Analyses of Irrigation Water

waters of six rivers and nine wells in California studied to establish their usefulness for irrigation

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This is the second of two articles on the quality of water and plant tolerance to salts. The previous article, in the October issue of California Agriculture, *explained the classification of irrigation waters in three groups:*

Class I. Excellent to Good—Safe and suitable for most plants under any condition of soil and climate.

Class II. Good to Injurious—Possibly harmful for certain crops under certain conditions of soil or climate.

Class III. Injurious to Unsatisfactory—Probably harmful to most crops and unsatisfactory for all but the most tolerant.

Classification of irrigation water into three groups is by necessity an arbitrary arrangement and is of value for the purpose of orientation and as a guide.

Analyses of six river and nine well waters in California are given in the accompanying table. Any of these waters with one constituent falling in a poorer group will automatically be placed in that class, although probably not of as poor a quality water as one having two constituents in the lower class.

The waters in the table are listed in the order of increasing salt concentrations. The river waters are Class I, except No. 4 which being high in boron, is placed in Class II.

Waters No. 1 and No. 2, very low in total salts, are typical of the river waters flowing from the high Sierra Mountains into the great valleys of California.

The San Joaquin River, No. 5, in the upper reaches has about the same concentration of salt as No. 1 and No. 2, but this sample includes some return flow or drainage water from the valley floor with an increase in salt concentration. The water is still first class, but indicates contamination.

Colorado River water, No. 6, is near the upper limits of Class I, but the principal salt in this water is calcium sulfate—gypsum—and is one of the least toxic of the salts occurring in irrigation water.

Well Waters

Many of the wells in California have Class I water. However, there are some areas and many individual wells that contain high concentrations of certain salts.

The well waters listed in the table are not necessarily typical irrigation waters, but rather have outstanding peculiarities.

No. 7 and No. 10 are representative of the Class I and represent the range of salt concentration that usually occurs in first quality well water. No. 10 predominates in calcium and magnesium bicarbonates, a form of lime not considered harmful. Many highly productive western soils are high in lime.

No. 8 is similar to seven except for its high percentage of sodium. When this type of irrigation water is used, infiltration problems soon develop. An irrigation water high in sodium percentage has a tendency to seal the surface soil preventing deep percolation.

No. 9 is extremely poor in quality because of the high boron content and high sodium percentage. The sodium soon would seal the soil and prevent the removal of boron by leaching, and before long the most boron-tolerant plant species would not survive.

No. 12 is classed as a second quality water because of the total concentration of salts—K = 137. None of the individual ions is extremely high and consequently it is a better water than No. 11 which has a high per cent sodium, although the total concentration of salts are less—K = 109.

Water No. 13 contains sodium chloride—common table salt—with the chloride content sufficiently high to place it definitely in Class III. Since chloride is one of the more toxic elements, its accumulation would be enhanced by sealing of the soil from the high percentage sodium.

Waters No. 14 and No. 15 are placed in Class II and III, respectively, because of their high salt content. Sulfates, predominating in these waters, are probably harmful to plant growth at the concentration of water No. 15, particularly when accompanied by a high sodium concentration.

Gypsum waters, mainly those containing calcium sulfate are not particularly harmful, and fairly high concentrations of gypsum can be tolerated.

Minerals in Waters

Well water, or underground water, contains minerals in varying proportions, depending upon the type of material through which the water percolates.

Water may enter water-bearing mate-

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Analyses of Selected River and Well Waters Used for Irrigation

No.[2]	K x 10^5 25° C	B p.p.m.	Milligram equivalents per liter						% Na	Class[1]
			Anions			Cations				
			HCO_3	Cl	SO_4	Ca	Mg	Na		
			River waters							
1 ...	6.4	.06	.55	.05	.03	.30	.11	.22	35	I
2 ...	7.7	.03	.70	.10	.31	.37	.16	.58	52	I
3 ...	15.0	.05	1.22	.13	.12	.63	.51	.26	18	I
4 ...	40.7	1.24	2.68	.81	.44	1.32	1.75	1.17	32	II
5 ...	46.7	.12	1.69	2.06	.58	1.26	1.10	2.01	46	I
6 ...	98.0	.16	2.46	2.05	5.73	4.78	1.74	3.57	34	I
			Well waters							
7 ...	26	.13	1.88	.34	.33	1.41	.44	.89	32	I
8 ...	27	.10	1.20	.68	.67	.21	.05	2.42	90	III
9 ...	79	6.90	2.39	2.47	2.48	.24	.02	7.28	96	III
10 ...	90	.51	8.87	1.13	1.02	2.49	5.81	2.83	25	I
11 ...	109	..	8.10	1.00	2.60	1.20	2.00	8.10	72	II
12 ...	137	.25	2.46	2.73	4.47	8.30	.75	3.96	30	II
13 ...	174	.71	1.02	12.04	1.80	2.14	.08	12.67	85	III
14 ...	255	.50	2.80	2.8	23.00	11.40	5.70	12.90	45	II
15 ...	433	1.63	2.75	8.55	41.74	12.37	16.71	27.39	49	III

[1] The underlined constituents place waters in Class II or III.

[2] 1—Mokelumne River, near Lodi. 2—Kern River, Beardsley Canal. 3—Sacramento River, 35 miles above Sacramento. 4—Cache Creek, Capay Dam. 5—San Joaquin River at El Solyo. 6—Colorado River, east side canal, Imperial Valley. 7 to 15—Selected wells used for irrigation in California.

WATER

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rials—generally, coarse sand and gravel strata—and as it slowly flows or percolates through the strata, it dissolves minerals from the rock and soil in varying quantities.

If the minerals dissolved are in the form of calcium and magnesium salts the water is known as hard water, and common soaps do not form suds readily in it. This type of water is usually considered good for irrigation purposes, as only occasionally do the calcium and magnesium salts reach a concentration toxic to plant growth. An example of this type of water would be No. 10 of the table.

Soft water, on the other hand, may come from either of two sources: *1*, rain water containing very few minerals; this usually will include runoff waters from melting snows or excessive rains, which have not had sufficient contact with the soil or rocks to dissolve appreciable quantities of minerals—such as river waters No. 1, No. 2, and No. 3; *2*, water containing a high percentage of sodium salts, such as well waters No. 8 and No. 9. These salts may reach a concentration toxic to plants, but even at low concentrations they cause a deterioration of the soil structure, and with their continued use the surface soil will seal and prevent the wetting of deeper layers.

Alkali Soils

When sodium salts in the form of chloride—common salt—and sulfates—glauber salts—accumulate in excessive amounts in the soil they are known as white alkali. Such accumulations may be possible from waters Nos. 13, 14, and 15. Some leaching of the surface soil should be provided, either by rainfall or excess irrigation to remove the excess soluble salts.

The accumulation of sodium carbonate or bicarbonate—soda ash—forms black alkali. Water No. 11 with its high bicarbonate and most of the cations such as sodium, would produce a black alkali if its salts are allowed to accumulate in the surface soil. Small quantities of these salts are much more toxic to plants than the white alkali.

White alkali is easily detected by the accumulation of white or gray salts on the surface of the soil.

The beginning of a black alkali soil is not easily recognized even though the sodium carbonate salts have produced a deteriorated soil structure, with a reduction in rate of water penetration. This condition can be caused by a much lower concentration of salt than usually occurs in the formation of white alkali soil.

The plants listed in the next column are divided into three major groups according to their salt tolerance.

In each of these divisions the more sensitive plants are placed first in each group with increasing salt tolerance progressively down the listing. Plant growth is governed by the concentration and toxicity of the salts dissolved in the soil solution. These salts may have been originally in the soil, or accumulated there from the salts in the irrigation water. The plants listed are provisional and subject to revision, as additional information is obtained. A number of factors may influence the salt tolerance of plants, such as climate, soil type, irrigation practice, and varietal differences and types of salt involved.

Relative tolerance of crop plants to salt constituents in the soil solution arranged in order of increasing tolerance:

Group I. Crops which may be grown on soils of weak salinity: Fruit crops: lemon, orange, apple, plum, peach, apricot, almond, pear, grapefruit. Field and truck crops: green beans, potato, sweet potato, eggplant, artichoke, cabbage, celery, peas, vetch. Forage crops: burnet, ladino clover, red clover, alsike clover, meadow foxtail, white dutch clover.

Group II. Crops which may be grown on soils of medium salinity: Fruit crops: olive, grape, fig, pomegranate. Field and truck crops: wheat, pepper, onion, squash, spinach, carrot, sunflower, lettuce, cantaloupe, rice, oats, rye, barley, sorghum, foxtail, millet, asparagus, tomato, flax, alfalfa. Forage crops: sickle milk vetch, sour clover, cicer milk vetch, tall meadow oat grass, smooth brome, big trefoil, reed canary, meadow fescue, blue grass, orchard grass, tall fescue, alfalfa, herbam clover, sudan grass, dallis grass, strawberry clover, birdsfoot trefoil, sweet clover.

Group III. Crops which may be grown on soils of strong salinity: Fruit crops: date palm. Field and truck crops: cotton, kale, rape, milo, garden beets, sugar beets. Forage crops: western wheat grass, beardless wild rye, Canada wild rye, fescue grass, rhodes grass, bermuda grass, nuttall alkali grass, salt grass, alkali sacaton.

Tolerance to black alkali—sodium carbonate salt—is not considered in the listing as this salt has a high toxic and corrosive action on the plants.

As a measure of tolerance, it is assumed that fair to good yields will be obtained under favorable conditions of climate, soil, and fertilizer.

Plant Tolerance for Boron

For convenience plants are divided into three groups according to their tolerance for boron, in the following listing. The plants that withstand only relatively low concentrations have been designated as sensitive, an intermediate group as semi-tolerant, and a final group as tolerant. However, in some cases and under certain conditions, there are no sharp lines of demarcation. Within a group the more sensitive plants have been listed first.

Relative Tolerance of Crop Plants to Boron

Group I (Sensitive)	Group II (Semi-tolerant)	Group III (Tolerant)
Lemon	Lima bean	Tobacco
Grapefruit	Sweet potato	Carrot
Avocado	Bell pepper	Lettuce
Orange	Tomato	Cabbage
Thornless blackberry	Pumpkin	Turnip
Apricot	Zinnia	Onion
Plum	Oat	Broad bean
Prune	Milo	Muskmelon
Peach	Corn	Gladiolus
Cherry	Wheat	Alfalfa
Persimmon	Barley	Sweet clover
Kadota fig	Olive	Garden beets
Grape	Rose	Mangel
Apple	Radish	Sugar beets
Pear	Sweet pea	Artichoke
American elm	Cotton	Palms
Navy bean	Sunflower	Asparagus
English walnut	Field pea	
Black walnut	Potato	
Pecan	Celery	
Cow pea	Vetch	

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PRICES

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same period while the over-all production of citrus has declined materially, largely because of unfavorable weather conditions.

Prices of meat animals, dairy products, and poultry and eggs have increased very materially in the last three years, particularly prices of meat animals—cattle, calves, sheep, lambs, and hogs. The prices in 1948 for these categories were the highest since 1924, the first year for which these indexes were computed.

Production of meat animals in California has increased by about 50% between 1925–1929 and 1942–1946 and has been maintained at about the latter level in the last three years. During the same period, the production of dairy products and particularly poultry and eggs has increased significantly.

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Index numbers for livestock and livestock products were constructed by Dr. I. M. Lee, Assistant Professor of Agricultural Economics, University of California College of Agriculture, Berkeley.

A more complete technical report of this study—Giannini Foundation Mimeographed Report No. 102, February 1950—may be obtained by writing to the Giannini Foundation of Agricultural Economics, University of California, Berkeley 4.