TRUST TERRITORY OF THE PACIFIC ISLANDS, SAIPAN, GUAM, AND AMERICAN SAMOA

GROUND-WATER QUALITY

By Johnson J.S. Yee

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FOREWORD

This report contains summary information on ground-water quality in one of the 50 States, Puerto Rico, the Virgin Islands, or the Trust Territories of the Pacific Islands, Saipan, Guam, and American Samoa. The material is extracted from the manuscript of the *1986 National Water Summary*, and with the exception of the illustrations, which will be reproduced in multi-color in the *1986 National Water Summary*, the format and content of this report is identical to the State ground-water-quality descriptions to be published in the *1986 National Water Summary*. Release of this information before formal publication in the *1986 National Water Summary* permits the earliest access by the public.

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The Trust Territory of the Pacific Islands (TTPI) has more than 2,100 tropical islands, which include the principal island (Saipan) of the Commonwealth of Northern Mariana Islands; Guam, Moen (Truk), and American Samoa (Tutuila), (fig. 1).

Ground water (fig. 2) is developed for public supply on the islands of Saipan, Guam, Tutuila (American Samoa), Moen (Truk), and Yap. Nearly all of Saipan's population of 20,000 depends on ground water. About 80 percent of Guam's 120,000 residents rely on water pumped from limestone aquifers in the northern part of the island. About 10,000 on Moen and 36,000 people on Tutuila rely on ground water for public and industrial supplies, (U.S. Geological Survey, 1985, p. 403). Population distribution in Saipan, Guam, Moen, and Tutuila is shown in figure 1*B*.

Except in Saipan, the quality of all ground water developed for public supplies is within the drinking-water standards recommended by the World Health Organization (WHO) (1984) for dissolved solids, 1,000 mg/L (milligrams per liter); chloride, 250 mg/L; and nitrate, 10 mg/L, as nitrogen. In major areas of ground-water withdrawal, the median concentration of dissolved solids is less than 1,000 mg/L, and in all areas, the median nitrate concentration, as nitrogen, is less than 10 mg/L (fig. 2*B*). Excessive pumping of the aquifers can cause reduction of hydraulic head that results in seawater intrusion into the freshwater zones. Degradation of the chemical quality of water is associated mainly with excessive pumping of ground water, which can result in increases of chloride concentrations to more than the 250 mg/L standard recommended by WHO for drinking-water supply. Degradation of water quality by seawater intrusion has occurred mainly in limestone aquifers of the southern and west-central parts of Saipan. Except for Guam, few data are available to evaluate organic constituents in ground-water resources. Guam's extensive monitoring efforts under the Safe Drinking Water Act reveal no organic contamination in its drinking-water supplies.

No hazardous-materials disposal sites are located in TTPI, Saipan, and American Samoa; and no ground water is being monitored under Federal Resources Conservation and Recovery Act of 1979 (RCRA) guidelines. On Guam, the landfill at Andersen Air Force Base is being monitored for closure purposes under RCRA procedures (fig. 3, site A) . The Ordot Landfill, also on Guam (fig. 3), has been included in the National Priorities List (NPL) of hazardous-waste sites by the U.S. Environmental Protection Agency (EPA) (1986a). This Superfund site requires additional evaluation and monitoring under Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Currently, (1986) contamination of ground water at the CERCLA site has not been detected. The U.S. Department of Defense (DOD) has identified 27 sites at three facil-

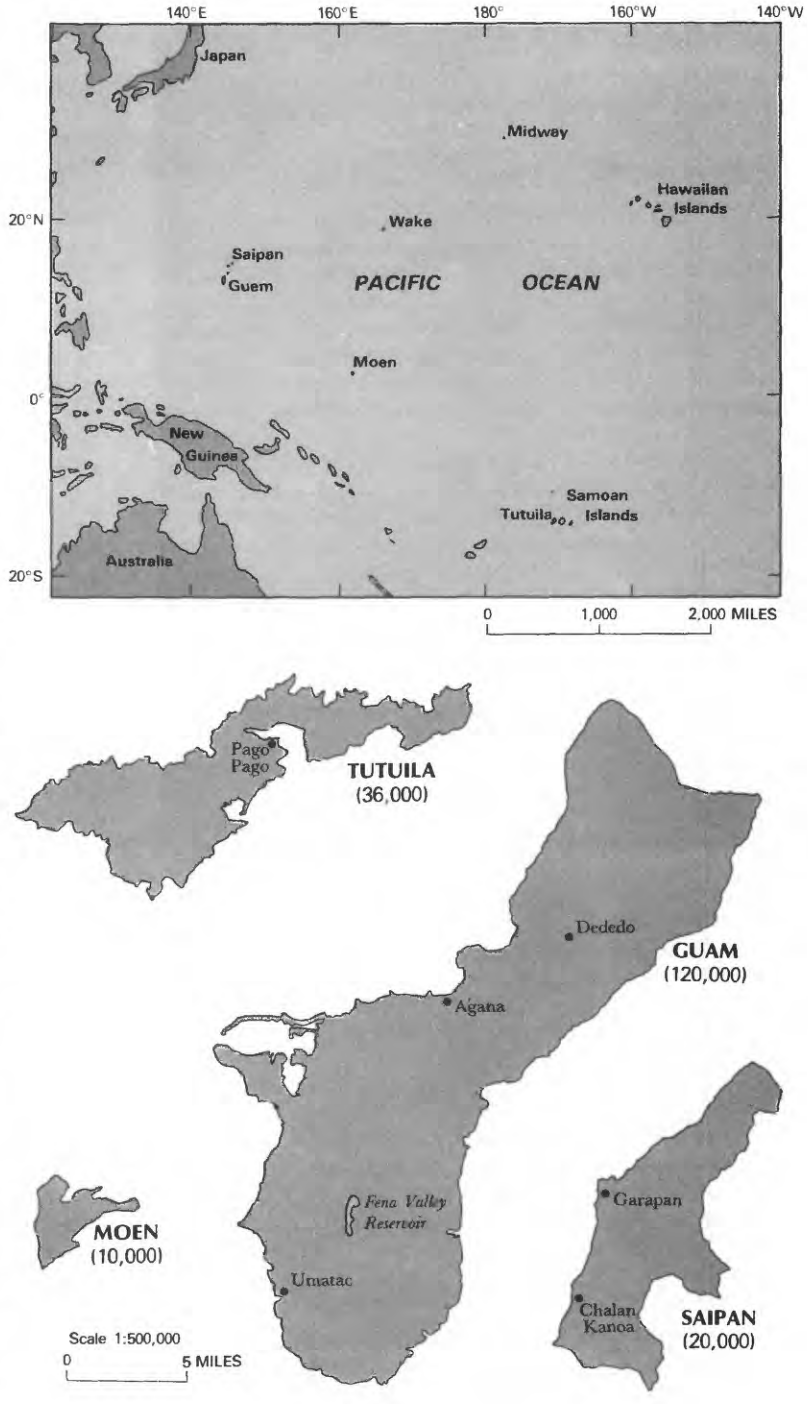

Figure 1. Selected geographic features and 1985 population distribution in Trust Territory of the Pacific Islands, Saipan, Guam, and American Samoa. *A*, Islands, selected cities, and major drainages. *B*, Population distribution, 1985; number in parenthesis is total by island. (Sources: *B*, Data from U.S. Bureau of the Census 1980 decennial census files; 1987 Pacific World Directory, and published reports.)

ities as having potential for contamination. The sites are scheduled for confirmation studies to determine if remedial action is required.

Beginning in 1979, the U.S. Geological Survey in cooperation with the governments of Saipan, Guam, American Samoa, and TTPI, initiated a ground-water-quality observation program to monitor chloride concentrations in wells to determine the extent of seawater intrusion into the freshwater lenses beneath the islands. By 1986, the program included chloride measurements at more than 64 wells. Few data on other inorganic constituents and none on organic constituents were collected as part of the program. Regulatory agencies on Guam, American Samoa, Saipan, and TTPI also collect water-quality data identified under the Safe Drinking Water Act.

WATER QUALITY IN PRINCIPAL AQUIFERS

Principal aquifers (fig. 2*A*) in the islands are: (1) the Tagpochau limestone and (2) the Mariana limestone on Saipan, (3) the Barrigada limestone, and (4) the Mariana limestone on Guam, (5) the Truk volcanic rock on Moen, and (6) the Leone volcanic rock on Tutuila. Water in these aquifers occurs as a basal freshwater lens that floats in equilibrium on the denser saline water. This lens is recharged by rainfall; if the recharge is reduced, thinning of the lens and subsequent encroachment by seawater can occur. Seawater encroachment, primarily upconing induced by excessive pumping, is the biggest threat to the islands' basal freshwater lens. In Guam, there also exists parabasal water, which is defined as basal water that rests on an impervious formation instead of floating on saltwater (Mink, 1976). Other ground-water bodies, small in comparison to the principal aquifers, are perched or isolated from the major basal-water aquifers.

BACKGROUND WATER QUALITY

A graphic summary of selected water-quality variables compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) is presented in figure 2*B*. The summary is based on dissolved-solids, hardness, nitrate (as nitrogen), and silica analyses of water samples collected from 1965 to 1985 from the principal aquifers on the Islands of Saipan, Guam, Moen, and Tutuila. The data base is not adequate to make statistical inferences for other aquifers. The data were interpreted without consideration of sample depth within the aquifer; where more than one chemical analysis was available, the median concentration for a site was used in the statistical analysis. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in a drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to the esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L nitrate (as nitrogen), and the secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids.

Limestone Aquifers

ISLAND OF SAIPAN

The Tagpochau and Mariana limestone aquifers are the most extensive aquifers in Saipan from which most of the withdrawal for public supply is made. Dissolved-solids concentrations in the Tagpochau aquifer ranged from about 325 to 2000 mg/L, and the median was about 850 mg/L. Dissolved solids in the Mariana aquifer ranged from about 250 to 2500 mg/L, and the median was about 600 mg/L. Median concentration of dissolved solids in water from other aquifers is more than 1,000 mg/L in some parts of southern and western Saipan. This concentration exceeds the EPA's national secondary drinking-water recommendation of 500 mg/L. Although these limits do not apply to water used for irrigation, the higher the concentration of dissolved solids, the less desirable the water is for irrigation or other beneficial uses.

Calcium and magnesium, which contribute to the hardness of water, are among the more soluble minerals in the limestone aquifers. Generally, within these aquifers, the higher the concentration of dissolved solids, the higher the hardness (fig. 2*B*). Water from the Tagpochau and Mariana limestone aquifers is classified as very hard, with median hardness concentrations (as calcium carbonate) of 372 mg/L and 330 mg/L, respectively.

Nitrate concentration, as nitrogen, is less than the recommended limit of 10 mg/L. No wells in Saipan produce water that exceeds this limit. Median concentration for nitrate, as nitrogen, is 2.5 mg/L in Tagpochau limestones, and 3.6 mg/L in Mariana limestones. These concentrations are higher than the median nitrate concentrations in water from volcanic-rock aquifers in Moen and Tutuila (fig. 2*B*, aquifers 5 and 6).

The median concentration for silica is less than 9.0 mg/L in water from the limestone aquifers (fig. 2*B*). In general, silica does not affect the beneficial use of water.

ISLAND OF GUAM

The Barrigada and Mariana limestone aquifers (fig. 2*B*, aquifers 3 and 4) are the two primary aquifers in northern Guam. About 70 percent of the water for Guam's public supplies is withdrawn from about 100 production wells completed in these aquifers (U.S. Geological Survey, 1985). In 1978 these aquifers, commonly called the Northern Guam Lens aquifer, were designated by the EPA as a "principal source aquifer", and special management of the aquifers to protect the quality of water from degradation has been stated by the Guam Environmental Protection Agency (GEPA). Substantial efforts have been made by the GEPA to manage and monitor this important ground-water resource.

In the Barrigada limestone aquifer, the median concentration of dissolved solids is 308 mg/L; and in the Mariana limestones aquifer, the median is 574 mg/L. The water in the aquifers is classified as very hard with hardness concentrations (as calcium carbonate) exceeding 200 mg/L (fig. 2*B*, aquifers 3 and 4). Median nitrate concentration, as nitrogen, is about 2 mg/L in the limestone aquifers. This is less than the EPA primary drinking-water standard of 10 mg/L. No wells produce water with nitrate concentrations that exceeds this limit. The median silica concentration is about 1 mg/L for all waters in the limestone aquifers.

Volcanic-Rock Aquifers

In water from the volcanic-rock aquifers in Moen and Tutuila, the median concentrations for dissolved solids are less than 500 mg/L; hardness is less than 125 mg/L; nitrate, as nitrogen, is less than 0.5 mg/L; and silica less than 38 mg/L. All concentrations are within the recommended limit for safe drinking water set by the WHO. One occurrence of nitrate exceeding 10 mg/L was reported for Tutuila (Paul Eyre, U.S. Geological Survey, written commun., 1986). Repeated sampling of the well showed a nitrate concentration of 0.7 mg/L.

EFFECTS OF LAND USE ON WATER QUALITY

Water quality has deteriorated in some areas as a result of seawater encroachment induced by excessive pumping or by dense placement of wells. Investigations by the U.S. Geological Survey and interpretation of data collected by local government agencies have documented increased chloride concentrations in well waters withdrawn from aquifers in Saipan, Guam, and American Samoa. Examples of the fluctuation of pumpage and increase of chloride concentration in selected wells in Guam are shown in figure 4.

Although no precipitation data are available for the period of record shown in figure 4, it is likely that some of the fluctuations in chloride concentrations are caused by decreases in precipitation. This is indicated in Well 18–2546–04, June 1982 through July 1983. During this period, constant rates of water withdrawal were accompanied by steadily increasing chloride concentrations; this probably indicates a dry year, reduced recharge to the freshwater basal lens, thinning of the freshwater lens, and subsequent seawater encroachment induced by heavy pumping.

Though waste-disposal practices have not been thoroughly investigated, these practices can affect the sanitary quality of the ground water in some of the Pacific Islands. Incidences of coliform densities in ground water that exceed drinking-water standards have been reported from Moen and Tutuila.

Urbanization

Population in the Trust Territory of the Pacific Islands is growing at an annual rate of 3.5 percent and is expected to double every 10 years if the current trend continues (Trust Territory Environmental Protection Board, 1985). The demands for water to meet this growth have resulted in intensive ground-water development on Moen island.

Saipan's population is expected to grow at an annual rate of 3 to 4 percent. To meet the demands for water, extensive pumping of existing wells and the drilling of new wells has taken place in the limestone aquifers. The effect of this development on the aquifers has been a reduction in the hydraulic head, which has induced seawater intrusion and caused an increase in dissolved solids in ground water. The dissolved-solids concentration in Saipan's limestone aquifer exceeds the EPA national secondary drinking-water standard of 500 mg/L. It is, however, within the maximum limit of 1,000 mg/L set by the WHO.

In Tutuila, American Samoa, contamination of wells by seawater has been induced by pumping, especially during dry periods, which has caused upconing of the underlying saltwater in the Leone volcanic-rock aquifer. Water from wells that tap this aquifer had chloride concentrations ranging from 7 to 1,200 mg/L during 1975 to 1983 (U.S. Geological Survey, 1985).

In addition to increased pumping, which induces saltwater intrusion and results in increased dissolved chloride, urbanization can cause a decrease of recharge to the aquifer. Because of the increase of impervious areas associated with urban development, much of the recharge from rainfall that normally would percolate down to the water table in recharge areas is lost by evaporation or runs off into storm drains.

Agriculture

Because of the limited availability of land in the western Pacific islands, agriculture is practical only on a small scale, and irrigation has little effect on the quality of ground water. However, the potential exists for fertilizers and pesticides, which are used to increase crop yield and to control insects, to contaminate the aquifers on Saipan, Guam, Moen, and Tutuila.

Waste-Disposal

Presently, no RCRA waste-disposal sites are operating on Saipan, Moen, or Tutuila. RCRA guidelines are being implemented at Andersen Air Force Base on Guam to monitor its landfill (fig. 3*B*, site A) as a part of the procedure to close the landfill. Also on Guam, one site is on the NPL for evaluation under CERCLA (fig. 3*A*). This is the major solid-waste disposal site for civilian activities on Guam. The GEPA has monitored the site since 1983 to determine the effect of the landfill on ground-water quality in the area. Results, thus far, have shown no ground-water contamination by leachate from the disposal site (Guam Environmental Protection Agency, 1986).

Military installations on Guam have a wide variety of waste-disposal areas, including active and inactive landfills, sludge and chemical disposal pits, and petroleum disposal areas.

As of September 1985, 27 hazardous-waste sites at 3 facilities in Guam (shown as "other" sites on fig. 3*A*) had been identified by the DOD as part of their Installation Restoration Program (IRP) as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the EPA Superfund program under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. The EPA presently ranks these sites under the hazard ranking system and may include them in the NPL. These sites are scheduled for confirmation studies to determine if remedial action is required.

Other waste-disposal sites on Saipan, Moen, and Tutuila are associated with landfills (fig. 3*B*) that are used to dispose of solid wastes from domestic and industrial activities. Except for Guam, few data are being collected to evaluate the effects of landfill sites on ground-water quality. Most landfills are located away from ground-water recharge areas. Trace metals and other organic chemicals commonly associated with landfills have not been detected in potable water supplies. The islands lack dense urban and industrial activities that produce the type of pollutant loads found in industrialized areas.

Potential for Water-Quality Changes

Seawater intrusion of the freshwater aquifers has the largest potential for future ground-water quality changes in Saipan, Guam, Tutuila, and the TTPI. Heavy pumping of the basal freshwater aquifers to meet increasing water demands has caused an increase in dissolved-solids concentrations in many wells. As little as 2 percent contamination of the freshwater by seawater will result in the water that exceeds the chloride standards recommended by the EPA's secondary drinking-water regulations. Although unused at present, treatment may be needed in the future to reduce dissolved solids or salinity in areas where drinking-water standards are exceeded.

Use of pesticides associated with urbanization and agricultural activities can introduce organic contaminants into the ground water. Current monitoring under the Safe Drinking Water Act (SDWA) guidelines indicates that concentrations of all constituents are less than the maximum contaminant levels established by the EPA. The SDWA constituents being monitored, however, do not include many of the pesticides being used on the islands.

The median nitrate, as nitrogen, concentration on Saipan, 3.6 mg/L, is the highest reported value from any of the limestone aquifers (fig. 2*B*). Guam's nitrate concentration which averages 2 to 2.5 mg/L, is reported to be twice the national average (Guam Environmental Protection Agency, 1982). GEPA data collected during 1986 not only confirmed these levels, but also showed some wells with greater than 5 mg/L nitrate, as nitrogen. The cause of these relatively high nitrate concentrations in ground water has not been fully determined. Indications are that leachates from surface waste-disposal activities such as cesspools, open-toilet facilities, and unregulated animal wastes may be the major causes of high nitrate concentrations in ground water. Nitrogen fixation by plants and buried bird guano may also contribute to nitrate concentrations in ground water.

Bacterial contamination in ground water has been reported in Moen and Tutuila, especially in shallow wells and spring areas where the rural population obtains most of its water supplies. The unsanitary quality of ground water in Moen probably is the cause of high incidences of amoebiasis, infectious hepatitis, and other bacterial and viral gastrointestinal problems among the population (Trust Territory Environmental Protection Board, 1985). Improving the sanitary quality of the water will require improving the sewer and waste-disposal systems on this island.

GROUND-WATER-QUALITY MANAGEMENT

The Trust Territory Environmental Protection Board monitors the quality of water resources in the TTPI. Each island group has its own Public Works Department that operates its central water-supply system. Saipan's water quality is monitored by the Commonwealth of Northern Mariana Islands, Division of Environmental Quality. Guam's water resources are monitored by GEPA, created by the 1973 Guam Environmental Protection Agency Act (Title LXI, Chapter 1). The GEPA is responsible for planning activities and the development of regulations to insure the protection and conservation of Guam's water resources. GEPA has established a comprehensive program to manage and monitor ground-water-quality on Guam. The program includes the extensive study and management of the Northern Guam Lens Aquifer (aquifers 3 and 4) implementing water-quality monitoring efforts, and creating a specific section within GEPA's Water Division to implement ground-water management policies. Tutuila's ground-water quality is monitored by the American Samoa Government (ASG), Office of Environmental Protection Agency. Chloride in ground water on Tutuila is monitored by the Department of Public Works, in cooperation with the U.S. Geological Survey as part of a program to measure saltwater intrusion into the basal aquifers.

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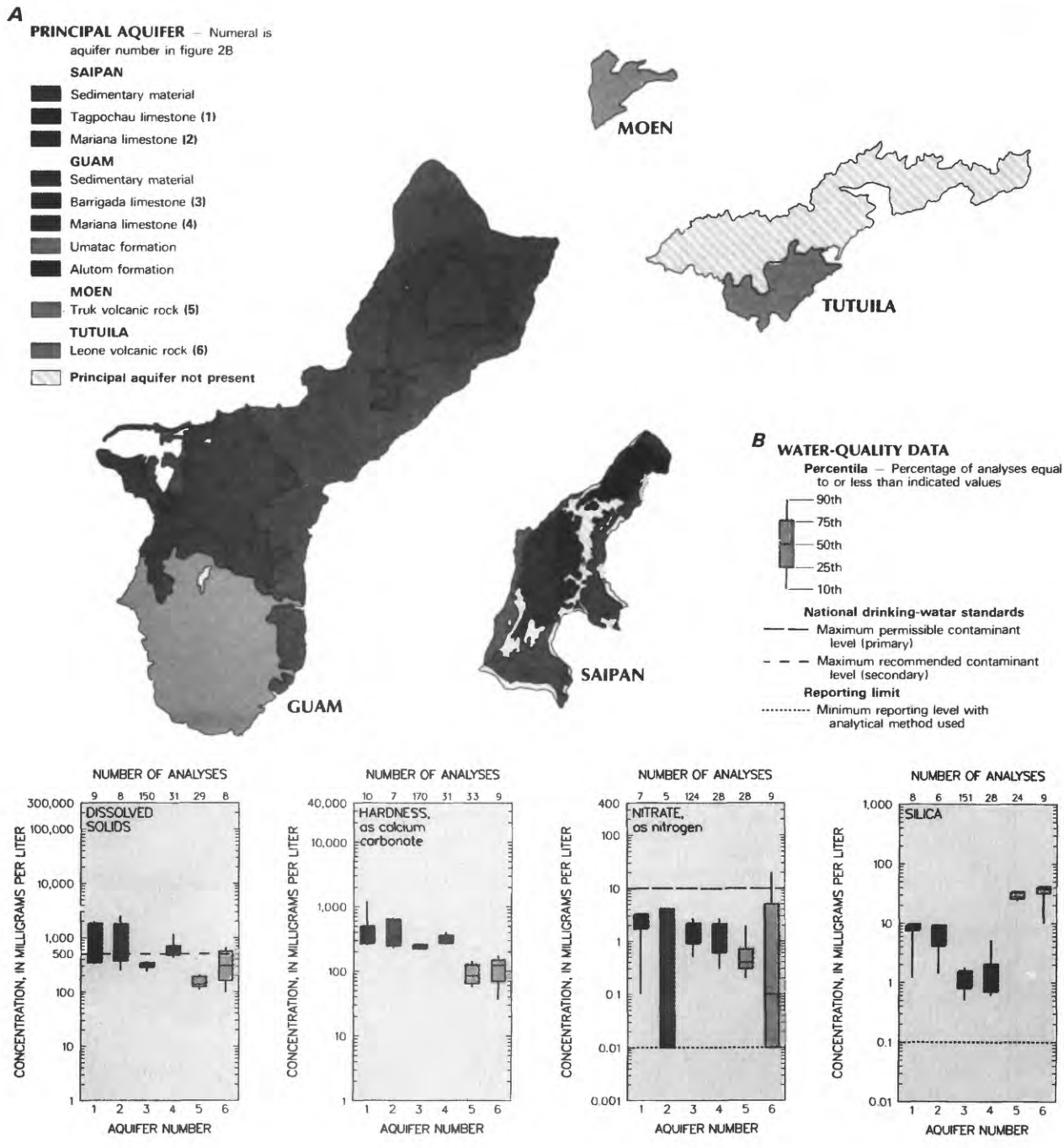

Figure 2. Principal aquifers and related water-quality data in Trust Territory of the Pacific Islands, Saipan, Guam, and American Samoa. *A*, Principal aquifers; *B*, Selected water-quality constituents and properties, as of 1985. (Sources: *A*, U.S. Geological Survey, 1985. *B*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

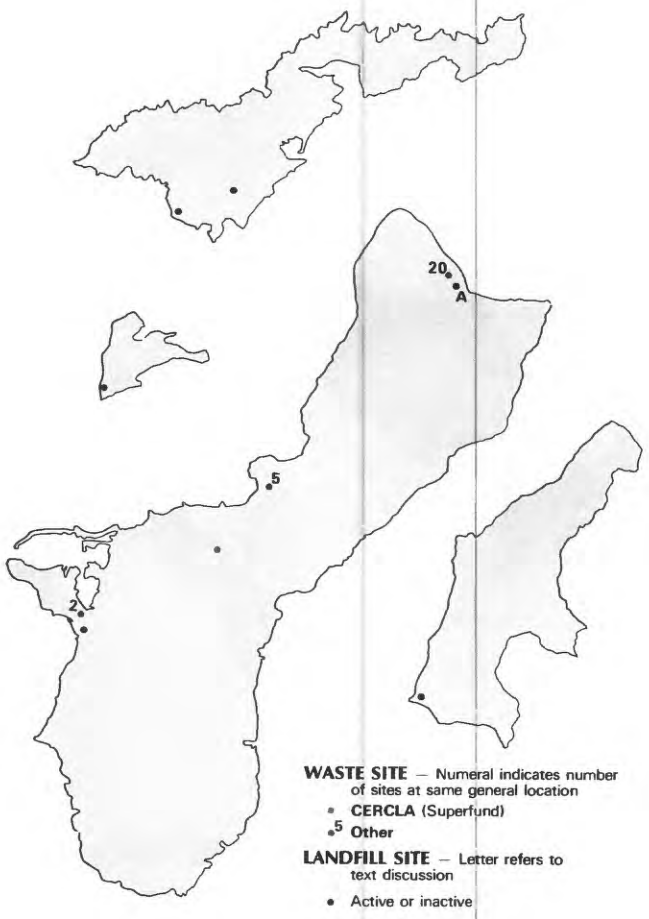

Figure 3. Selected waste sites and ground-water-quality information in Trust Territory of the Pacific Islands, Saipan, Guam, and American Samoa. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; and Department of Defense Installation Restoration Program (IRP) sites, as of 1986; private and government landfills, as of 1985. (Sources: U.S. Environmental Protection Agency, 1986c; U.S. Department of Defense, 1986; and, U.S. Geological Survey records.)

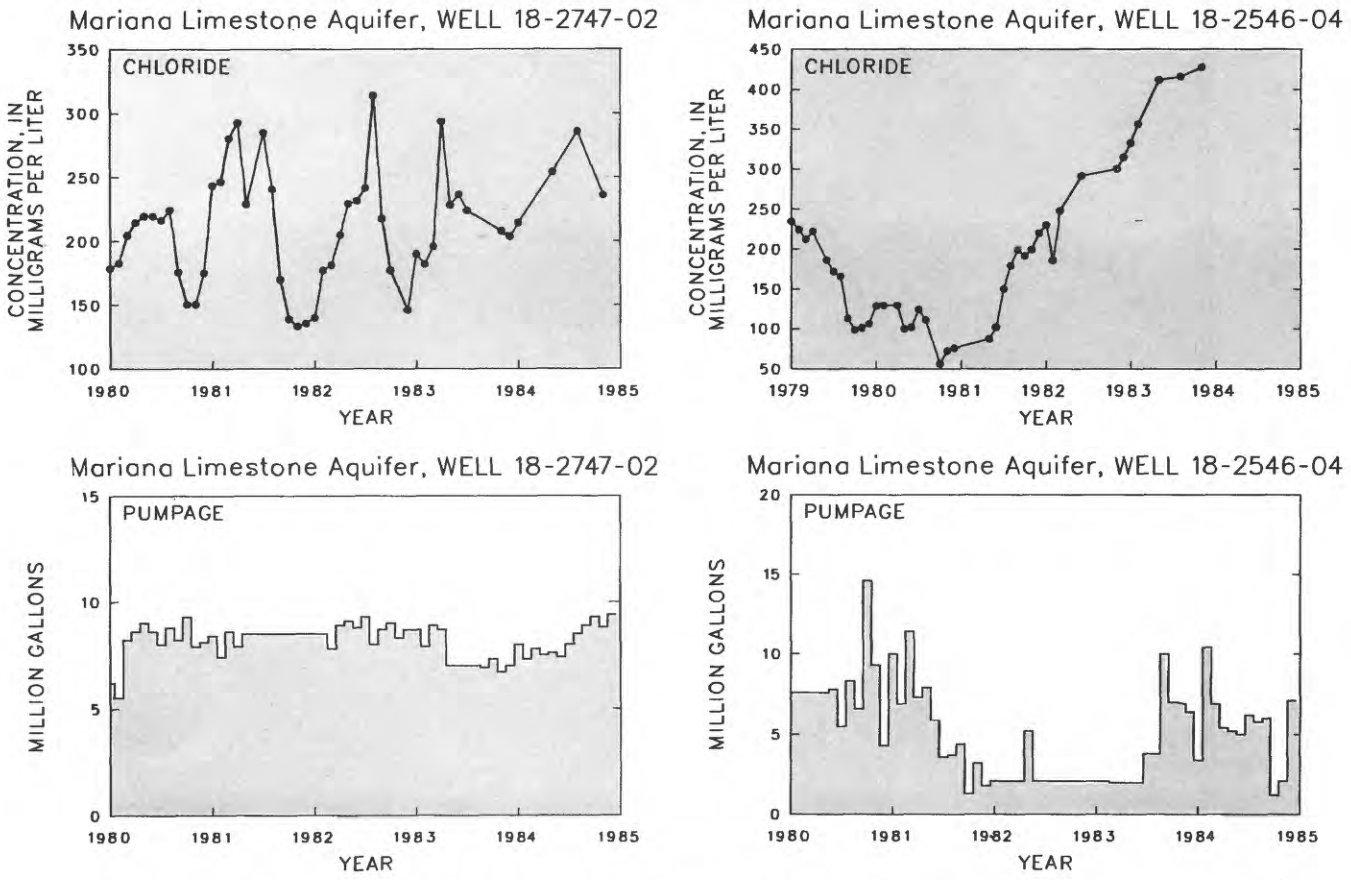

Figure 4. Long-term fluctuation pumpage and chloride concentration in selected wells in Guam, 1980–84. (Sources: U.S. Geological Survey files and Guam water-data-management system.)