Deer Island effluent characterization studies: January 1997-October 1997

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EXECUTIVE SUMMARY

The Massachusetts Water Resources Authority (MWRA) started to characterize the wastewater effluent of Deer Island Wastewater Treatment Plant (DIWTP) using "ultra-clean" techniques in November of 1991 as part of the Harbor and Outfall Monitoring program. This includes detection limits in the low part-per-trillion (ng/L) for certain organic compounds and low part-per-billion (µg/L) for trace metals. Nutrients, stable isotopes of nitrogen and sulfur, Clostridium perfringens spores, as well as influent to and effluent from the pilot treatment plant were measured from June of 1993 to December of 1995. Data from June 1993 to November 1994 is summarized in Hunt et al. (1995). Data from January to December of 1995 is summarized in Butler et al. (1997). This report summarizes the data collected in 1996 and 1997.

Composite samples of the DIWTP effluent were collected twice each month from January to June 1996, as well as August 1996. One composite sample was collected in March 1997, and composite samples were collected twice each month from April to July 1997. Eight samples were collected in September 1997, this included 4 influent and 4 effluent samples. Ten samples were collected in October 1997, with 4 influent samples, 4 effluent samples, and 2 samples from the secondary treatment battery. The samples were analyzed for silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), molybdenum (Mo), nickel (Ni), lead (Pb), and zinc (Zn); 20 polychlorinated biphenyl (PCB) congeners; C_{10} to C_{14} linear alkyl benzenes (LAB); 43 polynuclear aromatic hydrocarbons (PAH); and 17 chlorinated pesticides.

The range and averages of the trace metals and trace organic concentrations for 1996 and 1997 are summarized in Tables ES.1 and ES.2. The annual Deer Island loads of selected compounds from 1995 to 1997 are summarized in Table ES.3. Most values are expressed only to two significant figures. Certain treatment milestones reached during these monitoring periods had obvious effects on wastewater quality. A new primary treatment plant went on line in January 1995. Improvements as shown by removals of biochemical oxygen demand (BOD) and total suspended solids (TSS) became evident by June 1995. One out of three planned secondary treatment batteries became operational in August 1997, such that the DIWTP wastewater was receiving up to about 80% secondary treatment by September and October 1997, with obvious improvements in wastewater quality.

The Waterworks Division of MWRA started up an interim corrosion control facility in June 1996 with additions of carbon dioxide and sodium carbonate adjusted in stages in June 1996 and February 1997. The corrosion control program was initiated to control levels of copper and lead in drinking water. This may have contributed to some decreases in the drinking water lead

Table ES.1 Trace Metal Concentrations Measured in 1996 and 1997 (µg/L)

Metals	1996 Range	1996 Average	1997 Range	1997 Average
Ag	2.0 to 3.6	2.8	0.3 to 7.8	2.3
Cd	0.2 to 1.1	0.5	0.0 to 0.6	0.2
Cr	1.3 to 5.0	3.7	0.0 to 9.1	3
Cu	42.5 to 91.7	59.9	21.2 to 90.2	49
Hg	0.046 to 0.340	0.107	0.03 to 0.512*	0.19
Mo	6.1 to 22.1	12.1	5.1 to 16.8	11.3
Ni	3.7 to 8.0	5.2	3.5 to 11.8	6.2
Pb	4.8 to 12.5	7.9	3.1 to 7.5	5.6
Zn	53.7 to 78.7	67.3	21.8 to 62.2	52

**The mercury value of 0.512 µg/L could be an outlier. The 1997 average of Hg would be 0.147µg/L instead of 0.19 if this value were dropped.*

Table ES.2 Organic Concentrations Measured in 1996 and 1997 (ng/L)

Compound	1996 Range	1996 Average	1997 Range	1997 Average
Total PCB	0.0 to 35.9	9.5	0.0 to 24.6	11.5
Total LAB	2400 to 11,070	7200	56.2* to 12,410	8700
Total PAH	305* to 14,412	8500	1865 to 10,414	6700
Total DDT	0.0 to 25.0	4.6	0.0 to 11.9	4
Total Chlordane	0.0 to 32.0	7.5	0.0 to 17.0	4.9
Other Pesticides	0.0 to 32.5	8.2	0.0 to 26.0	10

**The total LAB value of 56.2 ng/L and the total PAH value of 305 ng/L are outliers. These values were not used for calculating annual averages.*

Table ES.3 Annual Deer Island Loads Measured from 1995 to 1997 (Kg/yr)

Compound	1995	1996	1997
Ag	1,300	1,000	700
Cd	170	160	80
Cr	5,200	1,400	870
Cu	21,000	21,000	15,000
Hg	33	38	60(40 to 47)*
Mo	4,500	4,200	3,400
Ni	2,100	1,900	1,900
Pb	3,800	3,000	1,700
Zn	25,000	25,000	16,000
Total PCB	17.3	3.1	3.9
Total LAB	3,400	1,800	1,700
Total PAH	5,800	3,100	2,200
Total DDT	3.7	2.8	1.5
Total Chlordanes	2.2	1.3	1.8
Other Pesticides	5.3	2.9	3.4

**47 Kg/yr is the estimated Deer Island Hg load if the 0.512 µg/L value was dropped. 40 Kg/yr is the estimated Deer Island Hg load if in addition the September 22 and 24 samples were mislabeled. See discussion in text.*

concentrations but the decrease of copper in wastewater influent is not as obvious. The future use of zinc polyphosphate for corrosion control is being considered and is of some concern with respect to its impact on wastewater and residual quality.

The second of the three planned secondary treatment batteries came on line by the end of January 1998. Wastewater from the Nut Island treatment plant is scheduled to be sent to Deer Island via the inter-harbor tunnel by May 1998. The new offshore outfall is scheduled to be operational by the end 1998.

The trace metal concentrations in DIWTP effluent is fairly typical compared to municipal wastewater effluents in the northeast. The levels show in general either decreasing trends (some due to treatment improvements) or relatively consistent levels since monitoring with low detection limits commenced. Ag, Cd, Pb and Zn all show decreasing trends. Cr and Ni remain at fairly constant levels (note that the annual Cr load in 1995 was elevated due to a single, very high concentration value measured in the effluent). Cu and Hg are mentioned in the Draft NPDES permit as prameters that require monthly reporting for the future discharge. Cu in 1996 and 1997 were always below the acute water quality criteria adjusted for dilution (120 µg/L). There is some indication that Cu levels tend to increase in the summer months, and may reflect increased corrosion due to warming and/or addition of copper sulfate in source waters for algae control. Hg in 1996 and 1997 were always below the chronic water quality criteria adjusted for dilution (0.79 µ g/L), the increase in 1997 may have been due to hospital clean-up operations. Mo shows a clear seasonal pattern with a peak in the summer (as observed previously), consistent with its use in cooling towers as a biocide.

The new primary treatment plant apparently improved the removal of all measured organics. The most common PCB compounds in effluent are congeners 118 and 153. Concentrations of individual congeners tend to be less than 10 ng/L. C_{10} and C_{11} compounds dominate the total LAB measured. The major PAH compounds in both the influent and effluent are the low molecular weight compounds (naphthalene and substituted naphthalene compounds). The major DDT detected is 4,4'-DDT, followed by 4,4'-DDE and 2,4'-DDD. Individual compounds tend to be less than 10 ng/L although one measured 4,4'-DDT value in April 1996 was 25 ng/L (still less than chronic water quality criteria adjusted for dilution of 0.06 µg/L = 60 ng/L) . The Chlordanes detected are alpha-chlordane and trans-nonachlor. The other most commonly observed pesticide is lindane (γ-BHC). They all occur at concentrations much less than published chronic water quality criteria adjusted for dilution. Secondary treatment had a pronounced effect on the removal of total PAH and DDT. However, total PCB and pesticides remain at low but constant levels.

All measured Deer Island wastewater contaminant loads from 1995 to 1997 showed a decreasing trend except for Hg, total PCB and total chlordanes. The increase in Hg could have been due to maintenance operations of hospitals as discussed further in the report. Dropping the Hg outlier value of 0.512 µg/L made the increase much less apparent. The increases in total PCB and chlordanes are fairly small and are at very low levels, which may reflect inherent variability due to these low level analyses.

The total MWRA effluent loading to Boston Harbor from both Deer Island and Nut Island wastewater treatment plants has been calculated by increasing the Deer Island wastewater effluent load by a factor of 1.5, based on flow assumptions discussed in Hunt et al. (1995) and Butler et al. (1997). Table ES.4 summarizes these loads and the projected load based on the ten wastewater effluent samples taken in September and October 1997 and a flow of 373 MGD (based on the average of both Deer Island and Nut Island wastewater flows from 1995 to 1997). These samples represent wastewater that has received 80% to 100% secondary treatment.

It can be seen that the projected wastewater discharge from Deer Island, after full secondary treatment, is of excellent quality with respect to the toxic contaminants that were measured. The projected concentrations and loads are consistent with the Draft NPDES permit findings that there is no reasonable concern that MWRA's discharge will cause, or contribute to, any exceedance of water quality standards with respect to the constituents reported here. There is a concern regarding PCBs due to the extremely low human health criteria. The PCB issue is complex and is related to the risk assessment methodology, current receiving water conditions, and issues with chemical measurements (aroclors versus congeners). The issue is not dealt with in this report.

Table ES.4 Annual MWRA Loads Measured from 1995 to 1997(expressed with two significant figures) and Projected Secondary Treatment Effluent Characteristics

Compound	1995 (Kg/yr)	1996 (Kg/yr)	1997 (Kg/yr)	Projected for Secondary (Kg/yr)	Projected for Secondary (µg/L)
Ag	1,900	1,500	1,000	620	1.2
Cd	260	240	110	21	0.04
Cr	7,900	2,000	1,300	490	0.95
Cu	31,000	32,000	22,000	14,000	26
Hg	50	57	90(71)	50	0.096
Mo	6,800	6,300	5,100	6,800	13.3
Ni	3,100	2,900	2,900	2,400	4.6
Pb	5,800	4,500	2,600	2,400	4.7
Zn	37,000	38,000	24,000	14,000	26.7
Total PCB	26	4.7	5.9	4.8	0.0093
Total LAB	5,100	2,700	2,600	1,900	3.594
Total PAH	8,700	4,700	3,300	1,400	2.728
Total DDT	5.6	4.2	2.3	0.67	0.0013
Total Chlordanes	3.3	2	2.7	0.48	0.00094
Other Pesticides	7.9	4.3	5.1	5	0.0096

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1.0 INTRODUCTION

The people of the metropolitan Boston area, through the Massachusetts Water Resources Authority (MWRA), are in the midst of an ambitious program to upgrade their sewage treatment facilities and improve the quality of Boston Harbor. This program includes the elimination of sludge discharge into the harbor, construction of new primary and secondary sewage treatment plants on Deer Island, conveyance of wastewater from the southern metropolitan area (now treated at Nut Island) to Deer Island via the inter-island tunnel, and relocation of the current effluent discharges in Boston Harbor to a new location in Massachusetts Bay. The effluent discharge relocation will be facilitated by a 9.5 mile long undersea tunnel and 55 release points known as diffusers.

1.1 Treatment Milestones

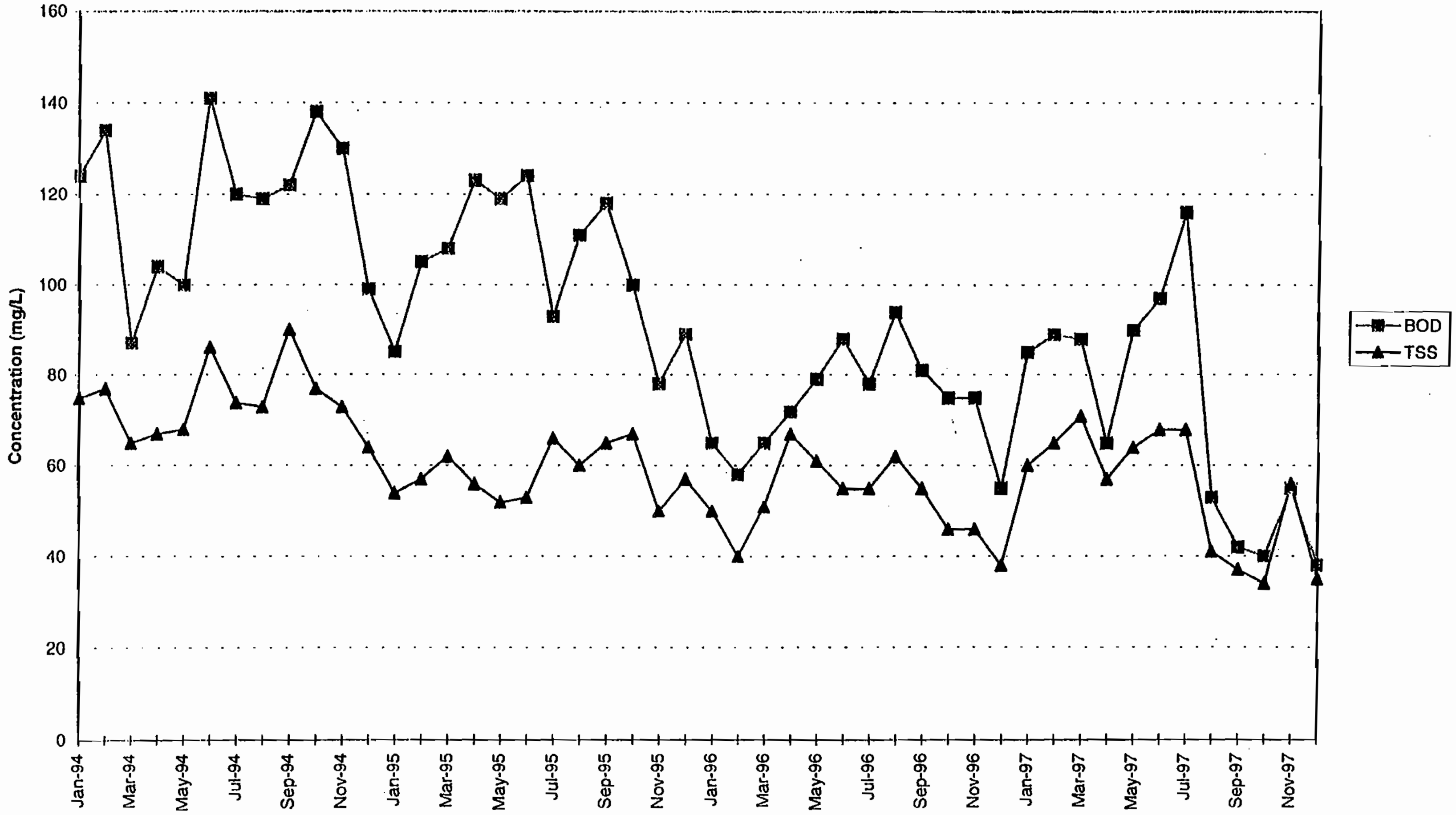
In December 1991, MWRA ended the practice of sludge discharge into Boston Harbor. It is now being recycled into fertilizer pellets at the sludge processing plant at the former site of the Fore River shipyard in Quincy. The new Deer Island primary treatment plant went into operation in early 1995, resulting in lower concentrations of biochemical oxygen demand (BOD) and total suspended solids (TSS) in wastewater effluent. Another major milestone was reached when the first of three planned secondary treatment batteries went on line at Deer Island in August 1997. Another battery of secondary treatment went on line in late January 1998. Figure 1 shows the improving wastewater effluent quality as measured by monthly average BOD and TSS values.

Regarding drinking water, an interim corrosion control facility went into operation at Marlboro in 1996. The pH and alkalinity of drinking water were increased to 7.5 and 20 mg/l as ($CaCO_3$) respectively, in June of 1996. These values increased further to 7.8 and 30 mg/l in February 1997. The increases were achieved by the addition of sodium hydroxide and sodium bicarbonate. The corrosion control program was put in place to reduce the concentrations of copper and lead in drinking water in response to Safe Drinking Water Act requirements. Sampling of tap water showed decreases in Pb levels, but not in Cu levels. The future use of zinc polyphosphates to control corrosion is also being contemplated, however the impact of this chemical on wastewater and residual quality needs to be evaluated carefully.

1.2 Effluent Monitoring

The current effluent program monitors nutrients, organic material, toxic contaminants, pathogens, solids, and oil and grease. The primary goal of the program is to ensure that discharge effluent

Figure 1
BOD & TSS of Deer Island Wastewater Effluent



meets required limitations as regulated by the National Pollutant Discharge Elimination System (NPDES) permit. An Outfall Monitoring Task Force (OMTF) was formed at the direction of the Massachusetts Executive Office of Environmental Affairs (EOEA) to provide guidance and recommendations on the overall MWRA harbor and bay monitoring program. The OMTF recognized the need to supplement the NPDES monitoring with more detailed effluent characterization studies (DECS). The purpose for DECS as described in the 1991 Baseline Studies is:

- Provide data on influent and effluent contaminant concentrations at part-per-trillion levels along with estimates of short-term (day to week) and long-term (month to year) variability.
- Identify unique tracers of sewage in the environment in order to provide non-routine data for effluent transport and fate modeling.

1.3 Studies from 1991 to 1995

MWRA sampled the Deer and Nut Island influent and effluent on 3 consecutive days in November 1991 (November 13, 14 and 15) and 3 alternate days in June 1992 (June 10, 12 and 14). 24 polynuclear aromatic hydrocarbons (PAH) , 12 pesticides and total polychlorinated biphenyls (PCB) were analyzed with reporting limit of 10 ng/L. The results of this study are available in MWRA (1993).

Bimonthly 24-hour composite samples of the Deer Island effluent were collected between June 1993 and November 1994. The samples collected between June and November 1993 were analyzed for Ag, Cd, Cr, Cu, Hg, Ni, Pb and Zn; an extended list of 40 PAH compounds; C_{10} to C_{14} linear alkyl benzenes (LAB); 20 PCB congeners; and 16 persistent chlorinated pesticides. Starting in December 1993, composite samples were also analyzed for *Clostridium perfringens* spores, and Mo, and grab samples for stable isotopes of nitrogen and sulfur. Also beginning in December 1993, grab samples were collected for nutrient analysis (NH_4, NO_2, NO_3, total dissolved inorganic nitrogen, particulate organic nitrogen, PO_4, total dissolved phosphorus, particulate organic phosphorus, dissolved silica, biogenic silica, dissolved and particulate organic carbon). The pilot plant influent plus the effluents of the primary and secondary treatment channels were sampled during five test events in 1993 and 1994 and analyzed for the same set of analytes described above. Detailed results of this study are available in Uhler et al. (1994) and Hunt et al. (1995).

In 1995, bimonthly monitoring of the Deer Island wastewater effluent resumed. Additionally, influent to the 1 MGD pilot treatment plant, as well as primary and secondary effluents from the pilot plant, were sampled monthly (except for February and April). The list of analytes are similar to the 1993/94 study except that the list of PAH compounds had increased to 43; the compound DDMU was added to the list of pesticides. Urea was also added to the list of nutrients. Discrete grab samples were collected for all nutrient analyses. Detailed results of these studies are available in Butler et al. (1997).

1.4 Work in 1996 and 1997

In 1996, the OMTF suggested reducing the frequency of DECS to quarterly. This was based on the results observed from 1993/94 to 1995. This report focuses on the years 1996 and 1997, with a reduced frequency of sampling, as well as a smaller number of parameters analyzed. Table 1 summarizes the collection dates, sample type, flow rate observed for the day of collection (for load calculation) and the bottle identification numbers. The actual compounds analyzed are summarized in Table 2. It was noted that the copper measurement was unusually high on August 16, 1996 (E96G2BA), and was attributed to the improper use of a copper fitting for sampling. The same sampling date also produced anomalous low results for the PAH measurements (E96G2AA). The total LAB value of 56 ng/L observed for the sample collected on September 24, 1997 (E97I5AA) is suspiciously low and results were not included for calculations. The mercury measurement for the sample collected on May 7, 1997 (EE97E1BA) is suspiciously high and not corroborated by independent sampling and analysis by the Dear Island laboratory. This still allowed for a total of 38 measurements for organics, and 40 samples for trace metals. The sampling in September and October 1997 included 8 influent and 2 effluent samples from the secondary treatment battery. The actual number of samples used for averaging and load calculations are 38 for organics (13 for 1996 and 25 for 1997), and 40 for trace metals (13 for 1996 and 27 for 1997).

Table 1 Samples Collected in 1996 and 1997

Collection Date	Type	Flow (MGD)	Organics Bottle ID	Metals Bottle ID
01/10/96	Effluent	203	E96A1AA	E96A1BA
01/12/96	Effluent	211	E96A2AA	E96A2BA
02/14/96	Effluent	306	E96B1AA	E96B1BA
02/16/96	Effluent	257	E96B2AA	E96B2BA
03/13/96	Effluent	283	E96C1AA	E96C1BA
03/15/96	Effluent	310	E96C2AA	E96C2BA
04/10/96	Effluent	299	E96D1AA	E96D1BA
04/12/96	Effluent	418	E96D2AA	E96D2BA
05/15/96	Effluent	246	E96E1AA	E96E1BA
05/17/96	Effluent	343	E96E2AA	E96E2BA
06/12/96	Effluent	218	E96F1AA	E96F1BA
06/14/96	Effluent	214	E96F2AA	E96F2BA
08/14/96	Effluent	226	E96G1AA	E96G1BA
08/16/96	Effluent	196	E96G2AA*	E96G2BA*
03/05/97	Effluent	221	E97C1AA	E97C1BA
04/09/97	Effluent	397	Not taken	E97D1BA
04/11/97	Effluent	339	E97D2AA	E97D2BA
05/07/97	Effluent	276	E97E1AA	E97E1BA *
05/09/97	Effluent	249	E97E2AA	E97E2BA
06/04/97	Effluent	226	Not taken	E97F1BA
06/06/97	Effluent	223	E97F2AA	E97F2BA
07/09/97	Effluent	188	E97G1AA	E97G1BA
07/11/97	Effluent	193	E97G2AA	E97G2BA
09/22/97	Influent	188	E97I1AA	E97I1BA
09/22/97	Effluent		E97I2AA	E97I2BA
09/24/97	Influent	181	E97I4AA	E97I4BA
09/24/97	Effluent		E97I5AA*	E97I5BA
09/26/97	Influent	180	E97I7AA	E97I7BA
09/26/97	Effluent		E97I8AA	E97I8BA
09/29/97	Influent	178	E97IAAA	E97IABA
09/29/97	Effluent		E97IBAA	E97IBBA
10/01/97	Influent	192	E97J1AA	E97J1BA
10/01/97	Effluent		E97J2AA	E97J2BA
10/03/97	Influent	178	E97J4AA	E97J4BA
10/03/97	Effluent		E97J5AA	E97J5BA
10/15/97	Influent	178	E97J7AA	E97J7BA
10/15/97	Secondary Battery Effluent		E97J8AA	E97J8BA
10/15/97	Effluent		E97J9AA	E97J9BA
10/17/97	Influent	176	E97JAAA	E97JABA
10/17/97	Secondary Battery Effluent		E97JBAA	E97JBBA
10/17/97	Effluent		E97JCAA	E97JCBA

*These samples showed some anomalous results for certain parameters, see discussion in text.

Table 2 Effluent Chemistry Analytes

Metals

Ag silver
Cd cadmium
Cu copper
Cr chromium
Hg mercury
Mo molybdenum
Ni nickel
Pb lead
Zn zinc

Polychlorinated biphenyls

2,4,-Cl_2(8)
2,2′,5-Cl_3(18)
2,4,4′-Cl_3(28)
2,2′,3,5′-Cl_4(44)
2,2′,5,5′-Cl_4(52)
2,3′,4,4′-Cl_4(66)
3,3′,4,4′-Cl_4(77)
2,2′4,5,5′-Cl_5(101)
2,3,3′,4,4′-Cl_5(105)
2,3′,4,4′5-Cl_5(118)
3,3′,4,4′,5-Cl_5(126)
2,2′,3,3,4,4′-Cl_6(128)
2,2′,3,4,4′,5-Cl_6(138)
2,2′4,4′,5,5′-Cl_6(153)
2,2′3,3,4,4′,5-Cl_7(170)
2,2′,3,4,4′,5,5′-Cl_7(180)
2,2′,3,4,5,5′,6-Cl_7(187)
2,2′,3,3′,4,4′,5,6-Cl_8(195)
2,2′,3,3′4,4′,5,5′,6-Cl_9(206)
Decachlorobiphenyl-Cl_{10}(209)

Linear alkyl benzenes (LAB)

phenyl decanes
phenyl undecanes
phenyl dodecanes
phenyl tridecanes
phenyl tetradecanes

Polynuclear aromatic hydrocarbons (PAH)

naphthalene
C_1-naphthalenes
C_2-naphthalenes
C_3-naphthalenes
acenaphthylene
acenaphthene
fluorene
C_1-fluorenes
C_2-fluorenes
C_3-fluorenes

PAH (continued)

anthracene
phenanthrene
C_1-phenanthrenes/anthracene
C_2-phenanthrenes/anthracene
C_3-phenanthrenes/anthracene
C_4-phenanthrenes/anthracene
dibenzothiophene
C_1-dibenzothiophenes
C_2-dibenzothiophenes
C_3-dibenzothiophenes
fluoranthene
pyrene
C_1-fluoranthenes/pyrenes
benzo[*a*]anthracene
chrysene
C_1-chrysene
C_2-chrysene
C_3-chrysene
C_4-chrysene
benzo[*b*]fluoranthene
benzo[*k*]fluoranthene
benzo[*a*]pyrene
dibenzo[*a,h*]anthracene
benzo[*g,h,i*]perylene
indeno[1,2,3-*c,d*]pyrene
perylene
biphenyl
benzo[*e*]pyrene
dibenzofuran
benzothiazole

Pesticides

hexachlorobenzene
lindane
heptachlor
aldrin
endrin
heptachlorepoxide
alpha-chlordane
trans-Nonachlor
dieldrin
mirex
o,p′-DDD
p,p′-DDD
o,p′-DDE
p,p′-DDE
o,p′-DDT
p,p′-DDT
DDMU

2.0 METHODOLOGY

2.1 Sample Collection

From January 1996 through October 1997, MWRA collected effluent samples from the Deer Island wastewater treatment plant (see Table 1 for actual collection dates). 24-hour composite samples were collected using Isco automated samplers. The composite samples were subsampled as follows:

- 500 mL for trace metal analysis (Ag, Cd, Cr, Cu, Mo, Ni, Pb, Zn)
- 500 mL for Hg analysis
- 2.5 L for trace organic analysis (PAH, pesticides and PCB)

The composite samples were stored on ice and shipped by courier to Envitec Laboratory for trace metal analysis and the Arthur D. Little Laboratory for trace organic analysis. All bottles for trace metal and Hg analysis were rigorously pre-cleaned in dilute, high-purity acids to ensure that extraneous contaminants were not present prior to sample collection. Sample-preserving acids were included in the bottles for metals before transferring to the control of MWRA. Samples for organic analysis were collected in 2.5-L amber glass I-Chem bottles.

2.2 Sample Analysis

The analytical methods are described in detail in Butler et al. (1995) and briefly summarized below. Method detection limit (MDL) goals are listed in Table 3 and compared against standard NPDES MDL and national water quality criteria.

Trace Metals: For all metals except Hg, 100 mL of the sample was spiked with 1 mL of hydrochloric acid and 1 mL of nitric acid. The sample volume was then reduced to about 10-20 mL by evaporation. The solution was then filtered through a Nuclepore 0.4 µm membrane and brought back to 100 mL. Ag, Cd, Cr, Cu, Mo, Ni, Pb and Zn concentrations were determined by inductively coupled plasma mass spectrophotometry (ICP-MS). Samples for Hg analysis were prepared by digesting approximately 50 mL of sample with $KMnO_4$ and $K_2S_2O_8$ and reduced to elemental Hg using $SnCl_2$. The reduced Hg was then extracted by volatilization and measured using cold vapor atomic absorption spectroscopy (CVAAS). Required MDL for the effluent were consistently met except Cd were non-detect in the secondary effluent.

Organic Contaminants: Samples for organic analysis were extracted following EPA Method 3510. Each effluent sample was transferred to a 3-L separatory funnel. The sample bottle was

Table 3 Method Detection Limit (MDL) Goals

Parameter	MDL Goal[1]	NPDES MDL[2]	Water Quality Criteria[3]
Metals	(µg/L)	(µg/L)	(µg/L)
Ag	0.50	1.0	2.3
Cd	0.50	2.0	9.3
Cu	0.50	10.0	2.9
Cr	1.0	3.0	50.0[4]
Hg	0.005	0.05	0.025
Mo	0.50	5.0	NA
Ni	1.00	8.0	8.3
Pb	0.50	2.0	5.6
Zn	2.00	6.0	86
Organic Analytes	(ng/L)	(ng/L)	(ng/L)
PCBs	1	500	30
LABs	50	NA	NA
PAH	10	10,000	16-710
Pesticides	1	20	1-30

[1] MDL goals are based on past project performance and the goal of detecting concentrations extant in the effluent or at least 5 times less than the corresponding lowest salt water aquatic life criteria.

[2] NPDES MDLs reported by MWRA in their NPDES monitoring reports; the listed MDLs are lower than Contract Laboratory Program (CLP) requirements.

[3] Water quality criteria listed are the lowest salt water aquatic life criteria published by EPA. Criteria listed for PAH and pesticides are the range of individual values; PAH criteria are lowest observed effects levels. Human health criteria are generally lower than the aquatic life criteria.

[4] As chromium VI.

NA means not available

rinsed with dichloromethane (DCM) and the rinseate added back to the separatory funnel. The appropriate surrogate internal standards were then added, and the sample serially extracted three times with 120 mL portions of DCM. The extract was next passed through a 20-g alumina column and eluted with 50 mL of DCM. The filtrate was then reduced in volume to about 1 mL using Kuderna-Danish and nitrogen concentration techniques. The concentrated extract was further cleaned by modified EPA Method 3640 using size-exclusion (gel permeation) high performance liquid chromatography (HPLC). The post-HPLC extract was concentrated to approximately 0.5 mL under nitrogen and recovery internal standards were added. The final extract was split for analysis. Half was used for PAH and LAB analysis; the other half was solvent exchanged with isooctane and analyzed for PCB and pesticides.

PAH and LAB compounds were analyzed by selected ion monitoring (SIM) gas chromatography mass spectrometry (GC/MS) following a modification of EPA Method 8270. PAH compounds were analyzed by monitoring for the most intense parent ion plus one confirmation ion for each target compound. LAB compounds were analyzed as five separate LAB groups (those with alkyl chains containing 10 to 14 carbon atoms) by monitoring the characteristic LAB m/z 91 molecular ion during the GC/MS analysis and summing the structural homologues within each group. Pesticides and PCB congeners were analyzed by capillary gas chromatography with electron capture detection (GC/ECD) using EPA Method 8080 modified to include additional analytes. All analytes were quantified using the internal standard method. Selected organic analytes often fell below listed MDL.

2.3 Data Treatment

In contrast to earlier treatments non-detects were treated as zeros and used in the calculation of averages. This is preferable to assuming certain values for non-detects. For example, there are 209 individual PCB congeners even though only 20 PCB congeners were measured in this study. The total PCB could be interpreted to be as high as 1045 ng/L (209 x 5 ng/L) if the conventional use of half the MDL (about 5 ng/L) was adopted even if not all of them are present or quantifiable.

Loadings were calculated by the multiplication of concentration by flow rate (with appropriate conversion factors). Monthly loadings were estimated by averaging individual loadings for that month if more than one sample were collected. Annual average concentrations and loads were calculated by averaging the monthly data and projecting for the year.

This simple calculation allows for a first-order estimate of MWRA's contribution of various contaminants to the Harbor and the Bays. This also provided a basis for comparison with contaminant loadings estimated by other investigators.

3.0 RESULTS AND DISCUSSION

The average monthly wastewater flow rates at the Deer Island wastewater treatment plant during 1996 and 1997 are shown in Figure 2. The peak flow period occurred near April and November, which is similar to 1994. In contrast, the peak flow in 1995 occurred near November. The flow data is consistent with the usual pattern of increasing flows during the spring and fall seasons. The loading variation is sometimes more helpful than concentration alone in accentuating pattern changes in contaminant occurrence. The loading rate is calculated by coupling the concentration with the same day flow.

3.1 Trace Metals

The actual MWRA effluent trace metal levels are summarized in Table 4 Trace metal levels in Deer Island wastewater effluent are fairly low when compared to other published wastewater effluents using similar detection limits. The data also show decreases in concentration for most metals with improvements in treatment. This is consistent with the hypothesis that many of the trace metals are particle-bound and improvements in particle removal will improve trace metal removal. The exceptions are Ni, the metalloids such as Cr (VI), and Mo.

MWRA also sampled the influent to DIWTP in September and October 1997. Table 5 shows the average influent (8 samples) and corresponding effluent (10 samples) concentrations. The corresponding removal efficiencies are also reported. The average effluent concentrations from this sampling period are used as projected concentrations at full secondary treatment. The MWRA effluent concentrations are comparable to a study of 17 municipal wastewaters from the New York and New Jersey area using similar low-level detection limit methods (U.S. EPA, 1991).

The trace metal effluent data can be broken down into four categories by concentration. First, Cd and Hg tend to be less than 1 µg/L. Second, the concentrations of Ag, Cr, Ni and Pb are similar and tend to be between 3 to 12 µg/L. Third, Mo is usually between 6 to 22 µg/L. Finally, the concentrations of Cu and Zn are similar and ranged between 10 to 90 µg/L. The high Hg value of 0.512 µg/L observed in the May 7, 1997 sample may be an outlier since it was not observed for samples taken concurrently by MWRA (Hall, personal communication). The beginning of secondary treatment in August 1997 improved the removal of all trace metals except Mo and Ni. This is consistent with the tendency of Mo and Ni to be less particle-bound.

Figure 2
Deer Island Wastewater Effluent Flow

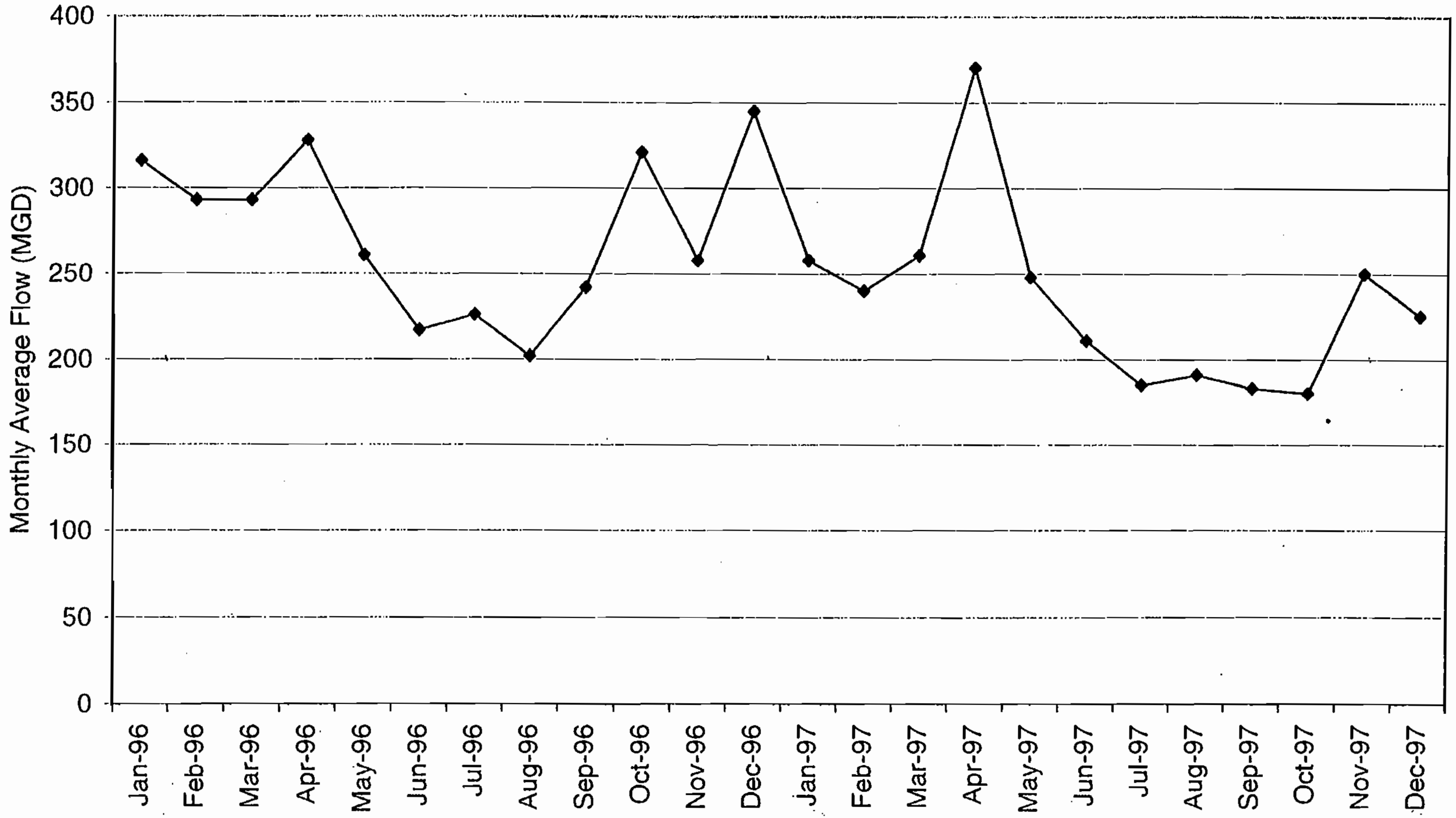


Table 4 Tracer Metal Concentrations in MWRA Effluent (µg/L)

	Ag	Cd	Cr	Cu	Mo	Ni	Pb	Zn	Hg
1/10/96	2.4	1.1	3.7	62.8	11.3	4.9	4.8	57.6	0.072
1/12/96	3.2	0.8	3.6	53.3	14.3	4.5	5.0	61.4	0.046
2/14/96	3.6	0.3	4.1	78.1	8.8	4.7	5.6	78.3	0.142
2/16/96	3.3	0.5	3.7	59.2	7.5	4.4	6.7	69.9	0.096
3/13/96	3.0	0.4	3.3	64.5	6.6	5.8	8.4	77.1	0.066
3/15/96	2.4	0.5	3.9	44.0	7.0	6.2	10.6	78.7	0.062
4/10/96	2.9	0.3	4.9	47.1	7.7	7.2	7.6	70.7	0.102
4/12/96	2.1	0.4	4.4	42.5	6.1	6.3	10.8	78.2	0.096
5/15/96	2.9	0.4	1.3	49.5	14.4	3.7	6.4	57.0	0.100
5/17/96	2.0	0.3	2.8	49.8	13.2	4.0	12.5	67.2	0.090
6/12/96	3.0	0.5	2.2	56.1	21.1	4.4	6.0	54.1	0.090
6/14/96	2.6	0.2	5.0	80.3	22.1	4.4	6.6	53.7	0.090
8/14/96	3.0	0.3	3.7	91.7	13.1	4.5	11.6	68.7	0.110
3/5/97	2.7	0.2	2.2	48.9	5.9	7.0	4.3	51.7	0.290
4/9/97	1.9	0.4	2.7	40.1	5.1	5.8	5.1	53.6	0.162
4/11/97	2.6	0.3	2.9	44.0	6.2	6.5	7.4	62.2	0.210
5/7/97	2.3	0.3	2.4	44.1	10.9	5.0	5.6	56.4	0.512 **
5/9/97	2.7	0.2	2.3	43.0	9.5	4.6	5.1	62.0	0.108
6/4/97	3.3	0.3	4.0	90.2	14.3	6.6	6.9	61.5	0.119
6/6/97	2.7	0.3	2.6	54.5	12.9	5.3	5.2	53.6	0.202
7/9/97	2.5	0.2	2.4	60.2	16.8	6.1	4.9	52.0	0.158
7/11/97	2.1	0.3	9.1	54.6	16.2	11.8	6.1	58.9	0.130
9/22/97	1.1	0.1	< 0.04	48.6	10.8	4.4	6.5	34.3	0.226 ***
9/24/97	2.4	0.1	1.6	34.6	14.6	4.3	5.2	36.3	0.118 ***
9/26/97	1.9	0.2	2.4	33.0	14.5	4.5	6.4	36.2	0.062
9/29/97	1.0	< 0.01	0.9	30.8	8.9	3.5	5.2	31.3	0.080
10/1/97	1.1	< 0.01	1.3	24.3	14.1	5.2	3.3	29.6	0.026
10/3/97	1.7	< 0.01	1.1	21.2	15.4	4.7	7.5	25.2	0.096
10/15/97	0.8	< 0.01	0.8	24.6	15.3	5.2	4.9	25.5	0.116
10/17/97	1.2	< 0.01	0.7	21.3	13.2	5.2	3.1	21.8	0.080
10/15/97*	0.3	< 0.01	0.5	12.4	14.2	4.9	3.8	15.4	0.086
10/17/97*	0.3	< 0.01	0.2	9.4	12.2	4.3	1.1	11.2	0.070

*Secondary battery effluent

** The possibility that this value is an outlier is further discussed in the text.

*** There is a possibility that the influent and effluent samples were mislabeled and that the actual Hg levels were 0.030 and 0.080 µg/L instead.

Table 5 Influent and Effluent Comparisons (Concentrations in µg/L)

	Ag	Cd	Cr	Cu	Mo	Ni	Pb	Zn	Hg
Average MWRA influent (Sep and Oct, 1997)	3.9	0.37	3.63	70.6	14	6.2	15.5	100.3	0.15
Average corresponding MWRA effluent	1.4	0.053	1.10	29.8	13.3	4.7	5.3	30	0.071 to 0.10*
MWRA secondary effluent (Oct 1997)	0.31	ND	0.33	10.9	13.2	4.6	2.4	13.3	0.078
Range from New York/ New Jersey Study	0.7 to 16	0.07 to 2.6	NA	10 to 102	NA	2.3 to 72.8	0.1 to 14	15.4 to 104	<0.004 to 0.158
Observed MWRA % removal	64	86	70	58	5	24	66	70	33 to 53
Observed secondary % removal	92	NA	91	85	5	26	85	87	48
Average annual % removal from Pilot Plant Study	84	58	49	74	20	17	81	62	51

New York/New Jersey results are from USEPA (1991) and represent wastewater sampled once from 17 municipalities with primary or secondary treatments.

* 0.071 is the average Hg effluent concentration assuming that the influent and effluent samples of September 22 and 24 were mislabeled. Otherwise the average is 0.100 µg/L.

ND Non-detect
NA Not applicable

Temporal Responses

The average monthly Cd and Hg concentration and loading are shown in Figures 3 and 4. Cd levels appear to be higher in 1996, ranging from 0.24 to 0.98 µg/L, with the highest value occurring in the January 10, 1996 sample. The range in 1997 prior to secondary treatment was 0.10 to 0.39 µg/L. The level of Cd in the MWRA influent (Table 5) is fairly low and averaged 0.37 µg/L. The corresponding secondary effluent samples were non-detect with a MDL of 0.010 µg/L. This would indicate a higher removal rate than observed during the pilot treatment plant study. However, concurrent monitoring by MWRA showed detectable levels of Cd in the 0.1 µg/L range (Hall, personal communication). This may reflect inherent variability of chemical analysis at low sub part-per-billion levels. It also points out the importance of performing an accurate mass balance (influent, effluent and residual concentrations) such that hypothesis can be formulated and tested. The Cd load variation is similar to the concentration variation, although Cd loads were relatively high in April for both 1996 and 1997. The Cd load was almost 800 g/d in Jan. of 1996 and 550 g/d in April of 1997.

Hg levels in 1996 ranged from 0.059 to 0.119 µg/L. The range in 1997 prior to secondary treatment was 0.144 to 0.310 µg/L. The possibility of the high value of 0.512 µg/L in the May 7, 1997 sample being an outlier has already been discussed. Hg levels in the September 22 and 24,1997 influent samples are lower than the effluent levels and may reflect mislabeling of sample bottles. Hg levels in effluent samples from the secondary treatment battery are also slightly higher than the actual effluent samples. But none of the mercury samples exceeded the chronic water quality criterion adjusted for dilution at 0.790 µg/L. The observed removal range for Hg was 33 to 53%. The higher removal rate of 53% was calculated assuming that the September 22 and 24 samples were mislabled, giving a lower removal rate than predicted from the pilot treatment plant study. Concurrent monitoring by MWRA showed a 50% removal of Hg by primary treatment alone (as opposed to the observed with a reasonable closure on mass balance).

Figure 3

Average monthly Cd & Hg concentrations

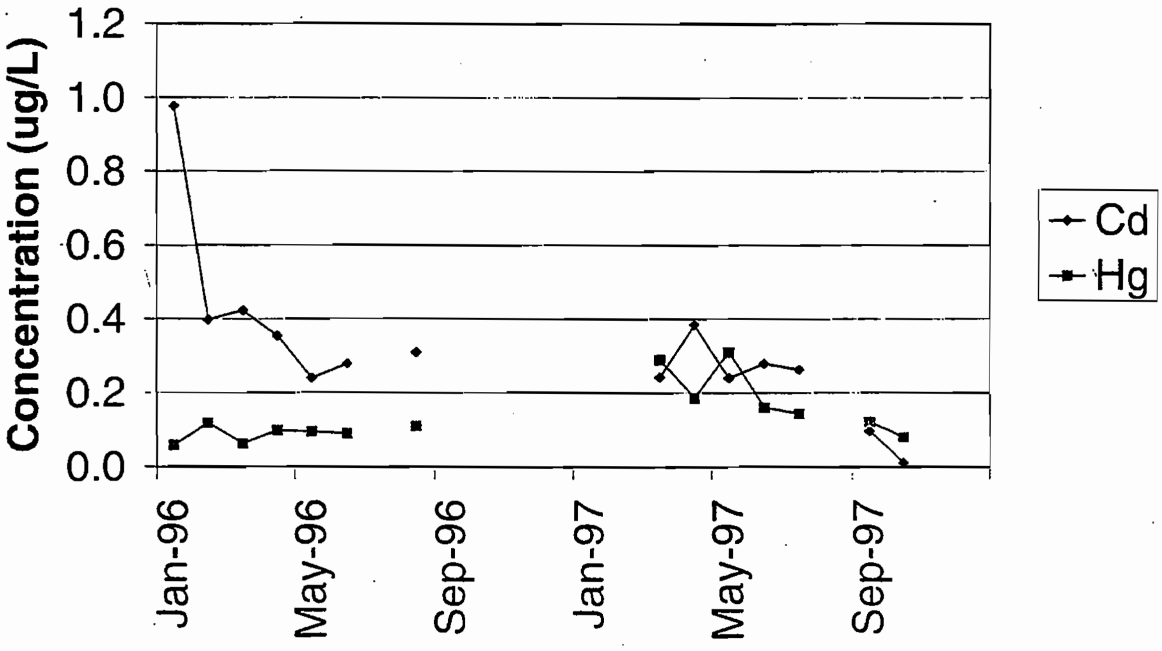
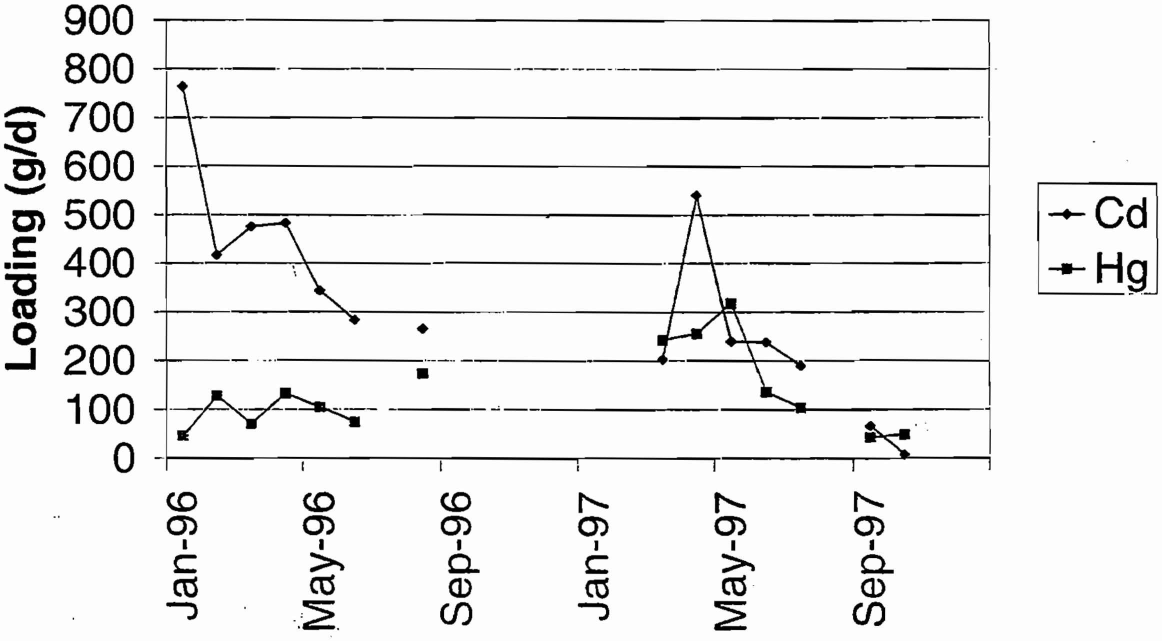


Figure 4

Average monthly Cd & Hg loads



It is probable that the actual Hg levels in effluent are lower than the values reported here. The Hg levels in the two secondary treatment samples were less than 0.090 µg/L. The maximum Hg load in 1996 was observed in August to be about 180 g/d. The maximum Hg load in 1997 would be about 260 g/d in April, if the 0.512 µg/L sample was dropped in May.

The average monthly Ag and Cr concentration and loading are shown in Figures 5 and 6. Ag levels were fairly consistent and ranged from 2.2 to 3.4 µg/L prior to secondary treatment, and decreased to 1.2 to 1.6 µg/L after September of 1997. The maximum Ag load occurred in February 1996 and in April 1997 at levels of about 3.7 and 3.1 Kg/d, respectively. Ag in MWRA influent and effluent seems fairly typical, and the observed removal rate of 70% is slightly lower than that observed from the pilot treatment plant study.

Cr concentrations ranged from 2.2 to 5.8 µg/L prior to secondary treatment. Cr values tend to be fairly consistent (this has been true since DECS began in 1993/94 except for an extremely high value measured in February of 1995). It was as low as non-detect with a MDL of 0.04 µg/L, and up to 2.4 µg/L in the September 26, 1997 sample. The maximum Cr load in 1996 occurred in April at 6.3 Kg/d, the maximum Cr load in 1997 occurred in July and was about 4.2 Kg/d. Cr in MWRA influent is relatively low, and the observed removal rate of 74% is somewhat higher than that observed from the pilot treatment plant study, which ranged from 49 to 62%.

The average monthly Ni and Pb concentration and loading are shown in Figures 7 and 8. Ni remained relatively constant around 5 µg/L with or without secondary treatment, although there was a high of 11.8 µg/L measured in the July 11, 1997 sample. In general the range is closer to 3.5 to 7.0 µg/L. The maximum Ni load occurred in April for both 1996 and 1997 at 9.1 and 8.6 Kg/d, respectively. The difficulty with Ni removal was also noted by Ekster and Jenkins for the San Jose/Santa Clara wastewater treatment plant. Ni in MWRA influent and effluent seems fairly typical, and the observed removal rate of 26% is slightly higher than that observed from the pilot treatment plant study of 14 to 17%. The marine chronic water quality criterion for Ni is 8.3 µg/L, and Ni in MWRA effluent should not be of concern since there is also dilution.

Pb concentration ranged from 4.9 to 11.6 µg/L in 1996 and seemed to be slightly higher than the range of 4.3 to 6.3 µg/L in 1997 prior to secondary treatment. It ranged from 4.7 to 5.8 µg/L after September of 1997. The maximum Pb load occurred in April for both 1996 and 1997 at 12.8 and 8.6 Kg/d, respectively. Pb in MWRA influent and effluent seems fairly typical, and the observed removal rate of 70% is somewhat lower than that observed from the pilot treatment plant study of about 80%.

Figure 5
Average monthly Ag & Cr concentrations

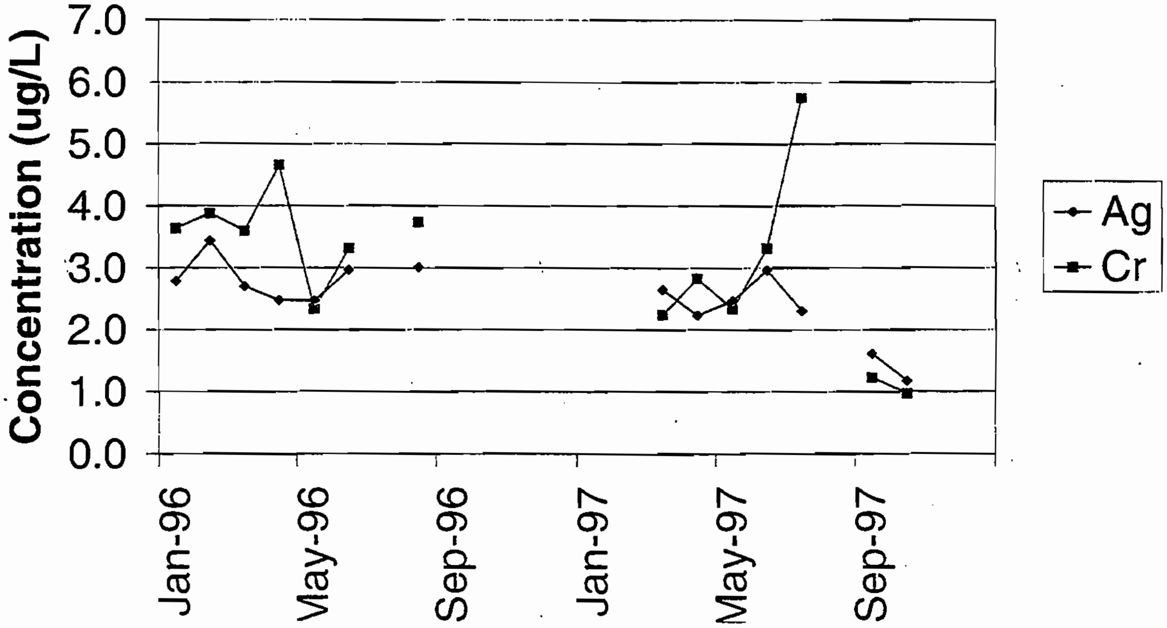


Figure 6
Average monthly Ag & Cr loads

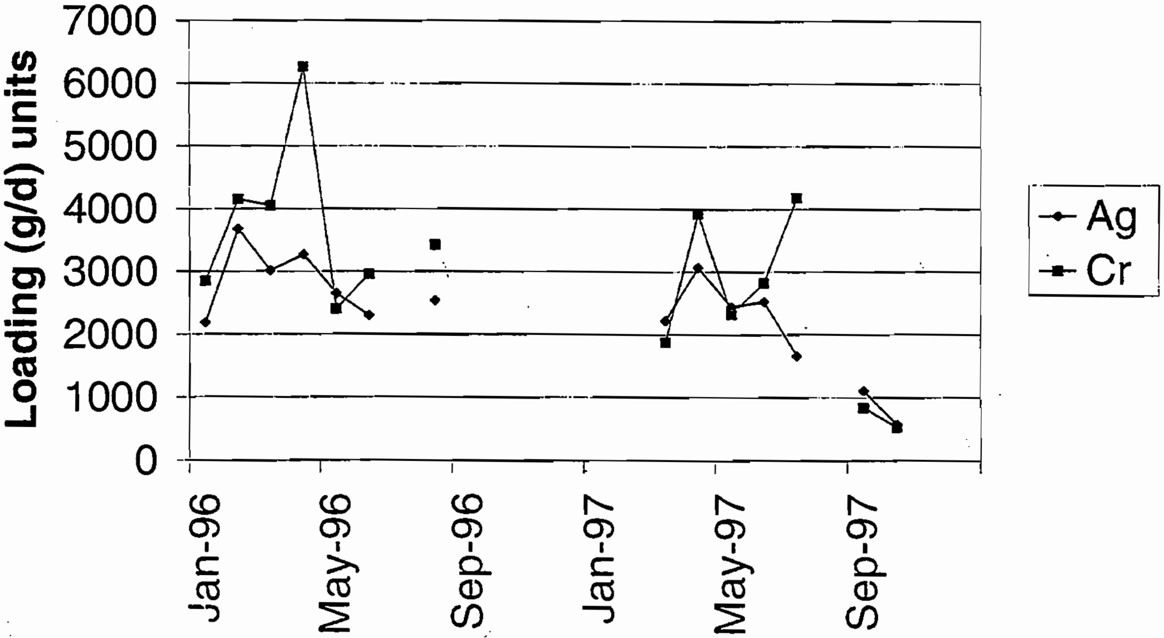


Figure 7
Average monthly Ni & Pb concentrations

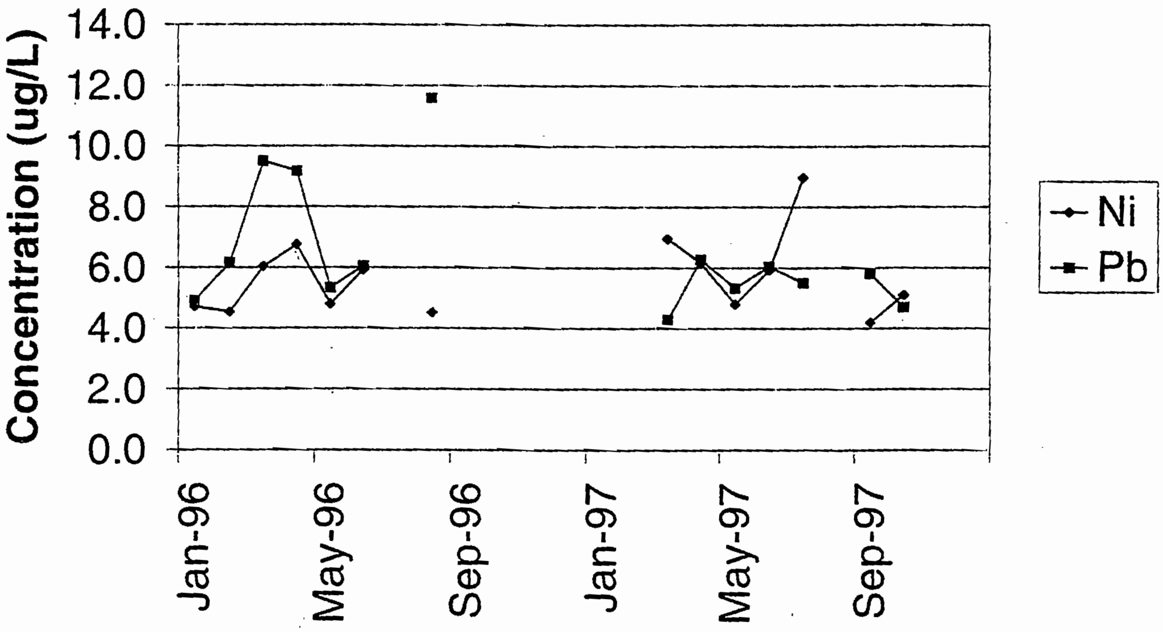
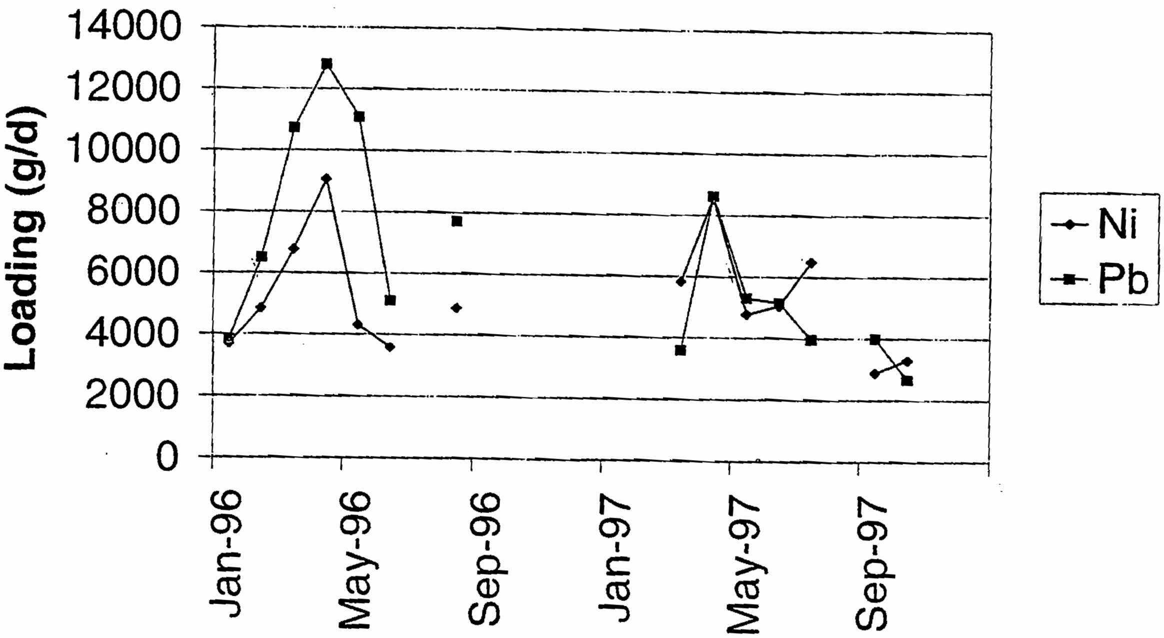


Figure 8
Average monthly Ni & Pb loads



The average monthly Cu and Zn concentration and loading are similar and shown in Figures 9 and 10. Cu concentrations ranged between 42 to 92 µg/L prior to secondary treatment. Cu in MWRA influent is typical for the northeast. Cu in effluent tends to increase in June and may reflect increases in the influent load due to seasonal corrosion effects or the addition of copper sulfate in source water reservoirs for algae control. The MWRA effluent Cu level seems to be fairly typical, with a somewhat lower removal rate (63%) than expected from the pilot treatment plant study (about 80%). Secondary treatment seemed able to produce effluent with less than 10 µg/L Cu, although the more typical range in 1997 was 23 to 37 µg/L. The maximum Cu load in 1996 occurred in August at 78.4 Kg/d. The maximum Cu load in 1997 occurred in June at 61.6 Kg/d.

Zn concentration ranged between 52 and 78 µg/L prior to secondary treatment. Zn in MWRA influent and effluent appears to be rather typical. Maximum Zn loads in 1996 and 1997 occurred in April at 102 and 80 Kg/d, respectively. The observed removal rate of 73% is somewhat higher than the pilot treatment study, which ranged from 62 to 69%. The range of Zn in effluent after secondary treatment was 26 to 35 µg/L. The Zn and Pb loads seemed to be highly correlated, with maximum values occurring together in the same months. This could be due to storm water impacts. High concurrent Zn and Pb concentrations were observed for storm samples in past CSO studies.

The average monthly Mo concentration and load is shown in Figures 11 and 12. Mo concentration is typically less than 10 µg/L but can increase to around 20 µg/L during the summer months. Mo shows the clearest seasonal increase and is attributed to its common use as a biocide in cooling towers. The maximum Mo load occurred in summer at levels of 17.6 Kg/d in June of 1996 and 11.9 Kg/d in July of 1997. The observed average removal rate of Mo is low, about 5%. The annual average Mo removal rate was 20% from the pilot treatment study. Mass balance on Mo levels in residuals appear to suggest higher removal rates than observed (Hall, personal communication). Mo is one of the contaminants of some concern in residual (bio-solid) quality in the past, but is not an issue in discharge to the marine environment.

Summary on Metal Loads

The metal loading rates (mass discharged per day) from 1993 to 1997 are further summarized as figures in the appendix. Annual loading rates from 1995 to 1997 are summarized in Table 6, with projected loading rates and concentrations when full secondary treatment is implemented. All metal loading rates except Hg have shown decreases from 1995 to 1997. The projected trace metal concentrations are based on the average of all 10 effluent samples collected in September and October 1997 and is somewhat conservative since full secondary treatment is expected to

Figure 9
Average monthly Cu & Zn concentrations

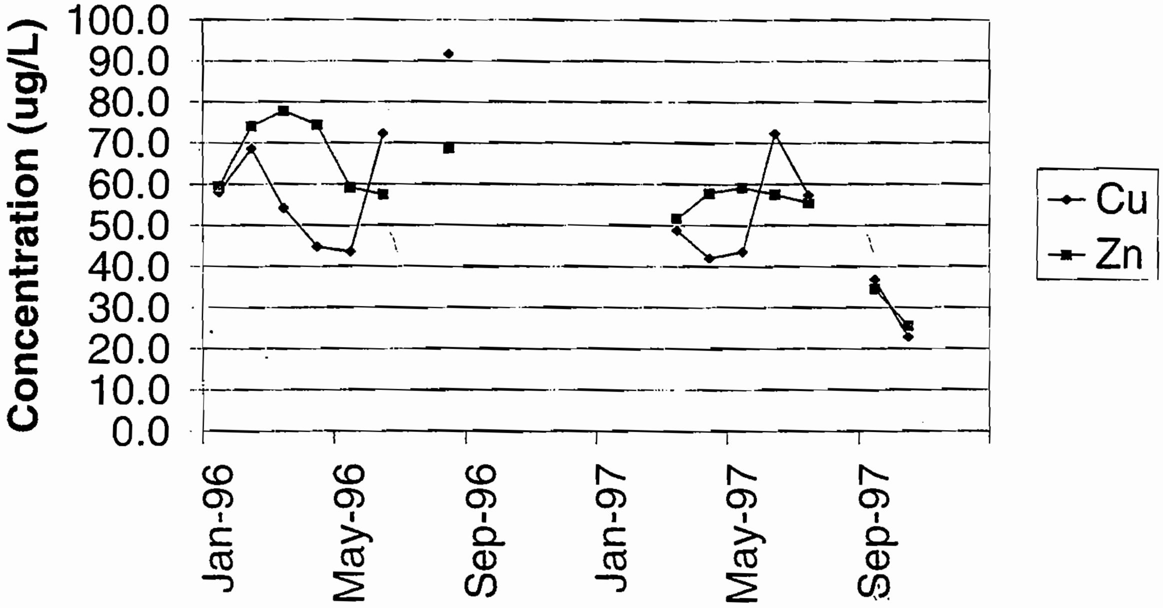


Figure 10
Average monthly Cu & Zn loads

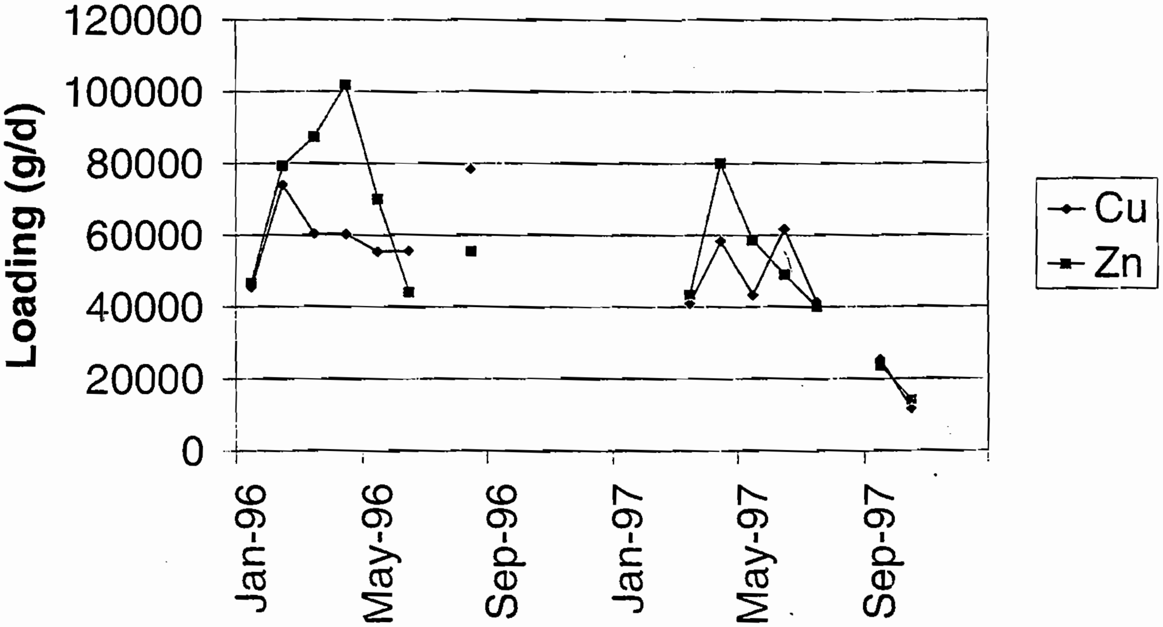


Figure 11
Average monthly Mo concentration

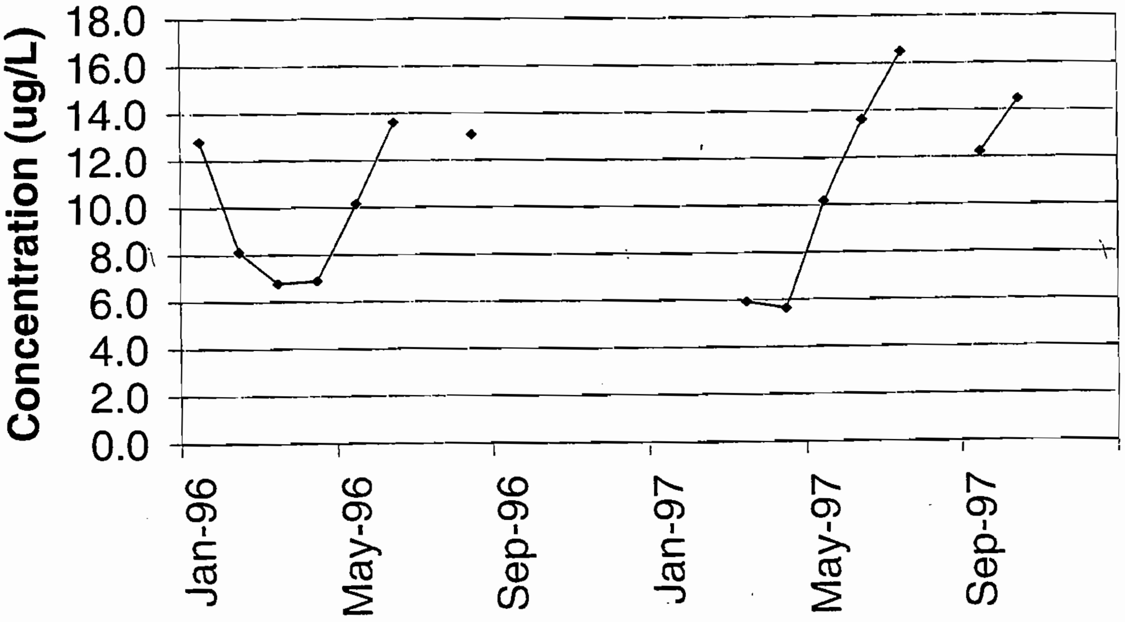


Figure 12
Average monthly Mo load

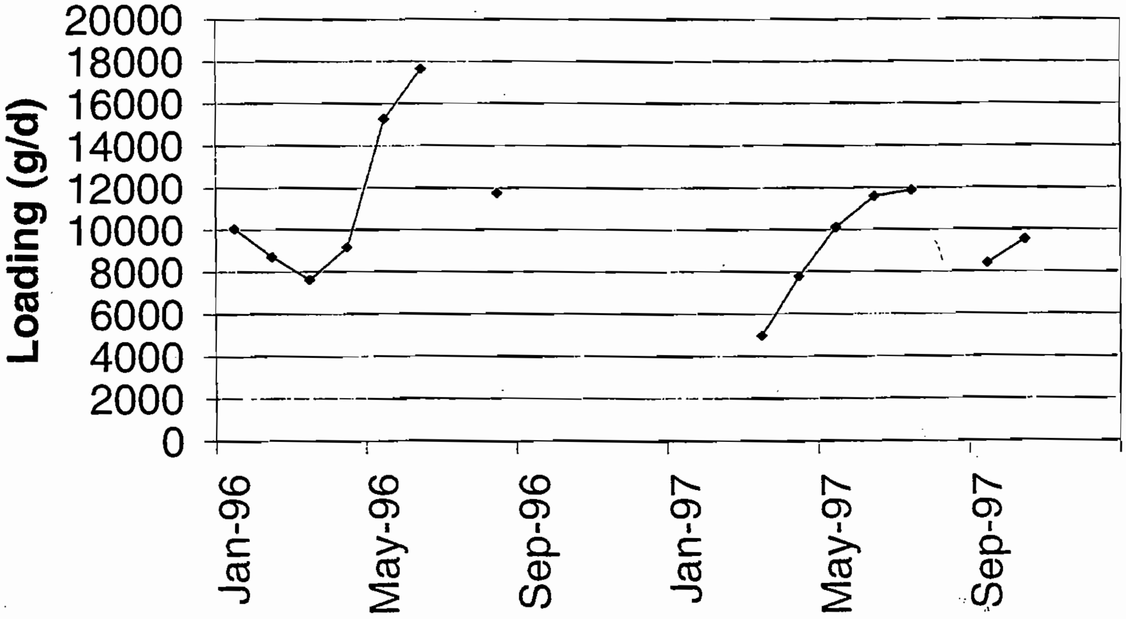


Table 6 Annual MWRA metal loads from 1995 to 1997 (expressed with two significant figures) and projected secondary effluent characteristics

Compound	1995 (Kg/yr)	1996 (Kg/yr)	1997 (Kg/yr)	SEIS Projection Mean (Kg/yr)	Projected for Secondary (Kg/yr)	Projected for Secondary (µg/L)
Ag	1,900	1,500	1,000	300	620	1.2
Cd	260	240	110	700	21	0.04
Cr	7,900	2,000	1,300	3,500	490	0.95
Cu	31,000	32,000	22,000	12,000	14,000	26
Hg	50	57	90(60 TO 71*)	205	50	0.096
Mo	6,800	6,300	5,100	NA	6,800	13.3
Ni	3,100	2,900	2,900	8,900	2,400	4.6
Pb	5,800	4,500	2,600	5,000	2,400	4.7
Zn	37,000	38,000	24,000	34,000	14,000	26.7

**The 1997 Hg load would be 71kg/yr if the 0.512 µg/L value was dropped. It would be 60 kg/yr if in addition it was assumed that the Sep 22 and 24 samples were mislabeled. See discussion in text.*

improve removals. This will compensate somewhat for other times when influent concentrations may be higher. The projected loading rates are calculated by multiplying the projected concentrations by 373 MGD (1.41 x 10^9 liters per day), which is the projected average MWRA discharge rate into Massachusetts Bay. The annual loading rates of all metals are projected to decrease even further, except for Hg and Ni, which will be relatively constant. Most metal loading rates are smaller than originally projected in the SEIS, except for Ag and Cu. The SEIS projection for Ag was based on older data and the increase may be partly due to better detection limits. The difference for Cu is not really substantial.

3.2 Trace Organic Compounds

The behavior of trace organic compounds in effluent can similarly be categorized by concentration. PCBs and chlorinated pesticide concentrations in effluent are typically less than 40 ng/L. PAH and LAB compounds are typically in the concentration range of 10,000 ng/L or less (10 µg/L). The inter-annual comparison for organic compounds present more of a challenge than for trace metals. The possibility that total PCB concentrations were artificially high prior to 1996 due to analytical interference (for PCB congeners 18 and 180) has been discussed in Mitchell et al. 1997. Start-up of the new primary treatment plant on Deer Island in 1995 entailed operational changes and a revision of sampling locations. Sludge re-circulation may have occurred, impacting samples collected in the first half of 1995.

Temporal response

It is important to note that there were changes in the method detection limit in 1996 and 1997. It was 5 ng/L from January to April of 1996, and decreased to about 2 ng/L from May to August of 1996. The MDL was 2.5 ng/L in 1997 The higher MDL in the beginning of 1996 may be the reason why organic contaminants were detected less frequently for that time period.

Polychlorinated biphenyls (PCBs): PCBs consist of 209 distinct molecules (congeners) of which about 150 appear at significant levels in various commercial mixtures. The MWRA analysis of PCBs includes the National Oceanic and Atmospheric Administration (NOAA) list of 18 congeners plus congeners 77 and 126. Mitchell et al. (1997) evaluated the sources and loading rates of PCB to Massachusetts Bay and pointed out that analytical interference may have contributed to artificially high total PCB concentrations. The most notable interference is due to congeners 18 and 180.

The average monthly total PCB concentration and load are shown in Figures 13 and 14. Actual concentrations are reported in Table 7. Total PCB is highly variable, ranging from 0 to 33 ng/L.

Figure 13 Temporal response of Tot PCB Concentration

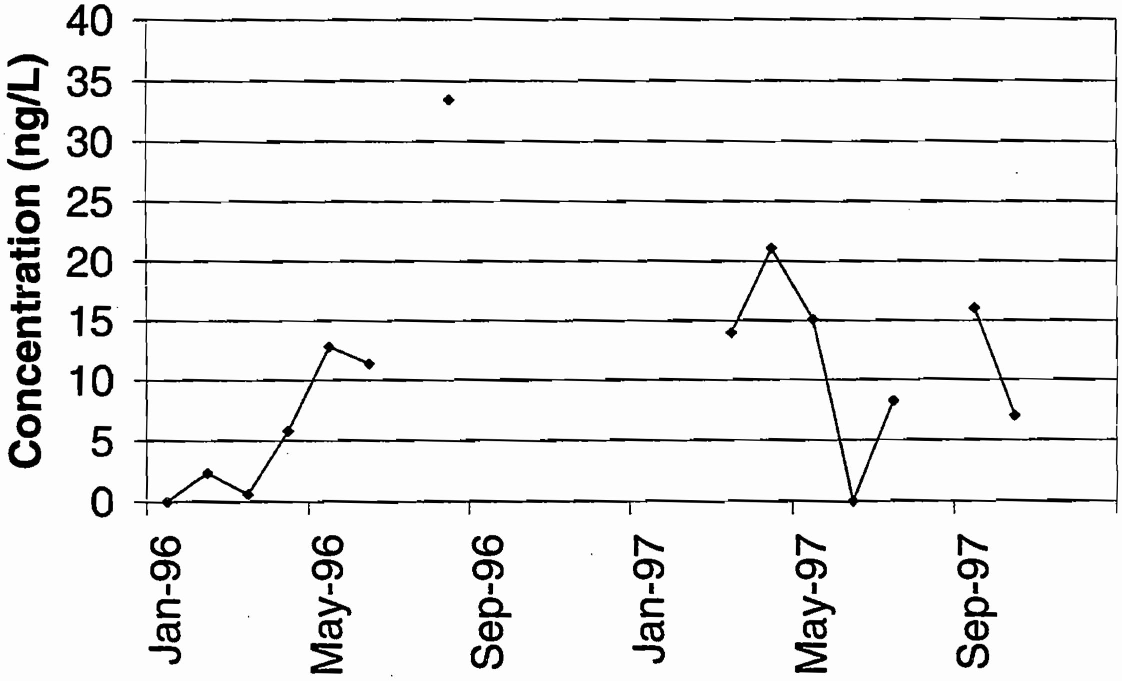


Figure 14 Temporal response of Tot PCB Load

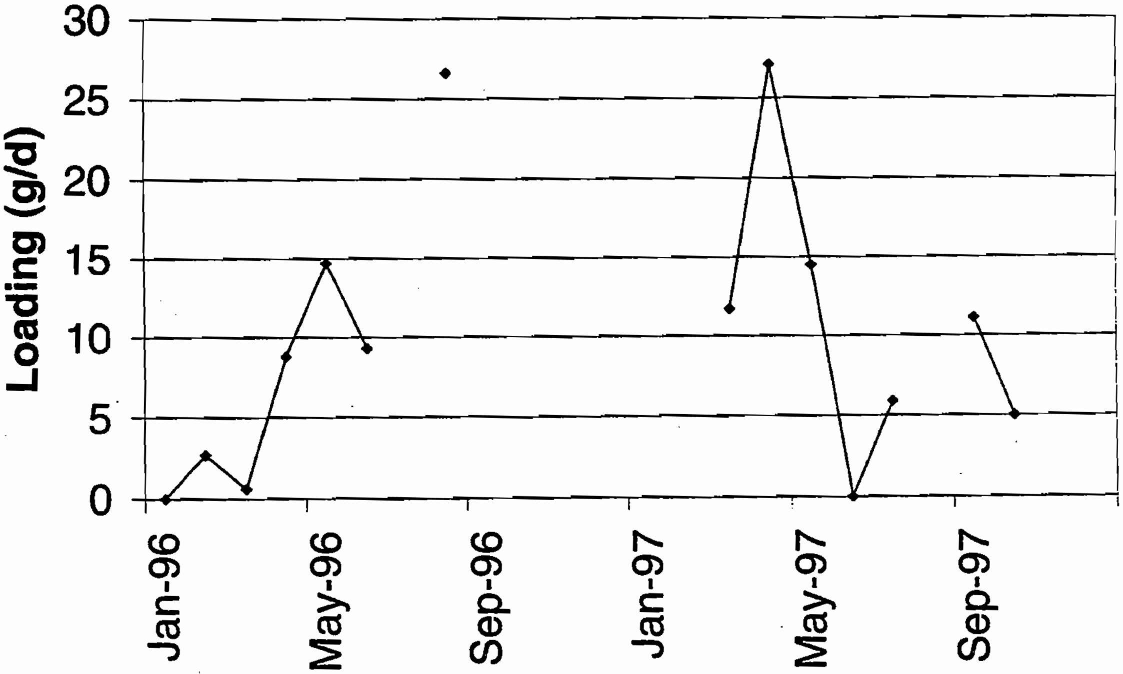


Table 7 PCB Concentrations (ng/L)

Collection	PCB CONGENER																				MDL	Total PCB
Date	8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209	(ng/L)	(ng/L)
01/10/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.00	0.0
01/12/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.00	0.0
02/14/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.7	1.0	ND	ND	ND	ND	5.00	4.7
02/16/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.00	0.0
03/13/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND	ND	5.00	1.2
03/15/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.00	0.0
04/10/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.6	ND	ND	ND	ND	5.00	1.6
04/12/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.0	ND	ND	ND	ND	5.00	10.0
05/15/96	ND	ND	ND	ND	ND	ND	ND	1.7 J	ND	3.8	ND	ND	2.0	2.3	ND	0.4	ND	ND	ND	ND	1.97	10.2
05/17/96	ND	ND	ND	ND	ND	ND	ND	1.5 J	ND	4.4	ND	0.99 J	3.5	4.0	ND	1.0	ND	ND	ND	ND	1.94	15.4
06/12/96	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.5	ND	ND	2.7	4.1	ND	0.5	ND	ND	ND	ND	1.93	11.6
06/14/96	ND	ND	3.0	ND	ND	ND	ND	1 J	ND	ND	ND	ND	2.4	4.0	ND	0.6	ND	ND	ND	ND	1.92	11.0
08/14/96	ND	ND	ND	ND	ND	ND	ND	5.4	ND	ND	ND	0.8 J	4.6 B	8.0	ND	2.7	9.5	ND	ND	ND	2.23	31.0
08/16/96	ND	ND	ND	ND	ND	ND	ND	4.9	ND	6.5	ND	2.7	13.0	ND	ND	2.6	6.2	ND	ND	ND	1.94	35.9
03/05/97	ND	ND	2.6	ND	ND	ND	ND	ND	ND	ND	ND	2.4 J	ND	3.6	2.1 J	ND	3.3	ND	ND	ND	2.50	14.0
04/11/97	ND	1.4 J	2.7	1 J	ND	ND	ND	2.6	2.1 J	ND	ND	ND	ND	5.0	2.4 J	ND	3.9	ND	ND	ND	2.50	21.1
05/07/97	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.2	ND	ND	ND	1.4 J	ND	ND	ND	ND	ND	ND	2.50	5.6
05/09/97	ND	ND	22.0	ND	ND	ND	ND	ND	ND	2.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.50	24.6
06/06/97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.60	0.0
07/09/97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	9.6	ND	ND	ND	ND	ND	ND	ND	ND	2.50	9.6
07/11/97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.9	ND	ND	ND	ND	ND	ND	ND	ND	2.50	6.9
09/22/97	4.1	ND	ND	ND	ND	ND	ND	4.8	ND	6.0	ND	ND	ND	ND	ND	ND	3.5	ND	ND	ND	2.50	20.4
09/24/97	ND	ND	ND	ND	ND	ND	ND	2.9	ND	7.5	1.4 J	ND	ND	ND	ND	ND	4.2	ND	0.25 J	ND	2.50	16.3
09/26/97	ND	ND	ND	ND	ND	ND	ND	2.4	ND	4.3	ND	ND	ND	ND	ND	ND	3.2	ND	ND	ND	2.50	9.9
09/29/97	6.6	ND	ND	ND	ND	ND	3.3	ND	ND	5.7	ND	ND	ND	2.1 J	ND	ND	ND	ND	ND	ND	2.50	17.7
10/01/97	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.8	ND	ND	ND	2.2 J	ND	ND	ND	ND	ND	ND	2.50	5.0
10/03/97	15.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2 J	ND	ND	ND	ND	ND	ND	2.50	17.0
10/15/97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.7J	ND	ND	1.5J	ND	ND	ND	2.50	3.2
10/17/97	ND	ND	ND	ND	ND	1.4J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.3J	ND	ND	ND	2.50	2.7
10/15/97*	ND	ND	ND	ND	ND	ND	ND	1.3 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.50	1.3
10/17/97*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.50	0.0

*Secondary battery effluent

J=Below method detection limit.

B Blank interference

The most common congeners that occur (excluding congeners 18 and 180 as discussed above) are 101, 118, 128, 138, 153 and 187. The inherent difficulty in quantifying PCB at these low levels is further illustrated by the data shown in Table 8. The average influent and effluent PCB congeners from September and October 1997 are summarized in Table 8, as well as the calculated removal rates. Congeners 8, 77 and 126 showed negative removal rates, even though congeners 8 and 77 constituted 29% and 17% of the total PCB quantified in the effluent. The occurrence of congeners 77 and 126 could also be an analytical artifact. The methods used to analyze for these two compounds did not include a carbon column clean-up technique which would isolate only co-planar PCB congeners and require a separate GC/ECD analysis. As noted in a letter to Mr. Ken Keay by Dr. Jack Schwartz (dated 12/26/96), other PCB congeners have the potential to co-elute with congeners 77 and 126. While the dual column confirmation method utilized by the laboratory contractor in 1996 served to minimize this issue, there is greater uncertainty associated with the congener 77 and 126 results due to the potential interferences from other PCB congeners. Congener 118 is of special interest because it is dioxin-like and is detected in MWRA effluent.

However, the two secondary treatment battery effluent samples showed non-detect total PCB (at 2.5 ng/L MDL) to 1.3 ng/L of congener 101 (which was less than the MDL). The maximum PCB load occurred at 27 g/d in August of 1996, and at 27 g/d in April of 1997. The average removal rate observed for September and October 1997 was 45%, this would increase to 71% if congeners 8, 77 and 126 were excluded in the effluent. This would be more in line with the removal rates observed in the pilot treatment plant study.

Polycyclic Aromatic Hydrocarbons (PAHs) and Linear Alkyl Benzenes (LABs): PAHs are a group of compounds composed of two or more fused aromatic rings. Some of these compounds are considered to be potential human carcinogens. EPA has identified 16 unsubstituted PAHs as priority pollutants. NOAA analyzes for 23 PAH compounds in their national status and trend program. MWRA expanded the list to 40 PAH compounds in 1993/94 and again to 43 compounds in 1995. Method detection limits have decreased and changes have occurred in how non-detects are treated. These complications make annual comparisons difficult. The same 40 PAH compounds from 1993/94 are reported here.

The temporal responses of total PAH and total LAB concentrations and loads are shown in Figures 15 and 16. The actual concentrations are reported in Table 9. The total PAH effluent concentration ranged from 5743 ng/L to 12446 ng/L prior to secondary treatment. The post-secondary treatment range was 2332 ng/L to 3848 ng/L. Table 10 summarized the average influent and effluent PAH and LAB concentrations from September and October 1997, as well as the calculated removal rates. The naphthalene and substituted naphthalenes constitute about

Table 8 PCB Distribution in Average Influent and Effluent

PCB Congener	Ave. Influent (ng/L)	% tot PCB	Ave. Effluent (ng/L)	% tot PCB	Removal %
8	0.0	0	2.6	29	undefined
18	0.0	0	0.0	0	NA
28	0.0	0	0.0	0	NA
44	0.0	0	0.0	0	NA
52	0.0	0	0.0	0	NA
66	0.0	0	0.0	0	NA
77	0.0	0	1.5	17	undefined
101	2.1	13	0.1	1	94
105	0.0	0	0.0	0	NA
118	3.1	19	2.8	32	8
126	0.0	0	0.1	2	undefined
128	0.5	3	0.0	0	100
138	0.0	0	0.0	0	NA
153	6.1	38	1.7	19	72
170	0.0	0	0.0	0	NA
180	0.0	0	0.0	0	NA
187	3.6	22	0.0	0	100
195	0.7	4	0.0	0	100
206	0.0	0	0.0	0	NA
209	0.0	0	0.0	0	NA
Total PCB (ng/L)	16.1		8.9		45

NA =Not applicable (not observed).

Figure 15 Temporal response of Tot PAH and LAB Concentrations

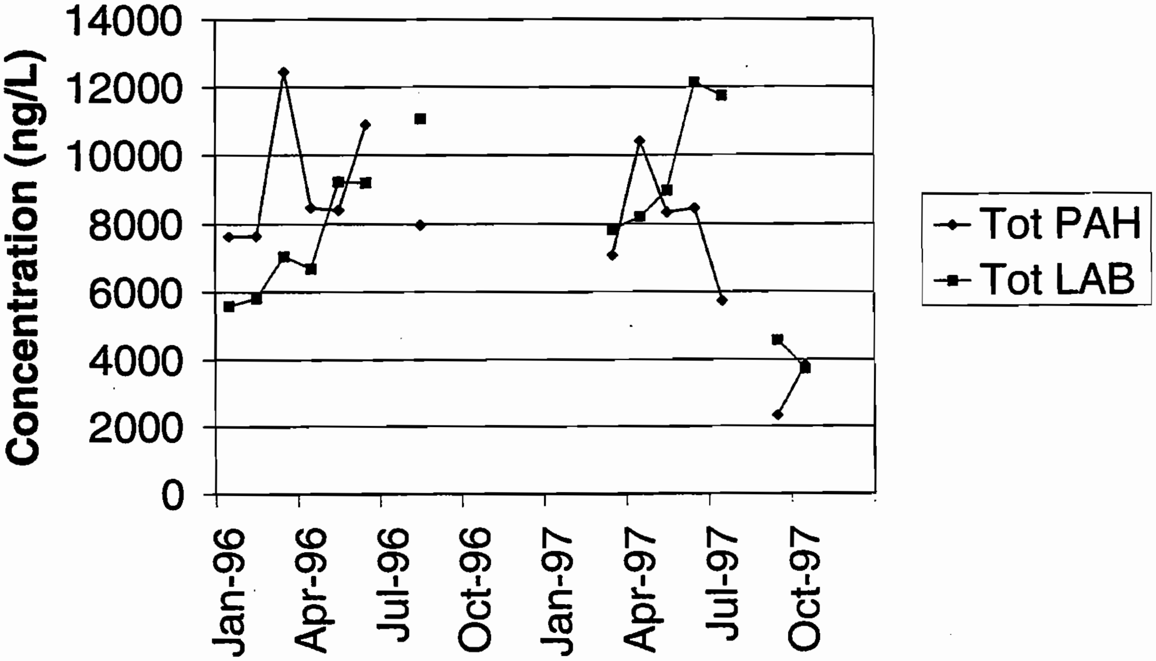


Figure 16 Temporal response of total PAH and LAB Loads

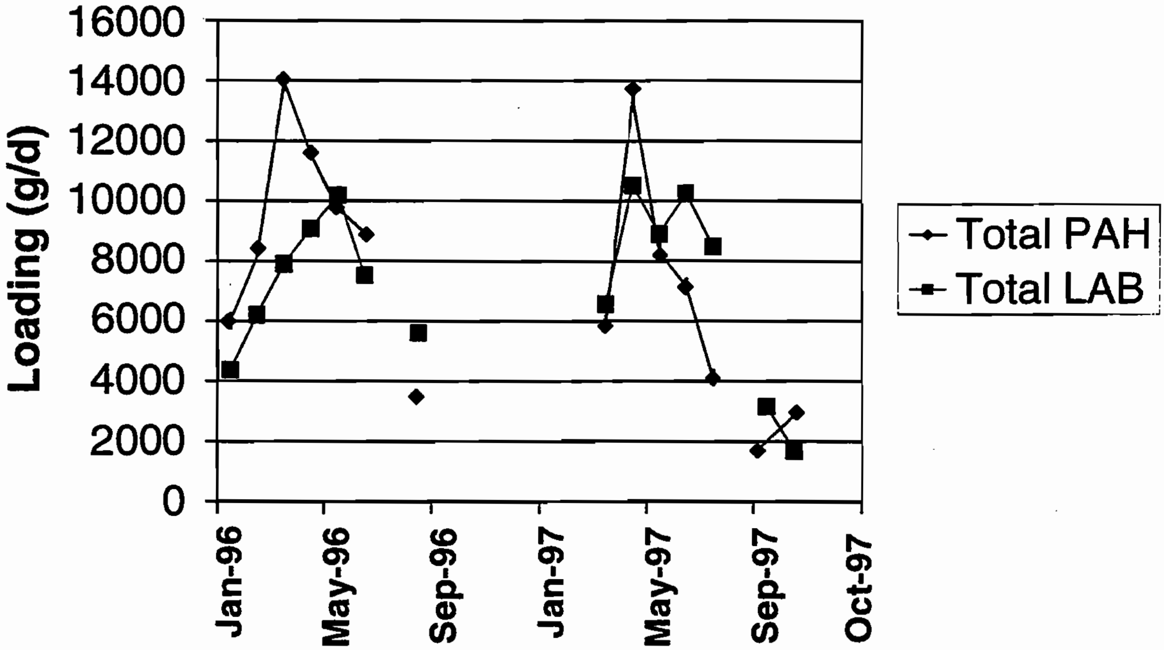


Table 9 PAH and LAB Concentrations (ng/L)

Field ID	E96A1AA	E96A2AA	E96B1AA	E96B2AA	E96C1AA	E96C2AA	E96D1AA
Collection Date	01/10/96	01/12/96	02/14/96	02/16/96	03/13/96	03/15/96	04/10/96
Min Reporting Limit (ng/L)	10	10	10	10	10	10	10
Naphthalene	630	850	770	850	940	860	720
C1-Naphthalenes	720	1100	820	930	1400	1000	770
C2-Naphthalenes	970	1400	1100	1200	2000	1600	1100
C3-Naphthalenes	750	1200	1000	920	2000	1700	1200
C4-Naphthalenes	390	480	430	360	1000	1000	680
Benzothiozol	190	200	160	110	400	380	210
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	66	90	90	89	120	110	95
Biphenyl	70	120	91	95	140	110	81
Dibenzofuran	38	53	46	49	69	66	54
Fluorene	80	110	100	100	150	120	98
C1-Fluorenes	150	200	180	150	280	260	260
C2-Fluorenes	210	260	230	190	420	420	290
C3-Fluorenes	230	270	250	220	490	540	300
Phenanthrene	220	280	280	280	340	370	250
Anthracene	13	23	35	32	45	49	28
C1-Phenanthrenes/anthracenes	340	390	370	310	450	490	310
C2-Phenanthrenes/anthracenes	390	420	400	330	520	560	360
C3-Phenanthrenes/anthracenes	210	220	210	180	350	340	220
C4-Phenanthrenes/anthracenes	100	92	97	90	220	190	160
Dibenzothiophene	32	44	41	39	59	63	38
C1-Dibenzothiophenes	83	110	110	91	170	190	100
C2-Dibenzothiophenes	140	170	170	140	270	310	170
C3-Dibenzothiophenes	120	140	140	110	240	270	150
Fluoranthene	93	120	150	170	220	260	160
Pyrene	100	120	150	160	200	230	150
C1-Fluoranthenes/pyrenes	92	98	110	100	160	170	100
C2-Fluoranthenes/pyrenes	96	88	69	75	120	110	88
C3-Fluoranthenes/pyrenes	58	50	46	36	79	64	53
Benzo[a]anthracene	33	35	44	51	59	74	44
Chrysene	41	44	55	63	89	99	63
C1-Chrysenes	35	36	29	33	54	51	36
C2-Chrysenes	32	28	24	34	48	44	34
C3-Chrysenes	22	22	22	27	34	27	25
C4-Chrysenes	ND	ND	ND	ND	31	26	22
Benzo[b]fluoranthene	53	60	47	64	92	120	68
Benzo[k]fluoranthene	15	25	16	22	29	36	25
Benzo[e]pyrene	31	36	26	36	52	63	40
Benzo[a]pyrene	16	0	23	27	46	60	36
Perylene	5.1 J	4.3 J	5.6 J	6 J	11	15	8.7 J
Indeno[1,2,3,-c,d]pyrene	21	24	20	28	40	50	31
Dibenzo[a,h]anthracene	ND	ND	ND	ND	9.8 J	12	7.6 J
Benzo[g,h,i]perylene	26	30	20	28	40	50	33
C10B-Phenyl decanes*	2300	2200	2400	2500	2500	2600	2400
C11B-Phenyl undecanes*	2200	2400	2500	2300	3200	2900	2900
C12B-Phenyl dodecanes*	970	920	930	810	1500	1400	1400
C13B-Phenyl tridecanes*	100	100	98	99	ND	ND	ND
C14B-Phenyl tetradecanes*	ND	ND	ND	ND	ND	ND	ND
Total PAH	6567	8704	7702	7604	12888	12005	8317
Total LAB	5570	5620	5928	5709	7200	6900	6700

*LAB Compounds

J = Below MDL

I = Standard Interference

B = Blank Interference

ND = Non-Detect

Field ID	E96D2AA	E96E1AA	E96E2AA	E96F1AA	E96F2AA	E96G1AA	E97C1AA
Collection Date	04/12/96	05/15/96	05/17/96	06/12/96	06/14/96	08/14/96	03/05/97
Min Reporting Limit (ng/L)	10	9.84	9.69	9.65	9.62	11.2	10
Naphthalene	670	950	1000	1200	720	860 B	640
C1-Naphthalenes	800	840	1300	1400	680	920 B	590
C2-Naphthalenes	1200	860	1400	2000	940	1100	1000
C3-Naphthalenes	1200	620	1000	1900	940	910	1100
C4-Naphthalenes	710	270	430	1100	570	440	730
Benzothiozol	170	190	420	260	350	1000	200
Acenaphthylene	ND	ND	ND	ND	ND	ND	7.9 J
Acenaphthene	93	110	140	180	110	98	83
Biphenyl	88	92	160	250	96	86 B	80
Dibenzofuran	48	58	83	86	63	56 B	46
Fluorene	100	120	170	230	120	110	100
C1-Fluorenes	190	170	290	410	200	170	200
C2-Fluorenes	290	190	370	630	310	270	250
C3-Fluorenes	370	170	320	720	360	200	290
Phenanthrene	260	31	45	41	26	50	190
Anthracene	35	260	450	410	260	300	25
C1-Phenanthrenes/anthracenes	340	250	490	660	310	340	270
C2-Phenanthrenes/anthracenes	380	230	430	720	350	310	310
C3-Phenanthrenes/anthracenes	240	92	190	440	180	170	160
C4-Phenanthrenes/anthracenes	130	65	130	270	110	130	86
Dibenzothiophene	42	49	72	76	48	58	30
C1-Dibenzothiophenes	110	96	170	210	120	100	160
C2-Dibenzothiophenes	180	130	220	360	190	140	150
C3-Dibenzothiophenes	150	77	160	320	150	100	120
Fluoranthene	170	130	300	140	110	220	96
Pyrene	160	130	270	170	110	200 B	94
C1-Fluoranthenes/pyrenes	110	69	140	180	89	110	73
C2-Fluoranthenes/pyrenes	92	42	98	130	66	71	51
C3-Fluoranthenes/pyrenes	55	20	41	78	35	30	25
Benzo[a]anthracene	52	38	87	40	31	64	27
Chrysene	120	50	140	50	37	82	35
C1-Chrysenes	40	28	56	42	24	38	16
C2-Chrysenes	33	ND	ND	42	23	20	13
C3-Chrysenes	22	ND	ND	ND	ND	ND	ND
C4-Chrysenes	20	ND	ND	ND	ND	ND	ND
Benzo[b]fluoranthene	76	51	140	37	29	87	28
Benzo[k]fluoranthene	27	15	40	13	9	31	8 J
Benzo[e]pyrene	43	28	75	22	17	51	17
Benzo[a]pyrene	43	23	64	20	14	50	15
Perylene	10	5.8 J	14	4.7 J	4	11 J	4.4 J
Indeno[1,2,3,-c,d]pyrene	35	25	58	15	11	41	16
Dibenzo[a,h]anthracene	9.4 J	ND	13	3.6 J	ND	9.1 J	2.1 J
Benzo[g,h,i]perylene	35	20	56	20 B	16 B	42 B	15
C10B-Phenyl decanes*	2300	3600	3100	3300	3600	4200	3500
C11B-Phenyl undecanes*	3100	4100	3500	3600	3700	4400	3300
C12B-Phenyl dodecanes*	1300	1800	1800	1800	1900	2200	990
C13B-Phenyl tridecanes*	ND	280	280	280	230	270	42
C14B-Phenyl tetradecanes*	ND	ND	ND	ND	ND	ND	ND
Total PAH	8631	6343	10473	14412	7377	7974	7077
Total LAB	6700	9780	8680	8980	9430	11070	7832

*LAB Compounds

J = Below MDL

I = Standard Interference

B = Blank Interference

ND = Non-Detect

Field ID	E97D2AA	E97E1AA	E97E2AA	E97F2AA	E97G1AA	E97G2AA	E97I2AA
Collection Date	04/11/97	05/07/97	05/09/97	06/06/97	07/09/97	07/11/97	08/22/97
Min Reporting Limit (ng/L)	10	10	10	10	10	10	10
Naphthalene	840	910	740	790	720	490	210
C1-Naphthalenes	810	960	660	810	500	360	230
C2-Naphthalenes	1400	1300	1000	1200	780	520	310
C3-Naphthalenes	1400	1600	1600	1100	790	520	270
C4-Naphthalenes	830	640	610	720	590	470	270
Benzothiozol	140	340	240	300	300	280	220
Acenaphthylene	11	8.3 J	8.3 J	ND	ND	ND	2.2 J
Acenaphthene	120	94	98	96	90	55	29
Biphenyl	86	100	88	97	65	41	23
Dibenzofuran	68	52	52	61	54	36	20
Fluorene	140	110	110	110	110	66	34
C1-Fluorenes	210	180	170	170	190	120	67
C2-Fluorenes	320	250	350	300	280	190	100
C3-Fluorenes	340	410	290	310	360	300	220
Phenanthrene	390	220	220	260	240	160	100
Anthracene	64	28	28	45	27	21	14
C1-Phenanthrenes/anthracenes	430	280	280	340	270	200	96
C2-Phenanthrenes/anthracenes	450	330	320	420	300	260	140
C3-Phenanthrenes/anthracenes	250	180	180	240	180	150	100
C4-Phenanthrenes/anthracenes	140	88	90	130	120	110	70
Dibenzothiophene	55	41	39	50	37	26	15
C1-Dibenzothiophenes	180	150	130	110	94	73	32
C2-Dibenzothiophenes	220	180	160	210	150	130	75
C3-Dibenzothiophenes	180	170	180	160	130	120	75
Fluoranthene	270	110	96	140	110	94	110
Pyrene	250	100	93	140	100	91	110
C1-Fluoranthenes/pyrenes	160	76	68	95	74	70	70
C2-Fluoranthenes/pyrenes	110	55	49	67	54	52	56
C3-Fluoranthenes/pyrenes	64	40	38	30	34	22	ND
Benzo[a]anthracene	100	33	30	57	36	34	42
Chrysene	100	38	32	55	39	36	48
C1-Chrysenes	57	19	18	25	21	21	19
C2-Chrysenes	40	16	16	28	17	16	12
C3-Chrysenes	30	ND	ND	17	ND	ND	ND
C4-Chrysenes	ND	ND	ND	ND	ND	ND	ND
Benzo[b]fluoranthene	130	43	42	52	32	32	64
Benzo[k]fluoranthene	40	15	11	14	10	10	15
Benzo[e]pyrene	71	25	23	27	19	19	34
Benzo[a]pyrene	72	22	21	25	18	18	30
Perylene	17	5.1 J	4.5 J	7 J	5.4 J	5.5 J	7.5 J
Indeno[1,2,3,-c,d]pyrene	69	ND	ND	24	13	13	29
Dibenzo[a,h]anthracene	12	ND	3.5 J	3.9 J	2.7 J	3.4 J	4 J
Benzo[g,h,i]perylene	62	24	17	22	15	16 B	28
C10B-Phenyl decanes*	3400	3000	3000	4400	4200	4900	3000
C11B-Phenyl undecanes*	3100	3500	3400	4800	4600	4900	2900
C12B-Phenyl dodecanes*	1500	1400	1600	2400	2000	2300	1400
C13B-Phenyl tridecanes*	210	740	1000	320	290	310	170
C14B-Phenyl tetradecanes*	ND	120	200	220	ND	ND	ND
Total PAH	10414	8807	7878	8461	6589	4897	3125
Total LAB	8210	8760	9200	12140	11090	12410	7470

*LAB Compounds

J = Below MDL

I = Standard Interference

B = Blank Interference

ND = Non-Detect

Field ID	E97I5AA	E97I8AA	E97IBAA	E97J2AA	E97J5AA	E97J9AA	E97JCAA
Collection Date	09/24/97	09/26/97	09/29/97	10/01/97	10/03/97	10/15/97	10/17/97
Min Reporting Limit (ng/L)	10	10	10	10	10	10	10
Naphthalene	190	200	230	210	190	130	270
C1-Naphthalenes	140	140	180	180	220	100	480
C2-Naphthalenes	180	190	240	280	400	190	990
C3-Naphthalenes	170	170	230	270	440	230	1100
C4-Naphthalenes	170	180	180	290	310	280	740
Benzothiozol	200	210	210	200	190	190	190
Acenaphthylene	2.5 J	1.9 J	2.8 J	2.6 J	1.6 J	1.3 J	3 J
Acenaphthene	25	25	30	52	32	21	62
Biphenyl	15	16	21	24	35	14	110
Dibenzofuran	14	16	21	42	23	20	49
Fluorene	23	25	35	60	39	31	100
C1-Fluorenes	41	44	51	64	76	67	200
C2-Fluorenes	73	62	85	120	120	130	340
C3-Fluorenes	120	110	110	160	140	160	360
Phenanthrene	65	57	80	190	85	63	150
Anthracene	11	9 J	11	35	12	13	15
C1-Phenanthrenes/anthracenes	62	54	83	110	120	95	310
C2-Phenanthrenes/anthracenes	100	84	110	130	160	150	420
C3-Phenanthrenes/anthracenes	78	58	69	74	88	100	250
C4-Phenanthrenes/anthracenes	55	33	37	50	43	59	96
Dibenzothiophene	8.8 J	9 J	12	20	14	9.6 J	30
C1-Dibenzothiophenes	22	20	30	38	45	35	97
C2-Dibenzothiophenes	52	42	58	65	68	78	180
C3-Dibenzothiophenes	60	42	56	57	66	72	160
Fluoranthene	58	42	48	150	48	54	54
Pyrene	81	61	58	120	58	66	77
C1-Fluoranthenes/pyrenes	49	39	48	76	40	52	66
C2-Fluoranthenes/pyrenes	40	29	32	40	23	34	38
C3-Fluoranthenes/pyrenes	ND	ND	ND	17	ND	17	14
Benzo[a]anthracene	28	20	20	56	17	22	18
Chrysene	34	22	22	49	16	21	19
C1-Chrysenes	15	9.5 J	11	16	7 J	10	8.3 J
C2-Chrysenes	9.2 J	6.6 J	7.1 J	7.8 J	4.6 J	6.1 J	ND
C3-Chrysenes	ND	ND	ND	ND	ND	ND	ND
C4-Chrysenes	ND	ND	ND	ND	ND	ND	ND
Benzo[b]fluoranthene	38	20	21	61	17	18	15
Benzo[k]fluoranthene	13	6.1 J	6 J	16	4.6 J	4.9 J	4.1 J
Benzo[e]pyrene	22	12	12	32	9.7 J	10	9.3 J
Benzo[a]pyrene	18	11	9.3 J	37	8.5 J	9.2 J	8 J
Perylene	4.6 J	3.2 J	2.5 J	9.9 J	2 J	2.4 J	2.4 J
Indeno[1,2,3,-c,d]pyrene	20	11	13	43	25	13	8.9 J
Dibenzo[a,h]anthracene	2.6 J	1.8 J	1.5 J	5.4 J	1.4 J	1.7 J	1.3 J
Benzo[g,h,i]perylene	18	12 B	9.4 J	36	8 J	8 J	9.7 J
C10B-Phenyl decanes*	28	1800	2100	1400	1100	1500	1400
C11B-Phenyl undecanes*	8.5 J	1800	2600	1600	1200	1600	1400
C12B-Phenyl dodecanes*	9.8 J	1000	1200	910	670	1000	750
C13B-Phenyl tridecanes*	4.8 J	120	160	110	74	120	100
C14B-Phenyl tetradecanes*	5.1 J	ND	ND	ND	ND	ND	ND
Total PAH	2088	1865	2251	3239	2994	2347	6813
Total LAB	56	4720	6060	4020	3044	4220	3650

*LAB Compounds

J = Below MDL

I = Standard Interference

B = Blank Interference

ND = Non-Detect

Field ID	E97J8AA	E97JBAA
Collection Date	10/15/1997*	10/17/1997*
Min Reporting Limit (ng/L)	10	10
Naphthalene	12 B	54
C1-Naphthalenes	4.5 JB	58
C2-Naphthalenes	12	200
C3-Naphthalenes	26	310
C4-Naphthalenes	140	220
Benzothiozol	210	200
Acenaphthylene	ND	0.94 J
Acenaphthene	3.3 J	30
Biphenyl	2 J	37
Dibenzofuran	9 J	32
Fluorene	5.2 J	44
C1-Fluorenes	23	69
C2-Fluorenes	65	120
C3-Fluorenes	100	110
Phenanthrene	6.4 JB	32
Anthracene	ND	6.1 J
C1-Phenanthrenes/anthracenes	15	66
C2-Phenanthrenes/anthracenes	71	100
C3-Phenanthrenes/anthracenes	47	52
C4-Phenanthrenes/anthracenes	25	22
Dibenzothiophene	ND	8.4 J
C1-Dibenzothiophenes	ND	30
C2-Dibenzothiophenes	36	47
C3-Dibenzothiophenes	36	35
Fluoranthene	21	24
Pyrene	36	34
C1-Fluoranthenes/pyrenes	23	21
C2-Fluoranthenes/pyrenes	20	18
C3-Fluoranthenes/pyrenes	ND	ND
Benzo[a]anthracene	10	8.1 J
Chrysene	9.1 J	6.9 J
C1-Chrysenes	3.6 J	2.6 J
C2-Chrysenes	ND	ND
C3-Chrysenes	ND	ND
C4-Chrysenes	ND	ND
Benzo[b]fluoranthene	5.3 J	3.8 J
Benzo[k]fluoranthene	1.4 J	1.6 J
Benzo[e]pyrene	4.1 J	2.6 J
Benzo[a]pyrene	3.5 J	2.7 J
Perylene	0.82 J	0.62 J
Indeno[1,2,3,-c,d]pyrene	3 J	1.7 J
Dibenzo[a,h]anthracene	0.55 J	ND
Benzo[g,h,i]perylene	2.4 J	1.7 J
C10B-Phenyl decanes*	540	460
C11B-Phenyl undecanes*	400	320 B
C12B-Phenyl dodecanes*	550	390
C13B-Phenyl tridecanes*	ND	37
C14B-Phenyl tetradecanes*	ND	ND
Total PAH	762	1795
Total LAB	1490	1207

*LAB Compounds

*secondary treatment effluent

J = Below MDL
I = Standard Interference
B = Blank Interference
ND = Non-Detect

Table 10 PAH and LAB Distribution in Average Influent and Effluent

	ave. influent (ng/L)	% tot PAH or LAB	ave. effluent (ng/L)	% tot PAH or LAB	removal %
Naphthalene	685	5.2	170	6.2	75
C1-Naphthalenes	840	6.3	173	6.3	79
C2-Naphthalenes	1584	11.9	299	10.9	81
C3-Naphthalenes	1819	13.7	322	11.7	82
C4-Naphthalenes	1299	9.8	278	10.2	79
Benzothiozol	299	2.3	202	7.4	32
Acenaphthylene	12	0.1	2	0.1	82
Acenaphthene	140	1.1	31	1.1	78
Biphenyl	108	0.8	30	1.1	72
Dibenzofuran	79	0.6	25	0.9	69
Fluorene	170	1.3	40	1.4	77
C1-Fluorenes	313	2.4	70	2.6	78
C2-Fluorenes	493	3.7	122	4.4	75
C3-Fluorenes	565	4.3	159	5.8	72
Phenanthrene	513	3.9	83	3.0	84
Anthracene	96	0.7	14	0.5	85
C1-Phenanthrenes/anthracenes	571	4.3	101	3.7	82
C2-Phenanthrenes/anthracenes	653	4.9	147	5.4	78
C3-Phenanthrenes/anthracenes	393	3.0	92	3.3	77
C4-Phenanthrenes/anthracenes	206	1.6	49	1.8	76
Dibenzothiophene	68	0.5	14	0.5	79
C1-Dibenzothiophenes	174	1.3	39	1.4	78
C2-Dibenzothiophenes	313	2.4	70	2.6	78
C3-Dibenzothiophenes	285	2.2	66	2.4	77
Fluoranthene	348	2.6	61	2.2	82
Pyrene	314	2.4	70	2.6	78
C1-Fluoranthenes/pyrenes	211	1.6	48	1.8	77
C2-Fluoranthenes/pyrenes	143	1.1	33	1.2	77
C3-Fluoranthenes/pyrenes	84	0.6	16	0.6	81
Benzo[a]anthracene	138	1.0	24	0.9	83
Chrysene	132	1.0	25	0.9	81
C1-Chrysenes	62	0.5	10	0.4	83
C2-Chrysenes	42	0.3	8	0.3	82
C3-Chrysenes	ND	0.0	ND	0.0	undefined
C4-Chrysenes	ND	0.0	ND	0.0	undefined
Benzo[b]fluoranthene	154	1.2	26	1.0	83
Benzo[k]fluoranthene	53	0.4	7	0.3	86
Benzo[e]pyrene	86	0.6	15	0.5	83
Benzo[a]pyrene	104	0.8	14	0.5	87
Perylene	27	0.2	4	0.1	87
Indeno[1,2,3,-c,d]pyrene	120	0.9	17	0.6	86
Dibenzo[a,h]anthracene	13	0.1	2	0.1	83
Benzo[g,h,i]perylene	77	0.6	13	0.5	83
C10B-Phenyl decanes*	3988	37.6	1333	37.1	67
C11B-Phenyl undecanes*	4338	40.9	1383	38.5	68
C12B-Phenyl dodecanes*	2013	19.0	788	21.9	61
C13B-Phenyl tridecanes*	259	2.4	90	2.5	65
C14B-Phenyl tetradecanes*	ND		ND		
Total PAH (ng/L)	13255		2737		79
Total LAB (ng/L)	10596		3594		66

*LAB Compounds.

50% of the total PAH in both the influent and effluent. The make-up of the total PAH is not changed substantially by treatment. The total average removal rate was 79%, with lower removals of the lower molecular weight (LMW) PAH compounds. The two secondary effluent concentrations were 762 and 1795 ng/L, and would have indicated high removal rates of greater than 90%. This is consistent with the pilot treatment plant study and published results of Clark et al. (1995). The maximum PAH load was 13.9 Kg/d in March of 1996 and 13.4 Kg/d in April of 1997.

Total LAB ranged from 5595 to 12140 ng/L prior to secondary treatment. The post-secondary treatment range was 3734 to 4577 ng/L. The level of 56 ng/L measured on September 24, 1997 is obviously an outlier. The total LAB is dominated by the C_{10} and C_{11} compounds, followed by C_{11} and to a much lesser degree C_{13} compounds. C_{14} LAB was detected in a few samples in 1997, but at low levels. The total average removal rate was 66%. The two secondary effluent concentrations were 1207 and 1490 ng/L, and would have indicated high removal rates of greater than 90%. This is consistent with the pilot treatment study. The maximum LAB load was 11 Kg/ in August of 1996 and 12.1 Kg/d in June of 1997.

Pesticides: Temporal responses of the various pesticides and loading rates are shown in Figures 17 and 18. Total DDTs include 2,4'-DDE; 4-4'-DDE; 2,4'-DDD; 4,4'-DDD; 2.4'-DDT and 4,4"-DDT. Total Chlordanes include heptachlor; heptachlor epoxide; alpha-chlordane and trans-nonachlor.

Other pesticides (referred to as total pesticides in the 1995 DECS report) include aldrin, hexachlorobenzene, gamma-BHC or lindane, dieldrin, endrin and mirex. In addition, DDMU was also analyzed for but was never detected. Actual concentrations are listed in Tables 11 to 13.

The pesticides seemed to follow seasonal trends, with high concentrations in April (e.g. DDT) and summer months (chlordanes as well as lindane). The April increase could have been high groundwater interaction with soil-bound compounds and infiltration, or inadvertent discharge. The temporal response of total DDT and total chlordanes are similar and somewhat different from the other pesticides. The increase in summer months may have been due to the application of herbicides and pesticides during the growing season.

Total DDT ranged from non-detect to 13 ng/L prior to September of 1997. Compounds detected consistently include 4,4'-DDE; 2,4'-DDD and 4,4'-DDT. Secondary treatment removed close to 90% of the influent total DDT, which is similar to that observed for the pilot treatment plant study. Total DDT in secondary effluent ranged from non-detect to 0.8 ng/L. Maximum DDT load in 1996 was 20 g/d in April, and about 10 g/d in both March and April of 1997.

Figure 17
Average monthly pesticide concentrations

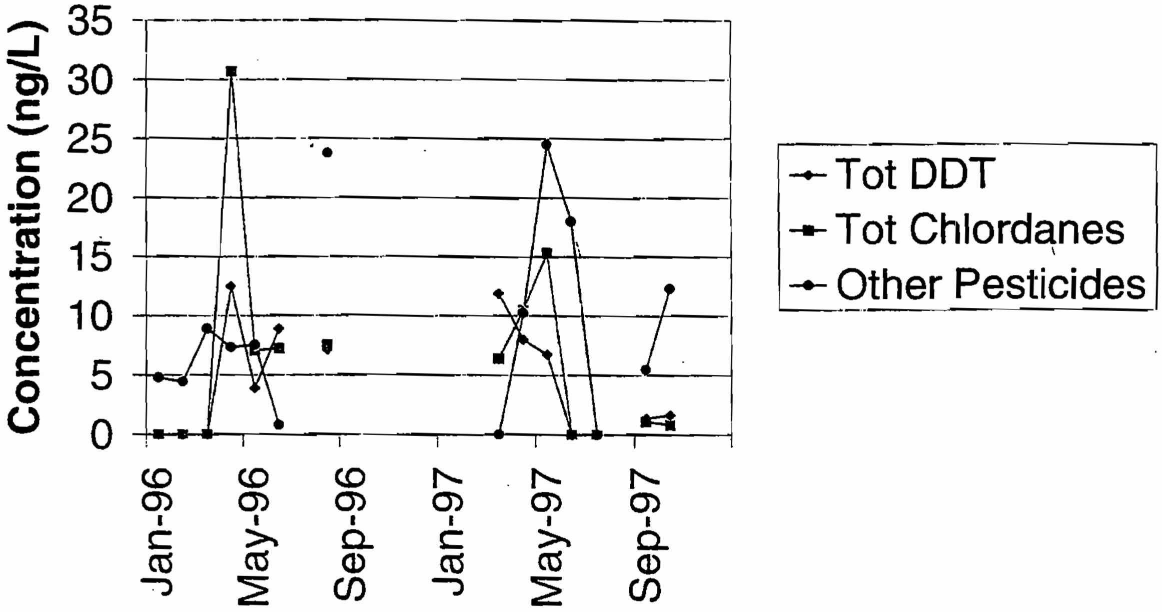


Figure 18
Average monthly pesticide loads

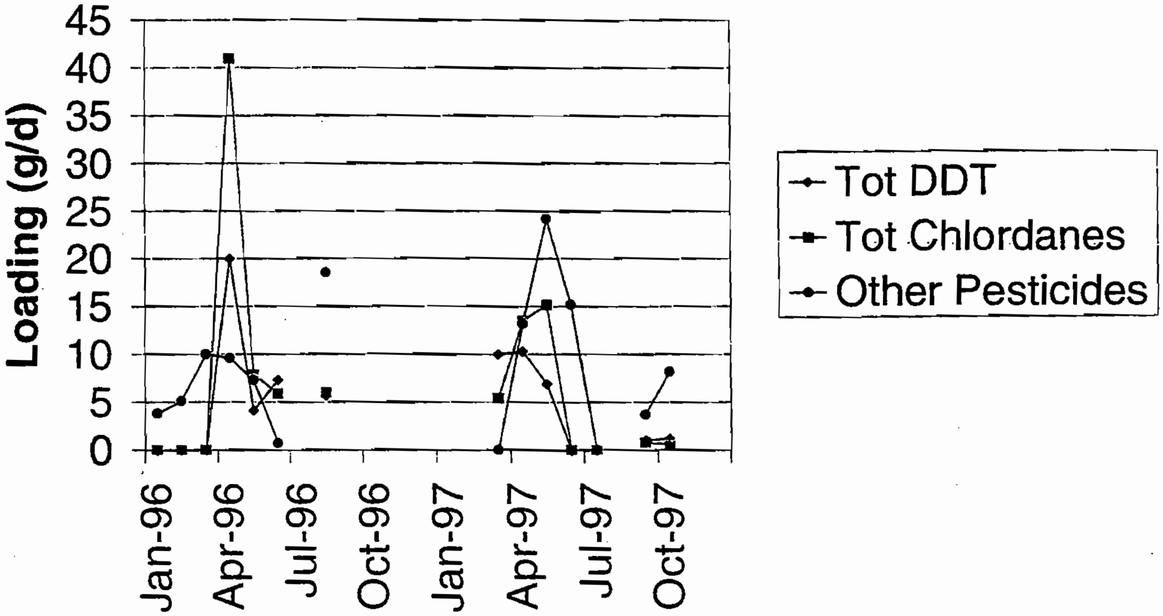


Table 11 Total DDT Concentrations (ng/L)

Collection Date	2,4'-DDE	4,4'-DDE	2,4'-DDD	4,4'-DDD	2,4'-DDT	4,4'-DDT	MDL (ng/L)	Tot DDT
01/10/96	ND	ND	ND	ND	ND	ND	5.00	ND
01/12/96	ND	ND	ND	ND	ND	ND	5.00	ND
02/14/96	ND	ND	ND	ND	ND	ND	5.00	ND
02/16/96	ND	ND	ND	ND	ND	ND	5.00	ND
03/13/96	ND	ND	ND	ND	ND	ND	5.00	ND
03/15/96	ND	ND	ND	ND	ND	ND	5.00	ND
04/10/96	ND	ND	ND	ND	ND	ND	5.00	ND
04/12/96	ND	ND	ND	ND	ND	25	5.00	25
05/15/96	ND	1.2 J	1.4 J	ND	ND	2.4	1.97	5
05/17/96	ND	0	0	ND	ND	2.8	1.94	2.8
06/12/96	ND	1.4 J	7.8	ND	ND	3	1.93	12.2
06/14/96	ND	2.4	0	ND	ND	3.2	1.92	5.6
08/14/96	ND	2.3	2.8	ND	ND	2.3	2.23	7.4
08/16/96	1.8	ND	ND	ND	ND	5.1	1.94	6.9
03/05/97	ND	3.1	1.6 J	ND	ND	7.2	2.50	11.9
04/11/97	ND	1.9 J	2.5	ND	ND	3.6	2.50	8.0
05/07/97	ND	2.9	0.68 J	ND	ND	7.1	2.50	10.7
05/09/97	ND	2.8	ND	ND	ND	ND	2.50	2.8
06/06/97	ND	ND	ND	ND	ND	ND	2.60	ND
07/09/97	ND	ND	ND	ND	ND	ND	2.50	ND
07/11/97	ND	ND	ND	ND	ND	ND	2.50	ND
09/22/97	ND	2.2 J	ND	ND	ND	ND	2.50	2.2
09/24/97	ND	2.1 J	ND	ND	ND	ND	2.50	2.1
09/26/97	ND	1.2 J	ND	ND	ND	ND	2.50	1.2
09/29/97	ND	ND	ND	ND	ND	ND	2.50	ND
10/01/97	ND	ND	ND	ND	ND	ND	2.50	ND
10/03/97	ND	ND	ND	ND	ND	ND	2.50	ND
10/15/97	ND	1.5 J	ND	ND	ND	1.4 J	2.50	2.9
10/17/97	ND	1.2 J	ND	ND	ND	2.5	2.50	3.7
10/15/97*	ND	ND	ND	ND	ND	ND	2.50	ND
10/17/97*	ND	ND	ND	ND	ND	0.8 J	2.50	0.8

* Secondary battery effluent.

J=Below MDL.

Table 12 Total Chlordane Concentrations (ng/L)

Collection Date	HEPTACHLOR	HEPTACHLOR EPOXIDE	ALPHA-CHLORDANE	TRANS-NONACHLOR	MDL (ng/L)	Tot Chlordanes
01/10/96	ND	ND	ND	ND	5.00	0
01/12/96	ND	ND	ND	ND	5.00	0
02/14/96	ND	ND	ND	ND	5.00	0
02/16/96	ND	ND	ND	ND	5.00	0
03/13/96	ND	ND	ND	ND	5.00	0
03/15/96	ND	ND	ND	ND	5.00	0
04/10/96	ND	ND	23	9	5.00	32
04/12/96	ND	ND	20	9.4	5.00	29.4
05/15/96	ND	ND	3.4	3.8	1.97	7.2
05/17/96	ND	ND	3	4	1.94	7
06/12/96	ND	ND	2.4	4.6	1.93	7
06/14/96	ND	ND	2.5	5	1.92	7.5
08/14/96	ND	ND	3.8	3.8	2.23	7.6
08/16/96	ND	ND	5.9	1.6 J	1.94	7.5
03/05/97	ND	ND	2.6	3.8	2.50	6.4
04/11/97	ND	ND	5.9	4.6	2.50	10.5
05/07/97	ND	ND	1.7 J	12	2.50	13.7
05/09/97	ND	ND	ND	17	2.50	17
06/06/97	ND	ND	ND	ND	2.60	0
07/09/97	ND	ND	ND	ND	2.50	0
07/11/97	ND	ND	ND	ND	2.50	0
09/22/97	ND	ND	1.8 J	ND	2.50	1.8
09/24/97	ND	ND	1 J	ND	2.50	1
09/26/97	ND	ND	0.7 J	ND	2.50	0.7
09/29/97	ND	ND	0.92 J	ND	2.50	0.92
10/01/97	ND	ND	1.1 J	ND	2.50	1.1
10/03/97	ND	ND	ND	ND	2.50	0
10/15/97	ND	ND	0.77 J	ND	2.50	0.77
10/17/97	ND	ND	0.38 J	1.2 J	2.50	1.58
10/15/1997*	ND	ND	ND	ND	2.50	0
10/17/1997*	ND	ND	ND	1.5 J	2.50	1.5

*Secondary battery effluent.

J=Below MDL.

Table 13 Other PesticidesConcentrations (ng/L)

Collection Date	ALDRIN	HCB	LINDANE OR GAMMA-BHC	DIELDRIN	ENDRIN	MIREX	Other Pesticides
01/10/96	ND	ND	ND	ND	ND	ND	0
01/12/96	ND	ND	9.6	ND	ND	ND	9.6
02/14/96	ND	ND	8.9	ND	ND	ND	8.9
02/16/96	ND	ND	ND	ND	ND	ND	0
03/13/96	ND	ND	9	ND	ND	ND	9
03/15/96	ND	ND	8.8	ND	ND	ND	8.8
04/10/96	ND	ND	9.2	ND	ND	ND	9.2
04/12/96	ND	ND	5.5	ND	ND	ND	5.5
05/15/96	ND	ND	13	0.9 J	ND	ND	13.9
05/17/96	ND	ND	ND	1.2 J	ND	ND	1.2
06/12/96	ND	ND	ND	1.6 J	ND	ND	1.6
06/14/96	ND	ND	ND	ND	ND	ND	0
08/14/96	ND	ND	15	ND	ND	ND	15
08/16/96	ND	ND	28	4.5 I	ND	ND	32.5
03/05/97	ND	ND	ND	ND	ND	ND	0
04/11/97	ND	0.26 J	10	ND	ND	ND	10.26
05/07/97	ND	ND	ND	23	ND	ND	23
05/09/97	ND	ND	ND	26	ND	ND	26
06/06/97	ND	ND	18	ND	ND	ND	18
07/09/97	ND	ND	ND	ND	ND	ND	0
07/11/97	ND	ND	ND	ND	ND	ND	0
09/22/97	ND	ND	ND	0.53 J	ND	ND	0.53
09/24/97	ND	ND	ND	0.4 J	ND	ND	0.4
09/26/97	ND	ND	ND	ND	ND	ND	0
09/29/97	ND	ND	21	ND	ND	ND	21
10/01/97	ND	ND	ND	ND	ND	ND	0
10/03/97	ND	ND	14	ND	ND	ND	14
10/15/97	ND	ND	11	ND	ND	ND	11
10/17/97	ND	0.97 J	13	ND	ND	ND	13.97
10/15/1997*	ND	ND	15	ND	ND	ND	15
10/17/1997*	ND	ND	20	ND	ND	ND	20

*Secondary battery effluent.

J=Below MDL.

I=Standard interference.

Total Chlordanes ranged from non-detect to 32 ng/L prior to September 1997. Only alpha-chlordane and trans-nonachlor are detected consistently. Secondary treatment removed close to 80% of the influent total chlordane, which is similar to that observed for the pilot treatment plant study. Total chlordane in the two secondary effluent samples ranged from non-detect to 1.5 ng/L. The maximum load for chlordanes occurred in April of 1996 at 41 g/d and 15 g/d in May of 1997.

Other pesticides ranged from non-detect to 24 ng/L prior to September of 1997. Lindane and dieldrin are the most commonly detected pesticides, although HCB was detected twice at below the MDL. The occurrence of dieldrin in May of 97 at about 25 ng/L is somewhat surprising and could be due to interference. Hunt et al (1995) discussed the anomalously high results of diedrin in 1993, and how re-analysis using dual-column confirmation showed that the result was due to an unknown interferent. The maximum load occurred in August of 1996 at 19 g/d and 24 g/d in May of 1997. The samples from September and October sometimes show effluent concentrations greater than influent concentrations. The two secondary effluent lindane concentrations were 15 and 20 ng/L. The pilot treatment plant study also had similar issues but reported a removal rate of about 64% for September and October 1995. This illustrates the same difficulty as with the PCBs in quantifying at such low levels with natural variability. Split samples measured by the Deer Island laboratory showed consistent positive removal of lindane.

Summary on Organic Loads

The organic loading rates (mass discharged per day) from 1993 to 1997 are further summarized as figures in the appendix (except for total LAB). Annual loading rates from 1995 to 1997 are summarized in Table 14, with projected loading rates and concentrations when full secondary treatment is implemented. All organic loading rates show decreases from 1995 to 1997 except for the chlordanes and other pesticides (mainly lindane). The projected organic concentrations are based on the average of all 10 effluent samples collected in September and October of 1997 (8 final and 2 secondary battery effluent samples) and is somewhat conservative since full secondary treatment is expected to improve removals. This will compensate somewhat for other times when influent concentrations may be higher. The projected loading rates are calculated by multiplying the projected concentrations by 373 MGD (1.41×10^9 liters per day), which is the projected average MWRA discharge rate into Massachusetts Bay. The projected annual loading rate of all organics are projected to decrease even further. All projected organic loading rates are smaller than originally projected in the SEIS.

Table 14 Annual MWRA organic loads from 1995 to 1997 (expressed with two significant figures) and projected secondary effluent characteristics

Compound	1995 (Kg/yr)	1996 (Kg/yr)	1997 (Kg/yr)	SEIS Projection Mean (Kg/yr)	Projected for Secondary (Kg/yr)	Project for Secondary (µg/L)
Total PCB	26	4.7	5.9	41	4.8	0.0093
Total LAB	5,100	2,700	2,600	NA	1,900	3.594
Total PAH	8,700	4,700	3,300	NA	1,400	2,728
Total DDT	5.6	4.2	2.3	2.8	0.67	0.0013
Total Chlordanes	3.3	2	2.7	13.7 (as heptachlor)	0.48 (ND as heptachlor)	0.00094
Other Pesticides	7.9	4.3	5.1	10.6 (as aldrin and dieldrin)	5 (0.00013 as aldrin and dieldrin)	0.0096

ND non detect

See the introductory text on p. 3-14 before temporal response section on how changes in MDL should be taken into consideration in comparing interannual values.

Table 15 Comparison of Deer Island effluent with Water Quality Criteria and Ambient Conditions

Parameter	Maximum concentration observed in 1996/97 (µg/L)	Projected Secondary effluent concentration (µg/L)	Human Health WQC x 364 (µg/L)	Chronic WQC x 48.3 (µg/L)	Acute WQC x 48.3 (µg/L)	Ambient Conditions* (µg/L)
Ag	7.8	1.2	3600	322	110	NA
Cd	1.1	0.04	18200	3040	2000	0.02-0.03
Cr(VI)**	9.1	0.95	NA	176	53000	0.1-0.18
Cu	91.7	26	52.4	1.5	140	0.1-0.3
Hg	0.512	0.096	4880	500	100	0.0005-0.0014
Mo	22.1	13.3	NA	NA	NA	NA
Ni	11.8	4.6	18200	340	3600	0.26-1.6
Pb	12.5	4.7	NA	5200	6800	0.03-0.19
Zn	78.7	26.7	NA	NA	4500	0.08-0.57
4,4'-DDT	0.025	0.0013	0.0087	0.061	6.3	0.000053 (total)
Dieldrin	0.026	0.000093	0.026	0.116	34.3	0.000011
Lindane	0.021	0.0096	6.8	NA	7.7	0.000062

*Ambient conditions for trace metals are ranges from Battelle (1992) for the Massachusetts Bay disposal site. Ambient conditions for pesticides are mean concentrations from Shea and Weisbrod (1997) for the Massachusetts Bay "B" buoy.

**This assumes that the Cr measured in Deer Island wastewater is Cr(VI) for a conservative comparison.

4.0 CONCLUSIONS

The effluent from DIWTP had shown consistent decreases for most parameters monitored in DECS, which was initiated as early as 1991 and continued through 1997. However, the introduction of secondary treatment on Deer Island in August of 1997 made a tremendous improvement to effluent quality. In this final section, the DIWTP effluent is compared with ambient conditions, water quality criteria, and expected dilutions. This information is summarized in Table 15.

The trace metal concentrations of DIWTP are fairly low and typical of municipal wastewater in the northeast. Trace metal concentration levels observed by Battelle in 1992 at the Massachusetts Bay disposal site were very low, indicating relatively pristine conditions. The projected undiluted secondary effluent from DIWTP exceed chronic water quality criteria (WQC) for Cu and Hg. The effluent also exceed ambient concentrations. With the high level of dilution available from the offshore diffuser network, the effluent is expected to meet the most stringent WQC (human health, chronic or acute) adjusted by their respective dilution factors (as provided by U.S. EPA). Regular NPDES monitoring (using methods with comparable detection limits) should suffice to characterize trace metal loads of DIWTP effluent. Effluent characterization with respect to metals should be coupled with influent and effluent monitoring, as well as residual quality in order to provide more useful information. Bio-monitoring with mussels at the new Massachusetts Bay outfall would be useful to ascertain trace metal impacts from the DIWTP discharge.

Monitoring by Shea and Weisbrod (1997) showed that the average PCB concentrations at the future outfall site was about 0.27 ng/L; total PAH about 6.5 ng/L, total DDT about 0.005 ng/L and higher levels of dieldrin and lindane. The projected undiluted secondary effluent from DIWTP are higher than ambient conditions for the pesticides mentioned. The undiluted total PCB of the future DIWTP effluent exceeds ambient levels by about a factor of 30. However, the effluent is expected to meet the most stringent WQC (human Health, chronic or acute) adjusted by their respective dilution factors(as provided by U.S. EPA) for the 3 pesticides.

The issue with PCBs can be further illustrated with the congener distribution of DIWTP effluent, observed mussel PCB deployed at Deer Island, and PCB measured in Boston Harbor by Shea and Wiesbrod (1997). The 1996 data is summarized in Table 16, and illustrated in Figure 19. It can be seen that there are other major sources of PCBs to Boston Harbor and Massachusetts Bay since many PCB congeners observed in Deer Island mussels and surface waters were not observed in DIWTP effluent. Of the PCB congeners that were observed in DIWTP, the ones that seemed also elevated in mussel and surface waters are PCB 101, 118, 138, 153, 170 and 187.

However , PCB 138 was not observed in 1997 DIWTP effluent. The PCB issue is further complicated by the human health criteria being expressed as aroclors, a commercial mixture of PCBs. Futher detailed effluent characterization with respect to PCBs seemed to be warrented, as well as bio-monitoring with mussels at the new Massachusetts Bay outfall for PCBs.

A similar picture applies to total PAH. DIWTP effluent total PAH is dominated by the low molecular weight two-ring naphthalene compounds. These are not readily bio-accumulated as shown in Table 17, which also summarized the 1996 data for DIWTP effluent total PAH, mussel total PAH at Deer Island, and observed total PAH in the future outfall site. The atmosphere and rivers as sources for the higher molecular weight PAHs have been discussed by Menzie and Cura (1995). The projected secondary effluent total PAH is about 2800 ng/L, dilution with ambient waters of about 6.5 ng/L at a dilution of 100 to 1 will raise ambient concentrations to 34 ng/L. The increase is substantial and probably measurable. However, past published water quality criteria for individual PAH compounds (before EPA rescinded them) were so high that this is not expected to be a problem. Bio-monitoring with mussels at the new Massachusetts Bay outfall for PAHs should be continued. Effluent characterization with respect to PAHs should be coupled with influent and effluent monitoring as well as residual quality in order to provide more useful information.

There are no water quality criteria for LABs, nor were they measured in ambient waters. The measurement of LABs was originally proposed as a potential tracer for MWRA effluent. The efficacy of using them as a tracer given the projected secondary effluent concentration of about 3600 ng/L and available dilution should be reviewed.

Table 16 PCB Distribution in 1996 Average Effluent, Mussel and Boston Harbor

Congener	Effluent (ng/L)	Mussel (ng/g dry wt)	Harbor (pg/L)	% of tot Effluent	% of tot Mussel	% of tot Harbor
8	0.0	2.4	52	0	1	3
18	0.0	0.42	61	0	0	4
28	0.2	7.9	60	2	3	4
44	0.0	10.3	55	0	4	4
52	0.0	14.8	69	0	5	4
66	0.0	14.6	64	0	5	4
77	0.0	0.75		0	0	0
101	1.0	32.8	139	11	12	9
105	0.0	15.4	76	0	6	5
118	1.4	36.4	75	14	13	5
126	0.0	0.6		0	0	0
128	0.3	7.6	10	3	3	1
138	2.0	10.4	300	21	4	19
153	1.6	52.4	205	17	19	13
170	0.3	3.1	62	3	1	4
180	1.5	45.4	149	16	17	10
187	1.1	14.6	96	12	5	6
195	0.0	0.41	11	0	0	1
206	0.0	0.35	23	0	0	1
209	0.0	0.24	40	0	0	3
Total PCB	9.5	270.87	1547			

Figure 19
PCB Distribution

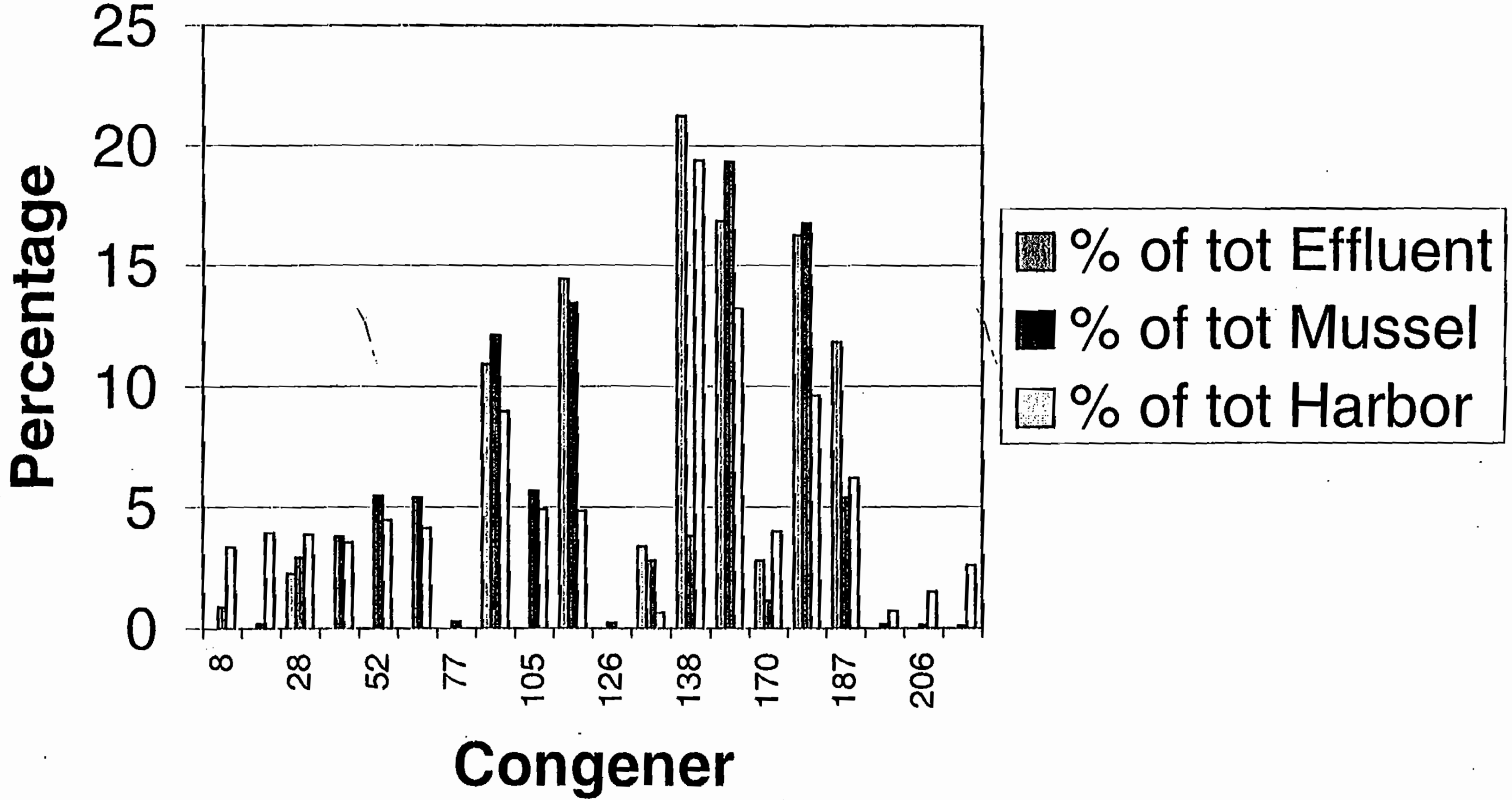


Table 17 PAH Distribution in 1996 Average Effluent, Mussel and Massachusetts Bay

PAH Compound	Effluent (ng/L)	Mussel (ng/g dry wt)	Mass Bay (pg/L)	% tot Effluent	% tot mussel	% tot Mass Bay
Naphthalene	848	26	1210	10.0	0.8	18.6
C1-Naphthalenes	975	22	811	11.4	0.7	12.4
C2-Naphthalenes	1298	48	450	15.2	1.5	6.9
C3-Naphthalenes	1180	96		13.8	3.0	
C4-Naphthalenes	605	162		7.1	5.0	
Benzothiozol	311	20		3.6	0.6	
Acenaphthylene	0	9	170	0.0	0.3	2.6
Acenaphthene	107	6	71	1.3	0.2	1.1
Biphenyl	114	8	295	1.3	0.2	4.5
Dibenzofuran	59	9	46	0.7	0.3	0.7
Fluorene	124	12	208	1.5	0.4	3.2
C1-Fluorenes	224	44	135	2.6	1.4	2.1
C2-Fluorenes	314	108		3.7	3.4	
C3-Fluorenes	342	223		4.0	6.9	
Phenanthrene	190	63	750	2.2	2.0	11.5
Anthracene	149	23	210	1.7	0.7	3.2
C1-Phenanthrenes/anthracenes	388	118		4.6	3.7	
C2-Phenanthrenes/anthracenes	415	240		4.9	7.5	
C3-Phenanthrenes/anthracenes	234	230		2.7	7.2	
C4-Phenanthrenes/anthracenes	137	154		1.6	4.8	
Dibenzothiophene	51	10	137	0.6	0.3	2.1
C1-Dibenzothiophenes	128	40		1.5	1.2	
C2-Dibenzothiophenes	199	148		2.3	4.6	
C3-Dibenzothiophenes	164	192		1.9	6.0	
Fluoranthene	173	206	367	2.0	6.4	5.6
Pyrene	165	174	328	1.9	5.4	5.0
C1-Fluoranthenes/pyrenes	118	152		1.4	4.7	
C2-Fluoranthenes/pyrenes	88	102		1.0	3.2	
C3-Fluoranthenes/pyrenes	50	57		0.6	1.8	
Benzo[a]anthracene	50	52	58	0.6	1.6	0.9
Chrysene	72	109	77	0.8	3.4	1.2
C1-Chrysenes	39	50		0.5	1.6	
C2-Chrysenes	28	26		0.3	0.8	
C3-Chrysenes	15	7		0.2	0.2	
C4-Chrysenes	8	7		0.1	0.2	
Benzo[b]fluoranthene	71	71	103	0.8	2.2	1.6
Benzo[k]fluoranthene	23	25	92	0.3	0.8	1.4
Benzo[e]pyrene	40	70	149	0.5	2.2	2.3
Benzo[a]pyrene	32	29	185	0.4	0.9	2.8
Perylene	8	9	44	0.1	0.3	0.7
Indeno[1,2,3,-c,d]pyrene	31	22	66	0.4	0.7	1.0
Dibenzo[a,h]anthracene	5	6	20	0.1	0.2	0.3
Benzo[g,h,i]perylene	32	28	47	0.4	0.9	0.7
Total	8522	3213	6519			

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APPENDIX A

Monthly Contaminant Concentrations and Loads in 1996 and 1997

Time	Flow (MGD)	Ag (ug/L)	Ag (Kg/d)	Cd (ug/L)	Cd (Kg/d)	Cr (ug/L)	Cr (Kg/d)	Cu (ug/L)	Cu (kg/d)	Mo (ug/L)	Mo (Kg/d)	Ni (ug/L)	Ni (Kg/d)
Jan-96	316	2.78	2.2	0.98	0.76	3.64	2.9	58.1	45.4	12.8	10.1	4.7	3.7
Feb-96	293	3.44	3.7	0.40	0.42	3.88	4.2	68.6	74.0	8.1	8.7	4.5	4.8
Mar-96	293	2.70	3.0	0.42	0.48	3.60	4.1	54.3	60.4	6.8	7.6	6.0	6.8
Apr-96	328	2.48	3.3	0.35	0.48	4.66	6.3	44.8	60.3	6.9	9.2	6.8	9.1
May-96	261	2.47	2.7	0.24	0.34	2.34	2.4	43.6	55.4	10.2	15.3	4.8	4.3
Jun-96	217	2.97	2.3	0.28	0.28	3.32	3.0	72.3	55.6	13.6	17.7	5.9	3.6
Jul-96	226												
Aug-96	202	3.01	2.5	0.31	0.27	3.74	3.4	91.7	78.4	13.1	11.8	4.5	4.9
Sep-96	242												
Oct-96	321												
Nov-96	258												
Dec-96	345												
Jan-97	258												
Feb-97	240												
Mar-97	261	2.65	2.2	0.24	0.20	2.25	1.9	48.9	41.0	5.9	5.0	7.0	5.8
Apr-97	370	2.23	3.1	0.39	0.54	2.83	3.9	42.0	58.3	5.6	7.8	6.2	8.6
May-97	248	2.47	2.4	0.24	0.24	2.34	2.3	43.6	43.3	10.2	10.1	4.8	4.8
Jun-97	211	2.97	2.5	0.28	0.24	3.32	2.8	72.3	61.6	13.6	11.6	5.9	5.0
Jul-97	185	2.30	1.7	0.26	0.19	5.75	4.2	57.4	41.3	16.5	11.9	9.0	6.5
Aug-97	191												
Sep-97	183	1.61	1.1	0.10	0.07	1.23	0.8	36.7	25.4	12.2	8.4	4.2	2.9
Oct-97	180	1.18	0.6	0.01	0.01	0.97	0.5	22.8	11.6	14.5	9.6	5.1	3.3
Nov-97	250												
Dec-97	225												

Time	Pb (ug/L)	Pb (Kg/d)	Zn (ug/L)	Zn (Kg/d)	Hg (ug/L)	Hg (g/d)
Jan-96	4.91	3.8	59.5	46.6	0.059	46
Feb-96	6.15	6.5	74.1	79.3	0.119	128
Mar-96	9.51	10.7	77.9	87.4	0.064	71
Apr-96	9.18	12.8	74.5	101.9	0.099	133
May-96	5.33	11.1	59.2	70.2	0.095	105
Jun-96	6.06	5.1	57.5	44.1	0.090	74
Jul-96						
Aug-96	11.60	7.7	68.7	55.5	0.110	174
Sep-96						
Oct-96						
Nov-96						
Dec-96						
Jan-97						
Feb-97						
Mar-97	4.30	3.6	51.7	43.4	0.290	243
Apr-97	6.29	8.6	57.9	80.1	0.186	256
May-97	5.33	5.3	59.2	58.6	0.310	318
Jun-97	6.06	5.2	57.5	49.0	0.161	136
Jul-97	5.51	4.0	55.5	40.1	0.144	104
Aug-97						
Sep-97	5.81	4.0	34.5	23.8	0.063 (0.1215)	43 (83)
Oct-97	4.70	2.7	25.5	14.1	0.080	49
Nov-97						
Dec-97						

number in bracket does not assume mislabeling of sample bottles

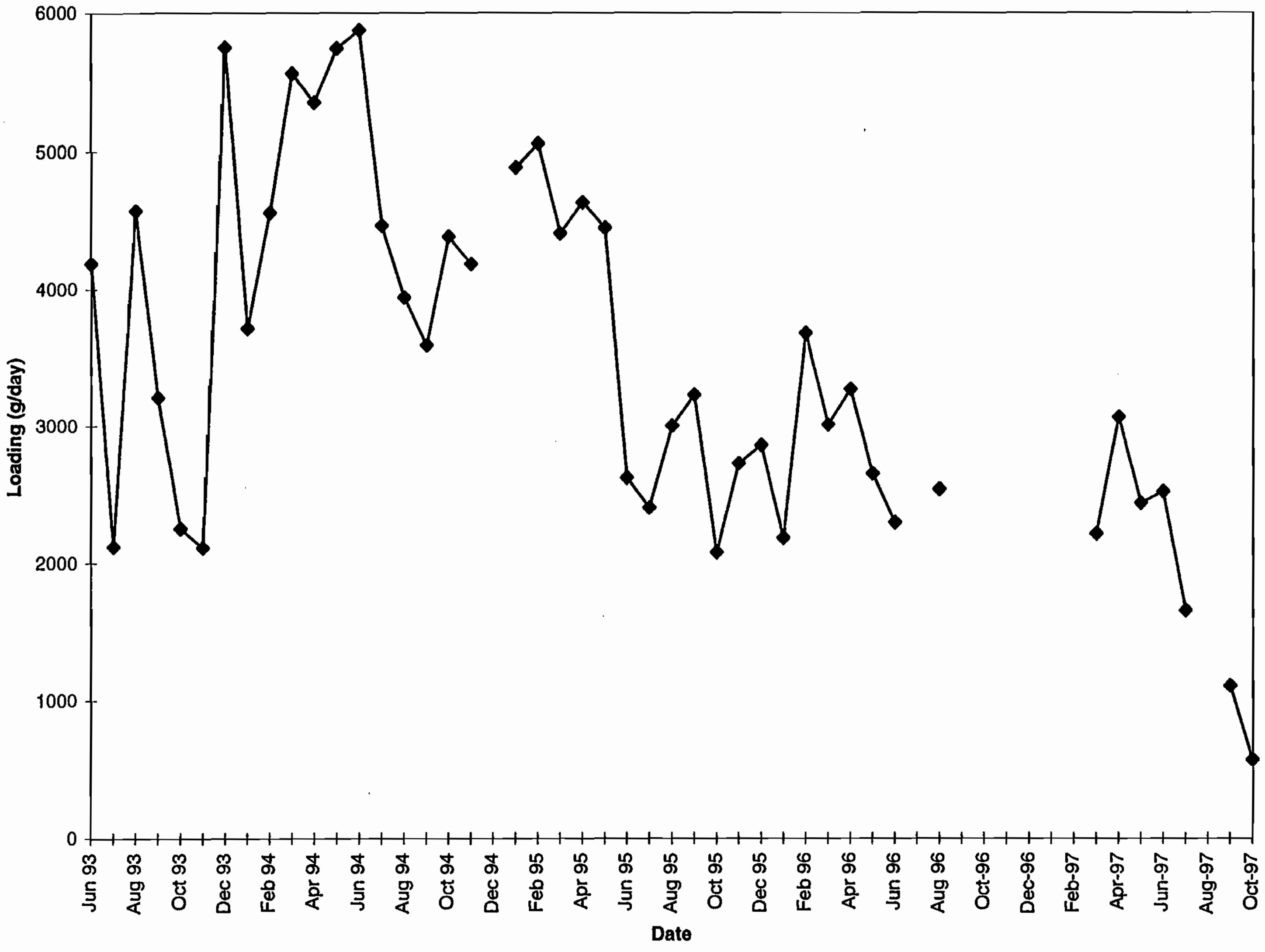
Time	Tot PCB (ug/L)	Tot PCB (g/d)	Tot PAH (ng/L)	Total PAH (Kg/d)	Tot LAB (ng/L)	Total LAB (Kg/d)	Tot DDT (ng/L)	Tot DDT (g/d)
Jan-96	0	0	7636	6.0	5595	4.4	0	0
Feb-96	2	3	7653	8.2	5819	6.2	0	0
Mar-96	1	1	12446	13.9	7050	7.9	0	0
Apr-96	6	9	8474	11.5	6700	9.1	13	20
May-96	13	15	8408	9.8	9230	10.2	4	4
Jun-96	11	9	10895	11.5	9205	7.5	9	7
Jul-96								
Aug-96	33	27	7974	3.5	11070	5.6	7	6
Sep-96								
Oct-96								
Nov-96								
Dec-96								
Jan-97								
Feb-97								
Mar-97	14	12	7077	5.9	7832	6.6	12	10
Apr-97	21	27	10414	13.4	8210	10.5	8	10
May-97	15	15	8343	8.3	8980	8.9	7	7
Jun-97	0	0	8461	7.2	12140	10.3	0	0
Jul-97	8	6	5743	4.1	11750	8.5	0	0
Aug-97								
Sep-97	16	11	2332	2.6	4577	3.2	1	1
Oct-97	7	5	3848	1.5	3734	1.7	2	1
Nov-97								
Dec-97								

Time	Tot Chlordanes (ng/L)	Tot Chlordanes (g/d)	Other Pesticides (ng/L)	Other Pesticides (g/d)
Jan-96	0	0	5	4
Feb-96	0	0	4	5
Mar-96	0	0	9	10
Apr-96	31	41	7	10
May-96	7	8	8	7
Jun-96	7	6	1	1
Jul-96				
Aug-96	8	6	24	19
Sep-96				
Oct-96				
Nov-96				
Dec-96				
Jan-97				
Feb-97				
Mar-97	6	5	0	0
Apr-97	11	14	10	13
May-97	15	15	25	24
Jun-97	0	0	18	15
Jul-97	0	0	0	0
Aug-97				
Sep-97	1	1	5	4
Oct-97	1	1	12	8
Nov-97				
Dec-97				

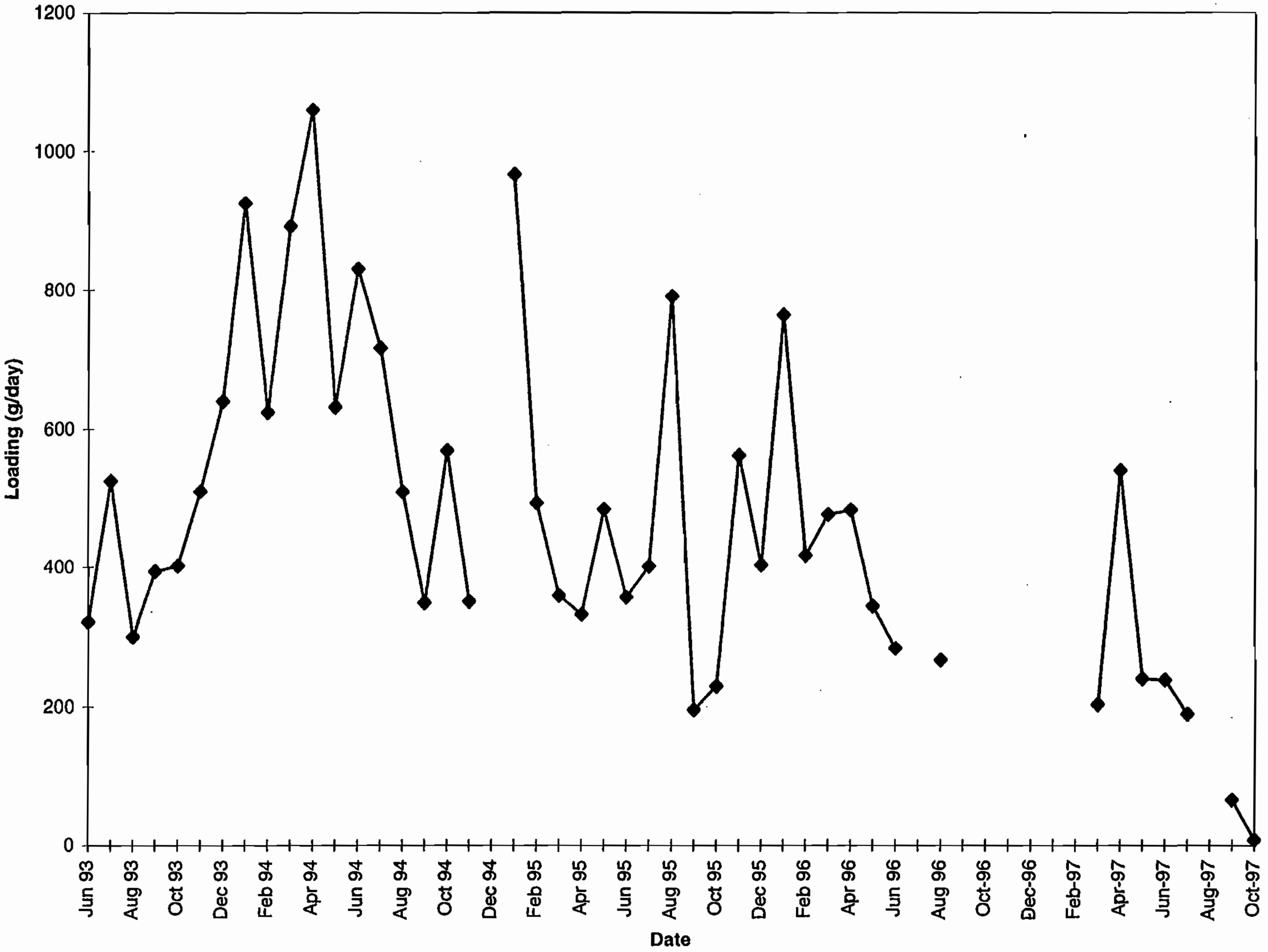
APPENDIX B

Monthly Contaminant Loading Plots from 1993 to 1997

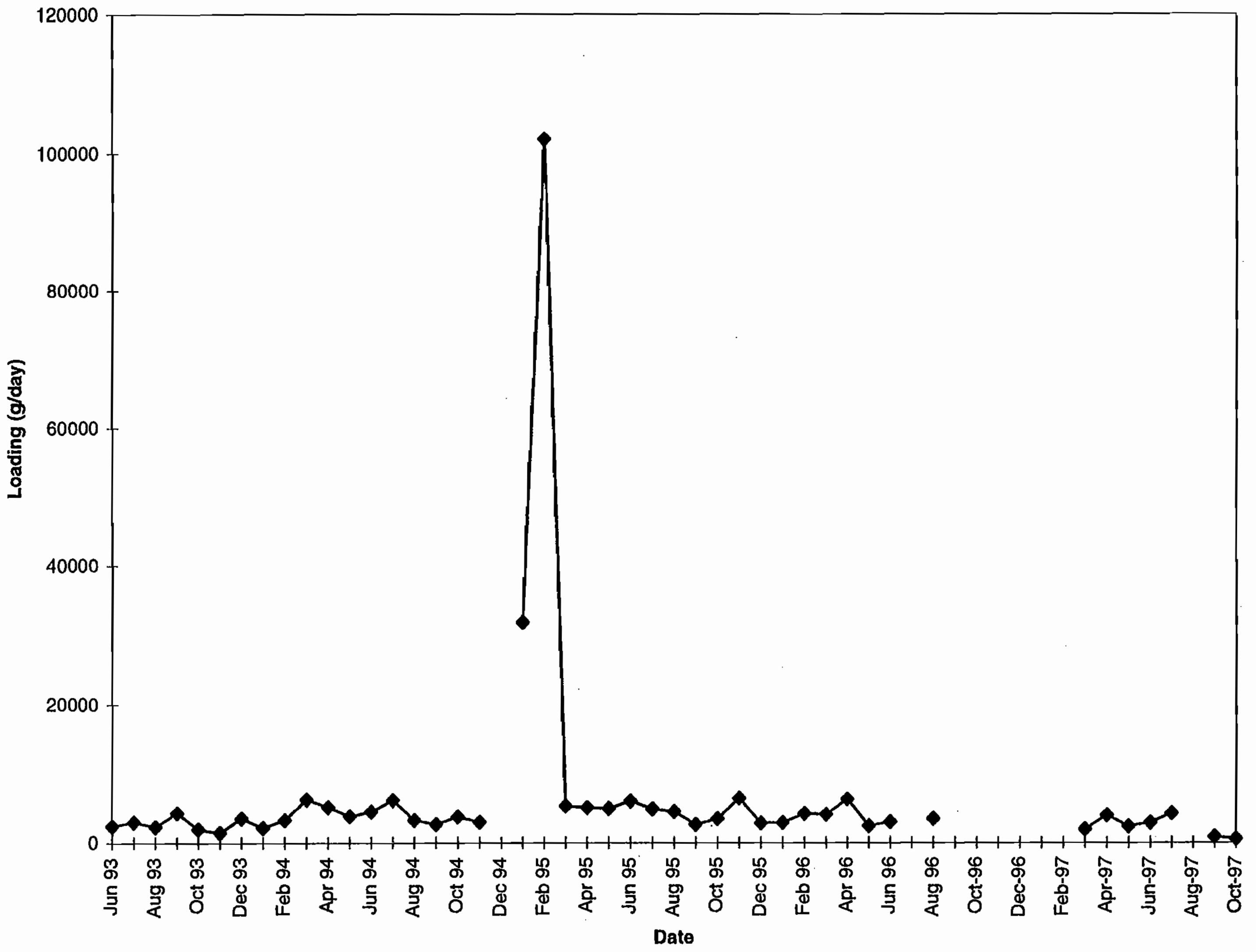
1993 - 1997 Ag Loading



1993 - 1997 Cd Loading



1993 - 1997 Cr Loading



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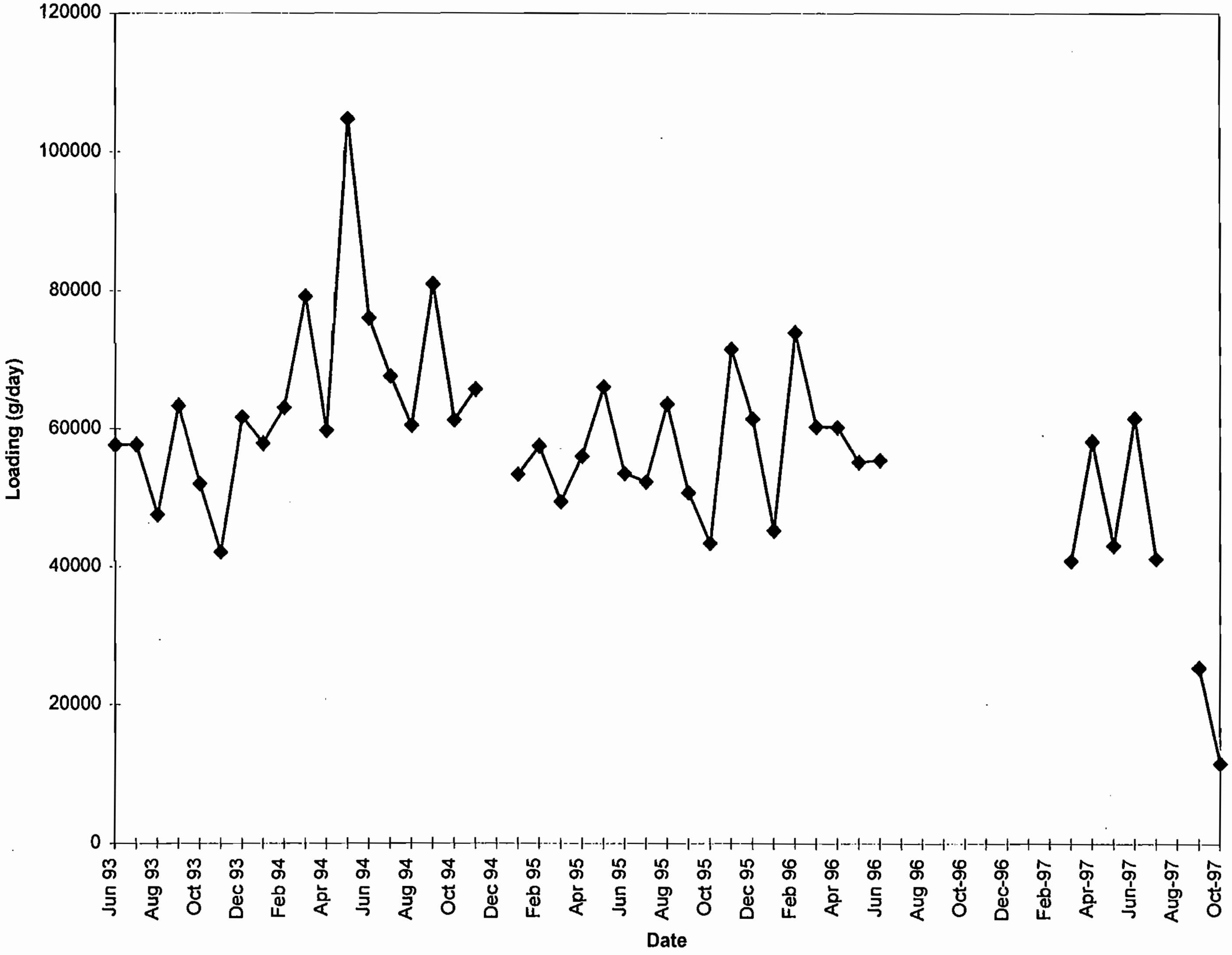

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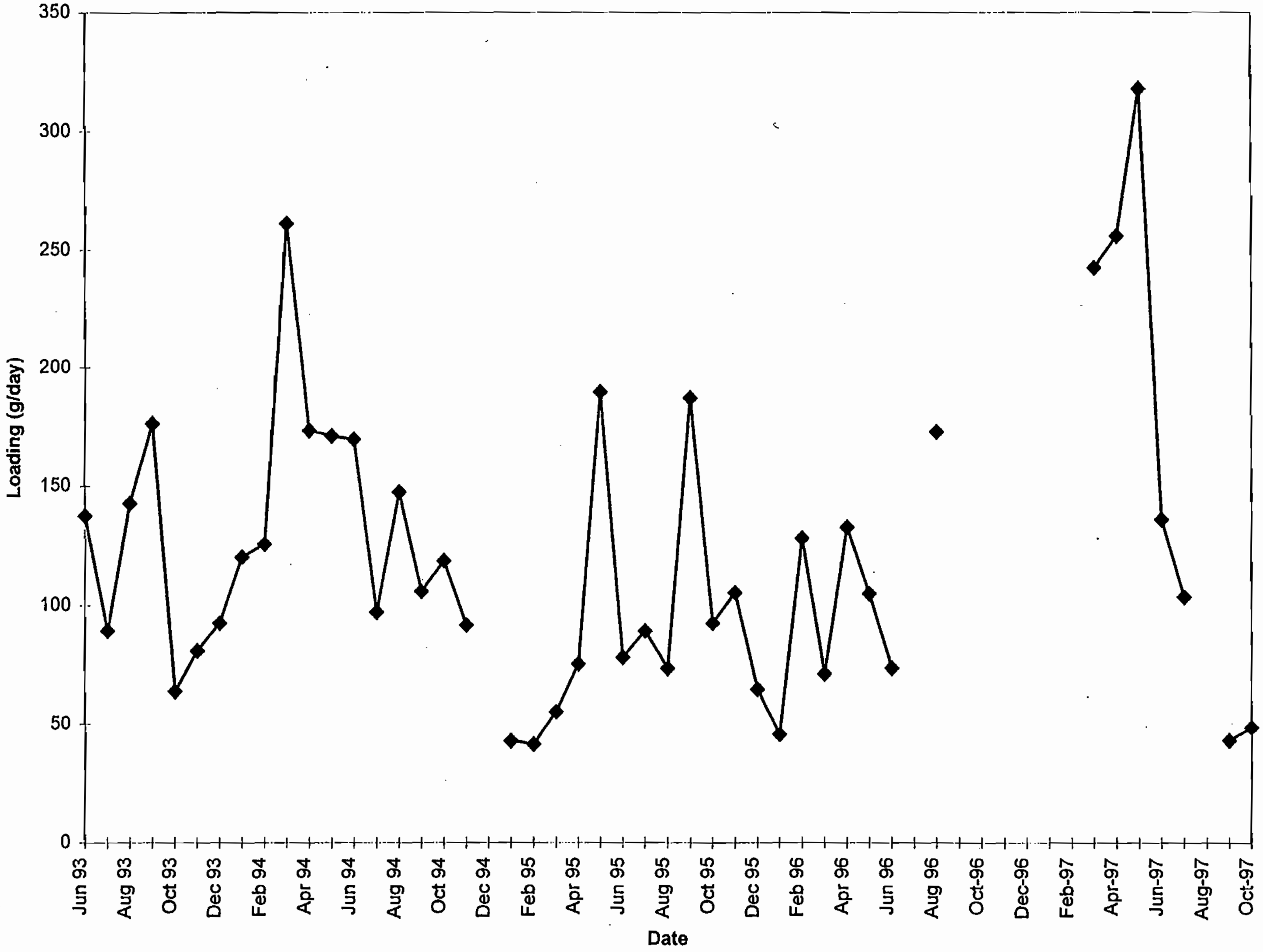

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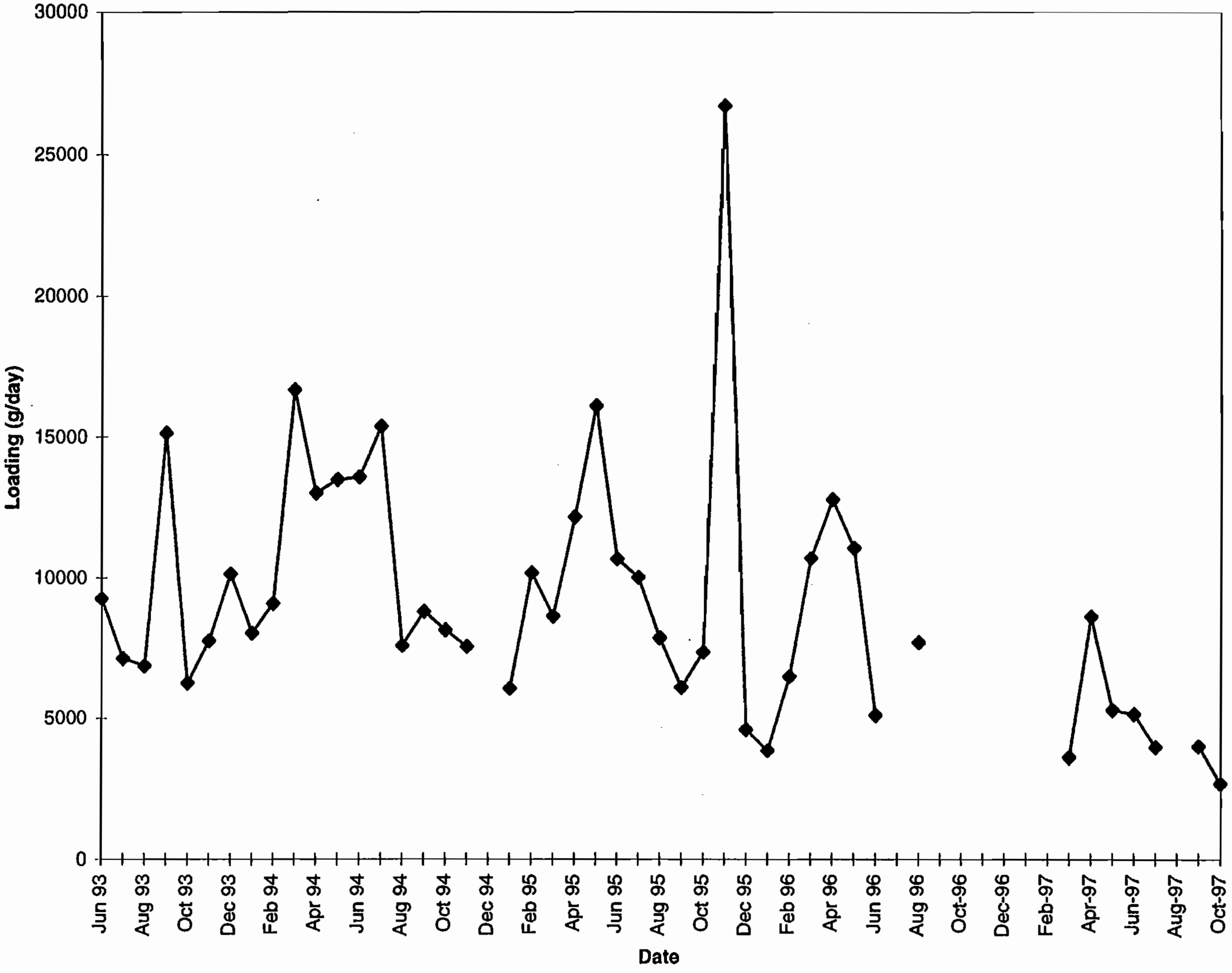
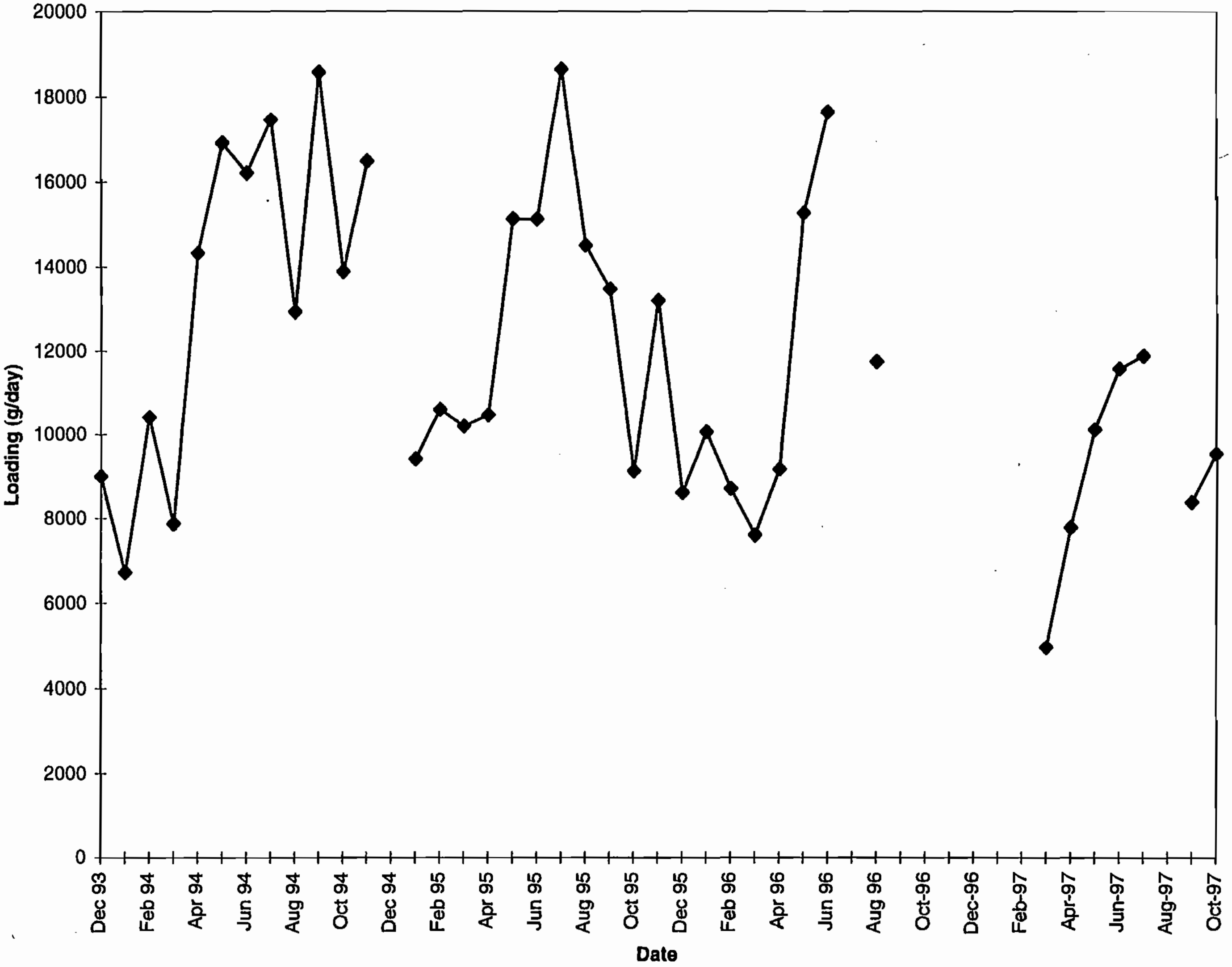
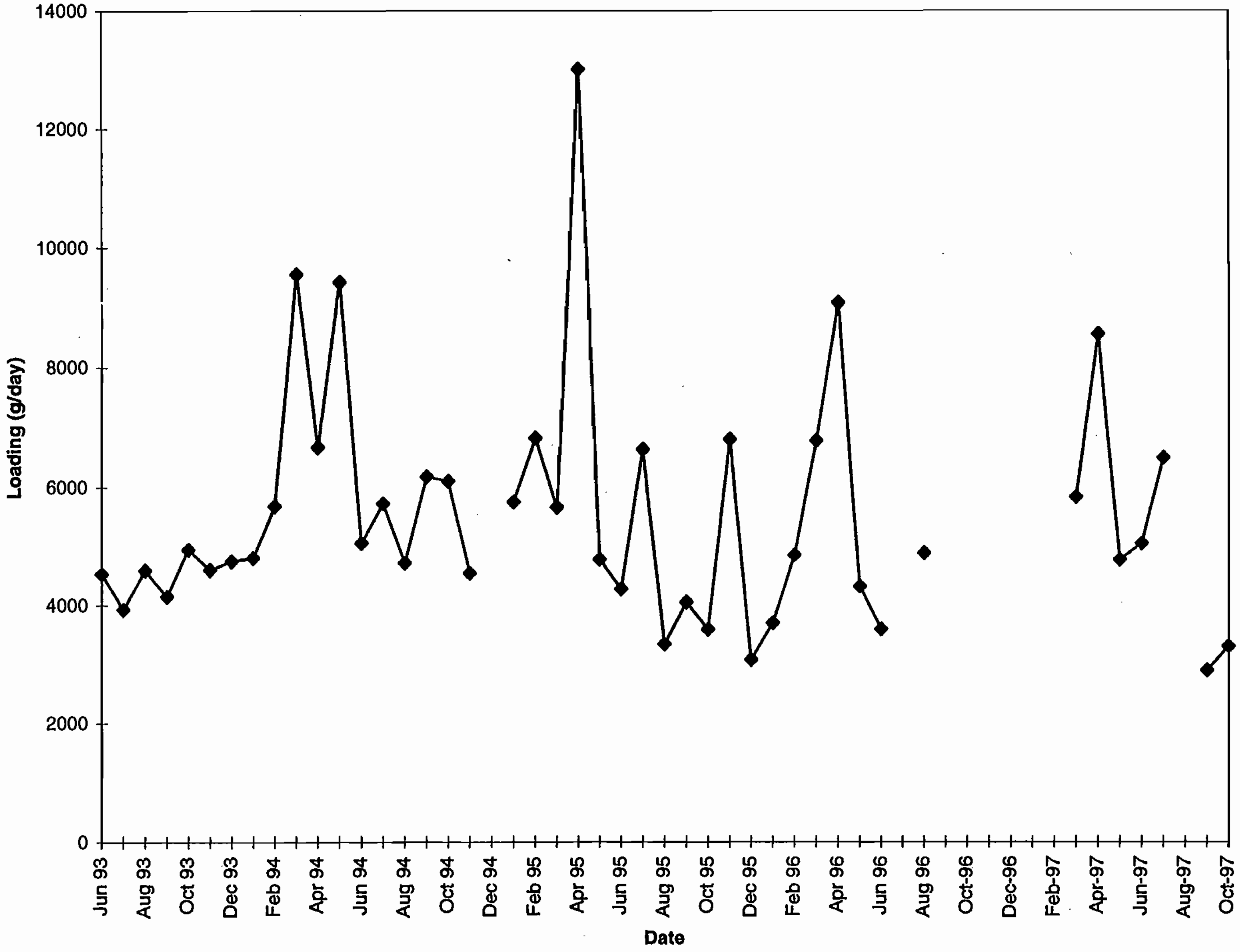
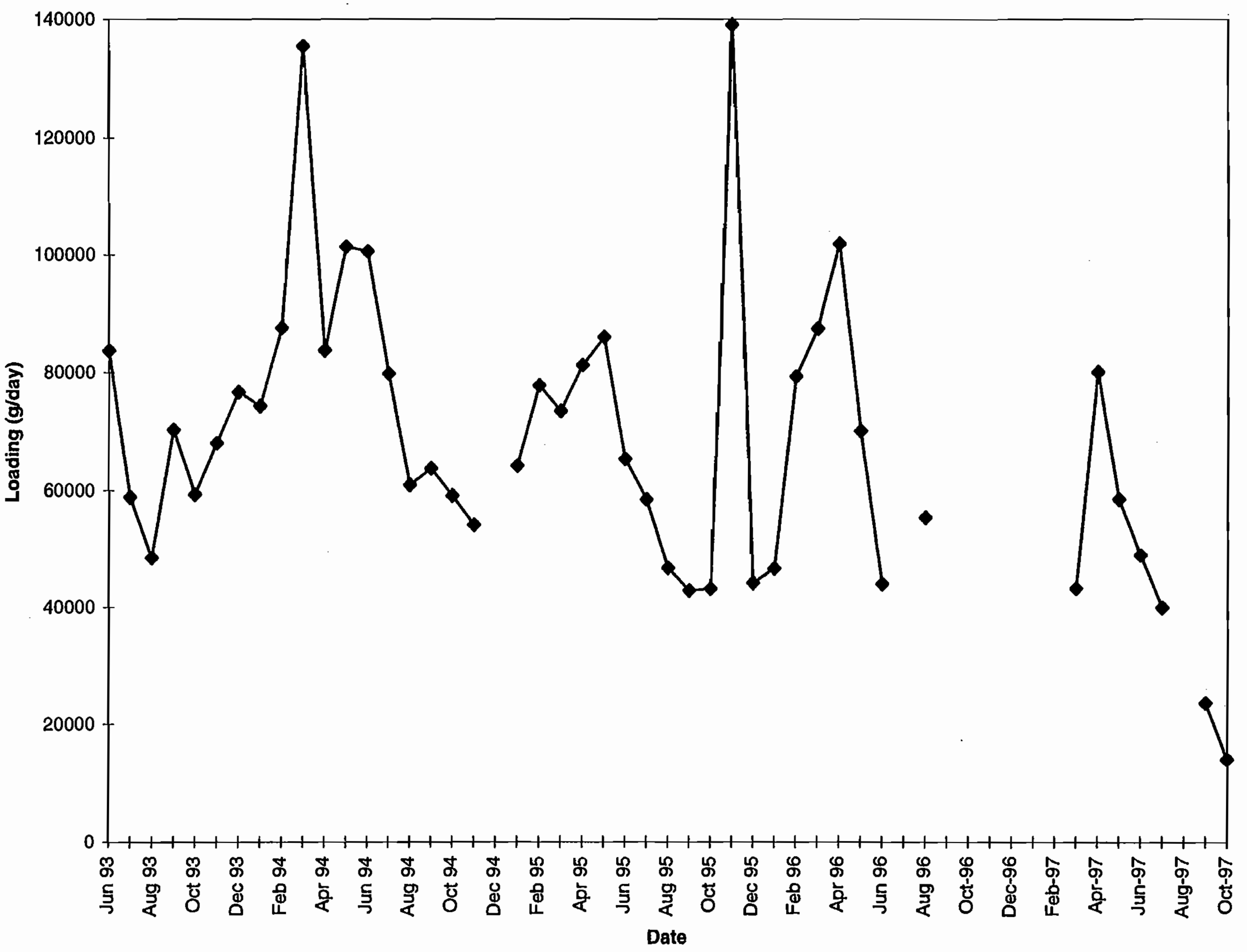




1993 - 1997 Mo Loading

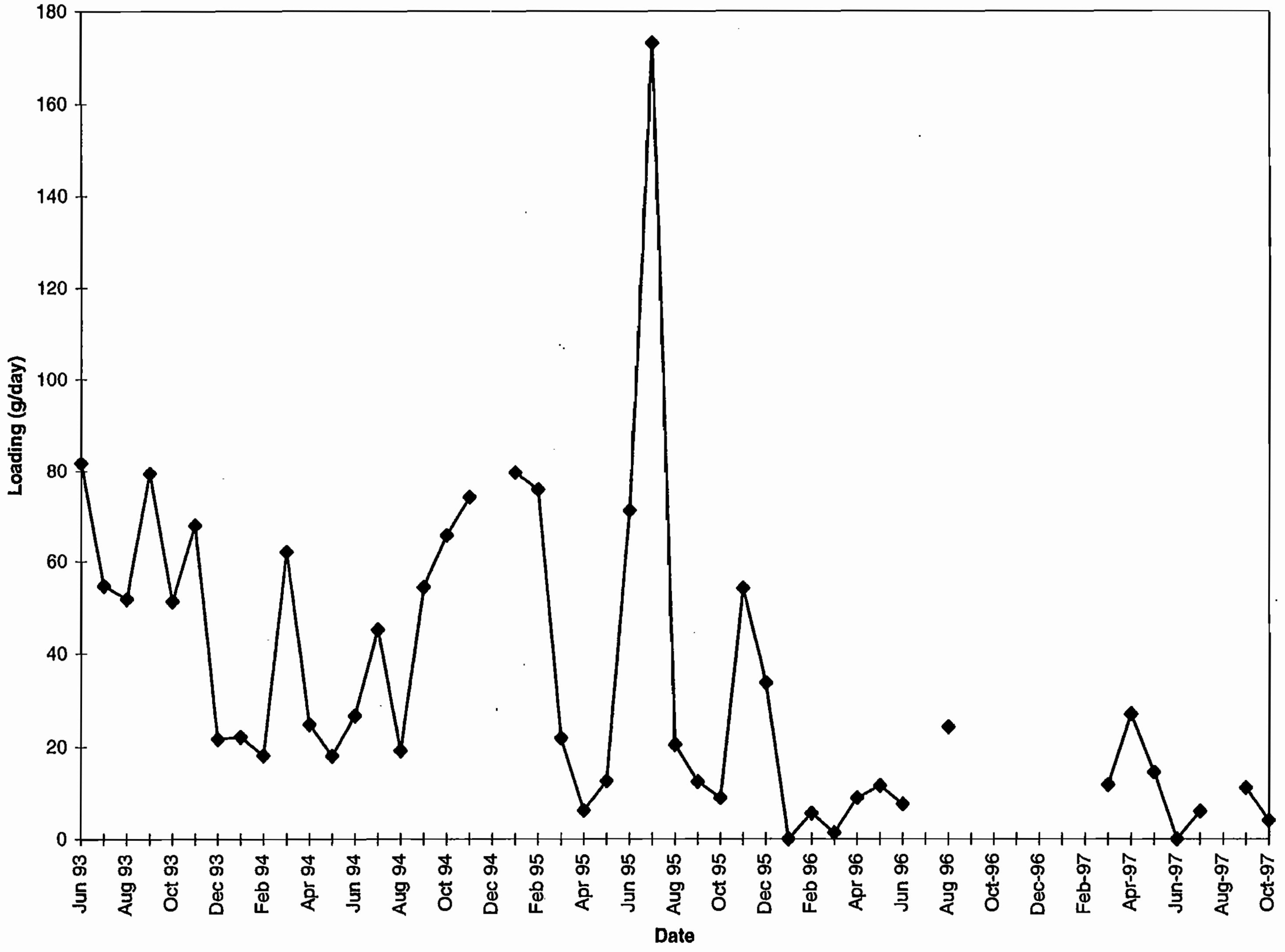


1993 - 1997 Ni Loading

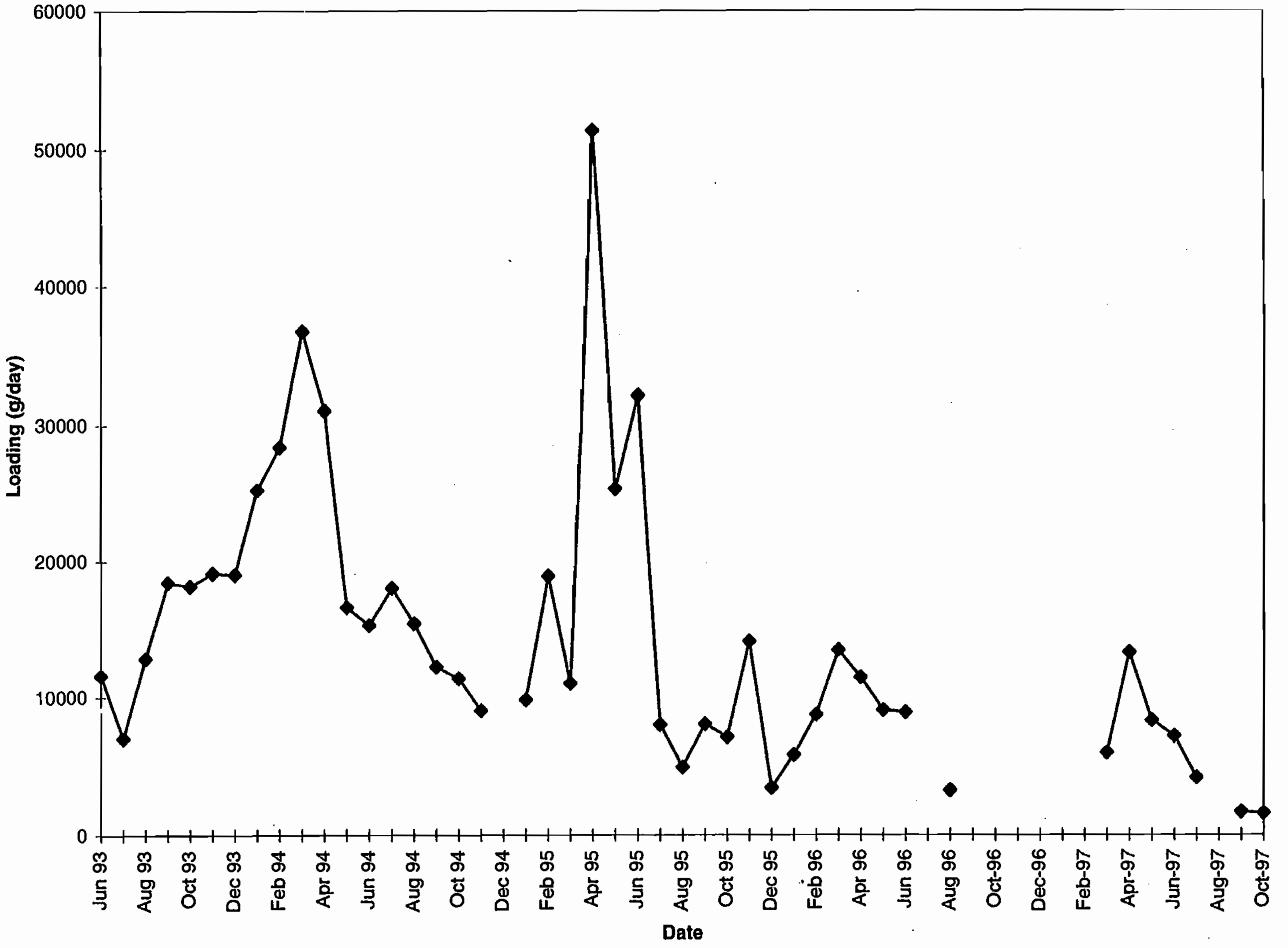


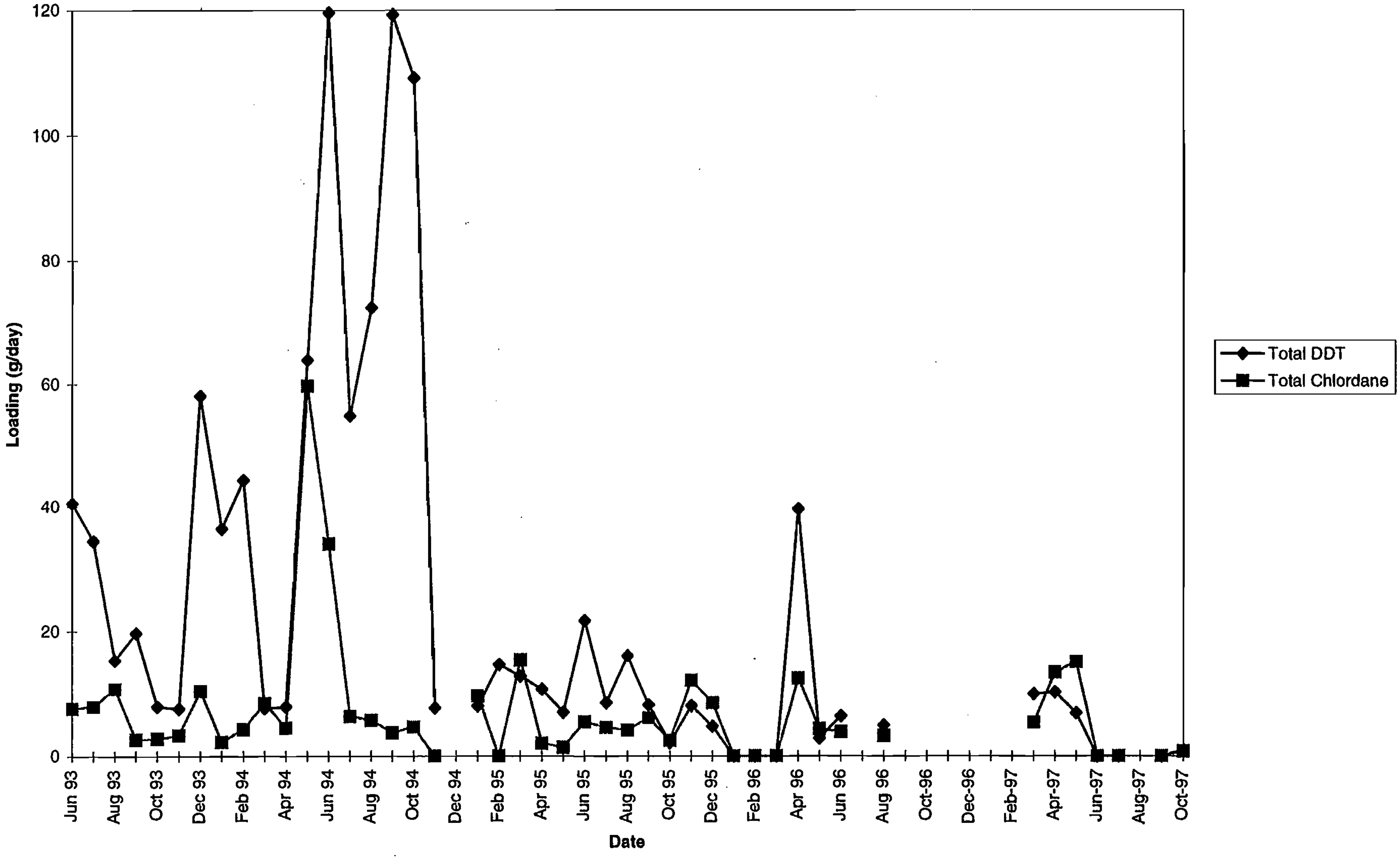
1993 - 1997 Zn Loading

1993 - 1997 Total PCB Loading



1993 - 1997 Total PAH Loading





1993 - 1997 Total DDT & Total Chlordane Loading

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