CALIFORNIA
Ground-Water Quality

Nearly 18 million people, about 69 percent of the population of California (fig. 1) rely on ground-water supplies. Ground water in principal aquifers (fig. 2) may not be suitable for all public-supply, domestic, agricultural, and industrial uses because of dissolved minerals or temperature but may support selected uses consistent with the quality of the water.

The California State Water Resources Control Board (SWRCB) made a ground-water-quality assessment from 1984 to 1985 based on designated water use in 139 of 461 ground-water basins in the State identified by the California Department of Water Resources (DWR). The 139 basins comprise 79 percent of the surface area of all basins and include the top-priority basins based on population, use, and water-quality problems. Ground-water quality in the 139 basins is generally good, based on criteria established by SWRCB. Seventy-six percent of the ground-water basins assessed support designated water uses; whereas, 14 percent partially support uses. Water quality is unknown in about 8 percent of the basins assessed. Ground water of poor quality was found in parts or all of 21 basins (California State Water Resources Control Board, 1986).

At 71 hazardous-waste sites (fig. 3), monitoring and evaluation of ground-water quality is required by the Federal Resource Conservation and Recovery Act (RCRA) of 1976. In addition to the RCRA sites, 34 other sites are included by the U.S. Environmental Protection Agency (EPA) in the National Priorities List (NPL) of hazardous-waste sites (U.S. Environmental Protection Agency, 1986c) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Ground-water contamination from organic solvents, pesticides, acids, and trace metals has been detected at 26 of the 34 CERCLA sites. The California Department of Health Services (DOHS) has about 120 additional sites on a State toxic substances priority list where monitoring and evaluation are in progress.

Twenty-three sites on 12 military installations were recommended for cleanup in phase IV of the U.S. Department of Defense (DOD) Installation Restoration Program (IRP), and remedial action has been completed at 11 sites as of September 1985.

Numerous ground-water-quality monitoring programs are conducted by other

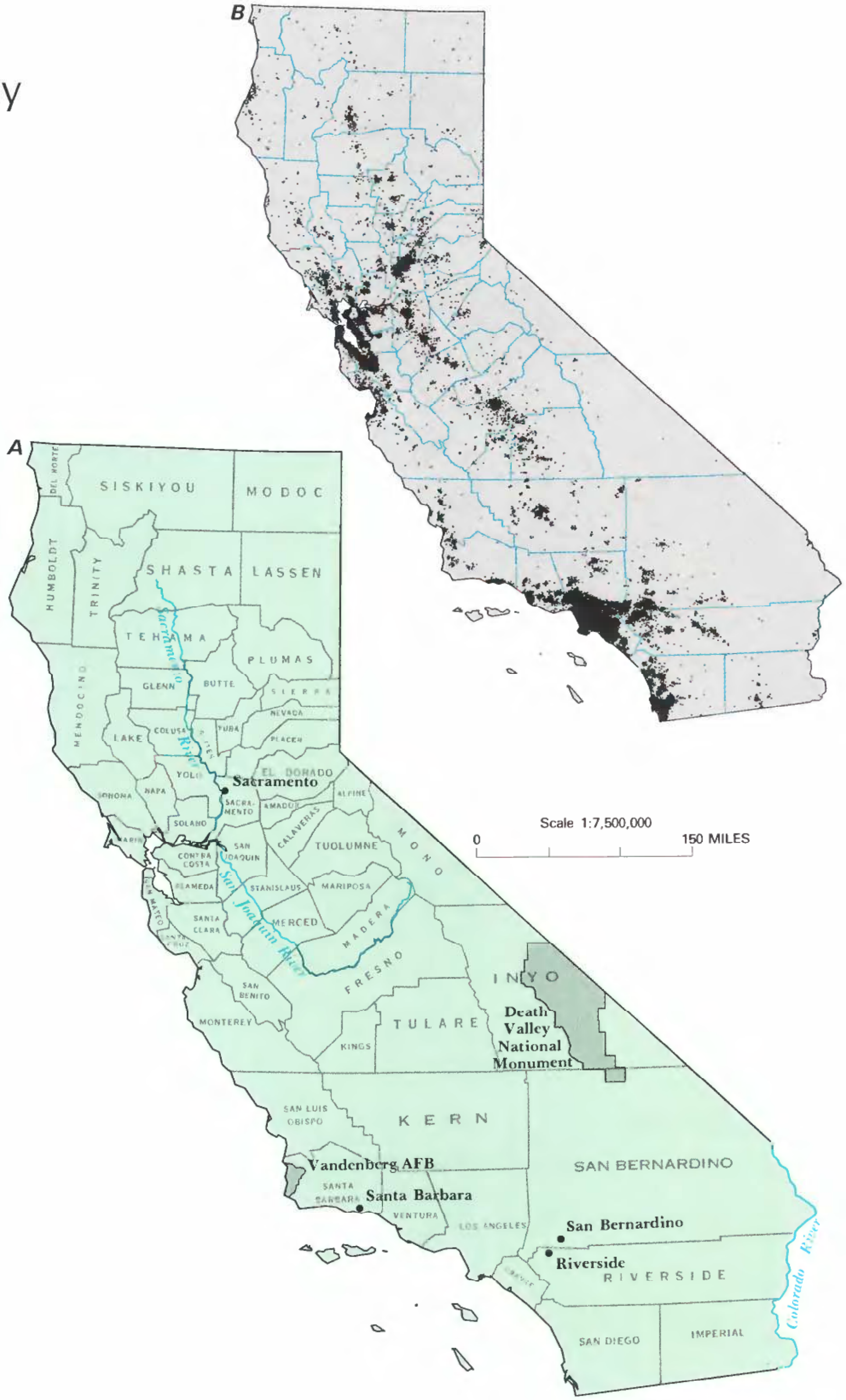

Figure 1. Selected geographic features and 1985 population distribution in California. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)

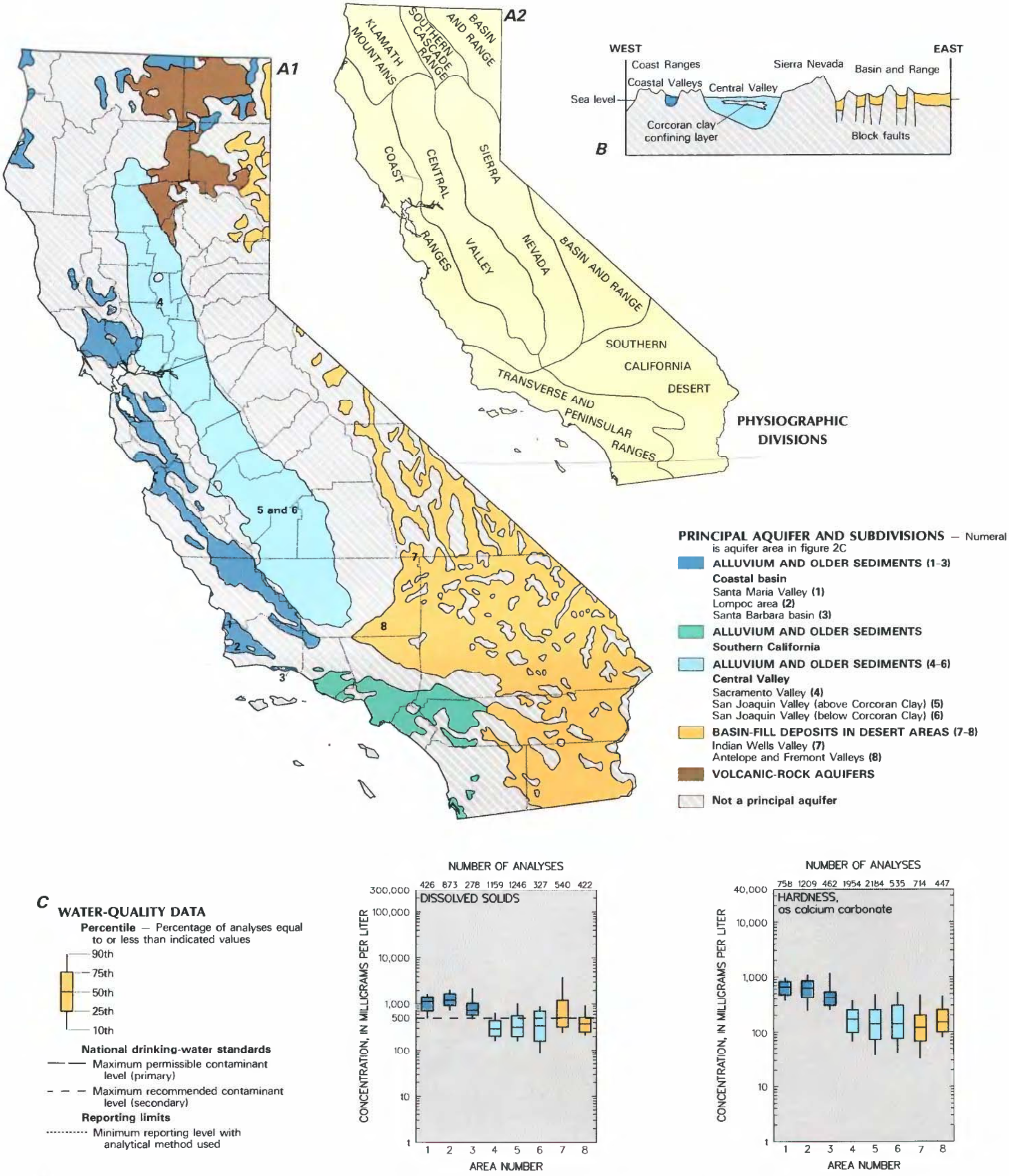

Figure 2. Principal aquifers and related water-quality data in California. *A1*, Principal aquifers; *A2*, Physiographic provinces. *B*, Generalized geologic section. *C*, Selected water-quality constituents and properties, as of 1986. (Sources: *A1*, California Department of Water Resources, 1975c, 1980a. *A2*, Fenneman, 1946. *B*, Compiled by A.M. Spieker from U.S. Geological Survey files. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

Federal, State, and local agencies. The DWR and cooperating agencies, including the U.S. Geological Survey, collect and analyze water-quality data from over 1,200 wells. Analyses from an additional 400 wells are furnished to DWR by other local water agencies. The SWRCB has compiled information, including well characteristics and analyses types, for all ground-water-quality networks statewide.

WATER QUALITY IN PRINCIPAL AQUIFERS

The two principal types of aquifers in California (fig. 2*A*1) are alluvium and older sediments, and volcanic rocks. The alluvial and sedimentary aquifers are geographically divided into four areas: coastal basins, southern California, Central Valley, and desert areas (U.S. Geological Survey, 1985, p. 147). Within these areas, DWR has identified 461 ground-water basins, of which 248 are considered significant sources of ground water (California Department of Water Resources, 1975a). The hydrologic characteristics of individual ground-water basins are governed by complex geologic relations, and multiple aquifers are common.

The volcanic rock aquifers are mainly in northern California. Most water is found in fractures, rubble zones, and sand and gravel layers interbedded between lava flows. The volcanic rock aquifers are not used extensively (U.S. Geological Survey, 1985, p. 150).

Ground water supplies about 40 percent of California's annual applied water needs. Ground-water withdrawals are largest in the Central Valley (fig. 2*A*2), which consists of the Sacramento and San Joaquin Valleys. Significant pumpage also occurs in southern California alluvial basins and in the Santa Clara and Salinas Valley coastal basins (U.S. Geological Survey, 1985, p. 151).

BACKGROUND WATER QUALITY

Diagrams summarizing dissolved-solids, hardness (as calcium carbonate), nitrate plus nitrite (as nitrogen), chloride, and boron data for aquifers in selected alluvial and sedimentary basins in California are shown in figure 2*C*. All data as of 1986 were compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE). Insufficient data were available to describe ground-water quality in the volcanic rock aquifers. Sample depth was considered only in the San Joaquin Valley, where diagrams are shown for samples above and below the Corcoran Clay (fig. 2*C*). Extreme constituent values discussed in the text are not shown. National standards that specify the maximum concentration or level of a contaminant in drinking-water supply have been established by the EPA (U.S. Environmental Protection Agency, 1986a,b). The primary maximum contaminant level standards are health related and legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen), and the secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids and 250 mg/L chloride.

Alluvium and Older Sediments—Coastal Basins

The Santa Maria Valley (fig. 2*A*1, area 1) is an extensively developed agricultural basin overlying coastal alluvium and older sediments. Excessive ground-water withdrawals and recycling of water for agricultural, municipal, and industrial uses have caused accumulation of solutes and increased concentrations of nitrate as nitrogen in ground water (Hughes, 1977). The most severe degradation of ground-water quality has occurred in the western part of the valley, where dissolved-solids concentrations may exceed 2,000 mg/L in shallow wells. The median concentration of dissolved solids is more than 1,000 mg/L (fig. 2*C*). Nitrate-plus-nitrite (as nitrogen) concentrations are as large as 50 mg/L in some areas, and concentrations in excess of 10 mg/L occur in more than 25 percent of the samples (fig. 2*C*).

Agriculture is a major land use in the Lompoc area (fig. 2*A*1, area 2). Ground water is the primary source of supply for agriculture in this area. The presence of Vandenberg Air Force Base and a Federal prison here have increased concerns about ground-water quality. Dissolved-solids concentrations are generally about 1,000 to 1,500 mg/L in the eastern part of the Lompoc area and 1,500 to 3,000 mg/L in the western part (Miller, 1976). Extremely large concentrations of dissolved solids (as much as 24,000 mg/L) in some wells near the coast are the result of saltwater intrusion. The median hardness of water samples is 630 mg/L (as calcium carbonate). Water with 180 mg/L or more hardness is classified as very hard (Hem, 1985). Drinking-water supplies delivered by local purveyors, including the Air Force, are treated to reduce the hardness to about 150 mg/L.

In the Santa Barbara basin (fig. 2*A*1, area 3), ground water provides part of the city water supply, which has been stressed by demands from increasing population. Evidence of saltwater intrusion has been found in wells near the coast for many years (Martin, 1984). Many wells, especially in the coastal area, yield water with dissolved-solids concentrations greater than 1,000 mg/L. The median concentration of dissolved solids in the basin is 738 mg/L. Inland, at production wells owned by the city of Santa Barbara, dissolved-solids concentrations are generally less than 500 mg/L. Chloride concentrations in ground water in the Santa Barbara basin range from 15 to 18,000 mg/L.

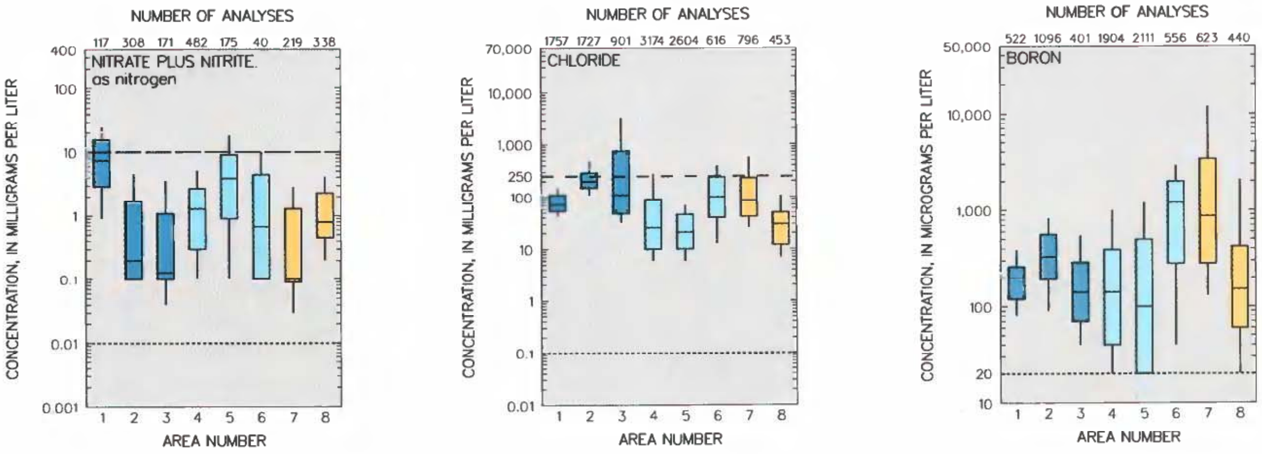

Figure 2. Principal aquifers and related water-quality data in California—Continued.

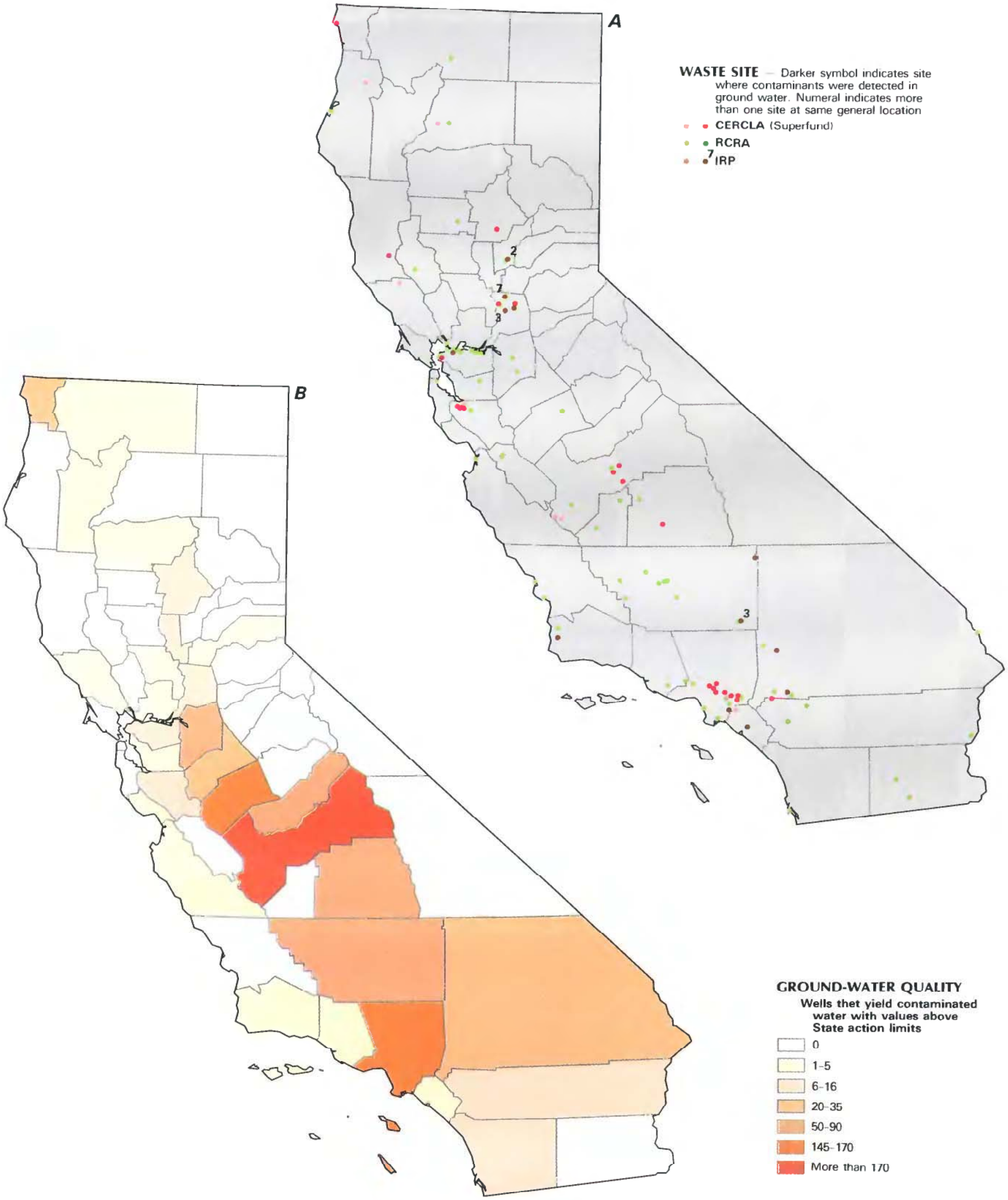

Figure 3. **Selected waste sites and ground-water-quality information in California.** *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; Resource Conservation and Recovery Act (RCRA) sites, as of 1986; and Department of Defense Installation Restoration Program (IRP) sites, as of 1985. *B*, Distribution of wells that yield contaminated water, as of 1986. *C*, County or municipal landfills, as of 1986. (Sources: *A*, U.S. Department of Defense, 1986; information from Environmental Protection Agency and California State Water Resources Control Board. *B*, Cohen and Bowes, 1984; California Department of Health Services, 1986; and information from California Regional Water Quality Control Boards. *C*, information from California Waste Management Board.)

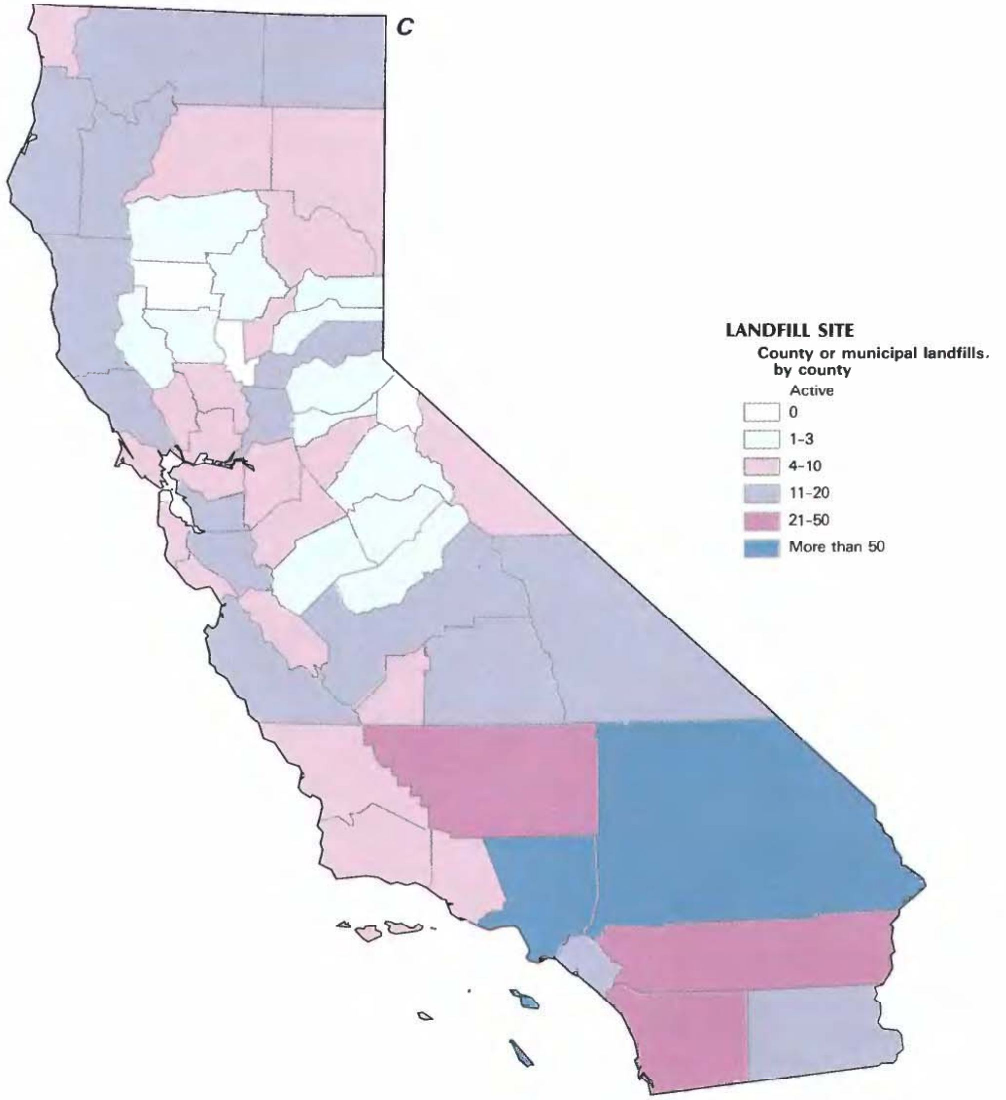

Figure 3. Selected waste sites and ground-water-quality information in California—Continued.

Alluvium and Older Sediments—Central Valley

In the Sacramento Valley (fig. 2*A*1, area 4), concentrations of dissolved solids are typically less than 500 mg/L. The median dissolved-solids concentration is 296 mg/L. Two large areas in the southern part of the Sacramento Valley have dissolved-solids concentrations ranging from 500 to 1,500 mg/L. Localized sites may contain concentrations greater than 1,500 mg/L (Fogelman, 1982). Hull (1984) postulated that upwelling of saline water from marine sedimentary deposits contributes to larger dissolved-solids concentrations in some areas. In the southwestern part of the Sacramento Valley, boron concentrations commonly exceed 750 μg/L (micrograms per liter) (Fogelman, 1983), the limit recommended by the EPA for long-term irrigation on boron-sensitive plants. Recharge from greatly mineralized thermal springs in the Coast Ranges (fig. 2*A*2) contributes to the large boron concentrations.

Ground-water quality differs areally and with depth in the primarily agricultural San Joaquin Valley (fig. 2*A*1, areas 5 and 6). Dilute surface-water runoff from crystalline rocks of the Sierra Nevada recharges the eastern side of the valley, whereas ground-water recharge from the west side originates in sedimentary rocks of the Coast Ranges. Above the Corcoran Clay (area 5), dissolved-solids concentrations increase from east to west. Concentrations range from less than 200 mg/L to more than 2,000 mg/L, with isolated concentrations larger than 8,000 mg/L. Below the confining clay layer (area 6), the distribution pattern is similar, but dissolved-solids concentrations rarely exceed 1,000 mg/L. Median values for nitrate plus nitrite (as nitrogen) are 3.9 mg/L in water samples from wells above the Corcoran Clay and 0.68 mg/L below the Corcoran Clay.

Basin-Fill Deposits in Desert Areas

Physiographically, many desert basins in California are characterized by broad alluvial fans and plains sloping to playas, creating closed drainage basins that are usually dry. Hydrologic characteristics can differ considerably from basin to basin and within basins. Indian Wells Valley and Antelope and Fremont Valleys (fig. 2*A*1, areas 7 and 8) are selected for discussion as having typical water-quality characteristics of many basin-fill deposits in desert areas.

Ground water is the only source of water in Indian Wells Valley (fig. 2*A*1, area 7). Water levels are declining as a result of increased public, industrial, and agricultural usage (Berenbrock, 1987). Poor-quality ground water has been documented in many areas of the valley, especially in the shallow playa deposits. There is a major concern that poor-quality water may move toward areas of significant pumping where water is still of relatively good quality. Dissolved-solids concentrations range from 190 to 67,000 mg/L, with the largest concentrations found in shallow wells in the playa. The median dissolved-solids concentration is 510 mg/L, only slightly exceeding the 500-mg/L drinking-water standard. Chloride concentrations range from 17 to 39,000 mg/L, with a median concentration of 86 mg/L.

Antelope and Fremont Valleys (fig. 2*A*1, area 8) are intersected by numerous faults and are separated hydrologically into many subbasins and areas. Generally, surface drainage terminates at the Rosamond and Rogers Lake playas in Antelope Valley, and Koehn Lake playa in Fremont Valley. Imported water from northern California into several areas of Antelope Valley has altered the natural hydrologic regime. Dissolved-solids concentrations are generally less than 500 mg/L in Antelope and Fremont Valleys, and the median concentration is 375 mg/L. Some wells, especially near the playas where drainage terminates, yield water with dissolved-solids concentrations as large as 4,200 mg/L; however, the 90-percentile concentration is less than 1,000 mg/L.

EFFECTS OF LAND USE ON WATER QUALITY

Water-quality degradation has occurred in many areas as a result of irrigation return flow, application of agricultural pesticides and fertilizers, improper waste disposal and industrial practices, and saltwater intrusion.

Agriculture

In 1980, nearly 200 commercial crops were grown on 9.5 million acres of irrigated land in California (California Department of Water Resources, 1983). Agriculture is extensive in most counties in the Central Valley, parts of Imperial, Riverside, and San Bernardino Counties, and many coastal and southern California basins. Widespread use of pesticides in these agricultural areas has contaminated hundreds of wells, and several State agencies have implemented pesticide-monitoring programs to document the extent of the problem.

Dibromochloropropane (DBCP) is the most widespread pesticide contaminant found in ground water. Of 8,190 private and public-supply wells sampled from 1979 through 1984, 2,522 wells had DBCP contamination. More than one-third of the wells sampled in Fresno County were contaminated with DBCP. In Merced, Tulare, and Madera Counties, nearly one-quarter of the sampled wells had DBCP contamination. The State action level of 1 part per billion DBCP was exceeded in 1,455 wells (Cohen and Bowes, 1984). State action levels are informal guidelines for drinking water based on health considerations. The action levels are not legally enforceable but are regarded by most water suppliers the same as maximum contaminant levels established by government regulations. More than 50 other pesticides, including 1,2-dichloropropane and ethylene dibromide (EDB), had been detected in samples from 255 wells through 1984.

In the central part of the western San Joaquin Valley, selenium concentrations in shallow ground water and subsurface agricultural drainage water commonly exceed 100 μg/L, and in places exceed 1,000 μg/L. In 1984, State and Federal agencies, including the U.S. Geological Survey, began intensive investigations of the occurrence, distribution, and movement of selenium in the San Joaquin Valley.

Industry

In 1980, organic chemicals were found in several domestic water-supply wells in Los Angeles County, and more than 50 wells were eventually closed. In response to the discovery of contamination of these wells and wells in the San Joaquin Valley and San Bernardino-Riverside area, the State legislature passed Assembly Bill 1803 in 1983. This bill requires monitoring of organic chemicals in public drinking-water systems in heavy- and light-industrial and agricultural areas. During phase I of the implementation of the Bill, large water systems with 200 or more hookups were monitored. Smaller water systems are currently being monitored in phase II.

In initial data from phase I, 33 organic chemicals were detected in ground-water samples. Five of the most frequently detected chemicals in descending order of occurrence were tetrachloroethylene, also called perchloroethylene (PCE), trichloroethylene (TCE), DBCP, chloroform, and 1,1-dichloroethylene (1,1-DCE). Four of the 5, and 29 of the 33 organic chemicals are used in industrial and manufacturing processes. Of 2,947 wells sampled during phase I, PCE was detected in 199 wells with a maximum concentration of 166 μg/L. TCE was detected in 188 wells with a maximum concentration of 538 μg/L. Concentrations of chloroform as large as 54 μg/L were found in 116 of the wells sampled, but some samples with large concentrations may be associated with chlorination of the well supply. Wells with the largest 1,1-DCE concentrations—as large as 78 μg/L—were generally from samples in greatly urbanized areas (California Department of Health Services, 1986).

Waste Disposal

Hazardous waste is disposed of at 71 RCRA sites (fig. 3*A*), creating a potential hazard to ground-water quality. The status of ground-water contamination near these sites is listed as "unknown" by EPA until additional monitoring programs are started and current data evaluated. However, ground-water contamination has been detected at 26 of the 34 CERCLA sites on the NPL (fig. 3*A*). The list of contaminants is extensive and includes industrial cleaning solvents, pesticides, acids, and trace metals. TCE and PCE have been found in the ground water at several of the 26 sites. At one site, leaking organic solvents disposed of in a lined evaporation pond contaminated more than 50 private wells. At another site, several private wells were contaminated with DBCP after wastes from pesticide and fertilizer production were disposed of in unlined ponds and in a company-owned landfill.

As of September 1985, 405 hazardous-waste sites at 34 facilities in California have been identified by the DOD as part of their IRP as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the EPA Superfund program under CERCLA, and has four phases: assessment (I), confirmation (II), technology development (III), and remedial action (IV). EPA presently ranks these sites under a hazardous ranking system and may include them in the NPL. Of the 405 sites evaluated under the program, one site contained contaminants but did not present a hazard to people or the environment. Twenty-three sites at 12 facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Remedial action at 11 of these sites has been completed under the program.

The distribution by county of wells that yield contaminated water above State action levels, as of 1986, are shown in figure 3*B* (based on information obtained from the SWRCB). Except for Fresno County, which had 1,052 wells that yield contaminated water exceeding State action levels, and Merced and Los Angeles Counties, the 12 other counties reporting wells that yield contaminated water had 90 or less.

California has 651 active county or municipal landfill sites (fig. 3*C*). Los Angeles County has 117 sites, followed by San Bernardino County (89), and Kern County (26). Sufficient data are not available for an evaluation of the effects of these sites on the quality of ground water. Total numbers of inactive or closed landfill sites are not available but probably number several hundred.

Saltwater Intrusion

Saltwater intrusion generally occurs in coastal areas when ground-water levels are lowered below sea level by pumping. Fourteen important coastal basins, including Santa Clara Valley (Santa Clara County), Morro basin (San Luis Obispo County), the Salinas Valley (Monterey County), Oxnard Plain basin (Ventura County), and coastal basins in Los Angeles and Orange Counties, have documented saltwater intrusion, and it is suspected in many other basins (California Department of Water Resources, 1975b). In many areas, such as Los Angeles and Orange Counties, inland migration of saltwater has been halted or reversed by reduced or controlled pumping, use of barrier injection wells, and (or) artificial recharge.

POTENTIAL FOR WATER-QUALITY CHANGES

Population in California is expected to increase by 10.6 million, from 23.8 million in 1980 to 34.4 million in 2010 (California Department of Water Resources, 1983). About 50 percent of the increase is expected in urbanized and water-deficient southern counties—Los Angeles, Orange, Riverside, San Bernardino, and San Diego. Irrigated acreage is projected to increase by about 700,000 acres, to 10.2 million acres in 2010, with increases primarily in the Central Valley. Overall, the State's average annual ground-water overdraft is projected to increase from 1.8 million acre-feet in 1980 to 2.9 million acre-feet in 2010.

On the basis of these projections, the potential for change in ground-water quality in many basins is considerable. In the past, overdraft of ground water has led to saltwater intrusion in some coastal basins. In other basins, overdraft has increased dissolved-solids concentrations in ground water. Increased pumpage may cause contaminated ground water to migrate toward pumping centers.

Agriculture and associated land uses—feed lots, septic tanks, and processing plants—have contaminated and changed the quality of ground water in many basins. Also, ground water in some urban basins has been contaminated and changed by leaky underground storage tanks, waste disposal, and the chemicals used in industry. Leakage of solvents and gasoline from underground storage tanks and piping is considered a major source of potential ground-water contamination. Numerous instances of contamination from leaks have occurred, from metropolitan areas to the isolated Stovepipe Wells Village in Death Valley National Monument.

Of additional concern are abandoned wells in areas that were primarily agricultural, but have been urbanized. If the abandoned wells are not properly sealed, they may act as conduits for contaminants from the land surface to ground water.

Changes in agricultural practices may be necessary to avoid increased salinity in shallow ground water. New and additional ways of transporting water to deficient areas also may be required. Enforcement of existing laws and protection-monitoring programs will be an essential part of safeguarding California's water supplies.

GROUND-WATER-QUALITY MANAGEMENT

The DWR and SWRCB are the principal water-management agencies of the State. DWR engages in statewide water-supply planning activities and conducts ground-water quantity and quality investigations in support of statewide planning efforts. Information, technical advice, and assistance are provided to other water agencies. The SWRCB and nine California Regional Water Quality Control Boards establish and enforce water-quality standards for State water supplies, including ground water. The DOHS investigates the quality of ground-water supplies used as sources of drinking water. The California Department of Food and Agriculture investigates ground-water supplies subject to pesticide contamination, and the California Department of Conservation, Division of Oil and Gas, controls oil- and gas-related underground-injection activities.

Federal water-quality legislation is implemented through several State agencies. The Public Water Supply provisions of the Safe Drinking Water Act are implemented by DOHS, as are CERCLA, RCRA, and the Toxic Substances Control Act. The Clean Water Act is administered by the SWRCB. Primary control for underground injection oil and gas wells (Class II) has been assigned to the Department of Conservation, Division of Oil and Gas, by EPA.

Users of ground water generally are not regulated. Exceptions are in adjudicated basins and in water districts that have powers to tax pumpage. Water rights in nine of the State's ground-water basins have been adjudicated as a result of conflicts among users. Pump taxes have been set by 5 of the 12 agencies authorized to do so. The SWRCB, in cooperation with DWR, is in the process of establishing water-well construction standards. Drillers are licensed by the Contractor's State License Board; well logs produced during drilling activities are maintained by DWR.

California is developing a ground-water protection strategy through the Interagency Coordinating Committee, an organization of State agencies having ground-water responsibilities. The committee is chaired by SWRCB, the lead agency for developing the strategy. Participating agencies include the Departments of Water Resources, Health Services, Conservation, Food and Agriculture, and the Waste Management Board. Development of the ground-water protection strategy is expected to be completed in 1987. A major feature of the strategy will be a policy of nondegradation of the ground-water resource.

Ground-water-level measurements by many agencies are compiled and monitored statewide by DWR (California Department of Water Resources, 1975c). Ground-water-quality monitoring programs are conducted by many agencies in California. The California State and Regional Water Quality Control Boards monitor ground-water quality under various programs related to waste-discharge regulation. The SWRCB funds DWR to do supplemental monitoring of mineral and suspected toxic-pollutant quality in four of the Priority I ground-water basins. This monitoring changes annually in the number and selection of wells and chemical constituents for each basin, expanding on the efforts of other government agencies. These data are being collected to meet the requirements of the EPA in accordance with Public Law 92–500 of the Federal Water Pollution Control Act Amendments of 1972 (California Department of Water Resources, 1980b, p. 3). Plans are underway for extension of this program to include more Priority I basins.

The DOHS is conducting a large-scale one-time program to monitor public ground-water supplies for toxic pollutants. This program is a result of passage of two State laws (Assembly Bill 1803 of 1984 and Assembly Bill 1803 of 1985). This work is well underway, and data from the program are available (California Department of Health Services, 1986). A third law (Assembly Bill 2058 of 1985) requires DOHS to initiate controls on underground injections. These controls are supposed to be consistent with, but more stringent than, those of the EPA.

Another State statute (Assembly Bill 2021 of 1985) requires the Department of Food and Agriculture to determine which pesticides have the capability to infiltrate the soil and contaminate ground water. Significant ground-water monitoring for pesticides will be done in support of this program, which has been implemented recently.

In addition to programs of State agencies, local agencies do significant ground-water-quality monitoring. The Santa Clara Valley Water District has done extensive monitoring for toxic organics in the Santa Clara Valley ground-water basin (Gloege, 1984). This basin is recharged by infiltration of surface water regulated by the Santa Clara Valley Water District. Water retailers pump from the basin, under control of the water district, which regulates and taxes withdrawals.

Cooperative programs between State and Federal agencies, including the U.S. Geological Survey, account for significant ground-water-level and -quality data collection at several hundred sites in the State.

The DWR has for many years maintained a limited statewide ground-water-quality monitoring network for mineral constituents. The DWR is budgeted for fiscal year 1986–87 to extend this program to the monitoring of toxic pollutants, in coordination with other agencies.

California is a large State, with vast and diverse ground-water resources. It can realistically be expected that several years of intensive work will be necessary to develop an effective ground-water-quality data base. The approach of State agencies will be to set priorities for the needed work and move ahead as rapidly as possible.

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