Marine Sediment Monitoring Program Progress Report

by
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Introduction

The Marine Benthic Monitoring Unit has initiated the revision and analysis of five years of data (1989-1993) compiled since the implementation of the Marine Sediment Monitoring Program of the Puget Sound Ambient Monitoring Program in 1988. These data include benthic abundance and species richness of macrofauna, sediment chemistry, and toxicity bioassays. Parameters being analyzed and methods of collection and analysis have been reported elsewhere (Striplin, 1988; Tetra Tech, 1990). The present progress report presents the 1993 sediment chemistry results, and compares these results to previous trends in sediment contaminants. Also, benthic abundance results are discussed in terms of possible effects of summer hypoxia in portions of Puget Sound.

Results of 1993 Sediment Chemistry

Concentrations of heavy metals were below sediment quality standards for seven of the eight metals of concern. Only mercury showed concentrations above sediment quality standards (0.41 mg/kg) in Sinclair Inlet (Station 34) and Dyes Inlet (Station 35) (Figure 1). In general, concentrations of metals were low, near background levels for most stations. Stations with highest cadmium concentrations were Inner Budd Inlet (Station 49), Inner Eld Inlet (Station 104R), Inner Case Inlet (Station 110R), and Henderson Bay (Station 114R) (Figure 2). Port Susan (Station 20) exhibited the highest chromium concentration (Figure 3), while South Hood Canal (Station 17) and Sinclair Inlet exhibited the highest copper concentrations (Figure 4). In addition to copper, both Sinclair Inlet and Dyes Inlet (Station 35) had the highest sediment concentrations for lead, silver, and zinc (Figures 5-7). Concentrations of metals in sediments in 1993 were similar to those found in previous years. Not surprisingly, these results suggest that concentrations of heavy metals are greatest near urban and industrial centers (e.g., Stations 34 and 35 near Bremerton), with one exception: the presence of cadmium in Eld Inlet, Case Inlet, and Henderson Bay. Sources of cadmium in South Puget Sound remain unexplained at this time.

Low-molecular weight polynuclear aromatic hydrocarbons (LPAH) exhibited low concentrations near the analytical detection limit at all stations in 1993. Higher concentrations were noted for anthracene (<40 mg/kg of organic carbon) and phenanthrene (<80 mg/kg of organic carbon) at Commencement Bay (Station 40). Highest total LPAH concentrations occurred in sediments of Commencement Bay and Elliot Bay (Station 33) (Figure 8), although levels of these hydrocarbons were well below the sediment quality standards for Puget Sound. Data from previous years also indicated highest LPAH concentrations at Stations 33 and 40. Because of the analytical and natural variability of organic carbon in sediments, annual trends of organic carbon-normalized data have not been analyzed. Longer databases are necessary before inter-annual variability in hydrocarbon concentrations can be correlated with increasing or decreasing inputs of pollutants to the system.

High-molecular weight polynuclear aromatic hydrocarbons (HPAH) exhibited increased concentrations in sediments of Eagle Harbor (Station 30), Elliot Bay (Station 33), Dyes Inlet (Station 35), and Commencement Bay (Station 40) (Figure 9). Highest concentrations occurred for benzo(a)pyrene, benzo(g,h,i)perylene, indeno(1,2,3-c,d)pyrene, chrysene, and dibenzo(a,h)anthracene at Station 33. Except for chrysene, these compounds exhibited concentrations above sediment quality standards. These data, however, should be used with caution, since they were normalized to total organic carbon values which were qualified as estimates.

One other compound, beta-coprostanol, was detected above the otherwise narrow band of chemical concentrations near analytical detection limits. Beta-coprostanol exhibited the highest concentration (670 μg/kg dry weight) in sediments of Commencement Bay (Station 41), and similar concentrations to those found in previous years (100-700 μg/kg dry weight) at all stations where the compound was detected. Sources of coprostanol in the marine environment are the bacterial breakdown of cholesterol. Thus, the compound's ubiquity in estuarine sediments may be associated with marine mammal populations, although higher concentrations near sewage point sources may occur.

Low Dissolved Oxygen: Potential Effects on Benthic Communities

Scrutiny of benthic data from 1992 revealed low abundances of macrofauna in Hood Canal at Tekiu Point (Station 304R) and Outer Lynch Cove (Station 305R). While additional data from these locations are needed to further assess community structure and variability, these data suggest that decreased abundances may be related to seasonal low dissolved oxygen episodes in Hood Canal. Hypoxia, the occurrence of dissolved oxygen below 2 mg/L in bottom waters, has been documented for portions of Hood Canal during late summer (Bell *et al.*, 1994).

Reduced dissolved oxygen concentrations are known to affect sediment and water-column processes with implications for the whole ecosystem. For instance, sediment nitrification rates are regulated by the availability of oxygen. Specifically, nitrification and denitrification processes are limited by shallow oxygen penetration in sediments (Kemp *et al.*, 1990). Consequently, increased nitrogen diffusing from the sediments becomes available for phytoplankton growth, increasing the organic load to the benthos and exacerbating the low dissolved oxygen problem. Also, redox potentials and the concentrations of sulfides in sediments can significantly influence the concentration of trace metals and their availability to organisms (Long, 1992).

Hypoxia effects on benthic communities are manifested through a major reduction of abundance and number of taxa (Llansó, 1992). This reduction becomes larger both spatially and temporally as the severity and duration of the hypoxic episodes increase. The most severe ecological consequences of hypoxia occur when there is a major reduction of prey for higher trophic levels. Both oxygen depletion and impoverishment of benthic resources may lead to a decline in local bottom-feeding fish populations. Reductions in the abundance of economically important fish and crustaceans have been documented during hypoxia (Pihl *et al.*, 1991; Llansó, 1992). Further, the periodicity of hypoxic episodes may lead to long-term alterations of benthic populations, largely as a reflection of the varying species tolerances and life-histories. For instance, Llansó (1991), and Llansó and Diaz (1994) have shown that the intensity and duration of low dissolved oxygen events is critical to survivorship in some common estuarine polychaetous annelids, and that local population persistence may be affected. Survivorship depends upon the species-specific tolerance to low dissolved oxygen, but differs among higher taxa: crustaceans and gastropods are generally more sensitive to hypoxia than annelids (Gaston, 1985).

In addition, to confront low dissolved oxygen and hydrogen sulfide in sediments, benthic organisms generally exhibit sublethal changes in behavior (Jorgensen, 1980; Llansó, 1991; Llansó and Diaz, 1994). For example, stress from low dissolved oxygen may elicit alterations in the burrowing behavior of polychaetous annelids. Such alterations may, in turn, affect the availability of infaunal benthic organisms to fish and crustaceans through a shift in their vertical distribution in sediments.

The identification of hypoxia as an indicator of reduced environmental quality in estuaries has often been associated with organic pollution and eutrophication. In Puget Sound, site-specific organic and nutrient inputs may, in combination with adverse physical conditions such as water-column density stratification, contribute to the development or intensification of hypoxia in bottom waters. This scenario is likely to occur in inlets with restricted water circulation that are experiencing rapid urban population growth. The lower reaches of Hood Canal is a case in point. In view of the importance of low dissolved oxygen effects on benthic community structure and distribution, these areas should be monitored more intensively, and the relationships between hypoxia and the benthos be established.

Acknowledgements

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REFERENCES

Bell, S.A., M.A. Golliet, and J.A. Newton, 1994 (in draft). Marine Water Column Ambient Monitoring Program: Wateryear 1993 Data Report. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

Gaston, G.R., 1985. "Effects of hypoxia on macrobenthos of the Inner Shelf off Cameron, Louisiana." Estuarine, Coastal and Shelf Science, 20:603-613.

Jorgensen, B.B., 1980. "Seasonal oxygen depletion in the bottom waters of a Danish fjord and its effects on the benthic community." Oikos, 34:68-76.

Kemp, W.M., P. Sampou, J. Caffrey, M. Mayer, K. Henriksen, and W.R. Boynton, 1990. "Ammonium recycling versus denitrification in Chesapeake Bay sediments." Limnology and Oceanography, 35:1545-1563.

Llansó, R.J., 1991. "Tolerance of low dissolved oxygen and hydrogen sulfide by the polychaete *Streblospio benedicti* (Webster)." Journal of Experimental Marine Biology and Ecology, 153:165-178.

------, 1992. "Effects of hypoxia on estuarine benthos: the lower Rappahannock River (Chesapeake Bay), a case study." Estuarine, Coastal and Shelf Science, 35:491-515.

------ and R.J. Diaz, 1994. "Tolerance to low dissolved oxygen by the tubicolous polychaete *Loimia medusa*." Journal of the Marine Biological Association of the United Kingdom, 74:143-148.

Long, E.R., 1992. "Ranges in chemical concentrations in sediments associated with adverse biological effects." Marine Pollution Bulletin, 24:38-45.

Pihl, L., S.P. Baden, and R.J. Diaz, 1991. "Effects of periodic hypoxia on distribution of demersal fish and crustaceans." Marine Biology, 108:349-360.

Striplin, P.L., 1988. Puget Sound Ambient Monitoring Program, Marine Sediment Quality Implementation Plan, Final Report from Washington State Department of Ecology to the Puget Sound Water Quality Authority. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA, 57 pp.

Tetra Tech, Inc., 1990. Puget Sound Ambient Monitoring Program 1989: Marine Sediment Monitoring, Final Report from Tetra Tech, Inc. to the Washington State Department of Ecology, Ambient Monitoring Section. Tetra Tech, Inc., Bellevue, WA, 262 pp.

FIGURES

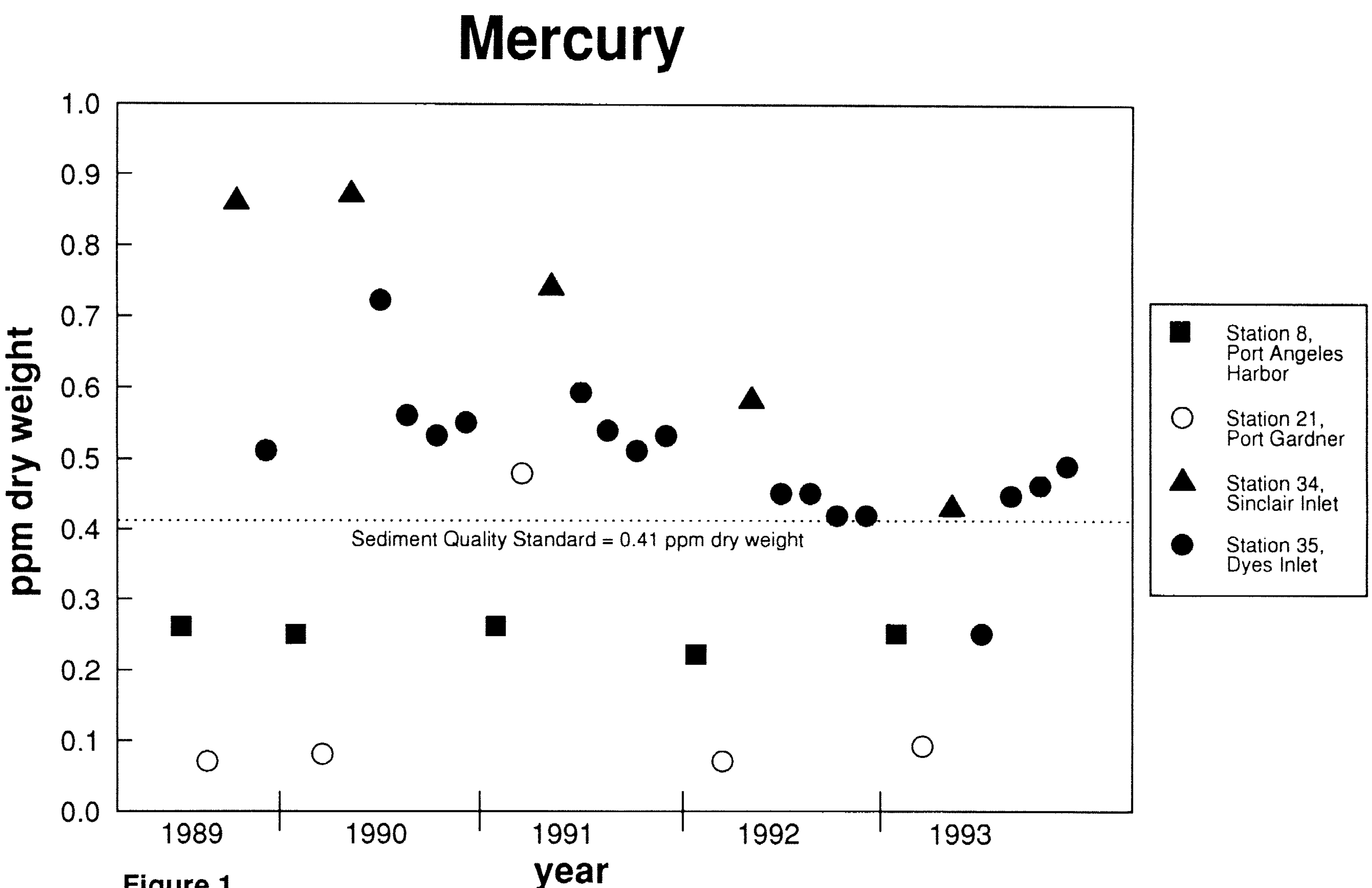

Figure 1

Notes
(1) Mercury undetected at Station 21 in 1989 and 1990, detection limit shown.
(2) All other 1989 and 1990 values, except 1989 Station 8, were qualified asestimates.

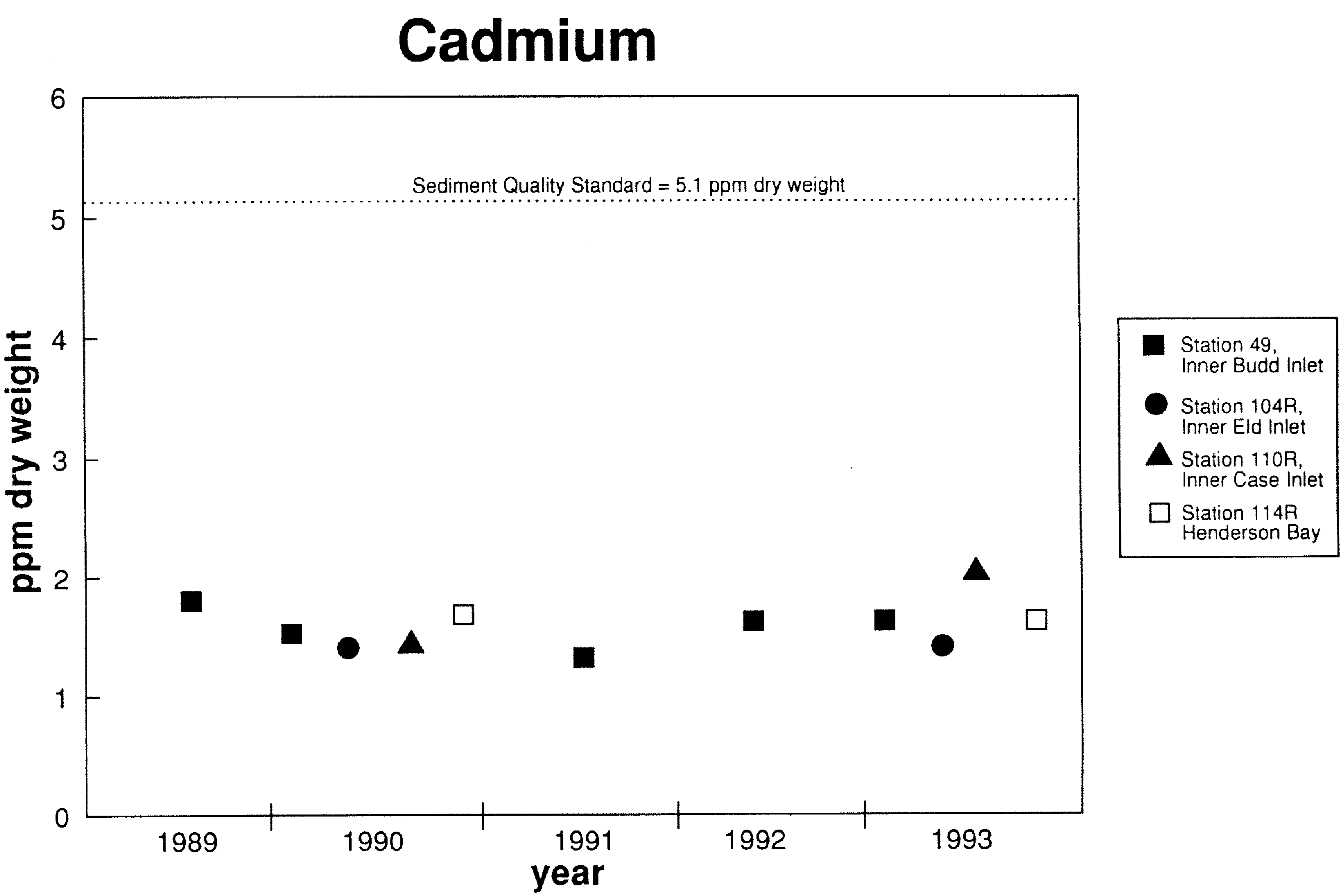

Figure 2

Note
(1) 1989 Station 49 cadmium value qualified as an estimate.

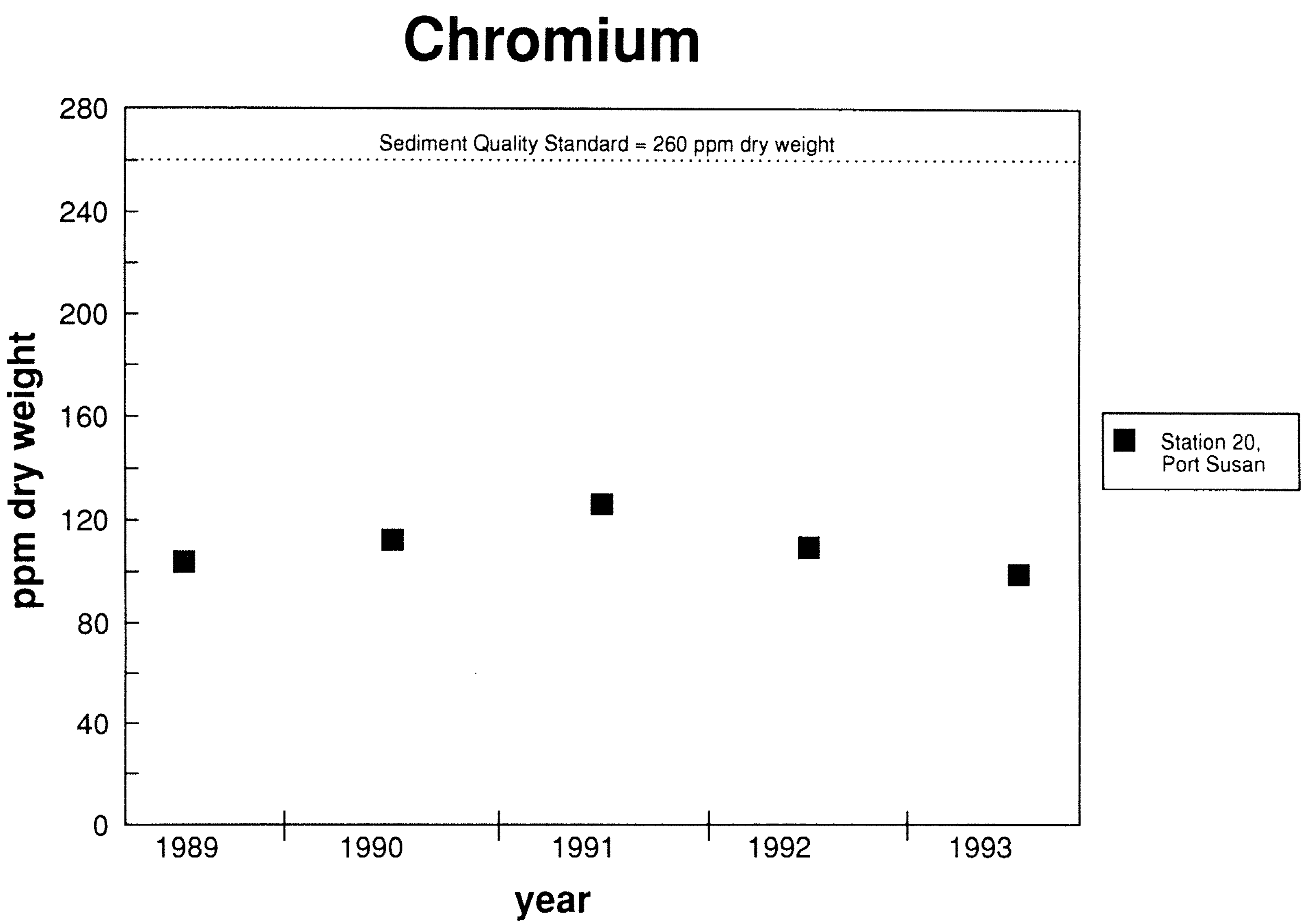
Chromium
280
240
200
160
120
80
40
0
ppm dry weight
Sediment Quality Standard = 260 ppm dry weight
1989
1990
1991
1992
1993
year
Station 20,
Port Susan

Figure 3

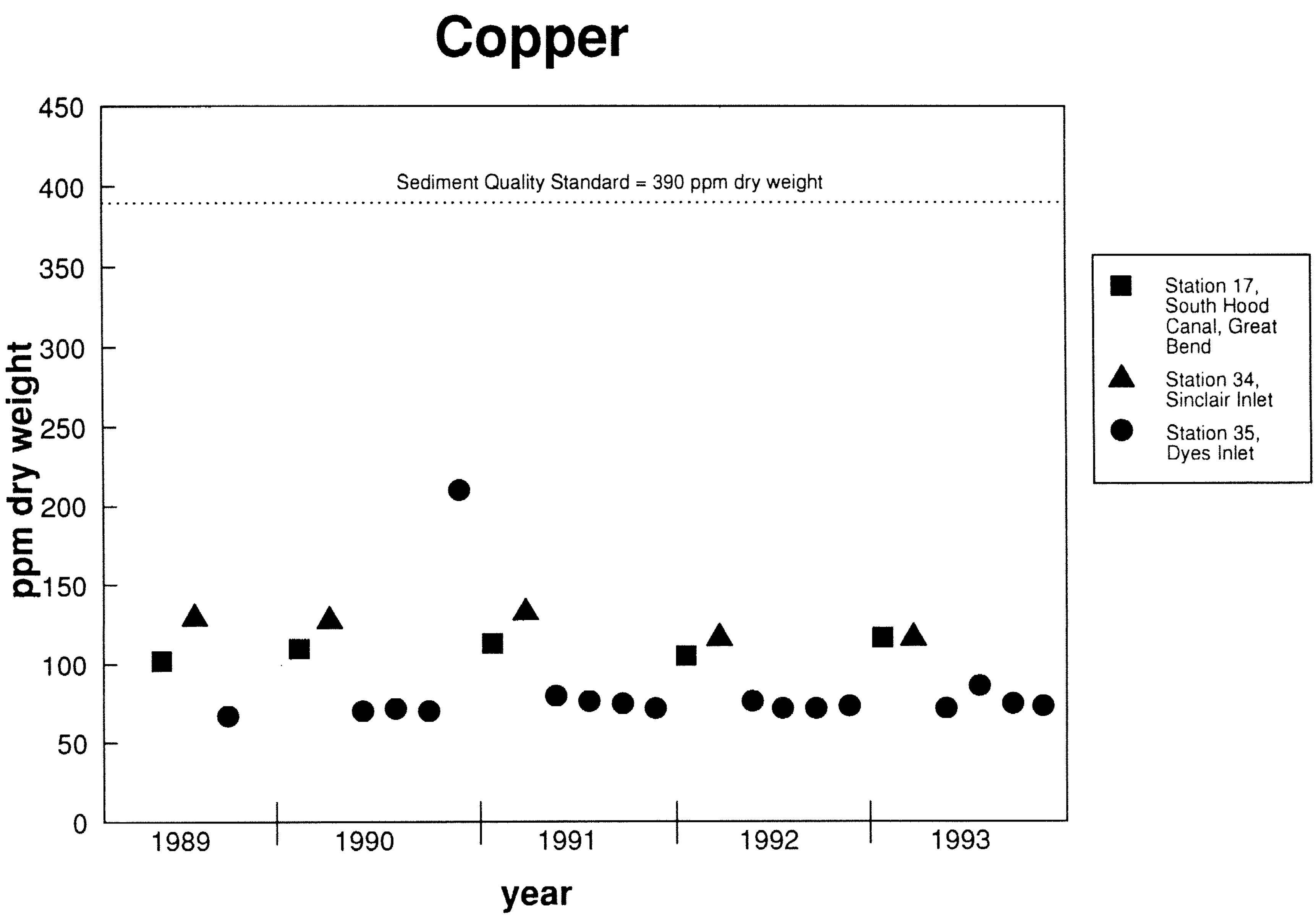
Copper
ppm dry weight
450
400
350
300
250
200
150
100
50
0
Sediment Quality Standard = 390 ppm dry weight
1989
1990
1991
1992
1993
year
Station 17, South Hood Canal, Great Bend
Station 34, Sinclair Inlet
Station 35, Dyes Inlet

Figure 4

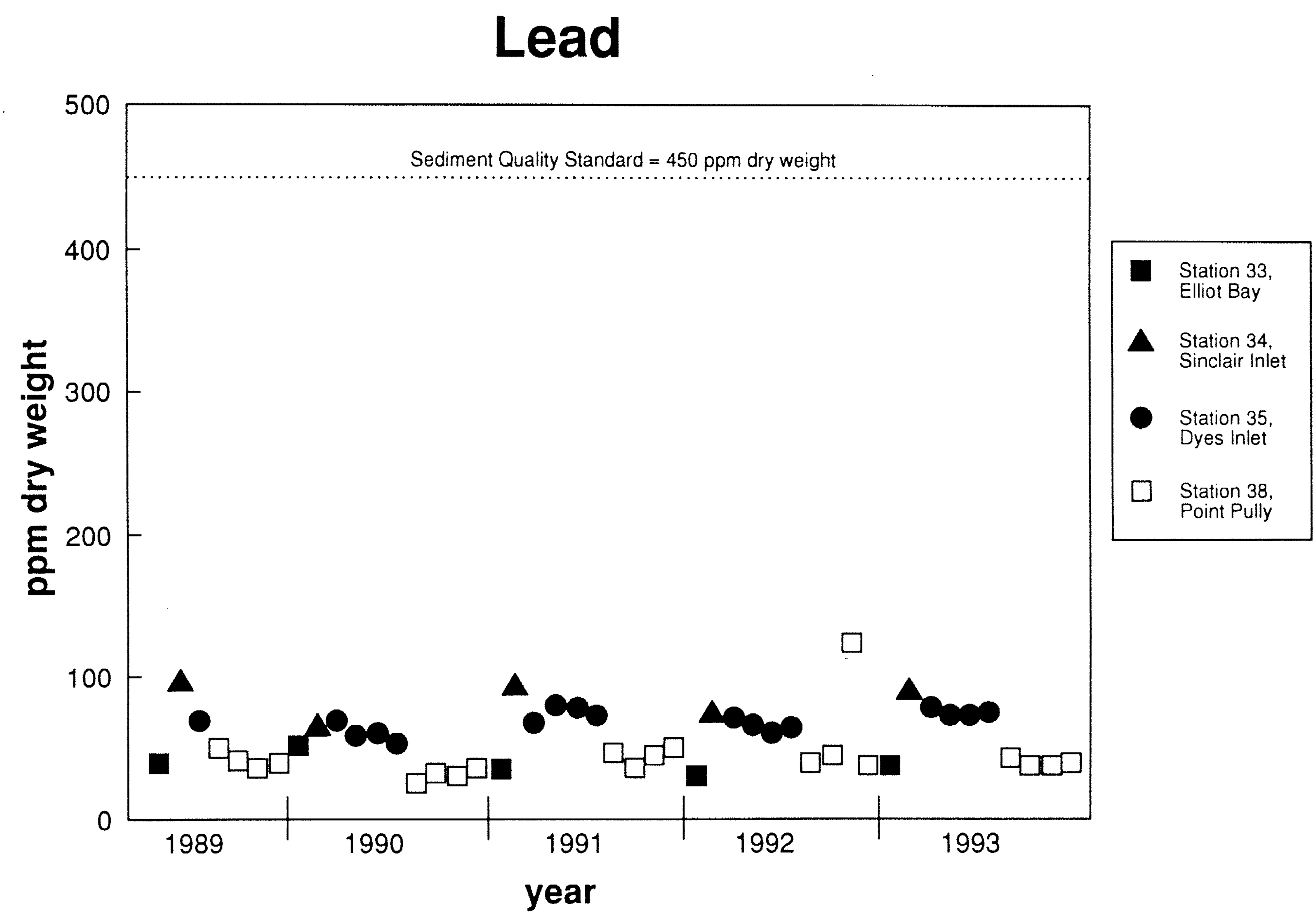
Lead
500
400
300
200
100
0
ppm dry weight
Sediment Quality Standard = 450 ppm dry weight
1989
1990
1991
1992
1993
year
Station 33, Elliot Bay
Station 34, Sinclair Inlet
Station 35, Dyes Inlet
Station 38, Point Pully

Figure 5

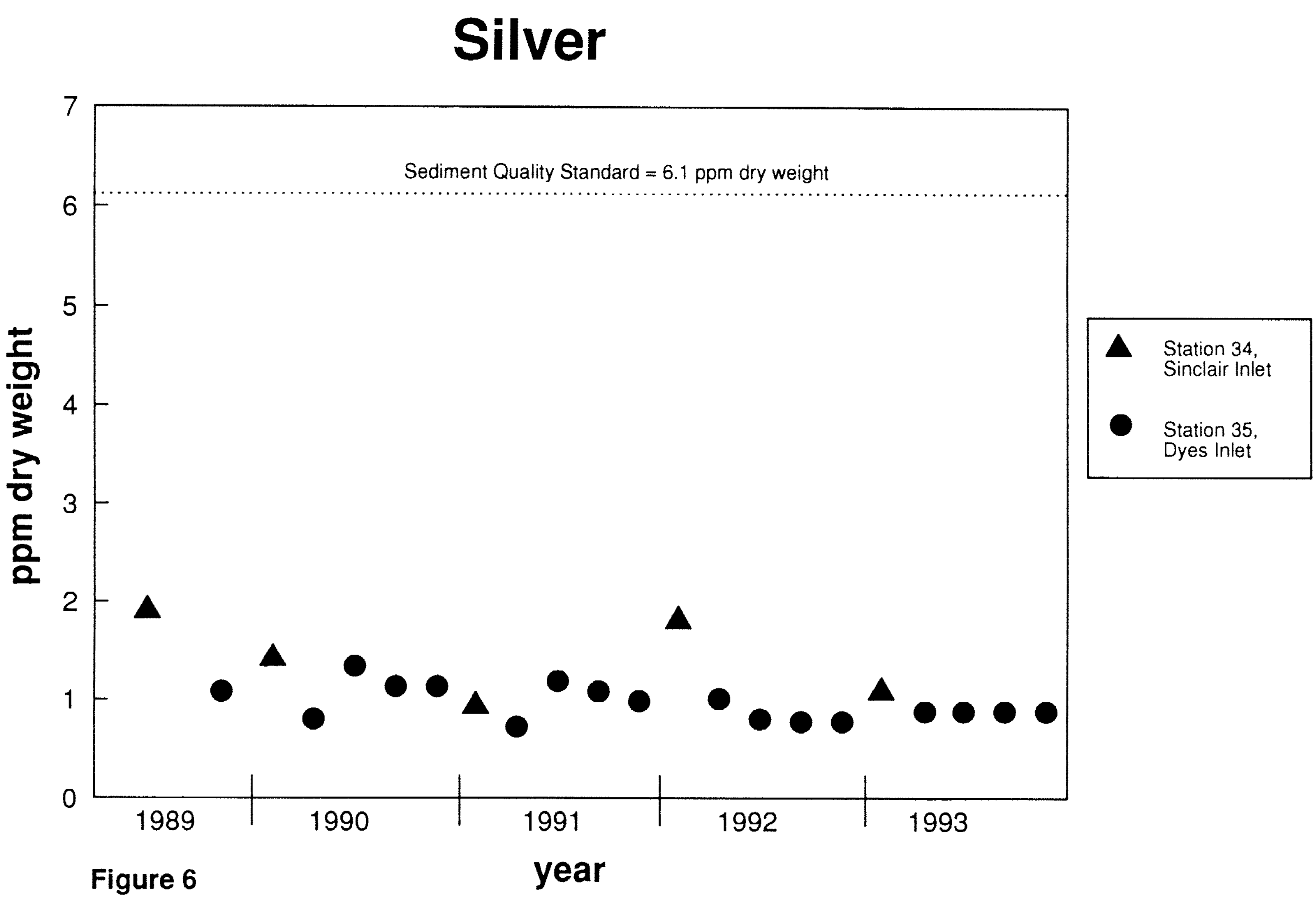

Figure 6

Note

(1) All 1991 values shown were qualified as estimates.

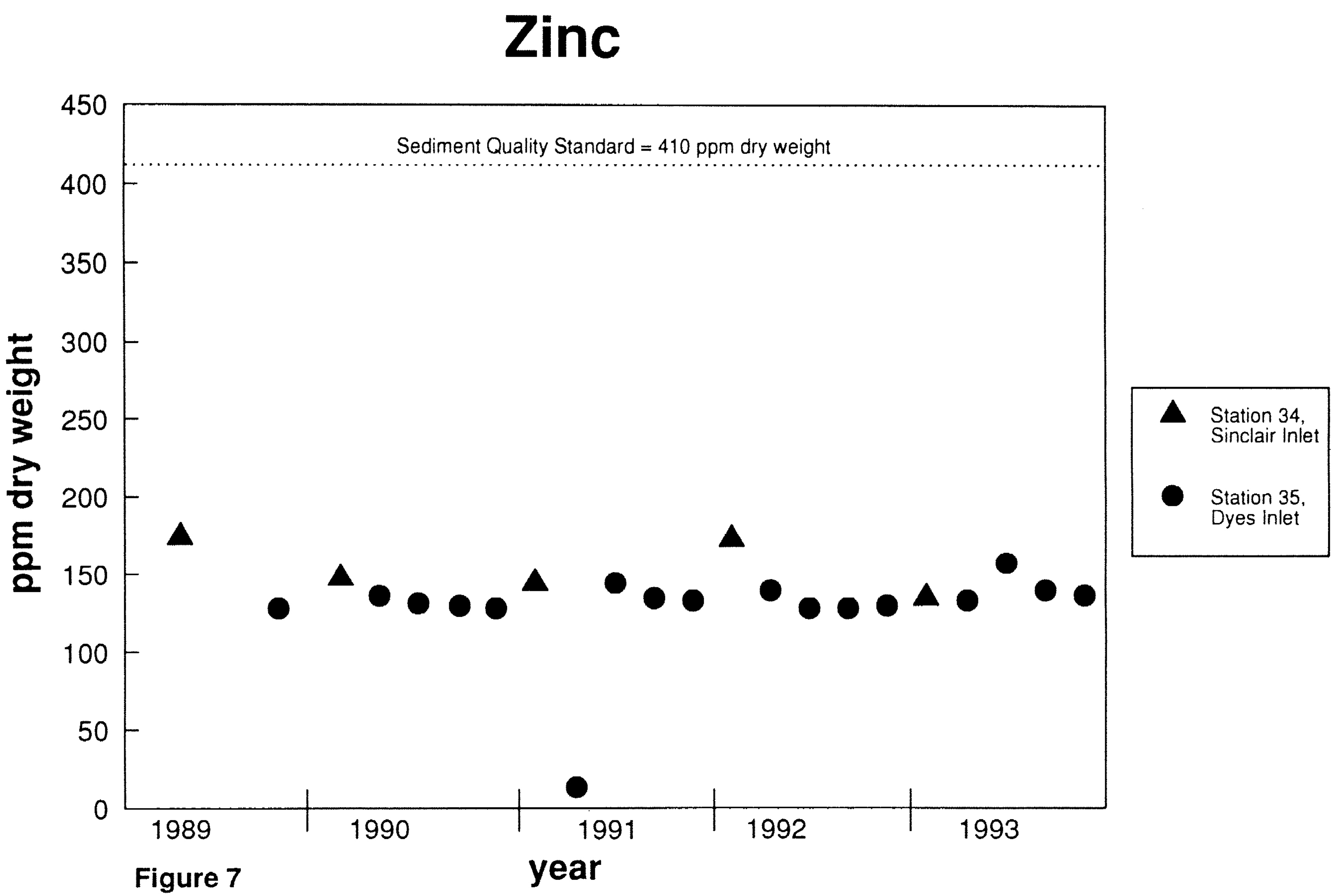

Figure 7

Note

(1) All 1990 and 1991 values shown were qualified as estimates.

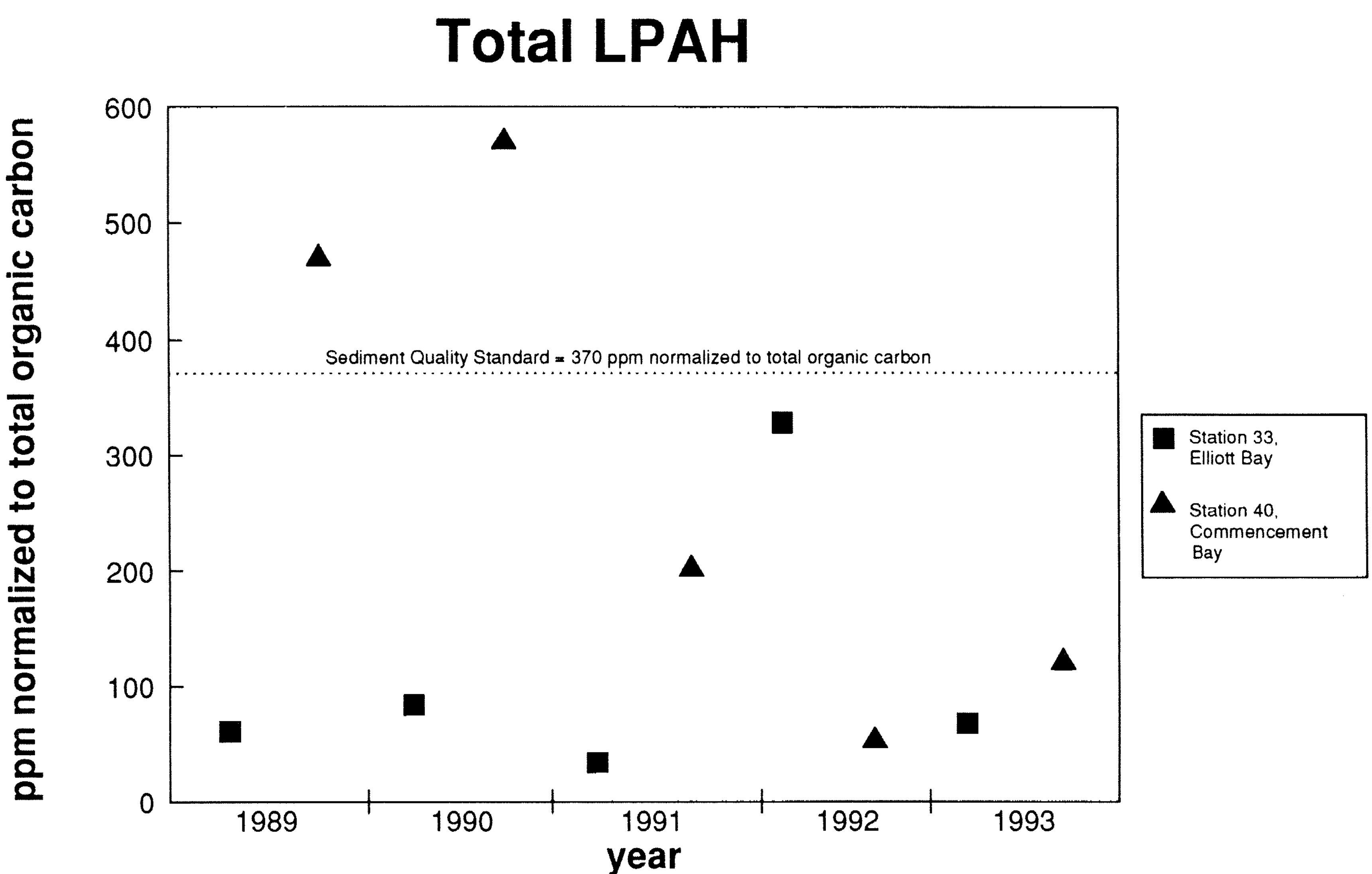

Figure 8

Notes

(1) 1991 and 1993 total organic carbon values used in calculating total LPAH were qualified as estimated values.

(2) Some compounds used in calculating total LPAH were qualified as estimates.

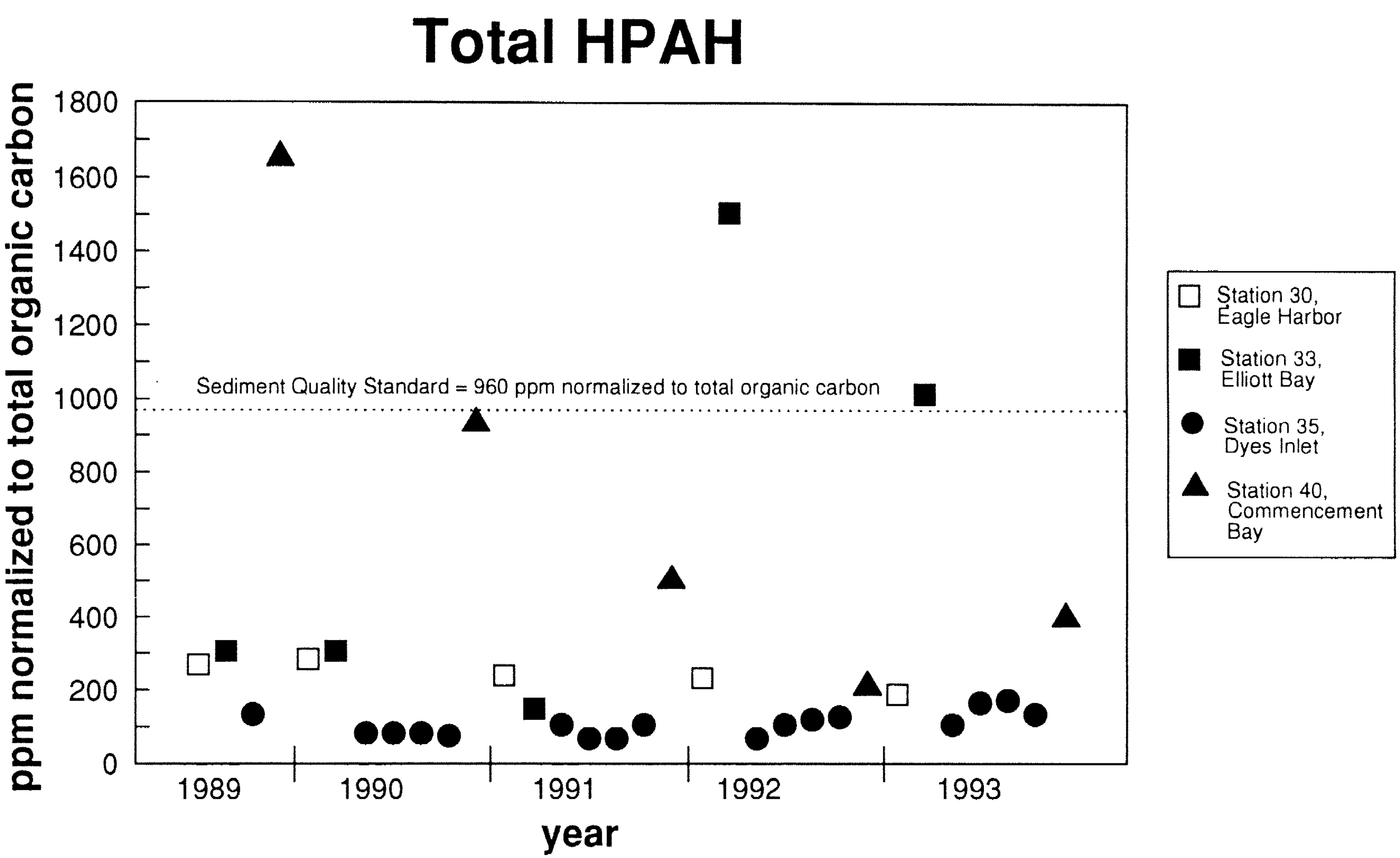

Figure 9

Notes

(1) 1991 and 1993 total organic carbon values used in calculating total LPAH were qualified as estimated values.

(2) Some compounds used in calculating total LPAH were qualified as estimates.