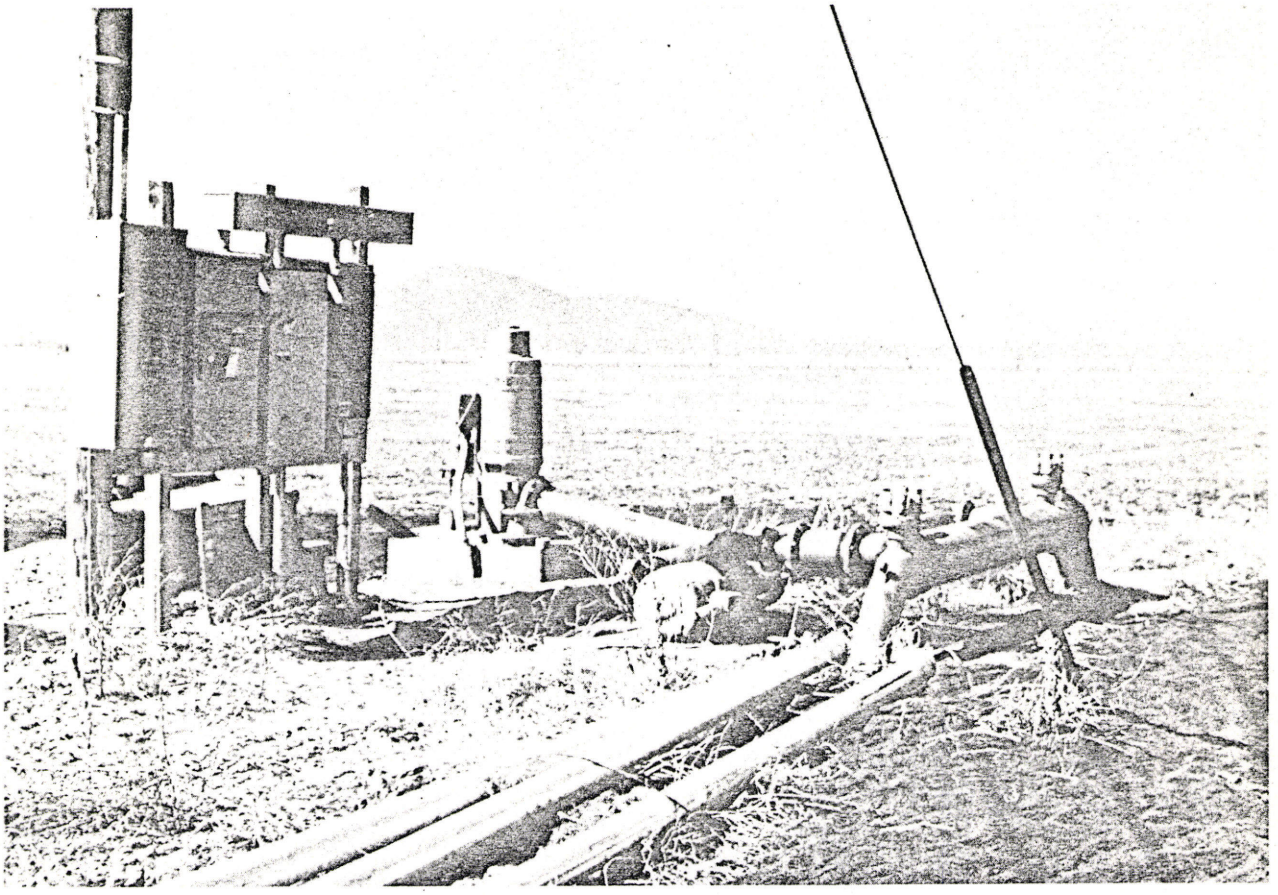
COOPERATIVE EXTENSION UNIVERSITY OF CALIFORNIA

SOIL and WATER

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Pumping plant for sprinkler system. (Photograph provided by Blaine R. Hanson.)

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TABLE OF CONTENTS

Page

1. SELECTION AND EVALUATION OF PUMPING SYSTEMS FOR MAXIMUM EFFICIENCY 1

2. SALT MANAGEMENT 4

3. SULFURIC ACID TREATMENT MAY SPEED RECLAMATION OF HIGH BORON SOILS 7

4. IRRIGATION COSTS 8

5. GROUND WATER RECHARGE: GOOD MOSQUITO PRODUCTION: BAD . . . 9

6. POLLUTION CONTROL FINANCING GUARANTEED 10

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SELECTION AND EVALUATION OF PUMPING SYSTEMS FOR MAXIMUM EFFICIENCY

The subject of energy seems to be attracting much attention, particularly so in agriculture. During the past year, operators of electric pumping plants have experienced large increases in electrical energy rates. These increased rates mean that operators must select and operate their plants as efficiently as possible. Use of pump characteristic curves will aid the operator in evaluating the performance of their plants.

Selection of Pumping Plants for Maximum Efficiency

Deep well turbine and centrifugal pumps are able to operate over a wide range of head - discharge conditions. However, good pump efficiencies may be experienced only over a limited range of operating conditions. If the operating conditions for a proposed pumping plant are known, pump characteristic curves can be used to select a pump that will be efficient for those conditions. The operating conditions are the discharge and the total dynamic head (TDH).

The design discharge is the discharge necessary to meet irrigation requirements and may be estimated from present irrigation practices. However, the discharge must not exceed the well yield. An initial estimate of the feasibility of obtaining the discharge might be made from discharge data on neighboring wells, but only by testing the well can one be certain of obtaining a particular discharge.

The major components of the total dynamic head are the pumping lift, pressure requirements for sprinkler systems or other pressurized systems, elevation differences, and friction losses in pipelines such as mainlines and laterals. Minor components such as the velocity head, losses due to pipe fittings and valves are usually small compared to the major components and can be neglected in most cases concerning irrigation wells.

In order to estimate the pumping lift the relationship between the drawdown and discharge must be known. This requires that a new well must be test-pumped. If the well is to be test-pumped at only one discharge, then that discharge should be at the design discharge. The duration of the test may exceed 24 hours. Details on well tests can be found in the University of California Experiment Station publication, Water, Wells and Pumps: Design, Construction, Operation and Maintenance, by V. H. Scott and J. C. Scalmanini (currently being printed).

Friction losses in any sprinkler laterals and mainlines, column pipe, and any other pipelines should also be included. These losses can be determined by consulting handbooks on hydraulics or irrigation system design or pump catalogs.

Elevation differences between the pumping plant and the irrigation system should also be included in the TDH. If the elevation of the irrigation system is greater than that of the pumping plant, the elevation difference should be added to the TDH.

When the discharge and the TDH have been estimated, an efficient pump for these conditions can be selected using pump characteristic curves contained in pump catalogs. These curves (Figure 1) describe the performance of a pump by a head-discharge curve, an efficiency-discharge curve, and brake horsepower-curve.

By utilizing these curves a pump can be selected that performs at a high efficiency matching the desired operating conditions. For example, consider the following data:

Estimated discharge	= 400 gpm,
Sprinkler pressure head	= 92 feet,
Friction losses	= 22 feet,
Elevation difference	= 10 feet,
Pumping lift	= 113 feet.

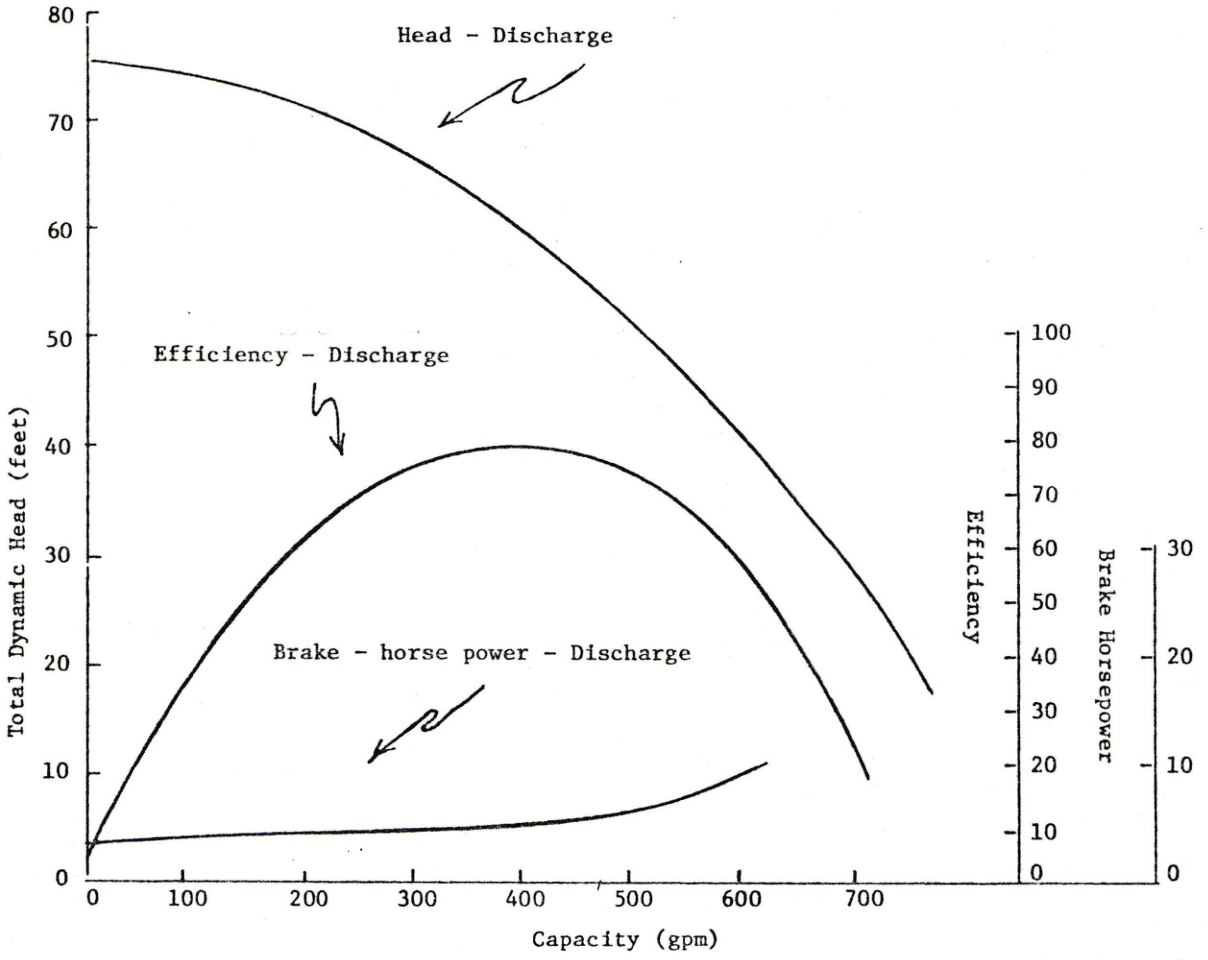


Figure 1. Pump characteristic curves.

The total dynamic head is

TDH = 92 + 22 + 10 + 113 = 237 feet

The pump catalog should now be consulted to find a pump that will supply 237 feet of TDH at 400 gpm at a high efficiency.

The pump whose performance is described by Figure 1 will provide 60 feet of TDH per stage at 400 gpm at an efficiency of 80 percent. Therefore, four stages of this pump will provide 240 feet of TDH, which is adequate for this system.

The selection process should also consider the possibility that the actual operating conditions may vary from the design conditions due to fluctuating water levels or discharge requirements. The characteristic curves can be used to select a pump that will operate efficiently over a range of head and discharges. From Figure 1, it can be seen that this particular pump will operate at an efficiency of at least 75 percent over a head range of 54-66 feet per pump stage and a discharge range of 310-490 gpm. However, if the head-discharge curve were relatively flat at the point of the design conditions, a small change in the water level may cause a much larger change in the discharge. This may not be desirable.

Once the pump is selected, then the brake-horsepower requirement can be found from the characteristic curve. This, in turn, can be used to select a properly sized motor or engine. For the above example, the brake-horsepower per stage are about seven horsepower. Thus, 28 horsepower are required to drive four stages. A 30 horsepower motor should be used for this pumping plant.

The overall efficiency of a pumping plant (includes both pump and motor/engine efficiencies) should be 60-70 percent for electric plants and 15-20 percent for natural gas plants. (It is believed that the overall efficiency of diesel and gasoline plants is similar to that of natural gas plants.) The overall efficiency can be calculated from

$E_o = E_m \times E_p \times E_D$

E_o = overall efficiency,

E_m = efficiency of motor or engine (about 90 percent for electric motors and about 20-25 percent for well-maintained natural gas engines).

E_D = efficiency of any gear boxes, belt drives, etc. If the pump and motor are direct-coupled, this term should be neglected.

Evaluation of Existing Pumping Plants

Causes of low efficiencies in existing pumping plants include an improperly selected pump, changes in water level, changes in discharge requirements, and pump wear. By conducting pumping tests and comparing the data with the pump characteristic curves, reasons for a low efficiency may be determined. This is illustrated by following examples.

Suppose a pumping plant test is conducted on the pump whose performance is described by Figure 1. The data obtained from this test are:

discharge	= 150 gpm,
TDH	= 220 feet,
overall efficiency	-= 36 percent.

For an electric plant, the pump efficiency can be calculated by divid-

ing 0.36 by 0.9 (efficiency of electric motor.) The pump efficiency is then determined to be 40 percent.

To determine the feet of TDH per stage for a four-stage pump, the measured TDH is divided by four or

$$\text{TDH per stage} = \frac{220}{4} = 55 \text{ feet.}$$

The pump characteristic curves can now be used to determine if the pump is operating as it should. From the head-discharge curve, it can be seen that at 55 feet of TDH per stage, the discharge should be about 450 gpm and the pump efficiency should be 78 percent. Since the pumping plant test revealed a discharge of 150 gpm and an efficiency of 36 percent, it is obvious that the pump is not operating as it should.

However, suppose the data from the pumping plant test were

discharge	= 110 gpm,
TDH	= 290 feet,
overall efficiency	= 36 percent.

The pump efficiency is 40 percent. The TDH per stage is about 73 feet.

From Figure 1, it can be seen that at 73 feet of TDH per stage the discharge should be about 110 gpm and the pump efficiency should be 40 percent. Therefore, even though the pump efficiency is low, a comparison of the test data with the performance curve indicates that the pump is operating as it should. The low efficiency may be due to a declining water table, a clogged well screen, or some other factor. However, if the pumping plant operator did not compare the test data with the performance curve, he may have assumed that the low efficiency was due to pump problems and may have needlessly spent money adjusting or pulling the pump.

Use of pump characteristic curves can aid pumping plant operators in selecting new pumps that will be efficient and in evaluating the performance of existing pumps. The result may be substantial savings in time and money. It is recommended that pumping plant operators obtain these curves from their pump dealer or pump manufacturer.

-- Blaine R. Hanson

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(Continued from last issue)

SALT MANAGEMENT

Salts accumulate if there is too little leaching. But, at how fast a rate? Is it necessary to leach during each irrigation season while the crop is growing? Or, can leaching safely be delayed to the winter when winter rains will help leach accumulated salinity.

The answer is maybe yes -- maybe no. But, in many cases, leaching can safely be postponed.

The need for leaching depends upon 1) the starting point salinity of the soil at the beginning of the irrigation season, 2) the salinity of the irrigation water to be used, 3) salt tolerance of the crop to be grown, and 4) the amount of water used by the crop.

On the starting point salinity, soil samples from each quarter of the root zone and analysis of each for soil salinity, ECe, should clarify the picture, and give the starting point soil salinity. Yield expectation can then be estimated using the average root zone salinity and the yield equation $Y = 100 - b\ (ECe-a)$ using data obtained from crop tolerance tables. This was discussed in the previous Soil and Water Newsletter. If soil salinity, ECe is acceptable,

look at the irrigation water salinity, ECw. If ECe is not acceptable, see the previous discussion (last issue) under "What Can Be Done If ECe Is Excessive".

The effect of water salinity can be estimated using the published water quality guidelines and crop tolerance tables. The 15% leaching assumed in the guidelines will need to come from both rainfall plus irrigation.

What About Zero Leaching?

We can estimate the short term salinity effect to be expected with no leaching if we know our starting point soil salinity, the salinity of the applied water, and the amount of water to be applied. Try the following.

Problem: How much increase in ECe can be expected if no leaching occurs during the year?

Solution: The salts applied in the irrigation water end up in the root zone and become part of the soil salinity, ECe, affecting yield of crop. The weight of salts applied in the irrigation water can be determined and the weight of water in the root zone at saturation can be estimated. This will give a weight of salts applied dissolved in a weight of water in the soil which can be converted to an expected rise in ECe due to irrigation water salinity.

Part A: By knowing the Ec of the irrigation water, ECw, the depth of the water applied, Aw, and the weight of an acre foot of water, the weight of salts added can be determined from

Weight of salts applied, in pounds = ECw x 640 x Aw x 2.715

where

ECw = salinity of the water from the water analysis, reported in millimhos per centimeter.

640 = conversion factor to give parts of salt per million parts of water. ECw x 640 = ppm.

Aw = applied water in acre feet of water per acre of land (either measured or estimated).

2.715= weight of an acre foot of water in millions of pounds (use this because ECw x 640 is in parts per million parts).

Part B: The weight of water in the root zone, if calculated for a saturated soil, agrees with the procedure used to determine ECe. Weight of water can be roughly determined from 1) The Saturation Percent (SP, from Lab. data), 2) the weight of an acre foot of soil (approximately 4 million pounds), and 3) the depth of rooting.

Weight of water = SP x wt. of an acre foot of soil x depth of rooting.

where

SP = saturation percentage from lab. data = the weight of water needed to saturate a known weight of soil, reported as percent. (SP can also be estimated from soil textures.) Use as a decimal faction rather than as %.

weight of an acre foot of soil = about 4 million pounds (4×10^6). (If a better value is available, use it).

Depth of root zone = root zone depth in feet (should include at least 75% to 90% of rooting depth).

Part C: Weight of salts added to the weight of water of the saturated root zone must then be converted to parts per million by multiplying by 1×10^6 and to ECe by dividing by the 640 conversion factor.

Problem Solution: Problem solution then becomes

rise in ECe =

$$\frac{\text{weight of salts}}{\text{weight of water}} \times \frac{1 \times 10^6}{640}$$

$$= \frac{ECw \times 640 \times Aw \times 2.715 \times 10^6}{SP \times 4 \times 10^6 \times \text{depth of rooting} \times 640}$$

Example: Given

ECw = 1.3 mmhos/cm

Aw = 3 ac. ft. of water per acre

SP = .60 (clay loam soil @ SP = 60%)

root zone = 4 feet

rise in ECe =

$$\frac{ECw \times 640 \times Aw \times 2.715 \times 10^6}{SP \times 4 \times 10^6 \times \text{depth of rooting} \times 640}$$

$$= \frac{1.3 \times 640 \times 3 \times 2.715 \times 10^6}{.60 \times 4 \times 10^6 \times 4 \times 640}$$

= 1.10 mmhos/cm

This says that using 3 acre feet of water of ECw = 1.3 mmho/cm to irrigate a crop with a four foot root zone, on a clay loam soil with an SP = 60% and no leaching, we would expect the ECe of the root zone to increase during the irrigation season by 1.10 ECe units (mmho/cm).

If the initial soil ECe and the water ECw are both within the tolerance of the crop at the start of the season (from crop tolerance tables), the above exercise (calculation) would indicate that the salinity added (ECe = 1.1) might well be tolerated for one year without leaching and still have no loss or relatively minor loss in yield. If the initial soil salinity is excessive, winter leaching is advisable to reduce effects of no leaching during the irrigation season. Irrigation could be at 100% efficiency (no leaching losses) without detrimental effects due to salinity. Leaching could be delayed to the following winter.

It takes Time to Accumulate Salts

Salts applied with each irrigation accumulate if no leaching occurs. The total seasonal accumulation however, is present only at the end of the irrigation season.

The later in the growth period that the salts reach excessive concentrations, the less will be the damage. By starting the season well below tolerance limits for the crop being grown, salts may not accumulate to excessive concentrations or may not become excessive until late in the season when damage will be minimal.

The early growth period is the critical time. Try to manage the water and soil to keep salts within crop tolerance at least during this period.

To repeat, salts cause less damage the later in the growth period they become excessive.

Crops are almost always more salt sensitive at germination and early seedling stage of growth than at later stages.

What about Germination?

Averages of salinity are not very useful to anticipate germination problems if salts are excessive in the surface soil area surrounding the germinating seed.

Rainfall or pre-plant irrigations may be relied upon to move salts away from the seed zone but the rains must be adequate or pre-plant irrigations

must be carefully managed.

Good rains, sprinkling, or other preplant irrigation applied to flat fields should easily control salts in the seed zone. But, bedded (listed) fields when irrigated through furrows often end up with excessive salinity in the top or high point of the bed. This may reduce or stop seed germination.

Give serious consideration to the salinity in the seed zone at germination. If there is any question about it (salts) check the salinity of a representative seed zone soil sample and proceed accordingly. ECe of 3 or 4 mmhos/cm is about maximum for good germination of sensitive crops. Once the developing roots reach a low salt area, however, the effects of salts near the seed become less of a factor. Sprinklers for germination are gaining favor for many reasons; for example, salinity control, uniformity of germination, temperature control, activation of weed control chemicals, and general saving of water otherwise lost to deep percolation and run-off.

In years of low winter rainfall, salinity often causes severe problems. In dry years good water management is essential for both germination and adequate crop supply. In drought years, leaching water to control salts may have to wait until water is plentiful. In some cases, if salts are excessive and may reduce yields to unacceptable levels, it would be a waste of water, time, and money to plant. Plant only the acres that can be properly irrigated and that have good potential to produce an economic crop. Reclamation of unproductive land can be done more efficiently in wet years when water is in surplus. This is the year to do the extra leaching and reduce soil salinity of problem areas. The rains will help but may still not be adequate to do the job. Some soil analyses will be helpful to insure salinity is under control.

-- R. S. Ayers

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SULFURIC ACID TREATMENT MAY SPEED RECLAMATION OF HIGH BORON SOILS

Scattered throughout California and other Southwestern states are areas of soil high in boron. Reclamation studies in the Coachella and San Joaquin Valleys have shown that leaching alone can remove excess boron. However, the quantity of water required is large -- it amounts to about three times as much as that needed to reclaim ordinary saline soils. This is due to the chemical affinity between boron and the oxides of aluminum and iron which are universally present in soils.

Results of some recent research by Mr. Prather at the U. S. Salinity Laboratory offer promise of making the reclamation of high boron soils less time consuming and less wasteful of water. A single treatment of soil with concentrated sulfuric acid (3.2 metric tons per hectare) before leaching was found to decrease by about 80 per cent the quantity of water required for removing the excess boron. Moreover, the beneficial effect of the acid treatment on boron removal was found to extend through the entire 80 centimeter depth of soil studied. This is believed to be attributable to the release of silicon at the soil surface by the acid treatment and the subsequent replacement of boron by silicon at deeper soil depths during leaching.

This encouraging lab finding is expected to be field tested in the near

future. Further details about the research reported above may be found in Soil Science Society of America Journal, Volume 41, Nov. - Dec., 1977, pp 1098 to 1101, "Sulfuric Acid As an Amendment for Reclaiming Soils High in Boron", by R. J. Prather.

-- Roy L. Branson

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IRRIGATION COSTS

The irrigation costs publication has been revised and is currently being prepared for publication. A thorough revision was needed to take into account recent changes in energy costs as well as improvements in technology. Presented below is a Summary Table of current investment energy and annual costs of different irrigation methods. Some of the more important assumptions involved in these calculations are as follows:

a) Water was pumped from a well with 100 feet pumping lift to irrigate one 160 acre farm by different methods.

b) The seasonal amount of water to be pumped is 3.0 acre-feet/acre under sprinkler and drip and 3.5 acre-feet/acre under surface irrigation.

c) Power costs were calculated based on P. G. & E. rate schedule dated July 19, 1977.

TABLE 1

Irrigation Method	Investment Cost $/acre	Energy Costs $/acre	Annual Costs $/acre
Surface			
1. Border*	$ 650.00	$26.80	$130.40
2. Furrow*			
a. Row crops	500.00	26.80	144.65
b. Orchards	500.00	26.80	202.65
Sprinkler			
3. Hand-move	510.00	53.10	187.65
4. Wheel-line	570.00	53.10	168.15
5. Center Pivot			
a. Low pressure with corner device	610.00	43.50	147.35
b. High pressure w/o** corner device	1030.00	70.20	208.00
6. Permanent	1050.00	53.10	205.15
Drip			
7. Mature orchards	800.00	38.10	204.30

* Land grading costs are included (earth movement of 800 cubic yards/acre).
** (Includes cost of unused land at corners .23 acres/acre).

Some conclusions may be drawn from the figures in Table 1.

a) It appears that surface irrigation is cheaper than any sprinkler or drip method, mainly due to its lower energy requirements.

b) If the intake rate of the soil is high enough for efficient center-pivot irrigation, the low-pressure center pivot with a corner device is the sprinkler method with the least annual cost.

c) The annual costs of a drip and a permanent sprinkler system are about the same. The water and energy savings produced by the drip system during the early years of the orchard has to be weighed against the possibility of frost protection obtainable with a permanent sprinkler system.

-- Elias Fereres

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GROUND WATER RECHARGE: GOOD
MOSQUITO PRODUCTION: BAD

Mosquito control agencies in California are already experiencing a severe mosquito problem as a result of extreme winter rainfall throughout the state. Now the heavy snow-pack is rapidly melting, swelling the rivers and streams to nearly flood levels. In the San Joaquin and Sacramento Valleys and in areas of Southern California pooling of surface water is producing mosquito breeding areas similar to the wet years of 1952, 1958, 1967 and 1969. The threat of an epidemic of mosquito borne encephalitis is being discussed and mosquito control agencies have been alerted to this possibility.

Under the circumstances, it is very important that the ample supply of water for irrigation and other agricultural purposes be used to best advantage. The following article by John Pehrson, Farm Advisor, Tulare County appears appropriate and timely:

Applying more irrigation water than a crop needs results in the additional water recharging underground supplies. The requirements for such applications are deep permeable soil and a supply of water that is reasonable in cost.

Because of the generous rainfall and snow-pack this year, there is ample runoff water available for preirrigation, salt leaching and underground storage. Abundant preirrigation followed by liberal application during the season promotes water moving past the root zone eventually finding its way into the underground basin. This recharging is a valuable supplement to flow in natural channels and ditches.

Growers with soils and crops that are adapted to receiving extra surface runoff water during May, June and July can reduce ground water pumping overdraft by utilizing present abundant supplies. Leaching harmful salts from the soil profile results with applications of water that move below the root zone. Although some loss of nutrients may occur with leaching, delayed fertilization offsets this problem.

During the growing season it is possible to apply additional water to crops that are growing on deep, permeable, well-drained soil. On these soils, field, forage, row and truck crops can tolerate a preirrigation plus about a 25 per cent or greater increase over consumptive use. Consumptive use of water for single an-

nual crops range from 1 1/2 to 2 1/2 acre feet, alfalfa and permanent pasture 4 to 5 feet, cotton 3 acre feet, tree and vine crops 2 1/2 to 3 acre feet. The additional water will help recharge overdrafted ground water basins.

-- John Pehrson

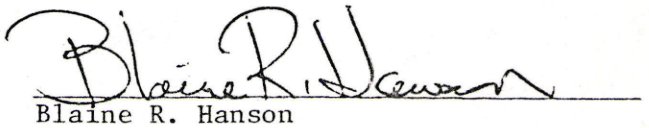
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POLLUTION CONTROL FINANCING GUARANTEED

An amendment to the Small Business Act and the Small Business Investment Act approved June 4, 1976, authorized the Small Business Administration to provide guarantees of financing to acquire facilities for the control of air, noise, or water pollution or contamination. The proposed rules designed to implement this authority were published in the Federal Register, Vol. 42, no. 236, Dec. 8, 1977. It would be appropriate to bring this to the attention of owners and managers of small, independently owned agricultural enterprises.

Editor's Note: The above article was published in the ANR (Agriculture and Natural Resources) Newsletter, Letter No. 1, Jan. 1978, USDA/Extension Service by H. G. Geyer.

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