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DEPARTMENT OF
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Creation and Analysis of Freshwater Sediment Quality Values in Washington State

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Creation and Analysis of Freshwater Sediment Quality Values in Washington State

by
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Prepared for the Sediment Management Unit in cooperation with Brett Betts
under a grant from
U.S. Environmental Protection Agency, Region 10, Seattle, Washington

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Abstract

We sought to derive chemical criteria that could predict possible biological effects in sediments. To develop chemical-based criteria, data from several bioassays (*Hyalella azteca,* Microtox® *Chironomus tentans*, *Daphnia magna*, *Ceriodaphnia dubia*, and *Hexagenia limbata)* and chemical analyses (metals, Polycyclic Aromatic Hydrocarbons (PAH), pesticide/PCB, semivolatiles) were merged from 33 studies and 245 stations in Washington and Oregon into a single database.

We tested the efficiency (correctly predicted/number predicted: 1 minus Type I error) and sensitivity (correctly predicted/impacted: 1 minus Type II error) that sediment quality values have in predicting biological effects. The values derived in this study were Apparent Effects Thresholds (AET) and Probable AET (PAET: 95th percentile of no effects stations) calculated from *Hyalella azteca* and Microtox®. The efficiency and sensitivity of other values including Ontario's Severe Effect Level (SEL), Environment Canada's Probable Effects Level (PEL) and Threshold Effect Level (TEL), EPA's Equilibrium Partitioning (EQP), and Washington State Department of Ecology's Marine Sediment Management Standards (SMS) were also tested and compared with values derived in this study.

For PAH, dry weight normalized values for AETs and PAETs were significantly more sensitive and efficient than organic carbon normalized values ($p<0.05$). TEL were always the most sensitive (fewest missed effects) and least efficient (most false alarms). The AET *Hyalella* were the reverse. In rough progression from most sensitive to least sensitive were TEL, SMS, PAET Microtox®, PEL, AET Microtox®, SEL, PAET *Hyalella* and AET *Hyalella*; from most efficient to least were AET *Hyalella*, SEL, AET Microtox®, PAET *Hyalella*, PAET Microtox®, SMS, PEL, TEL. With comparisons limited to the three PAH considered by EQP, the AET and PAET *Hyalella* and SEL errors were roughly equivalent to EQP; they were highly efficient but less sensitive than random selection.

We suggest a set of Freshwater Sediment Quality Values (FSQV) based on PAET Microtox® values for organics and SMS values for metals be considered as a threshold to detect biological effect. These FSQVs ranked second in sensitivity (80%) and fourth in efficiency (45%). Highly efficient AET *Hyalella* (96%) could provide a level above which detrimental biological effects are reasonably certain. The Lowest AET (LAET) between *Hyalella* and Microtox® could also be considered. Advantages of these values (LAET) are that its methods have been accepted and they provide slightly better efficiency than the FSQV above (46%). One major disadvantage over the FSQV is their reduced sensitivity (75%).

Acknowledgments

We would like to thank John Malek and EPA Region 10 for conceiving, initiating and supporting the Freshwater Sediments Project and providing the funding that made this work possible.

Many people contributed to this report. All individuals and organizations contacted in the search for data on freshwater sediments are listed in Appendix 3.

We are also grateful to these people and organizations:

- Keith Phillips, Brett Betts, and Tom Gries of the Sediment Management Unit, Washington State Department of Ecology (Ecology), provided guidance and funding throughout this project.
- Brett Betts and Brendon McFarland critically reviewed the report.
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- Dreas Nielson of PTI incorporated changes to SEDQUAL to accept freshwater data.
- Les Williams of URS provided technical assistance in testing for significant effects using the Microtox® bioassay.
- Bill Yake and Will Kendra of Ecology's Environmental Investigations and Laboratory Services (EILS) reviewed portions of the report.
- Special thanks to Dale Norton for his guidance of the project and review of the report.
- Joan LeTourneau formatted and edited the final report.

Introduction

Background

In 1991, the Washington State Department of Ecology (Ecology) adopted a state rule addressing sediment quality, the Sediment Management Standards (SMS), Chapter 173-204 WAC. The SMS were reviewed and approved by the U.S. Environmental Protection Agency (EPA) Region 10 pursuant to Section 303 of the Clean Water Act.

The adopted rule "reserves" section 340, Freshwater Sediment Quality Standards, which allows Ecology determinations on a case-by-case basis until such time as Ecology develops and adopts specific chemical and biological criteria for freshwater sediments. Ecology's Central Programs Sediment Management Unit (SMU) was awarded an EPA grant to perform several tasks in support of developing freshwater sediment quality standards. The goals of this grant are to do the following:

- Establish and periodically update a Freshwater Sediment Quality Database
- Summarize available sediment quality guidelines from the U.S. and Canada
- Conduct statistical analysis of the Freshwater Sediment Quality Database to identify initial Freshwater Sediment Quality Values (FSQVs) for Washington State

This document reports on the assembly and analysis of freshwater sediment chemistry and bioassay data collected in Washington State and Oregon. These data were analyzed to begin developing numerical sediment chemistry values which can be used to predict impacts to biological communities exposed to contaminated sediments. Eventually, these values will be used to assist EPA Region 10 and Ecology in managing contaminated freshwater sediments.

These preliminary figures should not be considered adopted or proposed sediment quality criteria.

The AET values calculated in this study are the result of Ecology's effort to develop sediment quality values for potential formal proposal and adoption into the SMS rule as freshwater sediment quality criteria. Prior to proposing any freshwater criteria for adoption, Ecology plans to convene a freshwater sediment criteria stakeholder review group to identify and discuss technical, policy, cost and other issues associated with adoption of specific freshwater sediment quality criteria. Ecology also plans to fully comply with state rule adoption procedures contained in the Administrative Procedure Act, Chapter 34.05 RCW for adoption of freshwater sediment quality criteria. However, this report and the values in this report do represent part of the body of scientific literature that may be cited by Ecology using federal and state best professional judgment authority for use in case-by-case regulatory activities affecting freshwater sediment quality in Washington State.

Overall Strategy

We derived several freshwater sediment quality values that could be used to predict biological effects based on chemical concentrations. To derive these values, stations in Washington and the Willamette River in Oregon where chemical and bioassay data were collected synoptically were collated into a database (FSEDQUAL for Freshwater SEDiment QUALity), a version of SEDQUAL, a database used for marine sediment quality data. Apparent Effects Threshholds (AETs) (PTI 1988) and variations of AETs were calculated from these freshwater sediment data in FSEDQUAL so that biological effects might be predicted from chemical concentrations in sediment. The abilities of these AETs and variants to predict the biological effects recorded in the FSEDQUAL were validated and compared with the abilities of other values provided by other regulatory agencies. From these comparisons, we can recommend different sets of freshwater sediment quality values that minimize error.

Methods

The methods for this study consisted of (1) collection of suitable studies, (2) quality assurance screening, (3) data entry, (4) analysis of bioassay significant effects, (5) derivation of sediment quality values, (6) evaluation of these values, and (7) comparisons with other sets of sediment quality values.

Database Creation, Data Collection and Quality Assurance

Database selection, modification, and data sources are discussed in Appendix 1. Quality assurance review methods and results for data entered into the database are shown in Appendix 2. The following briefly summarizes the Quality Assurance Strategy.

Because the freshwater sediments database is being proposed for a variety of uses with differing needs for data validation, it was agreed that it would be more useful to potential users to include <u>all</u> data, but to have a QA "grade" available for reference. Thus, we proposed a QA review system more for the purpose of grading sediment investigations based on the QA procedures conducted and less for the purpose of excluding/including data in the database, although on the basis of this review, we excluded six data sets. In addition, we proposed a system that would allow for upgrading of a QA "grade" as more supporting information (original laboratory documentation) is received.

For FSEDQUAL data, we incorporated many of the elements of the QA1 review (PTI 1989a) and added some additional QA criteria into a review we call Basic Quality Assurance. This approach grades each investigation from A through F on the types of QA protocols conducted and presented in the final report. It is hoped that with future upgrades of SEDQUAL, this QA grade can be retrieved along with any other data associated with a survey. <u>This grade does not necessarily reflect on the quality of data itself, but on the amount and types of quality assurance procedures completed and documented in the investigation</u>.

As a compromise between time and completeness, Basic Quality Assurance evaluations were completed for all synoptic (i.e. containing both chemical and biological data for a station) data sets entered into FSEDQUAL, and QA1-type reviews were conducted for all studies that set sediment quality values. Additional QA and validation work may be required if the numbers are used in formal rules adoption. Detailed scoring sheets for each individual survey are included in Appendix 2.

Data sets in FSEDQUAL

A total of 40 data sets that contained synoptic bioassay and chemistry data were found from over 200 contacts. Of these 40 synoptic data sets, in the Basic QA review, six were rejected for the following reasons that would make them incompatible for use in calculating AETs:

- In one case, the chemistry and bioassay analyses were done on different samples from different locations in a lake.
- In a second, questionable laboratory results (differing with several other studies) could not be confirmed because the laboratory was no longer in operation.
- Two were dropped because, though their sediments were from a freshwater source, they were equilibrated with sea-water for 30 days and tested with marine organisms.
- Another dropped survey used a non-conventional elutriate test with rainbow trout.
- The sixth dropped survey used a non-standard metals analysis method.

Of the remaining 33 studies, one was classified as having two separate phases for FSEDQUAL purposes because the sampling schedule was separated by a period of time longer than two months. Thus, the total number of data sets entered is 34, representing 33 separate investigations.

Table 1 lists the 34 data sets with synoptic data that have been entered into FSEDQUAL to be used to calculate Freshwater Sediment Quality Values. The surveys are listed by geographic region. Table 2 reviews the chemical classes analyzed in the studies. Most all studies examined metals and PAHs, but very few looked at dioxins and resin acids. Included in the other organics category are phenols, phthalates, chlorinated phenols, and volatiles.

Several different bioassays were tested in the 34 data sets. Table 3 reviews bioassays by study and location. Table 4 summarizes bioassays by organism and type of endpoint used in the 34 data sets. *Hyalella azteca* was the most common bioassay. Results from the 10- and 14-day *Hyalella azteca* bioassays were pooled in our analysis. The totals in Table 4 do not all match Table 3 due to the pooling of different endpoint types in Table 4. Some overlap occurred between the stations where *Hyalella*, Microtox® and Miscellaneous bioassays were conducted. Figure 1 illustrates the relative proportion of stations that were tested with the three groups of bioassays and shows that most stations (228) were tested with *Hyalella*. Twenty-seven stations were tested with Microtox®, *Hyalella* and at least one other bioassay together. *Hyalella* was the only test at 121 stations. Response and predictive abilities of these three bioassay data sets (*Hyalella*, Microtox®, and Miscellaneous) were compared with each other as described in Evaluation Methods.

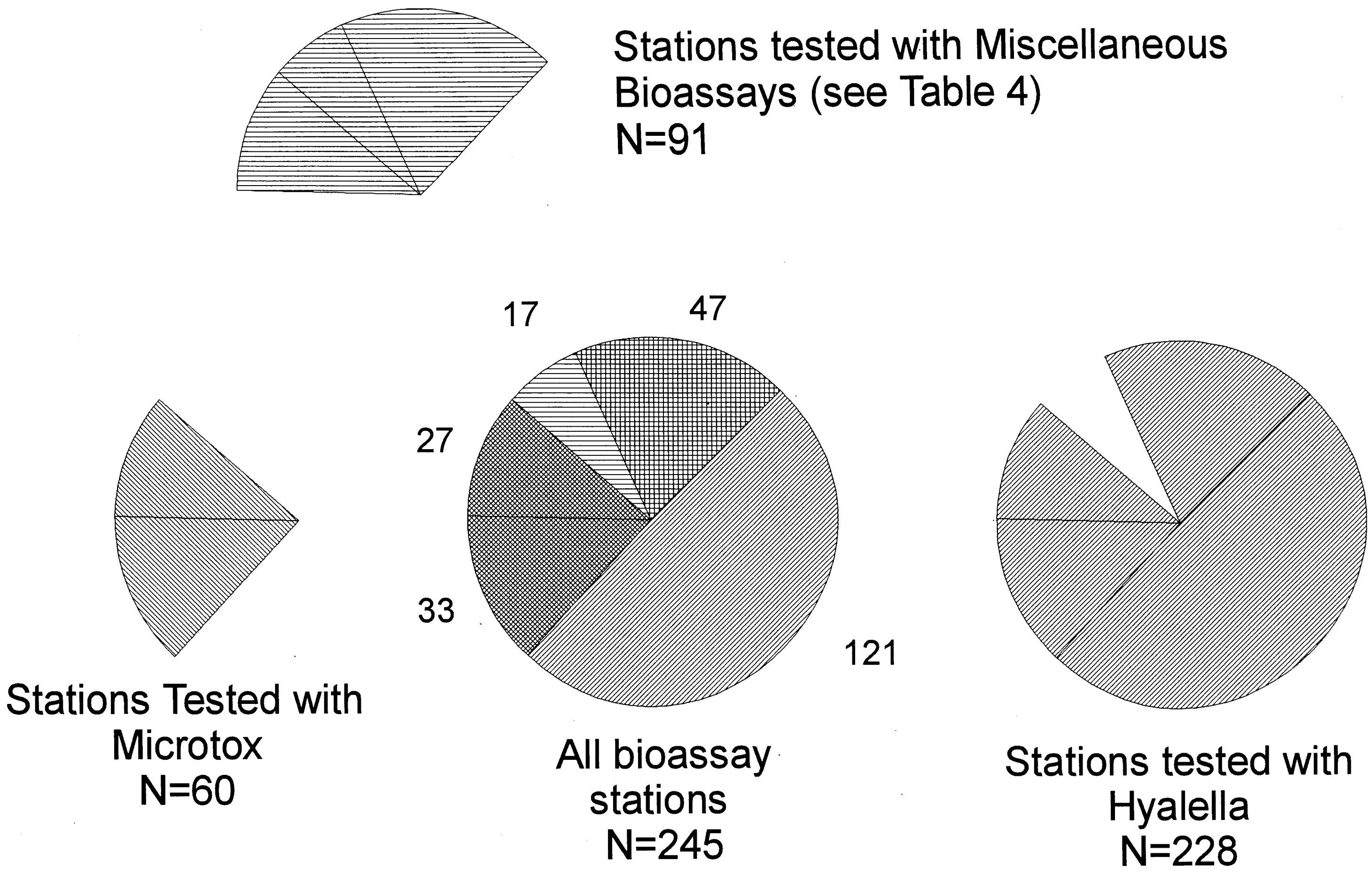


Figure 1. Three bioassay data sets on which performance of sediment values were tested. Sediment quality values were derived from Hyalella and Microtox data sets only.

Table 1 - Summary of sediment investigations used to derive sediment values.

FSEDQUAL SURVEY	FULL TITLE	DATE	AUTHORS/AGENCY
LOWER COLUMBIA REGION			
ALCOA90	ALCOA (Aluminum Company of America) - Class 2 Inspection	1990	Zinner/Ecology
CBSLOUGH	Columbia Slough Sediment Analysis and Remediation Project	1991	Dames & Moore
COLALU93	Columbia Aluminum Co. Goldendale, Washington Baseline Sediment ...	1994	ENSR
KALAMA	Kalama Chemical Company - Class 2 Inspection	1989	Heffner/Ecology
LCBWRS93	Lower Columbia River Bi-State Program -- Backwater Reconnaissance Study	1993	Tetra Tech
LWRCOLUM	Screening Survey for Chemical Contaminants and Toxicity in Sediments at Five ...	1988	Johnson & Norton/Ecology
LNVIEW90	Longview Fibre Company - Class 2 Inspection	1991	Das/Ecology
REYNOLDS	Reynolds Aluminum Company - Class 2 Inspection	1990	Heffner/Ecology
VALCOA93	ALCOA Vancouver Works	1994	ENSR
WEYLONG	Weyerhaeuser - Longview Pulp and Paper Mill - Class 2 Inspection	1991	Andreasson/Ecology
PUGET SOUND REGION			
CEDARRIV	Cedar River Delta Sediment Sampling and Analysis	1992	Golder Associates
EVERTSM94	Site Investigation Report - Everett Simpson Site	1994	PTI
FERNDALE	Ferndale Wastewater Treatment Plant - Class 2 Inspection	1989	Ruiz/Ecology
GWPLKUN	App. of Triad Approach to Freshwater Sediment Assessment: GWP	1986	Yake et al./Ecology
HANSVL91	Site Hazard Assessment Report -- Hansville Landfill -- Kitsap County, Wa	1991	SAIC
LKUNDRDK	Sediment Monitoring Program - Lake Union Drydock Company	1992	Hart-Crowser
LKUNION	Survey of Contaminants in Sediments in Lake Union	1992	Cubbage/Ecology
MARCO90	Marco Shipyard Sediment Monitoring	1990	Friedman & Bruya
MILLCRP2	Mill Creek and East Drain Sediment Sampling and Analysis Report	1993	Landau Associates
PAINEFLD	Survey for Chemical Contaminants at Paine Field	1987	Johnson & Norton/Ecology
QUEBAX1	Distribution of PAH's in Lake Washington (Quendall Terminals/J.H.B. Site)	1991	Norton/Ecology
QUEBAX2	Effects of PAH's in Sediments of Lake Washington - Phase 2	1992	Cubbage & Bennet/Ecology
QUEBAX3	Effects of PAH's in Sediments of Lake Washington - Phase 3	1992	Norton/Ecology
SEACOM94	Sediment Sampling Report - Seattle Commons Parcel C -- Seattle, Wa	1994	Shannon & Wilson, Inc.
STEILLK2	Copper in Sediments of Steilacoom Lake	1992	Bennet & Cubbage/Ecology
UNIMAR2	Environmental Sampling - UNIMAR Yard 1 Drydock Facility - Phase 2	1991	Geo Engineers, Fishpro
UPPER COLUMBIA RIVER REGION			
BOISECAS	Boise Cascade Mill - Class 2 Inspection	1993	Johnson & Heffner/Ecology
COLBSN92	Bulk Sediment Toxicity Tests of Selected Sites w/in Columbia Basin Irr...	1993	US Fish & Wildlife, USGS
LAKEROOS	Review of Metals, Bioassay, and Macroinvertabrate data in Lake Roosevelt	1991	Johnson/Ecology
LAKEROOS92	Sediment-Quality Assessment of Franklin D. Roosevelt Lake, Washington	1994	Bortleson et al, USGS
ROOSVMET	An Assessment of Metals Contamination in Lake Roosevelt	1989	Johnson et al./Ecology
SPOKNR94	Spokane River PCB Bioassay Study -- 1994	1994	Ecology
WILLAMETTE RIVER REGION			
MBCREOS1	McCormick and Baxter Creosoting Remedial Investigation - Phase 1	1992	PTI
MBCREOS2	McCormick and Baxter Creosoting Remedial Investigation - Phase 2	1992	PTI

Table 2 - Summary of chemistry analyses done by survey.

FSEDQUAL SURVEY	LOCATION	Metals	PAH's	Other Organics	Pesticides PCBs	Dioxins Furans	Resin Acids	ECOLOGY ID
LOWER COLUMBIA REGION								
ALCOA90	Columbia R. @ Vancouver	+	+	+	+	-	-	SY25
CBSLOUGH	Columbia Slough	+	+	+	+	-	-	SY2
COLALU93	Columbia River Near Goldendale,	+	+	-	-	-	-	SY34
KALAMA	Columbia R. @ Longview	+	+	+	+	-	-	SY20
LCBWRS93	Lower Columbia River	+	+	+	+	+	-	SY36
LWRCOLUM	Lower Columbia River Ports	+	+	+	+	+	+	SY4
LNVIEW90	Columbia R. @ Longview	+	+	+	+	+	+	SY24
REYNOLDS	Columbia R. @ Longview	+	+	+	+	-	-	SY18
VALCOA93	Lower Columbia River	+	+	+	+	-	-	SY33
WEYLONG	Columbia R. @ Longview	+	+	+	+	-	-	SY19
PUGET SOUND REGION								
CEDARRIV	Lake Washington	+	+	+	+	-	-	SY9
EVERTSM94	Snohomish River	+	-	-	+	-	-	SY40
FERNDALE	Nooksack River	+	+	+	+	-	-	SY17
GWPLKUN	Lake Union	+	+	-	-	-	-	SY23
HANSVL91	Kitsap County	+	-	+	+	-	-	SY30
LKUNDRDK	Lake Union	+	+	+	+	-	-	SY16
LKUNION	Lake Union	+	+	+	+	-	-	SY5
MARCO90	Lake Union	+	+	+	-	-	-	SY21
MILLCRP2	Mill Creek	+	+	+	-	-	-	SY8
PAINEFLD	Paine Field	+	+	-	-	-	-	SY6
QUEBAX1	Lake Washington	+	+	+	-	-	-	SY14
QUEBAX2	Lake Washington	-	+	+	-	-	-	SY15
QUEBAX3	Lake Washington	-	+	+	-	-	-	SY22
SEACOM94	Lake Union	+	+	+	+	-	-	SY31
STEILLK2	Steilacoom Lake	+	-	-	-	-	-	SY13
UNIMAR2	Lake Union	+	+	-	-	-	-	SY26
UPPER COLUMBIA RIVER REGION								
BOISECAS	Lake Wallula	+	-	+	+	+	+	SY12
COLBSN92	Assorted irrigation returns	+	+	-	-	-	-	SY37
LAKEROOS	Lake Roosevelt	+	-	-	-	-	-	SY10
LAKEROOS92	Lake Roosevelt	+	+	-	-	-	-	SY32
ROOSVMET	Lake Roosevelt	+	-	-	-	-	-	SY7
SPOKNR94	Spokane River	+	+	+	+	-	-	SY38
WILLAMETTE RIVER REGION								
MBCREOS1	Willamette River	+	+	+	+	+	-	SY1
MBCREOS2	Willamette River	+	+	+	+	+	-	SY1
TOTAL		32	28	24	20	6	3	

\+ analysis conducted

\- analysis not conducted

Note: Analyses may not have been performed on all samples taken within a survey, especially for surveys with large numbers of samples

Table 3 - Review of bioassays by survey, region and organism.

FSEDQUAL		Total	*HYALELLA*		MICROTOX		*DAPHNIA*		*CHIRON.*		*CERIODAPH.*		*HEXAGEN.*	
SURVEY	**LOCATION**	Stns	Hits	Stns	Hits	Stns	Hits	Stns	Hits	Stns	Hits	Stns	Hits	Stns
	LOWER COLUMBIA REGION													
ALCOA90	Columbia R. @ Vancouver	1	0	1										
CBSLOUGH	Columbia Slough	20	0	20										
COLALU93	Columbia River Near Goldendale, WA	6	1	6	3	6								
KALAMA88	Columbia R. @ Longview	3	0	3										
LCBWRS93	Lower Columbia River	13	0	13										
LWRCOLUM	Lower Columbia River Ports	12					0	12						
LNVIEW90	Columbia R. @ Longview	3	0	3	0	3								
REYNOLDS	Columbia R. @ Longview	3	0	3	0	3								
VALCOA93	Lower Columbia River	6	2	6										
WEYLONG	Columbia R. @ Longview	3	0	3	0	3								
	REGION SUBTOTAL	**70**	**3**	**58**	**3**	**15**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**0**
	PUGET SOUND REGION													
CEDARRIV	Lake Washington	5	5	5	0	5	0	5						
EVERTSM94	Snohomish River	4	0	4					1	4				
FERNDALE	Nooksack River	3	0	3										
GWPLKUN	Lake Union	1	1	1										
HANSVL91	Kitsap County	1	0	1										
LKUNDRDK	Lake Union	4	3	4										
LKUNION	Lake Union	9	2	9	8	9	1	9						
MARCO90	Lake Union	1	0	1										
MILLCRP2	Mill Creek	19	3	19					7	19				
PAINEFLD	Paine Field	5	0	5										
QUEBAX1	Lake Washington	4	1	4			0	4						
QUEBAX2	Lake Washington	4	3	4	3	4	0	4	1	4	0	4	0	4
QUEBAX3	Lake Washington	3	1	3	1	3								
SEACOM94	Lake Union	3	1	3	2	3								
STEILLK2	Steilacoom Lake	4	2	4	0	4	0	4	0	4	1	4	1	4
UNIMAR2	Lake Union	9	7	9										
	REGION SUBTOTAL	**79**	**29**	**79**	**14**	**28**	**1**	**26**	**9**	**31**	**1**	**8**	**1**	**8**
	UPPER COLUMBIA RIVER REGION													
BOISECAS	Lake Wallula	4	3	4	0	4								
COLBSN92	Assorted irrigation returns	5							0	5				
LAKEROOS	Lake Roosevelt	5	1	5	3	5	2	5						
LAKEROOS92	Lake Roosevelt	18	4	18							8	18		
ROOSVMET	Lake Roosevelt	2	0	2			0	2						
SPOKNR94	Spokane River	2	0	2	1	2								
	REGION SUBTOTAL	**36**	**8**	**31**	**4**	**11**	**2**	**7**	**0**	**5**	**8**	**18**	**0**	**0**
	WILLAMETTE RIVER REGION													
MBCREOS1	Willamette River	53	8	53										
MBCREOS2	Willamette River	7	2	7	3	6								
	REGION SUBTOTAL	**60**	**10**	**60**	**3**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	TOTAL ALL REGIONS	**245**	**50**	**228**	**24**	**60**	**3**	**45**	**9**	**36**	**9**	**26**	**1**	**8**

Hits = # of stations with statistically significant effects in bioassays

Stns = # of stations with bioassay testing

Table 4. Bioassays in Freshwater Sediment Quality Database

Bioassay	Endpoint	Stations	"Hits"*
Hyalella azteca	mortality	228	50
Microtox®	luminescence reduction	60	24
Miscellaneous	(see below)	91	22
Ceriodaphnia dubia	mortality	8	1
Ceriodaphnia dubia	reproduction	26	9
Chironomus tentans	mortality	31	8
Chironomus tentans	growth	9	1
Chironomus tentans	emergence	8	1
Daphnia magna	mortality	43	3
Daphnia pulex	mortality	2	0
Hexagenia limbata	mortality	8	1

* Statistically significant biological effects
Some stations had more than one type of endpoint for Ceriodaphnia and Chironomus.

Bioassay Analysis

Statistical significance of bioassay effects ("hits") were calculated for all data sets entered into FSEDQUAL. For all bioassays except Microtox®, percent survival at each study station was tested against background stations that were collected with each study. If a background station was not available or its performance showed a toxic effect, sediments collected outside a given study area but run with the bioassays were used as a control. Percent survival was analyzed for normality (Lillifors tests; Wilkinson, 1990) and if the data were not normally distributed at $p<0.05$ then the arcsine transformation was tested. If the transformed or untransformed data were normally distributed, study stations were tested with a T-test against the reference stations. If the data failed normality tests no matter what transformation was used, the data were compared with a pairwise analysis using the Mann-Whitney test. Significant hits were assigned at differences at $p<0.05$.

Microtox® bioassays were compared with reference areas using the Sediment Management Standards protocols for Microtox®: Either five replicates or two replicates (if five were not run) of the blank-corrected light output from the highest concentration were compared to reference areas with a T-test. Only those samples that showed at least a 20% reduction in light output and were significantly lower ($p<0.05$) than reference areas were considered hits.

Some have been concerned that the Dunnett's test may be more appropriate for these comparisons in that it accounts for experimentwise error. In so doing, it raises the threshold of significance in direct proportion to the number of stations compared with a given reference area. Thus, through correction for possible experimentwise error, significance can vary based on the number of samples taken in a given study so that one study with two test stations may have significant bioassay hits and another study with equivalent values but 20 test stations would have no hits. The only comparisons of concern for AET calculations are paired with the reference. A pairwise comparison with each station and the reference will allow a Type I error at p probability. As AETs are based on one end of a distribution of effects (the highest no effect level), concentrations lower than AETs may have effects some of the time and thus AETs are probably not overly conservative with respect to environment. Thus, the low likelihood of increasing the Type I error by using a pairwise comparison may increase slightly the conservative quality of AETs. Also, the Dunnett's has no non-parametric equivalent for data sets that are not normally distributed. A more detailed discussion of this issue is found in Michelsen and Shaw (1996).

Derivation of Sediment Quality Values

Two types of sediment quality values were created and evaluated against other proposed freshwater sediment quality values.

Apparent Effects Threshold

The Apparent Effects Threshold (AET) is defined as the concentration of a given chemical above which a statistically significant ($p<0.05$) biological effect ("hit"), for example, mortality, is always expected to occur (see Bioassay Analysis for description of "hit" definitions). Biological effects may be observed in sediments below an AET for a given chemical, and this effect may be caused by other chemicals that occur with the considered chemical. The AET value demarcates the upper boundary of a chemical concentration that may be tolerated by a given organism.

The AET application to marine sediments in Puget Sound is reviewed by PTI (1988) and they present information on reliability as well as the limits and strengths of the approach. Their AET evaluation also examined *in-situ* benthic community composition, data that we do not have for most stations entered into FSEDQUAL and will not consider further in this report. Other approaches to determine biological effects of chemicals are briefly reviewed in Giesy and Hoke (1990) and Batts and Cubbage (1994). An example of the AET approach is shown in Figure 2 and it illustrates the *Hyalella* AET for copper in freshwater sediments.

Probable Apparent Effects Threshold

We propose that a modification of the basic AET approach be considered and tested for freshwater sediments. The AET is based on the highest concentration for which no significant biological effect occurs. One concern with this approach is that it is effectively set by the outlier of a given group of data. For example, if a chemical was measured incorrectly and biased high at a station near the true (but unknown) effects threshold, the error in measurement could set the AET above the true effects threshold. The same problem will occur if a bioassay reference sample causes anomalously high mortality due to factors other than the chemical contamination and thus renders the test station to which it is compared a non-hit. These errors all tend to increase the AET. All measurements incur error and most repetitive measurement systems deal with error through focus on some indication of central tendency (median, mean, etc.) whose accuracy is increased with more samples. However, in the basic AET approach, since the threshold is set by the maximum, with more chemical and biological measurements of sediments, the AET must move ever higher owing to error of measurements. Any random error can only bias the AET higher. More measurements by themselves cannot ever lower the AET.

This problem can be allayed somewhat with rigorous quality assurance/quality control (QA/QC) procedures. However, even stringent QA/QC only reduces error bounds and, again, error will eventually bias the AET higher. With more measurements, the probability of a large error increases. PTI (1988) attempted to deal with this problem by excluding "anomalous" stations that showed no hits and set the AET at more than three times the concentration of the next highest station with no hit. This can effectively deal with gross errors or unique substrates but does little to counteract the drift, due to random errors, of the threshold towards higher concentrations.

To reduce the effects of random error, we derived and examined an alternative value, the Probable Apparent Effects Threshold (PAET). This PAET was derived as the 95th percentile of values from all stations with no significant biological effects and concentrations greater than the lowest hit level. Figure 3 shows the copper *Hyalella* mortality data, the AET and the 95th percentile PAET (PAET95) for copper. As more samples are taken across the range of copper values, the PAET will be refined, but will not be biased higher. Note that the PAET is in the midst of a group of data and the AET appears to be an outlier; this outlier station sets the AET and is in Lake Steilacoom, an area of extremely high copper sediment concentrations due to annual treatment of the lake with copper sulfate to kill algae. How much of this copper is bioavailable is unknown (Bennett and Cubbage, 1992, Ankley et al. 1993). The PAET reduces the likelihood that biological problems associated with this concentration of copper found at other stations will be dismissed as benign. We calculated PAET95 for *Hyalella* and Microtox®.

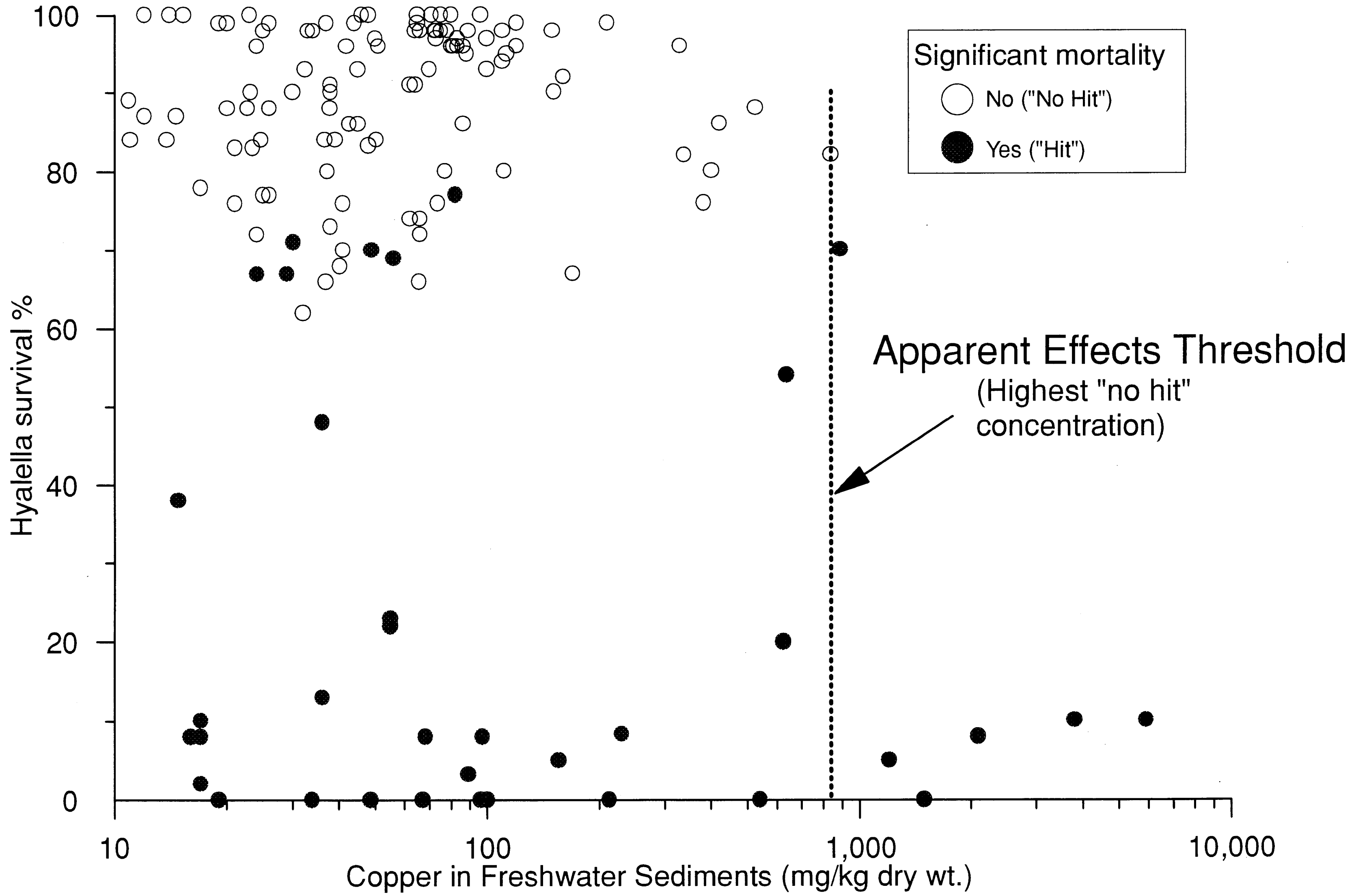


Figure 2. Hyalella Apparent Effects Threshold (AET) for copper.

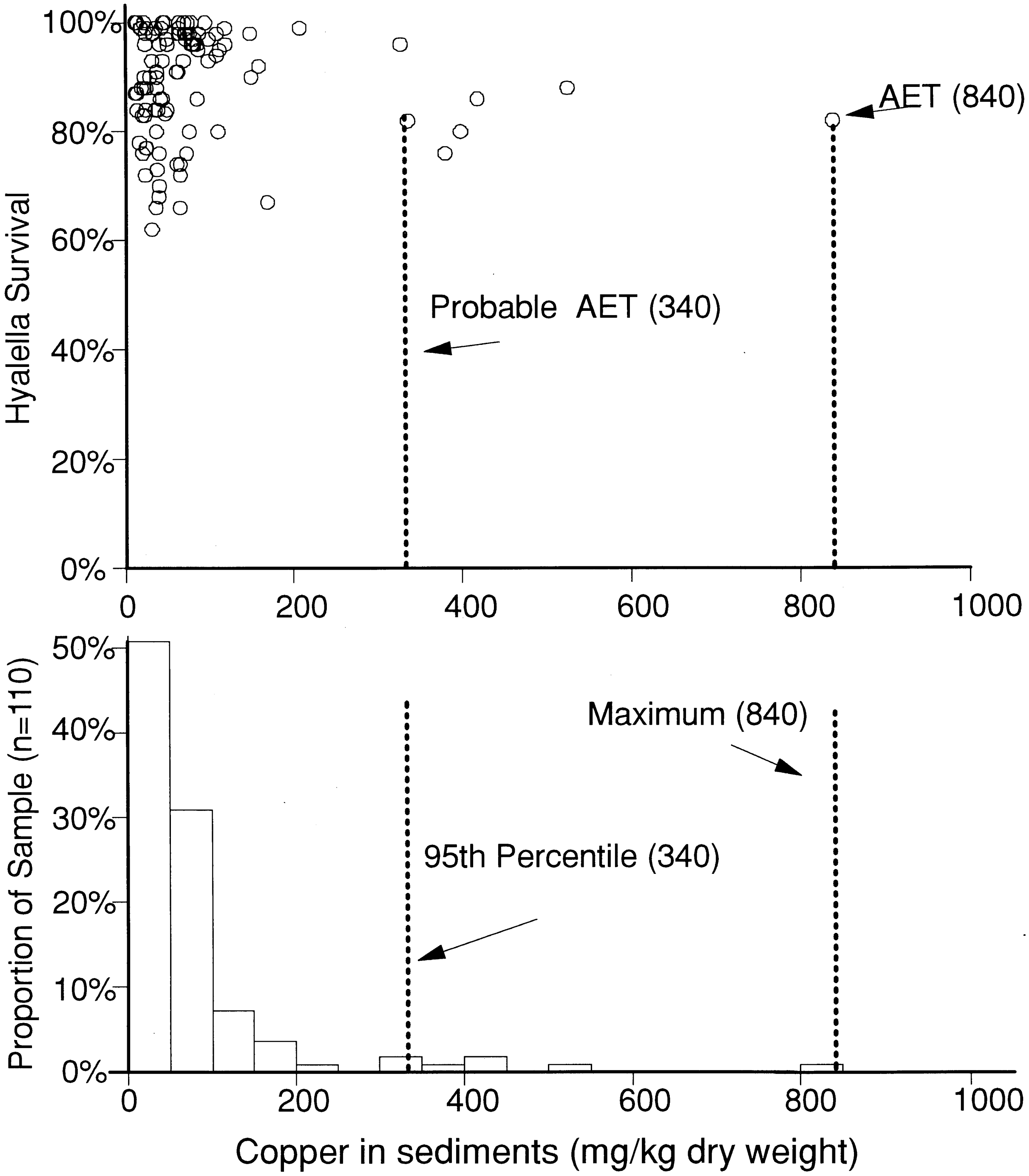


Figure 3. Derivation of Probable Apparent Effects Threshold (PAET) at the 95th percentile of the "non-hits" illustrated in Figure 3.

Calculation Methods

AETs and PAETs were calculated with a customized application written in Windows based Object Pascal (Delphi®) with Paradox® file handling utilities. The data were extracted and summarized from FSEDQUAL and converted to Paradox® files. Options included in the application allowed for organic compounds to be normalized to total organic carbon (TOC). Metals, phenolics and acid-based organics were normalized to dry weight basis. This custom application provided flexibility as well as easy tabulation of the number of samples and identification of stations that set the AETs.

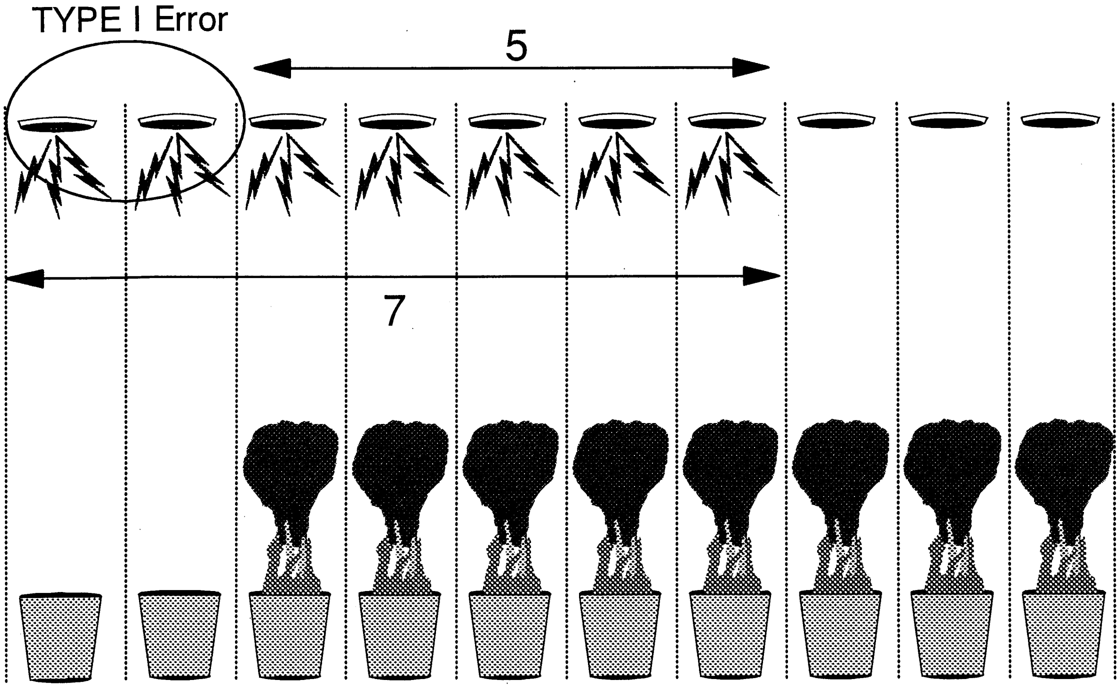
Evaluation Methods

The ability of the sediment quality values to predict biological effects is the core of the work reported here. We tested the ability of several proposed values from this study and other studies to predict biological effects from chemistry levels in the database. To evaluate freshwater sediment values, the number of stations in the database predicted by chemistry values to have biological effects were compared to the number of stations with measured biological effects. For evaluation of freshwater sediment quality values, a biological effect at a station in the database was defined as a statistically significant effect in any of the bioassays at the given station. The two measures of error we evaluated were sensitivity and efficiency and are defined below.

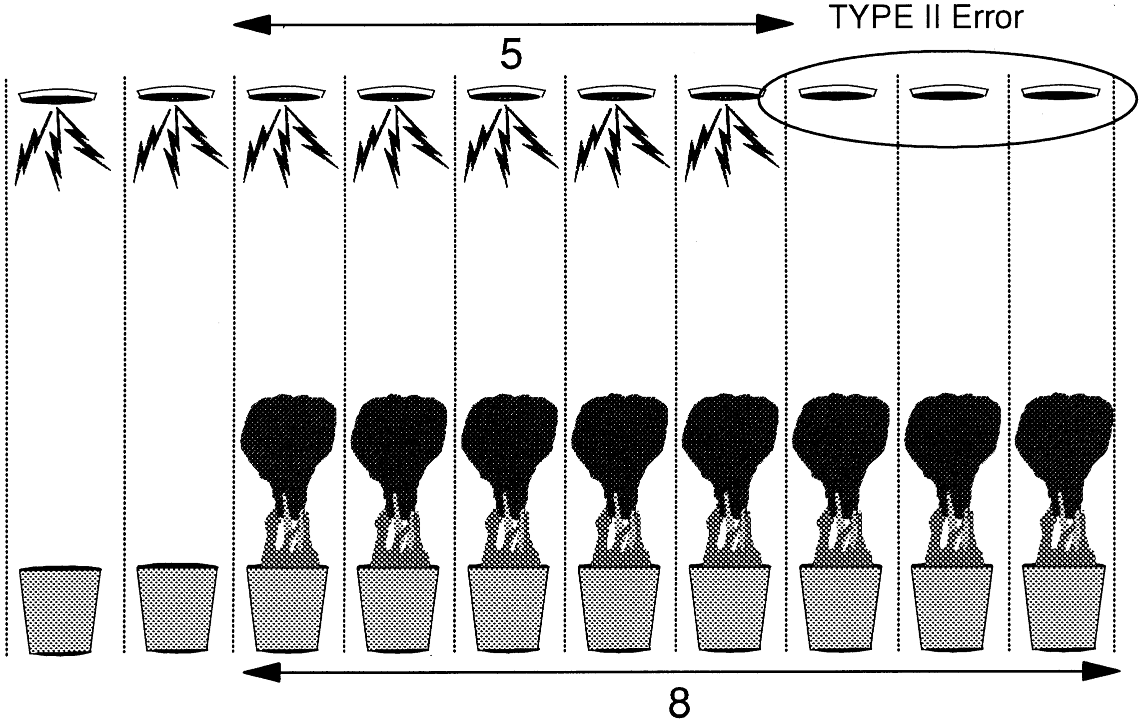
Sensitivity is measured as the ratio of stations correctly predicted as impacted to the number of stations impacted. Sensitivity increases as Type II error (no alarm - undetected effect, or false negative) decreases. Sensitivity could also be defined as one minus the Type II error rate.

Efficiency is the ratio of the number of stations where impacts were correctly predicted to the total number of stations predicted to be impacted. Efficiency increases as Type I error (false alarm) decreases. Efficiency could also be defined as one minus the Type I error rate.

Figure 4 illustrates sensitivity and efficiency in terms of smoke detectors (sediment quality values) and fires (biological effects). If the sediment quality values are sensitive, then the Type II (undetected effect) error will be minimized but the Type I error may be increased, a situation similar to a smoke alarm so sensitive that it not only detects fires but also detects burnt toast. Conversely, highly efficient sediment values will have a low Type I (false alarm) error at the possible cost of a high Type II error, analogous to a fire detector that only rings during a conflagration. The most efficient detector would be one with the batteries removed; it will never yield a false alarm error. The ideal set of sediment values would be both highly efficient and highly sensitive. The decision about which is the more



EFFICIENCY = Number of correctly predicted / number predicted
EFFICIENCY = 5/7 = 71%: The percent of alarms that were true.
The alarms displayed a TYPE I error 29% (2/7) of the time.



SENSITIVITY = Number of correctly predicted / number of impacted
SENSITIVITY = 5/8 = 63%: The percent of fires detected.
The alarms displayed a TYPE II error 37% (3/8) of the time.

Figure 4. Predictive performance of smoke alarms in detecting fires measured as efficiency and sensitivity. Sediment values can be considered alarms that signal biological toxicity.

important measure of sediment quality value performance, sensitivity or efficiency, is probably a policy decision. Which error is more crucial to reduce at the expense of the other depends on which end of the discharge pipe one stands.

A third measure of sediment quality value performance, reliability ((number of correctly predicted hits + correctly predicted non-hits) / total number tested) has been proposed to combine sensitivity and efficiency into one measure. We calculated and present reliability but caution against its use because of its incomparability across different sets of data and the potential blurring of the two distinct types of error. In this study, more stations had no biological effects than had effects, and thus the reliability measures would be higher for the more efficient values than for equivalently sensitive values. For example, if a data set had 200 stations and 150 had no effects, a set of values that predicted no hits at all would be 75% reliable -- an arguably poor depiction of its true performance. Conversely, if a set of values predicted 100 hits and identified all 50 true hits correctly, its reliability would be the same (75%) as the earlier hypothetical value that predicted no hits. Viewed another way, the first value would be 0% sensitive and 100% efficient. The second value would be 100% sensitive and 66% efficient, an arguably more valuable performance than the equivalently reliable first value. Though the appeal of a single measure of the accuracy of sediment quality values is strong, we believe no one measure clearly depicts the performance of a given value.

Efficiency of a given set of values tested against the bioassay data set that produced those values will by definition be 100%. To derive an independent measure of efficiency we tested values through sequential deletion of stations in the following manner: For each type of value (AET, PAET), all stations except one were used to derive a value. The ability of this value to predict biological effects at the deleted station was tallied. This station was then included and the next station in the database deleted; the values were then recalculated and tested against the new deleted station. This deletion and calculation was iterated through the whole database. Figure 5 illustrates this method.

Three groups of bioassays were also considered separately. The *Hyalella*-based values were tested against Microtox® and Miscellaneous bioassays, and Microtox® values were tested against pooled *Hyalella* and Miscellaneous bioassays. Figure 6 illustrates the relationships of these tests to show that several stations had more than one bioassay.

We compared performance, evaluated through efficiency and sensitivity of biological predictions on our database, among sediment quality guidelines derived in this study as well as values proposed or in use by other agencies in the U.S. or Canada. Table 5 describes these different sets of values. Most of the values -- Severe Effects Level (SEL), Probable Effects Level (PEL), Sediment Management Standards (SMS), etc. -- are based on an upper limit whereby concentrations above the limit are likely to cause harm to biological resources. The Threshold Effects Level (TEL) is a lower limit, in that

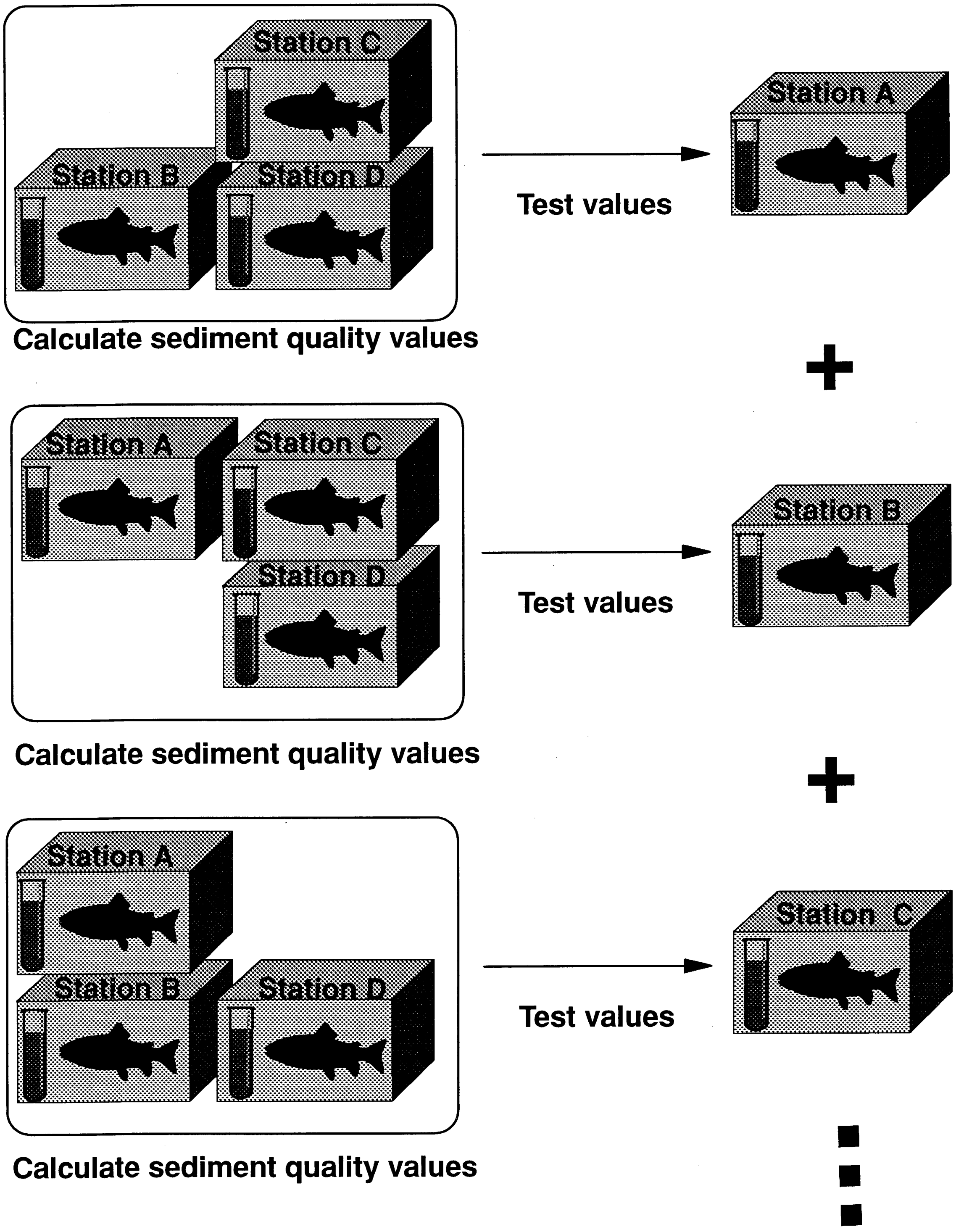


Figure 5. Method to calculate sensitivity and efficiency of sediment values using sequential station deletion.

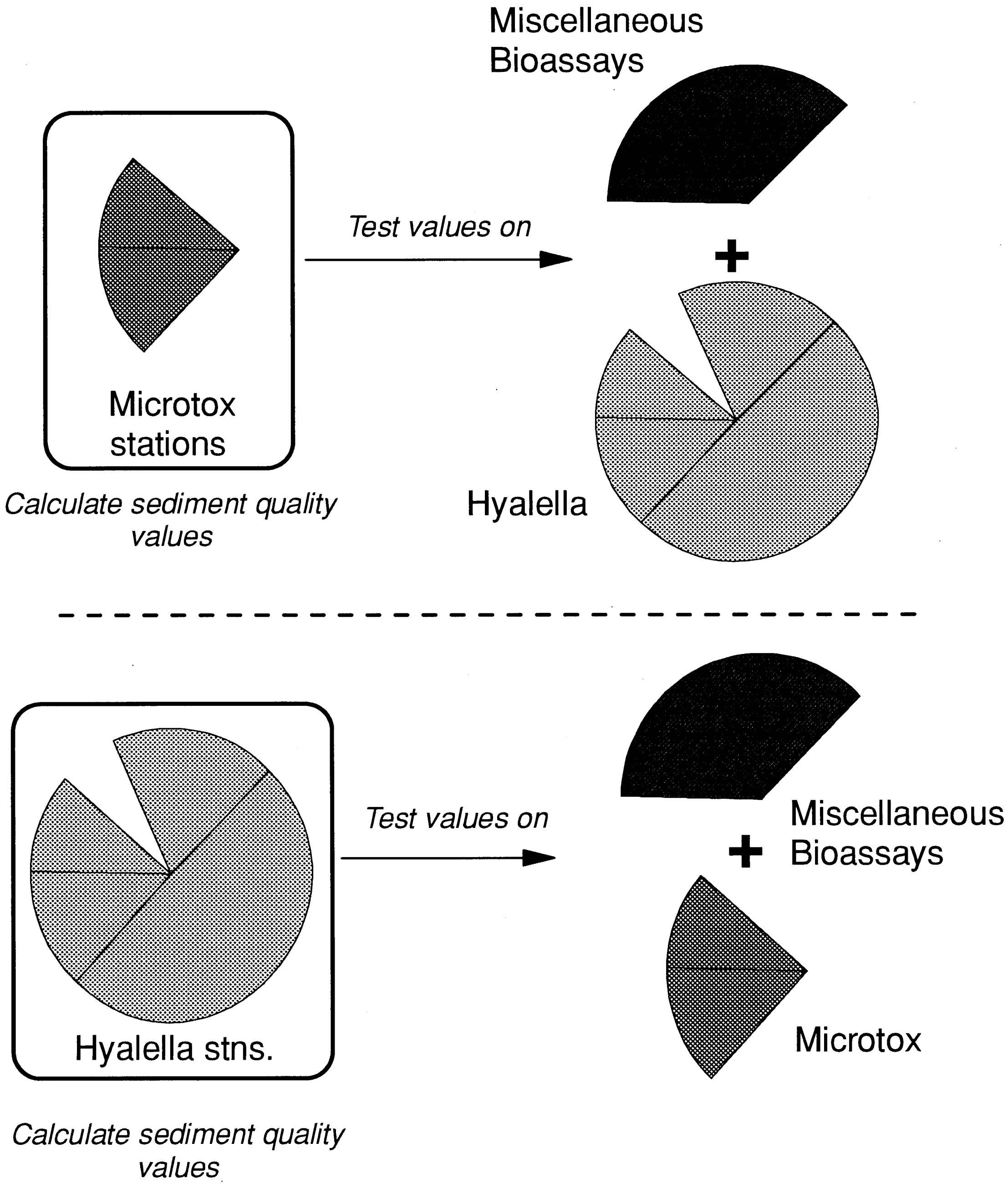


Figure 6. Scheme to assure independence for tests of sensitivity and efficiency of calculated values. Figure 5 illustrates another method (sequential deletion) used to maintain indepedence of value creation and tests of value performance.

concentrations below the TEL are probably not going to cause problems. The ability of values created in this study through sequential deletion to predict effects were compared with values shown in Table 5. Also, the performance of values created from one bioassay in predicting effects in another bioassay were compared with the predictive abilities of the values shown in Table 5.

Table 5. Sediment quality values tested on FSEDQUAL.

Value Abbr.	Value Name	Derivation Method	General Definition from Source	Source
SEL	Severe Effects Level	90th-95th percentile screening level concentration based on *in-situ* benthic community structure	Contaminant concentration would be detrimental to the majority of benthic species	Persaud 1994.
PEL	Probable Effects Level	geometric mean of the 50th percentile concentration of the effect data set and the 85th percentile of the *no effect* data set.	Adverse biological effects are frequently seen above PEL.	EC 1994
TEL	Threshold Effects Level	geometric mean of the 15th percentile concentration from the *effect* data set and the 50th percentile concentration from the *no effect* data set.	Adverse biological effects are rarely seen below TEL.	EC 1994
EQP	Equilibrium Partitioning	Water quality criteria applied to organics concentrations in water predicted with log-octanol partition coefficient.	Protective of benthic species	EPA 1993
SEN	Seuil d'Effets Nefastes	90th percentile screening level concentration based on *in-situ* benthic community structure	Concentration of a substance that will cause adverse effects in most living organisms.	EC&MOE 1992
SMS	Sediment Management Standards (MARINE)	Primarily lowest Apparent Effect Threshold of three bioassays and one measure of benthic community structure.	Adverse effects on biological resources.	WAC 173-204

Results

Sediment Quality Values

Table 6 lists the AET values for *Hyalella* and Microtox®. The first section of the table (6a) lists the AETs on a dry weight basis, and the second section (Table 6b) lists the values based on an organic carbon normalized basis. Information on the number of stations where the bioassays were tested, the number of stations with hits, the number of stations with chemical levels above the AET, and the survey that had the station that set the AET (the highest no hit concentration) is also shown. Note that some chemicals for which AETs were derived may only appear on the dry weight normalized or the organic carbon normalized parts of the table. By definition, AETs were only derived for those chemicals that had at least one station above the AET.

All *Hyalella* AETs except two (TCDD and Manganese) were derived from at least 40 stations. Many AETs were derived from over 100 stations. Microtox® AETs had far fewer stations per chemical than *Hyalella* with five Microtox® AETs set from fewer than 20 stations. Despite the fewer number of stations, the Microtox® AETs had, on average, more stations above the AET level than the *Hyalella* stations. The average number of stations with chemical concentrations above each *Hyalella* AET was 5.3 and the average for Microtox® was 7.2. This difference between bioassays was significant at $p<0.001$ ($n=50$) when tested with a paired t-test between the two bioassays for those chemicals where an AET was derived for both bioassays. This difference suggests that Microtox® was more sensitive.

Probable Apparent Effects Thresholds (PAETs) for *Hyalella* and Microtox® are shown in Table 7. Like Table 6, the first section of the Table (7a) lists the values on a dry weight basis, and the second section (Table 7b) lists the values based on total organic carbon. The number of stations where the bioassays were tested and the number of stations above the hit levels are listed in both sections. Note that because the PAET for a given chemical is not based on the values from any one station as AETs are, there is no single station that sets the PAET. By definition, the PAET will always be lower than the AET and thus there are usually more stations above the PAET than were above a comparable AET.

Sensitivity by Chemical Group and TOC Basis

Figure 7 shows the sensitivity of *Hyalella* AETs based on different combinations of chemicals. For example, when AETs are calculated from Pesticide/PCBs data only, they have a 10% sensitivity in predicting *Hyalella* effects. The highest sensitivity is created when all available chemistry data are tested. The change in sensitivity due to different chemical groups is most likely due to the fact that at different stations different chemicals

Table 6a. Apparent effects thresholds (AETs) for Hyalella azteca and Microtox (dry weight).

	Hyalella azteca					Microtox				
Chemical	AET	N	NH	NH> AET	Survey that set AET	AET	N	NH	NH> AET	Survey that set AET
PAH	**ug/kg dry weight**									
Naphthalene	140000	153	39	7	MBCREOS1	46000	25	22	3	MBCREOS2
Acenaphthylene	2600	151	39	9	MBCREOS1	2200	25	22	4	MBCREOS2
Acenaphthene	100000	147	38	7	MBCREOS1	4100	25	22	7	MBCREOS2
Fluorene	96000	148	39	7	MBCREOS2	4200	25	22	7	MBCREOS2
Phenanthrene	210000	153	40	8	MBCREOS1	15000	25	22	8	MBCREOS1
Anthracene	41000	150	39	9	MBCREOS1	2800	25	22	8	MBCREOS1
Total LPAH	440000	147	39	9	MBCREOS2	74000	25	22	7	MBCREOS2
Fluoranthene	130000	153	40	8	MBCREOS1	21000	25	22	7	LKUNION
Pyrene	85000	152	39	9	MBCREOS1	23000	25	22	9	MBCREOS2
Benz(a)anthracene	33000	134	35	10	MBCREOS1	7700	25	22	9	MBCREOS2
Chrysene	39000	149	39	11	MBCREOS2	11000	25	22	9	LKUNION
Total benzofluoranthenes	34000	126	33	13	MBCREOS1	16000	23	19	8	MBCREOS2
Benzo(a)pyrene	25000	143	39	9	UNIMAR2	11000	25	22	7	MBCREOS2
Indeno(1,2,3-cd)pyrene	15000	145	39	8	UNIMAR2	760	25	22	13	MBCREOS1
Dibenzo(a,h)anthracene	3500	145	38	4	QUEBAX2	230	25	22	4	MBCREOS2
Benzo(g,h,i)perylene	21000	139	36	6	MBCREOS2	1400	25	22	13	MBCREOS2
Total HPAH	310000	138	39	10	MBCREOS1	91000	25	22	10	MBCREOS2
Total PAH	700000	138	39	11	MBCREOS1	170000	25	22	8	MBCREOS2
Misc Organics	**ug/kg dry weight**									
Bis(2-ethylhexyl)phthalate	-----	86	25	0	------	750	16	9	7	REYNOLDS
Carbazole	1800	73	16	5	MBCREOS1	140	16	9	4	MBCREOS2
Di-n-butyl phthalate	43	88	19	1	PAINEFLD	-----	16	9	0	------
Dibenzofuran	32000	103	33	3	MBCREOS1	-----	-----	-----	-----	------
Phenol	48	70	16	2	ALCOA90	-----	19	1	0	------
Chlorinated organics	**ug/kg dry weight**									
2,3,7,8-TCDD	0.0088	26	6	1	LONGVW90	-----	7	0	0	------
Heptachlor epoxide	260	83	18	1	MILLCRP2	-----	19	8	0	------
PCB-1242	100	85	25	1	VALCOA93	-----	21	11	0	------
PCB-1254	350	86	27	3	CBSLOUGH	7.3	21	11	2	SEACOM94
Total PCB	820	86	28	3	PAINEFLD	21	21	11	8	SPOKNR94
Metals	**mg/kg dry weight**									
Antimony	64	67	22	1	LKUNDRDK	3	22	5	2	COLALU93
Arsenic	150	165	45	8	LKUNION	40	34	19	4	STEILLK2
Cadmium	12	122	41	6	LAKEROOS	7.6	31	16	3	COLALU93
Chromium total	280	143	35	1	MILLCRP2	-----	26	17	0	------
Copper	840	148	45	9	STEILLK2	-----	34	19	0	------
Lead	720	122	40	5	LKUNION	260	30	16	5	LAKROO92
Manganese	1800	39	11	1	LAKEROOS	-----	6	5	0	------
Mercury	2.7	123	41	1	LKUNDRDK	0.56	30	15	7	CBSLOUGH
Nickel	-----	85	34	0	------	46	28	14	7	SEACOM94
Silver	4.5	67	29	1	MILLCRP2	-----	19	5	0	------
Zinc	3200	144	44	9	LAKROO92	520	34	19	5	SPOKNR94
Conventionals	**mg/kg dry weight**									
Sulfides	920	40	16	1	LKUNION	130	15	17	7	COLALU93
Ammonia	930	48	17	1	STEILLK2	-----	17	10	0	
Total organic carbon (%)	25	170	43	1	QUEBAX1	14	36	24	2	MBCREOS2

N= Number of stations tested

NH= Number of stations with significant biological effects ("Hits")

NH>AET= Number of stations with "Hits" and levels higher than AET.

Table 6b. Apparent effects thresholds (AETs) for Hyalella azteca and Microtox (mg/kg OC).

	Hyalella azteca					Microtox				
Chemical	AET	N	NH	NH> AET	Survey that set AET	AET	N	NH	NH> AET	Survey that set AET
PAH	**mg/kg organic carbon**									
Naphthalene	2300	150	33	8	MBCREOS1	330	25	22	5	MBCREOS2
Acenaphthylene	83	148	33	4	MBCREOS1	16	25	22	5	MBCREOS1
Acenaphthene	3400	144	32	8	MBCREOS2	29	25	22	8	MBCREOS2
Fluorene	4200	145	33	7	MBCREOS2	30	25	22	8	MBCREOS2
Phenanthrene	9100	150	34	6	MBCREOS2	110	25	22	9	MBCREOS2
Anthracene	1700	147	33	8	MBCREOS2	26	25	22	11	MBCREOS2
Total LPAH	19000	144	33	8	MBCREOS2	530	25	22	9	MBCREOS2
Fluoranthene	4800	150	34	7	MBCREOS2	150	25	22	11	MBCREOS1
Pyrene	3100	149	33	7	MBCREOS2	160	25	22	11	MBCREOS2
Benz(A)Anthracene	920	131	29	7	MBCREOS1	55	25	22	12	MBCREOS2
Chrysene	1700	146	33	7	MBCREOS2	79	25	22	13	MBCREOS2
Total Benzofluoranthenes	1500	123	27	9	QUEBAX2	110	23	19	10	MBCREOS2
Benzo(A)Pyrene	910	140	33	5	QUEBAX2	79	25	22	12	MBCREOS2
Indeno(1,2,3-Cd)Pyrene	380	142	33	3	QUEBAX2	33	25	22	12	QUEBAX2
Dibenzo(A,H)Anthracene	160	142	32	3	QUEBAX2	10	25	22	6	QUEBAX2
Benzo(G,H,I)Perylene	910	136	30	3	MBCREOS2	30	25	22	15	QUEBAX2
Total HPAH	11000	135	33	10	MBCREOS2	650	25	22	13	MBCREOS2
Total PAH	30000	135	33	7	MBCREOS2	1200	25	22	10	MBCREOS2
Misc Organics	**mg/kg organic carbon**									
Carbazole	50	73	16	5	MBCREOS1	4.1	6	9	4	MBCREOS2
Di-N-Butyl Phthalate	11	87	19	1	ALCOA90	-----	16	9	0	------
Dibenzofuran	510	100	27	4	MBCREOS1	-----	-----	-----	-----	------
Chlorinated organics	**mg/kg organic carbon**									
Aldrin	11	81	18	1	MILLCRP2	-----	19	8	0	------
Heptachlor Epoxide	27	81	18	1	MILLCRP2	-----	19	8	0	------
PCB-1242	-----	81	19	0	-------	-----	21	11	0	------
PCB-1254	18	82	21	2	LKUNDRDK	0.73	21	11	2	SEACOM94
TOTAL PCB	-----	82	22	0	-------	2.6	21	11	5	SPOKNR94

N= Number of stations tested

NH= Number of stations with significant biological effects ("Hits")

NH>AET= Number of stations with "Hits" and levels higher than AET.

Table 7a. Probable Apparent Effects Thresholds (PAETs) for Hyalella azteca and Microtox. PAET is the 95th %ile of the no "hit" concentrations above the lowest "hit" level. See text for detailed explanation.

	Hyalella azteca				Microtox			
Chemical	PAET	N	NH	NH> AET	PAET	N	NH	NH> AET
PAH	**ug/kg dry weight**							
Naphthalene	47000	153	39	7	37000	25	13	3
Acenaphthylene	2000	151	39	9	1900	25	10	4
Acenaphthene	77000	147	38	7	3500	25	12	7
Fluorene	73000	148	39	7	3600	25	11	7
Phenanthrene	110000	153	40	8	5700	25	20	8
Anthracene	28000	150	39	9	2100	25	17	8
Total LPAH	330000	147	39	9	36000	25	20	8
Fluoranthene	75000	153	40	8	11000	25	21	9
Pyrene	46000	152	39	9	9600	25	21	9
Benz(a)anthracene	14000	134	35	10	5000	25	17	9
Chrysene	19000	149	39	11	7400	25	18	10
Total benzofluoranthenes	20000	126	33	13	11000	23	16	8
Benzo(a)pyrene	9700	143	39	9	7000	25	19	8
Indeno(1,2,3-cd)pyrene	4100	145	39	8	730	25	15	13
Dibenzo(a,h)anthracene	2200	145	38	4	230	25	6	4
Benzo(g,h,i)perylene	4900	139	36	6	1200	25	18	13
Total HPAH	170000	138	39	10	36000	25	22	10
Total PAH	400000	138	39	11	60000	25	22	10
Misc Organics	**ug/kg dry weight**							
Bis(2-ethylhexyl)phthalate	-----	86	25	0	635	16	8	7
Carbazole	1600	73	16	5	140	6	4	4
Di-n-butyl phthalate	42	88	19	1	-----	16	0	0
Dibenzofuran	2400	103	33	3	-----	-----	-----	-----
Phenol	48	70	16	2	-----	19	0	0
Chlorinated organics	**ug/kg dry weight**							
2,3,7,8-TCDD	0.0072	26	6	1	-----	7	0	0
Heptachlor epoxide	260	83	18	1	-----	19	0	0
PCB-1242	100	85	25	0	-----	21	0	0
PCB-1248	-----	86	27	0	21	21	1	1
PCB-1254	240	86	27	3	7.3	21	2	2
Total PCB	450	86	28	3	21	21	8	8
Metals	**mg/kg dry weight**							
Antimony	35	67	22	1	-----	22	2	0
Arsenic	19	165	45	8	24	34	14	4
Cadmium	9.3	122	41	6	7.6	31	14	3
Chromium total	110	143	35	1	70	26	9	2
Copper	340	148	45	9	-----	34	19	0
Lead	490	122	40	5	240	30	16	5
Manganese	1400	39	11	1	-----	6	5	0
Mercury	1.6	123	41	1	0.22	30	14	9
Nickel	-----	85	34	0	39	28	14	8
Silver	3.9	67	29	1	-----	19	2	0
Zinc	1000	144	44	9	500	34	19	6
Conventionals	**mg/kg dry weight**							
Sulfides	780	40	16	1	127	15	14	7
Ammonia	340	48	17	1	-----	17	10	0
Total organic carbon (in %)	7.1	170	43	1	14	36	24	2

N= Number of stations tested

NH= Number of stations with significant biological effects ("Hits")

NH>AET= Number of stations with "Hits" and levels higher than AET.

Table 7b. Probable Apparent Effects Thresholds (PAETs) for Hyalella azteca and Microtox. PAET is the 95th %ile of the no "hit" concentrations above the lowest "hit" level. See text for detailed explanation.

	Hyalella azteca				Microtox			
Chemical	PAET	N	NH	NH> AET	PAET	N	NH	NH> AET
PAH	**mg/kg organic carbon**							
Naphthalene	850	150	33	8	260	25	13	5
Acenaphthylene	39	148	33	4	14	25	10	5
Acenaphthene	1900	144	32	8	25	25	12	8
Fluorene	2000	145	33	7	26	25	11	8
Phenanthrene	2400	150	34	6	53	25	20	11
Anthracene	810	147	33	8	24	25	17	11
Total LPAH	6800	144	33	8	225	25	20	9
Fluoranthene	1600	150	34	7	110	25	21	13
Pyrene	1100	149	33	7	100	25	21	13
Benz(A)Anthracene	410	131	29	7	45	25	17	12
Chrysene	600	146	33	7	72	25	18	13
Total Benzofluoranthenes	540	123	27	9	100	23	16	10
Benzo(A)Pyrene	250	140	33	5	63	25	19	13
Indeno(1,2,3-Cd)Pyrene	140	142	33	3	30	25	15	12
Dibenzo(A,H)Anthracene	47	142	32	3	10	25	6	6
Benzo(G,H,I)Perylene	160	136	30	3	26	25	18	15
Total HPAH	4700	135	33	10	460	25	22	13
Total PAH	8500	135	33	7	630	25	22	13
Misc Organics	**mg/kg organic carbon**							
Carbazole	36	73	16	5	4.2	6	4	4
Di-N-Butyl Phthalate	11	87	19	1	-----	16	0	0
Dibenzofuran	79	100	27	4	-----	-----	-----	-----
N-Nitroso Diphenylamine	10	81	18	1	-----	19	0	0
Chlorinated organics	**mg/kg organic carbon**							
Aldrin	10	81	18	1	-----	19	0	0
Heptachlor Epoxide	24	81	18	1	-----	19	0	0
PCB-1254	16	82	21	2	0.73	21	2	2
Total PCBs	-----	82	22	0	2.6	21	8	5

N= Number of stations tested

NH= Number of stations with significant biological effects ("Hits")

NH>AET= Number of stations with "Hits" and levels higher than AET.

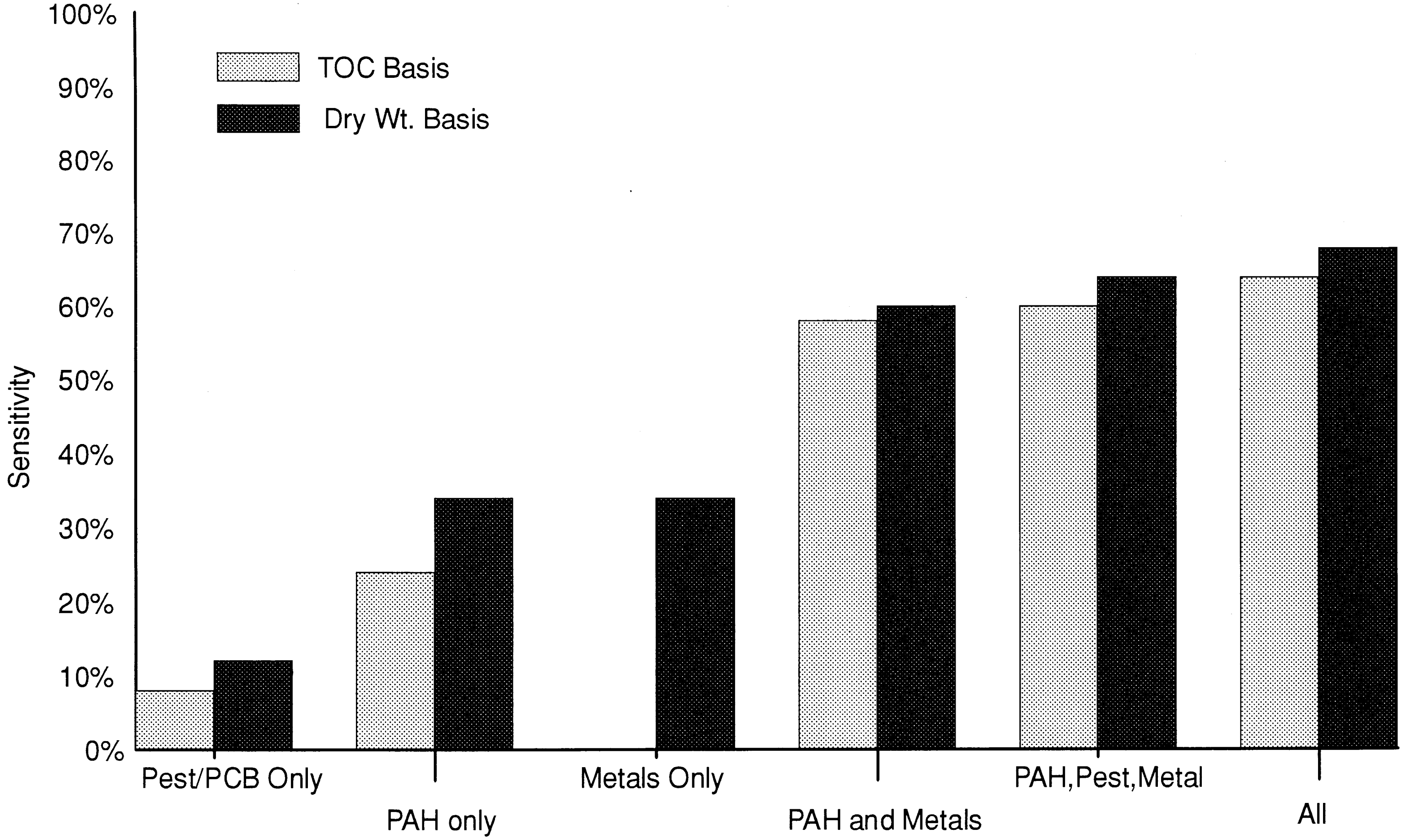


Figure 7. Sensitivity of Hyalella AET to different chemical groups when tested against Hyalella data set.

and groups are causing the biological effect. Figure 7 also shows that for PAH and PCBs/Pesticides, the dry weight measurements were more sensitive (had fewer Type II - undetected effects errors) than the TOC basis measurements. Metals were not tested with TOC normalization.

Table 8 compares sensitivity and efficiency between PAH and PCBs/Pesticides values based on TOC normalization and dry weight normalization. The dry weight versions of *Hyalella* and Microtox® AET and PAETs were more efficient, in those results that differed, in 7 of 9 tests. The dry weight-based values were also more sensitive in 5 of 6 tests that differed. When sensitivity and efficiency values are pooled, these differences between the performance of dry weight and TOC normalized values were significant ($p<0.05$, Wilcoxon test (non-parametric paired t-test)). Note that the *Hyalella* AET did not find a single significant biological effect in the Miscellaneous bioassay data set and thus its efficiency and sensitivity were 0%. Thus, based on this empirical evidence to improve performance, sediment quality values derived in this study were normalized to dry weight in comparisons of performance to other values.

Table 8. Comparison of predictive performance based on total organic carbon (TOC) and dry weight (DW) normalized measurements of PAH limited to sites where PAH were measured.

	Dataset	Efficiency		Sensitivity		N	
Value	tested against	TOC	DW	TOC	DW	Total	Hits
PAET Microtox	Miscellaneous	24%	35%	71%	86%	46	7
AET Microtox	Miscellaneous	28%	35%	71%	86%	46	7
PAET Hyalella	Miscellaneous	44%	43%	57%	43%	46	7
AET Hyalella	Miscellaneous	0%	25%	0%	14%	46	7
PAET Microtox	Hyalella	28%	38%	64%	64%	168	33
AET Microtox	Hyalella	31%	40%	61%	61%	168	33
PAET Hyalella	Hyalella	57%	62%	48%	48%	168	33
AET Hyalella	Hyalella	100% *	100% *	36%	42%	168	33
PAET Microtox	Microtox	83%	88%	68%	68%	47	22
AET Microtox	Microtox	100% *	100% *	68%	68%	47	22
PAET Hyalella	Microtox	100%	100%	18%	27%	47	22
AET Hyalella	Microtox	100%	90%	41%	41%	47	22

***Efficiency is defined as 100% when value is tested against dataset that created value.**

Comparison of Sensitivity and Efficiency of Different Values

Table 9 lists the chemical values for different freshwater sediment quality values. Most all the values are from freshwater studies with the only exception being the marine Sediment Management Standards used in Washington State. Most all these sediment quality values are either proposed for use in some regulatory environment or are incorporated as a rule or regulation. A more complete description of these values appears in Batts and Cubbage (1994). Table 9a shows organic compounds that have been TOC normalized. Table 9b shows organics on a dry weight basis. Table 9c shows metals on a dry weight basis. Note that some freshwater sediment values are only presented on a TOC or dry weight normalized basis.

The following sets of figures review sensitivity and efficiency, portrayed on two axes, of these sediment quality values in predicting effects on different subsets of the FSEDQUAL. In these figures, generally the upper graph in each figure shows the performance of values tested against the Microtox® and in some cases the Miscellaneous data set. The lower graph shows the equivalent measures of performance tested against the *Hyalella* and Miscellaneous data sets. Both graphs show the comparative sensitivity and efficiency of random choices (a "coin toss" between a hit and non-hit) of whether each station had significant biological effects. Note that figures will have differing levels of random efficiency because the calculations vary according to percent hits in a data set; however, all will have a 50% random sensitivity. These random thresholds provide a baseline to compare performance among tests.

General Performance

Figure 8 shows the sensitivity and efficiency of the Microtox® and *Hyalella* AET and PAET in predicting effects in the Microtox® data set (upper graph) and *Hyalella* data set (lower graph). For this figure only, Microtox® and *Hyalella* values were derived through sequential deletion to assure independence of efficiency results (see Evaluation Methods). When tested against the Microtox® data set, all values predicted Microtox® effects better than random, and ranged from the most efficient but least sensitive SEL to the 100% sensitive but least efficient Threshold Effects Level (TEL). In other words, TEL had no undetected effects errors (false negatives) but had the most false alarm errors (false positive). The Microtox® PAET was more sensitive than the Microtox® AET with very little reduction in efficiency. The Microtox® PAET was slightly more efficient than the Marine Sediment Management Standards. For *Hyalella* effects, all values performed better than random but the overall sensitivities and efficiencies were lower than for values tested against the Microtox® data set. When compared simply as levels above the random expected error rates, Microtox® values still had fewer errors in detecting Microtox® effects (Figure 8 upper graph) than *Hyalella* values had in detecting *Hyalella*

Table 9A. Comparison of AETs and PAETs derived in this study with guidelines and standards proposed by other agencies.

	Freshwater Values*									Marine
	AET (This study)		PAET (This study)		OMEE	EC	EC	EPA	ECMOE	Ecology
Chemical	*Hyalella*	Microtox	*Hyalella*	Microtox	SEL	PEL	TEL	EQP	SEN	SMS
PAH	**mg/kg organic carbon**									
Naphthalene	2300	330	850	260	-----	-----	-----	-----	60	99
Acenaphthylene	83	16	39	14	-----	-----	-----	-----	-----	66
Acenaphthene	3400	29	1900	25	-----	-----	-----	130	-----	16
Fluorene	4200	30	2000	26	160	-----	-----	-----	-----	23
Phenanthrene	9100	110	2400	53	950	-----	-----	180	80	100
Anthracene	1700	26	810	24	370	-----	-----	-----	-----	220
TOTAL LPAH	19000	530	6800	220	-----	-----	-----	-----	-----	370
Fluoranthene	4800	150	1600	110	1000	-----	-----	620	20	160
Pyrene	3100	160	1100	100	850	-----	-----	-----	100	1000
Benz(A)Anthracene	920	55	410	44	1500	-----	-----	-----	50	110
Chrysene	1700	79	600	72	460	-----	-----	-----	80	110
Total Benzofluoranthenes	1500	110	540	100	1300	-----	-----	-----	-----	230
Benzo(A)Pyrene	910	79	250	63	1400	-----	-----	-----	70	99
Indeno(1,2,3-Cd)Pyrene	380	33	140	30	320	-----	-----	-----	-----	34
Dibenzo(A,H)Anthracene	160	10	47	10	130	-----	-----	-----	-----	12
Benzo(G,H,I)Perylene	910	30	160	26	320	-----	-----	-----	-----	31
TOTAL HPAH	11000	650	4700	460	-----	-----	-----	-----	-----	960
TOTAL PAH	30000	1200	8500	630	10000	-----	-----	-----	-----	-----
Misc Organics	**mg/kg organic carbon**									
Bis(2-Ethylhexyl)Phthalate	-----	-----	-----	-----	-----	-----	-----	-----	-----	47
Carbazole	50	4.1	36	4.1	-----	-----	-----	-----	-----	-----
Di-N-Butyl Phthalate	11	-----	11	-----	-----	-----	-----	-----	-----	220
Dibenzofuran	510	-----	79	-----	-----	-----	-----	-----	-----	15
N-Nitroso Diphenylamine	-----	-----	-----	-----	-----	-----	-----	-----	-----	11
Chlorinated organics	**mg/kg organic carbon**									
Aldrin	11	-----	10	-----	8	-----	-----	-----	4	-----
Chlordane	-----	-----	-----	-----	1	-----	-----	-----	3	-----
Dieldrin	-----	-----	-----	-----	91	-----	-----	11	30	-----
Endrin	-----	-----	-----	-----	130	-----	-----	4.2	50	-----
Heptachlor Epoxide	27	-----	24	-----	5	-----	-----	-----	3	-----
Hexachlorobenzene	-----	-----	-----	-----	-----	-----	-----	-----	10	-----
HCB-Beta	-----	-----	-----	-----	21	-----	-----	-----	20	-----
HCB-Gamma	-----	-----	-----	-----	1	-----	-----	-----	0.9	-----
HCB-Alpha	-----	-----	-----	-----	10	-----	-----	-----	8	-----
P,P'-DDD	-----	-----	-----	-----	6	-----	-----	-----	6	-----
P,P'-DDE	-----	-----	-----	-----	19	-----	-----	-----	5	-----
P,P'-DDT	-----	-----	-----	-----	71	-----	-----	-----	5	-----
PCB-1016	-----	-----	-----	-----	53	-----	-----	-----	40	-----
PCB-1248	-----	-----	-----	-----	150	-----	-----	-----	60	-----
PCB-1254	18	0.73	16	0.73	34	-----	-----	-----	30	-----
PCB-1260	-----	-----	-----	-----	24	-----	-----	-----	20	-----
TOTAL PCB	-----	2.6	-----	2.6	530	-----	-----	-----	100	12

* See last page of table for explanation of values

Table 9B. Comparison of AETs and PAETs derived in this study with guidelines and standards proposed by other agencies.

	Freshwater Values*									Marine
	AET (This study)		PAET (This study)		OMEE	EC	EC	EPA	ECMOE	Ecology
Chemical	*Hyalella*	Microtox	*Hyalella*	Microtox	SEL	PEL	TEL	EQP	SEN	SMS
PAH	**ug/kg dry weight**									
Naphthalene	140000	46000	47000	37000	-----	-----	-----	-----	-----	-----
Acenaphthylene	2600	2200	2000	1900	-----	-----	-----	-----	-----	-----
Acenaphthene	100000	4100	77000	3500	-----	-----	-----	-----	-----	-----
Fluorene	96000	4200	73000	3600	-----	-----	-----	-----	-----	-----
Phenanthrene	210000	15000	110000	5700	-----	510	42	-----	-----	-----
Anthracene	41000	2800	28000	2100	-----	-----	-----	-----	-----	-----
TOTAL LPAH	440000	74000	330000	27000	-----	-----	-----	-----	-----	-----
Fluoranthene	130000	21000	75000	11000	-----	2400	110	-----	-----	-----
Pyrene	85000	23000	46000	9600	-----	880	53	-----	-----	-----
Benz(A)Anthracene	33000	7700	14000	5000	-----	380	32	-----	-----	-----
Chrysene	39000	11000	19000	7400	-----	860	57	-----	-----	-----
Total Benzofluoranthenes	34000	16000	20000	11000	-----	-----	-----	-----	-----	-----
Benzo(A)Pyrene	25000	11000	9700	7000	-----	780	32	-----	-----	-----
Indeno(1,2,3-Cd)Pyrene	15000	760	4100	730	-----	-----	-----	-----	-----	-----
Dibenzo(A,H)Anthracene	3500	230	2200	230	-----	-----	-----	-----	-----	-----
Benzo(G,H,I)Perylene	21000	1400	4900	1200	-----	-----	-----	-----	-----	-----
TOTAL HPAH	310000	91000	170000	36000	-----	-----	-----	-----	-----	-----
TOTAL PAH	700000	170000	400000	60000	-----	-----	-----	-----	-----	-----
Misc Organics	**ug/kg dry weight**									
Bis(2-Ethylhexyl)Phthalate	-----	750	-----	640	-----	-----	-----	-----	-----	-----
Carbazole	1800	140	1600	140	-----	-----	-----	-----	-----	-----
Di-N-Butyl Phthalate	43	-----	42	-----	-----	-----	-----	-----	-----	-----
Dibenzofuran	32000	-----	2400	-----	-----	-----	-----	-----	-----	-----
Pentachlorophenol	-----	-----	-----	-----	-----	-----	-----	-----	-----	360
Phenol	48	-----	48	-----	-----	-----	-----	-----	-----	420
Chlorinated organics	**ug/kg dry weight**									
2,3,7,8-TCDD	0.0088	-----	0.0072	-----	-----	-----	-----	-----	-----	-----
Chlordane	-----	-----	-----	-----	-----	8.9	4.5	-----	-----	-----
Dieldrin	-----	-----	-----	-----	-----	67	2.9	-----	-----	-----
Endrin	-----	-----	-----	-----	-----	62	2.7	-----	-----	-----
Heptachlor Epoxide	260	-----	260	-----	-----	-----	-----	-----	-----	-----
HCB-Alpha	-----	-----	-----	-----	-----	1.4	0.94	-----	-----	-----
P,P'-DDD	-----	-----	-----	-----	-----	8.5	3.5	-----	-----	-----
P,P'-DDE	-----	-----	-----	-----	-----	6.8	1.4	-----	-----	-----
P,P'-DDT	-----	-----	-----	-----	-----	4500	7	-----	-----	-----
PCB-1242	100	-----	100	-----	-----	-----	-----	-----	-----	-----
PCB-1248	-----	21	-----	21	-----	-----	-----	-----	-----	-----
PCB-1254	350	7.3	240	7.3	-----	-----	-----	-----	-----	-----
TOTAL PCB	820	21	450	21	-----	280	34	-----	-----	-----

* See last page of table for explanation of values

Table 9C. Comparison of AETs and PAETs derived in this study with guidelines and standards proposed by other agencies.

	Freshwater Values*									Marine
	AET (This study)		PAET (This study)		OMEE	EC	EC	EPA	ECMOE	Ecology
Chemical	*Hyalella*	Microtox	*Hyalella*	Microtox	SEL	PEL	TEL	EQP	SEN	SMS
Metals	**mg/kg dry weight**									
Antimony	64	3	35	2.9	-----	-----	-----	-----	-----	-----
Arsenic	150	40	19	19	33	17	5.9	-----	17	57
Cadmium	12	7.6	9.3	7.5	10	3.5	0.6	-----	3	5.1
Chromium total	280	-----	110	-----	110	90	37	-----	100	260
Copper	840	-----	340	-----	110	200	36	-----	86	390
Iron	-----	-----	-----	-----	40000	-----	-----	-----	-----	-----
Lead	720	260	490	240	250	91	35	-----	170	450
Manganese	1800	-----	1400	-----	1100	-----	-----	-----	-----	-----
Mercury	2.7	0.56	1.6	0.16	2	0.49	0.17	-----	1	0.41
Nickel	-----	46	-----	39	75	36	18	-----	61	-----
Silver	4.5	-----	3.9	-----	-----	-----	-----	-----	-----	6.1
Zinc	3200	520	1000	500	820	310	120	-----	540	410
Conventionals	**mg/kg dry weight**									
Ammonia	930	-----	340	-----	-----	-----	-----	-----	-----	-----
Sulfides	920	130	780	120	-----	-----	-----	-----	-----	-----
Total organic carbon (%)	25	14	7.1	14	10	-----	-----	-----	-----	-----

* Freshwater and Marine Values

Set of Values	Source
Hyalella AET	This study
Microtox AET	This study
Hyalella PAET	This study
Microtox PAET	This study
SEL (Severe Effects Level)	OMEE: Ontario Ministry of Environment and Energy (Persaud *et al*. 1993)
PEL (Probable Effects Level)	EC: Environment Canada (EC 1994)
TEL (Threshold Effects Level)	EC: Environment Canada (EC 1994)
EQP (Equilibrium Partitioning)	EPA: US Environmental Protection Agency (US Federal Register 1994)
SEN (Sueil d'Effets Nefastes)	ECMOE: Environment Canada and Quebec Ministry of the Environment (1992)
SMS (Sediment Management Standards)(MARINE)	Dept. of Ecology (WAC 173-204 1991)

(See Table 5 for a full description of different values)

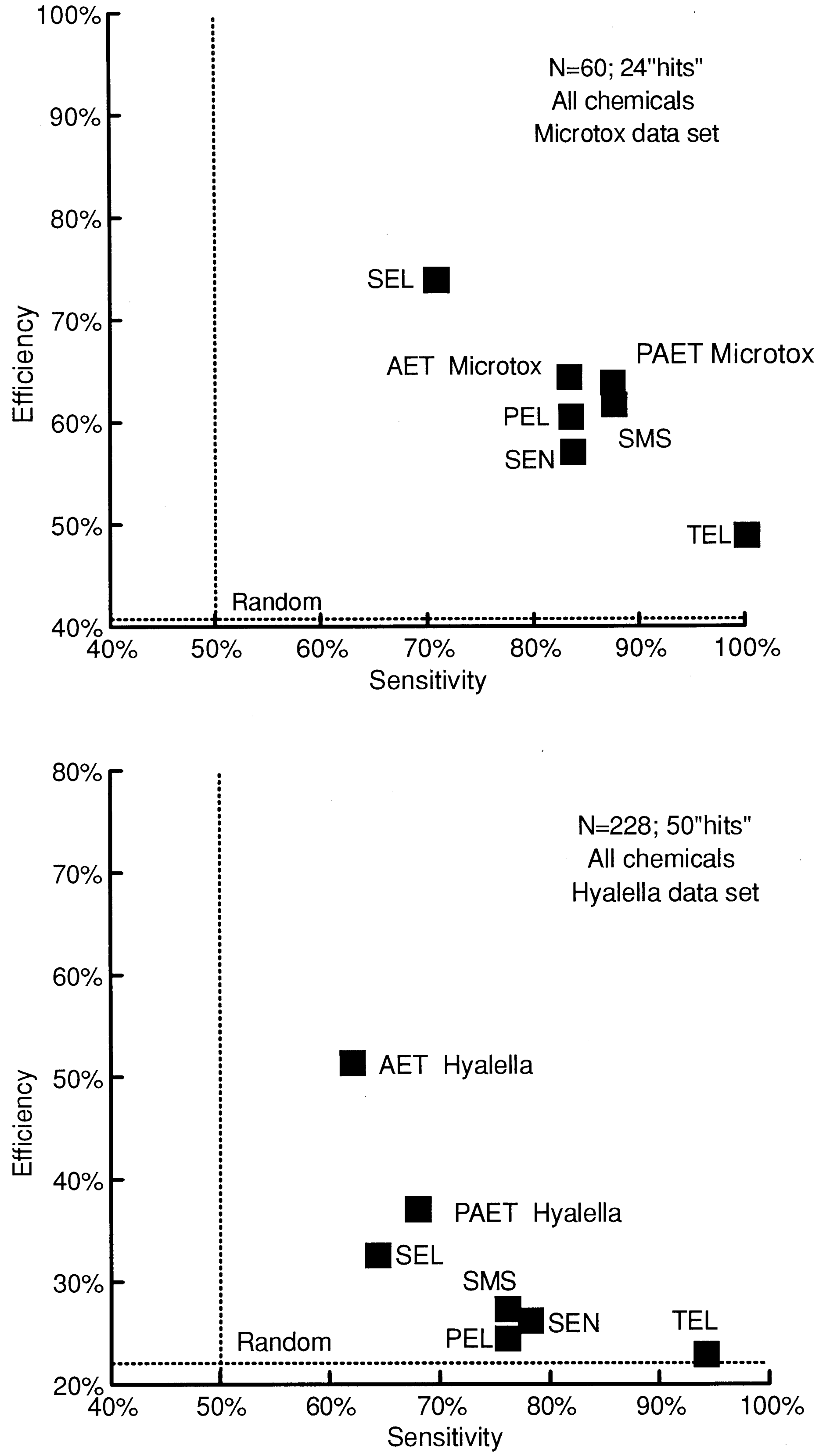


Figure 8. Efficiency and sensitivity of sediment quality values tested against Microtox data set (above) and Hyalella data set (lower). Microtox and Hyalella AET and PAET derived through sequential deletion of sites. Values are described in Table 5.

effects. The TEL was the most sensitive value but scored essentially no better than random in efficiency. In other words, the TEL had very few missed effects errors, but the false alarm errors were as numerous as would be found by flipping coins to determine effects. The *Hyalella* AET was the most efficient set of values at approximately 30 percentage points above random but only 12 percentage points above random sensitivity. The *Hyalella* PAET gained some sensitivity at a greater cost in efficiency.

The ability for values derived from one organism to predict damaging effects in other organisms is at the heart of sediment criteria development; one or two organisms become the surrogates for ecosystem-wide effects to biota. Thus, values derived from one organism need to be tested against other organisms to evaluate performance in the environment.

PAH Only

For the first series of comparisons among different values, we limited the comparison to three PAH (acenapthene, phenanthrene and fluoranthene) so that performance could be compared with the EQP approach which only has values for these three PAHs. In addition, in this comparison, the data sets were limited to those stations for which PAH were measured and thus excluded several metals-only stations.

Figure 9 shows the predictive performance of sediment quality values for only three PAH tested against the Microtox® and Miscellaneous data set (upper graph) *Hyalella* and Miscellaneous data set (lower graph). Microtox® AET and PAET were not tested against the Microtox® data set and *Hyalella* was not tested against the *Hyalella* data set. When only three PAH are considered, the *Hyalella* AET and PAET are extremely insensitive to Figure 8.

Microtox® and Miscellaneous effects but are highly efficient so that if a station exceeds the AET or PAET it is certain to have a biological effect. EQP and SEL are less efficient, but more sensitive. However all four are less sensitive than random. When tested against the *Hyalella* data set, again TEL is most sensitive and SEL is the least sensitive. All values were more efficient than random but EQP, Microtox® AET and PAET, and SEL were less sensitive than random.

Besides showing error rates based only on values for acenapthene, phenanthrene and fluoranthene, the Figure 9 details the performance for values when all PAH are considered. This comparison was included because several different PAH are usually found together and it is rare to find only the three PAH in the EQP approach without several other PAH. When all PAH were considered (i.e. values from all PAH were used to predict biological effects), most values gained sensitivity and lost efficiency.

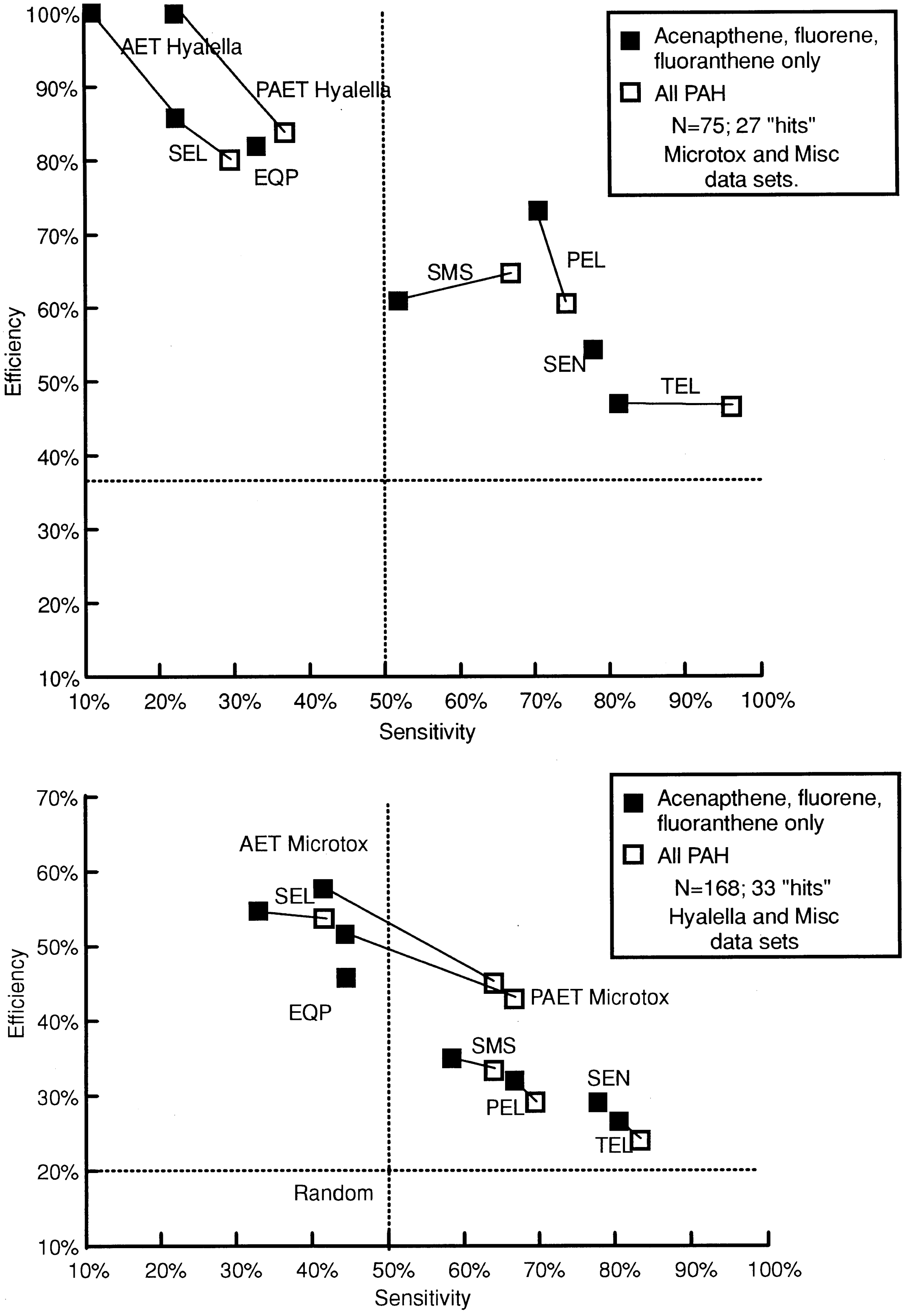


Figure 9. Efficiency and sensitivity of sediment quality values tested against the Microtox and Miscellaneous data sets (above) and Hyalella and Miscellaneous data sets (below). To allow comparison with EQP method, only the PAH listed above were compared and only sites with these PAH measurements were included. Lines connect values changed with the addition of all PAH measurements. Criteria described in Table 5.

Microtox® PAET and AET were more sensitive and efficient than most. Overall, when the other values are limited to the chemicals considered in the EQP method, the comparative EQP performance was neither exceptionally sensitive nor efficient.

Metals Only

To compare performance of metals sediment quality values only, the data sets were limited to those stations where metals were analyzed. Figure 10 shows the ability of these values to predict biological effects based solely on metals concentrations. The top graph shows that *Hyalella* AET is the most efficient but spectacularly insensitive in predicting effects in the Microtox® and Miscellaneous data set. TEL was the most sensitive in both figures. In predicting *Hyalella* and Miscellaneous effects, SMS was the most efficient and fairly sensitive.

Overall Comparison

All values illustrated already in Figures 8, 9, and 10 and those that will be illustrated in Figures 12 and 13 are shown in Table 10. Reliability scores are also included in this table. As described earlier, we do not think reliability is as useful a measure of performance as sensitivity and efficiency, but we include them here to be comparable to other studies.

In order to distill the previous performance comparisons into an overall score, the ranks of the sensitivity and efficiency results for sediment quality values tested against the three bioassay data sets -- *Hyalella,* Microtox®, and Miscellaneous -- were averaged. For example if EQP values were most sensitive in all three data sets among nine values, its sensitivity rank would be 1 ((1+1+1)/3). Because of its limited scope, however, EQP was excluded from consideration. Figure 11 depicts the results of these calculations. TEL ranked first in sensitivity, which means that it is the most sensitive set of values, and out of three tests it is the most sensitive in all three. However, with a rank of nine for efficiency, it is the least efficient set of values; it is most prone to false alarm (Type I) error. AET for *Hyalella* is most efficient but least sensitive of all the values.

Though a coarse summary, most values in Figure 11 are aligned linearly in a small band that clearly illustrates the usual compromise between sensitivity and efficiency: As values get more sensitive, they tend to lose efficiency in that they commit more false alarms. Conversely, as values get more efficient, they tend to lose sensitivity and miss stations with toxic effects. The two exceptions to this tradeoff are the Marine Sediment Management Standards and the Microtox® PAET. They are above the trade-off line between AET *Hyalella* and TEL, and they rank comparatively high in both sensitivity and efficiency.

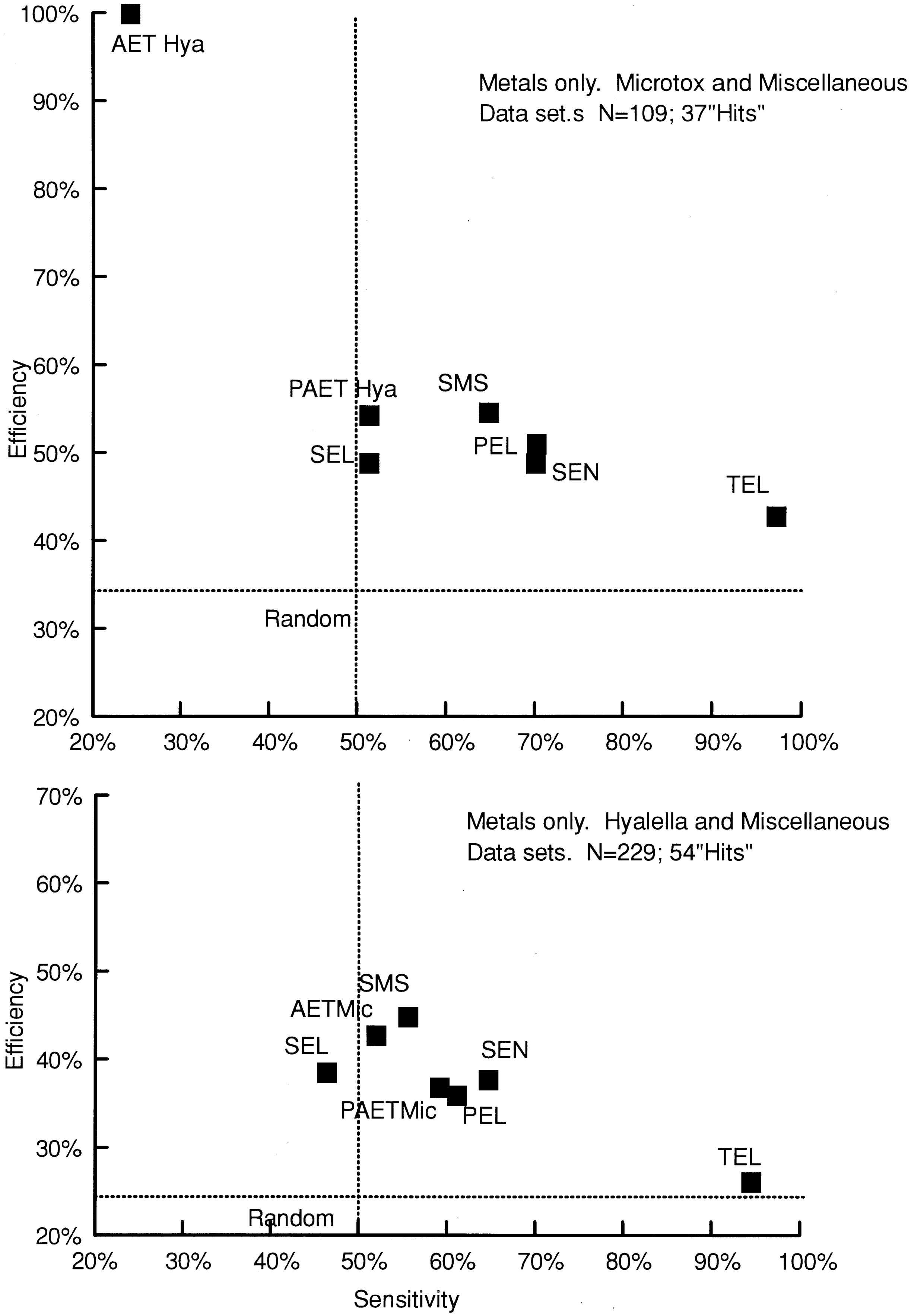


Figure 10. Efficiency and sensitivity of sediment quality values tested against the Microtox and Miscellaneous data sets (above) and Hyalella and Miscellaneous data sets(below) for metals only. Criteria described in Table 5.

Table 10. Results of comparisons of different sediment quality values. See text for explanation of values.

Sediment Quality Value	Tested against Data set(s)	Measure Basis	Total Hits	Total Non-hits	Predicted Hits	Correctly Predicted Hits	Efficiency	Sensitivity	Reliability
Figure 8 Data (All chemicals)									
PEL	Microtox	Dry Weight	24	36	33	20	0.61	0.83	0.72
SEL	Microtox	TOC	24	36	23	17	0.74	0.71	0.78
SEN	Microtox	TOC	24	36	35	20	0.57	0.83	0.68
SMS	Microtox	TOC	24	36	34	21	0.62	0.88	0.73
TEL	Microtox	Dry Weight	24	36	49	24	0.49	1.00	0.58
PAET Microtox *	Microtox	Dry Weight	24	36	33	21	0.64	0.88	0.75
AET Microtox*	Microtox	Dry Weight	24	36	31	20	0.65	0.83	0.75
AET Hyalella**	Microtox	Dry Weight	24	36	8	6	0.75	0.25	0.67
PAET Hyalella**	Microtox	Dry Weight	24	36	27	17	0.63	0.70	0.72
PEL	Hyalella	Dry Weight	50	178	155	38	0.25	0.76	0.43
SEL	Hyalella	TOC	50	178	98	32	0.33	0.64	0.63
SEN	Hyalella	TOC	50	178	148	39	0.26	0.78	0.47
SMS	Hyalella	TOC	50	178	139	38	0.27	0.76	0.50
TEL	Hyalella	Dry Weight	50	178	205	47	0.23	0.94	0.29
PAET Hyalella*	Hyalella	Dry Weight	50	178	92	34	0.37	0.68	0.68
AET Hyalella*	Hyalella	Dry Weight	50	178	60	31	0.52	0.62	0.79
AET Microtox**	Hyalella	Dry Weight	50	178	131	34	0.26	0.68	0.51
PAET Microtox**	Hyalella	Dry Weight	50	178	144	36	0.25	0.72	0.46
Figure 9 Data (3 PAH)									
EQP	Microtox and Misc	TOC	27	48	11	9	0.82	0.33	0.73
PEL	Microtox and Misc	Dry Weight	27	48	26	19	0.73	0.70	0.80
SEL	Microtox and Misc	TOC	27	48	7	6	0.86	0.22	0.71
SEN	Microtox and Misc	TOC	27	48	39	21	0.54	0.78	0.68
SMS	Microtox and Misc	TOC	27	48	23	14	0.61	0.52	0.71
TEL	Microtox and Misc	Dry Weight	27	48	47	22	0.47	0.81	0.60
AET Hyalella	Microtox and Misc	Dry Weight	27	48	3	3	1.00	0.11	0.68
PAET Hyalella	Microtox and Misc	Dry Weight	27	48	6	6	1.00	0.22	0.72
EQP	Hyalella and Misc	TOC	36	144	35	16	0.46	0.44	0.78
PEL	Hyalella and Misc	Dry Weight	36	144	75	24	0.32	0.67	0.65
SEL	Hyalella and Misc	TOC	36	144	22	12	0.55	0.33	0.81
SEN	Hyalella and Misc	TOC	36	144	96	28	0.29	0.78	0.58
SMS	Hyalella and Misc	TOC	36	144	60	21	0.35	0.58	0.70
TEL	Hyalella and Misc	Dry Weight	36	144	109	29	0.27	0.81	0.52
AET Microtox	Hyalella and Misc	Dry Weight	36	144	26	15	0.58	0.42	0.82
PAET Microtox	Hyalella and Misc	Dry Weight	36	144	31	16	0.52	0.44	0.81
Figure 10 Data (Metals Only)									
PEL	Microtox and Misc	Dry Weight	37	72	51	26	0.51	0.70	0.67
SEL	Microtox and Misc	Dry Weight	37	72	39	19	0.49	0.51	0.65
SEN	Microtox and Misc	Dry Weight	37	72	53	26	0.49	0.70	0.65
SMS	Microtox and Misc	Dry Weight	37	72	44	24	0.55	0.65	0.70
TEL	Microtox and Misc	Dry Weight	37	72	84	36	0.43	0.97	0.55
AET Hyalella	Microtox and Misc	Dry Weight	37	72	9	9	1.00	0.24	0.74
PAET Hyalella	Microtox and Misc	Dry Weight	37	72	35	19	0.54	0.51	0.69

*=Derived from sequential deletion　　**= Not shown in graphic

Table 10 (con't). Results of comparisons of different sediment quality values. See text for explanation of values.

Sediment Quality Value	Tested against Data set(s)	Measure Basis	Total Hits	Total Non-hits	Predicted Hits	Correctly Predicted Hits	Efficiency	Sensitivity	Reliability
Figure 10 Data (Metals Only) (Continued)									
PEL	Hyalella and Misc	Dry Weight	54	175	92	33	0.36	0.61	0.65
SEL	Hyalella and Misc	Dry Weight	54	175	65	25	0.38	0.46	0.70
SEN	Hyalella and Misc	Dry Weight	54	175	93	35	0.38	0.65	0.66
SMS	Hyalella and Misc	Dry Weight	54	175	67	30	0.45	0.56	0.73
TEL	Hyalella and Misc	Dry Weight	54	175	195	51	0.26	0.94	0.36
AET Microtox	Hyalella and Misc	Dry Weight	54	175	64	28	0.44	0.52	0.73
PAET Microtox	Hyalella and Misc	Dry Weight	54	175	87	32	0.37	0.59	0.66
Figure 12 Data (All chemicals)									
PEL	Microtox and Misc	Dry Weight	44	80	70	35	0.50	0.80	0.65
SEL	Microtox and Misc	TOC	44	80	52	29	0.56	0.66	0.69
SEN	Microtox and Misc	TOC	44	80	72	35	0.49	0.80	0.63
SMS	Microtox and Misc	TOC	44	80	69	37	0.54	0.84	0.69
TEL	Microtox and Misc	Dry Weight	44	80	99	42	0.42	0.95	0.52
AET Hyalella	Microtox and Misc	Dry Weight	44	80	18	15	0.83	0.34	0.74
PAET Hyalella	Microtox and Misc	Dry Weight	44	80	47	27	0.57	0.61	0.70
LAET Hyal/Micro	Microtox and Misc	Dry Weight	44	80	61	36	0.59	0.82	0.73
LPAET Hyal/Micro	Microtox and Misc	Dry Weight	44	80	78	39	0.50	0.89	0.65
FSQV	Microtox and Misc	Dry Weight	44	80	68	38	0.56	0.86	0.71
PEL	Hyalella and Misc	Dry Weight	61	184	158	46	0.29	0.75	0.48
SEL	Hyalella and Misc	TOC	61	184	97	39	0.40	0.64	0.67
SEN	Hyalella and Misc	TOC	61	184	153	47	0.31	0.77	0.51
SMS	Hyalella and Misc	TOC	61	184	142	47	0.33	0.77	0.56
TEL	Hyalella and Misc	Dry Weight	61	184	216	57	0.26	0.93	0.33
AET Microtox	Hyalella and Misc	Dry Weight	61	184	121	42	0.35	0.69	0.60
PAET Microtox	Hyalella and Misc	Dry Weight	61	184	139	46	0.33	0.75	0.56
LAET Hyal/Micro	Hyalella and Misc	Dry Weight	61	184	141	45	0.32	0.74	0.54
LPAET Hyal/Micro	Hyalella and Misc	Dry Weight	61	184	161	48	0.30	0.79	0.49
FSQV	Hyalella and Misc	Dry Weight	61	184	137	48	0.35	0.79	0.58
Figure 13 Data (All Chemicals)									
EQP	All	TOC	76	169	40	20	0.50	0.26	0.69
PEL	All	Dry Weight	76	169	158	58	0.37	0.76	0.52
SEL	All	TOC	76	169	97	47	0.48	0.62	0.68
SEN	All	TOC	76	169	153	59	0.39	0.78	0.55
SMS	All	TOC	76	169	142	60	0.42	0.79	0.60
TEL	All	Dry Weight	76	169	216	72	0.33	0.95	0.40
AET Microtox	All	Dry Weight	76	169	121	54	0.45	0.71	0.64
AET Hyalella	All	Dry Weight	76	169	35	34	0.97	0.45	0.82
PAET Microtox	All	Dry Weight	76	169	139	59	0.42	0.78	0.60
PAET Hyalella	All	Dry Weight	76	169	80	47	0.59	0.62	0.75
LAET Hyal/Micro	All	Dry Weight	76	169	125	57	0.46	0.75	0.64
LPAET Hyal/Micro	All	Dry Weight	76	169	147	61	0.41	0.80	0.59
FSQV	All	Dry Weight	76	169	136	61	0.45	0.80	0.63

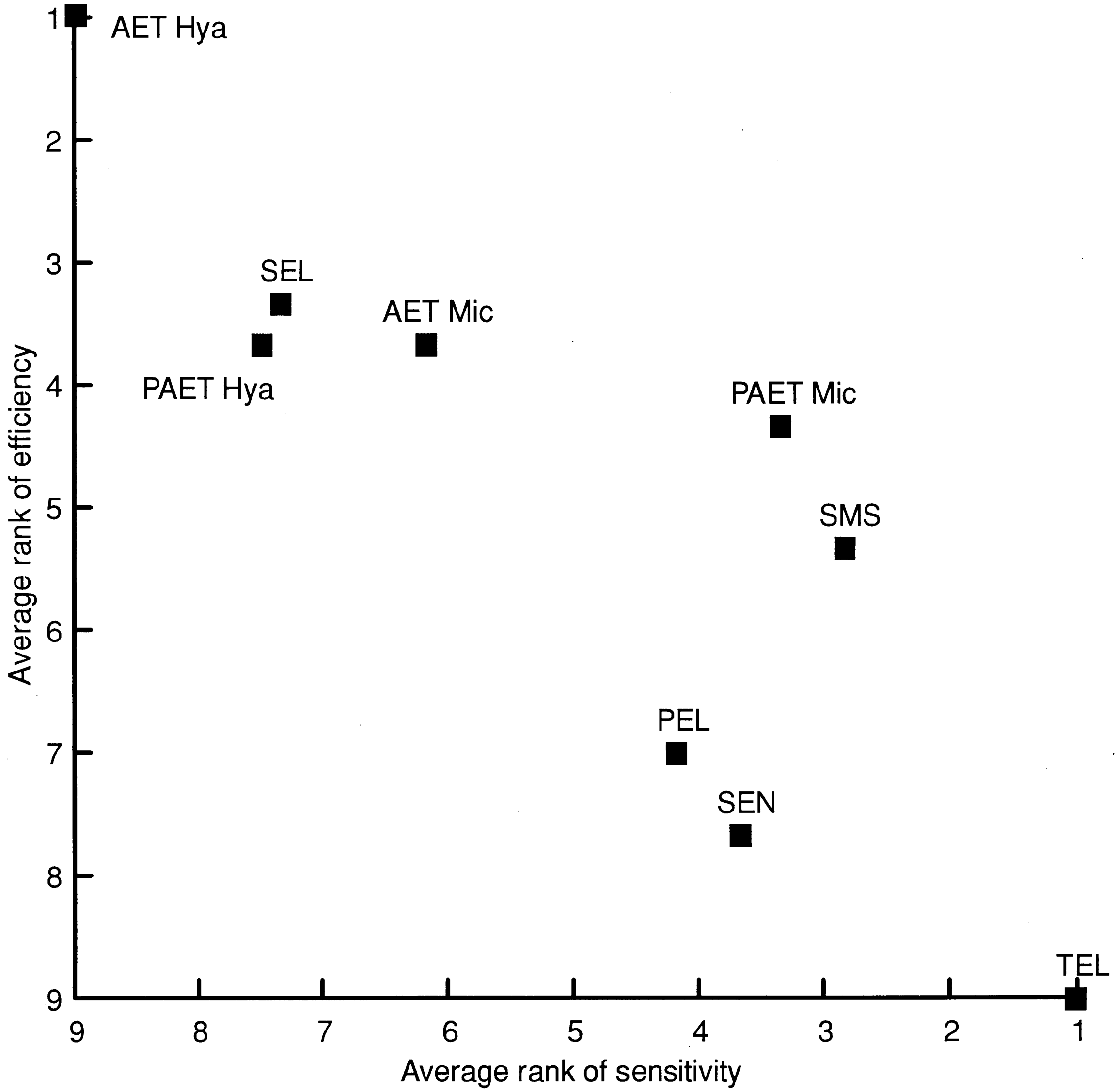


Figure 11. Average ranks of sensitivity and efficiency of different sediment quality values tested on Microtox, Hyalella and Miscellaneous data sets separately. Average rank of 1 means value was highest in all three data sets.

Derived Freshwater Sediment Quality Values

Based on results illustrated in Figures 8-11, we propose a hybrid of the Microtox® PAET and Marine SMS be considered to predict biological effects. Figure 8 shows that Microtox® PAET perform well in predicting PAH effects, and Figure 9 shows SMS is able to predict biological effects based on metals concentrations as well as or better than most of the other values considered in this study. Figure 10 shows the two sets of values (Microtox® PAET and SMS) perform better than other values examined. We propose blending the Microtox® PAET values for organics on a dry weight basis with SMS values for metals. An additional set of values considered are the Lowest Apparent Effects Threshold between the two AET calculated in this study (Microtox® and *Hyalella*). We included these LAET because they represent the same theoretical approach used to develop the Marine Sediment Management Standards. Table 11 lists the chemical values in the FSQV and the LAET.

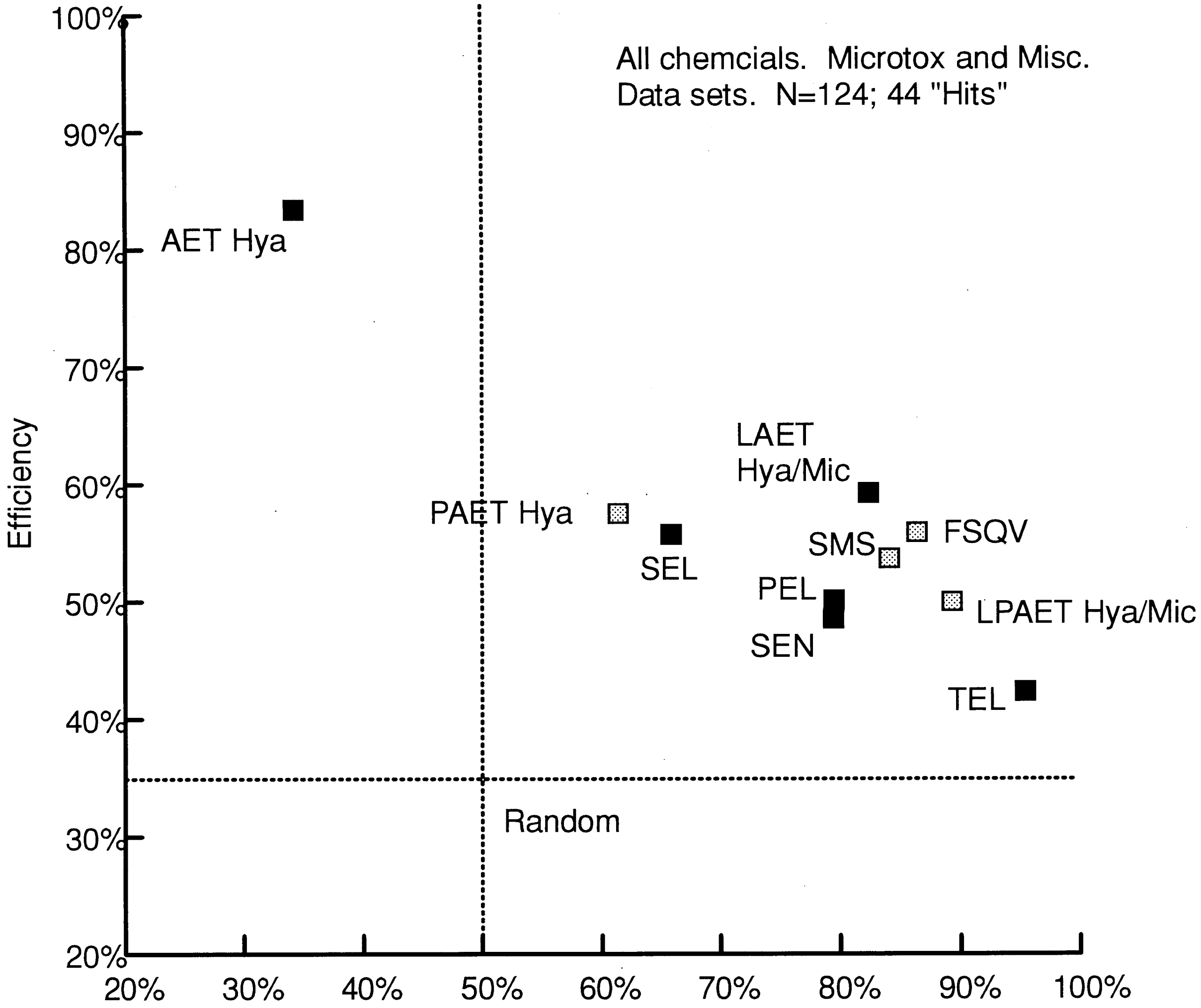
Figure 12 shows the performance of these FSQV, LAET and the LPAET (Lowest Probable Apparent Effects Threshold) in comparison with other values. We have shaded the symbols that represent either marine values or values derived with new methods outlined in this study. The top figure shows the performance in predicting effects in the Microtox® and Miscellaneous data set and the bottom shows the same comparison for the *Hyalella* and Miscellaneous data set. As always, for Microtox® and Miscellaneous the TEL was the most sensitive and least efficient. Among the conventional freshwater values or methods, the Lowest AET scored as the next most sensitive and the second most efficient set of values. When the new or marine values are considered, the Lowest Probable Apparent Effects Threshold had roughly the same efficiency as the PEL and SEN, but was more sensitive. The FSQV was third most sensitive and equivalently efficient to three other less sensitive values. AET *Hyalella* was the most efficient but extremely insensitive. When tested on the *Hyalella* and Miscellaneous data set, all values were less efficient than they were for Microtox® and Miscellaneous data set and they were equivalently or slightly less sensitive. The relative distribution of values in the *Hyalella* and Miscellaneous data set was similar to the Microtox® and Miscellaneous data set with TEL being the most sensitive and least efficient and the FSQV being second most sensitive and second most efficient.

The performance for all the values in predicting effects for all biological data are represented in Figure 13. The patterns illustrated in Figure 11 are repeated here: TEL is most sensitive and least efficient. AET *Hyalella* is most efficient and least sensitive of those values although the efficiency may be a reflection of the fact that most of the stations in the database had *Hyalella*; recall that efficiency of AET tested on the data set that created the AET is by definition 100%. Thus, this final efficiency measure of the *Hyalella* AET tested on all bioassays, which represent 93% of the stations, may be misleadingly high. In the earlier analyses we either controlled for these effects by using

Table 11. Possible Sediment Quality Values derived from this study.

	Values		Source	
Chemical	LAET*	FSQV**	LAET*	FSQV**
PAH	**ug/kg dry weight**			
Naphthalene	46000	37000	Mic AET	Mic PAET
Acenaphthylene	2200	1900	Mic AET	Mic PAET
Acenaphthene	4100	3500	Mic AET	Mic PAET
Fluorene	4200	3600	Mic AET	Mic PAET
Phenanthrene	15000	5700	Mic AET	Mic PAET
Anthracene	2800	2100	Mic AET	Mic PAET
TOTAL LPAH	74000	27000	Mic AET	Mic PAET
Fluoranthene	21000	11000	Mic AET	Mic PAET
Pyrene	23000	9600	Mic AET	Mic PAET
Benz(A)Anthracene	7700	5000	Mic AET	Mic PAET
Chrysene	11000	7400	Mic AET	Mic PAET
Total Benzofluoranthenes	16000	11000	Mic AET	Mic PAET
Benzo(A)Pyrene	11000	7000	Mic AET	Mic PAET
Indeno(1,2,3-Cd)Pyrene	760	730	Mic AET	Mic PAET
Dibenzo(A,H)Anthracene	230	230	Mic AET	Mic PAET
Benzo(G,H,I)Perylene	1400	1200	Mic AET	Mic PAET
TOTAL HPAH	91000	36000	Mic AET	Mic PAET
TOTAL PAH	170000	60000	Mic AET	Mic PAET
Misc Organics	**ug/kg dry weight**			
Bis(2-Ethylhexyl)Phthalate	750	640	Mic AET	Mic PAET
Di-N-Butyl Phthalate	43	-----	Hyal AET	-----
Dibenzofuran	32000	-----	Hyal AET	-----
Carbozole	140	140	Hyal AET	Mic PAET
Phenol	48	-----	Hyal AET	-----
Chlorinated organics				
Heptachlor Epoxide	260	-----	Hyal AET	-----
PCB-1248	21	21	Mic AET	Mic PAET
PCB-1254	7.3	7.3	Mic AET	Mic PAET
TOTAL PCB	21	21	Mic AET	Mic PAET
Metals	**mg/kg dry weight**			
Antimony	3	-----	Mic AET	-----
Arsenic	40	57	Mic AET	Marine SMS
Cadmium	7.6	5.1	Mic AET	Marine SMS
Chromium total	280	260	Hya AET	Marine SMS
Copper	840	390	Hya AET	Marine SMS
Lead	260	450	Mic AET	Marine SMS
Manganese	1800	-----	Hya AET	-----
Mercury	0.56	0.41	Mic AET	Marine SMS
Nickel	46	-----	Mic AET	-----
Silver	4.5	6.1	Hya AET	Marine SMS
Zinc	520	410	Mic AET	Marine SMS
Conventionals				
Sulfides	130	120	Mic AET	Mic PAET
Ammonia	930	-----	Hya AET	-----
Total organic carbon (%)	14	14	Mic AET	Mic PAET

*LAET = Lowest AET between Microtox and Hyalella AET
** FSQV = Freshwater Sediment Quality Values: Organics derived from PAET Microtox and Metals from Marine SMS.



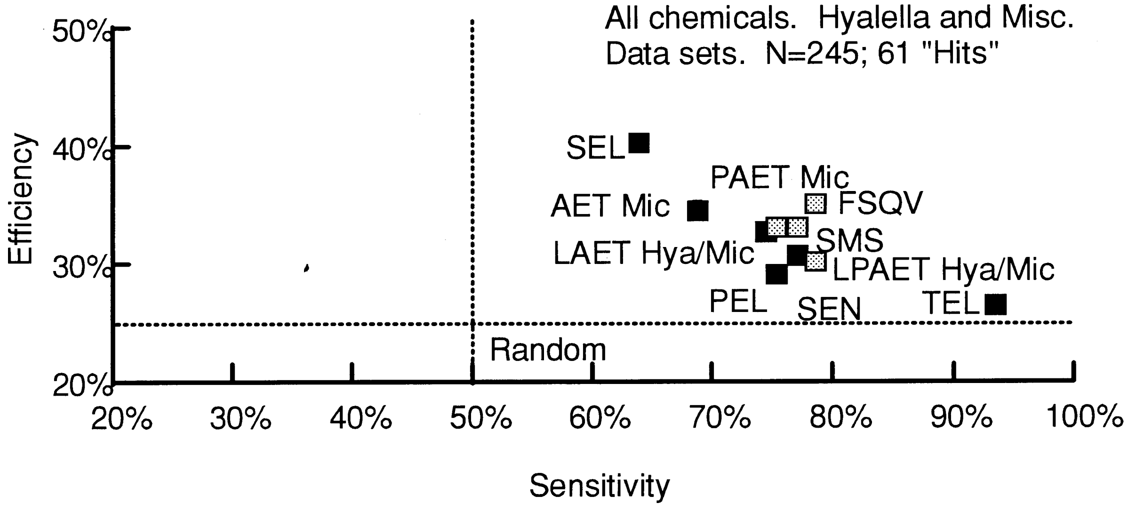


Figure 12. Efficiency and sensitivity of values tested against two data sets: Microtox and Miscellaneous (upper) and Hyalella and Miscellaneous (lower). FSQV = Freshwater Sediment Quality Values (see text for derivation methods). LAET = Lowest AET between Microtox and Hyalella. LPAET = Lowest PAET between Microtox and Hyalella. Shaded values are either marine-based or derived from new methods described in this report. All other values are listed in Table 5.

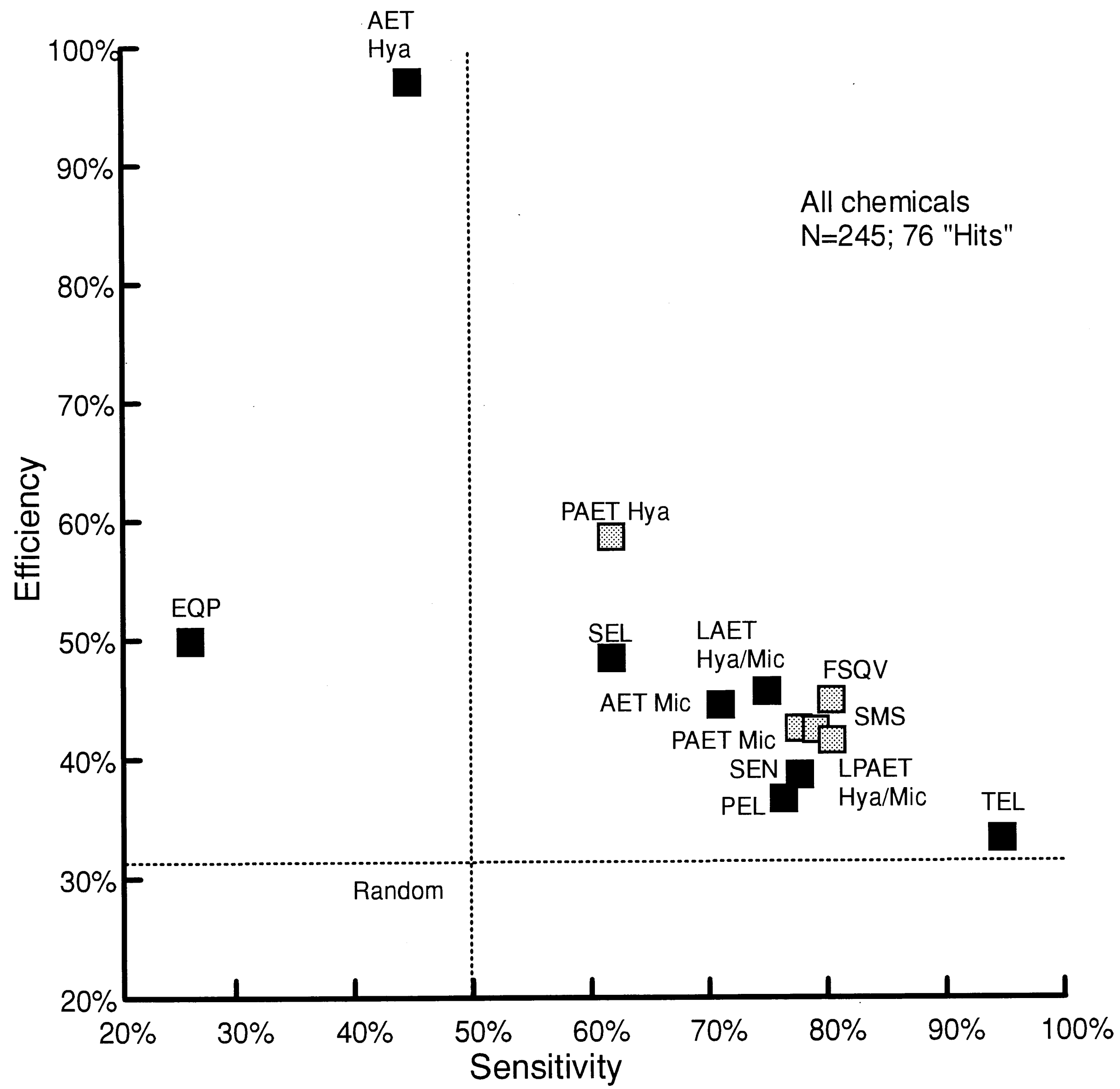


Figure 13. Efficiency and sensitivity of all sets of values compared against all bioassays in the database (Hyalella, Microtox, and Miscellaneous). FSQV is Freshwater Sediment Quality Values composed of Marine SMS metals values and PAET Mic organics on a dry weight basis. LAET is the lowest AET between Hyalella and Microtox. LPAET is the lowest PAET between Hyalella and Microtox. Shaded values are either marine-based or derived from new methods described in this report. Other values are listed in Table 5.

the sequential deletion technique or we tested *Hyalella* on Microtox® and the Miscellaneous data set. For comparison, we included EQP although it only included three PAH and it was, expectedly, the most insensitive of all values. If all values, including marine values and those derived with new methods described in this study are considered, FSQV was the second most sensitive and fifth most efficient (excluding EQP). The Marine SMS, the LPAET, and the PAET for Microtox® all had similar but slightly lower levels of performance. Of all the values, FSQV provides a comparatively robust prediction of biological effects in the database. The SEL tended to be efficient but insensitive, and the PEL and SEN were close to each other in performance.

If we limit consideration to those values derived through established methods in freshwater environments (black squares only), the Lowest AET provides roughly equivalent sensitivity to the PEL and SEN methods with some significant gains in efficiency. Its performance exceeds the sensitivity and efficiency of the AET for Microtox® alone.

Discussion

Relative Sensitivity of *Hyalella* and Microtox®

Microtox® was more sensitive than *Hyalella.* Microtox® values predicted effects in the *Hyalella* data set much more sensitively than *Hyalella* could predict Microtox® effects. Conversely, in the same comparisons, the Microtox® values were less efficient than the *Hyalella* values. However, the Microtox® values were always more sensitive and efficient than random, a level of effectiveness the *Hyalella* values could not always achieve. From these comparisons, we have good evidence the *Hyalella* AET are too insensitive to serve as a sentinel of low level of biological harm. We conclude that the *Hyalella* AET should not be used as a threshold of biological effects because levels below the *Hyalella* AET could be incorrectly considered safe for a wide variety of organisms. The *Hyalella* AET may find greater usefulness as a demarcation above which severe biological impact is reasonably certain.

TOC Issues

The improved sensitivity and efficiency of dry weight values over TOC normalized ones is surprising, given that most sediment quality values for organics are provided on the basis of TOC normalization. The Marine SMS, based on the AET, are based on TOC normalized values. PTI (1988) found equivalent sensitivity and efficiency between dry weight and TOC normalized values in the data set that was the basis for the Marine SMS. This equivalence between methods in these empirical field-based studies differs from conclusions found in laboratory bioassays and sorption data that strongly support the use of TOC normalization (PTI 1988). PTI (1988) hypothesized that TOC normalization would not be expected to outperform dry weight normalization if either sediment/interstitial water systems are not in equilibrium in the environment or sediment organic matter in the environment does not have uniform affinity for non-ionic organic compounds. We suggest that the variance added by the measurement error of TOC could also reduce the predictive success of TOC normalization.

The AET approach is empirical and does not rely upon an accurate model of toxicants in the environment nor on a mechanistic explanation. In the set of data considered in this study, the TOC normalization did not offer an empirical advantage in sensitivity or efficiency. Indeed, it was less accurate overall in prediction of effects. We do not advocate the modification of the Marine SMS but, on the basis of our results, we found it more prudent to use values that had higher predictive success, in this case the dry weight values. This intriguing result needs more research to resolve.

Rationale for Blending the Two Values

The blending of the values (Microtox® PAET and Marine SMS) into the FSQV was done to take advantage of the possible strengths of both values. The Microtox® PAET, while sensitive and efficient in predicting effects of PAH, had few metals values (i.e. many metals had no effects at the highest levels tested). The Marine SMS had several metals values. The blended values produced a compromise between sensitivity and efficiency, and together they provided an improvement over both the Microtox® PAET and the Marine SMS. This blend of marine and freshwater values is unusual and requires additional consideration before these values could be accepted.

Comparison between Marine Sediment Management Standards and FSQV

This relatively robust performance of the Marine SMS in predicting freshwater effects has several possible explanations. This good performance may be the result of the larger number of stations included in the calculations of SMS (334) than in the current study (245). Another plausible explanation is the SMS are based on the lowest AET of four different measures of biological effects instead of the two different measures available in this study. The greater breadth of tests that created these values may have improved the SMS performance, more than any potential incomparability between freshwater and marine organisms may have diminished it.

Though derived through an AET approach, the methods used to create the SMS differ from this study in one important way: The SMS are based on the lowest of four AETs -- Amphipod mortality, Microtox®, Oyster larvae abnormality, and *in situ* benthic infauna changes. Not all four tests occurred at every one of the 334 stations in the Marine Sediment database (SEDQUAL). Table 12 compares the bioassays used in developing the Marine Sediment Management Standards. Note that, like the current study, the most common bioassay in the SMS was an amphipod: either *Rhepoxynius* or *Ampelisca*. The next most common biological measure was benthic infaunal abundance. Benthic data are missing from this freshwater project. The next most common bioassay was the Oyster larval abnormality test. Finally, the least common was Microtox®.

Table 12. Comparison of bioassays used in Marine Sediment Management Standards.

Measure	Amphipod	Oyster	Benthic	Microtox
Number of sites	287	56	201	50
Number of chemicals for which bioassay is low AET	6	19	13	7
Percent of chemicals for which bioassay is low AET	13.3%	42.2%	28.9%	15.6%
Average rank of bioassay AET*	2.96	2.75	2.43	1.86

* Average rank of AET for those chemicals where all four bioassays derived an AET. 1= lowest AET, 4=highest AET

The bioassay that set the lowest AET for the most chemicals was the Oyster abnormality test and it set 42% of the low AET chemicals (Table 12). The benthic infaunal measures was the next most common low AET with 29% of the chemicals. Together, these two biological measures set nearly three-quarters of the low AET that became the SMS. The AETs derived in this freshwater study have no ecological analogues to these two Sediment Management Standards tests and thus the added bioassay data in the SMS may be one reason that the FSQV performs better than either the *Hyalella* or Microtox® AET. Viewed another way, if the SMS were limited to the bioassays available for this freshwater study (Amphipod and Microtox®), three-quarters of the values would be higher than they are today.

Another assessment of relative sensitivity of these four biological measures can be calculated by averaging the ranks of AET of the biological measures for each chemical that had an AET for all four bioassays. The average rank of a bioassay that always had the lowest AET would be one, and the bioassay that always had the highest would be four. Table 12 shows the lowest average rank was for Microtox® and the highest was the amphipod. These are not strict comparisons in that the stations where Oyster bioassays were conducted may not have been the same stations as Microtox®. Nevertheless, these two comparisons show that the amphipod AET was usually higher than the other biological measures, and therefore the least sensitive bioassay. This relative insensitivity of the amphipod to toxic chemicals in the marine environment matches our observations in this study that *Hyalella* is far less sensitive than Microtox® (see discussion above). Again, we caution against using the *Hyalella* AET as a low level demarcation of possible biological harm.

Comparisons of Other Values

The overall performance of other values was relatively consistent among. The Severe Effects Level (Persaud *et al.* 1993) values were, consistent with their definition of certain biological harm, relatively insensitive and somewhat efficient. The *Hyalella* AET was often more efficient at some cost in sensitivity, whereas the *Hyalella* PAET was often equivalently sensitive but more efficient than the SEL. The Probable Effects Level (Environment Canada 1994) had similar performance results to the SEN (Environment Canada and Ministry of the Environment, 1992): more sensitive but less efficient than the SEL. The Equilibrium Partitioning (EPA 1993) values were insensitive and moderately efficient, but they only considered three PAH. Reed et al. (1989) found the EQP approach significantly underperformed the AET approach in marine sediments from Puget Sound. When all sediment values were limited to three PAH, EQP was roughly equivalent to SEL in high efficiency and low sensitivity. Finally, TEL (Environment Canada 1994) was uniformly the most sensitive and least efficient, which again is consistent with its definition as the set of values below which no effects are likely. The Marine SMS and Microtox® PAET were similar in efficiency and sensitivity.

Possible Uses of Derived Values

The FSQV could be used in a manner similar to the lower set of values of the Marine Sediment Management Standards (the values compared throughout this report). Due to their sensitivity (80%), the FSQV delineate a level below which biological effects are unlikely to occur. In a testing program, stations above these levels could be tested with bioassays to substantiate or refute implied deleterious effects.

These values were not selected to be equally sensitive and efficient. The FSQV are provided to create a reasonably sensitive breakpoint below which problems are unlikely to occur and still provide some better-than-random estimate that the designation is not a "false alarm". Thus, the FSQV are selected to be more sensitive than efficient and err towards false alarm error (Type I) rather than missed effects error (Type II). The false alarm may be tested with further bioassays, but a missed effect error will rarely be corrected.

More sensitive values are found in the Threshold Effects Level from Environment Canada, but these levels have a potentially unacceptably high Type 1 (false alarm) error rate (low efficiency). Indeed, in achieving a high sensitivity in this database, the TEL defined 88% of the 245 stations as toxic, a potentially high percentage of stations to further evaluate. However, recall that these stations in the database are not randomly chosen for analysis and were usually investigated as part of suspected toxic conditions. Thus, if the TEL were used for screening of areas, we could expect a lower percentage of predicted impacts if areas low in toxic compounds were included. In other words, if more clean areas were included in the database, we suspect the low efficiency would improve. Therefore, if one wanted to be certain no potential toxic stations escaped detection, the TEL would be a useful set of values. Due to its consistently high efficiency, *Hyalella* AET could demarcate a level above which biological impact is reasonably certain, and money need not be expended on bioassays to confirm stations above these values. The problem with this approach is that it leaves a large number of stations (181 out of 245) in the gray zone at levels above certainly non-toxic (95% - TEL's sensitivity) and below certainly toxic (97% *Hyalella's* efficiency). The equivalent gray zone number with FSQV as a lower level sentinel is 101 out of 245. However, with FSQV being 80% sensitive rather than TEL's 95%, an additional 11 stations with toxic effects are not designated hits, and their biological effects would be missed if screened on the basis of chemistry only.

Acceptance of Derived Values

We have presented several values based upon new methods or modifications to established methods. We recognize that the widespread acceptance of these new and applications methods (PAET, use of marine values, blend of different values) may be a long journey along a rocky road and that such a journey may never be completed. With this understanding, we would like to review possible useful values in decreasing order of performance but also in increasing perceived strength of acceptance due to reliance on established methods.

FSQV

We have introduced two new concepts in the FSQV: 1) The Probable Apparent Effects Threshold and 2) the blending of two sets of values. Recall these values performed comparatively well and this study was undertaken to empirically evaluate performance. The blending was done primarily because the Microtox® results were missing several metals values. The mixture of two methods, though somewhat new, has some minor precedent in the use of the Lowest Apparent Effect Threshold in the Sediment Management Standards, in that results from more than one AET are compared and the lowest one used. Another precedent for the mixture of methods may be in the SEL, where researchers incorporated different methods for entire classes of chemicals (metals, organics, etc.) to derive criteria.

LPAET

The Lowest Probable Apparent Effects Threshold, described earlier, when used solely represents a decrease in efficiency over the FSQV, but without the mixture of different methods it may be more readily acceptable. The reasons in favor of adding some measure of central tendency to the AET in the form of the PAET are argued earlier in this report and could be elaborated in subsequent reports and analyses. The use of the lowest of a set of AETs has a strong precedent in the development of the Sediment Management Standards and could presumably be applied to PAET without much ado.

SMS (Marine LAET)

Though these numbers are based on the marine environment and some may be reluctant to apply these data to a freshwater environment, these standards have been extensively validated, quality assured, are based on twice the number of biological indicators as this study, reflect more stations, and performed well in our evaluations. The Marine SMS performance was only slightly less efficient and sensitive than the proposed FSQV and provides a more serviceable mix of efficiency and sensitivity than most of the other values.

LAET

The derivation of the Lowest AET between *Hyalella* and Microtox®, as a method, has ample precedent in the Marine SMS and we anticipate could be readily accepted. The LAET was more efficient than the top-ranked FSQV but had reduced sensitivity compared to all the options listed above. If these numbers will be the basis of an initial sentinel for possible harm, then we view the sensitivity values are comparatively more important than the efficiency values. One small hurdle in LAET acceptance may be that it is based on dry weight organic measures. In analyses recounted earlier, the dry weight normalized samples performed better. The use of these dry weight normalized values would reduce evaluation problems encountered in the marine SMS, where chemical levels in relatively "clean" areas are normalized to extremely low TOC values to produce apparently toxic stations.

Other Considerations

We have several admonitions that must be considered with the derived values in this study:

- The Microtox® values for organics are primarily based on saline extraction of Microtox®. The effectiveness of this method as well as the ecological relevance of this bioassay is contentious. Though an acute test, Microtox® has a subtle sublethal effect as its endpoint and thus could be expected to be a more sensitive indicator of biological harm than mortality or perhaps even growth. No potentially more sensitive measures such as changes in benthic community structure were available to create FSQV or the LAET as they were in the Marine SMS.

- These values were created and validated on short-term (a maximum of 14 days) bioassays only. Again, no benthic data were available to test derived values' (FSQV, LAET) ability to detect subtle *in-situ* effects. Many sets of bioassays were conducted by different labs and some bioassays in the Miscellaneous data set have not been standardized. Some sets of bioassays did not show a dose response relationship to increasing measured chemicals. Because they passed QA tests that included negative and positive controls, these bioassay results were included as authentic results.

- The validity of the Probable Apparent Effects Threshold approach has not been peer reviewed. The AET approach has been reviewed and accepted by the EPA Science Advisory Board and has resisted challenges to its usefulness. The PAET approach is proposed in this current study. If its soundness is considered unacceptably equivocal, we recommend using the Marine SMS as interim Freshwater Sediment Values. If the application of marine values to freshwater is unacceptable, then we recommend use of values derived with Lowest Apparent Effects Thresholds (LAET).

Conclusions

- Sensitivity and efficiency provide useful measures of predictive accuracy for several sets of sediment criteria.

- For PAH, dry weight normalized values for AETs and PAETs were significantly more sensitive and efficient than organic carbon normalized values ($p<0.05$).

- Threshold Effects Level (TEL) values were always the most sensitive (fewest missed effects) and least efficient (most false alarms). The AET *Hyalella* were the reverse with the fewest false alarms and the most missed effects.

- In rough progression, most sensitive to least sensitive were TEL, FSQV, LPAET, Marine SMS, PAET Microtox®, SEN, PEL, LAET, AET Microtox®, SEL, PAET *Hyalella* and AET *Hyalella.*

- From most efficient to least were AET *Hyalella*, SEL, LAET, FSQV, PAET *Hyalella,* AET Microtox®, PAET Microtox®, SMS, LPAET, SEN, PEL, and TEL.

- With comparisons limited to the three PAH considered by EQP, the AET and PAET *Hyalella* and SEL errors were roughly equivalent to EQP. They were highly efficient but less sensitive than random selection.

- We propose a FSQV based on PAET Microtox® values for organics and SMS values for metals be considered as a threshold to detect biological effects. These FSQVs ranked second in sensitivity (80%) and 5th in efficiency (45%).

Recommendations

- Test proposed values against data sets outside of Washington State to see if these results are consistent across different locations and bioassays.
- Search for better indicators of chronic effects whether they are more sensitive bioassays or benthic community effects measures.
- Recognize that the selection of FSQV based on efficiency and sensitivity measures requires a priority of one measure over the other. Reliability may be a less useful measure of predictive ability than combined measures of efficiency and sensitivity.
- Always compare predictive performance of values against random levels.
- Test and validate a third bioassay or benthic measure to be used in sediment quality values.
- Evaluate implications of FSQV or LAET on stations and sites in Washington State.

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Appendices

APPENDIX 1

CREATION OF DATABASE
AND
QUALITY ASSURANCE REVIEWS

We decided to store freshwater sediment data in SEDQUAL, a database used to track and analyze marine sediments written in FoxBase. We also decided to store these data separately from the existing marine data in order to 1) avoid overlap of geographic basins 2) to speed processing and 3) to reduce the complexity of making necessary changes and additions to attribute fields. This freshwater subset of SEDQUAL we call FSEDQUAL If compelling reasons to merge the datasets in FSEDQUAL and SEDQUAL appear, they can be joined. The major drawback of this approach to keep the data separate is that as the database structure is updated, it is necessary to keep track of two divergent forms of the system complicating any future merger of the two databases.

MODIFICATIONS TO SEDQUAL 2.0 AND DATA ENTRY METHODS

We have recorded all changes made to the original SEDQUAL program received from the Sediment Management Unit. These changes are listed chronologically and described below:

06/04/93 - received clean copy of SEDQUAL (vers. 2.0) from Sediment Management Unit, (contained no data)
06/04/93 - replaced stntypes.idx, stntypes.dbf files to update station types choices to include "lentic" and "lotic"
06/10/93 - replaced hittypes.idx, hittypes.dbf files to update hit type choices to include several freshwater tests
08/06/93 - replaced hittypes.idx, hittypes.dbf, hittypes.fox and codemenu.fox to add in more hit types and to correct internal problem
08/06/93 - added bioassay types, bioassay variables, basin and sub-basin codes interactively (via software-allowed editing).

Station Field

The station types field was amended to distinguish freshwater from marine stations and to distinguish between relatively dynamic (streams) and static (lakes) hydrologic environments. The categories of LE and LO refer to lentic (static) and lotic (moving) and are classified by having retention times of greater than and less than 15 days, respectively.

Basin/Sub-basin Field

The existing marine SEDQUAL basin and sub-basin fields were also inadequate to cover the needs of freshwater sediment surveys. Also there was no general system for naming and expanding the existing basins for non-marine areas. As a result, two alternative watershed basin systems were evaluated as possible Basin field candidates, the Hydrologic Unit Code

(HUC) system and the Water Resource Inventory Area (WRIA) system. The HUC system was chosen for three reasons; 1) it is a national system, 2) its boundaries generally do not run along or down the middle of major waterways (e.g. Columbia River, Puget Sound), and 3) it is already in use for classifying hydrologic data (e.g. RIVER REACH FILE). A map showing the HUC breakdown of watershed basins in Washington State appears in Figure 1. The HUC system incorporates an 8 digit code, with each 2 digits identifying a different level of sub-basin. For SEDQUAL purposes, this code was broken down into two components of 4 digits each, with the first segment entered in the basin field and the second segment added in the sub-basin field. Codes and their corresponding verbal description were added to allow for the entry of the initial data sets. Other HUC codes will have to be added as surveys from different areas are entered. A complete listing of all HUC codes and basin names within the state of Washington appears following.

Other Fields

Hit types, bioassay types, and bioassay variables were all updated to include variables appropriate to freshwater organisms. SEDQUAL fields with changed values and the possible choices for those fields are listed in Table 1. Values added specifically for freshwater sediment data appear with an asterisk.

To distinguish between the existing marine SEDQUAL database and the altered version created to house freshwater sediment data, we will refer to the latter version as FSEDQUAL.

SEDQUAL Data Entry Procedures

Procedures and requirements for entering all different types of data into SEDQUAL are documented in the SEDQUAL users guide (Nielsen, 1989). In addition, procedures for preparing LOTUS 123 spreadsheets for processing SEDQUAL-bound sediment data are documented in SEDQUAL data entry - Guidance version 2 (Gries, 1993). A short summary of the typical sequence of steps for entering data is given below:

1. Transfer hardcopy results to spreadsheet OR receive digital copy of data,
2. Manipulate spreadsheet to fit SEDQUAL data format requirements,
3. Convert spreadsheet to textfile and run SEDQUAL "format-check" program, and
4. Enter data into SEDQUAL.

The exact format required for data entering SEDQUAL is fairly complex and will not be reiterated here, however changes and additions to the sequence of steps will be described along with recommendations for standardizing the reporting of sediment analysis results.

Use of Microsoft Excel Spreadsheet Software

The major difference that we made in entering data into spreadsheets was in the use of Microsoft Excel software as opposed to the LOTUS 123 product that had been used for the entry of marine data. We chose to use Microsoft Excel because of its ability to process many spreadsheets at the same time and because Windows allowed for quick switching between

Excel, SEDQUAL and the DOS prompt. However, two difficulties arose when converting Microsoft Excel spreadsheets to text-files; 1) Excel delimits fields using tabs instead of spaces and 2) Excel leaves format- characters in fields that have text longer than the cell width. These idiosyncracies cause the SEDQUAL "format-check" program to fail. We overcame this problem by developing a short program in BASIC which converts the tabs to single spaces and removes all quote characters. A printout of this program is included in Appendix 7. This extra step takes a minimal amount of time and is well worth the time saved by the added benefits of using Excel and Windows.

Batch Processing

With 27 surveys to enter and approximately 23 text files created per survey to enter into FSEDQUAL, it became essential to look for ways to speed repetitive tasks. Batch programs were written to carry out the BASIC program and the SEDQUAL format check programs. An additional batch program was written to clean up working directories and archive files once a survey had been successfully entered into SEDQUAL. PKZIP software was used to condense and store all supporting files for a survey. When errors occurred in the format-check program, changes were made on the original spreadsheet and all subsequent steps were redone. A copy of all batch files used appears in Appendix 7.

Rules of Thumb

During data entry, numerous decisions must be made on how data are classified. In addition, exceptions to the rules inevitably come up and require special treatment. In order to minimize the variability of interpretations, we have documented our "Rules of Thumb."

- '*Sample and Station identifiers*' were named as closely as possible to the actual names listed in the hardcopy report (within the character limitation of SEDQUAL).
- '*Field Replicates*' was interpreted to mean any two samples that were collected at the same station on <u>different</u> grabs. Field replicates may and typically do have different sample-ID numbers but different *field replicate* numbers.
- *'Lab duplicates'* was interpreted to mean any two samples that were derived from the <u>same</u> homogenized grab, regardless of where the split occurred (i.e field or lab). Lab duplicates are required to have identical sample-ID numbers by SEDQUAL and are distinguished by their *lab duplicate* number.
- *'Sub-samples'* was interpreted to mean different depths or horizons of a single core or sample. Sub-samples may and typically do have the same sample-ID number and differ only in their *sub-sample* number.
- *'Latitude and longitudes'* were verified or determined by locating stations on USGS 7.5 minute maps. This information was then entered into an ARC/INFO GIS system. *'Basin/sub-basin codes'* were identified by overlaying the station data with the Hydrologic Unit Code data on the GIS. Basin codes were based on the HUC system of watershed delineation described above.
- A single investigation that sampled the same location at times that were more than two months apart was considered to be two separate surveys (and called different phases) for FSEDQUAL purposes.

- Biological effects results for *Hyalella azteca* bioassays were entered twice. Each *Hyalella* bioassay was recorded using the HYXX code where XX stands for the number of days of the test. In addition, these same results were also entered using the HY04 code to facilitate database queries of *Hyalella* in general, regardless of the number of days.
- Biological effects results for Microtox were also entered twice. The MICB code was used to store 'HITS' as determined using the PSSDA significance testing protocol, while the ARTT code was used to store Microtox 'HITS' as determined using an alternative protocol.

Error Checking

All data were entered into a "clean" copy of SEDQUAL (one that had no other data loaded). Once all data were successfully loaded, and preparation files archived and stored, original spreadsheet files were re-opened to check for a variety potential data-entry errors. Error-checking was purposely done more than two weeks after the original data entry to reduce familiarity with the data. This ensures more consistent and rigorous verification of digital data with original hard-copy results.

The most important elements of the error-checking procedure were a review of reporting units (PPM, PPB, etc.), a review of 10% of randomly selected values, and a review of the correct order and naming of chemical analyte codes. Some checking was done to ensure that treatment codes for metals were correct.

Biological 'HITS' were double checked to ensure that they corresponded with the appropriate sample-identifiers. While this effort to eliminate any errors in data entry was made, it is not an assurance that the database is error-free. Additional data-proofing should be considered in any follow-up work that is proposed for the FSEDQUAL database.

Priority for Entering Data

The priority for entering freshwater sediment data was determined by considering the most immediate use of the database: the calculation of apparent effects thresholds (AET's). consequently, the first priority was to enter synoptic data sets. Chemistry-only data sets which are usefull in screening potentially-impacted sites will become a high priority once sediment quality values have been determined. At the time of this report, we have entered all of the synoptic data sets, but none of the chemistry-only data sets into FSEDQUAL.

DATABASE CREATION

<u>Search Parameters</u>

In an effort to obtain additional studies on freshwater sediments from sources outside of the EILS program, we carried out an extensive data search. Geographically, the data search was limited to studies of freshwater sediments in Washington State and drainages to the Columbia River in Oregon. In coordination with the Sediment Management's Unit's efforts in collecting marine sediment data, we defined <u>freshwater</u> as any waterbody having a salinity content of less than 0.5 parts per thousand for more than six months of the year. Our primary focus in this data search was to obtain synoptic data sets (those with both chemistry and bioassay data), and secondarily to collect chemistry-only data sets.

Contacts

Phone contact was made with over 200 individuals from federal, state and local governments, consulting firms, private industries and other individuals that were involved with freshwater sediments testing and analysis. (A full list of these contacts appears in Appendix Table 1). The majority of these contacts were with the following agencies or departments: EPA Region 10, USGS water resources division (Portland and Tacoma), Seattle METRO, and the Washington State Department of Ecology Toxics Cleanup Program.

Quality Assurance

The final list of freshwater sediment investigations contained studies done by a wide variety of agencies and consulting firms and ranged over a period of twenty-three years. These investigations were performed with different goals and used widely varying methods for sampling, analysis, and quality control.

In order to describe the differences between investigations and to evaluate the suitability of these data for our purposes, two standard methods of quality assurance (QA) review already in use were considered:

QA1 (Puget Sound Dredged Disposal Analysis Guidance Manual - Data Quality Evaluation for Proposed Dredged Material Disposal Projects - PTI, 1989a) This method of quality assessment involves reviewing the internal quality control procedures conducted by each investigator or laboratory. The QA1 guidelines provide ranges for "acceptable" results from standard QA procedures (such as relative percent difference of duplicate samples, surrogate recovery, matrix spikes, etc.). A matrix containing all the QA procedures and how the survey "scored" is constructed for each investigation. A final determination of whether the investigation "passes" a QA1 review is based on the judgement of the reviewer.

QA2 (Data Validation Guidance Manual for Selected Sediment Variables - PTI, 1989b) This is a very thorough analysis requiring original laboratory documentation of each step of determining concentrations of chemical analytes. In short, values for 10% of the chemical results are redetermined, going through all of the necessary calculations that are required to come up with final values. This rigorous level of quality assurance has previously been reserved for qualifying data that is used in the determination of Marine Sediment Quality Values.

The major drawbacks of each of these methods of quality assurance is the need for laboratory documentation that is not typically included in the final report for a sediment investigation. In order to collect QA data from past investigations, the original sponsors who authorized the investigation, the consulting firm who carried out the investigation and perhaps even the contract laboratory that conducted the chemical analysis must all be contacted. While it should not be difficult to request this information when collecting future surveys, it is quite difficult to gather this information for historical work. Another problem with the above methods of quality assurance is the all-or-nothing nature of a pass/fail QA review.

Because the freshwater sediments database is being proposed for a variety of uses with differing needs for data validation, it was agreed that it would be more useful to potential users to include all data, but to have a QA "grade" available for reference. Thus, we proposed a QA review system more for the purpose of grading sediment investigations based on the QA procedures conducted and less for the purpose of excluding/including data. In addition, we proposed a system that would allow for upgrading of a QA "grade" as more supporting information (original laboratory documentation) is received.

For FSEDQUAL data, we incorporated many of the elements of the QA1 review and added some additional QA criteria into a review we call Basic Quality Assurance. The Basic Quality Assurance review is explained in Appendix 2. In short, this approach grades each investigation from A through F on the types of QA protocols conducted and presented in the final report. It is hoped that with future upgrades of SEDQUAL, this QA grade can be retrieved along with any other data associated with a survey. It is important to note that this grade does not necessarily reflect the quality of data itself, but on the amount and types of quality assurance procedures completed in the investigation.

As a compromise between time and completeness Basic Quality Assurance evaluations were completed for all synoptic data sets entered into FSEDQUAL and QA1-type reviews were conducted for all studies that set sediment quality values. Basic Quality Assurance evaluations should be a high priority for continued development of the FSEDQUAL database. Detailed scoring sheets for each individual surveys are included in Appendix 2.

APPENDIX 2 BASIC DATA QUALITY REVIEW

The following QA review is applied to all synoptic data sets considered for inclusion in the FSEDQUAL data base.

Basic Quality Assurance Review

Within the Basic QA review, the following basic procedures and results are sought. The basic QA review is conducted to summarize the amount and quality of QA procedures presented in each survey report. The surveys are then graded based on these summaries.

Acceptable Analysis methods:

- Chemistry:
  - PSEP (Puget Sound Estuary Program) protocols
  - Contract Laboratory Program (CLP) requirements
  - EPA SW 846
    - GC/MS methods for organics
    - Cold Vapor AA for mercury
    - ICP or Graphite furnace for other metals
- Bioassay:
  - ASTM methods for bioassays (including positive and negative controls)
  - PSEP (Puget Sound Estuary Program) protocols
  - For Microtox®, Microbics manual guidelines. (PSEP includes Microtox® protocols)

Minimum requirements to assess data quality:

- Sampling procedures are described
- Location information for sampling stations is provided
  - (preferably in Longitude/Latitude format)
- Features of Metals and Organics Analysis
  1) Laboratory method blank analysis
  2) Matrix spike analysis
     (A test on Certified Reference Material may substitute)
  3) Duplicate analysis (spike duplicate or regular analysis duplicate)
- Features of Organics Analysis only
  4) CLP specified surrogates and SW 846 specified surrogate recoveries
- Features of Bioassays Analysis
  5) Laboratory negative controls results

A Basic QA summary check list is generated based on presence or lack thereof of various elements in each survey. A numeric value between 0 and 2 is assigned to each summary element depending on the survey contents. A letter grade is then assigned based on the following sequential evaluation:

Data Quality Grades under Basic QA review:

On the basis of review of the report only, the following QA grades will be assigned based on their conformance to the above requirements.

QA Grade A

Report contains in-depth review of QA/QC. Accepted sampling and analytical methods (protocols) methods are described or listed. All required tests were conducted and resulting data provided. Discussion of exceptions and limitations is present.

QA Grade B

Report has a discussion of QA procedures and results, and describes or lists acceptable sampling and analysis methods. However, the report has one of the following problems:

- Does not provide QA test values,
- Lacks a required test,
- Evaluates only part of the data that the study included (*i.e.*, organics but ignores metals), or
- Fails to describe acceptable sampling and analysis methods

QA Grade C

Report has two of the problems above in level B.

- Report has presented minimal QA material, but claims to have followed established protocols

QA Grade D

Report has minimal mention of QA.

QA Grade F

Report makes no mention of steps used to assure data quality or data assurance results and provides no data to assure data quality. These data will not be entered into the database unless subsequent QA 1 review validates the data.

Note that since there is an order to this grading evaluation, the grade will not necessarily correlate exactly with the numeric score obtained in the summary evaluation. Bearing this exception in mind, the grading in general correlates with the summary scores as follows:

8	A
6 - 7	B
4 - 5	C
2 - 3	D
0 - 1	F

McCormick/Baxter Creosoting - Willamette River, Portland, Oregon

Contractor:	Oregon DEQ
Date:	1992
Ecology Code:	SY-1

General Information

QA Discussion:	summary
QA Document Referral:	yes
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	CLP
Metals Protocols:	CLP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	described

Miscellaneous

Holding Times:	described
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	some	1
Clarity/Completeness:	+	2

Total Score	7
GRADE	B

Columbia Slough - Quality Assurance Summary

Contractor:	City of Portland
Date:	1991
Ecology Code:	SY-2

General Information

QA Discussion:	yes
QA Document Referral:	no
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	PSEP
Metals Protocols:	PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	data listed
Blank Analysis:	data listed
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	yes
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score	8
GRADE	A

Tox. at 5 Lower Columbia Ports - Quality Assurance Summary

Contractor:	Ecology
Date:	1988
Ecology Code:	SY-4

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	CLP
Metals Protocols:	CLP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	described
Duplicate Analysis:	described
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	listed
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	none	0
Clarity/Completeness:	+	2

Total Score	6
GRADE	B

Contaminants in Lake Union - Quality Assurance Summary

Contractor:	Ecology
Date:	1992
Ecology Code:	SY-5

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	CLP
Metals Protocols:	PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	listed
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	some	1
Clarity/Completeness:	+	2

Total Score	7
GRADE	B

Contaminants at Paine Field - Quality Assurance Summary

Contractor:	Ecology
Date:	1987
Ecology Code:	SY-6

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	PSEP
Metals Protocols:	PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	described
Duplicate Analysis:	described
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	described
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	none	0
Clarity/Completeness:	+	2

Total Score	6
GRADE	B

Metals in Lake Roosevelt - Quality Assurance Summary

Contractor:	Ecology
Date:	1989
Ecology Code:	SY-7

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	not applicable
Metals Protocols:	not mentioned
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	not applicable
Duplicate Analysis:	data listed
Surrogate Recovery:	not applicable
Blank Analysis:	data listed
Bioassay Control:	yes
CRM (metals only):	list

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	-/+	1
QA Procedures:	4/4	2
Raw Data Support:	all	1
Clarity/Completeness:	+	2

Total Score	6
GRADE	B

Mill Creek/East Drain Sampling - Quality Assurance Summary

Contractor:	Landau
Date:	1992
Ecology Code:	SY-8

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	not mentioned
Organic Protocols:	not mentioned
Metals Protocols:	not mentioned
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	data listed
Blank Analysis:	data listed
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	listed
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	-/-	0
QA Procedures:	5/5	2
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score	6
GRADE	B

Cedar River Delta Sampling - Quality Assurance Summary

Contractor:	Golder Associates
Date:	1992
Ecology Code:	SY-9

General Information

QA Discussion:	summary
QA Document Referral:	yes
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	PSEP
Metals Protocols:	PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	data listed
Blank Analysis:	data listed
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	described
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score	8
GRADE	A

Review of Lake Roosevelt Data - Quality Assurance Summary

Contractor: Ecology
Date: 1989
Ecology Code: SY-10

General Information

QA Discussion: summary
QA Document Referral: no
QA Self Proclaimed: no

Protocols and Methods

Sampling Methods: described
Analysis Methods: listed
Organic Protocols: not applicable
Metals Protocols: reference PSEP
Bioassay Protocols: ASTM

Quality Assurance Procedures

Spike Recovery: not applicable
Duplicate Analysis: data listed
Surrogate Recovery: not applicable
Blank Analysis: not mentioned
Bioassay Control: yes
CRM (metals only): list

Miscellaneous

Holding Times: no
Detection Limits: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	3/4	1
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score 7
GRADE B

Boise Cascade - Class 2 - Quality Assurance Summary

Contractor: Ecology
Date: 1993
Ecology Code: SY-12

General Information

QA Discussion: summary
QA Document Referral: yes
QA Self Proclaimed: part

Protocols and Methods

Sampling Methods: described
Analysis Methods: listed
Organic Protocols: ref/PSEP
Metals Protocols: reference PSEP
Bioassay Protocols: ASTM

Quality Assurance Procedures

Spike Recovery: described
Duplicate Analysis: described
Surrogate Recovery: described
Blank Analysis: data listed
Bioassay Control: yes
CRM (metals only): not mentioned

Miscellaneous

Holding Times: described
Detection Limits: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	some	1
Clarity/Completeness:	+	2

Total Score 7
GRADE B

Copper in Steilacoom Lake - Quality Assurance Summary

Contractor:	Ecology
Date:	1992
Ecology Code:	SY-13

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	not applicable
Metals Protocols:	reference PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	not applicable
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	4/4	2
Raw Data Support:	some	1
Clarity/Completeness:	+	2

Total Score	7
GRADE	B

PAH's in Lake Washington (QB1) - Quality Assurance Summary

Contractor:	Ecology
Date:	1991
Ecology Code:	SY-14

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	PSEP
Analysis Methods:	listed
Organic Protocols:	ref/PSEP
Metals Protocols:	not applicable
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	described
Duplicate Analysis:	described
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	list

Miscellaneous

Holding Times:	described
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	some	1
Clarity/Completeness:	+	2

Total Score	7
GRADE	B

PAH's in Lake Washington (QB2) - Quality Assurance Summary

Contractor:	Ecology
Date:	1992
Ecology Code:	SY-15

General Information

QA Discussion:	summary
QA Document Referral:	no
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	ref/PSEP
Metals Protocols:	not applicable
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	some	1
Clarity/Completeness:	+	2

Total Score	7
GRADE	B

Lake Union Drydock Monitoring - Quality Assurance Summary

Contractor: Hart Crowser
Date: 1992
Ecology Code: SY-16

General Information

QA Discussion: summary
QA Document Referral: no
QA Self Proclaimed: part

Protocols and Methods

Sampling Methods: PSEP
Analysis Methods: listed
Organic Protocols: PSEP
Metals Protocols: PSEP
Bioassay Protocols: desc

Quality Assurance Procedures

Spike Recovery: data listed
Duplicate Analysis: data listed
Surrogate Recovery: data listed
Blank Analysis: data listed
Bioassay Control: yes
CRM (metals only): not mentioned

Miscellaneous

Holding Times: listed
Detection Limits: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score 8
GRADE A

Ferndale WWTP - Class 2 - Quality Assurance Summary

Contractor:	Ecology
Date:	1989
Ecology Code:	SY-17

General Information

QA Discussion:	none
QA Document Referral:	no
QA Self Proclaimed:	no

Protocols and Methods

Sampling Methods:	not mentioned
Analysis Methods:	not mentioned
Organic Protocols:	not mentioned
Metals Protocols:	not mentioned
Bioassay Protocols:	not mentioned

Quality Assurance Procedures

Spike Recovery:	not mentioned
Duplicate Analysis:	not mentioned
Surrogate Recovery:	not mentioned
Blank Analysis:	not mentioned
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	-/-	0
QA Procedures:	0/5	0
Raw Data Support:	none	0
Clarity/Completeness:	-	0

Total Score	0
GRADE	F

Reynolds Metal - Class 2 - Quality Assurance Summary

Contractor:	Ecology
Date:	1990
Ecology Code:	SY-18

General Information

QA Discussion:	none
QA Document Referral:	no
QA Self Proclaimed:	no

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	ref/PSEP
Metals Protocols:	reference PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	not mentioned
Duplicate Analysis:	not mentioned
Surrogate Recovery:	not mentioned
Blank Analysis:	not mentioned
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	1/5	0
Raw Data Support:	none	0
Clarity/Completeness:	-	0

Total Score	2
GRADE	D

Weyerhaeuser - Longview - Class 2 - Quality Assurance Summary

Contractor:	Ecology
Date:	1990
Ecology Code:	SY-19

General Information

QA Discussion:	summary
QA Document Referral:	yes
QA Self Proclaimed:	part

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	PSEP
Metals Protocols:	PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	data listed
Blank Analysis:	not mentioned
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	described
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	4/5	1
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score	7
GRADE	B

Kalama Chemical - Class 2 - Quality Assurance Summary

Contractor:	Ecology
Date:	1988
Ecology Code:	SY-20

General Information

QA Discussion:	none
QA Document Referral:	no
QA Self Proclaimed:	no

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	ref/PSEP
Metals Protocols:	reference PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	not mentioned
Duplicate Analysis:	not mentioned
Surrogate Recovery:	not mentioned
Blank Analysis:	data listed
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	1/5	0
Raw Data Support:	none	0
Clarity/Completeness:	-	0

Total Score	2
GRADE	D

Marco Shipyard Monitoring - Quality Assurance Summary

Contractor:	Marco Shipyard
Date:	1990
Ecology Code:	SY-21

General Information

QA Discussion:	none
QA Document Referral:	no
QA Self Proclaimed:	no

Protocols and Methods

Sampling Methods:	PSEP
Analysis Methods:	listed
Organic Protocols:	PSEP
Metals Protocols:	PSEP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	data listed
Duplicate Analysis:	data listed
Surrogate Recovery:	data listed
Blank Analysis:	data listed
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	all	2
Clarity/Completeness:	+	2

Total Score	8
GRADE	A

PAH's in Lake Washington (QB3) - Quality Assurance Summary

Contractor:	Ecology
Date:	1991
Ecology Code:	SY-22

General Information

QA Discussion:	summary
QA Document Referral:	yes
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	ref/PSEP
Metals Protocols:	not applicable
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	described
Duplicate Analysis:	described
Surrogate Recovery:	described
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	5/5	2
Raw Data Support:	none	0
Clarity/Completeness:	+	2

Total Score	6
GRADE	B

Triad Approach - Gas Works Park - Quality Assurance Summary

Contractor:	Ecology
Date:	1986
Ecology Code:	SY-23

General Information

QA Discussion:	minimal
QA Document Referral:	no
QA Self Proclaimed:	no

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	CLP
Metals Protocols:	CLP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	described
Duplicate Analysis:	not mentioned
Surrogate Recovery:	not applicable
Blank Analysis:	described
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	not mentioned
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	3/5	1
Raw Data Support:	none	0
Clarity/Completeness:	-/+	1

Total Score	4
GRADE	C

Longview Fibre - Class 2 - Quality Assurance Summary

Contractor:	Ecology
Date:	1991
Ecology Code:	SY-24

General Information

QA Discussion:	summary
QA Document Referral:	yes
QA Self Proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis Methods:	listed
Organic Protocols:	CLP
Metals Protocols:	CLP
Bioassay Protocols:	ASTM

Quality Assurance Procedures

Spike Recovery:	described
Duplicate Analysis:	described
Surrogate Recovery:	not mentioned
Blank Analysis:	not mentioned
Bioassay Control:	yes
CRM (metals only):	not mentioned

Miscellaneous

Holding Times:	described
Detection Limits:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	3/5	1
Raw Data Support:	none	0
Clarity/Completeness:	+	2

Total Score	5
GRADE	C

ALCOA - Class 2 - Quality Assurance Summary

Contractor: Ecology
Date: 1990
Ecology Code: SY-25

General Information

QA Discussion: none
QA Document Referral: no
QA Self Proclaimed: no

Protocols and Methods

Sampling Methods: PESP
Analysis Methods: listed
Organic Protocols: ref/PSEP
Metals Protocols: reference PSEP
Bioassay Protocols: ASTM

Quality Assurance Procedures

Spike Recovery: not mentioned
Duplicate Analysis: not mentioned
Surrogate Recovery: not mentioned
Blank Analysis: not mentioned
Bioassay Control: nm
CRM (metals only): not mentioned

Miscellaneous

Holding Times: not mentioned
Detection Limits: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	+/+	2
QA Procedures:	0/5	0
Raw Data Support:	none	0
Clarity/Completeness:	-	0

Total Score 2
GRADE D

Unimar - Yard 1 Sampling - Quality Assurance Summary

Contractor: GEO Engineers
Date: 1991
Ecology Code: SY-26

General Information

QA Discussion: summary
QA Document Referral: no
QA Self Proclaimed: yes

Protocols and Methods

Sampling Methods: described
Analysis Methods: listed
Organic Protocols: not mentioned
Metals Protocols: not mentioned
Bioassay Protocols: ASTM

Quality Assurance Procedures

Spike Recovery: data listed
Duplicate Analysis: data listed
Surrogate Recovery: data listed
Blank Analysis: data listed
Bioassay Control: yes
CRM (metals only): not mentioned

Miscellaneous

Holding Times: listed
Detection Limits: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods:	-/-	0
QA Procedures:	5/5	2
Raw Data Support:	all	2
Clarity/Completeness:	-/+	1

Total Score 5
GRADE C

Site Hazard Assessment Report -- Hansville Landfill -- Kitsap County, Washington

Contractor:	Science Applications International Corporation (SAIC)
Report Date:	1991
Ecology Code:	SY-30

General Information

QA Discussion:	yes
QA Document referral:	yes (in bibliography)
QA Self proclaimed:	yes

Protocols and Methods

Sampling Methods:	described minimally
Analysis methods:	listed
Organic protocols:	CLP, GC/MS
Metals protocols:	ICP
Bioassay protocols:	*Hyallela azteca* ASTM Method E 1383

Quality Assurance Procedures

Spike recovery:	metals declared, organics data listed
Duplicate analysis:	metals declared, organics data listed
Surrogate recovery:	organics data listed
Blank analysis:	organics data listed
Bioassay control:	yes
CRM (metals only):	not indicated

Miscellaneous

Holding times:	listed
Detection limit:	listed

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	+/1	1
QA Procedure	5/6	2
Raw Data Support	most	2
Clarity/Completeness	+/-	1
Total Score		6
Grade		B

Sediment Sampling Report - Seattle Commons Parcel C -- Seattle, Washington

Contractor: Shannon and Wilson
Report Date: 1994
Ecology Code: SY-31

General Information

QA Discussion: yes
QA Document referral: yes
QA Self proclaimed: yes

Protocols and Methods

Sampling Methods: listed; PSEP, described
Analysis methods: listed; PSEP
Organic protocols: GC/MS
Metals protocols: ICP, GFA, CVA
Bioassay protocols: *Hyallela azteca* ASTM 1383-92
Microtox Parametrix Protocol # 9017

Quality Assurance Procedures

Spike recovery: data listed
Duplicate analysis: data listed
Surrogate recovery: data listed
Blank analysis: data listed
Bioassay control: data listed
CRM (metals only): data listed

Miscellaneous

Holding times: yes
Detection limit: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	+/+	2
QA Procedure	6/6	2
Raw Data Support	yes	2
Clarity/Completeness	+/+	2
Total Score		8
Grade		A

Sediment-Quality Assessment of Franklin D. Roosevelt Lake, Washington

Contractor: US DOE, US EPA
Report Date: 1993
Ecology Code: SY-32

General Information

QA Discussion: yes
QA Document referral: yes
QA Self proclaimed: no

Protocols and Methods

Sampling Methods: described
Analysis methods: stated/listed
Organic protocols: no (may be buried in report somewhere; couldn't find on scan)
Metals protocols: ICP-MS, INAA, CVAAS
Bioassay protocols: *Hyallela azteca* acute
Ceriodaphnia dubia acute, and chronic
Microtox

Quality Assurance Procedures

Spike recovery: yes
Duplicate analysis: yes
Surrogate recovery: yes
Blank analysis: yes
Bioassay control: yes
CRM (metals only): yes

Miscellaneous

Holding times: stated for bioassays only
Detection limit: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	-/+	1
QA Procedure	6/6	2
Raw Data Support	yes	2
Clarity/Completeness	+/-	1
Total Score		6
Grade		C

ALCOA Vancouver Works

Contractor: ENSR
Report Date: 1994
Ecology Code: SY-33

General Information

QA Discussion: yes
QA Document referral: yes
QA Self proclaimed: yes

Protocols and Methods

Sampling Methods: described; PSEP
Analysis methods: listed
Organic protocols: EPA method 3510 with GC/MS (PAHs)
EPA method 3450/8080 (PCBs)
Metals protocols: EPA methods PSEP/2XX.X, /7471 depending on metal (all total digestion)
Bioassay protocols: *Hyallela azteca* acute 14-day ASTM 1383-1991, Ecology modified

Quality Assurance Procedures

Spike recovery: yes
Duplicate analysis: yes
Surrogate recovery: yes
Blank analysis: yes
Bioassay control: yes
CRM (metals only): no

Miscellaneous

Holding times: yes
Detection limit: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	+/+	2
QA Procedure	5/6	2
Raw Data Support	yes	2
Clarity/Completeness	+/+	2
Total Score		8
Grade		A

Columbia Aluminum Co. -- Goldendale, Washington -- Baseline Sediment Characterization

Contractor:	ENSR
Report Date:	1994
Ecology Code:	SY-34

General Information

QA Discussion:	yes (bioassay)
QA Document referral:	yes
QA Self proclaimed:	yes

Protocols and Methods

Sampling Methods:	described
Analysis methods:	yes
Organic protocols:	stated (EPA methods)
Metals protocols:	stated (EPA methods)
Bioassay protocols:	ASTM 1983 -- modified, described Microtox

Quality Assurance Procedures

Spike recovery:	yes
Duplicate analysis:	yes
Surrogate recovery:	yes
Blank analysis:	yes
Bioassay control:	yes
CRM (metals only):	no

Miscellaneous

Holding times:	yes
Detection limit:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	+/+	2
QA Procedure	5/6	2
Raw Data Support	yes	2
Clarity/Completeness	+/+	2
Total Score		8
Grade		A

Lower Columbia River Bi-State Program -- Backwater Reconnaissance Study

Contractor: Tetra Tech
Report Date: 1994
Ecology Code: SY-36

General Information

QA Discussion: yes
QA Document referral: yes
QA Self proclaimed: yes

Protocols and Methods

Sampling Methods: yes (per plan)
Analysis methods: yes
Organic protocols: EPA 8270 (GC/MS, SIM), EPA 8080 (GC/ECD)
Metals protocols: EPA (ICP)
Bioassay protocols: *Hyallela* acute 10-day
Microtox

Quality Assurance Procedures

Spike recovery: yes
Duplicate analysis: yes Per QA Plan
Surrogate recovery: yes
Blank analysis: yes
Bioassay control: yes; reference station
CRM (metals only): no

Miscellaneous

Holding times: no (may be there, haven't found yet)
Detection limit: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	+/+	2
QA Procedure	5/6	2
Raw Data Support	chem; yes bioassay; partial	1.5
Clarity/Completeness	-/+	1
Total Score		6.5
Grade		B

Bulk Sediment *Chironomus tentans* Toxicity Test Analysis of Selected Sites Within the Columbia Basin Irrigation Project

Contractor:	US Fish and Wildlife, USGS
Report Date:	1993
Ecology Code:	SY-37

General Information

QA Discussion:	minimal
QA Document referral:	no
QA Self proclaimed:	yes, verbal; Sandra Embry, 9/26/94

Protocols and Methods

Sampling Methods:	yes
Analysis methods:	yes
Organic protocols:	no
Metals protocols:	no
Bioassay protocols:	described

Quality Assurance Procedures

Spike recovery:	yes
Duplicate analysis:	yes
Surrogate recovery:	no
Blank analysis:	no
Bioassay control:	yes
CRM (metals only):	no

Miscellaneous

Holding times:	yes (exceeded on some tests)
Detection limit:	yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	-/+	1
QA Procedure	3/6	1
Raw Data Support	yes	2
Clarity/Completeness	-/-	1
Total Score		4
Grade		D

possible upgrade pending arrival of more QA info.

Spokane River PCB Bioassay Study -- 1994

Contractor: EILS
Report Date: 1994
Ecology Code: SY-38

General Information

QA Discussion: yes
QA Document referral: yes
QA Self proclaimed: yes

Protocols and Methods

Sampling Methods: PSEP
Analysis methods: CLP
Organic protocols: CLP
Metals protocols: CLP
Bioassay protocols: ASTM
Hyallela azteca chronic 10-day with acute endpoint
Chironomus tentans
Hexagenia
Microtox

Quality Assurance Procedures

Spike recovery: yes
Duplicate analysis: yes
Surrogate recovery: yes (PCB)
Blank analysis: yes
Bioassay control: yes
CRM (metals only): no

Miscellaneous

Holding times: yes
Detection limit: yes

BASIC QUALITY ASSURANCE SUMMARY

	Summary	BQA Score
Protocols/Methods	+/+	2
QA Procedure	5/6	2
Raw Data Support	yes	2
Clarity/Completeness	+/+	2
Total Score		8
Grade		A

Appendix 2. Contacts made in the search for freshwater sediment quality data in Washington State.

Last Name	First Name	Organization	Survey
Deklotz	Wesley	Applied Geo INC	SRCPP/Landfill 4 RI Fort Lewis
Erickson	Fran	Battelle Hanford	no
Crecelius	Eric	Battelle MFR	no
Dirkes	Roger	Battelle PNL	no
Ericson	Jerry	Beak Consultants	no
Shugrue	Tom	Beak Consultants	no
Crane	Paul	Boeing Corp.	no
Trotman	Ken	CH2MHILL	no
Galvin	David	City Light (Seattle)	possibly, METRO lake Washington Study
Hawkins	Steven	City of Portland	Apdix. to Columbia Slough Sed.
Ochsner	Jean	City of Portland	Columbia Slough Sediment Study
Graves	John	CREST	no
Smith	Skip	CWU	
Chartrand	Allen	Dames & Moore	no
Ferrier	Joel	Dames & Moore	no
Patrick	Glen	Dept of Health	no
Sagerser	Carl	Dept of Health	no
Hertzog	Phil	DNR	
Striplin	Betsy	DNR	
Brown	Ben	DOT	Lake Washington
Luster	Tom	ECO CEN PROG	no
Mix	Ted	ECO CEN PROG IND	alcoa-wenatchee smelter
Palko	Mike	ECO CEN PROG IND	no
Betts	Brett	ECO CEN PROG SMU	Western Processing/Mill Creek
Gries	Tom	ECO CEN PROG SMU	Cedar River
Manning	Sandy	ECO CEN PROG SMU	possibly
McFarland	Brenden	ECO CEN PROG SMU	VALCOA, Columbia Aluminum (Vancouver)
Hoselton	Anna	ECO CRO SHORE/WTR RE	no
Abbott	Don	ECO CRO TCP	
Burgdorff	Susan	ECO CRO TCP	
Barwin	Bob	ECO CRO WTR QUAL	no
Denkers	Joy	ECO EILS	no
Johnson	Art	ECO EILS	no
Serdar	Dave	ECO EILS	no
Yake	Bill	ECO EILS	Lake Roosevelt; USGS study
Plotnikoff	Rod	ECO EILS Benthic Lab	no
Stinson	Margeret	ECO EILS Manch. Lab	no
Hoover	Kim	ECO ERO	no
Michelson	Teresa	ECO NWRO	Unimar, Marine Service Center
Sotto	Brian	ECO NWRO	Champion-Ballard Mill Site RI
Atkinson	Elaine	ECO NWRO TCP	various sampling done for permits
Cargill	Dan	ECO NWRO TCP	no
Colburn	Gail	ECO NWRO TCP	no
Gallagher	Mike	ECO NWRO TCP	no
North	Debbie	ECO NWRO TCP	Lake union dry dock survey, MARCO ship.
Solomon	Fran	ECO NWRO TCP	no
Fitzpatrick	Kevin	ECO NWRO WTR QUAL	no
Garland	Dave	ECO NWRO WTR QUAL	no
Glynn	John	ECO NWRO WTR QUAL	
Kautz	Maria	ECO NWRO WTR QUAL	no
Canning	Doug	ECO SHORE/WTR RES	Wapato Lake
Blum	Mike	ECO SWRO TCP	Dupont/Weyerhauser site
Hayes	Mary Beth	ECO SWRO TCP	Vanc. spill/copper, Butterworth res, Mcn
Mcmillan	Russ	ECO SWRO TCP	no
Mercuri	Joyce	ECO SWRO TCP	no
Smith	Dave	ECO SWRO TCP	no
Stewart	Norm	ECO SWRO TCP	possibly, Black River Management Plan?
Randall	Loree	ECO SWRO WTR QUAL	no
Bergquist	Bob	ECO TCP	no
Cochran	Bruce	ECO TCP	Keyport Naval station, chemical only
Esget	Carol	ECO TCP	Bangor Op Units 1 & 2 -- chemical only
Gardner	Fred	ECO TCP	no
Harris	Bill	ECO TCP	no
Kuntz	Mike	ECO TCP	no

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Marchant	Paul	ECO TCP	Whidbey Island Naval Air Station RI
Maurer	Christopher	ECO TCP	Seq. Lake/ Fort Lewis , Park Marsh
Myers	Bill	ECO TCP	Whidbey Island, Bangor Sub base
Pointdexter	Chris	ECO TCP	RI on OUA/OUB BPA ROSS site
Raad	Ali	ECO TCP	Whidbey Island Naval Air Station RI Op Unit 3
Rogowski	Barry	ECO TCP	no
Thompson	Craig	ECO TCP	possibly, Navy CLEAN contracts around Bangor
Aaland	Neil	ECO WTR QUAL	Bistate (digital)
Maynard	Chris	ECO WTR QUAL	but not in organized format
McKee	Kim	ECO WTR QUAL	all Clean Lakes Program reports
Moore	Allen	ECO WTR QUAL	no
Offord	Brian	ECO WTR QUAL	Lower Columbia R. Bistate Backwater Survey
Palazzi	David	ECO WTR QUAL	Mt Vernon/Anacortes Management Plan
Saunders	Steve	ECO WTR QUAL	
Fagerness	Vicki	Ecochem	no
McCormick	Peter	Ecochem	no
Vandersypen	Joan	EcoSound Env. Cons.	possibly, thesis data on Cd and Cu spiked sed
Martin	Tom	ENSERCH Consultants	no
Pavlou	Spyros	ENSERCH Consultants	no
Conbere	Bill	ENSR	no, but contact for VALCOA and Col. Alu. reports
Morency	Dave	ENTRANCO	possibly, Wapato Lake, Long Lake
Oppenheimer	Jory	ENTRANCO	possibly, Skagit
Nimmons	Mike	ENVIRONS	no
Surowieck	Mike	ENVIRONS	no
Zimmerman	Jane	Everett Public Works	Silver Lake done by KCM
Chapman	Peter	EVS consultants	no
Dexter	Bob	EVS consultants	possibly, Lake Washington, NOAA, Superfund
Sholz	Al	EWU Fisheries	
Hooper	Thom	Fisheries	no
Samualson	Carl	Fisheries	no
Wofford	Paula	Ft. Lewis	no
Fisher	Sally	GeoEngineers	no
Pancoast	Bob	Golder Associates	no
Templeton	David	Hart-Crowser	no
Wineman	Marianne	Hart-Crowser	no
Einstead	Bob	HDR ConsultingCity of Portlar	no
Loehr	Lincoln	Heller Ehrman etal	no
Zisette	Rob	Herrera Env Cons	no
Schmoyer	Beth	Herrera Env Cons.	no
Schreiner	Ty	Kennedy, Jenks, Chi	no
Booth	Derrick	King Co SWM	no
Eckle	Bill	King Co SWM	possibly, starting own database now
Hubbard	Tom	King Co.	alternate contact re: Kate Rhoads
Rhoads	Kate	King Co.	no
Craehan	Kathy	King County ENV DIV	possibly, Wetlands sediment/Loren Rinault
Herrenkohl	Mark	Landau Associates	no
Rude	Pete	Landau Associates	no
Wilson	Julie	Landau Associates	possibly, Western Processing on Mill Creek
McDonald	Dan	McDonald Env Scienc	doing North American FSED project!!!!!
Brenner	Bob	METRO	yearly Stream Reports
Frodge	Jonathon	METRO	possibly, will look and send if available
Hanson	Lisa	METRO	Lake Union biblio and Metro studies
Houck	Doug	METRO	no
Munger	Sydney	METRO	no
Romberg	Pat	METRO	no
Malcolm	Rod	Muckleshoot Fisheries	no
Connor	Tom	Nisqually Tribe	no
Buchman	Mike	NMFS, NOAA	NOS-OMA52 (Long & Morgan)
Casillas	Ed	NMFS, NOAA	no
Dey	Doug	NMFS, NOAA	John Day Dam report
Ingersoll	Chris	NMFS, NOAA	no
Long	Ed	NMFS, NOAA	no
McCain	Bruce	NMFS, NOAA	1982 report on Duwamish, Mcalister Cr
Mebane	Chris	NMFS, NOAA	

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Schiewe	Mike	NMFS, NOAA	no
Holm	Kris	Northwest Pulp & Pa	no
Burnet	Paul	Oregon DEQ	Willamette River wood-treating RI
Drake	Doug	Oregon DEQ	possibly,Columbia River Samples near Umatilla
Rylko	Michael	Oregon DEQ	
Yon	Don	Oregon DEQ	no
Haisley	Rick	Oregon DEQ Lab	possibly, has some data
Cliff	Whitmus	Pantec	no
Renn	Sabina	Parametrix	no
Hannewell	Ray	Pierce Co Health	American Lake Restoration
McKay	Nancy	PSWQA	no
Yost	Lisa	PTI	Wilamette wood-treating RI (digital)
Sullivan	Bill	Puyallup Tribe	no
Swenson	Steve	R.W. Beck	no
Jennings	Dave	Renton, City of	no
Herrenkohl	Mark	SAIC Associates	no
Thompson	Tim	SAIC Associates	no
Tequita	Terry	Seattle City Light	Lake Union Doc
Thibert	Neil	Seattle Engineering	possibly, L. Union/Ship Canal Storm Drain sed
Whiteford	Marilou	Seattle Parks Dept	possibly, Gas Works Park report by tetra tech
Mark	Cliff	Seattle Planning De	Lake Union Docs
Hoyt	Brian	Seattle Water Dept	no
Little	Rand	Seattle Water Dept	no
Schwartz	Bob	Seattle Water Dept	no
McDowell	Dave	Shannon & Wilson CO	no
Dickison	Jeff	Sqaxin Island Tribe	no
Zielke	David	Steilacoom Lake Ass	no
Braun	Gary	Tetra Tech	Bistate (digital)
Clingman	Tom	Thurs County	possibly, Lawrence Lake, other lakes
Hanson	Kathy	Thurston Co Env Hth	possibly, few small surveys done for Thurston
Goldstein	Libby	URS	no
Okamato	Frank	URS	no
Kendall	Dave	US Army Corps of Eng.	no
Poole	Tom	US Army Corps of Eng.	no
Sterling	Stephanie	US Army Corps of Eng.	no
Wakeman	John	US Army Corps of Eng.	Park Marsh Draft Final
Fox	David	US Army Corps of Eng. (DAI	no
Miller	Tom	US Army Corps of Eng. (Wall	Snake River
Hattrup	Alan	US DOI Bureau of Reclm.	no
Armstrong	John	US EPA	no
Barton	Justine	US EPA	no
Collman	Sharon	US EPA	no
Cowgill	David	US EPA	ARCS report
Duncan	Bruce	US EPA	no
Harney	Nancy	US EPA	possibly, 2 creeks near BPA/ROSS site
Hayslip	Gretchen	US EPA	no
Hileman	Jim	US EPA	1984 Gas Works Park study
Justus	Peggy	US EPA	no
Keely	Karen	US EPA	possibly, hylebos creek, fife ditch arsenic
Kievit	Bob	US EPA	no
Lecrone	Judith	US EPA	possibly, Yakima pesticide data (Kim Mckee)
Malek	John	US EPA	no
Peterson	Ron	US EPA	no
Yearsley	John	US EPA	no
Block	Liz	US Fish and Wildlife	Columbia Basin Irrigation Project ('92)
Drury	Chris	US Navy	no
James	Tom	US Navy	
Jones	Ted	US Navy	no
Smith	Dean	US Navy	no
Haar	Dennis	USFS	no
Harrington	Connie	USFS	no
Ketcheson	Gary	USFS	no
Sanders	Robin	USFS Oly	no
Shuler	Carol	USFWS	Columbia River near Umatilla NWF

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Embry	Sandy	USGS	Columbia Irrigation Project
Fuhrer	Greg	USGS	no
Higgens	Tom	USGS	no
Lee	Doug	USGS	no
Munn	Mark	USGS	possibly, Roosevelt lake data avail May
Turney	Gary	USGS	no
Williamson	Sandy	USGS	Crab Creek basin, avail May
Fusté	Luis	USGS (Info Officer)	Puyallup Report
Miller	Jo	USGS (Info Officer)	Yakima Basin Study
Bortelson	Gil	USGS - Tacoma	Roosevelt Lake in September
Laninen	Julie	USGS Portland	
Rinella	Joe	USGS Portland	Yakima Basin trace organics
Childers	Dallas	USGS Vancouver	no
Horner	Rich	UW	no
Welsh	Gene	UW	no
Rinault	Loren	UW, water quality	no
Madenwald	Darlene	WA ENV Council	no
Tabutt	Betty	WA ENV COUNCIL (Oly)	no
Purcell	John	WA State Parks Dept	no
Schultz	Mark	WA State Parks Dept	no
Hinden	Ervin	Wash State Univ.	no
Funk	William	Water Res Ctr. WU	no
Juul	Steve	Water Res Ctr. WU	no
Schumaker	Rick	Water Res Ctr. WU	no
Houkal	Dana	Weston	no
Mosgrove	Nancy	Weston	no
Bean	Greg	Weyerhauser	no
Cyverson	Tim	Woodward/Clyde Cons	no
Oresik	Wendy	Woodward/Clyde Consult.	no
Matthews	Robin	WWU	no
Weigers	Janet	WWU Inst. of Watershed	possibly, Claypit Pond