Water-Resources Data Network Evaluation for Monterey County, California, Phase 2: Northern and Coastal Areas of Monterey County

By William E. Templin, Peter E. Smith, Myrna L. DeBortoli, and
Randall C. Schluter

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Conversion Factors

Multiply	By	To obtain
acre	0.4047	hectare
square mile (mi^2)	2.590	per square kilometer
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer

Temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$°C=5/9\ (°F-32).$$

Vertical Datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviations

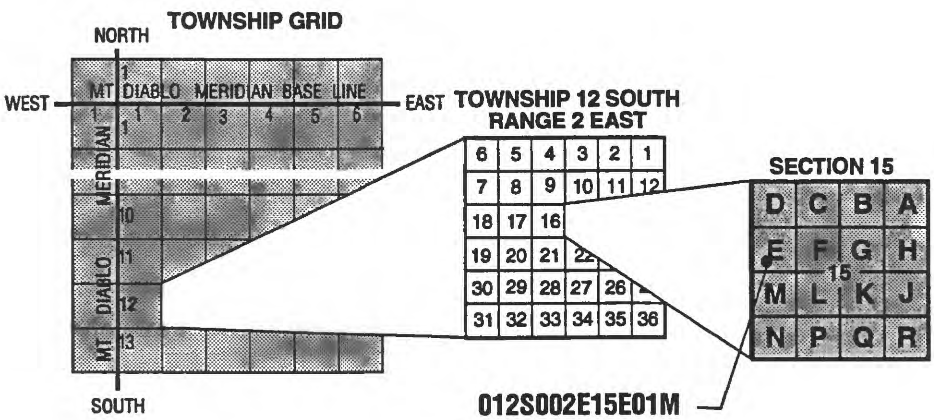
µg/L	micrograms per liter

Acronyms

CAWC	California American Water Company
CIMIS	Crop Irrigation Management Information Service
DWR	California Department of Water Resources
K-CERA	Kalman-Filtering for Cost-Effective Resource Allocation
MCFCWCD	Monterey County Flood Control and Conservation District
MPWMD	Monterey Peninsula Water Management District
NARI	Network Analysis for Regional Information (computer data manipulation procedures)
NASQAN	National Stream-Quality Accounting Network
NAWDEX	National Water Data Exchange
STORET	U.S. Environmental Protection Agency Data Base
USGS	U.S. Geological Survey
WATSTORE	U.S. Geological Survey Water-Data Storage and Retrieval System
WDIS	California Department of Water Resources Water Data Information System

Well-Numbering System

Wells are identified and numbered by the State of California according to their location in the system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are numbered sequentially in the order in which they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians: Humboldt (H), Mount Diablo (M), and San Bernardino (S). Because all wells in the study areas of this report are referenced to the Mount Diablo base line and meridian, the final letter "M" will be omitted. Well numbers consist of 15 characters and follow the format 012S002E015E01M. In this report, well numbers are abbreviated and written 12S/2E-15E1. The following diagram of the well-numbering system shows how well number 12S/2E-15E1 is derived.



WATER-RESOURCES DATA NETWORK EVALUATION FOR MONTEREY COUNTY, CALIFORNIA. PHASE 2: NORTHERN AND COASTAL AREAS OF MONTEREY COUNTY

By William E. Templin, Peter E. Smith, Myrna L. DeBortoli, and Randall C. Schluter

Abstract

This report presents an evaluation of water-resources data-collection networks in the northern and coastal areas of Monterey County, California. This evaluation was done by the U.S. Geological Survey in cooperation with the Monterey County Flood Control and Water Conservation District to evaluate precipitation, surface water, and ground water monitoring networks. This report describes existing monitoring networks in the study areas and areas where possible additional data-collection is needed.

During this study, 106 precipitation-quantity gages were identified, of which 84 were active; however, no precipitation-quality gages were identified in the study areas. The precipitaion-quantity gages were concentrated in the Monterey Peninsula and the northern part of the county. If the number of gages in these areas were reduced, coverage would still be adequate to meet most objectives; however, additional gages could improve coverage in the Tularcitos Creek basin and in the coastal areas south of Carmel to the county boundary. If collection of precipitation data were expanded to include monitoring precipitation quality, this expanded monitoring also could include monitoring precipitation for acid rain and pesticides.

Eleven continuous streamflow-gaging stations were identified during this study, of which seven were active. To meet the objectives of the streamflow networks outlined in this report, the seven active stations would need to be continued, four stations would need to be reactivated, and an additional six streamflow-gaging stations would need to be added.

Eleven stations that routinely were sampled for chemical constituents were identified in the study areas. Surface water in the lower Big Sur River basin was sampled annually for total coliform and fecal coliform bacteria, and the Big Sur River was sampled monthly at 16 stations for these bacteria. Routine sampling for chemical constituents also was done in the Big Sur River basin.

The Monterey County Flood Control and Water Conservation District maintained three networks in the study areas to measure ground-water levels: (1) the summer network, (2) the monthly network, and (3) the annual autumn network. The California American Water Company also did some ground-water-level monitoring in these areas. Well coverage for ground-water monitoring was dense in the seawater-intrusion area north of Moss Landing (possibly because of multiple overlying aquifers), but sparse in other parts of the study areas. During the study, 44 sections were identified as not monitored for ground-water levels. In an ideal ground-water-level network, wells would be evenly spaced, except where local conditions or correlations of wells make monitoring unnecessary. A total of 384 wells that monitor

ground-water levels and/or ground-water quality were identified during this study.

The Monterey County Flood Control and Water Conservation District sampled ground-water quality monthly during the irrigation season to monitor seawater intrusion. Once each year (during the summer), the wells in this network were monitored for chlorides, specific conductance, and nitrates. Additional samples were collected from each well once every 5 years for complete mineral analysis. The California Department of Health Services, the California American Water Company, the U.S. Army Health Service at Ford Ord, and the Monterey Peninsula Water Management District also monitored ground-water quality in wells in the study areas. Well coverage for the ground-water-quality networks was dense in the seawater-intrusion area north of Moss Landing, but sparse in the rest of the study areas. During this study, 54 sections were identified as not monitored for water quality.

INTRODUCTION

Continuing data collection and analyses are vital to efficient development and management of water resources. Data-collection programs need to be reevaluated and updated periodically to ensure that water managers have adequate information on water conditions and trends. Changes in population, land use, and agricultural practices can result in an increased demand for water; therefore, effective management of water resources, supported by data collection and analyses, becomes even more critical. However, costs of data collection and analyses need to be considered, and every site should be necessary to minimize redundancy.

This report presents an evaluation of precipitation, surface-water, and ground-water monitoring networks in the northern and coastal areas of Monterey County, California (fig. 1). This is the second in a series of three reports prepared in cooperation with the Monterey County Flood Control and Water Conservation District (MCFCWCD). (This agency is now called the Monterey County Water Resources Agency.) The phase 1 report (Showalter and Hoffard, 1986) presents an evaluation the southern Salinas River drainage basin, and the phase 3 report (Templin and Schluter, 1990) presents an evaluation of the northern Salinas River drainage basin.

Purpose and Scope

This report presents an evaluation of the water-resources data-collection networks (networks that monitor quantity and quality of precipitation, surface water, and ground water) in the northern and coastal areas of Monterey County. This report describes possible additional monitoring for networks that do not meet the objectives defined in this report and describes factors, such as geology, climate, hydrologic conditions, water use, and land use, which affect the design of the water-resources networks for the study areas. This report also summarizes generalized management and network objectives of water-resources networks (table 1, at back of report). These objectives guided the preparation of this report.

Approach

The approach of this report is similar to the approach of Showalter and Hoffard (1986, p. 7) and Templin and Schluter (1990), which includes (1) assessing the data needs of the study areas, (2) defining an ideal network, (3) describing and evaluating existing networks, and (4) suggesting improvements to network coverage. Specific approaches for each network evaluation vary considerably because of differences in the level of knowledge about precipitation, surface water, and ground water in the study areas and in the general state-of-the-art for network design in each of the water-resources disciplines. For example, considerably more research has been done on streamflow and precipitation networks than on water-quality and ground-water networks.

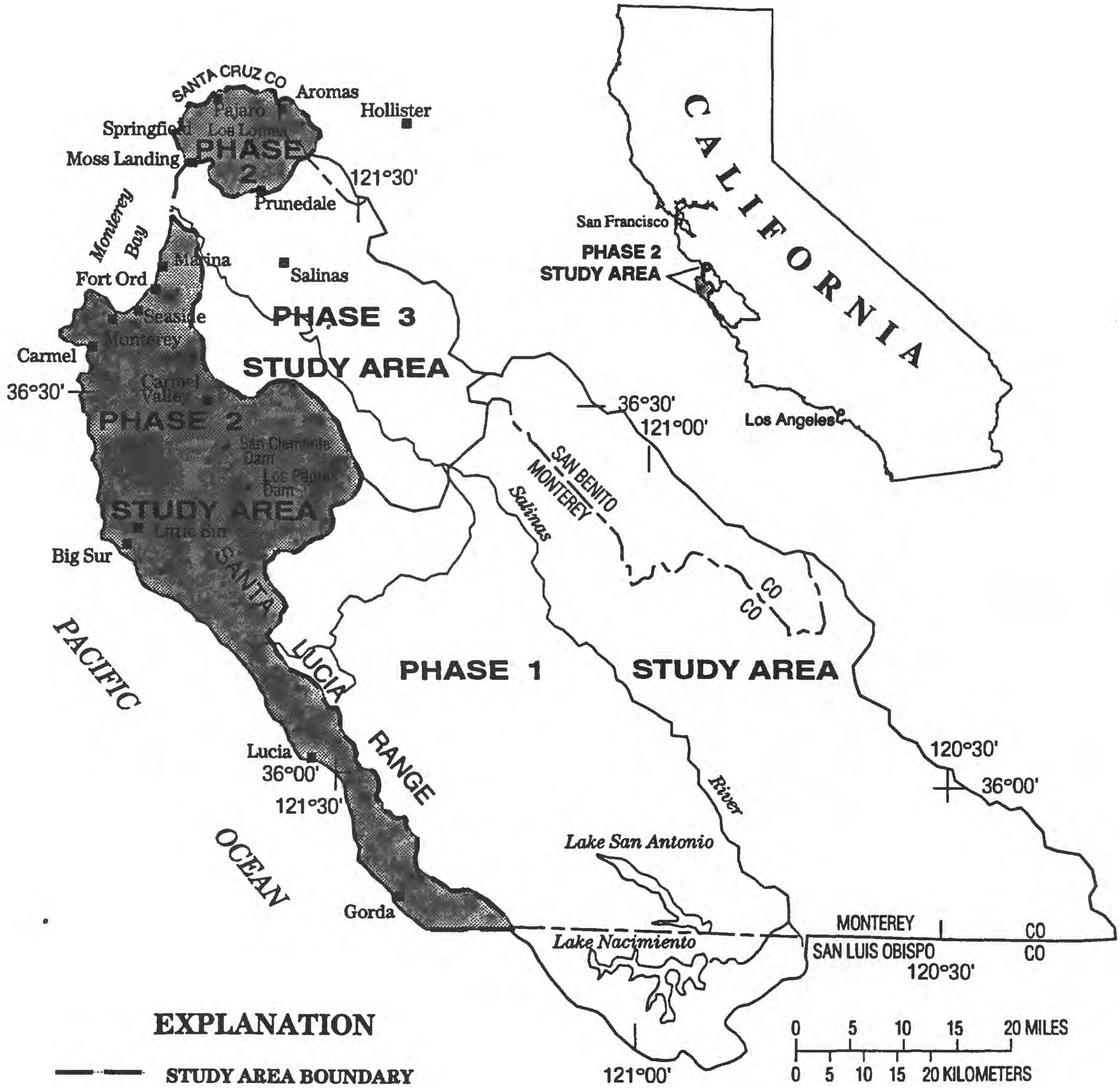


Figure 1. Location of study areas.

Location of Study Areas

Monterey County (fig. 1) is south of San Francisco in central coastal California. The study areas for this report included the northernmost part of Monterey County and most of the coastal basins. The only drainage into the Pacific Ocean from Monterey County not included in the phase 2 study areas was the Salinas River drainage basin. This basin is described in the other two reports in this series. In the area north of Marina, the boundary between the Salinas River drainage basin and the coastal basins is unclear because windblown deposits overlie the sedimentary alluvial deposits of the Salinas River drainage basin, creating a misleading appearance of basin boundaries at land surface (Zaman, 1985). The area for the phase 2 study is about 770 mi^2, extending about 80 mi long and as much as 25 mi wide. For this report, the basin boundaries are defined by the physiographic boundaries and area names used by MCFCWCD for the northern and coastal areas of the county.

Limitations

The lack of an up-to-date, computerized data base at the time of this study precluded the use of many sophisticated statistical techniques for network evaluation. Efforts to identify hydrologic data-collection activities in the study areas were restricted to reviews of computerized data bases, such as the U.S. Environmental Protection Agency's STORET, the U.S. Geological Survey Water-Data Storage and Retrieval System (WATSTORE) and the National Water Data Exchange (NAWDEX), the California Department of Water Resources Water Data Information System (WDIS), published versions of these data bases, and telephone interviews with water-resources authorities in the study areas. Efforts also included attempts to identify all hydrologic data collection in the study areas that may not have been available in the computerized data systems.

A continuing program is needed to design, review, evaluate, and redesign each network type because the needs of networks change with time. Monitoring activities change rapidly in the location and number of sites and in the properties, characteristics, and constituents monitored. Consequently, periodic updates of data-collection activities are vital to investigations of the type undertaken for this report.

Acknowledgments

The authors appreciate the assistance of personnel of many agencies, without whom this report could not have been completed:

Association of Monterey Bay Area Governments
California Air Resources Control Board
California American Water Company
California Department of Fish and Game
California Department of Forestry
California Department of Health Services
California Department of Parks and Recreation
California Department of Water Resources
California Regional Water Quality Control Board
California State Water Resources Control Board
George Nolte, Engineers
Granite Rock Company
H. Esmailli and Associates, Inc.
Monterey Bay Air Pollution Control District
Monterey County Flood Control and Water Conservation District
Monterey County Environmental Health Department
Monterey County Planning Department
Monterey Peninsula Water Management District
Northern Salinas Valley Mosquito Abatement District
Santa Cruz County Planning Department
U.S. Bureau of Land Management
U.S. Agricultural Extension Service
U.S. Forest Service
U.S. Naval Postgraduate School
U.S. Soil Conservation Service

CLIMATE

The northern and coastal areas of Monterey County have a Mediterranean climate. On-shore winds and fog, which are present most of the year, moderate weather conditions in this area.

Seasons are weakly defined and temperature variations are small (Monterey County Planning Department, 1980, p. 9). Winds cause upwelling of cold ocean water in Monterey Bay that often results in the formation of fog as saturated air from the ocean blows over the bay. The fog spreads over the coast and lower valleys. The rainy winter seasons are short and the summers are cool with little rainfall. Mean annual precipitation ranges from about 13 in. just north of the Monterey Peninsula to 75 in. in the higher altitudes of the Santa Lucia Range. Mean monthly temperatures near the coast range from 54°F in the winter to 60°F in the summer (Kapple and others, 1984, p. 3). More information on precipitation in the study areas is given in the "Precipitation Networks" section of this report.

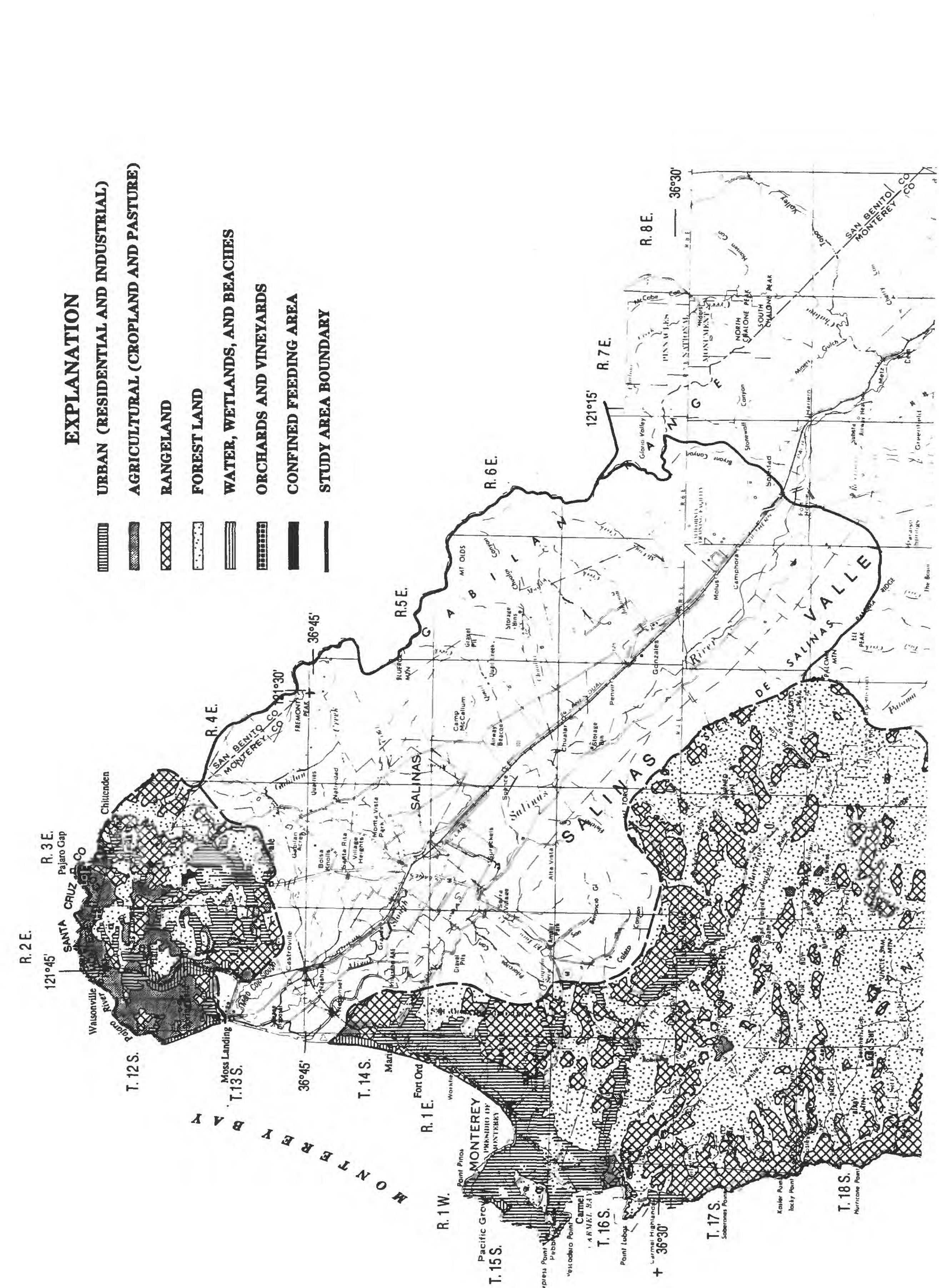
LAND USE

Land use affects water quality at all stages of the hydrologic cycle. Industrial emissions and pesticides enter the atmosphere and return in precipitation. Industrial and agricultural wastes wash into streams and seep into ground water. Water-supply contamination can result from point sources such as chemical spills, disposal of toxic consumer products, and leaks from underground storage tanks, and from nonpoint sources such as runoff from agricultural and urban land. Less than one-third of all sources of ground-water contamination comes from regulated waste dischargers (Magnuson, 1983). Correlations of feed lots, greenhouses, and nurseries with areas of nitrate contamination of ground water were substantiated in some areas of Monterey County (Bruce LaClergue, Monterey County Flood Control and Water Conservation District, written commun., 1984). Septic systems, fertilizer applications, spills, and runoff from storage operations also are probable sources of nitrates (Monterey County Flood Control and Water Conservation District, 1988, p. 1). Land use, therefore, needs to be considered during water-quality data collection and network evaluation.

Because ground-water-quality data commonly are sparse and usually are expensive to obtain, Karubian (1974) suggested relating types, amounts, and trends in ground-water contamination to human activities to supplement data collection. He researched methods of estimating the effects of human activities on ground-water quality. In particular, he studied the effects of unlined sedimentation basins and lagoons used by pulp-and-paper, petroleum refining, and primary metals industries; wastewater ponds used in phosphate mining; chemical fertilizers used in agriculture; and cattle feedlot operations. The supplementary approach suggested by Karubian (1974) was applied to this study using all the above types of contaminant sources to determine sites for monitoring.

A generalized land-use and land-cover map (fig. 2) was prepared for the study areas using maps by the U.S. Geological Survey (1976a; 1976b; 1978a). More-detailed land-use information also is available from the California Department of Water Resources (1971). Forest and rangeland (fig. 2) make up the highest percentage of land use in the study areas. In the northern part of the study areas, agricultural land use, chiefly croplands, pastures, orchards, vineyards, and confined-feeding operations, also make up a high percentage of land use. The Monterey Bay area, Monterey Peninsula, and Carmel Valley consist of large areas of residential and industrial urban developments.

Potential point sources of water-quality degradation provide further examples of how land use affects water-resource data needs (fig. 3). Major point-source dischargers are summarized in table 2 (at back of report). A report by Hart (1966, pl. 1) states that mineral deposits also may be possible point sources of water-quality degradation because of their natural constituents or because of the effects of human activities, such as irrigation that can result in leaching of trace elements from soil.


EXPLANATION
URBAN (RESIDENTIAL AND INDUSTRIAL)
AGRICULTURAL (CROPLAND AND PASTURE)
RANGELAND
FOREST LAND
WATER, WETLANDS, AND BEACHES
ORCHARDS AND VINEYARDS
CONFINED FEEDING AREA
STUDY AREA BOUNDARY
MONTEREY BAY
SAN BENITO CO
MONTEREY CO
SANTA CRUZ CO
SALINAS
MONTEREY
Pacific Grove
Carmel
Watsonville
Moss Landing
Castroville
Fort Ord
Chittenden
Pajaro Gap
Gonzales
Chualar
Soledad
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
T. 12 S.
T. 13 S.
T. 14 S.
T. 15 S.
T. 16 S.
T. 17 S.
T. 18 S.
121°45'
121°30'
121°15'
36°45'
36°30'

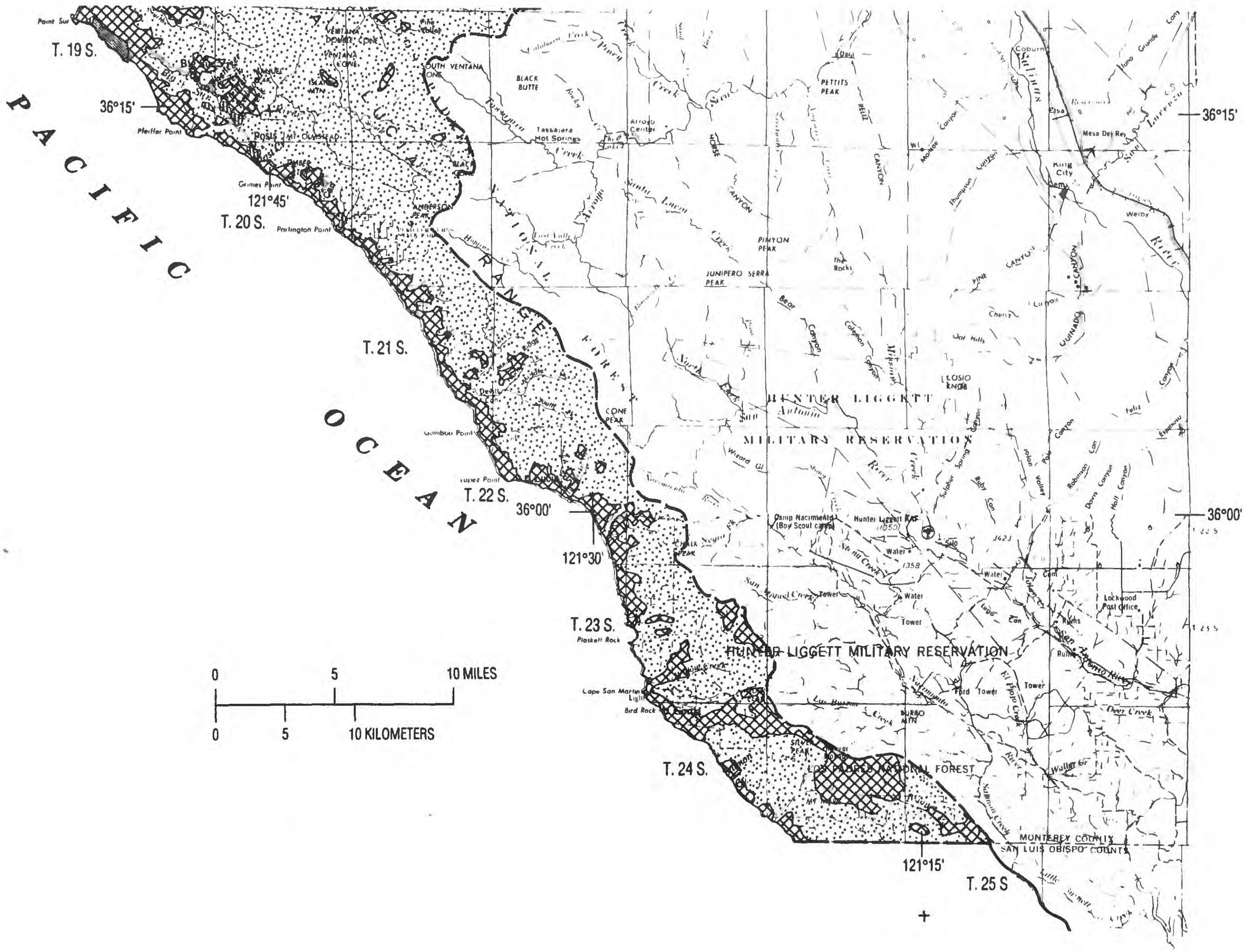
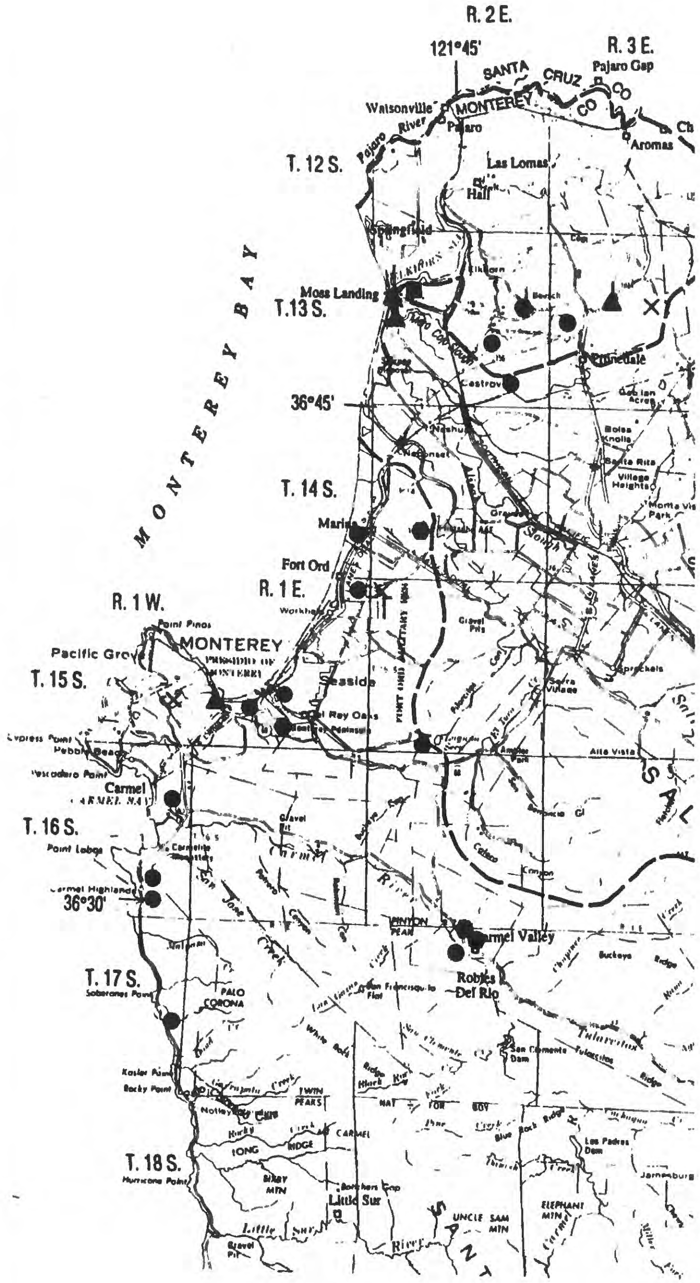


Figure 2. Land use in the northern and coastal areas of Monterey County, California.



EXPLANATION

TYPES OF POINT-SOURCE DISCHARGERS

	DISCHARGER	LOCATION
▲	**Industrial**	
	Kaiser Refractories	13S/2E-18
	Pacific Gas and Electric Company	13S/2E-18
⬣	**Airports**	
	Potential industrial dischargers	
	Elkhorn (Boesch)	13S/2E-13
	Fritzsche Field (Fort Ord Army Air Field)	14S/2E-29
	Monterey	15S/1E-33, 34
	Carmel Valley	17S/2E-3
●	**Municipal and domestic**	
	Sewage treatment plants under National Pollution Discharge Elimination System permit	
	Oak Hills	13S/2E-23
	Monte del Lago Mobile Home Park	13S/2E-35
	Cabana Holiday Mobile Home Park	13S/2E-18, 19
	Marina	14S/1E-25
	Seaside	15S/1E-27
	Monterey Wastewater Treatment Plant	15S/1E-29
	Laguna Seca Recreation Area, Road Race Agte, Ranch Estates	15S/2E-32
	Carmel Sanitation District	16S/1W-12
	Highlands Inn	16S/1W-26
	Carmel Highlands	16S/1W-35
	Carmel Valley Community Service District, Village Green and White Oaks, Carmel Valley Village	17S/2E-3, 11
	Carmel Valley Ranch	17S/2E-3
	Granite Canyon Marine Laboratory	17S/1W-24
	U.S. Navy, Point Sur	19S/1E-6
	Pfeiffer Big Sur State Park	19S/2E-30
	Escalen Institute	21S/3E-4, 9
	Potential Sewage Treatment Facility	
	U.S. Army, Fort Ord	15S/1E-1 (?)
×	**Solid-waste disposal sites**	
	Crazy Horse	13S/3E-15
	U.S. Army, Fort Ord	15S/2E-5, 6
■	**Agricultural point sources**	
	Moon Glow Dairy	13S/2E-8, 17
▬	STUDY AREA BOUNDARY	

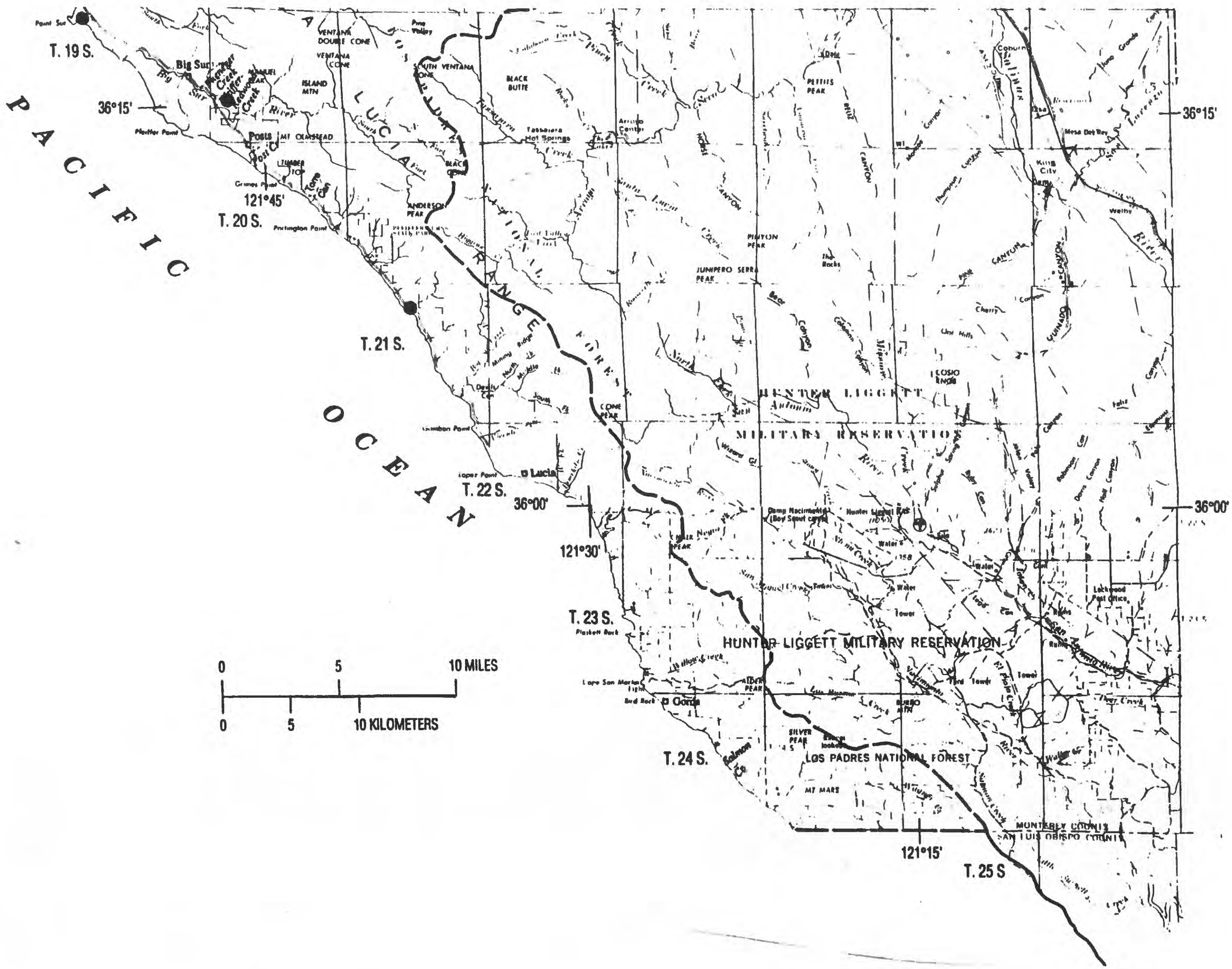


Figure 3. Point sources of concern for possible water-quality degradation in the northern and coastal areas of Monterey County, California.

WATER USE

Current and potential water uses need to be considered when establishing water-resources data networks because adequate water supplies are needed to meet anticipated demands and because the quality of water affects its potential for most uses. Various water uses can have negative effects on other water uses that are sensitive to low levels of acquired contaminants. For example, highly saline water cannot be used for drinking or irrigation (of most crops) unless it is treated, and treatment could make use of the saline water uneconomical. Irrigation water can collect sediments, salts, minerals, fertilizers, pesticides, trace elements, or other contaminants that would affect further use of the water.

For ground-water and surface-water data networks, it is important to consider that applications of water to agricultural fields can be a source of incidental ground-water recharge and flow in streams. As irrigation water collects contaminants and carries them to surface- and ground-water sources, it can have adverse effects on other uses of this water, such as water for livestock; fish and wildlife; and domestic, commercial, and industrial purposes.

Information on water use has been identified as a high priority need in Monterey County (table 3, at back of report). The largest water uses of developed water supplies in the northern and coastal areas of Monterey County are directly associated with agricultural and urban land use (fig. 2). Cropland and pasture account for a major part of land use in northern Monterey County and for some of the land use in the Carmel Valley and coastal areas. Native vegetation probably uses a substantial part of the undeveloped water supply in these areas. Measured pan evaporation ranges from about 40 in/yr at Carmel to 60 in/yr in the Carmel Valley. Estimates of water use by native vegetation can be found in a report by Anderson-Nichols and Company (1985) for the Salinas River area, but these estimates probably are not applicable for coastal vegetation.

Mobile laboratories were operated in Monterey County at the time of the study to provide data on water use and irrigation efficiency. Data from these laboratories have proven to be informative to local growers and water managers in the area (William Hurst, Monterey County Flood Control and Water Conservation District, oral commun., 1991). Further discussion of water use is included in the section "Possible Modifications," which describes precipitation-quantity networks, streamflow-gaging stations, surface-water-quality conditions, water-level changes, and ground-water-quality conditions.

PRECIPITATION NETWORKS

Precipitation networks are used to monitor spatial and temporal variations in precipitation. Factors such as geographic features can influence the distribution and quantity of precipitation and need to be considered when establishing a precipitation network. In addition, the objectives of the precipitation networks need to be understood in order to effectively design and refine the locations and number of sites in a network. A method of evaluating networks is needed that will take into consideration all factors that can affect network design. For example, precipitation maps showing lines of equal precipitation can be generated on the basis of a few or many data points and may represent mean annual averages for many years or just a few years. The number of data points and the period of available record will influence the appearance of the maps and can further influence the refinement of the networks as additional data are collected. Existing data-collection networks need to be described and possible changes in the location and number of monitoring sites need to be considered.

Precipitation-Quantity Networks

Precipitation Conditions

Mean annual precipitation in the study areas is distributed unevenly (fig. 4). The highest totals of mean annual precipitation are in the high altitudes of the Santa Lucia Range, but the scarcity of data and the extreme differences in distribution of precipitation at those altitudes make accurate estimates difficult. Estimates of mean annual precipitation (fig. 4) at the high altitudes of the Santa Lucia Range vary from 30 in. (Rantz, 1969; Renard, 1983) to 75 in. (California Department of Water Resources, 1956; Monterey County Planning Department, 1980, 1981a; Bruce LaClergue, Monterey County Flood Control and Water Conservation District, written commun., 1984). The lowest total mean annual precipitation was 13 in., recorded just north of the Monterey Peninsula. More than 90 percent of precipitation in the study areas falls from November through April. Between

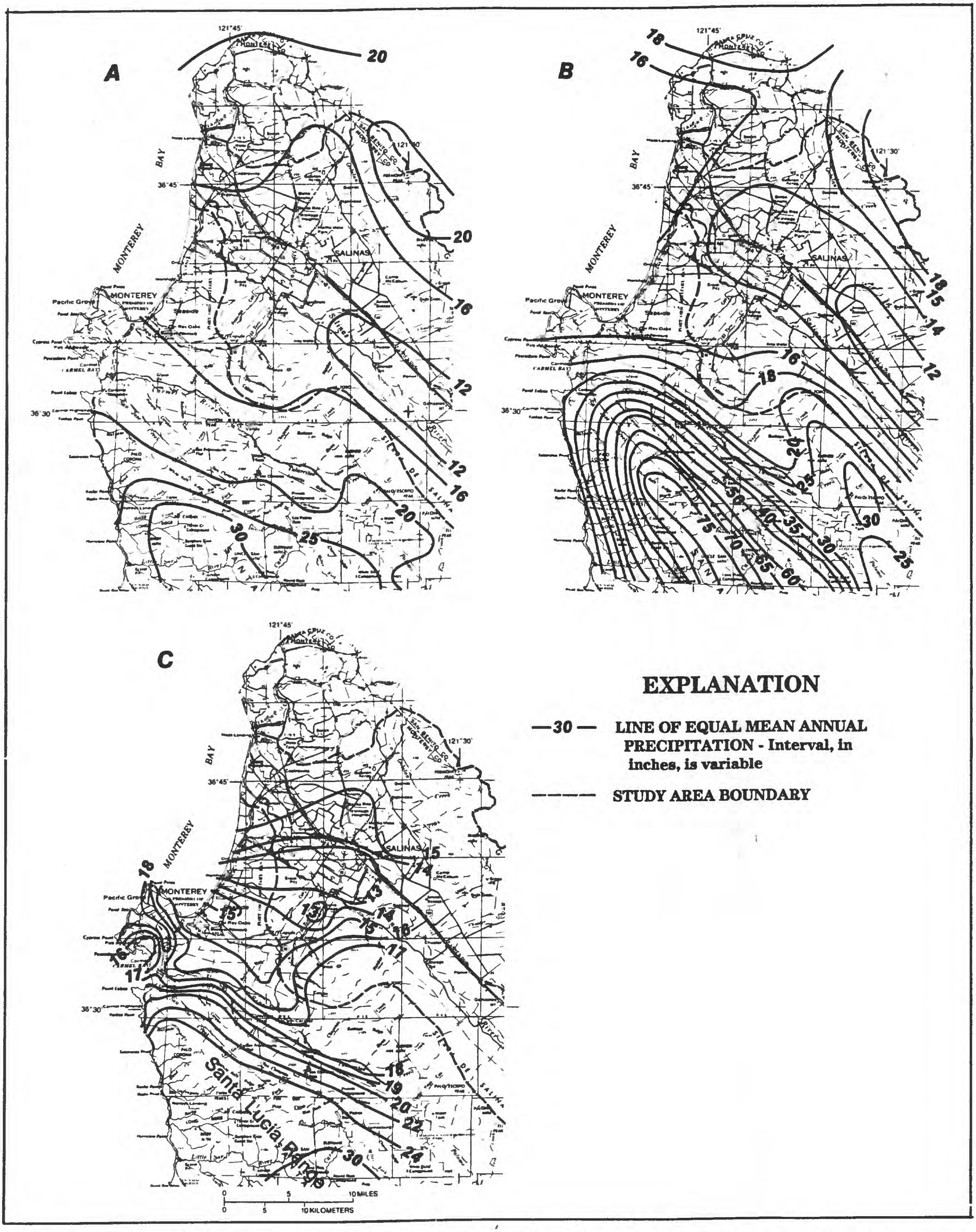


Figure 4. Mean annual precipitation in northern Monterey County, California. *A*, modified from Rantz (1969). *B*, modified from Monterey County Planning Department (1980; 1981a). *C*, modified from Renard (1983).

May and October, precipitation totals normally are less than 1 in. Distributions of monthly precipitation totals in Monterey County are available in the annual summaries of water-resources data published by the Monterey County Flood Control and Water Conservation District (1978).

Objectives

Two major objectives of precipitation-quantity networks are (1) to determine regional differences in precipitation quantity and (2) to identify factors that can influence the quantity of precipitation in an area (table 1). Data from precipitation-quantity networks can be used to establish spatial and temporal trends for short-term objectives, such as effective precipitation estimates needed to establish irrigation requirements for various crops. These networks also can be used to obtain storm-intensity and storm-duration data, which can be useful when designing storm-drain facilities and other related needs, such as retention reservoirs. Precipitation-quantity networks also can be used to provide data, such as mean monthly, seasonal, and annual precipitation totals, needed for the longer term objectives, such as water-supply and water-demand management. In addition, data from these networks can be used to determine the effects of natural and artificial features (such as lakes, reservoirs, and other large water bodies; irrigated areas; multi-story buildings; and industrial emissions) on precipitation characteristics. Finally, data from precipitation-quantity networks can provide information useful for quality assurance of precipitation measurements. Precipitation records can be influenced by failure to use standard methods of station installation, including precipitation-gage types, distances of sites above ground and away from structures, and sampling and analytical practices that can affect the values obtained (Linsley and others, 1982, p. 61).

Specific objectives for the precipitation-quantity networks in Monterey County include (1) measuring regional ambient conditions for estimating ground-water recharge; (2) estimating water supply for agricultural, domestic, and industrial uses; (3) flood warning; and (4) providing specific site data to aid erosion control, water-related engineering, water-rights management, and fire-hazard assessment (table 3).

Data needs for precipitation-quantity networks are presented in table 3 in order of priority of the specific network objectives. Network priorities reflect, in part, the precipitation-data uses reported by the Monterey County Flood Control and Water Conservation District (1977). Two primary data needs are measurements of long-term regional daily precipitation and measurements of short-term precipitation related to storm intensity and duration for 15- to 30-minute intervals. Precipitation data for the study areas primarily are used for water-balance computations to determine ground-water recharge and to improve estimates of availability of water for domestic and industrial uses. For this report, mean annual precipitation only was examined. Using available precipitation maps, mean annual precipitation only was analyzed to determine spatial distributions. No attempt was made to analyze the distribution of storm precipitation, although table 4 (at back of report) does identify precipitation gages in the study areas that could be used for this purpose. The precipitation gages are concentrated in the northern part of the study areas south to Carmel; this concentration of gages is due to concentrated development in these areas and, therefore, a greater need for assistance in design of storm-drain facilities. Precipitation-intensity data are used to predict storm frequency and to establish criteria for design of storm-drain facilities. Analyses of precipitation intensity and duration are not included in this report, but results of such analyses can be found in a report by the California Department of Water Resources (1976).

Methods of Evaluation

The methods used to evaluate precipitation-quantity networks for this study include (1) defining an ideal network to provide optimum coverage of the study areas, (2) identifying existing precipitation-quantity networks and evaluating precipitation-gage locations and periods of record, (3) examining existing precipitation maps of the study areas to identify discrepancies between maps and possible weaknesses in network coverage, and (4) describing possible modifications to existing monitoring networks in the study areas.

Precipitation Maps

Several precipitation maps are available that show mean annual precipitation for the study areas of this report (fig. 4). Rantz (1969) compiled a statewide map of mean annual precipitation; however, his map is not highly detailed. The section of his map that covers the study areas of this report was modified from a map by the U.S. Army Corps of Engineers (1957). A precipitation map, published in two reports by the Monterey County Planning Department (1980; 1981a), shows intervals of equal precipitation ranging from 2 to 5 in. A detailed precipitation map by Renard (1983) shows intervals of equal precipitation ranging from 1 to 6 in.; his map was based on 10 years of precipitation record (1969-79) and covers only the central part of Monterey County.

The maps by Rantz (1969) and Renard (1983) are in close agreement, but differ from the map in the reports by the Monterey County Planning Department (1980; 1981a). The most significant difference occurs in the area from the Carmel River to the Big Sur coast. The maps by Rantz (1969) and Renard (1983) show a maximum annual precipitation of 30 in. in the high altitudes of the Santa Lucia Range, whereas the map by the Monterey County Planning Department (1980; 1981a) shows a maximum of 75 in. This discrepancy probably was due to the scarcity of available data at the time of the study by Rantz. Long-term mean precipitation data have since been collected at the San Clemente and Los Padres Dams, which are in the areas where the discrepancy occurs.

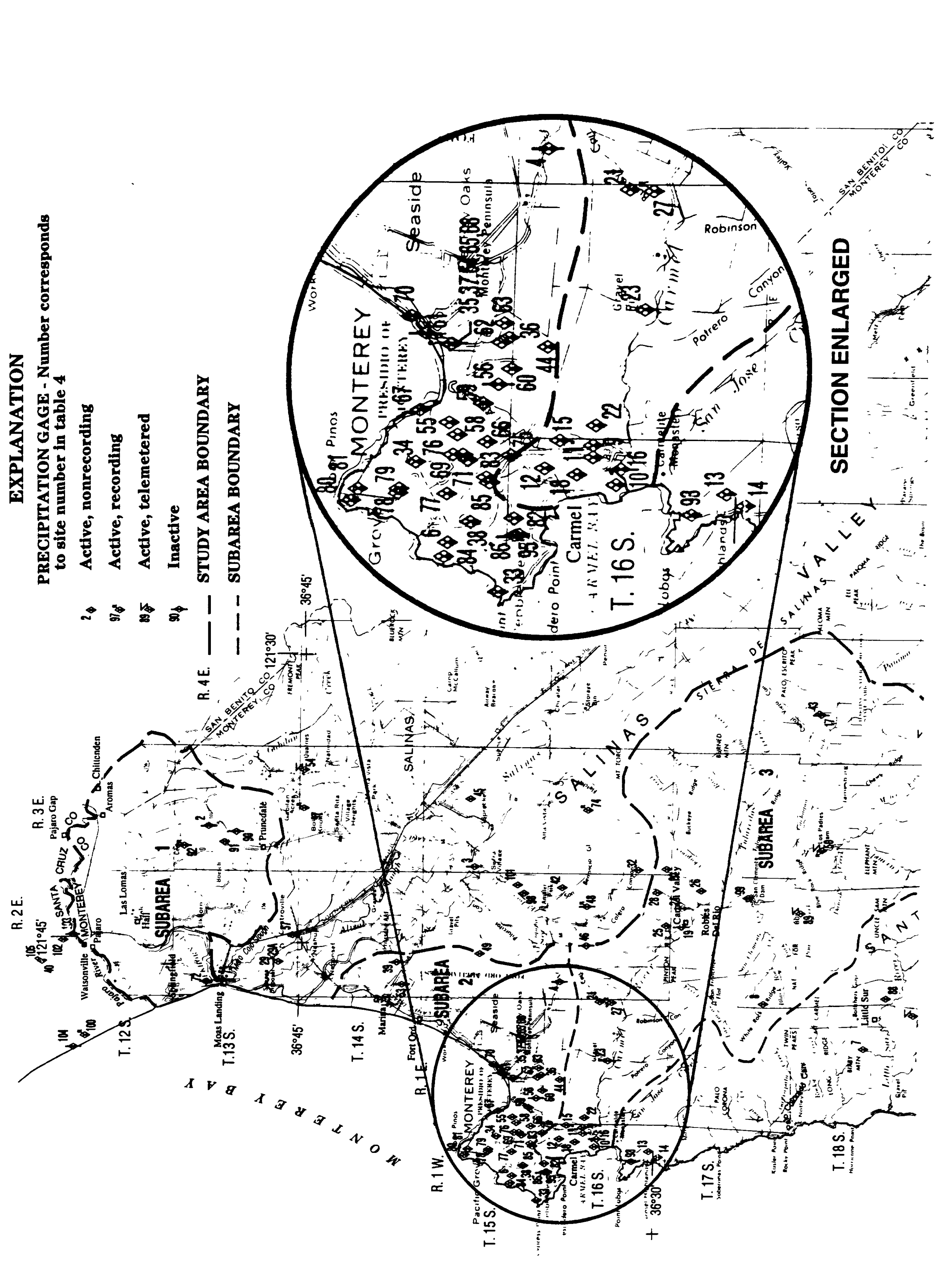
Data collected by several agencies provide a 53-year record of mean annual precipitation for San Clemente Dam of about 22 in. and a 25-year record for Los Padres Dam of about 28 in. These values agree with the values on maps by Rantz (1969) and Renard (1983), but differ markedly from the values on the map by the Monterey County Planning Department (1980; 1981a), which shows a mean annual precipitation of 40 in. at San Clemente Dam and 50 in. at Los Padres Dam. Why the values of mean annual precipitation on the map by the Monterey County Planning Department (1980; 1981a) are so much higher than the values on the maps by Rantz (1969) and Renard (1983) could not be determined during our evaluation; however, the differences may be due to the period of record and the specific precipitation gages used to construct the maps. Validation of these differences would require that the precipitation maps clearly show the location of the sites used to draw the lines of equal precipitation and the period of record for each site.

The passage of moisture-laden winds over mountain barriers has a marked effect on precipitation, and without data to define this orographic influence, accurate determination of the lines of equal precipitation in the Carmel River drainage basin and at the high altitudes of the Santa Lucia Range is difficult. At the high altitudes, only the Carmel 8 SE gage (site 8, table 4 and fig. 5) has a period of record longer than a few years. Between 1916 and 1938, mean annual precipitation at this gage was about 71 in., which differs from the total of about 30 in. reported by both Rantz (1969) and Renard (1983). However, it is similar to the mean annual precipitation of about 75 in. reported by the Monterey County Planning Department (1980; 1981a) for this area. Two flood-warning gages, Central Gage 33 and Pico Blanco 11 (sites 30 and 87, fig. 5), also confirm a mean annual precipitation of 75 in.; however, the periods of record for these gages are short (Bruce LaClergue, Monterey County Flood Control and Water Conservation District, written commun., 1984). Limited distribution of information on these gages may explain their omission by both Rantz and Renard.

Discrepancies in mean annual precipitation probably result because data are unavailable for the high altitudes of the Santa Lucia Range. Data for these high altitudes are needed to define more accurately the distribution of precipitation in this part of the study areas. A lack of accurate data for the western part of the Carmel River drainage basin also may be a significant problem because forecasts of surface- and ground-water supplies depend on accurate precipitation information. For the upper Big Sur River basin, the distribution of precipitation needs to be defined more clearly to better understand water supply in that area.

Description

All precipitation-gage sites in the study areas for which data historically have been reported are shown in figure 5 and described in table 4. These sites initially were identified by the California Department of Water Resources (1981a). Precipitation gages in the study areas of this report have been maintained by the National Weather Service, the U.S. Soil Conservation Service, the Pacific Gas and Electric Company, and the private sector (California Department of Water Resources, 1981a, p. 515-678). Information from


EXPLANATION
PRECIPITATION GAGE - Number corresponds to site number in table 4
Active, nonrecording
Active, recording
Active, telemetered
Inactive
STUDY AREA BOUNDARY
SUBAREA BOUNDARY
SECTION ENLARGED
MONTEREY BAY
SALINAS
SALINAS VALLEY
MONTEREY
Carmel
Seaside
SAN BENITO CO
MONTEREY CO
SANTA CRUZ CO
SUBAREA 1
SUBAREA 2
SUBAREA 3
T. 12 S.
T. 13 S.
T. 14 S.
T. 15 S.
T. 16 S.
T. 17 S.
T. 18 S.
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
36°45'
36°30'
121°45'
121°30'

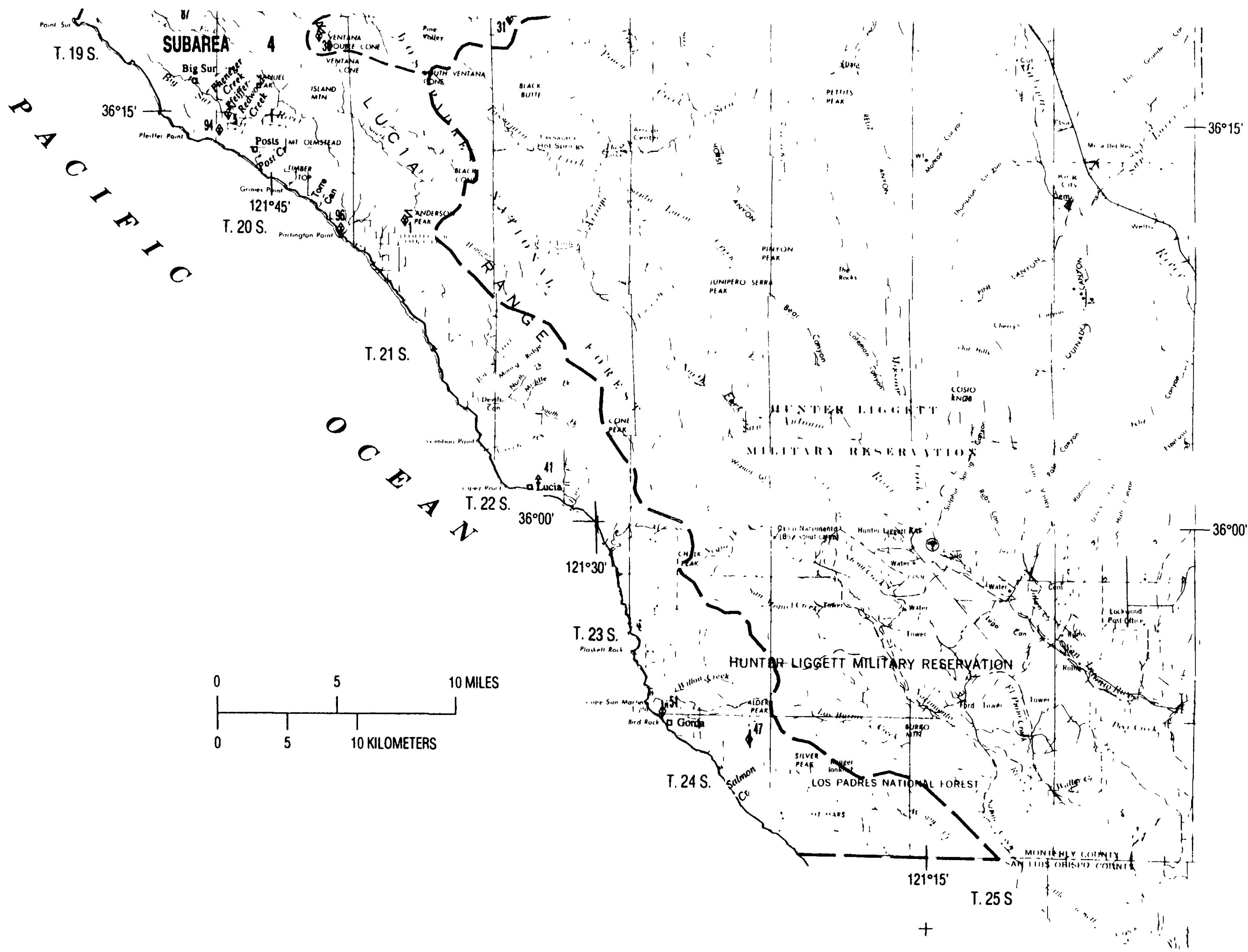


Figure 5. Precipitation gages in the northern and coastal areas of Monterey County, California.

these sources was combined with information from the MCFCWCD to produce a list of precipitation gages (table 4) in the study areas of this report; however, this list still may not be complete. Existing monitoring will need to be reviewed periodically to ensure that all monitoring is being included in the network.

In 1977, the MCFCWCD, in cooperation with the California Department of Water Resources (DWR) and the U.S. National Weather Service, installed six telemetered recording gages in remote parts of the study areas (fig. 5 and table 4). The primary purpose of these gages is flood warning. After several years of data are collected from these gages, the data can be used to estimate mean annual precipitation for areas that lack data. The MCFCWCD also maintained a precipitation-quantity network of 17 stations to monitor monthly precipitation (Monterey County Flood Control and Water Conservation District, 1977, p. 3, 28, and 29).

Professor R.J. Renard of the U.S. Navy Postgraduate School, Department of Meteorology, in Monterey, California, has developed a dense network of precipitation gages, particularly in the Monterey Peninsula area. Renard's (1983) map is based on this network. Many gages in this network are operated for the Department of Meteorology by observers. These observers record daily precipitation totals and, about every 2 months, send the data to the department (Steven M. Taylor, U.S. Naval Postgraduate School, written commun., May 5, 1995). However, much of these data are not readily available for use. Most gages in the precipitation network developed by Renard (1983) are included in figure 5 and listed in table 4 and are identified as U.S. Department of the Navy gages.

Factors Affecting Design

The spatial distribution of precipitation and the intended uses of the data collected from a precipitation network will determine the density of a precipitation-quantity network (Linsley and others, 1982, p. 61). In hydrologic studies, precipitation-quantity data commonly are used to determine long-term precipitation averaged at monthly, seasonal, or annual intervals. In the study areas, long-term mean precipitation-quantity data typically is used in computations of water balance. Precipitation-quantity data also are used to determine total storm precipitation for flood-related studies. In general, studies requiring individual storm-precipitation data need a denser network of precipitation gages than studies requiring long-term mean precipitation data.

Findings from the following studies indicate factors that need to be considered in the redesign of future precipitation-quantity networks for all counties in California. Hall and Barclay (1975) discussed methods of determining regional distribution of precipitation from measured data as the data relate to the overall prediction in catchment hydrology. Linsley and others (1982, p. 63) suggested a means to determine errors in precipitation averages computed from networks of various densities. The U.S. Weather Bureau (1947, p. 234) illustrated the standard error for precipitation averages as a function of network density and area for the Muskingum basin in Ohio. Their study indicated that, in general, errors in measuring precipitation increase with increasing regional mean precipitation and decrease with increasing network density, duration of precipitation, and size of area. Regional networks yield greater errors for storm precipitation duration and intensity than for monthly or seasonal precipitation because of the non-homogeneous (uneven) nature of precipitation. In addition, errors in precipitation totals were greater for thunderstorms than for larger weather systems because thunderstorms produce a more uneven spatial distribution of precipitation. Linsley and others (1982, p. 63) also indicated that measuring precipitation of summer storms may require a network density two to three times that required for winter storms in order to maintain equivalent degrees of accuracy. Additional information on precipitation-quantity network design, data collection, and analysis can be found in reports by the World Meteorological Organization (1972) and Linsley and others (1982).

A precipitation-quantity network generally is designed to represent the spatial distribution of precipitation for a given geographic area. Topography can have the most influence on the distribution of precipitation. Precipitation typically is distributed more uniformly on level or gently sloping terrain than on rugged terrain. Therefore, to obtain reliable regional precipitation data in a mountainous area, a dense network of precipitation gages is required. In temperate, Mediterranean, and tropical zones, the World Meteorological Organization (1974, p. 3.8-3.10) recommends a minimum density of one gage per 230 to 350 mi^2 in flat regions and one gage per 40 to 100 mi^2 in mountainous regions. In remote mountainous areas, the cost to install and maintain a network can be high because the gages may not be easily accessible and because observers for reading these gages may not be readily available.

In addition to topography, other factors can affect the design of precipitation networks, including (1) the method of installation, location, and density of precipitation gages, (2) the effects of different types of precipitation gages and the distances above ground or away from structures, and (3) sampling and analytical practices (Linsley and others, 1982, p. 61). Natural and artificial factors also affect precipitation characteristics and thus network design. These factors can include the location of lakes, reservoirs, oceans, and other large water bodies; mountain ranges; and microclimatic factors such as irrigated regions, multiple-story buildings, industrial emissions, wind patterns, and cloud-seeding operations. These factors all need to be considered during network design and evaluation. For a more thorough description of the types of precipitation gages and the maintenance and operation of these gages, the reader is referred to a report by Showalter and Hoffard (1986, p. 25). The information in their report is applicable for all precipitation networks in Monterey County.

Proximity of a region to water bodies is a major geographic factor that can affect the distribution and quantity of precipitation and thus network design. The location of a region with respect to general weather patterns, latitude, and proximity to moisture sources determines the climate for that region. Evaporation from oceans is the chief source of moisture for precipitation. Large continental water bodies, such as lakes, streams, and reservoirs account for no more than 10 percent of continental precipitation (Linsley and others, 1982, p. 55 and 70). Mountain barriers also affect the climate of a region. Wind and air temperature affect the distribution of precipitation. All the above factors need to be considered when evaluating precipitation networks for Monterey County or any other area.

Possible Modifications

For purposes of this report, the study areas are divided into four subareas (fig. 5). These subareas include the north Monterey County area (subarea 1); the Monterey area, including the Monterey Peninsula (subarea 2); the Carmel Valley (subarea 3); and the coastal area south of Carmel to the southern Monterey County border and bounded on the east by the Santa Lucia Range ridge (subarea 4).

Historical records indicate that there have been 16 precipitation gages in or near the subarea in the north Monterey County area. Of these 16 gages, 3 gages are in subarea 1, 4 gages are in southern Santa Cruz County, and 4 gages are in the northern Salinas drainage basin. At the time of this study, three of the four historically active continuous-record precipitation gages in or near subarea 1 were active. The eight remaining active gages were monitored only periodically. The distribution of gages in this subarea would be improved if one or two gages were added near Aromas, Hall, and Elkhorn.

Historical records indicate there have been 46 precipitation gages in or near the Monterey subarea (subarea 2). Of the 46 gages, 37 were active. Only 1 active gage was a continuous-record precipitation gage; the 36 remaining active gages were monitored only periodically. Precipitation gages in subarea 2 were concentrated on the Monterey Peninsula and exceeded the proposed ideal density needed (one or two per township) to meet water-use objectives. This density probably exceeded what was needed to meet the objectives for storm-drain design as well. However, to meet research objectives for documenting spatial intensity variations during a single storm, it was necessary to retain more gages per township. To improve the adequacy of data from the existing networks, recording gages would be needed near Marina, Seaside, and Laguna Seca. In areas of new development, the distribution of precipitation gages would need to be reevaluated to ensure that the gages are of sufficient density to meet the need for design of adequate storm-drain collection systems.

Historical records indicate that there have been 25 precipitation gages in or near Carmel River subarea (subarea 3). Of the 25 gages in subarea 3, 19 were active at the time of this study, and all 3 gages north of the subarea in the northwestern Salinas River drainage basin were active. Three active gages in the subarea were telemetered recording gages, and 4 gages in or near the subarea were continuous-record precipitation gages. The 15 remaining active gages were monitored only periodically.

For the relatively undeveloped southern coastal subarea (subarea 4), historical records were found for 14 precipitation gages. At the time of this study, 12 of these gages were active: 1 was a continuous-record gage, 3 were telemetered gages, and 8 were monitored only periodically. The remaining 2 gages were inactive; 1 was a continuous-record gage and 1 was monitored only periodically. This subarea includes about 10 townships, and therefore, a few additional recording gages would be needed to meet the water-use objectives of one or two per township.

To identify temporal and spatial trends in precipitation, historical precipitation data can be correlated with data from active and inactive precipitation gages in the study areas. If these correlations indicate that precipitation is uniform in the area, it may not be necessary to add precipitation gages in areas where none exist. However, these correlations would need to be rechecked periodically to retain confidence in the reliability of the precipitation-quantity data network. Because of the spatial and temporal variability of precipitation, correlations of active and inactive gages could produce questionable results. Unless the data are from networks with a dense concentration of gages (similar to the Monterey Peninsula), a detailed periodic analysis of precipitation data for Monterey County would be needed to maintain the network's reliability.

In addition to precipitation-quantity data, complete climate data and water-use data, such as withdrawal and release information from water suppliers, are needed to manage local water supplies. Complete climatic stations monitor air temperature, pan evaporation, relative humidity, solar radiation, and wind. Air temperature and pan evaporation data were collected by the California American Water Company (CAWC) at its Los Padres site (site 50, fig. 5). The Castroville Wastewater Treatment Plant had two gages (sites 29 and 29a, table 4). Complete climate data have been collected at site 29a as part of the Crop Irrigation Management Information Service network (CIMIS). Climate data were collected at this station for 5 years before it was removed in 1985 (Bruce LaClergue, Monterey County Flood Control and Water Conservation District, written commun., 1985). In 1986, the station was reinstalled and the collection of climate data resumed. Complete daily climate data also were collected at six sites outside the study areas as part of the statewide CIMIS network. The sites included Watsonville-Beach Avenue, Watsonville-Webb Road, Watsonville-Yamashita Nursery on San Juan Road, U.S. Department of Agriculture property near Spence, Soledad-Highway 101 near Camphora Gloria Road, and King City-McCarthy Vineyards (Thomas Hawkins, California Department of Water Resources, oral commun., 1985). The addition of complete climate stations or correlations with existing precipitation gages would help improve the accuracy of estimates of consumptive use in the study areas. In addition, mobile mini-weather stations, similar to those described by Simpson and Duell (1984), could be used to provide data that would be useful in improving estimates of consumptive use by native vegetation.

Precipitation-Quality Networks

Objectives

Generalized objectives for the precipitation-quality network are similar to those for the precipitation-quantity network (table 1) and include (1) determining precipitation quality and the effects of natural and artificial point and regional factors and (2) determining conditions that affect measurement of precipitation quality. Specific objectives for the precipitation-quality network are (1) to determine the effects of precipitation quality on surface- and ground-water quality and (2) to determine the effects of precipitation quality on property (table 3).

Possible Problems

Little is known about precipitation quality in the Monterey County area (James Goodridge, California Department of Water Resources, oral commun., 1983; Harold Hillman, Monterey Bay Air Pollution Control District, oral commun., 1983; Douglas Lawson, California Air Resources Control Board, oral commun., 1983). No known sampling network was operating at the time of this study. Primary air-quality concerns that can affect precipitation quality are ozone (smog), a by-product of nitrous-oxide emissions from automobiles, and emissions from the Pacific Gas and Electric Company powerplant at Moss Landing and from the Kaiser Refractory (a firebrick production plant) (Harold Hillman, Monterey Bay Air Pollution Control District, oral commun., 1983). Brief sampling near Prunedale and Hollister (15 mi northeast of Prunedale) indicated fallout from these sources at Hollister but not at Prunedale.

Atmospheric depositional problems, such as acid rain, have not been a major concern in Monterey County. A report by the Monterey County Planning Department (1981b) presents information on air and water quality, but does not refer to the potential effects of acid rain or any other atmospheric depositional problems. A review of acid-deposition research in California by the Western Oil and Gas Association

(1983) also indicated that there were no atmospheric depositional problems in Monterey County. Because air quality in the Monterey County area generally has been good, concern about acid rain has been minimal. Nearby Santa Cruz County has considered using the precipitation gages to sample water-quality constituents; but, because no need has been identified, sampling has not begun (Robert Golling, Santa Cruz County Planning Department, Watershed Management Section, oral commun., 1987). Precipitation-quality data for Monterey County could be used to establish precipitation conditions from which changes can be measured. The following discussion indicates some concerns that could be addressed through the use of a precipitation-quality network.

Acid Rain

A precipitation-quality network can be used to monitor acid rain. Acidic gases in the atmosphere can derive from natural sources, such as volcanoes and forest fires, but primarily result from human activities, such as burning fossil fuels (U.S. Geological Survey, 1984, p. 61). In areas generally unaffected by industrial emissions, precipitation has a minimum pH of about 5.0. The average pH of precipitation at six sampling sites in California during 1981 ranged from 5.2 to 5.8 (U.S. Geological Survey, 1984, p. 62), which is in the expected range considering natural carbon dioxide in the air (J.G. Setmire, U.S. Geological Survey, written commun., 1989). In comparison, a retrieval from the U.S. Environmental Protection Agency's STORET data base indicated that average pH in ground water in Monterey County between 1953 and 1980 was 7.5. This higher average pH probably was due to leaching of minerals from soils.

In the western United States, nitric acid typically is dominant in acid rain, whereas in the eastern United States sulfuric acid is dominant (Payton, 1982). However, Melack and others (1982, p. 35) reported that "sulfuric acid contributed about twice the acidity of nitric acid" in the east-central Sierra Nevada. The pH of convective-storm precipitation during the dry season of 1981 ranged from 3.7 to 4.9 (Melack and others, 1982). A lack of data for Monterey County limits our understanding of the conditions that exist within the study areas.

Pesticides

Pesticides in precipitation also can be monitored by a precipitation-quality network. During a study in Fresno, California, the insecticides, parathion, diazinon, and malathion, were detected in precipitation samples in concentrations of 0.26, 0.15, and 0.03 µg/L (microgram per liter), respectively (Shulters and others, 1989). The pesticides in these precipitation samples tentatively were related to their application to dormant fruit trees by truck-mounted sprayers. This method of application suspends large quantities of spray in the air that then can move with wind currents. Other methods of application, such as aerial crop dusting, can have similar results in some areas. Knowledge of the presence or absence of agricultural chemicals in precipitation can be of value to local water-resource managers and the general populace of the study areas.

Design

The ideal distribution of precipitation-quality sites could only be speculated on at the time of this study. Precipitation-quality networks initially could be designed similar to regional precipitation-quantity networks. An ideal precipitation-quality network (table 3) could begin with one sampling site per township. Sampling could be done to monitor the volume of wet and dry deposition and to monitor water-quality constituents, particularly pH and pesticides. This sampling could be coupled with continuous collection of climate data. Spaite and others (1980, p. 2) suggested that acid rain may be chiefly a local phenomenon. If they are correct, then precipitation-quality networks initially would be needed in all areas to establish baseline conditions. If problems are identified, monitoring of some constituents would need to be continued in some areas.

Methods of sampling, data collection, and analysis of precipitation quality were established during studies by Mehra (1982), Melack and others (1982), Strachan and Huneault (1982), and Shulters and others (1989). These methods, which are continually being improved on with time and experience, are not discussed in detail in this report because the methods vary with the specific type of data collected. However, a detailed review of these methods needs to be done before a precipitation-quality network is established in a specific study area to ensure that the data are representative and statistically sound.

To establish baseline conditions on the distribution of precipitation quality in the study areas, a precipitation-quality network could be established initially using active precipitation-quantity stations, with one or two sites per township. After selecting standardized sampling methods and determining the constituents to be monitored, a review of the precipitation-quantity data would be needed to determine if enough sites were selected or if some sites could be discontinued. As monitoring progresses, the sites would need to be evaluated to determine if they are representative of precipitation-quality conditions in each township or selected area.

SURFACE-WATER NETWORKS

Streamflow Networks

The highest priority needs for a streamflow network (table 3) include (1) formation of an integrated information system of continuous streamflow record that can be correlated with precipitation, (2) use of telemetered stage recorders at key lakes and streams, and (3) periodic and continuous data collection relating to water use, rainfall/runoff, and dam and hydroelectric plant operations. These and other needs are outlined in table 3.

Streamflow Conditions

Streamflow is closely related to rainfall and has about the same seasonal distribution. During the rainy season (November to April), streamflows normally are high, and during years of greater-than-normal rainfall, flooding can be a problem. Streamflows decline sharply in the dry summer months and many streams dry up completely. Demand for water is greatest during the dry season when supplies are least plentiful. In the Carmel River drainage basin where water supply is an especially critical issue, surface water is stored in the San Clemente and Los Padres Reservoirs (fig. 6). Increasing the size of San Clemente Reservoir has been proposed. Releases from these reservoirs are used to recharge ground water, which in turn is tapped for water supply. Thus, rainfall and surface and ground water in the study areas are closely interrelated.

Objectives

Generalized management objectives of the streamflow networks are (1) to determine benchmark-flow characteristics, such as peaks, mean daily flows, and low flows for all major streams in the county; (2) to identify temporal (seasonal and annual) and spatial trends in streamflow; (3) to identify the causes of change in streamflow, such as variation in annual and seasonal precipitation, land-use changes, instream water use, diversion, instream native vegetation growth, agricultural return flow, and channel stabilization or channelization; and (4) to determine best management options among the various water uses, such as instream water use for fish habitat, recreation, ground-water recharge, or diversions for agricultural, industrial, or municipal and domestic use (table 1). A complete study needs to be done to identify all withdrawal and return points for major streams in the study areas. When water-use quantities and spatial and temporal trends are determined, management decisions can be made on how best to allocate the water resources among the various uses.

The specific objectives of the streamflow networks are listed in table 3, as well as priority rankings, data needs, and other pertinent data. The categories of the specific objectives of a streamflow network were developed from 10 objectives proposed by Showalter and Hoffard (1986). These objectives include (1) assessment of effects of precipitation and streamflow on ground-water recharge, (2) determination of water use, (3) flood warning, (4) data collection for water-rights adjudication and engineering, (5) determination of sediment transport, (6) management of irrigation diversions, (7) instream-use management and planning, (8) development of relations to ungaged sites, (9) management of municipal and industrial development, and (10) assessment of potential sites for hydropower plants.

Methods of Evaluation

Several methods of evaluating streamflow-network design were identified during this study. A summary of these methods is provided because the methods were considered during the network evaluation and because the methods contributed to our analyses and may be of value in future evaluations.

In developing a technique to evaluate risks and benefits of additional data on the design of water-resource data networks, Davis and others (1972) considered that, by evaluating risk only in terms of failure, the risk of wasting capital by overdesign may be overlooked. They concluded that the Bayesian theory could be used to examine the consequential effects of all possible uncertain outcomes, including underdesign and overdesign. Davis and others (1972) applied this theory to the design of flood levees, but it can be applied to any design problem.

Maddock (1974) developed a method to measure the effects of discontinuing various streamflow-gaging stations on the information value of a network. Maddock's method was used by Carrigan and Golden (1975) and by Showalter and Hoffard (1986), but it was not appropriate for the evaluation of streamflow-gaging stations in the study areas for this report because of the general lack of existing stations.

Moss and Karlinger (1974) applied regression-analysis simulation to streamflow-gaging characteristics. They devised 13 steps for designing streamflow networks to obtain specific streamflow variables. This approach, which is based on the completeness of information and the levels of confidence needed for each required variable, could be used to evaluate all surface-water data-collection networks and possibly other water-resources networks as well.

Combinations of methods have been developed to improve the evaluation of water-resources data networks. A group of computer procedures called NARI (Network Analysis for Regional Information) combines the Bayesian theory similar to Davis and others (1972) with the regression analysis of Moss and Karlinger (1974). Tasker and Moss (1979) used NARI on a network of streamflow-gaging stations in northwest Arizona to establish a streamflow network for that area. That procedure established a relation between information content and data availability. Tasker and Moss (1979) also considered network operating costs for planning periods of 10, 20, and 30 years to determine the cost effectiveness of streamflow networks.

Moss and Gilroy (1980) developed K-CERA (Kalman-Filtering for Cost-Effective Resource Allocation) techniques that were used specifically for the "traveling hydrographer" optimization. These techniques involve minimizing the sum of variances in errors of estimation of annual mean discharge at each site in the network as a measure of the effectiveness of a network. These techniques tend to concentrate stream gages on larger, less stable streams where the potential for errors are greatest. Fontaine and others (1983) altered the K-CERA techniques to include streamflow variables pertinent to small streams as well as large streams (Judith A. Boohar, U.S. Geological Survey, written commun., 1989).

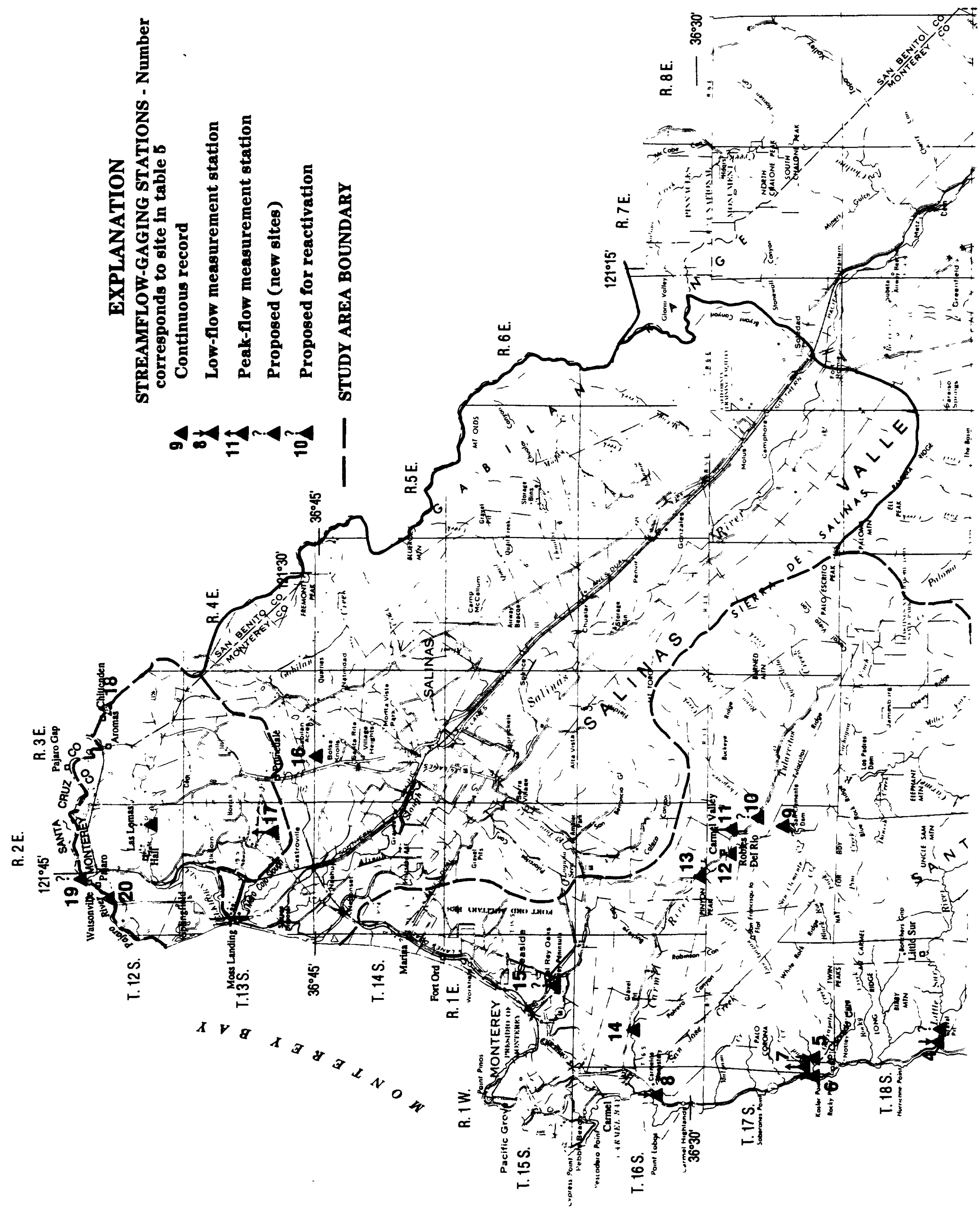
Fontaine and others (1983) developed a method to analyze streamflow networks. Their method became the prototype for a 5-year, nationwide analysis of all U.S. Geological Survey (USGS) streamflow networks. Their analysis defined and documented the most cost-effective means of obtaining streamflow information. The method by Fontaine and others (1983) (1) identified the principal uses of the streamflow data and related these uses to funding sources; (2) identified alternate, less costly methods of obtaining data, such as flow-routing or statistical regression models; and (3) defined strategies for operation of a streamflow-gaging program that minimizes uncertainty in streamflow data for given operating budgets. The primary variation in the method of Fontaine and others (1983) from previous methods was that streamflow-gaging activity no longer was considered a network of observation points but rather an integrated information system in which data were provided by measurement and synthesis.

For this report, streamflow networks were evaluated primarily by analyzing site locations, periods of record, and data collected (such as, stage elevations and discharge volumes). Streamflow networks also were evaluated by comparing data collected with data needs identified for the study areas.

Using the method established by Showalter and Hoffard (1986, p. 36), an ideal network was developed for this study that reflects the generalized management and network objectives (table 1) and specific objectives and data needs (table 3). Definitions of generalized ideal and actual network objectives were determined using the methods by Pederson and others (1978, p. 77) and Moss and others (1982, p. 1), respectively. Priority points for some of the networks were determined using the methods of Showalter and Hoffard (1986, p. 37), and site densities for most of the streamflow networks were determined.

Criteria for Site Selection

The objectives of an ideal network are used to select and evaluate individual sites for a streamflow network (table 1). Site selection is a complex process in which sometimes conflicting objectives and conditions must be reconciled. Data-collection requirements for a streamflow-gaging station often include peak stage, low-flow discharge, or continuous record of stage and discharge. The selection of sites for streamflow-gaging stations is dictated by the objectives of the streamflow network and the needs of water management (Carter and Davidian, 1968, p. 2). Streamflow-gaging stations generally are located so as


EXPLANATION
STREAMFLOW-GAGING STATIONS - Number corresponds to site in table 5
9 Continuous record
8 Low-flow measurement station
11 Peak-flow measurement station
? Proposed (new sites)
10 Proposed for reactivation
STUDY AREA BOUNDARY
MONTEREY BAY
SALINAS
MONTEREY
Carmel
Watsonville
Moss Landing
Castroville
Marina
Fort Ord
Seaside
Pacific Grove
Soledad
Gonzales
Chualar
Aromas
Carmel Valley
SAN BENITO CO
MONTEREY CO
SANTA CRUZ CO
SIERRA DE SALINAS
SALINAS VALLEY
121°45'
121°30'
121°15'
36°45'
36°30'
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
T. 12 S.
T. 13 S.
T. 14 S.
T. 15 S.
T. 16 S.
T. 17 S.
T. 18 S.

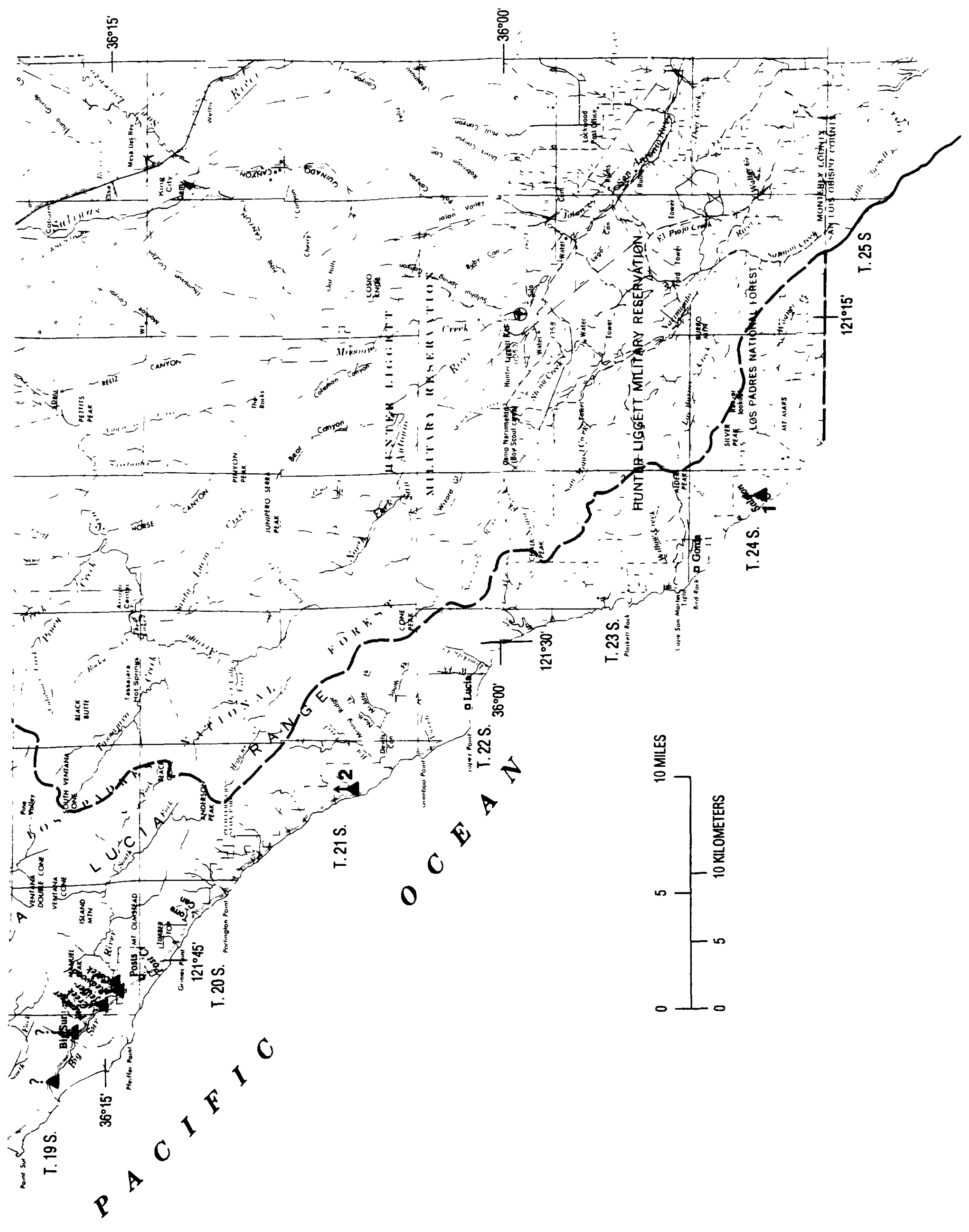


Figure 6. Streamflow-gaging stations in the northern and coastal areas of Monterey County, California.

to take advantage of the best available conditions for measuring stage and discharge and for developing stage-discharge relations. By contrast, there often is little freedom of site selection when establishing a station for water-management purposes and frequently records must be obtained under adverse hydrologic conditions. For example, if many of the major streams in an area have been converted into a series of pools by the construction of a dam, accurate records would still be necessary for operation of that dam. Water managers also would need accurate records of tidal-affected reaches of stream channels for water-supply, salinity-content, or waste-disposal purposes. Streamflow-gaging conditions, however, may be poor in areas that have only sand-channel streambeds where stage-discharge relations change continually with stage and velocity changes, as in the area near Prunedale Creek at Reese Circle (site 16, table 5 (at back of report), fig. 6).

Despite problems in selecting streamflow-gaging sites, certain criteria are important for establishing dependable gaging stations. The following criteria from Carter and Davidian (1968, p. 2-3) were proposed for selecting streamflow-gaging station locations:

- "Channel characteristics relative to a fixed and permanent relation between stage and discharge at the gage. A rock riffle or falls... indicates an ideal site. If a site on a stream with a movable bed needs to be accepted--for example, a sand-channel stream--it is best to locate the gage in as uniform a reach as possible away from obstructions in the channel, such as bridges.
- "Opportunity to install an artificial control.
- "Possibility of backwater from downstream tributaries or other sources. If a site where backwater occurs needs to be accepted, a uniform reach for measurement of slope needs to be sought in addition to the proper placement of an auxiliary gage. Unsteady flow, such as occurs in tidal-affected stream channels, requires similar consideration but, in addition, line power needs to be available to ensure simultaneous recording of stage at the two gages.
- "Availability of a nearby cross section where good discharge measurements can be made.
- "Proper placement of a stage gage with respect to the measuring section and to that part of the channel that controls the stage-discharge relation.
- "Suitability of existing structures for use in making high-flow discharge measurements or proper placement of a cableway for this purpose.
- "Possibility of flow bypassing a site in ground water or in flood channels.
- "Availability of line power or telephone lines where needed, for special instrumentation or for Telemark units.
- "Accessibility of a site by roads, particularly during flooding."

The likelihood of changes in stream channels needs to be considered when selecting streamflow-gaging station sites and determining frequency of related station visits needed to maintain high quality data. Frequent discharge measurements normally are necessary for defining the stage-discharge relation at any given site. Stage-discharge relations rarely are permanent because of stream-channel changes, such as aquatic growth, debris or ice accumulation, and conditions of scour and fill. Consequently, the frequency of measurements ideally is determined by the required reliability of the resulting data. As measurements and station visits become less frequent, the reliability of the resulting data decreases (U.S. Geological Survey, 1981, p. 20). All the above criteria and considerations were taken into account during the evaluation of streamflow-gaging station sites for this study. These sites are intended only as initial streamflow-gaging sites. A complete network to monitor all major streams in the study areas would require additional gages or the use of indirect methods to estimate flow in ungaged streams. Indirect methods include using high-water marks, cross sections, and stream profiles to calculate peak discharges.

Description of Streamflow-Gaging Stations

The existing streamflow network for the study areas consisted of 20 gaging stations (fig. 6). The type of station and the period of record collected for each station are described in table 5. Seven continuous-record gaging stations were active at the time of the study. The MCFCWCD operated the Prunedale Creek at Reese Circle station (site 16, fig. 6). In addition, the USGS maintained four active continuous-record gaging stations: Pajaro River at Chittenden (site 18), Carmel River near Carmel (site 14), Carmel River at Robles Del Rio (site 12), and Big Sur River near Big Sur (site 3). The CAWC maintained one station on the Carmel River below San Clemente Dam (site 9) until 1981 when the Monterey Peninsula Water Management District (MPWMD) assumed maintenance of this station. The MPWMD also maintained a station on Las Gazas Creek near Carmel Valley (site 13). This station (site 13) was operated by the MCFCWCD until 1978.

Five stations were operated by the USGS from 1960 to 1973 (table 5) as part of a program to collect annual peak-flow data for a study on the magnitude and frequency of floods in small drainage areas in California (Waananen and Crippen, 1977). Only annual peak-flow data are available for these stations; however, a compilation of basic data for these stations is provided in an earlier report by Waananen (1973). Four stations designated as low-flow measurement stations in table 5 are listed as partial-record stations in a report by the U.S. Geological Survey (1978b, p. 446). One or more streamflow measurements were made at each of these stations during the summer and early autumn of 1977, which was an extreme drought year.

Four of the 11 continuous-record streamflow-gaging stations in the study areas (table 5) were discontinued: Arroyo Del Rey at Del Rey Oaks (site 15) and Pajaro River at Watsonville (site 19) (both stations were operated by the USGS for 13 and 9 years, respectively), Pajaro River at McGowan Ranch (site 20) (operated by the DWR for 3 years in the late 1940's), and Tularcitos Creek near Carmel Valley (site 10) (operated by the MPWMD between 1981 and 1983).

Because the seven active continuous-record gaging stations are important to ongoing water-resources planning and management, their continued operation is consistent with the management and network goals outlined in this report. However, to increase the adequacy of this network, reactivation of the four discontinued stations and the addition of six new stations are proposed. The seven active stations are described in the following sections.

Big Sur River near Big Sur (11143000, site 3).--The USGS has operated this station since 1950. In 1973, the California State Legislature designated the Big Sur River a protected waterway and incorporated it into the California Protected Waterways Program. As a result, a protected waterway management plan for the Big Sur River was prepared (Stanley, 1982, p. 1). The plan identifies serious concerns in the Big Sur River drainage basin related to water supply, water quality, flooding, and a recreational fishery. With the completion of the protected waterway management plan and the likelihood of new studies on the river, this station is an increasingly important source of data.

Pajaro River at Chittenden (11159000, site 18).--This station is on the Pajaro River at Chittenden just upstream from Pajaro Gap where the river enters the valley floor. Recharge of aquifers used for water supply occurs downstream from this station. Water supply has become an increasingly important issue in this area because storage in the aquifers of the Pajaro River drainage basin has been critically depleted with time (Johnson, 1983). This streamflow-gaging station is an indicator of the water available for recharge. The station has been operated by the USGS since 1939 and is telemetered for flood-warning purposes. This station also is part of the National Stream-Quality Accounting Network (NASQAN) by which the USGS defines the regional variability of water-quality conditions nationwide and detects long-term changes in streamflow and stream quality.

Carmel River below San Clemente Dam (site 9).--This station is on the Carmel River above Tularcitos Creek tributary and just below San Clemente Dam. The CAWC operated this station from 1937 to 1981; the MPWMD assumed operation in 1981 (table 5). It is not clear, however, whether records of the early years of operation are available. A stage-discharge rating table was developed for this station about 30 years ago. More recently, the USGS developed a rating system using a series of eight discharge measurements made during the 1981-82 rainfall season. However, additional measurements for a wider range of flows (particularly low flows) are needed to improve this rating. Unless the records for this station have been adjusted to the newest ratings, they probably are not reliable. But, even the adjusted ratings might not be reliable because stage-discharge relations vary with time and stage. Therefore, it may be difficult to establish with accuracy conditions that may have existed at the time of historic flows if measurements were not made at the time of those flows. If operation of the station continues, better maintenance, a revised rating, and systematic compilation of records will be necessary. As of 1985, MPWMD measured streamflow at this station and at several temporary stations downstream to determine the quantity of surface water available for recharging the ground-water basin. The stage recorder at this station, however, has not been reliable and stage record has not been calculated routinely (Ken Greenwood, Monterey Peninsula Water Management District, oral commun., 1985). If the capacity of the San Clemente Reservoir is increased, as proposed, improved operation of this station will be even more important.

Carmel River at Robles Del Rio (11143200, site 12).--The USGS, in cooperation with the MCFCWCD, has operated this station since 1957. The principal water-resource priority in the Carmel River drainage basin is water supply. Surface- and ground-water diversions from the basin for municipal use on Monterey Peninsula and rapidly increasing water demands have created serious water shortages in recent years. Storage for water supply is provided by the San Clemente and Los Padres Reservoirs on the Carmel River. The streamflow-gaging station at Robles Del Rio is downstream from both reservoirs. The MPWMD is considering a proposal to enlarge San Clemente Reservoir at a projected cost of $47 million. Continued operation of this station is justified in order to record minimum flow downstream from the reservoirs, high flow for flood warning, and availability of water for ground-water recharge.

Las Gazas Creek near Carmel Valley (site 13).--This station was discontinued in 1978 by the MCFCWCD but was reactivated in 1981 by the MPWMD. Las Gazas Creek is the largest tributary into the Carmel River. Discharge records for this station are useful for estimating water available for ground-water recharge. Estimates of runoff from Las Gazas Creek also could be used to estimate runoff from some of the nearby smaller tributaries by using drainage-area ratios. The MPWMD plans to continue operation of this station (Francis Krebs, Monterey Peninsula Water Management District, oral commun., 1983).

Carmel River near Carmel (11143250, site 14).--The USGS has operated this station since 1962. Located in the Carmel Valley, this station measures runoff from the 53-mi^2 drainage area below the station at Robles Del Rio (site 12, fig. 6). The Carmel River station is important for determining ground-water recharge, which is determined using water-balance computations with the upstream Robles Del Rio station. Summer flows at the Carmel River station normally are less than flows at the Robles Del Rio station despite the additional drainage area. Recharge, therefore, is significant because diversions between the two stations are not substantial (Francis Krebs, Monterey Peninsula Water Management District, oral commun., 1983). As long as water supply is a critical issue in the Carmel Valley, continued operation of both stations on the lower Carmel River will be needed.

Prunedale Creek at Reese Circle (site 16).--Prunedale Creek, which is part of the larger Elkhorn and Moro Cojo Slough drainage area known as the Prunedale basin, drains a 7.33-mi^2 area. Ground-water recharge in the Prunedale basin primarily is from rainfall infiltrating the soil and percolating down to the water table. This station, used primarily to estimate recharge, has been operated by the MCFCWCD since 1970. Runoff and precipitation data for this station are used to calculate infiltration. Ground-water levels in the Prunedale basin have been declining steadily in recent years because of ground-water-storage depletion. Monitoring of recharge is necessary for effective management of this ground-water resource. This station is the only streamflow-gaging station in the Prunedale basin, and, therefore, its continued operation for determining potential ground-water recharge is justified. However, periodic inspection of this station and review of data compilation practices for gathering data at this station would need to be done to ensure the quality of record.

Possible Additional Streamflow-Gaging-Station Sites

Reactivation of four existing streamflow-gaging stations and the addition of six new stations have been proposed for the study areas (fig. 6). These stations could be used primarily to collect water-supply data, but the data also could be used for flood warning, computing sediment transport, and planning and management of instream flow requirements. These sites are proposed as possible gaging-station sites only; installation of any new stations would depend on priority of the information needed and on available funding. General criteria for site selection and justification of the proposed sites are given in the following sections.

General Criteria for Site Selection and Justification of Proposed Sites

Reactivated Stations

Tularcitos Creek near Carmel Valley.--A station was installed at Tularcitos Creek in 1981 by the MPWMD but was removed during the summer of 1983 during construction of a bridge. As of 1985, the MPWMD has made weekly streamflow measurements at this site, but no continuous-record stage gage is in place. Because Tularcitos Creek is the largest tributary to the Carmel River, a continuous-record stage gage at this site would be important for documenting streamflow entering the Carmel Valley. Data collected from a station at this site also could be useful for flood planning and for estimating runoff available for recharging ground-water supplies. The Tularcitos Creek station site also has been used to compute sediment yields. The Tularcitos Creek basin has been a source of large sediment yields that could disrupt the basin fisheries. If a correlation between flow and sediment yield can be established, a station at this site would provide estimates of continuous sediment discharge.

New station sites

Los Carneros Creek.--Los Carneros Creek flows directly into Elkhorn Slough and drains a part of the Prunedale basin. A streamflow-gaging station on Los Carneros Creek could be used to estimate ground-water recharge through infiltration as is done at the station on Prunedale Creek. Data collected at this site could be used to aid in resolving ground-water quantity and quality issues in this area.

Little Sur River Near Point Sur.--In 1973, the California Legislature designated the Little Sur River as a protected waterway. As a result, a protected waterway management plan was prepared (Harvey and Stanley Associates, Inc. and H. Esmailli and Associates, Inc., 1982, p. 1). The first recommendation of the plan was to install a streamflow-gaging station on the Little Sur River below the confluence with the South Fork to obtain baseline conditions for this site (Harvey and Stanley Associates, Inc. and H. Esmailli and Associates, Inc., 1982, p. 75). The Little Sur River drainage basin is largely undeveloped. Data collected at this site could provide valuable information for measuring the effects of any new activities in the basin. A station at this site would be used primarily to determine available water supplies and to aid in answering new requests for water appropriations. This station also could be used for studies on water quality and instream flow requirements for the anadromous fishery.

Big Sur River Below Big Sur.--A station below Big Sur near the mouth of the Big Sur River could be used to monitor low flow during the dry summer months. Because virtually all development in the Big Sur River basin has occurred downstream from the existing station, flow records from a station at the mouth of the river could be used with flow records from the upstream station to calculate total water used or recharged from the lower Big Sur River basin. Stanley (1982, p. 25) identified water supply as the chief concern in the lower Big Sur River basin. A new station at this site also could be used to provide baseline data to support management decisions concerning water supply. If funding and priorities allow, a continuous-record stage gage could be installed to provide needed data. A lower cost alternative to a station at this site would be to establish a low-flow measurement site where streamflow could be measured several times during the summer months for several years. The low-flow measurement site could be used to establish a relation with the upstream station.

Pheneger Creek, Pfeiffer-Redwood Creek, Post Creek, and Others.--Much of the water withdrawn from the lower Big Sur River basin is diverted from three tributaries: Pheneger Creek, Pfeiffer-Redwood Creek, and Post Creek. During low-flow periods, these creeks may not maintain sufficient flow to meet the water needs of juvenile steelhead trout (Stanley, 1982, p. 19-20). In fact, these creeks were dry at times during 1977, which was the second year of a 2-year drought (Stanley, 1982, p. 6, 13). Stations near the mouth of each creek could be used to record flow during the dry summer months. Data collection of this type would be useful in resolving water-supply concerns. When several years of data have been collected, correlations between flow at the continuous-record stage gage on the Big Sur River and flow on each of the creeks could be established. Reliable estimates of low flow could be made from the records of flow for the Big Sur River. If further development or diversion takes place in the Big Sur River basin or its tributaries, correlations between flow on the river and creeks would need to be reevaluated.

Several coastal streams south of Carmel, such as Malpalo Creek, Palo Colorado Canyon, Rocky Creek, and Torre Canyon, are primary sources of domestic water supply for rural communities. During future dry periods, these streams could be totally depleted by diversions for domestic purposes. The remaining instream flow, therefore, may be inadequate to sustain the riparian habitat and for fisheries and domestic uses. Investigations are needed to document these diversions during dry periods. Continuous-record stage gages would need to be installed at these sites to document water-supply availability and water use.

Surface-Water-Quality Networks

Surface-Water-Quality Conditions

The Monterey County Planning Department (1981b, p. 123-132) has reviewed surface-water-quality problems in the study areas (see table 6 [at back of report] and figure 7 for station names and locations). The following discussion is from the area-by-area summary of surface-water-quality conditions by the Monterey County Planning Department.

Water quality varies widely in the Pajaro River basin. The lower Pajaro River, which has had the most degraded water quality in Monterey County, passes through the county from its headwater at San Felipe Lake in Santa Clara County (about 15 mi northeast of the northernmost part of the study area) to the Pacific Ocean. The lower Pajaro River is managed jointly by Monterey and Santa Cruz Counties. Immediate water-quality problems in the river result from discharge of municipal and domestic wastewater, poor quality water entering through tributary streams that may originate in (or pass through) areas of alkaline soils, and agricultural irrigation-return flow. Occasional overflow from sewage-pump stations in Monterey and Santa Cruz Counties and inadequately treated sewage discharges pose threats of contamination of shellfish in nearshore Monterey Bay. Urbanization and irrigation-return flows have resulted in mineralization, which generally decreases with increased flow.

Elkhorn and Moro Cojo Sloughs also have water-quality problems. Some wetlands and former tidal marshes in the Elkhorn Slough basin are now under cultivation. Elkhorn Slough, an important salt marsh on the Pacific coastal flyway and the second largest wetland in California, is designated a national estuarine sanctuary. The principal water-quality problems in Elkhorn Slough are sedimentation and high levels of coliform bacteria. Sedimentation is related to land use and poor tidal flushing in this highly erodible basin. Erosion from strawberry production, road cuts, and inadequate landscaping on hillside developments is the primary source of sedimentation. High levels of coliform bacteria also are a problem in Elkhorn Slough, especially in its southern reaches, and therefore, the Monterey County Environmental Health Department has banned the commercial sale of shellfish from this slough for direct consumption. Sources of coliform bacteria include waste discharges from ships, industrial discharges, animal-husbandry operations, runoff, and drainwater.

Animal husbandry and agricultural practices also affect water quality in Moro Cojo Slough where seasonally high salt levels result from insufficient water circulation and drainage. The water and soil in this slough are degraded and do not support wildlife to the extent that Elkhorn Slough does. Sources of contamination in Moro Cojo Slough include natural mineralization, agricultural irrigation, and possibly seepage from a nearby tailing pond.

Water quality in Monterey Bay, especially the southernmost part of the bay, has been a concern for a long time. Municipal, industrial, and nonpoint discharges into the bay and its tributaries have raised nutrient, trace-metal, and bacteria levels. Elevated nutrient levels recorded at the Pacific Grove Marine Garden Fish Refuge and at Point Pinos in Pacific Grove and off the coast of Monterey have resulted in increased phytoplankton blooms and coliform contamination. Human activities and water use are the primary sources of trace metals, such as zinc and lead. The California State Water Resources Control Board conducts ongoing studies on trace metals in Monterey Bay. Trace-metal contaminations could be reduced by upgrading water treatment and restricting discharges only to areas that have adequate dilution capacities, but degradation of water quality would continue because of atmospheric deposition of pollutants and urban and agricultural discharges. The quality of the water along much of the Monterey County coast is related directly to urban development and is affected by varying levels of contamination. Below Point Sur, the water is less affected by human activities, and therefore, the water quality is good.

Generally, water quality in the Carmel River is good, but geology and land use affect the quality of the water in the lower reach of the river. Urban runoff, erosion, and sedimentation are the principal sources of contamination of the Carmel River. Lack of sewers poses a threat to the water quality of the Carmel River by contamination from individual septic systems. Nitrates in the river water from overloaded septic systems and urban runoff have caused the California Regional Water Quality Control Board to classify the river as having suspected problems.

In the Big Sur area between Point Lobos and the southern county boundary, rivers and creeks discharge directly into the Pacific Ocean. The water quality of most of these streams meets health standards. Generally, the water quality of the lower Big Sur River meets standards for body-contact recreation, although septic systems in the floodplain along the lower river could have adverse effects on water quality for recreational uses. During the drought of 1976-77, access to the lower river area was restricted because of high levels of coliform bacteria that may have come from heavily used campsites and inadequate human-waste disposal.

Degraded surface water impairs fish and wildlife habitats and reduces the amount of water available for agricultural, industrial, and recreational uses. The State of California has designated five aquatic areas in the county as areas of specific biological significance that require protection: the Marine Garden Fish Refuge and Hopkin's Marine Life Refuge in Pacific Grove; the Ecological Reserve in Point Lobos; Carmel Bay; Julia Pfeiffer Burns Underwater Park at Partington Point; and the ocean around the mouth of Salmon Creek. Discharge of poor quality water into these areas could disturb these unique biological communities.

Objectives

Generalized management and network objectives for all water-resources disciplines are given in table 1. Generalized management objectives for surface-water-quality networks are (1) to determine ambient concentrations of all water-quality constituents; (2) to determine spatial and temporal trends in water quality; (3) to identify all sources of contamination, such as native materials, line, point and nonpoint sources; and (4) to develop a management plan to control water quality of streams. Specific network objectives for this study area are given in table 3 with priority rankings and other pertinent data. These categories were expanded from those presented by Showalter and Hoffard (1986).

The data needs of an ideal surface-water-quality network (table 3) include routine and periodic complete analyses of water from streams and reservoirs for domestic, recreational, agricultural, and fish and wildlife uses. Sampling could be used to determine the trophic state of flow from reservoirs, to monitor the effects of geology and land use on water-quality trends, and to establish baseline data on water-quality characteristics, such as temperature and specific conductance for an entire basin and for specific streams. This data then could be used to assist in mosquito abatement, to evaluate compliance with water-quality criteria and standards, and to develop a water-quality rating system for stream reaches.

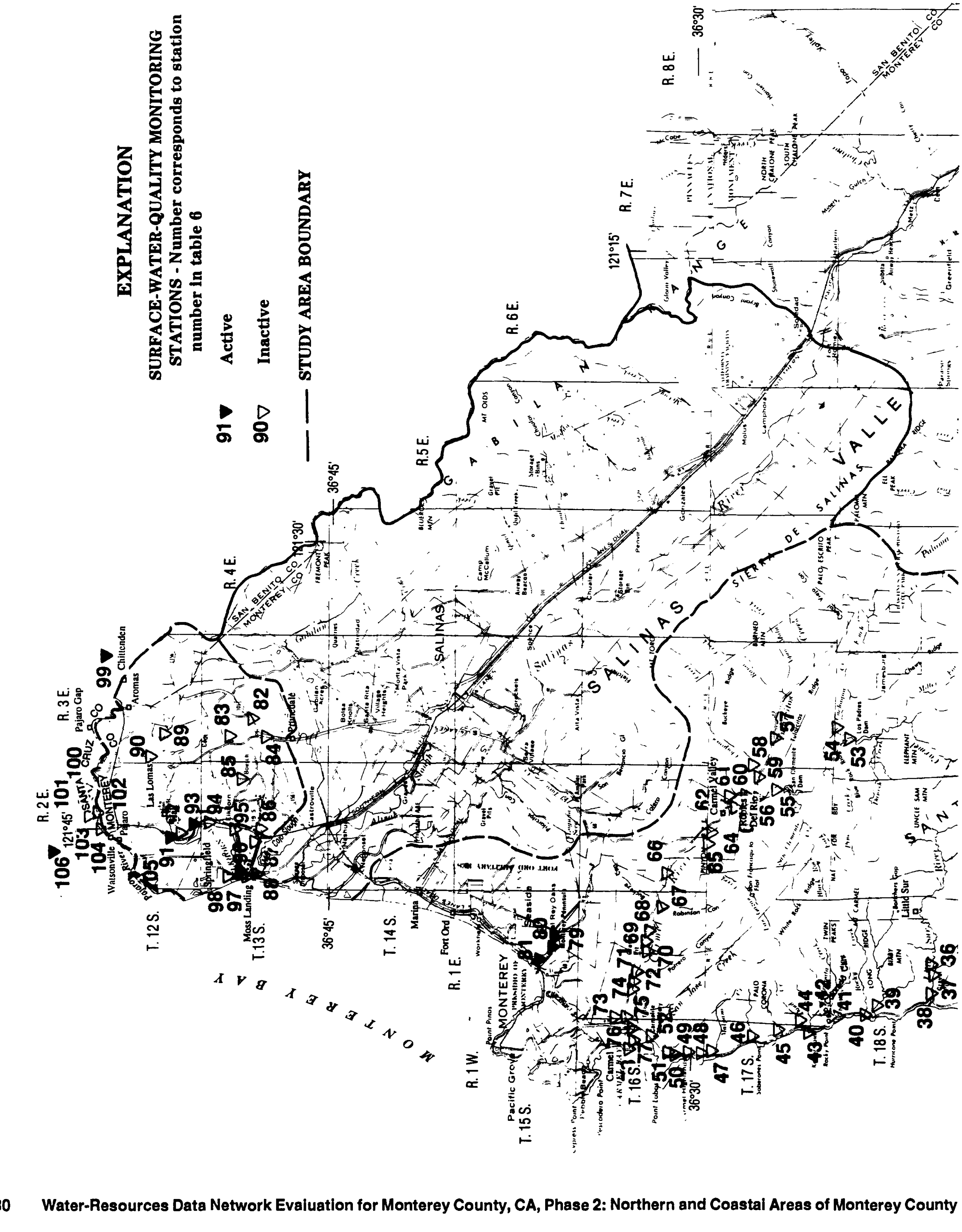
A stream-reach rating system for the study areas would be helpful for prioritizing the collection of data for reaches of streams. The rating system would be based on the priority of water uses for each reach and the perceived urgency of action on water-quality degradation. During development of a stream-reach rating system, records of routine and periodic complete chemical analyses could be used to categorize basins to establish baseline water-quality conditions. Water-use information collected from surface-water-quality networks (table 3) could be used to determine the relations between land use, water use, and water quality.

An ideal surface-water-quality network would provide data on general chemical quality, trace elements, bacteria, and all other potential contaminants for all streams in a study area at any given time. Such network saturation is impractical. However, an ideal network could produce more data than the existing networks currently are producing. Examples of data needs that could result in the need for additional networks are given in table 3 with priority rankings and other pertinent data. As networks are established, priorities may change and thus the objectives of the networks also may change.

Methods of Evaluation

For this study, surface-water-quality monitoring networks were evaluated by (1) assessing the data needs of the study areas, (2) defining ideal-network coverage (table 3), (3) locating and evaluating existing and potential surface-water-quality sampling sites, and (4) determining possible improvements to network coverage. For this report, the generalized management and network objectives for surface-water-quality monitoring (table 1) were developed on the basis of several methods of network evaluation, including methods by the United Nations Educational, Scientific, and Cultural Organization and World Health Organization-Group on Quality of Water (1978, p. 25-27), Koryak (1980), Ponce (1980) and Sanders (1980).

Using the objectives for monitoring surface-water quality, five categories were identified by the United Nations Educational, Scientific, and Cultural Organization International Hydrological Decade, and World Health Organization-Group on Quality of Water (1978, p. 25-27). These categories included "(1) classification of water resources according to quality and prospective uses, (2) collection of baseline data to identify the natural quality of water for determining changes for long periods, (3) water-quality surveil-


EXPLANATION
SURFACE-WATER-QUALITY MONITORING STATIONS - Number corresponds to station number in table 6
91 Active
90 Inactive
STUDY AREA BOUNDARY
MONTEREY BAY
SALINAS
Watsonville
Moss Landing
Castroville
Marina
Fort Ord
Seaside
MONTEREY
Pacific Grove
Carmel
Carmel Valley
Soledad
Gonzales
Chualar
Aromas
Chittenden
Pajaro Gap
Las Lomas
Point Pinos
Point Lobos
Little Sur
Hurricane Point
SIERRA DE SALINAS
SALINAS VALLEY
GABILAN RANGE
SAN BENITO CO
MONTEREY CO
SANTA CRUZ CO
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
R. 6 E.
R. 7 E.
R. 8 E.
T. 12 S.
T. 13 S.
T. 14 S.
T. 15 S.
T. 16 S.
T. 17 S.
T. 18 S.
121°45'
121°30'
121°15'
36°45'
36°30'

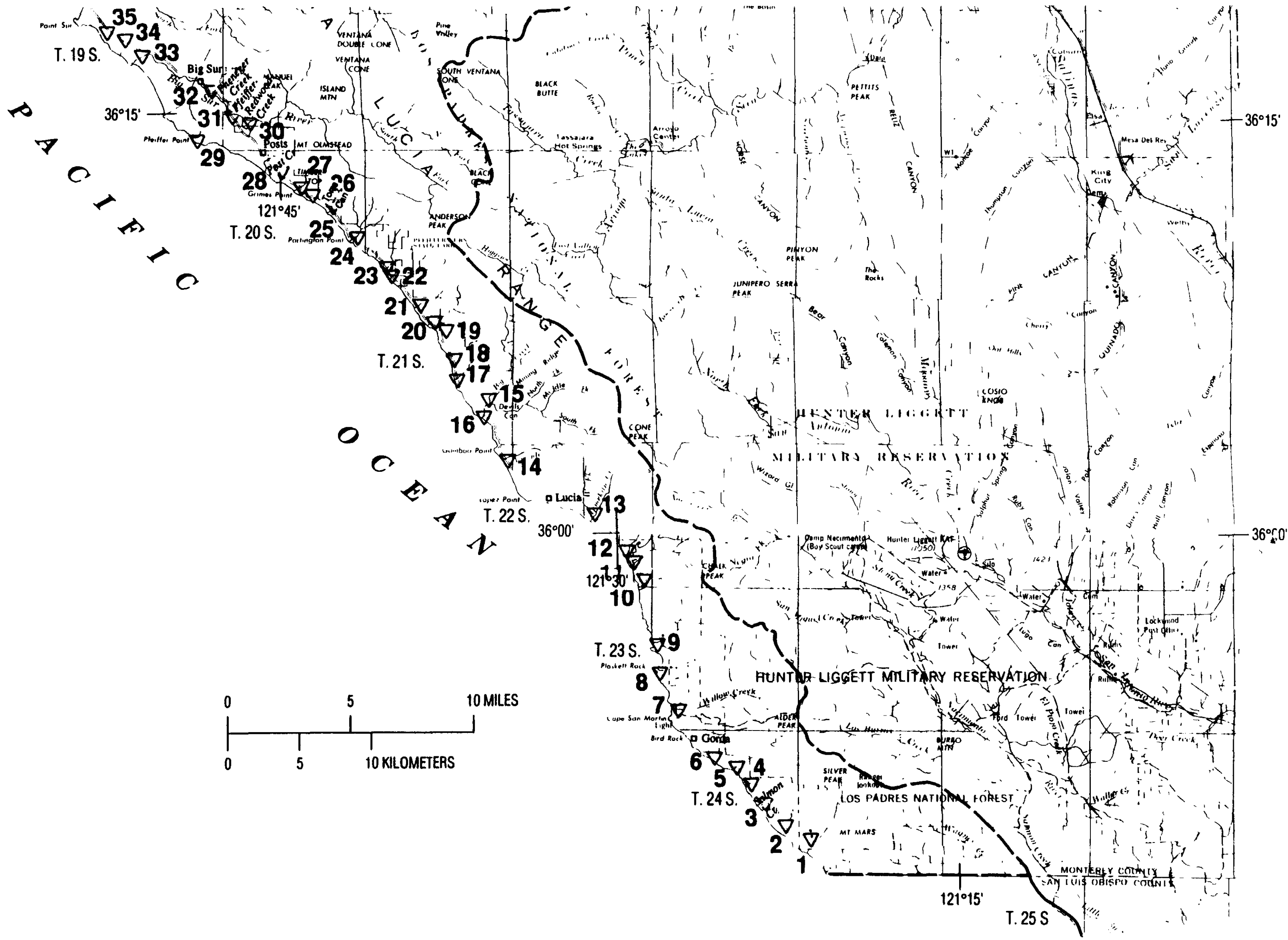


Figure 7. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California.

lance to determine the effectiveness of discharge-management programs, (4) investigation of cases of contamination to determine the range of contamination identified by surveillance and to provide corrective measures, and (5) forecasting water quality and estimating waste-assimilation capacity to provide information on which to base rational choices for water-contamination control measures and management alternatives."

Ward (1979) devised a flow-chart method to describe a monitoring program and a matrix to help organize the objectives of the monitoring program. He determined that (1) water-quality management strategies need to be tied closely to the objectives of the surface-water-quality network, (2) data use is poorly defined compared with data collection for monitoring water quality for regulatory purposes, and (3) the addition of new objectives or activities should be evaluated carefully before they are integrated into an existing network. Ward (1979) recognized that this method of developing a monitoring program was based on a subjective classification of objectives and activities, but he felt that it was a good first attempt at providing a basis on which future monitoring could be done to optimize the network.

Koryak (1980, p. 1) said that "the design of water-quality monitoring networks traditionally has been a subjective process. Decisions as to the number of stations in a network, station locations, sampling frequencies, and parameter coverage primarily are based on the intuitions and judgment of the individual designers." Koryak (1980) also stated that the initial step of network design—defining network objectives—probably was the most subjective and potentially controversial part of the process. Koryak (1980) suggested two basic objectives for monitoring surface-water quality, each requiring correspondingly different strategies. The first objective is long-term monitoring to identify water-quality characteristics and trends, which requires ongoing routine monitoring for long-term, fixed-time increments at permanent stations (stations for which no termination date for the collection of data has been designated). The second objective is short-term monitoring for deterministic water-quality investigations that entail synoptic monitoring. This type of monitoring often is required for regulatory enforcement primarily involving effluent and receiving-water monitoring. Synoptic monitoring can be scheduled to measure chronic water-quality conditions or unscheduled to measure acute conditions. Synoptic monitoring normally has a short-term or designated termination date.

Sanders (1980, p. 264) also considered defining objectives as the first step in network design. He suggested that if a network had several objectives, each objective should be determined and prioritized relative to the other objectives to provide the designer with guidance for compromises later in the design process. In addition, Sanders (1980) suggested that the objectives of the monitoring networks should be expressed in statistical terms to permit users of the data to specify the required accuracy in quantifiable terms and to provide the network designer with a more objective basis for design calculations. Once the objectives have been identified and stated in statistical terms, the network design can be reviewed for other factors, such as variables selected for monitoring, sampling-station locations, sampling frequencies, and the resulting data to determine the adequacy of an existing monitoring network and to suggest improvements.

A method for determining priorities for individual streams and stretches of streams is needed to evaluate existing and historical monitoring and to improve monitoring of surface-water-quality sites. Sanders (1980, p. 118) presented a method for selecting stream reaches that need to be monitored. This method requires that each stream reach and tributary be assigned a rating on its need for monitoring on the basis of the number and types of diversions from and discharges into it. This approach could provide the rating-system design needed for surface-water-quality monitoring networks in Monterey County.

Ponce (1980, p. 35) prepared a technical paper and a water-quality matrix of activities, concerns, and constituents to monitor surface-water quality for development of U.S. Forest Service surface-water-quality monitoring programs. The ideal-network approach designed for the study areas of the report (table 3) is similar to the matrix by Ponce.

Station Location and Sampling Frequency

According to Brown and others (1970, p. 4-8), the overall data needs of a surface-water-quality network will determine the location of a station and the frequency of sampling. If a sampling network is established to determine baseline data for water quality of a stream, each sampling station should represent the entire stream (stream reach), and therefore, should not be located where mixing of water is incomplete or where water composition differs significantly in the stream cross section. If a sampling station is established to measure water quality at a specific intake or discharge point, care should be taken not to mislead data users into thinking that the site is representative of the entire stream. If more precise data are required, many of the streams would need to be monitored continuously or at least frequently. Sampling frequency may be reduced for streams completely controlled by releases from storage reservoirs or by large constant ground-water inflow. To establish continuous water-quality conditions for a stream, continuous-recording and telemetering equipment could be used with periodic complete water-quality analyses.

When determining the number of stations and sampling frequency for the overall needs of a surface-water-quality network, two factors need to be considered: (1) How much risk of inaccurate data can be accepted and (2) how much of a financial investment can be made to obtain these data? To determine the reliability and cost-effectiveness of surface-water-quality monitoring, the reader is referred to a report by Tirsch and Male (1983) in which multivariate linear regression methods are discussed that help answer these questions.

Description

The surface-water-quality monitoring stations identified in this report include both inactive and active stations (fig. 7, table 6). At the time of this study, five agencies monitored surface-water quality in the study areas: (1) Northern Salinas Valley Mosquito Abatement District, (2) California State Water Resources Control Board, (3) U.S. Geological Survey, (4) California Department of Water Resources, and (5) Santa Cruz County Planning Department. The MCFCWCD did not operate any surface-water-quality monitoring stations at the time of this study.

Nine active stations were monitored for chemical water-quality constituents in the study areas. In the future, additional sites may be monitored on the Big Sur and Little Sur Rivers as recommended in the protected-waterway management plans for these rivers (Harvey and Stanley Associates, Inc. and H. Esmailli and Associates, Inc., 1982; Stanley, 1982). Because information on the chemical quality of the Big Sur River and its tributaries is lacking, Stanley (1982, p. 36) recommended that a water-management district be formed. This district could establish a monitoring network to characterize water quality in the basin.

According to Stanley (1982, p. 16, 17, and fig. 5), water in the lower Big Sur River basin occasionally is sampled by the Monterey County Environmental Health Department for chemical and bacterial analyses. Coliform bacteria are counted at the points where water systems serving two or more connections withdraw their water. The Big Sur River is sampled monthly at 16 stations; the water samples are analyzed for total coliform and fecal coliform bacteria. Of the 18 historical water-quality sampling sites on the lower Big Sur River noted by Stanley (1982), 15 were within the Los Padres National Forest and 3 were downstream of the forest. At the time of this study, no routine sampling was done for chemical analyses of stream water in the Big Sur River basin. Chemical analyses are done only when expansions of water systems are proposed.

Surface-water-quality monitoring stations identified for this study were insufficient to meet the general objectives (table 1) or specific objectives (table 3) outlined in this report. To better meet these objectives, monitoring at existing stations needs to be continued and new stations need to be added. New stations that may have been established recently would need to be evaluated when the network is redesigned. The new network then would need to be reviewed and compared to a stream-reach rating system to determine where additional sites would need to be added in the active network when funds and priorities allow. Data from these new stations then would need to be entered into a computer data base for more-detailed statistical analyses.

Stream-Reach Rating System

A method of determining priorities for individual streams and reaches of streams is needed so that MCFCWCD can begin monitoring additional surface-water-quality sites. Sanders (1980, p. 118) presented a method for selecting river reaches needing sampling stations. This method identifies each major stream and subdivides the streams into tributaries. Each stream and tributary then is assigned a rating of its need for monitoring on the basis of the number and types of diversions from and discharges into them. Sanders' method could be applied to improve surface-water-quality monitoring networks for Monterey County. The drainage-basin numbering system proposed by Durbin and others (1978, p. 44-46) for small tributary streams of the Salinas River needs to be expanded to include separate reaches of all streams in

Monterey County. The use of a stream reach identification system established by the U.S. Environmental Protection Agency would adequately meet the needs of Monterey County and lead to improved cooperation between local and Federal agencies with common interests. The result would provide an initial list of specific stream reaches that would need to be ranked by their priority of need for streamflow and surface-water-quality data.

GROUND-WATER NETWORKS

Ground-Water Conditions

The following introduction on ground-water conditions provides information on the geology, occurrence of ground water, ground-water flow, flow barriers, water-level changes, and ground-water-quality conditions in the study areas of this report because they each influence the existing monitoring networks.

Geology

The geology in the study areas is discussed in greater detail in several reports. Hart (1966) described the study areas as "typical of the southern Coast Ranges, being structurally and stratigraphically complex." His report includes a geologic map of Monterey County showing mines and mineral deposits that can influence the quality of surface and ground water in the county. Muir (1972) and Johnson (1983) described the geology of the northern part of the study areas as it relates to ground water. The geology near Marina, Fort Ord, Seaside, and Laguna Seca is discussed in reports by the California Department of Water Resources (1974), U.S. Army Corps of Engineers (1974a), Logan (1982a), and Muir (1982). The geology of the Carmel Valley is described in reports by Trask (1926), the California Department of Water Resources (1969; 1974), Clark and others (1974), Thorup (1976), Logan (1982b), Montgomery (1982), and Kapple and others (1984).

Reports on northern Monterey County by Johnson (1983) and on the Carmel Valley by Kapple and others (1984) provide prime examples of how local geology influences water levels. The Carmel Valley is an alluvial basin with distinct boundaries and three main sources of ground water: basement rocks, consolidated sedimentary rocks, and unconsolidated sediments. By contrast, northern Monterey County is a series of westward-dipping sedimentary strata with many different subareas (Johnson, 1983, pl. 3) where movement of ground water is influenced locally by surface topography and by subsurface lithology and structure. Geology affects ground-water-level monitoring in many ways, but the primary effect is noticeable in the complexity of variations in water-level altitudes. For example, in an alluvial basin such as Carmel Valley, which has three identified aquifers, it is necessary to space wells by surface area and depth for each aquifer. Once wells have been selected for monitoring each aquifer, the correlation of water levels between wells in the same aquifer should be fairly high. Northern Monterey County also has three aquifers that are influenced by surface and subsurface geology. Monitoring wells in this area may need to be spaced much closer because of lower correlations in water levels between wells in the same vicinity (Johnson, 1983).

Occurrence of Ground Water

The occurrence of ground water in Monterey County has been studied in the following specific areas: Pajaro-Springfield, Prunedale, Marina, Seaside, Laguna Seca-Canyon Del Rey, and the Carmel Valley (fig. 8). The Pajaro, Springfield, and Prunedale basins make up the northern part of the study area. Because of local differences in ground-water conditions in these basins, each basin requires specific reference in the following discussions.

Ground water in the northern part of the study areas occurs in a series of westward-dipping sedimentary strata (Johnson, 1983, p. 4). Water-bearing strata include alluvium and terrace deposits, such as the Aromas Sand and the Purisima Formation. Pumpage primarily is from the upper part of the Aromas Sand and from the alluvium and terrace deposits. Withdrawals from the Purisima Formation are not common, but this formation may have substantial water-bearing potential.

Fresh ground water in the Marina area seems to be marginal because of saltwater intrusion. In the Seaside area, most geologic formations contain ground water (Muir, 1982, p. 8), but only the Santa Margarita Sandstone, the Paso Robles Formation, the Aromas Sand, and the older dunes formations are significant sources of ground water. In the Carmel area, the younger alluvium and unconsolidated sediments contain ground water, but the younger alluvium is the most significant water-bearing unit (Kapple and others, 1984, p. 12).

Ground-Water Flow

The direction of ground-water flow varies with each specific geographic area and aquifer and may be influenced by pumpage variations during any given year. Water levels of wells are measured for many reasons, including the development of contour maps that generally indicate the probable direction of ground-water flow within a subarea or aquifer. Water levels in the study areas are measured by the MCFCWCD and the CAWC. Until 1977, the MCFCWCD published this data in an annual report, the last of which was published for autumn 1977 (Monterey County Flood

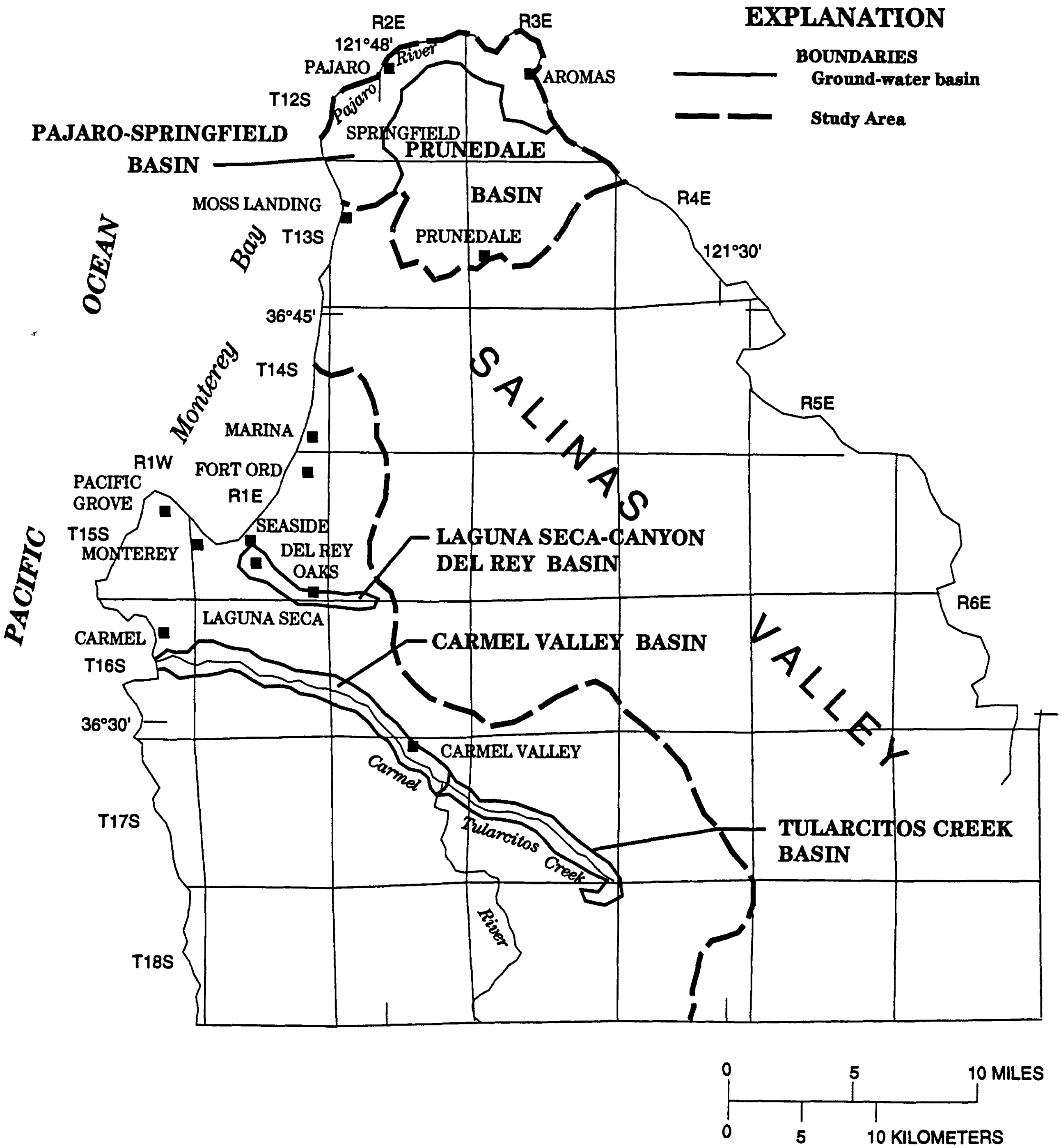


Figure 8. Ground-water basins in the northern and coastal areas of Monterey County, California.

Control and Water Conservation District, 1977). Only one water-level contour map in that report, the map for the Carmel Valley, is relevant to this report; however, reports are being prepared that will provide water-level contour maps for the Carmel Valley, Pajaro-Springfield areas, and the El Toro areas (phase 3 study area) through 1981 (Bruce LaClergue, Monterey County Flood Control and Water Conservation District, written commun., 1984). More-detailed ground-water-flow information is available in a two-dimensional, finite-element digital model developed by Kapple and others (1984) for the Carmel Valley alluvial ground-water basin.

The general direction of ground-water flow in the Pajaro Valley is described in a report by H. Esmailli and Associates, Inc. (1984, p. 12). Ground water in the northern part of Monterey County generally flows westward toward the ocean (Johnson, 1983, p. 8), but varies with subareas and aquifers. A report by Johnson (1983, pl. 2) shows the direction of ground-water flow by subarea for near-surface and deeper zones of the aquifers in this part of the study areas.

A report by Muir (1982, fig. 3) provides the approximate directions of ground-water flow near Fort Ord, Seaside, and Laguna Seca with flow south of Marina generally westward toward the Pacific Ocean. A water-level contour map of the Seaside area for spring 1973 shows that ground water probably flows toward the north and northwest (California Department of Water Resources, 1974). Logan (1982a, p. 27) noted that the ground-water-level contour maps by the California Department of Water Resources (1974) and by Muir (1982) used all available data from shallow and deep wells in the Seaside area, but that the results might be questionable because of the complex hydrology of the area, which includes a water table and a semiconfined and confined system of aquifers. Logan (1982a, p. 48) suggested that the data on hydraulic-head distributions are seriously deficient because these data relate to the various hydrogeologic units in the Seaside area. Installation of three to five additional monitoring wells and aquifer testing and geophysical logging would be necessary to resolve questions on hydraulic-head distribution in the aquifers in the Seaside area. Muir (1982, p. 33) recommended adding three recording rain gages in the Seaside area, probably to determine the effect of rainfall on ground-water recharge.

Information on ground-water flow is lacking for the Monterey Peninsula and the coastal area south of Carmel. The California Department of Water Resources (1981a) also indicated little or no available ground-water data in their records for those areas. This lack of data probably is related to an absence of significant water-bearing formations in these areas. To determine the presence of any wells in these areas, a well canvass would need to be done. If any wells are located, some wells would need to be added to the existing ground-water monitoring networks.

Flow Barriers

In the northern part of the study areas, ground-water flow is affected primarily by topography near the land surface and by lithology and geologic structure at depth (Johnson, 1983, p. 8). According to Johnson (1983, p. 13), "north of the granitic ridge," between Aromas and Prunedale, "in the Los Carneros drainage, ground water moves westward within the Aromas Sand across the Vergeles fault."

Muir (1982, p. 12) stated that the complex system of faults in the Seaside area seems to have had little or no effect on the direction of ground-water flow. Indirect evidence, however, indicates that some influence is likely because the offsets caused by the faults are larger than the thicknesses of many of the individual geologic strata (Logan, 1982a, p. 30-31). Logan (1982a, p. 11) found no consensus on flow barriers among available interpretations of fault locations in this area.

The Carmel Valley has three faults that may affect ground-water flow in that area: the Cypress Point Fault, the Navy Fault, and the Tularcitos Fault (Kapple and others, 1984, p. 12).

Hart (1966, pl. 1), Stanley (1982, p. 5), and Harvey and Stanley Associates, Inc., and H. Esmailli and Associates, Inc. (1982, p. 4), identified several faults in the Monterey coastal area that may have some hydrologic significance; however, that significance was not described.

Water-Level Changes

Water-level changes can have temporal trends as well as spatial variation. In the Seaside area, ground-water levels usually reach seasonal highs in early March and seasonal lows in mid-August (but seasonal lows can occur anytime between July and October) (Logan, 1982a, p. 21). Data on temporal trends in water levels are lacking for the Big Sur and Little Sur coastal areas (Stanley, 1982, p. 33; Harvey and Stanley Associates, Inc., and H. Esmailli and Associates, Inc., 1982, p. 75), and therefore, fluctuations in water levels of the primarily shallow alluvial aquifer in this area are unknown. Water levels probably are lower during the dry summer months when ground-water use increases. Reduced flow in the streams during the 1976-77 drought and the probable hydraulic connection between the streams and the shallow aquifer indicate that annual water levels probably are lower during drought years (Harvey and Stanley Associates, Inc., and H. Esmailli and Associates, Inc., 1982; Stanley, 1982).

Ground-Water-Quality Conditions

Ground-water-quality samples have been collected for several years in parts of the study areas of this report, but analyses of these samples were limited to chlorides and dissolved solids (Monterey County Flood Control and Water Conservation District, 1971, p. 1). These constituents were sampled to monitor seawater intrusion along the coast and to provide general information; other potentially contaminating constituents were not sampled. Between 1960 and 1976, the MCFCWCD maintained a water-quality program in cooperation with the DWR. The objectives of the cooperative program were to sample selected wells at 3- to 5-year intervals to identify water types and trends in water conditions. Samples were collected from most Monterey County ground-water basins and analyzed for general minerals. Since 1976, the program has been maintained by either the MCFCWCD or DWR. During the summer of 1971, the USGS sampled ground-water quality in areas of major agricultural, municipal, and domestic ground-water use in the Pajaro, Carmel, and Salinas Valleys and in the Prunedale, Marina, Seaside, El Toro, and Lockwood areas. A network of 250 agricultural and domestic wells was sampled for major mineral constituents; 100 of the wells were sampled for trace elements.

Ground-water quality in the coastal area south of Monterey Bay has not been monitored routinely by the MCFCWCD. Stanley (1982) and Harvey and Stanley Associates, Inc., and H. Esmailli and Associates, Inc. (1982) noted a lack of data on ground-water quality for the Big Sur and Little Sur River areas, respectively. However, the California Department of Health Services and the Monterey County Environmental Health Department usually have water-quality data that is provided by most public water suppliers as required by the Safe Drinking Water Act (U.S. Environmental Protection Agency, 1986). At least 26 wells were identified in the coastal area south of Monterey Bay (Stanley, 1982, fig. 5 and p. 14), some of which belong to water suppliers such as Dani Pfeiffer Ridge Mutual Water Company, Pfeiffer Ridge Mutual Water Company, Rancho Chaparral Mutual Water Company, and the Point Sur Naval Station. The remaining wells were identified as individual domestic wells.

Ground-Water-Level Networks

Objectives

Generalized management and network objectives (table 1) of the ground-water-level networks are (1) to determine regional water-level conditions to establish temporal and spatial trends, (2) to identify ground-water pumpage and recharge sources, and (3) to determine reservoir storage capacities and best-management practices to prevent ground-water- storage depletion and saltwater intrusion.

Specific objectives of the ground-water-level networks are described in table 3, as well as priority rankings and other pertinent data. The objectives are (1) to determine water balance and seawater intrusion, (2) to determine the effects of reservoir discharges on recharging ground-water storage, (3) to quantify ground-water storage in each basin, (4) to assess the adequacy of annual water-level measurements in monitoring storage changes, (5) to assess monthly water-level measurements when monitoring storage changes, (6) to quantify monthly ground-water pumpage (withdrawals), (7) to determine annual consumptive uses of ground water (urban, agricultural, and natural, such as phreatophytes), (8) to monitor ground-water-flow patterns and changes in response to stresses, (9) to determine outflows from ground water that contribute to streamflows (gaining reaches of streams), (10) to determine losing reaches of streams and the potential for enhancing ground-water recharge in these reaches, (11) to determine aquifer characteristics, (12) to determine aquifer boundaries, and (13) to analyze the influences of cones of depression at heavily pumped wells on water levels in other wells (such as those used for monitoring).

Methods of Evaluation

Ground-water-level networks may be evaluated in at least three ways: qualitatively, quantitatively, and statistically. Examples of qualitative analysis are work by Winner (1981, p. 18) and Blankenbaker and Farrar (1981, p. 6), who discussed characteristics of wells and subjectively assigned the wells to qualitative categories. Showalter and others (1984) and Templin (1984) took a quantitative approach in which numerical ratings were assigned to monitor wells on the basis of availability of well-construction data. A statistical method for network evaluation was proposed by Karlinger and Skrivan (1978) and was implemented by Sophocleous and others (1982) using kriging (a method of estimating values for unsampled locations). This method incorporates regionalized variables and semivariograms to determine the number of monitoring sites needed to attain the desired level of accuracy.

Ground-water-level networks identified during this study were evaluated using methods adapted from Showalter and others (1984) and Templin (1984). First, an ideal network was defined that addressed all known needs for ground-water-level data in the study areas. Second, existing networks were identified and wells and networks were classified according to well-construction data. Third, improvements in network coverage were developed to better approximate ideal-network coverage. Because statistical analysis of networks can provide valuable results, an evaluation of the type done by Karlinger and Skrivan (1978) or Sophocleous and others (1982) would need to be done when data become available. The adequacy of wells in existing monitoring networks representing actual conditions in the ground-water basins has not been established conclusively nor has the possible redundancy of information from existing networks been evaluated statistically. Despite these limitations, this report provides a basis for assessing the adequacy of ground-water-level networks in the study areas.

One of the specific objectives of a ground-water-level network is to collect data to identify withdrawals from the region's aquifers. Changes in water levels combined with aquifer storage parameters can be used to estimate net change in storage. Withdrawals can be estimated in different ways, but unless the method used is specified, the results may not be comparable. For example, withdrawals can be determined by correlating electrical use and pump efficiencies to estimate pumpage (unit-power consumption method) or by estimating the amount of water necessary for acreages of specific crops (consumptive-use method). Depending on the methods used, significant differences can result. For example, withdrawal estimates will differ if high or low estimates of unit-crop water use and irrigated acreage are assumed. Similarly, if pumpage estimates are based on electrical usage, reductions in meter readings to account for other possible electrical uses may change outflow estimates significantly. In both cases, calculations of annual pumpage trends need to be based on comparable periods, such as calendar years, water years, fiscal years, or rainfall years, and need to include the months of the year being evaluated.

Well and Network Classification

Ground-water networks operated by the MCFCWCD were evaluated for this study using well and network classifications established by Templin (1984). Results of the classification of three ground-water-level networks (represented by 183 wells) and two ground-water-quality networks (represented by 103 wells) are given in table 7 (some wells are in more than one network). Only historical data available on the computer-storage systems of the USGS, augmented with data from the files of the MCFCWCD, were used in this evaluation.

Well-Classification System

Each well in the ground-water-level and water-quality networks maintained by the MCFCWCD was classified according to the availability of data on its construction and lithology. The classification was based on the availability of five key items of information:

- Opening records (perforation intervals),
- Well depth,
- Casing record,
- Sealing record, (record that a seal exists), and
- Well-log availability.

Each well was classified according to which and how many of these five key items were available for that particular well, as follows:

- Class 1. All five key items are available and complete.
- Class 2. The opening record is available, but one or all of the remaining key items is lacking or incomplete.

- Class 3. The opening record is lacking, but one or more of the remaining key items is available.
- Class 4. All five key items are lacking.

The accuracy of this method of classification depends on the accuracy of the drillers' logs and other sources of data. Improvements in the accuracy of these data would improve the results of this method of classification. Therefore, if drillers accurately complete State-required driller's logs when wells are drilled, that data source and, subsequently, the quality of ground-water data would improve greatly. Quality assurance of the data supplied from driller's logs could be accomplished at the State or county level. In fact, county environmental health departments in California are more involved with driller's log files and quality assurance. Unfortunately, as financial resources decline, quality assurance also often declines.

Network-Classification System

Each of the ground-water-level and quality networks maintained by the MCFCWCD was assigned to one of the following four classes according to the relative number of class 1 and class 4 wells in the specific network (table 7) with the class 1 network being the most preferred and the class 4 network the least preferred.

- Class 1. More than 50 percent of wells in the network are class 1 wells.
- Class 2. Fifty percent or less of wells in the network are class 1 wells and less than 50 percent are class 4 wells.
- Class 3. Fifty percent of wells in the network are class 1 wells and 50 percent are class 4 wells.
- Class 4. Fifty percent or more of wells in the network are class 4 wells and less than 50 percent are class 1 wells.

The objective of this classification system is to eliminate all wells from the network that are not optimal for monitoring. Information on the construction of class 1 wells helps validate the data collected from them. Ideally, all wells in all networks would have class 1 designations and the networks would contain enough wells to provide the data needed to meet each specific monitoring objective.

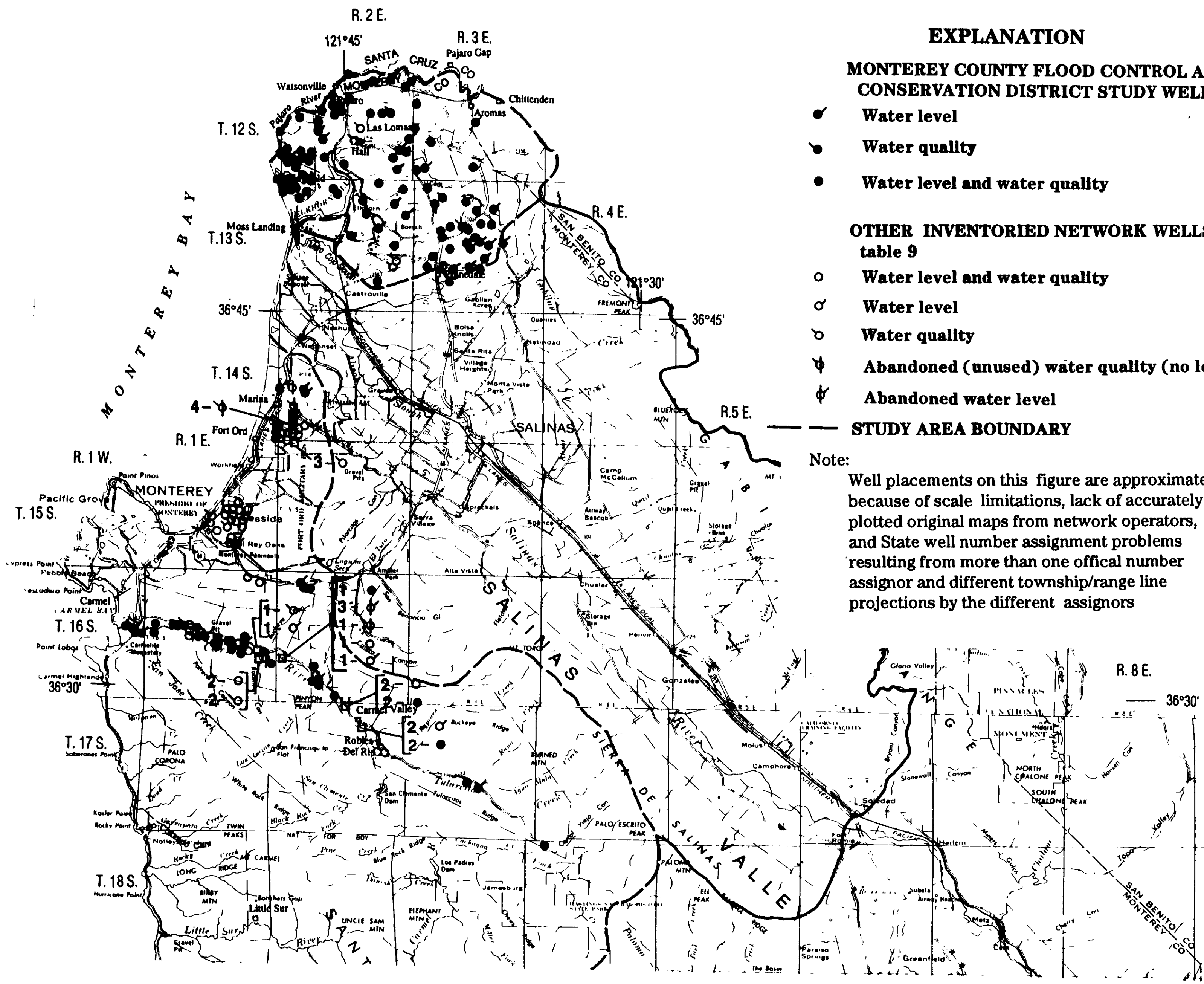
Description

Ground-water-level networks identified during this study are summarized in table 8 (at back of report). A total of 384 wells were identified in all networks, some of which were in more than one network. The annual autumn network usually is measured in December or January to obtain static water-level measurements at the end of the irrigation season. These measurements indicate changes in ground-water storage during the preceding year. The changes are considered the net result of all recharge and withdrawals from the individual aquifers. Wells in the annual autumn network are shown in figure 9 and can be identified using table 8 and the well-numbering system diagram.

Table 7. Classification of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California

[All networks are operated by the Monterey County Flood Control and Water Conservation District]

Total number of wells	Well-class distribution			
	Well class	Number of wells	Percent of network	Network class
Network 1. August water-level measurement				
25	1	5	20	2
	2	11	44	
	3	2	8	
	4	7	28	
Network 2. Monthly water-level measurement				
29	1	8	28	2
	2	8	28	
	3	8	28	
	4	5	16	
Network 3. Annual water-level measurement				
129	1	45	35	2
	2	31	24	
	3	19	15	
	4	33	26	
Network 4. Summer water-quality sampling				
15	1	5	33	2
	2	7	47	
	3	1	7	
	4	2	13	
Network 5. Annual water-quality sampling				
88	1	31	35	2
	2	21	24	
	3	17	19	
	4	19	22	



EXPLANATION

MONTEREY COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT STUDY WELLS

- **Water level**
- **Water quality**
- **Water level and water quality**

OTHER INVENTORIED NETWORK WELLS - See table 9

- **Water level and water quality**
- **Water level**
- **Water quality**
- **Abandoned (unused) water quality (no longer sampled)**
- **Abandoned water level**

— — STUDY AREA BOUNDARY

Note:

Well placements on this figure are approximate because of scale limitations, lack of accurately plotted original maps from network operators, and State well number assignment problems resulting from more than one offical number assignor and different township/range line projections by the different assignors

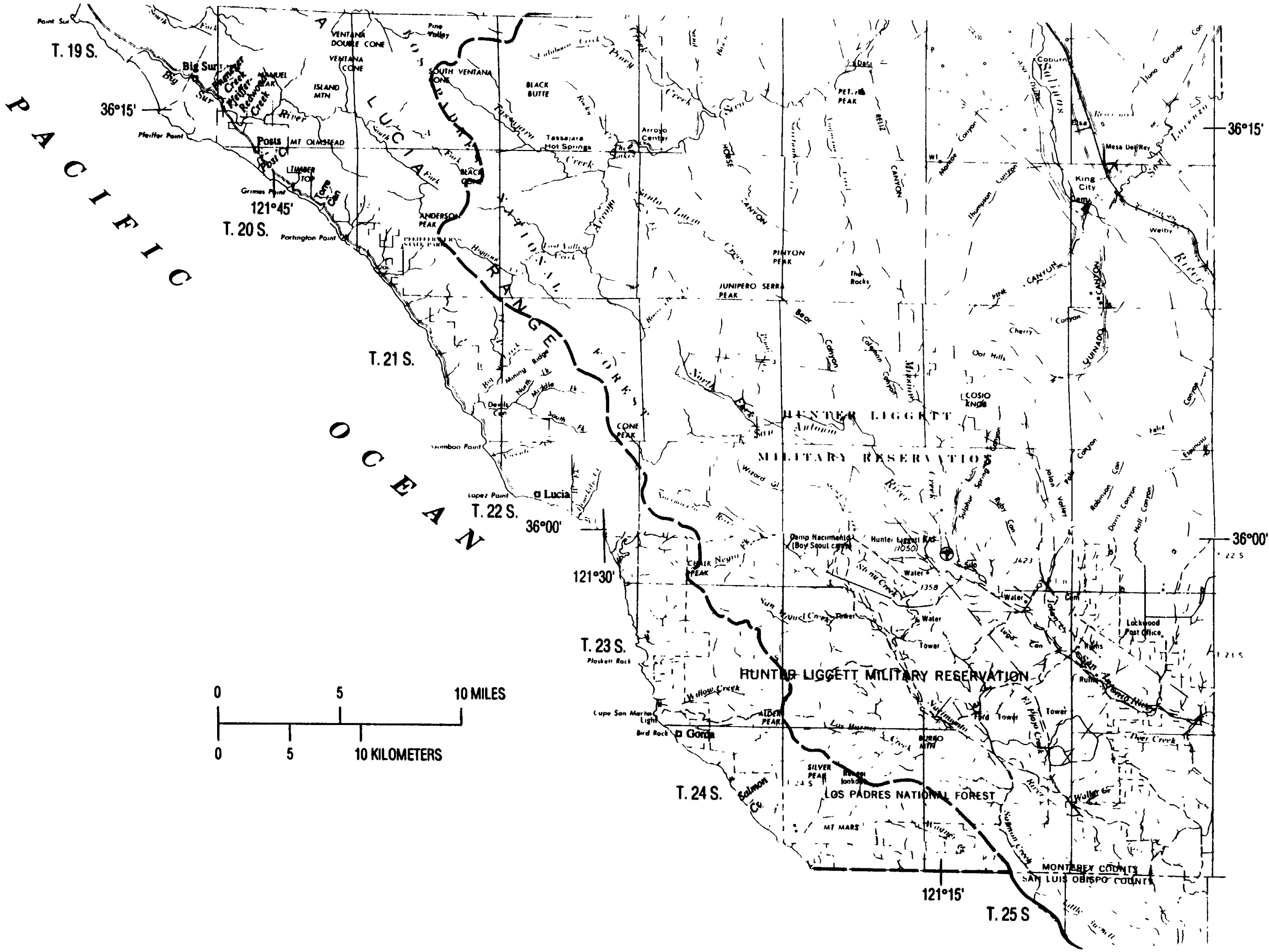


Figure 9. Ground-water observation wells in the northern and coastal areas of Monterey County, California.

The monthly ground-water-level network consists of key wells that are measured throughout the year to determine variations in ground-water levels. Changes in water levels in each aquifer are averaged, graphed, and compared with previous years to define the magnitude and timing of seasonal water-level highs and lows (Monterey County Flood Control and Water Conservation District, 1978). Static water-level measurements for every well every month are not always possible because of the heavy use of wells for irrigation for long durations. Missing measurements, therefore, are estimated from known well characteristics (depths and perforation intervals) and from measurements of nearby wells. Wells in the monthly network are shown in figure 9 and can be identified using table 8 and the well-numbering system diagram.

Wells in the summer network (table 8, fig. 9) are measured annually to determine the location and extent of ground-water troughs during peak irrigation periods. These troughs occur in the confined or semiconfined aquifers west of Salinas near the mouth of the Pajaro River. The troughs result from ground-water withdrawals in excess of recharge and/or from natural variations in aquifer characteristics that limit the responsiveness of the aquifers to variations in pressure head (Bruce LaClergue, Monterey County Flood Control and Water Conservation District, written commun., 1989, p. 10). "August troughs" develop when "water levels in wells fall below sea level and water flows both from the direction of the ocean and from inland to fill the trough" (Monterey County Flood Control and Water Conservation District, 1977, p. 3). The location and depth of the troughs indicate potential seawater intrusion. Troughs vary in position and depth from year to year because of changes in pumping and recharge conditions. Wells in the summer network are near the coast.

Ten wells in the Carmel Valley area with septic-tank leachate problems are monitored quarterly by the MCFCWCD, in cooperation with MPWMD, for water levels and quality. Twenty-seven wells in the same area are monitored monthly by the CAWC (table 8).

Possible Additional Monitoring

The distribution of ground-water-level monitoring wells in the active network is dense in the seawater-intruded areas north of Moss Landing probably because of multiple, overlying aquifers (fig. 9). Distribution of wells is sparse in the rest of the study areas. To provide an even spatial distribution of wells in this area, additional wells would need to be added, except where local conditions or well correlations make monitoring unnecessary. During this study, 44 sections were identified where no ground-water-level monitoring had been done by the MCFCWCD at the time of this study (table 9).

If available data for the study areas are sufficient to allow correlations between active and inactive wells in the ground-water-level monitoring network, additional wells would not be needed to meet the objectives of the ground-water-storage network. However, some key wells would be needed to define temporal variations in water levels for these areas; the key wells would be selected from wells that have good correlations with inactive wells in the network. Periodically, correlations between the wells would need to be rechecked to retain confidence in the adequacy of data from the network. In addition, timing of water-level variations needs to be understood in the various aquifers within the study areas to ensure that individual measurements represent seasonal water-level highs or lows. Continuous water-level recorders are needed to establish and maintain the seasonal water-level timing in each aquifer, so that any periodic water levels measured can be used to reliably represent points where they should be on the hydrograph of each well.

The MCFCWCD had monitored eight wells in the Marina area, but monitoring was discontinued because the shallow, private wells were not representative of the aquifers. The Salinas Valley P-180 and 400 aquifers were the primary sources of ground water for the Marina area, but these aquifers have since been intruded by seawater and are no longer used by the Marina County Water District. Currently, three wells are monitored by the Marina County Water District. The wells are perforated at depths of about 900 to 1,800 feet below land surface.

Table 9. Sections in the northern and coastal areas of Monterey County, California, where ground-water levels had not been monitored by the Monterey County Flood Control and Water Conservation District at the time of this study

Township/ Range	Section
T12S/R2E	9,13,17,21,22,23,24,26,27,28,34,35
T12S/R3E	14,15,17,20,22,23,24,25,26,27,28,32,34,35,36
T13S/R2E	7,8,9,11,15 22,23,24
T13S/R3E	1,2,3,5,6,7,18,27,28

In the Seaside, Laguna Seca, and Canyon Del Rey areas, the distribution of wells is concentrated in T. 15 S., R. 1 E., secs. 22 and 23. An expanded network of wells was proposed by Muir (1982, p. 34) that would improve the spatial distribution of the ground-water-level monitoring network in that area. However, even with the expanded network suggested by Muir (1982), additional wells would be needed in sections that are not monitored. For the regional ambient conditions network (C1a, table 3), fewer wells probably would be needed in sections where wells are not densely distributed provided that the key wells are representative of a wider area.

In the Carmel Valley, well distribution is dense in some areas and nonexistent in others. Because the Carmel Valley is narrow, it is difficult to see the distribution of the wells plotted in figure 9. However, enough detail is shown to see that, in the densely monitored areas, wells probably could be limited to one or two per section for each of the three major aquifers identified by Kapple and others (1984, pl. 1). In areas where existing wells have not been included in the monitoring network, some of the existing wells could be added to provide an even spatial distribution of wells (fig. 9). If there are no wells in those areas, new monitoring wells would need to be drilled.

In Monterey and the southern coastal areas, including Little Sur, Big Sur, Lucia, and Gorda, no wells were identified in networks operating at the time of this study. A canvass of existing wells would determine if the wells are used to supply water in those areas. The results of this well canvas then could be used to facilitate the selection of wells needed to augment the ground-water-storage network.

Data from the continuous-record gages of key wells could be used to develop hydrographs representative of various areas to ensure that measurements of key wells are timed appropriately to provide the highest priority data. Once a hydrograph has been developed that is representative of an area, measurement frequency may be reduced to semiannually or quarterly; however, the key wells would need to be checked periodically to reconfirm their representativeness. The highest priority water-level data are measurements of static levels midway between highs and lows; static levels usually occur in November (T.J. Durbin, U.S. Geological Survey, oral commun., 1984). These levels are used for ground-water modeling. Second priority water-level data include summer low and winter high water levels, which may occur between July and October and between March and May, respectively, depending on the predominant type of water use in an area. Third priority data are the midpoint in the declining hydrograph. Continuous-record gages would be needed on at least one well in each aquifer to indicate regional trends for determining when these measurements should be made.

Measurement of water levels in wells during peak water-use periods can present major problems. At the time of the measurements, the wells may be pumped or recently may have ceased being pumped, and thus accurate static water-level measurements would be difficult to obtain. It is important, therefore, for field personnel to note whether the measured water levels are from inactive, recently active, or currently pumped wells. Currently, water-level estimates for wells in the study areas are based on historical data and by comparison with nearby wells. A thorough study of each well in each network would be needed to determine if the water-level measurements of a well are representative of each aquifer or if a new monitoring well should be installed nearby.

A computerized data base is required for statistical and spatial analysis of well data in order to evaluate the need for continuation of each well in each network. Analysis of variance, cluster analysis, multivariate linear regression, and other statistical applications are readily available in software packages. In addition to this analysis, the location of each well in the computerized data base could be mechanically plotted to provide spatial analyses for each specific network objective within each basin or study area. This is too time consuming and costly to do routinely by hand. A cost-effective means of monitoring would be to coordinate visits to the wells to serve multiple purposes whenever possible.

Ground-Water-Quality Networks

Objectives

The generalized management objectives of the ground-water-quality networks are (1) to determine regional ambient water-quality conditions to establish spatial and temporal trends and (2) to identify ground-water use and potential sources of contamination to minimize contaminant buildup, reduce and eliminate sources of contamination, prevent additional contamination, and improve degraded water-quality conditions whenever possible (table 1).

The highest priority network goals are to determine (1) baseline data on ground-water quality, (2) the distribution of nitrates in probable problem areas, (3) the effects of ground-water quality on surface-water quality, and (4) the effects of geology and land use on ground-water quality in tributary areas of each ground-water basin (table 3). Following the examples of Showalter and others (1984) and Templin (1984), the information summarized in table 3 was used to develop an ideal-network coverage for the study areas. Suggestions for improving existing network coverage in Monterey County are based on this ideal-network design.

Description

The ground-water-quality monitoring program of the MCFCWCD consists of a network of wells that are sampled monthly between May and September and a network of wells that are sampled annually during the summer (table 10, at back of report). In the Pajaro-Springfield area, seawater intrusion poses an immediate and serious threat to ground-water use. Therefore, water samples are collected and analyzed once each month during the irrigation season to provide information on short-term trends in ground-water quality in this area.

For the summer network, the MCFCWCD collects water samples from operating wells once each year (during the summer); the samples then are analyzed for chlorides, specific conductance, and nitrates. Additional water samples are collected from some of these wells each summer for complete mineral analyses so that a complete analysis is done for each well once every 5 years. Data from this network are used to provide information on historical long-term trends in ground-water quality as indicated by concentrations of chlorides, nitrates, and other water-quality constituents. The MCFCWCD relies on the DWR classification system to determine the limitations of ground-water quality for agricultural purposes. This system is based on the range of values for dissolved solids, chloride, percent sodium, and boron-concentration (Monterey County Flood Control and Water Conservation District, 1978).

In a report by the Monterey County Flood Control and Water Conservation District (1978), ground-water quality is represented in graphs showing mean annual changes in specific conductance for each well in each aquifer or ground-water basin. The graphical approach used by Monterey County Flood Control and Water Conservation District (1978, p. 20) has some limitations. For example, at some wells, water quality is reported as average specific conductance; however, this may not reflect actual trends. As saltwater intrudes inland in this area, specific conductance in wells increases at higher than normal rates until the wells become unusable. Sampling of these wells then is discontinued. Because these abandoned, salty wells are no longer included in the data analyzed, water quality may seem to improve. This apparent improvement, however, merely reflects the exclusion of wells with high specific conductance (even if the wells are excluded from all years compared) and thereby lowers the average specific conductance for this area.

Averages of water-quality constituents only cannot be relied on to indicate water quality for an area. The range of values of water-quality constituents and the history of wells removed from the networks also would need to be included in the data analyzed in order to obtain adequate knowledge on the regional quality of ground water for a specific constituent. Data published prior to the Monterey County Flood Control and Water Conservation District's (1978) report used electrical conductivity to indicate dissolved solids. The relation between electrical conductivity and dissolved solids varies with time and space, depending on their local relation. Determination of electrical conductivity also varies with water temperature at the time of measurement. For this reason, the USGS measures specific conductance (electrical conductivity adjusted to 25°C) to obtain a more standard indicator of water quality. Until 1978, these factors had not been addressed in the annual data reports by the MCFCWCD; therefore, pre-1978 historical data on electrical conductivity data may not be comparable to post-1978 data on specific conductance. Use of the proper instruments and methodology, therefore, is extremely important in obtaining and analyzing water-quality samples. The District staff are aware of the importance of proper use of instruments and analytical procedures and are working to improve all aspects of their operations.

Possible Additional Monitoring

In addition to the monitoring done by the MCFCWCD, ground-water-quality data are collected by the MPWMD, CAWC, U.S. Army Health Service at Fort Ord, and other suppliers of drinking water. Sampling for water quality is required by the Safe Drinking Water Act (U.S. Environmental Protection

Agency, 1986); surveillance is done by the California Department of Health Services. Some monitoring networks in the study areas may not have been identified in our inventory and therefore may not be included in the list of ground-water wells in this report (table 10). The compilation of data in this report provides an initial point from which to build an understanding of the full extent of the data collection being done in the study areas.

The distribution of wells in the active ground-water monitoring networks is dense in the seawater-intrusion areas north of Moss Landing. However, future studies will require a few additional wells and the expansion of constituent analyses in order to establish a baseline ground-water monitoring network for this area. The distribution of wells in the rest of the study areas is sparse. To provide baseline data for the remaining areas, wells would need to be added to provide an even spatial distribution, except where local conditions or well correlations make monitoring unnecessary. The MCFCWCD did not monitor ground-water quality in 54 sections of the study areas in 1989 (table 11).

If historical data on constituents of concern are available for the areas not monitored by the MCFCWCD, additional wells may not be needed to expand the baseline network. Because determination of temporal and spatial variations in ground-water quality is a monitoring objective, key wells in the remaining study areas that correlate with the areas not monitored by the MCFCWCD may not need to be sampled. However, these correlations periodically would need to be rechecked to retain confidence in the reliability of the network data. In addition to the temporal and spatial variation of ground-water quality, constituents to be monitored and frequency of sampling also would need to be considered in network design. An ideal network would call for monitoring a broad range of water-quality characteristics on a quarterly basis. The ideal network could serve as an ultimate goal but that may not be feasible immediately. If future studies indicate that less frequent sampling and fewer constituents provide adequate information for an ideal network, this goal then could be revised.

Table 11. Sections in the northern and coastal areas of Monterey County, California, where ground-water quality had not been monitored by the Monterey County Flood Control and Water Conservation District at the time of this study

Township/ Range	Section
T12S/R2E	9,13,14,15,19,20,21,22,23,24,26,27,28,33,34, 35
T12S/R3E	14,15,16,17,20,21,22,23,24,25,26,27,28,32, 34,35,36
T13S/R2E	7,8,9,10,11,12,14,22,23
T13S/R3E	1,2,3,7,8,9,15,18,21,22,28,29

In addition to historical data, land use, geology, contamination sources, ground-water levels, and ground-water quality also need to be considered when establishing an ideal ground-water-quality monitoring network. For a network monitoring ambient water-quality conditions, land use could affect ground-water quality. Unless ambient ground-water conditions uniformly affect all wells within an area of a specific land use, the wells showing effects of land use should be avoided in a baseline network. However, such wells would need to be included in a separate network for monitoring the effects of point and regional contamination sources (table 3).

Available data on geology, historical ground-water levels, and ground-water quality are important in identifying sources of naturally occurring minerals and trace elements. Direction of ground-water flow and aquifer materials also influence the distribution of specific constituents. Identifying locations of known and potential sources of contamination (fig. 3) is important when establishing a ground-water-quality monitoring network because such areas may affect ground-water-quality conditions. For example, a well that is influenced by a known contamination source other than a natural source probably should not be selected for monitoring changes in baseline conditions.

Well distribution in water-quality monitoring networks in some parts of the study areas is similar to the well distribution in the ground-water-level networks. Therefore, correlations of wells in both ground-water networks are needed so that adjustments in well distribution will result in an even spatial distribution and density. In the Marina area, additional wells would be needed to monitor changes in baseline conditions. In the Seaside, Laguna Seca, and Canyon Del Rey areas, fewer wells probably would be needed to monitor changes in baseline conditions in the densely monitored sections, but some wells would need to be added in sections where there currently are no wells. In the Carmel Valley, probably only one or two wells per section would be needed for each of the valleys' three aquifers; however, for networks that have sections with no wells, some wells would need to be added. In the southern coastal area where no wells are being monitored, a well canvass would need to be done to determine which of the existing wells could be used for monitoring changes in baseline conditions.

SUMMARY AND CONCLUSIONS

This report evaluates existing water-resources data-collection networks that monitor the quantity and quality of precipitation, surface water, and ground water in the northern and coastal areas of Monterey County, California. The report includes an inventory of data-collection networks and a review of the literature and available data on water resources in the study areas. Information for some parts of the study areas is far greater than for other parts, but most available information is not sufficient to meet network and management goals defined in the report. Ideal networks are described in this report as a first attempt to define a total water-resources information system.

During this study, 106 precipitation-quantity gages were identified, of which 84 were active. These gages are concentrated in the Monterey Peninsula and the northern part of the county. If the number of gages in these areas were reduced, coverage could still be adequate. However, additional gages in the Tularcitos Creek basin and in the coastal areas south of Carmel to the county boundary would improve coverage in those areas. No precipitation-quality networks were found in the study areas; however, if data collection were expanded to include monitoring precipitation quality, the monitoring could be expanded to include monitoring precipitation for acid rain and pesticides.

During this study, 20 historical streamflow-gaging stations were identified of which 11 were continuous-record stations. In 1985, only 7 of the 11 continuous-record stations were active. To meet the objectives of the streamflow networks as outlined in this report, the seven active stations would need to be continued, four stations would need to be reactivated, and six new stations would need to be added.

Nine active stations in the study areas are monitored for chemical water-quality constituents. In the lower Big Sur River basin, monthly water samples are taken at 16 stations and are analyzed for total coliform and fecal coliform bacteria. No routine chemical-water-quality sampling is done in the Big Sur River basin.

Three ground-water-level networks were maintained by the MCFCWCD at the time of this study: (1) the summer network, (2) the monthly network, and (3) the annual autumn network. The CAWC monitored ground-water levels in 27 wells in the Carmel Valley. Well coverage was dense in the ground-water-level networks in some areas, but was sparse in other areas. During this study, 44 sections were identified in which no ground-water-level monitoring had been done by the MCFCWCD. In an ideal ground-water-level network, wells would be distributed so that they are evenly spaced, except where local conditions or correlations of wells make monitoring unnecessary. A total of 384 ground-water-level and ground-water-quality monitoring wells were identified during this study.

At the time of this study, the MCFCWCD sampled ground water monthly during the irrigation season to monitor seawater intrusion. Operating wells in the study areas were monitored for chlorides, specific conductance, and nitrates once each year during the summer. Additional water samples were collected from some of the wells each summer for complete mineral analysis so that a complete analysis could be done for each well once every 5 years. The MPWMD, CAWC, and the U.S. Army Health Service at Fort Ord also monitored water quality in the study areas. Well coverage in these ground-water-quality monitoring networks is similar to well coverage in the ground-water-level monitoring networks, that is, dense in the seawater-intrusion area north of Moss Landing, but sparse in the rest of the study areas. In an ideal ground-water-quality monitoring network, wells would be distributed so that they are spaced evenly, except where local conditions and well correlations make additional monitoring unnecessary. During the study, 54 sections were identified where water quality was not monitored by the MCFCWCD.

Six categories of hydrologic data were evaluated during this study. These include quantity and quality of precipitation, surface water, and ground water. A water-resource information system that would provide a regional data base for these categories would need to include baseline data on ambient water conditions. In addition, data could be collected to resolve specific existing or potential problems as needs arise. These data could be obtained from the monitoring networks established for each of the objectives identified for each hydrologic basin.

A computerized data base is required for statistical and spatial analyses of well data in order to evaluate the need for continuation of each well in each network. Analysis of variance, cluster analysis, multivariate linear regression, and other statistical applications are readily available in software packages. In addition to these analyses, the location of each well in the computerized data base could be mechanically plotted to provide spatial analysis for each specific network objective within each basin or study area. This is too time consuming and costly to do routinely by hand.

In conclusion, a water-resources data network evaluation requires that data are organized properly, contain adequate information on the specific sites, and are maintained routinely. Existing water-resources networks will need to be reevaluated when the above criteria are met.

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TABLES

Table 1. Generalized management and network objectives for water-resources networks

I. Generalized management objectives

A. Precipitation networks

1. Determine regional variations to establish spatial and temporal trends (such as daily, monthly, and annual totals).
2. Identify factors that may influence quantity or quality:
   a. Determine the effects of natural and human-influenced point and regional factors that may affect precipitation characteristics, such as lakes, reservoirs, oceans, estuaries, wetlands; regionally irrigated areas; multiple-story buildings; and industrial emissions.
   b. Determine conditions that may affect measurement values, such as standard methods of gaging-station installation (gage types, distance above ground and away from structures, and sampling and analytical practices).

B. Streamflow networks

1. Determine benchmark flow characteristics, such as peaks, mean daily flow, and low flow for all rivers and streams.
2. Identify temporal and spatial trends.
3. Identify causes of quantity changes, such as annual and seasonal precipitation variation, land-use changes, instream uses, diversions, agricultural return, channel stabilization, or channelization.
4. Determine best management options among the various water uses, such as instream water use for fish habitat, recreation, ground-water recharge, or diversions for agricultural, industrial, or municipal and domestic uses.

C. Surface-water-quality networks

1. Determine ambient concentrations of all water-quality constituents.
2. Determine spatial and temporal trends.
3. Identify sources of contaminants:
   a. Native (soils and geologic parent materials).
   b. Point sources (industrial, municipal and domestic, solid-waste disposal sites, and agriculturally related sites).
   c. Nonpoint sources, including but not limited to applied agricultural chemicals (pesticides and herbicides from agricultural and forest land-use and land-cover categories); cumulative effects of septic systems, mines, urban runoff, underground storage tanks, and rainfall ground-water discharge from water sources of lower quality than streams.
4. Develop a management plan to control water quality of streams.

D. Ground-water-level networks

1. Determine regional water-level conditions to establish spatial and temporal trends.
2. Identify sources of pumpage and recharge.
3. Determine storage capacities and best management practices to prevent overdraft and saltwater intrusion.

E. Ground-water-quality networks

1. Determine regional ambient water-quality conditions to establish spatial and temporal trends.
2. Identify sources of ground-water use and potential contamination to minimize contaminant buildup, reduce and eliminate sources of contamination, prevent additional contamination, and improve degraded water conditions whenever possible.

II. Generalized network objectives for all networks

A. Ideal-network objectives (Pederson and others, 1978, p. 77).

1. Establish a data base for water quantity and quality to achieve management objectives.
2. Provide complete spatial and temporal coverage to satisfy all data needs of the Monterey County Flood Control and Water Conservation District at an adequate level of accuracy.

B. Actual-network objectives (Moss and others, 1982, p. 1).

1. Optimum distribution of monitoring sites to provide a minimum-cost network or an integrated information system that will attain a prespecified accuracy and reliability.
2. Maximum information within budgetary and time constraints.

Table 2. Major point-source dischargers in the northern and coastal areas of Monterey County, California

[Modified from information on industrial dischargers under National Pollution Discharge Elimination System permit provided by the California Regional Water Quality Control Board, Central Coastal Region, San Luis Obispo, California. --, unknown; do, ditto]

Location: Township, range, and section are given. Sites are ordered by township, range, and section in ascending order

Properties and constituents of concern:
Biochemical oxygen demand, 5-day test (BOD_5) analysis recommended by California Regional Water Quality Control Board for discharge permits, Dermer and others (1980) and Pye and others (1983, p. 181) suggest BOD_5 may not be appropriate for ground-water-quality monitoring
Chlorine, total available, free available and/or dosage; see "Industrial dischargers under National Pollution Discharge Elimination System permit"
Flow, quantity of water entering or leaving the site (volume in gallons, monthly summaries of mean and maximum daily flow)
pH, negative logarithm of the hydrogen ion (acid/base conditions)
Total chlorinated pesticides, measured by summing the individual concentrations of aldrin, BHC, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, lindane, and polychlorinated biphenyls
Toxicity concentration, as described in written and oral communications with California State Water Resources Control Board and California Department of Fish and Game (1975)

Discharger	Location	Type of waste	Disposal method	Properties and constituents of concern
Industrial dischargers under National Pollution Discharge Elimination System permit				
Kaiser Refractories	13S/2E-18	Process water	Ocean outfall	*Effluent*: Flow, pH, temperature (degrees Fahrenheit), turbidity, biochemical oxygen demand, total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, cyanide, phenolic compounds, polychlorinated biphenyls, total chlorinated pesticides, oil and grease, toxicity concentration *Receiving water*: Light transmittance, pH, salinity, temperature (degrees Fahrenheit), turbidity, dissolved oxygen, coliform bacteria organisms *Bottom sediment*: Benthic (bottom dwelling) organisms, particle-size analysis
Pacific Gas and Electric Company, Moss Landing	13S/2E-18	Cooling water	do.	*Influent*: pH, temperature (degrees Fahrenheit), total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, cyanide, phenolic compounds, oil and grease *Effluent*: Flow, pH, temperature (degrees Fahrenheit), dissolved oxygen, chlorine, total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), arsenic, cadmium, chromium, copper, total iron, lead, mercury, nickel, silver, zinc, toxicity concentration, cyanide, phenolic compounds, polychlorinated biphenyls, oil and grease

Table 2. Major point-source dischargers in the northern and coastal areas of Monterey County, California--*Continued*

Discharger	Location	Type of waste	Disposal method	Properties and constituents of concern
Other potential industrial dischargers				
Airports:				
Elkhorn (Boesch)	13S/2E-13	Solvents	Land disposal	Trichloroethane and other similar solvents and unknown contaminants
Fritzsche Field (Fort Ord Army Air Field)..........	14S/2E-29	Airplane maintenance and burn pit	do.	Do.
Monterey	15S/1E-33,34	Solvents	do.	Do.
Carmel Valley	17S/2E-3	do.	do.	Do.
Municipal and domestic dischargers: Sewage treatment plants under National Pollution Discharge Elimination System permit				
Oak Hills	13S/2E-23	Sewage	Evaporation/ percolation ponds and land-surface disposal	*Influent*: Flow, sodium, chlorine, dissolved solids *Pond*: Sodium, chlorine, dissolved solids, nitrate, nitrogen (also may be used to indicate ammonia), ammonia *Ground water*: Ground-water levels, chlorine, dissolved solids, nitrogen (also may be used to indicate ammonia), nitrate, ammonia *Effluent*: Coliform bacteria organisms
Monte del Lago Mobile Home Park	13S/2E-35	do.	Evaporation/ percolation ponds	*Effluent*: Flow, coliform bacteria organisms, sodium, chlorine, total solids (dissolved, suspended, settleable)
Cabana Holiday Mobile Home Park	13S/3E-18,19	do.	do.	Do.
Marina	14S/1E-25	do.	do.	*Influent*: Biochemical oxygen demand, dissolved solids *Effluent*: pH, temperature (degrees Fahrenheit), turbidity, biochemical oxygen demand, chlorine, total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, cyanide, phenolic compounds, oil and grease, toxicity concentration, polychlorinated biphenyls, total chlorinated pesticides *Receiving water*: Shore coliform bacteria organisms *Bottom sediment*: Chemical oxygen demand, biochemical oxygen demand, sulfides, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, total organic carbon, phenolic compounds, particle-size analysis

Table 2. Major point-source dischargers in the northern and coastal areas of Monterey County, California--*Continued*

Discharger	Location	Type of waste	Disposal method	Properties and constituents of concern
Municipal and domestic dischargers: Sewage treatment plants under National Pollution Discharge Elimination System permit--*Continued*				
Seaside	15S/1E-27	Sewage	Monterey Bay	*Bottom sediment*: Chemical oxygen demand, biochemical oxygen demand, sulfides, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, total organic carbon, phenolic compounds, particle-size analysis
Monterey Wastewater Treatment Plant	15S/1E-29	do.	Monterey Bay	Do.
Laguna Seca Recreation Area, Road Race, Agte, Ranch Estates	15S/2E-32	do.	Septic systems	Flow, sludge depths, total sludge volume, total usable storage, percent full, depth of effluent in drainfields
Carmel Sanitation District	16S/1W-12	do.	Ocean outfall	*Influent*: Flow, biochemical oxygen demand, suspended solids *Effluent*: pH, temperature (degrees Fahrenheit), turbidity, biochemical oxygen demand, coliform bacteria organisms, chlorine, total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), total nitrogen (Kjeldahl, nitrite, and nitrate), arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, cyanide, phenolic compounds, oil and grease, toxicity concentration, polychlorinated biphenyls, total chlorinated pesticides *Quantity of sludge in drying beds*: moisture content (of sludge in drying beds), pH, total nitrogen (Kjeldahl, nitrite, and nitrate), total phosphorus, boron, cadmium, copper, chromium, lead, nickel, mercury, zinc, oil and grease *Receiving water*: Shoreline coliform bacteria organisms, water-column coliform bacteria organisms, ammonia, bioaccumulation and bioeffects[1] *Reclaimed water*: Flow, pH, turbidity, biochemical oxygen demand, coliform bacteria organisms, total solids (dissolved, suspended, settleable), cadmium, chromium
Highlands Inn	16S/1W-26	do.	do.	*Influent*: Biochemical oxygen demand, dissolved solids *Effluent*: Flow, pH, turbidity, biochemical oxygen demand, total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, cyanide, phenolic compounds, oil and grease, toxicity concentration *Receiving water*: Site observation for condition of outfall lines discoloration, floating substances, odor, and aquatic life

See footnote at end of table.

Table 2. Major point-source dischargers in the northern and coastal areas of Monterey County, California--*Continued*

Discharger	Location	Type of waste	Disposal method	Properties and constituents of concern
Municipal and domestic dischargers: Sewage treatment plants under National Pollution Discharge Elimination System permit--*Continued*				
Carmel Highlands	16S/1W-35	Sewage	Ocean outfall	--
Carmel Valley Community Service District, Village Green and White Oaks, Carmel Valley Village	17S/2E-3,11	do.	Septic systems	*Effluent*: Flow, dissolved solids; septic-systems sludge depth and volume, usable storage volume *Effluent*: Depth in drainfields *Ground water*: Four wells for ground-water levels, coliform bacteria organisms, dissolved solids, nitrate, ammonia
Carmel Valley Ranch	17S/2E-3	do.	Evaporation/ percolation ponds	*Ground water*: Six shallow wells for ground-water levels, specific conductance, chlorine, nitrate, ammonia *Lake*: Specific conductance, chlorine, dissolved solids, nitrate, ammonia
Granite Canyon Marine Laboratory	17S/1W-24	Sewage and operation wastes	Ocean outfall, evaporation/ percolation ponds	*Effluent*: Flow, observation of floating matter, discoloration, and condition of aquatic organisms
U.S. Navy, Point Sur	19S/1E-6	Sewage	Land disposal	*Influent*: Biochemical oxygen demand, suspended solids *Effluent*: Flow, pH, turbidity, biochemical oxygen demand, chlorine, total solids (dissolved, suspended, settleable), nitrogen (also may be used to indicate ammonia), arsenic, cadmium, chromium, copper, mercury, nickel, silver, zinc, cyanide, phenolic compounds, oil and grease, total chlorinated pesticides, toxicity concentration
Pfeiffer Big Sur State Park	19S/2E-30	do.	do.	Do.
Escalen Institute	21S/3E-4,9	do.	Septic system	*Effluent*: Flow, total solids (dissolved, suspended, settleable), oil and grease *Receiving water*: Observation of discoloration, floating substances, and odor

Table 2. Major point-source dischargers in the northern and coastal areas of Monterey County, California--*Continued*

Discharger	Location	Type of waste	Disposal method	Properties and constituents of concern
Municipal and domestic dischargers: Other potential sewage treatment facilities				
U.S. Army, Fort Ord	15S/2E-1 (?)	Sewage and other wastes	Unknown	Unknown
Municipal and domestic dischargers: Solid-waste disposal sites				
Crazy Horse	13S/3E-15	Solid wastes	Landfill	*Ground water*: Two wells in Aromas Formation: ground-water levels, specific conductance, pH, bicarbonate, chlorine, nitrogen (also may be used to indicate ammonia). Six leachate monitoring wells: ground-water levels, flow, specific conductance, pH, chemical oxygen demand, chlorine, total Kjeldahl nitrogen
U.S. Army, Fort Ord	15S/2E-5,6	Solid and demolition wastes	Landfill	Do.
Agricultural point sources				
Moon Glow Dairy	13S/2E-8,17	Dairy effluent	Land disposal	Potassium, sulfate, nitrate, ammonia, phosphate

[1]Mussels (50) are placed on stations and left from spring to autumn and then analyzed for trace elements, higher molecular weight, synthetic organics, and growth (as an indicator of physiological stress).

Table 3. Objectives, priorities, data needs, and pertinent data for water-resources data networks in the

[Priority points were developed for Monterey County Flood Control and Water Conservation District (Showalter and Hoffard,

Proposed monitoring components:

A, physical and indicator characteristics, such as temperature, pH, specific conductance, odor
B, common chemical analyses
Bio., biological (phytoplankton, zooplankton, algal growth potential, microplankton, fish tissue, muscle, and other biological indicator analyses)
BOD_5, Biochemical oxygen demand, 5-day test
CD, climate data, such as rain, air temperature, solar radiation, evaporation, evapotranspiration, relative humidity, wind movement

Proposed frequency:

A, annual
B, bimonthly
C, continuous
CS, continuous seasonally as needed
D, daily
M, monthly
Q, quarterly
T, twice annually
W, weekly

Network name	Specific network objectives	Priority points	Data needs
		Precipitation-quantity networks	
A1a	Ground-water recharge (regional ambient conditions)	10	Areal daily storm precipitation (U.S. Army Corps of Engineers, 1957) and other climate data
A1b	Water-supply estimates (for agricultural, domestic, and industrial uses)	9	do.
A1c	Flood warning	8	15- to 30-minute interval storm precipitation data
A1d	Specific site data for runoff determinations used in erosion control and design of culverts, levees, bridges, storm drains, flood channels, and dams; water-rights management; rainfall duration for use in National Forest Fire Danger Rating Components	7	do.
		Precipitation-quality networks	
A2a	Effects on surface- and ground-water quality (regional ambient conditions)	2	Daily wet and dry deposition volume and quality, and climate data
A2b	Effects on vegetation and personal property	1	do.

northern and coastal areas of Monterey County, California

1986, tables 4 and 13). ft, foot; do., ditto]

EI, environmental isotopes, such as H_2, H_3 (tritium), oxygen-18, and carbon-14
F, sanitary (total-coliform and fecal-coliform bacteria viruses)
FT, total flow, in gallons per day
G, all of the above quality constituents including trace elements, pesticides, and nutrients
SD, continuous stage-discharge record, with periodic flow measurements to establish and maintain the relation

Ideal network			
Site distribution	Site density	Proposed monitoring component	Proposed frequency
Precipitation-quantity networks--*Continued*			
Countywide	One or two per township	CD	C
do.	do.	CD	C
do.	do.	CD	C
do.	Three per township	CD	C
Precipitation-quality networks--*Continued*			
Countywide	One per township	pH and pesticides CD	D during storms C
do.	do.	pH and pesticides CD	D during storms C

Table 3. Objectives, priorities, data needs, and pertinent data for water-resources data networks in the

Network name	Specific network objectives	Priority points	Data needs
		Streamflow networks	
Bla	Ground-water recharge (regional ambient conditions)	10	Long-term areal integrated information system of continuous record and regional correlations with precipitation (Fontaine and others, 1983, p. 1)
B1b	Water-use quantity	9	Water withdrawals, deliveries, releases, returns, and consumptive use
B1c	Flood warning	8	Telemetered stage recorders at key lake and stream locations
Bld	Water rights	7	Continuous record upstream and downstream from all diversions (daily means, maximums, and minimum flow)
B1e	Site data for design of storm drains, dams, levees, flood channels, bridges, and culverts	7	Periodically revised rainfall-runoff relations following significant land-use changes or cumulatively significant changes, including flood-plain elevations developed from network B1a (recharge)
B1f	Determine sediment-transport downstream from dams	6	Periodic nonstorm, during and after storm sediment samples to estimate rates of reservoir siltation and effects of levee construction, recent urban growth areas, and agriculturally fire disturbed areas
B1g	Manage irrigation diversions and recharge	6	Data generated in network B1d and continuous records of all agricultural return flow and diversions
B1h	Potential hydropower plants	5	Site-selection information and begin continuous record at sites
B1i	Instream-use management and planning	4	Data from network B1d
B1j	Determine streamflow characteristics to develop regional relations to ungaged sites	3	25-year recurrence interval flood, drainage areas, mean annual precipitation (Riggs, 1973, p. 4)
B1k	Determine sediment-transport rates upstream from dams	2	Network B1f data, supplemented with similar data upstream from dams
B1l	Manage municipal and industrial uses	1	Data from network B1d, and continuous records of all agricultural return flows and diversions

Ideal network			
Site distribution	Site density	Proposed monitoring component	Proposed frequency
Streamflow networks--*Continued*			
Major tributaries	At first point of recharge, one per stream, and at major confluences	SD, peak flow	C at 30-minute intervals
All streams	Upstream and downstream from each point of inflow and outflow	SD	C at 30-minute intervals
All streams	Upstream and downstream from each point of inflow and outflow	SD	C at 30-minute intervals
One station at each location of change in stream characteristics	do.	SD	C at 30-minute intervals
Countywide	do.	Precipitation volume, in inches (Network A1d), and flow at sites (streams and bridges)	C
Upstream and downstream from dams	do.	Total sediment discharge SD, water temperature Trace elements Bed and bank samples for size analysis, composition and sources	D C M Q
Upstream and downstream from all diversions	Two per diversion	SD	CS
Site specific Pescadero and San Clemente Creeks	One per site	SD Water temperature Total sediment discharge Low flow	CS C D CS
Pajaro, Carmel, Big Sur, Little Sur Rivers	As needed		C D
All major drainages	do.	SD Precipitation volume, in inches	C D
Upstream from Los Padres, San Clemente Dams	One per dam	SD	D
Upstream and downstream from all diversions	Two per diversion	SD	C

Table 3. Objectives, priorities, data needs, and pertinent data for water-resources data networks in the

Network name	Specific network objectives	Priority points	Data needs
		Surface-water-quality networks	
B2a	Monitor water quality for domestic and irrigation uses	10	Routine, periodic complete analyses
B2b	Assess reservoir discharges for irrigation, domestic, and fish and wildlife uses	10	Routine, periodic sampling (during discharge periods) and determination of lake trophic levels (outside study area)
B2c	Develop a water-quality baseline (regional ambient conditions)	9	Stream-reach rating system to prioritize data collection based on specific needs. Complete analyses in relation to needs, with correlation to continuously measured indices, such as temperature and specific conductance
B2d	Determine flow and quality from specific creeks	8	Baseline data for specific creeks currently being developed or with the potential for significant future development
B2e	Determine trends for reservoir water quality	6	Water-quality monitoring, especially for effects of land uses (such as residential, timber harvest, forest fire, and mining) and natural geologic influences
B2f	Evaluate water-quality effects on instream uses (fish, recreation)	5	Stage/discharge data from network Bla and water-quality data to compare existing conditions to standards established for each type of water use (similar to Templin and others, 1986)
B2g	Mosquito abatement	4	Data pertinent to growth and reproduction of mosquitos and other pest insects, also possibly data on chemical abatement methods used
		Ground-water-level networks	
C1a	Determine each basin's water balance and seawater intrusion portion of inflow (regional ambient conditions)	10	Precipitation data from network A1d, streamflow data from network B1a, collect pumpage and water-level trend data (inflow, outflow, and storage)
C1b	Determine effect of reservoir discharges on ground-water storage	9	Streamflow data from network B1a, diversions data from B1d, information on hydraulically connected areas from network B2c, water-level and pumpage data from network C1a

Ideal network			
Site distribution	Site density	Proposed monitoring component	Proposed frequency
Surface-water-quality networks--*Continued*			
At all withdrawal locations	One per location	A B, trace elements Pesticides, nutrients F	C M B W
Carmel River downstream from Los Padres Reservoir	Two sites downstream from dam 1-30 ft 1-500 ft	EI, dissolved oxygen, water temperature, Quality:A,B	T
Prunedale Creek, Big Sur, Carmel, Little Sur, Parajaro Rivers	In reaches of known hydraulic connection with ground water	Quality:A,B, water temperature, specific conductance	Q C
Los Carneros, Pfeiffer-Redwood, Pheneger, Post, Tularcitos Creeks; Little Sur, Big Sur Rivers	Upstream from confluence with major tributary	SD Quality:A,B,	C Q
Los Padres, San Clemente Reservoirs	Three sites on each lake	Quality:A,B; bio.	M
Big Sur, Carmel, Little Sur, Pajaro Rivers	Sites near mouths, and downstream from all major diversions	SD, water temperature Quality:A,B Trace elements, pesticides	C M Q
Lakes, streams, wetlands, stock ponds, industrial holding ponds, street drains	As needed	Quality:A, specific gravity, turbidity, Biochemical oxygen demand, 5-day test, nutrients, bio. Mosquito larvae and adults	M W
Ground-water-level networks--*Continued*			
Subarea and countywide grid	One per subarea; as needed	Water levels Pumpage (from meters) and electrical usage	C,T C
Carmel Valley	As needed	Water levels Pumpage SD	C,T C M

Table 3. Objectives, priorities, data needs, and pertinent data for water-resources data networks in the

Net-work name	Specific network objectives	Prior-ity points	Data needs
	Ground-water-level networks--*Continued*		
C1c	Determine ground-water storage in each basin	9	Water-level and pumpage data from network Cla, perform pump and aquifer tests where not already available, interpret the data (Freeze and Cherry, 1979, p. 343; Todd, 1980, p. 45 and 362). Geologic information on location of freshwater-bearing deposits, and formation characteristics
C1d1	Determine accuracy of annual water-level measurements in monitoring changes in storage	7	Evaluation of existing water-level network and resultant data for its representativeness of regional conditions. Use of variables similar to what has been done by Sophocleous and others (1982) may be applicable to this analysis to determine the adequacy of current well densities for this purpose. A correlation analysis of the recharge/flow data from network B1j and the storage data from network C1c needs to be accomplished and an inflow/outflow/storage relation developed (Todd, 1980, p. 361-363). Use of available, or adaptable, management models (Bachmat and others, 1980, p. 39-40) could facilitate the effective use of available natural and financial resources
C1d2	Determine accuracy of monthly water-level measurements in monitoring changes in storage owing to seasonal pumping demands	6	Evaluation of existing water-level network and resultant data for its representativeness of regional conditions. Use of variables similar to what has been done by Sophocleous and others (1982) may be applicable to this analysis to determine the adequacy of current well densities for this purpose. A correlation analysis of the recharge flow data from network B1j and the storage data from network C1c needs to be accomplished and an inflow/outflow/storage relation developed (Todd, 1980, p. 361-363). Use of available or adaptable management models (Bachmat and others, 1980, p. 39-40) could facilitate the effective use of available natural and financial resources
C1e	Determine monthly ground-water pumpage	7	Pacific Gas and Electric records and pumpage (Mitten, 1976). Also collect pumpage from metered wells needed for networks C1a and C1c. Compare with California Department of Water Resources (1983a, p. 97-99); estimates are based on land use.

northern and coastal areas of Monterey County, California--*Continued*

Ideal network			
Site distribution	Site density	Proposed monitoring component	Proposed frequency
Ground-water level networks--*Continued*			
Grid ground-water basins	Density as needed to draw adequate contours	Water levels	C,M,T as needed
Carmel and Parjaro Valleys, northern Monterey County	Existing water-level monitoring sites	Water levels, geologic formation characteristics	C,M
do.	Existing water-level monitoring sites	Water levels, geologic formation characteristics	C,M
Carmel and Pajaro Valleys	All wells in basin	Metered pumpage and Pacific Gas and Electric Company records	M,A

Table 3. Objectives, priorities, data needs, and pertinent data for water-resources data networks in the

Network name	Specific network objectives	Priority points	Data needs
	Ground-water-level networks--*Continued*		
C1f	Determine annual consumptive use of applied water, phreatophytes, and precipitation in agriculture and urban areas	7	Land-use map (fig. 2) and determine areas of each land use, determine unit values of consumptive water use for each land use (Todd 1980, p. 361-362, California Department of Water Resouces (1975, p. 5; 1982b; 1983a; 1983b; 1984); Dunne and Leopard (1978, p. 95-162).
C1g	Monitor ground-water flow patterns	4	Topography, piezometric patterns, hydrochemical trends, environmental isotopes in the area, and soil land surface features (Freeze and Cherry 1979, p. 200-203).
C1h	Determine ground-water outflow from streams and creeks	4	Using information developed in B1a, C1c, C1g, and C2c, and determine baseflow, and use hydrograph separation to differentiate subsurface contributions
C1i	Determine location where river percolation could be enhanced to increase ground-water storage	4	Using information from C1g and C1h, determine areas of recharge, storage, and discharge. Study the effects of increased artificial recharge in stream channels on storage and discharge down gradient. Use of a refined ground-water-flow model could be preferable to trial and error
C1j1	Determine aquifer characteristics	5	A literature search needs to be done to determine the level of available information on aquifer properties for each ground-water basin. Where gaps exist, pumping tests need to be made, and information used to determine hydraulic conductivity, storativity, and transmissivity (Todd, 1980, p. 78 and 124).
C1j2	Determine aquifer boundaries	4	Need geologic information on flow barriers (faults and impermeable strata)
C1k	Analyze influence of cones of depression for large and small wells in monitoring networks	2	Need to know the influence of each well in a water-level network on each other wells in the network; and if a well is influenced by another well, need to evaluate that well's use in the network

Ideal network			
Site distribution	Site density	Proposed monitoring component	Proposed frequency
Ground-water level networks--*Continued*			
Carmel and Pajaro Valleys	Climate data stations, one per area;	CD	C,D
	Meters, one per well, and one per customer supplied	FT	C,D
All ground-water basins	Wells as needed	Water levels	C
		PU	M
		Quality:A,B,EI	C
Big Sur, Carmel, Little Sur, Pajaro Rivers	As needed	SD, water levels, pumpage (from meters) and electrical usage	C
Carmel, Little Sur, Pajaro Rivers	do.	SD, water levels, pumpage (from meters) and electrical usage	C
All ground-water basins	do.	Storage coefficient (storativity), hydraulic conductivity, transmissivity	A
do.	As needed	Storage coefficient (storativity), hydraulic conductivity, transmissivity	A
All ground-water basins	As needed	Pump and aquifer tests, storage coefficient hydraulic conductivity, transmissivity	A

Table 3. Objectives, priorities, data needs, and pertinent data for water-resources data networks in the

Network name	Specific network objectives	Priority points	Data needs
		Ground-water-quality networks	
C2a	Determine water-quality baseline, including specific conductance	10	Establish regional networks of representative wells monitored annually for complete analyses
C2b	Determine distribution of nitrates in probable problem areas	9	Would be done in network C2a; currently done in network 6 (Carmel Valley, for Monterey Penninsula Water Management District by Monterey County Flood Control and Water Conservation District)
C2c1	Determine effects of ground-water quality on effluent streams	8	Would entail study of geochemistry of streams and adjacent ground water (network C1g) for determination of which are losing and gaining and a comparison with baseline surface-water quality from network B2c
C2c2	Determine the need for establishing a ground-water data base for tributary areas	8	Use data gathered in networks B2c, B2d, and C2a to compare areal quality in tributary areas to the downstream ground-water basins to understand the influence of geologic parent materials and land uses in tributary areas on major basin ground-water quality
C2d	Develop a baseline of organics in ground water	7	Need data on total organic carbon, volatile organic carbon for comparison with results from network and known point sources to determine the relation of point sources to the surrounding environment
C2e	Determine regional effects of point sources and cumulative effects of point sources	6	Collect data on the extent of point-source plumes and compare with data from C2a and C2d
C2f	Determine regional effects on nonpoint sources (such as agricultural and urban areas)	5	Study typical areas of land use to determine cause effect of land-use practices
C2g	Determine native and human-caused sources of radioactive substances	4	Regional analyses for indicators of broader categories of substances and more specific analyses where high values are noted

Ideal network			
Site distribution	Site density	Proposed monitoring component	Proposed frequency
	Ground-water-quality networks--*Continued*		
All ground-water basins	Grid basins	G	Q
Carmel Valley, northern Monterey County	Bound and grid septic tank areas	A, nutrients, F, water levels	M
All ground-water basins	Wells, as needed	Water levels, pumpage (from meters and electrical usage) Quality:A,B, EI	C M M
Selected wells in recharge areas at points where tributaries enter the ground-water basin	As needed	Quality:A,B, geology land use	Q
Bound and grid all ground-water basins	do.	Total organic carbon, volatile organic carbon, EI	A
In areas of concentration of point sources (table 1, fig. 2)	Upgradient and down-gradient, dense enough to identify plumes if they exist	As needed	As needed
Select major urban and agricultural areas (fig. 2)	do.	do.	do.
Grid basin, more dense in industrial and military areas	As needed	Gross: Alpha, Beta radium, (Safe Drinking Water Act regulations,U.S. Environmental Protection Agency, 1986)	T

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California

[Data from California Department of Water Resources (1981a) and National Oceanic and Atmospheric Administration (1985). Gage numbers are assigned by the California Department of Water Resources. Site numbers refer to locations in figure 5. --, no data; n/a, not applicable]

Operating agency:
2925, U.S. Soil Conservation Service
3922, U.S. National Weather Service
5002, U.S. Department of the Army
5003, U.S. Department of the Navy
5050, California Department of Water Resources
5115, Monterey County Flood Control and Water Conservation District
5702, Individual owner
5703, California American Water Company
5706, Pacific Gas and Electric Company

Gage type:
Active: Gages where data are still being collected.
Nonrecording: Gages that collect rain, but must be read by someone.
Telemetered: Gages where records are transmitted in real-time to a central receiving location by phone or satellite media.
Recording: Gages having mechanical automatic recording capabilities (for example, paper tapes, charts, or data logger computer equipment).
Climate data and partial climate data.
Inactive: Gages where data have been collected (and records exist) but currently are not data collection/measurement sites.

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
1	Anderson Peak 77[1]	0202-05	5115	20S/3E	36°11'07"/ 121°38'51"	1977-present	Active, telemetered
2	Aromas South	0270-00	5702	13S/3E	36°49'00"/ 121°39'00"	--	Inactive
3	Associated Oil 8	0354-11	5702	15S/3E	36°37'48"/ 121°41'00"	1923-31	Inactive
4	Associated Oil 8H	0354-12	5702	16S/2E	36°34'06"/ 121°46'54"	1923-31	Inactive
5	Big Sur State Park	0790-00	3922	19S/2E	36°15'00"/ 121°47'00"	1914-present	Active, recording
6	Bird Rock Hiller	0813-01	5003	15S/1W	36°36'00"/ 121°57'00"	1952-present	Active, nonrecording
7	Bixby Mountain	0831-01	5003	18S/1E	36°21'14"/ 121°50'18"	1952-present	Active, nonrecording
8	Carmel 8 SE	1532-00	5702	17S/1E	36°25'30"/ 121°48'00"	1914-present	Active, nonrecording
9	Carmel Baldwin Place	1532-01	5003	16S/1W	36°33'00"/ 121°54'30"	1958-present	Active, nonrecording

See footnote at end of table.

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
10	Carmel Donnelly	1532-02	5003	16S/1W	36°32'30"/ 121°55'30"	1958-present	Active, nonrecording
11	Carmel Flanders	1532-03	5003	16S/1W	36°33'00"/ 121°54'48"	1946-present	Active, nonrecording
12	Carmel Graves	1532-04	5003	16S/1W	36°34'00"/ 121°55'06"	1956-present	Active, nonrecording
13	Carmel Highlands 37	1532-10	5003	16S/1W	36°30'12"/ 121°55'42"	1958-present	Active, nonrecording
14	Carmel Highlands 42	1532-11	5003	16S/1W	36°29'48"/ 121°56'00"	1958-present	Active, nonrecording
15	Carmel Hills Bauer	1532-20	5003	16S/1W	36°33'42"/ 121°54'24"	1958-present	Active, nonrecording
16	Carmel Sanitary District	1532-40	5002	16S/1W	36°32'24"/ 121°55'06"	--	Inactive
17	Carmel UC	1533-00	5002	18S/4E	36°23'12"/ 121°33'00"	--	Inactive
18	Carmel Updike	1533-50	5003	16S/1W	36°33'20"/ 121°55'15"	1970-present	Active, nonrecording
19	Carmel Valley	1534-00	3922	17S/2E	36°29'00"/ 121°44'00"	1926-78	Inactive
20	Carmel Valley, Elsberry	1534-05	5003	16S/2E	36°29'39"/ 121°41'01"	1972-present	Active, nonrecording
21	Carmel Valley, Groscup	1534-30	5003	16S/1E	36°32'22"/ 121°47'52"	1975-present	Active, nonrecording
22	Carmel Valley, Jung	1534-44	5003	16S/1E	36°32'57"/ 121°54'00"	1963-present	Active, nonrecording
23	Carmel Valley, Martin	1534-02	5003	16S/1E	36°32'00"/ 121°51'00"	1926-present	Active, nonrecording
24	Carmel Valley, Mathews	1534-48	5003	17S/2E	36°28'58"/ 121°43'02"	1980	Inactive
25	Carmel Valley, McDermet	1534-50	5003	16S/2E	36°29'39"/ 121°43'57"	1976-present	Active, nonrecording
26	Carmel Valley, Montgomery	1534-55	5003	17S/2E	36°28'12"/ 121°42'07"	1977-present	Active, nonrecording

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range)	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
27	Carmel Valley, Robinson Canyon	1534-25	5115	16S/1E	36°32'00"/ 121°48'00"	1968-present	Active, recording
28	Carmel Valley, Wallace Jr.	1534-90	5003	16S/2E	36°30'01"/ 121°42'13"	1960-present	Active, nonrecording
29	Castroville Wastewater Treatment Plant	1586-25	5115	13S/2E	36°46'00"/ 121°46'00"	1968-present	Active, recording
29a	Castroville Wastewater Treatment Plant[3]	n/a	5050	13S/2E	([2])	1980-present	Active, climate data
30	Central Gage 33[1]	1630-50	5115	19S/2E	36°17'59"/ 121°42'51"	1977-present	Active, telemetered
31	Chews Ridge[1]	1707-50	5115	19S/4E	36°18'42"/ 121°34'03"	1977-present	Active, telemetered
32	Corralde Tierra Hendrichs	2047-00	5003	16S/3E	36°30'51"/ 121°41'05"	1961-present	Active, nonrecording
33	Cypress Point Club	2251-01	5003	15S/1W	36°34'54"/ 121°58'18"	1954-present	Active, nonrecording
34	David Avenue Reservoir	2291-00	5003	15S/1W	36°38'48"/ 121°55'00"	1958-present	Active, nonrecording
35	Del Monte	2362-00	3922	15S/1E	36°36'00"/ 121°52'00"	1911-present	Active, recording
36	Del Monte Fairways	2362-02	5003	15S/1E	36°34'48"/ 121°51'48"	1958-present	Active, nonrecording
37	Del Monte Lodge[4]	2362-01	5003	15S/1E	36°36'00"/ 121°52'00"	1958-present	Active, nonrecording
38	Forest Lake	3135-11	5003	15S/1W	36°35'30"/ 121°56'30"	1895-present	Active, nonrecording
39	Fort Ord	3186-00	3922	14S/2E	36°41'00"/ 121°46'00"	1967-78	Inactive
40	Freedom	3232-01	2925	11S/2E	36°55'54"/ 121°46'06"	1930-present	Active, nonrecording

See footnotes at end of table.

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location		Period of record (calendar year)	Gage type
				Township/ range	Latitude/ longitude		
41	Harlan Ranch	3764-00	5702	22S/4E	36°01'30"/ 121°32'42"	1940- present	Active, nonrecording
42	Harper Canyon	3778-80	5702	16S/2E	36°34'03"/ 121°42'00"	1969- present	Active, nonrecording
43	Hastings Natural History State Reserve	3812-50	5003	18S/4E	36°23'18"/ 121°32'57"	1976- present	Active, nonrecording
44	Jacks Peak	4324-01	5003	15S/1E	36°38'48"/ 121°53'00"	1958- present	Active, nonrecording
45	Kaiser Refractories Quarry	n/a	5115	14S/3E		1958- present	Active, nonrecording
46	Laureles Grade	4836-50	5115	16S/2E	36°33'00"/ 121°45'00"	1976	Inactive, nonrecording
47	Los Burros	5120-01	5702	24S/5E	35°52'00"/ 121°23'00"	1895-1909	Inactive, nonrecording
48	Los Laureles	--	5115	16S/2E	36°33'00"/ 121°43'00"	1968- present	Active, recording
49	Los Laureles Grade Leipper	5127-10	5003	15S/2E	36°37'32"/ 121°45'31"	1972- present	Active, nonrecording
50	Los Padres Dam[5]	5143-00	5003/ 5703	18S/3E	--	1948- present	Active, partial climate, recording
51	Lucia Willow Springs	5184-00	3922	24S/5W	35°53'00"/ 121°27'00"	1937-78	Inactive
52	Marina City Water District	5370-00	5003	14S/1E	36°46'55"/ 121°48'15"	1970	Inactive
53	Marina Thormeyer	5340-50	5003	14S/2E	36°40'45"/ 121°47'10"	1976-80	Inactive
54	Mining Ridge 22[1]	--	5115	21S/4E	--	1977- present	Active, telemetered
55	Monterey	5795-00	3922	15S/1W	36°36'00"/ 121°54'00"	1847- present	Active, nonrecording
56	Monterey AP	5796-00	3922	15S/1E	36°35'00"/ 121°53'00"	1973-79	Inactive

See footnotes at end of table.

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range)	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
57	Monterey Bay Packing	--	5115	13S/2E	--	1960-present	Active, nonrecording
58	Monterey, Bunten Jr.	5800-10	5003	15S/1W	36°35'49"/ 121°54'18"	1974-present	Active, nonrecording
59	Monterey, Haltiner	5796-01	5003	15S/1E	36°35'18"/ 121°53'30"	1959-present	Active, nonrecording
60	Monterey, Mackensie	5800-23	5003	15S/1E	36°34'44"/ 121°52'36"	1972-present	Active, nonrecording
61	Monterey, Marine Term	5797-01	5702	15S/1E	36°36'36"/ 121°51'48"	1926-59	Inactive
62	Monterey, McMasters	5798-25	5003	15S/1E	36°34'58/" 121°51'55"	1978-present	Active, nonrecording
63	Monterey, Mendenhall	5798-50	5003	15S/1E	36°34'55"/ 121°51'25"	1979-present	Active, nonrecording
64	Monterey, Nal	5799-00	3922	15S/1E	36°36'00"/ 121°52'00"	1967-72	Inactive
65	Monterey Naval Postgraduate School	5796-05	5003	15S/1W	36°36'36"/ 121°52'00"	1957-present	Active, nonrecording
66	Monterey, Pierce	5800-75	5003	15S/1W	36°35'12"/ 121°54'28"	1961-present	Active, nonrecording
67	Monterey Coast Guard	--	5003	15S/1W	--	1978-present	Active, nonrecording
68	Monterey, Randolph	5796-05	5003	15S/1E	36°36'36"/ 121°52'00"	1958-present	Active, nonrecording
69	Monterey, Renard	5796-06	5003	15S/1W	36°35'42"/ 121°54/48"	1958-present	Active, nonrecording
70	Monterey Sewage Plant	5796-07	5003	15S/1E	36°37'42"/ 121°52'00"	1952-present	Active, nonrecording
71	Monterey, Van Der Bijl	5800-97	5003	15S/1W	36°35'35"/ 121°54'57"	1962-present	Active, nonrecording
72	Moss Landing	5878-00	5706	13S/2E	36°49'00"/ 121°47'06"	1957-present	Active, nonrecording

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
73	Moss Landing Pacific Gas and Electric Powerplant	5878-50	5706	13S/2E	36°48'23"/ 121°46'57"	1980-present	Active, nonrecording
74	Mount Toro	5998-80	5115	16S/3E	36°33'00"/ 121°38'00"	1968-present	Active, recording
75	New Monterey 2S	6166-01	5003	16S/1W	36°34'42"/ 121°54'48"	1960-present	Active, nonrecording
76	Noche Buena	6210-01	5003	15S/1W	36°35'54"/ 121°54'48"	1960-present	Active, nonrecording
77	Pacific Grove, Allen	6587-01	5003	15S/1W	36°36'00"/ 121°55'48"	1958-present	Active, nonrecording
78	Pacific Grove, Brown	6587-02	5003	15S/1W	36°37'00"/ 121°55'48"	1958-present	Active, nonrecording
79	Pacific Grove 29	6587-03	5003	15S/1W	36°37'00"/ 121°55'42"	1958-present	Active, nonrecording
80	Pacific Grove Inn	6587-04	5003	15S/1W	36°38'00"/ 121°56'00"	1951-present	Active, nonrecording
81	Pacific Grove	6587-40	5003	15S/1W	36°37'52"/ 121°55'42"	1975-present	Active, nonrecording
82	Pebble Beach, Baker	6774-01	5003	16S/1W	36°34'36"/ 121°56'24"	1958-present	Active, nonrecording
83	Pebble Beach, Frey	6774-10	5003	15S/1W	36°35'12"/ 121°55'22"	1957-present	Active, nonrecording
84	Pebble Beach, Leonard	6774-30	5003	15S/1W	36°36'02"/ 121°57'25"	1978-present	Active, nonrecording
85	Pebble Beach, Paquette	6774-40	5003	15S/1W	36°35'08"/ 121°55'30"	1974-present	Active, nonrecording
86	Pebble Beach, Powell	6774-50	5003	16S/1W	36°34'35"/ 121°56'50"	1957-61	Inactive, nonrecording
87	Pico Blanco 11[1]	6856-27	5115	18S/1E	36°19'05"/ 121°48'36"	1977-present	Active, telemetered

See footnote at end of table.

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
88	Pico Blanco Boy Scout Camp	6856-00	5702	18S/2E	36°20'18"/ 121°47'42"	1957-present	Active, nonrecording
89	Ponciano Ridge 88[1]	7053-50	5115	18S/2E	36°23'58"/ 121°43'16"	1977-present	Active, telemetered
90	Prunedale	7156-20	5702	13S/3E	36°47'50"/ 121°39'15"	--	Inactive, nonrecording
91	Prunedale, Breton	7156-25	5003	13S/3E	36°48'19"/ 121°39'48"	1978-present	Active, nonrecording
92	Prunedale Echo Valley	7156-50	5115	13S/3E	36°50'00"/ 121°40'00"	1968	Inactive, recording
93	Point Lobos State Reserve	7019-50	5003	16S/1W	36°30'55"/ 121°56'15"	1963-present	Active, nonrecording
94	Rancho Rico	7249-21	5702	19S/2E	36°14'24"/ 121°47'24"	1941-present	Active, nonrecording
95	Robles Del Rio	7499-01	5003	16S/1W	36°34'30"/ 121°56'48"	1958-present	Active, nonrecording
96	Roosevelt Ranch	7539-01	5702	20S/2E	36°10'48"/ 121°41'48"	1946-present	Active, nonrecording
97	Salinas Golf and Country Club	7669-30	5115	14S/3E	36°45'00"/ 121°38'00"	1968-present	Active, recording
98	Salinas Haney	7669-40	5003	15S/2E	36°35'40"/ 121°42'20"	1972-present	Active, nonrecording
99	San Clemente Dam	7731-00	3922/ 5703	17S/2E	36°26'12"/ 121°42'30"	1922-present	Active, nonrecording
100	Sunset Beach State Park	8680-00	3922	12S/1E	36°54'00"/ 121°50'00"	1956-present	Active, recording
101	Toro Regional Park	8972-11	5115	15S/2E	--	1969-present	Active, nonrecording
102	Watsonville	9467-00	5050	12S/2E	36°55'00"/ 121°45'00"	1881-present	Active, nonrecording

See footnote at end of table.

Table 4. Precipitation gages in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Gage name	Gage No.	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record (calendar year)	Gage type
103	Watsonville Junction	9471-01	2925	12S/2E	36°54'36"/ 121°44'42"	1874-1950	Inactive
104	Watsonville SW	9471-05	2925	12S/1E	36°54'30"/ 121°50'36"	1935-42	Inactive
105	Watsonville Waterworks	9473-00	3922	11S/2E	36°56'00"/ 121°46'00"	1880-present	Active, nonrecording

[1]Part of flood-warning network of telemetered gages.
[2]Latitude/longitude is assumed to be the same as site 29.
[3]Part of the Crop Irrigation Management Information Service (CIMIS) network.
[4]Air temperature and evaporation pan data are collected at the Los Padres damsite by California American Water Company.
[5]At or near the same location as the Del Monte station. Available information was insufficient to distinguish the sites as being different or the same.

Table 5. Streamflow-gaging stations in the northern and coastal areas of Monterey County, California

[Site numbers refer to station locations in figure 6. Operating agency: 5000, U.S. Geological Survey; 5050, California Department of Water Resources; 5115, Monterey County Flood Control and Water Conservation District; 5703, California American Water Company; 7995, Monterey Peninsula Water Management District. Type of station: C, continuous record; L, low-flow measurement; P, peak-flow measurement; Period of record is in calendar years; "present" is as of 1985]

Site No.	Station name	Station no.	Operating agency	Type of station	Period of record
1	Redwood Gulch near Jolon	11142600	5000	P	1960-73
2	Rat Creek near Lucia	11142800	5000	P	1960-73
3	Big Sur River near Big Sur	11143000	5000	C	1950-present
4	Little Sur River near Point Sur	11143020	5000	L	1977
5	Garrapata Creek below Joshua Creek, near Notleys Landing	11143045	5000	L	1977
6	Garrapata Creek at State Highway 1, near Notleys Landing	11143046	5000	L	1977
7	Doud Creek near Carmel	11143050	5000	P	1960-73
8	San Jose Creek near Carmel at Highway 1	11143100	5000	L	1977
9	Carmel River below San Clement Dam	([1])	5703 7995	C	1937-1981 1981-present
10	Tularcitos Creek near Carmel Valley[2]	([1])	7995	C	1981-83
11	Klondike Canyon near Carmel Valley	11143190	5000	P	1960-73
12	Carmel River at Robles Del Rio	11143200	5000/5115	C	1957-present
13	Las Gazas Creek near Carmel Valley	D4-1088	5115 7995	C	1968-78, 1981-present
14	Carmel River near Carmel	11143250	5000	C	1962-present
15	Arroyo Del Rey at Del Rey Oaks[3]	11143300	5000	C	1966-78
16	Prunedale Creek at Reese Circle	([1])	5115	C	1970-present
17	Moro Cojo Slough tributary near Castroville	11152700	5000	P	1960-73
18	Pajaro River at Chittenden[4]	11159000	5000	C	1939-present

See footnotes at end of table.

Table 5. Streamflow-gaging stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station no.	Operating agency	Type of station	Period of record
19	Pajaro River at Watsonville[3]	11159500	5000	C	1911-13, 1971-76
20	Pajaro River at McGowan Ranch[3]	11159600	5050	C	1946-48

[1]Station number has not been assigned by the U.S. Geological Survey.

[2]The beginning year of record for the station at Carmel River below San Clemente Dam, provided by the California American Water Company, Engineering Department, is only an estimate. Periods of record for this station are unavailable. Since 1981, the station has been operated by Monterey Peninsula Water Management District.

[3]Proposed for reactivation.

[4]Part of a flood-warning network of telemetered gages.

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California

[Site numbers refer to station locations in figure 7]

Operating agency:

1257, Northern Salinas Valley Mosquito Abatement District
2163, California State Water Resources Control Board
5000, U.S. Geological Survey (USGS)
5050, California Department of Water Resources (DWR)
5063, Santa Cruz County Planning Department

Sampling frequency codes:

S, single, one-time sample
1, very infrequent (less than 5 analyses)
2, infrequent (5-25 analyses)
3, frequent (more than 25 analyses)
N, no sampling identified
A, currently active

Summary of sampling frequencies

Frequency	Number of stations	Percent
S	32	30
1	38	36
2	27	25
3	9	9
Total	106	100

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/range	Location: Latitude/longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
1	Salmon Creek at Highway 1	D4-3003.5	5050	24S/6E	35°48'54"/ 121°21'30"	1953-70	2	N
2	Soda Springs Creek at Highway 1	D4-3005.5	5050	24S/5E	35°49'18"/ 121°22'24"	1953-70	2	N
3	Redwood Gulch near Jolon	D4-3010.0	5050	24S/5E	35°50'12"/ 121°23'24"	1953-70	2	N
4	Villa Creek at Highway 1	D4-3020.2	5050	24S/5E	35°50'54"/ 121°24'20"	1953-70	2	N
5	Alder Creek at Highway 1	D4-3035.3	5050	24S/5E	35°51'30"/ 121°24'54"	1953-70	2	N
6	Mud Creek at Highway 1	D4-3040.3	5050	24S/5E	35°51'48"/ 121°25'48"	1953-70	2	N
7	Willow Creek at Highway 1	D4-3050.2	5050	23S/5E	35°53'42"/ 121°27'30"	1953-77	2	S
8	Plaskett Creek at Highway 1	D4-3063.5	5050	23S/5E	35°55'18"/ 121°28'06"	1953-70	2	N
9	Prewitt Creek at Highway 1	D4-3068.5	5050	23S/5E	35°56'12"/ 121°28'12"	1953-70	1	N
10	Wild Cattle Creek at Highway 1	D4-3078.5	5050	22S/4E	35°58'12"/ 121°28'54"	1953-70	2	N
11	Mill Creek at Highway 1	D4-3081.5	5050	22S/4E	35°58'54"/ 121°29'37"	1953-70	2	S

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/range	Location: Latitude/longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
12	Kirk Creek at Highway 1	D4-3092.5	5050	22S/4E	35°59'24"/ 121°29'24"	1953-70	2	N
13	Limekiln Creek at Highway 1	D4-3105.5	5050	22S/4E	36°00'30"/ 121°31'06"	1953-70	2	N
14	Vicente Creek at Highway 1	D4-3180.5	5050	22S/3E	36°02'36"/ 121°35'00"	1953-70	2	N
15	Big Creek above Devil Creek	D4-3207.5	5050	21S/3E	36°04'54"/ 121°35'30"	1953	S	N
16	Big Creek at Highway 1	D4-3201.5	5050	21S/3E	36°04'18"/ 121°35'48"	1953-70	2	N
17	Rat Creek near Lucia	D4-4100.0	5050	21S/3E	36°05'30"/ 121°37'00"	1953-70	1	N
18	Dolan Canyon at Highway 1	D4-3240.5	5000	21S/3E	36°06'24"/ 121°37'16"	1953-70	1	N
19	Lime Creek at Highway 1	D4-3260.5	5050	21S/3E	36°07'18"/ 121°37'48"	1953-70	1	N
20	Hot Springs Creek at Highway 1	D4-3280.5	5050	21S/3E	36°07'30"/ 121°38'12"	1953-70	2	N
21	Buck Creek at Highway 1	D4-3300.3	5050	21S/3E	36°08'12"/ 121°38'42"	1969-70	1	N
22	Anderson Canyon at Highway 1	D4-3310.3	5050	20S/3E	36°09'12"/ 121°40'00"	1953-70	2	N
23	McWay Canyon at Highway 1	D4-3320.3	5050	20S/3E	36°09'30"/ 121°40'12"	1953-70	2	N
24	Partington Creek at Highway 1	D4-3330.3	5050	20S/2E	36°10'30"/ 121°41'32"	1953-70	2	N
25	Torre Canyon at Highway 1	D4-3335.5	5050	20S/2E	36°11'48"/ 121°42'30"	1953-70	1	N
26	Lafler Canyon at Highway 1	D4-3340.3	5050	20S/2E	36°12'12"/ 121°43'30"	1953-70	1	N
27	Grimes Canyon at Highway 1	D4-3345.3	5000	20S/2E	36°12'30"/ 121°44'00"	1953-70	1	N

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/range	Location: Latitude/longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
28	Castro Canyon at Highway 1	D4-3350.5	5050	20S/2E	36°13'00"/ 121°45'00"	1953-70	1	N
29	Sycamore Creek near mouth	D4-3470.5	5050	19S/1E	36°14'18"/ 121°48'42"	1953	S	N
30	Big Sur River at Big Sur	D4-2100.0	5050	19S/2E	36°14'42"/ 121°46'18"	1952-78	2	1
31	Big Sur River at Highway 1	D4-2090.2	5050	19S/2E	36°15'12"/ 121°47'06"	1969-77	1	S
32	Juan Higuera Creek at Highway 1	D4-2061.2	5050	19S/1E	36°15'52"/ 121°47'55"	1953-70	1	N
33	Big Sur River near mouth	D4-2003.3	5050	19S/1E	36°17'06"/ 121°51'12"	1953	1	N
34	Swiss Canyon at Highway 1	D4-3580.5	5050	19S/1E	36°17'42"/ 121°51'54"	1953-70	1	N
35	Little River Hill runoff at Highway 1	D4-3584.5	5050	19S/1E	36°18'06"/	1953 121°52'36"	S	N
36	Little Sur River above south fork	D4-3614.3	5050	18S/1E	36°19'48"/ 121°51'48"	1953-70	1	N
37	Little Sur River Old Coast Road	D4-3613.3	5050	18S/1E	36°19'42"/ 121°51'48"	1953-70	1	
38	Little Sur River at Highway 1	D4-3610.2	5050	18S/1E	36°19'54"/ 121°53'06"	1953-77	2	1
39	Bixby Creek at Old Coast Road	D4-3628.5	5050	18S/1E	36°22'12"/ 121°53'36"	1953-70	2	N
40	Rocky Creek at Highway 1	D4-3635.5	5050	18S/1E	36°22'42"/ 121°54'00"	1953-70	2	N
41	Palo Colorado Canyon Creek at Highway 1	D4-3638.5	5050	18S/1E	36°23'54"/ 121°54'12"	1953	1	N
42	Palo Colorado Canyon at Palo Colorado	D4-3640.5	5050	17S/1E	36°24'00"/ 121°54'06"	1970	S	N

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/range	Location: Latitude/longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
43	Garrapata Creek at Highway 1	D4-3645.5	5000	17S/1W	36°25'00"/ 121°54'42"	1953-70	2	N
44	Doud Creek near Carmel	D4-3650.0	5000	17S/1E	36°25'18"/ 121°54'48"	1953	1	N
45	Granite Creek at Highway 1	D4-3700.5	5000	17S/1W	36°26'12"/ 121°55'00"	1953-70	2	N
46	Soberanes Creek at Highway 1	D4-3743.5	5050	17S/1W	36°27'34"/ 121°55'24"	1953-70	1	N
47	Malpaso Creek at Highway 1	D4-3746.5	5050	17S/1W	36°28'48"/ 121°56'12"	1953-70	1	N
48	Wildcat Creek at end of Peter Pan Road	D4-3750.15	5050	16S/1W	36°29'24"/ 121°56'12"	1970	S	N
49	Wildcat Creek at Highway 1	D4-3749.5	5050	16S/1W	36°29'48"/ 121°56'06"	1953	1	N
50	Carmel Highlands Creek at Highway 1	D4-3770.5	5050	16S/1W	36°30'18"/ 121°56'12"	1970	S	N
51	Gibson Creek at Highway 1	D4-3780.5	5000	16S/1W	36°30'36"/ 121°56'12"	1953-70	1	N
52	San Jose Creek at Highway 1	D4-3800.5	5050	16S/1W	36°31'24"/ 121°55'30"	1955-70	2	N
53	Los Padres Reservoir	D4-1240.1	5050	18S/3E	36°23'08"/ 121°40'02"	1969	S	N
54	Cachagua Creek at Princes CP	D4-1400.5	5050	18S/3E	36°24'06"/ 121°39'30"	1969	S	N
55	Carmel River below San Clemente Dam	D4-1214.9	2163/ 5050	17S/2E	36°26'24"/ 121°42'17"	1983	N	S
56	Carmel River above filtration plant	D4-1212.5	2163/ 5050	17S/2E	36°27'14"/ 121°42'58"	1978	N	S
57	Tularcitos Creek at Girard Ranch	D4-1225.1	5050	17S/3E	36°26'36"/ 121°39'59"	1969	S	N

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
58	Chupines Creek at Carmel Valley Road	D4-1217.1	5050	17S/3E	36°27'12"/ 121°41'36"	1953-69	1	N
59	Tularcitos Creek at Douglas Ranch	D4-1215.1	5050	17S/2E	36°27'12"/ 121°41'48"	1969	1	N
60	Carmel River below Tularcitos Creek	D4-1211.5	2163/ 5050	17S/2E	36°27'56"/ 121°42'50"	1978	N	S
61	Carmel River near Camp Stephanie	D4-1205.1	5050	17S/2E	36°28'20"/ 121°43'20"	1969	S	N
62	Carmel River at Robles del Rio	D4-1200.0	5050	17S/2E	36°28'30"/ 121°43'36"	1953-82	3	3
63	Hitchcock Canyon in Robles del Rio	D4-1203.5	5000	17S/2E	36°28'24"/ 121°43'36"	1969	S	N
64	Carmel River at Beronda Road	D4-1095.1	5050	17S/2E	36°29'18"/ 121°44'48"	1969-70	1	N
65	Las Gazas Creek at Gazaz Road	D4-1088.5	5050	17S/2E	36°29'02"/ 121°45'01"	1969	S	N
66	Carmel River below Tomasini Canyon	D4-1077.5	2163/ 5050	16S/2E	36°30'58"/ 121°47'00"	1978	N	S
67	Robinson Canyon above Carmel Road	D4-1075.5	2163/ 5050	16S/1E	36°31'06"/ 121°48'38"	1953-78	1	S
68	Carmel River at Schulte Road bridge	D4-1063.5	2163/ 5050	16S/1E	36°31'32"/ 121°49'50"	1978	N	S
69	Carmel River at trailer park	D4-1061.5	2163/ 5050	16S/1E	36°31'34"/ 121°50'36"	1978	N	S
70	Carmel River at end of Poplar Road	D4-1060.5	5050	16S/1E	36°31'36"/ 121°50'54"	1974	N	S
71	Carmel River at San Carlos bridge	D4-1052.5	2163/ 5050	16S/1E	36°32'12"/ 121°52'12"	1974-78	N	S
72	Carmel River near Carmel	D4-1050.0	5050	16S/1E	36°32'20"/ 121°52'25"	1952-58	3	N

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/range	Location: Latitude/longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
73	Hatton Canyon Creek at Carmel Valley Road	D4-1022.5	5050	16S/1E	36°32'36"/ 121°54'18"	1953-69	1	N
74	Carmel River at Mallorca Road	D4-1048.5	2163/ 5050	16S/1E	36°23'20"/ 121°52'46"	1978	N	S
75	Carmel River drain into north of bridge	D4-1012.5	5050	16S/1E	36°32'12"/ 121°54'36"	1969	S	N
76	Carmel River at Highway 1	D4-1010.5	2163/ 5050	16S/1W	36°32'12"/ 121°54'42"	1969-83	1	1
77	Carmel River near mouth	D4-1008.5	2163/ 5050	16S/1W	36°32'12"/ 121°55'36"	1953-78	1	S
78	Pacific Ocean at Carmel sewage treatment plant outfall	D4-1007.6	5050	16S/1W	36°32'06"/ 121°55'42"	1970	S	N
79	Laguna Grande at inlet		1257	15S/1E		1975	N	3,A
80	Laguna Grande, east shore		1257	15S/1E		1975	N	3,A
81	Roberts Lake, east shore		1257	15S/1E		1975	N	3,A
82	Moro Canyon Creek at Highway 101 and San Miguel	D2-1070.2	5050	13S/3E	36°48'07"/ 121°39'35"	1970	S	N
83	San Miguel Canyon below Echo Valley	D2-1075.2	5050	13S/3E	36°49'01"/ 121°40'15"	1970	S	N
84	Vierra Canyon east of Highway 1	D2-1065.2	5050	13S/3E	36°47'32"/ 121°39'58"	1970	S	N
85	Pardise Canyon at mouth	D1-3090.2	5050	13S/2E	36°48'26"/ 121°42'10"	1970	S	N
86	Morro Cojo Slough east bank railroad south of Dolan	D1-3113.3	5050	13S/2E	36°47'22"/ 121°45'10"	1977	N	1

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location: Township/ range	Location: Latitude/ longitude	Period of record	Sampling frequency: Before 1973	Sampling frequency: 1973-present
87	Morro Cojo Slough west bank north-east of Highway 1	D1-3114.3	5050	13S/2E	36°47'51"/ 121°45'58"	1977	N	1
88	Old Salinas River Channel above First Tide Gate	D1-3111.3	5050	13S/2E	36°48'00"/ 121°47'15"	1977	N	1
89	Elkhorn Slough at bridge near Hall	D1-3220.2	5000	12S/3E	36°51'36"/ 121°40'18"	1970-72	1	N
90	Pond on San Miguel Canyon Road	D1-3260.2	5050	12S/3E	36°52'22"/ 121°41'20"	1970	S	N
91	Elkhorn Slough at Carneros Creek		1257	12S/2E		1975	N	3,A
92	Los Caneros drain west of Elkhorn River	D1-3115.3	5050	12S/2E	36°51'20"/ 121°45'15"	1977	N	1
93	Elkhorn Slough at Kirby Park		1257	12S/2E		1975	N	3,A
94	Strawberry and Swiss Canyon west of Elkhorn Road	D1-3118.3	5050	13S/2E	36°49'48"/ 121°44'10"	1977	N	1
95	Elkhorn Slough at Highway 1	D1-3150.3	5000	13S/2E	36°48'36"/ 121°47'00"	1953-70	1	N
96	Elkhorn Slough at Highway 1		1257	13S/2E		1975	N	3,A
97	Elkhorn Slough south bank north of Dolan Road	D1-3116.3	5000	13S/2E	36°48'48"/ 121°44'40"	1977	N	1
98	Bennett Slough above tide gate	D1-3110.3	5050	13S/2E	36°48'58"/ 121°47'18"	1977	N	1
99	Pajaro River at Chittenden	D1-1250.0	5000/ 5063	12S/3E	36°54'00"/ 121°35'54"	1951-83	3	3,A
100	Coward Creek at Pajaro River	D1-1112.5	5000	12S/2E	36°55'03"/ 121°42'39"	1978	N	S

Table 6. Surface-water-quality monitoring stations in the northern and coastal areas of Monterey County, California--*Continued*

Site No.	Station name	Station No. (DWR, USGS)	Operating agency	Location		Period of record	Sampling frequency	
				Township/ range	Latitude/ longitude		Before 1973	1973-present
101	Lake Tynan effluent at Pajaro River	D1-1111.3	5050	12S/2E	36°54'57"/ 121°43'23"	1978	N	S
102	Pajaro River above Salsipuedas Creek	D1-1110.3	5063/ 5050	12S/2E	36°54'33"/ 121°44'30"	1978	N	S
103	Salsipuedas Creek at Riverside Road	D1-1110.2	5050	12S/2E	36°54'36"/ 121°44'42"	1972-78	S	S
104	Pajaro River at Watsonville	11159500	5000	12S/2E	36°54'19"/ 121°45'01"	1977	N	S
105	Pajaro River at Thurwachter Road	D1-1075.3	5063/ 5050	12S/2E	36°52'48"/ 121°47'30"	1967-83	2	2,A
106	Corralitos Creek at Freedom	D1-1125	5000/ 5063	11S/2E	36°56'22"/ 121°46'10"	1956-83	N	2,A

Table 8. Inventory of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California

[For explanation of well classification and network classification see pp. 38 and 39. --, no data]

Well No.	Well class	Well No.	Well class	Well No.	Well class	Well No.	Well class
Network 1. Monterey County Flood Control and Water Conservation District August water-level measurement [Total well count, 25]							
Pajaro ground-water trough area [Well count, 25]							
12S/1E-24R3	1	12S/2E-20K1	1	12S/2E-30M2	2	13S/2E-04F1	3
12S/2E-15E1	1	20K2	1	30N1	2	05C2	1
16F1	4	29A1	2	31C2	4	05M1	3
16J1	4	29N1	4	31K1	2	06C1	2
16L1	4	29P1	2	32C1	2	06E2	2
16Q1	2	29R1	2	13S/1E-01A1	4	06E3	2
19A2	4						
Network 2. Monterey County Flood Control and Water Conservation District Monthly water-level measurement [Total well count, 29]							
Pajaro-Springfield area [Well count, 11]							
12S/2E-10D1	1	12S/2E-30M2	2	13S/2E-05M1	3	13S/2E-06E3	2
12E1	2	32C1	2	06C1	2	06R1	2
15E1	1	13S/1E-01A1	4	06E2	2		
Carmel Valley area [Well count, 18]							
16S/1W-13L1	4	16S/1E-17L1	3	16S/1E-22E1	4	16S/1E-23J2	4
13L3	2	18F2	3	22H1	3	23K1	1
13Q3	1	18P3	1	22J1	3	25B2	1
13R1	4	21B1	1	23F1	3	16S/2E-19N1	3
16S/1E-16L1	3	21C1	1				

Table 8. Inventory of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Well class	Well No.	Well class	Well No.	Well class	Well No.	Well class
Network 3. Monterey County Flood Control and Water Conservation District Annual water-level measurement [Total well count, 129]							
Pajaro-Springfield area [Well count, 42]							
12S/1E-24R3	1	12S/2E-16L1	4	12S/2E-31A1	2	12S/3E-21B1	1
36B1	4	16Q1	2	31C2	4	13S/1E-01A1	4
12S/2E-10D1	1	19A2	4	31K1	2	13S/2E-04F1	3
10J2	2	20K1	1	32C1	3	04K1	4
11E4[1]	4	20K2	1	12S/3E-07J2	2	05C2	1
12E1	2	29A1	2	08C1	3	05M1	3
12J1	2	29N1	4	08M1	4	06C1	2
12K1	2	29P1	2	16C2	1	06E2	2
15E1	1	29R1	2	18D1	2	06E3	2
16F1	4	30M2	2	18E4	4	06R1	2
16J1	4	30N1	2				
Hall area [Well count, 5]							
12S/2E-25J1	4	12S/2E-25N1	3	12S/2E-33H1	4	12S/2E-36L1	2
25K1	4						
Prunedale area [Well count, 42]							
12S/2E-14N1	3	13S/2E-03Q1	1	13S/3E-10G1	1	13S/3E-17F1	3
14Q1	2	10J1	1	10N1	3	17F2	1
25A1	2	12D1	1	10Q1	2	19H1	1
12S/3E-19M1	2	12K1	1	14M1	1	19Q1	3
29H1	2	13N1	1	15P1	1	20B2	4
30A1	1	14C1	1	16C3	1	20P1	1
31E1	1	26L1	3	16J1	2	21Q1	1
31G1	2	13S/3E-04L1	1	16Q1	1	22F1	1
33H1	1	04P1	1	16Q2	2	29A1	2
13S/2E-01K1	1	08D1	2	17B1	2	29K1	1
02C1	1	09H1	1				
Marina area [Well count, 4]							
14S/2E-30G3	1	14S/2E-31H1	1	14S/2E-31K2	1	14S/2E-32D4	1

See footnote at end of table.

Table 8. Inventory of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Well class	Well No.	Well class	Well No.	Well class	Well No.	Well class
Network 3. Monterey County Flood Control and Water Conservation District Annual water-level measurement--*Continued*							
Laguna Seca area [Well count, 6]							
15S/1E-26N2	3	16S/1E-02B1	4	16S/2E-05M4	4	16S/2E-05M7	1
16S/1E-01E1	4	16S/2E-05L2	4				
Carmel Valley area [Well count, 30]							
16S/1W-13L1	4	16S/1E-18P3	1	16S/1E-23F1	3	16S/2E-19N1	3
13L3	2	21B1	1	23F3	4	29G1	4
13Q3	1	21C1	1	23J2	4	29Q1	4
13R1	4	22C1	4	23K1	1	32A1	4
16S/1E-16L1	3	22E1	4	23L1	3	17S/3E-21H1	4
17L1	4	22E2	4	24M2	1	22L1	4
17L3	1	22H1	3	25B2	1	18S/4E-06A1	3
18F2	3	22J1	3				
Network 4. Monterey County Flood Control and Water Conservation District Annual summer water-quality sampling [Total well count, 15]							
Pajaro Valley area [Well count, 12]							
12S/1E-24R3	1	12S/2E-31A2	1	12S/2E-31P1	4	13S/2E-06G1	2
30M2	2	31C5	1	13S/2E-05C2	1	06R1	2
30N1	2	31K1	2	06E2	2	06P1	3
Carmel Valley area [Well count, 3]							
16S/1W-13L1	4	16S/1W-13Q3	2	16S/1E-18P3	2		

Table 8. Inventory of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Well class	Well No.	Well class	Well No.	Well class	Well No.	Well class
Network 5. Monterey County Flood Control and Water Conservation District Annual water-quality sampling [Total well count, 88]							
Pajaro Valley area [Well count, 33]							
12S/1E-24R3	1	12S/2E-16L1	4	12S/2E-30N1	2	12S/3E-18E4	4
12S/2E-10D1	1	16Q1	2	31A2	1	13S/2E-04F1	3
10J2	2	17R1	3	31C5	1	05C2	1
12J1	2	19A2	4	31K1	2	05M1	3
12K1	2	20K1	1	32N1	1	06C1	2
15E1	1	29N1	4	07J2	2	06E2	2
16F1	4	29P1	2	08C1	3	06G1	1
16H2	2	30M2	2	18D1	2	06R1	2
16J1	4						
Prunedale area [Well count, 32]							
12S/2E-13N1	2	12S/3E-31E1	1	13S/3E-04L1	1	13S/3E-16J2	3
14N1	3	33H1	1	05P1	1	17B1	2
14Q1	2	13S/2E-01K1	1	06G1	1	17F1	3
25J1	4	02C1	1	08D1	2	19H1	1
25N1	3	03Q1	1	10N1	3	19Q1	3
33H1	4	13N1	1	10Q1	2	20B2	4
12S/3E-19M1	2	15M1	1	16C2	4	20P1	1
30A1	1	26L1	3	16C3	1	27D1	2
Canyon Del Rey area [Well count, 1]							
16S/1E-02B1	4						
Laguna Seca area [Well count, 1]							
16S/2E-05M7	1						

Table 8. Inventory of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Well class	Well No.	Well class	Well No.	Well class	Well No.	Well class
Network 5. Monterey County Flood Control and Water Conservation District Annual water-quality sampling--*Continued*							
Carmel Valley area [Well count, 21]							
16S/1W-13L1	4	16S/1E-17R1	1	16S/1E-22H1	3	16S/2E-29G1	4
13Q3	1	18F2	3	23K1	1	29Q1	4
16S/1E-16L1	3	18P3	1	23L2	1	32A1	4
17J2	4	22C1	4	25B2	1	17S/3E-21H1	3
17L1	4	22E2	4	16S/2E-19N1	3	18S/4E-06A1	3
17L3	1						
Network 6. Monterey County Flood Control and Water Conservation District and Monterey Peninsula Water Management District Quarterly water-level measurement and water-quality sampling [Total well count, 10]							
Shallow wells monitoring septic-tank leachate problem area, Carmel Valley area [Well count, 10]							
16S/1E-17J4	1	16S/1E-23F1	3	16S/2E-33Q1	1	17S/2E-10B1	1
17R2	1	24M3	1	17S/2E-03P1	1		
23E4	1	24N5	1	03D(WW)[2]	--		
Network 7. California American Water Company Monthly water-level measurement [Total well count, 27]							
Carmel Valley area [Well count, 27]							
15S/1E-14N3	--	15S/1E-23D3	--	16S/1E-24N	--	16S/2E-29R1	--
22B1	--	27D1	--	24N2	--	29	--
22B3	--	27J2	--	16S/2E-19N	([2])	17S/2E-10A	--
22H3	--	27J3	--	19N	--	10A	--
22H4	--	16S/1E-23E2	--	19N	--	14A1	--
22H6	--	23L2	2	19N	([2])	14A2	--
23B1	--	24N1	--	19N6	--		

See footnote at end of table.

Table 8. Inventory of ground-water-level and ground-water-quality networks in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Well class	Well No.	Well class	Well No.	Well class	Well No.	Well class
Network 8. California Department of Health Services Triennial sampling for safe drinking water [Total well count, 45]							
[Well count, 45]							
12S/2E-22K1	--	14S/2E-32E	--	15S/1E-22Q1	--	16S/1E-24N1	--
27C1	--	15S/1E-14N3	--	23B1	--	24N2	--
13S/2E-24N1	--	21J2	--	23D3	--	24P1	([2])
24N2	--	21R4	--	23G2	--	16S/2E-19N5	([2])
14S/2E-19K1	([2])	22B1	--	23L1	--	19N6	--
30G2	([2])	22B2	--	23P1	--	29R1	--
30Q2	([2])	22B3	--	27D1	--	33Q1	2
31A1	([2])	22H3	--	27J2	--	17S/2E-03D1	--
31A	--	22H4	--	27J3	--	03D2	--
31C2	([2])	22H5	--	16S/1E-23E2	--	14A1	--
31J	--	22H6	--	23L2	2	14A2	--
32D2	([2])						
Network 9. U.S. Army Health Service, Ford Ord [Total well count, 16]							
[Well count, 16]							
14S/1E-36H1	4	14S/2E-31H2	2	14S/2E-31M1	4	14S/2E-32D2	2
36J1	2	31J1	2	31M2	2	32D3	2
36R1	2	31K1	2	31N1	2	15S/1E-14M1	4
14S/2E-31H1	2	31L1	2	31P1	2	14N1	2

[1]Called 11F1 before 1947.
[2]Water West, local well identification.
[3]Abandoned.

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California

[Available information on file with the Monterey County Flood Control and Water Conservation District (MCFCWCD) is coded as follows: C, current measurements or samples; P, previous measurements or samples; Q, water-quality data; L, water-level data. Agency codes are assigned by the California Department of Water Resources (DWR) as follows: 2669, city of Seaside; 5060, California Department of Health Services (Berkeley Laboratory); 5115, MCFCWCD; 5703, California American Water Company; 5811, California American Water Company, Monterey Laboratory; 7705, Marina County Water District Laboratory; 7995, Monterey Peninsula Water Management District; USAHS, U.S. Army Health Service at Ford Ord. --, no data.]

Well No.	Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
12S/1E- 24R3	1,3,4,5	CQL	1		5115
36B1	3	CL	4		5115
12S/2E- 10D1	2,3,5	CQL	1		5115
10J2	3,5	CQL	2		5115
11E4	3	CL	4		5115
12E1	2,3	CL	2		5115
12J1	3,5	CQL	2		5115
12K1	3,5	CQL	2		5115
13N1	5	CQPL	2		5115
14N1	3,5	CQL	3		5115
14Q1	3,5	CQL	2		5115
15E1	1,2,3,5	CQL	1		5115
16F1	1,3,5	CQL	4		5115
16H2	5	CQ	2		5115
16J1	1,3,5	CQL	4		5115
16L1	1,3,5	CQL	4		5115
16Q1	1,3,5	CQL	2		5115
17R1	5	CQ	3		5115
19A2	1,3,5	CQL	4		5115
20K1	1,3,5	CQL	1		5115
20K2	1,3	CLPQ	1		5115
22K1	8	--	--	Las Lomas 2	5060
25A1	3	CLPQ	2		5115
25J1	3,5	CQL	4		5115
25K1	3	CQL	4		5115
25N1	3,5	CLQ	3		5115
27C1	8	--	--	Las Lomas 1	5060
29A1	1,3	CLPQ	2		5115
29N1	1,3,5	CQL	4		5115
29P1	1,3,5	CQL	2		5115
29R1	1,3	CLPQ	2		5115
30M2	1,2,3,4,5	CQL	2		5115
30N1	1,3,4,5	CQL	2		5115

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
12S/2E- 31A1	3	CLPQ	2		5115
31A2	4,5	CQ	1		5115
31C2	1,3	CLPQ	4		5115
31C5	4,5	CQ	1		5115
31K1	1,3,4,5	CQ	2		5115
31P1	4	CQ	4		5115
32C1	1,2,3	CLPQ	3		5115
32N1[1]	5	CQ	1		5115
33H1	3,5	CQL	4		5115
36L1	3	CLPQ	2		5115
12S/3E- 07J2	3,5	CQL	2		5115
08C1	3,5	CQL	3		5115
08M1	3	CLPQ	4		5115
16C2	2,3	CL	1		5115
18D1	3,5	CQL	2		5115
18E4	3,5	CQL	4		5115
19M1	3,5	CQL	2		5115
21B1	3	CL	1		5115
29H1[2]	3	CL	2		5115
30A1	3,5	CQL	1		5115
31E1	3,5	CQL	1		5115
31G1	3	CLPQ	2		5115
33H1	3,5	CQL	1		5115
13S/1E- 01A1	1,2,3	CLPQ	4		5115
13S/2E- 01K1	3,5	CQL	1		5115
02C1	3,5	CQL	1		5115
03Q1	3,5	CQL	1		5115
04F1	1,3,5	CQL	3		5115
04K1	3	CLPQ	4		5115
05C2	1,3,4,5	CQL	1		5115
05M1	1,2,3,5	CQL	3		5115
06C1	1,2,3,5	CQL	2		5115
06E2	1,2,3,4,5	CQL	2		5115
06E3	1,2,3	CL	2		5115
06G1	4,5	CQ	1		5115
06P1	4	CQ	3		5115
06R1	2,3,4,5	CQL	2		5115
10J1[3]	3	CLPQ	1		5115
12D1	3	CQL	1		5115
12K1[3]	3	CLPQ	1		5115
13N1	3,5	CQL	1		5115
14C1	3	CL	1		5115
15M1	5	CQ	1		5115
24N1	8	--	--	Oak Hills 1	5060

See footnotes at end of table.

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
13S/2E- 24N2	8	--	--	Oak Hills 2	5160
26L1	3,5	CQL	3		5115
13S/3E- 04L1	3,5	CQL	1		5115
04P1	3	CL	1		5115
05P1	5	CQPL	1		5115
06G1	5	CQ	1		5115
08D1	3,5	CQL	2		5115
09H1	3	CL	1		5115
10G1	3	CL	1		5115
10N1	3,5	CQL	3		5115
10Q1	3,5	CQL	2		5115
14M1	3	CL	1		5115
15P1	3	CL	1		5115
16C2	5	CQ	4		5115
16C3	3,5	CQL	1		5115
16J1	3	CL	2		5115
16J2	5	CQ	3		5115
16Q1	3	CL	1		5115
16Q2	3	CL	2		5115
17B1	3,5	CQL	2		5115
17F1	3,5	CQL	3		5115
17F2	3	CL	1		5115
19H1	3,5	CQL	1		5115
19Q1	3,5	CQL	3		5115
20B2	3,5	CQL	4		5115
20P1	3,5	CQL	1		5115
21Q1	3	CL	1		5115
22F1	3	CL	1		5115
27D1	5	CQPL	2		5115
29A1	3	CLPQ	2		5115
29K1	3	CL	1		5115
14S/1E- 25R2	3	--	4		5115
36H1	9	--	4		USAHS
36J1	9	--	2		USAHS
36R1	9	--	2		USAHS
14S/2E- 19K1[4]	8	--	--	Marina 7	5060, 7705
30G2[4]	8	--	--	Marina 6	5060, 7705
30G3	3	CQ	1	Marina 12	5115
30Q2[4]	8	--	--	Marina 3	5060, 7705
31A1[4]	8	--	--	Marina 5	7705

See footnotes at end of table.

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
14S/2E- 31C2[4]	8	--	--	Marina 4	7705
31H1	3,8,9	CQ	1	Marina 10	5115, USAHS, 5060, 7705
31J1	9	--	2		USAHS
31K1	9	CQ	2		USAHS
31K2	3,8	CQ	1	Marina 9	5115, 5060
31L1	9	--	2		USAHS
31M1	9	--	4		USAHS
31M2	9	--	2		USAHS
31N1	9	--	2		USAHS
31P1	9	--	2		USAHS
32D2[4]	8,9	--	2	Marina 8	5060, 7705, USAHS
32D3	9	--	2		USAHS
32D4	3	CQ	1	Marina 11	5115
32E	8	--	--	Marina 8a	5060, 7705
15S/1E- 14M1	9	--	4		USAHS
14N1	9	--	2		USAHS
14N3	7,8	--	--	Military	5811, 5060
21J2	8	--	--	Orange	5060
21R4	8	--	--	Elm	USAHS
22B1	7,8	--	--	Playa 1	5811, 5060
22B2	8	--	--	Playa 2	5060
22B3	7,8	--	--	Playa 3	5811, 5060
22H3	7,8	--	--	La Salle 2	USAHS
22H4	7,8	--	--	La Salle 1	USAHS
22H5	8	--	--	Darwin	5060
22H6	7,8	--	--	Harding	5811, 5060
22Q1	8	--	--	Palm	5060
23B1	7,8	--	--	Ord Grove	5811, 5060
23D3	7,8	--	--	Luzern	USAHS
23G2	8	--	--	Seaside 3	5060, 2669

See footnotes at end of table.

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California--*Continued*

Well No.		Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
15S/1E-	23L1	8	--	--	Seaside 2	USAHS
	23P1	8	--	--	Seaside 1	USAHS
	26N2	3	CLPQ	3		5115
	27D1	7,8	--	--	Harcourt	5811, 5060
	27J2	7,8	--	--	Plumas 2	5060
	27J3	7,8	--	--	Plumas 3	5060
16S/1W-	13L1	2,3,5	CQL	4		5115
	13L3	2,3	CLPQ	2		5115
	13Q3	2,3,4,5	--	2		5115
	13R1	2,3	--	4		5115
16S/1E-	01E1	3	CLPQ	4		5115
	02B1	3,5	CQL	4		5115
	16L1	2,3,5	CQL	3		5115
	17J2	5	CQ	4		5115
	17J4	6	CQL	1		7995, 5115
	17L1	2,3,5	CQL	3		5115
	17L3	3,5	CQL	1		5115
	17R1	5	CQ	1		5115
	17R2	6	CQL	1		7995, 5115
	18F2	2,3,5	CQL	3		5115
	18P3	2,3,4,5	CQL	1		5115
	21B1	2,3	CLPQ	1		5115
	21C1	2,3	CLPQ	1		5115
	22C1	3,5	CQL	4		5115
	22E1	2,3	CQL	4		5115
	22E2	3,5	CQL	4		5115
	22H1	2,3,5	CQL	3		5115
	22J1	2,3	CLPQ	3		5115
	23E2[5]	7,8	--	--	Schulte	5115
	23E4	6	CQL	1		7995, 5115
	23F1	2,3,6	CLQ	3		5115, 7995
	23F3	3	CL	4		5115
	23J2	2,3	CL	4		5115
	23K1	2,3,5	CQL	1		5115
	23L1	3	CLPQ	3		5115
	23L2	5,7,8	CQ	1	Manor	5115, 5811, 5060
	24M2	3	CQ	1		5115

See footnotes at end of table.

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California--*Continued*

Well No.		Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
16S/1E-	24M3	6	CQL	1		7995, 5115
	24N1[6]	7,8	--	--	Berwick 1	5811, 5060
	24N	7	--	--	Berwick 7R	5811
	24N1	7,8	--	--	Begonia	5811, 5060
	24N5[7]	6	CQL	1		7995, 5115
	24P1[8]	8	--	--	Berwick 2	5811, 5060
	25B2	2,3,5	CQL	1		5115
16S/2E-	05L2	3	CL	4		5115
	05M4	3	CL	4		5115
	05M7	3,5	CQL	1		5115
	19N1	2,3,5	--	3		5115
	19N[8]	7	--	--	Scarlett 1	5811
	19N	7	--	--	Scarlett 2	5811
	19N5[8]	8	--	--	Scarlett 4	5811, 5060
	19N[8]	7	--	--	Scarlett 5	5811
	19N6	7,8	--	--	Scarlett 6	5811, 5060
	19N[8]	7	--	--	Scarlett 7	5811
	29G1	3,5	CQL	4		5115
	29Q1	3,5	CQL	4		5115
	29R1[9]	7,8	--	--	Las Laureles 5	5811, 5060
	29[9]	7	--	--	Las Laureles 6	5811
	32A1	3,5	CQL	4		5115
	33K1	6	--	--		7995, 5115
	33Q1	6	CQL	1		7995, 5115
	33Q1[10]	8	--	--	Rancho Del Monte 3	5060
17S/2E-	03(MS)	6	CQL	--	Mary Signorey	7995, 5115
	03D(WW)	6	CQL	--	Water West	5115, 7995
	03D1	8	--	--	Rancho Del Monte 1	5060
	03D2	8	--	--	Rancho Del Monte 2	5060
	10A1	6	CQL	--		7995, 5115

See footnotes at end of table.

Table 10. Index of ground-water network wells in the northern and coastal areas of Monterey County, California--*Continued*

Well No.	Site Nos. (table 6)	Available information	Well class	Local identification	Agency code
17S/2E- 10A	7	--	--	Robles 1	5811
10A	7	--	--	Robles 2	5811
10B1	6	CQL	1		7995 5115
11(LR)	6	--	--	Laguna Robles	7995, 5115
14A1[11]	7,8	--	--	Russell 2	5811, 5060
14A2[11]	7,8	--	--	Russell 4	5060
17S/3E- 21H1	3,5	CQL	4		5115
22L1	3	CL	4		5115
18S/4E- 06A1	3,5	CQL	3		5115

[1]No sample since 1979.
[2]No measurement since 1980.
[3]No water-quality sampling has been done since 1981 when the well was abandoned.
[4]Abandoned.
[5]Plots in 22J.
[6]Number may be questionable; see 24N5.
[7]May have been called 24N1 before September 10, 1982.
[8]Abandoned.
[9]Plots in 29J.
[10]May be the same well as in network 6.
[11]Plots in 11R.