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MAPS SHOWING AREAS IN THE SAN FRANCISCO BAY REGION WHERE NITRATE, BORON, AND DISSOLVED SOLIDS IN GROUND WATER MAY INFLUENCE LOCAL OR REGIONAL DEVELOPMENT

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INTRODUCTION

This report is intended to provide regional planners, local government officials, and water users with information on the nitrate, boron, and dissolved-solids content of ground water in the San Francisco Bay region.

The report is a compilation of data obtained from chemical analyses made during 1945-70. Places where nitrate in ground water has exceeded 45 mg/l (milligrams per liter) and boron has exceeded 1 mg/l, standards established by the U.S. Public Health Service and the U.S. Salinity Laboratory Staff, respectively, and places where dissolved solids have exceeded 2,000 mg/l are shown on the maps (sheets 1, 2, 3) by symbols. Areas where the maximum concentration of dissolved solids in ground water generally has been less than 500 mg/l, 500 to 1,000 mg/l, and greater than 1,000 mg/l, and areas for which readily available chemical-quality data are lacking, are outlined. Changes in the specific conductance and approximate dissolved-solids content of ground water at 66 sites (wells) are shown by graphs for 1960-70.

The maps were prepared to provide a general inventory of ground-water quality in the San Francisco Bay region. Hence, the maps may fulfill general informational needs, and serve as guides for planning more specific water-quality investigations by water managers and by planners considering prudent urban development.

The presentation is necessarily generalized because the occurrence and movement of ground water in the region are complex, and because information that changes with time and is derived from a three-dimensional aquifer system is inherently difficult to present on maps. In many areas chemical data are not shown because of the lack of information. In some areas constituents other than those considered herein may also influence local ground-water use.

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Sources of data - Many of the chemical analyses included in this compilation have been published in the California Department of Water Resources series, "Quality of Ground Waters in California" (1958, 1960a, 1960b, 1961, 1964a, 1964b) and its successor series, "Hydrologic Data" (1965 through 1971, annually). Other analyses have been published in California Division of Water Resources (1956); Cardwell (1958, 1965); Kunkel and Upson (1960); Thomasson, Olmsted, and LeRoux (1960); Dale and Rantz (1966); Berkstresser (1968a, 1968b); Averett, Wood, and Muir (1971), and California Department of Water Resources (1971). A small number of analyses have been obtained from unpublished records in the files of the U.S. Geological Survey and the California Department of Water Resources.

Reports describing the chemical quality of ground water and the water-bearing characteristics of the rocks are available for areas outlined on the index map (sheet 1). In addition, reports that summarize the hydrologic properties of the rocks and chemical quality of both ground water and surface water in many areas not shown on the index map are listed in Bulletin 170-69 of the California Department of Water Resources (1970) and in Publication 37 of the California Water Quality Control Board (1967).

Discussion of terminology - Dissolved solids, total solids, and total dissolved solids are terms used more or less synonymously for the anhydrous residues of the dissolved substances in water. The concentration of the anhydrous residue may be determined from the weight of the dry residue remaining after an accurately measured sample has been evaporated to dryness, or an approximate concentration of dissolved material in water may be calculated if the concentrations of major ions are known. The dissolved-solids measurement is widely used in evaluating water quality and is a convenient means of comparing waters over a period of time or from different sources.

Specific electrical conductance, or specific conductance, of water is the reciprocal of the resistance measured between opposite faces of a centimeter cube of solution at a specified temperature. Because a relation exists between the conductivity of water and the dissolved-solids content, measurements of specific conductance can be used as a general indication of the concentration of dissolved materials. In most parts of the San Francisco Bay region, the relation between dissolved solids and specific conductance is fairly simple and direct. Chemical data from more than 400 wells show that a useful approximation of the dissolved-solids content of water can be obtained by multiplying the recorded specific conductance by a factor of 0.6. Thus, the maps reflect ranges in dissolved solids that were determined in the laboratory or calculated from measured values of specific conductance.

The two most common units for reporting water analysis are parts per million (ppm), a weight-per-weight unit, and milligrams per liter (mg/l), a weight-per-volume unit. Parts per million represents the weight of solute, expressed in milligrams, in 1 kilogram of solution. Milligrams per liter represents the weight of solute in 1 liter of solution. The two units are exactly equivalent for pure water at 3.98°C; at other temperatures or with the introduction of dissolved mineral matter, a change in density occurs, resulting in a divergence of values. For practical purposes, however, the two units may be considered as approximately equal until the concentration of dissolved solids exceeds about 7,000 mg/l (Hem, 1970, p. 80).

DISSOLVED SOLIDS

All salts in solution affect the physical and chemical properties of the water. Dissolved salts, or dissolved solids, in drinking water are of concern because of the taste and laxative properties that they may impart. The U.S. Public Health Service (1962) recommends that drinking and culinary water on carriers subject to Federal quarantine regulations contain not more than 500 mg/l of dissolved solids if other more suitable supplies are or can be made available. This recommendation is based on considerations of taste, but water containing higher concentrations may be ingested without producing harmful physiological effects. Many communities in the United States use public supplies containing more than 1,000 mg/l of dissolved solids because less mineralized water is not available, and at least 100 communities use water containing more than 2,000 mg/l (U.S. Public Health Service, 1962, p. 33). Gastric disturbances may be associated with a change to drinking water containing a considerably higher concentration of dissolved solids than that to which one is accustomed; however, the concentration of dissolved solids in the water is usually less important in this regard than is the concentration of some specific salts present in solution. Water containing more than a few thousand milligrams per liter of dissolved salts is generally not very palatable, although those accustomed to highly mineralized water may complain that water containing a smaller concentration tastes flat. At sufficiently high concentrations, water becomes unfit for human consumption; the upper limit of dissolved solids in water useable for drinking is placed at 4,000 mg/l by McKee and Wolf (1963, p. 182) and "in the range above 5,000 mg/l" by the U.S. Public Health Service (1962, p. 34).

Livestock tolerances to dissolved substances in water are reported to be dependent upon the specific mineral content. The National Technical Advisory Committee on Water Quality Criteria (1968, p. 133) reported that,

> "...practical experience and a limited amount of controlled experimental work indicate that chickens, swine, cattle, and sheep can survive and remain healthy on saline waters containing up to 15,000 mg/l of minerals such as bicarbonates, chlorides, and sulfates of sodium and calcium and up to 10,000 mg/l for the corresponding salts of potassium and magnesium. The limits of tolerance to alkaline waters, those containing sodium and calcium carbonates, are around 5,000 mg/l."

The upper limit of dissolved solids in water used for industrial purposes is highly variable and dependent on the specific use or product. Few industrial processes will permit the use of more than 1,000 mg/l dissolved solids (Rainwater and Thatcher, 1960, p. 269). The presence of undesirable amounts of dissolved solids can cause foaming in boilers and interference with the appearance, color, or taste of many finished industrial products which require the use of water during processing (McKee and Wolf, 1963, p. 182).

One of the more important considerations for irrigation water is the effect of dissolved solids on the osmotic pressure of the soil solution. The difference in osmotic pressure between the soil and plant solutions controls the water uptake of plants. Concentrated soil solutions diminish uptake and may cause wilting of crops in fields apparently having adequate water content. The U.S. Salinity Laboratory Staff (1954, p. 76) classified the salinity hazard of irrigation water, in terms of specific conductance, as follows: less than 250 micromhos, low; 250 to 750 micromhos, medium; 750 to 2,250 micromhos, high; and greater than 2,250 micromhos, very high. This classification is but a general guide, however, as the satisfactory use of a particular water for irrigation depends on many factors other than the dissolved-solids content, such as the relative proportions of some ions present, concentrations of certain potentially toxic ions, soil characteristics, drainage, irrigation practices, and crops grown. New composite guides relating specific problems, such as salinity, permeability, and toxicity, to their severity are currently (1972) being developed for various crops by the U.S. Salinity Laboratory Staff.

The maps show areas where the maximum concentration of dissolved solids generally has not exceeded 500 mg/l; areas where the maximum concentration has been greater than 500 mg/l but less than 1,000 mg/l; areas where the maximum concentration has exceeded 1,000 mg/l; and places where the maximum concentration has exceeded 2,000 mg/l.

The graphs show changes in the specific conductance and approximate dissolved-solids content of water from wells sampled during the period 1960-70. Small fluctuations shown in the graphs (wells 4S/1W-21F and -35P, inset map, sheet 3) reflect minor changes in the chemical quality of water produced by the well, and are probably due to variations in recharge to and discharge from the ground-water reservoir, time between pumping periods, and the length of time the well had been pumped when the sample was collected. Large fluctuations shown in the graphs (wells 4S/1W-18H and 5S/1W-9J, inset map, sheet 3) probably indicate major changes in the chemical quality of water being supplied to the aquifer and well. Thus, the graphs can be used to evaluate general water quality, to compare water in one area with water in another area, and to indicate places where water quality has changed significantly during the 10-year period.

NITRATE

Nitrate occurs naturally in rainwater and in soils. Certain species of bacteria in soil and the blue-green algae and other microbiota occurring in water can extract nitrogen from the air and convert it into nitrate. Dissolved nitrate is a major nutrient for plants, and that which is utilized by plants is partly returned to the soil when the plants die. Nitrate in the soil is artificially increased by man when nitrate fertilizers are used, and concentrations derived from organic wastes may occur in barnyards, feeding pens, and other places where large numbers of animals are confined. Nitrate is also an important byproduct of decomposing wastes from fruit and vegetable canneries, cesspools, septic tanks, and sewage-treatment plants.

In natural water nitrate concentrations range from a few tenths to several hundred milligrams per liter, but seldom exceed 10 mg/l (Rainwater and Thatcher, 1960, p. 216). The U.S. Public Health Service (1962, p. 7) recommends that drinking water contain not more than 45 mg/l of nitrate if other more suitable supplies are or can be made available, and that in areas where the nitrate content is known to occur in excess of this concentration, the public should be warned of the potential dangers of using the water for infant feeding.

In the San Francisco Bay region, nitrate in ground water has exceeded 45 mg/l in a small area east of Vacaville (sheet 2); in Clayton Valley (sheet 2); Livermore Valley and the Altamont Hills (sheet 3); an area along the east side of San Francisco Bay extending from Fremont to Oakland (sheet 3); in the vicinity of Old Gilroy (sheet 3); and in several places between San Jose and San Francisco Bay (sheet 3).

BORON

Boron is a minor constituent of most natural waters. Ocean water contains about 4.6 mg/l of boron (Hem, 1970, p. 187); the natural ground and surface waters of North America usually contain less than 1 mg/l of boron (National Technical Advisory Committee on Water Quality Criteria, 1968, p. 23). The ground water of some areas, however, particularly those areas underlain by marine sedimentary rocks and fractured igneous rocks, may contain higher concentrations. Water in volcanic areas and the water of many thermal springs may also contain unusually high concentrations of boron.

Boron in drinking water is not generally regarded as a hazard to humans, although the ingestion of unusually large concentrations may interfere with digestion and cause various symptoms of distress (McKee and Wolf, 1963, p. 147). The element is not known to perform any vital function in human or animal nutrition, but is essential in minute amounts to the nutrition of the higher plants. Only a small excess over the amount needed, however, is toxic to some types of plants. Water containing more than 1.0 mg/l of boron is classified as "doubtful" for boron-sensitive crops, such as many nut, fruit, and citrus trees, and water containing more than 1.25 mg/l of boron is classified as "unsuitable" for these plants (Hem, 1970, p. 329, after U.S. Salinity Laboratory Staff). Boron-tolerant crops, such as asparagus, alfalfa, onions, cabbage, and lettuce, may incur slight to moderate injury from water containing 2.0 to 4.0 mg/l of boron, and damage to all crops may result from the application of water containing more than 4.0 mg/l of boron (National Technical Advisory Committee on Water Quality Criteria, 1968, p. 153).

In the San Francisco Bay region, boron in ground water has been found to exceed 1.0 mg/l at places in Alexander Valley (sheet 1); in a few wells north and west of Santa Rosa (sheet 1); at places in Napa and Sonoma Valleys (sheet 2); in a large area north and east of Suisun Bay (sheet 2); in Ygnacio and Clayton Valleys (sheet 2); in the vicinity of Mt. Diablo (sheet 2); along the western border of the San Joaquin Valley (sheets 2 and 3); in wells and springs located in the hills east of San Leandro, Hayward, and Fremont (sheet 3); east of Berryessa in the Santa Clara Valley (sheet 3); in Livermore Valley and in the Altamont Hills (sheet 3). In the Altamont Hills, east of Livermore Valley, boron in ground water commonly ranges from 20 to 100 mg/l. One well (3S/1E-26Q) located southwest of the Clifton Court forebay (sheet 3) has yielded water containing 180 mg/l boron.

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