STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA, 1991-93

U.S. GEOLOGICAL SURVEY
Open-File Report 94-480

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

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Honolulu, Hawaii
1995

U.S. DEPARTMENT OF THE INTERIOR
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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, 1991-93

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 are presented from January 1991 through December 1993. This report concentrates on data from fourth quarter 1993, and references historic data from 1991 and 1992.

1. RAINFALL--Total rainfall for 1993 was 95 inches which is 10 percent below the mean annual rainfall of 106 inches. In comparison, total rainfalls in 1992 and 1991 were 93 inches and 130 inches, respectively.

2. GROUND-WATER WITHDRAWAL--Ground-water withdrawal has averaged 954,000 gallons per day during 1993, while withdrawals in 1992 and 1991 averaged 936,000 gallons per day and 927,000 gallons per day, respectively. In each of the five areas of ground-water production, withdrawals have remained steady since 1991.

3. CHLORIDE CONCENTRATION OF PUMPED WATER--At the end of December 1993, the chloride concentration of the composite water supply was 36 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 during the last quarter (October through December 1993) ranged between 35 and 75 milligrams per liter.

4. CHLORIDE CONCENTRATION OF GROUND WATER IN MONITORING WELLS--Chloride concentrations in monitoring wells at Cantonment and Air Operations decreased during the last quarter (October through December 1993) after having risen progressively during the previous quarter (July through September 1993). There has been a general trend of increasing chloride concentrations in the deeper monitoring wells since the 1992 dry season, which began in March 1992.

5. FUEL-DIVERSION PROGRAM--A fuel spill 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.

STATUS OF GROUND-WATER RESOURCES AT U.S. NAVY SUPPORT FACILITY, DIEGO GARCIA: SUMMARY OF HYDROLOGIC AND CLIMATIC DATA, 1991-93

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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 from five production areas (fig. 1). Pumped water from the Cantonment and Air Operations areas combined account for about 99 percent of the total island pumpage. The remainder is pumped for local use at the other three areas. The system has been in operation since 1978 and has provided about 1 Mgal/d since 1984.

Long-term ground-water management is facilitated by a cooperative agreement between the Navy Support Facility and the U.S. Geological Survey (USGS). The Diego Garcia Long-Term Ground-Water Management Program involves data collection and analysis of daily rainfall, daily pumpage for individual wells, and chloride concentrations of water from all production and monitoring wells. The data are stored in a computerized database and analyzed for hydrologic responses to pumping and climatic variability. This report summarizes recent hydrologic events and can help to identify trends in the data.

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 1991 through December 1993. Data of primary relevance to the water supply are:

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

The narrative that follows refers to selected graphs to highlight recent trends in the data for the fourth quarter 1993. Graphs of these data are presented in the "Hydrologic Data Section" at the end of this summary. 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, 1991-93
C. Graphs of weekly chloride concentration of pumped water, 1991-93

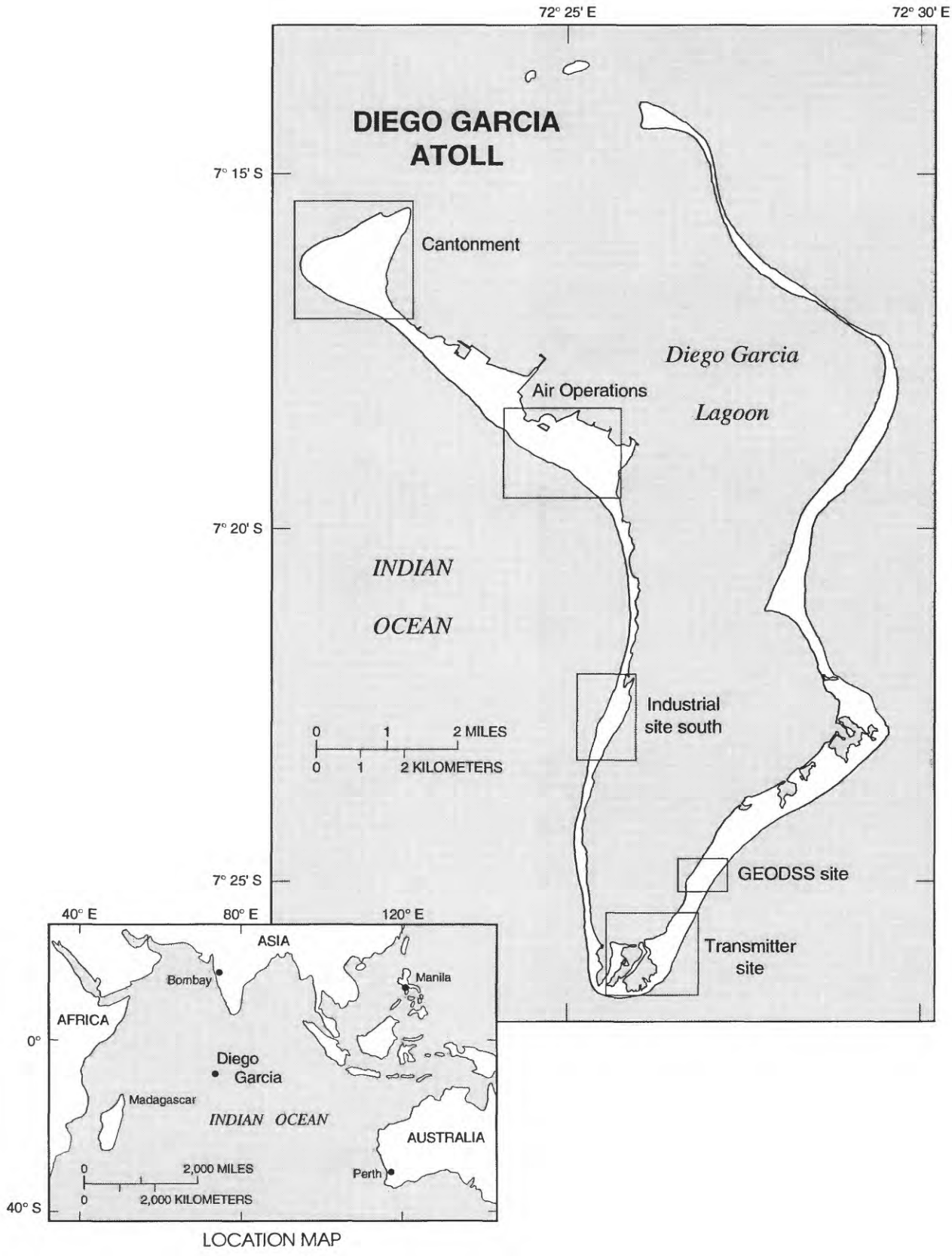


Figure 1. Areas of ground-water production, Diego Garcia.

RAINFALL

Background.--The mean annual rainfall at Diego Garcia for the fixed base period 1951-90 is 105.73 in/yr, with considerable month-to-month and year-to-year variability. A wet season occurs from about September through February, and a dry season occurs from about March through August.

Recent trends.--Total rainfall in 1993 was 94.77 in., which is 10 percent below the mean annual of 105.73 in. For comparison, rainfall in 1992 was 92.99 in., or 12 percent below the mean annual rainfall, while rainfall in 1991 was 130.25 in., or 23 percent above the mean. A low rainfall pattern has occurred for two years beginning in 1992.

In figure 2, the pattern of the smoothed rainfall departure during the 1993 dry season resembles that during the 1992 dry season. The wet season rainfall from September 1992 through February 1993 was deficient, producing weaker-than-normal positive anomalies in the smoothed rainfall departures. The result is a persistent negative or near-zero departure period starting in March 1992 and lasting though 1993. Prominent negative departures have occurred in 1984, 1985, and 1989, and have corresponded with documented periods of freshwater lens shrinkage, saltwater intrusion, and increased salinity in pumped water (C.D. Hunt, U.S. Geological Survey, written commun., 1993).

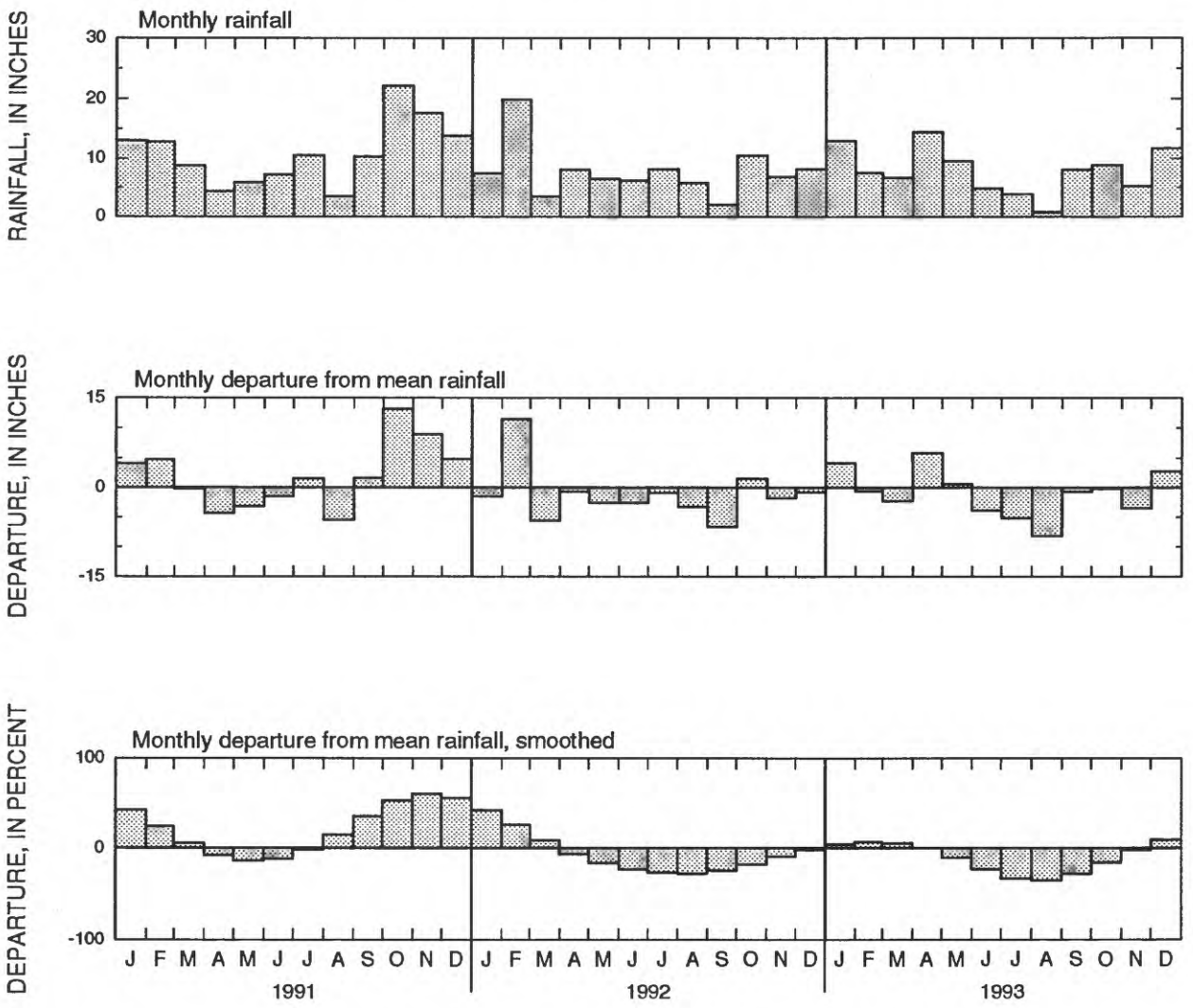


Figure 2. Monthly rainfall and monthly departure from mean rainfall at Air Operations, Diego Garcia, 1991-93. Mean rainfall, in inches per month, is the mean annual rainfall divided by 12. Smoothed monthly departure from mean rainfall is calculated with an 11-point, center-weighted, moving average filter with weighting factors that approximate the normal probability distribution.

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. 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 of monthly mean withdrawal islandwide and for each ground-water production area from 1991 through 1993. Patterns of withdrawal in 1993 have not changed appreciably from prior years in most areas. Total islandwide withdrawal has increased by three percent from 1991 to 1993 with the Cantonment area supplying most of the extra demand. Pumpage from the Cantonment area has also increased since 1991 because of the May 1991 through April 1992 closure of 10 Air Operations wells due to a fuel spill near to those wells. Six Air Operations wells still do not pump to the water supply because of the fuel spill. Wells AO-5 and AO-6 at Air Operations were inactive for most of the fourth quarter 1993 due to inoperable pumps at both sites.

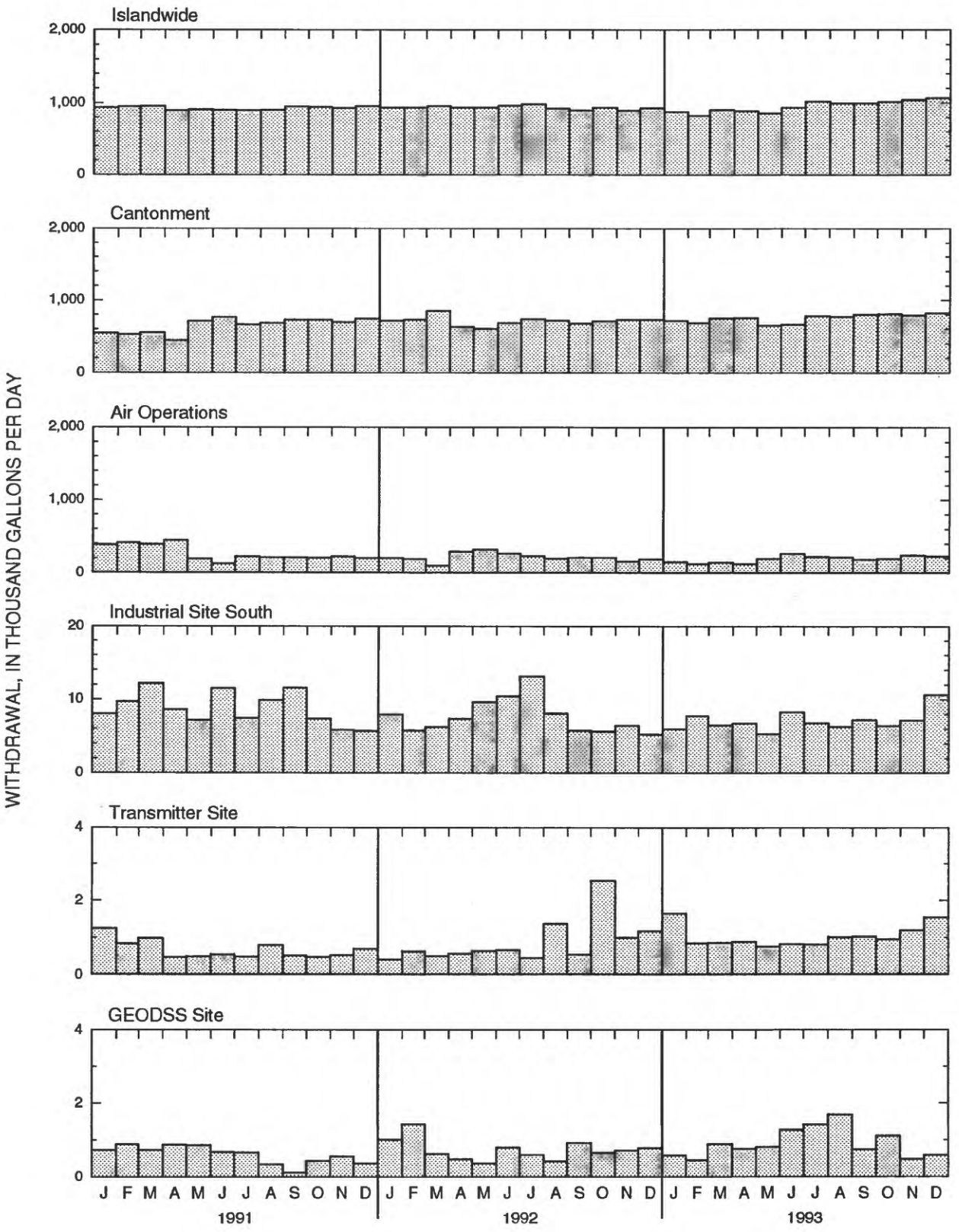


Figure 3. Monthly mean ground-water withdrawal islandwide and in the ground-water production areas, Diego Garcia, 1991-93.

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 established by the U.S. Environmental Protection Agency. 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 weekly 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 is a mixture of ground water from wells in both the Air Operations and Cantonment areas. This composite tank accounts for about 99 percent of total, islandwide pumpage. Thus, water sampled from the Cantonment tank is used as a representative index of chloride concentration for the overall water supply.

Recent trends.--The chloride concentration of the composite water supply at the end of December 1993 was 36 mg/L, well below the 250 mg/L secondary drinking water standard. The range of chloride concentrations for the composite water supply was between 35 to 75 mg/L for the last quarter (October through December 1993). Chloride concentrations in all ground-water production areas rose during the 1992 dry season and leveled off or declined slightly in 1993 (fig. 4). The increases coincided with the 1992 dry season and the declines coincided with the subsequent 1992-93 wet season, as indicated by the smoothed rainfall departures.

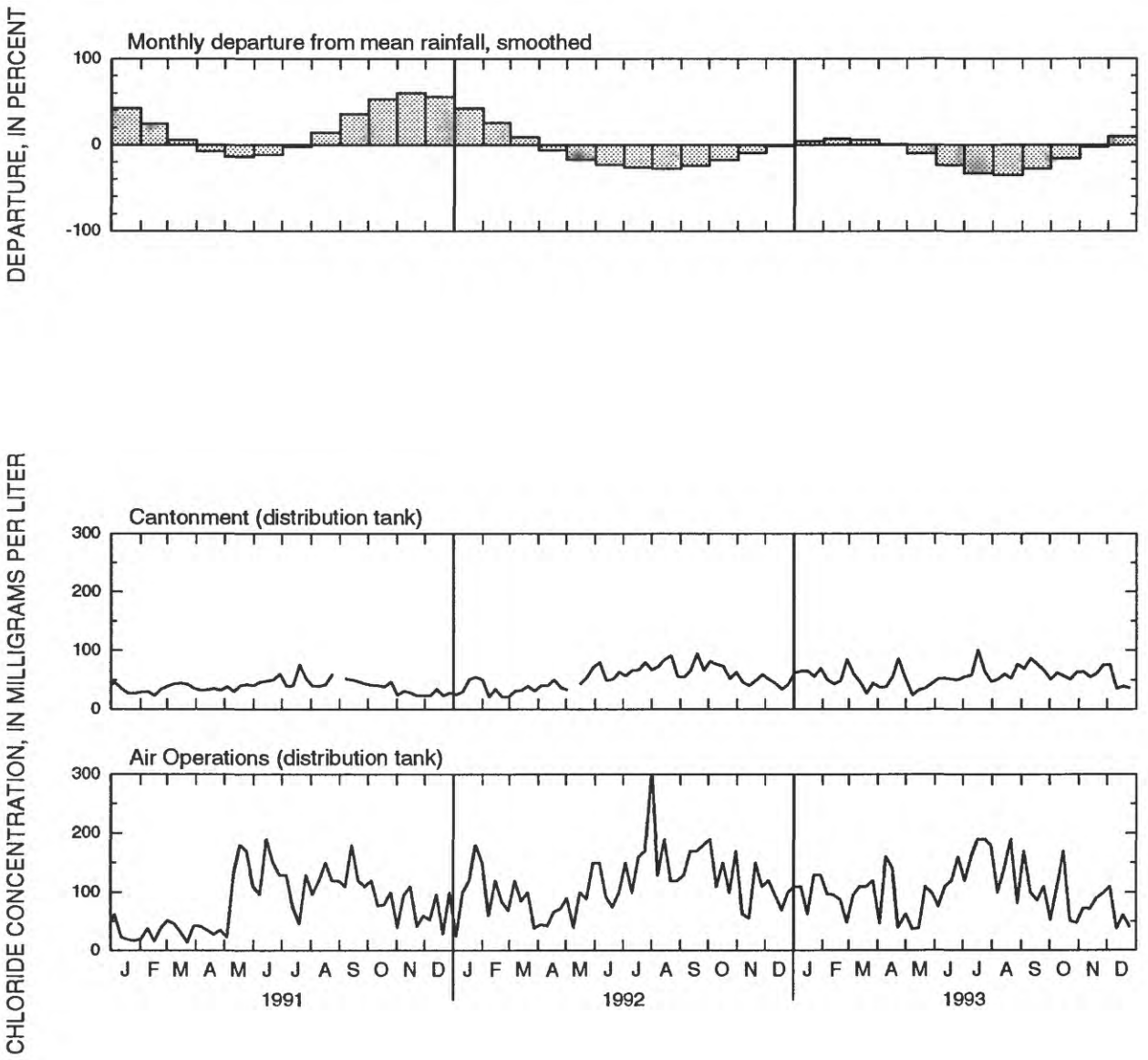


Figure 4. Weekly chloride concentration of pumped water in the ground-water production areas, Diego Garcia, 1991-93. Rainfall departure data are shown for comparison.

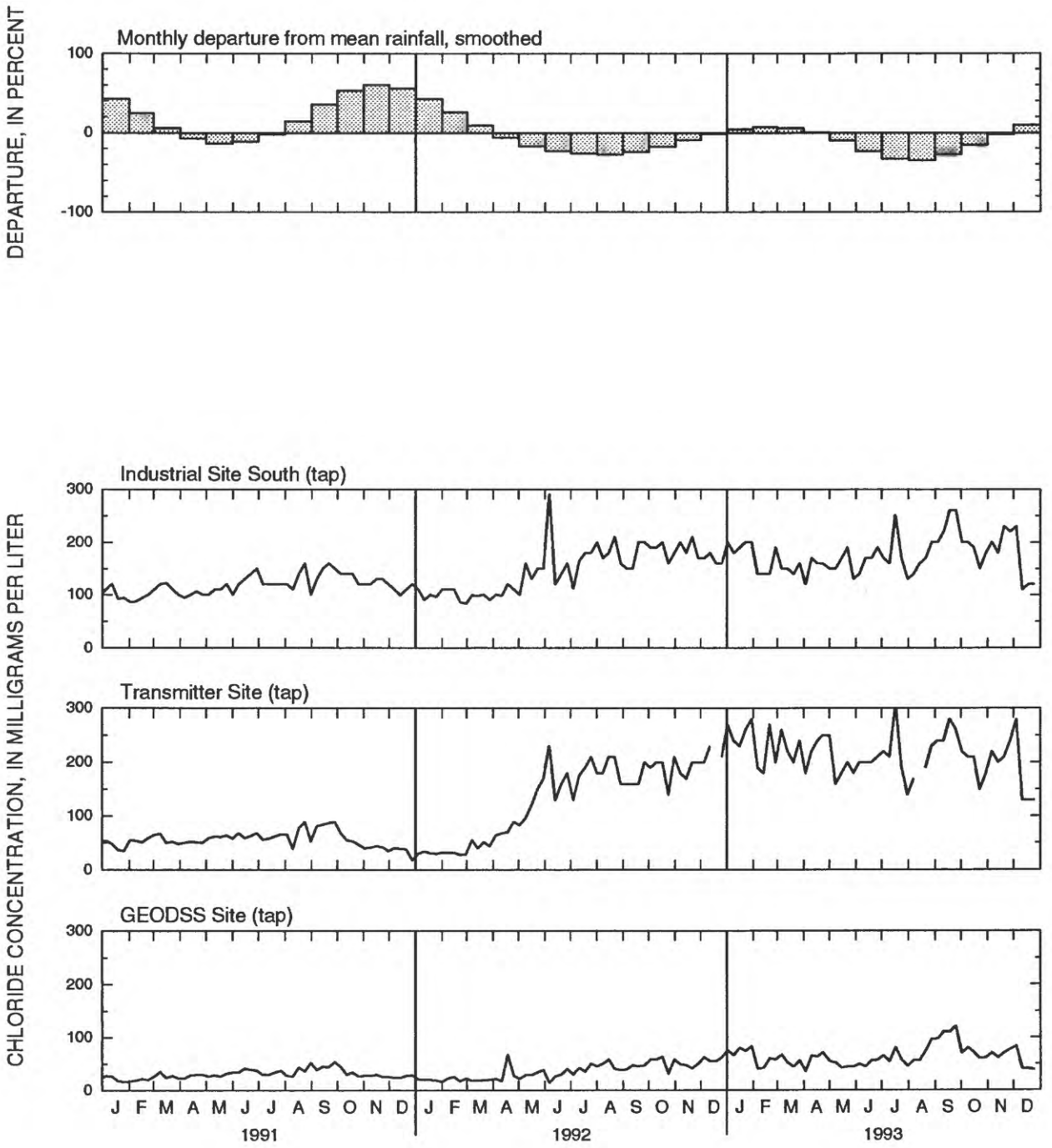


Figure 4 continued.--Weekly chloride concentration of pumped water in the ground-water production areas, Diego Garcia, 1991-93. Rainfall departure data are shown for comparison.

CHLORIDE CONCENTRATION OF GROUND WATER IN MONITORING WELLS

Background.--Chloride concentration of ground water is measured monthly at 35 monitoring well sites. 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 have been selected to show trends in chloride concentration of ground water at Cantonment and Air Operations Areas, respectively. Figures 5 and 6 show time series of chloride concentration at different depths at these sites, with smoothed rainfall departures included in the figures for climatic reference. Chloride concentrations of the water increased at both sites during third quarter 1993 and then declined to the 1992-93 wet season (September 1992 through February 1993) levels by the end of 1993. The increases in chloride concentration corresponding to the 1993 dry season (March through August 1993) are larger than the increases recorded during the 1992 dry season. The records show an apparent inverse correspondence to the smoothed rainfall departures, with higher chloride concentration in the dry season and lower concentration in the wet season.

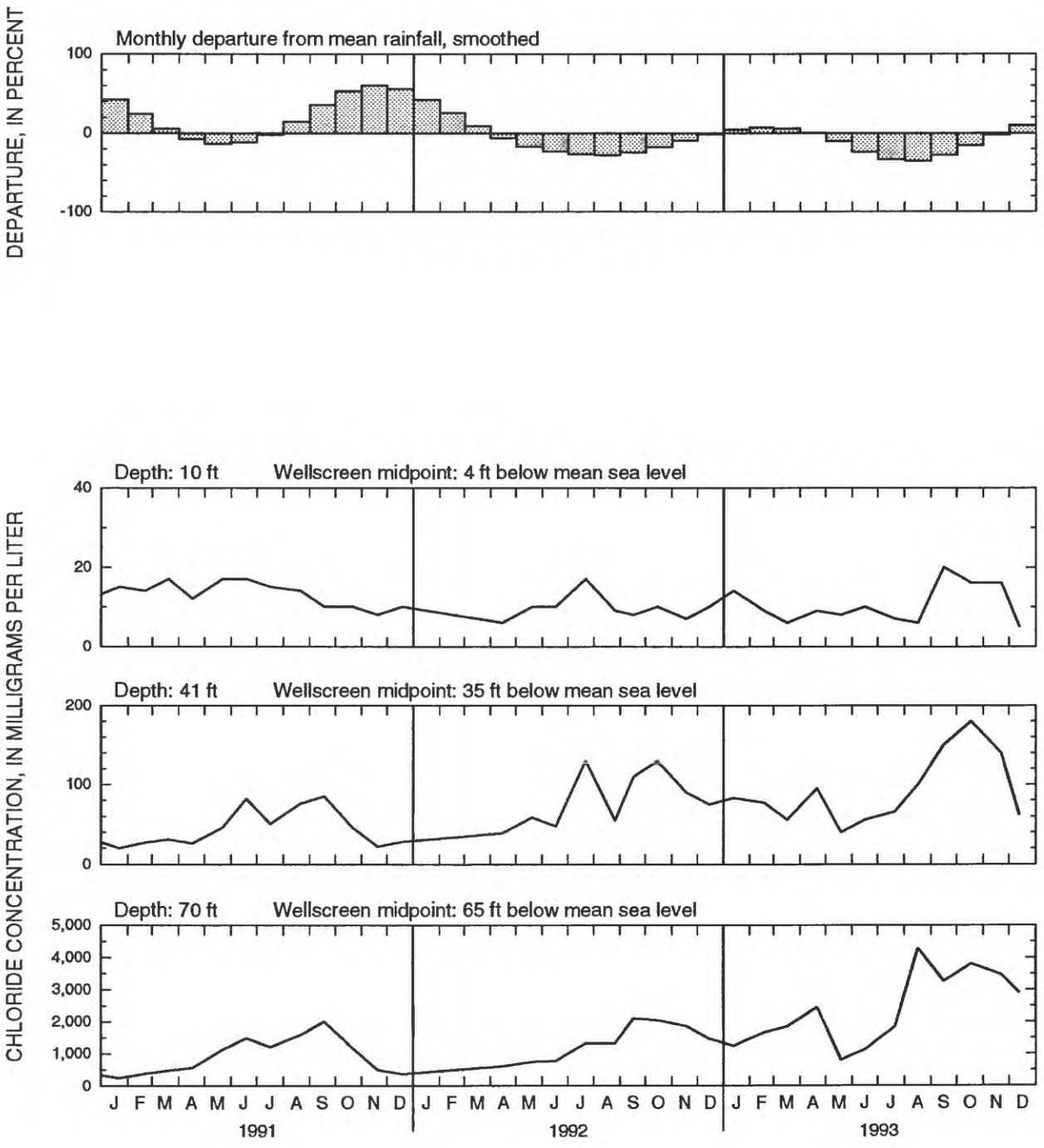


Figure 5. Monthly chloride concentration of ground water in monitoring wells at site AW16 at Cantonment, Diego Garcia, 1991-93. Rainfall departure data are shown for comparison.

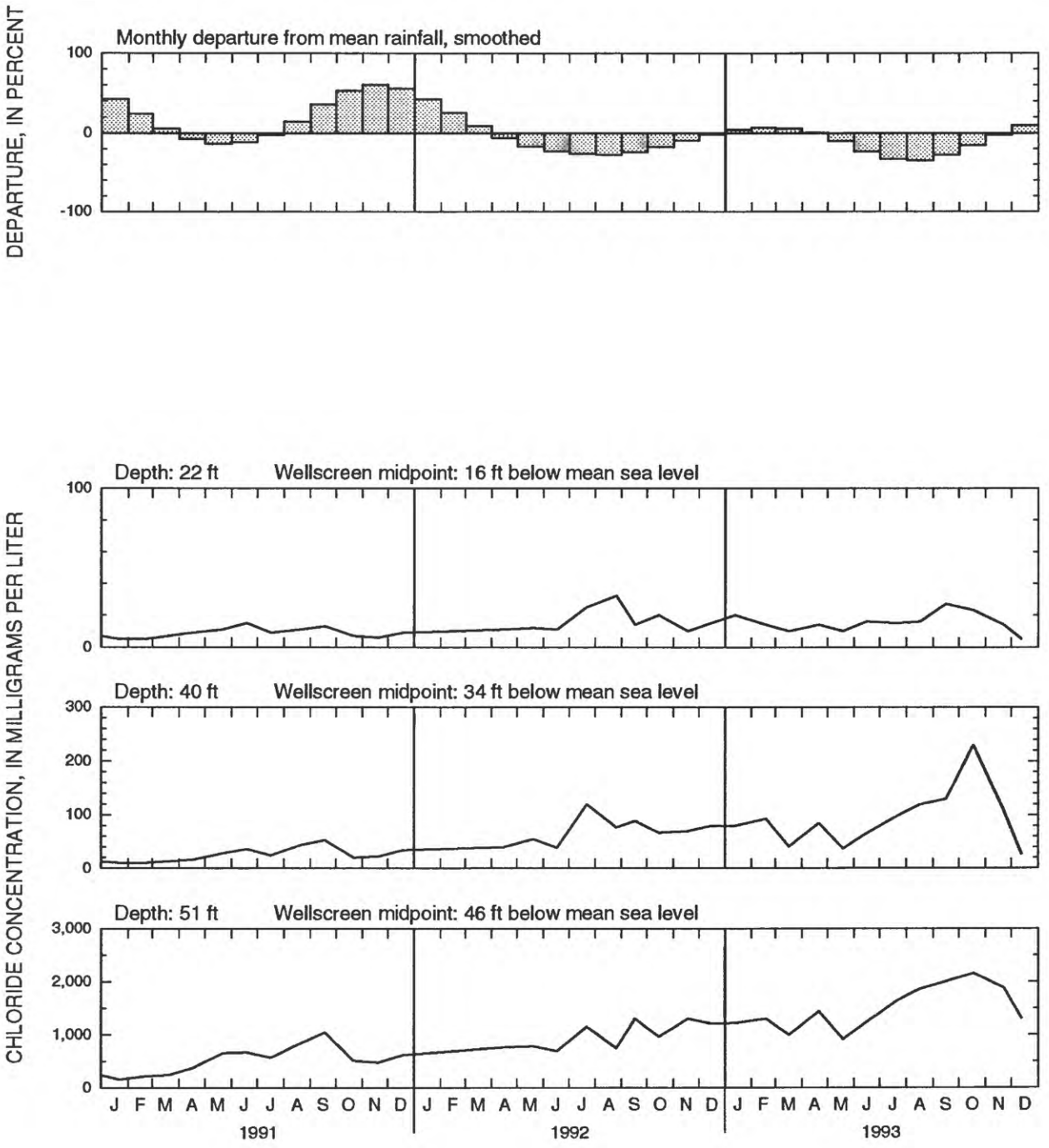


Figure 6. Monthly chloride concentration of ground water in monitoring wells at site BW09 at Air Operations, Diego Garcia, 1991-93. Rainfall departure data are shown for comparison.

FUEL-DIVERSION PROGRAM AT AIR OPERATIONS

The normal pattern of ground-water withdrawal at Air Operations has been disrupted since May 1991 by a jet-fuel spill 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 spill (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.

The hydraulic diversion program is based on the following target withdrawal and injection rates:

AO-14 - withdrawal at 70,000 gal/d
AO-15 - withdrawal at 80,000 gal/d
AO-10 - injection at 30,000 gal/d
AO-11 - injection at 50,000 gal/d
AO-12 - injection at 70,000 gal/d
AO-13 - off
Total recirculation: 150,000 gal/d

Injection data for wells AO-10, 11, 12 from May 10, 1993 through December 1993 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.

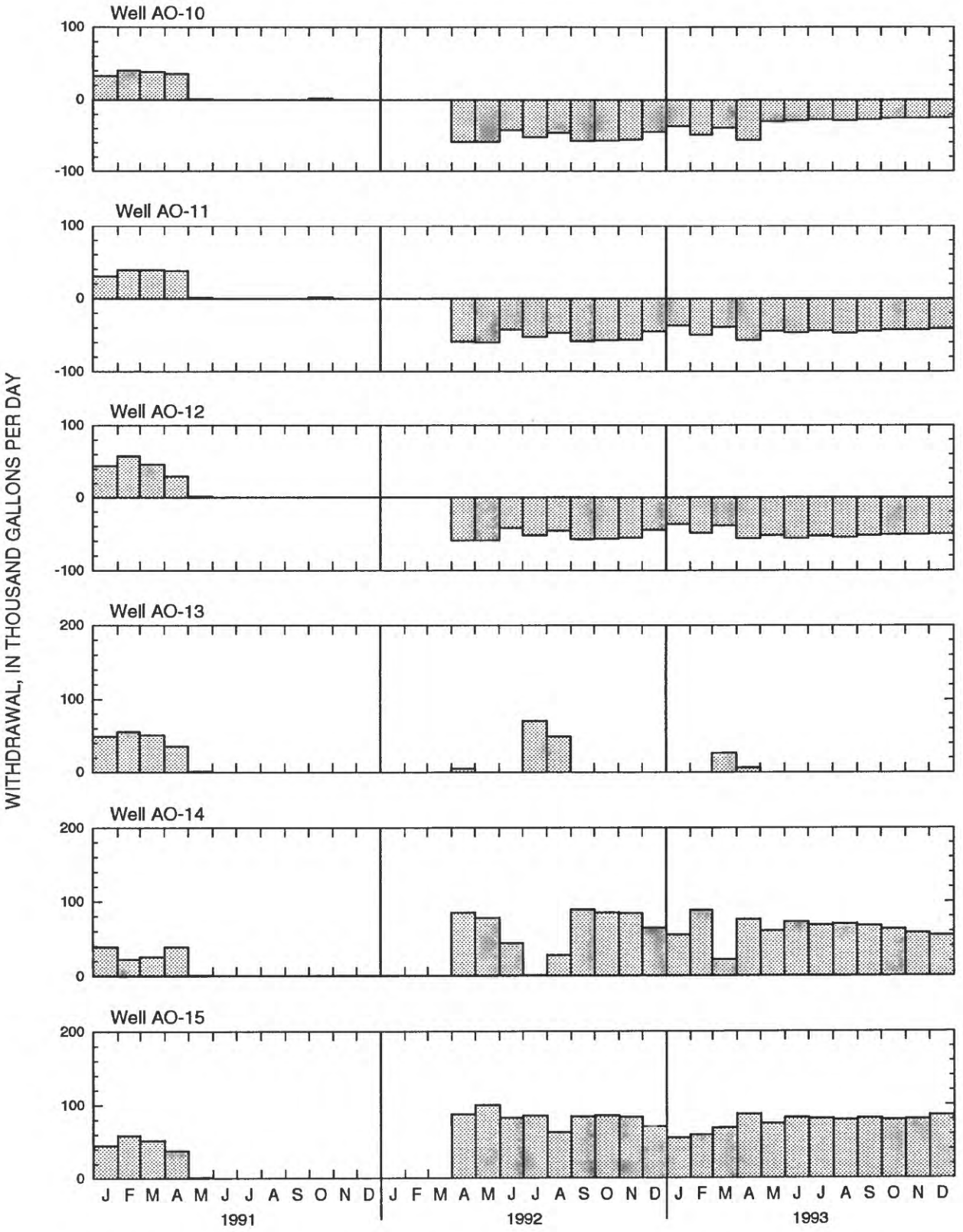


Figure 7. Monthly mean ground-water withdrawal and injection at wells AO-10 through AO-15 at Air Operations, Diego Garcia, 1991-93. Injection is plotted as negative withdrawal.

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, 1991-93
C. Graphs of weekly chloride concentration of pumped ground water, 1991-93

DESCRIPTIONS OF PRINCIPAL PRODUCTION SOURCES AT CANTONMENT AND AIR OPERATIONS AREAS

Cantonment Area

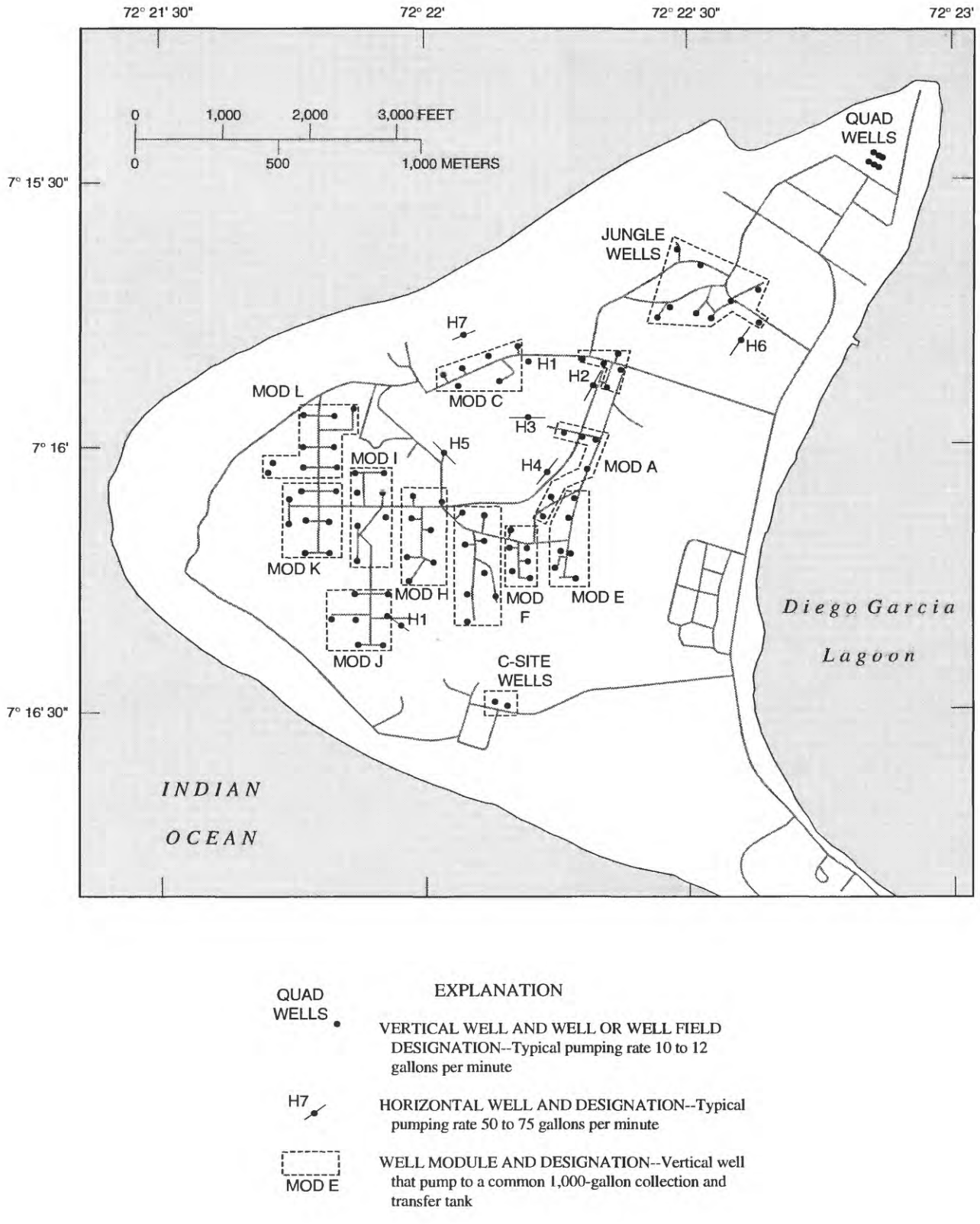
1. Modules A, C through L - each module is a well field of 5 to 8 vertical wells that pump to a common collection/transfer tank.
2. Module B is a horizontal well with a collection/transfer tank; has not pumped since August 1986.
3. Wells H1 through H7 are horizontal wells.
4. Quad wells are a well field 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 spill.
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.

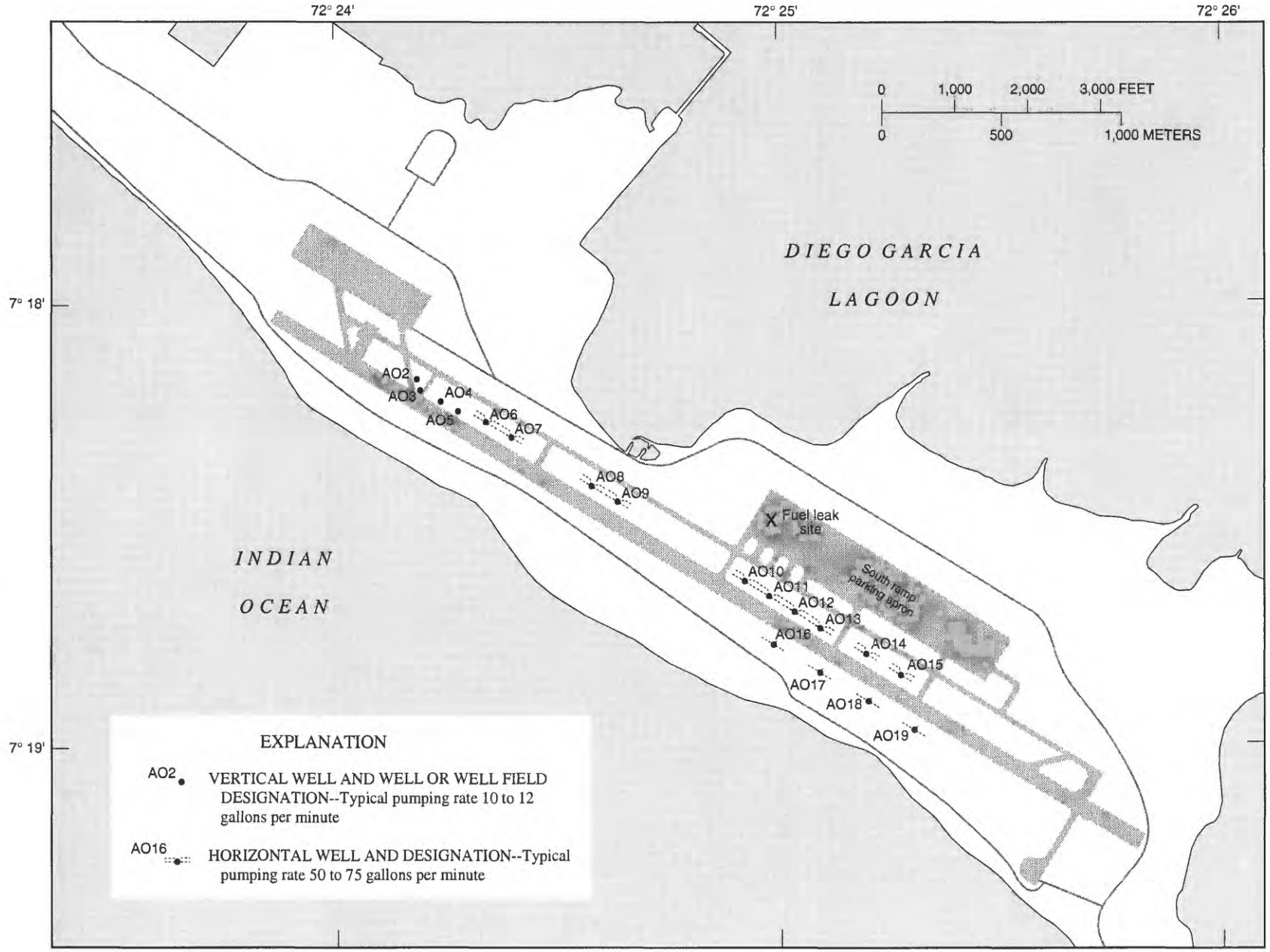
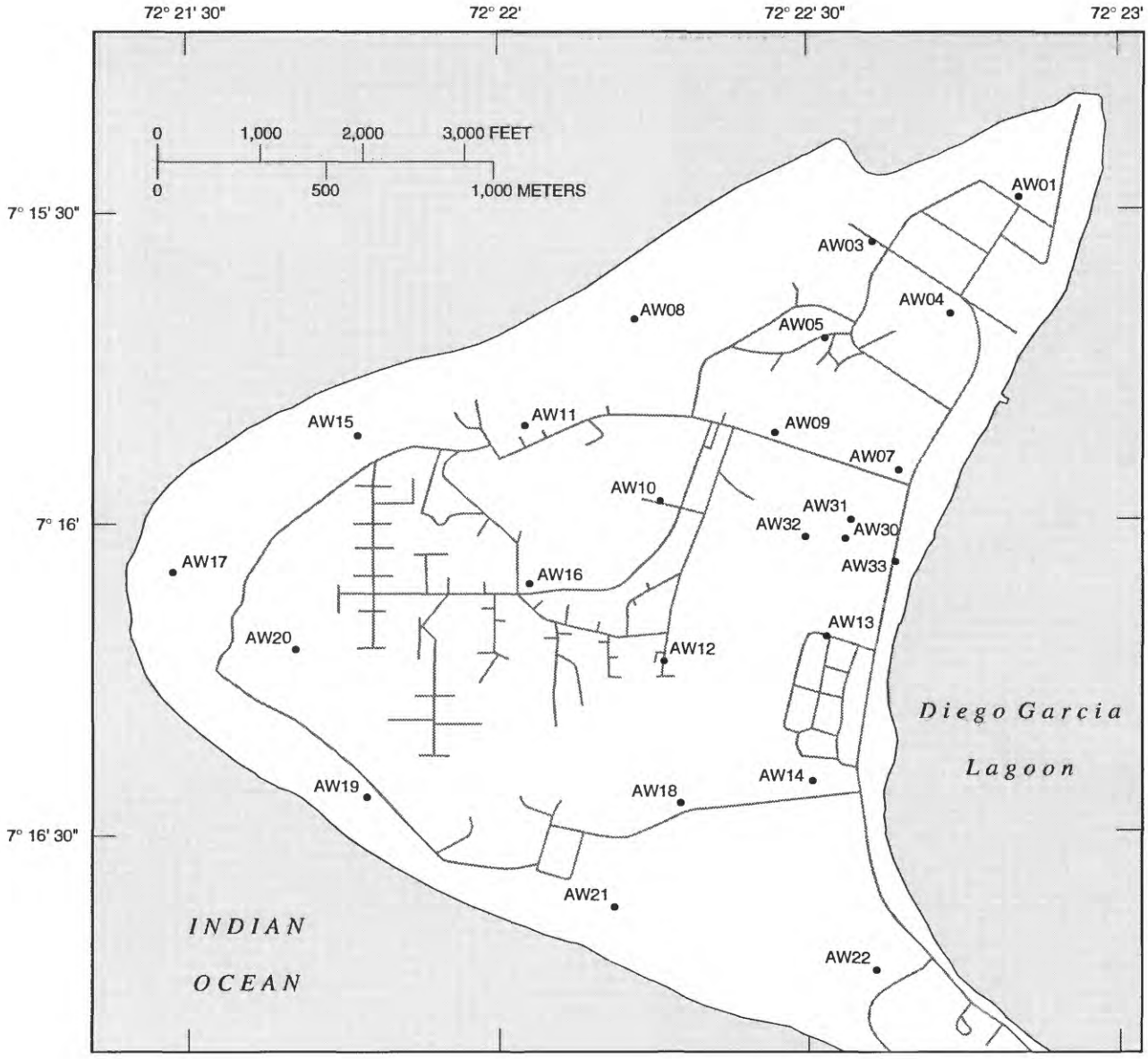


Figure A2. Ground-water production wells at Air Operations, Diego Garcia.



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.

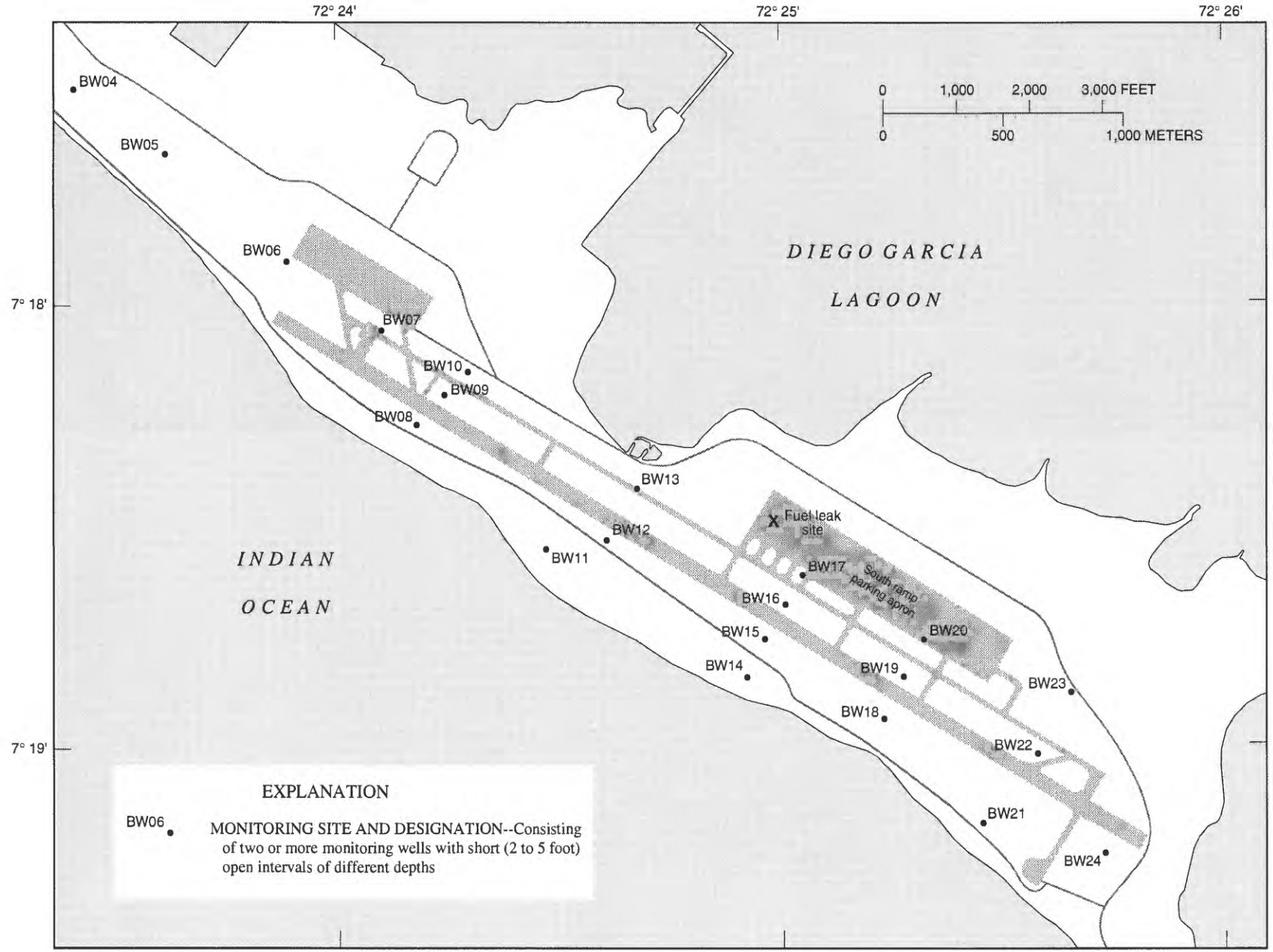


Figure A4. Monitoring wells at Air Operations, Diego Garcia.

SECTION B

Graphs of monthly mean ground-water withdrawal, 1991-93

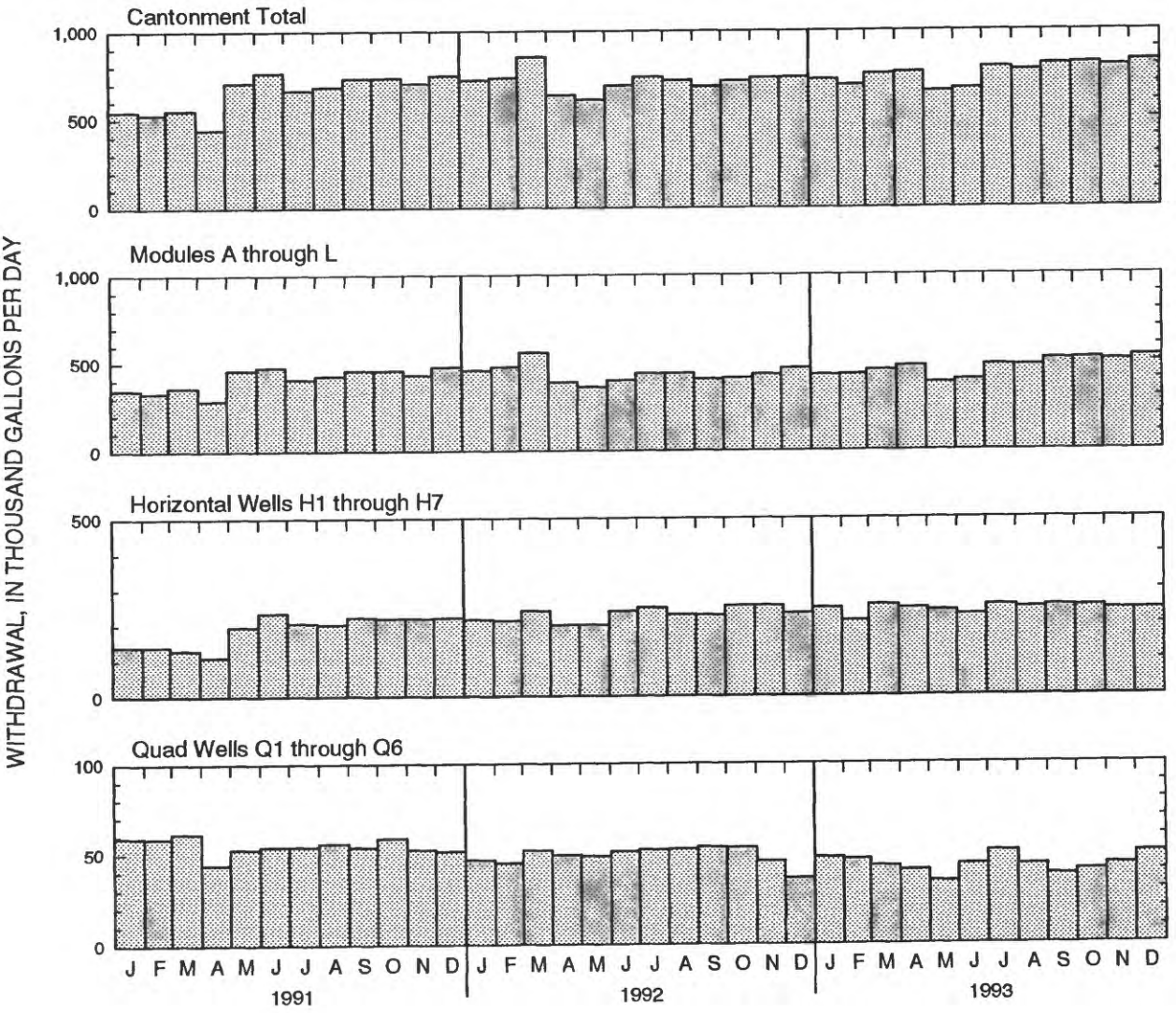


Figure B1. Monthly mean ground-water withdrawal at Cantonment, Diego Garcia, 1991-93.

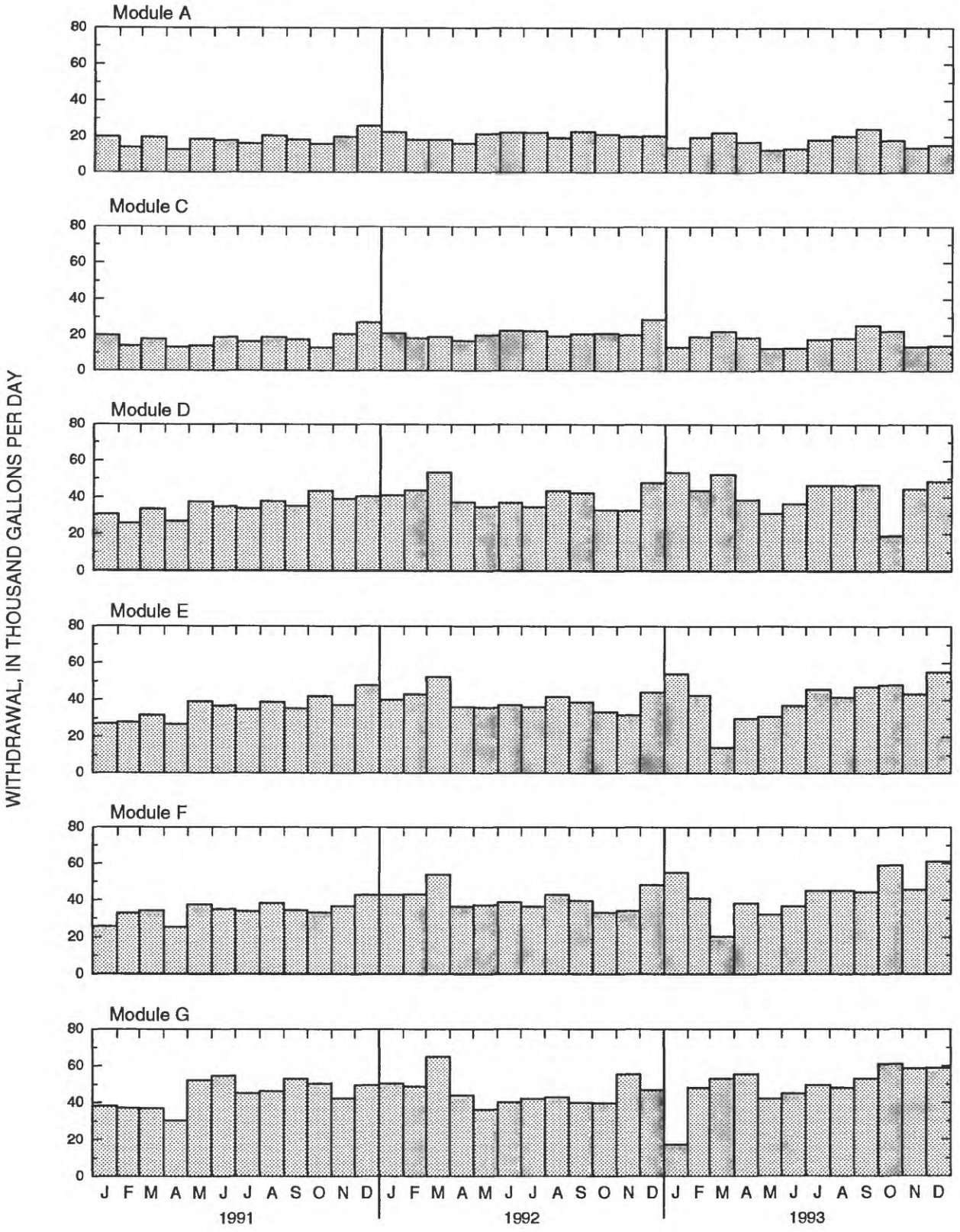


Figure B2. Monthly mean ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, 1991-93.

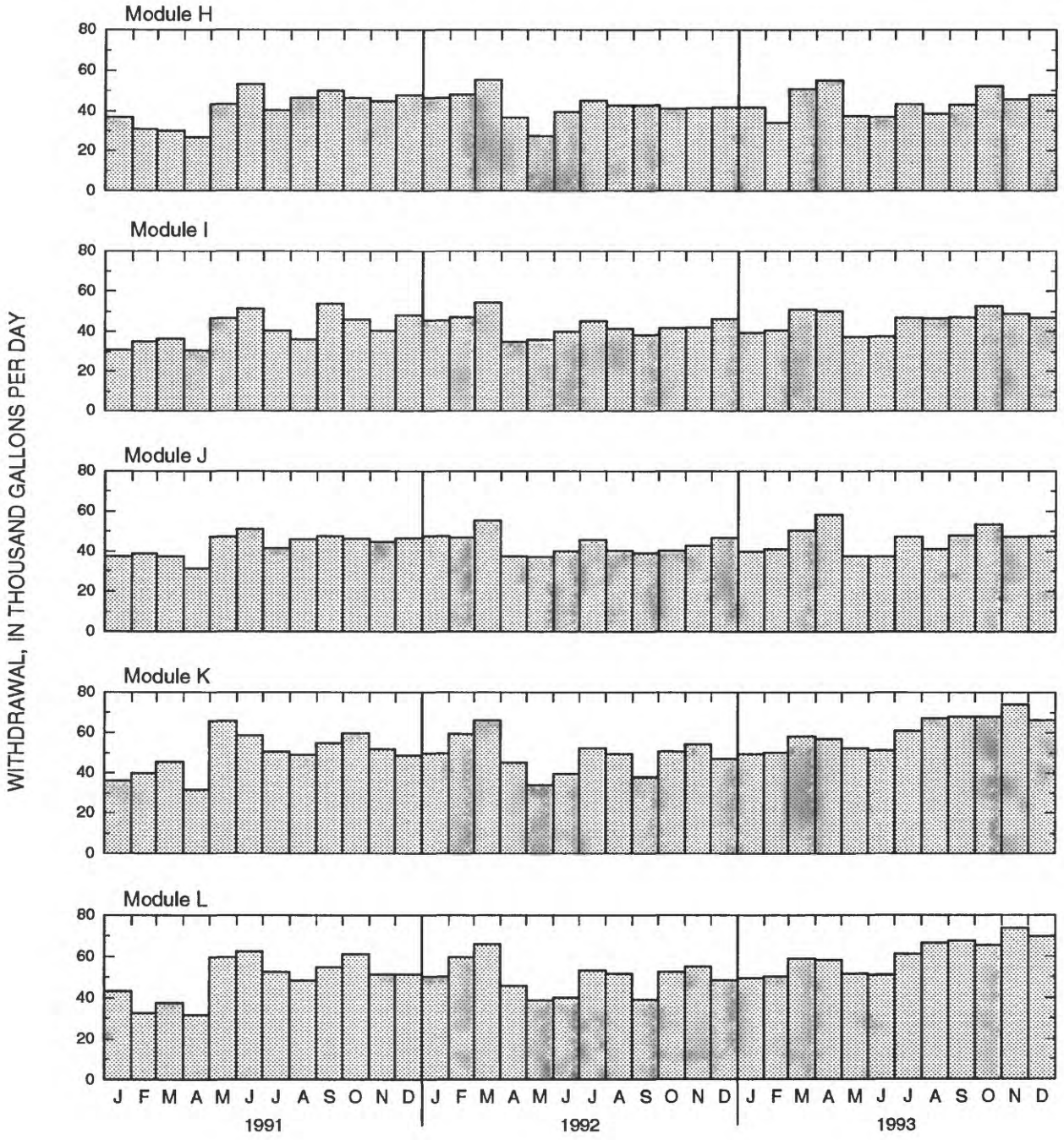


Figure B2 continued.--Monthly mean ground-water withdrawal at Modules A through L at Cantonment, Diego Garcia, 1991-93.

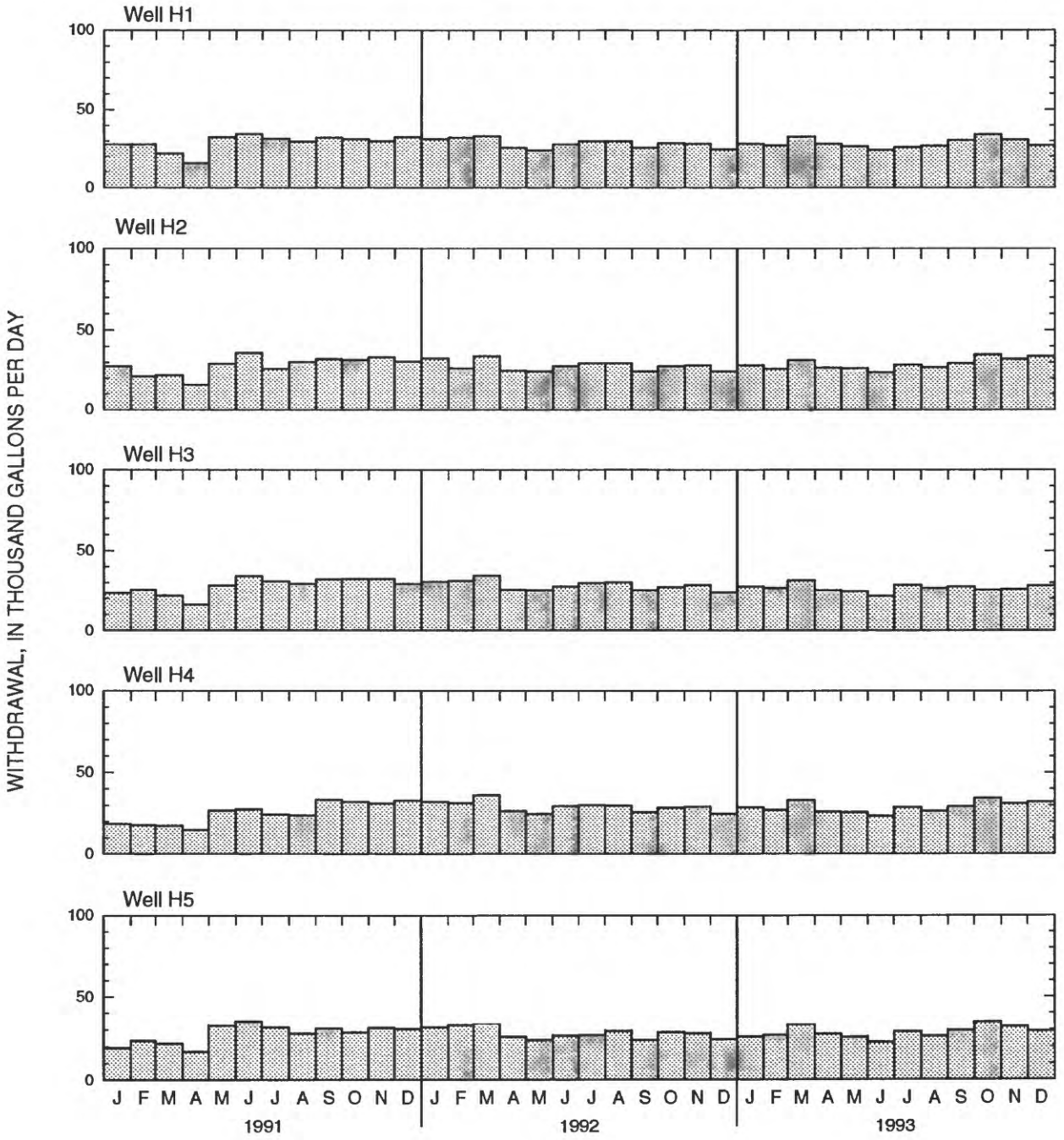


Figure B3. Monthly mean ground-water withdrawal at wells H1 through H7 at Cantonment, Diego Garcia, 1991-93.

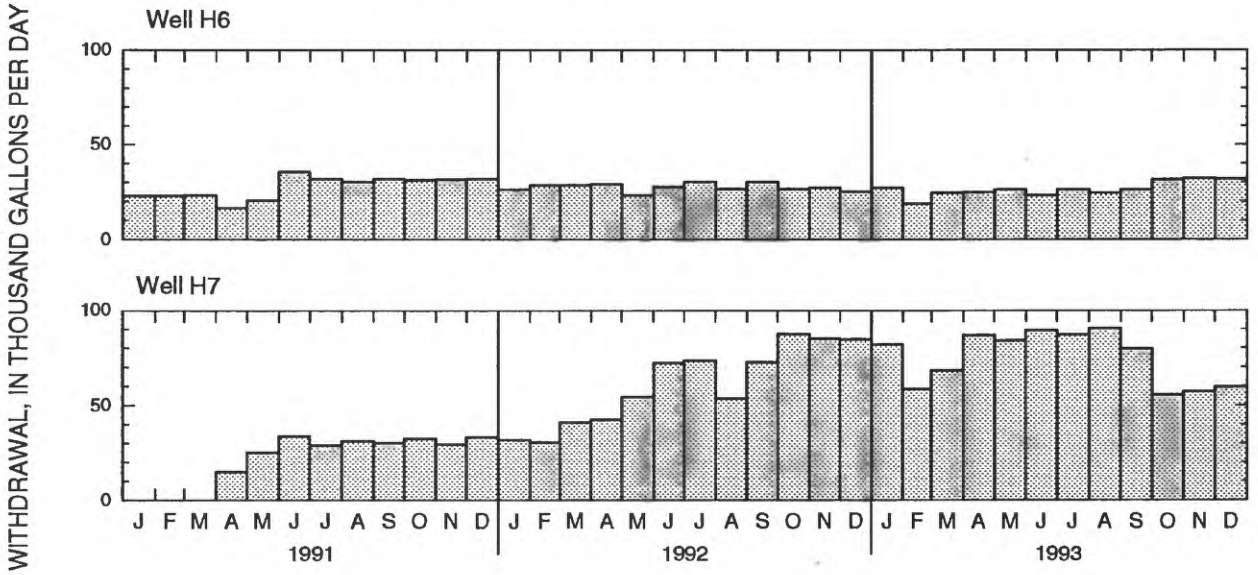


Figure B3 continued.--Monthly mean ground-water withdrawal at wells H1 through H7 at Cantonment, Diego Garcia, 1991-93.

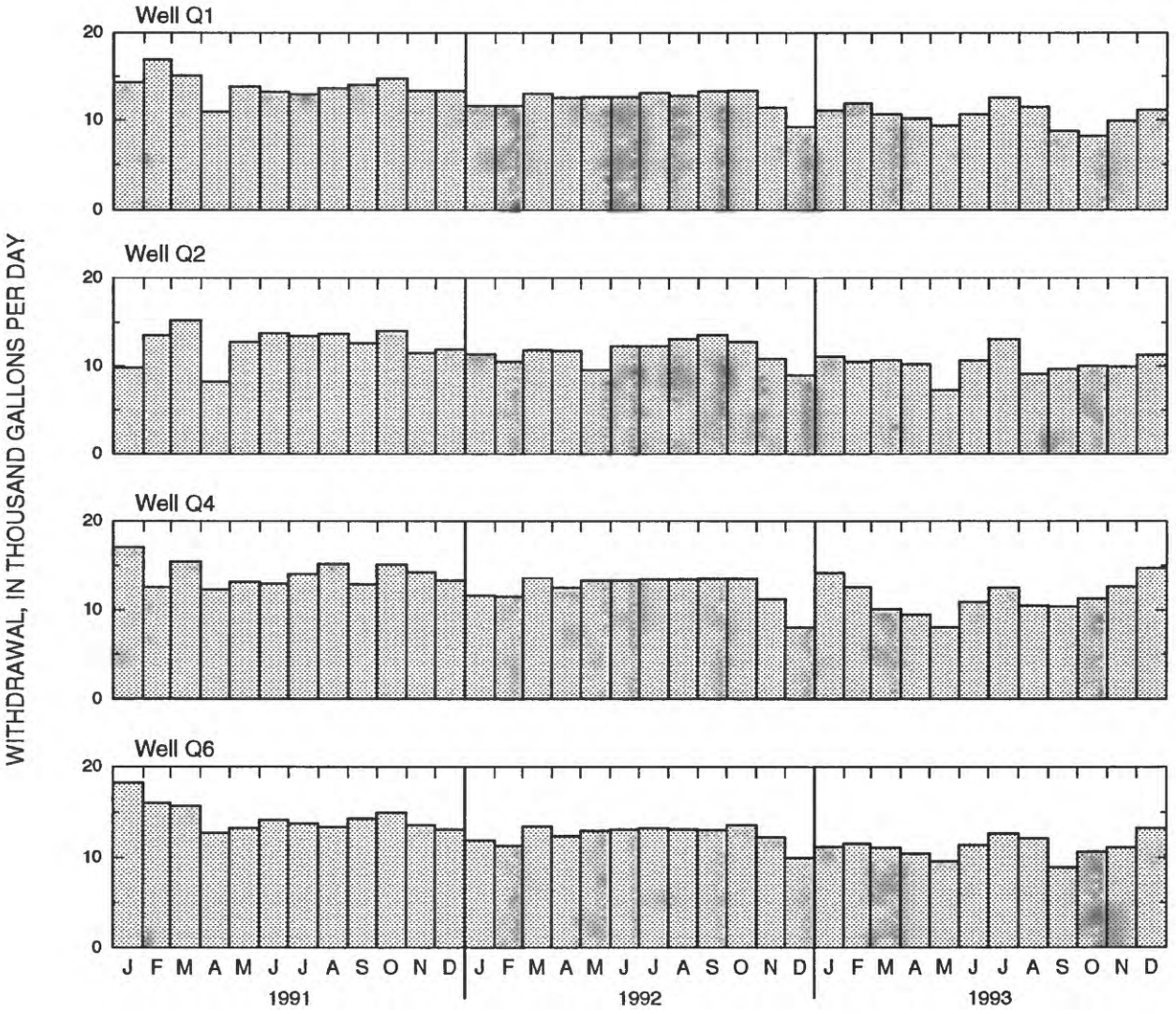


Figure B4. Monthly mean ground-water withdrawal at wells Q1, Q2, Q4, and Q6 at Cantonment, Diego Garcia, 1991-93.

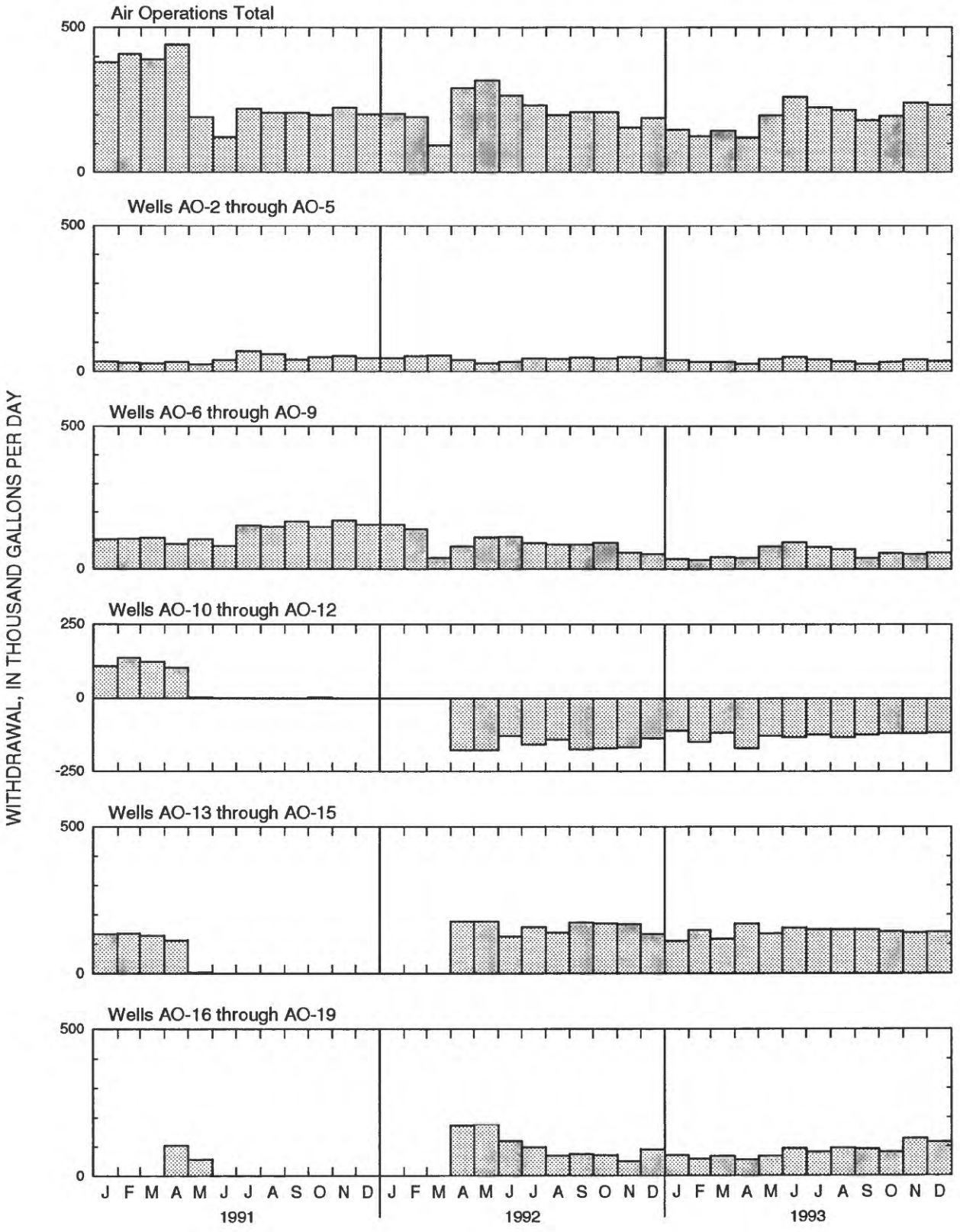


Figure B5. Monthly mean ground-water withdrawal and injection at Air Operations, Diego Garcia, 1991-93. Injection is plotted as negative withdrawal.

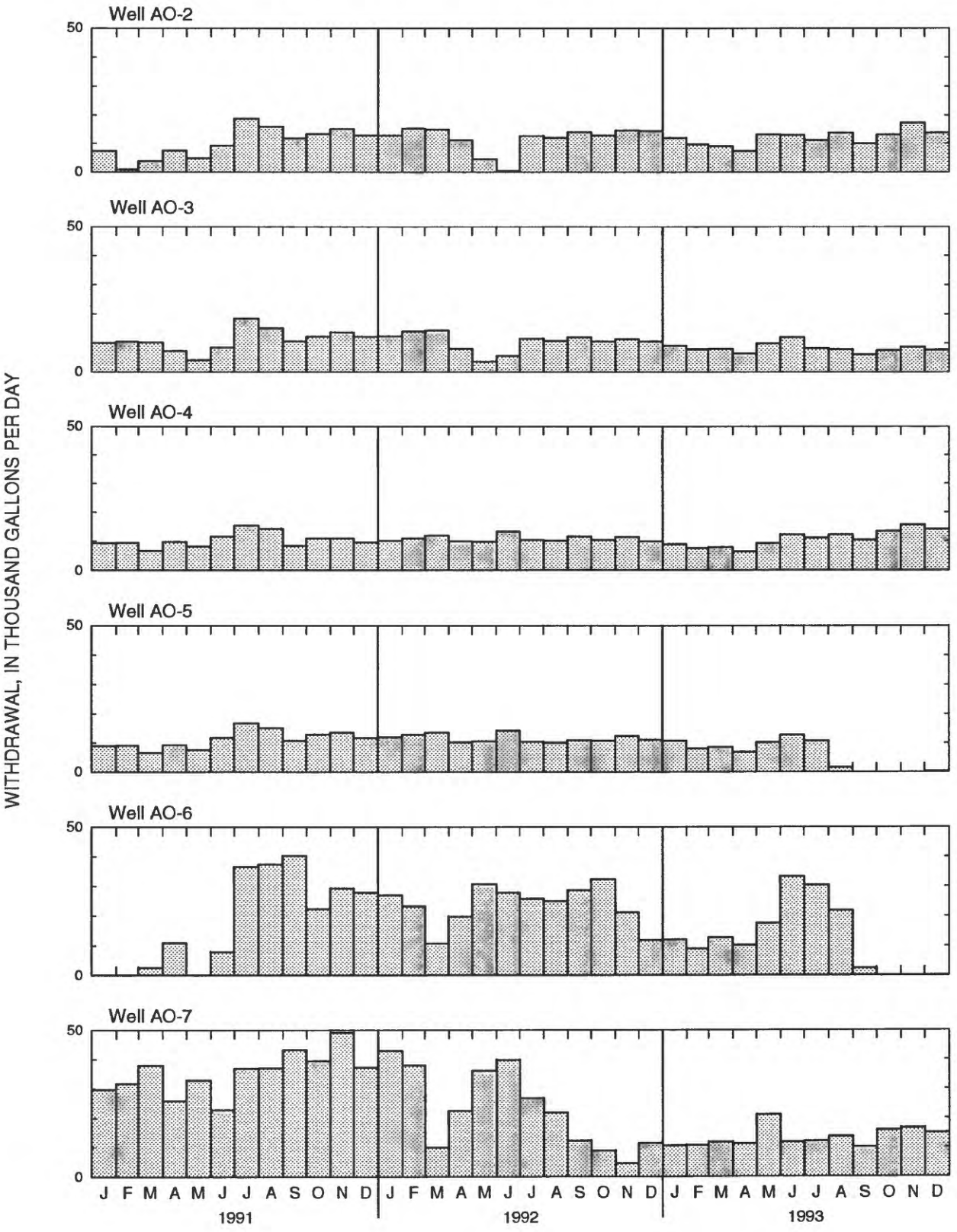


Figure B6. Monthly mean ground-water withdrawal and injection at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1991-93. Injection is plotted as negative withdrawal.

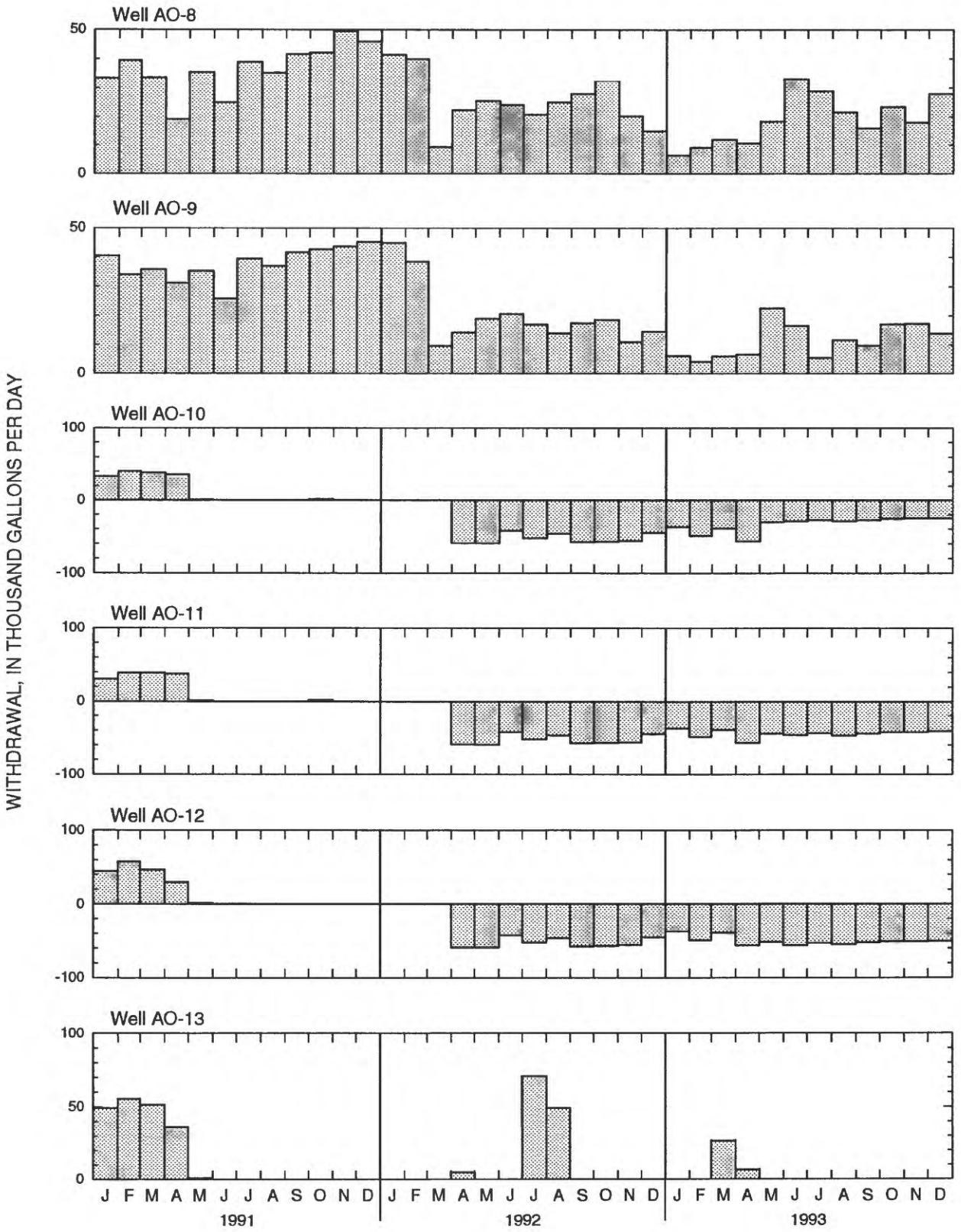


Figure B6 continued.--Monthly mean ground-water withdrawal and injection at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1991-93. Injection is plotted as negative withdrawal.

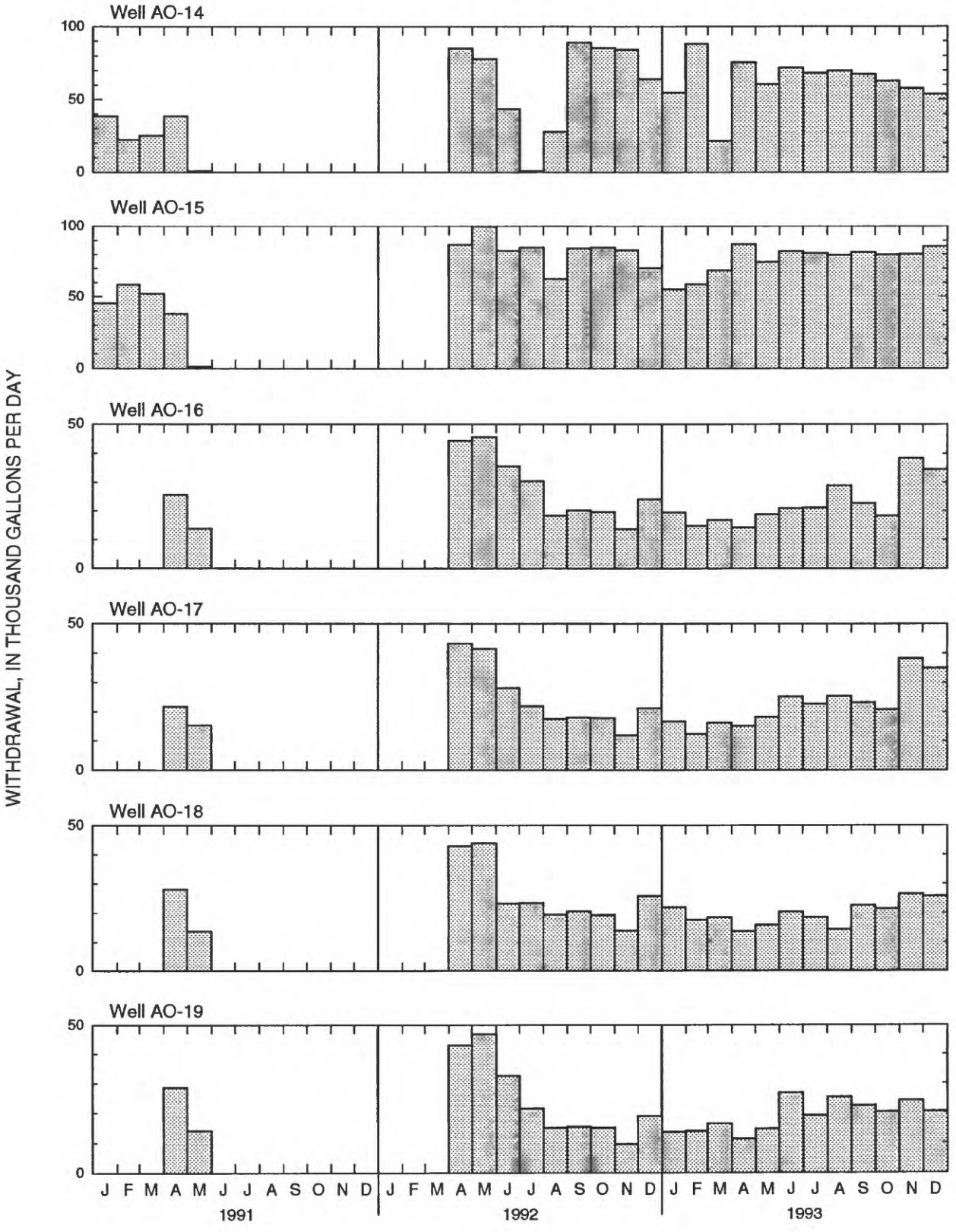


Figure B6 continued.--Monthly mean ground-water withdrawal and injection at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1991-93. Injection is plotted as negative withdrawal.

SECTION C

Graphs of weekly chloride concentration of pumped ground water, 1991-93

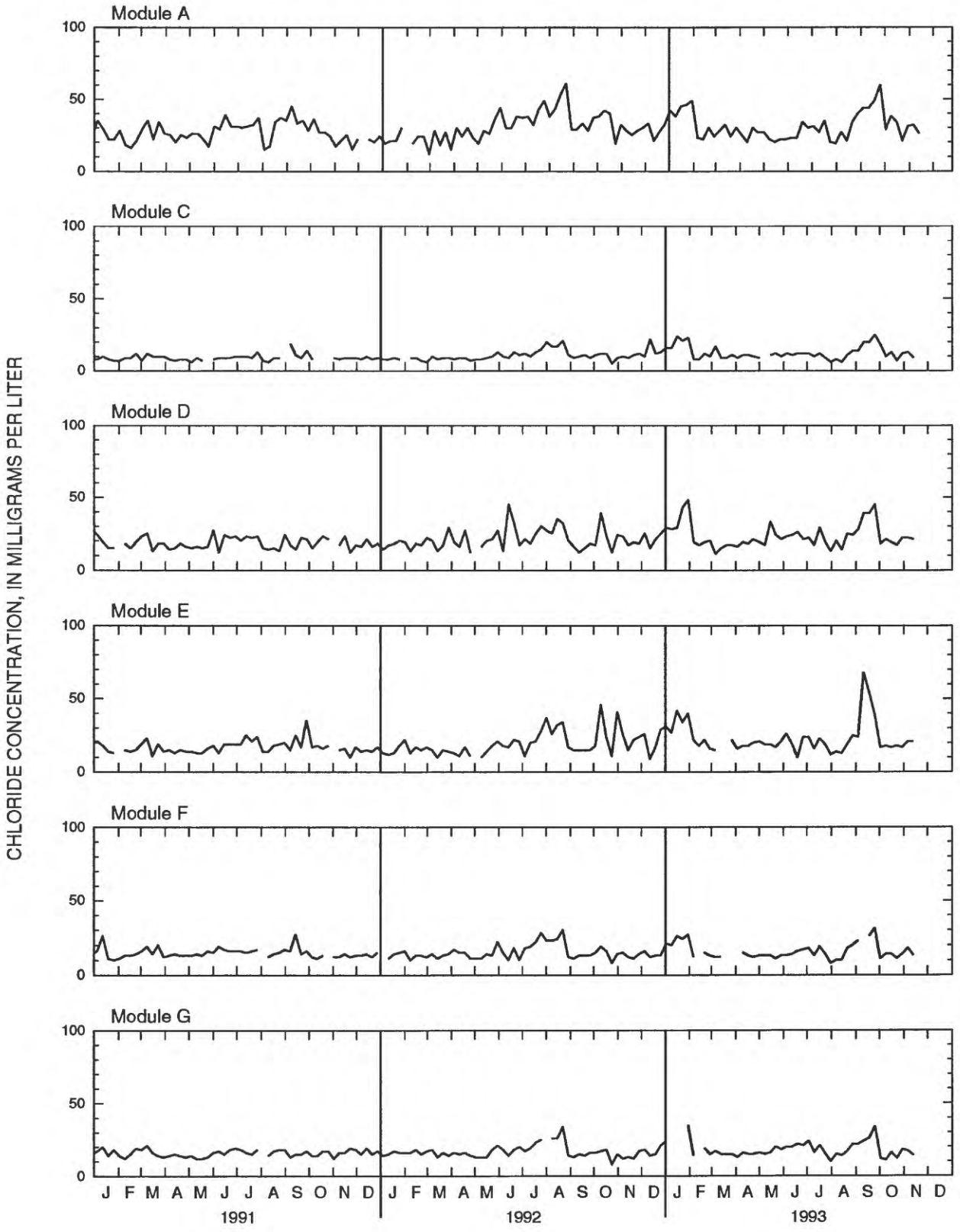


Figure C1. Weekly chloride concentration of pumped water at Modules A through L at Cantonment, Diego Garcia, 1991-93.

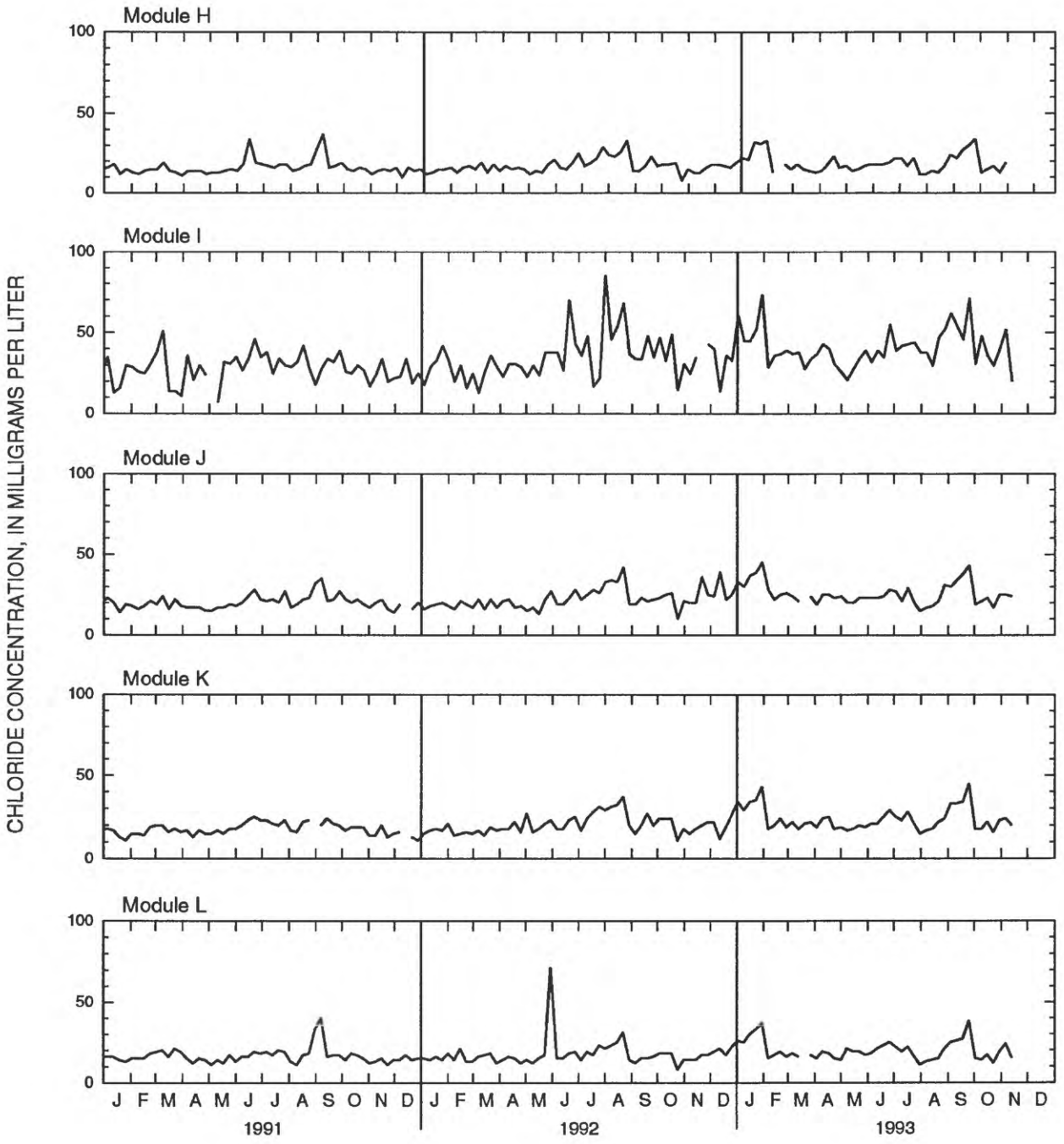


Figure C1 continued.--Weekly chloride concentration of pumped water at Modules A through L at Cantonment, Diego Garcia, 1991-93.

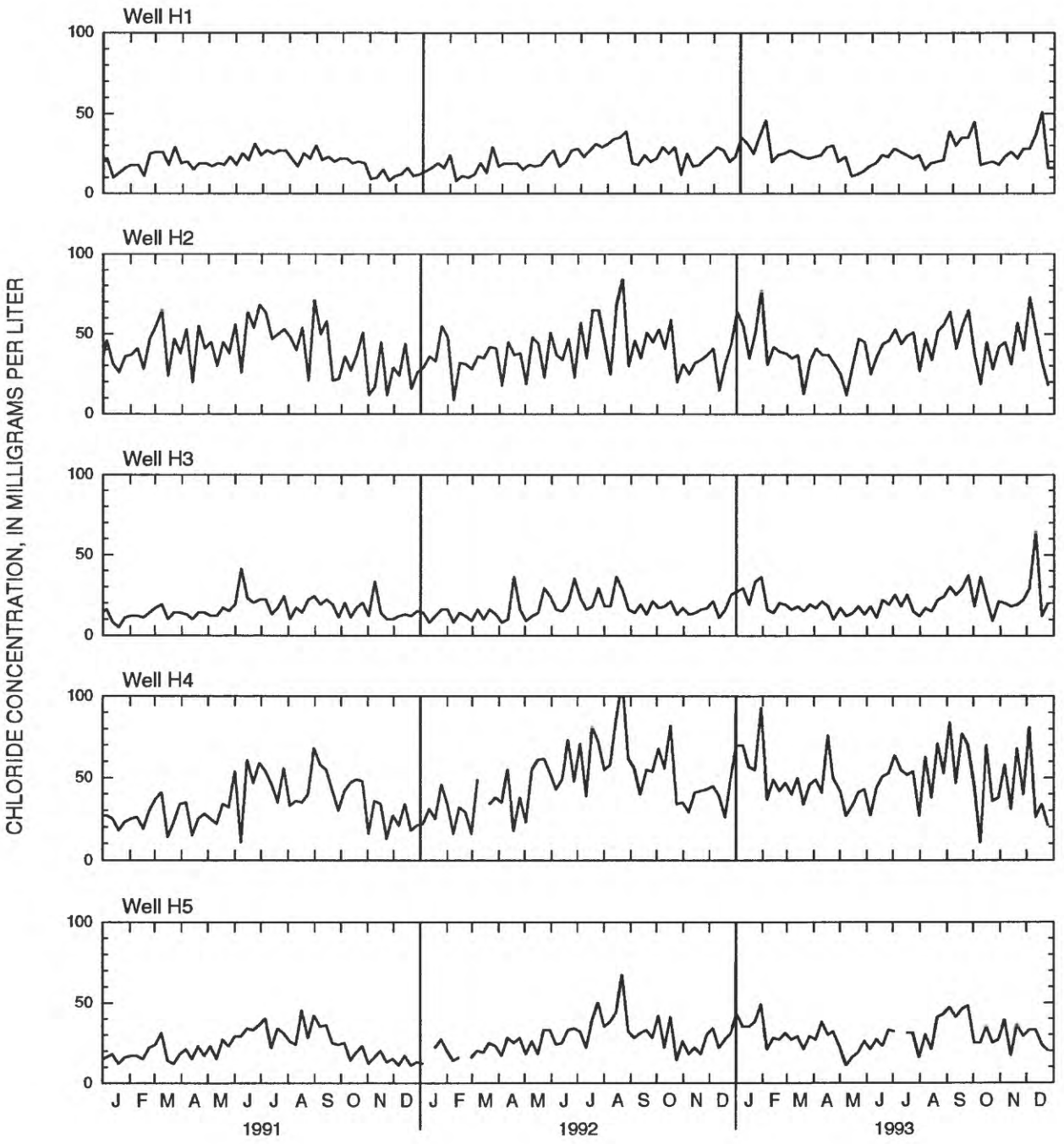


Figure C2. Weekly chloride concentration of pumped water at wells H1 through H7 at Cantonment, Diego Garcia, 1991-93.

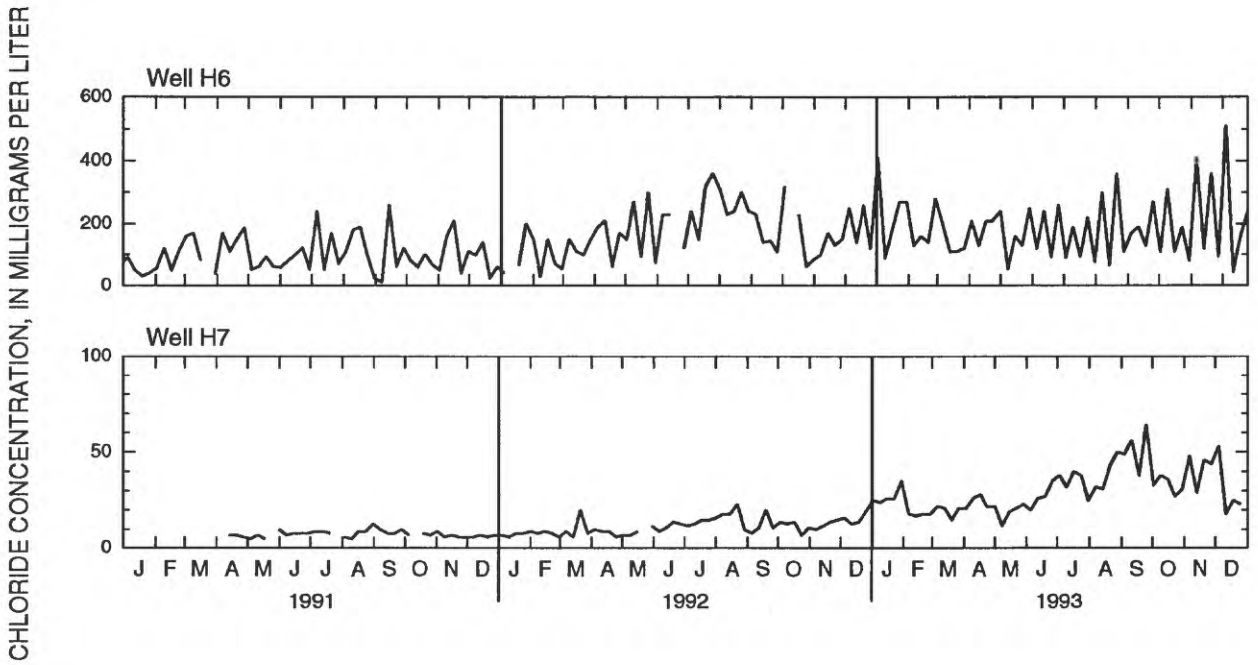


Figure C2 continued.--Weekly chloride concentration of pumped water at wells H1 through H7 at Cantonment, Diego Garcia, 1991-93.

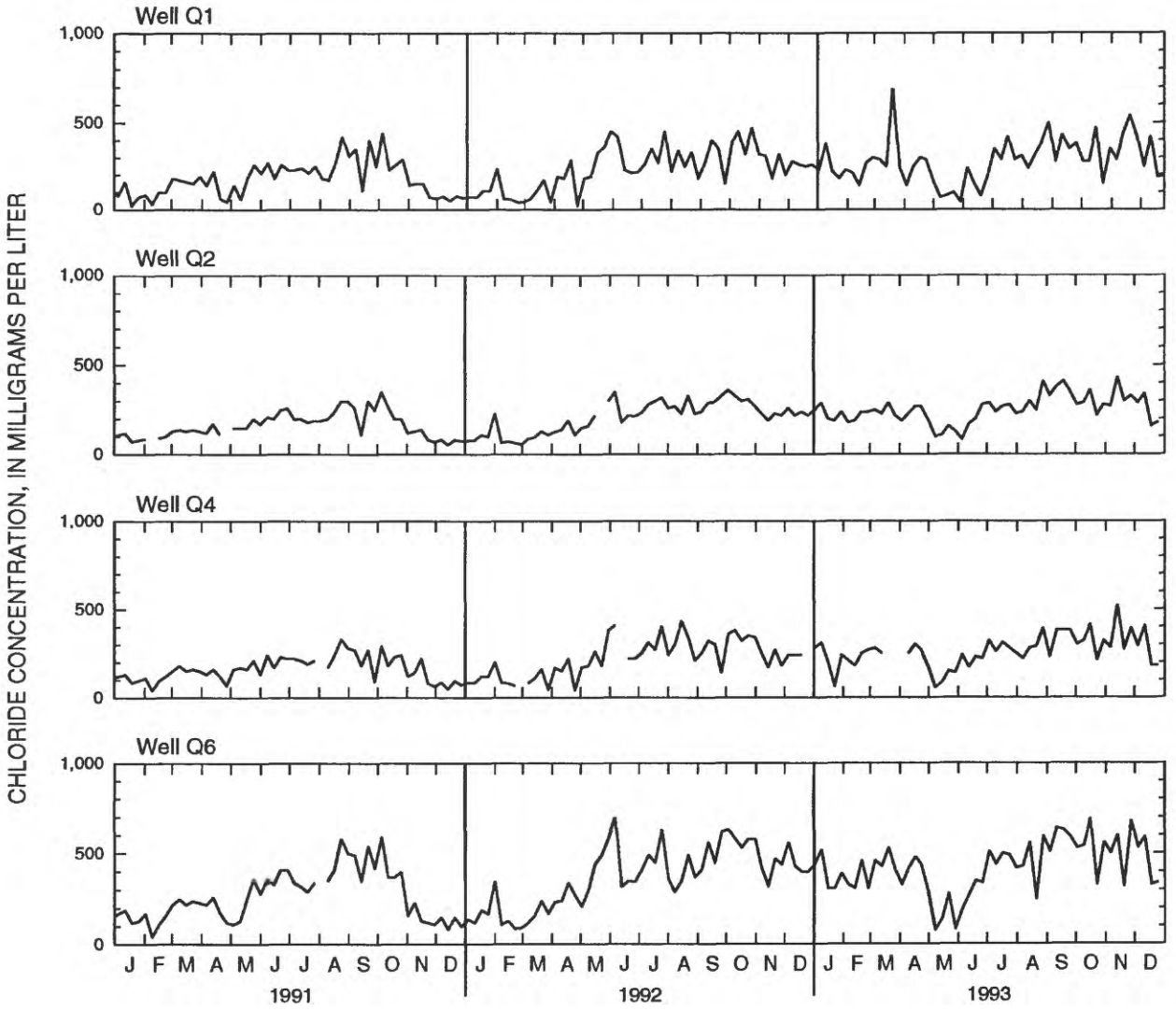


Figure C3. Weekly chloride concentration of pumped water at wells Q1, Q2, Q4, and Q6 at Cantonment, Diego Garcia, 1991-93.

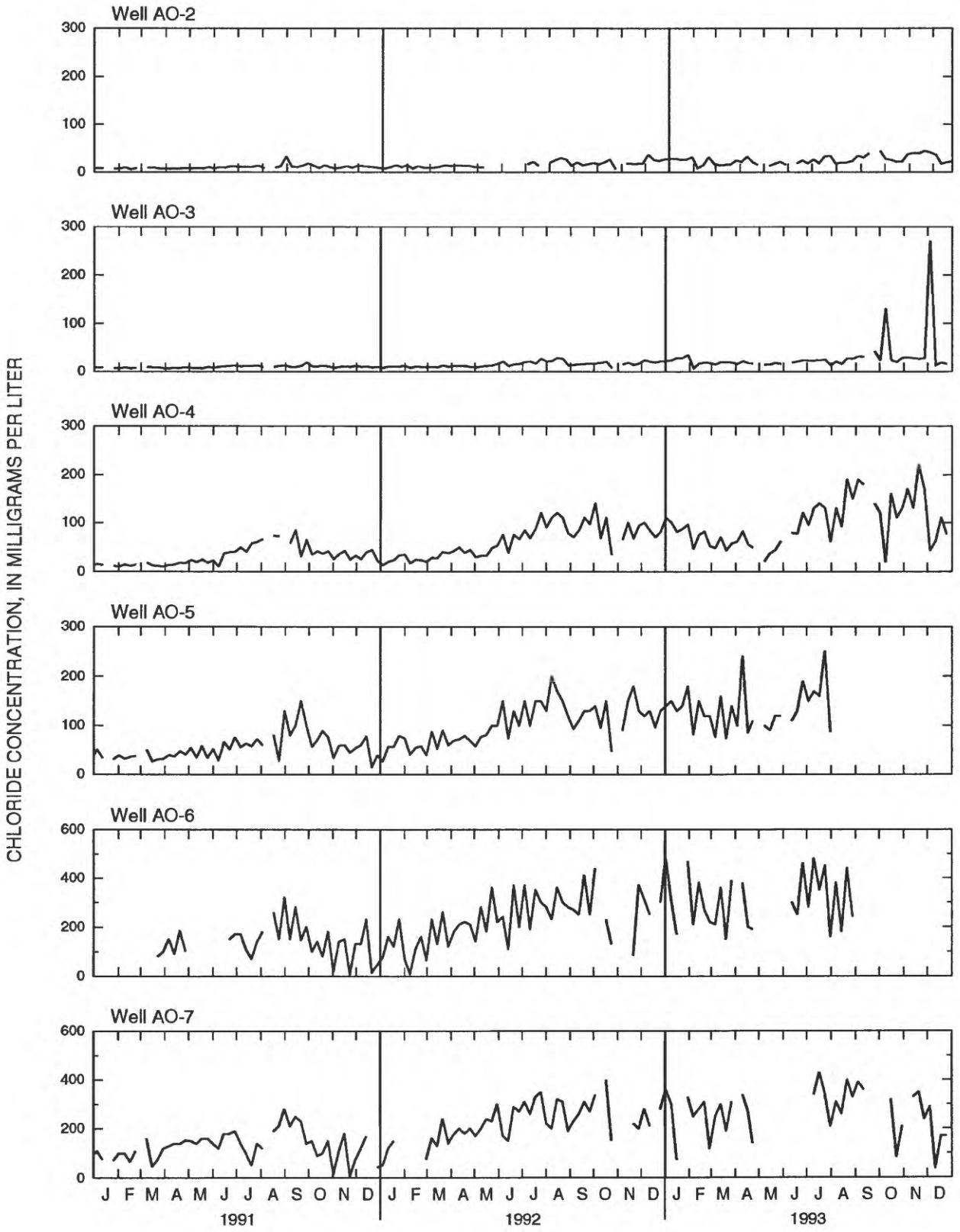


Figure C4. Weekly chloride concentration of pumped water at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1991-93.

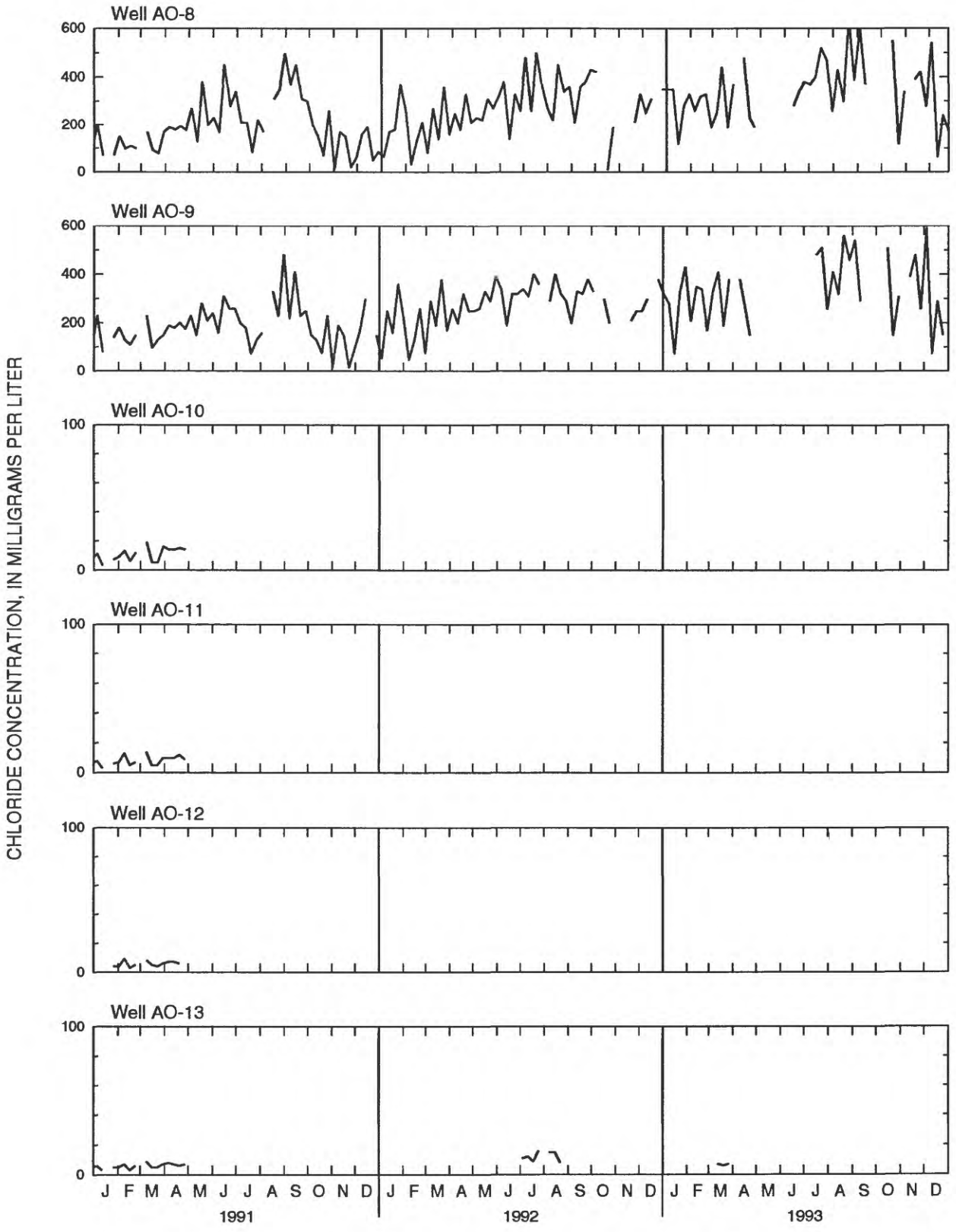


Figure C4 continued.--Weekly chloride concentration of pumped water at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1991-93.

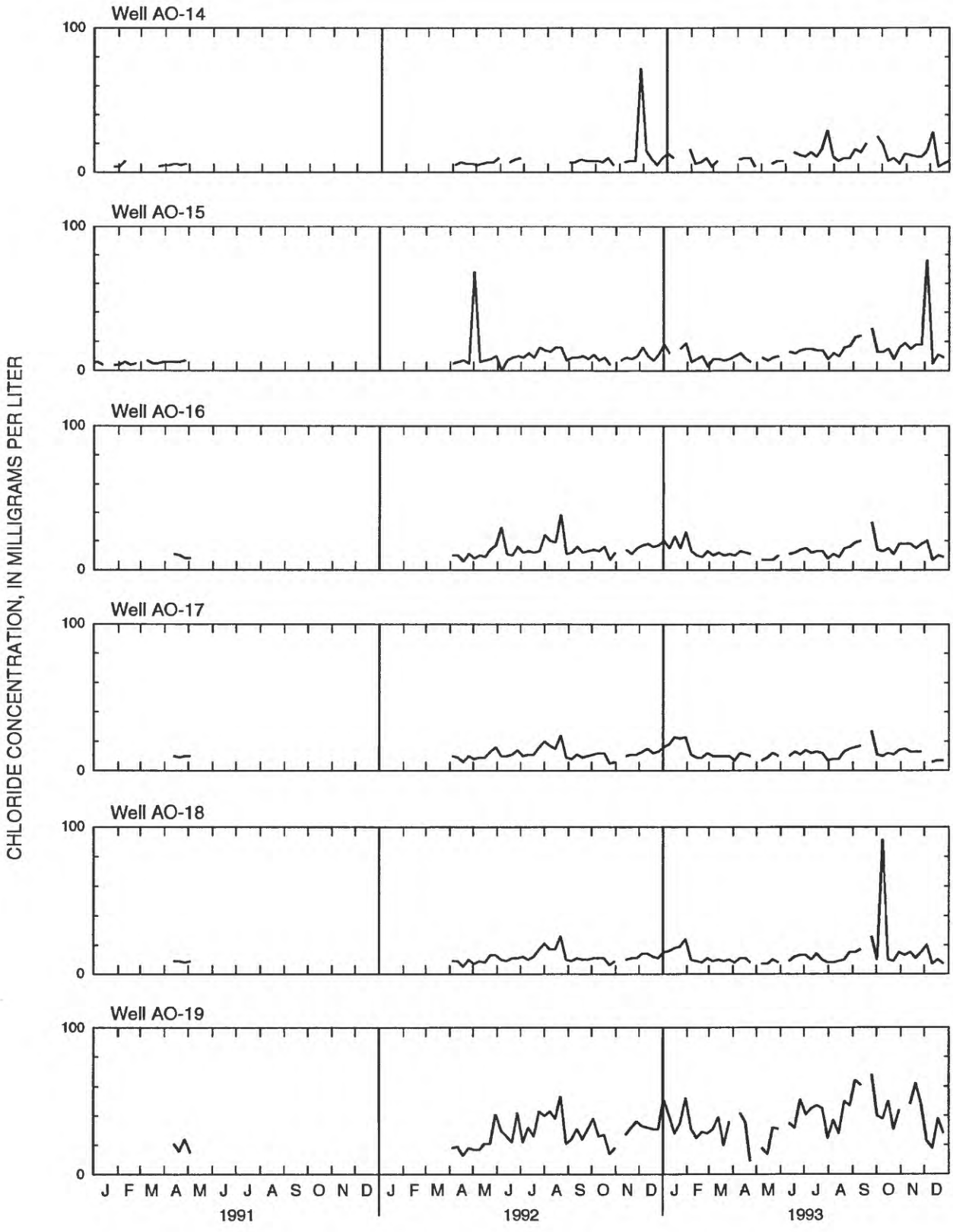


Figure C4 continued.--Weekly chloride concentration of pumped water at wells AO-2 through AO-19 at Air Operations, Diego Garcia, 1991-93.