An Assessment of Sediment Injury in the Grand Calumet River, Indiana Harbor Canal, Indiana Harbor, and the Nearshore Areas of Lake Michigan

Volume III - Figures

Prepared for:

U.S. Fish and Wildlife Service
Bloomington Field Office
620 South Walker Street
Bloomington, Indiana 47403

Prepared – October 2000 – by:

Donald D. MacDonald
MacDonald Environmental Sciences Ltd.
2376 Yellow Point Road
Nanaimo, British Columbia
V9X 1W5

Christopher G. Ingersoll
Columbia Environmental Research Center
United States Geological Survey
4200 New Haven Road
Columbia, Missouri 65201

In Association with:
Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, Massachusetts
02140

An Assessment of Sediment Injury in the Grand Calumet River, Indiana Harbor Canal, Indiana Harbor, and the Nearshore Areas of Lake Michigan

Volume III - Figures

Prepared for:

U.S. Fish and Wildlife Service
Bloomington Field Office
620 South Walker Street
Bloomington, Indiana 47403

Prepared – October 2000 – by:

Donald D. MacDonald
MacDonald Environmental Sciences Ltd.
2376 Yellow Point Road
Nanaimo, British Columbia
V9X 1W5

Christopher G. Ingersoll
Columbia Environmental Research Center
United States Geological Survey
4200 New Haven Road
Columbia, Missouri 65201

In Association with:

Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

Volume III - Figures (under this cover)

Other Volumes in this Report
- **Volume I - Text**
- **Volume III - Figures**
- **Volume IV - Appendices**

Table of Contents i
List of Acronyms viii

Chapter 1

Figure 1.1 Map of study area 1
Figure 1.2 Map of study area showing reach boundaries 2
Figure 1.3 Map of study area showing the locations of discharges to receiving waters 3

Chapter 4

Figure 4.1 Location of sediment sampling stations for Lucas and Steinfeld (1972) 4
Figure 4.2 Location of sediment sampling stations for USACE (1980a) 5
Figure 4.3 Location of sediment sampling stations for USACE (1980b) 6
Figure 4.4 Location of sediment and benthic macroinvertebrate sampling stations for Polls *et al*. (1993), 1982 and 1986 sample dates 7
Figure 4.5 Location of sediment sampling stations for USACE (1983) 8
Figure 4.6 Location of benthic macroinvertebrate sampling stations for Polls and Dennison (1984) 9
Figure 4.7 Location of sediment and benthic macroinvertebrate sampling stations for LTI (1984) 10
Figure 4.8 Location of sediment sampling stations for USEPA (1986a) 11
Figure 4.9 Location of sediment sampling stations for Polls (1988) 12
Figure 4.10 Location of sediment sampling stations for IDEM (1994) 13
Figure 4.11 Location of sediment sampling stations for Hoke *et al*. (1993) 14
Figure 4.12 Location of sediment sampling stations for Unger (1992) 15
Figure 4.13 Location of sediment and benthic macroinvertebrate sampling stations for USEPA (1996a) 16
Figure 4.14 Location of sediment and benthic macroinvertebrate sampling stations for Risatti and Ross (1989) 17
Figure 4.15 Location of sediment sampling stations for HNTB (1989) 18
Figure 4.16 Location of sediment sampling stations for HNTB (1990) 19

Figure 4.17 Location of sediment sampling stations for HNTB (1991) 20
Figure 4.18 Location of sediment sampling stations for USEPA (1990) 21
Figure 4.19 Location of sediment sampling stations for USEPA (1996b) 22
Figure 4.20 Location of sediment sampling stations for Floyd-Browne (1993) 23
Figure 4.21 Location of sediment sampling stations for USEPA (1991, 1992c) 24
Figure 4.22 Location of benthic macroinvertebrate sampling stations for Rainbolt (1993) 25
Figure 4.23 Location of sediment sampling stations for USACE (1994) 26
Figure 4.24 Location of sediment sampling stations for Burton (1994); Dorkin (1994) 27
Figure 4.25 Location of benthic macroinvertebrate sampling stations for IDEM (2000a) 28
Figure 4.26 Location of sediment and benthic macroinvertebrate sampling stations for Sobiech *et al*. (1994) 29
Figure 4.27 Location of benthic macroinvertebrate sampling stations for Stewart *et al.* (1999) 30
Figure 4.28 Location of sediment sampling stations for Gillespie *et al*. (1998); USDOI (1994) 31
Figure 4.29 Location of sediment sampling stations for USACE (1996) 32
Figure 4.30 Location of sediment sampling stations for RETEC (1997) 33
Figure 4.31 Location of sediment sampling stations for ENTACT, Inc. (1998) and TechLaw, Inc. (1998) 34
Figure 4.32a Location of sediment sampling stations for Simon (2000) 35
Figure 4.32b Location of sediment sampling stations for Simon (2000) 36
Figure 4.33 Location of sediment and benthic macroinvertebrate sampling stations for ThermoRetec (1999) 37
Figure 4.34 Location of sediment and benthic macroinvertebrate sampling stations for URS Greiner Woodward Clyde (1999) 38
Figure 4.35 Location of benthic macroinvertebrate sampling stations for Simon *et al.* (2000) 39
Figure 4.36 Location of sediment sampling stations for IDEM (1998) 40
Figure 4.37 Location of sediment sampling stations for Exponent (1999) and Tetra Tech EM Inc. (1998) 41
Figure 4.38 Location of sediment sampling stations for Maxim Technologies (1999); USGS (1999) 42
Figure 4.39 Location of sediment sampling stations for IDEM (1999) 43

Chapter 5

Figure 5.1 Location of sampling stations for surficial sediment chemistry in the GCRL 44
Figure 5.2 Location of sampling stations for sub-surface sediment chemistry in the GCRL 45
Figure 5.3 Location of sampling stations for sediment toxicity testing in the GCRL 46
Figure 5.4 Location of sampling stations for tissue chemistry in the GCRL 47
Figure 5.5 Spatial distribution of mean PEC-Qs in surficial sediments within the GCRL 48
Figure 5.6 Areal extent of injury to surficial sediments in the GCRL 49
Figure 5.7 Spatial distribution of mean PEC-Qs in sub-surface sediments within the GCRL 50
Figure 5.8 Areal extent of injury to sub-surface sediments in the GCRL 51
Figure 5.9 Areal extent of sediment toxicity in the GCRL 52

Chapter 6

Figure 6.1 Location of sampling stations for surficial sediment chemistry in the EBGCR-I 53
Figure 6.2 Location of sampling stations for sub-surface sediment chemistry in the EBGCR-I 54
Figure 6.3 Location of sampling stations for sediment toxicity testing in the EBGCR-I 55
Figure 6.4 Areal extent of altered benthic invertebrate communities in the EBGCR-I 56
Figure 6.5 Location of sampling stations for tissue chemistry in the EBGCR-I 57
Figure 6.6 Spatial distribution of mean PEC-Qs in surficial sediments within the EBGCR-I 58
Figure 6.7 Areal extent of injury to surficial sediments in the EBGCR-I 59
Figure 6.8 Spatial distribution of mean PEC-Qs in sub-surface sediments within the EBGCR-I 60
Figure 6.9 Areal extent of injury to sub-surface sediments in the EBGCR-I 61
Figure 6.10 Areal extent of sediment toxicity in the EBGCR-I 62

Chapter 7

Figure 7.1 Location of sampling stations for surficial sediment chemistry in the EBGCR-II 63
Figure 7.2 Location of sampling stations for sub-surface sediment chemistry in the EBGCR-II 64
Figure 7.3 Location of sampling stations for sediment toxicity testing in the EBGCR-II 65
Figure 7.4 Areal extent of altered benthic invertebrate communities in the EBGCR-II 66
Figure 7.5 Location of sampling stations for tissue chemistry in the EBGCR-II 67
Figure 7.6 Spatial distribution of mean PEC-Qs in surficial sediments within the EBGCR-II 68
Figure 7.7 Areal extent of injury to surficial sediments in the EBGCR-II 69
Figure 7.8 Spatial distribution of mean PEC-Qs in sub-surface sediments within the EBGCR-II 70
Figure 7.9 Areal extent of injury to sub-surface sediments in the EBGCR-II 71
Figure 7.10 Areal extent of sediment toxicity in the EBGCR-II 72

Chapter 8

Figure 8.1 Location of sampling stations for surficial sediment chemistry in the WBGCR-I 73
Figure 8.2 Location of sampling stations for sub-surface sediment chemistry in the WBGCR-I 74
Figure 8.3 Location of sampling stations for sediment toxicity testing in the WBGCR-I 75
Figure 8.4 Areal extent of altered benthic invertebrate communities in the WBGCR-I 76
Figure 8.5 Location of sampling stations for tissue chemistry in the WBGCR-I 77
Figure 8.6 Spatial distribution of mean PEC-Qs in surficial sediments within the WBGCR-I 78
Figure 8.7 Areal extent of injury to surficial sediments in the WBGCR-I 79
Figure 8.8 Spatial distribution of mean PEC-Qs in sub-surface sediments within the WBGCR-I 80
Figure 8.9 Areal extent of injury to sub-surface sediments in the WBGCR-I 81
Figure 8.10 Areal extent of sediment toxicity in the WBGCR-I 82

Chapter 9

Figure 9.1 Location of sampling stations for surficial sediment chemistry in the WBGCR-II 83
Figure 9.2 Location of sampling stations for sub-surface sediment chemistry in the WBGCR-II 84
Figure 9.3 Location of sampling stations for sediment toxicity testing in the WBGCR-II 85
Figure 9.4 Areal extent of altered and unaltered benthic invertebrate communities in the WBGCR-II 86
Figure 9.5 Location of sampling stations for tissue chemistry in the WBGCR-II 87
Figure 9.6 Spatial distribution of mean PEC-Qs in surficial sediments within the WBGCR-II 88
Figure 9.7 Areal extent of injury to surficial sediments in the WBGCR-II 89
Figure 9.8 Spatial distribution of mean PEC-Qs in sub-surface sediments within the WBGCR-II 90
Figure 9.9 Areal extent of injury to sub-surface sediments in the WBGCR-II 91
Figure 9.10 Areal extent of sediment toxicity in the WBGCR-II 92

Chapter 10

Figure 10.1 Location of sampling stations for surficial sediment chemistry in the IHC 93
Figure 10.2 Location of sampling stations for sub-surface sediment chemistry in the IHC 94
Figure 10.3 Location of sampling stations for sediment toxicity testing in the IHC . . . 95
Figure 10.4 Areal extent of altered benthic invertebrate communities in the IHC 96
Figure 10.5 Location of sampling stations for tissue chemistry in the IHC 97
Figure 10.6 Spatial distribution of mean PEC-Qs in surficial sediments within the IHC 98
Figure 10.7 Areal extent of injury to surficial sediments in the IHC 99
Figure 10.8 Spatial distribution of mean PEC-Qs in sub-surface sediments within the IHC 100
Figure 10.9 Areal extent of injury to sub-surface sediments in the IHC 101
Figure 10.10 Areal extent of sediment toxicity in the IHC 102

Chapter 11

Figure 11.1 Location of sampling stations for surficial sediment chemistry in the LGB 103
Figure 11.2 Location of sampling stations for sub-surface sediment chemistry in the LGB 104
Figure 11.3 Location of sampling stations for sediment toxicity testing in the LGB 105
Figure 11.4 Areal extent of altered benthic invertebrate communities in the LGB . . . 106
Figure 11.5 Spatial distribution of mean PEC-Qs in surficial sediments within the LGB 107
Figure 11.6 Areal extent of injury to surficial sediments in the LGB 108
Figure 11.7 Spatial distribution of mean PEC-Qs in sub-surface sediments within the LGB 109
Figure 11.8 Areal extent of injury to sub-surface sediments in the LGB 110
Figure 11.9 Areal extent of sediment toxicity in the LGB 111

Chapter 12

Figure 12.1 Location of sampling stations for surficial sediment chemistry in the USC 112
Figure 12.2 Location of sampling stations for sub-surface sediment chemistry in the USC 113
Figure 12.3 Location of sampling stations for sediment toxicity testing in the USC . . 114
Figure 12.4 Areal extent of altered and unaltered benthic invertebrate communities in the USC 115
Figure 12.5 Location of sampling stations for tissue chemistry in the USC 116
Figure 12.6a Spatial distribution of mean PEC-Qs in surficial sediments within the Columbus Drive to Forks segment of the USC 117
Figure 12.6b Spatial distribution of mean PEC-Qs in surficial sediments within the Indianapolis Boulevard to Forks segment of the USC 118
Figure 12.6c Spatial distribution of mean PEC-Qs in surficial sediments within the Forks to the Indiana Harbor entrance segment of the USC 119
Figure 12.7 Areal extent of injury to surficial sediments in the USC 120
Figure 12.8a Spatial distribution of mean PEC-Qs in sub-surface sediments within the Columbus Drive to Forks segment of the USC 121
Figure 12.8b Spatial distribution of mean PEC-Qs in sub-surface sediments within the Indianapolis Boulevard to Forks segment of the USC 122
Figure 12.8c Spatial distribution of mean PEC-Qs in sub-surface sediments within the Forks to the Indiana Harbor entrance segment of the USC 123
Figure 12.9 Areal extent of injury to sub-surface sediments in the USC 124
Figure 12.10 Areal extent of sediment toxicity in the USC 125

Chapter 13

Figure 13.1a Location of sampling stations for surficial sediment chemistry in the IH 126
Figure 13.1b Location of sampling stations for surficial sediment chemistry within the nearshore areas of Lake Michigan 127
Figure 13.2 Location of sampling stations for sub-surface sediment chemistry in the IH and nearshore areas of Lake Michigan 128
Figure 13.3 Location of sampling stations for sediment toxicity testing in the IH and nearshore areas of Lake Michigan 129
Figure 13.4a Areal extent of altered and unaltered benthic invertebrate communities in the IH 130
Figure 13.4b Areal extent of altered and unaltered benthic invertebrate communities within the nearshore areas of Lake Michigan 131
Figure 13.5 Location of sampling stations for tissue chemistry in the IH and nearshore areas of Lake Michigan 132
Figure 13.6a Spatial distribution of mean PEC-Qs in surficial sediment within the IH 133
Figure 13.6b Spatial distribution of mean PEC-Qs in surficial sediments within the eastern section of the nearshore areas of Lake Michigan 134
Figure 13.6c Spatial distribution of mean PEC-Qs in surficial sediments within the northern section of the nearshore areas of Lake Michigan 135
Figure 13.6d Spatial distribution of mean PEC-Qs in surficial sediments within the western section of the nearshore areas of Lake Michigan 136
Figure 13.7a Areal extent of injury to surficial sediments in the IH 137
Figure 13.7b Areal extent of injury to surficial sediments within the nearshore areas of Lake Michigan 138
Figure 13.8 Spatial distribution of mean PEC-Qs in sub-surface sediments within the IH and nearshore areas of Lake Michigan 139
Figure 13.9 Areal extent of injury to sub-surface sediments in the IH and nearshore areas of Lake Michigan 140
Figure 13.10 Areal extent of sediment toxicity in the IH and nearshore areas of Lake Michigan 141

Chapter 14

Figure 14.1 Areal extent of injury to surficial sediments in the Assessment Area 142
Figure 14.2 Areal extent of injury to sub-surface sediments in the Assessment Area 143
Figure 14.3 Areal extent of sediment toxicity in the Assessment Area 144
Figure 14.4 Areal extent of altered and unaltered benthic invertebrate communities in the Assessment Area 145

List of Acronyms

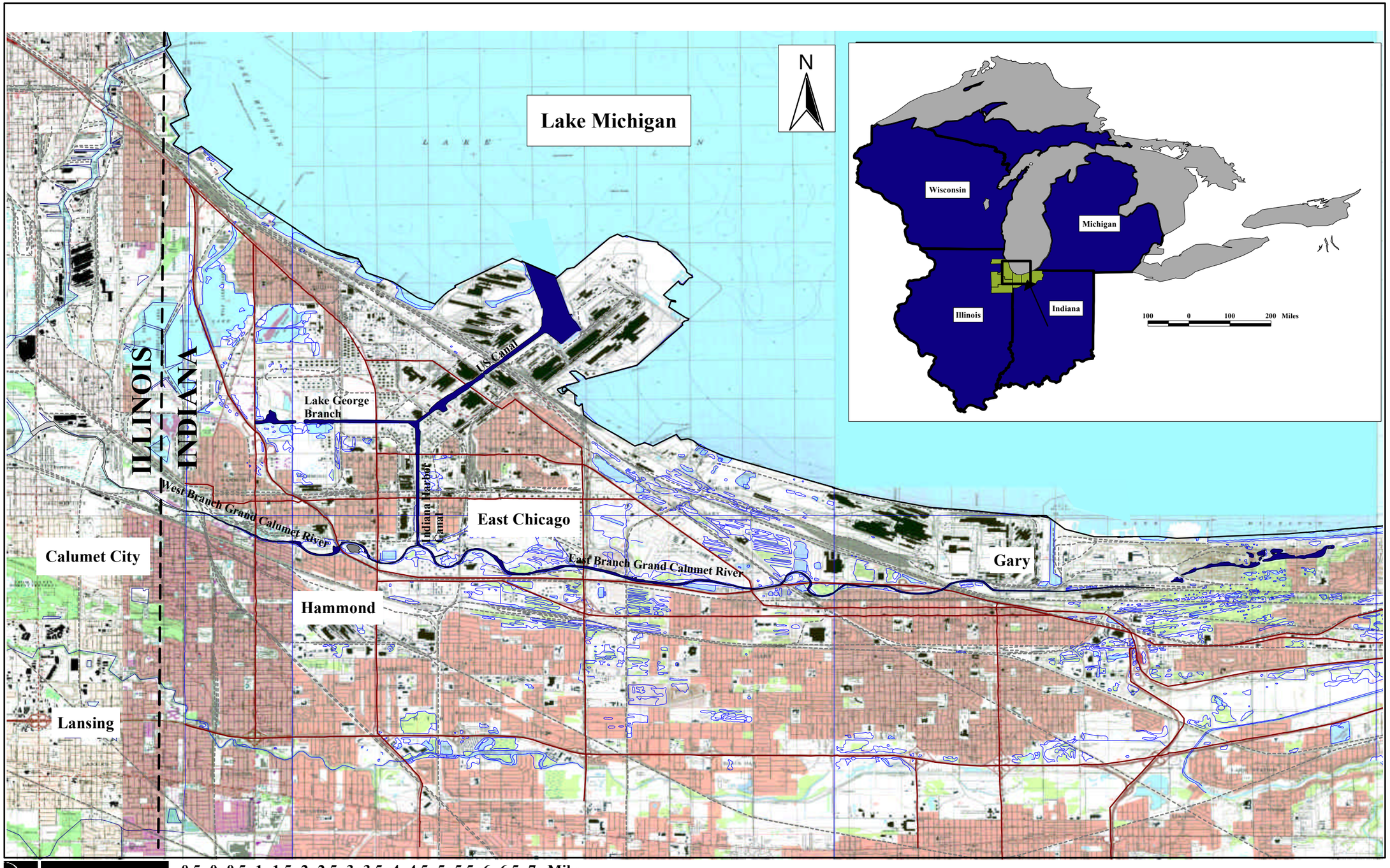
%	percent
10-d	10 days
12-d	12 days
14-d	14 days
15-min	15 minutes
20-d	20 days
2,3,7,8-TCDD	tetrachlorodibenzo-*p*-dioxin
28-d	28 days
30-min	30 minutes
48-h	48 hours
7-d	7 days
8-d	8 days
96-h	96 hours
AOC	Area of Concern
ARCS Program	Assessment and Remediation of Contaminated Sediments in the Great Lakes Program
ASTM	American Society for Testing and Materials
AVS	acid volatile sulfides
BSAF	biota-sediment bioaccumulation factor
CCBP	Central Corn Belt Plain
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601 et seq.
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CI	confidence interval
CSO	combined sewer overflow
DDTs	*p,p*'-DDT, *o,p*'-DDT, *p,p*'-DDE, *o,p*'-DDE, *p,p*'-DDD, *o,p*'-DDD, and any metabolite or degradation product
DELT	deformities, fin erosion, lesions, and tumors
DL	detection limit
DO	dissolved oxygen
DQO	data quality objective
DuPont	E.I. du Pont de Nemours
DW	dry weight
EB	east branch
EBGCR	East Branch of the Grand Calumet River
EBGCR-I	East Branch of the Grand Calumet River I

EBGCR-II	East Branch of the Grand Calumet River II
EC	Environment Canada
EC_{50}	median effective concentration
ECBP	Eastern Corn Belt Plain
EPT	Ephemeroptera, Plecoptera, Trichoptera
FIELDS	Fully Integrated Environmental Location Decision Support
gamma-BHC	gamma-hexachlorocyclohexane (lindane)
GCRL	Grand Calumet River Lagoons
GIS	geographic information system
HC	Health Canada
HNTB	Howard, Needles, Tammen and Bergendoff Architects, Engineers, and Planners
IBI	Index of biotic integrity
ID	insufficient data
IDEM	Indiana Department of Environmental Management
IEC	Industrial Economics, Inc.
IH	Indiana Harbor
IHC	Indiana Harbor Canal
IJC	International Joint Commission
IL	Illinois
IN	Indiana
LC_{50}	median lethal concentration
LEP	Little East Pond
LGB	Lake George Branch
LM	Lake Michigan
LTI	Limno-Tech, Inc.
LWP	Little West Pond
mean PEC-Q	mean probable effect concentration quotient
MESL	MacDonald Environmental Sciences Ltd.
mg	milligrams
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mIBI	macroinvertebrate index of biotic integrity
mm	millimeters
MS	Microsoft
n	number of samples
NA	not applicable (i.e., all <DL values were >PEC; therefore total was not calculated)
NA'	not applicable (i.e., toxicity test or chemical analyses not performed).
ND	not determined; compounds were measured as less than the detection limit, but the detection limit is unknown
ND'	not determined; toxicity not determined because mortality was > 40%
ND"	not determined; the lab considered sample to be a hazard to personnel

NE	northeast
NG	no guideline available
NH_3	unionized ammonia
NH_4^+	ionized ammonia
NIPSCO	Northern Indiana Public Service Company
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge and Elimination System
NR	not reported
NRDA	Natural Resource Damage Assessment
NT	not toxic
NW	northwest
NYSDEC	New York State Department of Environmental Conservation
OC	organic carbon
OEPA	Ohio Environmental Protection Agency
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	probable effect concentration (consensus-based)
PEC-Q	probable effect concentration quotient
QA/QC	quality assurance/quality control
QHEI	qualitative habitat evaluation index
RCRA	Resource Conservation and Recovery Act
RETEC	Remediation Technologies, Inc.
S.U.	standard unit
SAB	Science Advisory Board
SE	southeast
SEC	sediment effect concentration (consensus-based)
SEM	simultaneously extracted metals
SEM-AVS	simultaneously extracted metal minus acid volatile sulfides
SETAC	Society of Environmental Toxicology and Chemistry
SOD	sediment oxygen demand
SQG	sediment quality guideline
STP	sewage treatment plant
sum DDD	*p,p*'-DDD + *o,p*'-DDD
sum DDE	*p,p*'-DDE + *o,p*'-DDE
sum DDT	*p,p*'-DDT + *o,p*'-DDT
SVOC	semi-volatile organic chemical
SW	southwest
T	toxic
TEC	threshold effect concentration (consensus-based)
ThermoRetec	ThermoRetec Consulting Corporation
TOC	total organic carbon
Total DDT	*p,p*'-DDT, *o,p*'-DDT, *p,p*'-DDE, *o,p*'-DDE, *p,p*'-DDD, and *o,p*'-DDD
TRG	tissue residue guideline

U.S. Steel	United States Steel (Division of USX Corporation)
USACE	United States Army Corps of Engineers
USC	United States Canal
USDOI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USS Lead	USS Lead Refinery, Inc.
VOC	volatile organic compound
WB	west branch
WBGCR	West Branch of the Grand Calumet River
WBGCR-I	West Branch of the Grand Calumet River I
WBGCR-II	West Branch of the Grand Calumet River II
WW	wet weight
WWTP	wastewater treatment plant
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µmol/g	micromoles per gram

Figure 1.1. Map of study area.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

Figures

Chapter 4 - Existing Information on SQ Conditions in the Assessment Area

Figure 4.1. Location of sediment sampling stations for Lucas and Steinfeld (1972).

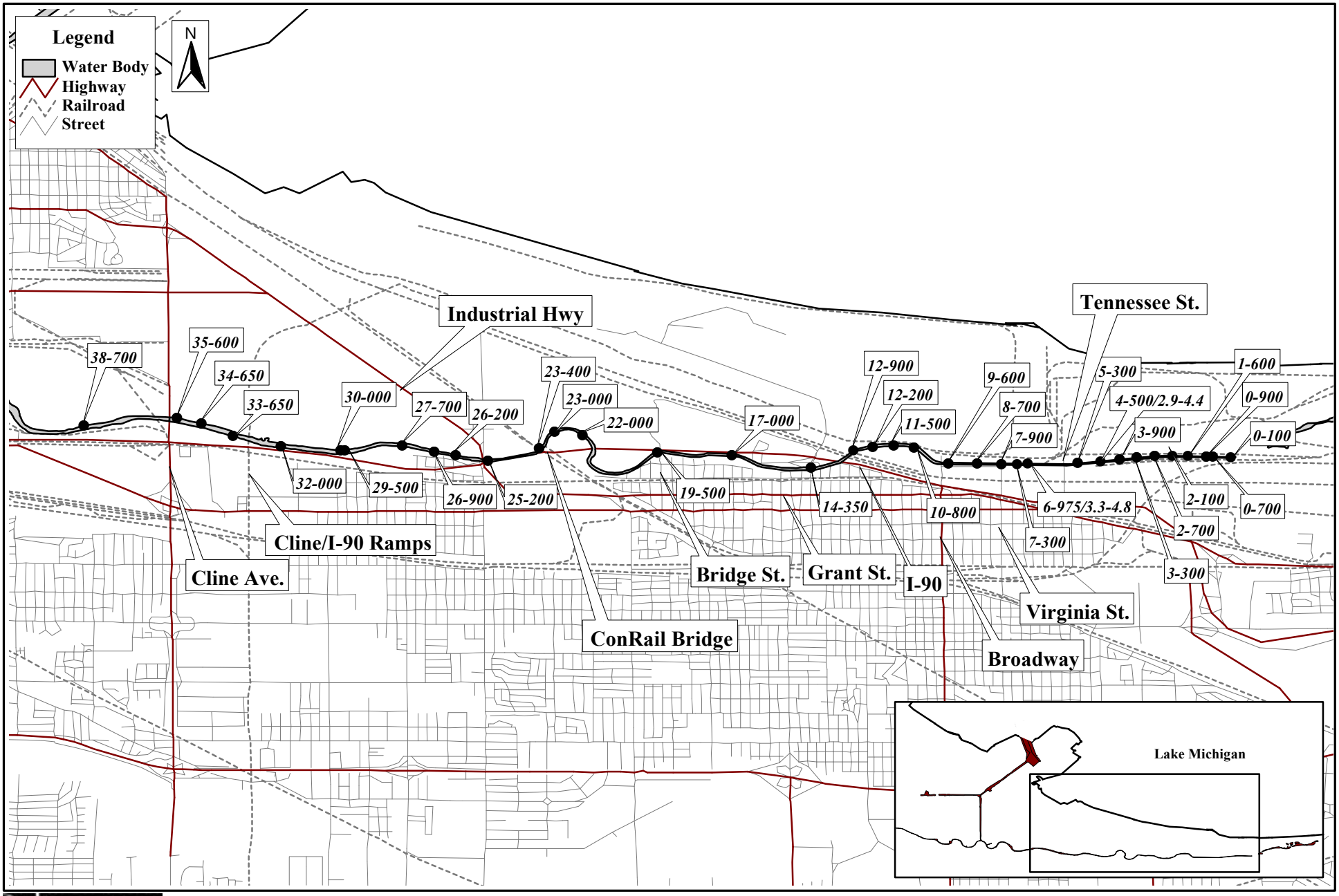
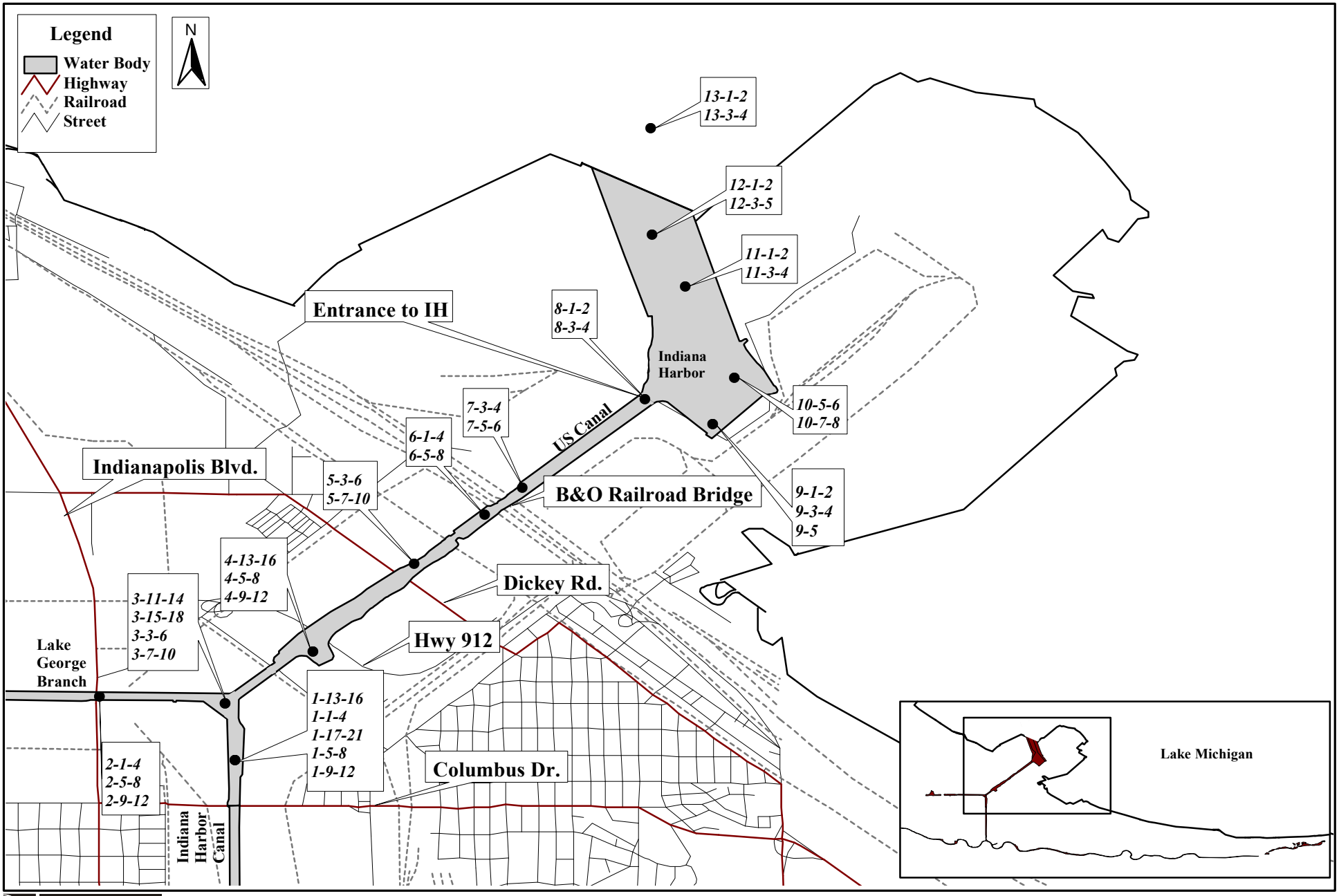


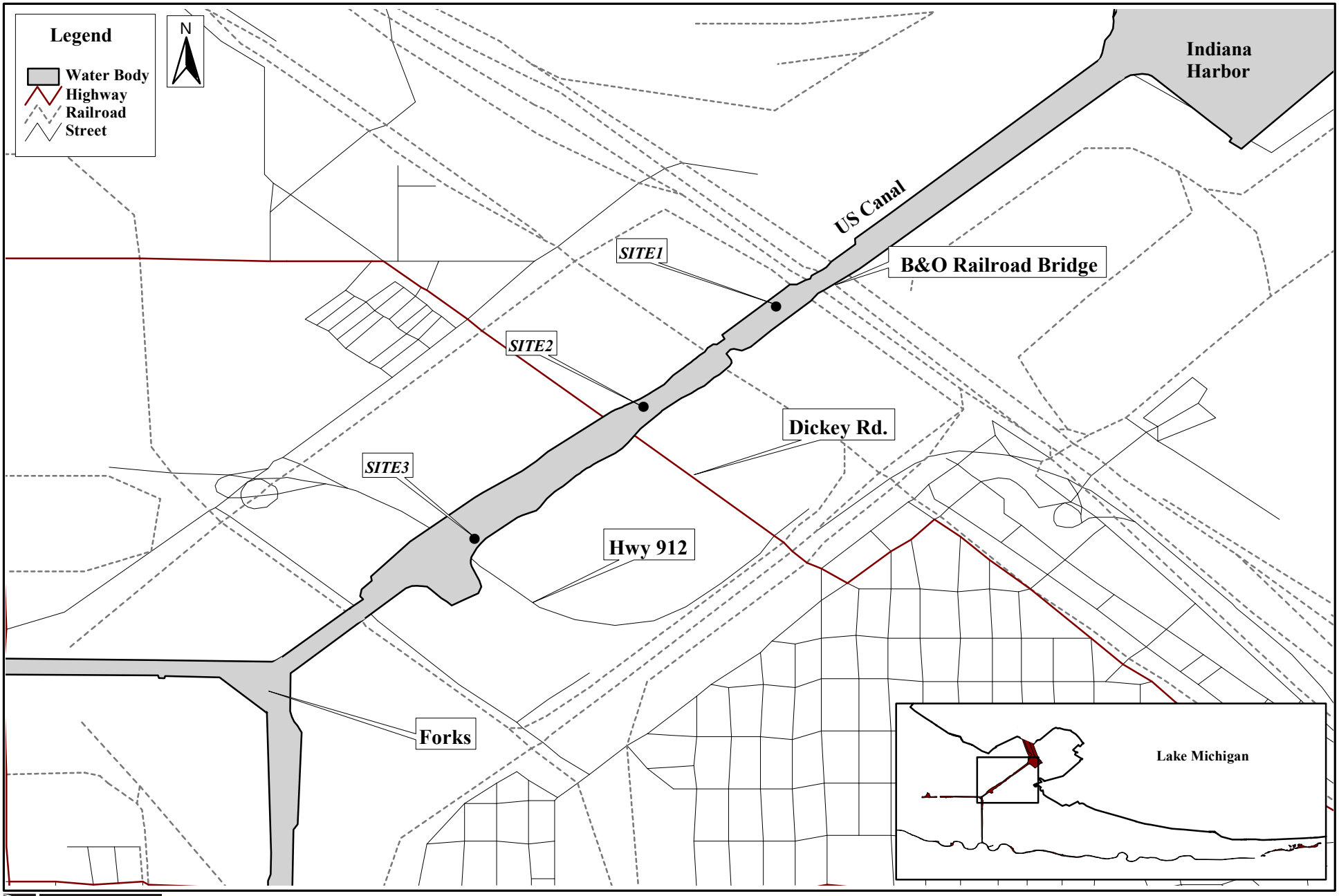
Figure 4.2. Location of sediment sampling stations for USACE (1980a).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

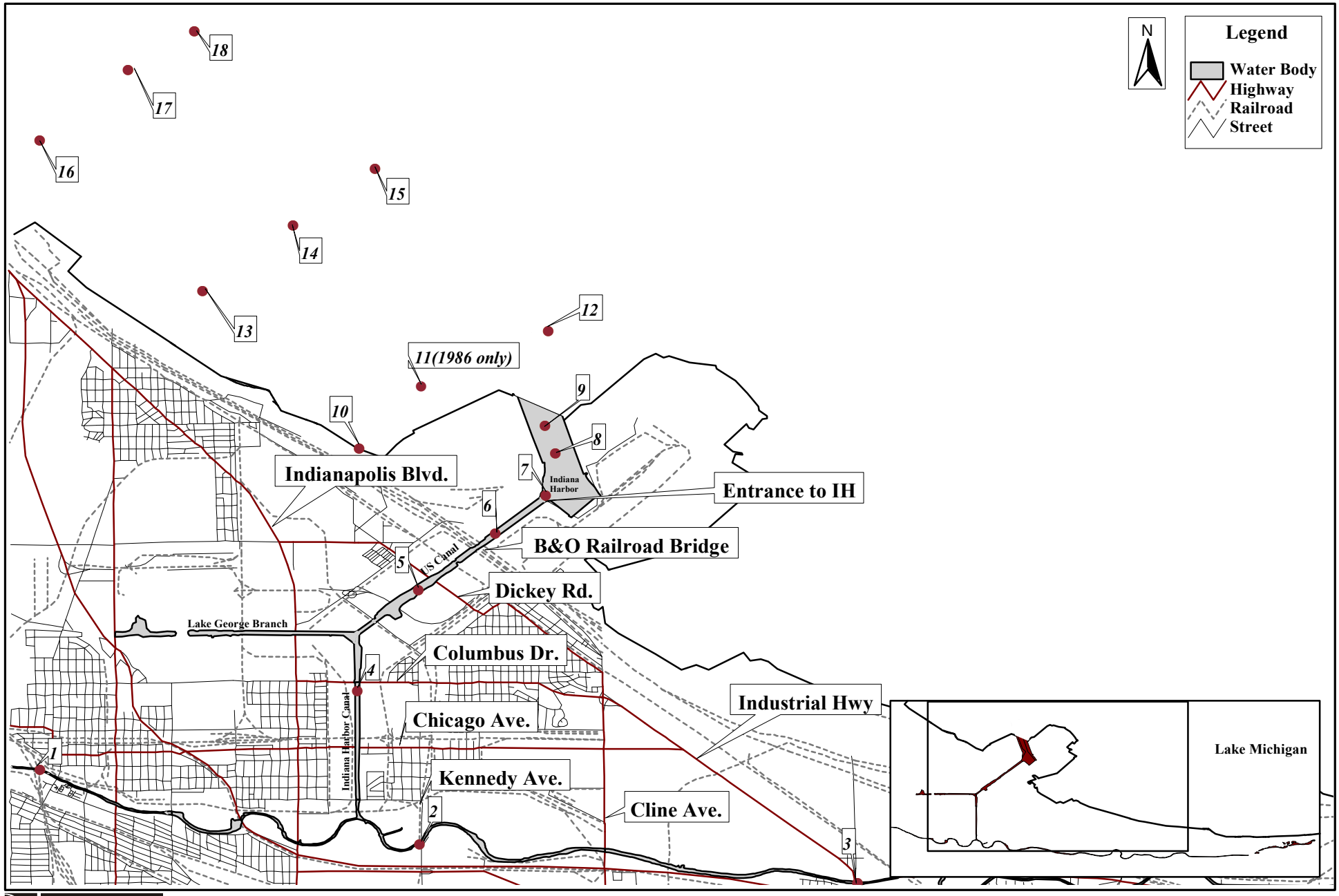
Figure 4.3. Location of sediment sampling stations for USACE (1980b).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

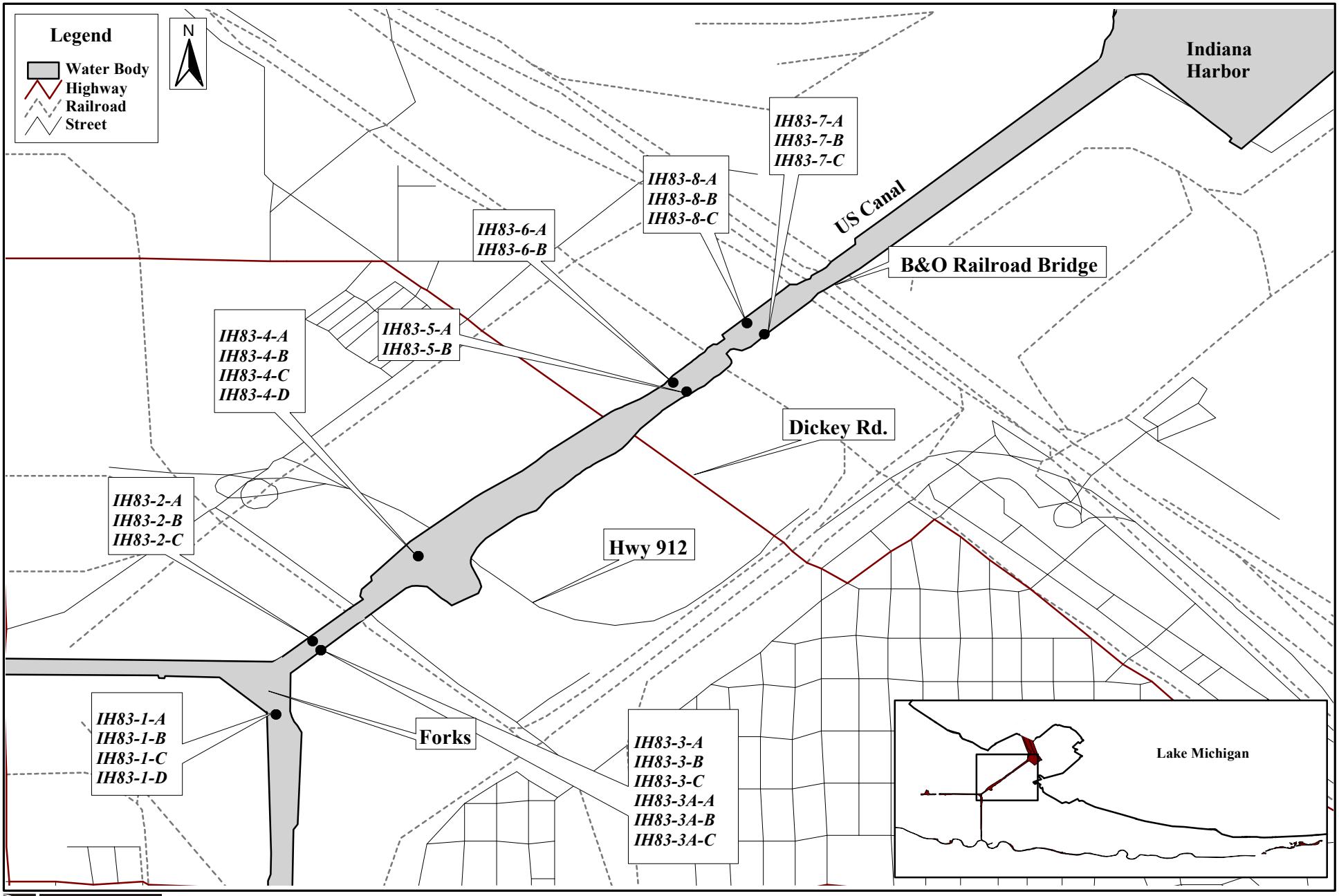
Figure 4.4. Location of sediment and benthic macroinvertebrate sampling stations for Polls et al. (1993), 1982 and 1986 sample dates.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 Miles

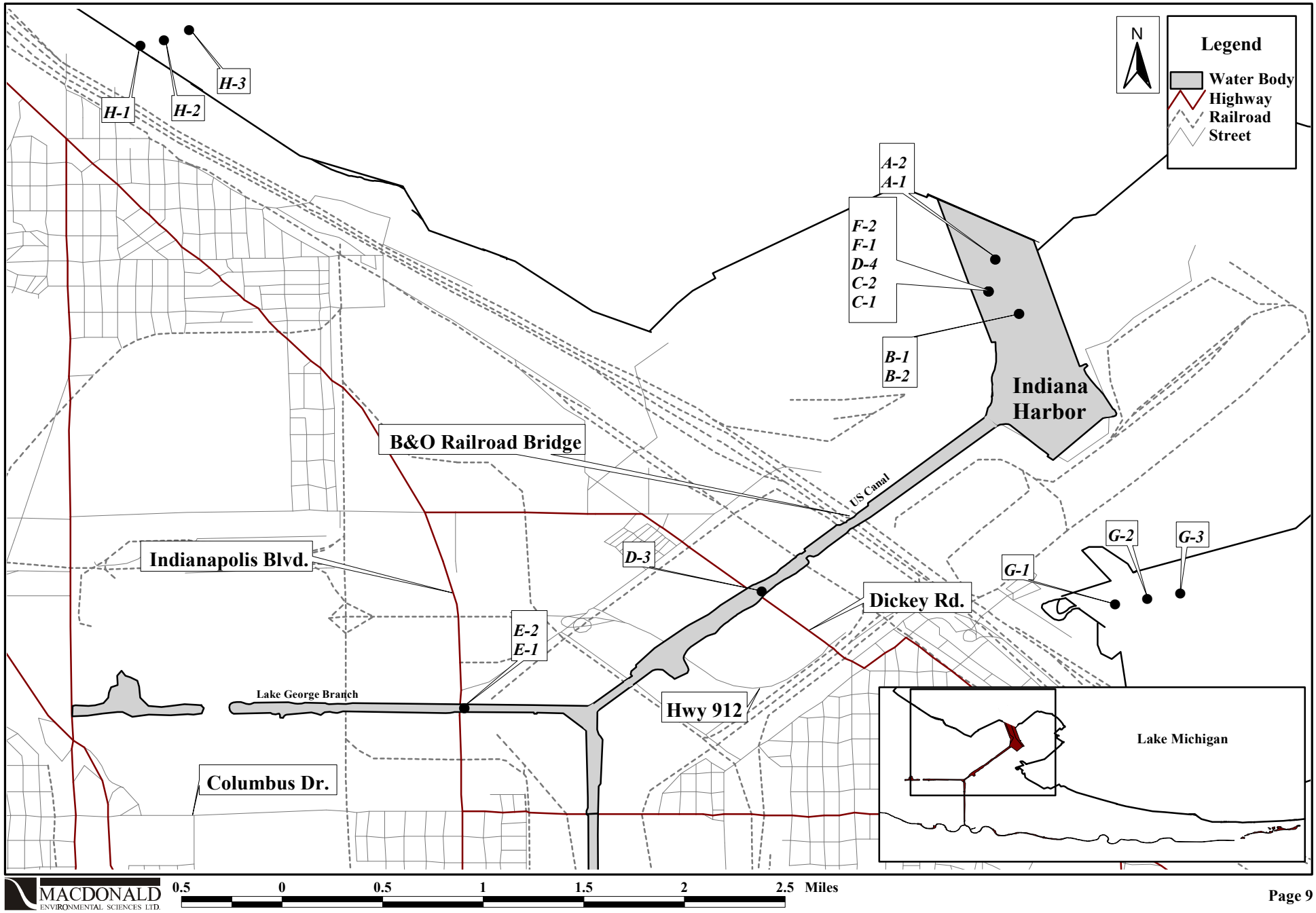
Figure 4.5. Location of sediment sampling stations for USACE (1983).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

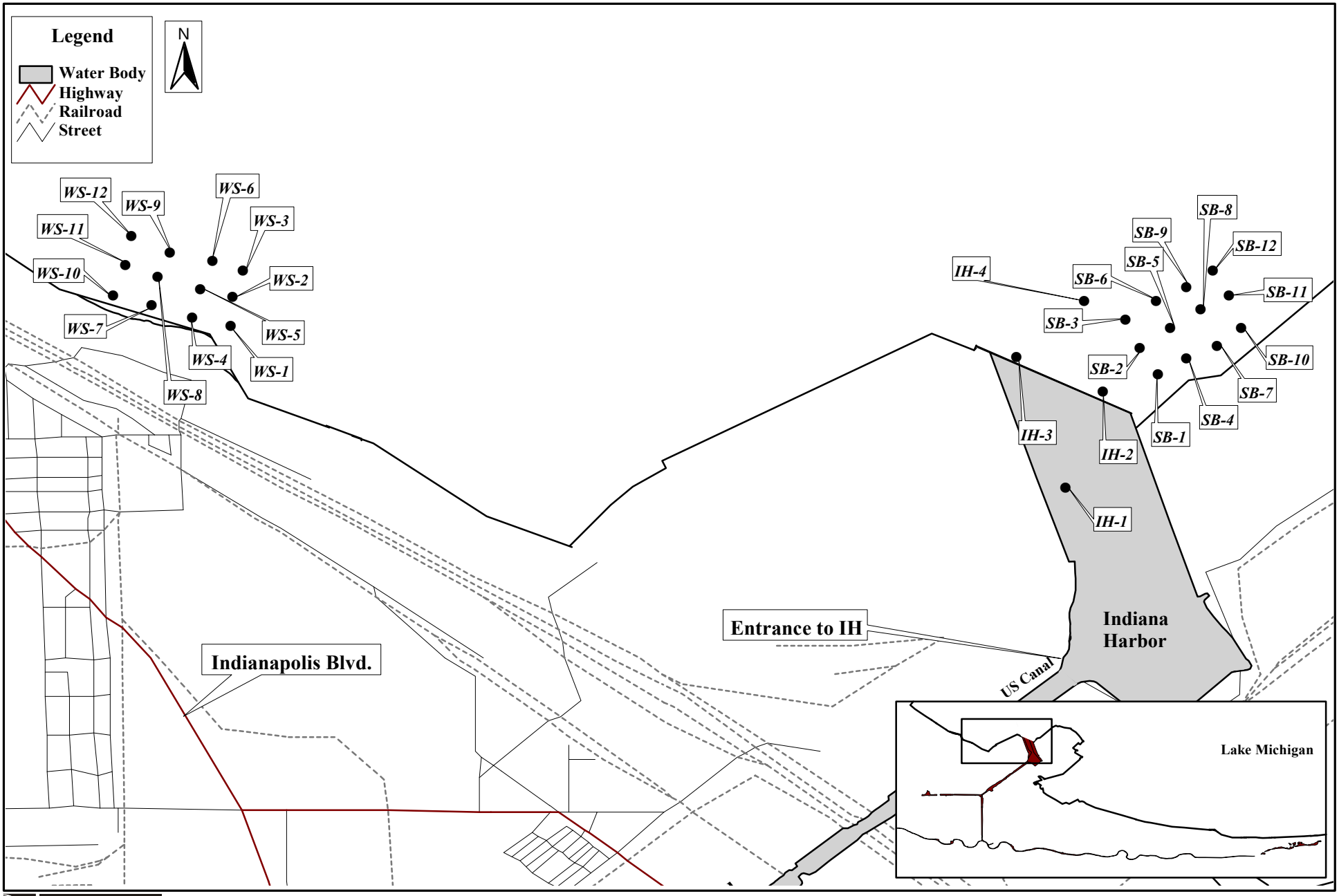
0.5 0 0.5 Miles

Figure 4.6. Location of benthic macroinvertebrate sampling stations for Polls and Dennison (1984).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

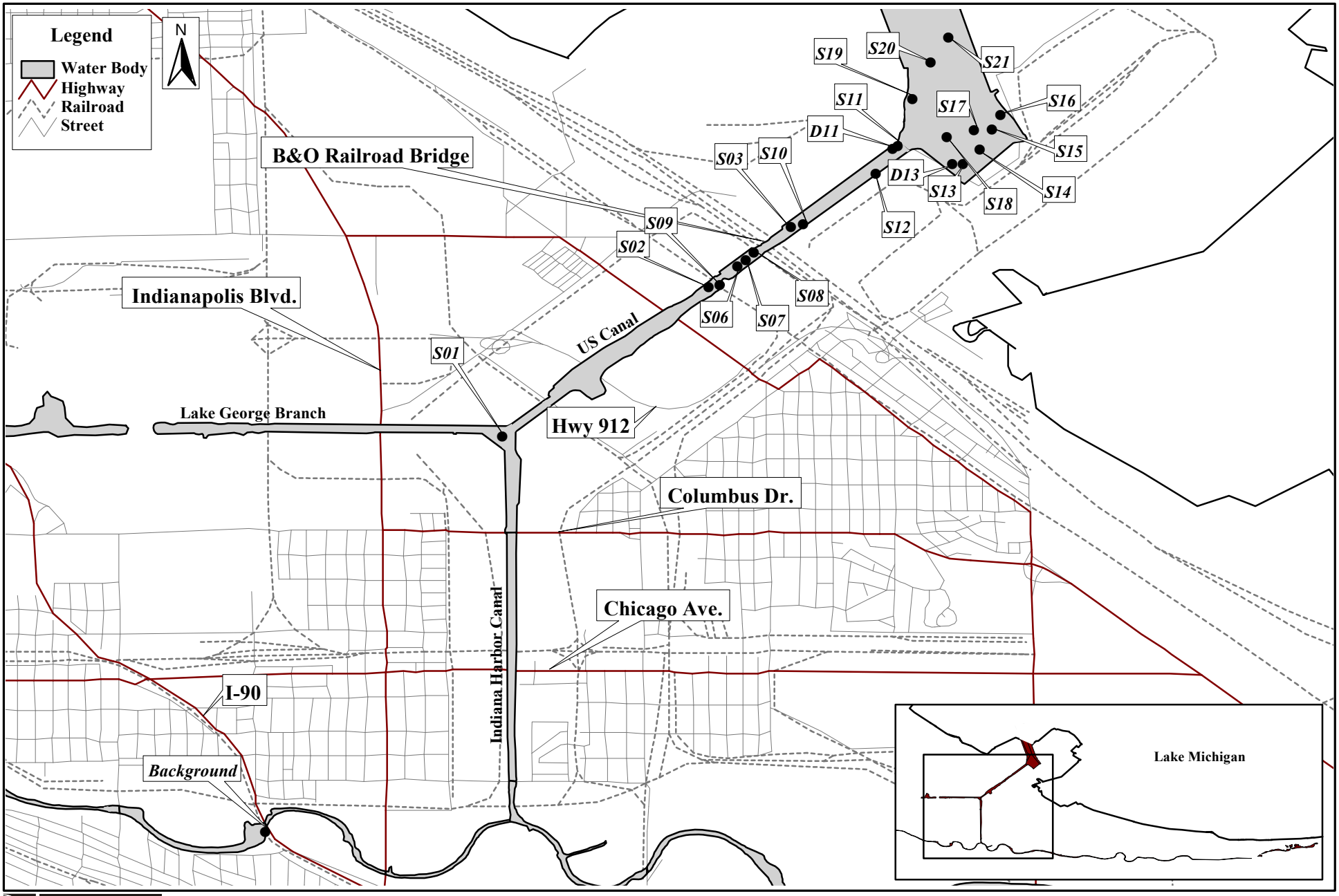
Figure 4.7. Location of sediment and benthic macroinvertebrate sampling stations for LTI (1984).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 Miles

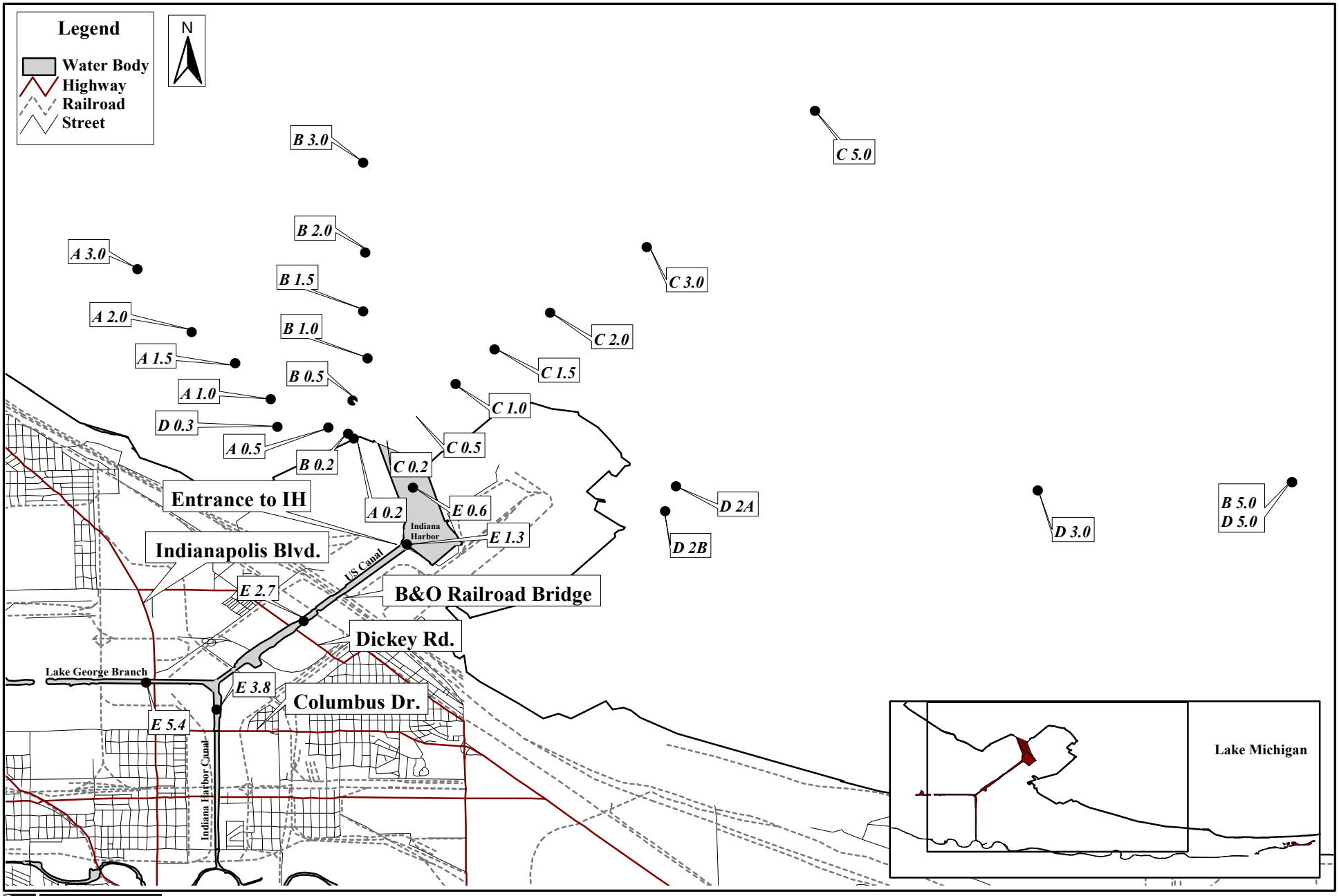
Figure 4.8. Location of sediment sampling stations for USEPA (1986a).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

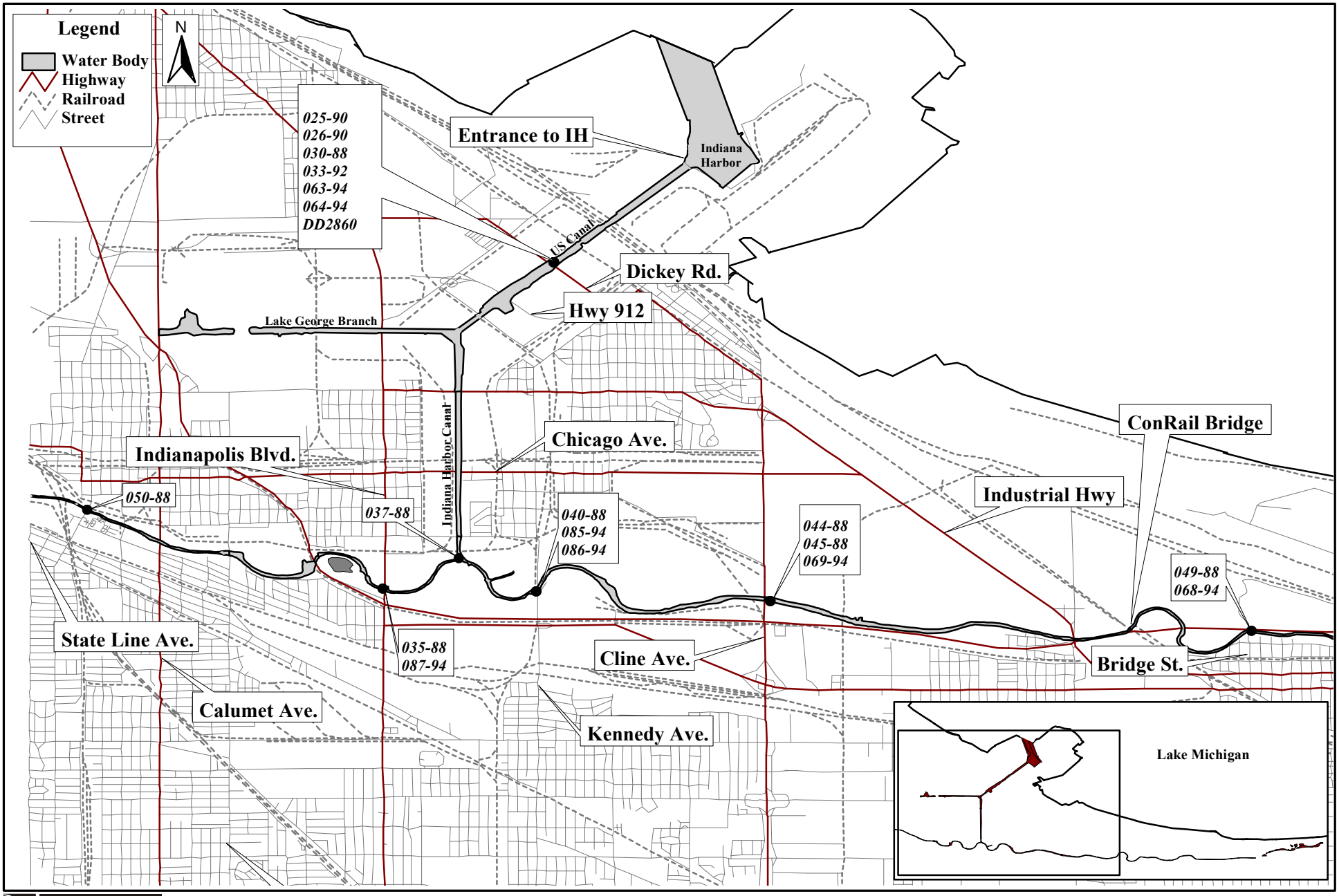
Figure 4.9. Location of sediment sampling stations for Polls (1988).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 Miles

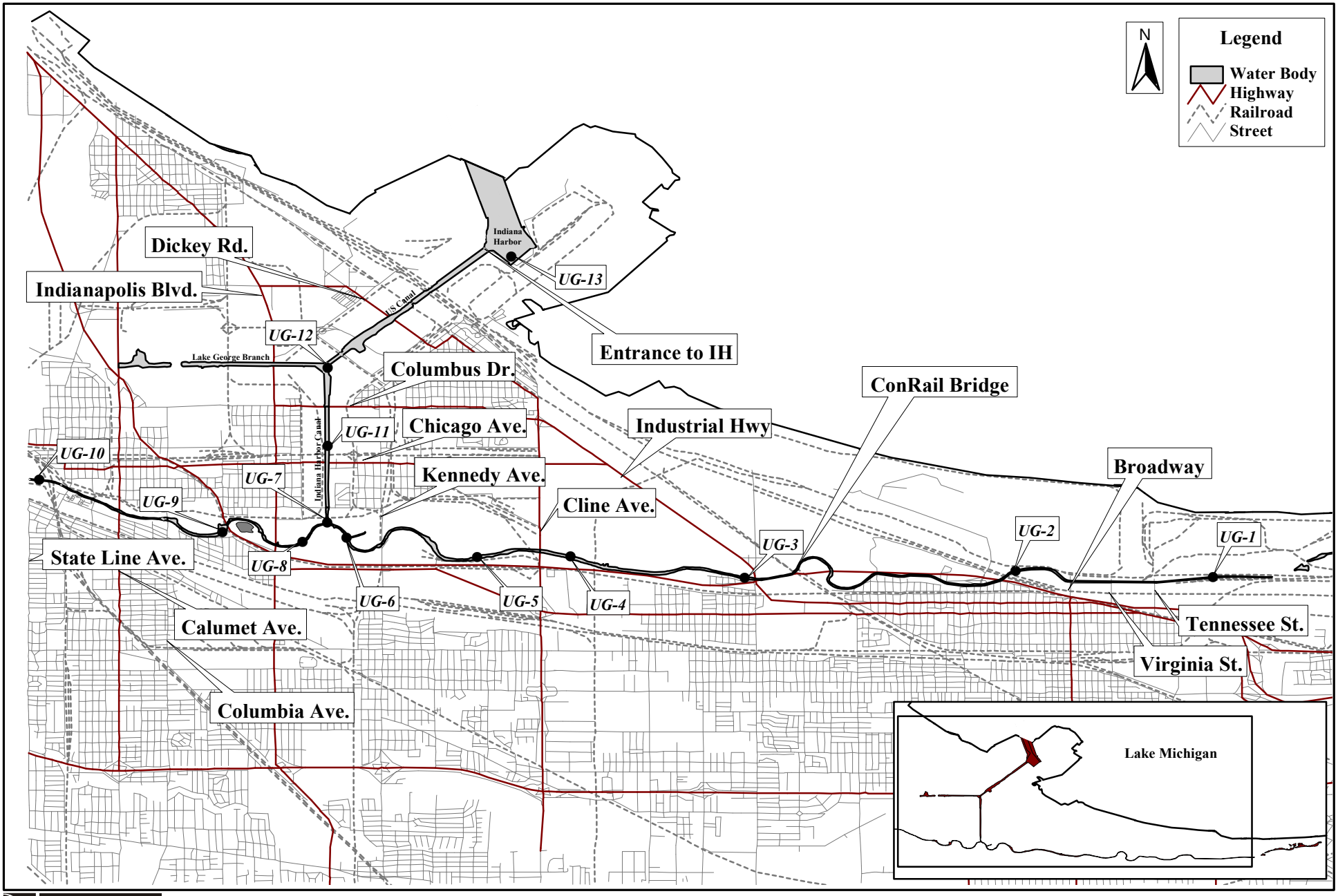
Figure 4.10. Location of sediment sampling stations for IDEM (1994).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

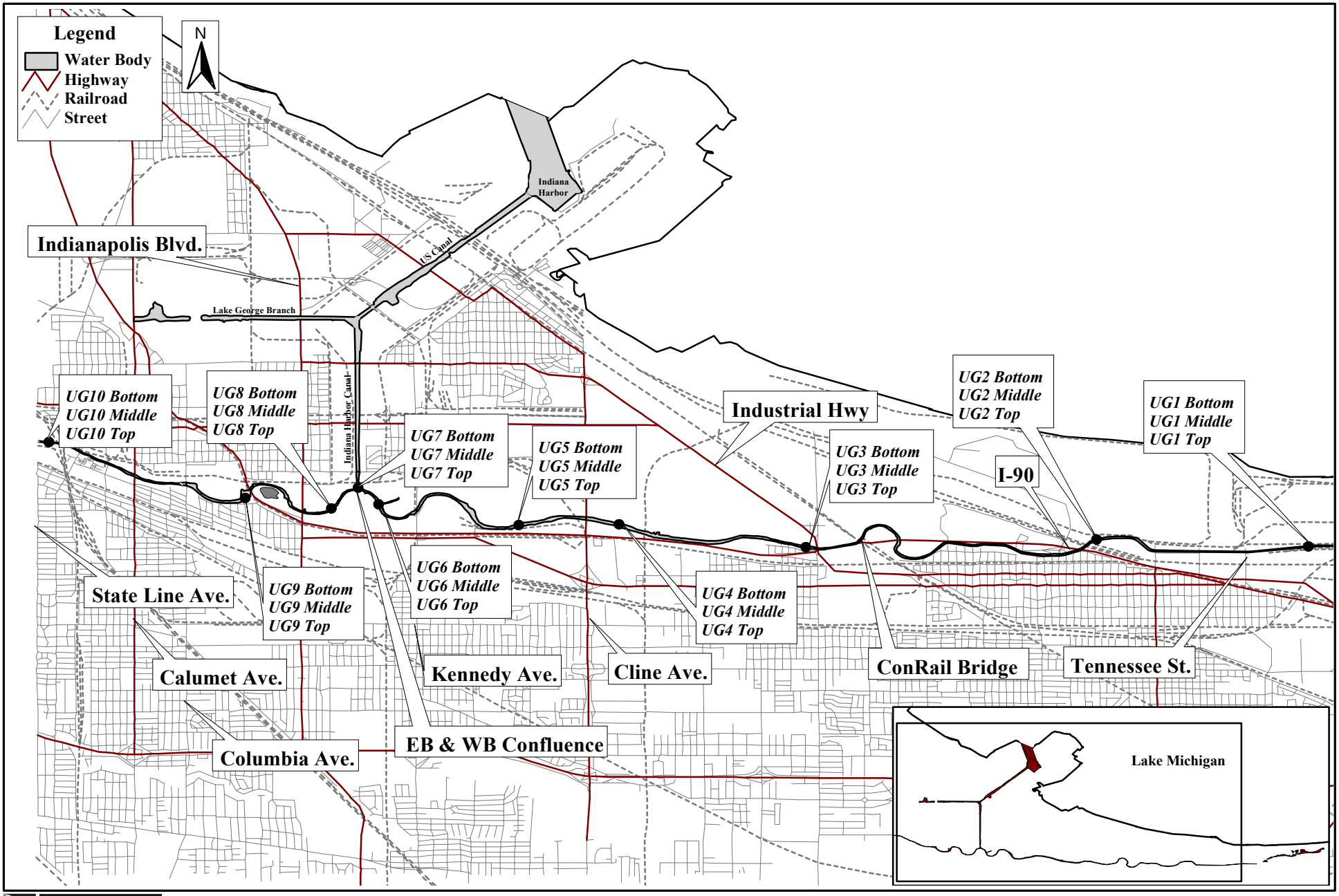
Figure 4.11. Location of sediment sampling stations for Hoke et al. (1993).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

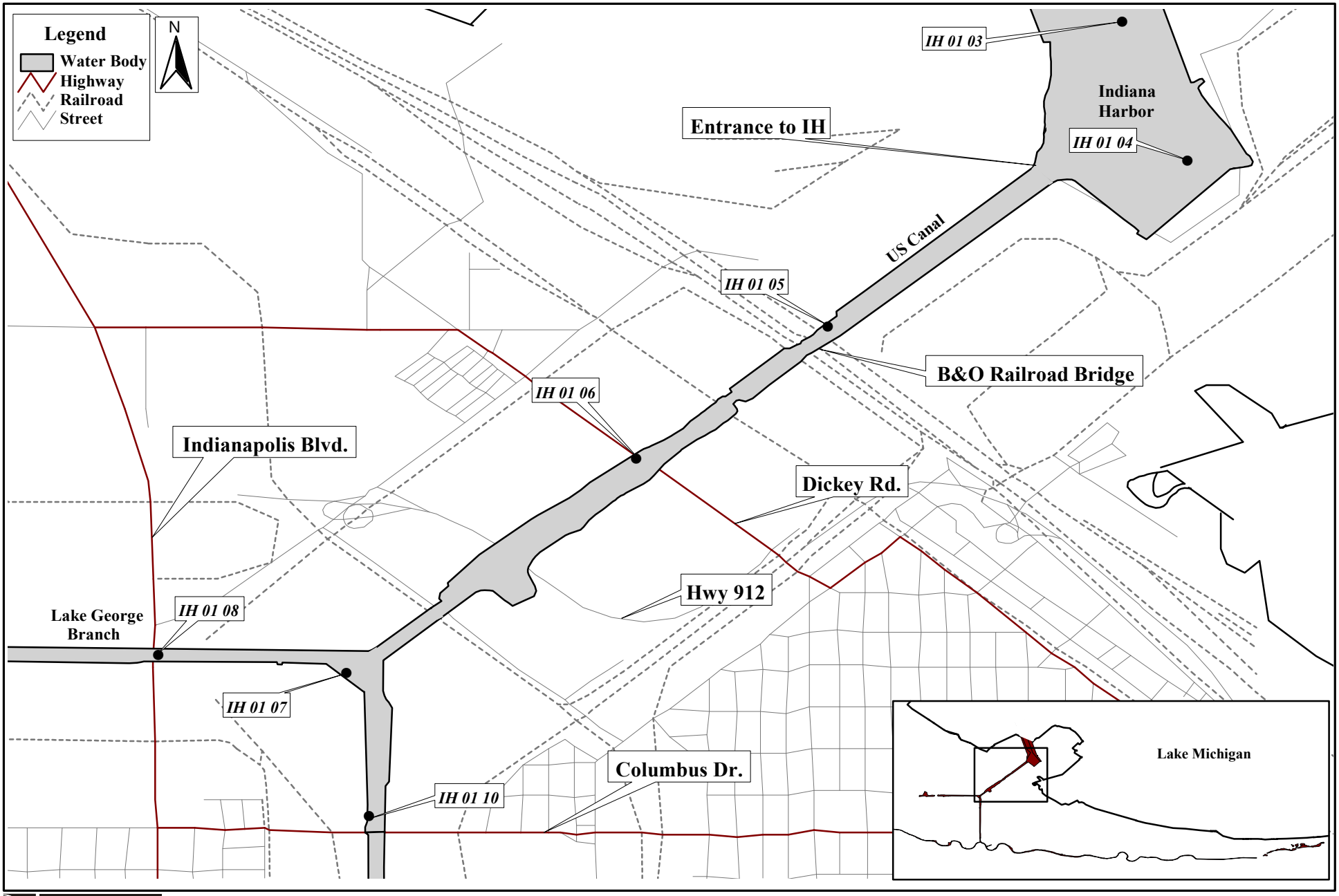
Figure 4.12. Location of sediment sampling stations for Unger (1992).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

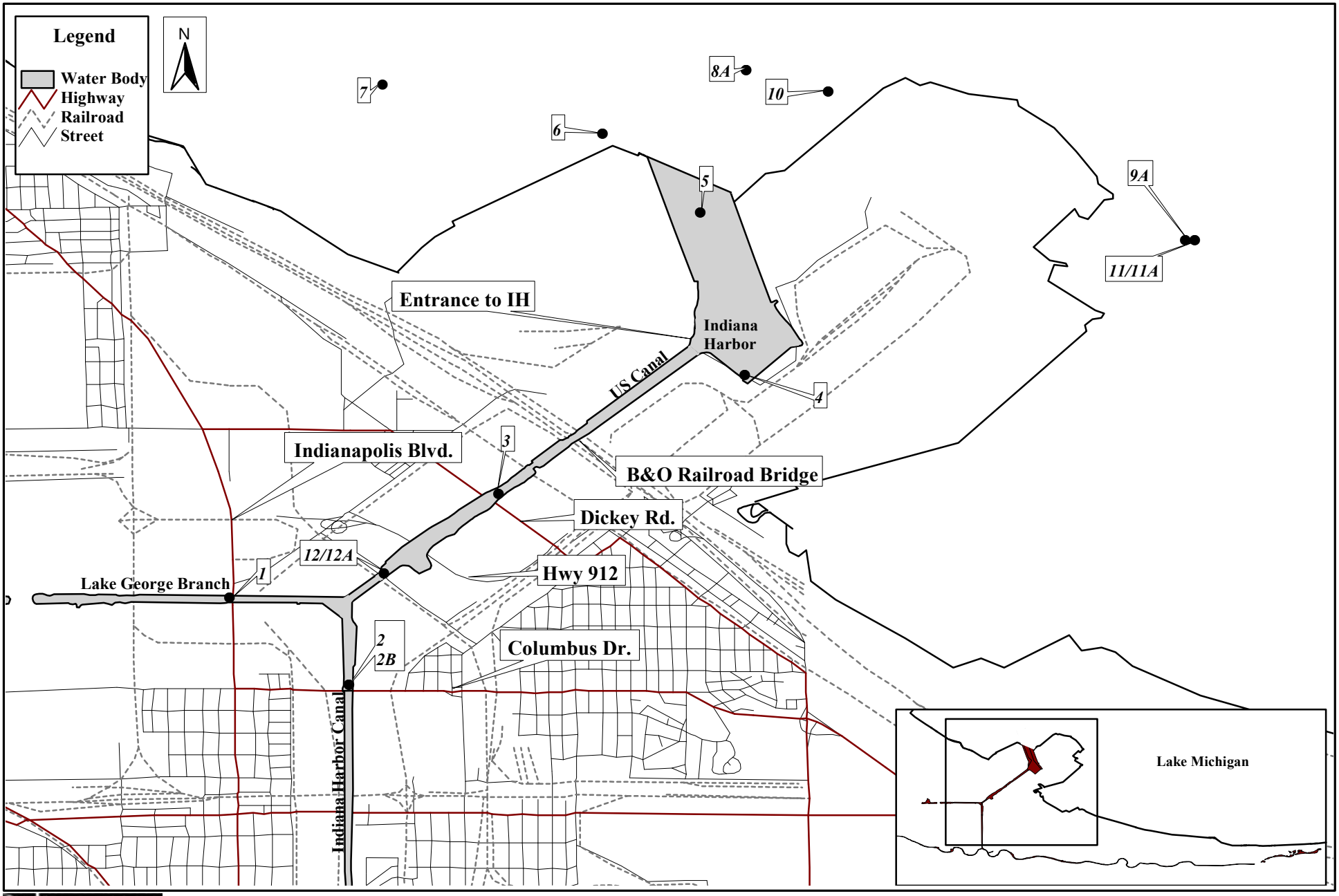
Figure 4.13. Location of sediment and benthic macroinvertebrate sampling stations for USEPA (1996a).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

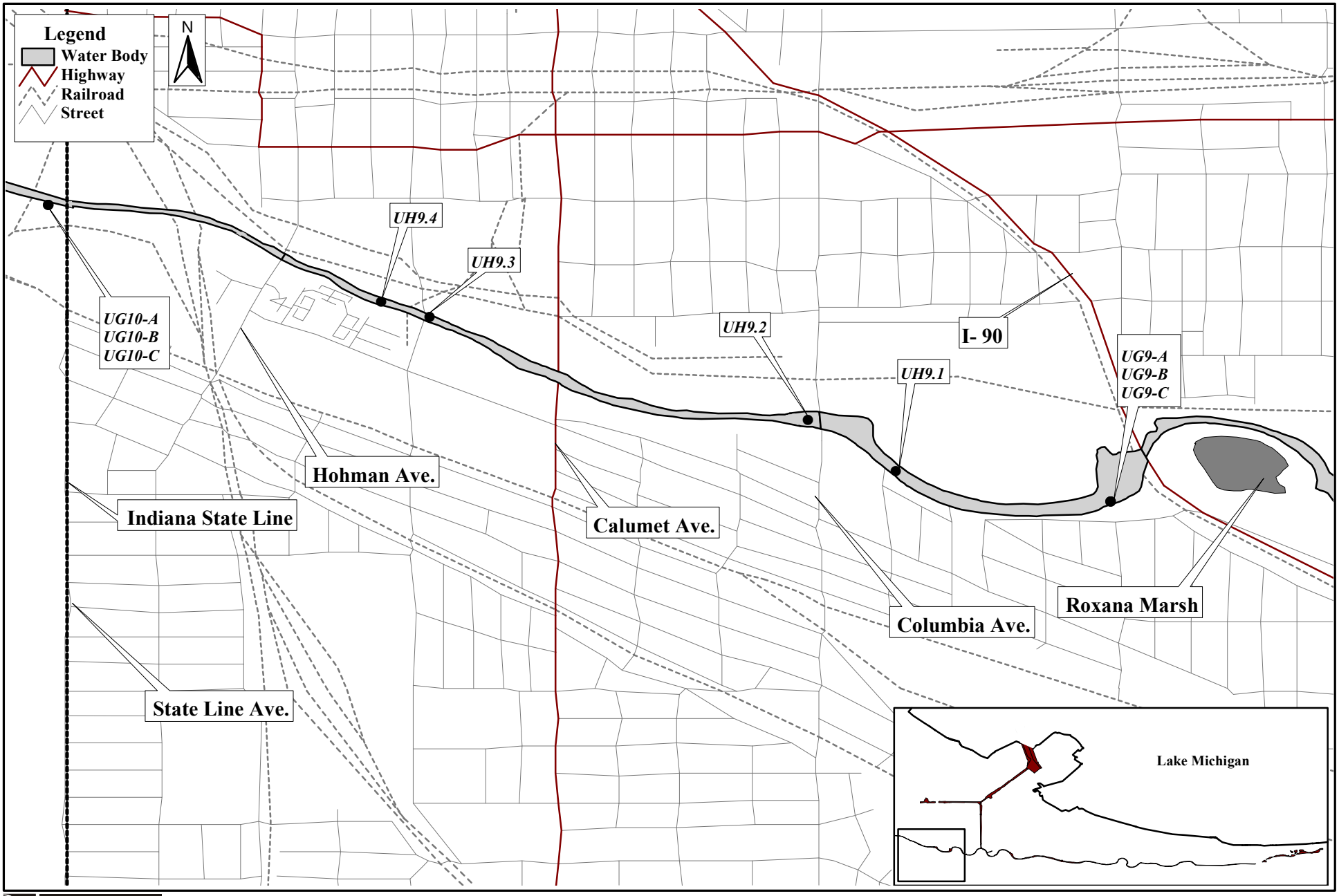
Figure 4.14. Location of sediment and benthic macroinvertebrate sampling stations for Risatti and Ross (1989).



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 Miles

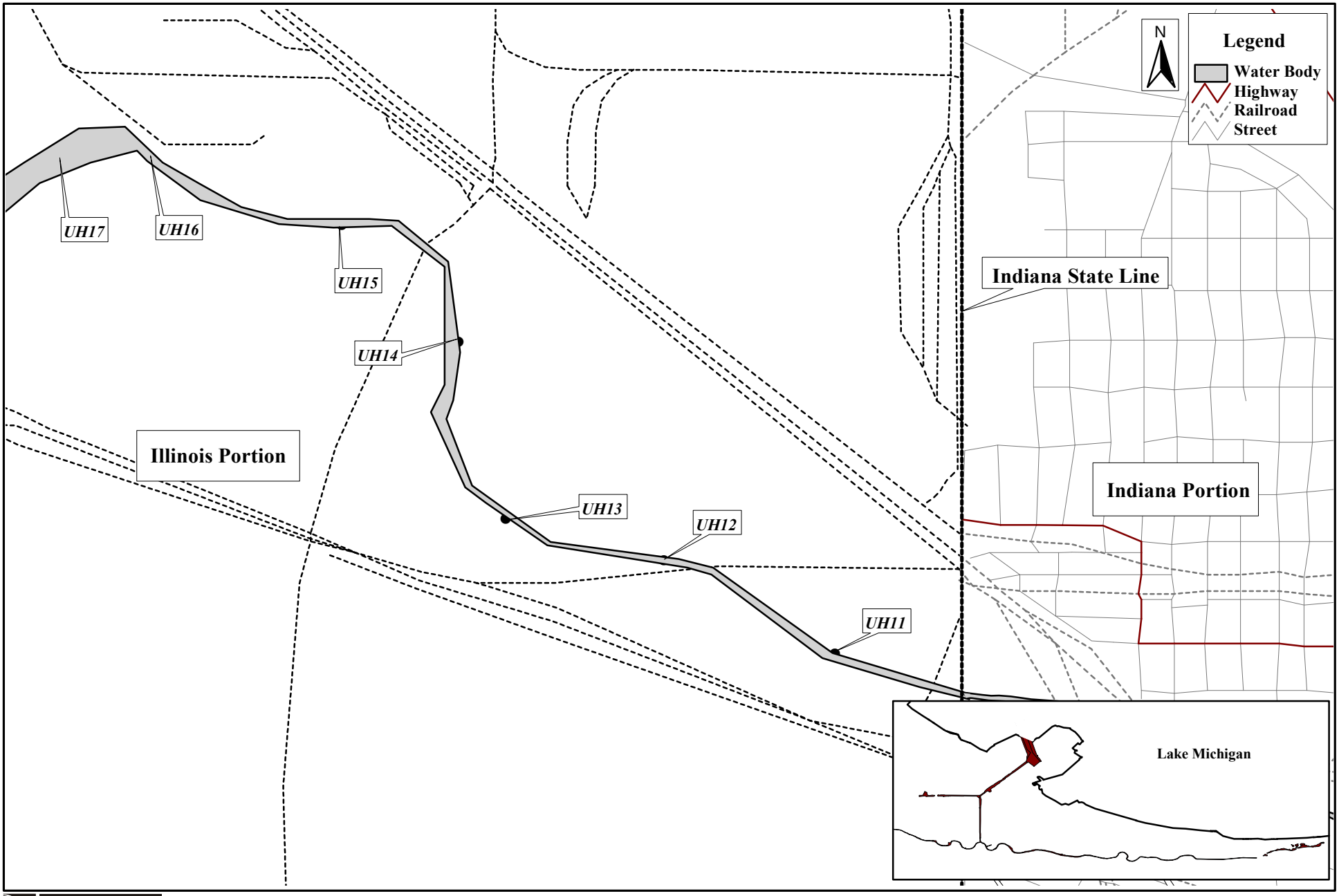
Figure 4.15. Location of sediment sampling stations for HNTB (1989).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 Miles

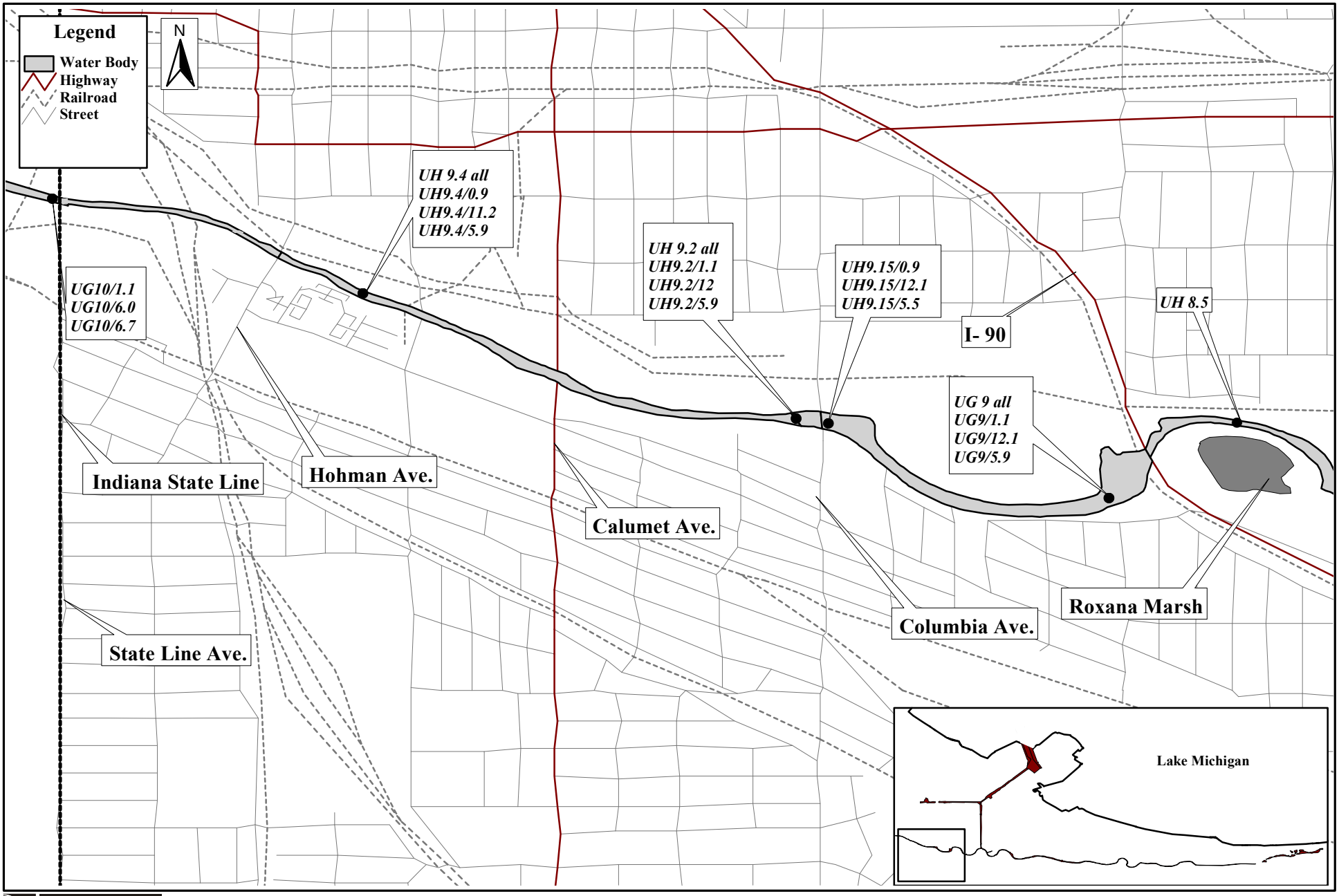
Figure 4.16. Location of sediment sampling stations for HNTB (1990).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 Miles

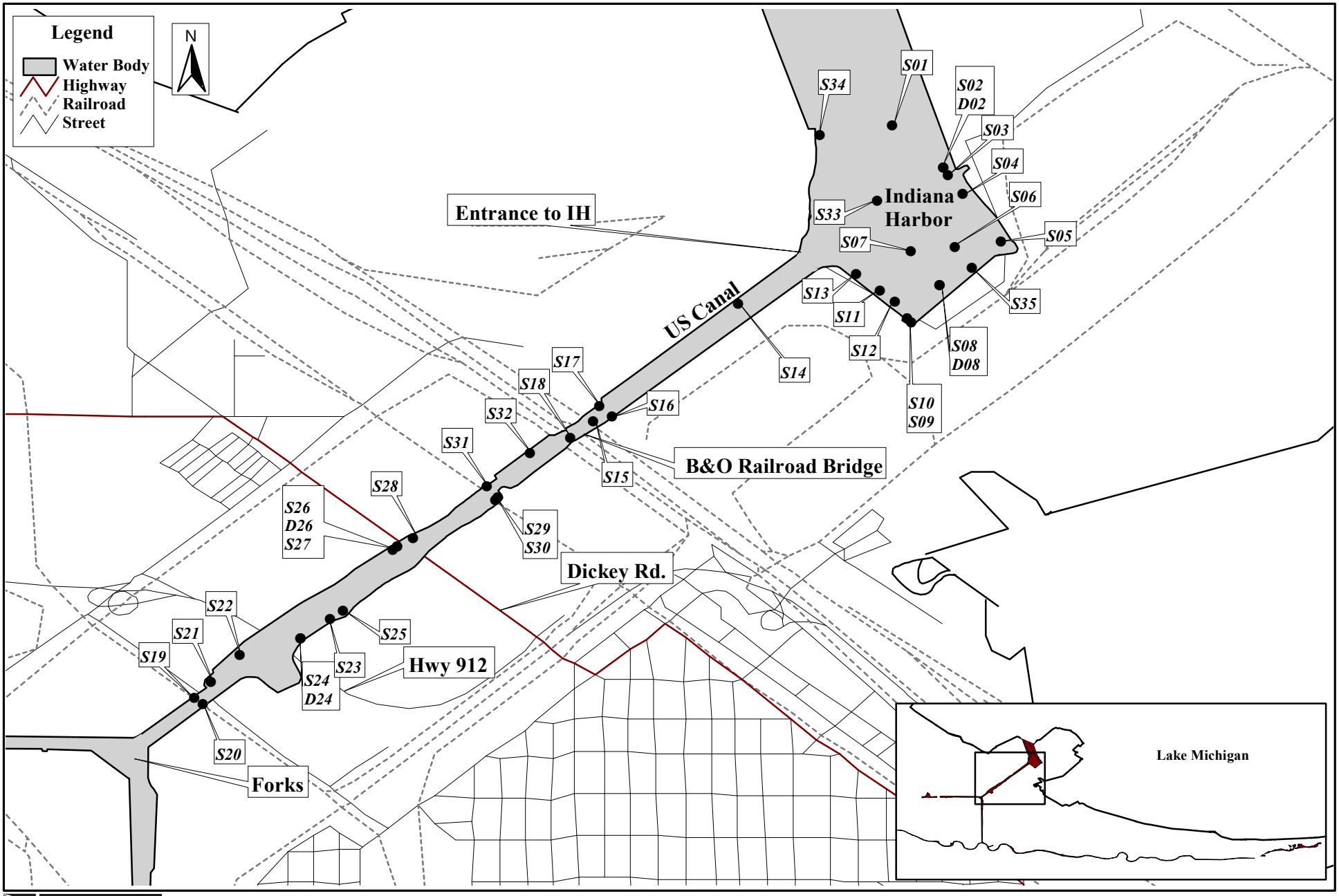
Figure 4.17. Location of sediment sampling stations for HNTB (1991).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 Miles

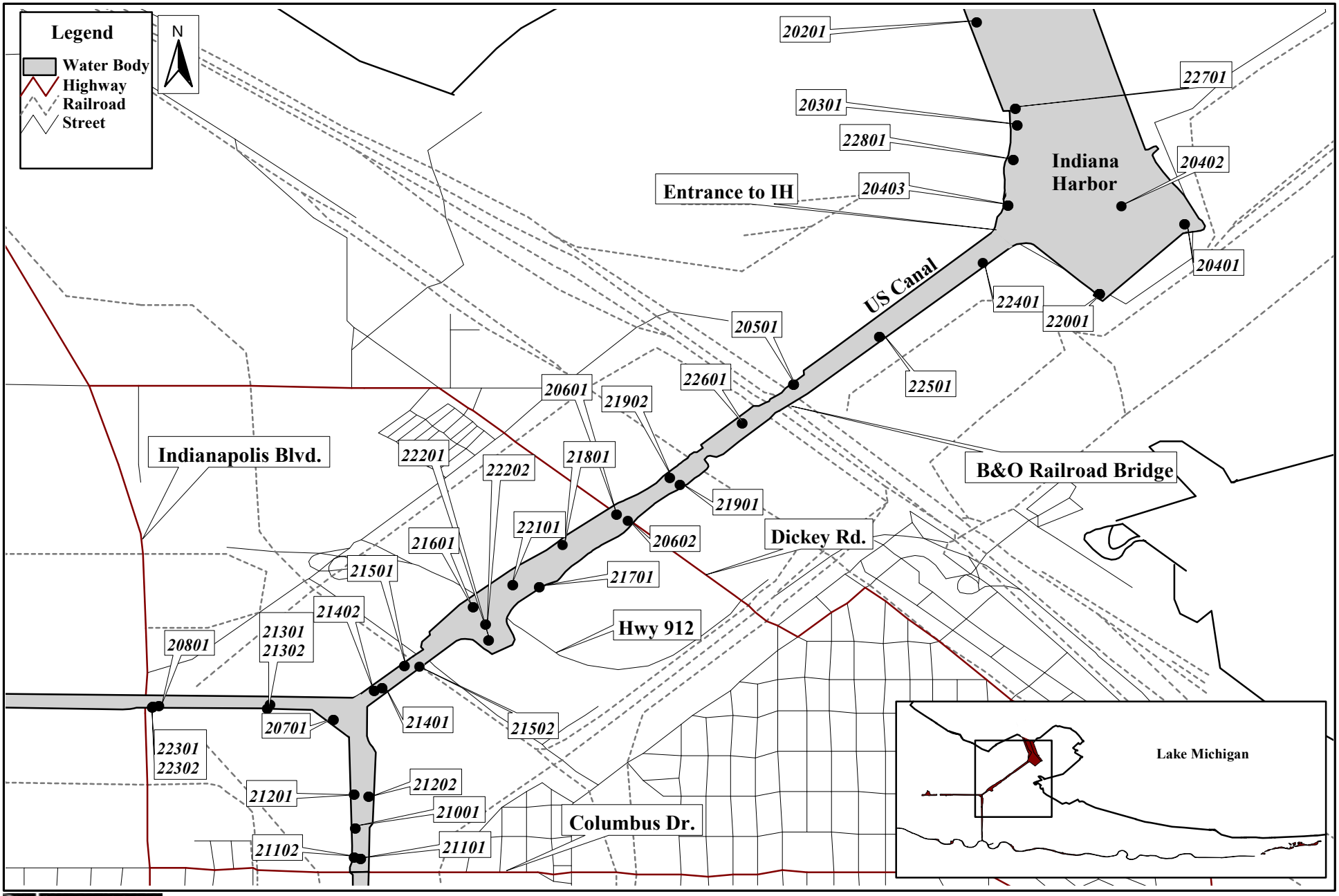
Figure 4.18. Location of sediment sampling stations for USEPA (1990).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

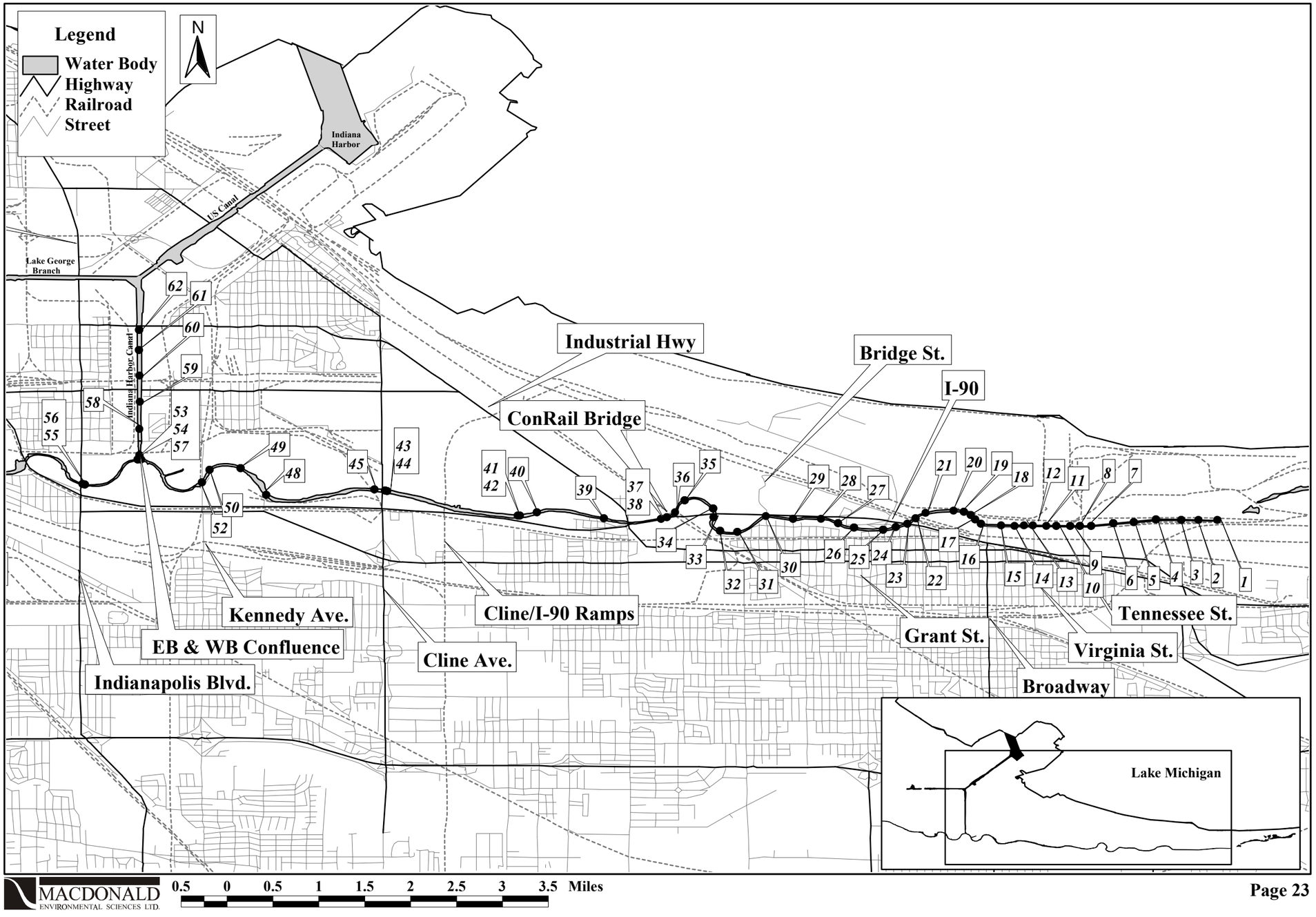
Figure 4.19. Location of sediment sampling stations for USEPA (1996b).



MACDONALD ENVIRONMENTAL SCIENCES LTD

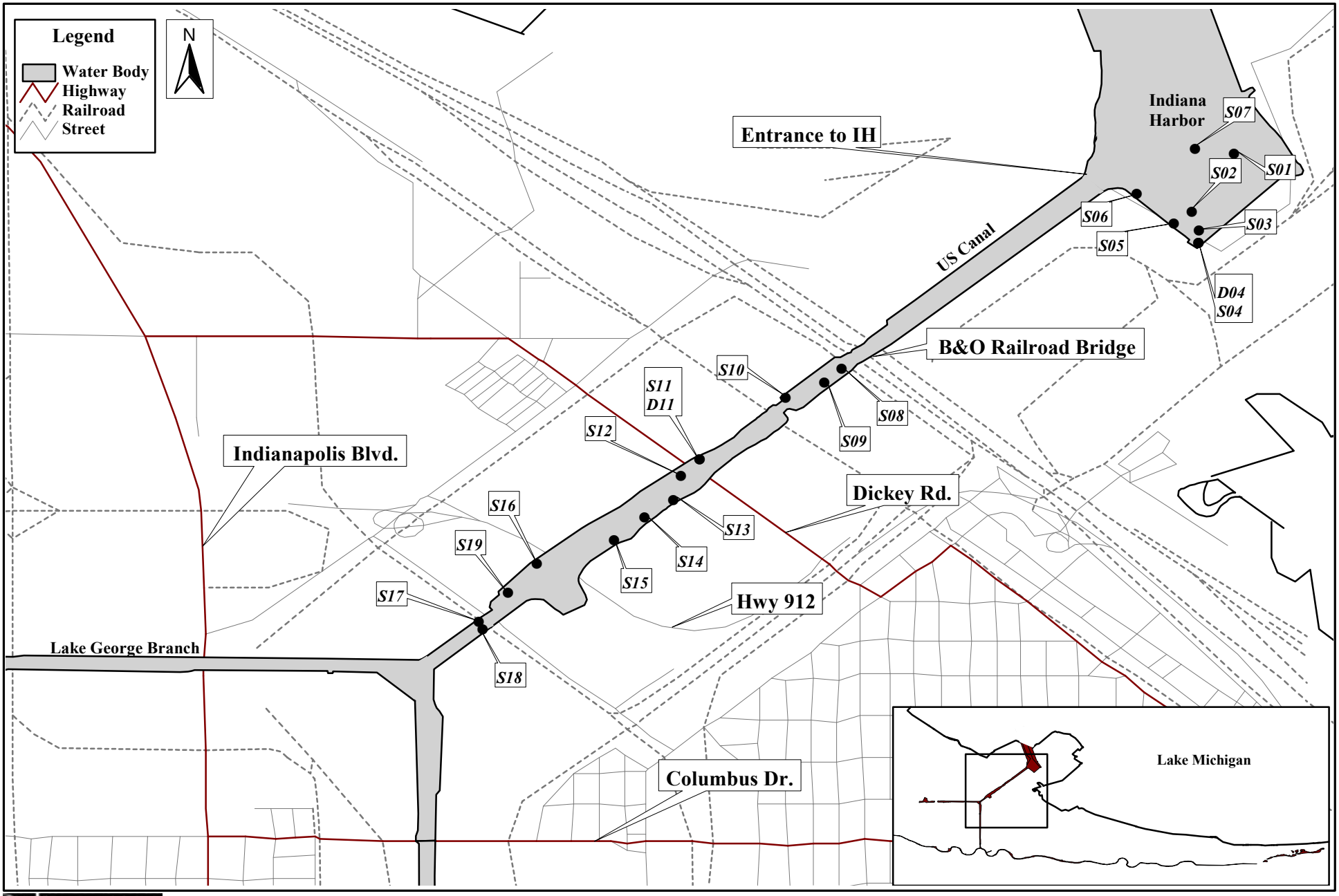
0.5 0 0.5 Miles

Figure 4.20. Location of sediment sampling stations for Floyd-Browne (1993).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

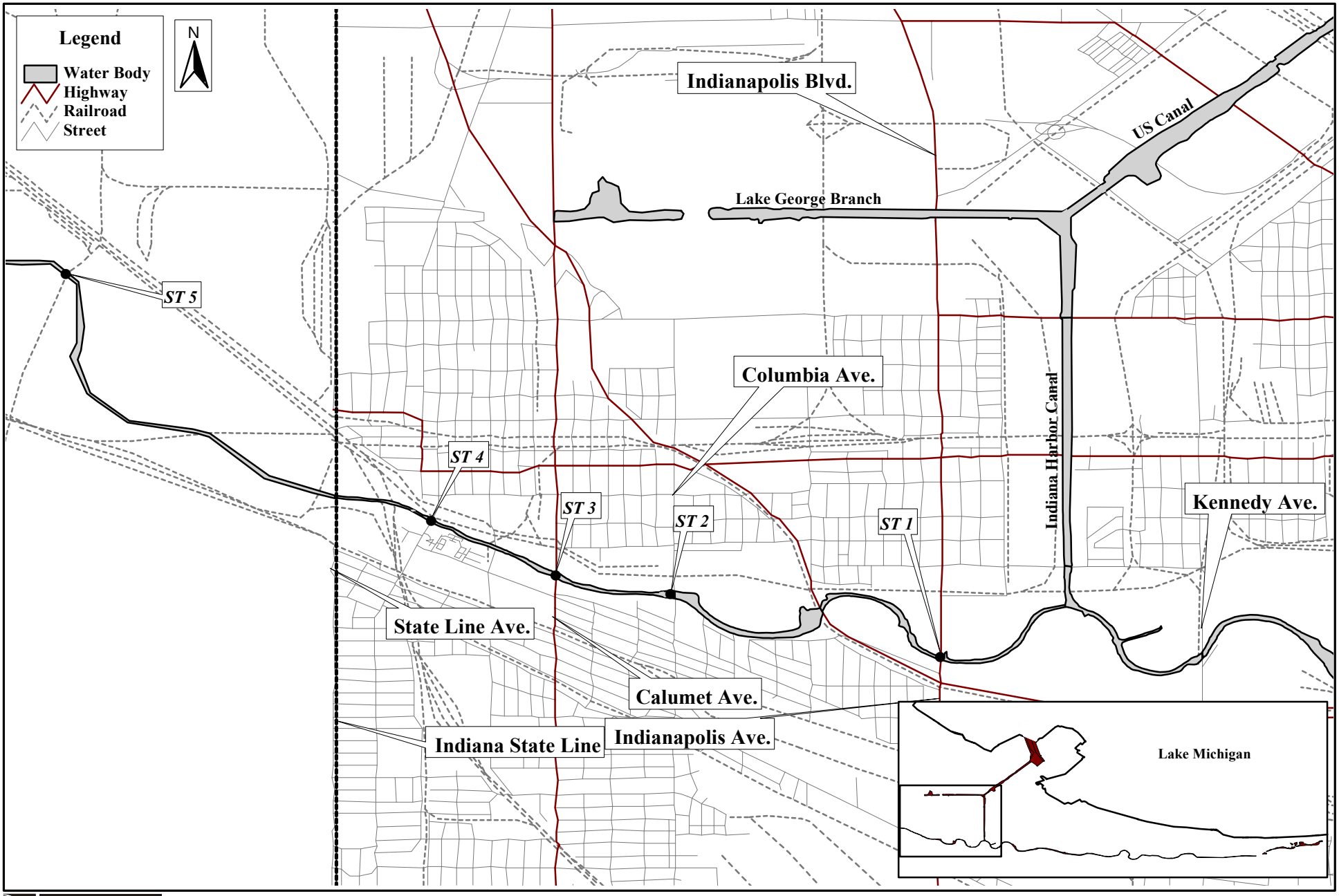
Figure 4.21. Location of sediment sampling stations for USEPA (1991, 1992c).



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 Miles

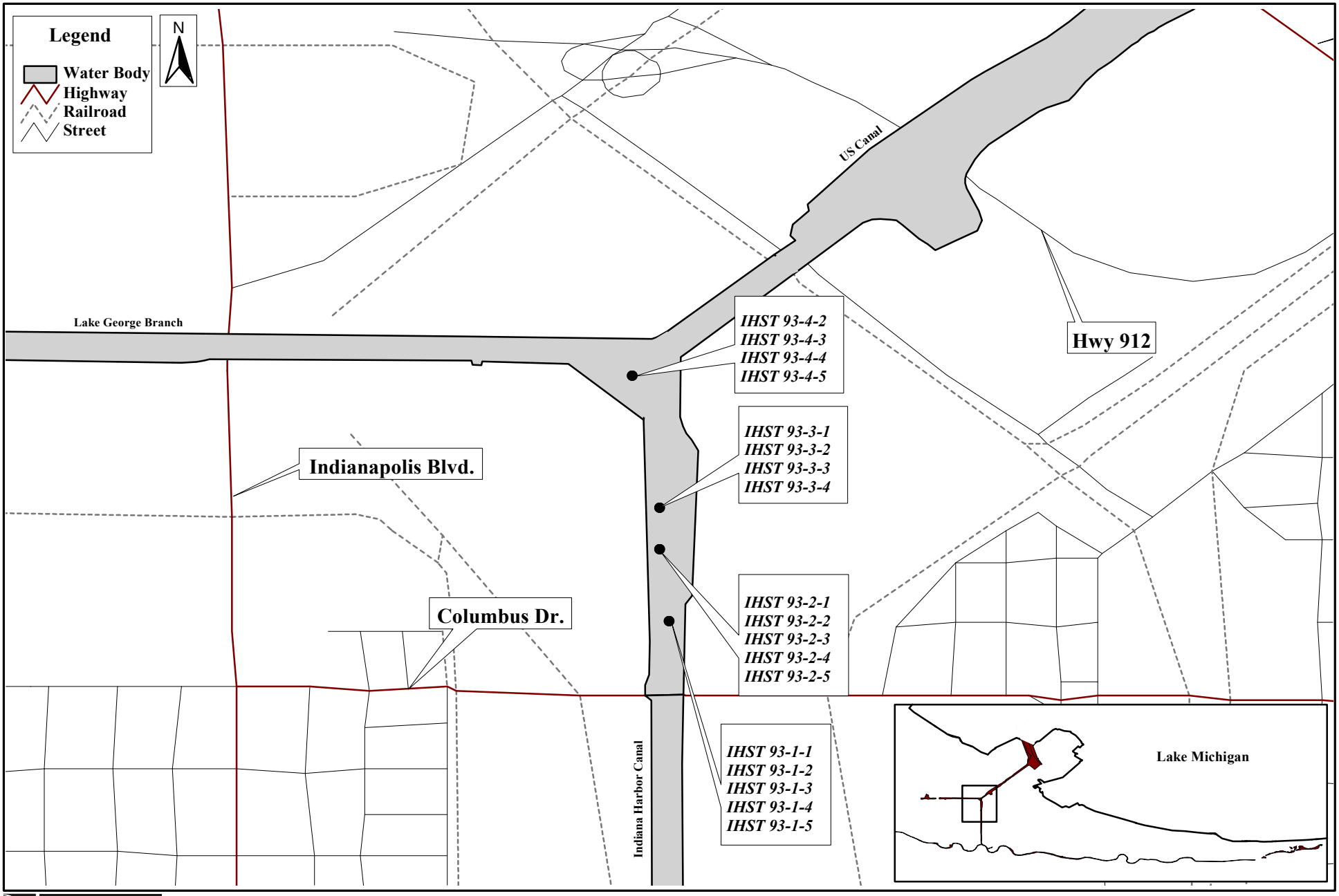
Figure 4.22. Location of benthic macroinvertebrate sampling stations for Rainbolt (1993).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 4.23. Location of sediment sampling stations for USACE (1994).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

Figure 4.24. Location of sediment sampling stations for Burton (1994); Dorkin (1994).

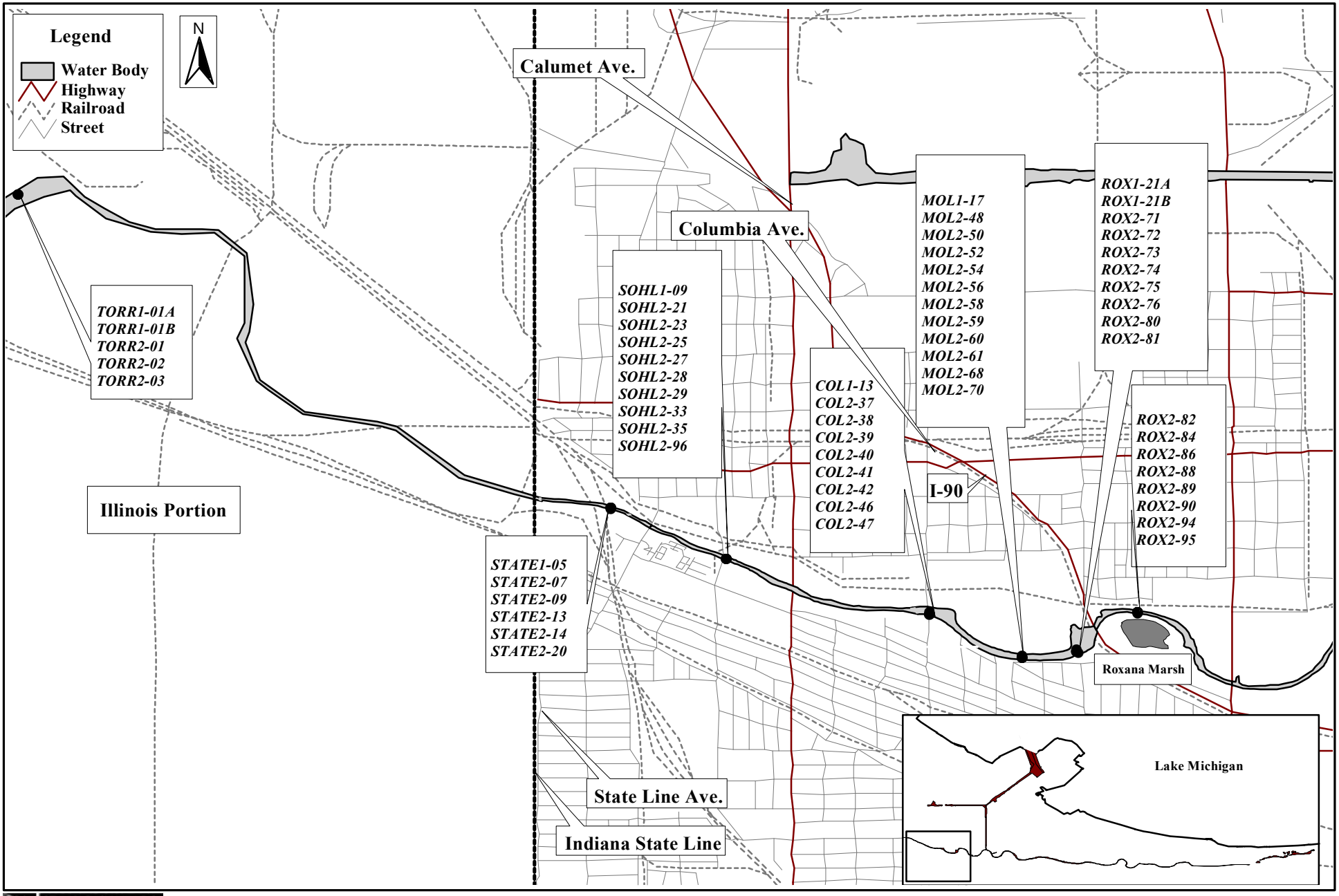
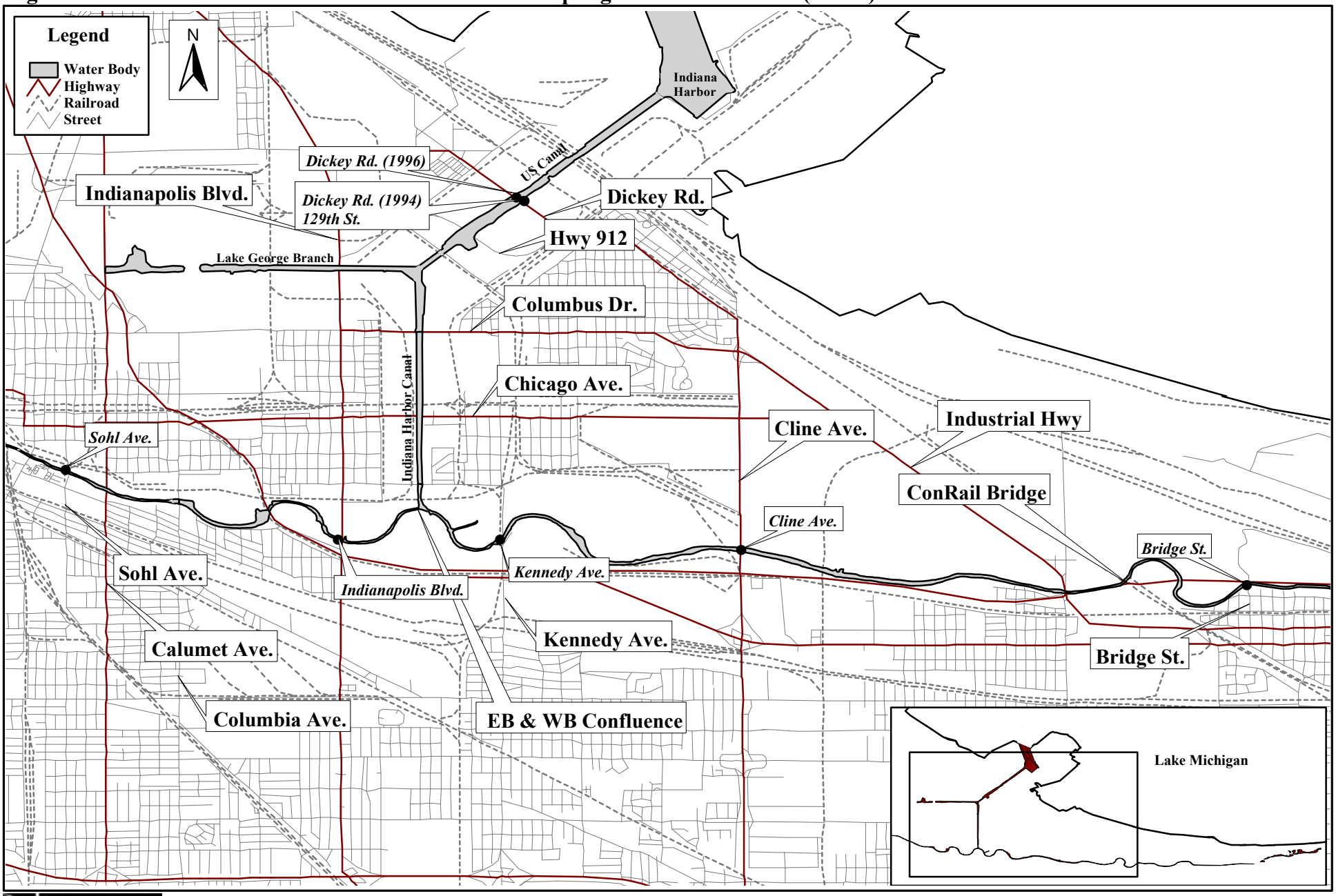


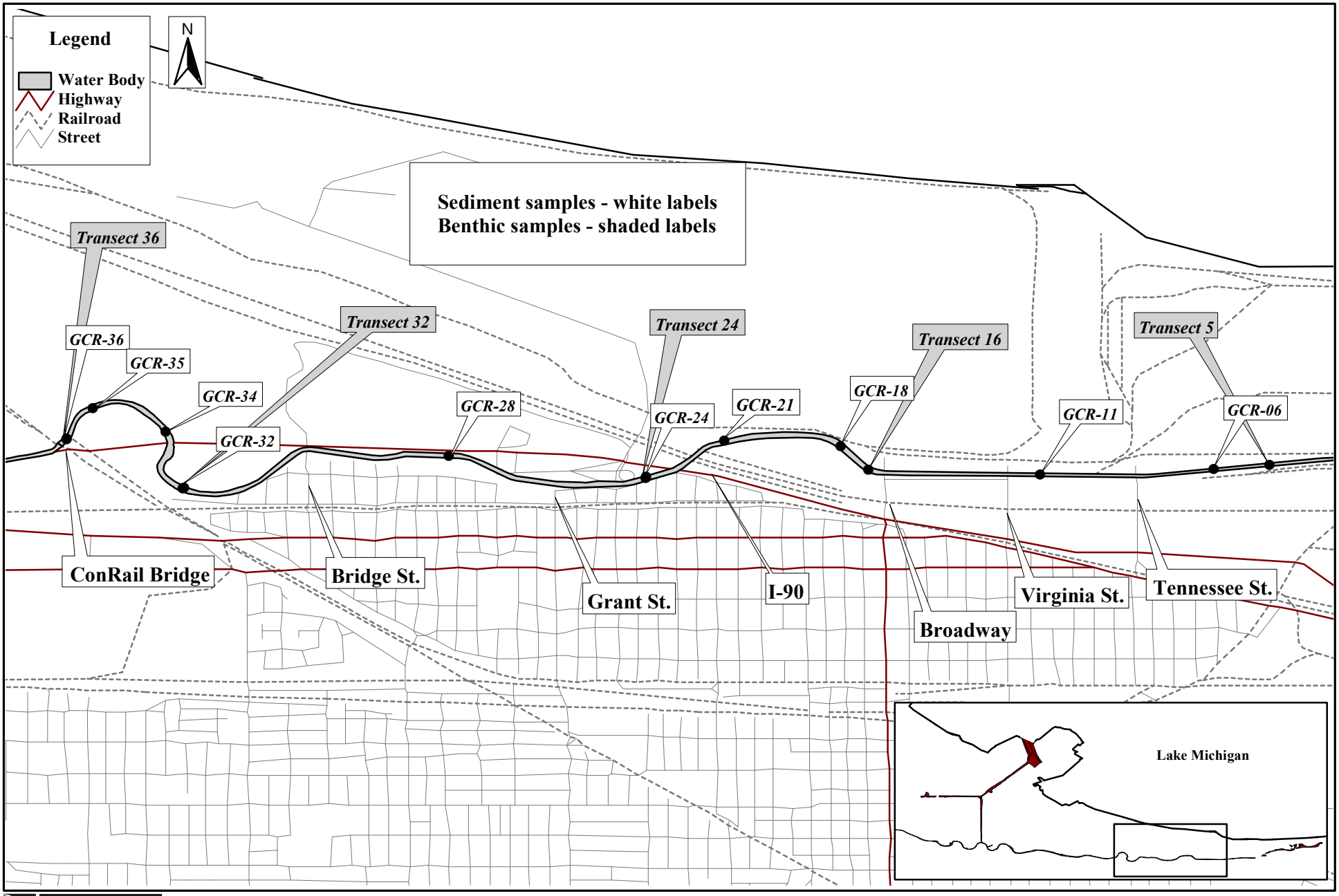
Figure 4.25. Location of benthic macroinvertebrate sampling stations for IDEM (2000a).



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

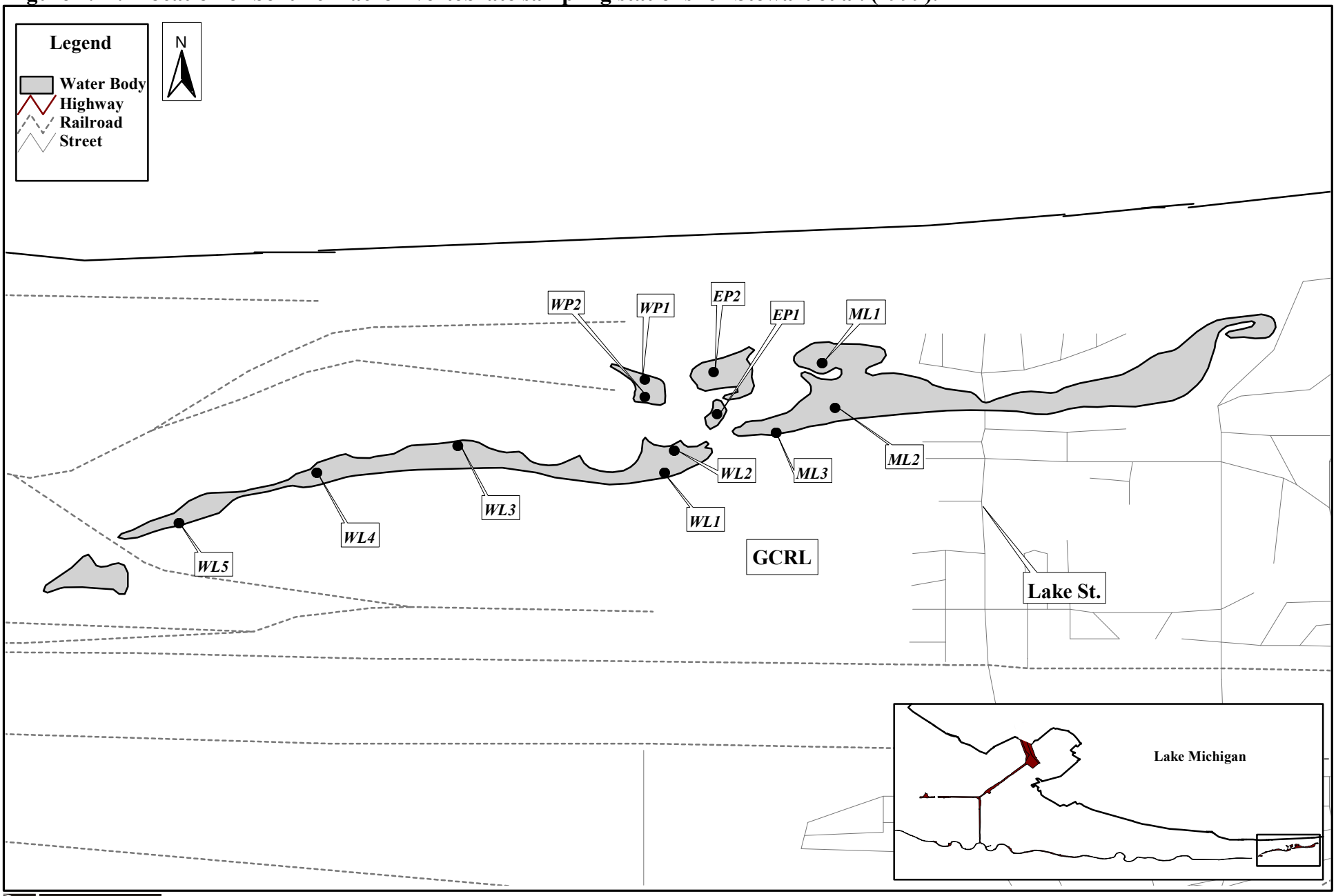
Figure 4.26. Location of sediment and benthic macroinvertebrate sampling stations for Sobiech et al. (1994).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 Miles

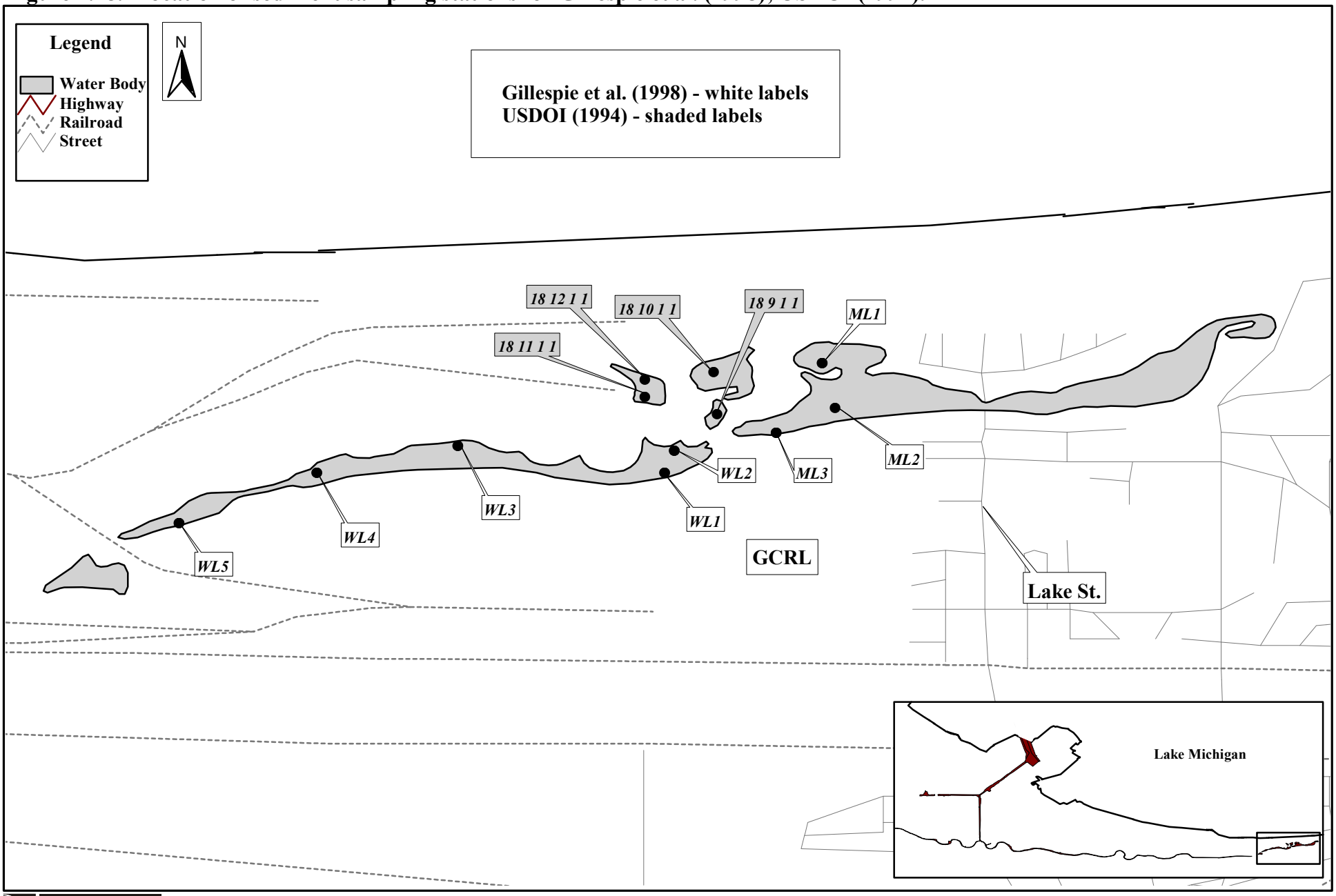
Figure 4.27. Location of benthic macroinvertebrate sampling stations for Stewart et al. (1999).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

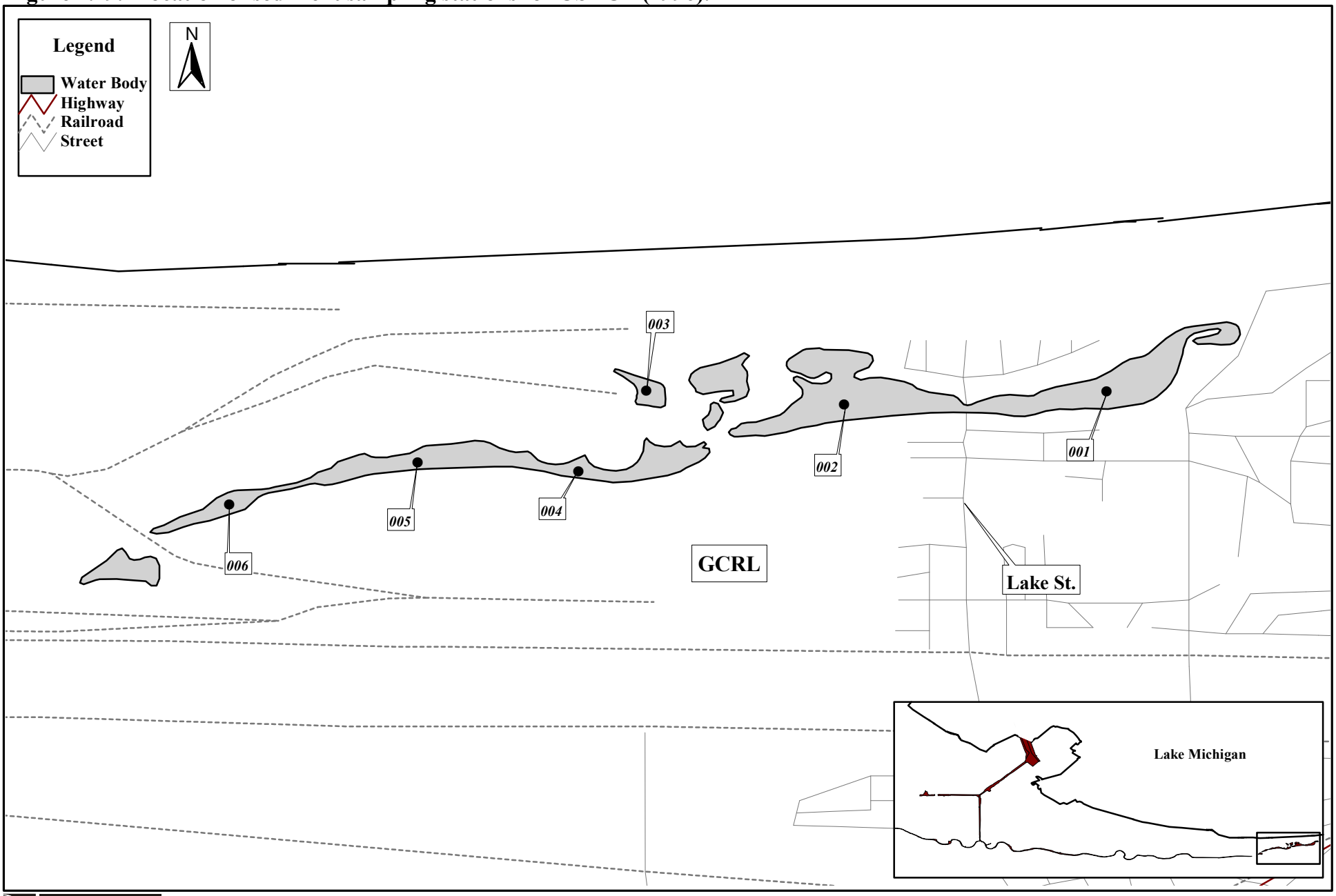
Figure 4.28. Location of sediment sampling stations for Gillespie et al. (1998); USDOI (1994).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

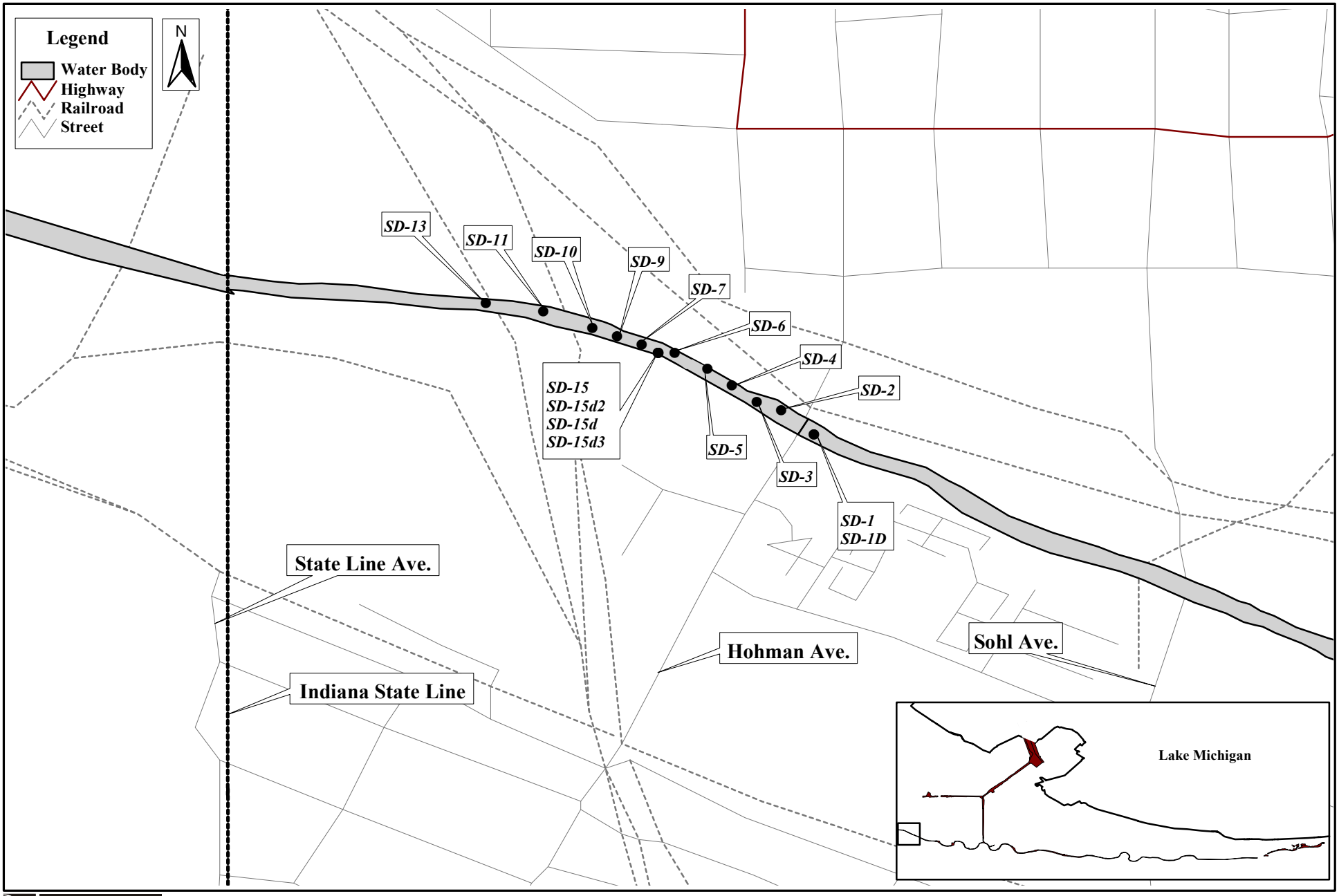
Figure 4.29. Location of sediment sampling stations for USACE (1996).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

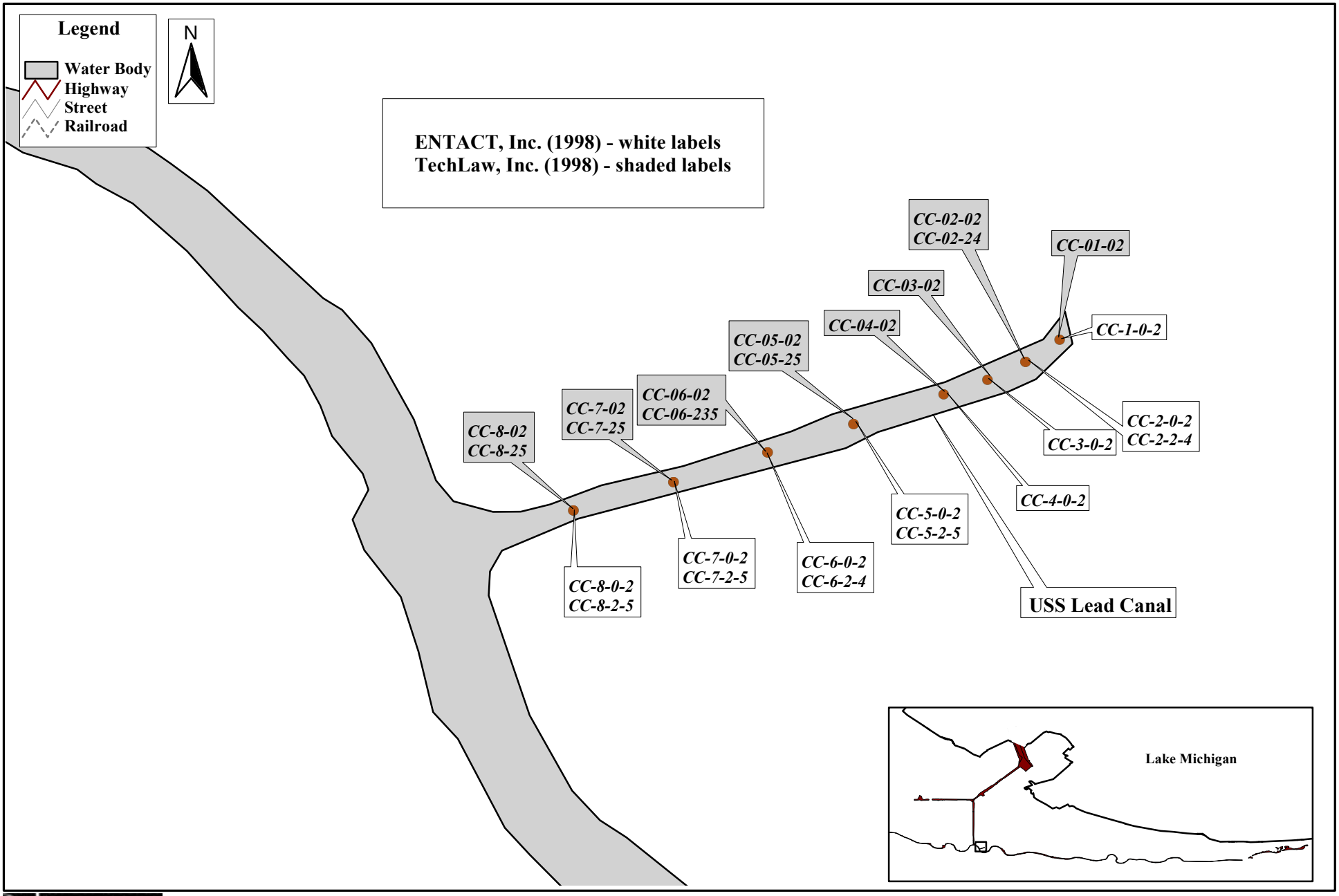
Figure 4.30. Location of sediment sampling stations for RETEC (1997).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.1 0 0.1 0.2 0.3 0.4 Miles

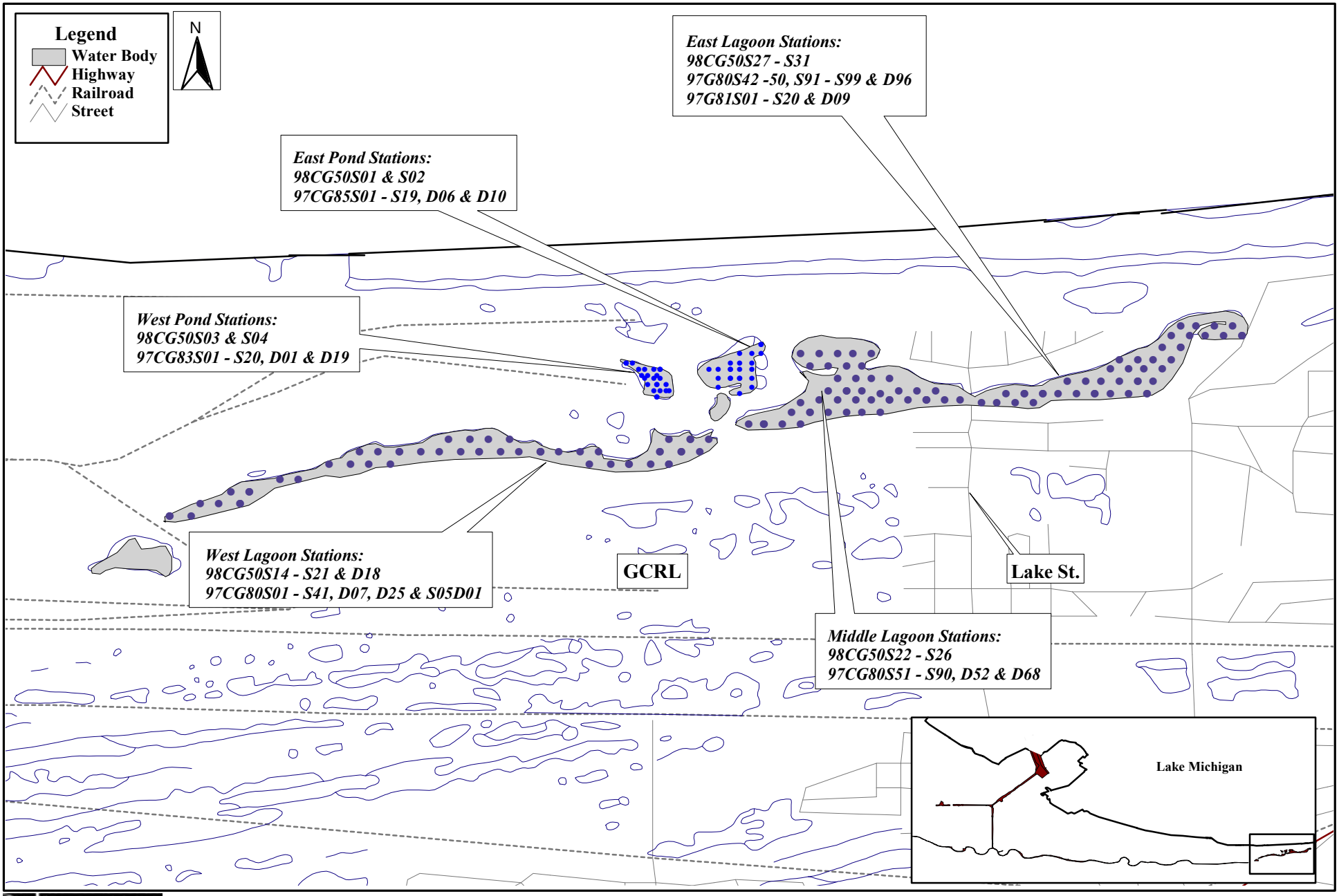
Figure 4.31. Location of sediment sampling stations for ENTACT, Inc. (1998) and TechLaw, Inc. (1998).



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.05 0 0.05 0.1 0.15 Miles

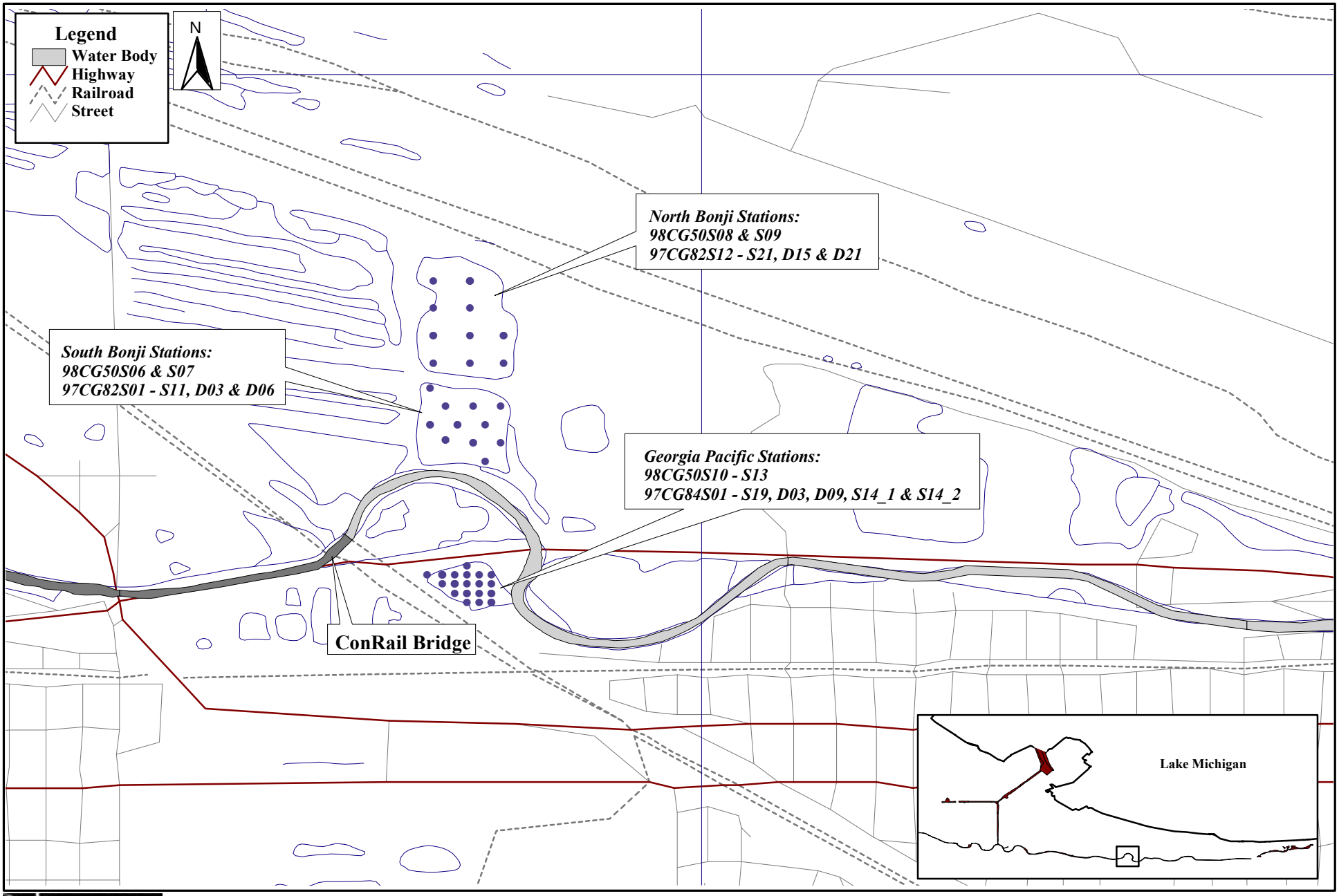
Figure 4.32a. Location of sediment sampling stations for Simon (2000).



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 Miles

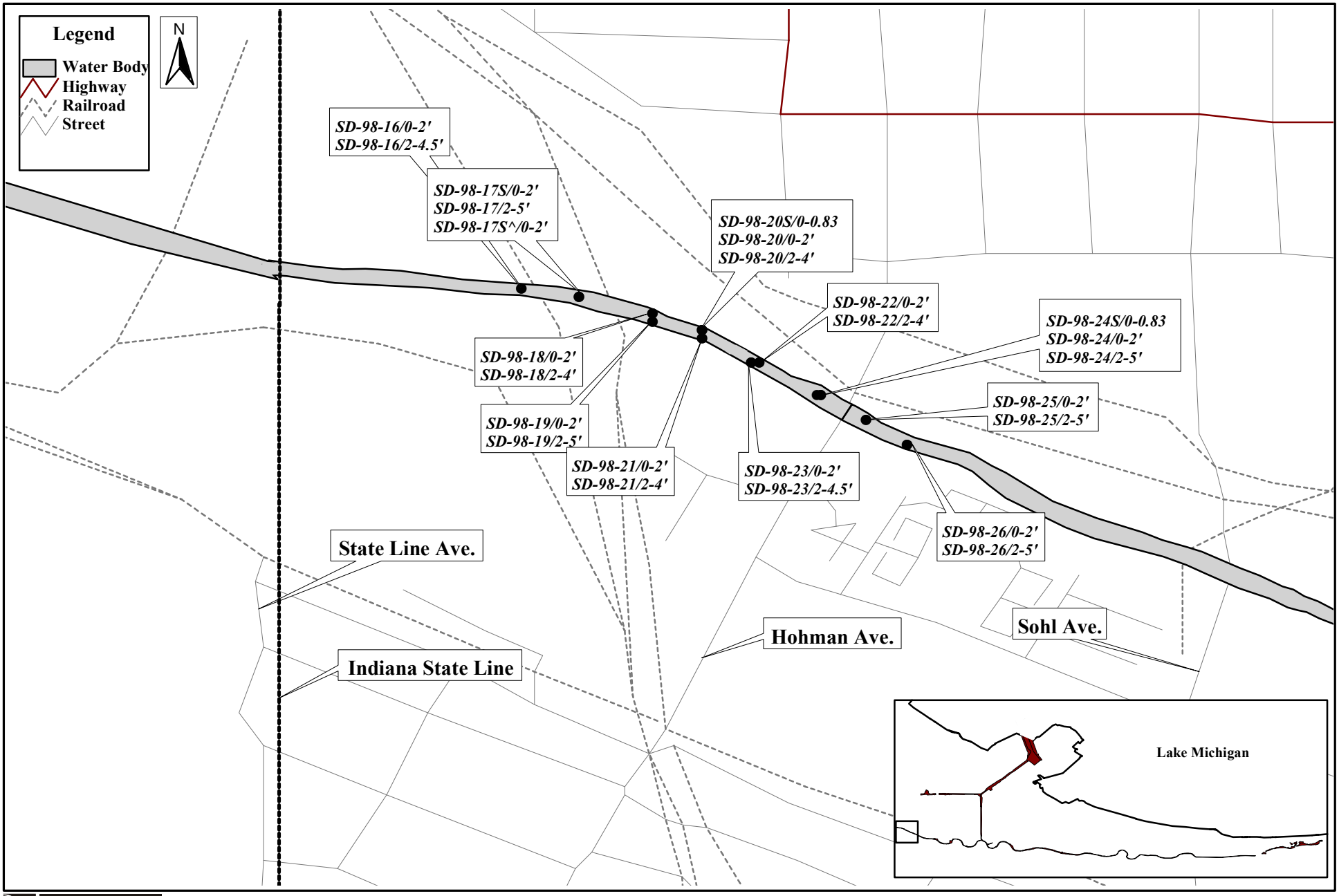
Figure 4.32b. Location of sediment sampling stations for Simon (2000).



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

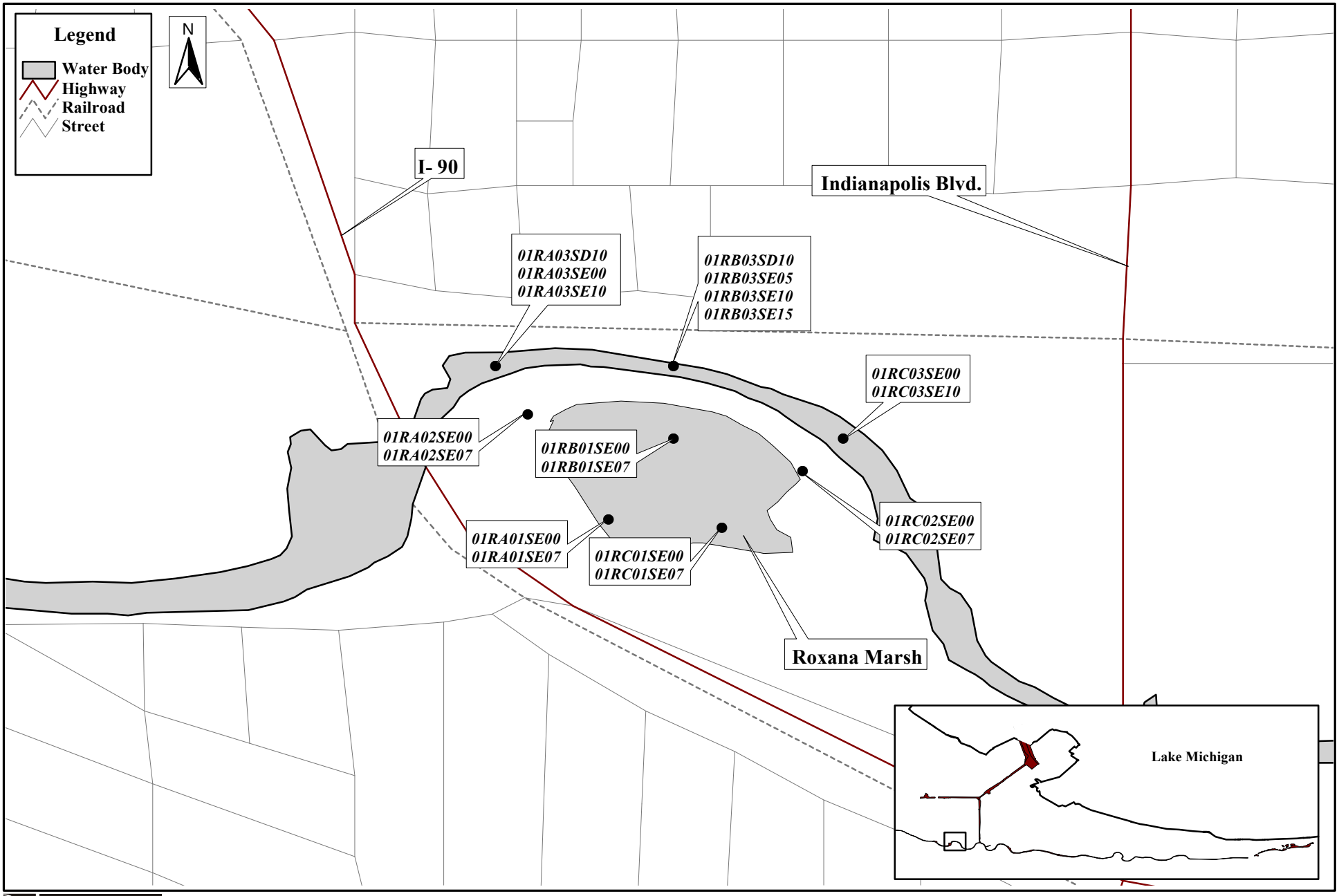
Figure 4.33. Location of sediment and benthic macroinvertebrate sampling stations for ThermoRetec (1999).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.1 0 0.1 0.2 0.3 0.4 Miles

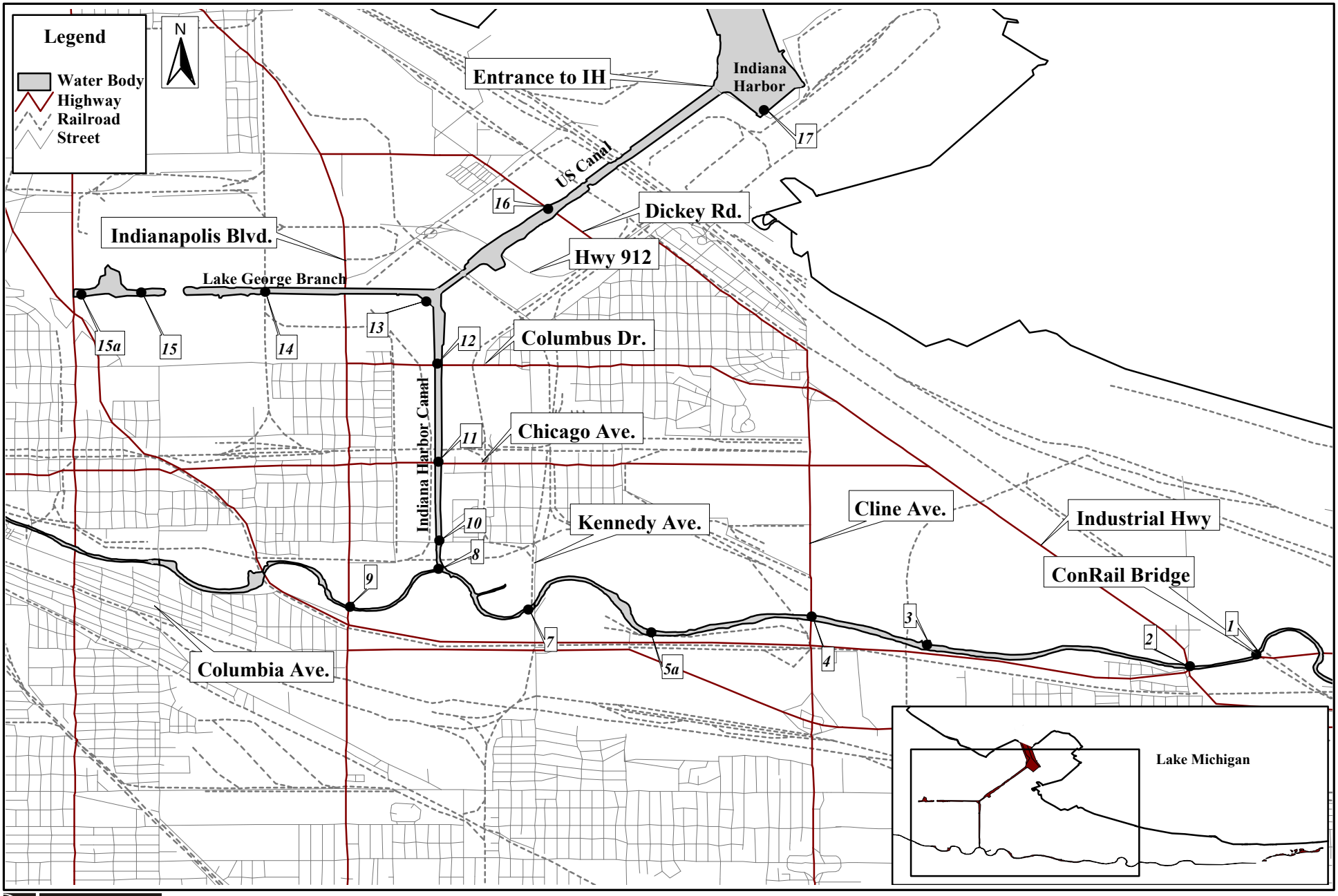
Figure 4.34. Location of sediment and benthic macroinvertebrate sampling stations for URS Greiner Woodward Clyde (1999).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0 0.5 Miles

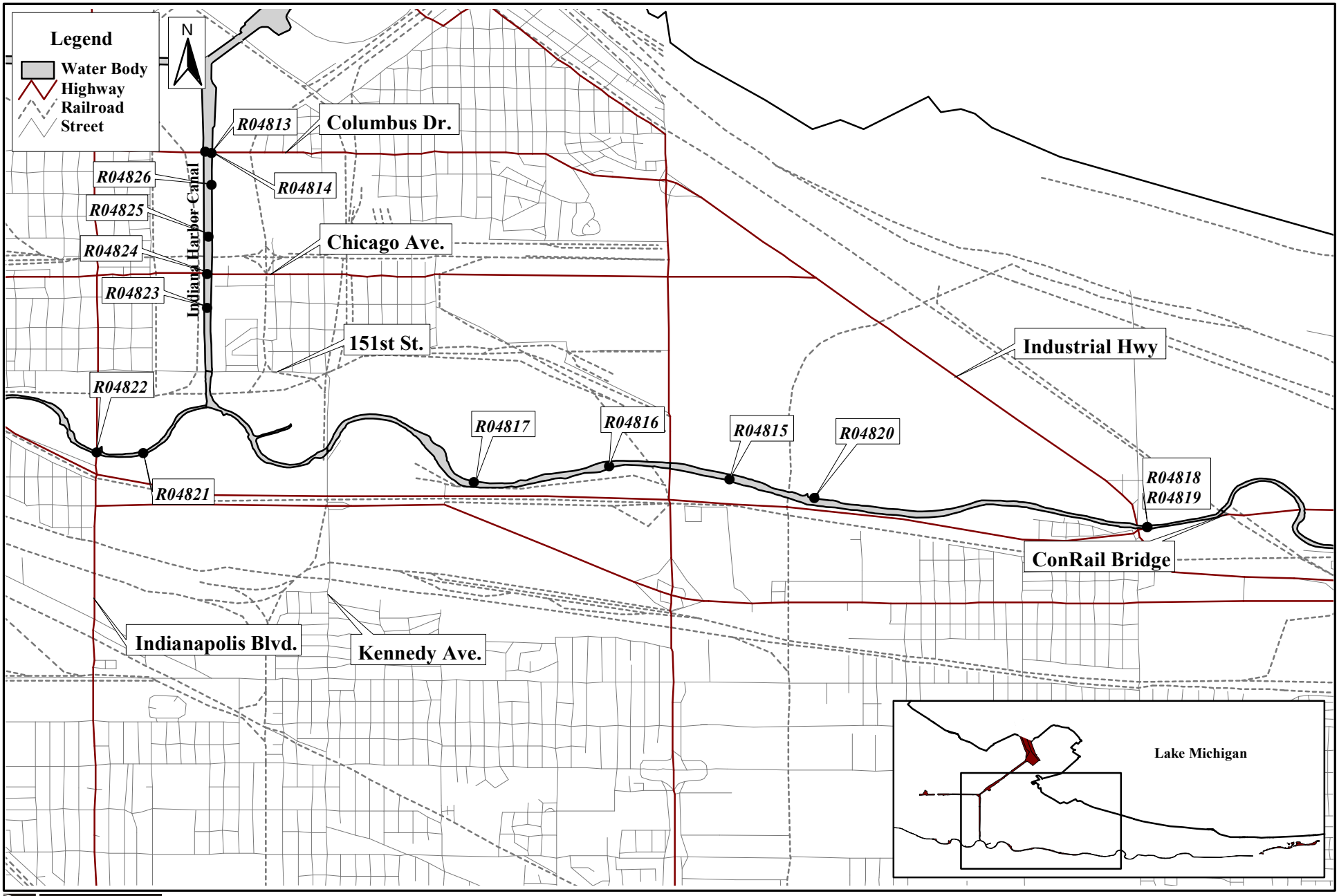
Figure 4.35. Location of benthic macroinvertebrate sampling stations for Simon et al. (2000).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 4.36. Location of sediment sampling stations for IDEM (1998).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 4.37. Location of sediment sampling stations for Exponent (1999) and Tetra Tech EM Inc. (1998).

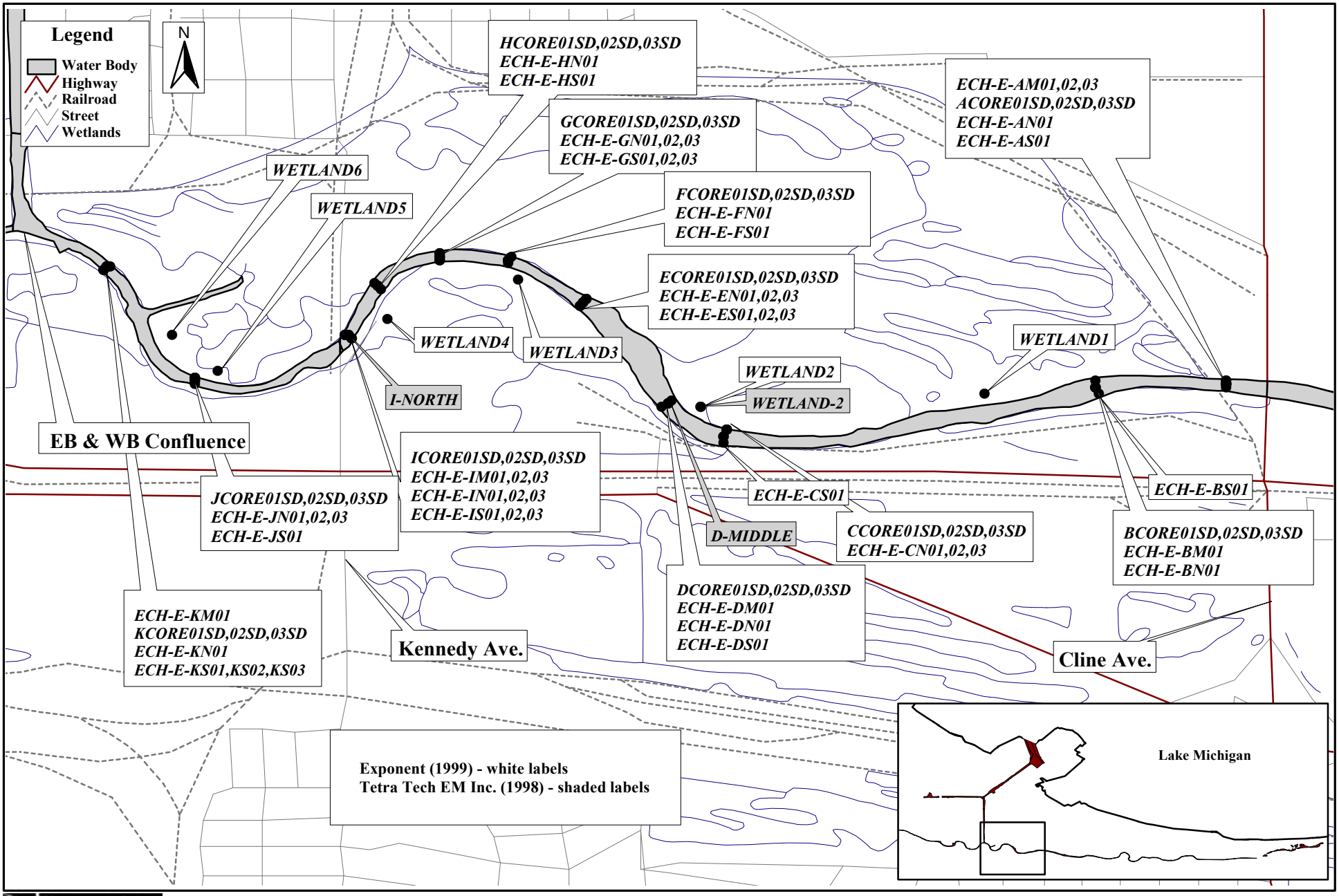


Figure 4.38. Location of sediment sampling stations for Maxim Technologies (1999); USGS (1999).

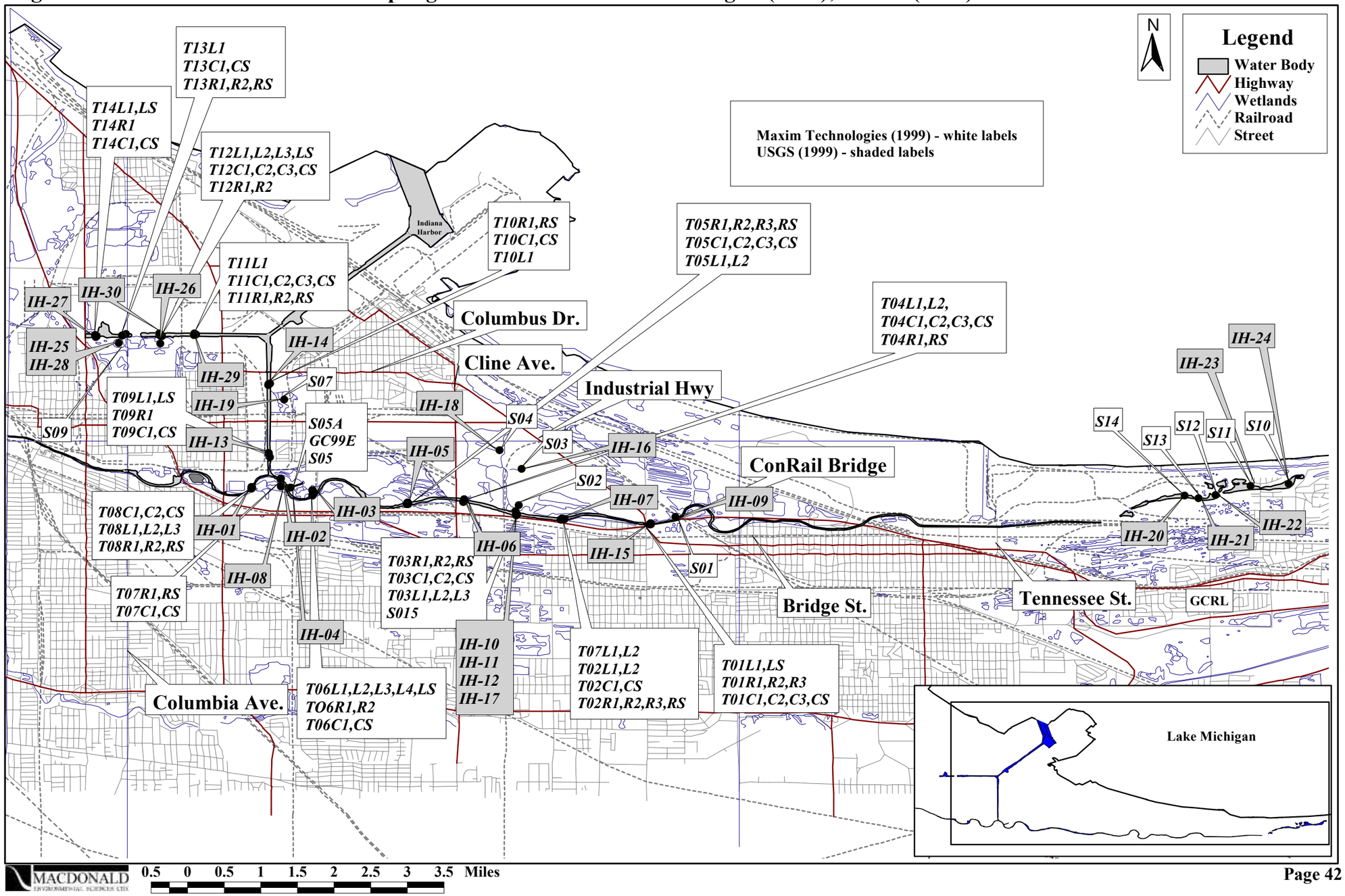
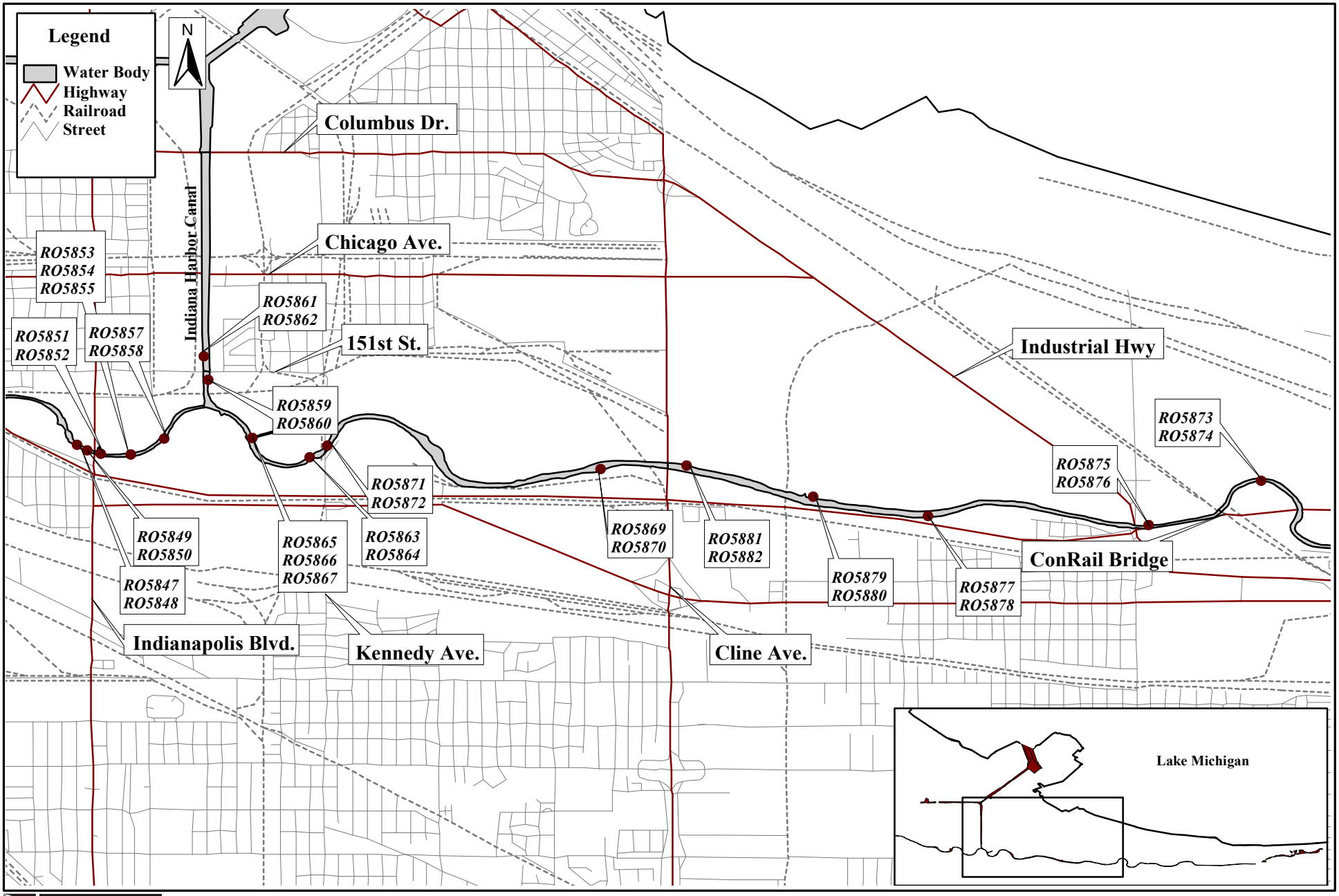


Figure 4.39. Location of sediment sampling stations for IDEM (1999).



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 1.5 2 2.5 Miles

Figures

Chapter 5 - Grand Calumet River Lagoons

Figure 5.1. Location of sampling stations for surficial sediment chemistry in the GCRL.

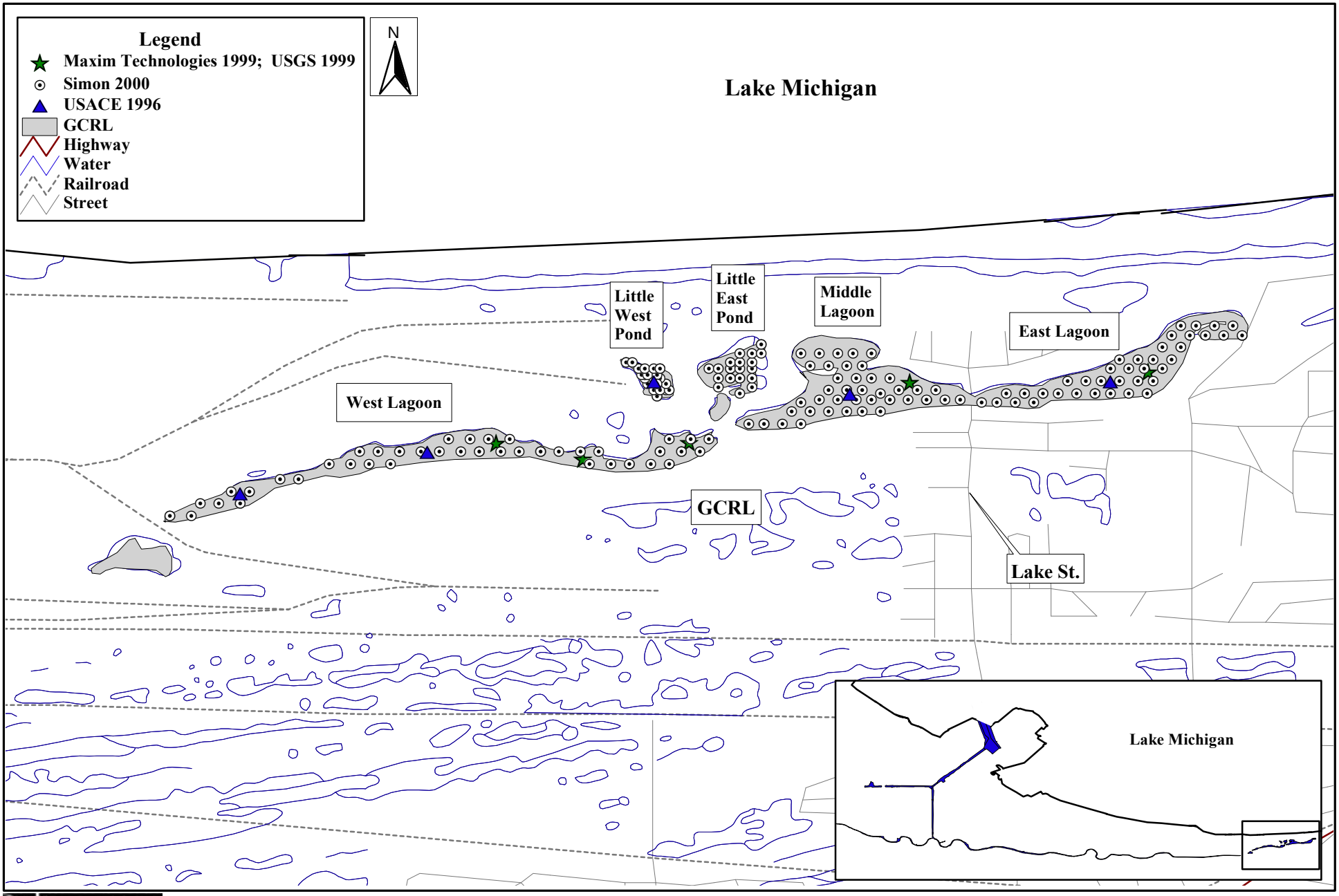


Figure 5.2. Location of sampling stations for sub-surface sediment chemistry in the GCRL.

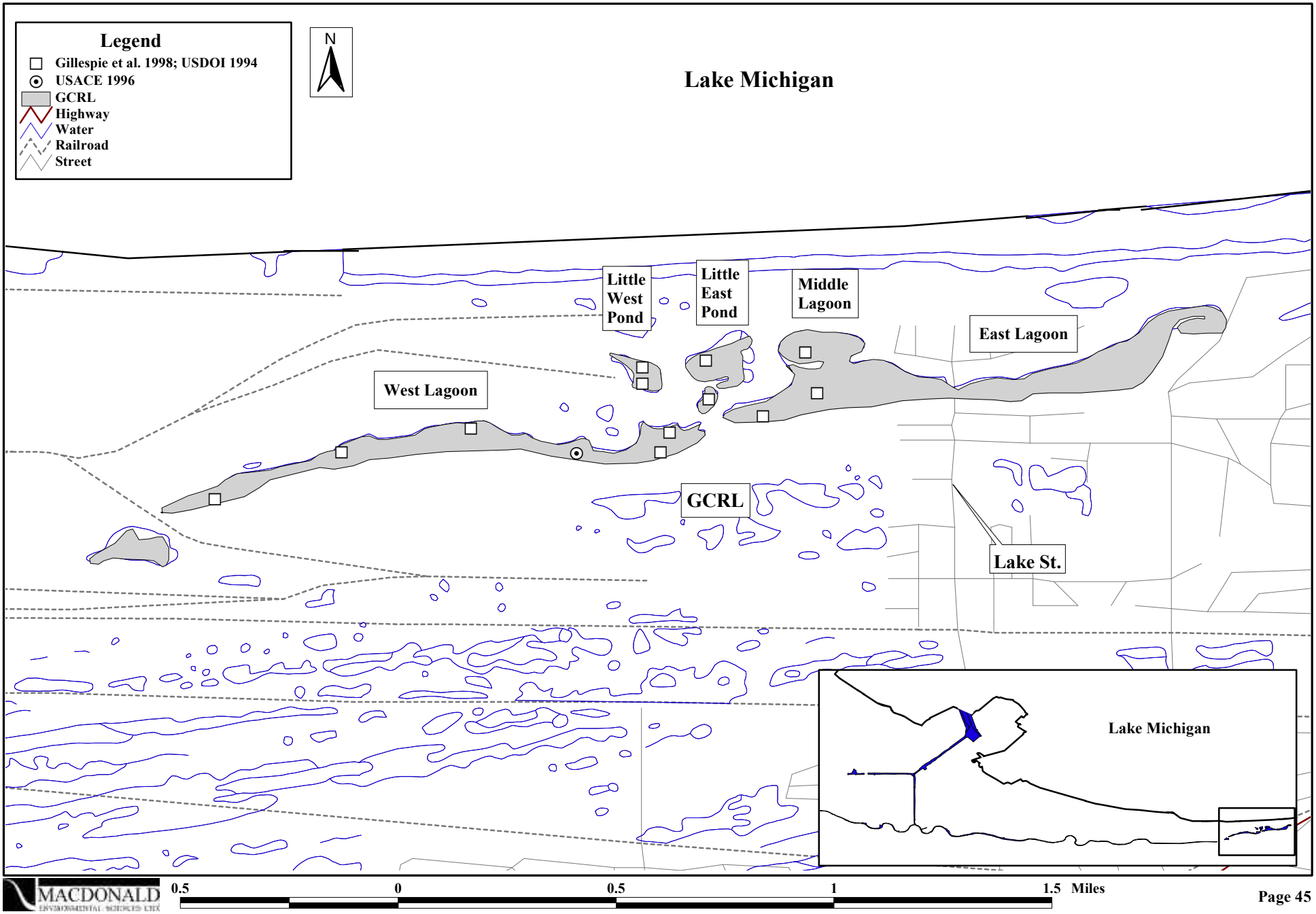


Figure 5.3. Location of sampling stations for sediment toxicity testing in the GCRL.

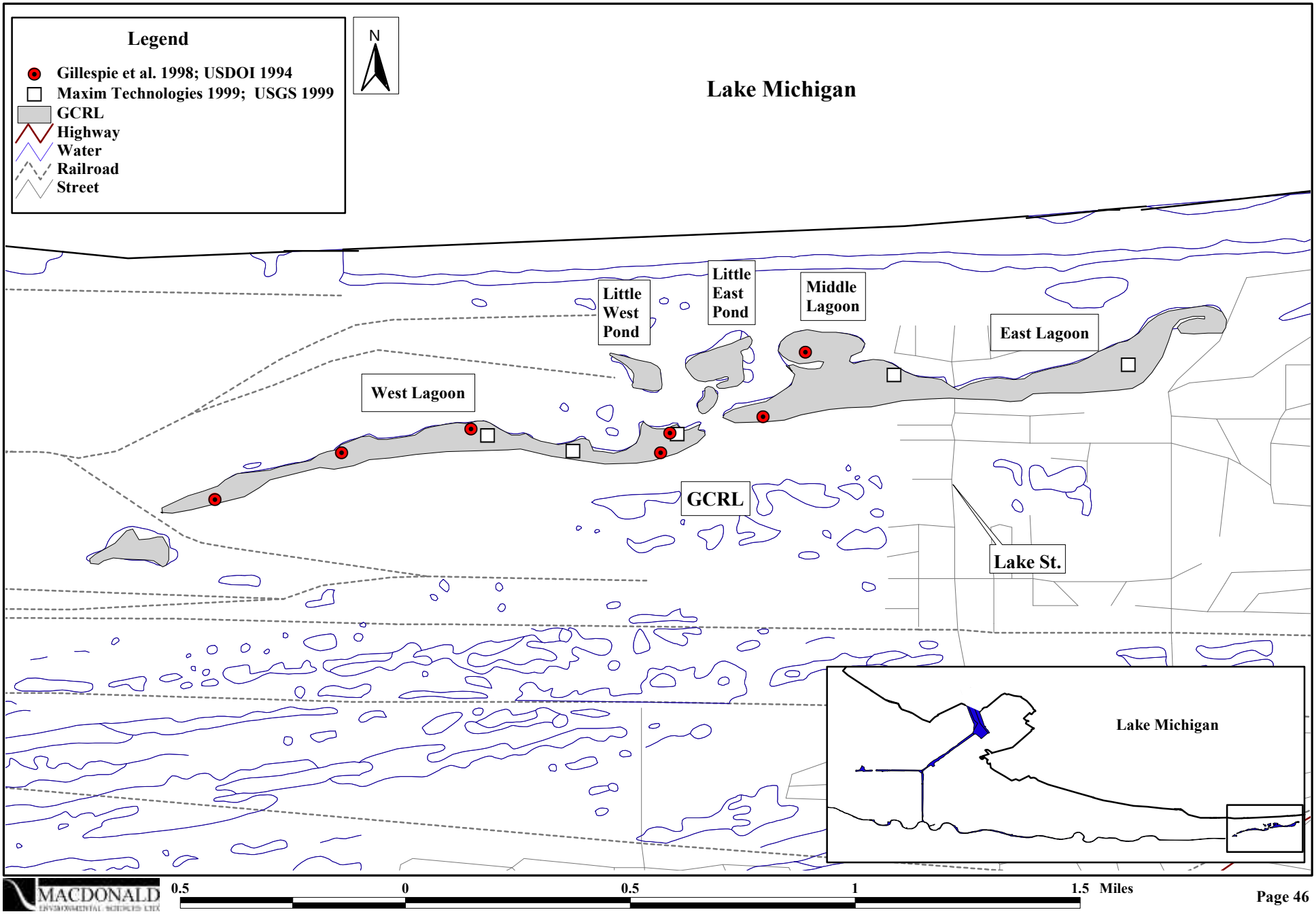
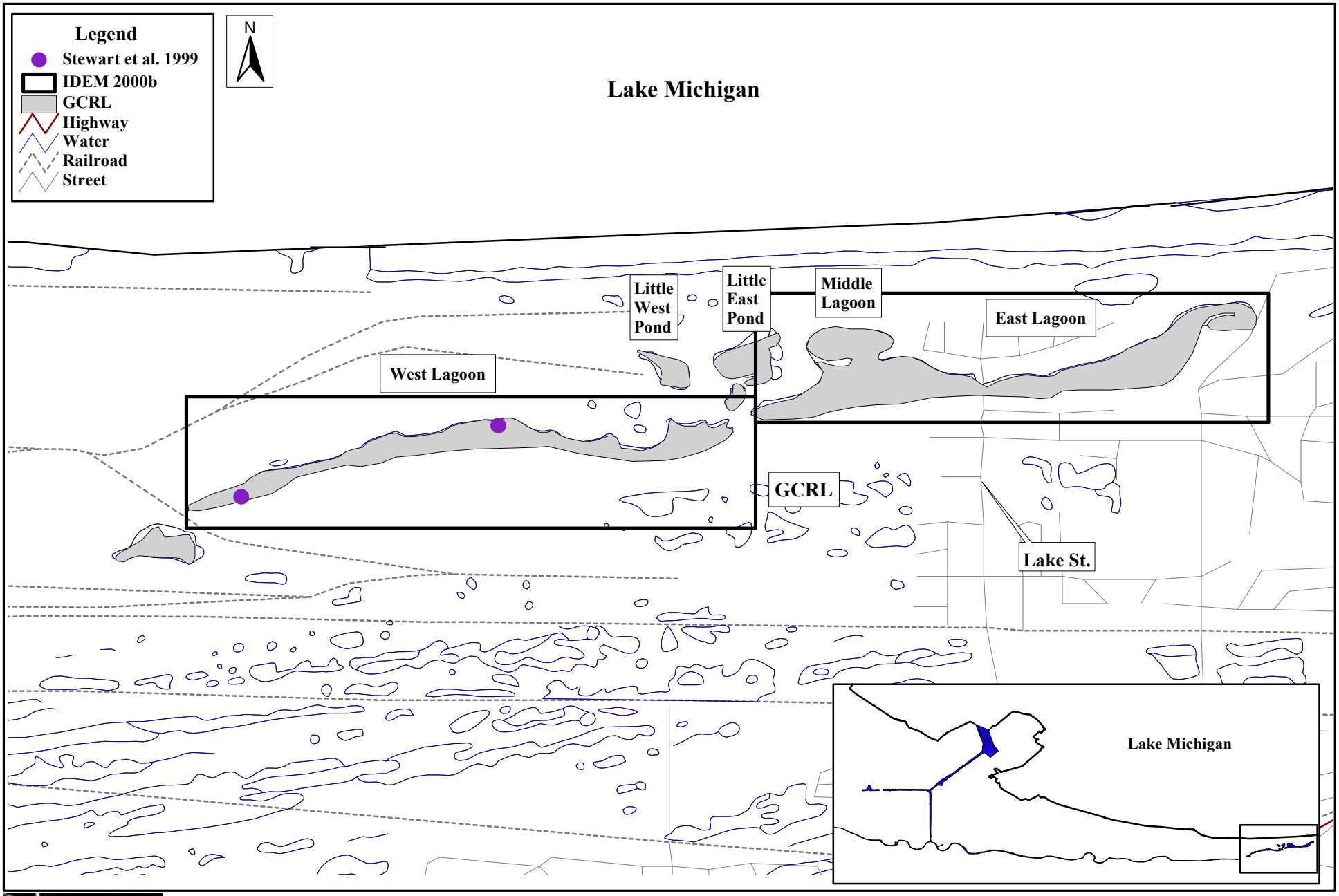


Figure 5.4. Location of sampling stations for tissue chemistry in the GCRL.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

Figure 5.5. Spatial distribution of mean PEC-Qs in surficial sediments within the GCRL.

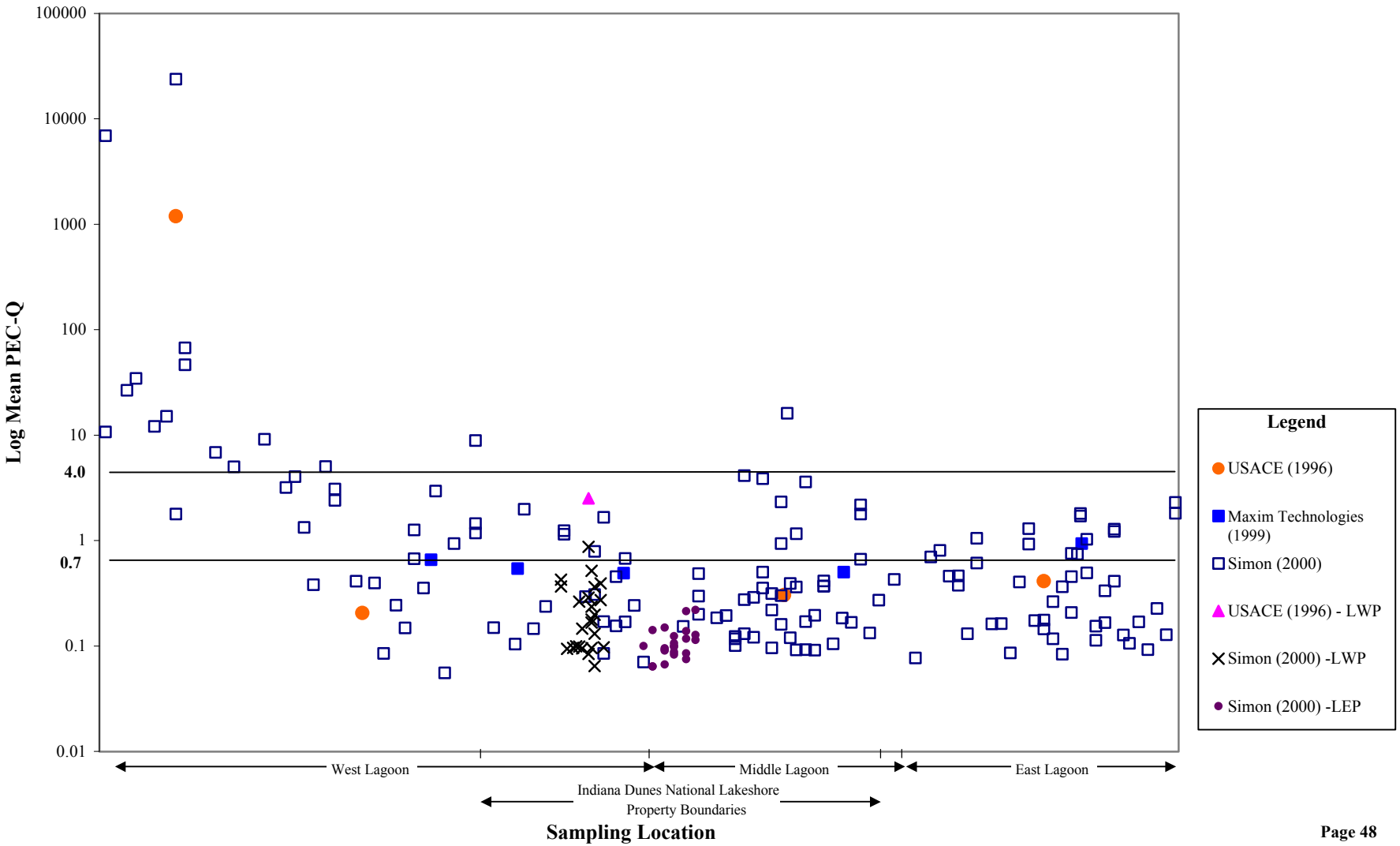
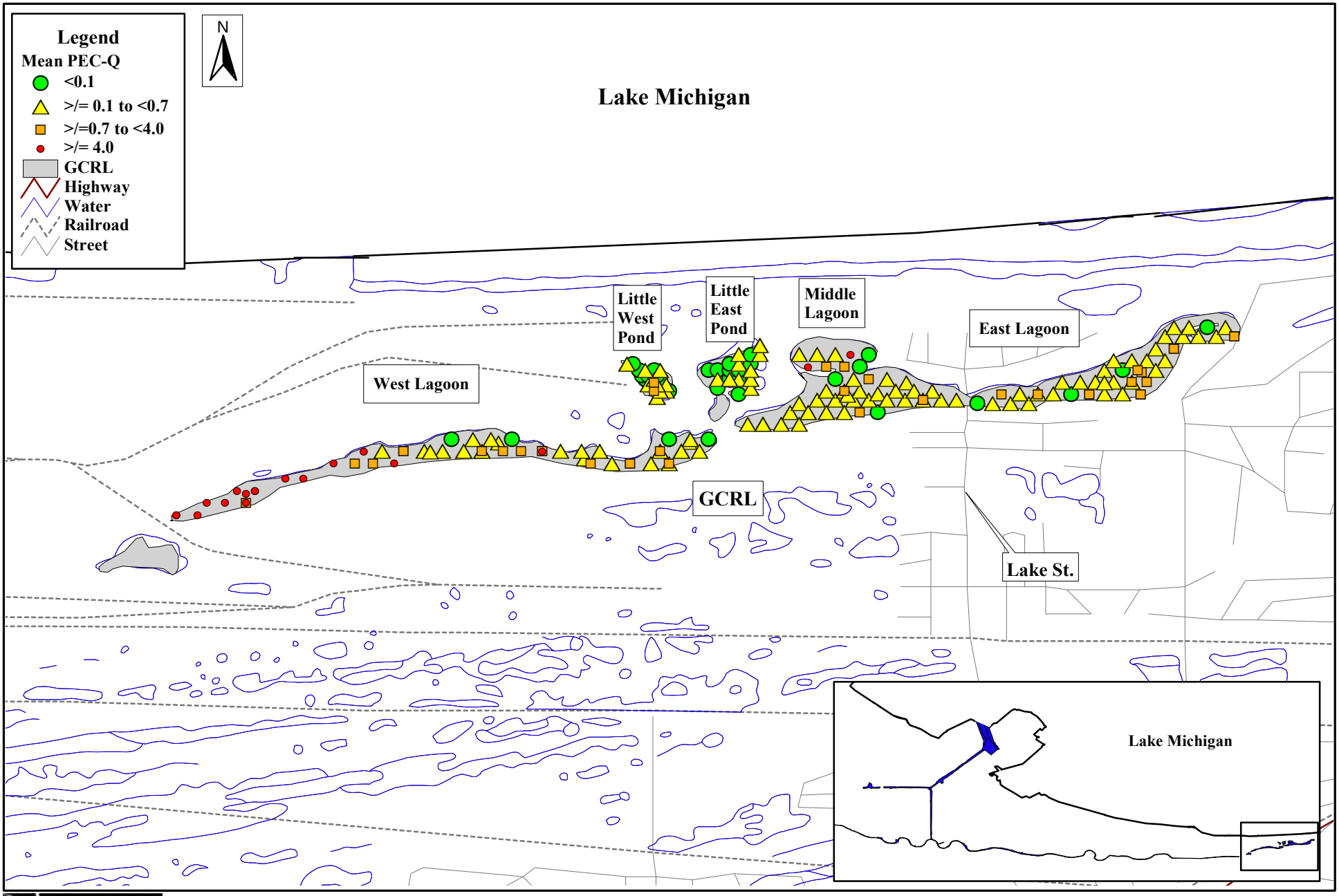


Figure 5.6. Areal extent of injury to surficial sediments in the GCRL.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

Figure 5.7. Spatial distribution of mean PEC-Qs in sub-surface sediments within the GCRL.

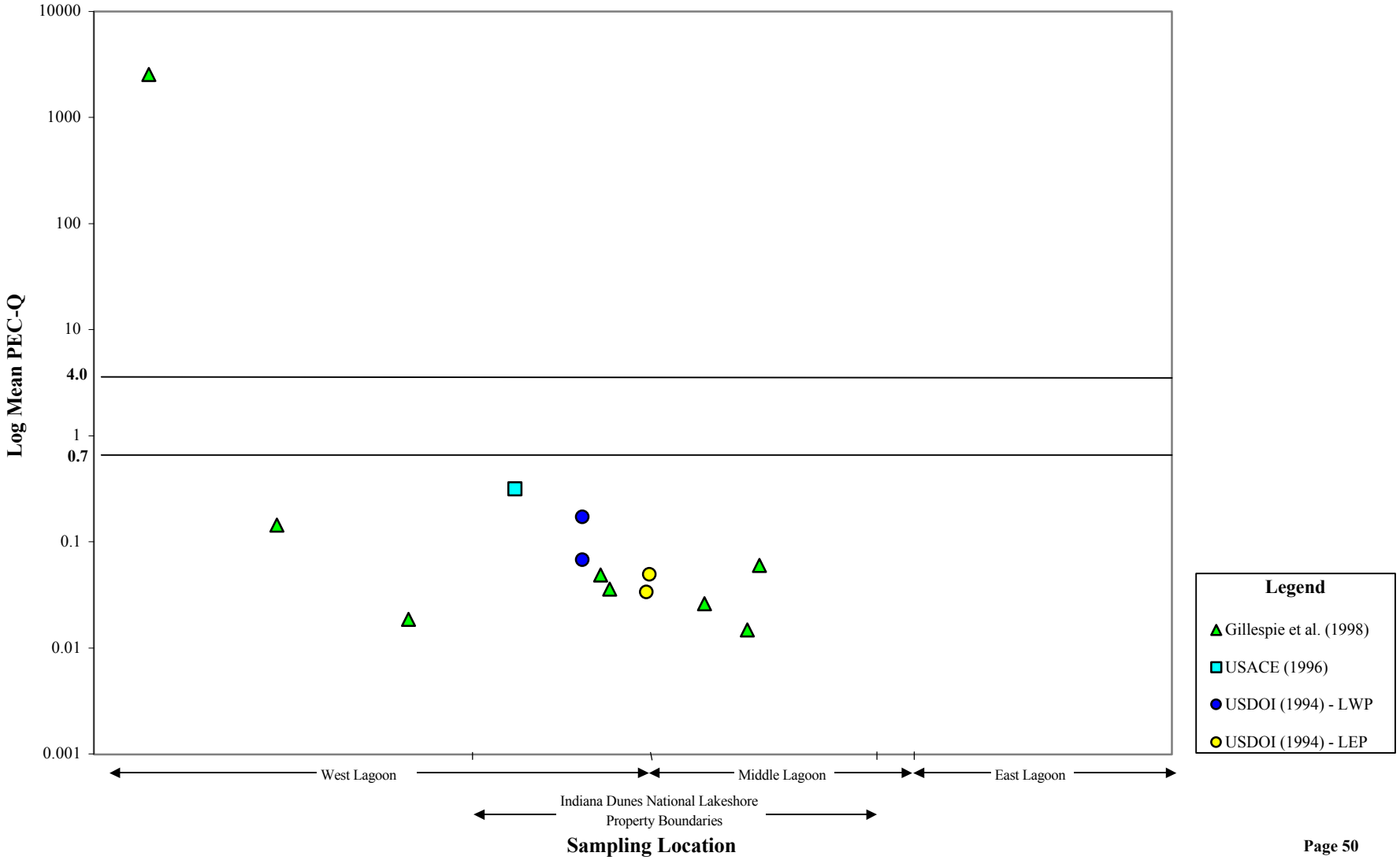


Figure 5.8. Areal extent of injury to sub-surface sediments in the GCRL.

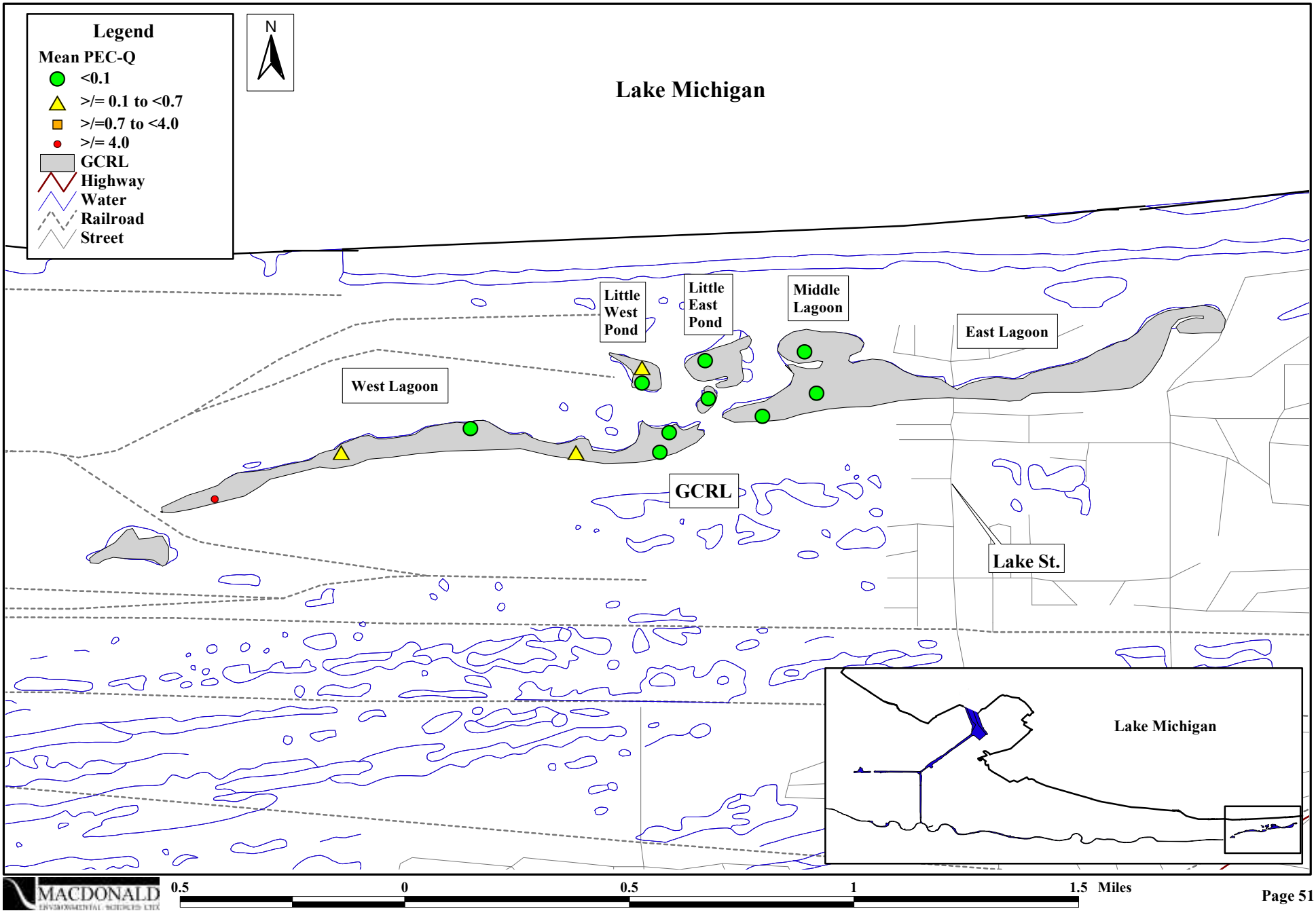
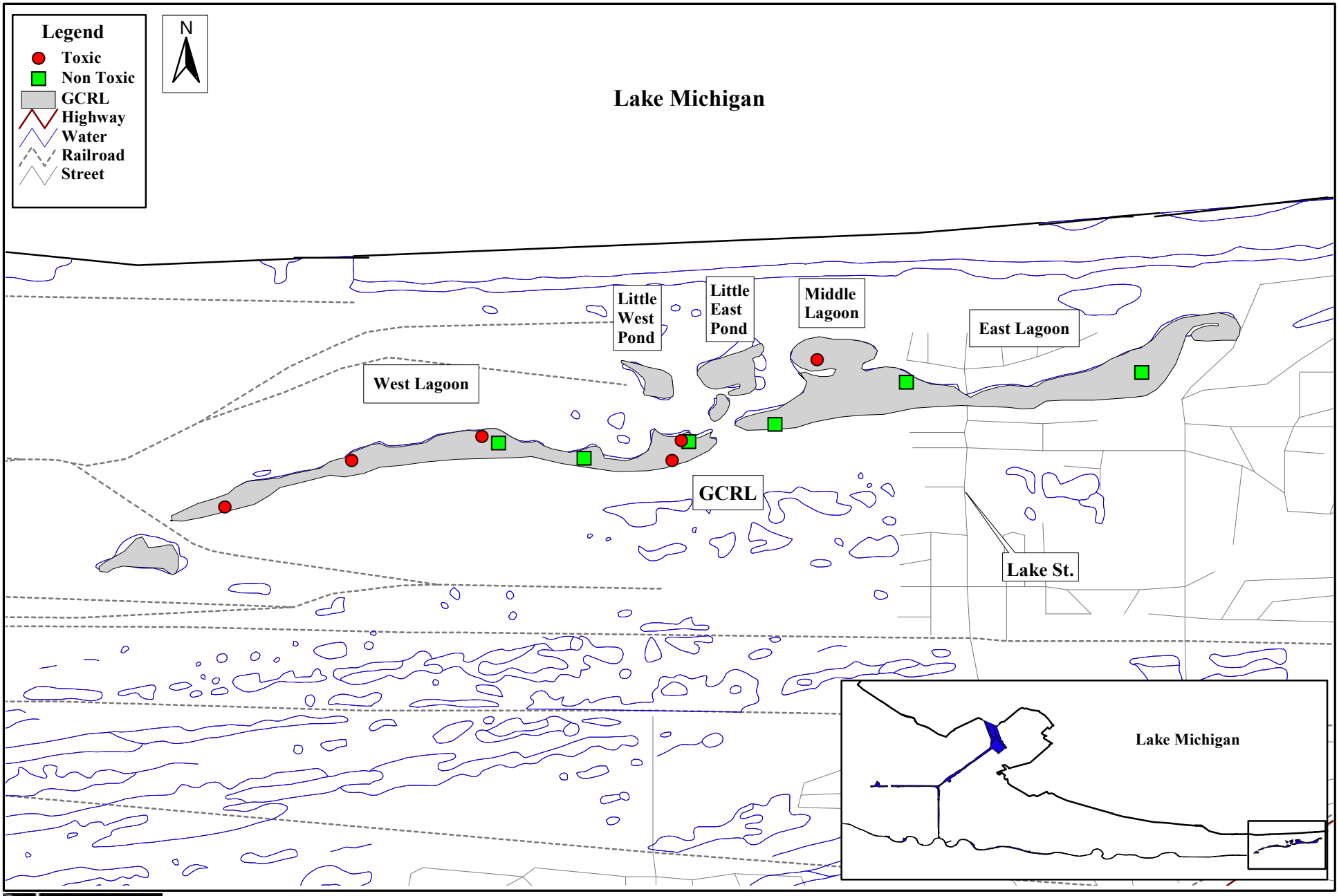


Figure 5.9. Areal extent of sediment toxicity in the GCRL.



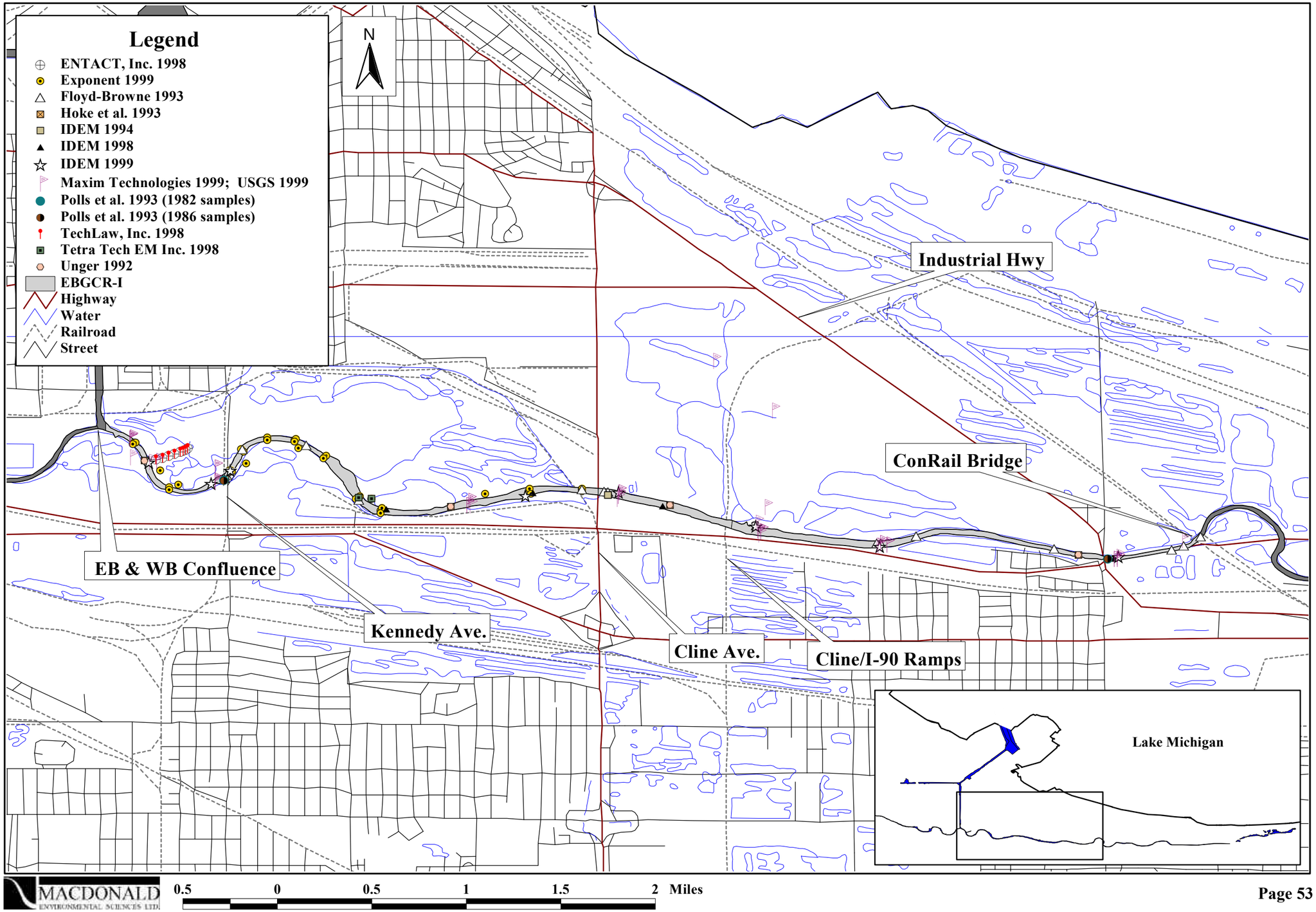
MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

Figures

Chapter 6 - East Branch of the Grand Calumet River - I

Figure 6.1. Location of sampling stations for surficial sediment chemistry in the EBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

Figure 6.2. Location of sampling stations for sub-surface sediment chemistry in the EBGCR-I.

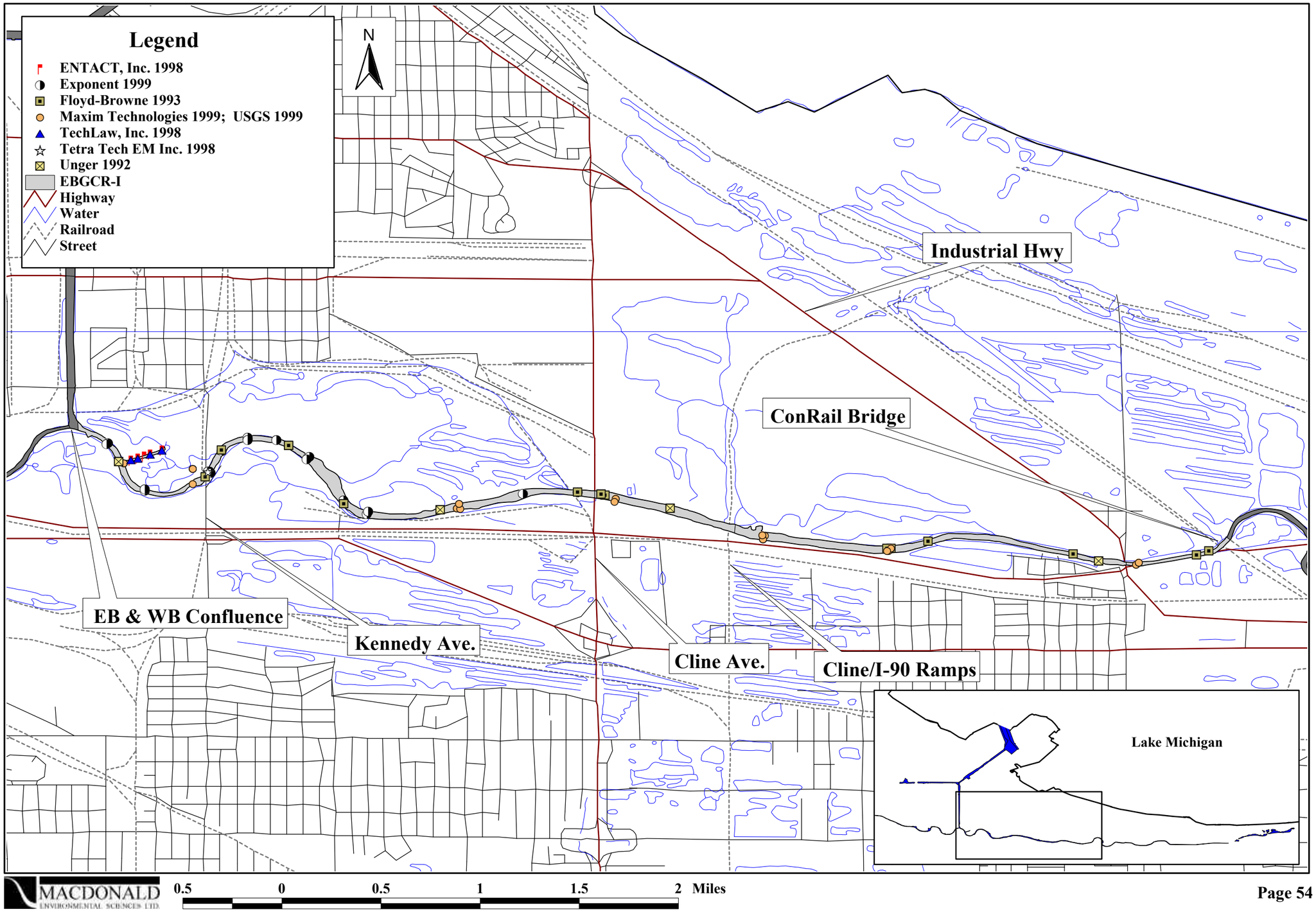


Figure 6.3. Location of sampling stations for sediment toxicity testing in the EBGCR-I.

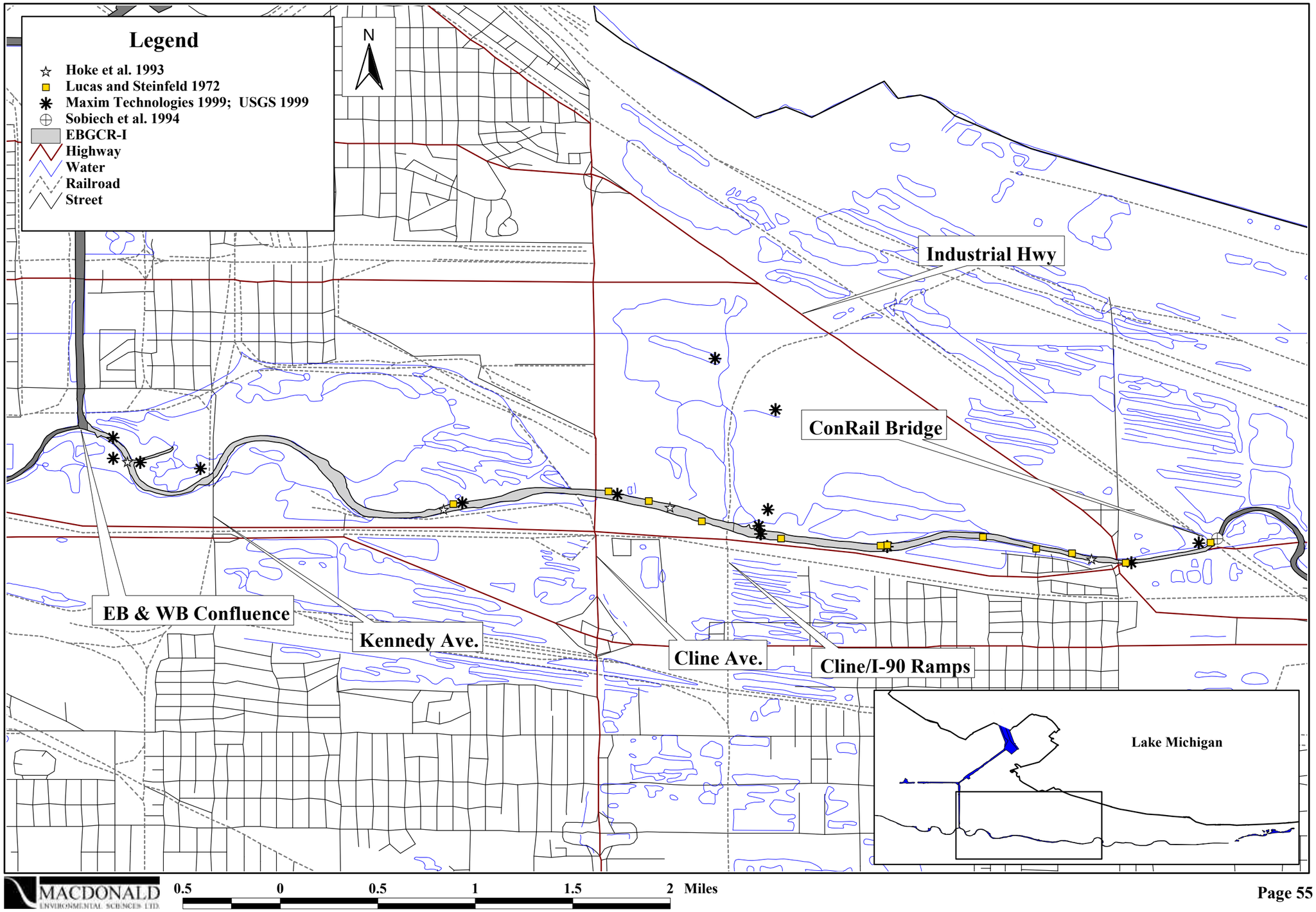


Figure 6.4. Areal extent of altered benthic invertebrate communities in the EBGCR-I.

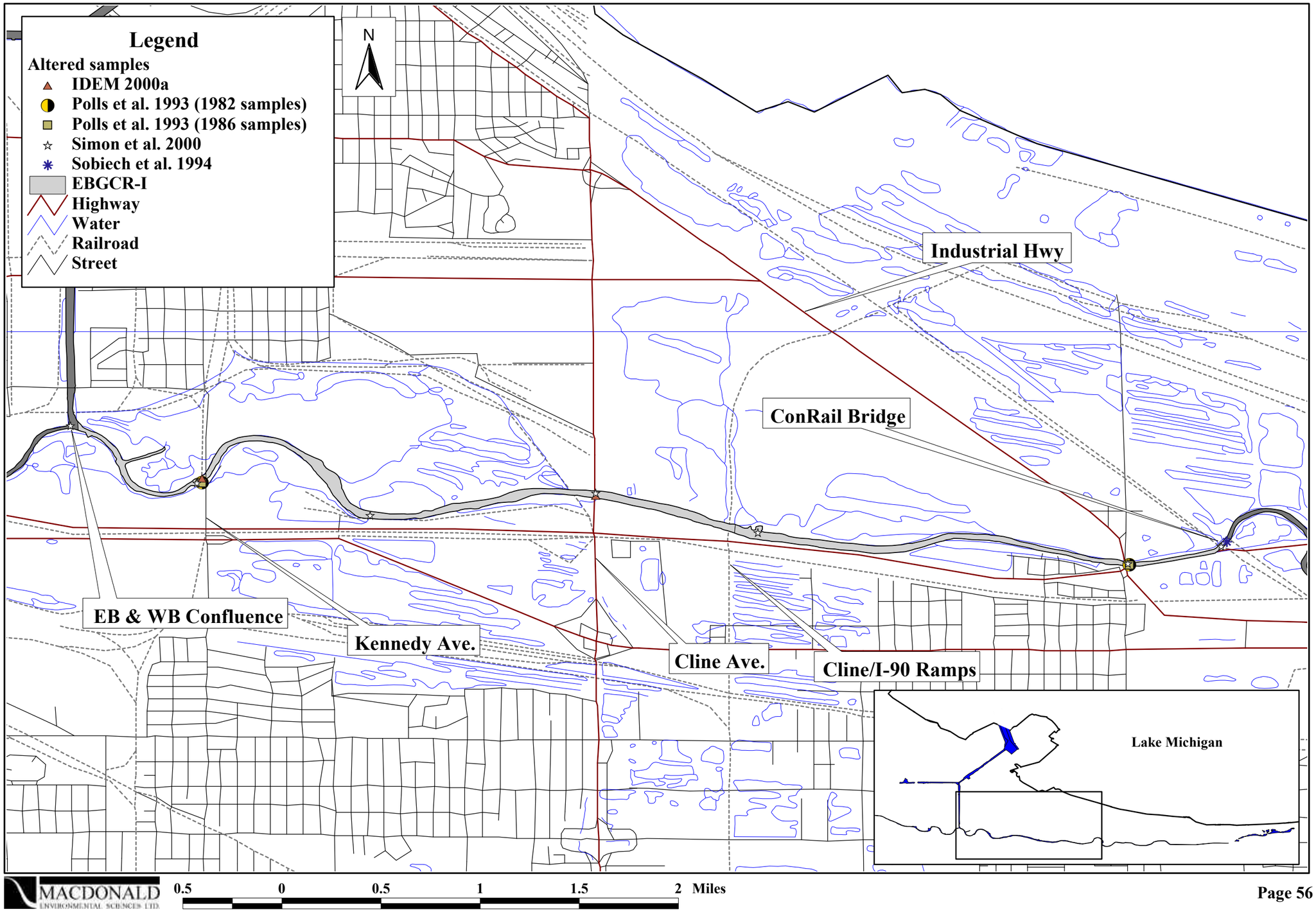
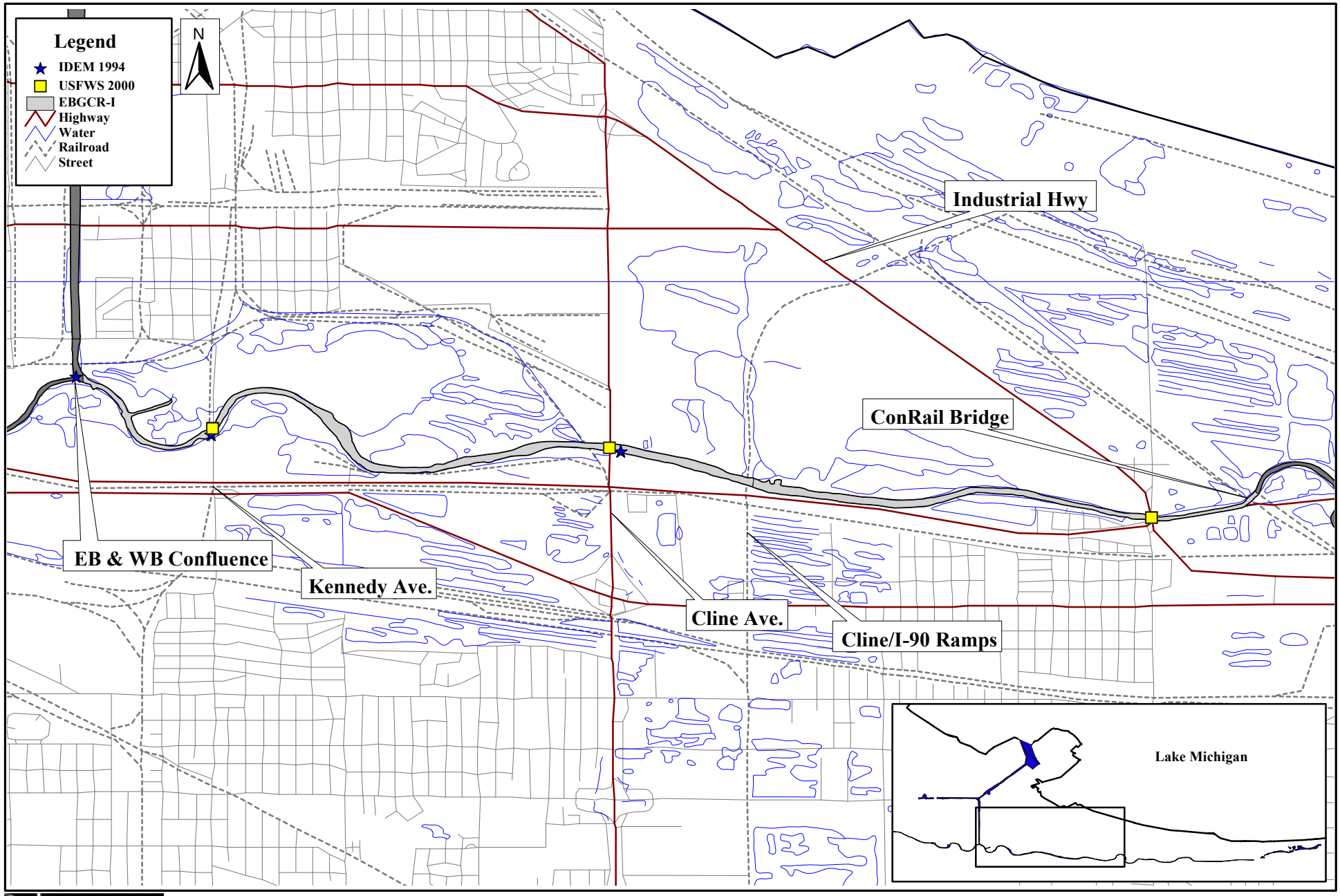


Figure 6.5. Location of sampling stations for tissue chemistry in the EBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 6.6. Spatial distribution of mean PEC-Qs in surficial sediments within the EBGCR-I.

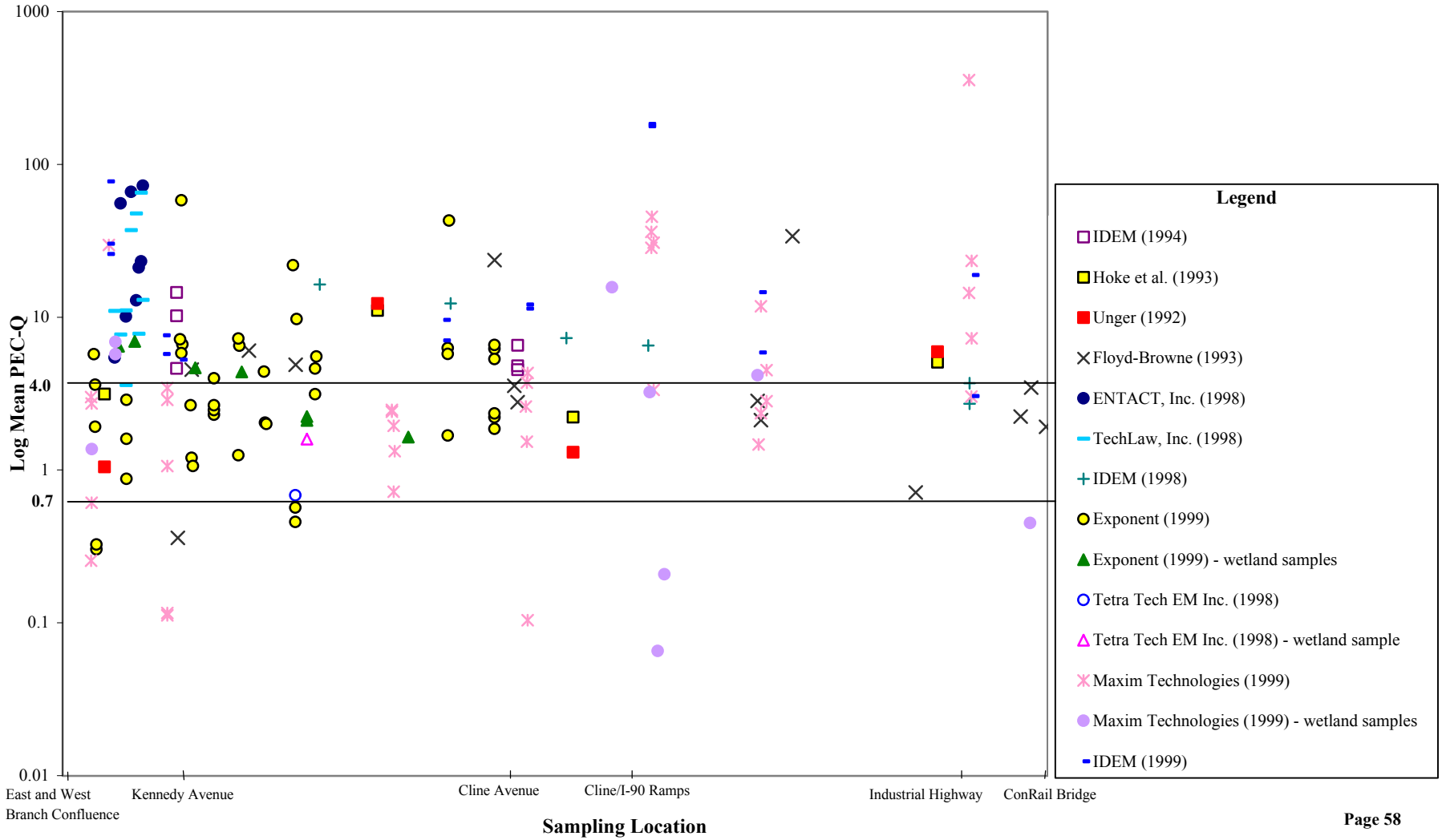
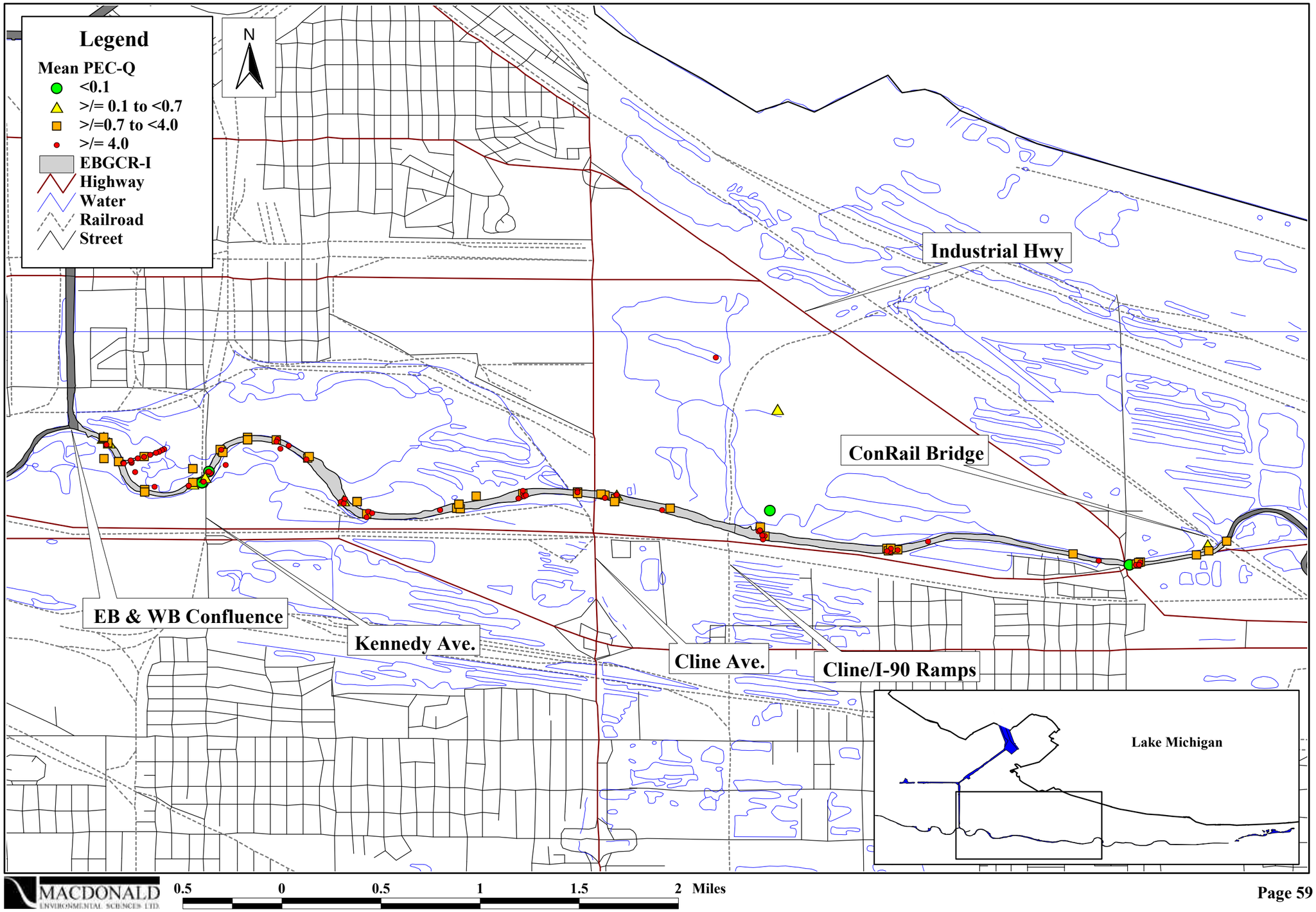


Figure 6.7. Areal extent of injury to surficial sediments in the EBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

Figure 6.8. Spatial distribution of mean PEC-Qs in sub-surface sediments within the EBGCR-I.

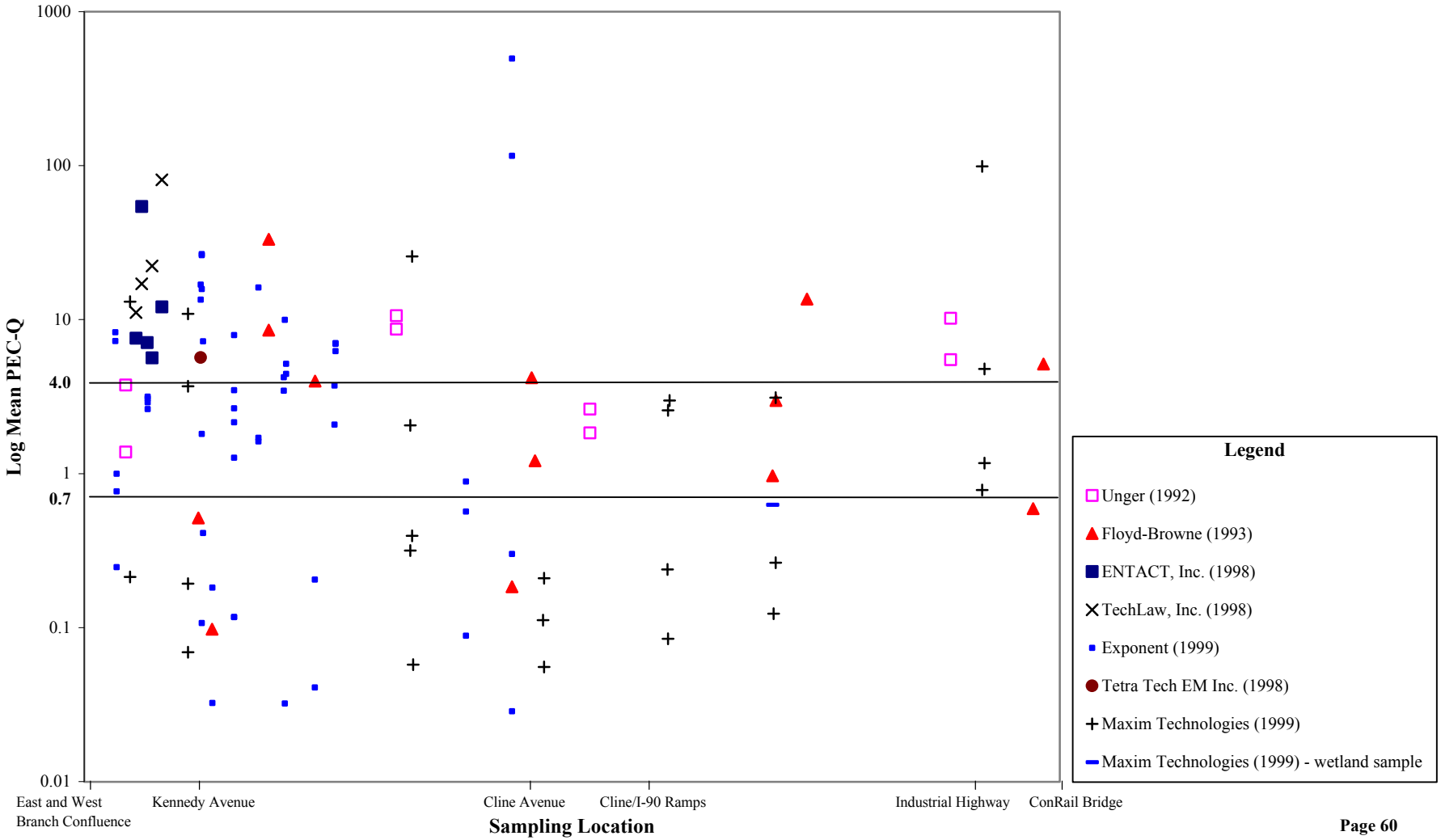


Figure 6.9. Areal extent of injury to sub-surface sediments in the EBGCR-I.

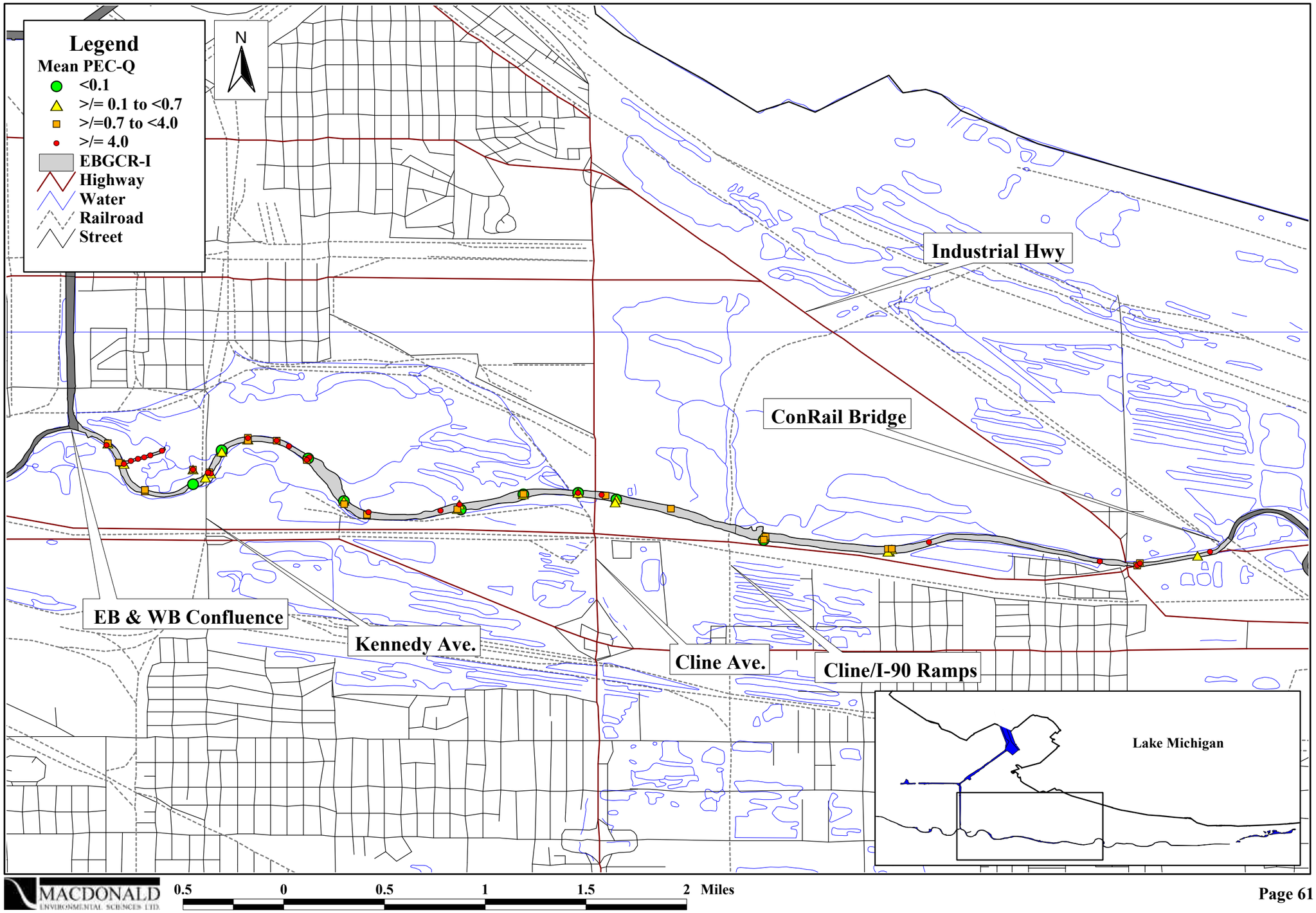
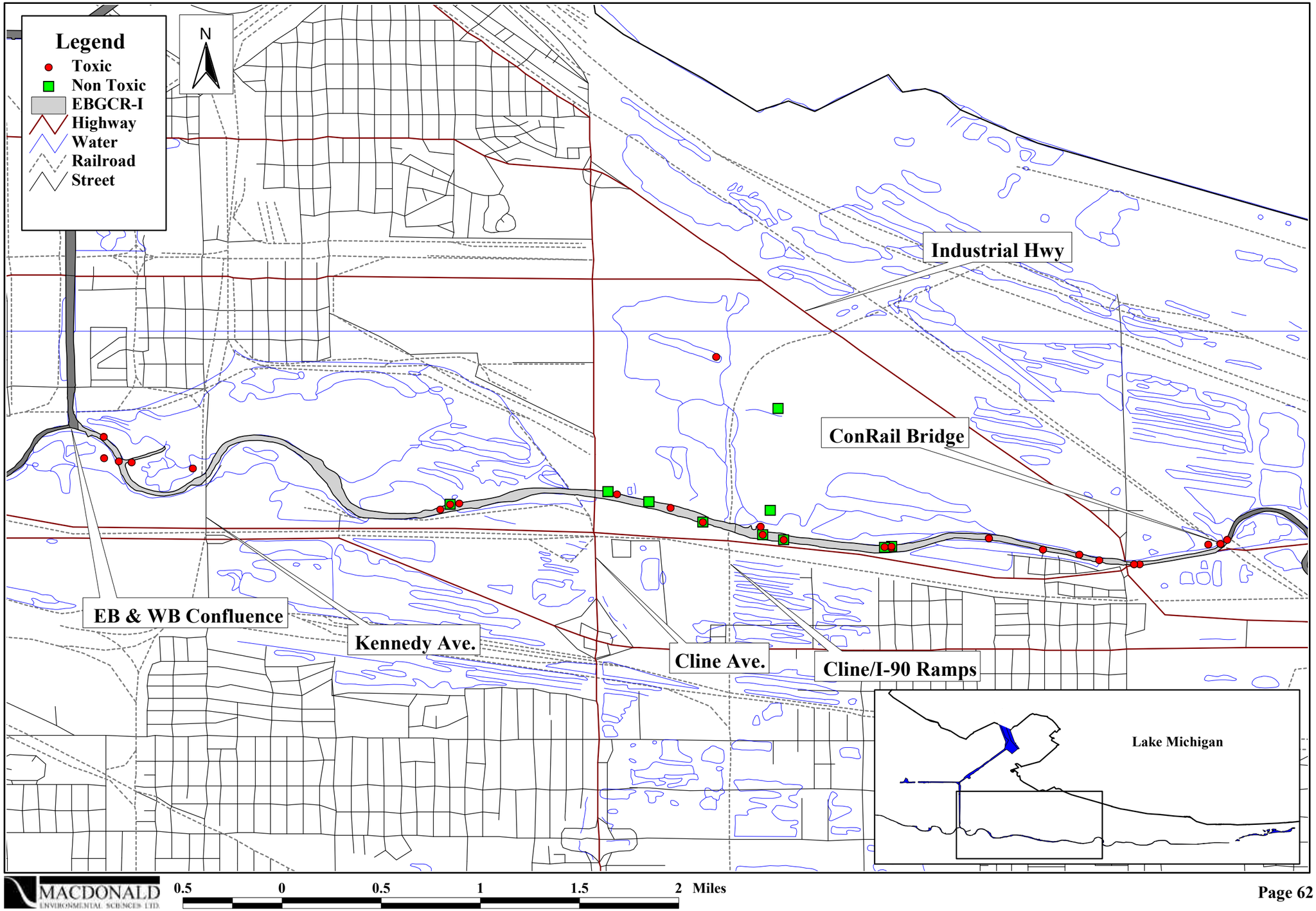


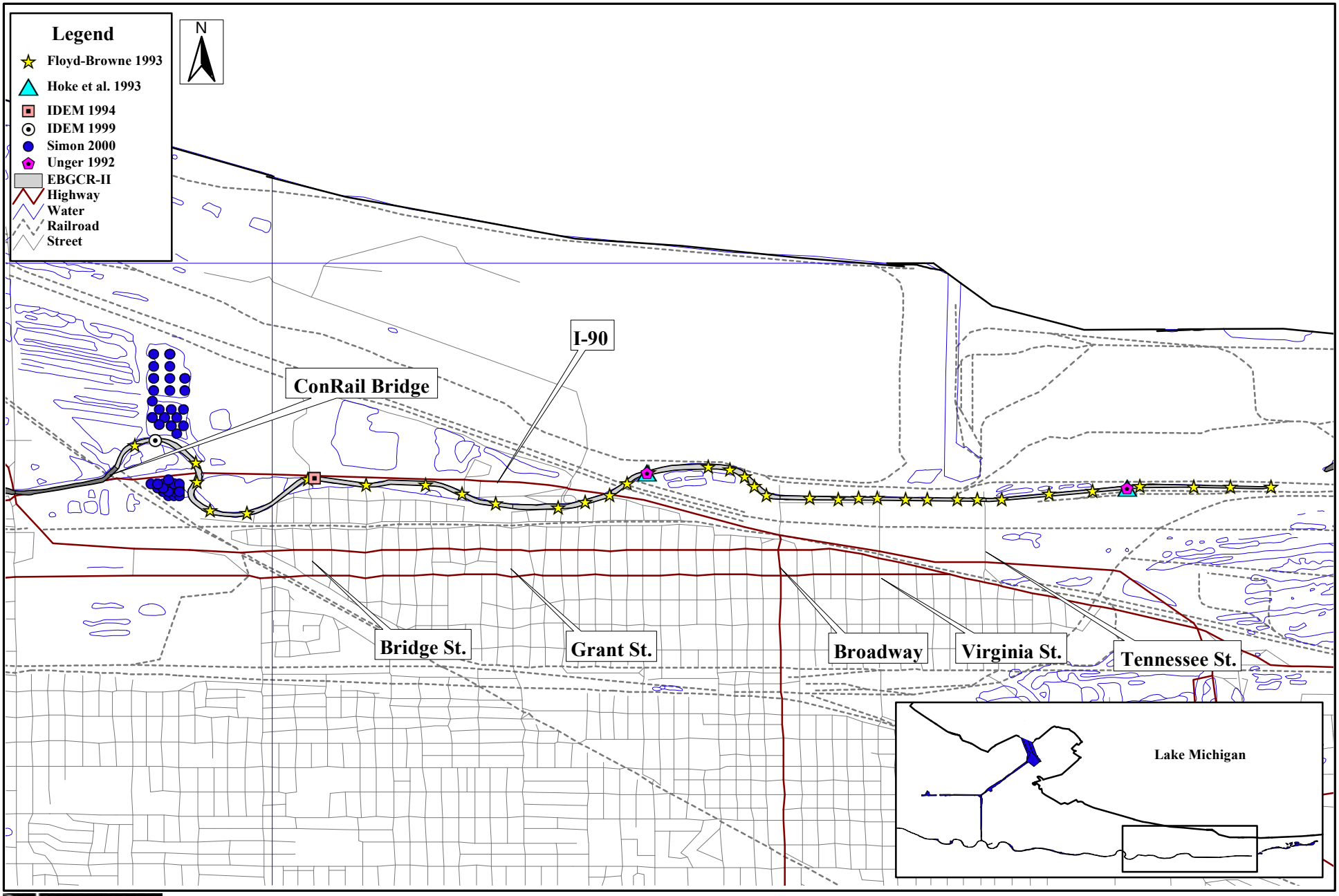
Figure 6.10. Areal extent of sediment toxicity in the EBGCR-I.



Figures

Chapter 7 - East Branch of the Grand Calumet River - II

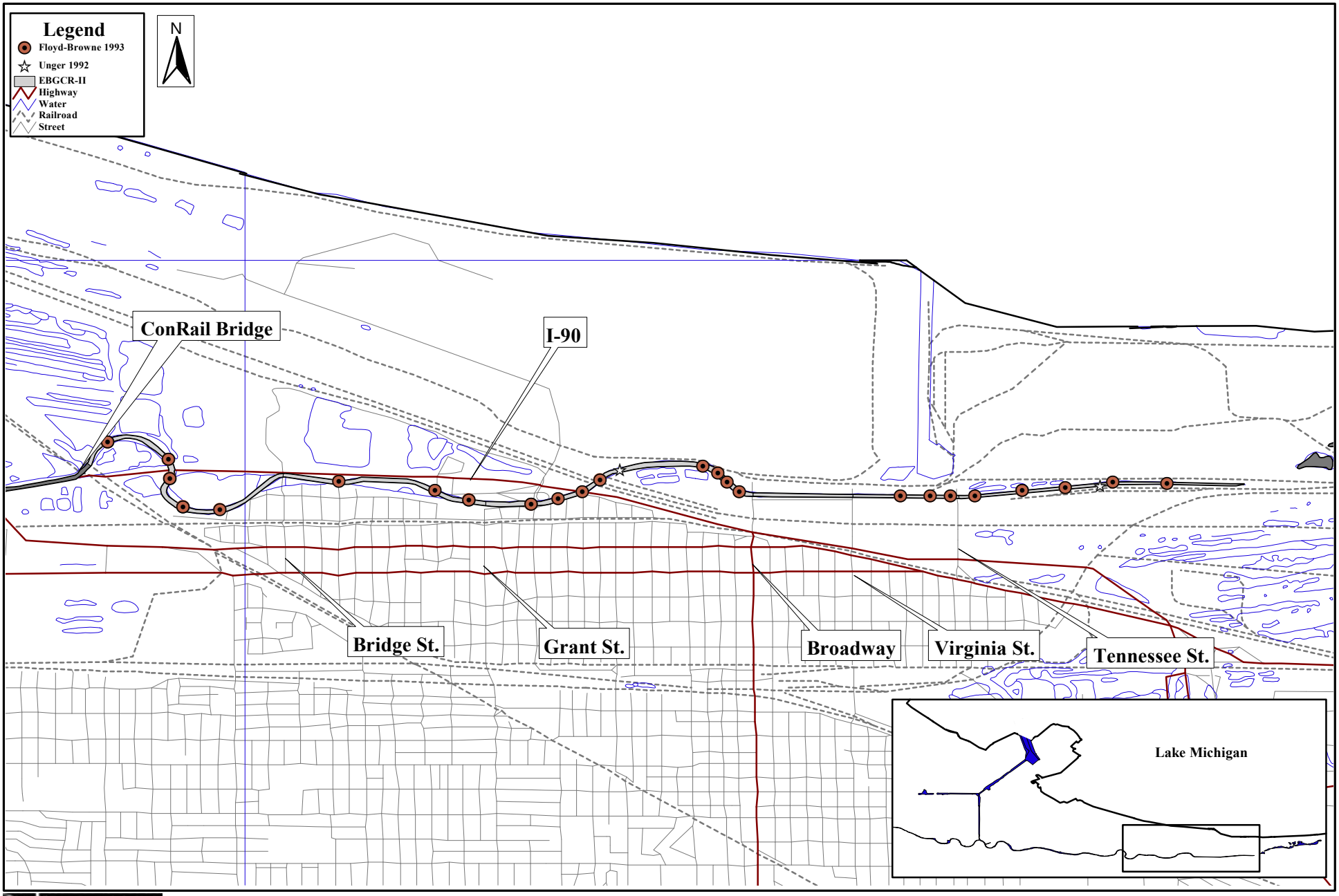
Figure 7.1. Location of sampling stations for surficial sediment chemistry in the EBGCR-II.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

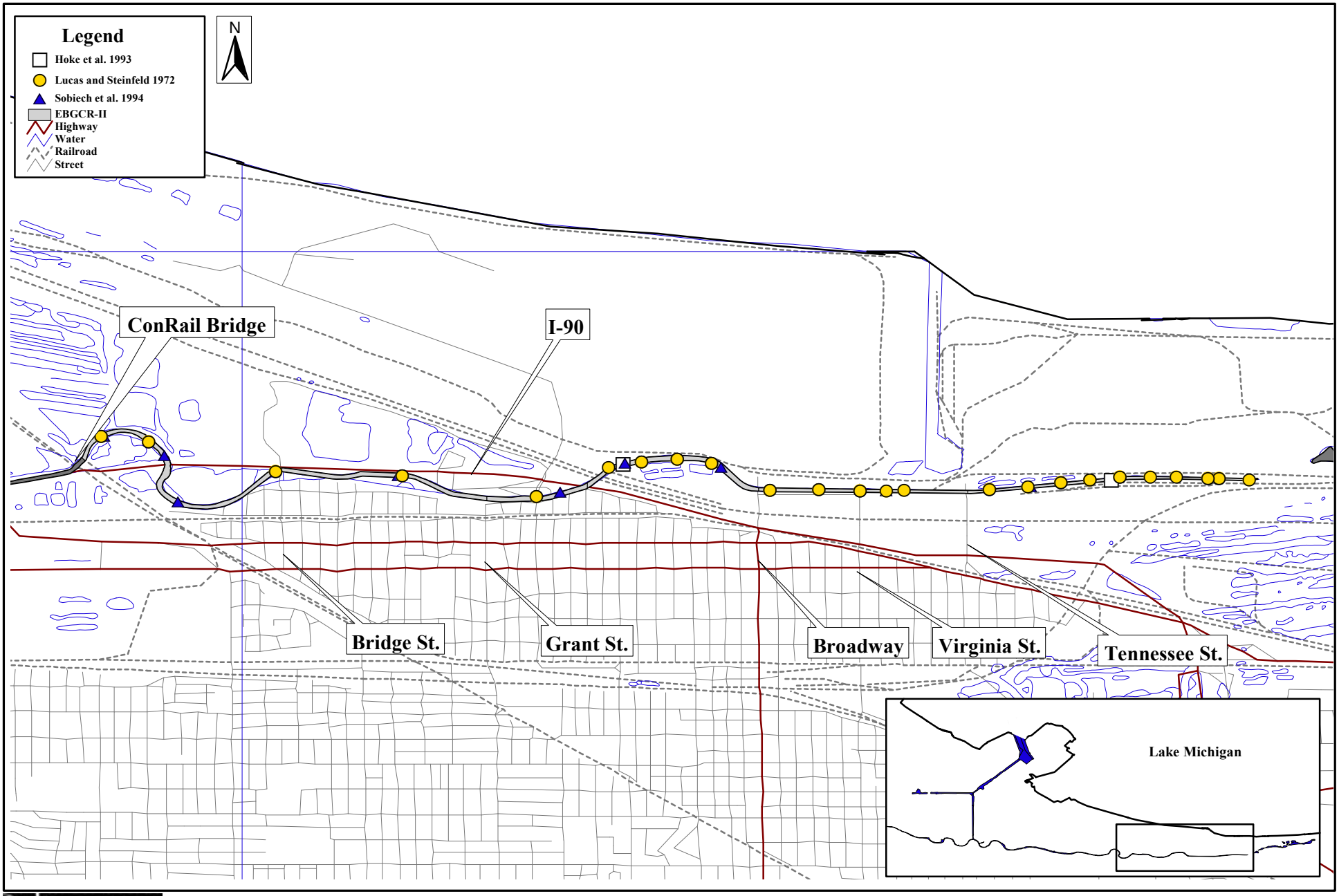
Figure 7.2. Location of sampling stations for sub-surface sediment chemistry in the EBGCR-II.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

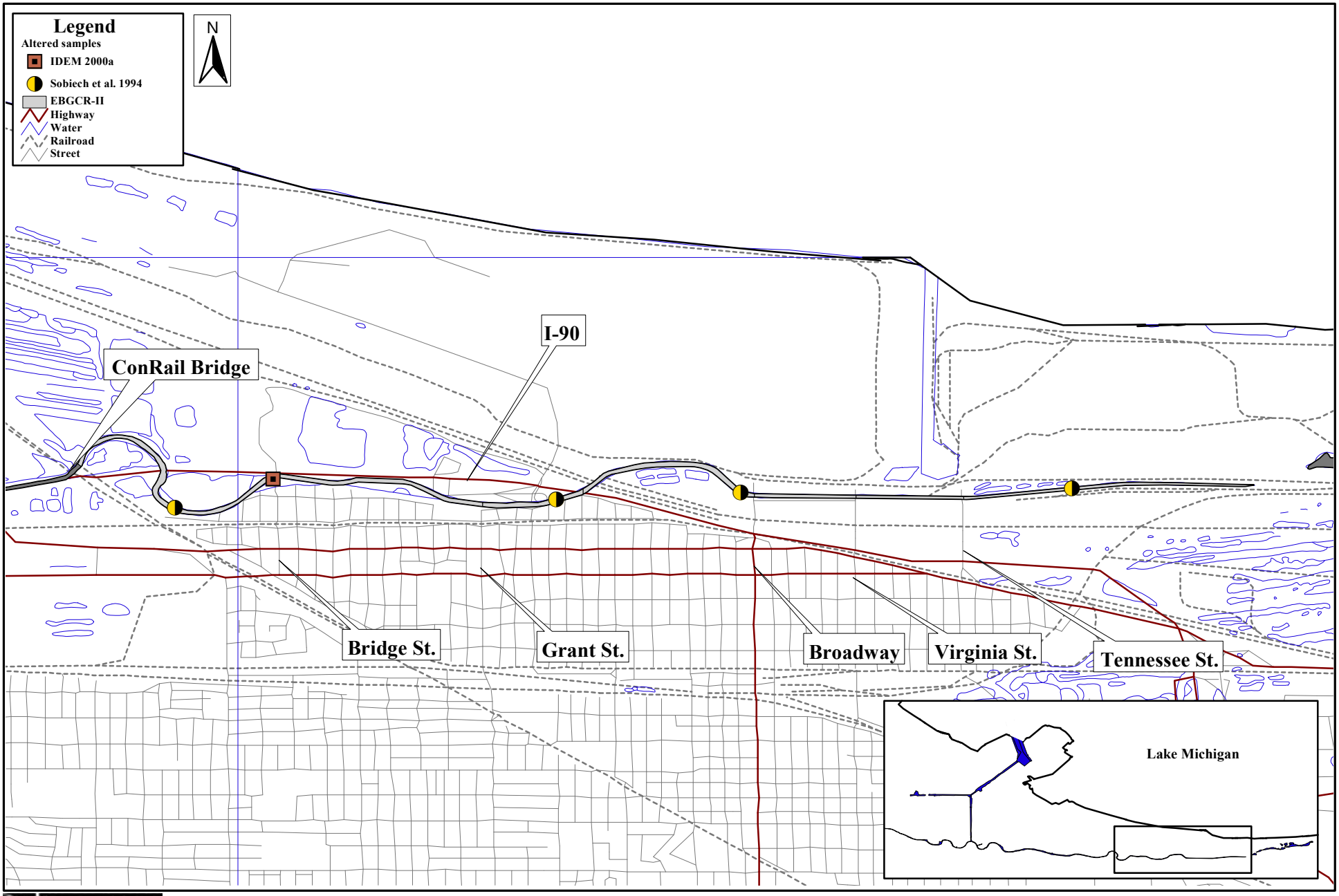
Figure 7.3. Location of sampling stations for sediment toxicity testing in the EBGCR-II.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 7.4. Areal extent of altered benthic invertebrate communities in the EBGCR-II.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 7.5. Location of sampling stations for tissue chemistry in the EBGCR-II.

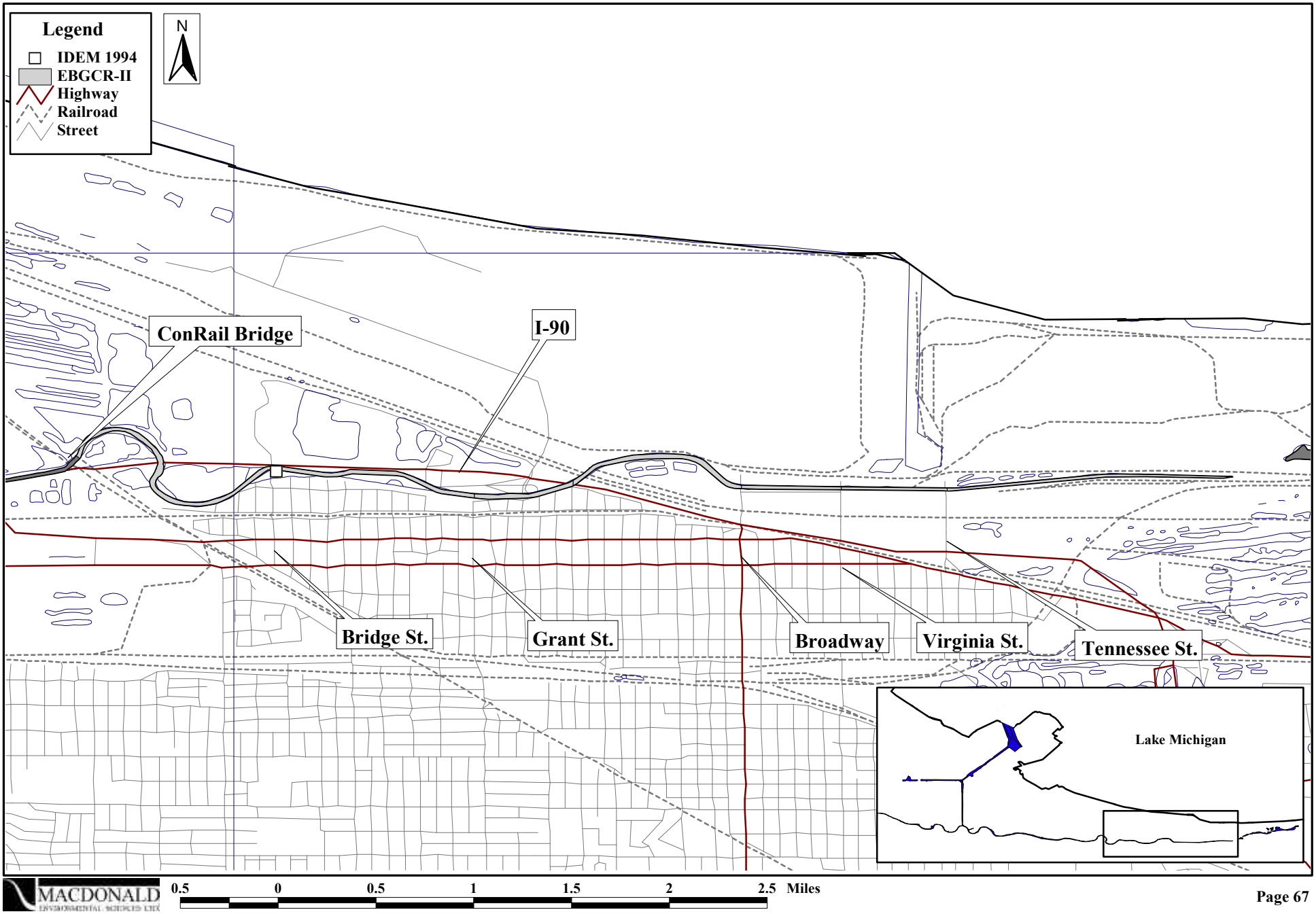


Figure 7.6. Spatial distribution of mean PEC-Qs in surficial sediments within the EBGCR-II.

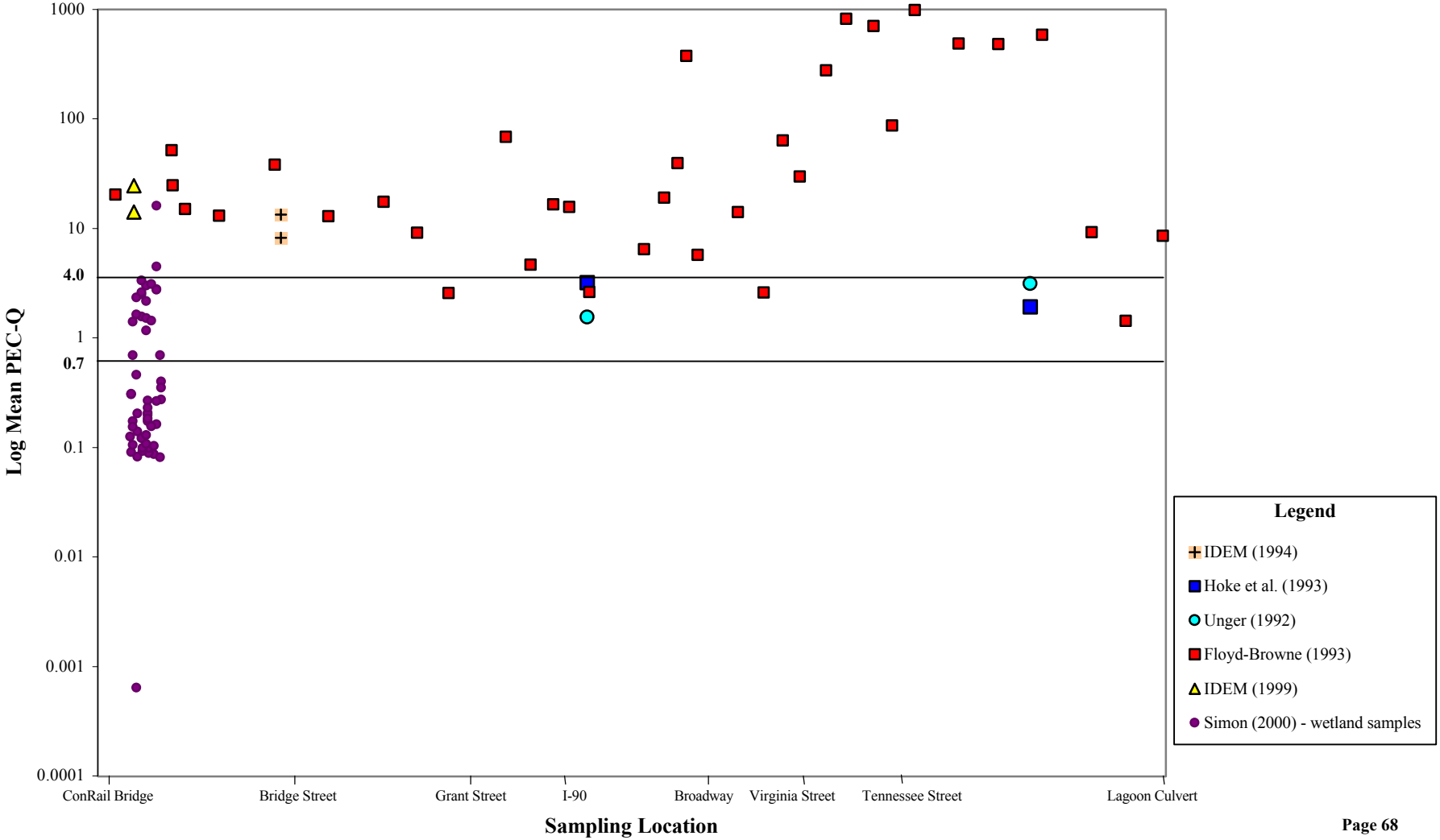
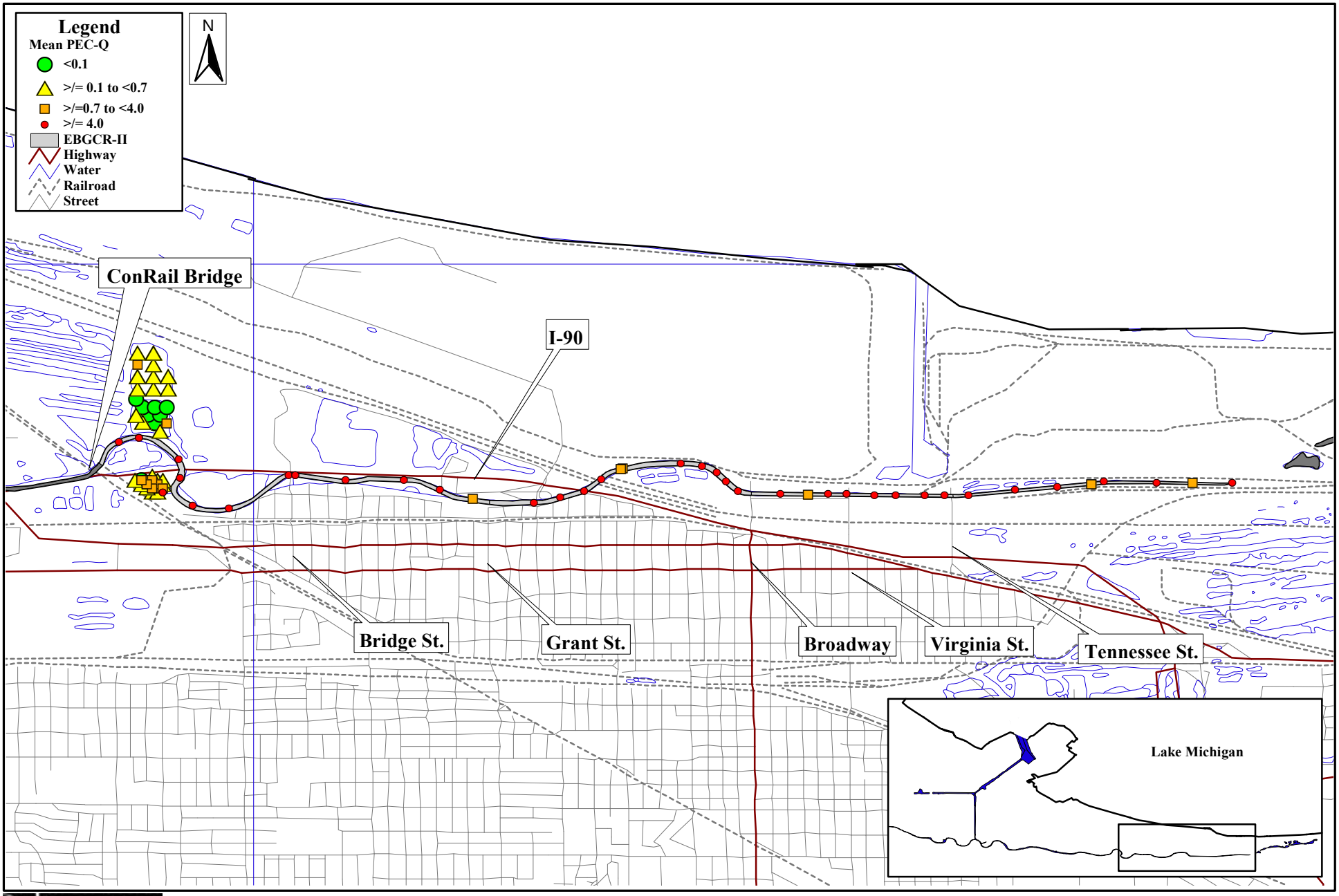


Figure 7.7. Areal extent of injury to surficial sediments in the EBGCR-II.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 7.8. Spatial distribution of mean PEC-Qs in sub-surface sediments within the the EBGCR-II.

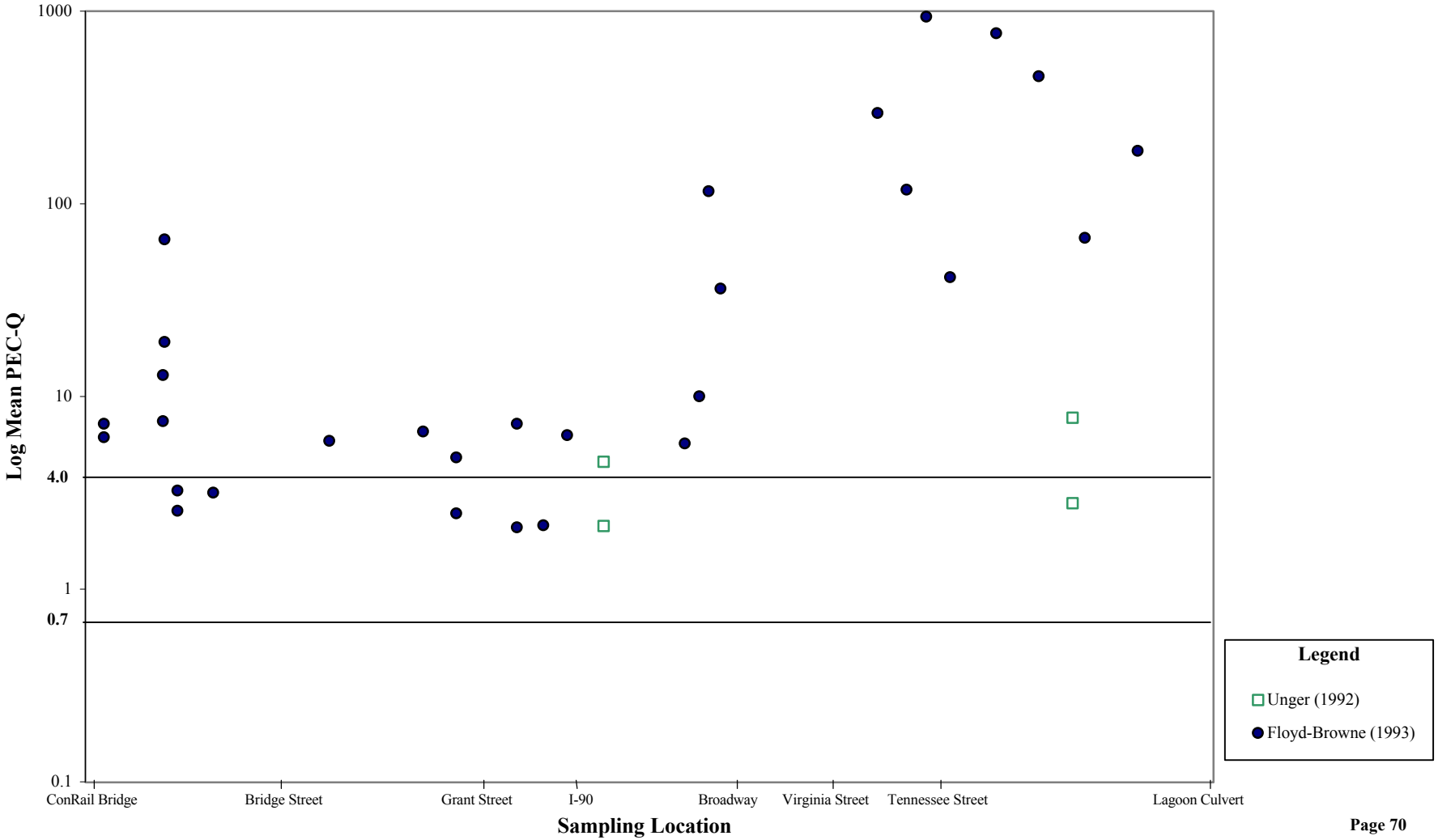
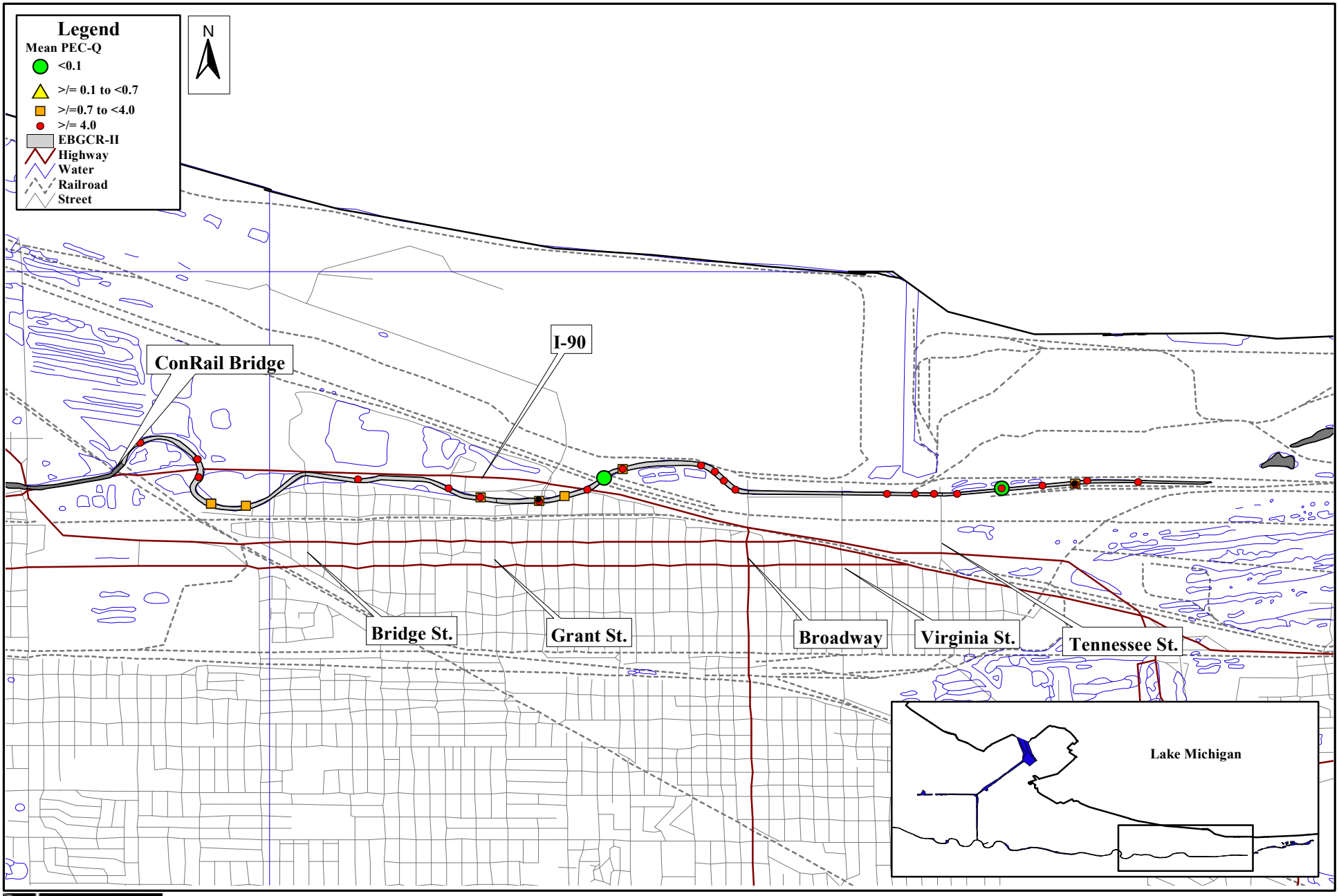


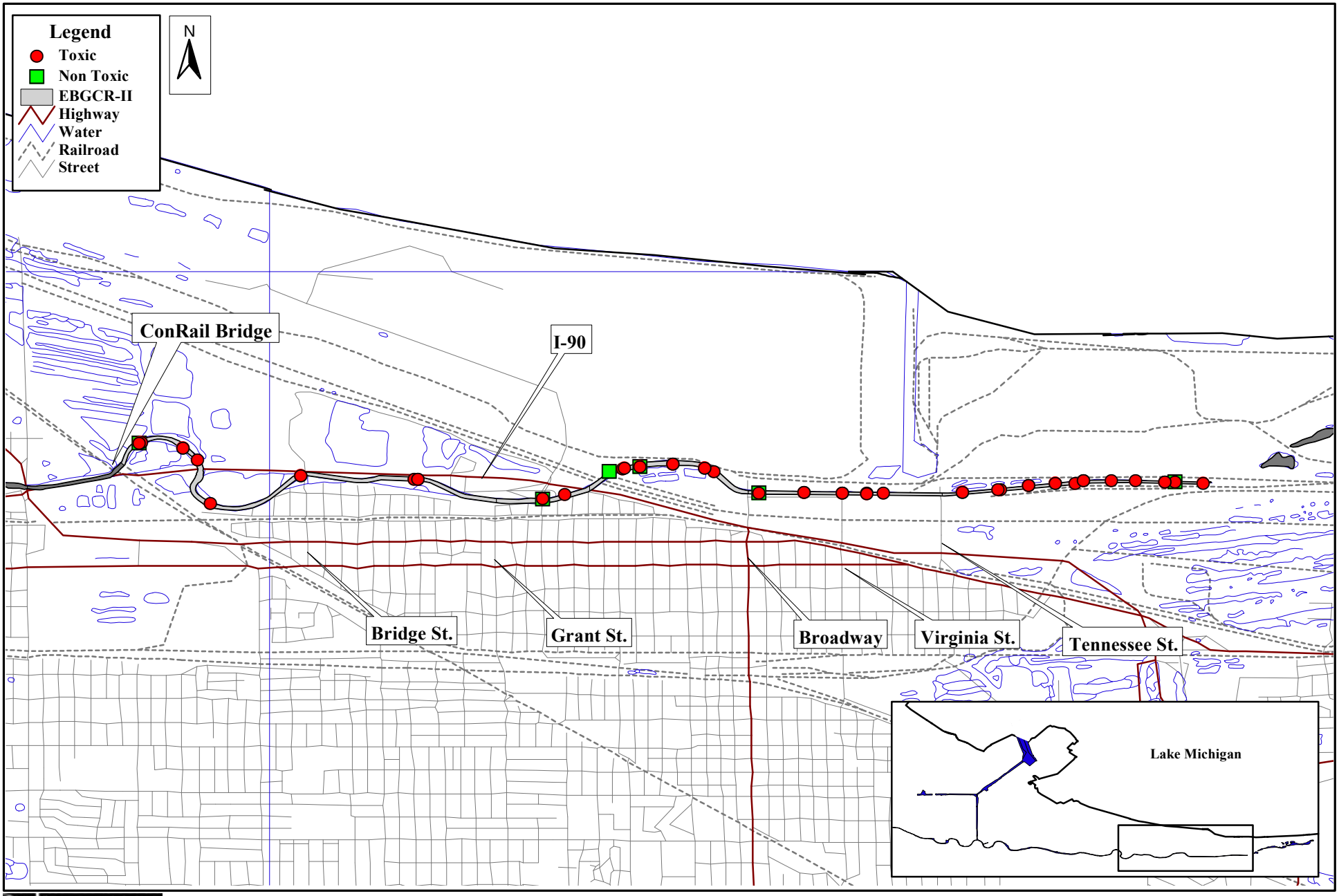
Figure 7.9. Areal extent of injury to sub-surface sediments in the EBGCR-II.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

Figure 7.10. Areal extent of sediment toxicity in the EBGCR-II.



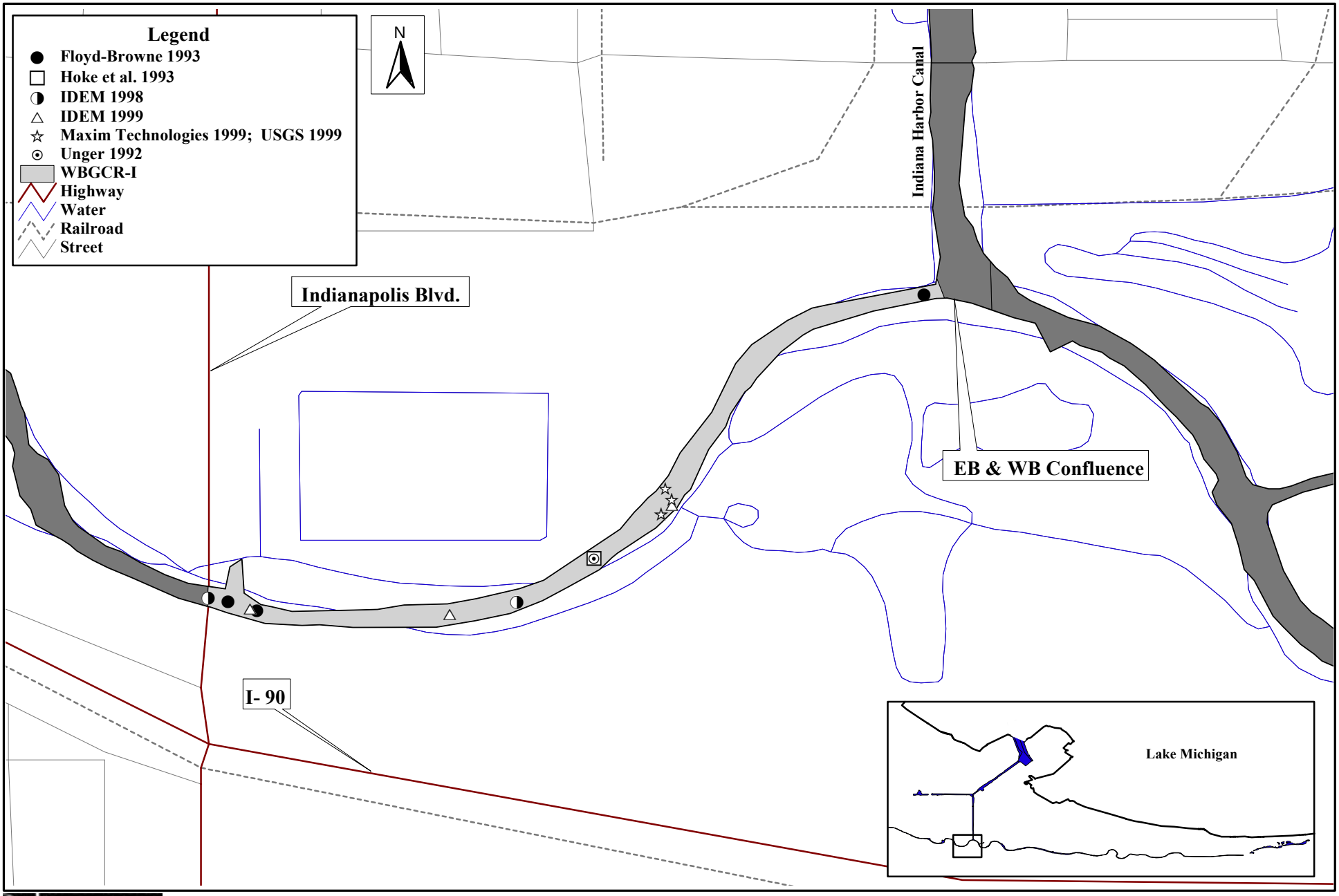
MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 2 2.5 Miles

Figures

Chapter 8 - West Branch of the Grand Calumet River - I

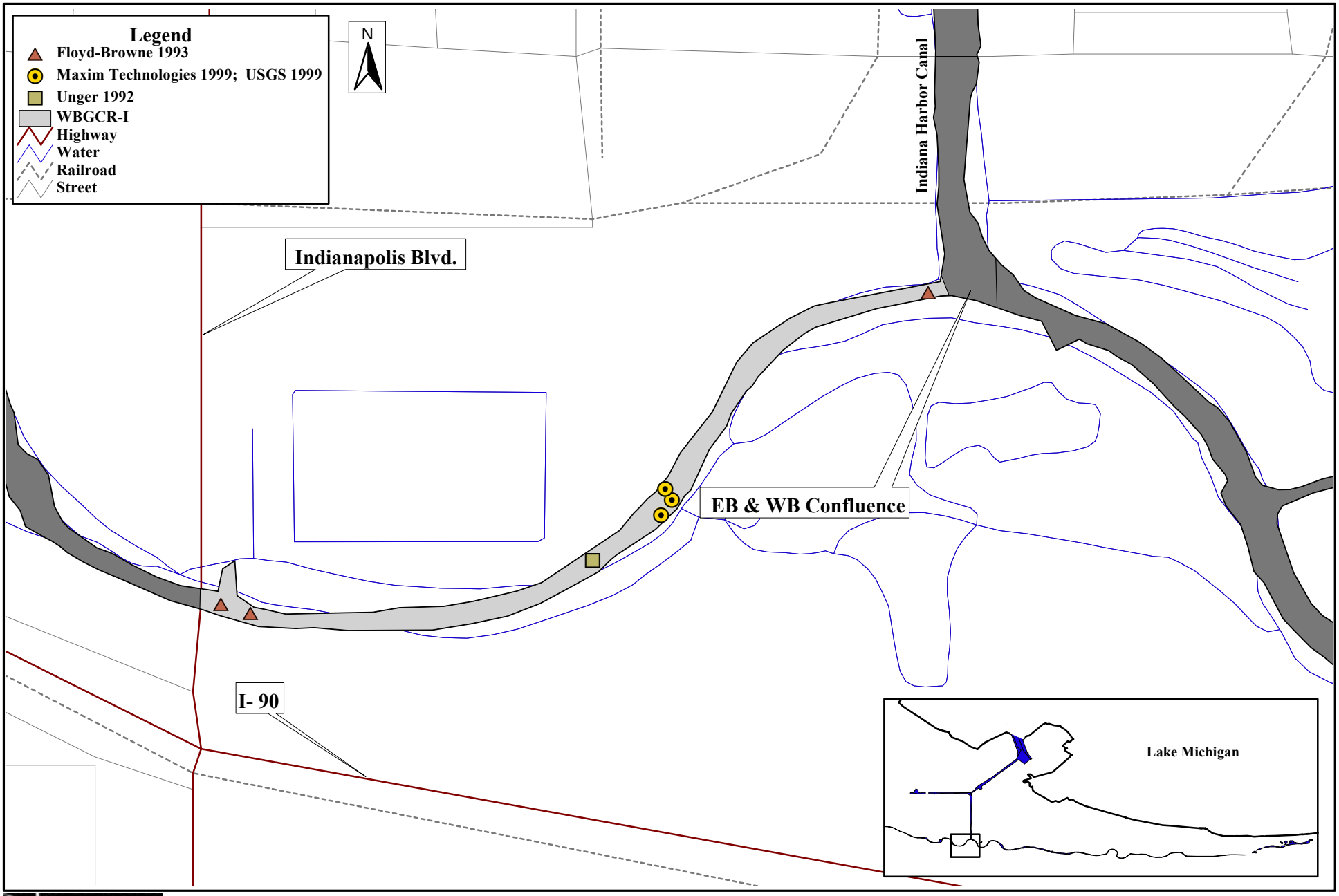
Figure 8.1. Location of sampling stations for surficial sediment chemistry in the WBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.1 0 0.1 0.2 0.3 0.4 Miles

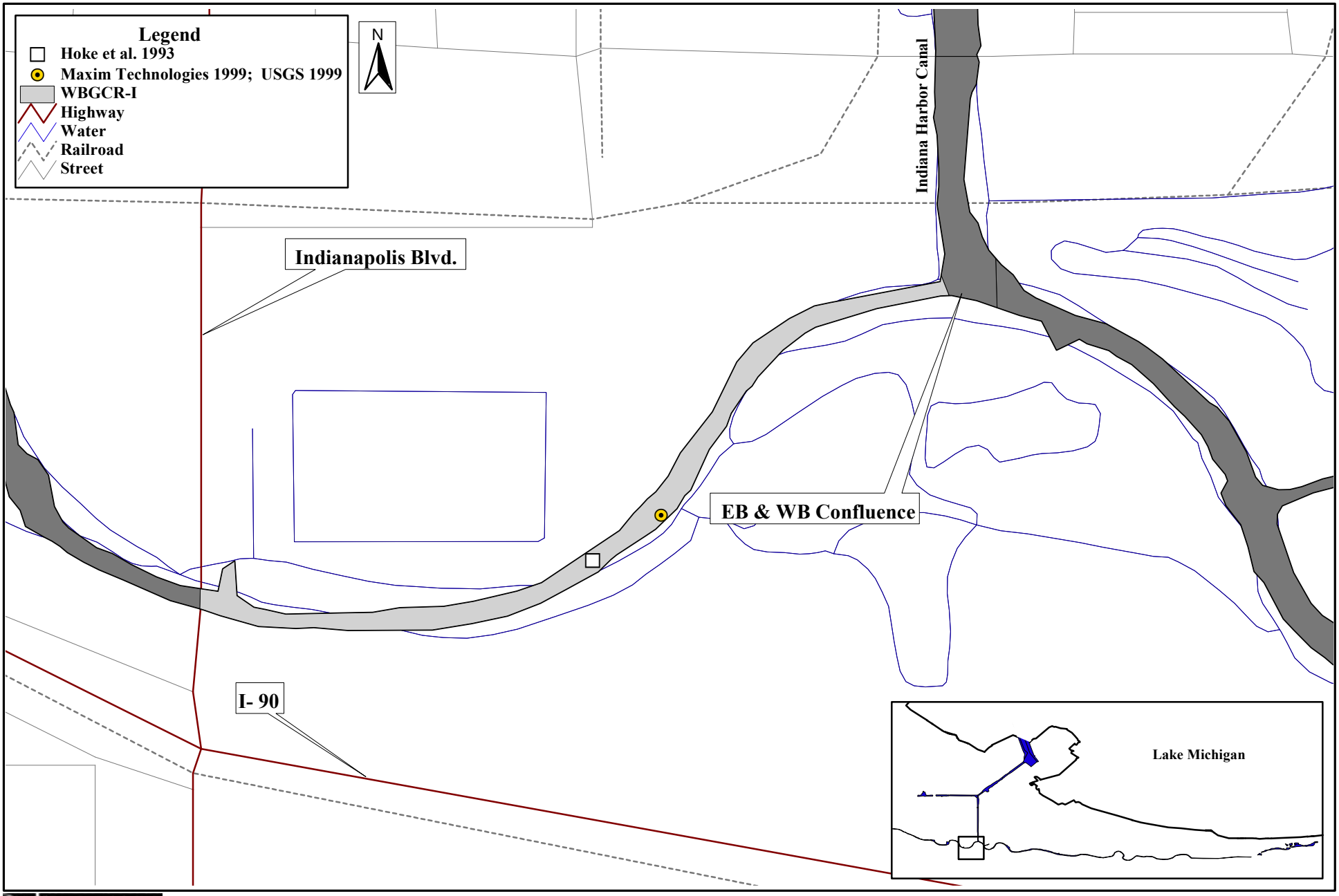
Figure 8.2. Location of sampling stations for sub-surface sediment chemistry in the WBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.1 0 0.1 0.2 0.3 0.4 Miles

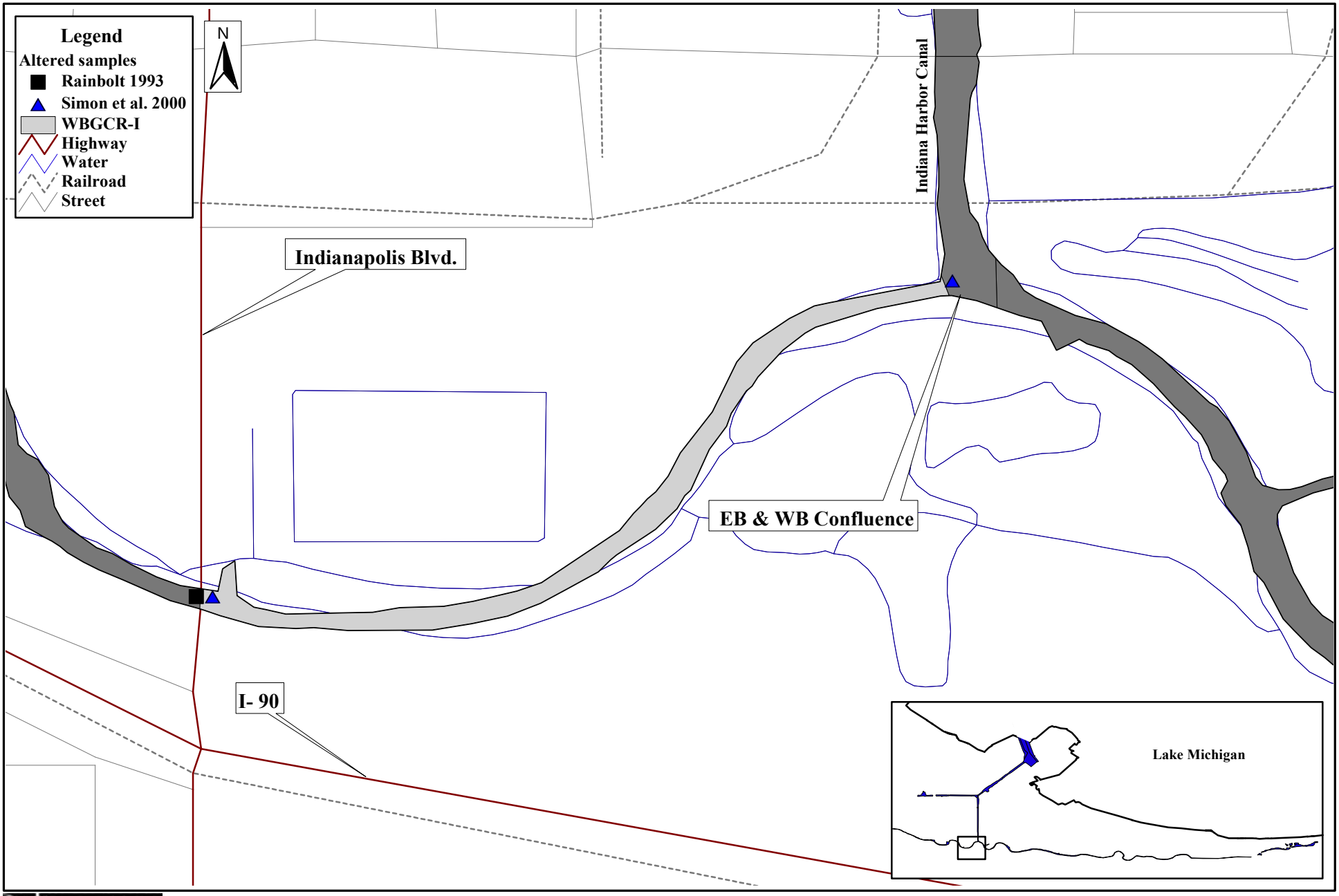
Figure 8.3. Location of sampling stations for sediment toxicity testing in the WBGCR-I.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.1 0 0.1 0.2 0.3 0.4 Miles

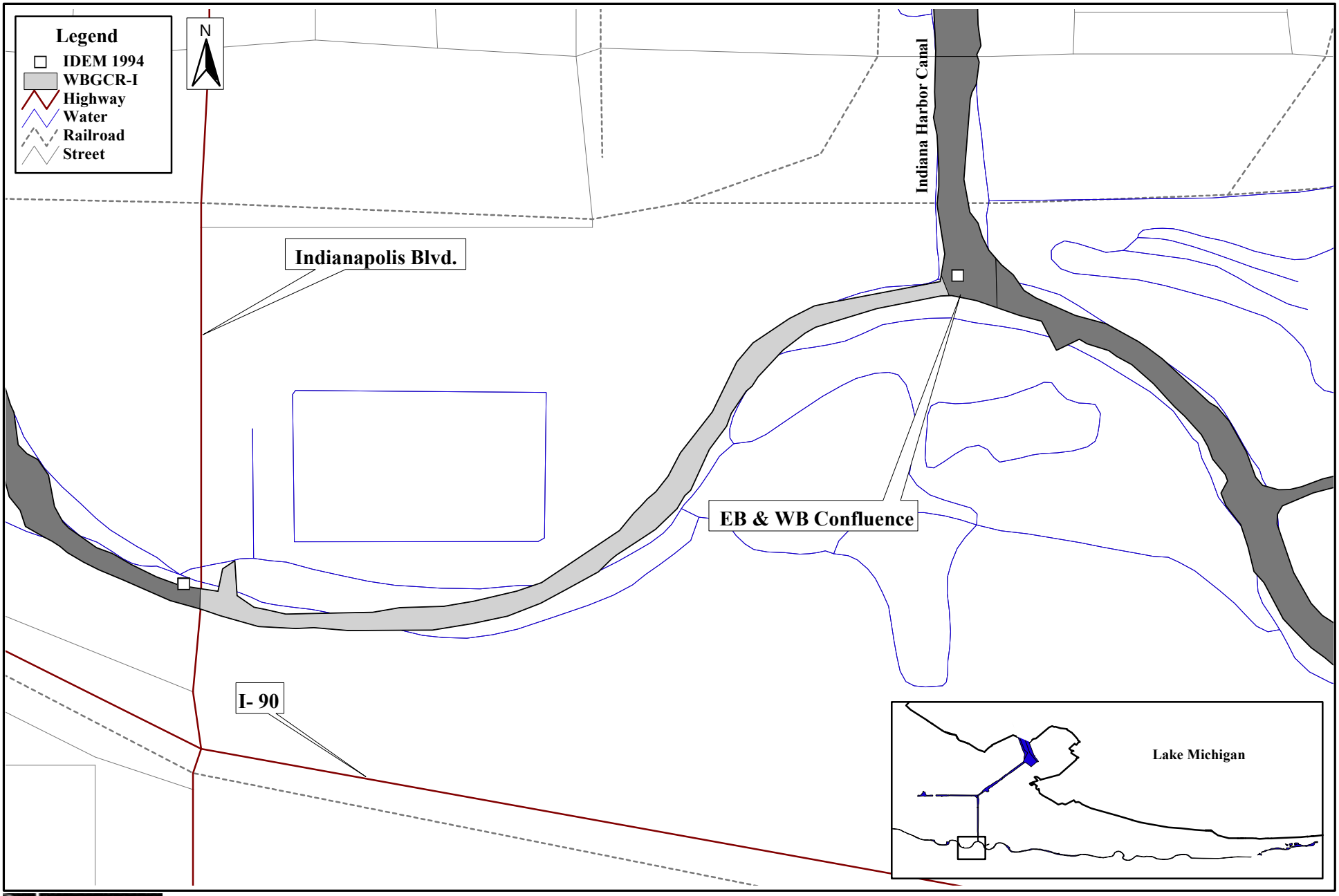
Figure 8.4. Areal extent of altered benthic invertebrate communities in the WBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.1 0 0.1 0.2 0.3 0.4 Miles

Figure 8.5. Location of sampling stations for tissue chemistry in the WBGCR-I.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.1 0 0.1 0.2 0.3 0.4 Miles

Figure 8.6. Spatial distribution of mean PEC-Qs in surficial sediments within the WBGCR-I.

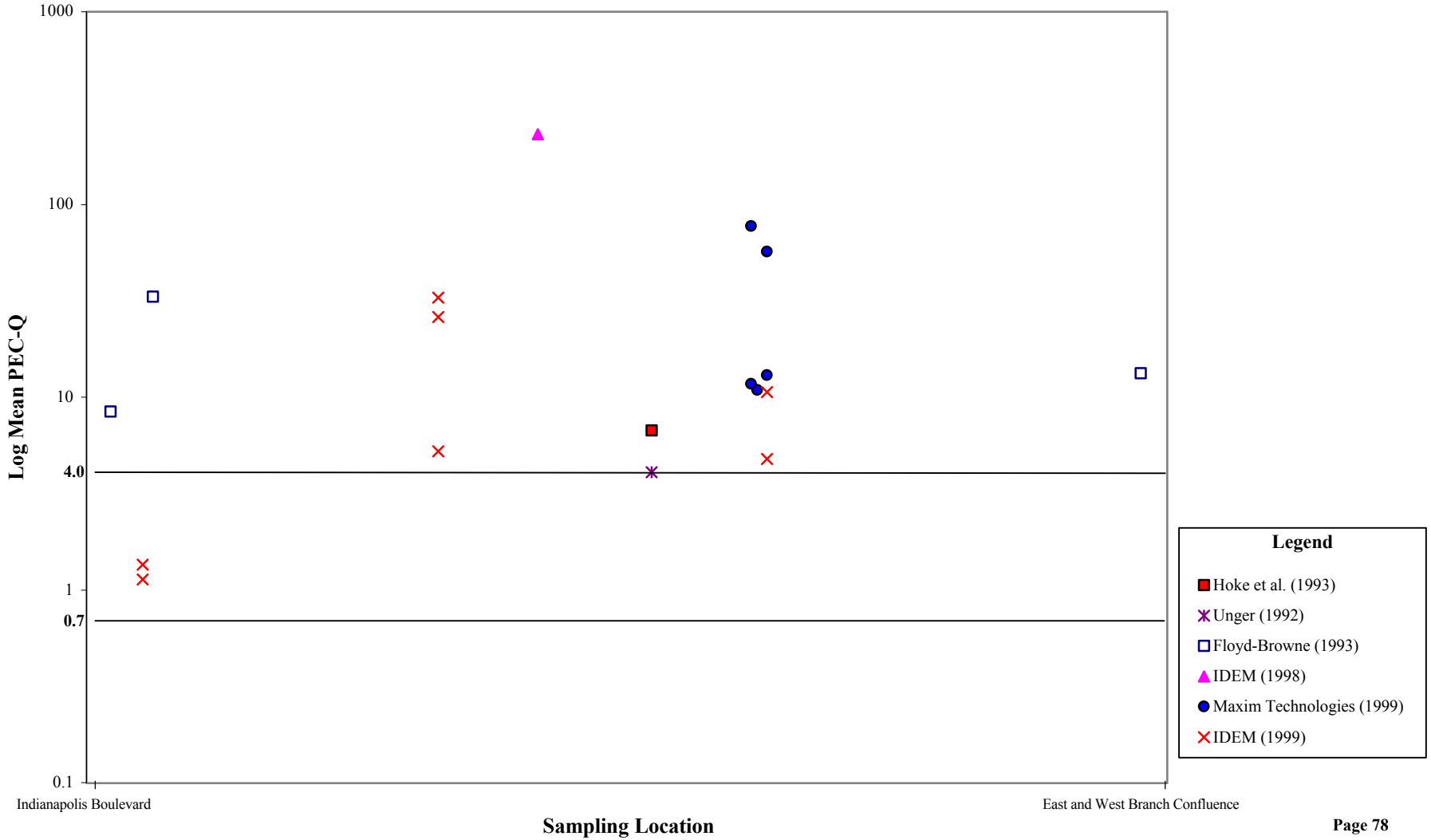
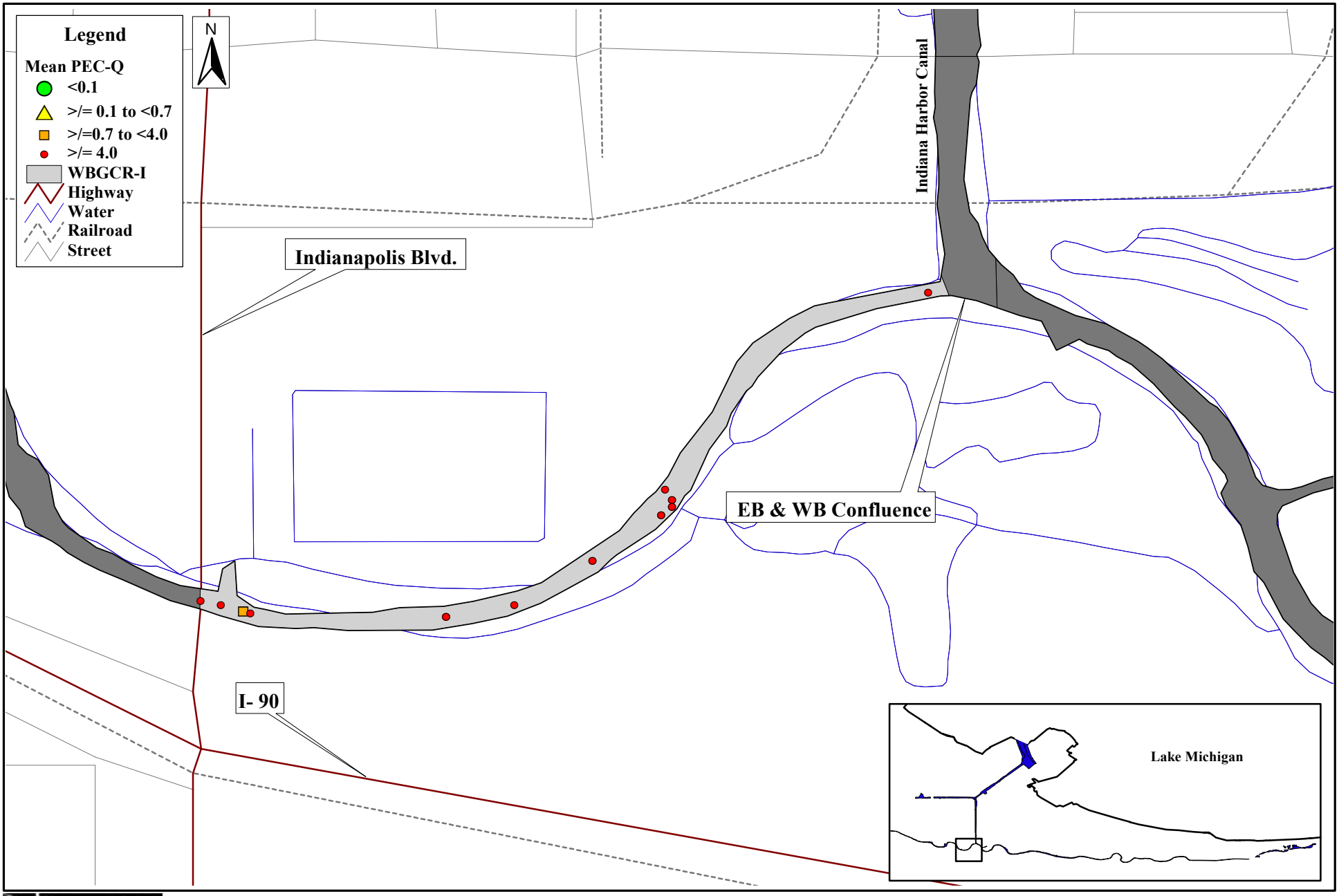


Figure 8.7. Areal extent of injury to surficial sediments in the WBGCR-I.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.1 0 0.1 0.2 0.3 0.4 Miles

Figure 8.8. Spatial distribution of mean PEC-Qs in sub-surface sediments within the WBGCR-I.

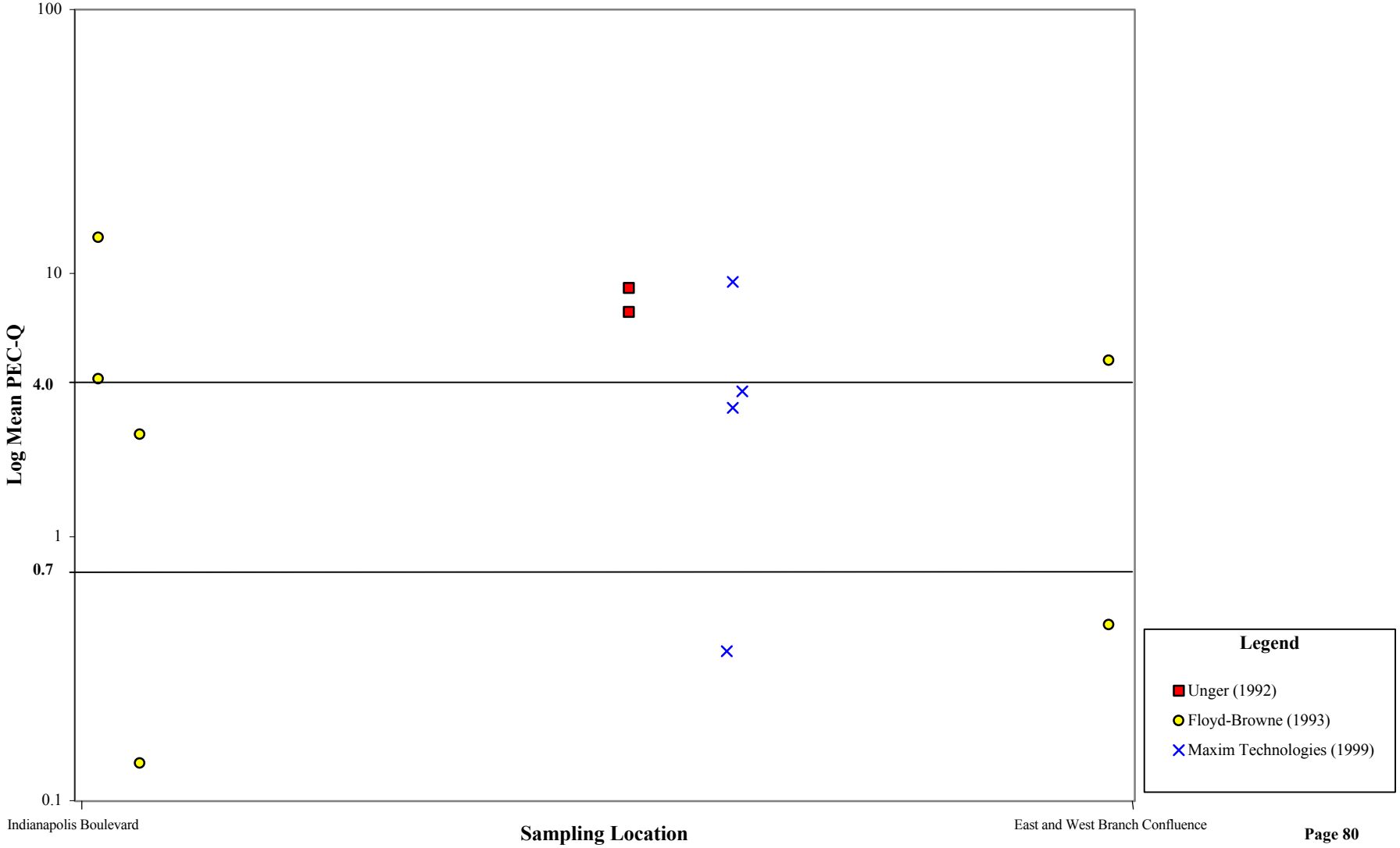


Figure 8.9. Areal extent of injury to sub-surface sediments in the WBGCR-I.

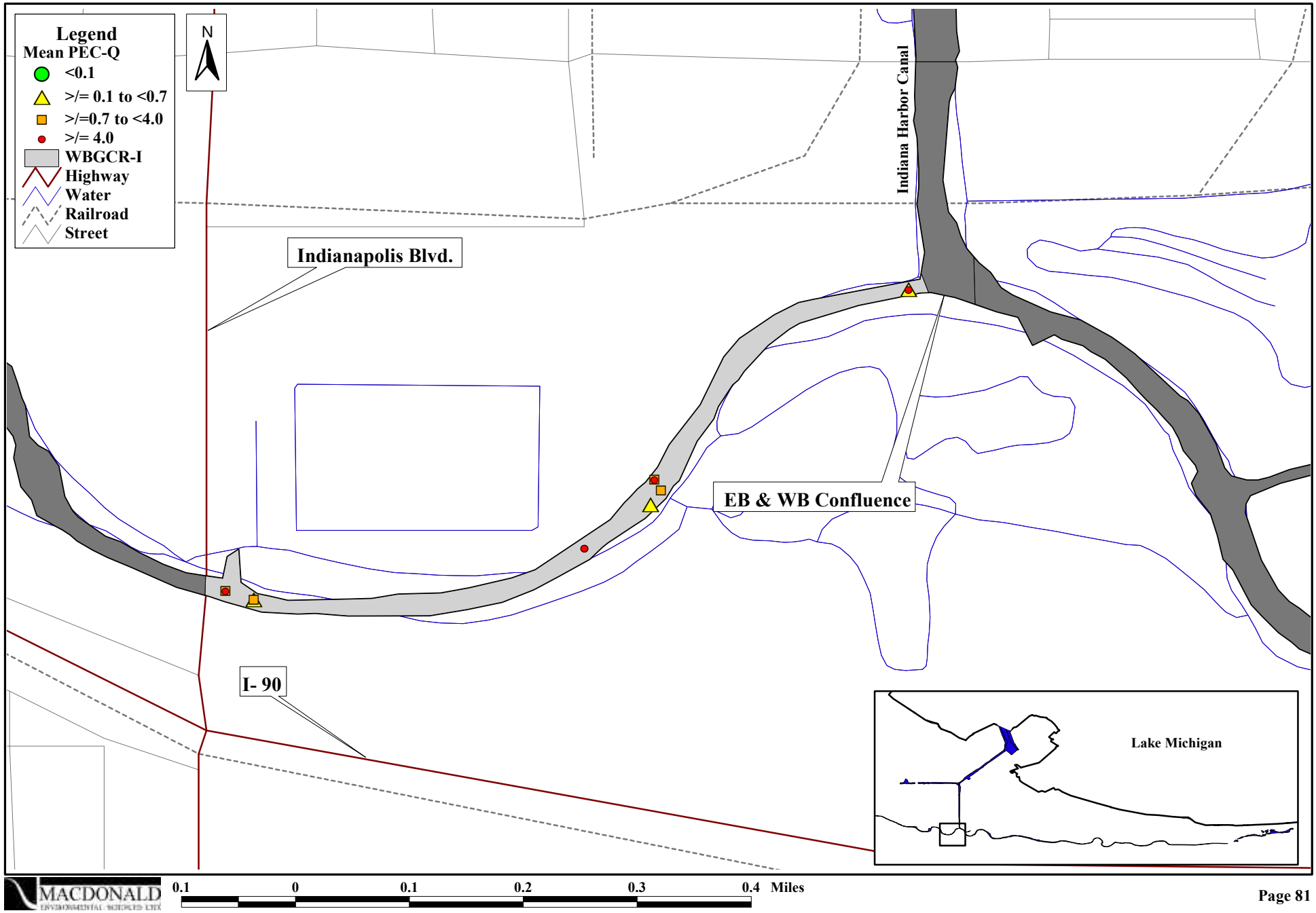
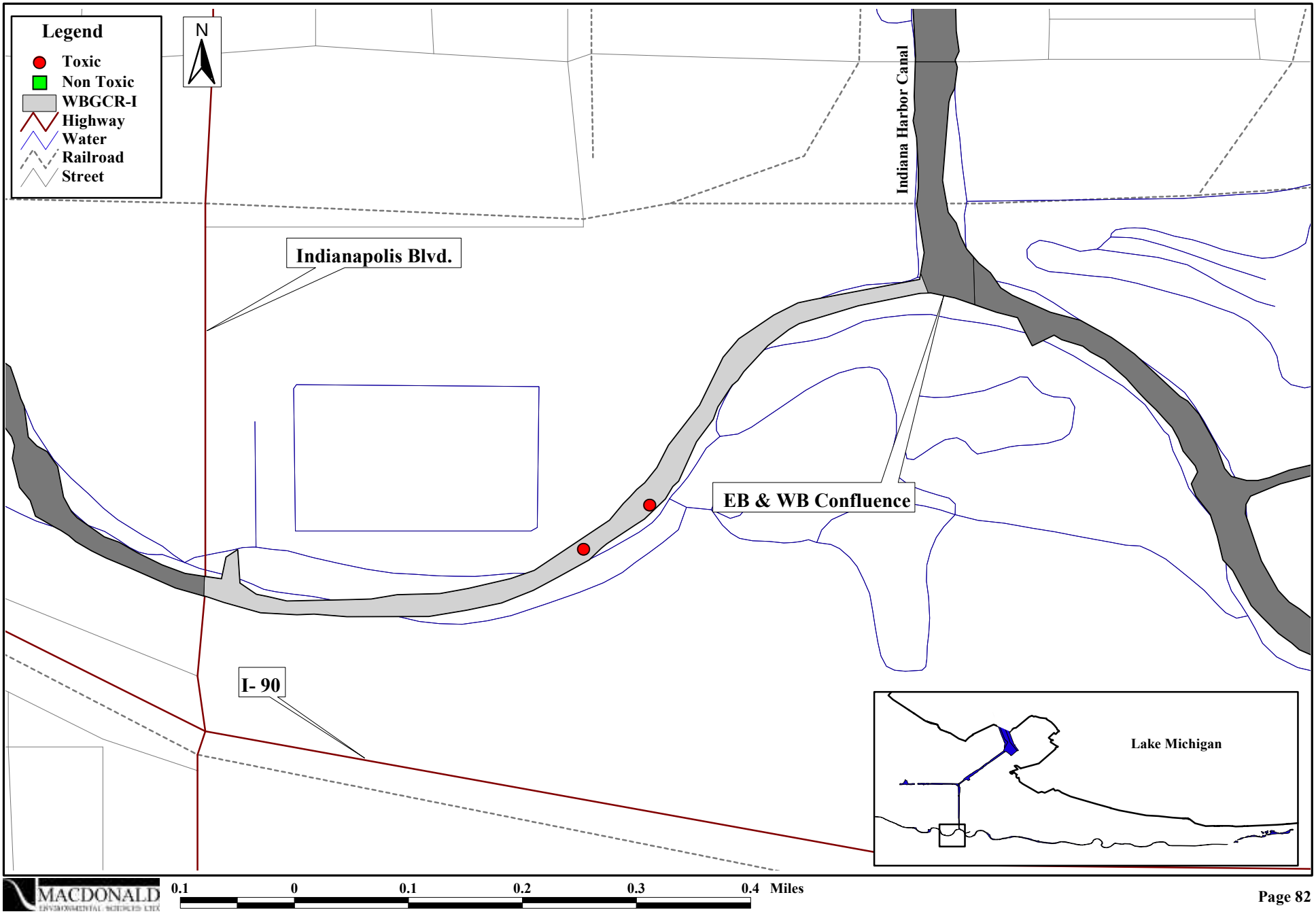


Figure 8.10. Areal extent of sediment toxicity in the WBGCR-I.



Figures

Chapter 9 - West Branch of the Grand Calumet River - II

Figure 9.1. Location of sampling stations for surficial sediment chemistry in the WBGCR-II.

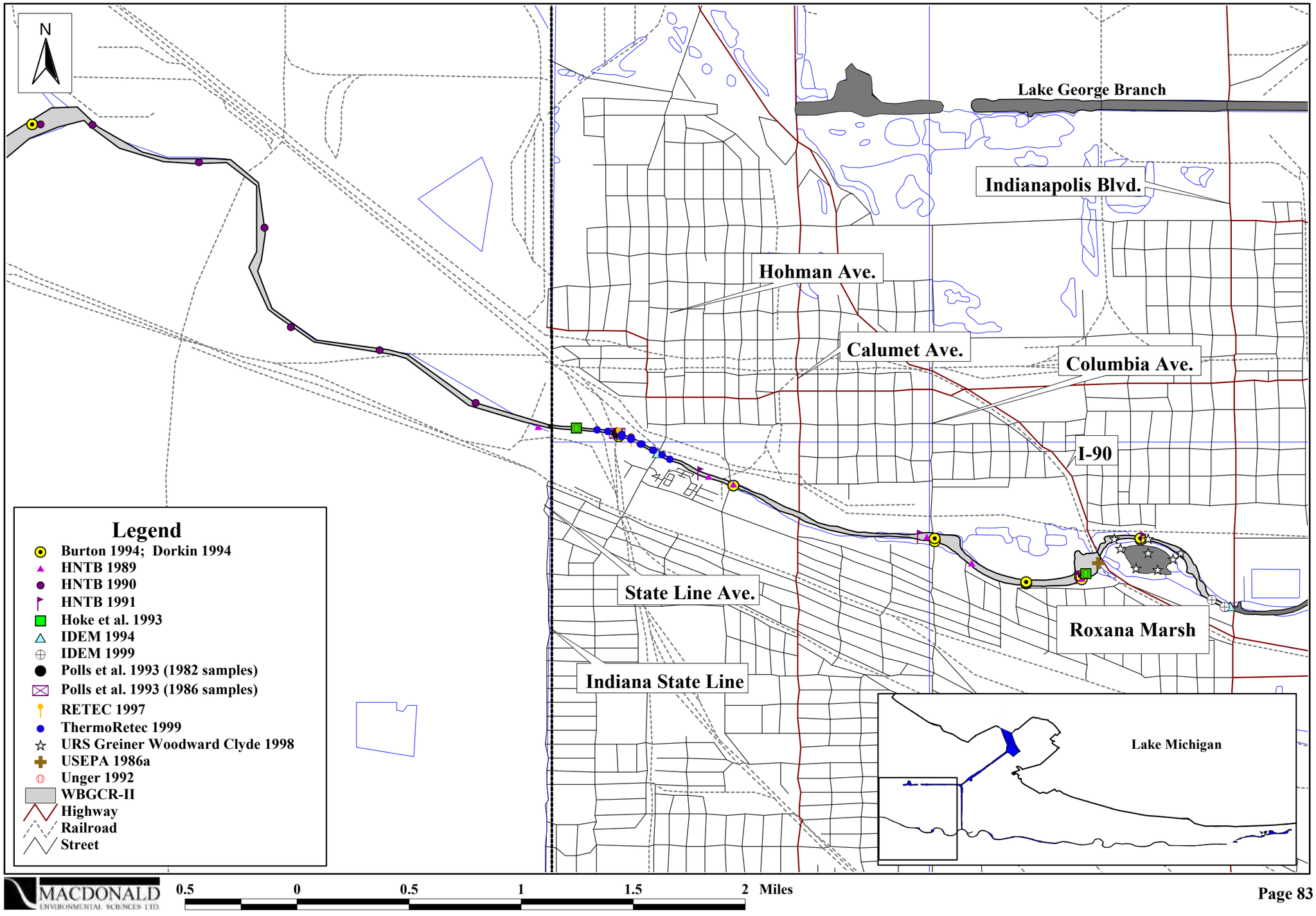


Figure 9.2. Location of sampling stations for sub-surface sediment chemistry in the WBGCR-II.

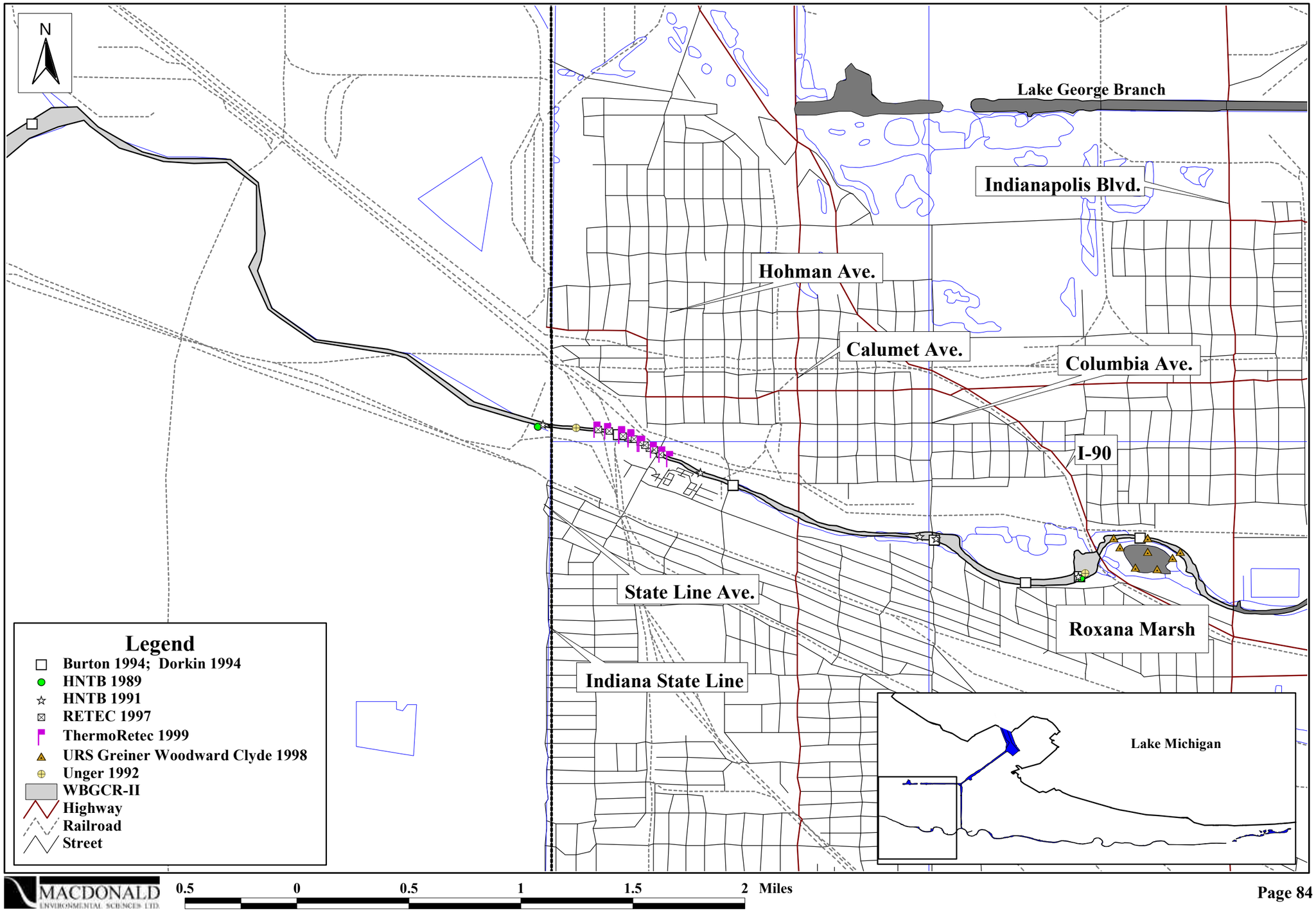
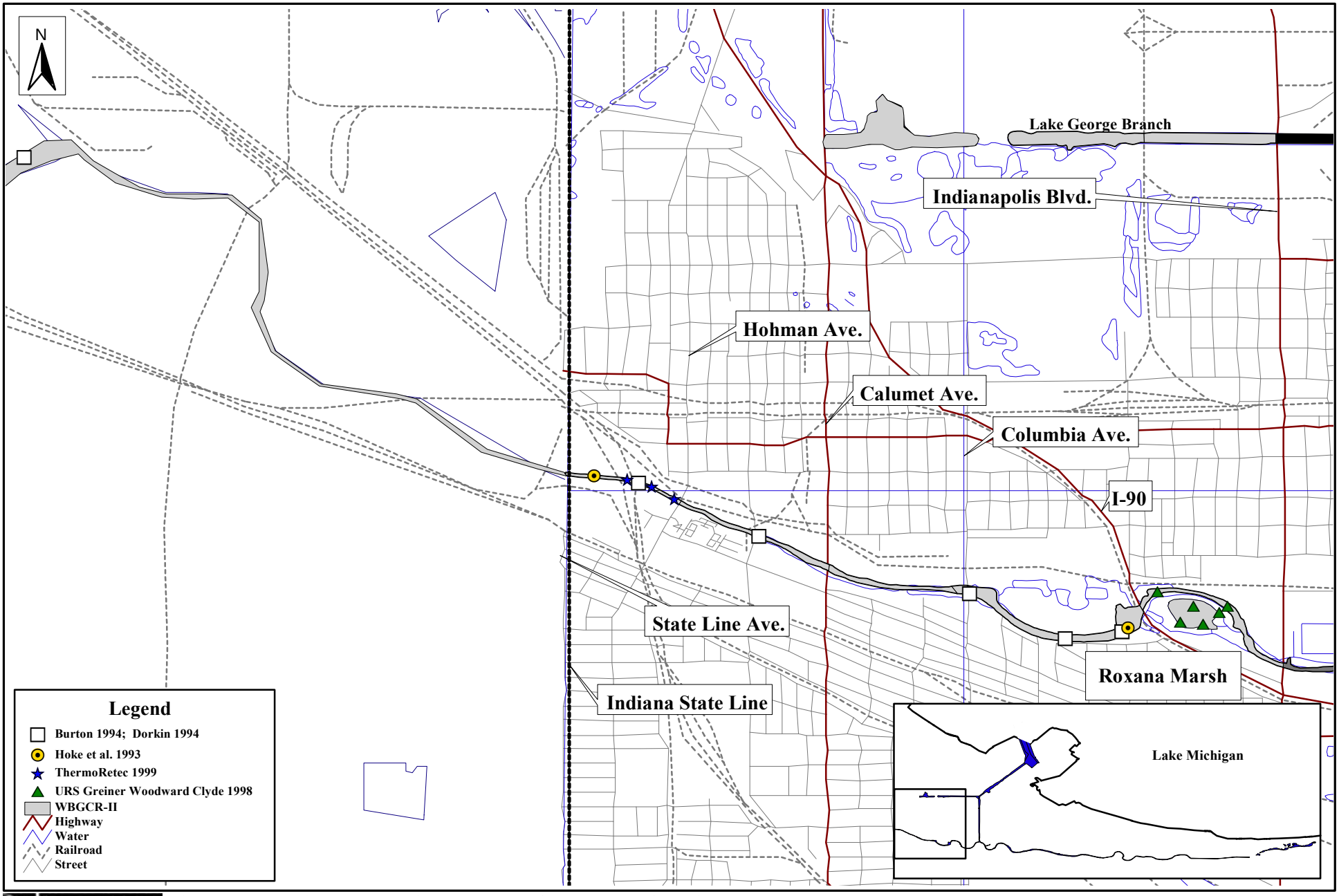


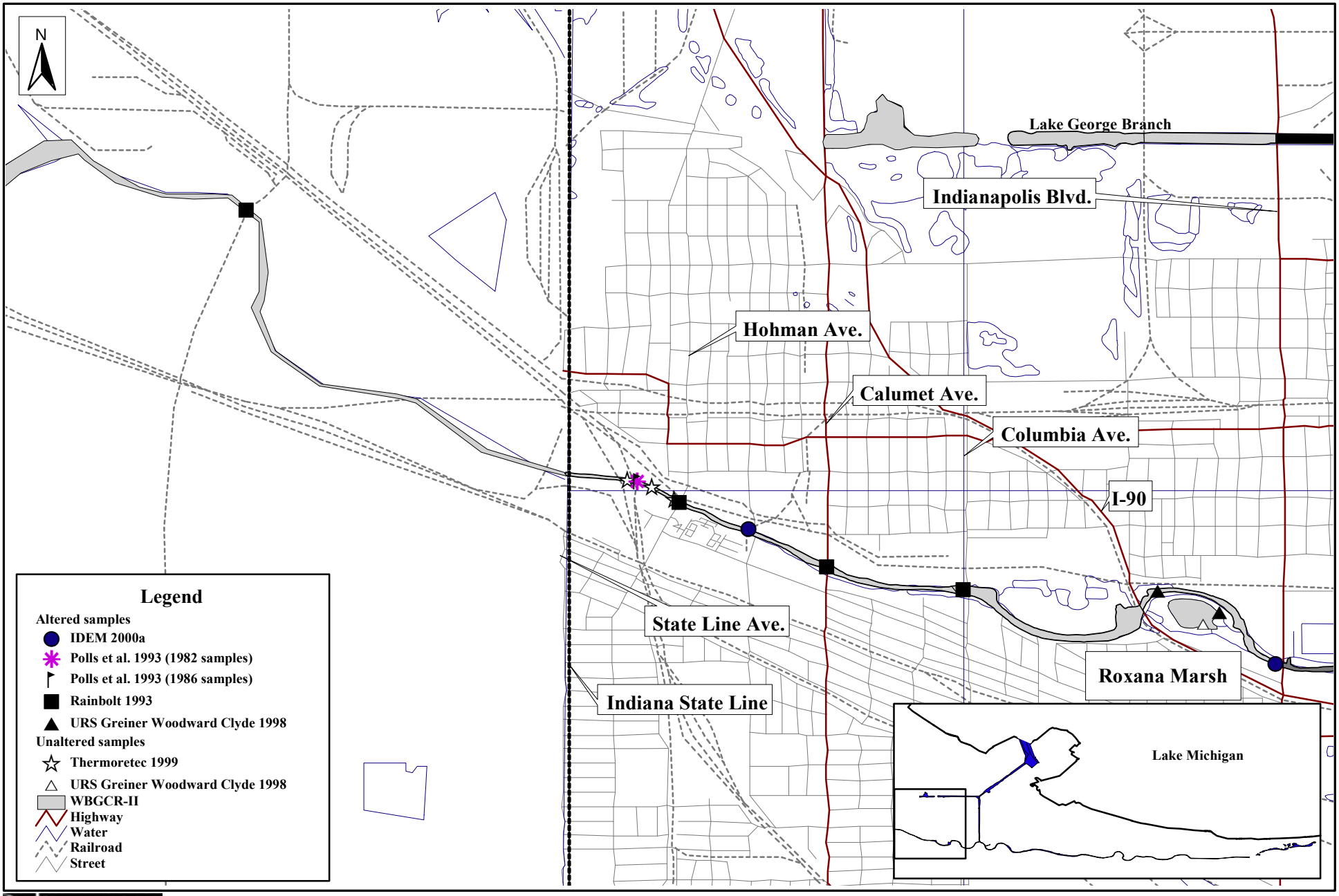
Figure 9.3. Location of sampling stations for sediment toxicity testing in the WBGCR-II.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

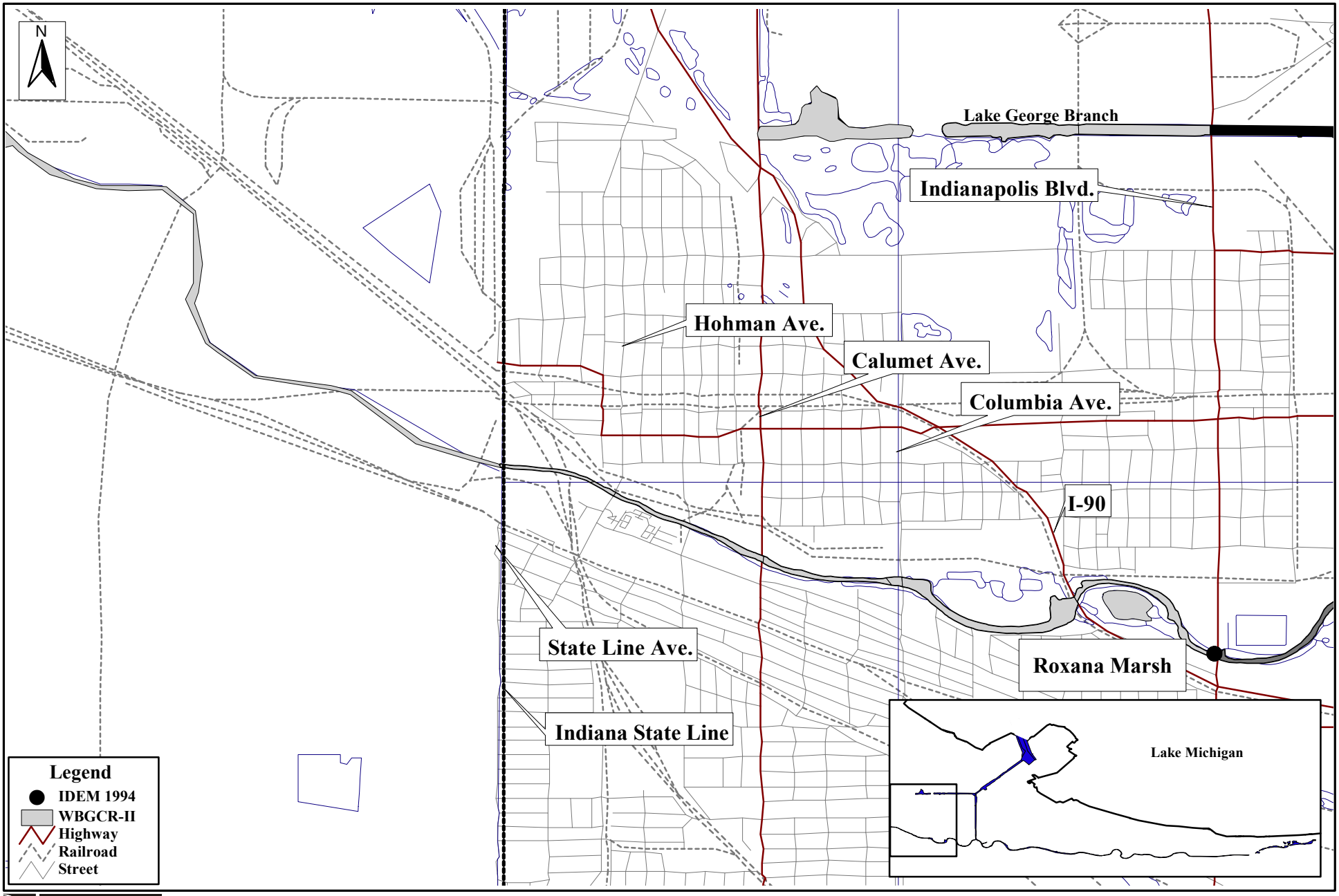
Figure 9.4. Areal extent of altered and unaltered benthic invertebrate communities in the WBGCR-II.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

Figure 9.5. Location of sampling stations for tissue chemistry in the WBGCR-II.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 1 Miles

Figure 9.6. Spatial distribution of mean PEC-Qs in surficial sediments within the WBGCR-II.

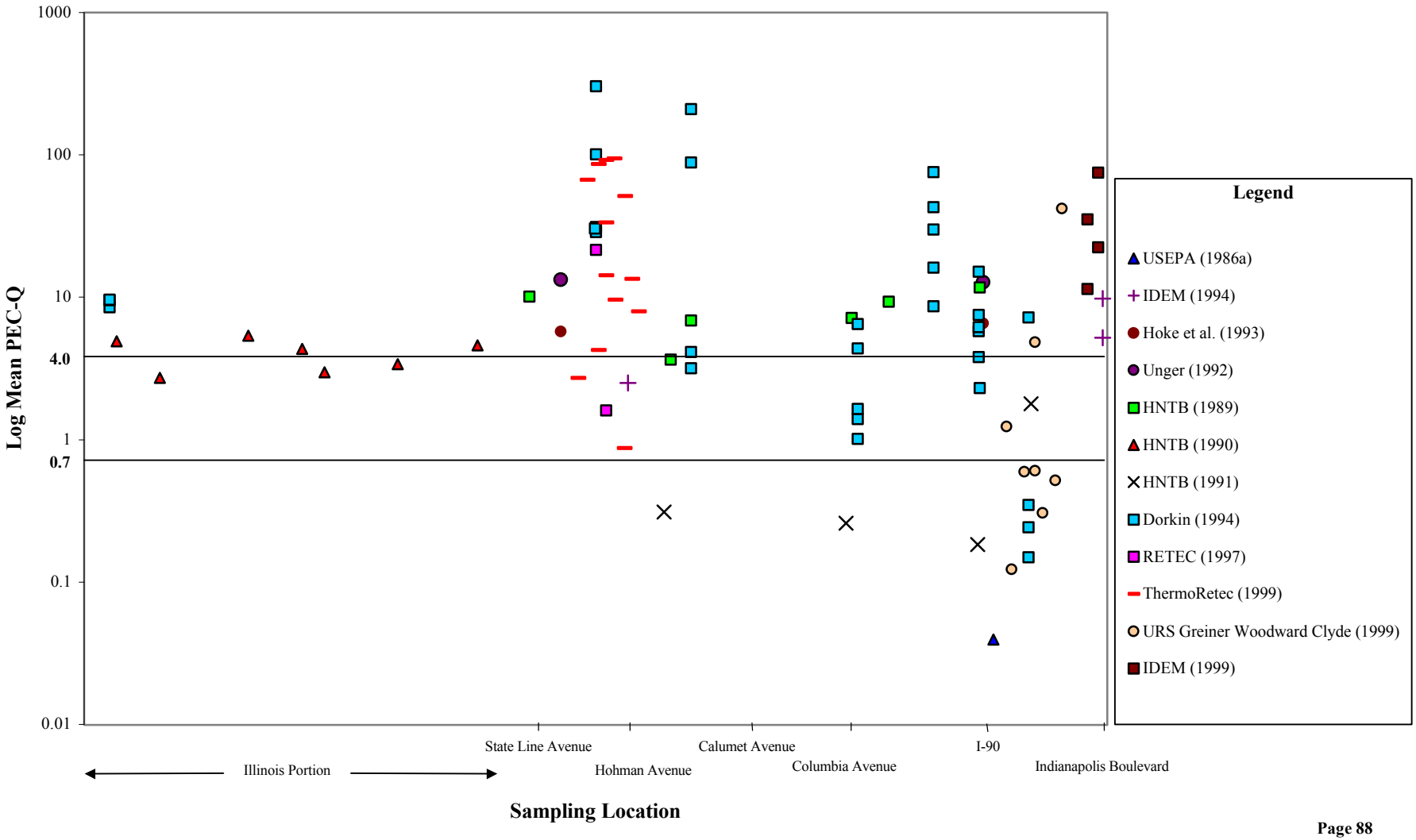


Figure 9.7. Areal extent of injury to surficial sediments in the WBGCR-II.

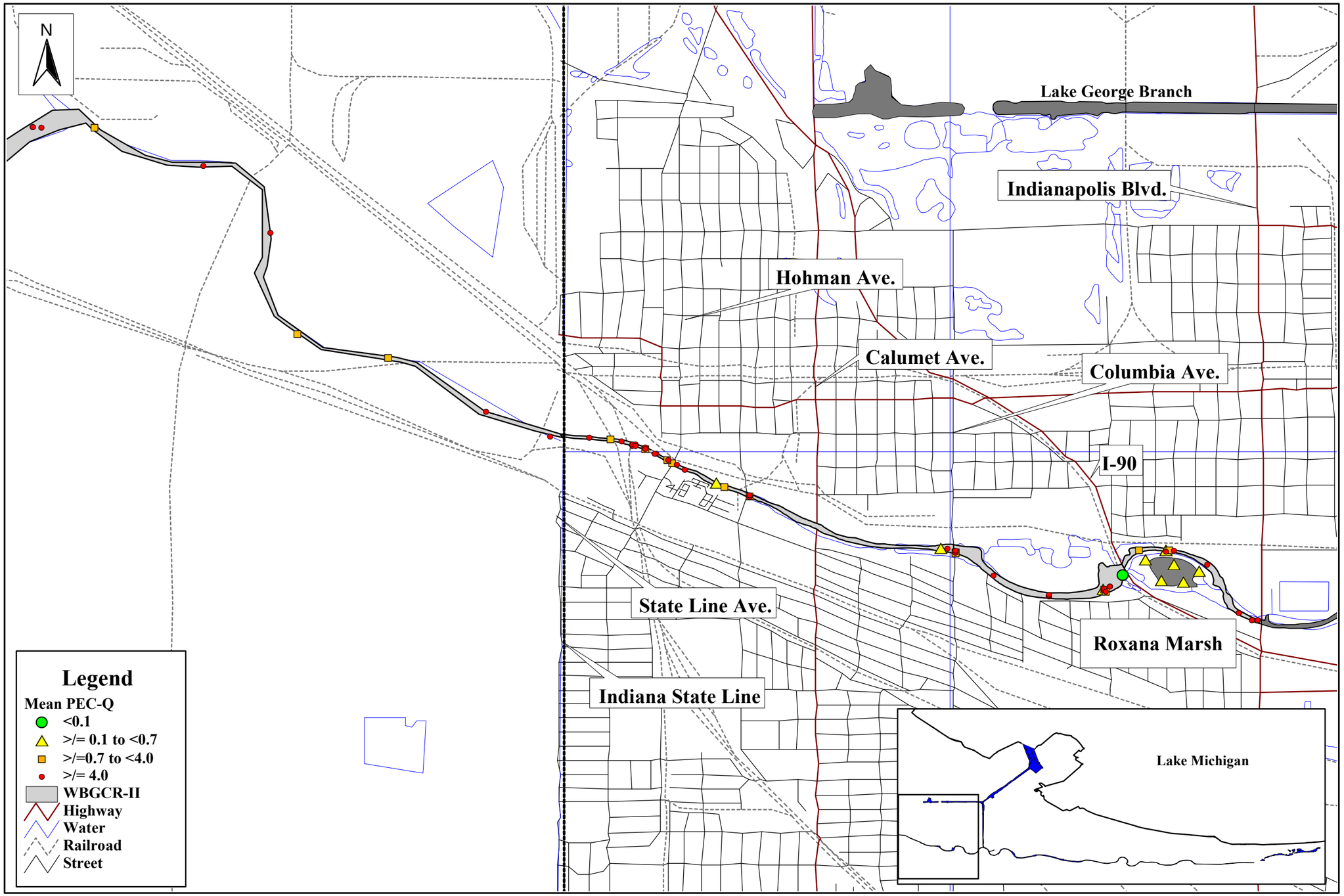


Figure 9.8. Spatial distribution of mean PEC-Qs in sub-surface sediments within the WBGCR-II.

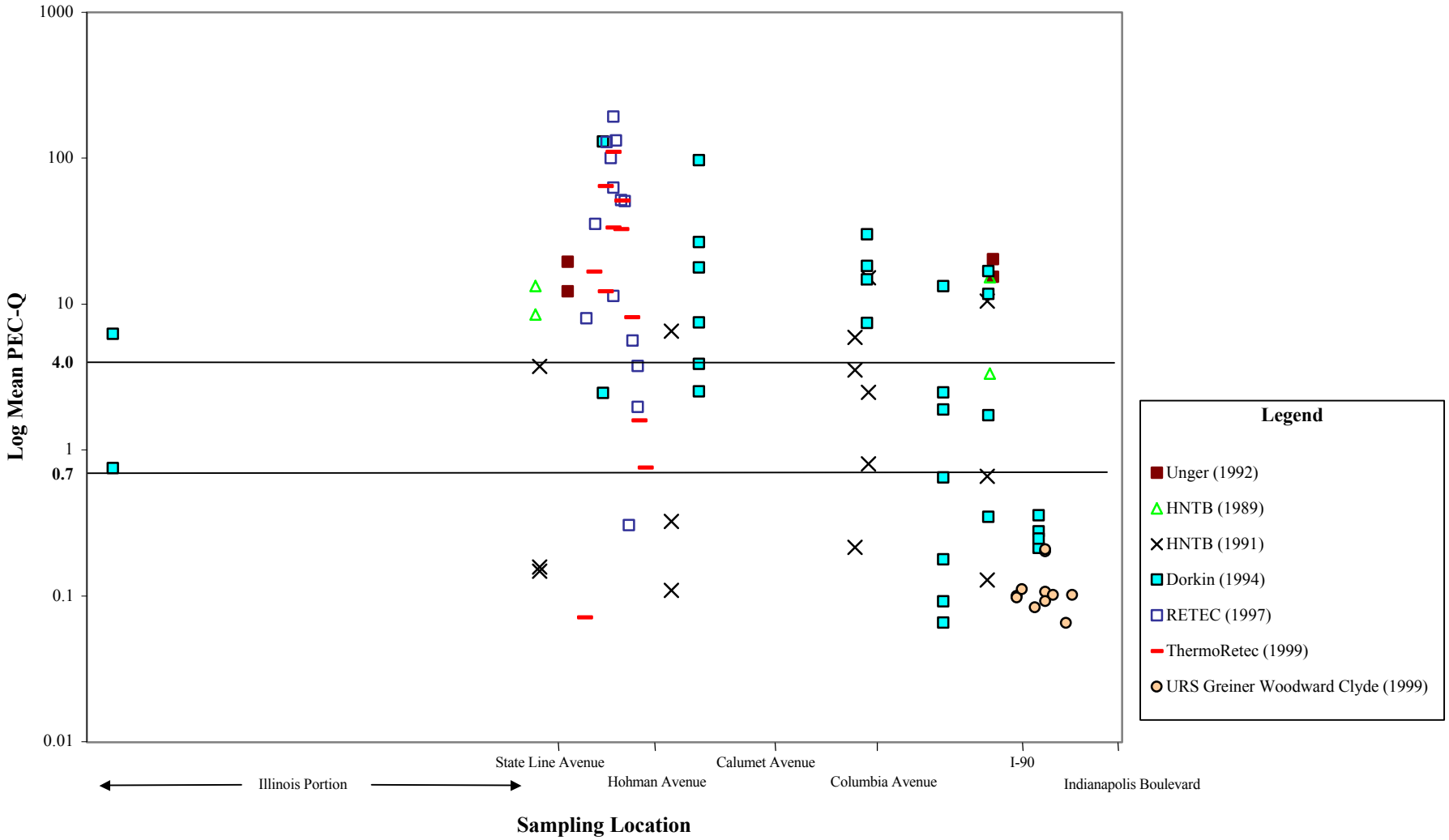


Figure 9.9. Areal extent of injury to sub-surface sediments in the WBGCR-II.

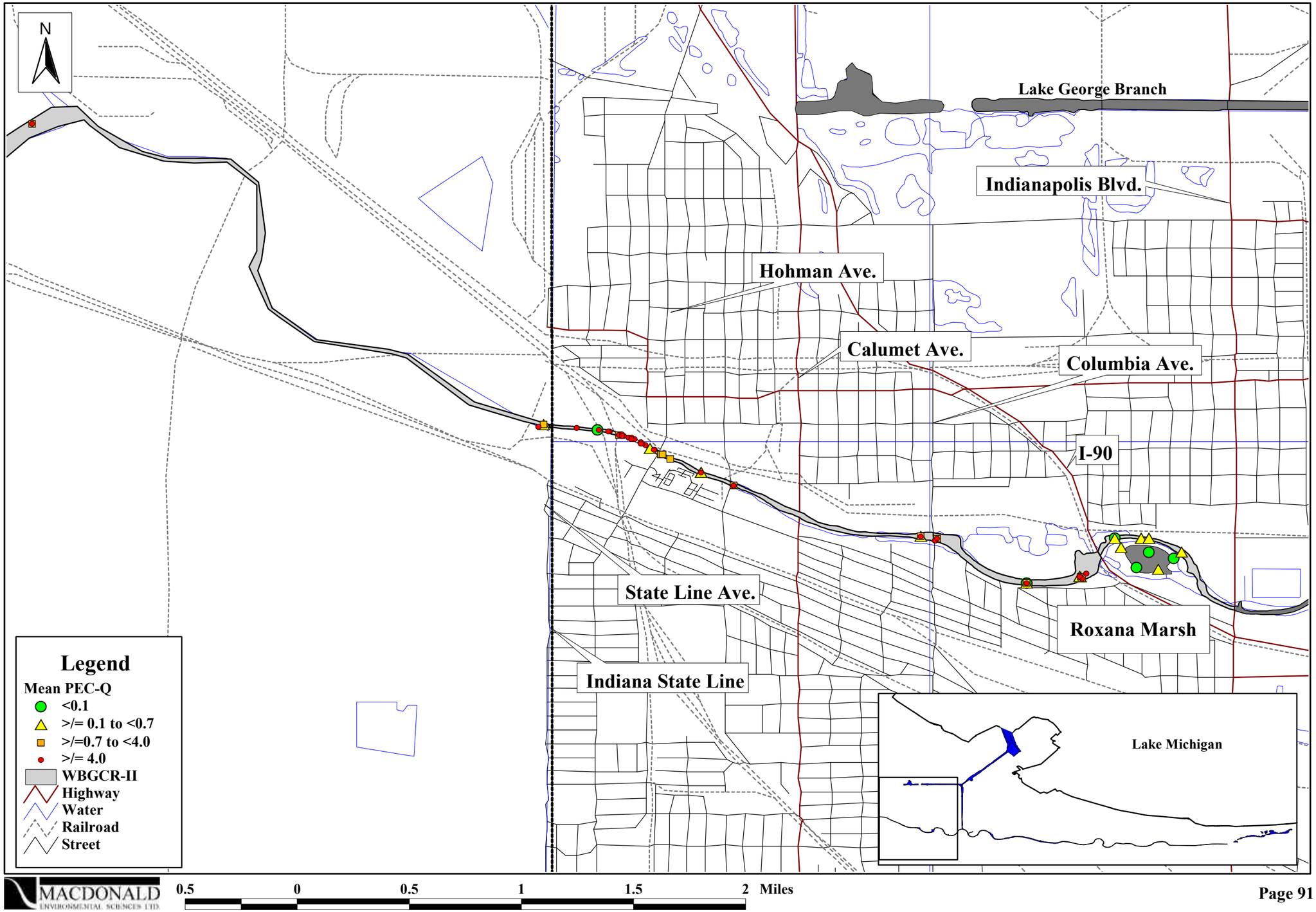
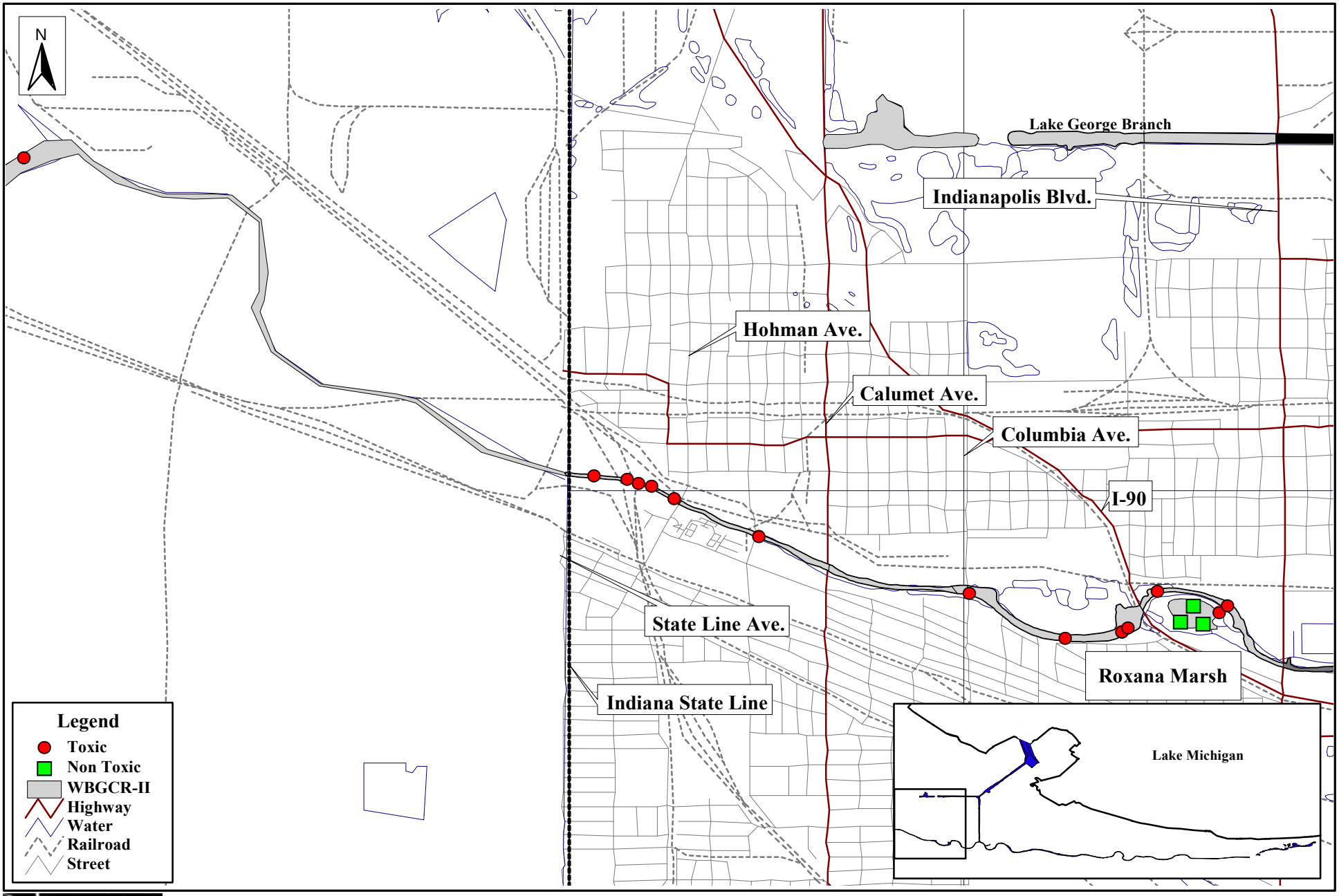


Figure 9.10. Areal extent of sediment toxicity in the WBGCR-II.



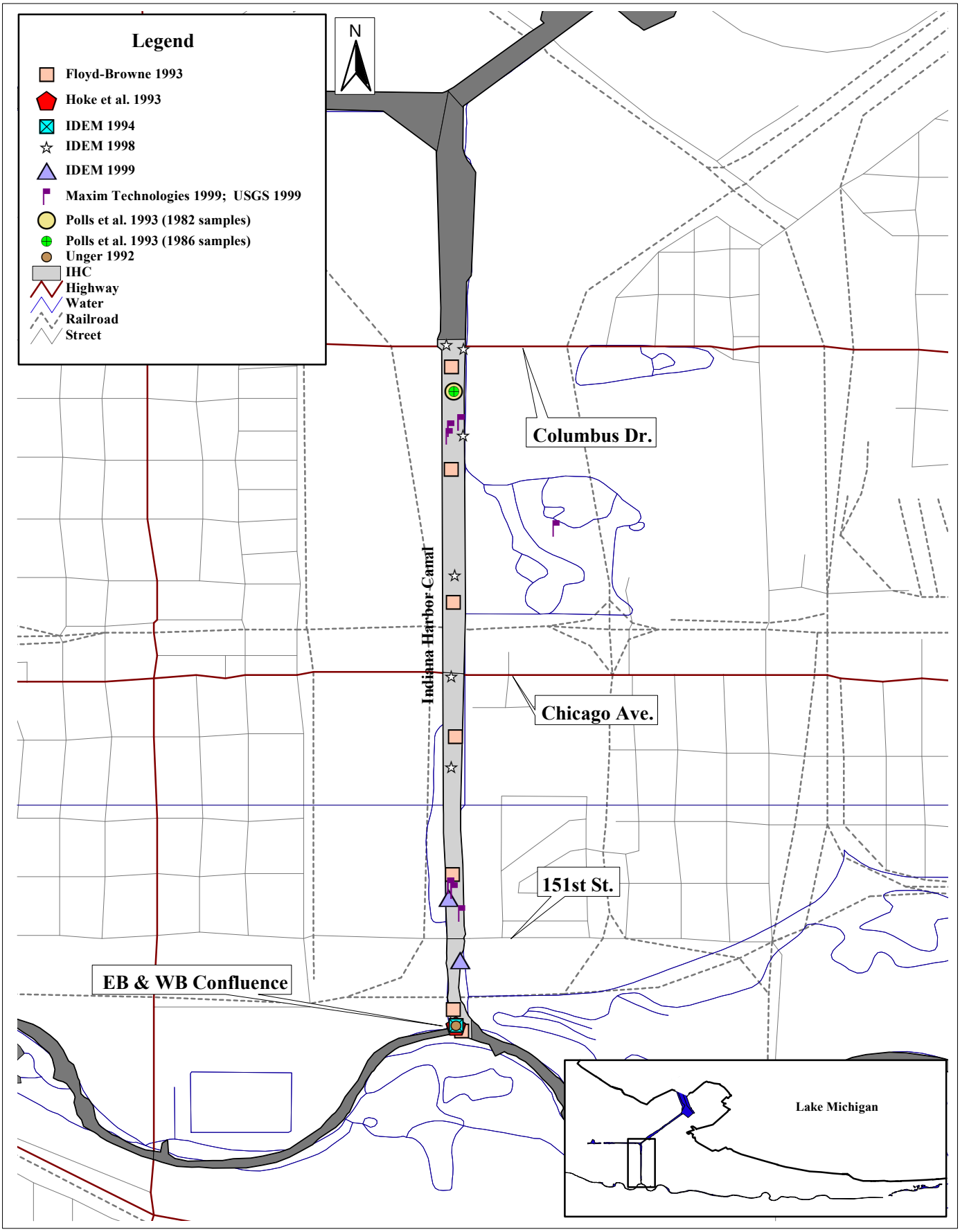
MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 Miles

Figures

Chapter 10 - Indiana Harbor Canal

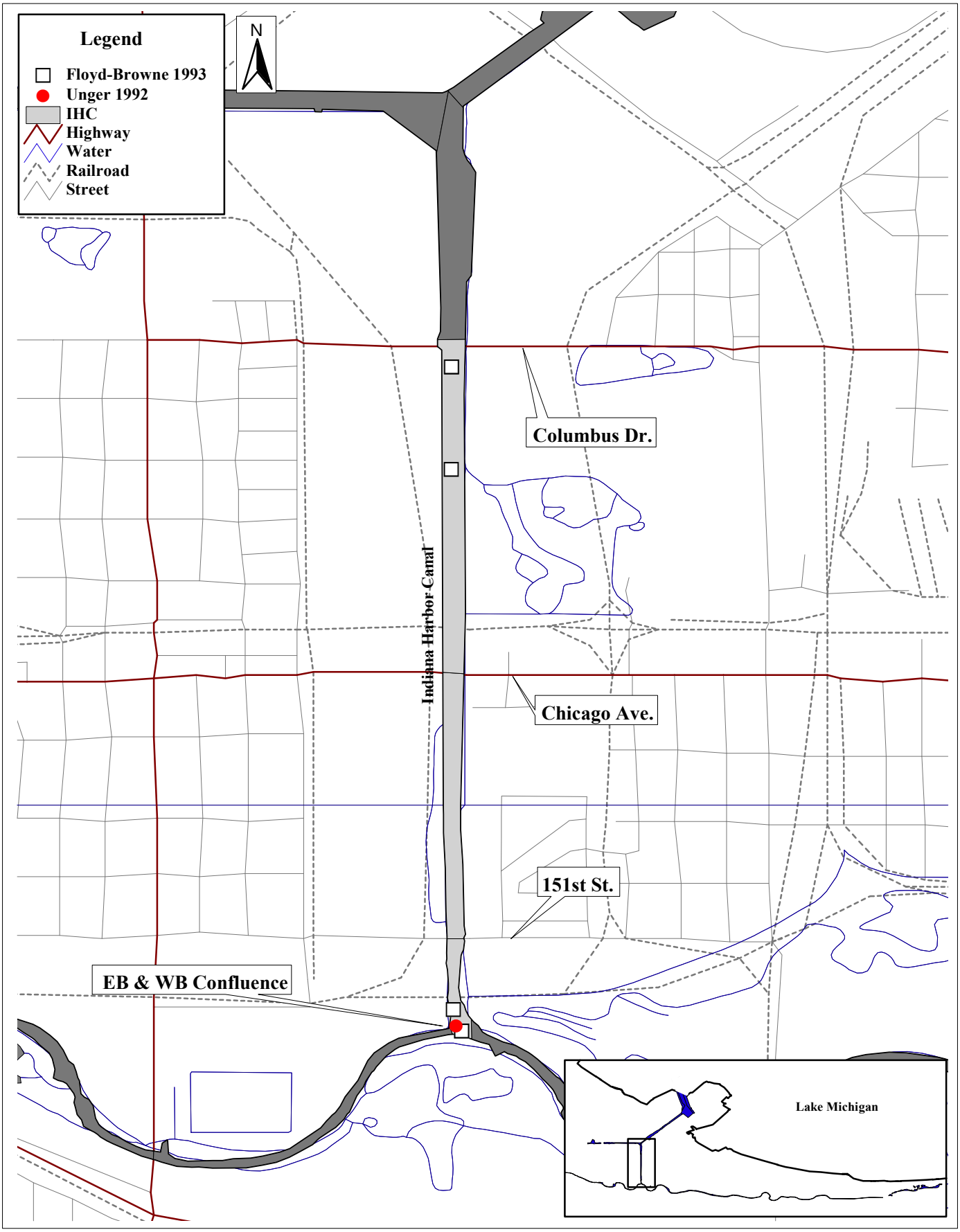
Figure 10.1. Location of sampling stations for surficial sediment chemistry in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

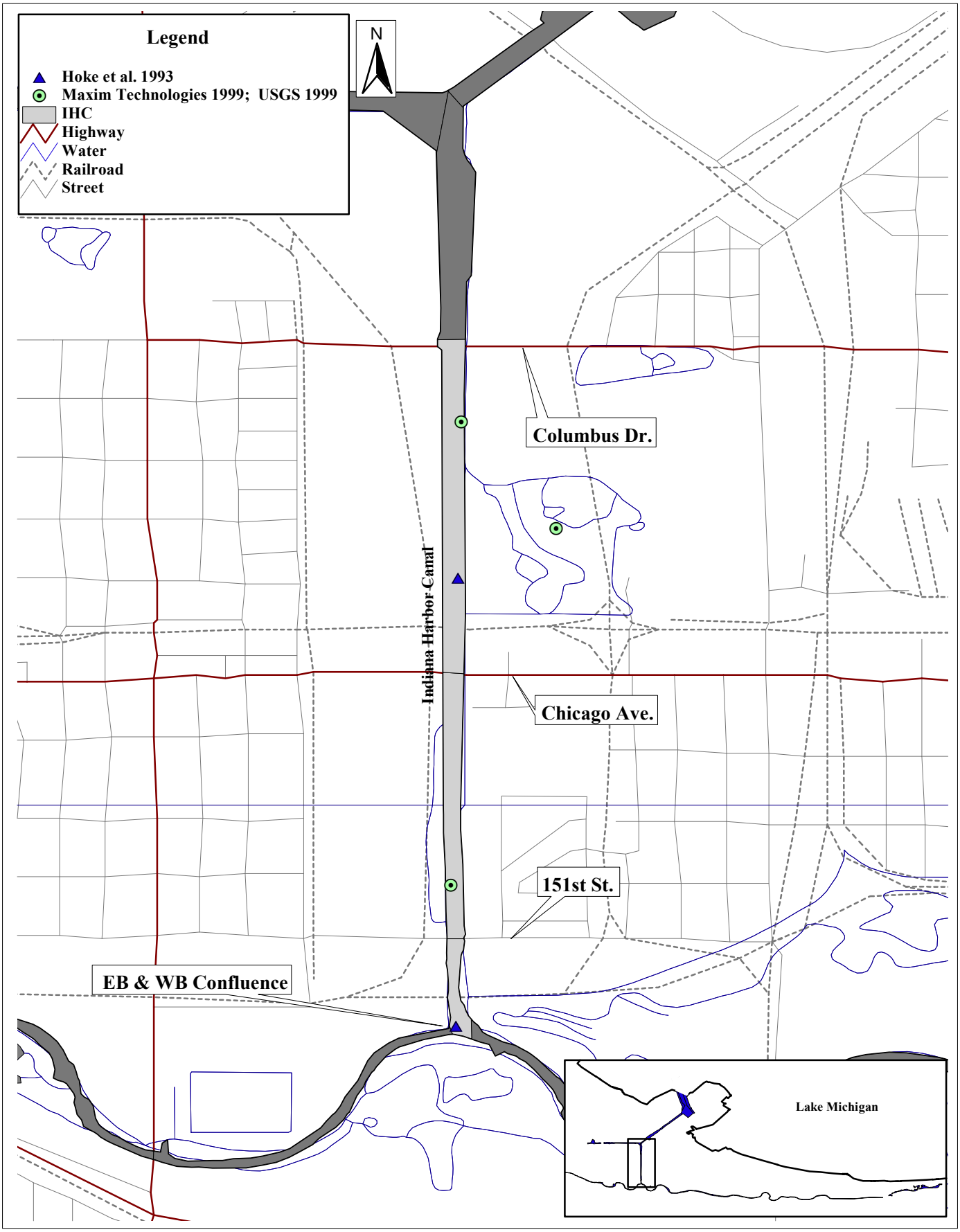
Figure 10.2. Location of sampling stations for sub-surface sediment chemistry in the IHC



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

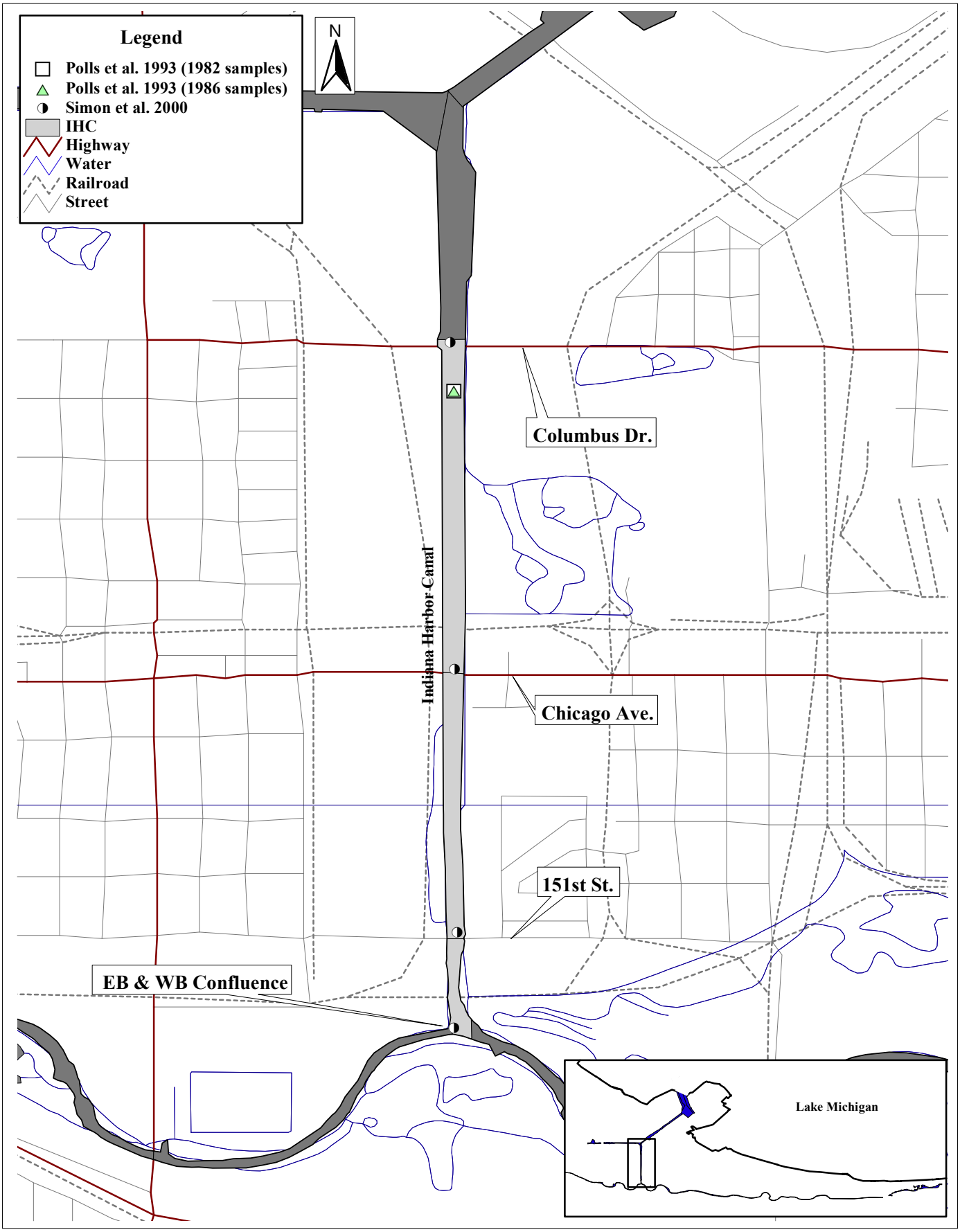
Figure 10.3. Location of sampling stations for sediment toxicity testing in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

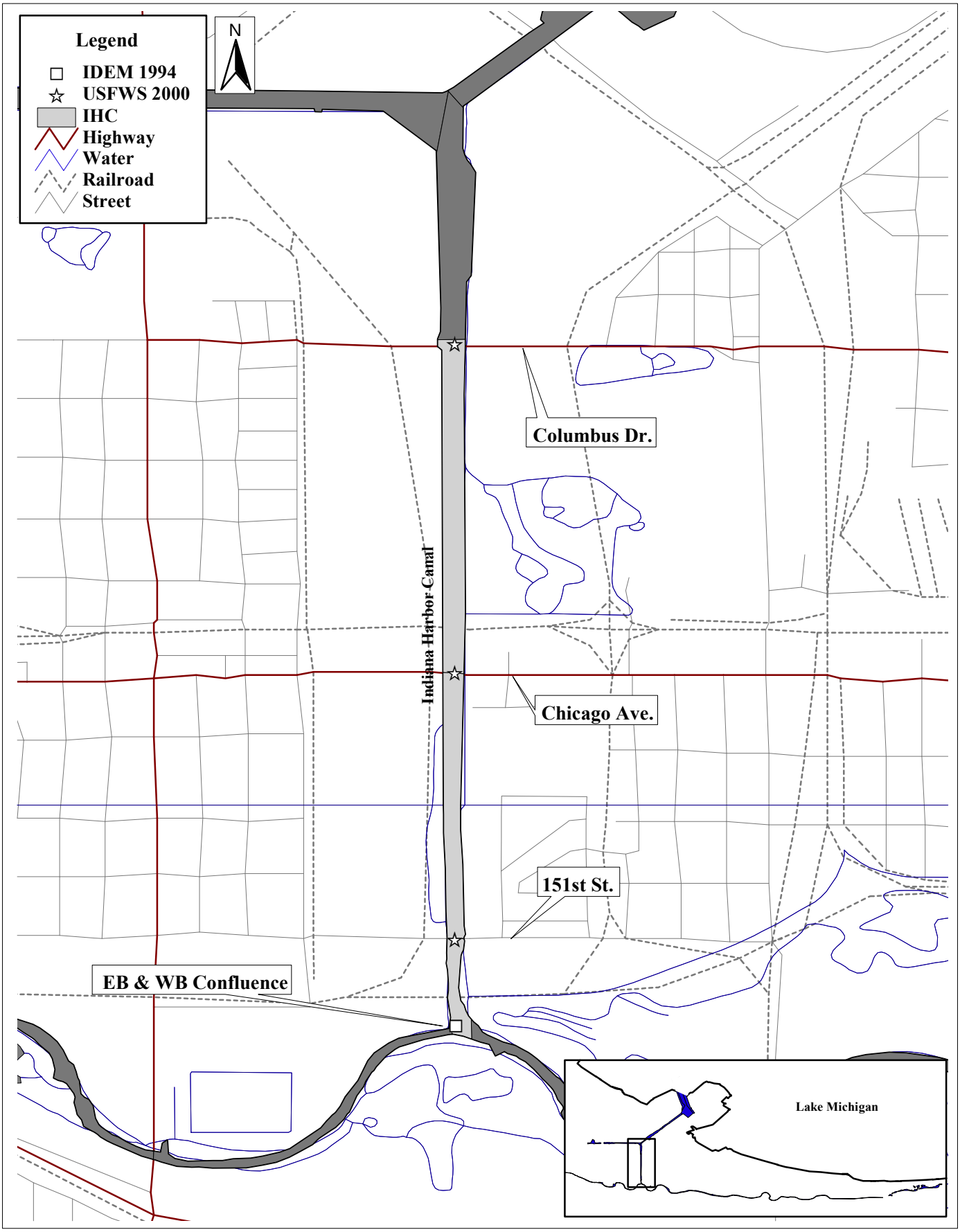
Figure 10.4. Areal exent of altered benthic invertebrate communities in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

Figure 10.5. Location of sampling stations for tissue chemistry in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

Figure 10.6. Spatial distribution of mean PEC-Qs in surficial sediments within the IHC.

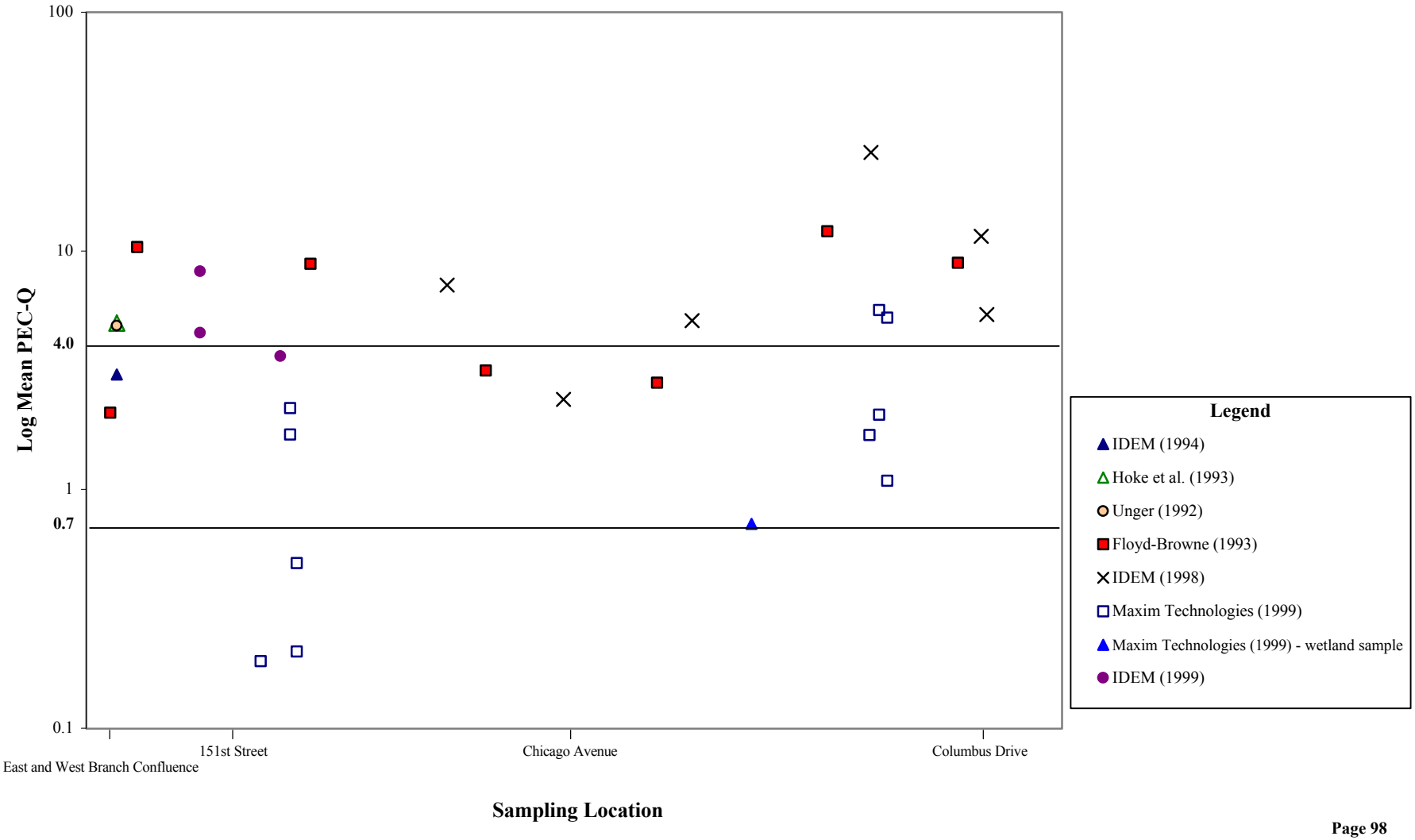
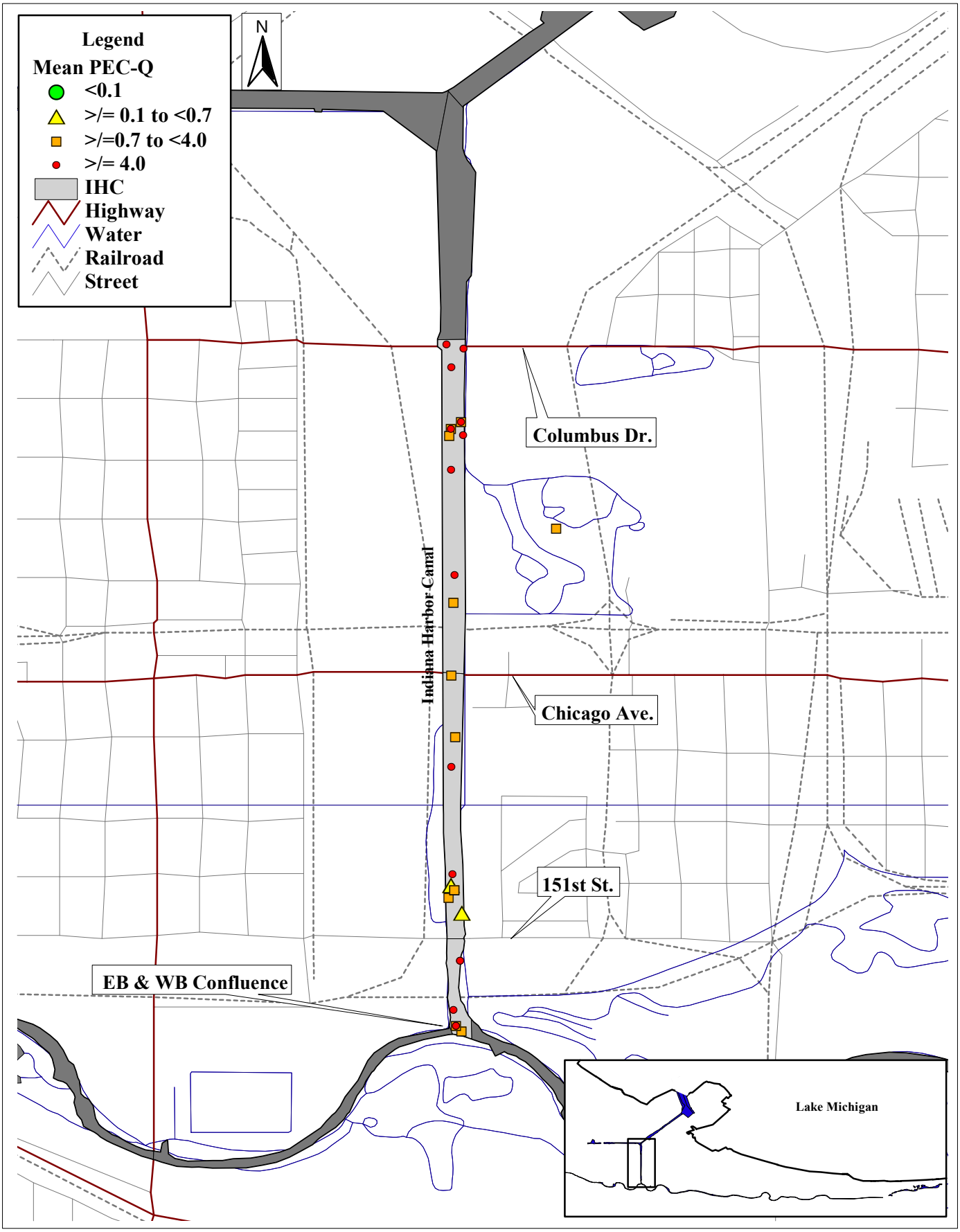


Figure 10.7. Areal extent of injury to surficial sediments in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

Figure 10.8. Spatial distribution of mean PEC-Qs in sub-surface sediments within the IHC.

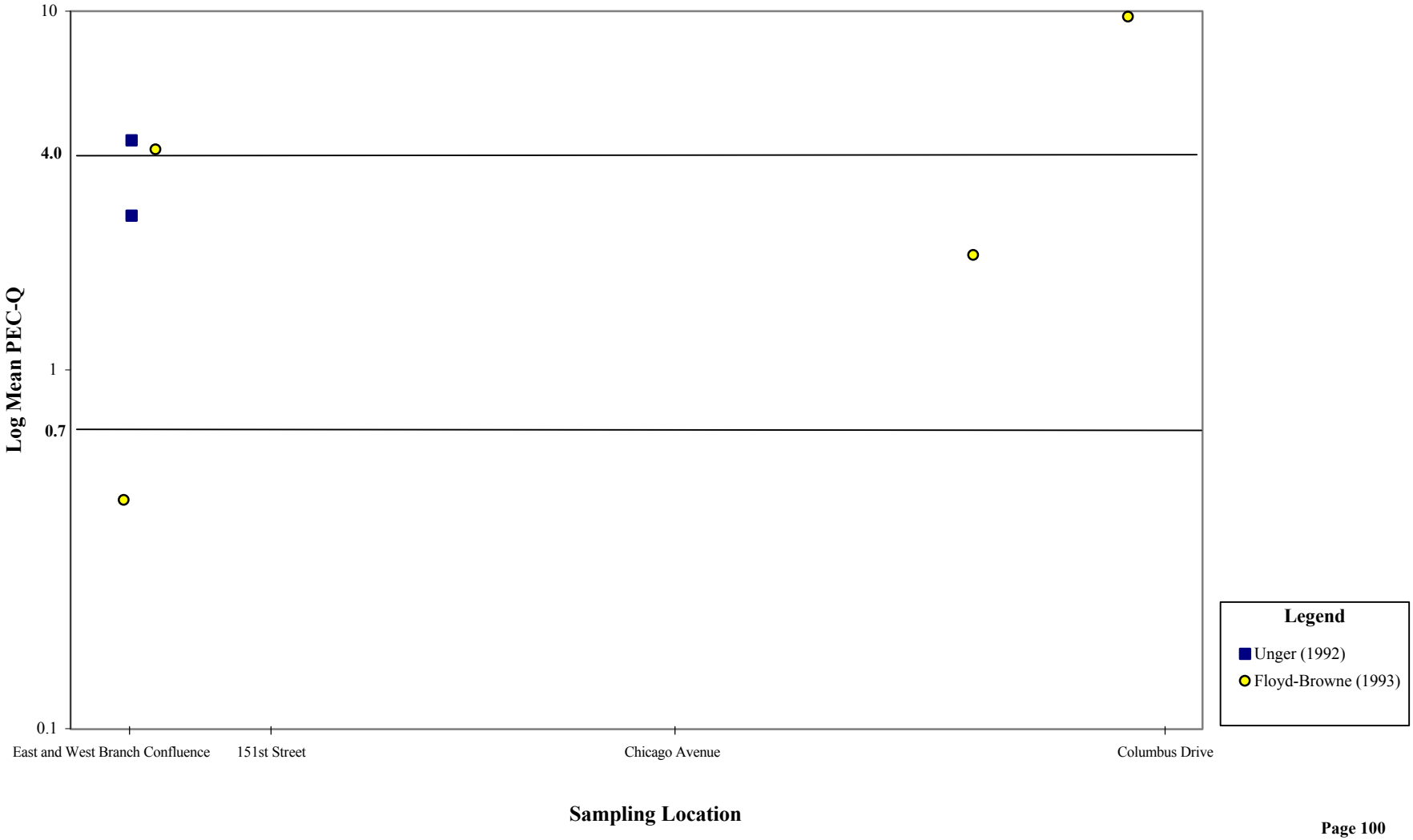
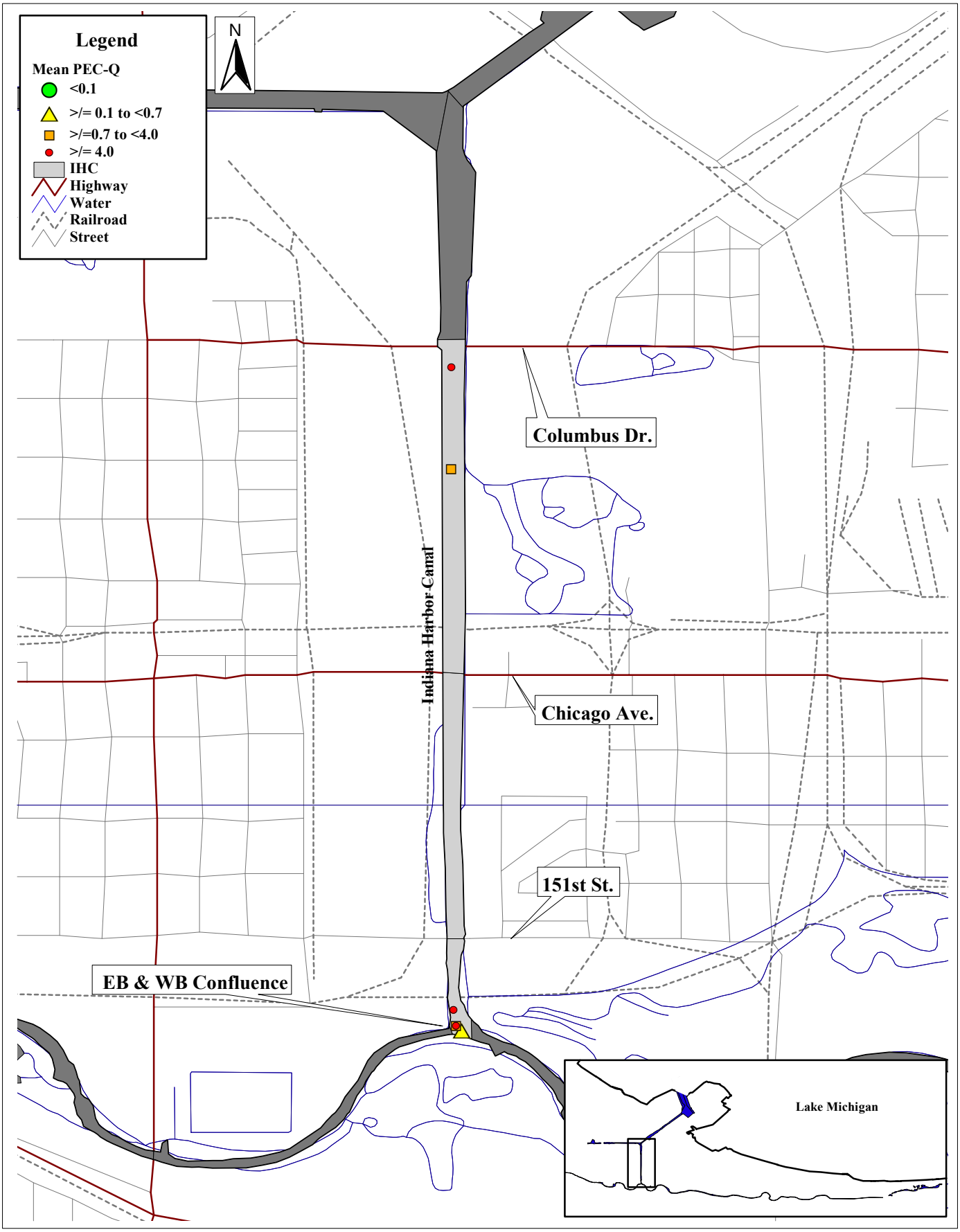


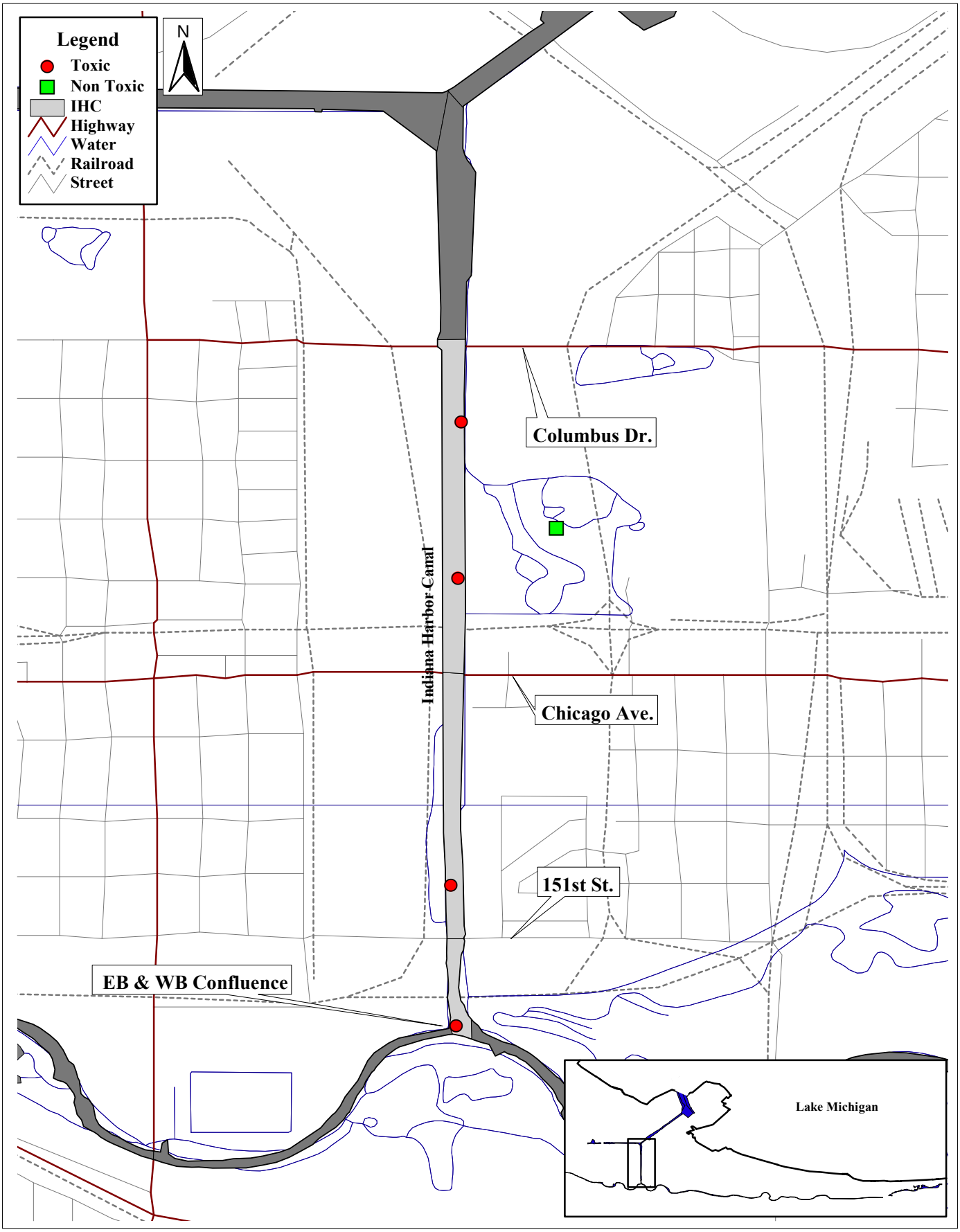
Figure 10.9. Areal extent of injury to sub-surface sediments in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

Figure 10.10. Areal extent of sediment toxicity in the IHC.



MACDONALD ENVIRONMENTAL SCIENCES LTD.

0.5 0 0.5 Miles

Figures

Chapter II - Lake George Branch

Figure 11.1. Location of sampling stations for surficial sediment chemistry in the LGB.

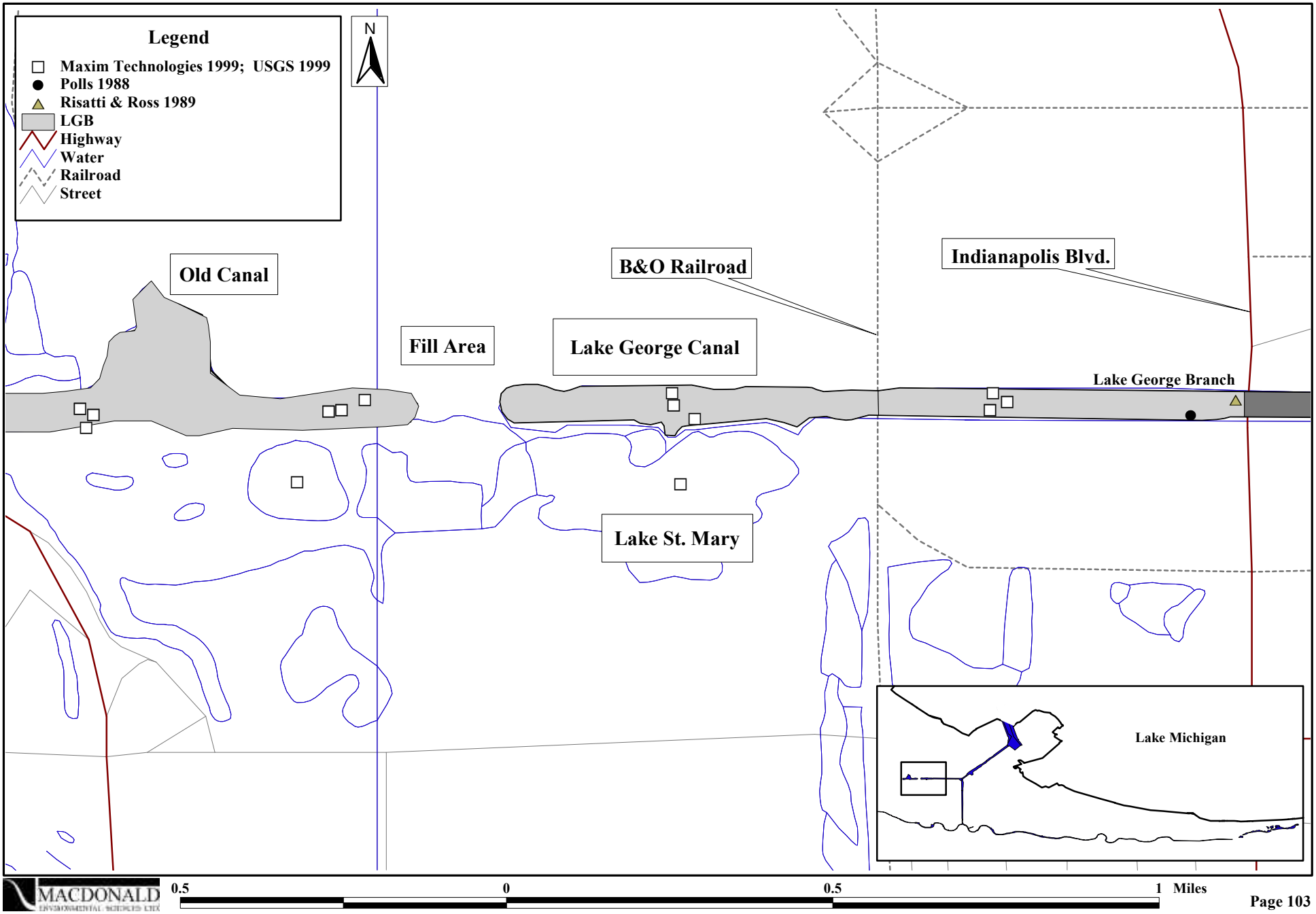


Figure 11.2. Location of sampling stations for sub-surface sediment chemistry in the LGB.

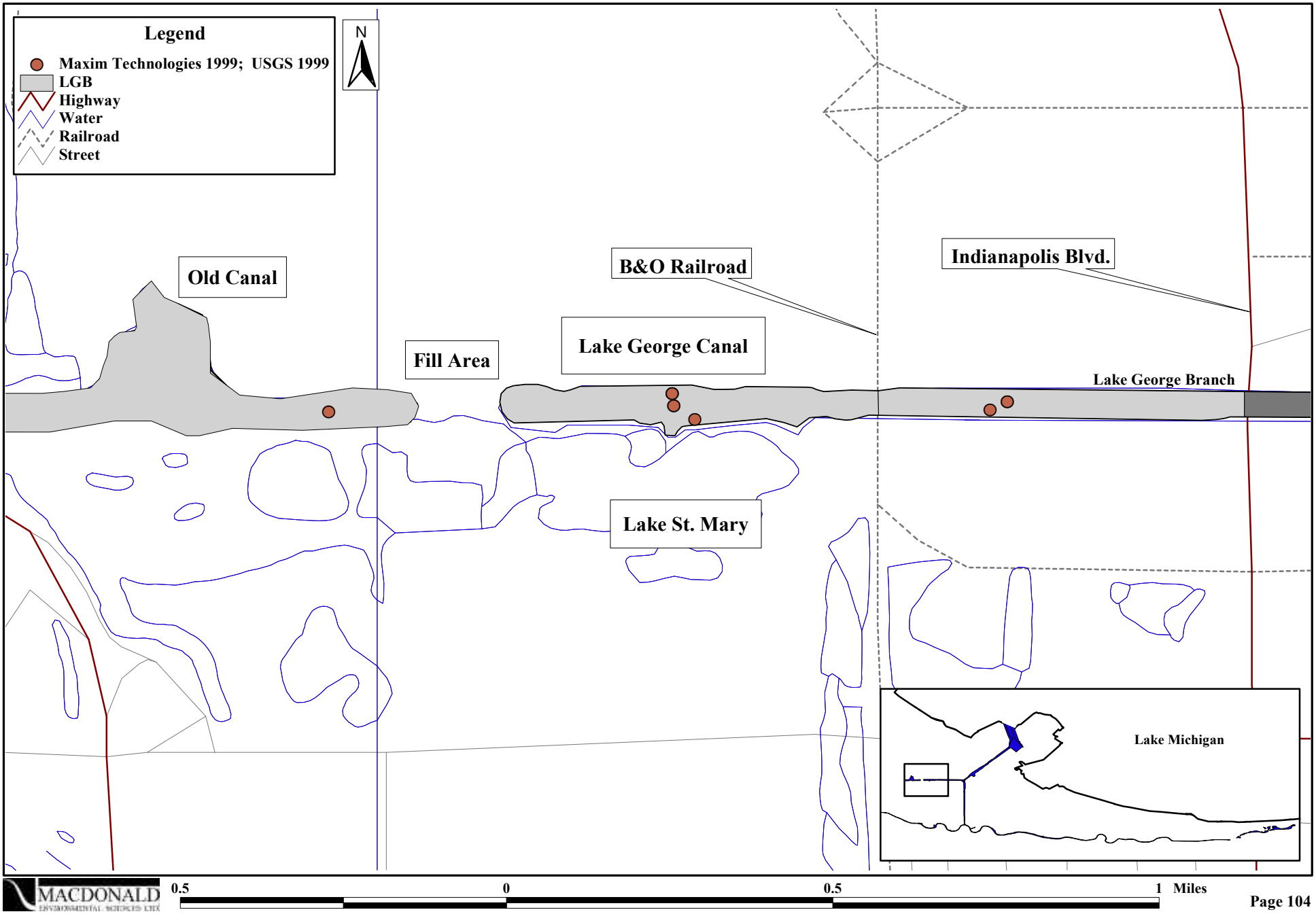


Figure 11.3. Location of sampling stations for sediment toxicity testing in the LGB.

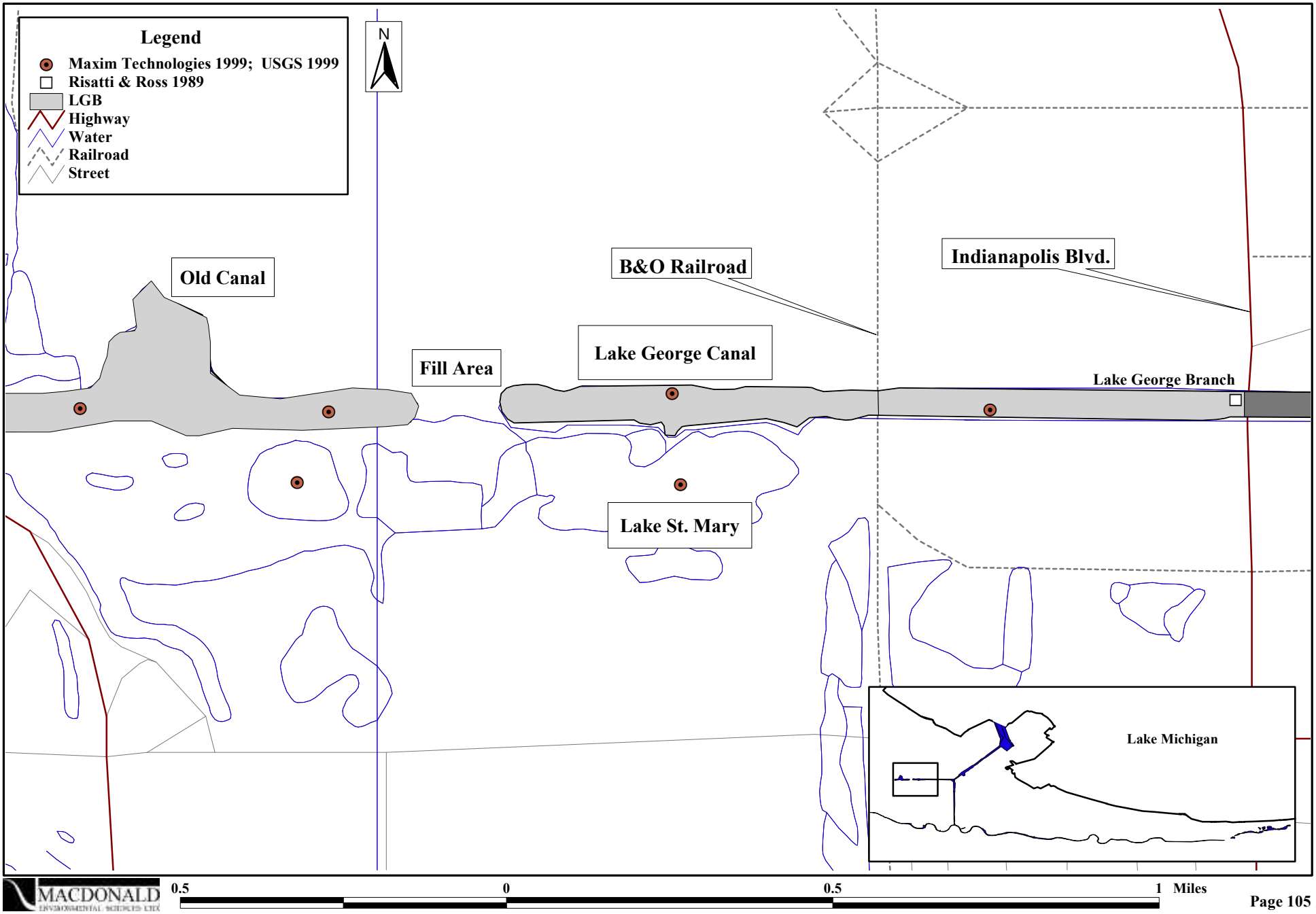


Figure 11.4. Areal extent of altered benthic invertebrate communities in the LGB.

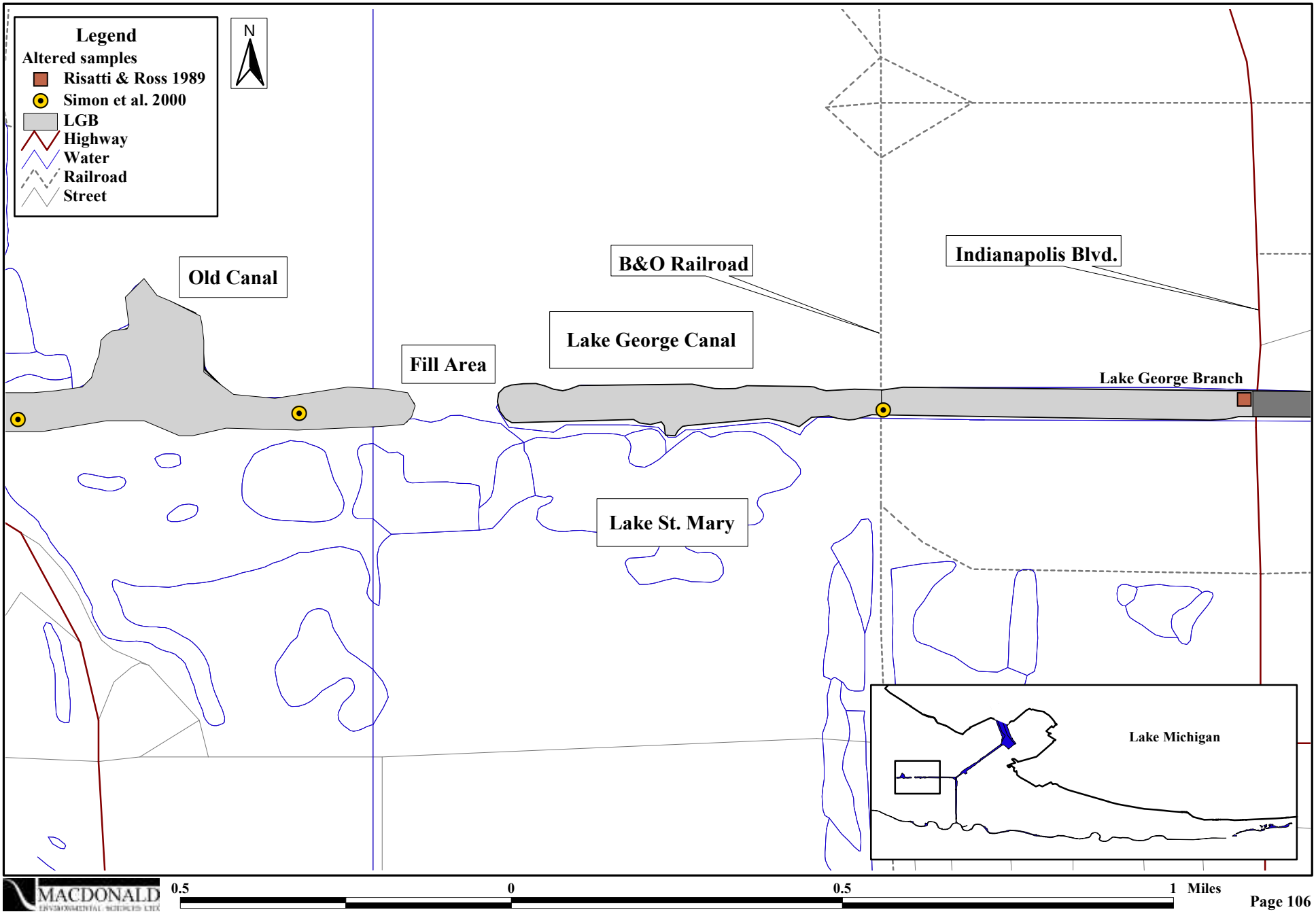


Figure 11.5. Spatial distribution of mean PEC-Qs in surficial sediments within the LGB.

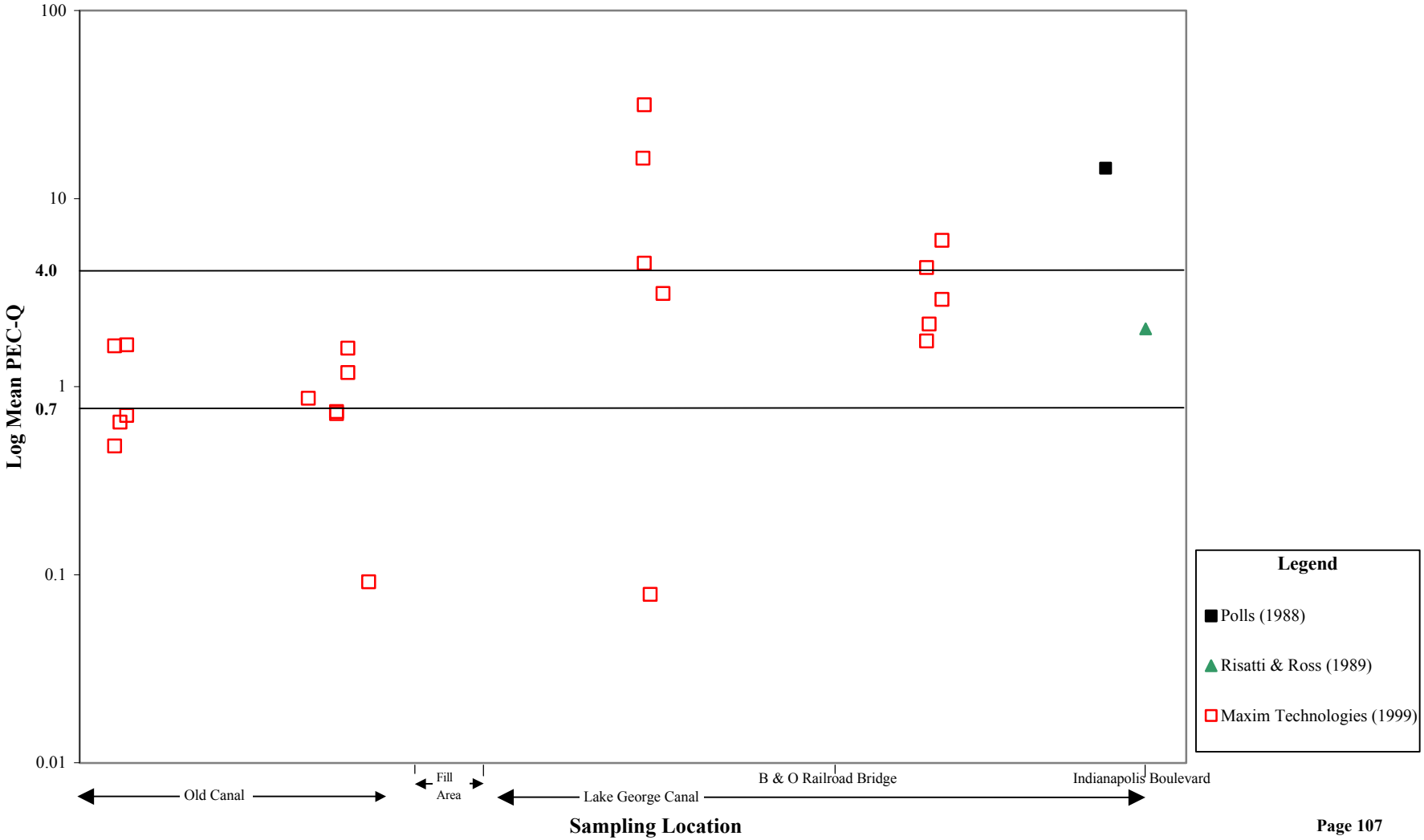
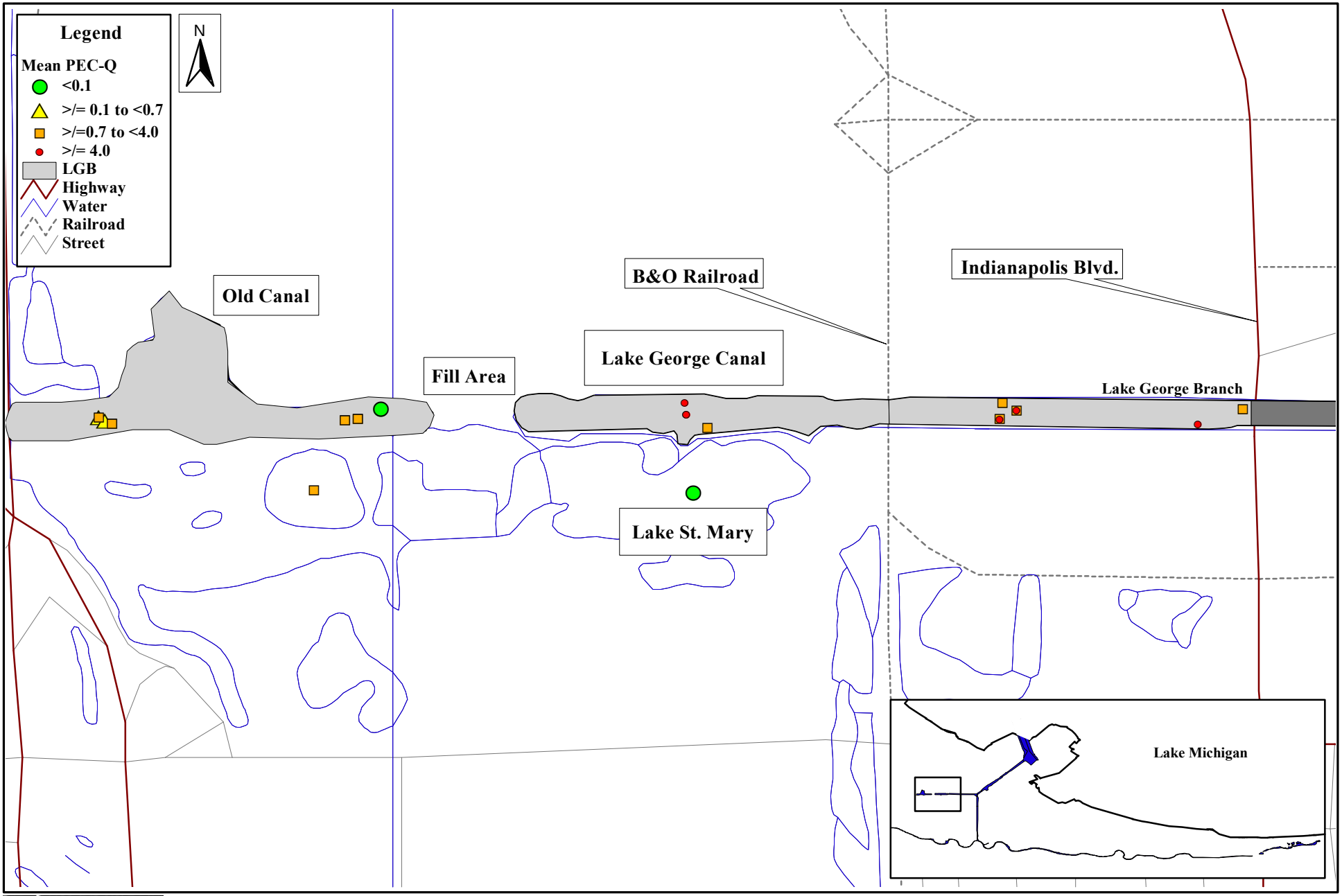


Figure 11.6. Areal extent of injury to surficial sediments in the LGB.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 11.7. Spatial distribution of mean PEC-Qs in sub-surface sediments within the LGB.

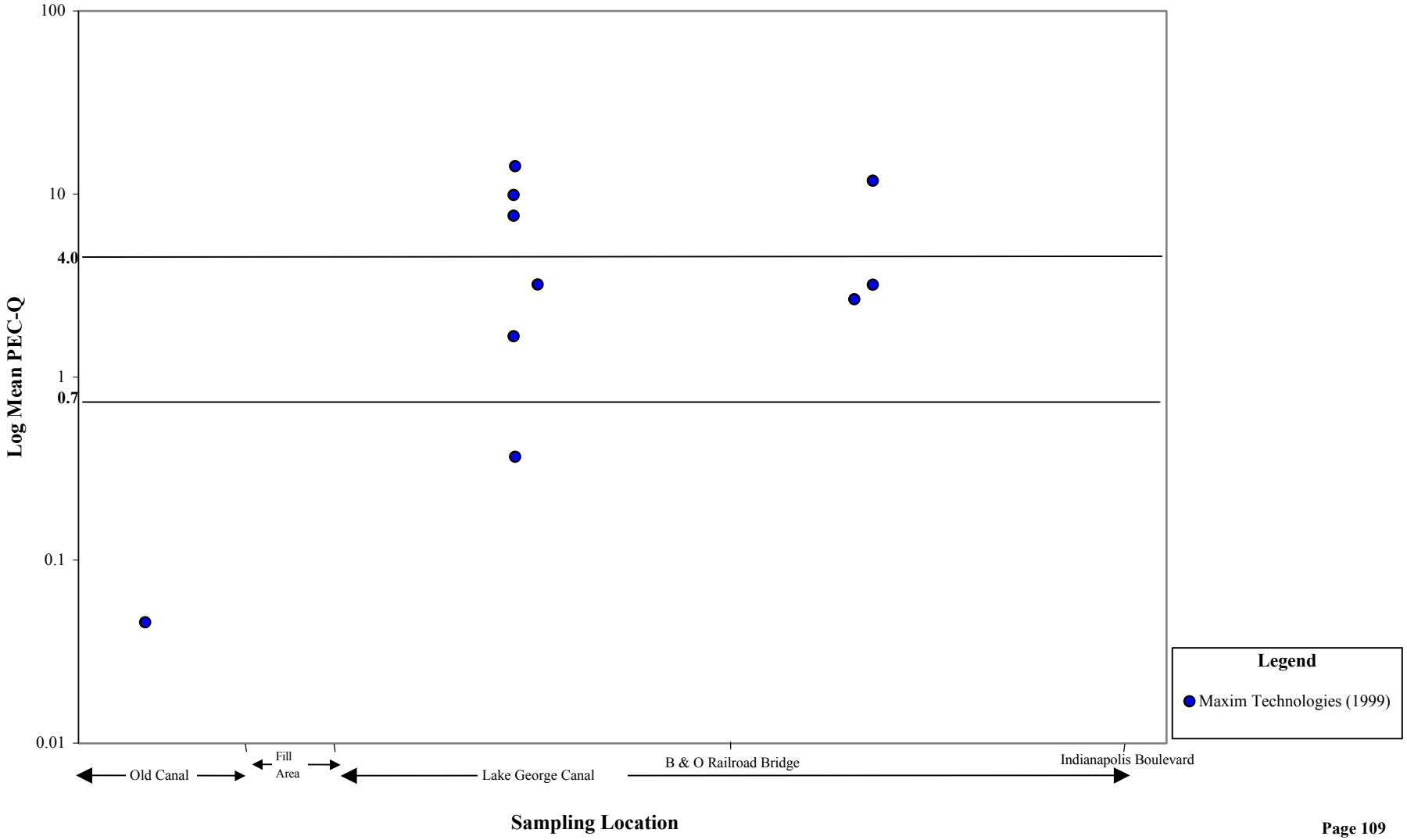
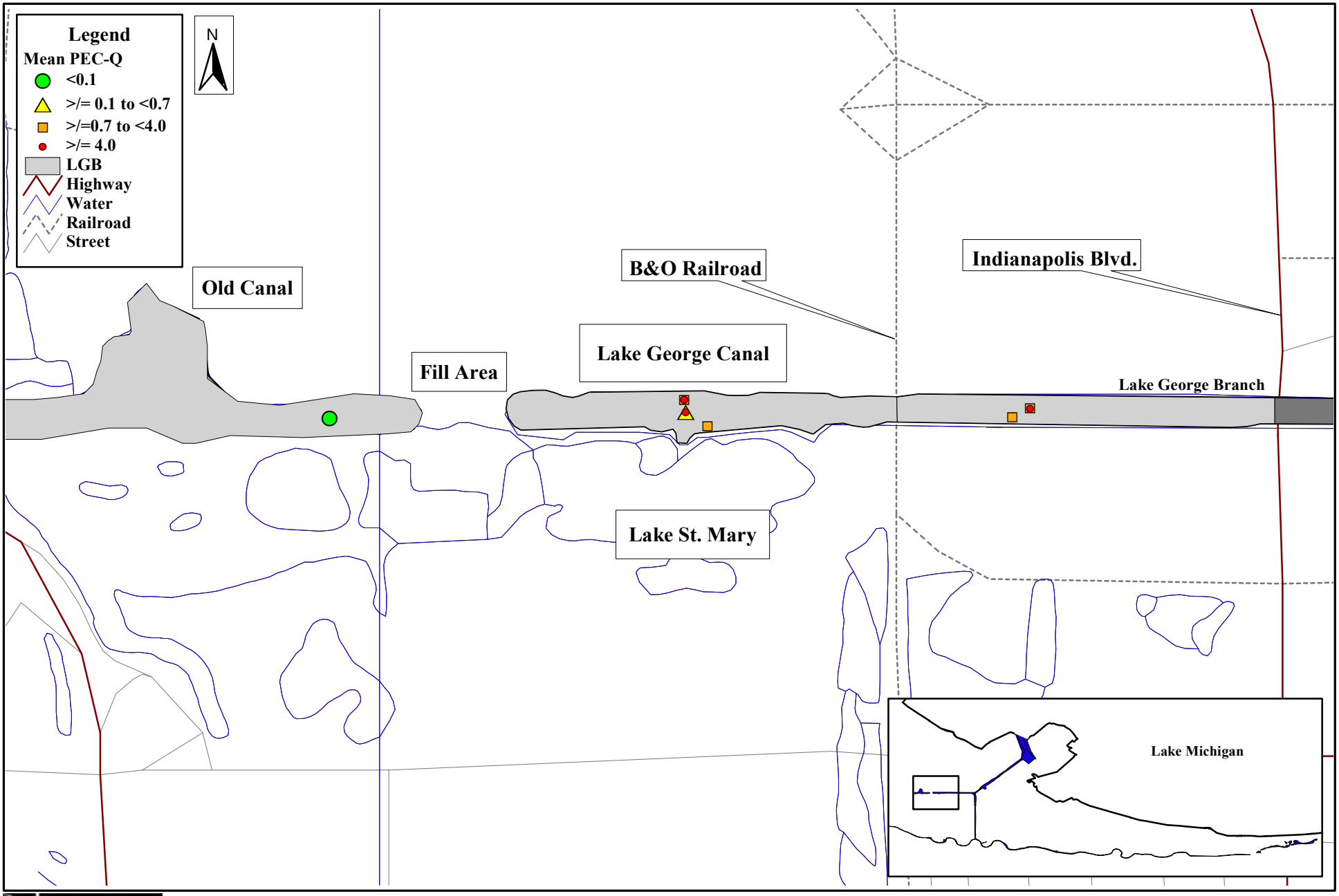


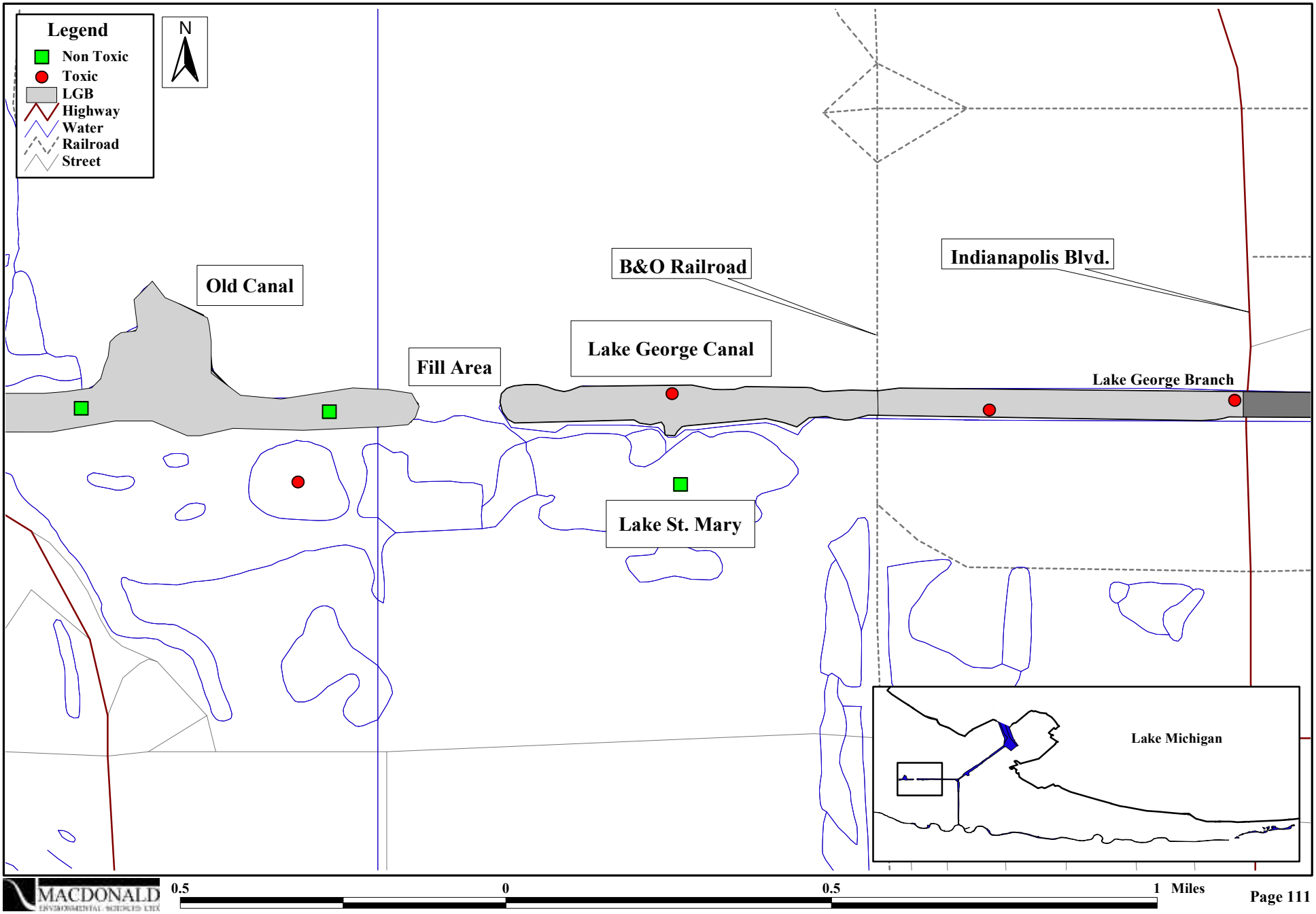
Figure 11.8. Areal extent of injury to sub-surface sediments in the LGB.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 11.9. Areal extent of sediment toxicity in the LGB.



Figures

Chapter I2 - US Canal

Figure 12.1. Location of sampling stations for surficial sediment chemistry in the USC.

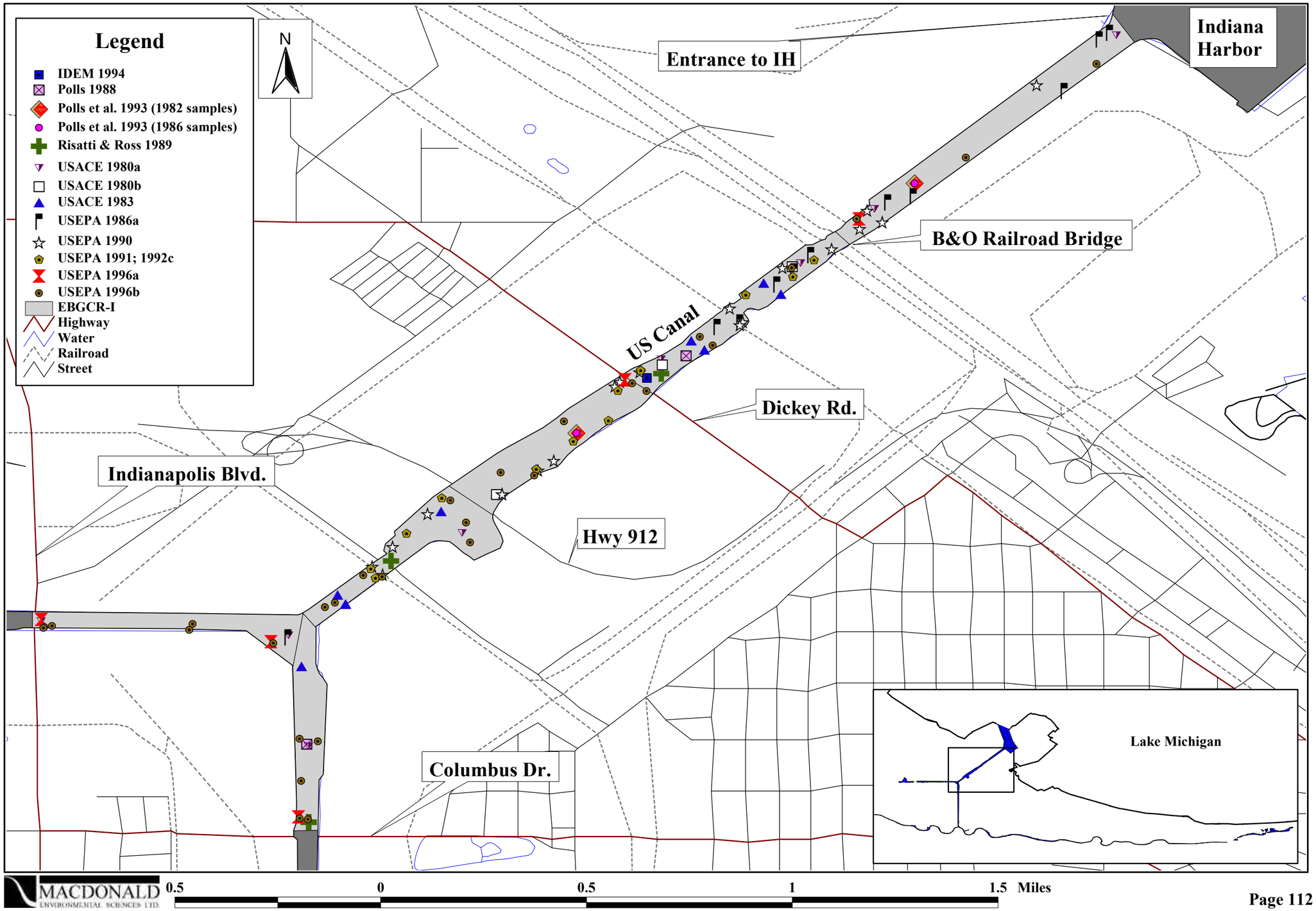
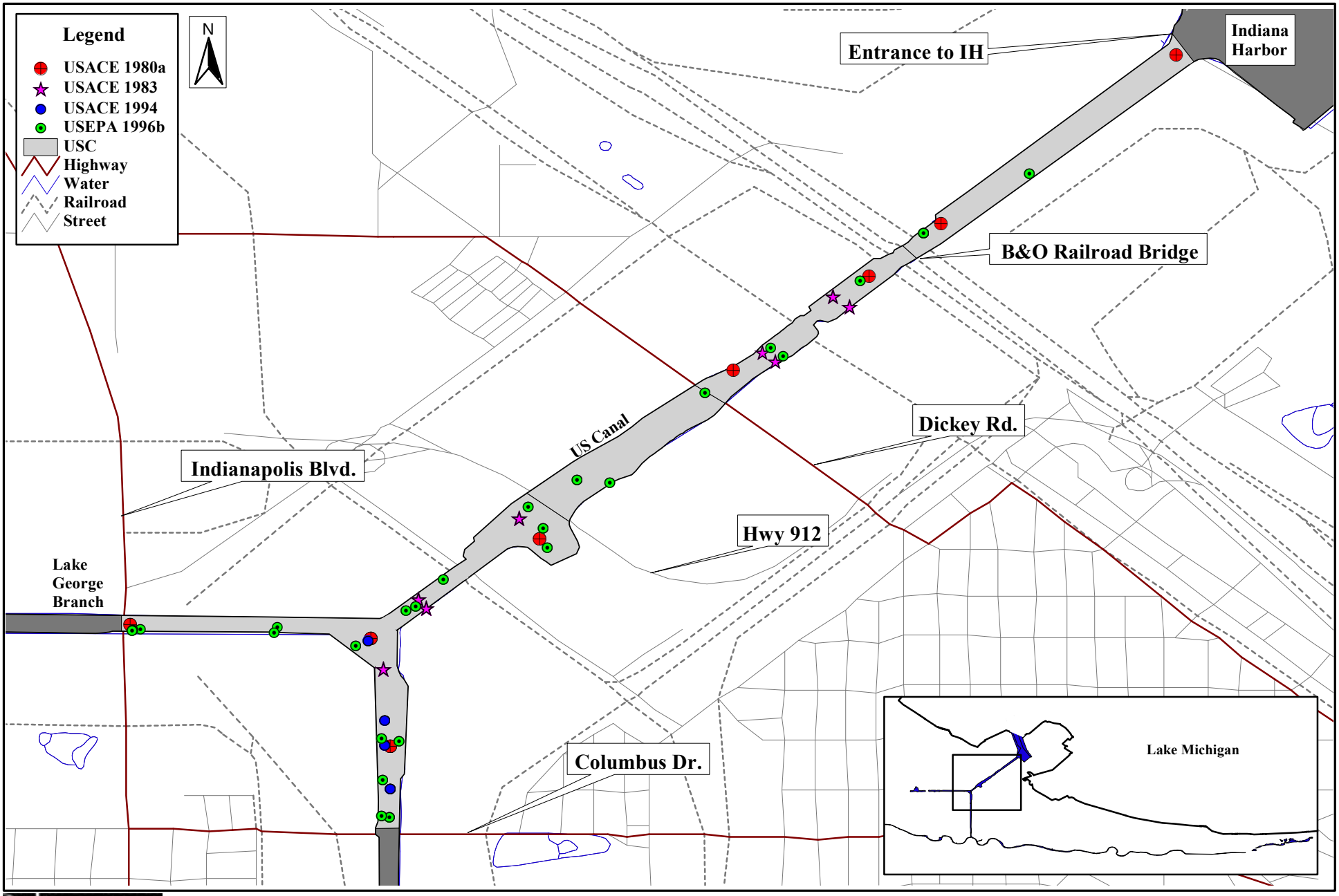


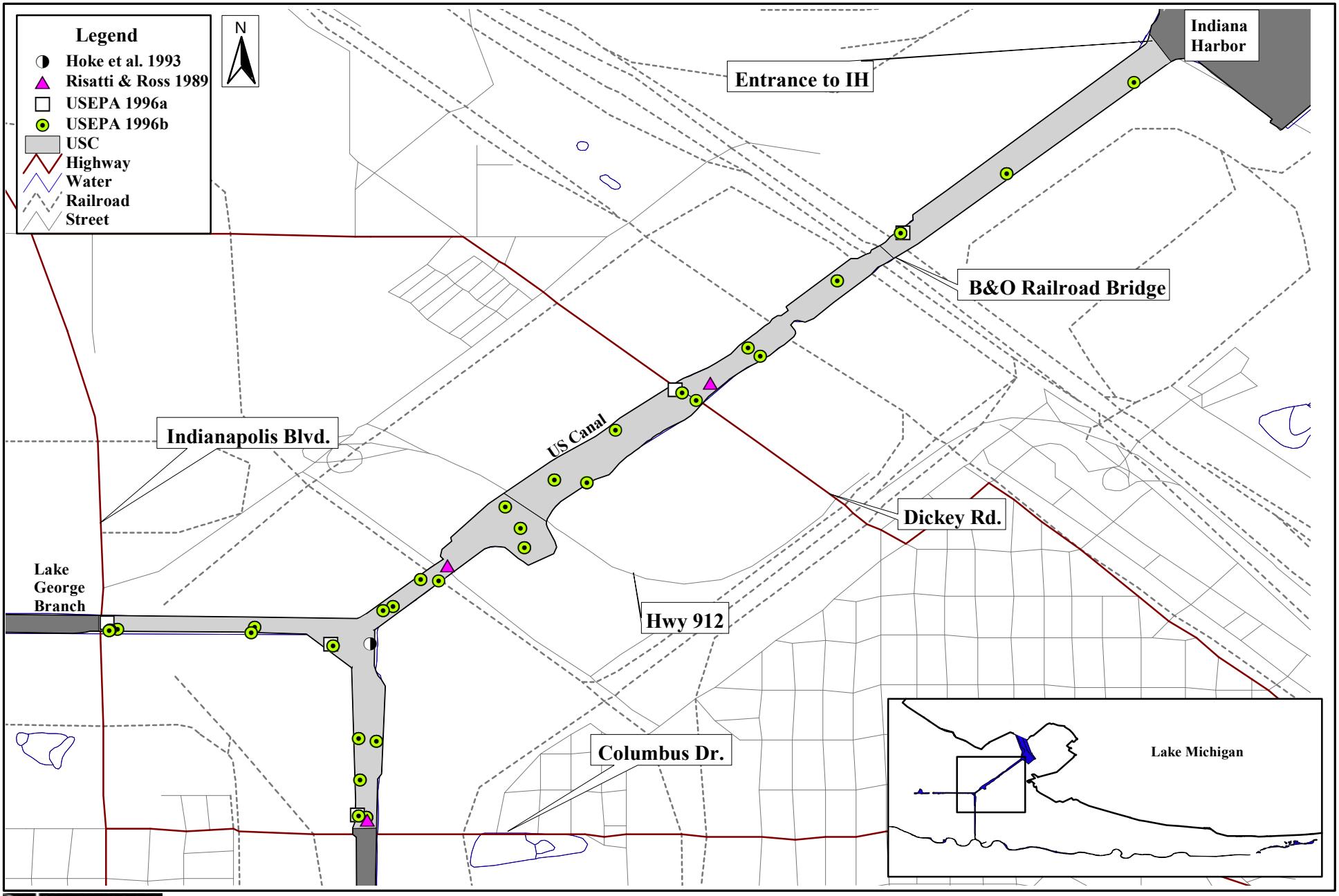
Figure 12.2. Location of sampling stations for sub-surface sediment chemistry in the USC.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

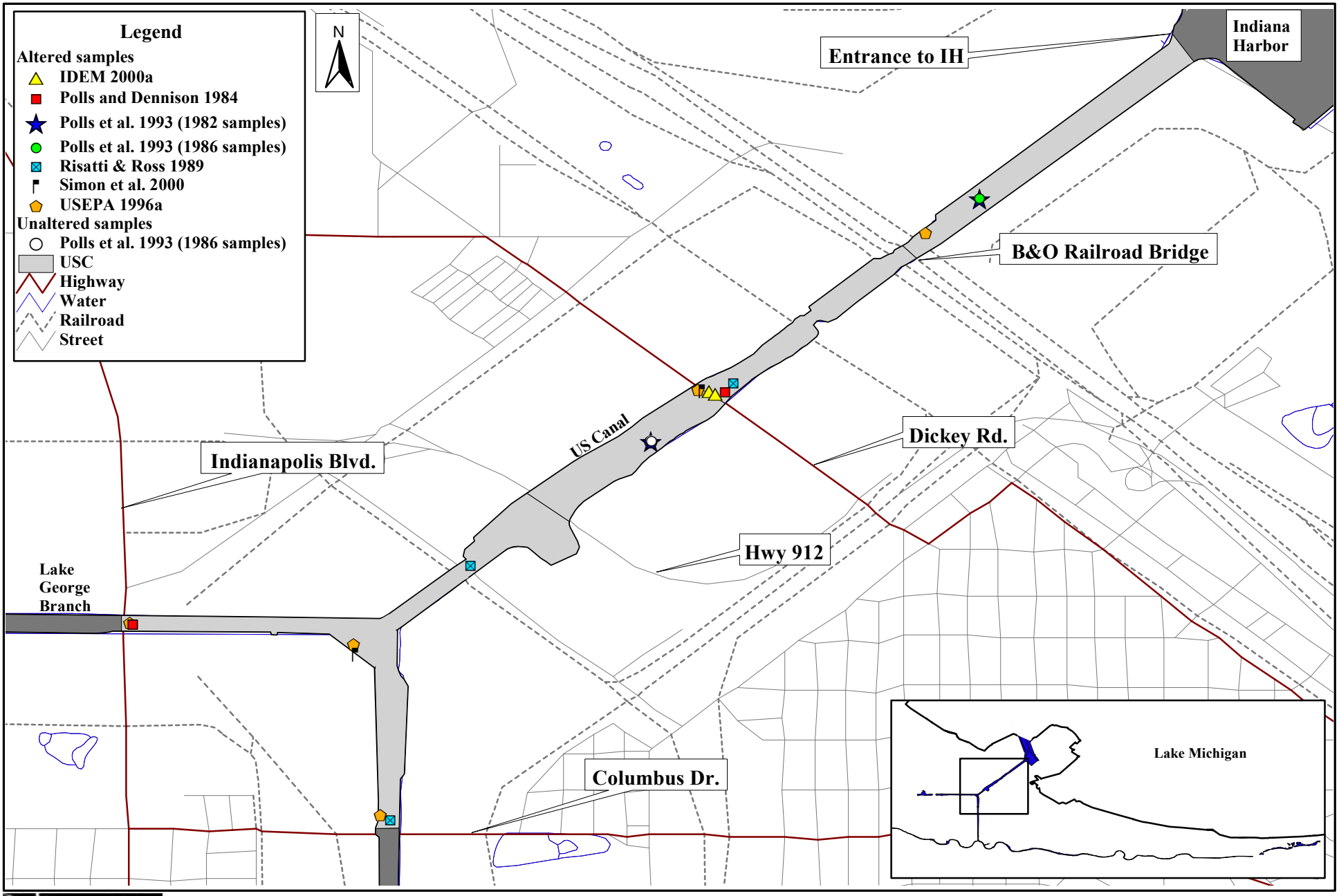
Figure 12.3. Location of sampling stations for sediment toxicity testing in the USC.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

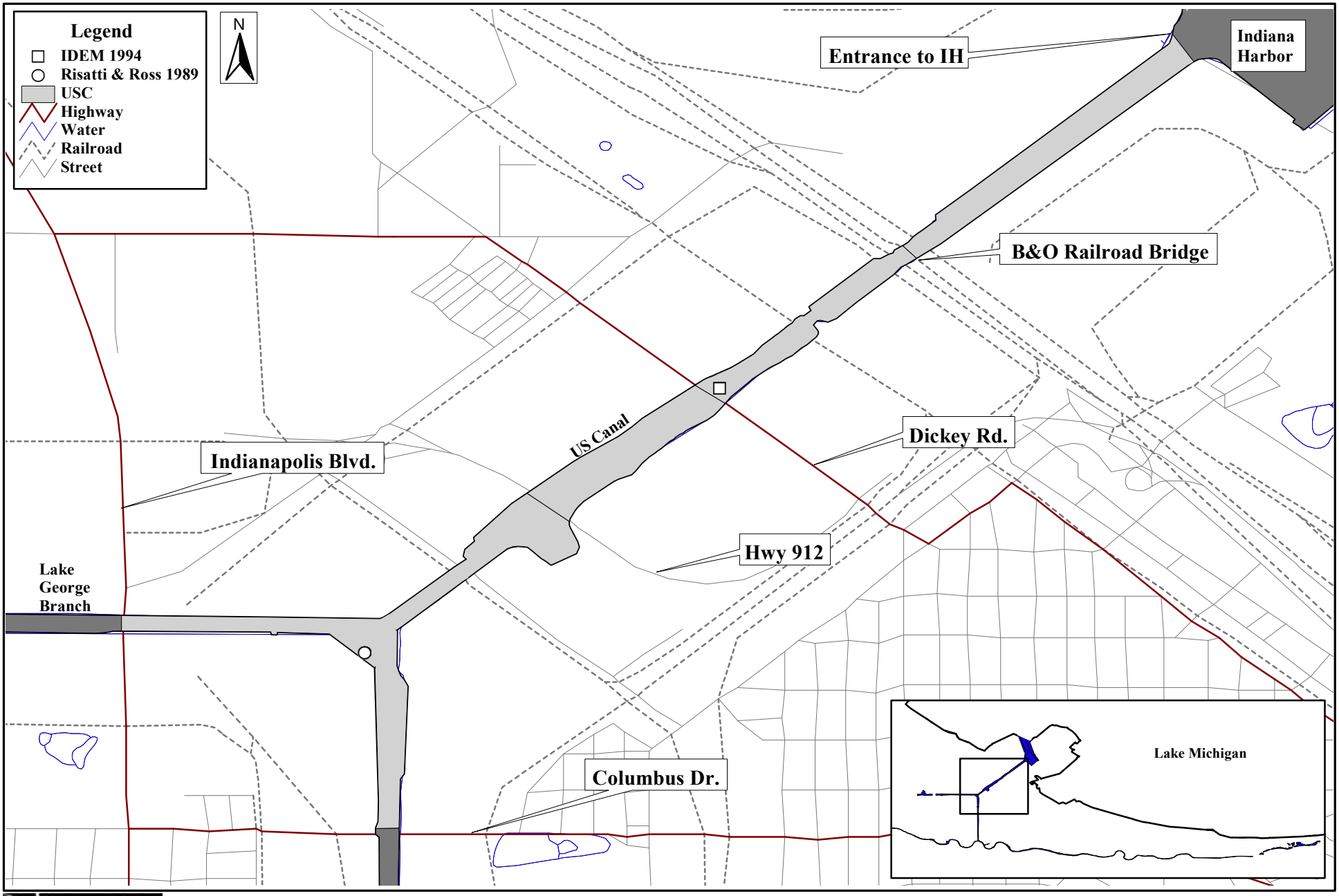
Figure 12.4. Areal extent of altered and unaltered benthic invertebrate communities in the USC.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 12.5. Location of sampling stations for tissue chemistry in the USC.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 12.6a. Spatial distribution of mean PEC-Qs in surficial sediments within the Columbus Drive to Forks segment of the USC.

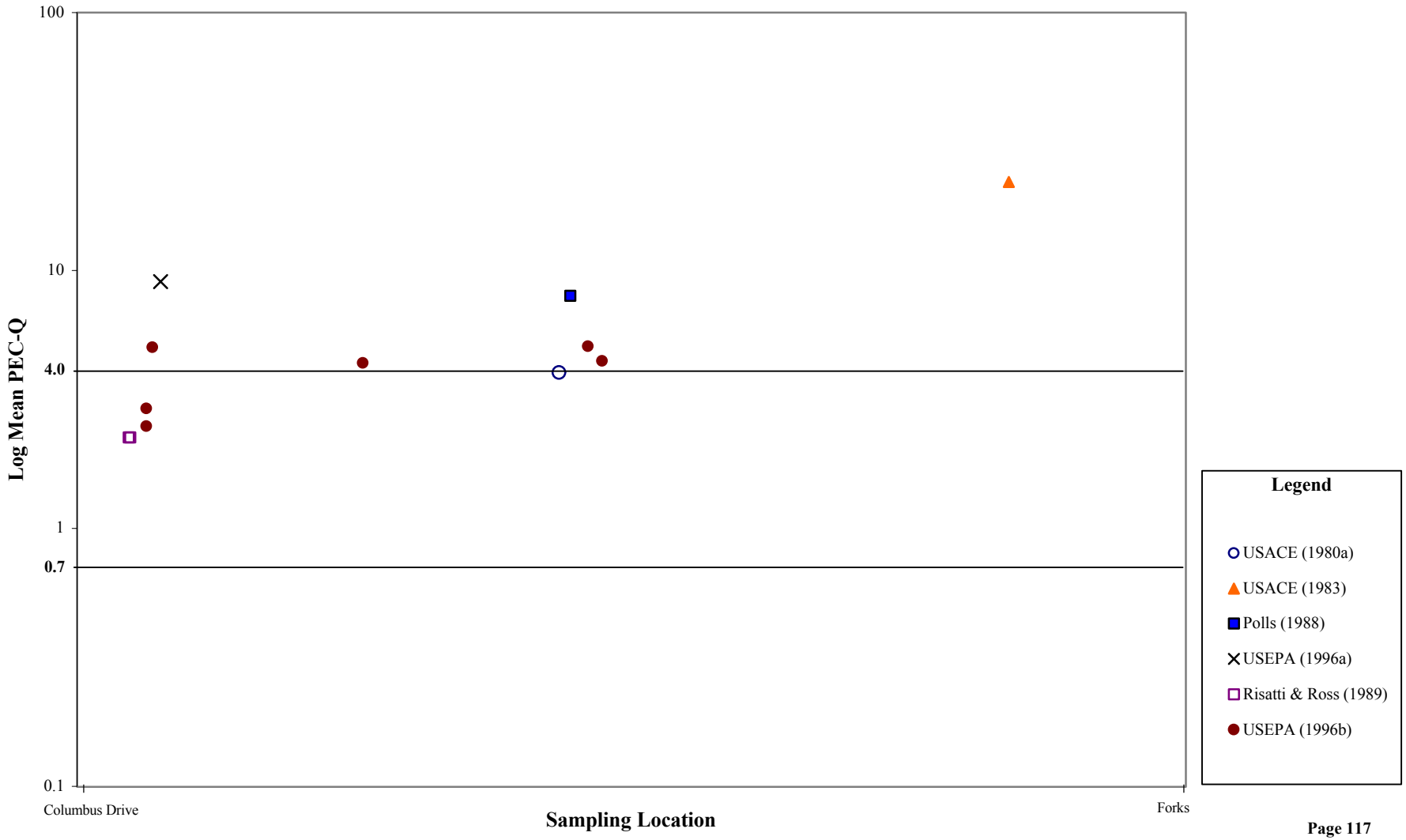


Figure 12.6b. Spatial distribution of mean PEC-Qs in surficial sediments within the Indianapolis Boulevard to Forks segment of the USC.

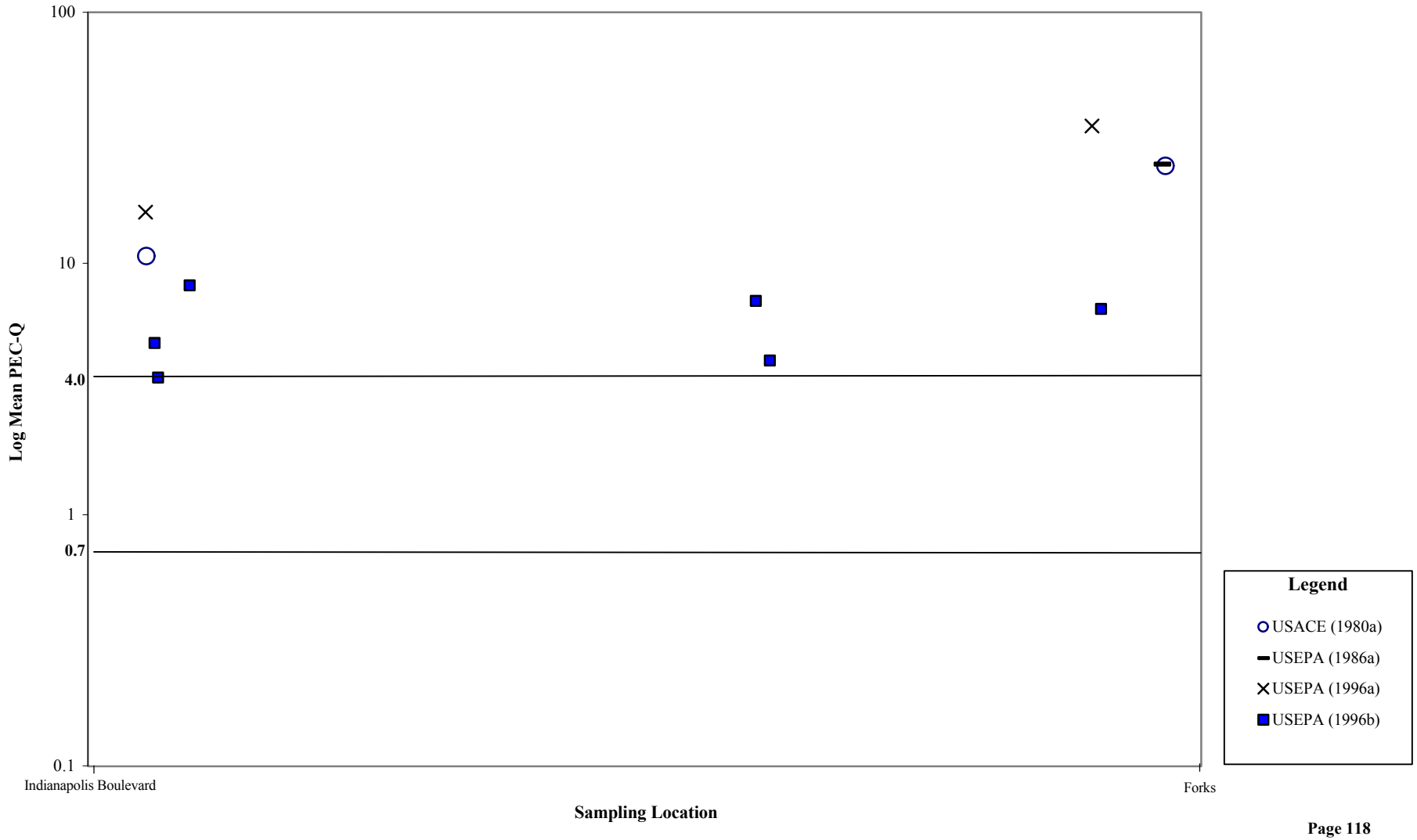


Figure 12.6c. Spatial distribution of mean PEC-Qs in surficial sediments within the Forks to the Indiana Harbor entrance segment of the USC.

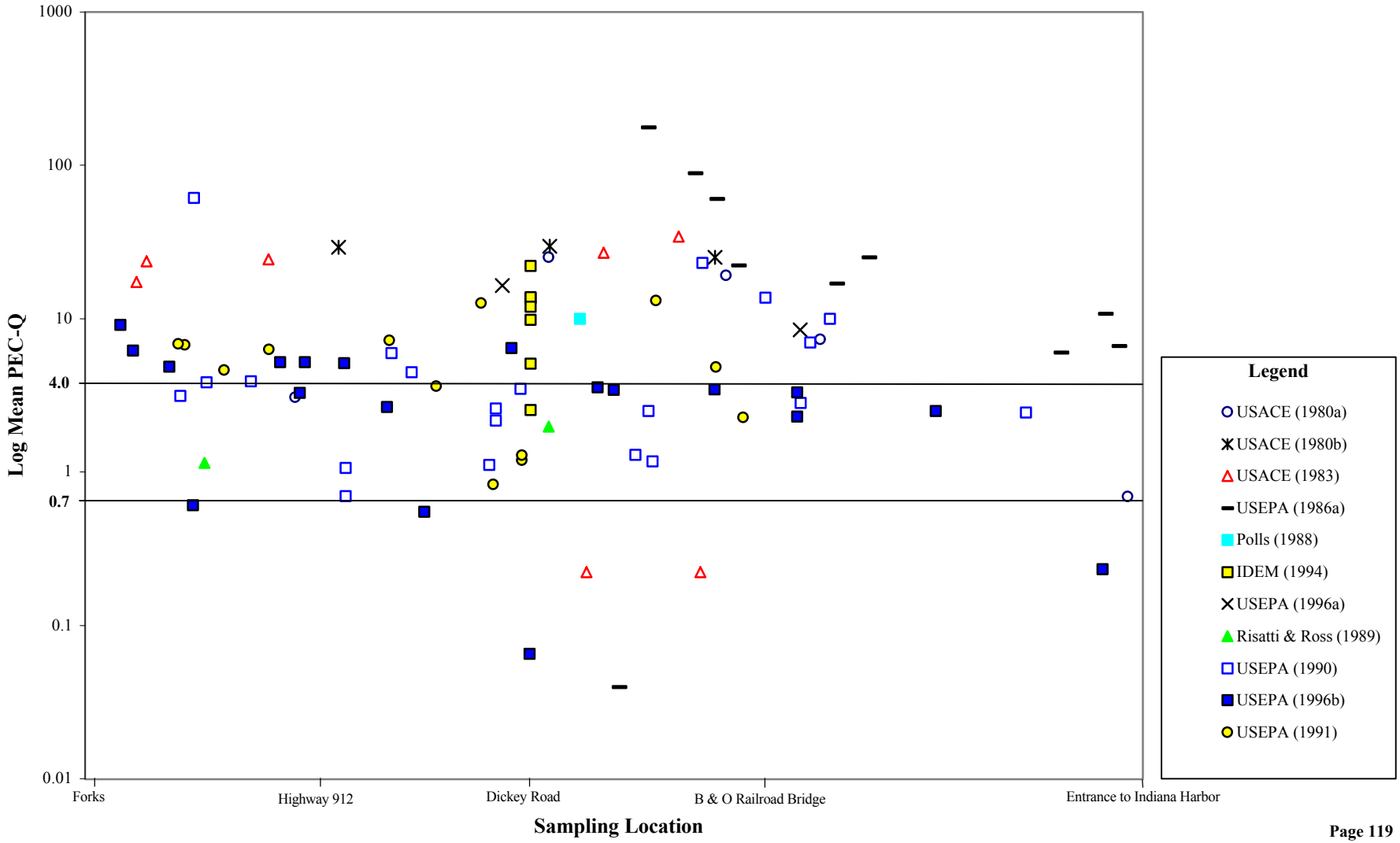


Figure 12.7. Areal extent of injury to surficial sediments in the USC.

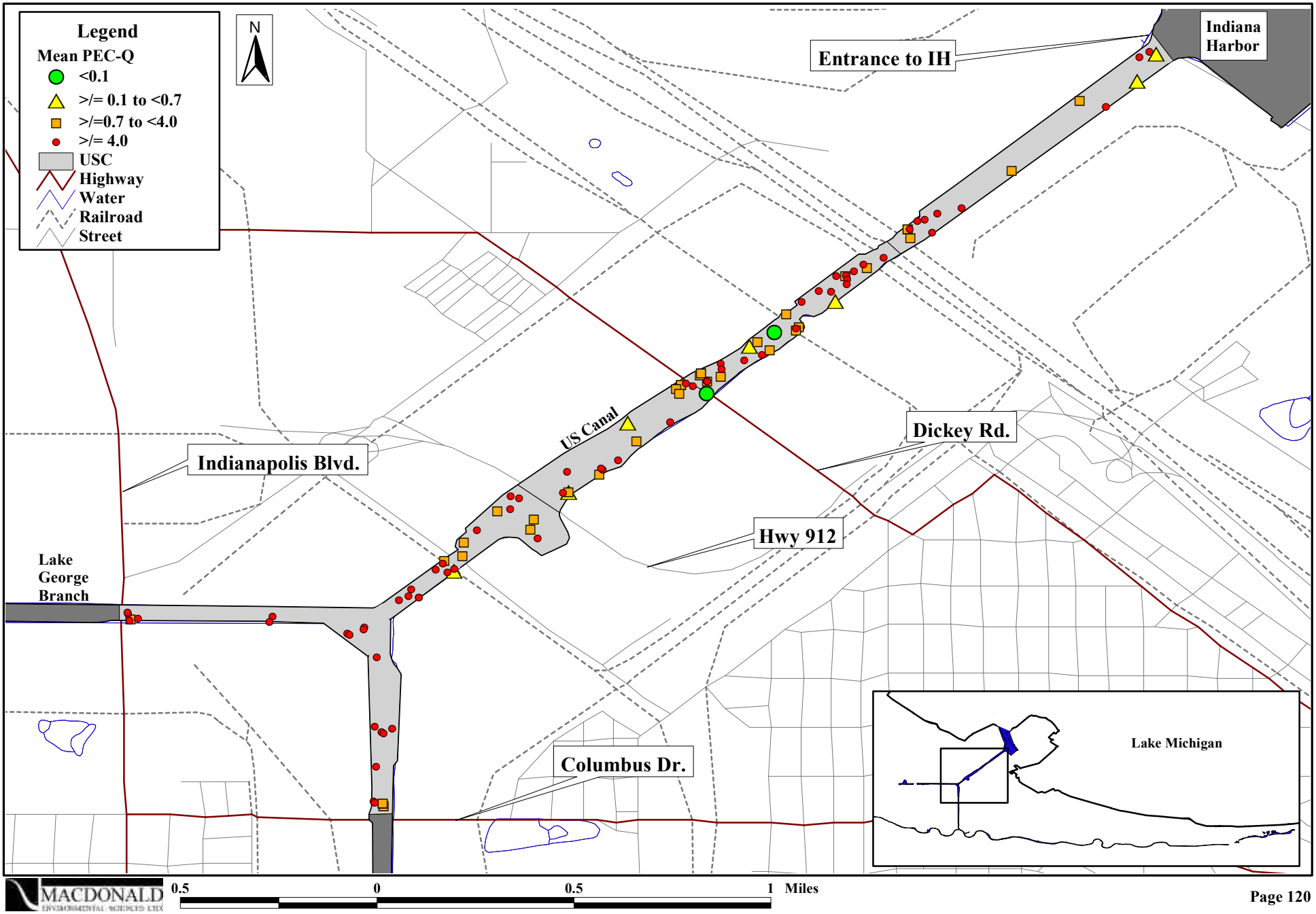


Figure 12.8a. Spatial distribution of mean PEC-Qs in sub-surface sediments within the Columbus Drive to Forks segment of the USC.

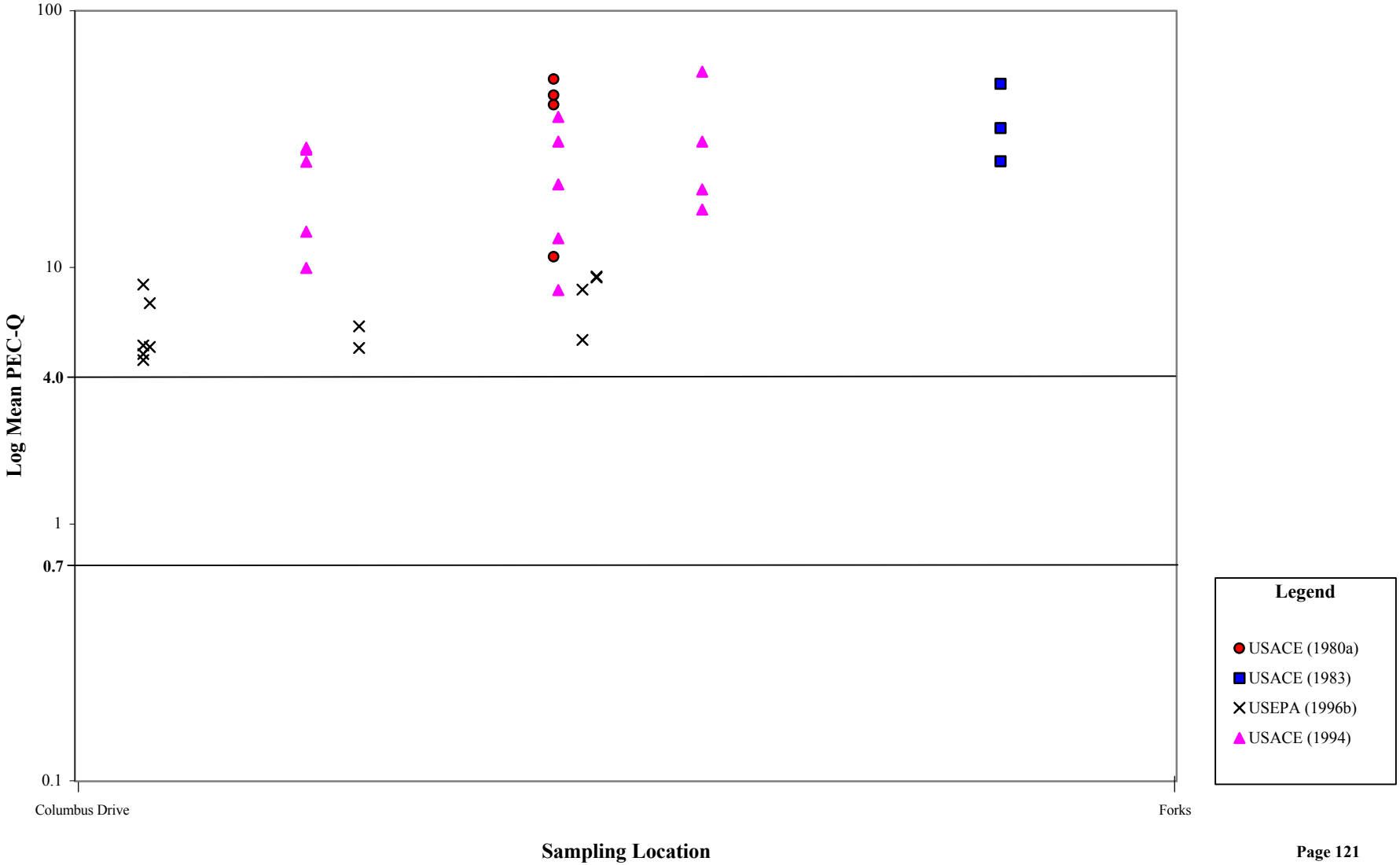


Figure 12.8b. Spatial distribution of mean PEC-Qs in sub-surface sediments within the Indianapolis Boulevard to Forks segment of the USC.

Figure 12.8c. Spatial distribution of mean PEC-Qs in sub-surface sediments within the Forks to the Indiana Harbor entrance segment of the USC.

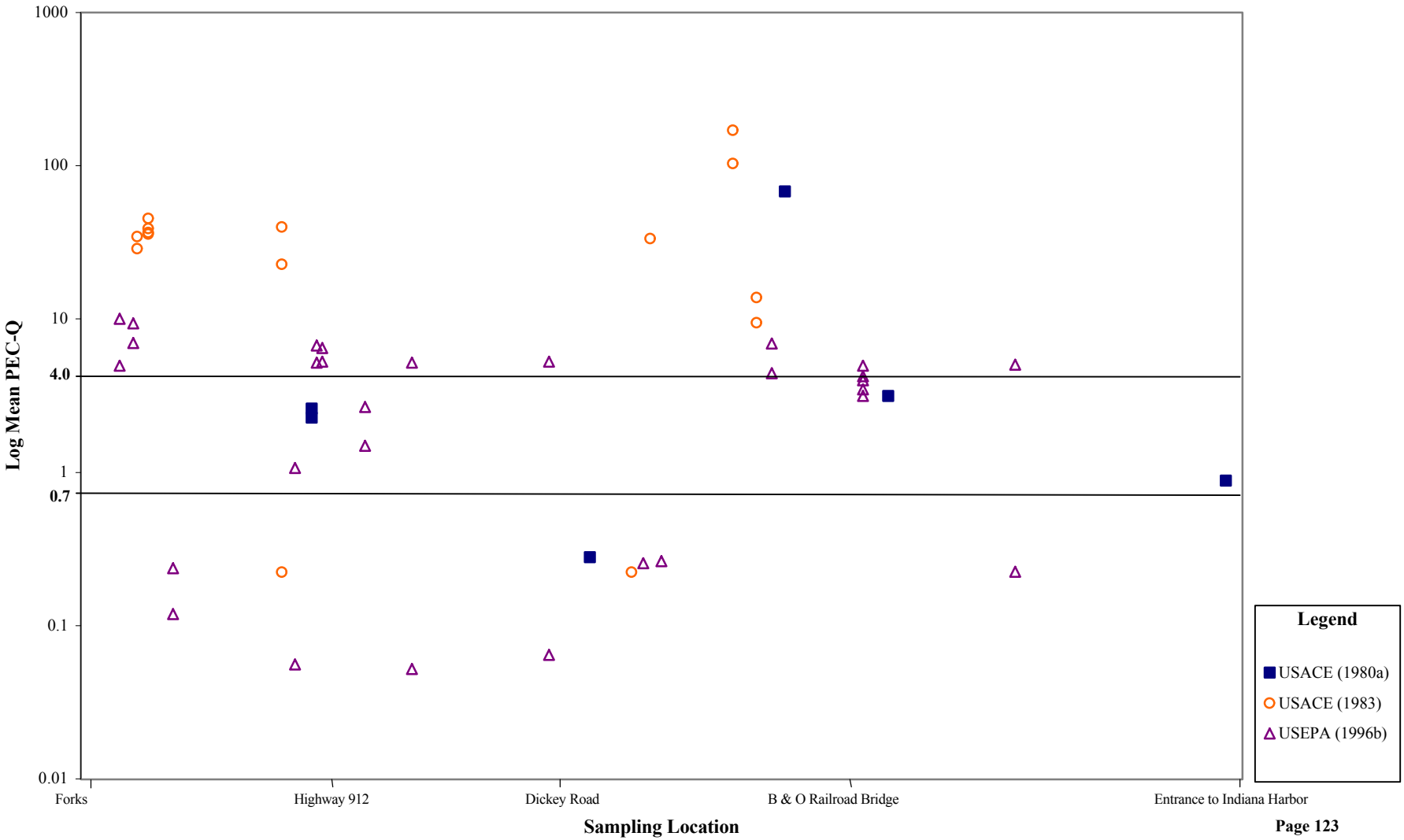


Figure 12.9. Areal extent of injury to sub-surface sediments in the USC.

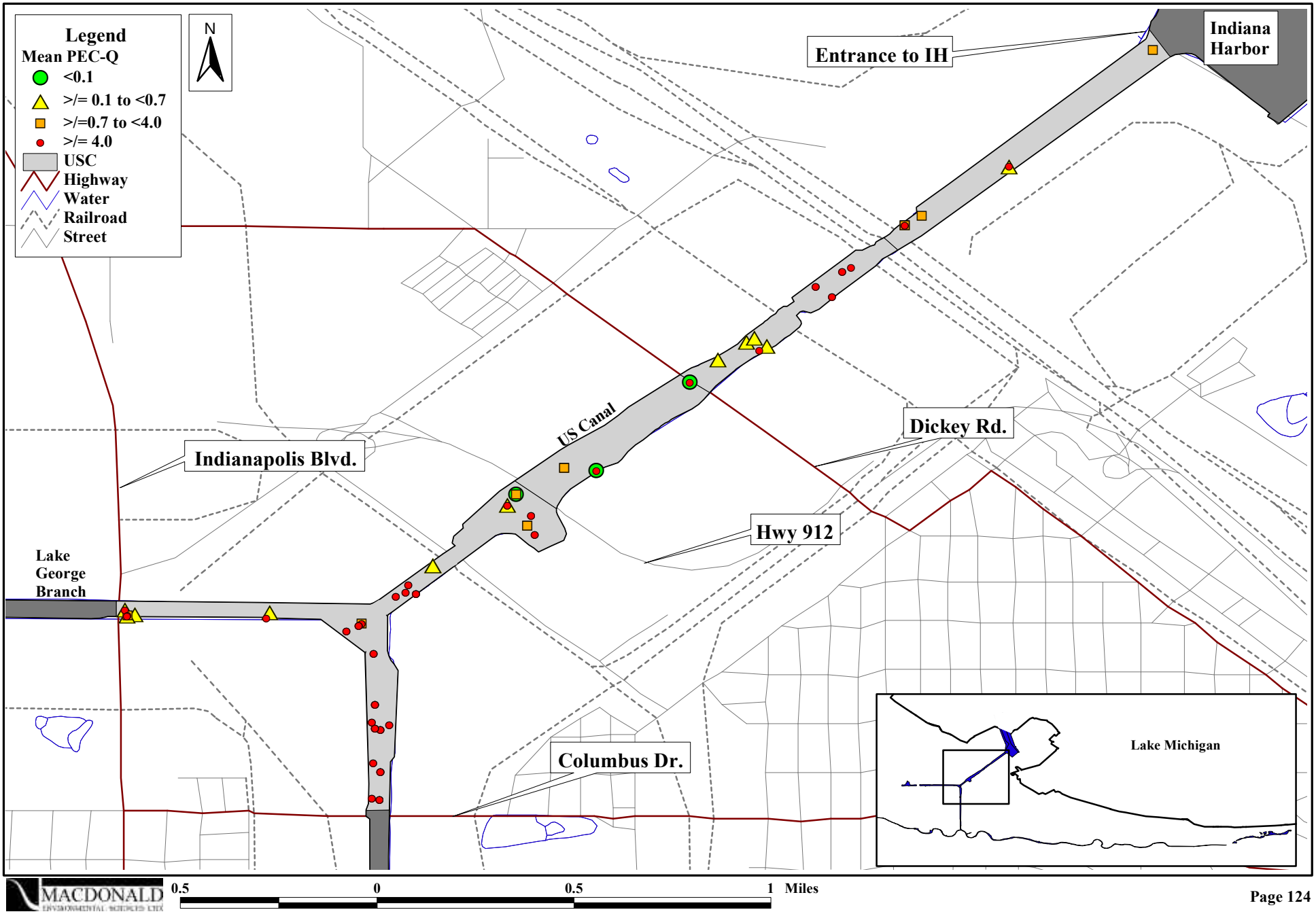
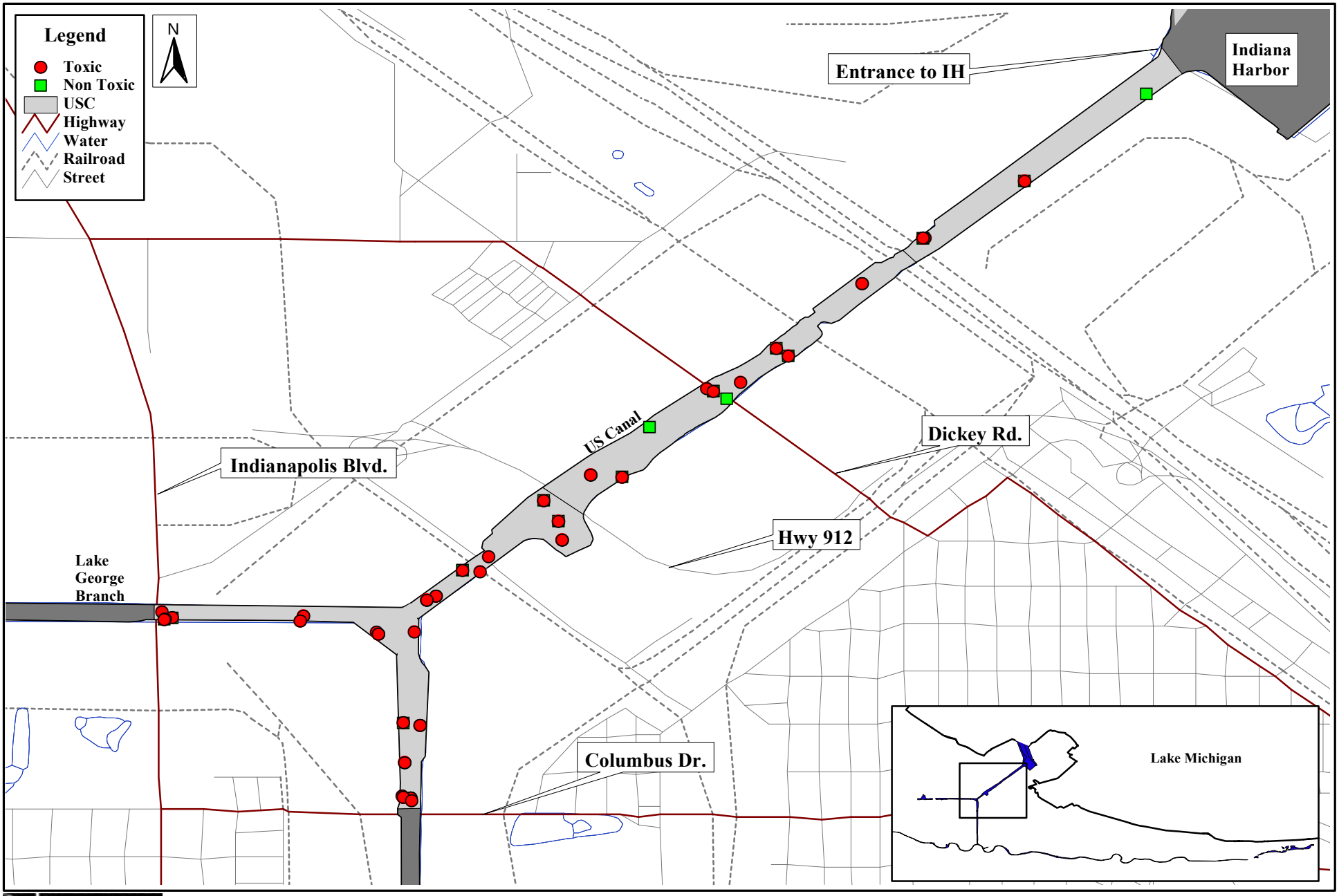


Figure 12.10. Areal extent of sediment toxicity in the USC.



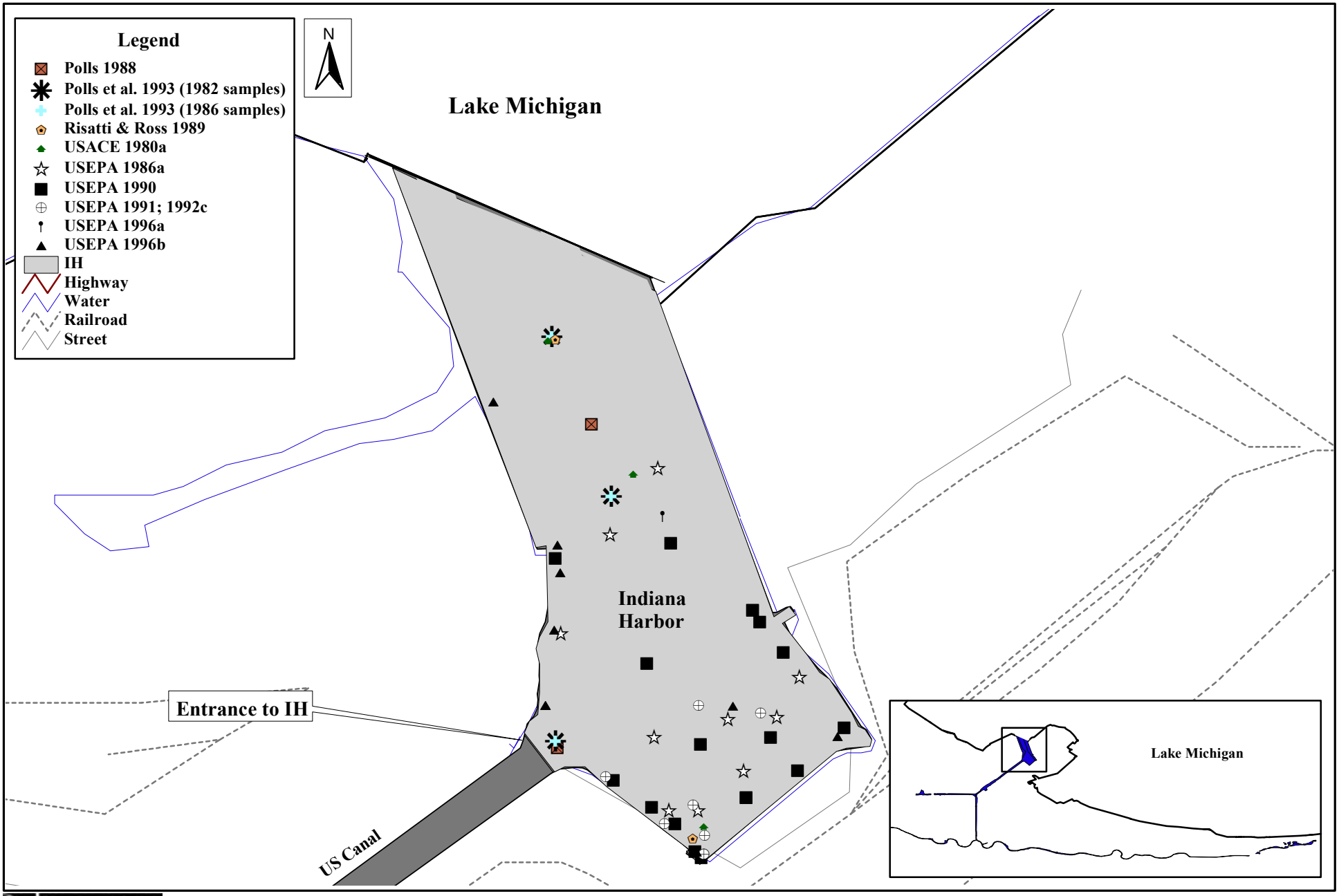
MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figures

Chapter I3 - Indiana Harbor

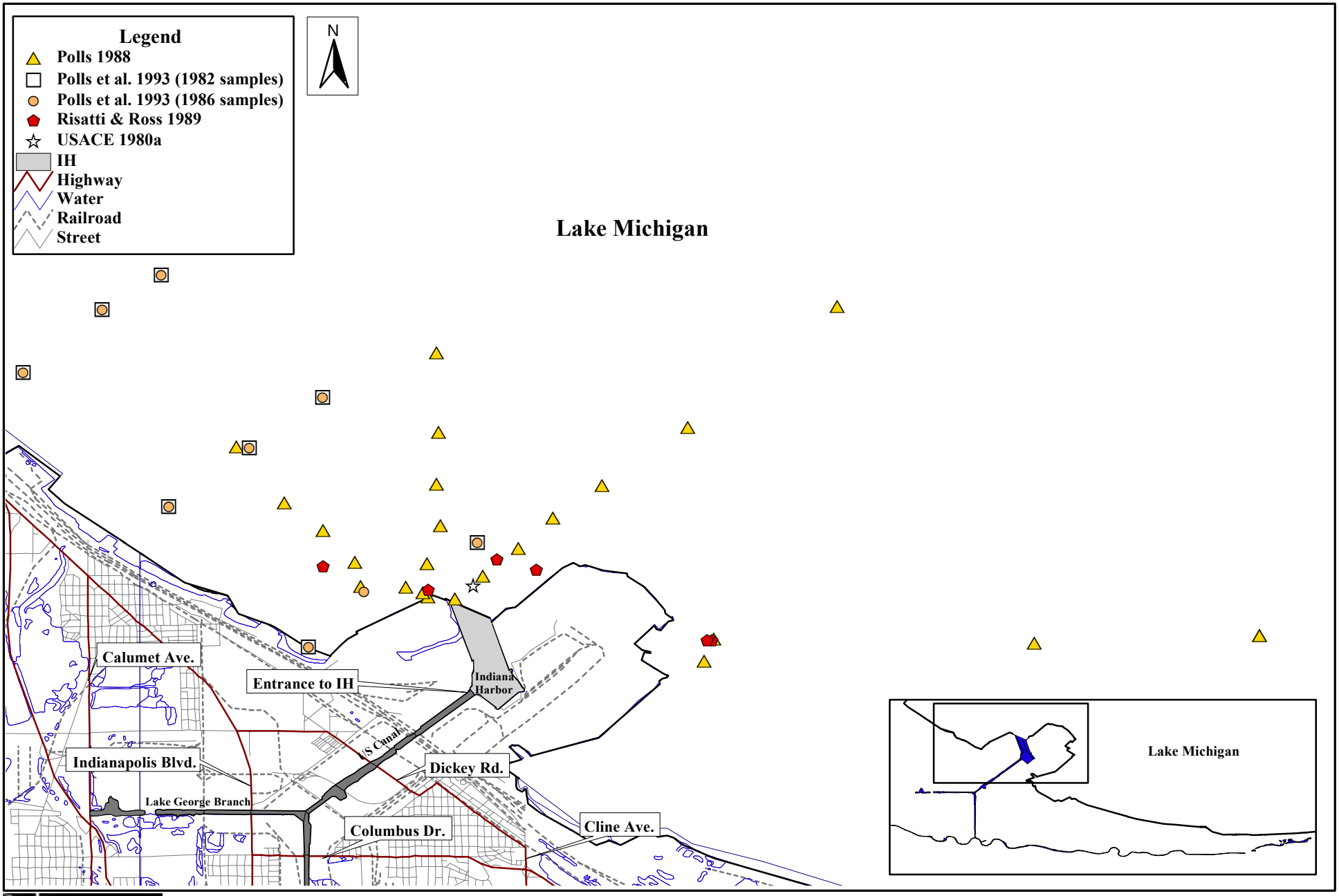
Figure 13.1a. Location of sampling stations for surficial sediment chemistry in the IH.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 Miles

Figure 13.1b. Location of sampling stations for surficial sediment chemistry within the nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 2 Miles

Figure 13.2. Location of sampling stations for sub-surface sediment chemistry in the IH and nearshore areas of Lake Michigan.

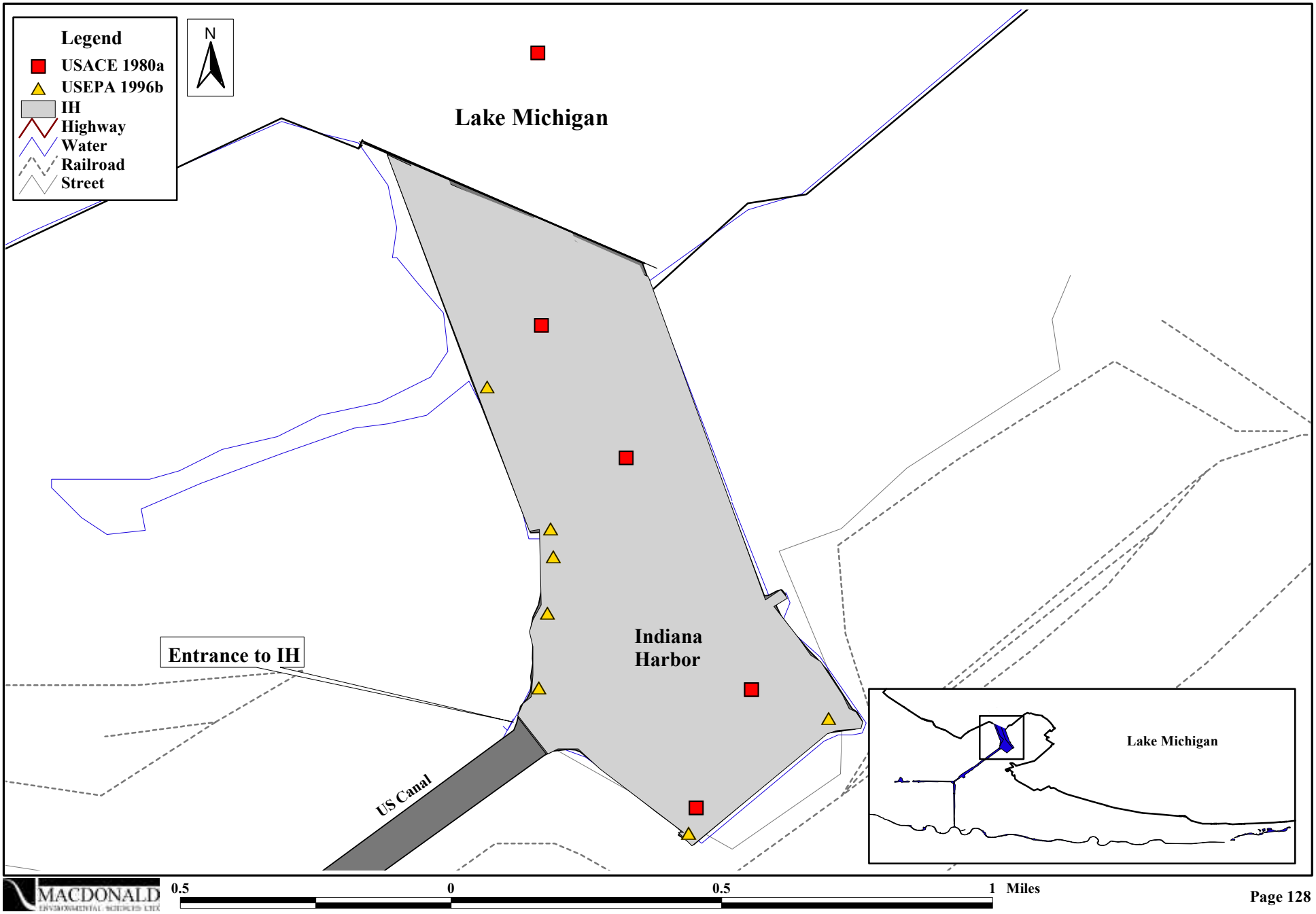
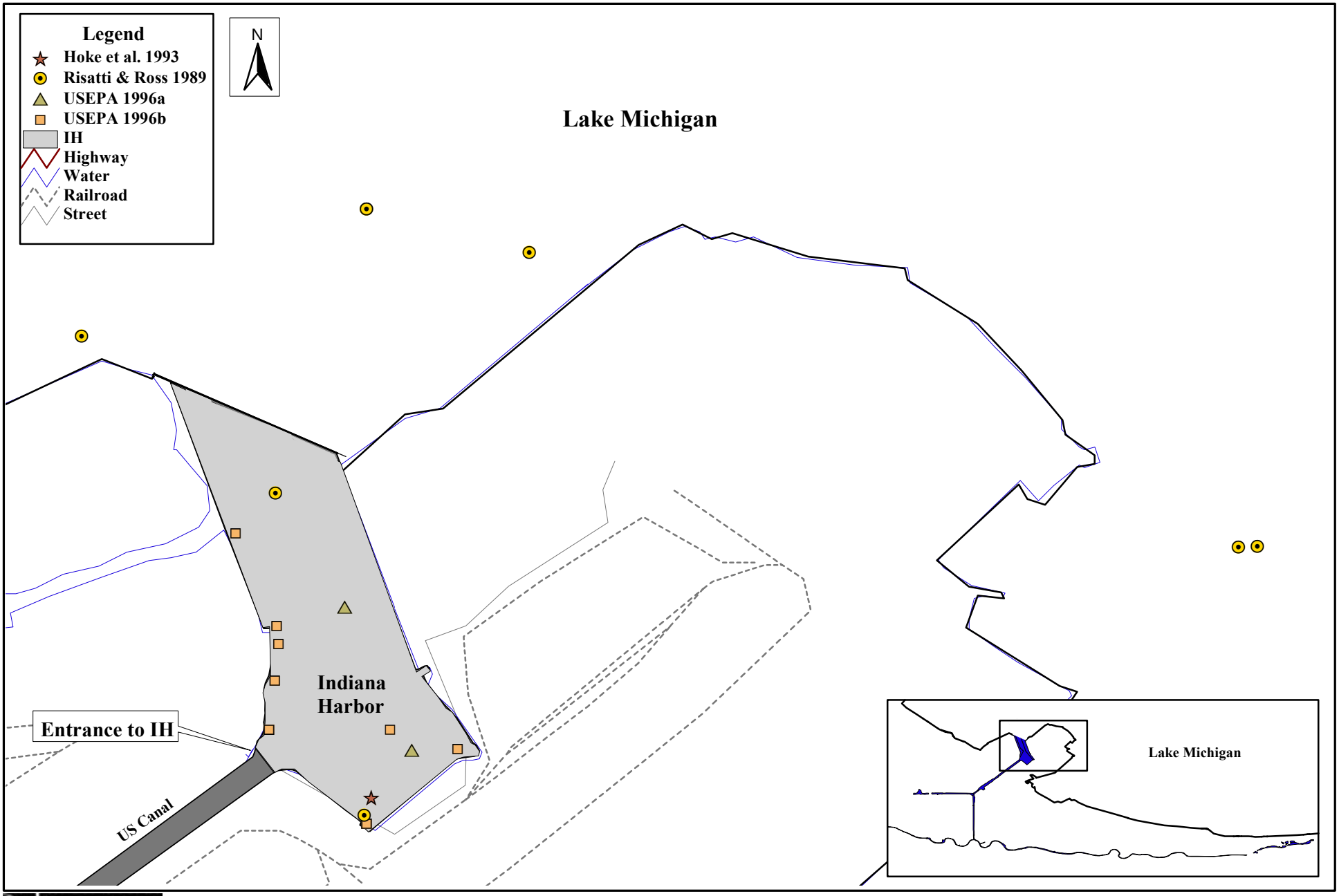


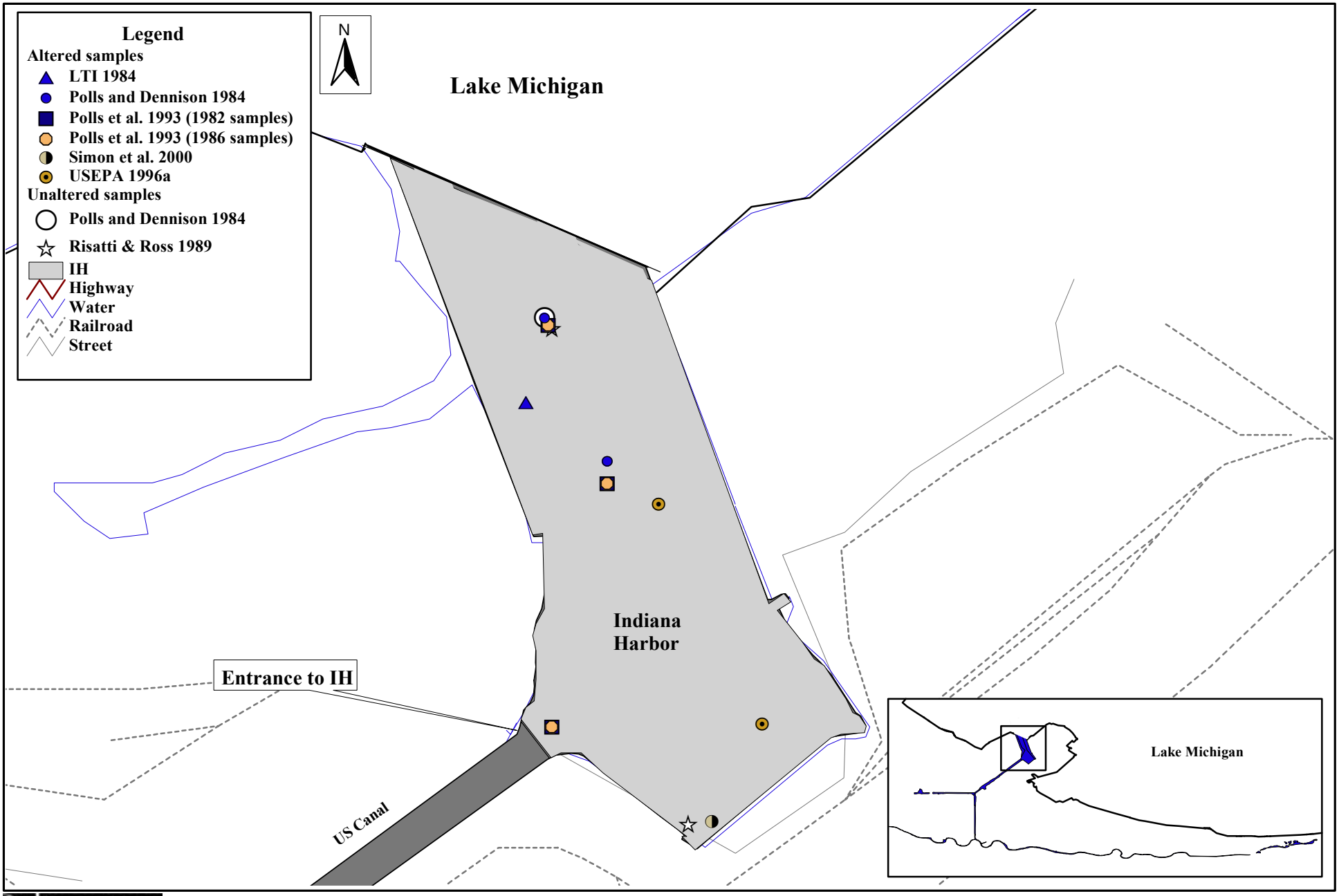
Figure 13.3. Location of sampling stations for sediment toxicity testing in the IH and nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

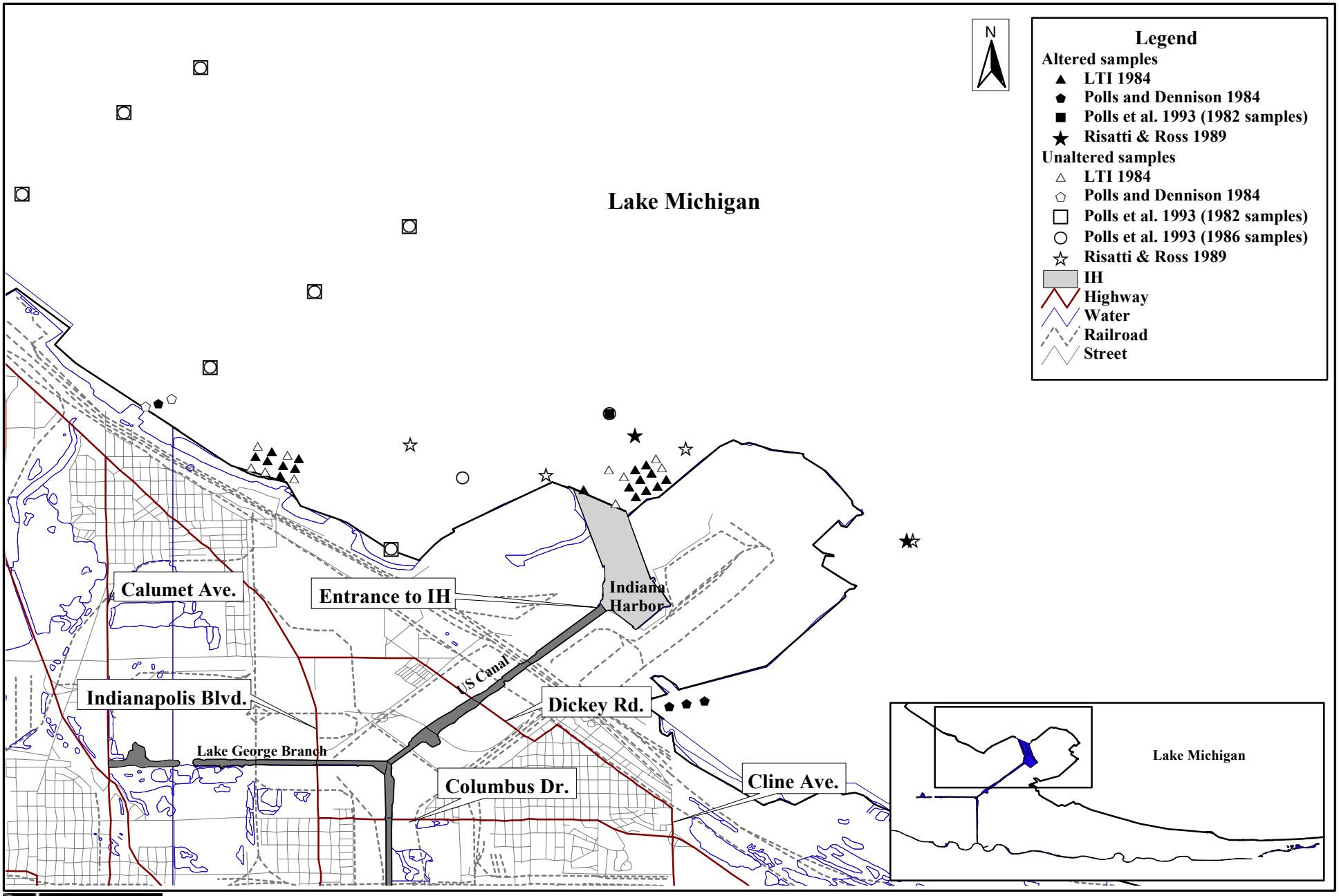
Figure 13.4a. Areal extent of altered and unaltered benthic invertebrate communities in the IH.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 Miles

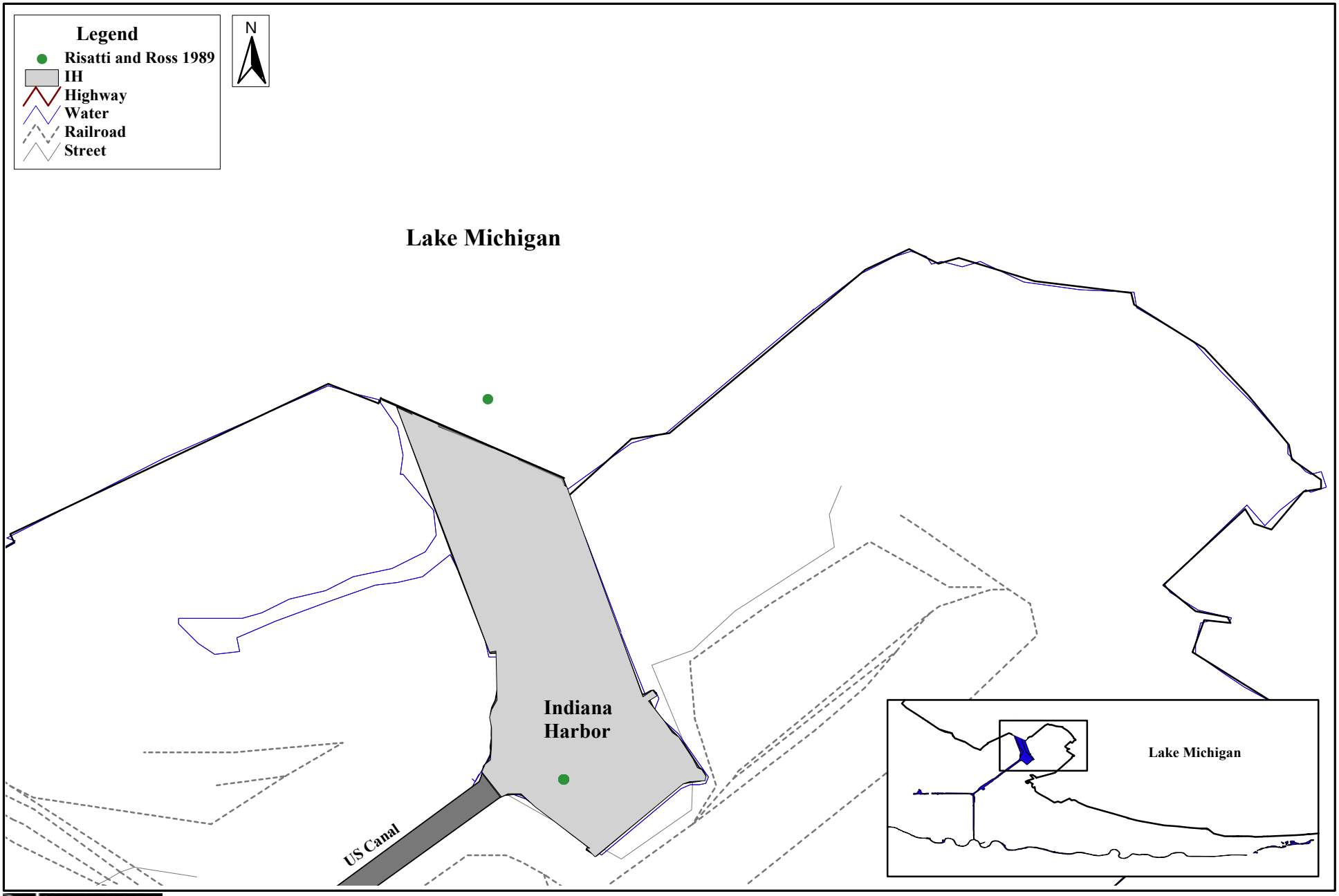
Figure 13.4b. Areal extent of altered benthic invertebrate communities within the nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 1.5 2 Miles

Figure 13.5. Location of sampling stations for tissue chemistry in the IH and nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 13.6a. Spatial distribution of mean PEC-Qs in surficial sediments within the IH.

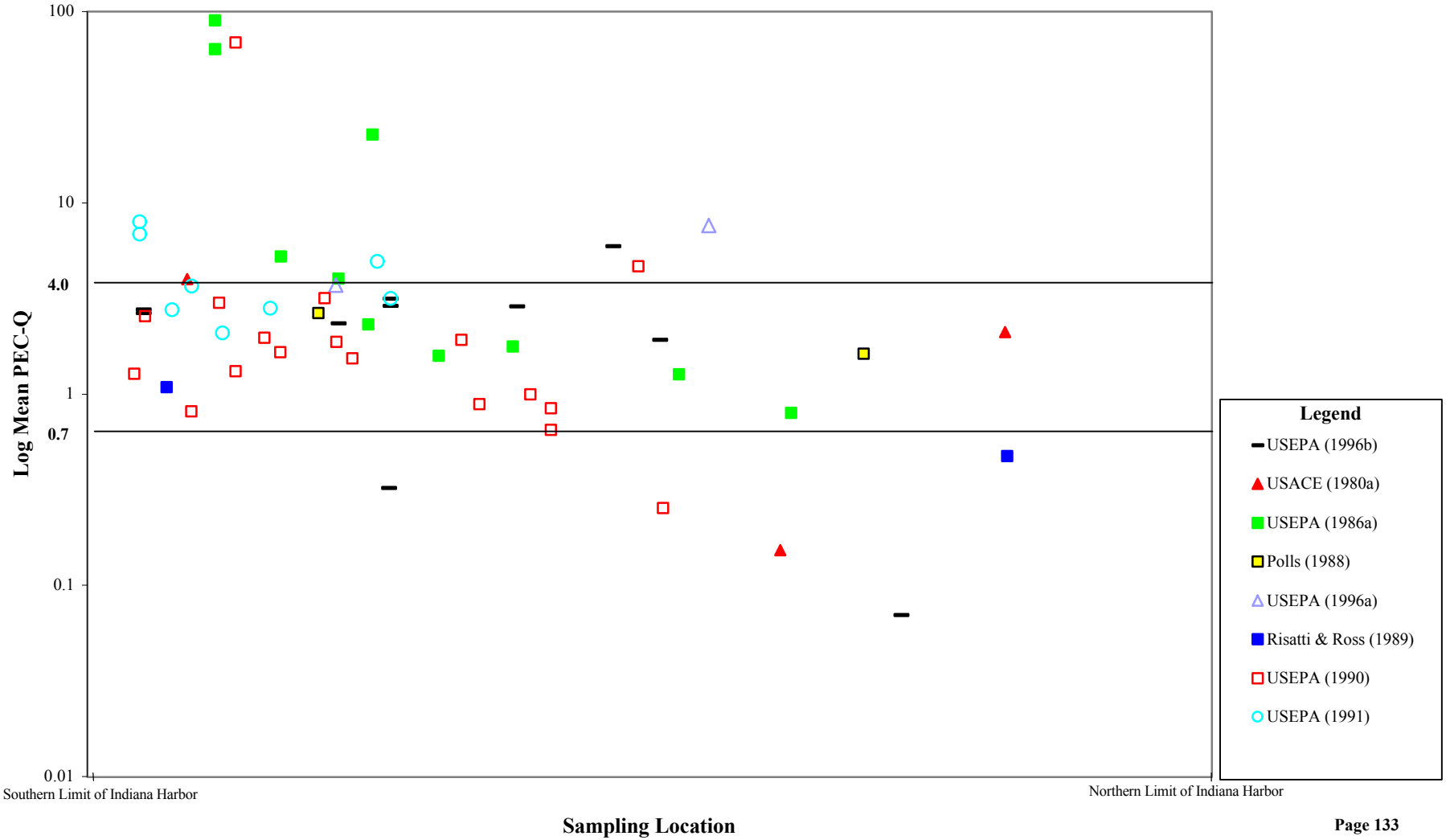


Figure 13.6b. Spatial distribution of mean PEC-Qs in surficial sediments within the eastern section of the nearshore areas of Lake Michigan.

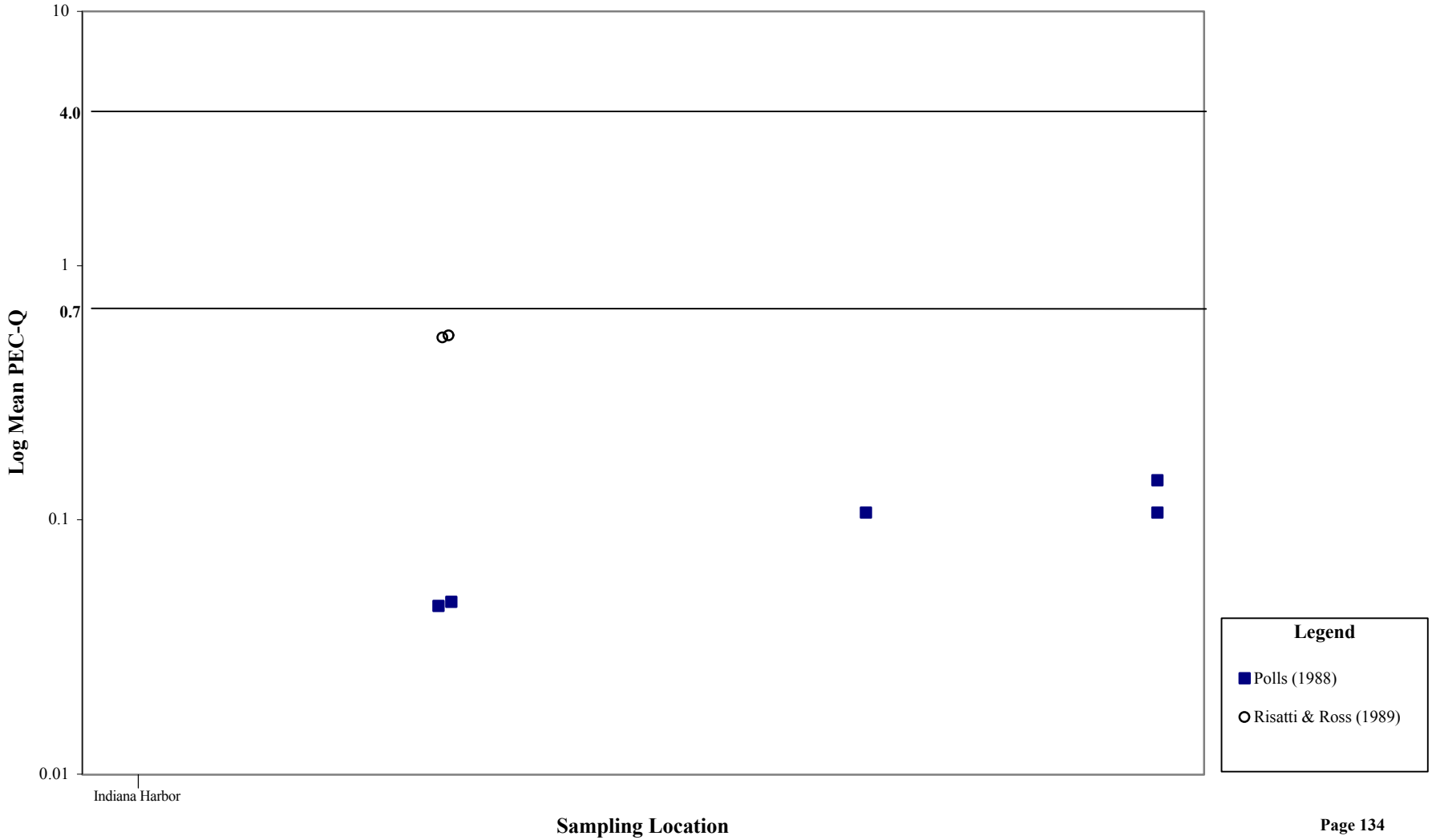


Figure 13.6c. Spatial distribution of mean PEC-Qs in surficial sediment within the northern section of the nearshore areas of Lake Michigan.

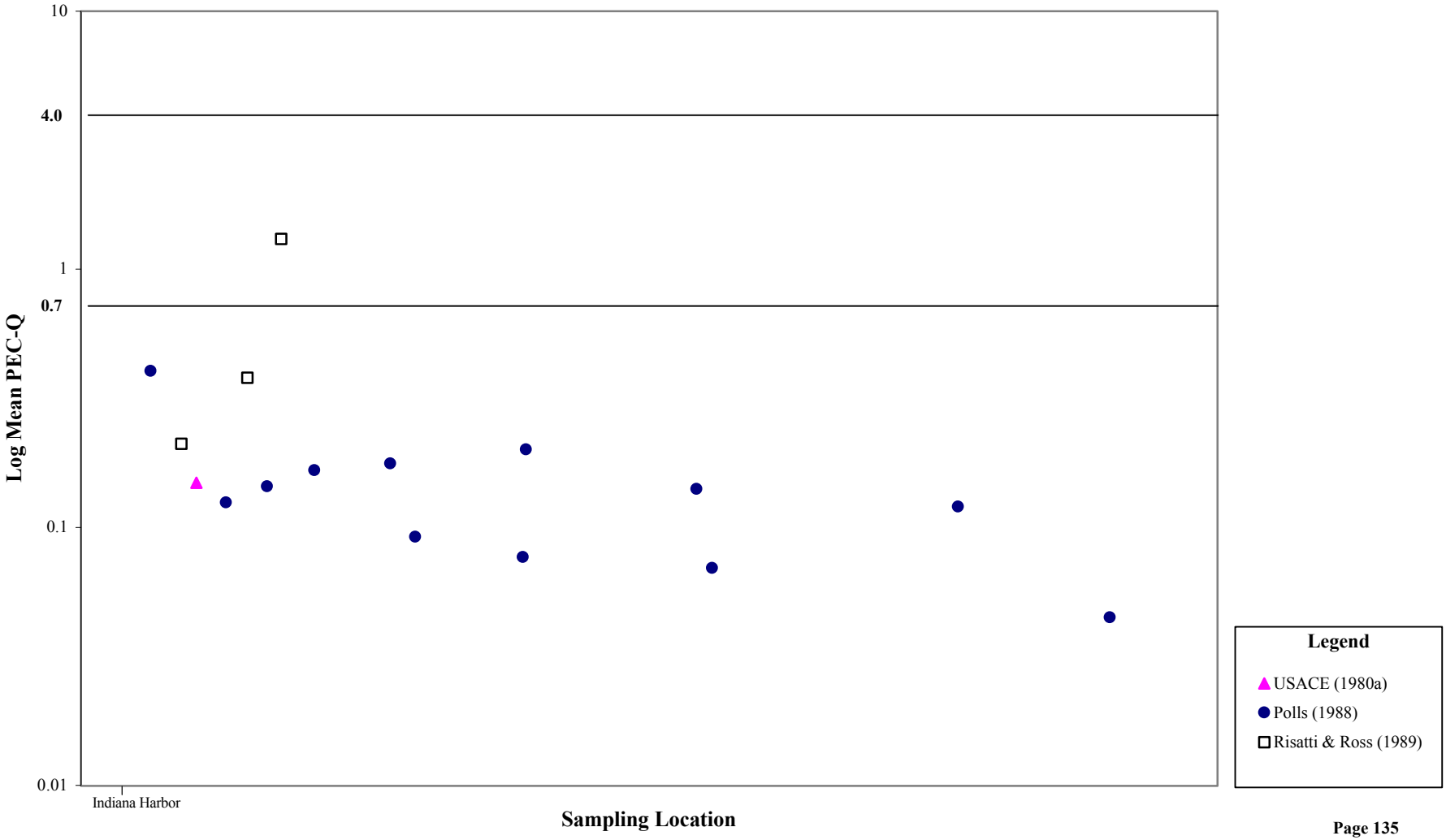


Figure 13.6d. Spatial distribution of mean PEC-Qs in surficial sediments within the western section of the nearshore areas of Lake Michigan.

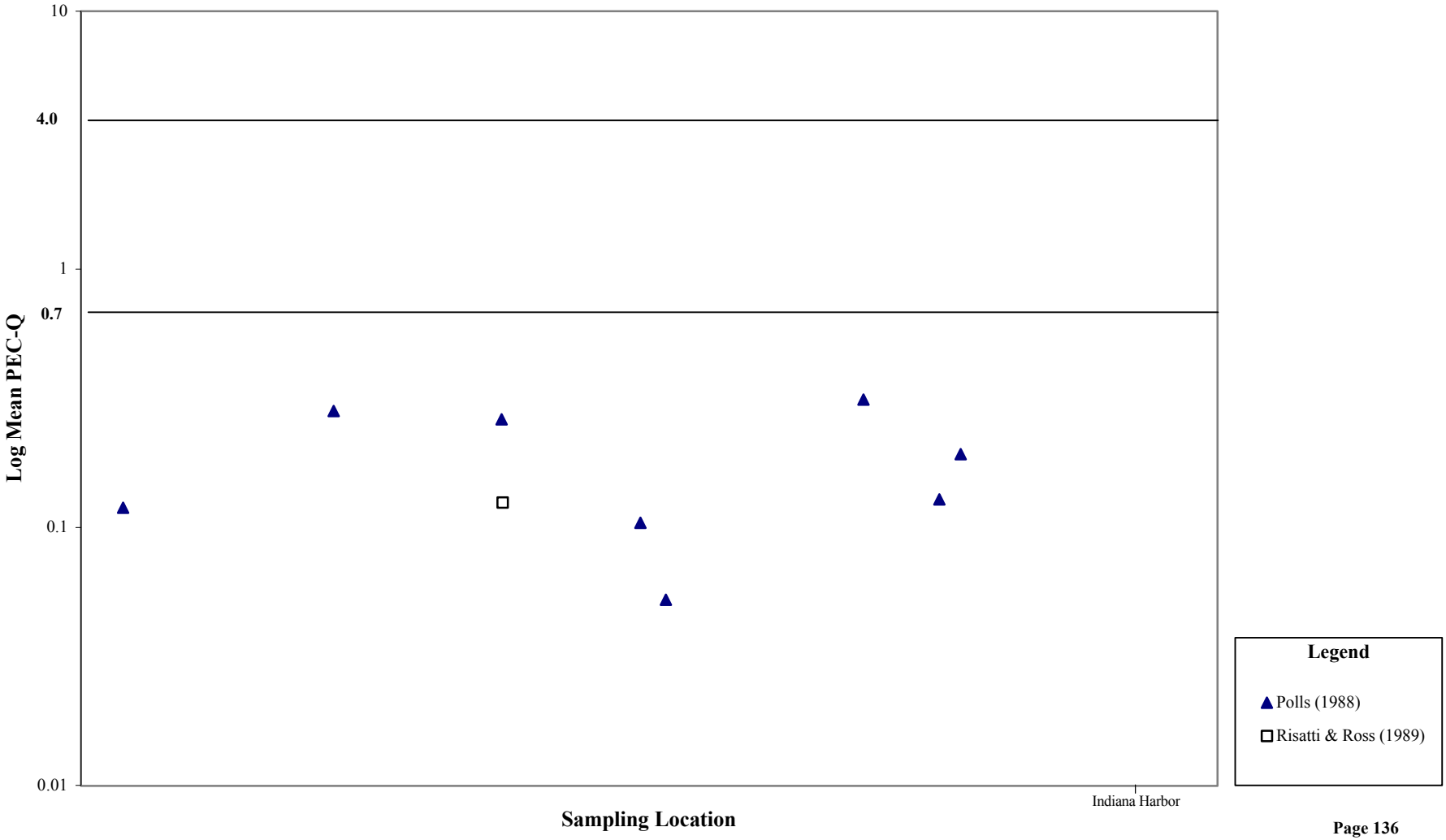
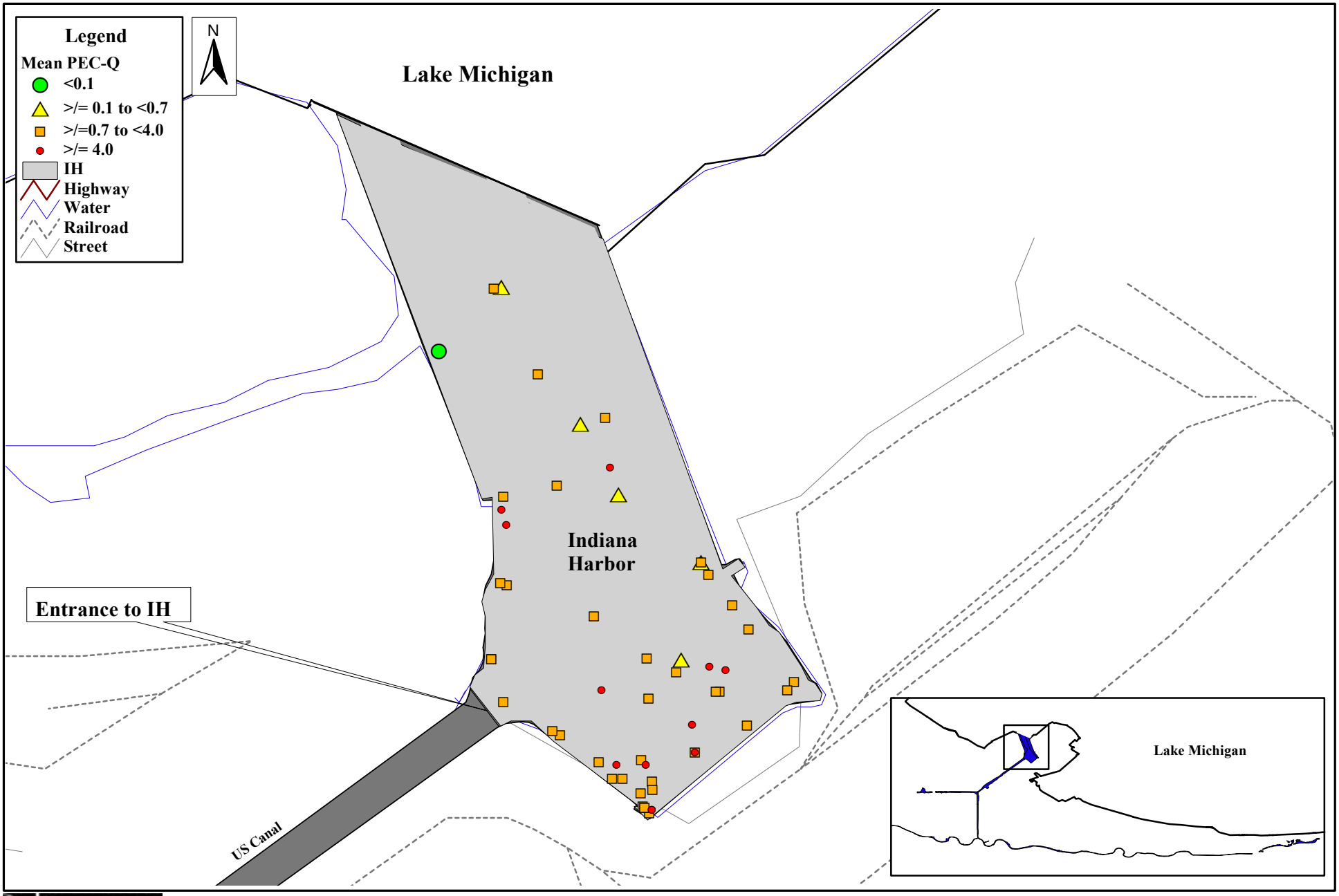


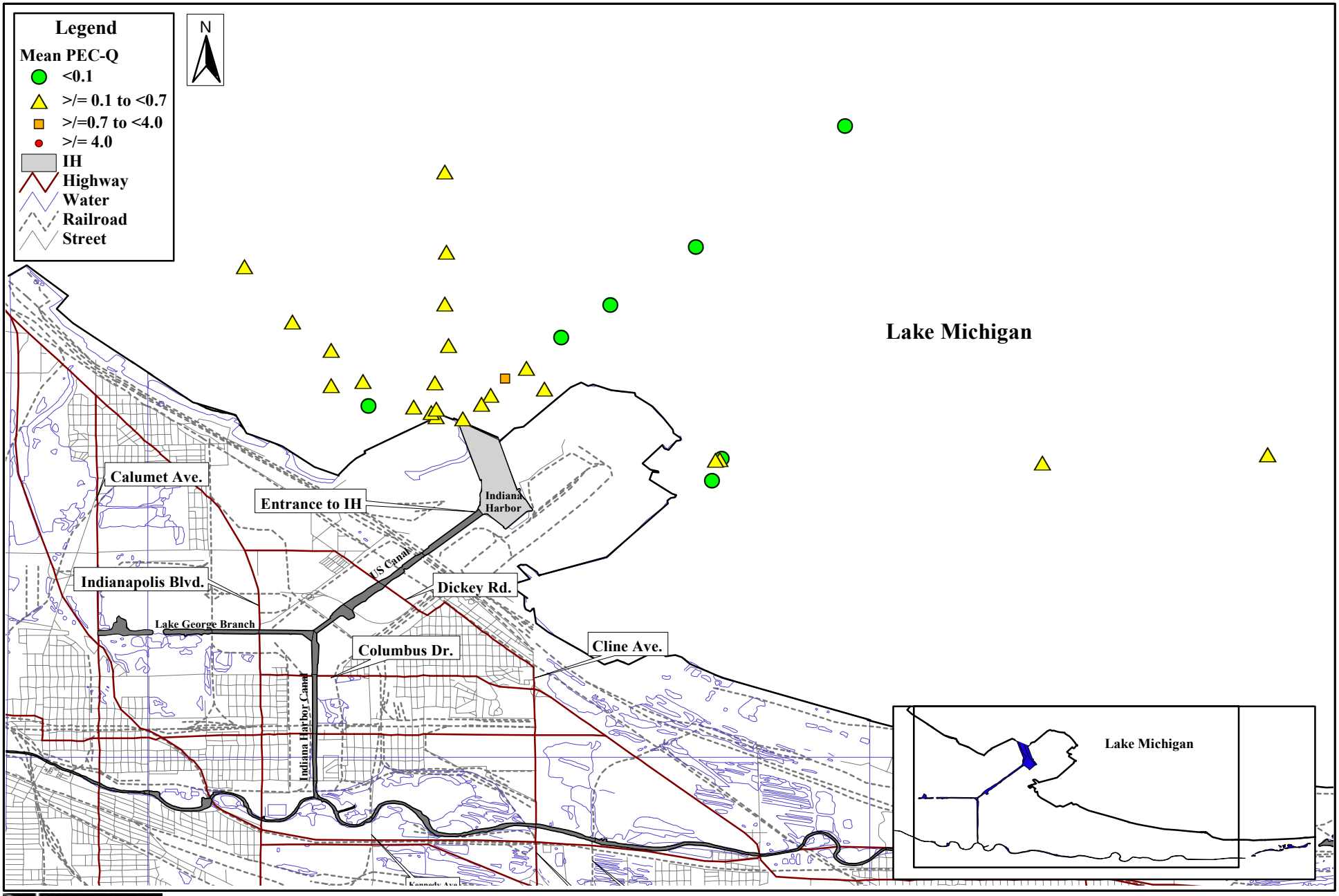
Figure 13.7a. Areal extent of injury to surficial sediments in the IH.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 13.7b. Areal extent of injury to surficial sediments within the nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SERVICES LTD

0.5 0 0.5 1 1.5 2 Miles

Figure 13.8. Spatial distribution of mean PEC-Qs in sub-surface sediments within the IH and nearshore areas of Lake Michigan.

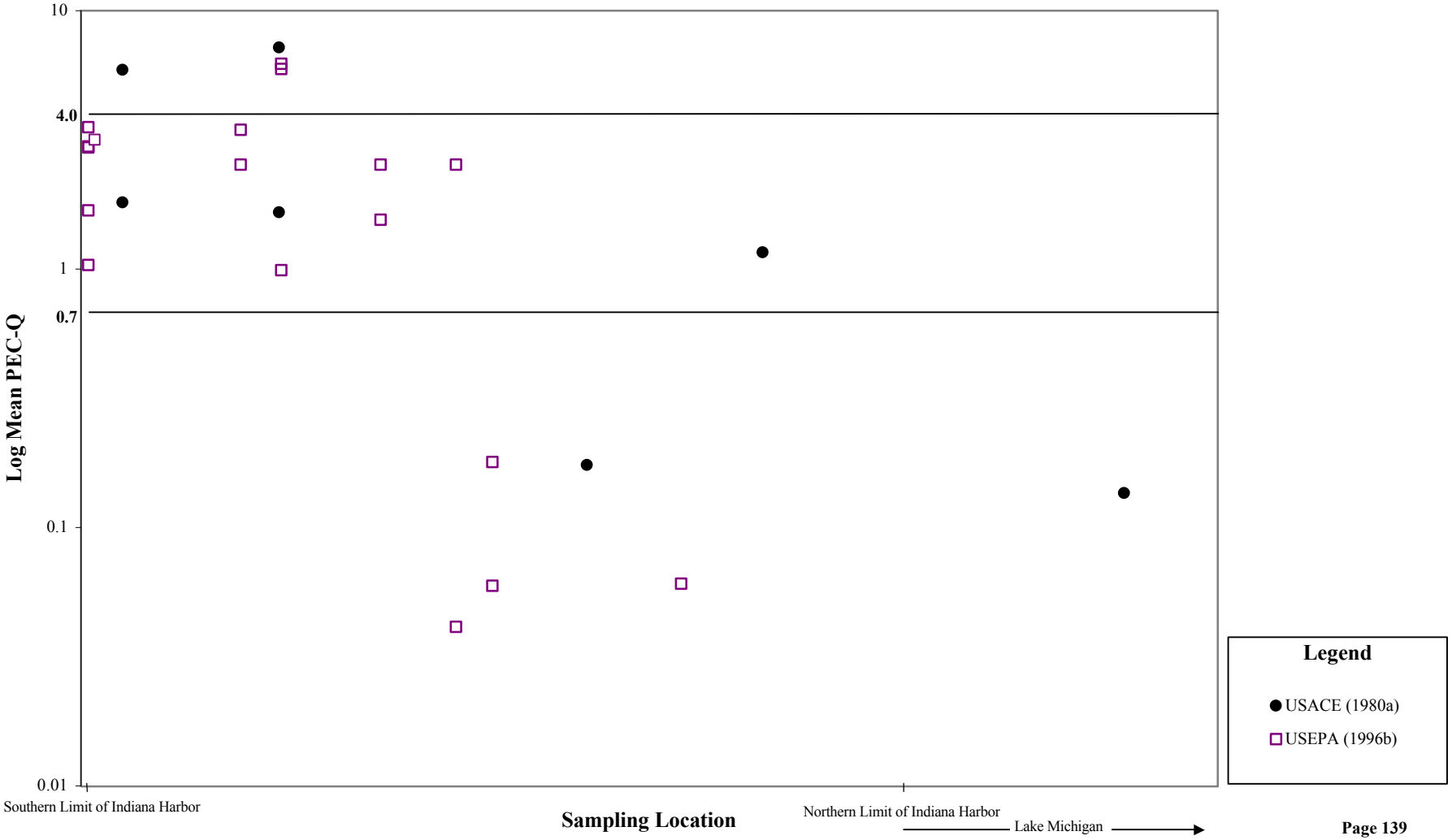
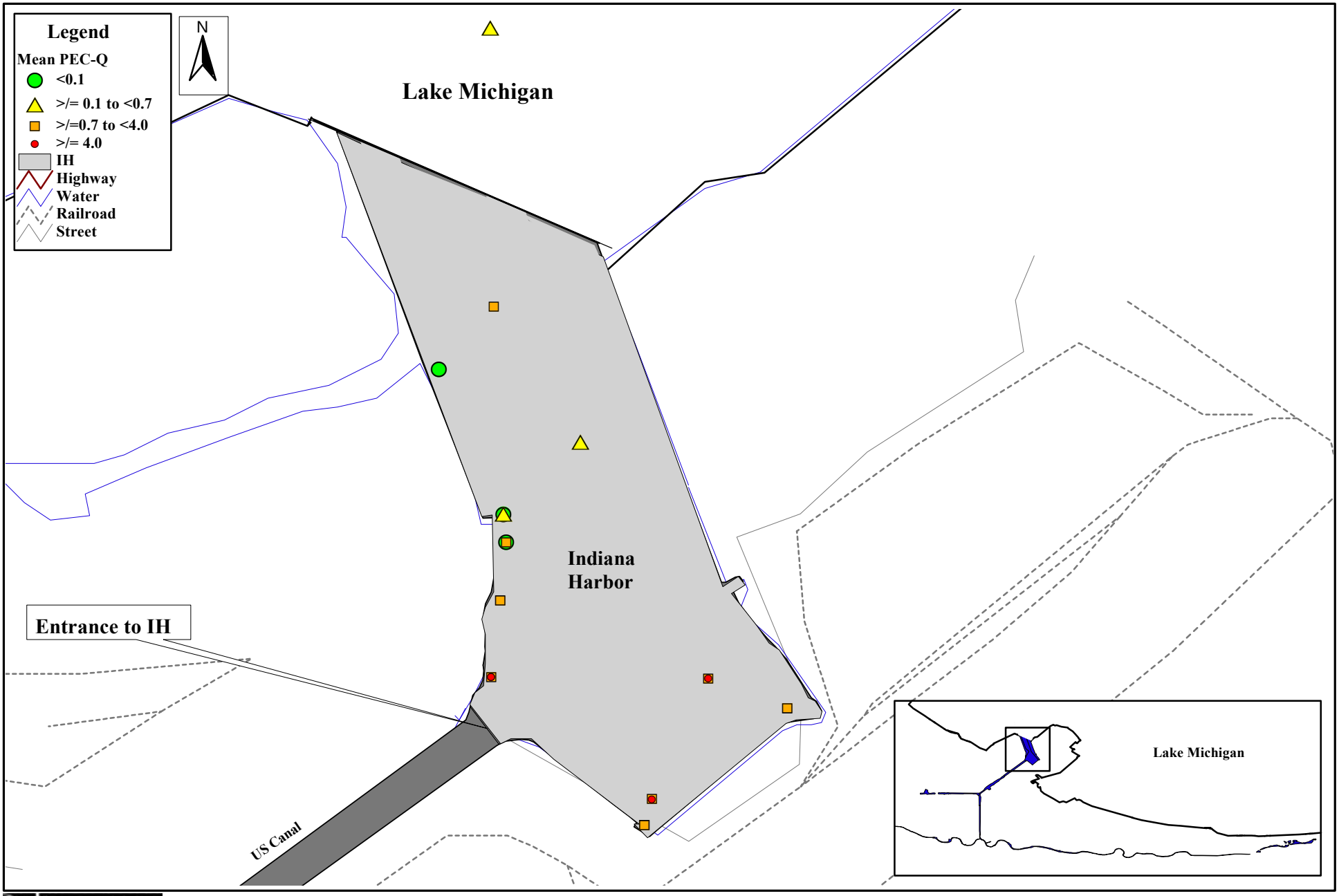


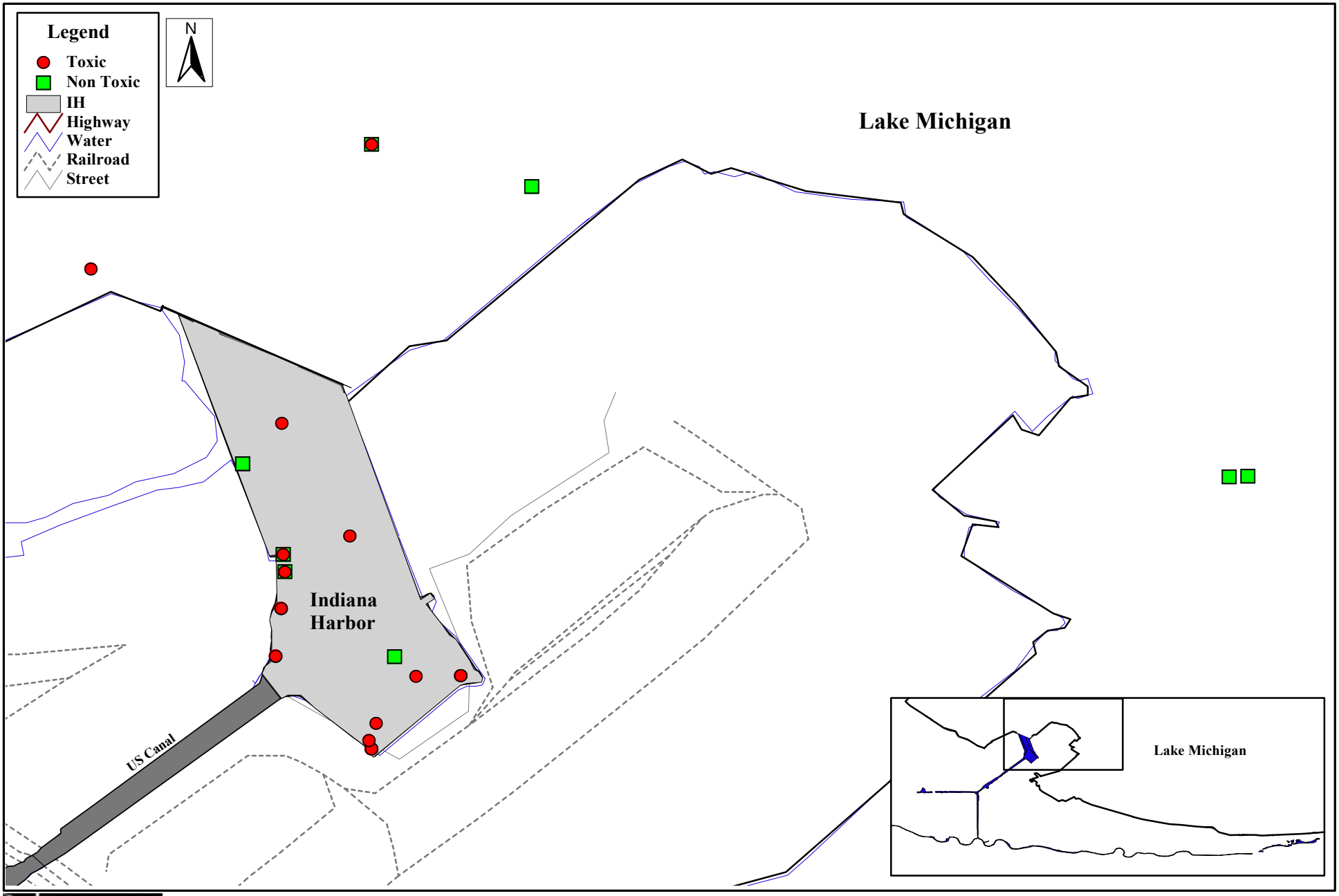
Figure 13.9. Areal extent of injury to sub-surface sediments in the IH and nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figure 13.10. Areal extent of sediment toxicity in the IH and nearshore areas of Lake Michigan.



MACDONALD ENVIRONMENTAL SCIENCES LTD

0.5 0 0.5 1 Miles

Figures

Chapter 14 - Summary of Sediment Injury for the Assessment Area

Figure 14.1. Areal extent of injury to surficial sediments in the Assessment Area.

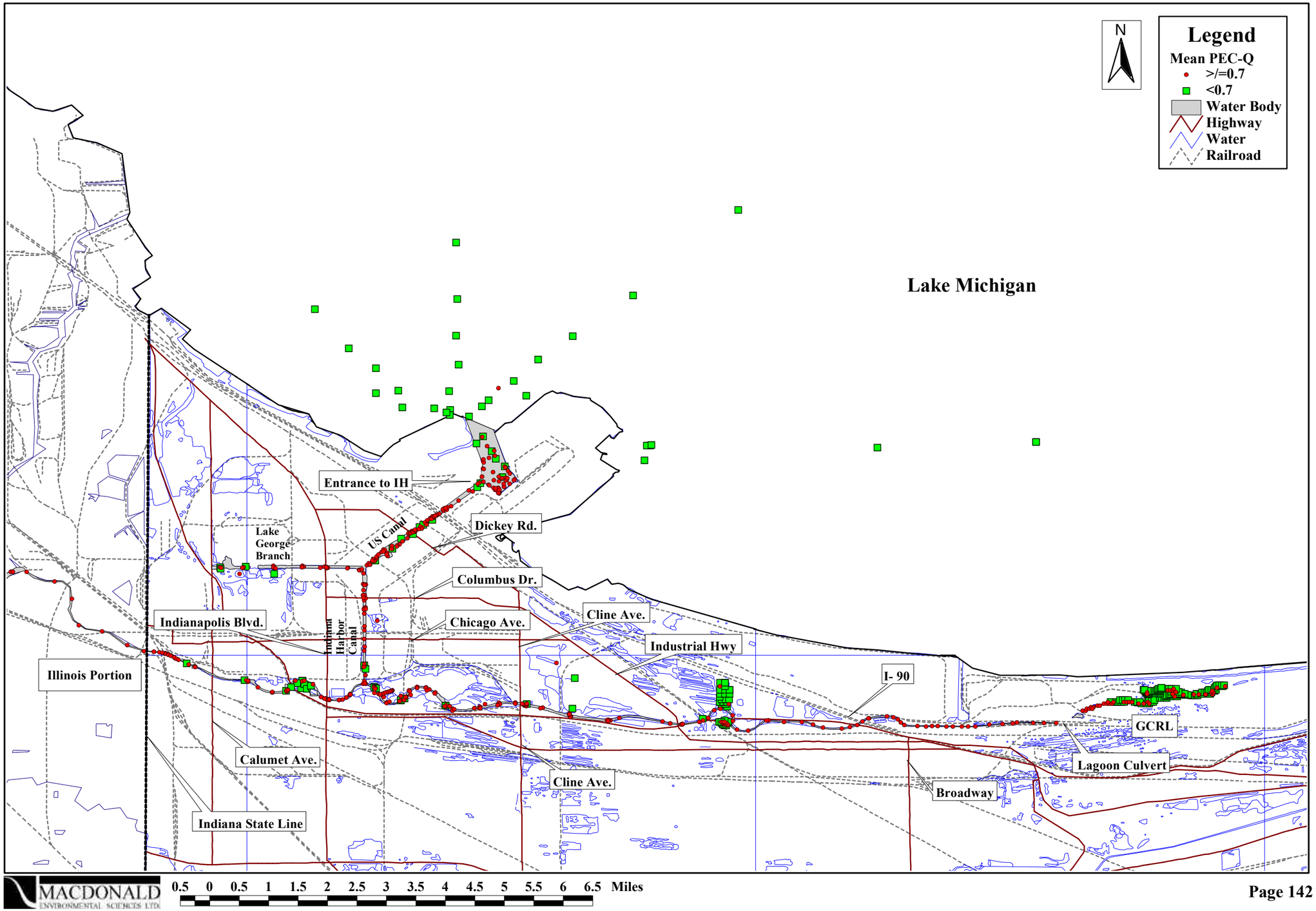


Figure 14.2. Areal extent of injury to sub-surface sediments in the Assessment Area.

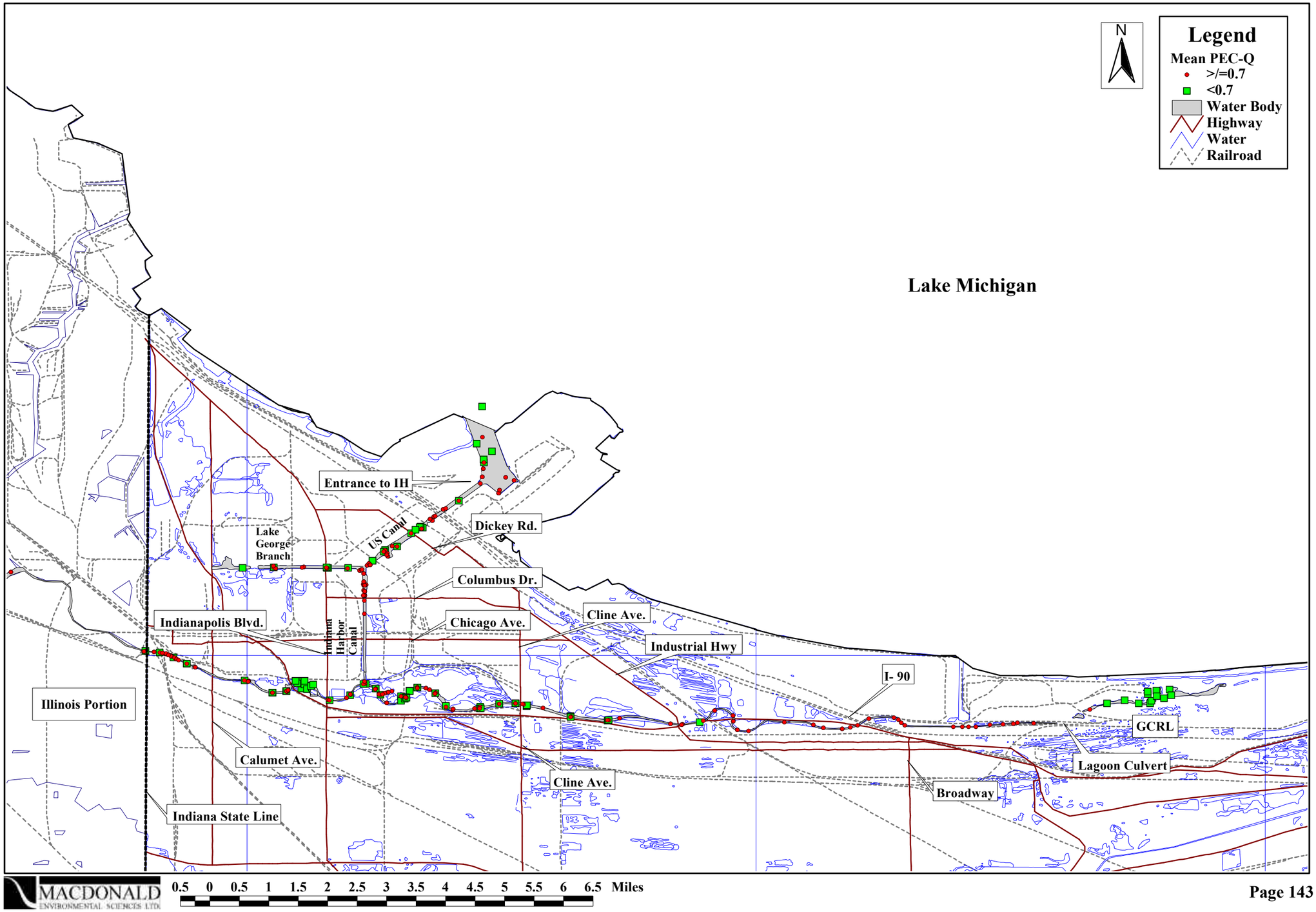


Figure 14.3. Areal extent of sediment toxicity in Assessment Area.

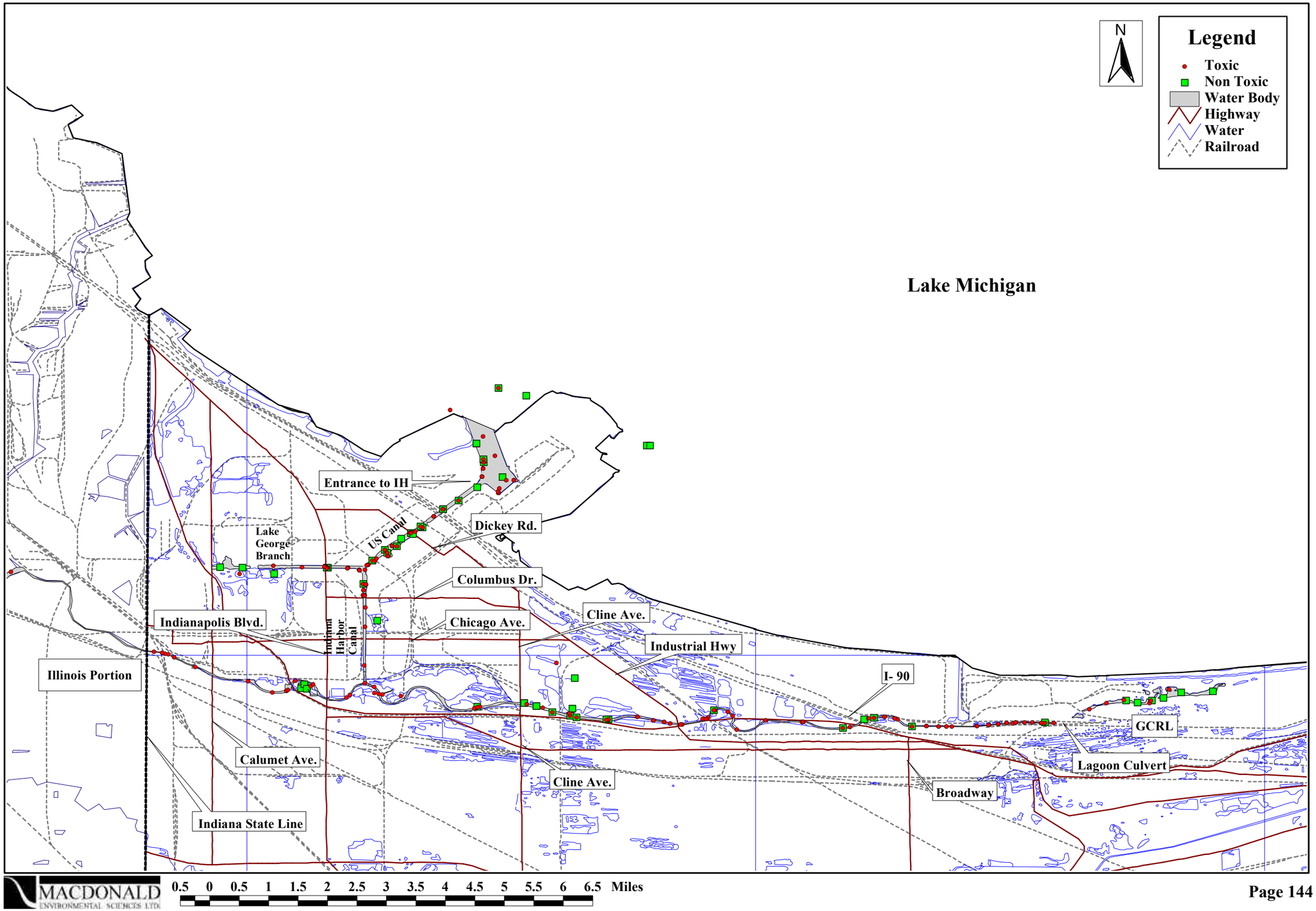
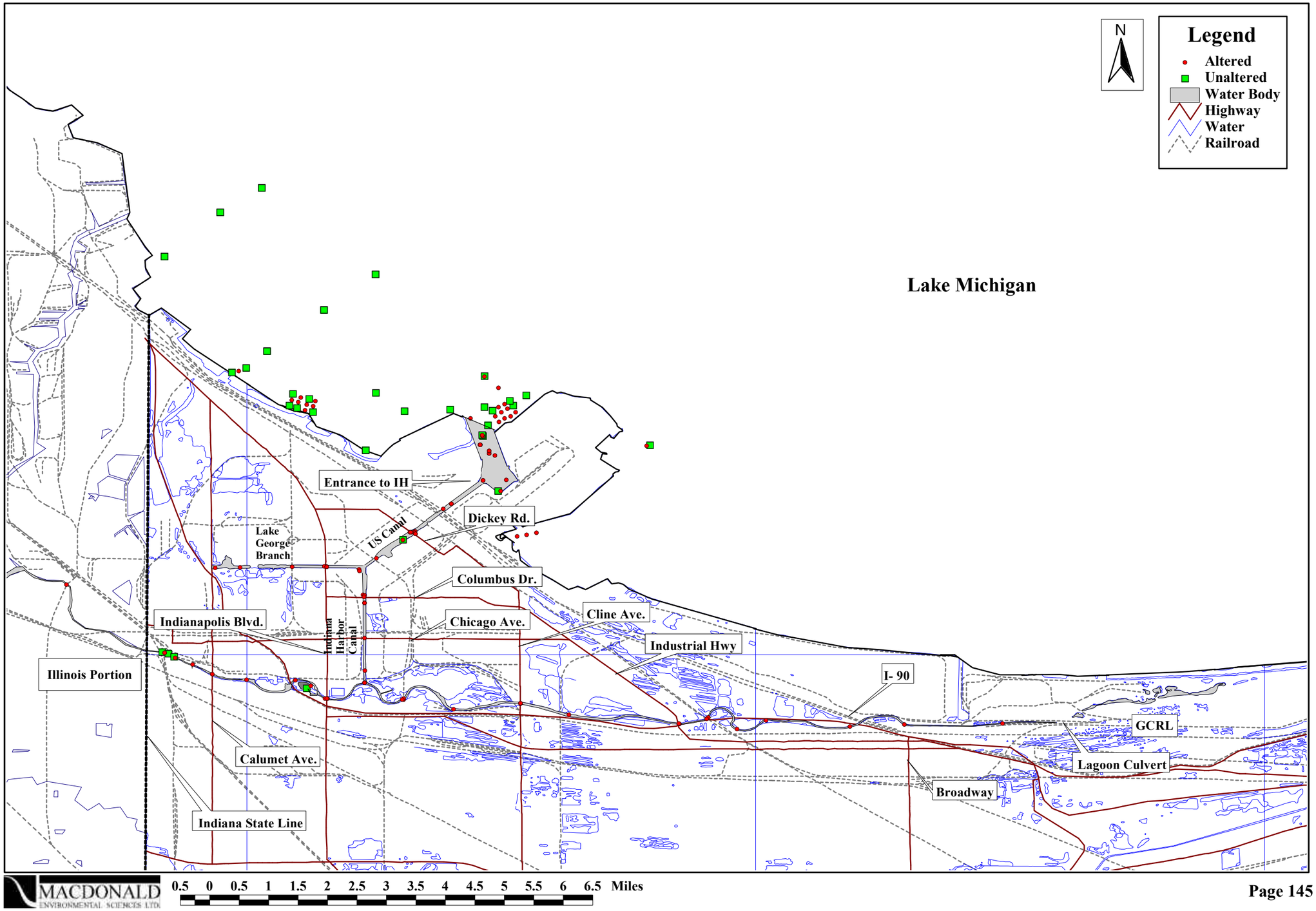



Figure 14.4. Areal extent of altered and unaltered benthic invertebrate communitites in the Assessment Area.