500	11,000	5,000	4,500	4,500	4,500	3,000	1,600	1,800
Cotton									
Tree fruits and vines								4,400	4,500
Livestock	100	100	100	100	200	200	200	300	300
Total agricultural	32,200	33,400	48,400	65,800	80,200	71,100	51,500	84,500	105,700
Nonagricultural use									
Residential-commercial									800
Military-industrial									400
Total nonagricultural	200	200	300	300	400	400	400	600	1,200
Estimated net water consumption	32,400	33,600	48,700	66,100	80,600	71,500	51,900	85,100	106,900
Less estimated net water consumption for gravity-irrigated crops	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total estimated net draft on ground water in Antelope Valley	29,400	30,600	45,700	63,100	77,600	68,500	48,900	82,100	103,900

(Continued on next page.)

Appendix Table 8 continued

Water use category	1946	1947	1948	1949	1950	1951	Future estimates	
							1955	1960
Agricultural use								
Crops								
Alfalfa	95,100	104,700	113,900	117,500	116,300	120,300		
Permanent pasture	5,200	4,500	5,600	5,400	8,600	12,100		
Irrigated grain	3,900	4,700	4,500	5,200	10,200	6,300		
Miscellaneous field and truck	4,200	3,900	4,400	2,000	2,100	2,800		
Cotton	—	—	—	—	300	2,400		
Tree fruits and vines	4,600	4,800	4,800	5,500	5,500	5,500		
Livestock	400	400	500	500	600	700		
Total agricultural	113,400	123,000	133,700	136,100	143,600	150,100	182,000	225,000
Nonagricultural use								
Residential-commercial	900	900	1,000	1,100	1,200	1,400	3,000	5,000
Military-industrial	300	200	200	200	300	600	1,200	1,600
Total nonagricultural	1,200	1,100	1,200	1,300	1,500	2,000	4,200	6,600
Estimated net water consumption	114,600	124,100	134,900	136,400	145,100	152,100	186,200	231,600
Less estimated net water consumption for gravity-irrigated crops ^a	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Total estimated net draft on ground water in Antelope Valley	111,600	121,100	131,900	133,400	142,100	149,100	183,200	228,600

a/ Divert 7,500 acre-feet per year, of which 1,500 acre-feet are assumed to be evaporated from storage, leaving 6,000 acre-feet to be delivered to crops. Assuming 50 per cent irrigation efficiency, 3,000 acre-feet will be used consumptively each year.

Source: Table 2.2, Table 4.3, Snyder, J. Herbert, *op. cit.*

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APPENDIX TABLE 9
Typical Costs of Pumping Installations, Antelope Valley

	Initial cost	Average value b/	Expected life c/	Fixed annual charges per year a/			Total annual fixed charges per year
				Interest at 5 per cent	Taxes and insurance at 2 per cent	Depreciation d/	
	dollars	dollars	years			dollars	
<u>1925 e/</u>							
To pump 450 gal. per min. with 20 h.p. electric motor from 350-ft. well f/							
Well and casing	1,002	501	25	25.05	10.02	40.80	
Electric motor and pump assembly	1,200	600	20	30.00	12.00	60.00	
Total	2,202	1,101	--	55.05	22.02	100.80	177.87
To pump 900 gal. per min. with 40 h.p. electric motor from 450-ft. well g/							
Well and casing	1,665	833	25	41.65	16.65	66.60	
Electric motor and pump assembly	1,800	900	20	45.00	18.00	90.00	
Total	3,465	1,733	--	86.65	34.65	156.60	277.90
<u>1951 h/</u>							
To pump 450 gal. per min. with 40 h.p. electric motor from 500-ft. gravel-packed well f/							
Well and casing	3,500	1,750	25	85.00	35.00	140.00	
Electric motor and pump assembly	4,900	2,450	20	122.50	49.00	245.00	
Total	8,400	4,200	--	207.50	84.00	385.00	676.50

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Appendix Table 9 (Continued)

	Initial cost	Average value ^{b/}	Expected life ^{c/} years	Fixed annual charges per year ^{d/} (overhead charges)		Total annual fixed charges per year
				Interest at 5 per cent	Taxes and insurance: Depreciation at 2 per cent	
	dollars	dollars	years	dollars	dollars	dollars
To pump 900 gal. per min. with 75 h.p. electric motor from 750-ft. gravel-packed well ^{e/}						
Well and casing	6,375	3,188	25	159.40	63.75	255.00
Electric motor and pump assembly	8,150	4,075	20	203.75	81.50	407.50
Total	14,525	7,263	--	363.15	145.25	662.50
To pump 1,800 gal. per min. with 150 h.p. electric motor from 1,000-ft. gravel-packed well ^{e/}						1,170.90
Well and casing	9,500	4,750	25	237.50	95.00	380.00
Electric motor and pump assembly	12,000	6,000	20	300.00	120.00	600.00
Total	21,500	10,750	--	537.50	215.00	980.00
						1,732.50

a/ Annual rate of charge based on A. Molenaar, "Costs of Pumping Water for Irrigation," 1947, Univ. of Calif. Dept. of Irrigation, Davis, California. Processed.

b/ Average value is assumed to be one-half the initial cost.

c/ Expected life for motor and pump assembly depends upon total hours of use and whether or not water level is falling rapidly. Periodic replacement of bowls (due to cavitation, mechanical wear, or suspended material) or extension of the pumping column (due to a falling water table) will shorten the estimated expected life and increase total annual fixed charges slightly.

d/ It is assumed that pump, motor, and assembly are capable of handling an increase in pumping lift of about 100 feet before replacement becomes necessary. Replacement of old pump and motor is a capital expenditure to be incurred about every 100 feet. The addition to total annual fixed charges when such a change occurs will be small when compared to the total.

e/ Installations capable of pumping average volumes indicated for a range of pumping lift of 75-200 feet.

f/ Capable of supply a 40-acre alfalfa unit.

g/ Capable of supplying an 80-acre alfalfa unit.

h/ Installations capable of pumping average volumes indicated for a range of pumping lift of 200-350 feet.

i/ Capable of supplying a 160-acre alfalfa unit.

Sources: Interviews with well drillers and farmers in Antelope Valley.

APPENDIX TABLE 10

Prices Received by California Producers, 1920-1951

Year	Alfalfa ^a dollars per ton	Antelope Valley ^b / alfalfa	Field corn dollars per hundredweight	Wheat dollars per hundredweight	Grain sorghum (includes milo)	Cotton cents per pound	Beef cattle cents per pound
1920	22.35		1.73	3.68	1.68	13.60	9.20
1921	12.35		1.55	2.03	1.38	16.97	6.40
1922	14.65		1.63	1.83	1.95	23.97	6.40
1923	15.75		1.95	1.77	1.88	31.43	6.10
1924	20.35		2.40	2.23	2.43	23.78	6.50
1925	16.15		1.80	2.53	1.75	19.77	6.90
1926	14.45		1.85	2.17	1.70	13.75	6.90
1927	14.35		2.07	2.11	1.93	19.97	7.40
1928	16.85		2.05	2.05	1.64	18.93	9.50
1929	17.75		1.82	1.95	1.89	17.24	9.40
1930	13.75	13.50	1.28	1.50	1.27	9.59	7.90
1931	12.35	11.90	1.03	.97	.89	6.15	5.60
1932	8.85	9.48	.90	.88	.80	7.09	4.50
1933	9.85	11.25	1.07	1.30	.98	10.86	4.05
1934	11.55	13.22	1.65	1.32	1.39	12.98	4.35
1935	10.45	13.50	1.32	1.30	1.05	11.65	6.50
1936	14.05	15.58	1.90	1.55	1.57	12.65	6.10
1937	14.45	16.54	1.25	1.58	1.18	8.75	7.20
1938	10.55	11.60	1.18	1.08	.95	9.05	6.30
1939	11.05	13.31	1.35	1.27	1.23	9.60	7.00

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Appendix Table 10 continued.

Year	Alfalfa ^{a/} dollars per ton	Antelope Valley ^{b/} alfalfa dollars per ton	Field corn dollars per hundredweight	Wheat dollars per hundredweight	Grain sorghum (includes milo) dollars per hundredweight	Cotton cents per pound	Beef cattle cents per pound
1940	9.60	12.71	1.45	1.28	1.09	11.97	7.40
1941	14.70	18.86	1.67	1.71	1.50	17.31	8.60
1942	19.50	24.45	2.08	1.90	1.70	19.22	10.50
1943	23.80	26.50	2.38	2.45	2.64	20.34	12.20
1944	24.00	25.75	2.26	2.55	2.09	20.89	11.60
1945	23.60	25.57	2.37	2.63	2.66	22.12	12.70
1946	28.40	32.41	2.83	3.38	2.79	30.94	14.60
1947	24.60	27.16	4.65	4.00	4.13	33.31	18.50
1948	27.80	31.21	2.90	3.62	2.66	31.35	22.60
1949	22.20	23.34	2.58	3.33	2.59	28.17	19.10
1950	19.70	24.10	3.12	3.40	2.61	41.30	22.60
1951	30.20	35.67	3.58	3.66	3.08	40.10	28.60

^{a/} Baling premiums of \$2.35 per ton arbitrarily added to prices received for loose alfalfa for period 1920-1939. Baled hay prices begin 1940.

^{b/} Begins May 1 each year and carries to April 30 the year following.

Source: California Crop and Livestock Reporting Service. "Prices Received by California Producers for Farm Commodities, 1909-1951."