TABLES

Table 1. List of Confirmed and Possible Use Impairments in the St. Louis River AOC (adapted from MPCA and WDNR 1992)

Indicator of Use Impairments	Evidence of Use Impairments	Comments
Confirmed Impairments		
Fish consumption advisories	• Consumption advisories have been issued by MN and WI, most recently in 1999	• PCBs, Hg
Degraded fish populations	• Impact of introduction of exotic fish species (e.g., ruffe)	
Degraded wildlife populations	• Decline in the number of threatened and endangered species	
Incidence of fish tumors and other abnormalities	• Observed in harbor in 1991 and Crawford Creek in 1985	• More data are needed
Degradation of benthos	• Documented in Stryker Bay and Hog Island Inlet	• Surveys conducted recently to document extent of problem
Restrictions on dredging	• Contaminated sediments observed in many areas within AOC	
Excessive loading of sediments and nutrients to Lake Superior	• High sediment and nutrients loads from AOC	
Beach closings/body contact	• Sewage bypasses have occurred, with associated bacterial problems	
Degradation of aesthetics	• Oily materials have been observed at Stryker Bay and at Hog Island Inlet/Newton Creek	• Other areas may also be affected
Loss of fish and wildlife habitat	• Habitat loss has been documented at Stryker Bay and at Hog Island Inlet/Newton Creek	• Continued loss of physical habitats limit fish and wildlife populations

Table 1. Continued

Indicator of Use Impairments	Evidence of Use Impairments	Comments
Possible Impairments		
Fish tainting	• Fish tainting has been noted historically; current evidence is conflicting	• Studies to determine the existence and extent of tainting are ongoing
Bird or animal deformities/ reproductive problems	• Low reproductive success has been observed in common terns; however, the reasons are unclear	• Factors could include toxics, habitat loss, competition

Table 2. List of Studies Which Investigated Sediment Quality in the St. Louis River AOC Since 1992

Location	Sampling Year(s)	Toxicity Tests	Sediment Chemistry	Benthic Data	Reference
Thomson, Forbay, Fond du Lac Reservoirs	1992, 1993	Amphipod	Hg, PCBs, TCDD, Cs-137	No	Schubauer-Berigan & Crane 1996
Duluth-Superior Harbor	1993	Amphipod, Midge, Microtox, Mutatox	Metals, Hg, PAHs, PCBs, TCDDs, TCDFs, Pesticides, Ammonia, TOC, Cs-137	No	Schubauer-Berigan & Crane 1997
USX Superfund Site	1993	Amphipod, Midge, Microtox, Mutatox	Metals, Hg, PAHs, Ammonia, Cyanide, Oil & Grease, TOC, Phenol	No	MPCA unpublished data
Newton Creek/Hog Island Inlet	1993, 1994	Amphipod, Midge, Cladoceran, Fathead Minnow	Metals, Hg, DROs, PAHs, Oil & Grease, Ammonia, Cyanide, TOC, Particle Size	Yes	Redman & Janisch 1995
Duluth-Superior Harbor	1994	Amphipod, Midge	SEM Metals, AVS, As, Pb, Hg, TCDDs, TCDFs, Pesticides, PAHs, PCBs, Ammonia, TOC, Tributyltin, Particle Size	Yes	Crane *et al*. 1997
Lakehead Pipe Line (North of Hog Island Inlet)	1995	Amphipod, Midge, Cladoceran	Metals, Hg, DROs, PAHs, Oil & Grease, Ammonia, TOC, Particle Size	No	Wenck Associates 1995
Upper St. Louis River: Thomson and Forbay Reservoirs	1995	No	Hg, methyl Hg, grain size	No	ENSR 1996

Table 2. Continued

Location	Sampling Year(s)	Toxicity Tests	Sediment Chemistry	Benthic Data	Reference
Knife Falls, Potlatch, Scanlon, Thomson, Forbay, and Fond du Lac Reservoirs	1995, 1996	No	Hg	Yes	Glass *et al*. 1998
St. Louis River AOC	1995, 1996	Amphipod, Midge, Microtox	SEM Metals, AVS, Hg, PAHs, TOC, Particle Size	Yes	Breneman *et al*. 2000 and USEPA in prep.
Duluth-Superior Harbor	1995, 1996	Amphipod, Midge, Cladoceran, Fathead Minnow, Lumbriculus Bioaccumulation	Metals, Hg, Ammonia Phosphorus, Cyanide, COD, TOC, Oil & Grease, PCBs, PAHs, Pesticides, Particle Size	No	TMA 1996
Vicinity of WLSSD, Duluth Harbor	1996	No	Toxaphene	No	MPCA unpublished data
Interlake/Duluth Tar Superfund Site	1996	Amphipod, Midge, Microtox	SEM Metals, AVS, PAHs, TOC, Metals, Hg, Ammonia, Cyanide, BTEX, Particle Size	Yes	IT Corporation 1997
Slip C, Duluth Harbor	1997	No	Hg, Pb, PAHs, PCBs, TOC, Particle Size	No	Crane 1999a
Minnesota Slip, Duluth Harbor	1998	No	Hg, Pb, PAHs, TOC	No	MPCA unpublished data

Table 2. Continued

Location	Sampling Year(s)	Toxicity Tests	Sediment Chemistry	Benthic Data	Reference
Duluth-Superior Harbor	1999	Lumbriculus Screening, Bioaccumulation	Hg, PAHs, PCBs, TOC	No	Crane 1999b
Dakota Pier, Duluth Harbor	1999	No	Metals, Hg, PAHs, Ammonia, Cyanide, Sulfate, TOC	No	MPCA unpublished data
Minnesota Slip, Duluth Harbor	1999	Amphipod, Midge	Metals, Hg, PAHs, PCBs, AVS, SEM, TOC, Particle Size	No	Crane 1999c
Lower St. Louis River Estuary	1999	No	Toxaphene, Cs-137 Pb-210, TOC	No	King 1999b

Sediment Chemistry: As = arsenic; Cs = cesium; Hg = mercury; Pb = lead; PAHs = polycyclic aromatic hydrocarbons; PCBs = polychlorinated biphenyls; TCDDs and TCDFs = tetrachlorodibenzo-p-dioxins and - furans; DROs = diesel range organics; SEM = simultaneously extractable metals; AVS = acid volatile sulfides; BTEX = benzene, toluene, ethylbenzene, and xylene; TOC = total organic carbon; COD = chemical oxygen demand.

Table 3. Ecosystem Objectives for the St. Louis River AOC (MPCA and WDNR 1992)

Ecosystem Objectives for the St. Louis River Area of Concern
1. To achieve and maintain a quality of water that protects the integrity of the ecosystem and which is amenable to safe recreational uses, including body contact recreation such as swimming;
2. To implement a staged river cleanup which results in the remediation of existing polluted sites and prevents further degradation;
3. To establish and maintain a coordinated monitoring network and an information management and analysis system for the St. Louis River AOC;
4. To identify and evaluate all existing point and non-point pollution sources, including regional airborne contributions, contaminated sediments, and episodic sources such as spills;
5. To reduce pollutant inputs, including nutrient and sediment loadings from point and non-point sources;
6. To reduce toxic substance inputs to the St. Louis River AOC through the following steps: • assuring that water quality meets or exceeds the ambient water quality standards of both states for the classification of the water body; • initiating and maintaining a program of no net increase in the discharges of toxic substances (anti-degradation policy); • executing a program to eliminate discharges of toxic substances over the long term; and, • substituting and developing nontoxic substances for use in or in connection with industrial, commercial, agricultural, and urban applications (pollution prevention);
7. To decrease the need for dredging through reductions in sediment loading, to establish environmentally sound and economically feasible procedures for maintenance dredging, and to improve dredged materials management by increasing the beneficial use of these materials (i.e., through sorting activities at the Erie Pier CDF);
8. To protect and restore fish and wildlife habitat, including fish spawning and nursery areas, and aquatic and/or upland breeding, nesting, or migration habitats;

Table 3. Continued

Ecosystem Objectives for the St. Louis River Area of Concern
9. To identify and protect remaining wetlands, including development of a program of no further loss of wetlands in or along the St. Louis River or associated harbor areas, no loss of critical wetlands or wetland functions, no net loss of wetlands in the drainage basin, and an overall policy of restoring and/or enhancing diminished or drained wetlands. Any unavoidable wetland losses shall be compensated for by the establishment of replacement wetlands of equal value on a two for one basis;
10. To maintain a healthy and well balanced aquatic ecosystem, where native species can live and reproduce naturally and are not restricted from thriving due to substrate degradation;
11. To manage the St. Louis and Nemadji River systems in a geographically and functionally unified manner. A coordinated approach should be taken by both states in the planning and implementation of ecosystem programs;
12. To facilitate participation in the RAP process by all stakeholders, ensuring effective community involvement in developing and implementing an achievable plan of action;
13. To plan water dependent development projects in a manner that is consistent with the other objectives;
14. To expand public awareness and understanding of the value of attaining and maintaining a healthy ecosystem within the St. Louis River AOC and the role of the individual in that effort;
15. To enhance the variety of water-oriented recreational opportunities throughout the Area of Concern, including public access to the water and shore, trails, beaches, and facilities for fishing from shore; and,
16. To restore and preserve as much scenic beauty to the area as possible.

Table 4. Narrative Objectives and Potential Indicators for Designated Water Uses in the St. Louis River AOC

Water Use	Narrative Objectives	Potential Indicators
Aquatic Life	• No significant acute or chronic toxicity to sediment-dwelling organisms	• Acute and chronic sediment toxicity tests
	• Minimal potential for bioaccumulation	• Tissue residue levels in invertebrates or fish
	• No significant impairment of the benthic community	• Benthic invertebrate community status; SQTs; Sediment chemistry
	• No increase in incidence of tumors/deformities over background levels	• Incidence of tumors/deformities in fish
Wildlife	• Minimal potential for bioaccumulation	• Sediment chemistry; residue-based SQTs
	• No significant bioaccumulation in fish and wildlife	• Tissue residue levels in fish/wildlife
	• No increase in incidence of tumors/deformities over background levels	• Incidence of tumors/deformities
Human Health	• No adverse effects on human health	• Tissue residue levels in fish/wildlife; sediment Chemistry; residue-based SQTs; incidence of Skin irritation, respiratory and learning
Recreation and Aesthetics	• No significant reduction in fish and wildlife populations	• Fish and wildlife population status
	• No significant impairment of fish and wildlife habitats	• Sediment chemistry; SQTs
	• No tainting of fish flesh	• Reports of tainted fish flesh
	• No fish consumption advisories	• Incidence of consumption advisories
Navigation and Shipping	• No hazardous levels of contamination	• Sediment chemistry; SQTs
	• No significant toxicity to sediment-dwelling organisms	• Acute and chronic sediment toxicity tests
	• Minimal potential for bioaccumulation	• Tissue residue levels in invertebrates/fish/wildlife

SQTs = sediment quality targets.

Table 5. Relative Priority of Recommended Metrics for Assessing Sediment Quality Conditions in the St. Louis River AOC

Ecosystem Health Indicator	Candidate Metrics	Relative Priority
Sediment Quality Triad	Triad evaluation table	High
Sediment Chemistry	Concentrations of contaminants of concern	High
	% incidence of predicted toxicity	High
	Mean PEC quotient	High
	Total Organic Carbon	High
	SEM minus AVS	Moderate
Sediment Toxicity	10-day *Hyalella azteca* survival and growth	High
	10-day *Chironomus tentans* survival and growth	High
	42-day *Hyalella azteca* survival, growth, and reproduction	Moderate
	Life-cycle Chironomid test	Low
	In situ toxicity tests	Low
	Microtox®/Mutatox®	Low
Benthic Invertebrate Community Structure	Diversity	High
	Evenness	High
	Presence/absence of indicator species	High
	Biomass	Low
Physical Characteristics	Particle size	High
	Sedimentation rate	Moderate
	% depositional area	Moderate
Water Chemistry	Concentrations of contaminants of concern	Moderate
	Dissolved oxygen in overlying water	Moderate
	Dissolved oxygen in porewater	Moderate
	Ammonia in porewater	Moderate
	Hydrogen sulfide in porewater	Moderate
	Biological oxygen demand in porewater	Low
Tissue Chemistry (including bioaccumulation studies)	Concentrations of contaminants in macroinvertebrate, fish, and wildlife tissues	High
	28-day *Lumbriculus variegatus* bioaccumulation	High
	Number of fish and wildlife advisories	High
	Hazard quotients	High

Table 5. Continued

Ecosystem Health Indicator	Candidate Metrics	Relative Priority
Porewater Toxicity	48 hr *Daphnia magna* survival	Moderate
	7-day *Ceriodaphnia dubia* survival and growth	Low
	7-day fathead minnow (larval) survival and growth	Low
	Microtox®	Low
Biomarkers in Fish	Number of preneoplastic and neoplastic lesions in fish livers	High
	Presence of external tumors	High
	P450 activity	Low
	Internal parasite loads in fish	Low
	External parasite loads in fish	Low
Water Column and Elutriate Toxicity	96 hr *Selenastrum capricornutum* cell yield and cell density	Low
	48 hr *Daphnia magna* (or *Ceriodaphnia dubia*) survival	Low
	7-day *Ceriodaphnia dubia* survival and growth	Low
	7-day fathead minnow (larval) survival and growth	Low
	96 hr rainbow trout (juvenile) or fathead minnow (juvenile) survival	Low

PEC = probable effect concentration; SEM = simultaneously extractable metals; AVS = acid volatile sulfides.

Table 6. Summary of Sediment Toxicity Data for the St. Louis River AOC

Reference	Species	Medium	Duration	Endpoint
Ankley *et al*. (1994)	*Chironomus tentans*	Bulk sediment	10-d	Growth (weight-mg)
Ankley *et al*. (1994)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
Ankley *et al*. (1994)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival/normal & UV
Ankley *et al*. (1994)	*Chironomus tentans*	Bulk sediment	10-d	Percent weight using UV light
Ankley *et al*. (1994)	*Hyalella azteca*	Bulk sediment	10-d	Growth (weight-mg)
Ankley *et al*. (1994)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival
Ankley *et al*. (1994)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival/normal & UV
Ankley *et al*. (1994)	*Hyalella azteca*	Bulk sediment	10-d	Percent weight using UV light
Ankley *et al*. (1994)	*Lumbriculus variegatus*	Bulk sediment	10-d	Growth (weight-mg)
Ankley *et al*. (1994)	*Lumbriculus variegatus*	Bulk sediment	10-d	Percent survival
Ankley *et al*. (1994)	*Lumbriculus variegatus*	Bulk sediment	10-d	Percent survival/normal & UV
Ankley *et al*. (1994)	*Lumbriculus variegatus*	Bulk sediment	10-d	Percent weight using UV light
Crane *et al*. (1997)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
Crane *et al*. (1997)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival
IT Corp. (1997)	*Chironomus tentans*	Bulk sediment	10-d	Growth (weight-mg)
IT Corp. (1997)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
IT Corp. (1997)	*Hyalella azteca*	Bulk sediment	10-d	Growth (weight-mg)
IT Corp. (1997)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival
MPCA (1996)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
MPCA (1997b)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
MPCA (1997b)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival
MPCA (1997b)	*Photobacterium phosphoreum*	Bulk sediment	30-min	Bioluminescence (EC50 expressed as % DW sediment)
MPCA (1997b)	*Photobacterium phosphoreum*	Porewater	30-min	% Reduction in bioluminescence (relative to control)

Table 6. Continued

Reference	Species	Medium	Duration	Endpoint
MPCA (1997c)	*Chironomus tentans*	Bulk sediment	10-d	Growth (weight-mg)
MPCA (1997c)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
MPCA (1997c)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival
MPCA (1997c)	*Photobacterium phosphoreum*	Bulk sediment	15-min	Bioluminescence (EC50 expressed as % DW sediment)
MPCA (1997c)	*Photobacterium phosphoreum*	Porewater	15-min	% Reduction in bioluminescence (relative to control)
Smith *et al*. (1992)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
Smith *et al*. (1992)	*Daphnia magna*	Bulk sediment	48-h	Percent survival
Wenck Associates Inc. (1995)	*Ceriodaphnia dubia*	Bulk sediment	48-h	Percent survival
Wenck Associates Inc. (1995)	*Chironomus tentans*	Bulk sediment	10-d	Growth (weight-mg)
Wenck Associates Inc. (1995)	*Chironomus tentans*	Bulk sediment	10-d	Percent survival
Wenck Associates Inc. (1995)	*Hyalella azteca*	Bulk sediment	10-d	Percent survival

UV = ultraviolet; DW = dry weight

Table 7. Summary of the Strengths and Limitations of Existing Approaches for Deriving Numerical Sediment Quality Guidelines

Approach	Strengths	Limitations
Screening Level Concentration Approach		
	• Based on biological effects • Sufficient data are generally available for many chemicals • Suitable for all classes of chemicals and most types of sediments	• Not possible to establish cause and effect relationships • Large database of matching sediment chemistry and benthic invertebrate community structure data is required • Bioavailability is not considered
Effects Range and Effects Level Approaches		
	• Based on biological effects • All types of biological data are considered • Suitable for all classes of chemicals and most types of sediments • Provides a weight-of-evidence approach • Provides data summaries for evaluating sediment quality	• Large database of matching sediment chemistry and biological effects data is required • Not possible to establish cause and effect relationships • Bioavailability is not considered
Apparent Effects Threshold Approach		
	• Based on biological effects • All types of biological data are considered • Suitable for all classes of chemicals and most types of sediments	• Extensive site-specific database is required • Not possible to establish cause and effect relationships • Risk of under- or over- protection of resource • Bioavailabiltiy is not considered
Equilibrium Partitioning Approach		
	• Based on biological effects • Suitable for many classes of chemicals and most types of sediments • Bioavailability is considered • Supports cause and effect evaluations	• Water quality criteria are not available for some substances • *In situ* sediments are rarely at equilibrium • Further field validation is needed • Guidelines for single chemicals do not account for effects of mixtures of contaminants

Table 7. Continued

Approach	Strengths	Limitations
Logistic Regression Modeling Approach		
	• Based on sediment toxicity test results • Suitable for all classes of chemicals and most types of sediments • Provides SQGs that are associated with a specific probability of observing sediment toxicity • Provides SQGs that are species and endpoint specific • Factors that influence bioavailability can be considered	• Large database of matching sediment chemistry and biological effects data is required • Not possible to establish cause and effect relationships • Bioavailability is not considered
Consensus-Based Sediment Quality Guidelines Approach		
	• Provide a unifying synthesis of the existing sediment quality guidelines • Reflect causal rather than correlative effects • Account for the effects of contaminant mixtures in sediments • Predictive ability in freshwater sediments has been demonstrated	• Bioavailability is not considered
Tissue Residue Approach		
	• Simple to apply • Bioaccumulation is considered • A protocol for the derivation of tissue residue guidelines is available	• Tissue residue guidelines for wildlife and human health are not yet available for most chemicals

Table 8. Candidate Sediment Quality Targets Used in the Predictive Ability Evaluation

Chemical	Level I SQTs	Level II SQTs	Source[†]
Metals (in mg/kg DW)			
Arsenic[§]	9.8	33	MacDonald *et al*. (2000a)
Cadmium*[§]	0.99	5.0	MacDonald *et al*. (2000a)
Chromium[§]	43	110	MacDonald *et al*. (2000a)
Copper*[§]	32	150	MacDonald *et al*. (2000a)
Lead*[§]	36	130	MacDonald *et al*. (2000a)
Mercury	0.18	1.1	MacDonald *et al*. (2000a)
Nickel[§]	23	49	MacDonald *et al*. (2000a)
Zinc*[§]	120	460	MacDonald *et al*. (2000a)
PAHs (in µg/kg DW)			
Acenaphthene	6.7	89	CCME (1999)
Acenaphthylene	5.9	128	CCME (1999)
Anthracene*	57	850	MacDonald *et al*. (2000a)
Fluorene	77	540	MacDonald *et al*. (2000a)
2-Methylnaphthalene	20	200	CCME (1999)
Naphthalene*[§]	180	560	MacDonald *et al*. (2000a)
Phenanthrene*[§]	200	1200	MacDonald *et al*. (2000a)
Benz(a)anthracene*[§]	110	1100	MacDonald *et al*. (2000a)
Benzo(a)pyrene*[§]	150	1500	MacDonald *et al*. (2000a)
Chrysene*[§]	170	1300	MacDonald *et al*. (2000a)
Dibenz[a,h]anthracene	33	135	MacDonald *et al*. (2000a); CCME (1999)
Fluoranthene*	420	2200	MacDonald *et al*. (2000a)
Pyrene*[§]	200	1500	MacDonald *et al*. (2000a)
Total PAHs*[§]	1600	23000	MacDonald *et al*. (2000a)
PCBs (in µg/kg DW)			
Total PCBs*[§]	60	680	MacDonald *et al*. (2000a)
Pesticides (in µg/kg DW)			
Chlordane*	3.2	18	MacDonald *et al*. (2000a)
Dieldrin*	1.9	62	MacDonald *et al*. (2000a)
sum DDD*	4.9	28	MacDonald *et al*. (2000a)
sum DDE*[§]	3.2	31	MacDonald *et al*. (2000a)
sum DDT*	4.2	63	MacDonald *et al*. (2000a)
Total DDT*	5.3	570	MacDonald *et al*. (2000a)

Table 8. Continued

Chemical	Level I SQTs	Level II SQTs	Source[†]
Endrin	2.2	210	MacDonald *et al*. (2000a)
Heptachlor epoxide*	2.5	16	MacDonald *et al*. (2000a)
Lindane (gamma-BHC)	2.4	5.0	MacDonald *et al*. (2000a)
Toxaphene	0.10	32	CCME (1999); NYSDEC (1999)[¥]

SQTs = sediment quality targets; DW = dry weight.

[†] Some SQT values were rounded to two significant figures from the original source.

* Reliable consensus-based TEC values that were adopted as Level I SQTs [i.e., predictive ability ≥ 75% and ≥ 20 samples below the TEC (MacDonald *et al.* 2000a)].

[§] Reliable consensus-based PEC values that were adopted as Level II SQTs [i.e., predictive ability ≥75% and ≥20 samples predicted to be toxic (MacDonald *et al.* 2000a)].

[¥] originally based on µg/g OC (NYSDEC 1999); assumed TOC = 1%.

Table 9. Incidence of Sediment Toxicity in the St. Louis River AOC Within Ranges of Contaminant Concentrations Defined by the SQTs

Chemical	≤ Level I SQT	> Level I SQT to ≤ Level II SQT	> Level II SQT
Metals			
Arsenic[§]	5 of 14 (36%)	3 of 10 (30%)	1 of 1 (100%)
Cadmium*[§]	11 of 92 (12%)	16 of 53 (30%)	2 of 2 (100%)
Chromium[§]	1 of 2 (50%)	3 of 8 (38%)	3 of 3 (100%)
Copper*[§]	19 of 121 (16%)	7 of 16 (44%)	3 of 4 (75%)
Lead*[§]	12 of 102 (12%)	8 of 30 (27%)	9 of 15 (60%)
Mercury	7 of 70 (10%)	18 of 84 (21%)	4 of 5 (80%)
Nickel[§]	22 of 130 (17%)	1 of 2 (50%)	5 of 6 (83%)
Zinc*[§]	9 of 97 (9%)	16 of 44 (36%)	4 of 4 (100%)
PAHs			
2-Methylnaphthalene	0 of 0 (0%)	3 of 5 (60%)	4 of 6 (67%)
Acenaphthene	1 of 25 (4%)	10 of 51 (20%)	14 of 34 (41%)
Acenaphthylene	0 of 17 (0%)	9 of 62 (15%)	13 of 28 (46%)
Anthracene*	1 of 29 (3.4%)	14 of 60 (23%)	10 of 21 (48%)
Fluorene	3 of 46 (6.5%)	13 of 45 (29%)	9 of 19 (47%)
Naphthalene*[§]	6 of 52 (12%)	6 of 27 (22%)	13 of 29 (45%)
Phenanthrene*[§]	1 of 31 (3.2%)	12 of 49 (24%)	12 of 30 (40%)
Benz(a)anthracene*[§]	0 of 28 (0%)	7 of 38 (18%)	15 of 41 (36%)
Benzo(a)pyrene*[§]	0 of 28 (0%)	13 of 55 (24%)	12 of 27 (44%)
Chrysene*[§]	0 of 29 (0%)	11 of 44 (25%)	14 of 37 (38%)
Dibenz(a,h)anthracene	1 of 32 (3.1%)	8 of 26 (31%)	13 of 49 (26%)
Fluoranthene*	2 of 32 (6.2%)	9 of 46 (20%)	14 of 32 (44%)
Pyrene*[§]	1 of 28 (3.6%)	8 of 39 (21%)	16 of 43 (37%)
Total PAHs*[§]	1 of 30 (3.3%)	15 of 64 (23%)	9 of 20 (45%)
PCBs			
Total PCBs*[§]	0 of 3 (0%)	2 of 18 (11%)	0 of 1 (0%)
Pesticides (in µg/kg DW)			
Chlordane*	ND	ND	ND
Dieldrin*	ND	ND	ND
sum DDD*	ND	ND	ND
sum DDE*[§]	ND	ND	ND
sum DDT*	ND	ND	ND
Total DDT*	ND	ND	ND

Table 9. Continued

Chemical	≤ Level I SQT	> Level I SQT to ≤ Level II SQT	> Level II SQT
Pesticides (continued)			
Endrin	ND	ND	ND
Heptachlor epoxide*	ND	ND	ND
Lindane (gamma-BHC)	ND	ND	ND
Toxaphene	ND	ND	ND

ND = not determined--no matching data available; SQT = sediment quality target.

* Reliable consensus-based TEC values that were adopted as Level I SQTs [i.e., predictive ability ≥75% and ≥20 samples below the TEC (MacDonald *et al.* 2000b)].

§ Reliable consensus-based PEC values that were adopted as Level II SQTs [i.e., predictive ability ≥75% and ≥20 samples predicted to be toxic (MacDonald *et al.* 2000b)].

Note: Incidence of toxicity was calculated using the results of all tests combined (i.e., a sediment sample was designated as toxic if it was shown to be significantly toxic in one or more toxicity test, excluding the results of the Microtox® and Mutatox® assays).

Table 10. Incidence of Toxicity for Mean PEC-Q Ranges as Determined Using Matching Sediment Chemistry and Toxicity Data from the St. Louis River AOC

Mean PEC-Q Range	Incidence of Toxicity			
	10-day Amphipod Growth or Survival	**10-day Midge Growth or Survival**	**All Tests Combined (excluding Microtox®)**	**All Tests Combined (including Microtox®)**
≤0.1	6.8% (3 of 44 samples)	6.5% (3 of 46 samples)	10% (5 of 49 samples)	49% (24 of 49 samples)
>0.1 to ≤0.5	11% (9 of 80 samples)	12% (9 of 74 samples)	16% (14 of 87 samples)	48% (42 of 87 samples)
>0.5 to ≤1.0	30% (3 of 10 samples)	20% (2 of 10 samples)	27% (3 of 11 samples)	36% (4 of 11 samples)
>1.0 to ≤5.0	27% (3 of 11 samples)	36% (4 of 11 samples)	36% (5 of 14 samples)	64% (9 of 14 samples)
>5.0	75% (3 of 4 samples)	100% (5 of 5 samples)	100% (5 of 5 samples)	100% (5 of 5 samples)
Overall	14% (21 of 149 samples)	16% (23 of 146 samples)	19% (32 of 166 samples)	51% (84 of 166 samples)

PEC-Q = probable effect concentration quotient.
For 10-day amphipod tests, the survival and growth of *Hyalella azteca* were measured.
For 10-day midge tests, the survival and growth of *Chironomus tentans* were measured.
Sites 102-TR and 044-TR, from the R-EMAP study (Breneman *et al*. 2000), were removed from the incidence of toxicity calculations due to incomplete sediment chemistry data (i.e., PAHs, PCBs) for these known contaminated areas.

Table 11. Proportion of the Great Lakes and North American Data Sets that are Comprised of Amphipod and Midge Toxicity Data from the St. Louis River AOC (USEPA 2000a)

Mean PEC-Q Range	**10-14 day Amphipod Tests Great Lakes Portion**	**10-14 day Amphipod Tests N. American Portion**	**10-14 day Midge Tests Great Lakes Portion**	**10-14 day Midge Tests N. American Portion**
≤0.1	88% (44 of 50 samples)	31% (44 of 140 samples)	47% (46 of 98 samples)	39% (46 of 118 samples)
>0.1 to ≤0.5	59% (80 of 136 samples)	29% (80 of 278 samples)	35% (74 of 209 samples)	25% (74 of 296 samples)
>0.5 to ≤1.0	27% (10 of 37 samples)	14% (10 of 72 samples)	23% (10 of 44 samples)	16% (10 of 62 samples)
>1.0 to ≤5.0	23% (11 of 48 samples)	12% (11 of 90 samples)	16% (11 of 68 samples)	13% (11 of 86 samples)
>5.0	12% (4 of 34 samples)	6% (4 of 67 samples)	14% (5 of 35 samples)	12% (5 of 41 samples)
Overall	49% (149 of 305 samples)	23% (149 of 647 samples)	32% (146 of 454 samples)	24% (146 of 603 samples)

PEC-Q = probable effect concentration quotient; AOC = Area of Concern.
Sites 102-TR and 044-TR, from the R-EMAP study (Breneman *et al*. 2000), were removed from the incidence of toxicity calculations due to incomplete sediment chemistry data (i.e., PAHs, PCBs) for these known contaminated areas.

Table 12. Predictive Ability of the Consensus-based SQGs in Freshwater Sediments Based on the Results of 10-14 day Amphipod Tests

Mean PEC-Q Range	Incidence of Toxicity (%) and 95% Confidence Intervals (%)*: 10-14 day *Hyalella azteca* Tests** (n)					
	St. Louis River AOC	Other Great Lakes Sites***	Other North American Sites***	Non-Great Lakes Sites	All Great Lakes Sites	All North American Sites
≤ 0.1	6.8% (n = 44) (0 – 17%)	50% (n = 6) (not calculated)	24% (n = 96) (13 – 35%)	22% (n = 90) (11 – 33%)	12% (n = 50) (0 – 24%)	18% (n = 140) (10 – 26%)
>0.1 to ≤0.5	11% (n = 80) (2 – 20%)	25% (n = 56) (10 – 40%)	19% (n = 198) (12 – 26%)	16% (n = 142) (8 – 24%)	17% (n = 136) (9 – 25%)	16% (n = 278) (10 – 22%)
>0.5 to ≤1.0	30% (n = 10)	52% (n = 27)	37% (n = 62)	26% (n = 35)	46% (n = 37)	36% (n = 72)
>1.0 to ≤5.0	27% (n = 11)	68% (n = 37)	42% (n = 79)	19% (n = 42)	58% (n = 48)	40% (n = 90)
>5.0	75% (n = 4)	77% (n = 30)	70% (n = 63)	64% (n = 33)	76% (n = 34)	70% (n = 67)

SQG = sediment quality guideline; PEC-Q = probable effect concentration quotient.
For 10-14 day amphipod tests, the survival and growth of *Hyalella azteca* were measured.
* 95% confidence intervals were only calculated for those mean PEC-Q ranges that had more than 20 samples from the St. Louis River AOC.
** Excludes sites 102-TR and 044-TR, from the R-MAP study (Breneman *et al.* 2000), due to incomplete sediment chemistry data (i.e., PAHs, PCBs) for these known contaminated areas.
*** Excludes the St. Louis River AOC data.

Table 13. Predictive Ability of the Consensus-based SQGs in Freshwater Sediments Based on the Results of 10-14 day Midge Tests

Mean PEC-Q Range	Incidence of Toxicity (%) and 95% Confidence Intervals (%)*: 10-14 day Midge Tests** (n)					
	St. Louis River AOC	Other Great Lakes Sites***	Other North American Sites***	Non-Great Lakes Sites	All Great Lakes Sites	All North American Sites
≤ 0.1	6.5% (n = 46) (0 – 16%)	19% (n = 52) (5 – 33%)	28% (n = 72) (14 – 42%)	50% (n = 20) (21 – 79%)	13% (n = 98) (4 – 22%)	19% (n = 118) (10 – 28%)
>0.1 to ≤0.5	12% (n = 74) (2 – 22%)	23% (n = 135) (14 – 32%)	18% (n = 222) (11 – 25%)	12% (n = 87) (3 – 21%)	19% (n = 209) (12 – 26%)	17% (n = 296) (11 – 23%)
>0.5 to ≤1.0	20% (n = 10)	59% (n = 34)	46% (n = 52)	22% (n = 18)	50% (n = 44)	42% (n = 62)
>1.0 to ≤5.0	36% (n = 11)	47% (n = 57)	43% (n = 75)	28% (n = 18)	46% (n = 68)	42% (n = 86)
>5.0	100% (n = 5)	63% (n = 30)	61% (n = 36)	50% (n = 6)	68% (n = 35)	66% (n = 41)

SQG = sediment quality guideline; PEC-Q = probable effect concentration quotient.
For 10-14 day midge tests, the survival and growth of *Chironomius tentans* were measured.
* 95% confidence intervals were only calculated for those mean PEC-Q ranges that had more than 20 samples from the St. Louis River AOC.
** Excludes sites 102-TR and 044-TR, from the R-EMAP study (Breneman *et al.* 2000) due to incomplete sediment chemistry data (i.e., PAHs, PCBs) for these known contaminated areas.
*** Excludes the St. Louis River AOC data.

Table 14. Recommended Level I and Level II Sediment Quality Targets for the Protection of Sediment-dwelling Organisms

Chemical	Aquatic Life		
	Level I SQT	Level II SQT	Source[†]
Metals (in mg/kg DW)			
Arsenic[§]	9.8	33	MacDonald *et al*. (2000a)
Cadmium*[§]	0.99	5.0	MacDonald *et al*. (2000a)
Chromium[§]	43	110	MacDonald *et al*. (2000a)
Copper*[§]	32	150	MacDonald *et al*. (2000a)
Lead*[§]	36	130	MacDonald *et al*. (2000a)
Mercury	0.18	1.1	MacDonald *et al*. (2000a)
Nickel[§]	23	49	MacDonald *et al*. (2000a)
Zinc*[§]	120	460	MacDonald *et al*. (2000a)
PAHs (in µg/kg DW)			
2-Methylnaphthalene	20	200	CCME (1999)
Acenaphthene	6.7	89	CCME (1999)
Acenaphthylene	5.9	130	CCME (1999)
Anthracene*	57	850	MacDonald *et al*. (2000a)
Fluorene	77	540	MacDonald *et al*. (2000a)
Naphthalene*[§]	180	560	MacDonald *et al*. (2000a)
Phenanthrene*[§]	200	1200	MacDonald *et al*. (2000a)
Benz(a)anthracene*[§]	110	1100	MacDonald *et al*. (2000a)
Benzo(a)pyrene*[§]	150	1500	MacDonald *et al*. (2000a)
Chrysene*[§]	170	1300	MacDonald *et al*. (2000a)
Dibenz(a,h)anthracene	33	140	MacDonald *et al*. (2000a); CCME (1999)
Fluoranthene*	420	2200	MacDonald *et al*. (2000a)
Pyrene*[§]	200	1500	MacDonald *et al*. (2000a)
Total PAHs*[§]	1600	23000	MacDonald *et al*. (2000a)
PCBs (in µg/kg DW)			
Total PCBs*[§]	60	680	MacDonald *et al*. (2000a)
Pesticides (in µg/kg DW)			
Chlordane*	3.2	18	MacDonald *et al*. (2000a)
Dieldrin*	1.9	62	MacDonald *et al*. (2000a)
Sum DDD*	4.9	28	MacDonald *et al*. (2000a)

Table 14. Continued

Chemical	Aquatic Life Level I SQT	Aquatic Life Level II SQT	Source[†]
Pesticides (continued)			
Sum DDE*[§]	3.2	31	MacDonald *et al*. (2000a)
Sum DDT*	4.2	63	MacDonald *et al*. (2000a)
Total DDT*	5.3	570	MacDonald *et al*. (2000a)
Endrin	2.2	210	MacDonald *et al*. (2000a)
Heptachlor epoxide*	2.5	16	MacDonald *et al*. (2000a)
Lindane (gamma-BHC)	2.4	5	MacDonald *et al*. (2000a)
Toxaphene	0.1	32	NYSDEC (1999)[¥]
Mean PEC-Q	0.1	0.6	USEPA 2000a

SQT = sediment quality target; TEQ = toxic equivalent; PEC-Q = probable effect concentration quotient.
[†] Some SQT values were rounded to two significant figures from the original source.
* Reliable consensus-based TEC values that were adopted as Level I SQTs [i.e., predictive ability ≥75% and ≥20 samples below the TEC (MacDonald *et al.* 2000a)].
[§] Reliable consensus-based PEC values that were adopted as Level II SQTs [i.e., predictive ability ≥75% and ≥20 samples predicted to be toxic (MacDonald *et al.* 2000a)].
[¥] originally based on µg/g OC; assumed TOC = 1%.

Table 15. Recommended Sediment Quality Targets for the Protection of Wildlife and Human Health

	Wildlife		Human Health	
Substance	**SQT**	**Source**	**SQT**	**Source**
Metals (in mg/kg OC)				
Arsenic	NR	NA	NR	NA
Cadmium	NR	NA	NR	NA
Chromium	NR	NA	NR	NA
Copper	NR	NA	NR	NA
Lead	NR	NA	NR	NA
Mercury	NR	NA	NR	NA
Nickel	NR	NA	NR	NA
Zinc	NR	NA	NR	NA
PCBs (in µg/kg OC)				
Total PCBs	1400	NYSDEC (1999)	0.8	NYSDEC (1999)
PAHs (in µg/kg OC)				
Acenaphthene	NR	NA	NR	NA
Acenaphthylene	NR	NA	NR	NA
Anthracene	NR	NA	NR	NA
Fluorene	NR	NA	NR	NA
Naphthalene	NR	NA	NR	NA
2-Methylnaphthalene	NR	NA	NR	NA
Phenanthrene	NR	NA	NR	NA
Benz(a)anthracene	NR	NA	NR	NA
Benzo(a)pyrene	NR	NA	1300	NYSDEC (1999)
Chrysene	NR	NA	NR	NA
Dibenz(a,h)anthracene	NR	NA	NR	NA
Fluoranthene	NR	NA	NR	NA
Pyrene	NR	NA	NR	NA
Total PAHs	NR	NA	NR	NA

Table 15. Continued

	Wildlife		Human Health	
Substance	**SQT**	**Source**	**SQT**	**Source**
Organochlorine Pesticides (in µg/kg OC)				
Chlordane	6	NYSDEC (1999)	1	NYSDEC (1999)
Dieldrin	770*	NYSDEC (1999)	100	NYSDEC (1999)
Sum DDT	NR	NA	NR	NA
Sum DDE	NR	NA	NR	NA
Sum DDD	NR	NA	NR	NA
Total DDTs	1000	NYSDEC (1999)	10	NYSDEC (1999)
Endrin	800	NYSDEC (1999)	800	NYSDEC (1999)
Heptachlor and Heptachlor epoxide	30	NYSDEC (1999)	0.8	NYSDEC (1999)
Lindane (gamma-BHC)	1500	NYSDEC (1999)	60	NYSDEC (1999)
Mirex	3700	NYSDEC (1999)	70	NYSDEC (1999)
Toxaphene	NR	NA	20	NYSDEC (1999)
Dioxins and Furans (µg/kg OC)				
TCDD TEQs†	0.2	NYSDEC (1999)	10	NYSDEC (1999)

NA = not applicable; NR = not reported; OC = organic carbon.
* applies to aldrin and dieldrin.
† Toxic equivalency factors (TEFs) for individual dioxin and furan congeners, in combination with their chemical concentration, can be used to calculate the total TCDD toxic equivalents concentration (TEQs) contributed by all dioxin-like congeners in the mixture. Thus, TEQs are calculated using the following equation which assumes dose additivity (WHO 1998): $TEQ = \Sigma (PCDD_i \times TEF_i) + \Sigma (PCDF_i \times TEF_i)$

FIGURES

Figure 1. Map of the St. Louis River Area of Concern.

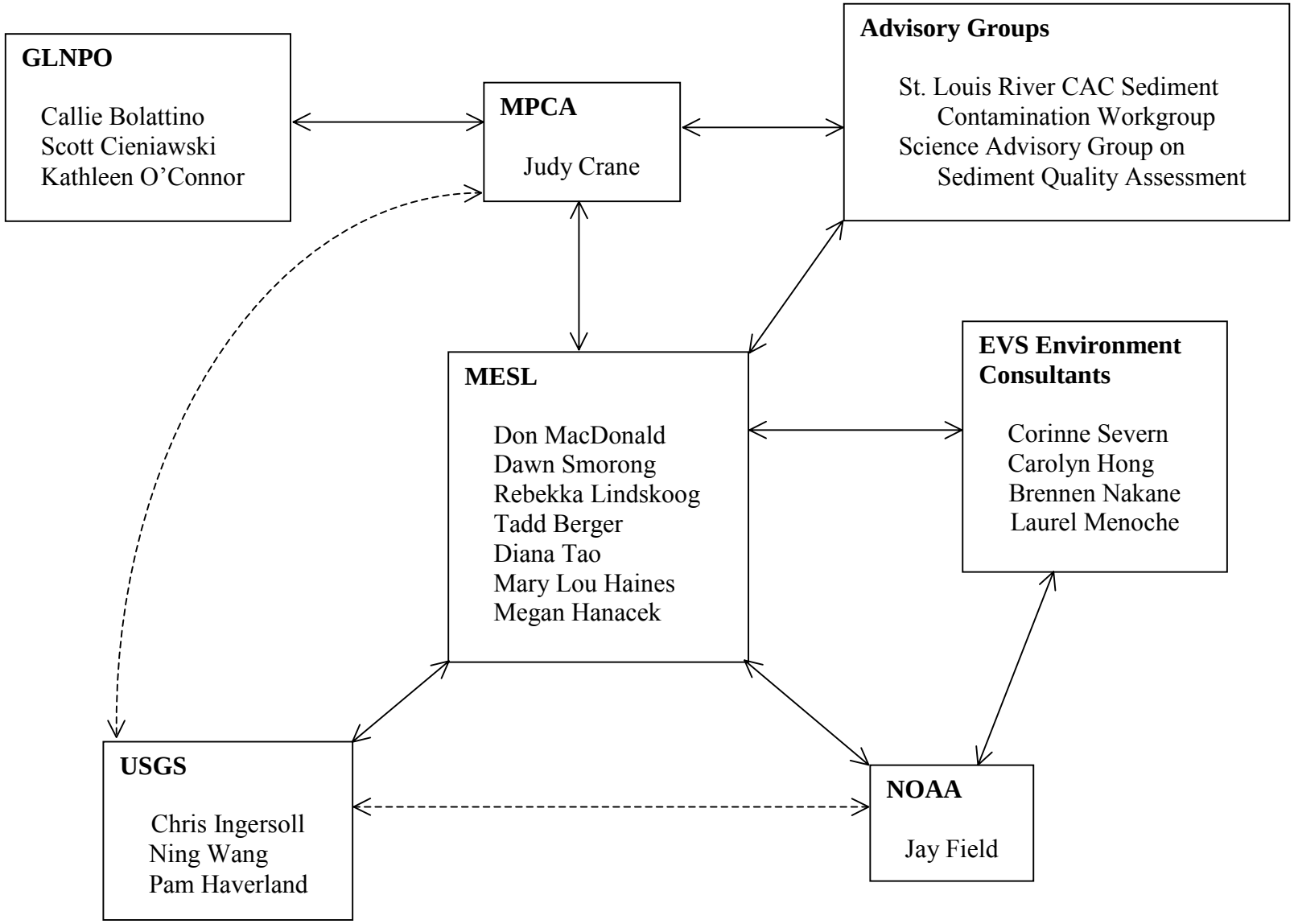

Figure 2. Study team.

Figure 3. Map of the Duluth/Superior Harbor, including locations of areas sampled in 1994.

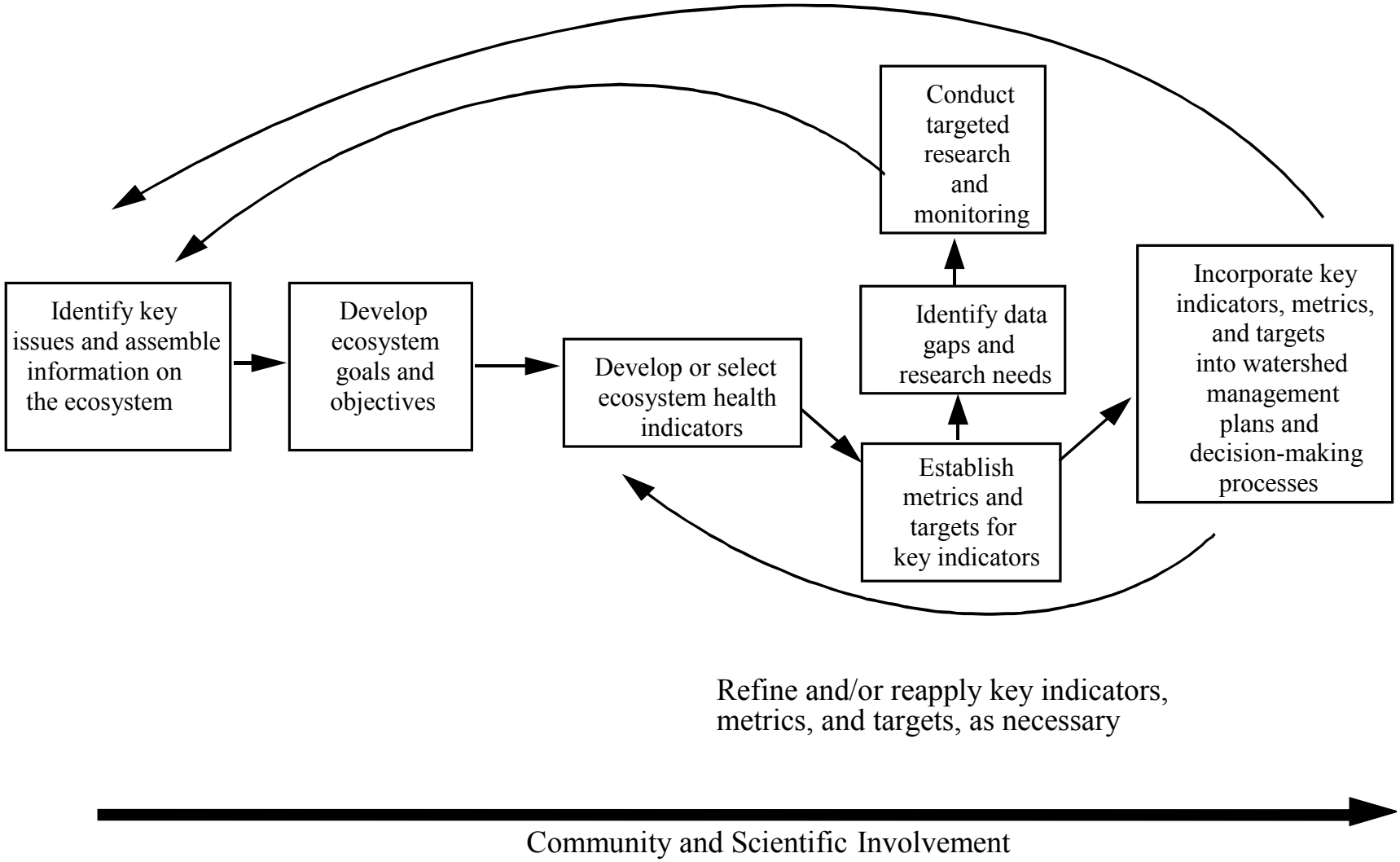

Figure 4. A framework for ecosystem-based management (CCME 1996).

Figure 5. Distribution of mean PEC-Q values for surficial sediment samples collected from the St. Louis River AOC.

Figure 6. Distribution of mean PEC-Q values for surficial sediment samples collected from the northern section of the Duluth-Superior Harbor.

Figure 7. Distribution of mean PEC-Q values for surficial sediment samples collected from the Interlake/Duluth Tar Superfund site.

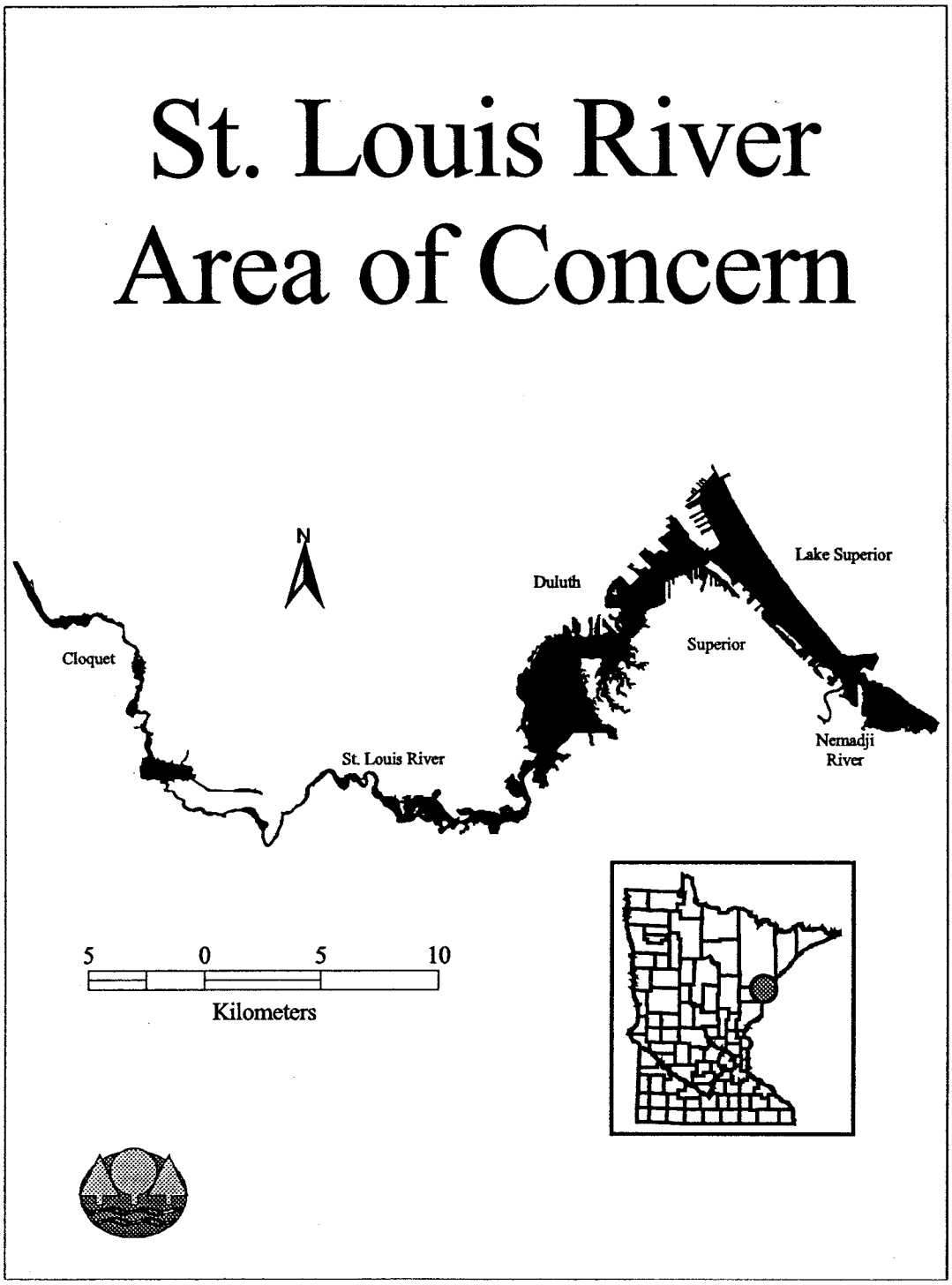

Figure 1. Map of the St. Louis River Area of Concern.

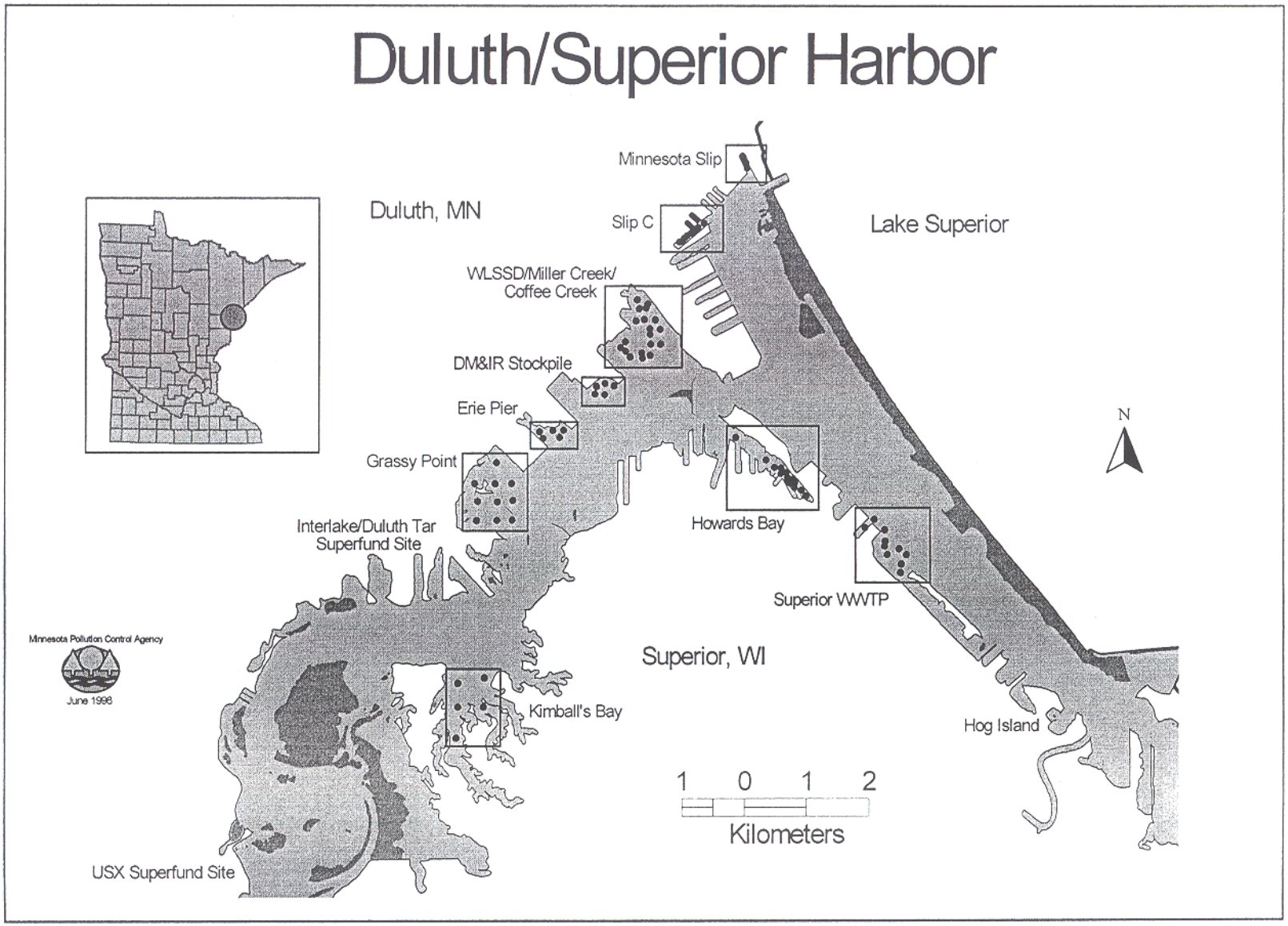

Figure 3. Map of the Duluth/Superior Harbor, including locations of areas sampled in 1994.