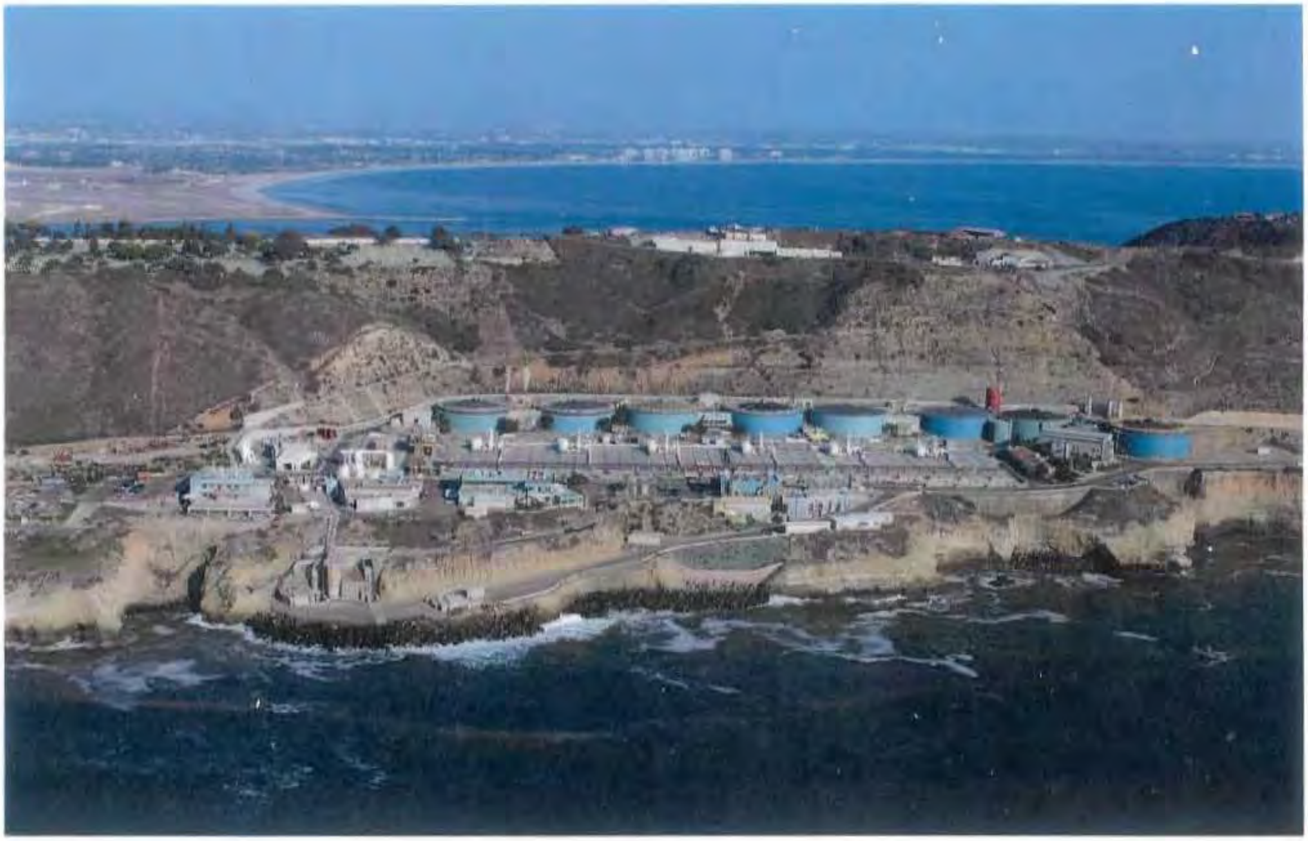
APPLICATION FOR RENEWAL OF
NPDES CA0107409 and
301(h) MODIFIED SECONDARY TREATMENT REQUIREMENTS

Point Loma Ocean Outfall



VOLUME IV
APPENDICES A thru F

City of San Diego
Metropolitan Wastewater Department

November 2007

Application for Renewal of NPDES CA0107409

&

301(h) Modified Secondary Treatment Requirements for Biochemical Oxygen Demand and Total Suspended Solids

POINT LOMA OCEAN OUTFALL &

POINT LOMA WASTEWATER TREATMENT PLANT

Submitted under provisions of
Section 301(h) of the Clean Water Act

City of San Diego
Metropolitan Wastewater Department
9192 Topaz Way
San Diego, CA 92123
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November 2007
(updated)

APPLICATION FOR RENEWAL OF NPDES CA0107409
&
301(h) MODIFIEDSECONDARY TREATMENT REQUIREMENTS

CITY OF SAN DIEGO
POINT LOMA OCEAN OUTFALL

November 2007
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VOLUME IV

TECHNICAL APPENDICES A through F

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Appendix B	**Point Loma Ocean Outfall**
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Metro System Facilities and Operations

APPENDIX A

METRO SYSTEM FACILITIES AND OPERATIONS

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List of Abbreviations

BAF	biological aerated filter
BOD	biochemical oxygen demand
CBOD	carbonaceous oxygen demand
CFU	colony forming units
COMC	City of San Diego Central Operations and Management Center
COMNET	City of San Diego Control Operations and Management Network
ft	feet
gpm	gallons per minute
gpd	gallons per day
MBC	Metro Biosolids Center
Metro System	San Diego Metropolitan Sewer System
mg	million gallons
mgd	million gallons per day
mg/l	milligrams per liter
MOC	Metro Operations Center
MWWD	City of San Diego Metropolitan Wastewater Department
NMI	North Metro Interceptor
NTU	Nephelometric Turbidity Units
O&M	operations and maintenance
Point Loma WTP	Point Loma Wastewater Treatment Plant
RAS	return activated sludge
SANDAG	San Diego Association of Governments
SMI	South Metro Interceptor
SMPs	standard preventative maintenance procedures
South Bay WRP	South Bay Water Reclamation Plant
South Bay WTP	South Bay Wastewater Treatment Plant
TDS	total dissolved solids
TSS	total suspended solids
VSS	volatile suspended solids
WAS	waste activated sludge

APPENDIX A

METROPOLITAN SEWERAGE SYSTEM FACILITIES AND OPERATIONS

A.1 INTRODUCTION

This appendix describes existing Metro System facilities and future facilities that will be required to meet projected NPDES permit requirements and provide required system and hydraulic capacity during the next twenty years.

Overview and Participating Agencies. The San Diego Metropolitan Sewage System (Metro System) provides for the conveyance, treatment, reuse, and disposal of wastewater within a 450-square-mile service area for the City of San Diego and regional participating agencies. Metro System facilities include wastewater collection interceptors and pump stations, wastewater treatment and water recycling plants, sludge pipelines and solids handling facilities, and two land/ocean outfall systems.

Metro System facilities are owned by the City of San Diego and are managed and operated by the City's Metropolitan Wastewater Department (MWWD). MWWD's mission is to:

> *Provide the public with a safe, efficient, and cost-effective regional sewer system as well as manage urban runoff to protect the environment, supplement our water supply, and meet regulatory standards.*

The City administers and executes contracts with each participating agency, monitors flows to the Metro System, bills and collects payments from participating agencies, and disburses all monies spent in connection with the Metro System.

Wastewater collection systems that discharge to the Metro System are owned and operated by respective participating agencies. Currently, wastewater flows from the City of San Diego comprise approximately 70 percent of the total Metro System flows. Remaining Metro System wastewater flows are contributed by fifteen Metro System participating agencies. Table A-1 presents the Metro System participating agencies. Participating agency input to Metro System planning and operation is provided through the San Diego Metropolitan Wastewater Commission.

Table A-1
Metro System Participating Agencies

Municipalities	Water/Wastewater Districts	Sanitation/Maintenance Districts
City of Chula Vista City of Coronado City of Del Mar City of El Cajon City of Imperial Beach City of La Mesa City of National City City of Poway	Otay Water District Padre Dam Municipal Water District	Lakeside/Alpine Sanitation District Lemon Grove Sanitation District Spring Valley Sanitation District East Otay Sewer Maintenance District Winter Gardens Sewer Maintenance Dist.

Figure A-1 (page A-3) presents the Metro System service area and the boundaries of the participating agencies. Figure A-1 also presents the location of key Metro System facilities. Figure A-2 (located after page A-4) presents a schematic of current Metro System facilities.

A.2 DESCRIPTION OF FACILITIES

Facilities Overview. The following five groups of facilities comprise the Metro System:

- wastewater conveyance facilities,
- the Point Loma Wastewater Treatment Plant and Ocean Outfall,
- the North City Water Reclamation Plant,
- the Metro Biosolids Center (MBC) and sludge conveyance facilities, and
- the South Bay Water Reclamation Plant and Ocean Outfall.

A.2.1 Wastewater Conveyance Facilities

Collection System Overview. Key wastewater collection facilities that comprise the northern portion of the Metro System service area include Pump Station No. 64, the Rose Canyon Trunk Sewer, and the North Metro Interceptor (NMI). Wastewater collected from this northern portion is conveyed to Pump Station No. 2 and the Point Loma Wastewater Treatment Plant (Point Loma WTP).

Figure A-1
Location of Metro System Facilities

Wastewater from the majority of the southern region of the Metro System is directed to the Point Loma WTP via the South Metro Interceptor (SMI) and Pump Station Nos. 1 and 2. A portion of the wastewater generated within the southern portion of the Metro System is directed to the South Bay Water Reclamation Plant (South Bay WRP) via the Otay River Pump Station and Grove Avenue Pump Station. The NMI and SMI converge at Pump Station No. 2, which pumps the combined wastewater through two force mains to the Point Loma Tunnel and Interceptor Sewer, which in turn conveys the flow to the Point Loma WTP for treatment and ocean disposal.

Pump Station No. 64. Pump Station No. 64 serves the northernmost 87 square miles of the north region of the Metro Service area, including the cities of Poway and Del Mar. The pumping facility, built in 1970 and upgraded in 1988, consists of:

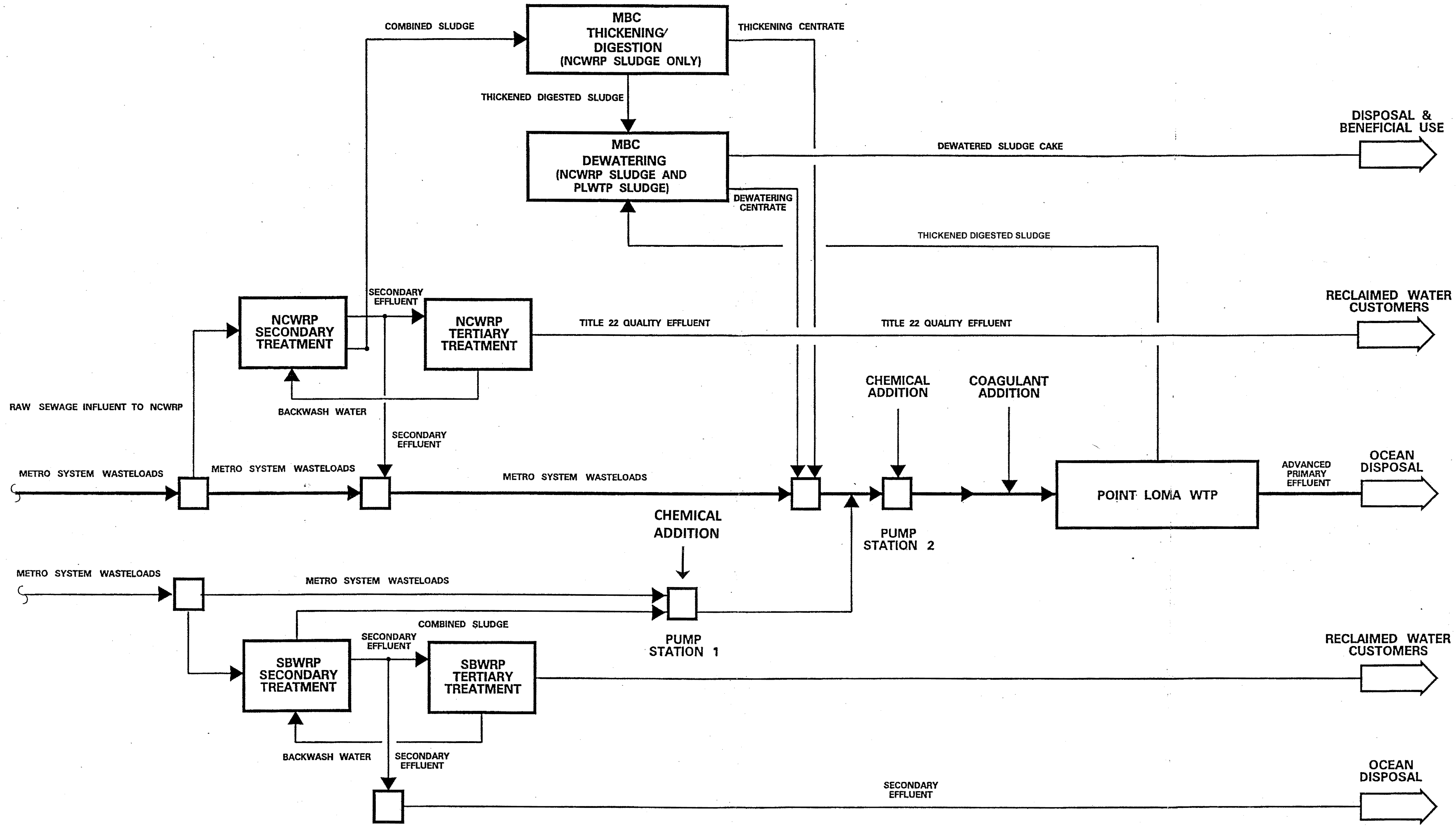
- eight sets of two pumps connected in series and housed in two separate buildings (the East and the West Stations),
- a separate screening structure housing two mechanically-cleaned bar screens and one manually-cleaned bar screen, and
- an odor control facility, also housed in a separate building.

Capacities of individual pumps range from 3400 gallons per minute (gpm) to 8700 gpm, and motor horsepower ranges from 200 to 500. The total capacity of Pump Station No. 64 is 73 mgd. Pump Station No. 64 discharges to the City of San Diego’s Rose Canyon Trunk Sewer.

Rose Canyon Trunk Sewer. The Rose Canyon Trunk Sewer conveys wastewater approximately five miles from the northern portion of the City of San Diego to the North Metro Interceptor. The City recently completed work to parallel the original 72-inch-diameter Rose Canyon Trunk Sewer with a 24,000-foot-long interceptor that ranges from 48 inches to 60 inches in diameter. Wastewater from the Rose Canyon Trunk Sewer discharges to the Morena Boulevard and East Mission Bay Interceptors, which in turn discharge to the NMI.

In addition to conveying untreated wastewater, excess treated effluent from the North City WRP is discharged to the Rose Canyon Trunk Sewer for transport to the Point Loma WTP for retreatment and ocean discharge.

North Metro Interceptor (NMI). The NMI conveys wastewater flows from the north region and a portion of the central region of the Metro System service area to Pump System No. 2. The NMI consists of two semi-parallel pipelines. The original 96-inch-diameter NMI ("West NMI") is 2.4 miles in length and begins at the San Diego River channel on the east side of I-5 and traverses north-



METRO SYSTEM PROCESS SCHEMATIC

FIGURE A-2

to-south along several local streets and across the site of the U.S. Marine Corps Recruit Depot until it reaches Pump Station No. 2.

A new 2.8-mile-long semi-parallel NMI ("East NMI") was constructed in 1996. The West NMI relief interceptor begins as a 108-inch sewer on the north side of the San Diego River, where it collects the flow from the new 78-inch North Mission Valley Interceptor. (See Figure A-1) The 108-inch NMI crosses the San Diego River and picks up flow from the 30-inch South Mission Valley Interceptor. It then crosses under Interstate Highways 8 and 5, and traverses in a southerly direction approximately a half-mile east of the 96-inch West NMI. At Barnett Avenue, it turns to the west and reaches the alignment of the original 96-inch NMI, where it increases in size from 108 to 114 inches. The 114-inch East NMI then parallels the 96-inch West NMI in a southerly direction for approximately 1 mile to Pump Station No. 2.

South Metro Interceptor (SMI). The SMI (see Figure A-1 on page A-3) conveys wastewater flows to Pump Station No. 2 from the southern region and portions of the central region of the Metro System service area. The upstream reach of the SMI extends from the City of Imperial Beach to Pump Station No. 1. This 7.6-mile SMI interceptor ranges from 42 to 96 inches in diameter. The downstream reach of the SMI runs between Pump Station No. 1 and Pump Station No. 2, and includes 1.6 miles of 72-inch force main, 1.0 mile of 78-inch sewer, 2.1 miles of 84-inch cross-town tunnel sewer, 0.3 miles of 102-inch sewer, and 1.7 miles of 108-inch sewer.

Pump Station No. 1. Pump Station No. 1 (see Figure A-1) conveys flows from the SMI to Pump Station No. 2. Pump Station No. 1 is a conventional reinforced concrete structure equipped with six vertical dry pit pumping units, each driven by a 600-horsepower electric motor. With one unit as standby, the pumping capacity is approximately 160 million gallons per day (mgd). The pump station was initially placed in operation in 1963 with three pumps, and a fourth unit was added in 1974. The last two pumps were added in 1993. Pump Station No. 1 also includes chemical additional facilities for odor and sulfide control. (Chemical use at Pump Station No. 1 and other Metro System facilities is detailed in Section A.2.7 on page A-38.)

Pump Station No. 2. Pump Station No. 2 is the terminus of the NMI and SMI. (See Figure A-1) Virtually all inflow to the Point Loma WTP is conveyed via Pump Station No. 2. Pump Station No. 2 is a reinforced concrete structure equipped with eight dry pit pumping units, each rated at 50,000 gpm. Six pumps are driven by 2250-horsepower electric motors and the other two by 2400-horsepower natural gas fueled engines. With one pump serving as a standby unit, the pumping capacity is approximately 432 mgd. Ferric chloride and other chemicals (see Section A.2.7) are added to the flow at Pump Station No. 2 for odor control and to assist in coagulation/sedimentation at the Point Loma WTP.

Pump Station No. 2 discharges wastewater to the east portal of the Point Loma Tunnel through two 87-inch diameter force mains, respectively 2.9 and 2.7 miles long. One force main, installed in 1963, follows a land route while the second force main, installed in 1975, is routed underneath San Diego Bay. The Point Loma Tunnel conveys wastewater under the Point Loma peninsula. It is 108 inches in diameter and 0.8 miles long. The Point Loma Interceptor Sewer begins at the tunnel's west portal, is 114 inches in diameter and 1.5 miles long, and terminates at the Point Loma WTP headworks.

Grove Avenue Pump Station. The Grove Avenue Pump Station (see Figure A-1) is located three miles north of the South Bay WRP and conveys wastewater from a portion of the southern region of the Metro System to the South Bay WRP. The pump station diverts wastewater from the San Ysidro Trunk Sewer and the Otay Valley Pump Station to the South Bay WRP via a 30-inch diameter force main. This station is capable of providing up to 15 mgd of wastewater to the South Bay WRP.

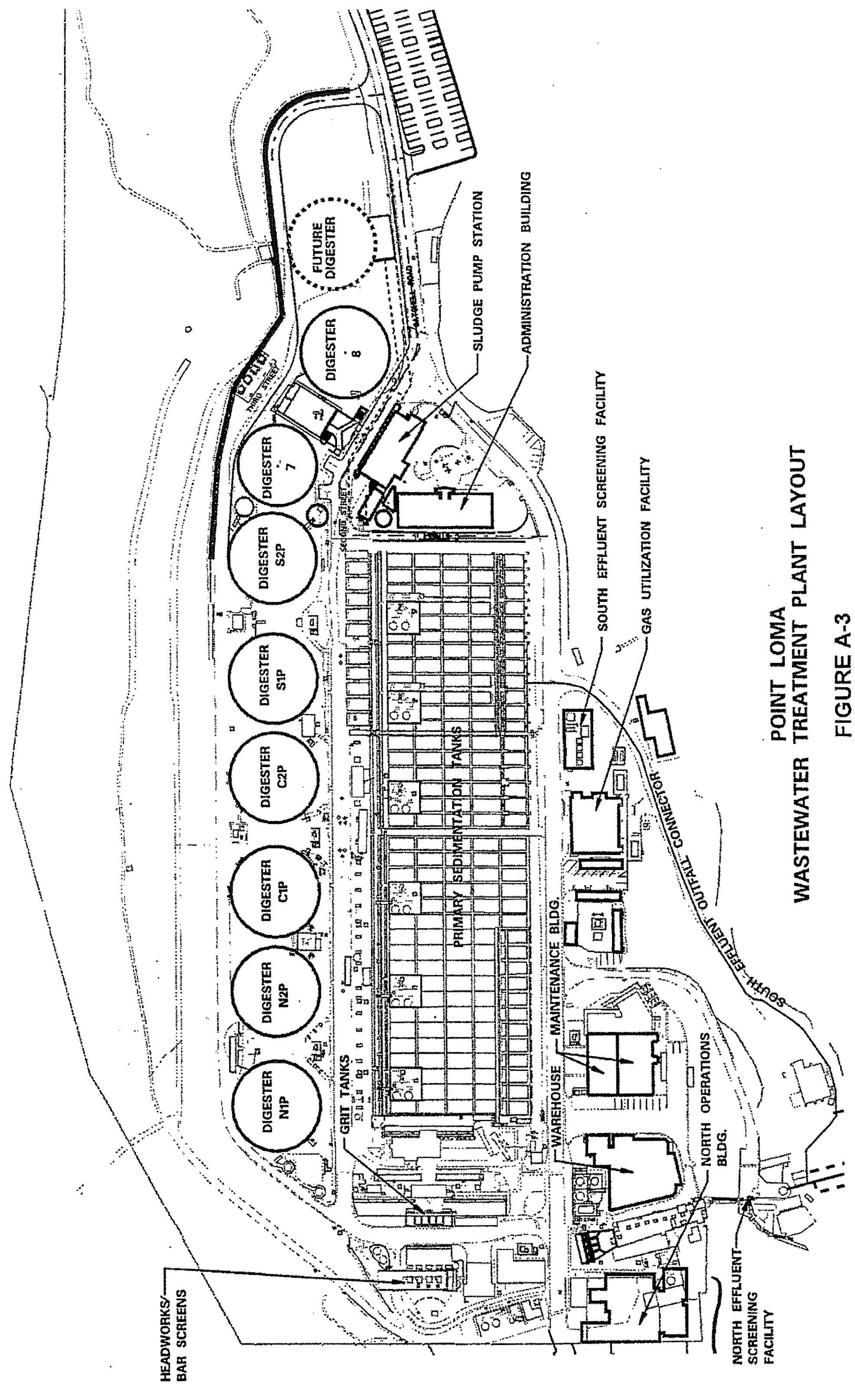
The design capacity of the Grove Avenue Pump Station is 15 mgd (average flow) and 18 mgd (peak flow). The pumps are vertical, mixed-flow, non-clog, centrifugal with variable speed drives. The pump station features a below-grade, trench-type, self-cleaning wet well. The pump room is a below-grade structure that houses the pumps, discharge piping and valves, and the pump control valves. The motor room houses the pump motors with the pump motors connected to the pumps through extended shafting. The motor room and motor control rooms are situated at-grade and above the 100-year flood level to protect the electrical equipment and motors from damage and failure from flooding.

Otay River Pump Station. The Otay River Pumping Station conveys wastewater from the Otay River portion of the Metro System service area to the Grove Avenue Pump Station via a conveyance system that is comprised of:

- a 9,300 foot-long 24-inch force main and 3,400-foot-long gravity main to divert flows from the Otay and Chula Vista Trunk Sewers, and
- a 700-foot-long, 36-inch gravity line between Hollister Street and the Grove Avenue Pump Station.

A.2.2 Point Loma WTP and Ocean Outfall

Overview. The Point Loma WTP is a chemically-assisted primary treatment plant. The plant has rated capacities (with one sedimentation tank out of service) of 240 mgd average annual daily flow and 432 mgd peak wet weather flow. The plant layout is presented in Figure A-3 (page A-7). These processes include:



POINT LOMA
WASTEWATER TREATMENT PLANT LAYOUT

FIGURE A-3

- mechanical self-cleaning climber screens to remove rags, paper, and other floatable material from the raw wastewater,
- aerated grit removal including grit tanks, separators and washers,
- chemical addition to enhance settling to achieve at least 80 percent removal of suspended solids,
- sedimentation where flocculated solids (sludge) settle to the bottom of the sedimentation tanks and scum floats to the surface, and
- sludge and scum removal facilities.

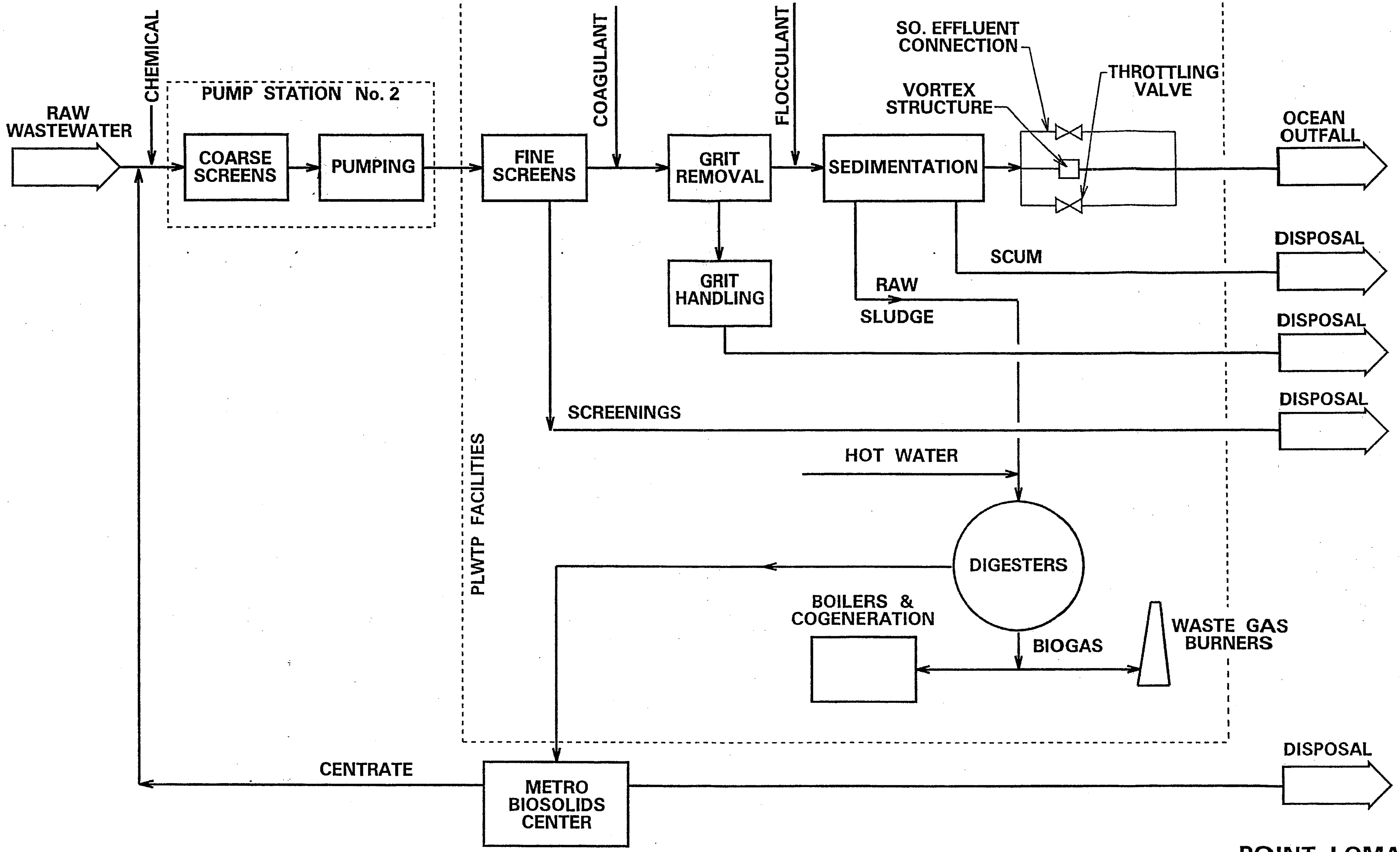
Figure A-4 presents a schematic of wastewater treatment process at the Point Loma WTP. Table A-2 (page A-9) presents design criteria for Point Loma WTP unit processes. Onsite solids treatment at the Point Loma WTP consists of anaerobic sludge digestion. Digested sludge is transported via pipeline to the Metropolitan Biosolids Center for dewatering and disposal. Screenings, grit, and scum are trucked to a landfill for disposal.

Plant Inflow. In addition to receiving raw wastewater from both the northern and southern portions of the Metro System service area, the Point Loma WTP may also receive treated effluent from the North City WRP. During the non-irrigation season, secondary North City WRP effluent is discharged to the Point Loma WTP via the NMI for retreatment and disposal. Additionally, during times when North City WRP recycled water production exceeds demands, excess North City recycled water may also be conveyed to the Point Loma WTP for treatment and disposal.

Preliminary Treatment. Raw wastewater from Pump Station No. 2 flows into the Point Loma WTP through five 15 mm mesh mechanically cleaned bar screens. Screened raw wastewater then enters a single basin from which it flows through six parallel Parshall flumes where plant influent flow is measured. Preliminary treatment is also performed at Pump Station No. 2 where the coarse bar screens are located.

Grit Removal. The Parshall flumes also apportion flow equally between six aerated grit removal tanks. Settled grit is extracted from the tanks, separated, washed, and conveyed to a hopper for truck loading. The grit removal tanks are covered to contain odors. Foul air is drawn from under the covers and treated in two-stage scrubbers.

Chemical Coagulation. Chemical coagulants are added to the screened raw wastewater to enhance settling of suspended solids. Section A.2.7 summarizes chemical use, application points, typical dose rates, and purposes of chemical addition at the Point Loma WTP. Ferric chloride mixing occurs in the Parshall flumes, and anionic polymer (for flocculation) is added in the influent channel to the sedimentation tanks.



POINT LOMA WASTEWATER TREATMENT PLANT PROCESS SCHEMATIC DIAGRAM

FIGURE A-4

Table A-2
Design Criteria and Loadings
Point Loma Wastewater Treatment Plant[1]

PROCESS	UNIT	VALUE
INFLUENT FLOW [2]		
At Annual Average Daily Flow (AADF)	mgd	240
At Peak Wet Weather Flow (PWWF)	mgd	432
PRELIMINARY TREATMENT		
At Pump Station No. 2		
Number of screens	-	4
Channel width	feet	9.5
Clear opening between bars	millimeters	30
At Treatment Plant		
Number of screens	-	5
Peak Hydraulic Capacity, each	mgd	108
Channel width	feet	7
Clear opening between bars	millimeters	15
GRIT REMOVAL		
Number of Tanks	-	6
Detention Time @ PWWF	minutes	2.8
Tanks S1, S2, C1 and C2[3]		
Width	feet	20
Length	feet	60
Capacity, each	mgd	62
Tanks N1 and N2[3]		
Width	feet	24
Length	feet	88
Capacity, each	mgd	91
SEDIMENTATION		
Number of Tanks	-	12
Total Width	feet	63.7
Length	feet	224
Average Liquid Depth		
Tanks 1 through 6	feet	16.5
Tanks 7 through 12	feet	16.5
Overflow Rate at AADF[4]	gpd/ft^2	1,529
Maximum Hydraulic Capacity, each tank	mgd	21.9
SLUDGE DIGESTION	0	
Number of Digesters	-	8
Diameter, Digesters 1-6 and 8	feet	125
Diameter, Digester 7	feet	110
Side Water Depth	feet	35
Volume, Digesters 1-6 and 8 (7 used as hold tank)	ft^3	430,000
Average Detention Time (7 tanks)	days	23
Suspended Solids Loading	lbs dry solids/mg	2,300
Volatile Solids Loading (7 tanks)	lbs solids/ft/dy	0.08
Biogas Production (7 tanks)	std. ft^3/hr	222,800

[1] *Point Loma Wastewater Treatment Plant Master Plan* - August 1994. Updated in 2000.

[2] Based on 12 sedimentation tanks. Capacities increased to 240 mgd (average flow) and 432 mgd (peak flow) when sedimentation Tanks Nos. 11 and 12 were added.

[3] Grit removal tanks S1 and S2 were built in 1963; C1 and C2 in 1982; N1 and N2 in 1989.

[4] With one tank out-of-service.

Caustic soda, sodium hypochlorite, salt, and ferrous chloride are added (see Section A.2.7 on page A-38) to assist in odor control, while hydrogen peroxide is used to regenerate iron salts for coagulation.

Sedimentation. Following chemical addition, the partially treated wastewater flows into a distribution channel for diversion into the twelve sedimentation tanks. Each sedimentation tank consists of three 20-foot wide bays provided with chain and flight sludge and scum collectors. Sludge is scraped along the bottom to a common hopper (at the tank influent end) provided with a cross collector. Scum is skimmed from the tank surface at the opposite end.

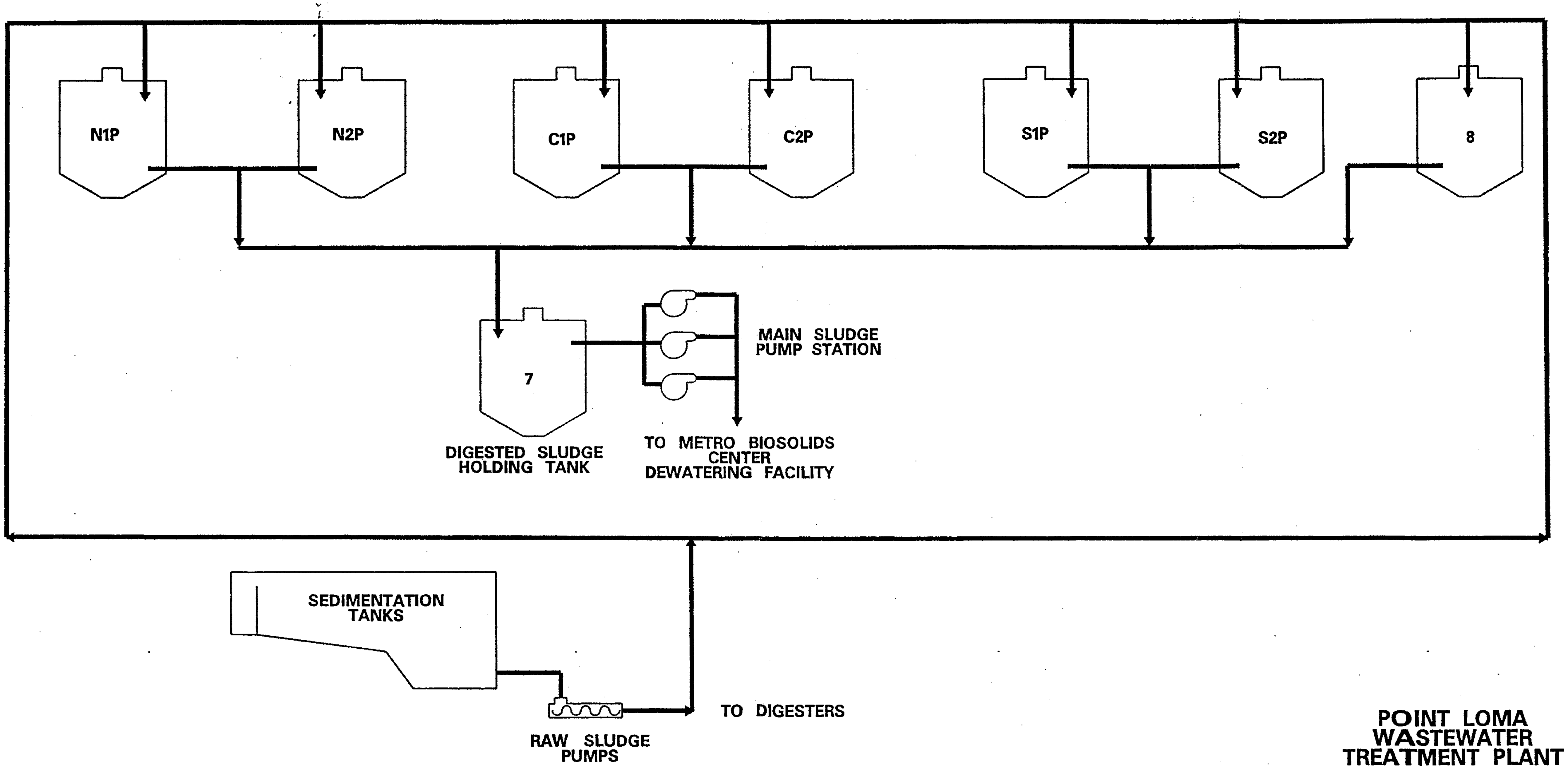
To control odors, each primary sedimentation tank is covered. Foul air from the sedimentation basins (as well as air from all other plant processes) is exhausted to an odor control system. The odor control system includes two-stage scrubbers that incorporate both caustic soda and hydrogen peroxide scrubbing. Scrubbed air is treated through activated carbon adsorption prior to release.

Effluent Discharge System. From the sedimentation tanks, treated effluent enters the effluent channel. Plant effluent can be diverted north through four 30-mm Parkson traveling screens and then either through an 84-inch sleeve valve or over a weir and into a vortex structure. Plant effluent can also be diverted south through four 30-mm Parkson traveling screens and then, based on flow and equipment configuration, a combination of three 54-inch sleeve valves and a 54-inch ball valve.

Point Loma Ocean Outfall. Treated effluent from Point Loma WTP is discharged to the Pacific Ocean though the Point Loma Ocean Outfall. The Point Loma Ocean Outfall discharges treated effluent at a depth of approximately 320 feet approximately 4.5 miles offshore. A detailed description of the Point Loma Ocean Outfall is presented in Appendix B.

Onsite Solids Handling. The influent screenings are removed by bar screens and dumped onto a shaftless screw conveyor for transport to a screenings compactor. After the compaction process, the screenings are deposited into a storage bin via a discharge shoot. After it is determined that the screenings bin is full, the material is analyzed for solids concentrations to meet the 20 percent solids disposal requirement. Once the disposal requirement is met, the screenings are picked up by rail truck and transported directly to a sanitary landfill for disposal.

Grit removed in the aerated grit tanks is pumped to cyclones where it separates from the wastewater. From the cyclones, grit is discharged to screw type classifiers for washing. Washed grit is then



POINT LOMA
WASTEWATER
TREATMENT PLANT
SLUDGE DIGESTION
SCHEMATIC DIAGRAM

FIGURE A-5

deposited into a hopper from where it is loaded onto a bin and analyzed for solids concentration to meet a 40 percent solids concentration disposal requirement. Once the targeted 40 percent solids concentration is achieved, the material is picked up by a rail truck and transported directly to sanitary landfill for disposal.

Sludge Digestion. Raw sludge is pumped from the sedimentation tanks to up to seven anaerobic digesters: N1P, N2P, C1P, C2P, S1P, S2P, and Digester 8. Digester 7 is used as a digested sludge holding tank. All the digesters are heated by hot water using external heating units. Mixing is performed by gas circulation with the exception of Digester 7, which uses a pump mixing system. A schematic diagram of the sludge digestion system is shown on Figure A-5.

Approximately 2.5 to 3.0 million cubic feet per day of biogas are produced during the digestion process. Of this total, approximately 1.5 million cubic feet is used as fuel for the plant's cogeneration facility, which consists of two engine/generator sets that together produce about 4570 kilowatts of power, over one third of which is used on site in the operation of the treatment plant. Excess power is sold to Sempra Energy Solutions. The remaining digester gas generated at the plant is either used to fuel boilers for digester heating or is flared as an odor-free disposal measure.

Sludge Pumping and Screening. Digested sludge is pumped to MBC for processing and dewatering. The sludge pump station at the Point Loma WTP features multiple levels. The lower level houses three large positive displacement diaphragm pumps, each rated at 750 gpm. The pumps discharge the sludge via a 21- mile-long pipeline to the MBC for dewatering.

The top level contains five in-line sludge screens. The original and ultimate intent is to screen raw sludge, although they have also been used in the past to screen digested sludge prior to pumping. Each screen can process 450 gpm and has a screen opening of 5 millimeters and 2 millimeters. Screenings are conveyed to loading hoppers in the building. As needed, the sludge screenings are transported to a sanitary landfill for disposal.

Staffing and Operations. Consistent with its size and pivotal role within the Metro System, the Point Loma WTP is fully staffed 24 hours per day, 7 days a week. Plant staffing includes:

- 28 operators,
- 13 maintenance staff,
- 4 maintenance-planning staff,
- 4 electricians, and
- 5 instrumentation and control technicians.

The operations staff is supported by an administration, engineering, clerical and support staff of 17. The day shift (Monday through Friday) consists of the Plant Superintendent, the Senior Operations Supervisor, a shift supervisor, and five operators.

A Process Control Group, consisting of two supervisors and one operator, supports the day-shift staff. The Process Control Group performs non-routine functions such as developing operating procedures, developing and implementing testing programs, purchasing chemicals, monitoring and assessing process trends, and process trouble-shooting. Operating data is also collected by the Process Control Group. The night shift consists of one shift supervisor and three operators. A fourth operator is added to staff the swing and weekend shifts.

The maintenance staff is divided into four crews:

- Breakdown Maintenance crew for emergency repairs
- Preventive Maintenance crew for routine equipment maintenance
- Construction crew for in-house construction projects
- Electrical and Instrumentation maintenance crew

Except for minor tests and analysis, all laboratory work for process control and regulatory compliance is performed off-site at certified laboratories run by MWWD's Environmental Monitoring and Technical Services Division.

Operator Training. Operator training is an ongoing activity at the Point Loma WTP. All plant personnel receive special training in plant safety procedures. The City contracted with an outside firm to upgrade the site-specific technical training program to be consistent with the programs developed for the North City WRP and MBC. A computer-based Process Control Training Simulator was developed as part of this program.

All Point Loma WTP operators are required to hold a Certificate of Competence issued by the California Water Resources Control Board (Grades I through V). Entry level operators must have a Grade II certificate. The current breakdown by grade among the plant's staff is as follows:

Grade	No. of Certified Staff
I - OIT	4
II	8
III	10
IV	2
V	4

The Point Loma WTP Operations and Maintenance (O&M) Manual includes start-up and shutdown instructions for the plant process units. These instructions are complemented by established procedures (written in memo format) for operating plant function. Lock-out/tag-out procedures exist for each piece of electrically driven equipment. A number of the existing operating instructions have been converted into detailed Standard Operating Procedures (SOPs). The plant employs a computerized maintenance management system to schedule preventative and corrective maintenance tasks.

ISO 14001 Certification. The Metro System's Wastewater Treatment and Disposal Division was the first municipal wastewater treatment organization in the nation to receive the prestigious ISO 14001 Certification. The American Bureau of Shipping-Quality Evaluations has certified that Metro=s Environmental Management System (which relates to the operation and management of all Metro facilities) conforms to the international standard for environmental management.

A.2.3 North City WRP

Overview. The North City Water Reclamation Plant (North City WRP) is an advanced wastewater treatment facility capable of producing recycled water that complies with requirements of Title 22, Division 4 of the California Code of Regulations for unrestricted body contact.

Figure A-6 presents the layout of the North City WRP. The North City WRP provides a capacity to treat 30 mgd (average flow) and can produce up to 27 mgd of recycled water. Figure A-7 presents a schematic of the North City WRP. The main liquid treatment train consists of:

- influent pumping,
- screening,
- aerated grit removal,
- primary sedimentation with sludge and scum removal,
- sideline flow equalization,
- anoxic-aerobic activated sludge consisting of anoxic mixing with mixed liquor recycle and fine bubble aeration,
- secondary clarification with scum removal,
- mixed liquor and excess sludge wasting,
- chemical addition for coagulation,
- flocculation,
- tertiary filtration through anthracite coal media, and
- effluent chlorination.

Table A-3 (pages A-15 through A-17) presents North City WRP design criteria for each unit treatment process. Tertiary treated recycled water produced at the North City WRP is discharged to a regional conveyance system for transport to qualified recycled water users. Excess secondary treated effluent is discharged to the Rose Canyon Trunk Sewer for conveyance to the NMI and Point Loma WTP. Sludge from the North City WRP is pumped to the Metro Biosolids Center for processing.

Plant Inflows. Most wastewater processed at the North City WRP is diverted from the 72-inch diameter Rose Canyon Trunk Sewer. This sewer receives the discharge from Pump Station No. 64. Diverted wastewater is conveyed through an 84-inch gravity pipeline to the North City WRP Influent Pump Station. Flows discharged from Pump Station No. 64 in excess of North City WRP influent feed rates continue down the Rose Canyon Trunk Sewer to the NMI and the Point Loma WTP.

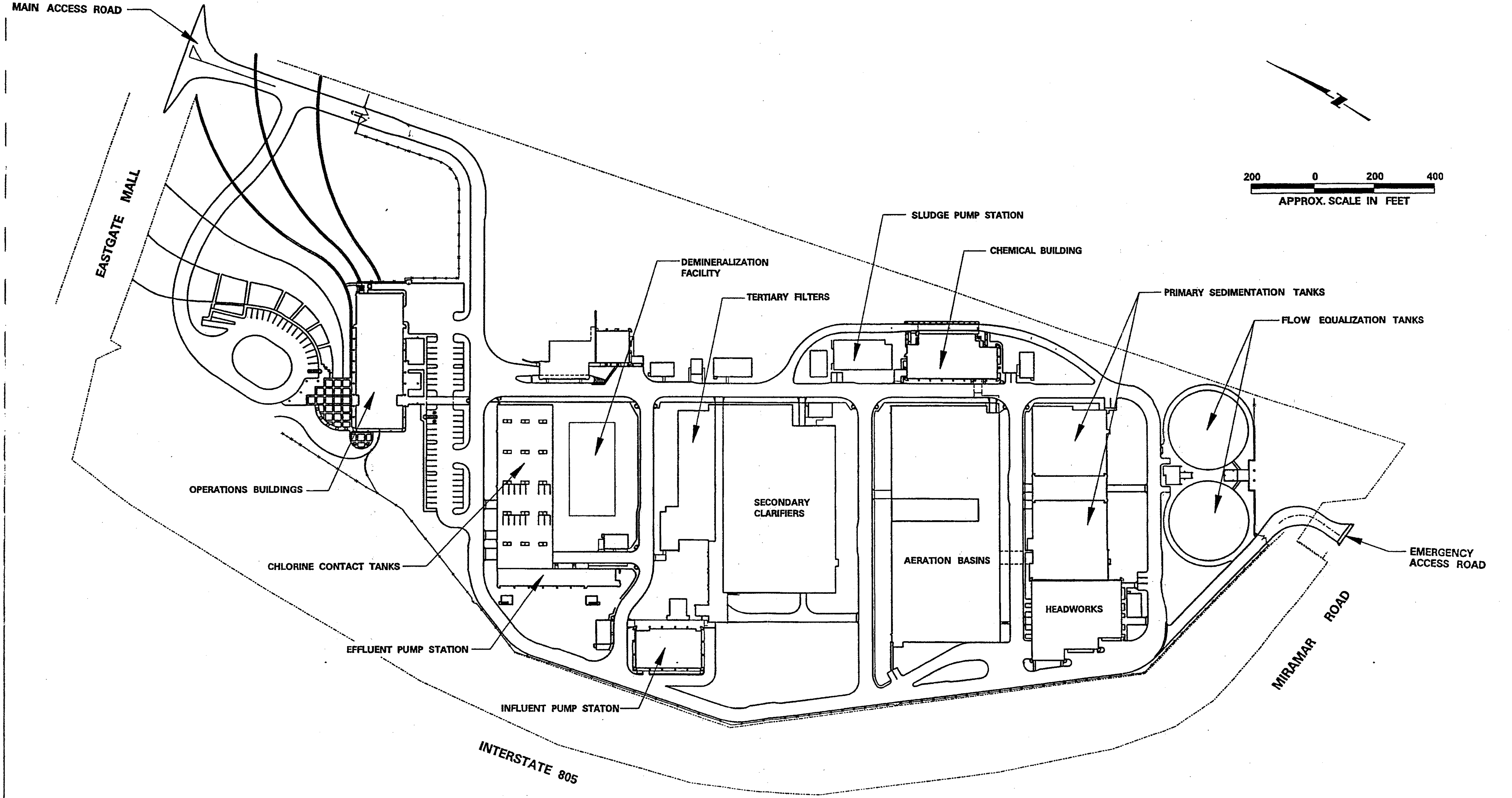
The North City WRP may also received inflow from the Peñasquitos Pump Station via a pressure/gravity pipeline which discharges directly into the plant's headworks. This pump station, which has an initial peak flow capacity of 12 mgd, diverts wastewater from the Peñasquitos Trunk Sewer and Pump Station No. 64.

Influent Pumping. The North City WRP Influent Pump Station lifts incoming wastewater (plus recycled flows) to the plant's headworks. The station, of conventional wet well/dry well design, houses four variable speed pumps together with ancillary systems and controls. Space is available to add a fifth pump in the future. The flow range of each pumping unit is 6,000 to 17,300 gallons per minute (gpm). A hydraulically-operated influent sluice gate is provided to isolate the pump station in case of power failure or flooding of the dry well. Chemicals (ferric chloride and chlorine solution) can be added at the wet well for liquid phase odor control. Two-stage scrubbers are provided to treat odors released within the influent pump station. Chemical use at the Influent Pump Station and other North City WRP facilities is summarized in Section A.2.7 (page A-38).

Screening. The plant's headworks building houses two mechanically-cleaned bar screens to remove large solids from the influent. A third unit could be installed in the future. Screenings are raked from the bar screens, pressed, and conveyed to a hopper located over a truck loading area.

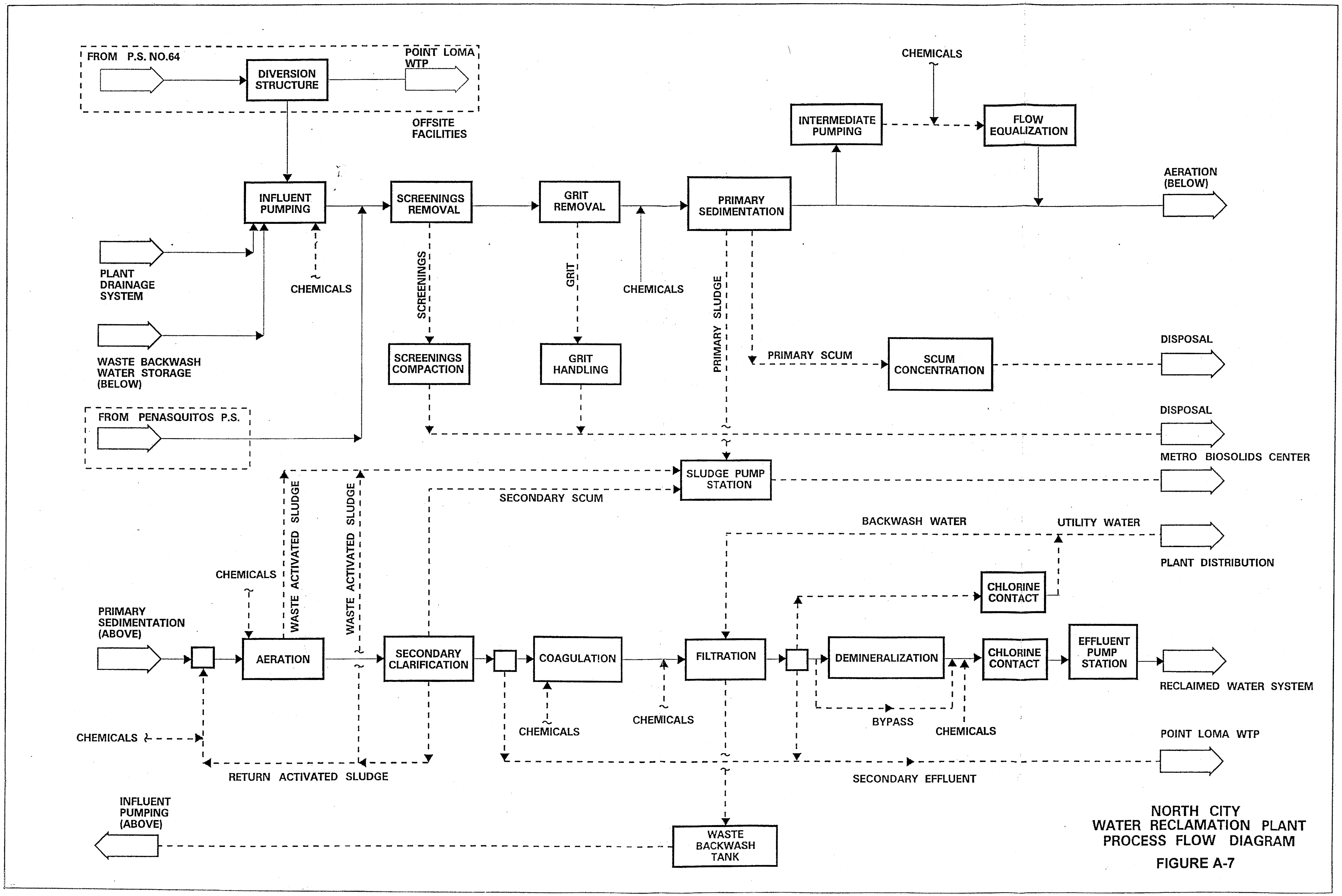
Grit Removal. Grit is removed in two aerated and baffled grit tanks. Grit removed in each tank is deposited into three hoppers. From the hoppers, the grit is pumped to cyclonic separators followed by grit classifiers/washers. Washed grit is conveyed to storage hoppers. Grit is loaded onto trucks for hauling from the storage hoppers.

Agitation air is provided by three positive displacement blowers. The grit tanks are covered to contain odors. Foul air is drawn from under the covers and treated in two-stage scrubbers.



NORTH CITY WATER RECLAMAT
PLANT LAYOUT

FIGURE A-6



NORTH CITY
WATER RECLAMATION PLANT
PROCESS FLOW DIAGRAM

FIGURE A-7

Table A-3
Design Criteria and Loadings
North City Water Reclamation Plant

PROCESS	UNITS	Average	Peak
PLANT INFLUENT			
Flow	mgd	30	60
Total Suspended Solids	mg/l	250	
	lbs/day	62,588	
Biochemical Oxygen Demand	mg/l	250	
	lbs/day	62,588	
INFLUENT PUMP STATION DISCHARGE (Includes in plant recycles for Phase 1 only)			
Flow	mgd	33.82	60
Total Suspended Solids	mg/l	253	
	lbs/day	71,508	
Biochemical Oxygen Demand	mg/l	238	
	lbs/day	67,096	
SCREENING			
Type: Mechanically Cleaned "Climber Type"			
Number of Mechanical Screens		1	1
Number of Bypass Mechanical Screens		1	1
Total Installed Mechanical Screens		2	2
GRIT REMOVAL			
Type: Aerated Grit Removal			
Total Number of Units	-	2	2
Width	feet	20	20
Length	feet	60	60
Average Water Depth	feet	14	14
Total Volume	ft^3	33,600	33,600
Detention Time (all units in service)	minutes	10.7	6
Detention Time (one unit out of service)	minutes	5.4	3
PRIMARY SEDIMENTATION			
Type: Rectangular - Conventional			
Total Influent			
Flow	mgd	33.82	60
Total Suspended Solids	lbs/day	74,011	
Biochemical Oxygen Demand	lbs/day	67,096	
Total Number of Units	-	6	6
Width	feet	20	20
Length	feet	208	208
Average Depth	feet	11	11
Total Area	ft^2	24,960	24,960
Total Volume	ft^3	274,560	274,560
Surface Overflow Rate			
w/all units in service	gpd/ft^2	1,355	2,404
w/one unit out of service	gpd/ft^2	1,626	2,885
Detention time			
w/all units in service	minutes	87	49
w/one unit out of service	minutes	73	41
Weir Loading			
w/all units in service	gpd/foot	22,190	39,370
w/one unit out of service	gpd/foot	26,628	47,244
Percent Removals			
Biochemical Oxygen Demand	%	26	25
Total Suspended Solids	%	60	60
FLOW EQUALIZATION BASINS			
Type: Circular Prestressed Tanks			
Number of Units	-	2	2
Diameter, each	feet	140	
Maximum Nominal Depth	feet	29	
Maximum Storage Volume, All Basins	ft^3	858,000	
Percent of Average Primary Effluent Flow	%	19	
PRIMARY EFFLUENT/RAS MIX BASIN			
Volume	ft^3	11,060	11,060
Detention Time (Based on PEF + RAS)	minutes	3.6	2.5
Mixing Power Input	HP/1,000 ft^3	1.2	1.2

Table A-3
Design Criteria and Loadings
North City Water Reclamation Plant

PROCESS	UNITS	Average	Peak
AERATION BASINS			
Reactor Type: Single Pass-Plug Flow Anoxic/ Aerobic Air Activated Sludge			
Influent (Equalized Primary Effluent)			
Flow	mgd	32.8	48
BOD_5	lbs/day	49,946	97,263
Total Suspended Solids	lbs/day	29,604	55,641
Total Number of Basins	-	7	7
Basin Width	feet	20	20
Basin Depth	feet	20	20
Number of Anoxic Cells per Basin	-	3	3
Anoxic Cells w/Standby Aeration	-	2	2
Anoxic Cell Length	feet	27	27
Number of Aerobic Zones per Basin	-	1	1
Number of Aeration Grids per Basin	-	4	4
Length of Aeration Grid	feet	78	78
Total Aerobic Zone Length Per Basin	feet	312	312
Total Basin Length (Anoxic and Aerobic)	feet	392	392
Total Anoxic Volume	ft^3	224,000	224,000
Total Aerobic Volume	ft^3	873,600	873,600
Total Basin Volume	ft^3	1,097,600	1,097,600
Anoxic Volume As % Total Basin	%	20	20
Anoxic Detention Time - Maximum			
w/all units in service	hours	1.2	0.8
w/one unit out of service	hours	1.1	0.7
Aerobic Detention Time - Minimum			
w/all units in service	hours	4.8	3.3
w/one unit out of service	hours	4.1	2.8
Anoxic + Aerobic Detention Time			
w/all units in service	hours	6.0	4.1
w/one unit out of service	hours	5.22	3.5
Mixed Liquor			
Suspended Solids (MLSS)	mg/l	2,474	3,000
Volatile Suspended Solids (MLVSS)	mg/l	1,927	2,372
Mean Cell Residence Time			
w/all units in service	days	5.0	3.0
w/one unit out of service	days	4.3	2.6
F/M MLTSS			
w/all units in service	-	0.30	0.45
w/one unit out of service	-	0.35	0.53
Waste Activated Sludge (WAS) (based on wasting MLSS)			
WAS TSS Mass Rate	lbs/day	40,274	79,268
WAS TSS Concentration	mg/l	2,474	3,000
WAS Flow	mgd	1.95	3.17
WAS LBS TSS/LB BOD_5 Removed	-	0.85	0.85
Net Actual Oxygen Demand	lbs/day	62,581	103,430
SECONDARY CLARIFICATION			
Type: Rectangular - Conventional			
Influent Flow (PEF only)	mgd	30.9	44.8
Return Activated Sludge (RAS)			
RAS Flow	mgd	20.5	29.8
RAS TSS Concentration	mg/l	6,184	7,500
Mixed Liquor			
Flow (Less WAS)	mgd	51.3	74.6
TSS Concentration			

Table A-3
Design Criteria and Loadings
North City Water Reclamation Plant

PROCESS	UNITS	Average	Peak
Mixed Liquor (continued)	mg/l	2,474	3,000
Total Number of Units			
Width	-	14	14
Depth	feet	20	20
Nominal Depth	feet	180	180
Total Area	feet	15	15
Total Volume	ft^3	50,400	50,400
Surface Overflow Rate	ft^3	756,000	756,000
w/all units in service			
w/one unit out of service	gpd/ ft^2	611	890
Solids Loading Rate (w/MLSS waste)	gpd/ ft^2	658	958
w/all units in service			
w/one unit out of service	lbs/ ft^2-day	21	37
	lbs/ ft^2-day	23	40
Weir Loading			
w/all units in service	gpd/foot	15,350	22,342
w/one unit out of service	gpd/foot	16,531	24,061
SECONDARY EFFLUENT BYPASS TO OUTFALL			
Minimum Flow	mgd	0	12.8
Maximum Flow	mgd	30.8	44.8
TERTIARY FILTRATION			
Type: Monomedia			
Total Influent Flow	mgd	30.73	32
Total Number of Units	-	6	6
Width	feet	21	21
Length	feet	53	53
Total Area	ft^2	6,678	6,678
Filtration Rate			
w/one unit out of service	gpm/ ft^2	3.8	4.0
w/two units out of service	gpm/ ft^2	4.8	5.0
DEMINERALIZATION			
Type: Ionics electro dialysis reversal (EDR)			
Number of Trains	-	3	3
Capacity of Each Train	mgd	1.1	1.1
WASTE BACKWASH TANK			
Type: Rectangular & Integral w/Influent Pump Station Structure			
Maximum Instantaneous Inflow	gpm	22,222	22,222
Number of Units	-	1	1
Volume per Backwash Event	mg	0.26	0.26
Backwash Water Per Day	mgd	2.3	3.6
Outflow Rate	gpm	1,611	2,517
Maximum Depth	feet	30	30
Volume	mg	0.66	0.66
	ft^3	87,690	87,690
Volume as % Daily BW Volume	%	28	18
CHLORINE CONTACT			
Total Influent Flow	mgd	30.73	32
Total Number of Contact Tanks	-	3	3
Width, Each Tank	feet	14.5	14.5
Length, Each Pass	feet	290	290
Length, Each Tank	feet	580	580
Depth	feet	14.5	14.5
Total Volume, All Tanks	ft^3	365,835	365,835
Detention Time	minutes	128	123

Primary Sedimentation. Six primary sedimentation tanks (three more could be added in the future) are provided to remove settleable (sludge) and floatable (scum) material from the degritted wastewater. Settled wastewater overflows into the effluent launders at each tank from where it is discharged into the primary effluent channel. Primary sludge is scraped by longitudinal chain and flight collectors to sludge hoppers located at the inlet end of the tanks. From the hoppers, the sludge is removed by variable speed pumps, passes through sludge grinders and is discharged into the Sludge Pump Station.

Scum floating on the tanks surface is skimmed by the returning flights to the effluent end of each tank, collected in rotating pipe scum skimmers, and pumped to the scum concentrators. The primary tanks are covered to contain odors. Foul air exhausted from under the covers is passed through two-stage scrubbers. Section A.2.7 (page A-38) summarizes chemical use, application points, and typical dose rates at the North City WRP.

Flow Equalization. The primary purpose of flow equalization at North City WRP is to attenuate diurnal flow variations through the plant's secondary and tertiary treatment processes. By maintaining reasonably constant flow through the secondary, tertiary, and disinfection processes, the sizing of these processes can be optimized since these facilities do not have to accommodate plant peak flows.

Sideline flow equalization is provided at the North City WRP by diverting peak diurnal flows into two 140-foot diameter, 29-foot deep circular equalization basins. Diverted flow is pumped to the equalization basins and is returned by gravity back to the treatment process when the influent flow drops below average.

Primary effluent is pumped to the equalization basins by variable speed pumps. Primary effluent stored in the basins (up to 6.4 million gallons total for both basins) is returned through a modulating control valve. The basins are covered to minimize odors and chemicals can be added for this purpose. Foul air is transferred to the primary sedimentation tanks where it is used as "sweep" air. A washdown system is provided to clean the equalization basins every time a basin empties.

Activated Sludge Aeration. Secondary treatment at North City WRP is provided by the activated sludge process of aeration, clarification, and the return of the settled activated sludge to the aeration tanks.

Aeration at North City WRP takes place in plug flow reactors that incorporate anoxic selectors to improve sludge settling characteristics. Equalized primary effluent and return activated sludge

(RAS) are mixed before flowing by gravity into an aerated distribution channel, which splits the flow equally among seven aeration basins (three more could be added later). Each basin is divided into four zones: the first three zones comprise the anoxic selector and occupy 20 percent of the total basin volume. The remainder of the volume is occupied by the aerobic zone. The primary effluent plus RAS mixture combines in the first anoxic zone with mixed liquor recycle which is pumped from the end of the aerobic zone of each basin. Each anoxic zone is equipped with a submersible mixer and fine bubble aeration is provided in the aerobic zone. Mixed liquor from all basins flows into an effluent collection channel to be conveyed by gravity to the secondary clarifier influent distribution channel. A sump in the effluent collection channel allows wasting excess activated sludge from the mixed liquor stream.

Aeration air for the activated sludge process is supplied by four centrifugal blowers. Three centrifugal pumps are provided to transfer waste mixed liquor to the Sludge Pump Station. Agitation air is supplied by two centrifugal blowers. The aeration basins are covered to contain odors and the foul air is treated in three single-stage scrubbers.

Secondary Clarification. Solid-liquid separation in the activated sludge process takes place in the secondary clarifiers. Clarified liquid is conveyed to additional treatment processes (filtration and disinfection) while the solids are returned to the aeration basins (as RAS). A portion of these solids is wasted (waste activated sludge) to maintain the process in balance.

North City WRP includes 14 rectangular-clarifiers (seven more could be added in a subsequent phase). Each tank is provided with a longitudinal chain and flight collector to move settled sludge towards the effluent end and scum towards the inlet end. Clarified liquid flows over two effluent launders and discharges to the secondary effluent collection channel. Each clarifier is equipped with a centrifugal pump to return sludge to the aeration basins (there is a spare return activated sludge pump for each pair of secondary clarifiers). Two waste activated sludge pumps are provided to transfer waste activated sludge to the Sludge Pump Station. Secondary scum is also pumped to this station.

Coagulation and Filtration. The purpose of the coagulation and filtration processes is to remove additional suspended solids from the plant's secondary effluent in order to meet the requirements of Title 22. Coagulation involves the addition of chemicals to promote the agglomeration (i.e. flocculation) of solids to increase their removal during the subsequent granular media filtration.

Chemicals injected in advance of tertiary filtration at the North City WRP include anionic polymer and sodium hypochlorite. (See Table A-7 on page A-40 for North City WRP chemical use). Two static mixers are provided to thoroughly mix the chemicals with secondary effluent before the effluent is distributed onto six (four more could be added in the future) monomedia gravity filters. Each of the six filters is 21 feet by 53 feet in size. Filtered effluent is collected in the underdrain system and flows into a control structure which routes the effluent to the disinfection process. Filter backwash is provided by two vertical turbine pumps. Disinfected plant effluent is used for backwashing. Two centrifugal blowers provide air to scour the filter media during each backwashing cycle.

Demineralization. A demineralization facility was added at the North City WRP in 1998 to reduce the salinity of the recycled water produced at the plant. The facility was needed to meet MWWD's objective for total dissolved solids (TDS) of 1,000 mg/l for the recycled water intended for landscape irrigation. In 1999, the facility was expanded by adding a second stage to the existing two single-stage trains, and by adding a third two-stage train. The combined capacity of the three trains is 3.3 mgd.

The demineralization facility uses Ionics electro dialysis reversal technology. The facility product water is blended with bypass tertiary effluent water to produce the desired TDS levels in the recycled water.

Disinfection. Filtered North City WRP recycled water is disinfected using sodium hypochlorite. The disinfection system is designed to satisfy the requirements of Title 22 for recycled water intended for unrestricted body contact. The required contact time for disinfection is provided in three two-pass plug flow tanks. (Sufficient area exists at the North City WSP to allow two more tanks to be added in the future.) The plant's disinfection system consists of storage tanks, chemical feed pumps, piping, and controls.

Effluent Pumping. The effluent pumping system provides recycled water for outside users as well as for internal uses. The latter includes filter backwash water and utility water for washdown, cooling, pump seal water, and landscape irrigation.

Excess recycled water (during the irrigation season) and secondary effluent (during the non-irrigation season) is discharged by gravity to the Rose Canyon Trunk Sewer to be retreated at the Point Loma WTP. Waste plant streams are also returned to this sewer.

Onsite Solids Handling. Screenings and grit are temporarily stored in hoppers and then loaded onto trucks for disposal at a landfill. Scum removed from the surface of the primary sedimentation tanks flows into a sump. Two submersible pumps are provided to pump scum to the concentrators housed in the headworks building. Alternatively, primary scum can be routed to the Sludge Pump Station. Concentrated scum is transferred by positive displacement pumps to a receiving tank for off-site disposal. Secondary scum is pumped to the Sludge Pump Station. The onsite Sludge Pump Station transfers primary sludge, waste activated sludge, and secondary scum to the MBC. Two pumps are provided, but the pump station is sized to provide sufficient space to add a third unit at a later date. Each pump is rated at 2900 gpm against a head of 216 feet and is driven by a 300 hp motor.

Operations and Staffing. The North City WRP is fully staffed 7 days a week from 5:00am to 3:00 pm. During off hours the plant is controlled from the City's centralized control center. (Section A.6 presents a description of the City of San Diego's Central Operations and Management Center, or COMC.) Plant personnel currently include 19 operators and 12 maintenance personnel, supported by an engineering, administrative and support staff of four. The day shift (Monday through Friday) consists of the Plant Superintendent, a senior supervisor, a shift supervisor, and five operators. The maintenance staff is divided into an electrical and instrumentation crew, and a mechanical preventive maintenance crew. Except for minor tests and analysis, all laboratory work for process control and regulatory compliance is performed off-site at certified laboratories run by MWWD's Environmental Monitoring and Technical Services Division.

Operator Training. The comprehensive North City operator training program consists of three components:

1. Grade II Operator Training
   The site-specific operator training programs provide operators with the necessary knowledge, skills, and abilities to enable them to safely and efficiently operate the North City WRP. The training was developed so that it may be presented either by an instructor or given to the student for self-paced instruction with supervision.
2. Maintenance Certification Training
   The objective of this program is to prepare personnel for the Mechanical Technology certification examination offered by the California Water Pollution Control Association. Maintenance certification training includes self-paced lessons from existing training programs and other self-paced lessons.
3. Maintenance Facility Training
   Materials developed under this program provide maintenance technicians with the skills, knowledge and abilities necessary to safely and efficiently maintain the facilities and equipment provided at the North City WRP.

An Operations Manual (Volume I of the O&M Manual) for the North City WRP covers each major unit process and associated systems and system components. Standard Operating Procedures (SOPs) have been developed for each unit process unit to supplement the information given in the Operations Manual. These SOPs are compiled into Volume II of the O&M Manual. Additionally, standard preventive maintenance procedures (SMPs) and schedules for mechanical and electrical equipment have been developed from the manufacturer's supplied technical literature and are incorporated into Volume III (the Maintenance Manual) of the O&M Manual. These procedures are input into a computerized maintenance management system.

MWWD's Control Operations and Management Network (COMNET) includes a state-of-the-art process control training simulator. The simulator allows operators to train and develop experience in handling a variety of routine and emergency process scenarios and in interacting with the operations control system.

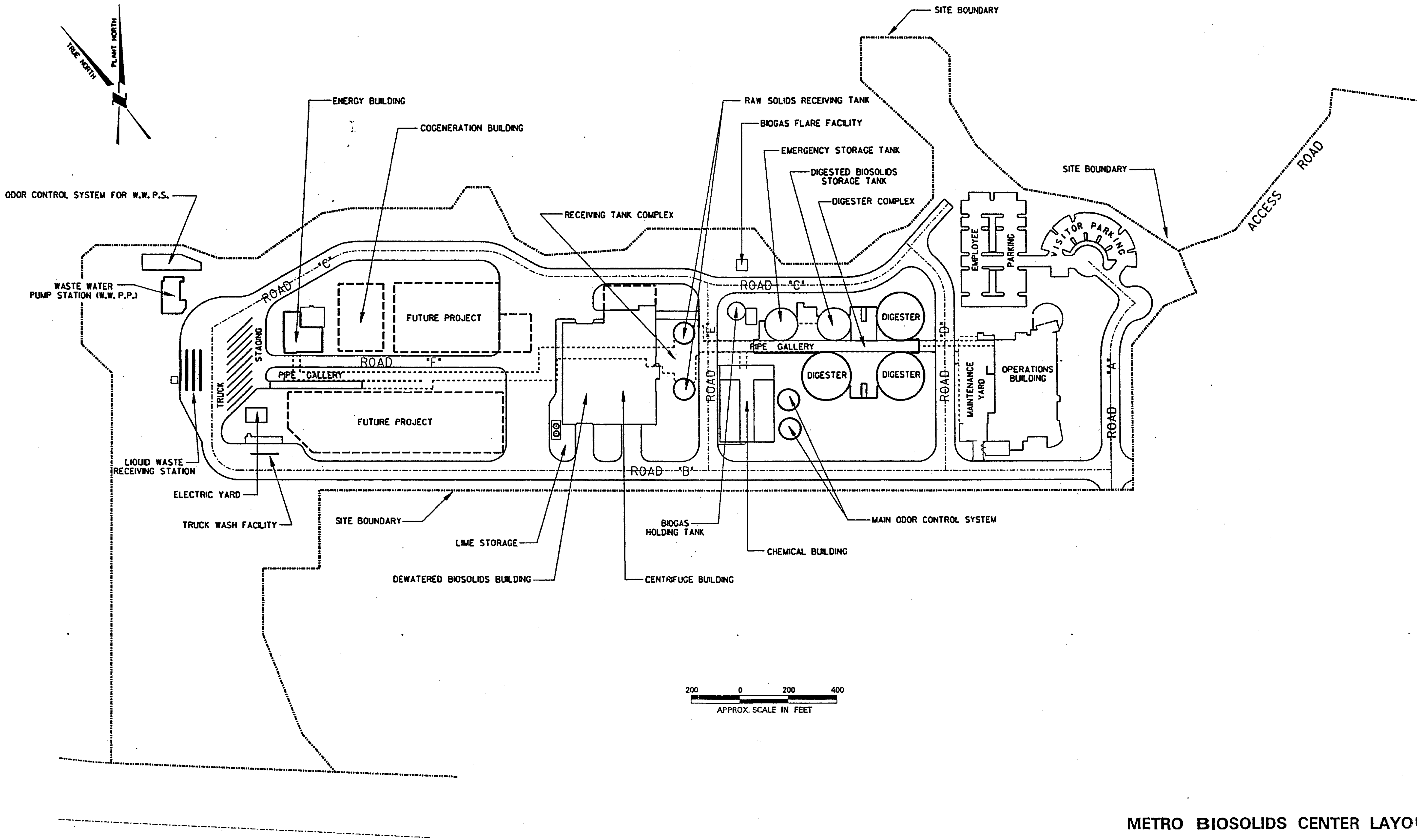
A.4 Metro Biosolids Center

Overview. The Metro Biosolids Center (MBC) is located on Marine Corps Air Station Miramar. MBC provides for dewatering of sludge from the Point Loma WTP and thickening, anaerobic digestion, and dewatering of sludge form the North City WRP.

Figure A-8 presents the layout of MBC facilities. Figures A-9 and A-10 present a schematic of MBC operations. Table A-4 (pages A-23 through A-26) summarizes design criteria for the MBC unit processes. Digested sludge from Point Loma WTP is pumped to blending tanks at MBC where it is mixed with sludge from the onsite digesters. The blended sludges are pumped to the dewatering building where dewatering is provided by high-solids type centrifuges. Cake storage silos provide approximately three days of capacity.

Raw Sludge Equalization. The Raw Sludge Receiving Tanks receive raw sludge from the North City WRP. The tanks are sized to dampen peak flows and allow downstream MBC solids handling facilities to operate at a near-constant flow. Each receiving tank is 45 feet in diameter and has a liquid depth of 45 feet. A pump mixing system is provided. The tanks have a PVC liner cast into the concrete of the roof and walls to reduce the potential for corrosion. The tanks are not insulated, but are connected to the odor control system. Transfer pumps are recessed-impeller centrifugal type and have capacity to transfer the full contents of the tanks in about two days.

Sludge Degritting. Raw sludge degritting is provided ahead of the thickening centrifuges to protect downstream equipment from excessive wear due to abrasion. The degritting process utilizes three teacup degritting units each rated at 1.5 mgd followed by two snail dewatering units. The teacup degritters operate by inducing a vortex flow within the vessel as influent flow enters at the tangent of the vessel. The heavier grit falls to the bottom and the degritted sludge exits the top of the vessel. A constant underflow from the teacup is fed to the snail which dewaters the grit and deposits it into two roll-off grit containers.



METRO BIOSOLIDS CENTER LAYO

FIGURE A-8

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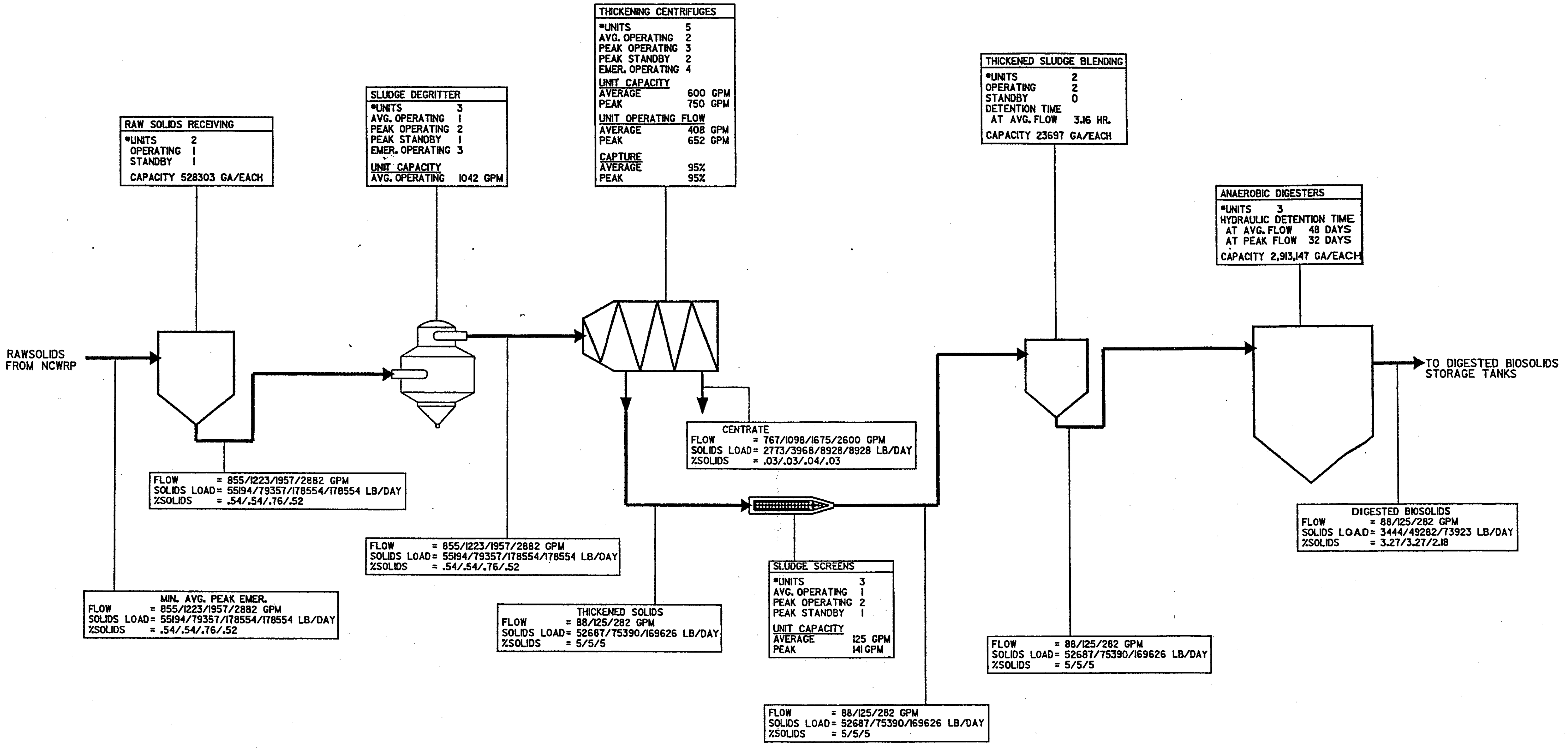


MINIMUM AVERAGE FLOW
AVERAGE FLOW
PEAK FLOW
EMERGENCY FLOW
FLOW = 71/93/131/204

NOTE: FLOW DIAGRAM INDICATES DESIGN BASIS FOR FACILITIES. FOR INFORMATION ONLY.

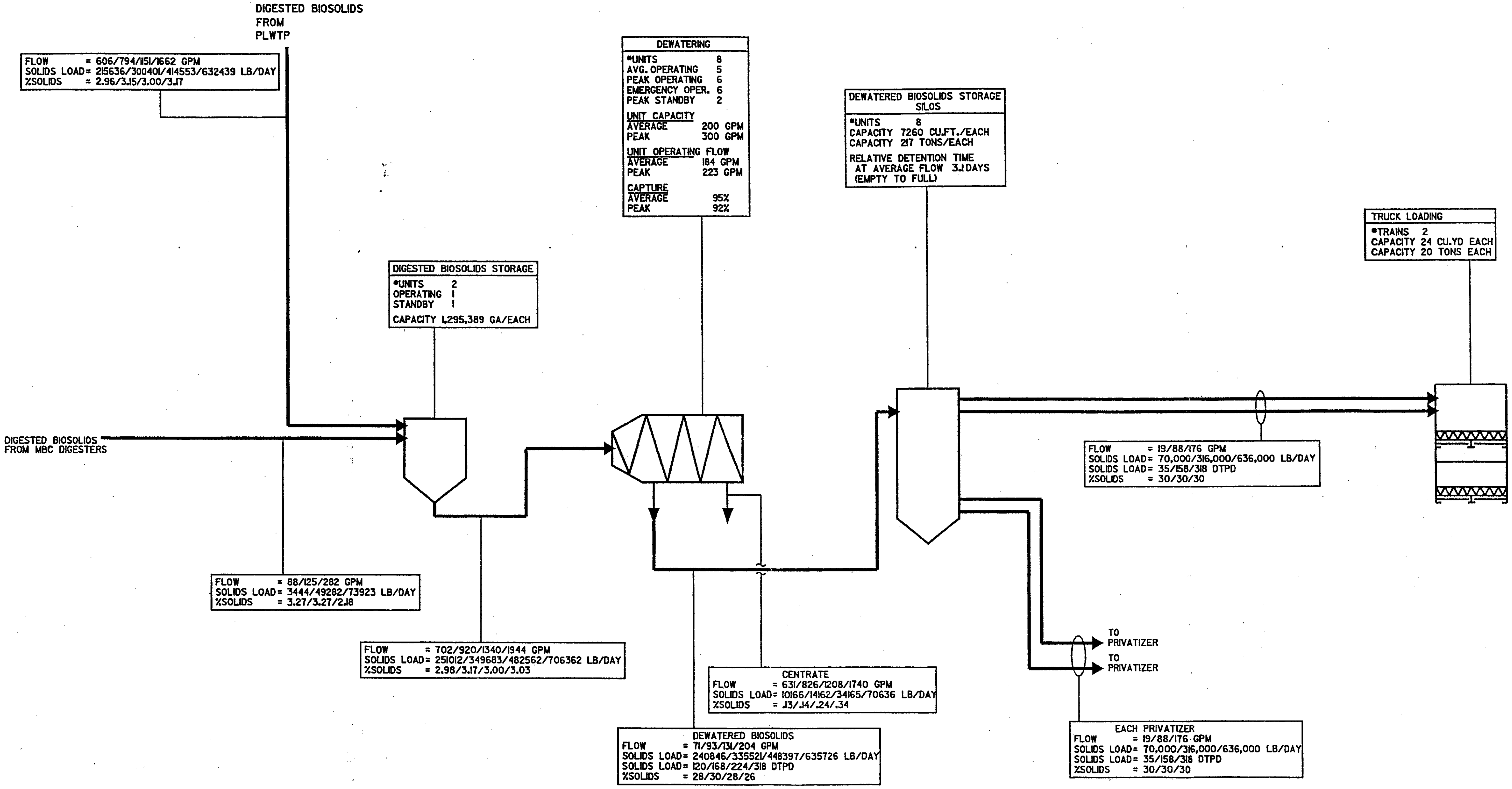
LEGEND

GA	GALLONS
GPM	GALLONS PER MINUTE
LB/DAY	POUNDS PER DAY
NCWRP	NORTH CITY WATER RECLAMATION PLANT

METRO BIOSOLIDS CENTER
PROCESS FLOW DIAGRAM - 1

FIGURE A-9

R:\RAIDA\CLEANWATER\PRJ\WAIVER\WAVH31-2A.DGN



LEGEND	
DTPD	DRY TONS PER DAY
GPM	GALLONS PER MINUTE
NSPF	NORTERN SLUDGE PROCESSING FACILITY
PLWTP	POINT LOMA WASTEWATER TREATMENT PLANT
LB/DAY	POUNDS PER DAY
GA/EACH	GALLONS EACH

MINIMUM AVERAGE FLOW
AVERAGE FLOW
PEAK FLOW
EMERGENCY FLOW
FLOW = 71/93/131/204

NOTE: FLOW DIAGRAM INDICATES DESIGN BASIS FOR FACILITIES. FOR INFORMATION ONLY.

METRO BIOSOLIDS CENTER
PROCESS FLOW DIAGRAM - 2

FIGURE A-10

Table A-4
Design Criteria for Metro Biosolids Center

PROCESS	UNITS	VALUE	
		Average	Peak
RAW SLUDGE FLOWS FROM NORTH CITY WRP			
Influent Sludge	mgd	1.76	2.82
Influent Sludge Loading at peaking factor of 2.25	lbs/day	79,357	178,554
	dry tons/day	39.7	89.3
RAW SLUDGE RECEIVING TANK			
Type: Circular Covered			
Flow	mgd	1.76	2.82
Flow	gpm	1,223	1,957
Solids Loading	lbs/day	79,357	178,554
	dry tons/day	40	89
Solids Concentration	%	0.54	0.76
Emergency Duration	hours	-	12
Difference between Peak & Average Flows	gpd	-	1,056,606
Required Storage Volume	gallons	-	528,303
Total Tank Volume	gallons	-	528,303
	ft^3	-	70,629
Number of Tanks Provided		-	2
Dimensions: Diameter	feet	-	45
Depth	feet	-	45
Total Volume	ft^3	-	141,258
	gallons	-	1,056,606
Detention time			
w/o Thickening	hours	-	7.20
@ Peak Flow w/Thickening in Avg. Condition	days	-	0.50
@ Peak Flow w//o Thickening	hours	-	4.50
THICKENING CENTRIFUGES			
Influent Flow	mgd	1.76	2.82
	gpm	1,223	1,957
Influent Sludge Loading	lbs/day	79,357	178,554
	dry tons/day	40	89
Feed Solids Concentration	%	0.54	0.76
Operating Schedule	hours/day	24	24
	days/week	7	7
Unit Capacity	gpm	600	750
Number of Units Required	each	2.0	2.6
Final Design Selection			
Number of Units Provided	-	5	5
Number of Units in Service	-	3	3
Size of Units			
Unit Capacity	gpm	600	750
Total Capacity	gpm	1800	2,250
Actual Unit Loading	gpm	408	652
Percent Capture	%	95	95
Thickened Sludge Solids	lbs/day	73,390	169,626
	dry tons/day	37.7	84.8
Thickened Sludge Concentration	%	5	5
Thickened Sludge Flow	mgd	0.18	0.41
Centrate Flow	mgd	1.58	2.41
Centrate Solids	lbs/day	3,968	8,928
	dry tons/day	2.0	4.5
Centrate Solids Concentration	mg/l	301.1	444.0
	%	0.03	0.94

Table A-4
Design Criteria for
Metro Biosolids Center

PROCESS	UNITS	VALUE	
		Average	Peak
THICKENED SLUDGE BLENDING TANK			
Type: Dual Compartment Covered			
Thickened Sludge Flow	Mgd	0.18	0.41
Total Number of Units	-	2	2
Dimensions			
Length	feet	12	12
Width	feet	12	12
Depth	feet	11	11
Unit Volume	ft^3	1,584	1,584
	gallons	11,848	11,848
Total Volume	ft^3	3,168	3,168
	gallons	23,697	23,697
Detention time	minutes	189	84
Detention Time w/one Unit Out-of-Service	minutes	94	42
SLUDGE SCREENS			
Type: Screw Strain - Press			
Thickened Sludge Flow	mgd	0.18	0.41
Total Number of Units	-	3	3
Number of Units in Service	-	1	2
Flow per Screen	mgd	0.12	0.14
	gpm	84	94
Flow per Screen w/one Out-of-Service	gpm	125	141
Screen Slot Opening	inches	0.2	0.2
ANAEROBIC DIGESTERS			
Thickened Sludge			
Flow at peaking factor = 1.5	mgd	0.18	0.27
Concentration	%	5	5
Total Thickened Sludge			
Solids at peaking factor = 2.25	lbs/day	75,390	169,626
	dry tons/day	38	85
Volatile Suspended Solids	%	69	69
	lbs/day	52,215	78,323
	dry tons/day	26	39
Design Criteria			
Detention time (minimum)	days	20	15
Final Design Selection			
Total Volume Required	gallons	3,615,805	4,067,780
	ft^3	483,396	543,821
Total Volume Required (0.1 lb VSS/cubic ft.)	ft^3	522,153	522,153
	gallons	3,905,706	3,905,706
Number of Units Provided	-	3	3
Unit Volume Required	ft^3	174,051	181,274
	gallons	1,301,902	1,355,927
Liquid Depth	feet	45	45
Diameter Calculated	feet	70	72
Diameter Provided	feet	105	105
Unit Volume Provided	ft^3	389,458	389,458
	gallons	2,913,147	2,913,147
Total Volume Provided	ft^3	1,168,374	1,168,374
	gallons	8,739,440	8,739,440
Hydraulic Resident Time (HRT)			
All Units in Service	days	48	32
One Unit Out-of-Service	days	32	21

Table A-4
Design Criteria for
Metro Biosolids Center

PROCESS	UNITS	VALUE	
		Average	Peak
Volatile Suspended Solids Loading			
All Units in Service	lbs/ft^3	0.04	0.07
One Unit Out-of-Service	lbs/ft^3	0.07	0.10
Volatile Suspended Solids Reduction	%	50	50
Volatile Suspended Solids Destroyed	lbs/day	26,108	39,161
	dry tons/day	13	20
Biogas Produced @15 cu.ft/lb VSS	ft^3/day	391,615	587,422
(70 degrees F., pressure: 9.5 in. water)			
Digested Sludge	lbs/day	49,282	73,923
	dry tons/day	24.6	37.0
	mgd	0.18	0.27
POINT LOMA DIGESTED SOLIDS			
Peak Flow = Peak Solids @ 3% Concentration	mgd	1.14	1.66
	gpm	794.2	1,150.6
Solids Loading at peaking factor = 1.38	lbs/day	300,401	414,553
	dry tons/day	150	207
Solids Concentration	mg/l	31,497	30,000
	%	3.15	3.00
Emergency Duration	days	-	1
Sludge Volume Accumulated @ 1500 gpm average and 2250 gpm peak	gallons	-	3,240,000
Peak Dewatering Capacity	gpd	-	1,944,000
Total Tank Volume	gal	-	1,296,000
	ft^3	-	173,262
Number of Tanks Provided		-	2
Tank Volume	gal	-	1,296,000
	ft^3		173,262
Tank Sidewater Depth	feet	-	45
Tank Diameter		-	
Calculated	feet		70
Selected	feet		70
Tank Selected Volume	gal	-	1,295,389
	ft^3		173,180
Detention Time w/no Dewatering	days	-	0.78
Total Volume Provided	gallons	-	2,590,777
Storage at PLWTP Pumping Peak Flow w/no Dewatering	days	-	1.33
Total Flow to Centrifuges Running @ Emergency Rate	gpd	-	2,592,000
Difference Between Maximum Pumping Rate & Emergency Flow	gpd	-	648,000
Time Required to Empty the Tanks	hours	-	16.63
CENTRIFUGE DEWATERING (Combined Flows)			
Total Digested Solids			
Flow	mgd	1.32	1.93
	gpm	919.7	1,339.4
Solids Loading	lbs/day	349,683	482,562
	dry tons/day	175	241
Average Digested Solids Concentration	%	3.17	3.00
Operating Schedule	hours/day	24	24
	days/wk	7	7
Unit Capacity	gpm	200	225
Number of Units Required	-	4.6	6.0

Table A-4
Design Criteria for
Metro Biosolids Center

PROCESS	UNITS	VALUE	
		Average	Peak
No. of Units Required (2-Stand-by @ Peak)	-	8	8
No. of Units in Service		5	6
Flow Rate Per Unit	Gpm	184	223
Solids Load per Unit (including polymer)	gpm	70,636	117,727
Maximum Flow Rate per Unit	gpm	200	300
Final Design Selection			
No. of Units Provided (2 Stand-by @ Peak)	-	8	8
No. of Units in Service		5	6
Flow Rate per Unit	Gpm	184	324
Solids Load Per Unit (including Polymer)	lbs/day	70,636	117,727
Size of Unit			
Unit Capacity	gpm	200	225
Total Capacity	gpm	1,000	1,350
Percent Capture	%	95	92
Dewatered Sludge (including polymer)			
Solids	lbs/day	335,521	448,397
	dry tons/day	167.8	224.2
Concentration	%	30	28
Flow	mgd	0.13	0.19
Centrate			
Flow	mgd	1.19	1.74
Solids	lbs/day	14,162	34,165
	dry tons/day	7.1	17.1
Concentration	mg/l	1,427	2,359
	%	0.14	0.24
DEWATERED SLUDGE STORAGE			
Dewatered Sludge			
Solids	lbs/day	335,521	448,397
	dry tons/day	168	224
Concentration	%	30	28
Flow	mgd	0.13	0.19
Volume	ft^3/day	17,928	25,671
Final Design			
Silo type: Cylindrical Live Bottom Silo			
Unit Size			
Silo Diameter	feet	18	18
Silo Height	feet	28	28
Silo Working Volume	ft^3	7,122	7,122
Number of Units Provided for Peak	-	8	8
Conditions Total Volume Available	ft^3	56,929	56,929
	yd^3	2,108	2,108
Storage Available	days	3.18	2.22
Storage Available (Emergency)	days	1.59	1.59

Sludge Thickening. The mixed primary and waste activated sludge is thickened using high solids centrifuges. Thickening sludge by means of centrifuges is a continuous (24-hours per day, 7-days per week) process where the wet sludge, at about 0.5 percent to 0.8 percent dry solids, conditioned with a polymer, is thickened by centrifugal force in a high-speed rotating drum. The thickened solids are removed from the drum by means of a concentric screw conveyor rotating at a different speed than the drum.

Thickened sludge is discharged through a chute to a wet well located below the centrifuges. The wet well is constructed of concrete and lined to reduce the potential for corrosion. Positive displacement pumps transfer thickened sludge from the wet well to the Thickened Sludge Blending Tanks. Centrate is discharged though a centrate chute and collected in a gravity line and transported to the Wastewater Pump Station.

To limit possible corrosion to the centrifuge and adjacent equipment and the escape of foul air, the centrifuge is ventilated and the foul air is treated at the process odor control system. The wet wells are also ventilated and the foul air treated in the odor control system.

Thickened Sludge Screening. Sludge screening is provided prior to pumping sludge from the North City WRP to the MBC. Additionally, in-line screens are provided at the MBC to improve the aesthetic value and marketability of the processed biosolids, and reduce the problems associated with fibrous material normally encountered in biosolids processing. The thickened sludge is pumped from the thickened sludge wet wells through the in-line screens. Screened sludge is separated from the feed on the inside of the screen. The screened sludge passes through to thickened sludge blending tanks. The separated screenings are transported by an internal screw mechanism to a press zone where the screenings are continuously dewatered and ejected to a screw conveyor. Lime may be added to screenings to control the odor at the end of the collector conveyor and before the discharge conveyor. The discharge conveyor mixes the screenings with the lime and discharges the dewatered screenings for landfill disposal. The screening room and the room where compacted screenings are stored are ducted to the odor control system.

Thickened Sludge Blending. The dual compartment thickened sludge blending tanks receive thickened and screened sludge from two thickened sludge wet wells. Since the quality of the sludge may vary from each well, the blending tank functions to provide a more homogeneous feed to the digesters. Additionally, as a backup to the Metro System scum disposal contracts, provisions are made to receive concentrated primary scum trucked in from water reclamation plants.

Two blending tanks are provided. The blending tanks are sized for a 30-minute detention time at peak flow. Tanks are 12 square feet each and have a liquid depth of about 11 feet. Centrifugal pumps are provided to mix the contents of the blending tanks. Variable speed, positive displacement, digester feed pumps withdraw sludge from the blending tanks. Foul air from the tanks is treated by the odor control system.

Sludge Digestion. Single stage, high rate, complete mix anaerobic digesters are provided with overflow withdrawal. The digesters are pump-mixed and heated in the mesophilic range between 92° to 98°F, and provide for 45 to 50 percent reduction of influent volatile suspended solids (VSS).

The three 105-foot-diameter digesters provide a total volume of 12 million gallons. Each digester is equipped with a pumped mixing system. External axial flow pumps are used to mix the digesters. A minimum of a three-hour turnover time is provided by the pumped mixing system. Two day tanks and four feed pumps have been provided in the digester complex to store and feed ferric chloride into the digesters for hydrogen sulfide and scale control.

Digested Biosolids Storage. The digested biosolids storage tanks provide storage for digested biosolids from both the Point Loma WTP and onsite digesters. The tanks are sized to provide a minimum storage duration of two days under peak flow conditions.

Biosolids Dewatering. The digested biosolids are dewatered using the centrifuges. The solids are conveyed from one end of the centrifuge to the other and discharged over adjustable weirs. Eight 200 gpm centrifuges are currently installed. The centrifuges are fed from the digested biosolids storage tanks through dedicated progressive cavity pumps. Centrifuge centrate flows over adjustable weirs on the outer rotating bowl at the end opposite the dewatered cake discharge. Centrate flows by gravity to the wastewater pump station where it is discharged back to the Point Loma WTP.

Digested biosolids are conditioned with polymer and ferrous chloride. To eliminate a source of foul air and to limit possible corrosion of centrifuge parts, the centrifuge case is vented to the foul air system via the dewatered biosolids collection bin. The centrate line and dewatered biosolids cake storage silos are also vented to the foul air system for treatment.

Dewatered Biosolids Pumping, Storage, and Loading. Dewatered biosolids are transported from the dewatered biosolids collection bins to the dewatered biosolids storage silos by piston pumps. Dewatered biosolids storage silos are provided with sufficient capacity to store a minimum of three days of dewatered biosolids at average flow. The dewatered biosolids are pumped from the dewatered biosolids storage silos into a pug mill which breaks up the cake and distributes it into the receiving bin. Bomb bay doors on the bottom of the bin open emptying the dewatered biosolids into a waiting truck or tractor trailer.

Wastewater Pumping. A wastewater pump station receives wastewater and centrate from various processes and pumps it to a sewer connection to the Metro System downstream of the North City WRP influent. The centrate and wastewater then flow to the Point Loma WTP for treatment and disposal.

Cogeneration. A privatized cogeneration facility constructed and operated by Minnesota Methane San Diego, LLC is located adjacent to the Energy Building. This facility houses four tandem Caterpillar 3516 reciprocating piston engines linked to one generator each. The engines burn landfill gas collected from the Miramar Landfill as well as digester gas generated in the MBC digesters. The combined output of these four generators is 6.4 megawatts of electricity. Waste heat from the engine jacket water cooling system provides all the heat necessary to heat the digesters as well as comfort heating for the buildings. An absorption chiller is sized to provide 500 tons of chilled water to the site as well from waste heat collected from the engines as well as supplemental heat from a boiler.

Operations and Staffing. The MBC is fully staffed 24 hours per day, 7 days a week. Currently, plant personnel include 22 operators and 8 maintenance people. Engineering, clerical and support staff add 4 positions.

The day shift (Monday through Friday) consists of the Plant Superintendent, a shift supervisor and five operators. The maintenance staff is divided into two crews:

- Breakdown Maintenance crew for emergency repairs
- Preventive Maintenance crew for routine equipment maintenance

Except for minor tests and analysis, all laboratory work for process control and regulatory compliance is performed off-site at certified laboratories run by MWWD=s Environmental Monitoring and Technical Services Division.

Operator Training. A formal training program has been implemented for the MBC staff that addresses both operational process control concepts and task based duties. As appropriate, lessons are presented regarding building systems and process support systems.

In the operational process control classes, staff learn unit process, intended functions, and how to operate the processes in the most efficient manner. Process evaluation techniques are also part of the training, which focus on how to utilize and interpret data generated from the sampling, analysis, and monitoring programs to maximize quality product and minimize costs. Training also focuses on upstream and downstream facilities so operators can understand how each can impact the unit operations at the MBC. Responses to changes in upstream or downstream operations are also addressed. Task based training consisted of both classroom and hands-on or field training. Sampling, analysis, monitoring/ adjustments, and equipment operation (startup, shut down) are addressed. Additional courses are provided to address training for operation of the MBC thickeners and digesters.

A.5 South Bay WRP and Ocean Outfall

Overview. The South Bay WRP was brought online in 2001 to treat wastewater from portions of the southern region of the Metro System service area. The South Bay WRP is an advanced wastewater treatment facility that produces recycled water that complies with requirements of Title 22, Division 4 of the California Code of Regulations for unrestricted body contact.

Figure A-11 (page A-31) presents the layout of the South Bay WRP. Figure A-12 (after page A-32) presents a schematic of South Bay WRP processes. The hydraulic capacity of the South Bay WRP is 18 mgd, and the plant can produce up to 15 mgd of tertiary treated recycled water.

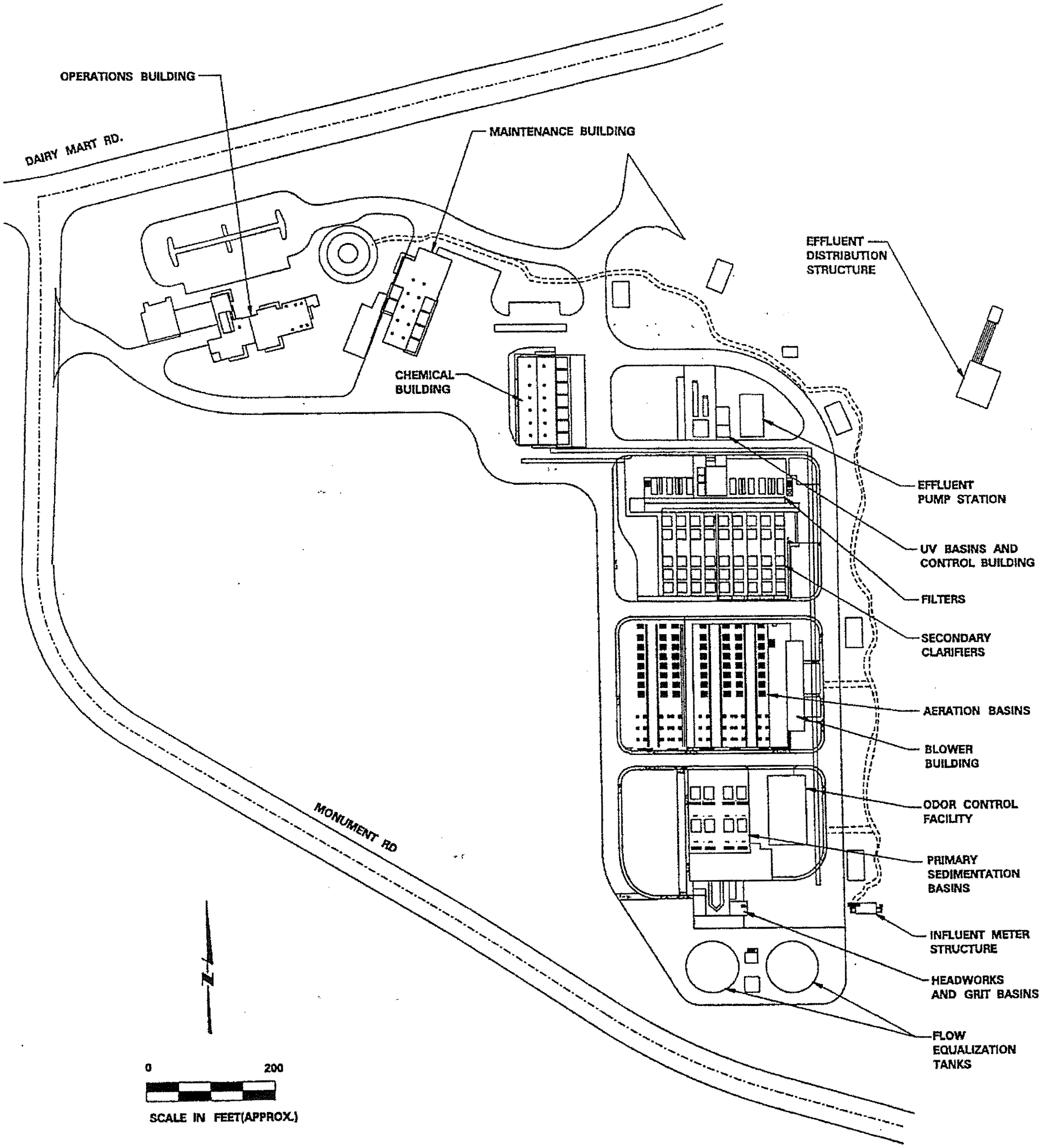
Table A-5 (pages A-32 through A-34) presents design criteria for South Bay WRP treatment processes. The main liquid treatment train consists of:

- influent pumping,
- screening,
- grit removal,
- primary sedimentation,
- sideline flow equalization,
- air activated sludge process with an anoxic selector zone,
- secondary clarification,
- chemical addition for coagulation,
- tertiary filtration through deep bed mono-media filters, and
- UV disinfection.

South Bay WRP tertiary treated effluent is directed to a regional recycled water conveyance system for reuse. Use of South Bay WRP recycled water totaled approximately 4270 acre-feet per year (AFY) during 2007, and is projected at 6370 AFY during 2008 and approximately 7490 AFY during 2012. South Bay WRP flows in excess of recycled water demands receive secondary treatment and are discharged through the South Bay Land Outfall (SBLO) and South Bay Ocean Outfall (SBOO).

Plant Inflow. As discussed in Section A.2, raw wastewater in southern portion of the Metro System is intercepted at the Grove Avenue Pump Station and Otay Valley Pump Stations and directed to the South Bay WRP for treatment.

Section A.2.7 (page A-38) summarizes chemical use, application points, typical dose rates, and the purposes of chemical addition at the South Bay WRP



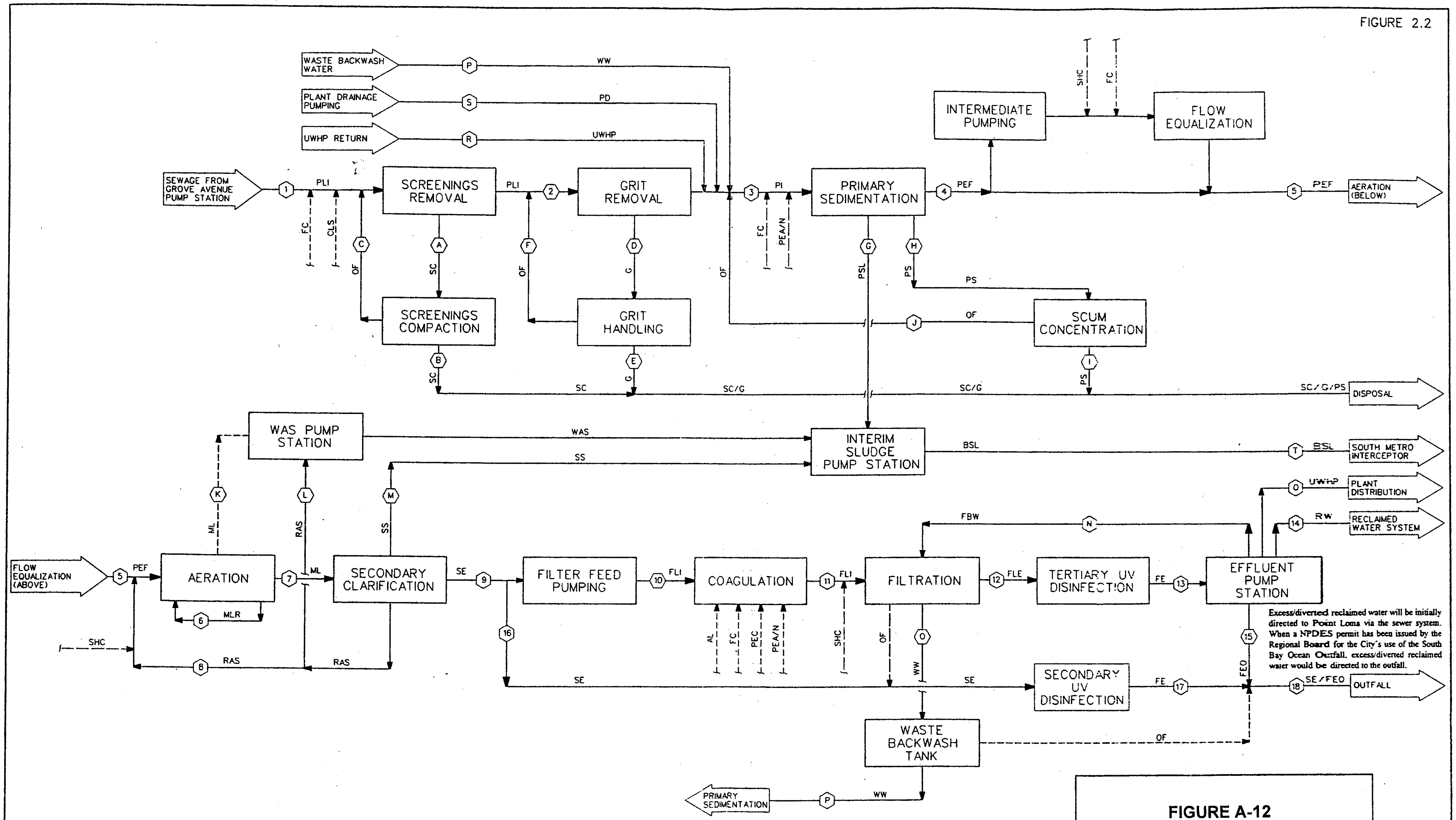
SOUTH BAY WATER RECLAMATION PLANT LAYOUT

FIGURE A-11

Table A-5
Design Criteria and Loadings
South Bay Water Reclamation Plant[1]

		Parameter Value	
PROCESS	UNITS	Average	Peak
PLANT INFLUENT			
Flow	mgd	15	18
Total Suspended Solids	mg/l	270	
Biochemical Oxygen Demand	lbs/day	33,799	
	mg/l	300	
	lbs/day	37,555	
SCREENING			
Type: Mechanical Bar Screens			
Number of Mechanical Screens	-	2	2
Channel Width	feet	3.0	3.0
Channel Depth	feet	4.42	4.42
GRIT REMOVAL			
Type: Aerated Grit Removal			
Total Number of Units	-	2	2
Width	feet	15	15
Length	feet	30	30
Average Water Depth	feet.	10	10
Total Volume	ft^3	120,000	120,000
Surface overflow rate (all units in service)	gpd/ft^2	1,646	1,947
Surface overflow rate (one unit out of service)	gpd/ft^2	2,058	2,438
PRIMARY SEDIMENTATION			
Type: Rectangular - Conventional			
Total Influent			
Flow	mgd	16.46	19.47
Total Suspended Solids	lbs/day	70,993	
Biochemical Oxygen Demand	lbs/day	76,958	
Total Number of Units	-	5	5
Width	feet	20	20
Length	feet	100	100
Average Depth	feet	12	12
Surface Overflow Rate			
w/all units in service	gpd/ft^2	1,646	1,947
w/one unit out of service	gpd/ft^2	2,058	2,438
Detention time			
w/all units in service	minutes	79	66
w/one unit out of service	minutes	63	53
Percent Removals			
Biochemical Oxygen Demand	%	30	
Total Suspended Solids	%	60	
FLOW EQUALIZATION BASINS			
Type: Circular Prestressed Tanks			
Number of Units	-	2	2
Diameter, each	feet	80	80
Maximum Nominal Depth	feet	19	19
Maximum Storage Volume, All Basins	ft^3	191,000	191,000
Percent of Average Primary Effluent Flow	%	19	
PRIMARY EFFLUENT/RAS MIX BASIN			
Volume	ft^3	11,060	11,060
Detention Time (Based on PEF + RAS)	min	3.6	2.5
Mixing Power Input	$hp/1,000\ ft^3$	1.2	1.2
AERATION BASINS			
Reactor Type: Air Activated w/Anoxic Selectors			
Influent (Equalized Primary Effluent)			
Flow	mgd	15.34	18.0
BOD_5	lbs/day	53,871	
Total Suspended Solids	lbs/day	28,397	
Total Number of Basins	-	8	8
Basin Width	feet	25	25
Basin Depth	feet	15	15
Number of Anoxic Cells per Basin	-	3	3

FIGURE 2.2



Excess/diverted reclaimed water will be initially directed to Point Loma via the sewer system. When a NPDES permit has been issued by the Regional Board for the City's use of the South Bay Ocean Outfall, excess/diverted reclaimed water would be directed to the outfall.

FIGURE A-12

Schematic of SBWRP Treatment Processes

30% DESIGN SUBMITTAL

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

PARSONS ENGINEERING SCIENCE, INC.
IN ASSOCIATION WITH
HYA CONSULTING ENGINEERS, INC.

SCALE
HORIZONTAL
VERTICAL

METROPOLITAN WASTEWATER DEPARTMENT
City of San Diego

From *South Bay Water Reclamation Plant, Engineering Report Pursuant to the Production, Distribution and Use of Reclaimed Water.* Parsons Engineering Science and City of San Diego Metropolitan Wastewater Department. August 1995.

Table A-5
Design Criteria and Loadings
South Bay Water Reclamation Plant[1]

		Parameter Value	
PROCESS	UNITS	Average	Peak
Anoxic Cells w/Standby Aeration	-	2	2
Anoxic Cell Length	feet	16.67	16.67
Number of Aerobic Zones per Basin	-	1	1
Number of Aeration Grids per Basin	-	4	4
Length of Aeration Grid	feet	30	30
Total Aerobic Zone Length Per Basin	feet	140	140
Total Basin Length (Anoxic and Aerobic)	feet	190	190
Total Anoxic Volume	ft^3	180,000	189,000
Total Aerobic Volume	ft^3	504,000	504,000
Total Basin Volume	ft^3	684,000	684,000
Anoxic Volume As % Total Basin	%	26	20
Anoxic Detention Time	hours	2.1	1.8
Aerobic Detention Time	hours	5.9	5.0
Anoxic + Aerobic Detention Time	hours	8.0	6.8
Mixed Liquor			
Suspended Solids (MLSS)	mg/l	2,800	
Volatile Suspended Solids (MLVSS)	mg/l	2,240	
Mean Cell Residence Time	days	5.3	2.8
Waste Activated Sludge (WAS) (based on wasting MLSS)			
WAS TSS Mass Rate	lbs/day	41,048	
WAS TSS Concentration	mg/l	7,000	
WAS Flow	mgd	0.7	
WAS LBS TSS/LB BOD_5 Removed	-	0.8	
Net Actual Oxygen Demand	lbs/day	64,500	
SECONDARY CLARIFICATION			
Type: Rectangular - Conventional			
Influent Flow (PEF only)	mgd	30.9	44.8
Return Activated Sludge (RAS)			
RAS Flow	mgd	20.5	29.8
RAS TSS Concentration	mg/l	6,184	7,500
Mixed Liquor			
Flow (Less WAS)	mgd	24.76	29,21
TSS Concentration	mg/l	2,800	
Total Number of Units	-	9	9
Width	feet	20	20
Depth	feet	130	130
Nominal Depth	feet	15	15
Total Area	ft^2	23,400	23,400
Total Volume	ft^2	351,000	351,000
Surface Overflow Rate			
w/all units in service	gpd/ft^2	656	
w/one unit out of service	gpd/ft^2		856
Solids Loading Rate (w/MLSS waste)			
w/all units in service	lbs/ft^2-day	24.7	
w/one unit out of service	lbs/ft^2-day		32.8
TERTIARY FILTRATION			
Type: Monomedia			
Total Influent Flow	mgd	15	
Total Number of Units	-	7	7
Width	feet	15	15
Length	feet	30	30
Tank Depth	feet	19	19
Total Area	ft^2	3,150	3,150
Filtration Rate			
w/one unit out of service	gpm/ft^2	3.31	
w/two units out of service	gpm/ft^2	3.86	

Table A-5
Design Criteria and Loadings
South Bay Water Reclamation Plant[1]

		Parameter Value	
PROCESS	UNITS	Average	Peak
WASTE BACKWASH TANK			
Type: Rectangular & Concrete			
Maximum Instantaneous Inflow	gpm	22,222	22,222
Number of Units	-	1	1
Volume per Backwash Event	mg	0.1	0.26
Backwash Water Per Day	mgd	2.3	3.6
Outflow Rate	gpm	1,611	2,517
Maximum Depth	feet	30	30
Volume	mg	0.66	0.66
	ft^3	87,690	87,690
Volume as % Daily BW Volume	%	28	18
TERTIARY DISINFECTION			
Type: UV			
Design Flow	mgd	15	15
Influent Turbidity	NTU	2	2
Total Number of Disinfection Channels	-	1	1
Width	inches	82	82
Depth	inches	140	140
Length	feet	68	68
Volume	ft^3	5,420	5,240
Residence Time (theoretical)	minutes	3.9	3.9
Residence Time (estimated)	minutes	3.5	3.5
UV Lamps: med. pressure/high intensity mercury			
Wavelength	nanometers	253.7	253.7
Number of Banks	-	4	4
Modules per Bank	-	11	11
Lamps per Module	-	8	8
Lamps per Bank	-	88	88
Total Number of Lamps	-	352	352
Lamp Arc Length	inches	10	10
Lamp Life	hours	13,000	13,000
Lamp Output	µWatts/sec/cm^2	140,000	140,000
Minimum Exposure Time	seconds	3.4	3.4
UV Channel			
Unobstructed Approach Length	feet	8	8
Unobstructed Downstream Length	feet	8	8
UV Intensity Probes	-	4	4
Fluid Transmittance Probes	-	1	1

[1] From Appendix A of the 2000 South Bay WRP Report of Waste Discharge.

Headworks. Influent wastewater flow is metered and conveyed to mechanically-cleaned bar screens and an aerated grit removal system. The headworks facility shares a common cast-in-place concrete structure with the primary sedimentation basins. Screening, screening compaction, grit classification and scum concentration are located in the headworks building. Grit from the aerated grit chambers is dewatered and transported to a landfill for disposal.

Primary Sedimentation. The primary treatment facilities receive wastewater that has been treated to remove screenings and grit. Settled solids are withdrawn from the primary sedimentation tanks and conveyed to the Sludge Transfer Pump Station. The primary sludge, together with secondary scum and waste activated sludge, is pumped to the SMI for subsequent removal at the Point Loma WTP. Scum is removed from the primary sedimentation tanks and pumped to a scum concentration tank in the headworks building. Primary effluent flow is metered and the flow to the aeration facilities is controlled to maintain equalized flow. Excess primary effluent flows by gravity to the flow equalization pump station. The primary sedimentation facilities share a cast-in-place concrete structure with the headworks facility and the equalization pumping facilities.

Flow Equalization. The flow equalization facilities consist of the flow equalization pump station and two storage tanks. The flow equalization pump station adjoins the primary effluent channel. The storage tanks are located south of the headworks building.

Aeration Basins and Blower Building. The South Bay WRP uses the air activated sludge process with an anoxic selector zone. The aeration basins are cast in place reinforced concrete tanks. The aerobic portion of each basin operates as a single pass, plug flow reactor capable of achieving full nitrification. The nitrified mixed liquor is returned to an anoxic zone at the influent end of the basins for denitrification.

The blower building is an above ground single story building located adjacent to the aeration basins that houses the aeration air blowers along with the channel blowers and service and instrument air supply system. The waste activated sludge pump station is integral with the aeration basins structure. The WAS wet well receive either mixed liquor from the mixed liquor channel or returned activated sludge pumped from the secondary clarifiers. WAS pumps are located in a dry pit adjacent to the WAS wet well and will pump WAS to the interim sludge pump station.

Secondary Clarification. The secondary clarification process removes suspended solids from the mixed liquor process flow from the aeration basins. Supernatant clarified effluent flows out of the clarifiers through launders. The clarified effluent is either pumped to the tertiary treatment facilities or is discharged to the South Bay Ocean Outfall. Settled solids are collected in a sludge hopper in each clarifier, thickened by gravity, then pumped from the hoppers to the aeration process (as RAS) or are discharged as WAS back into the Metro System for treatment at the Point Loma WTP.

The secondary sedimentation facilities share a cast-in-place concrete structure with the tertiary filtration facilities. The secondary effluent channel adjoins the filter influent channel. The space below the channels between the clarifiers and the filters houses the return activated sludge pumps and the filter piping. The tertiary intermediate pump station and the plant drainage pump station are integral with the clarifier/filter structure. The WAS pump station is located in the aeration basins structure.

Tertiary Filters. Depending upon recycled water demands, some or all of the secondary effluent flow is pumped to the tertiary filtration system. Filter influent is pretreated with alum or ferric chloride and/or polymer chemical addition and static mixing for coagulation. The effluent is filtered using deep bed mono-media filters of cast-in-place concrete construction. The filters are backwashed with air and water. Backwash water is pumped to the filters from the effluent pump station. Waste backwash water is temporarily held in a waste backwash storage tank adjacent to the filters and pumped back to the primary sedimentation influent channel at a constant rate.

The filtration facilities share a common cast-in-place concrete structure with the secondary clarifiers. The secondary effluent channel adjoins the filter influent channel. The return activated sludge pump and the filter gallery share a common space in the structure under the channels. The filter feed pump station is located on the eastern side of the secondary clarifier structure at the secondary effluent channel. The filters, waste backwash water storage tank, coagulation room, air scour blower room, and filter control room are part of the filtration structure. The filter backwash pumps and the possible future filter surface wash pumps are located in the effluent pump station.

Ultraviolet Disinfection. South Bay WRP recycled water is disinfected using an ultraviolet (UV) disinfection process. The medium-pressure, high intensity UV disinfection process was designed in accordance with the State Department of Health Services (DHS) UV Disinfection Guidelines for Wastewater Reclamation. Sodium hypochlorite is added after UV disinfection to maintain a chlorine residual.

Air Emissions/Odor Control. The South Bay WRP odor control system includes two-stage scrubber system consisting of a packed tower chemical scrubber followed by an activated carbon scrubber. The chemical scrubber removes 90 percent or more of the H_2S concentration. Caustic and hypochlorite solutions are used as the principle scrubbing agents in the packed tower scrubber. This unit is followed by an activated carbon scrubber using a dual bed. The activated carbon scrubber consistently removes 95 percent of the remaining H_2S and most other organic odors remaining after wet chemical scrubbing.

Solids Disposal. Solids generated by the South Bay WRP treatment processes are discharged back into the SMI via an 8-inch diameter pipeline for conveyance to and removal at the Point Loma WTP.

South Bay Ocean Outfall. The South Bay Ocean Outfall is jointly-owned by the International Boundary and Water Commission (U.S. Section IBWC) and the City of San Diego. The outfall discharges wastewater from both the South Bay WRP and from the IBWC=s International Wastewater Treatment Plant.

The outfall has an average daily flow capacity of 174 million gallons per day (mgd) and a peak flow capacity of 333 mgd. The City of San Diego has purchased use of up to 40 percent of the outfall (up to 74 mgd average daily flow capacity and 133 mgd of peak flow capacity). The remaining outfall capacity will be used by the International Wastewater Treatment Plant. The South Bay Ocean Outfall includes an underground tunnel from the western terminus of the South Bay Land Outfall to roughly 13,500 feet offshore, where it surfaces and continues along the sea floor ending in a Y-shaped structure and two diffuser legs approximately 3.5 miles offshore at a depth of about 95 feet.

A.2.6 Centralized Wastewater Operations Controls

The City's Central Operations and Management Center (COMC) features a distributed instrumentation, control, and data communications system that integrates monitoring and control of the treatment, storage, metering, and pumping facilities in the Metro System and the City of San Diego's wastewater system. Ultimately, more than 200 facilities will be monitored and controlled either from the Distributed Control System at each facility or from the COMC control room.

The system integrates all facility support automation systems such as fire alarm, management information systems, electronic operations and maintenance manuals, card access systems, process control training simulators, and energy management systems. Presently, the Metro System facilities that are monitored and controlled from COMC include:

- the Point Loma WTP,
- the North City WRP,
- the MBC,
- Pump Station Nos. 1 & 2, and
- the Peñasquitos Pump Station.

A SCADA (supervisory control and data acquisition) system is integrated within the monitoring and control system. This system currently monitors 12 of the City of San Diego's municipal pump stations and monitors and controls valve stations using spread-spectrum radio communication. In the future, this system will include all of the City's pump stations and a total of more than 100 facilities.

COMC is located at the Metropolitan Operation Center II (MOC II) in the Kearny Mesa area. A Department Information Network, using a City-owned fiber optic cable network, provides remote monitoring, control and communications of all remote facilities from COMC. Although each facility also has a control room, COMC has full control capability for each facility, and has an operator on duty 24-hours a day to provide either back-up for the facility operators, or full remote control without a local operator.

COMC has two custom-designed operations consoles, with 10 SUN computer workstations, printers, telephone and radio communications, and closed-circuit television controls. Four 72-inch projection displays on the front wall of the control room provide additional monitoring. The operator workstations provide graphical representations of the treatment process at each facility. Real-time information is continuously displayed and updated every second. To aid in operator training, and to provide quick identification of process areas, many of the screen graphics use realistic isometric (three-dimensional) drawings of the buildings, with cutaway views of the equipment inside. Altogether, more than 1200 graphics are available, organized with links between graphics to make retrieval and access easy. To avoid having separate closed circuit television monitors, the camera views appear within a movable window on the process displays.

A.2.7 Summary of Chemical Use at Metro System Facilities

Table A-6 (pages A-39) summarizes chemicals used at Metro System pump stations. As shown in Table A-6, chemical use at Metro System pump stations is primarily for odor control, although chemicals added at Pump Station No. 2 also assist flocculation at the Point Loma WTP.

Table A-7 (page A-40) summarizes chemicals used at Metro System treatment and solids handling facilities, including application points, typical dose rates, and the purposes of the chemical use. As shown in Table A-7, chemical use at MBC is for odor control and flocculation. Chemical use at the Point Loma WTP, North City WRP, and South Bay WRP is for odor control, coagulation/flocculation, turbidity control, algae control, and filament control.

Table A-6
Summary of Chemical Use at Metro System Pump Stations

Chemical	*Application Point*	*Purpose*	*Typical Dosage*
PUMP STATION NO. 1			
Ferrous Chloride	Influent wetwell	Sulfide control in wastewater	20-30 mg/L
Sodium Hydroxide	Odor scrubber(s)	Odor control	2-3 gpd
Sodium Hypochlorite	Odor scrubber(s)	Odor control	0.5 - 1 gpd
PUMP STATION NO. 2			
Ferric Chloride	Influent wetwell	Flocculation at Point Loma WTP	0-15 mg/L
Hydrogen Peroxide	Influent wetwell	Iron recovery and ferric reduction at Point Loma WTP	0 - 5 mg/L
Sodium Hydroxide	Odor scrubber(s)	Odor control	5 gpd
Sodium Hypochlorite	Odor scrubber(s)	Odor control	25 - 30 gpd
Hydrogen Peroxide	Influent wetwell	Regenerate iron salts for coagulation	0 - 5 mg/L
PUMP STATION NO. 64			
Sodium hypochlorite	Odor scrubber(s)	Odor control	25 gpd
PUMP STATION NO. 65			
Sodium hypochlorite	Odor scrubber(s)	Odor control	30 gpd
PENASQUITOS PUMP STATION			
Ferrous chloride	Influent wetwell	Odor control force main	450 gpd
Sodium hydroxide	Odor scrubber(s)	Odor control	1 gpd
Sodium hypochlorite	Odor scrubber(s)	Odor control	3-5 gpd

Table A-7
Chemical Use at Metro System Treatment and Solids Handling Facilities

Chemical	*Application Point*	*Purpose*	*Typical Dosage*
METRO BIOSOLIDS CENTER			
Ferric chloride	Feed flow/centrifuges	Flocculation and scale control	39 mg/L
Ferrous chloride	Digester in service	Control of hydrogen sulfide gas	310 mg/L
Mannich polymer	Feed flow/centrifuges	Flocculation	2.4 mg/L
Sodium hydroxide	Wet scrubbers	Odor control, adjust ORP[1]	1014 mg/L
Sodium hypochlorite	Wet scrubbers	Odor control, adjust pH	1790 mg/L
NORTH CITY WRP			
Anionic Polymer	Aeration Effluent Channel	Turbidity control	60 lbs/day
Sodium Hydroxide	Influent PS/headworks/primary	Odor control	30 gpd
Ferric Chloride	Sludge pump station	Odor control	500 gpd
Hydrochloric Acid 31%	Influent PS /headworks/primary	Odor control	7.8 gpd
Sodium Hypochlorite	Influent PS/headworks/primary	Odor control	300 gpd
Sodium Hypochlorite	Filter effluent	NC disinfection	1500 gpd
POINT LOMA WTP			
Anionic Polymer	Flumes to sedimentation basins	Flocculation	0.14 mg/L
Caustic Soda	Odor tower wet scrubber	Odor control	ORP>575
Ferric Chloride	Parshall flumes	Coagulation	13-24 mg/L
Ferrous Chloride	Sludge blending tank	Hydrogen sulfide control at digesters	475-900 mg/L
Hydrogen Peroxide	Y structure upstream	Regenerate iron salts for coagulation	0-5 mg/L
Salt	Water softener	Odor control	500 lbs/day
Sodium Hypochlorite	Odor tower wet scrubber	Odor control	ORP[1] > 575
SOUTH BAY WRP			
Alum (poly-alum)	Tertiary filters main influent line	Coagulant aid/turbidity control	10mg/L
Sodium hydroxide	Odor control wet scrubbers	Odor control	>9.0 pH units
Sodium hypochlorite	Odor control wet scrubbers	Odor control	ORP[1] >575
Sodium hypochlorite	UV influent channel	Algae control	5 mg/L
Sodium hypochlorite	Header lines	Odor control	10 mg/L
Sodium hypochlorite	RAS header lines	Filament control	1 mg/L

A.2.8 Secondary Treatment Studies

While this 301(h) application is based on maintaining advanced primary treatment at the Point Loma WTP, the City has performed feasibility and pilot plant studies to assess means of achieving compliance with secondary treatment standards at the Point Loma WTP. In 2005, the City completed an assessment entitled: *Biological Aerated Filter Pilot Study Report* (Brown and Caldwell and City of San Diego, June 2005). The study assessed the biological aerated filter (BAF) process as a potential means of providing space-effective secondary treatment at the Point Loma WTP.

Pilot testing conducted as part of the study confirmed that BAF technology is capable of polishing advanced primary effluent sufficiently to comply with federal secondary treatment standards for TSS and CBOD (carbonaceous BOD) under both wet weather and dry weather conditions. During pilot tests conducted under a range of load conditions, the BAF process reduced Point Loma WTP effluent TSS concentrations to below 30 mg/l and reduced 30-day average CBOD concentrations to 25 mg/l or less. The pilot studies also demonstrated that the BAF process would result in a 2-log or more reduction in total coliform, fecal coliform, and enterococcus.

The 2005 Brown & Caldwell study (and associated subsequent work) assessed alternative BAF processes and configurations for incorporating BAF technology into existing Point Loma WTP facilities. The studies also assessed BAF costs, siting issues, and operational/implementation issues. The studies concluded that the BAF process would generate approximately 170,000 pounds per day of additional biosolids.

The studies concluded that BAF facilities could be sited within the existing Point Loma WTP footprint, but this would require onsite pumping. (Flows currently travel by gravity through the advanced primary wastewater treatment processes.) Secondary treatment operations under this BAF configuration would entail significant electrical power needs. The Point Loma WTP is currently a net energy producer. All Point Loma WTP power needs are currently supplied by an onsite cogeneration facility, and excess power (averaging approximately 155 megawatt-hours per day) is sold to SDG&E. If BAF secondary treatment facilities are constructed within the current Point Loma WTP plant site, Point Loma WTP energy needs would increase by approximately 400 megawatt-hours per day, and the Point Loma WTP would have to import approximately 250 megawatt-hours per day of electrical power from the local grid.

While the technical feasibility of reducing Point Loma WTP effluent BOD and TSS concentrations has been demonstrated, the City does not currently have any plans to incorporate BAF technology at the Point Loma WTP. The City also does not have any current plans to further assess environmental consequences (e.g. increased power consumption, carbon emissions, chemical use, traffic) associated with implementing BAF at the Point Loma WTP.

A.3 PROJECTED WASTEWATER FLOWS AND LOADS

This section presents the projected wastewater flows and loads for the Metro System service area through the year 2027. Flow projections include both average annual daily flows and peak wet weather flows. Wastewater loads are projected for total suspended solids (TSS) and biochemical oxygen demand (BOD). These projections, considered along with the capacities of existing facilities and the anticipated requirements of future NPDES permits, form the basis for planning of future Metro System facilities discussed in Section A.4.

A.3.1 Projected Wastewater Flows

MWWD annually prepares updates for two sets of Metro System wastewater flow projections. The first set of flow projections is developed for long-range facilities planning, and projected flows are based on population projections and long-term wastewater unit flow generation rates. The City also prepares annual flow projections that are used for developing short-term revenue projections. Flow projections developed for short-term revenue projections are based on extrapolation of recent short-term flow trends.

Population Projections. Flow and load projections for both of these flow projection scenarios are developed on the basis of population forecasts adopted by the San Diego Association of Governments (SANDAG). Population within the Metro System service areas has increased from approximately 1,740,000 (1990 Census) to approximately 1,927,000 (2000 Census), representing an annual growth rate of 1.07 percent from 1990 to 2000. SANDAG's population forecast for the next 20 years (2008-2027) is presented in Table A-8 (page A-43).

As shown in Table A-8, SANDAG projects the annual growth rate to gradually decline as urban land available for development approaches buildout by 2030. The increase in Metro System population between 2008 and 2027 is estimated at approximately 400,000 representing a total increase of 19 percent. Areal redevelopment and population densification are expected to occur to accommodate further long-term growth.

Long-Range Facilities Planning Flow Estimates. Flow projections developed for long-range facilities planning are based on adopted regional population projections and long-term Metro System unit wastewater generation data (daily flow per capita). In developing the long-term facilities planning flow estimates, year-to-year variations in wet-weather season infiltration and inflow (I/I) are averaged out to eliminate bias associated with short-term variations. Table A-8 (page A-43) presents flow and load projections developed for facilities planning purposes. As shown in Table A-8, total Metro System wastewater flows are projected at 244 mgd by 2027.

Table A-8
Metro System Service Area Population, Flow, and Load Projections for Long-Term Facilities Planning

Year	Metro System Population[a]	Total Metro System Flows		Total Metro System Loads		Projected PLOO Discharge	
		Average Flow[b] (mgd)	Peak Flow[c] (mgd)	TSS [d] (metric tons per year)	BOD [d] (metric tons per year)	Projected Flow[e] (mgd)	TSS [f] (metric tons per year)
2008	2,158,399	206	458	75,800	81,800	191	11,400
2009	2,180,528	208	463	76,600	82,600	193	11,500
2010	2,202,658	210	467	78,800	83,400	194	11,800
2011	2,225,981	212	471	78,000	84,300	195	11,700
2012	2,249,305	214	476	78,800	85,200	197	11,800
2013	2,272,629	216	481	79,600	86,100	199	11,900
2014	2,295,953	219	486	80,400	86,900	202	12,100
2015	2,319,276	221	491	81,300	87,700	203	12,200
2016	2,341,012	224	495	81,900	88,600	205	12,300
2017	2,362,748	225	500	82,800	89,400	207	12,400
2018	2,384,484	227	504	83,400	90,200	209	12,500
2019	2,406,220	229	509	84,300	91,000	211	12,600
2020	2,427,957	231	513	84,900	91,900	212	12,700
2021	2,446,596	233	517	85,600	92,500	214	12,800
2022	2,465,236	234	521	86,200	93,200	215	12,900
2023	2,483,876	236	525	86,900	93,900	217	13,000
2024	2,502,515	238	528	87,400	94,500	219	13,100
2025	2,521,155	240	532	88,100	95,200	221[g]	13,200[g]
2026	2,542,780	242	537	88,900	96,000	222[g]	13,300[g]
2027	2,564,405	244	541	89,600	96,800	224[g]	13,400[g]

[a] SANDAG Series 10 Forecasts are used for the system-wide flow projections unless more specific data are acquired. SANDAG provided regional forecasts in a five-year increment, e.g. 2010, 2015, 2020, etc,; straight-line interpolation was applied to determine projections for other years. The specific projection data provided by the City of Chula Vista was incorporated in this flow projection.

[b] System-wide Metro System generated annual average daily flow for facility planning purposes. The facilities planning flow projection are based on the highest unit generation rate in the past 5 years and a 10-year return period wet weather flow.

[c] Peak-hour wet-weather flow for a 10-year return period, per MWWD System wide Planning Design Event Analysis for Peak Flows and Volumes - PS1 and PS2, April 24, 1997.

[d] Average annual system-wide Metro System generated loads expressed in dry metric tons per year. Projections are based on the 10-year-return average annual dry weather flow and the highest waste strengths in the past 5 years for facility planning purpose. Values are rounded to nearest 100 metric tons per year.

[e] Average annual PLOO flow projections based on Metro System flow projections for long-term facilities planning. Average annual PLOO flows will vary depending on hydrologic conditions, recycled water demands, and SBOO flows. The above approximations are based on average annual recycled water use in the North City WRP service area of 7210 AFY in 2008, 7760 AFY by 2010, 8260 AFY by 2012, linearly increasing beyond 2012 to 8.9 mgd (9970 AFY) by year 2027. Estimates are also based on combined South Bay WRP reuse and SBOO flows of 6730 AFY in 2008, 6930 AFY in 2010, 7490 AFY in 2012, linearly increasing beyond 2012 to 7.9 mgd (8850 AFY) by year 2027. Estimates also based on net annual Metro System flow reductions of 3.0 mgd from recycled water use from the Padre Dam MWD Santee WRP and the Otay Water District WRF.

[f] The Point Loma WTP is required to achieve a minimum month system-wide TSS removal of 80 percent. During the past five years, the Point Loma WTP has consistently achieved a system-wide average annual TSS removal in excess of 85 percent. The above Point Loma outfall TSS mass emission estimates are based on the listed average annual Metro System system-wide TSS loads and an annual average 85 percent system-wide removal of TSS. Actual future TSS mass emissions may be greater or less than these values depending on system-wide influent TSS mass emissions and system-wide percent removals. Estimates rounded to nearest 100 metric tons per year.

[g] Estimates do not incorporate flow and TSS mass emission reductions that will occur when the 21 mgd South Bay WTO and onsite South Bay solids processing facilities are brought online (currently scheduled for approximately year 2025). When the 21 mgd South Bay WTP and onsite processing facilities are brought online, PLOO flows and PLOO effluent TSS mass emissions will be reduced below the estimated values shown above. Depending on future Metro System flows and solids mass emissions, the 21 mgd South Bay WTP and associated onsite solids processing facilities may be brought online earlier or later than year 2025.

Flows discharged to the PLOO will depend on area populations, unit flow generation rates and water conservation, hydrologic conditions, and the degree of recycled water use within the Metro System. The flow projections presented in Table A-8 are based on maintaining the current long-term trends. As shown in Table A-8, average long-term Metro System wastewater flows are predicted to increase from 206 mgd in year 2008 to 244 mgd in year 2027, which represents an average annual growth rate of 0.9 percent.

The Point Loma WTP is required to achieve a minimum month system-wide TSS removal of 80 percent. During the past five years, the Point Loma WTP has consistently achieved a system-wide average annual TSS removal in excess of 85 percent. Assuming that system-wide mass emissions remain at approximately 85 percent, average annual PLOO TSS mass emissions of approximately 13,000 metric tons per year are projected by year 2023.

Short-Term Revenue Projection Flow Estimates. In addition to the long-term facilities planning flow projections presented in Table A-8, the City also prepares annual flow projections used to develop short-term revenue projections. Flow projections developed for short-term revenue projections are based on extrapolation of recent short-term flow trends. Table A-9 (page A-45) presents Metro System flow extrapolations based on recent short-term trends.

While the flows presented in Table A-9 are useful for short-term revenue projections, the flows in Table A-8 are appropriate for use in long-range facilities planning. As a result, flow projections presented in Table A-8 are used throughout this 301(h) NPDES application in discussion of projected flows, projected loads, and planned facilities.

Peak Wastewater Flow Projections. Peak wet weather flow projections (presented in Table A-8 on page A-43) were developed through the use of a continuous simulation model which computes infiltration/inflow (I/I) and adds it to the projected average flow. The model simulates flows on an hourly time step using 50 years of historical rainfall records, Metro-specific calibrated I/I hydrograph parameters, and the assumption that future increases in I/I will be proportional to future increases in AADF.

The model results were statistically analyzed to determine peak flows corresponding to a range of probabilities of occurrence (return periods). For the purposes of facilities planning, a 10-year return period has been adopted as the basis for peak wet weather flow projections. On the basis of the flow modeling, potential peak wet weather flows are projected to be slightly more than double the average annual flows for any given year within the 10-year planning period.

Table A-9
Metro System Service Area Population, Flow, and Load Projections for Short-Term Revenue Planning

Year	Metro System Population(a	Total Metro System Flows	Total Metro System Loads		Projected PLOO Discharge	
		Average Flow(b) (mgd)	TSS (c) (metric tons per year)	BOD (c) (metric tons per year)	Projected Flow(d) (mgd)	TSS (e) (metric tons per year)
2008	2,158,399	189	71,700	72,000	174	10,800
2009	2,180,528	191	72,500	72,700	176	10,900
2010	2,202,658	193	73,200	73,500	177	11,000
2011	2,225,981	195	74,000	74,200	178	11,100
2012	2,249,305	197	74,700	75,000	180	11,200
2013	2,272,629	199	75,500	75,800	182	11,300
2014	2,295,953	201	76,100	76,500	184	11,400
2015	2,319,276	203	77,000	77,300	185	11,600
2016	2,341,012	205	77,600	78,000	187	11,600
2017	2,362,748	206	78,300	78,600	188	11,700
2018	2,384,484	208	79,100	79,300	190	11,900
2019	2,406,220	210	79,800	80,100	192	12,000
2020	2,427,957	212	80,400	80,800	193	12,100
2021	2,446,596	214	81,100	81,400	195	12,200
2022	2,465,236	215	81,600	81,900	196	12,200
2023	2,483,876	217	82,300	82,600	198	12,300
2024	2,502,515	218	82,900	83,100	199	12,400
2025	2,521,155	220	83,400	83,800	201(f)	12,500(f)
2026	2,542,780	222	84,300	84,400	202(f)	12,600(f)
2027	2,564,405	224	84,900	85,200	204(f)	12,700(f)

(a) SANDAG Series 10 Forecasts are used for the system-wide flow projections unless more specific data are acquired. SANDAG provided regional forecasts in a five-year increment, e.g. 2010, 2015, 2020, etc,; straight-line interpolation was applied to determine projections for other years. The specific projection data provided by the City of Chula Vista was incorporated in this flow projection.

(b) System-wide Metro System generated annual average daily flow for short-term revenue projection purposes. Estimated system-wide annual average daily flows include the wet weather component contributed by storm water inflows and infiltration. The flow projection is based on the Fiscal Year 2006 unit generation rate and 2-year return period wet weather flow representing the median value. The above flow estimates are developed for finance planning purposes.

(c) Average annual system-generated loads expressed in dry metric tons per year. These projections are based on the 2-year return annual average daily flow and Fiscal Year 2006 waste strengths. Values are rounded to nearest 100 metric tons per year.

(d) Average annual PLOO flow projections based on Metro System flow projections for short-term revenue planning. Average annual PLOO flows will vary depending on hydrologic conditions, recycled water demands, and SBOO flows. The above approximations are based on average annual recycled water use in the North City WRP service area of 7210 AFY in 2008, 7760 AFY by 2010, 8260 AFY by 2012, linearly increasing beyond 2012 to 8.9 mgd (9970 AFY) by year 2027. Estimates are also based on combined South Bay WRP reuse and SBOO flows of 6730 AFY in 2008, 6930 AFY in 2010, 7490 AFY in 2012, linearly increasing beyond 2012 to 7.9 mgd (8850 AFY) by year 2027. Estimates also based on net annual Metro System flow reductions of 3.0 mgd from recycled water use from the Padre Dam MWD Santee WRP and the Otay Water District WRF.

(e) The Point Loma WTP is required to achieve a minimum month system-wide TSS removal of 80 percent. During the past five years, the Point Loma WTP has consistently achieved a system-wide average annual TSS removal in excess of 85 percent. The above Point Loma outfall TSS mass emission estimates are based on the listed average annual Metro System system-wide TSS loads and an annual average 85 percent system-wide removal of TSS. Actual future TSS mass emissions may be greater or less than these values depending on system-wide influent TSS mass emissions and system-wide percent removals. Estimates rounded to nearest 100 metric tons per year.

(f) Estimates do not incorporate flow and TSS mass emission reductions that will occur when the 21 mgd South Bay WTO and onsite South Bay solids processing facilities are brought online (currently scheduled for approximately year 2025). When the 21 mgd South Bay WTP and onsite processing facilities are brought online, PLOO flows and PLOO effluent TSS mass emissions will be reduced below the estimated values shown above. Depending on future Metro System flows and solids mass emissions, the 21 mgd South Bay WTP and associated onsite solids processing facilities may be brought online earlier or later than year 2025.

A.3.2 Wastewater Load Projections

Average annual daily loads for total suspended solids (TSS) and biochemical oxygen demand (BOD) have been computed (see Table A-8) based on historic influent records at the Point Loma WTP over the past 15 years. The measurements represent all flows tributary to the plant, including the Tijuana Emergency Connection, hauled septage, chemical additions, and solids returned from the former and current biosolids handling facilities.

Analysis of historical unit load generation rates (daily pounds per capita) during the past 15 years has shown that the rates exhibit considerable year-to-year variability due to a variety of contributing factors, and may continue to do so in the future. For the purposes of projecting future loads, it has been assumed that the current unit generation rates will rise gradually in the next decade based on the prospect for continuing economic growth.

As shown in Table A-8 (page A-43), TSS and BOD loads generated in the Metro System are predicted to increase over the next 20 years (starting with the year 2008 projection) at the same average annual rates (0.9 percent) as the projected annual rate of increase in flow.

A.4 PROPOSED METRO SYSTEM IMPROVEMENTS

This section provides an overview of the new facilities and existing facility improvements that will be required to meet discharge permit conditions and to provide adequate hydraulic capacity. Two categories of facility improvements will be required within the next 20 years to meet Metro System needs:

- facilities required to handle projected increased Metro System hydraulic and solids loadings, and
- facilities required to comply with revised California Ocean Plan bacteriological standards.

A.4.1 Facilities Required to Handle Increased Flows and Loads

As shown on Table A-8 (page A-43), increases in Metro System hydraulic and solids loadings are projected at approximately 0.9 percent per year over the next 20 years. Table A-10 (page A-47) summarizes proposed Metro System improvements required within the next 20 years to accommodate projected increased flow and solids loads.

Table A-10
Future Metro System Facilities Improvements Required to Handle Projected Flows and Loads

Facility	Capacity	Approximate Year Required[1]
South Bay WTP and onsite solids processing facilities[2]	21 mgd[4]	2025
South Bay Pump Station and conveyance improvements[3]	21 mgd[4]	2025

1 Approximate year based on current flow projections. Scheduled implementation of these facilities will be reviewed and updated on a five-year basis.
2 Includes onsite solids digestion, dewatering, and handling facilities to eliminate the need to convey South Bay WTP and South Bay WRP solids to the Point Loma WTP.
3 Includes conveyance force main to connect the South Bay Pump Station to the South Bay WTP.
4 Average dry weather flow capacity of 21 mgd, with peak flow hydraulic capacity of 44 mgd.

Facilities required within the next 20 years to handle these projected increased Metro System loadings include:

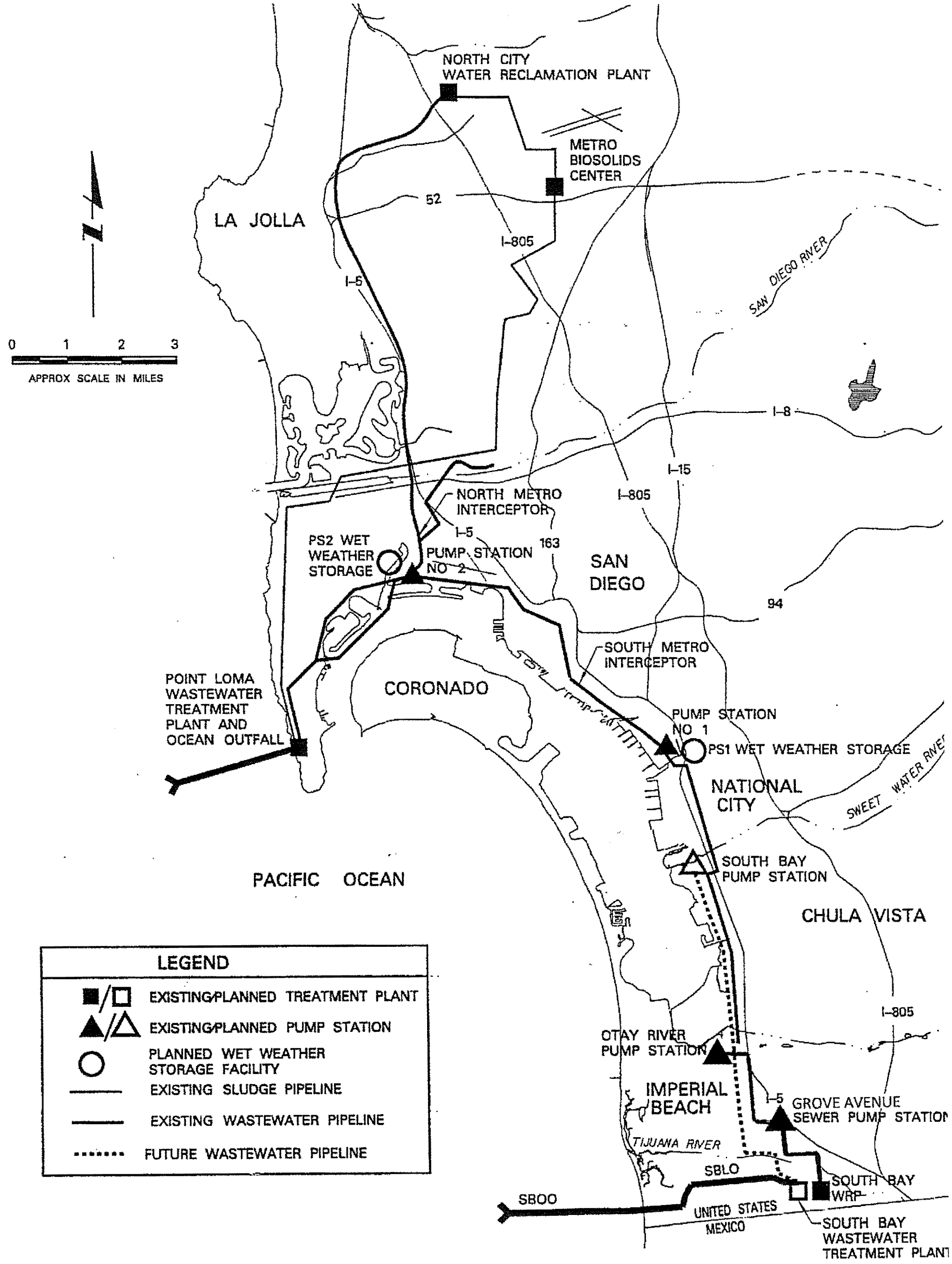
- implementation of the South Bay Wastewater Treatment Plant (South Bay WTP) and its associated solids processing facilities, and
- construction of the South Bay Pump Station and associated conveyance system upgrades.

Figure A-13 (page A-48) presents the location of capacity-related Metro System facilities improvements required during the next 20 years.

South Bay Wastewater Treatment Plant. The 21 mgd South Bay Pump Station, 21 mgd South Bay WTP, and associated South Bay solids processing facilities will be required by approximately year 2025 to meet anticipated Metro System hydraulic capacity needs and to ensure that PLOO TSS mass emission rates are maintained below permitted levels.

The South Bay WTP will be constructed on land immediately adjacent to the South Bay WRP, and will discharge its effluent to the South Bay Ocean Outfall. With a peak hydraulic capacity of 44 mgd, these facilities will provide additional hydraulic and solids loading relief to downstream Metro System facilities. Provisions will be made for a second stage expansion to a treatment capacity of 49 mgd (103 mgd peak flow).

The South Bay WTP will also include facilities to process solids from the South Bay WTP and South Bay WRP for beneficial use or disposal, negating the need to continue the current practice of returning South Bay WRP solids to the SMI for treatment at the Point Loma WTP. Additionally, the South Bay WTP will include a cogeneration facility that will produce power that is used by both the South Bay WTP and South Bay WRP.



EXISTING AND PLANNED METRO SYSTEM FACILITIES

Figure A-13

The South Bay WTP will be constructed on the Dairy Mart Road site adjacent to the South Bay WRP. The South Bay WTP will reduce flows and solids directed to the South Metro Interceptor (SMI), Pump Station No. 1, Pump Station No. 2, and the Point Loma WTP by treating wastewater presently conveyed to and treated at the Point Loma WTP. Raw wastewater will be diverted from the SMI by the South Bay Pump Station and Conveyance System. The South Bay WTP will produce secondary effluent suitable for ocean disposal via the South Bay Ocean Outfall.

Due to its location next to the South Bay WRP, the South Bay WTP will share common facilities and will have numerous interfaces with the South Bay WRP. Both plants will be operated by the same MWWD operations and maintenance staff and will share a central control room, an operations building, and a maintenance building.

Solids handling facilities at the South Bay WTP will be interfaced with the South Bay WRP. Primary solids, secondary solids and scum from the South Bay WRP will be diverted to the South Bay WTP for thickening and processing. The primary scum from the South Bay WRP will also be pumped to the South Bay WTP. The South Bay WTP and South Bay WRP will share connected potable water and fire protection water systems. Additionally, the plants will also share hot water and power generated at the proposed South Bay WTP cogeneration facility.

South Bay Pump Station and Conveyance System. Construction of the South Bay WTP will require diversions of wastewater from the South Bay area that presently flows to the Point Loma WTP. The South Bay Pump Station and Conveyance System will intercept wastewater from the SMI upstream from Pump Station No. 1 and convey it via force main to the South Bay WTP.

The South Bay Pump Station will be sized for an average flow of 21 mgd and a peak flow of 44 mgd in the first phase. The pumps will be vertical, non-clog centrifugal pumps with variable speed drives. The wet well will be of the self-cleaning type. Screens on raw wastewater will be located at the South Bay WTP and not at the pumping station. All water surfaces will be enclosed and odors captured and treated in a state-of-the-art odor control system.

A 9-mile force main will be constructed to convey wastewater from the South Bay Pump Station to the South Bay WTP. The force main will be constructed in a single stage, and sized at 57 inches in diameter to handle both initial South Bay WTP flows (21 mgd average and 44 mgd peak) and ultimate projected flows (49 mgd average and 103 mgd peak).

Wet-Weather Flow Equalization. The City is assessing the need to add equalization storage at Pump Station Nos. 1 and 2 (see Figure A-13) to increase peak wet-weather capacity of the Metro System conveyance facilities. Wet weather equalization storage improvements at Pump Station Nos. 1 and 2 will be evaluated as part of the City's ongoing assessment of Metro System flows and hydraulic capacity.

Ongoing Equipment Upgrades and Rehabilitation. In addition to the new facilities shown in Table A-10 (page A-47), ongoing upgrade and rehabilitation of equipment and components at existing Metro System facilities will take place within the next 20 years.

A.4.2 Facilities Required to Achieve Recreational Body-Contact Standards

Overview. The City's existing NPDES permit does not require disinfection of Point Loma WTP effluent prior to discharge to the Point Loma Ocean Outfall (PLOO). As a result of 2005 revisions to the California Ocean Plan (see Appendix T), however, it is possible that the Regional Board may apply Ocean Plan body-contact bacteriological standards (previously only applied to the shore zone and kelp bed) throughout the entire depth of the ocean water column within the three nautical mile limit of State-regulated waters.

As described in Appendix B, the PLOO consists of a 4.5-mile-long outfall that discharges to a Y-shaped diffuser, with each leg of the diffuser extending approximately an additional 0.5 miles. The PLOO discharges beyond the three-mile-limit of State-regulated waters and is designed to minimize the potential for onshore transport of the discharged wastewater.

An analysis of receiving water bacteriological concentrations from 2000 to mid-2007 confirms the effectiveness of the outfall design in preventing onshore movement of discharged wastewaters. This analysis (see Appendix C) demonstrated that the outfall discharge maintained compliance with body-contact recreational standards at the three-mile limit on almost all occasions. From a database of over 10,800 bacteriological samples, the outfall achieved:

- Greater than 99.9 percent of the time with recreational body-contact standards for total coliform and fecal coliform at the edge of the three-mile limit of State-regulated waters, and
- More than 99.7 percent compliance with recreational body-contact standards for enterococcus at the edge of the three-mile limit.

The infrequent instances of PLOO-related elevated coliform concentrations that have been observed are primarily limited to elevated coliform or enterococcus counts at the ocean bottom at or near the three-mile limit. (It should be noted that during significant storm events, the San Diego River discharge plume can extend several miles to sea and several miles downcoast, causing wide-spread bacteriological non-compliance within and beyond the three mile coastal limit of State waters. Such noncompliance, however, is not related to the Point Loma WTP effluent discharge.)

The Ocean Plan establishes receiving water recreational body-contact standards on the basis of geometric means and single sample maximum values. The PLOO discharge (see Appendix C) consistently complies with the Ocean Plan geometric mean standards. As documented in Appendix C, the only potential for Ocean Plan noncompliance would occur if an isolated high receiving water value were to exceed the Ocean Plan single sample mean standards.

Table A-11 presents a comparison of maximum observed receiving water quality in offshore stations (at depth) with the 2005 Ocean Plan standards for water contact recreation. As shown in Table A-11, reducing PLOO effluent concentrations of pathogen indicator organisms by approximately 2.1 logarithms (approximately 99 percent reduction) would prevent the discharge from causing exceedence of Ocean Plan recreational body-contact recreational standards within the three-mile-limit of State waters at all depths. (Again, while such a 2.1 log reduction would ensure that the Point Loma WTP does not cause exceedance of body-contact standards in State waters, it should be noted that the Ocean Plan bacteriological standards, particularly near the shore, will continue to be at risk for exceedance due to shore-related storm runoff, low-flow runoff, and other shore activities not related to the Point Loma WTP discharge.)

Table A-11
Required Reductions in Regulated Pathogen Indicator Organisms to Assure Compliance

Regulated Pathogen Indicator Organism	Ocean Plan Standard[1] (CFU per 100 ml)	Highest Offshore Result[2] 2003-2007 (CFU per 100 ml)	Reduction in Effluent Concentration Required to Meet Standard
Total Coliform	10,000	130,000[3] (est.)	1.1 log
Fecal Coliform	400	13,000	1.5 log
Enterococcus	104	2200	1.4 log
Total Coliform when Total:Fecal Rations are Greater than 0.1	1000	130,000[3] (est.)	2.1 log in T. Coliform

1 Bacteriological standard from the 2005 version of the Ocean Plan. (See Appendix T)
2 Highest concentration recorded in any single sample. See Appendix C.
3 Actual sample value was ">16,000". The 130,000 CFU per 100 ml total coliform concentration was estimated on the basis of fecal coliform results from the sample.

The City proposes to implement effluent disinfection at the Point Loma WTP to achieve a 2.1 logarithm reduction in pathogen indicator organisms. Such a reduction in Point Loma WTP effluent indicator organisms will allow the PLOO discharge to comply with Ocean Plan recreational water contact bacteriological standards at all depths in all State-regulated waters. In this way, the City can assure future compliance with Ocean Plan body-contact recreational standards even if the Regional Board chooses to designate all State-regulated ocean waters as a body contact recreation zone. (To date, the Regional Board has applied the Ocean Plan water contact recreational standards only to areas where water contact recreation is likely to occur - in coastal waters and kelp beds.)

Installation of Prototype Disinfection Equipment. The City has developed a prototype disinfection plan that is based on achieving a minimum 2.1 log reduction in regulated pathogen indicator organisms (e.g. total coliform, fecal coliform, and enterococcus). Prototype disinfection operations are based on the following:

- injection of a sodium hypochlorite solution in the effluent channel at a dose rate of 7.0 mg/l, and
- use of the outfall transport time to provide the required contact time to achieve the 2.1 log reduction.

As documented in Appendix D, the proposed 7 mg/l sodium hypochlorite dose rate will achieve the required 2.1 log reduction in indicator organisms while being entirely consumed by effluent chlorine demand during outfall transport, allowing the PLOO discharge to maintain a zero chlorine residual as the effluent enters the outfall diffuser.

Initial studies (see Appendix D) demonstrate that the proposed 7 mg/l dose rate will not lead to the formation of chlorination byproducts that exceed allowable Ocean Plan receiving water concentrations. Toxicity analyses of the disinfected Point Loma WTP effluent show that the discharge will remain in compliance with applicable acute and chronic toxicity standards.

Figure A-14 (located after page A-52) presents the layout of prototype effluent disinfection facilities at the Point Loma WTP. Sodium hypochlorite is already delivered to and stored at the Point Loma WTP, as part of onsite odor tower scrubbing operations. This existing sodium hypochlorite facility (along with an existing 1-inch-diameter pipeline) is utilized as part of the prototype effluent disinfection plan, along with the following new facilities:

- expanded onsite sodium hypochlorite bulk storage capacity,
- sodium hypochlorite feed pumps and controls to regulate sodium hypochlorite dose rates into the Point Loma WTP effluent, and

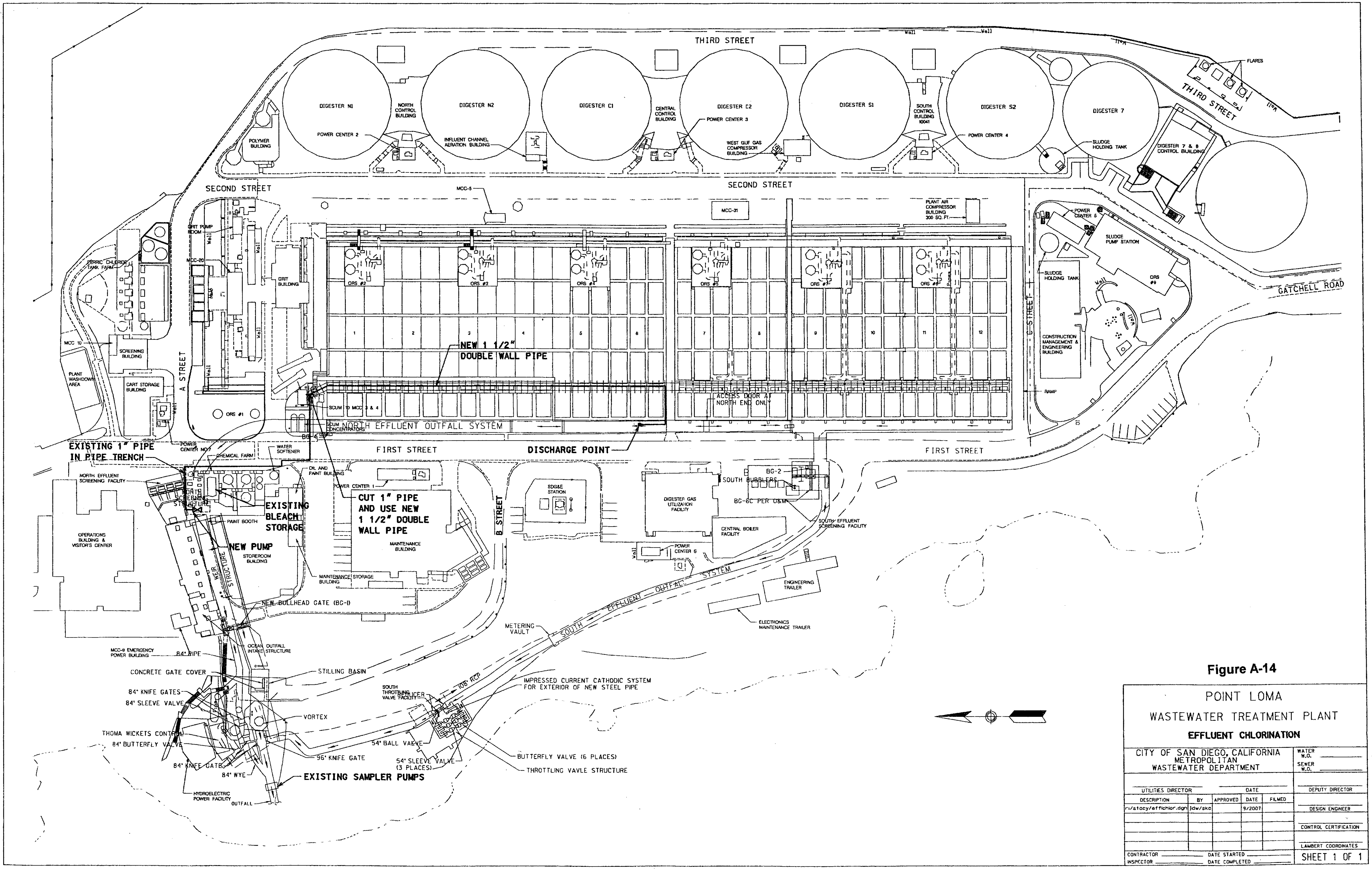


Figure A-14

POINT LOMA
WASTEWATER TREATMENT PLANT
EFFLUENT CHLORINATION

CITY OF SAN DIEGO, CALIFORNIA
METROPOLITAN
WASTEWATER DEPARTMENT

WATER W.O. ____
SEWER W.O. ____

UTILITIES DIRECTOR ____ DATE ____
DEPUTY DIRECTOR ____

DESCRIPTION	BY	APPROVED	DATE	FILMED
r:/stacy/efflchlor.dgn	jdw/skc		9/2007	

DESIGN ENGINEER ____
CONTROL CERTIFICATION ____
LAMBERT COORDINATES ____

CONTRACTOR ____ DATE STARTED ____
INSPECTOR ____ DATE COMPLETED ____

SHEET 1 OF 1

- a conveyance and injection system (small diameter double wall pipe) to deliver the sodium hypochlorite from the existing storage site to the Point Loma WTP effluent channel (see Figure A-14) and distribute the disinfectant into the channel flow.

As part of the prototype disinfection facilities, sodium hypochlorite feed rates would be manually regulated by plant operators to match effluent flows.

The City has designed and installed the prototype effluent disinfection facilities at the Point Loma WTP, and has submitted a request to the Regional Board (see Appendix U) to initiate operation of the disinfection facilities in accordance with requirements established within Order No. R9-2002-0025 (and addenda thereto). Operation of the prototype disinfection facilities will be initiated upon receipt of Regional Board approval.

Disinfection Studies and Potential Upgrade. In conjunction with implementing the effluent disinfection system, the City may initiate special studies to assess the disinfection efficiency and cost-effectiveness of the prototype disinfection system.

The City may propose future modification of the prototype disinfection facilities or operations in accordance the results of such studies. The City will not implement any significant modifications to the prototype effluent disinfection system, however, without first obtaining approval from the Regional Board.

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Appendix B

Point Loma Ocean Outfall

APPENDIX B

POINT LOMA OCEAN OUTFALL

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APPENDIX B

POINT LOMA OCEAN OUTFALL

B.1 INTRODUCTION

This appendix provides detailed information on the Point Loma outfall and diffuser system, and supplements the data provided in response to Question II.A.8 in the Large Applicant Questionnaire (Volume III).

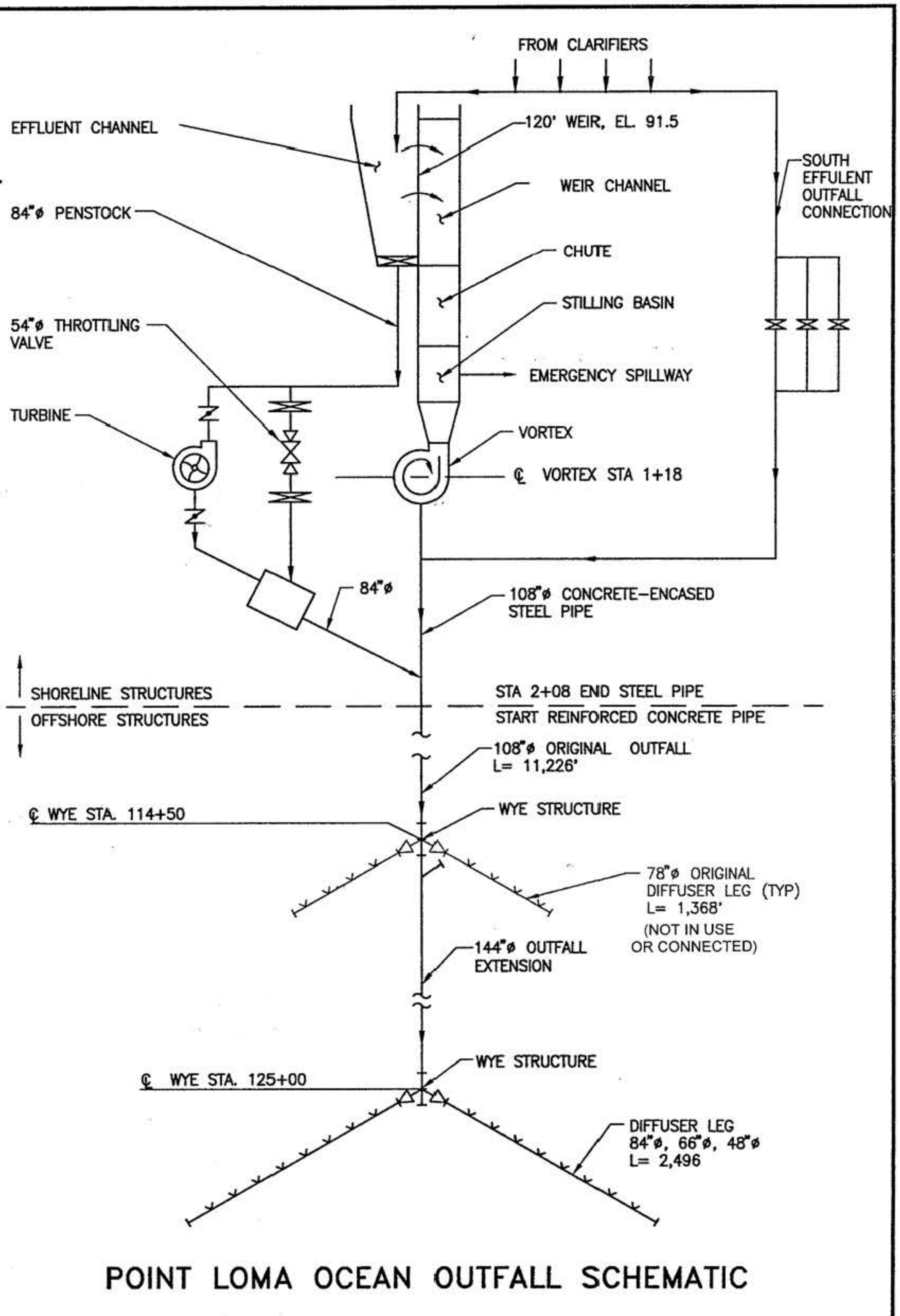
The Point Loma Ocean Outfall consists of an original 3,422-meter-long (11,226-foot-long) outfall section that was constructed in 1963 and a 3,732-meter-long (12,246-foot-long) extension that was added in 1993. The total length of the outfall system is 7,154 meters (23,472 feet).

B.2 SHORE FACILITIES

Figure B-1 (page B-2) presents a schematic of how the Point Loma Ocean Outfall is connected to the Point Loma Wastewater Treatment Plant. As illustrated in Figure B-1, the shore structures consist of the four units in parallel:

- the vortex,
- the throttling valve,
- the hydroelectric turbine, and
- the South Effluent Outfall Connection (SEOC).

The principal function of the shore structure is to safely dissipate excess head. The hydroelectric unit generates electricity, and is intended to operate in parallel with the throttling valve. The SEOC provides an additional parallel path to the outfall and is intended to avoid problems of air entrainment that have affected the performance of the vortex structure. Peak flows will be routed through the SEOC circuit and low flow could be routed through the throttling valve. For the foreseeable future, the SEOC will provide the main pathway to the ocean outfall, with the vortex working only as a stand pipe.



POINT LOMA OCEAN OUTFALL SCHEMATIC

FIGURE B-1

B.3 ORIGINAL OUTFALL

Construction of the original Point Loma outfall and diffuser system was completed in 1963. The main barrel of the outfall consists of 3,422 meters (11,226 feet) of 2.74-meter (9-foot) diameter, reinforced concrete pipe with a wall thickness of 25.4 centimeters (10 inches).

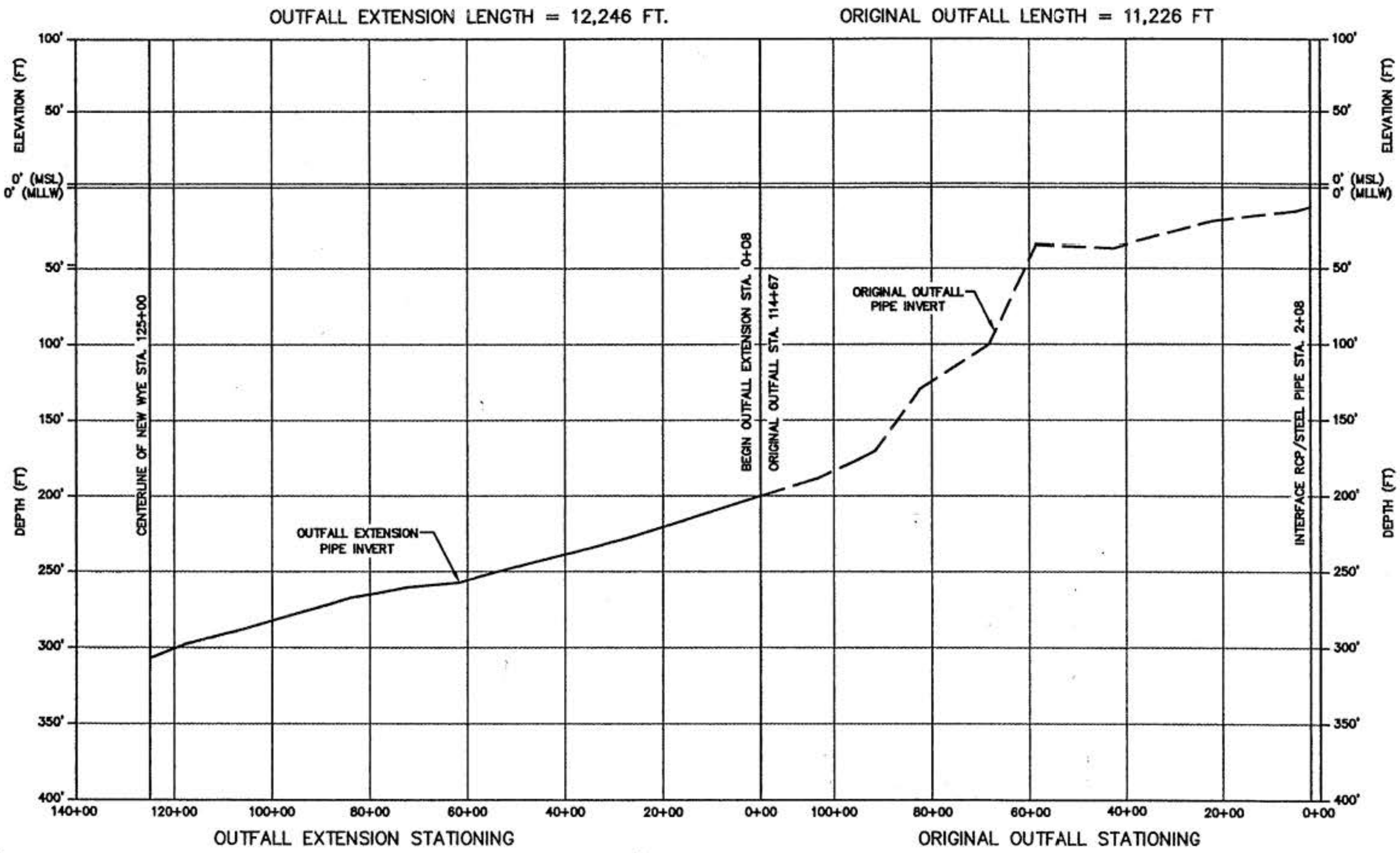
Figure B-2 (page B-4) presents the profile of the original and extended sections of the Point Loma Ocean Outfall. The offshore portion of the main barrel (original section of the outfall) starts at Station 2+08 at the connection to the 2.74-meter (9-foot) diameter, concrete-encased, steel pipe leading from the Vortex Structure. Station 2+08 is approximately 6.1 meters (20 feet) downstream from the connection with the 2.13-meter (7-foot) diameter conduit from the throttling valve and turbine. At Station 114+34, the main barrel of the original outfall ends at the connection to the diffuser wye structure. (Note: Each outfall station represents 100 feet of length. Station 114+34, for example, represents a distance of 11,434 feet from the beginning of the structure.)

The original outfall was constructed using bell and spigot pipe with double gaskets at each joint. The bell end of the pipe is of the raised type to provide additional strength at the joint. The original section of the outfall is not internally lined.

Figure B-3 (page B-5) presents typical details for joints within the outfall. Joints within the original section of the outfall include a monel tube (see upper diagram of Figure B-3) that connects the outside of the spigot to the space between the two gasket grooves. This arrangement was used at the time of construction to facilitate hydrostatic testing of the joint for leakage. The test tube is connected to a coupling imbedded in the wall of the pipe. After testing, the coupling was sealed with a threaded plug.

In the construction of the original main barrel, three typical sections were used. Between Station 2+08 and Station 26+50, the main barrel was constructed in a trench with the entire pipe below seabed. The pipe was placed in the trench with a minimum bedding thickness up to the spring line of 30.5 centimeters (1 foot). Above the spring line, the trench was backfilled with concrete and a minimum concrete thickness of 61.0 centimeters (2 feet) was maintained over the top of the pipe.

Between Station 26+50 and Station 30+40, a transition zone occurs where the pipe emerges from the rock trench and is laid on the ocean floor. The spring line of the main barrel was constructed roughly at the seabed.

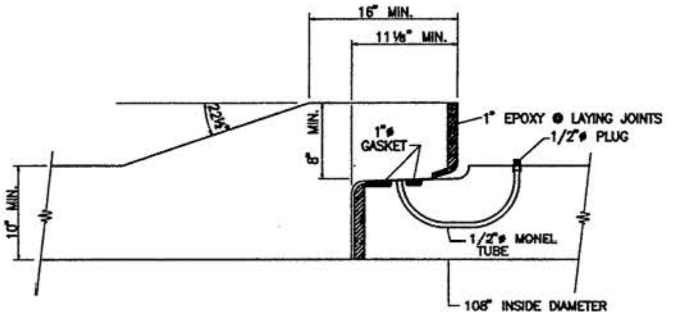


ELEVATION RELATIVE TO MEAN SEA LEVEL (MSL)
DEPTH RELATIVE TO MEAN LOWER LOW WATER (MLLW)
MSL = MLLW + 2.9 FT.

FIGURE B-2

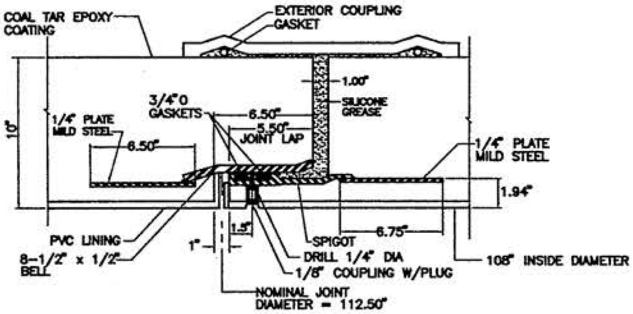
POINT LOMA OCEAN OUTFALL PROFILE

POINT LOMA OCEAN OUTFALL JOINT DETAILS



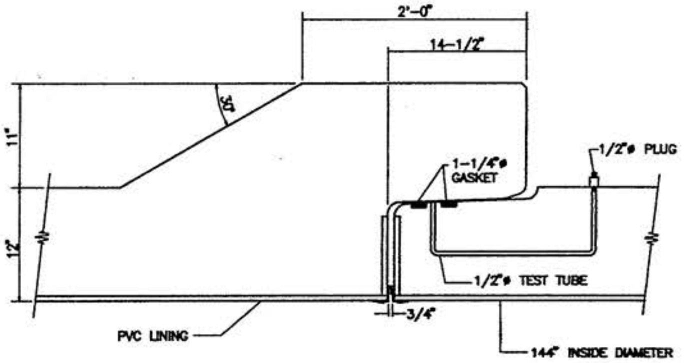
ORIGINAL POINT LOMA OUTFALL JOINT DETAIL

NTS



POINT LOMA REPLO JOINT DETAIL

NTS



POINT LOMA EXTENSION JOINT DETAIL

NTS

FIGURE B-3

Between Station 30+40 and Station 114+34, the main barrel was placed on bedding with a minimum clearance of 30.5 centimeters (1 foot) from the seabed to the bottom of the pipe. The bedding ballast extends up to the spring line. Side slopes for the bedding ballast were set at 1.5:1 (horizontal to vertical). In the months immediately following construction of the original outfall, additional rip rap consisting of one ton boulders was placed on top of the existing ballast rock from Station 26+50 to Station 62+50.

Wye Structure and Original Diffuser. The original diffusers and wye structure incorporate provisions for isolation and flushing. Slots were provided for the insertion of reinforced concrete bulkheads (gates) at the following locations: (1) at the inlet to each diffuser leg at the wye structure, and (2) on the main barrel of the wye structure, immediately downstream of the diffuser leg connections. At the end-structure of each diffuser leg, a bolted bulkhead was provided. Flow into the original diffusers is presently blocked by bulkheads which were inserted at the time of inauguration of the outfall extension.

The original diffuser of the Point Loma Ocean Outfall is no longer in service. The diffuser ports remain open, but outfall flow to the diffuser legs is blocked.

Emergency Repairs of 1992. On February 2, 1992, a major failure of the original outfall occurred between Station 33+28 and Station 37+61. Emergency repair work was designed and completed within 60 days of the failure and involved:

- replacing 132 meters (433 feet) of the main barrel using 2.74 meter (9 foot) diameter reinforced concrete pipe with a 360 degree-PVC lining,
- installing bedding, intermediate rock, and armor rock for the 132 meter (433 foot) section;
- providing cover that included 1.5 ton (median) armor rock with a minimum thickness of 1.37 meters (4.5 feet) above the top of the pipe from Station 27+90 to Station 60+00;
- providing armor rock flush with the top of the pipe from Station 60+00 to Station 67+15; and
- installing a manhole and air relief valve assembly at Station 3+52.50.

Details of the typical pipe joint used for the emergency repair work are shown on Figure B-3. The joint is formed by steel rings on the pipe bell and spigot. Pipe is of the double gasket, flush bell type. Each pipe joint has a 0.635 centimeter (1/4 inch) diameter tube between the interior of the pipe at the spigot and the space between the two gasket grooves. This arrangement was used at the time of construction for hydrostatic testing of the joints for leakage.

A 1.9-centimeter (3/4-inch) thick, 45.7-centimeter (18-inch) wide external steel split sleeve surrounds each joint and incorporates two ring gaskets to provide a tight seal. Silicone grease was injected into the annular space between the sleeve and the outside wall of the pipe through 2.54-centimeter (1-inch) diameter fittings on the coupling.

A special closure piece was fabricated to effect the closure of the repair work. The closure piece incorporated a 7.62-meter (25-foot) long, internal steel cylinder which provided support for two, 4.15-meter (13 feet 7 ½ inch) long, reinforced concrete, telescoping pipe sections. Double gaskets on each of the telescoping pipe sections provided a seal between the internal steel cylinder and the pipe. A reinforced, tremie concrete collar joined the telescoping pipe sections. The integrity of joints on each of the two telescoping pipe sections was tested by means of 1.27-centimeter (½-inch) diameter, PVC test tubes between the exterior of the closure piece and the middle of the gasket grooves.

B.4 OUTFALL EXTENSION

The Point Loma ocean outfall extension was completed in 1993. The extended outfall discharges wastewater approximately 4.5 miles offshore – beyond the 3 mile limit of State-regulated ocean waters. The profile of the outfall extension is presented in Figure B-2 (page B-4). The outfall extension was designed to achieve a 75-year service life.

The main barrel of the outfall extension is connected to the original wye structure immediately downstream from the original diffuser legs. A slot for a reinforced concrete bulkhead is located in the original wye structure between the diffuser legs and the connection for the outfall extension. The bulkhead has been removed to allow flow to pass through the outfall extension, and a lid has been secured to the top of the slot.

Between the start of the outfall extension at Station 0+08 and Station 1+97, the diameter of the reinforced concrete pipe conduit is 2.74 meters (108 inches) and the wall thickness is 25.4 centimeters (10 inches). Pipe in this section of the outfall extension is of the extended bell type. A typical joint detail for the outfall extension is presented in the lower diagram of Figure B-3 (page B-5).

The main barrel of the outfall extension has double-gasket bell and spigot joints. As illustrated on Figure B-3, the joint has a tube between the outside of the spigot and the space between the two gasket grooves. This arrangement was used at the time of construction to test each joint for leakage. A special self closing male fitting was provided at the test port on each pipe spigot for use in pressure testing of the pipe joint. The integrity of each joint may be retested in the future with the use of the special male fitting and mating test equipment.

The top 90 degrees of the inside circumference of the main barrel, centered on the crown of the pipe, is provided with a polyvinylchoride (PVC) liner that is permanently imbedded in the concrete with integral locking extensions. Vertical surfaces at pipe joints are lined with PVC that is bonded to the pipe with a (T Lock) specialized adhesive.

A maintenance access hatch is provided in the outfall extension at Station 0+20 on the 2.74-meter (9-foot) section of the outfall extension. The cover of the 1.06 meter (42-inch) opening is made of cast hi-resist alloy that has a low rise (almost flush with the exterior of the pipe). A two-inch threaded opening, presently plugged, will allow piezometric testing of the outfall at future times.

The main barrel was laid on a leveled course of bedding material. Following placement of the main barrel, bedding was completed and then ballast rock was placed up to the spring line.

Intermediate Wye. A special transition pipe is provided at Station 1+97 which increases the outfall extension diameter from 2.74 to 3.66 meters (108 to 144 inches). The intermediate wye structure starts at the downstream end of the transition pipe (Station 2+21). The purpose of the intermediate wye structure is to allow for the future connection of a 3.66-meter (12-foot) diameter outfall that will parallel and replace the original outfall. The wye branch is oriented at 45 degrees to the main barrel and intersects the main barrel at Station 2+50. A reinforced concrete bulkhead is currently set in a special slot on the wye and will be removed upon connection of the parallel outfall conduit. Two monel lifting hooks are provided for retrieval of the bulkhead.

Constructed of a combination of 1.9 cm (3/4 inch) steel plate and 5.2 cm (2 inch) reinforced concrete liner, the intermediate wye is set within a 5.79-meter (19-foot) high, 14.63-meter (48-foot) diameter, circular steel plate crib. The space between the wye and the steel ring is backfilled with rock which provides thrust restraint.

Cathodic protection for the steel plate ring at the intermediate wye is provided by a total of 14 active and 14 passive sacrificial anodes arranged in two rows around the periphery of the ring. All anodes are aluminum alloy ingots that contain 3 percent zinc by weight and are joined to the steel plate ring by bonding cables. Each ingot weighs approximately 90 pounds. The passive anodes are completely encapsulated in a wax-tape coating to reduce or eliminate current output.

The anodes on the intermediate wye will be consumed (sacrificed) for the protection of the structure as current is discharged from them into the surrounding soil or seawater. It is estimated the active sacrificial anodes will be consumed in about 50 years. At that time or earlier, it will be necessary to remove the wax-tape coating from the passive anode surfaces using a brush. Upon activation, the life of the passive anodes should exceed the service life of the original outfall. Because it is difficult to estimate the rate of consumption of an anode, the condition of the anodes are monitored to determine when activation of the passive anodes is required.

Between the downstream end of the intermediate wye at Station 2+79 and the upstream end of the diffuser wye structure at Station 127+74, the diameter of the conduit is 3.66 meters (144 inches) and the wall thickness is 30.5 centimeters (12 inches). Pipe joints, lining, bedding, ballast, and exterior marking are identical to those described for the 2.74-meter (9-foot) diameter portion of the outfall extension.

Maintenance access hatches (identical to the one located in the area between the original and intermediate wye) are provided at an interval of roughly 305 meters (1,000 feet) on the 3.66-meter (12-foot) diameter portion of the main barrel. Twelve access hatches are provided between the intermediate wye and the diffuser wye structures.

Outfall Diffuser Wye. The diffusers branch from the main outfall at the diffuser wye structure (Station 125+00) at a bottom depth of approximately 94.6 meters (310 feet) below MLLW. The diffuser wye, similar to the intermediate wye, is also constructed of combined fabricated steel plate and reinforced concrete liner, and is set within a 5.8-meter (19-foot) high, 12.8-meter (42-foot) diameter, circular steel plate crib. The space between the wye and the steel ring is backfilled with gravel and provides thrust restraint.

Cathodic protection for the steel plate ring at the intermediate wye is provided by a total of 12 active and 12 passive sacrificial anodes arranged in two rows around the periphery of the ring. All anodes are aluminum alloy ingots that contain 3 percent zinc by weight and are joined to the steel plate ring by bonding cables. Each ingot weighs approximately 90 pounds. The passive anodes are completely encapsulated in a wax-tape coating to reduce or eliminate current output.

The anodes on the diffuser wye will be consumed (sacrificed) for the protection of the structure as current is discharged from them into the surrounding soil or seawater. As per the intermediate wye, the estimated anode life for the diffuser wye is also estimated to be over 50 years. At the time of depletion of the active anodes, it will be necessary to remove the wax-tape coating from the passive anode surfaces using a brush. Upon activation, the life of the passive anodes for the diffuser wye is estimated to be over 50 years.

Slots for three reinforced concrete bulkheads (gates) are provided at the diffuser wye structure inside the steel plate crib. Two of the bulkheads can be used to shut off flow to the two diffuser legs and can be used during outfall maintenance.

As part of routine maintenance, a bulkhead would be inserted at one diffuser leg to enable flow to be routed to the other leg. Isolation of each leg allows for cleaning, inspection, or repair of the blocked diffuser leg with a minimum interruption of flow. Under normal operation, the diffuser slide gates are not in place and the gate slot is covered by a reinforced concrete lid.

A third slot is provided on the 3.66-meter (12-foot) diameter main barrel, immediately downstream from the diffuser branches. This slot, which normally has the bulkhead in place, allows full diameter access to the main barrel of the outfall and could be used for mainline cleaning or for a future outfall extension.

The reinforced concrete lids are rectangular in shape and are secured in place by ten, 3.175-centimeter (1.25-inch) diameter monel bolts and rest on collars that are integrally cast into the diffuser wye. A 3.8-centimeter (1.5-inch) thick, 7.6-centimeter (3-inch) wide gasket is in a rectangular pattern on the collar to ensure a watertight seal. Two lifting hooks are provided on each lid.

A 5.08-centimeter (2-inch) diameter port is located in the crown of the pipe at Station 124+71, immediately upstream of the wye. The purpose of the port is to prevent the accumulation of air, oil, grease, and floatable materials that could otherwise impair the function of the diffusers. A maintenance access hatch is provided in the diffuser wye structure at Station 124+89.50.

Outfall Diffuser Legs. The two diffuser legs for the outfall extension are built on the seabed at a depth between 93 and 95 meters (306 and 313 feet) below MLLW. The diffuser legs are oriented N 17° 13′ W, and 11° 16′ W, with an internal angle of roughly 151.5 degrees. Each diffuser leg is 760 meters (2,496 feet) long and consists of 2.135-, 1.68-, and 1.2-meter (7-, 5.5-, and 4-foot) internal diameter pipe. Pipe lengths, port spacings, and numbers of ports on each diffuser leg are summarized in Tables B-1 and B-2 (page B-11). Diffuser ports are set in the middle of each pipe on opposite sides, 15.2 cm (6 inches) above the springline of the pipe.

Table B-1
Extended Point Loma Outfall Diffuser Configuration
(Metric Units)

Section Length Per Leg (m)	Internal Diameter (m)	Pipe Thickness (cm)	Port Spacing[1] (m)	Port Diameter (cm)	Number of Ports per Leg	Approx. Range of Depth[2] MLLW (m)	Port Design Flow Rate (m^3/sec) (maximum)
307.2	2.13	22.86	7.32	9.53	84	93.3 - 94.2	0.0477
256.0	1.68	22.86	7.32	10.80	70	94.2 - 94.8	0.0503
197.5	1.22	22.86	7.32	12.07	54	94.8 - 95.4	0.0493

1 Port spacing shown is for ports on the same side of diffuser leg. Ports are located on both sides on the diffuser leg.
2 Distance from the centerline of the ports to the ocean surface.

Table B-2
Extended Point Loma Outfall Diffuser Configuration
(English Units)

Section Length Per Leg (ft)	Internal Diameter (ft)	Pipe Thickness (in.)	Port Spacing[1] (ft)	Port Diameter (in.)	Number of Ports per Leg	Approx. Range of Depth[2] MLLW (ft)	Port Design Flow Rate (mgd) (maximum)
1008	7.0	9	24	3.75	84	306-309	1.09
840	5.5	9	24	4.25	70	309-311	1.15
648	4.0	9	24	4.75	54	311-313	1.13

1 Port spacing shown is for ports on the same side of diffuser leg. Ports are located on both sides on the diffuser leg.
2 Distance from the centerline of the ports to the ocean surface.

The diffusers, excluding the final 48.8-meter (160-foot) long section of the 1.2-meter (4-foot) diffuser, are constructed of PVC-lined, reinforced concrete pipe similar to the pipe used for construction of the main barrel. Unlike the main barrel of the outfall extension, all pipe joints on the diffuser have a single gasket.

The final 48.8-meter (160-foot) section of each diffuser leg is constructed of a single piece of steel pipe which serves as a restraining block. Steel plate used in fabrication of the pipe has a thickness of 1.59 centimeters (5/8 inches) and is lined internally with 12.7 centimeters (5 inches) of reinforced concrete. Externally, the steel is coated with a 180 mil thick layer of carboline. Cathodic protection for the steel diffuser section is provided by two active and two passive sacrificial anode bands arranged on the top of the pipe. All anodes are aluminum alloy ingots that contain 3 percent zinc by weight and are joined to the steel plate ring by welded straps. Each ingot weighs approximately 45 pounds. The passive anodes are completely encapsulated in a 30-mil thick PVC shield to reduce or eliminate current output. The PVC shield on the passive anodes will be removed at a future date to replace depleted active anodes. The estimated life of the active anodes is in excess of 50 years.

The internal lining and bedding of the diffusers are identical to main barrel of the outfall extension. Bedding for the diffusers is similar to that for the main barrel, however, the ballast is depressed at the ports to avoid blockage of the flow. Likewise, the stripe painted along the springline of the diffuser to indicate the height of the ballast rock, is depressed in a "V" shape at the ports. A line is also painted along the circumference of the diffuser from the top of the pipe to each individual diffuser port.

B.5 OUTFALL OPERATING PARAMETERS

Design Flows. Design flows for the Point Loma Ocean Outfall are presented in Table B-3. The average dry weather capacity of the outfall of 10.51 m^3/second (240 mgd) matches the rated average annual capacity of the Point Loma Wastewater Treatment Plant.

Table B-3
Design Flows

Flow Condition	Flow Rate	
	(m^3/sec)	(mgd)
Minimum flow	3.15	72
Average dry weather flow	10.51	240
Peak wet weather flow	18.92	432

The outfall extension was designed based on a maximum allowable hydraulic gradeline (HGL) elevation of 24.8 meters (81.5 feet) above MSL at the interconnection between the steel and concrete sections of the original outfall (Station 2+08). Station 2+08 is located roughly 18.3 meters (60 feet) downstream from the South Effluent Outfall Connection.

Outfall Hydraulics. The hydraulic grade line at the shore structure of the Point Loma Ocean Outfall varies with the tide level and the headlosses through the outfall. Headlosses in the main outfall barrel and diffuser legs are a function of the flow rate through the system. Table B-4 (page B-13) presents projected maximum hydraulic gradelines for the outfall. Table B-5 presents projected minimum hydraulic gradeline elevations. Figure B-4 (page B-14) graphically depicts the range of outfall hydraulic gradeline at the shore facilities.

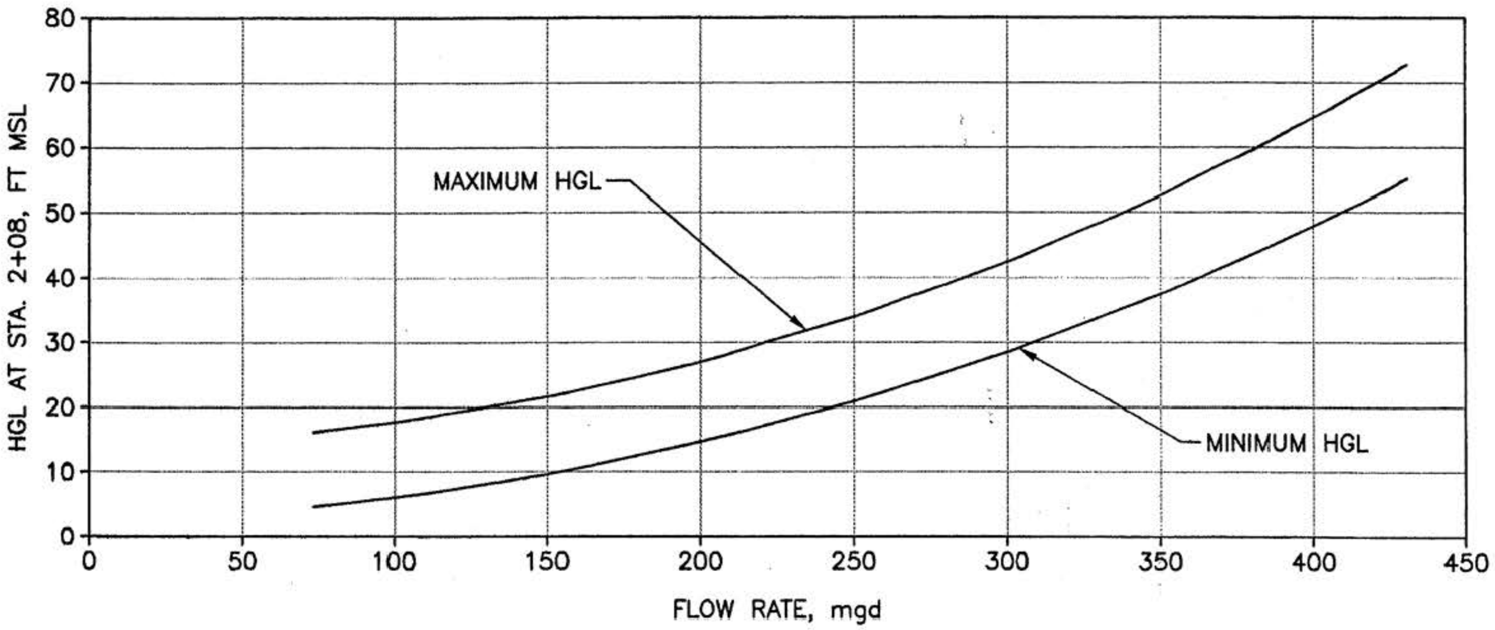
The outfall extension was designed on the basis of a 18.93 m^3/second peak flow (432 mgd) concurrent with a 50-year high tide of 2.5 meters (8.2 feet) above MLLW (5.3 feet above MSL). The minimum tide level is estimated to be 0.67 meters (2.2 feet) below MLLW (5.1 feet below MSL).

Table B-4
Total Head Requirement
Maximum Hydraulic Gradeline

Flow (mgd)	Tide Level (ft MSL)	Headlosses					Maximum Hydraulic Gradeline (ft MSL)
		Original Outfall (ft)	Outfall Extension (ft)	Diffusers (ft)	Density Head (ft)	Minor Losses (ft)	
72	5.3	1.1	0.3	0.2	8.7	0.00	15.6
100	5.3	2.2	0.5	0.4	8.7	0.1	17.1
150	5.3	4.8	1.2	0.9	8.7	0.1	21.1
200	5.3	8.6	2.1	1.6	8.7	0.3	26.6
250	5.3	13.4	3.3	2.5	8.7	0.4	33.6
300	5.3	19.4	4.7	3.7	8.7	0.6	42.3
350	5.3	26.3	6.4	5.0	8.7	0.8	52.5
400	5.3	34.4	8.3	6.5	8.7	1.0	64.3
432	5.3	40.1	9.7	7.6	8.7	1.2	72.7

Table B-5
Total Head Requirement
Minimum Head Requirement

Flow (mgd)	Tide Level (ft MSL)	Headlosses					Maximum Hydraulic Gradeline (ft MSL)
		Original Outfall (ft)	Outfall Extension (ft)	Diffusers (ft)	Density Head (ft)	Minor Losses (ft)	
72	-5.1	1.0	0.2	0.2	7.9	0.00	4.3
100	-5.1	2.0	0.4	0.4	7.9	0.1	5.6
150	-5.1	4.4	0.8	0.9	7.9	0.1	9.1
200	-5.1	7.9	1.4	1.6	7.9	0.3	14.0
250	-5.1	12.4	2.2	2.5	7.9	0.4	20.3
300	-5.1	17.8	3.2	3.7	7.9	0.6	28.0
350	-5.1	24.2	4.3	5.0	7.9	0.8	37.1
400	-5.1	31.6	5.6	6.5	7.9	1.0	47.6
432	-5.1	36.9	6.6	7.6	7.9	1.2	55.1



ESTIMATED HYDRAULIC GRADELINE ELEVATION
AT SHORE FACILITIES

FIGURE B-4

The elevation of the ocean surface varies with the tide stage. For effluent to be discharged through the diffuser ports, the head in the diffuser must overcome the existing tide level. In addition, the head associated with the density difference between seawater and the plant effluent must be overcome.

This latter term, called the "density head", is equivalent to the product of the height of the water column above the diffuser ports and the difference between the specific gravity of seawater (1.026) and the plant effluent (0.9967). The outfall extension diffusers have been designed to avoid seawater intrusion into the diffuser ports at the minimum design flow of 3.15 m^3/second (72 mgd). Seawater intrusion is a problem that occurs in some outfalls during periods of low flow when there are excessive differences in depth over the length of a diffuser. When the head available at the deeper diffuser ports is less than the differential density head between the beginning and end of the diffuser, seawater is able to enter the lower reaches of the diffuser. Sediments carried by the seawater can settle in the diffuser and may not be resuspended when the flow is increased.

Headlosses in the Main Outfall Barrel. Headlosses in the main outfall barrel were estimated on the basis of the results of hydraulic testing conducted in 1989 and 1990. (Engineering Science, 1991). Headlosses in the main barrel were estimated with the aid of the Manning's equation. Table B-6 presents assigned Manning's coefficients. Headlosses were computed assuming no air in the system.

Table B-6
Headlosses in the Main Barrel

Condition	Main Barrel Section	Manning's "n"
Maximum headloss:	Original outfall Outfall extension	0.0146 0.0146
Minimum headloss:	Original outfall Outfall extension	0.0140 0.0120

REFERENCES

Engineering-Science, Inc. *Point Loma Outfall Extension Report*, Volume II, Engineering Studies. 1991.

City of San Diego Metropolitan Wastewater Department. *301(h) Application for Modification of Secondary Treatment Requirements. Point Loma Ocean Outfall.* April 1995.

Appendix C

Compliance with Water Contact Standards

APPENDIX C

COMPLIANCE WITH WATER CONTACT STANDARDS

(As may apply in future permits)

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APPENDIX C

COMPLIANCE WITH WATER CONTACT STANDARDS

(As may apply in future permits)

ABSTRACT

This appendix reviews recreational water contact standards established in the 2005 version of the *California Ocean Plan* (Ocean Plan). Point Loma bacteriological receiving water quality data from recent years are compared with the new 2005 Ocean Plan recreational water contact standards. On the basis of this comparison, it is concluded that the PLOO discharge achieves complete compliance with the Ocean Plan recreational water contact standards in all areas historically designated as recreational water contact zones, such as beaches, waters within 1000 feet (305 m) of the shore or shallower than 30 feet (9 m), and the Point Loma kelp bed. Substantial compliance with the new 2005 Ocean Plan water contact standards is also demonstrated in offshore waters as well. Occasional exceedance of the recreational water contact standards, however, may occur at depths exceeding 130 feet (40 m) at stations approximately three nautical miles (5.6 km) offshore. If regulators apply the water contact recreational standards to all depths within all State-regulated waters, a 2.1 logarithm (approximately a 99 percent) reduction in Point Loma effluent indicator organisms would be required to ensure that the Point Loma Ocean Outfall (PLOO) discharge complies with the new 2005 Ocean Plan recreational water contact standards.

C.1 INTRODUCTION

Overview. Order No. R9-2002-0025 (NPDES CA0107409) regulates the discharge of treated wastewater from the City of San Diego, E.W. Blom Point Loma Metropolitan Wastewater Treatment Plant (Point Loma WTP) to the Pacific Ocean through the PLOO. NPDES permits issued by the Regional Board are required to implement applicable receiving water standards established in the Ocean Plan.

The Ocean Plan establishes recreational water contact bacteriological concentration standards to protect human health associated with water contact recreation uses (e.g. swimming, wading, bathing, surfing, diving, sailboarding, body boarding, etc.). Original Ocean Plan standards to protect such water contact recreational uses included establishing concentration standards for total and fecal coliform for waters within 1000 feet (305 m) of the shoreline or within the 30 foot (9 m) depth contour. In the 1980s, the Ocean Plan was modified to include kelp beds within the zone protected by the Ocean Plan water contact bacteriological standards.

Bacteriological standards within Order No. R9-2002-0025 are based on the 2001 version of the Ocean Plan. As documented in Appendix G (Beneficial Uses), the PLOO discharge has achieved complete compliance with the bacteriological standards established within Order No. R9-2002-0025.

In 2005, the State Water Resources Control Board (State Board) adopted a revised version of the Ocean Plan. The 2005 version of the Ocean Plan:

- established revised concentration standards for total and fecal coliform that are more stringent than the standards in the 2001 version of the Ocean Plan,
- established water contact standards for enterococcus, and
- applied these standards in all areas designated by the Regional Board as water contact recreational areas (REC-1).

Purpose of Appendix. This appendix presents an assessment of compliance with the 2005 Ocean Plan water contact bacteriological standards. As a means of assessing compliance with the 2005 Ocean Plan water contact standards, this appendix compares recent bacteriological data collected in shore, kelp bed, and offshore stations with the 2005 Ocean Plan water contact standards. Two scenarios are investigated. First, compliance with the 2005 Ocean Plan water contact standards are evaluated in water contact areas designated within Order No. R9-2002-0025, specifically areas within:

- 1000 feet (305 m) from shore or within the 30-foot (9 m) depth contour, whichever is less, and
- the Point Loma kelp bed.

In anticipation that the 2005 Ocean Plan water contact standards may be applied in the renewed or future PLOO NPDES permits to all State-regulated waters, the second scenario assesses how the PLOO discharge would comply with the 2005 Ocean Plan water contact standards at all depths within three-nautical-miles (5.6 km) of the shore (all State-regulated waters).

C.2 RECREATIONAL WATER CONTACT STANDARDS

Table C-1 summarizes water contact standards established with Order No. R9-2002-0025. For comparison, Table C-1 also presents water contact standards established in the 2005 Ocean Plan.

Table C-1
Comparison of 2005 Ocean Plan Bacteriological Standards with Standards within Order No. R9-2002-0025

Standards within Order No. R9-2002-0025[1]	2005 Ocean Plan Standards[2]
(1) Water-Contact Standards Within a zone bounded by the shoreline and a distance of 1,000 feet from the shoreline or the 30-foot depth contour, whichever is further from the shoreline, and in areas outside this zone used for water-contact sports, as determined by the Regional Board, but including all kelp beds, the following bacterial objectives shall be maintained throughout the water column: (a) Samples of water from each sampling station shall have a density of total coliform organisms less than 1,000 per 100 ml (10 per ml); provided that not more than 20 percent of the samples at any sampling station, in any 30-day period, may exceed 1,000 per 100 ml (10 per ml), and provided further that no single sample when verified by a repeat sample taken within 48 hours shall exceed 10,000 per 100 ml (100 per ml). (b) The fecal coliform density based on a minimum of not less than five samples for any 30-day period, shall not exceed a geometric mean of 200 per 100 ml nor shall more than 10 percent of the total samples during any 60-day period exceed 400 per 100 ml. The "Initial Dilution Zone" of wastewater outfalls shall be excluded from designation as "kelp beds" for purposes of bacterial standards. Adventitious assemblages of kelp plants on waste discharge structures (e.g., outfall pipes and diffusers) do not constitute kelp beds for purposes of bacterial standards. Kelp beds, for purposes of the bacteriological standards of this order and permit, are significant aggregations of marine algae of the genera *Macrocystis* and *Nereocystis* plants throughout the water column.	1. Both the SWRCB and the California Department of Health Services (DHS) have established standards to protect water contact recreation in coastal waters from bacterial contamination. Subsection "a" of this section contains bacterial objectives adopted by the SWRCB for ocean waters used for water contact recreation. Subsection "b" describes the bacteriological standards adopted by DHS for coastal waters adjacent to public beaches and public water contact sports areas in ocean waters. a. SWRCB Water-Contact Standards (1) Within a zone bounded by the shoreline and a distance of 1,000 feet from The shoreline or the 30-foot depth contour, whichever is further from the Shoreline, and in areas outside this zone used for water contact sports, As determined by the Regional Board (i.e., waters designated as REC-1), but including all kelp* beds, the following bacterial objectives shall be maintained throughout the water column: 30-day Geometric Mean – The following standards are based on the geometric mean of the five most recent samples from each site: i. Total coliform density shall not exceed 1,000 per 100 ml; ii. Fecal coliform density shall not exceed 200 per 100 ml; and iii. Enterococcus density shall not exceed 35 per 100 ml. Single Sample Maximum: i. Total coliform density shall not exceed 10,000 per 100 ml; ii. Fecal coliform density shall not exceed 400 per 100 ml; iii. Enterococcus density shall not exceed 104 per 100 ml; and iv. Total coliform density shall not exceed 1,000 per 100 ml when the fecal coliform/total coliform ration exceeds 0.1. (2) The "Initial* Dilution Zone" of wastewater outfalls shall be excluded from designation as "kelp* beds" for purposes of bacterial standards, and Regional Boards should recommend extension of such exclusion zone where warranted to the SWRCB (for consideration under Chapter III.H.). Adventitious assemblages of kelp plants on waste discharge structures (e.g., outfall pipes and diffusers) do not constitute kelp* beds for purposes of bacterial standards.

1 Receiving Water Limitation C.1.a(1) of Order No. R9-2002-0025.
2 Receiving Water Quality Objective II.B.1.a of the 2005 Ocean Plan.

C.3 PROJECTED COMPLIANCE WITH OCEAN PLAN STANDARDS

To assess potential future compliance of the PLOO discharge with the new 2005 Ocean Plan bacteriological standards, receiving water bacteriological data from past years are compared with the new concentration standards for each regulated parameters. Per provisions within Order No. R9-20002-0025, the City has collected years of receiving water data on total coliform, fecal coliform, and enterococcus concentrations at the PLOO shore, kelp bed, and offshore sampling stations. As a result, a robust data base exists on which to assess compliance with each of the new 2005 Ocean Plan standards.

Initial Screening and Focus on Single Sample Maximums. As a first step in assessing compliance, an initial screening effort was conducted to determine which Ocean Plan bacteriological parameters were most critical in determining compliance. This initial screening analysis concluded that overwhelming majority of the bacteriological concentrations within the Point Loma shore, kelp bed, and offshore stations are consistently low. As a result, the initial screening indicated complete compliance with the 2005 Ocean Plan geometric mean standards in the shore and kelp bed areas (Scenario 1) and within all water depths in all State-regulated waters (Scenario 2).

Because of the abundance of low concentration data values, noncompliance with the Ocean Plan geometric mean standards occurs only when one or more single samples show exceptionally high bacteriological concentrations. As a result, noncompliance with the 30-day geometric mean standards would not occur unless significant noncompliance occurs with the single sample maximums over a range of depths. For this reason, this analysis focuses on compliance with the 2005 Ocean Plan single sample maximum standards. As presented in Table C-1, these single sample maximums include four bacteriological parameters:

- Total coliform (not to exceed a single sample maximum of 10,000 per 100 ml),
- Fecal coliform (not to exceed a single sample maximum of 400 per 100 ml),
- Enterococcus (not to exceed a single sample maximum of 104 per 100 ml), and
- Total coliform, when fecal:total ratios are greater than 0.1 (not to exceed a single sample maximum of 1,000 per 100 ml).

Shoreline Compliance. As noted, Order No. R9-2002-0025 applies Ocean Plan recreation water contact bacteriological standards within the Point Loma kelp bed and within shore and beach areas within 1000 feet (305 m) from shore or to the 30-foot (9 m) depth contour, whichever is farther.

Table C-2 summarizes data from shore sampling stations for the period August 2003 through July 2007. Shoreline stations presented in Table C-2 include stations between Mission Beach and the southerly tip of Point Loma, as specified in Order No. R9-2002-0025 and Addendum No.1 thereto. Attachment C1 summarizes the sampling stations and presents a compilation of all bacteriological data collected at the stations during the 2000-2007 period.

It must be noted that shoreline water quality can be impacted by many sources including storm water, urban runoff and sewer over flows, as well as birds and other animals. Previous work has established the lack of a relationship between shoreline water quality and the PLOO. Sampling results from intermediate stations located between the PLOO and shore stations confirm that the PLOO is not the source of occasional high concentrations seen at the shore stations. As summarized in Table C-2, the shoreline meets the standards of the 2005 Ocean Plan.

Table C-2
Analysis of Compliance with 2005 Ocean Plan Water Contact Standards
Shore Stations D4 – D12[1]
Using Data from August 2003 through July 2007

Regulated Pathogen Indicator Organism[2]	Single Sample Maximum[2] (CFU per 100 ml)	Number of Samples[3]	Percent Compliance[4]
Total Coliform	10,000	1951	100%
Fecal Coliform	400	1951	99.2%
Enterococcus	104	1951	96.7%
T. Coliform (when TC:FC ratio > 0.1)	1000	1951	99.4%

[1] Shore stations D4 is located at the tip of Point Loma, and Stations D5 through D12 are located northward along Point Loma, Ocean Beach, and Mission Beach.

[2] Recreational water contact standards established in the 2005 California Ocean Plan.

[3] Total number of Samples at Shore Stations D4 through D12 from August 2003 through July 2007.

[4] Number of total samples (as a percent) that complied with both the 2001 Ocean Plan water contact standards (addressed within Order No. R9-2002-0025) and Ocean Plan standards adopted in 2005. Discharges from shoreline sources represents the cause of each instance of shoreline exceedance of the Ocean Plan standards., Coliform compliance in offshore stations (between the PLOO discharge and shoreline) document that the PLOO discharge does not influence bacteriological water quality at these shore stations.

Kelp Bed Compliance. Data for the Point Loma kelp forest are taken from the monitoring stations that have historically been used to define this area (per Order No. R9-2002-0025 and prior NPDES permits). Compliance at kelp bed stations are evaluated from calendar year 2000 through July 2007. Kelp bed bacteriological data from this period are included as Attachment C1.

Table C-3 presents a summary of compliance with 2005 Ocean Plan standards based on data from January 2000 to July 2007. Table C-4 (page C-7) documents the few instances of sample results during 2000-2007 that would not have complied with the 2005 Ocean Plan standards.

As shown in Table C-4, virtual 100 percent compliance with the 2005 Ocean Plan standards occurred, except during major storm events when shoreline discharges were swept out to sea and impinged on the kelp bed. Discounting the storm events, only a few isolated samples had values in excess of 2005 Ocean Plan standards, and these samples were from the ocean surface, indicating that the high values resulted from surface contamination rather than from the PLOO outfall (and its submerged wastefield).

Table C-3
Analysis of Compliance with 2005 Ocean Plan Water Contact Standards
Point Loma Kelp Bed Stations[1]
Using Data from 2000 - 2007

Regulated Pathogen Indicator Organism[2]	Single Sample Maximum[2] (CFU per 100 ml)	Number of Samples[3]	Percent Compliance[4]
Total Coliform	10,000	10,876	99.9
Fecal Coliform	400	10,876	99.9
Enterococcus	104	10,876	99.7
T. Coliform (when TC:FC ratio > 0.1)	1000	10,876	99.9

1 Includes data from the eight Point Loma kelp bed stations for the period January 2000 through July 2007. This table presents all data collected, and does not eliminate samples where the cause of the exceedance was specifically related to rain events, to discharges from San Diego Bay or the San Diego River, or discharges from shoreline sources.

2 Recreational water contact standards established in the 2005 California Ocean Plan.

3 Total number of kelp bed station samples from January 2000 through July 2007.

4 Number of total samples (as a percent) that complied with both the 2001 Ocean Plan water contact standards (addressed within Order No. R9-2002-0025) and Ocean Plan standards adopted in 2005. Includes events where the exceedances were caused by shore contamination, discharges from San Diego Bay or the San Diego River.

Table C-4
Year by Year Summary of Kelp Bed Compliance with 2005 Ocean Plan Water Contact Bacteriological Standards

Calendar Year	Number of Samples	Number of Samples that Exceeded the 2005 Ocean Plan Water Contact Standards	Number of Samples that Exceeded the 2005 Ocean Plan Water Contact Standards Due to Storm Events	Notes
2000	1440	1	0	Single surface water sample at single station for enterococcus
2001	1440	2	0	Single surface water samples for enterococcus only
2002	1440	0	0	NA
2003	1440	1	0	Single surface water sample for enterococcus only
2004	1440	21[1]	21[1]	All exceedences were associated with rain events in October, November and December 2004.
2005	1440	6[1]	6[1]	All exceedances were associated with rain events January 2005
2006	1440	0	0	NA
2007[2]	720[2]	2	0	Fecal:Total at a single station

1 From Oct. 2004 through Jan. 2005 several significant rain events impacted stations via San Diego Bay flushing and shoreline runoff plumes. All other exceedences were for a single indicator only and not confirmed by any other water quality parameter measured at that time. The source is most likely an artifact of sample and analytical variance and not reflective of water quality.

2 Year 2007 receiving water samples through June 2007.

Compliance with Water Contact Standards in Offshore Waters. Under Scenario 2, bacteriological data from all depths at offshore stations within (or near) the three-nautical-mile limit of State-regulated waters are compared with recreational water contact standards established in the 2005 Ocean Plan.

Table C-5 (page C-8) summarizes data from the offshore stations. As shown in Table C-5, all but a small percentage of samples collected in these offshore waters complied with recreational water contact standards established in the 2005 Ocean Plan. The occasional exceptions were exceedences at depths of 40 meters (130 feet) or greater - depths and distances offshore typically beyond the range of recreational SBUBA divers.

Data shown in Table C-5 are from January 2000 through June 2007. Attachment C1 presents available bacteriological sampling data for offshore stations during this period.

Table C-5
Analysis of Compliance with 2005 Ocean Plan Water Contact Standards
Offshore Stations within State-Regulated Waters[1]
Available Data from 2000 - 2007

Parameter	Single Sample Maximum[2] (CFU per 100 ml)	Number of Samples[3]	Percent Compliance[4]
Total Coliform	10,000	1,470	97.9[5]
Fecal Coliform	400	1,470	94.6[5]
Enterococcus	104	1,470	95.8[5]
T. Coliform (when TC:FC ratio > 0.1)	1000	1,470	92.2[5]

1 Includes available data from 2000 through June 2007 from offshore stations within three nautical miles of the coast that are not within the Point Loma kelp bed.
2 Recreational water contact standards established in the 2005 California Ocean Plan.
3 Total number of offshore station samples from October 2003 through June 2007.
4 Number of total samples (as a percent) that complied with both the 2001 Ocean Plan water contact standards (addressed within Order No. R9-2002-0025) and Ocean Plan standards adopted in 2005.
5 Exceedences typically occur at a depth greater than 40 meters (130 feet) at stations near the three-nautical-mile limit of State-regulated waters.

The foregoing discussion demonstrates that the PLOO is in compliance with the new 2005 Ocean Plan standards in areas historically used for (or designated as) water contact recreation zones. As summarized in Table C-5 (data are in Attachment C1), the offshore stations (at all water depths) achieve compliance with recreational water contact standards from 92 to 98 percent of the time, with the exceedances typically limited to samples collected from water depths below 40 meters (130 feet). At or near the surface, the offshore stations achieved complete compliance with the 2005 Ocean Plan water contact standards.

C.4 TARGET REDUCTION OF INDICATOR ORGANISMS

Maximum receiving water bacteriological concentrations from the offshore stations (at depth) were compared with the 2005 Ocean Plan water contact standards to determine the degree of reduction in Point Loma WTP indicator organisms that would be required to achieve 100 percent compliance with the Ocean Plan water contact standards at all location and at all depths within the three-nautical-mile limit of State-regulated waters.

Table C-6 presents a comparison of maximum observed receiving water quality in offshore stations (at depth) with the 2005 Ocean Plan standards for water contact recreation. From this comparison, the degree of reduction in Point Loma WTP indicator organisms is estimated in order to ensure that all offshore stations (at all depths) would comply with the 2005 Ocean Plan recreational water contact standards. (As previously noted, the single sample maximums represent the most critical compliance parameter- the PLOO discharge is in compliance with geometric mean standards established in the 2005 Ocean Plan.)

Table C-6
Required Reductions in Effluent Indicator Organisms to Assure Compliance

Parameter	Standard[1] (CFU per 100 ml)	Highest Offshore Result[2] 2003-2007 (CFU per 100 ml)	Reduction Required to Meet Standard
Total Coliform	10,000	130,000[3] (est.)	1.1 log
Fecal Coliform	400	13,000	1.5 log
Enterococcus	104	2200	1.4 log
Total Coliform when Total:Fecal Rations are Greater than 0.1	1000	130,000[3] (est.)	2.1 log in T. Coliform

1 Bacteriological standard from the 2005 version of the Ocean Plan.
2 Highest concentration recorded in any single sample. See Tables C-2 through C-5 for the sample periods
3 Actual sample value was ">16,000". The 130,000 CFU per 100 ml total coliform concentration was estimated on the basis of fecal coliform results from the sample.

Based on the evaluation of data, it was determined that a 2.1-logarithm (approximately 99 percent) reduction in indicator organisms (see Table C-6) in the Point Loma WTP effluent would ensure compliance with the 2005 Ocean Plan recreational water contact standards at all depths and all locations within State-regulated waters. It should be noted that the evaluation summarized in Table C-6 is conservative, as the evaluation is based on the highest result ever observed, even if (1) the result occurred only once and (2) the concentration may not have been conclusively caused by the PLOO discharge.

C.5 SUMMARY

It is concluded that the PLOO discharge is in compliance with the new 2005 California State Ocean Plan standards in areas that have been historically designated as recreational water contact zones (e.g. coastal areas and the Point Loma kelp bed). Substantial compliance with the 2005 Ocean Plan recreational water contact standards are achieved throughout all State-regulated waters, including offshore waters.

Inconsistent compliance is demonstrated, however, at depths exceeding 40 meters (130 feet) at stations near the three-nautical-mile limit of State-regulated waters. To address the inconsistent compliance, an evaluation was performed determine the level of reduction of indicator organisms would be required in the Point Loma WTP effluent in order to assure compliance with 2005 Ocean Plan water contact standards. Using a conservative calculation method, it was determined that approximately a 2.1 log reduction in each organism would insure compliance with the 2005 Ocean Plan water contacts standards at all depths and all locations within State-regulated waters.

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Appendix D

Effluent Disinfection Evaluation

APPENDIX D

EFFLUENT DISINFECTION EVALUATION

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APPENDIX D

EFFLUENT DISINFECTION EVALUATION

ABSTRACT

This appendix assesses the effluent disinfection operations required to achieve a 2.1 log (approximately 99 percent) reduction in pathogen indicator organisms in the Point Loma Wastewater Treatment Plant (Point Loma WTP) effluent. Achieving a 2.1 logarithm reduction in concentrations of indicator organisms within the Point Loma WTP effluent would allow the discharge to comply with Ocean Plan recreational body contact bacteriological standards at all depths in all State-regulated waters.

The selected disinfection plan is based on using travel time in the Point Loma Ocean Outfall (PLOO) as disinfection contact time, and selecting a disinfectant dose rate that:

- achieves a minimum 2.1 logarithm (approximately 99 percent) reduction in pathogen indicator organisms,
- leaves zero (or near-zero) chlorine residual by the time the effluent exits the PLOO outfall diffuser, and
- complies with applicable Ocean Plan standards for effluent toxicity and chlorinated byproducts.

On the basis of bench-scale laboratory tests, a sodium hypochlorite dose rate of 7 mg/l is found to achieve all three goals. Toxicity tests on disinfected effluent confirm that the disinfected effluent complies with Ocean Plan standards for acute toxicity.

D.1 INTRODUCTION

As documented in Appendices C and G, the depth, ocean stratification, outfall dilution, and distance offshore allows the existing PLOO discharge to comply with Ocean Plan recreational water contact standards in all zones within 1000 feet (305 m) of the shoreline, within the 30-foot (9-meter) depth contour, and within the Point Loma kelp bed.

Degree of Required Indicator Organism Reduction. An analysis of over 10,000 offshore bacterial samples within the three-nautical-mile limit of the shore (State-regulated waters) showed significant compliance with Ocean Plan total coliform, fecal coliform, and enterococcus standards at almost all sampling locations. As documented in Appendix C, however, an exception to this occasionally occurs at stations near the three-mile-limit at depths of 130 feet (40 m) or greater. Higher indicator organism concentrations occasionally occur at these depths.

The evaluation of water contact standards (see Appendix C) demonstrated that the Ocean Plan single sample limits were more critical than the geometric means in determining compliance. From the comprehensive offshore bacteriological monitoring data base, the largest single sample concentrations were identified and compared to the respective Ocean Plan water contact standards. On the basis of this comparison, Table D-1 presents the logarithmic degree of indicator organism reduction required in the Point Loma WTP effluent to ensure compliance with Ocean Plan recreational water contact standards. As shown in Table D-1, a 2.1 log reduction in Point Loma WTP indicator organisms is required to ensure compliance with Ocean Plan recreational water contact bacteriological standards at all depths at all locations within the three-nautical-mile limit of State-regulated waters.

Table D-1
Reduction of Indicator Organisms to Ensure Compliance

Indicator organism	Reduction Required[1]
T. Coliform	1.1 log
Fecal Coliform	1.5 log
Enterococcus	1.4 log
Total Coliform (Fecal:Total Ratio > 0.1)	2.1 log[2]

1 Logarithmic reduction required to achieve compliance with Ocean Plan recreational water contact standards at all depths within all State-regulated waters. Data from Appendix C.
2 Logarithmic reduction in total coliform required.

Study Approach. Construction of area-intensive disinfection facilities is not an option at the Point Loma WTP site due to space and boundary restrictions. As a result of these space considerations, disinfection options at the site are limited. An opportunity exists, however, to make use of existing facilities in developing means of disinfecting the Point Loma WTP effluent.

Facilities currently exist at the Point Loma WTP site for storing and handling sodium hypochlorite (a disinfecting chemical currently used onsite for odor control). Additionally, the effluent travel time within the PLOO affords the opportunity for long contact times to achieve effective reduction in pathogen indicator organisms.

The City organized a bench-scale laboratory disinfection study to assess whether sodium hypochlorite could be used in conjunction with the outfall travel time to achieve the 2.1 log reduction while ensuring that the Point Loma WTP effluent complied with:

- receiving water chlorine residual requirements,
- effluent toxicity requirements, and
- Ocean Plan receiving water standards for chlorinated byproducts.

This appendix presents the results of the bench-scale laboratory study. In conjunction with this laboratory study, an engineering and operations implementation plan was also developed (see Appendix A).

D.2 OBJECTIVES OF THE DISINFECTION EVALUATION

The bench-scale laboratory study had two key objectives. A first objective was to determine if sufficient reduction in indicator organisms could be achieved by sodium hypochlorite solution dosages within the contact times available through outfall transport. The second objective was to determine if such dosage rates were in keeping with complying with other Ocean Plan standards, including standards for chlorine residual, toxicity, and receiving water quality. This “in-pipe” chlorination study was based on meeting the target reduction in indicator organisms displayed in Table D-1 (page D-2).

The Ocean Plan allows for a certain amount of free chlorine to be discharged. (The Ocean Plan establishes 6-month median, daily maximum, and instantaneous maximum chlorine residual standards of 2, 4, and 8 µg/l, respectively, to be achieved after completion of initial dilution.) To conservatively assure compliance with the chlorine residual standard and to minimize the formation of by-products, the laboratory study targeted a near zero residual at the end of the outfall. Several effluent flow rate scenarios were included in the study. These included:

- 432 mgd, which is the hydraulic maximum flow capacity of the Point Loma WTP,
- 240 mgd, which is the average daily dry weather capacity of the Point Loma WTP, and
- 180 mgd, a flow slightly above the average daily flow rate that the facility is currently experiencing.

These flow scenarios sufficiently bracket what the facility may experience to assure that the laboratory study can adequately address compliance with discharge standards for free chlorine. Those flow rates equate to specific effluent travel times through the outfall structure that would be utilized for chlorine contact and dissipation of the free chlorine through reaction with the effluent. As part of the bench-scale testing, measurements were made after a contact time of 5 minutes because this is the estimated average time between the locations in the Point Loma WTP where the sodium hypochlorite would be applied and where the effluent samples would be taken. It will also be utilized as a feedback control point for application of the disinfectant.

To be conservative, disinfection contact times used in the study were approximately one-third shorter than actual travel times through the PLOO for the three flow scenarios. Table D-2 presents the conservative contact times used within the study.

Table D-2
Estimated Outfall Contact Times Used for Analysis[1]

Flow rate (MGD)	Assumed Contact Time[1] (minutes)
180	90
240	68
432	38

1 As presented in Table III.B-1 (page III.B-2) of the Large Applicant Questionnaire (Volume III), actual PLOO travel times are estimated at approximately 52 minutes for a 432 mgd flow and 94 minutes for a 240 mgd flow. To be conservative, slower travel times (by approximately a factor of one-third) are used in the disinfection analysis to ensure adequate indicator organism reduction and to ensure that the chlorine residual is eliminated prior to discharge to the ocean.

D.3 RESULTS OF LABORATORY BENCH SCALE DISINFECTION STUDY

Reduction in Indicator Organisms. Point Loma WTP effluent was dosed at various concentrations with a solution of sodium hypochlorite. After initial testing, the dosing target range of 6 to 8 mg/l as NaOCL was selected for more intensive testing. During the tests, measurements were taken at various times for chlorine residual and bacteriological reduction. Additionally, measurements were made at 38, 60 and 90 minutes (the assumed contact times for the three flow scenarios shown in Table D-2).

Results of the testing at a 6, 7, and 8 mg/l sodium hypochlorite dose rates are respectively presented in Tables D-3, D-4, and D-5 (page D-5).

Table D-3
Summary of Results of Laboratory "In-Pipe" Disinfection Study[1]
Initial Sodium Hypochlorite Dose Rate of 6.0 mg/l

Concentration as NaOCl (mg/l)	Contact Time[2] (minutes)	Average Total Coliform Log-Reduction	Average Fecal Coliform Log-Reduction	Average Enterococcus Log-Reduction
6.0[3]	0	---	---	---
0.0[4]	38	1.0	1.6	1.0
0.01[4]	60	1.1	1.6	1.2
0.0[4]	90	1.0	1.6	1.3

1 Results from bench-scale tests on Point Loma WTP advanced primary effluent. Tests conducted during October 2007.
2 Contact time after addition of target dosage of sodium hypochlorite.
3 Initial disinfectant concentration is a calculated value.
4 Chlorine residual value measured in the effluent after the indicated time.

Table D-4
Summary of Results of Laboratory "In-Pipe" Disinfection Study[1]
Initial Sodium Hypochlorite Dose Rate of 7.0 mg/l

Concentration as NaOCl (mg/l)	Contact Time[2] (minutes)	Average Total Coliform Log-Reduction	Average Fecal Coliform Log-Reduction	Average Enterococcus Log-Reduction
7.0[3]	0	---	---	---
0.18[4]	5	---	---	---
0.08[4]	38	2.3	2.8	1.9
0.07[4]	60	2.5	3.0	1.9
0.07[4]	90	2.6	3.0	2.1

1 Results from bench-scale tests on Point Loma WTP advanced primary effluent. Tests conducted during October 2007.
2 Contact time after addition of target dosage of sodium hypochlorite.
3 Initial disinfectant concentration is a calculated value.
4 Chlorine residual value measured in the effluent after the indicated time.

Table D-5
Summary of Results of Laboratory "In-Pipe" Disinfection Study[1]
Initial Sodium Hypochlorite Dose Rate of 8.0 mg/l

Concentration as NaOCl (mg/l)	Contact Time[2] (minutes)	Average Total Coliform Log-Reduction	Average Fecal Coliform Log-Reduction	Average Enterococcus Log-Reduction
8.0[3]	0	---	---	---
1.04[4]	5	---	---	---
0.66[4]	38	3.8	3.9	2.3
0.51[4]	60	3.8	3.8	2.4
0.40[4]	90	4.0	4.0	2.4

1 Results from bench-scale tests on Point Loma WTP advanced primary effluent. Tests conducted during October 2007.
2 Contact time after addition of target dosage of sodium hypochlorite.
3 Initial disinfectant concentration is a calculated value.
4 Chlorine residual value measured in the effluent after the indicated time.

Acute Toxicity Testing. To assess possible effects of chlorination on effluent toxicity, final effluent after disinfection (with or without any chlorine residual that may have been present) was also tested for compliance with the effluent toxicity standards. Order No. R9-2002-0025 specifies effluent toxicity testing on the more sensitive of two species: *Atherinops affinis* (topsmelt) and *Mysidopsis bahia* (shrimp).

Table D-6 summarizes results of special toxicity tests of disinfected Point Loma WTP effluent for *Mysidopsis bahia* (shrimp). A total of six tests (each on a different day) were performed on *Mysidopsis bahia*. Each of the tests compared *Mysidopsis bahia* acute toxicity in undisinfected Point Loma WTP effluent with effluent disinfected with either (or both) a 7 mg/l or 8 mg/l dose of NaOCl with 90 minute contact time. As shown in Table D-6, acute toxicity values for *Mysidopsis bahia* were within permitted limits for all tests at both chlorine dose rates.

Table D-6
Summary of Toxicity Tests Conducted on Disinfected Effluent
Acute Toxicity - *Mysidopsis Bahia* Survival

Sample[2]	*Mysidopsis Bahia* (Shrimp) Acute Toxicity[1] (TUa)						
	Test # 1	Test #2	Test #3	Test #4	Test #5	Test #6	NPDES Permit Limit[3] (TUa)
Point Loma effluent (PLE) neat[4]	<3.06	3.31	<3.10	<3.23	< 3.23	< 3.23	6.5
PLE + 8 mg/l NaOCl at t=90 min.	4.44	<3.19	Not tested[6]	4.21	< 3.23	3.57	6.5
PLE + 7 mg/l NaOCl at T=90 min.	Not tested[5]	Not tested[5]	<3.10	4.34	3.49	< 3.23	6.5

1 Test method: 96-hour static renewal Mysidopsis bahia survival
2 Six different tests were conducted and compared to non-disinfected effluent and the NPDES permit limit.
3 Acute toxicity standard established within Order No. R9-2002-0025.
4 Undisinfected Point Loma effluent
5 Toxicity is tested after an 8 mg/l dose and 90 minute contact time under Test #1 and #2. Toxicity at a 7 mg/l dose rate was not performed, as toxicity levels were low for both the undisinfected Point Loma effluent and effluent treated with an 8 mg/l dose of sodium hypochlorite.
6 Toxicity is tested after a 7 mg/l dose and 90 minute contact time under Test #3.

Table D-7 (page D-7) summarizes results of special toxicity tests of disinfected Point Loma WTP effluent for *Atherinops affinis* (topsmelt). A total of three tests (each on a different day) were performed on topsmelt. Each of the tests compared topsmelt acute toxicity in undisinfected Point Loma WTP effluent with effluent disinfected with 7 mg/l and 8 mg/l doses of NaOCl with 90 minute contact times. As shown in Table D-7, each of the tests performed on the 8 mg/l chlorine dose rates were within permitted acute toxicity limits. One of the three tests performed using a 7 mg/l NaOCl dose rate showed a topsmelt acute toxicity in excess of 6.5 TUa. The test performed on this same split effluent sample at an 8 mg/l dose rate, however, had an acute toxicity of less than 5 TUa. As a result, the topsmelt test result that exceeded the 6.5 TUa limit is considered an anomaly. Additional testing, however, is underway to confirm this analysis.

Table D-7
Summary of Toxicity Tests Conducted on Disinfected Effluent
Acute Toxicity - *Atherinops Affinis* Survival

Sample[2]	*Atherinops Affinis* (Topsmelt) Acute Toxicity[1] (TUa)			
	Test # 1	Test #2	Test #3	NPDES Permit Limit[3] (TUa)
Point Loma effluent (PLE) neat[4]	<3.23	< 3.23	< 3.23	6.5
PLE + 8 mg/l NaOCl at t=90 min.	4.95	3.82	4.28	6.5
PLE + 7 mg/l NaOCl at T=90 min.	8.04	4.44	3.93	6.5

1 Test method: 96-hour static renewal Mysidopsis bahia survival
2 Three different tests were conducted and compared to non-disinfected effluent and the NPDES permit limit.
3 Acute toxicity standard established within Order No. R9-2002-0025.
4 Undisinfected Point Loma effluent

D.4 SUMMARY OF EFFLUENT DISINFECTION EVALUATION

Attainment of Targeted Indicator Organism Reduction. The laboratory bench scale testing established (see Table D-4) that dosing the Point Loma WTP effluent with sodium hypochlorite solution to attain a 7.0 mg/l dose rate as it leaves the primary sedimentations basins will achieve the targeted reduction in indicator organisms. At a contact time of 60 minutes, a 2.5 log reduction in total coliform is achieved, along with a 3.0 log reduction in fecal coliform and a 1.9 log reduction in enterococcus.

Such a degree of reduction would ensure that the PLOO discharge would comply with Ocean Plan recreational water contact standards at all depths within three nautical miles of the coast.

Consumption of Residual. As shown in Table D-4 (page D-5), the 7.0 mg/l sodium hypochlorite dose rate would be almost fully consumed by the time the Point Loma WTP effluent exits the PLOO and is discharged to the ocean. The laboratory testing indicates a dosage of sodium hypochlorite solution that results in an initial concentration of 7.0 mg/l in the effluent will result in complete compliance with Ocean Plan chlorine residual standards after 38 minutes of contact time - a time shorter than the estimated minimum PLOO travel time under any flow scenario.

Lack of Toxicity Effects. As shown in Table D-6 (page D-6), disinfecting the Point Loma WTP effluent with either a 7.0 mg/l or 8.0 mg/l sodium hypochlorite dose rate does not result in acute toxicity values for *Mysidopsis bahia* in excess of permitted limits. The special toxicity testing also showed that topsmelt acute toxicity remained within normal limits for the 8.0 mg/l sodium hypochlorite dose rate. While one of three topsmelt acute toxicity samples at a 7.0 mg/l dose rate exceeded 6.5 TUa, the topsmelt acute toxicity was less than 5.0 TUa in this same split effluent sample at a dose rate of 8.0 mg/l, suggesting that the test result for the 7.0 mg/l dose rate was an anomaly.

Compliance with Ocean Plan Table B Standards. Table B of the Ocean Plan establishes receiving water standards for a variety of toxic organic and inorganic compounds. The potential exists for methane or benzene compounds in the Point Loma WTP effluent to become halogenated, creating such chlorinated byproducts as chloroform, chloromethane, dichloromethane, chlorodibromomethane, dichlorobromomethane, chlorinated phenolic compounds, and others.

As shown in Table D-8, the PLOO discharge currently complies with the Ocean Plan Table B standard for phenolic compounds by a factor of 400.

Table D-8
Compliance with Ocean Plan Standards for Phenol and Chlorinated Phenols

Parameter	Units	Ocean Plan Receiving Water Standard (to be achieved upon completion of initial dilution)	Maximum Observed 6-Month Median 2002-2006[2]	Maximum 6-Month Median Receiving Water Concentration after Initial Dilution[3]	Approximate Factor by Which Compliance is Achieved[4]
		6-month median			
Phenolic Compounds	μg/l	30	15.3	0.075	400
Chlorinated phenolics	μg/l	1	ND[5]	0.075[6]	13

1 From California Ocean Plan, Table B.
2 Maximum observed 6-month median Point Loma WTP effluent phenol concentration during 2002-2006. See Table 3-2 on page 3-3.
3 Projected maximum 6-month median receiving water concentrations are computed on the basis of (1) the maximum observed 6-month median concentration of the Point Loma WTP effluent during 2002-2006, and (2) a minimum initial dilution of 204:1.
4 Ratio between maximum computed receiving water concentration after initial dilution and the corresponding Ocean Plan standard.
5 ND indicates not detected at the listed MDL.
6 Maximum receiving water concentration for chlorinated phenols if the Point Loma WTP effluent were to have a chlorinated phenolic concentration equal to the observed concentration of non-chlorinated phenol.

Even if the Ocean Plan standard for chlorinated phenol were applied to unchlorinated phenols in the Point Loma WTP effluent, the PLOO discharge would continue to comply with the Ocean Plan standard by a significant margin.

Compliance is also projected for other common halogenated compounds. As shown in Table D-9, the Point Loma discharge complies with Ocean Plan Table B standards for common disinfection byproducts (e.g. halogenated methanes and benzenes) by several orders of magnitude. Because of this large compliance margin, if concentrations of these compounds in the PLOO discharge were to increase as a result of effluent chlorination, the discharge should continue to achieve complete compliance with Ocean Plan Table B standards.

Table D-9
Compliance with Ocean Plan Standards
Common Halogenated Methane and Benzene Compounds

Common Disinfection Byproduct	Concentration in Φg/P				Approximate Factor by Which Compliance is Achieved[4]
	Ocean Plan Receiving Water Standard[1] (to be achieved upon completion of initial dilution)	Point Loma WTP Effluent MDL	Point Loma WTP Maximum Month Effluent Concentration 2002-2006[2]	Maximum Receiving Water Concentration after Initial Dilution[3]	
	30-Day Average				
Chlorodibromomethane	8.6	1.0	2.9	0.0140	610
Chloroform	130	1.0	11.2	0.055	2400
1,4-dichlorobenzene	18	2.3	3.8	0.019	950
Dichlorobromomethane	6.2	1.0	3.7	0.018	340
dichloromethane (methylene chloride)	450	1.0	17.9	0.087	5200
bromomethane (methyl bromide)	130[7]	1.0	ND[5]	< 0.0049	> 27,000
chloromethane (methyl chloride)	130[7]	1.0	1.2	0.0059	22,000

[1] From California *Ocean Plan*, Table B. Constituents listed in order of appearance in Table B.

[2] Point Loma WTP effluent maximum observed concentration during 2002-2006.

[3] Computed receiving water concentration upon completion of initial dilution. Computation based on the 204 to 1 minimum month initial dilution assigned in Order No. R9-2002-0025 and the maximum Point Loma WTP effluent concentration from 2002-2006.

[4] Ratio between maximum computed receiving water concentration after initial dilution and the corresponding Ocean Plan standard.

[5] ND indicates not detected at the listed MDL. Maximum receiving water concentrations for these non-detected constituents are computed using the MDL, and are reported as "<x µg/l".

Disinfection Implementation. As a result of the above bench-scale laboratory studies, a prototype disinfection system (see Appendix A) has been designed and installed at the Point Loma WTP. The City has submitted a formal request to the Regional Board and EPA (see Appendix U) to begin operation of this prototype disinfection system under the requirements of Order No. R9-2002-0025. Point Loma WTP effluent disinfection operations will be initiated upon receipt of Regional Board approval.

Ongoing Operational Evaluation. Upon Regional Board approval and implementation of the Point Loma WTP effluent disinfection prototype system, Point Loma WTP disinfection facilities will be continuously operated so as to assure no lapses in compliance. The prototype system will be operated so as to duplicate the above-described laboratory scale results at the treatment plant.

As part of this continuously-operated disinfection system, special effluent and receiving water samples will be collected and evaluated to confirm compliance with recreational body-contact standards within State-regulated waters. The prototype disinfection facilities or operations may be modified in the future if ongoing monitoring and evaluation of the prototype system indicate that such modifications would result in greater disinfection efficiency or cost-effectiveness. Regional Board approval would be solicited and obtained, however, prior to implementing any significant modifications to the prototype Point Loma WTP disinfection system.

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Appendix E

Benthic Sediments and Organisms

APPENDIX E

BENTHIC SEDIMENTS AND ORGANISMS

Analysis of Receiving Waters Monitoring Data Collected around the Point Loma Ocean Outfall (July 1991 - December 2006)

City of San Diego

NPDES Permit Application
and 301(h) Application

Submitted to

United States Environmental Protection Agency

November 2007
(updated)

Prepared by

City of San Diego
Metropolitan Wastewater Department
Environmental Monitoring & Technical Services Division

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Appendix E
Benthic Sediments and Organisms

Section E.1 – Summary of Findings

The City of San Diego's discharge of municipal waste water into offshore marine waters maintains natural conditions in sediments and biota beyond the wastewater zone of initial dilution (ZID). Monitoring benthic sediment conditions and assessing the status of marine invertebrate and fish communities are conducted to assess outfall related impacts and is described in this Appendix. San Diego's offshore monitoring program has collected and analyzed more than 3400 benthic samples (sediments and infauna) from different monitoring stations around the Point Loma Ocean Outfall and surrounding areas from 1991 through 2006. In addition, nearly 430 otter trawls have been performed during this time to monitor demersal fish and megabenthic invertebrate communities in the region, while additional trawls and rig fishing activities have been conducted to monitor the bioaccumulation of contaminants in fish tissues (see Appendix F). Overall, 10 quarterly pre-discharge surveys (July 1991-October 1993) were conducted to assess naturally occurring conditions and their temporal and spatial patterns of variability, while data from 45 post-discharge surveys (January 1994-July 2006) have been analyzed to detect changes that may indicate outfall related effects.

After 13 years of wastewater discharge from the extended Point Loma outfall, monitoring results show only minor changes beyond the ZID boundary off Point Loma. Chemical and biological conditions of the sediments indicate no environmentally significant changes associated with the discharge. The only evidence of organic or contaminant loading of the sediments are small increases in sulfides and BOD at sites located within about 300 m of the outfall. Although some changes have occurred that correspond to the initiation of discharge, benthic habitats outside the ZID boundary are characterized by infaunal communities comprised of indigenous species populations representative of natural conditions. Key parameters such as infaunal abundance, species diversity, the

Benthic Response Index (BRI), and patterns of key “indicator” species, are being maintained within the limits of variability that typify natural benthic communities of the Southern California Bight (SCB) continental shelf. Finally, analysis of trawl-caught fish and invertebrate communities show no evidence of outfall effects.

Sediments

Sediment conditions off Point Loma were analyzed based on a total of 372 0.1-m^2 grab samples collected at the 12 stations located at outfall depths. Of the samples collected at these 12 stations, 60 were collected prior to discharge and 312 during the post-discharge period. The latter includes 168 samples for the period covered in the City’s previous 2001 waiver application (i.e., 1994-2000) and 144 samples for the period from 2001 through 2006.

Wastewater discharge is not significantly affecting sediment quality in the vicinity of the Point Loma outfall. Since the outfall began operation, there has been little evidence of organic and contaminant loading in the area. Most measured parameters continue to exist at levels within the range of natural variability for the San Diego region and other SCB reference areas. Increases in levels of arsenic, chromium, copper, iron, nickel, and zinc in 1994 shortly after discharge began were not sustained. The only sustained effects were mostly restricted to a few sites located nearest the outfall pipe (i.e., ~120-300 m), including station E14 near the ZID boundary just west of the center of the outfall wye, and stations E11 and E17 located near the ends of the southern and northern diffuser legs, respectively. These effects included an increase in sediment particle size through time, measurable increases in sulfide concentrations, as well as smaller increases in BOD levels. Consequently, the discharge is not affecting sediment quality to the point that it will degrade the resident marine biota.

Benthic Infauna

The benthic infaunal communities off Point Loma were analyzed based on a total of 743 0.1-m^2 grab samples collected at the 12 stations located at outfall depths during January and July from 1991 through 2006. Of the samples collected at these sites, 120 were collected prior to discharge (1991-1993) and 623 afterwards (1994-2006).

Benthic communities around the Point Loma Ocean Outfall continue to be dominated by SCB prevalent ophiuroid-polychaete based assemblages, and have mirrored changes that have occurred throughout the SCB since monitoring began. For example, the brittle star *Amphiodia urtica* and the spionid polychaete *Spiophanes duplex* were dominant species during both the pre- and post-discharge periods. Polychaetes continue to account for the greatest number of species and individuals overall. Similar assemblages dominate much of the southern California benthos, including the San Diego region, although patches of other benthic assemblages occur in areas of different sediment types. The shifts in community composition that have occurred over time off Point Loma probably represent variation in southern California assemblages related to large-scale oceanographic events such as El Niños, to natural population fluctuations, and habitat heterogeneity.

Although variable, infaunal communities off Point Loma have remained steady between years in terms of the number of species, number of individuals, and dominance. The values for these parameters off Point Loma are similar to other sites throughout the San Diego region and the entire SCB. In spite of this overall stability, comparisons of data from the pre- and post-discharge periods indicate some trends. For example, there has been a general increase in the total abundance and number of species of benthic infauna since wastewater discharge began, continuing an upward trend that started prior to the discharge. The increase in species richness was most pronounced nearest the outfall, contrary to what would be expected if environmental degradation were occurring. Increases in infaunal abundance were also generally accompanied by decreases in dominance, another pattern contrary to known pollution effects. Considering the nature of above changes, benthic communities around the Point Loma Ocean Outfall are not being dominated by a few pollution tolerant species.

Other changes in the benthos near the outfall also suggest moderate effects coincident with anthropogenic activities. For example, the increased variability in number of species and infaunal abundance at near-ZID station E14 since discharge began may be indicative of community destabilization. A similar increase in the benthic response index (BRI) at this station during the post discharge period may also be indicative of enrichment or disturbance events. However, BRI values at this and all other sites are still considered characteristic of reference conditions. Finally, the patchiness of sediments near the outfall and the corresponding shifts in assemblage structure suggest that changes in the area may be related to localized physical disturbance (e.g., shifting sediment types) as well as to organic enrichment.

Populations of some indicator organisms also revealed changes that correspond to organic enrichment near the outfall, while populations of others revealed no evidence of impact. For example, there was a significant change in the difference between ophiuroid (*Amphiodia* spp) populations that occur near the outfall (i.e., station E14) and those present at reference sites. The difference in *Amphiodia* populations was due to both a decrease in numbers of this brittle star near the outfall and corresponding increases at the "control" sites during the post-discharge period. More recently, however, populations of *Amphiodia* at these sites have become more similar, particularly between 2004 and 2006. Although changes in *Amphiodia* populations at station E14 may be related to organic enrichment, other factors such as increased predation pressure near the outfall pipe may be important. Whether or not these changes are related to organic enrichment, predation, or some other factor, abundances of *Amphiodia* off Point Loma are still within the range of those occurring naturally in the SCB. Patterns of change in populations of the polychaete *Capitella "capitata,"* the bivalve *Parvilucina tenuiscuplta,* and ostracods of the genus *Euphilomedes* also suggest a subtle enrichment effect near the outfall; however, densities of these organisms are low and within the range of natural variation for the SCB. Other benthic invertebrates that have been suggested as bioindicators (e.g., *Mediomastus, Dorvillea, Armandia, Rhepoxynius, Ampelisca)* also revealed few changes that would indicate habitat degradation near the outfall.

Although some changes in benthic assemblages have appeared in the receiving waters off Point Loma, these assemblages are still similar to those present prior to discharge and to natural indigenous communities of the southern California outer continental shelf. Thus, after 13 years of operation, the discharge of wastewater through the Point Loma outfall has not caused any biologically changes in benthic community structure that may be construed as degradation.

Demersal Fishes and Megabenthic Invertebrates

Demersal fish and megabenthic invertebrate communities were analyzed based on a total of 186 otter trawls taken at six stations off of Point Loma during January and July from 1991 through 2006. Of these trawls, 30 were performed prior to discharge (1991-1993) and 156 afterwards (1994-2006).

Analyses of temporal and spatial patterns did not reveal any effects on trawl-caught fish and invertebrate communities in the area that could be attributed to the Point Loma outfall. Despite the high variability of both communities, patterns of change in species richness and abundance were similar at stations near the outfall and at those farther away. Although the abundance of some dominant fish, such as the Pacific sanddab, declined at the nearfield stations in proportion to the overall post-discharge population, sanddab abundances were within the range of natural variability described for reference areas in the SCB. Furthermore, no changes in community structure were detected in the nearfield assemblages that corresponded to the initiation of wastewater discharge. Finally, the lack of physical abnormalities and indicators of disease such as fin rot, lesions and tumors suggest that fish populations have remained healthy off Point Loma since monitoring began.

Deep Benthic Pilot Study

Little is known about benthic conditions on the continental slope off southern California, although this region may be a major sink for the accumulation of sediments and other materials that may originate from a variety of point and non-point sources. In an effort to begin investigating such habitats as part of its enhanced ocean monitoring objectives for the Point Loma outfall region, the City of San Diego, in collaboration with the Scripps Institution of Oceanography, implemented a Deep Benthic Pilot Study (DBPS) in October 2005. The DBPS was designed to target depositional areas in the Loma Sea

Valley located west of the City's monitoring region for the Point Loma outfall and an EPA designated disposal site. Sixteen sites were distributed at depths around 200, 300, 400 and 500m along four offshore transects and modified to target areas most susceptible to sediment accumulation. Sites were classified into three "classes" based on geographic location, sediment composition, and steepness of slope. Samples were collected at each site for assessment of both sediment quality (grain size, chemistry) and biotic (infaunal communities) conditions. Preliminary analyses of the sediment data have been completed (see below), while assessment of the associated infaunal communities is underway. The preliminary summary report for this project is included as Attachment E.4 of this appendix, while a final comprehensive report is expected to be completed by the end of 2008.

As part of the DBPS, benthic sediments were analyzed for grain size, total organic carbon, total nitrogen, total volatile solids, sulfides, trace metals, pesticides, and PCBs. Bottom water conditions were characterized based on CTD data. Preliminary results show no evidence of significant contaminant accumulation in these deeper habitats off San Diego that may have originated from the Point Loma outfall, the LA-5 disposal site or other sources. No chlorinated pesticides or PCBs were detected at any of the 16 sites. Sediment chemistries were closely linked to grain size compositions. Sediments sampled from the axial valley of the submarine canyon where materials are most likely to accumulate were much coarser and had correspondingly lower concentrations of metals and organic enrichment than sediments collected from the alluvial plain of the canyon and nearby shelf slope. Alluvial and deep sediments were organically enriched leading to low oxygen concentrations in the overlying water.

Section E.2 – Introduction

The City of San Diego began voluntary pre-discharge monitoring for the extended deepwater Point Loma Ocean Outfall (PLOO) in July 1991. The design of the monitoring program was determined by members of the City's Ocean Monitoring Program through consultation with the Region IX office of the United States Environmental Protection Agency (EPA) and the San Diego Regional Water Quality Control Board (RWQCB). The aim of the program was to establish fixed stations at various distances and depths from the diffuser pipe, which would be monitored to evaluate the quality of sediments and their associated invertebrate and fish communities in order to determine whether or not changes in these communities might be attributed to discharge from the outfall.

The geographic coordinates and depths of the benthic and trawl monitoring stations for the Point Loma region are available in the City's Ocean Monitoring Program Quality Assurance Manual (e.g., City of San Diego 2004a) or the appropriate Monitoring and Reporting Programs (MRPs) associated with NPDES Permit No. CA107409. A total of 23 benthic stations were originally established, including: (a) 12 stations located at the outfall discharge depth along the 98-m contour; (b) five shallower stations along the 88-m depth contour; and (c) six deeper stations in along the 116-m depth contour. Eight trawl stations were established along transects parallel to the 100-m depth contour considered representative of offshore environs. A complicating factor of the overall site design is the presence of the U.S. Army Corps of Engineers dredge spoils disposal site (designated LA-5), located about 3300 m southwest of the outfall. Physical and chemical changes in sediments associated with the LA-5 disposal site have been previously documented (e.g., SAIC 1990).

Construction of the Point Loma outfall extension was completed in November 1993 and discharge was initiated at the deepwater location (~100 m). The results and findings presented in this application include analyses of data collected from July 1991 through the end of calendar year 2006 for sediment conditions (sediment grain size and chemistry), benthic infauna communities, and demersal fish and megabenthic invertebrate communities. This represents an update of the analyses presented in the City's 2001 301(h) waiver application, which addressed monitoring data through calendar year 2000. Since that time, however, significant changes were made to the MRP requirements for the Point Loma region with the adoption of Addendum No. 1 to Order No. R9-2002-0025, NPDES Permit No. CA0107409, which may affect comparisons between periods. Thus, all data were completely reanalyzed for this application in order to account for such factors. Major changes to the benthic and trawl monitoring requirements that became effective on August 1, 2003 include:

1) Number of benthic stations reduced from 23 to 22 (sampling at station B13 discontinued);
2) Benthic infauna sampling added at two stations previously monitored for sediment quality only (i.e., stations E1 and E3);
3) Benthic stations subdivided into primary and secondary sites to accommodate regional monitoring and/or special studies:
    a) Primary core stations comprise 12 sites along the 98-m outfall depth contour (monitoring at these sites retained during regional or special study surveys);
    b) Secondary core stations comprise 10 sites along 88-m and 116-m depth contours (requirements for sampling these sites may be relaxed to allow participation in regional efforts or special projects).
4) Number of trawl stations reduced from eight to six (i.e. sampling at stations SD9 and SD11 discontinued);
5) Biomass requirement discontinued for invertebrates collected at benthic and trawl sites;
6) Benthic response index (BRI) replaced the infaunal trophic index (ITI) as the major environmental disturbance index for infaunal communities;
7) Benthic and trawl sampling frequency modified from a quarterly (January, April, July, October) to semiannual (i.e., January, July) schedule.

Overall, a total of 55 quarterly or semiannual benthic or trawl surveys have been conducted off Point Loma between July 1991 and December 2006. These include 10 surveys of pre-discharge conditions (1991-1993) and 45 surveys of post-discharge conditions (1994-2006). All data from the above surveys have been analyzed and reported in annual receiving waters monitoring reports for the Point Loma Ocean Outfall (City of San Diego 1995-2007).

Section E.3 – General Methodology

All sampling and analytical methodologies follow guidelines established by the Environmental Protection Agency (EPA 1987a, 1987b) and as defined by NPDES Permit No. CA0107409. Additional details regarding monitoring for the Point Loma Ocean Outfall are available in the City of San Diego's Quality Assurance Manuals (e.g., City of San Diego 2004a) and Annual Receiving Waters Monitoring Reports (e.g., City of San Diego 2007a). Careful sample logging and custody procedures are followed throughout the program so that all samples and data are readily tracked and inventoried from the collection process through laboratory analysis and data reporting.

All benthic sediment and infauna samples were collected using a single or double 0.1 m^2 Van Veen grab. This type of grab is highly regarded for its sampling capabilities, including depth of penetration, lack of pressure wave upon impact, and ease of use. The criteria established by the EPA to ensure consistency of grab samples were followed with regard to sample disturbance and depth of penetration (EPA 1987a). Infaunal analyses are based on two replicate grab samples per station during each sampling period, while the corresponding sediment analyses are based on a single sample at each station. Demersal fish and megabenthic invertebrate communities were sampled using a 7.6 m Marinovich otter trawl net fitted with a 1.3 cm cod-end mesh (see Mearns and Allen 1978). Analyses of these trawl surveys are based on a single trawl per station during each sampling period.

Benthic Database: Sediments and Infauna

Previous analyses of benthic sediments and infaunal communities in the vicinity of the Point Loma deepwater outfall have been based on the results of all surveys conducted from July 1991 through the end of 2006 and reported in City of San Diego (1995-2007). This includes a total of 10 pre-discharge surveys (July 1991-October 1993) and 45 post-discharge surveys (January 1994-July 2006). The subsequent sediment quality database consists of information from a total of 1206 0.1-m^2 samples (54 surveys, 22-23 stations, 1 sample/station), while the biological (infauna) database consists of data from 2262 0.1-m^2

samples (55 surveys, 21-22 stations, 2 replicates per station) (see Table E-1). These databases represent about 121 m^2 and 226 m^2 of seafloor sediments, respectively. However, since sediment conditions and benthic community structure varies with depth in the SCB and elsewhere, the analyses presented in this application focus on data collected at the 12 stations located along the 98-m (320 ft) depth contour (i.e., outfall discharge depth). From north to south, these "primary core" stations are B12, B9, E26, E25, E23, E20, E17, E14, E11, E8, E5, and E2. Additionally, benthic sampling frequency was changed from a quarterly (January, April, July, October) to semiannual (January, July) schedule in late 2003 as discussed in Section E.2 (i.e., October and April samples were last collected in 2002 and 2003, respectively). Thus, in order to allow for consistent spatial and temporal comparisons, data from the shallower 88-m sites and deeper 116-m sites, as well as all April and October survey data, are not included in the analyses performed herein. Overall, the analytical benthic database for this appendix includes data from 372 sediment grabs and 743 infauna grabs. However, data for all benthic samples collected for the Point Loma monitoring program are included in the electronic files that have been submitted with this report. Analyses of these additional data have shown no evidence of outfall-related impacts (see City of San Diego 1995-2007).

The City has also conducted annual region-wide surveys off the coast of San Diego since 1994 as part of regular receiving waters monitoring requirements for the South Bay Ocean Outfall (i.e., NPDES Permit Nos. CA0108928 and CA0109045) or as part of larger multi-agency surveys of the entire SCB (e.g., Bergen et al. 1998, 2001; Noblet et al. 2002; Ranasinghe et al. 2003, 2007, Schiff et al. 2006). These surveys utilize the USEPA probability-based EMAP random sampling design and cover a geographic area ranging from Del Mar in northern San Diego County south to the USA/Mexico border. Preliminary results of a long-term assessment of the surveys conducted from 1994 to 2003 are considered herein. A total of 324 different sites were sampled during this 10-year period ranging in depth from nine to 461 m. Patterns of benthic community structure and various environmental parameters were assessed using a suite of univariate and multivariate statistics. Of these sites, 156 comprised a single major cluster representing the mid-shelf region and encompassing the Point Loma Ocean Outfall monitoring stations. Consequently, values for various community and sediment parameters

TABLE E-1

Number of benthic sediment and infauna grabs collected and analyzed at Point Loma deepwater outfall stations from 1991 through 2006.

Year	Sediment Grabs *	Infauna Grabs †
1991	46	84
1992	92	168
1993	92	168
1994	92	168
1995	92	167
1996	92	168
1997	69	168
1998	92	168
1999	92	165
2000	92	168
2001	92	168
2002	92	168
2003	58	108
2004	35	70
2005	34	68
2006	44	88
Total	**1206**	**2262**
Pre-discharge (1991-1993)	230	420
Post-discharge (1994-2006)	976	1842

[*] Sediment grabs not collected in October 1997 (resource exchange)

[†] Four infuana grabs excluded from analysis due to poor preservation (Station E23, Rep 2, October 1995; station B11, Rep 1, January 1999; station E7, Rep 2, April 1999; station E8, Rep 1, July 1999)

associated with this group of sites are used in part to estimate background conditions for the region that are most relevant to the Point Loma monitoring program. The results from this regional assessment were also used to calculate tolerance interval boundaries for a number of benthic community parameters for the San Diego region (see Attachment E.1). Additionally, data from these and subsequent surveys in 2004-2006 were used to create contour plots of various sediment parameters in order to compare regional sediment conditions during the 1994-2000 and 2001-2006 post-discharge periods (see Attachment E.5). Such regional data are not available for the pre-discharge period.

Trawl Database: Demersal Fishes and Megabenthic Invertebrates

Prior analyses of demersal fish and megabenthic invertebrate communities surrounding the deepwater Point Loma outfall have been based on the results of all surveys conducted from July 1991 through the end of 2006 and reported in City of San Diego (1995-2007). This includes a total of 10 pre-discharge surveys (July 1991-October 1993) and 45 post-discharge surveys (January 1994-July 2006). The subsequent trawl database consists of information from a total of 428 trawls (55 surveys, 6-8 stations, 1 sample/station) surrounding the deepwater discharge site. Although a second replicate trawl was taken at each station through 1995, only data from the first trawl are considered here for comparison to subsequent years (i.e., n = 572 with replicate trawls included). As listed in Section E.2, both the number of trawl stations and the sampling frequency were reduced in late 2003 due to a modification of the monitoring program. Specifically, sampling was discontinued at trawl stations SD9 and SD11, while sampling frequency was changed from a quarterly (January, April, July, October) to semiannual (January, July) schedule. Thus, in order to allow for consistent spatial and temporal comparisons, data from stations SD9 and SD11, as well as all April and October survey data, are not included in the analyses performed herein. Additionally, since measurements of invertebrate community biomass were discontinued after July 2003, an analysis of these data is not considered in this report. Overall, the analytical database for trawl-caught fishes and invertebrates database includes data from 308 trawls. However, data for all trawls collected for the Point Loma monitoring program are included in the electronic files that have been submitted with this report. Previous analyses of these additional data have shown no evidence of outfall-related impacts (see City of San Diego 1995-2007).

Section E.4 – Sediment Conditions

The City of San Diego has been monitoring marine sediment conditions in areas surrounding the extended Point Loma Ocean Outfall since 1991. Benthic surveys were conducted quarterly (January, April, July, October) from July 1991 through July 2003, after which sampling was modified to semiannual surveys during January and July of each year (see Section E.2). Locations for all benthic stations sampled during these periods are shown in Figure E-1. This section focuses on grain size distribution and the accumulation of organic solids and toxic contaminants during the pre- and post-discharge monitoring periods in order to evaluate the possible effects of wastewater discharge.

Data Sets and Analyses

Since sediment conditions often vary with depth, changes near the Point Loma Ocean Outfall were evaluated by focusing on data collected at stations located at outfall discharge depths. From north to south, these 12 stations are B12, B9, E26, E25, E23, E20, E17, E14, E11, E8, E5, and E2. Additionally, the following analyses are based on a dataset consisting of the results from just the January and July surveys conducted at the above 12 stations from July 1991 through July 2006 (see Sections E.2 and E.3 for a complete description of dataset reduction). This includes five pre-discharge surveys (July 1991-July 1993) and 26 post-discharge surveys (January 1994-July 2006) with the subsequent database consisting of information from a total of approximately 372 0.1-m^2 samples (31 surveys, 12 stations, 1 sample per station). Overall, the above surveys included 60 grab samples for the pre-discharge period and 312 grab samples for the post-discharge period. Additionally, the post-discharge period includes 168 samples (14 surveys) from 1994-2000 that were analyzed during the last waiver application, and 144 samples (12 surveys) from 2001-2006, which covers the current application period. Some

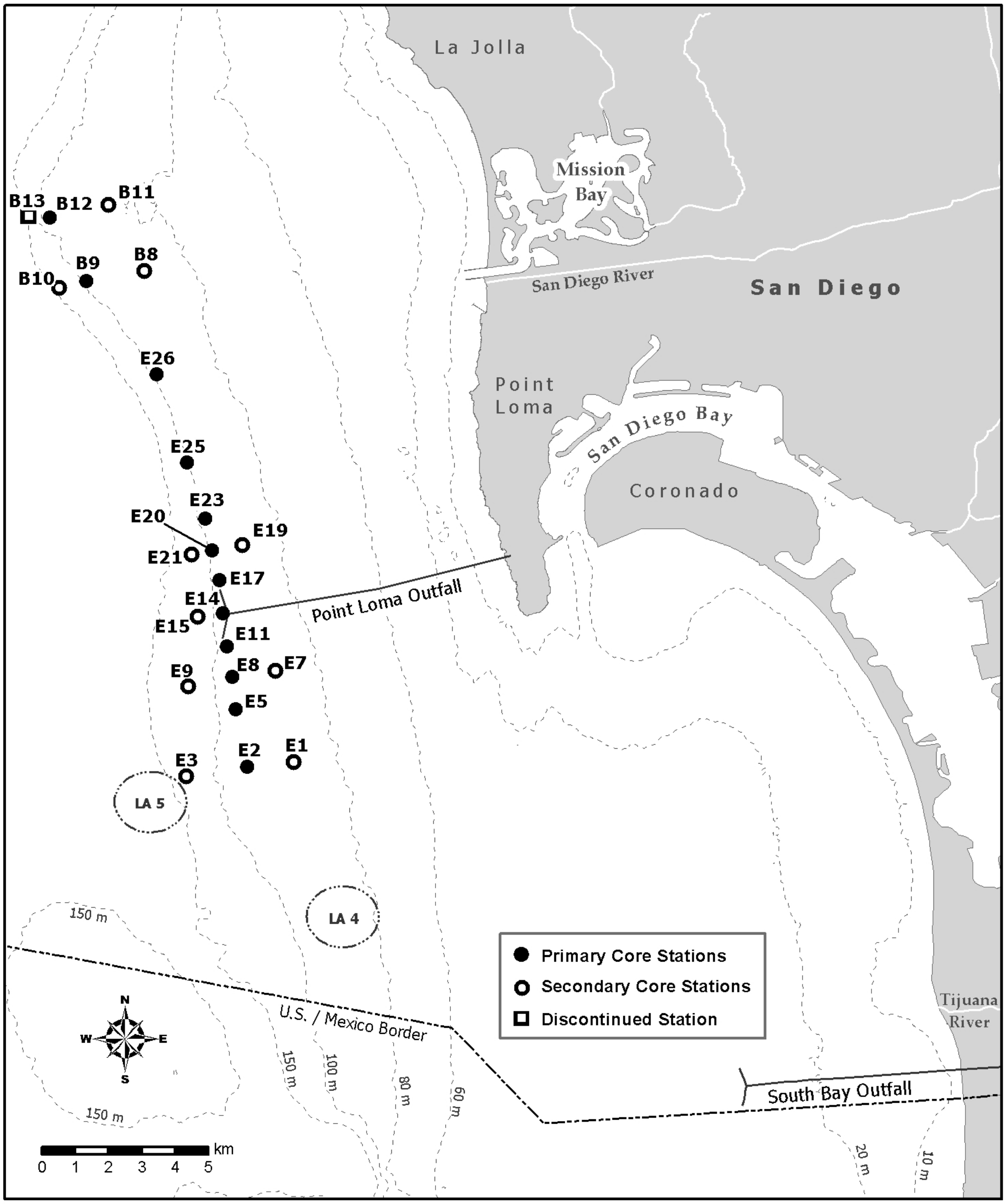


FIGURE E-1. Benthic sediment and infauna monitoring stations surrounding the City of San Diego's Point Loma Ocean Outfall. Primary core stations = 12 sites located along the 98-m outfall discharge depth contour that are the focus of the analyses presented herein. See text (Section E.2) for details of analyses and changes to sampling program over time. LA-4 and LA-5 = EPA designated dredge materials disposal sites.

comparisons are limited to data collected only during the summer (July) surveys in order to minimize differences due to natural seasonal fluctuations.

The outfall depth stations are located along the 98-m depth contour spanning the terminus of the Point Loma outfall (Figure E-1). Station E14 is nearest the outfall, located about 111 m north and 256 m west of the center of the diffuser wye. This station is considered the near-ZID or ZID boundary station and is the site most likely to be impacted by wastewater discharge. Stations E11 and E17 are the closest nearfield stations, located approximately 204 m from the ends of the diffuser legs. The remaining “E” stations are considered farfield sites. The “B” stations are located farther from the outfall (>11 km) and were originally selected to represent reference or control sites.

The following parameters were evaluated in assessing impacts on the sediments. Grain size parameters included mean particle size (mm), mean and median phi, percent sand, and percent fines (silt and clay combined). Measures of organic loading included total organic carbon (TOC), total volatile solids (TVS), total nitrogen (TN), biochemical oxygen demand (BOD), and sulfides. Trace metals examined included aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc. In addition, sediment concentrations of the pesticide DDT, polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) were evaluated. Outfall-related effects were evaluated in terms of (1) the range of natural variability under reference conditions, (2) the magnitude and spatial extent of any changes, and (3) an assessment of the potential for adverse effects. Estimates of natural variability pertaining to sediment conditions in the SCB have been extracted from various regional and bight-wide surveys conducted since 1985 (see Table E-2). These include the 1985 and 1990 SCCWRP reference surveys (Thompson et al. 1987, 1992), the 1994 Southern California Bight Pilot Project (see Schiff and Gossett 1998), the Southern California Bight Regional Monitoring Programs in 1998 (Bight′98) and 2003 (Bight′03) (see Bergen et al. 2001, Noblet et al. 2002, Schiff et al. 2006), and annual surveys of the San Diego coastal region from Mexico to Del Mar that have been conducted since 1994 as part of NPDES monitoring requirements for the South Bay Ocean Outfall (e.g., City of San Diego 1997b, 1998b, 1999a, 2002b, 2003b, 2004c, 2005b, 2006b, 2007b).

TABLE E-2

Comparison of select sediment grain size and chemistry data for the City of San Diego's Point Loma Ocean Outfall (PLOO) benthic stations with data from the SCCWRP 60-m and 150-m reference surveys, 1994 Southern California Bight Pilot Project (SCBPP), 1998 and 2003 Southern California Bight Regional Surveys (Bight'98, Bight'03), and San Diego Regional Surveys (1994-2003, see Attachment E.1). PLOO data are presented for outfall depth stations only (98 m) and are expressed as means for all 12 stations combined during the pre-discharge (1991-1993) and post-discharge (1994-2006) periods. SCCWRP data are presented for the 60-m and 150-m surveys and are expressed as approximate averages for the 1985 and 1990 surveys combined. SCBPP, Bight'98 and Bight'03 data are expressed as mean values per 0.1 m^2 for the "mid-shelf" strata.

	SCCWRP Reference Surveys *		SCB 1994, 1998 and 2003 Regional Surveys †			San Diego Regional Surveys	PLOO Surveys (1991-2006)	
	60-m	150-m	SCBPP	Bight'98	Bight'03		Pre-discharge	Post-discharge
Grain Size								
%Fines	53	62	43	32	45	43.3	40.2	36.7
%Sand	47	38	—	—	—	55.9	59.6	61.8
Organics								
TOC (ppm)	0.6	0.8	0.7	0.9	0.8	0.6	0.5	0.6
Metals (ppm)								
Cadmium	0.2	0.3	0.3	0.4	0.4	0.05	1.3	0.3
Chromium	26	31	39	30	36	19.3	17.3	17.4
Copper	10	14	15	13	12	10.8	7.4	8.7
Lead	6	7	11	12	7	2.9	1.8	2.7
Nickel	12	14	18	23	14	8.3	6.6	7.1
Silver	~0.1	< 0.1	0.3	0.5	0.1	0.02	0.1	0.03
Zinc	47	54	59	58	47	34.4	28	29.3
Pesiticides and PCBs								
DDT (ppt)	16000	23000	40800	53830	36000	744	1300	800
PCBs (ppt)	16000	17000	13300‡	6460	2400	102	Ar ‡	100

* Thompson et al. 1987, 1992

† Schiff and Gossett 1988; Noblet et al. 2002; Schiff et al. 2006.

‡ PCBs measured as Aroclors for PLOO region prior to April 1998 and as congeners thereafter; therefore pre-discharge values are not listed. SCBPP mean represents mean of congeners and arochlors.

Results

Grain Size Distribution

Measurement of sediment grain or particle size allows for a better interpretation of the interaction of benthic animals with the environment. For example, differences in sediment composition (e.g., fine vs. coarse particles) and associated levels of organic loading can affect burrowing, tube building and feeding abilities of infaunal invertebrates, thus leading to changes in benthic community structure. Parameters such as grain size and the dispersion of sediment particles are indicative of the hydrodynamic regime in the benthos, while physical properties of the sediments (size, shape, density, mineralogy) interact with deposited organic particles to create new conditions in sediment carbon coupling at the boundary layer.

Grain size characteristics of sediments around the Point Loma outfall are summarized in Table E-3, while trends for mean particle size (mm), median phi, and percent fines are presented in Figures E-2 through E-4. Sediment composition off Point Loma is within the range of natural variability seen for other mid-shelf environments off southern California. Average grain sizes for all sites during the pre- and post-discharge periods were 0.06 mm (4.1 phi) and 0.07 mm (4.0 phi), respectively, while the percentage of fine sediments (silt and clay) averaged about 40% and 37% during these times. Differences between most sites were not significant in terms of the composition of sand, silt and clay; although sediments at station E14 showed a slight increase in mean particle size after discharge began (Table E-3). This change is likely related to the movement of ballast materials used to support the outfall pipe and the presence of patchy sediments in the area. The latter is evident in Figure E-2 that shows very coarse sediments collected during the summers of 1995 and 2006 at this near-ZID site. In addition, there has been little change in grain size characteristics since the previous waiver application in 2001 (i.e., years 1994-2000 vs. 2001-2006). However, sediments at northern reference station B12 were frequently characterized by the presence of very coarse materials such as shell hash and gravel, which distinguished this station from most other sites along the outfall depth contour. Relatively coarse materials were also characteristic of one of the southernmost stations

TABLE E-3

Summary of sediment grain size and chemistry data for the City of San Diego's Point Loma Ocean Outfall benthic stations; outfall depth stations only (n=12). Data are for January and July surveys only from 1991-2006; Pre-discharge surveys = 1991-1993 (n=5); Post-discharge surveys = 1994-2006 (n=26). See text for details of data reductions.

	Pre-discharge Surveys (1991-1993)				1994-2000 Post-discharge			2001-2006 Post-discharge			All Post-discharge Surveys (1994-2006)			
	All Sites		Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites		Outfall Stn. E14	Ref. Stn. B9
	Mean	Range	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean
Grain Size *														
Mean particle size (mm)	0.061	0.04 - 0.09	0.062	0.054	0.067	0.097	0.065	0.070	0.108	0.054	0.069	0.04 - 0.49	0.102	0.060
Mean Phi size	4.1	3.5 - 4.5	4.0	4.2	4.0	3.6	4.0	3.9	3.6	4.2	4.0	1.0 - 4.6	3.6	4.1
Median Phi	3.7	3.1 - 4.0	3.7	3.8	3.6	3.3	3.6	3.6	3.2	3.7	3.6	-0.3 - 4.1	3.3	3.7
% Fines (silt + clay)	40.2	28.3 - 51.7	39.0	42.4	37.2	30.0	39.0	36.2	28.7	40.8	36.7	10.8 - 52.8	29.4	39.8
% Sand	59.6	48.3 - 71.7	60.7	57.1	61.4	63.5	60.0	62.3	65.1	58.7	61.8	13.6 - 85.6	64.3	59.4
Organic Indicators														
TOC (%)[†]	0.534	0.41 - 1.04	0.471	0.583	0.590	0.408	0.613	0.615	0.475	0.647	0.602	0.25 - 3.66	0.439	0.629
TN (%)[†]	0.036	0.02 - 0.06	0.031	0.046	0.048	0.040	0.053	0.053	0.045	0.057	0.050	0 - 0.19	0.042	0.055
TVS (%)	2.15	1.0 - 3.30	2.07	2.37	2.52	1.94	2.94	2.43	1.96	3.15	2.48	1.02 - 4.71	1.95	3.03
BOD (ppm)	270	95 - 501	254	301	302	371	309	324	468	312	312	123 - 936	415	310
Sulfides (ppm)	1.2	0 - 5.3	1.7	0.5	4.8	20.8	1.7	3.9	16.2	1.2	4.4	0 - 53.2	18.6	1.5
Metals (ppm)														
Aluminum[†]	—	—	—	—	10249	8176	10382	10206	8013	11262	10230	5240 - 22800	8101	10788
Arsenic	2.4	1.3 - 4.0	2.2	2.1	3.5	4.0	3.5	3.2	3.4	3.5	3.4	2.1 - 7.2	3.7	3.5
Beryllium	0.4	0 - 2.0	0.2	0.5	0.4	0.3	0.2	0.1	0.1	0.2	0.3	0 - 3.1	0.2	0.2
Cadmium	1.3	0 - 5.7	1.1	1.3	0.4	0.4	0.5	0.1	0.1	0.1	0.3	0 - 5.7	0.2	0.3
Chromium	17.3	9.0 - 32.4	15.8	21.8	17.3	15.9	21.5	17.6	14.6	22.8	17.4	8.1 - 40.6	15.3	22.1
Copper	7.4	4.0 - 16.0	6.7	6.8	8.8	7.5	13.1	8.6	8.3	8.7	8.7	2.7 - 82.4	7.9	11.1
Iron[†]	12408	9700 - 20300	10250	14450	13500	11068	16814	14023	11016	18550	13741	8480 - 27200	11044	17615
Lead	1.8	0 - 12.0	1.0	1.2	1.8	0.2	2.4	3.9	2.8	4.2	2.7	0 - 15.5	1.4	3.2
Manganese[†]	—	—	—	—	94	85	102	125	110	137	111	48 - 317	99	121
Mercury	0.011	0 - 0.09	0.006	0.002	0.012	0.010	0.009	0.024	0.017	0.023	0.017	0 - 0.9	0.013	0.016
Nickel	6.6	0 - 10.0	5.7	7.3	7.8	8.9	8.2	6.3	6.5	7.2	7.1	0 - 29.0	7.8	7.7
Selenium	0.2	0 - 0.9	0.2	0.3	0.2	0.2	0.3	0.1	0.1	0.1	0.1	0 - 0.4	0.1	0.2
Silver	0.117	0 - 4.0	0.000	0.600	0.0	0.0	0.0	0.054	0.045	0.057	0.025	0 - 0.91	0.021	0.026
Zinc	28.0	18.0 - 47.0	25.2	31.6	30.5	25.6	44.9	27.8	23.7	33.9	29.3	12.4 - 176.0	24.8	39.8
Pesticides, PCBs, PAHs														
Total DDT (ppt)	1281	0 - 7300	970	1640	1284	575	4720	137	42	412	755	0 - 44830	329	2732
Total PCB (ppt)[‡]	—	—	—	—	113	0	0	62	0	0	77	0 - 5800	0	0
Total PAH (ppb)	0.0	0 - 0	0.0	0.0	0.7	0.0	0.0	101.4	66.1	103.2	46.8	0 - 2578.6	29.1	47.6

* Grain size data = 1992-2006 (1991 data not comparable due to different methodology).

[†] Total organic carbon (TOC) and total nitrogen (TN) not measured prior to October 1992; iron not measured prior to January 1993; aluminum and manganese not measured prior to 1994.

[‡] PCBs measured as Aroclors prior to April 1998 and as congeners thereafter; therefore PCB data reported herein are limted to congeners only (i.e., July 1998-2006).

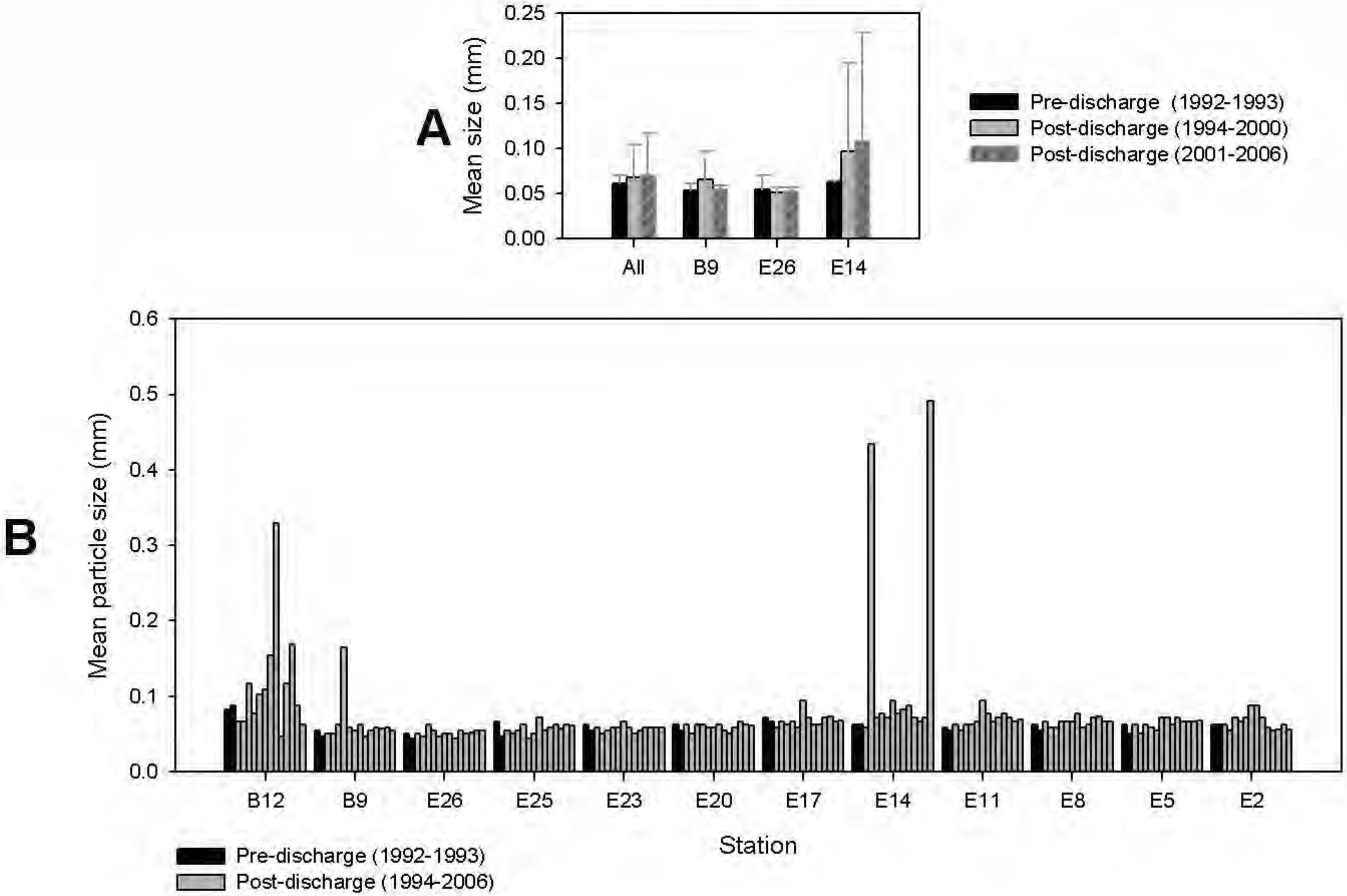


FIGURE E-2. Mean particle size (mm) of sediments at outfall depths near the Point Loma Ocean Outfall (1992-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all sites. Data from 1991 were not comparable, and are not included (see text).

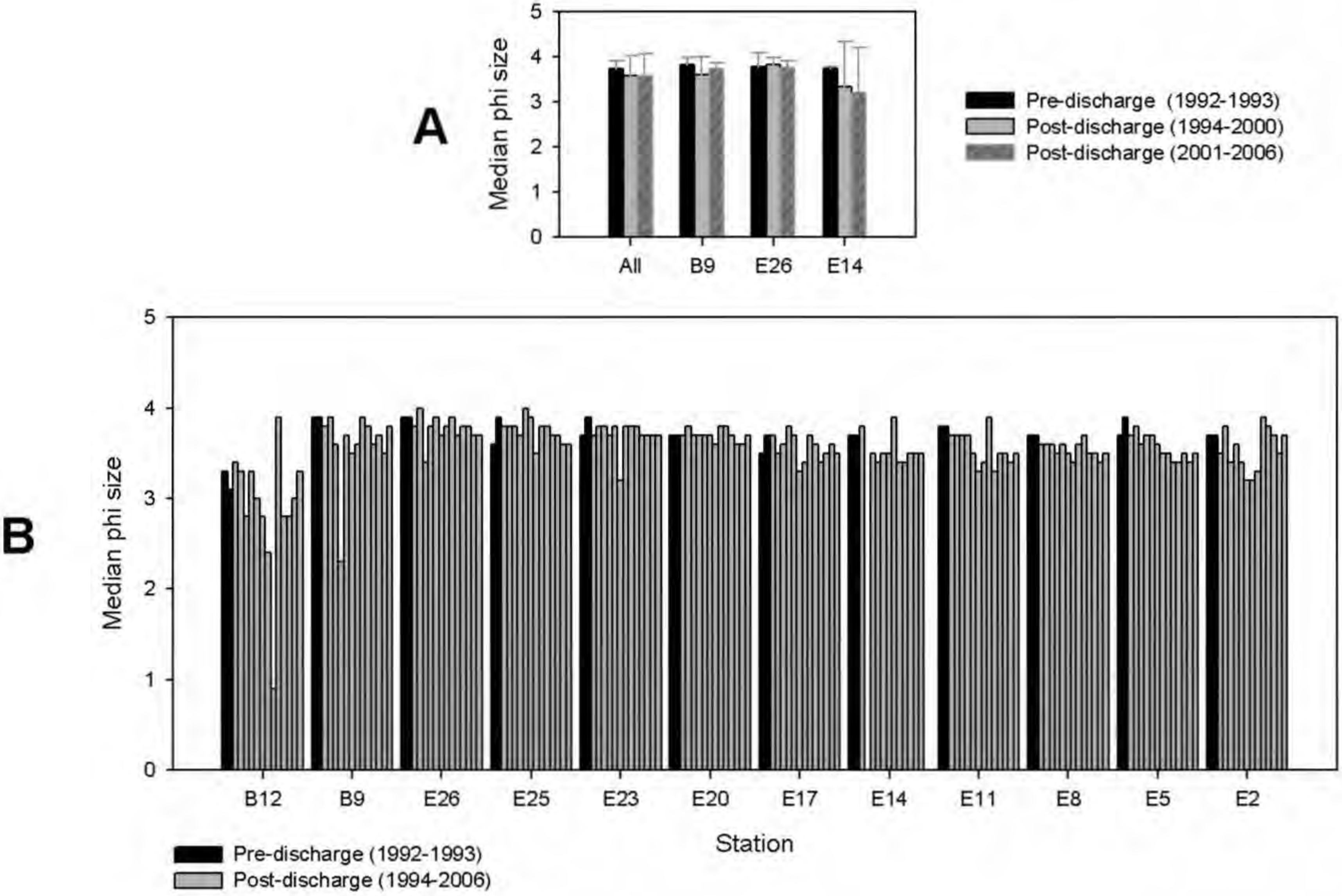


FIGURE E-3. Median phi size of sediments at outfall depths near the Point Loma Ocean Outfall (1992-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all sites. Data from 1991 not comparable, not included (see text).

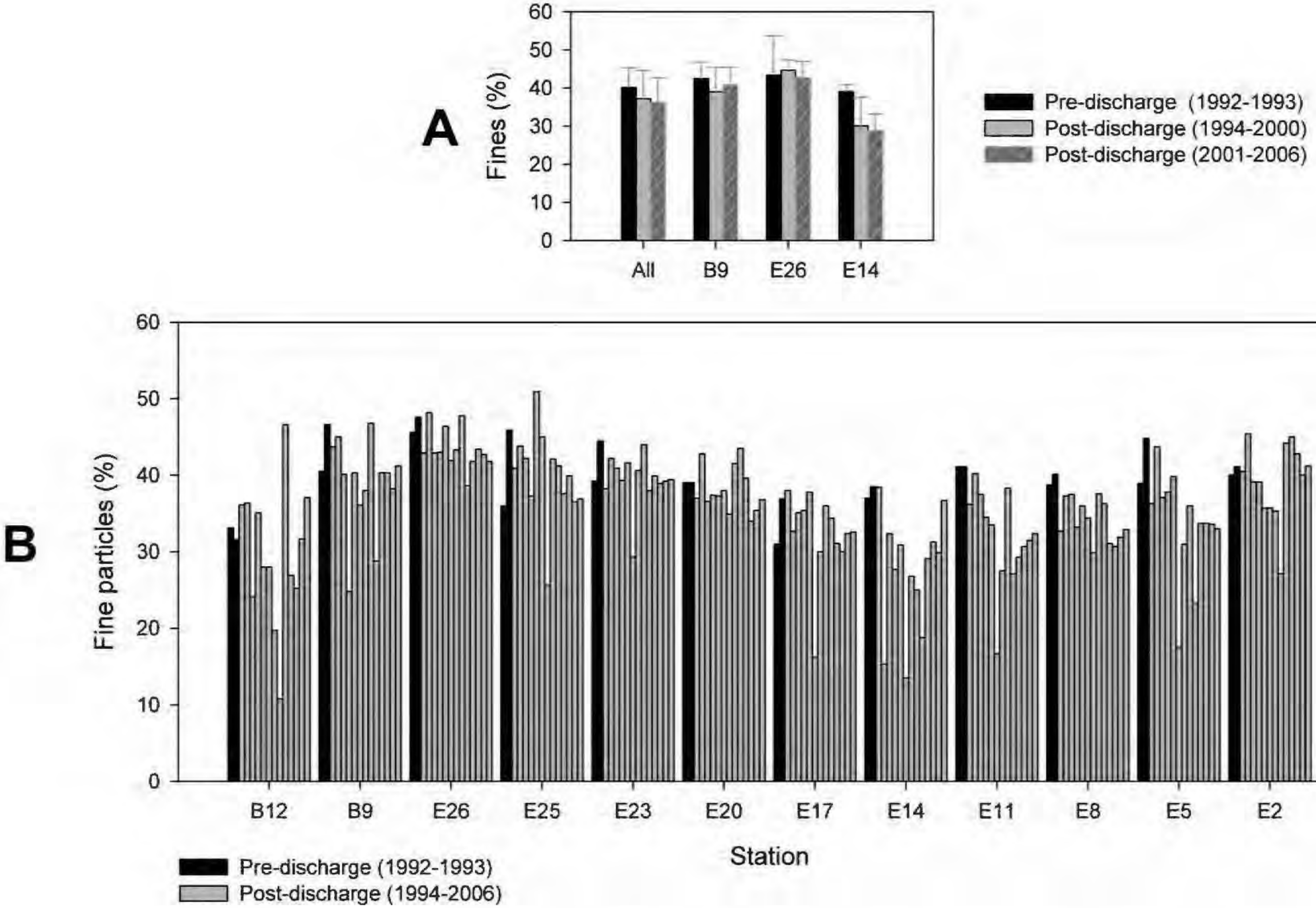


FIGURE E-4. Percent fines (silt and clay) in sediments at outfall depths near the Point Loma Ocean Outfall (1992-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations. Data from 1991 were not comparable, and are not included (see text).

(E2) located near the LA-5 dredge materials disposal site. Overall, there appeared to be no consistent changes over time that might correspond to discharge-related effects.

Organic Indicators

Concentrations of total organic carbon (TOC), total volatile solids (TVS), total nitrogen, biochemical oxygen demand (BOD), and sulfides are measured as indicators of organic loading in sediments. TOC and TVS represent more direct measurements of carbon imported as fine particulate matter.

Total Organic Carbon: TOC was not measured prior to October 1992; pre-discharge values represent those for only the January and July 1993 surveys (i.e., two quarters). Operation of the Point Loma outfall appeared to have no effect on local TOC concentrations, with TOC averaging 0.5% at all sites during the pre-discharge period and 0.6% during the post-discharge period (Table E-3). There was little difference in concentrations recorded near the outfall (e.g., station E14) and at reference areas farther away (e.g., station B9). TOC concentrations at northern station B12 have been highly variable; however comparison of values at other outfall depth sites from the summer surveys revealed no discharge related spatial or temporal patterns (Figure E-5b). Recent increases in TOC sediment concentrations during the last couple of years may be attributable to region-wide inputs from heavy storm activity in 2005. Finally, TOC values off Point Loma were generally similar to those from reference areas in the SCB as well as for other regional stations monitored off San Diego each year (Table E-2). The absence of carbon accumulation in the area indicates that sediment microbes and organisms off Point Loma are capable of maintaining oxidative metabolism at a rate exceeding carbon input.

Total Volatile Solids: TVS are a measure of organic carbon and nitrogenous material that can be metabolized and solubilized in both receiving waters and sediments. There was little change in TVS concentrations off Point Loma between the pre- and post-discharge periods (Figure E-6a). TVS levels averaged 2.1% at all sites prior to discharge and 2.5% afterwards (Table E-3). These levels are typical of background conditions that

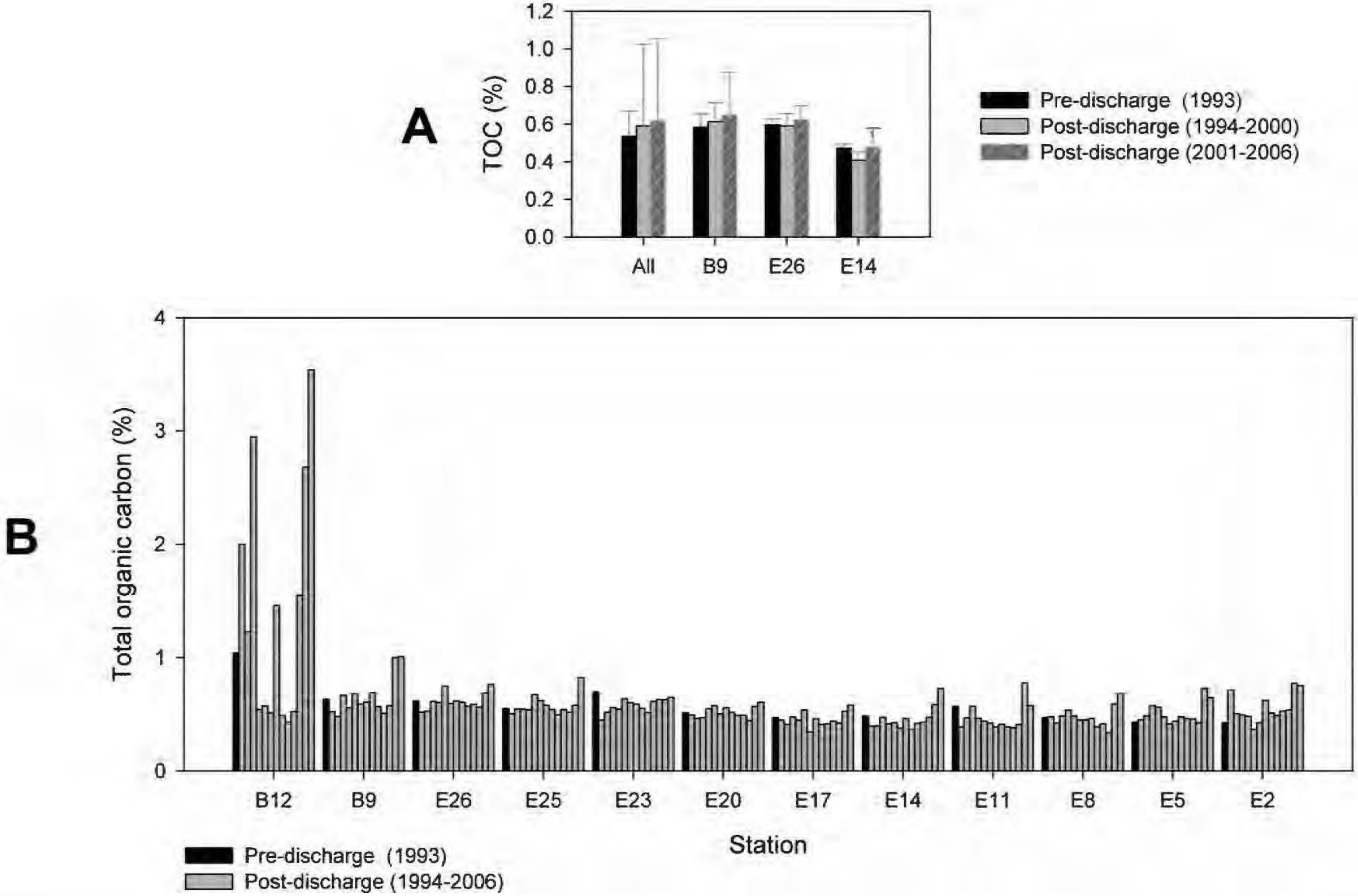


FIGURE E-5. Total organic carbon (%, TOC) in sediments at outfall depths near the Point Loma Ocean Outfall (1993-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations. Total organic carbon was not measured prior to 1993.

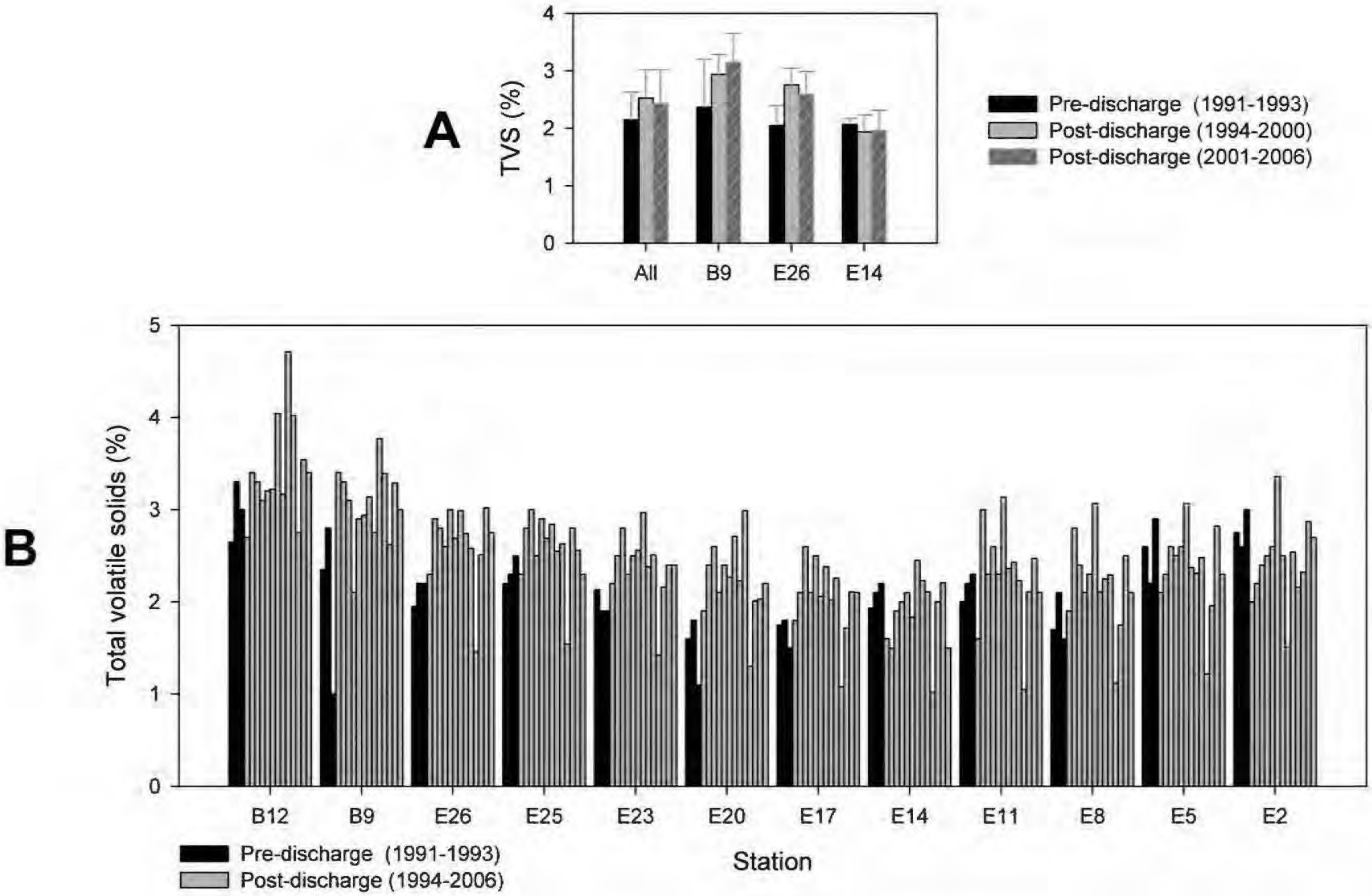


FIGURE E-6. Total volatile solids (%, TVS) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

occur in sediments up to 200 m depth in the SCB (see Bascom et al. 1979), which indicate that wastewater discharge via the the outfall has not had any impact in terms of TVS. In fact, TVS concentrations decreased slightly nearest the outfall after discharge began, with values at near-ZID station E14 remaining lower or similar to sites located farther away since that time (Figure E-6b).

Total Nitrogen: The total nitrogen in sediments was not measured prior to October 1992. Therefore, pre-discharge values represent data from only two surveys, January and July 1993. No apparent outfall effects were evident, with there being little difference between pre- and post-discharge nitrogen levels (Figure E-7a). Sediment nitrogen concentrations averaged <0.04% at all sites during the pre-discharge period and around 0.05% during the post-discharge period (Table E-3). Comparison of data for the summer surveys only also indicated no pattern consistent with an outfall effect (Figure E-7b).

Biochemical Oxygen Demand: BOD is a measure of the level of oxidative metabolism of discharged organic material by bacteria. There was a slight increase in BOD at sites off Point Loma between the pre- and post-discharge periods (Figure E-8). The greatest increase in average BOD concentrations since discharge began has occurred at station E14, which is located about 120 m from the center of the outfall diffuser legs. This pattern is consistent with predictions that a light sprinkling of organic material from the outfall might occur within or near the ZID. Overall, BOD averaged 270 ppm at outfall depths during the pre-discharge January and July surveys and 312 ppm afterwards (Table E-3). Although the highest values occurred in 2006, these may be related to high organic loading resulting from heavy storm activity in 2005 or possibly plankton blooms. However, these values are well within the range of typical background levels of 250-1000 ppm that have been reported for SCB sediments (e.g., Bascom 1979, Word and Mearns 1979).

Sulfides: Sediment sulfides showed a distinct outfall related pattern at discharge depths restricted to the three stations nearest the outfall. Concentrations increased sharply after discharge began at station E14 located about 120 m from the center of the diffuser legs, and to a lesser extent at stations E11 and E17 located ~ 250-300 m from the ends of the

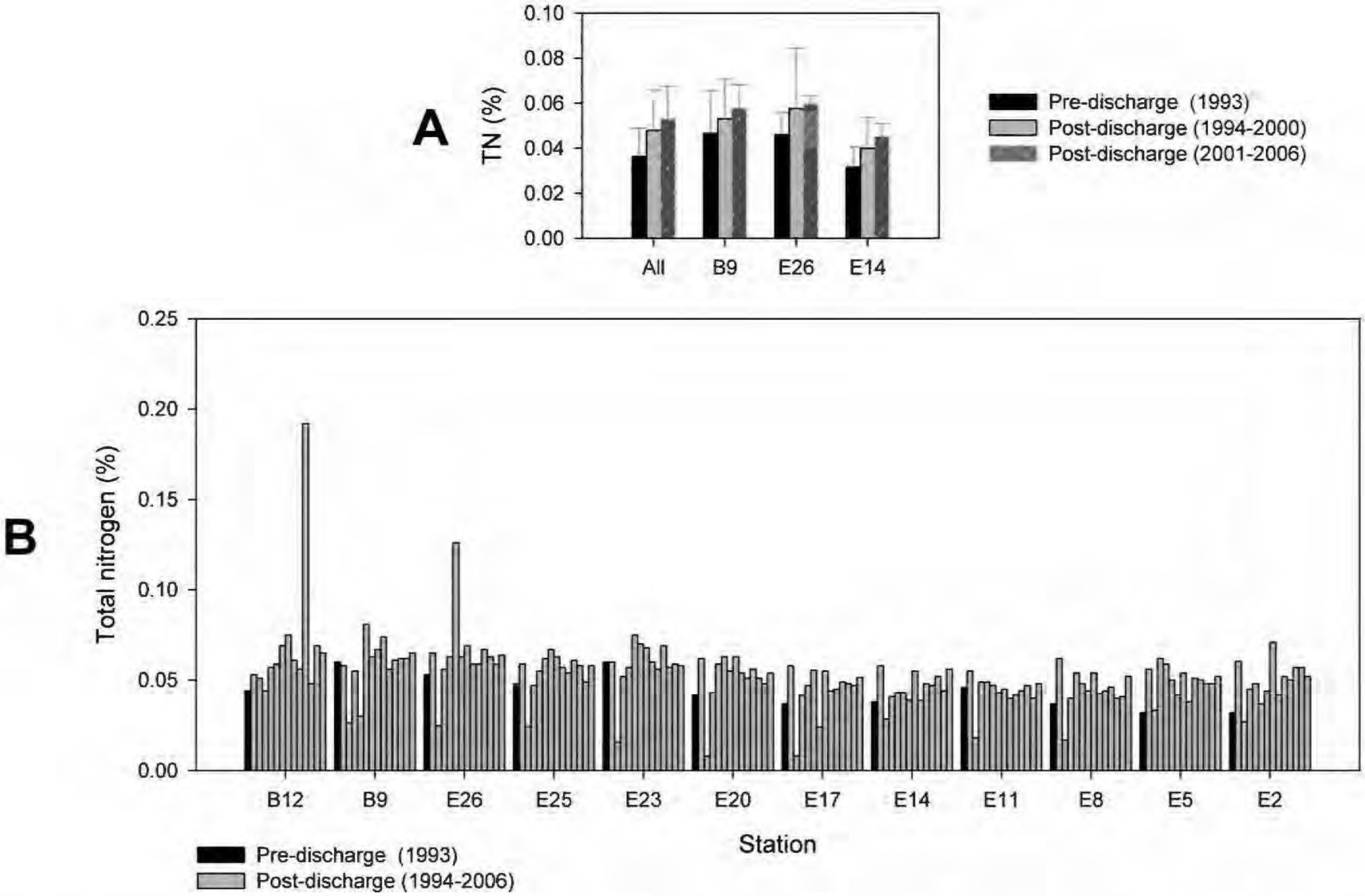


FIGURE E-7. Total nitrogen (%, TN) in sediments at outfall depths near the Point Loma Ocean Outfall (1993-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations. Total nitrogen was not measured prior to 1993.

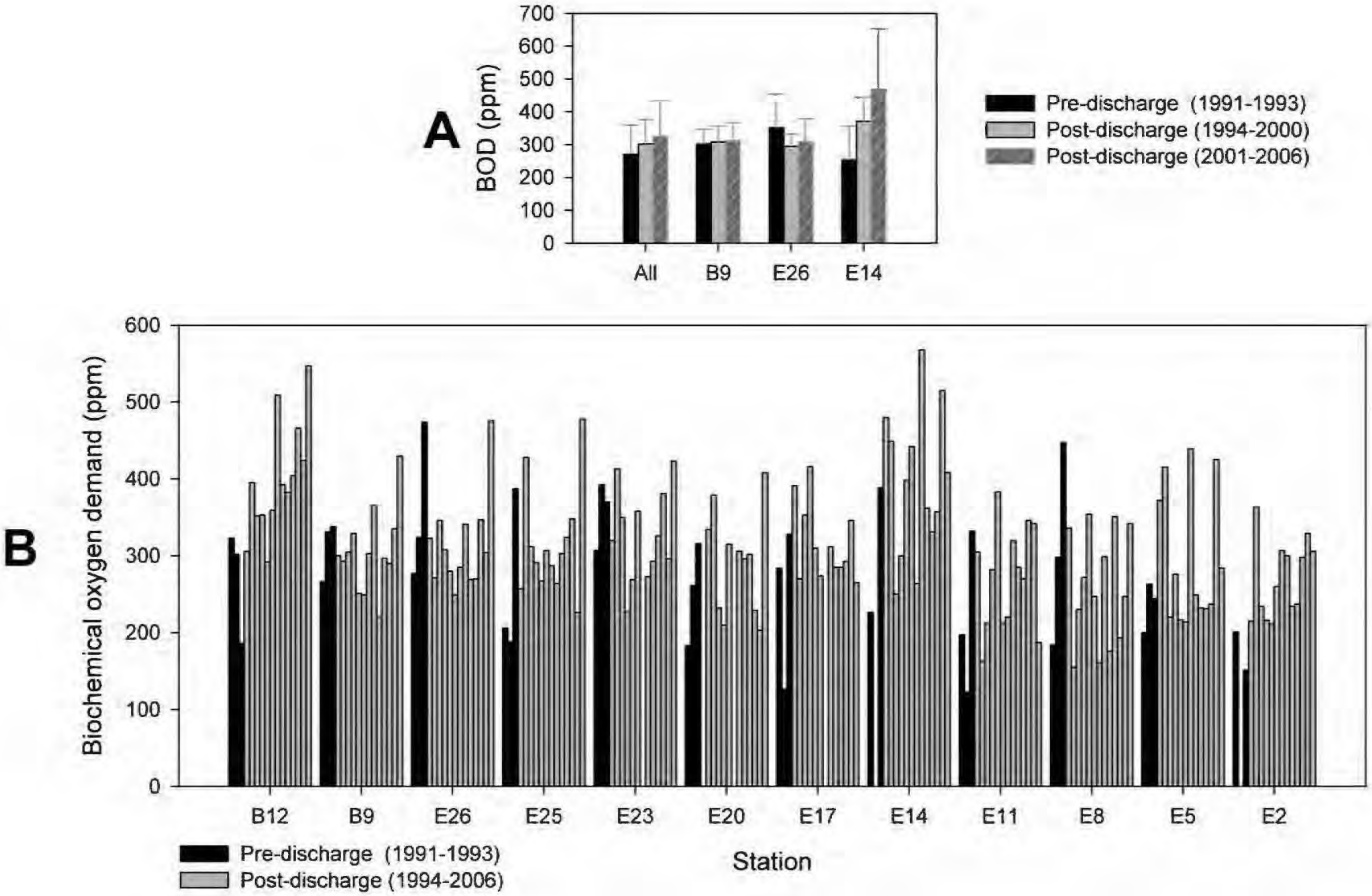


FIGURE E-8. Biochemical oxygen demand (ppm, BOD) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

diffuser legs (Figure E-9). For example, sulfide levels at E14 increased from an average of 1.7 ppm prior to discharge to 18.6 ppm afterwards (Table E-3). Although sediment sulfides were not measured in the SCB reference surveys by means similar to the City's ocean monitoring program, comparable measurements have shown sulfide levels exceeding 50 ppm off Newport Beach (e.g., CSDOC 1993) and greater than 500 ppm off the terminated 7-mile sludge outfall in Santa Monica Bay (City of Los Angeles 1990). There is no evidence that this small increase in sulfide concentrations is affecting sediment quality to the point that it will degrade the resident marine biota.

Trace Metals

Aluminum (Al): Aluminum was not analyzed during the pre-discharge period. There was little difference in aluminum levels between near and far-field stations during the post-discharge period that can be attributed to wastewater discharge (Table E-3, Figure E-10). Concentrations averaged approximately 10,200 ppm at all sites during the two post-discharge periods (1994-2000 and 2001-2006) (Table E-3). Generally, aluminum concentrations in sediments near the outfall site were lower than the more distant reference sites. For example, sediments at station E14 averaged 8101 ppm aluminum over all surveys, while reference site B9 averaged 10,788 ppm over the same period. The higher aluminum concentrations observed in 2004 and 2005 (e.g., see Figure E-10b) were probably related to increases in sediment deposition associated with heavy rainfall (see City of San Diego 2006a, b). Similar patterns were observed for iron and manganese, two other metals that may associated with terrestrial runoff (see below).

Arsenic (As): Arsenic concentrations averaged 2.4 ppm over all sites during the pre-discharge period and 3.4 ppm afterwards (Table E-3). Although this post-discharge increase occurred at all sites, it was most pronounced at northern reference station B12 and secondarily at station E14 located nearest the outfall (Figure E-11b). Additionally, overall arsenic levels appear to have decreased slightly during the past 6 years (2001-2006) compared to the 1994-2000 post-discharge period analyzed for the previous waiver application (see Figure E-11a). The lack of any clear spatial trend makes it unlikely that changes in arsenic concentrations were related to outfall operation. Furthermore, arsenic

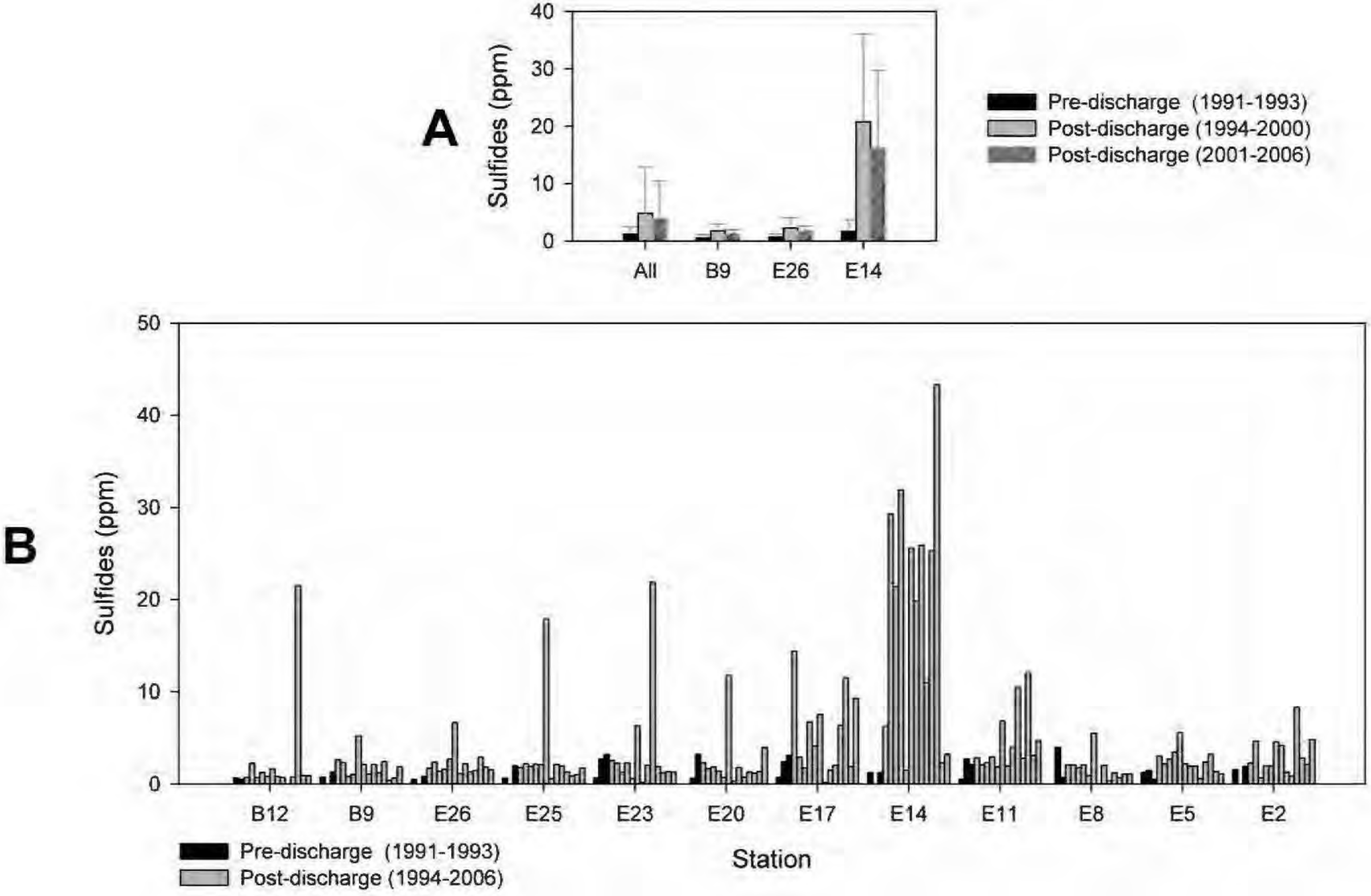


FIGURE E-9. Sediment sulfide concentrations (ppm) at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

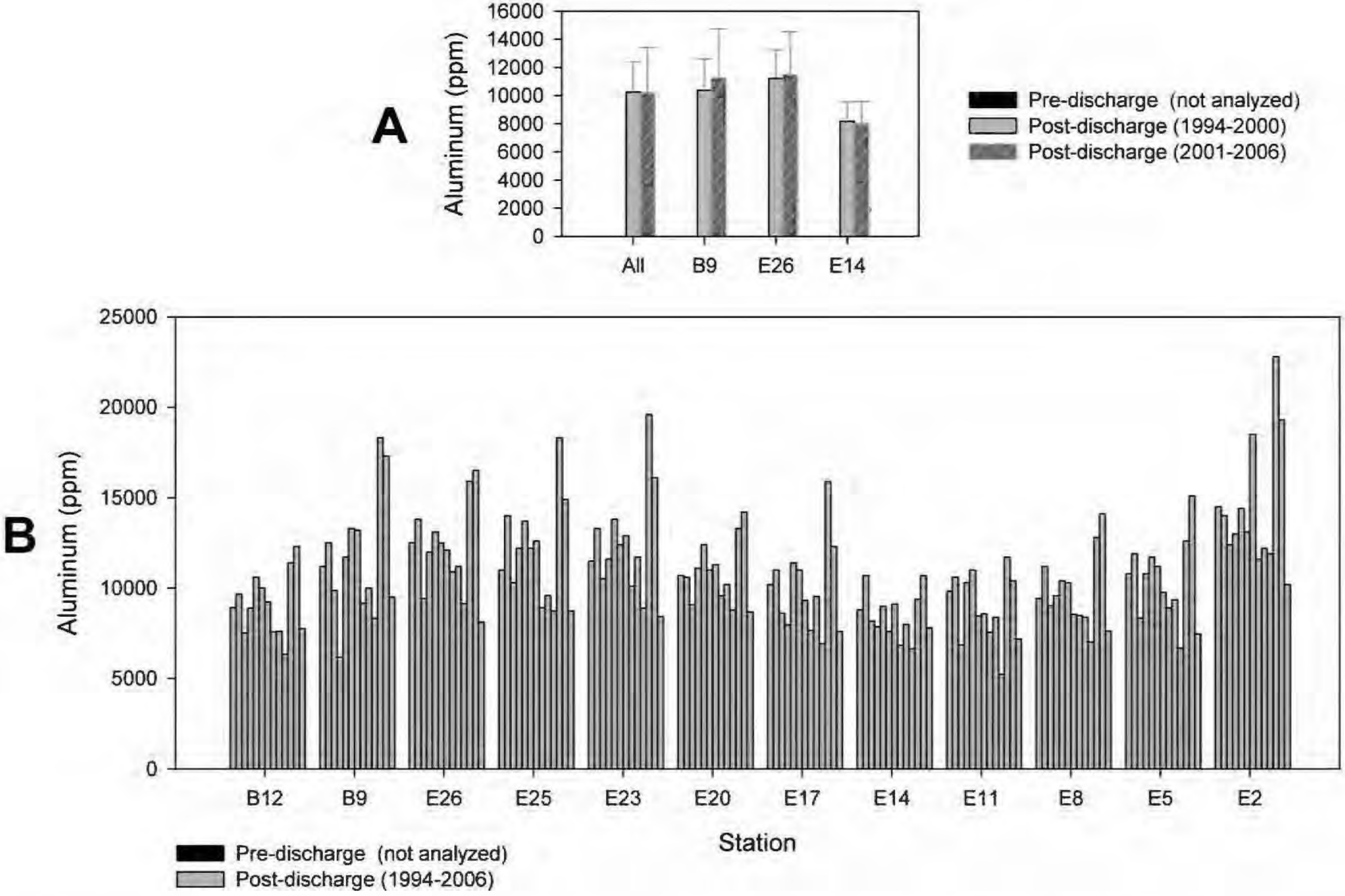


FIGURE E-10 Aluminum concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1994-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

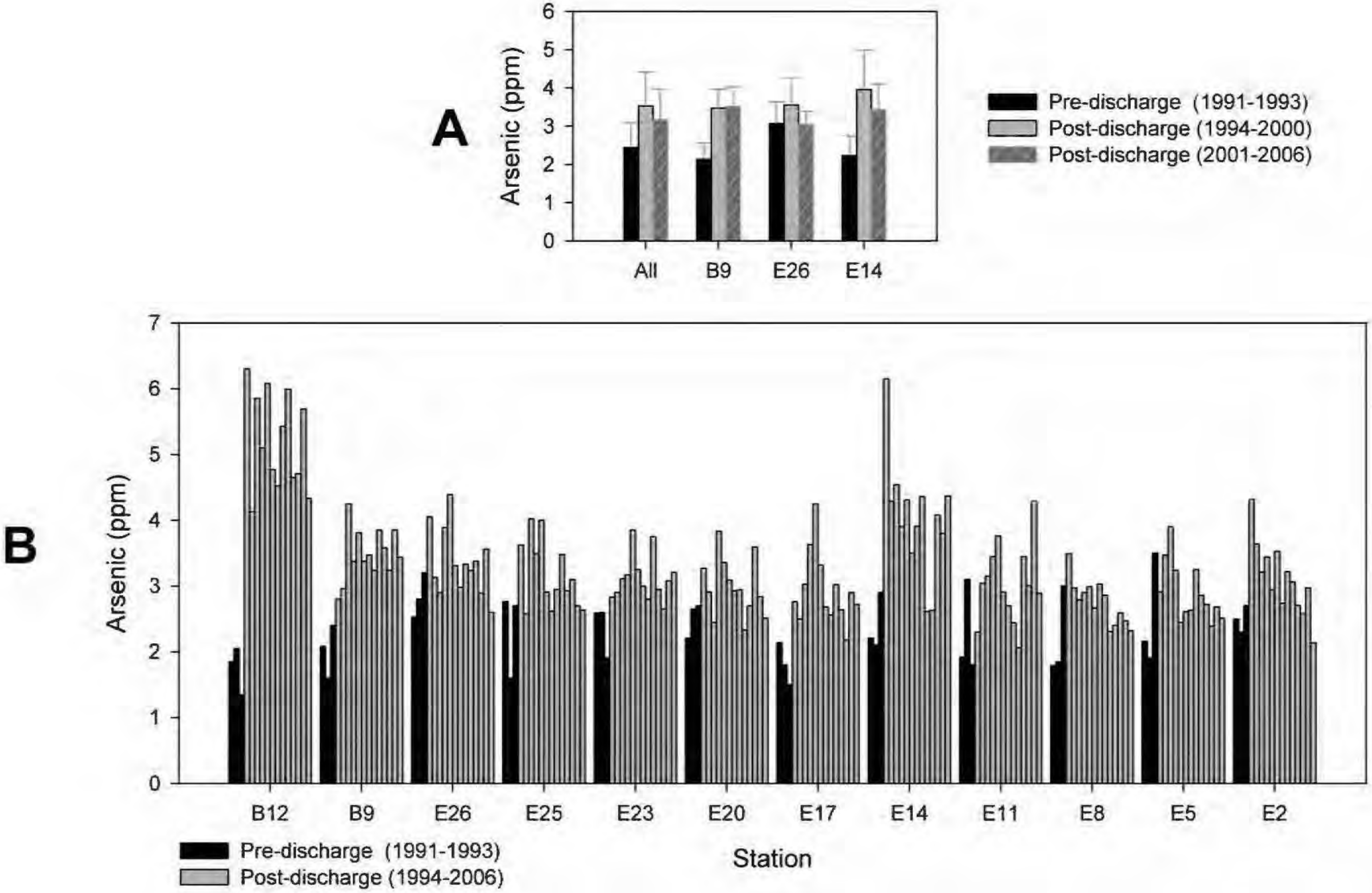


FIGURE E-11. Arsenic concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

levels are relatively low for the region overall, ranging to a maximum of only 7.2 ppm. Such values are below the typical background concentrations of up to 10 ppm reported for the SCB (see Mearns et al. 1991), thus indicating that there has not been any significant buildup of arsenic in the vicinity of the Point Loma outfall.

Beryllium (Be): Beryllium concentrations were generally low throughout the region and revealed no patterns consistent with an outfall related effect (Figure E-12). Sediment concentrations of this metal were variable, ranging from below detection limits to a maximum of 3.1 ppm (Table E-3). Overall values averaged 0.4 ppm during the pre-discharge period and 0.3 ppm during the post-discharge period (Table E-3).

Cadmium (Cd): Cadmium concentrations averaged 1.3 ppm over all sites during the pre-discharge period and 0.3 ppm afterwards (Table E-3). It is unclear what is responsible for the apparent decrease during the post-discharge period, since variation was very high at all sites (Figure E-13a). Review of the data from the summer surveys only provided no additional clarification, with concentrations of cadmium being relatively high (~2-4.5 ppm) at all sites in 1993 and below detection limits at most other times (Figure E-13b). The apparent increase in the frequency of detected cadmium values at most sites from 2003-2006 represents an artifact of improved methodological abilities (i.e., lower MDL). Overall, cadmium levels in the sediments off Point Loma are not significant.

Chromium (Cr): Chromium concentrations averaged 17.3 ppm at all sites prior to discharge and 17.4 ppm afterwards (Table E-3). These values are generally lower than typical background conditions in the SCB, which range from 26-36 ppm (Table E-2). In addition, although all stations show similar temporal patterns, chromium levels were generally higher at the northern reference stations B9 and B12 than at the other sites (Figure E-14).

Copper (Cu): Copper concentrations averaged 7.4 ppm during the pre-discharge period and 8.7 ppm during the post-discharge period (Table E-3). Overall, values off Point Loma were within the range of natural variability observed throughout the SCB (see Table E-2). Copper levels have generally been highest at station E2 located near the LA-5 dredged

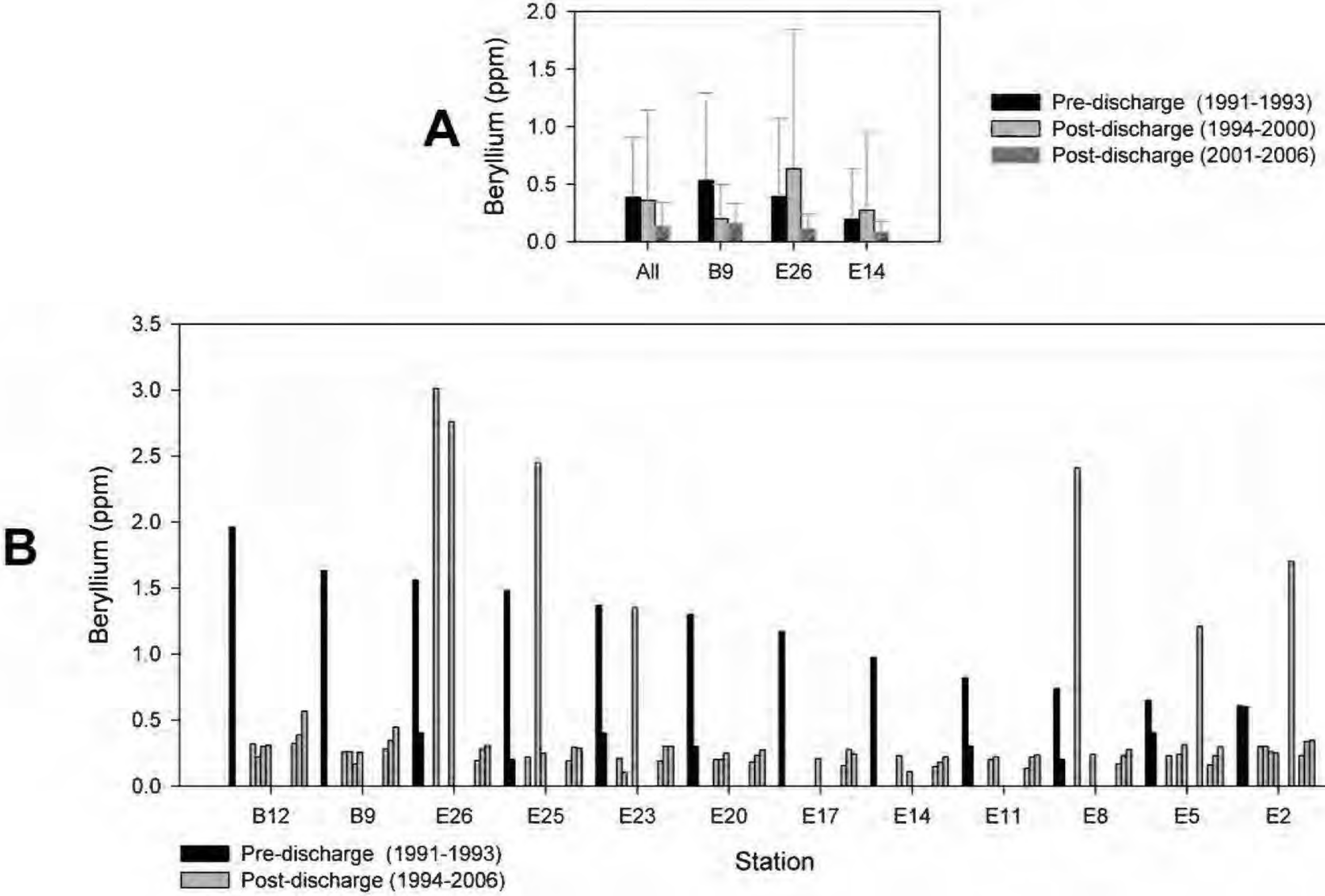


FIGURE E-12. Beryllium concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

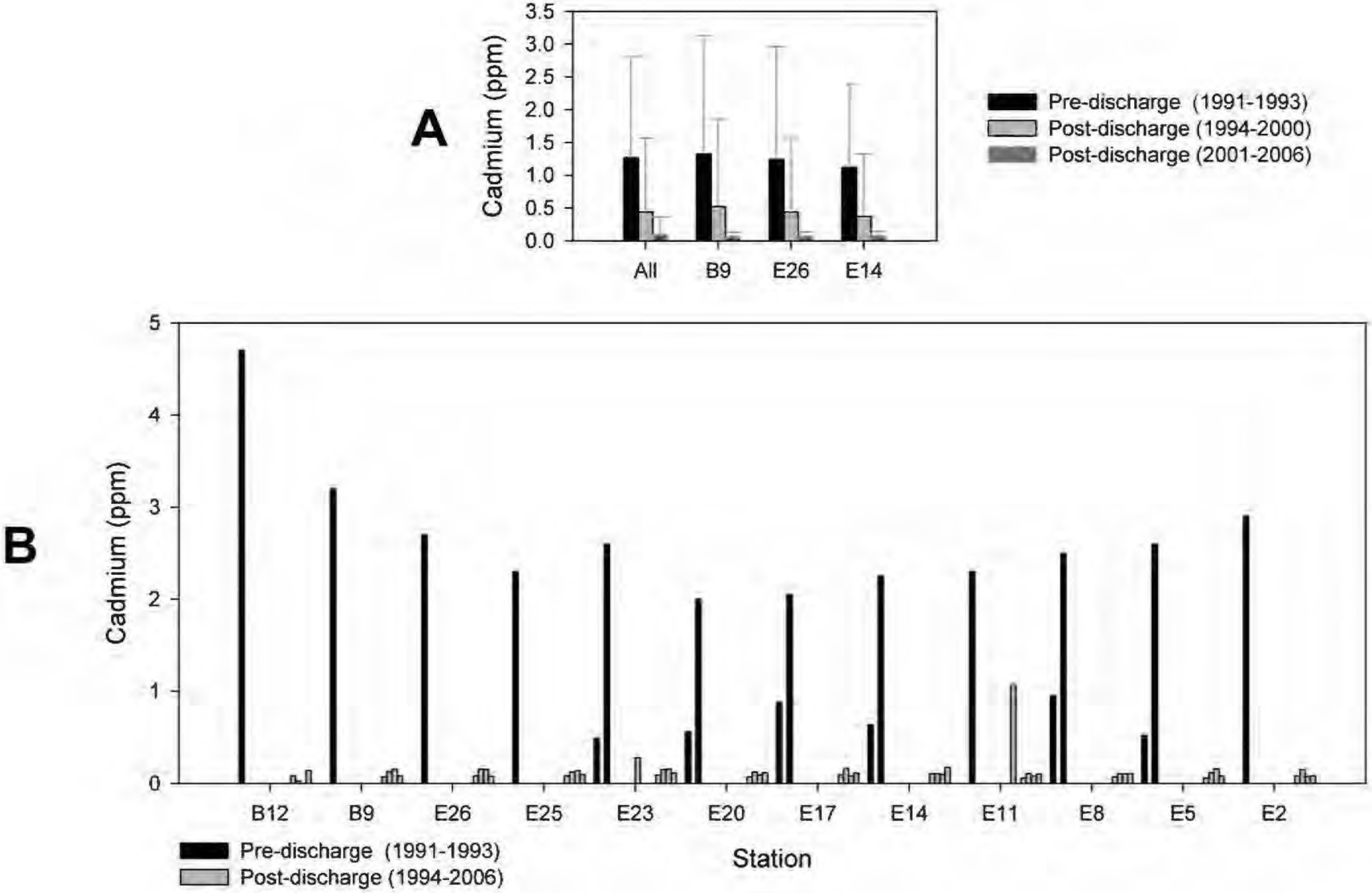


FIGURE E-13. Cadmium concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

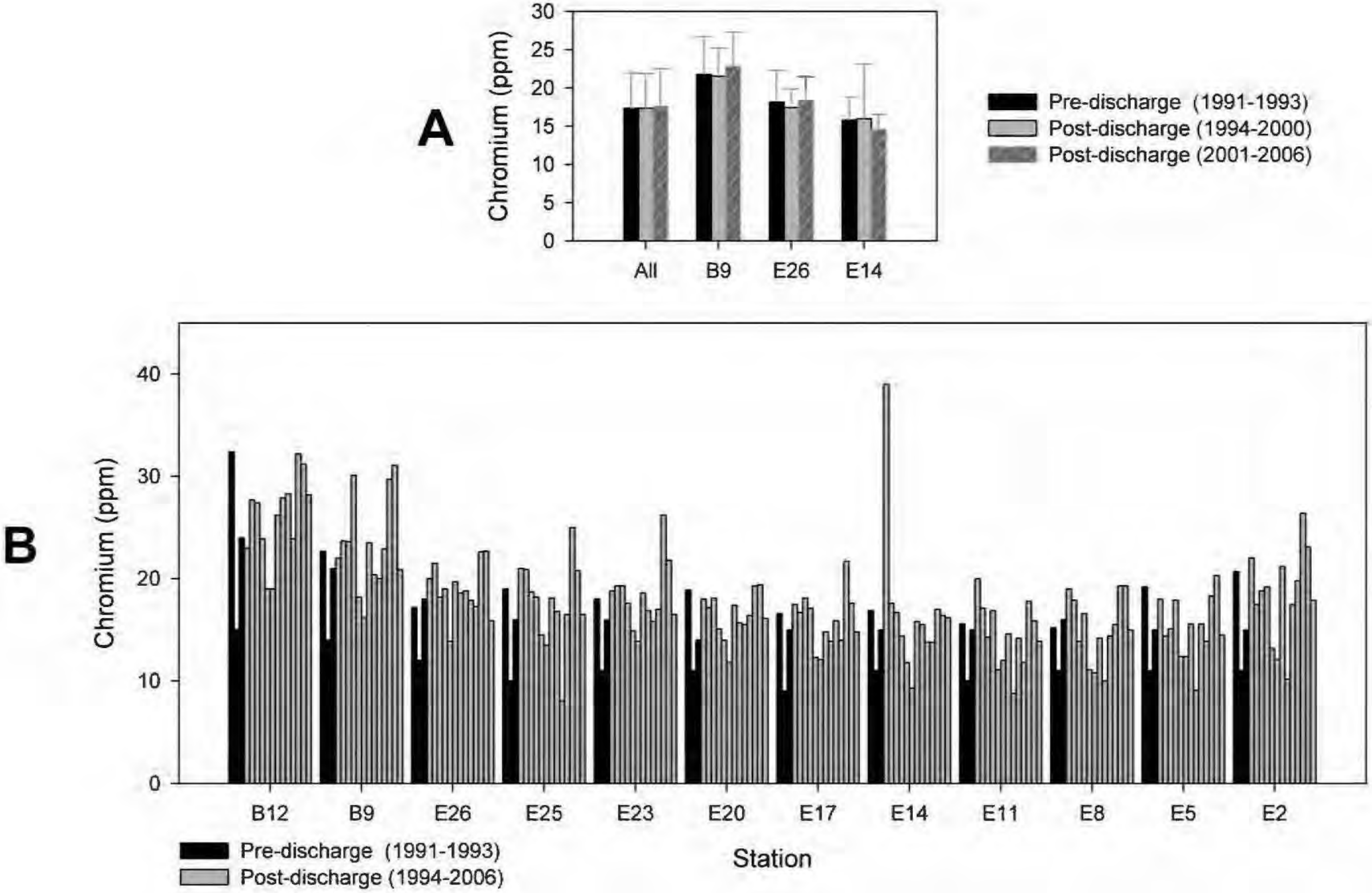


FIGURE E-14. Chromium concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

materials disposal site, although there was a single anomalous spike during the summer of 1997 at reference station B9 (Figure E-15). There does not appear to be any outfall-related trend in sediment copper concentrations off Point Loma (Figure E-15b).

Iron (Fe): Iron levels were not analyzed in 1991 and 1992; therefore pre-discharge values are for 1993 only. No outfall effects have been evident, with there being little difference between pre- and post-discharge iron levels (Table E-3, Figure E-16). Concentrations averaged 12,408 ppm at all sites during 1993 compared to 13,741 ppm during the post-discharge period (Table E-3). The higher iron concentrations observed in 2004 and 2005 (e.g., see Figure E-16b) were likely related to increases in sediment deposition and fluxes in plankton populations associated with heavy storm activity. For example, extensive sedimentary plumes were observed during these years from aerial and satellite imagery (City of San Diego 2006a). Additionally, similar patterns were observed for aluminum and manganese, two other metals that may associated with terrestrial runoff.

Lead (Pb): Lead concentrations in Point Loma sediments ranged from below detection limits to about 15.5 ppm (Table E-3). Generally, lead concentrations were higher at station E2, south of the discharge and near the LA-5 dredge materials disposal site. There were no clear patterns relative to the outfall, with concentrations averaging 1.8 ppm at all sites prior to discharge and 2.7 ppm after discharge began. These values are lower than background concentrations for the SCB of around 6-12 ppm (Table E-2). A comparison of data from the summer surveys was inconclusive since lead was not detected during July of either 1992 or 1993 and only rarely during July 1991 (Figure E-17b).

Manganese (Mn): Manganese was not analyzed during the pre-discharge period, therefore comparisons are limited to the two post-discharge periods (1994-2000 and 2001-2006). Overall, manganese levels were similar across the suite of 98-m stations, and there was little difference between near and far-field stations during the post-discharge period that can be attributed to wastewater discharge (Table E-3, Figure E-18). The higher manganese concentrations observed in 2004 and 2005 (e.g., see Figure E-18b) are likely related to increases in sediment deposition associated with heavy storm activity

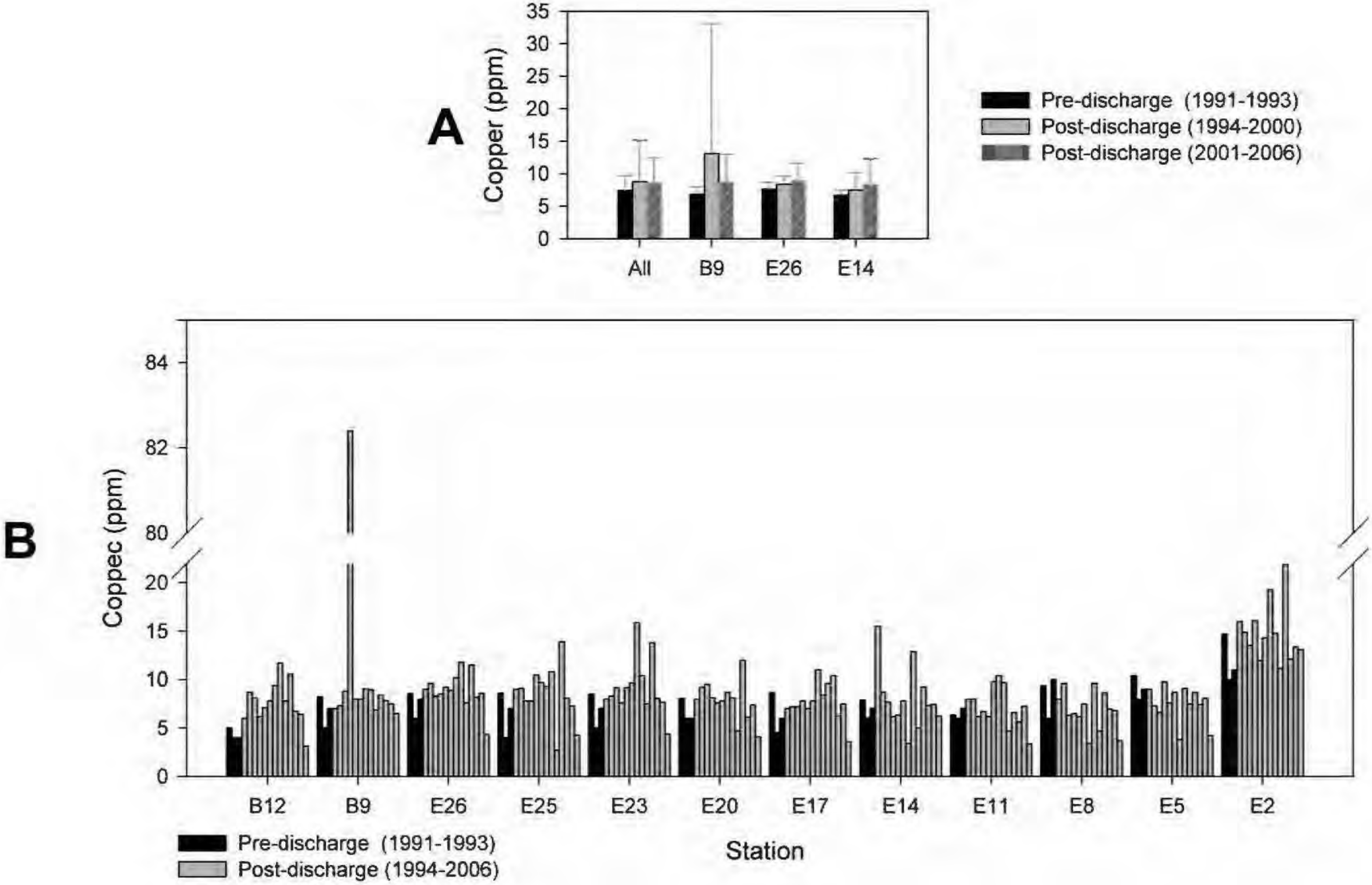


FIGURE E-15. Copper concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

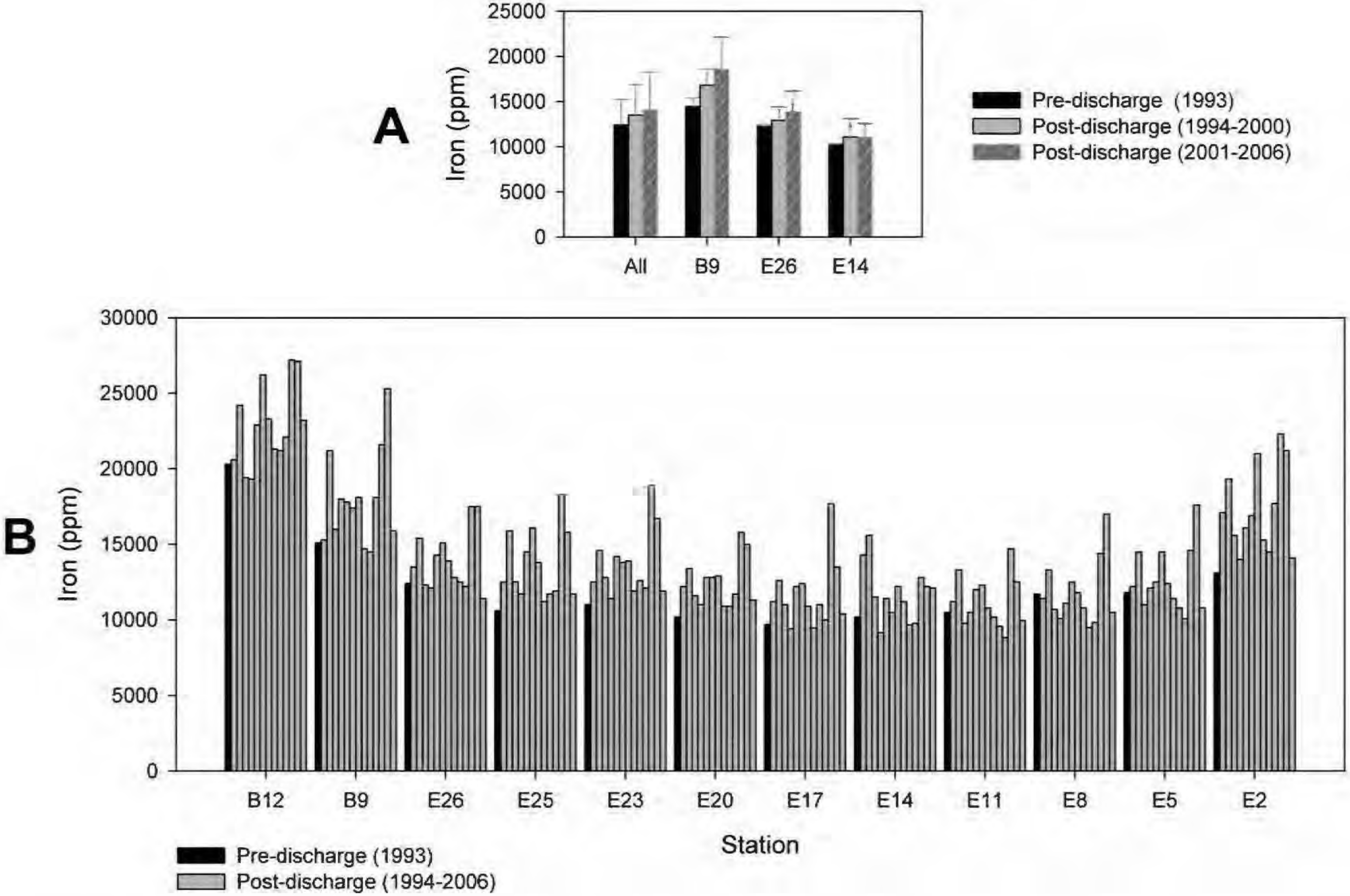


FIGURE E-16. Iron concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1993-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations. Iron was not measured prior to 1993.

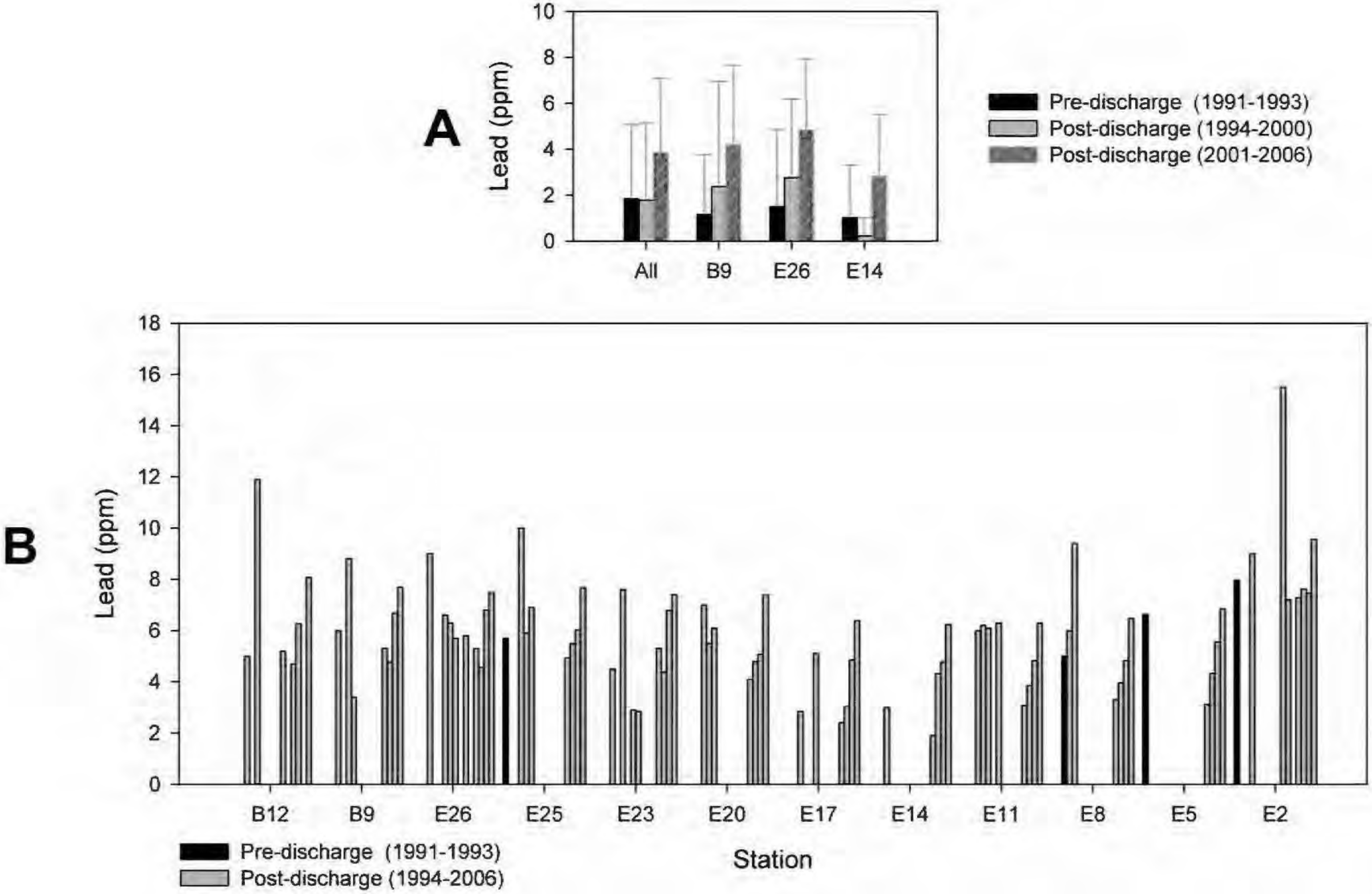


FIGURE E-17. Lead concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

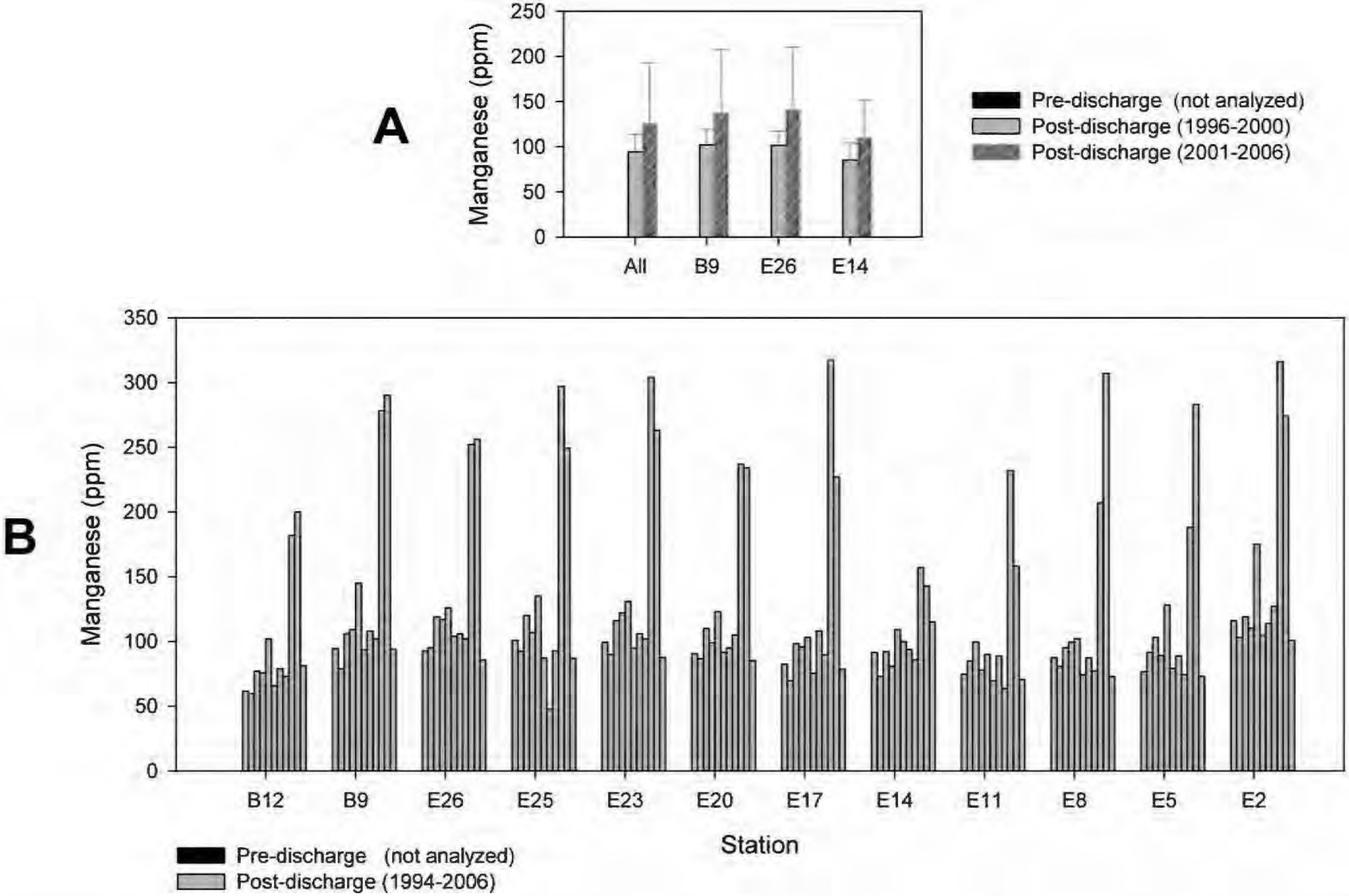


FIGURE E-18 Manganese concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1996-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations. Manganese was not measured prior to 1996.

(see City of San Diego 2006a, b). Similar patterns were observed for iron and aluminum, two other metals that may associated with terrestrial runoff.

Mercury (Hg): Mercury concentrations were low at all sites off Point Loma, averaging <0.011 ppm during the pre-discharge years and 0.017 ppm since discharge began (Table E-3). Maximum concentrations did not exceed 0.09 ppm. A review of the data from the summer surveys only indicted no outfall-related patterns (Figure E-19b).

Nickel (Ni): Nickel concentrations ranged from below detection limits to 29.0 ppm, with an average of 6.6 ppm before outfall operation and 7.1 ppm afterwards (Table E-3). These values are generally below the average background values for the SCB (Table E-2), and are within the range of natural variability observed in various reference surveys. There is no evidence that discharge from the outfall is resulting in any sustained accumulation of nickel in local sediments (see Figure E-20).

Selenium (Se): Selenium concentrations provided no evidence of any outfall-related effects. Sediment concentrations averaged about 0.2 ppm over all sites and surveys, and no value exceeded 1.0 ppm (Table E-3). These values are similar to background shelf sediment conditions reported by Young (1975). Comparison of data from the summer surveys revealed few changes other than unusually high selenium levels during July of 1993 prior to outfall operation and a lack of detected values at most sites since 2003 (Figure E-21b).

Silver (Ag): Silver has rarely been detected in Point Loma sediments, usually occurring at concentrations near or below method detection limits. Overall concentrations averaged about 0.1 ppm during the pre-discharge period and <0.03 ppm thereafter (Table E-3).

Zinc (Zn): Zinc concentrations averaged 28.0 ppm in Point Loma sediments during the pre-discharge period and 29.3 ppm afterwards (Tables E-3). These levels are lower than those reported for reference conditions in the SCB (Table E-2). A comparison of zinc data over time revealed no evidence of any outfall-related changes (Figure E-22).

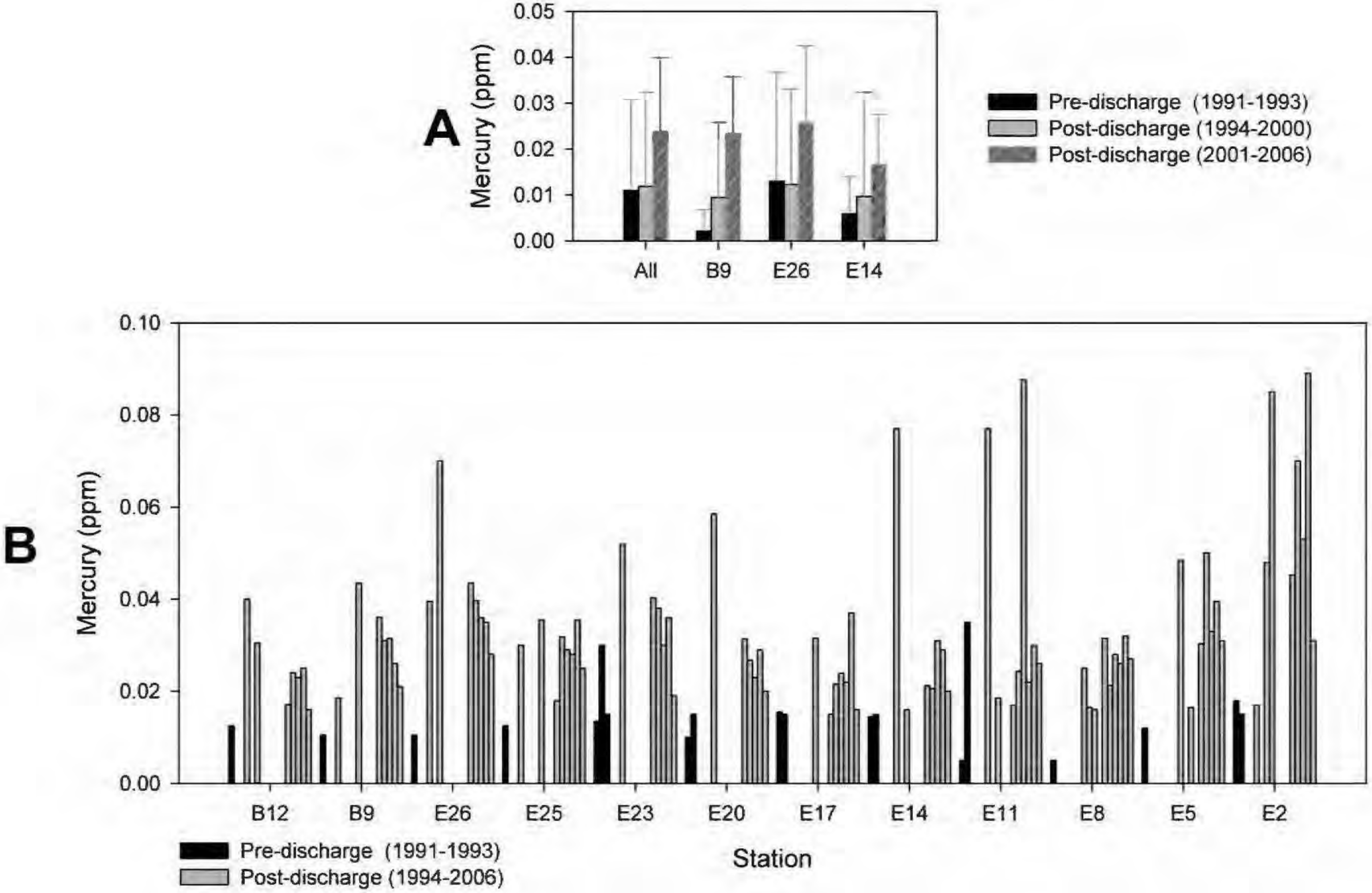


FIGURE E-19. Mercury concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

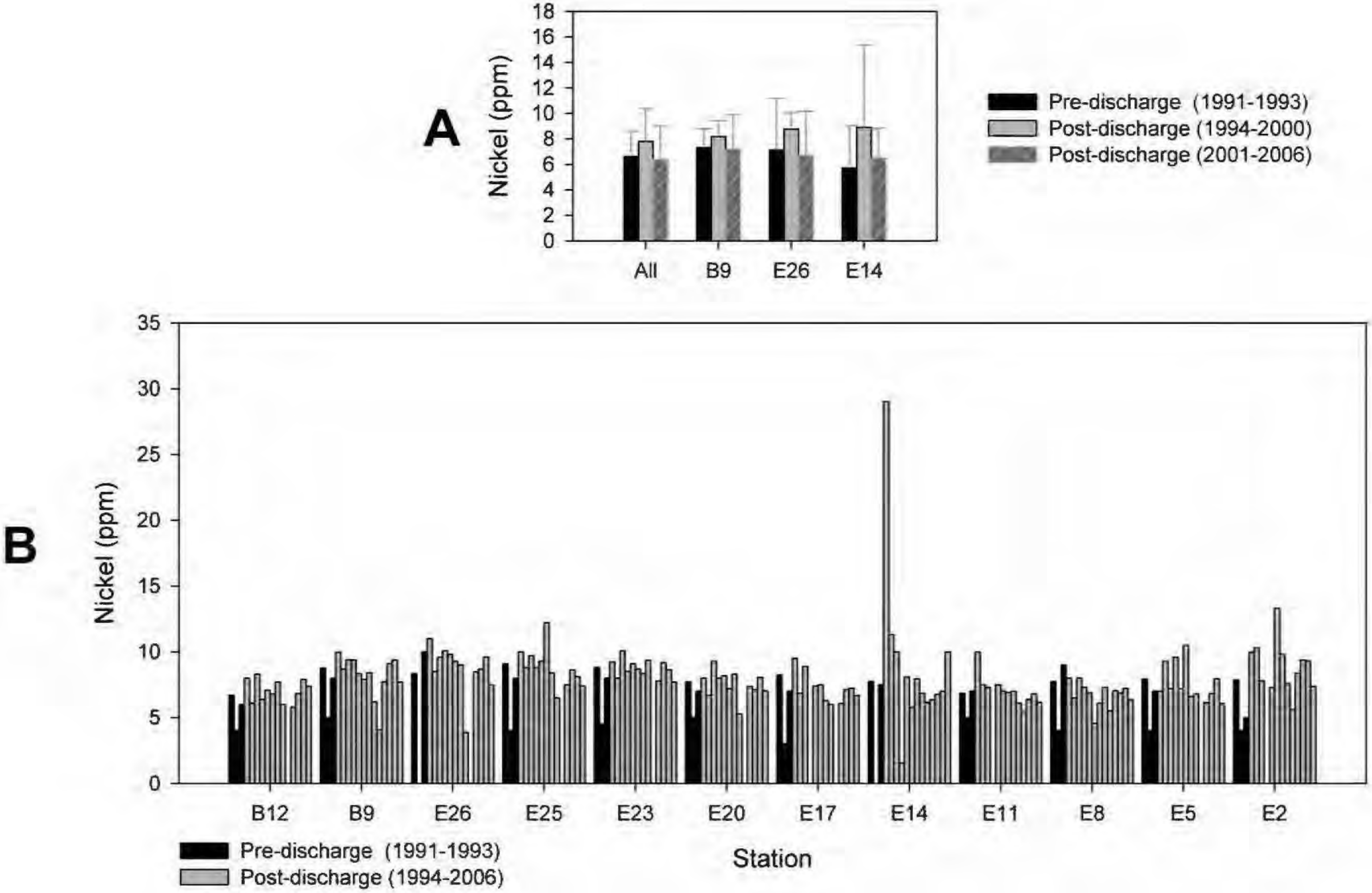


FIGURE E-20. Nickel concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

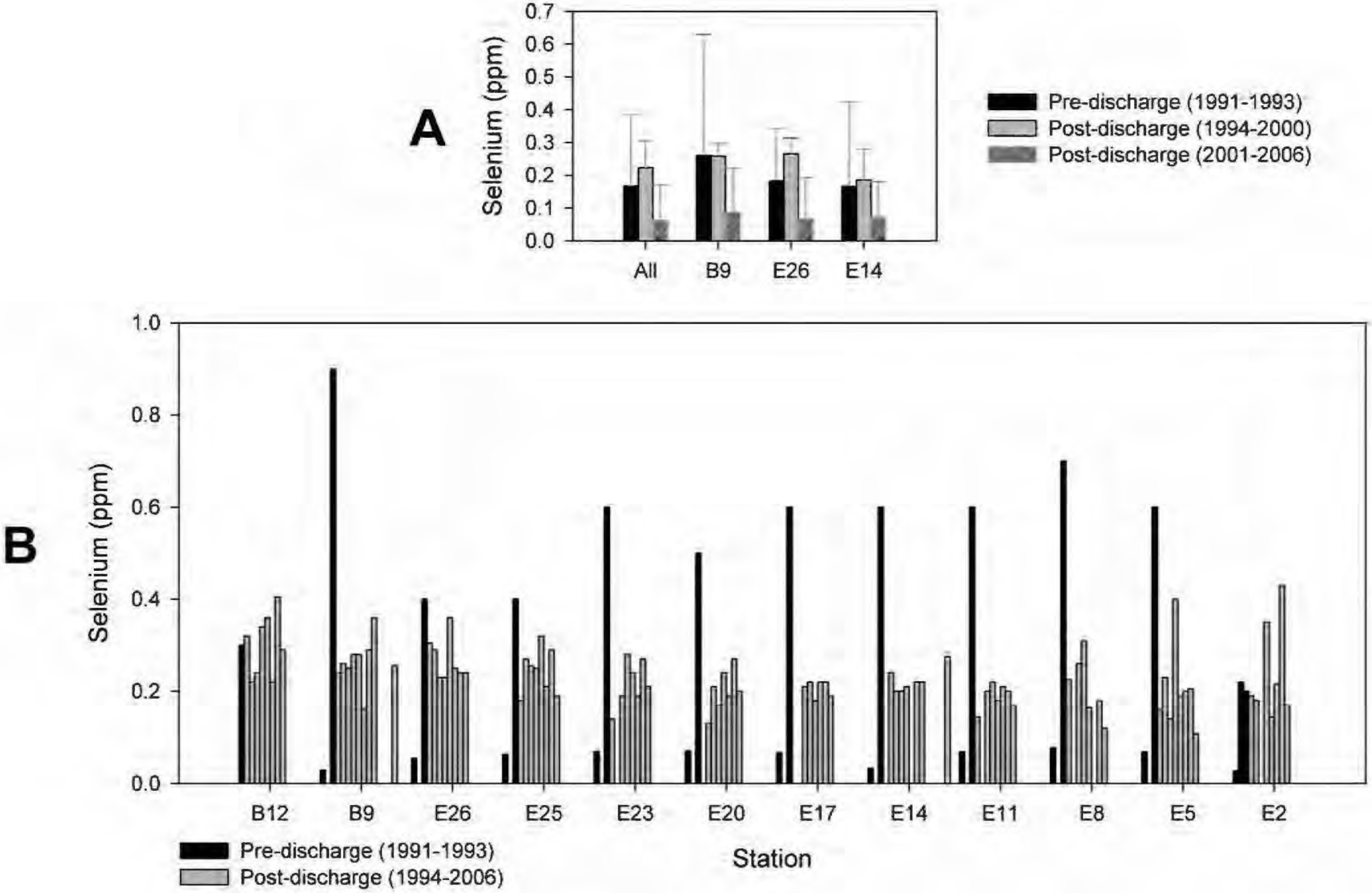


FIGURE E-21. Selenium concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

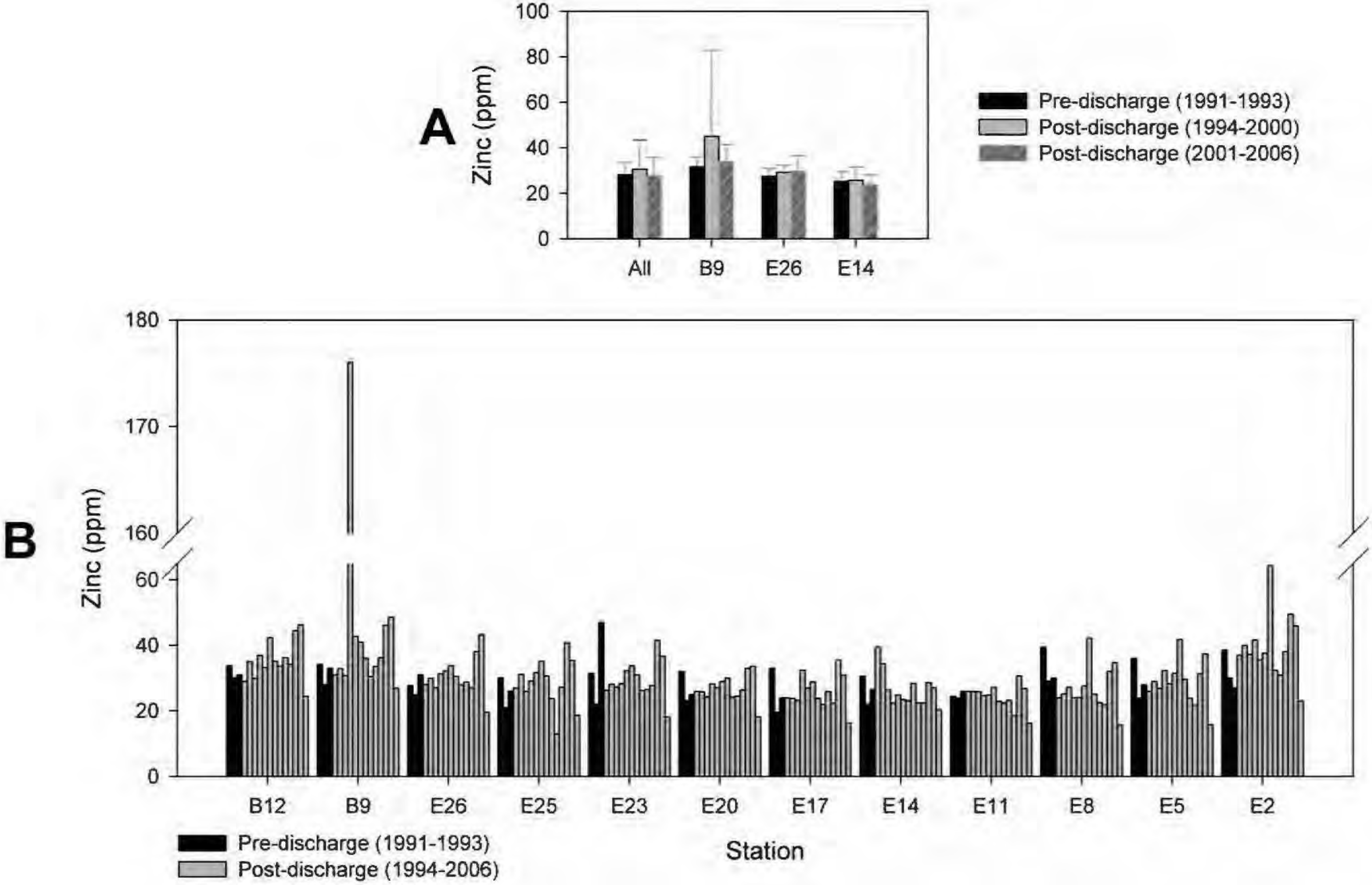


FIGURE E-22. Zinc concentrations (ppm) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

Pesticides, PCBs, and PAHs

<u>Total DDT</u>: DDT was detected at all outfall depth stations off Point Loma, but there was no evidence of any outfall-related effect (Figure E-23b). Sediment concentrations were generally low, averaging 1281 and 755 parts per trillion (ppt) during the pre- and post-discharge periods, respectively (Table E-3). These values are also lower than those measured during various SCB reference surveys (Table E-2). However, exceptionally high DDT values have been reported on two occasions at outfall depths off Point Loma, including northern reference station B9 (44,830 ppt) in January 1999 and southern station E2 (40,900 ppt) located just east of the LA-5 disposal site in July 1995, indicating sources unrelated to the PLOO discharge. Region-wide total DDT concentrations peaked in 1993, just 2 years into a 7-year period when 10 large dredging projects disposed contaminated sediments from San Diego Bay at the LA-5 site (Steinberger et al. 2003, City of San Diego 2006a). Similarly, discharges from Mission Bay and the San Diego River during periods of heavy rainfall may affect sediment conditions at the more northern sites (see City of San Diego 2007a).

<u>Total PCB</u>: PCBs were measured as Aroclors prior to April 1998 and as congeners since that time. Consequently, the data from these two periods are not comparable. No PCB Aroclors were detected in sediments at the outfall depth stations from 1991 through 1998. Since that time PCB congeners have been detected in sediment samples from only 4 stations along the 98-m depth contour (i.e., stations E2, E5, E17, and E25). The highest values observed occurred at station E2 located near the LA-5 dredge materials disposal site. There were no patterns relative to outfall operation.

<u>Total PAH</u>: PAHs were generally detected in low concentrations near or below method detection limits off Point Loma (Table E-3). For example, from 2001 through 2006, no sediments at outfall depths exceeded the ERL of 4022 ppb for PAHs (see City of San Diego, 2002a, 2003a, 2004b, 2005a, 2006a, 2007a). In fact, during this time only sediments at one deeper station (E9 at 116 m) in 2005 have contained total PAHs above the ERL (see City of San Diego 2006a). Additionally, PAHs detected in sediments at

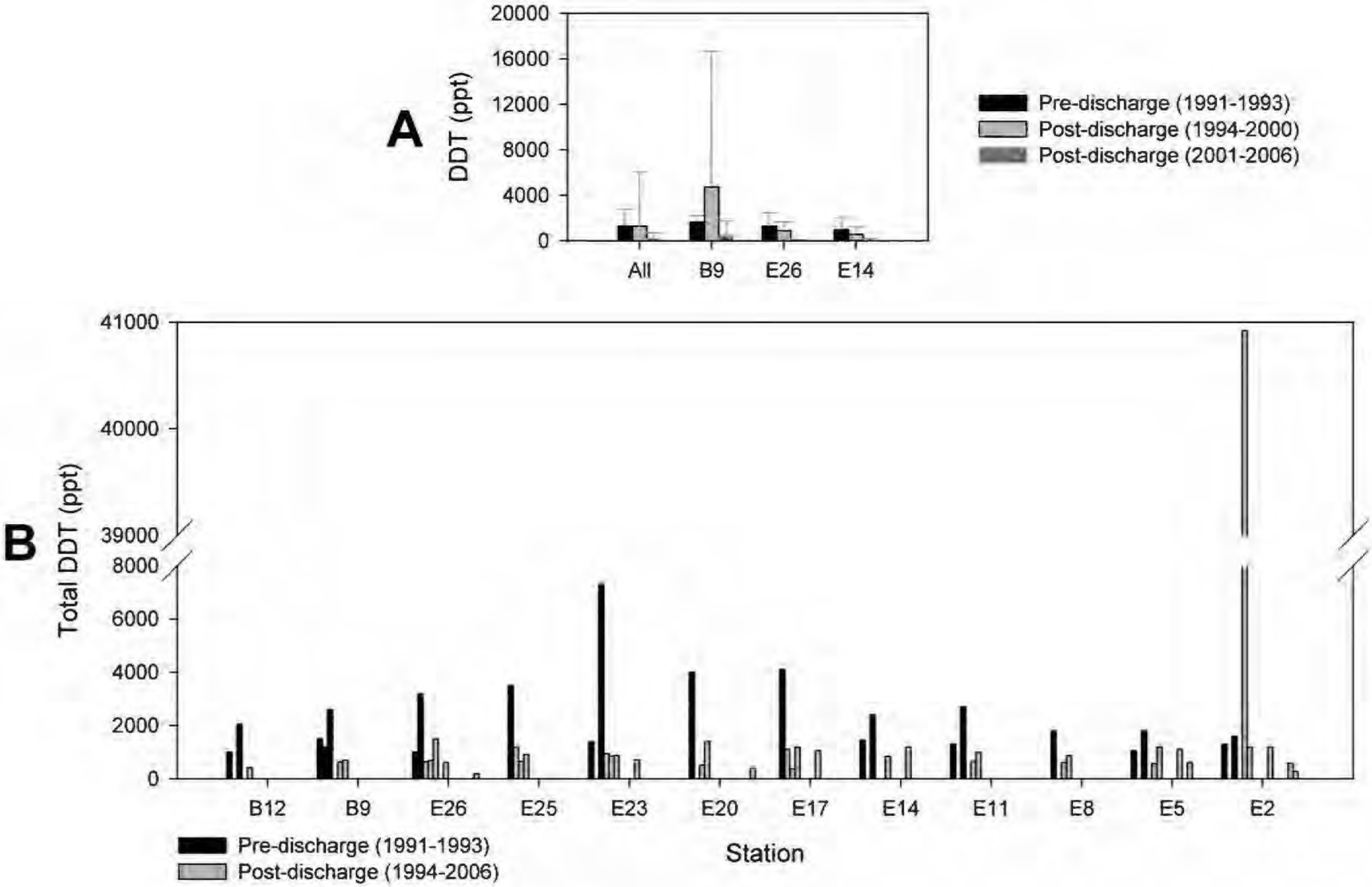


FIGURE E-23. Total DDT concentrations (ppt) in sediments at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 std. dev.); (B) July surveys only, all stations.

station E9 and further south have largely been attributed to short dumps intended for the LA-5 disposal site (see Anderson et al. 1993).

Summary of Sediment Conditions

Wastewater discharge is not significantly affecting sediment quality in the vicinity of the Point Loma outfall. After 13 years of outfall operation, there is little to no evidence of organic and contaminant loading in the area, with measured parameters existing at levels within the range of natural variability for reference areas off San Diego and throughout the SCB. Although there were some increases in levels of arsenic, chromium, copper, iron, nickel, and zinc in 1994 shortly after discharge began, these increases were not sustained. The only sustained effects were restricted to mostly a few sites located nearest the outfall pipe (i.e., ~120-300 m), including station E14 near the center of the outfall wye, and stations E11 and E17 located near the ends of the southern and northern diffuser legs, respectively. These effects included an increase in sediment particle size through time, measurable increases in sulfide concentrations, as well as smaller increases in BOD levels. Consequently, there is no evidence that the discharge is affecting the quality of benthic sediments to the point that it will degrade the resident marine biota.

Section E.5 – Benthic Infauna

The City of San Diego has been monitoring benthic infaunal communities around the extended Point Loma Ocean Outfall since 1991. Benthic surveys were conducted quarterly (January, April, July, October) from July 1991 through July 2003, after which sampling was modified to semiannual surveys during January and July of each year (see Section E.2). The locations for all benthic stations sampled during these periods are shown in Figure E-1. The accumulation of organic solids and toxic contaminants in sediments has already been discussed in the previous section. This section focuses on the results of the benthic infaunal analyses from the pre- and post-discharge monitoring periods to evaluate the possible effects of wastewater discharge.

Data Sets and Analyses

Since macrobenthic assemblages conditions often vary with depth, changes near the Point Loma Ocean Outfall were evaluated by focusing on data collected at stations located at outfall discharge depths. From north to south, these 12 stations are B12, B9, E26, E25, E23, E20, E17, E14, E11, E8, E5 and E2. The following analyses of benthic communities in the region are based on a dataset consisting of the results from all January and July surveys conducted at the above 12 stations from July 1991 through July 2006 (see Sections E.2 and E.3 for a complete description of dataset reduction). This includes five pre-discharge surveys (July 1991-July1993), and 26 post-discharge surveys (January 1994-July 2006) with the subsequent biological database consisting of information from a total of 743 0.1-m^2 samples (31 surveys, 12 stations, 2 replicates per station), representing about 74 m^2 of sea floor sediments; a few replicates were excluded from the analyses due to preservation problems (see Table E-1). Overall, the above surveys included 120 grab samples for the pre-discharge period and 623 grab samples for the post-discharge period. Additionally, the post-discharge period includes 335 samples (14 surveys) from 1994-2000 that were analyzed during the last waiver application, and 288 samples (12 surveys) from 2001-2006, which covers the current application period. Since benthic communities also vary considerably with season, some comparisons presented herein are limited to data collected only during the summer surveys (i.e., July).

The outfall depth stations are located along the 98-m depth contour and span the terminus of the outfall (Figure E-1). Station E14 is located nearest the outfall, approximately 111 meters north and 256 meters west of the center of the diffuser wye. This station is considered the near-ZID or ZID boundary station and is the most likely site to be impacted by wastewater discharge. Stations E11 and E17 are the closest nearfield stations, located approximately 204 m from the south and north ends of the diffuser legs, respectively. The remaining “E” stations are considered farfield sites. The “B” stations are located >11 km from the outfall and were originally selected to represent reference or control sites. However, benthic communities differed between the “B” and “E” stations prior to operation of the outfall (Smith and Riege 1994; City of San Diego 1995a). Thus, station E26 was chosen to represent an additional control or reference site. This station is located ~8 km from the outfall and is considered the least likely “E” station to be impacted.

The following key community parameters were evaluated in assessing impacts on the benthos: (1) number of species per grab sample (i.e., species richness or species diversity), (2) number of individuals per sample (abundance), (3) dominance (Swartz dominance), (4) the benthic response index (BRI), (5) abundances of major taxa (e.g., polychaetes, echinoderms, crustaceans, molluscs), (6) abundances of various pollution sensitive, pollution tolerant or opportunistic species (i.e., bioindicators), and (7) abundances of numerically dominant taxa (i.e., top 10 species by abundance). Additional comparisons of changes in the benthos were made using the BACIP statistical design (see Box A). Outfall-related effects were evaluated in terms of (1) the range of natural variability under reference conditions, (2) the magnitude and spatial extent of the effect, and (3) an assessment of the potential for adverse effects. Estimates of natural variability for benthic community parameters in the SCB have been extracted from various regional and bight-wide surveys conducted since 1985 (see Table E-4). These studies include the 1985 and 1990 SCCWRP reference surveys (Thompson et al. 1987, 1992), the 1994 Southern California Bight Pilot Project (Bergen et al. 1998, 2001), the 1998 and 2003 Southern California Bight Regional Monitoring Programs (i.e., Bight′98 and Bight′03, respectively; Ranasinghe et al. 2003, 2007), annual region-wide surveys of the San Diego mainland shelf conducted as part of regular South Bay monitoring requirements, and tolerance intervals calculated from these latter annual surveys off San Diego (see Attachment E.1).

Results

Major Community Parameters

Number of Species: One potential indicator of environmental degradation would be a reduction in benthic species diversity or the number of species near an outfall. The number of species off Point Loma averaged 86 per 0.1 m^2 over all January and July

Box A

BACIP Analysis Methods

A BACIP (Before-After-Control-Impact-Paired) statistical model was used to test the null hypothesis (H_0) that there were no changes in various community parameters due to operation of the Point Loma outfall (see Bernstein and Zalinski 1983; Stewart-Oaten et al. 1986, 1992; Osenberg et al. 1994). Briefly, the BACIP model tests differences between control (reference) and impact sites at times before (i.e., 1991-1993) and after (i.e., 1994-2006) an "impact" event (i.e., the onset of discharge). Overall, the Point Loma outfall dataset includes 2.5 years (10 quarterly surveys) of "Before Impact" data and 13 years (45 quarterly or semiannual surveys) of "After Impact" data. However, for the analyses presented herein, these data were limited to results from the January and July surveys only (see Section E.3), resulting in a reduced data set of 5 pre-discharge surveys and 26 post-discharge surveys. The "E" stations, located within 8 km of the outfall, are the most likely to be affected by the discharge. Station E14 was selected as the "impact" site for all analyses; this station is located nearest the Zone of Initial Dilution (ZID) and is probably the site most susceptible to impact. In contrast, the "B" stations are located farther from the outfall (>11 km) and are the obvious candidates for reference or "control" sites. However, benthic communities at the "B" and "E" stations differed prior to operation of the outfall (Smith and Riege 1994; City of San Diego 1995a). Thus, two stations (E26 and B9) were selected to represent separate control sites in subsequent analyses. Station E26 is located ~8 km from the outfall and is considered the "E" station least likely to be impacted. Previous analyses suggested that station B9 was one of the most appropriate "B" stations for comparison with the "E" stations (Smith and Riege 1994; City of San Diego 1995a). Six dependent variables were analyzed, including three community parameters (number of species, infaunal abundance, and BRI) and abundances of three taxa known to be sensitive to organic enrichment. These indicator taxa included ophiuroids in the genus *Amphiodia* (mostly *A. urtica*) and amphipods in the genera *Ampelisca* (Family Ampeliscidae) and *Rhepoxynius* (Family Phoxocephalidae).

All BACIP analyses were initially interpreted using a conventional Type I error rate of $\alpha = 0.05$. However, the substantial spatial and temporal variation inherent in many biological communities may often lead to an increased chance of Type II error, i.e., falsely concluding that no impact has occurred when it actually has (e.g., Underwood 1990; Fairweather 1991; Otway 1995; Otway et al. 1996). One possible solution to this problem is to increase the probability of Type I error (i.e., falsely concluding that an impact has occurred) by changing the α from 0.05 to 0.10, thereby increasing the power of the tests and making the detection of "impacts" less conservative (Otway 1995; Otway et al. 1996). Consequently, all non-significant results at $\alpha = 0.05$ were also interpreted using the higher Type I error rate of $\alpha = 0.10$.

TABLE E-4

Comparison of benthic species richness, abundance, and BRI values for the City of San Diego's Point Loma Ocean Outfall (PLOO) benthic stations with data from the SCCWRP 60-m and 150-m reference surveys, 1994 Southern California Bight Pilot Project (SCBPP), 1998 and 2003 Southern California Bight Regional Surveys (Bight'98, Bight'03), and San Diego Regional Surveys (1994-2003, see Attachment E.1). PLOO data are presented for outfall depth stations only (98 m) and are expressed as means for all 12 stations combined during the pre-discharge (1991-1993) and post-discharge (1994-2006) periods. SCCWRP data are presented for the 60-m and 150-m surveys and are expressed as approximate averages for the 1985 and 1990 surveys combined. SCBPP, Bight'98 and Bight'03 data are expressed as mean values per 0.1 m2 for the "mid-shelf" strata. Numbers in parentheses = range of minimum and maximum values.

	SCCWRP Reference Surveys *		SCB 1994, 1998 and 2003 Regional Surveys [†]			San Diego Regional Surveys	PLOO Surveys (1991-2006)	
	60-m	150-m	SCBPP	Bight'98	Bight'03		Pre-discharge	Post-discharge
Species Richness	63 - 83 (41 - 104)	47 - 62 (37 - 73)	84.5 (18 - 162)	61.5 (7 - 166)	62.4 (2 - 158)	116.2 (57 - 226)	67.0 (36 - 100)	90.0 (12 - 145)
Abundance	344 - 625 (208 - 1200)	152 - 245 (110 - 288)	385.2 (35 - 1696)	291.7 (11 - 1830)	274.2 (5 - 2298)	416.5 (129 - 1082)	273.9 (79 - 551)	369.0 (47 - 966)
BRI [‡]	—	—	—	16.6 (-15.8 - 47.3)	15.8 (-12.0 - 47.3)	6.4 (-4.3 - 21.4)	4.2 (-4.6 - 15.3)	5.0 (-5.6 - 22.6)

* Thompson et al. 1987, 1992

[†] Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007.

[‡] BRI values not calculated forn SCCWRP and SCBPP surveys.

surveys at the 12 outfall-depth stations, with an average of 67 and 90 species during the pre- and post-discharge periods, respectively (Table E-5). Although highly variable (e.g., 12-145 species per station), the number of species per grab was generally higher during the post-discharge period (Figure E-24). This post-discharge increase was more pronounced at station E14 nearest the outfall, although a similar pattern is apparent at stations E2, E11 and B12. BACIP results demonstrated a significant change in the difference in species diversity between station E14 and both reference sites (Table E-6, Figure E-24); however all stations show similar pre- and post-discharge trends relative to tolerance interval boundaries calculated for the San Diego mainland shelf (see Attachment E.1).

The above increases may or may not be related to wastewater discharge. First, the increase could be part of a larger regional phenomenon as the number of species began to increase prior to discharge, and this increase has occurred at all stations regardless of proximity to the outfall. Second, the relatively large increase in species at station E14 may be related more to proximity to the outfall pipe and sediment heterogeneity (e.g., migration of ballast-particles into surrounding habitats) than to organic enrichment. Two other stations characterized by relatively coarse and unstable sediments, stations E2 to the south and B12 to the north, also displayed relatively large increases in species diversity. Third, numbers of infaunal species around the outfall are still generally within the range of natural variability seen at other SCB and San Diego reference areas (Table E-4; Attachment E.1). Whatever the reasons, wastewater discharge of the Point Loma outfall is not causing any reductions in the number of benthic species in the area.

Infaunal Abundance: Changes in total infaunal abundance are often used to demonstrate an outfall effect, although specific changes may vary depending upon the level of organic enrichment. For example, abundances are generally predicted to increase in response to low to moderate levels of enrichment. This increase is generally not considered adverse unless it is accompanied by a reduction in the number of species present. As organic input increases, the number of species may begin to decline while populations of tolerant species increase. Extremely high abundances associated with reduced numbers of species is often considered an indication of an adverse outfall effect. Benthic abundances would

TABLE E-5

Summary of benthic infauna abundance, species richness (no. of species), Swartz dominance, and benthic response index (BRI) values for the City of San Diego's Point Loma Ocean Outfall benthic stations; outfall depth stations only (n=12). Data are for January and July surveys only from 1991-2006 and are expressed as numbers per 0.1 m^2 grab. Pre-discharge surveys = 1991-1993 (n=5); Post-discharge surveys = 1994-2006 (n=26); See text for details of data reductions.

	Pre-discharge Surveys (1991-1993)				1994-2000 Post-discharge			2001-2006 Post-discharge			All Post-discharge Surveys (1994-2006)			
	All Sites		Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites		Outfall Stn. E14	Ref. Stn. B9
	Mean	Range	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean
Abundance														
All Invertebrates	273.9	79 - 551	261.9	236.9	372.9	439.7	319.6	365.3	490.3	342.2	369.4	47 - 966	463.0	330.1
Polychaetes	155.8	44 - 424	154.2	132.0	224.6	295.9	197.7	216.2	331.8	199.2	220.7	35 - 827	312.4	198.4
Crustaceans	46.1	10 - 102	44.6	51.4	55.3	70.3	43.0	66.4	84.2	60.8	60.4	11 - 178	76.7	51.2
Molluscs	18.6	3 - 102	11.9	12.7	26.2	42.4	15.8	29.6	50.6	23.1	27.8	2 - 139	46.2	19.2
Echinoderms	49.7	9 - 92	48.0	36.3	60.9	24.4	58.2	47.0	15.0	55.3	54.5	1 - 179	20.0	56.9
Misc. Other Taxa	3.7	0 - 14	3.2	12.7	6.0	7.2	4.9	6.0	8.8	4.0	6.0	0 - 31	8.0	4.5
Species Richness	67.0	36 - 100	66.2	65.8	87.8	99.2	82.3	93.3	106.0	85.0	90.3	12 - 145	102.3	83.5
Swartz Dominance	19	8 - 31	20	20	26	31	26	30	29	26	27.8	3 - 50	30.0	26.0
BRI	4.2	-4.6 - 13.5	4.9	6.1	4.0	12.0	1.8	6.2	13.9	2.3	5.0	-5.6 - 22.6	12.9	2.0

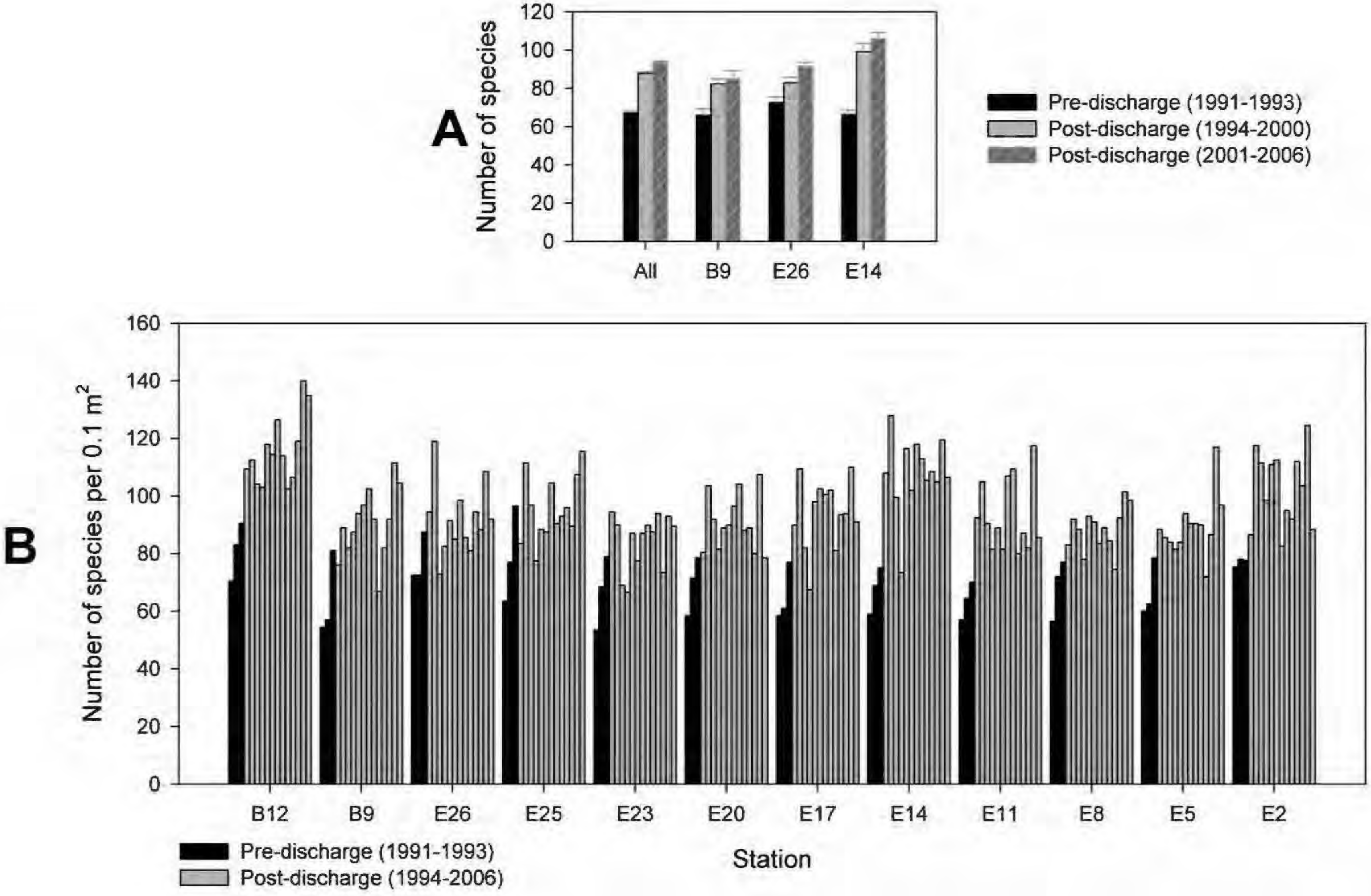


FIGURE E-24. Number of species of benthic infauna at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

TABLE E-6

Results of BACIP t-tests for species richness, infaunal abundance, benthic response index (BRI), and the abundance of several representative taxa around the Point Loma Ocean Outfall (1991-2006). Impact site (I) = near-ZID station E14; Control sites (C) = farfield station E26 or northern reference station B9. Before impact period = July 1991 to July 1993 (n = 5 surveys); After impact period = January 1994 to July 2006 (n = 26 surveys); Critical t value = 1.70 for α = 0.05 and t = 0.85 for α = 0.1 (one-tailed t-tests, df = 29); ns = not significant at either the α = 0.05 or α = 0.1 levels.

	Comparison (C vs. I)	**Before Impact**		**After Impact**			
		Mean Δ	**Variance**	**Mean Δ**	**Variance**	**t**	**p-value**
Species richness	E26 vs. E14	7.4	5.4	17.9	5.2	-3.22	0.002
	B9 vs. E14	7.8	3.4	19.4	7.5	-3.53	0.001
Abundance	E26 vs. E14	74.1	664.8	136.4	479.5	-1.84	0.038
	B9 vs. E14	59.8	216.8	134.8	407.0	-3.00	0.003
BRI	E26 vs. E14	1.9	0.3	9.3	0.2	-10.57	< 0.001
	B9 vs. E14	4.0	0.7	10.9	0.2	-6.99	< 0.001
***Amphiodia* spp**	E26 vs. E14	9.0	8.7	43.0	24.8	-5.88	< 0.001
	B9 vs. E14	12.2	27.9	36.0	15.3	-3.61	0.001
***Ampelisca* spp**	E26 vs. E14	4.0	2.3	5.2	0.7	-0.70	ns
	B9 vs. E14	4.6	1.1	5.0	0.5	-0.33	ns
***Rhepoxynius* spp**	E26 vs. E14	3.0	0.8	3.5	0.2	-0.52	ns
	B9 vs. E14	2.1	0.3	3.3	0.2	-1.77	0.043

then be expected to decline when levels of organic enrichment reach the point of causing anoxic sediment conditions. Thus, evidence of high organic loadings coupled with reduced benthic abundances would be indicative of polluted or degraded conditions.

The number of infaunal animals averaged 354 per 0.1 m^2 over all the surveys analyzed herein at outfall depths off Point Loma (Table E-5). Overall, infaunal abundances increased about 35% between the pre-discharge and post-discharge periods, averaging 274 and 369 animals per grab, respectively. In spite of this general increase, there were no clear spatial patterns in the region, and infaunal abundances at all stations were within the tolerance interval bounds for the San Diego region (see Attachment E.1). Although highly variable (i.e., 47-966 animals/grab), abundances were generally higher at all stations in the post-discharge period than during the previous three years (Figure E-25), which me be due at lest in part to increases associated with the major El Nino event that began in 1998. For example, densities at near-ZID station E14 increased from an average of 262 animals per 0.1 m^2 grab during the pre-discharge years to 463 per grab afterwards. Although the increase at E14 could also be an enhancement effect, abundances also increased at sites considered beyond the outfall's influence (e.g., stations E26 and B9); abundances at E26 increased from 335 to 425 per grab, while those at B9 increased from 237 to 330 animals per grab. According to BACIP results, there was a significant change in the difference in abundance values between station E14 and both control sites (Table E-6, Figure E-25). Although these results support an outfall-related pattern, the effect appears minor as infaunal abundances at all sites off Point Loma are generally similar to those reported from various reference surveys throughout San Diego and the entire SCB (Table E-4). This suggests that abundances near the Point Loma outfall are within the range of natural variability seen throughout mainland shelf benthic habitats of the SCB.

There does appear to have been a shift in relative abundance by phyla that may be related to the outfall, although the proportion of echinoderms and polychaetes were fairly consistent between the pre- and post-discharge periods when averaged over all sites (i.e., differences of 18-15% for echinoderms and 57-60% for polychaetes; see Table E-5). In contrast, the relative abundance of echinoderms at station E14 near the outfall wye decreased from an average of 18% prior to discharge to 4% after discharge began. During

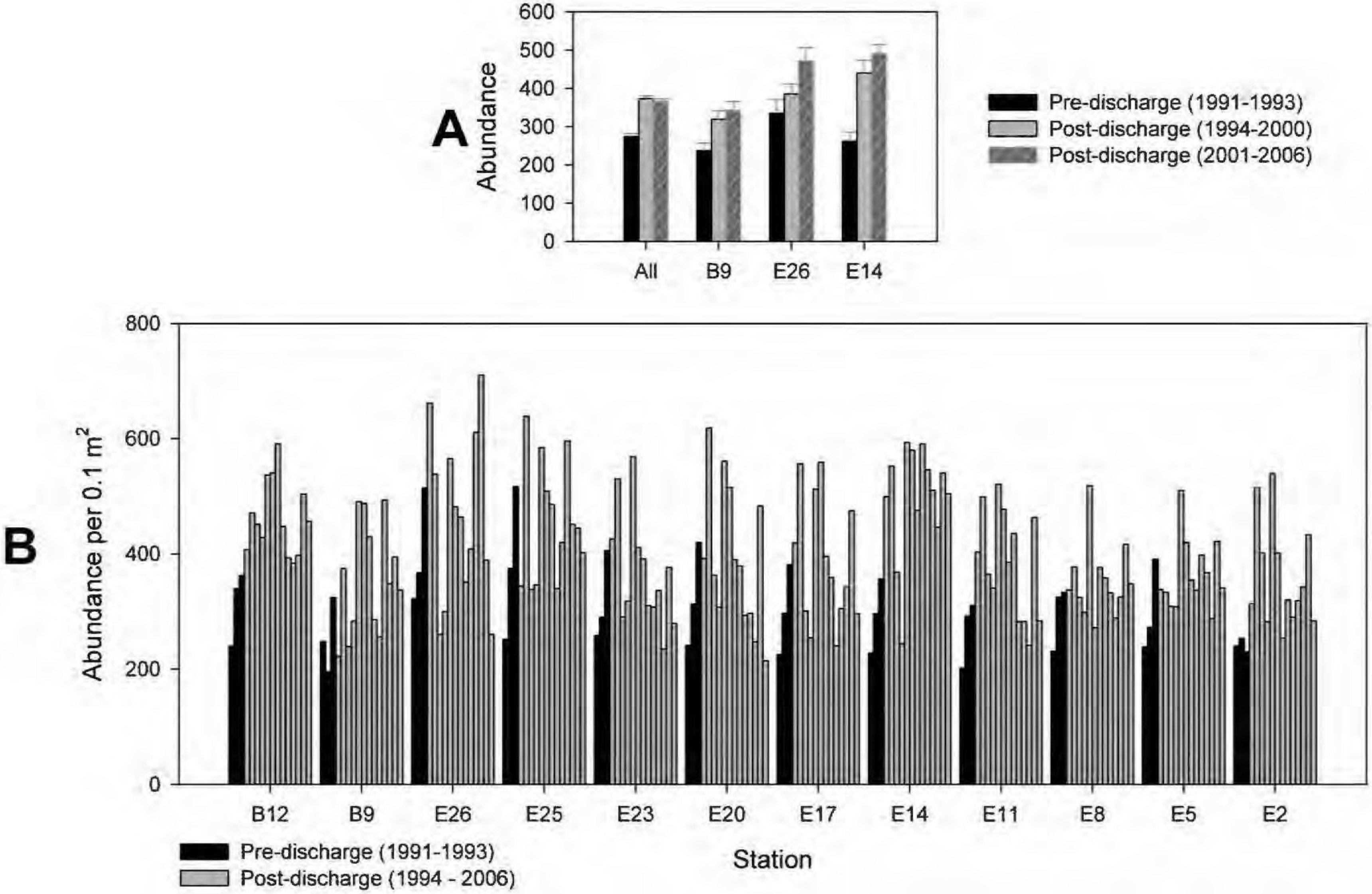


FIGURE E-25. Abundance of benthic infauna at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

this same period, polychaete and mollusc abundances increased from 59 to 67% and 5 to 10%, respectively. Although such changes are common near ocean outfalls, similar patterns occurred elsewhere. For example, echinoderm abundance decreased from 10% to 6%, polychaete abundance increased from 39% to 54%, while mollusc abundances decreased from 27 to 17% at station B12, a site located far to the north and considered to lie beyond the influence of the outfall. Other farfield stations (i.e., B9 and E26) displayed little change over time in terms of these relative abundances.

Dominance: Dominance is an indicator of benthic community structure which reflects shifts in the relative abundance of species (rather than the total number of species). Severely polluted areas are typically dominated by a few pollution tolerant species, whereas more pristine areas tend to have a more even distribution of species. One measure of dominance is the minimum number of species whose combined abundance accounts for 75% of the individuals in a sample (Swartz *et al*. 1986, Ferraro *et al*. 1994). Consequently, dominance as discussed herein is inversely proportional to numerical dominance, such that low index values indicate communities dominated by few species.

Dominance actually decreased (i.e., index values increased) off Point Loma after initiation of wastewater discharge (Figure E-26). For example, the Swartz dominance index values averaged 19 over all sites during the pre-discharge period and 28 afterwards (Table E-5). This pattern was apparent even at station E14 near the outfall, where the number of species dominating the benthos increased from about 20 to 30 between these periods. Thus, post-discharge communities in the region are characterized by a more even distribution of species than prior to discharge. It is clear that benthic community abundances around the Point Loma outfall are not being numerically dominated by a few pollution tolerant species.

Benthic Response Index: The BRI is a numerical index that incorporates the abundance-weighted average pollution tolerance score of various benthic invertebrates into a single number (Smith et al. 2001). Index values below 25 suggest undisturbed communities or "reference conditions," and those in the range of 25-33 represent "a minor deviation from

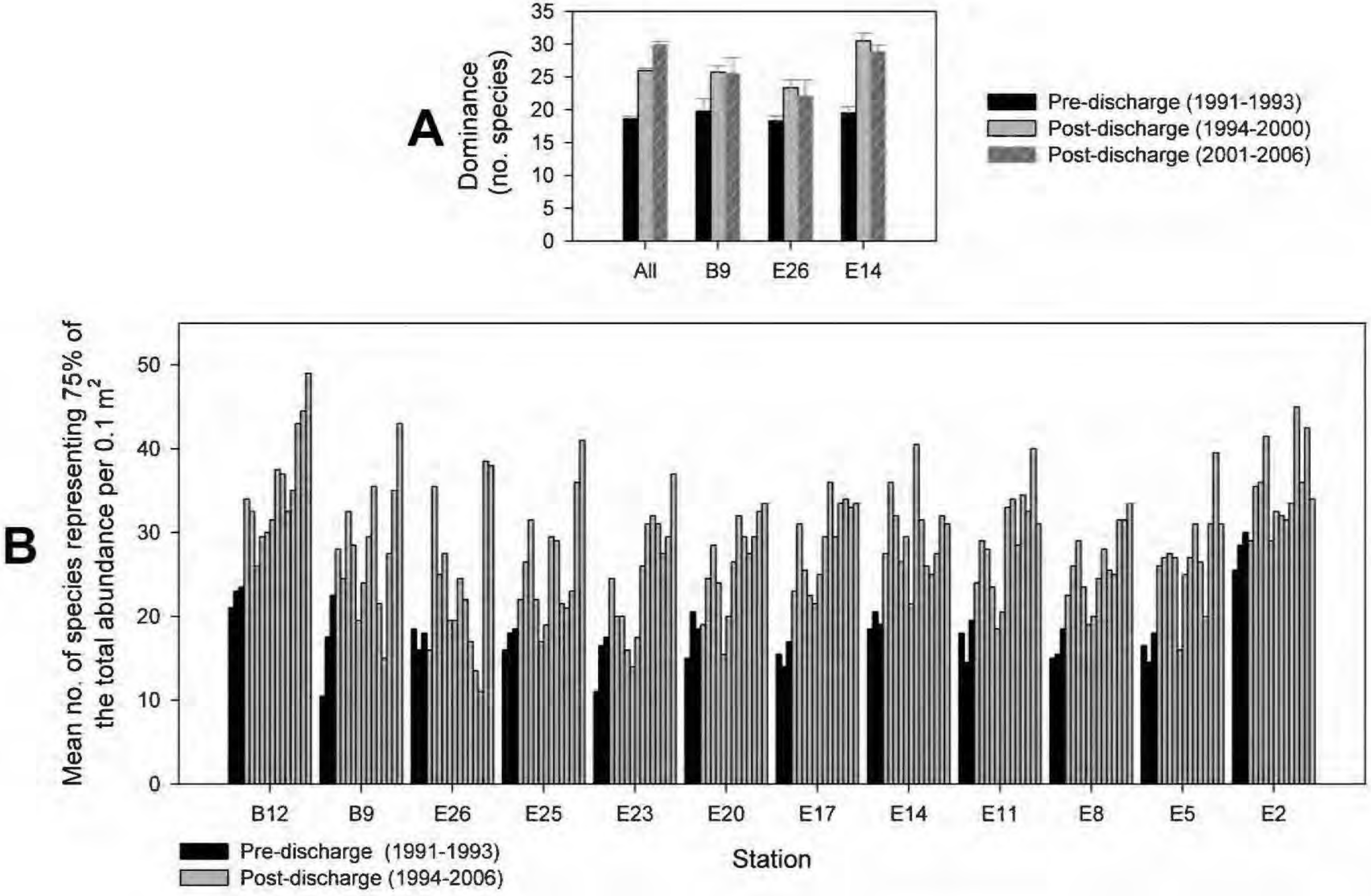


FIGURE E-26. Swartz dominance values at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

reference condition." BRI values greater than 44 indicate a loss of community function. Because the BRI was developed from data collected within the SCB over several decades, the index is largely driven by the abundance of many of the species that are common off Point Loma.

Overall, BRI values have shown relatively little change off Point Loma since 1991 (Figures E-27 and E-28). Index values for the region averaged ≤5 over all surveys, ranging from -4.6 to 13.5 per station during the pre-discharge period and from -5.6 to 22.6 during the post-discharge period (Table E-5). The highest values occurred at station E14 nearest the outfall, where values have become elevated relative to other sites since 1994. According to BACIP results, there was a significant change in the difference in BRI values between this station and both control sites (Table E-6). Although these data suggest an outfall related pattern, the effect appears minor and restricted to the ZID boundary sampling site. First, values at the nearest upcoast (E17) and downcoast (E11) stations were only minimally elevated, suggesting only a localized phenomenon (see City of San Diego, 2002a, 2003a, 2004b, 2005a, 2006a, 2007a). Second, while BRI values at station E14 have risen above the upper tolerance interval in recent years, these values still remain below 25 and are considered characteristic of "reference" conditions for the SCB (see Figure E-28; Attachment E.1). The single high BRI value of 22 was likely a response to the presence of a small population of the polychaete *Armandia brevis* in July 2006.

Abundance of Major Taxa and Indicator Species

Polychaeta: Polychaete worms represented the most abundant benthic invertebrates off Point Loma, comprising 57-60% of the macrofauna at the outfall depth stations during the pre- and post-charge periods, respectively (Table E-5). Although the proportion of polychaetes has remained relatively stable between these periods, actual densities increased approximately 42% from an average of 156 polychaetes per 0.1 m^2 grab prior to outfall operation to 221 per grab during the post-discharge period.

A comparison of data collected just during the summer surveys suggested little evidence of any outfall related temporal or spatial trends (Figure E-29b). Although the number of

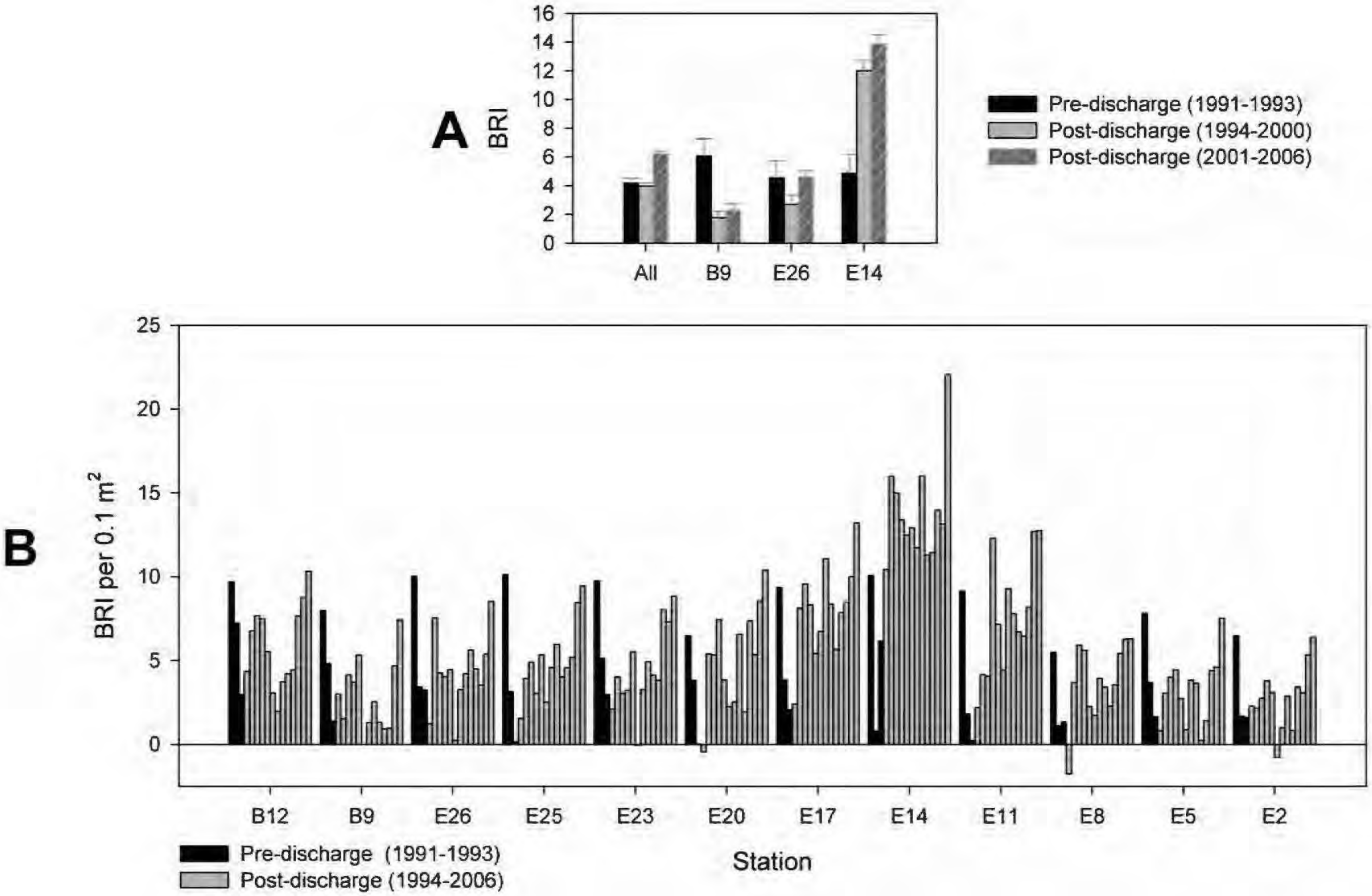


FIGURE E-27. Benthic response index (BRI) at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

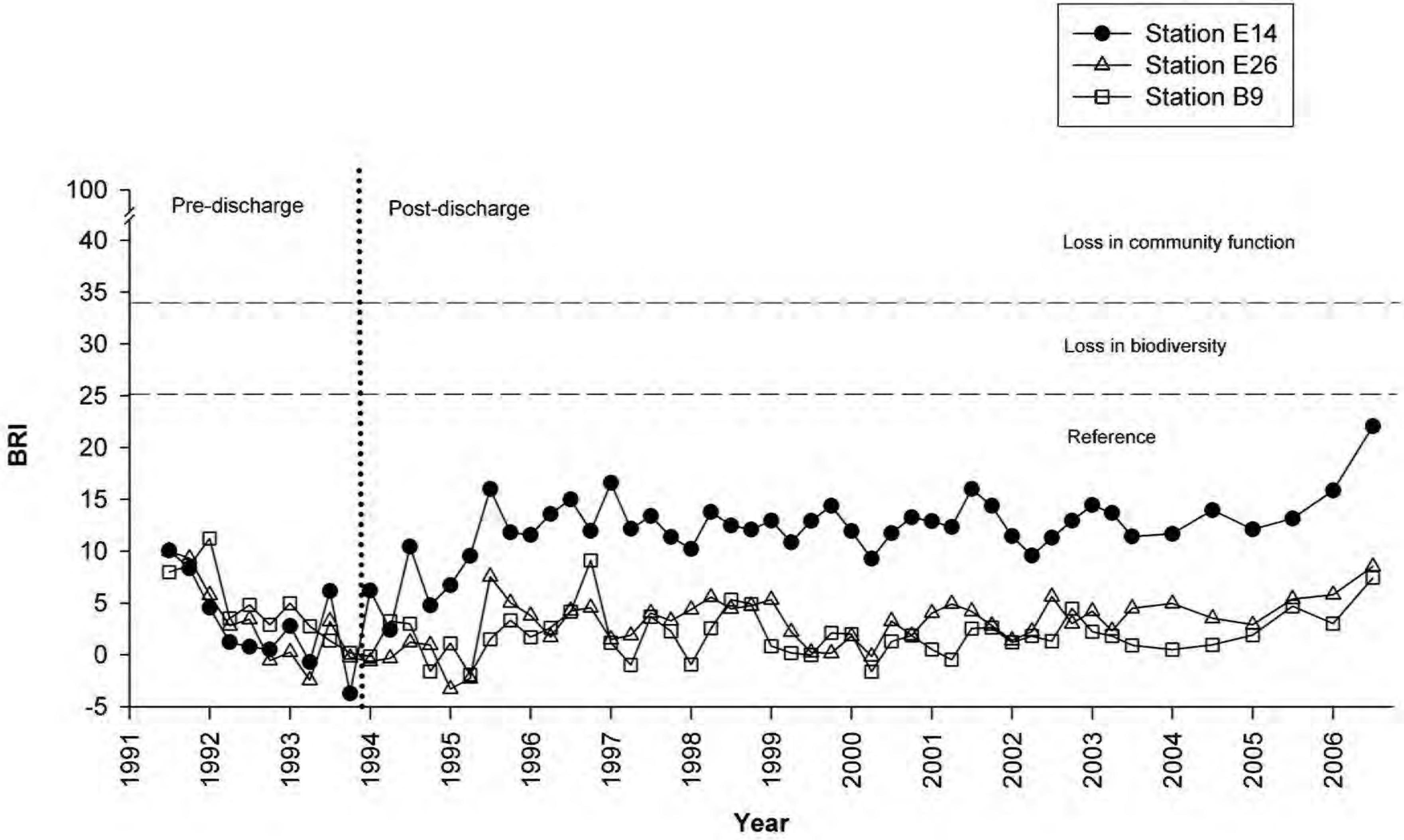


FIGURE E-28. BRI values at near-ZID station E14, farfield station E26, and reference station B9, Point Loma Ocean Outfall (1991-2006). Environmental descriptions (Reference, Loss in biodiversity, Loss in community function) after Smith et al. (2001).

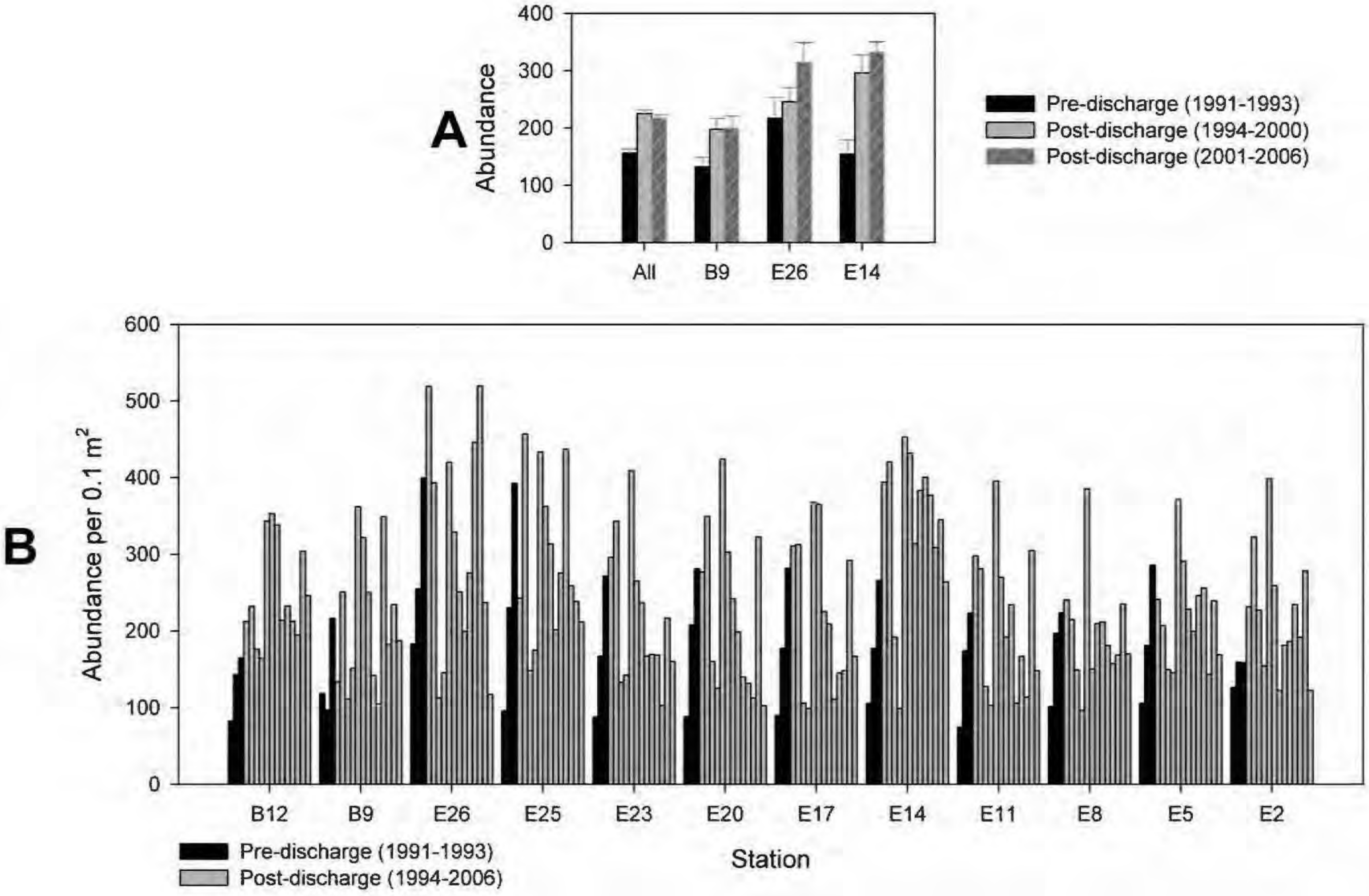


FIGURE E-29. Polychaete abundance at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

polychaetes increased near the outfall (i.e., station E14) during 1994 and 1995, this appeared to be a continuation of a general pattern that began prior to wastewater discharge. Polychaete populations then declined considerably during 1996 and 1997, after which they increased again between 1998 and 2000 at station E14. Similar alternating patterns of population increases and decreases have occurred throughout the region, regardless of proximity to the Point Loma outfall, and are likely related to natural population responses to changing oceanographic conditions (e.g., El Niño/La Niña). For example, there was little difference in the changes that occurred near the outfall and at station E26 located to the north, beyond the outfall's influence. Much of the change in densities is in response to the cyclical nature of some numerically dominant polychaetes. For instance, populations of two such polychaetes, *Myriochele striolata* and *Proclea* sp A, have varied considerably over time (City of San Diego 2007a). Such variation can have significant effects on other community descriptive statistics (e.g., dominance, diversity, and abundance) or environmental indices (i.e., BRI) that use the abundance of indicator species in their equations.

The seven most abundant polychaetes over all surveys were, in descending order: the terebellid *Proclea* sp A, the oweniid *Myriochele striolata* (=*Myriochele* sp M), the spionid *Spiophanes duplex* (previously known as *S. missionensis*), another terebellid *Phisidia sanctamariae* (=*Lanassa* sp D), the pectinariid *Pectinaria californiensis*, the cirratulid *Chaetozone hartmanae*, and another spionid *Prionospio jubata* (see Table E-7). Of these species, *Spiophanes duplex*, *Proclea* sp A, and *Phisidia sanctamariae* dominated both the pre-discharge and post-discharge assemblages. Combined, these three species comprised 24% of the polychaete fauna and 14% of the total number of invertebrates at outfall depths off Point Loma.

Several polychaete species that occur in southern California waters are useful indicators of organic loading. These include the well known pollution indicator *Capitella "capitata*," other capitellids of the genus *Mediomastus*, the dorvilleid *Dorvillea longicornis*, and the opheliid *Armandia brevis*. The *Capitella* recognized here represents a cosmopolitan species complex of several physiologically and genetically distinct sibling species (see Grassle and Grassle 1974, 1976, 1978). *Capitella* has been recognized for rapid population expansions in areas of organic loading or other disturbances, and its significance as a marine pollution indicator has been examined extensively (see Word et al. 1977; Grassle and Grassle 1976, 1978; Cuomo 1985; Tenore and Chesney 1985). In the SCB, these worms may reach densities of 1000 or more per 1.0 m^2 (i.e., ~100/0.1 m^2 grab) in areas of excessive organic deposits (Word et al. 1977). Although background densities of this polychaete are usually near zero, they may be occasionally higher where organic detritus accumulates naturally or where sediments are physically disturbed.

Capitella occurs rarely and in low abundances in sediments off Point Loma, with population densities averaging 0.5 and 3.5 per 0.1 m^2 at outfall depths during the pre- and post-discharge periods, respectively (Table E-7). Although average densities increased from about zero to 10.8 worms per grab at near-ZID station E14 after discharge began (range = 0-53/grab) and above the lower tolerance interval boundary (see Attachment E.1), these densities are still well below those indicative of polluted sediments (i.e., ~1000 per m^2). The relatively low abundance and sporadic occurrence of this polychaete off Point Loma suggests no substantial organic loading or habitat degradation near the outfall. Instead, population fluctuations at this site may be related to local physical disturbances associated with proximity to the outfall as well as to slight organic enrichment.

Capitellid polychaetes of the genus *Mediomastus* are also capable of population expansion in transitional areas of moderate organic enrichment, where they typically exceed densities of 10 worms per 0.1 m^2 (i.e., 100/m^2, see Word et al. 1977). *Mediomastus* densities averaged 4.1 animals per 0.1 m^2 at outfall depths off Point Loma, increasing slightly from 1.7 to 4.5 worms per sample between the pre- and post-discharge periods (Table E-7). Although densities were slightly higher at station E14 during the post-discharge period (i.e., 10.5/0.1 m^2), these values are indicative of only moderate organic enrichment.

Two other polychaetes used as indicators of organic loading in benthic sediments, the dorvilleid *Dorvillea longicornis* and the opheliid *Armandia brevis*, have also occurred only rarely off Point Loma, with only 32 specimens being collected at outfall depths

TABLE E-7

Abundances of Southern California Bight (SCB) benthic infauna indicator taxa and dominant species near the City of San Diego's Point Loma Ocean Outfall; outfall depth stations only (n=12). Data are for January and July surveys only from 1991 through 2006 and are expressed as numbers per 0.1 m^2 grab. Pre-discharge surveys = 1991-1993 (n=5); Post-discharge surveys = 1994-2006 (n=26); See text for details of data reductions.

	Pre-discharge Surveys (1991-1993)				1994-2000 Post-discharge			2001-2006 Post-discharge			All Post-discharge Surveys (1994-2006)			
	All Sites		Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites	Outfall Stn. E14	Ref. Stn. B9	All Sites		Outfall Stn. E14	Ref. Stn. B9
	Mean	Range	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Range	Mean	Mean
SCB Indicator Taxa														
Amphiodia spp (EO)	42.0	5 - 85	40.7	29.1	44.9	14.1	46.8	37.5	8.0	47.7	41.5	0 - 124	11.3	47.2
Euphilomedes spp (CO)	17.3	2 - 54	18.0	21.2	15.0	25.6	6.8	20.4	36.0	9.5	17.5	0 - 87	30.4	8.0
Ampelisca spp (CA)	6.9	0 - 21	7.8	6.6	10.0	8.1	10.6	10.5	8.0	12.7	10.2	0 - 30	8.1	11.6
Rhepoxynius spp (CA)	5.5	0 - 17	4.6	6.7	4.3	4.3	2.8	6.4	6.1	5.3	5.3	0 - 30	5.1	4.0
Parvilucina tenuisculpta (MB)	4.1	0 - 19	1.0	4.6	3.5	10.6	2.0	4.4	8.7	4.2	3.9	0 - 54	9.7	3.0
Capitella "capitata" (P)	0.5	0 - 1	0.0	0.5	3.4	12.0	0.7	3.7	9.5	0.5	3.5	0 - 53	10.9	0.7
Mediomastus spp (P)	1.7	0 - 16	3.0	2.7	3.4	9.5	1.9	5.8	11.6	2.9	4.5	0 - 40	10.5	2.3
Dominant Taxa off Point Loma *														
Amphiodia urtica (EO)	37.8	0 - 85	36.6	24.6	28.5	8.6	31.7	27.5	4.2	38.1	28.0	0 - 78	6.6	34.7
Proclea sp A (P)	15.8	0 - 78	11.6	9.8	19.6	13.1	13.8	19.5	15.7	11.1	19.5	0 - 111	14.3	12.5
Myriochele striolata (P)	8.3	0 - 128	1.8	1.0	6.6	7.5	5.3	55.4	90.7	68.5	27.3	0 - 630	47.1	40.0
Spiophanes duplex (P) †	33.8	2 - 139	38.2	27.6	20.1	10.3	23.7	5.4	1.8	6.1	13.6	0 - 123	6.4	12.6
Phisidia sanctaemariae (P)	9.1	0 - 47	8.7	3.5	26.8	39.7	19.1	4.7	3.7	5.1	16.9	0 - 217	23.9	9.2
Amphiodia sp (EO) ‡	2.3	0 - 10	2.0	1.0	13.8	4.1	10.4	8.6	3.3	7.7	11.4	0 - 60	3.7	17.8
Euphilomedes producta (CO)	12.4	2 - 50	11.4	21.1	10.1	12.3	6.5	8.4	11.0	8.5	9.3	0 - 62	11.7	7.4
Amphiuridae (EO) ‡	4.4	0 - 18	3.6	2.8	11.9	6.8	8.4	6.2	4.5	3.6	9.3	0 - 81	5.8	6.2
Pectinaria californiensis (P)	11.2	0 - 43	6.5	14.4	12.8	12.4	11.7	2.3	2.1	2.3	8.2	0 - 76	7.7	7.6
Chaetozone hartmanae (P)	1.4	0 - 12	0.6	1.5	8.5	17.9	6.4	10.9	18.6	14.1	9.6	0 - 65	18.2	10.1
Euphilomedes carcharodonta (CO)	6.1	0 - 37	6.7	0.5	6.1	14.3	0.8	12.8	25.0	1.6	9.4	0 - 52	19.4	1.3
Prionospio jubata (P)	3.2	0 - 17	3.4	3.0	3.4	5.6	1.5	10.8	21.5	4.9	7.0	0 - 114	12.9	3.1
Myriochele gracilis (P)	3.8	0 - 26	2.3	5.3	4.8	3.1	8.5	9.5	13.5	9.8	6.9	0 - 68	7.9	9.1

* Dominant Taxa = 10 most abundant taxa collected during either the pre-discharge (n = 120) or post-discharge periods (n = 336).

† *Spiophanes duplex* = previously reported as *S. missionensis*.

‡ *Amphiodia* sp and Amphiuridae probably represent juvenile (i.e., unidentifiable) *Amphiodia urtica*.

Taxa Codes: EO = Echinodermata, Ophiuroidea; P = Polychaeta; CO = Crustacea, Ostracoda; CA = Crustacea, Amphipoda; MB = Mollusca, Bivalvia.

since monitoring began. Of these specimens, only 20 occurred in the January and July surveys analyzed herein. These records include a total of 2 specimens of *D. longicornis* collected at station E14 in July 1994, while 18 specimens of *A. brevis* have been collected since 1992 (i.e., one specimen at E25 in January 1992, two specimens at E23 and one specimen at E11 in July 2005, one specimen at B9 in January 2006, and 13 specimens at station E14 in July 2006). Consequently, populations of these indicator species provide little evidence of organic loading in benthic sediments. The lack of such precursors indicates no habitat degradation is occurring off Point Loma.

Echinodermata: Echinoderms accounted for 15% of the total infaunal abundance at outfall depths off Point Loma, with a moderate increase apparent between the pre- and post-discharge periods (Table E-5). This increase was due primarily to higher abundances since 2001 (i.e., 1994-2000 post-discharge period in Table E-5).

The ophiuroid *Amphiodia urtica* has been suggested as a key bioindicator, because it is one of the most abundant species at mainland shelf depths in the SCB and its populations tend to decline near wastewater outfalls (e.g., Barnard and Ziesenhenne 1961; Thompson, et al. 1993; Bergen 1995; Scanland 1995; Mauer and Nguyen 1996). *Amphiodia urtica* was the most abundant echinoderm in the Point Loma region, comprising at least 55% of all echinoderm taxa sampled, including unidentified juveniles (Table E-7). This species was also the most abundant invertebrate overall. Populations of *A. urtica* averaged about 38 animals per 0.1 m^2 grab during the pre-discharge period compared to 28 per grab during the post-discharge period (Table E-7). Although these changes suggest an area-wide decrease after discharge began, the numbers may be misleading. For example, juvenile *A. urtica* are difficult or impossible to identify reliably to species, and identifications of young animals therefore tend to be either at the genus (i.e., *Amphiodia* sp) or family (Amphiuridae) level. Both of these taxa have also been recorded as dominants off Point Loma. Additionally, a congener of this species, *A. digitata*, also occurs in the region, although in much lower numbers and typically in coarser sediments; this species accounted for less than 6% of all *Amphiodia* off Point Loma. If we look at combined abundances of *Amphiodia*, there is little difference between pre-and post-discharge populations overall (Table E-7). Abundances did vary between stations, with stations E2, E14, and B12 having the lowest abundances in the pre- and post-discharge years (Figure E-30); however all stations had *Amphiodia* abundances that were within tolerance interval boundaries for the region (Attachment E.1). There was a significant change in the difference in abundances between station E14 and both of the “control” sites (E26 and B9) since the outfall began operation (Table E-6). For example, average *Amphiodia* abundances decreased about 82% at E14, while they remained relatively high at sites further away from the outfall (see Figure E-30). Although this pattern is consistent with the predicted effects of organic enrichment, predation by fish predators (e.g., basses and surfperch) attracted to the outfall pipe may also contribute to reduced *Amphiodia* numbers in nearby areas such as station E14 (e.g., see Davis et al. 1982, Ambrose and Anderson 1990, Posey and Ambrose 1994). For example, *Amphiodia* abundances at nearby stations E17 and E11 appear much less affected by the wastewater discharge (Figure E-30). Whether or not these population changes are due to wastewater discharge, increased predation pressure, or some other factor, abundances of *Amphiodia* near the outfall and elsewhere are still within the range of natural variability seen at similar depths throughout the SCB (e.g., Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007).

Crustacea: As a group, crustaceans represented about 17% of the total infaunal abundance (Table E-5). Crustacean abundances tended to be slightly higher during the post-discharge period than prior to discharge, although there was little change in the relative proportion of this taxon to most other groups (i.e., 17% pre-discharge versus 16% post-discharge over all sites). Overall, there does not appear to be any consistent outfall-related pattern in crustacean abundances (Figure E-31). Crustacea comprised 17% of the overall invertebrate abundance at station E14 before and after the initiation of discharge.

The ostracod *Euphilomedes producta* was the most abundant crustacean, being the seventh most abundant species inhabiting the benthos off Point Loma (Table E-7). This species and its congener, *E. carcharodonta*, are of interest as bioindicators since their abundances are generally considered to increase near outfalls. There appears to be a slight enhancement in numbers of *Euphilomedes* near the outfall (i.e., at stations E11, E14, E17) despite the apparently cyclic nature of their populations (Figure E-32). For example,

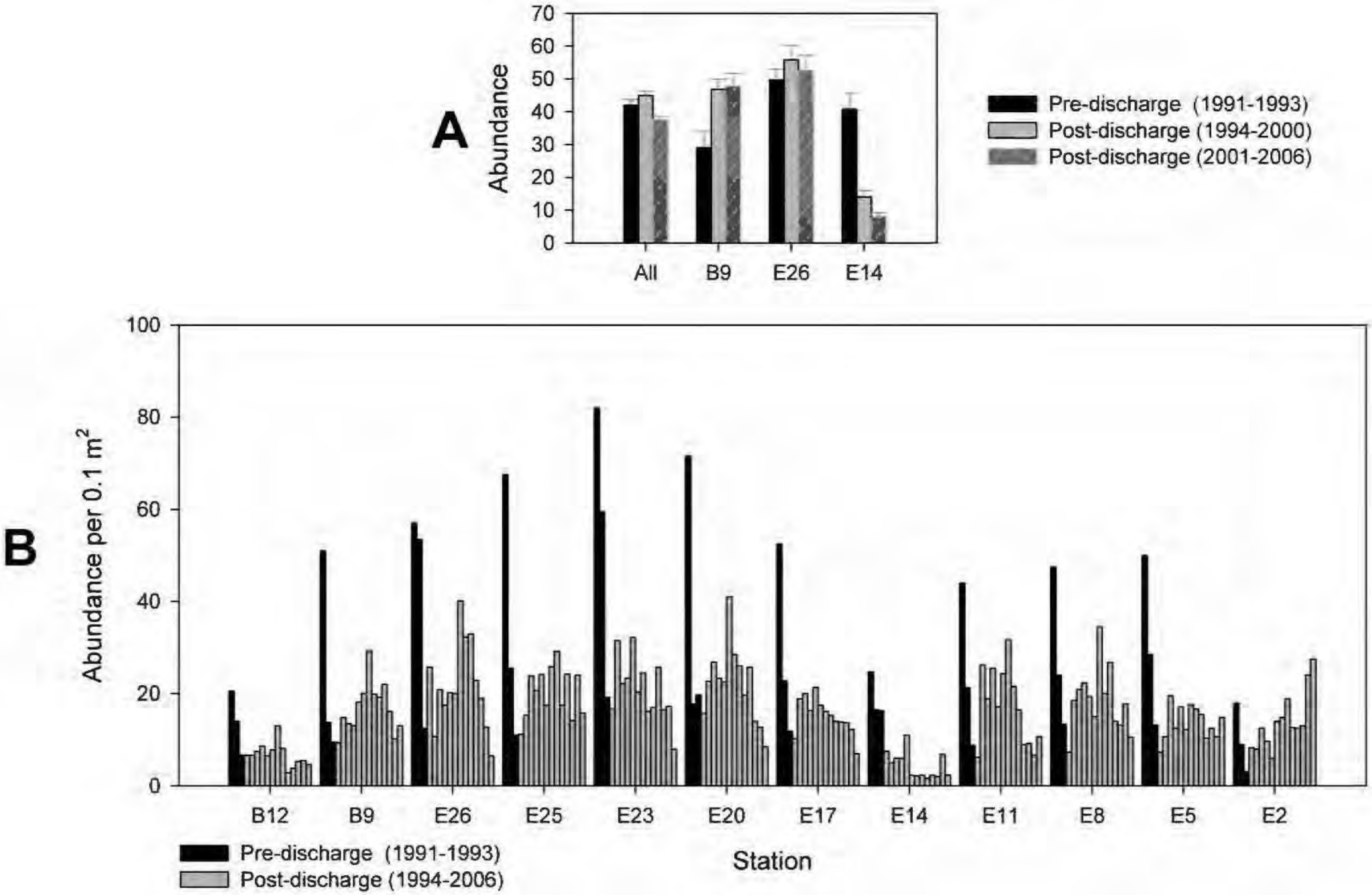


FIGURE E-30. Abundance of *Amphiodia* spp (Echinodermata, Ophiuroidea) at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 SE); (B) July surveys only, all stations.

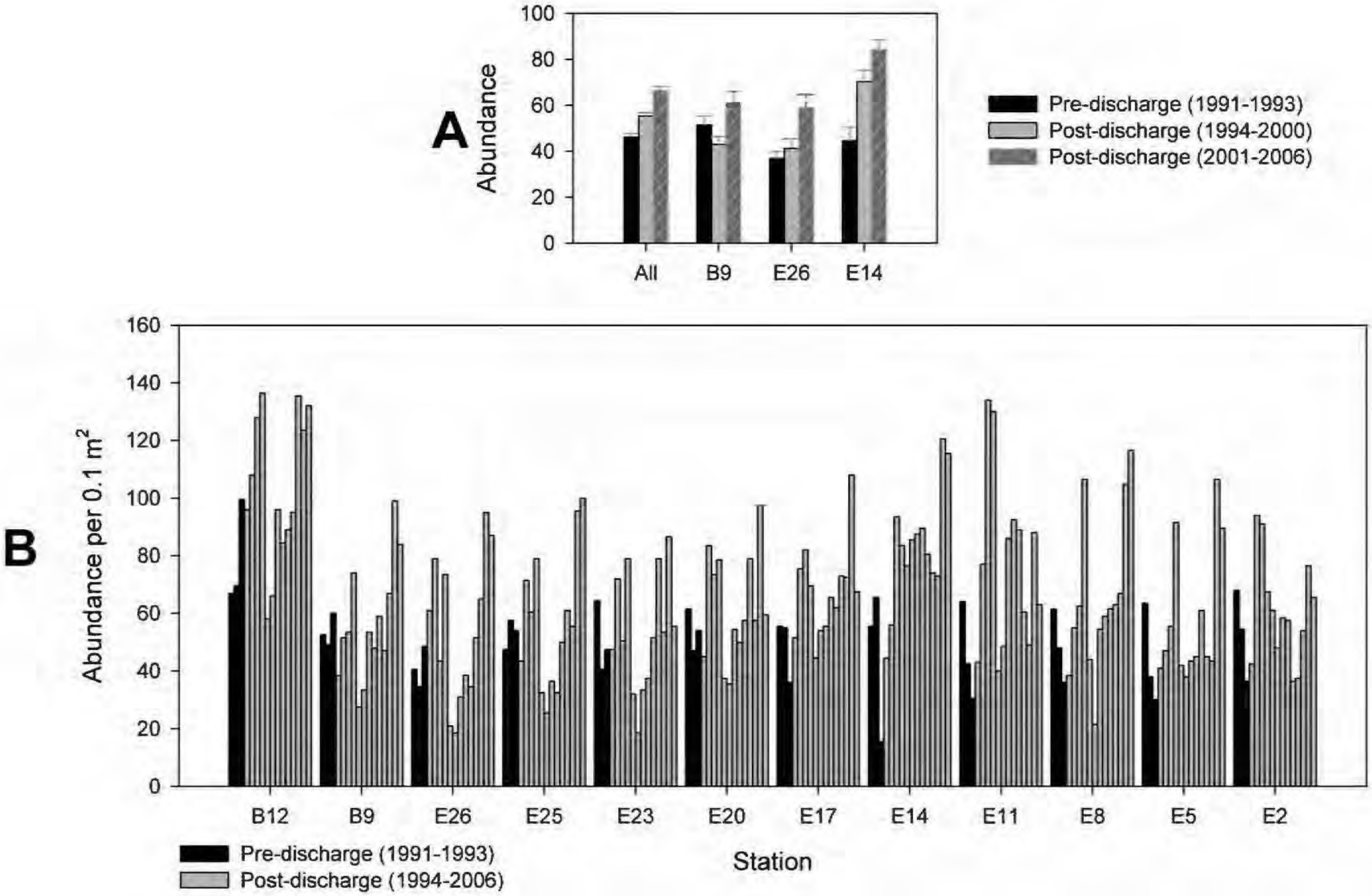


FIGURE E-31. Crustacean abundance at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

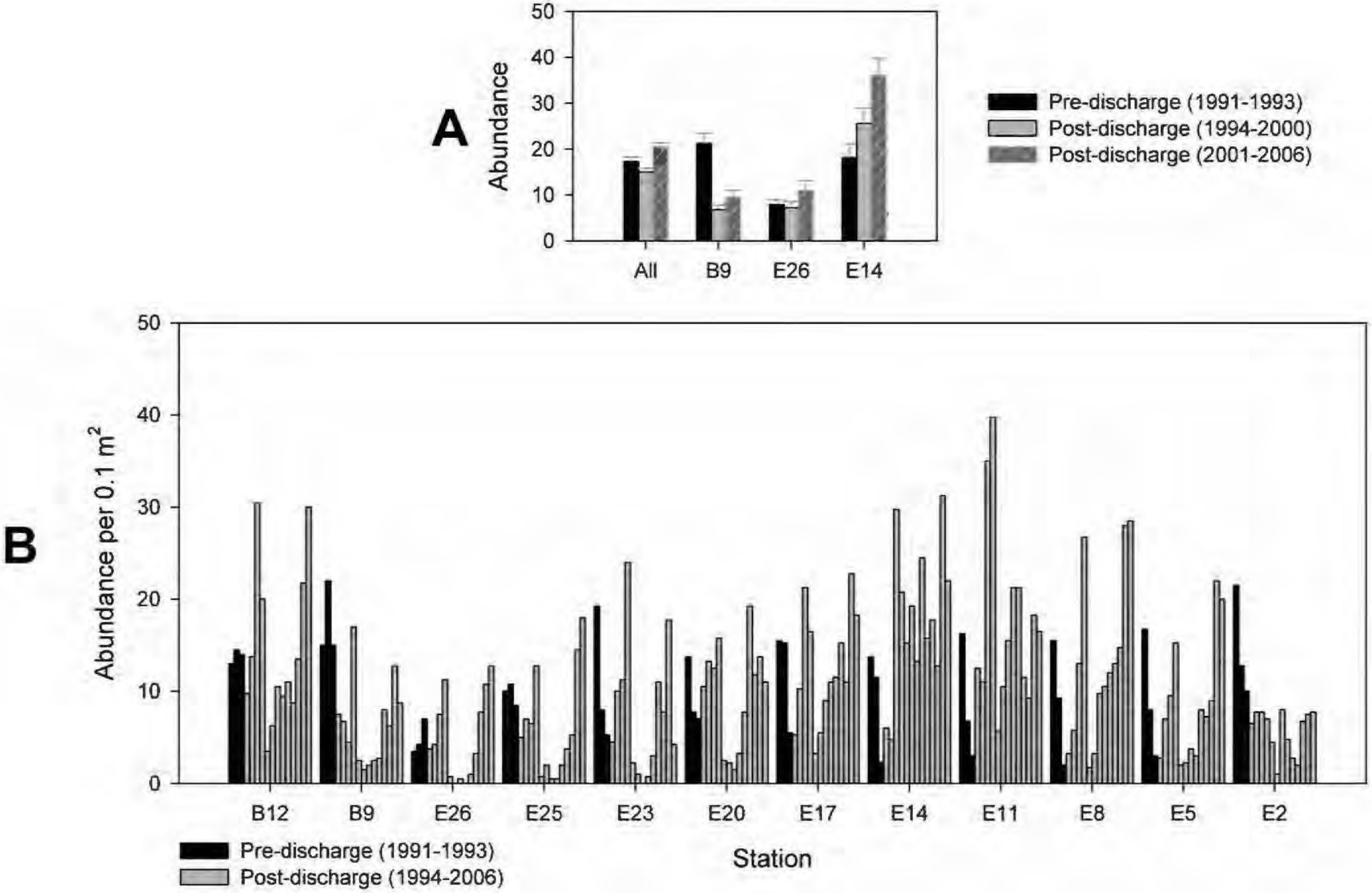


FIGURE E-32. Abundance of *Euphilomedes* spp (Crustacea, Ostracoda) at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 SE); (B) July surveys only, all stations.

average abundances of these species combined (*Euphilomedes* spp) increased from about 18 per 0.1 m^2 grab at station E14 during the pre-discharge period to around 30 animals per grab afterwards. In contrast, abundances of these ostracods decreased from about 21 to 8 individuals per grab at reference station B9 over this same time period. Ostracod abundances above the upper tolerance interval for San Diego are wide spread (Attachment E.1), and may be indicative of region-wide effect associated with inputs from storm related discharges, plankton degradation, or other sources of enrichment.

Abundances of other crustacean taxa known to be sensitive to organic enrichment were also examined. These included amphipods in the genera *Ampelisca* (Family Ampeliscidae) and *Rhepoxynius* (Family Phoxocephalidae). Although BACIP results demonstrate no significant change in mean differences between E14 and either reference site for populations of *Ampelisca* spp, they show mixed results for populations of *Rhepoxynius* spp with populations at station E14 being significantly different from those at reference station B9, but not station E26 (Table E-6). However, caution should be exercised in interpreting these results given the relatively low abundances of these amphipods. In fact, despite the differences indicated by the BACIP tests, average abundances of these amphipods actually changed very little near the Point Loma outfall and were within the tolerance interval boundaries calculated for the region (Attachment E.1). This suggests that whatever changes were occurring had little to do with wastewater discharge. *Ampelisca* spp, for example, averaged 7.8 and 8.1 amphipods per grab at station E14 during the pre- and post-discharge periods, respectively, while *Rhepoxynius* averaged about 4.6 and 5.1 individuals per grab during these times. In contrast, abundances of *Ampelisca* at reference station B9 increased slightly from 6.6 to 11.6 individuals per grab), while abundances of *Rhepoxynius* declined from 6.7 to 2.8 individuals per grab between 1994 and 2000 (i.e., see Table E-7, 1994-2000 post-discharge period), but then rebounded afterwards (i.e., 5.3 individuals per grab).

<u>Mollusca</u>: Molluscs, mostly bivalves and gastropods, represented about 7% of the infaunal abundance off Point Loma (Table E-5). Changes in mollusc populations suggested an apparent outfall-related pattern, with densities increasing more near the outfall than at sites further away during the post-discharge period (Figure E-33). For

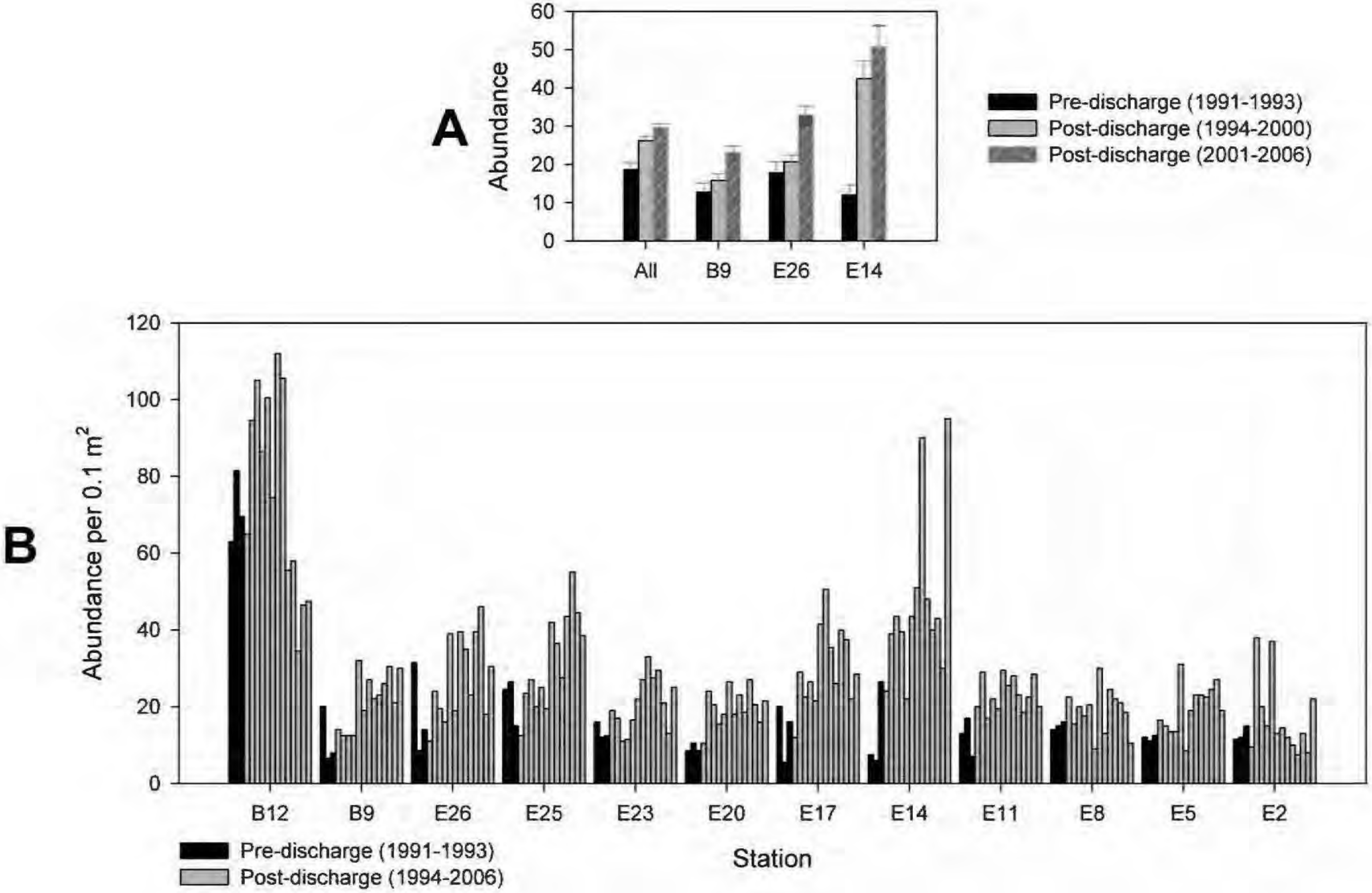


FIGURE E-33. Mollusc abundance at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1SE); (B) July surveys only, all stations.

example, the average number of molluscs increased from 12 to 46 animals per grab at station E14 nearest the outfall while remaining relatively stable (e.g., 13-19 animals/grab) at reference station B9.

The bivalve *Parvilucina tenuisculpta* has been suggested as an indicator species that is found in high abundances in areas of moderate organic enrichment. However, populations of this species averaged only 3.9 animals per 0.1 m^2 off Point Loma during the entire post-discharge period (Table E-7). Comparison among sites did indicate that numbers of *Parvilucina* increased somewhat at the nearfield stations and decreased at the farfield stations after the onset of discharge (Figure E-34). However, as with *Euphilomedes* spp, abundances above calculated tolerance intervals are widespread (Attachment E.1). Although this enhancement near the outfall is consistent with an enrichment effect, *Parvilucina* densities off Point Loma are still within the range of those that occur at similar depths throughout the SCB.

Summary of Effects on Benthic Community Structure

Benthic communities around the Point Loma Ocean Outfall continue to be dominated by ophiuroid-polychaete based assemblages, with few major changes having occurred since monitoring began (see City of San Diego 1995a, b, 1996, 1997a, 1998a, 1999a, 2000b, 2001, 2002a, 2003a, 2004a, 2005a, 2006a, 2007a). The brittle star *Amphiodia urtica* and the spionid polychaete *Spiophanes duplex* dominated assemblages during both the pre- and post-discharge periods. Polychaetes continue to account for the greatest number of species and individuals, while the ophiuroid *Amphiodia urtica* is the most abundant individual species in both periods. Similar assemblages have been described by Barnard and Ziesenhenne (1961), Jones (1969), Fauchald and Jones (1979), Thompson et al. (1987, 1992, 1993), EcoAnalysis et al. (1993), Zmarzly et al. (1994), Diener and Fuller (1995), Bergen et al. (1998, 1999), and Ranasinghe et al. (2003, 2007). This wide-spread assemblage dominates the southern California benthos, including mainland shelf depths throughout the entire San Diego coastal region (see City of San Diego 1997b, 1998b, 1999b, 2002b, 2003b, 2004b, 2005b, 2006b, 2007b), although patches of other benthic assemblages occur where different sediment types are found (e.g., near river mouths and

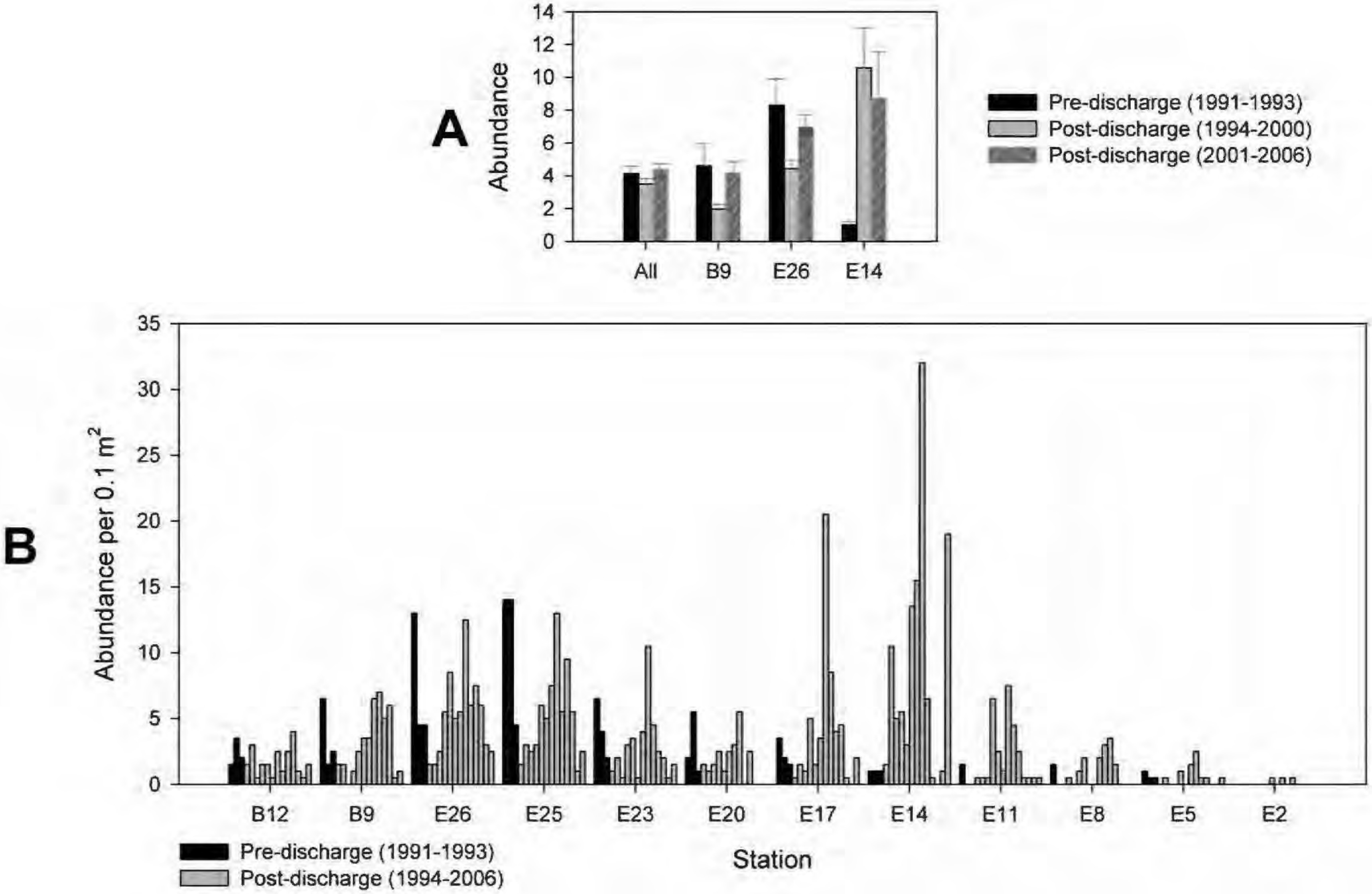


FIGURE E-34. Abundance of *Parvilucina tenuisculpta* (Mollusca, Bivalvia) at outfall depths near the Point Loma Ocean Outfall (1991-2006). (A) pre- vs. post-discharge summary (means + 1 SE); (B) July surveys only, all stations.

submarine canyons). The shifts in community composition that have occurred over time probably represent variation in southern California assemblages related to such things as large-scale oceanographic events (e.g., El Niño/La Niña conditions), stochastic natural events, or natural population fluctuations.

Although variable, benthic communities off Point Loma have remained similar between years in terms of the number of species, number of individuals, and dominance (e.g., see City of San Diego 2002-2007a for recent years). In addition, values for these parameters are similar to those described for other sites throughout southern California (e.g., Thompson et al. 1992; EcoAnalysis et al. 1993; Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007). In spite of this overall stability, a comparison of pre- and post-discharge data for the Point Loma region indicates some general trends. For example, there was an overall increase in the number of species and infaunal abundances after discharge began. However, the increase in species appeared most pronounced nearest the outfall, a pattern opposite that expected if environmental degradation were occurring. In addition, the increase in abundances was accompanied by a general decrease in dominance, a pattern also inconsistent with predicted pollution effects. There did appear to be a minor shift in the relative abundance of phyla at some sites that may be related to the outfall, with echinoderms decreasing and polychaetes and molluscs increasing after the onset of wastewater discharge. However, evaluating the net effects it is clear that benthic communities surrounding the Point Loma outfall are not numerically dominated by a few pollution tolerant species, a precursor to adverse environmental impact.

BACIP analyses revealed a few patterns in the difference between the likely impact site (station E14) and the “control” sites (stations E26 and B9) that could be attributed to the onset of discharge (Table E-6). The total number of species, infaunal abundance, abundance of ophiuroids (*Amphiodia* spp), and BRI values demonstrated a significant change between the impact site and both “control” sites since the outfall began operation. It is unclear what caused the difference in the number of infaunal species, since species richness has increased across all sampling sites. Higher species richness values near the outfall may be related to the greater variability at the impact site or to a decline in ophiuroid populations (see Ambrose 1993). Additionally, the difference in *Amphiodia* populations is due to both a decrease in numbers near the outfall and corresponding increases at the "control" sites during the post-discharge period. Although the decrease near the outfall is consistent with organic enrichment predictions, reduced *Amphiodia* numbers could also be an artifact of the outfall pipe attracting predators (e.g., Davis et al. 1982). In addition, populations of *Amphiodia* have declined at the farfield stations in recent years, an affect that may be related to natural population fluctuations. Whether or not these population changes are due to wastewater discharge, increased predation pressure, or some other factor, abundances of *Amphiodia* near the outfall and elsewhere are still within the range of natural variability seen at similar depths throughout the SCB (see Bergen et al. 1998, 2001; Ranasinghe et al. 2003, 2007). The difference in BRI values was due to an increase in this index at the impact site after discharge began and a corresponding decrease at the reference sites. Although this pattern is consistent with a disturbance event, BRI values at this and all other sites are still considered characteristic of reference conditions. The results were more ambiguous for abundances of amphipod crustaceans, in part because the indicator taxa considered occurred in fairly low abundances. There was no net change in the mean difference between sites for numbers of ampeliscid amphipods, while there has been a significant change in abundances of phoxocephalid amphipods between the impact site and "control" site B9, but not E26. Finally, although stations near the PLOO demonstrated some change in mean differences for several of these parameters, values for station E14 were typically within tolerance limits calculated from the San Diego region (Attachment E.1).

Patterns of change in populations of the polychaete *Capitella* "*capitata*," the bivalve *Parvilucina tenuiscuplta*, and ostracods of the genus *Euphilomedes* suggest a slight enrichment effect near the outfall; however densities of these organisms are still within the range of natural variation for the SCB. Other polychaetes that have been suggested as bioindicators also revealed little evidence of outfall related changes. For example, populations of worms in the genera *Mediomastus*, *Dorvillea* and *Armandia* underwent few changes that could indicate significant organic loading or habitat degradation in the vicinity of the outfall, although a one-time rise in the populations of *Armandia* (n = 13) at station E14 in 2006 caused that station's BRI value to increase.

A few other changes near the outfall may suggest some effects coincident with anthropogenic activities. For example, the increased variability in number of species and infaunal abundance at station E14 since discharge began may be indicative of community destabilization (see Warwick and Clarke 1993; Zmarzly et al. 1994). Sediment sulfides and BOD have also increased at this station since 1993 (see Section E.4). Finally, the occurrence of coarse sediments at station E14 at various times in the past and the corresponding shifts in assemblage structure suggest that some of these changes may be related to localized physical disturbances associated with the presence of the outfall pipe (e.g., shifting or patchy sediments, presence of construction debris), as well as to organic enrichment (e.g., see City of San Diego 1999b, 2000b).

While it is difficult to detect specific or direct effects of the City of San Diego’s ocean outfall on the offshore benthos, it is possible to see some changes occurring nearest the discharge site. Perhaps because of the minimal extent of these changes, it is not possible to determine whether these effects are due to the physical structure of the outfall or to organic enrichment associated with the discharge of effluent. Such impacts have spatial and temporal dimensions that vary depending on a range of biological and physical factors. In addition, abundances of soft-bottom invertebrates exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, 1992b; Otway 1995). The effects associated with the discharge of advanced primary (APT) and secondary treated sewage may also be negligible or difficult to detect in areas subjected to strong currents that facilitate the dispersion of the wastewater plume (see Diener and Fuller 1995). The minimal impact reported for San Diego's previous shallow water outfall (e.g., Zmarzly et al. 1994), combined with the high level of wastewater treatment (APT), an increased minimum dilution factor of 204:1 (vs. 113:1 at the old discharge site), and the deepwater location of the extended outfall decrease the chances that this discharge has or will impact the nearby benthos. Although some changes in benthic assemblages have occurred, assemblages near the outfall are still similar to those observed prior to discharge and to natural indigenous communities of the southern California outer continental shelf. Thus, after 13 years of operation, wastewater discharge through the Point Loma outfall has not caused degradation in benthic community structure.

Section E.6 – Demersal Fishes and Megabenthic Invertebrates

The City of San Diego has been monitoring demersal fish and megabenthic invertebrate communities in the offshore region surrounding the extended Point Loma Ocean Outfall since July 1991. Trawl surveys were conducted quarterly (January, April, July October) from July 1991 through July 2003, after which sampling was modified to semiannual surveys during January and July each year (see Figure E-35 for station locations). This section summarizes the results of the trawl surveys conducted during the pre-discharge and post-discharge monitoring periods to evaluate possible effects of the wastewater discharge.

Data Sets and Analyses

The following analyses of demersal fish and megabenthic invertebrate communities at the Point Loma outfall monitoring stations are based on a dataset consisting of the results from all January and July trawl surveys conducted from July 1991 through July 2006 at six stations (see Sections E.2 and E.3 for a description of dataset reduction). This includes five pre-discharge surveys (July 1991-July 1993) and 26 post-discharge surveys (January 1994-July 2006) with the subsequent database consisting of information collected from a total of 186 trawls (31 surveys, 6 stations, 1 replicate per station). Although a second replicate trawl was taken at each station through 1995, only data from the first trawl are considered here for comparison to subsequent years. Overall, the above surveys include 30 trawls for the pre-discharge period and 156 trawls for the post-discharge period. The post-discharge period includes 84 trawls (14 surveys) from 1994-2000 that were analyzed for the last waiver application, and 72 trawls (12 surveys) from 2001-2006, which covers the current application period. In addition, since fish and invertebrate communities often vary with seasons, some comparisons are limited to data collected during the summer (July) surveys. This summary of fish and invertebrate populations off Point Loma focuses on community parameters such as the number of species (species richness), total abundances, and changes in the abundance of dominant or common species.

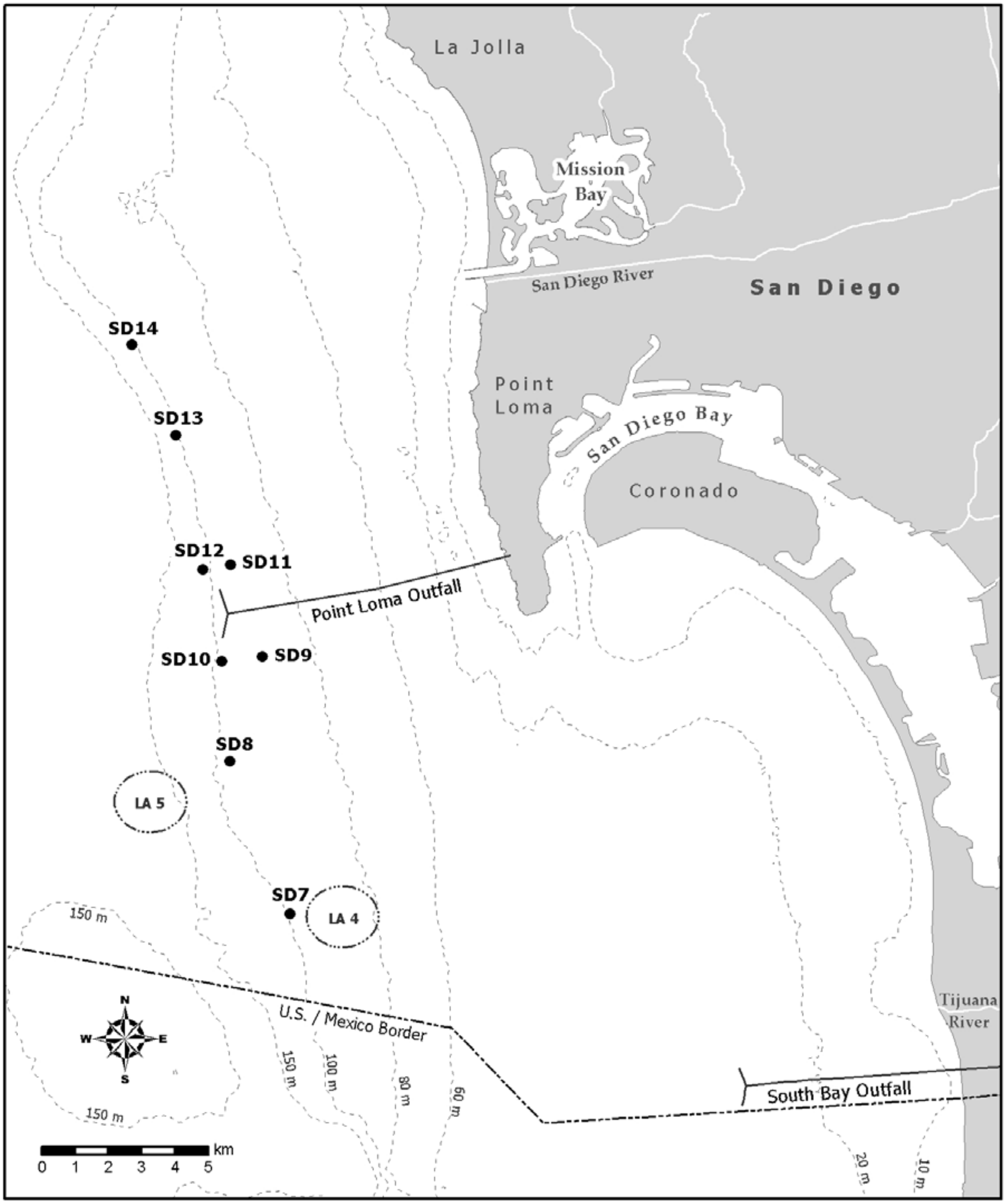


FIGURE E-35. Otter trawl monitoring stations surrounding the City of San Diego's Point Loma Ocean Outfall. Stations SD7, SD8, SD10, SD12, SD13, SD14 = current monitoring sites that are the focus of the analyses presented herein; sampling at stations SD9 and SD11 was discontinued in late 2003. See text (Section E.2) for details of analyses and changes to sampling program over time. LA-4 and LA-5 = EPA designated dredge materials disposal sites.

Bottom-dwelling fish and invertebrate populations were sampled at each of the six trawl stations. These stations are located at depths of approximately 100 m (330 ft) and range from about 8 km north to 9 km south of the outfall (Figure E-35). For purposes of analysis and discussion, these stations are grouped into nearfield and farfield (or reference) sites. Stations SD10 and SD12 are located within 1.2 km of the outfall and are considered the nearfield stations. Stations SD7, SD8, SD13 and SD14 are located farther away and are considered the farfield stations; SD7 and SD8 are the southern farfield stations, and SD13 and SD14 are the northern farfield stations.

Demersal fish and megabenthic invertebrates were collected using a 7.6 m Marinovich otter trawl net with a 1.3 cm cod-end mesh (see Mearns and Allen 1978). The net was towed for 10 minutes of bottom time at about 2.5 knots along a predetermined heading. All captured organisms were identified to species or to the lowest taxon possible in the field or returned to the laboratory for further identification. For fish, the total number of individuals and total biomass (wet weight, kg) were recorded for each species. Additionally, each individual fish was inspected for the presence of external parasites or physical anomalies (e.g., tumors, fin erosion, discoloration) and measured to the nearest centimeter size class (standard length). For invertebrates, the total number of individuals was recorded per species. When the white sea urchin, *Lytechinus pictus*, was collected in large numbers, its abundance was estimated by multiplying the total number of individuals per 1.0 kg subsample by the total urchin biomass.

Results

Demersal Fishes

A total of 61,580 fishes were collected in 186 trawls conducted off Point Loma during January and July from 1991 through 2006 (Attachment E.2). These fishes comprised 75 different taxa, including 71 distinct species. Overall, the demersal fish community was dominated by Pacific sanddabs, which alone accounted for approximately 50% of the total catch over these years. Other relatively abundant species off Point Loma include the yellowchin sculpin (~13%), halfbanded rockfish (~8%), Dover sole (~6%) and longspine combfish (~5%). All of these species are common in the types of soft-bottom habitats that characterize much of this region and the mainland shelf of the SCB. There appears to be only minor differences between the pre- and post-discharge periods at the nearfield and farfield sites (see Table E-8). For example, the relative abundance of Pacific sanddabs comprised a smaller proportion of the nearfield fish assemblage during the post-discharge period than prior to discharge, while they remained the same over time at the farfield sites. The opposite pattern was true for longspine combfish and halfbanded rockfish.

Patterns of change in species richness (number of species) values for the demersal fish community were similar at the nearfield and farfield stations during the pre-discharge and post-discharge periods (Table E-9, Figure E-36). Overall, an average of 13-15 species was collected per haul during these two periods. However, individual hauls of fish were highly variable, ranging from 7 to 26 species each. Variation in the number of species at the nearfield stations was within the range of that seen at the farfield stations over time (Figure E-36a). In addition, no changes in species richness were observed near the outfall that coincided with the onset of discharge (Figure E-36b). Consequently, there were no apparent temporal or spatial trends in the number of fish species that might suggest an outfall-related impact.

The total fish catch was also highly variable over time, ranging from 44 to 2322 fishes per haul (Table E-9, Figure E-37). Average abundances were higher during the post-discharge period at both nearfield and farfield sites (Table E-9). The number of fish per haul increased about 53% (from 208 to 440 individuals) at the nearfield stations and about 39% (from 217 to 354 individuals) at the farfield stations between these periods. Most of this change, however, occurred during 2001-2006. For example, the nearfield stations averaged 582 individuals per haul from 2001-2006, relative to 319 in the 1994-2000 post-discharge period and 208 prior to discharge. The farfield stations averaged 217 in each period prior to 2001, and 310 from 2001-2006. Abundances were somewhat lower at the southernmost stations (SD7, SD8) than elsewhere (Figure E-37a, b), and nearfield abundances were generally more similar to those at the northern sites (stations

TABLE E-8

Summary of dominant fish species collected off Point Loma during January and July trawls from 1991 through 2006 (n=31 surveys); these fishes represent 95% of the total abundance caught during this time. Data are presented for both pre-discharge (1991-1993) and post-discharge (1994-2006) periods and summarized for all six trawl stations combined and separately for the two nearfield stations (SD10, SD12) and four farfield stations (SD7, SD8, SD13, SD14). Data are expressed as the percent of total abundance and as the mean abundance per trawl.

	All Stations (n = 6)				Nearfield Stations (n = 2)				Farfield Stations (n = 4)			
	Pre-discharge	Post-discharge			Pre-discharge	Post-discharge			Pre-discharge	Post-discharge		
	(1991-1993)	(1994-2000)	(2001-2006)	(1994-2006)	(1991-1993)	(1994-2000)	(2001-2006)	(1994-2006)	(1991-1993)	(1994-2000)	(2001-2006)	(1994-2006)
Percent Abundance												
Pacific sanddab	55	51	47	49	57	52	34	41	55	50	59	55
Plainfin midshipman	10	5	1	3	8	4	1	2	11	5	2	3
Yellowchin sculpin	6	17	11	13	3	15	13	14	8	18	9	13
Stripetail rockfish	4	5	2	3	7	4	1	2	2	5	2	4
Dover sole	4	5	7	6	4	6	6	6	4	4	7	6
Longspine combfish	4	3	7	5	4	3	10	7	3	3	5	4
Longfin sanddab	3	5	1	3	2	3	1	2	3	6	2	4
Pink seaperch	3	1	1	1	2	2	1	1	3	1	1	1
Halfbanded rockfish	2	1	15	9	3	2	27	17	1	1	5	3
Shortspine combfish	2	1	1	1	1	1	1	1	2	1	1	1
California tonguefish	1	2	1	1	1	1	1	1	1	2	1	1
Mean Abundance												
Pacific sanddab	118	150	199	173	117	166	196	180	119	143	201	170
Plainfin midshipman	22	14	5	10	17	14	4	9	24	13	6	10
Yellowchin sculpin	13	50	45	47	7	49	75	61	17	50	29	41
Stripetail rockfish	8	13	7	11	15	11	7	9	4	15	8	11
Dover sole	9	15	28	21	9	19	38	28	9	12	23	17
Longspine combfish	8	8	31	19	9	11	58	32	8	7	18	12
Longfin sanddab	5	15	5	10	4	10	3	7	6	17	5	12
Pink seaperch	6	4	4	4	5	5	4	5	6	3	4	3
Halfbanded rockfish	4	3	63	31	5	6	157	75	3	2	15	8
Shortspine combfish	3	2	6	4	2	2	8	4	4	2	5	3
California tonguefish	2	5	4	4	2	4	3	4	2	5	4	4

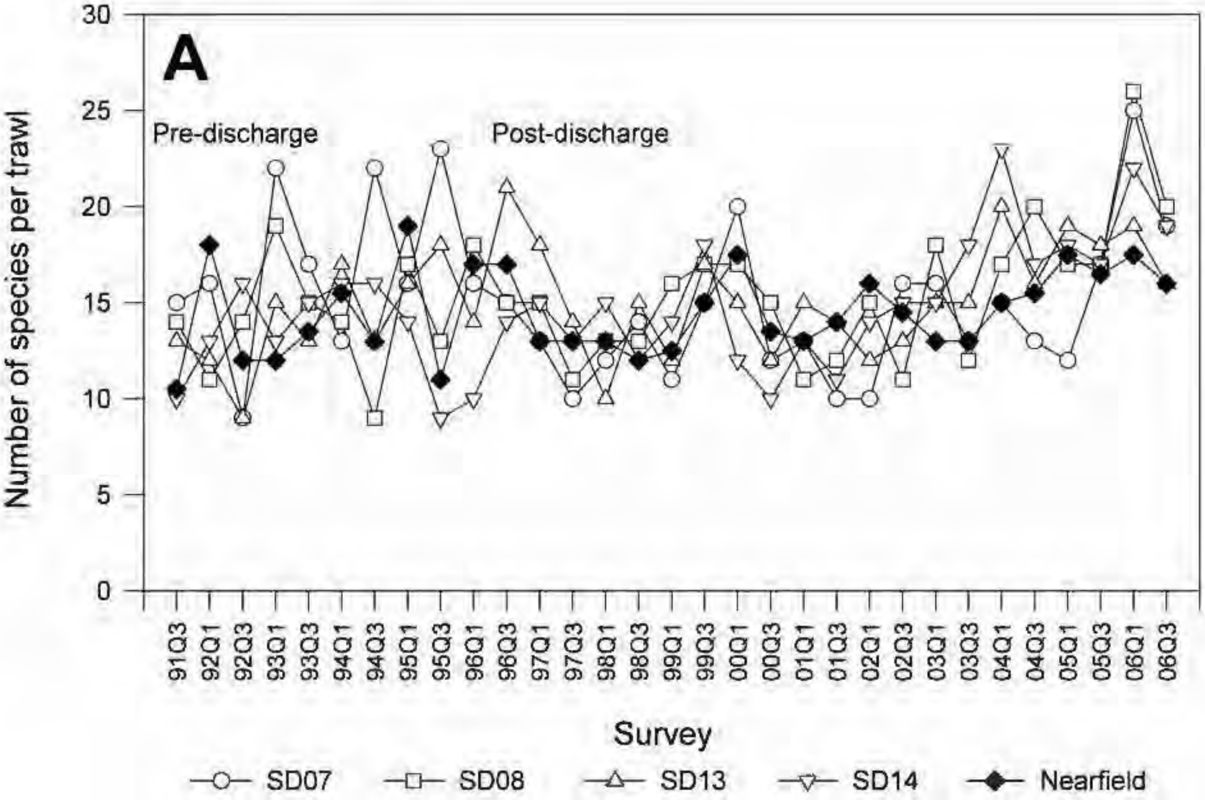
TABLE E-9

Summary of the number of fish species, fish abundance, and diversity (H') for the January and July Point Loma Ocean Outfall (PLOO) trawl surveys (n=31) compared to the SCCWRP 1985 reference survey, 1994 Southern California Bight Pilot Project (SCBPP), and 1998 and 2003 Southern California Bight Regional Surveys (Bight'98, Bight'03). PLOO data are presented for both pre-discharge (1991-1993) and post-discharge (1994-2006) periods and summarized for all six trawl stations combined and separately for the two nearfield stations (SD10, SD12) and four farfield stations (SD7, SD8, SD13, SD14). All data are expressed as means with ranges in parentheses.

	SCCWRP Survey *		**SCB 1994, 1998, and 2003 Regional Surveys †**			**PLOO Surveys (1991-2006)**					
						Pre-discharge			**Post-discharge**		
	60-m	**150-m**	**SCBPP**	**Bight'98**	**Bight'03**	**Nearfield**	**Farfield**	**All Stations**	**Nearfield**	**Farfield**	**All Stations**
Species Richness	12 (5-16)	14 (8-22)	13 (3-18)	11 (0-26)	12 (3-24)	13 (8-19)	14 (9-22)	14 (8-22)	15 (7-20)	15 (9-26)	15 (7-26)
Abundance	201 (37-513)	334 (77-775)	157 (3-781)	157 (0-2102)	220 (8-942)	208 (63-399)	217 (51-453)	214 (51-453)	440 (44-2322)	310 (50-695)	354 (44-2322)
Diversity	1.4 (0.6-2.0)	1.6 (0.9-2.2)	1.6 (0.4-2.6)	1.6 (0-2.4)	1.6 (0.2-2.3)	1.4 (0.1-2.3)	1.5 (1.1-2.0)	1.4 (0.7-2.3)	1.4 (0.8-2.1)	1.5 (0.8-2.2)	1.4 (0.8-2.2)

* Southern California Bight Reference Survey (n=13 trawls)

† Southern California Bight Regional Monitoring Programs (n = 114, 257, and 181, respectively).



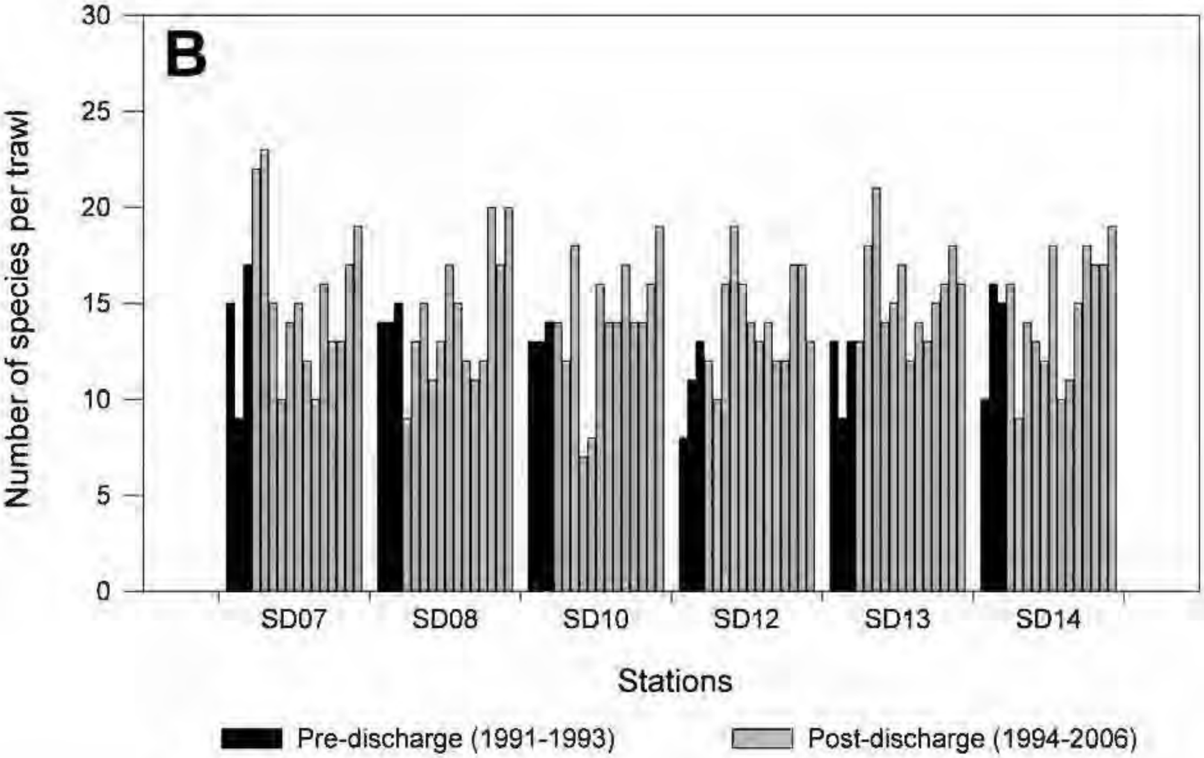


FIGURE E-36. Number of demersal fish species near the Point Loma Ocean Outfall (1991-2006). (A) no. species/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations vs combined nearfield stations (SD10, SD12); (B) no. species/trawl at each station, July surveys only.

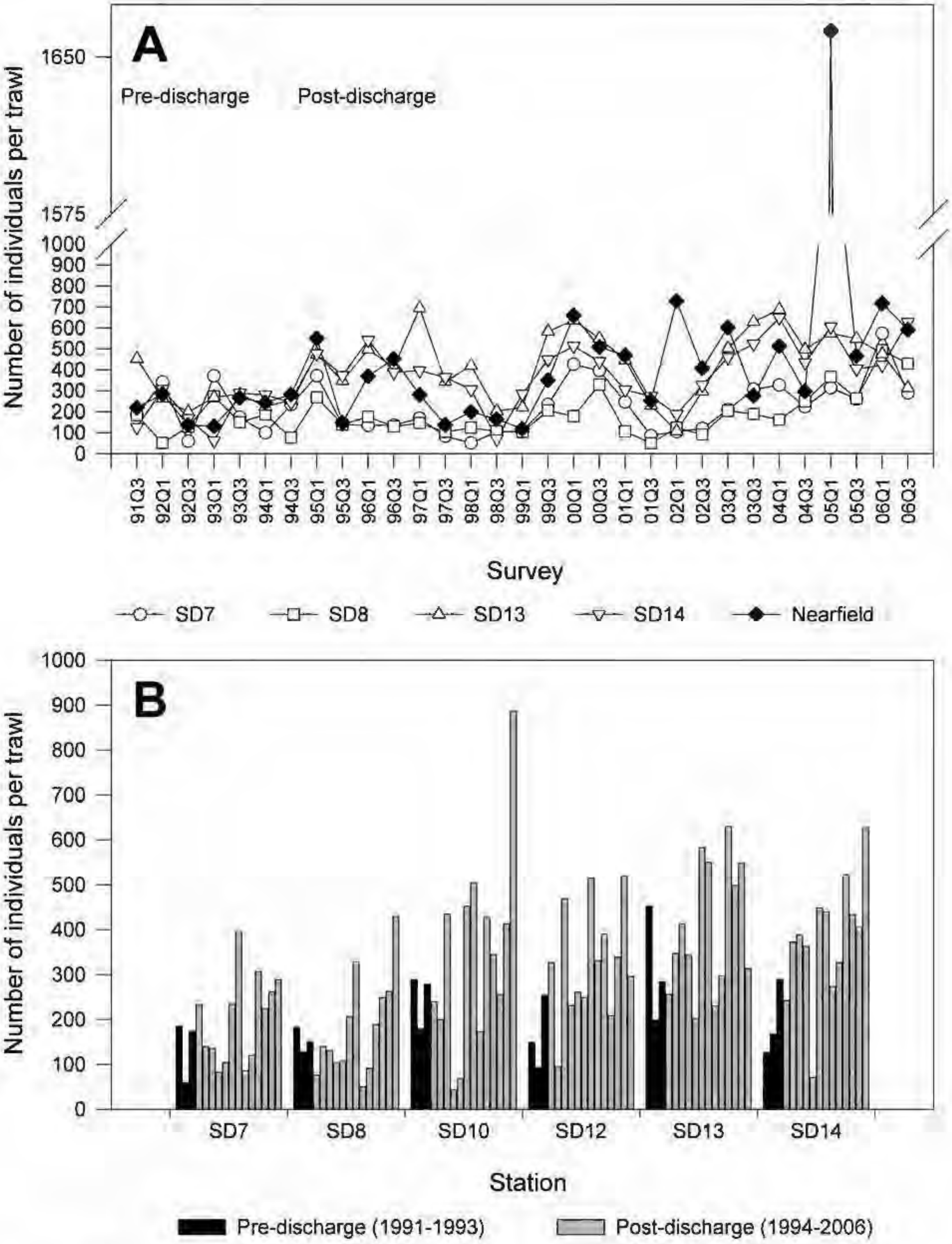


FIGURE E-37. Abundance of demersal fishes near the Point Loma Ocean Outfall (1991-2006). (A) abundance/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations vs combined nearfield stations (SD10, SD12); (B) abundance/trawl at each station, July surveys only.

SD13 and SD14). As with species richness, the variability in fish abundances over time at the nearfield stations was within the range of that seen at the farfield sites (Figure E-37a). The single exception occurred in January 2005 when large numbers of halfbanded rockfish were collected at stations SD10 and SD12 (see City of San Diego 2006). In addition, there were no discernable changes among the nearfield stations that coincided with the onset of discharge (Figure E-37b).

A large amount of the variability described above is due to fluctuations in populations of dominant species. For example, Pacific sanddabs consistently comprised the largest fraction of the trawl catches, accounting for 55% and 49% of the region's fish communities during the pre- and post-discharge periods, respectively (Table E-8). However, numbers of this species varied greatly among all stations (Figure E-38a). At the farfield stations, the number of Pacific sanddabs ranged from 15 to 231 fish per haul prior to discharge, and from 8 to 453 fish afterwards (Figure E-38a). The range of sanddab abundances was generally similar at all sites. There was no indication of influence due to proximity of the outfall. The dramatic region-wide decrease in sanddab abundances between 1997 and 1998 was probably related to the presence of warmer waters associated with the 1997-1998 El Niño. Pacific sanddabs tend to be associated with cooler water temperatures (see Eschmeyer et al. 1983). Thus, populations of this species might be expected to decline during an El Niño event. A similar, but less dramatic decline occurred in 2001-2002, which was then followed by increases in abundances at the north farfield stations from 2003-2004 (see City of San Diego 2006).

Populations of several other dominant or occasionally abundant species also displayed considerable variability (Figures E-38). For example, populations of yellowchin sculpin have undergone seasonal fluctuations in numbers since monitoring began, with especially large catches occurring occasionally during the post-discharge period (Figure E-38b). Dover sole also appear to undergo cyclic population fluctuations (Figure E-38c); however, these changes are probably associated with changes in oceanic temperatures (i.e., higher numbers during colder regimes). More sporadic were occurrences of large populations of species such as halfbanded rockfish and longspine combfish (Figures E-38d, e). Longspine combfish were collected in large numbers at the nearfield stations

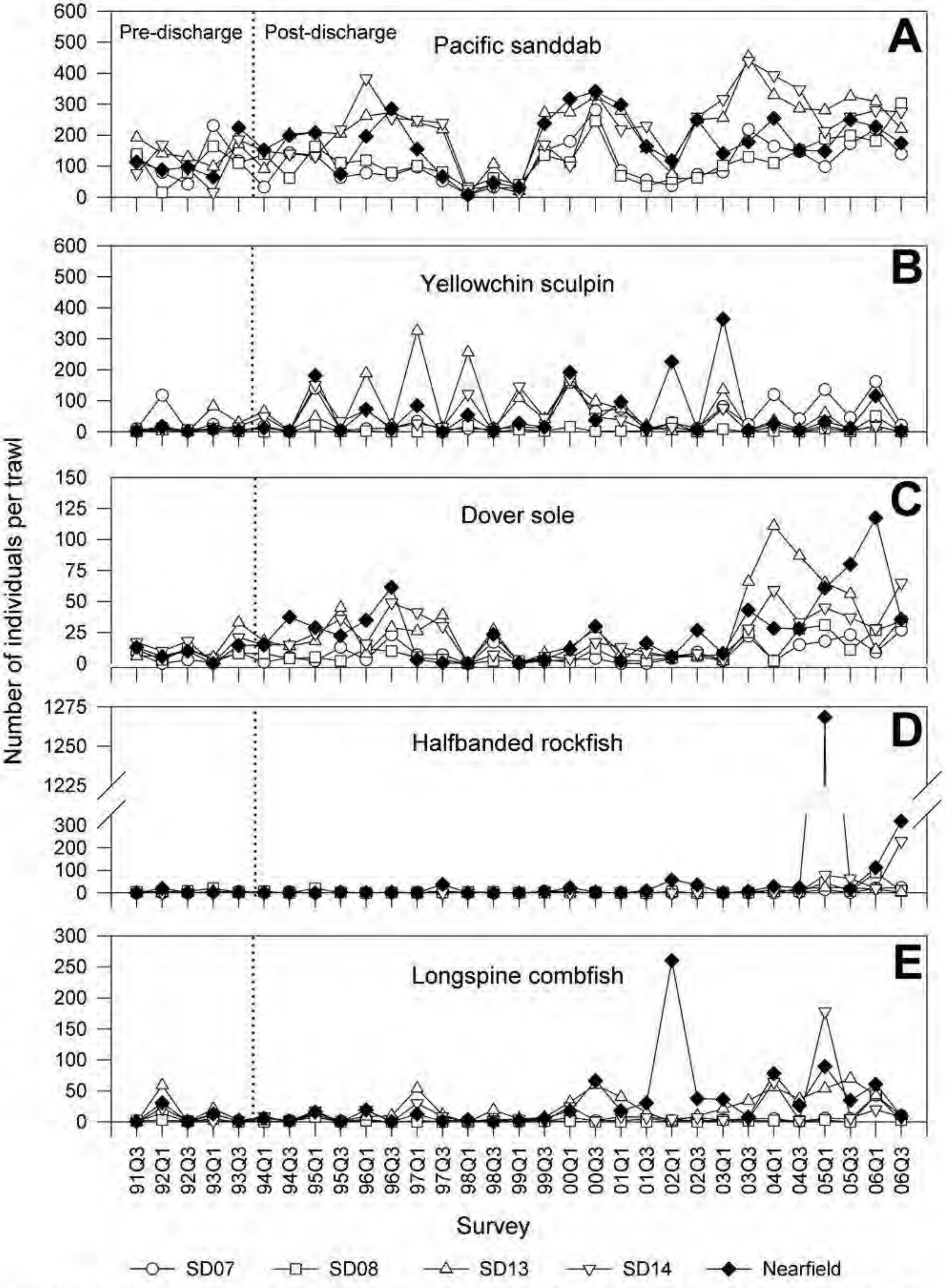


FIGURE E-38. Abundance of dominant fish species near the Point Loma Ocean Outfall (1991-2006) for south (SD7, SD8) and north (SD13, SD14) farfield stations vs combined nearfield stations (SD10, SD12); (A) Pacific sanddab; (B) yellowchin sculpin; (C) Dover sole; (D) halfbanded rockish; (E) longspine combfish.

in January 2002 and 2005, while halfbanded rockfish were also collected in very large numbers at these sites in January 2005 and July 2006. Otherwise these species occurred in much lower numbers. Overall, fluctuations in populations of these dominant fish near the outfall were within the range of variability observed at farfield sites. Thus, wastewater discharge is not negatively affecting demersal fish assemblages off Point Loma.

Megabenthic Invertebrates

A total of 337,390 megabenthic invertebrates, comprising 133 taxa, were recorded in the 186 January and July trawls off Point Loma between 1991 and 2006 (Attachment E.3). The sea urchin *Lytechinus pictus* dominated these trawl-caught assemblages, accounting for about 94% of the total catch. Other occasionally abundant species included the sea pen *Acanthoptilum* sp, and the sea urchin *Allocentrotus fragilis*. Most of the remaining species were captured infrequently and/or in low numbers, with 85 taxa being represented by 10 or fewer individuals since monitoring began.

The number of invertebrate species collected ranged from 3 to 29 per haul, with there being little difference in average numbers between the nearfield and farfield sites or between the pre-discharge and post-discharge periods (Figure E-39). Overall, invertebrate species richness averaged about 12 species per haul off Point Loma. Species richness at the nearfield sites was within the range of variability observed at the farfield stations over time (Figure E-39a). In addition, no clear spatial patterns were found that coincided with the onset of wastewater discharge (Figure E-39b). For example, higher species richness at the southern stations (SD7, SD8, SD10) relative to those further north (SD12, SD13, SD14) are likely due to differences in sediment composition and not proximity to the outfall. Moreover, although species richness increased in 1994 after discharge began, the increase occurred at all stations and returned to pre-discharge levels by July 1997. Overall, there are no temporal or spatial trends in the number of trawl-caught invertebrate species that might suggest an outfall-related impact.

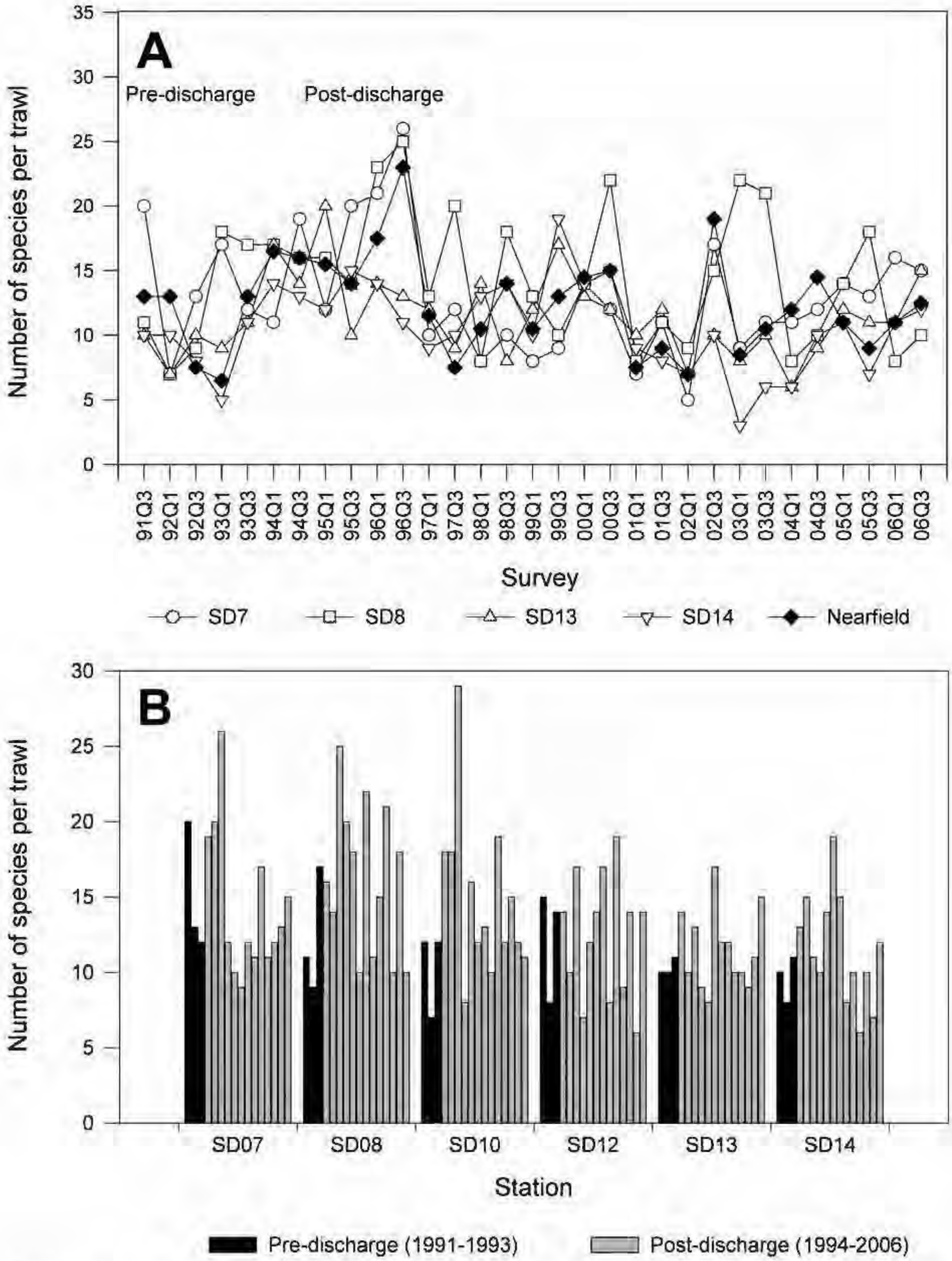


FIGURE E-39. Number of megabenthic invertebrate species near the Point Loma Ocean Outfall (1991-2006). (A) no. species/trawl for south (SD7, SD8) and north (SD13, SD14) farfield stations vs combined nearfield stations (SD10, SD12); (B) no. species/trawl at each station, July surveys only.

The total catch of invertebrates varied tremendously between trawls, ranging from 24 to 11,177 individuals per haul (Figure E-40). These numbers mostly reflect large fluctuations in abundances of the sea urchin *Lytechinus pictus* (see Table E-10). Invertebrate abundances were generally higher during the pre-discharge years when the number of individuals averaged 2013 per haul off Point Loma. In contrast, trawl invertebrates averaged 1776 individual per haul during the post-discharge period. Overall, total abundances were highly variable over time at all stations (Figure E-40), which again primarily reflected changes in *L. pictus* populations. Although abundances of some invertebrates did vary between the pre- and post-discharge surveys, these changes did not appear to be outfall-related. For example, the tuna crab *Pleuroncodes planipes* was more abundant prior to discharge (Table E-10); however this was due to large hauls of these crabs associated with El Niño conditions in 1992. Other species were more abundant during the post-discharge period, including the urchin *Allocentrotus fragilis*, the sea pen *Acanthoptilum* sp, and the shrimp *Sicyonia ingentis*. As with species richness, higher abundances at the southern stations relative to sites further north are likely due to differences in sediment composition. However, increases in these populations occurred at all stations, with no obvious patterns that could be attributed to outfall operation.

Summary of Effects on Demersal Fish and Invertebrate Communities

Analyses of temporal and spatial patterns did not reveal any effects on trawl-caught fish and invertebrate communities in the area that could be attributed to the Point Loma outfall. Despite high variability in both communities, patterns of change in species richness and abundance were similar at stations near the outfall and farther away. Sanddab abundances were within the range of natural variability described for reference areas in the SCB. In addition, no changes in demersal fish community structure were detected in nearfield assemblages that corresponded to the initiation of wastewater discharge at the end of 1993. Furthermore, although the abundance of some dominant fish (e.g., Pacific sanddab) of Point Loma declined at the nearfield stations in proportion to the overall post-discharge population, they remained within the range of natural variability described for reference areas in the SCB (e.g., Word and Mearns 1979; Thompson et al. 1987, 1992; Allen et al. 1998, 2003). Finally, the lack of physical

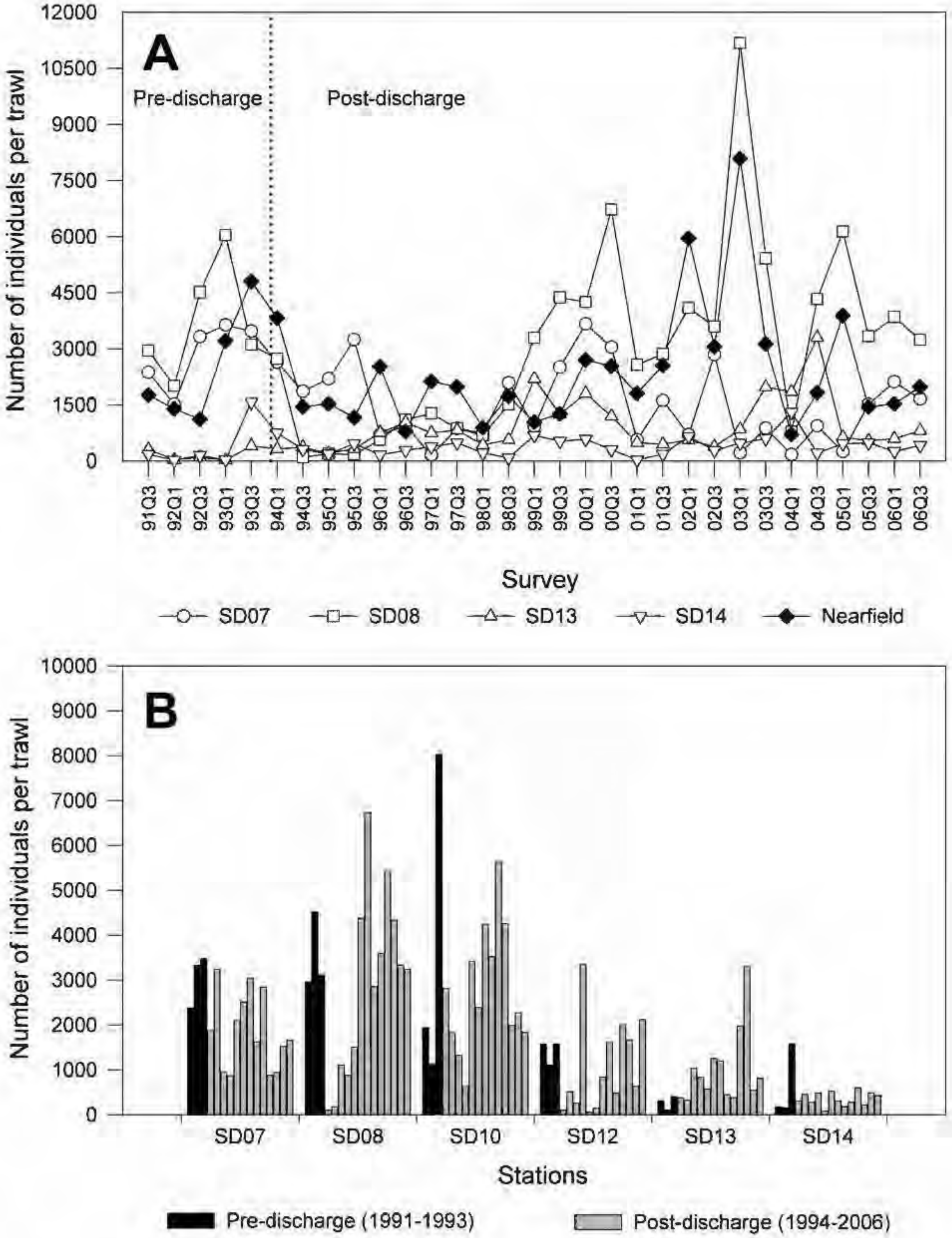


FIGURE E-40. Abundance of megabenthic invertebrates near the Point Loma Ocean Outfall (1991-2006). (A) abundance for south (SD7, SD8) and north (SD13, SD14) farfield stations vs combined nearfield stations (SD10, SD12); (B) abundance/trawl for each station, July surveys only.

TABLE E-10

Summary of dominant megabenthic invertebrates collected off Point Loma during January and July trawls from 1991 through 2006 (n = 31 surveys). Data are presented for both pre-discharge (1991-1993) and post-discharge (1994-2006) periods and summarized for all 6 trawl stations combined and separately for the 2 nearfield stations (SD10, SD12) and 4 farfield stations (SD7, SD8, SD13, SD14). Data are expressed as the percent of total abundance and as the mean abundance per trawl.

	All Stations (n = 6)				**Nearfield Stations** (n = 2)				**Farfield Stations** (n = 4)			
	Pre-discharge	**Post-discharge**			**Pre-discharge**	**Post-discharge**			**Pre-discharge**	**Post-discharge**		
	(1991-1993)	**(1994-2000)**	**(2001-2006)**	**(1994-2006)**	**(1991-1993)**	**(1994-2000)**	**(2001-2006)**	**(1994-2006)**	**(1991-1993)**	**(1994-2000)**	**(2001-2006)**	**(1994-2006)**
Percent Abundance												
Lytechinus pictus	97	92	94	93	99	96	93	94	97	89	96	93
Acanthoptilum sp	1	3	3	3	<1	1	6	4	<1	5	2	2
Allocentrotus fragilis	<1	1	1	1	<1	<1	<1	<1	1	2	<1	3
Mean Abundance												
Lytechinus pictus	1959	1337	2031	1657	2421	1753	2788	2231	1728	1129	1652	1371
Acanthoptilum sp	1	51	64	57	<1	24	178	95	1	64	6	37
Allocentrotus fragilis	16	18	26	22	5	8	10	9	22	24	34	28
Sicyonia ingentis	<1	14	2	8	<1	8	1	5	0	17	2	10
Parastichopus californicus	6	6	4	5	1	3	2	2	8	7	4	6
Astropecten verrilli	3	5	5	5	4	8	5	7	3	4	4	4
Luidia foliolata	4	3	4	3	4	4	3	3	4	2	5	3
Loligo opalescens	2	1	3	2	2	1	2	1	2	1	3	2
Platymera gaudichaudii	<1	2	2	2	<1	1	<1	<1	0	2	2	2
Thesea sp B	1	2	1	1	1	2	2	2	1	2	1	1
Ophiura luetkenii	1	1	1	1	1	1	1	1	2	1	2	1
Octopus rubescens	1	1	1	1	1	1	<1	1	2	2	1	1
Pleuroncodes planipes	6	<1	<1	<1	4	<1	0	<1	8	<1	<1	<1
Crangon alaskensis	2	1	1	1	3	2	1	2	1	1	<1	1
Pleurobranchaea californica	<1	1	1	1	<1	1	2	2	<1	1	1	1
Florometra serratissima	2	<1	1	<1	<1	<1	<1	<1	3	<1	1	1

abnormalities and indicators of disease such as fin rot, lesions or tumors suggest that fish populations have remained healthy off Point Loma since monitoring began (e.g., City of San Diego 2007a).

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ATTACHMENTS

Appendix E

Benthic Sediments & Organisms

Attachment E.1: 10-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

Attachment E.2: Demersal Fish Species Collected off Point Loma

Attachment E.3: Megabenthic Invertebrates Collected off Point Loma

Attachment E.4: Summary Report for the San Diego Deep Benthic Pilot Study

Attachment E.5: San Diego Regional Sediment Quality Contour Plots (1994-2006)

Attachment E.1

10-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

Attachment E.1

10-Year San Diego Regional Benthic Assessment and Reference Tolerance Intervals

Introduction

An understanding of reference conditions is crucial to evaluating the results from environmental monitoring studies. Characterization of these background conditions using relevant indicators help to define what is natural (i.e., not anthropogenically impacted), allows for the establishment of baselines and the identification of appropriate control sites. The City of San Diego has conducted regional benthic surveys of the continental shelf and slope off San Diego since 1994. The main objectives of these surveys are to characterize the benthic conditions for this diverse coastal region from the US/Mexico border to northern San Diego County and to identify areas impacted by anthropogenic or natural events. Several other reference studies have been conducted previously in the Southern California Bight (e.g., Word and Mearns 1979, EcoAnalysis et al. 1993, Bergen et al. 1998, 2001, Smith et al. 2001, Ranasinghe et al. 2003, 2007) as well as two others that calculated tolerance intervals for important environmental indicators in the San Diego region (Smith and Riege 1998, Smith 2001).

For environmental data, the tolerance interval is a statistical tool used to define the putative natural range of values for reference variables. It is the confidence interval bound of a specific percentile of a data distribution. For example, it can describe with a desired degree of statistical certainty, the lower 10th and upper 90th percentile of infaunal abundance found among regional monitoring stations. Since the tolerance interval bound describes a range instead of a parameter (e.g. the mean), it compensates for the greater variability commonly found in environmental monitoring data. Also, since it incorporates confidence intervals, it allows for a more statistically rigorous comparison of reference versus impacted sites than means or ranges. For in-depth statistical descriptions of tolerance intervals used in environmental monitoring see Smith and Riege (1998), Smith (2002) and Smith et al. (2005).

The objectives of this appendix are to identify benthic sites or communities likely to provide the most appropriate reference values for environmental indicators within the Point Loma Ocean Outfall (PLOO) region and to quantify their tolerance intervals.

Dataset and Methods

The benthic macrofauna samples analyzed herein were collected annually from 1994 through 2003 using the USEPA probability-based EMAP random sampling design. The surveys in 1995-1997 and 1999-2002 were performed as part of the NPDES monitoring programs for the South Bay Ocean Outfall (see City of San Diego 2007 for details), while surveys in 1994, 1998 and 2003 were conducted as part of several large regional surveys of the entire Southern California Bight (see Bergen et al. 1998, Ranasinghe et al. 2003, 2007). The study area ranged from off Del Mar in northern San Diego County south to the US/Mexico border. Three hundred and twenty-four different sites, ranging in depth from 9 to 461 m, were sampled during this 10-year period. Patterns of macrobenthic community structure and various environmental variables were assessed using univariate statistics and the Bray-Curtis multivariate cluster analysis.

Tolerance intervals were calculated for 12 environmental indicators: abundance of three pollution sensitive indicator taxa (*Ampelisca* spp, *Rhepoxynius* spp, and *Amphiodia* spp), abundance of three pollution tolerant indicator taxa (*Euphilomedes* spp, *Parvilucina tenisculpta*, and *Capitella "capitata"*), species richness (number of species), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance index (minimum number of species accounting for 75% of the total abundance in each grab), and the benthic response index (BRI). Indicator data were tested for approximation to a normal distribution using the Shapiro-Wilk test for normality and transformed when appropriate. Where transformation did not improve normality, nonparametric tolerance intervals were computed from raw data. Parametric tolerance intervals were computed for the 10th and 90th percentiles with confidence intervals of 95% (α=0.05). Non parametric tolerance intervals were computed for the 5th and 95th percentiles with confidence intervals of 95% (α=0.05). Indicator variables from the PLOO primary core monitoring stations along the 98-m outfall depth contour sampled from 1991-2006 were plotted and compared to the calculated tolerance intervals.

Spatial and temporal variability should be considered when choosing tolerance interval reference sites. Because benthic macrofaunal variables change with depth, limiting control stations to an appropriate depth range can improve comparison between reference and nonreference sites. One way to do that is to select stations confined within a strata range. Unfortunately, this does not take into account spatial heterogeneity within strata (e.g., varying sediment composition, organic loading). Using ordination and cluster analyses to identify control sites within a geographic region may mitigate some aspects of the spatial variability. These analyses can identify benthic assemblages or communities that often are limited to certain depth ranges due to various ecological reasons. If an assemblage covers the region of interest, it is more appropriate to use the stations that comprise that population than groups of sites based on arbitrary depth delineations. Also, analysis of samples from long-term studies group assemblages without respect to sampling date which could mitigate potential positive within-year correlations. Further, these types of assemblages can identify appropriate reference areas as they could accurately represent the spatial and depth habitat surrounding, but not including, a suspected impact. In this study, ordination and cluster analyses were used to identify the appropriate reference sites off San Diego for comparisons with the regular PLOO monitoring stations.

Results

A total of 1341 taxa (mostly species) and 107,863 individuals were collected and identified during the 10-year random sampling surveys. Region wide, infaunal abundances ranged from 39 to 1467 individuals per sample (mean =317) and the total number of species ranged from 21 to 266 per sample (mean = 101 species). Although the results from univariate analyses varied, values for most community parameters were comparable to historical values recorded elsewhere for the Southern California Bight (Figure E.1-1 and see Appendix E, Table E4).

Cluster analysis and ordination of sites discriminated between 10 habitat-related macrobenthic assemblages off San Diego (cluster groups A–J in Figure E.1-2) from 1994 through 2003. Benthic communities in the region remained dominated by ophiuroid-polychaete based assemblages throughout this period; with few major changes occurring since monitoring began. These groups were stratified along depth contours and sediment types associated with variations in seafloor topography, but displayed no spatial patterns relative to point source inputs (Figure E.1-3). Species composition differed among the 10 cluster groups and relative abundances of dominant taxa defined the assemblages (Table E.1-1). The stations comprising the largest cluster, group F (156 of the 324 sites), mirrored the PLOO 98-m primary core stations in terms of geographic location and depth. These similarities suggest that Group F represents a suitable reference assemblage and for comparisons of environmental variables to the PLOO stations. The group F stations were generally confined between the 60-m and 120-m depth contours ranging from near Solana Beach in the north to the Tijuana River region in the south. Sediment grain sizes at these stations were mixed, averaging about 43% fines and 56% sand with trace coarse particles. Total Organic Carbon (TOC) at the F group stations ranged from 0.3-1.1% (mean = 0.6%). Finally, previous studies have suggested minor changes in the benthic community at a few sites located within about 0.5 km of the outfall discharge site. Consequently, we took a conservative approach and group F stations located within 1.5 km of the PLOO were eliminated from the tolerance interval calculations as their indicator values could be affected by discharge or the physical structure of the wye.

Tolerance intervals for the group F reference data (excluding those closest to the PLOO) are shown in Table E.1-2. Both upper and lower bounds are reported with bolded values indicating thresholds for the direction of response expected from environmental impact. The indicator taxa variables and Pielou's evenness index (J') were computed with nonparametric intervals. All other variables were transformed if required and parametric tolerance intervals were calculated.

Scatter plots of indicator variables from the 98 m core monitoring stations sampled between 1994-2006 fit well, with some minor exceptions, within the upper and lower bounds calculated from the reference data (Figure E.1-4).

Discussion

Tolerance interval bounds computed from the group F assemblage sites provide an accurate assessment of reference conditions based on environmental variables. The use of tolerance interval bounds for benthic infaunal monitoring provides a level of statistical certainty when comparing impacted to reference sites. Further, tolerance interval bounds compliment other statistically rigorous methods of impact detection like BACIP analyses and can be used in conjunction to provide a broader context to those data. Tolerance interval bounds help to put assumed impacts into perspective. For example, if the value of an indicator variable from an impact site is near or within the interval bounds, impact can be deemed minimal or non existent. The further impact values deviate from the reference bound, the more serious the impact should be judged.

Previous studies have calculated tolerance interval bounds for the San Diego region between 1994-1996 (Smith and Riege 1998) and 1994-1999 (Smith 2001). This study builds on those works and is comparable to their findings. Data collected for this study covered 149 sites on the coastal shelf surrounding the PLOO and spanned 10 years (1994-2003). This large sample size and longer temporal component increases sensitivity and effectiveness of detecting impacts as well as integrates changes to the indicator variables across time (Hunt et al. 2001). Further, the use of cluster analysis to identify an appropriate reference area is novel and avoids arbitrary site selection in favor of an ecological approach. Overall, these bounds provide a robust and appropriate reference for comparison to potential impacts to the region due to discharge from the PLOO. Lastly, tolerance intervals should be updated over time to incorporate spatio-temporal changes (e.g., ENSO events or shifts in sediment composition) which may affect tolerance interval bounds of reference conditions in the PLOO region.

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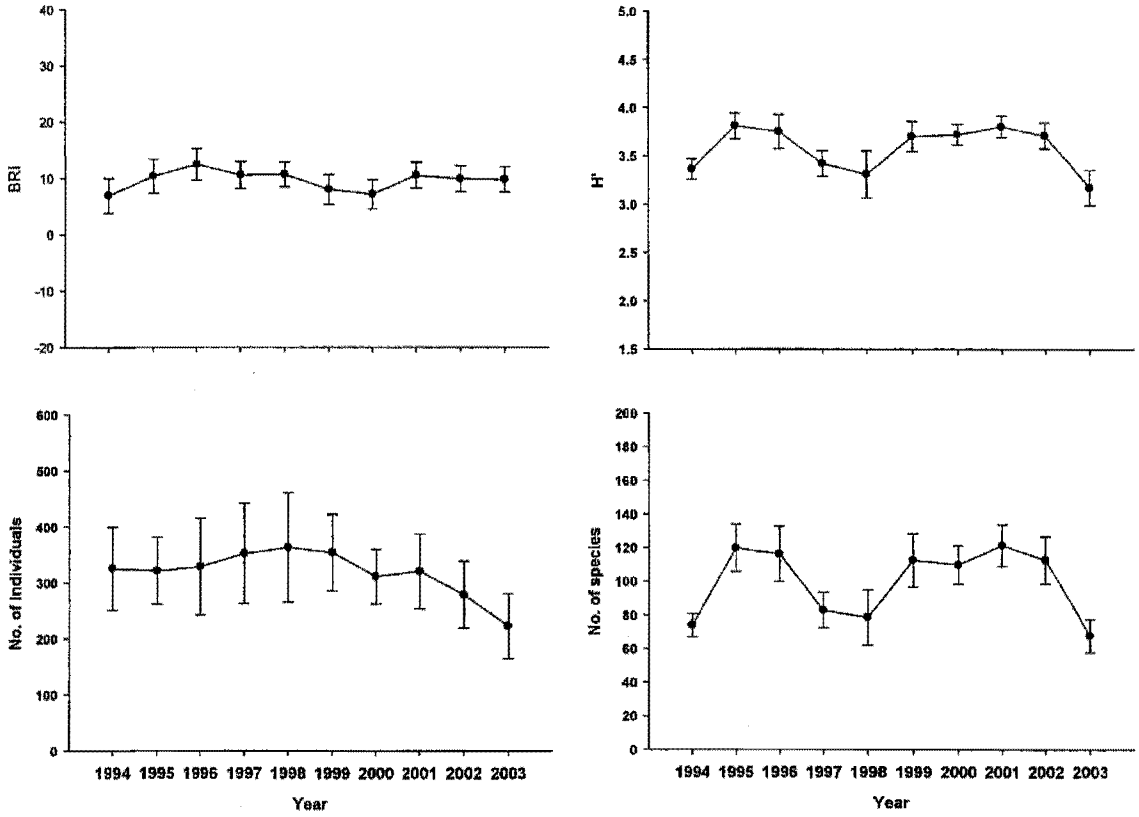

FIGURE E.1-1.
Comparison of several benthic community parameters at randomly selected regional stations sampled off the coast of San Diego from 1994-2003. Data are expressed as means per 0.1 m^2 ± 95% CI (n>26 per year).

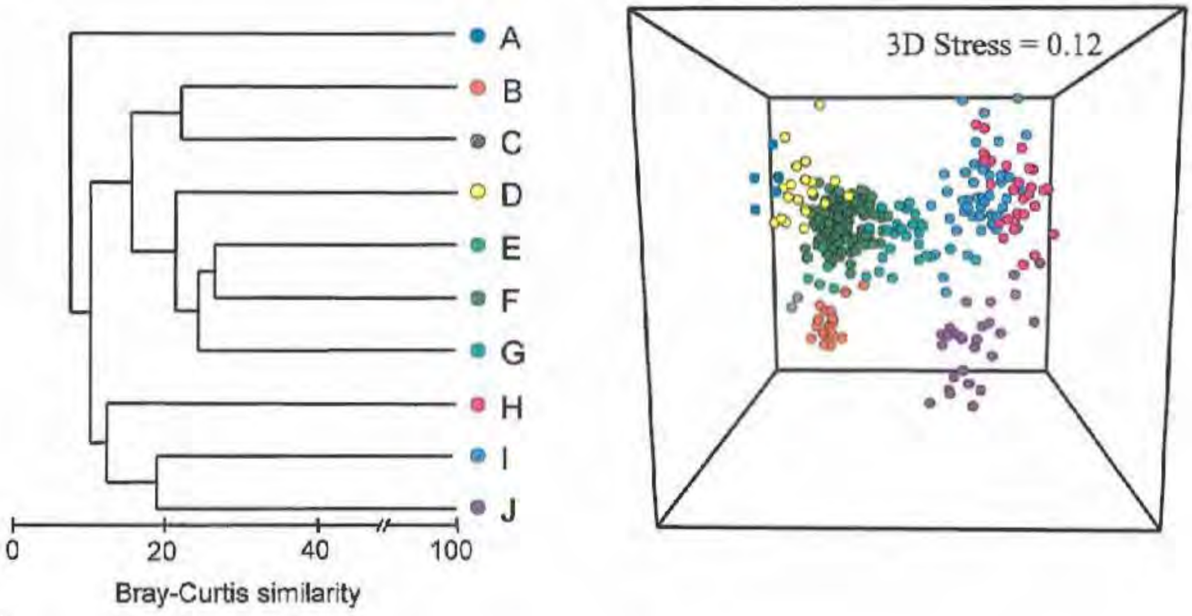

FIGURE E.1-2.
Cluster analysis and 3-D MDS ordination results of the macrofaunal abundance data for randomly selected regional stations sampled off San Diego from 1994-2003.

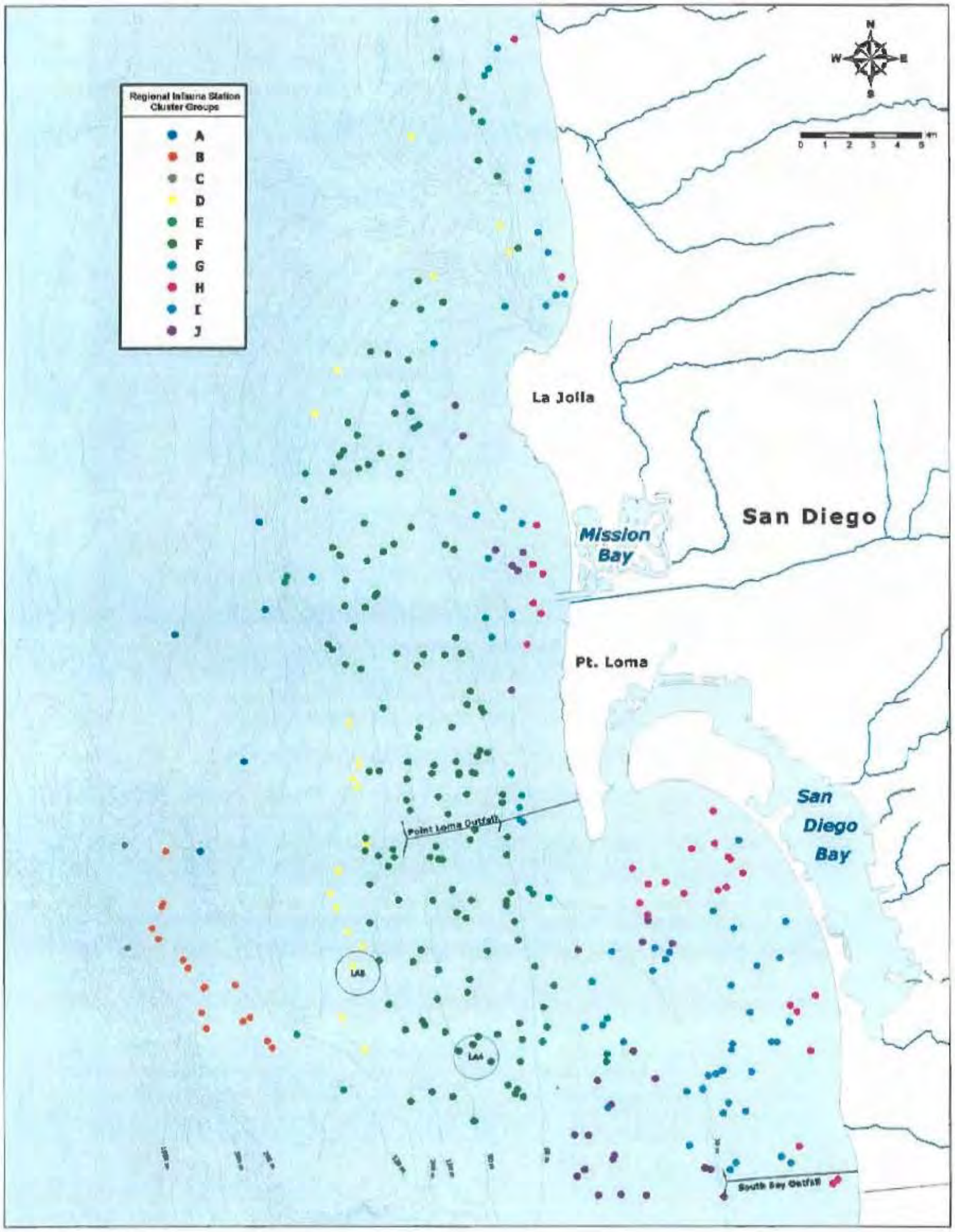

FIGURE E.1-3.

Results of ordination and classification analyses of macrofaunal abundance of randomly selected regional benthic stations sampled from 1994-2003. Cluster groups are color-coded to reveal spatial patterns in the distribution of benthic assemblages. Data from cluster group F (dark green; excluding sites nearest the PLOO terminus) were used to calculate tolerance intervals.

TABLE E.1-2

Tolerance interval bounds for various environmental indicators calculated from benthic data for randomly selected regional sites sampled from 1994-2003. P(norm) = the p value from a Shapiro-Wilk test for normality of the underlying data distribution. Parametric tolerance intervals computed for the 10th and 90th percentiles for indicators with p(norm) >0.15. Data were transformed when p(norm) for raw data were <0.15. Where transformation did not improve normality, nonparametric tolerance intervals for the 5th and 95th percentile were computed. Bolded values indicate thresholds for the direction of response predicted from environmental impact.

Indicator	p(norm)	Transformation	Lower bound	Upper bound
***Ampelisca* spp**	<0.001*		**1**	29
***Rhepoxynius* spp**	<0.001*		**0**	13
***Amphiodia* spp**	<0.001*		**1**	216
***Euphilomedes* spp**	<0.001*		0	**34**
Parvilucina tenisculpta	<0.001*		0	**12**
Capitella capitata	<0.001*		0	**2**
Evenness	0.024*		**0.75**	**0.86**
Abundance	0.238	ln	**230**	**671**
Species richness	0.729	ln	**72**	**175**
BRI	0.711	√	-0.65	**15**
Swartz dominance	0.868	√	**7**	44
Diversity	0.302		**3.4**	**4.3**

* Non-parametric tolerance interval bounds computed

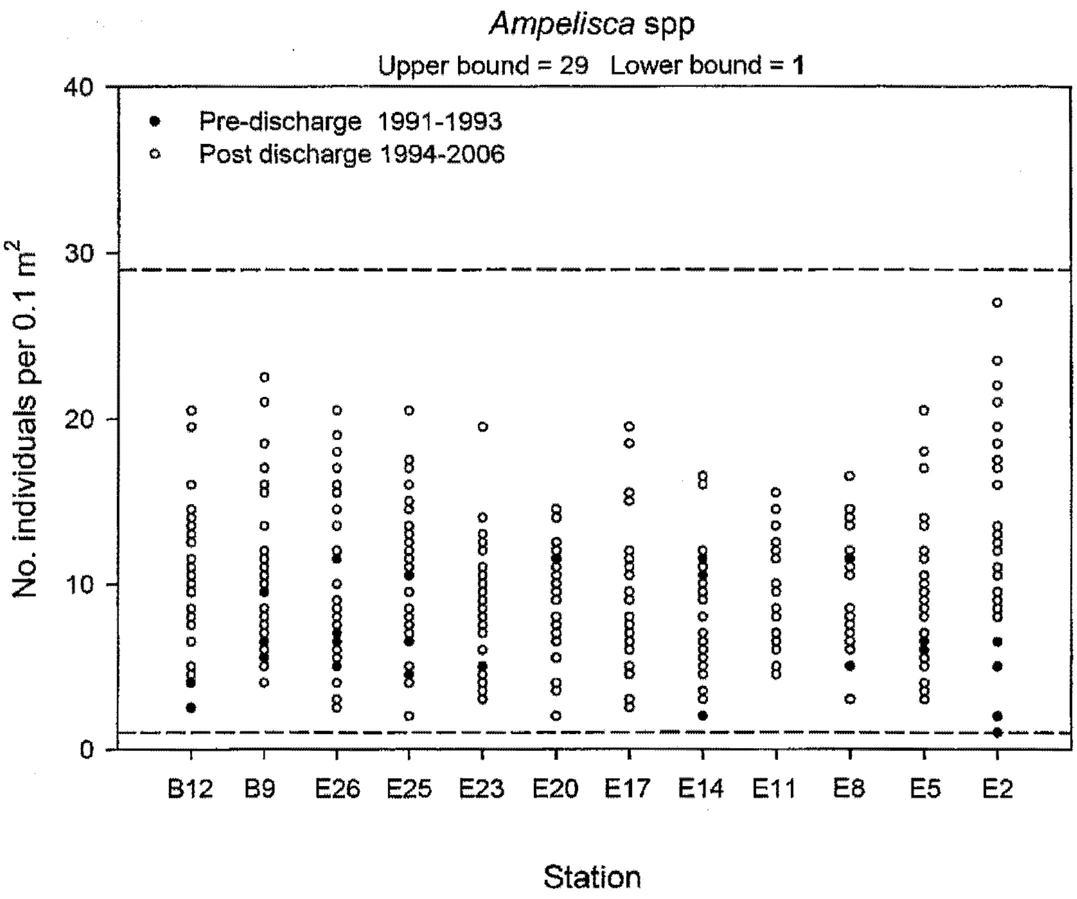

FIGURE E.1-4
Indicator values for the PLOO 98-m core monitoring stations collected 1991-2006. Horizontal dashed lines indicate upper and lower tolerance intervals calculated from cluster group F sites for regional data collected from 1994-2003 (see text).

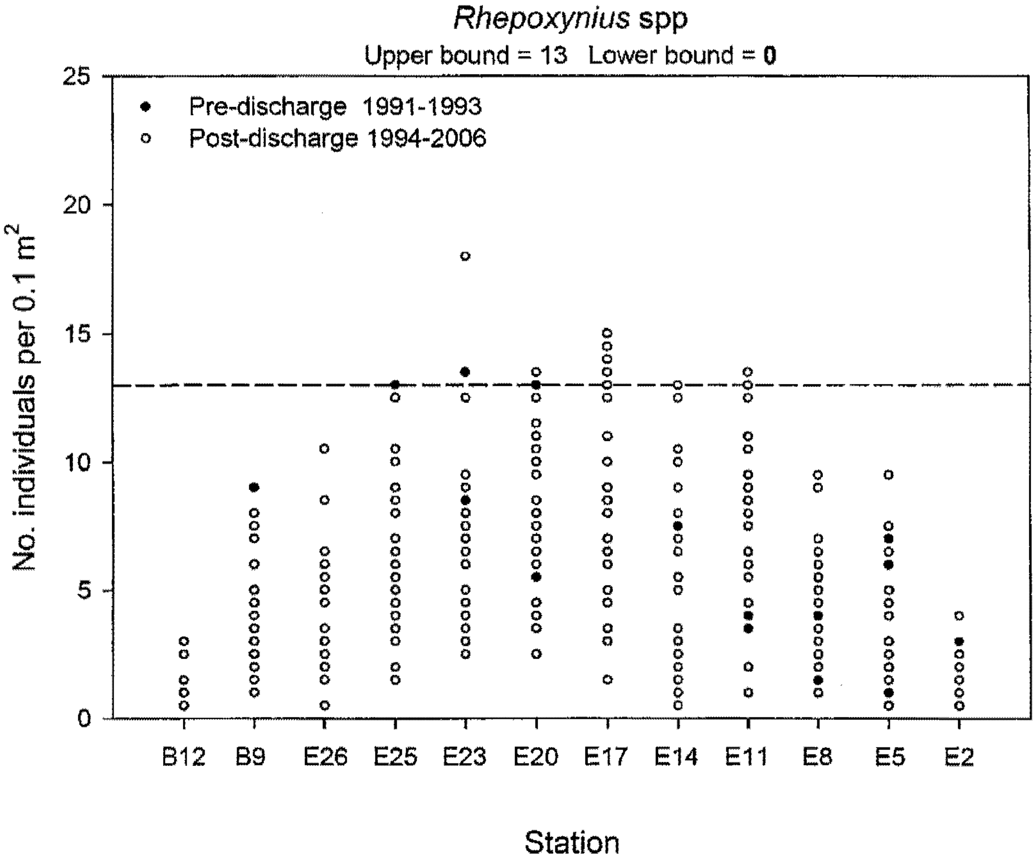

FIGURE E.1-4. (continued)

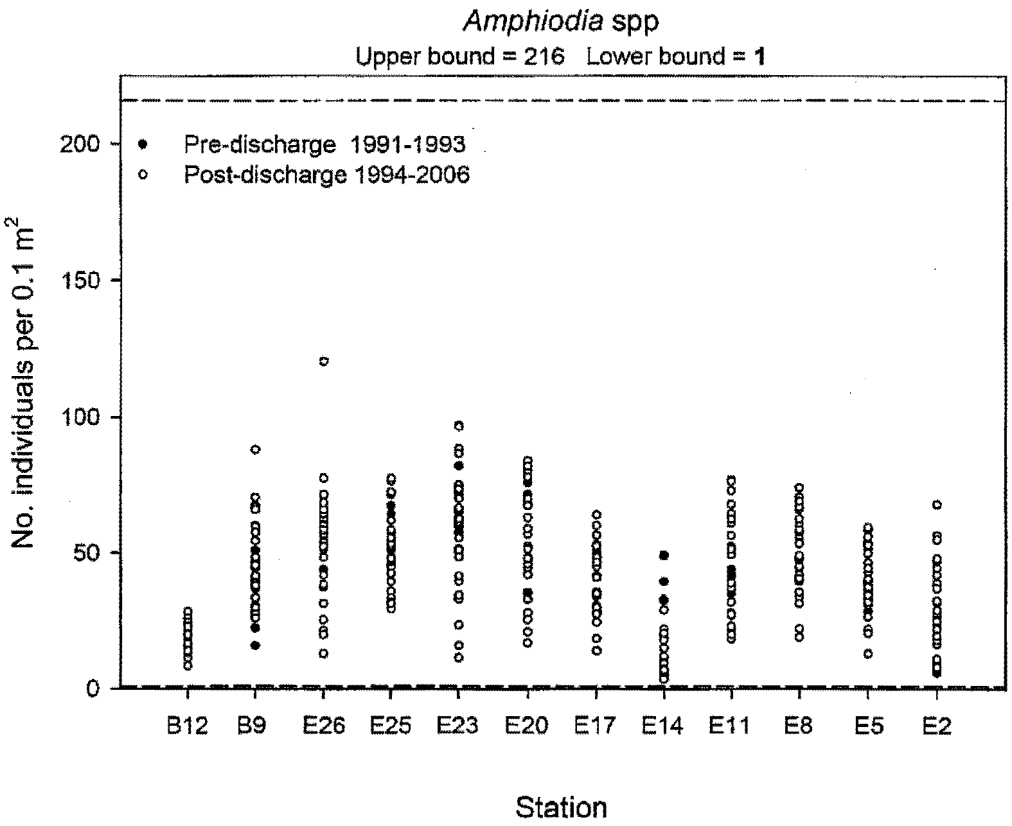

FIGURE E.1-4. (continued)

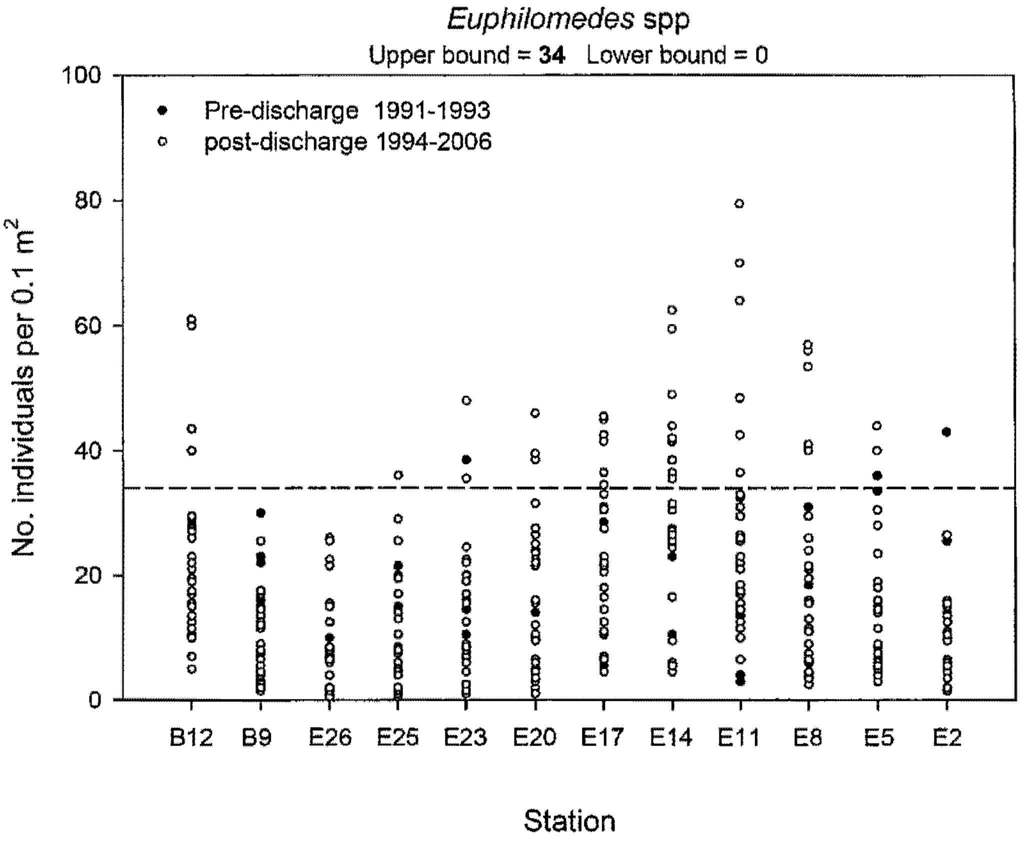

FIGURE E.1-4. (continued)

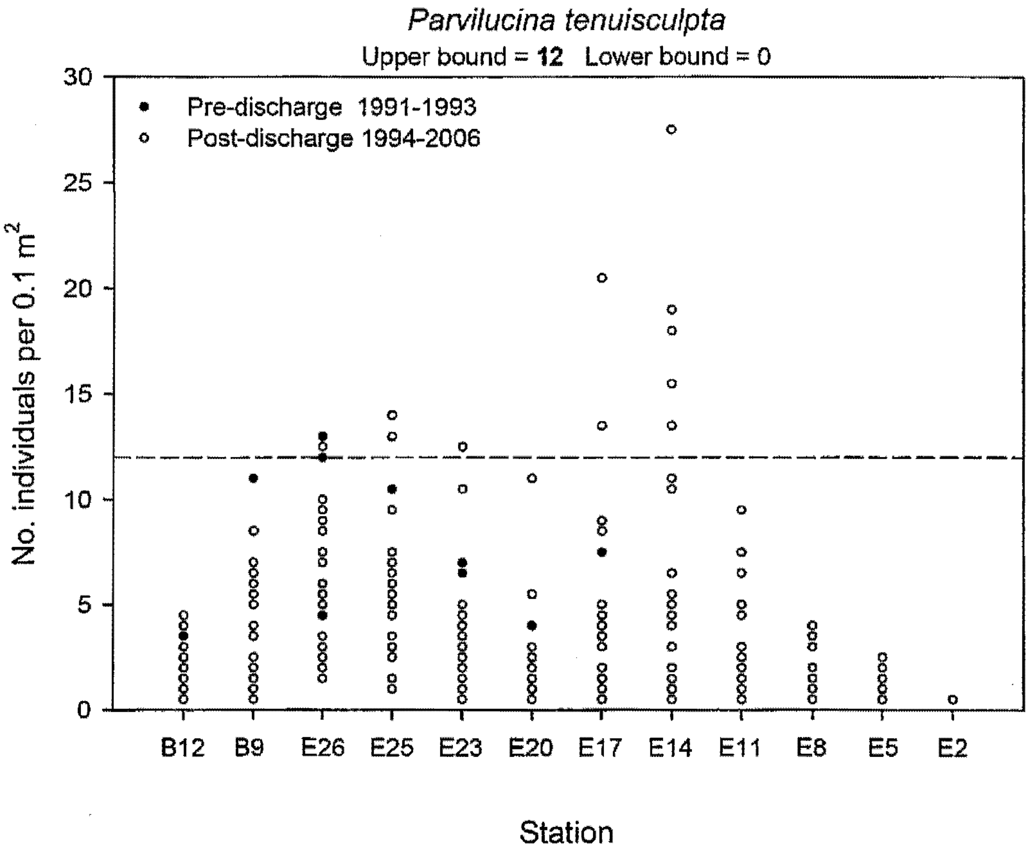

FIGURE E.1-4. (continued)

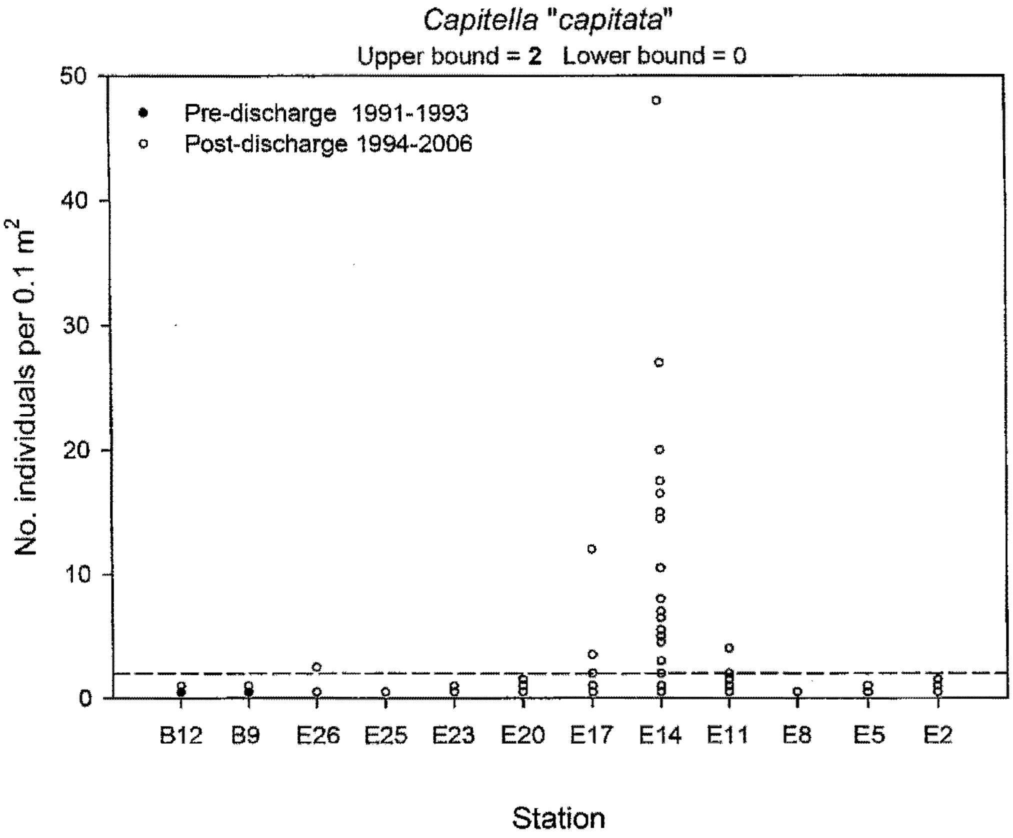

FIGURE E.1-4. (continued)

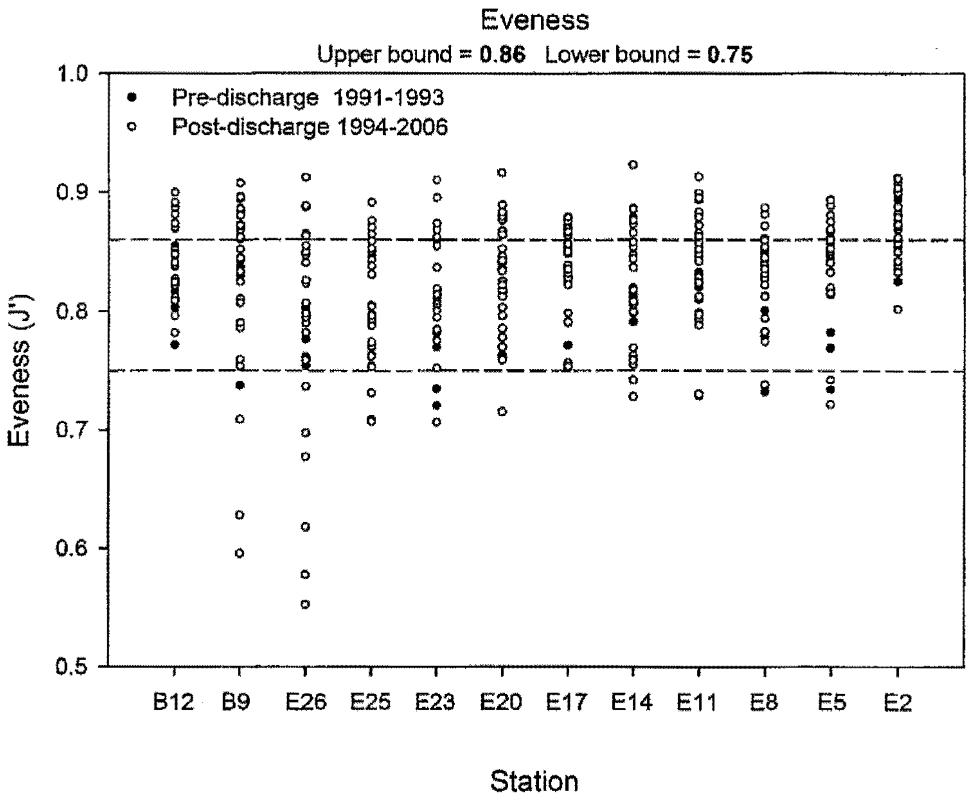

FIGURE E.1-4. (continued)

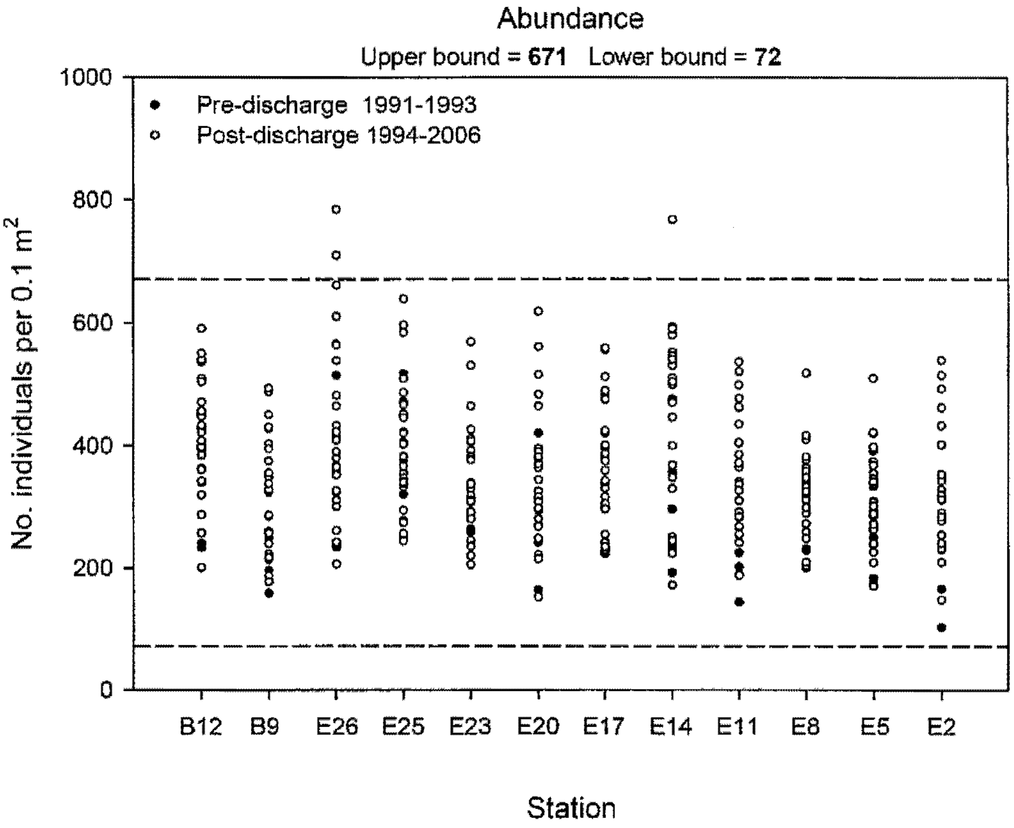

FIGURE E.1-4. (continued)

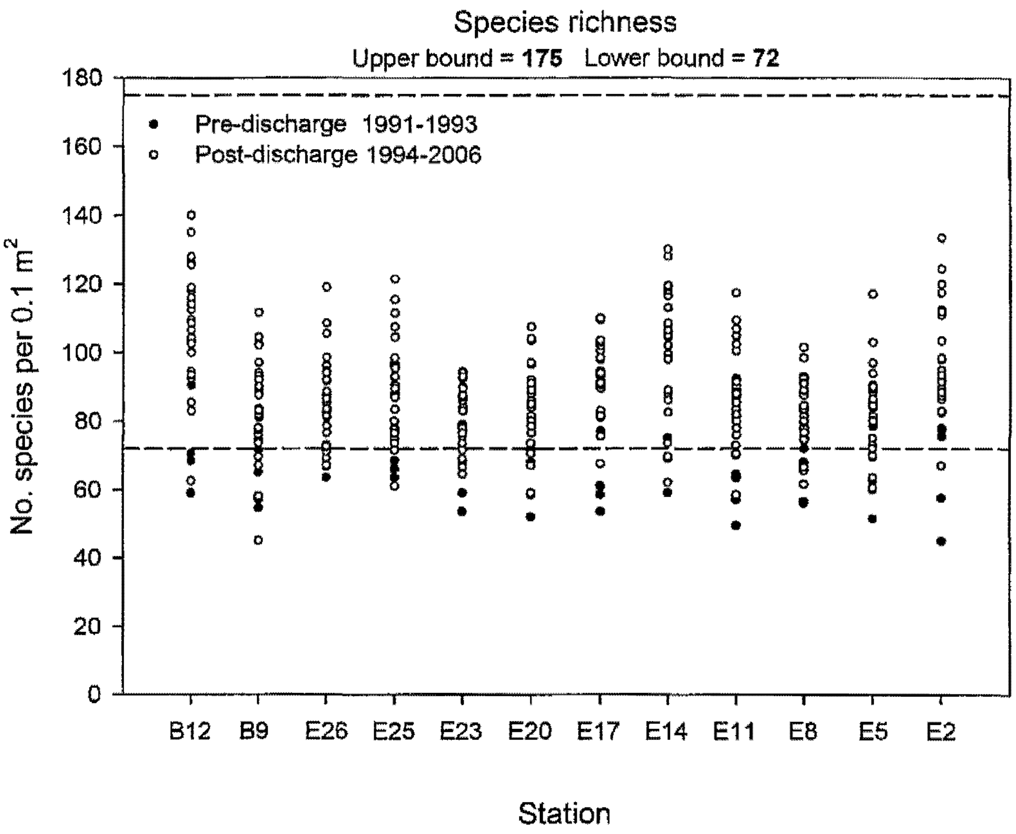

FIGURE E.1-4. (continued)

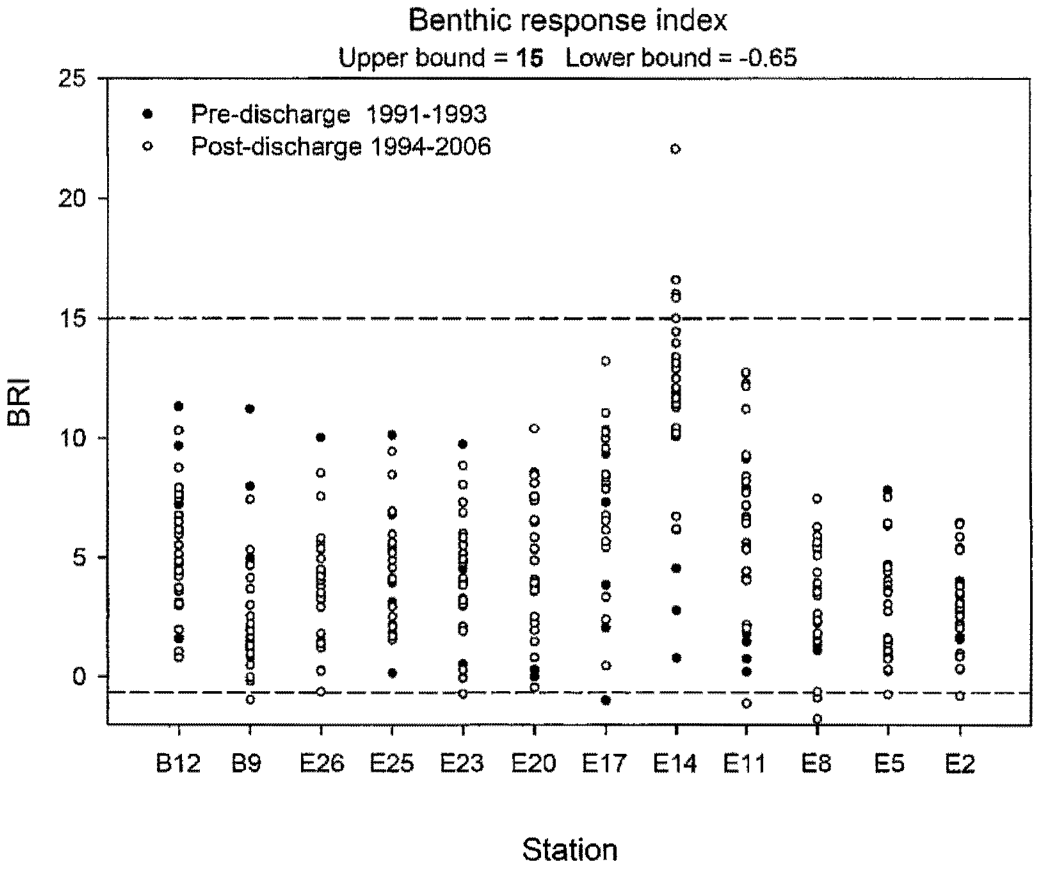

FIGURE E.1-4. (continued)

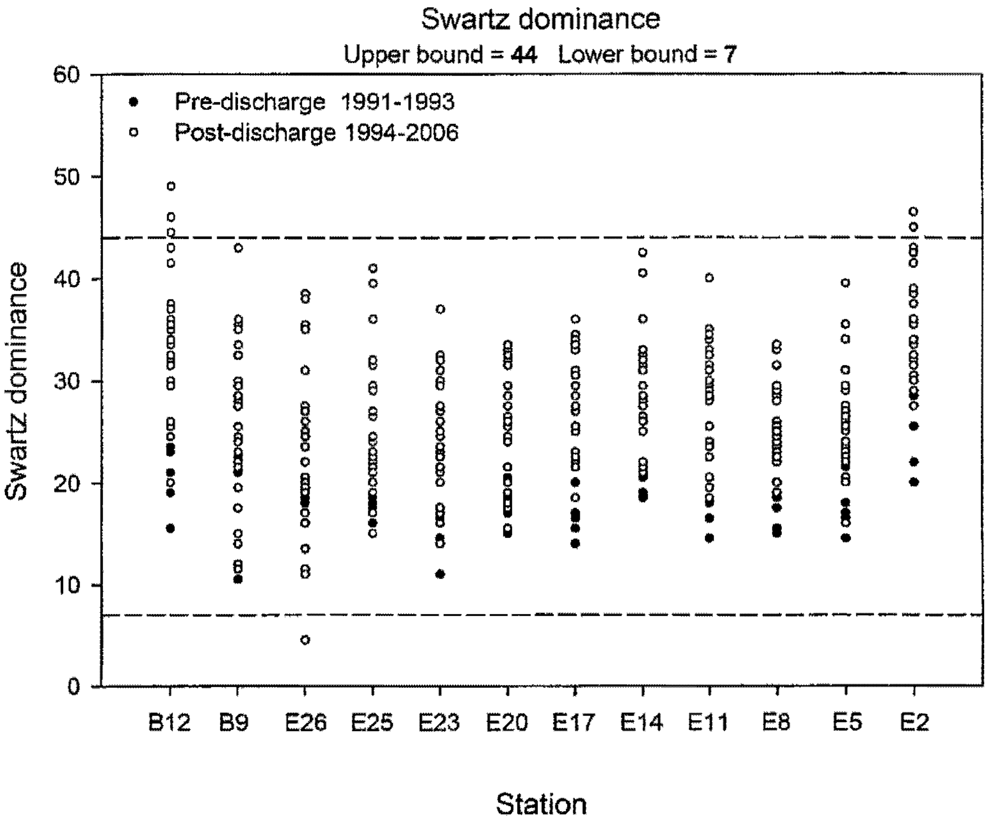

FIGURE E.1-4. (continued)

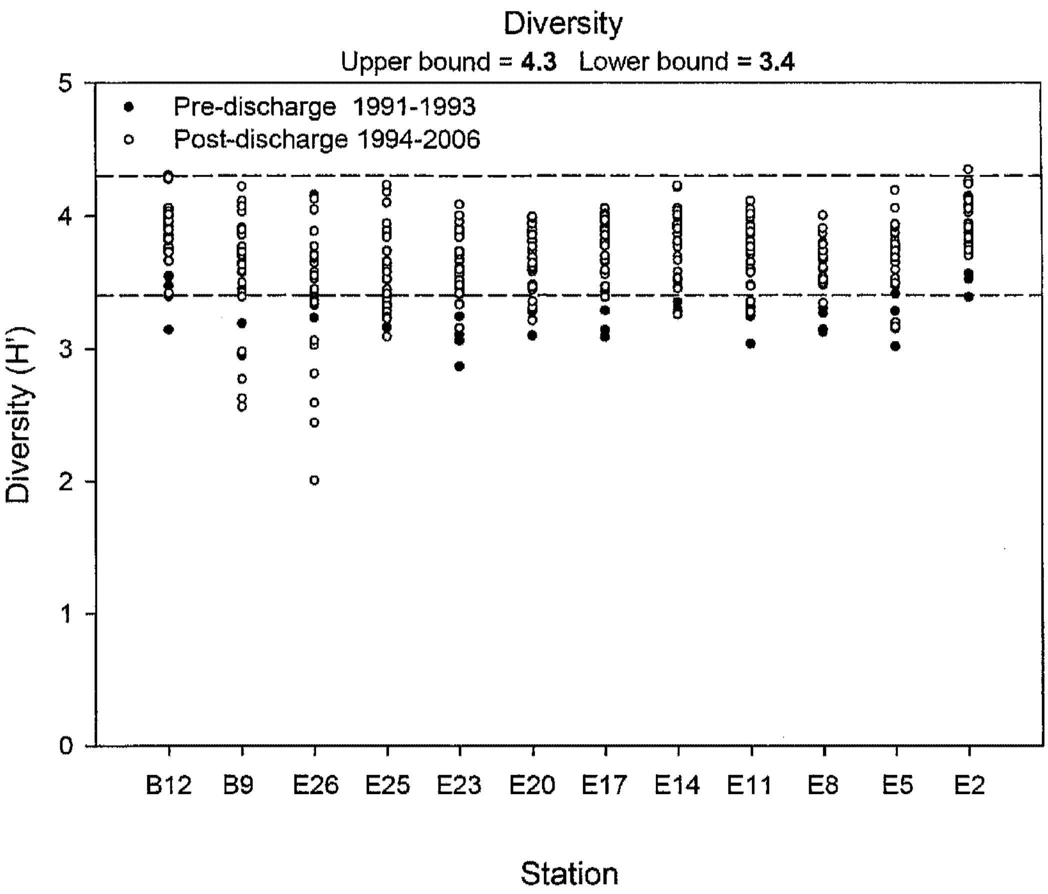

FIGURE E.1-4. (continued)

Attachment E.2

Demersal Fish Species Collected off Point Loma

Attachment E.2

Summary of demersal fish species captured at six trawl stations (SD7, SD8, SD10, SD12-SD14) around the Point Loma Ocean Outfall from the January and July surveys, 1991 through 2006. Data are number of fish collected (N), minimum (Min), maximum (Max), and mean standard length (cm). Taxonomic arrangement and scientific names are of Eschmeyer (1998) and Allen (2005).

			Length (cm)		
Taxon/Species		**N**	**Min**	**Max**	**Mean**
MYXINIFORMES					
Myxinidae					
Eptatretus stoutii	Pacific hagfish	1	52	52	52
CHIMAERIFORMES					
Chimaeridae					
Hydrolagus colliei	spotted ratfish	7	29	40	34
RAJIFORMES					
Rajidae					
Bathyraja interrupta	sandpaper skate	1	20	20	20
Raja binoculata	big skate	2	19	45	32
Raja inornata	California skate	42	10	60	32
Raja stellulata	starry skate	3	17	24	21
CLUPEIFORMES					
Engraulidae					
Engraulis mordax	northern anchovy	1	13	13	13
OSMERIFORMES					
Argentinidae					
Argentina sialis	Pacific argentine	303	3	13	8
AULOPIFORMES					
Synodontidae					
Synodus lucioceps	California lizardfish	232	9	40	16
LAMPRIDIFROMES					
Trachipteridae					
Trachipterus altivelis	king-of-the-salmon	1	11	11	11
OPHIDIIFORMES					
Ophidiidae					
Chilara taylori	spotted cuskeel	52	10	24	16
Bythitidae					
Brosmophycis marginata	red brotula	1	37	37	37
GADIFORMES					
Merlucciidae					
Merluccius productus	Pacific hake	3	20	38	28
BATRACHOIDIFORMES					
Batrachoididae					
Porichthys myriaster	specklefin midshipman	1	29	29	29
Porichthys notatus	plainfin midshipman	2185	3	21	10
GASTEROSTEIFORMES					
Macroramphosidae					
Macrorhamphosus gracilis	slender snipefish	1	10	10	10

Attachment E.2 (*continued*)

Taxon/Species		N	Length (cm) Min	Max	Mean
SCORPAENIFORMES					
Scorpaenidae					
Scorpaena gutta	California scorpionfish	315	13	47	19
Sebastes chlorostictus	greenspotted rockfish	83	4	20	10
Sebastes dallii	calico rockfish	5	7	14	12
Sebastes elongatus	greenstriped rockfish	155	3	31	8
Sebastes eos	pink rockfish	19	5	11	9
Sebastes goodei	chilipepper rockfish	8	10	16	14
Sebastes hopkinsi	squarespot rockfish	53	7	23	14
Sebastes jordani	shortbelly rockfish	1	12	12	12
Sebastes levis	cowcod	8	6	9	8
Sebastes miniatus	vermilion rockfish	6	27	36	30
Sebastes rosenblatti	greenblotched rockfish	140	3	29	10
Sebastes rubrivinctus	flag rockfish	31	4	24	9
Sebastes saxicola	stripetail rockfish	1890	4	15	8
Sebastes semicinctus	halfbanded rockfish	4872	4	18	9
Sebastes umbrosus	honeycomb rockfish	1	14	14	14
Sebastes zacentrus	sharpchin rockfish	2	11	12	12
Sebastes spp	unidentified rockfish	65	2	13	6
Triglidae					
Prionotus stephanophrys	lumptail searobin	4	7	15	10
Hexagrammidae					
Ophiodon elongatus	lingcod	15	11	47	19
Zaniolepis frenata	shortspine combfish	649	6	19	13
Zaniolepis latipinnis	longspine combfish	3183	5	17	12
Cottidae					
Chitonotus pugetensis	roughback sculpin	185	3	17	8
Icelinus fimbriatus	fringed sculpin	2	14	15	15
Icelinus quadriseriatus	yellowchin sculpin	7795	3	10	6
Icelinus tenuis	spotfin sculpin	253	4	11	8
Radulinus asprellus	slim sculpin	1	8	8	8
Agonidae					
Odontopyxis trispinosa	pygmy poacher	33	7	14	8
Xeneretmus latifrons	blacktip poacher	39	3	15	13
Xeneretmus triacanthus	bluespotted poacher	19	8	16	12
PERCIFORMES					
Carangidae					
Trachurus symmetricus	Pacific jack mackerel	2	4	17	11
Sciaenidae					
Genyonemus lineatus	white croaker	17	18	27	23
Embiotocidae					
Cymatogaster aggregata	shiner perch	1	12	12	12
Zalembius rosaceus	pink seaperch	762	4	14	8

Attachment E.2 (*continued*)

Taxon/Species		N	Length (cm) Min	Max	Mean
Bathymasteridae					
Rathbunella alleni	stripedfin ronquil	1	13	13	13
Rathbunella hypoplecta	bluebanded ronquil	15	8	17	12
Zoarcidae					
Lycodes cortezianus	bigfin eelpout	16	14	25	21
Lycodes pacificus	blackbelly eelpout	141	12	25	19
Stichaeidae					
Plectobranchus evides	bluebarred prickleback	1	10	10	10
Uranoscopidae					
Kathetostoma averruncus	smooth stargazer	2	9	19	14
Callionymidae					
Synchiropus atrilabiatus	blacklip dragonet	1	9	9	9
Gobiidae		1	3	3	3
Lepidogobius lepidus	bay goby	240	4	8	6
Rhinogobiops nicholsii	blackeye goby	8	4	8	6
Scombidae					
Scomber japonicus	chub mackerel	1	20	20	20
Centrolophidae					
Icichthys lockingtoni	medusafish	3	6	7	7
Stromateidae					
Peprilis simillimus	Pacific pompano	1	8	8	8
PLEURONECTIFORMES					
	unidentified flatfish	46	3	8	4
Paralichthyidae					
Citharichthys fragilis	gulf sanddab	72	6	15	11
Citharichthys sordidus	Pacific sanddab	30542	3	24	9
Citharichthys stigmaeus	speckled sanddab	7	4	11	6
Citharichthys xanthostigma	longfin sanddab	1729	3	20	12
Citharichthys spp	Citharichthys sp	3	3	4	3
Hippoglossina stomata	bigmouth sole	190	6	30	17
Pleuronectidae					
Lyopsetta exilis	slender sole	376	4	17	12
Glyptocephalus zachirus	rex sole	3	11	15	13
Microstomus pacificus	Dover sole	3517	4	25	10
Parophrys vetulus	English sole	405	9	31	17
Pleuronichthys verticalis	hornyhead turbot	91	7	24	15
Cynoglossidae					
Symphurus atricaudus	California tonguefish	718	6	17	13

Attachment E.3

Megabenthic Invertebrates Collected off Point Loma

Attachment E.3

Summary of megabenthic invertebrate species captured six 100-m trawl stations (SD7-SD8, SD10, SD12-SD14) around the Point Loma Ocean Outfall, January and July surveys 1991 through 2006. Data include total number of individuals collected (N). Taxonomic arrangement according to SCAMIT (2001).

Taxon	Species	N
PORIFERA		5
UNKNOWN	*Porifera* sp SD3	1
DEMOSPONGIAE		1
HADROMERIDA		
Suberitidae		
	Suberites suberea	2
CNIDARIA		
ANTHOZOA		2
STOLONIFERA		
Telestidae		
	Telesto californica	1
ALCYONACEA (= GORGONACEA)		
Gorgoniidae		3
	Adelogorgia phyllosclera	6
	Eugorgia rubens	1
Muriceidae		
	Thesea sp B	248
PENNATULACEA		
Virgulariidae		10
	Acanthoptilum sp	8868
	Stylatula elongata	3
	Virgularia agassizii	6
Pennatulidae		
	Ptilosarcus gurneyi	1
ACTINIARIA		1
Metridiidae		
	Metridium farcimen	105
MOLLUSCA		
POLYPLACOPHORA		2
GASTROPODA		1
VETIGASTROPODA		
Calliostomatidae		
	Calliostoma tricolor	1
	Calliostoma turbinum	12
Trochidae		
	Tegula aureotincta	1
NEOTAENIOGLOSSA		
Ovulidae		
	Neosimnia aequalis	27
	Neosimnia barbarensis	6
Lamellariidae		
	Lamellaria diegoensis	2

Attachment E.3 (*continued*)

Taxon	Species	N
Bursidae		
	Crossata californica	2
NEOGASTROPODA		
Muricidae		
	Pteropurpura macroptera	2
Nassariidae		
	Nassarius insculptus	2
Fasciolariidae		
	Fusinus barbarensis	17
Cancellariidae		
	Cancellaria cooperii	14
	Cancellaria crawfordiana	19
Turridae		
	Antiplanes catalinae	5
	Megasurcula carpenteriana	95
CEPHALASPIDEA		
Philinidae		
	Philine alba	10
	Philine auriformis	52
	Philine sp	2
NOTASPIDEA		
Pleurobranchidae		
	Pleurobranchaea californica	156
NUDIBRANCHIA		
DORIDOIDA		1
Platydorididae		
	Platydoris macfarlandi	2
Goniodorididae		
	Okenia vancouverensis	1
Onchidorididae		
	Acanthodoris brunnea	1
Tritoniidae		
	Tritonia diomedea	34
Arminidae		
	Armina californica	33
BIVALVIA		
VENEROIDA		
Chamidae		
	Pseudochama granti	1
CEPHALOPODA		
SEPIOIDEA		
Sepiolidae		
	Rossia pacifica	113
TEUTHIDA		
Loliginidae		
	Loligo opalescens	308

Attachment E.3 *(continued)*

Taxon	Species	N
OCTOPODA		
Octopodidae		
	Octopus californicus	1
	Octopus rubescens	228
	Octopus veligero	1
ANNELIDA		
POLYCHAETA		
PHYLLODOCIDA		
Aphroditidae		
	Aphrodita sp	2
Polynoidae		
	Arctonoe pulchra	41
SABELLIDA		
Serpulidae		
	Protula superba	6
ARTHROPODA		
PYCNOGONIDA		
PEGMATA		
Nymphonidae		
	Nymphon pixellae	127
CIRRIPEDIA		
THORACICA		
Scalpellidae		
	Hamatoscalpellum californicum	55
MALACOSTRACA		
STOMATOPODA		
Hemisquillidae		
	Hemisquilla ensigera californiensis	12
Squillidae		
	Schmittius politus	6
ISOPODA		
Aegidae		
	Rocinela angustata	1
Corallanidae		
	Excorallana truncata	1
Cymothoidae		
	Elthusa vulgaris	14
DECAPODA (includes CARIDEA, PAGUROIDEA, PENAEIDEA)		
Solenoceridae		
	Solenocera mutator	11
Sicyoniidae		
	Sicyonia ingentis	1335
Pandalidae		
	Pandalus platyceros	9
	Pantomus affinis	8

Attachment E.3 (*continued*)

Taxon				**Species**	**N**
			Hippolytidae		
				Eualus subtilis	1
				Heptacarpus tenuissimus	1
			Crangonidae		
				Crangon alaskensis	199
				Crangon nigromaculata	1
				Metacrangon spinosissima	2
				Neocrangon resima	7
				Neocrangon zacae	41
			Axiidae		
				Calocarides spinulicauda	1
			Diogenidae		
				Paguristes bakeri	9
				Paguristes turgidus	38
			Paguroidae		2
			Paguridae		1
				Orthopagurus minimus	1
				Pagurus spilocarpus	2
			Lithodidae		
				Paralithodes californiensis	1
				Paralithodes rathbuni	4
			Galatheidae		
				Pleuroncodes planipes	206
			Homolidae		
				Moloha faxoni	2
			Calappidae		
				Platymera gaudichaudii	266
			Majidae		1
				Loxorhynchus crispatus	12
				Loxorhynchus grandis	5
				Podochela hemphillii	3
				Podochela lobifrons	32
				Pyromaia tuberculata	6
			Parthenopidae		
				Heterocrypta occidentalis	1
			Palicidae		
				Palicus cortezi	1
ECHINODERMATA					
	CRINOIDEA				
		COMATULIDA			
			Antedonidae		
				Florometra serratissima	114
	ASTEROIDEA				3
		PAXILLOSIDA			
			Luidiidae		
				Luidia armata	74
				Luidia asthenosoma	73
				Luidia foliolata	617
				Luidia sp	4

Attachment E.3 (*continued*)

Taxon	Species	N
Astropectinidae		
	Astropecten ornatissimus	10
	Astropecten verrilli	872
	Astropecten sp	4
VALVATIDA		
Goniasteridae		
	Ceramaster patagonicus	2
	Mediaster aequalis	17
Asterinidae		
	Asterina miniata	1
SPINULOSIDA		
Poraniidae		
	Poraniopsis inflata	1
Echinasteridae		
	Henricia leviuscula	2
	Henricia sp	1
FORCIPULATIDA		
Asteriidae		
	Pycnopodia helianthoides	3
	Rathbunaster californicus	4
	Stylasterias forreri	1
OPHIUROIDEA		3
OPHIURIDA		
Ophiacanthidae		1
	Ophiacantha diplasia	4
Ophiactidae		
	Ophiopholis bakeri	64
Amphiuridae		16
	Amphichondrius granulatus	72
	Amphiodia urtica	11
	Amphiodia sp	6
	Amphipholis squamata	6
	Amphiura arcystata	2
Ophiotricidae		
	Ophiothrix spiculata	30
Ophionereidae		
	Ophionereis eurybrachiplax	1
Ophiuridae		
	Ophiura luetkenii	246
ECHINOIDEA		3
TEMNOPLEUROIDA		
Toxopneustidae		
	Lytechinus pictus	317317
ECHINOIDA		
Strongylocentrotidae		
	Allocentrotus fragilis	3888

Taxon	Species	N
SPATANGOIDA		
Brissidae		
	Brissopsis pacfica	17
Spatangidae		
	Spatangus californicus	70
Loveniidae		
	Lovenia cordiformis	20
HOLOTHUROIDEA		
ASPIDOCHIROTIDA		
Stichopodidae		
	Parastichopus californicus	912
BRACHIOPODA		
ARTICULATA		
TEREBRATULIDA		
Dallinidae		
	Terebratalia occidentalis	2
CHORDATA		
ASCIDIACEA		1
PHLEBOBRANCHIATA		
Cionidae		
	Ciona intestinalis	3
STOLIDOBRANCHIATE		
Styelidae		
	Styela sp	1
Pyuridae		
	Pyura sp	1

Attachment E.4

Summary Report for the San Diego Deep Benthic Pilot Study

Phase 1 Summary Report for the San Diego Deep Benthic Pilot Study

Prepared by:

City of San Diego
Ocean Monitoring Program
Metropolitan Wastewater Department
Environmental Monitoring and Technical Services Division

November 2006

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Appendices

Deep Benthic Pilot Study

INTRODUCTION

The Scripps Institution of Oceanography (SIO) was hired by the City of San Diego (City) to assess the adequacy of the City's Ocean Monitoring Program in providing the data and scientific understanding necessary to answer relevant questions about the effects of the Point Loma Ocean Outfall on the marine environment off San Diego. This work, the Point Loma Outfall Project (PLOP), was performed by a team of SIO scientists who reviewed the City's existing monitoring efforts and capabilities and compared these to programs conducted elsewhere for similar ocean outfalls. The results of this scientific review were summarized in a peer-reviewed report (SIO 2004), which was submitted to the City in September 2004. This information was also conveyed to state and federal regulators and to other interested stakeholders, including the San Diego Regional Water Quality Control Board (RWQCB), the United States Environmental Protection Agency (USEPA), and local environmental organizations (i.e., Bay Council). The final PLOP report included a summary of major findings and a subsequent list of prioritized recommendations for enhanced environmental monitoring of the San Diego coastal region.

A primary recommendation of the PLOP report was that a special studies program should be developed and implemented to examine the need to extend the City's benthic monitoring program to additional areas where sediments may accumulate. It was also recommended that new target areas include deeper slope and submarine canyon habitats located further offshore of the Point Loma outfall, as well as the nearby LA-5 dredged materials disposal site (see Gardner et al. 1998a).

The Deep Benthic Pilot Study was designed to begin assessing the quality of deep benthic habitats that occur off Point Loma, San Diego, California. Specifically, the pilot study targets sediment quality at depths greater than 200 m in the Loma Sea Valley located offshore of the regular Point Loma monitoring region. The project represents a "strategic process study" as defined under the regulatory requirements that govern the Point Loma Wastewater Treatment Plant's discharge of wastewater to the Pacific Ocean (Addendum No. 1 to Order No. R9-2002-0025, NPDES Permit No. CA0107409). Such special studies represent a unique mechanism to focus monitoring efforts on specific questions as defined in the model monitoring program that was developed for large ocean dischargers in southern California (Schiff et al. 2001).

The general scope, direction and level of effort of the pilot study (e.g., sampling area, distribution and number of sites, biotic and abiotic parameters) were agreed upon during negotiations between the City, SIO, RWQCB, USEPA and Bay Council. The final study design, including the rationale for the specific location and selection of sampling sites, was developed collaboratively by representatives of the City and SIO (Stebbins and Parnell 2005).

MATERIALS AND METHODS

Site Distribution

The area of coverage was initially defined by distributing a total of 16 sampling sites at approximately 4 different depths (200, 300, 400, 500 m). To enhance the final analysis, these provisional station locations were then modified by: a) targeting areas where sediments and contaminants are most likely to accumulate, and b) nesting the sampling sites into groups of similar microhabitats (e.g., sediment type, slope). These "microhabitat" assessments were made by evaluating data available from the high-resolution multibeam seafloor mapping survey conducted off San Diego in 1998 by the U.S. Geological Survey (Gardner et al. 1998a, b). Additionally, the relationship between the multibeam data and sediment structure was examined by comparing backscatter values from the USGS survey to known values for grain size distribution at the City's regular benthic monitoring stations (Stebbins and Parnell 2005).

The 16 deep sampling sites were classified into 3 groups (site classes) based on geographic location, sediment composition, and steepness of slope. Additionally, each class was represented by sites distributed along (or near) the 200, 300, 400 and 500 m isobaths. The locations of each site are shown in **Figure 1**, while specific target coordinates and depths are listed in **Table 1**.

Class 1 Sites (n = 4): Class 1 includes 4 sites at 4 different depths (approximately 200, 300, 400, 500 m) located in the axial valley/alluvial fan region of the Loma Sea Valley (see Figure 1). These sites occur along the valley of the local submarine canyon where sediments are most likely to accumulate. Specific locations were identified in areas at the bottom of the valley that had at least 200 to 300 m of 0–2% sloping area. The deepest site in the alluvial fan area (station DB13) is located a little off the valley axis and in slightly deeper water than most other sites (~537 m). This site had a particularly low backscatter value (177), which indicated the presence of fine sediments and thus an area with an increased chance of contaminant accumulation.

Class 2 Sites (n = 8): Class 2 includes replicate samples at each of 4 depths (approximately 200, 300, 400, 500 m) for a total of 8 sites (see Figure 1). Sites were selected from larger areas characterized by relatively soft sediments (i.e., backscatter = 170–184) and a slope of less than 2%. The backscatter ranges were chosen from inspection of the relationship between phi size and backscatter (Stebbins and Parnell 2005). Backscatter values in the range of 170–184 were generally characteristic of relatively fine sediment sites (i.e., most "E" stations); while coarser sediment sites at some of the anomalous northern "reference" stations tend to have higher backscatter. Overall, the low slope and predicted soft sediments suggest that the Class 2 sites are also in areas of likely sediment accumulation.

Class 3 Sites (n = 4): Class 3 includes 4 sites at depths (approximately 200, 300, 400, 500 m) located in steeper sloping areas of the Loma Sea Valley (see Figure 1). The Class 3 sites were placed in areas of relatively soft sediments similar to those of Class 2 (i.e., backscatter = 170–184), but with a steeper 2–5% slope. Although sediments at the Class 3 sites are less stable than those of Class 1 or Class 2, these steeper habitats need to be sampled as much of the slope area offshore of the shelf characterized by fine sediments falls within this slope range.

Field Sampling

A chain-rigged double Van Veen grab (0.1 m^2 for each grab) was used to collect one grab sample per station for infauna in October 2005. The temperature and depth of penetration of each sample were recorded. Each grab sample was checked for sample disturbance and depth of penetration, according to the criteria established for the USEPA (1987). Samples collected for benthic community assessment were sieved aboard ship through a nested 1.0 mm and 0.3 mm screen setup. The organisms retained on the 1.0 mm screen (macrofauna) and the 0.3 mm screen (meiofauna) were placed in separate containers,

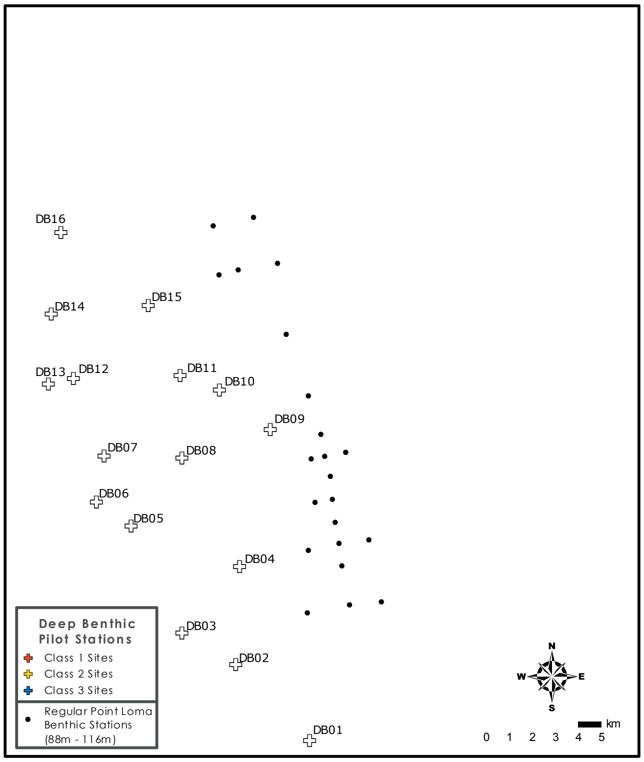

Figure 1

Station locations for Deep Benthic Pilot Study stations surveyed in October 2005.

Table 1

Station information and sample depths for all Deep Benthic Pilot Study stations surveyed during October 2005. Site classes: Class 1=axial valley of Loma Sea Valley, Class 2=relatively softer sediments and slope <2%, Class 3=relatively softer sediments and 2%< slope <5%. Grab=station depth during grab sampling (m). CTD=maximum depth (m) that the CTD reached. Difference=distance between the grab depth and the maximum depth that the CTD achieved.

Station Information					Bottom Sample Depth		
Site class	Station	Latitude	Longitude	Sample Date	Grab	CTD	Difference
1	DB01	32° 34.293’	117° 20.034’	10/13/05	202	198	4
	DB03	32° 36.761’	117° 23.089’	10/14/05	303	298	5
	DB06	32° 39.887’	117° 25.052’	10/18/05	414	410	4
	DB13	32° 42.625’	117° 26.181’	10/18/05	542	535	7
2	DB02	32° 36.038’	117° 21.743’	10/13/05	199	202	-3
	DB04	32° 38.319’	117° 21.726’	10/14/05	202	201	1
	DB05	32° 39.338’	117° 24.238’	10/17/05	318	317	1
	DB08	32° 40.882’	117° 23.044’	10/17/05	314	310	4
	DB07	32° 40.981’	117° 24.865’	10/18/05	401	399	2
	DB15	32° 44.480’	117° 23.790’	10/24/05	402	400	2
	DB16	32° 46.214’	117° 25.844’	10/24/05	502	478	24
	DB12	32° 42.795’	117° 25.584’	10/18/05	519	514	5
3	DB09	32° 41.570’	117° 20.998’	10/14/05	204	200	4
	DB10	32° 42.546’	117° 22.142’	10/17/05	302	303	-1
	DB11	32° 42.904’	117° 23.063’	10/17/05	400	397	3
	DB14	32° 44.265’	117° 26.161’	10/24/05	508	497	11

relaxed for 30 minutes in a magnesium sulfate solution, and then fixed in buffered formalin.

An additional grab sample was collected at each station for the analysis of various physical and chemical parameters of the sediment. These samples were taken from the top 2 cm of the sediment surface and processed according to the procedures (e.g., holding times, target analyte list) established for the Southern California Bight 2003 Regional Monitoring Project as appropriate (Bight′03 Coastal Ecology Committee 2003). For parameters not subject to Bight′03 protocols (e.g., sulfides), sample processing followed the protocols specified in the City’s NPDES permit (see City of San Diego 2004, 2005).

Bottom water conditions at each station were characterized based on data collected using a SeaBird CTD instrument. One CTD cast was performed at each site following successful collection of the benthic grab samples. Water column profiles of temperature, transmissivity, dissolved oxygen, pH, salinity, density, and chlorophyll *a* were generated. The Sea-Bird CTD collects these physical/chemical data at a rate of 8 scans per second. These scans were then internally averaged to create water column profiles with data readings at a rate of 1 per meter.

Laboratory Analyses

Sediments

All sediment analyses were performed by the City’s Wastewater Chemistry Laboratory. Particle size analyses were performed using a Horiba LA-920 laser analyzer, which measures particles ranging in size from 0 to 11 phi (0.5–2000). The fraction of coarser sediments (e.g., very coarse sand, gravel, shell hash) in each sample was determined by measuring the weight of particles retained on a 2.0 mm mesh sieve and expressed as the percent weight of the total sample sieved. All sediment samples were analyzed for grain size, total organic carbon (TOC), total nitrogen (TN), total solids

Table 2

Target list for trace metals, pesticides, and PCBs analyzed for sediment samples collected at Deep Benthic Pilot Study stations in October 2005.

Trace Metals	Pesticides	PCBs	
Aluminum	4,4’-DDT	PCB-18	PCB-128
Antimony	2,4’-DDT	PCB-28	PCB-138
Arsenic	4,4’-DDD	PCB-37	PCB-149
Barium	2,4’-DDD	PCB-44	PCB-151
Beryllium	4,4’-DDE	PCB-49	PCB-153
Cadmium	2,4’-DDE	PCB-52	PCB-156
Chromium	α-Chlordane	PCB-66	PCB-157
Copper	γ-Chlordane	PCB-70	PCB-158
Iron		PCB-74	PCB-167
Lead		PCB-77	PCB-168
Manganese		PCB-81	PCB-169
Mercury		PCB-87	PCB-170
Nickel		PCB-99	PCB-177
Selenium		PCB-101	PCB-180
Silver		PCB-105	PCB-183
Thallium		PCB-110	PCB-187
Tin		PCB-114	PCB-189
Zinc		PCB-118	PCB-194
		PCB-119	PCB-201
		PCB-123	PCB-206
		PCB-126	

(TS), total volatile solids (TVS), sulfides, trace metals, chlorinated pesticides, and polychlorinated biphenyl compounds (PCBs). The Bight′03 target list for metals, pesticides and PCBs was used (**Table 2**). Some parameters were determined to be present in a sample with high confidence (i.e., peaks confirmed by mass-spectrometry), but at levels below the MDL. These data represent estimated values and are denoted with an “E” preceding the reported value.

Macrofauna

After fixation in formalin for at least 72 hrs, each benthic infauna sample was rinsed in fresh water and transferred to 70% ethanol. The organisms in each sample were sorted into 6 major taxonomic groups by an outside contractor, Merkel & Associates, Inc., San Diego, California. These groups included polychaetes, crustaceans, mollusks, ophiuroid echinoderms, other echinoderms, and all other taxa combined. Upon return to the City’s laboratory, all animals were identified to the lowest possible taxon and enumerated by City marine biologists. Between 5 and 10% of all benthic samples were resorted by a second marine biologist as a quality assurance check. Additional information concerning equipment, analytical techniques, and quality assurance procedures are included in the Ocean Monitoring Program’s Quality Assurance Project Plan (City of San Diego, in prep).

Data Analyses

Benthic macrofauna abundance data were entered into an ORACLE database following specific QA/QC procedures (see City of San Diego, in prep). City marine biologists performed the data analyses using various data management and statistical software packages (e.g., Oracle, PRIMER, SAS).

The following descriptive statistics and ecological indices were determined for the benthic invertebrate community collected at each station.

- Species Richness per Grab: number of species per 0.1 m^2
- Infaunal Abundance: number of individuals per 0.1 m^2
- Shannon Diversity Index (H′) (Shannon and Weaver 1949)
- Pielou Evenness (J′) (Pielou 1977): calculated as $J' = H'/H'_{max}$, where $H'_{max} = \ln(S)$
- Swartz 75% Dominance Index: calculated as number of species comprising top 75% by abundance

Classification analysis (hierarchical agglomerative clustering) was employed to illustrate spatial patterns in the distribution of benthic assemblages. This analysis was performed with the software program PRIMER using the abundance per station for each infaunal species.

Table 3

Bottom water properties at all Deep Benthic Pilot Study stations sampled in October 2005. See text for the description of site classes. Depth=depth of station (m). CTD depth=maximum depth (m) that the CTD reached. Most CTD bottom depths were within 5 m of the official station depth; exceptions=stations DB13 (-7 m), DB14 (-11 m), and DB16 (-24 m). Temperature=Temp (°C), salinity (ppt), density (δ/θ), dissolved oxygen=DO (mg/L), pH, transmissivity=XMS (%), and chlorophyll *a*=Chl *a* (µg/L).

Station information		Bottom water characterisitics						
Site class	**Station**	**Temp**	**Salinity**	**Density**	**DO**	**pH**	**XMS**	**Chl** a
1	DB01	10.2	34.3	26.4	1.5	7.6	63	0.23
	DB03	8.5	34.3	26.6	1.6	7.7	64	0.20
	DB06	6.8	34.3	26.9	1.0	7.5	70	0.20
	DB13	6.1	34.3	27.0	0.5	7.5	65	0.21
2	DB02	10.8	34.3	26.2	1.4	7.7	66	0.23
	DB04	10.9	34.0	26.0	1.3	7.7	54	0.22
	DB05	8.5	34.3	26.6	1.6	7.7	84	0.37
	DB08	8.9	34.3	26.6	1.8	7.7	81	0.24
	DB07	7.2	34.3	26.8	1.2	7.5	74	0.21
	DB15	6.8	34.3	26.9	0.9	7.6	70	0.18
	DB16	6.3	34.3	27.0	0.6	7.6	76	0.18
	DB12	6.3	34.3	27.0	0.6	7.5	63	0.20
3	DB09	11.0	34.2	26.2	1.1	7.7	76	0.17
	DB10	8.5	34.3	26.6	1.6	7.6	69	0.23
	DB11	7.1	33.7	26.4	1.2	7.6	72	0.24
	DB14	6.1	33.8	26.6	0.5	7.5	70	0.18

RESULTS

An in-depth analysis of sediment and benthic infauna data will be included in the final Phase 2 Comprehensive Report. Bottom water characteristics from the CTD casts are presented in **Table 3**. Summaries of sediment characteristics for organic loading indicators (**Table 4**), metals (**Table 5**), and particle size parameters (**Table 6**) are also presented. Pesticides and PCBs were not detected in any of the sediment samples collected. The raw data for the sediment particle grain size are presented in **Appendix A**.

Macrofaunal species richness, abundance, diversity (H′), evenness (J′), and Swartz dominance values are summarized in **Table 7**. Species richness is presented as the number of species. Abundances are given as the total number of organisms. Diversity and evenness were calculated based on the number of species per station (S) and the abundance of each species. A cluster analysis illustrates the biological patterns at the community level for all benthic stations sampled during the October 2005 survey (**Figure 2**). In addition, **Appendix B** contains a listing of the species comprising the Swartz Dominance Index by station. **Appendix C** contains a listing of the raw data for each station. The visual observations recorded at each station are presented in **Appendix D**.

Table 4

Summary of organic loading indicators at Deep Benthic Pilot Study stations sampled in October 2005. See text for the description of site classes. Depth=depth of station (m). Sulfides=ppm. Total nitrogen=TN (%wt), total organic carbon=TOC (%wt), total solids=TS (%wt), and total volatile solids=TVS (%wt).

Site class	Station	Depth	Sulfides	TN	TOC	TS	TVS
1	DB01	202	1.7	0.084	1.71	66.0	3.28
	DB03	303	2.2	0.143	2.67	59.9	5.25
	DB06	414	0.6	0.097	2.09	64.5	4.22
	DB13	542	8.3	0.257	3.32	41.4	9.88
	Class mean	*365*	*3.2*	*0.145*	*2.45*	*58.0*	*5.66*
2	DB02	199	4.2	0.158	2.69	53.0	6.42
	DB04	202	28.3	0.166	2.43	51.8	6.73
	DB08	314	21.5	0.215	2.95	42.8	8.84
	DB05	318	29.2	0.230	3.41	46.9	8.55
	DB07	401	10.4	0.233	3.28	44.3	8.81
	DB15	402	2.9	0.185	2.67	48.3	7.71
	DB16	502	3.5	0.240	3.21	41.9	10.20
	DB12	519	18.2	0.270	3.34	43.9	9.02
	Class mean	*357*	*14.8*	*0.212*	*3.00*	*46.6*	*8.29*
3	DB09	204	9.5	0.121	1.85	57.4	4.91
	DB10	302	32.6	0.236	3.02	44.4	9.06
	DB11	400	18.7	0.252	3.21	42.4	8.88
	DB14	508	3.2	0.226	3.08	39.7	9.46
	Class mean	*354*	*16.0*	*0.209*	*2.79*	*46.0*	*8.08*
	Overall mean (n=16)	358	12.2	0.195	2.81	49.3	7.58
	Mean by depth range						
	199–299 m (n=4)	202	10.9	0.132	2.17	57.1	5.34
	300–399 m (n=4)	309	21.4	0.206	3.01	48.5	7.93
	400–499 m (n=4)	404	8.1	0.192	2.81	49.9	7.41
	500 m + (n=4)	518	8.3	0.248	3.24	41.7	9.64

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Table 5

Summary of metal concentrations (ppm) at Deep Benthic Pilot Study stations sampled during October 2005. See text for the description of site classes. Depth=depth of station (m).

Site class	Station	Depth	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe
1	DB01	202	14100	1.65	2.59	41.70	0.239	0.107	21.2	8.5	15500
	DB03	303	18000	2.05	4.28	78.70	0.333	0.240	34.3	14.2	20200
	DB06	414	11200	1.43	3.32	72.10	0.296	0.166	31.2	6.4	17400
	DB13	542	34900	2.88	3.11	195.00	0.470	0.550	48.0	23.1	28100
	Class mean	*365*	*19550*	*2.00*	*3.33*	*96.88*	*0.335*	*0.266*	*33.7*	*13.1*	*20300*
2	DB02	199	25100	2.41	3.00	80.50	0.364	0.205	36.8	18.1	23000
	DB04	202	31500	2.53	3.85	107.00	0.402	0.205	40.8	25.7	27000
	DB08	314	30300	2.73	3.09	106.00	0.419	0.303	45.7	22.4	26400
	DB05	318	28800	2.69	3.14	106.00	0.414	0.325	43.4	20.1	25600
	DB07	401	30800	2.64	3.06	130.00	0.431	0.284	46.4	24.3	27000
	DB15	402	27800	2.31	2.95	126.00	0.381	0.421	40.0	17.0	24600
	DB16	502	32500	2.36	2.91	188.00	0.442	0.505	49.4	24.2	27500
	DB12	519	32000	2.67	3.42	175.00	0.430	0.501	45.6	22.5	26800
	Class mean	*357*	*29850*	*2.54*	*3.18*	*127.31*	*0.410*	*0.344*	*43.5*	*21.8*	*25988*
3	DB09	204	25000	2.63	2.81	71.80	0.344	0.256	35.3	17.7	23300
	DB10	302	30100	2.85	3.28	104.00	0.437	0.312	44.1	23.9	28200
	DB11	400	30000	2.74	3.48	122.00	0.428	0.460	46.5	22.2	26700
	DB14	508	31300	2.54	2.87	170.00	0.416	0.522	45.5	22.2	25800
	Class mean	*354*	*29100*	*2.69*	*3.11*	*116.95*	*0.406*	*0.388*	*42.9*	*21.5*	*26000*
	Overall mean (n=16)	358	27088	2.44	3.20	117.11	0.390	0.335	40.9	19.5	24569
	Mean by depth range										
	199–299 m (n=4)	202	23925	2.31	3.06	75.25	0.337	0.193	33.5	17.5	22200
	300–399 m (n=4)	309	26800	2.58	3.45	98.68	0.401	0.295	41.9	20.2	25100
	400–499 m (n=4)	404	24950	2.28	3.20	112.53	0.384	0.333	41.0	17.5	23925
	500 m + (n = 4)	518	32675	2.61	3.08	182.00	0.440	0.520	47.1	23.0	27050

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Table 5 continued

Site class	Station	Depth	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
1	DB01	202	1.41	211	0.016	9.5	0.326	0.00	0.00	0.55	21.9
	DB03	303	3.20	177	0.038	15.4	0.736	0.00	0.00	1.26	28.7
	DB06	414	2.16	112	0.054	10.4	0.506	0.00	0.00	0.75	16.9
	DB13	542	2.43	327	0.053	27.3	1.290	0.00	0.00	1.11	43.6
	Class mean	*365*	*2.30*	*207*	*0.040*	*15.7*	*0.715*	*0.00*	*0.00*	*0.92*	*27.8*
2	DB02	199	3.22	273	0.111	18.3	0.550	0.00	0.00	1.09	35.8
	DB04	202	6.15	334	0.153	20.1	0.698	0.00	0.00	1.69	38.2
	DB08	314	3.84	305	0.068	24.5	0.949	0.00	0.00	1.16	46.9
	DB05	318	3.18	292	0.062	23.7	1.040	0.00	0.00	1.24	43.2
	DB07	401	3.46	320	0.056	25.2	1.220	0.00	0.00	1.06	44.1
	DB15	402	3.04	318	0.050	21.3	1.020	0.00	0.00	1.21	34.3
	DB16	502	2.84	318	0.066	29.5	1.450	0.00	0.00	1.17	44.9
	DB12	519	2.72	322	0.059	25.8	1.480	0.00	0.00	1.09	41.6
	Class mean	*357*	*3.56*	*310*	*0.078*	*23.6*	*1.051*	*0.00*	*0.00*	*1.21*	*41.1*
3	DB09	204	2.50	329	0.071	16.1	0.413	0.00	0.35	0.97	38.2
	DB10	302	5.65	313	0.075	24.5	0.909	0.00	0.00	1.42	54.7
	DB11	400	2.66	308	0.051	25.6	1.220	0.00	0.00	0.88	49.3
	DB14	508	1.74	324	0.048	26.0	1.420	0.00	0.00	0.86	39.3
	Class mean	*354*	*3.14*	*319*	*0.061*	*23.1*	*0.991*	*0.00*	*0.09*	*1.03*	*45.4*
	Overall mean (n=16)	358	3.14	286	0.064	21.5	0.952	0.00	0.02	1.09	38.9
	Mean by depth range										
	199–299 m (n=4)	202	3.32	287	0.088	16.0	0.497	0.00	0.09	1.08	33.5
	300–399 m (n=4)	309	3.97	272	0.061	22.0	0.909	0.00	0.00	1.27	43.4
	400–499 m (n=4)	404	2.83	265	0.053	20.6	0.992	0.00	0.00	0.97	36.2
	500 m + (n=4)	518	2.43	323	0.056	27.2	1.410	0.00	0.00	1.06	42.4

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Table 6

Summary of particle size parameters at Deep Benthic Pilot Study stations sampled during October 2005. See text for the description of site classes. Depth=depth of station (m). Mean particle size (Mean), standard deviation (SD), median particle size (Median), skewness, and kurtosis are reported as phi size. Sediment type is reported as coarse, sand, and fines (%).

Site class	Station	Depth	Mean	SD	Median	Skewness	Kurtosis	Coarse	Sand	Fines
1	DB01	202	4.2	1.8	3.3	0.6	0.8	0	61	39
	DB03	303	4.6	2.1	4.6	0.0	0.7	0	43	57
	DB06	414	4.3	2.2	3.9	0.2	0.8	1	50	49
	DB13	542	5.7	1.6	5.9	-0.1	1.0	0	15	85
	Class mean	*365*	*4.7*	*1.9*	*4.4*	*0.2*	*0.9*	*0*	*42*	*57*
2	DB02	199	4.9	1.7	4.7	0.2	0.8	0	35	65
	DB04	202	5.2	1.7	5.2	0.1	0.9	0	25	75
	DB08	314	5.4	1.6	5.6	-0.1	1.0	0	19	81
	DB05	318	5.3	1.6	5.4	-0.1	0.9	0	23	77
	DB07	401	5.5	1.5	5.6	-0.1	1.0	0	17	83
	DB15	402	5.3	1.6	5.4	-0.1	0.9	0	23	77
	DB16	502	5.7	1.5	5.9	-0.2	1.1	0	13	87
	DB12	519	5.7	1.7	5.9	-0.1	1.0	0	17	83
	Class mean	*357*	*5.4*	*1.6*	*5.5*	*-0.0*	*1.0*	*0*	*21*	*79*
3	DB09	204	4.9	1.6	4.6	0.3	0.8	0	34	66
	DB10	302	5.4	1.6	5.6	-0.1	1.0	0	20	80
	DB11	400	5.6	1.4	5.7	-0.1	1.0	0	14	86
	DB14	508	5.6	1.5	5.8	-0.1	1.0	0	15	85
	Class mean	*354*	*5.4*	*1.5*	*5.4*	*-0.0*	*1.0*	*0*	*21*	*79*
	Overall Mean (n=16)	358	5.2	1.7	5.2	0.0	0.9	0	27	73
	Mean by depth range									
	199–299 m (n=4)	202	4.8	1.7	4.5	0.3	0.9	0	39	61
	300–399 m (n=4)	309	5.2	1.7	5.3	-0.0	0.9	0	26	74
	400–499 m (n=4)	404	5.2	1.7	5.2	-0.0	0.9	0	26	74
	500 m + (n=4)	518	5.7	1.6	5.9	-0.1	1.0	0	15	85

Table 7

Benthic macrofaunal community parameters at Deep Benthic Pilot Study stations sampled during October 2005. See text for the description of site classes. Depth=depth of station (m). Data are from single grabs. Species richness=SR (no. species/0.1 m^2), abundance=Abun (no. organisms/0.1 m^2), diversity=H′, evenness=J′, and Swartz dominance=Dom (no. species comprising 75% of a community by abundance).

Site class	Station	Depth	SR	Abun	H′	J′	Dom
1	DB01	202	127	436	4.30	0.89	44
	DB03	303	80	215	4.02	0.92	36
	DB06	414	49	151	3.35	0.86	18
	DB13	542	30	51	3.19	0.94	18
2	DB02	199	67	164	3.84	0.91	29
	DB04	202	42	113	3.18	0.85	18
	DB05	318	35	88	2.93	0.83	13
	DB08	314	45	98	3.40	0.89	21
	DB07	401	30	58	3.12	0.92	16
	DB15	402	35	67	3.23	0.91	19
	DB16	502	22	60	2.73	0.88	9
	DB12	519	28	41	3.17	0.95	18
3	DB09	204	62	187	3.57	0.86	24
	DB10	302	41	151	2.75	0.74	11
	DB11	400	23	40	2.94	0.94	13
	DB14	508	15	47	1.69	0.62	4

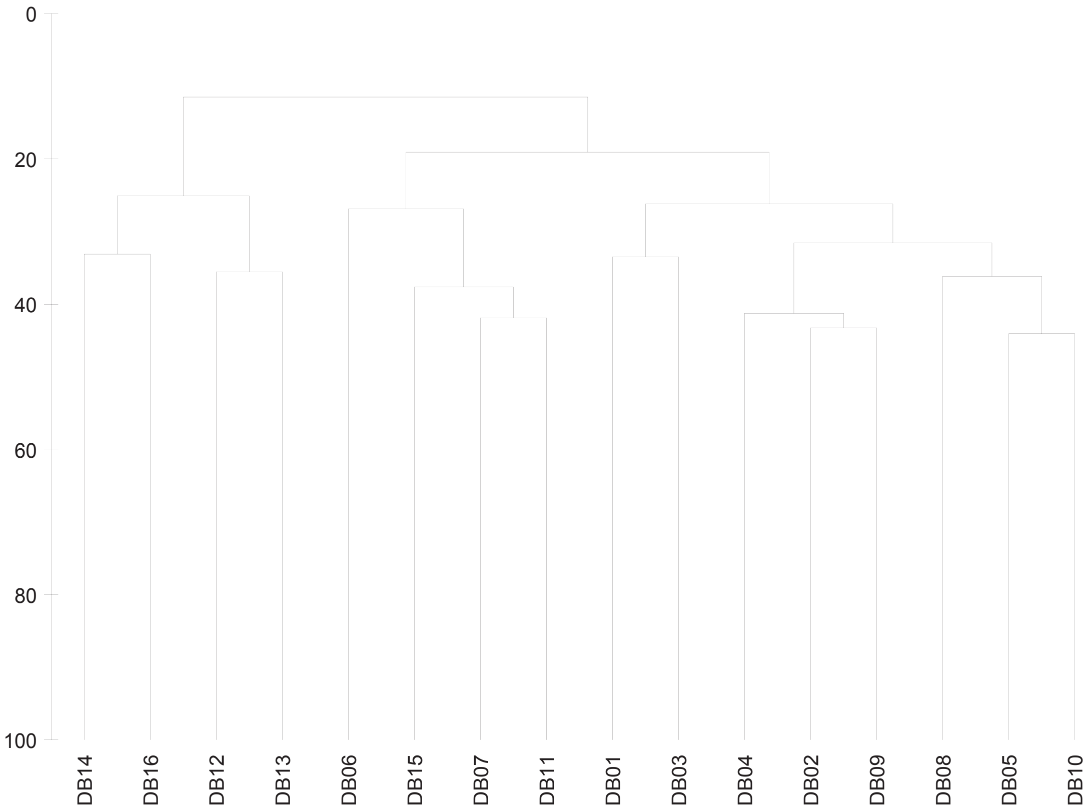


Figure 2
Preliminary station dendrogram resulting from cluster analysis of macrofaunal abundance data for Deep Benthic Pilot Study stations sampled in October 2005.

Appendix A

Particle grain size data from the Deep Benthic Pilot Study stations sampled in October 2005.

Microns	Phi size	DB01	DB02	DB03	DB04	DB05	DB06	DB07	DB08
<0.500	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>0.5 to 1	10	0.00	0.23	0.26	0.78	0.10	0.11	0.11	0.12
>1 to 1.5		0.41	0.69	0.75	1.00	0.60	0.56	0.64	0.66
>1.5 to 2	9	0.67	0.99	1.04	1.27	0.94	0.79	0.97	0.99
>2.0 to 2.4		0.67	0.96	0.99	1.15	0.96	0.76	0.97	0.99
>2.4 to 2.9		0.92	1.28	1.30	1.48	1.34	1.01	1.34	1.36
>2.9 to 3.4		0.98	1.34	1.34	1.50	1.44	1.06	1.45	1.46
>3.4 to 3.9	8	1.09	1.46	1.45	1.59	1.63	1.16	1.64	1.64
>3.9 to 4		0.23	0.30	0.30	0.33	0.35	0.24	0.35	0.35
>4.0 to 4.3		0.65	0.87	0.87	0.94	1.00	0.70	1.01	1.01
>4.3 to 4.5		0.42	0.56	0.56	0.61	0.64	0.45	0.66	0.65
>4.5 to 5		1.12	1.49	1.49	1.60	1.76	1.22	1.80	1.78
>5 to 5.5		1.10	1.48	1.49	1.59	1.78	1.22	1.84	1.80
>5.5 to 5.7		0.42	0.57	0.57	0.61	0.69	0.47	0.71	0.70
>5.7 to 5.9		0.42	0.56	0.57	0.60	0.68	0.47	0.71	0.69
>5.9 to 7.8	7	3.84	5.21	5.32	5.65	6.59	4.44	6.94	6.75
>7.8 to 8		0.37	0.52	0.54	0.58	0.68	0.46	0.73	0.71
>8 to 8.5		0.89	1.25	1.29	1.39	1.63	1.09	1.75	1.69
>8.5 to 8.9		0.68	0.96	0.99	1.07	1.26	0.84	1.35	1.30
>8.9 to 9.1		0.34	0.48	0.50	0.54	0.64	0.43	0.69	0.67
>9.1 to 9.5		0.65	0.93	0.97	1.05	1.24	0.82	1.34	1.29
>9.5 to 9.8		0.47	0.67	0.70	0.76	0.89	0.60	0.97	0.94
>9.8 to 10.1		0.45	0.65	0.68	0.74	0.87	0.58	0.94	0.91
>10.1 to 10.6		0.75	1.11	1.15	1.28	1.50	0.99	1.65	1.59
>10.6 to 11.1		0.71	1.06	1.10	1.22	1.43	0.95	1.57	1.51
>11.1 to 11.3		0.28	0.41	0.43	0.47	0.55	0.37	0.61	0.59
>11.3 to 11.7	6	0.53	0.79	0.82	0.92	1.08	0.71	1.19	1.14
>11.7 to 14		2.60	4.06	4.18	4.82	5.54	3.65	6.18	5.96
>14 to 14.8		0.79	1.27	1.30	1.53	1.74	1.14	1.95	1.88
>14.8 to 15.6		0.73	1.20	1.21	1.46	1.64	1.07	1.84	1.79
>15.6 to 16		0.34	0.58	0.57	0.71	0.78	0.51	0.88	0.86
>16 to 20		2.88	5.06	4.91	6.27	6.81	4.38	7.73	7.53
>20 to 23		1.63	3.11	2.84	3.96	4.10	2.57	4.67	4.60
>23 to 27		1.74	3.59	3.03	4.59	4.55	2.76	5.15	5.13
>27 to 31	5	1.46	3.22	2.46	4.07	3.87	2.25	4.33	4.33
>31 to 32		0.34	0.77	0.54	0.96	0.89	0.50	0.98	0.98
>32 to 35.6		1.16	2.69	1.81	3.25	3.01	1.66	3.27	3.26
>35.6 to 37		0.44	1.03	0.64	1.20	1.10	0.59	1.17	1.16
>37 to 39.6		0.79	1.85	1.13	2.12	1.95	1.04	2.06	2.03
>39.6 to 43.6		1.29	2.92	1.60	3.09	2.83	1.50	2.89	2.81
>43.6 to 44		0.12	0.28	0.15	0.29	0.27	0.14	0.27	0.27
>44 to 45		0.31	0.69	0.38	0.72	0.66	0.35	0.67	0.65
>45 to 46.4		0.51	1.05	0.52	1.00	0.91	0.50	0.89	0.85
>46.4 to 53		2.37	4.63	2.28	4.30	3.94	2.21	3.80	3.65
>53 to 62.5	4	4.01	6.23	2.94	5.09	4.68	2.98	4.23	4.09
>62.5 to 64		0.68	0.92	0.43	0.70	0.64	0.45	0.56	0.54
>64 to 71.7		3.79	4.33	2.12	3.13	2.90	2.27	2.42	2.38
>71.7 to 74		1.18	1.19	0.60	0.82	0.76	0.66	0.61	0.61
>74 to 79.6		2.99	2.65	1.41	1.77	1.66	1.59	1.30	1.29

Appendix A continued

Microns	Phi size	DB01	DB02	DB03	DB04	DB05	DB06	DB07	DB08
>79.6 to 87.6		4.45	3.29	1.92	2.10	1.97	2.23	1.46	1.48
>87.6 to 88		0.21	0.16	0.09	0.10	0.09	0.11	0.07	0.07
>88 to 90		1.16	0.70	0.47	0.43	0.41	0.57	0.29	0.30
>90 to 105		8.33	4.42	3.37	2.68	2.52	4.15	1.72	1.79
>105 to 125	3	9.47	3.94	4.20	2.36	2.21	5.30	1.41	1.53
>125 to 149		8.19	2.92	4.57	1.80	1.66	5.67	1.01	1.15
>149 to 160		2.59	0.86	1.88	0.56	0.51	2.22	0.31	0.37
>160 to 177		3.20	1.04	2.65	0.70	0.64	3.03	0.39	0.47
>177 to 197		2.49	0.80	2.65	0.58	0.53	2.83	0.32	0.41
>197 to 210		1.13	0.35	1.44	0.28	0.26	1.45	0.16	0.22
>210 to 217		0.52	0.16	0.72	0.13	0.12	0.71	0.08	0.11
>217 to 245		1.59	0.48	2.41	0.42	0.39	2.30	0.25	0.36
>245 to 250	2	0.22	0.07	0.37	0.06	0.06	0.34	0.04	0.06
>250 to 300		1.54	0.43	2.84	0.46	0.42	2.53	0.29	0.47
>300 to 320		0.37	0.08	0.75	0.12	0.11	0.65	0.08	0.15
>320 to 350		0.49	0.11	1.00	0.16	0.14	0.86	0.11	0.21
>350 to 360		0.13	0.02	0.27	0.04	0.04	0.23	0.03	0.07
>360 to 400		0.48	0.07	0.98	0.16	0.14	0.84	0.10	0.25
>400 to 420		0.20	0.00	0.40	0.07	0.06	0.35	0.04	0.12
>420 to 440		0.19	0.00	0.38	0.06	0.05	0.34	0.04	0.11
>440 to 500	1	0.53	0.00	1.00	0.17	0.13	0.89	0.02	0.31
>500 to 590		0.58	0.00	0.83	0.04	0.03	1.16	0.00	0.08
>590 to 630		0.23	0.00	0.16	0.00	0.00	0.48	0.00	0.00
>630 to 696		0.31	0.00	0.18	0.00	0.00	0.74	0.00	0.00
>696 to 710		0.04	0.00	0.00	0.00	0.00	0.15	0.00	0.00
>710 to 773		0.17	0.00	0.00	0.00	0.00	0.65	0.00	0.00
>773 to 840		0.01	0.00	0.00	0.00	0.00	0.63	0.00	0.00
>840 to 850		0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
>850 to 930		0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
>930 to 1000	0	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00
1000 to 1100		0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00
>1100 to 1190		0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00
>1190 to 1300		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1300 to 1410		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1410 to 1680		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1680 to 2000	-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>2000		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Microns	Phi size	DB09	DB10	DB11	DB12	DB13	DB14	DB15	DB16
<0.500	11	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00
>0.5 to 1	10	0.10	0.25	0.26	1.02	0.59	0.39	0.11	0.28
>1 to 1.5		0.57	0.76	0.74	1.25	1.02	0.84	0.59	0.83
>1.5 to 2	9	0.83	1.10	1.07	1.56	1.41	1.18	0.87	1.20
>2.0 to 2.4		0.81	1.07	1.05	1.39	1.32	1.14	0.86	1.17
>2.4 to 2.9		1.08	1.44	1.42	1.79	1.74	1.53	1.19	1.58
>2.9 to 3.4		1.13	1.52	1.51	1.82	1.81	1.62	1.28	1.69
>3.4 to 3.9	8	1.24	1.67	1.69	1.94	1.97	1.79	1.44	1.88
>3.9 to 4		0.26	0.35	0.36	0.41	0.42	0.38	0.31	0.40
>4.0 to 4.3		0.74	1.02	1.04	1.17	1.19	1.10	0.89	1.16

Appendix A continued

Microns	Phi size	DB09	DB10	DB11	DB12	DB13	DB14	DB15	DB16
>4.3 to 4.5		1.27	1.78	1.83	2.02	2.08	1.94	1.58	2.05
>4.5 to 5		1.26	1.79	1.87	2.02	2.09	1.98	1.62	2.09
>5 to 5.5		0.49	0.70	0.73	0.78	0.81	0.77	0.63	0.81
>5.5 to 5.7		0.48	0.69	0.72	0.77	0.80	0.76	0.62	0.81
>5.7 to 5.9		4.50	6.62	7.05	7.34	7.70	7.45	6.17	7.92
>5.9 to 7.8	7	0.46	0.69	0.75	0.76	0.80	0.79	0.66	0.84
>7.8 to 8		1.10	1.65	1.79	1.81	1.91	1.88	1.57	2.01
>8 to 8.5		0.85	1.27	1.38	1.39	1.47	1.45	1.22	1.55
>8.5 to 8.9		0.43	0.65	0.71	0.70	0.75	0.74	0.63	0.79
>8.9 to 9.1		0.83	1.26	1.38	1.36	1.44	1.44	1.22	1.54
>9.1 to 9.5		0.60	0.91	1.00	0.99	1.04	1.04	0.88	1.11
>9.5 to 9.8		0.58	0.88	0.97	0.96	1.01	1.01	0.85	1.08
>9.8 to 10.1		1.01	1.54	1.71	1.65	1.75	1.77	1.51	1.90
>10.1 to 10.6		0.96	1.47	1.63	1.57	1.67	1.69	1.44	1.81
>10.6 to 11.1		0.37	0.57	0.63	0.61	0.65	0.65	0.56	0.70
>11.1 to 11.3		0.73	1.11	1.23	1.18	1.25	1.27	1.09	1.36
>11.3 to 11.7	6	3.82	5.76	6.48	6.04	6.41	6.59	5.76	7.06
>11.7 to 14		1.22	1.82	2.06	1.88	2.00	2.07	1.83	2.22
>14 to 14.8		1.17	1.72	1.95	1.76	1.87	1.94	1.74	2.08
>14.8 to 15.6		0.57	0.83	0.94	0.84	0.89	0.93	0.84	0.99
>15.6 to 16		5.13	7.26	8.24	7.23	7.64	8.01	7.38	8.54
>16 to 20		3.33	4.43	5.02	4.25	4.46	4.72	4.52	5.00
>20 to 23		4.03	4.94	5.54	4.58	4.76	5.05	5.02	5.28
>23 to 27		3.77	4.19	4.61	3.78	3.87	4.09	4.22	4.18
>27 to 31	5	0.93	0.95	1.03	0.85	0.85	0.90	0.95	0.90
>31 to 32		3.26	3.19	3.39	2.81	2.81	2.96	3.16	2.91
>32 to 35.6		1.27	1.15	1.19	1.00	0.98	1.03	1.13	0.99
>35.6 to 37		2.28	2.02	2.08	1.75	1.72	1.81	1.98	1.71
>37 to 39.6		3.62	2.84	2.83	2.45	2.36	2.47	2.79	2.23
>39.6 to 43.6		0.34	0.27	0.27	0.23	0.22	0.24	0.26	0.21
>43.6 to 44		0.85	0.66	0.66	0.57	0.55	0.58	0.65	0.52
>44 to 45		1.29	0.89	0.85	0.76	0.72	0.75	0.88	0.64
>45 to 46.4		5.68	3.81	3.60	3.26	3.06	3.20	3.80	2.72
>46.4 to 53		7.40	4.37	3.92	3.74	3.45	3.60	4.54	2.91
>53 to 62.5	4	1.06	0.59	0.51	0.50	0.46	0.48	0.63	0.38
>62.5 to 64		4.88	2.61	2.19	2.23	2.04	2.11	2.84	1.65
>64 to 71.7		1.30	0.67	0.55	0.58	0.52	0.54	0.75	0.42
>71.7 to 74		2.84	1.44	1.15	1.24	1.13	1.16	1.63	0.89
>74 to 79.6		3.38	1.67	1.28	1.44	1.31	1.34	1.95	1.02
>87.6 to 88		0.16	0.08	0.06	0.07	0.06	0.06	0.09	0.05
>88 to 90		0.68	0.34	0.25	0.29	0.27	0.27	0.40	0.21
>90 to 105		4.12	2.04	1.45	1.78	1.62	1.64	2.51	1.27
>105 to 125	3	3.33	1.74	1.13	1.52	1.40	1.39	2.23	1.12
>125 to 149		2.22	1.28	0.75	1.11	1.05	1.01	1.68	0.87
>149 to 160		0.61	0.39	0.21	0.34	0.32	0.30	0.52	0.28
>160 to 177		0.71	0.49	0.25	0.42	0.40	0.37	0.64	0.35
>177 to 197		0.52	0.41	0.18	0.34	0.33	0.30	0.52	0.30
>197 to 210		0.23	0.20	0.08	0.16	0.16	0.14	0.25	0.15
>210 to 217		0.10	0.10	0.04	0.08	0.08	0.07	0.12	0.07
>217 to 245		0.31	0.32	0.09	0.25	0.24	0.22	0.38	0.23

Appendix A continued

Microns	Phi size	DB09	DB10	DB11	DB12	DB13	DB14	DB15	DB16
>245 to 250	2	0.04	0.05	0.01	0.04	0.04	0.03	0.05	0.03
>250 to 300		0.28	0.37	0.02	0.27	0.26	0.23	0.40	0.25
>300 to 320		0.06	0.10	0.00	0.07	0.07	0.06	0.10	0.06
>320 to 350		0.07	0.14	0.00	0.10	0.09	0.07	0.13	0.07
>350 to 360		0.00	0.04	0.00	0.03	0.02	0.00	0.03	0.00
>360 to 400		0.00	0.15	0.00	0.09	0.08	0.00	0.12	0.00
>400 to 420		0.00	0.06	0.00	0.04	0.00	0.00	0.05	0.00
>420 to 440		0.00	0.06	0.00	0.04	0.00	0.00	0.05	0.00
>440 to 500	1	0.00	0.16	0.00	0.02	0.00	0.00	0.11	0.00
>500 to 590		0.00	0.04	0.00	0.00	0.00	0.00	0.03	0.00
>590 to 630		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>630 to 696		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>696 to 710		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>710 to 773		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>773 to 840		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>840 to 850		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>850 to 930		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>930 to 1000	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1000 to 1100		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1100 to 1190		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1190 to 1300		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1300 to 1410		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1410 to 1680		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>1680 to 2000	-1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>2000		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B

Taxa composing 75% of the total macrofaunal abundance at each Deep Benthic Pilot Study station in October 2005. Abundance = number of animals per 0.1m^2.

Species name	Abundance
Station DB01	
MEDIOMASTUS SP	31
SPIOPHANES KIMBALLI	19
AOROIDES SP A	18
PARAPRIONOSPIO PINNATA	15
PARADIOPATRA PARVA	15
APHELOCHAETA SP LA1	15
COMPRESSIDENS STEARNSII	15
DECAMASTUS GRACILIS	14
PRIONOSPIO (PRIONOSPIO) JUBATA	13
TANAELLA PROPINQUUS	12
NOTOMASTUS SP A	11
LANASSA VENUSTA VENUSTA	9
AMPELISCA PACIFICA	8
EXOGONE LOUREI	7
PISTA ESTEVANICA	7
EUCLYMENINAE SP A	7
SPIOPHANES BERKELEYORUM	7
AMPHARETE ACUTIFRONS	7
APHELOCHAETA SP	7
MONOCULODES EMARGINATUS	6
AMPHIURIDAE	6
AMPELISCA BREVISIMULATA	5
PARVILUCINA TENUISCULPTA	5
ADONTORHINA CYCLIA	5
MALDANE SARSI	4
MALDANIDAE	4
RHEPOXYNIUS BICUSPIDATUS	4
NICIPPE TUMIDA	4
AMPHIODIA URTICA	4
DRILONEREIS LONGA	3
PHISIDIA SANCTAEMARIAE	3
MAYERELLA BANKSIA	3
CAECOGNATHIA CRENULATIFRONS	3
PHOTIS SP	3
APHELOCHAETA GLANDARIA	3
PROCAMPYLASPIS CAENOSA	3
BRISSOPSIS PACIFICA	3
DIASTYLIS CRENELLATA	3
APHELOCHAETA MONILARIS	3
POLYCIRRUS SP A	3
NASSARIUS INSCULPTUS	3
BIBORIN SP	3
NEPHTYS CORNUTA	2
ARICIDEA (ACMIRA) CATHERINAE	2

Species name	Abundance
Station DB02	
SPIOPHANES KIMBALLI	19
PARAPRIONOSPIO PINNATA	9
AMPELISCA BREVISIMULATA	8
PARADIOPATRA PARVA	7
CAECOGNATHIA CRENULATIFRONS	6
SPIOPHANES BERKELEYORUM	5
AMPELISCA PACIFICA	5
MALDANIDAE	4
HALIOPHASMA GEMINATUM	4
AMPELISCA CAREYI	4
ONUPHIS GEOPHILIFORMIS	4
PHOTIS SP SD11	4
AMPHARETE FINMARCHICA	3
MEDIOMASTUS SP	3
GLYCINDE ARMIGERA	3
MALDANE SARSI	3
TEREBELLIDES CALIFORNICA	3
PECTINARIA CALIFORNIENSIS	3
ADONTORHINA CYCLIA	3
PRIONOSPIO (PRIONOSPIO) JUBATA	3
TANAELLA PROPINQUUS	3
DIPOLYDORA SOCIALIS	3
RHODINE BITORQUATA	2
LYSIPPE SP A	2
LEVINSENIA GRACILIS	2
NICIPPE TUMIDA	2
VOLVULELLA CYLINDRICA	2
TELLINIDAE	2
ANOBOTHRUS GRACILIS	2
Station DB03	
PARAPRIONOSPIO PINNATA	17
PHILOMEDES DENTATA	16
MALDANIDAE	9
AMPHARETIDAE	8
AMPHIPHOLIS SQUAMATA	8
COMPRESSIDENS STEARNSII	7
EUCLYMENINAE SP A	6
TELLINA CARPENTERI	6
LUMBRINERIS SP GROUP I	5
PISTA ESTEVANICA	4
SPIOPHANES BERKELEYORUM	4
PECTINARIA CALIFORNIENSIS	4
AMPHIODIA DIGITATA	4
MALMGRENIELLA SP	4
AMPHIOPLUS STRONGYLOPLAX	4
MALDANE CALIFORNIENSIS	4

Appendix B continued

Species name	**Abundance**
Station DB03 continued	
ECLYSIPPE TRILOBATA	3
MYRIOCHELE GRACILIS	3
NOTOMASTUS SP	3
AMPHARETE SP	3
AMPELISCA PACIFICA	3
TELLINIDAE	3
ANOBOTHRUS GRACILIS	3
NOTOMASTUS SP A	3
PHYLLOCHAETOPTERUS LIMICOLUS	3
SPIOPHANES KIMBALLI	3
AMPELISCA CF BREVISIMULATA	3
SYRRHOE SP A	3
DRILONEREIS SP	2
AMAGE ANOPS	2
MEDIOMASTUS SP	2
GLYCINDE ARMIGERA	2
OWENIA COLLARIS	2
HALIOPHASMA GEMINATUM	2
TANAIDACEA	2
Station DB04	
SPIOPHANES KIMBALLI	28
PHYLLOCHAETOPTERUS LIMICOLUS	9
MELINNA HETERODONTA	6
PARAPRIONOSPIO PINNATA	5
CAECOGNATHIA CRENULATIFRONS	4
MALDANE SARSI	3
SPIOPHANES BERKELEYORUM	3
AMPELISCA PACIFICA	3
AMPELISCA BREVISIMULATA	3
DOUGALOPLUS AMPHACANTHUS	3
SAMYTHA CALIFORNIENSIS	3
HETEROPHOXUS SP	3
COMPRESSIDENS STEARNSII	3
AMPHARETE FINMARCHICA	2
ARICIDEA (ACMIRA) SIMPLEX	2
PARADIOPATRA PARVA	2
SCOLETOMA TETRAURA (= SPP COMPLEX)	2
Station DB05	
MALDANE SARSI	23
PARAPRIONOSPIO PINNATA	10
SPIOPHANES KIMBALLI	7
AMPELISCA UNSOCALAE	4
PECTINARIA CALIFORNIENSIS	3
PHYLLOCHAETOPTERUS LIMICOLUS	3
APHELOCHAETA MONILARIS	3
PRIONOSPIO (PRIONOSPIO) EHLERSI	3

Species name	**Abundance**
Station DB05 continued	
MYRIOCHELE GRACILIS	2
PRAXILLELLA PACIFICA	2
THYASIRA FLEXUOSA	2
ANOBOTHRUS GRACILIS	2
AMPELISCA CF BREVISIMULATA	2
Station DB06	
TELLINA CADIENI	21
COMPRESSIDENS STEARNSII	20
AMPHIURIDAE	11
TELLINA CARPENTERI	7
MACOMA CARLOTTENSIS	7
POLYSCHIDES TOLMIEI	6
PARAPRIONOSPIO PINNATA	5
DECAMASTUS GRACILIS	5
AMPHISSA BICOLOR	5
MALDANIDAE	4
OPHIUROIDEA	4
NUCULANA CONCEPTIONIS	4
AMPELISCA UNSOCALAE	4
ONUPHIS GEOPHILIFORMIS	3
MEDIOMASTUS SP	2
EUCLYMENINAE SP A	2
GONIADA MACULATA	2
Station DB07	
NUCULANA CONCEPTIONIS	10
MALDANE SARSI	5
POLYSCHIDES TOLMIEI	4
ECLYSIPPE TRILOBATA	3
BRISSOPSIS PACIFICA	3
AMPELISCA UNSOCALAE	3
PARAPRIONOSPIO PINNATA	2
TRAVISIA PUPA	2
MELINNA HETERODONTA	2
COMPRESSIDENS STEARNSII	2
AMPHIOPLUS STRONGYLOPLAX	2
MALLETIA FABA	2
ONUPHIS IRIDESCENS	1
CHLOEIA PINNATA	1
TEREBELLIDES CALIFORNICA	1
Station DB08	
PARAPRIONOSPIO PINNATA	13
SPIOPHANES KIMBALLI	10
AMPELISCA UNSOCALAE	7
AMPELISCA PACIFICA	5
EUDORELLA PACIFICA	5
MELINNA HETERODONTA	5

Appendix B continued

Species name	Abundance
Station DB08 continued	
PHYLLOCHAETOPTERUS LIMICOLUS	4
AGLAOPHAMUS VERRILLI	3
MALDANE SARSI	3
MALDANIDAE	2
CAECOGNATHIA CRENULATIFRONS	2
VOLVULELLA CYLINDRICA	2
PRIONOSPIO (PRIONOSPIO) EHLERSI	2
LEITOSCOLOPLOS SP A	2
POLYSCHIDES TOLMIEI	2
COMPRESSIDENS STEARNSII	2
PHYLLODOCE GROENLANDICA	1
NEPHTYS CORNUTA	1
BRADA PLURIBRANCHIATA	1
MEDIOMASTUS SP	1
Station DB09	
SPIOPHANES BERKELEYORUM	28
PARADIOPATRA PARVA	16
SPIOPHANES KIMBALLI	15
LEVINSENIA GRACILIS	10
MELINNA HETERODONTA	8
MEDIOMASTUS SP	7
ARICIDEA (ALLIA) SP A	5
MALDANE SARSI	5
PARAPRIONOSPIO PINNATA	5
NEPHTYS FERRUGINEA	4
AMPHICTEIS SCAPHOBRANCHIATA	4
DIASTYLIS CRENELLATA	4
ONUPHIS SP	3
PRIONOSPIO (MINUSPIO) LIGHTI	3
PECTINARIA CALIFORNIENSIS	3
BATHYMEDON PUMILUS	3
PHYLLOCHAETOPTERUS LIMICOLUS	3
HETEROPHOXUS ELLISI	3
ONUPHIS IRIDESCENS	2
DRILONEREIS SP	2
NEPHTYS CORNUTA	2
AMPHARETIDAE	2
AMPELISCA PACIFICA	2
Station DB10	
MALDANE SARSI	49
PARAPRIONOSPIO PINNATA	21
SPIOPHANES KIMBALLI	12
APHELOCHAETA MONILARIS	9
ONUPHIS IRIDESCENS	4
HALIOPHASMA GEMINATUM	4
SPIOPHANES BERKELEYORUM	3
AMPELISCA PACIFICA	3

Species name	Abundance
Station D10 continued	
PRIONOSPIO (PRIONOSPIO) JUBATA	3
TANAELLA PROPINQUUS	3
Station DB11	
PARAPRIONOSPIO PINNATA	6
LEITOSCOLOPLOS SP A	4
SCAPHOPODA SP SD1	3
LUMBRICLYMENE SP	3
PHYLLODOCE GROENLANDICA	2
ONUPHIS IRIDESCENS	2
BRISSOPSIS PACIFICA	2
SPATANGOIDA	2
AMPELISCA UNSOCALAE	2
LAONICE NUCHALA	1
MALDANE SARSI	1
SPIOPHANES BERKELEYORUM	1
TEREBELLIDES CALIFORNICA	1
Station DB12	
ECLYSIPPE TRILOBATA	5
ONUPHIS IRIDESCENS	3
PHORONIS SP	3
YOLDIIDAE	3
KINBERGONUPHIS VEXILLARIA	2
LEUCON BISHOPI	2
MUNNOPSURUS SP	2
MYRIOCHELE GRACILIS	1
GLYCINDE ARMIGERA	1
AMPHARETIDAE	1
HALIOPHASMA GEMINATUM	1
ENNUCULA TENUIS	1
LISTRIOLOBUS PELODES	1
VIRGULARIIDAE	1
FAUVELIOPSIS SP SD1	1
PHYLLOCHAETOPTERUS LIMICOLUS	1
DENTALIUM VALLICOLENS	1
Station DB13	
ANCISTROSYLLIS GROENLANDICA	6
STERNASPIS FOSSOR	5
ECLYSIPPE TRILOBATA	4
HARPINIOPSIS EPISTOMATA	3
MALDANE CALIFORNIENSIS	3
GLYCINDE ARMIGERA	2
DENTALIUM VALLICOLENS	2
BRISSOPSIS SP LA1	2
YOLDIIDAE	2
FAUVELIOPSIS GLABRA	2
SIGAMBRA TENTACULATA	1

Species name	Abundance
Station DB13 continued	
MYRIOCHELE GRACILIS	1
CAPITELLIDAE	1
MALDANE SARSI	1
MALDANIDAE	1
PRIONOSPIO (PRIONOSPIO) SP	1
PECTINARIA CALIFORNIENSIS	1
Station DB14	
MALDANE SARSI	28
MALDANIDAE	4
YOLDIIDAE	2
Station DB15	
AMPHIURIDAE	11
MALDANE SARSI	6
PARAPRIONOSPIO PINNATA	5
PECTINARIA CALIFORNIENSIS	4
CYCLOCARDIA VENTRICOSA	3
AMPELISCA UNSOCALAE	3
CHLOEIA PINNATA	2
ENNUCULA TENUIS	2
CHIRIDOTA SP	2
OPHIUROIDEA	2
LEITOSCOLOPLOS SP A	2
NUCULANA CONCEPTIONIS	2
ONUPHIS IRIDESCENS	1
DRILONEREIS SP	1
MONTICELLINA SIBLINA	1
MYRIOCHELE GRACILIS	1
LAONICE CIRRATA	1
HALIOPHASMA GEMINATUM	1
Station DB16	
MALDANE SARSI	10
BRADA PLURIBRANCHIATA	9
YOLDIIDAE	7
MALDANE SP	5
ECLYSIPPE TRILOBATA	3
FAUVELIOPSIS SP SD1	3
LISTRIOLOBUS HEXAMYOTUS	3
TRITELLA TENUISSIMA	3
MALDANIDAE	2

Appendix C

Macrofaunal abundance data per species for each Deep Benthic Pilot Study station sampled in October 2005. Abundance = number of animals per 0.1m^2.

Species name	Station	Date	Abundance
ADONTORHINA CYCLIA	DB01	13-Oct-05	5
AMPELISCA BREVISIMULATA	DB01	13-Oct-05	5
AMPELISCA HANCOCKI	DB01	13-Oct-05	1
AMPELISCA PACIFICA	DB01	13-Oct-05	8
AMPHARETE ACUTIFRONS	DB01	13-Oct-05	7
AMPHARETE FINMARCHICA	DB01	13-Oct-05	1
AMPHARETIDAE	DB01	13-Oct-05	1
AMPHICHONDRIUS GRANULATUS	DB01	13-Oct-05	2
AMPHIODIA URTICA	DB01	13-Oct-05	4
AMPHIPHOLIS SQUAMATA	DB01	13-Oct-05	2
AMPHIURA ARCYSTATA	DB01	13-Oct-05	1
AMPHIURIDAE	DB01	13-Oct-05	6
AMYGDALUM POLITUM	DB01	13-Oct-05	1
ANOBOTHRUS GRACILIS	DB01	13-Oct-05	1
ANONYX LILLJEBORGI	DB01	13-Oct-05	1
AOROIDES SP A	DB01	13-Oct-05	18
APHELOCHAETA GLANDARIA	DB01	13-Oct-05	3
APHELOCHAETA MONILARIS	DB01	13-Oct-05	3
APHELOCHAETA SP	DB01	13-Oct-05	7
APHELOCHAETA SP LA1	DB01	13-Oct-05	15
ARICIDEA (ACMIRA) CATHERINAE	DB01	13-Oct-05	2
ARICIDEA (ALLIA) SP A	DB01	13-Oct-05	1
ARICIDEA (ARICIDEA) LONGOBRANCHIATA	DB01	13-Oct-05	2
ARICIDEA (ARICIDEA) WASSI	DB01	13-Oct-05	1
ARTACAMELLA HANCOCKI	DB01	13-Oct-05	1
ASTEROIDEA	DB01	13-Oct-05	1
BATHYMEDON PUMILUS	DB01	13-Oct-05	1
BIBORIN SP	DB01	13-Oct-05	3
BRISASTER LATIFRONS	DB01	13-Oct-05	1
BRISSOPSIS PACIFICA	DB01	13-Oct-05	3
CAECOGNATHIA CRENULATIFRONS	DB01	13-Oct-05	3
CHAETOZONE SP SD4	DB01	13-Oct-05	1
CHIRIDOTA SP	DB01	13-Oct-05	1
COMPRESSIDENS STEARNSII	DB01	13-Oct-05	15
DECAMASTUS GRACILIS	DB01	13-Oct-05	14
DEFLEXILODES NORVEGICUS	DB01	13-Oct-05	1
DIASTYLIS CRENELLATA	DB01	13-Oct-05	3
DIPOLYDORA SOCIALIS	DB01	13-Oct-05	1
DRILONEREIS LONGA	DB01	13-Oct-05	3
EUCHONE SP SD2	DB01	13-Oct-05	1
EUCLYMENINAE	DB01	13-Oct-05	2
EUCLYMENINAE SP A	DB01	13-Oct-05	7
EUDORELLA PACIFICA	DB01	13-Oct-05	1
EUDORELLOPSIS LONGIROSTRIS	DB01	13-Oct-05	2
EXOGONE LOUREI	DB01	13-Oct-05	7
FAUVELIOPSIS SP SD1	DB01	13-Oct-05	1
GLYCERA NANA	DB01	13-Oct-05	2
GLYCERA SP	DB01	13-Oct-05	1

Species name	Station	Date	Abundance
GLYCINDE ARMIGERA	DB01	13-Oct-05	1
GNATHIA PRODUCTATRIDENS	DB01	13-Oct-05	1
HALIANTHELLA SP A	DB01	13-Oct-05	1
HALIOPHASMA GEMINATUM	DB01	13-Oct-05	1
HEMIPROTO SP A	DB01	13-Oct-05	2
HETEROPHOXUS OCULATUS	DB01	13-Oct-05	1
JASMINEIRA SP B	DB01	13-Oct-05	1
KURTZINA BETA	DB01	13-Oct-05	1
LANASSA VENUSTA VENUSTA	DB01	13-Oct-05	9
LEVINSENIA GRACILIS	DB01	13-Oct-05	2
LEVINSENIA OCULATA	DB01	13-Oct-05	1
LINEIDAE	DB01	13-Oct-05	1
LUMBRINERIS CRUZENSIS	DB01	13-Oct-05	2
LYSIPPE SP B	DB01	13-Oct-05	1
MACOMA SP	DB01	13-Oct-05	1
MALDANE SARSI	DB01	13-Oct-05	4
MALDANIDAE	DB01	13-Oct-05	4
MALMGRENIELLA SCRIPTORIA	DB01	13-Oct-05	1
MALMGRENIELLA SP A	DB01	13-Oct-05	1
MAYERELLA BANKSIA	DB01	13-Oct-05	3
MEDIOMASTUS SP	DB01	13-Oct-05	31
MELINNA OCULATA	DB01	13-Oct-05	2
METAPHOXUS FREQUENS	DB01	13-Oct-05	1
MOLPADIA INTERMEDIA	DB01	13-Oct-05	1
MONOCULODES EMARGINATUS	DB01	13-Oct-05	6
MOOREONUPHIS NEBULOSA	DB01	13-Oct-05	1
MOOREONUPHIS SEGMENTISPADIX	DB01	13-Oct-05	2
MYRIOCHELE GRACILIS	DB01	13-Oct-05	2
NASSARIUS INSCULPTUS	DB01	13-Oct-05	3
NEMATODA	DB01	13-Oct-05	1
NEPHASOMA DIAPHANES	DB01	13-Oct-05	2
NEPHTYS CORNUTA	DB01	13-Oct-05	2
NEPHTYS FERRUGINEA	DB01	13-Oct-05	1
NEREIS SP	DB01	13-Oct-05	1
NICIPPE TUMIDA	DB01	13-Oct-05	4
NOTOMASTUS SP A	DB01	13-Oct-05	11
ODOSTOMIA SP	DB01	13-Oct-05	1
ONUPHIDAE	DB01	13-Oct-05	2
ONUPHIS GEOPHILIFORMIS	DB01	13-Oct-05	1
OPHIUROIDEA	DB01	13-Oct-05	1
ORCHOMENE DECIPIENS	DB01	13-Oct-05	1
PALAEONEMERTEA	DB01	13-Oct-05	1
PARADIOPATRA PARVA	DB01	13-Oct-05	15
PARAPRIONOSPIO PINNATA	DB01	13-Oct-05	15
PARVILUCINA TENUISCULPTA	DB01	13-Oct-05	5
PECTINARIA CALIFORNIENSIS	DB01	13-Oct-05	2
PHERUSA NEGLIGENS	DB01	13-Oct-05	2
PHILINE CALIFORNICA	DB01	13-Oct-05	1
PHISIDIA SANCTAEMARIAE	DB01	13-Oct-05	3
PHOTIS BREVIPES	DB01	13-Oct-05	2

Species name	Station	Date	Abundance
PHOTIS LACIA	DB01	13-Oct-05	2
PHOTIS SP	DB01	13-Oct-05	3
PHOTIS SP SD11	DB01	13-Oct-05	1
PHYLLOCHAETOPTERUS LIMICOLUS	DB01	13-Oct-05	1
PISTA ESTEVANICA	DB01	13-Oct-05	7
POLYCIRRUS SP	DB01	13-Oct-05	2
POLYCIRRUS SP A	DB01	13-Oct-05	3
POTAMETHUS SP A	DB01	13-Oct-05	1
PRAXILLELLA PACIFICA	DB01	13-Oct-05	2
PRIONOSPIO (MINUSPIO) LIGHTI	DB01	13-Oct-05	2
PRIONOSPIO (PRIONOSPIO) DUBIA	DB01	13-Oct-05	1
PRIONOSPIO (PRIONOSPIO) JUBATA	DB01	13-Oct-05	13
PROCAMPYLASPIS CAENOSA	DB01	13-Oct-05	3
RHEPOXYNIUS BICUSPIDATUS	DB01	13-Oct-05	4
SCOLETOMA TETRAURA (= SPP COMPLEX)	DB01	13-Oct-05	1
SCOLOPLOS ARMIGER (= SPP COMPLEX)	DB01	13-Oct-05	1
SOSANOPSIS SP A	DB01	13-Oct-05	1
SPIOPHANES BERKELEYORUM	DB01	13-Oct-05	7
SPIOPHANES DUPLEX	DB01	13-Oct-05	2
SPIOPHANES KIMBALLI	DB01	13-Oct-05	19
SPIOPHANES SP	DB01	13-Oct-05	2
SYLLIS (EHLERSIA) HETEROCHAETA	DB01	13-Oct-05	1
TANAELLA PROPINQUUS	DB01	13-Oct-05	12
TELLINA CARPENTERI	DB01	13-Oct-05	2
TEREBELLIDES CALIFORNICA	DB01	13-Oct-05	2
TEREBELLIDES REISHI	DB01	13-Oct-05	1
TEREBELLIDES SP	DB01	13-Oct-05	1
TUBULANUS POLYMORPHUS	DB01	13-Oct-05	2
WESTWOODILLA CAECULA	DB01	13-Oct-05	1
ADONTORHINA CYCLIA	DB02	13-Oct-05	3
ALVANIA ROSANA	DB02	13-Oct-05	1
AMPELISCA BREVISIMULATA	DB02	13-Oct-05	8
AMPELISCA CAREYI	DB02	13-Oct-05	4
AMPELISCA CF BREVISIMULATA	DB02	13-Oct-05	2
AMPELISCA HANCOCKI	DB02	13-Oct-05	1
AMPELISCA PACIFICA	DB02	13-Oct-05	5
AMPHARETE ACUTIFRONS	DB02	13-Oct-05	1
AMPHARETE FINMARCHICA	DB02	13-Oct-05	3
AMYGDALUM POLITUM	DB02	13-Oct-05	1
ANARTHRURIDAE	DB02	13-Oct-05	1
ANOBOTHRUS GRACILIS	DB02	13-Oct-05	2
ANONYX LILLJEBORGI	DB02	13-Oct-05	1
APHELOCHAETA MONILARIS	DB02	13-Oct-05	1
CAECOGNATHIA CRENULATIFRONS	DB02	13-Oct-05	6
CEPHALOPHOXOIDES HOMILIS	DB02	13-Oct-05	1
CHAETODERMA PACIFICUM	DB02	13-Oct-05	1
CHIRIDOTA SP	DB02	13-Oct-05	1
CHONE SP B	DB02	13-Oct-05	1
CIRROPHORUS BRANCHIATUS	DB02	13-Oct-05	2
DIASTYLIS CRENELLATA	DB02	13-Oct-05	1

Species name	Station	Date	Abundance
DIPOLYDORA SOCIALIS	DB02	13-Oct-05	3
DOUGALOPLUS AMPHACANTHUS	DB02	13-Oct-05	1
DRILONEREIS SP	DB02	13-Oct-05	1
EUCLYMENINAE SP A	DB02	13-Oct-05	1
EUDORELLA PACIFICA	DB02	13-Oct-05	1
GLYCINDE ARMIGERA	DB02	13-Oct-05	3
GONIADA BRUNNEA	DB02	13-Oct-05	1
HALIOPHASMA GEMINATUM	DB02	13-Oct-05	4
HETEROPHOXUS ELLISI	DB02	13-Oct-05	1
HETEROPHOXUS SP	DB02	13-Oct-05	1
LANASSA VENUSTA VENUSTA	DB02	13-Oct-05	1
LEVINSENIA GRACILIS	DB02	13-Oct-05	2
LINEUS BILINEATUS	DB02	13-Oct-05	1
LYSIPPE SP A	DB02	13-Oct-05	2
MALDANE SARSI	DB02	13-Oct-05	3
MALDANIDAE	DB02	13-Oct-05	4
MEDIOMASTUS SP	DB02	13-Oct-05	3
MELINNA OCULATA	DB02	13-Oct-05	1
MONTICELLINA CRYPTICA	DB02	13-Oct-05	1
MONTICELLINA SP SD8	DB02	13-Oct-05	1
MONTICELLINA TESSELATA	DB02	13-Oct-05	1
NICIPPE TUMIDA	DB02	13-Oct-05	2
ONUPHIS GEOPHILIFORMIS	DB02	13-Oct-05	4
ONUPHIS IRIDESCENS	DB02	13-Oct-05	1
OPHIUROIDEA	DB02	13-Oct-05	1
PARADIOPATRA PARVA	DB02	13-Oct-05	7
PARAPRIONOSPIO PINNATA	DB02	13-Oct-05	9
PARVILUCINA TENUISCULPTA	DB02	13-Oct-05	1
PECTINARIA CALIFORNIENSIS	DB02	13-Oct-05	3
PHOTIS SP SD11	DB02	13-Oct-05	4
PHYLLOCHAETOPTERUS LIMICOLUS	DB02	13-Oct-05	1
POLYCIRRUS SP A	DB02	13-Oct-05	1
PRIONOSPIO (PRIONOSPIO) JUBATA	DB02	13-Oct-05	3
RHODINE BITORQUATA	DB02	13-Oct-05	2
ROCINELA ANGUSTATA	DB02	13-Oct-05	1
SCHISTURELLA COCULA	DB02	13-Oct-05	1
SCOLETOMA TETRAURA (= SPP COMPLEX)	DB02	13-Oct-05	2
SOSANOPSIS SP A	DB02	13-Oct-05	1
SPIOCHAETOPTERUS COSTARUM	DB02	13-Oct-05	1
SPIOPHANES BERKELEYORUM	DB02	13-Oct-05	5
SPIOPHANES DUPLEX	DB02	13-Oct-05	1
SPIOPHANES KIMBALLI	DB02	13-Oct-05	19
TANAELLA PROPINQUUS	DB02	13-Oct-05	3
TELLINIDAE	DB02	13-Oct-05	2
TEREBELLIDES CALIFORNICA	DB02	13-Oct-05	3
VOLVULELLA CYLINDRICA	DB02	13-Oct-05	2
ADONTORHINA CYCLIA	DB03	14-Oct-05	2
ALVANIA ROSANA	DB03	14-Oct-05	1
AMAGE ANOPS	DB03	14-Oct-05	2
AMERICHELIDIUM SHOEMAKERI	DB03	14-Oct-05	1

Species name	Station	Date	Abundance
AMPELISCA CF BREVISIMULATA	DB03	14-Oct-05	3
AMPELISCA PACIFICA	DB03	14-Oct-05	3
AMPHARETE SP	DB03	14-Oct-05	3
AMPHARETIDAE	DB03	14-Oct-05	8
AMPHIODIA DIGITATA	DB03	14-Oct-05	4
AMPHIOPLUS STRONGYLOPLAX	DB03	14-Oct-05	4
AMPHIPHOLIS SQUAMATA	DB03	14-Oct-05	8
AMPHIURIDAE	DB03	14-Oct-05	2
ANOBOTHRUS GRACILIS	DB03	14-Oct-05	3
ANONYX LILLJEBORGI	DB03	14-Oct-05	1
AOROIDES SP A	DB03	14-Oct-05	1
APHELOCHAETA MONILARIS	DB03	14-Oct-05	1
APHELOCHAETA TIGRINA	DB03	14-Oct-05	1
ARAPHURA BREVIARIA	DB03	14-Oct-05	1
ARAPHURA CUSPIROSTRIS	DB03	14-Oct-05	1
ARGISSA HAMATIPES	DB03	14-Oct-05	1
BATHYLEBERIS HANCOCKI	DB03	14-Oct-05	1
CAECOGNATHIA CRENULATIFRONS	DB03	14-Oct-05	2
CAPITELLIDAE	DB03	14-Oct-05	1
CEPHALOPHOXOIDES HOMILIS	DB03	14-Oct-05	1
CHIRIDOTA SP	DB03	14-Oct-05	2
CHLOEIA PINNATA	DB03	14-Oct-05	1
COMPRESSIDENS STEARNSII	DB03	14-Oct-05	7
DECAMASTUS GRACILIS	DB03	14-Oct-05	2
DEFLEXILODES NORVEGICUS	DB03	14-Oct-05	1
DIASTYLIS CRENELLATA	DB03	14-Oct-05	2
DRILONEREIS SP	DB03	14-Oct-05	2
ECLYSIPPE TRILOBATA	DB03	14-Oct-05	3
EUCLYMENINAE SP A	DB03	14-Oct-05	6
GASTROPTERON PACIFICUM	DB03	14-Oct-05	2
GLYCINDE ARMIGERA	DB03	14-Oct-05	2
HALIOPHASMA GEMINATUM	DB03	14-Oct-05	2
HEMILAMPROPS SP B	DB03	14-Oct-05	2
LANASSA VENUSTA VENUSTA	DB03	14-Oct-05	1
LAONICE NUCHALA	DB03	14-Oct-05	1
LUMBRINERIS CRUZENSIS	DB03	14-Oct-05	1
LUMBRINERIS SP GROUP I	DB03	14-Oct-05	5
MALDANE CALIFORNIENSIS	DB03	14-Oct-05	4
MALDANIDAE	DB03	14-Oct-05	9
MALMGRENIELLA SP	DB03	14-Oct-05	4
MEDIOMASTUS SP	DB03	14-Oct-05	2
MYRIOCHELE GRACILIS	DB03	14-Oct-05	3
MYRIOCHELE STRIOLATA	DB03	14-Oct-05	1
NEAEROMYA COMPRESSA	DB03	14-Oct-05	2
NEPHTYS FERRUGINEA	DB03	14-Oct-05	1
NICIPPE TUMIDA	DB03	14-Oct-05	2
NOTOMASTUS LATERICEUS	DB03	14-Oct-05	1
NOTOMASTUS SP	DB03	14-Oct-05	3
NOTOMASTUS SP A	DB03	14-Oct-05	3
OWENIA COLLARIS	DB03	14-Oct-05	2

Species name	Station	Date	Abundance
PARADIOPATRA PARVA	DB03	14-Oct-05	1
PARAPRIONOSPIO PINNATA	DB03	14-Oct-05	17
PECTINARIA CALIFORNIENSIS	DB03	14-Oct-05	4
PECTINOIDEA	DB03	14-Oct-05	1
PHILOMEDES DENTATA	DB03	14-Oct-05	16
PHOTIS SP	DB03	14-Oct-05	1
PHYLLOCHAETOPTERUS LIMICOLUS	DB03	14-Oct-05	3
PHYLLODOCE GROENLANDICA	DB03	14-Oct-05	1
PISTA ESTEVANICA	DB03	14-Oct-05	4
POLYCIRRUS SP A	DB03	14-Oct-05	1
POLYSCHIDES TOLMIEI	DB03	14-Oct-05	1
PRAXILLELLA PACIFICA	DB03	14-Oct-05	1
PROCLEA SP A	DB03	14-Oct-05	1
PSEUDOTARANIS STRONGI	DB03	14-Oct-05	1
SCAPHOPODA	DB03	14-Oct-05	1
SPIOPHANES BERKELEYORUM	DB03	14-Oct-05	4
SPIOPHANES KIMBALLI	DB03	14-Oct-05	3
SYLLIDES MIKELI	DB03	14-Oct-05	1
SYNIDOTEA SP	DB03	14-Oct-05	1
SYRRHOE SP A	DB03	14-Oct-05	3
TANAIDACEA	DB03	14-Oct-05	2
TELLINA CARPENTERI	DB03	14-Oct-05	6
TELLINIDAE	DB03	14-Oct-05	3
TEREBELLIDES CALIFORNICA	DB03	14-Oct-05	1
TURBONILLA SP	DB03	14-Oct-05	1
WESTWOODILLA CAECULA	DB03	14-Oct-05	1
AGLAOPHAMUS VERRILLI	DB04	14-Oct-05	1
AMPELISCA BREVISIMULATA	DB04	14-Oct-05	3
AMPELISCA CAREYI	DB04	14-Oct-05	1
AMPELISCA PACIFICA	DB04	14-Oct-05	3
AMPHARETE ACUTIFRONS	DB04	14-Oct-05	2
AMPHARETE FINMARCHICA	DB04	14-Oct-05	2
AMPHICTEIS SCAPHOBRANCHIATA	DB04	14-Oct-05	1
APHELOCHAETA MONILARIS	DB04	14-Oct-05	1
ARICIDEA (ACMIRA) SIMPLEX	DB04	14-Oct-05	2
ARICIDEA (ALLIA) SP A	DB04	14-Oct-05	1
AXINOPSIDA SERRICATA	DB04	14-Oct-05	1
CAECOGNATHIA CRENULATIFRONS	DB04	14-Oct-05	4
COMPRESSIDENS STEARNSII	DB04	14-Oct-05	3
DIASTYLIS PELLUCIDA	DB04	14-Oct-05	1
DOUGALOPLUS AMPHACANTHUS	DB04	14-Oct-05	3
GLYCERA NANA	DB04	14-Oct-05	1
GONIADA MACULATA	DB04	14-Oct-05	1
HALIOPHASMA GEMINATUM	DB04	14-Oct-05	1
HARPINIOPSIS FULGENS	DB04	14-Oct-05	1
HETEROPHOXUS ELLISI	DB04	14-Oct-05	2
HETEROPHOXUS OCULATUS	DB04	14-Oct-05	1
HETEROPHOXUS SP	DB04	14-Oct-05	3
LAONICE CIRRATA	DB04	14-Oct-05	1
MAGELONA BERKELEYI	DB04	14-Oct-05	1

Species name	Station	Date	Abundance
MALDANE SARSI	DB04	14-Oct-05	3
MALMGRENIELLA SP A	DB04	14-Oct-05	1
MEDIOMASTUS SP	DB04	14-Oct-05	1
MELINNA HETERODONTA	DB04	14-Oct-05	6
MELINNA SP	DB04	14-Oct-05	2
ONUPHIS GEOPHILIFORMIS	DB04	14-Oct-05	1
OPHIUROIDEA	DB04	14-Oct-05	2
PARADIOPATRA PARVA	DB04	14-Oct-05	2
PARAPRIONOSPIO PINNATA	DB04	14-Oct-05	5
PARVILUCINA TENUISCULPTA	DB04	14-Oct-05	1
PHYLLOCHAETOPTERUS LIMICOLUS	DB04	14-Oct-05	9
PRIONOSPIO (PRIONOSPIO) EHLERSI	DB04	14-Oct-05	1
SAMYTHA CALIFORNIENSIS	DB04	14-Oct-05	3
SCOLETOMA TETRAURA (= SPP COMPLEX)	DB04	14-Oct-05	2
SPIOCHAETOPTERUS COSTARUM	DB04	14-Oct-05	1
SPIOPHANES BERKELEYORUM	DB04	14-Oct-05	3
SPIOPHANES KIMBALLI	DB04	14-Oct-05	28
TELLINIDAE	DB04	14-Oct-05	1
AMPELISCA CF BREVISIMULATA	DB05	17-Oct-05	2
AMPELISCA FURCIGERA	DB05	17-Oct-05	1
AMPELISCA UNSOCALAE	DB05	17-Oct-05	4
AMPHARETE FINMARCHICA	DB05	17-Oct-05	1
AMPHIOPLUS STRONGYLOPLAX	DB05	17-Oct-05	2
AMPHIURIDAE	DB05	17-Oct-05	1
ANOBOTHRUS GRACILIS	DB05	17-Oct-05	2
APHELOCHAETA MONILARIS	DB05	17-Oct-05	3
APHELOCHAETA SP	DB05	17-Oct-05	1
APHRODITA LONGIPALPA	DB05	17-Oct-05	1
BOREOTROPHON AVALONENSIS	DB05	17-Oct-05	1
CHONE SP SD3	DB05	17-Oct-05	1
COMPRESSIDENS STEARNSII	DB05	17-Oct-05	1
DIASTYLIS PELLUCIDA	DB05	17-Oct-05	1
GASTROPTERON PACIFICUM	DB05	17-Oct-05	1
HALIOPHASMA GEMINATUM	DB05	17-Oct-05	1
LYSIPPE SP B	DB05	17-Oct-05	1
MALDANE SARSI	DB05	17-Oct-05	23
MELINNA HETERODONTA	DB05	17-Oct-05	1
MYRIOCHELE GRACILIS	DB05	17-Oct-05	2
NEPHTYS FERRUGINEA	DB05	17-Oct-05	1
PARAPRIONOSPIO PINNATA	DB05	17-Oct-05	10
PECTINARIA CALIFORNIENSIS	DB05	17-Oct-05	3
PHYLLOCHAETOPTERUS LIMICOLUS	DB05	17-Oct-05	3
PRAXILLELLA PACIFICA	DB05	17-Oct-05	2
PRIONOSPIO (PRIONOSPIO) EHLERSI	DB05	17-Oct-05	3
RHODINE BITORQUATA	DB05	17-Oct-05	1
SPIOPHANES KIMBALLI	DB05	17-Oct-05	7
TANAIDACEA	DB05	17-Oct-05	1
TEREBELLIDES CALIFORNICA	DB05	17-Oct-05	1
TEREBELLIDES REISHI	DB05	17-Oct-05	1

Species name	Station	Date	
THYASIRA FLEXUOSA	DB05	17-Oct-05	2
VOLVULELLA CYLINDRICA	DB05	17-Oct-05	1
AMPELISCA UNSOCALAE	DB06	18-Oct-05	4
AMPHIOPLUS STRONGYLOPLAX	DB06	18-Oct-05	1
AMPHIPORUS SP	DB06	18-Oct-05	1
AMPHISSA BICOLOR	DB06	18-Oct-05	5
AMPHIURIDAE	DB06	18-Oct-05	11
ANOBOTHRUS GRACILIS	DB06	18-Oct-05	1
BALCIS OLDROYDAE	DB06	18-Oct-05	2
BRISSOPSIS PACIFICA	DB06	18-Oct-05	2
BRUZELIA TUBERCULATA	DB06	18-Oct-05	1
CHLOEIA PINNATA	DB06	18-Oct-05	1
CLYMENURA GRACILIS	DB06	18-Oct-05	1
COMPRESSIDENS STEARNSII	DB06	18-Oct-05	20
DECAMASTUS GRACILIS	DB06	18-Oct-05	5
DIASTYLIS PELLUCIDA	DB06	18-Oct-05	2
EUCLYMENINAE SP A	DB06	18-Oct-05	2
EUSPIRA SP	DB06	18-Oct-05	1
FALCIDENS HARTMANAE	DB06	18-Oct-05	1
FAUVELIOPSIS SP SD1	DB06	18-Oct-05	2
GLYCERA NANA	DB06	18-Oct-05	1
GONIADA MACULATA	DB06	18-Oct-05	2
HALIOPHASMA GEMINATUM	DB06	18-Oct-05	1
LEPTOPHOXUS FALCATUS ICELUS	DB06	18-Oct-05	1
LEPTOSTYLIS ABDITIS	DB06	18-Oct-05	1
LIMIFOSSOR FRATULA	DB06	18-Oct-05	2
LINEIDAE	DB06	18-Oct-05	2
LUMBRINERIDAE	DB06	18-Oct-05	1
MACOMA CARLOTTENSIS	DB06	18-Oct-05	7
MALDANIDAE	DB06	18-Oct-05	4
MEDIOMASTUS SP	DB06	18-Oct-05	2
MONTICELLINA SIBLINA	DB06	18-Oct-05	1
MUNNOGONIUM TILLERAE	DB06	18-Oct-05	1
NOTOMASTUS SP A	DB06	18-Oct-05	1
NUCULANA CONCEPTIONIS	DB06	18-Oct-05	4
ONUPHIS GEOPHILIFORMIS	DB06	18-Oct-05	3
OPHIUROIDEA	DB06	18-Oct-05	4
PARAPRIONOSPIO PINNATA	DB06	18-Oct-05	5
PHOTIS LACIA	DB06	18-Oct-05	1
POLYSCHIDES TOLMIEI	DB06	18-Oct-05	6
PSEUDOTARANIS STRONGI	DB06	18-Oct-05	1
SCAPHOPODA	DB06	18-Oct-05	1
SOLAMEN COLUMBIANUM	DB06	18-Oct-05	1
SPIOCHAETOPTERUS COSTARUM	DB06	18-Oct-05	1
SPIOPHANES BERKELEYORUM	DB06	18-Oct-05	1
SPIOPHANES KIMBALLI	DB06	18-Oct-05	1
TELLINA CADIENI	DB06	18-Oct-05	21
TELLINA CARPENTERI	DB06	18-Oct-05	7
TYPHLOTANAIS WILLIAMSI	DB06	18-Oct-05	1
VOLVULELLA CYLINDRICA	DB06	18-Oct-05	2

Species name	Station	Date	Abundance
WESTWOODILLA CAECULA	DB06	18-Oct-05	1
AGLAOPHAMUS SP	DB07	18-Oct-05	1
AMPELISCA UNSOCALAE	DB07	18-Oct-05	3
AMPHIOPLUS STRONGYLOPLAX	DB07	18-Oct-05	2
AMPHIURIDAE	DB07	18-Oct-05	1
BRISSOPSIS PACIFICA	DB07	18-Oct-05	3
CERIANTHARIA	DB07	18-Oct-05	1
CHLOEIA PINNATA	DB07	18-Oct-05	1
COMPRESSIDENS STEARNSII	DB07	18-Oct-05	2
ECLYSIPPE TRILOBATA	DB07	18-Oct-05	3
ERANNO LAGUNAE	DB07	18-Oct-05	1
FAUVELIOPSIS SP SD1	DB07	18-Oct-05	1
LEITOSCOLOPLOS SP A	DB07	18-Oct-05	1
LYSIPPE SP B	DB07	18-Oct-05	1
MALDANE SARSI	DB07	18-Oct-05	5
MALLETIA FABA	DB07	18-Oct-05	2
MELINNA HETERODONTA	DB07	18-Oct-05	2
NUCULANA CONCEPTIONIS	DB07	18-Oct-05	10
ONUPHIS IRIDESCENS	DB07	18-Oct-05	1
PARAPRIONOSPIO PINNATA	DB07	18-Oct-05	2
PHILINE AURIFORMIS	DB07	18-Oct-05	1
PHYLLOCHAETOPTERUS LIMICOLUS	DB07	18-Oct-05	1
POLYSCHIDES TOLMIEI	DB07	18-Oct-05	4
SAMYTHA CALIFORNIENSIS	DB07	18-Oct-05	1
SCAPHOPODA	DB07	18-Oct-05	1
SCAPHOPODA SP SD1	DB07	18-Oct-05	1
TELLINA CADIENI	DB07	18-Oct-05	1
TEREBELLIDES CALIFORNICA	DB07	18-Oct-05	1
THYASIRA FLEXUOSA	DB07	18-Oct-05	1
TRAVISIA PUPA	DB07	18-Oct-05	2
YOLDIIDAE	DB07	18-Oct-05	1
ADONTORHINA CYCLIA	DB08	17-Oct-05	1
AGLAOPHAMUS VERRILLI	DB08	17-Oct-05	3
AMPELISCA FURCIGERA	DB08	17-Oct-05	1
AMPELISCA PACIFICA	DB08	17-Oct-05	5
AMPELISCA UNSOCALAE	DB08	17-Oct-05	7
AMYGDALUM POLITUM	DB08	17-Oct-05	1
ANCISTROSYLLIS GROENLANDICA	DB08	17-Oct-05	1
BATHYMEDON PUMILUS	DB08	17-Oct-05	1
BRADA PLURIBRANCHIATA	DB08	17-Oct-05	1
BRISSOPSIS PACIFICA	DB08	17-Oct-05	1
CAECOGNATHIA CRENULATIFRONS	DB08	17-Oct-05	2
CERIANTHARIA	DB08	17-Oct-05	1
CHIRIDOTA SP	DB08	17-Oct-05	1
CHONE SP B	DB08	17-Oct-05	1
COMPRESSIDENS STEARNSII	DB08	17-Oct-05	2
CYCLOCARDIA SP	DB08	17-Oct-05	1
DIASTYLIS PELLUCIDA	DB08	17-Oct-05	1
EUCLYMENINAE	DB08	17-Oct-05	1
EUCLYMENINAE SP A	DB08	17-Oct-05	1

Species name	Station	Date	Abundance
EUDORELLA PACIFICA	DB08	17-Oct-05	5
HETEROPHOXUS ELLISI	DB08	17-Oct-05	1
HOLMESIELLA ANOMALA	DB08	17-Oct-05	1
LEITOSCOLOPLOS SP A	DB08	17-Oct-05	2
LEPTOPHOXUS FALCATUS ICELUS	DB08	17-Oct-05	1
LINEIDAE	DB08	17-Oct-05	1
LUMBRINERIS SP GROUP I	DB08	17-Oct-05	1
MALDANE SARSI	DB08	17-Oct-05	3
MALDANIDAE	DB08	17-Oct-05	2
MEDIOMASTUS SP	DB08	17-Oct-05	1
MELINNA HETERODONTA	DB08	17-Oct-05	5
MICROGLYPHIS BREVICULA	DB08	17-Oct-05	1
MONOCULODES LATISSIMANUS	DB08	17-Oct-05	1
NEOCRANGON ZACAE	DB08	17-Oct-05	1
NEPHTYS CAECOIDES	DB08	17-Oct-05	1
NEPHTYS CORNUTA	DB08	17-Oct-05	1
PARAPRIONOSPIO PINNATA	DB08	17-Oct-05	13
PHYLLOCHAETOPTERUS LIMICOLUS	DB08	17-Oct-05	4
PHYLLODOCE GROENLANDICA	DB08	17-Oct-05	1
POLYSCHIDES TOLMIEI	DB08	17-Oct-05	2
PRIONOSPIO (PRIONOSPIO) EHLERSI	DB08	17-Oct-05	2
SAMYTHA CALIFORNIENSIS	DB08	17-Oct-05	1
SPIOPHANES BERKELEYORUM	DB08	17-Oct-05	1
SPIOPHANES KIMBALLI	DB08	17-Oct-05	10
TANAELLA PROPINQUUS	DB08	17-Oct-05	1
VOLVULELLA CYLINDRICA	DB08	17-Oct-05	2
ACTEON TRASKII	DB09	14-Oct-05	1
ADONTORHINA CYCLIA	DB09	14-Oct-05	1
AMPELISCA HANCOCKI	DB09	14-Oct-05	1
AMPELISCA PACIFICA	DB09	14-Oct-05	2
AMPELISCA UNSOCALAE	DB09	14-Oct-05	1
AMPHARETE ACUTIFRONS	DB09	14-Oct-05	1
AMPHARETIDAE	DB09	14-Oct-05	2
AMPHICTEIS SCAPHOBRANCHIATA	DB09	14-Oct-05	4
APHELOCHAETA SP	DB09	14-Oct-05	1
ARGISSA HAMATIPES	DB09	14-Oct-05	1
ARICIDEA (ALLIA) SP A	DB09	14-Oct-05	5
BATHYMEDON PUMILUS	DB09	14-Oct-05	3
BIVALVIA	DB09	14-Oct-05	2
CAECOGNATHIA CRENULATIFRONS	DB09	14-Oct-05	2
CHAETODERMA PACIFICUM	DB09	14-Oct-05	2
CIRROPHORUS BRANCHIATUS	DB09	14-Oct-05	2
COSSURA SP	DB09	14-Oct-05	1
CUSPIDARIA PARAPODEMA	DB09	14-Oct-05	1
DIASTYLIS CRENELLATA	DB09	14-Oct-05	4
DIASTYLIS PELLUCIDA	DB09	14-Oct-05	1
DIPOLYDORA SOCIALIS	DB09	14-Oct-05	1
DOUGALOPLUS AMPHACANTHUS	DB09	14-Oct-05	2
DRILONEREIS SP	DB09	14-Oct-05	2
EUCLYMENINAE	DB09	14-Oct-05	2

Species name	Station	Date	Abundance
EUDORELLA PACIFICA	DB09	14-Oct-05	2
EULIMIDAE	DB09	14-Oct-05	1
GLYCERA NANA	DB09	14-Oct-05	1
GLYCINDE ARMIGERA	DB09	14-Oct-05	1
HETEROPHOXUS ELLISI	DB09	14-Oct-05	3
LAONICE CIRRATA	DB09	14-Oct-05	1
LEVINSENIA GRACILIS	DB09	14-Oct-05	10
LINEUS BILINEATUS	DB09	14-Oct-05	2
LUMBRINERIS CRUZENSIS	DB09	14-Oct-05	1
MAGELONA SP B	DB09	14-Oct-05	1
MALDANE SARSI	DB09	14-Oct-05	5
MEDIOMASTUS SP	DB09	14-Oct-05	7
MELINNA HETERODONTA	DB09	14-Oct-05	8
MONOCULODES EMARGINATUS	DB09	14-Oct-05	1
MONTICELLINA CRYPTICA	DB09	14-Oct-05	1
MYRIOCHELE GRACILIS	DB09	14-Oct-05	1
NEPHTYS CORNUTA	DB09	14-Oct-05	2
NEPHTYS FERRUGINEA	DB09	14-Oct-05	4
ONUPHIS IRIDESCENS	DB09	14-Oct-05	2
ONUPHIS SP	DB09	14-Oct-05	3
PARADIOPATRA PARVA	DB09	14-Oct-05	16
PARAONIDAE	DB09	14-Oct-05	1
PARAPRIONOSPIO PINNATA	DB09	14-Oct-05	5
PARDALISCA SP	DB09	14-Oct-05	1
PECTINARIA CALIFORNIENSIS	DB09	14-Oct-05	3
PHYLLOCHAETOPTERUS LIMICOLUS	DB09	14-Oct-05	3
PRIONOSPIO (MINUSPIO) LIGHTI	DB09	14-Oct-05	3
PRIONOSPIO (PRIONOSPIO) JUBATA	DB09	14-Oct-05	2
PROTOMEDEIA ARTICULATA (= SPP COMPLEX)	DB09	14-Oct-05	1
SCOLETOMA TETRAURA (= SPP COMPLEX)	DB09	14-Oct-05	1
SPIOCHAETOPTERUS COSTARUM	DB09	14-Oct-05	1
SPIOPHANES BERKELEYORUM	DB09	14-Oct-05	28
SPIOPHANES KIMBALLI	DB09	14-Oct-05	15
TELLINA CARPENTERI	DB09	14-Oct-05	1
TELLINIDAE	DB09	14-Oct-05	1
TYPHLOTANAIS WILLIAMSI	DB09	14-Oct-05	1
VOLVULELLA PANAMICA	DB09	14-Oct-05	1
VOLVULELLA SP	DB09	14-Oct-05	1
ADONTORHINA CYCLIA	DB10	17-Oct-05	1
AGLAOPHAMUS VERRILLI	DB10	17-Oct-05	1
AMAGE ANOPS	DB10	17-Oct-05	1
AMPELISCA PACIFICA	DB10	17-Oct-05	3
AMPELISCA SP	DB10	17-Oct-05	1
AMPELISCA UNSOCALAE	DB10	17-Oct-05	2
AMPHARETE FINMARCHICA	DB10	17-Oct-05	2
AMPHIOPLUS STRONGYLOPLAX	DB10	17-Oct-05	2
ANOBOTHRUS GRACILIS	DB10	17-Oct-05	2
APHELOCHAETA MONILARIS	DB10	17-Oct-05	9
BRISASTER LATIFRONS	DB10	17-Oct-05	1
CAECOGNATHIA CRENULATIFRONS	DB10	17-Oct-05	2

Species name	Station	Date	Abundance
CEPHALOPHOXOIDES HOMILIS	DB10	17-Oct-05	1
CHAETOZONE SP	DB10	17-Oct-05	1
COMPRESSIDENS STEARNSII	DB10	17-Oct-05	3
DIASTYLIS PELLUCIDA	DB10	17-Oct-05	1
ENOPLA	DB10	17-Oct-05	1
EUDORELLA PACIFICA	DB10	17-Oct-05	1
FALCIDENS HARTMANAE	DB10	17-Oct-05	1
HALIOPHASMA GEMINATUM	DB10	17-Oct-05	4
LEPTOPHOXUS FALCATUS ICELUS	DB10	17-Oct-05	1
LIMIFOSSOR FRATULA	DB10	17-Oct-05	1
LINEUS BILINEATUS	DB10	17-Oct-05	1
LUMBRINERIDAE	DB10	17-Oct-05	1
MALDANE SARSI	DB10	17-Oct-05	49
MELINNA HETERODONTA	DB10	17-Oct-05	1
ONUPHIS IRIDESCENS	DB10	17-Oct-05	4
PARAPRIONOSPIO PINNATA	DB10	17-Oct-05	21
PECTINARIA CALIFORNIENSIS	DB10	17-Oct-05	1
PETALOCLYMENE PACIFICA	DB10	17-Oct-05	3
PHYLLODOCE GROENLANDICA	DB10	17-Oct-05	1
PRIONOSPIO (PRIONOSPIO) JUBATA	DB10	17-Oct-05	3
RHODINE BITORQUATA	DB10	17-Oct-05	1
SCAPHOPODA	DB10	17-Oct-05	1
SPIOCHAETOPTERUS COSTARUM	DB10	17-Oct-05	1
SPIOPHANES BERKELEYORUM	DB10	17-Oct-05	3
SPIOPHANES KIMBALLI	DB10	17-Oct-05	12
STERNASPIS FOSSOR	DB10	17-Oct-05	1
TANAELLA PROPINQUUS	DB10	17-Oct-05	3
TUBULANUS POLYMORPHUS	DB10	17-Oct-05	1
TYPHLOTANAIS WILLIAMSI	DB10	17-Oct-05	1
ACHARAX JOHNSONI	DB11	17-Oct-05	1
AMPELISCA UNSOCALAE	DB11	17-Oct-05	2
AMPHIOPLUS STRONGYLOPLAX	DB11	17-Oct-05	1
AMPHISSA BICOLOR	DB11	17-Oct-05	1
APHELOCHAETA MONILARIS	DB11	17-Oct-05	1
BRISSOPSIS PACIFICA	DB11	17-Oct-05	2
CHAETODERMA NANULUM	DB11	17-Oct-05	1
COMPRESSIDENS STEARNSII	DB11	17-Oct-05	1
LAONICE NUCHALA	DB11	17-Oct-05	1
LEITOSCOLOPLOS SP A	DB11	17-Oct-05	4
LUMBRICLYMENE SP	DB11	17-Oct-05	3
MALDANE SARSI	DB11	17-Oct-05	1
NUCULANA CONCEPTIONIS	DB11	17-Oct-05	1
ONUPHIS IRIDESCENS	DB11	17-Oct-05	2
PARAPRIONOSPIO PINNATA	DB11	17-Oct-05	6
PHORONIS SP	DB11	17-Oct-05	1
PHYLLODOCE GROENLANDICA	DB11	17-Oct-05	2
SCAPHOPODA	DB11	17-Oct-05	1
SCAPHOPODA SP SD1	DB11	17-Oct-05	3
SPATANGOIDA	DB11	17-Oct-05	2
SPIOPHANES BERKELEYORUM	DB11	17-Oct-05	1

Species name	Station	Date	Abundance
TEREBELLIDES CALIFORNICA	DB11	17-Oct-05	1
YOLDIIDAE	DB11	17-Oct-05	1
AMERICHELIDIUM SHOEMAKERI	DB12	18-Oct-05	1
AMPHARETIDAE	DB12	18-Oct-05	1
BATHYLEBERIS HANCOCKI	DB12	18-Oct-05	1
CIRROPHORUS BRANCHIATUS	DB12	18-Oct-05	1
DENTALIUM VALLICOLENS	DB12	18-Oct-05	1
ECLYSIPPE TRILOBATA	DB12	18-Oct-05	5
EDWARDSIIDAE	DB12	18-Oct-05	1
ENNUCULA TENUIS	DB12	18-Oct-05	1
FAUVELIOPSIS SP SD1	DB12	18-Oct-05	1
GLYCINDE ARMIGERA	DB12	18-Oct-05	1
HALIOPHASMA GEMINATUM	DB12	18-Oct-05	1
HARPINIOPSIS EPISTOMATA	DB12	18-Oct-05	1
KINBERGONUPHIS VEXILLARIA	DB12	18-Oct-05	2
LEUCON BISHOPI	DB12	18-Oct-05	2
LEUCON DECLIVIS	DB12	18-Oct-05	1
LISTRIOLOBUS PELODES	DB12	18-Oct-05	1
MALDANE CALIFORNIENSIS	DB12	18-Oct-05	1
MELINNA HETERODONTA	DB12	18-Oct-05	1
MONTICELLINA SP	DB12	18-Oct-05	1
MUNNOPSURUS SP	DB12	18-Oct-05	2
MYRIOCHELE GRACILIS	DB12	18-Oct-05	1
ONUPHIS IRIDESCENS	DB12	18-Oct-05	3
PHORONIS SP	DB12	18-Oct-05	3
PHYLLOCHAETOPTERUS LIMICOLUS	DB12	18-Oct-05	1
POLYSCHIDES TOLMIEI	DB12	18-Oct-05	1
SOSANOPSIS SP A	DB12	18-Oct-05	1
VIRGULARIIDAE	DB12	18-Oct-05	1
YOLDIIDAE	DB12	18-Oct-05	3
ACHARAX JOHNSONI	DB13	18-Oct-05	1
ANCISTROSYLLIS GROENLANDICA	DB13	18-Oct-05	6
BIVALVIA	DB13	18-Oct-05	1
BRISSOPSIS SP LA1	DB13	18-Oct-05	2
CAMPYLASPIS SP O	DB13	18-Oct-05	1
CAPITELLIDAE	DB13	18-Oct-05	1
DENTALIUM VALLICOLENS	DB13	18-Oct-05	2
ECLYSIPPE TRILOBATA	DB13	18-Oct-05	4
EUDORELLA PACIFICA	DB13	18-Oct-05	1
FAUVELIOPSIS GLABRA	DB13	18-Oct-05	2
GLYCINDE ARMIGERA	DB13	18-Oct-05	2
HARPINIOPSIS EPISTOMATA	DB13	18-Oct-05	3
HETERONEMERTEA SP SD2	DB13	18-Oct-05	1
KINBERGONUPHIS VEXILLARIA	DB13	18-Oct-05	1
LEUCON BISHOPI	DB13	18-Oct-05	1
LINEIDAE	DB13	18-Oct-05	1
MALDANE CALIFORNIENSIS	DB13	18-Oct-05	3
MALDANE SARSI	DB13	18-Oct-05	1
MALDANE SP	DB13	18-Oct-05	1
MALDANIDAE	DB13	18-Oct-05	1

Species name	Station	Date	Abundance
MONTICELLINA CRYPTICA	DB13	18-Oct-05	1
MONTICELLINA SP	DB13	18-Oct-05	1
MYRIOCHELE GRACILIS	DB13	18-Oct-05	1
PECTINARIA CALIFORNIENSIS	DB13	18-Oct-05	1
POLYSCHIDES TOLMIEI	DB13	18-Oct-05	1
PRIONOSPIO (PRIONOSPIO) SP	DB13	18-Oct-05	1
SCAPHOPODA	DB13	18-Oct-05	1
SIGAMBRA TENTACULATA	DB13	18-Oct-05	1
STERNASPIS FOSSOR	DB13	18-Oct-05	5
YOLDIIDAE	DB13	18-Oct-05	2
ARICIDEA (ACMIRA) SP SD2	DB14	24-Oct-05	1
BATHYMEDON COVILHANI	DB14	24-Oct-05	1
BIVALVIA	DB14	24-Oct-05	1
BRISSOPSIS PACIFICA	DB14	24-Oct-05	1
BYBLIS BARBARENSIS	DB14	24-Oct-05	2
FAUVELIOPSIS SP SD1	DB14	24-Oct-05	1
KINBERGONUPHIS VEXILLARIA	DB14	24-Oct-05	1
LEUCON BISHOPI	DB14	24-Oct-05	1
LEUCON DECLIVIS	DB14	24-Oct-05	1
MALDANE SARSI	DB14	24-Oct-05	28
MALDANIDAE	DB14	24-Oct-05	4
MYRIOCHELE STRIOLATA	DB14	24-Oct-05	1
NEILONELLA RITTERI	DB14	24-Oct-05	1
ONUPHIS IRIDESCENS	DB14	24-Oct-05	1
YOLDIIDAE	DB14	24-Oct-05	2
AMPELISCA UNSOCALAE	DB15	24-Oct-05	3
AMPHIOPLUS STRONGYLOPLAX	DB15	24-Oct-05	1
AMPHISSA BICOLOR	DB15	24-Oct-05	1
AMPHIURIDAE	DB15	24-Oct-05	11
BATHYMEDON PUMILUS	DB15	24-Oct-05	1
BIVALVIA	DB15	24-Oct-05	1
BRISASTER LATIFRONS	DB15	24-Oct-05	1
CHAETODERMA NANULUM	DB15	24-Oct-05	1
CHIRIDOTA SP	DB15	24-Oct-05	2
CHLOEIA PINNATA	DB15	24-Oct-05	2
CYCLOCARDIA VENTRICOSA	DB15	24-Oct-05	3
DRILONEREIS SP	DB15	24-Oct-05	1
ENNUCULA TENUIS	DB15	24-Oct-05	2
FAUVELIOPSIS SP SD1	DB15	24-Oct-05	1
HALIOPHASMA GEMINATUM	DB15	24-Oct-05	1
HARPINIOPSIS EMERYI	DB15	24-Oct-05	1
HARPINIOPSIS FULGENS	DB15	24-Oct-05	1
HETEROPHOXUS SP	DB15	24-Oct-05	1
LAONICE CIRRATA	DB15	24-Oct-05	1
LEITOSCOLOPLOS SP A	DB15	24-Oct-05	2
LIMIFOSSOR FRATULA	DB15	24-Oct-05	1
MALDANE SARSI	DB15	24-Oct-05	6
MONTICELLINA CRYPTICA	DB15	24-Oct-05	1
MONTICELLINA SIBLINA	DB15	24-Oct-05	1

Appendix C continued

Species name	Station	Date	Abundance
MYRIOCHELE GRACILIS	DB15	24-Oct-05	1
NUCULANA CONCEPTIONIS	DB15	24-Oct-05	2
ONUPHIS IRIDESCENS	DB15	24-Oct-05	1
OPHIUROIDEA	DB15	24-Oct-05	2
PARAPRIONOSPIO PINNATA	DB15	24-Oct-05	5
PECTINARIA CALIFORNIENSIS	DB15	24-Oct-05	4
POLYSCHIDES TOLMIEI	DB15	24-Oct-05	1
PRIONOSPIO (PRIONOSPIO) JUBATA	DB15	24-Oct-05	1
SCAPHOPODA	DB15	24-Oct-05	1
THYASIRA FLEXUOSA	DB15	24-Oct-05	1
YOLDIIDAE	DB15	24-Oct-05	1
AMPELISCA UNSOCALAE	DB16	24-Oct-05	1
ASTYRIS PERMODESTA	DB16	24-Oct-05	1
BRADA PLURIBRANCHIATA	DB16	24-Oct-05	9
CEREBRATULUS CALIFORNIENSIS	DB16	24-Oct-05	2
ECLYSIPPE TRILOBATA	DB16	24-Oct-05	3
FAUVELIOPSIS SP SD1	DB16	24-Oct-05	3
GASTROPTERON PACIFICUM	DB16	24-Oct-05	1
HALIOPHASMA GEMINATUM	DB16	24-Oct-05	1
HARPINIOPSIS EMERYI	DB16	24-Oct-05	1
KINBERGONUPHIS VEXILLARIA	DB16	24-Oct-05	1
LEUCON DECLIVIS	DB16	24-Oct-05	1
LISTRIOLOBUS HEXAMYOTUS	DB16	24-Oct-05	3
MALDANE SARSI	DB16	24-Oct-05	10
MALDANE SP	DB16	24-Oct-05	5
MALDANIDAE	DB16	24-Oct-05	2
MONTICELLINA CRYPTICA	DB16	24-Oct-05	1
NUCULANA CONCEPTIONIS	DB16	24-Oct-05	1
POLYSCHIDES TOLMIEI	DB16	24-Oct-05	2
SCAPHOPODA	DB16	24-Oct-05	1
SUBADYTE MEXICANA	DB16	24-Oct-05	1
TRITELLA TENUISSIMA	DB16	24-Oct-05	3
YOLDIIDAE	DB16	24-Oct-05	7

Appendix D

Visual observations for Deep Benthic Pilot Study stations sampled during October 2005.

Visual Observations

Sample Date: 13-OCT-05

Station: DB01

Parameter	**Value**
Depth m	202
Arrive Time	1033
Depart Time	1217
Air Temp C	19.0
Weather	Overcast
Visibility mi	5
Wind Speed Kts	4.0
Wind Dir.	S
Comments	CTD cast taken, Infauna grab: one sample cup for each mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	10
Sediment Type (rep 1)	Silt with fine sand

Station: DB02

Parameter	**Value**
Depth m	199
Arrive Time	1232
Depart Time	1324
Air Temp C	19.0
Weather	Clear
Visibility mi	10
Wind Speed Kts	9.0
Wind Dir.	W
Comments	Large isopod removed from grab and taken to lab, Infauna grab: one sample cup for each mesh size (1 mm and 0.3 mm), CTD cast taken
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	10
Sediment Type (rep 1)	Clay with silt

Sample Date: 14-OCT-05

Station: DB03

Parameter	***Value***
Depth m	303
Arrive Time	1124
Depart Time	1157
Air Temp C	20.0
Weather	Clear
Visibility mi	15
Wind Speed Kts	7.0
Wind Dir.	NE
Comments	CTD cast, Animal grab #1, additional sediment characteristic: w/clay; sample cups: 4 from 0.3 mm; 1 from 1 mm.
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	9
Sediment Type (rep 1)	Silt with fine sand

Station: DB04

Parameter	***Value***
Depth m	202
Arrive Time	1000
Depart Time	1044
Air Temp C	20.0
Weather	Clear
Visibility mi	15
Wind Speed Kts	3.0
Wind Dir.	N
Comments	CTD cast, One sample cup for each mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	11
Sediment Type (rep 1)	Silt with clay

Station: DB09

Parameter	***Value***
Depth m	204
Arrive Time	0844
Depart Time	0940
Air Temp C	19.0
Weather	Clear
Visibility mi	15
Wind Speed Kts	1.0
Wind Dir.	E
Comments	CTD cast; One sample cup for each mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	10
Sediment Type (rep 1)	Silt with clay

Sample Date: 17-OCT-05

Station: DB05

Parameter	***Value***
Depth m	318
Arrive Time	1120
Depart Time	1213
Air Temp C	16.0
Weather	Rain
Visibility mi	6
Wind Speed Kts	6.0
Wind Dir.	W
Comments	CTD taken first, One sample cup for each mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	4
Sediment Temp. (rep 1) C	8
Sediment Type (rep 1)	Silt with clay

Station: DB08

Parameter	***Value***
Depth m	314
Arrive Time	1013
Depart Time	1057
Air Temp C	16.0
Weather	Rain
Visibility mi	10
Wind Speed Kts	7.0
Wind Dir.	E
Comments	CTD taken after benthic grab; One sample cup per mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	4
Sediment Temp. (rep 1) C	8
Sediment Type (rep 1)	Silt with clay

Station: DB10

Parameter	***Value***
Depth m	302
Arrive Time	0801
Depart Time	0856
Air Temp C	17.0
Weather	Overcast
Visibility mi	12
Wind Speed Kts	0.0
Comments	CTD cast; One sample cup for each mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	8
Sediment Type (rep 1)	Silt with clay

Sample Date: 17-OCT-05

Station: DB11

Parameter	***Value***
Depth m	400
Arrive Time	0903
Depart Time	1003
Air Temp C	16.0
Weather	Overcast
Visibility mi	12
Wind Speed Kts	14.0
Wind Dir.	W
Comments	Weather getting nasty; CTD cast taken after grab; One sample for each mesh size (1 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	8
Sediment Type (rep 1)	Silt

Sample Date: 18-OCT-05

Station: DB06

Parameter	***Value***
Depth m	414
Arrive Time	0807
Depart Time	0921
Air Temp C	17.0
Weather	Partly Cloudy
Visibility mi	15
Wind Speed Kts	11.0
Wind Dir.	NE
Comments	CTD taken 2nd, Two sample cups for 0.3 mm component, One sample cup for 1.0 mm mesh size
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	7
Sediment Type (rep 1)	Silt and sand

Station: DB07

Parameter	***Value***
Depth m	401
Arrive Time	0927
Depart Time	1034
Air Temp C	18.0
Weather	Partly Cloudy
Visibility mi	15
Wind Speed Kts	7.0
Wind Dir.	S
Comments	CTD taken 2nd, One sample cup per mesh size (1.0 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	6
Sediment Type (rep 1)	Silt

Station: DB12

Parameter	***Value***
Depth m	519
Arrive Time	1049
Depart Time	1204
Air Temp C	17.0
Weather	Partly Cloudy
Visibility mi	15
Wind Speed Kts	5.0
Wind Dir.	NE
Comments	CTD taken 2nd; One sample cup per mesh size (1.0 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	6
Sediment Type (rep 1)	Silt

Sample Date: 18-OCT-05

Station: DB13

Parameter	***Value***
Depth m	542
Arrive Time	1205
Depart Time	1313
Air Temp C	18.0
Weather	Partly Cloudy
Visibility mi	15
Wind Speed Kts	8.0
Wind Dir.	SE
Comments	CTD taken 2nd; One sample cup per mesh size (1.0 mm and 0.3 mm)
Wave Ht Low ft	3
Sediment Temp. (rep 1) C	5
Sediment Type (rep 1)	Silt

Sample Date: 24-OCT-05

Station: DB14

Parameter	Value
Depth m	508
Arrive Time	1059
Depart Time	1200
Air Temp C	16.0
Weather	Fog
Visibility mi	2
Wind Speed Kts	6.0
Wind Dir.	W
Comments	One sample cup for each mesh size (1.0 mm and 0.3 mm)
Wave Ht Low ft	4
Sediment Temp. (rep 1) C	7
Sediment Type (rep 1)	Silt and clay

Station: DB15

Parameter	Value
Depth m	402
Arrive Time	1209
Depart Time	1325
Air Temp C	17.0
Weather	Overcast
Visibility mi	8
Wind Speed Kts	7.0
Wind Dir.	NE
Comments	One sample cup for each mesh size (1.0 mm and 0.3 mm), Sediment: Clay and silt with fine sand.
Wave Ht Low ft	4
Sediment Temp. (rep 1) C	7
Sediment Type (rep 1)	Clay and silt

Station: DB16

Parameter	Value
Depth m	502
Arrive Time	0822
Depart Time	1033
Air Temp C	16.0
Weather	Fog
Visibility mi	2
Wind Speed Kts	11.0
Wind Dir.	SE
Comments	One sample cup for each mesh size (1.0 mm and 0.3 mm)
Wave Ht Low ft	4
Sediment Temp. (rep 1) C	6
Sediment Type (rep 1)	Clay and silt

Attachment E.5

San Diego Regional Sediment Quality Contour Plots

(1994-2006)

Attachment E.5

San Diego Regional Sediment Quality Contour Plots (1994-2006)

Introduction

In order to compare overall sediment quality conditions off San Diego during the last two NPDES permit periods, contour plots of most sediment quality parameters analyzed in Appendix E (see Section E.4, page E-13) were constructed using data collected from a number of regional benthic surveys of the continental shelf and slope. These surveys have been conducted by the City of San Diego since 1994 in order to characterize benthic conditions for the large and diverse coastal region that ranges from the US/Mexico border to northern San Diego County (~Del Mar), and to identify areas impacted by anthropogenic or natural events. The main objective of this attachment is to provide side-by-side comparisons of regional sediment conditions off San Diego during the 1994-2000 and 2001-2006 post-discharge periods. These results can be compared to sediment data presented earlier in this application for the regular fixed-grid monitoring sites surrounding the Point Loma Ocean Outfall (PLOO). Such regional data are not available prior to 1994, so it was not possible to prepare similar contour plots for the 1991-1993 pre-discharge period.

Dataset and Methods

The regional sediment samples analyzed herein were collected annually from 1994 through 2006. Except for 2004, these surveys utilized the USEPA probability-based EMAP random sampling design. Surveys in 1995-1997, 1999-2002, and 2005-2006 were performed as part of regular NPDES monitoring activities for the South Bay Ocean Outfall (see City of San Diego 2007 for details), while surveys in 1994, 1998 and 2003 were conducted as part of the Southern California Bight Pilot Project and the Bight'98 and Bight'03 surveys of the entire Southern California Bight (see Schiff and Gossett 1998, Noblet et al. 2002, Schiff et al. 2006). The 2004 regional data were a component of the San Diego Sediment Mapping Study (see Stebbins et al. 2004).

The contour plots (maps) presented herein were generated using the default settings in ESRI's ArcGIS Spatial Analyst inverse-distance weighted interpolation algorithm. The resulting grid layer provides estimated values for unsampled areas that fall between sampled locations. It should be noted that it is not possible to assess the level of accuracy for estimated values in unsampled areas using this deterministic interpolation method.

Contour maps were created for the 1994-2000 post-discharge period (235 sites) and the 2001-2006 post-discharge period (390 sites) for each of the parameters listed below.

Sediment grain size distributions were mapped using percent fines, which represents the silt and clay fractions combined (Figure E.5-1). Several other grain size parameters reported for the PLOO fixed sites are not included here as they provided redundant information (i.e., mean particle size, mean and median phi, and percent sand). Measures of organic loading that were mapped include total organic carbon (Figure E.5-2), total volatile solids (Figure E.5-3), total nitrogen (Figure E.5-4), and sulfides (Figure E.5-5). Biochemical oxygen demand (BOD), although included in fixed-site monitoring around the PLOO, has not been a required analyte for the regional surveys. Trace metals mapped include aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc (Figures E.5-6 though E.5-19). Sediment concentrations of DDT were also mapped for the San Diego region (Figure E.5-20). Regional contour maps for PCBs are not included due to non-comparability of data between some years (i.e., Aroclors vs. congeners) and the rarity of detectable values. PAHs are also not included due to low concentrations near or below the MDL.

Literature Cited

City of San Diego. (2007). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant) 2006. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Noblet, J. A., E. Y. Zeng, R. Baird, R. W. Gossett, R. J. Ozretich, and C. R. Phillips. (2002). Southern California Bight 1998 Regional Monitoring Program: VI. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Schiff, K., and R. W. Gossett. (1998). Southern California Bight 1994 Pilot Project: III. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Schiff, K., K. Maruya, and K. Christenson. (2006). Southern California Bight 2003 Regional Monitoring Program: II. Sediment Chemistry. Southern California Coastal Water Research Project, Westminster, CA.

Stebbins, T. D., K. C. Schiff, and K. Ritter. (2004). San Diego Sediment Mapping Study: Workplan for Generating Scientifically Defensible Maps of Sediment Condition in the San Diego Region. 11 pp.

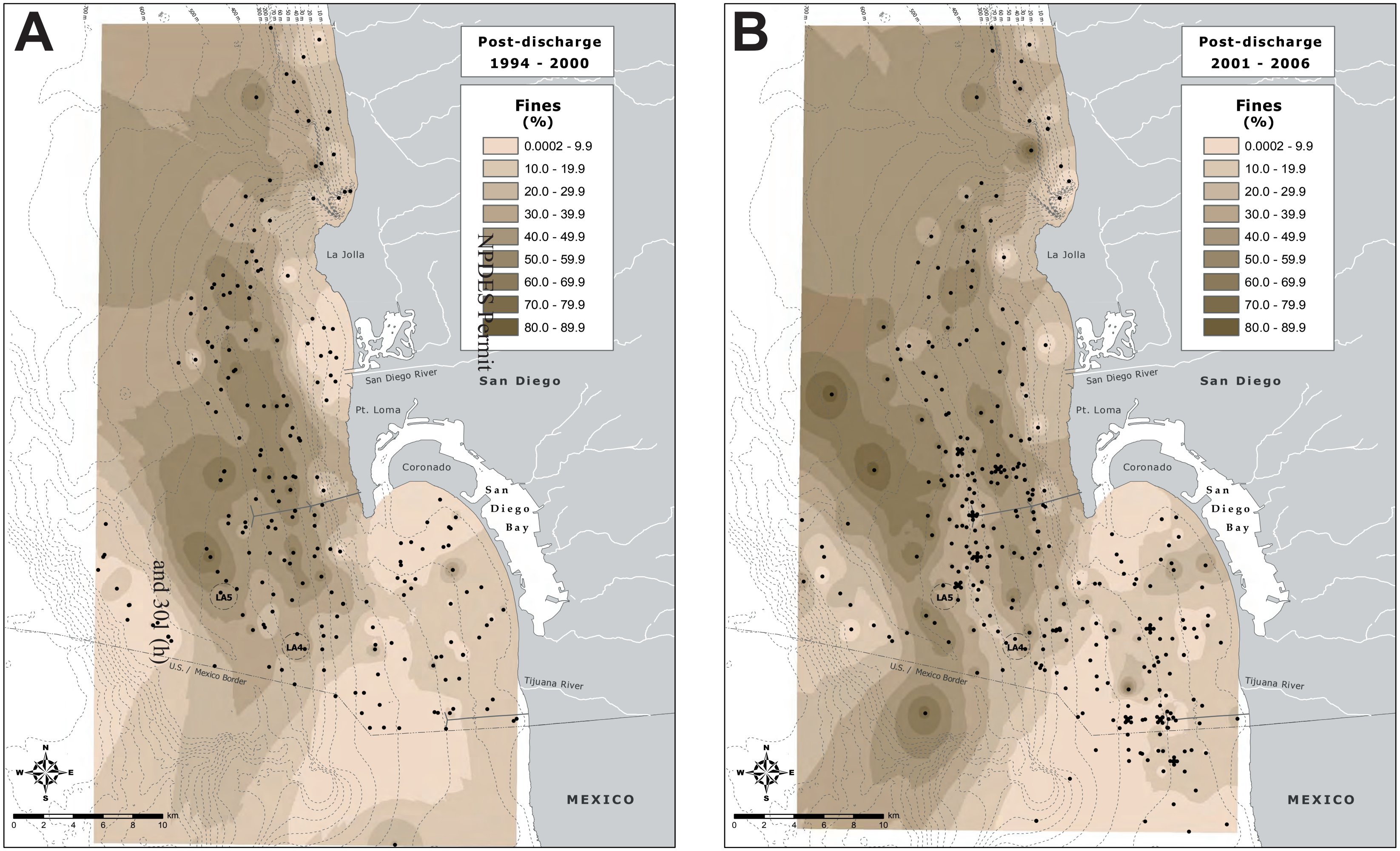


FIGURE E.5-1.
Comparison of sediment particle size distribution for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed as %fines (silt + clay fractions combined) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

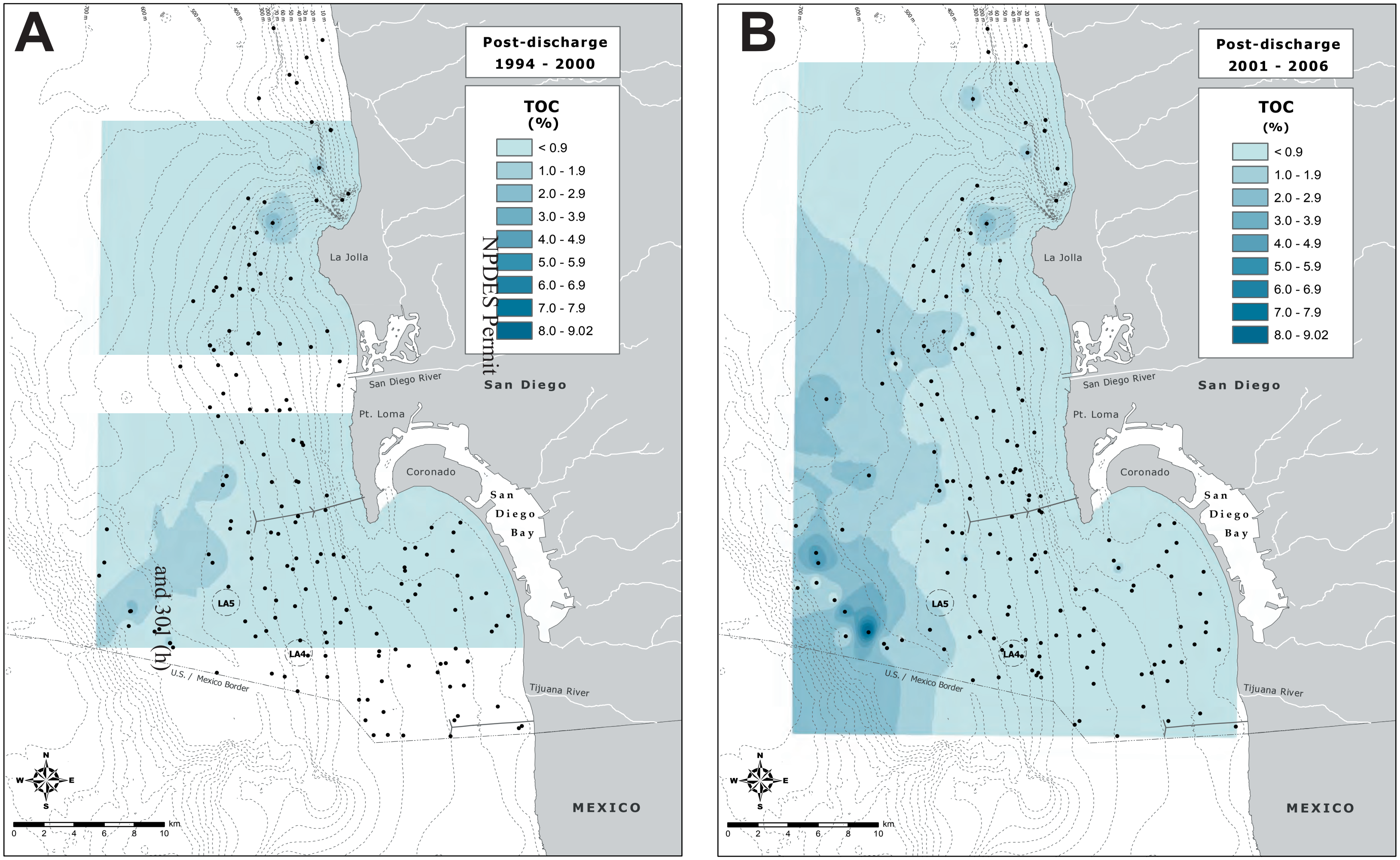


FIGURE E.5-2.
Comparison of total organic carbon (TOC) in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed as %TOC and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

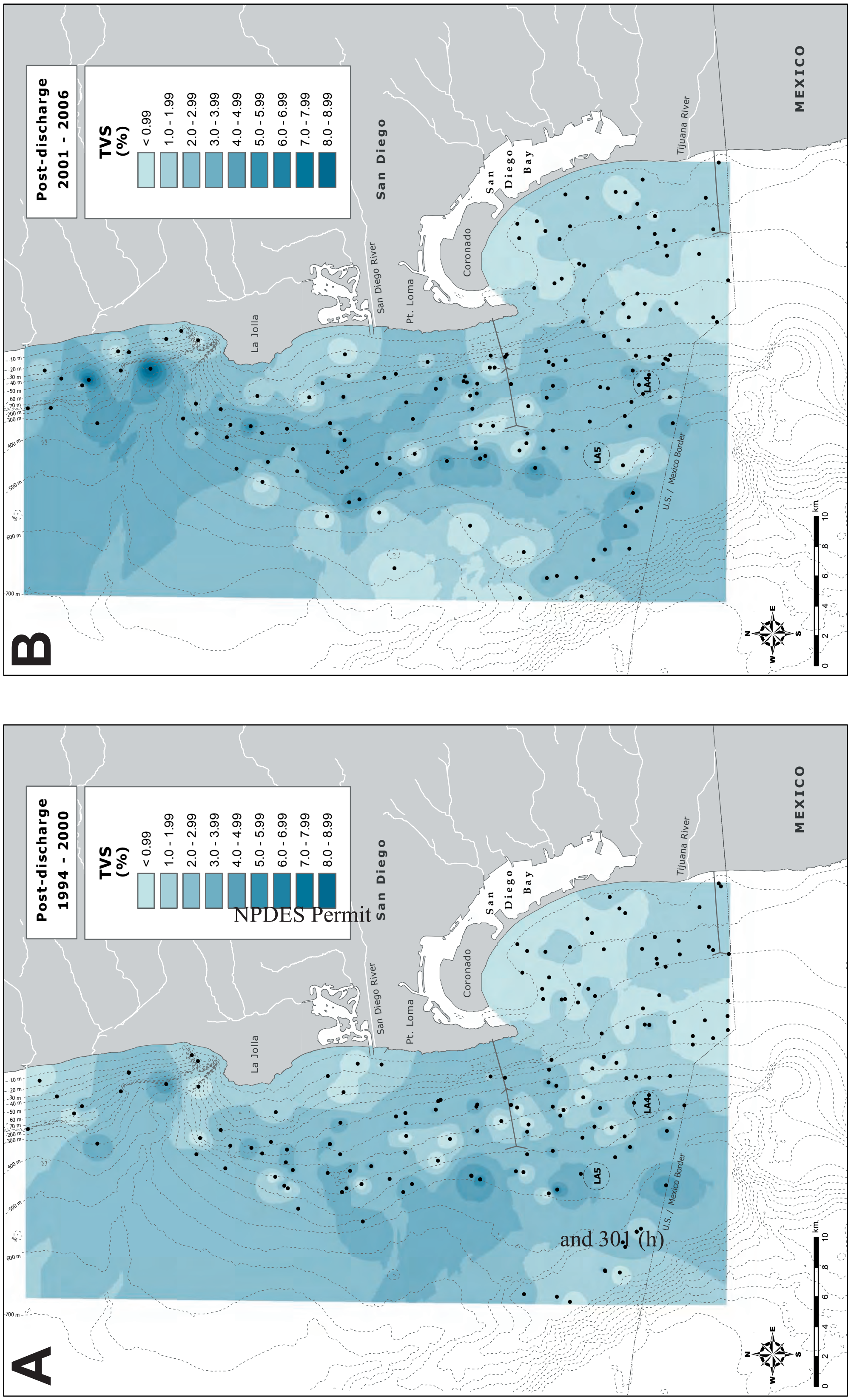


FIGURE E.5-3.
Comparison of total volatile solids (TVS) in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed as %TVS and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

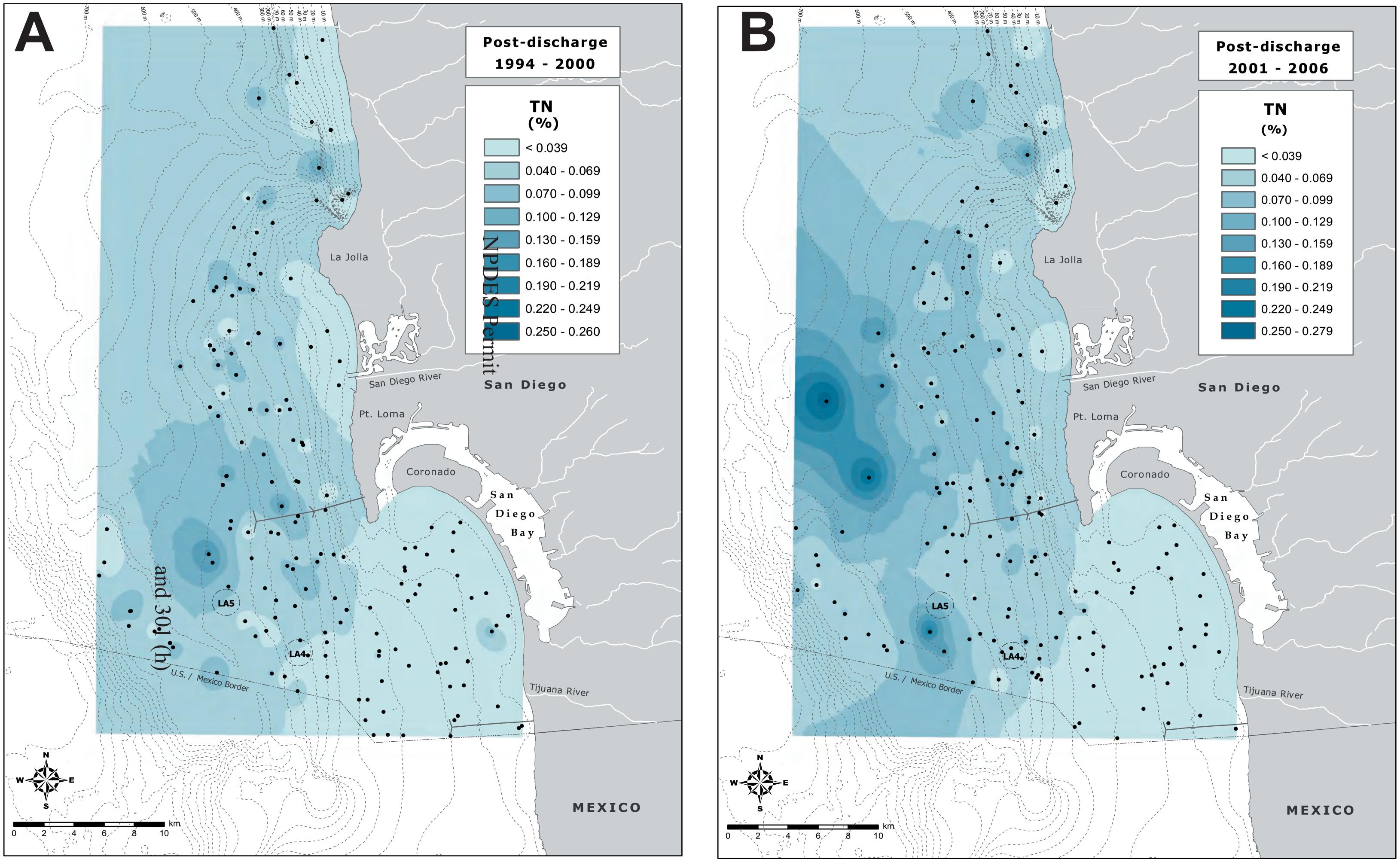


FIGURE E.5-4.
Comparison of total nitrogen (TN) in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed as %TN and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

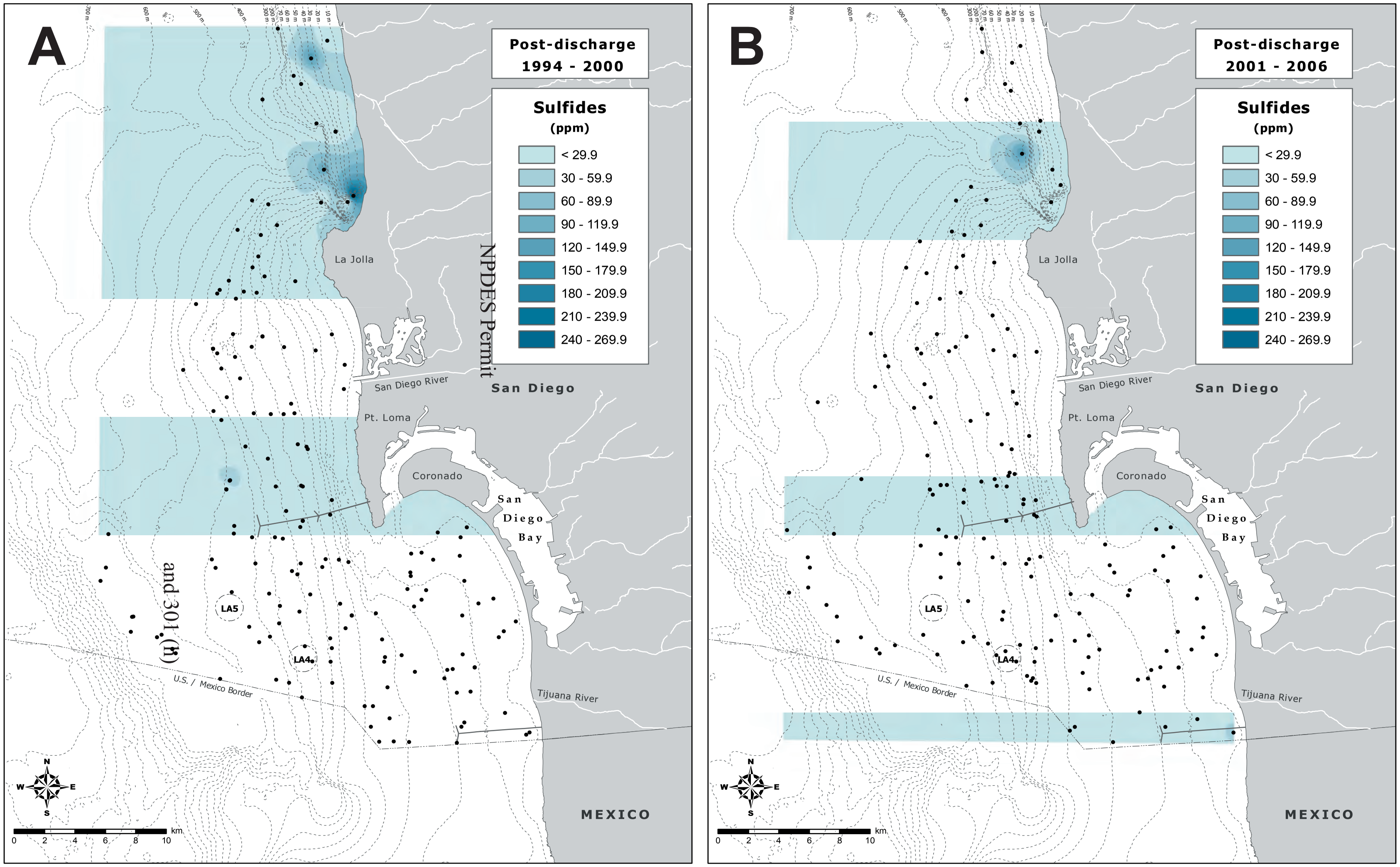


FIGURE E.5-5.

Comparison of sulfide concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in ppm (mg/Kg) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

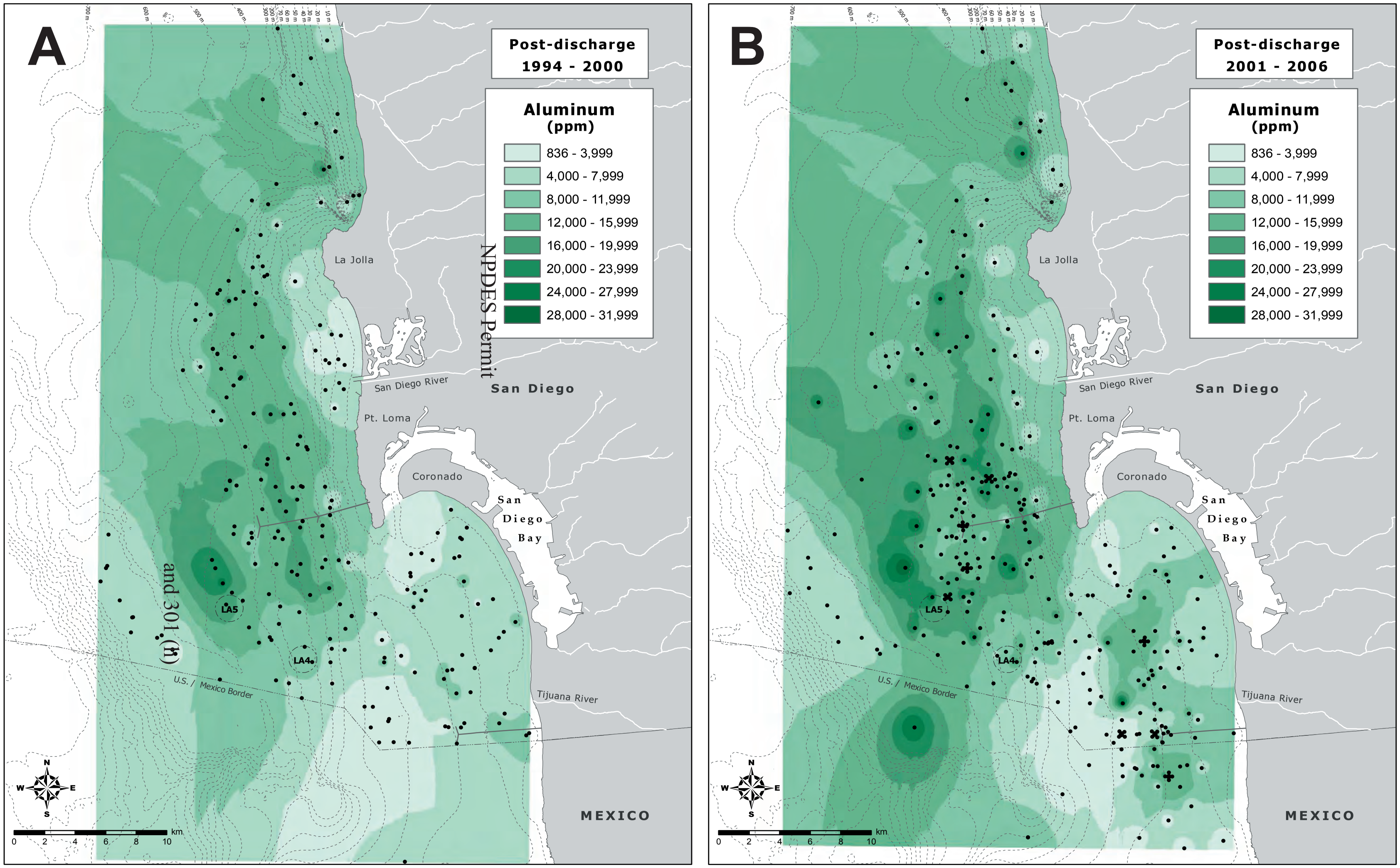


FIGURE E.5-6.
Comparison of aluminum concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

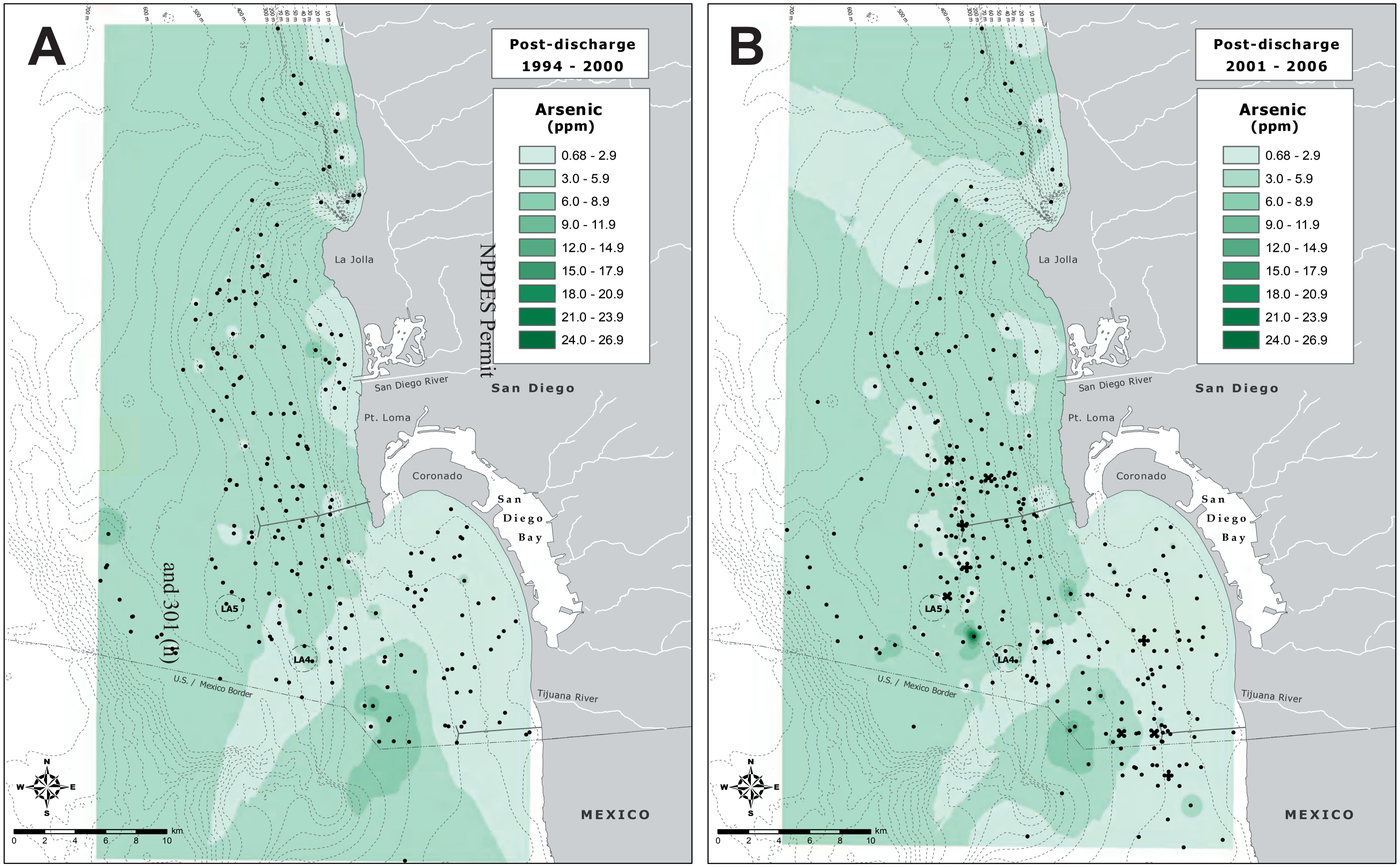


FIGURE E.5-7.
Comparison of arsenic concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

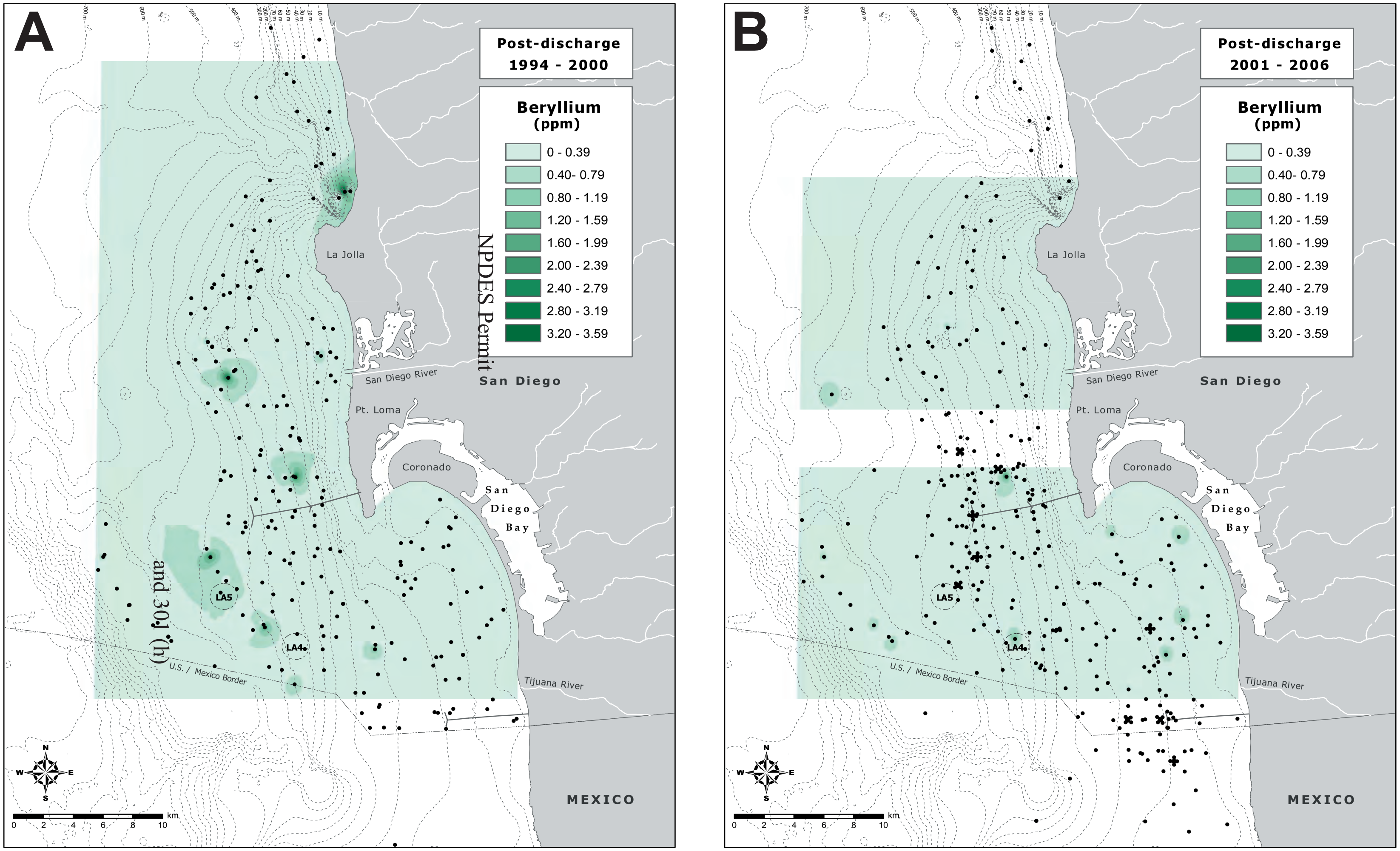


FIGURE E.5-8.
Comparison of beryllium concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

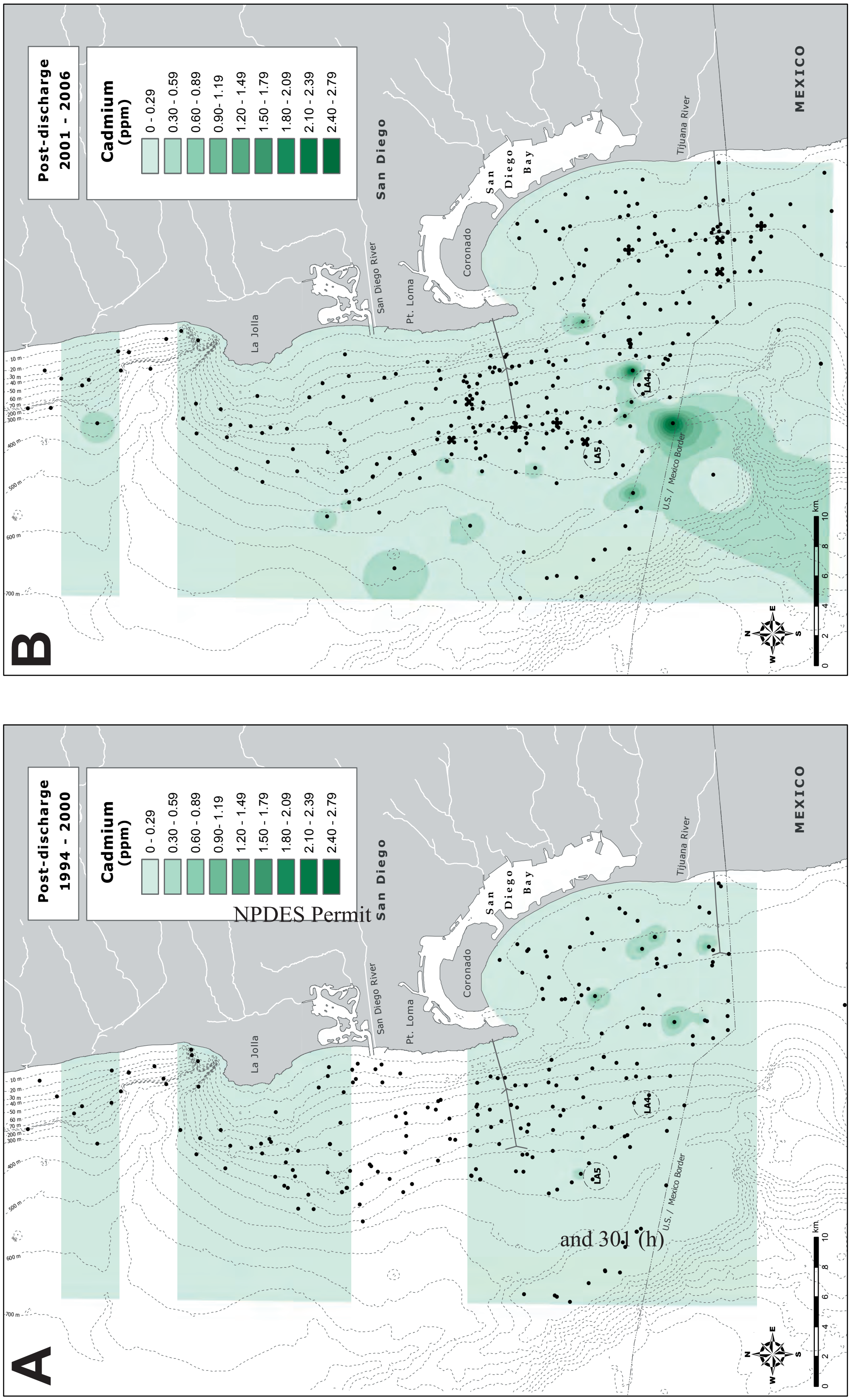


FIGURE E.5-9.

Comparison of cadmium concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

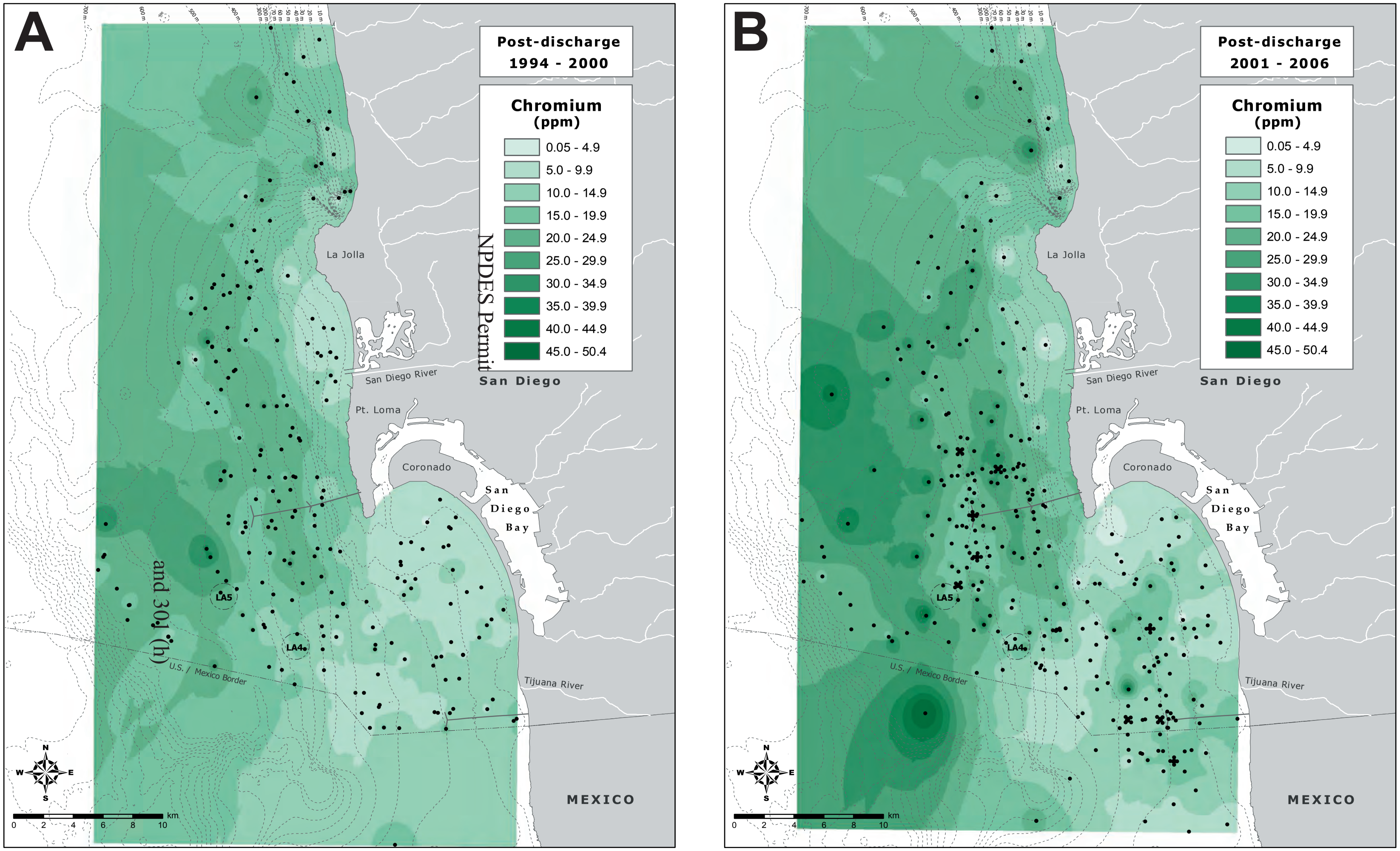


FIGURE E.5-10.
Comparison of chromium concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

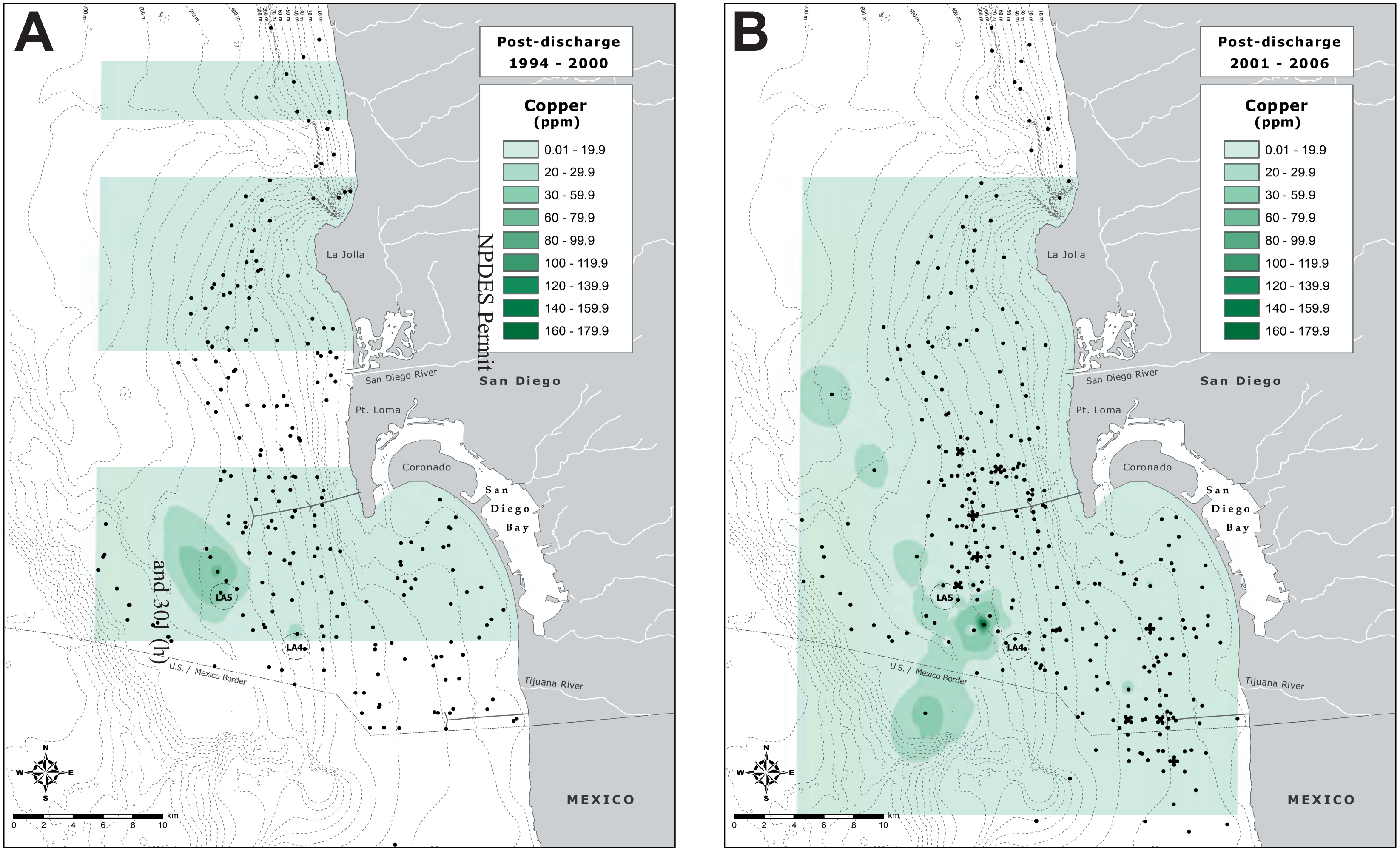
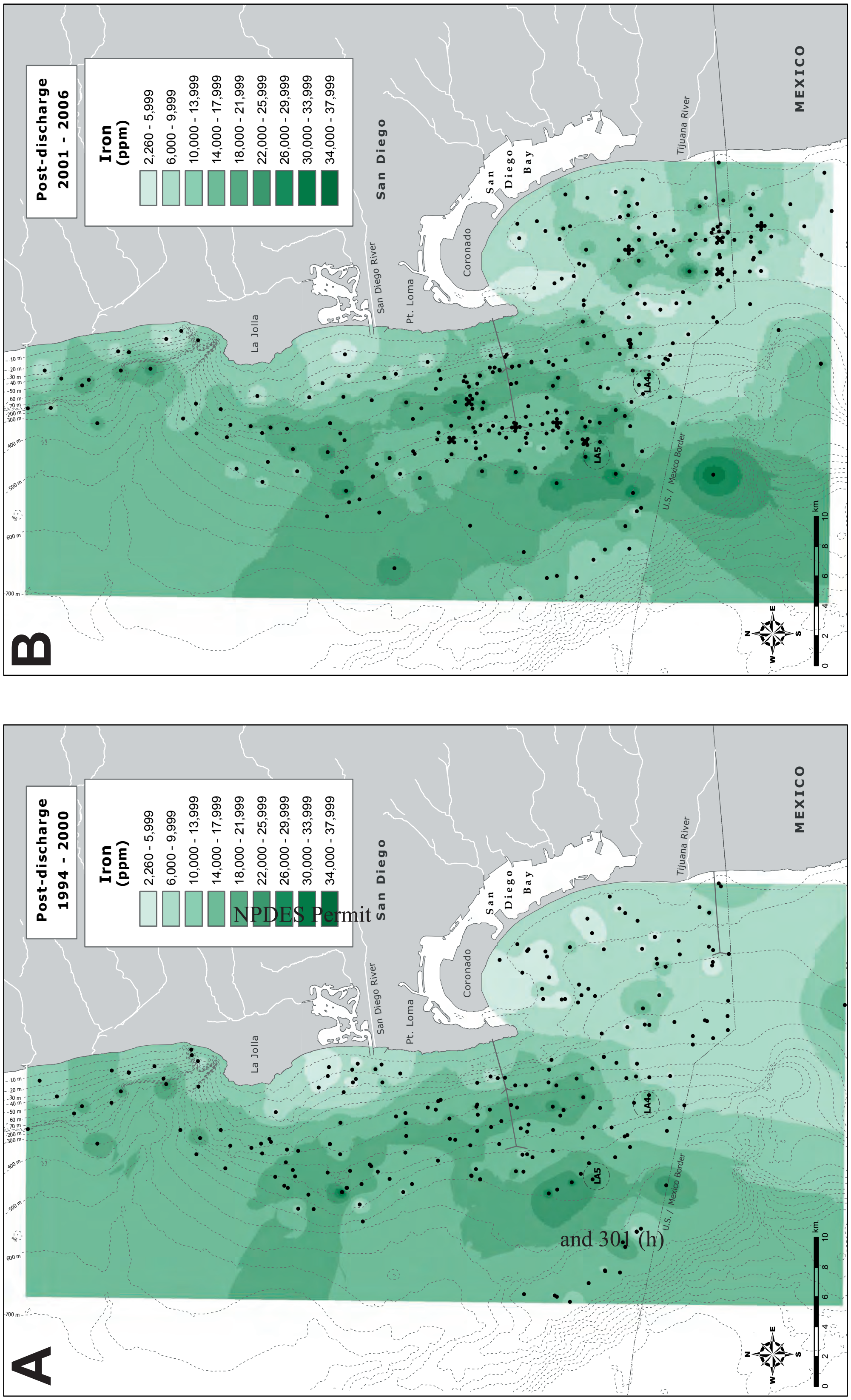


FIGURE E.5-11.
Comparison of copper concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight’98 and Bight’03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).



NPDES Permit

and 301 (h)

FIGURE E.5-12.
Comparison of iron concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

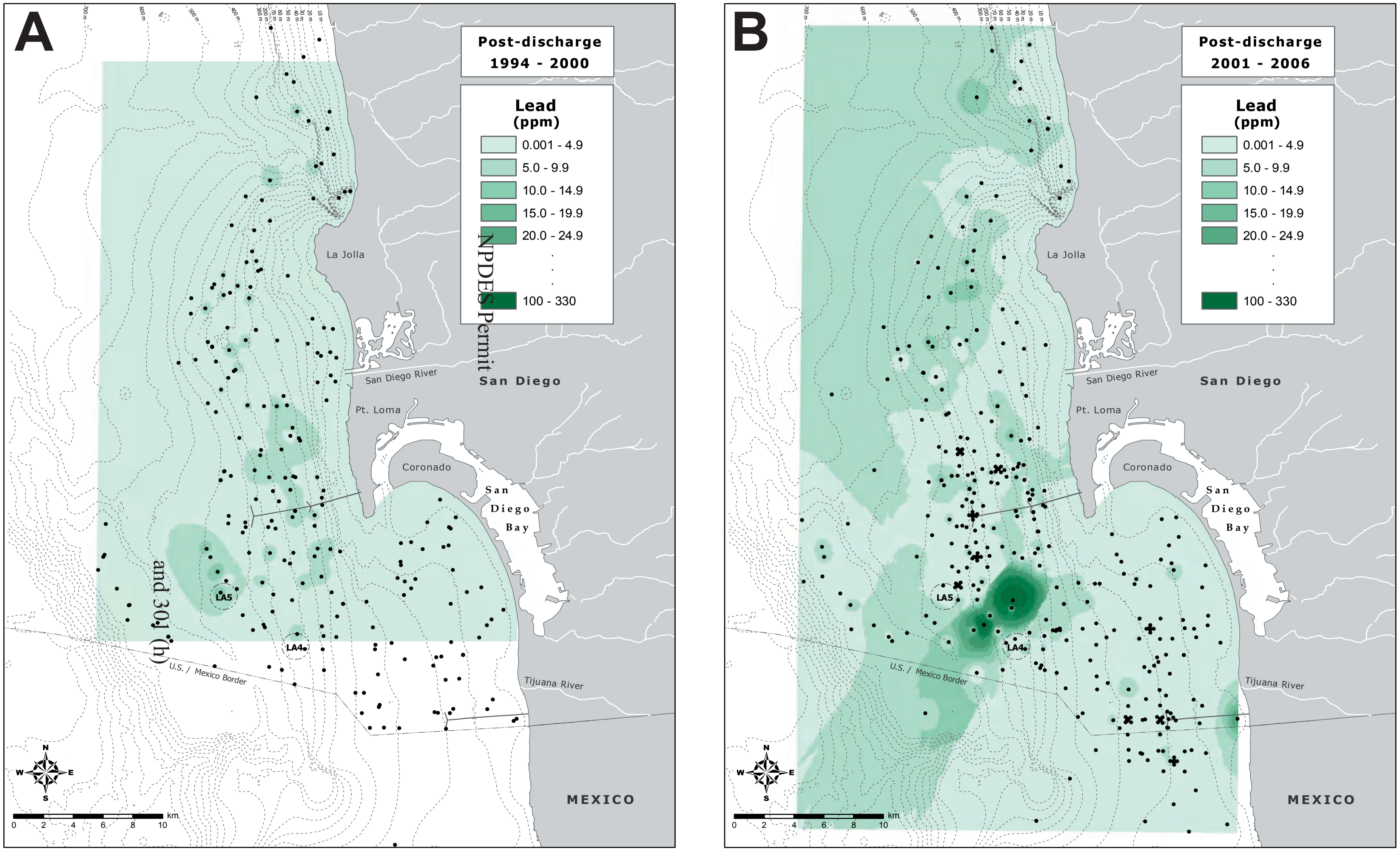


FIGURE E.5-13.
Comparison of lead concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

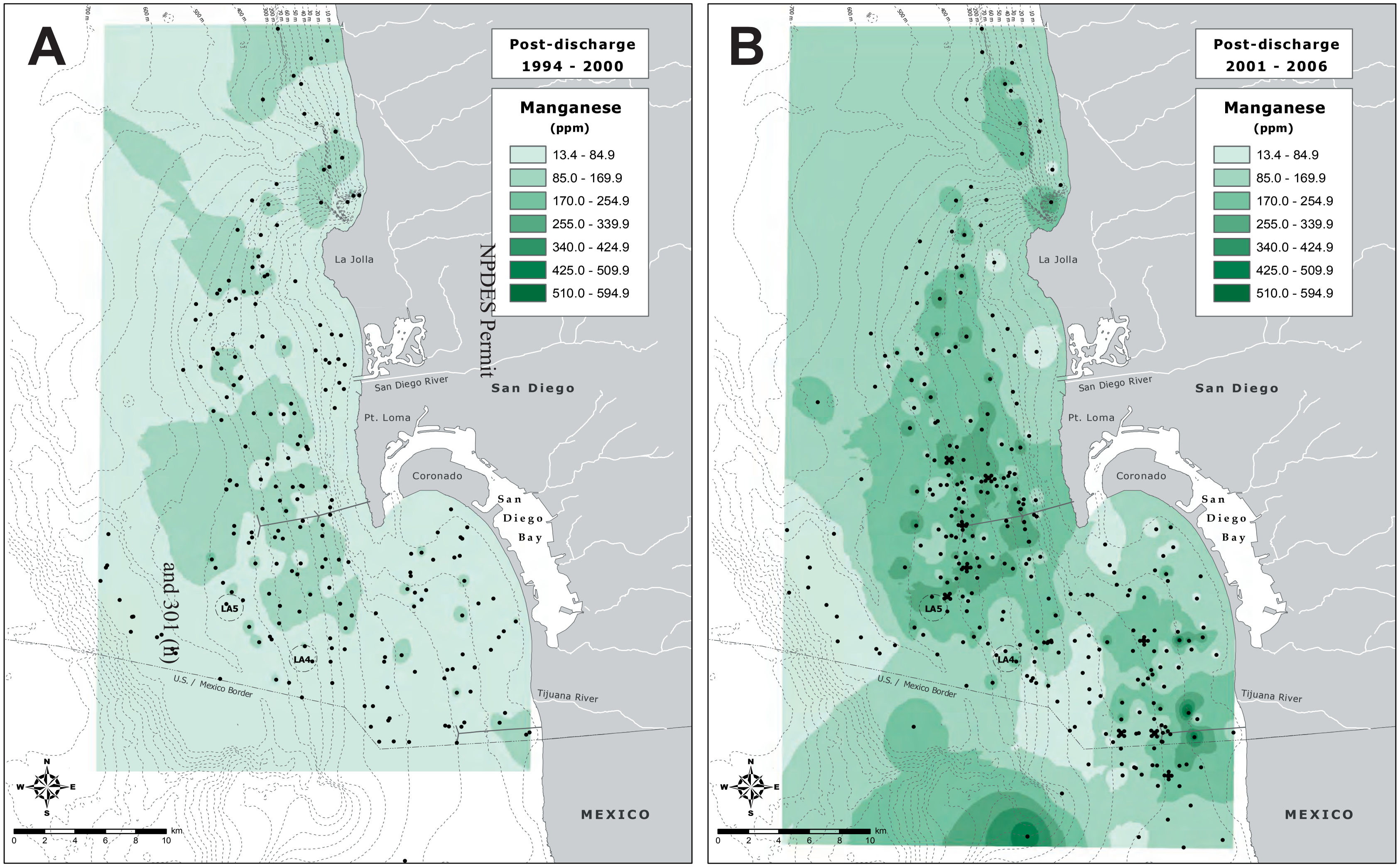


FIGURE E.5-14.
Comparison of manganese concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

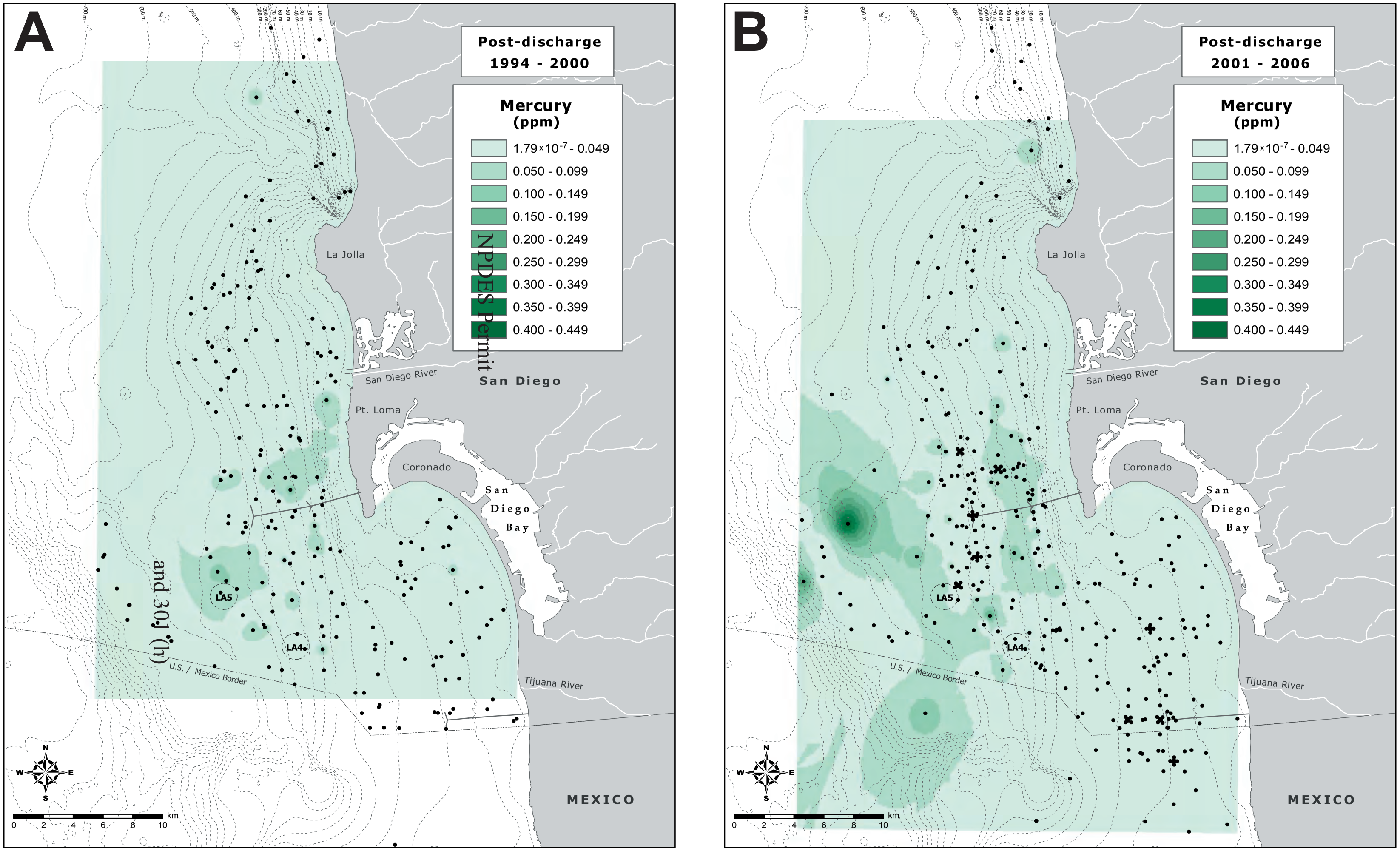


FIGURE E.5-15.
Comparison of mercury concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

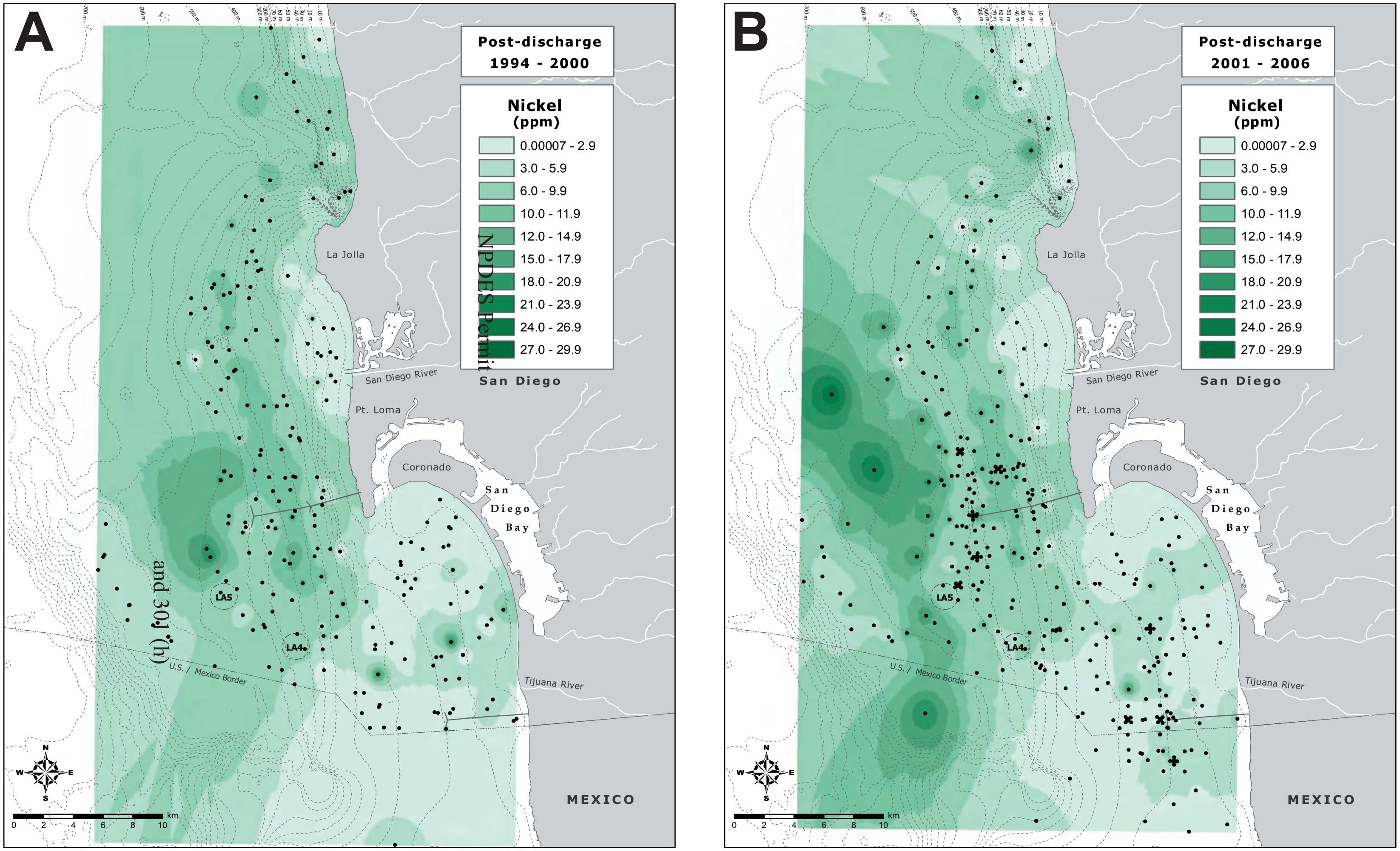


FIGURE E.5-16.
Comparison of nickel concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

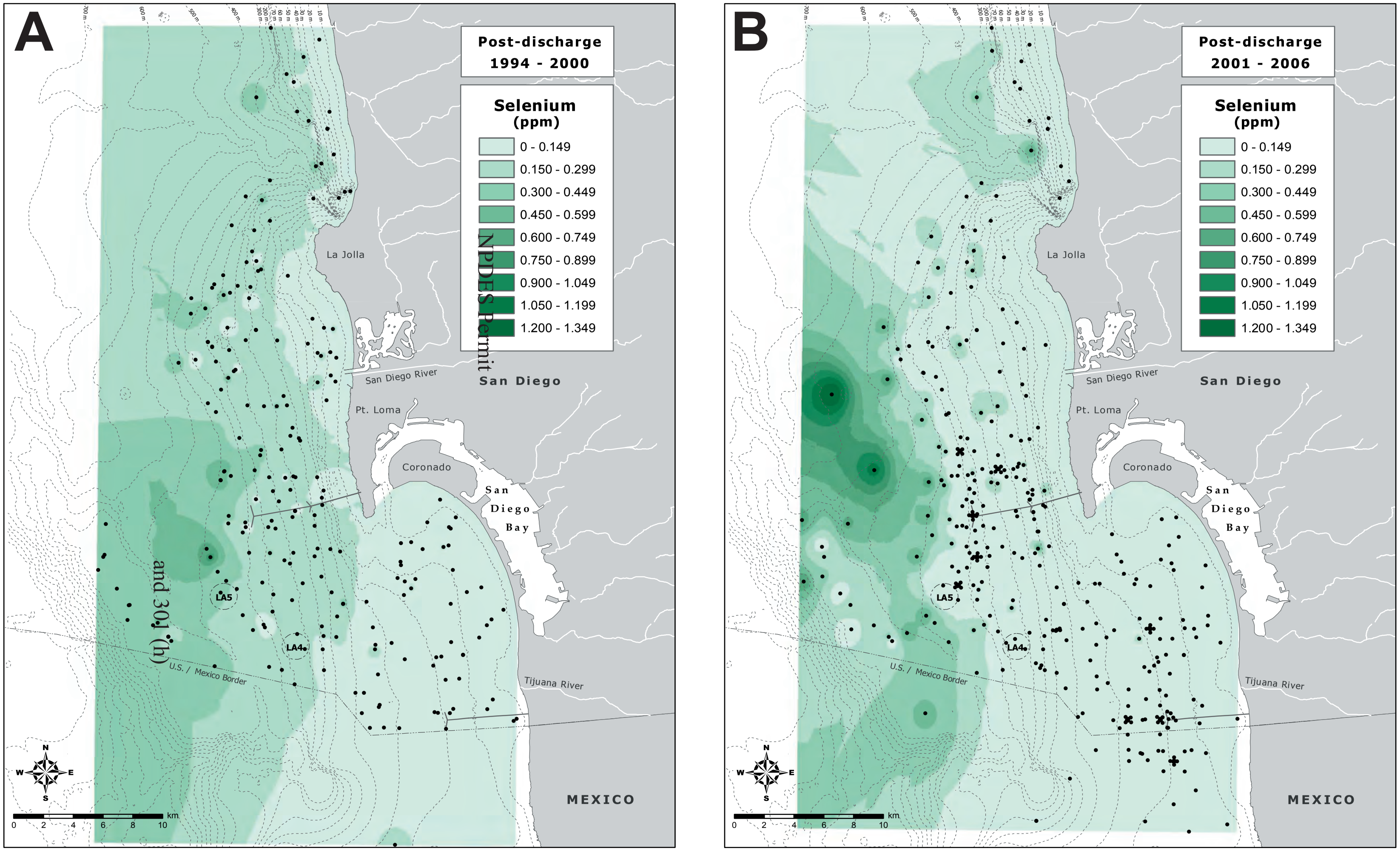


FIGURE E.5-17.
Comparison of selenium concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

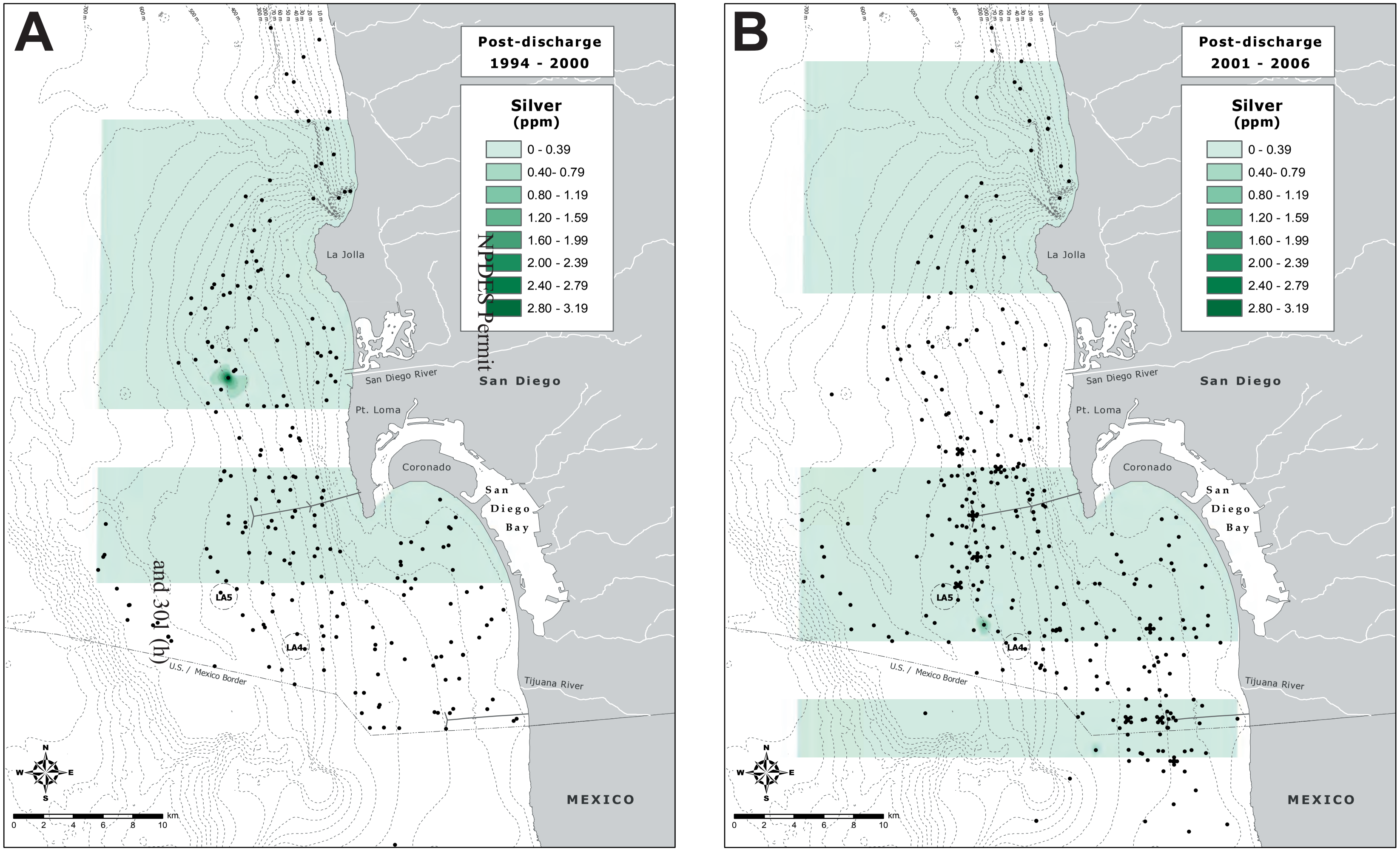


FIGURE E.5-18.
Comparison of silver concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

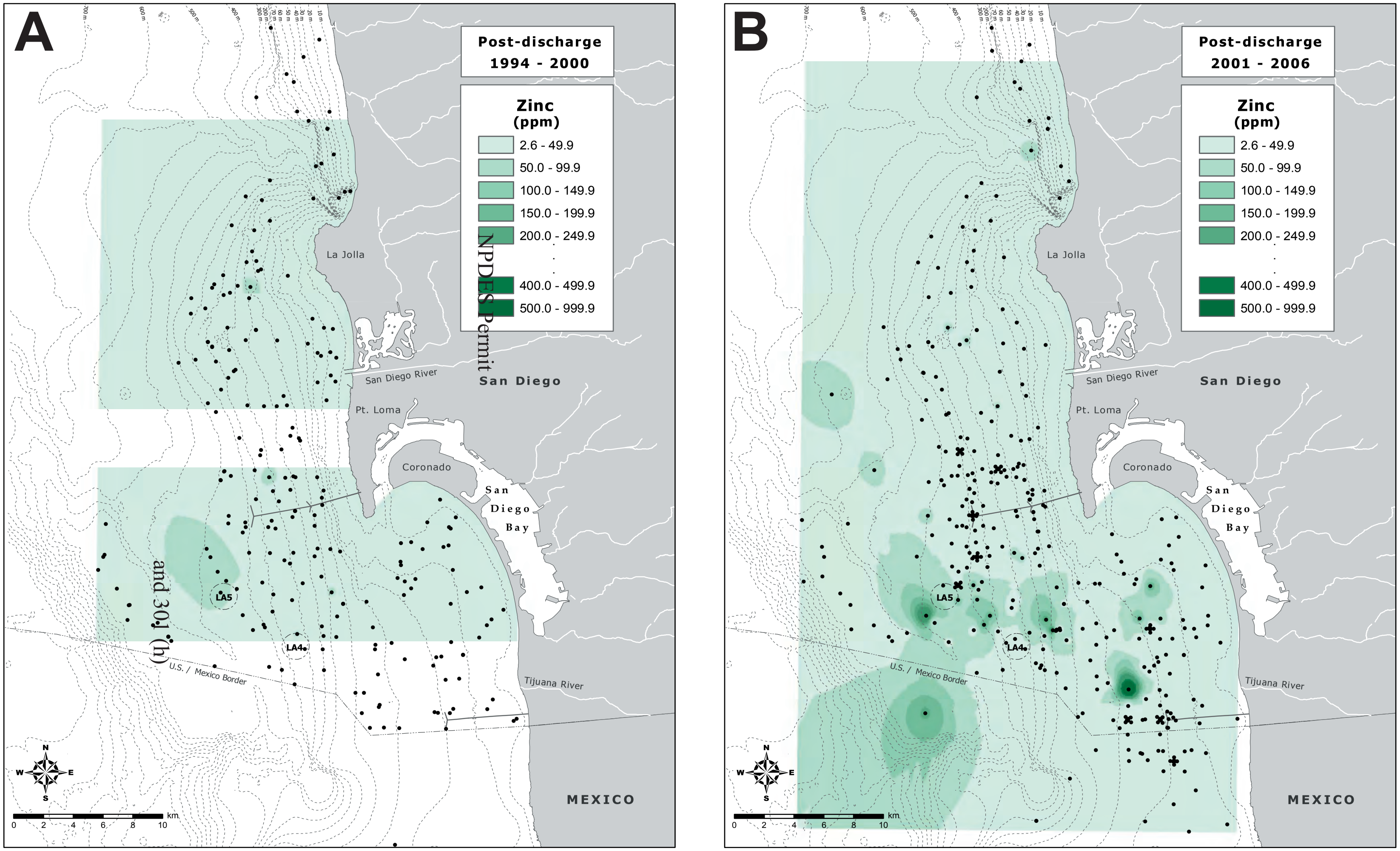


FIGURE E.5-19.
Comparison of zinc concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per million (ppm) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

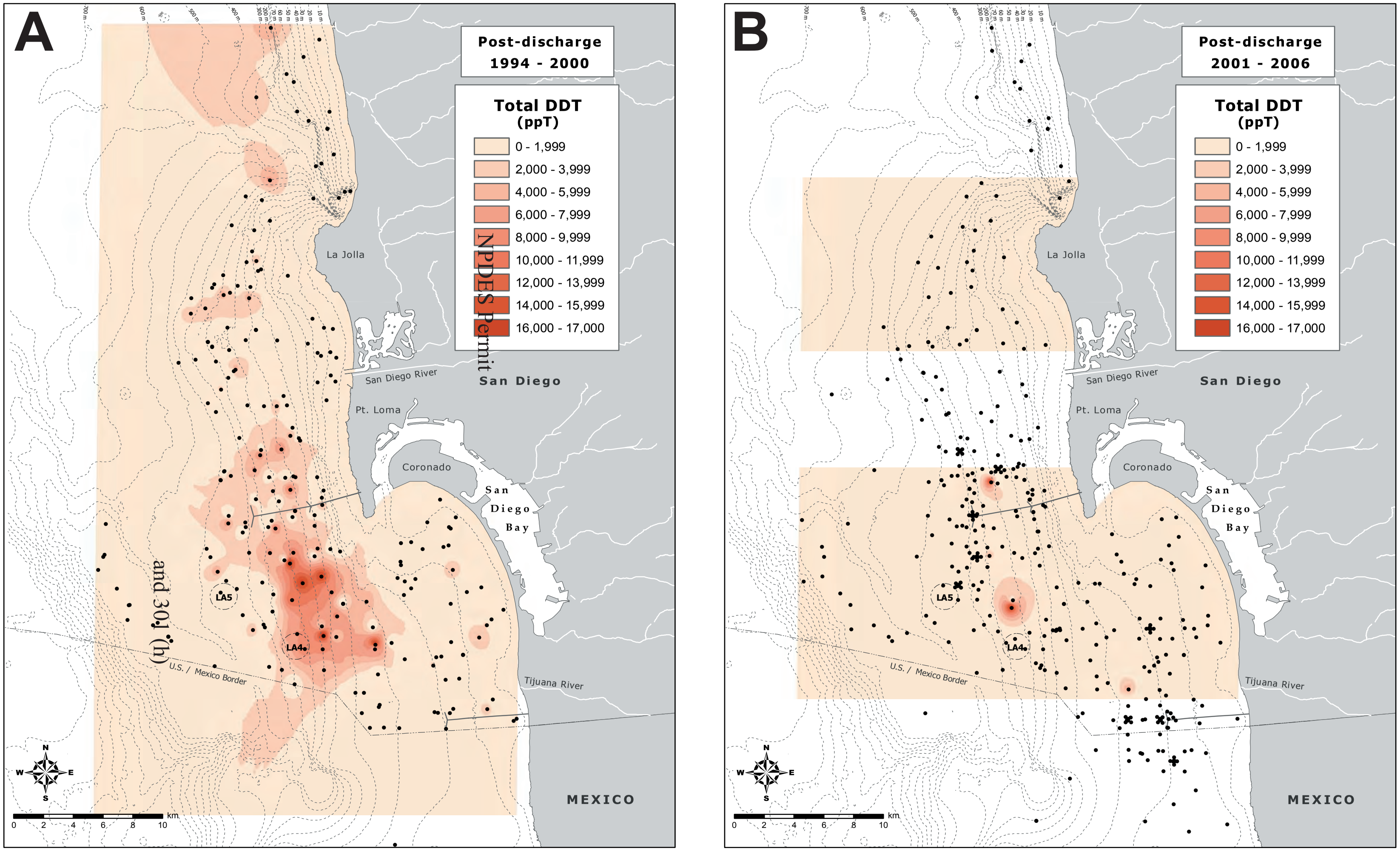


FIGURE E.5-20.
Comparison of DDT concentrations in sediments for the San Diego coastal region during the 1994-2000 (A) and 2001-2006 (B) post-discharge periods. Data are expressed in parts per trillion (ppT) and were calculated using results from the San Diego annual regional surveys (1995-1997, 1999-2002, 2005-2006), the Southern California Bight Pilot Project (1994), the Bight'98 and Bight'03 regional monitoring programs (1998, 2003), and the San Diego Sediment Mapping Study (2004).

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Appendix F

Bioaccumulation Assessment

APPENDIX F

BIOACCUMULATION ASSESSMENT

Analysis of Receiving Waters Monitoring Data Collected around the Point Loma Ocean Outfall (October 1995 - December 2006)

City of San Diego

NPDES Permit Application
and 301(h) Application

Submitted to

United States Environmental Protection Agency

November 2007
(updated)

Prepared by

City of San Diego
Metropolitan Wastewater Department
Environmental Monitoring & Technical Services Division

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Appendix F

Bioaccumulation Assessment

Section F.1 – Summary of Findings

Demersal fishes can accumulate chemical contaminants from the environment, including surrounding waters, benthic sediments, and from the food they consume. The City of San Diego currently monitors the bioaccumulation of contaminants in fishes inhabiting areas surrounding the Point Loma Ocean Outfall by analyzing liver and muscle tissue samples of species collected from four trawl zones (6 stations) and two rig fishing stations. These stations are located along the mainland shelf at depth ranges similar to where wastewater is discharged (~98 m). Specific species are targeted for analysis based on their ecological or commercial importance.

Results are presented for contaminant levels of 11 metals, DDT and other chlorinated pesticides, polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) measured in 23 species of fish collected from surveys conducted between October 1995 and October 2006. Three trace metals (mercury, selenium and zinc) occurred at low levels in nearly every liver and muscle tissue sample, but showed no temporal or spatial patterns with respect to the onset of wastewater discharge or distance from the outfall. Detection rates of some metals sampled and analyzed were highly variable. For example, arsenic, cadmium and copper occurred in 3 – 100% of the muscle samples and 44 – 85% of the liver samples. Other metals, including chromium, lead, nickel, silver and tin were detected infrequently. Concentrations of these metals in fish tissues varied substantially in space and time, although they showed no patterns relative to the Point Loma outfall. Concentrations of chromium, mercury, selenium or zinc rarely exceeded the Median International Standard (MIS) for these four metals, or the Food and Drug Administration (FDA) and California Department of Health Services (CDHS) advisory levels for mercury. In contrast, arsenic concentrations often exceeded the MIS. Overall, metal concentrations were considerably less in the muscle tissues of fish than in liver tissues, and contaminant loads were generally within the range of those reported previously for other Southern California Bight (SCB) fish assemblages.

DDT occurred in all species of fish with detection rates greater than 90% for liver and muscle tissues. Concentrations of DDT were highly variable, ranging from non-detected to maximum values of 878 ppb in muscle tissues and 23,336 ppb in liver tissues. However, there was no correlation between these concentrations and distance from the Point Loma outfall, and DDT residues in fish muscles were below seafood consumption limits. Several other chlorinated pesticides were detected in the tissues of fish off Point Loma, of which hexachlorobenzene and total chlordane were most prevalent. Although these two pesticides have been detected at all stations in recent years, concentrations were low and revealed no patterns relative to the outfall or wastewater discharge.

PCB compounds were also prevalent in fish tissues, occurring in 91% of the liver samples and 43% of muscle samples. Maximum total PCB concentrations were 13,264 ppb in liver and about 99 ppb in muscle tissues. Most samples showed slightly higher average concentrations near the LA-5 disposal site than in the other areas. There does not appear to be any relationship between concentrations of either total PCBs or individual PCB congeners in fish tissues and distance from the Point Loma outfall.

PAHs were rarely detected in liver or muscle tissue samples. Fish rapidly metabolize most PAH compounds and excrete them in bile, therefore making them hard to detect in fish tissues. For that reason, PAHs were eliminated from the NPDES permit that took affect in October 2003.

Section F.2 – Introduction

Bioaccumulation is the process of biological uptake and retention of chemical contaminants from various exposure pathways (USEPA 2000). Marine organisms can accumulate pollutants through adsorption or absorption of dissolved chemical constituents from the surrounding water or from the ingestion and assimilation of pollutants from different food sources (Rand 1995). Because of their proximity to seafloor sediments, demersal fish and other bottom dwelling organisms can also be exposed to pollutants thru ingestion of suspended particulates and the subsequent assimilation of chemicals into body tissues. Once a contaminant becomes incorporated into an organism's tissues, it may resist normal metabolic excretion and accumulate (Walker et al. 1996). In addition, higher trophic level organisms may feed on contaminated prey and further concentrate pollutants in their tissues (Suedel et al. 1994). This food web magnification may lead to tissue burdens in fish that have both ecological and human health implications (USEPA 1997).

The City of San Diego's Ocean Monitoring Program includes extensive sampling to detect any effects on demersal fish communities associated with wastewater discharge from the Point Loma Ocean Outfall (PLOO). The bioaccumulation portion of the program presently consists of two components, including: (1) analysis of liver tissues from trawl-caught fishes; (2) analysis of muscle tissues from fishes collected by rig fishing. Fishes collected from trawling activities are considered representative of the general demersal fish community that dominates the region, and certain species are targeted based on their ecological significance (i.e., prevalence in the community). Chemical analyses are performed using livers of these fishes because this is the organ where contaminants typically concentrate. In contrast, fishes targeted for collection at rig fishing sites represent species from a typical sport fisher's catch, and are therefore of recreational and commercial importance. Muscle tissue is analyzed from these fish because it is the tissue most often consumed by humans, and therefore the results have implications concerning seafood safety issues and public health.

The data presented represents an update of the analyses presented in the City's previous 301(h) waiver application in 2001, which addressed monitoring data collected from 1995 through calendar year 2000. Since that time, however, significant changes were made to the MRP requirements for the Point Loma region with the adoption of Addendum No. 1 to Order No. R9-2002-0025, NPDES Permit No. CA0107409, which may affect comparisons between periods. Thus, all data were completely reanalyzed for this application in order to account for such factors. Four major changes to the bioaccumulation monitoring requirements that became effective on August 1, 2003 include:

1) The number of trawl stations was reduced from 8 to 6 (sampling at stations SD9 and SD11 was discontinued);
2) The 6 trawl stations were divided into four zones from which only liver tissue samples were collected (both muscle and liver tissue samples were previously collected at these sites);
3) Fishes collected by rig fishing were sampled only for muscle tissues to address local seafood safety issues (both muscle and liver tissue samples were previously collected at these sites);
4) Sampling frequency modified from a semiannual (April, October) to annual (i.e., October) schedule.

Section F.3 – General Methodology

Appendix F reviews the results of the bioaccumulation analyses for fishes collected off San Diego for the period October 1995 through October 2006. The fishes analyzed herein were collected from six trawling stations corresponding to four zones and at two rig fishing locations (stations RF1 and RF2) (see Figure F-1). Trawl Zone 1 represents the nearfield zone and is defined as the area within a 1-km radius of stations SD10 and SD12, which are located just south and just north of the PLOO, respectively; Trawl Zone 2 is considered the northern farfield zone, defined as the area within a 1-km radius of stations SD13 and SD14;

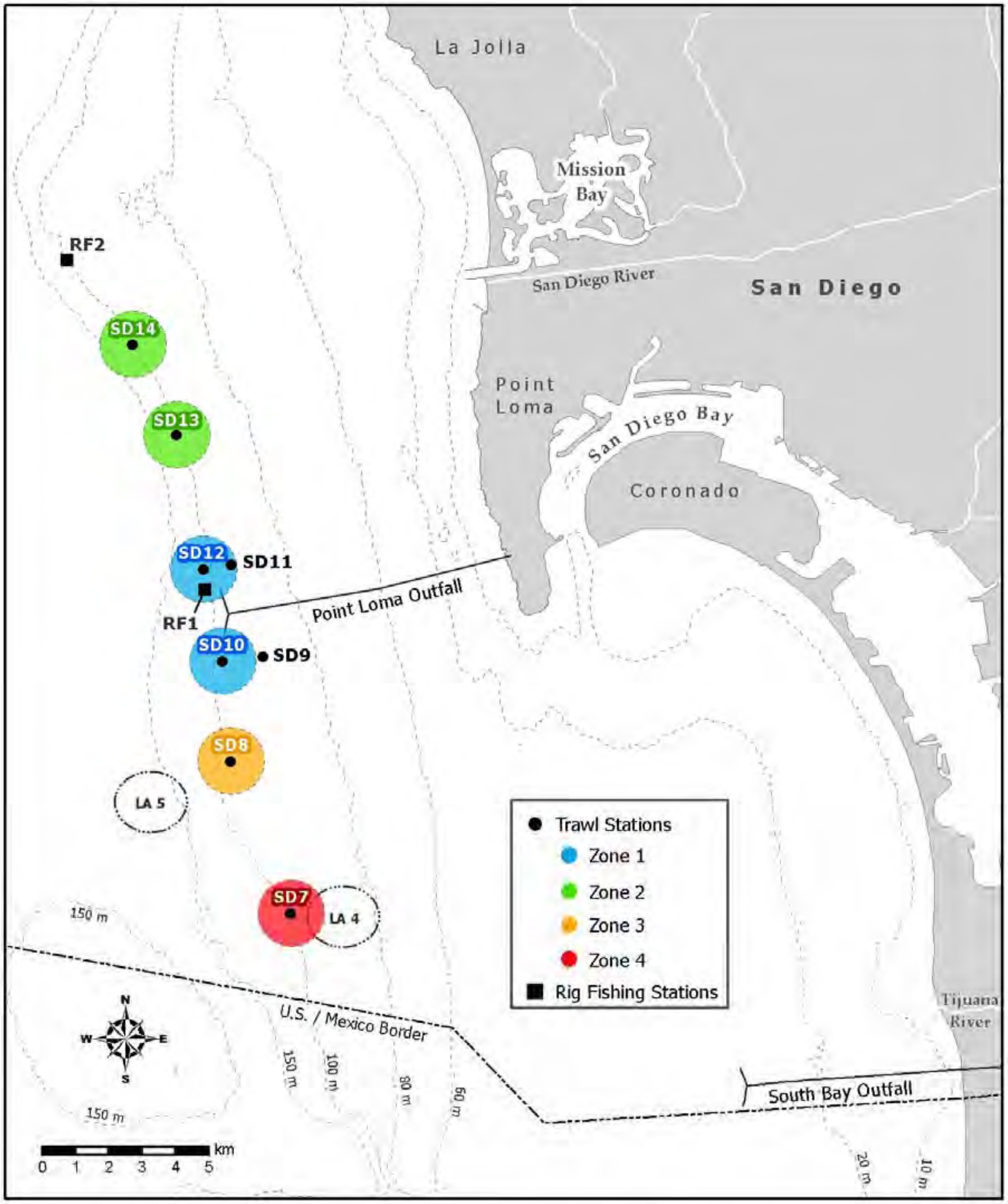

FIGURE F-1. Otter trawl and rig fishing monitoring stations and fish collection zones surrounding the City of San Diego's Point Loma Ocean Outfall. Stations SD7, SD8, SD10, SD12, SD13, SD14=current monitoring sites that are the focus of the analyses presented herein; sampling at stations SD9 and SD11 was discontinued in late 2003. See text for details of zone descriptions and changes to sampling program over time. LA-4 and LA-5 = EPA designated dredge materials disposal sites.

Trawl Zone 3 is defined as the area within a 1-km radius of station SD8 and represents a farfield zone near the LA-5 dredged materials disposal site; Trawl Zone 4 is considered the southernmost farfield zone, and is defined as the area centered within a 1-km radius of station SD7. Trawl-caught fishes were collected, measured, and weighed following guidelines described in Appendix E, Section E.6. Fishes were collected at the rig fishing sites using rod and reel fishing tackle, and then also measured and weighed. Table F-1 lists the scientific and common names of the different flatfishes and rockfishes taken for assessment of contaminant bioaccumulation.

Fishes were collected semi-annually (April, October) from October 1995 through April 2003. During this time, 3 composite liver tissue samples and 3 muscle tissue samples were obtained at each station. Beginning in August 2003 as a result of NPDES permit revisions (see Section F.2), fishes for bioaccumulation analysis were only collected during October each year. Additionally, the individual trawl stations were combined into the 4 trawl zones described above. Also effective at this time is that muscle tissues were no longer required to be collected for trawl-caught fishes, while liver tissues were no longer required for fish collected at the rig fishing sites. Initially, up to 9 composite liver samples were obtained per trawl zone; however, the number of required liver tissue samples was reduced to 3 per zone in October 2005. The number of required composite muscle tissue samples remained the same at the rig fishing stations (i.e., 3 per station).

For all samples, only fish greater than 12 cm standard length were retained for tissue analyses. Composite samples were typically made up of a single species, with a minimum of 3 individuals comprising each composite; the only exceptions being when multiple species of a single genus were required to obtain the minimum number of fish for a sample. The species caught at each station or zone in sufficient quantity to make up adequate tissue samples are indicated in Tables F-2 and F-3.

Tissue samples (liver and muscle) were analyzed for trace metals, chlorinated pesticides, polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) through April 2003. Beginning with the October 2003 survey, analysis of PAHs was

TABLE F-1
Scientific and common names of fishes analyzed as part of the City of San Diego's Ocean Monitoring Program.

Common Name	Scientific Name
TRAWL-CAUGHT	
Bigmouth sole	*Hippoglossina stomata*
Dover sole	*Microstomus pacificus*
English sole	*Pleuronectes vetulus*
Hornyhead turbot	*Pleuronichthys verticalis*
Longfin sanddab	*Citharichthys xanthostigma*
Pacific sanddab	*Citharichthys sordidus*
Mixed sanddab	*Citharichthys* spp.
California scorpionfish	*Scorpaena guttata*
Flag rockfish	*Sebastes rubrivinctus*
Greenblotched rockfish	*Sebastes rosenblatti*
Greenspotted rockfish	*Sebastes chlorostictus*
Halfbanded rockfish	*Sebastes semicinctus*
Squarespot rockfish	*Sebastes hopkinsi*
Stripetail rockfish	*Sebastes saxicola*
Vermilion rockfish	*Sebastes miniatus*
Mixed rockfish	*Sebastes* spp.
HOOK and LINE CAUGHT	
California scorpionfish	*Scorpaena guttata*
Bocaccio	*Sebastes paucuspinis*
Canary rockfish	*Sebastes pinniger*
Copper rockfish	*Sebastes caurinus*
Flag rockfish	*Sebastes rubrivinctus*
Greenspotted rockfish	*Sebastes chlorostictus*
Rosethorn rockfish	*Sebastes helvomaculatus*
Speckled rockfish	*Sebastes ovalis*
Squarespot rockfish	*Sebastes hopkinsi*
Starry rockfish	*Sebastes constellatus*
Vermilion rockfish	*Sebastes miniatus*
Yellowtail rockfish	*Sebastes flavidus*
Mixed rockfish	*Sebastes spp.*

TABLE F-2

Summary of fish species collected by station for tissue analysis from October 1995 through April 2003. LS= longfin sanddab; PS=Pacific sanddab; DS=Dover sole; ES=English sole; CS=California scorpionfish; MR=mixed rockfish; BS=bigmouth sole; HT=hornyhead turbot; HR=halfbanded rockfish; GR=greenblotched rockfish; SR=stripetail rockfish; VR=vermilion rockfish; StR=starry rockfish; SqR=squarespot rockfish; SpR=speckled rockfish; CR=copper rockfish; CaR=canary rockfish; FR=flag rockfish; MS=mixed sanddabs; B=Bocaccio; GsR=greenspotted rockfish; ns=not sampled; na=not applicable.

Station	Zone	Rep	Oct-95	Apr 96*	Oct 96	Apr-97	Oct-97	Apr 98*	Oct 98	Apr 99	Oct 99	Apr 00	Oct 00	Apr 01	Oct 01	Apr 02	Oct 02	Apr 03
SD7	Zone 4	1	LS	CS/LS	LS	LS	LS	CS	LS	CS	LS	LS	LS	LS	LS	PS	LS	PS
		2	LS	CS/LS	LS	CS	LS	CS	LS	CS	LS	CS	HT[a]	CS	LS	ES	DS[a]	CS
		3	LS	LS/LS	LS	CS	HT[g]	CS	LS	CS	LS	CS	CS	CS	LS	CS	LS	CS
SD8	Zone 3	1	LS	LS[a]/LS	PS	LS	LS	CS/CS[d]	LS	PS[a]	FR	LS	LS	VR	PS	PS	CS	CS
		2	LS	LS[b,c]/PS	LS	PS	HR	CS[e]	LS	LS	FR	CS	MR	GR	PS	GR[h]	LS	PS
		3	PS	MR[b]/MR	MR	DS	HR	CS	LS	CS	LS	DS	CS**	MR	GsR	LS	PS	PS
SD10	Zone 1	1	LS	PS[b,d]/PS	LS	HR	LS	CS	LS[a]	CS	LS	LS	LS	DS[a]	ES	PS	LS	CS
		2	LS	CS/SR	LS	CS	LS	CS[e]	LS	CS	LS	CS	LS	MS[a]	ES	CS[h]	PS	CS
		3	DS	CS/CS[b,d]	ES	CS	CS	CS	CS	CS	LS	LS	CS	CS	PS	CS	CS	CS
SD12	Zone 1	1	PS	CS/LS	ES	CS	LS	PS[a]	CS	CS	CS	CS	CS	CS	LS	LS	CS	PS
		2	CS	LS[a]/PS	ES	CS	CS	DS[a,d]	CS	CS	CS	CS	CS	CS	GR	PS	DS	CS
		3	CS	ns/PS	GR	CS	CS	CS	LS[a]	CS	CS	CS	CS	CS	CS	CS	PS	CS
SD13	Zone 2	1	LS	CS/CS	ES	DS[a]	CS	CS	LS[a]	CS	LS	PS	LS	LS	LS	LS	LS	CS
		2	LS	CS/PS	PS	PS[e]	LS	CS	CS[a]	CS	CS	CS	PS	CS	CS	PS	CS	LS
		3	LS	PS[b,d]/PS	LS	ns/BS	LS	CS	CS	CS	CS	CS	ES	CS	GsR	CS	CS	PS
SD14	Zone 2	1	PS	SqR[b,d]/DS[g,d]	LS	LS[f]	LS	BS[a]	LS[a]	PS	LS	CS	PS	CS	LS	PS	PS	PS
		2	PS	PS[b,c]/PS	PS	DS[a]	LS	CS	LS[a]	CS	CS	CS	LS	CS	PS	PS	PS	PS
		3	PS	CS/CS	PS	BS[a]	LS	CS	CS[a]	CS	CS	CS	LS	CS	CS	CS	PS	CS
RF1	na	1	CR	MR[b]/MR	CR	VR	CS	VR	MR[a]	MR	CS	CR	VR	CR	VR	VR	CR	VR
		2	VR	MR/MR	VR	VR	CS	VR	CS	VR	CS	CR	VR	VR	VR	CR	CR	MR
		3	VR	MR/MR	MR	VR	MR	VR	CR	CR	CS	CR	MR	VR	CR	CS	MR	VR
RF2	na	1	MR	SpR/SpR	SpR	StR	StR	StR	StR	MR	SpR	MR	VR	B	StR	MR	FR	MR
		2	MR	ns/SpR	SpR	SpR[e]	SqR[f]	CS	VR	FR	CS	VR	MR	MR	MR	VR	VR**	B
		3	CaR	ns/SpR	MR	SpR[a]	SpR[e]	MR	VR	MR	VR	StR	VR	MR	ns	FR	ns	MR

*First sample is liver tissue, second is muscle tissue

** only two specimens used in composite sample

a) no metals; b) no metals except Hg, Se, As; c) no pesticides, PAHs, PCBs; d) no PAHs; e) no metals except Hg, Se; f) no Se; g) no metals except Hg; h) no Hg

TABLE F-3

Summary of fish species collected by station for tissue analysis from October 2003 through October 2006. LS= longfin sanddab; PS=Pacific sanddab; ES=English sole; MR=mixed rockfish; BS=bigmouth sole; HT=hornyhead turbot; GR=greenblotched rockfish; VR=vermilion rockfish; SqR=squarespot rockfish; SpR=speckled rockfish; StR=starry rockfish;CR=copper rockfish; RR=rosethorn rockfish; YR=yellowtail rockfish; na=not applicable.

Station	**Zone**	**Rep**	**Oct-03**[b]	**Oct-04**[b]	**Oct-05**[b]	**Oct-06**[b]
SD7	Zone 4	1	PS	PS	PS	PS
	Zone 4	2	PS	PS	PS	PS
	Zone 4	3	PS	PS	PS	ES
	Zone 4	4	BS[a]			
	Zone 4	5	LS[a]			
SD8	Zone 3	1	PS	PS	PS	PS
	Zone 3	2	PS	PS	PS	PS
	Zone 3	3	PS	PS	PS	PS
	Zone 3	4		ES		
	Zone 3	5		ES		
	Zone 3	6		LS		
SD10/SD12	Zone 1	1	ES	ES	PS	PS
	Zone 1	2	ES	ES	PS	PS
	Zone 1	3	ES	ES	PS	PS
	Zone 1	4	PS	PS		
	Zone 1	5	PS	PS		
	Zone 1	6	PS	PS		
	Zone 1	7	HT	LS		
	Zone 1	8	HT[a]	LS		
	Zone 1	9		LS		
SD13/SD14	Zone 2	1	LS	ES	PS	PS
	Zone 2	2	LS	ES	PS	PS
	Zone 2	3	LS	ES	PS	PS
	Zone 2	4	ES	PS		
	Zone 2	5	ES	PS		
	Zone 2	6	ES	PS		
	Zone 2	7	PS	LS		
	Zone 2	8	PS	LS		
	Zone 2	9	PS	LS		
RF1	na	1	CR	CR	RR	CR
		2	MR	CR	MR	CR
		3	VR	MR	MR	CR
RF2	na	1	VR	GR	SqR	StR
		2	VR	MR	SqR	YR
		3	VR	MR	SpR	YR

a) no metals; b) no PAHs

discontinued for fish tissues. In addition, values for pollutants comprised of many individual constituents (e.g., DDT and PCBs) are reported herein as totals (e.g., total DDT and total PCB). A detailed description of the analytical protocols may be obtained from the City of San Diego Wastewater Chemistry Laboratory (City of San Diego 2007a).

The data presented in this report are limited to: (a) detected values; and (b) estimated values for parameters determined to be present in a sample with high confidence (i.e., peaks are confirmed by mass-spectrometry), although they occur at levels below the MDL. Consideration of only detected values (i.e., ignoring nondetects) is used herein as a conservative way of handling contaminant concentrations as it creates a strong upward bias in the data and respective summary statistics, and therefore may represent a worst-case scenario (e.g., see Helsel 2005a, b, 2006 for discussions of nondetect data).

For the sake of continuity between the two permit periods, all analyses of data from trawled fishes were limited to the six trawl stations currently sampled. Stations sampled prior to October 2003 were assigned to their corresponding zone. Spatial and temporal analyses of the trawl-caught samples were further limited to liver tissues from California scorpionfish and Pacific and longfin sanddabs. The latter two species are also considered collectively as a "sanddab feeding guild" after Allen et al. (2002). The California scorpionfish and sanddab feeding guild form the best basis for the bioaccumulation assessment of the trawled data because of their sample size and coverage in both space and time. However, targeting of California scorpionfish for tissue analysis ended in April 2003, and data presented herein represent only those samples collected from October 1995 through April 2003. Since concentrations of contaminants vary with season, temporal comparisons presented in various figures were further limited to data collected only during the October surveys. Spatial and temporal analyses for the rig fishing stations were limited to various rockfish species, with temporal comparisons also based on data collected from only the October surveys each year.

Section F.4 – Results and Discussion

Metals

Mercury: Mercury is a common trace element in ocean waters and sediments and has a wide variety of natural and anthropogenic sources (Mearns et al. 1991). It may be injected into the atmosphere by volcanism, transported into coastal waters by rain and runoff, or released directly into the ocean through geothermal springs. Man-made sources include the use of mercury in fungicides, plastics, medical preparations, and in smelting and mining processes, while electrochemical industries also generate mercury waste. Although elemental mercury is moderately toxic, organic mercury compounds (e.g., methylmercury) are highly toxic. Additionally, organic mercury readily penetrates biological membranes and may bioaccumulate in the tissues of organisms at higher trophic levels due to its chemical stability and lipid solubility.

Mercury is probably the metal with the greatest potential for bioaccumulation in Southern California Bight marine organisms (Mearns et al. 1991). It is also the only metal with action limits set by the U.S. Food and Drug Administration (FDA) and the California Department of Health Services (CDHS) for fish and shellfish sold for human consumption (USEPA 1997). Although typically found in low concentrations in southern California invertebrates, concentrations of total mercury reach their highest levels at the top of the food web. For example, one of, if not the highest, mercury concentrations (~8.2 ppm) observed to date in a southern California marine animal was found in the muscle tissue of a white shark captured near Santa Catalina Island (Schafer et al. 1982). Elevated levels of mercury have also been reported in muscle tissues of other carnivorous fish, with swordfish having the highest reported value of 2.6 ppm for the bony fish (Mearns et al. 1991).

Studies in the Southern California Bight (SCB) over the last 30 years have shown no relationship between elevated concentrations of mercury in marine organisms and point sources of contamination. Eganhouse and Young (1978) found that in spite of elevated mercury levels in Palos Verdes sediments, resident animals had low tissue concentrations of both total and organic mercury. In addition, mercury levels in edible tissues of seafood organisms collected near a major point source of contamination were comparable to samples from offshore islands and coastal control sites (see Young et al., 1981). Other investigations also indicate that mercury levels in southern California fish have not increased with exposure to contaminated sediments (Mearns et al. 1991).

Tissue concentrations of mercury in all trawl and rig-caught fish collected off Point Loma from October 1995 through the end of 2006 are summarized in Table F-4. Mercury was detected in the tissues of all species sampled, with overall detection rates of 87% for liver tissues and 92% for muscle tissues. Concentrations of mercury in muscles were generally lower than in livers, which would be expected since the liver is the primary site of detoxification of contaminants. Overall, mercury averaged 0.115 ppm in fish muscle tissues off Point Loma, ranging from a low of 0.012 ppm for several species to a high of 1.25 ppm for vermilion rockfish. Concentrations in liver tissues averaged 0.181 ppm, ranging from 0.012 ppm for several species to 1.16 ppm for flag rockfish. Mercury concentrations were generally lower in flatfish than rockfish. This result is expected since flatfish generally feed at a lower trophic level and are also not as long lived as rockfish. The muscle and liver tissue values for both individual species and all species combined are similar to mercury levels reported in the City's prior waiver applications (City of San Diego 1995, 2001a, b). Results for California scorpionfish and the sanddab feeding guild are discussed separately below.

Data on mercury concentrations in California scorpionfish liver and muscle tissues from October 1995 to April 2003 are summarized by zone in Table F-5. Levels of mercury in both muscle and liver tissue samples were similar across trawl zones with no apparent trend across the Point Loma shelf. Average mercury concentrations were slightly higher in fishes collected at the nearfield and northern farfield sites (i.e., trawl zones 1 and 2) than at the southern farfield sites (i.e., trawl zones 3 and 4). However, these differences may be related to the much larger sample size at the northern sites, which provided a greater opportunity to

Table F-4

Summary of mercury concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	3	100	0.055	0.087	0.074
Dover sole	3	3	100	0.056	0.139	0.100	10	8	80	0.020	0.048	0.037
English sole	23	20	87	0.013	0.130	0.054	8	8	100	0.012	0.072	0.032
Hornyhead turbot	2	2	100	0.121	0.137	0.129	2	1	50	0.075	0.075	0.075
Longfin sanddab	89	75	84	0.012	0.238	0.090	87	78	90	0.012	0.118	0.064
Pacific sanddab	90	71	79	0.012	0.579	0.069	49	37	76	0.014	0.112	0.036
Mixed sanddabs	0	na	na	na	na	na	1	1	100	0.059	0.059	0.059
Rockfish:												
California scorpionfish	124	114	92	0.014	0.556	0.148	120	117	98	0.012	0.483	0.152
Bocaccio	2	2	100	0.144	0.474	0.309	2	2	100	0.058	0.193	0.125
Canary rockfish	1	1	100	0.094	0.094	0.094	1	1	100	0.063	0.063	0.063
Copper rockfish	12	12	100	0.073	0.878	0.333	18	18	100	0.079	0.790	0.279
Flag rockfish	5	4	80	0.108	1.160	0.390	5	4	80	0.099	0.648	0.253
Greenblotched rockfish	3	3	100	0.050	0.146	0.103	3	3	100	0.053	0.146	0.086
Greenspotted rockfish	3	3	100	0.054	0.349	0.158	3	3	100	0.186	0.325	0.267
Halfbanded rockfish	3	3	100	0.079	0.131	0.099	3	3	100	0.069	0.085	0.079
Mixed rockfish	27	23	85	0.013	1.130	0.258	34	32	94	0.012	0.595	0.151
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	0.108	0.108	0.108
Speckled rockfish	6	6	100	0.012	0.216	0.127	10	10	100	0.027	0.175	0.073
Squarespot rockfish	2	2	100	0.246	0.660	0.453	3	3	100	0.148	0.260	0.207
Starry rockfish	6	6	100	0.102	0.684	0.280	7	7	100	0.112	0.276	0.196
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	0.069	0.069	0.069
Vermilion rockfish	28	23	82	0.012	0.259	0.058	32	30	94	0.012	1.250	0.092
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.072	0.079	0.075
OVERALL SPECIES	429	373	87	0.012	1.160	0.181	405	373	92	0.012	1.250	0.115

TABLE F-5

Summary of mercury concentrations (ppm) in scorpionfish and sanddab tissues by trawl zone, and rockfish at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-April 2003 for scorpionfish and October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Scorpionfish	**Liver Tissues**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	51	34	8	16
Min	0.016	0.014	0.035	0.027
Max	0.556	0.418	0.265	0.323
Mean	0.174	0.141	0.122	0.108
Median	0.154	0.121	0.084	0.080
Std Dev	0.110	0.098	0.094	0.080
95% CI	0.030	0.033	0.065	0.039

	Muscle Tissues			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	49	37	8	16
Min	0.052	0.012	0.042	0.025
Max	0.483	0.329	0.339	0.351
Mean	0.174	0.133	0.147	0.139
Median	0.156	0.118	0.143	0.119
Std Dev	0.087	0.078	0.101	0.082
95% CI	0.024	0.025	0.070	0.040

Sanddabs	**Liver Tissues**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	37	48	34	27
Min	0.012	0.012	0.012	0.034
Max	0.579	0.165	0.151	0.221
Mean	0.096	0.059	0.075	0.098
Median	0.077	0.054	0.076	0.092
95% CI	0.030	0.008	0.012	0.017

	Muscle Tissues			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	25	37	25	28
Min	0.014	0.012	0.012	0.030
Max	0.116	0.112	0.118	0.113
Mean	0.057	0.049	0.045	0.070
Median	0.054	0.048	0.043	0.070
95% CI	0.011	0.007	0.010	0.009

Rockfish	**Liver**		**Muscle**	
	RF1	**RF2**	**RF1**	**RF2**
N	38	33	50	52
Min	0.012	0.012	0.012	0.012
Max	0.878	1.160	1.250	0.648
Mean	0.183	0.241	0.192	0.130
Median	0.086	0.134	0.088	0.088
95% CI	0.068	0.098	0.071	0.033

obtain an occasional high value. Overall, these results are similar to those reported in previous waiver applications (City of San Diego 1995, 2001).

Mercury concentrations in sanddab liver and muscle tissues from 1995 through 2006 are summarized by zone in Table F-5 and Figures F-2 and F-3. The average concentration of mercury in liver tissues for the sanddab feeding guild ranged from 0.059 to 0.098 ppm, while concentrations in muscle tissues averaged 0.045 – 0.070 ppm, both remarkably narrow ranges. No discernable relationship to the outfall was evident amongst zones for the sanddab feeding guild in terms of mercury concentrations in fish tissues over all surveys combined (Figure F-2) or over time (Figure F-3), although variation did appear greater in the range of values for the zone 1 (nearfield) fishes.

Data on mercury concentrations in liver and muscle tissues from rockfish collected at the two rig fishing sites are summarized in Table F-5 and Figures F-4 and F-5. The average liver concentrations for rockfish at stations RF1 (nearfield) and RF2 (farfield) were 0.183 and 0.241 ppm, respectively), while muscle mercury levels were 0.192 and 0.130 ppm. No discernable relationship to wastewater discharge was evident over all surveys combined (Figure F-4) or over time (Figure F-5).

The limits set by the FDA and CDHS for mercury in seafood sold for human consumption is 1.0 ppm and 0.5 ppm, respectively (Mearns et al. 1991). Table F-6 compares these thresholds to the maximum concentration for muscle tissues from each rockfish species collected at the rig-fishing sites. Figure F-6 presents the mean and maximum concentrations of mercury in muscle tissues for all fish species collected in the Point Loma region from October 1995 though 2006. On average, no species had mercury concentrations that exceeded either the CDHS or FDA limits; although copper rockfish, flag rockfish, vermilion rockfish, and mixed rockfish samples each had maximum values above the CDHS limit, with the maximum value for vermilion rockfish also exceeding the FDA limit. Finally, California scorpionfish had a muscle tissue concentration of mercury averaging 0.152 ppm with a maximum value of

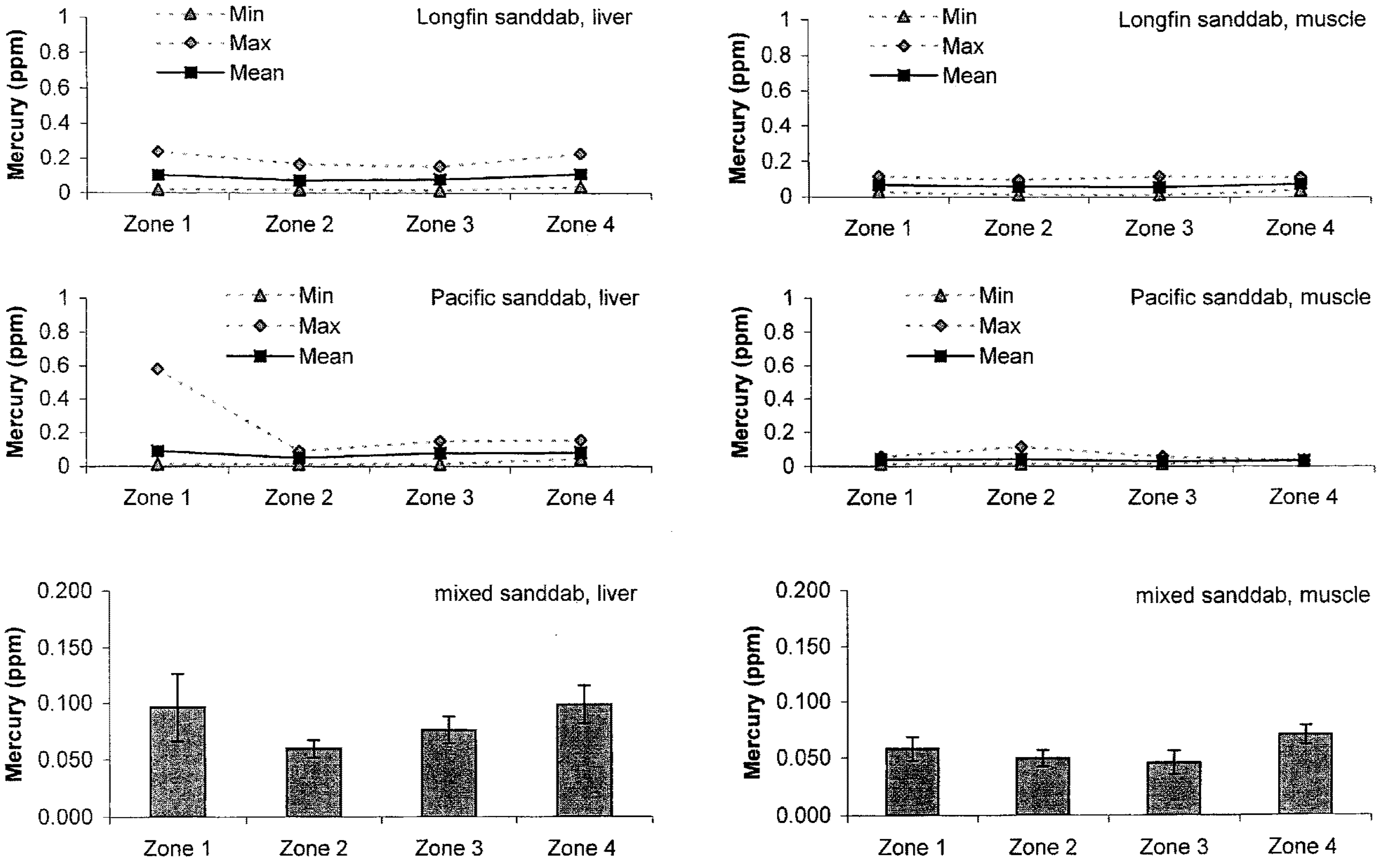

FIGURE F-2. Comparisons of mercury concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

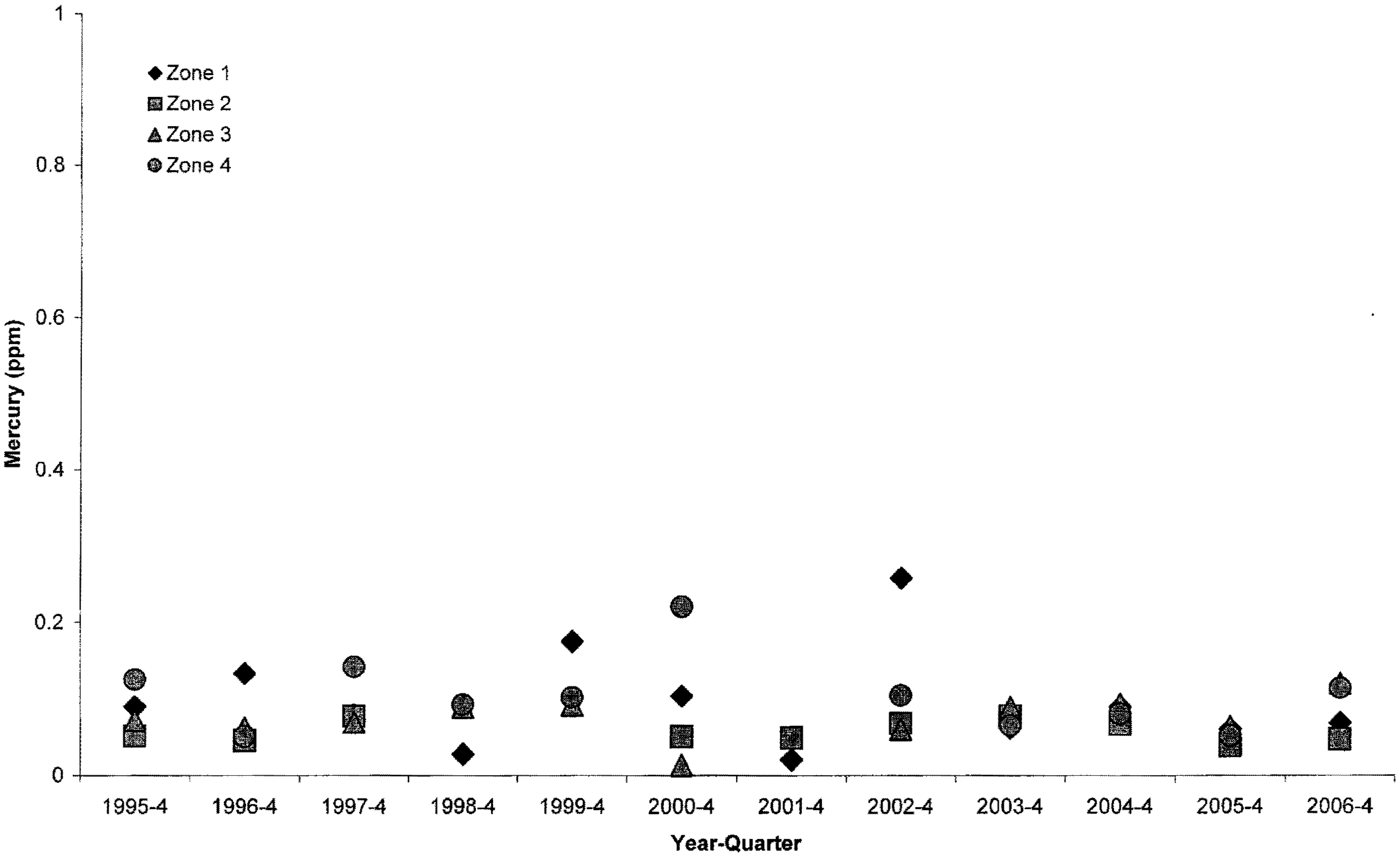

FIGURE F-3. Mercury concentrations (ppm) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

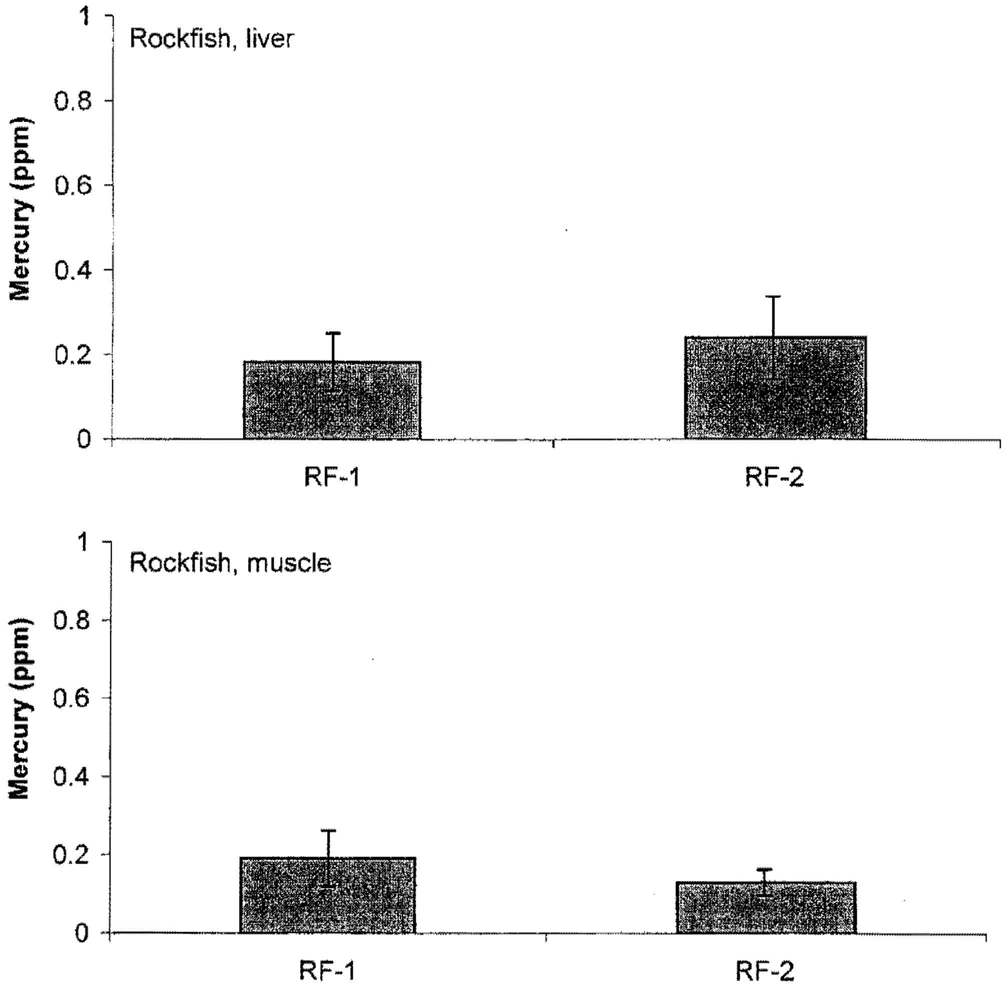

FIGURE F-4. Comparison of mercury concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

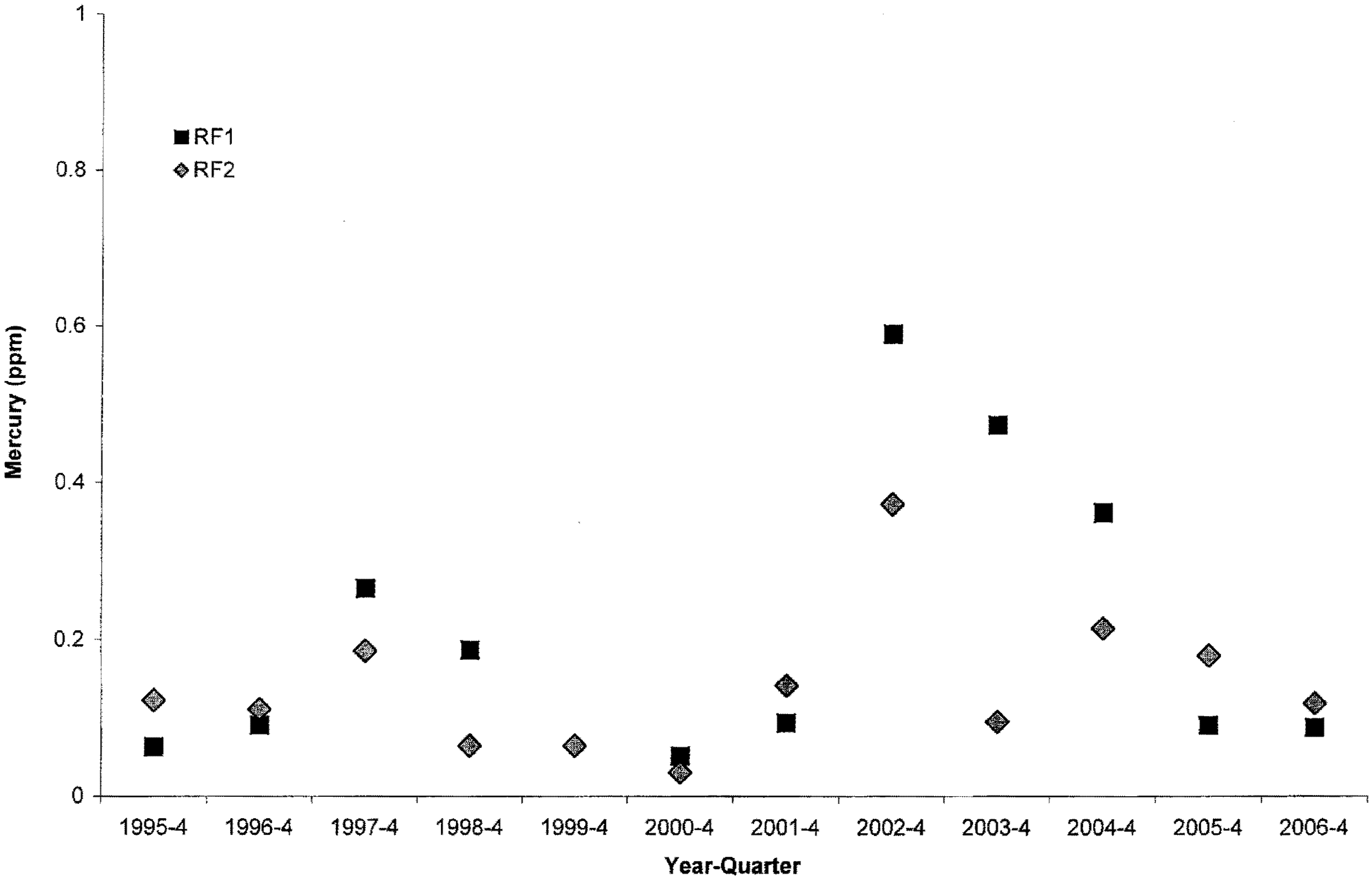

FIGURE F-5. Mercury concentrations (ppm) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

TABLE F-6

Maximum concentrations (ppm) of various metals and total DDT in muscle tissue samples for California scorpionfish and each rockfish species collected at all trawl and rig fishing station sampled between October 1995 and October 2006; nd= not detected.

	Arsenic	**Chromium**	**Copper**	**Mercury**	**Selenium**	**Zinc**	**tDDT**
Rockfish:							
Bocaccio	1.50	nd	1.79	0.193	0.296	3.35	0.010
Canary rockfish	nd	0.76	nd	0.063	0.250	3.82	0.014
Copper rockfish	4.11	0.53	4.79	0.790	0.690	15.20	0.217
Flag rockfish	2.15	nd	1.31	0.648	0.380	3.40	0.071
Greenblotched rockfish	2.40	1.97	9.59	0.146	0.200	5.17	0.023
Greenspotted rockfish	2.90	0.45	3.85	0.325	0.290	4.11	0.029
Halfbanded rockfish	3.03	0.53	nd	0.085	1.000	3.03	0.012
Rosethorn rockfish	2.49	nd	0.76	0.108	0.367	2.91	0.002
Speckled rockfish	1.71	0.56	0.88	0.175	0.352	4.11	0.016
Squarespot rockfish	2.54	0.09	0.46	0.260	0.440	3.37	0.020
Starry rockfish	1.32	0.42	5.88	0.276	0.450	11.10	0.119
Stripetail rockfish	nd	nd	nd	0.069	0.175	3.07	0.018
Vermilion rockfish	15.20	0.79	8.56	1.250	0.545	14.30	0.040
Yellowtail rockfish	0.46	0.47	0.45	0.079	0.350	4.28	0.006
California scorpionfish	12.90	1.41	22.20	0.483	0.750	16.80	0.878
US FDA Action Limit*				1.00			5
Median International Standard*	1.40	1.00	20	0.500	0.300	70	5

* From Table 2.3 in Mearns et al. 1991. US FDA action limit for total DDT is for fish muscle tissue, US FDA mercury action limits and all international standards are for shellfish, but are often applied to fish. All limits apply to the sale of seafood for human consumption.

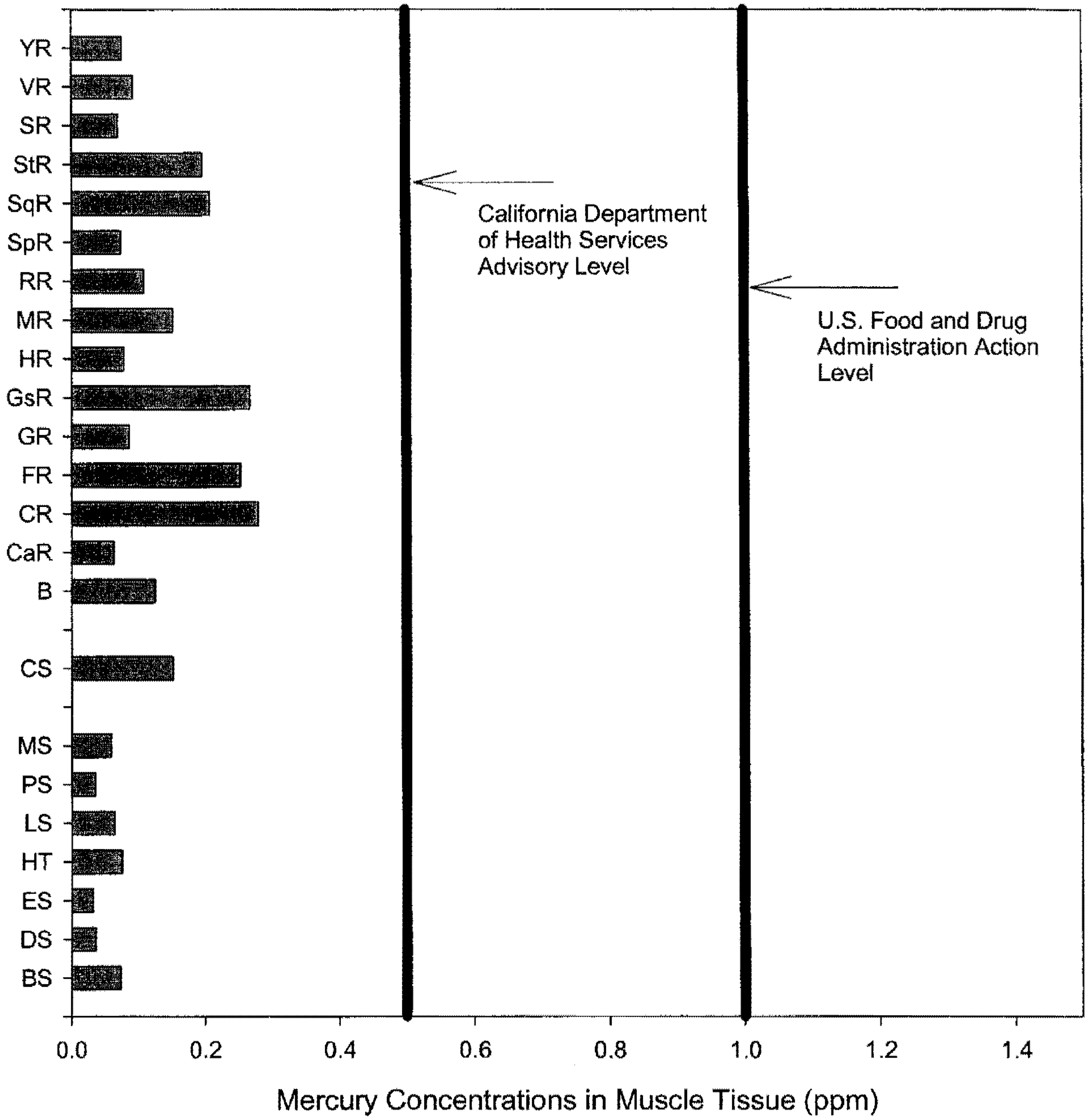

Figure F-6. Mean concentrations of mercury in muscle tissues of all fishes collected off San Diego at trawl and rig fishing stations compared to California Department of Health Services Advisory Levels and U.S. FDA action level. See Tables F-2 and F-3 for species abbreviations.

0.483 ppm, which is within the range of historical values detected throughout the SCB (Mearns et al. 1991).

Arsenic: Arsenic is a common trace element, well known for its toxic effects. It occurs naturally in seawater and is used by man in herbicides, insecticides, wood preservatives, and in a variety of industrial applications (Mearns et al. 1991). In organisms, it is detoxified via production of organic forms of arsenic which are less toxic and more readily excreted. Southern California marine coastal waters have a significant natural source of arsenic originating from the Punta Bunda submarine hot springs in Baja California. These hot springs discharge water containing up to 420,500 ppb arsenic compared to 3 ppb that naturally occur in seawater. For reference purposes, arsenic concentrations in Point Loma wastewater effluent ranged from <0.4 to 0.68 ppb during calendar year 2006.

Arsenic occurs in high concentrations in sediments throughout the southern California marine environment. Arsenic in outfall depth sediments off Point Loma have ranged from 1.3 to 7.2 ppm (1300-7200 ppb) since monitoring began, with means of 2.4 and 3.4 ppm (2400-3400 ppb) during the pre- and post-discharge periods, respectively (see Table E-3, Appendix E). These concentrations are comparable to background conditions in the southern California Bight reported by Mearns et al. (1991) and found regionally off San Diego.

Arsenic had an overall detection rate of 59% in liver samples and 74% in muscle samples from all trawl and rig-caught fish off Point Loma (Table F-7). Concentrations of arsenic in muscle tissue from fishes ranged from 0.46 ppm in yellowtail rockfish to 21 ppm in longfin sanddab. Liver tissues often had arsenic concentrations lower than muscle tissues, again with the highest concentrations occurring in longfin sanddabs. Data for California scorpionfish, the sanddab feeding guild, and rockfish are summarized in Table F-8 and Figures F-7 through F-10. There were no consistent trends in arsenic residues relative to the Point Loma outfall or the onset of wastewater discharge. Maximum arsenic concentrations were higher for California scorpionfish collected at trawl zone 1 than the other zones, but mean values were equivalent across all areas. In contrast, arsenic concentrations in sanddab tissues were

TABLE F-7

Summary of arsenic concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	1	33	3.67	3.67	3.67
Dover sole	3	2	67	0.07	3.70	1.89	10	8	80	2.03	5.40	3.87
English sole	23	21	91	1.80	33.90	7.05	8	7	88	4.00	13.70	7.95
Hornyhead turbot	1	1	100	4.79	4.79	4.79	2	2	100	5.44	5.50	5.47
Longfin sanddab	86	68	79	0.06	18.50	8.06	87	75	86	2.20	21.00	11.25
Pacific sanddab	85	70	82	0.06	12.40	3.25	49	39	80	1.40	6.50	3.62
Mixed sanddabs	0	na	na	na	na	na	1	1	100	5.70	5.70	5.70
Rockfish:												
California scorpionfish	121	54	45	1.40	14.10	3.15	121	99	82	1.48	12.90	4.65
Bocaccio	2	1	50	1.40	1.40	1.40	2	1	50	1.50	1.50	1.50
Canary rockfish	1	0	0	nd	nd	nd	1	0	0	nd	nd	nd
Copper rockfish	12	2	17	1.82	5.20	3.51	18	10	56	0.68	4.11	1.94
Flag rockfish	5	1	20	1.90	1.90	1.90	5	1	20	2.15	2.15	2.15
Greenblotched rockfish	3	1	33	1.55	1.55	1.55	3	2	67	1.83	2.40	2.11
Greenspotted rockfish	3	0	0	nd	nd	nd	4	3	75	1.40	2.90	2.08
Halfbanded rockfish	3	1	33	3.83	3.83	3.83	3	2	67	2.98	3.03	3.00
Mixed rockfish	25	7	28	1.50	14.00	3.64	34	19	56	1.19	6.10	2.60
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	2.49	2.49	2.49
Speckled rockfish	4	1	25	1.44	1.44	1.44	10	3	30	1.40	1.71	1.59
Squarespot rockfish	1	0	0	nd	nd	nd	3	3	100	1.84	2.54	2.18
Starry rockfish	6	1	17	4.70	4.70	4.70	7	1	14	1.32	1.32	1.32
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	13	46	1.90	4.81	2.92	32	22	69	1.42	15.20	5.05
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	1	50	0.46	0.46	0.46
OVERALL SPECIES	412	244	59	0.06	33.90	3.54	407	301	74	0.46	21.00	3.55

TABLE F-8

Summary of arsenic concentrations (ppm) in scorpionfish and sanddab tissues by trawl zone, and rockfish at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-April 2003 for scorpionfish and October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Scorpionfish	**Liver**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	22	19	4	6
Min	1.50	1.40	1.60	1.60
Max	14.10	6.80	10.50	9.20
Mean	3.38	2.49	4.37	3.51
Median	2.36	2.20	2.70	2.37
95% CI	1.33	0.58	4.05	2.30
	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	36	31	8	15
Min	1.49	1.48	1.85	2.10
Max	12.90	10.80	6.12	6.92
Mean	4.51	5.14	4.63	4.11
Median	3.90	4.56	5.00	4.07
95% CI	0.81	0.91	0.93	0.82

Sanddabs	**Liver**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	31	46	28	33
Min	0.06	0.06	0.07	0.31
Max	12.80	18.50	15.30	13.30
Mean	5.54	5.98	5.07	5.67
Median	5.58	4.61	3.52	5.00
95% CI	1.33	1.32	1.71	1.33
	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	26	42	21	25
Min	2.20	2.03	1.40	4.10
Max	17.10	16.10	21.00	16.40
Mean	8.68	7.31	9.41	10.17
Median	9.54	6.86	10.40	9.80
95% CI	1.68	1.21	2.78	1.33

Rockfish	**Liver**		**Muscle**	
	RF1	**RF2**	**RF1**	**RF2**
N	15	10	36	25
Min	1.50	1.44	0.68	0.46
Max	14.00	4.70	15.20	11.40
Mean	3.61	2.43	3.40	3.03
Median	2.50	1.91	2.51	2.15
95% CI	1.58	0.68	1.12	0.97

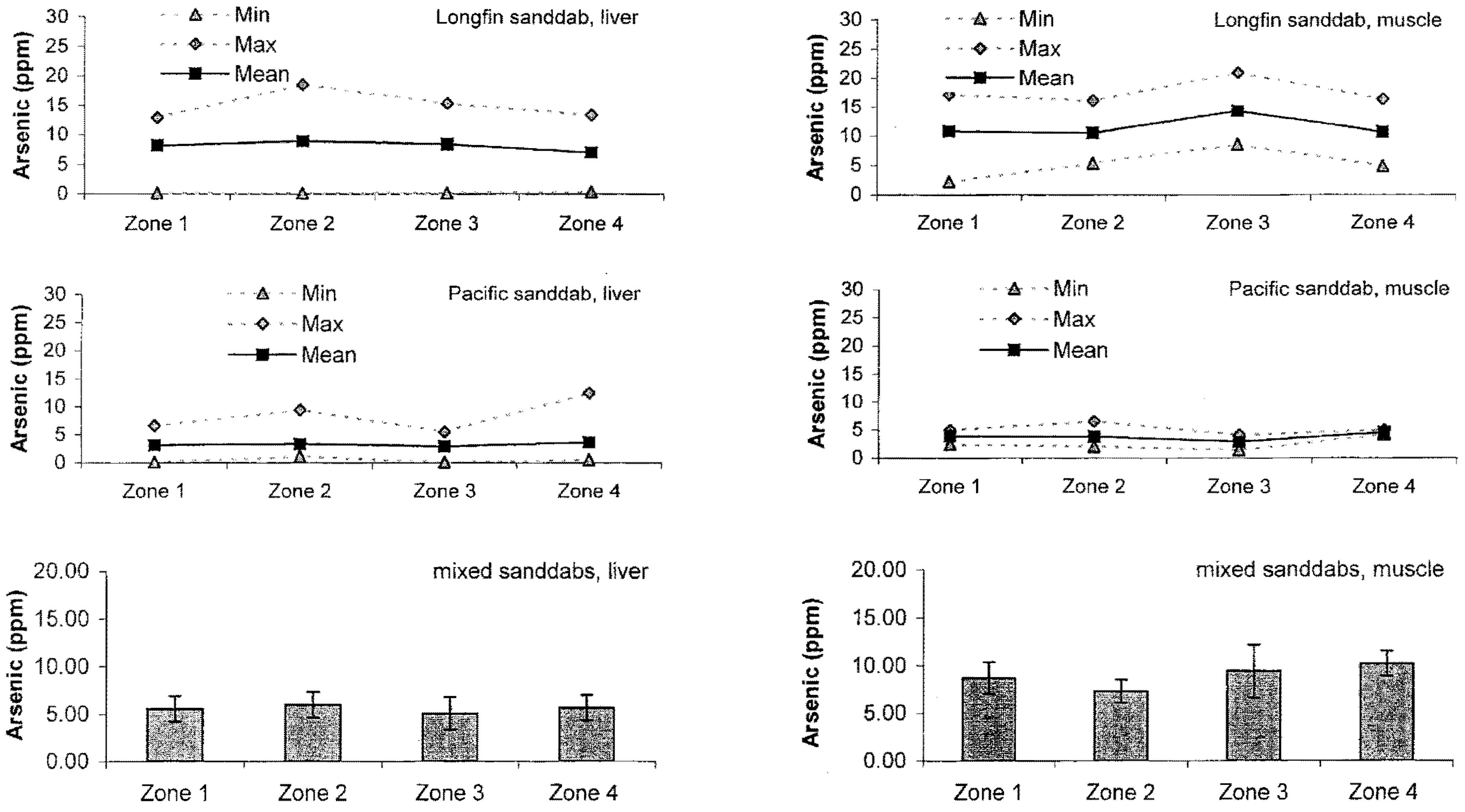

FIGURE F-7. Comparisons of arsenic concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

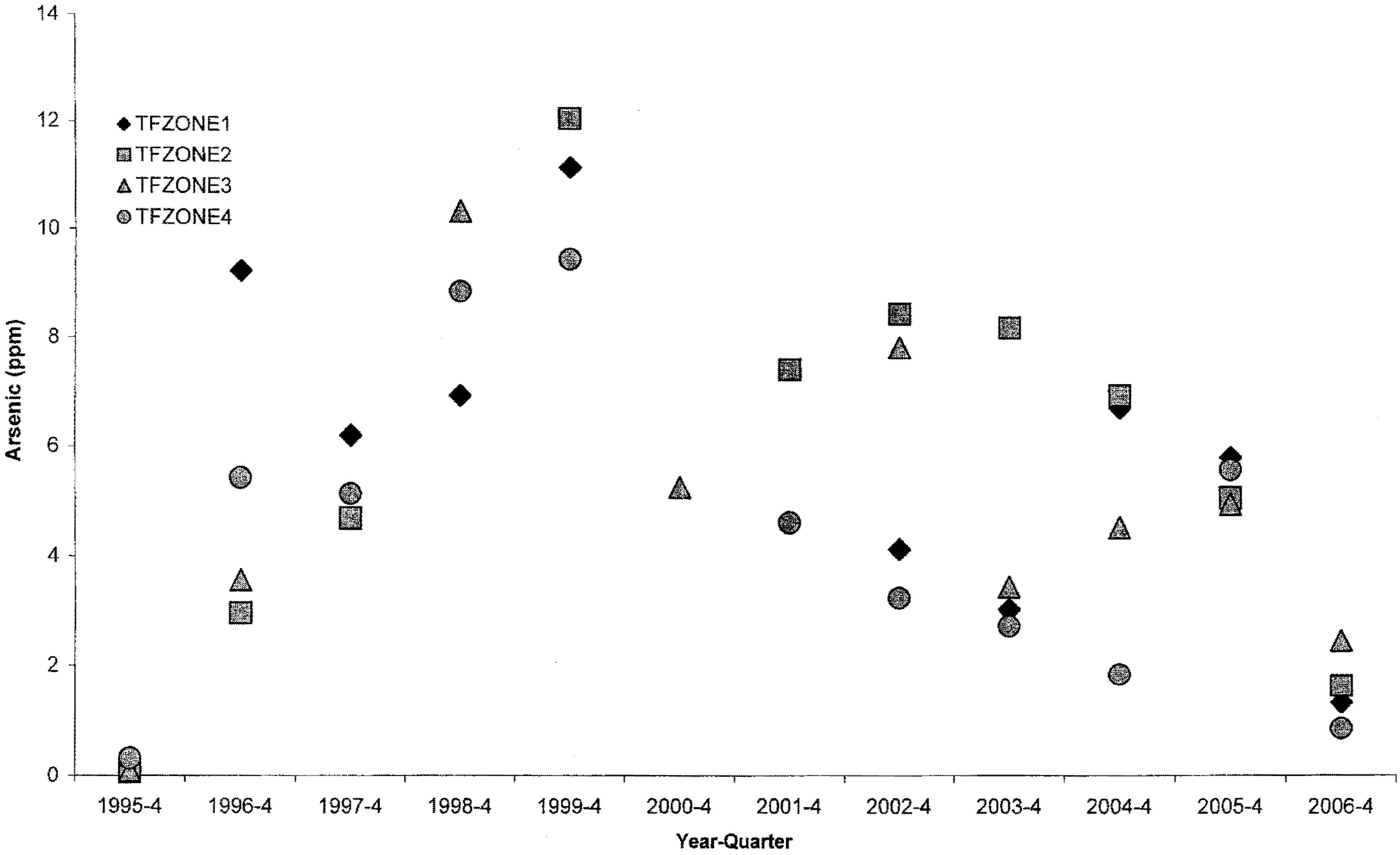

FIGURE F-8. Arsenic concentrations (ppm) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

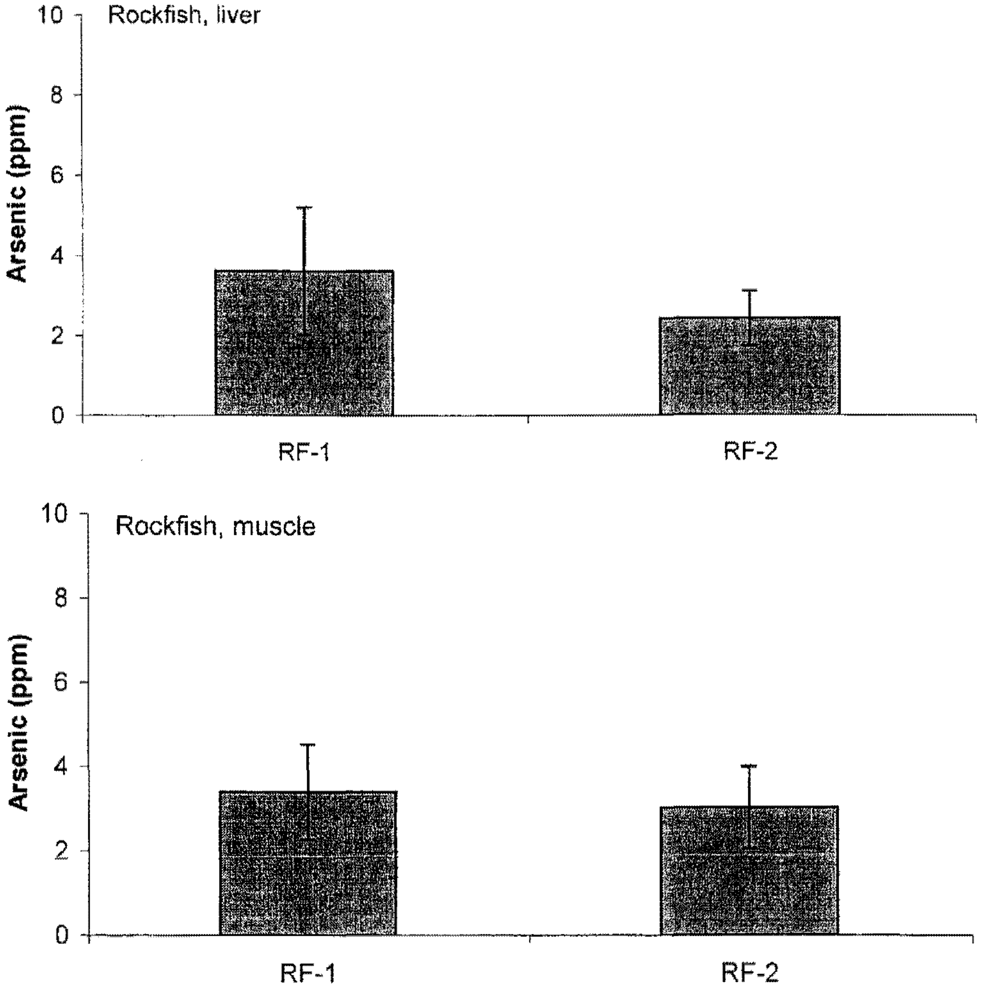

FIGURE F-9. Comparison of arsenic concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

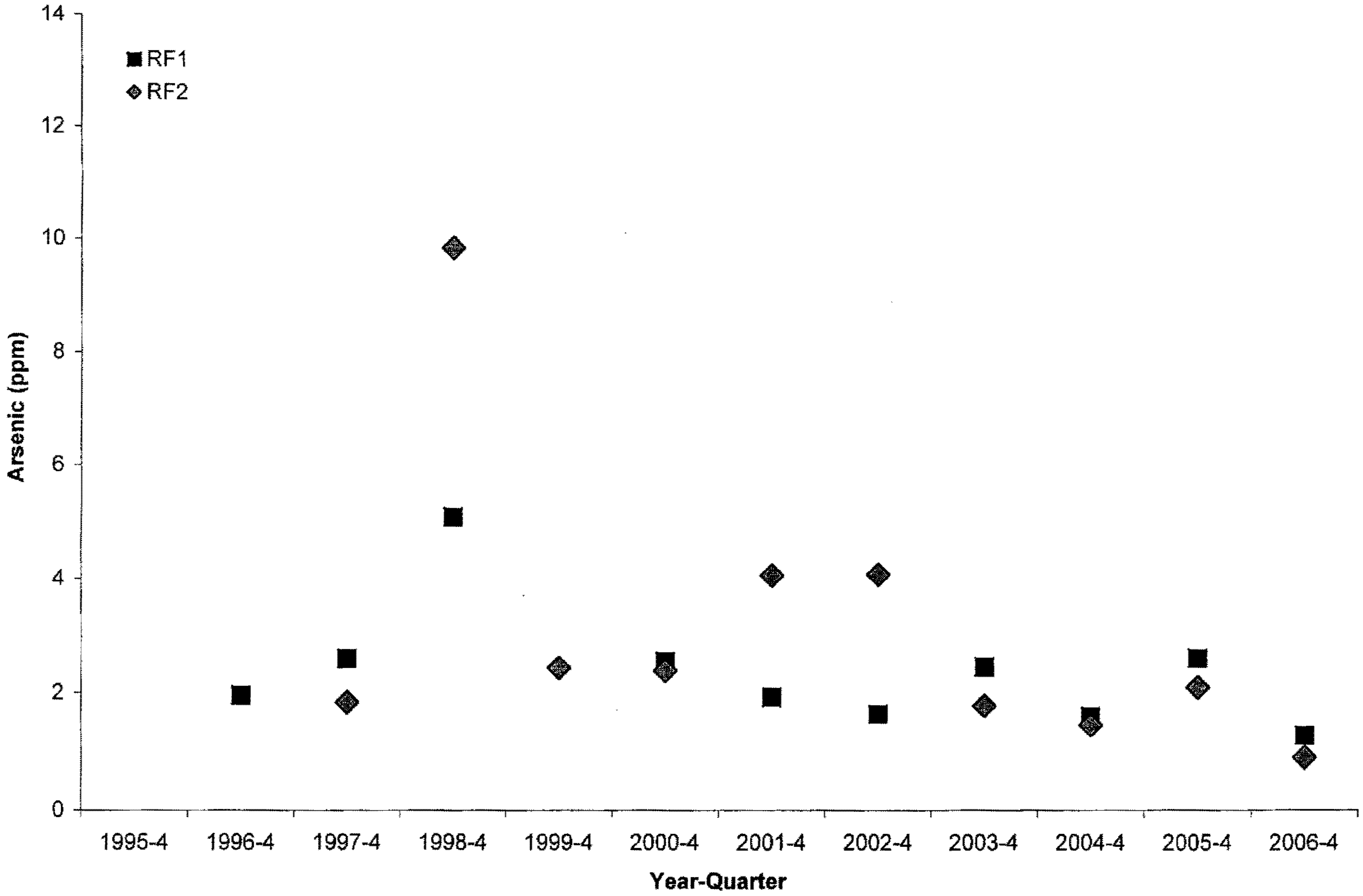

FIGURE F-10. Arsenic concentrations (ppm) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

somewhat higher in zone 3 fish (i.e., near the LA-5 disposal site) than from any of the other zones. Finally, arsenic values were highest in 1998 and 1999 at the rig-fishing and trawl stations, respectively, while they were near their lowest levels in October 2006.

There are no FDA or CDHS standards for arsenic in food. However, arsenic concentrations in fishes caught off Point Loma are high relative to the Median International Standard (MIS) of 1.4 ppm applied to shellfish and to the sale of seafood for human consumption in some countries (Figure F-11 and Table F-6). Additionally, Mearns et al. (1991) reviewed studies conducted in the SCB and concluded that (a) there is no correspondence between point sources of arsenic and arsenic concentrations in the tissues of marine animals, and (b) arsenic tissue concentrations generally decrease with trophic level. Consequently, high levels of arsenic in regional fishes are probably due to elevated levels that occur in the natural environment and not to exposure to anthropogenic sources and subsequent food web magnification.

Cadmium: Cadmium is widely used in electroplating, as a pigment in paints, in batteries, and as a plastic stabilizer. It has been one of the metals targeted for source control in the San Diego pretreatment program resulting in a significant decline in effluent concentrations over time. For example, cadmium was not detected in PLOO wastewater effluent samples analyzed in 2006. While cadmium has been detected in 85% of liver tissue samples from fishes collected off Point Loma over the past 12 years, it was found in only 3% of the muscle tissue samples (Table F-9). Cadmium concentrations in liver tissues ranged from 0.34 ppm in a mixed rockfish sample to 16.1 ppm in a squarespot rockfish sample; cadmium concentrations in muscle tissues ranged from 0.14 ppm in a yellowtail rockfish sample to 0.69 ppm in a longfin sanddab sample.

The cadmium data summarized in Table F-10 and Figures F-12 through F-14 show no consistent differences in the bioaccumulation of this metal between fishes captured at the nearfield and farfield trawl zones or between the two rig fishing sites. However, cadmium levels increased across all zones in October 2003. This region wide increase off San Diego,

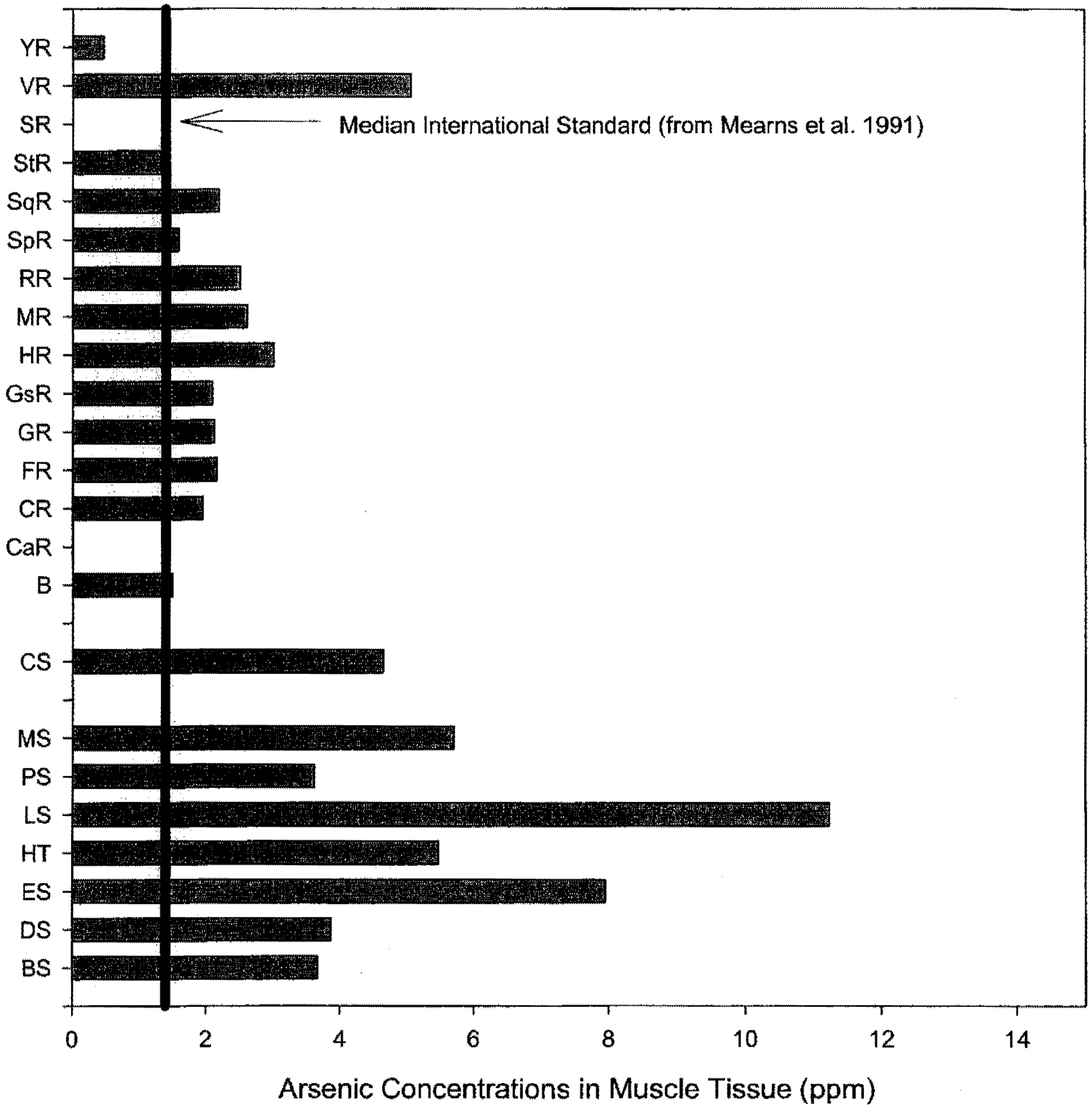

Figure F-11. Mean concentrations of arsenic in muscle tissues of all fishes collected off San Diego at trawl and rig fishing stations compared to the median international standard. See Table F-2 and F-3 for species abbreviations.

Table F-9

Summary of cadmium concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	0	0	nd	nd	nd
Dover sole	3	0	0	nd	nd	nd	10	0	0	nd	nd	nd
English sole	23	17	74	0.36	1.07	0.68	8	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	5.07	5.07	5.07	2	0	0	nd	nd	nd
Longfin sanddab	86	72	84	0.37	4.79	1.95	87	3	3	0.37	0.69	0.51
Pacific sanddab	85	79	93	0.38	10.10	3.85	49	0	0	nd	nd	nd
Mixed sanddabs	0	na	na	na	na	na	1	0	0	nd	nd	nd
Rockfish:												
California scorpionfish	121	114	94	0.41	6.51	2.56	121	2	2	0.35	0.39	0.37
Bocaccio	2	1	50	0.95	0.95	0.95	2	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd	1	0	0	nd	nd	nd
Copper rockfish	12	11	92	0.67	5.64	3.12	18	3	17	0.15	0.18	0.16
Flag rockfish	5	1	20	1.40	1.40	1.40	5	0	0	nd	nd	nd
Greenblotched rockfish	3	3	100	0.46	3.75	1.69	3	0	0	nd	nd	nd
Greenspotted rockfish	3	2	67	1.77	1.99	1.88	4	0	0	nd	nd	nd
Halfbanded rockfish	3	3	100	1.09	1.71	1.34	3	0	0	nd	nd	nd
Mixed rockfish	25	23	92	0.34	7.59	2.25	34	0	0	nd	nd	nd
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Speckled rockfish	4	4	100	3.81	12.80	7.86	10	0	0	nd	nd	nd
Squarespot rockfish	1	1	100	16.10	16.10	16.10	3	0	0	nd	nd	nd
Starry rockfish	6	5	83	0.35	2.23	0.79	7	1	14	0.16	0.16	0.16
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	12	43	0.41	3.06	1.09	32	0	0	nd	nd	nd
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.14	0.16	0.15
OVERALL SPECIES	412	349	85	0.34	16.10	3.29	407	11	3	0.14	0.69	0.27

TABLE F-10

Summary of cadmium concentrations (ppm) in sanddab tissues by trawl zone and rockfish tissues at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Sanddabs	**Liver** **Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
N	36	56	29	30
Min	0.38	0.37	0.58	0.99
Max	7.08	7.40	8.75	10.10
Mean	3.08	2.52	3.04	3.49
Median	2.66	2.01	2.59	2.46
95% CI	0.62	0.42	0.78	0.90

	Muscle **Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
N	1	1	1	0
Min	0.37	0.46	0.69	
Max	0.37	0.46	0.69	
Mean	0.37	0.46	0.69	0
Median	0.37	0.46	0.69	

Rockfish	**Liver** **RF1**	**RF2**	**Muscle** **RF1**	**RF2**
N	22	32	3	3
Min	0.36	0.34	0.15	0.14
Max	5.64	16.10	0.18	0.16
Mean	2.47	2.60	0.16	0.15
Median	2.71	1.33	0.15	0.16
95% CI	0.69	1.28	0.02	0.01

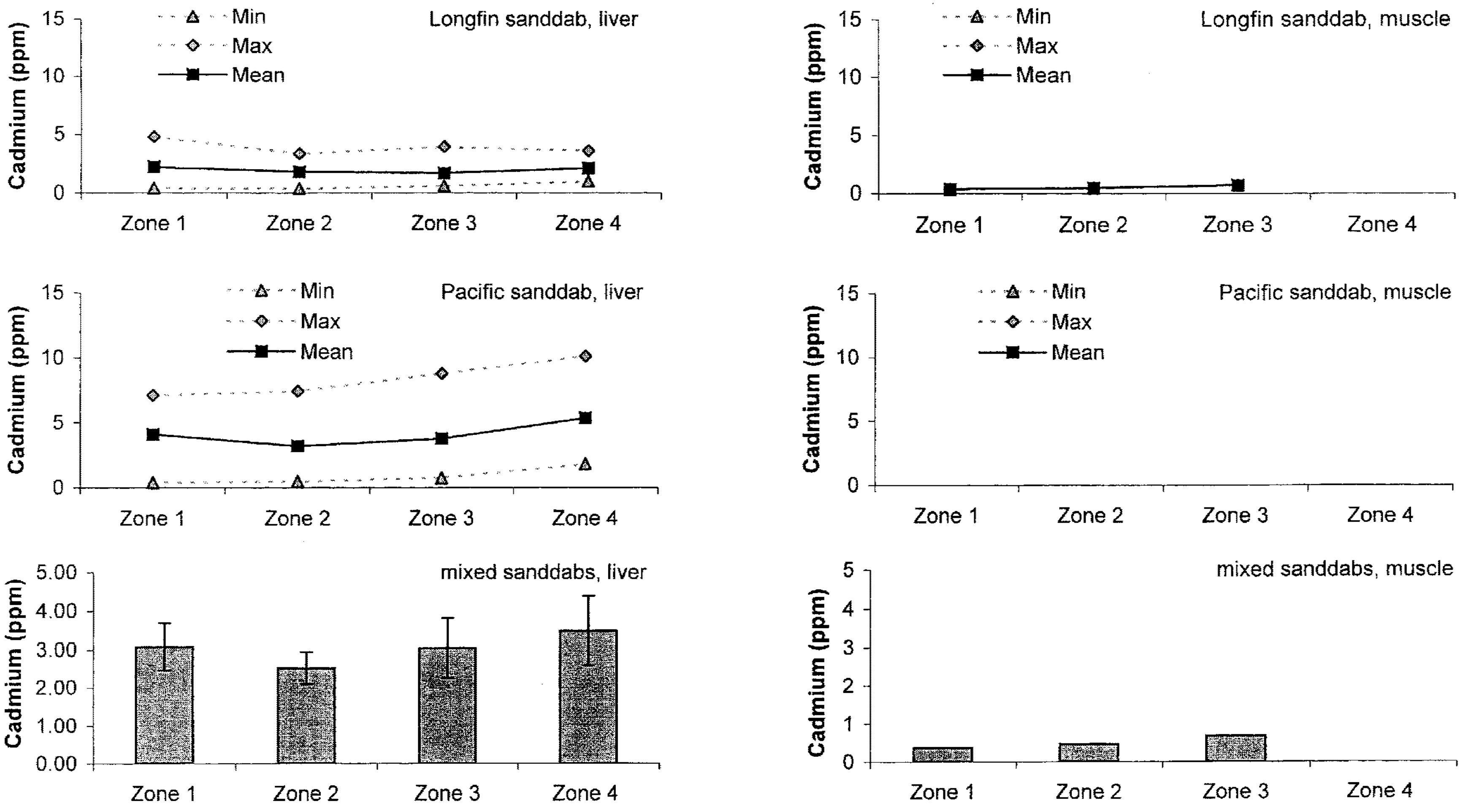

FIGURE F-12. Comparisons of cadmium concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

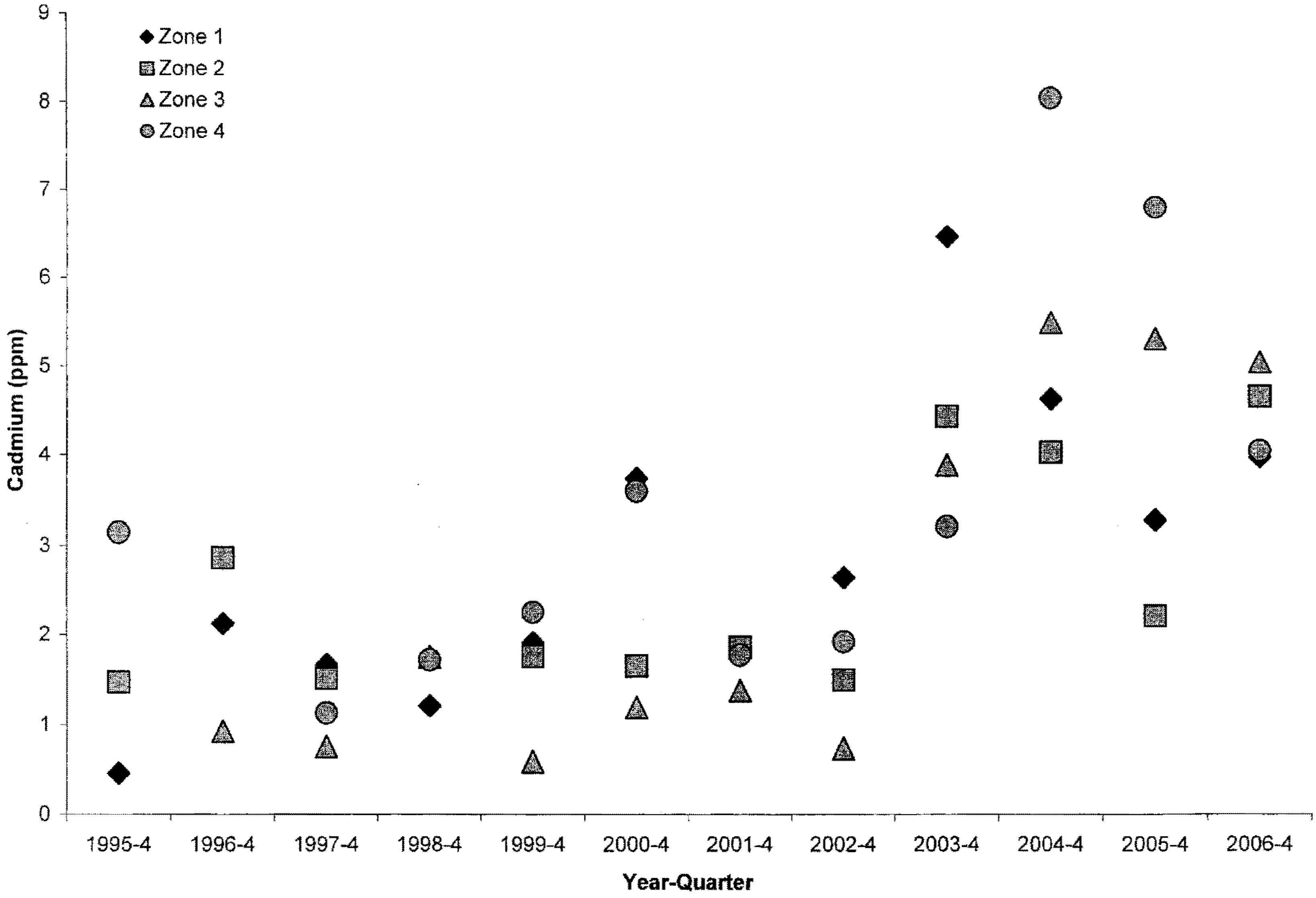

FIGURE F-13. Cadmium concentrations (ppm) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

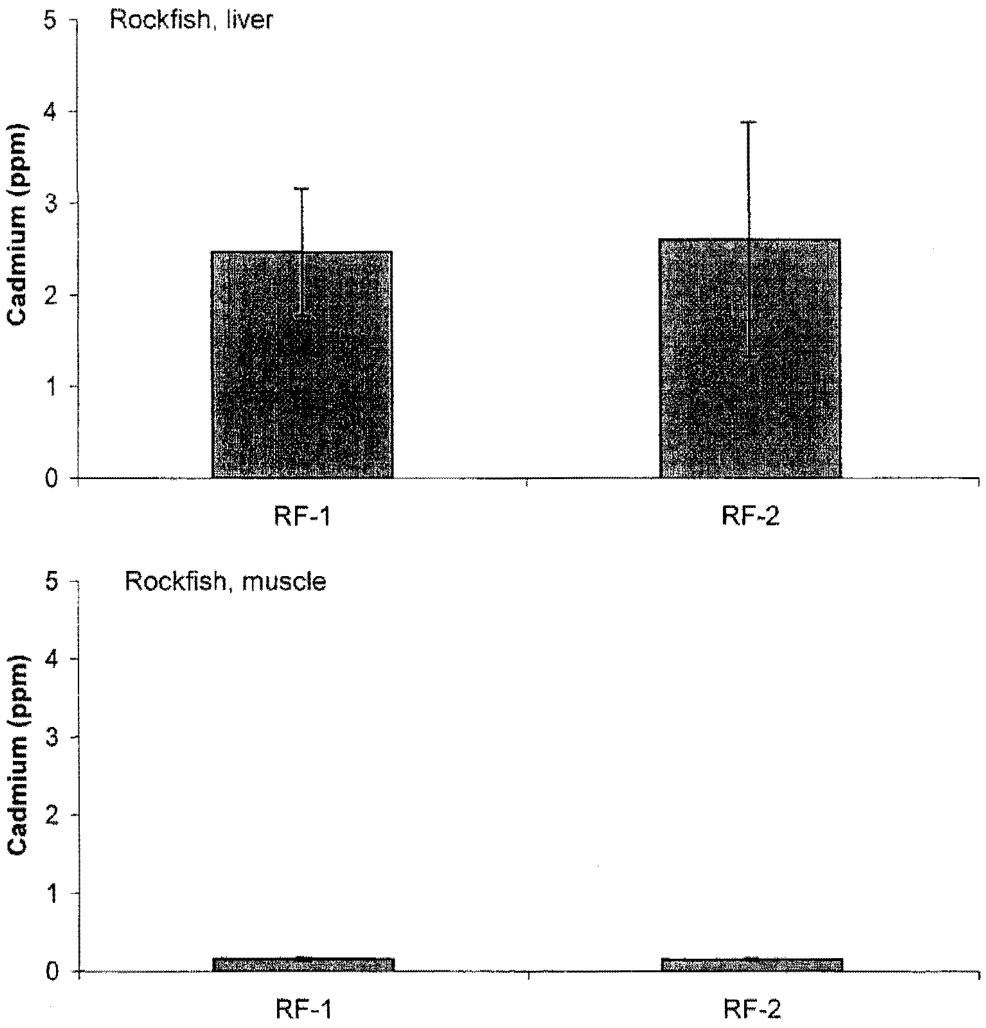

FIGURE F-14. Comparison of cadmium concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

which has been sustained since that time, corresponds to a permit-driven change in sample collection requirements that resulted in Pacific sanddabs replacing longfin sanddabs as the dominant trawl-caught species used for bioaccumulation assessments. Overall, cadmium concentrations in liver tissues of Point Loma fish have averaged 3.85 ppm for Pacific sanddabs compared to 1.95 ppm for longfin sanddabs (Table F-9).

Chromium: Chromium has also been a target of source control efforts for the San Diego metal plating industry. Detectable levels of chromium in fish tissues were limited to relatively few samples overall, with detection rates of 38% for liver and 19% for muscle (Table F-11). Liver concentrations of chromium ranged from 0.17 to 22.8 ppm, while muscle concentrations ranged from 0.08 to 6.45 ppm. Maximum chromium levels in muscle tissues were less than the Median International Standard (MIS) of 1.0 ppm in all species except the greenblotched rockfish and California scorpionfish (Table F-6). The chromium data summarized in Table F-12 and Figures F-15 through F-18 reveal no discernable spatial or temporal patterns that correlate with wastewater discharge from the Point Loma outfall. For example, chromium concentrations in sanddab muscle tissues were highest in trawl zone 3 fish (i.e., near the LA-5 dredge materials disposal site), while the highest liver concentrations occurred in fish from trawl zone 1 due to an anomalous value measured in October 2002 (see Figure F-16).

Copper: Copper is typically the metal that occurs in the second highest concentrations in Point Loma effluent due to its widespread use in industrial, commercial and household products and applications (i.e., zinc occurs in higher concentrations; see below). For example, copper is leached from many materials that are part of the sewage flow entering the treatment plant, and it also originates from copper water pipes. Even so, copper concentrations in Point Loma effluent have decreased to about 25 μg/L as a result of source control.

Overall, copper was detected in 100% of the liver tissue samples and 44% of the muscle tissue samples from fishes collected off Point Loma (Table F-13). Average copper

Table F-11

Summary of chromium concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	0	0	nd	nd	nd
Dover sole	3	0	0	nd	nd	nd	10	0	0	nd	nd	nd
English sole	23	18	78	0.17	1.14	0.33	8	2	25	0.36	0.40	0.38
Hornyhead turbot	1	1	100	0.27	0.27	0.27	2	2	100	0.48	0.74	0.61
Longfin sanddab	86	35	41	0.23	22.80	1.51	87	14	16	0.33	5.43	1.18
Pacific sanddab	85	52	61	0.17	4.48	0.56	49	8	16	0.30	6.45	1.22
Mixed sanddabs	0	na	na	na	na	na	1	0	0	nd	nd	nd
Rockfish:												
California scorpionfish	121	24	20	0.30	4.29	1.02	121	13	11	0.38	1.41	0.56
Bocaccio	2	0	0	nd	nd	nd	2	0	0	nd	nd	nd
Canary rockfish	1	1	100	1.96	1.96	1.96	1	1	100	0.76	0.76	0.76
Copper rockfish	12	1	8	1.56	1.56	1.56	18	6	33	0.18	0.53	0.32
Flag rockfish	5	0	0	nd	nd	nd	5	0	0	nd	nd	nd
Greenblotched rockfish	3	1	33	1.14	1.14	1.14	3	1	33	1.97	1.97	1.97
Greenspotted rockfish	3	0	0	nd	nd	nd	4	2	50	0.19	0.45	0.32
Halfbanded rockfish	3	2	67	0.38	1.23	0.80	3	2	67	0.36	0.53	0.45
Mixed rockfish	25	10	40	0.32	2.41	0.86	34	9	26	0.08	1.78	0.56
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Speckled rockfish	4	1	25	0.44	0.44	0.44	10	1	10	0.56	0.56	0.56
Squarespot rockfish	1	0	0	nd	nd	nd	3	1	33	0.09	0.09	0.09
Starry rockfish	6	2	33	0.39	0.48	0.43	7	3	43	0.33	0.42	0.37
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	9	32	0.33	2.03	0.98	32	11	34	0.13	0.79	0.37
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.36	0.47	0.42
OVERALL SPECIES	412	157	38	0.17	22.80	0.91	407	78	19	0.08	6.45	0.63

TABLE F-12

Summary of chromium concentrations (ppm) in sanddab tissues by trawl zone and rockfish tissues at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Sanddabs	Liver **Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
N	22	32	15	18
Min	0.22	0.17	0.20	0.27
Max	22.80	4.33	4.48	2.06
Mean	1.52	0.75	0.86	0.66
Median	0.35	0.39	0.38	0.43
95% CI	1.99	0.34	0.62	0.23

	Muscle **Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
N	5	9	3	5
Min	0.30	0.35	0.36	0.33
Max	1.05	0.96	6.45	5.43
Mean	0.49	0.72	2.48	1.97
Median	0.37	0.85	0.63	0.39
95% CI	0.28	0.14	3.89	2.04

Rockfish	**Liver**		**Muscle**	
	RF1	**RF2**	**RF1**	**RF2**
N	11.00	12.00	16.00	18.00
Min	0.33	0.32	0.08	0.09
Max	2.41	2.03	1.06	1.78
Mean	1.02	0.83	0.34	0.44
Median	0.90	0.47	0.33	0.35
95% CI	0.39	0.36	0.11	0.18

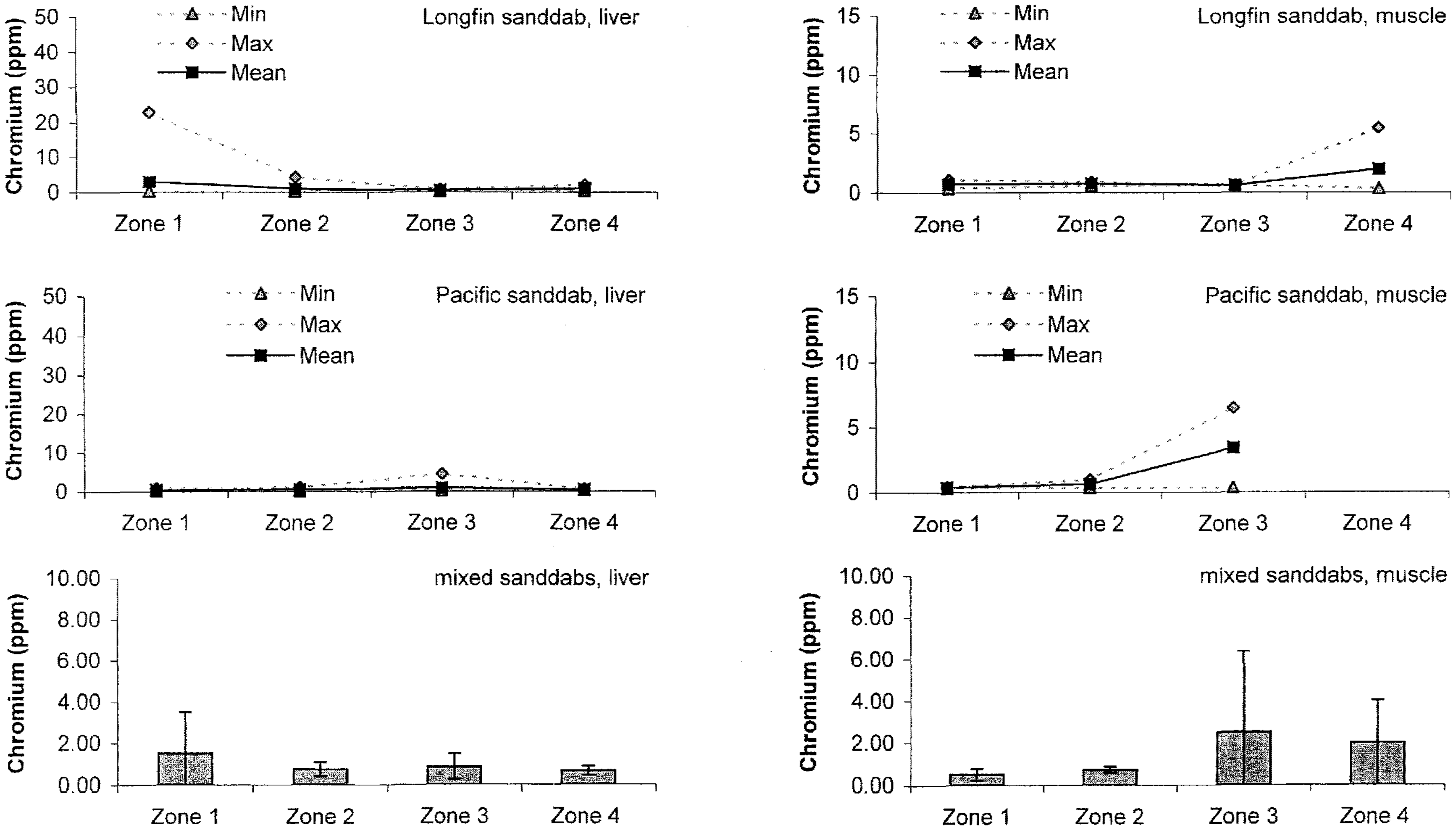

FIGURE F-15. Comparisons of chromium concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

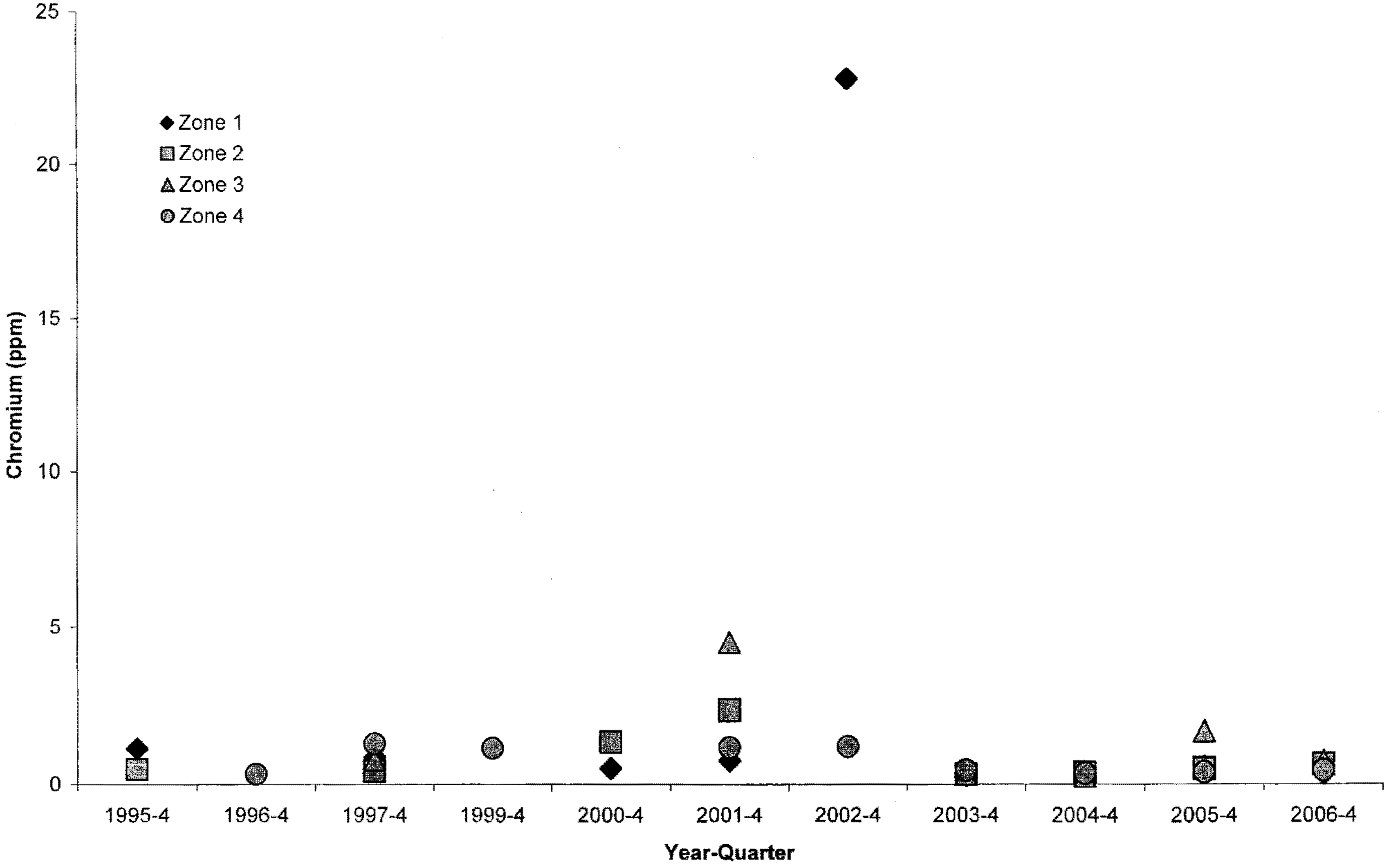

FIGURE F-16. Chromium concentrations (ppm) in sanddab guild liver tissues for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

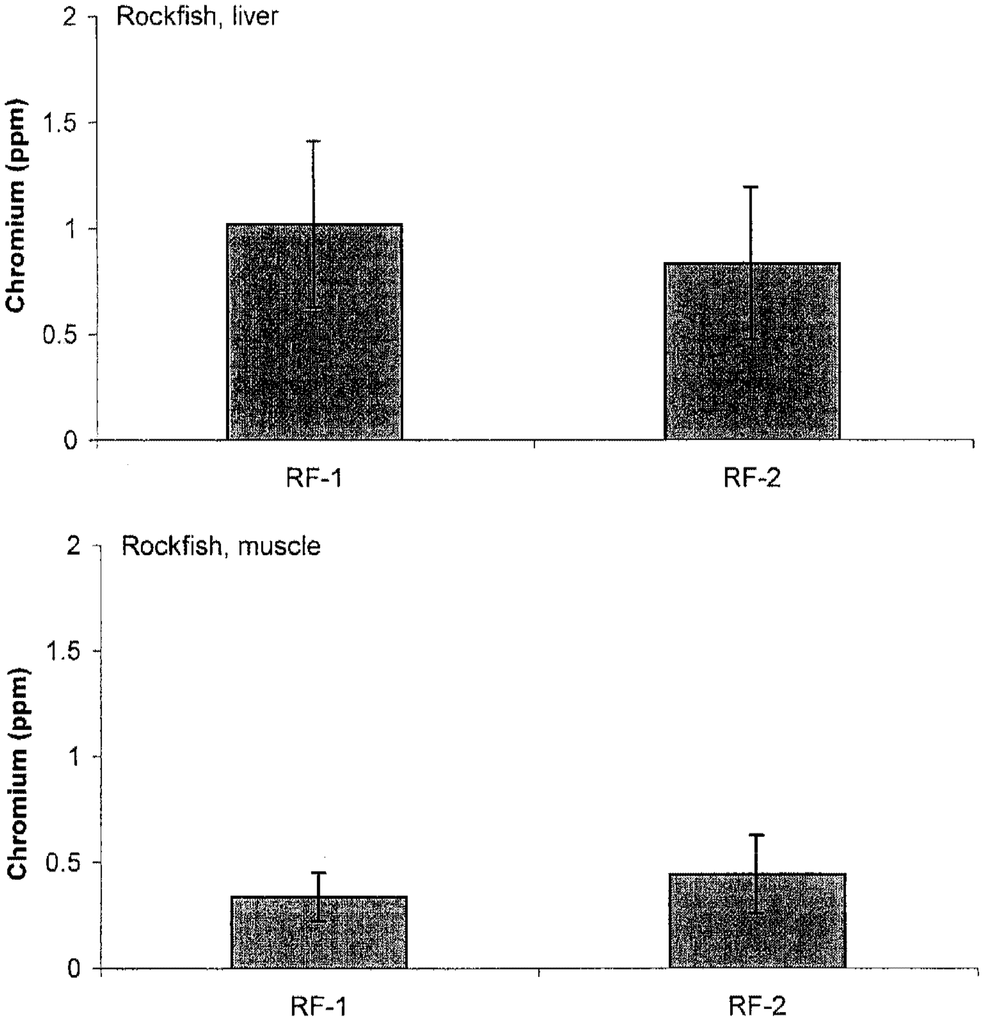

FIGURE F-17. Comparison of chromium concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

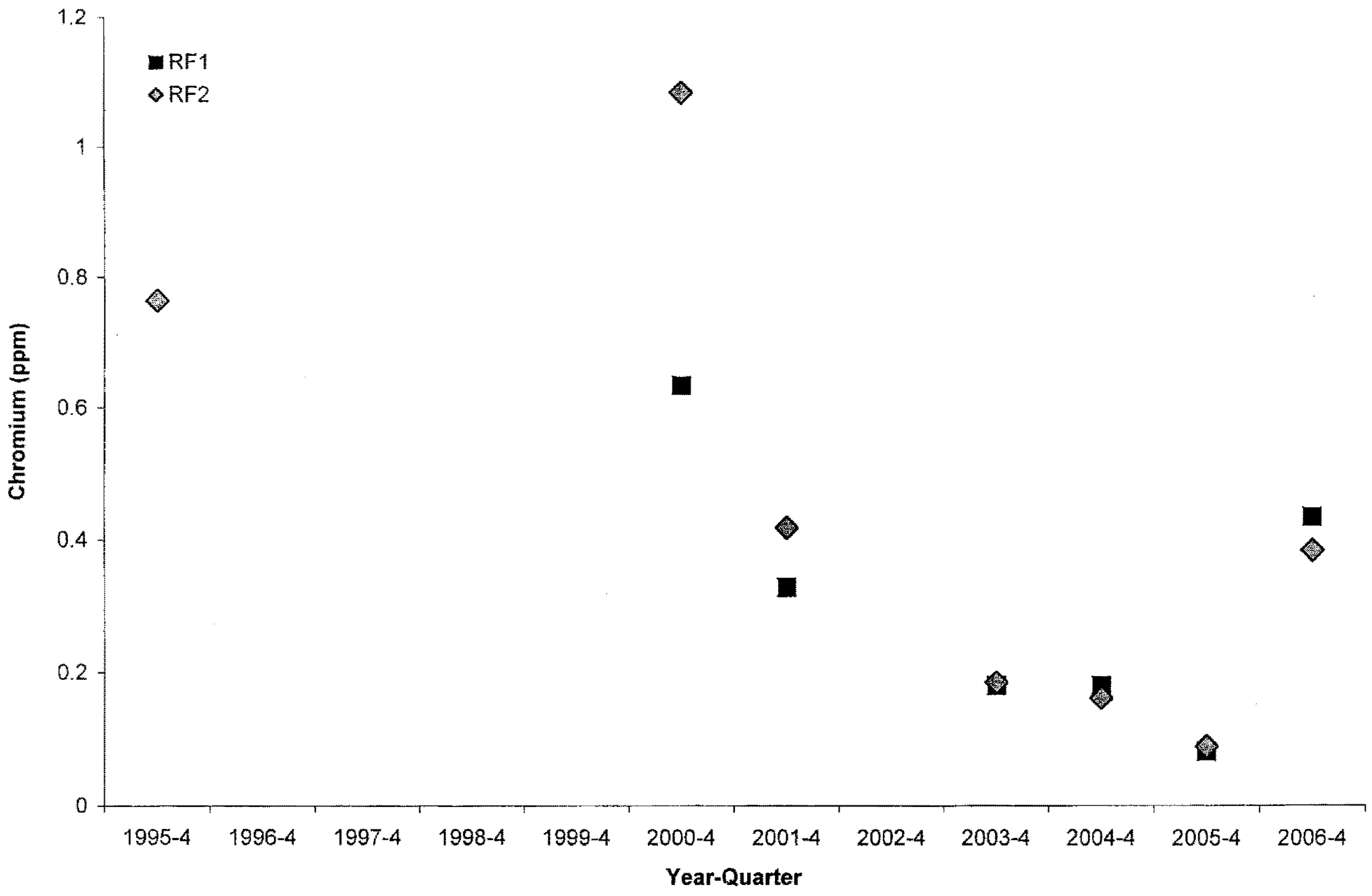

FIGURE F-18. Chromium concentrations (ppm) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

Table F-13

Summary of copper concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**FREQ**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**FREQ**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	2	67	0.97	1.08	1.02
Dover sole	3	3	100	1.48	4.30	3.05	10	2	20	3.26	6.19	4.72
English sole	23	23	100	0.86	15.80	5.38	8	2	25	1.18	2.35	1.76
Hornyhead turbot	1	1	100	5.74	5.74	5.74	2	1	50	3.01	3.01	3.01
Longfin sanddab	86	86	100	1.31	31.20	7.49	87	23	26	0.76	8.58	3.09
Pacific sanddab	85	84	99	1.24	16.50	5.62	49	15	31	0.76	9.70	3.16
Mixed sanddabs	0	na	na	na	na	na	1	1	100	4.21	4.21	4.21
Rockfish:												
California scorpionfish	121	121	100	6.10	84.10	26.61	121	65	54	0.76	22.20	3.37
Bocaccio	2	2	100	14.90	21.10	18.00	2	2	100	1.76	1.79	1.77
Canary rockfish	1	1	100	5.19	5.19	5.19	1	0	0	nd	nd	nd
Copper rockfish	12	12	100	4.33	17.80	9.29	18	13	72	0.14	4.79	1.70
Flag rockfish	5	5	100	3.54	166.00	49.67	5	3	60	1.12	1.31	1.21
Greenblotched rockfish	3	3	100	3.87	22.20	10.39	3	1	33	9.59	9.59	9.59
Greenspotted rockfish	3	3	100	11.70	22.20	16.77	4	2	50	0.14	3.85	1.99
Halfbanded rockfish	3	3	100	2.01	13.40	8.94	3	0	0	nd	nd	nd
Mixed rockfish	25	25	100	2.99	22.30	10.55	34	20	59	0.11	8.96	2.67
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	0.76	0.76	0.76
Speckled rockfish	4	4	100	5.19	11.00	7.22	10	4	40	0.26	0.88	0.68
Squarespot rockfish	1	1	100	26.70	26.70	26.70	3	2	67	0.25	0.46	0.36
Starry rockfish	6	6	100	8.27	26.20	12.83	7	3	43	0.33	5.88	2.93
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	28	100	1.63	21.50	6.87	32	16	50	0.32	8.56	3.33
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.38	0.45	0.42
OVERALL SPECIES	412	411	100	0.86	166.00	13.13	407	180	44	0.11	22.20	2.59

concentrations were 13.13 ppm in liver tissues and 2.59 ppm in muscle tissues. The maximum concentration in liver tissues was 166 ppm from a flag rockfish sample. The highest concentration observed in muscle tissues was 22.2 ppm from a California scorpionfish sample; this value was slightly higher than the MIS of 20 ppm (Table F-6). All other rockfish species had much lower maximum muscle tissue concentrations of copper. The copper data summarized in Table F-14 and Figures F-19 through F-22 also show no discernable spatial or temporal relationships to the Point Loma outfall among either the trawl or rig fishing sites. Although copper concentrations were higher in samples from fish collected at all stations from 2000 to 2002, tissue concentrations of this metal have since returned to their lower levels (see Figures F-20 and F-22).

Lead: Lead is widely distributed in the environment as a result of its prior use in gasoline and paints. Lead in wastewater has its origin in various industrial uses and lead solder in water piping systems. Lead levels in wastewater have been declining over the years and are now mostly below detection levels in the Point Loma effluent.

Lead was only detected in three of the muscle tissue samples analyzed between October 1995 and October 2006 for Point Loma fish (Table F-15). Additionally, only 37 of the 412 samples (9%) of liver tissue had detectable levels of lead. The highest concentration of 8.8 ppm lead occurred in the liver tissue from a Pacific sanddab sample.

Nickel: Nickel also has broad industrial applications and has become widespread in the environment. However, it was only detected in 11% of the liver tissues samples and 5% of the muscle tissue samples for Point Loma fish analyzed from 1995 through 2006 (Table F-16). The maximum concentration of 18.9 ppm nickel was found in a longfin sanddab liver sample. Concentrations of nickel in muscle tissues were all less than 4 ppm.

Selenium: Natural weathering of rocks and soils accounts for most of the selenium in the environment although it also has agriculture and industrial uses. Considered an essential biological element, selenium has anti-carcinogenic properties and appears to protect against

TABLE F-14

Summary of copper concentrations (ppm) in sanddab tissues by trawl zone and rockfish tissues at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Sanddabs	**Liver** **Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
N	40	59	35	36
Min	1.66	1.31	1.24	2.83
Max	16.50	17.30	31.20	16.00
Mean	6.12	6.95	6.28	6.73
Median	5.11	5.60	4.68	6.20
95% CI	1.14	1.07	1.68	1.08

	Muscle **Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
N	13	15	4	7
Min	0.98	0.85	0.76	0.76
Max	8.39	8.58	7.73	9.70
Mean	2.33	3.63	3.18	3.61
Median	1.45	3.40	2.11	3.59
95% CI	1.13	1.23	3.16	2.43

Rockfish	**Liver** **RF1**	**RF2**	**Muscle** **RF1**	**RF2**
N	39	37	31	30
Min	1.63	2.44	0.11	0.14
Max	19.10	26.70	8.96	5.88
Mean	7.22	10.59	2.46	1.72
Median	6.33	9.49	1.69	0.86
95% CI	1.40	1.83	0.86	0.68

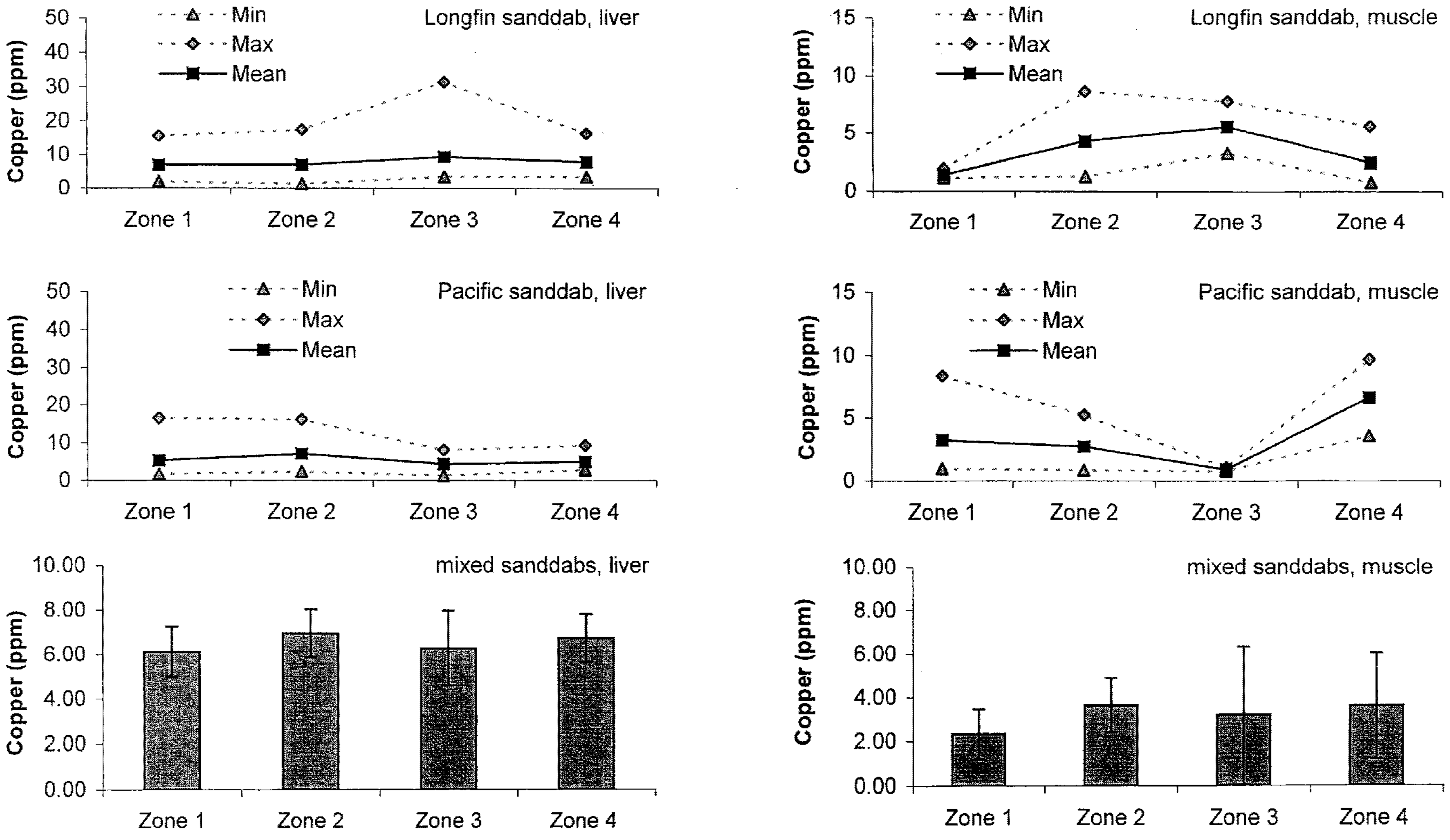

FIGURE F-19. Comparisons of copper concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

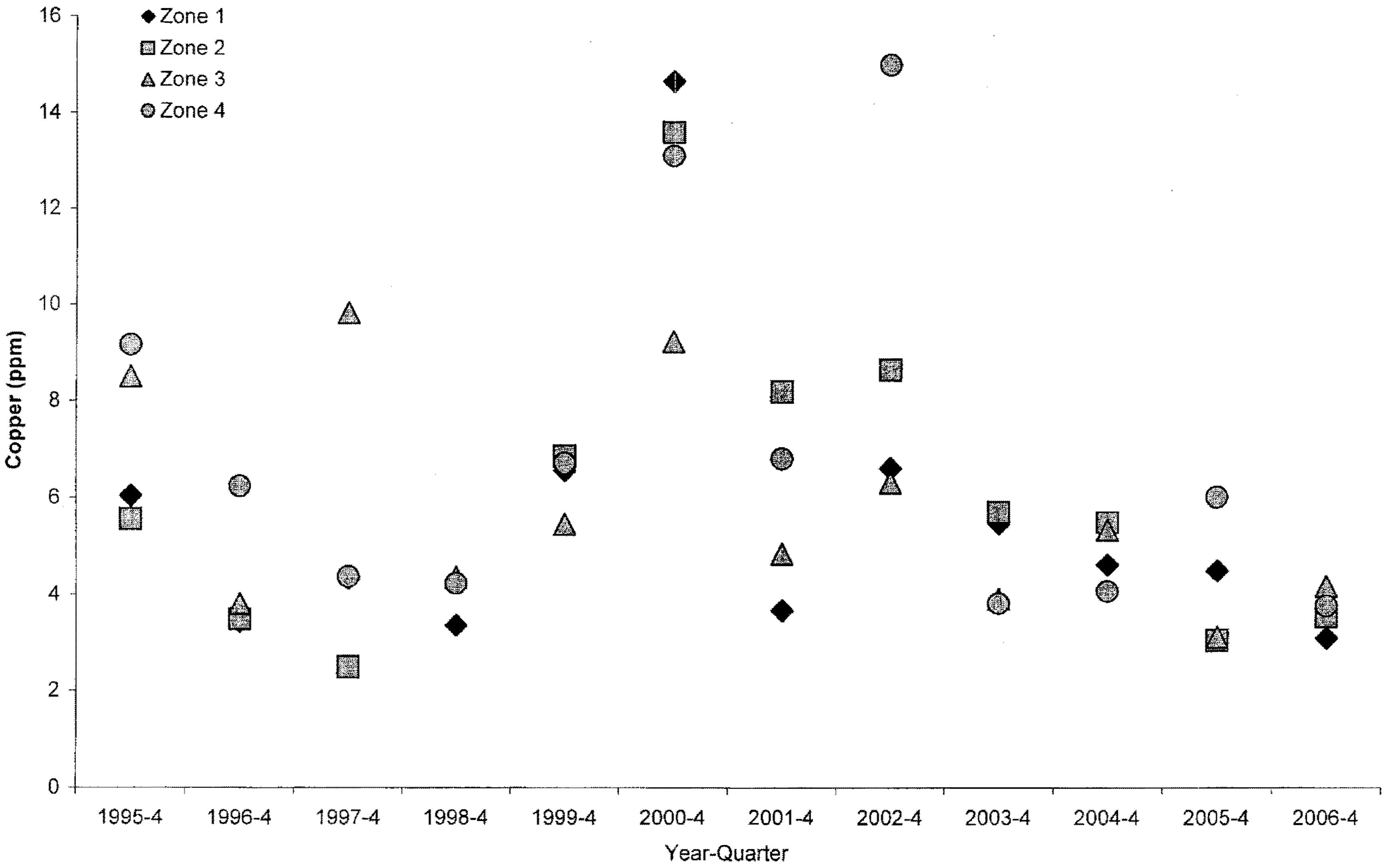

FIGURE F-20. Copper concentrations (ppm) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

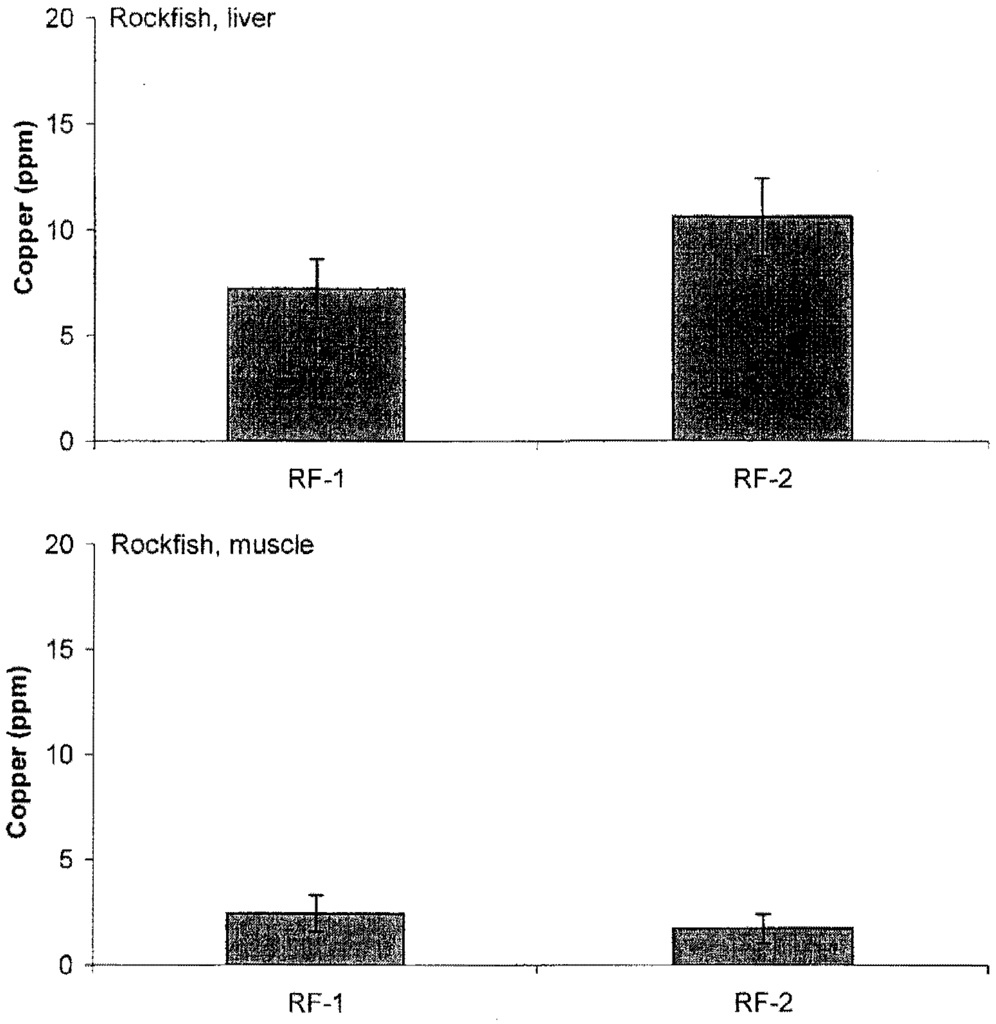

FIGURE F-21. Comparison of copper concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

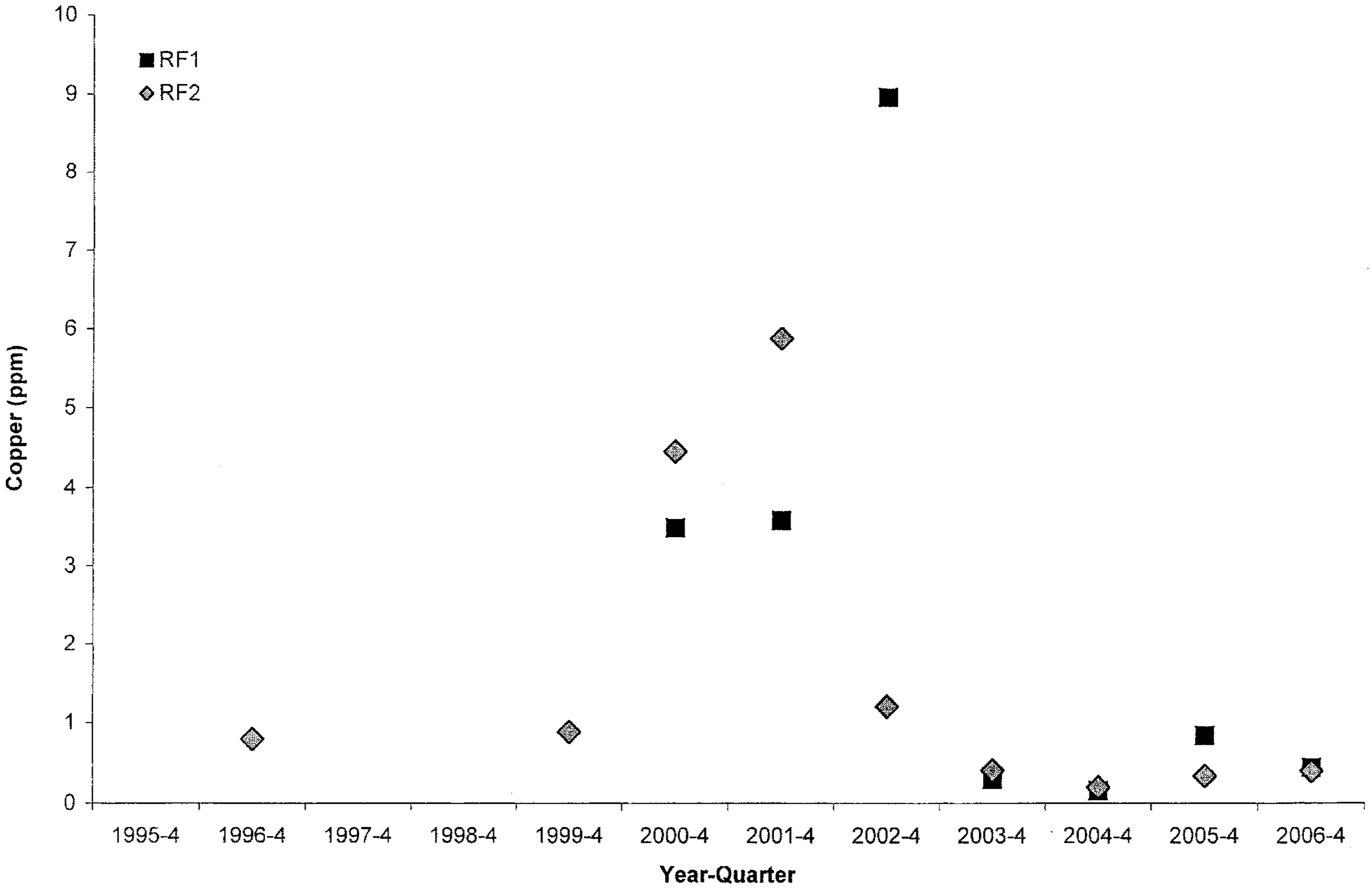

FIGURE F-22. Copper concentrations (ppm) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

Table F-15

Summary of lead concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	0	0	nd	nd	nd
Dover sole	3	0	0	nd	nd	nd	10	0	0	nd	nd	nd
English sole	23	10	43	0.40	1.76	0.81	8	0	0	nd	nd	nd
Hornyhead turbot	1	0	0	nd	nd	nd	2	0	0	nd	nd	nd
Longfin sanddab	86	2	2	2.60	5.70	4.15	87	0	0	nd	nd	nd
Pacific sanddab	85	17	20	0.47	8.80	1.88	49	0	0	nd	nd	nd
Mixed sanddabs	0	na	na	na	na	na	1	0	0	nd	nd	nd
Rockfish:												
California scorpionfish	121	6	5	2.60	3.50	2.95	121	0	0	nd	nd	nd
Bocaccio	2	0	0	nd	nd	nd	2	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd	1	0	0	nd	nd	nd
Copper rockfish	12	1	8	2.50	2.50	2.50	18	0	0	nd	nd	nd
Flag rockfish	5	0	0	nd	nd	nd	5	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Greenspotted rockfish	3	0	0	nd	nd	nd	4	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Mixed rockfish	25	1	4	2.50	2.50	2.50	34	0	0	nd	nd	nd
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Speckled rockfish	4	0	0	nd	nd	nd	10	1	10	0.34	0.34	0.34
Squarespot rockfish	1	0	0	nd	nd	nd	3	2	67	0.32	0.42	0.37
Starry rockfish	6	0	0	nd	nd	nd	7	0	0	nd	nd	nd
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	0	0	nd	nd	nd	32	0	0	nd	nd	nd
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	0	0	nd	nd	nd
OVERALL SPECIES	412	37	9	0.40	8.80	2.46	407	3	1	0.32	0.42	0.35

Table F-16

Summary of nickel concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	1	33	2.12	2.12	2.12
Dover sole	3	0	0	nd	nd	nd	10	0	0	nd	nd	nd
English sole	23	7	30	0.17	3.64	0.67	8	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	0.20	0.20	0.20	2	0	0	nd	nd	nd
Longfin sanddab	86	6	7	0.10	18.90	3.60	87	7	8	0.79	2.06	1.38
Pacific sanddab	85	23	27	0.10	2.26	0.34	49	3	6	0.88	3.25	1.69
Mixed sanddabs	0	na	na	na	na	na	1	0	0	nd	nd	nd
Rockfish:												
California scorpionfish	121	4	3	0.79	0.97	0.89	121	0	0	nd	nd	nd
Bocaccio	2	0	0	nd	nd	nd	2	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd	1	0	0	nd	nd	nd
Copper rockfish	12	0	0	nd	nd	nd	18	3	17	0.14	0.38	0.23
Flag rockfish	5	1	20	0.91	0.91	0.91	5	0	0	nd	nd	nd
Greenblotched rockfish	3	1	33	2.46	2.46	2.46	3	1	33	1.10	1.10	1.10
Greenspotted rockfish	3	0	0	nd	nd	nd	4	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Mixed rockfish	25	1	4	0.81	0.81	0.81	34	1	3	1.29	1.29	1.29
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Speckled rockfish	4	0	0	nd	nd	nd	10	0	0	nd	nd	nd
Squarespot rockfish	1	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Starry rockfish	6	1	17	0.79	0.79	0.79	7	1	14	0.14	0.14	0.14
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	2	7	0.79	1.09	0.94	32	0	0	nd	nd	nd
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.15	0.16	0.16
OVERALL SPECIES	412	47	11	0.10	18.90	1.16	407	19	5	0.14	3.25	1.01

toxic effects of other metals such as arsenic, cadmium, copper, mercury, silver, and thallium (Mearns et al. 1991). At high concentrations, however, selenium itself has considerable toxicity and can adversely affect species of fish and birds. For example, selenium, concentrated by evaporation of agricultural water in the Kesterson Wildlife Refuge (San Joaquin Valley, California), was found to cause wildlife mortalities and reproductive deformities (Burau 1985).

Selenium was detected in 100% of the liver tissue samples and 97% of the muscle tissues samples for fish collected off Point Loma between 1995 and 2006 (Table F-17). Concentrations of selenium in fish muscles averaged less than 1 ppm, while liver tissue levels were considerably higher, reaching almost 10 ppm. The maximum muscle tissue concentration in California scorpionfish and 9 species of rockfish collected at the rig fishing stations exceeded the MIS of 0.3 ppm (Table F-6).

The selenium data summarized in Table F-18 and Figures F-23 through F-26 show no discernable relationship to distance from the outfall for fish from the four trawl zones or two rig fishing stations over all surveys combined, or over time.

Silver: Silver has historically been present in wastewater as a result of its use in photography and dentistry. However, these inputs have dropped significantly over the years with the implementation of stringent source control measures.

Silver has been detected in only four muscle tissue samples from fishes collected off Point Loma, with all concentrations less than 3 ppm (Table F-19). In contrast, this metal has been detected at concentrations up to 11.7 ppm in 74 of the 412 liver tissue samples (~18%). There are no U.S. or international standards for concentrations of silver in seafood.

Tin: Historically, sources of tin to the ocean environment have included marine paints, municipal sewage, industrial discharges, and aerial fallout (Mearns et al. 1991). These inputs

Table F-17

Summary of selenium concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	3	100	0.130	0.240	0.172
Dover sole	3	3	100	0.720	2.770	1.753	10	10	100	0.130	1.100	0.404
English sole	23	23	100	0.990	3.210	2.262	8	8	100	0.160	0.630	0.288
Hornyhead turbot	1	1	100	0.888	0.888	0.888	2	1	50	0.310	0.310	0.310
Longfin sanddab	87	87	100	0.610	4.370	1.842	87	87	100	0.210	3.270	0.825
Pacific sanddab	89	89	100	0.260	3.230	0.936	49	41	84	0.130	0.830	0.253
Mixed sanddabs	0	na	na	na	na	na	1	1	100	1.570	1.570	1.570
Rockfish:												
California scorpionfish	124	124	100	0.420	4.550	0.867	121	119	98	0.130	0.750	0.273
Bocaccio	2	2	100	0.980	2.600	1.790	2	2	100	0.180	0.296	0.238
Canary rockfish	1	1	100	1.120	1.120	1.120	1	1	100	0.250	0.250	0.250
Copper rockfish	12	12	100	1.010	2.020	1.510	18	18	100	0.130	0.690	0.388
Flag rockfish	5	5	100	1.420	3.360	2.392	5	5	100	0.230	0.380	0.298
Greenblotched rockfish	3	3	100	1.030	3.050	2.087	3	3	100	0.130	0.200	0.173
Greenspotted rockfish	3	3	100	2.370	2.870	2.683	4	4	100	0.160	0.290	0.230
Halfbanded rockfish	3	3	100	1.690	4.990	3.430	3	3	100	0.440	1.000	0.707
Mixed rockfish	27	27	100	0.910	3.220	1.918	34	32	94	0.130	0.550	0.296
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	0.367	0.367	0.367
Speckled rockfish	6	6	100	3.550	9.630	5.208	10	10	100	0.130	0.352	0.234
Squarespot rockfish	1	1	100	3.380	3.380	3.380	3	3	100	0.275	0.440	0.360
Starry rockfish	6	6	100	1.250	1.710	1.510	7	7	100	0.240	0.450	0.343
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	0.175	0.175	0.175
Vermilion rockfish	28	28	100	0.850	2.480	1.488	32	32	100	0.140	0.545	0.264
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.303	0.350	0.327
OVERALL SPECIES	424	424	100	0.26	9.63	2.06	407	394	97	0.13	3.27	0.38

TABLE F-18

Summary of selenium concentrations (ppm) in scorpionfish and sanddab tissues by trawl zone, and rockfish at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-April 2003 for scorpionfish and October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Scorpionfish		**Liver**		
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	52	37	8	18
Min	0.560	0.560	0.632	0.420
Max	4.550	1.200	2.290	1.040
Mean	0.862	0.840	1.231	0.738
Median	0.765	0.830	1.055	0.730
95% CI	0.147	0.052	0.396	0.077

		Muscle		
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	50	37	8	15
Min	0.130	0.150	0.150	0.150
Max	0.528	0.750	0.525	0.350
Mean	0.277	0.286	0.270	0.245
Median	0.260	0.270	0.240	0.230
95% CI	0.028	0.036	0.087	0.030

Sanddabs		**Liver**		
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	41	61	37	37
Min	0.260	0.440	0.495	0.553
Max	3.510	4.370	3.730	2.770
Mean	1.329	1.484	1.325	1.338
Median	1.130	1.140	1.030	1.200
95% CI	0.240	0.237	0.252	0.178

		Muscle		
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	30	46	24	28
Min	0.150	0.130	0.130	0.160
Max	1.700	2.620	2.800	3.270
Mean	0.451	0.486	0.719	1.037
Median	0.405	0.335	0.477	0.707
95% CI	0.104	0.136	0.243	0.302

Rockfish	**Liver**		**Muscle**	
	RF1	**RF2**	**RF1**	**RF2**
N	40	38	51	54
Min	0.850	1.020	0.130	0.130
Max	2.480	9.630	0.690	0.550
Mean	1.529	2.341	0.321	0.282
Median	1.530	1.715	0.305	0.280
95% CI	0.116	0.521	0.036	0.026

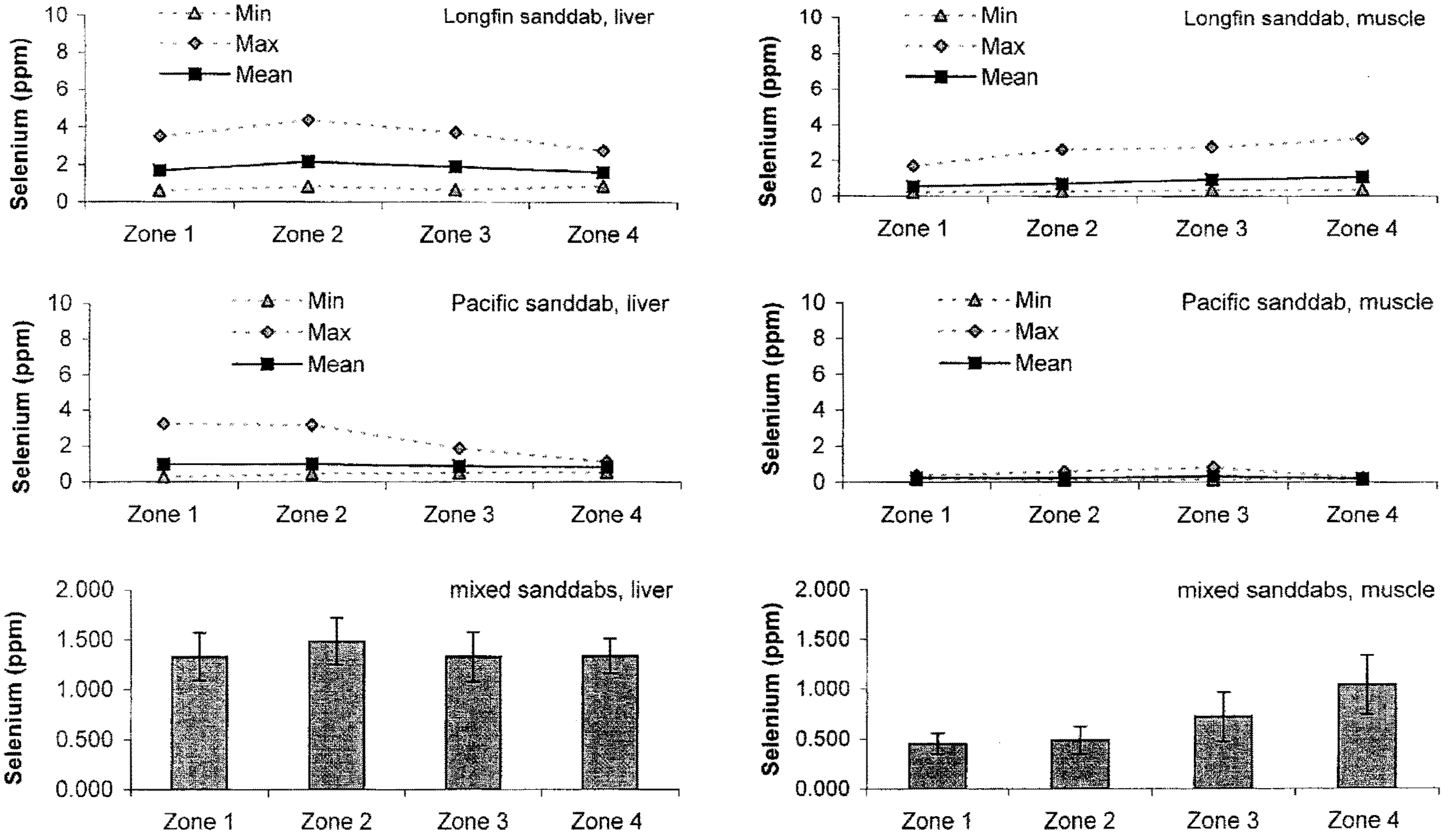

FIGURE F-23. Comparisons of selenium concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

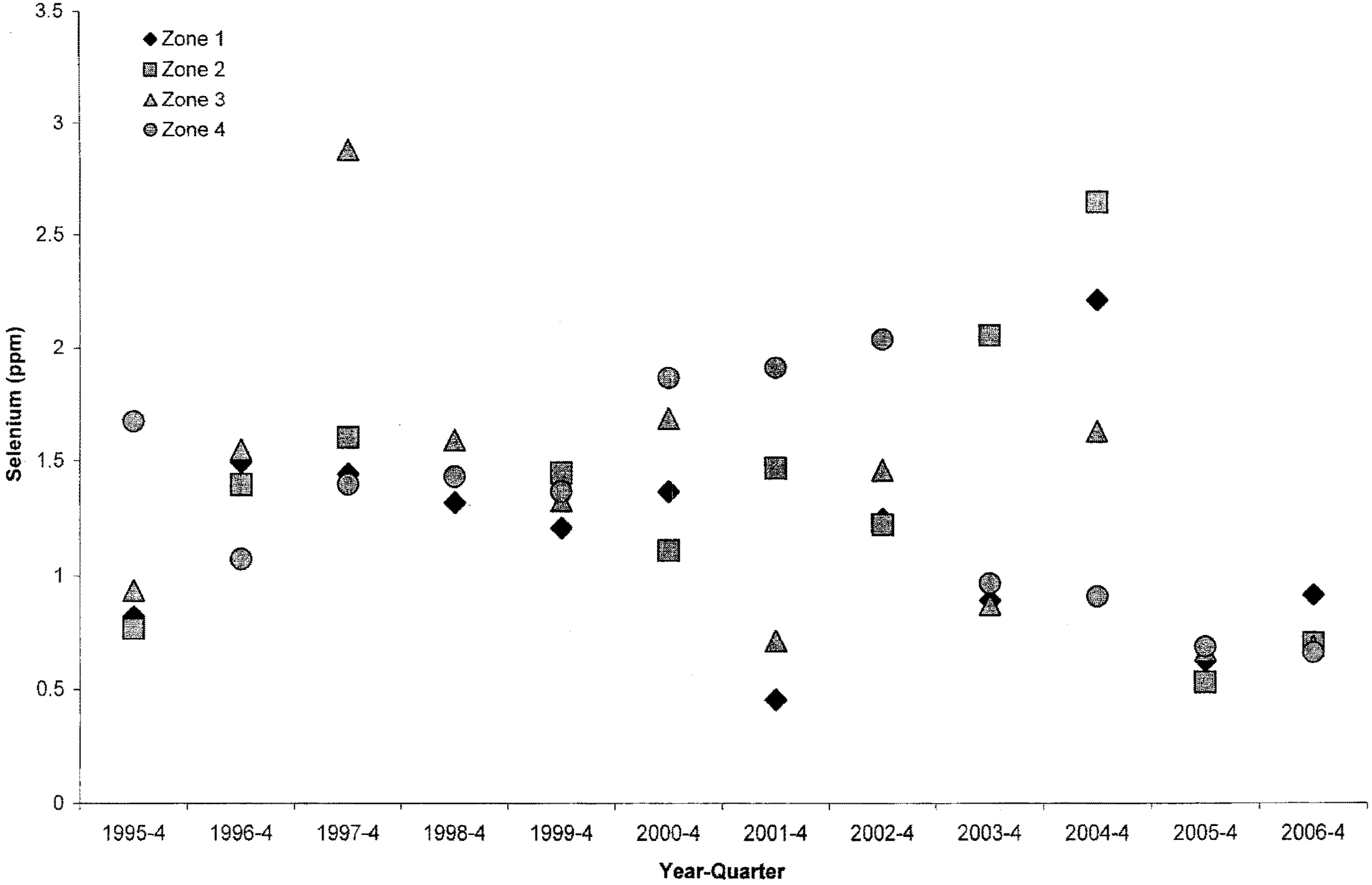

FIGURE F-24. Selenium concentrations (ppm) in sanddab guild liver tissue for trawl Zone1 versus Zones 2-4 for October surveys from 1995-2006.

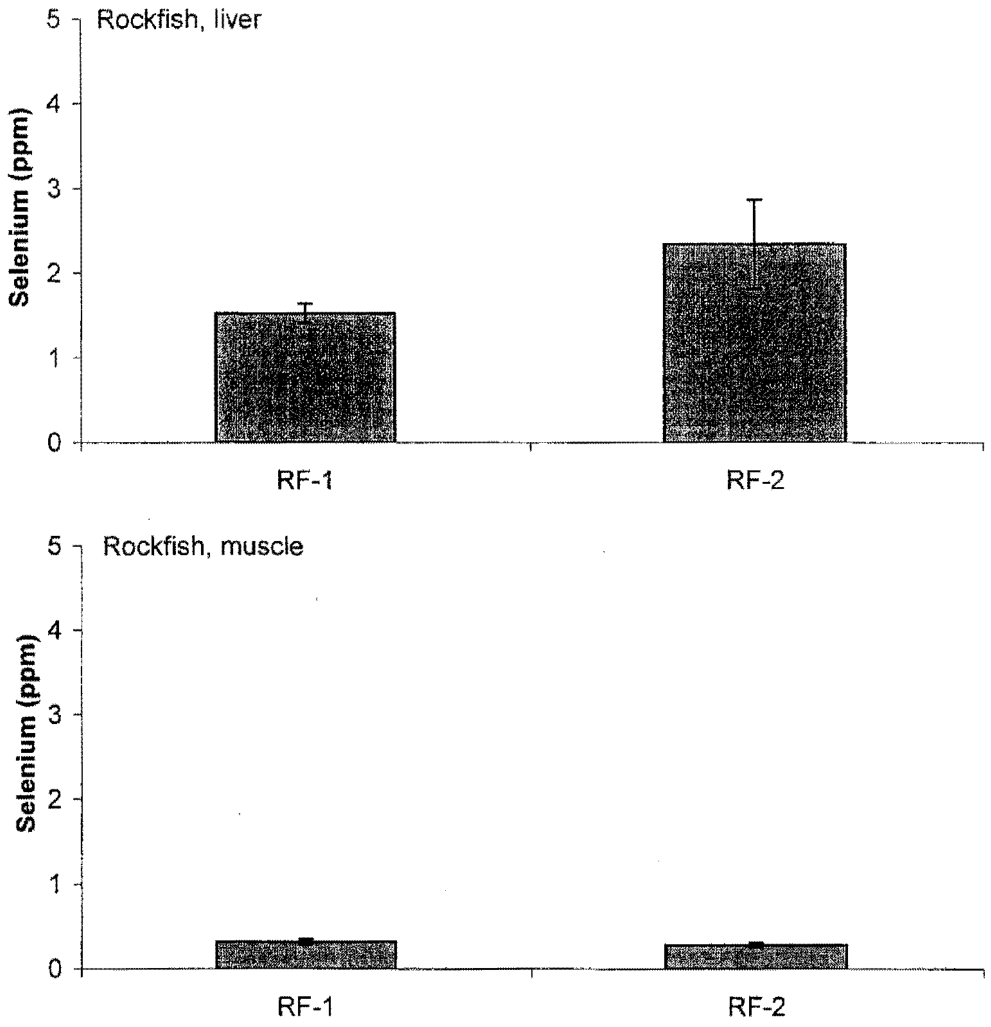

FIGURE F-25. Comparison of selenium concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

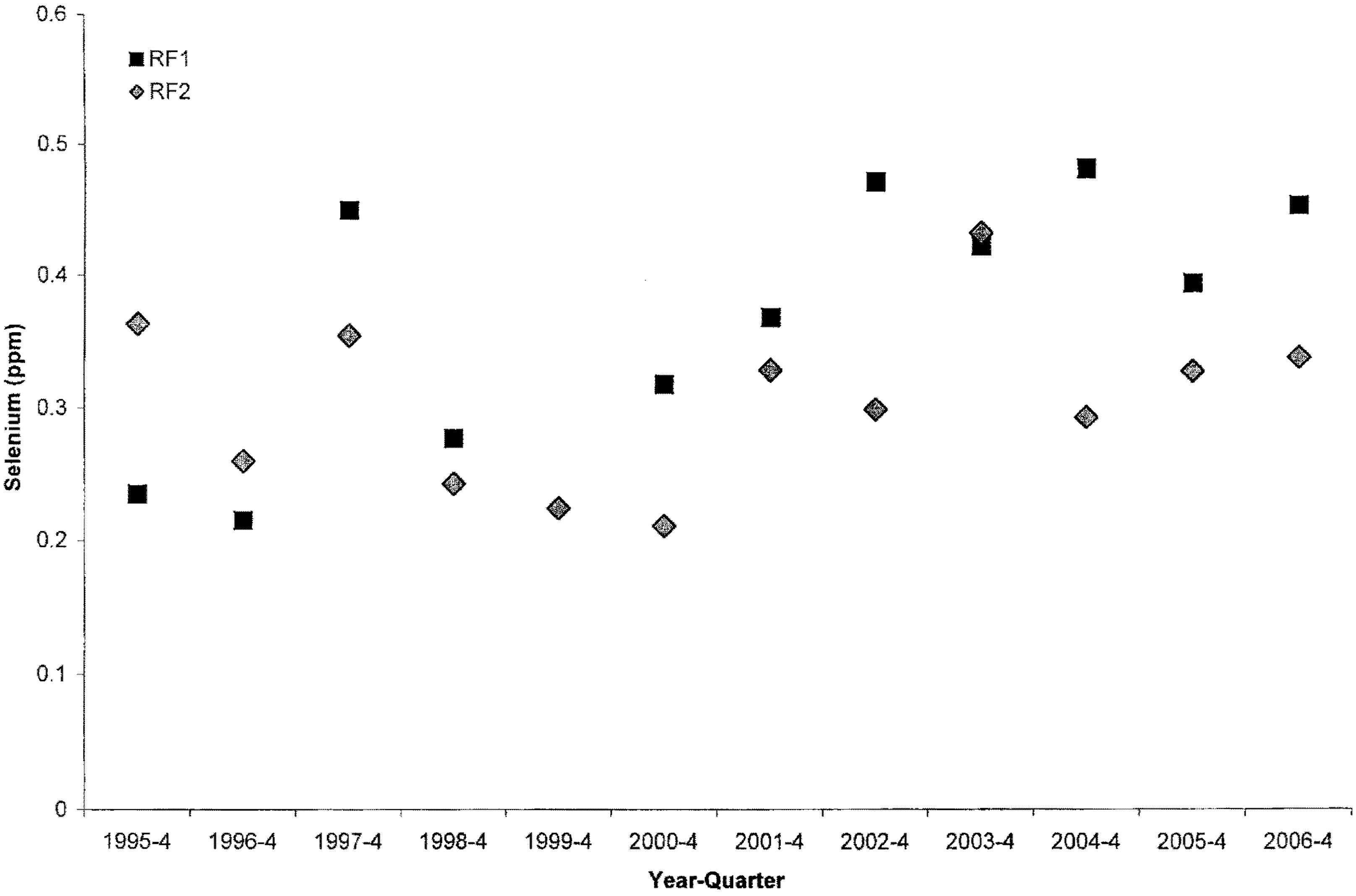

FIGURE F-26. Selenium concentrations (ppm) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

Table F-19

Summary of silver concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	0	0	nd	nd	nd
Dover sole	3	0	0	nd	nd	nd	10	0	0	nd	nd	nd
English sole	23	15	65	0.06	0.49	0.19	8	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	0.27	0.27	0.27	2	0	0	nd	nd	nd
Longfin sanddab	86	15	17	0.16	1.14	0.45	87	1	1	0.93	0.93	0.93
Pacific sanddab	85	31	36	0.06	1.66	0.21	49	0	0	nd	nd	nd
Mixed sanddabs	0	na	na	na	na	na	1	0	0	nd	nd	nd
Rockfish:												
California scorpionfish	121	9	7	0.62	1.12	0.84	121	1	1	2.68	2.68	2.68
Bocaccio	2	0	0	nd	nd	nd	2	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd	1	0	0	nd	nd	nd
Copper rockfish	12	0	0	nd	nd	nd	18	0	0	nd	nd	nd
Flag rockfish	5	1	20	0.68	0.68	0.68	5	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd	3	1	33	2.45	2.45	2.45
Greenspotted rockfish	3	0	0	nd	nd	nd	4	0	0	nd	nd	nd
Halfbanded rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Mixed rockfish	25	2	8	0.62	11.70	6.16	34	0	0	nd	nd	nd
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Speckled rockfish	4	0	0	nd	nd	nd	10	1	10	0.50	0.50	0.50
Squarespot rockfish	1	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Starry rockfish	6	0	0	nd	nd	nd	7	0	0	nd	nd	nd
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	0	0	nd	nd	nd	32	0	0	nd	nd	nd
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	0	0	nd	nd	nd
OVERALL SPECIES	412	74	18	0.06	11.70	1.26	407	4	1	0.50	2.68	1.64

have dropped significantly over the years with the implementation of source control measures and increased regulation.

As with silver, detection rates of tin have been relatively low in the tissues of fishes sampled off Point Loma. For example, only 16% and 4% of the liver and muscle tissue samples, respectively, have been found with concentrations high enough to be detected (Table F-20). Concentrations of tin in liver tissues were as high as 90.5 ppm, whereas concentrations in muscle tissues were all less than 11 ppm.

<u>Zinc</u>: Zinc is the metal with typically the highest metal loads in Point Loma effluent. This metal is used routinely in batteries, vehicle tires, and in a variety of industrial, commercial and household products, and it has been found distributed throughout the southern California marine environment. However, source control efforts have resulted in decreasing concentrations of zinc in Point Loma wastewater and bringing average effluent concentrations down to 25 μg/L for 2006.

Zinc was detected in every liver and muscle tissue sample analyzed between October 1995 and October 2006 (Table F-21). Zinc concentrations in muscle tissues from fishes collected off Point Loma falls within a relatively narrow range of values, averaging 2.3 - 5.5 ppm for the 21 species of fish analyzed. In addition, all of the muscle tissue concentrations were well below the MIS of 70 ppm for zinc (Table F-6). Concentrations of zinc in liver tissues were much higher and more variable than in muscles. Overall, there is no consistent or discernable trend relative to wastewater discharge in space or time for zinc (Table F-22, Figures F-27 through F-30). While peak values for trawl-caught fish were measured at zones 1 and 3 using liver tissues and at zones 1 and 2 for muscle tissues, the highest zinc concentrations in liver samples at the rig-fishing sites were found at the northern reference station (RF2).

Table F-20

Summary of tin concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	0	0	nd	nd	nd
Dover sole	3	0	0	nd	nd	nd	10	0	0	nd	nd	nd
English sole	23	14	61	0.3	1.8	0.8	8	0	0	nd	nd	nd
Hornyhead turbot	1	1	100	1.2	1.2	1.2	2	0	0	nd	nd	nd
Longfin sanddab	86	10	12	0.5	1.6	0.8	87	0	0	nd	nd	nd
Pacific sanddab	85	37	44	0.3	90.5	4.1	49	0	0	nd	nd	nd
Mixed sanddabs	0	na	na	na	na	na	1	0	0	nd	nd	nd
Rockfish:												
California scorpionfish	121	4	3	7.4	12.7	10.1	121	1	1	10.5	10.5	10.5
Bocaccio	2	0	0	nd	nd	nd	2	0	0	nd	nd	nd
Canary rockfish	1	0	0	nd	nd	nd	1	0	0	nd	nd	nd
Copper rockfish	12	0	0	nd	nd	nd	18	4	22	0.6	1.8	1.4
Flag rockfish	5	0	0	nd	nd	nd	5	0	0	nd	nd	nd
Greenblotched rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Greenspotted rockfish	3	0	0	nd	nd	nd	4	1	25	0.2	0.2	0.2
Halfbanded rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Mixed rockfish	25	1	4	31.0	31.0	31.0	34	3	9	0.4	0.5	0.4
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Speckled rockfish	4	0	0	nd	nd	nd	10	0	0	nd	nd	nd
Squarespot rockfish	1	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Starry rockfish	6	0	0	nd	nd	nd	7	1	14	1.5	1.5	1.5
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	0	0	nd	nd	nd	32	4	13	0.5	0.6	0.5
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	1.7	1.7	1.7
OVERALL SPECIES	412	67	16	0.3	90.5	8.0	407	16	4	0.2	10.5	2.3

Table F-21

Summary of zinc concentrations (ppm) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	0	na	na	na	na	na	3	3	100	2.4	2.5	2.5
Dover sole	3	3	100	19.4	40.2	29.5	10	10	100	2.4	3.2	2.7
English sole	23	23	100	27.6	86.9	50.6	8	8	100	2.2	4.4	3.2
Hornyhead turbot	1	1	100	65.1	65.1	65.1	2	2	100	2.4	3.8	3.1
Longfin sanddab	86	86	100	10.3	80.2	22.9	87	87	100	1.5	5.6	2.8
Pacific sanddab	85	85	100	8.6	41.4	22.4	49	49	100	1.2	9.6	3.1
Mixed sanddabs	0	na	na	na	na	na	1	1	100	2.3	2.3	2.3
Rockfish:												
California scorpionfish	121	121	100	22.9	213.0	102.3	120	120	100	1.4	16.8	4.5
Bocaccio	2	2	100	44.8	76.6	60.7	2	2	100	3.1	3.3	3.2
Canary rockfish	1	1	100	22.1	22.1	22.1	1	1	100	3.8	3.8	3.8
Copper rockfish	12	12	100	25.5	59.9	42.9	18	18	100	2.0	15.2	5.5
Flag rockfish	5	5	100	49.5	101.0	69.7	5	5	100	2.3	3.4	3.0
Greenblotched rockfish	3	3	100	45.5	66.8	55.6	3	3	100	3.1	5.2	3.9
Greenspotted rockfish	3	3	100	46.8	72.8	61.7	4	4	100	3.1	4.1	3.5
Halfbanded rockfish	3	3	100	12.9	74.4	42.7	3	3	100	2.2	3.0	2.6
Mixed rockfish	25	25	100	18.5	118.0	50.3	34	34	100	1.7	10.0	3.4
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	2.9	2.9	2.9
Speckled rockfish	4	4	100	31.9	41.7	36.9	10	10	100	2.1	4.1	3.0
Squarespot rockfish	1	1	100	216.0	216.0	216.0	3	3	100	3.2	3.4	3.3
Starry rockfish	6	6	100	47.9	110.0	81.3	7	7	100	1.8	11.1	4.4
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	3.1	3.1	3.1
Vermilion rockfish	28	28	100	17.5	55.0	25.2	32	32	100	1.0	14.3	3.8
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	3.8	4.3	4.0
OVERALL SPECIES	412	412	100	8.6	216.0	58.8	406	406	100	1.0	16.8	3.4

TABLE F-22

Summary of zinc concentrations (ppm) in sanddab tissues by trawl zone and rockfish tissues at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Sanddabs	**Liver**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	40	59	35	37
Min	8.61	14.90	13.80	15.40
Max	59.40	41.40	80.20	39.70
Mean	21.66	21.82	25.71	22.23
Median	21.50	21.40	22.80	21.80
95% CI	2.42	1.20	4.45	1.51
	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	33	50	26	28
Min	1.22	1.51	1.84	1.75
Max	9.59	9.07	4.82	5.04
Mean	3.12	2.83	2.90	2.74
Median	2.75	2.66	2.87	2.61
95% CI	0.51	0.31	0.27	0.23

Rockfish	**Liver**		**Muscle**	
	RF1	**RF2**	**RF1**	**RF2**
N	39	37	53	54
Min	17.50	18.50	1.69	1.02
Max	70.20	216.00	15.20	14.30
Mean	33.78	54.27	4.10	3.70
Median	26.60	47.40	3.60	3.26
95% CI	4.66	11.80	0.63	0.57

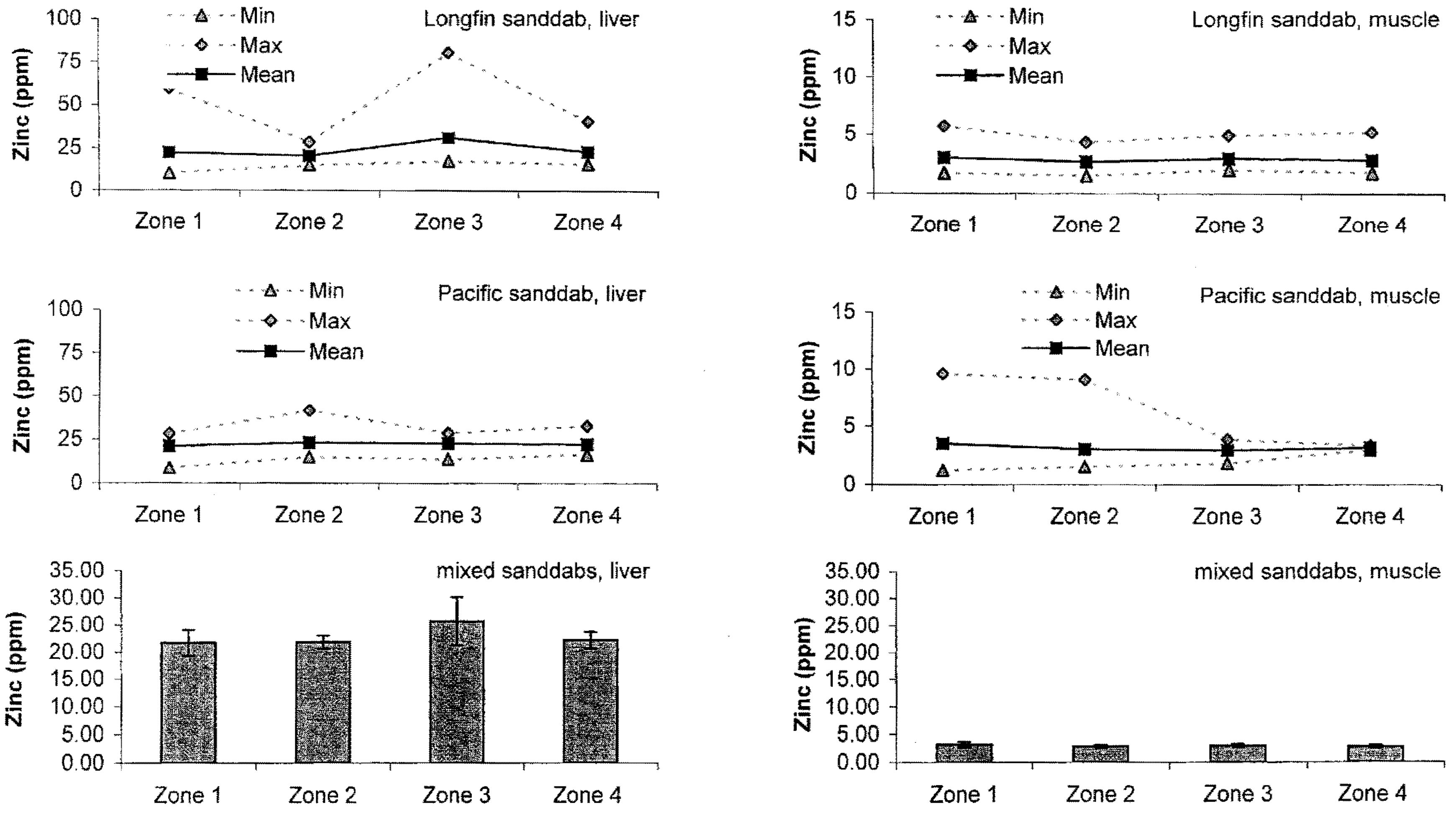

FIGURE F-27. Comparisons of zinc concentrations (ppm) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

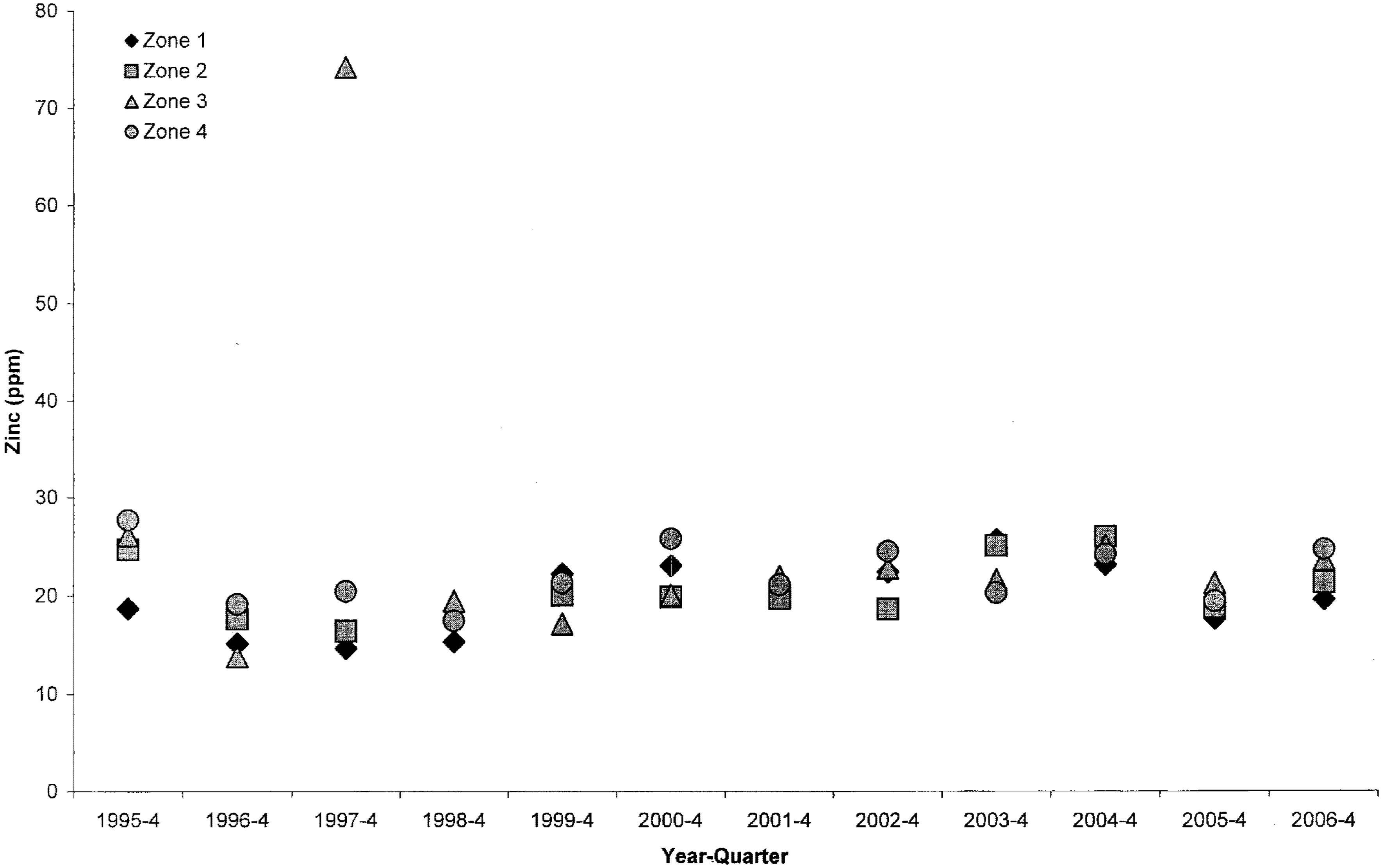

FIGURE F-28. Zinc concentrations (ppm) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

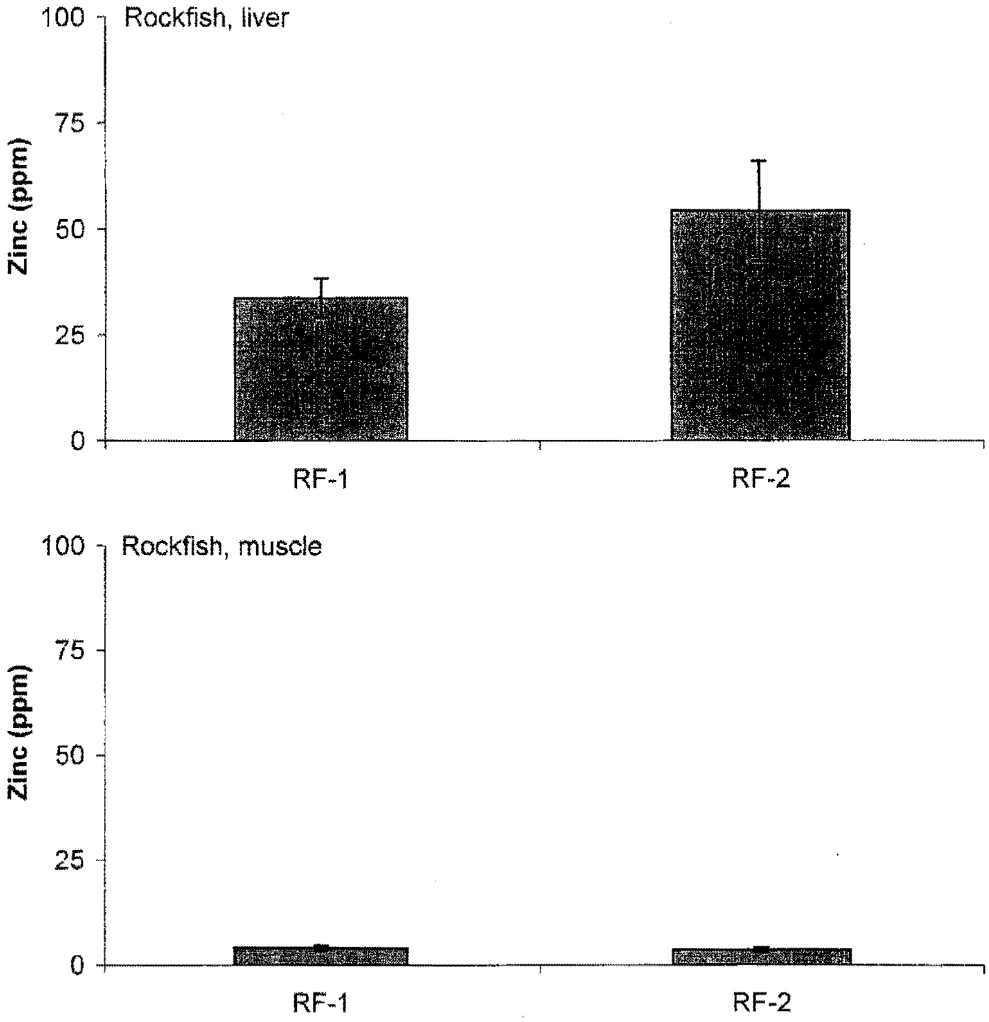

FIGURE F-29. Comparison of zinc concentrations (ppm) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

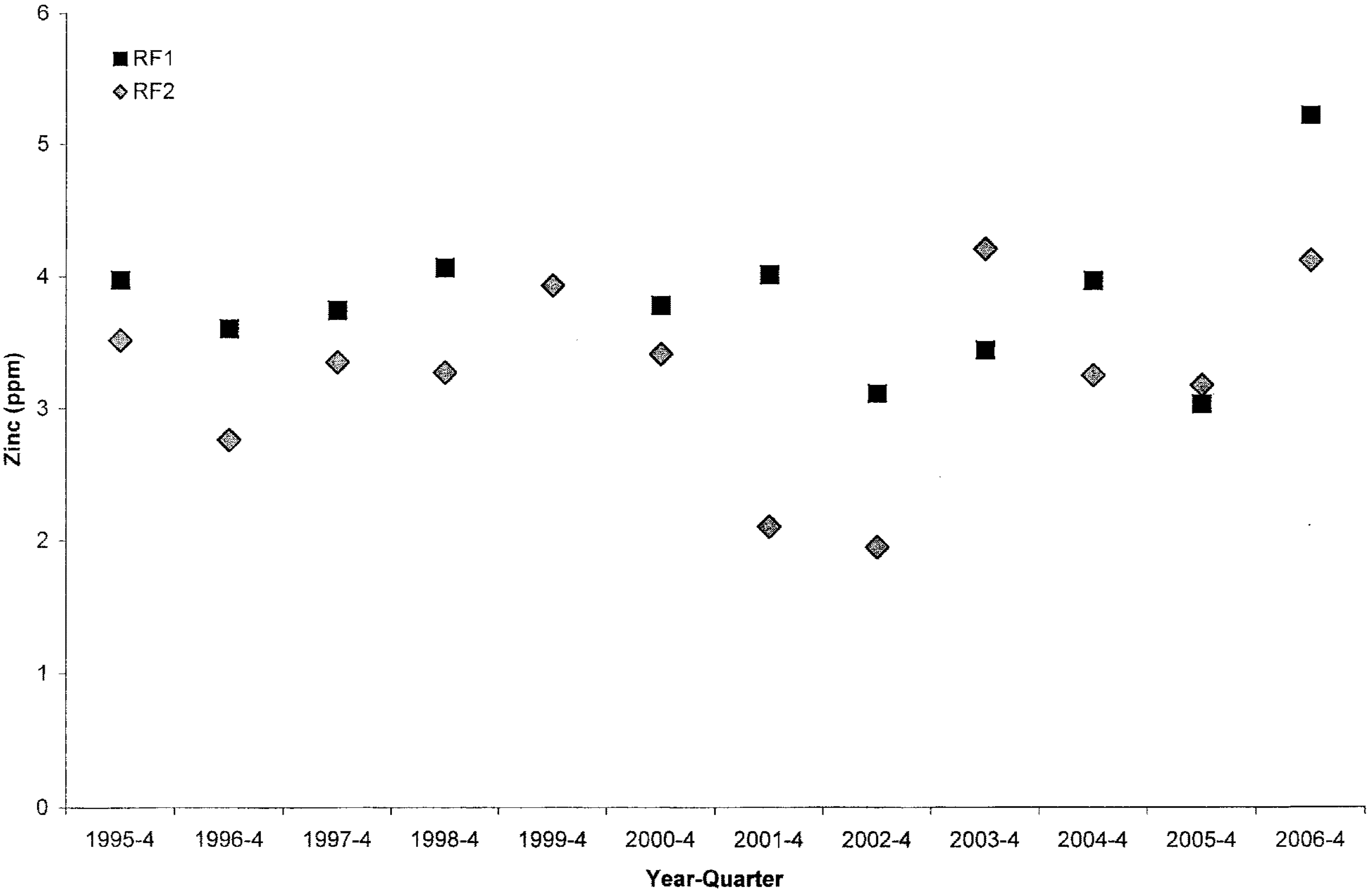

FIGURE F-30. Zinc concentrations (ppm) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

Chlorinated Hydrocarbons

Chlorinated hydrocarbons like the pesticide DDT and polychlorinated biphenyl compounds (PCBs) are persistent environmental contaminants with widespread distribution and well-known bioaccumulation in southern California. The impact of these synthetic chemicals was most notable in the late 1960s and 1970s when DDT discharged from Whites Point outfall in Los Angeles County accumulated in fish-eating birds and marine mammals causing reproductive effects and population declines (Mearns et al. 1991). Since the ban of these chemicals in the early 1970s, environmental levels have steadily decreased. Most current residues in marine animals are from the reservoir of these contaminants still present in marine sediments (i.e., legacy contaminants), especially off the Palos Verdes Peninsula and in some local bays and harbors.

DDT and PCBs were not detected in Point Loma effluent from 1996-2006. DDT was detected in sediments at all outfall stations off Point Loma, although at low levels compared to elsewhere in southern California and without any apparent outfall-related effect on benthic invertebrates (see Appendix E, Section E.4). PCBs were only found intermittently in sediments off Point Loma, with the highest values occurring near the LA-5 dredge materials disposal site (see Appendix E, Section E.4).

<u>DDT and other Chlorinated Pesticides</u>: DDT was found in all species of fish collected off Point Loma, with detection rates of 99% for liver tissues and 93% for muscle tissues (Table F-23). Concentrations of total DDT in Point Loma area fish tissues were highly variable, with values ranging from 37 to 23,336 ppb in liver tissues and from 1 to 878 ppb in muscle tissues. The highest concentration was found in a liver sample from California scorpionfish collected in trawl zone 2 (Table F-24). Muscle tissue values were all low relative to the 5 ppm (5,000 ppb) limit set by the FDA as well as the MIS (Table F-6). There does not appear to be any relationship between total DDT concentrations and distance from the Point Loma outfall (Table F-24, Figures F-31 through F-34). DDT concentrations in

Table F-23

Summary of total DDT concentrations (ppb) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	3	3	100	88	349	222	3	3	100	2	4	3
Dover sole	9	9	100	37	425	131	10	7	70	2	20	6
English sole	23	23	100	47	2713	345	8	8	100	2	15	10
Hornyhead turbot	4	4	100	170	252	204	2	1	50	3	3	3
Longfin sanddab	96	94	98	350	3800	1291	87	73	84	1	19	6
Pacific sanddab	90	89	99	147	1845	560	49	42	86	1	43	4
Mixed sanddabs	1	1	100	751	751	751	1	1	100	2	2	2
Rockfish:												
California scorpionfish	126	126	100	138	23366	1666	121	121	100	4	878	46
Bocaccio	2	2	100	233	280	256	2	2	100	7	10	8
Canary rockfish	1	1	100	460	460	460	1	1	100	14	14	14
Copper rockfish	12	12	100	243	2662	963	18	17	94	5	217	40
Flag rockfish	5	5	100	636	1930	1098	5	5	100	1	71	29
Greenblotched rockfish	3	3	100	140	749	501	3	3	100	8	23	13
Greenspotted rockfish	3	3	100	228	961	482	4	4	100	3	29	13
Halfbanded rockfish	3	3	100	180	370	290	3	3	100	10	12	11
Mixed rockfish	28	28	100	105	2700	649	34	33	97	4	83	22
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	2	2	2
Speckled rockfish	7	7	100	130	620	308	10	9	90	3	16	7
Squarespot rockfish	2	2	100	210	1300	755	3	3	100	12	20	16
Starry rockfish	6	6	100	370	1378	861	7	7	100	19	119	64
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	18	18	18
Vermilion rockfish	28	28	100	150	1172	410	32	31	97	3	40	14
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	4	6	5
OVERALL SPECIES	452	449	99	37	23366	610	407	378	93	1	878	15

TABLE F-24

Summary of total DDT concentrations (ppb) in scorpionfish and sanddab tissues by trawl zone, and rockfish at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-April 2003 for scorpionfish and October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Scorpionfish	**Liver**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	52	39	8	18
Min	310.0	190.0	137.8	535.7
Max	23210.0	23366.0	7981.8	3882.0
Mean	1841.3	1774.4	1660.5	1150.0
Median	961.5	1070.0	728.2	904.6
95% CI	1008.6	1171.1	1796.4	374.3
	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	49	38	8	16
Min	4.2	3.5	4.1	9.3
Max	826.7	877.5	134.0	65.0
Mean	52.5	48.9	36.4	33.8
Median	23.9	23.9	27.2	34.3
95% CI	33.7	44.4	28.5	9.8

Sanddabs	**Liver**			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	45	62	38	38
Min	225.7	147.3	268.3	172.3
Max	2280.0	2242.2	2400.0	3800.0
Mean	996.5	799.9	878.8	1140.5
Median	862.1	741.0	730.3	969.5
95% CI	168.1	118.1	168.4	250.5
	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	28	41	21	25
Min	1.0	0.7	0.9	1.1
Max	19.3	43.0	12.0	11.0
Mean	5.0	5.6	4.9	5.7
Median	3.8	3.4	4.6	5.1
95% CI	1.4	2.2	1.3	1.3

Rockfish	**Liver**		**Muscle**	
	RF1	**RF2**	**RF1**	**RF2**
N	41	40	51	52
Min	150.0	104.6	2.3	1.3
Max	2700.0	1378.0	217.3	118.8
Mean	739.3	484.6	25.1	22.2
Median	415.0	358.5	12.0	13.1
95% CI	208.7	110.0	9.8	6.7

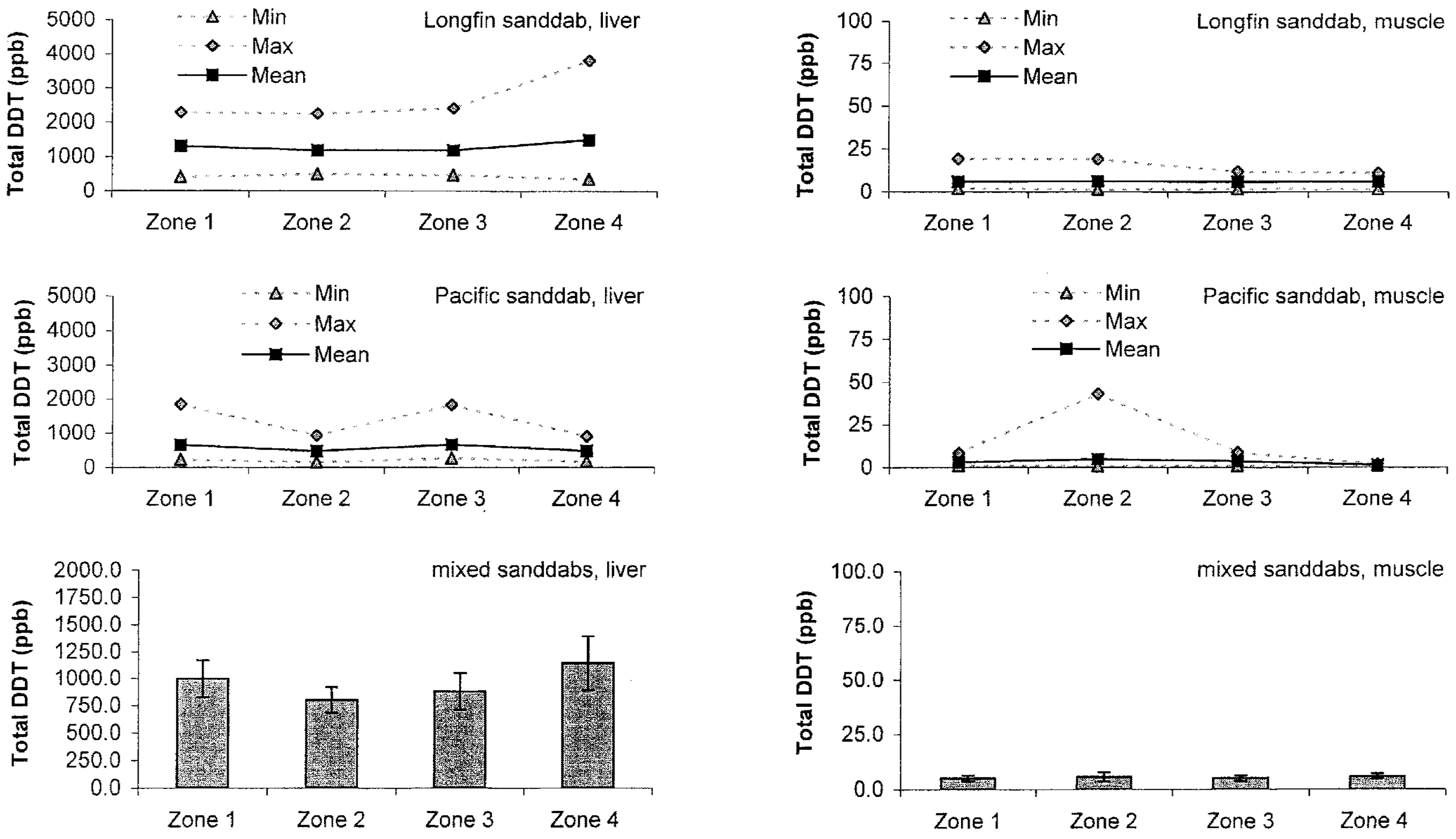

FIGURE F-31. Comparisons of total DDT concentrations (ppb) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

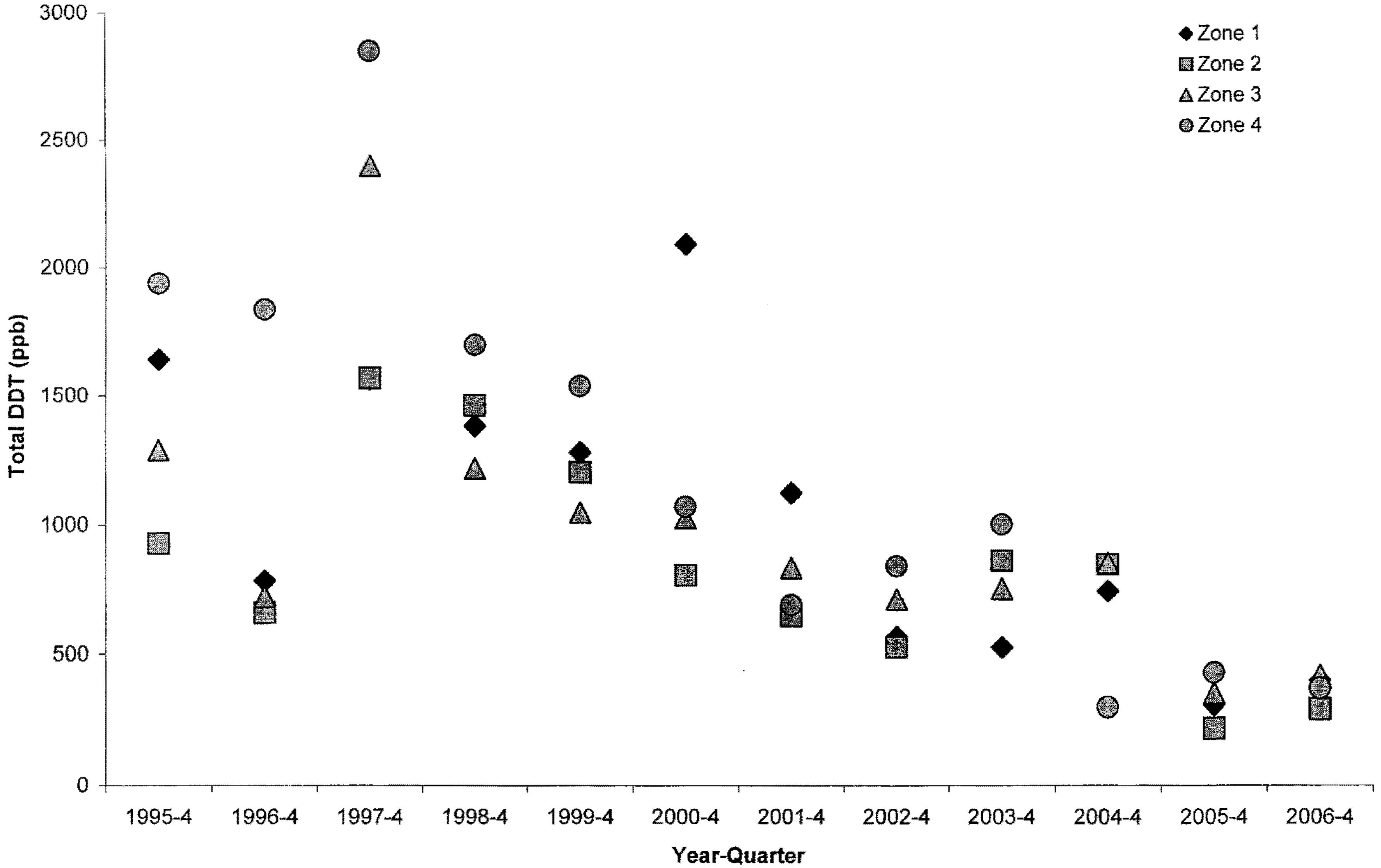

FIGURE F-32. Total DDT concentrations (ppb) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

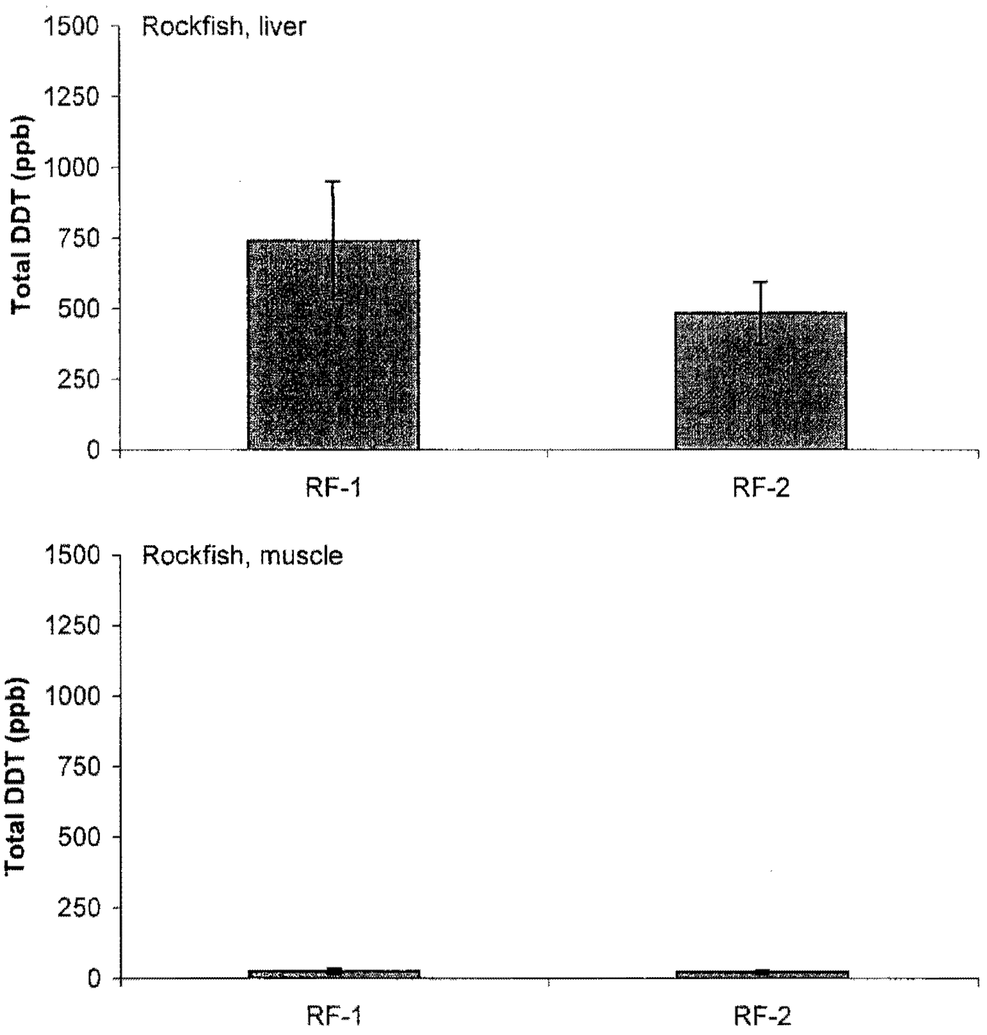

FIGURE F-33. Comparison of total DDT concentrations (ppb) in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

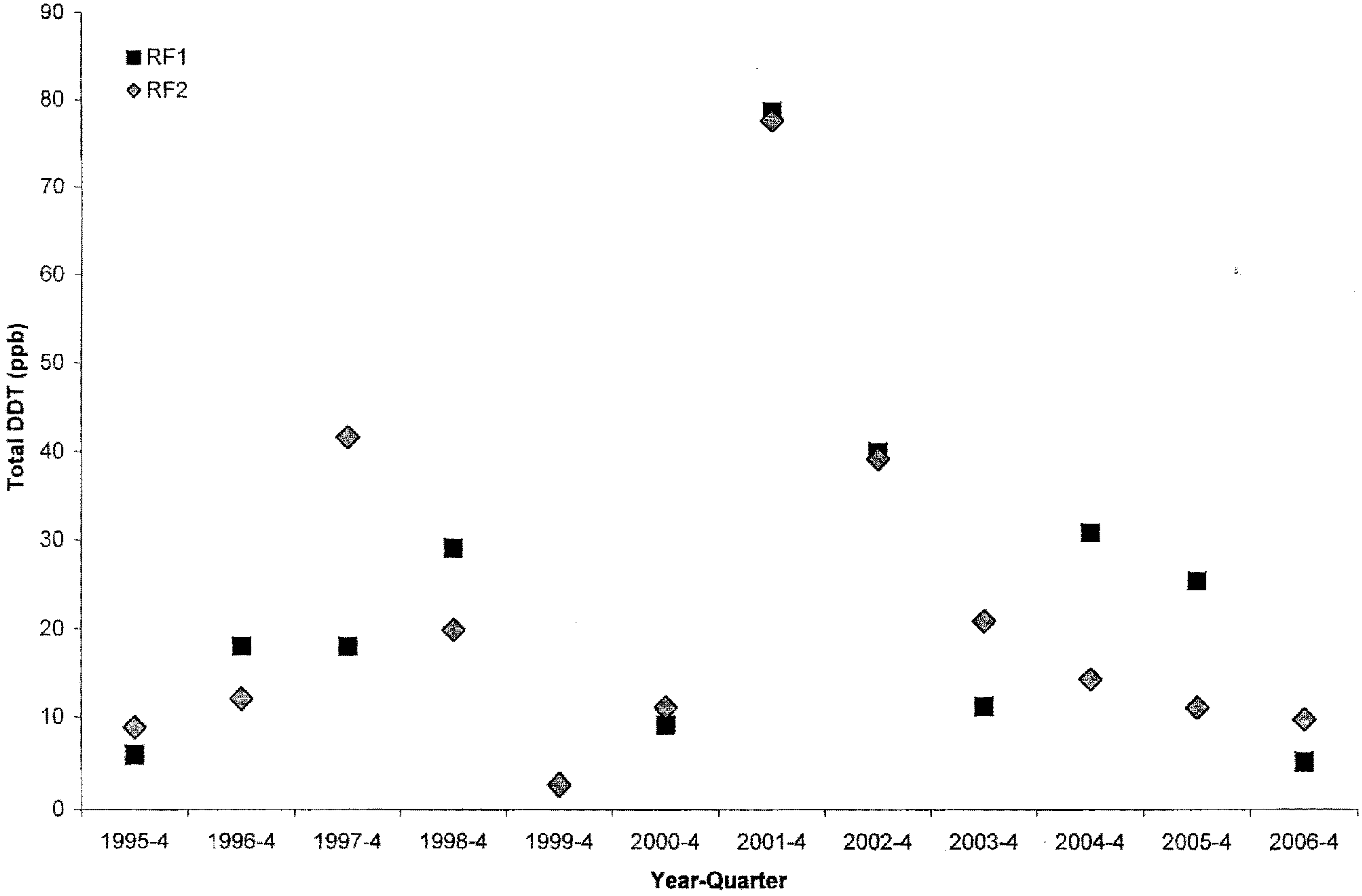

FIGURE F-34. Total DDT concentrations (ppb) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

sanddab tissues show a general decline over time at all stations and zones. This pattern corresponds to changes observed in benthic sediments as well (see Appendix E).

Several other chlorinated pesticides have been detected in fish tissues off Point Loma, but their detection rates and concentrations have consistently been low in muscle tissues, and highly variable in liver tissues (Table F-25). For example, overall detection rates for (beta) endosulphan, endrin, mirex, dieldrin and total BHC were below 5%, while those of hexachlorobenzene and total chlordane were 39% and 52%, respectively. Detection rates for these compounds have risen in recent years as analytical methods have improved. For example, the detection rate of total Chlordane in fish liver tissues was 100% in 2005 and 2006 (City of San Diego 2006, 2007b), while it was often 50% or less prior to 2001. Concentrations of these pesticides were also highly variable, but tended to be highest in California scorpionfish, and longfin and Pacific sanddabs. These pesticides were detected in fish samples from all stations, no matter what distance the stations were from the outfall.

PCBs: PCBs were detected in all but two species of fish collected off Point Loma from October 1995 through 2006, including 91% of liver tissue samples and 43% of muscle tissue samples. Maximum concentrations of total PCB (sum of all congeners detected) was 13,264 ppb in liver tissues and 98.6 ppb in muscles (Table F-26). California scorpionfish, longfin sanddabs, and Pacific sanddabs all averaged slightly higher total PCB concentrations in samples from trawl zone 3 located near the LA-5 disposal site than in samples from the other three zones (Table F-27, Figure F-35). This pattern was especially prevalent in sanddabs with higher PCB concentrations occurring in fish collected near LA-5 during 8 of 12 years (Figure F-36). There also is no distinguishable pattern relative to the outfall in total PCB concentrations in rockfish samples collected at the two rig fishing sites (Table F-27, Figures F-37 and F-38).

A more detailed analysis of the distribution of individual PCB congeners detected in fish tissues revealed similar patterns. For example, 44 different congeners were detected in sanddab liver tissue samples collected between 1995 and 2006 (Figure F-39). Concentrations

Table F-25

Summary of chlorinated pesticide concentrations (ppb) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

		Liver						Muscle					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Mirex	Longfin sanddab	96	5	5	1.70	48.00	11.64	87	0	0	nd	nd	nd
	Pacific sanddab	90	2	2	1.10	3.65	2.37	49	0	0	nd	nd	nd
	Mixed sanddab	1	1	100	3.30	3.30	3.30	1	0	0	nd	nd	nd
	California scorpionfish	126	1	1	1.90	1.90	1.90	121	0	0	nd	nd	nd
	OVERALL SPECIES	452	9	2	1.10	48.00	4.80	407	0	0	0.00	0.00	0.00
Hexachlorobenzene	Bigmouth sole	3	1	33	1.40	1.40	1.40	3	0	0	nd	nd	nd
	Dover sole	9	3	33	0.70	24.00	8.60	10	1	10	0.20	0.20	0.20
	English sole	23	12	52	0.90	2.70	1.61	8	1	13	0.15	0.15	0.15
	Hornyhead turbot	4	2	50	1.70	2.00	1.85	2	0	0	nd	nd	nd
	Longfin sanddab	96	29	30	1.20	13.50	3.93	87	6	7	0.10	4.15	0.81
	Pacific sanddab	90	72	80	1.70	18.00	5.01	49	6	12	0.20	15.00	2.77
	Mixed sanddab	1	1	100	2.30	2.30	2.30	1	0	0	nd	nd	nd
	California scorpionfish	126	32	25	0.80	13.40	3.64	121	12	10	0.10	0.50	0.20
	Bocaccio	2	0	0	nd	nd	nd	2	1	50	0.10	0.10	0.10
	Copper rockfish	12	4	33	2.10	4.65	3.44	18	10	56	0.10	1.00	0.27
	Flag rockfish	5	2	40	1.30	2.00	1.65	5	2	40	0.40	1.98	1.19
	Greenblotched rockfish	3	2	67	1.80	2.80	2.30	3	1	33	0.20	0.20	0.20
	Greenspotted rockfish	3	3	100	0.80	4.00	2.77	4	2	50	0.10	0.30	0.20
	Mixed rockfish	28	5	18	1.50	3.20	2.50	34	11	32	0.10	3.63	0.65
	Speckled rockfish	7	0	0	nd	nd	nd	10	1	10	0.10	0.10	0.10
	Squarespot rockfish	2	0	0	nd	nd	nd	3	2	67	0.10	0.20	0.15
	Starry rockfish	6	1	17	4.80	4.80	4.80	7	2	29	0.20	0.50	0.35
	Vermilion rockfish	28	8	29	1.60	5.30	2.86	32	11	34	0.10	1.33	0.43
	Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.10	0.10	0.10
	OVERALL SPECIES	452	177	39	0.70	24.00	3.24	407	71	17	0.10	15.00	0.10

Table F-25 continued.

		Liver						Muscle					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Endrin	Longfin sanddab	96	1	1	50.00	50.00	50.00	87	0	0	nd	nd	nd
	Pacific sanddab	90	2	2	11.00	90.00	50.50	49	0	0	nd	nd	nd
	California scorpionfish	126	2	2	7.61	68.00	37.80	121	1	1	2.09	2.09	2.09
	OVERALL SPECIES	452	5	1	7.61	90.00	46.10	407	1	0	2.09	2.09	2.09
Dieldrin	Longfin sanddab	96	2	2	14.00	15.80	14.90	87	0	0	nd	nd	nd
	Pacific sanddab	90	1	1	93.00	93.00	93.00	49	0	0	nd	nd	nd
	California scorpionfish	126	2	2	14.30	36.00	25.15	121	1	1	1.39	1.39	1.39
	OVERALL SPECIES	452	15	3	7.61	93.00	45.35	407	3	1	1.39	2.09	1.39
Beta Endosulfan	California scorpionfish	90	1	1	290.00	290.00	290.00	85	0	0	nd	nd	nd
	OVERALL SPECIES	258	1	<1	290.00	290.00	290.00	265	0	0	nd	nd	nd
BHC, Alpha isomer	Longfin sanddab	49	1	2	45.00	45.00	45.00	38	0	0	nd	nd	nd
	Pacific sanddab	76	4	5	6.80	18.00	11.12	29	0	0	nd	nd	nd
	California scorpionfish	80	2	3	5.40	29.50	17.45	80	0	0	nd	nd	nd
	OVERALL SPECIES	290	7	2	5.40	45.00	24.52	238	0	0	nd	nd	nd
BHC, Beta isomer	Longfin sanddab	49	2	4	27.00	53.00	40.00	38	0	0	nd	nd	nd
	Pacific sanddab	76	2	3	5.70	22.00	13.85	29	1	3	0.50	0.50	0.50
	California scorpionfish	80	1	1	74.00	74.00	74.00	80	1	1	1.40	1.40	1.40
	Mixed rockfish	16	0	0	nd	nd	nd	22	1	5	0.60	0.60	0.60
	Squarespot rockfish	0	ns	ns	ns	ns	ns	2	1	50	5.80	5.80	5.80
	OVERALL SPECIES	290	5	2	5.70	74.00	42.62	238	4	2	0.50	5.80	0.50
BHC, Delta isomer	Longfin sanddab	49	1	2	160.00	160.00	160.00	38	0	0	nd	nd	nd
	Pacific sanddab	76	2	3	3.40	43.00	23.20	29	0	0	nd	nd	nd
	California scorpionfish	80	1	1	6.90	6.90	6.90	80	0	0	nd	nd	nd
	Mixed rockfish	16	0	0	nd	nd	nd	22	1	5	0.50	0.50	0.50
	Squarespot rockfish	0	ns	ns	ns	ns	ns	2	1	50	7.60	7.60	7.60
	OVERALL SPECIES	290	4	1	3.40	160.00	63.37	238	2	1	0.50	7.60	0.50

Table F-25 continued.

		Liver						Muscle					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
BHC, Gamma isomer	Longfin sanddab	96	2	2	19.00	130.00	74.50	87	0	0	nd	nd	nd
	OVERALL SPECIES	452	2	<1	19.00	130.00	74.50	407	0	0	nd	nd	nd
tBHC	Longfin sanddab	96	3	3	19.00	388.00	144.67	87	0	0	nd	nd	nd
	Pacific sanddab	90	6	7	6.80	61.00	19.77	49	1	2	0.50	0.50	0.50
	California scorpionfish	126	3	2	6.90	79.40	38.60	121	1	1	1.40	1.40	1.40
	Mixed rockfish	28	0	0	nd	nd	nd	34	1	3	1.10	1.10	1.10
	Squarespot rockfish	2	0	0	nd	nd	nd	3	1	33	13.40	13.40	13.40
	OVERALL SPECIES	452	12	3	6.80	388.00	67.68	407	4	1	0.50	13.40	0.50
Alpha (cis) Chlordane	Longfin sanddab	96	32	33	4.05	58.00	11.37	87	0	0	nd	nd	nd
	Pacific sanddab	90	65	72	2.90	31.00	8.08	49	0	0	nd	nd	nd
	Mixed sanddab	1	1	100	6.00	6.00	6.00	1	0	0	nd	nd	nd
	California scorpionfish	126	17	13	3.20	21.50	8.12	121	4	3	0.40	0.40	0.40
	Bocaccio	2	1	50	3.90	3.90	3.90	2	0	0	nd	nd	nd
	Copper rockfish	12	4	33	7.20	10.50	8.96	18	2	11	0.50	0.70	0.60
	Greenblotched rockfish	3	1	33	4.40	4.40	4.40	3	0	0	nd	nd	nd
	Greenspotted rockfish	3	1	33	5.80	5.80	5.80	4	0	0	nd	nd	nd
	Mixed rockfish	28	2	7	7.10	7.60	7.35	34	5	15	0.30	1.00	0.56
	Squarespot rockfish	2	0	0	nd	nd	nd	3	1	33	0.90	0.90	0.90
	Starry rockfish	6	1	17	9.30	9.30	9.30	7	2	29	0.30	1.30	0.80
	Vermilion rockfish	28	6	21	3.30	13.30	6.58	32	2	6	1.30	1.33	1.31
	OVERALL SPECIES	452	131	29	2.90	58.00	7.26	407	16	4	0.30	1.33	0.76
Gamma (trans) Chlordane	Longfin sanddab	49	4	8	4.80	16.00	10.17	38	0	0	nd	nd	nd
	Pacific sanddab	76	11	14	1.10	21.00	4.38	29	0	0	nd	nd	nd
	California scorpionfish	80	1	1	27.00	27.00	27.00	80	1	1	1.00	1.00	1.00
	Mixed rockfish	16	0	0	nd	nd	nd	22	2	9	0.30	0.60	0.45
	Squarespot rockfish	0	ns	ns	ns	ns	ns	2	1	50	1.00	1.00	1.00
	Vermilion rockfish	17	0	0	nd	nd	nd	21	1	5	0.70	0.70	0.70
	OVERALL SPECIES	290	16	6	1.10	27.00	13.85	238	5	2	0.30	1.00	0.79

Table F-25 continued.

		Liver						Muscle					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Cis Nonachlor	Longfin sanddab	49	8	16	5.70	19.00	12.26	38	0	0	nd	nd	nd
	Pacific sanddab	76	24	32	2.50	7.60	3.98	29	0	0	nd	nd	nd
	California scorpionfish	80	2	3	4.40	13.00	8.70	80	0	0	nd	nd	nd
	Mixed rockfish	16	0	0	nd	nd	nd	22	2	9	0.40	0.50	0.45
	Starry rockfish	2	0	0	nd	nd	nd	3	1	33	0.60	0.60	0.60
	OVERALL SPECIES	290	34	12	2.50	19.00	8.32	238	3	1	0.40	0.60	0.45
Trans Nonachlor	English sole	23	1	4	3.30	3.30	3.30	8	0	0	nd	nd	nd
	Longfin sanddab	96	52	54	4.20	91.00	18.42	87	0	0	nd	nd	nd
	Pacific sanddab	90	71	79	4.50	28.00	10.06	49	0	0	nd	nd	nd
	Mixed sanddab	1	1	100	11.00	11.00	11.00	1	0	0	nd	nd	nd
	California scorpionfish	126	67	53	5.07	78.00	15.92	121	12	10	0.50	1.30	0.83
	Bocaccio	2	1	50	4.70	4.70	4.70	2	0	0	nd	nd	nd
	Copper rockfish	12	7	58	12.50	25.70	18.60	18	7	39	0.10	1.50	0.66
	Flag rockfish	5	3	60	7.50	15.00	10.59	5	1	20	0.90	0.90	0.90
	Greenblotched rockfish	3	2	67	7.20	13.00	10.10	3	0	0	nd	nd	nd
	Greenspotted rockfish	3	2	67	5.80	20.00	12.90	4	1	25	0.40	0.40	0.40
	Mixed rockfish	28	10	36	2.40	27.90	10.29	34	6	18	0.40	1.20	0.67
	Squarespot rockfish	2	0	0	nd	nd	nd	3	1	33	0.40	0.40	0.40
	Starry rockfish	6	2	33	13.90	19.00	16.45	7	2	29	0.30	2.40	1.35
	Vermilion rockfish	28	9	32	4.50	14.00	7.73	32	0	0	nd	nd	nd
	Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	1	50	0.10	0.10	0.10
	OVERALL SPECIES	452	228	50	2.40	91.00	11.54	407	31	8	0.10	2.40	0.66
Heptachlor	Longfin sanddab	96	1	1	12.50	12.50	12.50	87	0	0	nd	nd	nd
	Pacific sanddab	90	0	0	nd	nd	nd	49	1	2	0.30	0.30	0.30
	OVERALL SPECIES	452	1	<1	12.50	12.50	12.50	407	1	<1	0.30	0.30	0.30

Table F-25 continued.

		Liver						Muscle					
Pesticide	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Total Chlordane	English sole	23	1	4	3.30	3.30	3.30	8	0	0	nd	nd	nd
	Longfin sanddab	96	54	56	4.20	128.00	27.27	87	0	0	nd	nd	nd
	Pacific sanddab	90	72	80	6.70	64.00	19.21	49	1	2	0.30	0.30	0.30
	Mixed sanddab	1	1	100	17.00	17.00	17.00	1	0	0	nd	nd	nd
	California scorpionfish	126	68	54	5.07	78.00	18.37	121	13	11	0.50	1.50	0.97
	Bocaccio	2	1	50	8.60	8.60	8.60	2	0	0	nd	nd	nd
	Copper rockfish	12	7	58	15.00	31.50	23.72	18	7	39	0.10	2.20	0.84
	Flag rockfish	5	3	60	7.50	15.00	10.59	5	1	20	0.90	0.90	0.90
	Greenblotched rockfish	3	2	67	11.60	13.00	12.30	3	0	0	nd	nd	nd
	Greenspotted rockfish	3	2	67	5.80	25.80	15.80	4	1	25	0.40	0.40	0.40
	Mixed rockfish	28	11	39	2.40	27.90	10.69	34	7	21	0.50	2.70	1.23
	Squarespot rockfish	2	0	0	nd	nd	nd	3	1	33	2.30	2.30	2.30
	Starry rockfish	6	2	33	13.90	28.30	21.10	7	2	29	0.60	4.30	2.45
	Vermilion rockfish	28	10	36	3.30	22.80	10.91	32	2	6	1.33	2.00	1.66
	Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	1	50	0.10	0.10	0.10
	OVERALL SPECIES	452	234	52	2.40	128.00	15.30	407	36	9	0.10	4.30	1.11

Table F-26

Summary of total PCB concentrations (ppb) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

	Liver						Muscle					
Species	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
Flatfish:												
Bigmouth sole	3	2	67	80.6	82.0	81.3	3	0	0	nd	nd	nd
Dover sole	9	6	67	12.0	222.6	87.3	10	5	50	1.0	10.2	5.9
English sole	23	20	87	39.6	326.5	132.1	8	3	38	0.1	8.8	4.2
Hornyhead turbot	4	4	100	48.0	155.8	93.1	2	0	0	nd	nd	nd
Longfin sanddab	96	96	100	107.0	2929.0	836.4	87	21	24	0.3	14.0	4.1
Pacific sanddab	90	90	100	46.0	2978.0	339.7	49	21	43	0.1	15.6	1.7
Mixed sanddabs	1	1	100	541.3	541.3	541.3	1	1	100	1.0	1.0	1.0
Rockfish:												
California scorpionfish	126	117	93	11.0	13264.0	568.7	121	52	43	0.9	90.0	12.9
Bocaccio	2	2	100	67.6	101.3	84.5	2	2	100	0.8	9.2	5.0
Canary rockfish	1	1	100	703.8	703.8	703.8	1	1	100	15.0	15.0	15.0
Copper rockfish	12	12	100	27.0	1603.6	506.5	18	13	72	1.3	76.8	16.8
Flag rockfish	5	5	100	101.0	2227.0	897.5	5	3	60	0.3	33.7	19.5
Greenblotched rockfish	3	2	67	384.3	1175.0	779.7	3	2	67	12.5	18.6	15.6
Greenspotted rockfish	3	3	100	251.6	545.3	363.7	4	4	100	3.5	13.3	6.9
Halfbanded rockfish	3	0	0	nd	nd	nd	3	0	0	nd	nd	nd
Mixed rockfish	28	23	82	6.6	5320.0	653.7	34	19	56	0.8	98.6	23.3
Rosethorn rockfish	0	ns	ns	ns	ns	ns	1	1	100	0.8	0.8	0.8
Speckled rockfish	7	0	0	nd	nd	nd	10	2	20	1.3	5.0	3.2
Squarespot rockfish	2	1	50	398.0	398.0	398.0	3	3	100	3.2	5.0	4.0
Starry rockfish	6	5	83	134.0	448.3	241.7	7	4	57	7.3	54.0	26.0
Stripetail rockfish	0	ns	ns	ns	ns	ns	1	0	0	nd	nd	nd
Vermilion rockfish	28	23	82	33.1	979.4	233.9	32	17	53	1.1	28.0	6.5
Yellowtail rockfish	0	ns	ns	ns	ns	ns	2	2	100	0.5	1.2	0.9
OVERALL SPECIES	452	413	91	6.6	13264.0	419.0	407	176	43	0.1	98.6	9.1

TABLE F-27

Summary of total PCB concentrations (ppb) in scorpionfish and sanddab tissues by trawl zone, and rockfish at rig fishing stations. Data are summarized over all samples collected during the April and October surveys between October 1995-April 2003 for scorpionfish and October 1995-October 2006 for sanddabs and rockfish. CI = confidence interval.

Scorpionfish	Liver			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	45.0	38.0	8.0	17.0
Min	40.0	11.0	32.0	94.0
Max	2345.0	13264.0	3066.0	1004.0
Mean	500.2	705.6	904.3	393.6
Median	435.0	219.9	402.0	336.4
95% CI	124.2	678.0	728.2	112.5

	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	25.0	14.0	4.0	7.0
Min	0.9	1.2	2.4	1.7
Max	90.0	69.4	20.3	23.1
Mean	15.4	10.3	9.1	12.7
Median	6.7	4.0	6.9	15.0
95% CI	8.1	9.2	8.0	6.0

Sanddabs	Liver			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	45	65	38	38
Min	134.3	46.0	119.5	66.4
Max	2129.4	1797.3	2978.0	1626.0
Mean	648.6	389.8	956.6	526.1
Median	513.0	305.2	683.1	516.4
95% CI	140.7	72.6	248.5	101.4

	Muscle			
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
N	9	16	10	7
Min	0.1	0.2	0.3	0.2
Max	14.0	15.6	12.5	3.2
Mean	2.4	2.8	4.4	1.6
Median	0.8	0.6	2.35	1.4
95% CI	2.9	2.1	2.9	0.7

Rockfish	Liver		Muscle	
	RF1	**RF2**	**RF1**	**RF2**
N	38	26	30	32
Min	27.0	6.6	0.8	0.3
Max	1603.6	1677.0	76.8	89.3
Mean	358.4	272.3	13.1	13.7
Median	200.5	139.4	6.7	5.0
95% CI	110.8	132.9	5.6	7.2

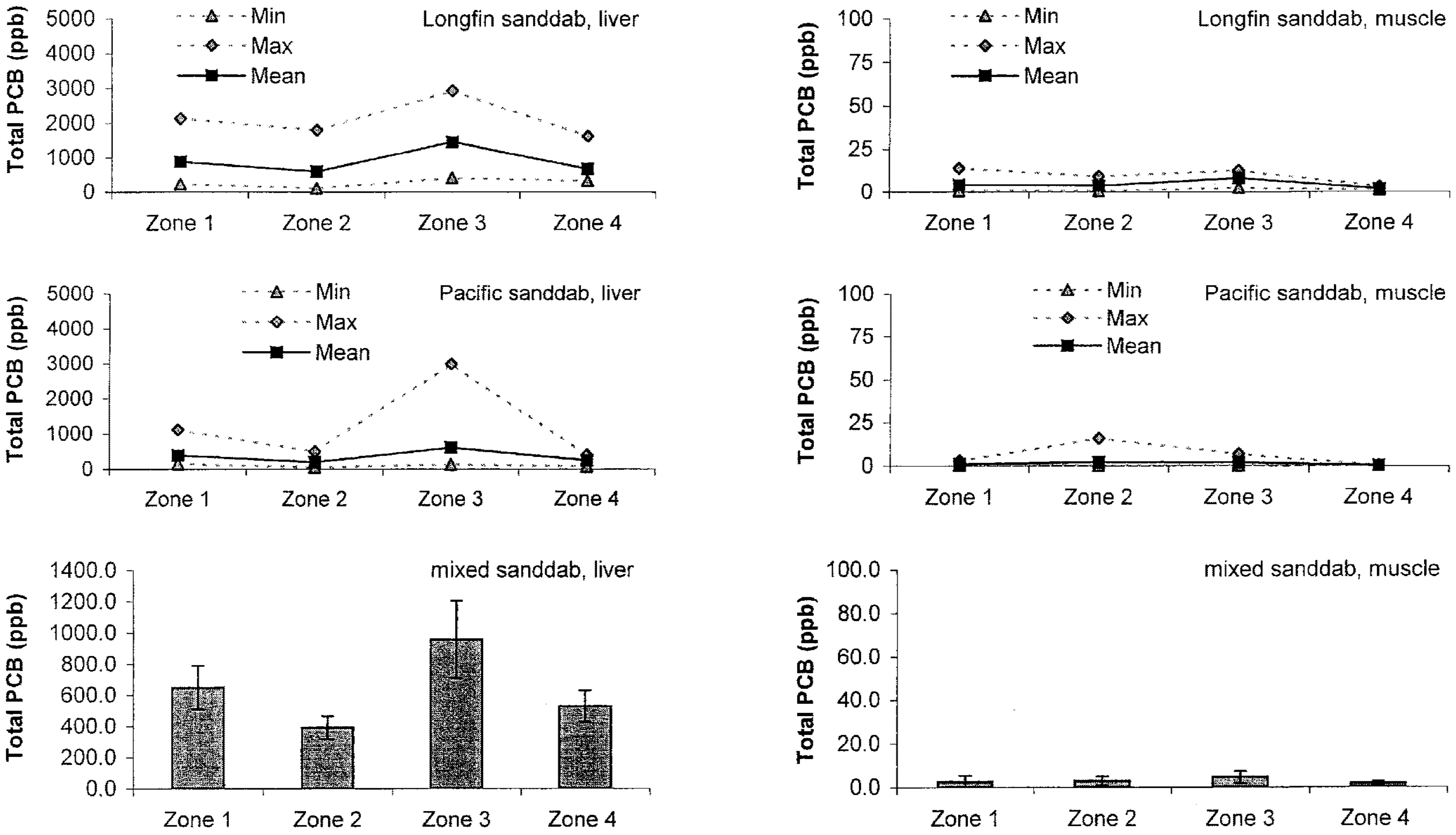

FIGURE F-35. Comparisons of total PCB concentrations (ppb) in sanddabs by trawl zone. Liver data are summarized over all surveys (April and October) between October 1995 and October 2006; muscle data are summarized over all surveys (April and October) between October 1995 and April 2003. Data for mixed sanddabs (liver and muscle) are means +/- 95% confidence limits.

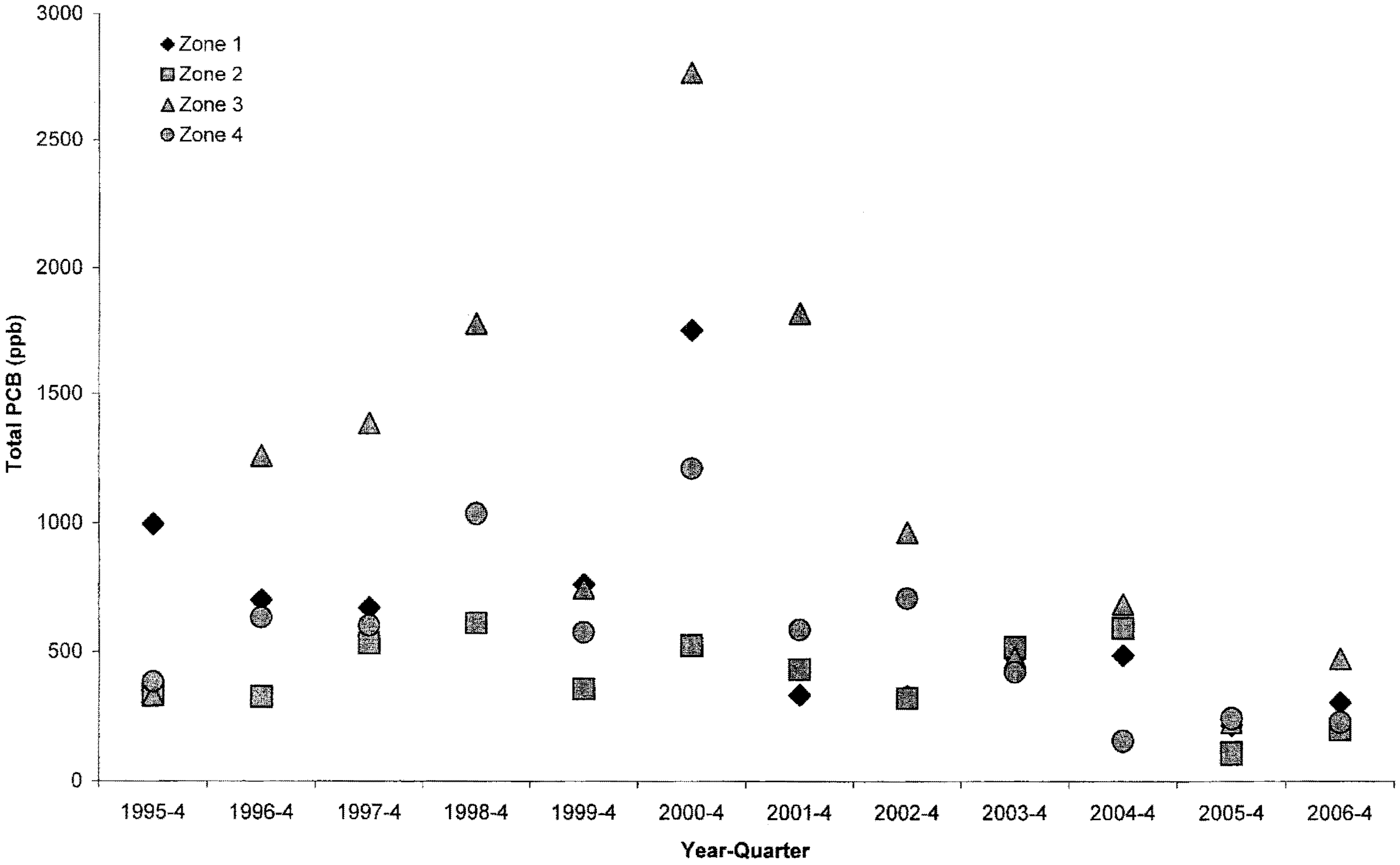

FIGURE F-36. Total PCB concentrations (ppb) in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4 for October surveys from 1995-2006.

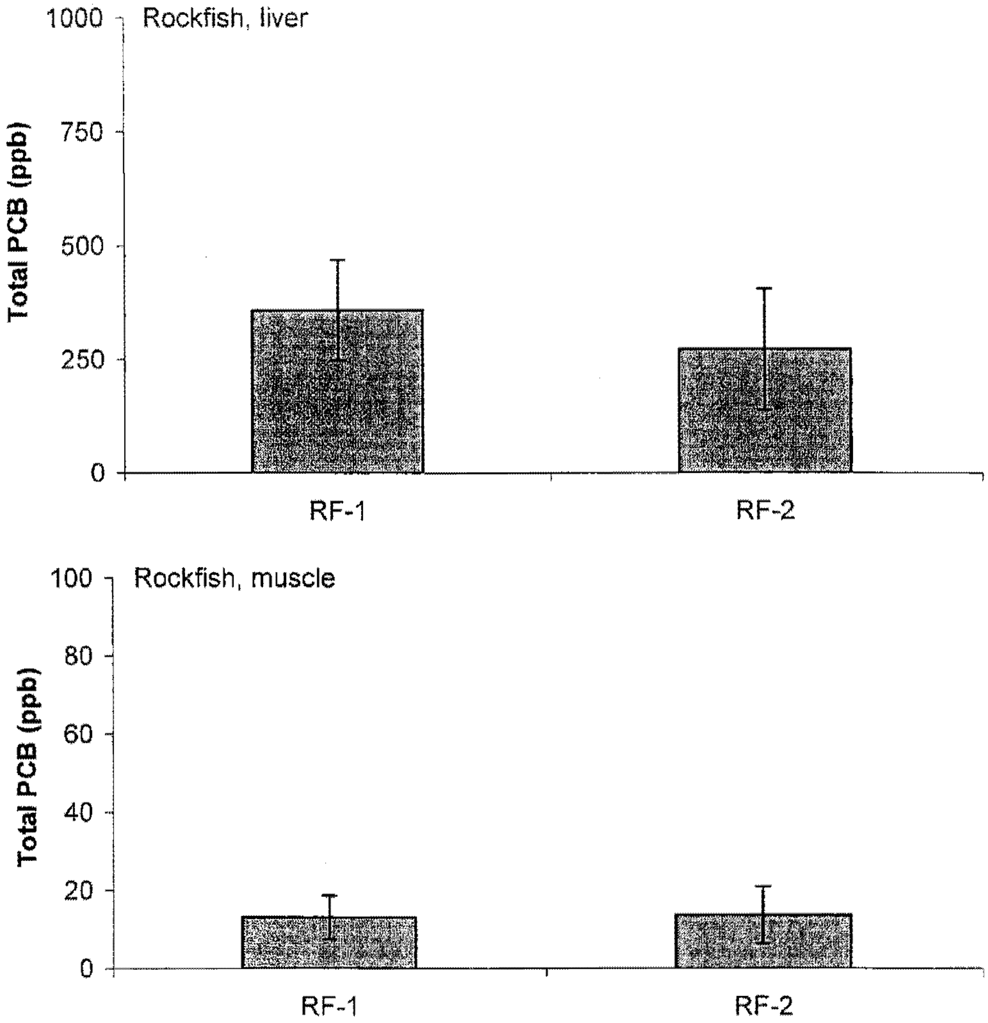

FIGURE F-37. Comparison of total PCB concentrations in rockfish by rig fishing station. Data are means +/- 95% confidence intervals and are summarized over all surveys (April and October) between October 1995 and October 2006.

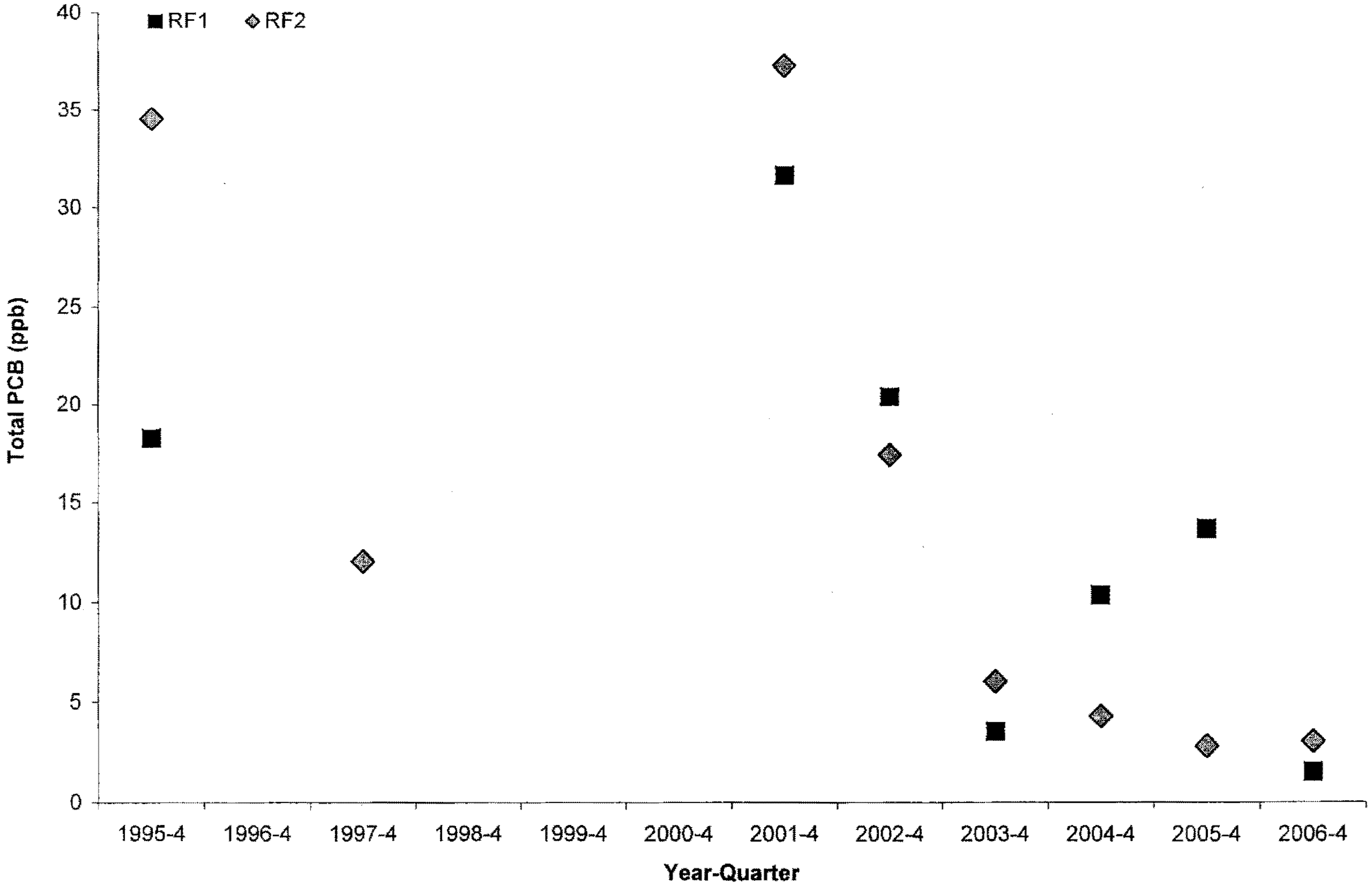

FIGURE F-38. Total PCB concentrations (ppb) in rockfish muscle tissue from rig fishing stations for October surveys from 1995-2006.

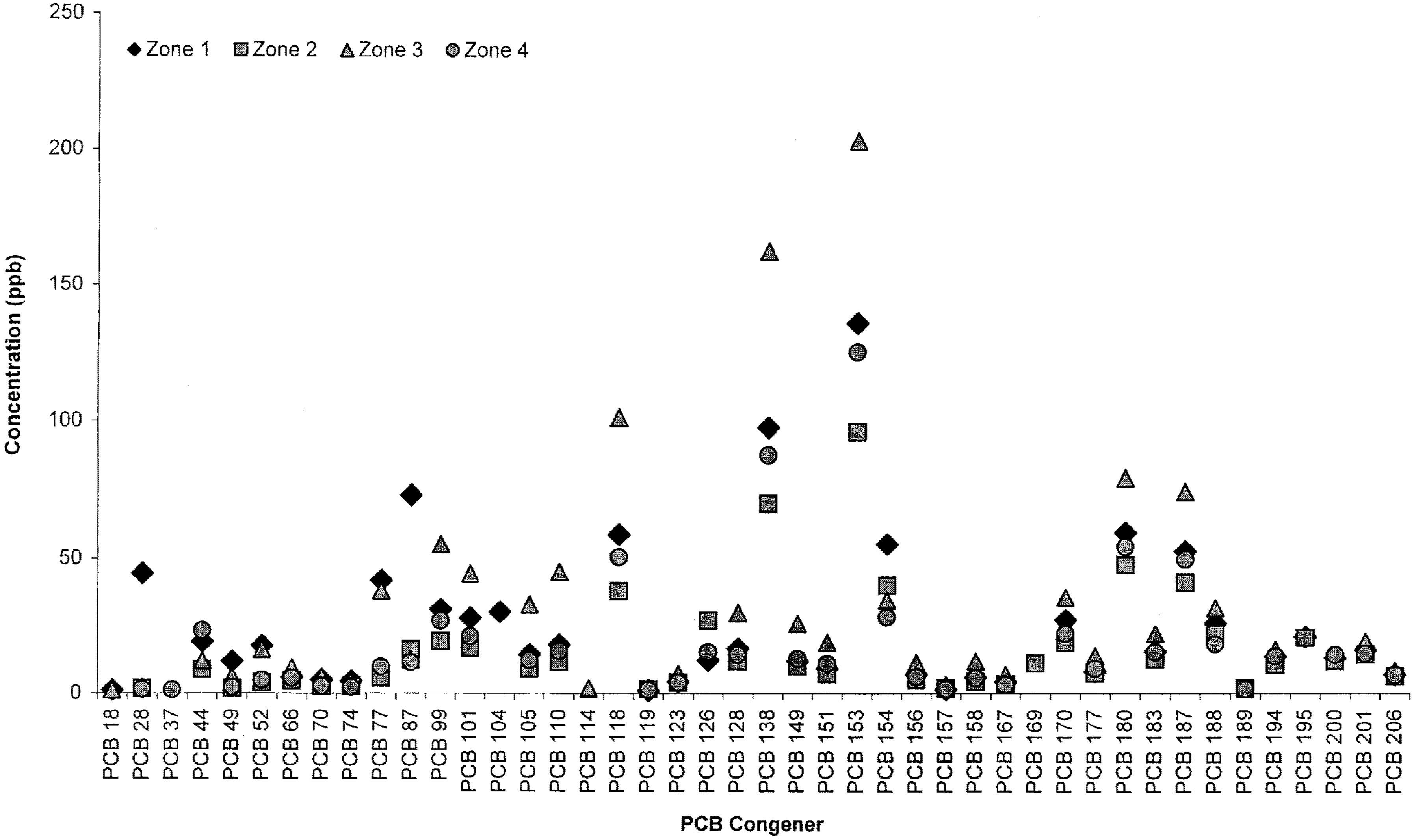

FIGURE F-39. Concentrations (ppb) of individual PCB congeners in sanddab guild liver tissue for trawl Zone 1 versus Zones 2-4. Data are means of all surveys (April and October) sampled between 1995-2006.

of most of these PCBs were highest in fish collected near the LA-5 site (i.e., trawl zone 3). The five congeners with the highest concentrations in liver tissues were PCB-153/168, PCB-138, PCB-118, PCB-180, and PCB-187. In contrast, a total of 34 different congeners were detected in rockfish muscle samples during this period (Figure F-40). Most concentrations were very low (<1 ppb), with the three highest values (~4-9 ppb) being for congeners PCB-126, PCB-87, and PCB-8. Overall, there were no patterns consistent with an outfall effect.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) consist of two or more benzene rings fused in linear or cluster arrangements, and are a fraction of the hydrocarbons found in fossil fuels (Mearns et al. 1991). Fish rapidly metabolize most PAH compounds and excrete them in bile, therefore making them hard to detect in fish tissues. For that reason, PAHs were eliminated from the NPDES permit that took effect in October 2003. Between October 1995 and April 2003, PAHs were detected in 4 of 371 liver samples (~1%) and 2 of 387 muscle samples (~0.5%) (Table F-28). PAHs that were detected include 1-methylphenanthrene, 2,3,5-trimethylnaphthalene, 2,6-dimethylnaphthalene, anthracene, benzo(A)anthracene, benzo(e)pyrene, biphenyl, dibenzo(A,H)anthracene, fluoranthene, perylene, phenanthrene, and pyrene.

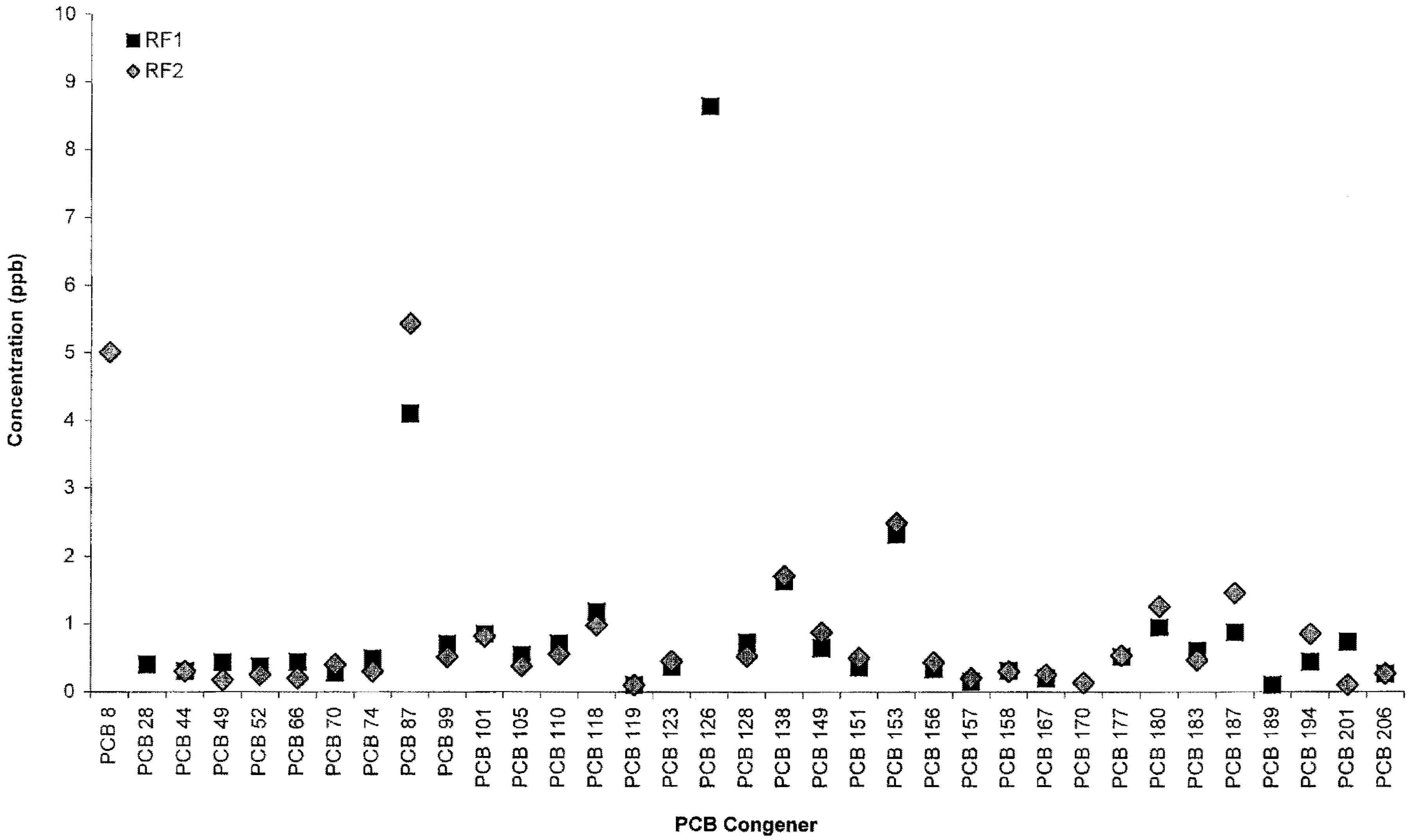

FIGURE F-40. Concentrations (ppb) of individual PCB congeners in rockfish muscle tissue for each rig fishing station. Data are means of all surveys (April and October) sampled between 1995-2006.

Table F-28

Summary of PAH concentrations (ppb) in liver and muscle tissue samples for each fish species sampled between October 1995 and October 2006. Data are summarized over all samples collected at all trawl and rig fishing stations during all surveys (April and October); ns=not sampled, na=not analyzed, nd=not detected.

		Liver						Muscle					
Parameter	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
1-methylphenanthrene	California scorpionfish	125	1	1	220	220	220	120	0	0	nd	nd	nd
	Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	220	220	220
2,3,5-trimethylnaphthalene	Pacific sanddab	41	1	2	451	451	451	49	0	0	nd	nd	nd
2,6-dimethylnaphthalene	Pacific sanddab	41	1	2	417	417	417	49	0	0	nd	nd	nd
Anthracene	California scorpionfish	125	1	1	240	240	240	120	0	0	nd	nd	nd
Benzo[A]anthracene	California scorpionfish	125	1	1	315	315	315	120	0	0	nd	nd	nd
Benzo[e]pyrene	Vermilion rockfish	28	0	0	nd	nd	nd	28	1	4	230	230	230
Biphenyl	Pacific sanddab	41	1	2	485	485	485	49	0	0	nd	nd	nd
Dibenzo(A,H)anthracene	California scorpionfish	125	1	1	170	170	170	120	0	0	nd	nd	nd
Fluoranthene	California scorpionfish	125	1	1	200	200	200	120	0	0	nd	nd	nd
	Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	200	200	200
Perylene	California scorpionfish	125	1	1	515	515	515	120	0	0	nd	nd	nd
	Mixed rockfish	28	1	4	221	221	221	31	0	0	nd	nd	nd
Phenanthrene	Longfin sanddab	85	1	1	79	79	79	87	0	0	nd	nd	nd
	California scorpionfish	125	1	1	260	260	260	120	0	0	nd	nd	nd
Pyrene	California scorpionfish	125	1	1	240	240	240	120	0	0	nd	nd	nd

Table F-28 continued.

		Liver						Muscle					
Parameter	**Species**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**	**Total**	**Detect**	**Freq**	**Min**	**Max**	**Avg**
tPAH	Longfin sanddab	85	1	1	79	79	79	87	0	0	nd	nd	nd
	California scorpionfish	125	1	1	2160	2160	2160	120	0	0	nd	nd	nd
	Pacific sanddab	41	1	2	1353	1353	1353	49	0	0	nd	nd	nd
	Mixed rockfish	28	1	4	221	221	221	31	0	0	nd	nd	nd
	Stripetail rockfish	0	ns	ns	ns	ns	ns	1	1	100	420	420	420
	Vermilion rockfish	28	0	0	nd	nd	nd	28	1	4	230	230	230
	OVERALL FISH	371	4	1	79	2160	953	387	2	1	230	420	325

Section F.5 – Summary and Conclusions

Concentrations of metals and organic compounds detected in tissue samples from fish collected off Point Loma are within the range of concentrations found throughout Southern California Bight (SCB) fish assemblages (see Mearns et al. 1991, Allen et al. 1998, 2002). In addition, concentrations of these contaminants were generally similar to those reported previously by the City of San Diego for this survey area. Concentrations of most measured parameters were similar in fish across trawl zones or stations, and no relationships were evident with proximity to the outfall.

The occurrence of metals and chlorinated hydrocarbons in local fish tissues may be due to many factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs, as being ubiquitous in the SCB. In addition, certain areas along the San Diego shelf (e.g., trawl zones 2–4, station RF2) have sediments containing relatively high concentrations of these contaminants (see Appendix E, Section E.4). Further, many metals (e.g., aluminum, arsenic, iron, and selenium) occur naturally in the environment, and little information is available on background levels in fish tissues. In fact, Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work regarding PCBs and DDT in southern California waters (e.g., Allen et al. 1998, 2002).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different species of fish. For example, exposure to contaminants can vary greatly between species and also among individuals of the same species depending on migration habits (Otway 1991). Fish may be exposed to contaminants in one highly contaminated area and then move into an area that is less contaminated. This may explain why many of the pesticides and PCBs detected in fish off Point Loma were found in either low concentrations or not detected at all in sediments surrounding the outfall. In addition, differences in feeding habits, age, reproductive status, and gender can affect the amount of contaminants a fish will retain in its tissues (e.g., Connell 1987, Evans et al. 1993). These factors make comparisons of contaminants among species and between stations complex.

Overall, there was no evidence that the discharge of wastewater via the Point Loma outfall has caused abnormal body burdens of any toxic pollutants known to have adverse effects on marine fishes or their consumers. Fishes collected in the region do not appear to be significantly affected by the discharge of wastewater from the outfall or from other possible sources of contamination. For example, concentrations of mercury and DDT in the muscles of sport fish collected in the area were below FDA human consumption limits. Finally, the absence of physical abnormalities or any indication of disease (e.g., fin rot, tumors) on local fishes indicates that populations in the Point Loma region remain healthy after 13 years of wastewater discharge (e.g., see City of San Diego 2007b).

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