STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA, JANUARY 1993 THROUGH MARCH 1995

U.S. GEOLOGICAL SURVEY
Open-File Report 95-473

Prepared in cooperation with the
U.S. DEPARTMENT OF THE NAVY
NAVY SUPPORT FACILITY, DIEGO GARCIA

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by Jill D. Torikai

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Honolulu, Hawaii
1995

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CONVERSION FACTORS AND ABBREVIATION

Multiply	By	To obtain
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
gallon per day (gal/d)	3.785	liter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year

Abbreviation used in water-quality descriptions
mg/L = milligram per liter

STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA, JANUARY 1993 THROUGH MARCH 1995

EXECUTIVE SUMMARY

This report contains hydrologic and climatic data that describe the status of ground-water resources at U.S. Navy Support Facility, Diego Garcia. Data presented are from January 1993 through March 1995, although the report focuses on hydrologic events from January through March 1995.

1. RAINFALL--Cumulative rainfall for January through March 1995 was about 42 inches which is higher than the mean cumulative rainfall of about 33 inches for the same 3 months in a year. January and February are part of the annual wet season and March is the start of the annual dry season. Rainfall for each month was above average from the respective mean monthly rainfall.

2. GROUND-WATER WITHDRAWAL--Ground-water withdrawal during January through March 1995 averaged 894,600 gallons per day. Withdrawal for the same 3 months in 1994 averaged 999,600 gallons per day.

3. CHLORIDE CONCENTRATION OF PUMPED GROUND WATER--At the end of March 1995, the chloride concentration of the composite water supply was 26 milligrams per liter, well below the 250 milligrams per liter secondary drinking-water standard established by the U.S. Environmental Protection Agency. Chloride concentrations of the composite water supply from January through March 1995 ranged between 19 and 49 milligrams per liter.

4. CHLORIDE CONCENTRATION OF GROUND WATER IN MONITORING WELLS--Chloride concentration of ground water in monitoring wells at Cantonment and Air Operations decreased since November 1994. The deepest monitoring wells show declines in chloride concentration by as much as 4000 milligrams per liter.

5. FUEL-DIVERSION PROGRAM AT AIR OPERATIONS--A fuel leak at Air Operations caused the shutdown of ten wells in May 1991. Four of the wells resumed pumping for water-supply purposes in April 1992. The remaining six wells are being used to hydraulically contain and divert fuel migration by recirculating about 150,000 gallons of water each day.

STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA, JANUARY 1993 THROUGH MARCH 1995

By Jill D. Torikai

INTRODUCTION

Background

Diego Garcia Atoll is a British Indian Ocean Territory and the site of a U.S. Navy Support Facility. The island's drinking-water supply is derived from ground water by a system of more than 100 shallow wells in five production areas (fig. 1). Water from the Cantonment and Air Operations areas combined account for about 99 percent of total island pumpage. The remainder is pumped for local use at Industrial Site South, Transmitter Site, and GEODSS Site. The system has been in operation since 1978 and has provided about 1 Mgal/d since 1984.

Long-term ground-water management has been facilitated by a cooperative agreement between the Navy Support Facility and the U.S. Geological Survey (USGS) since 1984. The Diego Garcia Long-Term Ground-Water Management Program involves data collection and analysis of daily rainfall, daily pumpage from individual wells, and chloride concentrations of water from all production and monitoring wells. The data are provided to the USGS by the Navy Support Facility, Public Works Department on Diego Garcia. The data are analyzed for hydrologic responses to pumping and climatic variability, and recent trends in the data are identified. This report is part of a series of quarterly data reports regarding Diego Garcia.

Organization of Report

This data summary contains hydrologic and climatic data that describe the status of ground-water resources at Navy Support Facility, Diego Garcia. Data presented are from January 1993 through March 1995. Data of primary relevance to the water supply are:

1. Rainfall
2. Volume of ground water withdrawn at production wells
3. Chloride concentration of pumped ground water
4. Chloride concentration of ground water sampled from monitoring wells
5. Volume of ground water injected at Air Operations

The following narrative highlights trends in the data for January through March 1995. Ground-water withdrawal and chloride concentrations of water from individual wells are presented in the "Hydrologic-Data Section." The data section contains the following:

A. Maps of production and monitoring wells at Cantonment and Air Operations
B. Graphs of monthly mean ground-water withdrawal, January 1993 through March 1995
C. Graphs of chloride concentration of pumped water, January 1993 through March 1995

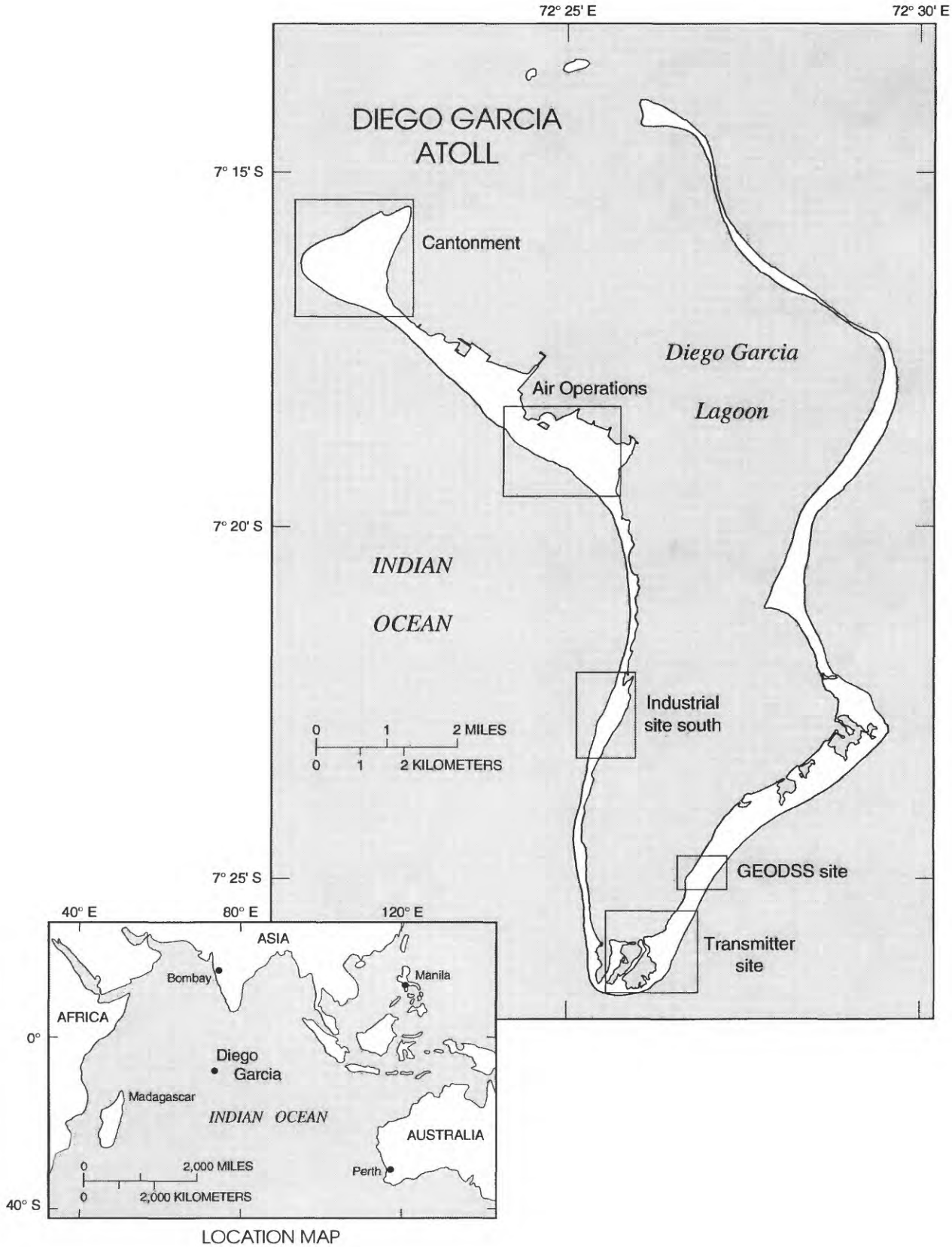


Figure 1. Areas of ground-water production, Diego Garcia.

RAINFALL

Background.--The mean annual rainfall at Diego Garcia for the fixed base period 1951-90 is 105.78 in/yr. Rainfall varies considerably from month to month and from year to year. A wet season occurs from about September through February, and a dry season occurs from about March through August.

Recent trends.--Cumulative rainfall for January through March 1995 was 41.98 inches which is more than the mean cumulative rainfall of 32.52 inches for the first 3 months of a year. For the same 3 months in 1993 and 1994, the cumulative rainfall was 27.38 inches and 37.37 inches, respectively. In 1993, the total rainfall of 94.77 inches was 10 percent below the mean annual rainfall, while in 1994 the total rainfall of 131.17 inches was 24 percent above the mean.

Figure 2 shows graphs of recorded rainfall amounts and rainfall departures from mean monthly rainfall values that were averaged for the base period 1951-90. Periods of below average rainfall can be inferred from the graph when the departure from the mean monthly rainfall is less than zero. Monthly rainfall for January through March 1995 was greater than the mean monthly rainfall for each month.

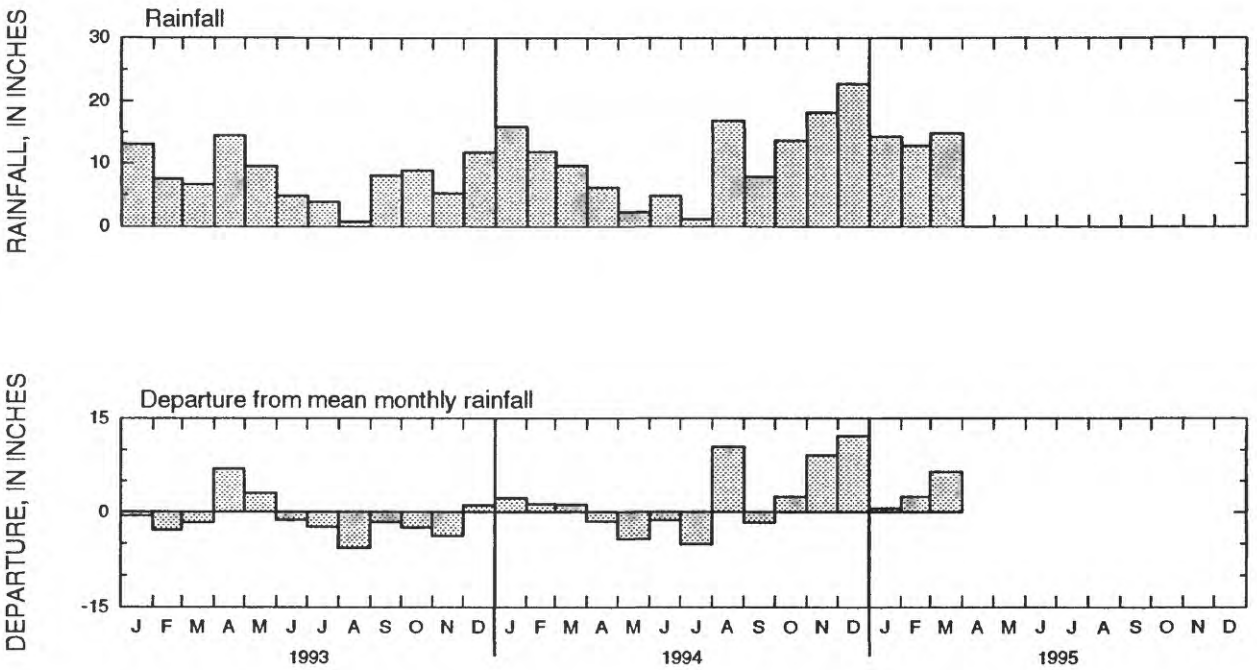


Figure 2. Monthly rainfall and monthly departure from mean monthly rainfall at Air Operations, Diego Garcia, January 1993 through March 1995.

GROUND-WATER WITHDRAWAL

Background.--Withdrawal is measured by flow meters at all production wells and storage tanks in the water system, and is recorded daily. There are 102 production wells that are situated in five ground-water production areas, of which 80 wells are in the Cantonment area and 18 are in the Air Operations area (figs. A1, A2). The wells in the Cantonment area are further divided into sub-groups, and the measured ground-water withdrawals are reported as such in this summary.

Recent trends.--Figure 3 shows time-series graphs of monthly mean withdrawal islandwide and in each ground-water production area from January 1993 through March 1995. Patterns of withdrawal during the first quarter of 1995 have not changed significantly from 1993-94 in all areas. Total islandwide withdrawal decreased from 999,600 gal/d during January through March 1994 to 894,600 gal/d during January through March 1995.

Pumpage from the Cantonment area increased in 1991 when the area began supplying an extra demand due to decreased pumpage at Air Operations. Ten wells at Air Operations were temporarily closed from May 1991 through April 1992 due to an underground fuel pipeline leak near those wells. Pumping has since resumed at four wells in the water-supply system, but six Air Operations wells still do not pump to the water supply because of the close proximity to the fuel leak. Ground-water withdrawals from the other ground-water production areas have been held at fairly regular rates since 1992.

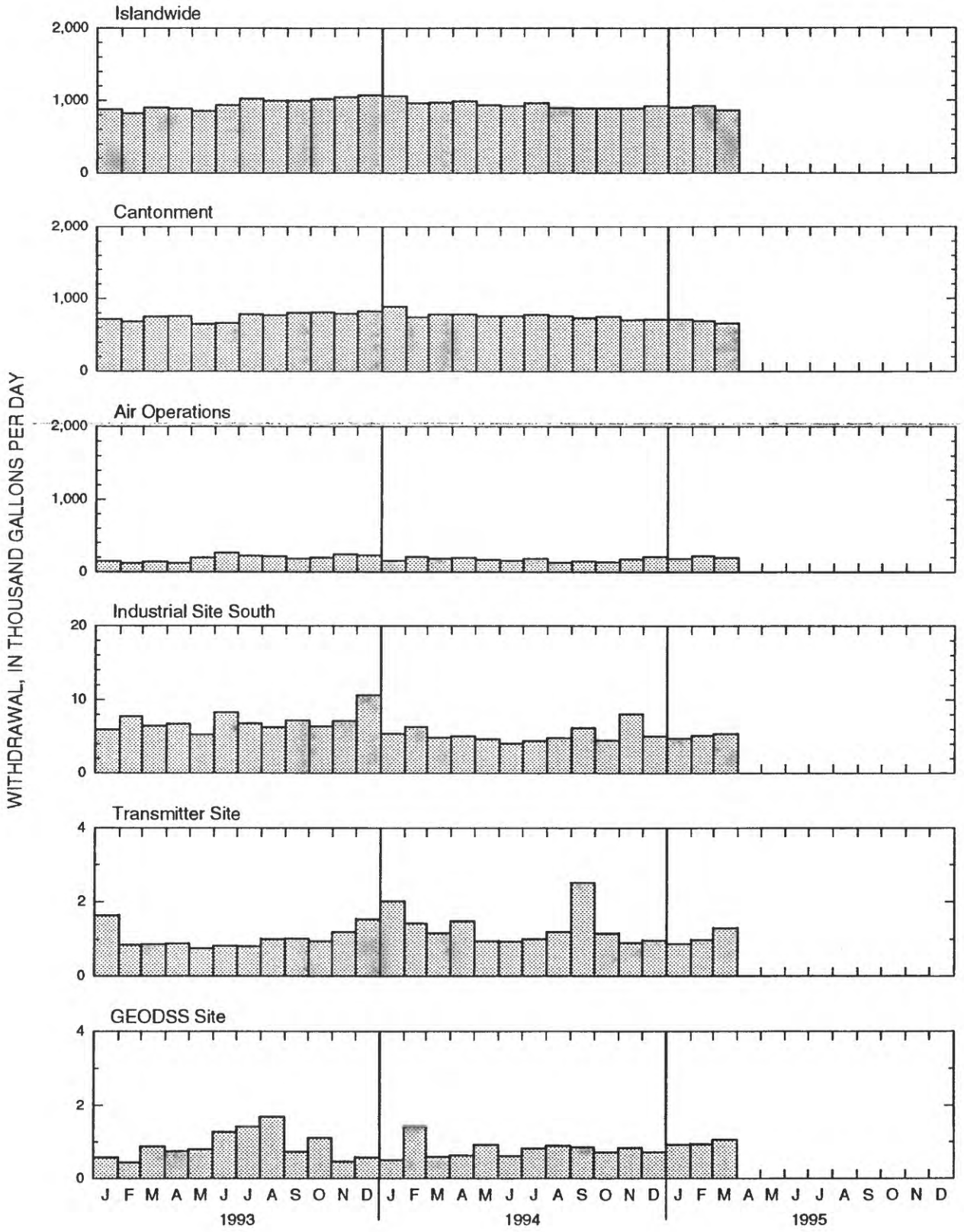


Figure 3. Monthly mean ground-water withdrawal islandwide and in the ground-water production areas, Diego Garcia, January 1993 through March 1995.

CHLORIDE CONCENTRATION OF PUMPED GROUND WATER

Background.--Chloride concentration is used as a quantitative measure of salinity in this summary. Chloride concentration in seawater at Diego Garcia is about 19,500 mg/L whereas a concentration of 250 mg/L is the maximum contaminant level (MCL) under secondary drinking-water standards (U.S. Environmental Protection Agency, 1991). Secondary standards are not enforceable limits, but instead establish goals for constituents that may affect the aesthetic qualities of drinking water, such as taste or color.

Water is sampled at weekly intervals at all wells and storage tanks in the production system. Water in the Air Operations tank is a blend of ground water withdrawn from wells in the Air Operations area only, whereas the Cantonment tank water is a mixture of ground water from wells in both the Air Operations and Cantonment areas. This composite tank transmits about 99 percent of total island pumpage. Thus, the chloride concentration of water sampled from the Cantonment tank is considered representative of the overall water supply.

Recent trends.--The chloride concentration of the composite water supply at the end of March 1995 was 26 mg/L, well below the 250 mg/L secondary drinking-water standard. The range of chloride concentrations for the composite water supply ranged from 19 to 49 mg/L from January through March 1995 (fig. 4). Chloride concentrations of the composite water in the Cantonment tank has remained at less than 100 mg/L since 1990 (Torikai, in press). The chloride concentration of water sampled from the Air Operations tank has fluctuated between about 50 to 200 mg/L since 1992, but has remained at about 50 mg/L since November 1994. Chloride concentrations of water sampled from Industrial Site South and Transmitter Site are 100 to 300 mg/L, and are about 100 mg/L at GEODSS Site during the first quarter of 1995.

Decreases in chloride concentration of less than 100 mg/L in Modules A through L and in wells H1 through H7 at Cantonment, and in wells AO-2 through AO-9 at Air Operations were observed from about October 1994 through March 1995 (see figs. C1 and C2 in the Hydrologic-Data Section C, p. 34-37, and fig. C4 in the Hydrologic-Data Section C, p. 39-41). Wells Q1, Q2, Q4, and Q6 at the Cantonment area show similar trends, but the decrease in chloride concentration is about 200 mg/L (see figs. C3 in the Hydrologic-Data Section C, p. 38).

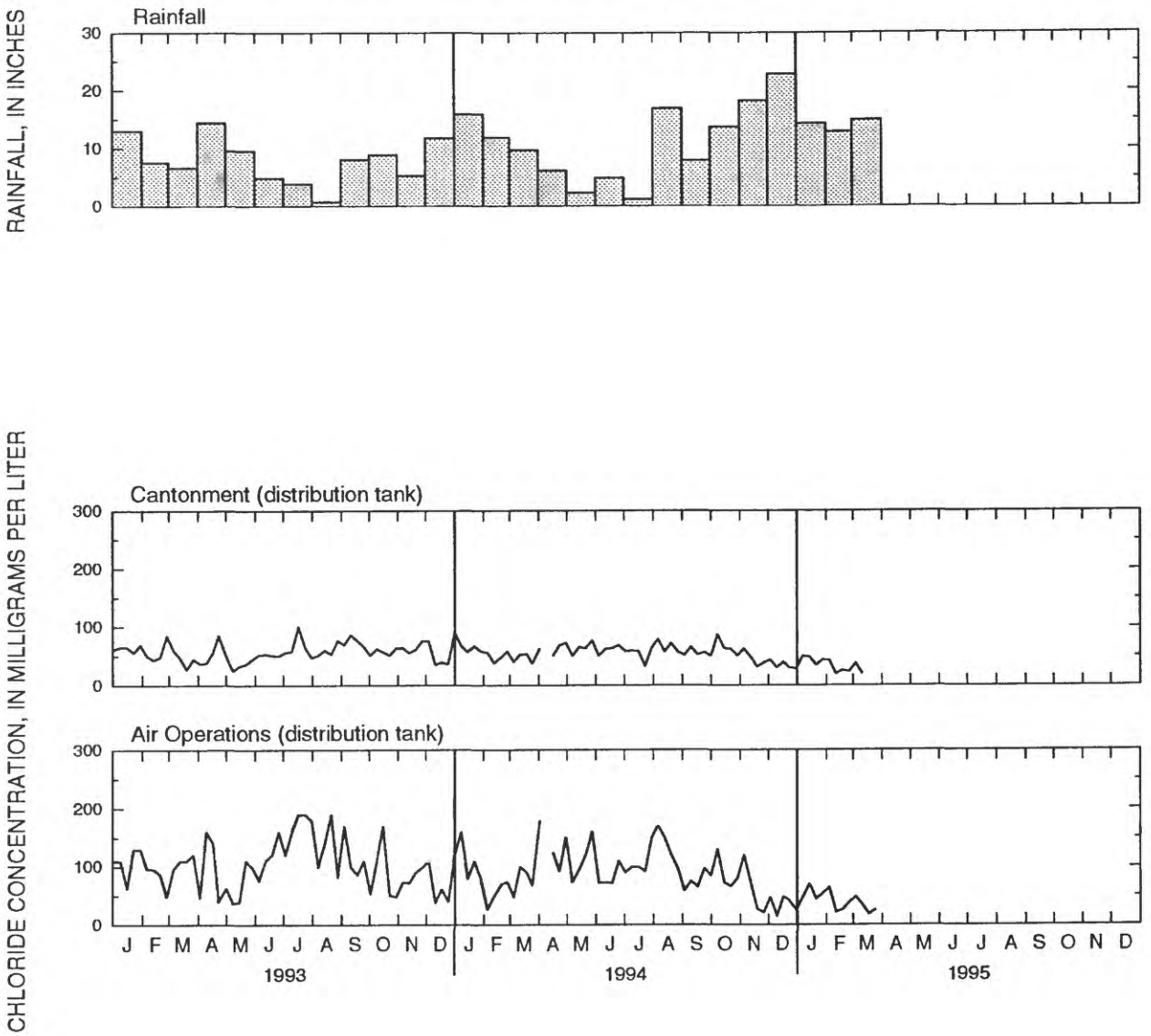


Figure 4. Chloride concentration of pumped water (sampled at weekly intervals) in the ground-water production areas, Diego Garcia, January 1993 through March 1995. Rainfall data are shown for comparison.

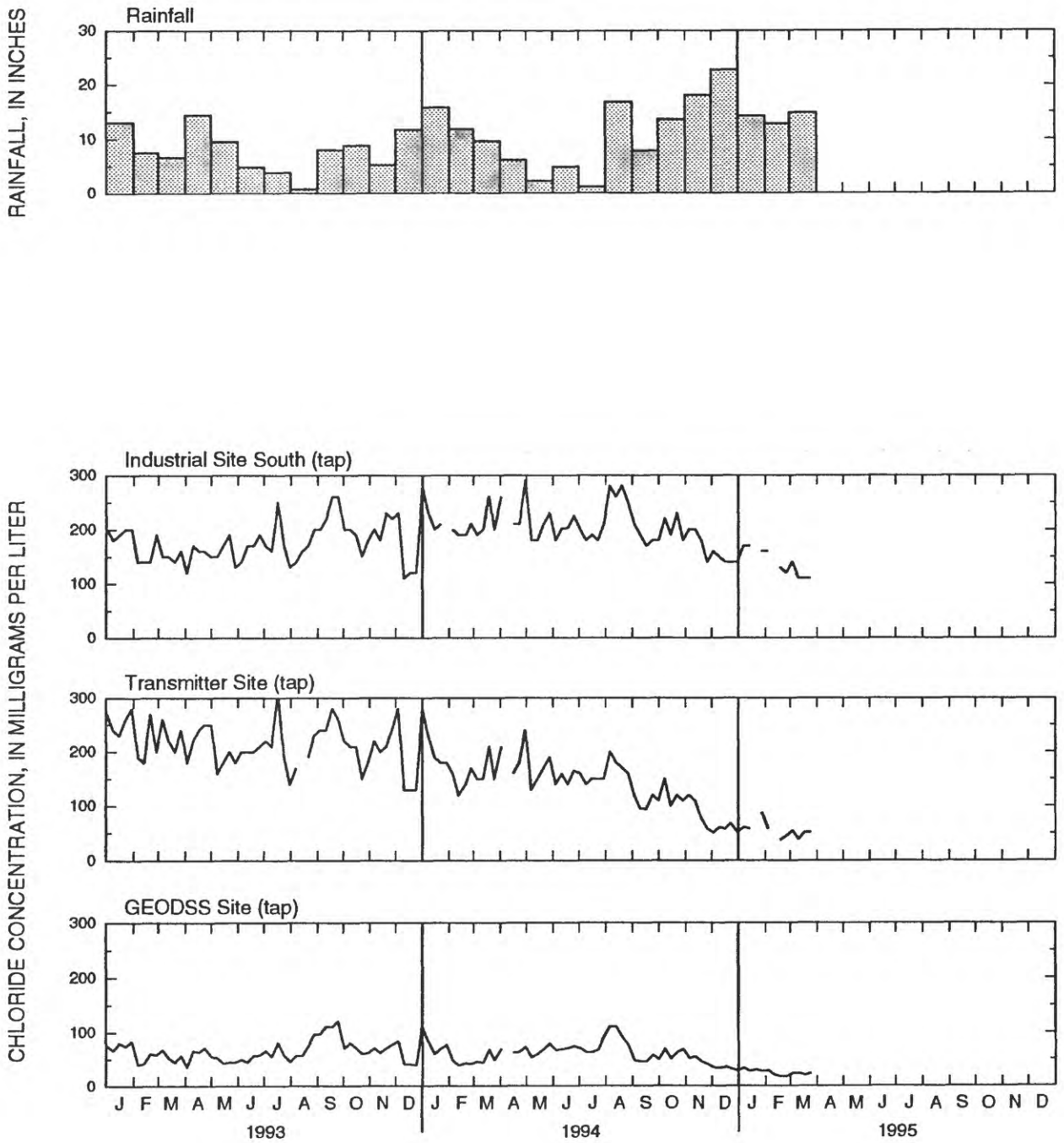


Figure 4 continued.--Chloride concentration of pumped water (sampled at weekly intervals) in the ground-water production areas, Diego Garcia, January 1993 through March 1995. Rainfall data are shown for comparison.

CHLORIDE CONCENTRATION OF GROUND WATER IN MONITORING WELLS

Background.--Ground-water chloride concentration is measured monthly at 35 monitoring-well sites to help estimate freshwater-lens thickness and indicate possible saltwater upconing due to above average pumping (figs. A3, A4). Each site comprises several wells, with each well having a short screened (open) interval that bottoms at a different depth. The deeper wells typically tap the freshwater-saltwater mixing zone that underlies the freshwater lenses.

Recent trends.--Monitoring sites AW16 and BW09 were selected to show trends in ground-water chloride concentration at Cantonment and Air Operations Areas, respectively. Figures 5 and 6 show time-series graphs of chloride concentration at different depths at these sites, with rainfall data included in the figures for climatic reference. Chloride concentrations of the water decreased or leveled off at both sites during January through March 1995. A general trend of increasing chloride concentrations was observed in the deepest monitoring wells since the 1992 dry season. However, since November 1994, these same wells show declines in chloride concentrations by as much as 4000 mg/L.

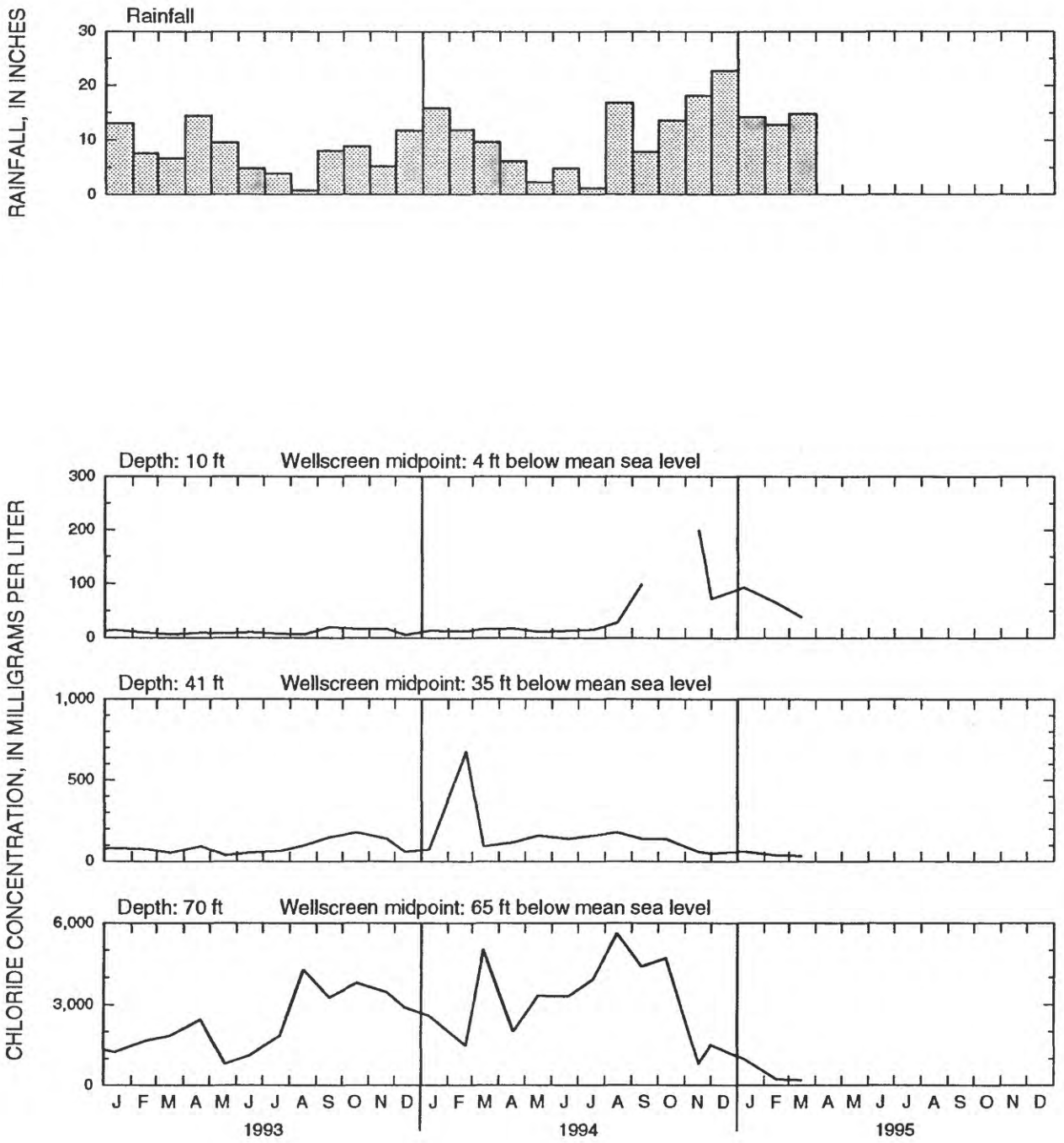


Figure 5. Chloride concentration of ground water (sampled at monthly intervals) in monitoring wells at site AW16 at Cantonment, Diego Garcia, January 1993 through March 1995. Rainfall data are shown for comparison.

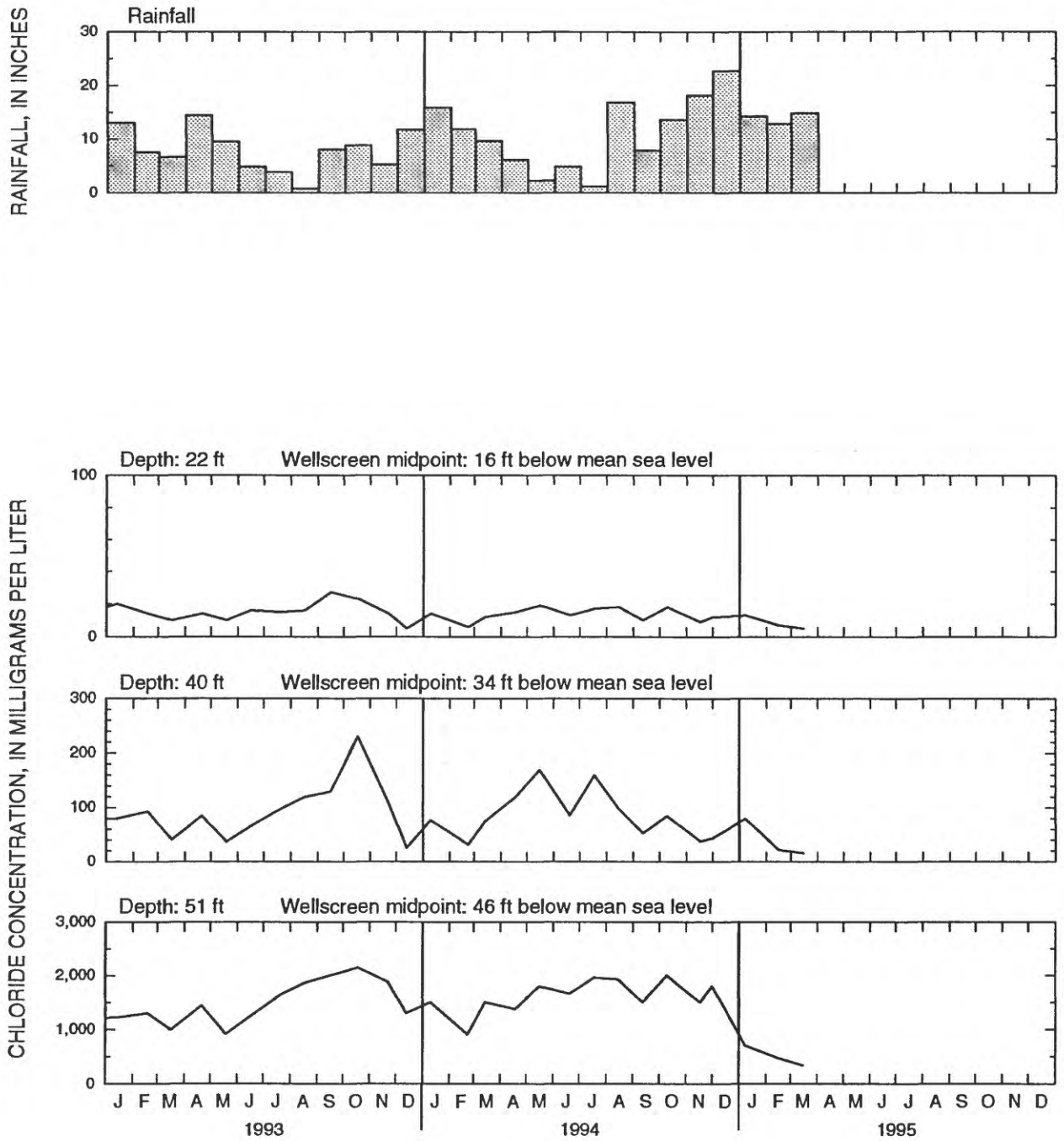


Figure 6. Chloride concentration of ground water (sampled at monthly intervals) in monitoring wells at site BW09 at Air Operations, Diego Garcia, January 1993 through March 1995. Rainfall data are shown for comparison.

FUEL-DIVERSION PROGRAM AT AIR OPERATIONS

Background.--The normal pattern of ground-water withdrawal at Air Operations has been disrupted since May 1991 by a jet-fuel leak at the South Ramp Parking Apron (fig. A2). In April 1992, a program was initiated to hydraulically divert fuel away from the production wells. The fuel-diversion program consists of pumping water from wells AO-14 and AO-15 and directing this water through the common collection main to the wells nearest the leak (AO-10, 11, 12), where it is injected back into the aquifer. Wells AO-10 through AO-15 were shut down from May 1991 to April 1992, but have since been used in the closed recirculation loop of withdrawal and injection.

Injection data for wells AO-10, 11, 12 from May 10, 1993 through September 1994 are actual water-meter readings. From April 1992 through early May 1993, meter readings of injection were not available, and daily injection at each of the three wells was estimated to be one-third of the total daily withdrawal from wells AO-13, 14, 15 which provided the injection-supply water. Monthly mean withdrawal and injection at wells AO-10 through AO-15 are shown in figure 7.

Recent trends.--Withdrawal and injection rates for the hydraulic-diversion program are based on target rates for wells AO-10 through AO-15, with total water recirculation of about 150,000 gal/d (table 1).

Table 1. Target and actual withdrawal and injection rates for hydraulic-diversion program.
[Injection is denoted by negative values; all values are in gallons per day.]

Well	Target rates	Daily mean rates, January through March 1995
AO-10	-30,000	-30,100
AO-11	-50,000	-52,400
AO-12	-70,000	-65,900
AO-13	0	0
AO-14	70,000	76,200
AO-15	80,000	76,600

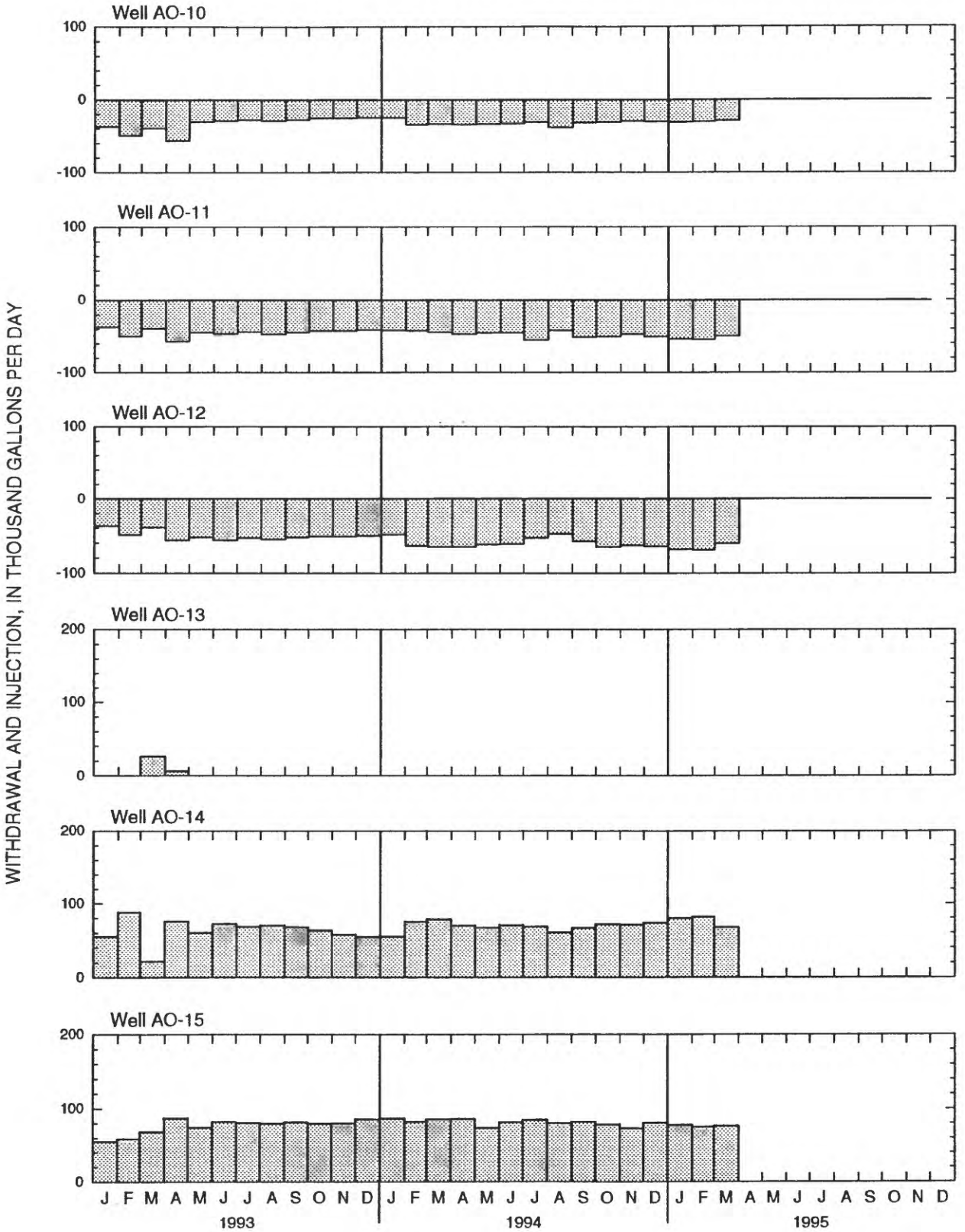


Figure 7. Monthly mean ground-water withdrawal and injection at wells AO-10 through AO-15 at Air Operations, Diego Garcia, January 1993 through March 1995. Injection is plotted as negative.

HYDROLOGIC-DATA SECTION

TYPES OF DATA INCLUDED

A. Maps of production and monitoring wells at Cantonment and Air Operations
B. Graphs of monthly mean ground-water withdrawal, January 1993 through March 1995
C. Graphs of chloride concentration of pumped water, January 1993 through March 1995

DESCRIPTIONS OF PRINCIPAL PRODUCTION SOURCES AT CANTONMENT AND AIR OPERATIONS AREAS

Cantonment Area

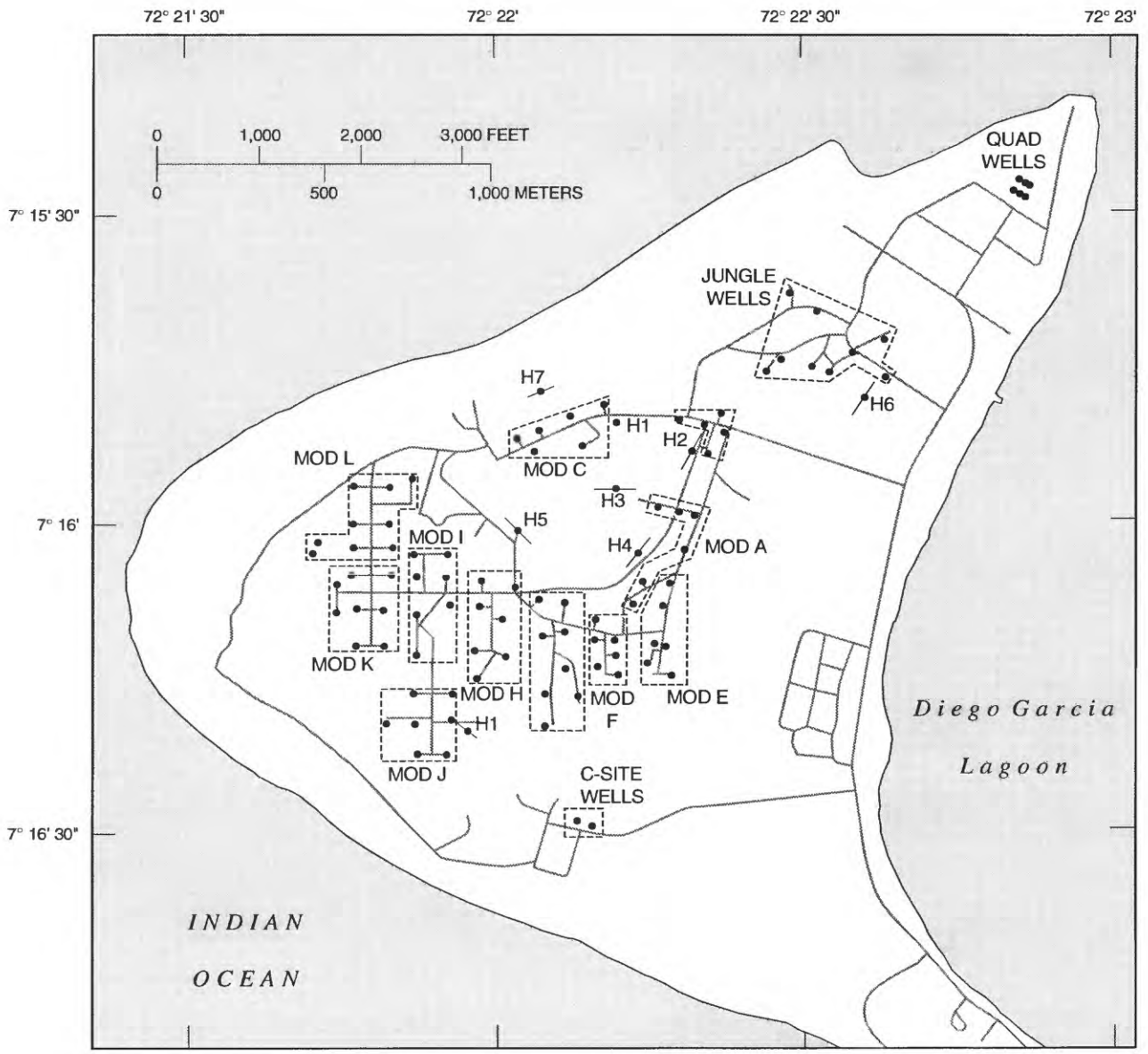
1. Modules A, C through L - each module is a well field of five to eight vertical wells that are pumped to a common collection/transfer tank.
2. Module B is a horizontal well with a collection/transfer tank; has not pumped since August 1986.
3. Wells H1 through H7 are horizontal wells.
4. Quad wells are a well field of four vertical wells.
5. Jungle wells are a well field of 11 vertical wells; have not pumped since February 1987.

Air Operations Area

1. Wells AO-2 through AO-5 are vertical wells.
2. Wells AO-6 through AO-9 are horizontal wells.
3. Wells AO-10 through AO-12 are horizontal wells; currently receiving injection water to divert fuel contaminants from a nearby leak. No samples are currently collected for chloride-concentration analysis.
4. Wells AO-13 through AO-15 are horizontal wells; AO-14 and AO-15 are currently pumping water to injection wells AO-10 through AO-12, while AO-13 is not pumping.
5. AO-16 through AO-19 are horizontal wells.

SECTION A

Maps of production and monitoring wells at Cantonment and Air Operations



EXPLANATION

QUAD WELLS — VERTICAL WELL AND WELL OR WELL FIELD DESIGNATION--Typical pumping rate 10 to 12 gallons per minute

H7 — HORIZONTAL WELL AND DESIGNATION--Typical pumping rate 50 to 75 gallons per minute

MOD E — WELL MODULE AND DESIGNATION--Vertical well that pump to a common 1,000-gallon collection and transfer tank

Figure A1. Ground-water production wells and well fields at Cantonment, Diego Garcia.

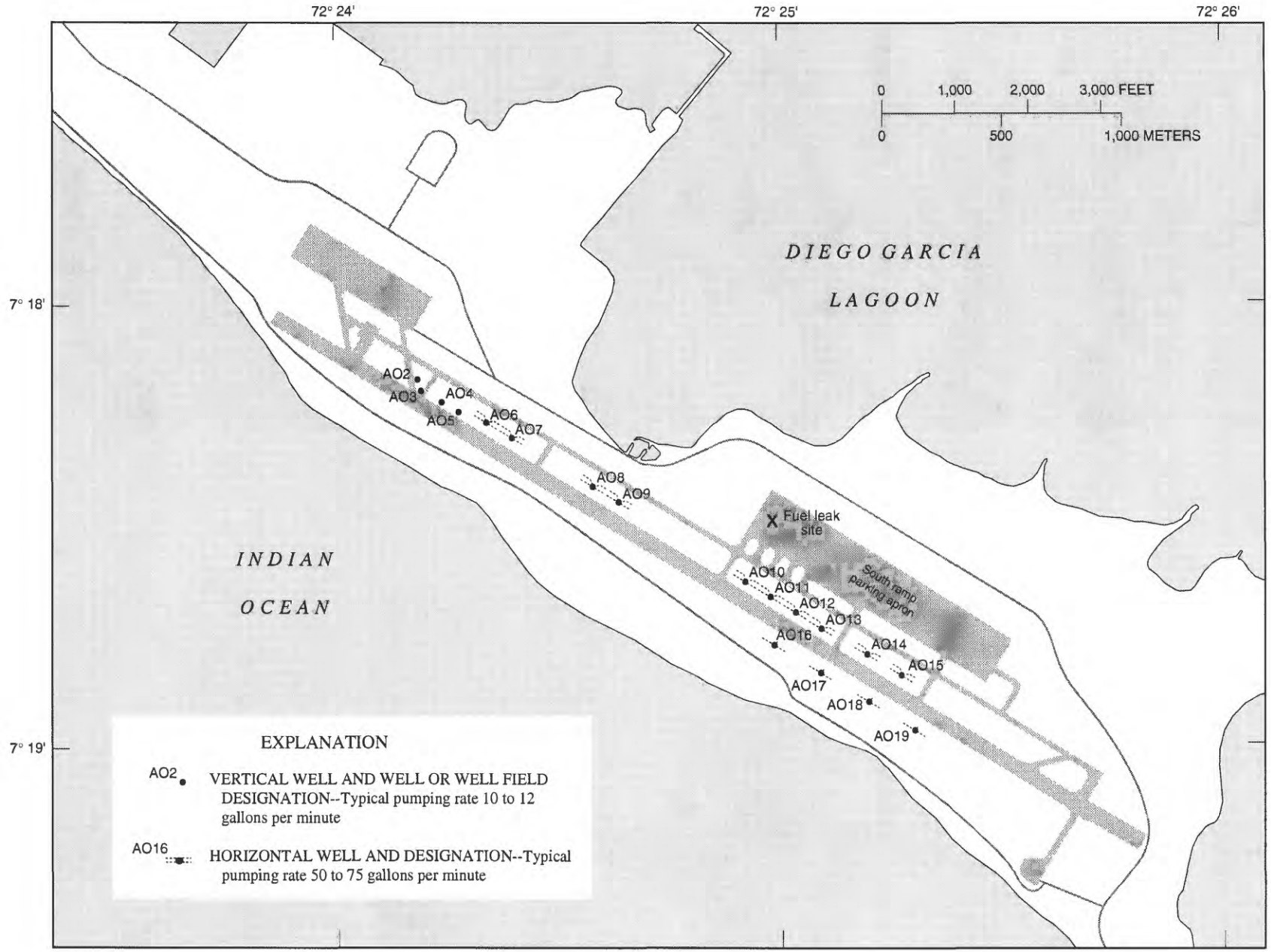
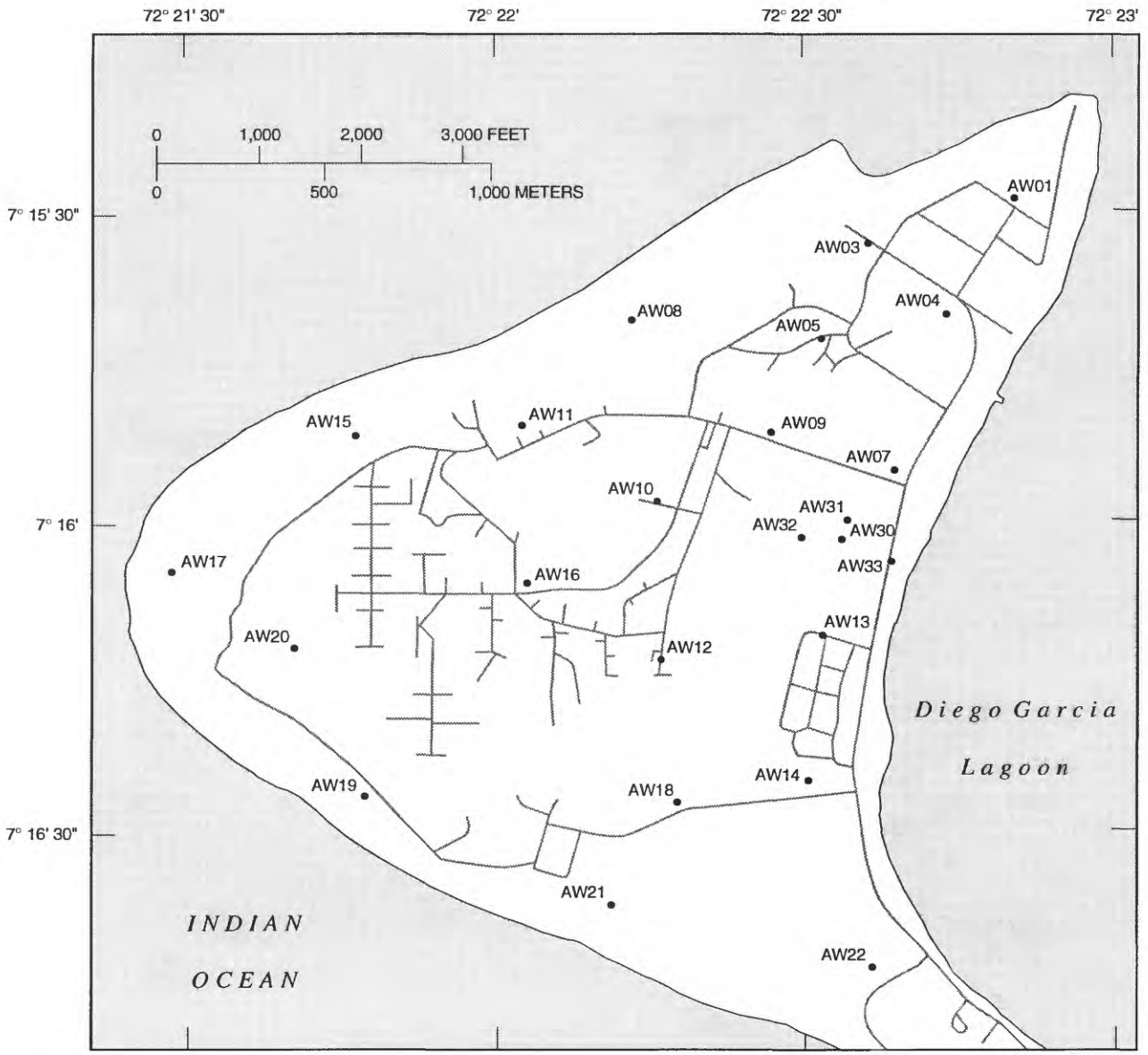


Figure A2. Ground-water production wells at Air Operations, Diego Garcia.



EXPLANATION

AW21 • MONITORING SITE AND DESIGNATION--Consisting of two or more monitoring wells with short (2 to 5 foot) open intervals of different depths

Figure A3. Monitoring wells at Cantonment, Diego Garcia.

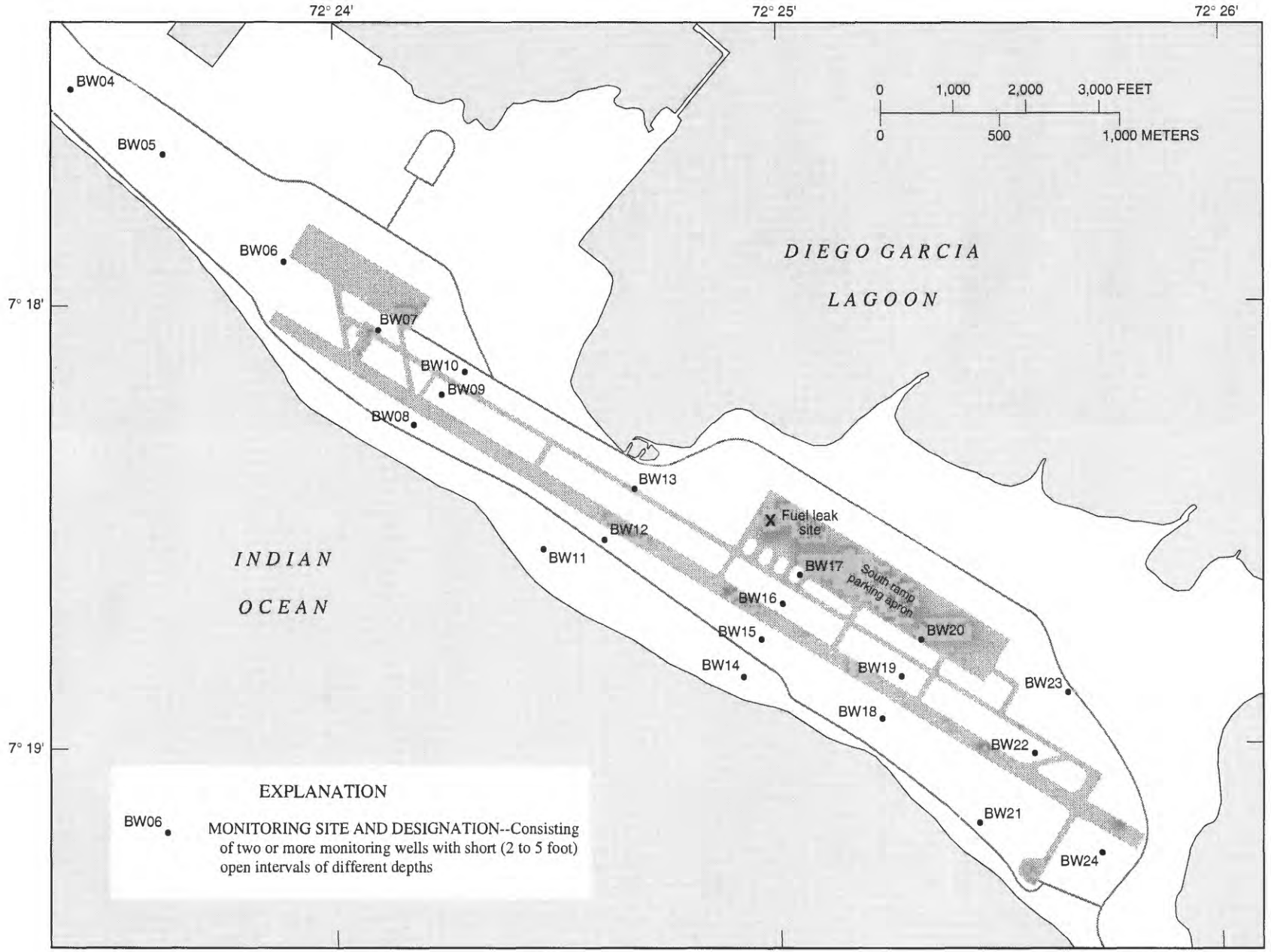


Figure A4. Monitoring wells at Air Operations, Diego Garcia.

SECTION B

Graphs of monthly mean ground-water withdrawal, January 1993 through March 1995

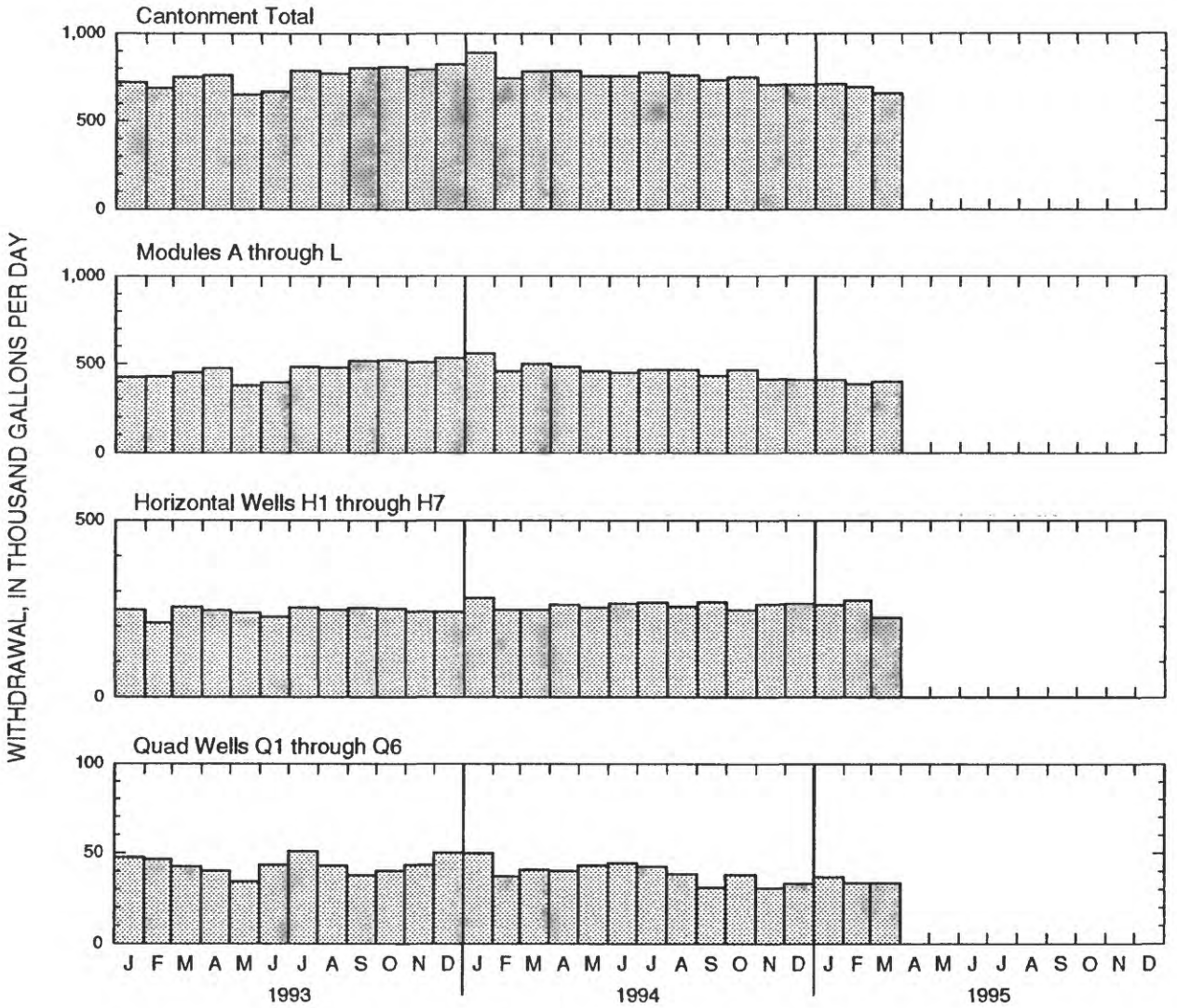


Figure B1. Monthly mean ground-water withdrawal at Cantonment, Diego Garcia, January 1993 through March 1995.

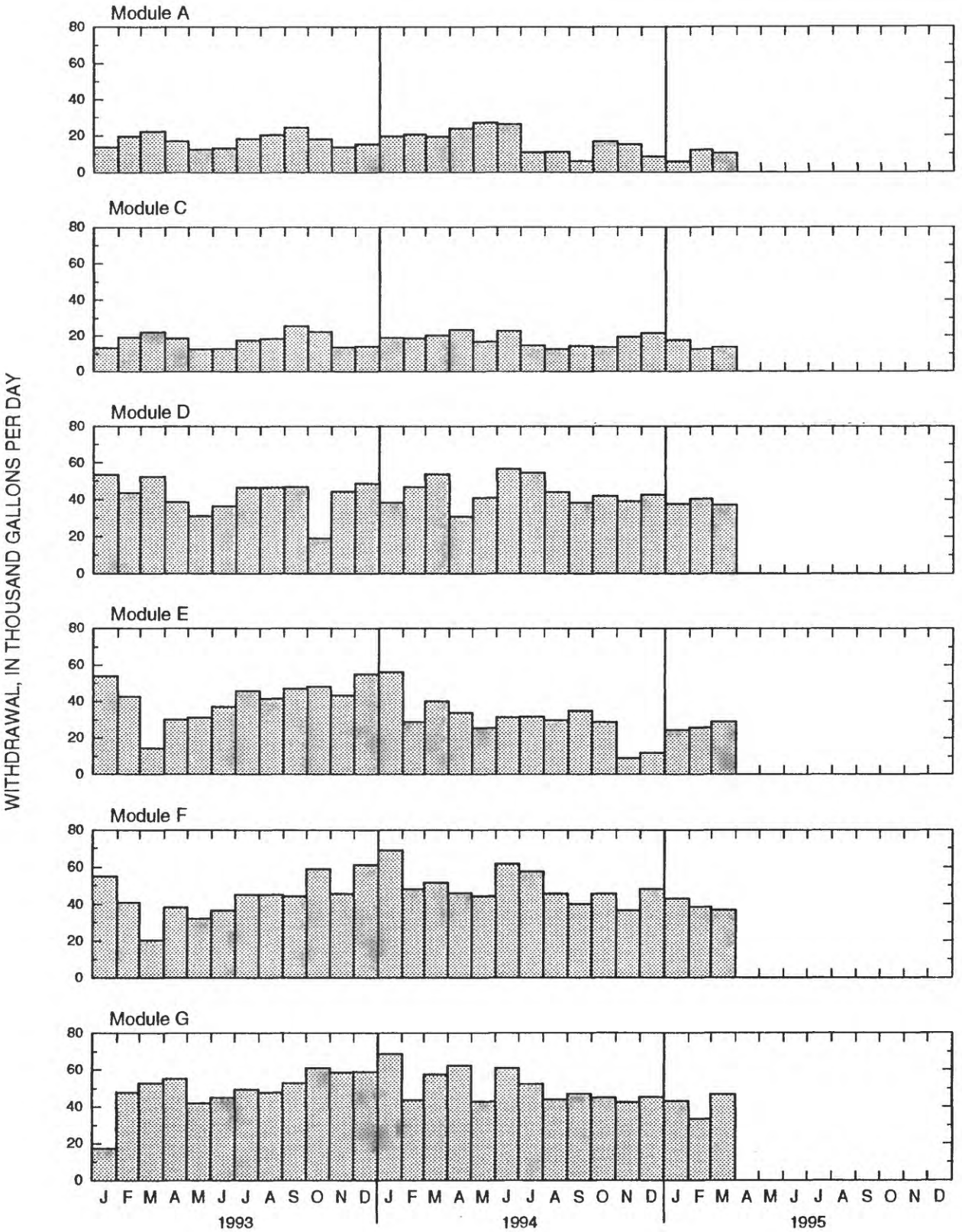


Figure B2. Monthly mean ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, January 1993 through March 1995.

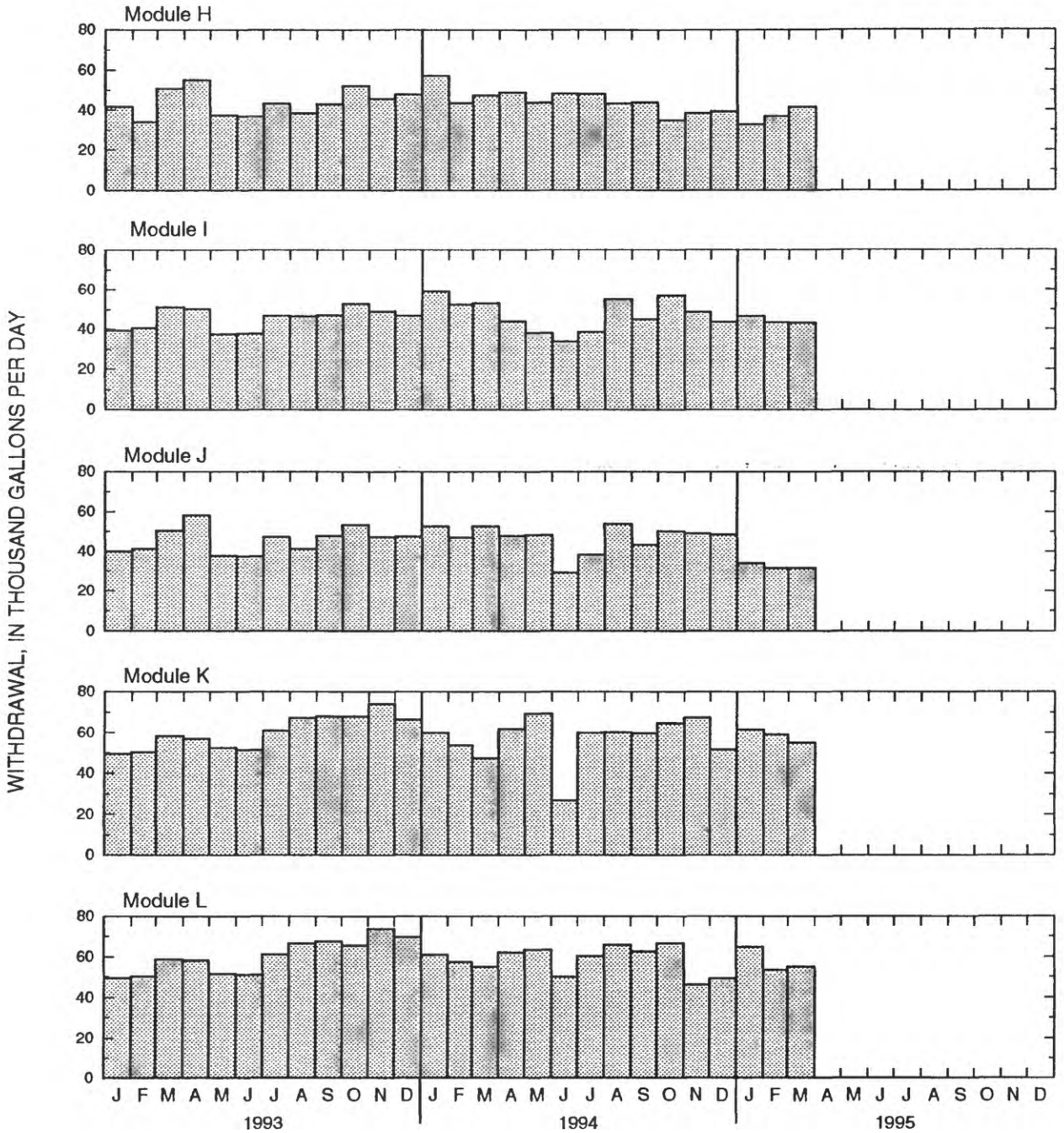


Figure B2 continued.--Monthly mean ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, January 1993 through March 1995.

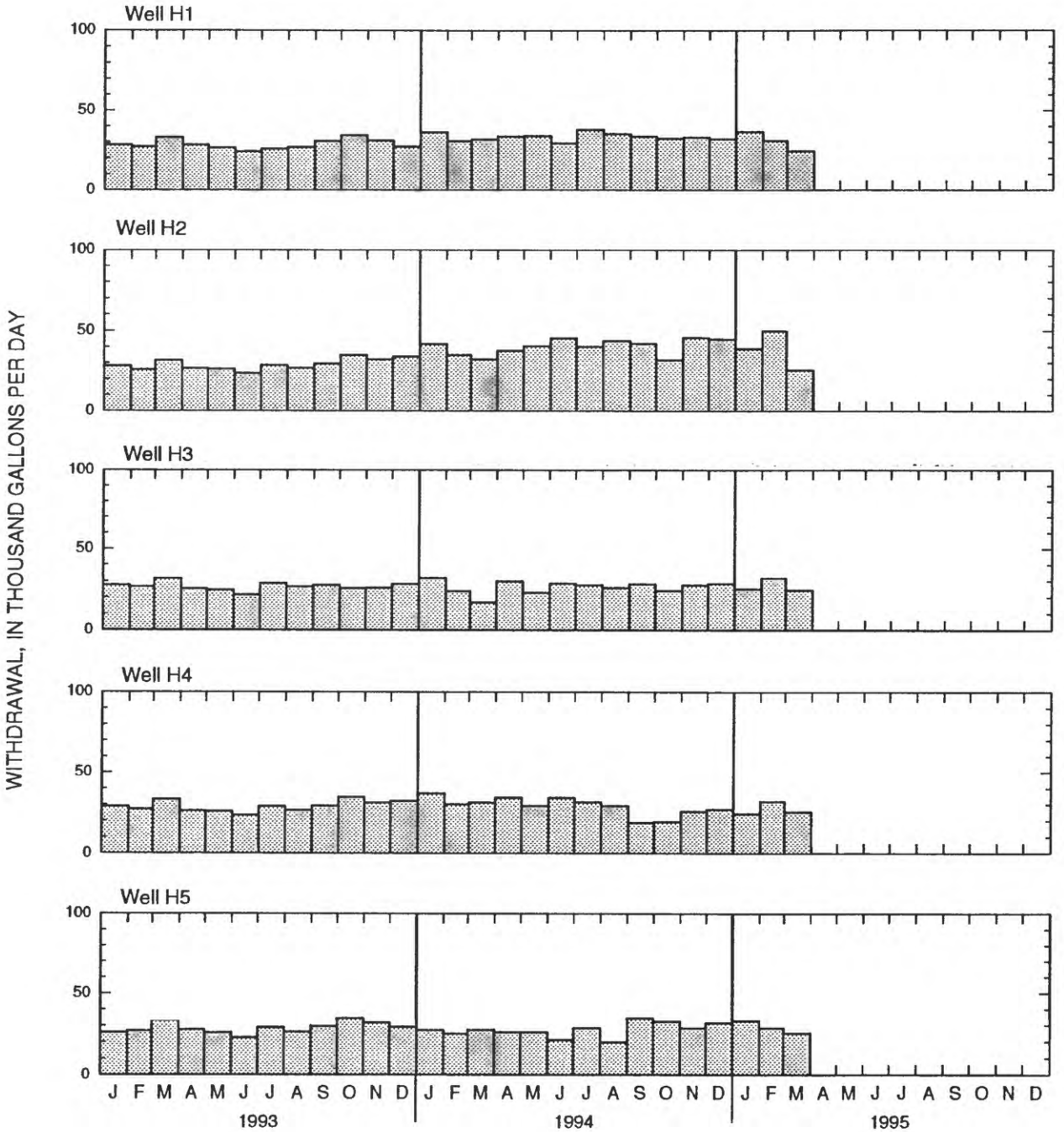


Figure B3. Monthly mean ground-water withdrawal at wells H1 through H7 at Cantonment, Diego Garcia, January 1993 through March 1995.

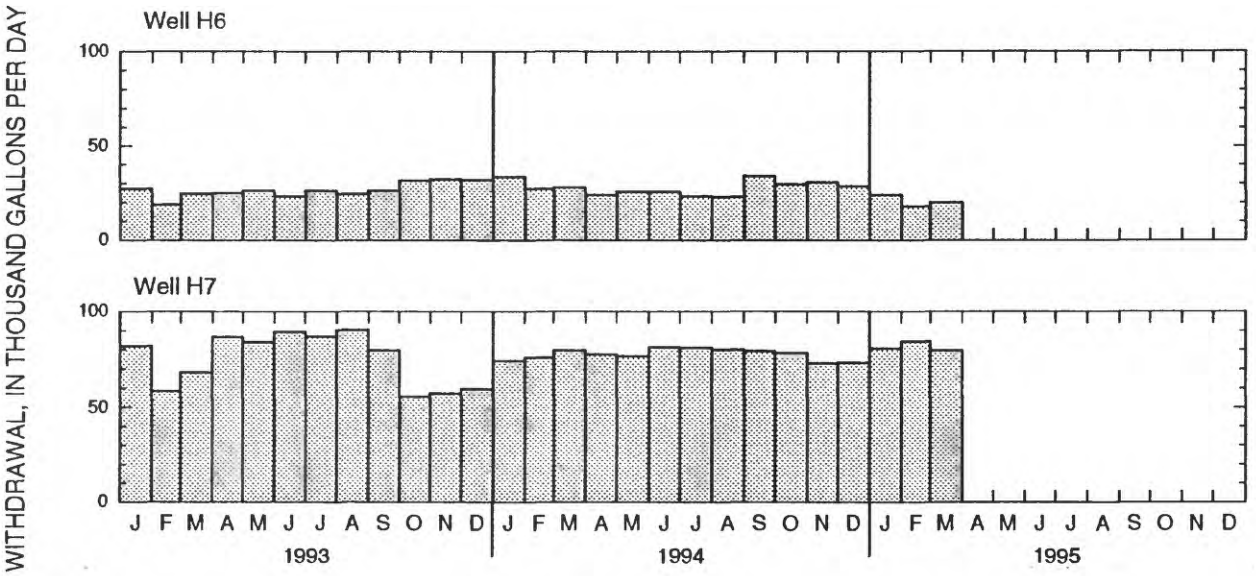


Figure B3 continued.--Monthly mean ground-water withdrawal at wells H1 through H7 at Cantonment, Diego Garcia, January 1993 through March 1995.

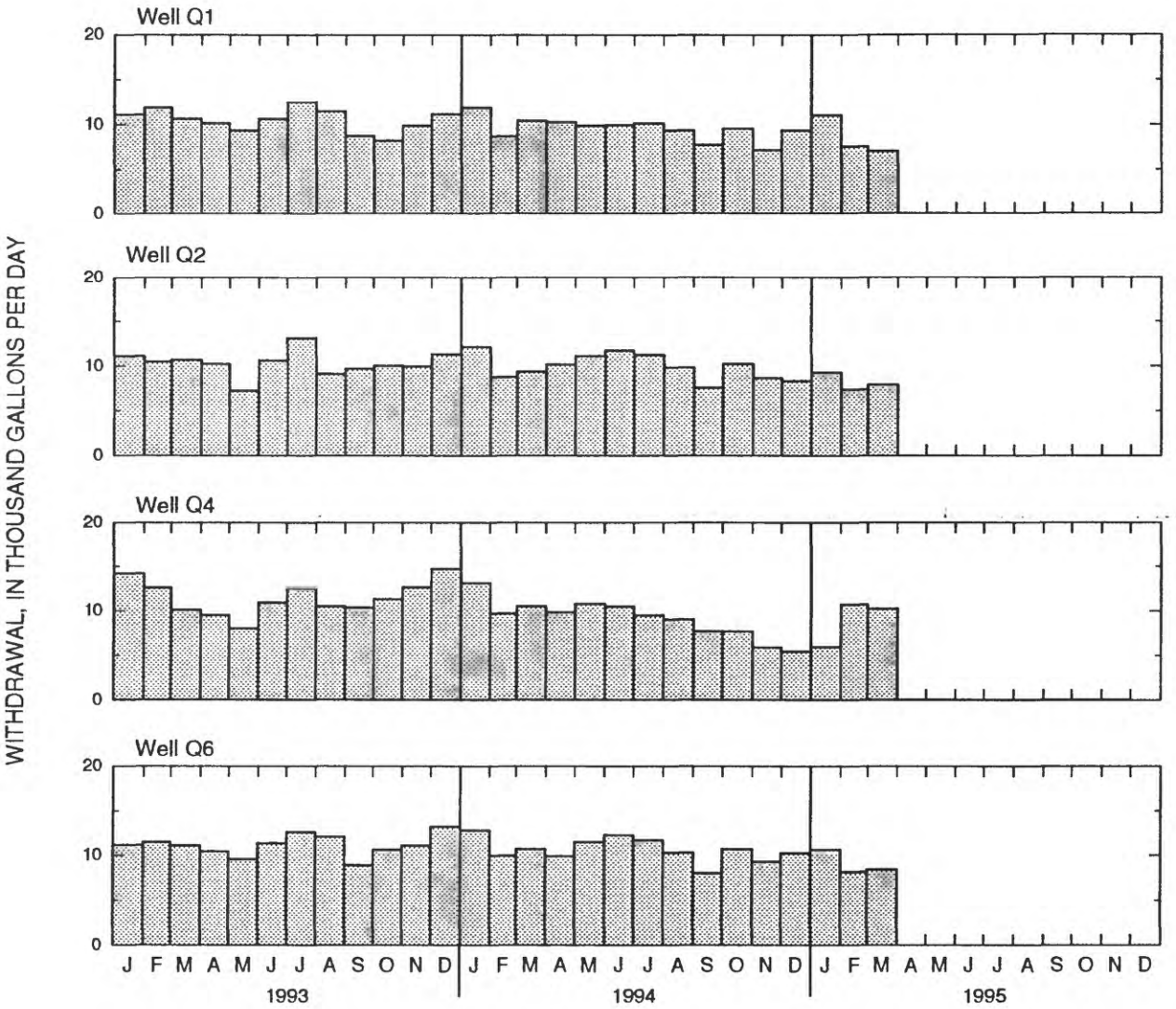


Figure B4. Monthly mean ground-water withdrawal at wells Q1, Q2, Q4, and Q6 at Cantonment, Diego Garcia, January 1993 through March 1995.

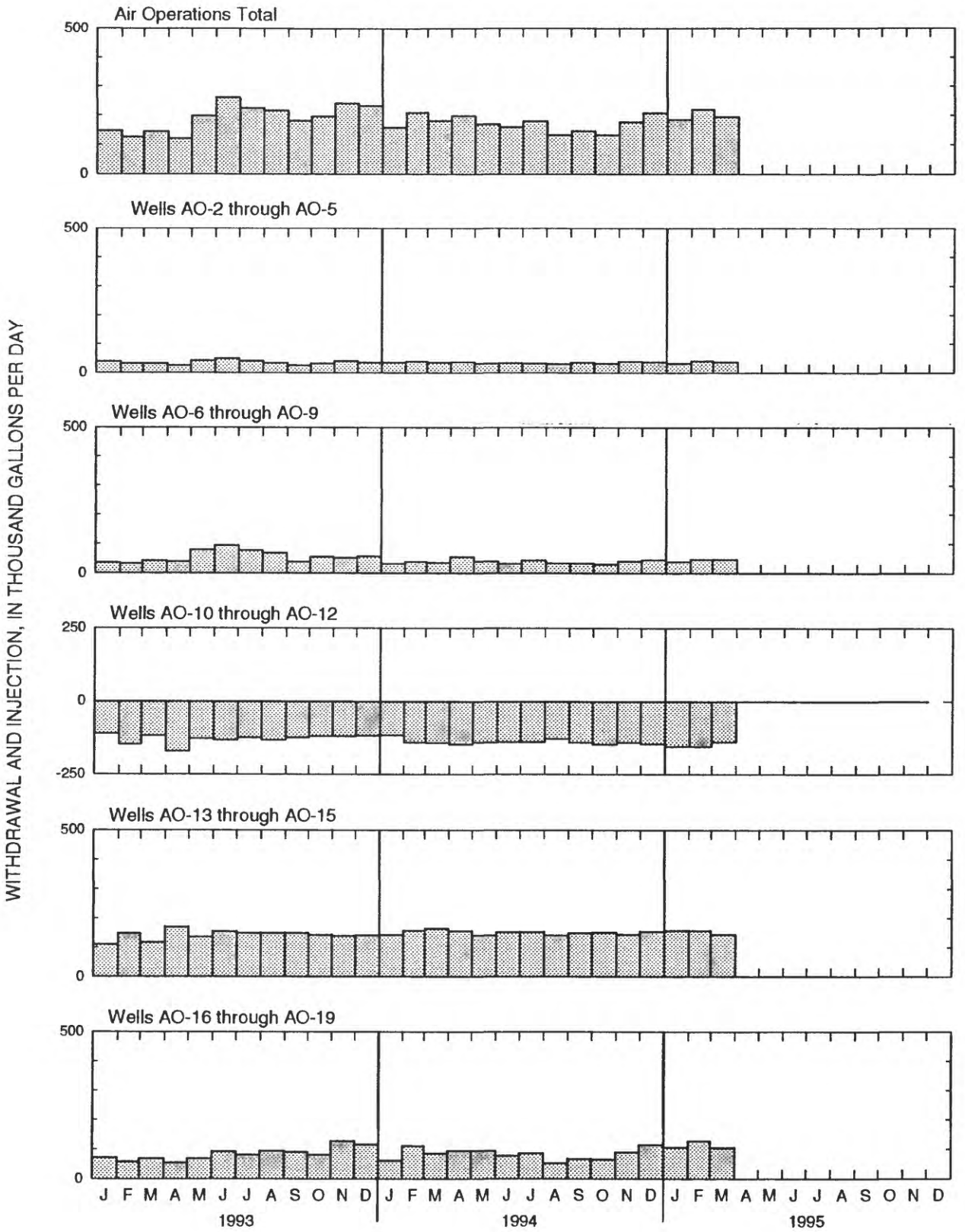


Figure B5. Monthly mean ground-water withdrawal and injection at Air Operations, Diego Garcia, January 1993 through March 1995. Injection is plotted as negative.

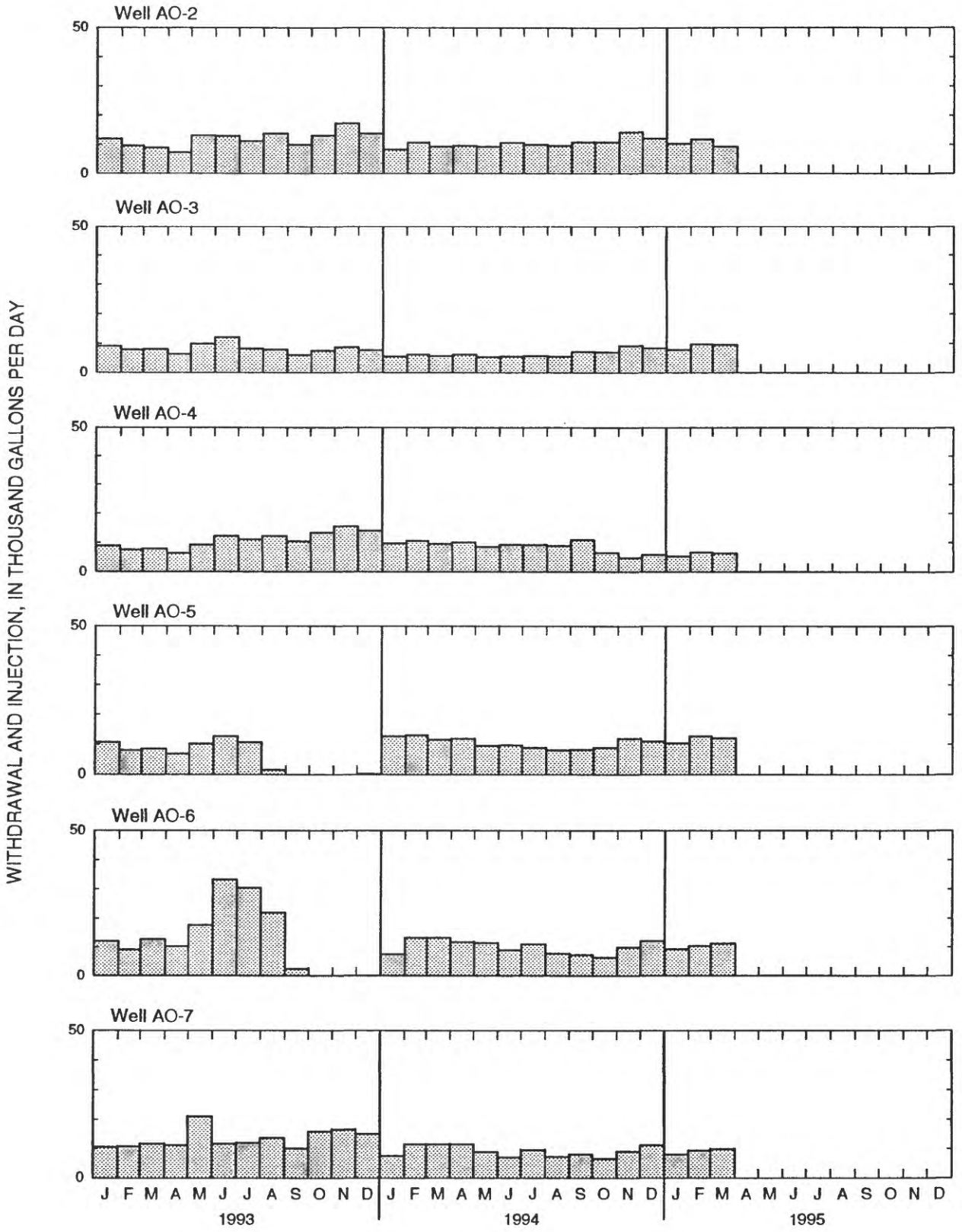


Figure B6. Monthly mean ground-water withdrawal and injection at wells AO-2 through AO-19 at Air Operations, Diego Garcia, January 1993 through March 1995. Injection is plotted as negative.

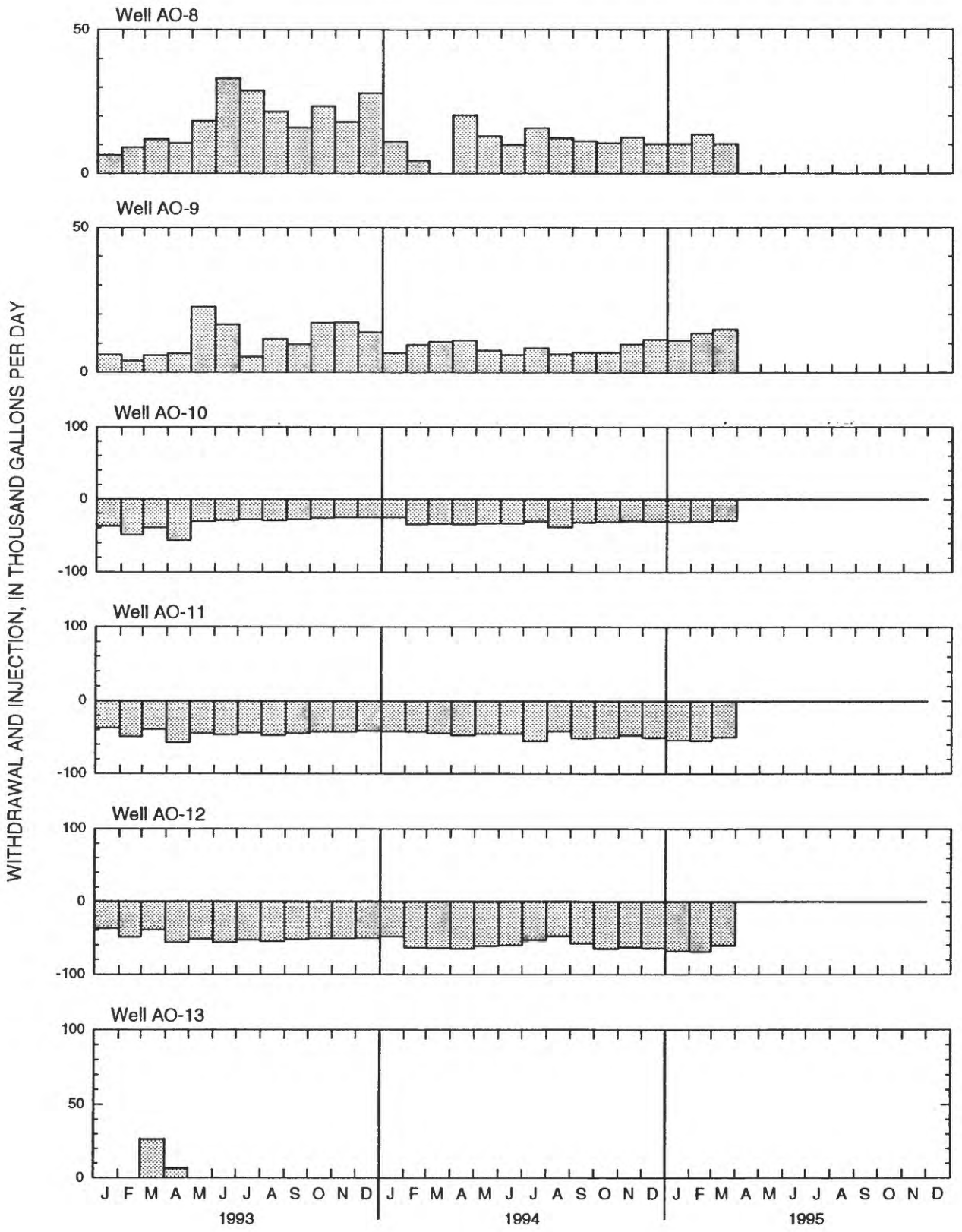


Figure B6 continued.--Monthly mean ground-water withdrawal and injection at wells AO-2 through AO-19 at Air Operations, Diego Garcia, January 1993 through March 1995. Injection is plotted as negative.

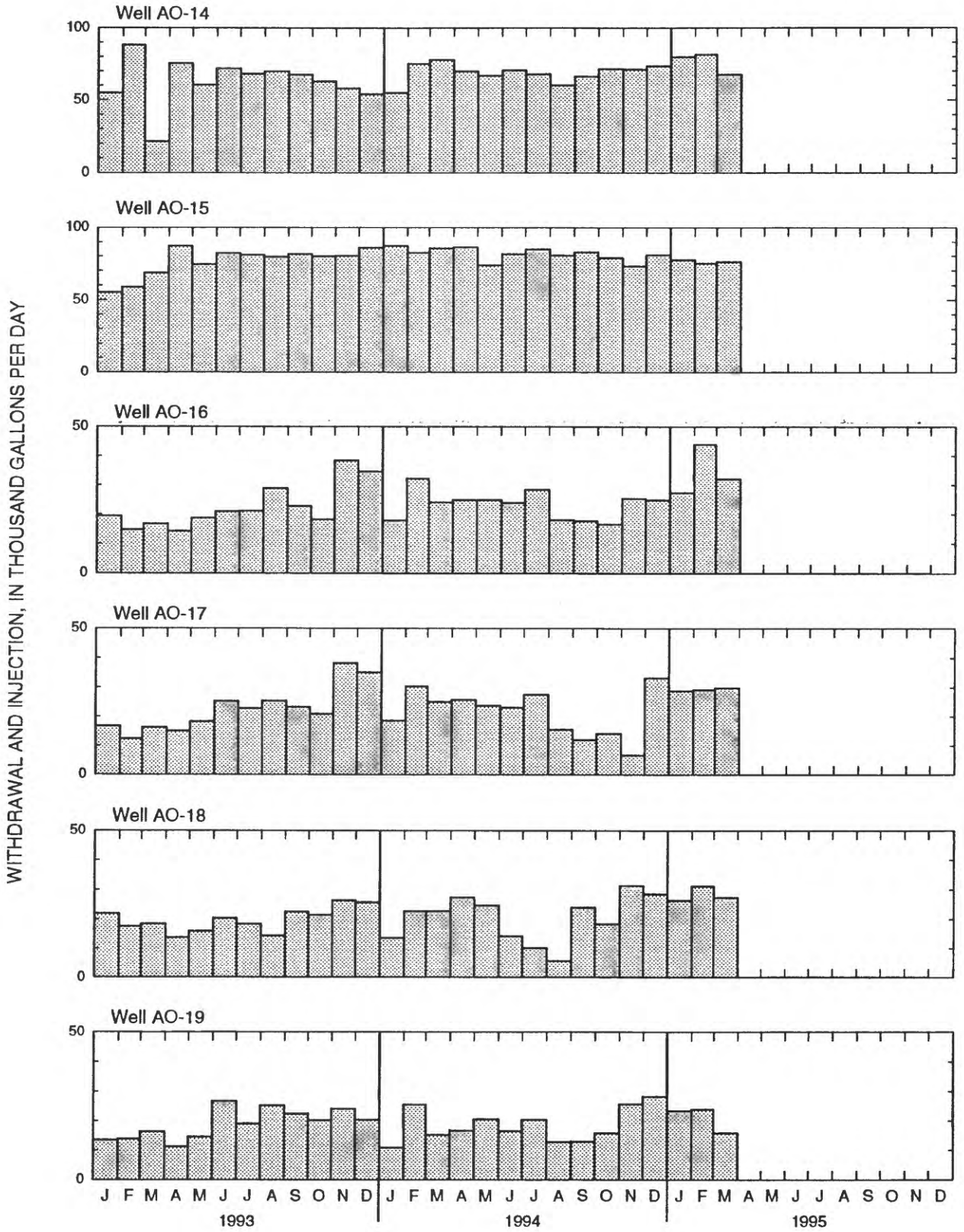


Figure B6 continued.--Monthly mean ground-water withdrawal and injection at wells AO-2 through AO-19 at Air Operations, Diego Garcia, January 1993 through March 1995. Injection is plotted as negative.

SECTION C

Graphs of chloride concentration of pumped water, January 1993 through March 1995

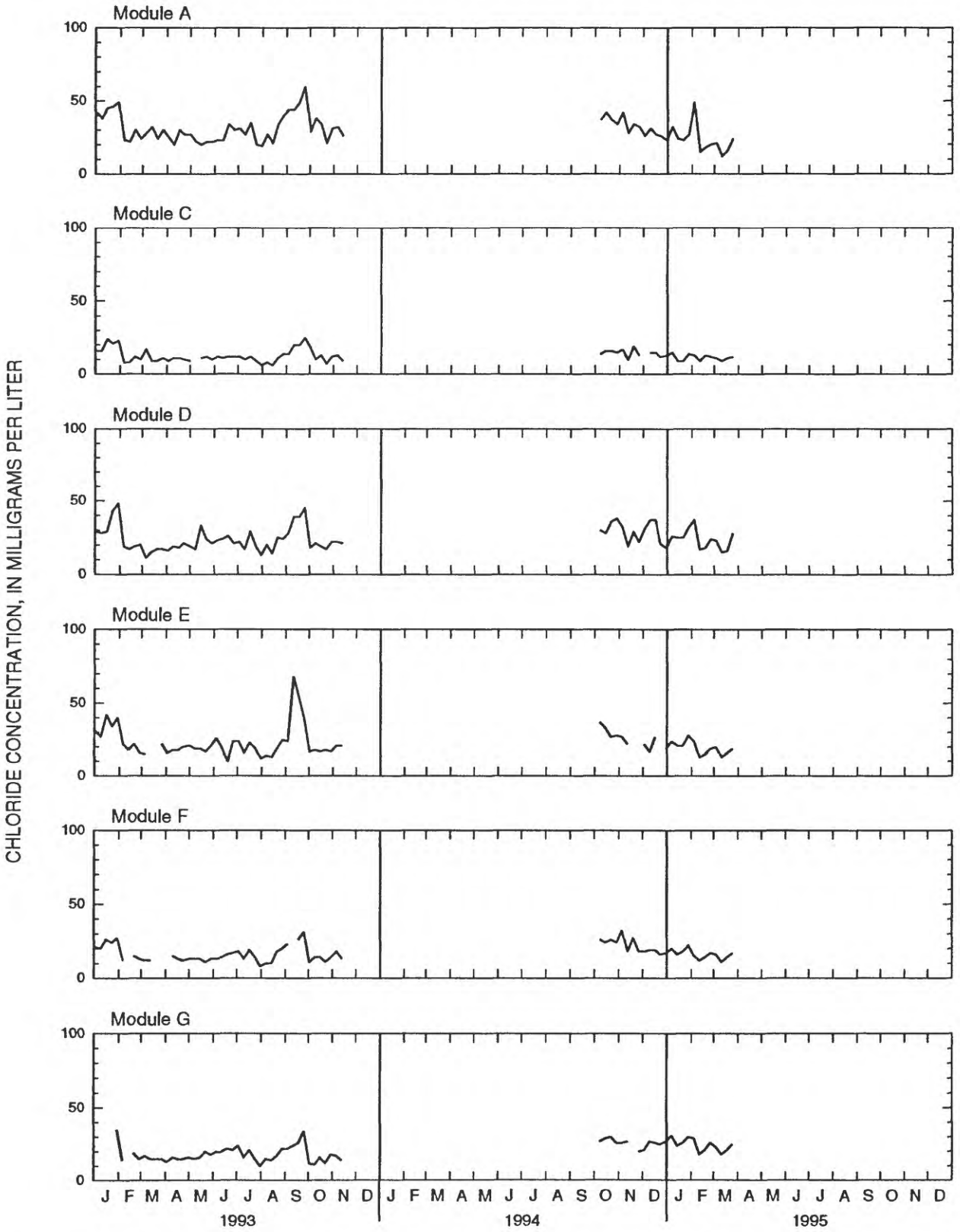


Figure C1. Chloride concentration of pumped water (sampled at weekly intervals) at Modules A through L at Cantonment, Diego Garcia, January 1993 through March 1995. Data not available for November 1993 through September 1994.

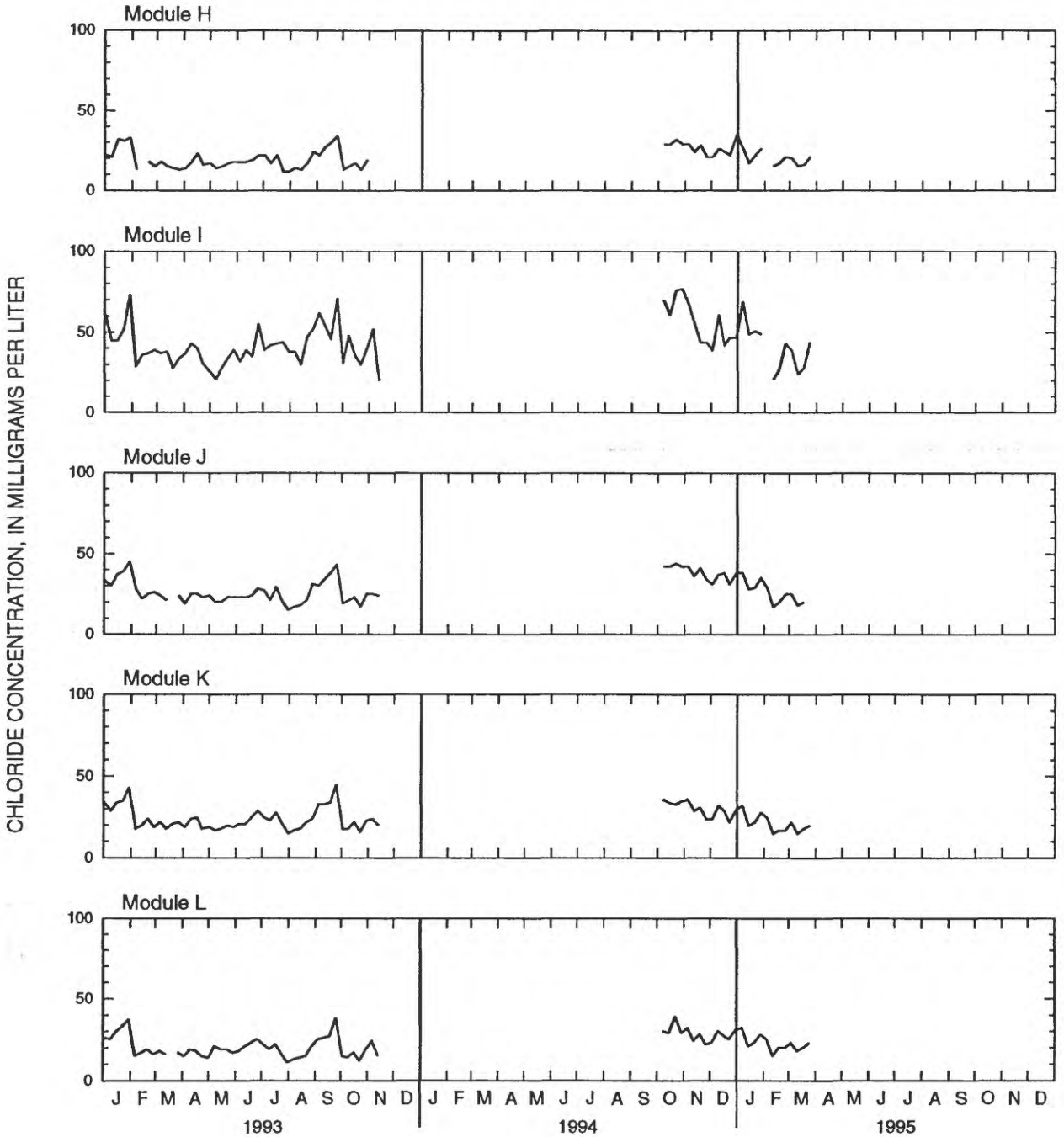


Figure C1 continued.--Chloride concentration of pumped water (sampled at weekly intervals) at Modules A through L at Cantonment, Diego Garcia, January 1993 through March 1995. Data not available for November 1993 through September 1994.

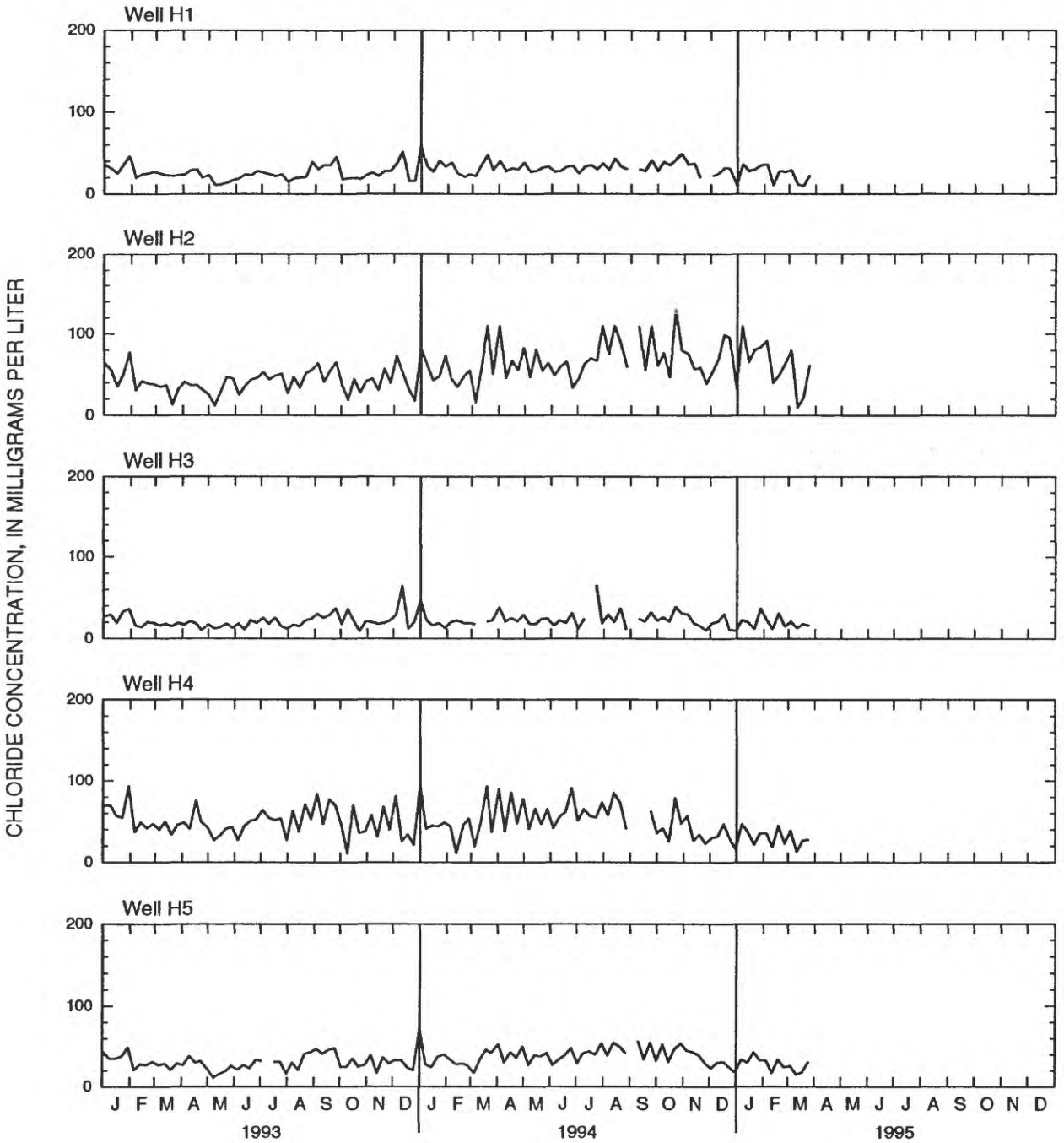


Figure C2. Chloride concentration of pumped water (sampled at weekly intervals) at wells H1 through H7 at Cantonment, Diego Garcia, January 1993 through March 1995.

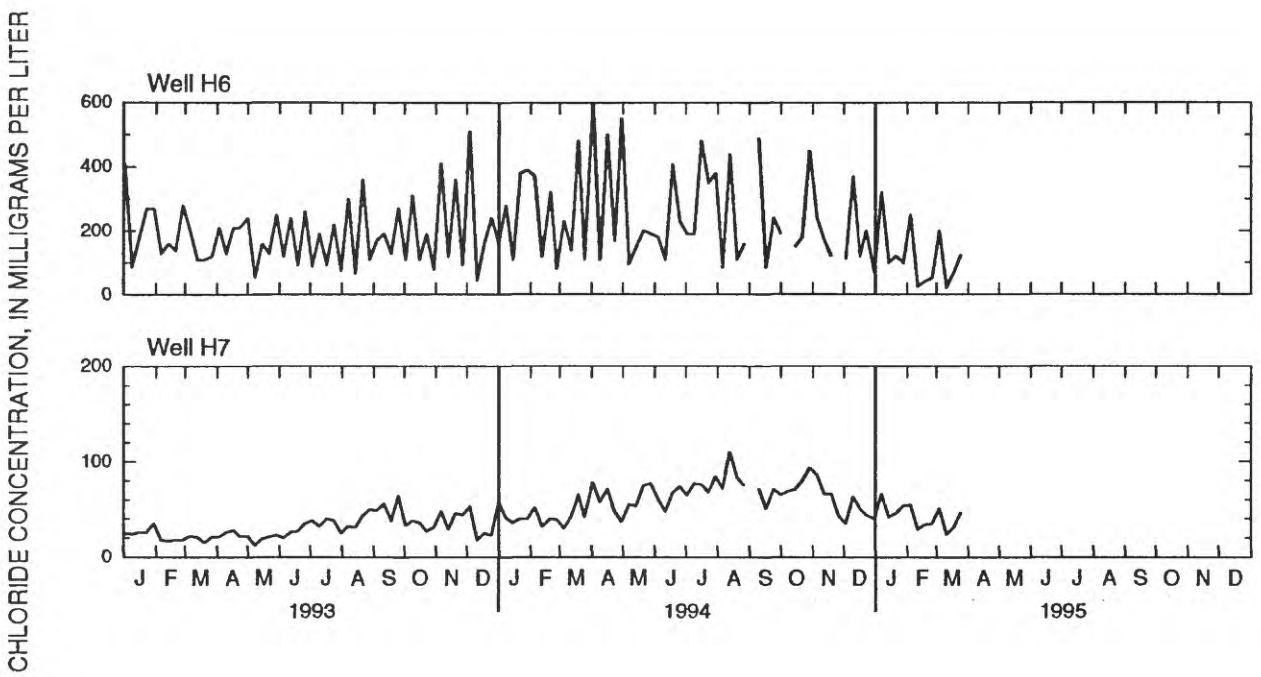


Figure C2 continued.--Chloride concentration of pumped water (sampled at weekly intervals) at wells H1 through H7 at Cantonment, Diego Garcia, January 1993 through March 1995.

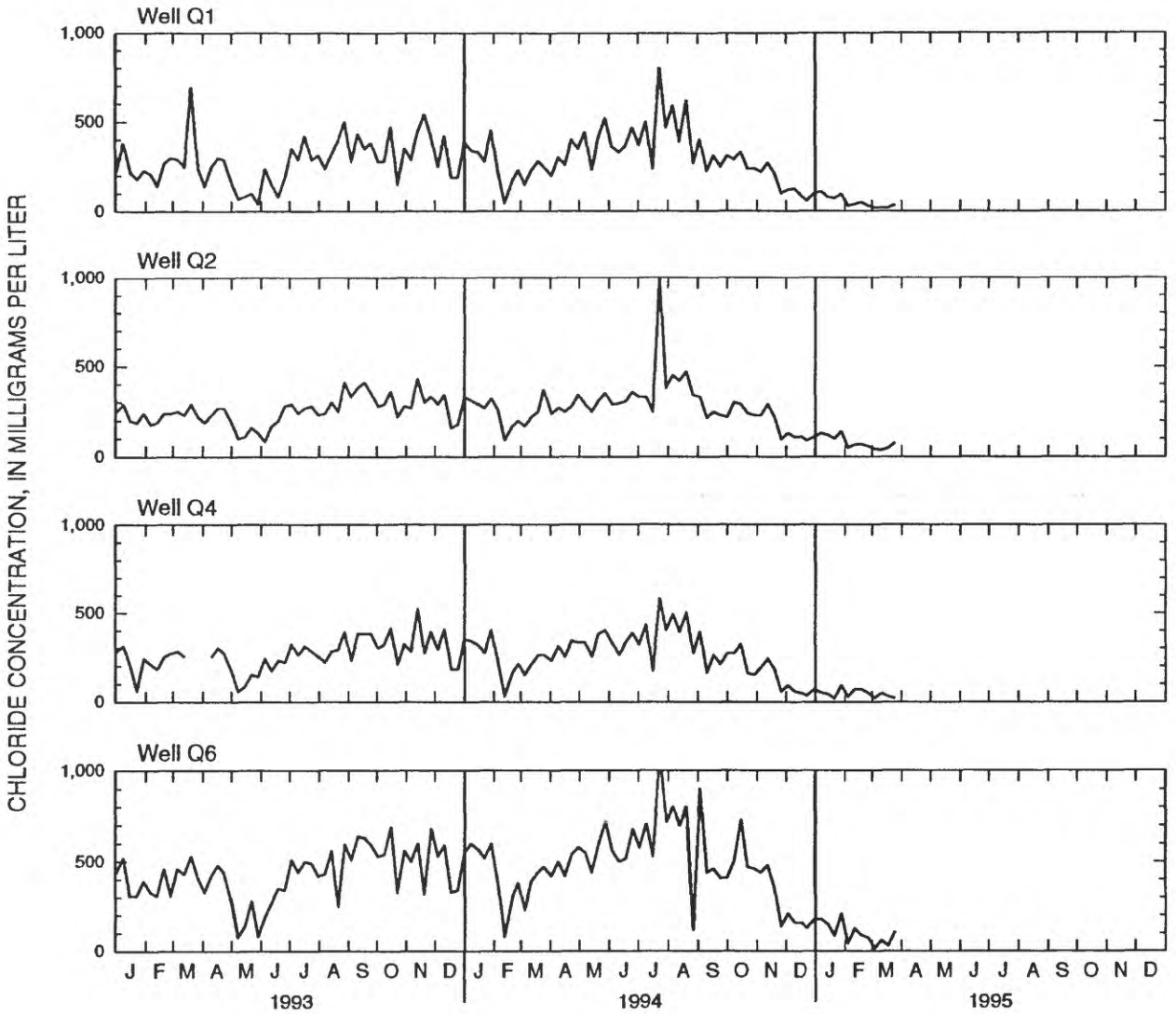


Figure C3. Chloride concentration of pumped water (sampled at weekly intervals) at wells Q1, Q2, Q4, and Q6 at Cantonment, Diego Garcia, January 1993 through March 1995.

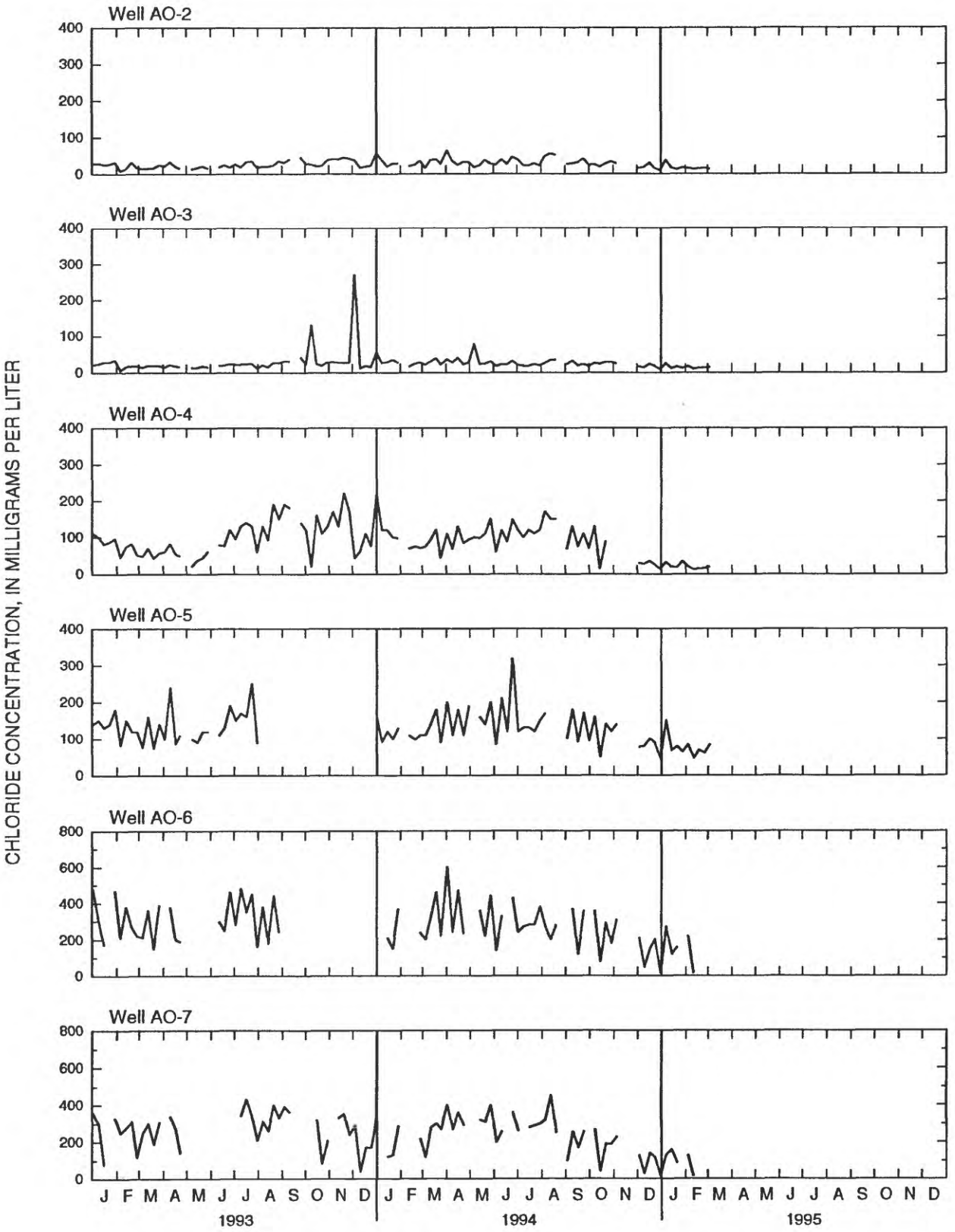


Figure C4. Chloride concentration of pumped water (sampled at weekly intervals) at wells AO-2 through AO-19 at Air Operations, Diego Garcia, January 1993 through March 1995. Water from well AO-13 has not been sampled since April 1993.

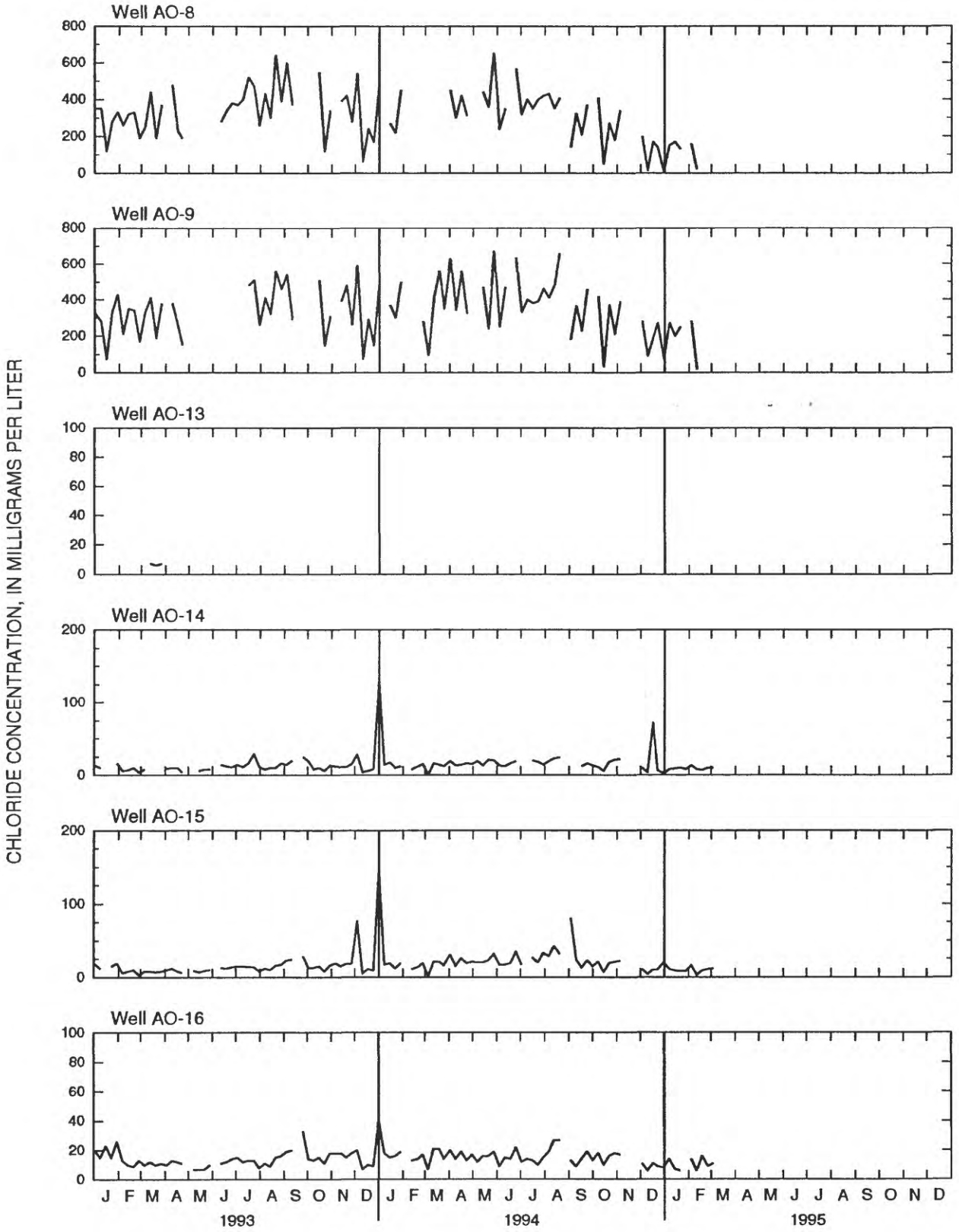


Figure C4 continued.--Chloride concentration of pumped water (sampled at weekly intervals) at wells AO-2 through AO-19 at Air Operations, Diego Garcia, January 1993 through March 1995. Water from well AO-13 has not been sampled since April 1993.

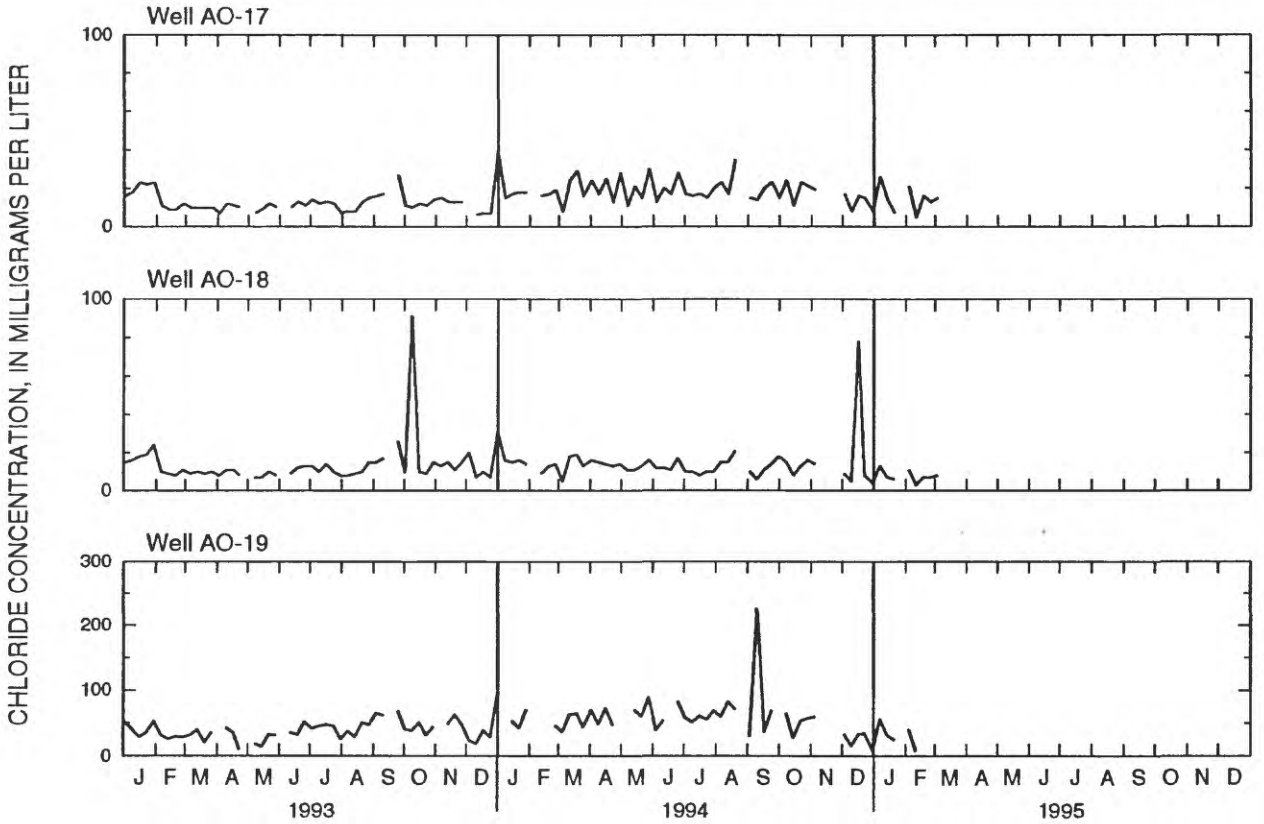


Figure C4 continued.--Chloride concentration of pumped water (sampled at weekly intervals) at wells AO-2 through AO-19 at Air Operations, Diego Garcia, January 1993 through March 1995. Water from well AO-13 has not been sampled since April 1993.

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