HAWK INLET MONITORING PROGRAM
2011 ANNUAL REPORT

Hecla Greens Creek Mining Company

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1.0 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 2500 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 at the facilities near Hawk Inlet. The mine and mill facilities (920 area) are located over 6 miles up Greens Creek from Hawk Inlet tidewater.

Zinc, lead, silver, and gold are the target recovery metals. The Greens Creek Mine operations began in August 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 2000 ton/day 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 deposited in a surface dry-stack tailings pile near Hawk Inlet. Concentrate is transported from the mill to the Hawk Inlet area, where it is stored until it is shipped off-site.

Support facilities to the mining and milling operation at Hawk Inlet include core storage, concentrate storage and shipping, barge port facilities, and camp housing. A domestic waste water treatment plant is located at the Hawk Inlet port site.

Two waste water discharge outfalls and 10 storm water discharge sites are authorized by the HGCMC National Pollutant Discharge Elimination System (NPDES) Permit Number AK-004320-6. Outfall 001 provides an emergency backup discharge point for the Hawk Inlet Camp treated domestic sewage located at the Hawk Inlet port facilities. Under normal operating conditions, the Hawk Inlet camp treated sewage is combined with area surface runoff, and pumped up to the Tailings Area. Here it is combined with effluent streams from the 920 and the Tailings Basin areas, treated, and discharged through the submarine NPDES Outfall 002 onto the ocean floor in Hawk Inlet. Authority over the federal permitting, compliance and enforcement NPDES program transferred to the State (ADEC) in November of 2010 for the mining industry.

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 midchannel 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 1981, 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 Associates, 1981). At that rate, it is estimated that the Inlet will completely flush at least once every five tidal cycles. Based on the mine output up through 1995, the input of effluent from the mining operations over this flushing period represents approximately 0.009 percent of the total flushing volume (Ridgeway, 2003).

For more in-depth information on the physical and biological characteristics of Hawk Inlet, see *Technical Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations*, Ridgeway, October 2003.

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 and semi-annual monitoring events have generated an extensive time-series data set of coincident metal levels in water, sediment, and marine tissue samples.

This *Hawk Inlet Monitoring Program 2011 Annual Report* has been prepared by Hecla Greens Creek Mining Company (HGCMC) in accordance with Section I.D.5 of the National Pollutant Discharge Elimination System (NPDES) Permit AK-004320-6. Authority over the federal permitting, compliance and enforcement NPDES program transferred to the State (ADEC) in November of 2010 for the mining industry. Reporting the Hawk Inlet monitoring program data in an annual report is a requirement of this permit, which became effective July 1, 2005. Prior to this, the data were reported to EPA and ADEC in quarterly seawater reports.

The primary objective of the Hawk Inlet monitoring program is to document the water quality, sediment 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, and sediment and invertebrate samples are taken each year in the spring and in the fall at four and seven locations, respectively. Figure 1-1 shows a site map with the sampling locations. Table 1-1 summarizes the requirements of the permit for sample parameters, sample preservation and holding time, sampling frequency, analytical methods and method required detection limits (MDLs). 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, 2009).

TABLE 1-1 Summary of NPDES Permit Sampling Requirements for Hawk Inlet

NPDES 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											
I.D.1 Table 4	Dissolved Cadmium	Quarterly	Grab (1 sample for all metals)	1 ea. 500 ml Teflon bottle (1 bottle for all metals)	HNO_3 to pH <2 by lab	Battelle Marine Sciences	6 months	EPA 213.2/ 1638	0.10	µg/L	MDLs set by NPDES permit Section I.D.1, Table 4
I.D.1 Table 4	Dissolved Copper	Quarterly						EPA 220.2/ 1638	0.03	µg/L	
I.D.1 Table 4	Dissolved Lead	Quarterly						EPA 239.2/ 1638	0.05	µg/L	
I.D.1 Table 4	Total Mercury	Quarterly					28 days	EPA 245.1/ 1631	0.20	µg/L	
I.D.1 Table 4	Dissolved Zinc	Quarterly					6 months	EPA 289.2/ 1638	0.20	µg/L	
I.D.1 Table 4	Total Suspended Solids	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	Admiralty Environmental Labs	7 days	EPA 160.2/ SM 2540D	--	mg/L	
I.D.1 Table 4	Turbidity	Quarterly	Grab	1 ea. 1 liter plastic bottle	Cool to 4°C	Admiralty Environmental	48 hours	EPA 180.1	--	NTU	
I.D.1 Table 4	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	1.00	µg/L	Add 0.6g ascorbic acid, if chlorine is present.
I.D.1 Table 4	pH	Quarterly	Grab	NA	NA	Field measurement	15 min	EPA 150.1/ SM 4500-H, B	--	SU	
I.D.1 Table 4	Conductivity	Quarterly	Grab	NA	NA	Field measurement	20 days	EPA 120.1	--	µmhos/cm	
I.D.1 Table 4	Temperature	Quarterly	Grab	NA	NA	Field measurement	15 min	NA	--	°C	
BIOACCUMULATION WATER SEDIMENT MONITORING											
I.D.2 Table 5	Total Cadmium	Semi-annual	Grab	2 ea. 8 oz. plastic or glass jar	Freeze sample	Columbia Analytical Services (CAS)		PSEP/GFAA	0.30	mg/Kg	MDLs set by NPDES permit Section I.D.2, Table 5
I.D.2 Table 5	Total Copper	Semi-annual	Grab			CAS		PSEP/ICP	15.00	mg/Kg	
I.D.2 Table 5	Total Lead	Semi-annual	Grab			CAS		PSEP/ICP	0.50	mg/Kg	NMFS request dupilicate sampling
I.D.2 Table 5	Total Mercury	Semi-annual	Grab			CAS		PSEP/ EPA 7471A	0.02	mg/Kg	
I.D.2 Table 5	Total Zinc	Semi-annual	Grab			CAS		PSEP/ICP	15.00	mg/Kg	
BIOACCUMULATION WATER IN-SITU BIOASSAY MONITORING											
I.D.3 Table 6	Total Cadmium	Semi-annual	Grab	2 ea. 8 oz. plastic or glass jar	Freeze sample	CAS		EPA 200.8/ 6020	not specified	mg/Kg	NMFS request dupilicate sampling since Fall 2004
I.D.3 Table 6	Total Copper	Semi-annual	Grab			CAS		EPA 200.8/ 6020	not specified	mg/Kg	
I.D.3 Table 6	Total Lead	Semi-annual	Grab			CAS		EPA 200.8/ 6020	not specified	mg/Kg	
I.D.3 Table 6	Total Mercury	Semi-annual	Grab			CAS		EPA 7471A	not specified	mg/Kg	
I.D.3 Table 6	Total Zinc	Semi-annual	Grab			CAS		EPA 200.8/ 6020	not specified	mg/Kg	

This report presents information on each of the three media sampled in Hawk Inlet: water column, sediment and in-situ bioassay. All results for the samples collected in 2011 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 2011, and the reasons for the deviations.

1.3 Deviation(s) from Monitoring Program and Incidents in 2011

There were no deviations from the monitoring program in 2011.

Incidents that occurred in Hawk Inlet in 2011 are noted below, along with corrective and preventive actions:

- On October 25, 2011, the tide came up under the cannery building where there was a small amount of diesel from an unknown source, and the water picked about 1/4 cup of it into the water, creating a sheen. The sheen was very dispersed over the water surface (rainbow appearance). The sheen dissipated when the tide went out soon afterward. Since the source is unknown this area continues to be monitored closely. Cleanup was done under the cannery building using absorbents for the minor amount of liquid and a shovel and bag to handle the seaweed that had a diesel odor. Visual checks of the area later in the afternoon and for two weeks afterwards didn’t observe any additional free product under the building or a sheen in the water.

2.0 WATER COLUMN MONITORING

The receiving water column monitoring requirements originate from Section I.D.1 and Table 4 of the NPDES 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.

Three ocean 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 above the 002 diffuser in the mixing zone. Samples at all three locations are taken at a depth of five feet.

Water samples are sent to Battelle Marine Science Lab in Sequim, Washington, for low level dissolved trace metals analyses, ACZ Laboratory in Steamboat Springs, Colorado for WAD CN, Admiralty Environmental in Juneau, Alaska for pH, conductivity, total suspended solids, and turbidity analyses. Temperature, pH, turbidity and conductivity are measured in the field by the Environmental staff.

2.1 2011 Analytical Results

The tables in this section summarize the results for the quarterly water column monitoring conducted in 2011.

TABLE 2-1 Hawk Inlet Field Parameters 2011 (sample depth 5')

	Sample Date	Sample Time	Weather Conditions	Conductivity (µmhos/cm)	pH	Temp. (°C)
Site 106						
	2/8/11	10:13	clear, calm	49,210	7.84	4.3
	6/16/11	8:12	cloudy	48,700	8.07	10.6
	9/13/11	8:40	clear, calm	42,790	8.05	10.2
	10/4/11	13:27	rainy	25,010	8.16	7.7
Site 107						
	2/8/11	9:40	clear, calm	48,670	7.86	3.7
	6/16/11	7:30	cloudy	48,200	8.02	9.8
	9/13/11	8:09	cloudy	44,230	7.91	10.4
	10/4/11	12:50	rainy	23,630	8.15	7.9
Site 108						
	2/8/11	9:58	clear, calm	47,980	7.86	3.6
	6/16/11	7:49	cloudy	48,900	7.98	9.4
	9/13/11	8:24	rainy	44,030	8.00	10.3
	10/4/11	13:11	rainy	23,360	8.16	7.8

TABLE 2-2 Hawk Inlet Water Column Monitoring 2011: Nonmetal Parameters
(ACZ Laboratories and Admiralty Environmental) (sample depth 5')

	Sample Date	TSS (mg/L)	Turbidity (NTU)	WAD CN (µg/L)	pH (su)	Conductivity (µmhos/cm)
Site 106						
	2/8/11	26	<21	<3.0	7.70	29,900
	6/16/11	24	2.7	<3.0	8.30	50,700
	9/13/11	24	3.5	<3.0	7.90	43,800
	10/4/11	17	3.80	<3.0	7.90	46,400
Site 107						
	2/8/11	26	<21	<3.0	7.80	30,600
	6/16/11	27	11	<3.0	8.30	50,600
	9/13/11	22	1.9	<3.0	8.00	44,700
	10/4/11	15	3.50	<3.0	7.90	46,000
Site 108						
	2/8/11	25	<21	<3.0	7.80	29,900
	6/16/11	27	5.9	<3.0	8.30	51,300
	9/13/11	22	3.7	<3.0	8.00	44,000
	10/4/11	23	0.60	<3.0	7.90	46,100

TABLE 2-3 Hawk Inlet Water Column Monitoring Results 2011: Metals
(Battelle Marine Sciences Laboratory) (sample depth 5')

	Sample Date	Cd (µg/L) Dissolved	Cu (µg/L) Dissolved	Pb (µg/L) Dissolved	Hg (µg/L) Total	Zn (µg/L) Dissolved
Lab MDL		*(0.002)*	*(0.023)*	*(0.001)*	*(0.0001)*	*(0.042)*
Req. MDL		*(0.10)*	*(0.03)*	*(0.05)*	*(0.0002)*	*(0.20)*
Site 106						
	2/8/11	0.0819	0.274	0.0726	0.000518	1.33
	6/16/11	0.0496	0.361	0.0262	0.000891	0.115
	9/13/11	0.0648	0.273	0.0273	0.000304	2.45
	10/4/11	0.0760	0.352	0.0441	0.000334	2.15
Site 107						
	2/8/11	0.0842	0.283	0.0376	0.000337	1.10
	6/16/11	0.0585	0.747	0.1230	0.000654	1.22
	9/13/11	0.0647	0.865	0.0558	0.000519	1.03
	10/4/11	0.0789	0.549	0.0571	0.000518	3.25
Site 108						
	2/8/11	0.0824	0.228	0.0369	0.000376	1.16
	6/16/11	0.0556	0.472	0.0503	0.000939	1.51
	9/13/11	0.0680	0.401	0.0453	0.000367	1.58
	10/4/11	0.0746	0.323	0.0310	0.000448	2.27

2.2 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 the HGCMC results remain within or below these standards in all historical and 2011 samples.

The elevated WAD CN results for 2009 and 2010 are likely an artifact of instrumentation and other analytical difficulties at the laboratory rather than actual concentrations in the samples. Valley Environmental Laboratory purchased new instrumentation in 2009, updating their extraction apparatus and spectrophotometer. Potential issues with new instrumentation, along with the difficult matrix that these samples are in (ocean water), and the low detection limit that is required (<1 µg/L), can result in interferences that affect the results. An additional reason to question the validity of these results can be found in the WAD CN analyses of the HGCMC discharges to Hawk Inlet. In 2010, of the 52 samples of discharge water, 50 of the WAD CN results were < 3.0 µg/L. Because of these discrepancies, HGCMC collected additional duplicate WAD CN samples in 2010 and sent them to labs other than Valley to be analyzed. Duplicate samples for the 1st, 2nd and 4th quarters were sent to ACZ Laboratory, as well as to Analytica Laboratory for the 4th quarter samples. All duplicate samples from the two additional labs showed below detection limits of WAD CN (<3 and <1.2 µg/L, respectively). With the results of the WAD CN in the discharge water, as well as the duplicate sampling results, HGCMC decided that Valley Laboratory's results were suspect, and proposed to use ACZ Laboratory for future analysis of WAD CN samples. HGCMC sent all WAD CN samples in 2011 to ACZ Laboratories and the results were all below the detection limit of <3 µg/L.

Table 2-4 summarizes the past five year's average metals values for the sea water samples, compared to the current year's results.

TABLE 2-4 Hawk Inlet Water Column Average Dissolved Metal Concentrations

	Cd (µg/L)		**Cu** (µg/L)		**Pb** (µg/L)		**Hg** (TOTAL - µg/L)		**Zn** (µg/L)	
	2006,2007, 2008, 2009, and 2010	**2011**	**2006,2007 , 2008, 2009, and 2010**	**2011**	**2006,2007, 2008, 2009, and 2010**	**2011**	**2006,2007, 2008, 2009, and 2010**	**2011**	**2006,2007, 2008, 2009, and 2010**	**2011**
Site 106	0.0698	0.0681	0.366	0.315	0.0995	0.0426	0.000559	0.000512	1.00	1.51
Site 107	0.0732	0.0716	0.461	0.661	0.1195	0.0684	0.001201	0.000507	1.35	1.65
Site 108	0.0704	0.0702	0.399	0.356	0.0945	0.0409	0.001066	0.000533	1.25	1.63

2.3 QA/QC Results

Battelle Marine Sciences Laboratory, ACZ Laboratories, and Admiralty Environmental analyzed the required parameters (see 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 2011 sea water samples (taken quarterly – 1Q11, 2Q11, 3Q11, and 4Q11).

<u>Battelle Marine Science (low level dissolved trace metals analyses in salt water matrices):</u>
1Q11: Target detection limits were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within data quality objective of ±25%. Method blank results were less than five times the MDL for all metals.

2Q11: Target detection limits were met for all metals. Standard reference material (SRM), matrix spike and duplicate results were within the default criteria of ±25%. The field blank detected Mercury and Copper at less than five times the MDL, but Zinc and Lead were detected at higher concentrations.

3Q11: Target detection limits were met for all metals. Method blank results were less than the MDL for all metals. Detected levels in the blanks were less than five times the MDL. Standard reference material (SRM), matrix spike and duplicate results were within the default criteria of ±25%.

4Q11: Target detection limits were met for all metals. Detected levels were less than five times the MDL for all metals in the method blank. Standard reference material (SRM), matrix spike and duplicate results were within the default criteria of ±25%. The Zinc in the field blank was detected at well above the MDL and at high enough concentrations to impact field sample concentrations.

<u>ACZ Laboratories (WAD cyanide analyses):</u>
1Q11: Method-specified preservation criteria cannot be met due to sample matrix.

2Q11: The samples were received outside of the recommended temperature range of 0 to 6 degrees C. Method-specified preservation criteria cannot be met due to sample matrix.

3Q11: Method-specified preservation criteria cannot be met due to sample matrix.

4Q11: The samples were received outside of the recommended temperature range of 0 to 6 degrees C. Method-specified preservation criteria cannot be met due to sample matrix.

<u>Admiralty Environmental (total suspended solids (TSS), pH, conductivity, and turbidity analyses):</u>
1Q11, 2Q11, 3Q11, 4Q11: All method specifications and required MDLs were met.

3.0 SEDIMENT MONITORING

The requirements for the sediment monitoring originate from Section I.D.2, Sediment Monitoring, and Table 5 of the NPDES permit. The objective of this element of the monitoring program is to provide scientifically valid data on five specific trace metal parameters from sediments at four locations in Hawk Inlet. These data are used to evaluate potential changes in the Hawk Inlet marine environment.

The sediment samples are collected semi-annually in the spring and fall at the Greens Creek delta (Site S-1), Pile Driver Cove near the mouth of the inlet (Site S-2), near the ore dock (Site S-4), and under the ship's berth near the old cannery (Site S-5N and S-5S which bracket the area where concentrate was spilled in 1989). The samples are analyzed at Columbia Analytical Services, Inc. in Kelso, Washington for total concentrations of five trace metals (Cd, Cu, Pb, Hg, and Zn).

An additional location, Site S-3, has also been sampled for sediments since the 1980s. Site S-3 is located at the head of Hawk Inlet. Data collected from Site S-3 exhibited different trends from the other two background stations (S-1 and S-2). Most metals at S-3 were found at higher levels than at S-1 or S-2. Field observations of a mass wasting event in the watershed above S-3 appears to have released metals from abandoned historic mine workings (Alaska Rand Group) into the environment (Ridgeway, 2003). For this reason, when the reissued permit became effective July 1, 2005, S-3 was dropped from the list of active sediment sampling sites. Therefore, data from S-3 are not presented in this report.

3.1 2011 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 labels I, II, and III denote duplicate samples taken at each sample site.

TABLE 3-1 Hawk Inlet Sediment Monitoring Field Parameters 2011

Locations	Date Sampled	Time Sampled	Weather Conditions	Tide Ht.
S-1	5/15/11	6:00	clear	-2.1
	8/11/11	6:00	rain	-0.6
S-2	5/16/11	7:00	clear	-3.3
	8/11/11	7:00	rain	-0.6
S-4	5/17/11	9:00	clear	-3.7
	8/12/11	7:00	rain	-1.3
S-5S	5/15/11	12:30	clear	14.6
	8/8/11	15:00	clear	5.0
S-5N	5/15/11	12:00	clear	14.5
	8/8/11	15:30	clear	5.2

TABLE 3-2 Hawk Inlet Sediment Results for Spring 2011
(Columbia Analytical Services Laboratory)

Sample No.	Sample date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
Lab MRL		*(0.02)*	*(0.1, 1.8, 1.9)*	*(0.05,0.96, 0.95, 0.94, 0.93, 0.92, 2.37)*	*(0.02)*	*(0.5, 0.49, 0.48, 0.47, 9.15, 9.30, 9.38, 9.52, 9.59, 23.7)*
Required MDL		*(0.3)*	*(15.0)*	*(0.05)*	*(0.02)*	*(15.0)*
S-1 Sediments-Metals I	5/15/11	0.14	14.8	5.69	0.03	109
S-1 Sediments-Metals II	5/15/11	0.12	16.3	5.79	0.03	105
S-1 Sediments-Metals III	5/15/11	0.11	13.4	5.82	0.03	100
S-2 Sediments-Metals I	5/16/11	0.11	8.6	1.62	<0.02	45.4
S-2 Sediments-Metals II	5/16/11	0.10	7.5	1.33	<0.02	37.5
S-2 Sediments-Metals III	5/16/11	0.10	8.1	1.56	<0.02	39.8
S-4 Sediments-Metals I	5/17/11	0.29	104	16.3	0.03	61.6
S-4 Sediments-Metals II	5/1711	0.24	14.8	16.1	0.03	59
S-4 Sediments-Metals III	5/17/11	0.28	110	17.9	0.03	64.2
S-5N Sediments-Metals I	5/15/11	1.33	109	205	0.12	342
S-5N Sediments-Metals II	5/15/11	1.29	420	313	0.15	301
S-5N Sediments-Metals III	5/15/11	2.59	70.5	470	0.13	471
S-5S Sediments-Metals I	5/15/11	5.52	257	377	0.48	1330
S-5S Sediments-Metals II	5/15/11	4.04	67.1	262	1.18	941
S-5S Sediments-Metals III	5/15/11	15.6	147	542	0.47	3390

TABLE 3-3 Hawk Inlet Sediment Results for Fall 2011
(Columbia Analytical Services Laboratory)

Sample No.	Sample date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
Lab MRL		*(0.007, 0.009, 0.01, 0.02)*	*(0.04, 0.05, 0.07, 0.08, 0.9, 1.0, 1.1)*	*(0.02, 0.03, 0.04, 0.05, 0.50)*	*(0.02)*	*(0.2, 0.3, 0.4, 5.0)*
Required MDL		*(0.3)*	*(15.0)*	*(0.05)*	*(0.02)*	*(15.0)*
S-1 Sediments-Metals I	8/13/11	0.121	13.8	6.59	0.04	105
S-1 Sediments-Metals II	8/13/11	0.118	14.4	6.76	0.03	107
S-1 Sediments-Metals III	8/13/11	0.129	14.2	5.75	0.002	106
S-2 Sediments-Metals I	8/14/11	0.106	8.02	1.67	<0.02	36.9
S-2 Sediments-Metals II	8/14/11	0.11	9.22	1.59	<0.02	43.8
S-2 Sediments-Metals III	8/14/11	0.106	9.45	1.6	<0.02	41.9
S-4 Sediments-Metals I	8/14/11	0.204	12.1	12.7	0.02	47
S-4 Sediments-Metals II	8/14/11	0.23	13.8	14.1	<0.02	58.9
S-4 Sediments-Metals III	8/14/11	0.165	15.8	13.8	<0.02	52.7
S-5N Sediments-Metals I	8/8/11	3.6	97.7	289	0.17	946
S-5N Sediments-Metals II	8/8/11	1.95	71.4	177	0.22	500
S-5N Sediments-Metals III	8/8/11	2.26	109	184	0.11	532
S-5S Sediments-Metals I	8/8/11	3.18	86.1	176	0.2	776
S-5S Sediments-Metals II	8/8/11	3.06	210	314	0.23	729
S-5S Sediments-Metals III	8/8/11	2.34	60	315	0.14	1030

3.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in August 1989, sediment and biota tissues were sampled for heavy metal concentrations. Sampling sites S-1 and S-2 were chosen to represent natural conditions; therefore, results from these sites from June of 1984 until August 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 (Table 3-4), 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 cannery operation and mine exploration work and are not suitable for background calculations.

TABLE 3-4 Hawk Inlet Sediment Data: Pre-Production Baseline, Production Period and Current Year Comparison

Metal	Pre-Production (6/1984-8/1989)			Production (9/1989-9/2010)			Current Year 2011		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Cd	0.245	0.03	0.87	0.203	0.060	0.89	0.119	0.106	0.140
Cu	18.75	11.9	33	14.6	7.5	39.5	11.3	8.0	14.8
Pb	6.72	2.2	13	5.76	<0.02	23.7	3.89	1.62	6.59
Hg	0.035	0.002	0.094	0.019	0.02	0.14	0.035	0.030	0.040
Zn	96.0	52.8	155	73.1	26.1	185	87.7	36.9	109.0

NOTE: Data are compilation of results from Stations S-1 and S-2; underlined average values higher than baseline

The comparison of pre-production and production sediment metal values in Table 3-4 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 below the production period's average values for all metals except mercury and zinc. In 2010, the same was shown for mercury but the zinc concentration was below the production period's average value (HGCMC, 2011). Also, all of the 2006 average metals concentrations were greater than the average production values (KGCMC, 2007). Based on these data, it appears that heavy metals in sediment continue to vary from year to year, and have not increased above the range of area-wide baseline levels during mining years.

Figures 3-1 through 3-5 show the time series plots for cadmium, copper, lead, mercury and zinc for sampling sites S-1 and S-2. Linear regression analyses on the data plots indicate that all five metal's concentration have not increased with time.

Sampling sites S-4 and S-5S and S-5N are located near the ore concentrate loading facility. In 1989, the first attempt to load a barge with ore concentrate resulted in a spill of concentrate into Hawk Inlet. A suction dredge company was brought on-site in 1995 to dredge the available concentrate off of the ocean floor. This effort was confounded somewhat by the residual debris from the 1974 cannery facility fire. Although clean-up efforts were extensive, liter-sized pockets of concentrate are still observed throughout the area. Prop wash from ore ships and associated tug boats continues to both re-suspend these pockets and also mix them with natural sediments.

After the 1995 clean-up, the sampling methodology at S-5 was expanded. The site was sub-divided into two separate locations: adding site S-5S located on the south side of the spill area, to complement S-5N located on the north side. Following the spill, metal concentrations in the sediment in this area have been elevated and variable. Figures 3-6 through 3-10 show the metal time series graphs for these three sites.

Table 3-5 shows the average metal concentrations and the associated standard deviations for each sediment sampling site during pre-production and production. Production data do not including the current year's results. 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.

TABLE 3-5 Average and Standard Deviation Values for Pre-Production and Production Sediment Data

Metal (mg/kg dw)	S-1 pre-production (9/1984-8/1989)		S-1 production (9/1989 - 9/2010)		S-2 pre-production (9/1984-8/1989)		S-2 production (9/1989 - 9/2010)	
	avg	stdev	avg	stdev	avg	stdev	avg	stdev
Cd	0.253	0.222	0.235	0.183	0.236	0.119	0.171	0.082
Cu	22.50	5.19	17.3	7.3	15.0	2.68	2.79	1.77
Pb	8.175	2.628	<u>8.74</u>	4.51	5.26	2.16	2.79	1.77
Hg	0.0441	0.0209	0.0286	0.0333	0.0253	0.0150	0.009	0.0203
Zn	129.18	11.55	100.3	30.8	62.9	6.7	45.9	13.7

Metal (mg/kg dw)	S-4 pre-production (9/1984-8/1989)		S-4 production (9/1989 - 9/2010)		S-5N post spill (9/1989 - 9/2010)		S-5S post spill (6/1995 - 9/2010)	
	avg	stdev	avg	stdev	avg	stdev	avg	stdev
Cd	0.761	1.097	<u>0.903</u>	0.897	12.7	40.5	3.76	3.78
Cu	49.0	19.3	<u>52.7</u>	56.1	250.9	388.0	84.2	42.3
Pb	108.2	136.8	<u>115.6</u>	136.9	1019	2376	255.4	196.4
Hg	0.115	0.083	<u>0.207</u>	0.598	2.00	5.63	0.377	0.305
Zn	179.2	125.5	<u>186.1</u>	186.2	2054	5525	778.2	764.3

NOTE: Underlined averages are higher than pre-production averages

3.3 QA/QC Results

Columbia Analytical Services analyzed the required parameters (see Table 1-1) in the sediment samples. Complete QA plans and reports are kept on file in the lab's office and are available upon request. The remainder of this section summarizes any relevant QA/QC results that were exceptions for the spring and fall sampling events in 2011.

Spring 2011:
The matrix spike recovery of Zinc for sample S-1 Sediment Metals I was outside control criteria. Recovery in the LCS was acceptable, which indicated the analytical batch was in control. The matrix spike outlier suggested a potential high bias in this matrix.

Fall 2011:
No anomalies associated with the analysis of these samples were observed.

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 (the standard deviation relative to the mean, expressed as a percent) is shown for the duplicate samples from 2011 in Table 3-6.

TABLE 3-6 RSDs for Duplicate Sediment Samples

SAMPLE ID	DATE	Cd	Cu	Pb	Hg	Zn
		(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)
	DL	0.05	0.1	0.05	0.02	0.5
S-1 Sediments-Metals I	5/15/11	0.14	14.8	5.69	0.03	109
S-1 Sediments-Metals II	5/15/11	0.12	16.3	5.79	0.03	105
S-1 Sediments-Metals III	5/15/11	0.11	13.4	5.82	0.03	100
RSD		***--***	***9.78***	***1.18***	***--***	***4.31***
S-2 Sediments-Metals I	5/16/11	0.11	8.6	1.62	<0.02	45.4
S-2 Sediments-Metals II	5/16/11	0.10	7.5	1.33	<0.02	37.5
S-2 Sediments-Metals III	5/16/11	0.10	8.1	1.56	<0.02	39.8
RSD		***--***	***6.83***	***10.18***	***--***	***9.93***
S-4 Sediments-Metals I	5/17/11	0.29	104	16.3	0.03	61.6
S-4 Sediments-Metals II	5/17/11	0.24	14.8	16.1	0.03	59
S-4 Sediments-Metals III	5/17/11	0.28	110	17.9	0.03	64.2
RSD		***9.80***	***69.61***	***5.88***	***--***	***4.22***
S-5N Sediments-Metals I	5/15/11	1.33	109	205	0.12	342
S-5N Sediments-Metals II	5/15/11	1.29	420	131	0.15	301
S-5N Sediments-Metals III	5/15/11	2.59	70.5	470	0.13	471
RSD		***42.57***	***95.90***	***40.46***	***11.46***	***23.89***
S-5S Sediments-Metals I	5/15/11	5.52	257	377	0.48	1330
S-5S Sediments-Metals II	5/15/11	4.04	67.1	262	1.18	941
S-5S Sediments-Metals III	5/15/11	15.6	147	542	0.47	3390
RSD		***75.01***	***60.72***	***35.75***	***57.33***	***69.74***

-- indicates RSD was not calculated because one or more of the values was less than 4 times the DL

SAMPLE ID	DATE	Cd	Cu	Pb	Hg	Zn
		(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)
	DL	0.05	0.1	0.05	0.02	0.5
S-1 Sediments-Metals I	8/13/11	0.12	13.8	6.59	0.04	105
S-1 Sediments-Metals II	8/13/11	0.12	14.4	6.76	0.03	107
S-1 Sediments-Metals III	8/13/11	0.13	14.2	5.75	0.02	106
RSD		***--***	***2.16***	***8.49***	***--***	***0.94***
S-2 Sediments-Metals I	8/14/11	0.11	8.02	1.67	<0.02	36.9
S-2 Sediments-Metals II	8/14/11	0.11	9.22	1.59	<0.02	43.8
S-2 Sediments-Metals III	8/14/11	0.11	9.45	1.6	<0.02	41.9
RSD		***--***	***8.63***	***2.69***	***--***	***8.72***
S-4 Sediments-Metals I	8/14/11	0.20	12.1	12.7	0.02	47
S-4 Sediments-Metals II	8/14/11	0.23	13.8	14.1	<0.02	58.9
S-4 Sediments-Metals III	8/14/11	0.17	15.8	13.8	<0.02	52.7
RSD		***16.39***	***13.32***	***5.45***	***--***	***11.26***

S-5N Sediments-Metals I	8/8/11	3.60	97.7	289	0.17	946
S-5N Sediments-Metals II	8/8/11	1.95	71.4	177	0.22	500
S-5N Sediments-Metals III	8/8/11	2.26	109	184	0.11	532
RSD		***33.69***	***20.81***	***28.96***	***33.05***	***37.73***
S-5S Sediments-Metals I	8/8/11	3.18	86.1	176	0.20	776
S-5S Sediments-Metals II	8/8/11	3.06	210	314	0.23	729
S-5S Sediments-Metals III	8/8/11	2.34	60	315	0.14	1030
RSD		***15.89***	***67.51***	***29.80***	***24.12***	***19.16***

-- indicates RSD was not calculated because one or more of the values was less than 4 times the DL

The data quality objectives for the RSD are less than or equal to 30 percent, when the values are at least four times the detection limit. Thirteen out of the 40 (approximately 33 percent) RSDs calculated for the 2011 duplicate samples were not within this data quality objective. All of the thirteen samples that were out of the required limits were from sample sites S-5S, S-5N, and S-4, which are the sites that surround the area near the shiploader where a concentrate spill occurred in 1989. Due to the isolated pockets of concentrate remaining from the clean-up effort in 1995, sampling at these sites continues to show the greatest variability with associated higher RSDs typical of mixed population samples.

4.0 IN-SITU BIOASSAYS

The requirements for the bioassay monitoring originate from Section I.D.3, In-situ Bioassays, and Table 5 of the NPDES permit. The objective of this element of the monitoring program is to provide scientifically valid data on five specific trace metal parameters from the tissues of polychaete worms (*Nephtys*) and mussels 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 semi-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 (*Mytilus edulis*). Data gathered from this area measures the response in organisms in the immediate vicinity of the process effluent discharge. In most other areas of Hawk Inlet, the bottom is covered with sediment. Consequently, samples of sediment dwelling polychaete worms (*Nephtys procera*), and when available sediment dwelling bivalves (*Cockles* and *Littleneck Clams*) are collected at three additional sites (S-1, S-2, and S-4).

An additional location, Site S-3, has also been sampled for biota since the 1980s. Site S-3 is located at the head of Hawk Inlet. Field observations of a mass wasting event in the watershed above S-3 appears to have released metals from abandoned historic mine workings (Alaska Rand Group) into the environment (Ridgeway, 2003). For this reason, when the reissued permit became effective July 1, 2005, S-3 was dropped from the list of active bioassay sampling sites. Therefore, data from S-3 are not presented in this report.

4.1 2011 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. Tables 4-2 and 4-3 in this section summarize the total metals results for the semi-annual bioassays. Sample labels I, II, and III denote duplicate samples taken at each site. Duplicate samples are not taken for all species due to the negative impact such removal would have on the relatively sparse populations present on the Hawk Inlet bioassay monitoring sample sites.

TABLE 4-1 Hawk Inlet Tissue Sampling Field Data 2011

Locations	Sample Type	Date Sampled	Time Sampled	Weather Conditions	Tide Ht.
S-1	Nephtys	5/15/11	6:30	clear	-2.0
	Cockle	5/15/11	7:00	clear	-2.0
	Nephtys	8/11/11	6:15	rain	-0.6
	Cockle	8/11/11	6:30	rain	-0.7
S-2	Nephtys	5/15/11	6:30	clear	-3.1
	Cockle	5/16/11	8:00	clear	-3.0
	Littleneck	5/16/11	9:00	clear	-2.8
	Nephtys	8/11/11	7:15	rain	-0.4
	Cockle	8/11/11	7:30	rain	-0.3
	Littleneck	8/11/11	7:45	rain	-0.1
S-4	Nephtys	5/17/11	9:30	clear	-3.5
	Cockle	5/17/11	9:45	clear	-3.4
	Nephtys	8/12/11	7:15	rain	-1.2
	Cockle	8/14/11	7:45	rain	-1.0
STN-1	Mussels	5/23/11	14:30	rain	1.7
	Mussels	8/13/11	8:30	lt rain	-0.8
STN-2	Mussels	5/23/11	15:00	rain	1.8
	Mussels	8/13/11	9:00	lt rain	-0.5
STN-3	Mussels	5/23/11	14:00	rain	1.5
	Mussels	8/13/11	8:45	lt rain	-0.7
ESL	Mussels	5/23/11	15:30	rain	2.0
	Mussels	8/13/11	8:00	lt rain	-1.0

TABLE 4-2 Hawk Inlet Tissue Results for Spring 2011
(Columbia Analytical Services Laboratory)

Sample No.	Sample date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
BIOASSAYS						
Lab MRL		(0.02)	(0.1)	(0.02)	(0.02)	(0.5)
S-1 Nephyts I	5/15/11	3.32	7.6	0.51	0.04	250
S-1 Nephyts II	5/15/11	3.32	8.1	0.77	0.05	199
S-1 Nephyts III	5/15/11	3.51	7.9	0.41	0.06	189
S-1 Cockles	5/15/11	0.97	5.3	0.83	0.05	91.2
S-2 Nephyts I	5/16/11	1.11	6.1	0.54	0.02	190
S-2 Nephyts II	5/16/11	0.80	5.6	0.47	<0.02	162
S-2 Nephyts III	5/16/11	0.84	5.6	0.50	<0.02	168
S-2 Cockles	5/16/11	1.01	4.0	0.54	0.03	87.3
S-2 Littlenecks	5/16/11	2.02	7.1	0.31	0.02	83.7
S-4 Nephyts I	5/17/11	0.54	10.2	3.83	0.02	180
S-4 Nephyts II	5/17/11	0.59	6.3	4.27	<0.02	192
S-4 Nephyts III	5/17/11	0.51	6.3	3.80	0.02	196
S-4 Cockles	5/17/11	0.50	4.9	2.97	0.03	86.5
STN-1 Mussels	5/23/11	8.24	7.1	0.86	0.05	98.1
STN-2 Mussels	5/23/11	7.07	9.1	0.63	0.05	100
STN-3 Mussels	5/23/11	7.17	6.3	0.63	0.04	90.1
ESL Mussels	5/23/11	5.72	7.6	0.75	0.03	90.2

TABLE 4-3 Hawk Inlet Tissue Results for Fall 2011
(Columbia Analytical Services Laboratory)

Sample No.	Sample date	Cd (mg/kg dw)	Cu (mg/kg dw)	Pb (mg/kg dw)	Hg (mg/kg dw)	Zn (mg/kg dw)
BIOASSAYS						
Lab MRL		(0.02)	(0.1)	(0.05)	(0.02)	(0.5)
S-1 Nephyts I	8/13/11	2.75	6.7	0.31	0.08	200
S-1 Nephyts II	8/13/11	2.85	5.9	0.29	0.04	202
S-1 Nephyts III	8/13/11	2.78	4.9	0.29	0.04	201
S-1 Cockles	8/13/11	0.62	2.9	0.68	0.03	55.9
S-2 Nephyts I	8/14/11	1.14	6.7	0.49	0.02	203
S-2 Nephyts II	8/14/11	1.07	7.3	0.46	0.03	178
S-2 Nephyts III	8/14/11	1.03	6.7	0.42	0.02	154
S-2 Cockles	8/14/11	0.61	13.3	0.28	0.02	53.8
S-2 Littlenecks	8/14/11	2.57	6.0	0.18	<0.02	72.3
S-4 Nephyts I	8/14/11	0.53	10.3	4.11	0.03	174
S-4 Nephyts II	8/14/11	0.48	5.8	3.7	0.02	162
S-4 Nephyts III	8/14/11	0.59	12.9	3.57	0.03	168
S-4 Cockles	8/14/11	1.05	3.9	4.87	0.04	70.7
STN-1 Mussels	8/15/11	8.99	6.1	0.76	0.03	103
STN-2 Mussels	8/15/11	8.29	5.5	0.48	0.03	75.4
STN-3 Mussels	8/15/11	9.52	7.9	0.62	0.02	97.2
ESL Mussels	8/15/11	8.64	7.2	1.17	0.03	87.7

4.2 Data Evaluation

Prior to opening the Greens Creek mine for full production in August 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 and S-2 from June of 1984 until August 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 (Table 4-4 and 4-5).

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."

TABLE 4-4 Hawk Inlet Mussels Tissue Data: Pre-Production Baseline, Production Period and Current Year Comparison

Metal	**Pre-Production (6/1984-8/1989)**			**Production (9/1989-9/2010)**			**Current Year 2011**		
	Avg	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Cd	7.67	3.25	15.76	<u>7.90</u>	<0.5	14.5	<u>7.96</u>	5.72	9.52
Cu	8.50	5.5	21.1	<u>8.54</u>	1.3	110	7.10	5.5	9.10
Pb	0.572	0.15	1.73	<u>2.74</u>	<0.02	92.5	<u>0.74</u>	0.48	1.17
Hg	0.064	0.018	0.56	0.037	<0.02	0.070	0.035	0.02	0.050
Zn	88.39	65.0	142	84.43	49	126	<u>92.71</u>	75.4	103

Data are compilation of results from Stations ESL, STN-1, STN-2 and STN-3

Average lead concentrations in mussel tissues are currently approximately five times higher during the production period than the pre-production period. Average lead values in 2011 were higher than the pre-production, but lower than the production average values. Average zinc values in 2011 were higher than pre-production and production values.

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."

TABLE 4-5 Hawk Inlet *Nephtys* Tissue Data: Pre-Production Baseline, Production Period and Current Year Comparison

Metal	Pre-Production (6/1984-8/1989)			Production (9/1989-9/2010)			Current Year 2011		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Cd	2.65	0.24	6.91	2.03	0.28	4.97	2.08	1.11	3.32
Cu	10.24	6.24	17.4	10.18	4.3	42.1	6.78	6.10	7.60
Pb	0.478	0.13	1.07	<u>0.995</u>	<0.02	4.76	0.463	0.310	0.540
Hg	0.033	0.009	0.074	<u>0.046</u>	<0.02	1.67	<u>0.040</u>	0.020	0.080
Zn	206	121	303	187.3	62.6	357	<u>210.8</u>	190	250

Data are compilation of results from Stations S-1 and S-2

Average lead and mercury concentrations in the indicator polychaete worm, *Nephtys*, increased during production, and mercury and zinc were higher in 2011 than the pre-production averages. Cadmium and copper concentrations were lower in average production and current year values compared to pre-production averages. All metals concentrations will continue to be monitored.

Tables 4-6 and 4-7 show the average and standard deviation results for pre-production and production periods for the individual sites for mussels and *Nephtys*, respectively. Table 4-6 shows larger standard deviations in production levels of lead and copper concentrations in mussels at all sites. Also, copper shows a large increase in standard deviation for the ESL site during production sampling. This is thought to be due to a single extreme and potentially anomalous value of 110 mg/kg dw from 1992. Table 4-7 shows larger standard deviations in production levels of lead concentrations in Nephtys at S-1, S-2 and S-4.

TABLE 4-6 Average and Standard Deviation Values for Pre-Production and Production Mussel Data

Metal (mg/kg dw)	ESL				STN-1				STN-2			
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2010)		pre-production (9/1984-8/1989)		production (9/1989 - 9/2010)		pre-production (9/1984-8/1989)		production (9/1989 - 9/2010)	
	avg	stdev	avg	stdev	avg	stdev	avg	stdev	avg	stdev	avg	stdev
Cd	6.171	1.782	6.604	1.672	7.483	1.718	7.813	1.869	8.012	3.006	8.857	2.562
Cu	9.61	3.77	11.07	16.65	8.05	1.19	7.45	1.79	7.82	1.02	8.09	4.01
Pb	0.526	0.260	1.391	0.782	0.661	0.437	1.390	0.872	0.453	0.269	4.616	19.022
Hg	0.0344	0.012	0.0407	0.0771	0.1014	0.1421	0.0359	0.0175	0.0378	0.0122	0.0339	0.0203
Zn	90.22	8.07	82.61	14.99	88.53	15.44	83.69	14.30	83.02	14.53	85.42	18.35

Metal (mg/kg dw)	STN-3			
	pre-production (9/1984-8/1989)		production (9/1989 - 9/2010)	
	avg	stdev	avg	stdev
Cd	9.003	2.811	8.311	1.990
Cu	8.54	1.58	7.53	2.21
Pb	0.65	0.24	3.57	14.08
Hg	0.084	0.150	0.036	0.020
Zn	91.80	17.92	86.00	16.56

Underlined concentrations are higher than pre-production averages

TABLE 4-7 Average and Standard Deviation Values for Pre-Production and Production *Nephtys* Data

Metal (mg/kg dw)	S-1 *Nephtys* pre-production (9/1984-8/1989)		S-1 *Nephtys* production (9/1989 - 9/2010)		S-2 *Nephtys* pre-production (9/1984-8/1989)		S-2 *Nephtys* production (9/1989 - 9/2010)	
	avg	stdev	avg	stdev	avg	stdev	avg	stdev
Cd	3.910	1.716	2.895	0.907	1.396	0.846	1.155	0.512
Cu	9.27	1.41	<u>11.18</u>	6.75	11.21	3.56	9.17	4.09
Pb	0.452	0.157	<u>1.196</u>	1.023	0.503	0.258	<u>0.794</u>	0.442
Hg	0.0465	0.0103	0.0402	0.0231	0.0191	0.0077	<u>0.0511</u>	0.2535
Zn	243.33	42.96	207.70	40.87	168.56	34.45	166.83	40.30

Metal (mg/kg dw)	S-4 *Nephtys* pre-production (9/1984-8/1989)		S-4 *Nephtys* production (9/1989 - 9/2010)	
	avg	stdev	avg	stdev
Cd	0.926	0.723	<u>1.100</u>	0.716
Cu	21.02	9.25	<u>24.77</u>	20.31
Pb	3.65	1.08	<u>11.78</u>	13.51
Hg	0.060	0.062	0.025	0.022
Zn	210.20	17.91	203.41	58.90

Underlined concentrations are higher than pre-production averages

Additional tissue samples of *Cockles and Littlenecks* were collected in 2011. Table 4-8 summarizes the average metal values for the available data for these additional tissue samples. Only *Cockles* at site S-4 has pre-production period data available for comparison (Table 4-8).

TABLE 4-8 Summary of Results for Additional Tissue Samples

Metal-average (mg/kg dw)	S-2 *Cockles*	S-2 *Littlenecks*	S-4 *Cockles*	
	(1999-2011)	(1999-2011)	(5/84-7/89)	(9/89-2011)
Cd	0.78	2.24	0.714	0.70
Cu	4.66	9.38	9.27	6.84
Pb	0.558	0.433	9.92	7.155
Hg	0.018	0.016	0.036	0.034
Zn	68.9	79.8	100.1	76.8

Effluent toxicity testing, conducted since the mining operations began, was discontinued in 2005 with re-issuance of the NPDES Permit (AK-004320-6). Over the 21 years of initially acute toxicity testing (February 1989 – October 1998), and then chronic toxicity testing (November 1998 – June 2005) no sublethal deleterious effects to tested marine aquatic organisms from prolonged exposure to the treated KGCMC effluent was determined to be likely:

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

4.3 QA/QC Results

Columbia Analytical Services (CAS) analyzed the required parameters (see Table 1-1) in the bioassay samples. Complete QA plans and reports are kept on file in the lab's office and are available upon request. The remainder of this section summarizes the relevant QA/QC results for the spring and fall sampling events in 2011.

Spring 2011:
The control criteria for matrix spike recovery of Zinc for sample S-1 Nephtyls I was not applicable. The analyzed concentration in the sample was significantly higher than the added spike concentration, preventing accurate evaluation of the spike recovery.

Fall 2011:
No anomalies associated with the analysis of these samples were observed.

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 (the standard deviation relative to the mean, expressed as a percent) is shown for the duplicate samples in Table 4-9. The data quality objectives for the RSD are less than or equal to 30 percent, when the values are at least four times the detection limit. Two out of the 24 (approximately 8 percent) of the RSDs calculated for the 2011 duplicate samples was not within this data quality objective.

TABLE 4-9 Relative Standard Deviation (RSD) for Duplicate Tissue Samples

-- Indicates the RSD was not calculated because one or more of the results was not greater than four times the detection limit (DL)

SAMPLE ID	DATE	Cd	Cu	Pb	Hg	Zn
		(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)
		0.02	0.1	0.02	0.02	0.5
S-1 Nephyts I	5/15/11	3.32	7.6	0.51	0.04	250
S-1 Nephyts II	5/15/11	3.32	8.1	0.77	0.05	199
S-1 Nephyts III	5/15/11	3.51	7.9	0.41	0.06	189
RSD		***3.42***	***3.20***	***32.99***	**--**	***15.38***
S-2 Nephyts I	5/16/11	1.11	6.1	0.54	0.02	190
S-2 Nephyts II	5/16/11	0.80	5.6	0.47	<0.02	162
S-2 Nephyts III	5/16/11	0.84	5.6	0.50	<0.02	168
RSD		***18.4***	***5.01***	***6.98***	**--**	***8.51***
S-4 Nephyts I	5/17/11	0.54	10.2	3.83	0.02	180
S-4 Nephyts II	5/17/11	0.59	6.3	4.27	<0.02	192
S-4 Nephyts III	5/17/11	0.51	6.3	3.8	0.02	196
RSD		***7.39***	***29.63***	***6.63***	**--**	***4.40***
S-1 Nephyts I	8/13/11	2.75	6.7	0.31	0.08	200
S-1 Nephyts II	8/13/11	2.85	5.9	0.29	0.04	202
S-1 Nephyts III	8/13/11	2.78	4.9	0.29	0.04	201
RSD		***1.84***	***15.46***	***3.89***	**--**	***0.50***
S-2 Nephyts I	8/14/11	1.14	6.7	0.49	0.02	203
S-2 Nephyts II	8/14/11	1.07	7.3	0.46	0.03	178
S-2 Nephyts III	8/14/11	1.03	6.7	0.42	0.02	154
RSD		***5.16***	***5.02***	***7.69***	**--**	***13.74***
S-4 Nephyts I	8/14/11	0.53	10.3	4.11	0.03	174
S-4 Nephyts II	8/14/11	0.48	5.8	3.7	0.02	162
S-4 Nephyts III	8/14/11	0.59	12.9	3.57	0.03	168
RSD		***10.33***	***37.16***	***7.43***	**--**	***3.57***

5.0 CONCLUSIONS

The current status of the health of marine and aquatic ecosystems can be viewed based on the number of types of species present in an area (species diversity, or "biodiversity"), the number of individuals from each species in an area (species abundance), and quality of the environment (habitat integrity relative to pristine conditions).

For the marine environment, there are no data available to numerically compare diversity or abundance of organisms between pre-mining and post-mining years. Observations by fishermen and researchers suggest that the physical features and biotic communities of Hawk Inlet remain intact following over a decade of operation of the mine and they remain similar to adjacent inlets (Ridgeway, 2003). Halibut and crab numbers are reported to have declined significantly with the closing of the fish processing facilities which previously operated at the now Hawk Inlet Cannery which currently provides the HGCMC port facilities.

Marine species which consume sedentary seafloor organisms such as worms and bivalves would be most susceptible to trophic transfer of some metals. 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. Pacific halibut also have similar consumption patterns to these species. All of these species consume worms, bivalves, and crab.

Other migratory and resident fish, mammals, and birds which consume seafloor-dwelling organisms near the ore loading dock would also likely encounter elevated metal levels in their diet in restricted sites within Hawk Inlet. There are no data available to evaluate whether metals are increasing through trophic transfer, or biomagnification at higher trophic levels in Hawk Inlet marine species such as fish, crab and mammals. However, given the mobility of the afore-mentioned species, and the restricted HGCMC-associated locations of higher metal loading, it is unlikely that any of these species would show a significant effect attributable to mining activities in the vicinity of Hawk Inlet.

6.0 REFERENCES

Greens Creek Tailings Disposal: Final Environmental Impact Statement; USDA Forest Service, November 2003.

Kennecott Greens Creek Mining Company, Hawk Inlet Monitoring Program 2005 Annual Report, January 2006.

Kennecott Greens Creek Mining Company, Hawk Inlet Monitoring Program 2006 Annual Report, April 2007.

Kennecott Greens Creek Mining Company, Hawk Inlet Monitoring Program 2007 Annual Report, January 2008.

Hecla Greens Creek Mining Company, Hawk Inlet Monitoring Program 2008 Annual Report, January 2009.

Hecla Greens Creek Mining Company, Hawk Inlet Monitoring Program 2009 Annual Report, January 2010.

Hecla Greens Creek Mining Company, Hawk Inlet Monitoring Program 2010 Annual Report, January 2011.

Kennecott Greens Creek Mine Risk Assessment NPDES Permit No. AK-004320-6, Admiralty Island, Alaska, Oregon Institute of Oceanography, and Remediation Technologies, Inc. June 22, 1998

National Pollutant Discharge Elimination System (NPDES) permit AK-004320-6, USEPA, effective date July 1, 2005.

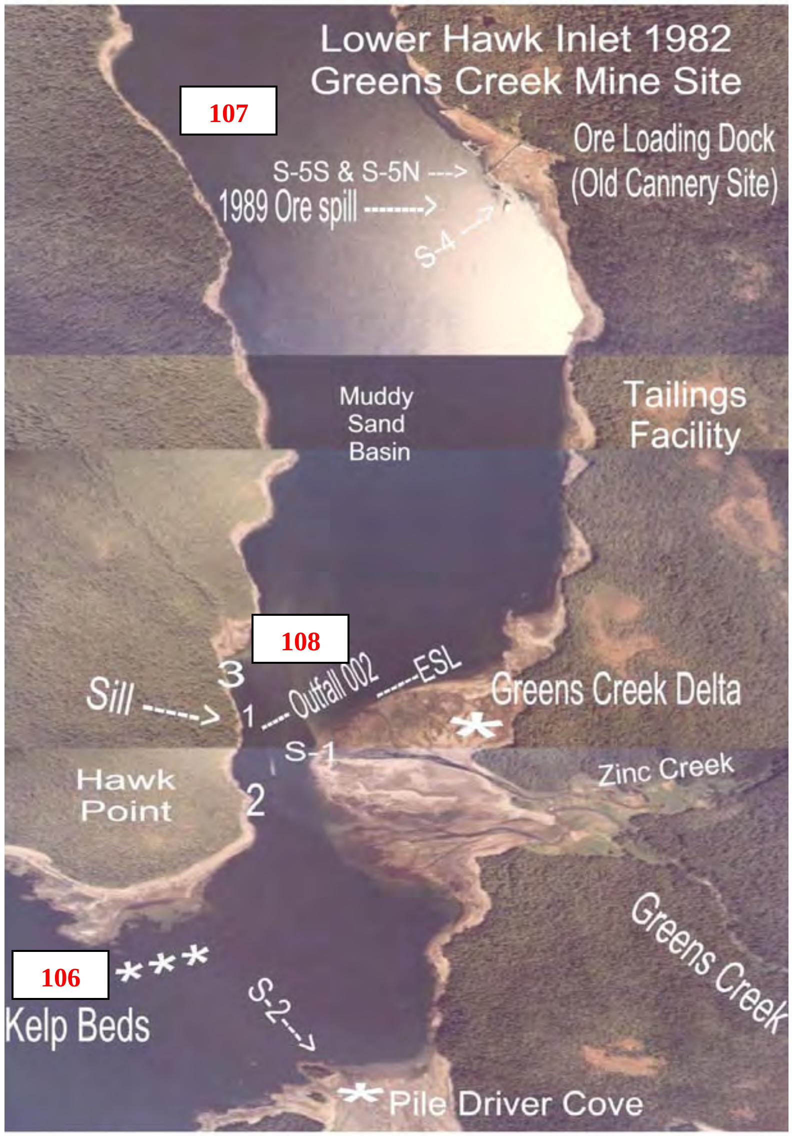
NPDES Quality Assurance Project (QAP), KGCMC, December 2009.

Oregon Institute of Oceanography (OIO) 1984 – 2002. Laboratory Results of Semi-Annual NPDES sediment and mussel tissue sampling in Hawk Inlet, Alaska. Columbia Analytical Lab Data for years 1984-2002.

Technical Review of the Status of Essential Fish Habitat in Hawk Inlet Subsequent to Mining Operations, M. Ridgeway, Oceanus Alaska, October 2003.

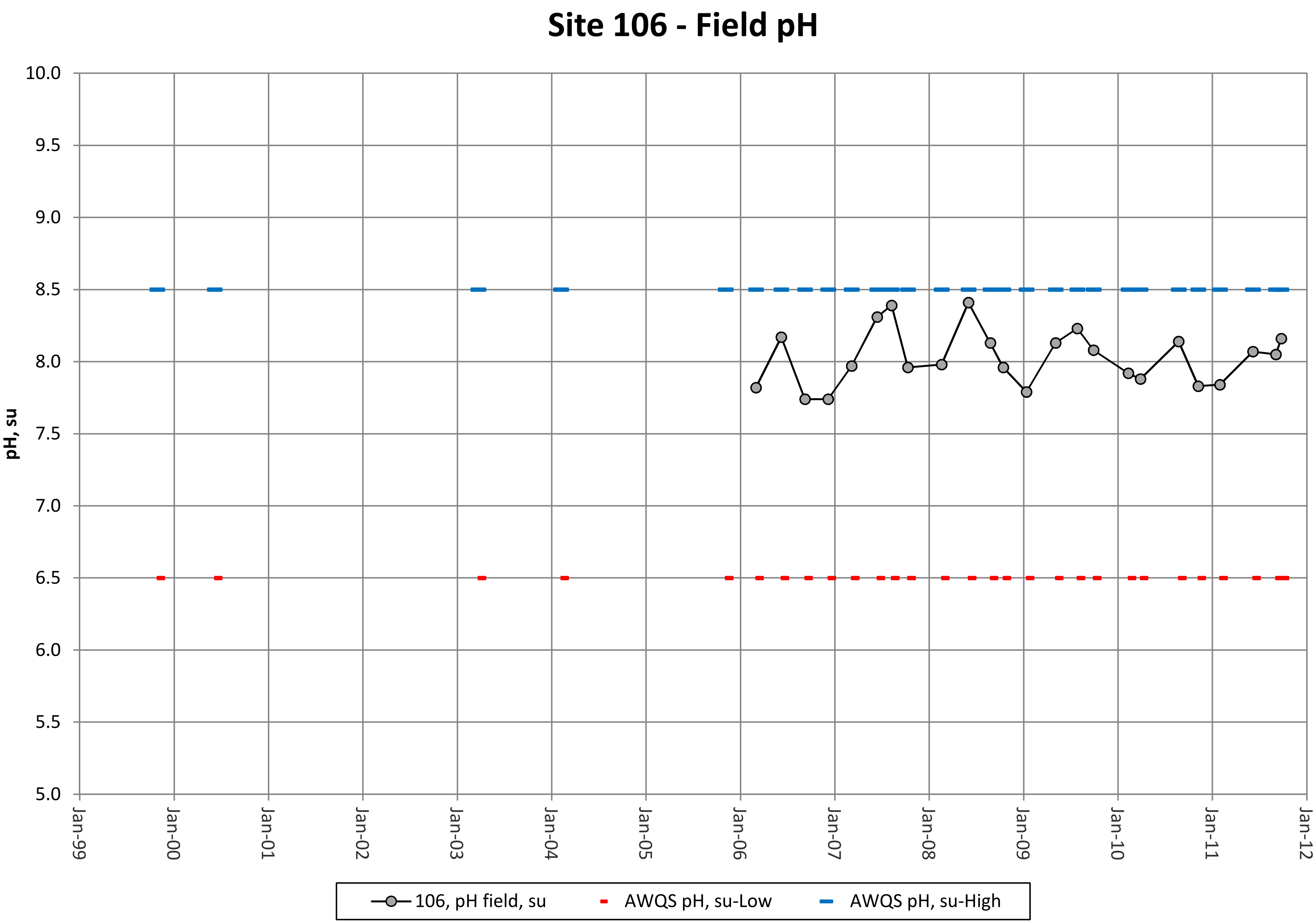
FIGURES

FIGURE 1-1 Aerial Photo of Lower Hawk Inlet, Admiralty Island with Water, Sediment and Tissue Sampling Site Locations



NOTES: Sites 106, 107 and 108 are sea water sampling sites.
S-1, S-2, S-4 and S-5 are sediment and *Nephtys* and *Nereis* sampling sites.
(Station S-3 – not shown – is at the head of Hawk Inlet.)
Stations 1, 2, 3 and ESL are mussel sampling sites.

Figure 2-1a



Site 106 - Field pH
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
pH, su
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
106, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-1b

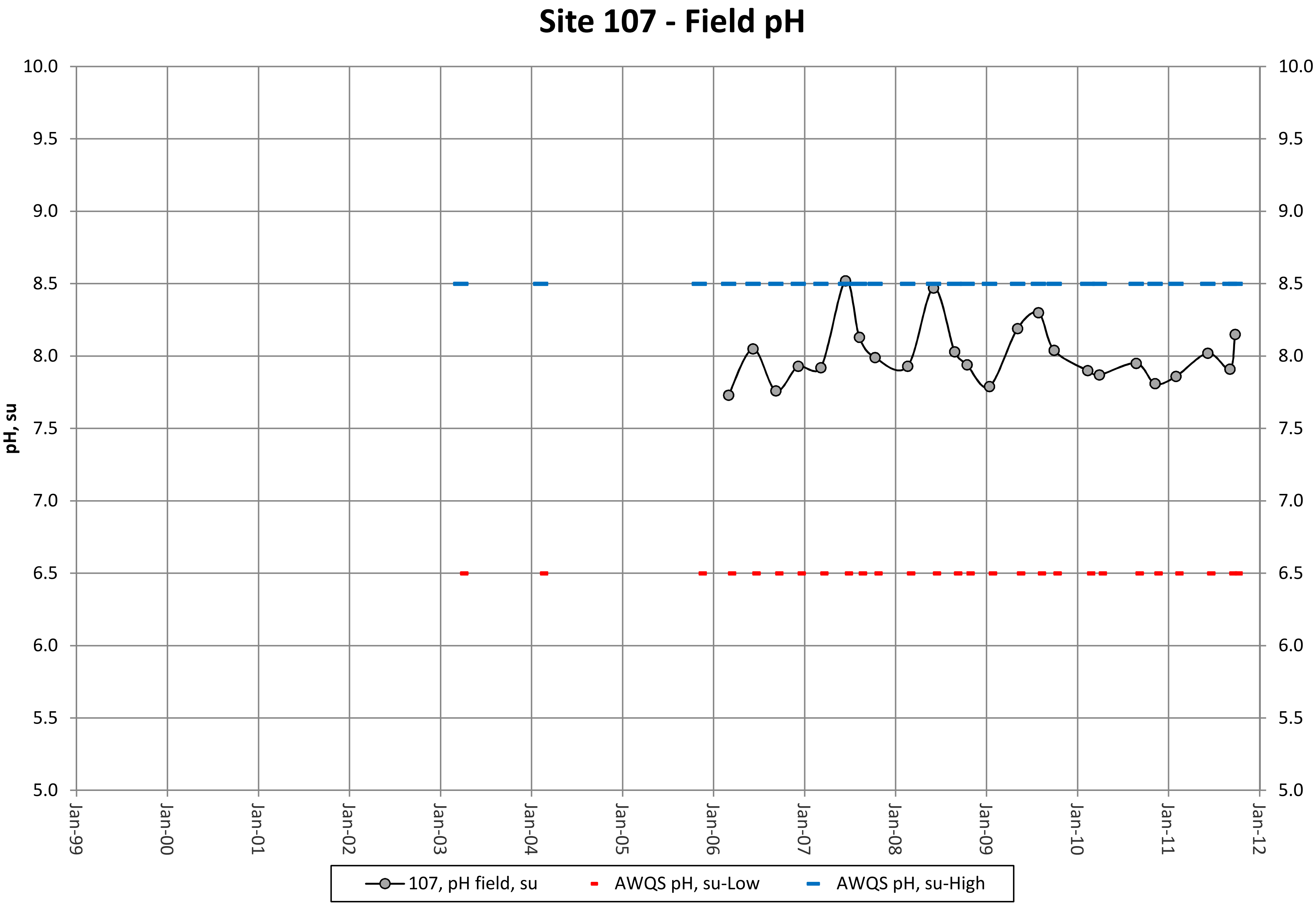

Site 107 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
107, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-1c

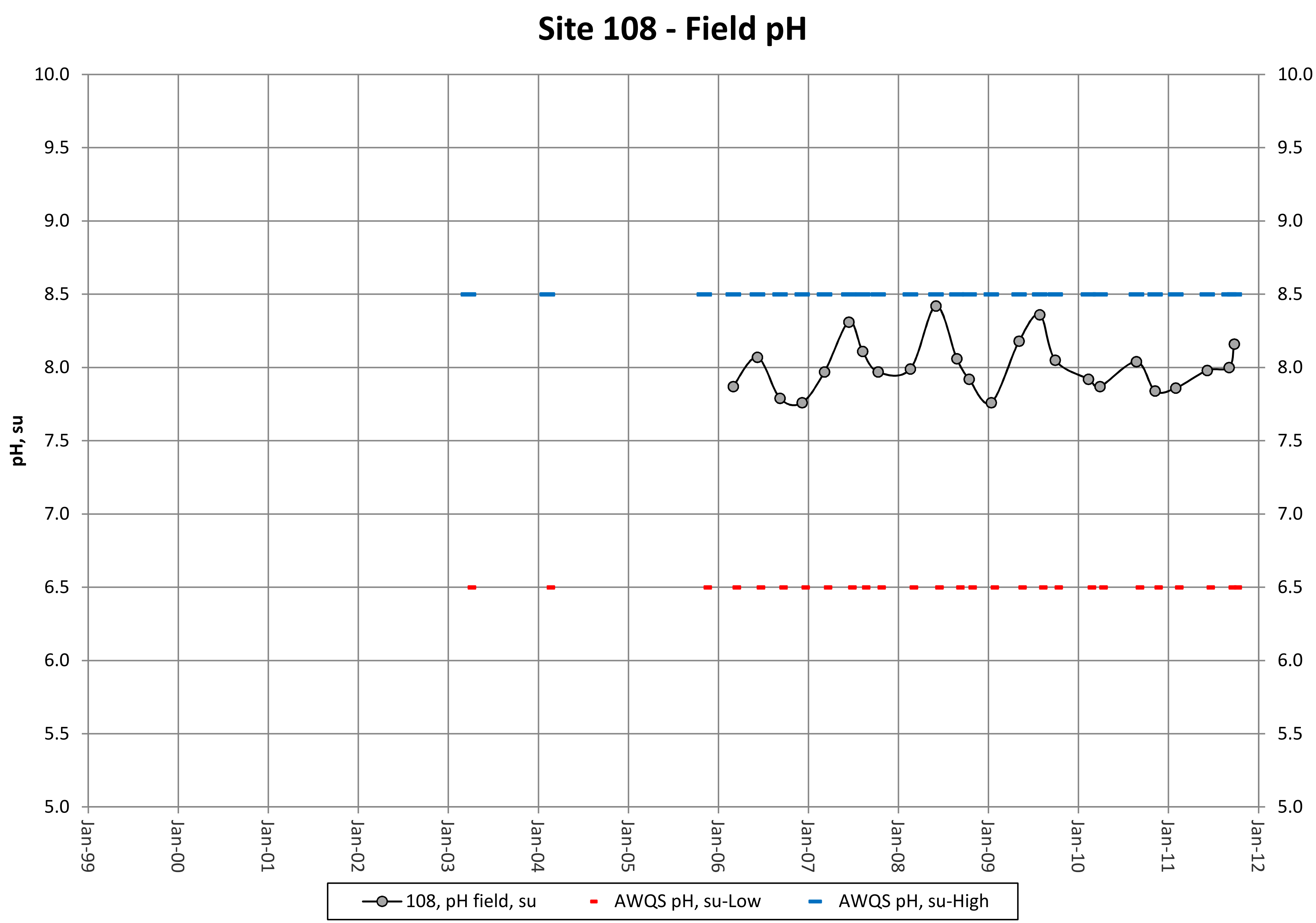

Site 108 - Field pH
pH, su
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
108, pH field, su
AWQS pH, su-Low
AWQS pH, su-High

Figure 2-2a

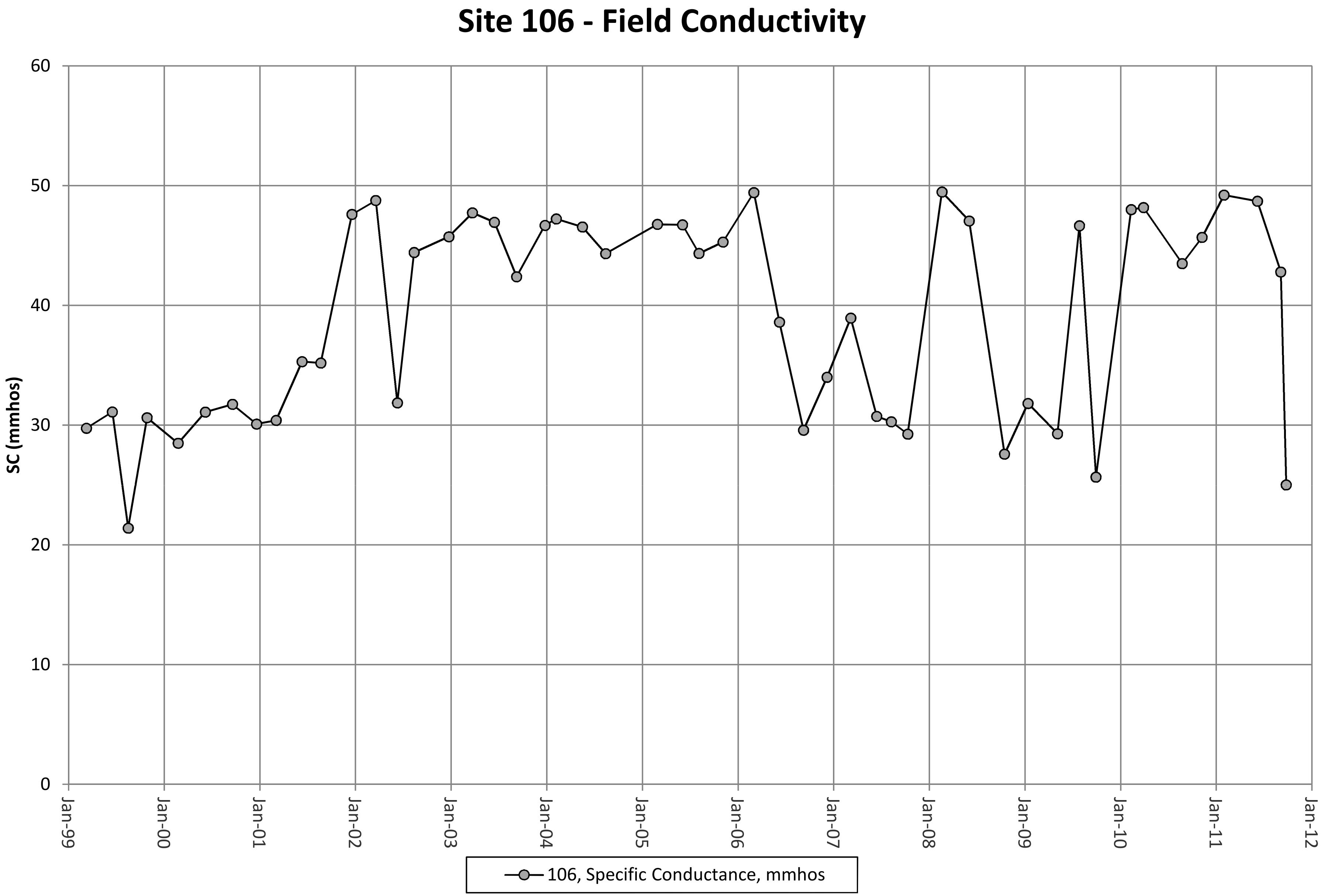
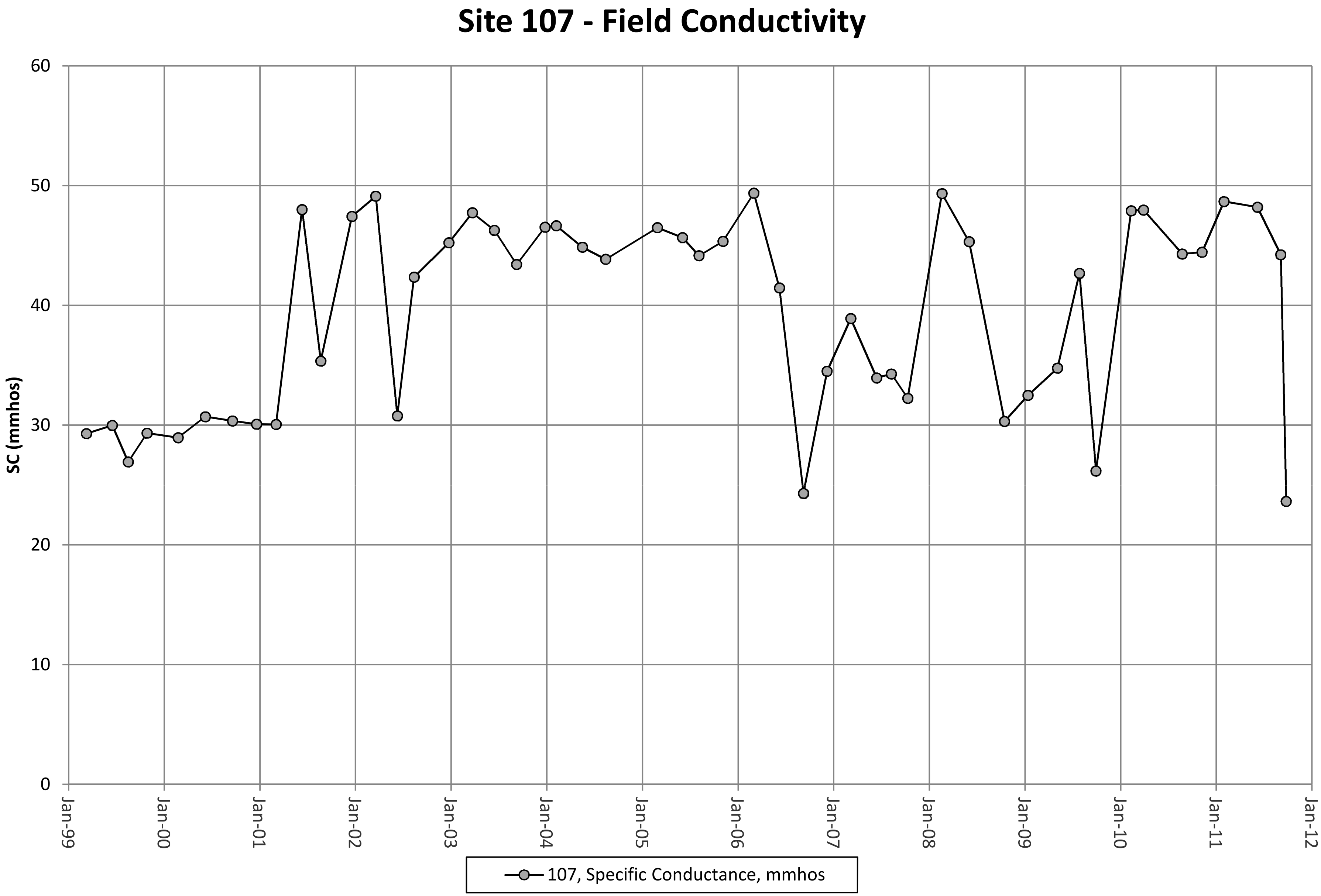
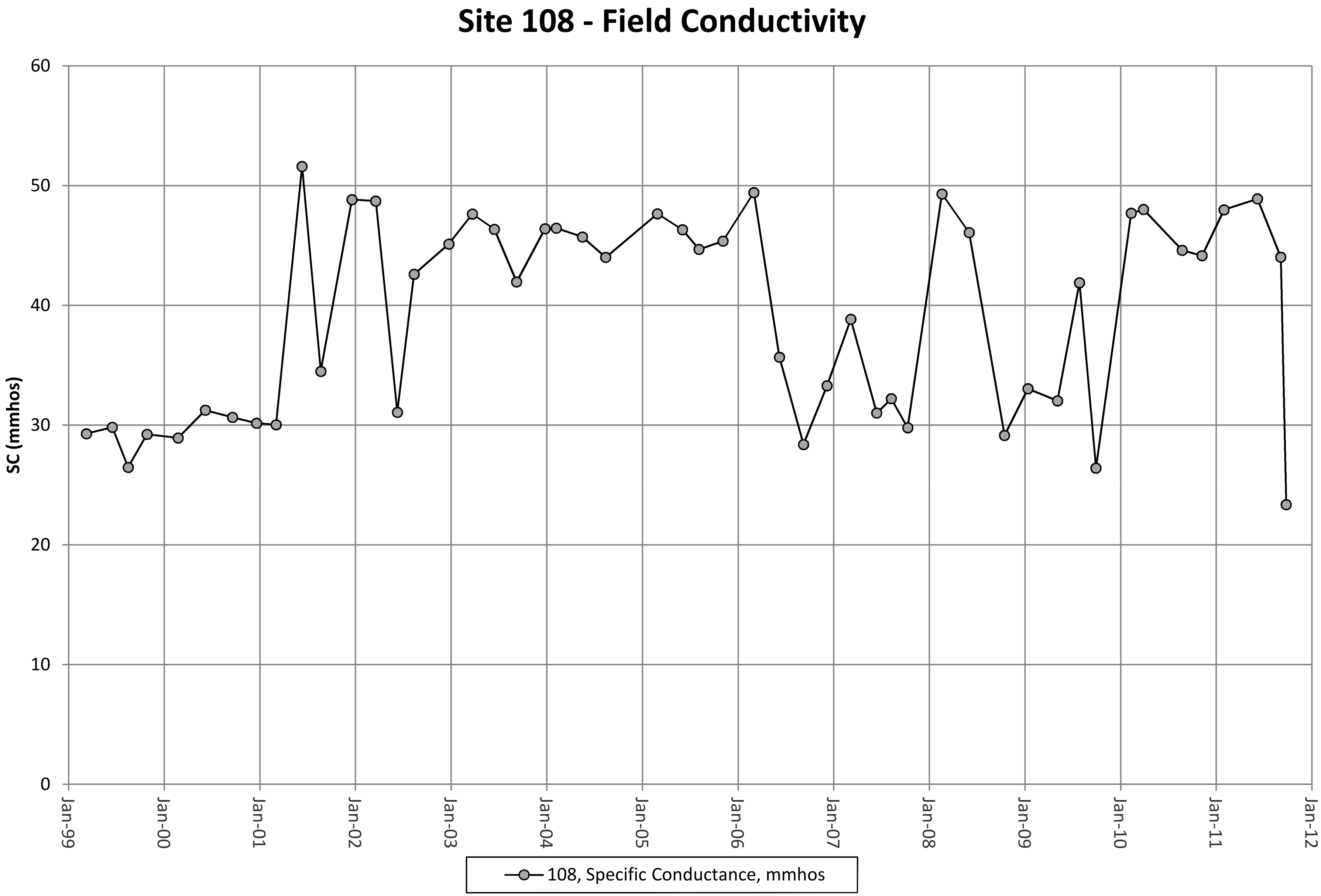

Site 106 - Field Conductivity
SC (mmhos)
0
10
20
30
40
50
60
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
106, Specific Conductance, mmhos

Figure 2-2b



Site 107 - Field Conductivity
SC (mmhos)
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
107, Specific Conductance, mmhos

Figure 2-2c



Site 108 - Field Conductivity
SC (mmhos)
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
108, Specific Conductance, mmhos

Figure 2-3a

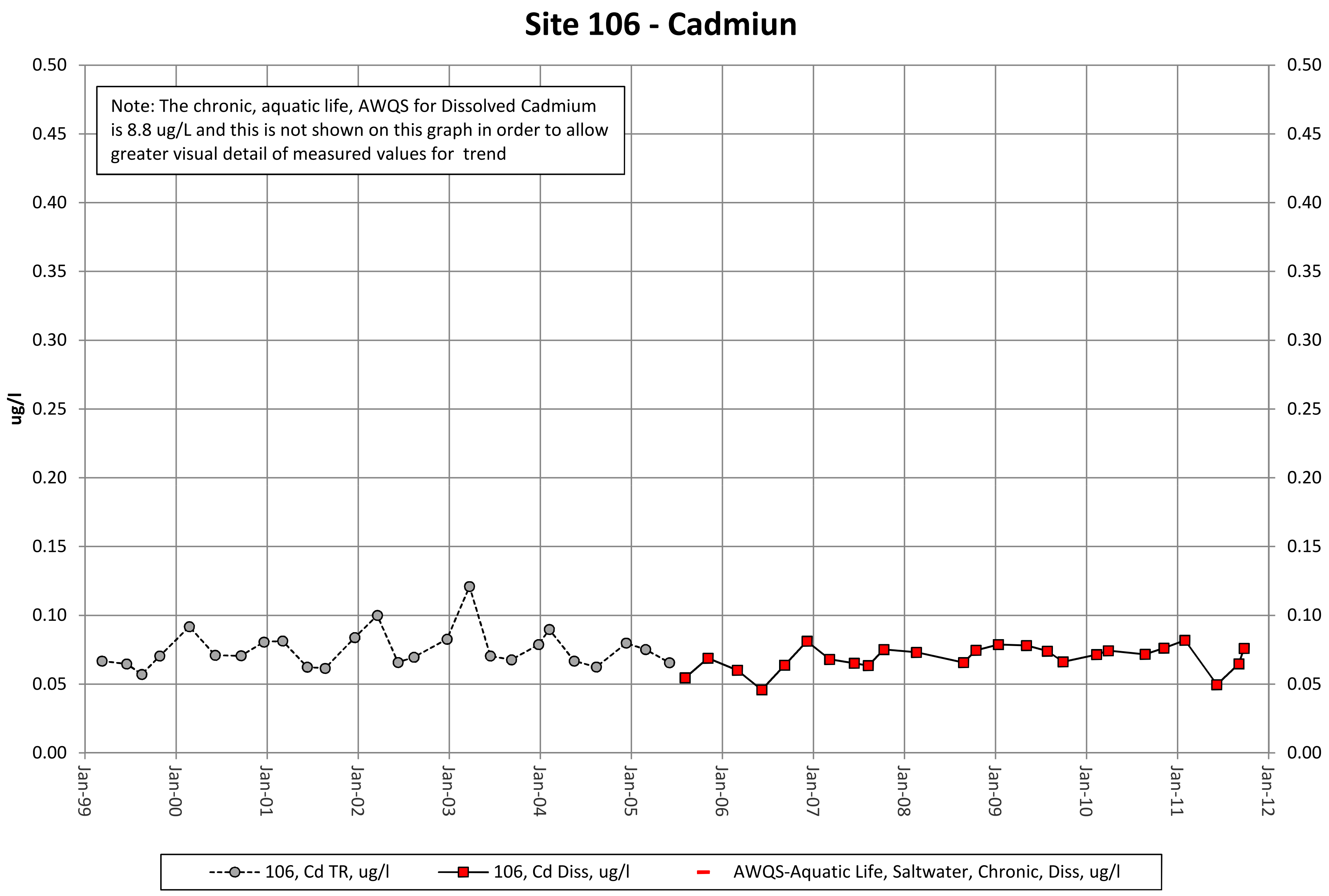
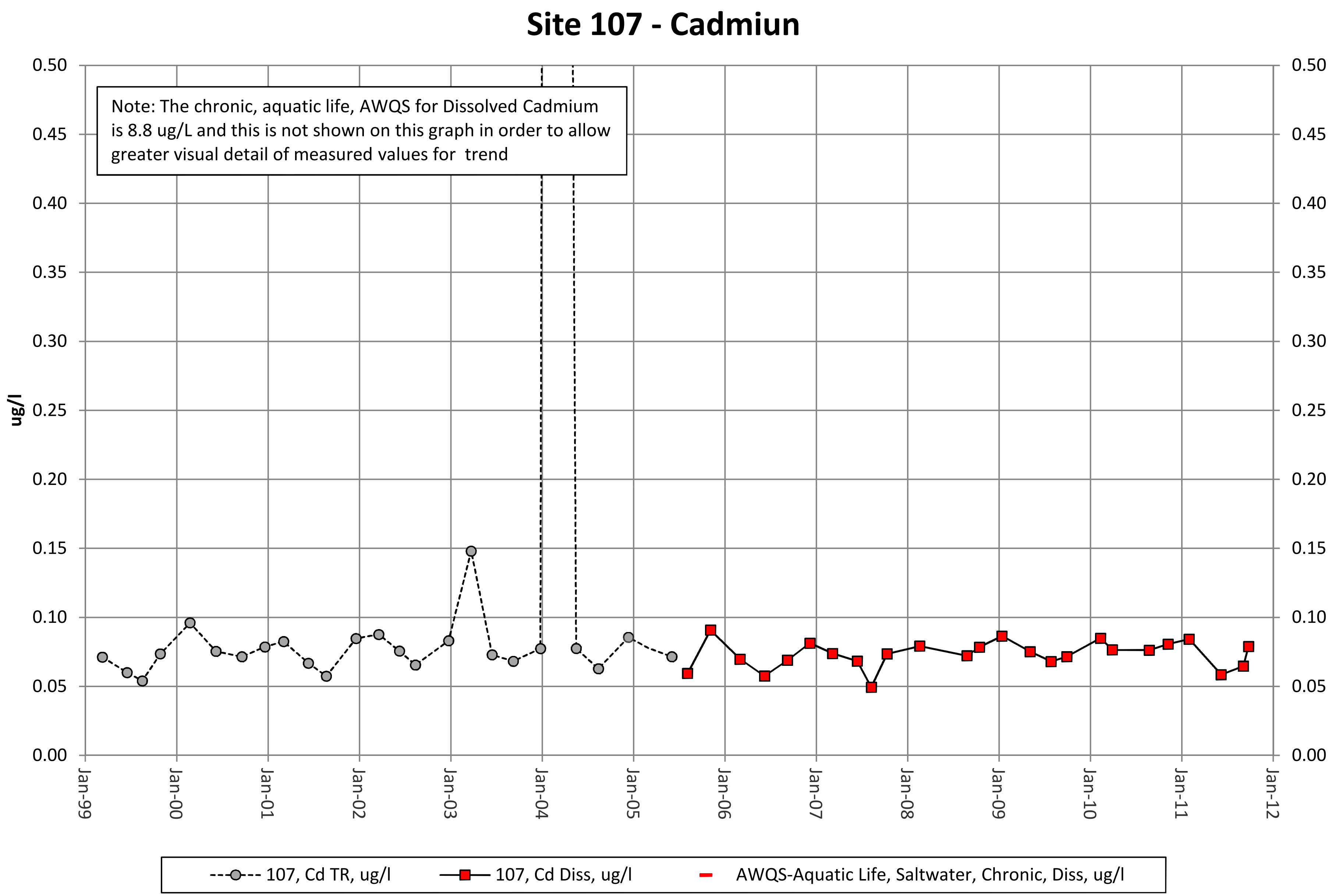

Site 106 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend
ug/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05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

Figure 2-3c

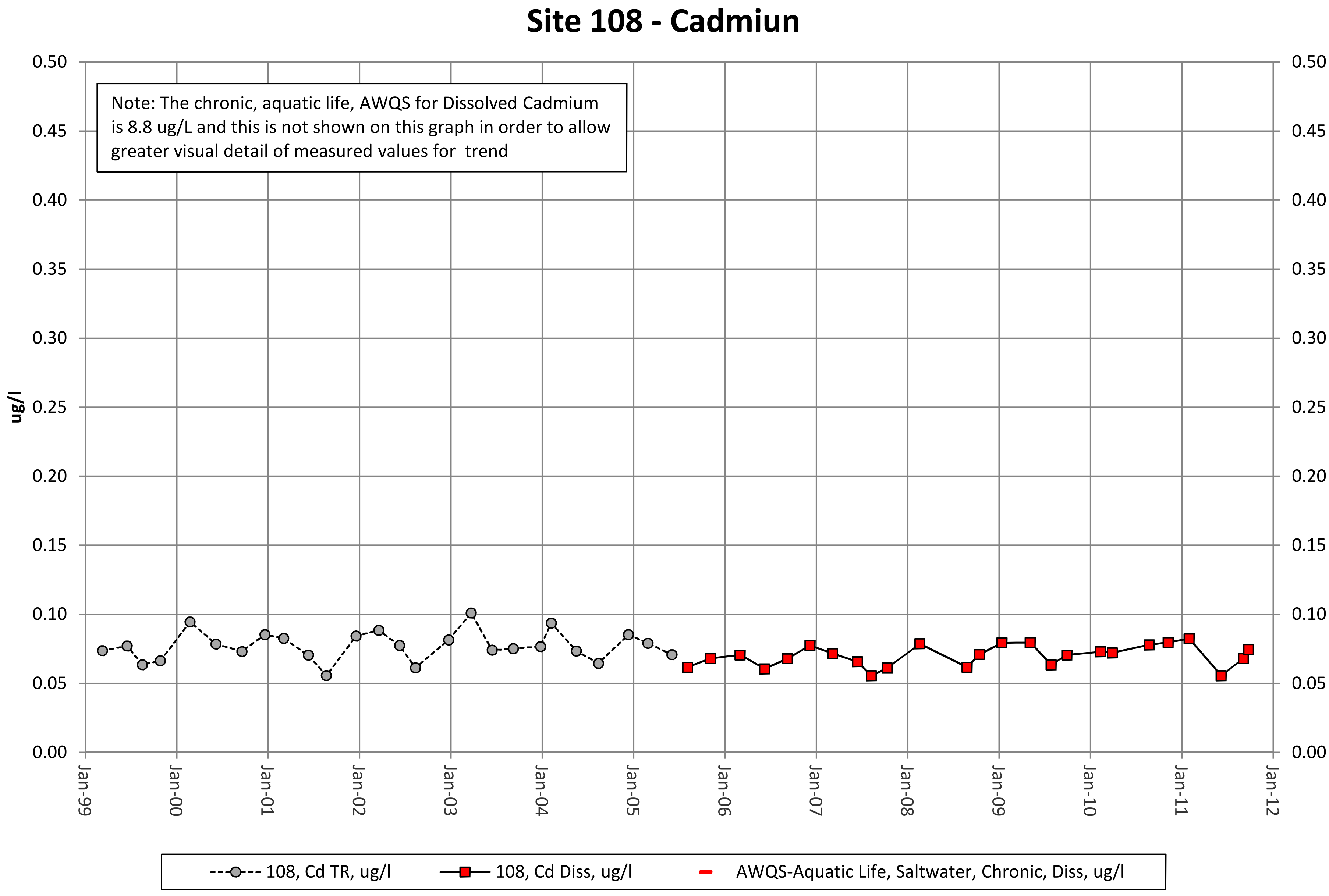
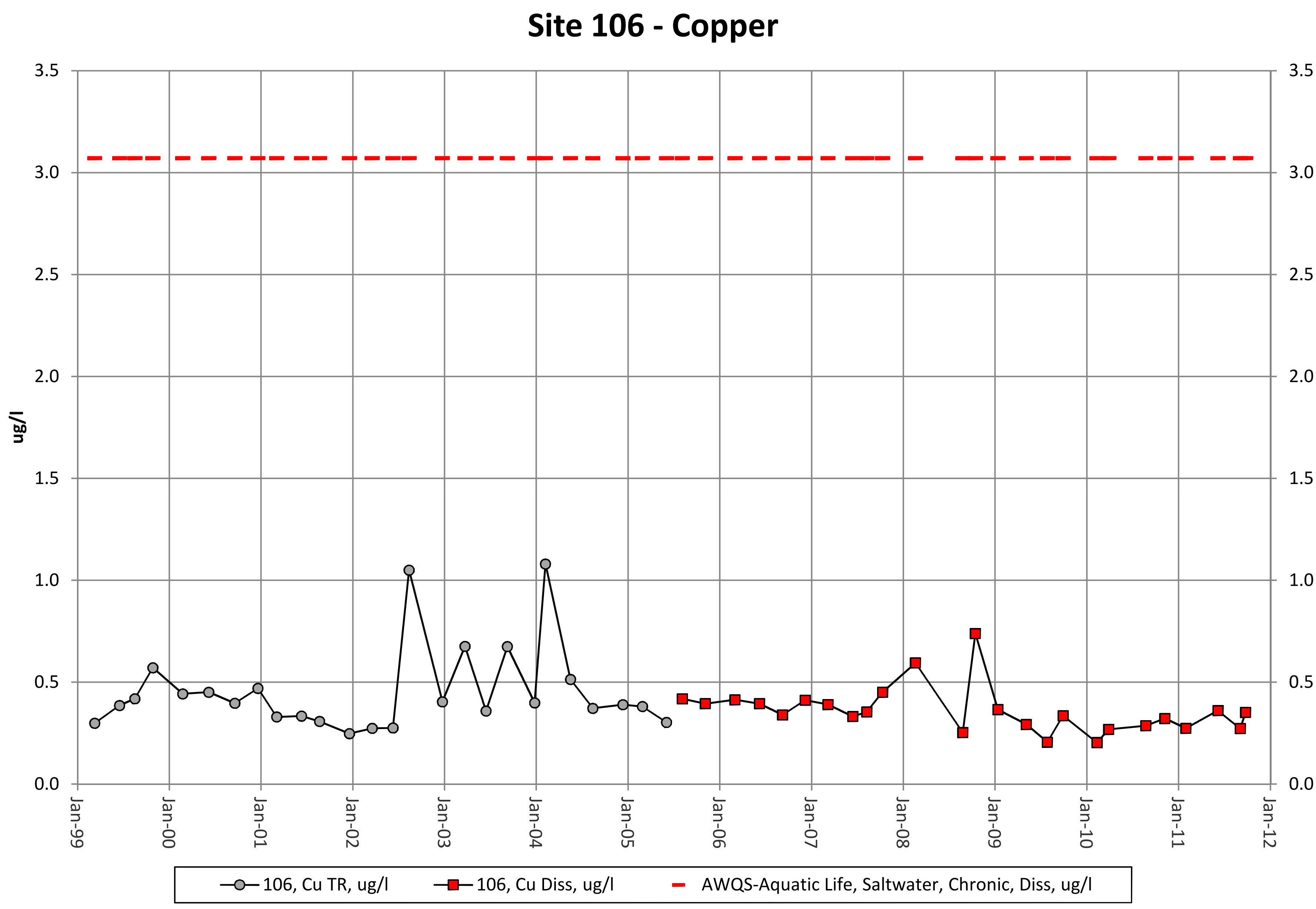

Site 108 - Cadmiun
Note: The chronic, aquatic life, AWQS for Dissolved Cadmium is 8.8 ug/L and this is not shown on this graph in order to allow greater visual detail of measured values for trend
ug/l
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05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

Figure 2-4a



Site 106 - Copper
ug/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
106, Cu TR, ug/l
106, Cu Diss, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

Figure 2-4b

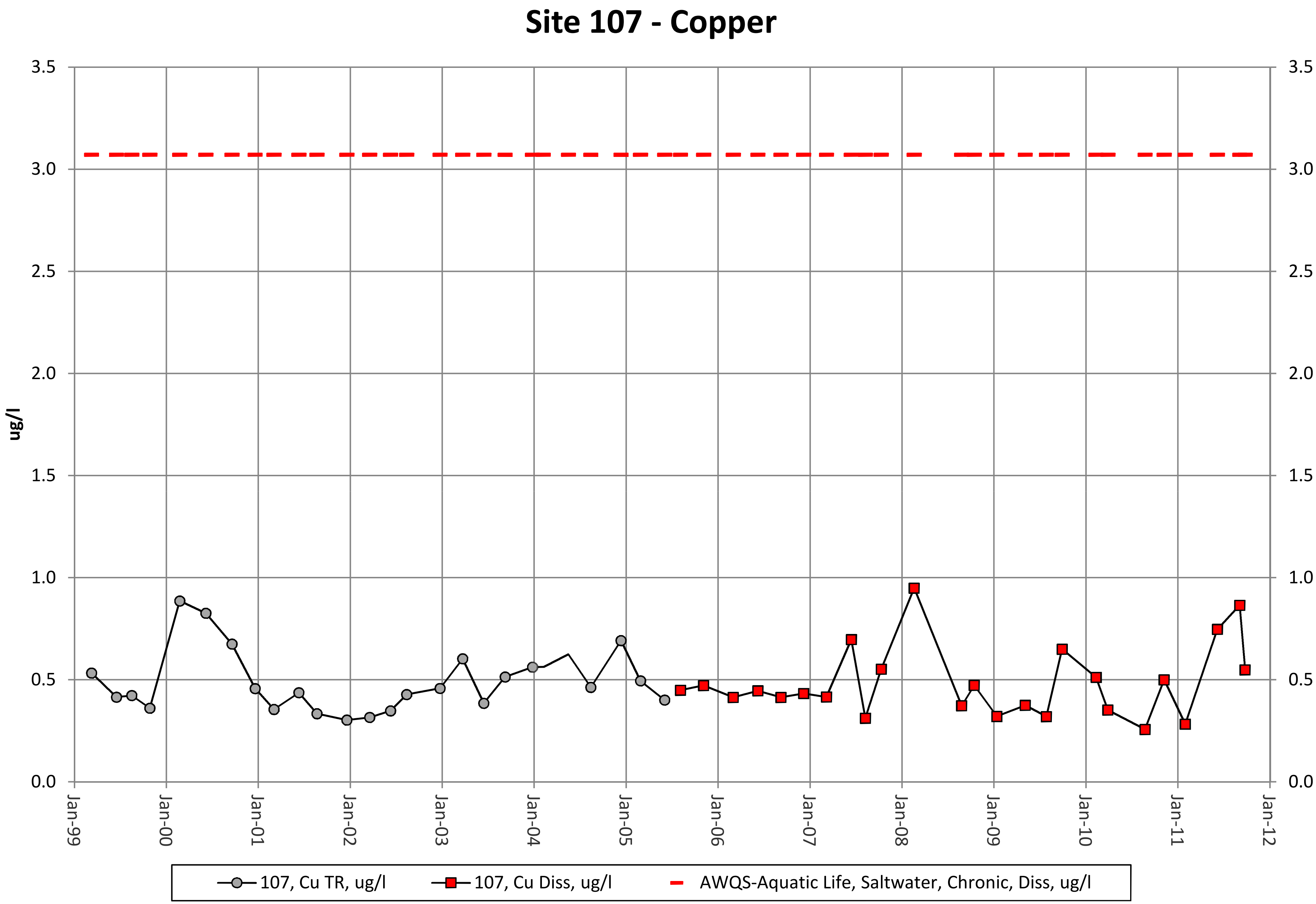
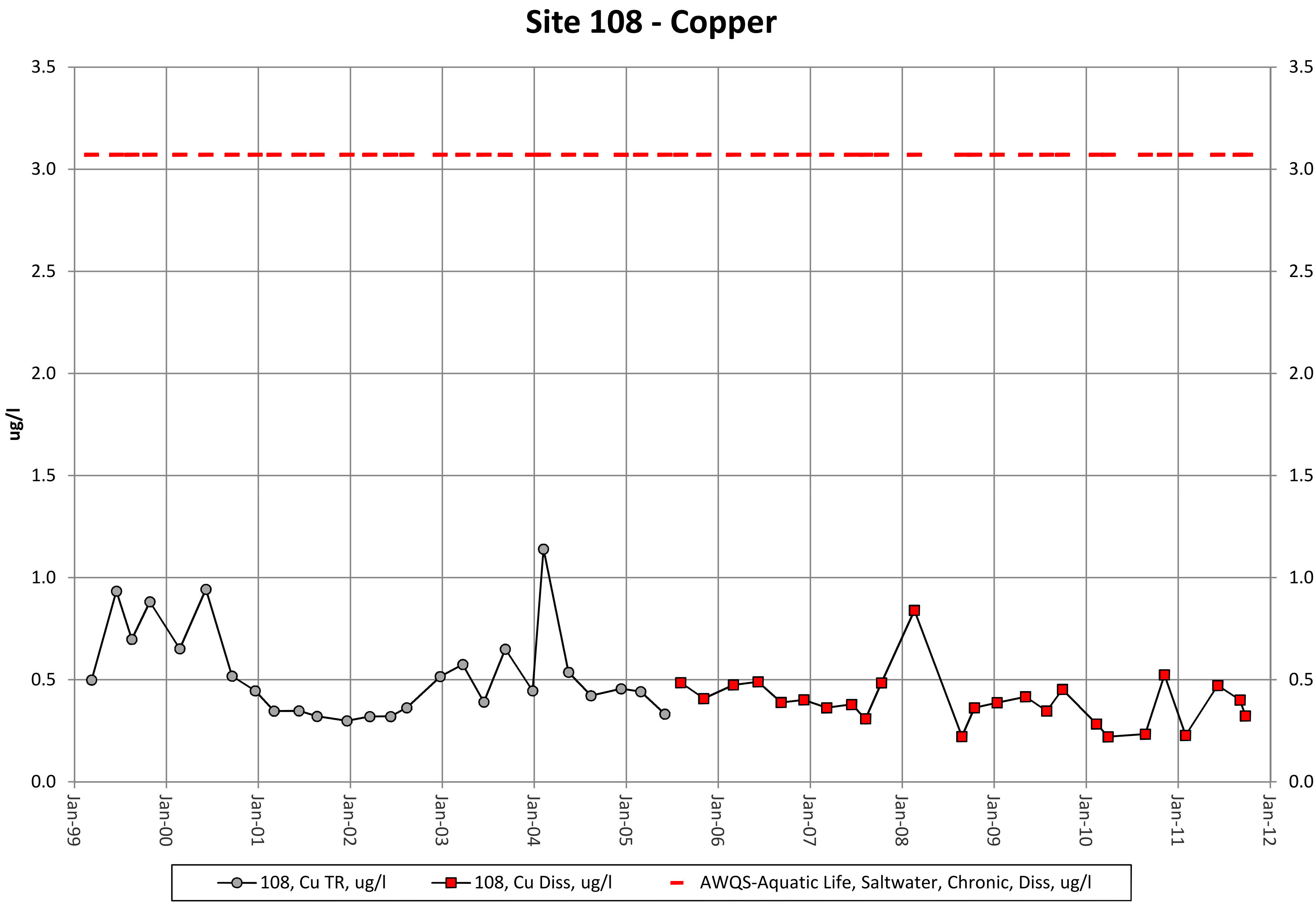
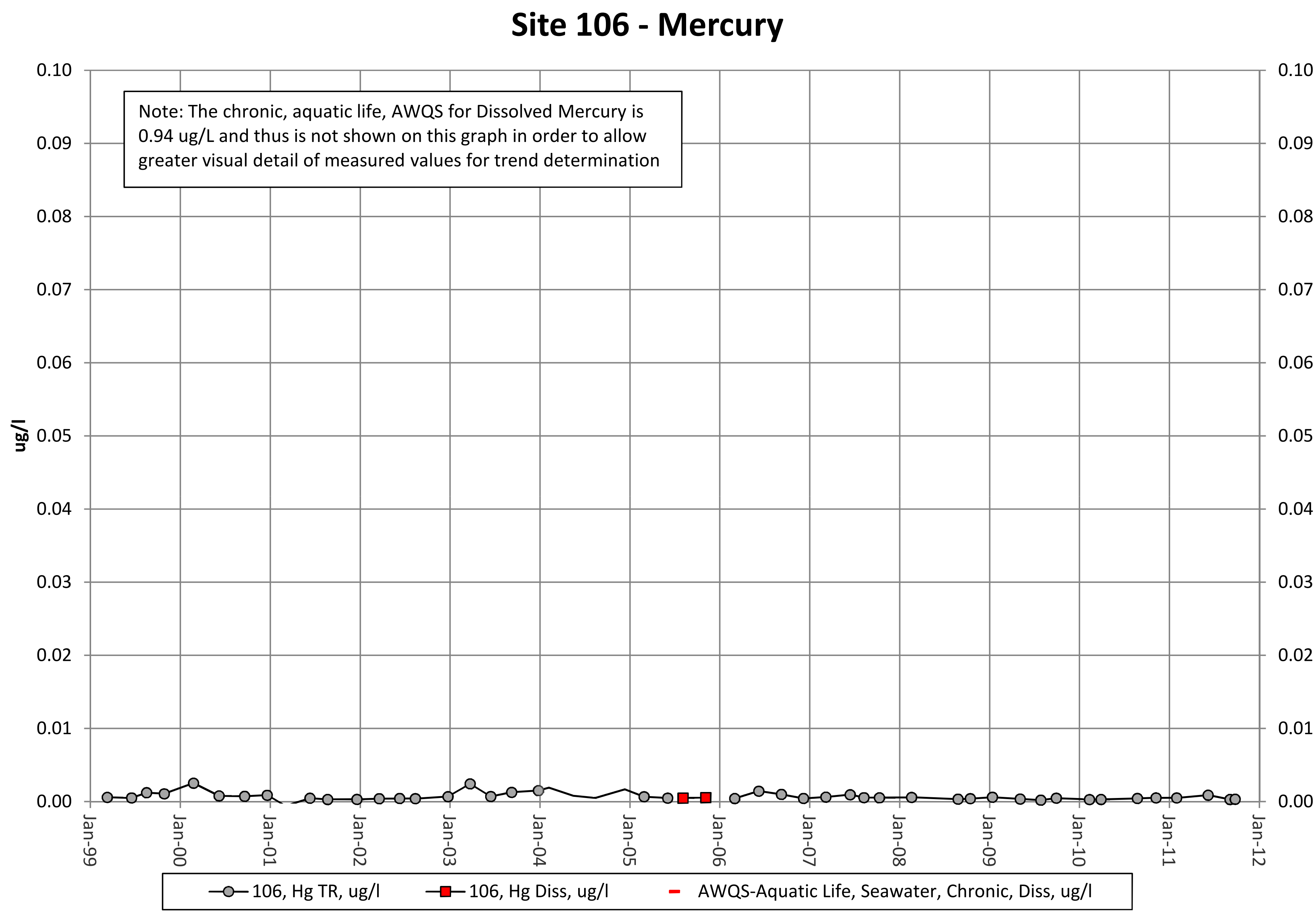

Site 107 - Copper
ug/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
107, Cu TR, ug/l
107, Cu Diss, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

Figure 2-4c



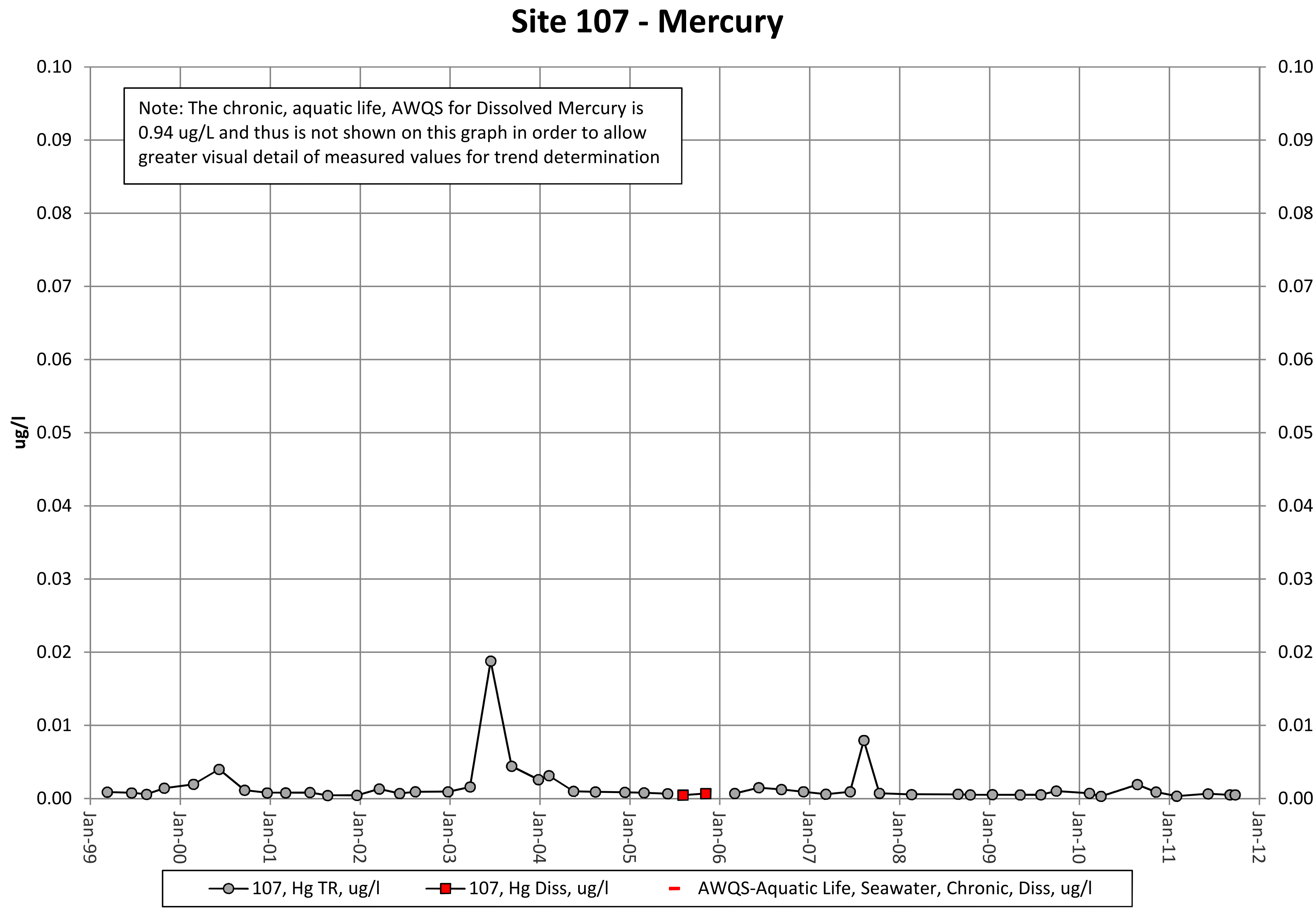
Site 108 - Copper
ug/l
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
108, Cu TR, ug/l
108, Cu Diss, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

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
ug/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
106, Hg TR, ug/l
106, Hg Diss, ug/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, ug/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
ug/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
107, Hg TR, ug/l
107, Hg Diss, ug/l
AWQS-Aquatic Life, Seawater, Chronic, Diss, ug/l

Figure 2-5c

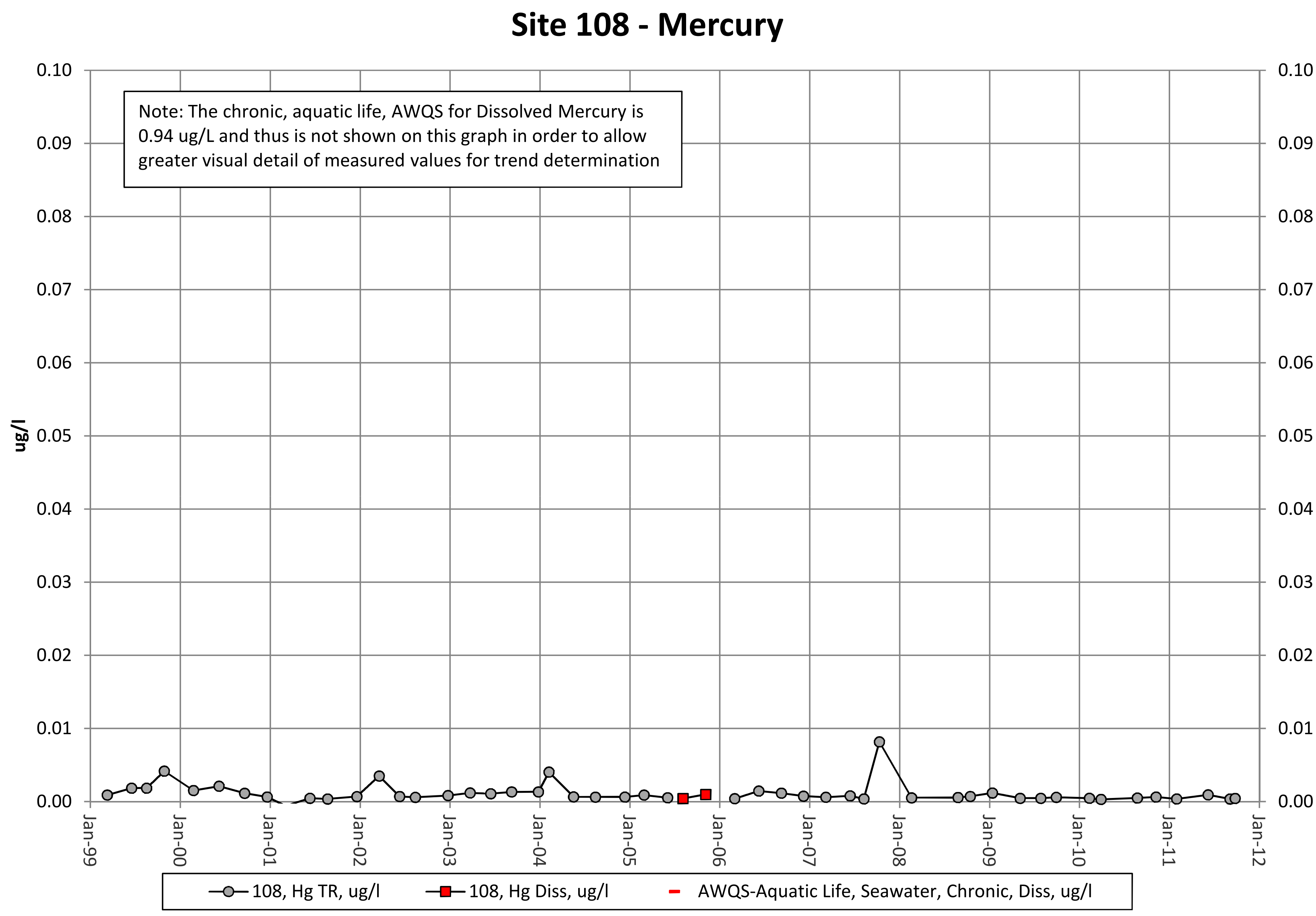
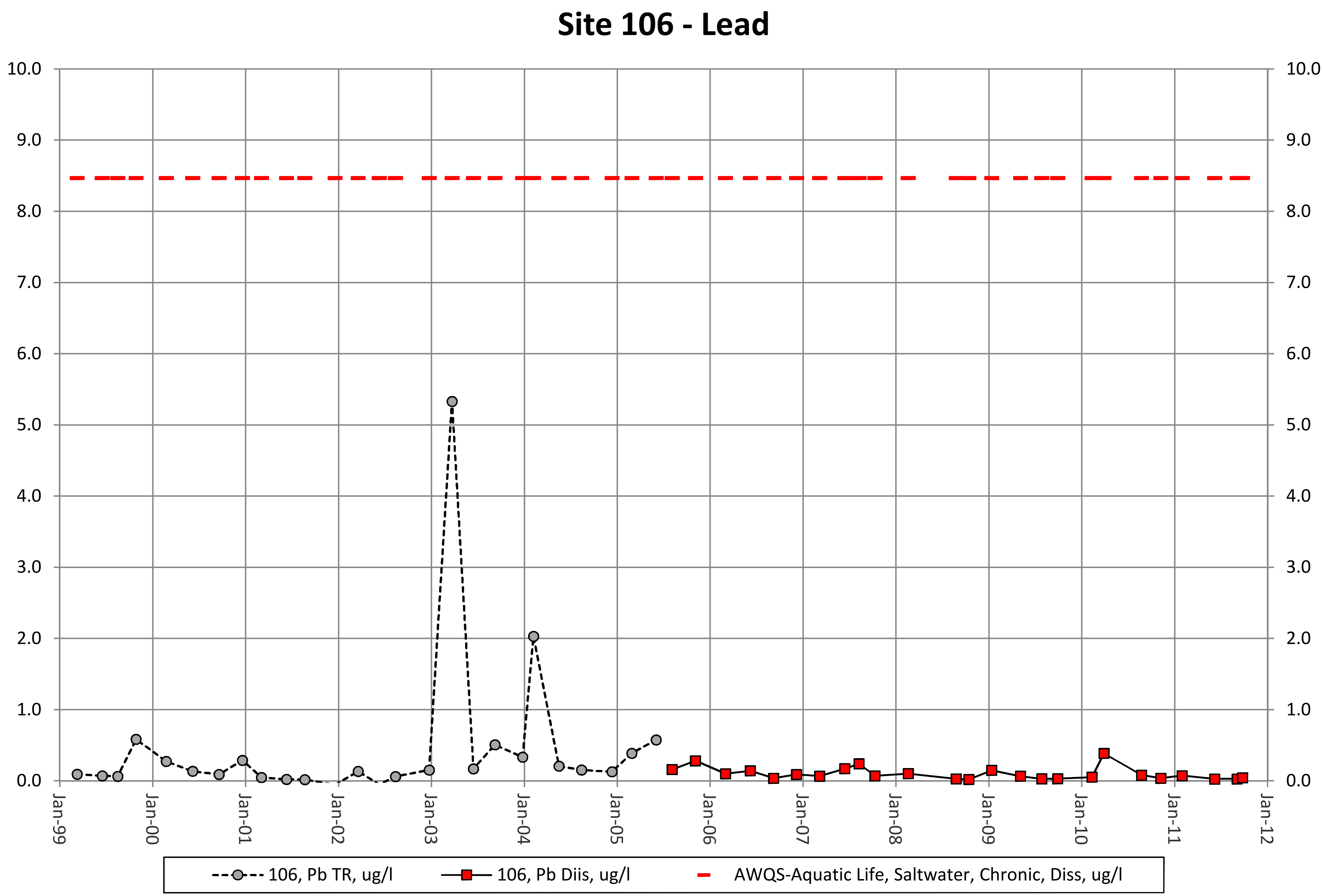

Site 108 - Mercury
Note: The chronic, aquatic life, AWQS for Dissolved Mercury is 0.94 ug/L and thus is not shown on this graph in order to allow greater visual detail of measured values for trend determination
ug/l
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03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

Figure 2-6a



Site 106 - Lead
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
106, Pb TR, ug/l
106, Pb Diis, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

Figure 2-6b

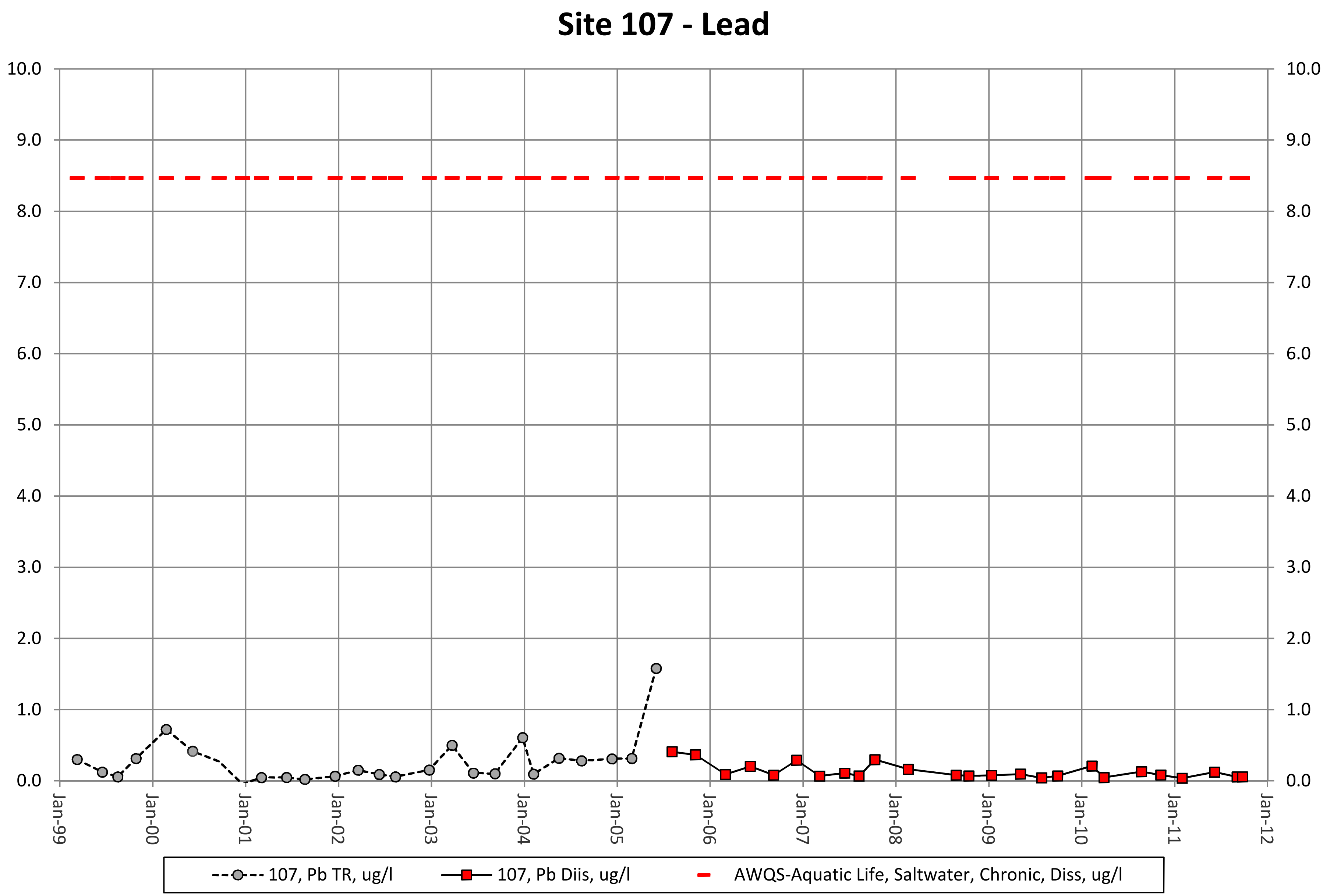
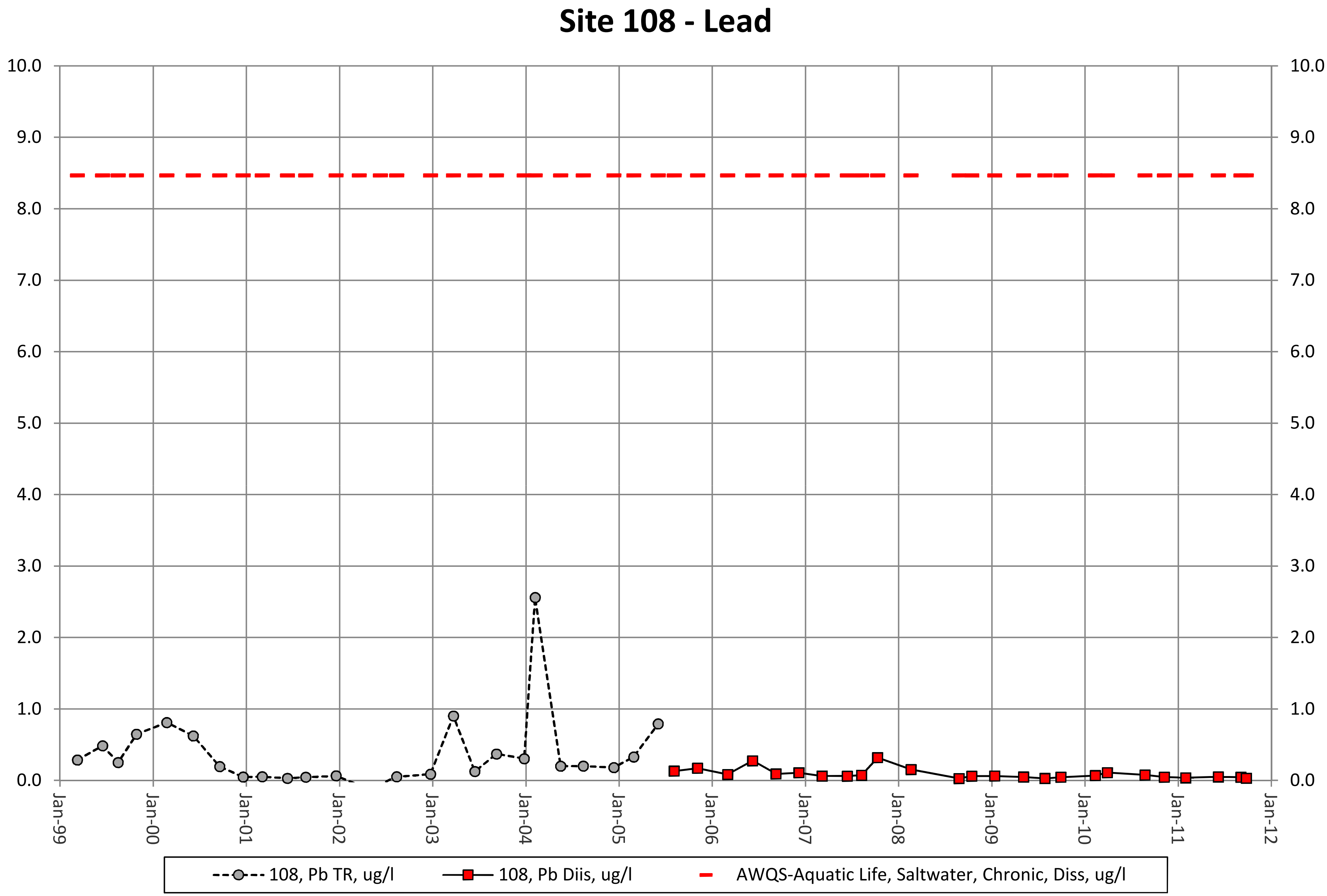

Site 107 - Lead
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
107, Pb TR, ug/l
107, Pb Diis, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

Figure 2-6c



Site 108 - Lead
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
108, Pb TR, ug/l
108, Pb Diis, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

Figure 2-7a

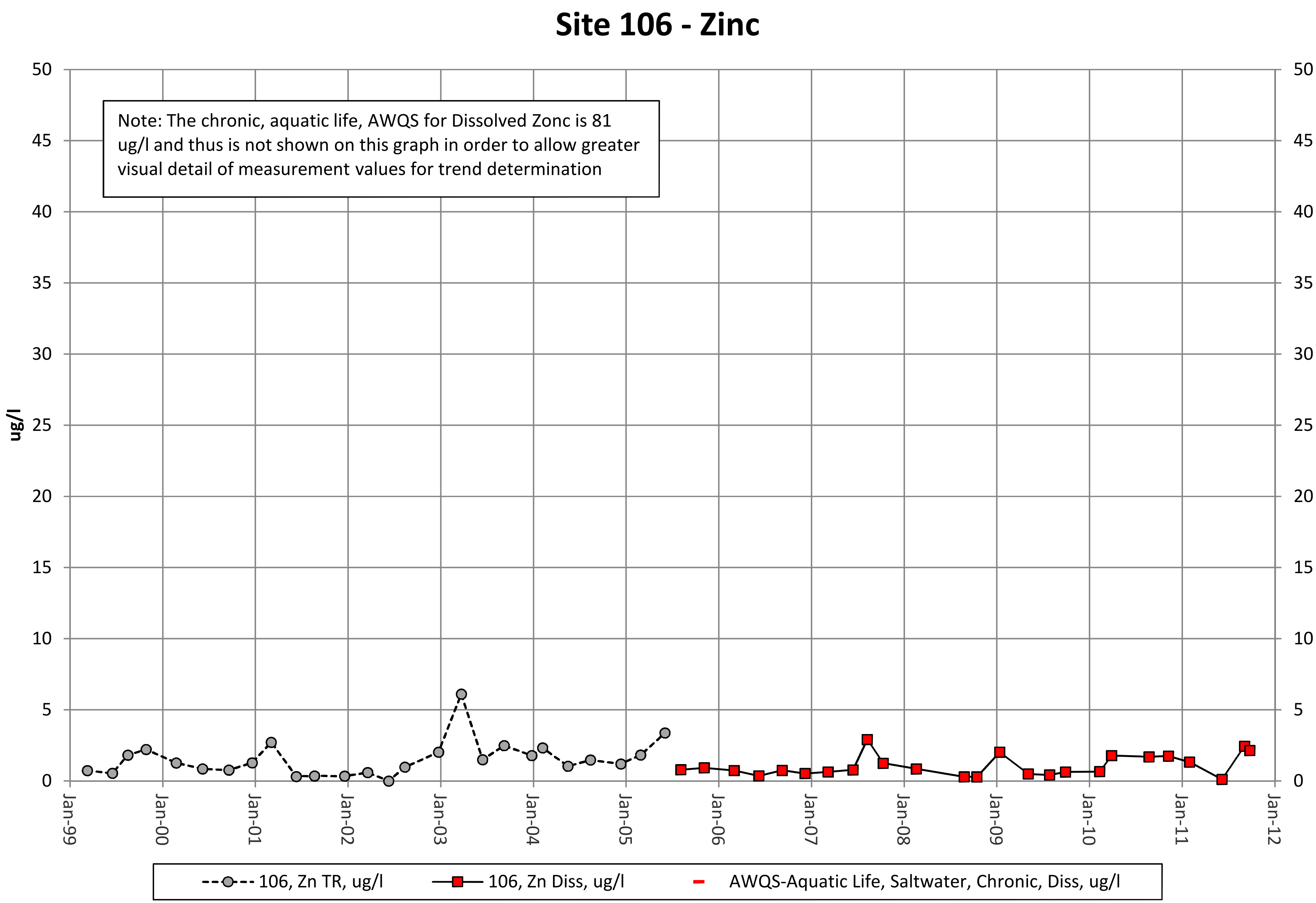
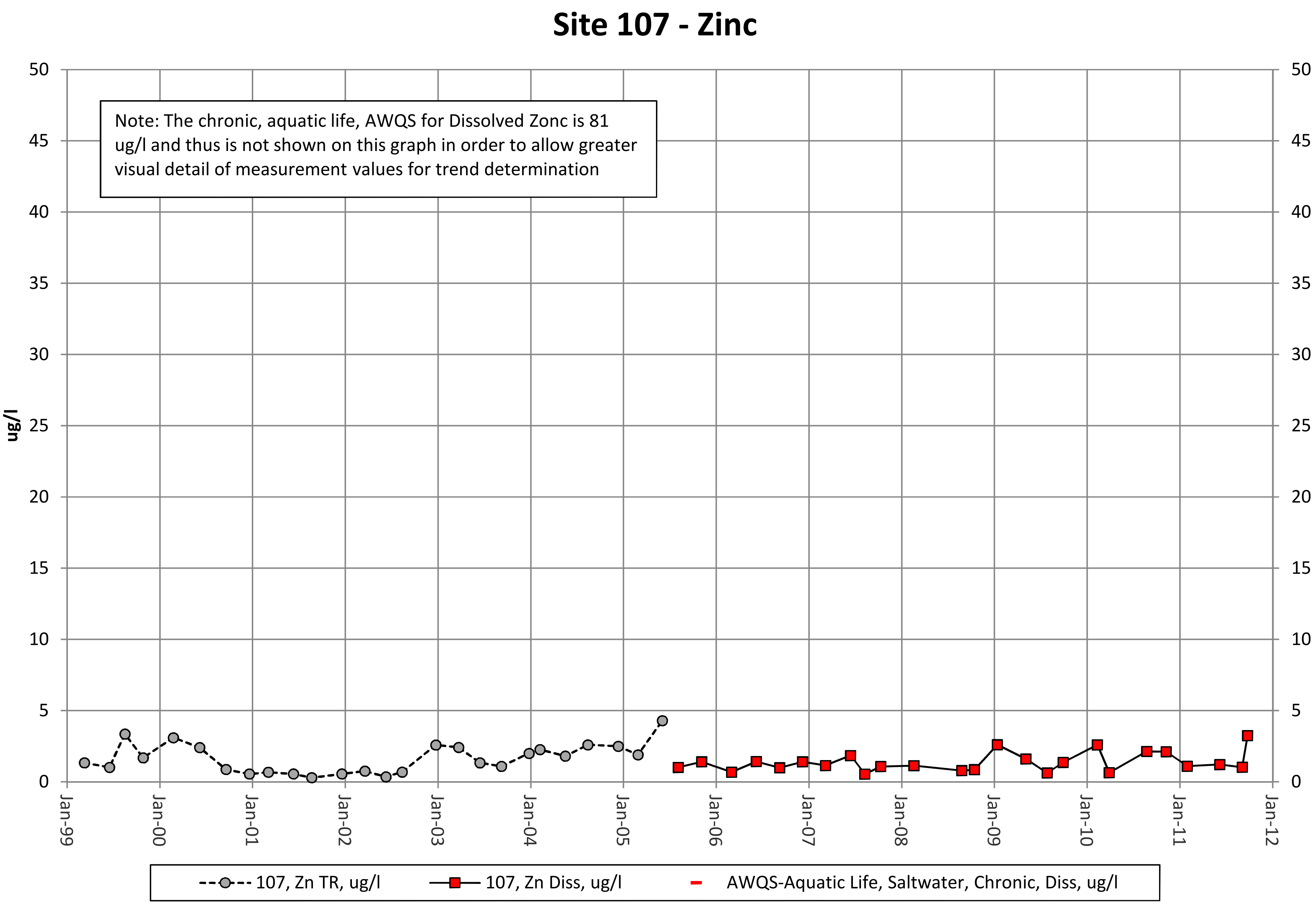
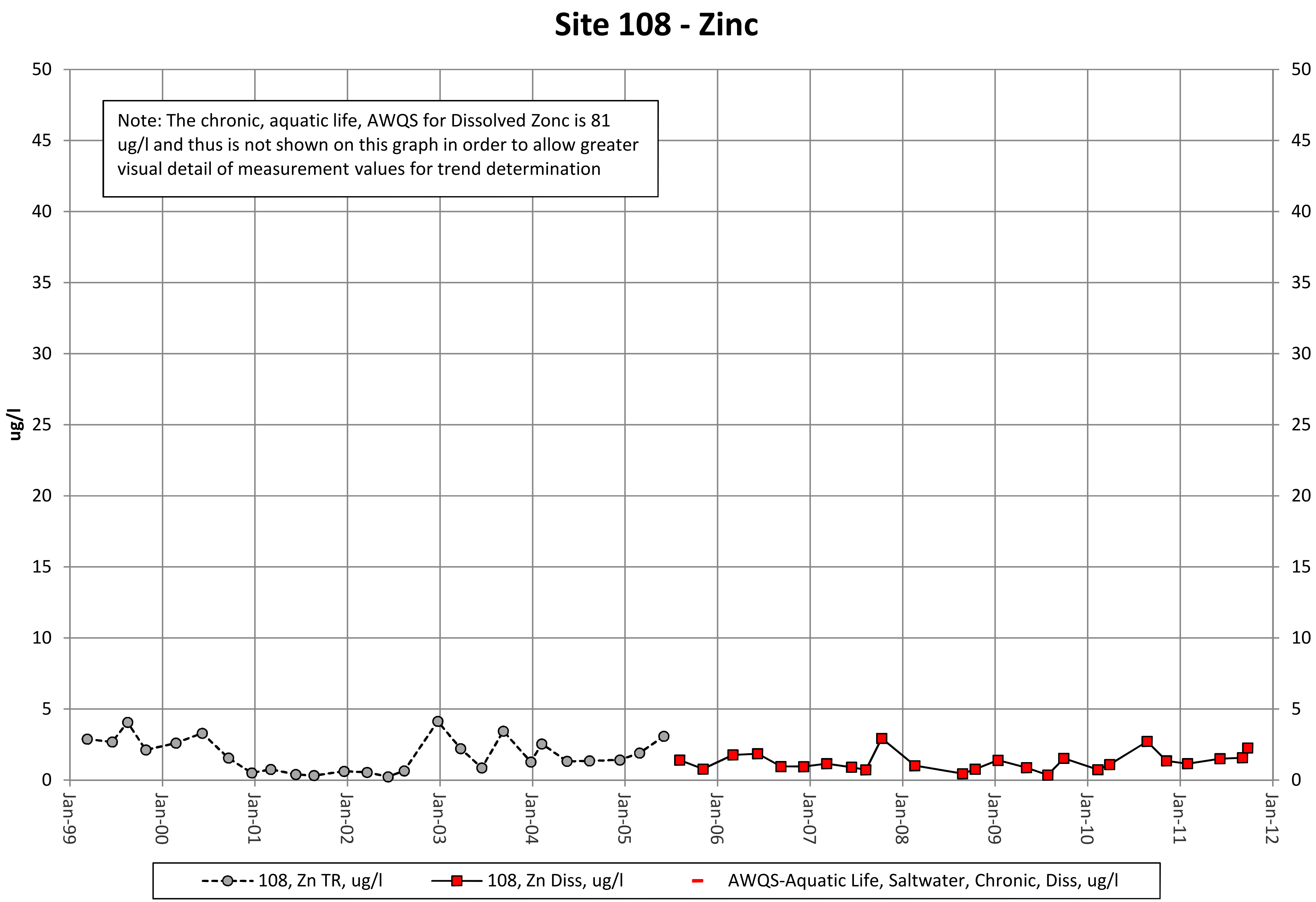

Site 106 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zonc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measurement values for trend determination
ug/l
50
45
40
35
30
25
20
15
10
5
0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07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

Figure 2-7b



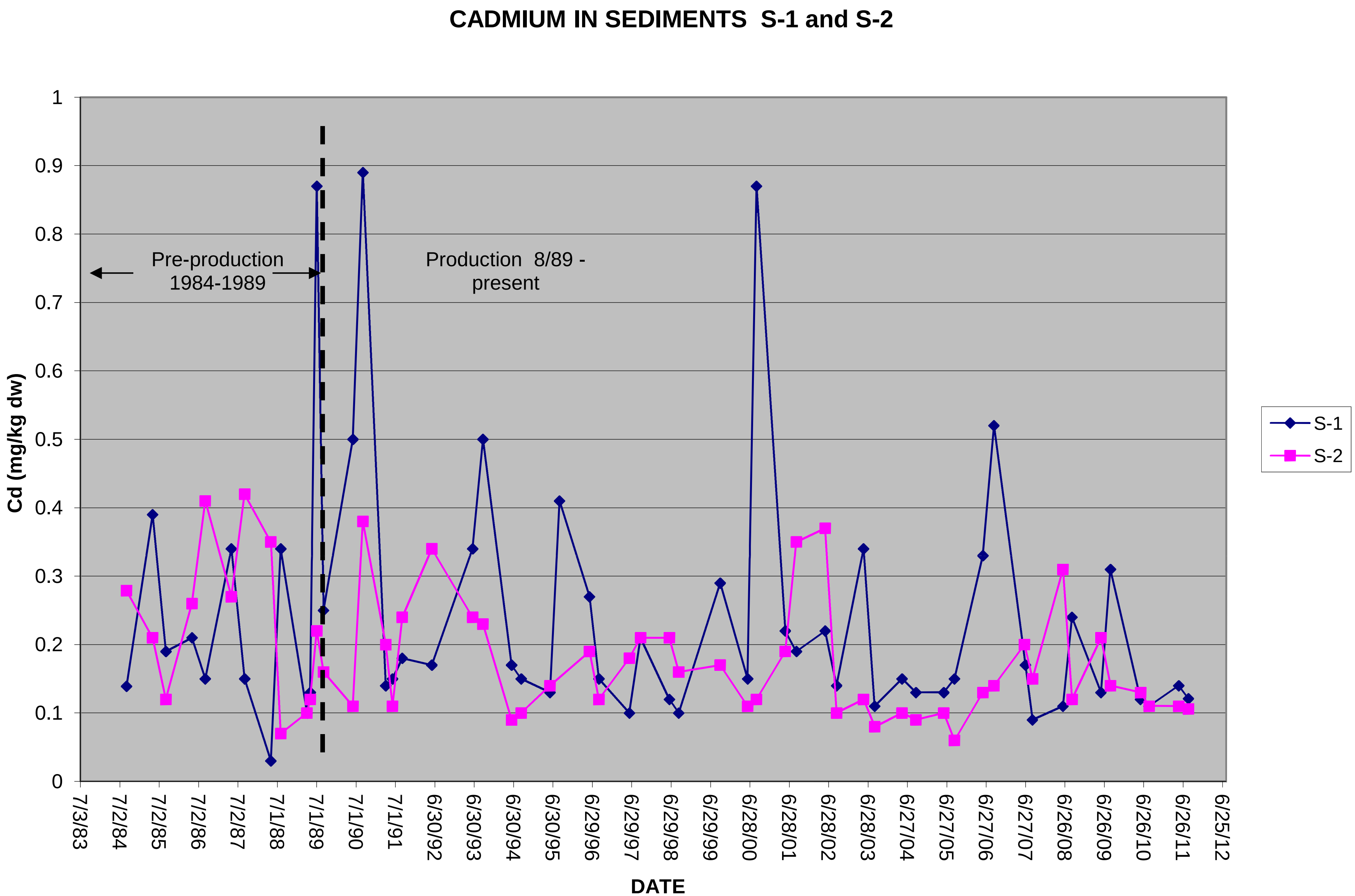
Site 107 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zonc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measurement values for trend determination
ug/l
50
45
40
35
30
25
20
15
10
5
0
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07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

Figure 2-7c



Site 108 - Zinc
Note: The chronic, aquatic life, AWQS for Dissolved Zonc is 81 ug/l and thus is not shown on this graph in order to allow greater visual detail of measurement values for trend determination
ug/l
50
45
40
35
30
25
20
15
10
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
108, Zn TR, ug/l
108, Zn Diss, ug/l
AWQS-Aquatic Life, Saltwater, Chronic, Diss, ug/l

FIGURE 3-1



CADMIUM IN SEDIMENTS S-1 and S-2
Cd (mg/kg dw)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-production
1984-1989
Production 8/89 -
present
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-1
S-2

FIGURE 3-2

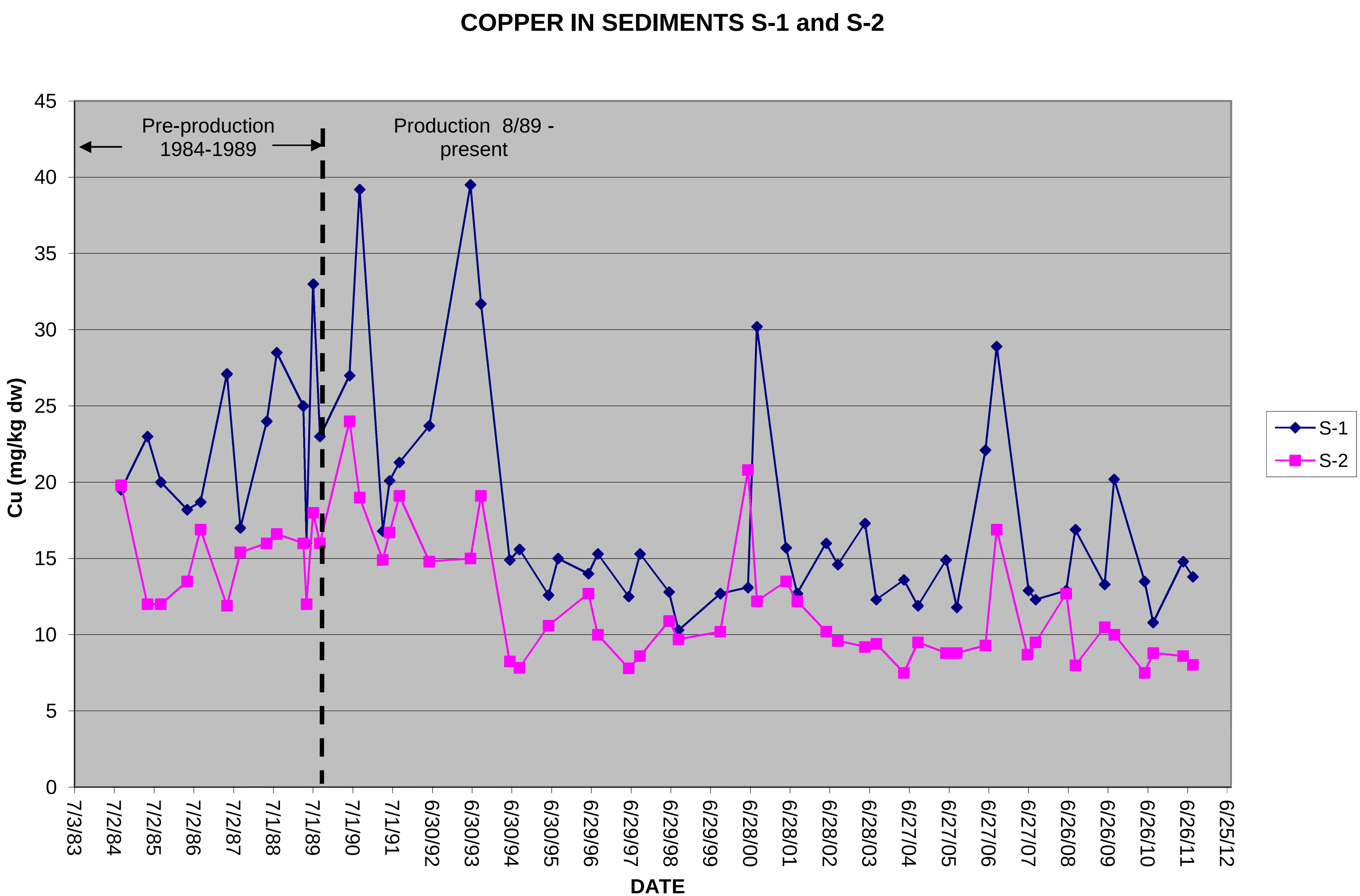
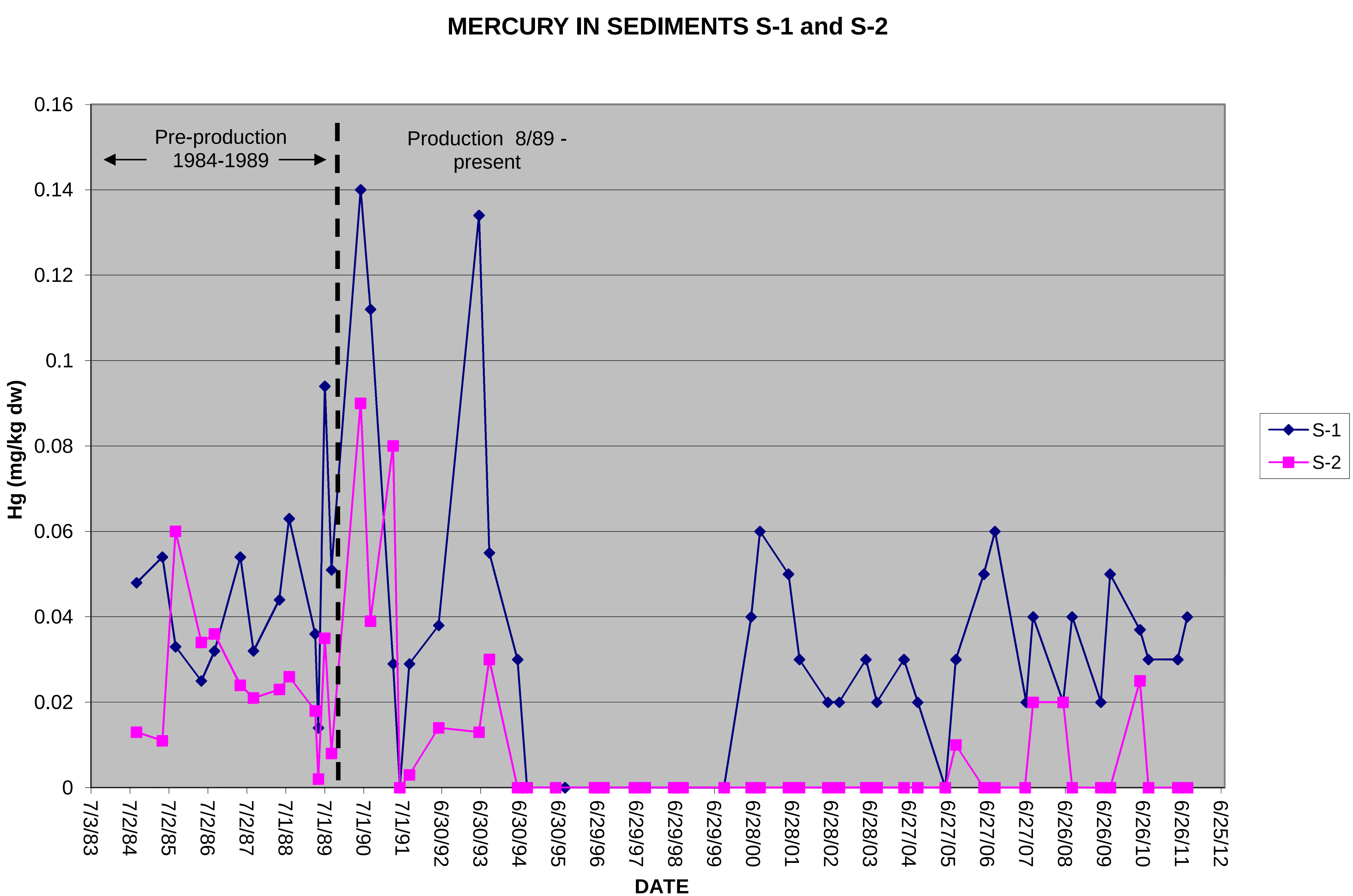

COPPER IN SEDIMENTS S-1 and S-2
Pre-production
1984-1989
Production 8/89 -
present
Cu (mg/kg dw)
45
40
35
30
25
20
15
10
5
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-1
S-2

FIGURE 3-3



MERCURY IN SEDIMENTS S-1 and S-2
Hg (mg/kg dw)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Pre-production 1984-1989
Production 8/89 - present
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-1
S-2

FIGURE 3-4

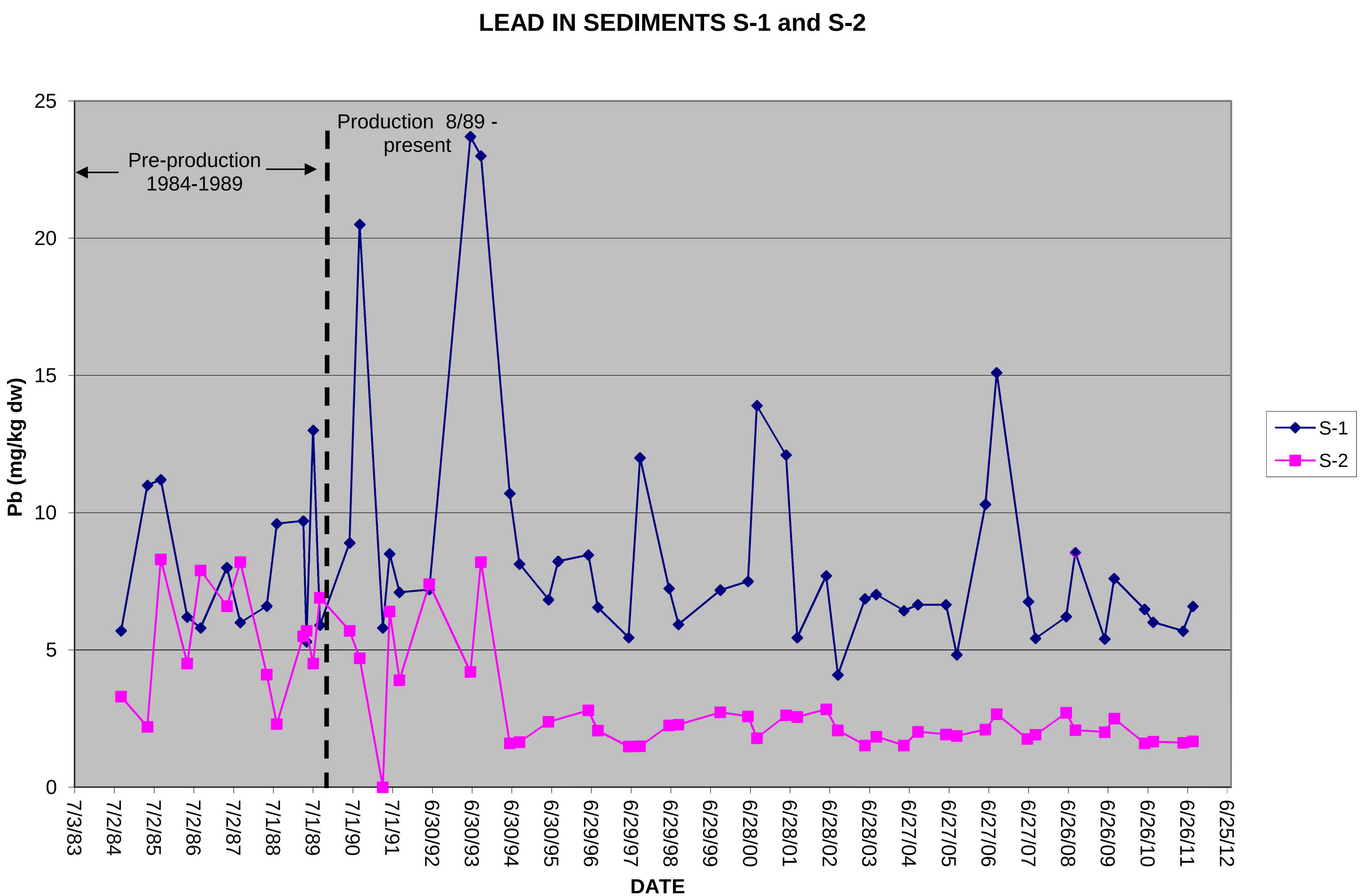
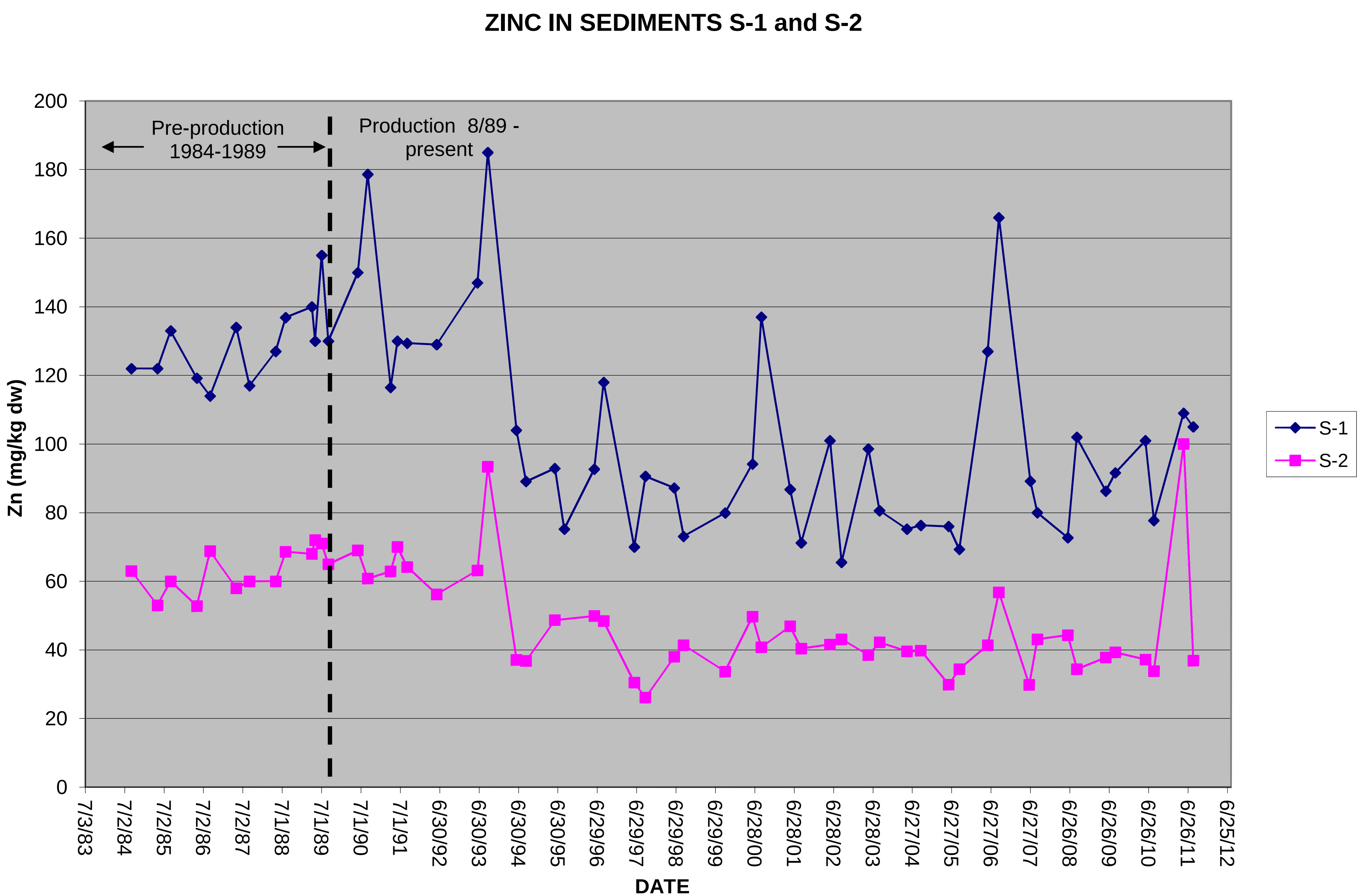

LEAD IN SEDIMENTS S-1 and S-2
Pb (mg/kg dw)
DATE
Pre-production
1984-1989
Production 8/89 -
present
S-1
S-2
0
5
10
15
20
25
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12

FIGURE 3-5



ZINC IN SEDIMENTS S-1 and S-2
Zn (mg/kg dw)
200
180
160
140
120
100
80
60
40
20
0
Pre-production 1984-1989
Production 8/89 - present
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-1
S-2

FIGURE 3-6

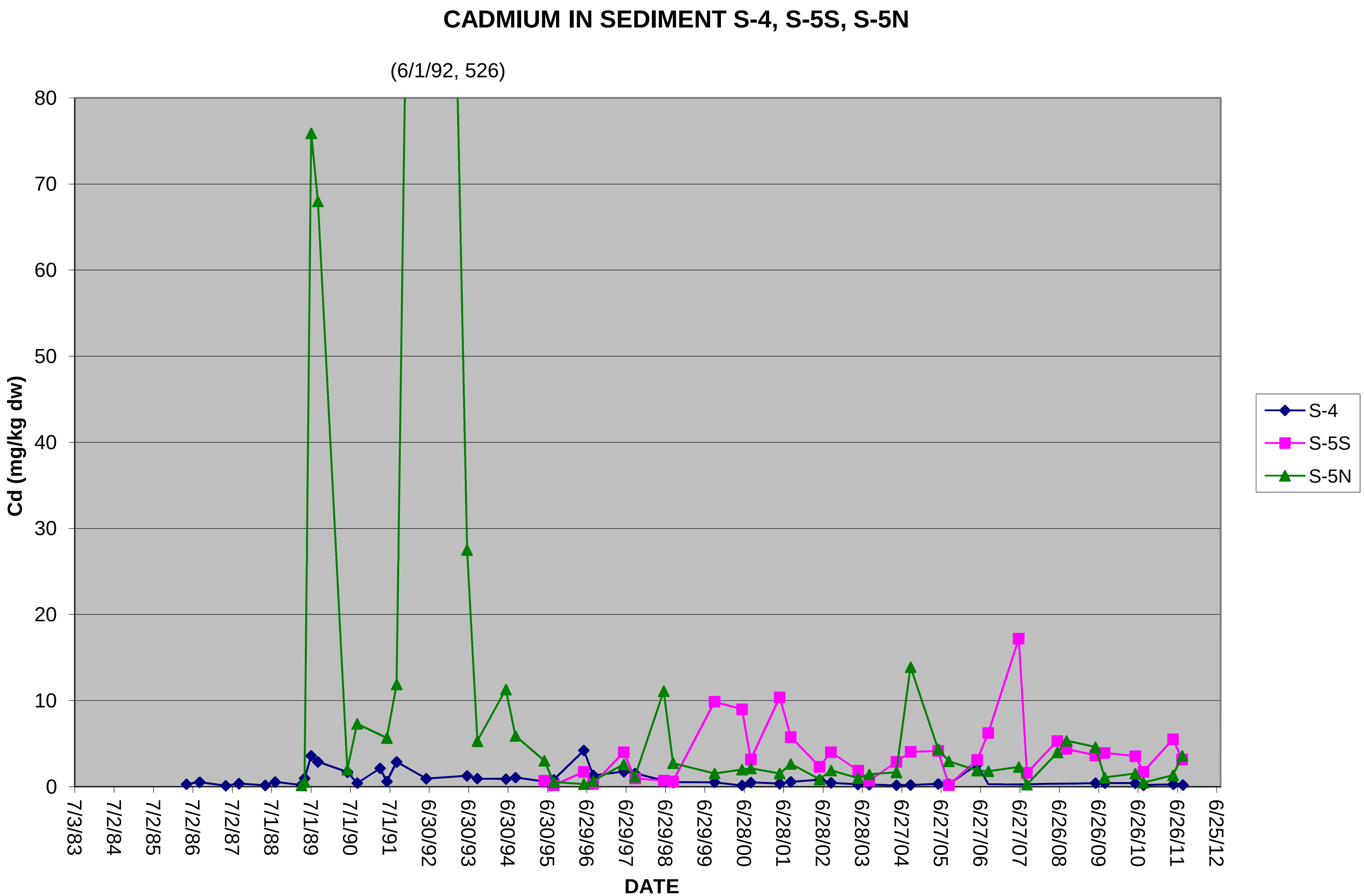

CADMIUM IN SEDIMENT S-4, S-5S, S-5N
(6/1/92, 526)
Cd (mg/kg dw)
80
70
60
50
40
30
20
10
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-4
S-5S
S-5N

FIGURE 3-7

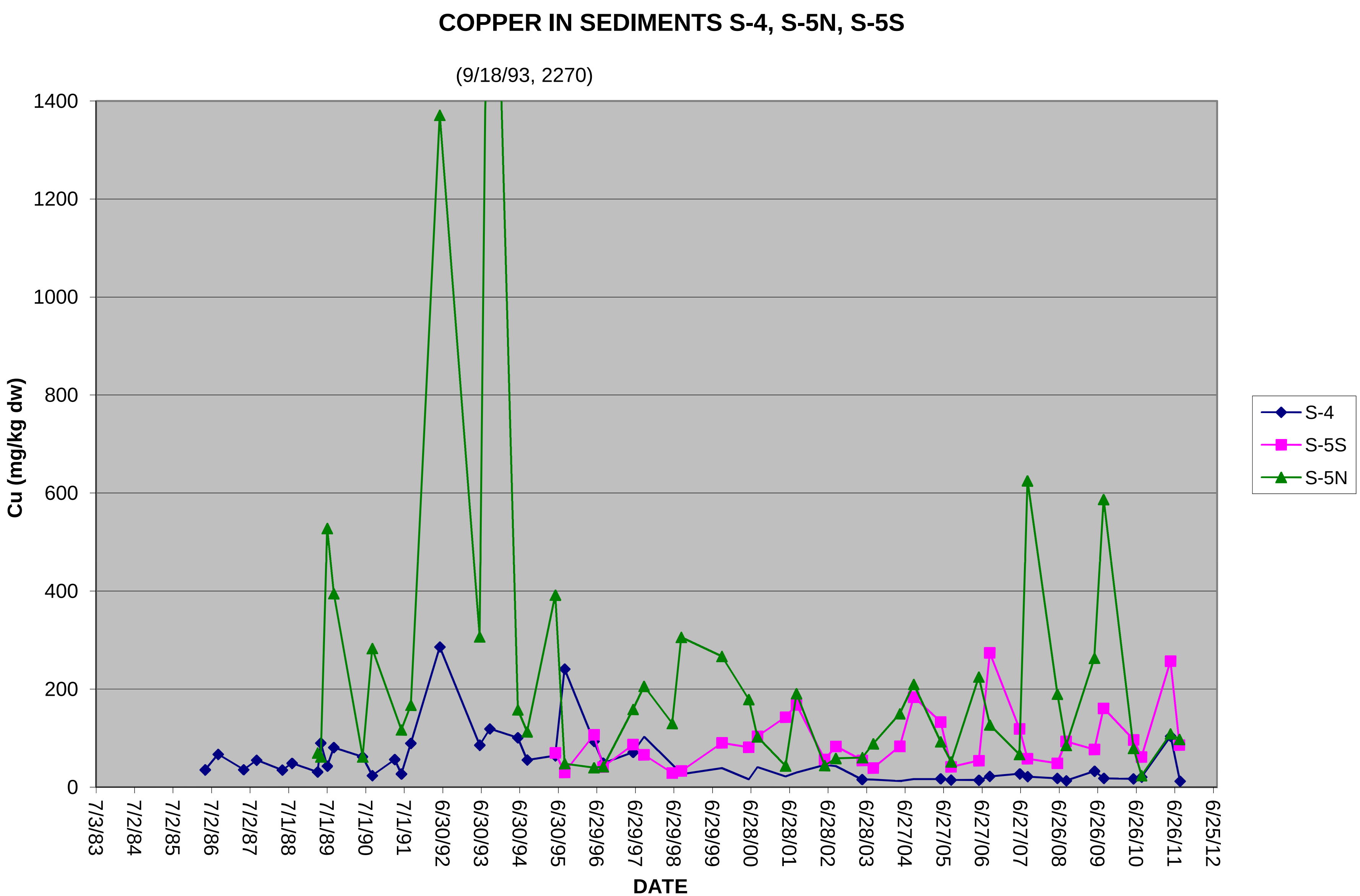

COPPER IN SEDIMENTS S-4, S-5N, S-5S
(9/18/93, 2270)
1400
1200
1000
800
600
400
200
0
Cu (mg/kg dw)
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-4
S-5S
S-5N

FIGURE 3-8

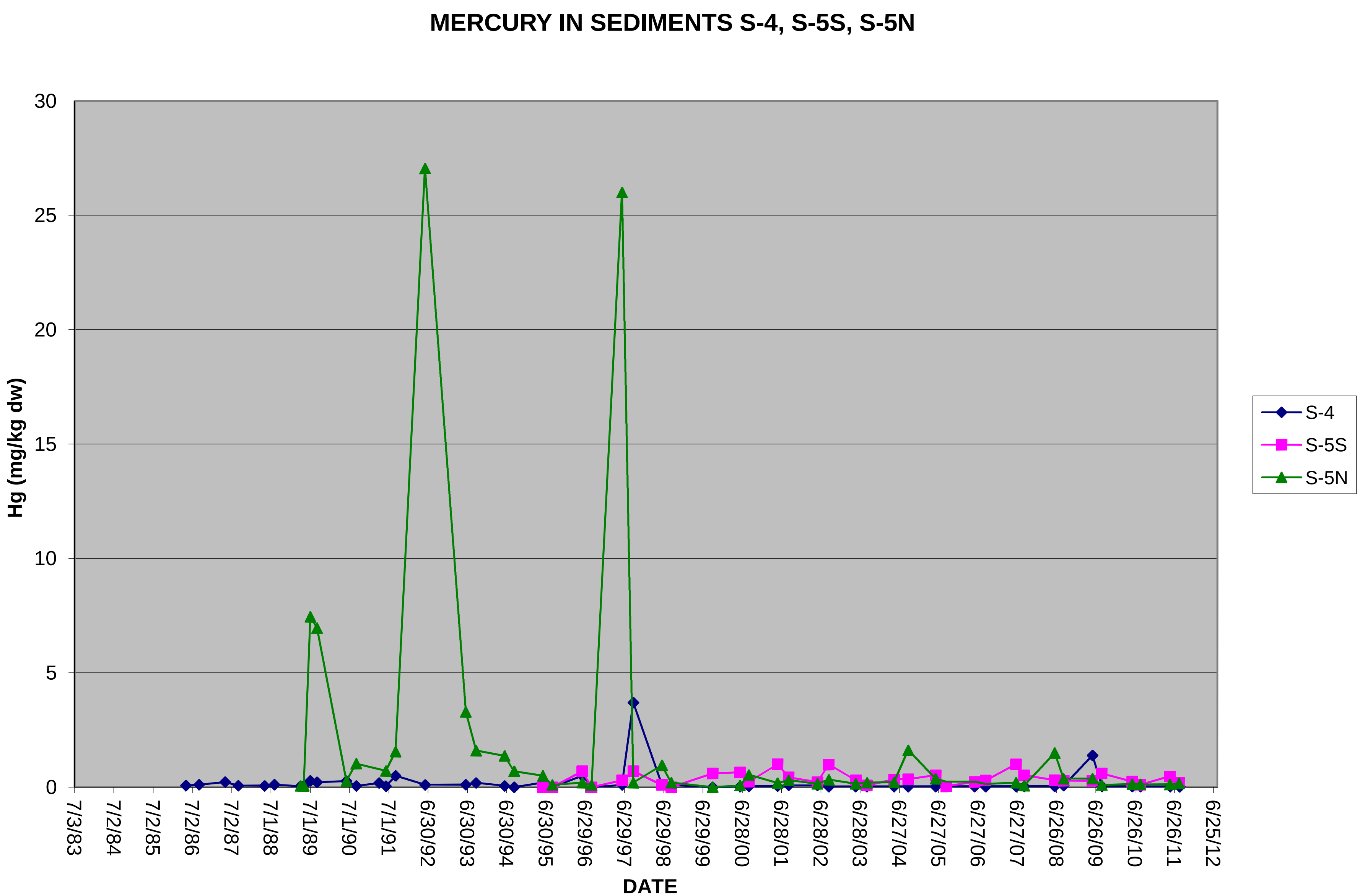
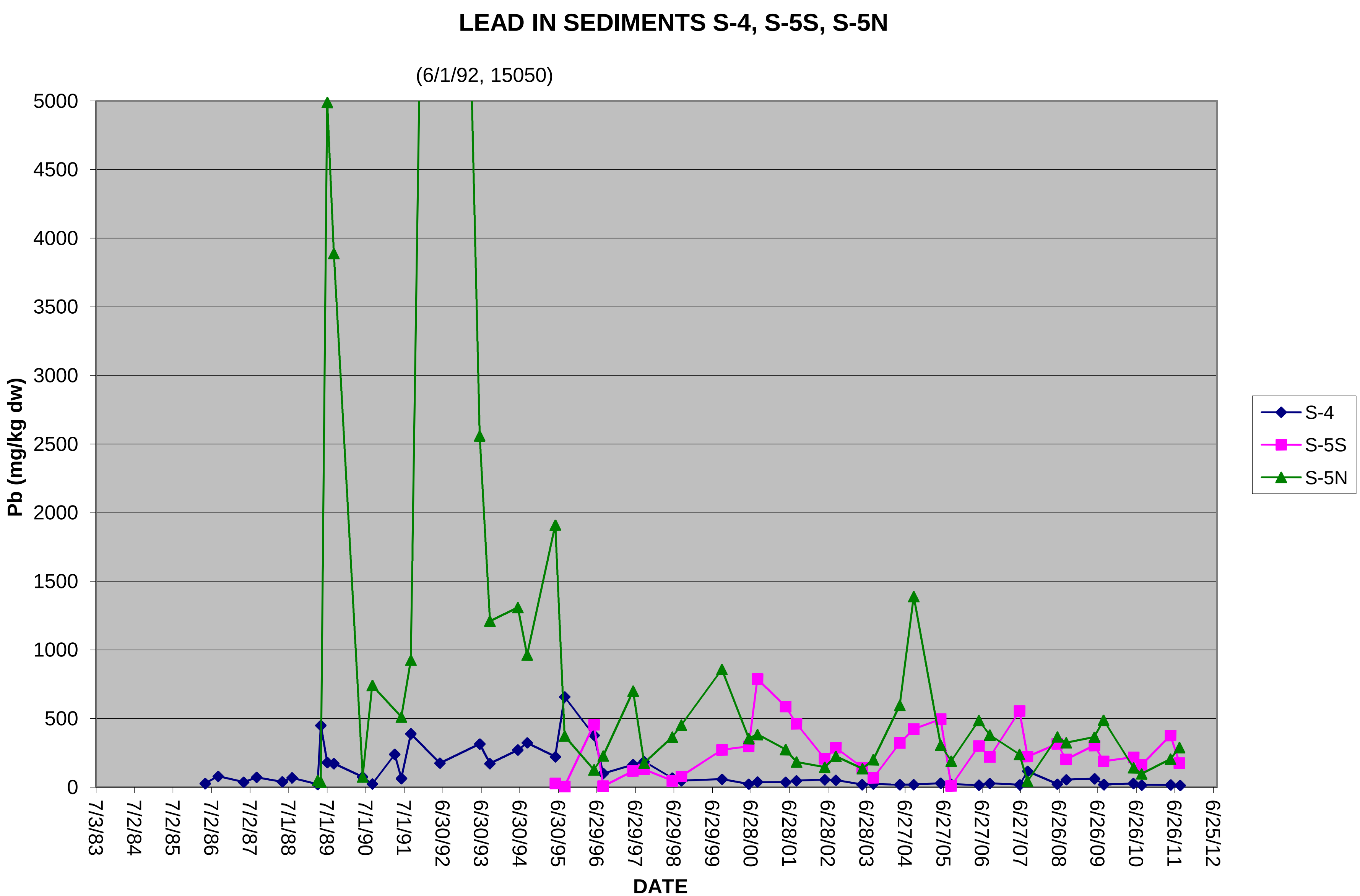

MERCURY IN SEDIMENTS S-4, S-5S, S-5N
30
25
20
15
10
5
0
Hg (mg/kg dw)
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-4
S-5S
S-5N

FIGURE 3-9



LEAD IN SEDIMENTS S-4, S-5S, S-5N
(6/1/92, 15050)
Pb (mg/kg dw)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-4
S-5S
S-5N

FIGURE 3-10

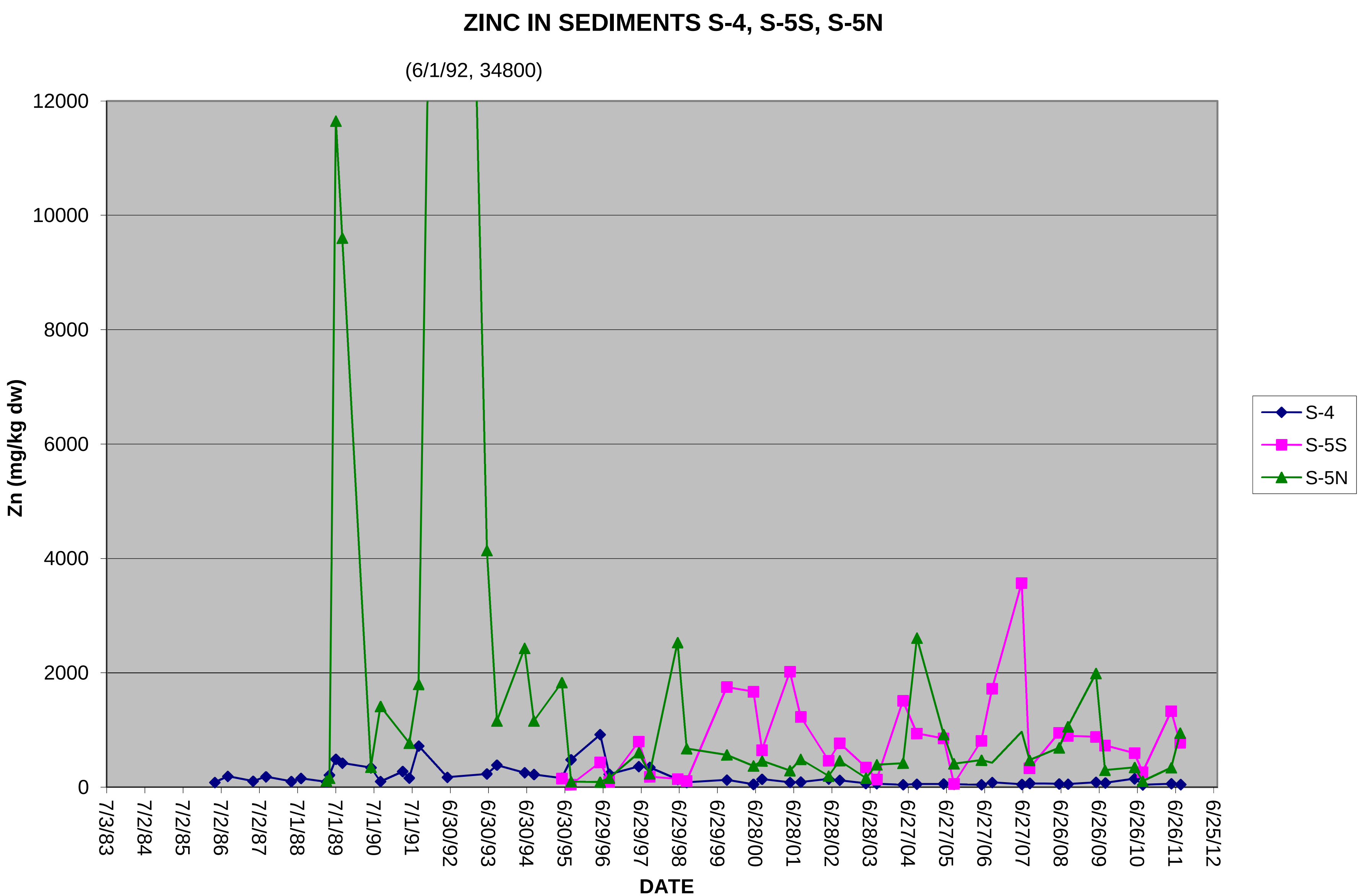
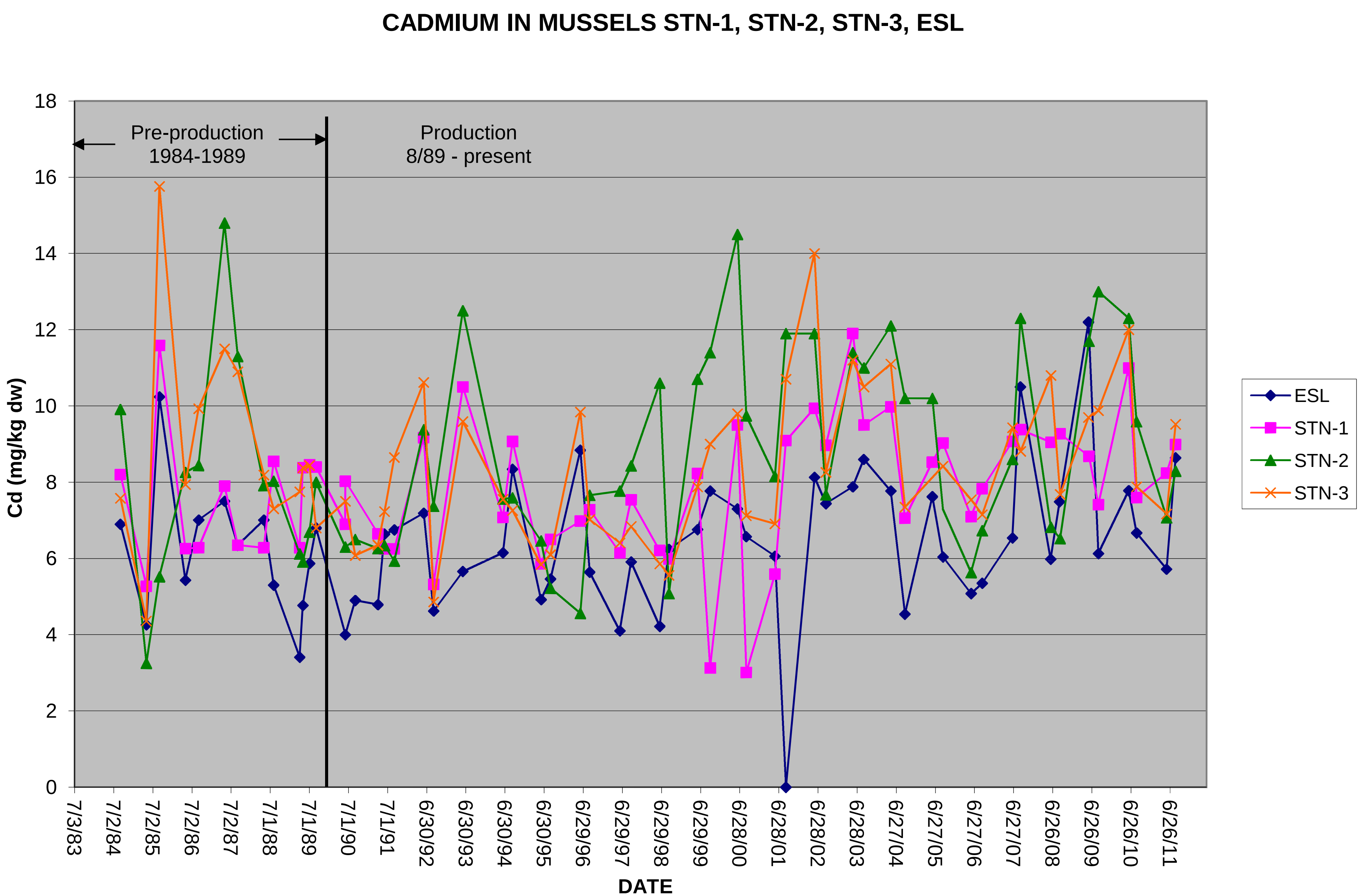
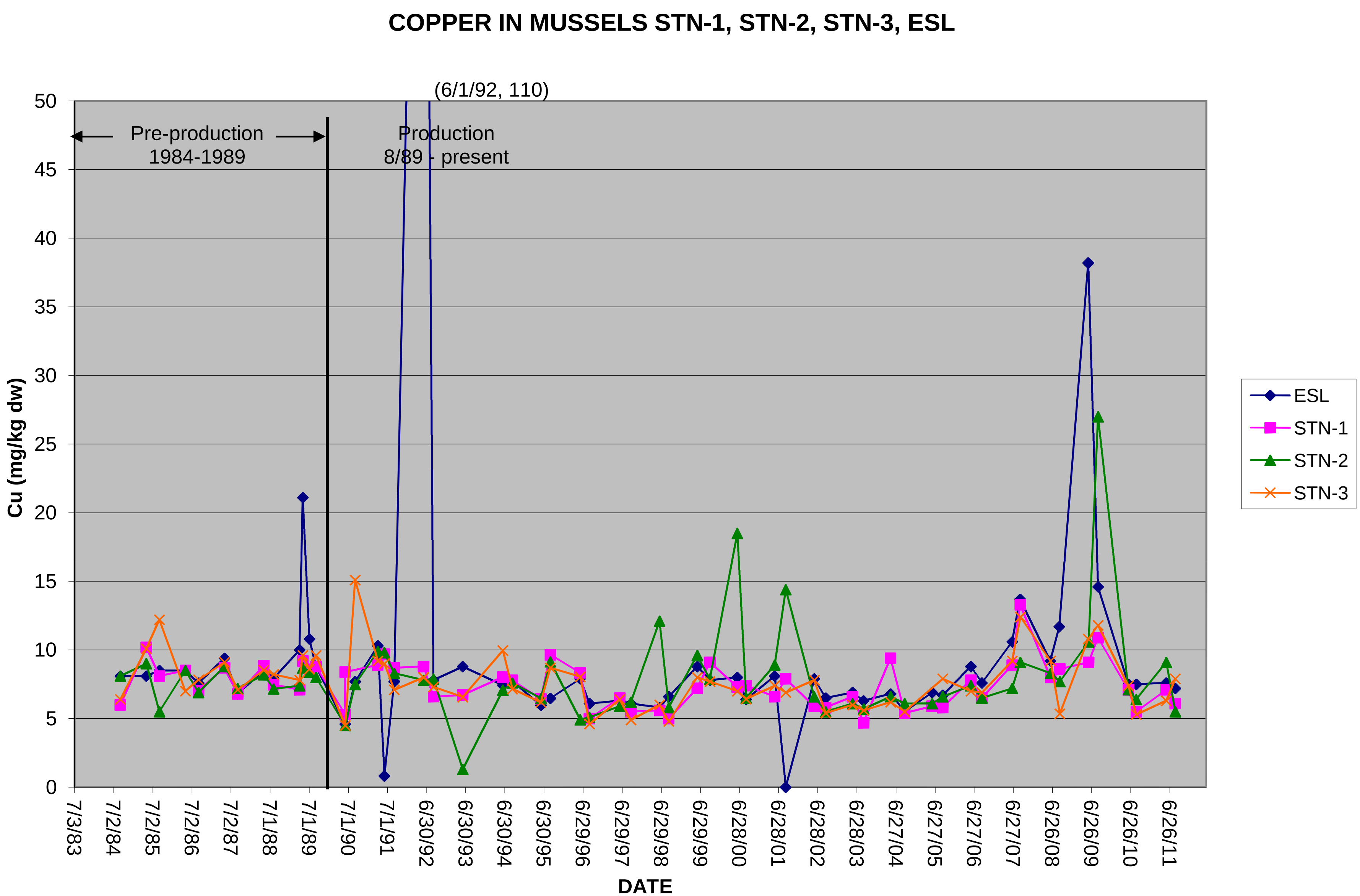

ZINC IN SEDIMENTS S-4, S-5S, S-5N
(6/1/92, 34800)
12000
10000
8000
6000
4000
2000
0
Zn (mg/kg dw)
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
6/25/12
DATE
S-4
S-5S
S-5N

FIGURE 4-1



CADMIUM IN MUSSELS STN-1, STN-2, STN-3, ESL
Pre-production
1984-1989
Production
8/89 - present
Cd (mg/kg dw)
18
16
14
12
10
8
6
4
2
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
ESL
STN-1
STN-2
STN-3

FIGURE 4-2



COPPER IN MUSSELS STN-1, STN-2, STN-3, ESL
(6/1/92, 110)
Pre-production
1984-1989
Production
8/89 - present
Cu (mg/kg dw)
50
45
40
35
30
25
20
15
10
5
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
ESL
STN-1
STN-2
STN-3

FIGURE 4-3

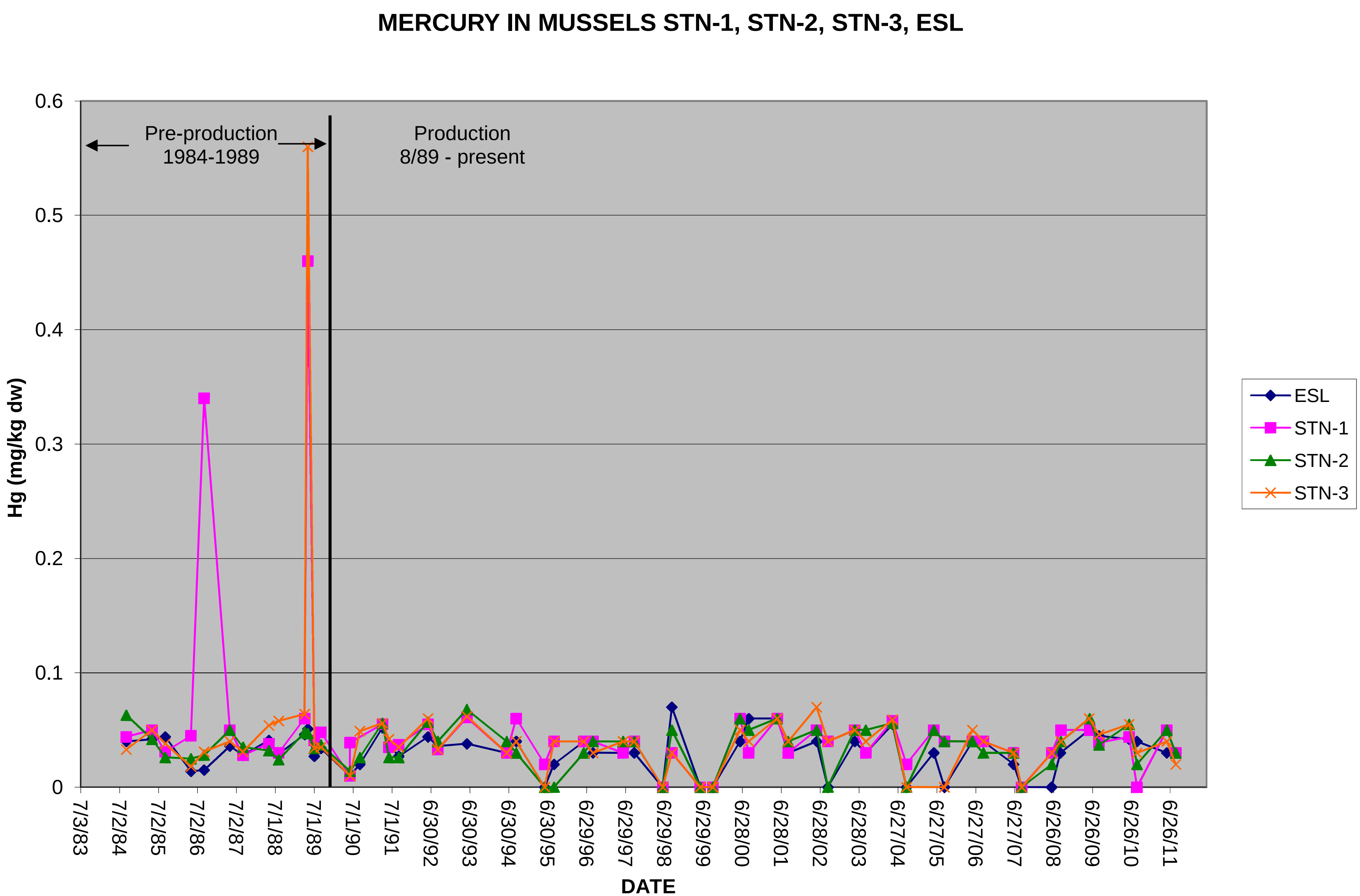
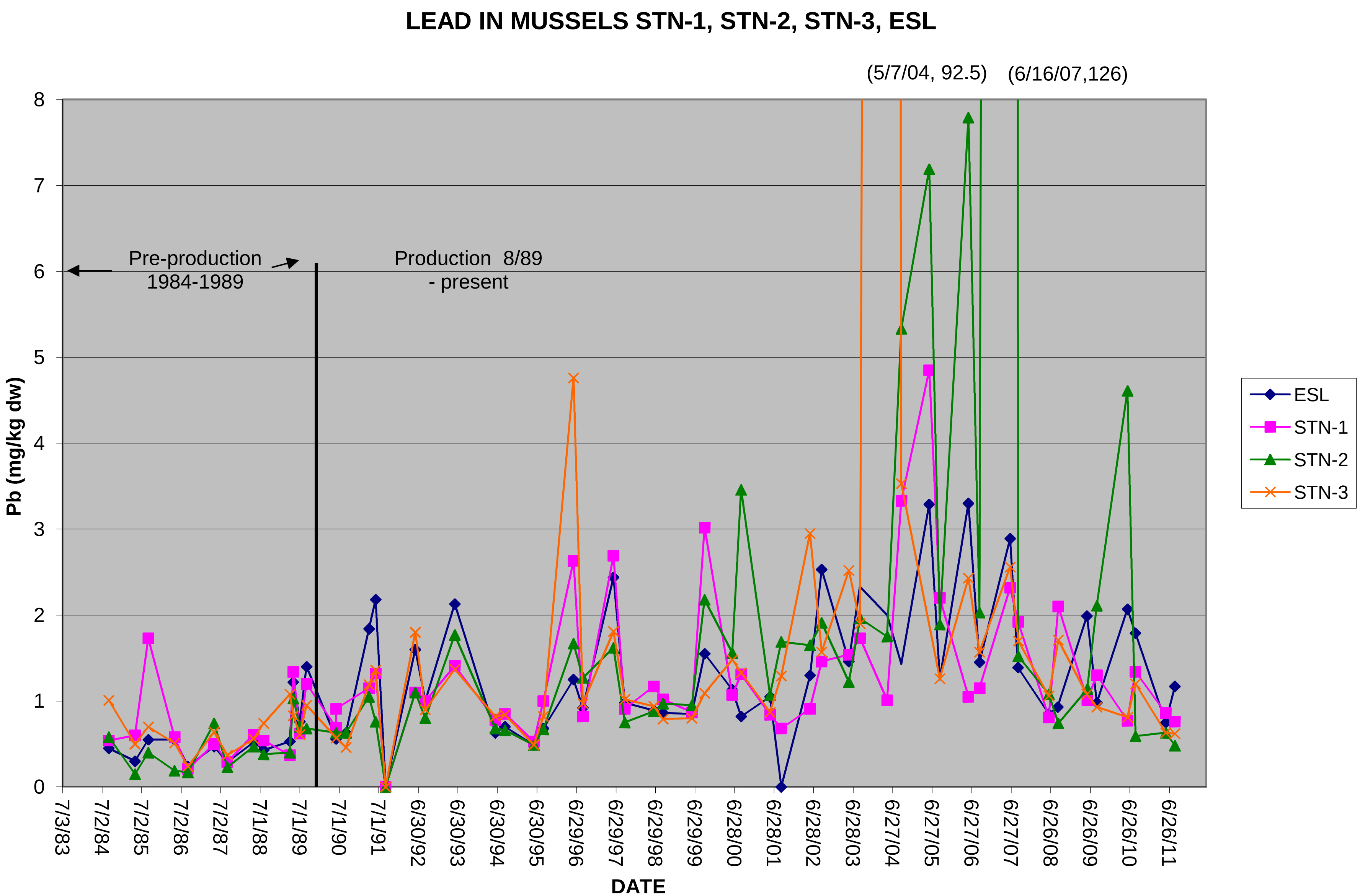
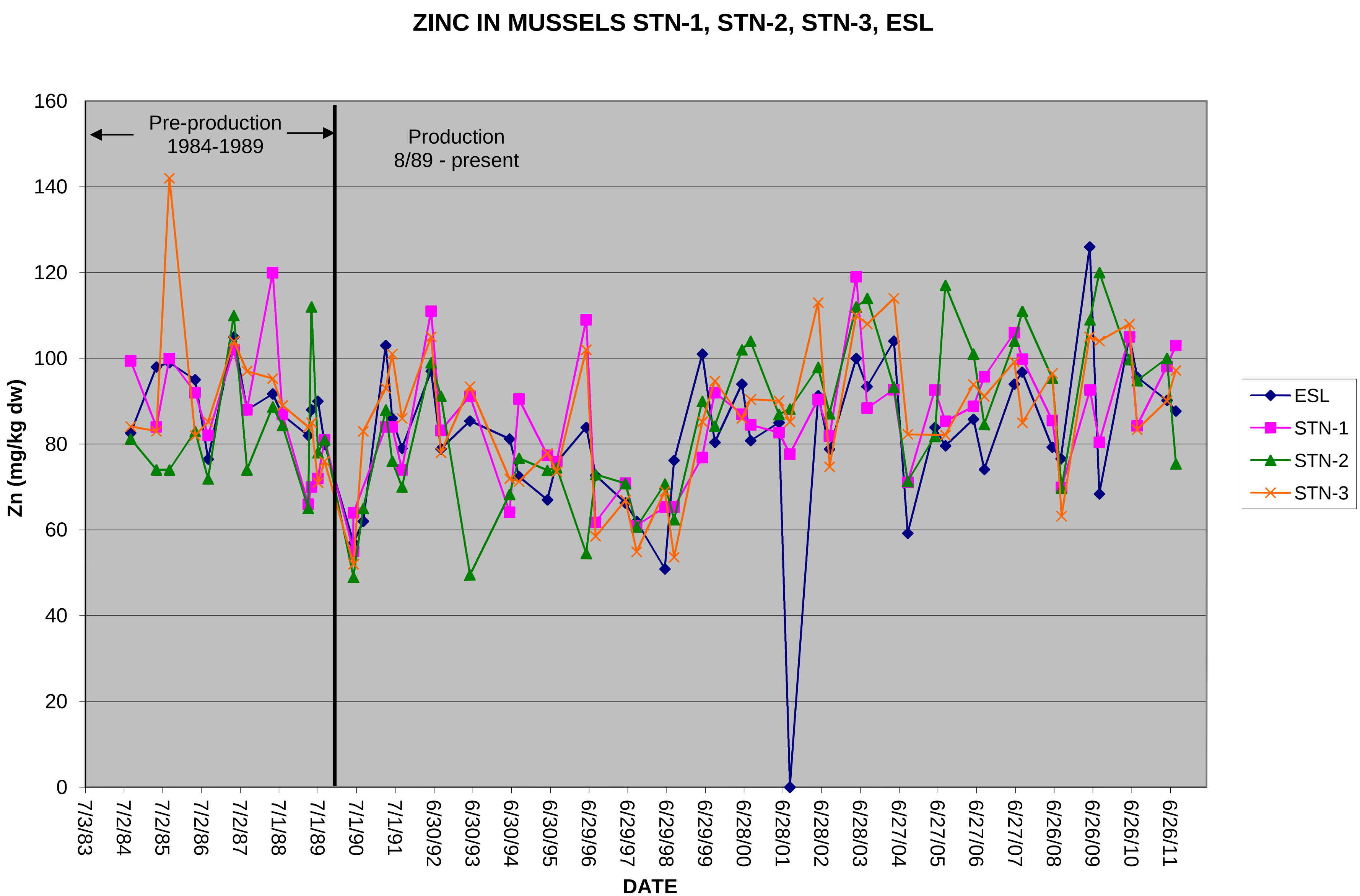

MERCURY IN MUSSELS STN-1, STN-2, STN-3, ESL
Hg (mg/kg dw)
0.6
0.5
0.4
0.3
0.2
0.1
0
Pre-production
1984-1989
Production
8/89 - present
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
ESL
STN-1
STN-2
STN-3

FIGURE 4-4



LEAD IN MUSSELS STN-1, STN-2, STN-3, ESL
(5/7/04, 92.5)
(6/16/07,126)
Pre-production
1984-1989
Production 8/89
- present
Pb (mg/kg dw)
8
7
6
5
4
3
2
1
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
ESL
STN-1
STN-2
STN-3

FIGURE 4-5



ZINC IN MUSSELS STN-1, STN-2, STN-3, ESL
Pre-production
1984-1989
Production
8/89 - present
Zn (mg/kg dw)
160
140
120
100
80
60
40
20
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
ESL
STN-1
STN-2
STN-3

FIGURE 4-6

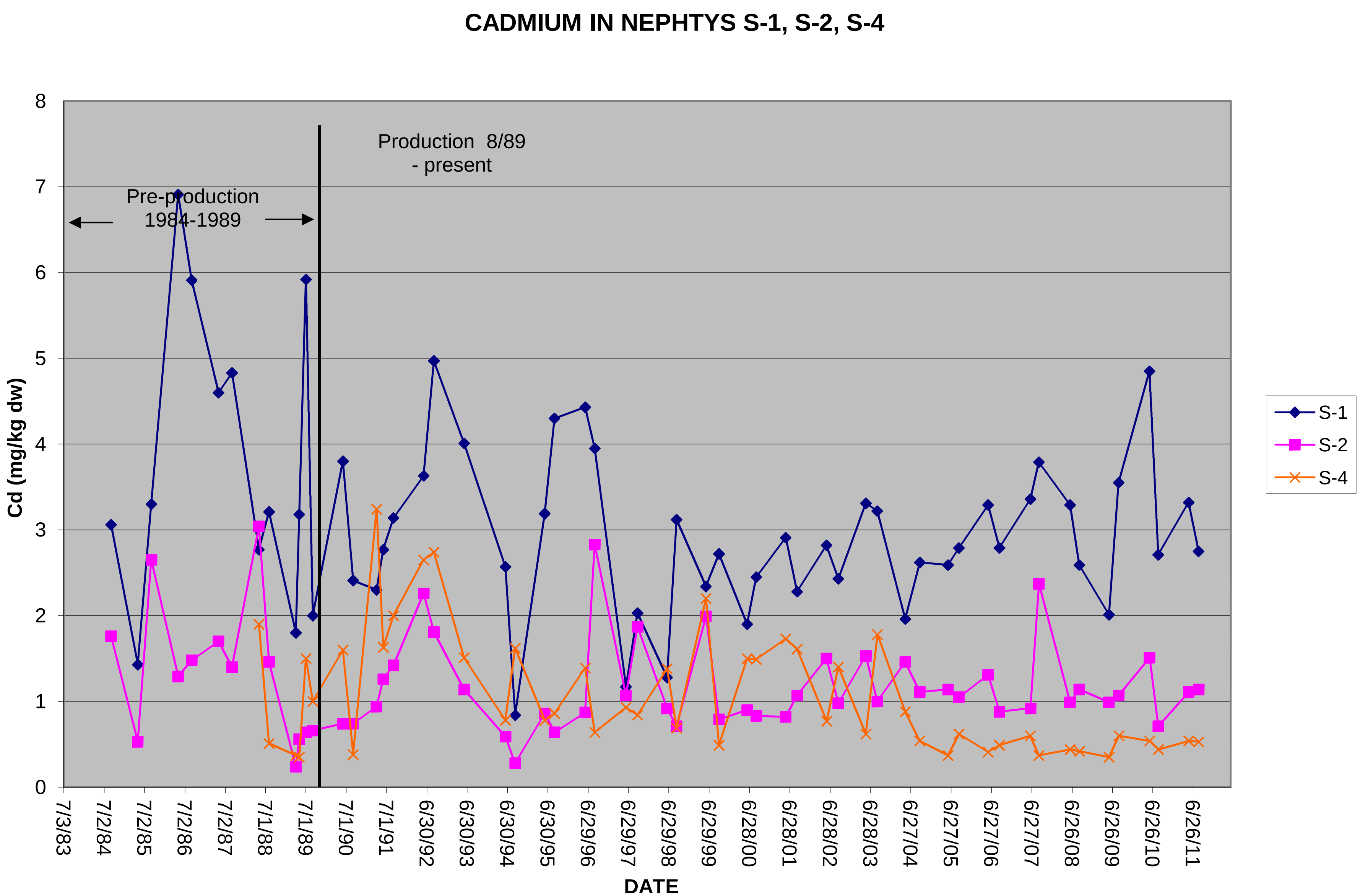
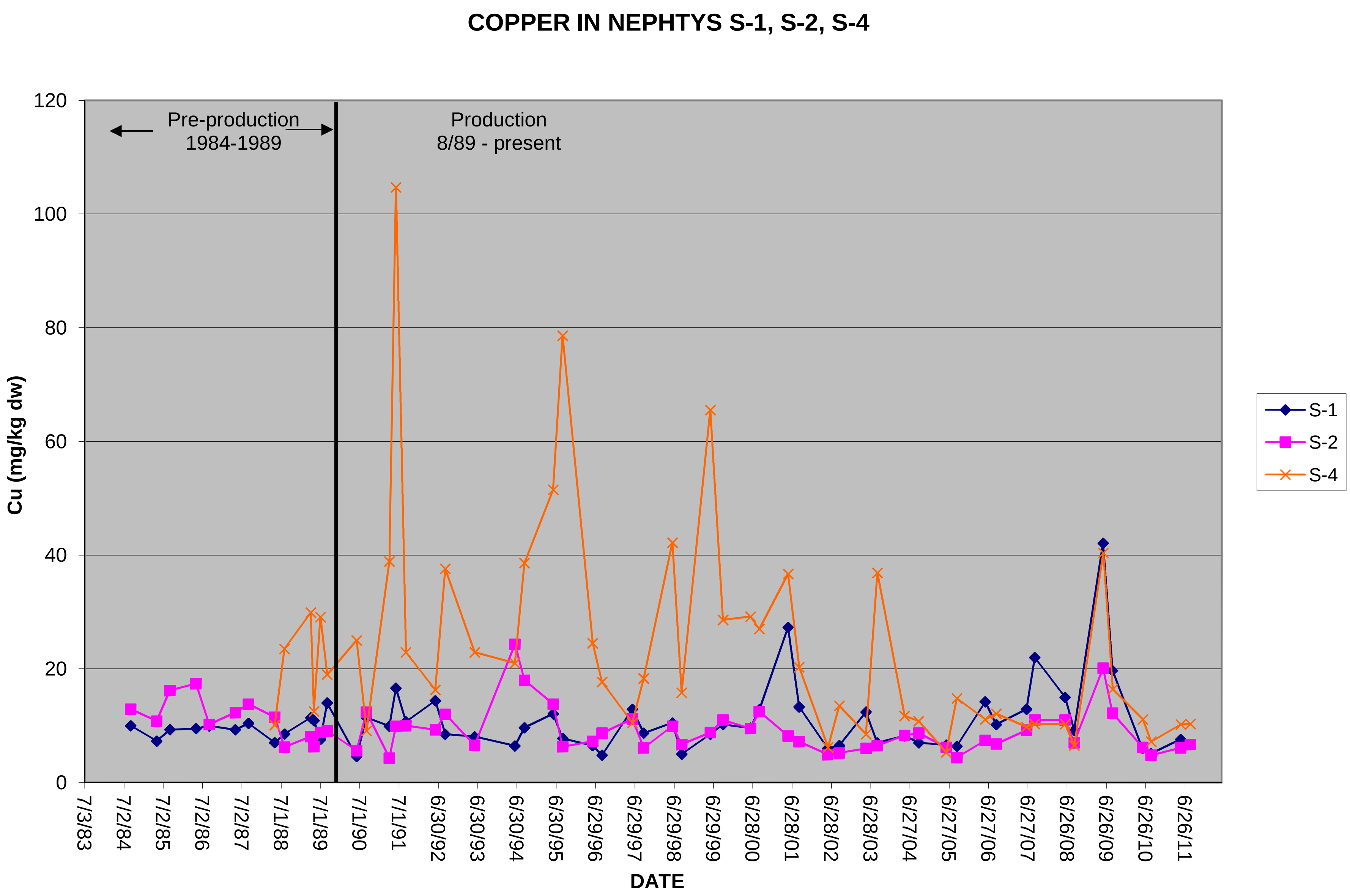

CADMIUM IN NEPHTYS S-1, S-2, S-4
Cd (mg/kg dw)
0
1
2
3
4
5
6
7
8
Production 8/89
- present
Pre-production
1984-1989
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
S-1
S-2
S-4

FIGURE 4-7



COPPER IN NEPHTYS S-1, S-2, S-4
Cu (mg/kg dw)
120
100
80
60
40
20
0
Pre-production
1984-1989
Production
8/89 - present
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
S-1
S-2
S-4

FIGURE 4-8

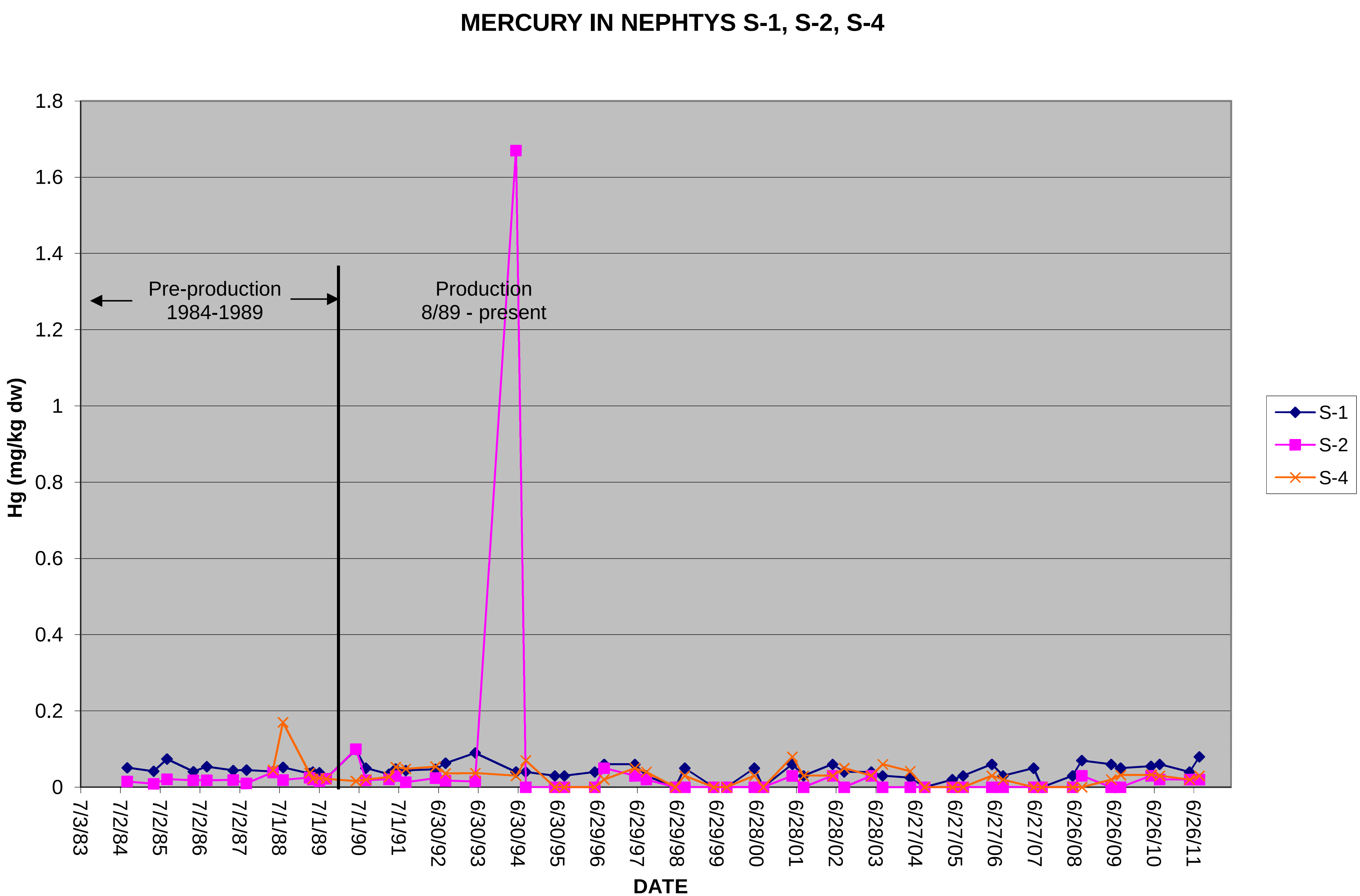

MERCURY IN NEPHTYS S-1, S-2, S-4
Pre-production
1984-1989
Production
8/89 - present
Hg (mg/kg dw)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
S-1
S-2
S-4

FIGURE 4-9

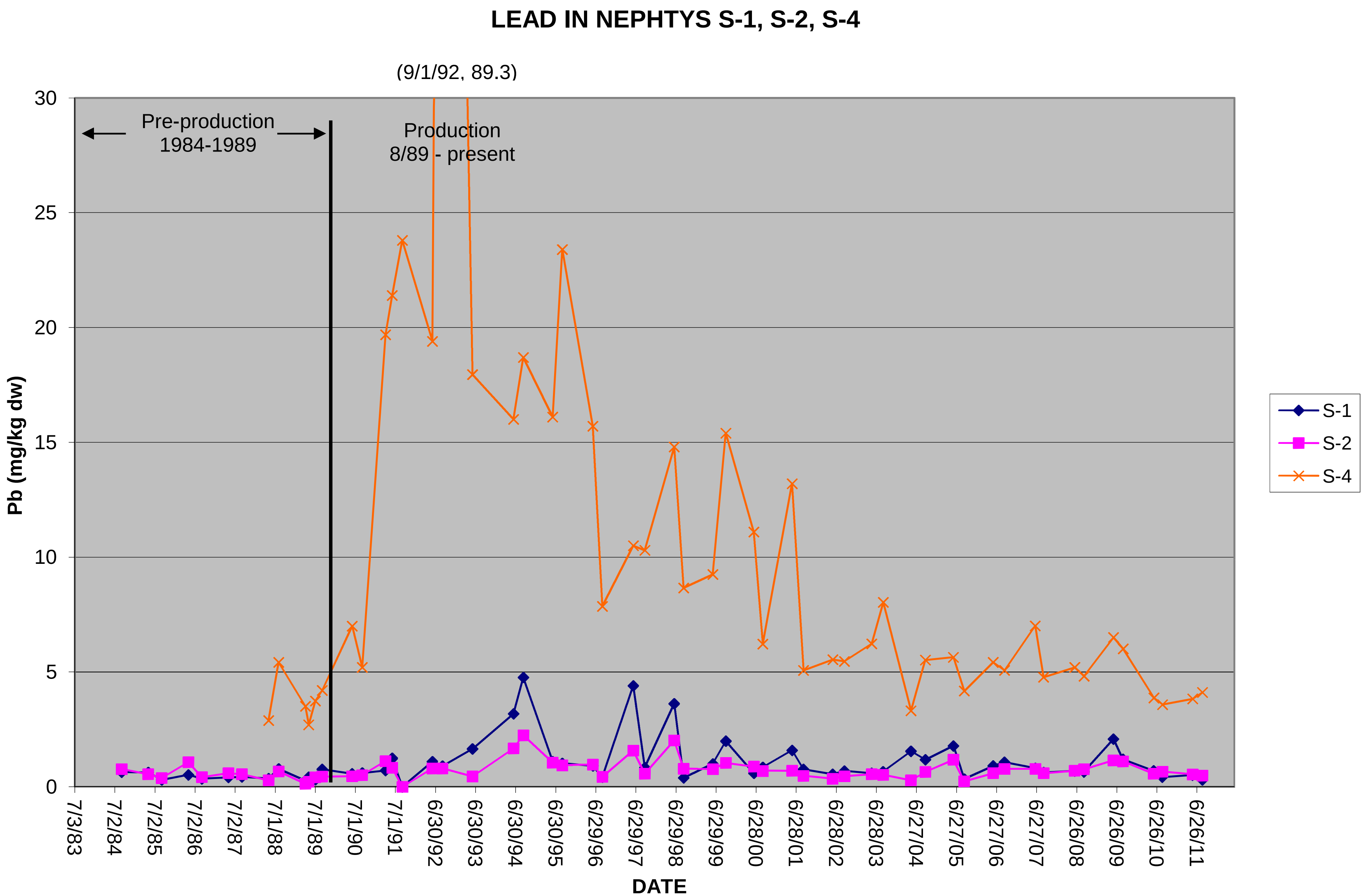
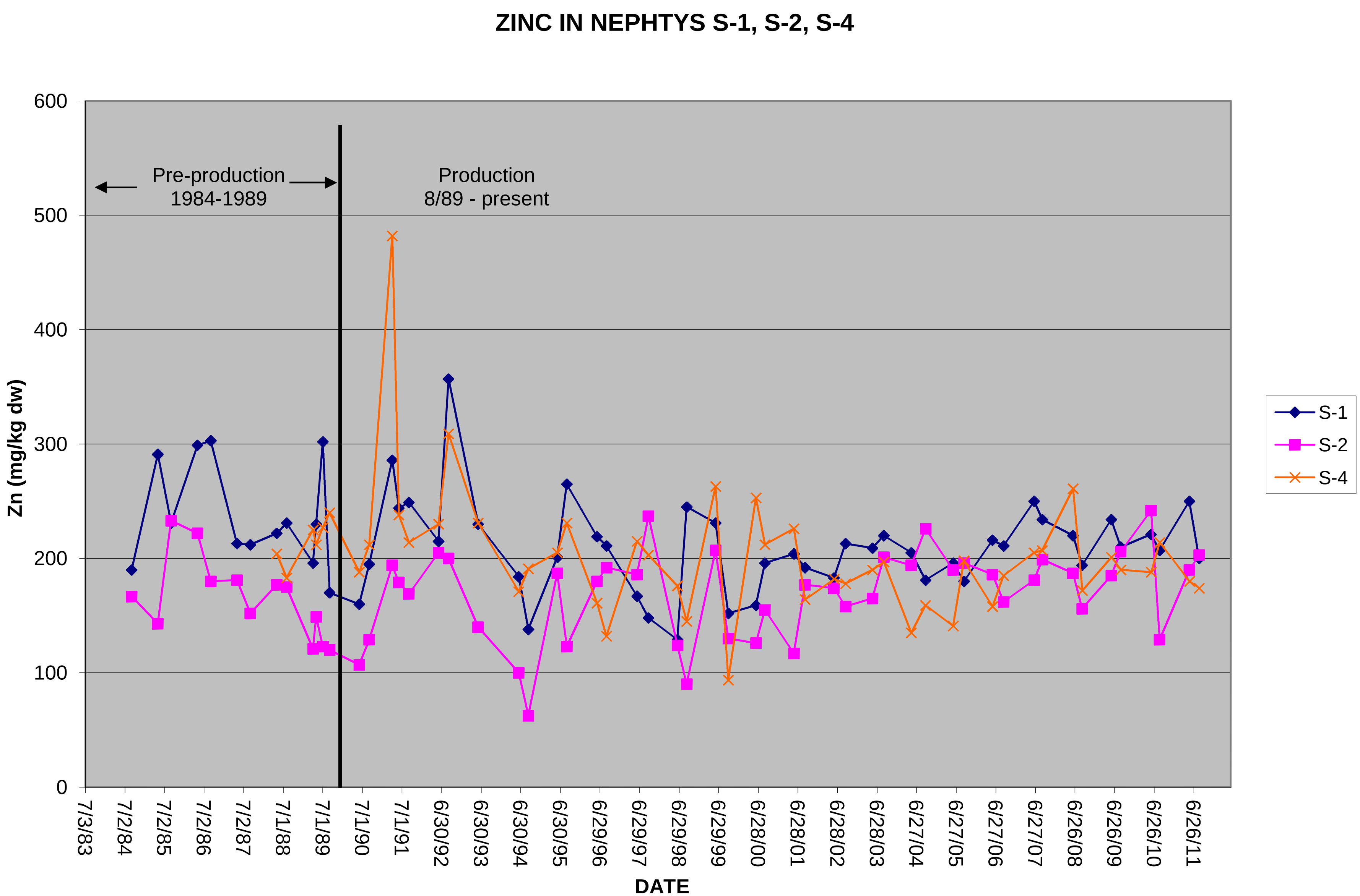

LEAD IN NEPHTYS S-1, S-2, S-4
(9/1/92, 89.3)
Pre-production
1984-1989
Production
8/89 - present
Pb (mg/kg dw)
0
5
10
15
20
25
30
DATE
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
S-1
S-2
S-4

FIGURE 4-10



ZINC IN NEPHTYS S-1, S-2, S-4
Zn (mg/kg dw)
600
500
400
300
200
100
0
Pre-production
1984-1989
Production
8/89 - present
7/3/83
7/2/84
7/2/85
7/2/86
7/2/87
7/1/88
7/1/89
7/1/90
7/1/91
6/30/92
6/30/93
6/30/94
6/30/95
6/29/96
6/29/97
6/29/98
6/29/99
6/28/00
6/28/01
6/28/02
6/28/03
6/27/04
6/27/05
6/27/06
6/27/07
6/26/08
6/26/09
6/26/10
6/26/11
DATE
S-1
S-2
S-4