HAWK INLET MONITORING PROGRAM 2017 ANNUAL REPORT

Hecla Greens Creek Mining Company

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HAWK INLET MONITORING PROGRAM 2017 ANNUAL REPORT

1. INTRODUCTION

1.1 Site Description

The Greens Creek Mine on Admiralty Island is located 18 miles southwest of the city of Juneau, Alaska. Dense forests cover the mountain slopes up to an elevation of 2,500 feet, above which the vegetation is alpine. The climate is maritime, with precipitation similar to that in Juneau, averaging 60 to 70 inches per year at the mine site, and 45 to 55 inches per year near the port facilities. The mine and mill facilities (920 area) are located over 6 miles from Hawk Inlet tidewater.

Zinc, lead, silver, and gold are the target recovery metals. The Greens Creek Mine production of ore concentrate began in February 1989, and operated approximately four years before production was suspended in April 1993. The mine and mill were recommissioned and operations restarted in mid-1996. A milling facility and appurtenant support facilities are in place at the 920 area. Filter pressed tailings from the milling process are backfilled in the mine and also deposited at a surface dry-stack tailings pile. Ore concentrate (concentrate) is transported from the mill to the Hawk Inlet port facilities area (Port), where it is stored until it is shipped offsite. Support facilities to the mining and milling operation at the Port include rock core storage, concentrate storage, shipping port, and shift housing. A domestic waste water treatment plant is also located at the Port.

One wastewater discharge outfall and 10 stormwater discharge sites are authorized by the HGCMC Alaska Pollutant Discharge Elimination System (APDES) Permit Number AK-004320-6. Sewage effluent previously discharged through Outfall 001 is combined with area surface runoff, and pumped to Pond 7. At Pond 7, the water is combined with effluent streams from the 920 and the Tailings Facility, treated, and discharged through the submarine APDES Outfall 002 to the ocean at the mouth of Hawk Inlet. Authority over the federal permitting, compliance and enforcement of the NPDES program transferred to the State in November of 2010 for the mining industry. This report fulfills the requirements of APDES Permit Number AK-004320-6, reissued October 1st, 2015.

Hawk Inlet is a marine inlet formed during the late Holocene glaciation and is underlain by a series of late-Paleozoic to Mesozoic phyllitic-schist and greenstone formations. Hawk Inlet extends seven miles north from Chatham Strait to a tidal mudflat estuary about 0.6

miles in diameter. The narrow channel connecting the Inlet to Chatham Strait, located between the top of the Greens Creek delta and the western shore of Hawk Inlet, has a minimum low tide depth of 35 feet. The mid-channel depth ranges from 35 feet to 250 feet. The Inlet has regular, twice-daily tides, with a maximum tidal variation of 25 feet. On the flood tide, the surface 35-foot layer contains the bulk of the water transport entering the Inlet and is then flushed out on the ebb tide. Flushing describes the rate and extent to which a body of water is replenished by tidal or other currents. Flushing rates are also indicative of the length of time that mining effluent may remain in a water body and become incorporated into the physical and biological ecosystem through ingestion, adsorption or other means. In 1983, dispersion dye testing in Hawk Inlet determined that over each tidal cycle, an average of 13 billion gallons of water is flushed from the Inlet (SEA 1983). At that rate, it is estimated that the Inlet completely flushes once every five tidal cycles. Based on the average daily output in 2017, the input of effluent from the mining operations over a day represents approximately 0.007% of the total volume flushed daily.

Greens Creek geology exploration began in 1973, which led to predevelopment of mining operations in 1986. Prior to this the Hawk Inlet cannery was constructed in 1910 and operated until it burned in 1976. It is estimated the summer population at Hawk Inlet during cannery operation was 500. Additionally, up until 1946, gold was being mined near Hawk Inlet beginning in 1919 at the Alaska Empire Mine (Forest Service 2013). "In September 2014, the Forest Service conducted a Preliminary Assessment/Site Inspection of the Alaska Empire Mine site. Elevated concentrations of metals were found in the soil, sediment, surface water and groundwater at the Upper Camp as well as soil stained by petroleum hydrocarbons. Tailings piles with elevated concentrations remain adjacent to the creek and continue to erode tailings into the creek." (Palmieri 2016)

Factor in the historical and current use of Hawk Inlet's commercial fishing industry and there is a substantial amount of anthropogenic effects which cannot all be attributable to the Greens Creek mining operation.

1.2 Hawk Inlet Monitoring Program

In anticipation of the Greens Creek Mine development, government agencies, scientists and biological consultants carried out surveys of marine life and baseline studies of heavy metals in the environment beginning in the early 1980s. Several researchers have studied marine life in Hawk Inlet, and the on-going quarterly, semi-annual, and annual monitoring events have generated an extensive time-series data set of coincident metal levels in water, sediment, and marine tissue samples.

The primary objective of the Hawk Inlet monitoring program is to document the water quality, sediment chemistry, and biological conditions in receiving waters and marine environments that may be impacted by the mine's operations. Sea water is sampled quarterly at three locations in Hawk Inlet. Sediment and invertebrate samples are collected annually at three (five locations every three years) and seven locations, respectively (Figure 1-1). Table 1-1 summarizes the requirements of the permit for sample parameters, sample preservation and holding time, sampling frequency, analytical method and required method detection limits (MDL). Specific quality assurance/quality control (QA/QC) requirements (i.e., sampling procedures, documentation, chain of custody processes, calibration procedures and frequency, data validation, corrective actions, etc.) are outlined in the NPDES Quality Assurance Plan: Project Monitoring Manual (HGCMC 2015).

Table 1-1. Summary of Permit Sampling Requirements for Hawk Inlet

APDES Requirement	Parameter	Required Sampling Frequency	Sample Type	Sample Container	Sample Preservation	Laboratory	Holding Time	Analytical Method(s)	Minimum Required Method Detection Limit	Units	Comments
RECEIVING WATER COLUMN MONITORING											
1.6.1.1.3 Table 5	Dissolved Cadmium	Quarterly	Grab (1 sample for Cd, Cu, Pb, Zn)	1 ea. 500 ml Teflon bottle (1 bottle for Cd, Cu, Pb, Zn)	HNO_3 to pH <2 by lab	Battelle Marine Sciences	6 months	EPA 213.2/ 1638	0.10	µg/L	MDLs set by APDES permit Section 1.6.1.1.3, Table 5
1.6.1.1.3 Table 5	Dissolved Copper	Quarterly						EPA 220.2/ 1638	0.03	µg/L	
1.6.1.1.3 Table 5	Dissolved Lead	Quarterly						EPA 239.2/ 1638	0.05	µg/L	
1.6.1.1.3 Table 5	Dissolved Zinc	Quarterly					6 months	EPA 289.2/ 1638	0.200	µg/L	
1.6.1.1.3 Table 5	Total Mercury	Quarterly	Grab	1 ea. 250 ml Teflon bottle			28 days	EPA 245.1/ 1631	0.002	µg/L	
1.6.1.1.3 Table 5	Total Suspended Solids	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	ACZ Labs	7 days	EPA 160.2/ SM 2540D	--	mg/L	
1.6.1.1.3 Table 5	Turbidity	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	Field measurement	48 hours	EPA 180.1	--	NTU	
1.6.1.1.3 Table 5	WAD Cyanide	Quarterly	Grab	1 ea 1 liter plastic bottle	NaOH to pH >12, cool to 4°C	ACZ Labs	14 days	EPA 335.2/ SM 4500-CN-E	5.00	µg/L	Add 0.6g ascorbic acid, if chlorine is present.
1.6.1.1.3 Table 5	pH	Quarterly	Grab	NA	NA	Field measurement	15 min	EPA 150.1/ SM 4500-H, B	--	SU	
1.6.1.1.3 Table 5	Conductivity	Quarterly	Grab	NA	NA	Field measurement	20 days	EPA 120.1	--	µmhos/cm	
1.6.1.1.3 Table 5	Temperature	Quarterly	Grab	NA	NA	Field measurement	15 min	NA	--	°C	
BIOACCUMULATION WATER SEDIMENT MONITORING											
1.6.1.2.3 Table 6	Total Cadmium	Annual	Grab	6 ea. 8 oz. plastic or glass jar	Chill and ice sample (not frozen)	ALS Environmental		PSEP/GFAA	0.30	mg/Kg	MDLs set by APDES permit Section 1.6.1.2.3, Table 6
1.6.1.2.3 Table 6	Total Copper	Annual	Grab			ALS		PSEP/ICP	15.00	mg/Kg	
1.6.1.2.3 Table 6	Total Lead	Annual	Grab			ALS		PSEP/ICP	0.50	mg/Kg	NMFS request dupilicate sampling
1.6.1.2.3 Table 6	Total Mercury	Annual	Grab			ALS		PSEP/ EPA 7471A	0.02	mg/Kg	
1.6.1.2.3 Table 6	Total Zinc	Annual	Grab			ALS		PSEP/ICP	15.00	mg/Kg	
BIOACCUMULATION WATER IN-SITU BIOASSAY MONITORING											
1.6.1.3.2 Table 7	Total Cadmium	Annual	Grab	6 ea. 8 oz. plastic or glass jar	Chill and ice sample (not frozen)	ALS		EPA 200.8/ 6020	not specified	mg/Kg	NMFS request dupilicate sampling since Fall 2004
1.6.1.3.2 Table 7	Total Copper	Annual	Grab			ALS		EPA 200.8/ 6020	not specified	mg/Kg	
1.6.1.3.2 Table 7	Total Lead	Annual	Grab			ALS		EPA 200.8/ 6020	not specified	mg/Kg	
1.6.1.3.2 Table 7	Total Mercury	Annual	Grab			ALS		EPA 7471A	not specified	mg/Kg	
1.6.1.3.2 Table 7	Total Zinc	Annual	Grab			ALS		EPA 200.8/ 6020	not specified	mg/Kg	

In May 2017, Marine Taxonomic Services surveyed the 002 Outfall pipeline for corrosion and damage. A CD of the survey footage can be found as Appendix B. The following points summarize the major findings of the inspection:

- The outfall pipeline and hardware is in good overall condition. No cracks or leaks were found, and all
- The zinc anode end caps installed to protect the stainless hardware show considerable corrosion in some cases. Those caps are being maintained through replacement of approximately 1/3rd of the caps per annual inspection event.
- The minimal sediment accretion inside the diffuser is not a threat to discharge flow rates and requires no maintenance or removal at the present time.

This report presents information on each of the three media sampled in Hawk Inlet: water column, sediment, and in-situ bioassay. Results for the samples collected in 2017 are presented, along with the associated QA/QC data. Statistical evaluation of the data showing averages, variations, and changes over time are also included. The next section describes any deviations from the monitoring program that occurred in 2017, and the reasons for the deviations.

1.3 Deviation(s) from Monitoring Program and Incidents

There were no reportable deviations in the 2017 monitoring program.

2. WATER COLUMN MONITORING

The receiving water column monitoring requirements originate from Section 1.6.1.1 and Table 5 of the APDES permit. The objective of the receiving water column monitoring element of the sampling program is to provide scientifically valid data on specific physical and chemical parameters for Hawk Inlet water quality. These data are used to evaluate potential changes in the Hawk Inlet marine environment.

In fulfillment of the first EPA issued NPDES permit in 1987, Greens Creek Mining Company sampled quarterly at five locations (104, 105, 106, 107, and 108) for ten total recoverable metals (Ag, As, Ni, Zn, Cd, Cr, Cu, Hg, Pb, and Se) at depths of five feet and 20 feet. In 1998 the NPDES permit was reissued, with the number of sample locations reduced to three (106, 107, and 108) and a reduction in the metals analyzed to five metals (Cd, Cu, Pb, Hg, and Zn), collected at a depth of five feet on a quarterly basis.

Currently three seawater sites in Hawk Inlet are sampled to monitor potential water quality effects from the mine. Seawater samples are collected quarterly from the sites on an outgoing tide, with the Chatham Strait sample (Site 106) collected just after low slack water. The two other sites are Station 107, located about mid-way east-west in Hawk Inlet and west of the ship loader facility, and Station 108, located proximal to the 002 diffuser in the mixing zone. Samples at all three locations are taken at a depth of five feet. Sample timing in each quarter is tide and weather dependent.

Water samples are sent to Battelle Marine Science Lab in Sequim, Washington, for low level dissolved trace metals analyses (Cd, Cu, Pb, and Zn), total mercury and ACZ Laboratories in Steamboat Springs, Colorado for WAD CN and total suspended solids analyses. Temperature, pH, turbidity and conductivity are measured in the field by the Environmental staff.

2.1 Analytical Results

The tables in this section summarize the results for the quarterly water column monitoring conducted in 2017.

Table 2-1. Hawk Inlet Field Parameters 2017 (sample depth 5')

Quarter	Sample date	Site Number	Sample Time	Water Temperature (°C)	pH (s.u.)	Conductivity (umhos/cm @ 25°C)	Turbidity (NTU)
1	28-Mar-17	106	08:27	4.3	7.8	50,500	2.77
		107	07:52	4.1	7.76	50,200	1.41
		108	08:08	4.2	7.77	50,400	3.28
2	16-May-17	106	11:50	6.9	8.26	50,400	1.34
		107	11:15	8.3	8.23	47,890	1.7
		108	11:35	7.3	8.26	49,500	2.01
3	15-Aug-17	106	13:55	11.8	8.11	47,250	0.91
		107	13:20	12.7	8.16	46,300	0.63
		108	13:35	12.7	8.17	46,220	0.88
4	24-Oct-17	106	09:45	7.6	7.77	47,060	2.78
		107	10:25	7.4	7.82	46,050	2.09
		108	10:05	7.7	7.84	46,510	2.28

Table 2-2. Hawk Inlet Water Column Monitoring: Nonmetal Parameters (ACZ Laboratories) (sample depth 5')

Site	Sample Quarter	TSS (mg/L)	WAD CN (µg/L)
	Lab MDL	*(5.0)*	*(3.0)*
	Req. MDL		*(5.0)*
106	1	23	-3
	2	26	-3
	3	19	-3
	4	11	-3
107	1	25	-3
	2	65	-3
	3	29	-3
	4	17	-3
108	1	22	-3
	2	49	-3
	3	22	-3
	4	8	-3

Note: "-" denotes the sample was analyzed for, but was not detected above the level of the method detection limit.

Table 2-3. Hawk Inlet Water Column Monitoring Results: Metals (Battelle Marine Sciences Laboratory) (sample depth 5')

Site	Sample Quarter	Cd (µg/L) Dissolved	Cu (µg/L) Dissolved	Hg (µg/L) Total	Pb (µg/L) Dissolved	Zn (µg/L) Dissolved
	Lab MDL	*(0.002)*	*(0.023)*	*(0.0001)*	*(0.001)*	*(0.042)*
	Req. MDL	*(0.10)*	*(0.03)*	*(0.002)*	*(0.05)*	*(0.20)*
106	1	0.0828	0.177	0.000186	0.01070	0.32
	2	0.0735	0.199	0.000191	0.00706	0.09
	3	0.0506	0.169	0.000182	0.00388	-0.04
	4	0.0760	0.218	0.000320	0.00361	0.26
107	1	0.0864	0.203	0.000215	0.00548	0.43
	2	0.0704	0.248	0.001350	0.00587	0.28
	3	0.0418	0.189	0.000141	0.00612	0.07
	4	0.0760	0.279	0.000435	0.01170	0.50
108	1	0.0868	0.201	0.000237	0.00800	0.48
	2	0.0730	0.206	0.000238	0.00620	0.18
	3	0.0451	0.209	0.000279	0.00625	0.35
	4	0.0771	0.226	0.000302	0.00355	0.28

Note: "-" denotes the sample was analyzed for, but was not detected above the level of the method detection limit.

Table 2-4 Site 35 APDES Outfall 002 and Water Column Site 108 Results

Site	Analyte	Units	Quarter 1	*MDL*	Quarter 2	*MDL*	Quarter 3	*MDL*	Quarter 4	*MDL*
APDES Outfall 002 Site 35	Cd Total	µg/L	0.7	0.1	-0.1	0.1	-0.1	0.1	0.3	0.1
	Cu Total	µg/L	1.2	0.5	0.6	0.5	0.4	0.4	1	0.4
	Hg Total	µg/L	-0.2	0.2	-0.2	0.2	-0.2	0.2	-0.2	0.2
	Pb Total	µg/L	31.7	0.1	41.9	0.1	39.6	0.1	10.1	0.1
	Zn Total	µg/L	85.0	2	16.0	2	12.0	2	61.0	2
	TSS	mg/L	-5.0	5	-5.0	5	-5.0	5	-5.0	5
	WAD CN	µg/L	-3.0	3	-3.0	3	-3.0	3	-3.0	3
	pH	s.u.	8.22	--	8.26	--	7.96	--	7.93	--
Water Column Site 108	Cd Dissolved	µg/L	0.0868	0.002	0.0730	0.002	0.0451	0.002	0.0771	0.002
	Cu Dissolved	µg/L	0.201	0.023	0.206	0.023	0.209	0.023	0.226	0.023
	Hg Total	µg/L	0.0002	0.0001	0.0002	0.0001	0.0003	0.0001	0.0003	0.0001
	Pb Dissolved	µg/L	0.0080	0.001	0.0062	0.001	0.0063	0.001	0.0036	0.001
	Zn Dissolved	µg/L	0.481	0.042	0.183	0.042	0.354	0.042	0.275	0.042
	TSS	mg/L	22.0	5	49.0	5	22.0	5	8.0	5
	WAD CN	µg/L	-3.0	3	-3.0	3	-3.0	3	-3.0	3
	pH	s.u.	7.77	--	8.26	--	8.17	--	7.84	--

Note: "-" denotes the sample was analyzed for, but was not detected above the level of the method detection limit.

Samples for Site 108 were collected on the same day as Outfall 002.

Data Evaluation

Figures 2-1a, b, c through 2-7a, b, c show the time series plots of field pH, conductivity, cadmium, copper, lead, mercury and zinc for stations 106 (2-1a through 2-7a), 107 (2-1b through 2-7b) and 108 (2-1c through 2-7c). The Alaska Water Quality Standards (AWQS) for marine aquatic life – chronic levels, are shown or noted on the graphs where applicable. The graphs show that Hawk Inlet water quality has remained within or below AWQS standards in all historical and 2017 samples.

WAD cyanide results were below the laboratory minimum detection limit (MDL) in 2017 (Table 2-2). In prior reports, it was noted that the laboratory failed to meet the required MDL of 1.0 µg/L. The WAD cyanide MDL was revised in the APDES Permit Number AK0043206 from 1.0 µg/L to 5.0 µg/L effective October 1st, 2015.

Table 2-4 summarizes the 2017 quarterly site 35 APDES outfall 002 and water column seawater station 108 results. The outfall 002 results remain significantly below the permitted effluent limits for total cadmium (100 µg/L daily max and 50 µg/L monthly average), total copper (99 µg/L daily max and 39 µg/L monthly average), total mercury (1.9 µg/L daily max and 1.0 µg/L monthly average), total lead (327 µg/L daily max and 123 µg/L monthly average), total zinc (1,000 µg/L daily max and 500 µg/L monthly average), and pH (not less than 6.0 or greater than 9.0 standard units). Outfall 002 results ranged from 12 to 1000 times less than the daily effluent max limits for all five metals. Similarly station 108 data remain significantly below AWQS for marine life for dissolved cadmium (8.8 µg/L), dissolved copper (3.1 µg/L), dissolved mercury (0.9401 µg/L), dissolved lead (8.054 µg/L), and dissolved zinc (81.488 µg/L). Station 108 results ranged from 13 to 3900 times less than the AWQS for all five metals. The sampling requirements for outfall 002 and station 108 differ in multiple respects. Comparison requires looking at the above permit effluent limits and AWQS while factoring in dissolved metals concentrations (lower MDLs) vs. total metals concentrations (higher MDLs).

Table 2-5 is a comparison of metal values averaged from 2012 through 2016 (n=20) and the 2017 (n=4) results. All 2017 results remain below the previous five year average.

Table 2-5. Hawk Inlet Water Column Average Dissolved Metal Concentrations

	Cd (µg/L)		Cu (µg/L)		Pb (µg/L)		Hg (Total - µg/L)		Zn (µg/L)	
Site	2012 through 2016	2017	2012 through 2016	2017	2012 through 2016	2017	2012 through 2016	2017	2012 through 2016	2017
106	0.0712	0.0707	0.2697	0.1908	0.0113	0.0063	0.0004	0.0002	0.6152	0.1731
107	0.0739	0.0687	0.3806	0.2298	0.0223	0.0073	0.0005	0.0005	0.7550	0.3195
108	0.0747	0.0705	0.3245	0.2105	0.0207	0.0060	0.0004	0.0003	0.8735	0.3233

2.2 QA/QC Results

Battelle Marine Sciences Laboratory, ACZ Laboratories, and Admiralty Environmental analyzed the required parameters (refer to Table 1-1) in the sea water samples. Complete QA plans and reports are kept on file in each lab's office and are available upon request. The remainder of this section summarizes the relevant QA/QC results from each laboratory for the quarterly 2017 sea water samples. Elevated levels of zinc in the field blanks, often at levels higher than all the other sea water samples, have been noted consistently by Battelle for this sampling program.

Battelle Marine Science (low level dissolved trace metals analyses in salt water matrices):
1Q: Zn was detected substantially above the MDL in the field blank; however the sample concentrations were typical for these samples, so it appears the contamination was confined to the field blank. Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within our default criteria of ±25%.

2Q: Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within our default criteria of ±25%.

3Q: Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within our default criteria of ±25%.

4Q16: Target detection limits (TDLs) were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within our default criteria of ±25%.

ACZ Laboratories (WAD cyanide analyses):
1Q: No certification qualifiers associated with this analysis.
2Q: No certification qualifiers associated with this analysis.
3Q: No certification qualifiers associated with this analysis.
4Q: No certification qualifiers associated with this analysis.

3. SEDIMENT MONITORING

The requirements for the sediment monitoring originate from Section I.D.2, Sediment Monitoring, and Table 5 of the APDES permit. The objective of this element of the monitoring program is to provide scientifically valid data on five specific trace metal parameters analyzed at dry weight (dw) from sediments at four locations in Hawk Inlet (see Figure 1-1 for locations). These data are used to evaluate potential changes in the Hawk Inlet marine environment over time.

Sediment samples were collected semi-annually through 2015, with the reissuance of the permit the sampling frequency was changed to annual. Samples are collected at the Greens Creek delta (Site S-1), Pile Driver Cove near the mouth of the inlet (Site S-2), ~400 feet south of the concentrate loading facility (Site S-4), and under the loading facility (Sites S-5N and S-5S which bracket the area where concentrate was spilled in 1989). Samples are analyzed at ALS Environmental (formerly Columbia Analytical Services, Inc.) in Kelso, Washington for total concentrations of five trace metals (cadmium [Cd], copper [Cu], lead [Pb], mercury [Hg], and zinc [Zn]).

An additional station S-3 located near the head of Hawk Inlet, established as a background site, has also been sampled for sediment and biota since the 1980s. Though dropped from the official sampling program in the early 2000s HGCMC continued to monitor the site yearly, and has included the data in this report.

3.1 Sediment Analytical Results

All sediment samples were collected by Marine Taxonomic Services, LTD. The sample locations, dates, times, weather conditions, and tides are shown in Table 3-1. Tables 3-2 and 3-3 in this section summarize the total metals results for the semi-annual sediment monitoring events. Sample repetitions (reps) 1 through 6 denote replicate samples taken at each sample site.

Table 3-1. Hawk Inlet Sediment Monitoring Field Parameters

Locations	Date Sampled	Time Sampled (24 hour)	Air Temperature (°F)	Weather Conditions	Tide (ft MLLW)
S-1	5/24/2017	07:15	45	Overcast	-2.3
S-2	5/24/2017	06:45	45	Overcast	-2.5
S-4	5/25/2017	06:30	45	Overcast	-3.5

Table 3-2. Hawk Inlet Sediment Results (ALS Environmental)

Site	Rep	Sample Date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
		Req. MDL					
S-1 Sediments	1	5/24/2017	0.124	14.1	10.10	0.033	102.0
	2		0.140	15.6	6.12	<0.02	99.0
	3		0.102	13.3	6.02	0.026	89.2
	4		0.130	15.8	5.75	0.036	104.0
	5		0.115	17.6	6.00	0.026	104.0
	6		0.117	15.2	5.60	0.021	97.4
S-2 Sediments	1	5/24/2017	0.102	9.47	1.78	<0.019	44.8
	2		0.092	8.47	1.64	<0.017	38.9
	3		0.098	10.1	1.76	<0.02	43.3
	4		0.099	9.24	1.84	<0.017	44.7
	5		0.081	9.1	1.74	<0.021	39.5
	6		0.083	7.92	1.58	<0.018	38.4
S-4 Sediments	1	5/25/2017	0.309	17.1	21.40	0.028	59.2
	2		0.273	19	13.50	0.028	60.6
	3		0.272	16.6	23.90	0.028	53.0
	4		0.266	14.5	11.10	0.029	50.1
	5		0.291	22.1	67.70	0.029	66.8
	6		0.363	21.9	20.30	0.036	67.6

Notes: Method Reporting Limit (MRL) – Define by ALS Environmental as being times the MDL (or greater).
Method Reporting Limit (MRL) – Listed in the Appendix.
"<" denotes the sample was analyzed for, but was not detected above the MRL/MDL.

3.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in 1989, sediment and biota tissues were sampled for heavy metal concentrations. Sampling sites S-1, S-2, and S-3 were chosen to represent natural conditions; therefore, results from these sites from September of 1984 until January of 1989 were used to calculate baseline, pre-production values. These data are useful as baseline values against which to compare metal values after mining began, and the results for the current year's sampling. Sampling sites S-4, and S-5 are thought to have been influenced by the old industrial cannery operation and are not used for background comparisons.

Table 3-3. Sediment Data: Pre-Production Baseline, Production Period and Current Year Comparison using a compilation of results from Stations S-1, S-2, (and S-3 for Pre-Production only)

Period	Statistic	Cd	Cu	Pb	Hg	Zn
		mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw
Pre-Production (9/1984-1/1989) (n = 27)	Avg	0.37	24.6	7.70	0.046	104.2
	Min	0.03	11.9	2.20	0.011	11.0
	Max	1.09	55.2	15.10	0.102	200.0
Production (2/1989-9/2015) (n = 230)	Avg	0.18	13.7	5.04	0.024	72.9
	Min	0.06	6.0	1.32	0.002	26.1
	Max	0.90	39.5	23.70	0.140	188.0
Current Year 2017 (n=6)	Avg	0.09	9.1	1.72	0.009	41.6
	Min	0.08	7.9	1.58	0.009	38.4
	Max	0.10	10.1	1.84	0.011	44.8

Note: non-detects are averaged using half of the MRL value.

The comparison of pre-production and production sediment metal values in Table 3-3 shows that across Stations S-1 and S-2, the average metal levels are lower during the production/mining period than they were during pre-production. The current year's results show the average metals levels to be equal or below the production period's average values for all metals. Based on these data, it appears that heavy metals in sediment continue to vary from year to year, and there are no apparent trends in metals concentrations when concentrations from production years are compared to pre-production concentrations.

Figures 3-1 through 3-5 show the time series plots for cadmium, copper, lead, mercury and zinc including replicate samples for sample site S-1. Figures 3-6 through 3-10 show the time series plots for cadmium, copper, lead, mercury and zinc including replicate samples for sample site S-2. .Replicate samples are plotted with a single point, representing the mean value of the data, and error bars represent the overall distribution of the data.

Sampling sites S-4 and S-5N and S-5S are located near the ore concentrate loading facility. In May 1989, the first attempt to load a barge with bulk ore concentrate resulted in a spill of approximately 1,000 pounds of bulk ore concentrate into Hawk Inlet. During the re-commissioning of the mine (mid-nineties) State and Federal agencies provided oversight as Greens Creek Mine cleaned up the spilled concentrate. A suction dredge contractor removed approximately 550 cubic yards of concentrate and sediment from the spill site in 1994. This effort was confounded by the residual debris from the 1974 cannery facility fire. Metal scrap was removed from the area along with inert debris. Although clean-up efforts were extensive, annual sediment monitoring indicates that there may still be some concentrate present at the spill site.

Following the 1994 clean-up effort at the concentrate spill site, the sampling methodology at S-5 was expanded. The site was sub-divided into two separate locations. Sampling site S-5S was added on the south side of the spill area. This station complements S-5N located on the north side of the spill area (site S-5N is a continuation of the original site 5). Average concentrations of heavy metals at S-4 and S5-N remain below or equal to average concentrations reported since production began. However, following the spill, metal concentrations in the sediment as S-5S have been elevated and variable. Sites S-5N and S-5S are sampled every three years and will be sampled again in 2019. See the 2016 Hawk Inlet Monitoring report for a discussion of heavy metals at sites S-5N and S-5S. Figures 3-11 through 3-15 show the metal time series graphs for site S-4. Figures 3-16 through 3-20 show the metal time series graphs for site S-5N. Figures 3-21 through 3-25 show the metal time series graphs for site S-5S. Since 2004 replicate samples have been taken at each site and all replicates were included; plotted by the mean and include the standard error bars, unless otherwise noted.

Table 3-4 shows the average metal concentrations and the associated standard deviations for each sediment sampling site during pre-production, production, and the current year. Pre-production sediment metals average values show some consistency across stations, but the standard deviations for these data indicate high variability, representative of typical natural distributions. Beginning in the fall of 2004 replicate sampling of these sites was initiated.

Table 3-4. Sediment Data Comparison of Pre-Production, Production, Post Cleanup, and Current Year Values for Sites S-1, S-2, S-4, S-5N, and S-5S

Station	Period	Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Hg (mg/kg)		Zn (mg/kg)	
		Avg	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*
S-1	**Pre-Production (9/1984 - 1/1989)**	0.22	0.1	21.8	4.1	7.8	2.3	0.04	0.01	125.0	8.1
	Production (2/1989 - 5/2016)	0.20	0.2	16.5	6.0	7.5	3.3	0.03	0.02	99.8	27.5
	Reporting Year 2017	0.12	0.0	15.3	1.4	6.6	1.6	0.03	0.01	99.3	5.1
S-2	**Pre-Production (9/1984 - 1/1989)**	0.27	0.1	14.9	2.6	5.3	2.4	0.03	0.01	60.5	5.4
	Production (2/1989 - 5/2016)	0.15	0.1	10.7	3.9	2.4	1.3	0.01	0.01	43.6	12.3
	Reporting Year 2017	0.09	0.0	9.1	0.7	1.7	0.1	0.01	0.00	41.6	2.7
S-3	**Pre-Production (9/1984 - 1/1989)**	0.62	0.3	37.0	9.1	10.0	3.3	0.07	0.02	127.0	49.8
	Production (2/1989 - 5/2016)	0.72	0.3	34.9	12.0	13.8	4.9	0.08	0.03	128.8	39.7
	Reporting Year 2017	<u>1.08</u>	0.1	<u>58.7</u>	1.8	<u>21.3</u>	0.6	<u>0.09</u>	0.01	<u>189.0</u>	6.4
S-4	**Pre-Production (9/1984 - 1/1989)**	0.34	0.2	46.2	12.1	53.8	20.2	0.11	0.06	136.5	41.6
	Production (2/1989 - 5/2016)	0.55	0.7	34.4	39.2	63.0	100.2	0.10	0.36	115.1	131.4
	Reporting Year 2017	0.30	0.0	18.5	2.8	26.3	19.0	0.03	0.00	59.6	6.5
S-5N	**Production (2/1989 - 5/2016)**	7.04	25.9	178.5	263.8	751.4	1659.9	1.03	3.63	1193.8	3550.7
S-5S	**Production (2/1989 - 5/2016)**	3.72	3.4	106.5	81.7	341.9	369.8	0.33	0.26	812.1	733.2

Note: Non-detects are averaged using half of the MRL value; underlined average values higher than baseline.

3.3 QA/QC Results

ALS Environmental analyzed the required parameters (see Table 1-1) in the sediment samples. Complete QA plans and reports are kept on file at the ALS Environmental office and are available upon request. The remainder of this section summarizes any relevant QA/QC results that were exceptions for the 2017 sampling event.

The Relative Percent Difference (RPD) for the replicate samples is calculated as follows:

$$RPD = \frac{(\text{sample result} - \text{duplicate result}) * 100}{(\text{sample result} + \text{duplicate result}) / 2}$$

Beginning in the fall of 2004, duplicate samples have been collected from each site, where possible, to address a National Marine Fisheries Service request. Precision can be calculated from the results of duplicate samples. In this case, the Relative Standard Deviation (RSD) is calculated as follows:

$$RSD = \frac{\text{standard deviation} * 100}{\text{sample mean}}$$

The RSD is shown for the duplicate samples from 2017 in Table 3-5.

The data quality objective for the RSD is that it is less than or equal to 30 percent, when the values are at least four times the detection limit. All RSDs calculated for the 2017 dataset were within this data quality objective.

Table 3-5. Relative Standard Deviation for Replicate Sediment Samples

Sample ID	Rep	Date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
S-1 Sediments	1	5/24/2017	0.124	14.1	10.10	0.033	102
	2		0.14	15.6	6.12	<0.02	99
	3		0.102	13.3	6.02	0.026	89.2
	4		0.13	15.8	5.75	0.036	104
	5		0.115	17.6	6.00	0.026	104
	6		0.117	15.2	5.60	0.021	97.4
		RSD (%)	***10.83***	***9.7***	***26.16***	***21.21***	***5.6***
S-2 Sediments	1	5/24/2017	0.102	9.47	1.78	<0.019	44.8
	2		0.092	8.47	1.64	<0.017	38.9
	3		0.098	10.1	1.76	<0.020	43.3
	4		0.099	9.24	1.84	<0.017	44.7
	5		0.081	9.1	1.74	<0.021	39.5
	6		0.083	7.92	1.58	<0.018	38.4
		RSD (%)	***9.49***	***8.5***	***5.56***	***--***	***7.2***
S-4 Sediments	1	5/25/2017	0.309	17.1	21.4	0.028	59.2
	2		0.273	19.0	13.5	0.028	60.6
	3		0.272	16.6	23.9	0.028	53
	4		0.266	14.5	11.1	0.029	50.1
	5		0.291	22.1	67.7	0.029	66.8
	6		0.363	21.9	20.3	0.036	67.6
		RSD (%)	***12.37***	***16.4***	***79.25***	***10.59***	***11.9***
"--" indicates RSD was not calculated because one or more of the values was less than 4 times the MRL.							
"<" denotes the sample was analyzed for, but was not detected above the MRL/MDL.							

4. IN-SITU BIOASSAYS

The requirements for the bioassay monitoring originate from Section 1.6.1.3, In-situ Bioassays, and Table 7 of the APDES permit. The objective of this monitoring element is to provide scientifically valid data on five specific trace metal parameters analyzed at dry weight from the tissues of polychaete worms (*Nephtys*) and bay mussels (*Mytilus edulis*) at seven locations in Hawk Inlet. These data are used to evaluate potential changes in the Hawk Inlet marine environment.

Bioaccumulation in-situ bioassay sampling in Hawk Inlet consists of annual testing of trace metal tissue burdens of selected species of invertebrate organisms with different feeding guilds. In the Hawk Inlet sill area, where no fine grained sediments occur, four sites (Stations STN-1, STN-2, STN-3 and East Shoal Light (ESL)) are used for in-situ bioassay monitoring of trace metals in bay mussels. Data gathered from this area measures the response in organisms in the immediate vicinity of the 002 Outfall discharge. In most other areas of Hawk Inlet, the bottom is covered with sediment. Consequently, samples of sediment dwelling polychaete worms (*Nephtys procera and Nereis sp.*) are collected at three additional sites (S-1, S-2, and S-4). *Nereis sp*. were not encountered in sufficient numbers for analysis in 2017 and so only *Nephtys* were collected.

4.1 Analytical Results

All tissue samples were collected by Marine Taxonomic Services, LTD. The sample locations, types, dates, times, weather conditions, and tides are shown in Table 4-1. Table 4-2 summarizes the total metals results for the annual bioassays. Sample repetitions (reps) 1 through 6 denote replicate samples taken at each site.

Table 4-1. Hawk Inlet Tissue Sampling Field Data

Locations	Sample Type	Date Sampled	Time Sampled (24 hour)	Air Temperature (°F)	Weather Conditions	Tide (ft MLLW)
S-1	*Nephtys*	5/24/2017	08:00	45	Overcast	-2.0
S-2	*Nephtys*	5/24/2017	06:45	45	Overcast	-2.5
S-3	*Nephtys*	5/25/2017	09:00	45	Overcast	-3.0
S-4	*Nephtys*	5/25/2017	06:30	45	Overcast	-3.5
STN-1	Mussels	5/24/2017	17:00	50	Overcast	1.5
STN-2	Mussels	5/24/2017	17:50	50	Overcast	0.8
STN-3	Mussels	5/24/2017	19:00	50	Overcast	0.5
ESL	Mussels	5/24/2017	20:00	50	Overcast	0.9

Table 4-2. Hawk Inlet Tissue Bioassay Results for 2017 (ALS Environmental)

Site	Rep	Sample Date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
S-1 *Nephyts*	1	5/24/2017	2.96	10.7	0.53	0.037	265.0
	2		2.67	9.02	0.46	<0.02	243.0
	3		2.50	9.46	0.45	0.034	231.0
	4		2.80	9.04	0.47	<0.02	253.0
	5		2.84	8.6	0.42	<0.02	233.0
	6		2.66	8.69	0.44	<0.02	242.0
S-2 *Nephyts*	1	5/24/2017	1.15	7.7	0.49	<0.018	141.0
	2		1.03	6.98	0.47	<0.02	134.0
	3		1.02	6.7	0.43	<0.02	132.0
	4		1.10	7.14	0.47	<0.02	135.0
	5		1.06	6.87	0.44	<0.02	134.0
	6		1.04	7.04	0.44	<0.02	129.0
S-3 *Nephyts*	1	5/25/2017	0.75	10.2	3.57	0.036	159.0
	2		0.67	8.14	2.85	<0.02	137.0
	3		0.69	8.03	2.97	<0.02	138.0
	4		0.63	8.92	2.92	<0.02	139.0
	5		0.71	8.38	3.01	<0.02	141.0
	6		0.69	8.6	3.01	<0.02	141.0
STN-1 Mussels	1	5/24/2017	12.60	13.2	0.59	0.040	100.0
	2		12.40	12.4	0.57	0.053	106.0
	3		12.10	12.5	0.57	0.050	104.0
	4		11.70	11.9	0.52	0.060	94.7
	5		12.70	12.7	0.69	0.052	98.6
	6		12.40	12.5	0.53	0.051	99.5
STN-2 Mussels	1	5/24/2017	9.20	14.7	0.41	0.035	92.1
	2		8.87	13.7	0.38	0.037	97.6
	3		8.75	13.1	0.37	0.039	89.6
	4		8.96	13.8	0.40	0.043	93.6
	5		9.08	13.6	0.39	0.033	93.4
	6		9.25	13.1	0.40	0.036	90.3
STN-3 Mussels	1	5/24/2017	13.50	10.7	0.58	0.048	94.8
	2		13.10	9.98	0.58	0.049	96.0
	3		12.10	9.33	0.51	0.042	92.9
	4		12.30	9.78	0.53	0.053	96.5
	5		12.90	9.18	0.52	0.050	90.8
	6		12.70	9.8	0.55	0.050	94.4
ESL Mussels	1	5/24/2017	6.39	12.7	0.43	0.026	80.9
	2		6.15	11.1	0.40	<0.02	77.8
	3		6.08	11.2	0.53	<0.019	79.7
	4		6.10	11.5	0.45	0.033	80.6
	5		6.17	11.3	0.42	<0.02	82.7
	6		6.09	11	0.50	<0.02	79.5

"<" denotes the sample was analyzed for, but was not detected above the MRL/MDL

4.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in 1989, sediment and biota tissues were sampled for heavy metal concentrations. Results for mussels from sites STN-1, STN-2, STN-3 and ESL, and for *Nephtys* from sites S-1, S-2, and S-3 from September of 1984 until January of 1989 were used to calculate baseline, pre-production values. These data are useful as baseline values against which to compare metal values after mining began and the results for the current year's sampling.

As noted by Oceanographic Institute of Oregon in the 1998 Kennecott Greens Creek Mine Risk Assessment (p 4-3),

> "Sampling stations were selected to demonstrate a range of potential exposures including "worst case" exposure to Outfall discharges. Some of the test organisms placed in cages directly on the Outfall diffuser ports lived for six months. These results indicate that even maximum exposure to the Outfall discharge result in no acute effects."

Average lead concentrations in mussel tissues were approximately five times higher during the production period than the pre-production period (Table 4-3). Average lead values were equal to the pre-production (0.50 mg/kg dw) and 1.8 mg/kg lower than production average values (2.29 mg/kg dw). Average zinc values (91.9 mg/kg dw) were nearly equal in concentration to pre-production values (91.1 mg/kg dw) and production values (91.0 mg/kg dw). Average cadmium values (10.07 mg/kg dw) were higher than pre-production values (7.99 mg/kg dw) and production values (8.32 mg/kg). Average copper concentration (11.87 mg/kg dw) was greater than both pre-production concentration (8.08 mg/kg dw) and production concentration (8.10 mg/kg dw). Average concentration for mercury was comparable to pre-production average concentration. Figures 4-1 through 4-20 show the time series plots for cadmium, copper, lead, mercury and zinc in mussel samples for sample sites STN-1, STN-2, STN-3, and ESL. Error bars were included for the replicate samples taken in 2016 and 2017. Prior to the reissued 2015 APDES permit, replicate mussel tissue samples were not collected.

Table 4-3. Mussels Tissue Data: Pre-Production, Production, and Current Year - Sites STN-1, STN-2, STN-3, and ESL.

Period	Statistic	Cd	Cu	Pb	Hg	Zn
		mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw
Pre-Production (9/1984-1/1989) (n = 36)	Avg	7.99	8.08	0.50	0.05	91.1
	Min	3.25	5.5	0.15	0.014	71.9
	Max	15.76	12.2	1.73	0.34	142.0
Production (2/1989-9/2015) (n = 248)	Avg	8.32	8.10	2.29	0.05	91.0
	Min	3.01	0.82	0.32	0.01	49.0
	Max	15.9	110	126	0.56	167.0
Current Year 2017 (n=6)	Avg	10.07	11.87	0.49	0.04	91.9
	Min	6.08	9.18	0.37	0.026	77.8
	Max	13.5	14.7	0.686	0.06	106.0

Notes: Non-detects are averaged using half of the MDL value; underlined average values higher than baseline.

When compared to the "Mussel Watch" averages for Alaska, cadmium and zinc exceeded these averages (2.87 mg/kg and 87.95 mg/kg, respectively) during pre-production. Cadmium and lead exceeded these averages (2.87 mg/kg and 1.17 mg/kg, respectively) during production. These levels were similarly noted in the 2003 Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations (p 57):

> "…the average mining production period metal levels are generally below Mussel Watch averages for Alaska. The exception to this is Cd, which was above Mussel Watch Alaska averages prior to and subsequent to mining operations. Because the USFWS Hawk Inlet-wide levels of Pb increased similarly to the outfall monitoring site levels of Pb, these increases over time may be due to natural increases in Pb in the environment."

Trace metal concentrations averaged for *Nephtys* sampled in 2017 are varied when compared to pre-production and production stages of monitoring (Table 4-4). Cadmium (1.35 mg/kg dw), copper (8.04 mg/kg dw), mercury (0.04 mg/kg dw) and zinc (182 mg/kg dw) where reported at concentrations below or equal to both the pre-production and production stages of monitoring. Average lead concentration for 2017 (1.20 mg/kg dw) is above pre-production, but below production averages.

Table 4-4. Hawk Inlet *Nephtys* Tissue Data: Pre-Production Baseline, Production Period and Current Year Comparison using a compilation of results from Stations S-1, S-2 (and S-3 for Pre-Production only)

Period	Statistic	Cd	Cu	Pb	Hg	Zn
		mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg dw
Pre-Production (9/1984-1/1989) (n = 36)	Avg	2.69	11.31	0.90	0.04	210
	Min	0.51	6.24	0.28	0.009	143
	Max	6.91	23.5	5.42	0.17	303
Production (2/1989-9/2015) (n = 248)	Avg	1.63	12.71	3.03	0.04	195
	Min	0.24	3.9	0.1	0.01	63
	Max	8.33	104.7	89.3	0.099	482
Current Year 2017 (n=6)	Avg	1.35	8.04	<u>1.20</u>	0.04	182
	Min	0.63	6.61	0.42	0.034	129
	Max	2.96	10.7	3.57	0.059	265

Notes: Non-detects are averaged using half of the MDL value; underlined average values higher than baseline.

The average and standard deviation results for pre-production, production and current year periods for the individual sites for mussels is provided in Table 4-5. Table 4-5 shows larger standard deviations in production levels of zinc concentrations in mussels at all sites. Larger standard deviations were also noticed for lead at STN-2 and STN-3, as well as copper at ESL. In 2017, STN-1 and STN-2 had zinc and cadmium concentrations higher than the pre-production and production period.

Table 4-5. Average and Standard Deviation Values for Pre-Production, Production, and Current Year Mussel Data – Sites STN-1, STN-2, STN-3, and ESL.

Station	Period	Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Hg (mg/kg)		Zn (mg/kg)	
		Avg	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*
ESL	**Pre-Production (9/1984 - 1/1989) (n=9)**	6.67	1.60	8.16	0.68	0.42	0.11	0.03	0.01	91.4	8.4
	Production (2/1989 - 5/2016) (n=62)	6.68	1.84	9.90	13.66	1.29	0.75	0.04	0.02	85.8	19.6
	Reporting Year 2017 (n=6)	6.16	0.11	11.47	0.57	0.46	0.05	0.02	0.01	80.2	1.5
STN-1	**Pre-Production (9/1984 - 1/1989) (n=9)**	7.41	1.80	7.96	1.20	0.62	0.41	0.07	0.09	94.9	11.2
	Production (2/1989 - 5/2016) (n=62)	8.49	2.11	7.35	1.66	1.44	0.88	0.05	0.05	92.7	26.1
	Reporting Year 2017 (n=6)	12.32	0.33	12.53	0.39	0.58	0.05	0.05	0.01	100.5	3.7
STN-2	**Pre-Production (9/1984 - 1/1989) (n=9)**	8.60	3.10	7.71	1.05	0.37	0.19	0.04	0.01	82.4	11.2
	Production (2/1989 - 5/2016) (n=62)	9.19	2.54	7.69	3.44	3.54	15.74	0.04	0.02	92.7	27.3
	Reporting Year 2017 (n=6)	9.02	0.18	13.67	0.54	0.39	0.01	0.04	0.00	92.8	2.6
STN-3	**Pre-Production (9/1984 - 1/1989) (n=9)**	9.27	3.05	8.50	1.69	0.59	0.21	0.04	0.01	95.7	17.8
	Production (2/1989 - 5/2016) (n=62)	8.79	1.92	7.34	1.95	2.85	11.55	0.05	0.07	91.3	18.4
	Reporting Year 2017 (n=6)	12.77	0.47	9.80	0.49	0.54	0.03	0.05	0.00	94.2	1.9

Notes: Underlined concentrations are higher than pre-production averages. Non-detects are averaged using half of the MRL/MDL value.

The historical and year 2017 metals concentration in *Nephtys* is shown in Table 4-6. Concentrations of cadmium and mercury in *Nephtys* show general decline over time. Cadmium and mercury average concentrations were lower at all four sampled stations for both production relative to pre-production and 2017 relative to pre-production. Moreover, cadmium and mercury levels were lower in 2017 than the production average. This same trend has been observed for zinc at S-1 and S-4. Zinc concentrations in 2017 were in between the pre-production and production levels at S-2. Various trends in copper were reported at all three stations; increase at S-1, almost no change at S-2, and a decrease at S-4. Lead concentrations at S-1 and S-2 have been higher on average since production began relative to pre-production; however, 2017 concentrations were lower than the average for the other production years. At S-4, lead concentrations were much lower in 2017 than the production average and lower than pre-production average concentration. Beginning in the fall of 2004 replicate sampling of *Nephtys* was initiated. The replicate samples are reflected averaged in Table 4-6. Figures 4-21 through 4-35 show the time series plots for cadmium, copper, lead, mercury and zinc including replicate samples in *Nephtys* for sample sites S-1, S-2, and S-4. Replicate samples are plotted by the mean and include standard error bars.

Table 4-6. Average and Standard Deviation Values for Pre-Production, Production, and Current Year *Nephtys* Data – Sites S-1, S-2, S-3, and S-4

Station	Period	Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Hg (mg/kg)		Zn (mg/kg)	
		Avg	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*	*Avg*	*Stdev*
S-1	**Pre-Production (9/1984 - 1/1989) (n=9)**	4.00	1.61	9.04	1.12	0.49	0.15	0.05	0.01	243.6	40.1
	Production (2/1989 - 5/2016) (n=110)	2.98	1.02	9.97	5.46	0.95	0.78	0.04	0.02	212.2	34.6
	Reporting Year 2017 (n=6)	2.74	0.15	9.25	0.70	0.46	0.03	0.02	0.01	244.5	11.7
S-2	**Pre-Production (9/1984 - 1/1989) (n=9)**	1.70	0.70	12.37	3.12	0.59	0.22	0.02	0.01	181.1	27.7
	Production (2/1989 - 5/2016) (n=110)	1.10	0.48	8.66	4.75	0.70	0.35	0.02	0.01	174.3	33.7
	Reporting Year 2017 (n=6)	1.07	0.05	7.07	0.31	0.46	0.02	0.01	0.00	134.2	3.6
S-3	**Pre-Production (9/1984 - 1/1989) (n=8)**	4.08	2.45	16.45	4.92	0.82	0.45	0.14	0.22	241.4	70.7
	Production (2/1989 - 5/2016) (n=108)	2.11	1.15	13.87	15.23	0.85	0.70	0.04	0.02	238.6	43.9
	Reporting Year 2017 (n=6)	0.90	0.04	7.11	0.35	0.82	0.03	0.03	0.02	207.0	4.5
S-4	**Pre-Production (9/1984 - 1/1989) (n=2)**	1.21	0.70	16.80	6.70	4.16	1.27	0.11	0.06	193.5	10.5
	Production (2/1989 - 5/2016) (n=110)	0.81	0.56	19.52	16.34	7.44	9.11	0.03	0.02	198.7	42.0
	Reporting Year 2017 (n=6)	0.69	0.04	8.71	0.73	3.06	0.24	0.01	0.01	142.5	7.5

Notes: Underlined concentrations are higher than pre-production averages. Non-detects are averaged using half of the MRL/MDL value.

Effluent toxicity testing, conducted since the mining operations began, was discontinued in 2005 with reissuance of the NPDES Permit (AK-004320-6). Between February 1989 and October 1998, acute toxicity testing was performed using treated effluent. Between November 1998 and June 2005, chronic toxicity testing was performed. The previously performed toxicity testing showed no lethal or sub-lethal deleterious effects to tested marine aquatic organisms from prolonged exposure to the treated effluent;

> "The data show that the effluent from Outfall 002 has no reasonable potential to contribute to an exceedance of the (Alaska) WQS for toxicity." (USEPA Fact Sheet dated October 28, 2004; page 14, Section VI.B Whole Effluent Toxicity Testing).

QA/QC Results

ALS Environmental analyzed the required parameters (see Table 1-1) for the bioassay samples. Complete QA plans and reports are kept on file at the ALS Environmental office and are available upon request. The remainder of this section summarizes the relevant QA/QC results for 2017 sampling.

No anomalies associated with the analysis of these samples were observed.

Beginning in the fall of 2004, replicate samples have been collected from each site, where possible, to address a National Marine Fisheries Service request. Precision can be calculated from the results of duplicate samples. In this case, RSD is shown for the duplicate samples in Table 4-7. The data quality objective for the RSD is that it is less than or equal to 30%, when the values are at least four times the detection limit. All of the RSDs calculated for the 2017 duplicate samples were within this data quality objective.

Table 4-7. Relative Standard Deviation for Replicate Tissue Samples

Sample ID	Rep	Date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
S-1 *Nephtys*	1	5/24/2017	3.0	10.7	0.5	0.037	265.0
	2		2.7	9.0	0.5	<0.02	243.0
	3		2.5	9.5	0.5	0.034	231.0
	4		2.8	9.0	0.5	<0.02	253.0
	5		2.8	8.6	0.4	<0.02	233.0
	6		2.7	8.7	0.4	<0.02	242.0
		RSD (%)	***5.9***	***8.3***	***8.1***	***5.98***	***5.2***
S-2 *Nephtys*	1	5/24/2017	1.2	7.7	0.5	<0.018	141.0
	2		1.0	7.0	0.5	<0.02	134.0
	3		1.0	6.7	0.4	<0.02	132.0
	4		1.1	7.1	0.5	<0.02	135.0
	5		1.1	6.9	0.4	<0.02	134.0
	6		1.0	7.0	0.4	<0.02	129.0
		RSD (%)	***4.7***	***4.8***	***5.3***	**--**	***3.0***
S-4 *Nephtys*	1	5/25/2017	0.8	10.2	3.6	0.036	159.0
	2		0.7	8.1	2.9	<0.02	137.0
	3		0.7	8.0	3.0	<0.02	138.0
	4		0.6	8.9	2.9	<0.02	139.0
	5		0.7	8.4	3.0	<0.02	141.0
	6		0.7	8.6	3.0	<0.02	141.0
		RSD (%)	***5.82***	***9.1***	***8.49***	**--**	***5.8***

"--" indicates RSD was not calculated because three or more of the values was less than 4 times the MRL
"<" denotes the sample was analyzed for, but was not detected above the MRL/MDL.

5. CONCLUSIONS

Water quality, sediments, and invertebrate tissue monitoring began in Hawk Inlet prior to production to establish a baseline against which future monitoring (during production) could be evaluated within the context of potential natural changes over time. Greens Creek Mine has established a 30+ year monitoring database for many of the sites used to establish the original baseline. This monitoring program has been modified as needed (e.g. splitting of S-5 into S-5N and S-5S and dropping of S-3) to account for changes at the site and to facilitate compliances with the APDES permit.

Long-term water column monitoring for cadmium, copper, lead, mercury, and zinc indicates no impairment (exceedance of marine water quality standards) of the Hawk Inlet water column.

Sediment monitoring at S-1, S-2, and S-3 has been occurring annually for 30+ years. When comparing S-1 which is located in the vicinity of the 002 outfall to S-2, a background site located over 1.5 miles to the south, it is evident that some metal concentrations at the two sites exhibit similar concentration ranges. This year, average concentrations of copper, lead, and zinc were noticeably higher at S-1 than S-2. However, these values remain within close range of average values reported during pre-production and production. Given the spatial distance but similar concentrations between the sites, the sediment metal concentrations for most metals at S-1 appear within the range of natural conditions.

Observations by fishermen and researchers suggest that the physical features and biotic communities of Hawk Inlet remain intact following over two decades of mine operation and they remain similar to adjacent inlets. Ridgeway (2003) made a similar statement following the first decade of operation. Halibut and crab numbers are reported to have declined significantly with the closing of the fish processing facilities which previously operated at the Hawk Inlet Cannery, which is now the HGCMC port facility.

Marine species which live within sediments or filter water are susceptible to incorporating metals within their tissues. Moreover, when these organisms are also sedentary or otherwise unable to move appreciable distances, they become potential indicators of local sediment and water quality conditions. The Hawk Inlet Monitoring Program was designed to monitor the potential impact of the mine's discharge on such indicator species. Based on the suite of species listed as having Essential Fish Habitat in Hawk Inlet, the species most likely to encounter these elevated metal levels through their diet and habitat uses would include the flatfishes (e.g. yellowfin sole, arrowtooth flounder, flathead sole, and rock sole), pacific cod, sculpin and crab species. These species are extremely mobile predators, in comparison to the mussels and polychaetes monitored in the mine-associated areas (i.e. diffuser and port facility) that are constantly exposed to the water and sediment of interest.

Cadmium and zinc levels from tissue monitoring of *Nephtys* are reported at higher concentrations than that reported for sediment at sites S-1 and S-2. All other metal concentrations observed for *Nephtys* tissue are approximately equal or far less than the average concentrations reported for sediment. Average concentrations of heavy metals decrease from S-1 to S-2. If the temporal variation in the sediment load at S-1 was a result of discharge from the 002 Outfall, the similar variation observed at S-2 would not be expected. This similarity in temporal variation and with spatial distances occurs with the other metals as well. HGCMC believes that the variation in concentration monitored in organisms near the 002 outfall is natural and that the monitoring program is sufficient for detecting changes.

The effectiveness of the sediment monitoring system for detecting change can be evaluated by examining metal concentrations at sites near the ship loader (S-4 and S-5 (N and S)). These sites are influenced from the original activities of the cannery, the burning down of the cannery in 1974, and concentrate spillage associated with the ship loader spill in 1989. For example, prior to the spill, pre-production lead levels at S-4 were approximately 50 mg/kg dw. Post concentrate spillage, between 1989-1994, resulted in drastic increase of lead concentration (around 200 mg/kg dw) at S-4. During re-commissioning (mid 1990s) sediments were dredged in the vicinity of the ship loader. Following dredging, the average lead level returned to pre-productions levels. Since the early 2000's lead levels at S-4 have routinely been less than 30 mg/kg, attributed to natural process (e.g. sedimentation) and repeated debris cleanup efforts of dive crews that have removed contaminated materials associated with pre-mine site users (e.g. batteries).

For several decades the dive crew has been removing lead acid batteries on an annual basis from Hawk Inlet, discarded during the operations of the Cannery (Photograph 4-1). In addition, sediment monitoring has provided useful information by showcasing the significant discrepancies in high trace metal concentrations at S-5S vs. the lower concentrations observed at S-5N. The differences in values at all three of these sites indicates where heavy and low concentrations of metals are currently and provides insight about anthropogenic processes and/or environmental conditions effecting trace metal concentrations in this area.

Photograph 5-1. Several lead acid batteries from the Cannery operation removed from Hawk Inlet in 2017

As discussed in the report, there have been some elevated metal concentrations in the invertebrate and sediment samples. Particularly, regarding elevated concentrations of cadmium and zinc in sampled mussel tissue. However, the recent tissue for *Nephtys* samples are similar to pre-mining levels and the sediments exhibit similar variation despite their spatial distances. The difference in trace metal concentration in the tissues of these two types of organisms may relate to the difference in location of the organisms being sampled. Distinctions in life history regarding where they feed, how they feed, what they feed on, and how their metabolic processes react to various analytes may influence reported concentrations. Lastly, the older an organism is the more time it has been subjected to trace metals in question. Assuming the organism cannot metabolize the trace metal efficiently, bioaccumulation will result. These results indicate that there is natural variability, the relatively low trophic level organisms studied are not greatly impacted, and that the APDES monitoring program is effective for measuring potential impacts associated with the Greens Creek Mine.

6. REFERENCES

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USDA Forest Service (2013). *Greens Creek Mine Tailings Disposal Facility Expansion: Final Environmental Impact Statement and Record of Decision*.

FIGURES

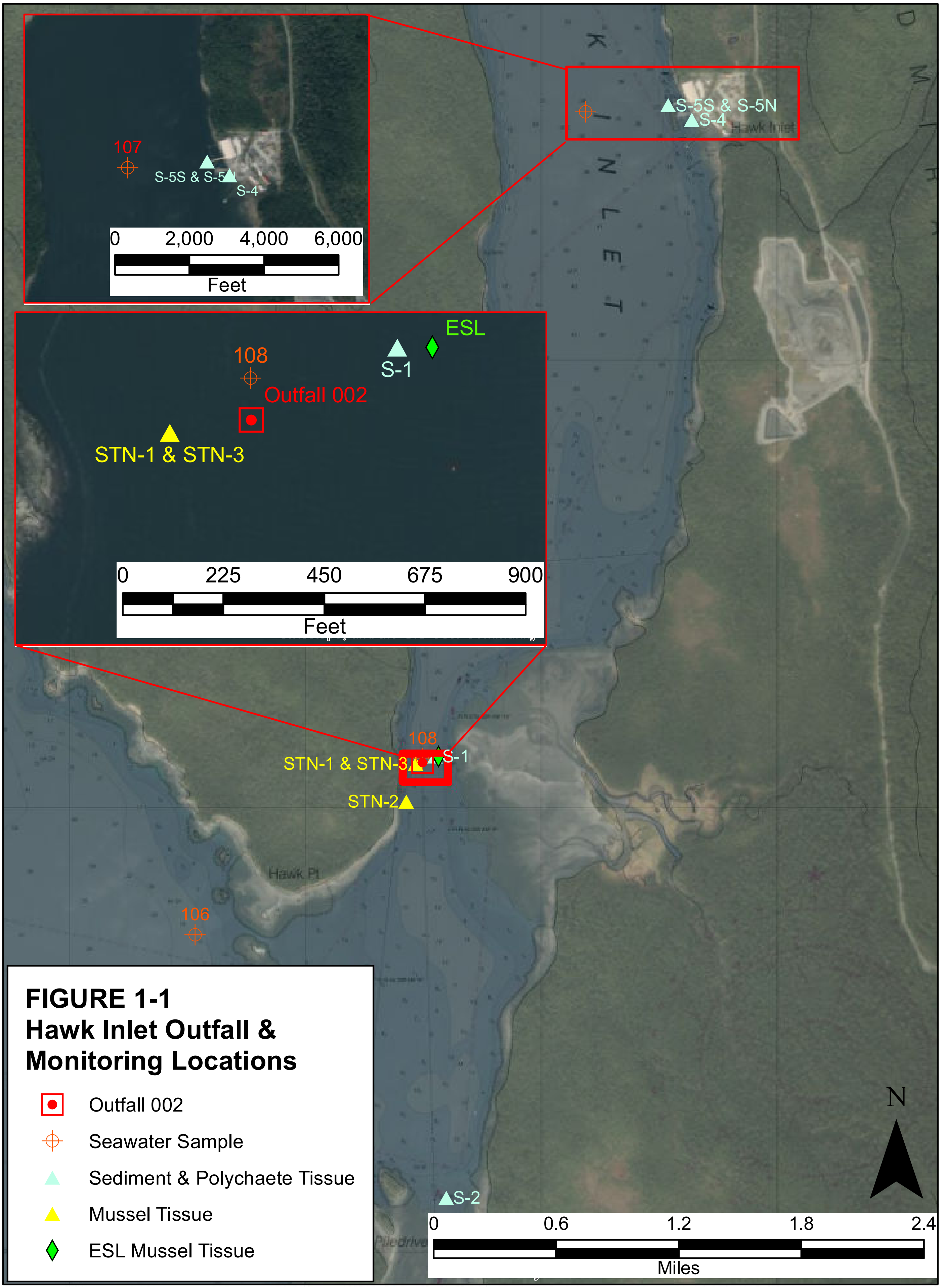
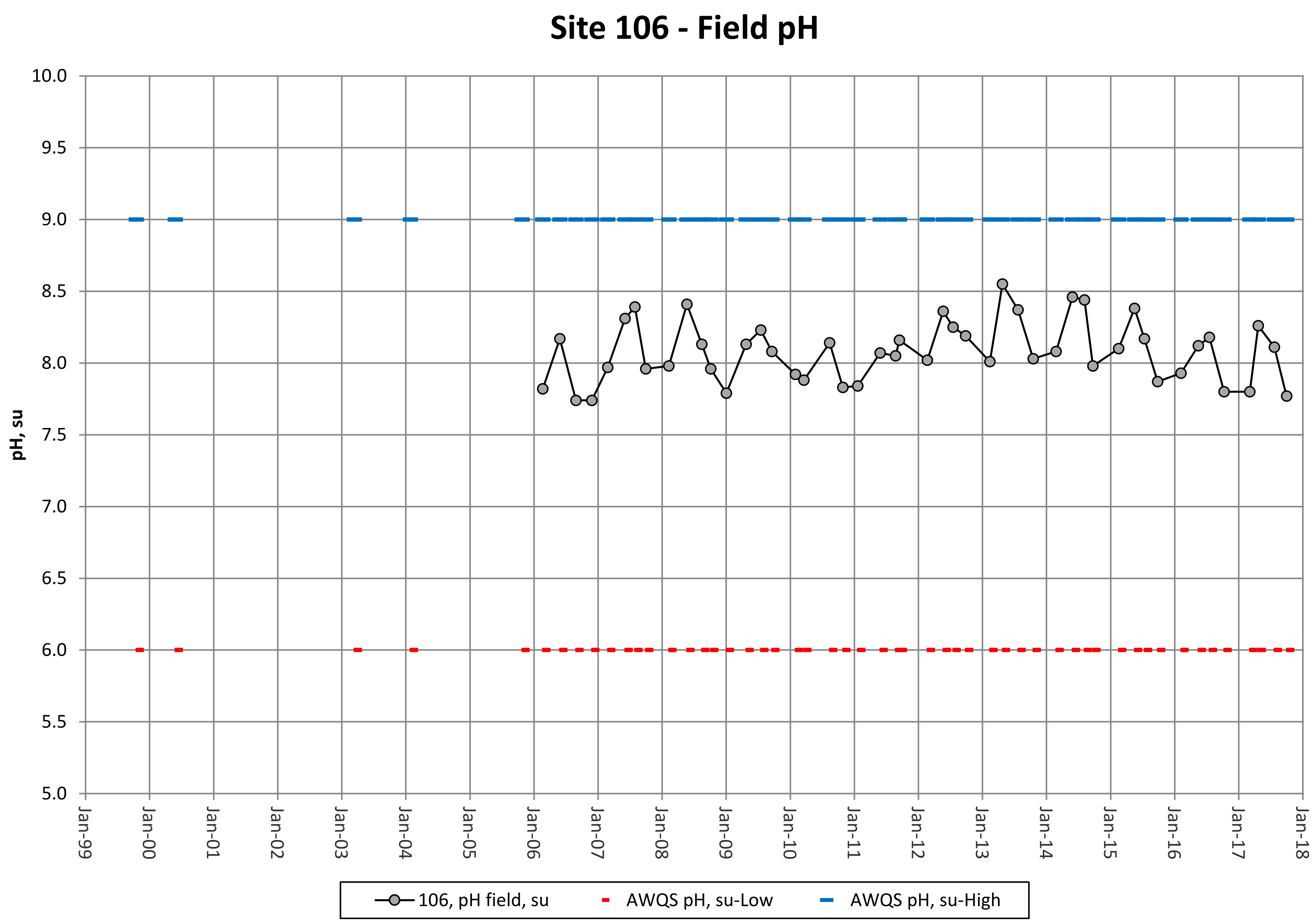


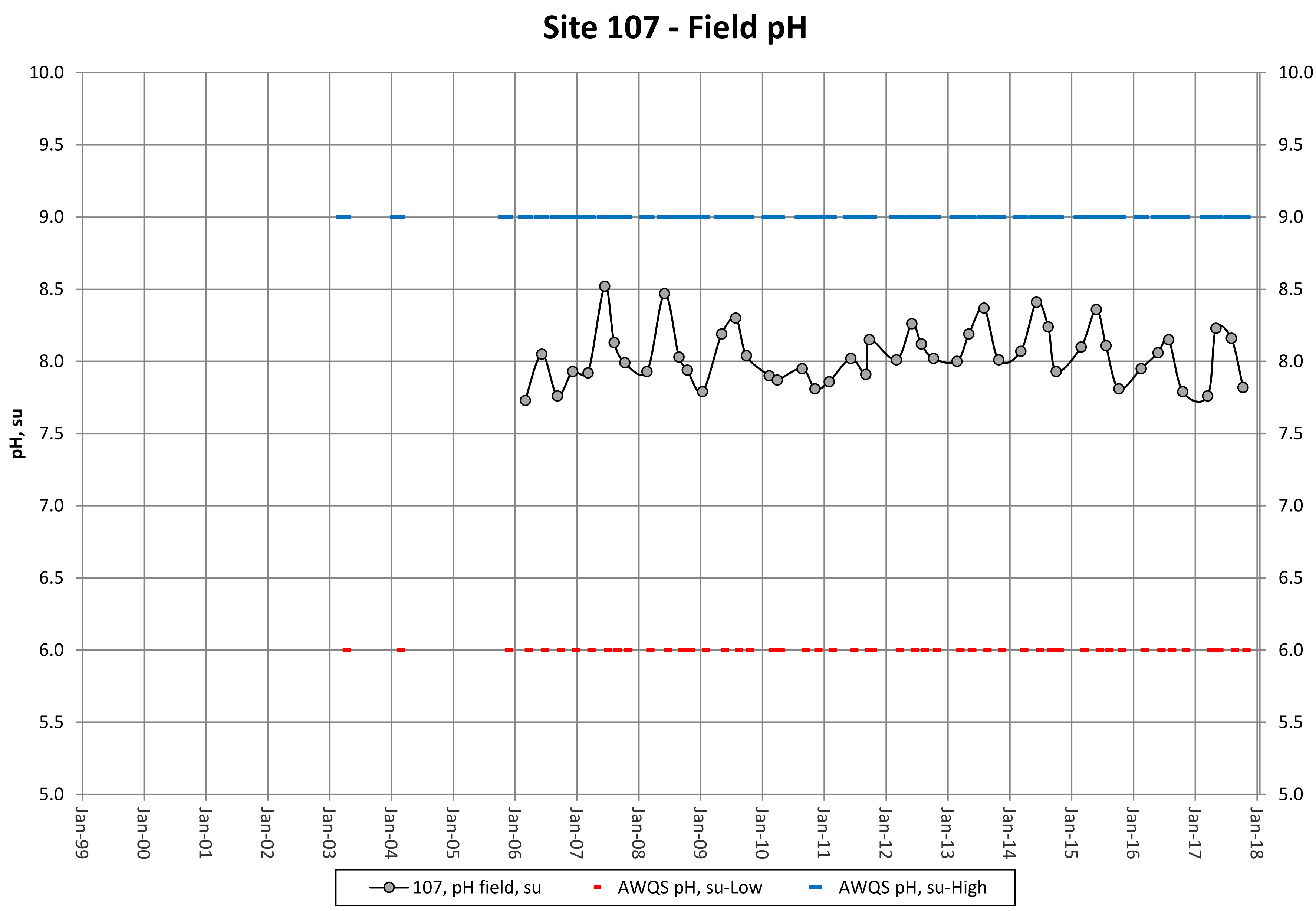
FIGURE 1-1
Hawk Inlet Outfall & Monitoring Locations
Outfall 002
Seawater Sample
Sediment & Polychaete Tissue
Mussel Tissue
ESL Mussel Tissue
107
S-5S & S-5N
S-4
0
2,000
4,000
6,000
Feet
108
ESL
S-1
Outfall 002
STN-1 & STN-3
0
225
450
675
900
Feet
STN-2
Hawk Pt
106
S-2
N
0
0.6
1.2
1.8
2.4
Miles

Figure 2-1a



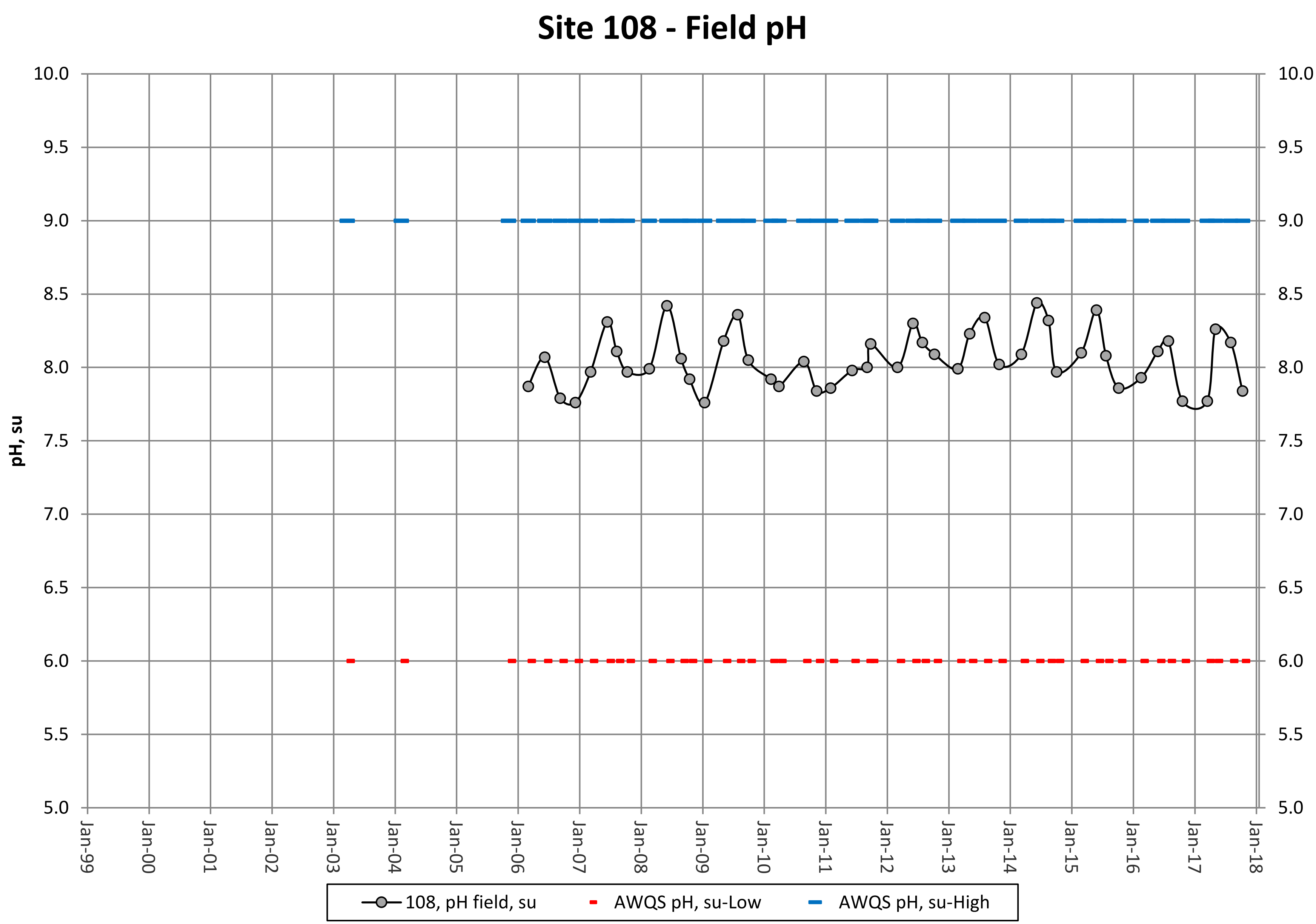
Site 106 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
106, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-1b



Site 107 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
107, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-1c



Site 108 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-2a

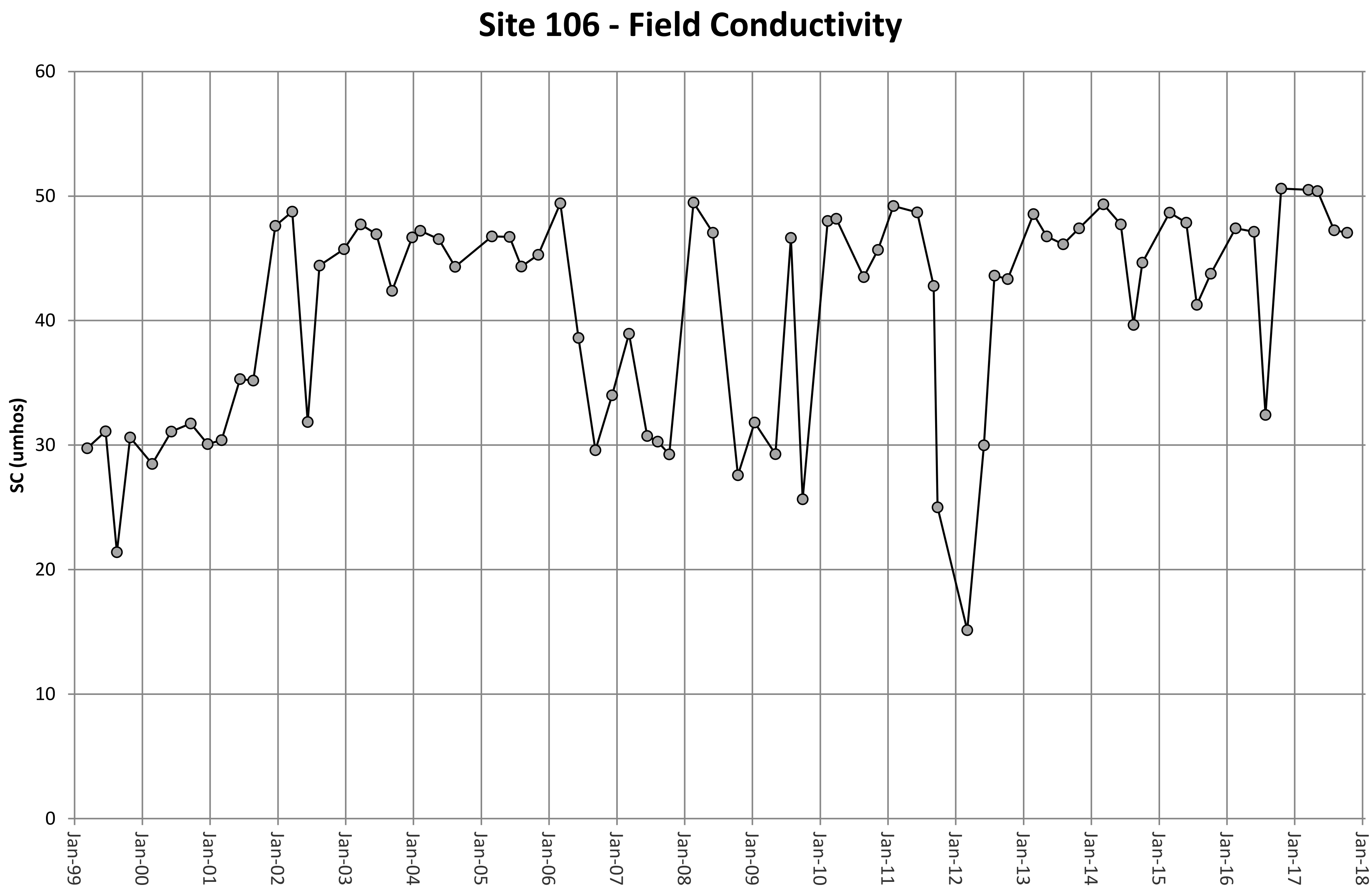

Site 106 - Field Conductivity
SC (umhos)
0
10
20
30
40
50
60
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18

Figure 2-2b

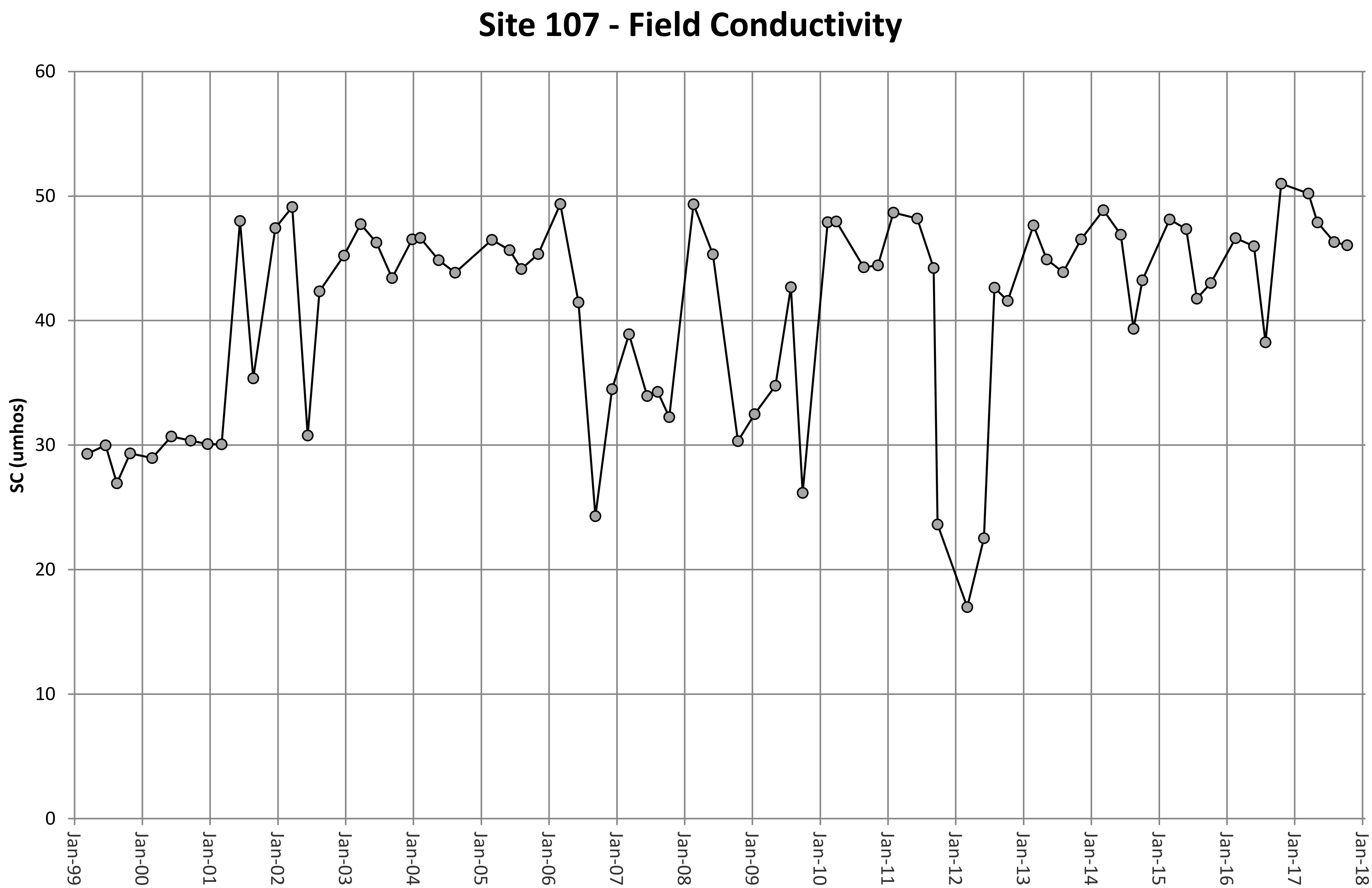
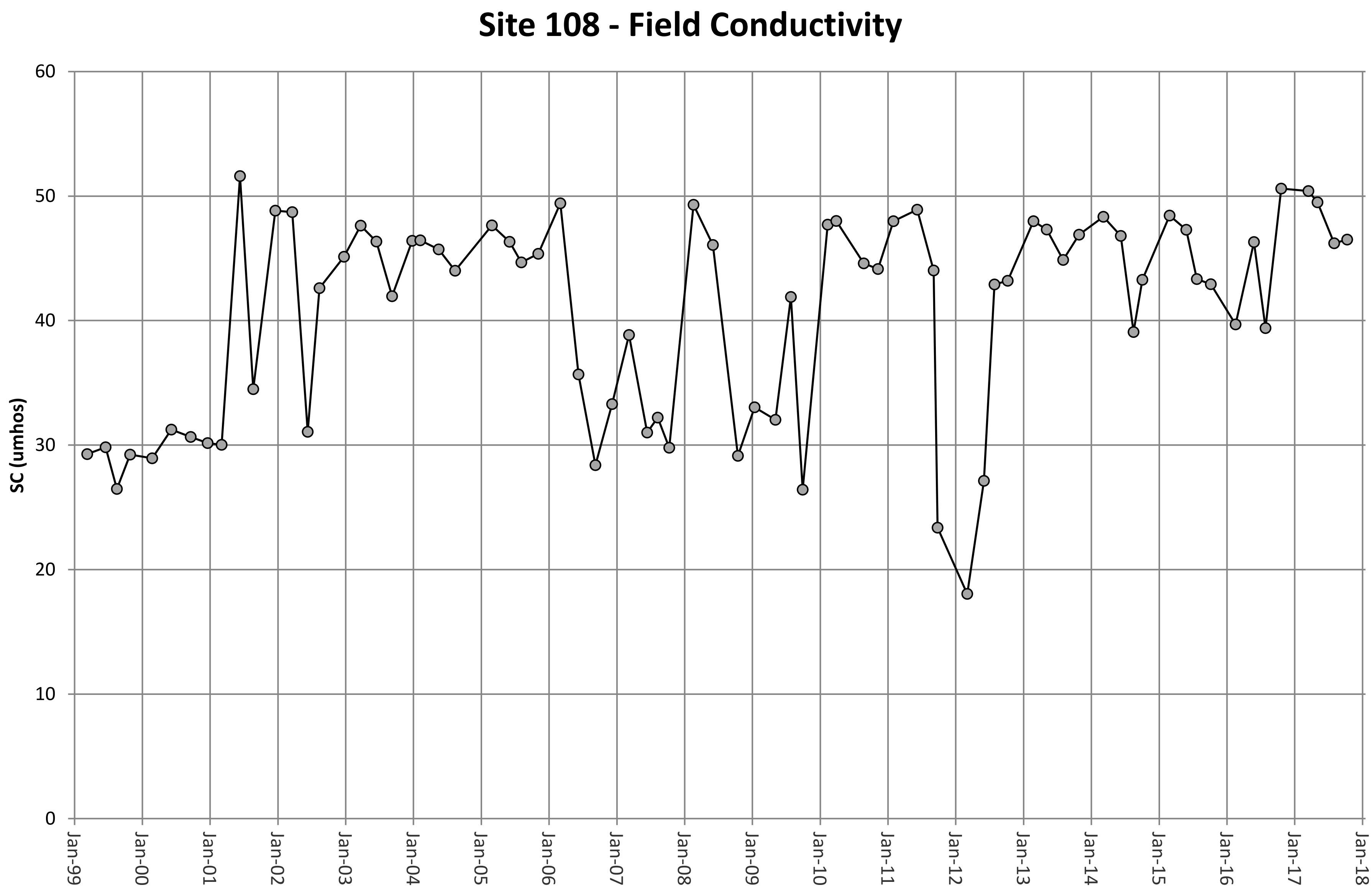
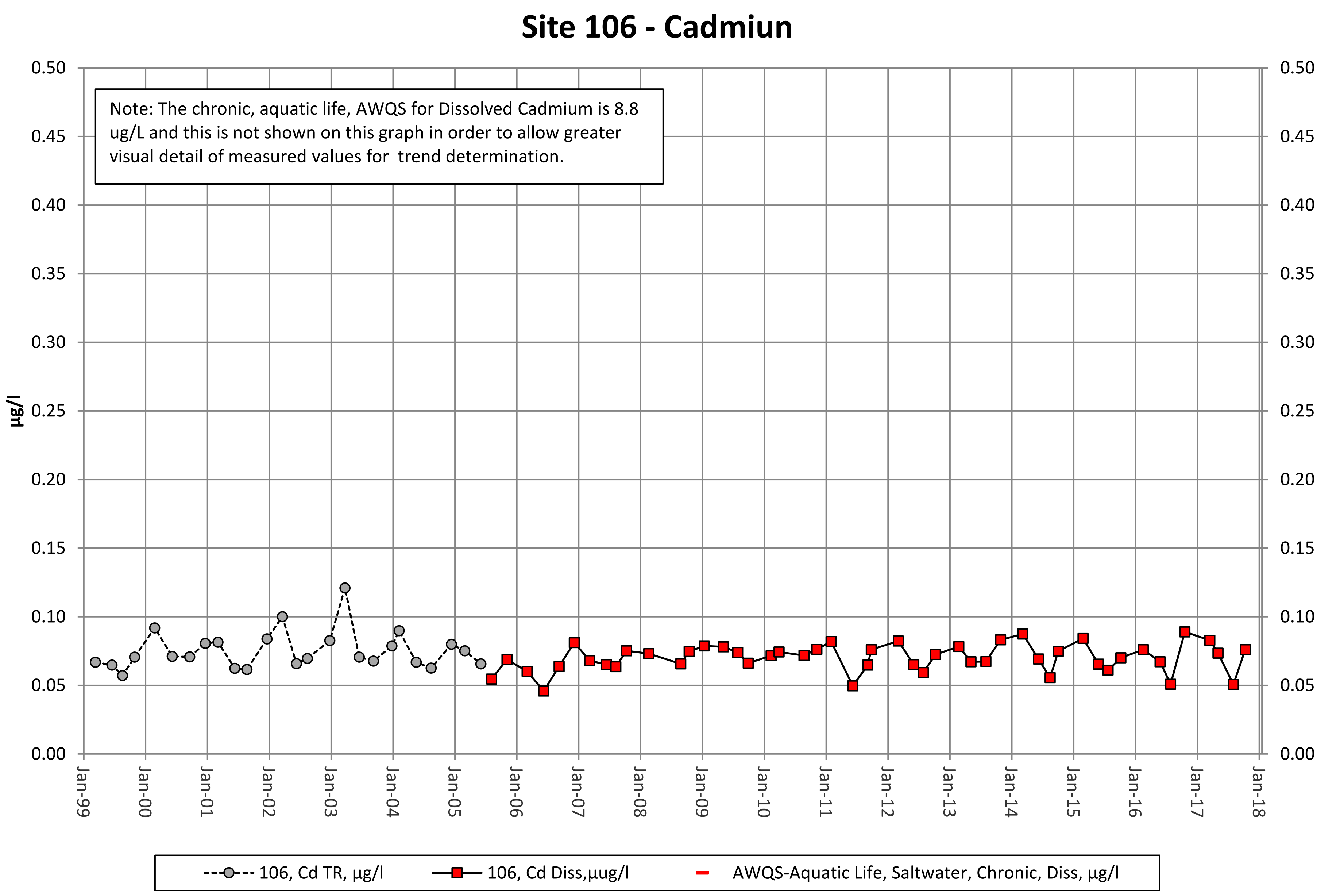

Site 107 - Field Conductivity
SC (umhos)
0
10
20
30
40
50
60
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18

Figure 2-2c



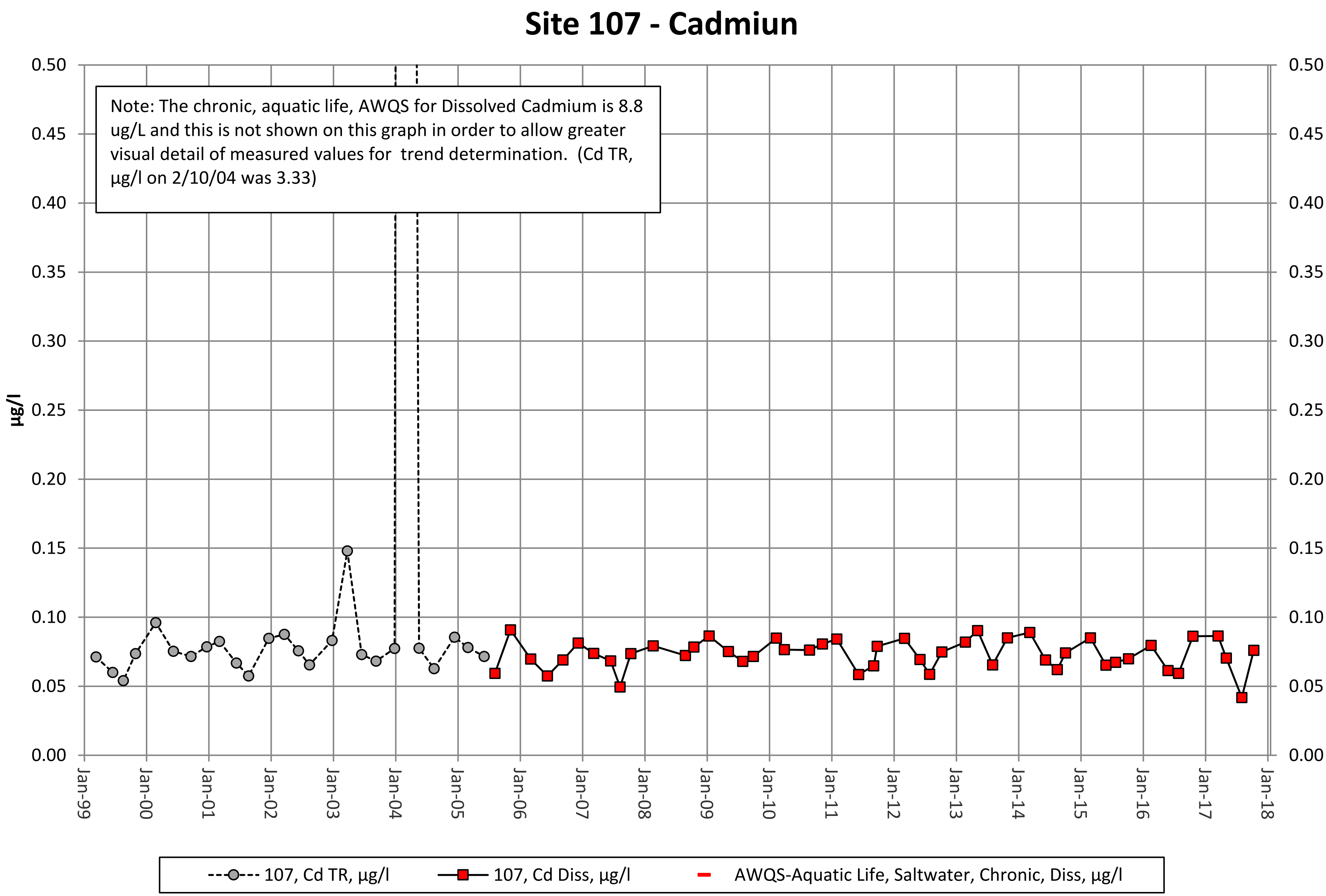
Site 108 - Field Conductivity
SC (umhos)
60
50
40
30
20
10
0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18

Figure 2-3a



Site 106 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination.
µg/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
106, Cd TR, µg/l
106, Cd Diss,µug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-3b



Site 107 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination. (Cd TR, µg/l on 2/10/04 was 3.33)
µg/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
107, Cd TR, µg/l
107, Cd Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-3c

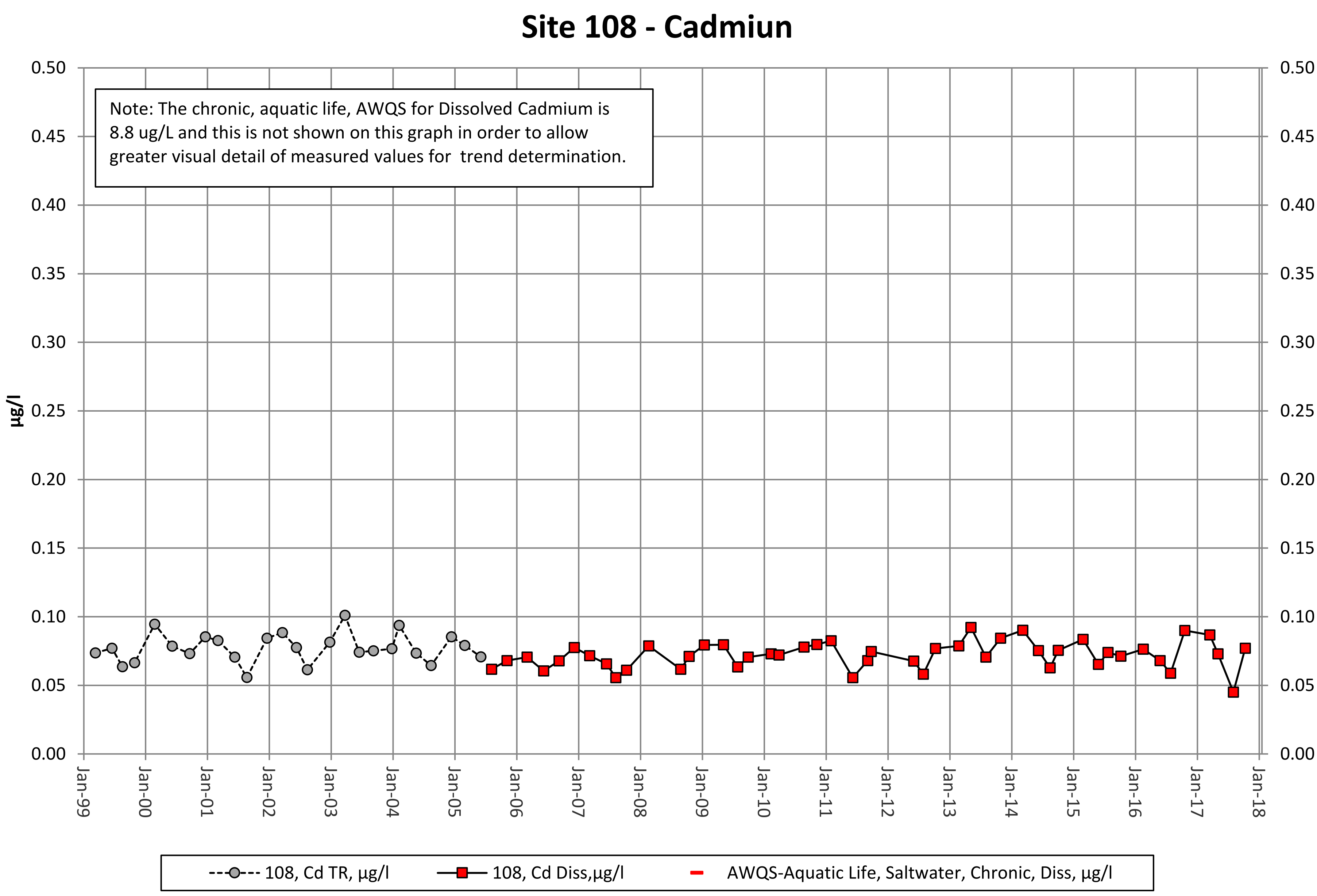
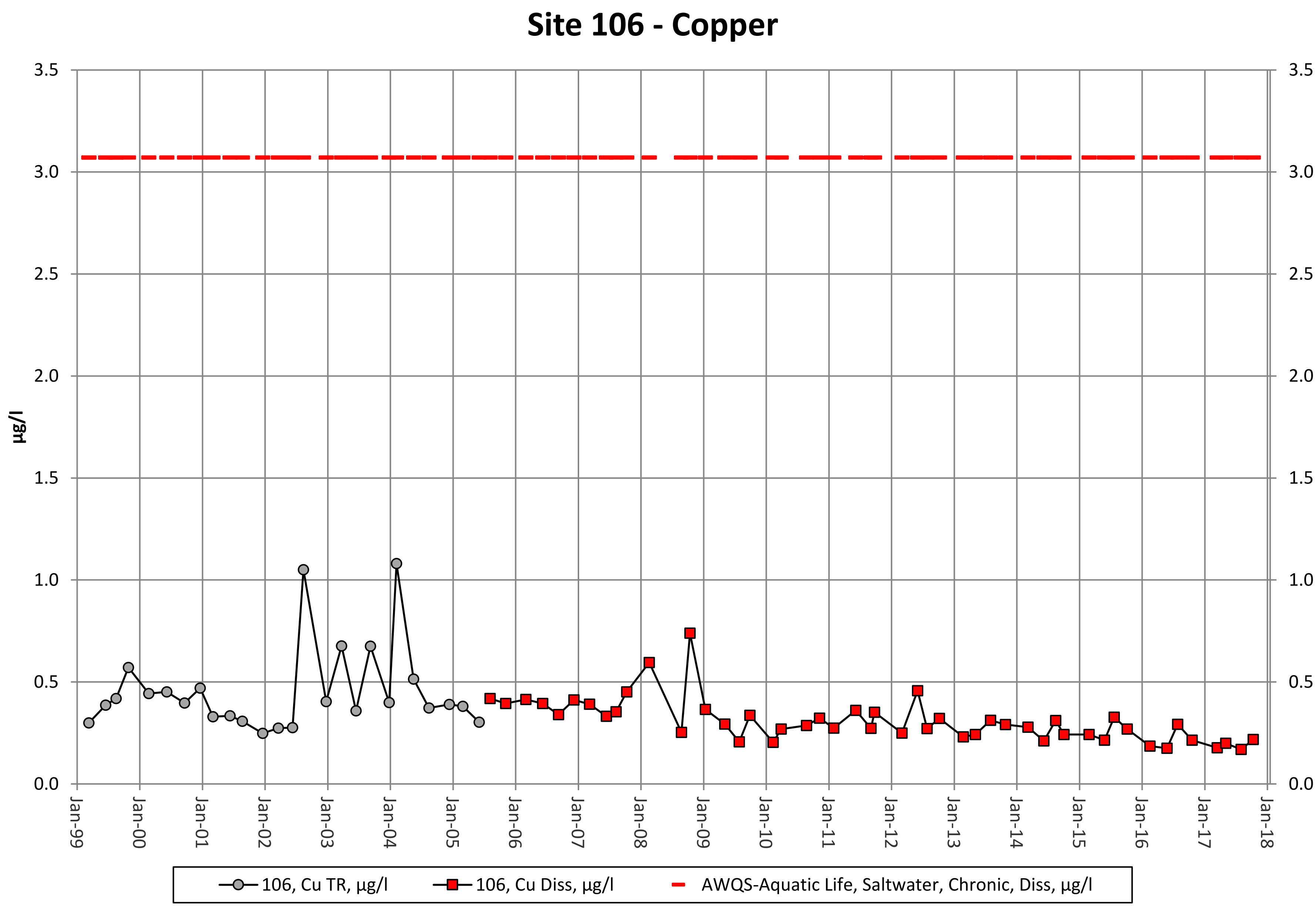
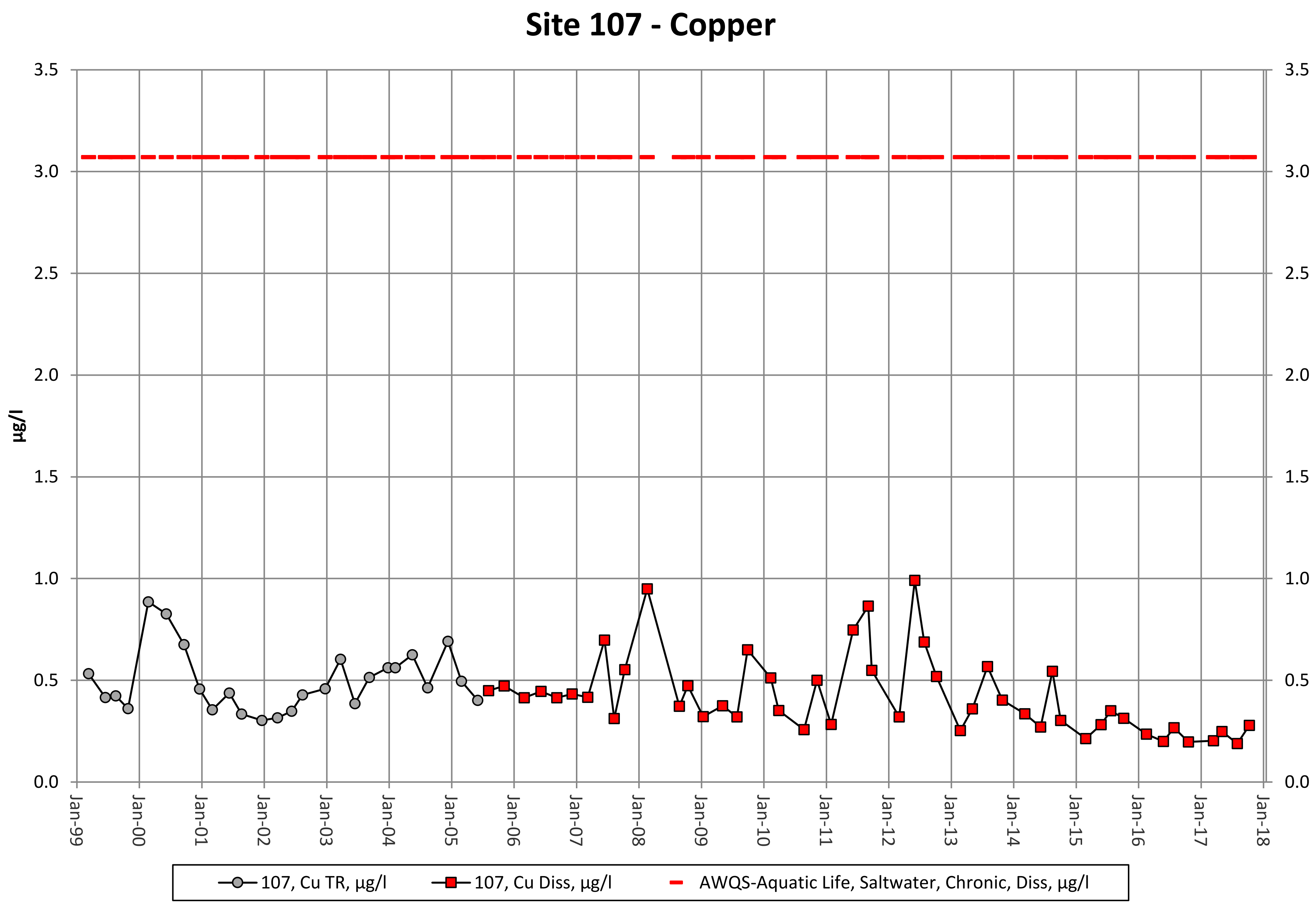

Site 108 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend determination.
µg/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, Cd TR, µg/l
108, Cd Diss,µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-4a



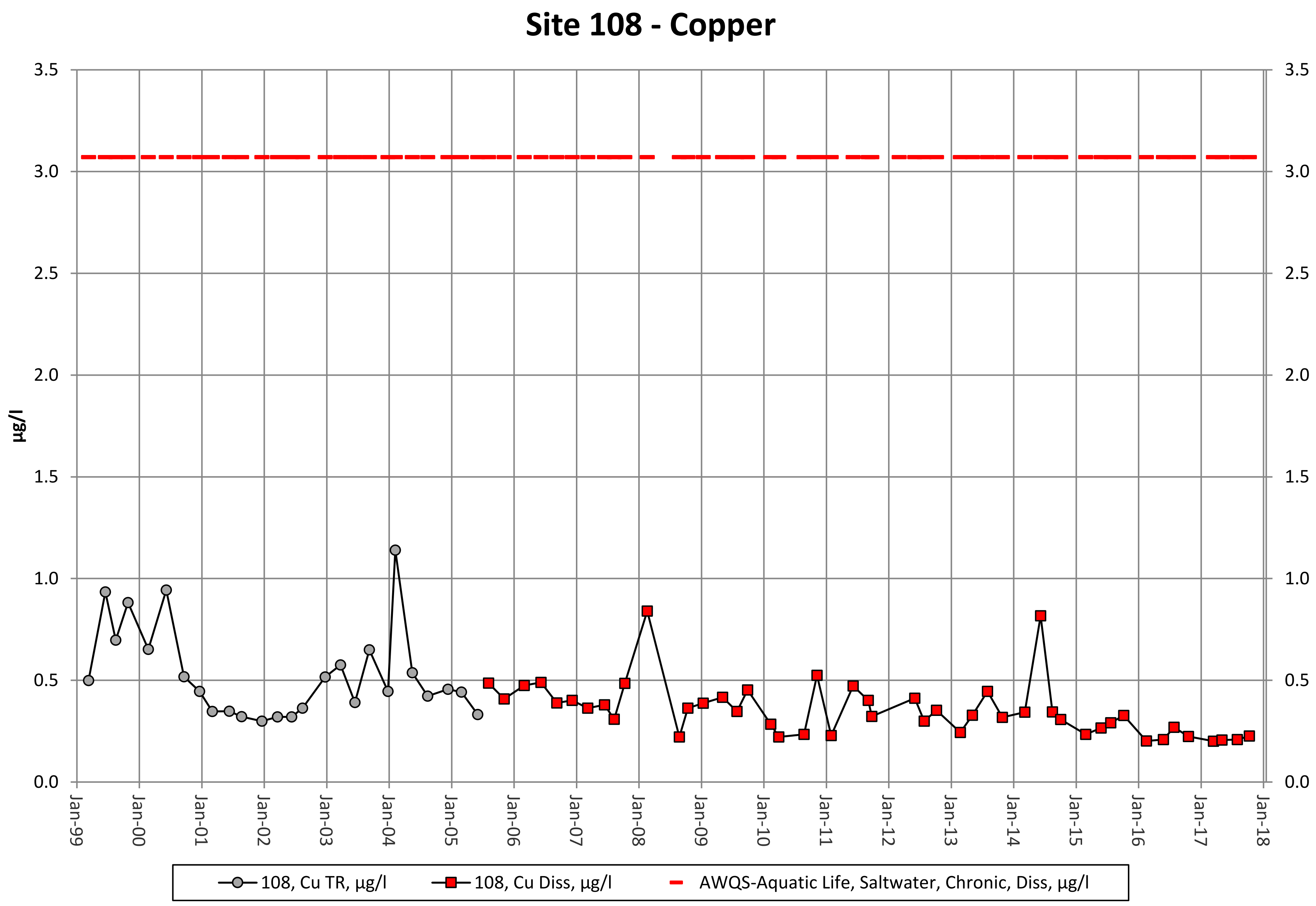
Site 106 - Copper
µg/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
106, Cu TR, µg/l
106, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-4b



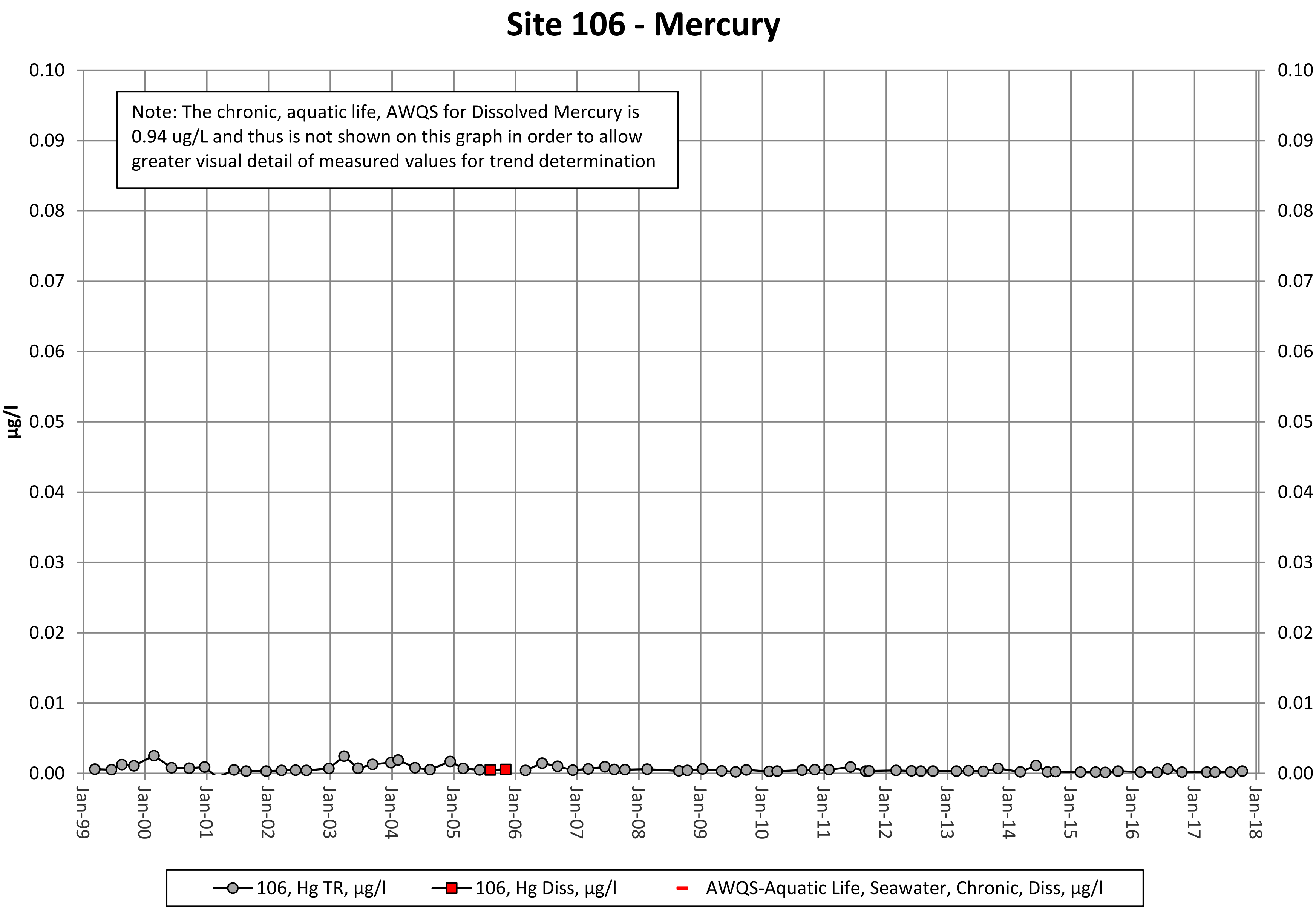
Site 107 - Copper
µg/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
107, Cu TR, µg/l
107, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-4c



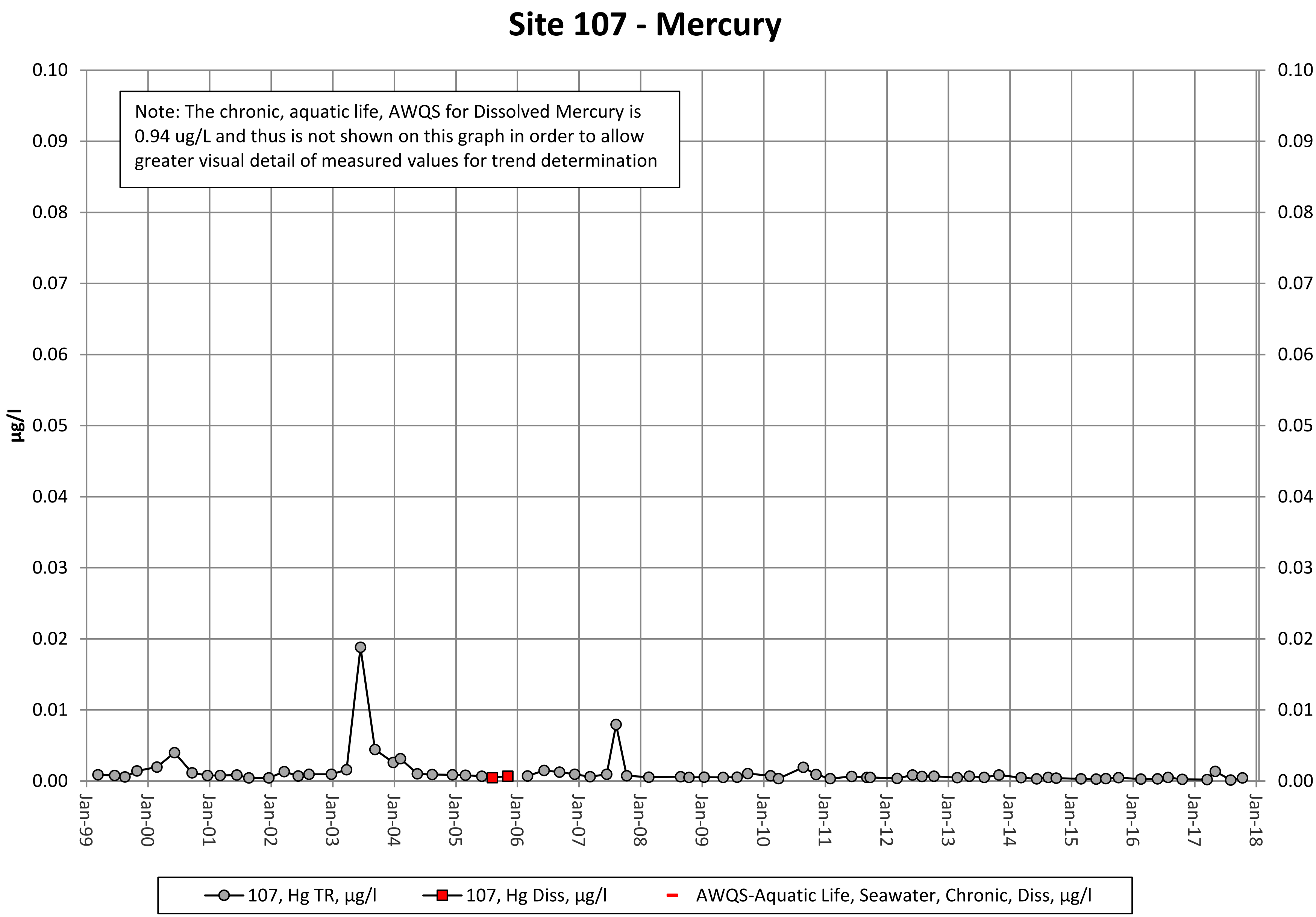
Site 108 - Copper
µg/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, Cu TR, µg/l
108, Cu Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-5a



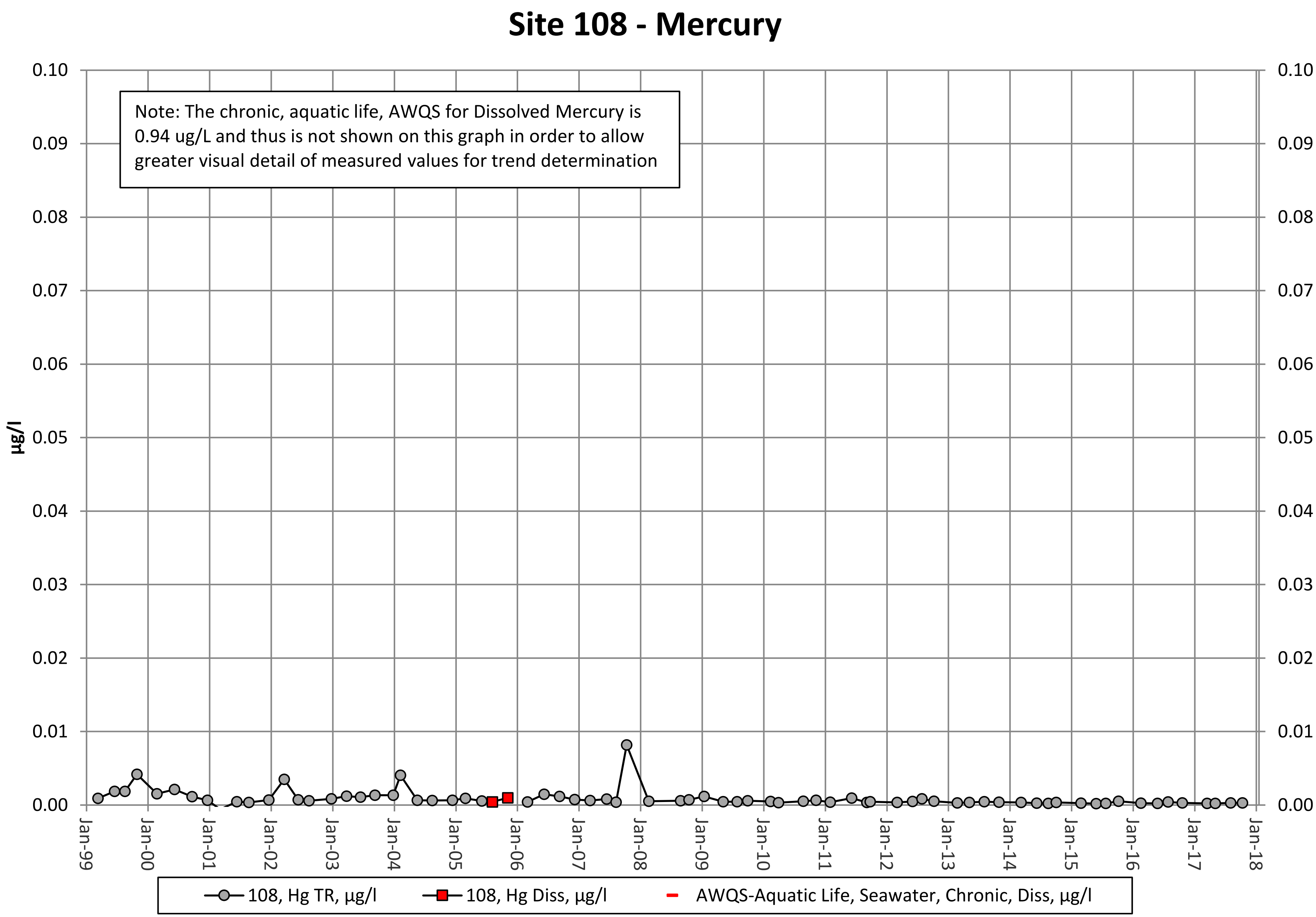
Site 106 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
106, Hg TR, µg/l
106, Hg Diss, µg/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, µg/l

Figure 2-5b



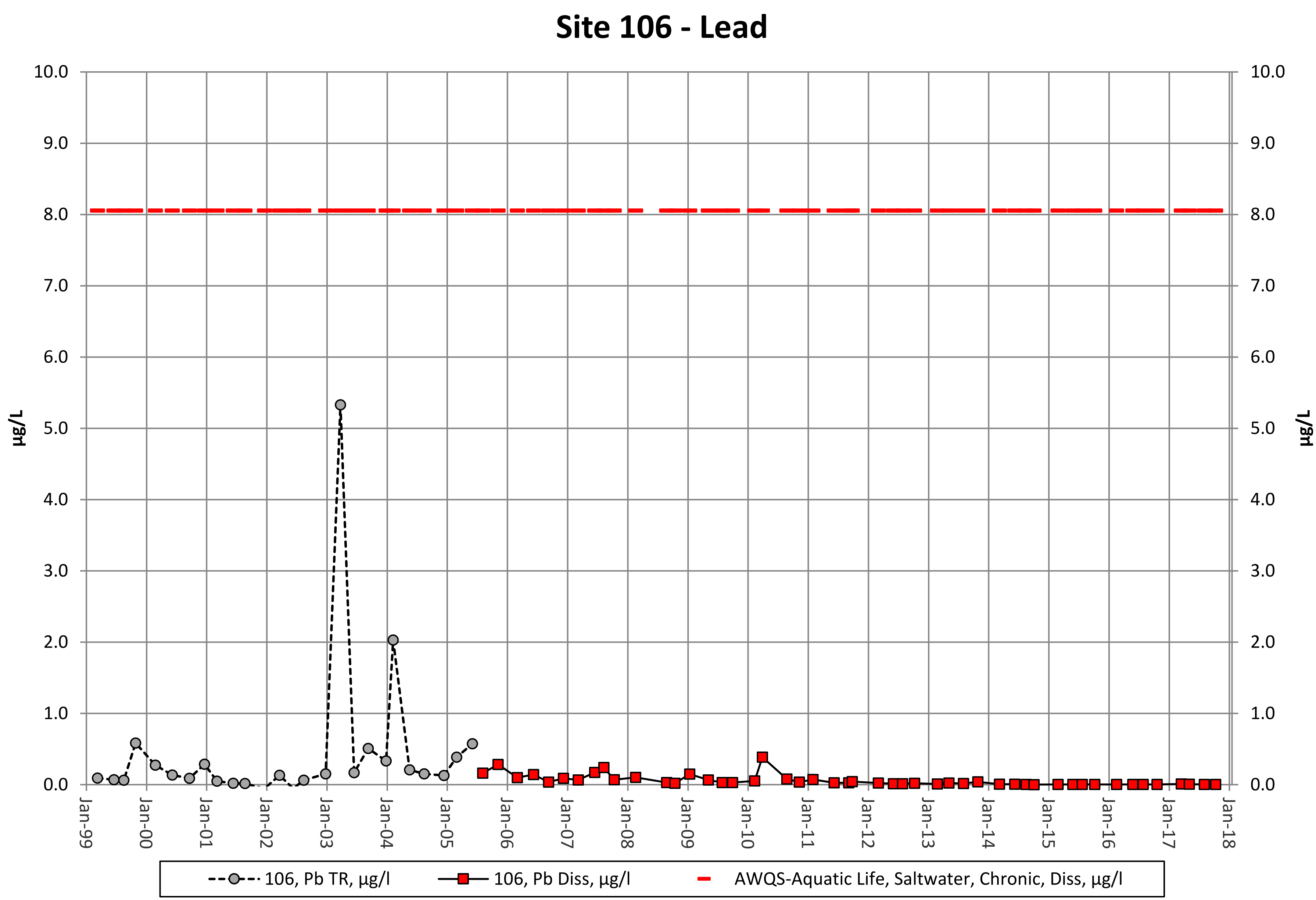
Site 107 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
107, Hg TR, µg/l
107, Hg Diss, µg/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, µg/l

Figure 2-5c



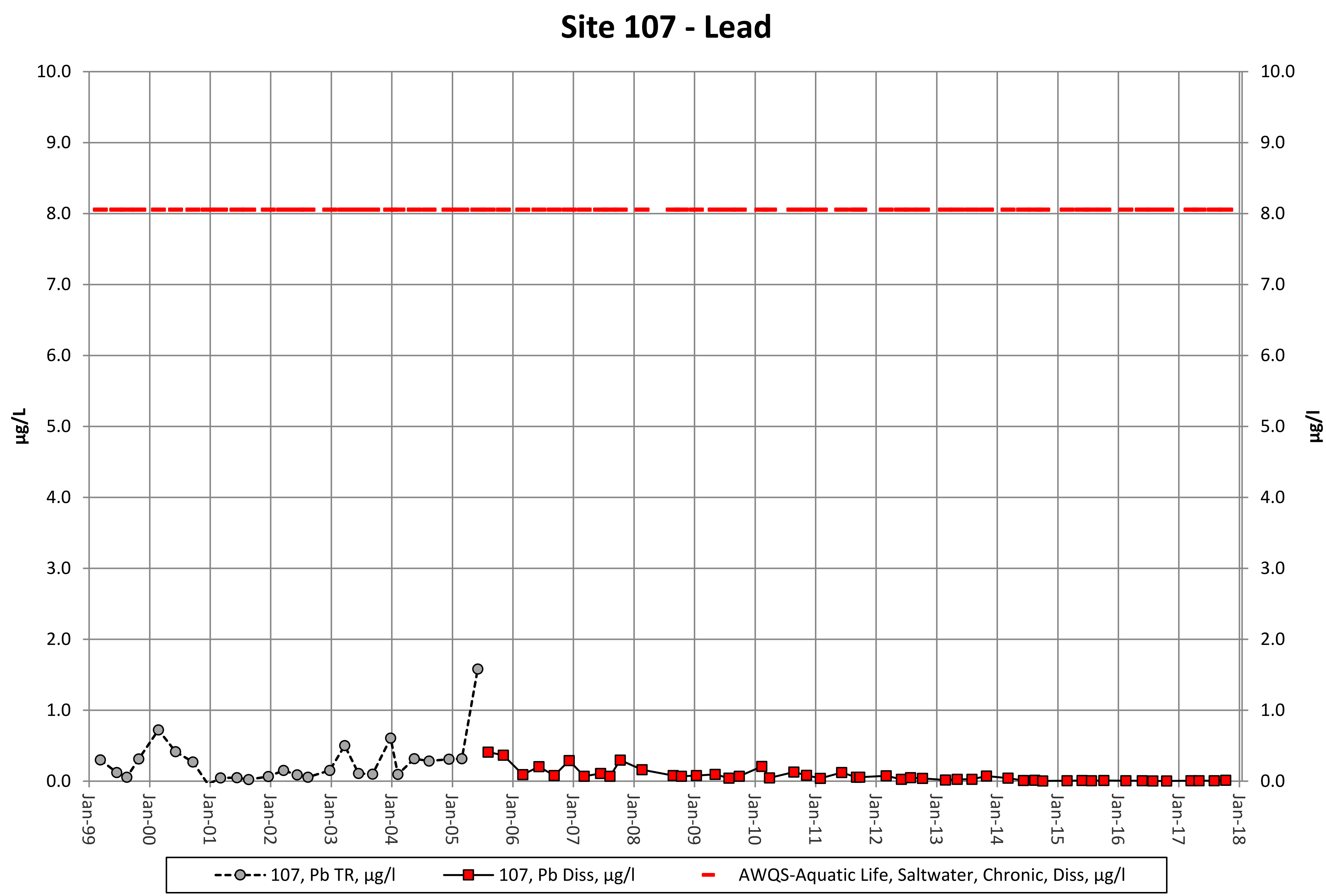
Site 108 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, Hg TR, µg/l
108, Hg Diss, µg/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, µg/l

Figure 2-6a



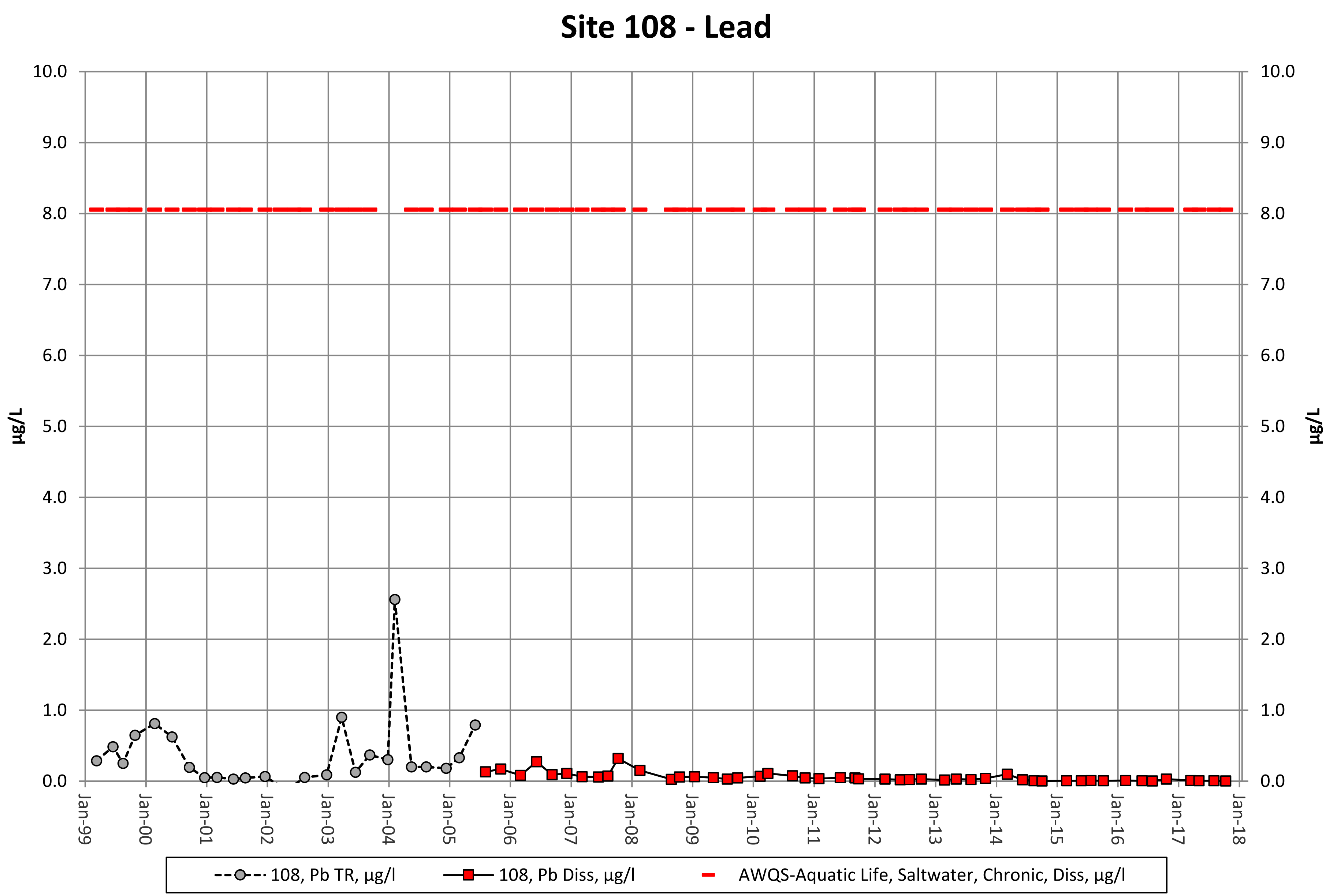
Site 106 - Lead
µg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
106, Pb TR, µg/l
106, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-6b



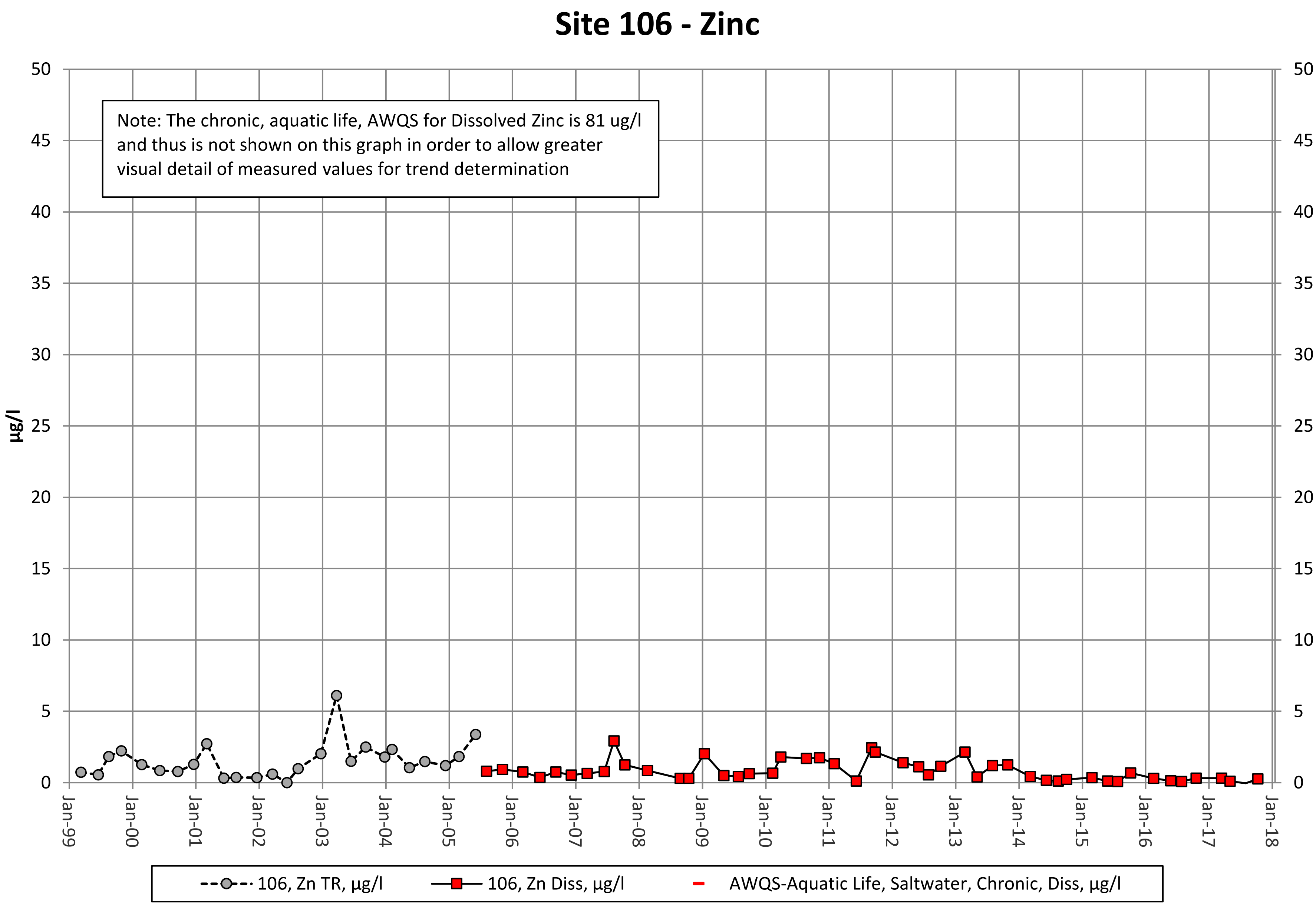
Site 107 - Lead
µg/L
µg/l
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
107, Pb TR, µg/l
107, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-6c



Site 108 - Lead
µg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, Pb TR, µg/l
108, Pb Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-7a



Site 106 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0
5
10
15
20
25
30
35
40
45
50
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
106, Zn TR, µg/l
106, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-7b

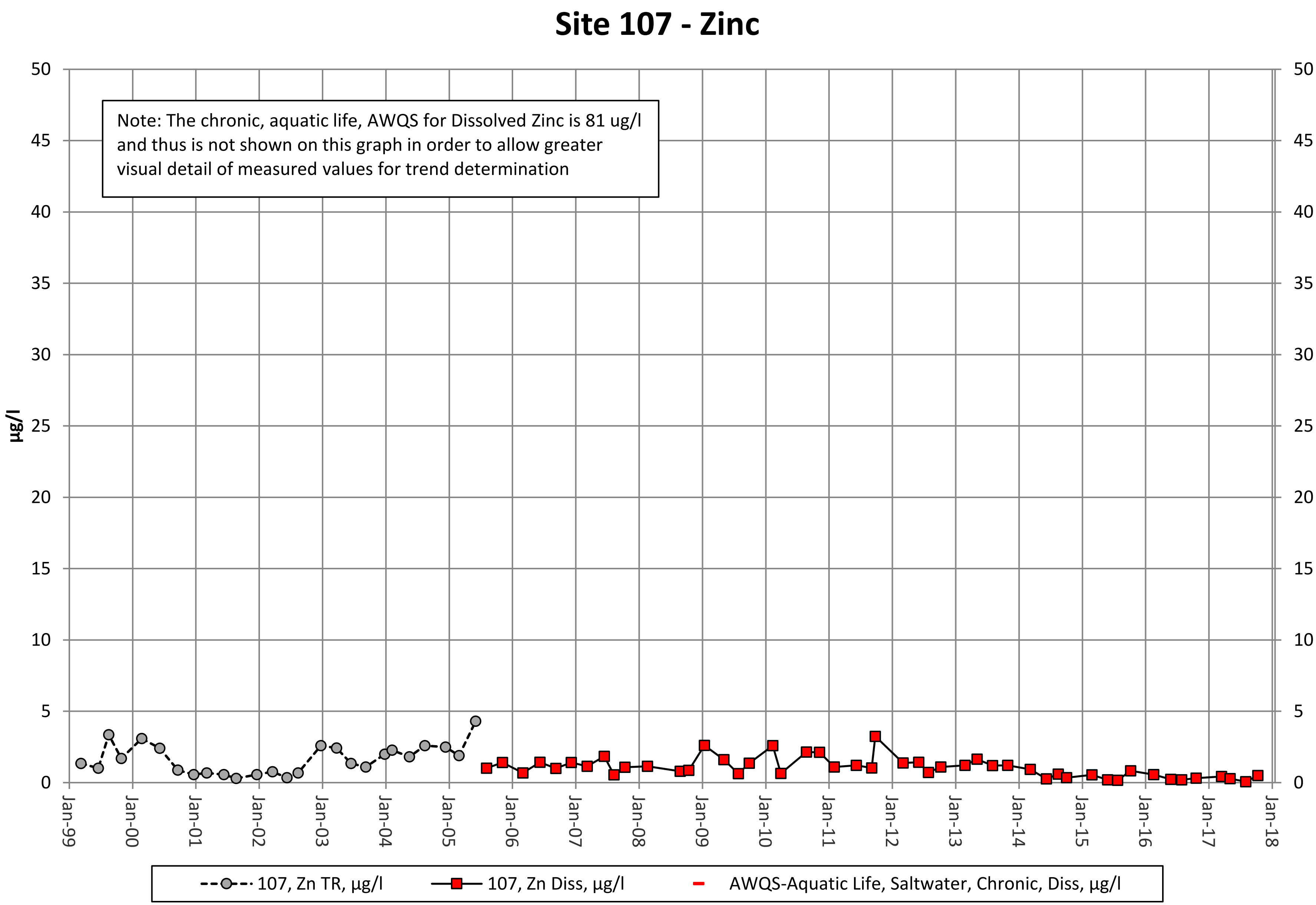
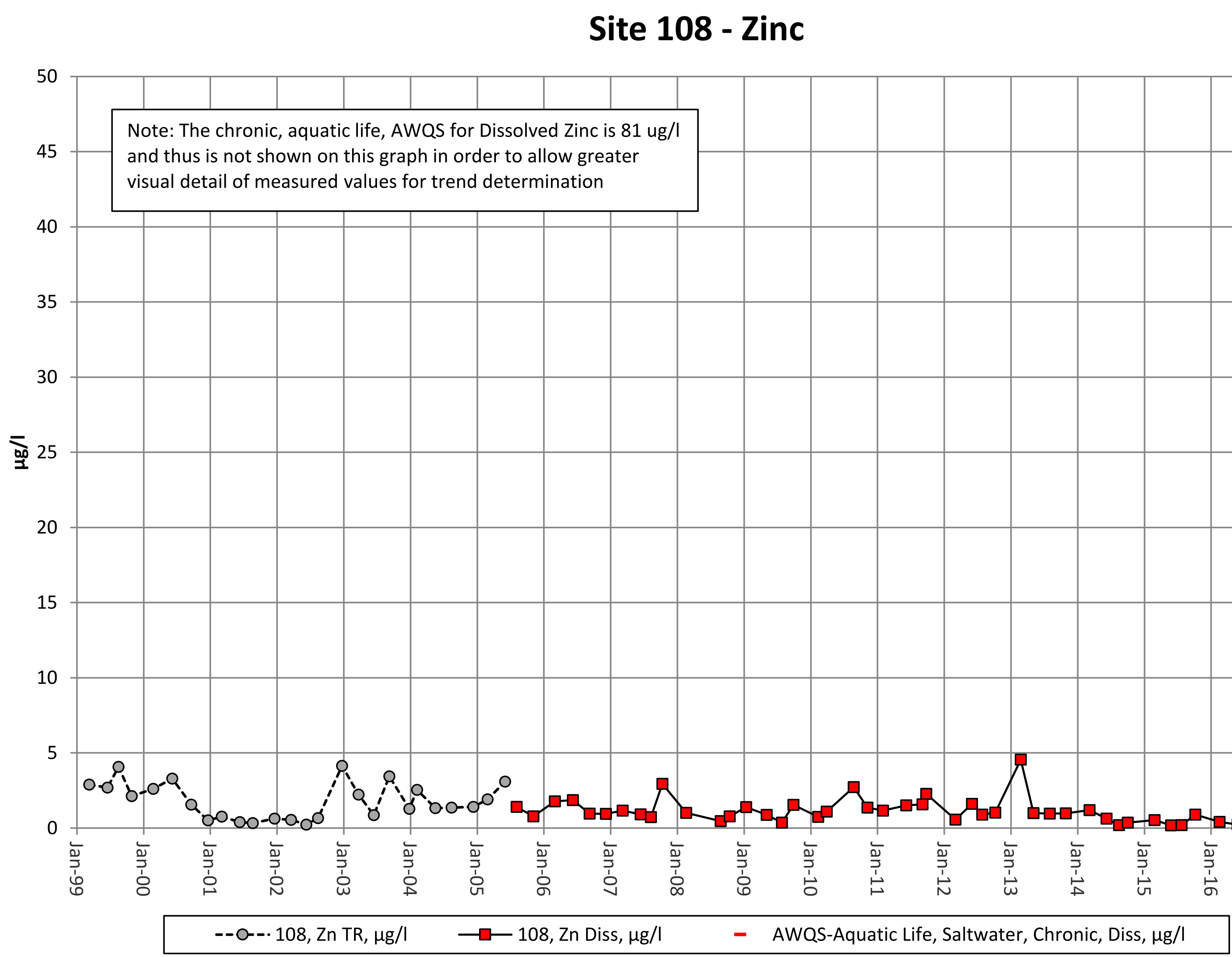
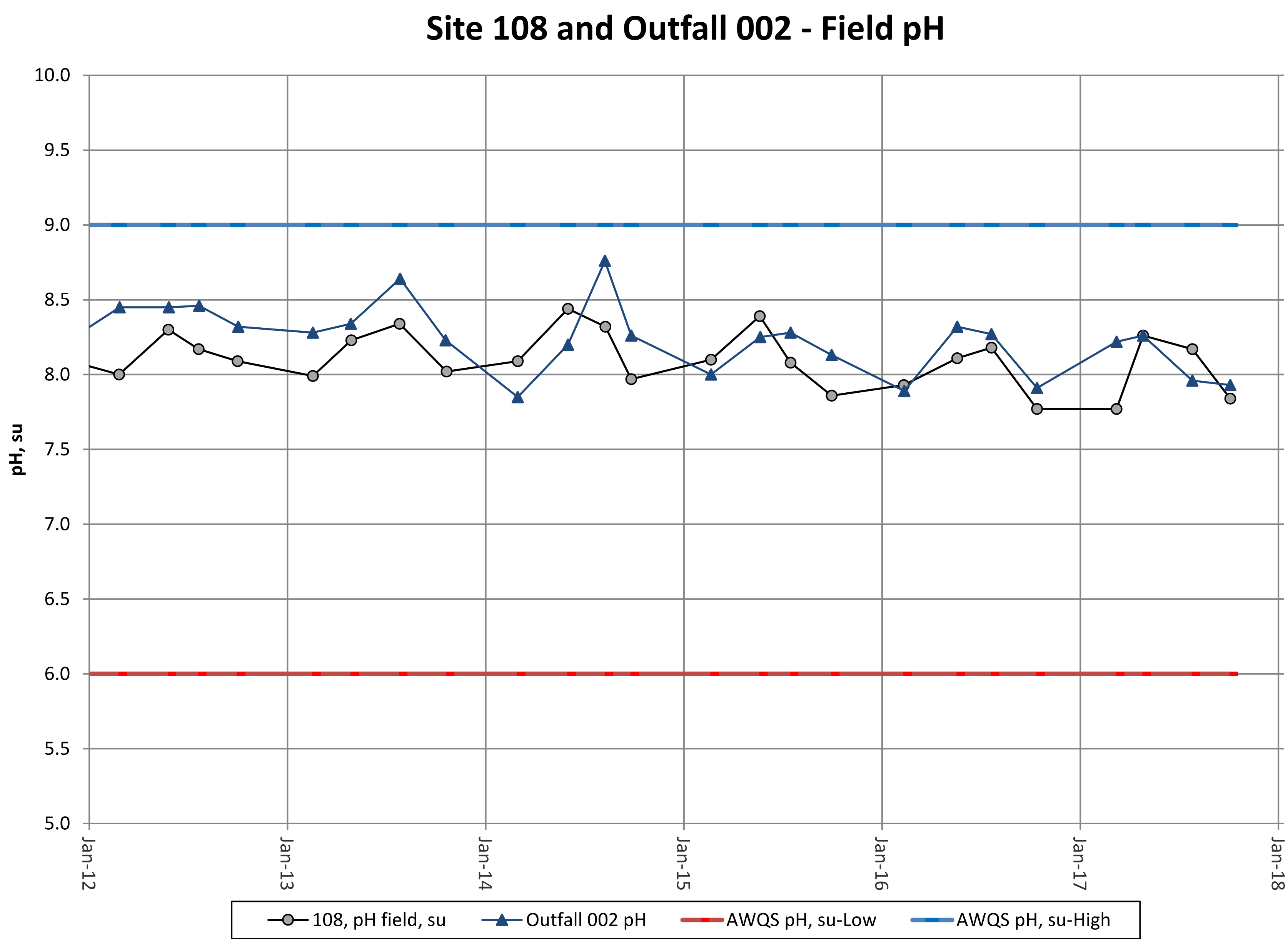

Site 107 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0
5
10
15
20
25
30
35
40
45
50
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
107, Zn TR, µg/l
107, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-7c



Site 108 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zinc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
µg/l
0
5
10
15
20
25
30
35
40
45
50
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, Zn TR, µg/l
108, Zn Diss, µg/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, µg/l

Figure 2-8a


Site 108 and Outfall 002 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
108, pH field, su
Outfall 002 pH
AWQS pH, su-Low
AWQS pH, su-High

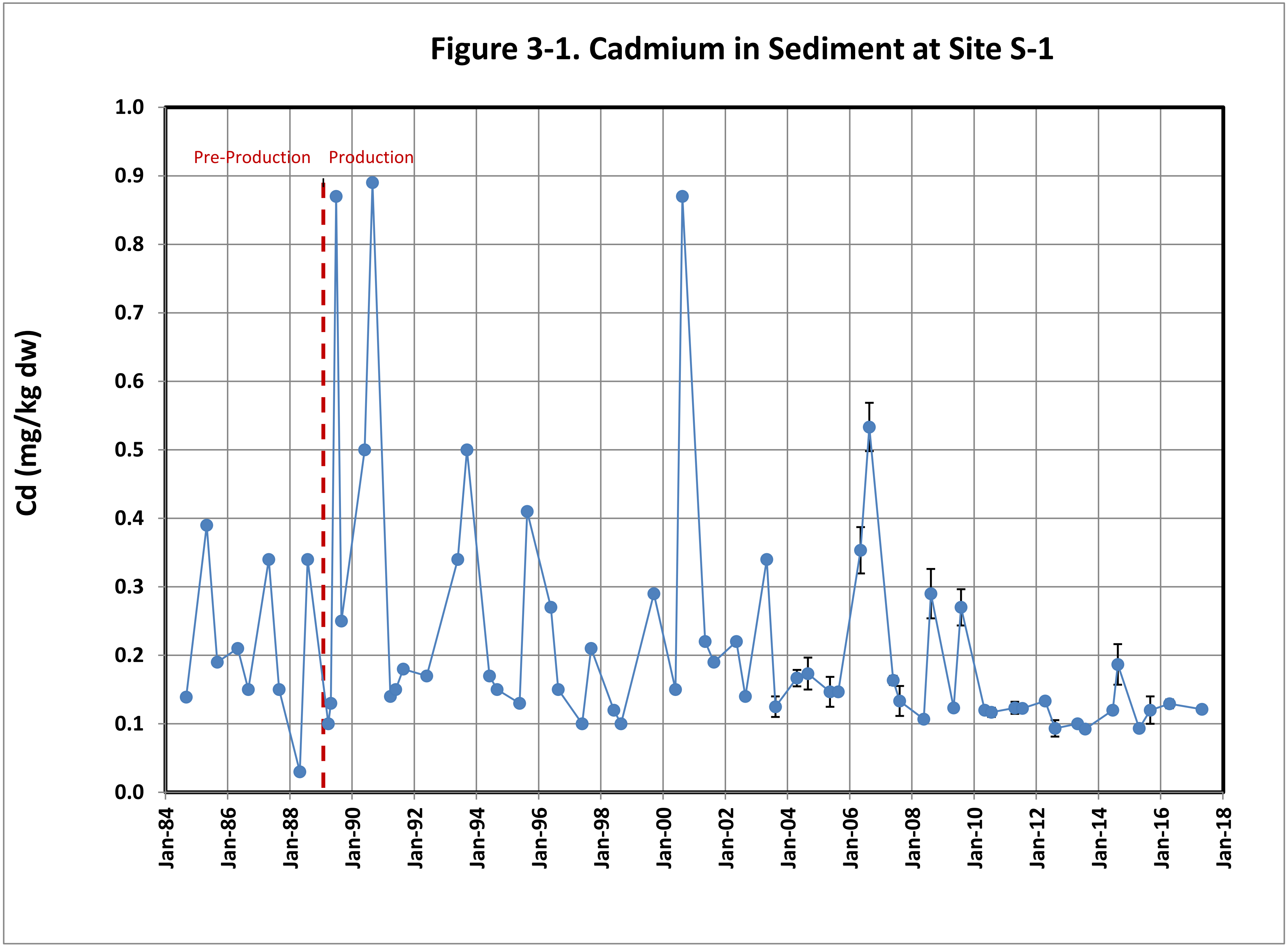


Figure 3-1. Cadmium in Sediment at Site S-1
Cd (mg/kg dw)
Pre-Production
Production
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

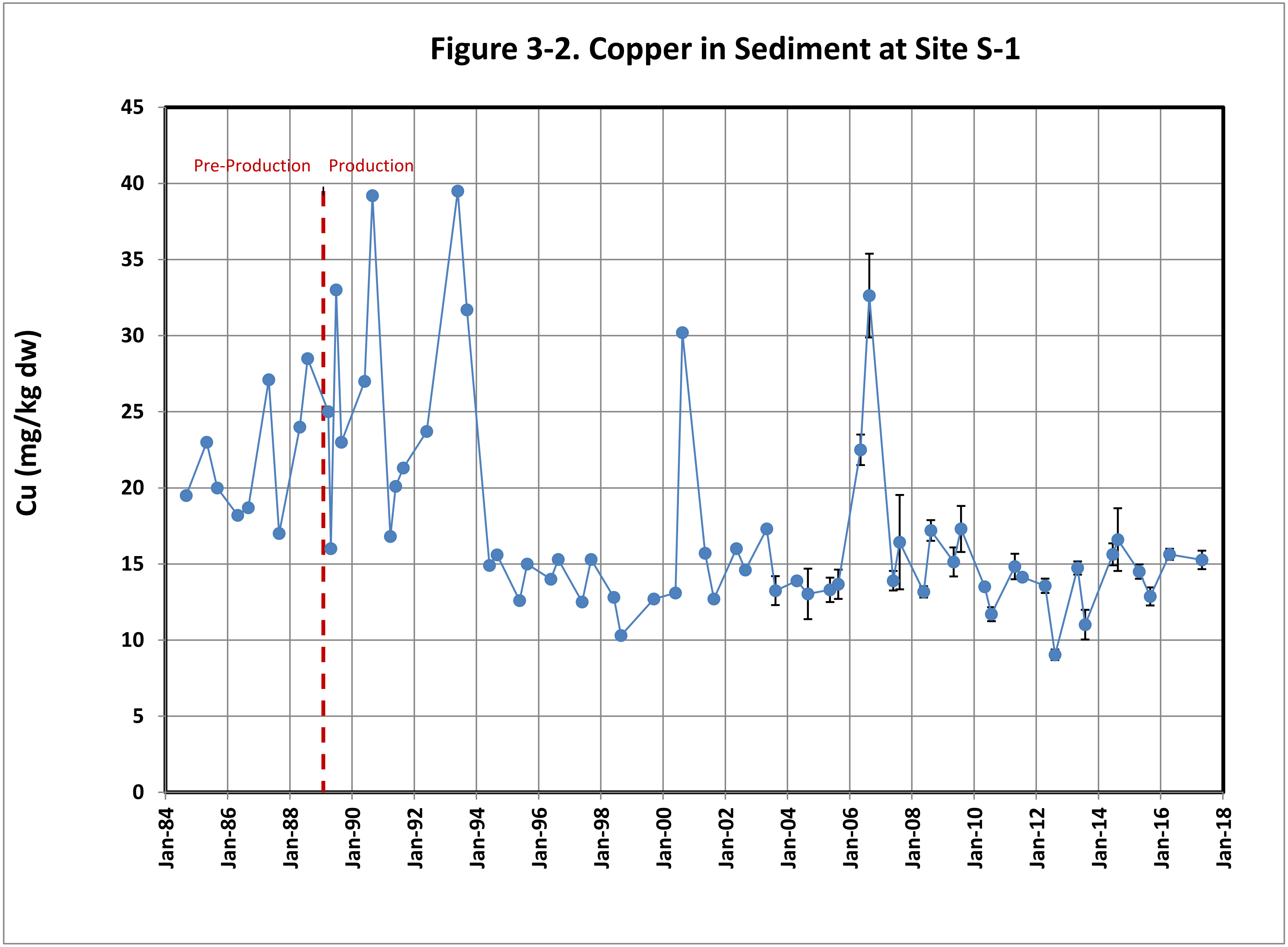
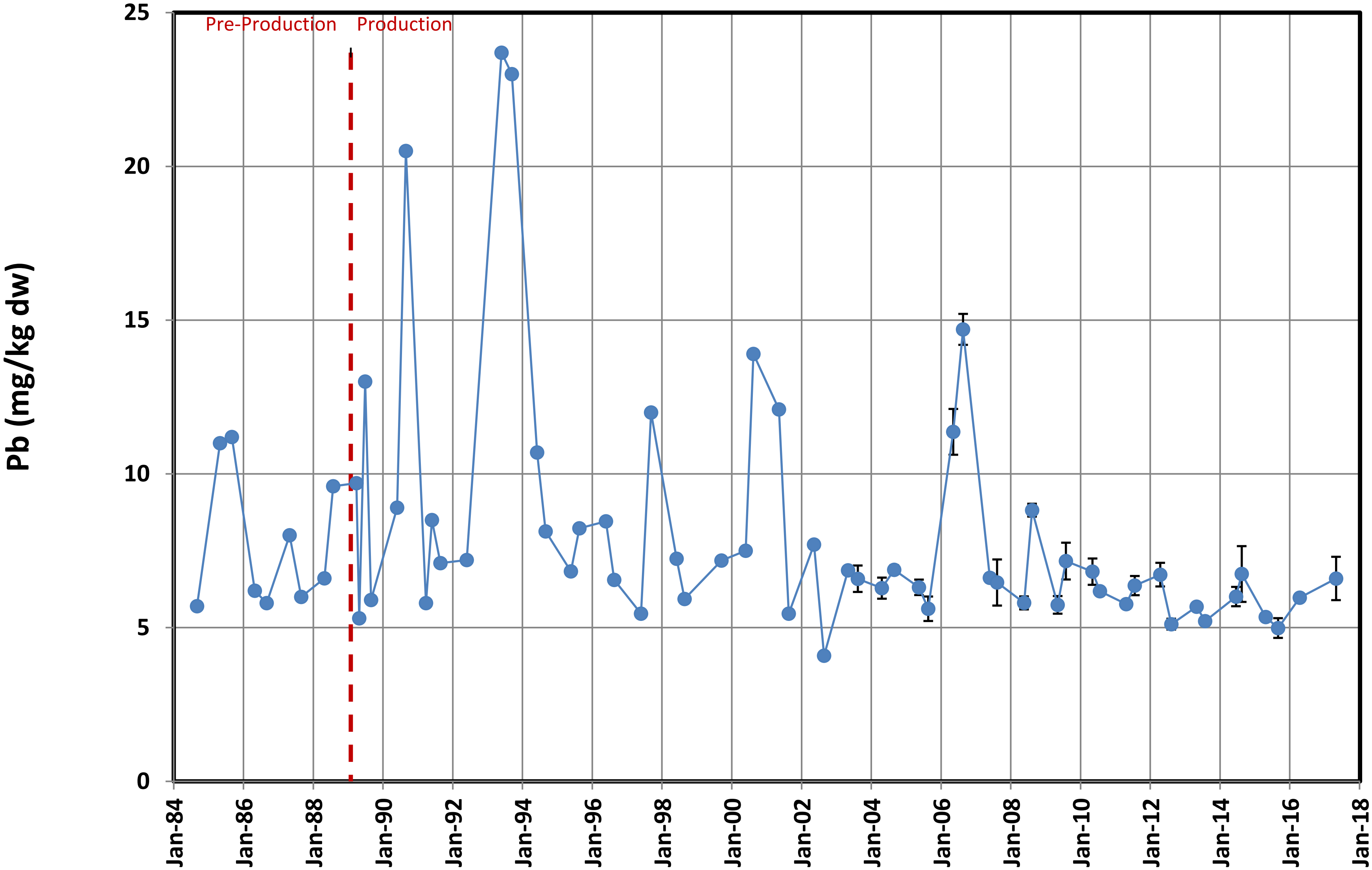


Figure 3-2. Copper in Sediment at Site S-1
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
35
40
45
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

Figure 3-3. Lead in Sediment at Site S-1



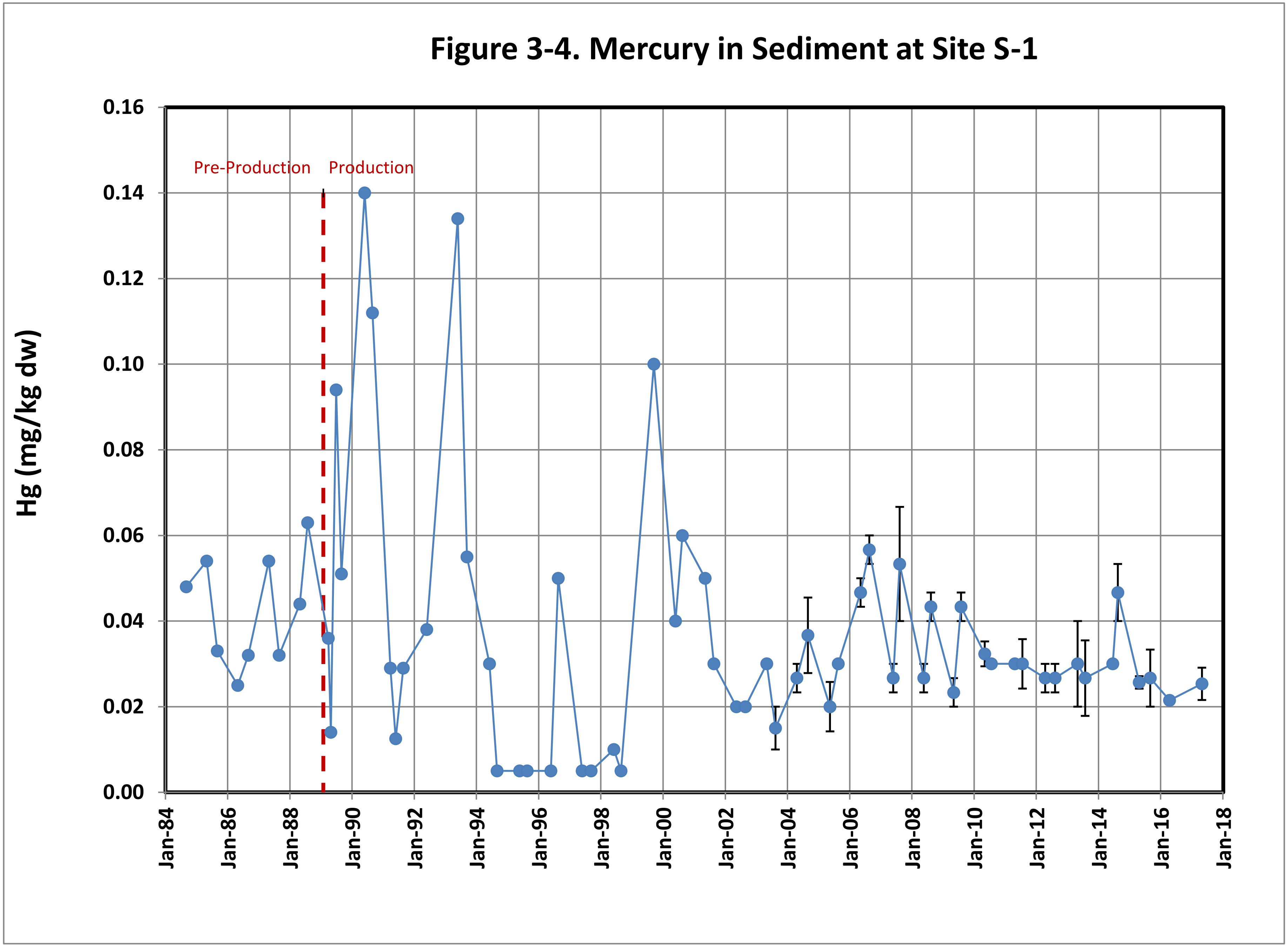


Figure 3-4. Mercury in Sediment at Site S-1
Hg (mg/kg dw)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

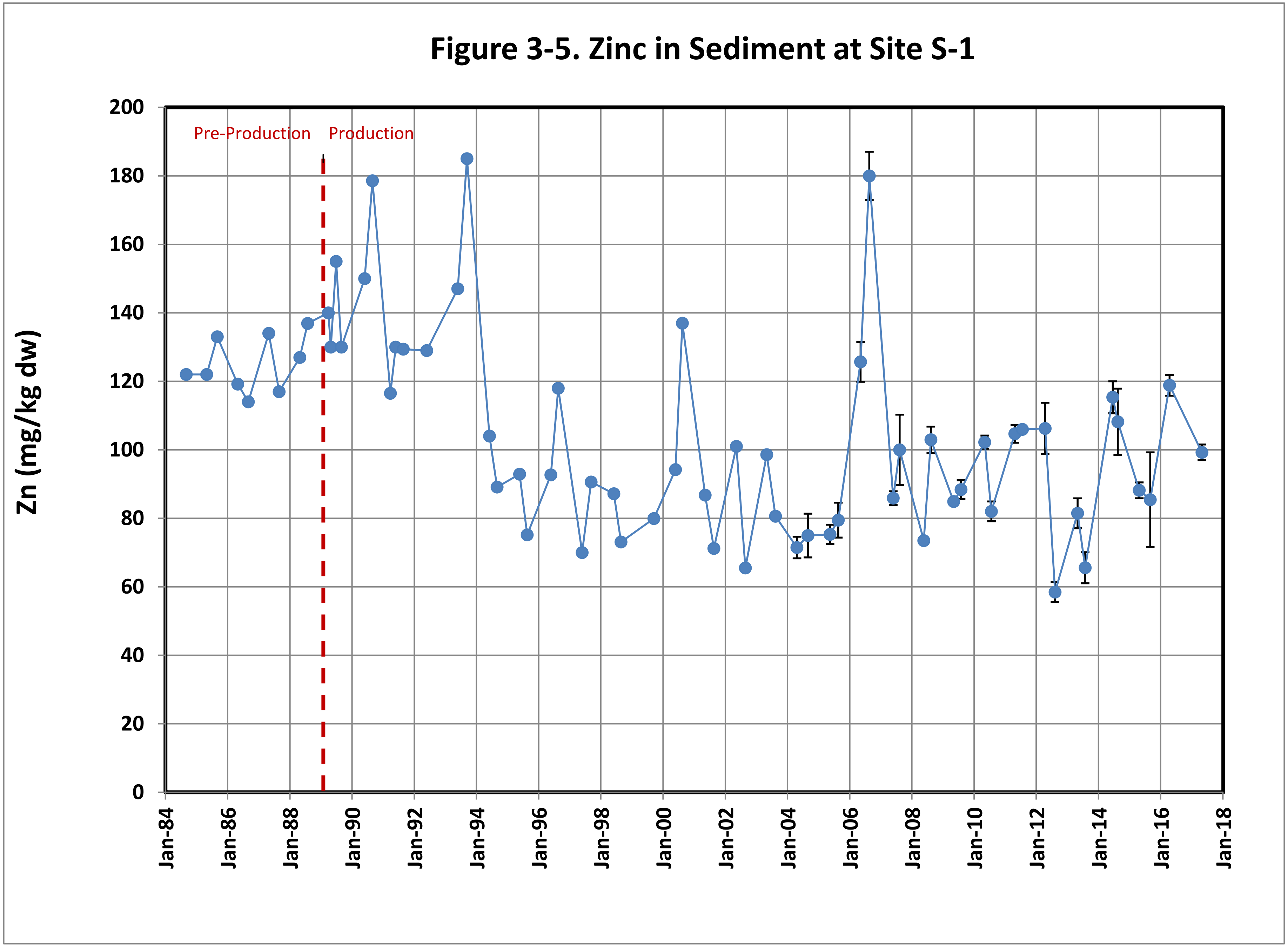


Figure 3-5. Zinc in Sediment at Site S-1
Pre-Production
Production
Zn (mg/kg dw)
200
180
160
140
120
100
80
60
40
20
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

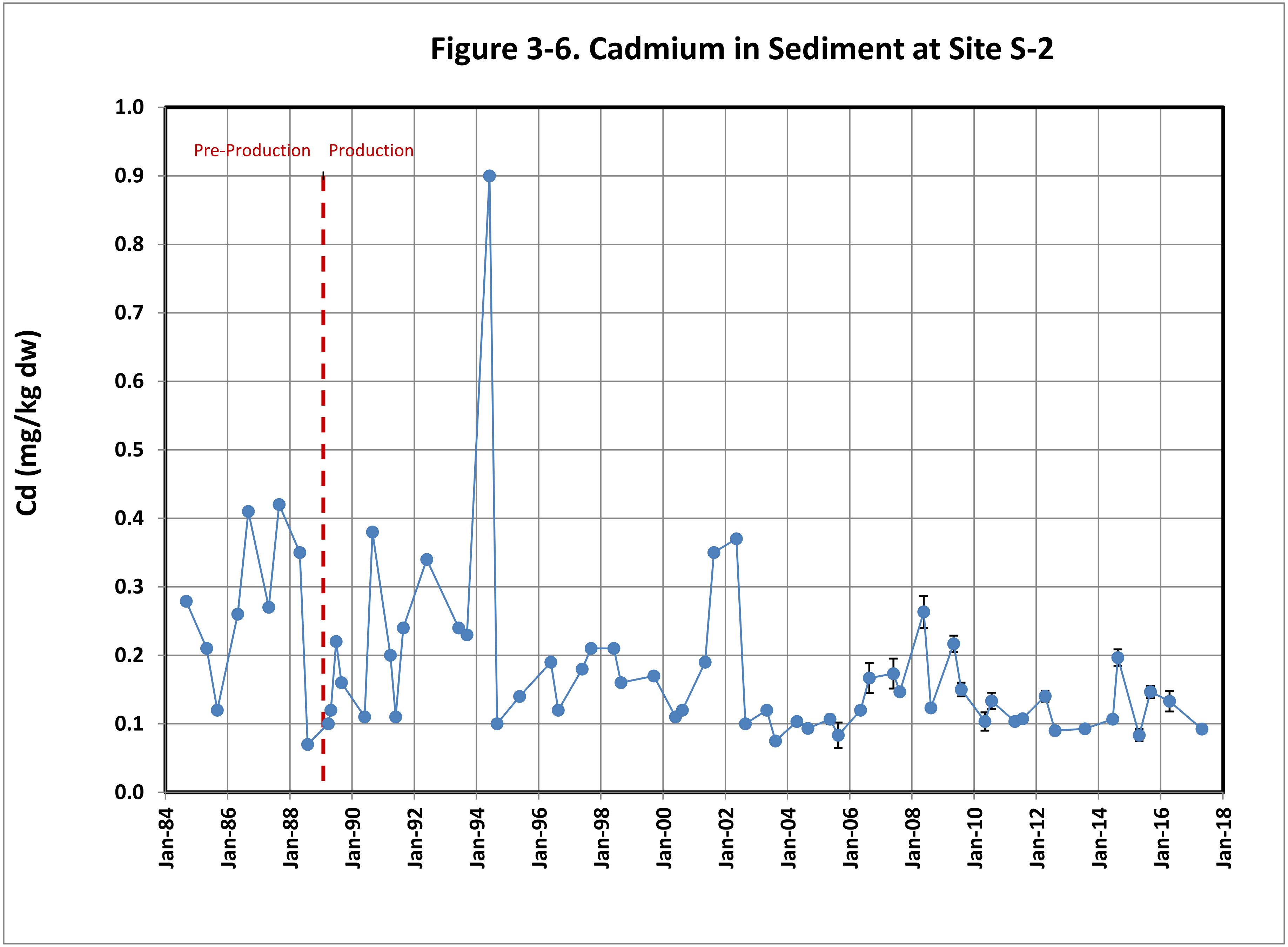


Figure 3-6. Cadmium in Sediment at Site S-2
Cd (mg/kg dw)
Pre-Production
Production
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

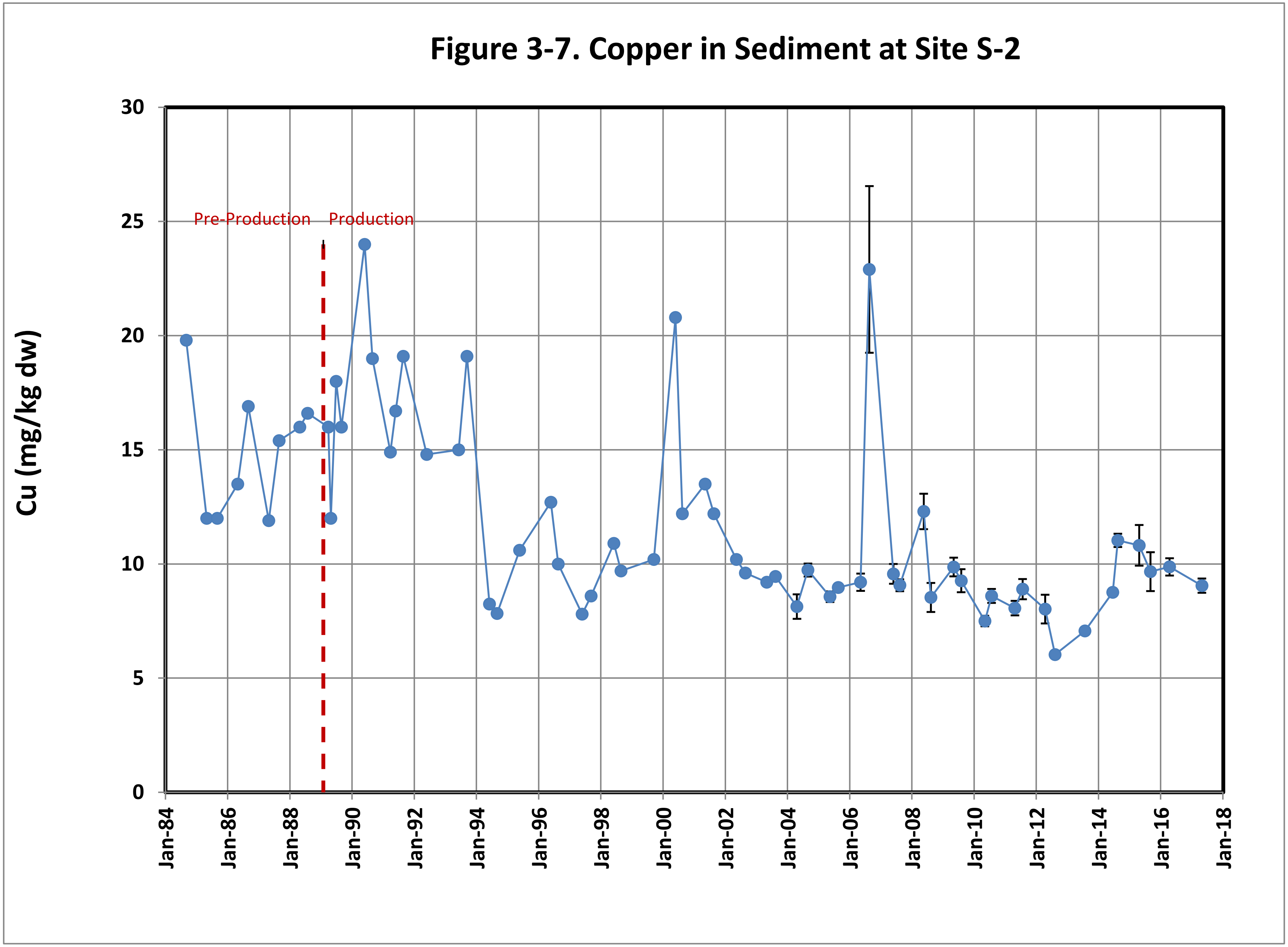


Figure 3-7. Copper in Sediment at Site S-2
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

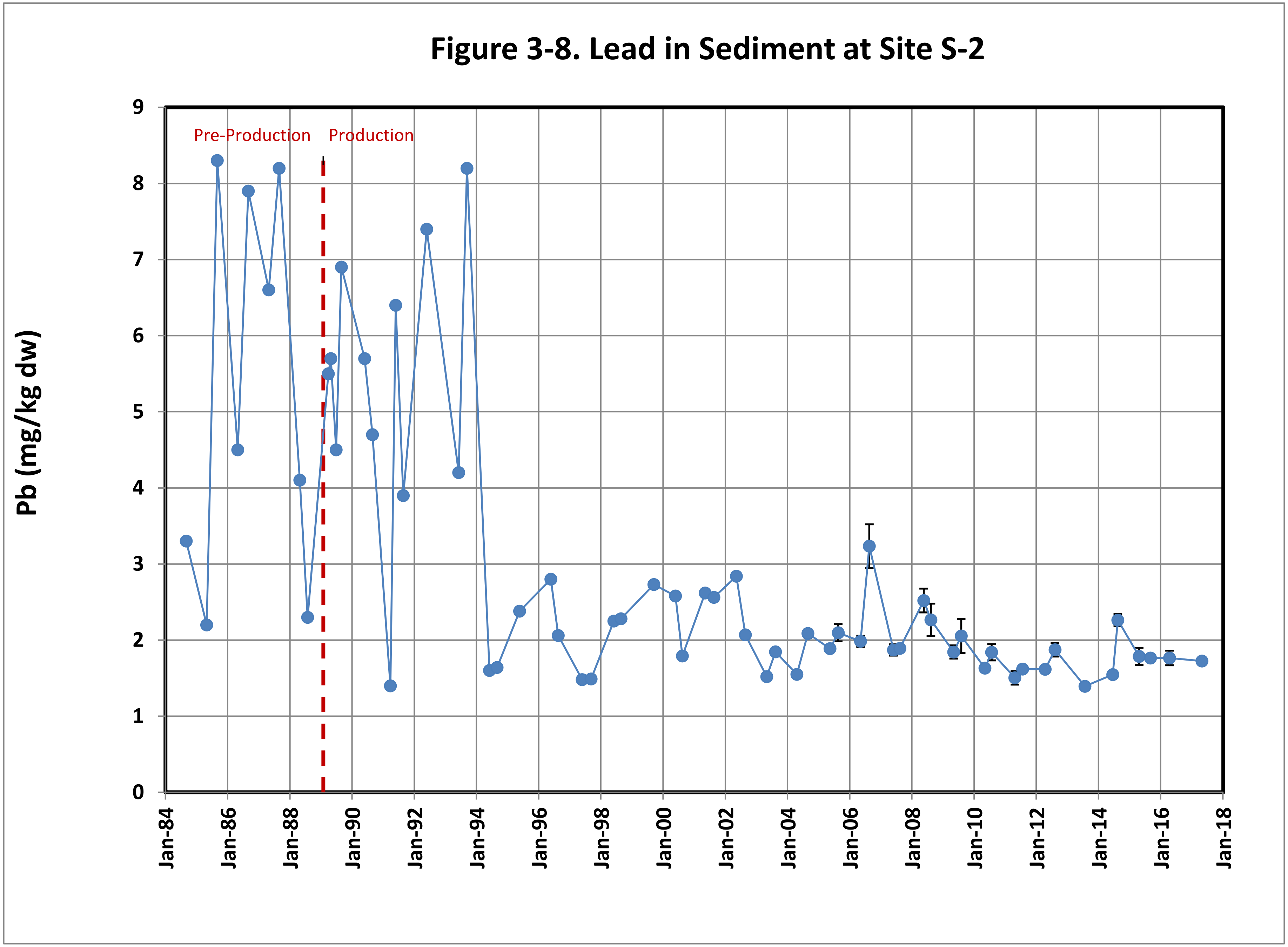


Figure 3-8. Lead in Sediment at Site S-2
Pb (mg/kg dw)
Pre-Production
Production
0
1
2
3
4
5
6
7
8
9
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

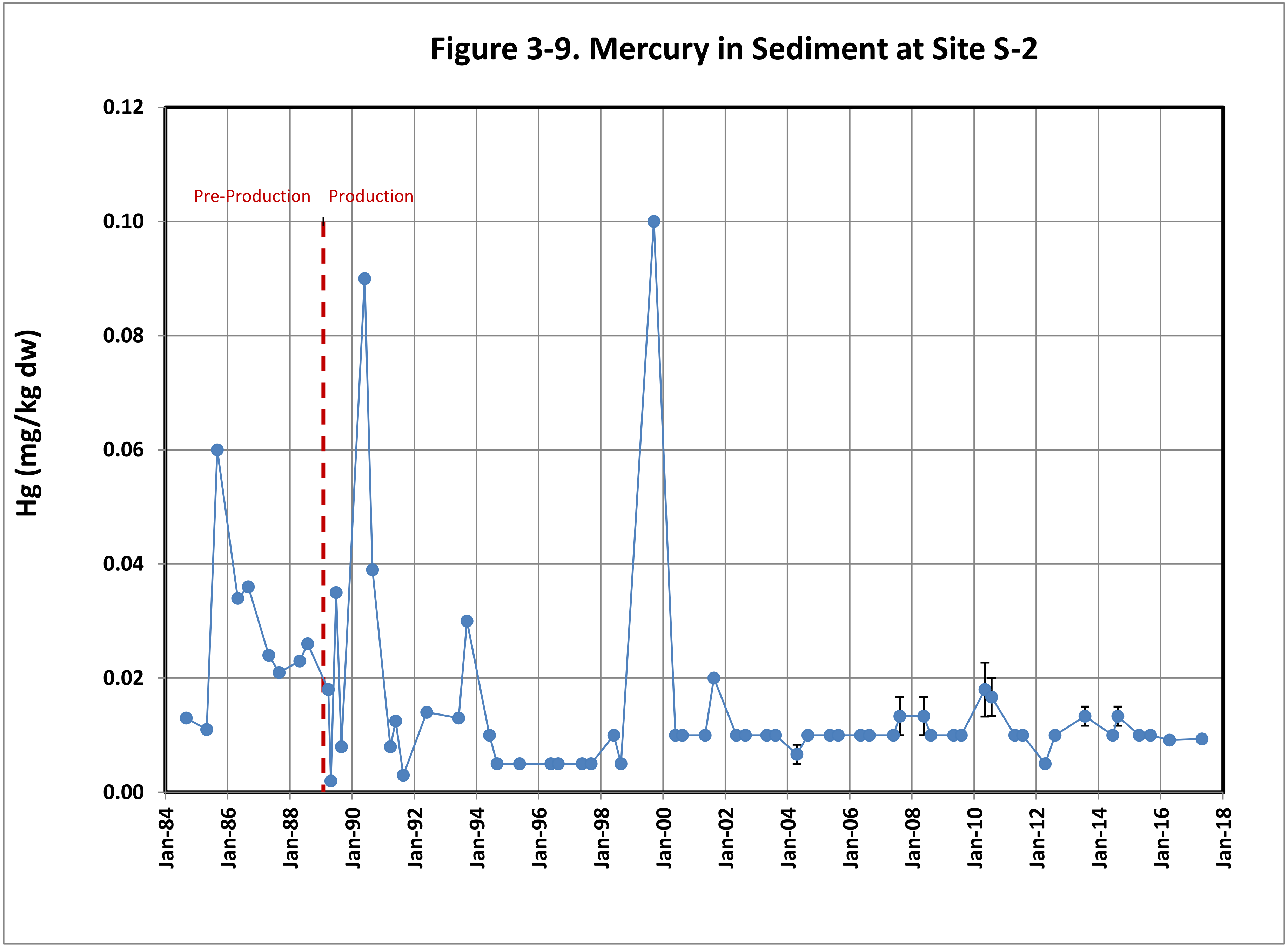


Figure 3-9. Mercury in Sediment at Site S-2
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

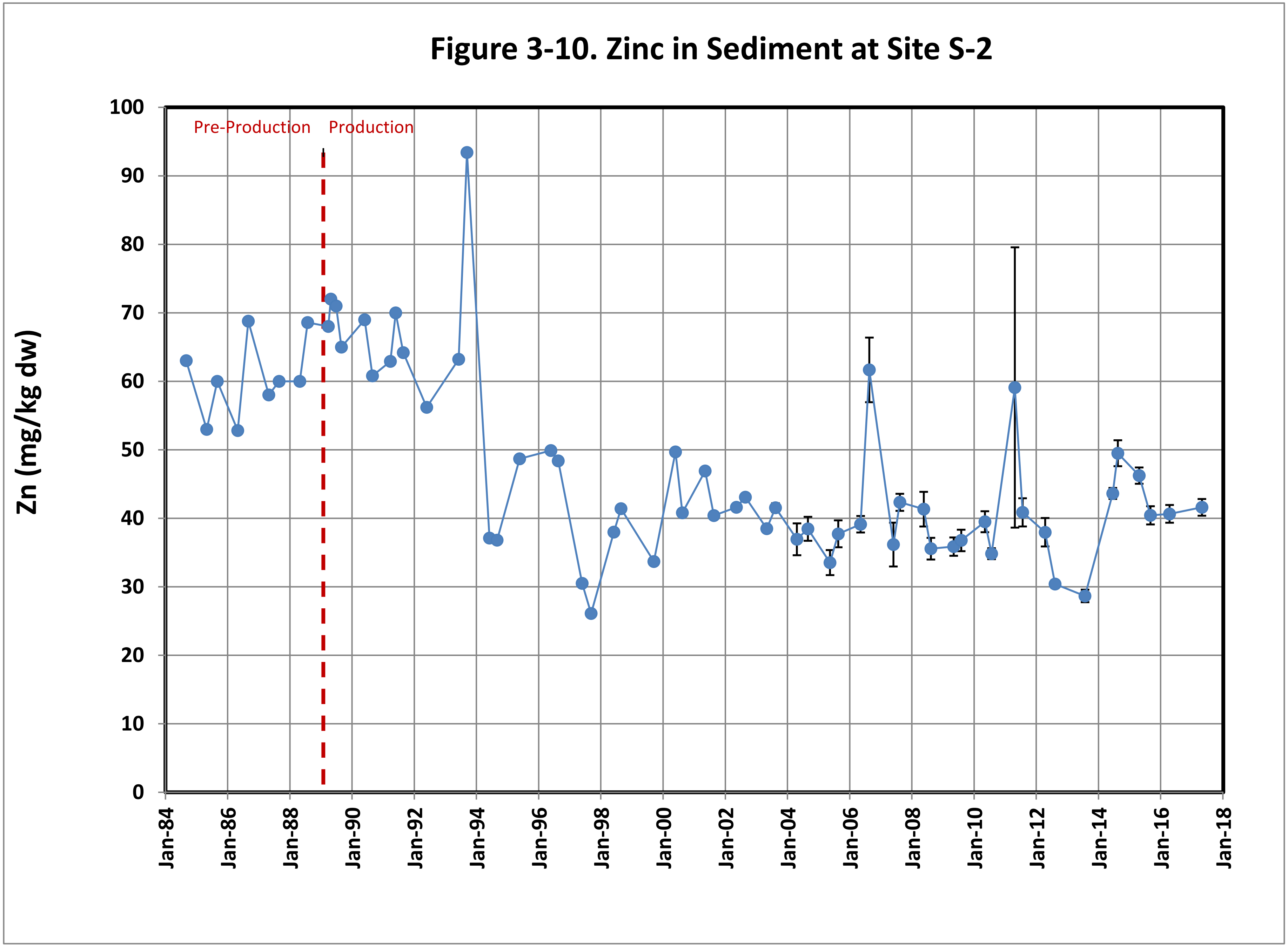


Figure 3-10. Zinc in Sediment at Site S-2
Zn (mg/kg dw)
Pre-Production
Production
0
10
20
30
40
50
60
70
80
90
100
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

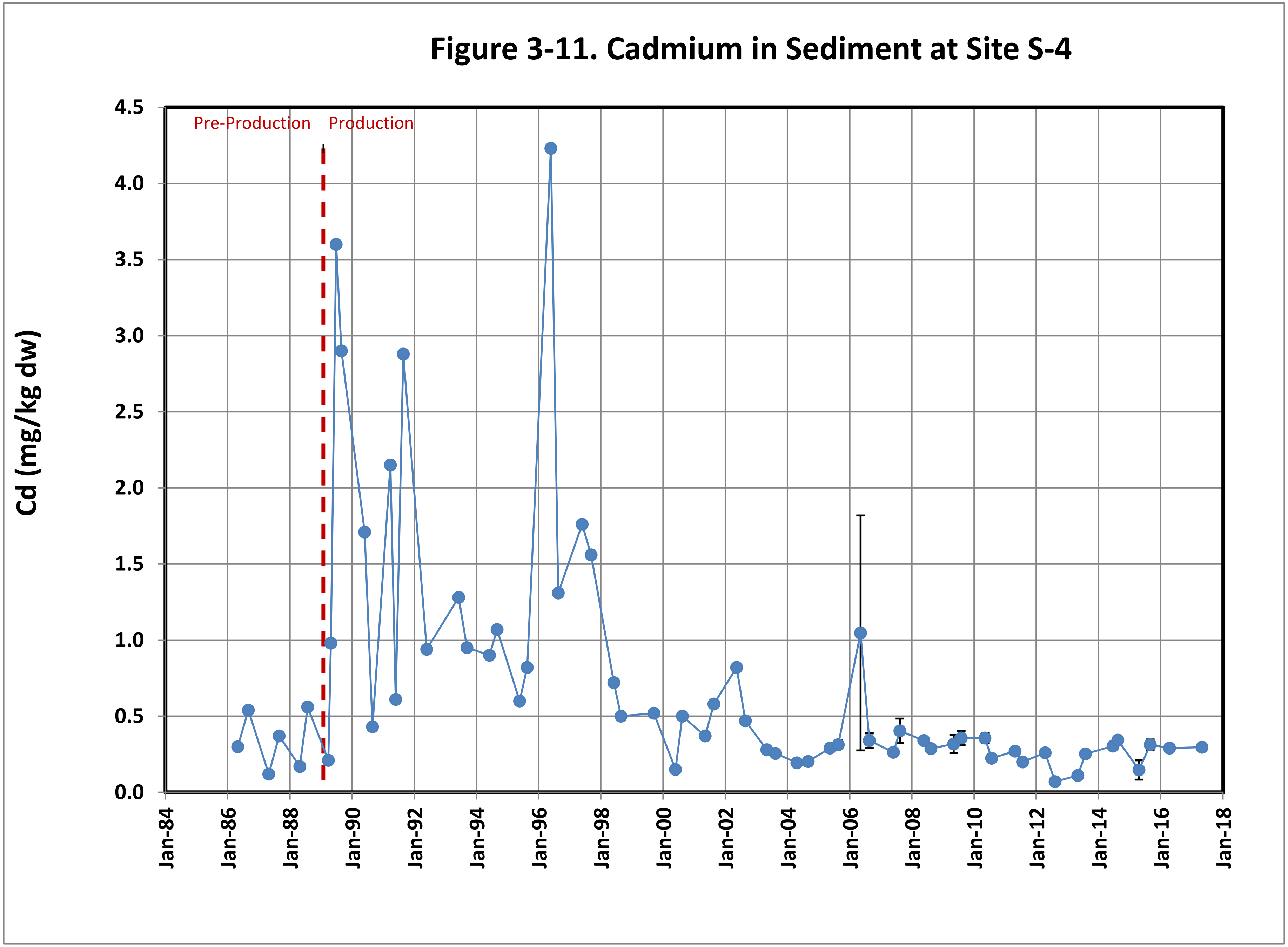


Figure 3-11. Cadmium in Sediment at Site S-4
Pre-Production
Production
Cd (mg/kg dw)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

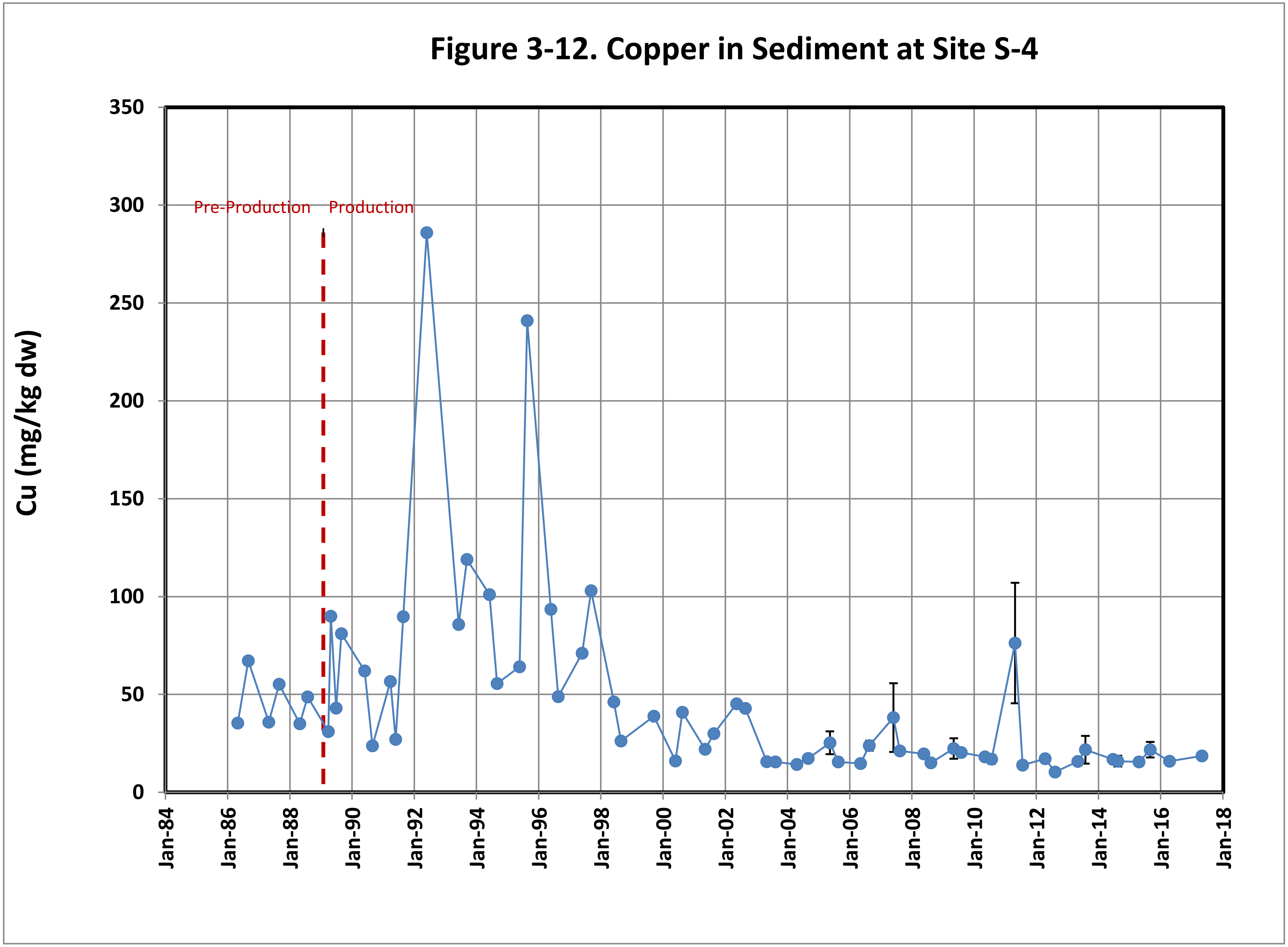


Figure 3-12. Copper in Sediment at Site S-4
Cu (mg/kg dw)
350
300
250
200
150
100
50
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

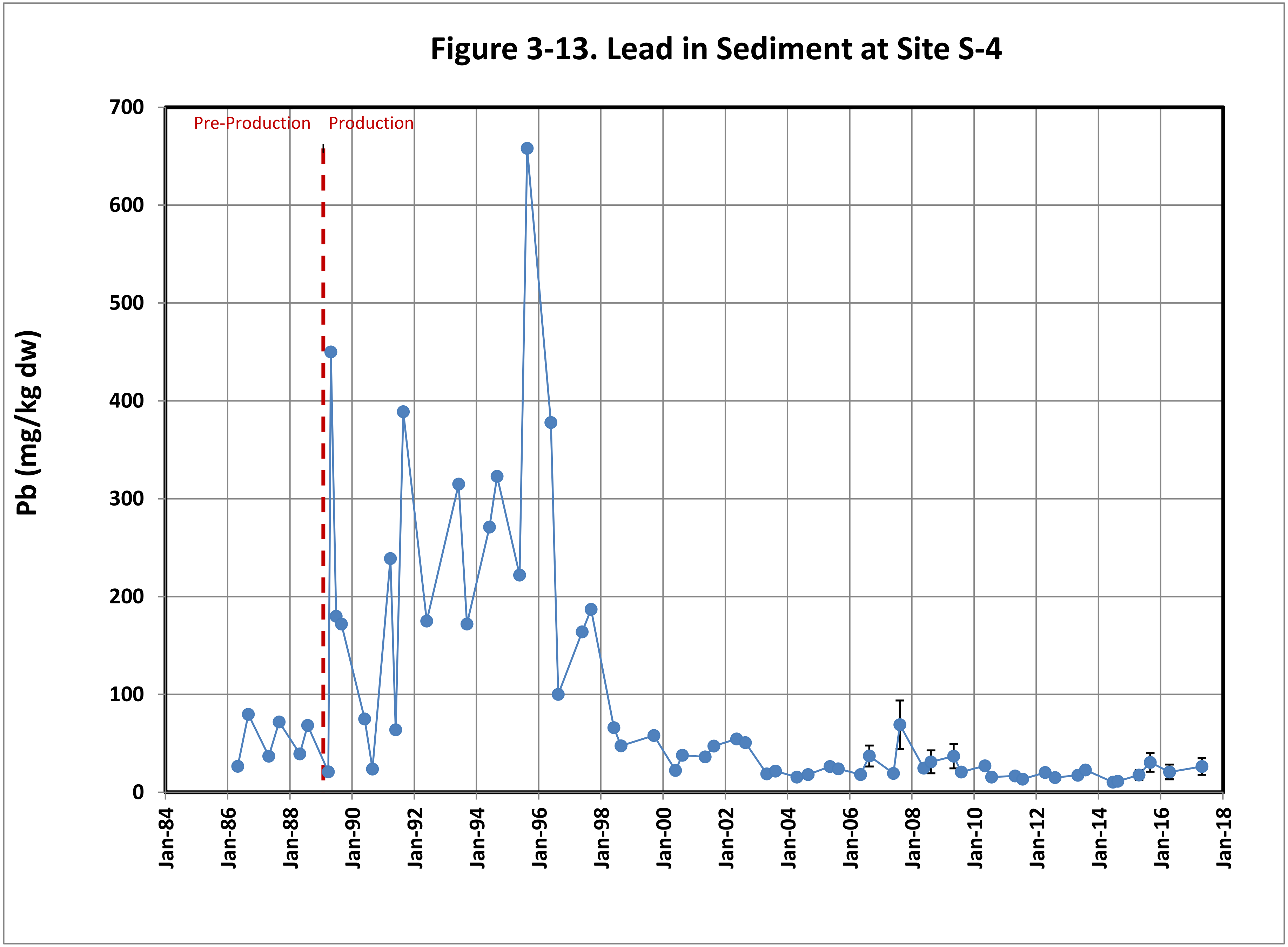


Figure 3-13. Lead in Sediment at Site S-4
Pb (mg/kg dw)
700
600
500
400
300
200
100
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

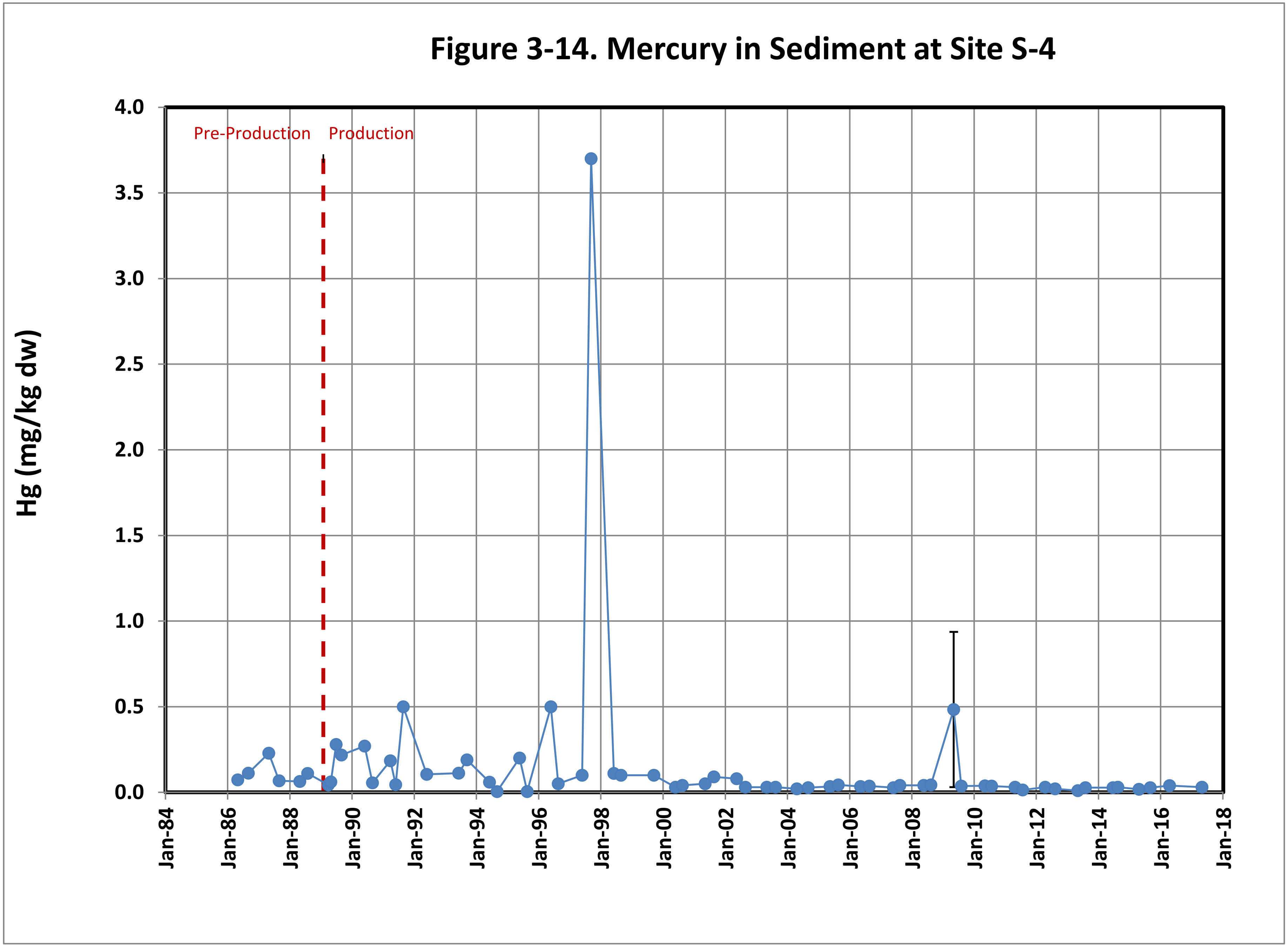


Figure 3-14. Mercury in Sediment at Site S-4
Pre-Production
Production
Hg (mg/kg dw)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

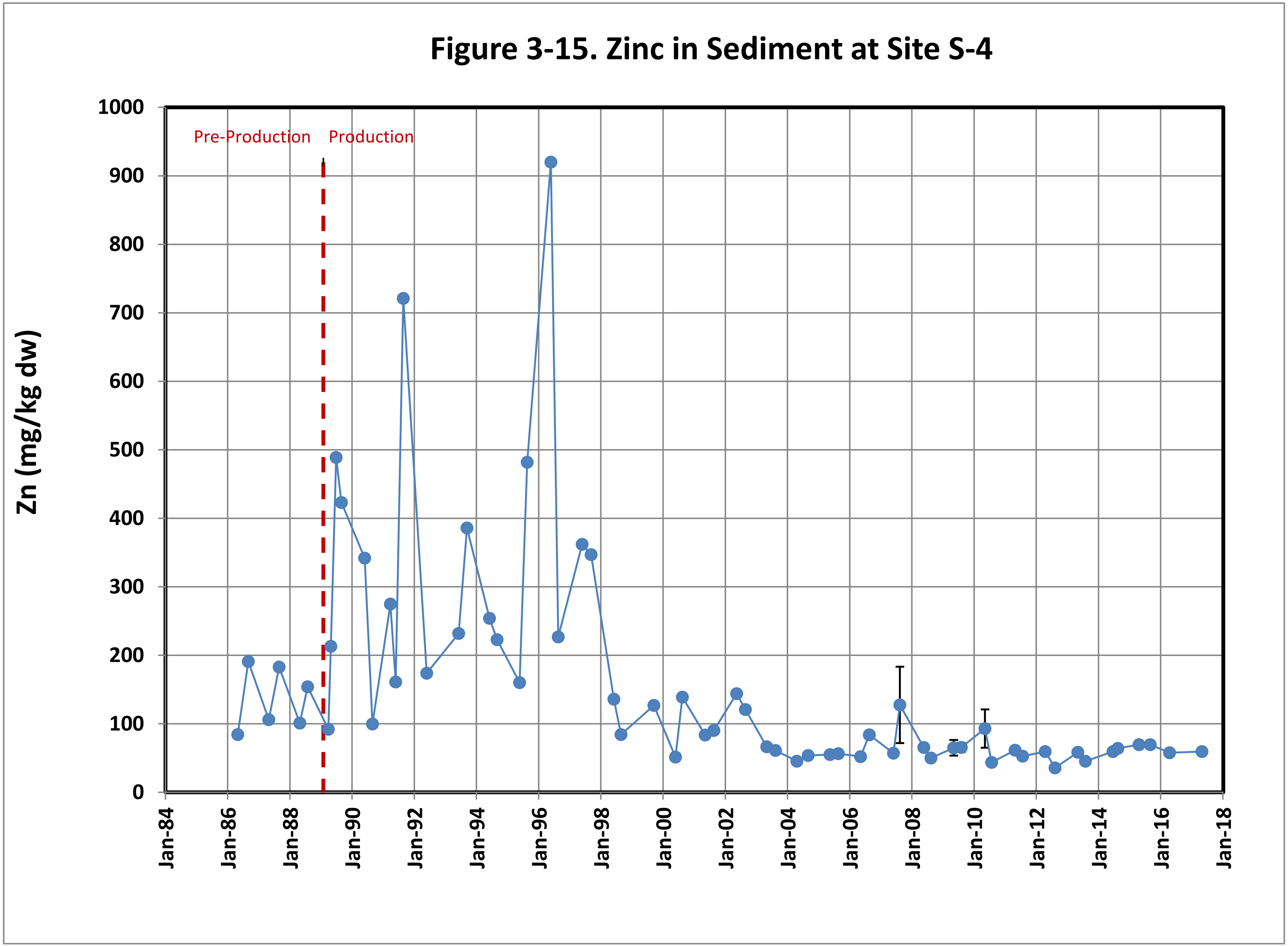


Figure 3-15. Zinc in Sediment at Site S-4
Zn (mg/kg dw)
Pre-Production
Production
0
100
200
300
400
500
600
700
800
900
1000
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

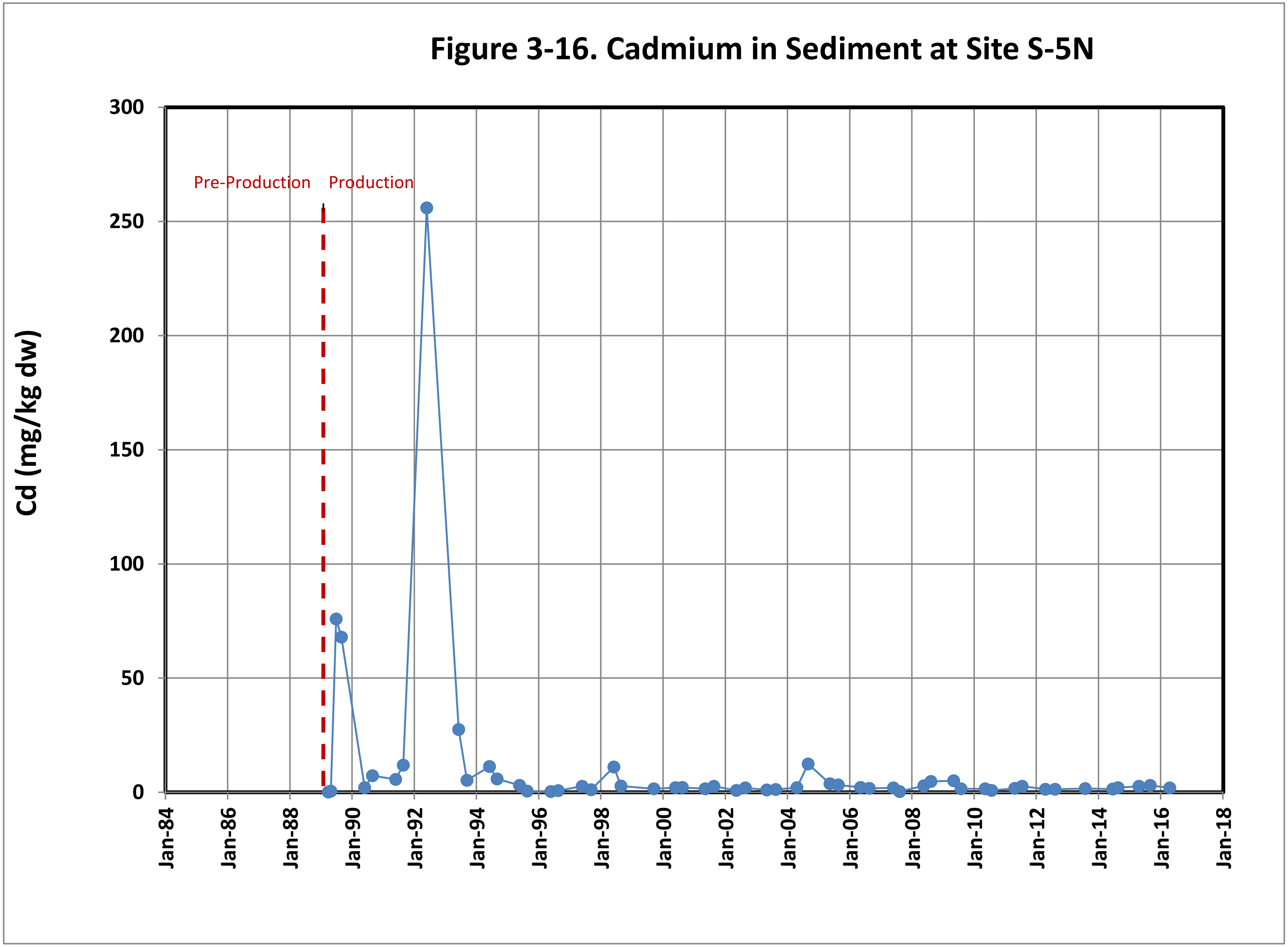


Figure 3-16. Cadmium in Sediment at Site S-5N
Cd (mg/kg dw)
300
250
200
150
100
50
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

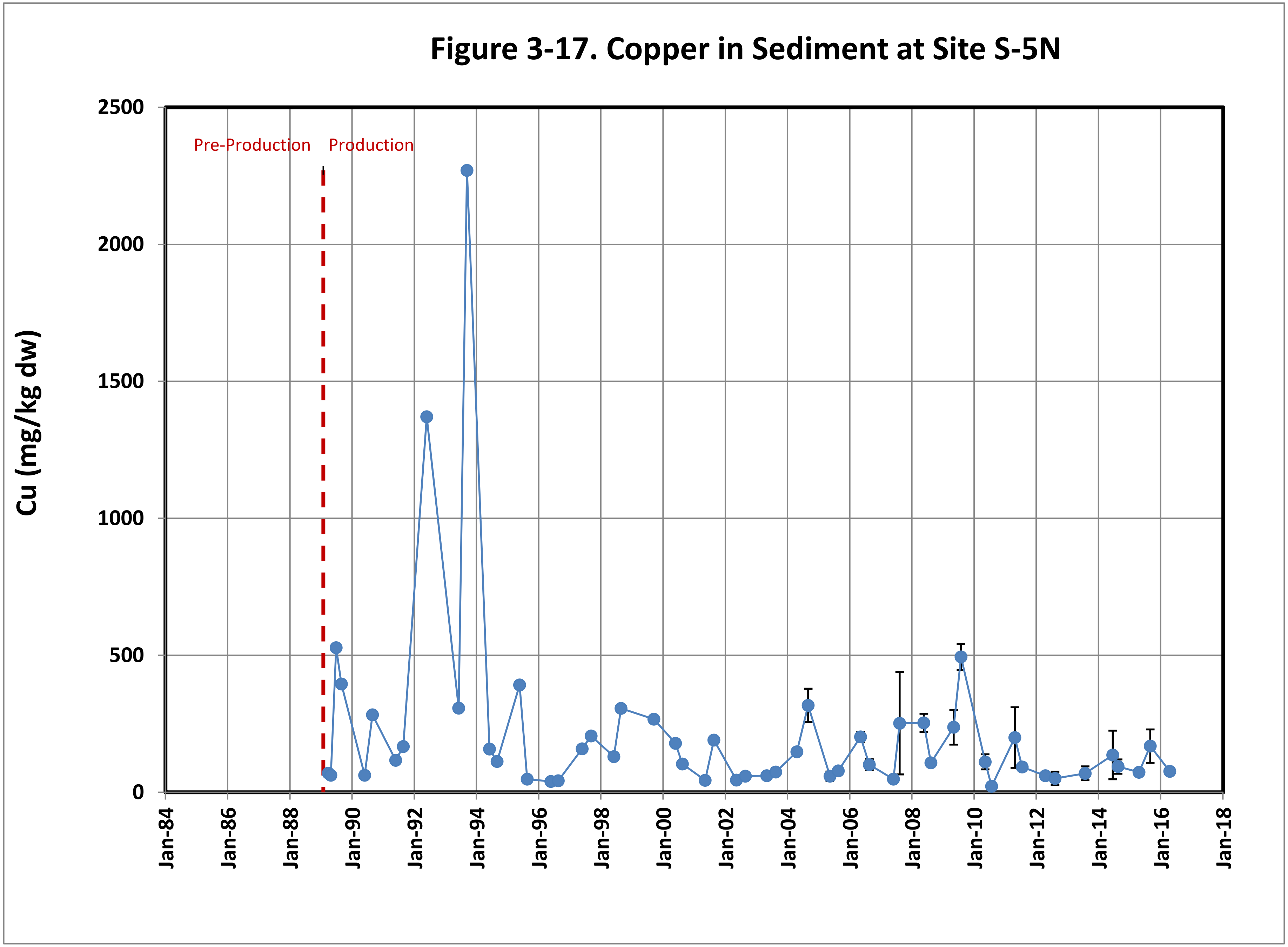


Figure 3-17. Copper in Sediment at Site S-5N
Cu (mg/kg dw)
2500
2000
1500
1000
500
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

Figure 3-18. Lead in Sediment at Site S-5N

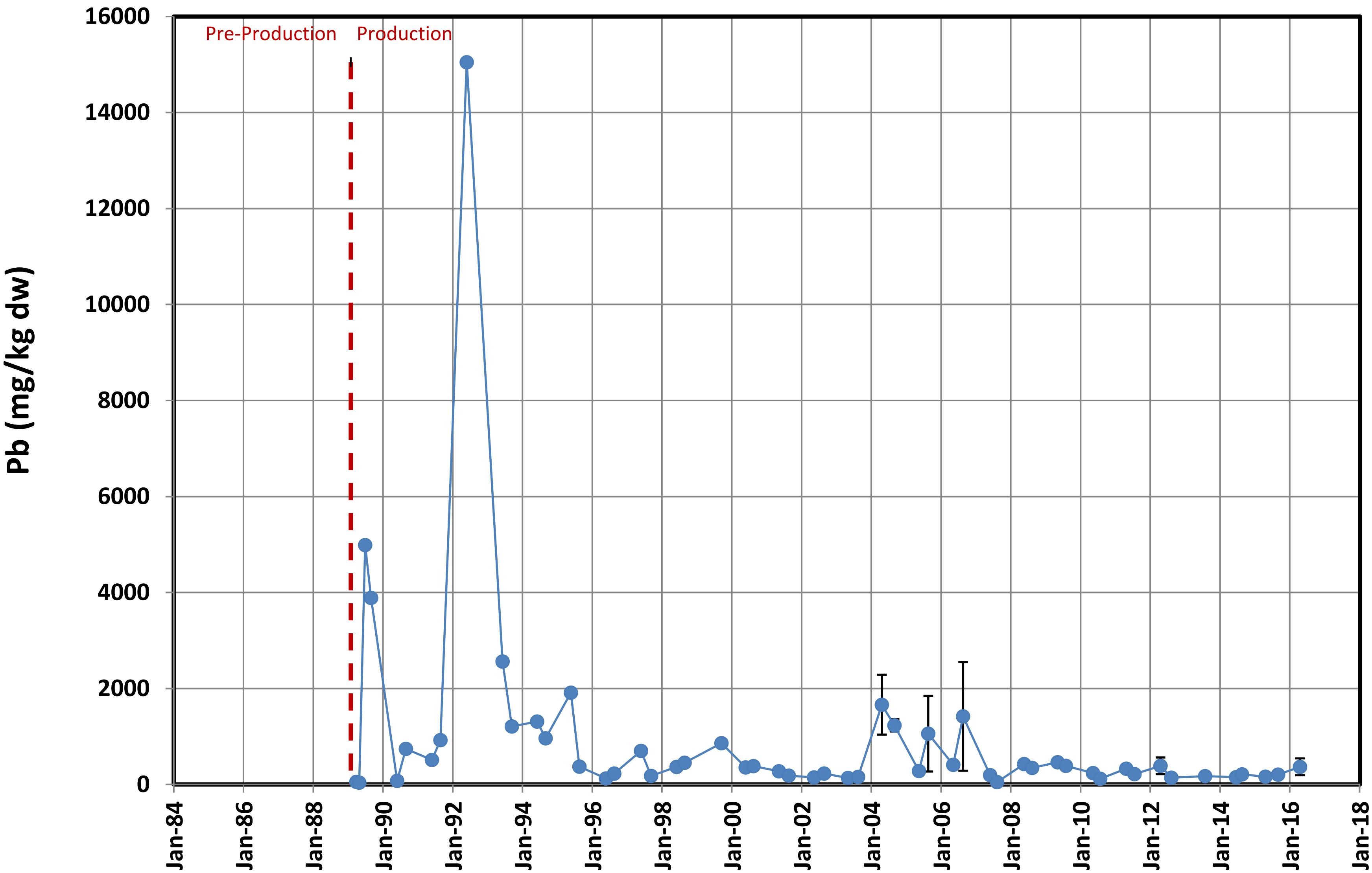
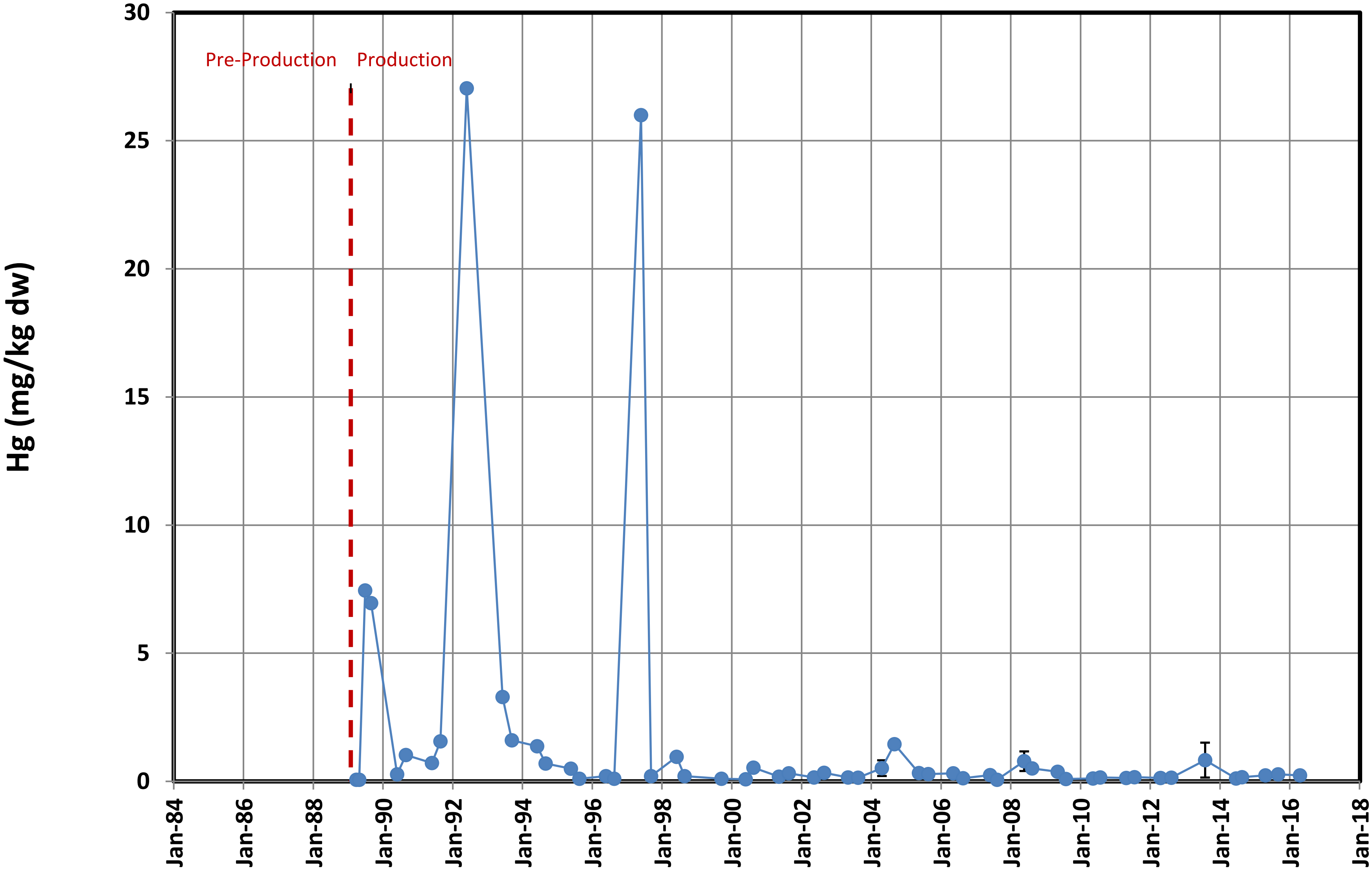


Figure 3-19. Mercury in Sediment at Site S-5N



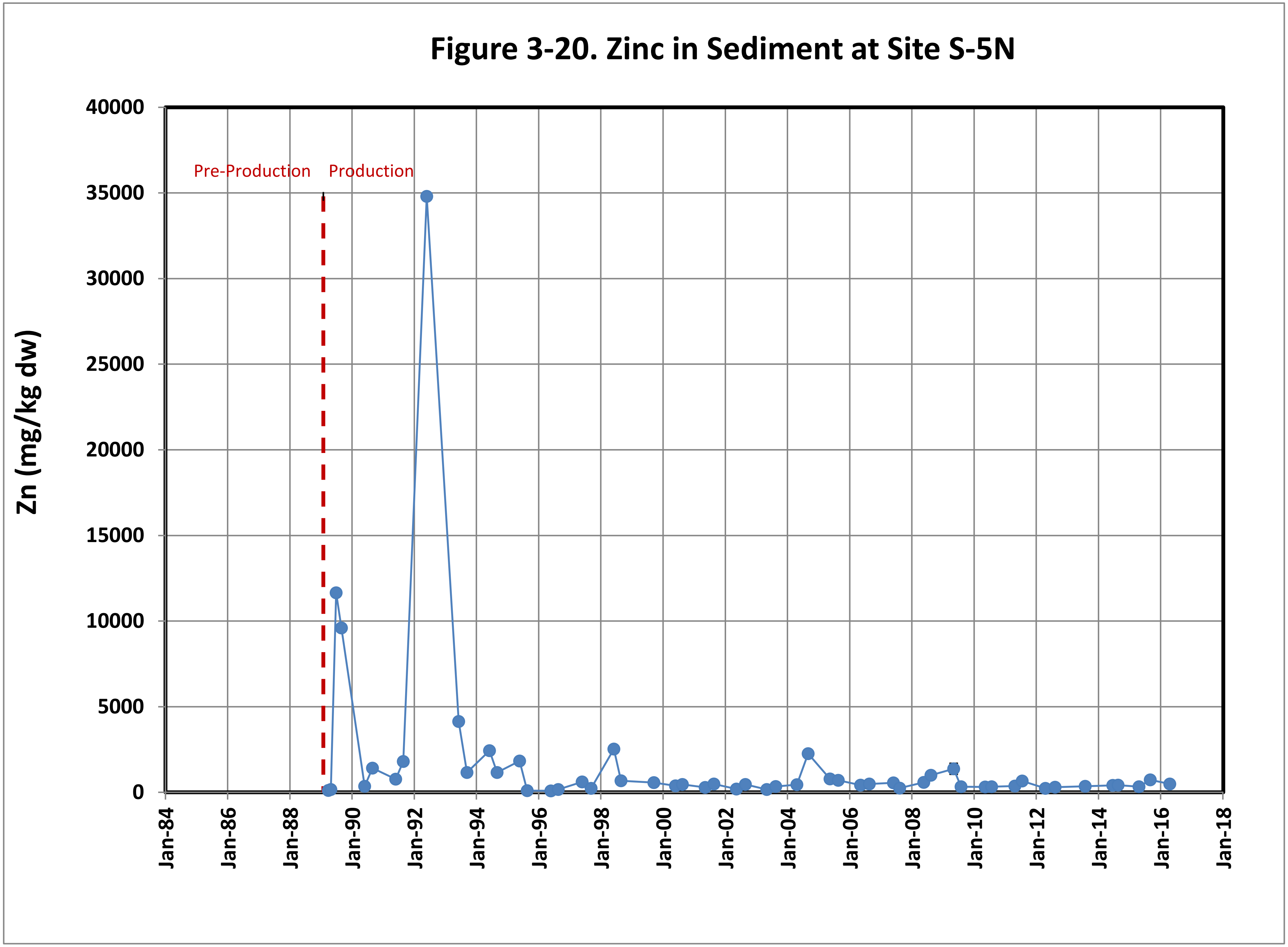


Figure 3-20. Zinc in Sediment at Site S-5N
Zn (mg/kg dw)
Pre-Production
Production
40000
35000
30000
25000
20000
15000
10000
5000
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

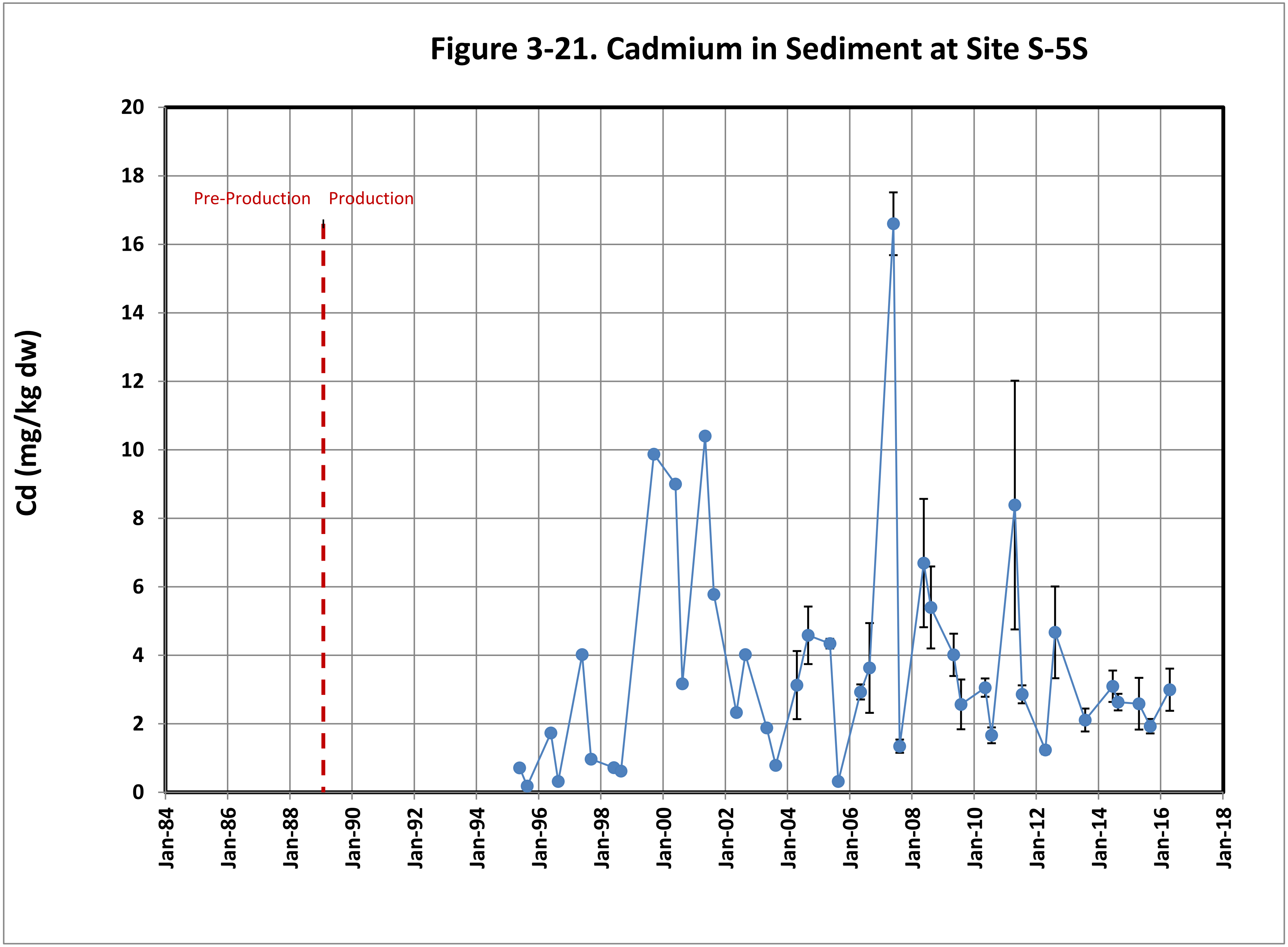


Figure 3-21. Cadmium in Sediment at Site S-5S
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
18
20
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

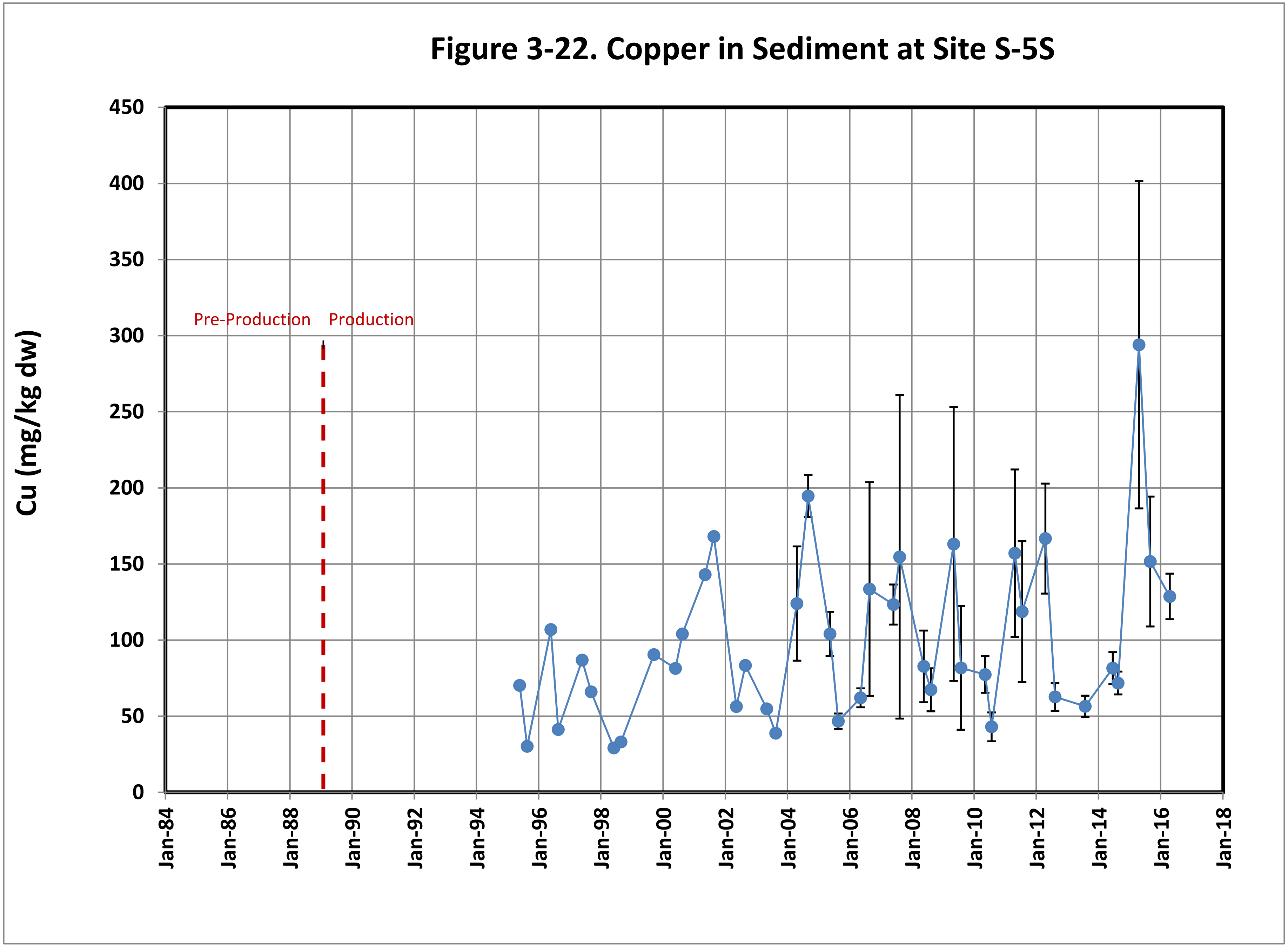


Figure 3-22. Copper in Sediment at Site S-5S
Cu (mg/kg dw)
0
50
100
150
200
250
300
350
400
450
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

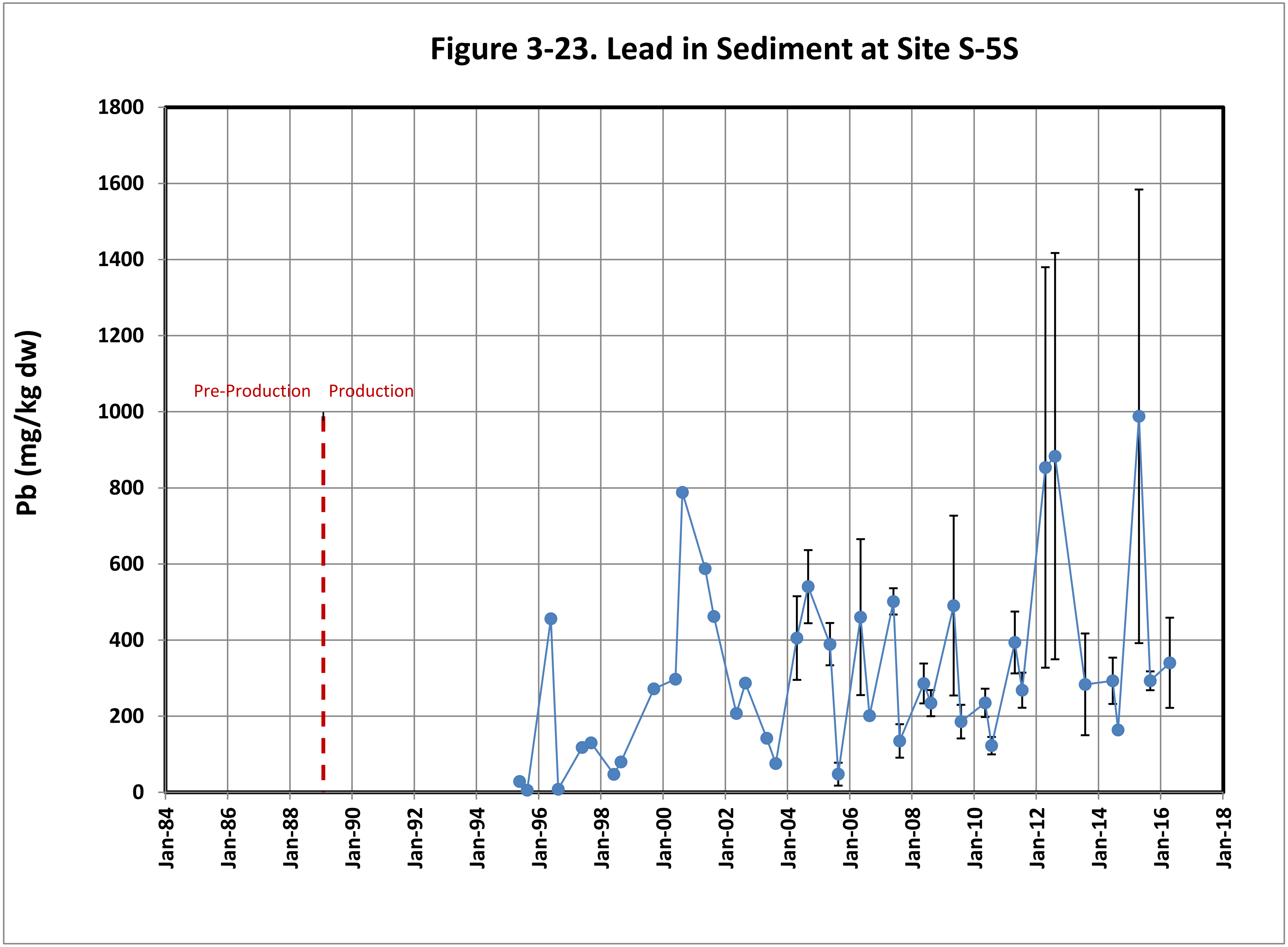


Figure 3-23. Lead in Sediment at Site S-5S
Pb (mg/kg dw)
1800
1600
1400
1200
1000
800
600
400
200
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

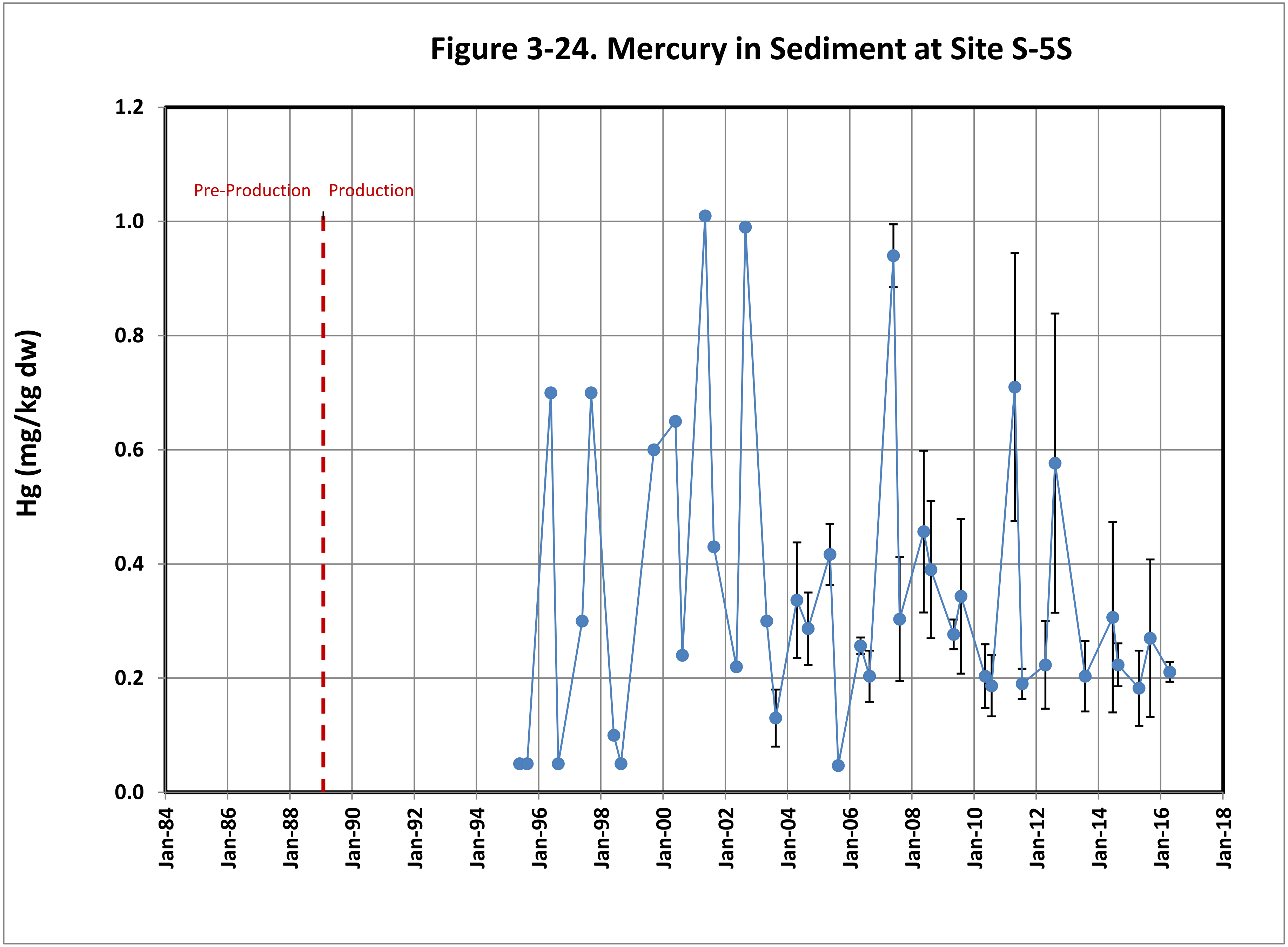
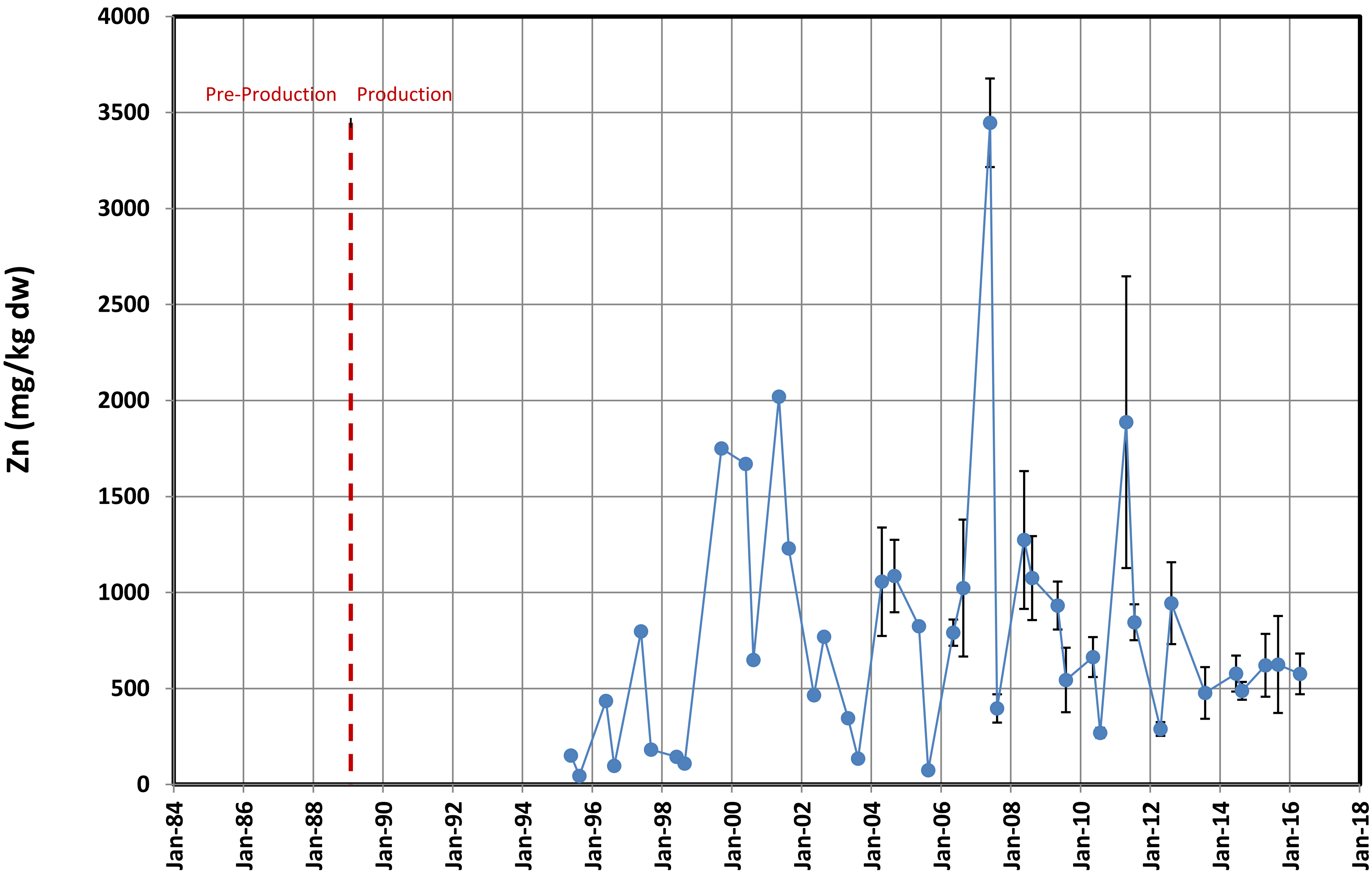


Figure 3-24. Mercury in Sediment at Site S-5S
Hg (mg/kg dw)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

Figure 3-25. Zinc in Sediment at Site S-5S



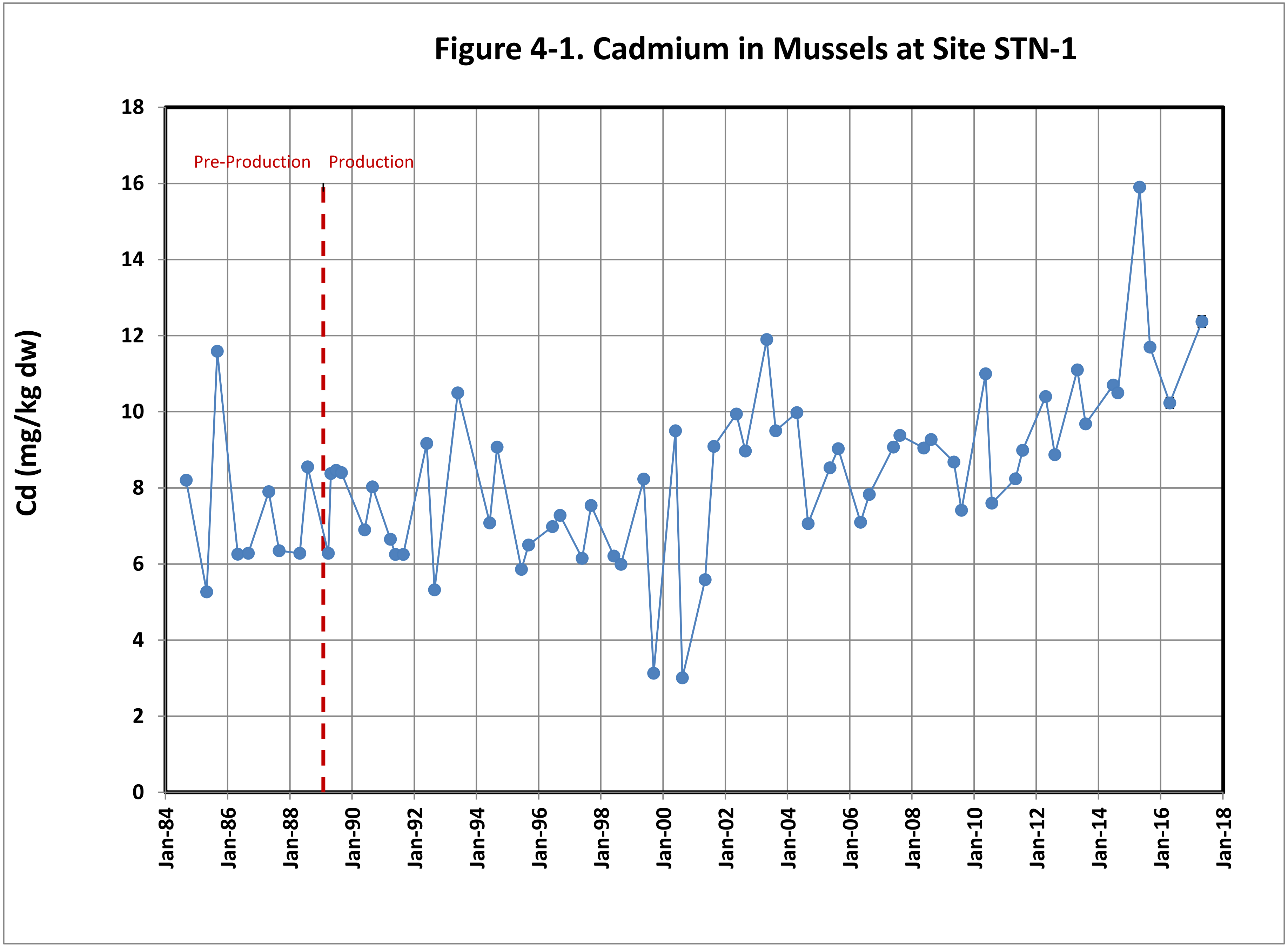


Figure 4-1. Cadmium in Mussels at Site STN-1
Pre-Production
Production
Cd (mg/kg dw)
0
2
4
6
8
10
12
14
16
18
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

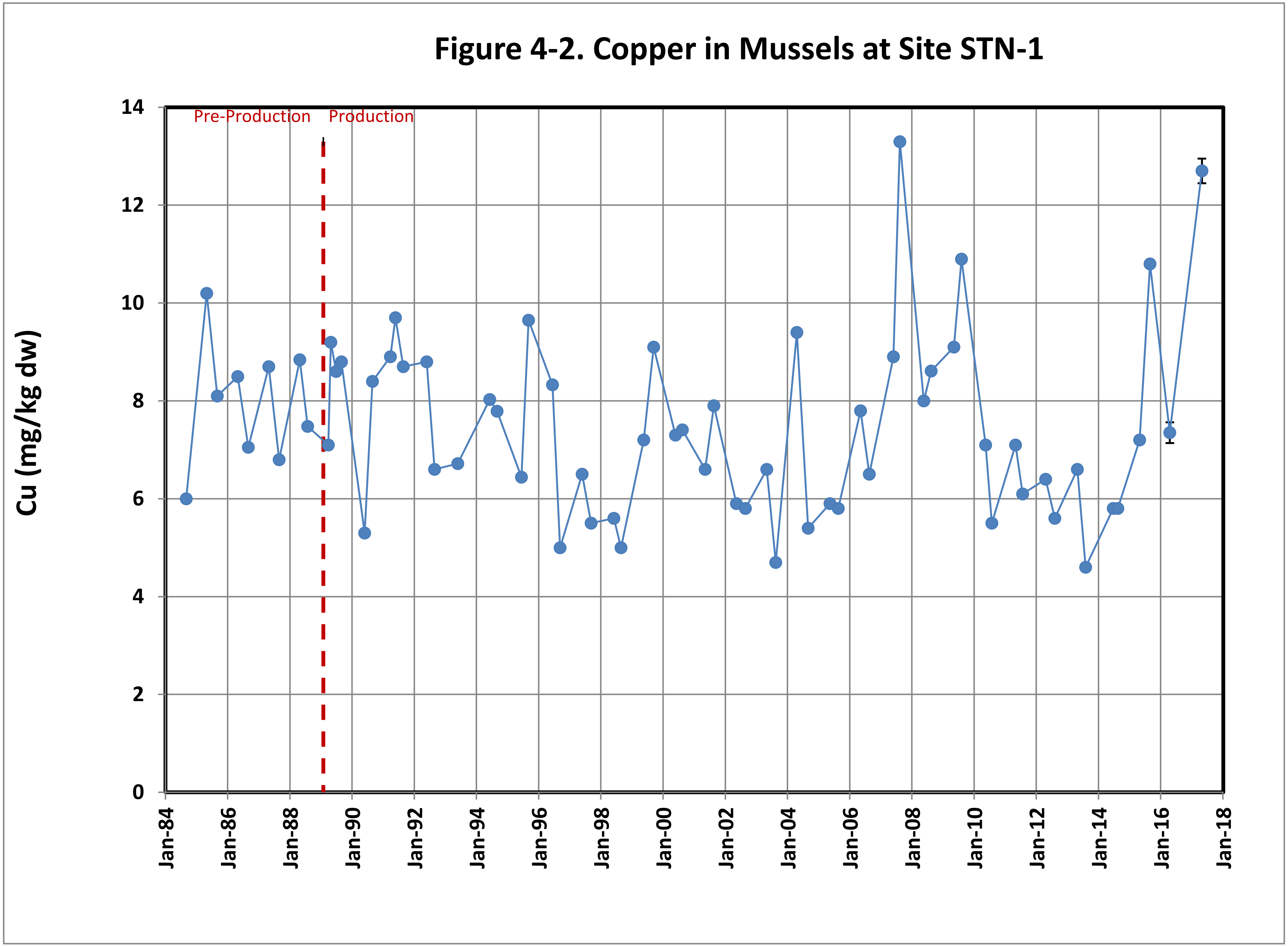


Figure 4-2. Copper in Mussels at Site STN-1
Cu (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

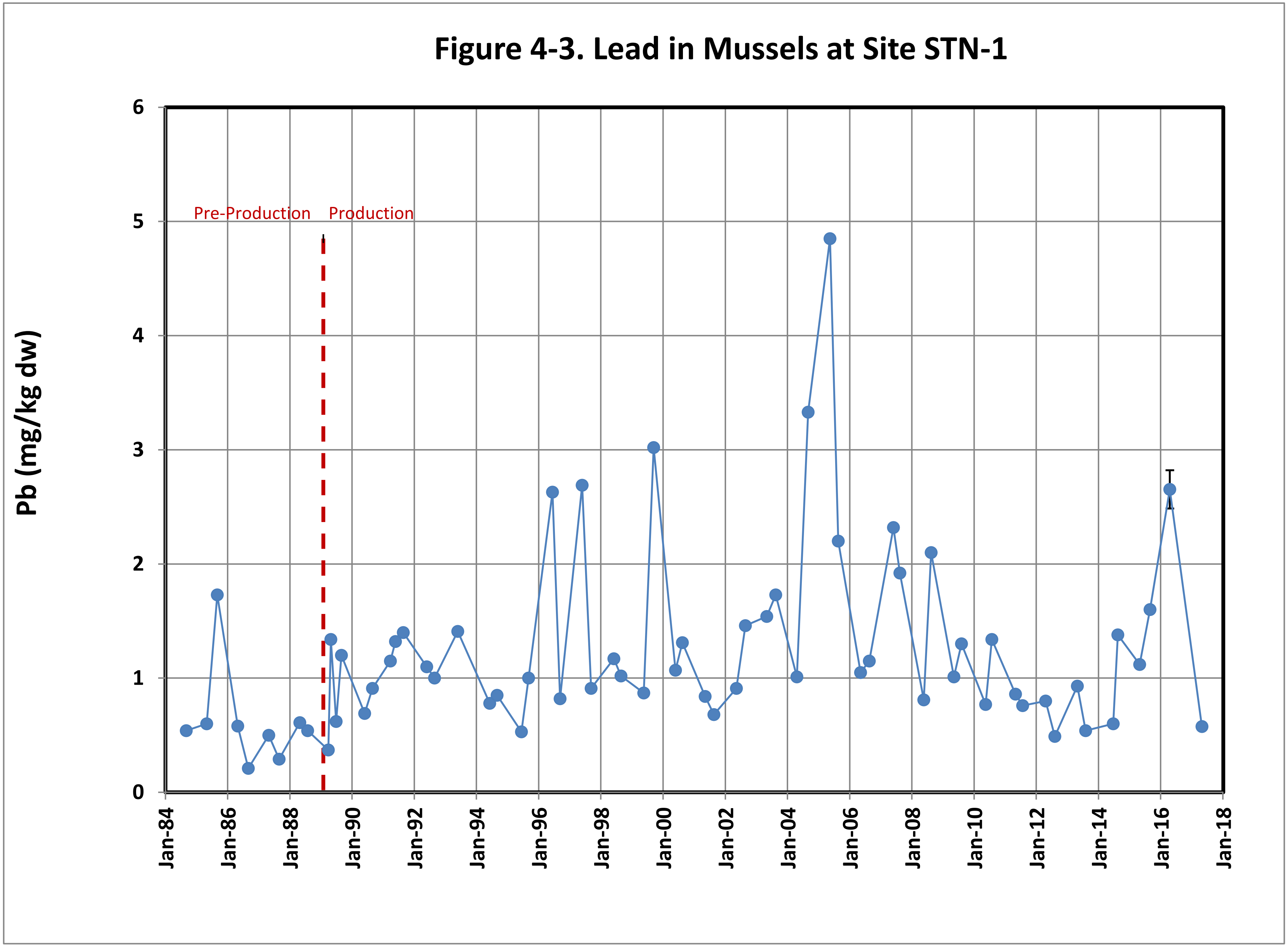


Figure 4-3. Lead in Mussels at Site STN-1
Pb (mg/kg dw)
0
1
2
3
4
5
6
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

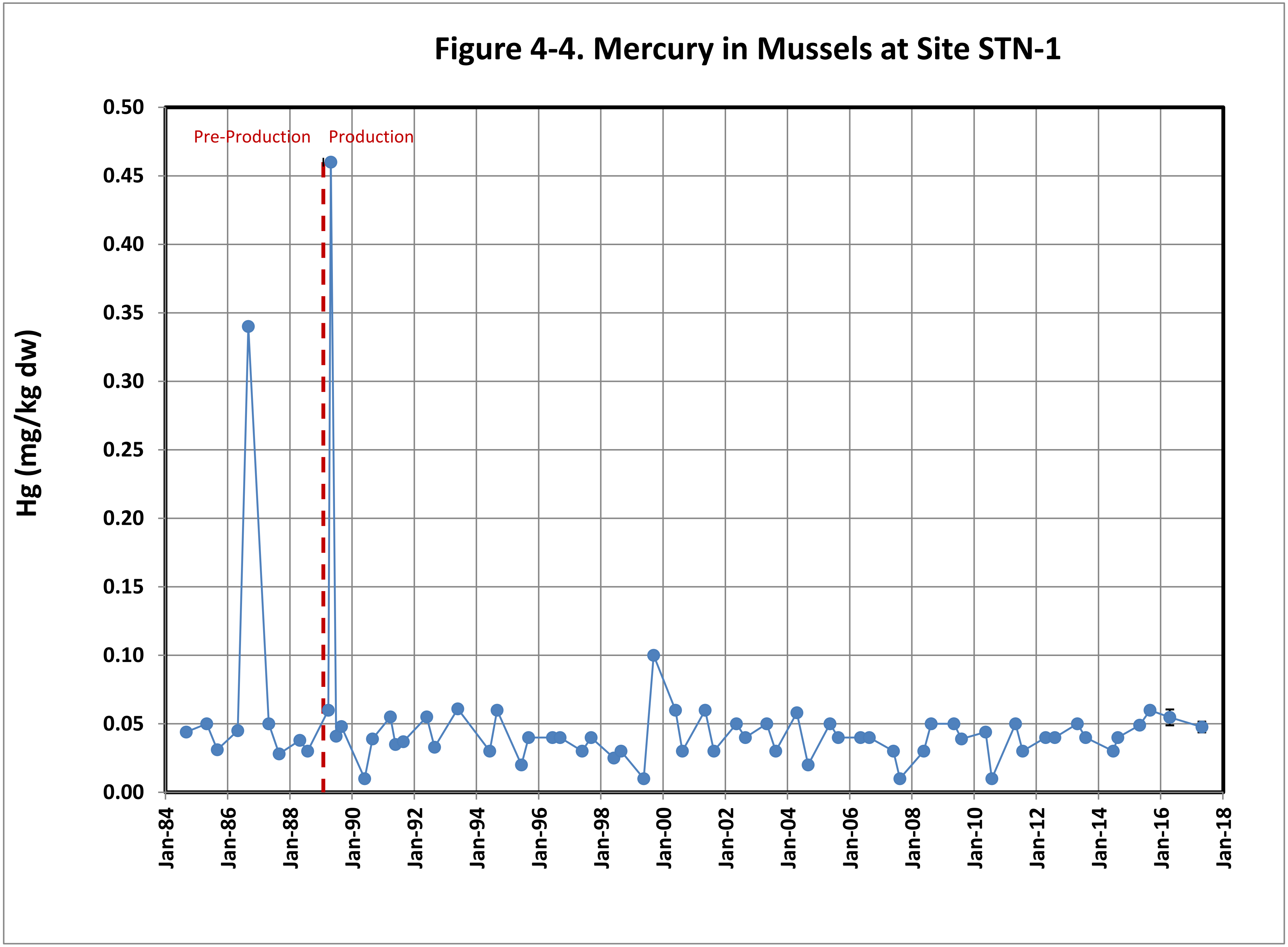
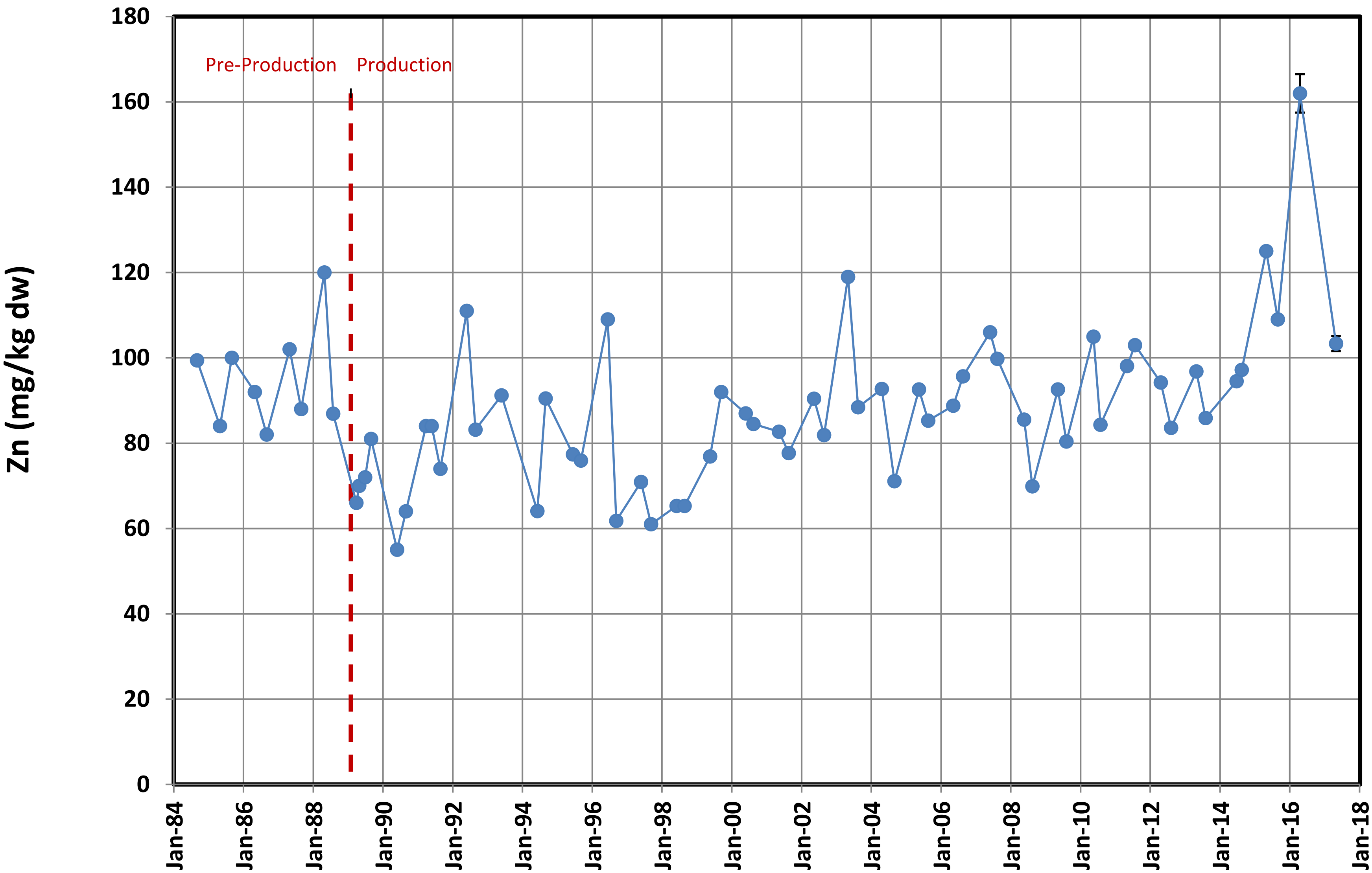


Figure 4-4. Mercury in Mussels at Site STN-1
Hg (mg/kg dw)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

Figure 4-5. Zinc in Mussels at Site STN-1



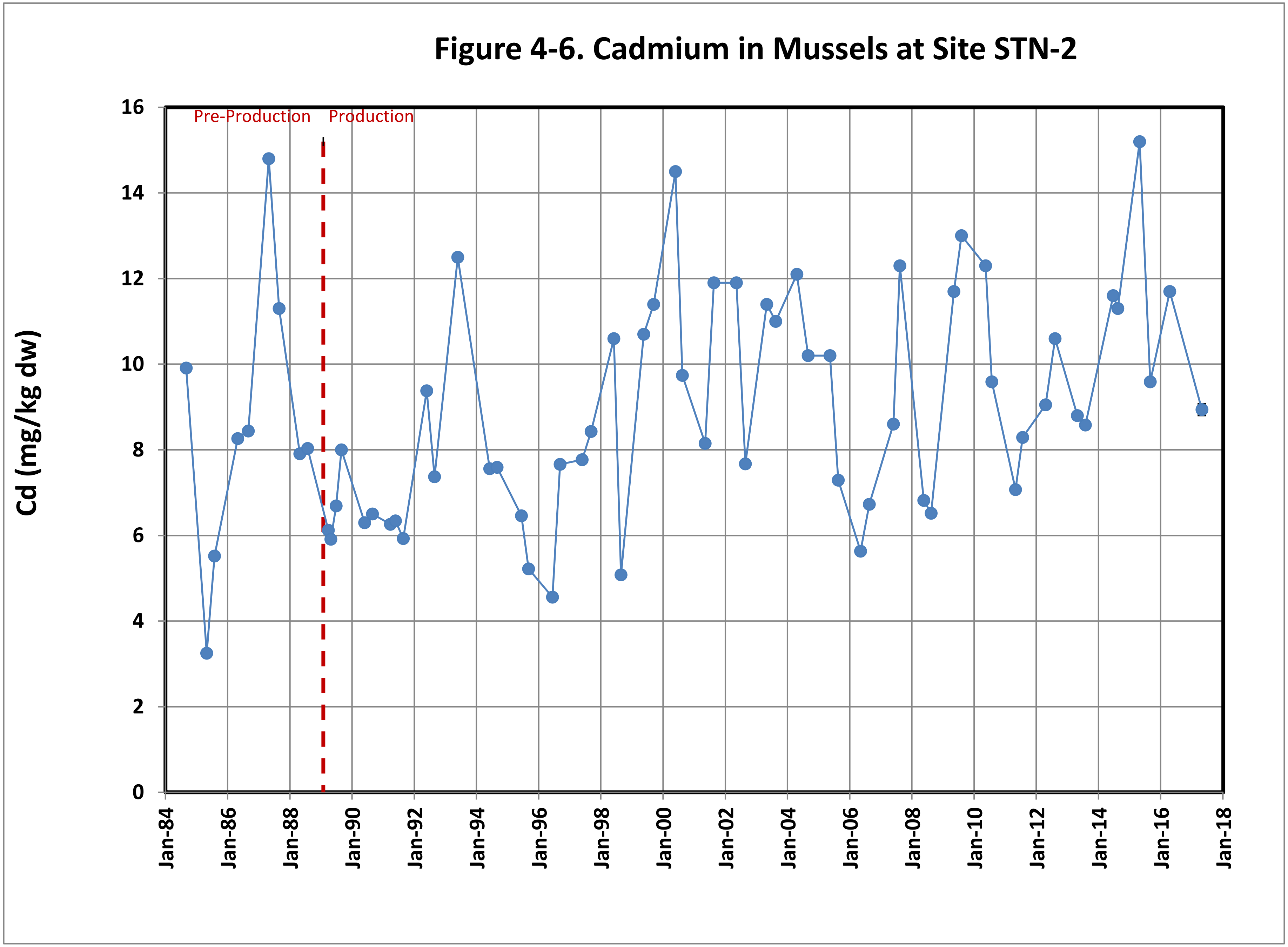
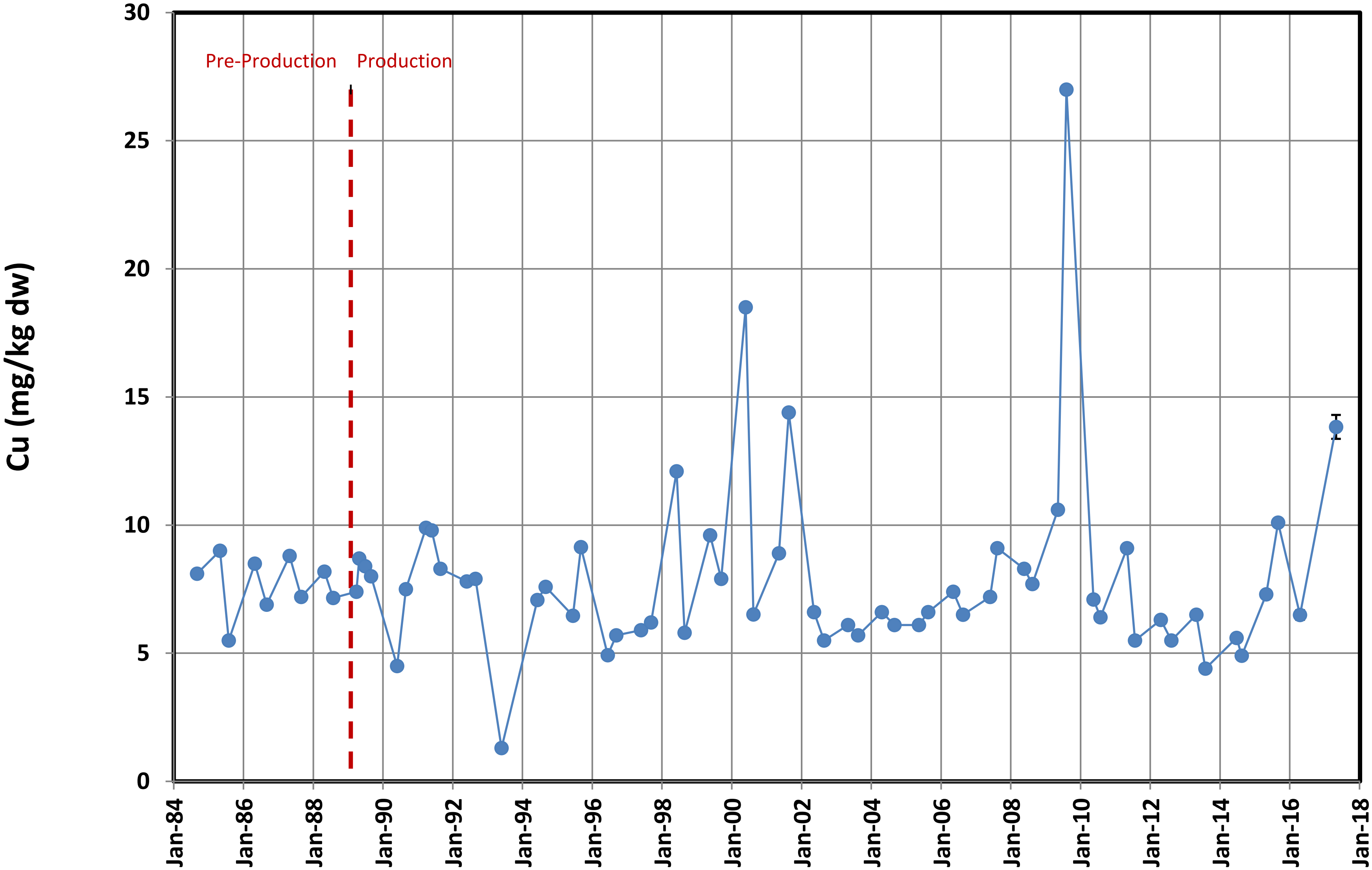


Figure 4-6. Cadmium in Mussels at Site STN-2
Pre-Production
Production
Cd (mg/kg dw)
0
2
4
6
8
10
12
14
16
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

Figure 4-7. Copper in Mussels at Site STN-2



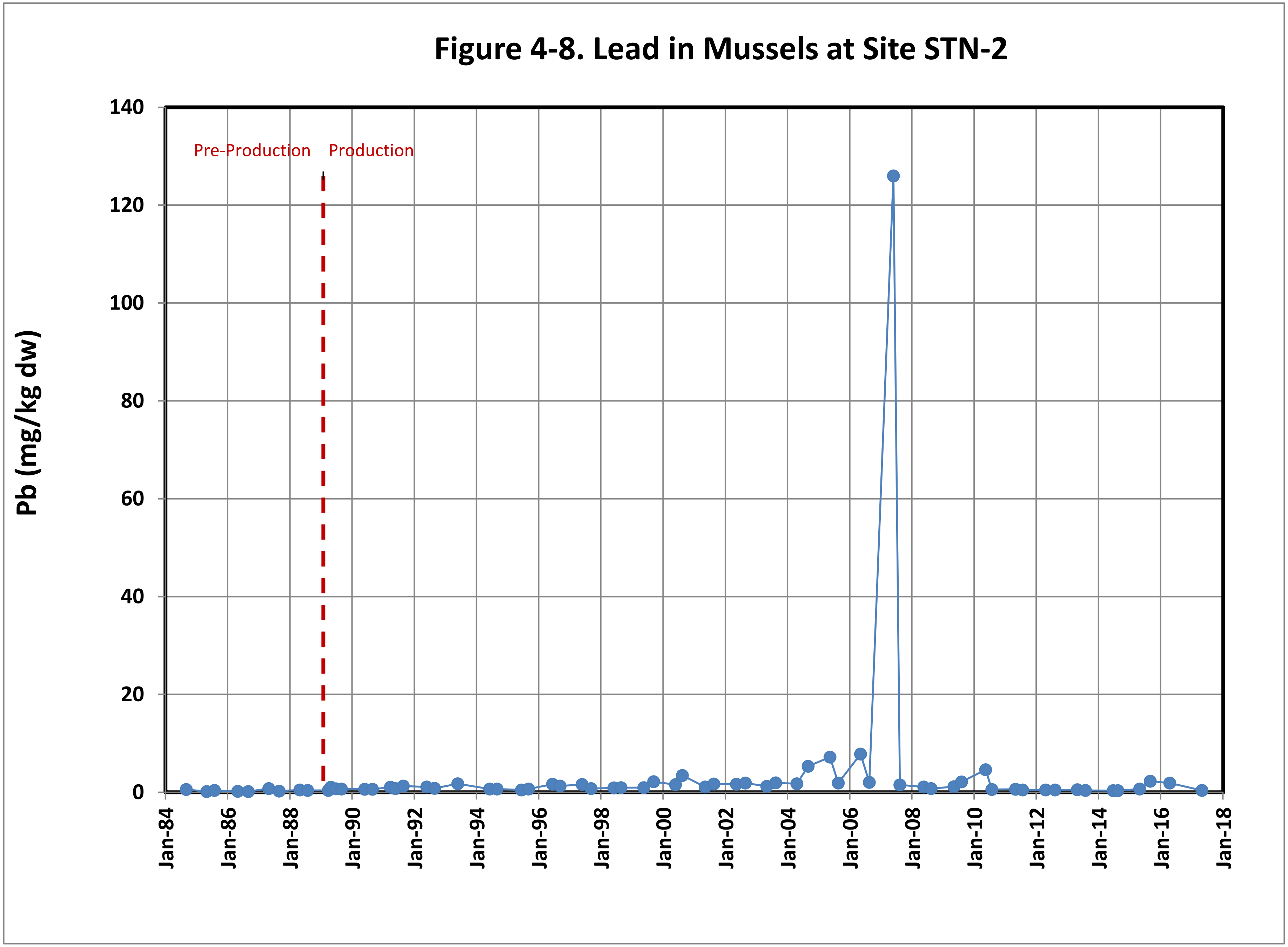


Figure 4-8. Lead in Mussels at Site STN-2
Pb (mg/kg dw)
140
120
100
80
60
40
20
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

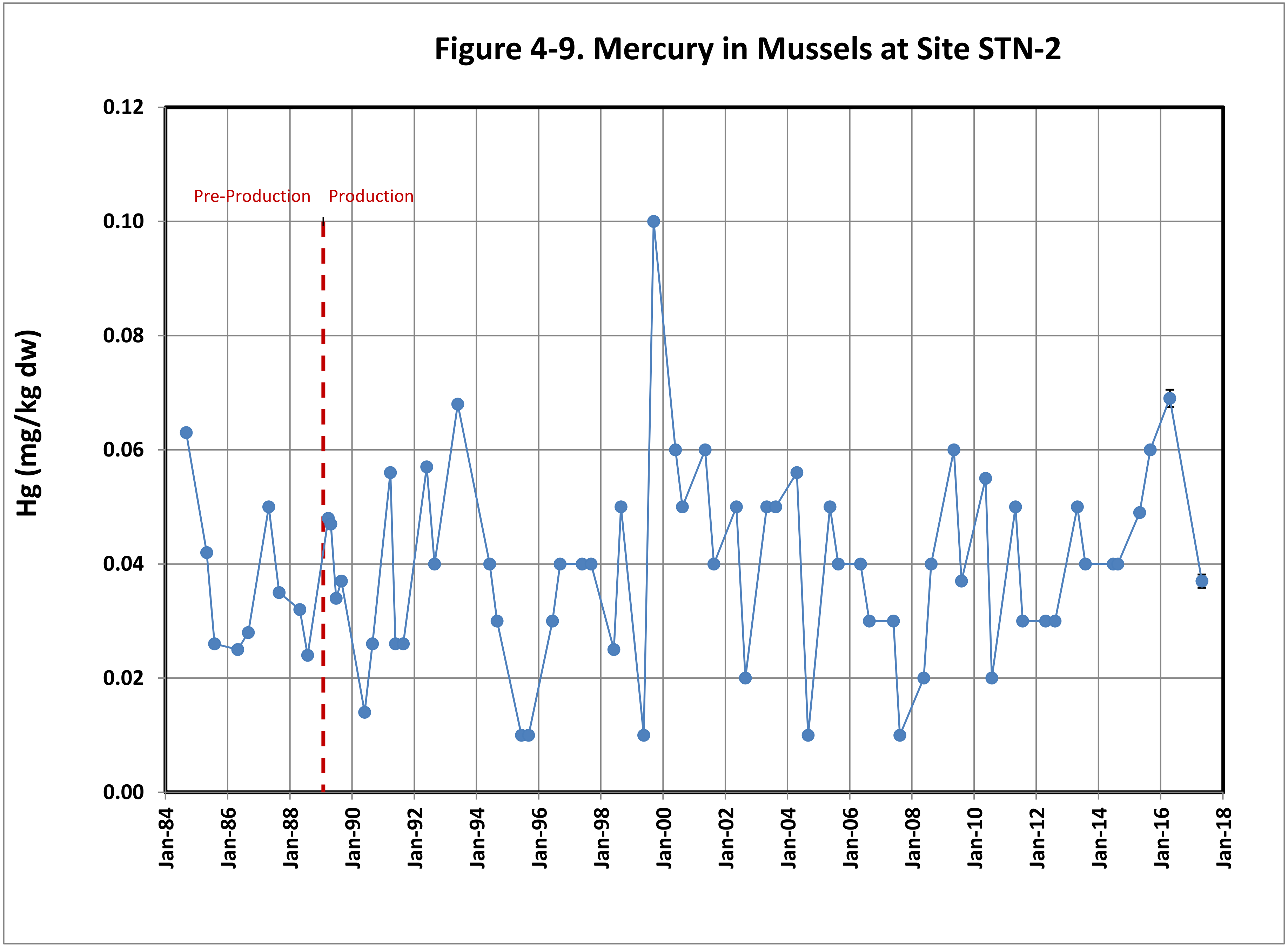


Figure 4-9. Mercury in Mussels at Site STN-2
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

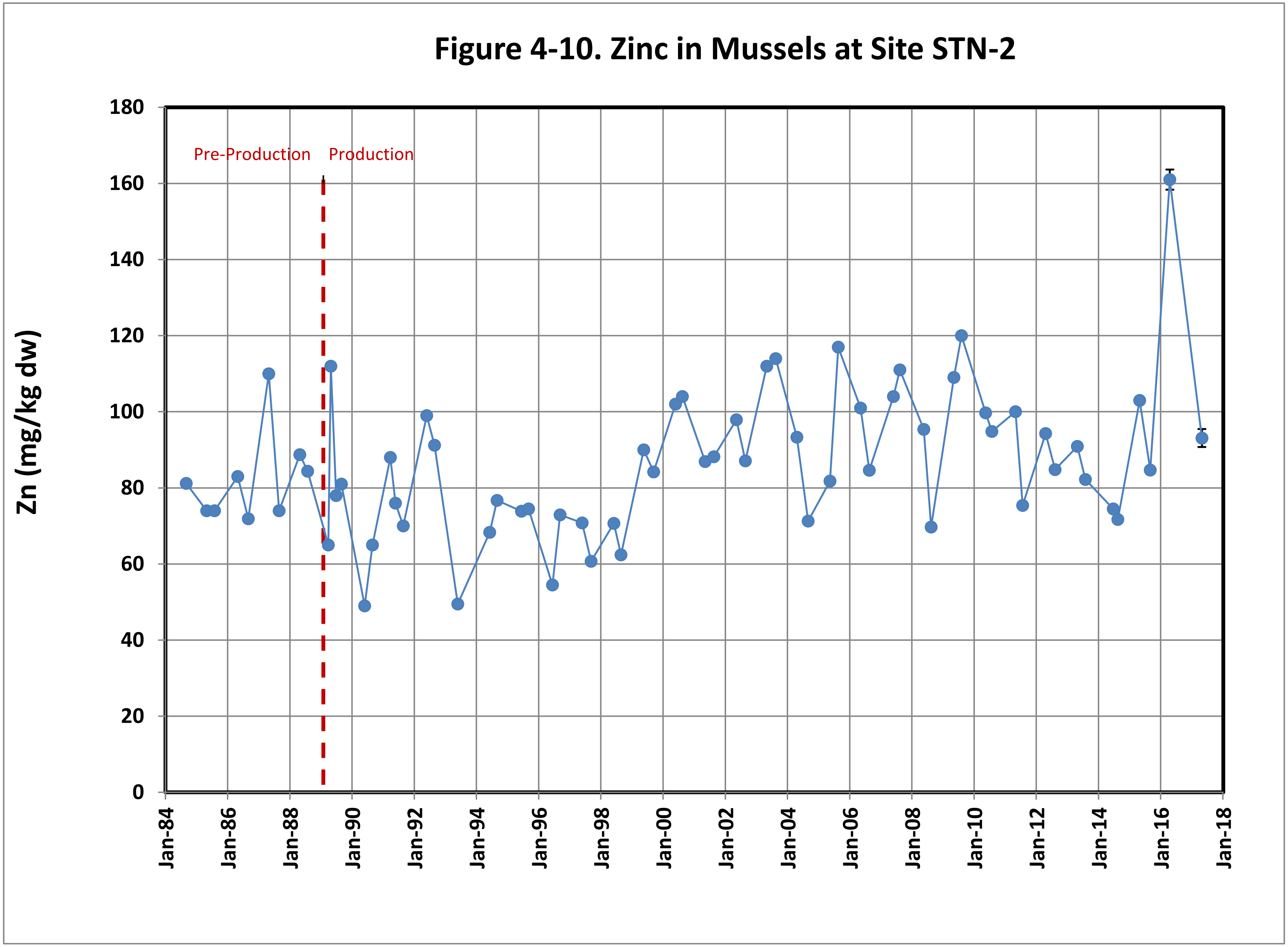


Figure 4-10. Zinc in Mussels at Site STN-2
Zn (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
140
160
180
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

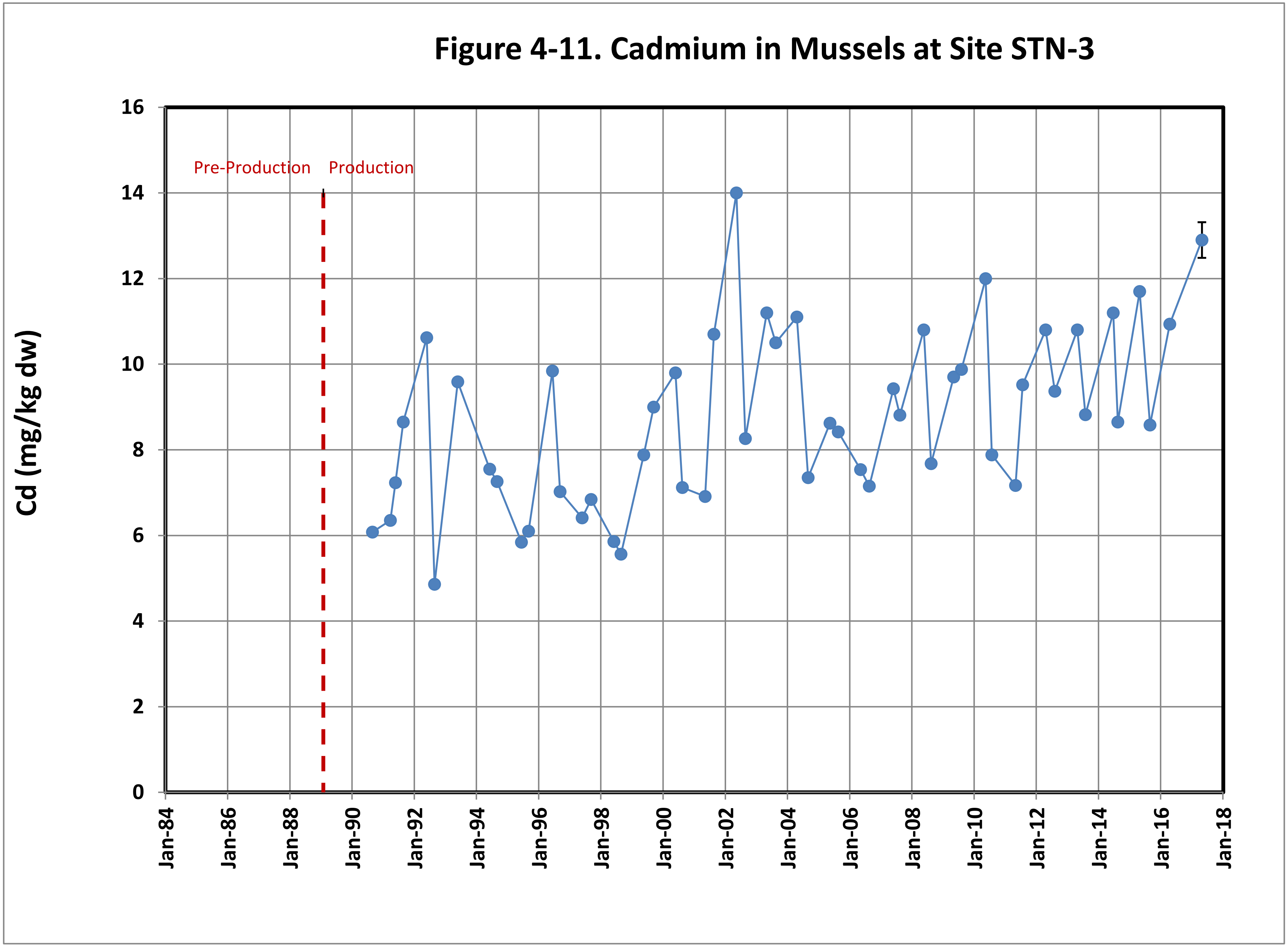


Figure 4-11. Cadmium in Mussels at Site STN-3
Cd (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

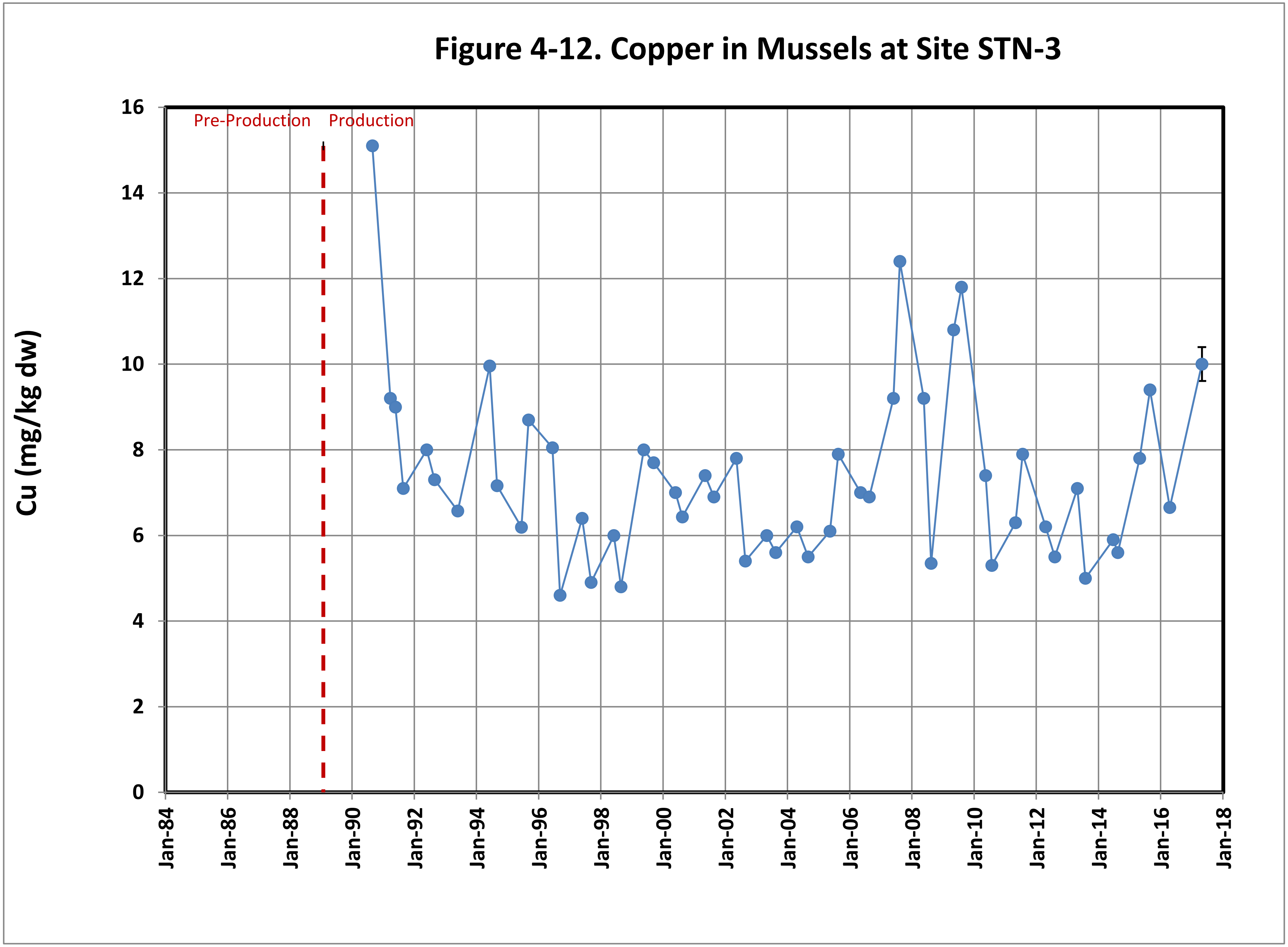


Figure 4-12. Copper in Mussels at Site STN-3
Cu (mg/kg dw)
Pre-Production
Production
0
2
4
6
8
10
12
14
16
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
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Jan-08
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Jan-12
Jan-14
Jan-16
Jan-18

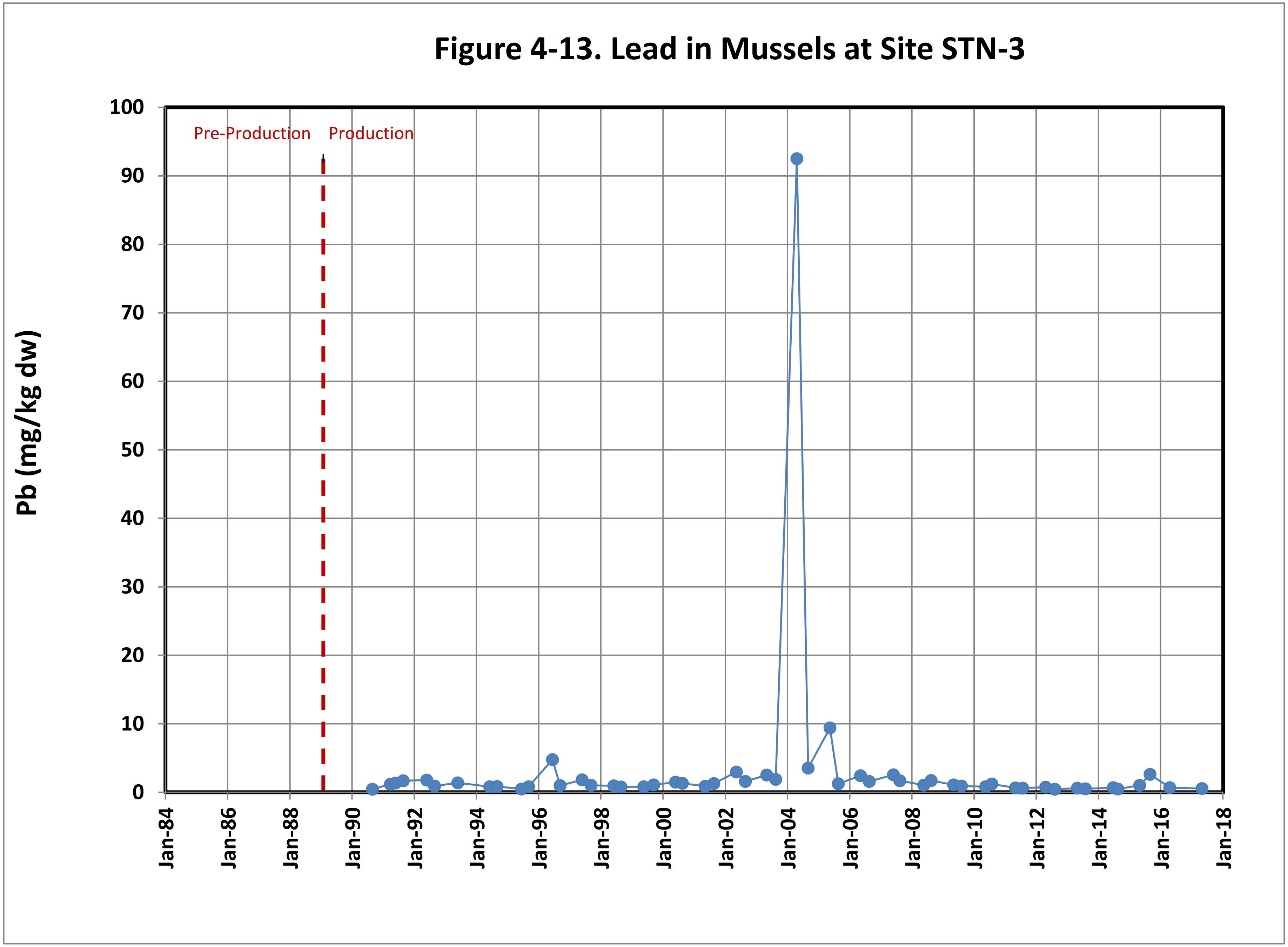


Figure 4-13. Lead in Mussels at Site STN-3
Pb (mg/kg dw)
Pre-Production
Production
0
10
20
30
40
50
60
70
80
90
100
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

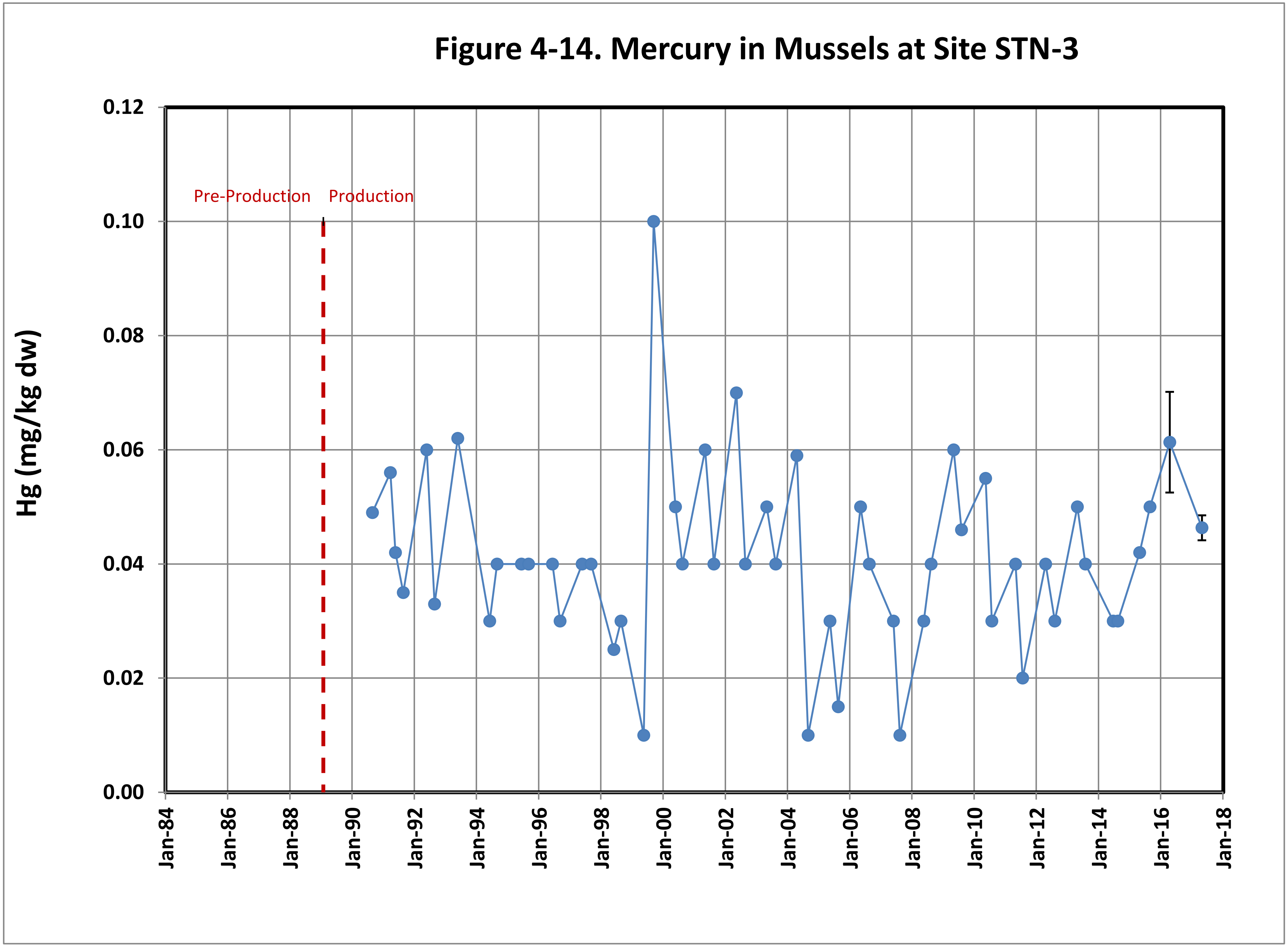


Figure 4-14. Mercury in Mussels at Site STN-3
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

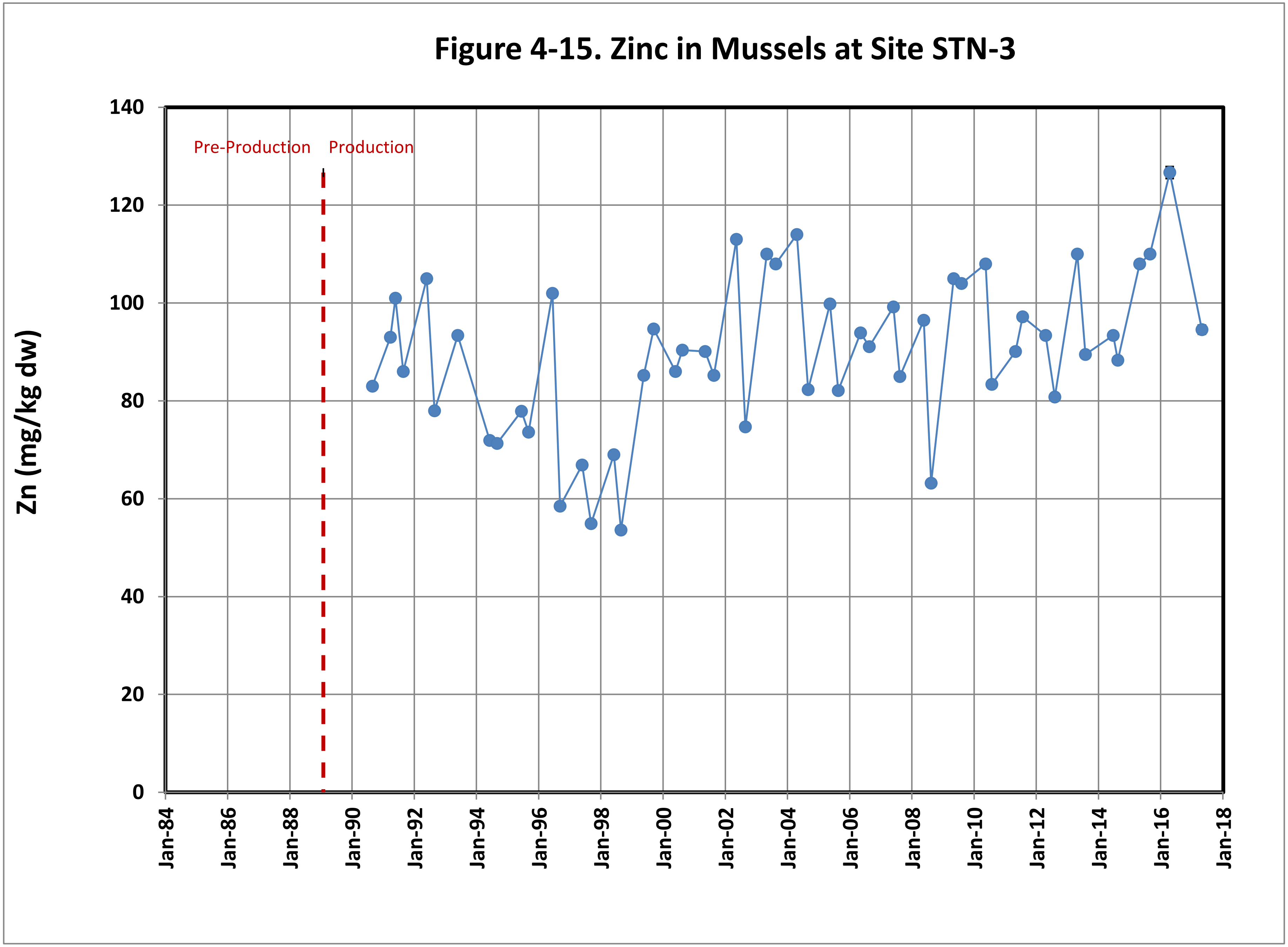


Figure 4-15. Zinc in Mussels at Site STN-3
Zn (mg/kg dw)
140
120
100
80
60
40
20
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

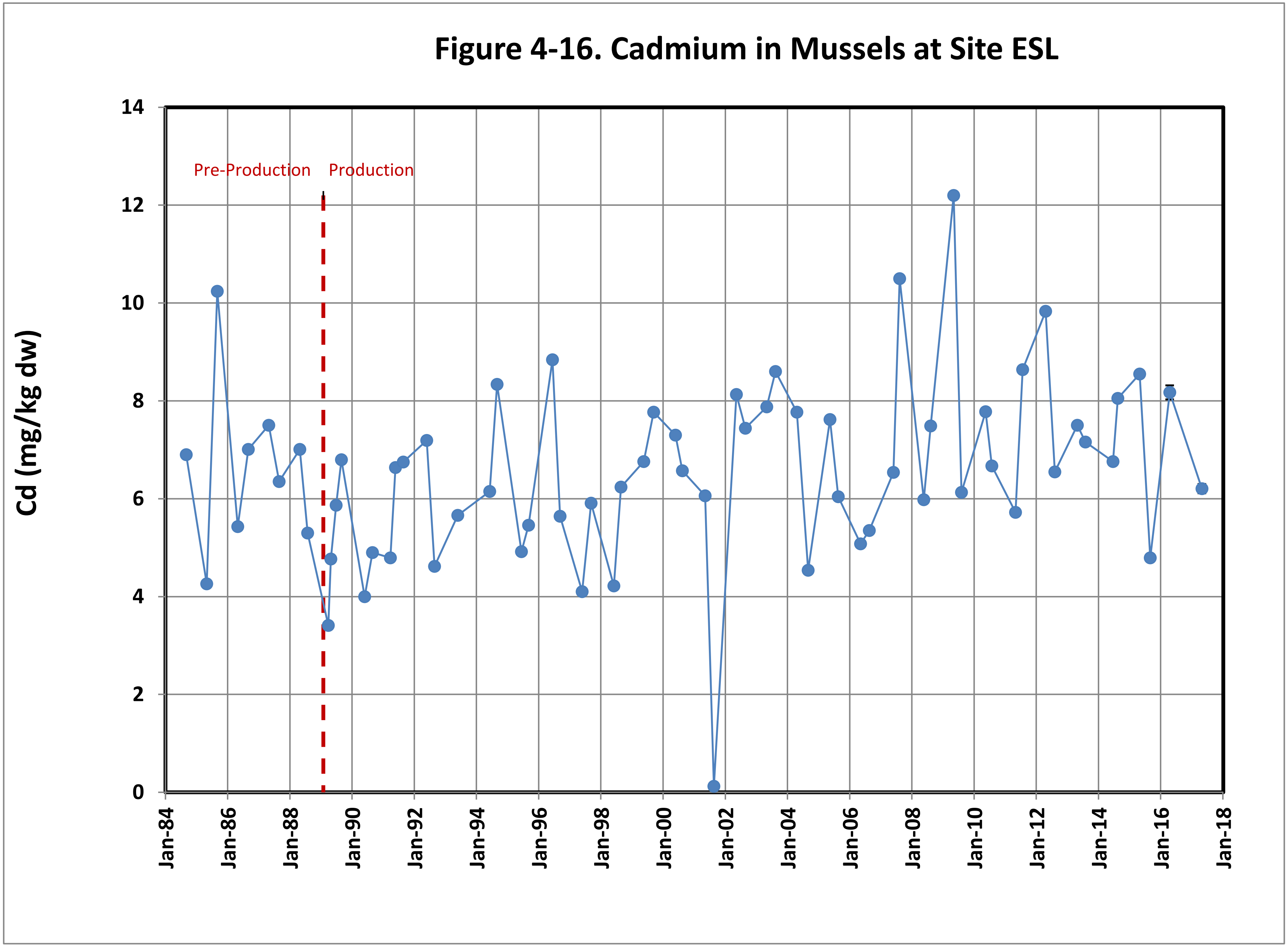


Figure 4-16. Cadmium in Mussels at Site ESL
Cd (mg/kg dw)
14
12
10
8
6
4
2
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

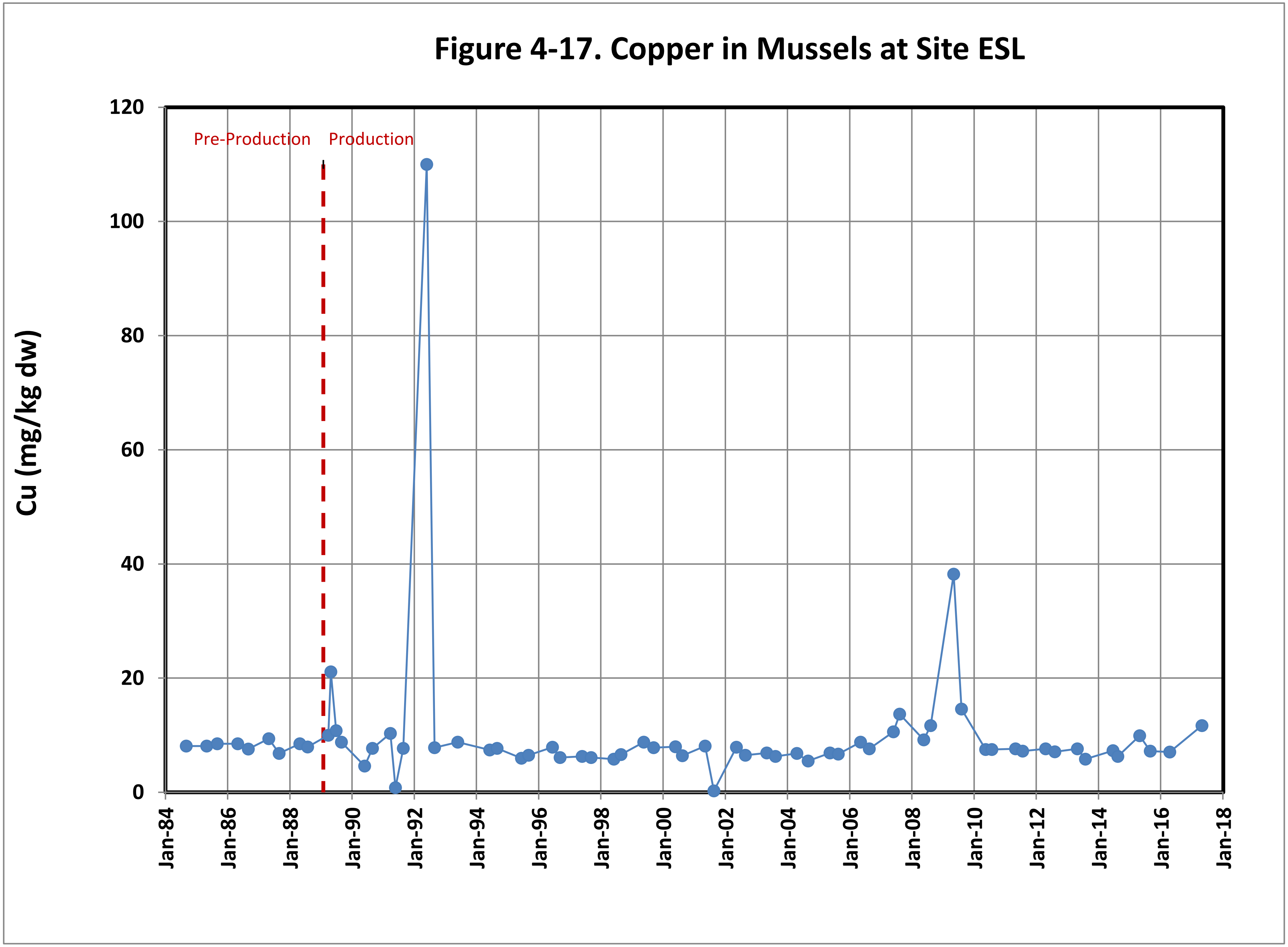
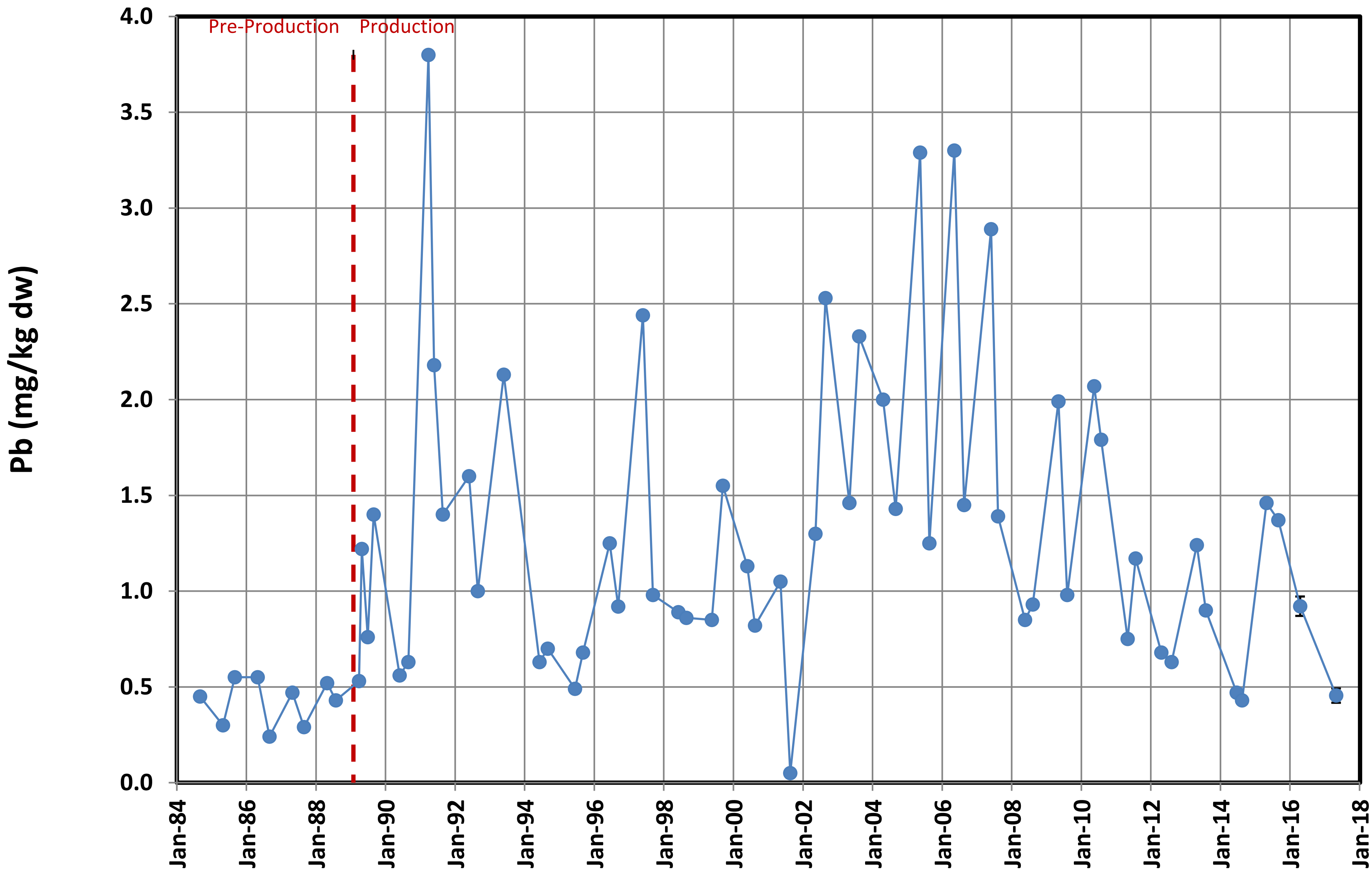


Figure 4-17. Copper in Mussels at Site ESL
Pre-Production
Production
Cu (mg/kg dw)
0
20
40
60
80
100
120
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

Figure 4-18. Lead in Mussels at Site ESL



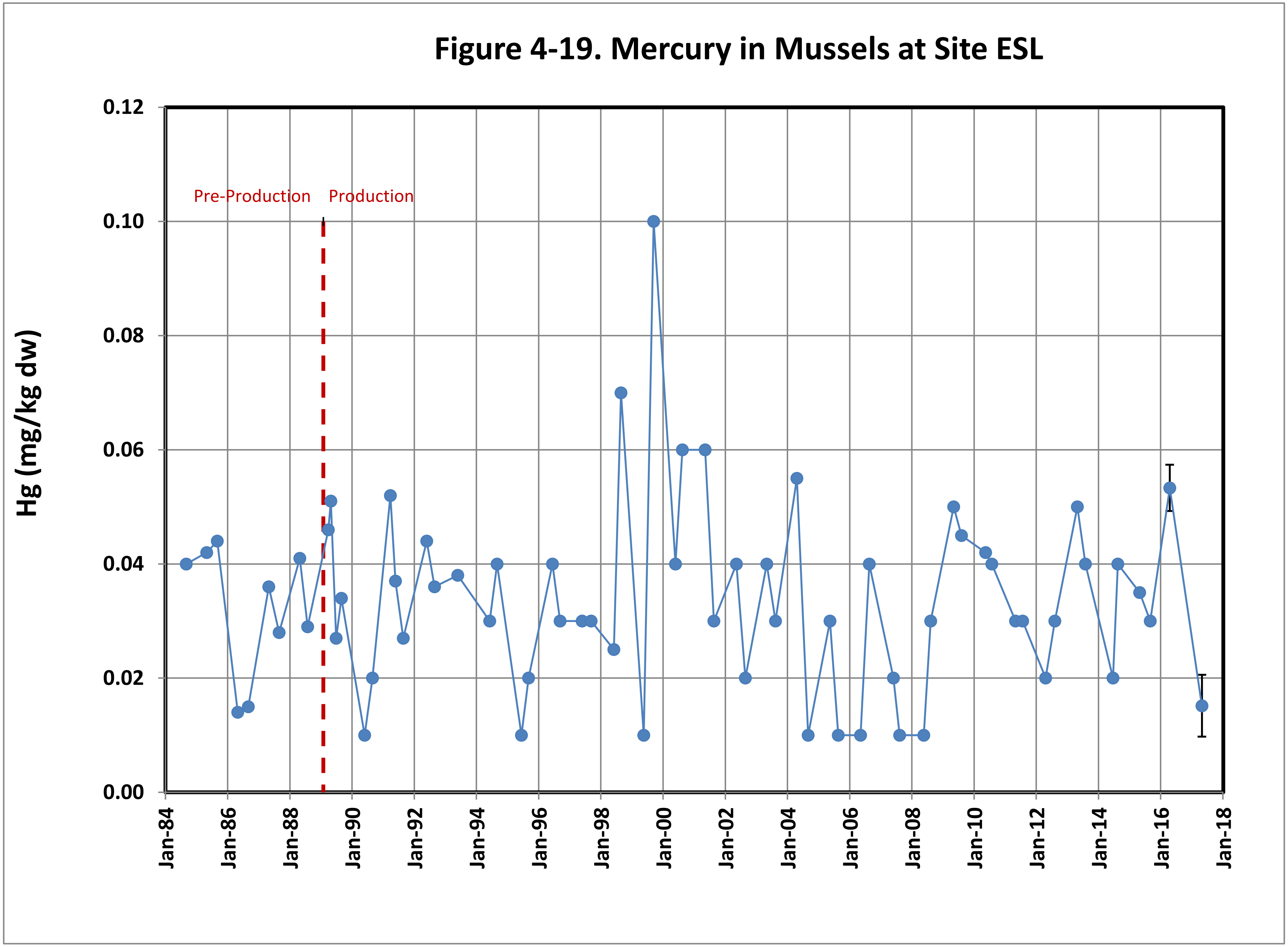


Figure 4-19. Mercury in Mussels at Site ESL
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

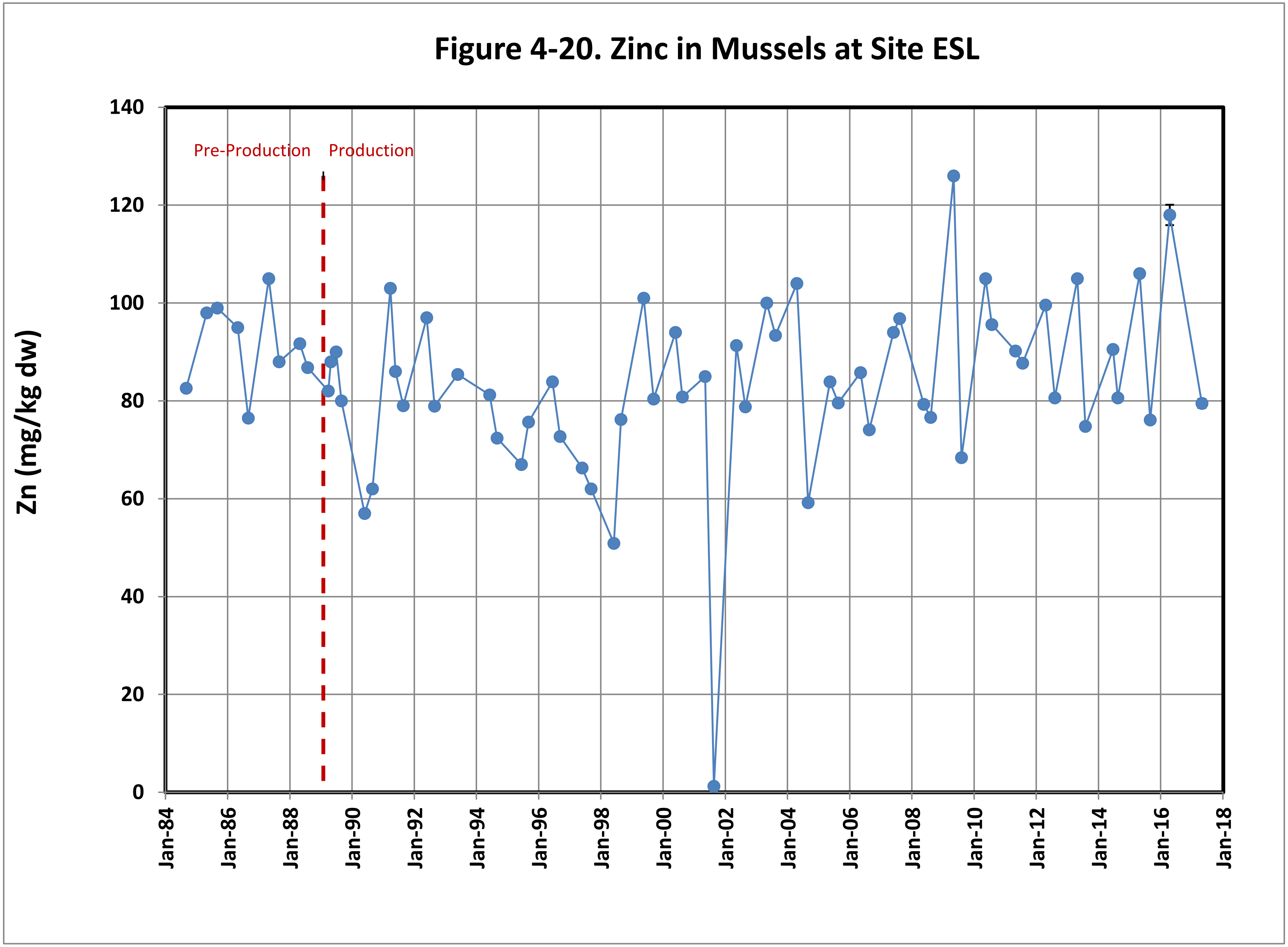


Figure 4-20. Zinc in Mussels at Site ESL
Zn (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
140
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

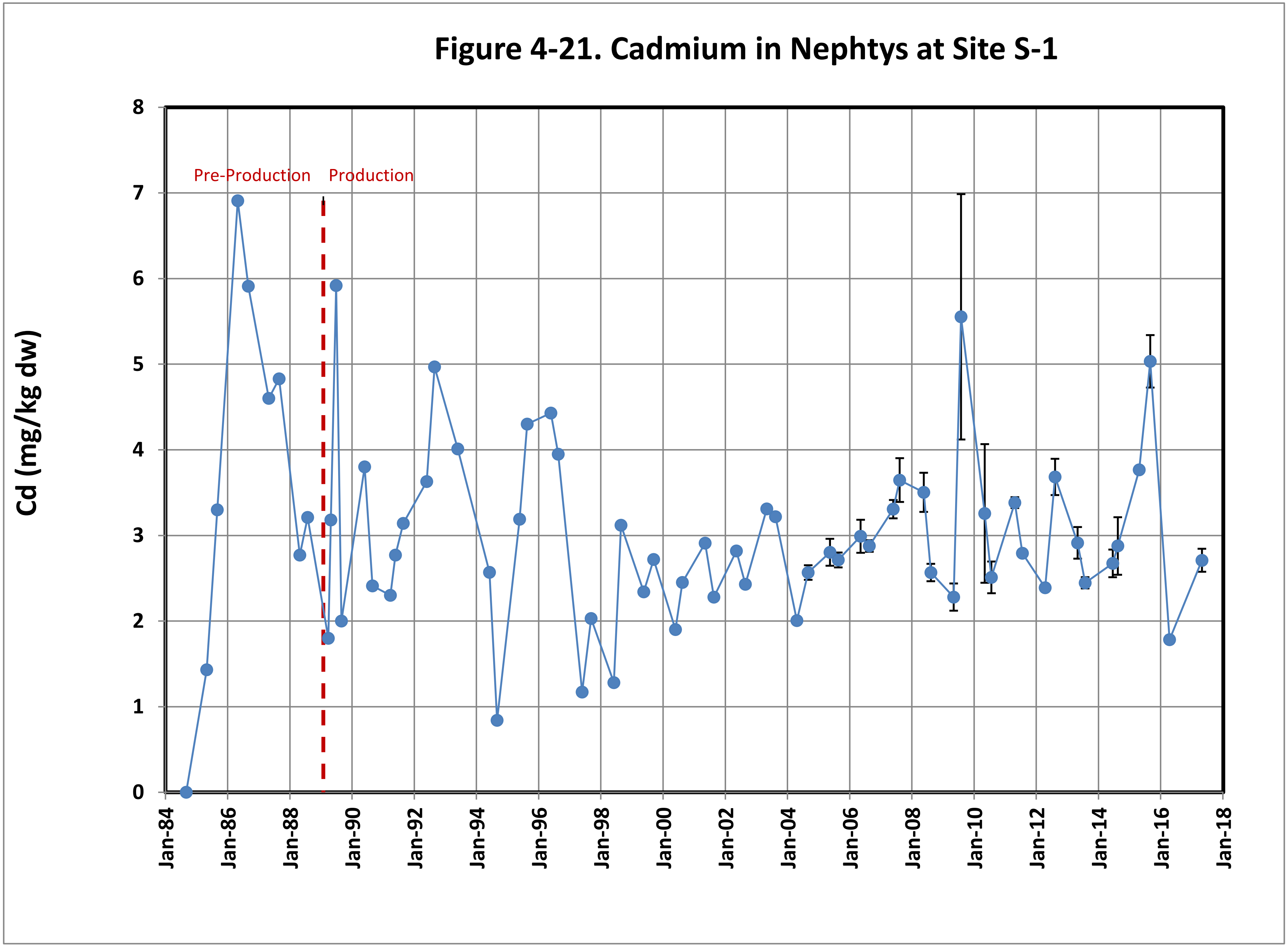


Figure 4-21. Cadmium in Nephtys at Site S-1
Cd (mg/kg dw)
Pre-Production
Production
0
1
2
3
4
5
6
7
8
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

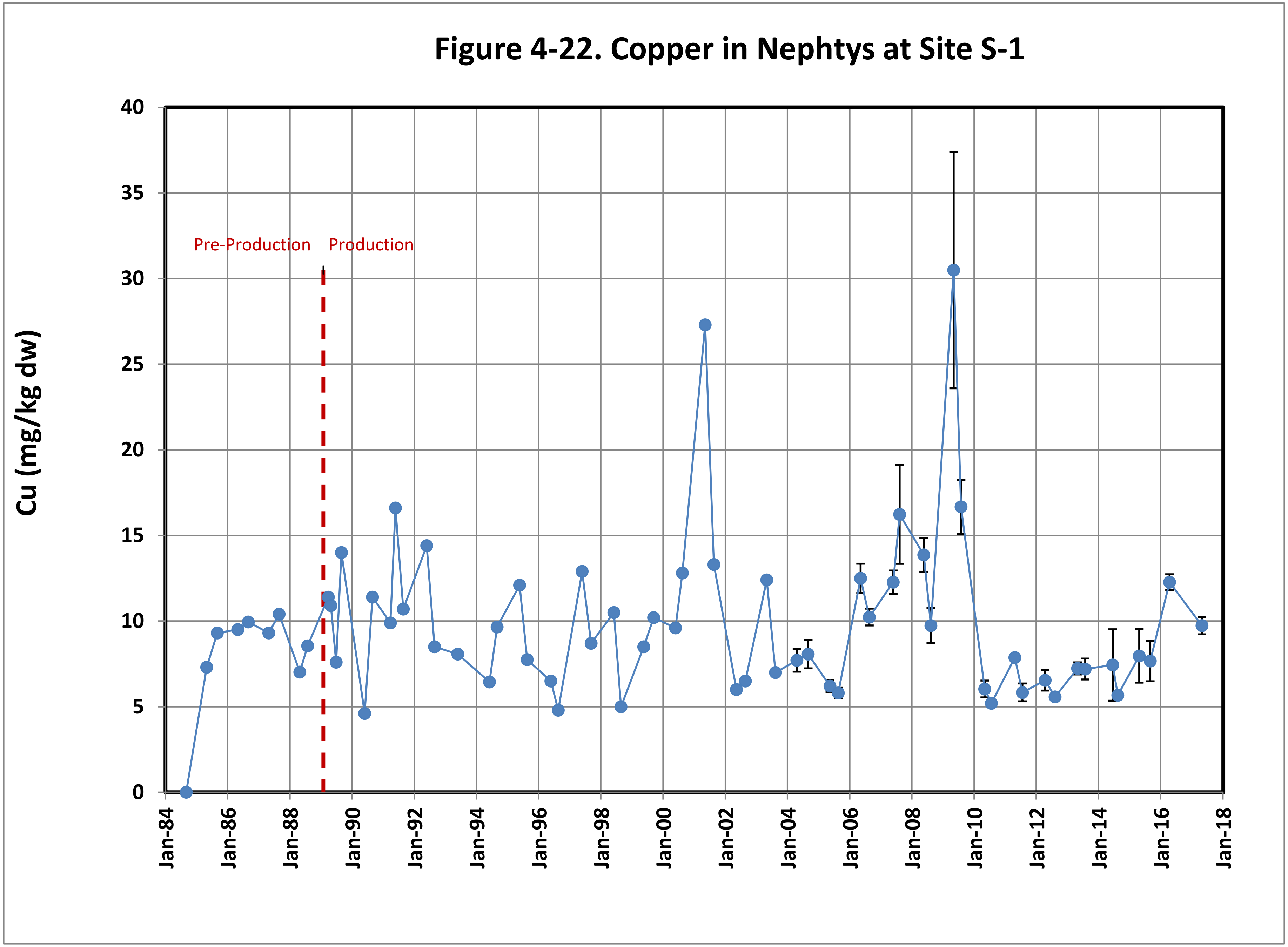


Figure 4-22. Copper in Nephtys at Site S-1
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
35
40
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

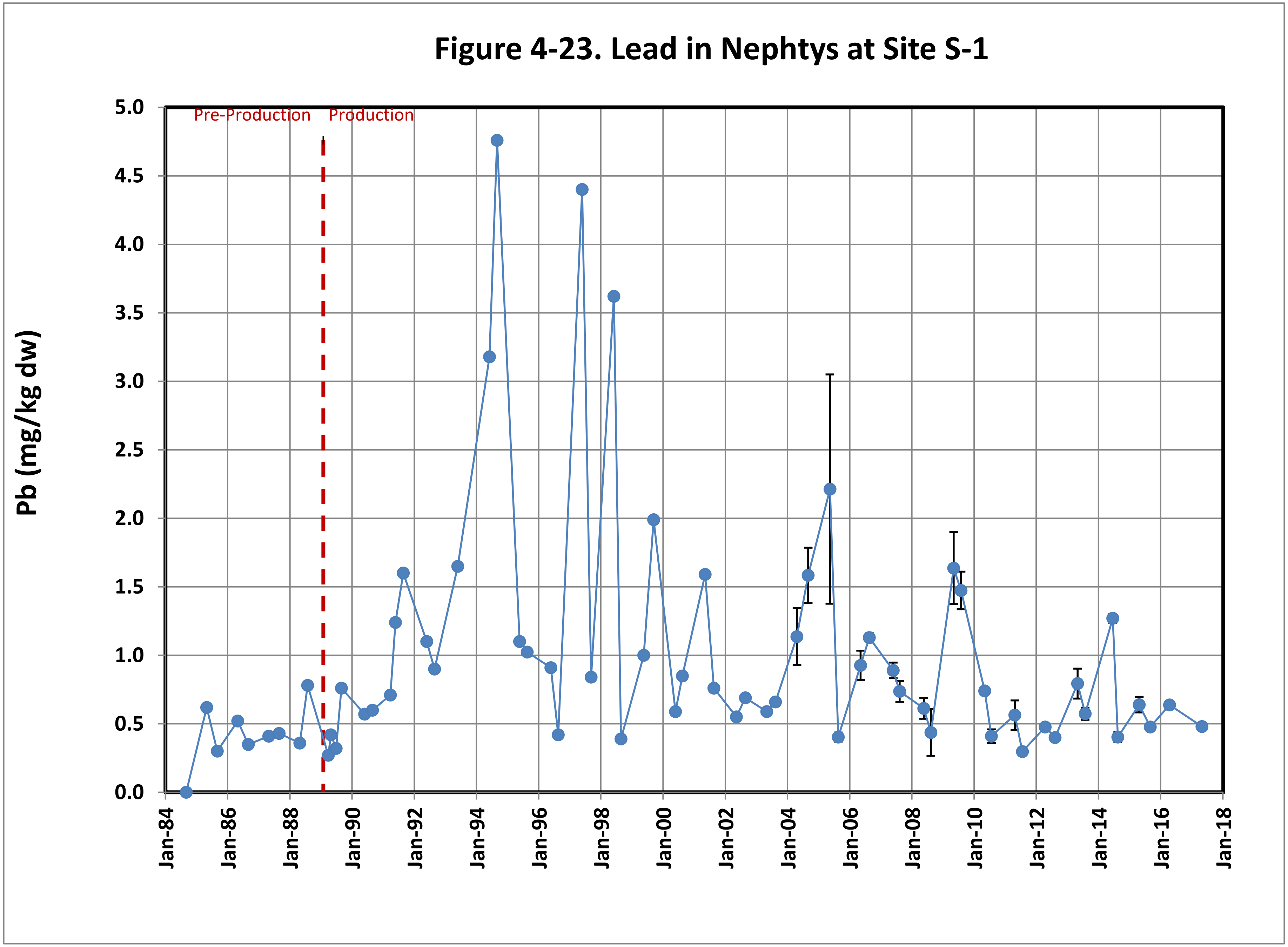


Figure 4-23. Lead in Nephtys at Site S-1
Pre-Production
Production
Pb (mg/kg dw)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

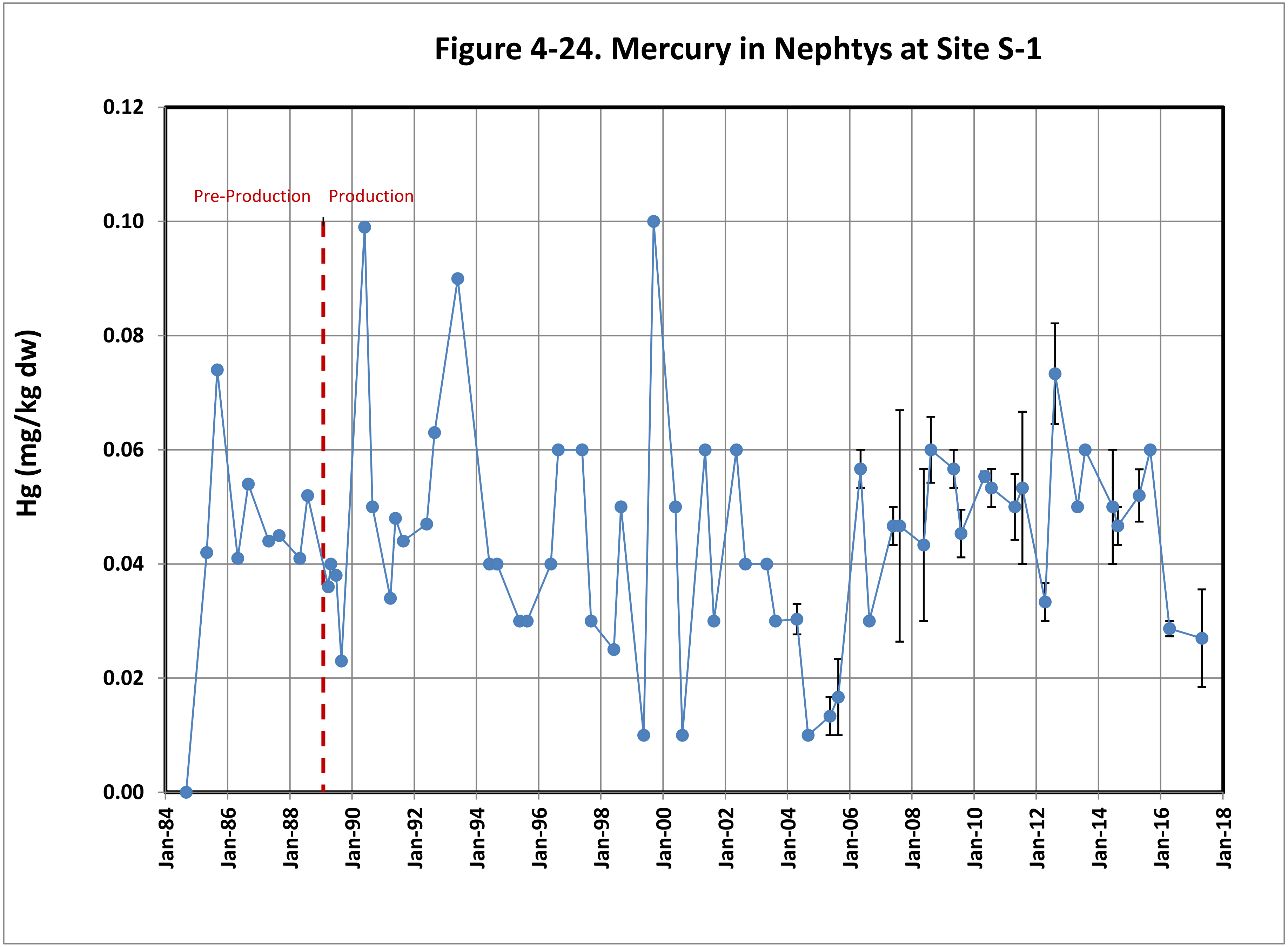


Figure 4-24. Mercury in Nephtys at Site S-1
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

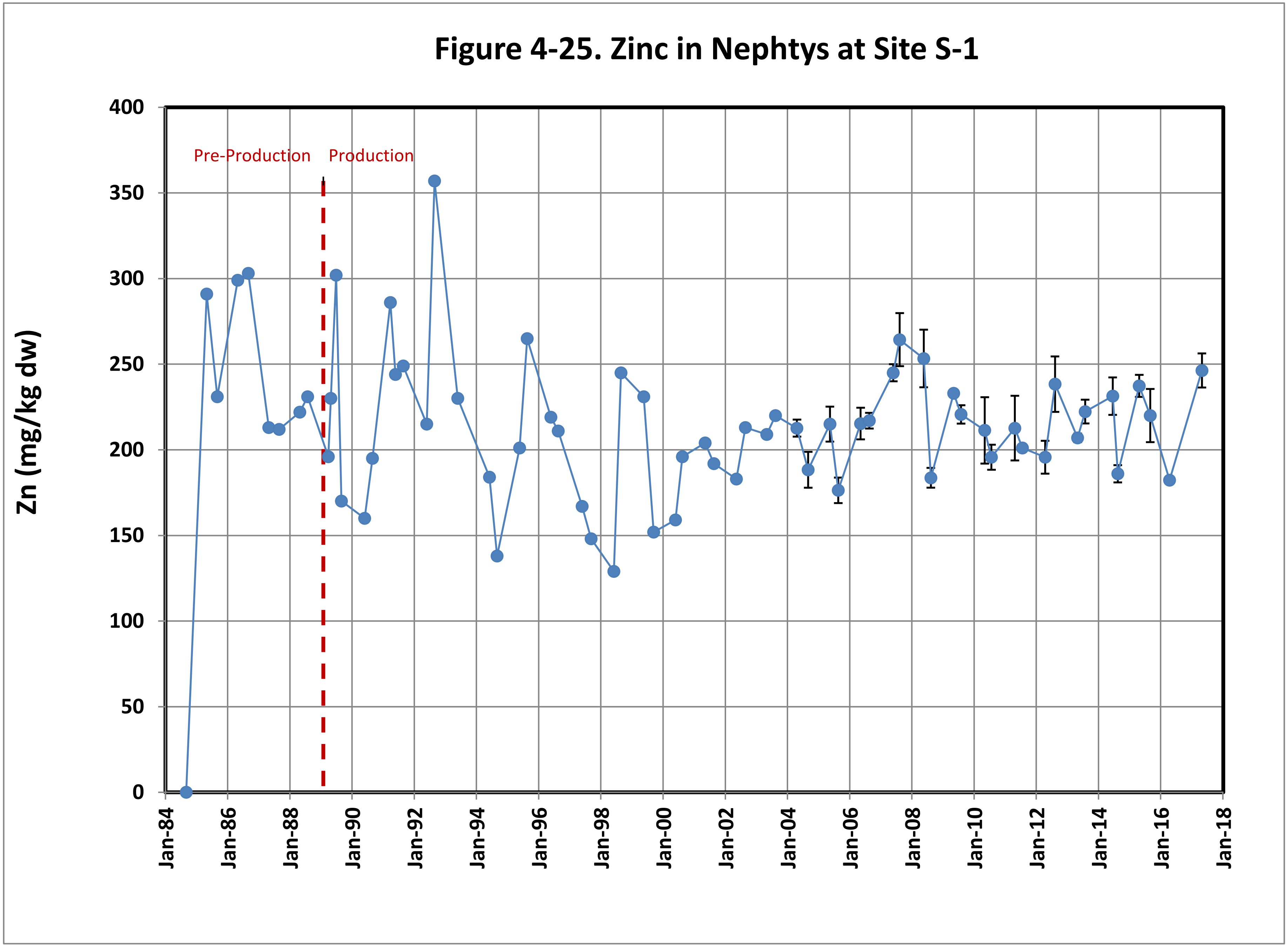


Figure 4-25. Zinc in Nephtys at Site S-1
Zn (mg/kg dw)
Pre-Production
Production
0
50
100
150
200
250
300
350
400
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

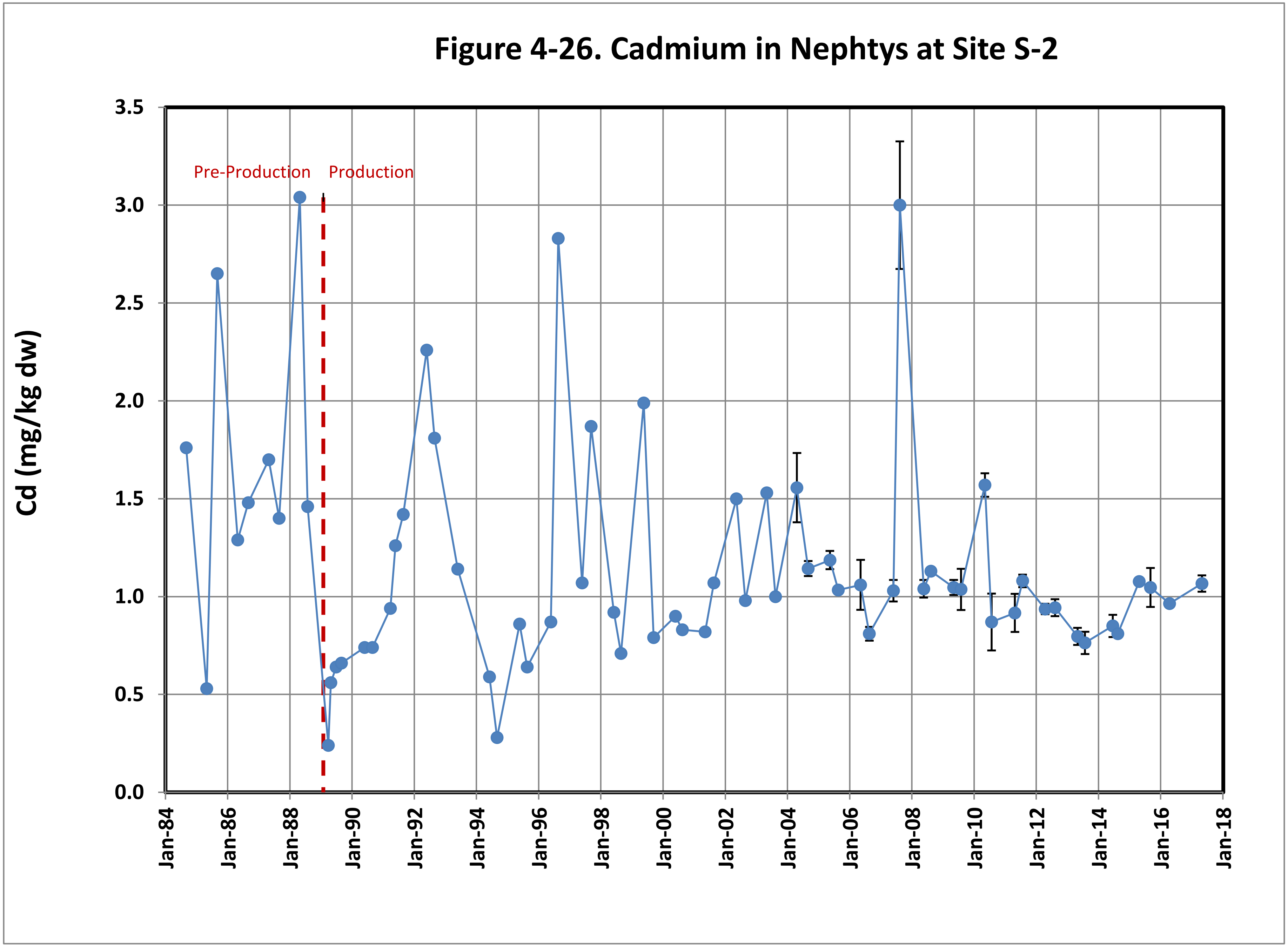


Figure 4-26. Cadmium in Nephtys at Site S-2
Cd (mg/kg dw)
Pre-Production
Production
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

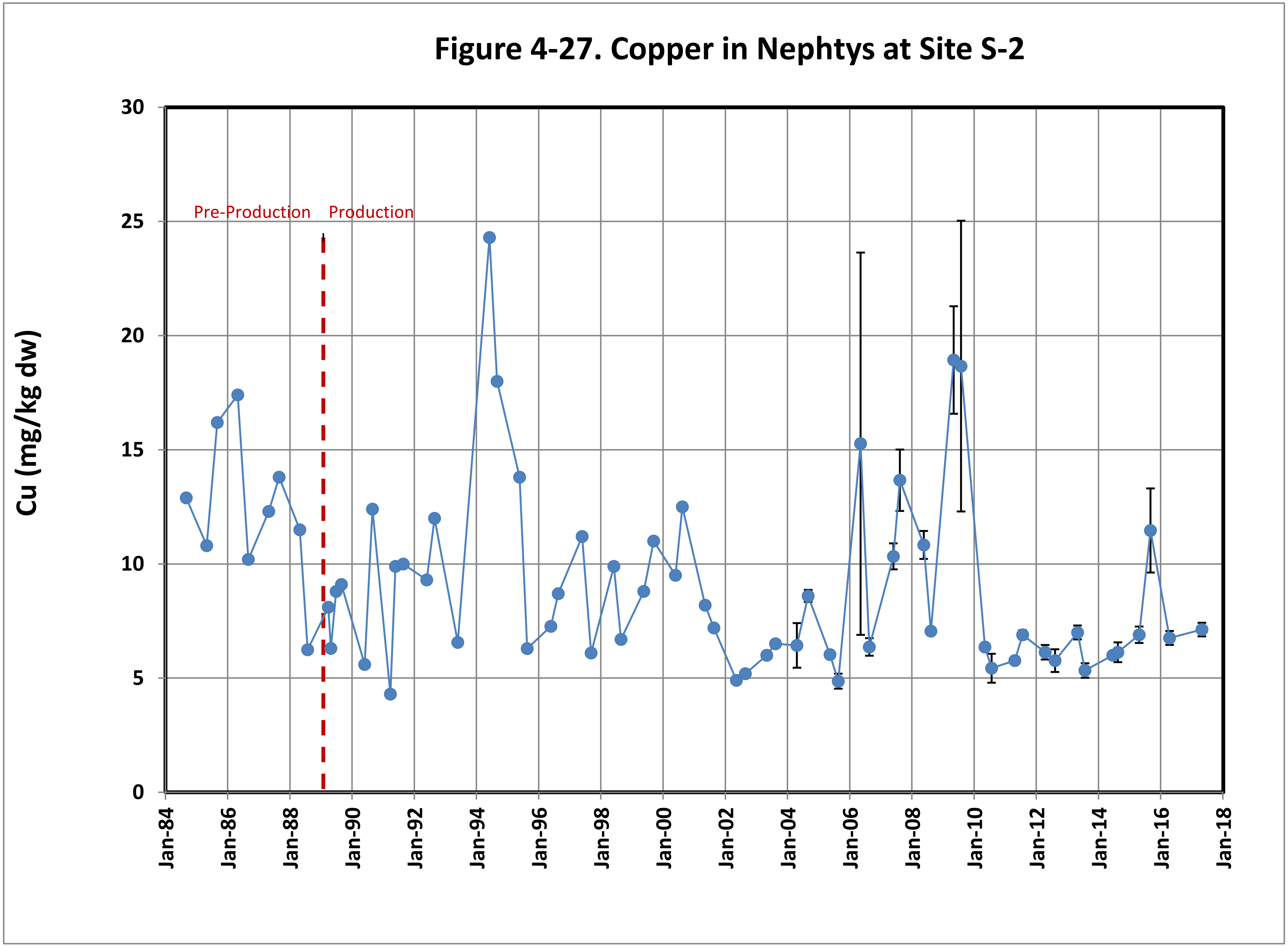


Figure 4-27. Copper in Nephtys at Site S-2
Cu (mg/kg dw)
Pre-Production
Production
0
5
10
15
20
25
30
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

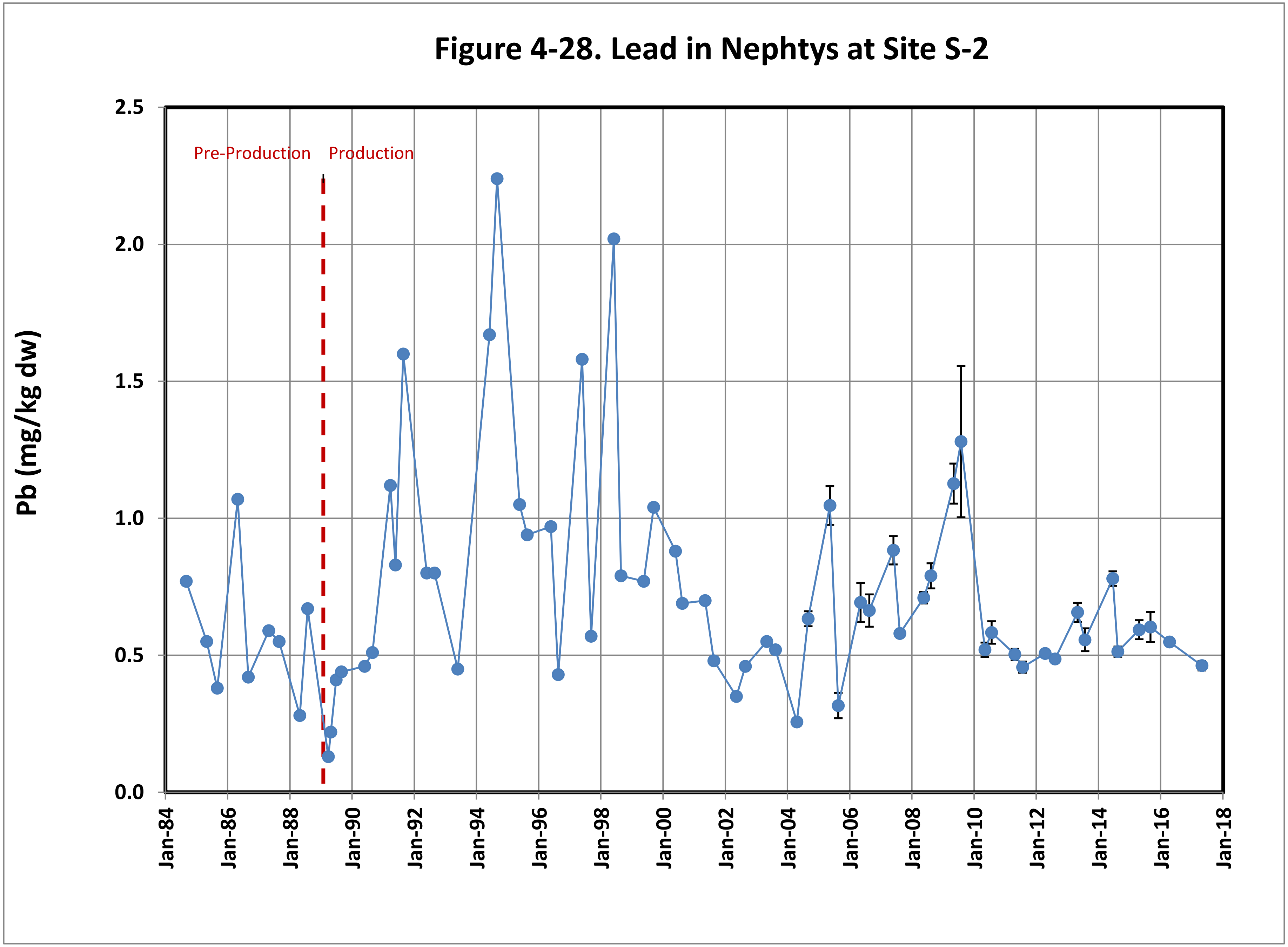


Figure 4-28. Lead in Nephtys at Site S-2
Pb (mg/kg dw)
2.5
2.0
1.5
1.0
0.5
0.0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

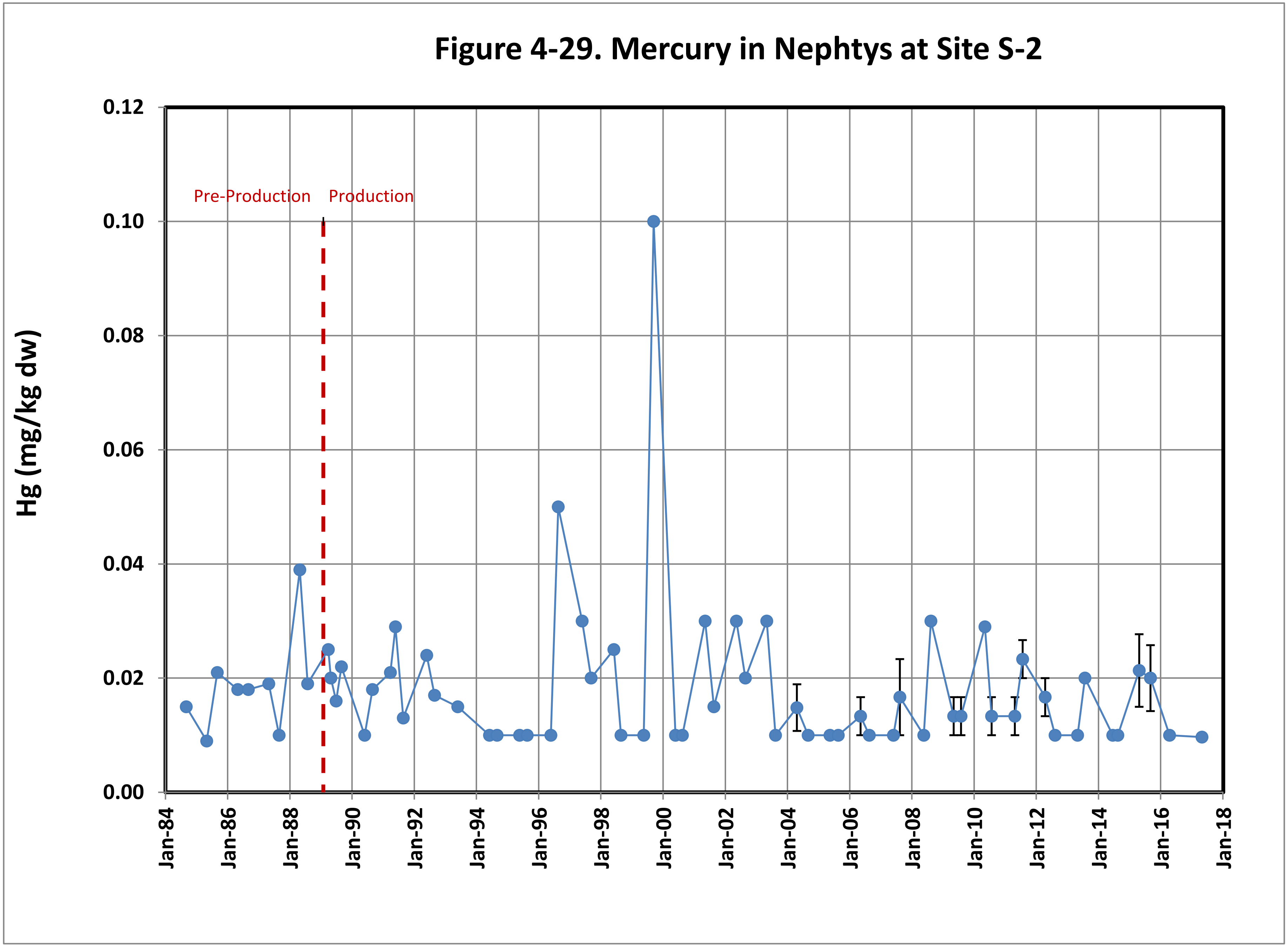


Figure 4-29. Mercury in Nephtys at Site S-2
Hg (mg/kg dw)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

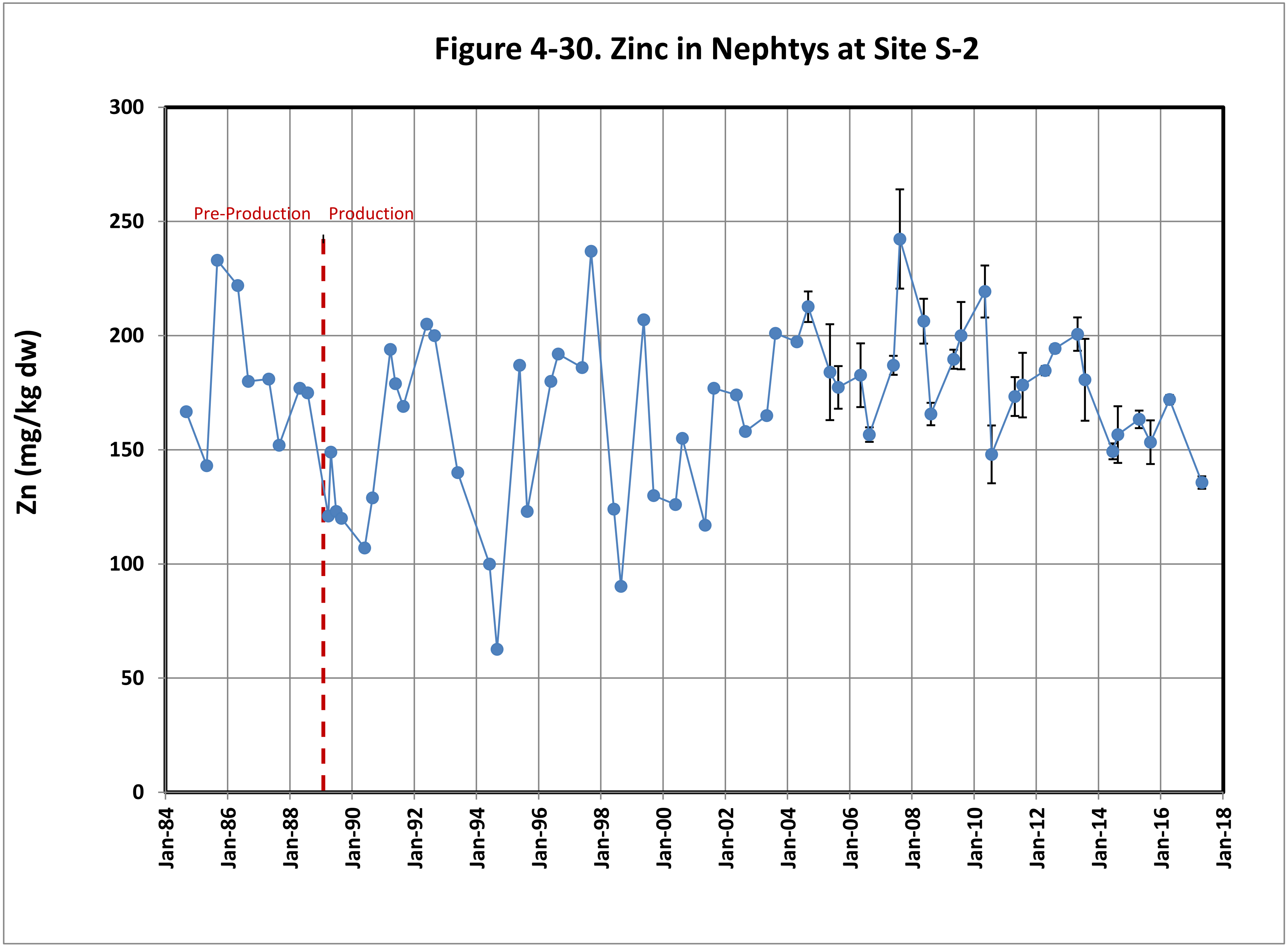


Figure 4-30. Zinc in Nephtys at Site S-2
Zn (mg/kg dw)
Pre-Production
Production
300
250
200
150
100
50
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
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Jan-12
Jan-14
Jan-16
Jan-18

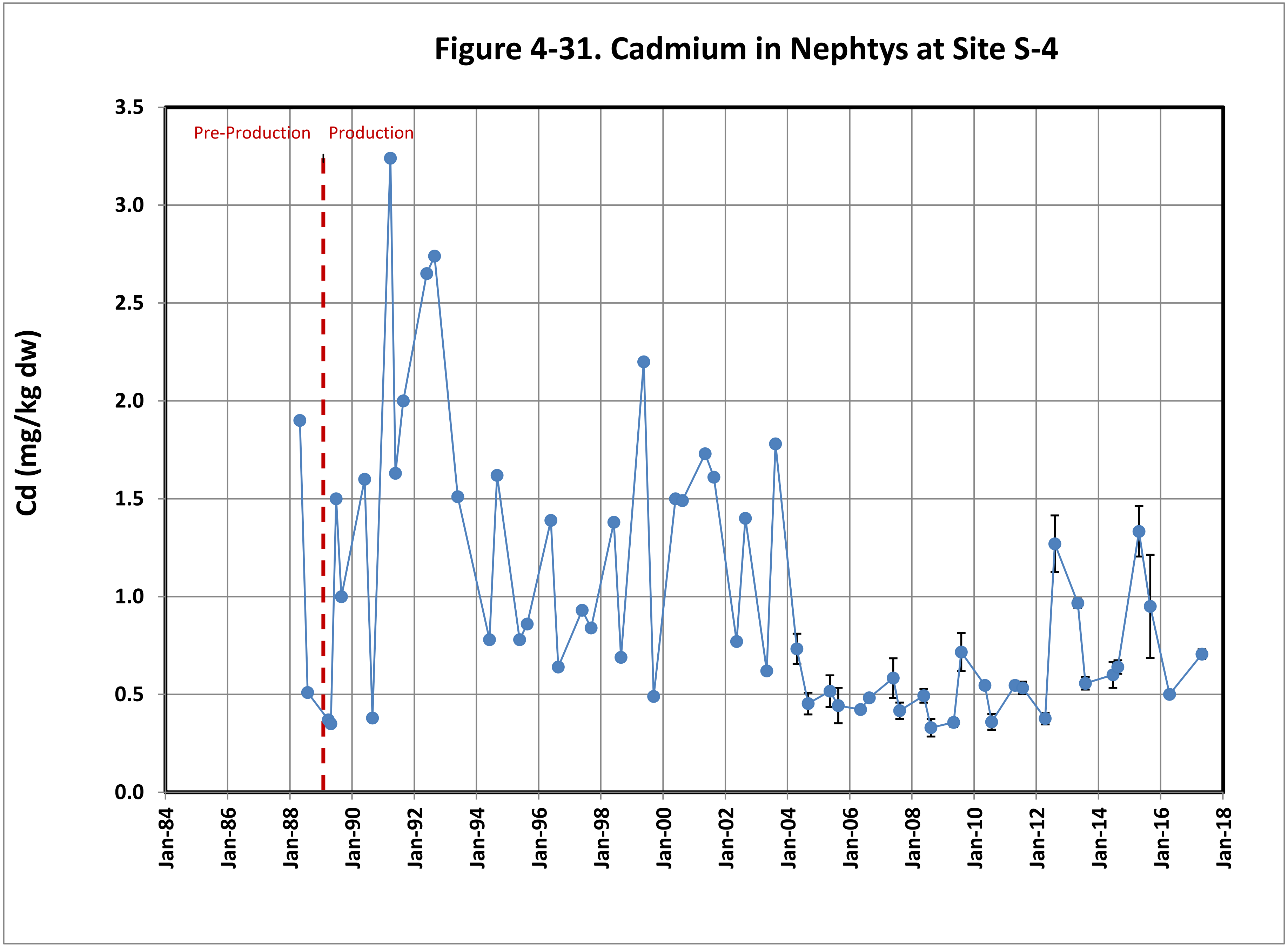

Figure 4-31. Cadmium in Nephtys at Site S-4
Cd (mg/kg dw)
Pre-Production
Production
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

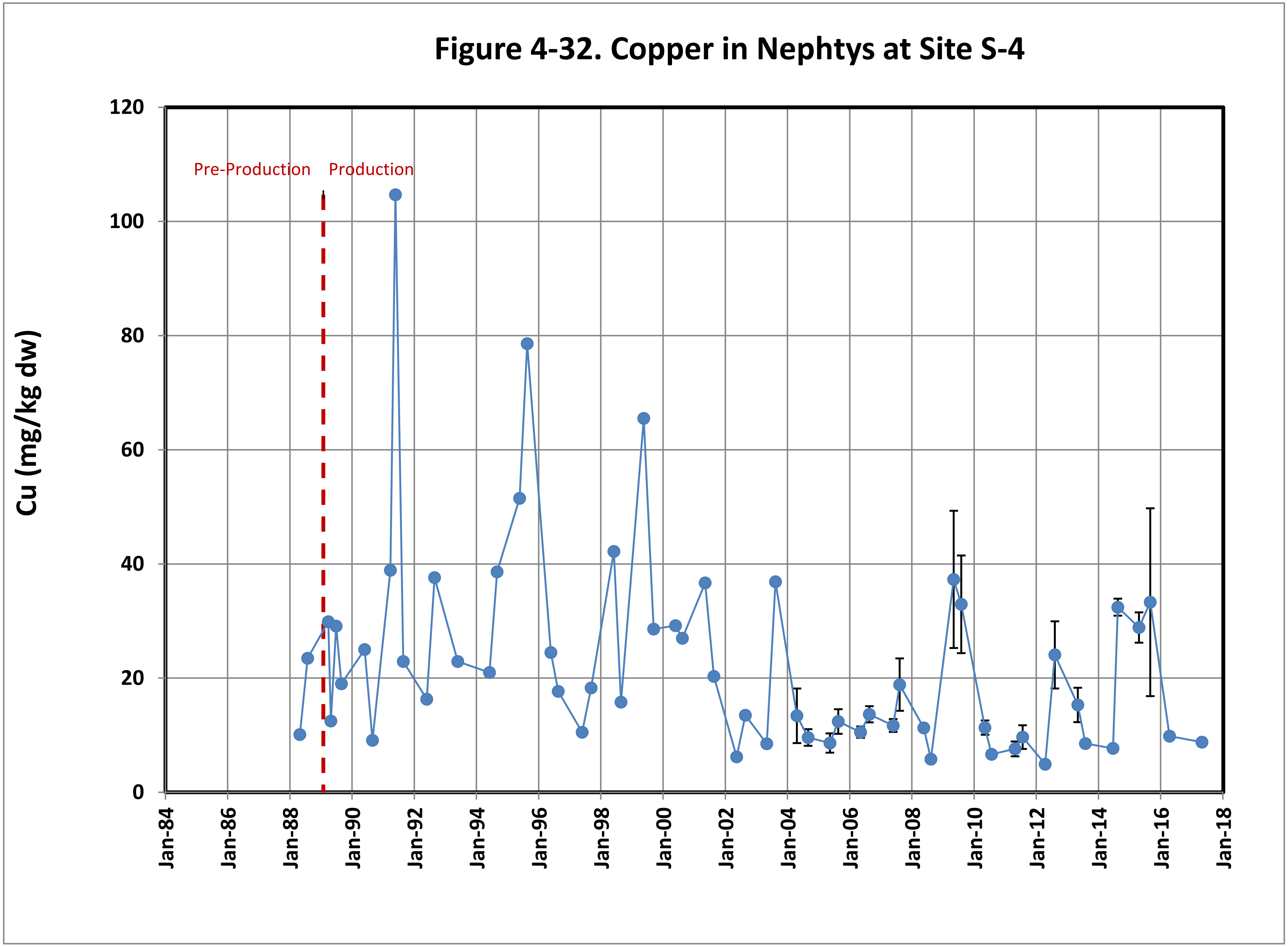

Figure 4-32. Copper in Nephtys at Site S-4
Cu (mg/kg dw)
Pre-Production
Production
0
20
40
60
80
100
120
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

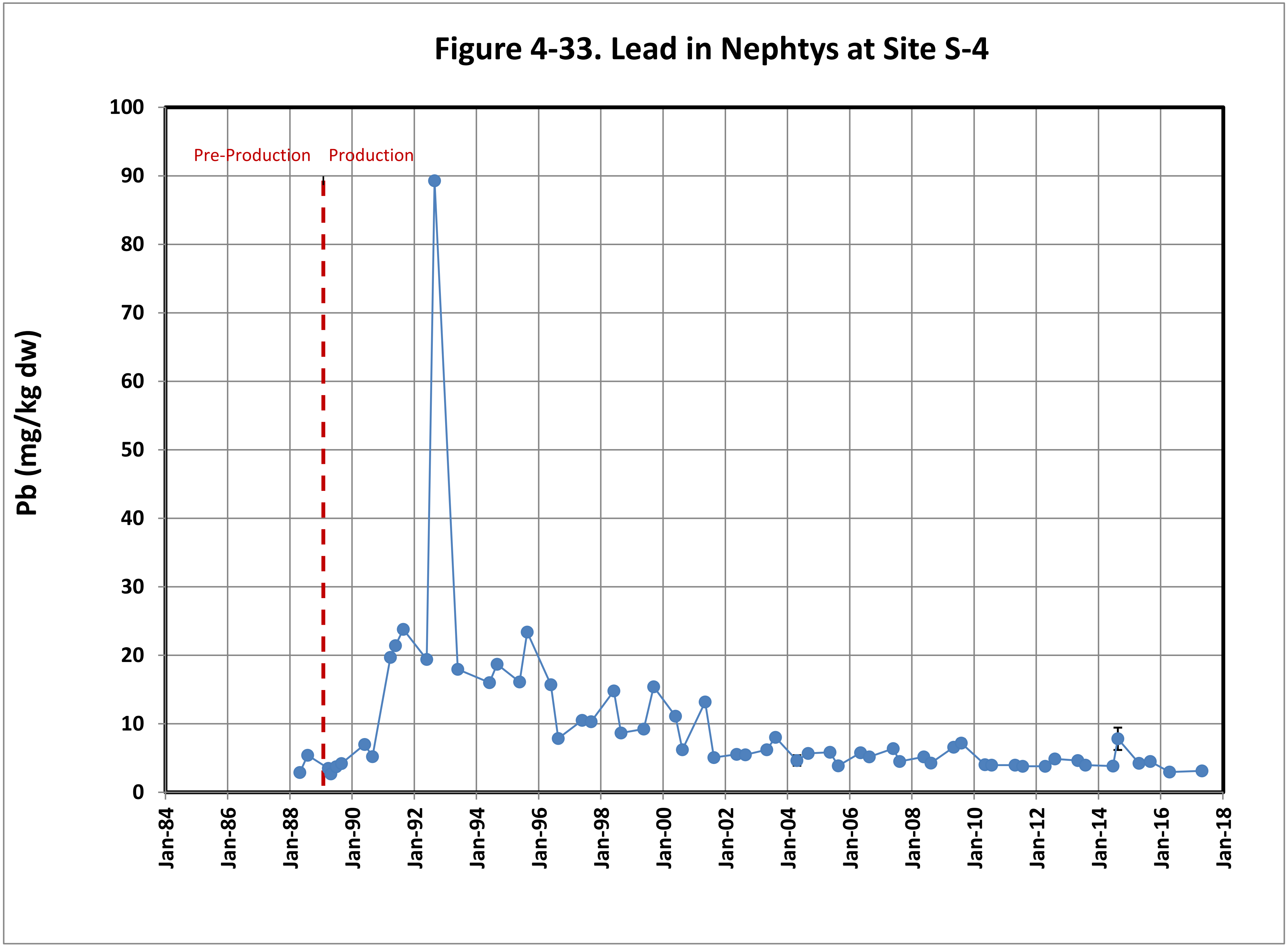

Figure 4-33. Lead in Nephtys at Site S-4
Pre-Production
Production
Pb (mg/kg dw)
100
90
80
70
60
50
40
30
20
10
0
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

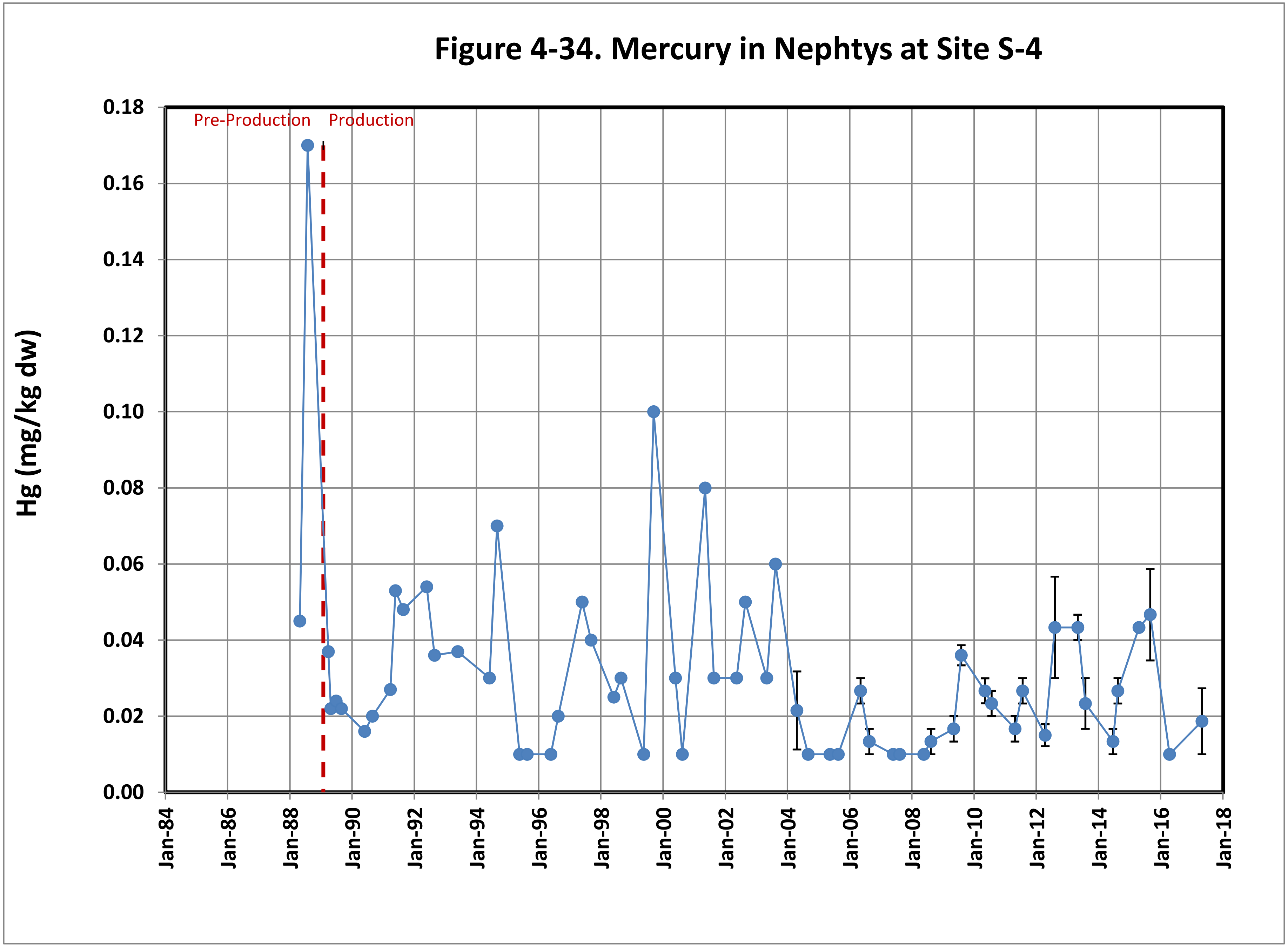

Figure 4-34. Mercury in Nephtys at Site S-4
Hg (mg/kg dw)
Pre-Production
Production
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

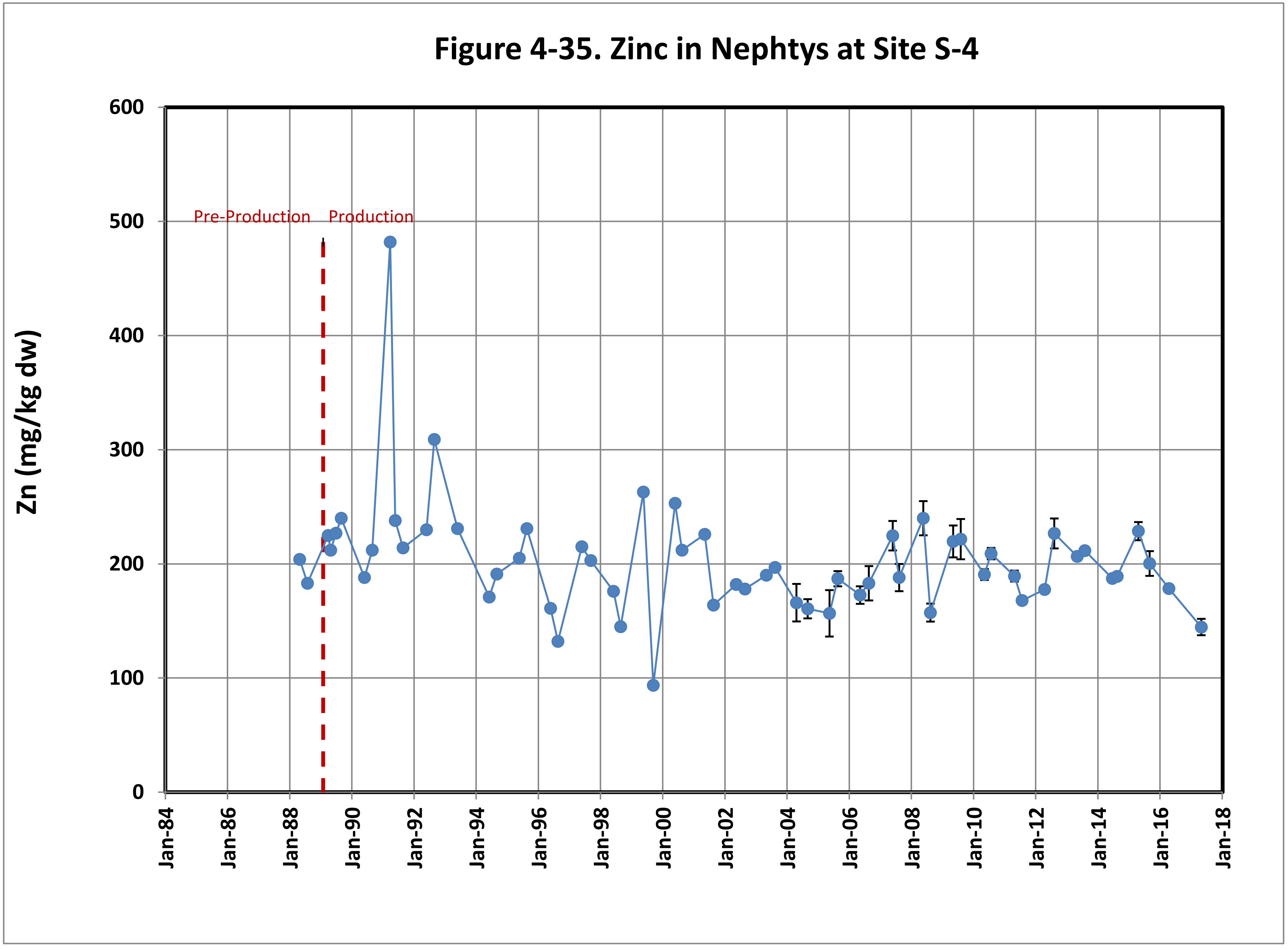

Figure 4-35. Zinc in Nephtys at Site S-4
Zn (mg/kg dw)
600
500
400
300
200
100
0
Pre-Production
Production
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06
Jan-08
Jan-10
Jan-12
Jan-14
Jan-16
Jan-18

APPENDIX A

Sediment Method Reporting Limit

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-1 / Replicate I	Sediment	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.050
		Mercury, Total	0.019
		Zinc, Total	0.50
S-1 / Replicate II	Sediment	Cadmium, Total	0.019
		Copper, Total	0.095
		Lead, Total	0.047
		Mercury, Total	0.020
		Zinc, Total	0.47
S-1 / Replicate III	Sediment	Cadmium, Total	0.018
		Copper, Total	0.089
		Lead, Total	0.044
		Mercury, Total	0.020
		Zinc, Total	0.44
S-1 / Replicate IV	Sediment	Cadmium, Total	0.019
		Copper, Total	0.097
		Lead, Total	0.049
		Mercury, Total	0.019
		Zinc, Total	0.49
S-1 / Replicate V	Sediment	Cadmium, Total	0.019
		Copper, Total	0.097
		Lead, Total	0.048
		Mercury, Total	0.020
		Zinc, Total	0.48
S-1 / Replicate VI	Sediment	Cadmium, Total	0.019
		Copper, Total	0.096
		Lead, Total	0.048
		Mercury, Total	0.020
		Zinc, Total	0.48
S-2 / Replicate I	Sediment	Cadmium, Total	0.020
		Copper, Total	0.098
		Lead, Total	0.049
		Mercury, Total	0.019
		Zinc, Total	0.49
S-2 / Replicate II	Sediment	Cadmium, Total	0.019
		Copper, Total	0.097
		Lead, Total	0.049
		Mercury, Total	0.017
		Zinc, Total	0.49

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-2 / Replicate III	Sediment	Cadmium, Total	0.021
		Copper, Total	0.10
		Lead, Total	0.052
		Mercury, Total	0.020
		Zinc, Total	0.52
S-2 / Replicate IV	Sediment	Cadmium, Total	0.019
		Copper, Total	0.093
		Lead, Total	0.046
		Mercury, Total	0.017
		Zinc, Total	0.46
S-2 / Replicate V	Sediment	Cadmium, Total	0.019
		Copper, Total	0.096
		Lead, Total	0.048
		Mercury, Total	0.021
		Zinc, Total	0.48
S-2 / Replicate VI	Sediment	Cadmium, Total	0.018
		Copper, Total	0.090
		Lead, Total	0.045
		Mercury, Total	0.018
		Zinc, Total	0.45
S-3 / Replicate I	Sediment	Cadmium, Total	0.031
		Copper, Total	0.15
		Lead, Total	0.076
		Mercury, Total	0.031
		Zinc, Total	0.76
S-3 / Replicate II	Sediment	Cadmium, Total	0.033
		Copper, Total	0.17
		Lead, Total	0.083
		Mercury, Total	0.028
		Zinc, Total	0.83
S-3 / Replicate III	Sediment	Cadmium, Total	0.029
		Copper, Total	0.15
		Lead, Total	0.073
		Mercury, Total	0.028
		Zinc, Total	0.73
S-3 / Replicate IV	Sediment	Cadmium, Total	0.024
		Copper, Total	0.12
		Lead, Total	0.061
		Mercury, Total	0.027
		Zinc, Total	0.61

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-3 / Replicate V	Sediment	Cadmium, Total	0.027
		Copper, Total	0.13
		Lead, Total	0.067
		Mercury, Total	0.029
		Zinc, Total	0.67
S-3 / Replicate VI	Sediment	Cadmium, Total	0.027
		Copper, Total	0.14
		Lead, Total	0.068
		Mercury, Total	0.028
		Zinc, Total	0.68
S-4 / Replicate I	Sediment	Cadmium, Total	0.019
		Copper, Total	0.097
		Lead, Total	0.048
		Mercury, Total	0.018
		Zinc, Total	0.48
S-4 / Replicate II	Sediment	Cadmium, Total	0.017
		Copper, Total	0.087
		Lead, Total	0.044
		Mercury, Total	0.017
		Zinc, Total	0.44
S-4 / Replicate III	Sediment	Cadmium, Total	0.022
		Copper, Total	0.11
		Lead, Total	0.054
		Mercury, Total	0.022
		Zinc, Total	0.54
S-4 / Replicate IV	Sediment	Cadmium, Total	0.021
		Copper, Total	0.10
		Lead, Total	0.051
		Mercury, Total	0.020
		Zinc, Total	0.51
S-4 / Replicate V	Sediment	Cadmium, Total	0.018
		Copper, Total	0.090
		Lead, Total	0.045
		Mercury, Total	0.021
		Zinc, Total	0.45
S-4 / Replicate VI	Sediment	Cadmium, Total	0.021
		Copper, Total	0.10
		Lead, Total	0.052
		Mercury, Total	0.022
		Zinc, Total	0.52

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-1 Nephtys I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
S-2 Nephtys I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.018
		Zinc, Total	0.50
S-3 Nephtys I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-4 Nephtys I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-1 Mussel I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
STN-2 Mussel I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
STN-3 Mussel I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
S-1 Nephtys II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-1 Nephtys III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-1 Nephtys IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-1 Nephtys V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-1 Nephtys VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-2 Nephtys II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-2 Nephtys III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-2 Nephtys IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-2 Nephtys V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-2 Nephtys VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-3 Nephtys II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-3 Nephtys III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-3 Nephtys IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-3 Nephtys V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-3 Nephtys VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-4 Nephtys II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-4 Nephtys III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
S-4 Nephtys IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-4 Nephtys V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
S-4 Nephtys VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-1 Mussel II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-1 Mussel III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
STN-1 Mussel IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-1 Mussel V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-1 Mussel VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
STN-2 Mussel II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-2 Mussel III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
STN-2 Mussel IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
STN-2 Mussel V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-2 Mussel VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
STN-3 Mussel II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-3 Mussel III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-3 Mussel IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50

Method Reporting Limit (MRL) = 3 x MDL

Sample	Matrix	Analyte	Reporting Limit (mg/Kg DW)
STN-3 Mussel V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
STN-3 Mussel VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
ESL Mussel I	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
ESL Mussel II	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
ESL Mussel III	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.019
		Zinc, Total	0.50
ESL Mussel IV	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.10
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
ESL Mussel V	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.099
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50
ESL Mussel VI	Animal Tissue	Cadmium, Total	0.020
		Copper, Total	0.100
		Lead, Total	0.020
		Mercury, Total	0.020
		Zinc, Total	0.50

Method Reporting Limit (MRL) = 3 x MDL

APPENDIX B

Outfall Survey Footage

Provided electronically to the Alaska Department of Environmental Conservation