Lake Michigan Tributary Monitoring Project

1. Background and Problem

1.1. Introduction

The Lake Michigan Mass Balance (LMMB) project was a multi-million dollar, multi-agency effort to measure the loadings, fate, and transport of contaminants within Lake Michigan. A substantial amount of data was collected between 1993 and 1995 from Lake Michigan tributaries, air deposition, and Lake Michigan water, sediment, and biota. Research was conducted to evaluate processes such as air-water exchange and the sediment-water interface. The project focused on PCBs, trans-nonachlor, atrazine, and total mercury, although tributary and air deposition samples also were analyzed for additional parameters such as trace metals, other chlorinated pesticides, and nutrients. The development of a mass balance model, the final component of this study, currently is nearing completion.

The LMMB Work Plan identified four specific objectives for the project. These objectives were:

1. **Estimate pollutant loading rates** — Environmental sampling of major media to allow estimation of relative loading rates of critical pollutants to the Lake Michigan Basin.
2. **Establish baseline** — Environmental sampling and estimated loading rates to establish a baseline against which future progress and contaminant reductions can be gauged.
3. **Predict benefits associated with load reductions** — The completed mass balance model will provide a predictive tool that environmental decision-makers and managers may use to evaluate the benefits of specific load reduction scenarios.
4. **Understand ecosystem dynamics** — Information from the extensive LMMB monitoring and modeling efforts will improve our scientific understanding of the environmental processes governing contaminant cycling and availability within relatively closed ecosystems.

Approximately ten years have passed since the completion of the Lake Michigan Mass Balance (LMMB) sampling effort. There is a desire to resample the LMMB sampling sites in order to generate updated load estimates. However, there is considerably less funding available today than was available during the mass balance effort. Therefore, this proposal outlines a scaled-back work effort that would generate data for four of the original eleven LMMB sites.

This proposal describes the work needed to revisit select Lake Michigan tributaries, with an overall objective of characterizing present-day water column contaminant concentrations and loadings. This proposal also describes the sensitivity and error analyses that would be performed in order to understand the considerable uncertainty associated with loads calculated from a reduced level of effort relative to the original mass balance work.

1.2. Problem

Each of the four states that border Lake Michigan administers its own water-quality monitoring program. The objectives of these programs mostly focus on determining the degree to which water quality standards are being met in accordance with Clean Water Act regulations. However, the environmental management agencies within each of these states also have other state-driven objectives that they are trying to meet. In addition, federal agencies, such as the U.S. EPA and the U.S. Geological Survey, as well as local agencies, academic institutions and other non-governmental organizations engage in different forms of water quality monitoring and research along tributaries to Lake Michigan.

Each of these programs is administered independently, and this makes it difficult to assemble data from across the basin to draw basinwide conclusions about inputs and processes within the whole lake system.

In addition, funding in 2005 is even tighter than it was in 1994-1995. It is not currently possible to re-visit all Lake Michigan Mass Balance sampling sites with the same sample analyte and sample frequency schedules.

The problem, then, is to design a less ambitious sampling plan that still yields useful information about tributary loadings throughout the Lake Michigan Basin.

1.3. Background

In 1994 and 1995, a basinwide monitoring project was designed to model cross-media loadings and processes throughout the lake for four pollutants. As one component of the Lake Michigan Mass Balance Project, water samples were collected from eleven major tributaries to Lake Michigan. The objectives of the tributary sampling were to identify relative loading rates of pollutants from tributaries to Lake Michigan, and to compare tributary loading rates to other media, such as air and sediments. The water samples were analyzed for a variety of parameters, including conventional parameters, nutrients, total mercury, trace metals, atrazine, trans-nonachlor, and PCBs. Flow measurements were also were made, allowing for the calculation of loading rate estimates to Lake Michigan from each tributary.

While the results from these models are still being compiled, some results are now available. Tributary monitoring was an important part of the Lake Michigan Mass Balance Study. Results from tributary monitoring were used to calculate the total amount, or loading, of a pollutant entering the lake from a river. While only load information is normally reported, information on pollutant concentrations is of interest to those in the watersheds, as well as the broader Lake Michigan community. Pollutant concentrations affect those living along the river and its estuary or harbor, leading to potential local problems.

For example, the Fox River has high, overall PCB concentrations and loads, as do the Kalamazoo River and Grand Calumet Harbor. However, the Sheboygan River and Milwaukee River have higher-than-average concentrations, but relatively low loads. Relatively high average concentrations are often associated with known sediment reservoirs of PCBs and may represent areas historically associated with industrial activity and PCB discharges into the rivers. Conversely, the Grand River has a relatively low PCB concentration, but a large load. This is due to the large flow of the Grand River – a large volume of water with low PCB concentrations can introduce more PCBs to the lake than a small volume of water with relatively high PCB concentrations.

2. Objectives and Scope

The work detailed in this section is designed to yield updated water column contaminant concentration and loading data for a subset of the tributaries and contaminants originally included in the Lake Michigan Mass Balance project.

2.1. Objectives

There are three main objectives for this proposed work:

1. Characterize present-day water column PCB, nutrient, and mercury concentrations at four of the original eleven Lake Michigan Mass Balance sampling sites.
2. Estimate mass loading for each of the four sampled Lake Michigan tributaries.
3. Estimate the uncertainty associated with each of the loading estimates.

The original Lake Michigan Mass Balance water column sampling was designed to determine loads from each tributary with 95% confidence intervals of ± %25. It is unclear whether these objectives were met. In addition, the sampling frequencies proposed here are limited by budget, and cannot duplicate the sampling frequencies that were part of the Lake Michigan Mass Balance. Therefore, this proposal will include the estimation of uncertainty in the load estimates as a work element.

2.2. Scope of Work

In order to meet project objectives, the following tasks are proposed:

1. Base Data Collection. Collect a current, basic set of water column PCB data at a subset of the sampling points used in the 1994-1995 Lake Michigan Mass Balance effort. The four proposed sites are: **Lower Fox River**, **Grand River**, **Kalamazoo River**, and the **Grand Calumet River**. Sampling would be scheduled, with several additional "storm-chasing" samples included (except for the Grand Cal, where all samples would be scheduled).
2. Data Analysis and Load Calculation. Water column concentration data will be compared to LMMB data, and the non-parametric Mann-Whitney test will be applied to assess whether there are significant differences between current data and data from the original LMMB. Congener data will be summed, and all results greater than the level of detection will be included in the summation. Loads will be calculated by applying Beale's stratified ratio estimator.
3. Error Estimation. The sensitivity of Beale's stratified ratio estimator (BRE) to sample size will be tested through Monte-Carlo simulation. The 1994-1995 data will be repeatedly subsampled, and the BRE method will be used to calculate a load for each of these data subsets. The relationship between the 95% confidence interval about the mean and sample size will be determined.
4. Report Writing. A brief Scientific Research Investigations Report (SRIR) will be written summarizing data collection and analysis efforts.

The base data collection (Task 1) would be completed in fiscal year (FY) 2005. Data analysis and error estimation (Tasks 2 and 3), and report writing (Task 4) would be completed in FY 2006.

3. Benefits

The work proposed here would support program efforts currently supported by a variety of agencies:

- Lake Michigan Mass Balance Modeling: this effort would benefit from the acquisition of a present-day validation data set.
- Lake Michigan LaMP and Great Lakes Binational Toxics Strategy: both of these programs would benefit from a revised set of water column PCB data and mass loading estimates.

- Superfund - Fox River NRDA/PCB Release Sites: at this site, it has been argued that natural attenuation is lowering concentrations in all media with a half-life on the order of 5-7 years. The work proposed here will have the statistical power to detect such a trend, if one exists.

It would also be beneficial to develop a regular cycle within which state-monitoring programs would be synchronized to allow for credible and scientifically sound basin wide comparison. This would not only enhance the knowledge and understanding of pollutant loading gained through the Lake Michigan Mass Balance Study, but it would also help to dynamically refine pollutant load and concentration forecasting.

These improvements would help resource managers to better focus and tailor their efforts on current and future problem areas.

4. Approach

The approach outlined here outlines a range of sampling strategies designed to meet the stated objectives.

4.1. Sampling Program Parameters

The parameters for a proposed sampling plan are specified in this section. We assumed that the primary contaminant of concern is PCB, and that all other contaminants would be sampled with the same timing and frequency as the PCB sampling.

4.1.1. Contaminants

While a primary focus of the sampling is on PCBs, other contaminants will require some level of effort. Estimates of mercury loads require separate preparation, sampling and analysis, but were part of the original suite of contaminants for the LMMBS effort. Nutrient load estimates are also important, particularly to modelers estimating algal production as part of the food web model. This provides input to bioaccumulation modeling.

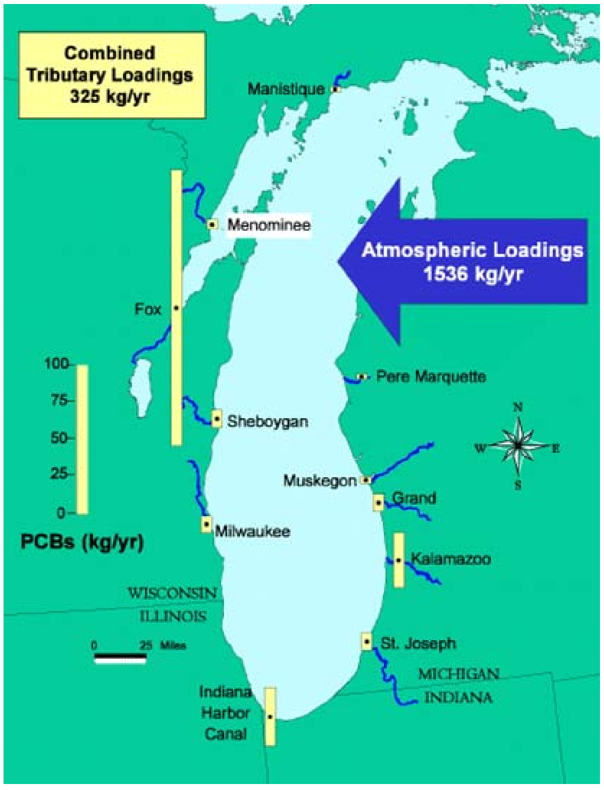
Therefore, this proposal assumes that an appropriate subset of LMMB contaminants is:

- PCB (congener-specific, dissolved + particulate)
- Mercury (total and methylated, dissolved + particulate)
- Nutrients (total P, orthophosphate, TKN, nitrate + nitrite, ammonia)
- Suspended sediment, particulate organic carbon, and dissolved organic carbon

4.1.2. Sample Sites

One way to optimize sampling is to rank the tributaries by their estimated, or previously measured, loads, and sample those tributaries which are estimated to provide a

Figure 1. Lake Michigan Mass Balance estimated tributary PCB loadings (U.S. EPA, 2004)



large percentage of the load. This eliminates sampling in at least some of the tributaries.

Total tributary loads for the 1994 and 1995 periods indicate that a large percentage of the load to Lake Michigan could be estimated using by sampling a handful of tributaries.

The Fox River is the largest tributary source of PCBs to Lake Michigan, contributing over 60 percent of the PCB load to the lake. Following this, the Grand Calumet and Kalamazoo rivers each contribute approximately 11 percent of the load. The next group of tributaries, the Sheboygan, Milwaukee, Grand and St. Joseph rivers, each contribute an additional three percent. The last group of tributaries, the Menominee, Muskegon, Manistique and Pere Marquette rivers, each contribute one percent or less to the total load. Figure 1 summarizes the PCB mass loads as estimated in the Lake Michigan Mass Balance.

These percentages indicate that estimating the loads from the Fox, Grand Calumet, and Kalamazoo rivers, and a tributary from the next group, could quantify almost 90 percent of the measurable load to Lake Michigan.

This proposal assumes sampling will be conducted at the **Fox**, **Kalamazoo**, **Grand Calumet**, and **Grand** rivers.

4.1.3. Sample Numbers

The Lake Michigan Mass Balance workplan specified that the objective for sampling was to generate loads for each tributary with 95% confidence intervals of ± 25%. The LMMB target number of samples for the four tributaries considered in this proposal were:

- 36 samples at Grand River
- 26 samples at Fox River, Kalamazoo River
- 16 samples at Grand Calumet

The actual confidence interval associated with the LMMB loads is impossible to know. Richards and Holloway (1987) note that "paradoxically, the requirements for a good sampling program cannot be calculated without first having some data from a good sampling program."

However, the LMMB data sets provide us with some insight as to how water column contaminant concentrations change over time, and with flow and temperature.

We found statistically significant correlations ($\alpha<0.05$) between air temperature (as a surrogate for water temperature) and dissolved PCB concentrations for all four tributaries. We found a statistically-significant correlation between flow and particulate PCB for the Kalamazoo River only. In the case of the Kalamazoo River, the regression relationship is significant, but weak and negative: as flows increase, PCB decreases, presumably due to dilution. The regression analyses are included as attachments to this document.

The weak or non-existent correlations between flow and PCB concentration suggest that there are limited gains to be realized from a sampling program which is stratified by flow. The correlations between air temperature and PCB concentration suggest that samples need to be spread out more or less evenly over a wide range of temperatures (i.e. seasons). Therefore, in the next section of this document we propose a sampling strategy that is similar to what Robertson (2003) describes as "monthly sampling with storm chasing." For budgetary reasons, the total number of samples proposed is 12 for the four tributaries. Thus, scheduled sampling in November 2005, January 2006, and monthly sampling between March and October will yield 10 samples, with 2 samples remaining for "storm chasing" samples.

4.1.4. Statistical Power of Sample Design

We examined the number of samples that might be needed to detect various degrees of true change in mean or median concentrations within each tributary. To do this, we assumed that the 1994-1995 data could be represented with a normal probability density function (PDF), with mean and standard deviation as per the LMMB data for each tributary.

We then assumed that the 2005 data could be represented by another normal probability density function, with the mean and standard deviation set to some fraction of that observed in the LMMB data. We generated 1000 sets of numbers using these PDFs, comparing each with a two-tailed t-test. We recorded the number of times that the t-test indicated a statistically significant difference, given that the "2005" PDF was defined by a known, smaller mean and standard deviation.

The results indicate that at the 12 sample range, we can expect to reliably (i.e. $1-\beta>0.95$) detect a true change in the mean on the order of 50%. In other words, if the 2005 sample mean has halved (relative to 1994-1995), we generally have greater than 95% chance of detecting that change using a two-tailed t-test, at the 12 sample level.

To reliably detect more subtle changes in the mean concentration would require many more samples at each tributary. The results of our power analyses are attached.

For reference, others have estimated the "half-life" of PCB in the Lower Fox River at between 5 and 13 years. If this number is truly 5 years, the sampling proposed here should detect those changes. If, however, the "half-life" is closer to 13 years, there is a slim chance (i.e. 15%-30%) that we will detect this change as statistically significant.

We did not apply this "Monte-Carlo" methodology to load calculations, due to time and budget constraints. We expect that applying Monte-Carlo techniques to the 1994-1995 calculations using the Beale Ratio Estimator will allow us to make retrospective statements regarding the accuracy and precision of load estimates made using 2005 data.

4.2. Proposed Field Sampling Options

Two field sampling options are presented in this section.

The first strategy, dubbed "minimalist," attempts to sample each of the four tribs on a scheduled basis, with several event samples thrown in. At this level of effort, there simply are not enough samples available to justify a more complicated sample stratification.

The second strategy, dubbed "mass balance revisited," is primarily included for comparison purposes.

While the LMMB sampling plan anticipated the calculation of loads with 95% confidence intervals of ± 25%, all should recognize that the 12-sample strategy will likely not yield load estimates of similar quality.

4.2.1. "Minimalist"

This option assumes that 12 samples are obtained and analyzed from each of the four tributaries considered here. Scheduled sampling in November 2005, January 2006, and monthly between March and October will yield 10 samples, with 2 samples remaining for "storm chasing" samples.

The Grand Calumet will be sampled monthly between March 2005 and February 2006, with no attempts at "storm chasing."

4.2.2. "Mass Balance Revisited"

This option would attempt to closely mimic the sample numbers and collection strategy built into the Lake Michigan Mass Balance. Samples would be allocated as follows:

- 36 samples at Grand River
- 26 samples at Fox River, Kalamazoo River
- 16 samples at Grand Calumet

In addition, as was the case with the 1994-1995 sampling, about 2/3 of samples will be earmarked for "high flow" event samples, while the remaining samples will be stratified between low flow and high flow as indicated in Table 1, below.

Table 1. Lake Michigan Mass Balance sample stratification scheme.

Tributary	Sample Volume	High Flow	Low Flow	Total	Frequency
Grand Calumet	80 liters	all samples scheduled		16	
Pere Marquette	80 liters	11	5	16	1/6.5 days
Muskegon	80 liters	18	8	16	1/4 days
Kalamazoo	80 liters	18	8	26	1/4 days
St. Joseph	80 liters	18	8	26	1/4 days
Grand	160 liters	24	12	36	1/3 days
Manistique	160 liters	18	8	16	1/4 days
Menominee	80 liters	18	8	26	1/4 days
Fox	80 liters	18	8	26	1/4 days
Milwaukee	80 liters	30	15	45	1/2.5 days
Sheboygan	80 liters	30	15	45	1/2.5 days

In Table 1, above, the "frequency" column specifies how often samples were to be taken once the high-flow threshold was reached. For example, when high-flow conditions were reached for the Menominee River, samples were to be taken at a rate of about one per four days in order to capture information over the course of the event. "High flow" was defined in the LMMB as any event that "exceeds the upper twentieth percentile of flow" based on historical flow records maintained by the USGS (U.S. EPA, 1997).

Regardless of which sampling option is ultimately selected, we assume that sample volumes for this project will be identical to those specified in Table 1.

4.3. Analytical Schedule

The analytical schedule for the “minimalist” option is given in the following table.

Analytical Costs:Fox, Grand, Grand Calumet, Kalamazoo River

Laboratory	Analyte	Method	Unit Cost	Total Cost	Number of Field Samples	Number of Field Duplicates	Number of Blank Samples	Total Number of Samples
WI State Lab of Hygiene	PCB CONGENERS IN SURFACE WATER - PREP	O1293P3	$405.00	$5,670.00	12	1	1	14
	PCB CONGENERS IN 80L SURFACE WATER - PARTICULATE	O1293E2	$324.00	$4,536.00	12	1	1	14
	PCB CONGENERS IN 80L SURFACE WATER - DISSOLVED	O1293E1	$324.00	$4,536.00	12	1	1	14
	AMMONIA-N (SM 4500-NH3H)	I440NLD	$23.00	$299.00	12	1	0	13
	NITRATE PLUS NITRITE-N	I460MLD	$23.00	$299.00	12	1	0	13
	TOTAL KJELDAHL NITROGEN	I470BLT	$24.15	$313.95	12	1	0	13
	TOTAL PHOSPHORUS	I520PLT	$17.25	$224.25	12	1	0	13
	ORTHOPHOSPHATE AS P, LOW RANGE	I530ALD	$28.75	$373.75	12	1	0	13
	TOTAL SOLIDS	I640FLT	$17.25	$224.25	12	1	0	13
	SUSPENDED SOLIDS	I650HLT	$21.85	$284.05	12	1	0	13
	VOLATILE SUSPENDED SOLIDS	I650HLT	$11.50	$149.50	12	1	0	13
USGS National Water Quality Lab	Organic Carbon, Dissolved, (DOC), Water, Filtered, GLASS FIBER, Sulfuric Acid Preserved	NWQL 2613	$31.14	$404.82	12	1	0	13
	Carbon, inorganic plus organic, suspended (Total Particulate Carbon (TPC))	NWQL 2606 / EPA440.0	$33.54	$436.02	12	1	0	13
USGS WI Mercury Lab	Total Mercury in water (WHOLE WATER)	WDML SOP001	$100.00	$1,400.00	12	1	1	14
	Methyl Mercury in water (WHOLE WATER)	WDML SOP004 + SOP005	$150.00	$2,100.00	12	1	1	14
	Total Mercury in water (FILTER - i.e. particulate fraction))	WDML SOP001	$100.00	$1,400.00	12	1	1	14
	Methyl Mercury in water (FILTER - i.e. particulate fraction)	WDML SOP004 + SOP005	$150.00	$2,100.00	12	1	1	14
			TOTAL:	***$24,750.59***				

References for several of the methods listed in the table above are included in the “references” section of this document.

The total analytical cost for the **“Minimalist”** option is **$99,000**. The analytical costs for each tributary is estimated at $24,750.

The analytical cost for the **“Mass Balance Revisited”** option is considerably higher: the Fox and Kalamazoo Rivers each would cost $49,730; the Grand would cost $67,575, and the Grand Cal would cost $31,888, for a total analytical budget of **$198,930**.

In order to avoid USGS overhead charges, Great Lakes Commission should plan on contracting directly with the Wisconsin State Laboratory of Hygiene to cover analysis costs.

4.4. Data Analysis and Load Computation

In addition to the field component of this work , there is additional work required to perform basic data validation, compute loads and estimate the bias and precision associated with the load estimates. The following tasks are proposed as part of this effort, to be completed by the USGS, Wisconsin District.

- Perform basic data validation
- Perform congener summation and other data reduction
- Calculate loads using the Beale Ratio Estimator for each tributary
- Conduct Monte-Carlo analysis of 1994-1995 data to assess the effect of smaller sample sizes on the resulting loading estimates
- Assume that precision and bias for the 2005 effort can be generated through Monte-Carlo analysis of the 1994-1995 data, using 10 scheduled samples + 2 “storm chasing” samples as the basis for subsetting the 1994-1995 data
- Compare 1994-1995 loads to 2005 loads

By “basic data validation,” we mean at most a “Tier 1” validation that might include the following activities:

- Review of the data package for completeness
- Review of chain of custody forms (against laboratory reported information) for signatures, sample condition upon receipt by the laboratory, and sample preservation
- Review of holding times
- Review of quality control (qc) summaries
- Review of blank results for possible field or laboratory contamination
- Random checks of raw data for interference problems or system control problems (e.g., baseline anomalies, baseline drifts, etc.)
- Review and summary of field duplicate results

4.5. In-kind and Other Activities

In addition to the activities discussed elsewhere in this proposal, numerous other activities will or are being performed by other agencies. We are assuming that the following tasks will be or are being completed:

- Incorporation of 2005 data into GLENDA (GLNPO)
- Ongoing trib monitoring (MI DEQ and GLNPO)
- Funding for additional PCB, Hg, Nutrients (GLNPO)
- Completion of 94/95 loads (Methyl Mercury) **(USGS, WI – Hall) (DONE)**

- Meet and discuss results with States (2 meetings about May 2006 and October 2006**) (GLC and EPA – Beck)**

4.6. Report

Wisconsin District USGS proposes to summarize all project analytical results, load estimates, and bias and precision estimates, in a brief USGS Scientific Investigations Report (SIR). This report will include:

- Basic data validation summary
- Summary statistics for all tributaries and all constituents
- Loading estimates for all tributaries and all constituents
- Monte-Carlo analysis of 1994-1995 loading estimates and the bias and precision involved in subsampling
- Comparisons of 1994-1995 concentration data with 2005 concentration data
- Comparisons of 1994-1995 loading estimates with 2005 loading estimates

5. Budget and Timeline

Subsections 5.1 and 5.2 present the Wisconsin District USGS costs and analytical costs associated with the two options considered. Subsection 5.3 includes rough cost estimates for all project elements, along with a timeline for proposed activities.

5.1. "Minimalist" Sampling Option

The table below summarizes the costs that would be incurred by the Wisconsin District USGS for field sampling, planning, data validation and analysis, and load calculation activities. The table also includes costs of analysis for the constituents of concern at each of the four tributaries. The table ***does not*** include costs associated with Michigan District USGS field and data analysis activities, nor does it include costs for other data management activities performed by the Great Lakes Commission or by the EPA Great Lakes National Program Office.

Category	Cost	Notes
Labor cost, Year 1 – FIELD	$22,000	Fox River – field effort only
Labor cost, Year 1 - PLANNING	$17,500	Costs involved in power analysis, load calculations for Mercury, review of previous workplans
Labor cost, Year 2	$60,000	Covers costs involved in basic data validation, summary statistic generation, load calculation, estimation of bias and precision, and report writing and publication
Analytical cost	$24,750	Fox River only

Category	Cost	Notes
Analytical cost	$74,250	Grand, Grand Calumet, and Kalamazoo Rivers
SUM:	***$198,500***	

5.2. *"Mass Balance Revisited" Sampling Option*

The table below summarizes the costs that would be incurred by the Wisconsin District USGS for field sampling, planning, data validation and analysis, and load calculation activities. The table also includes costs of analysis for the constituents of concern at each of the four tributaries. The table ***does not*** include costs associated with Michigan District USGS field and data analysis activities, nor does it include costs for other data management activities performed by the Great Lakes Commission or by the EPA Great Lakes National Program Office.

Category	Cost	Notes
Labor cost, Year 1 – FIELD	$39,000	Fox River – field effort only
Labor cost, Year 1 - PLANNING	$17,500	Costs involved in power analysis, load calculations for Mercury, review of previous workplans
Labor cost, Year 2	$60,000	Covers costs involved in basic data validation, summary statistic generation, load calculation, estimation of bias and precision, and report writing and publication
Analytical cost	$49,700	Fox River only
Analytical cost	$149,230	Grand, Grand Calumet, and Kalamazoo Rivers
SUM:	***$315,430***	

5.3. Summary of Schedule and Project Costs

The summary presented in the table below attempts to capture the estimated costs for all involved agencies, and shows the anticipated project timeline.

Task	Who Does	Who Pays	Costs	Qt 3 04	Qt 4 - 04	Qt1 - 05	Qt2 - 05	Qt3 - 05	Qt4 - 05	Qt1 - 06	Qt2 - 06	Qt3 - 06	Qt4 - 06	Qt1 - 07
Prioritize Constituents and Locations	LMMCC	LMMCC	In Kind ($7K)	X										
Run loads for Methyl Mercury	USGS	USGS	In Kind ($3K)	X										
Model sampling strategies	USGS	USGS	In Kind ($15K)		X									
Develop Final Proposal	LMMCC	LMMCC	In Kind ($3K)			X								
Develop QAPP	GLC	GLC	In Kind ($3K)			X								
Field Sampling	USGS	EPA/MDEQ/USGS	($30/50/20K)				X	X	X					
Lab Analyses	USGS/SLOH	EPA/MDEQ/USGS	($40/40/20K)					X	X	X				
Data Management	EPA/MDEQ	EPA/MDEQ	($5/5K)					X	X	X	X			
Data Interpretation	USGS	EPA/USGS	($24/14K)							X	X	X		
Interpretation Meetings	EPA/GLC/USGS	EPA/GLC/USGS	($6/2/2K)									X	X	
Reports	USGS	EPA/USGS	($14/6K)										X	X
			$10 K LMMCC											
			$119K EPA											
			$95K MDEQ											
			$80K USGS											
			$5K GLC											
			$309K Total											

6. References

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Regression: Fox River Particulate PCB ~ Air Temperature

Regression Summary
P TOTALS vs. Air_Temp

Count	43
Num. Missing	0
|R|	.576
R Squared	.331
Adjusted R Squared	.315
RMS Residual	20.390

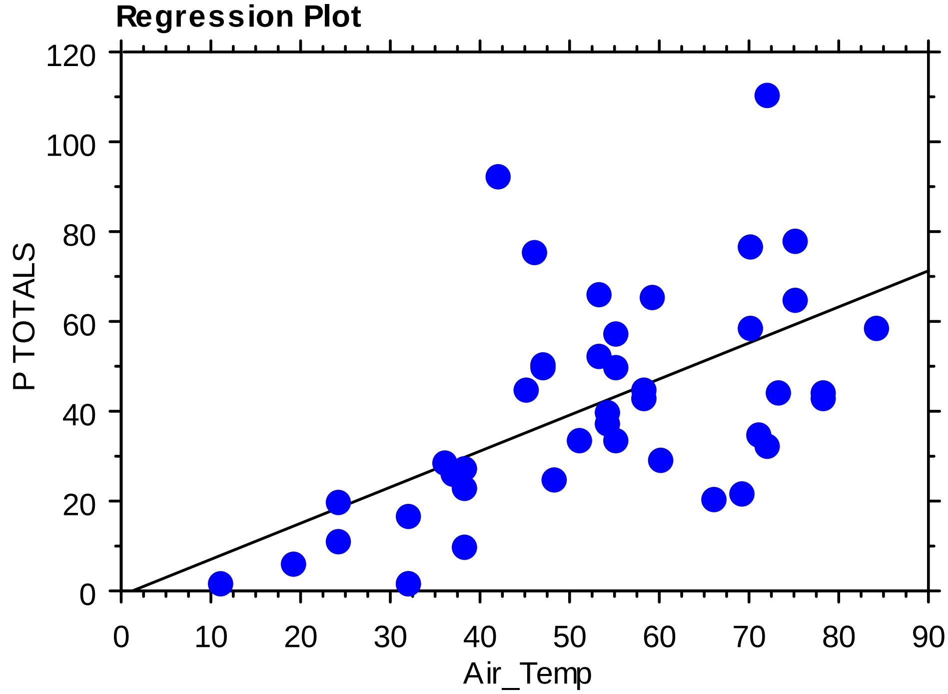
ANOVA Table
P TOTALS vs. Air_Temp

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	8444.787	8444.787	20.312	<.0001
Residual	41	17045.517	415.744		
Total	42	25490.304			

Regression Coefficients
P TOTALS vs. Air_Temp

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-.931	9.795	-.931	-.095	.9247
Air_Temp	.799	.177	.576	4.507	<.0001

Regression Plot



Y = -.931 + .799 * X; R^2 = .331

Regression: Fox River Dissolved PCB ~ Air Temperature

Regression Summary
D TOTALS vs. Air_Temp

Count	43
Num. Missing	0
|R|	.735
R Squared	.541
Adjusted R Squared	.529
RMS Residual	5.159

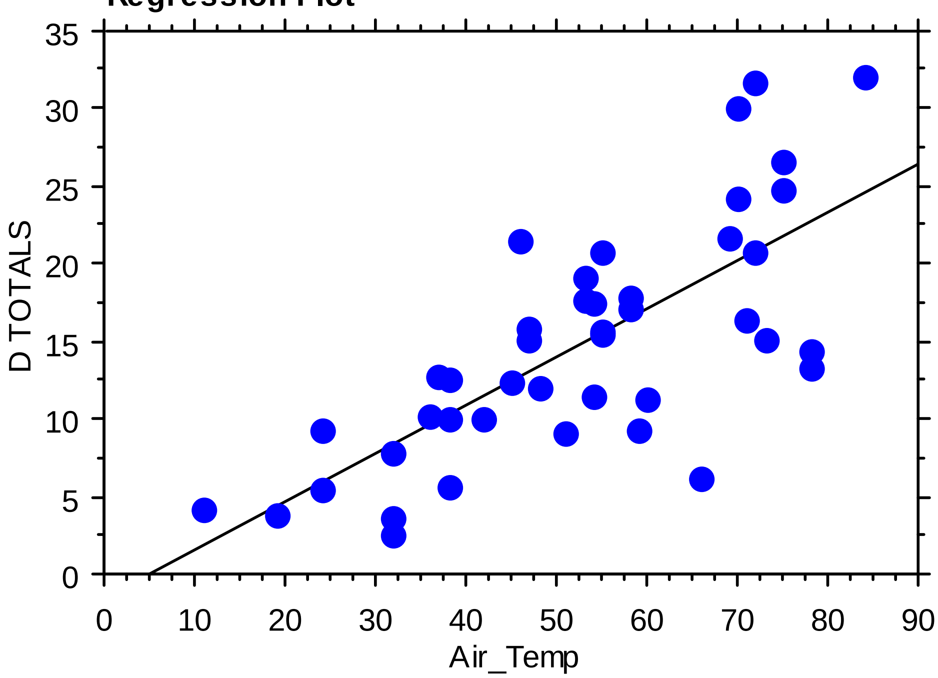
ANOVA Table
D TOTALS vs. Air_Temp

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	1284.233	1284.233	48.260	<.0001
Residual	41	1091.043	26.611		
Total	42	2375.276			

Regression Coefficients
D TOTALS vs. Air_Temp

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-1.555	2.478	-1.555	-.627	.5339
Air_Temp	.311	.045	.735	6.947	<.0001

Regression Plot



Y = -1.555 + .311 * X; R^2 = .541

Regression: Fox River Total PCB ~ Air Temperature

Regression Summary
TOTAL PCB ng/L vs. Air_Temp

Count	43
Num. Missing	0
|R|	.642
R Squared	.413
Adjusted R Squared	.398
RMS Residual	23.796

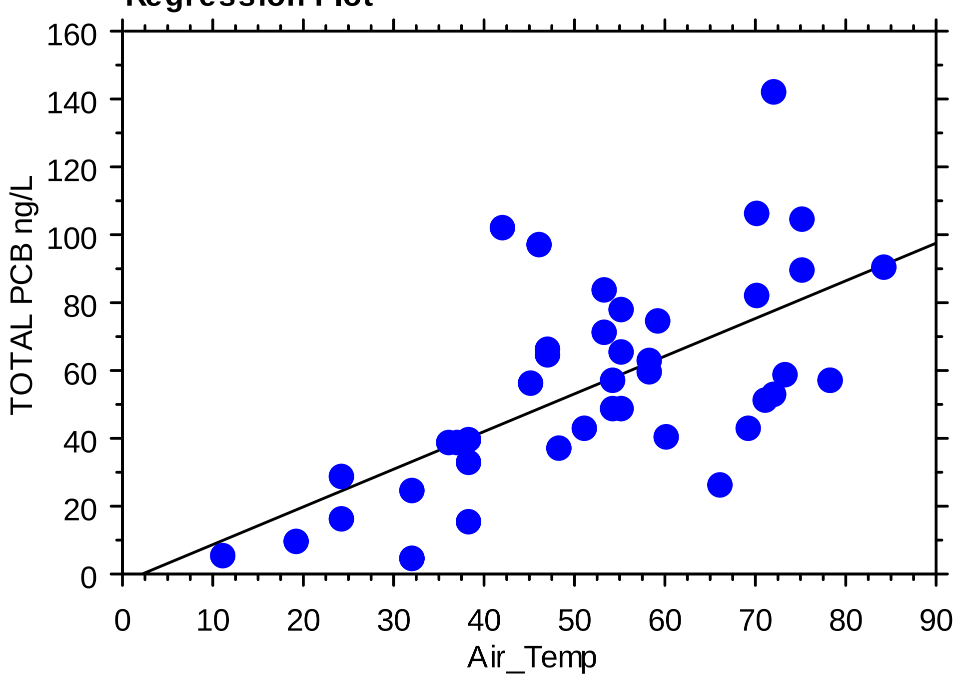
ANOVA Table
TOTAL PCB ng/L vs. Air_Temp

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	16315.393	16315.393	28.812	<.0001
Residual	41	23216.910	566.266		
Total	42	39532.303			

Regression Coefficients
TOTAL PCB ng/L vs. Air_Temp

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-2.486	11.431	-2.486	-.217	.8289
Air_Temp	1.110	.207	.642	5.368	<.0001

Regression Plot



Y = -2.486 + 1.11 * X; R^2 = .413

Regression: Fox River Total PCB ~ Discharge

Regression Summary
TOTAL PCB ng/L vs. Q

Count	43
Num. Missing	0
|R|	.041
R Squared	.002
Adjusted R Squared	•
RMS Residual	31.025

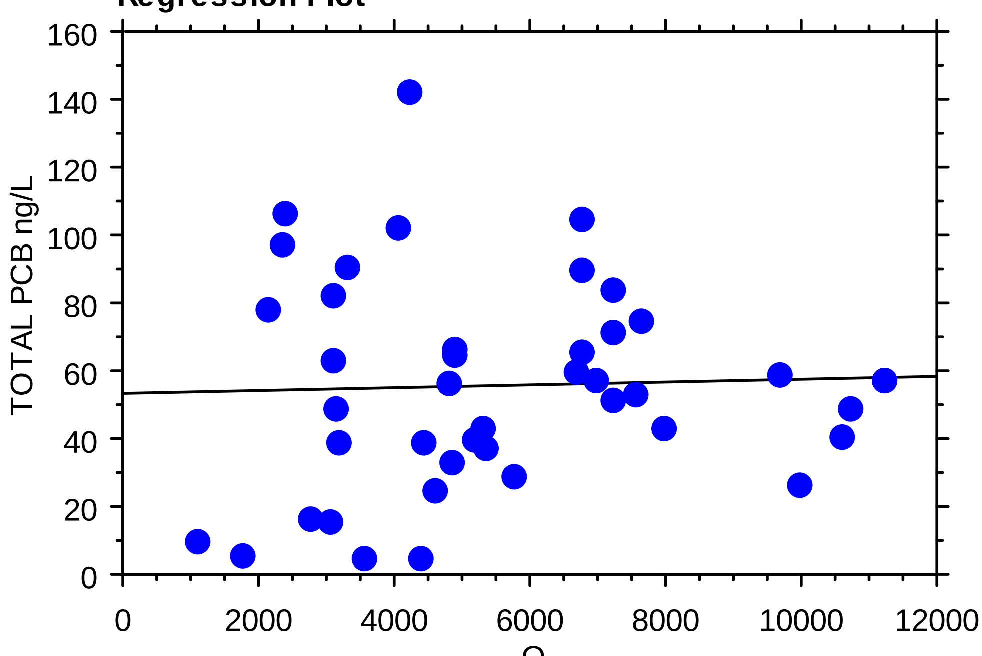
ANOVA Table
TOTAL PCB ng/L vs. Q

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	66.674	66.674	.069	.7937
Residual	41	39465.629	962.576		
Total	42	39532.303			

Regression Coefficients
TOTAL PCB ng/L vs. Q

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	53.094	10.965	53.094	4.842	<.0001
Q	4.676E-4	.002	.041	.263	.7937

Regression Plot



Y = 53.094 + 4.676E-4 * X; R^2 = .002

Multiple Regression: Total PCB ~ 5 Independents

Regression Summary
TOTAL PCB ng/L vs. 5 Independents

Count	43
Num. Missing	0
|R|	.745
R Squared	.555
Adjusted R Squared	.495
RMS Residual	21.811

ANOVA Table
TOTAL PCB ng/L vs. 5 Independents

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	5	21930.222	4386.044	9.220	<.0001
Residual	37	17602.081	475.732		
Total	42	39532.303			

Regression Coefficients
TOTAL PCB ng/L vs. 5 Independents

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-.573	11.679	-.573	-.049	.9612
Q	1.224E-5	.008	.001	.002	.9988
delQ	-.006	.004	-.214	-1.660	.1053
three_day	-.004	.009	-.328	-.465	.6444
Air_Temp	1.583	.270	.916	5.868	<.0001
Solar_Rad_Langley_day	-.017	.023	-.105	-.719	.4767

Correlation Matrix: 1994-1995 Fox River Water Column PCB

Correlation Coefficient
Hypothesized Correlation = 0

	Correlation	Count	Z-Value	P-Value	95% Lower	95% Upper
TOTAL PCB ng/L, Q	.041	43	.260	.7950	-.263	.337
TOTAL PCB ng/L, delQ	-.100	43	-.638	.5238	-.389	.206
TOTAL PCB ng/L, Solar_Rad_Langley_day	.342	43	2.257	.0240	.047	.583
TOTAL PCB ng/L, Air_Temp	.642	43	4.821	<.0001	.424	.790
TOTAL PCB ng/L, D TOTALS	.847	43	7.879	<.0001	.733	.915
TOTAL PCB ng/L, P TOTALS	.987	43	15.845	<.0001	.976	.993
TOTAL PCB ng/L, three_day	.058	43	.369	.7124	-.246	.352
TOTAL PCB ng/L, delQ3	-.074	43	-.468	.6397	-.366	.232
Q, delQ	.313	43	2.050	.0404	.014	.561
Q, Solar_Rad_Langley_day	.317	43	2.078	.0377	.019	.564
Q, Air_Temp	.507	43	3.530	.0004	.243	.700
Q, D TOTALS	-.035	43	-.223	.8235	-.332	.268
Q, P TOTALS	.062	43	.392	.6950	-.243	.356
Q, three_day	.986	43	15.671	<.0001	.974	.992
Q, delQ3	.477	43	3.284	.0010	.206	.680
delQ, Solar_Rad_Langley_day	-.144	43	-.918	.3586	-.426	.163
delQ, Air_Temp	.206	43	1.323	.1859	-.100	.477
delQ, D TOTALS	.031	43	.194	.8458	-.272	.328
delQ, P TOTALS	-.134	43	-.856	.3921	-.418	.173
delQ, three_day	.278	43	1.803	.0714	-.025	.533
delQ, delQ3	.314	43	2.057	.0397	.015	.562
Solar_Rad_Langley_day, Air_Temp	.563	43	4.026	<.0001	.316	.738
Solar_Rad_Langley_day, D TOTALS	.444	43	3.022	.0025	.166	.657
Solar_Rad_Langley_day, P TOTALS	.291	43	1.893	.0583	-.011	.544
Solar_Rad_Langley_day, three_day	.300	43	1.960	.0500	-2.238E-6	.551
Solar_Rad_Langley_day, delQ3	.217	43	1.394	.1634	-.089	.486
Air_Temp, D TOTALS	.735	43	5.946	<.0001	.558	.848
Air_Temp, P TOTALS	.576	43	4.148	<.0001	.333	.747
Air_Temp, three_day	.520	43	3.646	.0003	.260	.710
Air_Temp, delQ3	.133	43	.847	.3969	-.174	.417
D TOTALS, P TOTALS	.750	43	6.149	<.0001	.580	.857
D TOTALS, three_day	-.016	43	-.099	.9214	-.314	.286
D TOTALS, delQ3	-.118	43	-.749	.4541	-.404	.189
P TOTALS, three_day	.077	43	.490	.6244	-.228	.369
P TOTALS, delQ3	-.056	43	-.355	.7227	-.351	.249
three_day, delQ3	.324	43	2.125	.0336	.026	.569

Regression:
1994-1995 Grand River Water Column PCB ~ Discharge

Regression Summary
TOTAL PCBs ng/L vs. Flow

Count	53
Num. Missing	1
R	.117
R Squared	.014
Adjusted R Squared	•
RMS Residual	.730

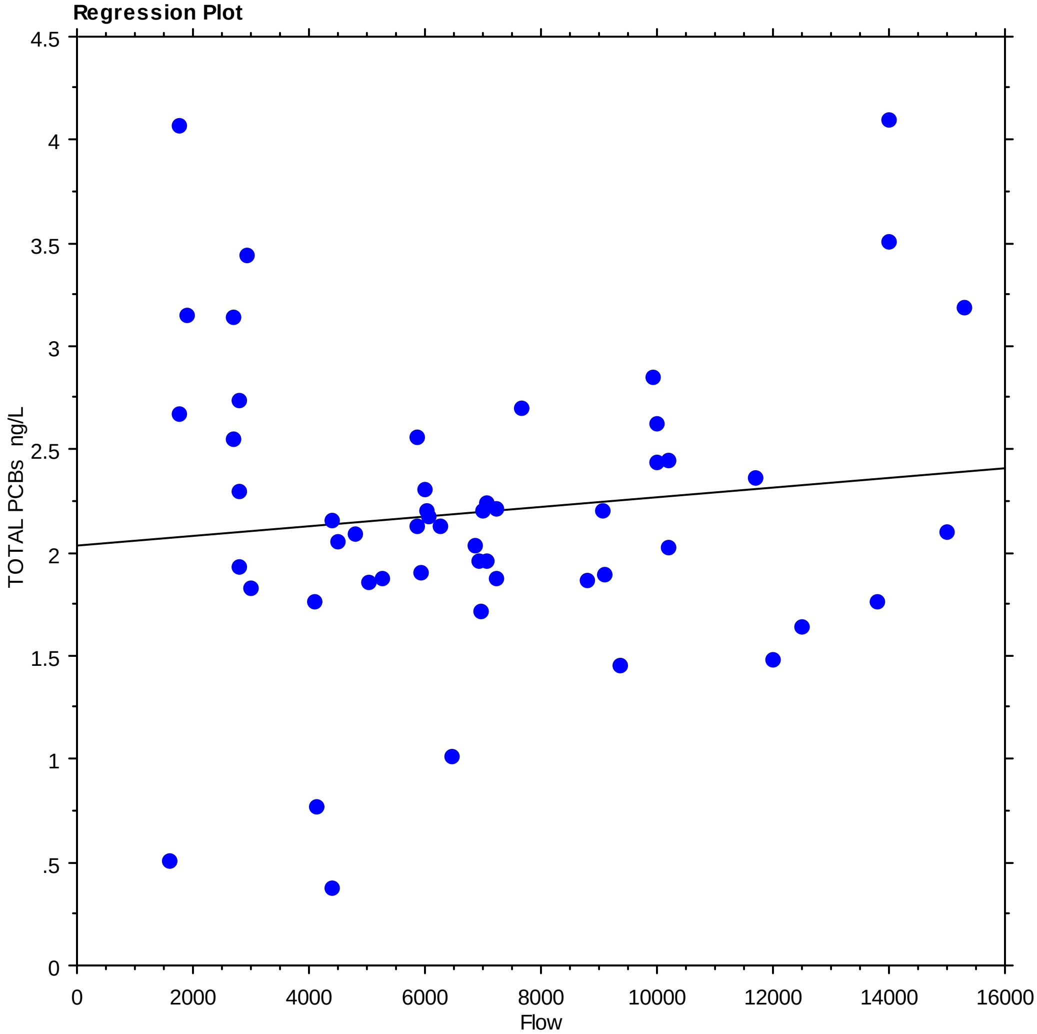
ANOVA Table
TOTAL PCBs ng/L vs. Flow

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	.374	.374	.702	.4060
Residual	51	27.202	.533		
Total	52	27.576			

Regression Coefficients
TOTAL PCBs ng/L vs. Flow

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2.037	.217	2.037	9.400	<.0001
Flow	2.300E-5	2.745E-5	.117	.838	.4060

Regression Plot



Y = 2.037 + 2.3E-5 * X; R^2 = .014

Regression:
1994-1995 Grand River Water Column PCB ~ Air Temperature

Regression Summary
TOTAL PCBs ng/L vs. Air_Temp

Count	54
Num. Missing	0
|R|	.277
R Squared	.077
Adjusted R Squared	.059
RMS Residual	.708

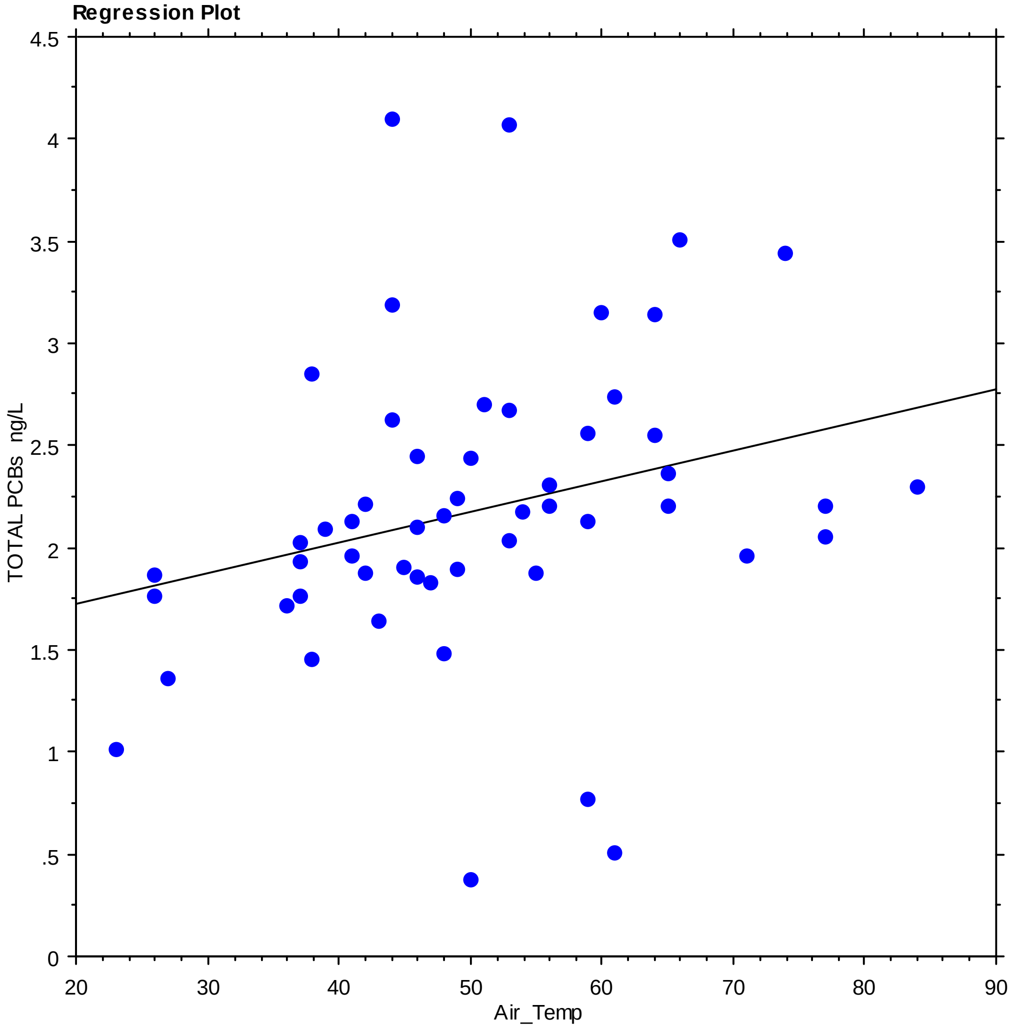
ANOVA Table
TOTAL PCBs ng/L vs. Air_Temp

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	2.169	2.169	4.322	.0426
Residual	52	26.096	.502		
Total	53	28.265			

Regression Coefficients
TOTAL PCBs ng/L vs. Air_Temp

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1.420	.379	1.420	3.743	.0005
Air_Temp	.015	.007	.277	2.079	.0426

Regression Plot



Y = 1.42 + .015 * X; R^2 = .077

Regression:
1994-1995 Grand Calumet River Water Column PCB ~ Discharge

Regression Summary
TOTAL PCBs ng/L vs. Discharge

Count	14
Num. Missing	2
R	.384
R Squared	.147
Adjusted R Squared	.076
RMS Residual	22.545

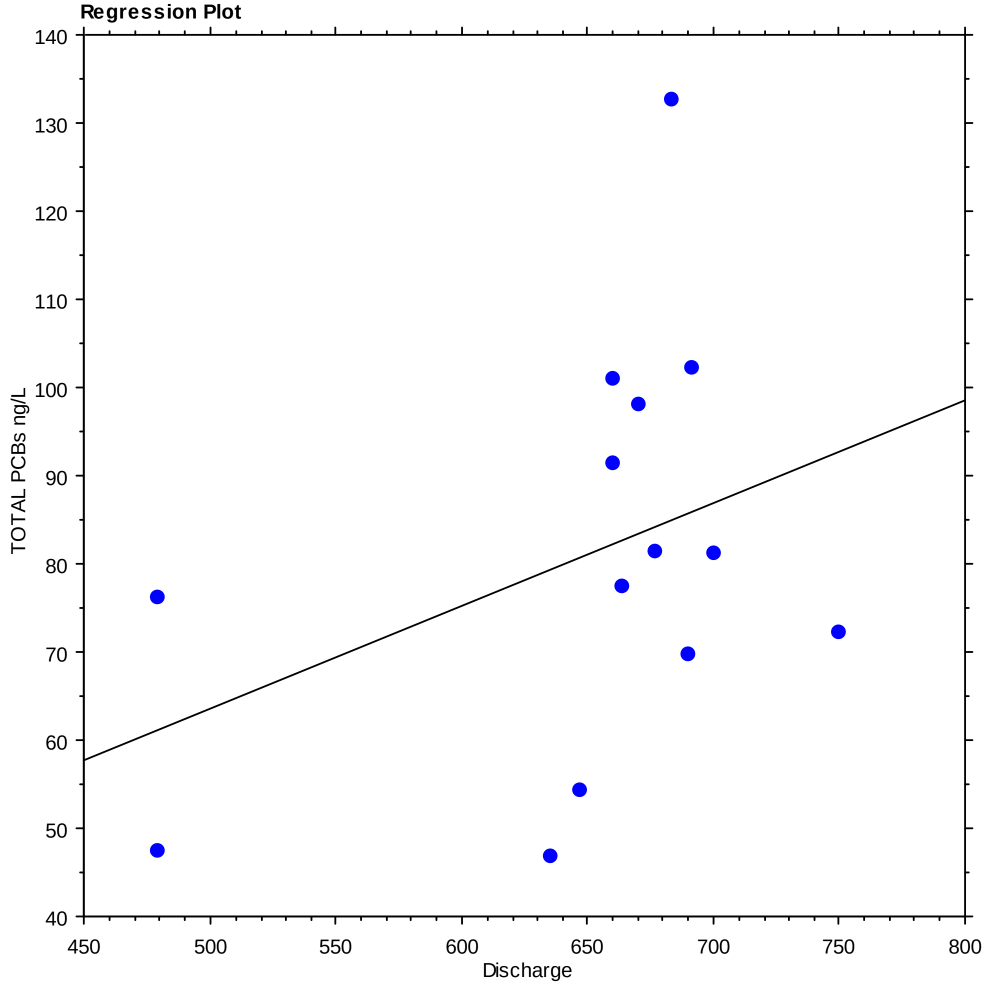
ANOVA Table
TOTAL PCBs ng/L vs. Discharge

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	1053.645	1053.645	2.073	.1755
Residual	12	6099.524	508.294		
Total	13	7153.169			

Regression Coefficients
TOTAL PCBs ng/L vs. Discharge

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	5.070	53.035	5.070	.096	.9254
Discharge	.117	.081	.384	1.440	.1755

Regression Plot



Y = 5.07 + .117 * X; R^2 = .147

Regression:
1994-1995 Grand Calumet River Water Column PCB ~ Air Temperature

Regression Summary
TOTAL PCBs ng/L vs. Air_Temp

Count	16
Num. Missing	0
|R|	.075
R Squared	.006
Adjusted R Squared	•
RMS Residual	24.660

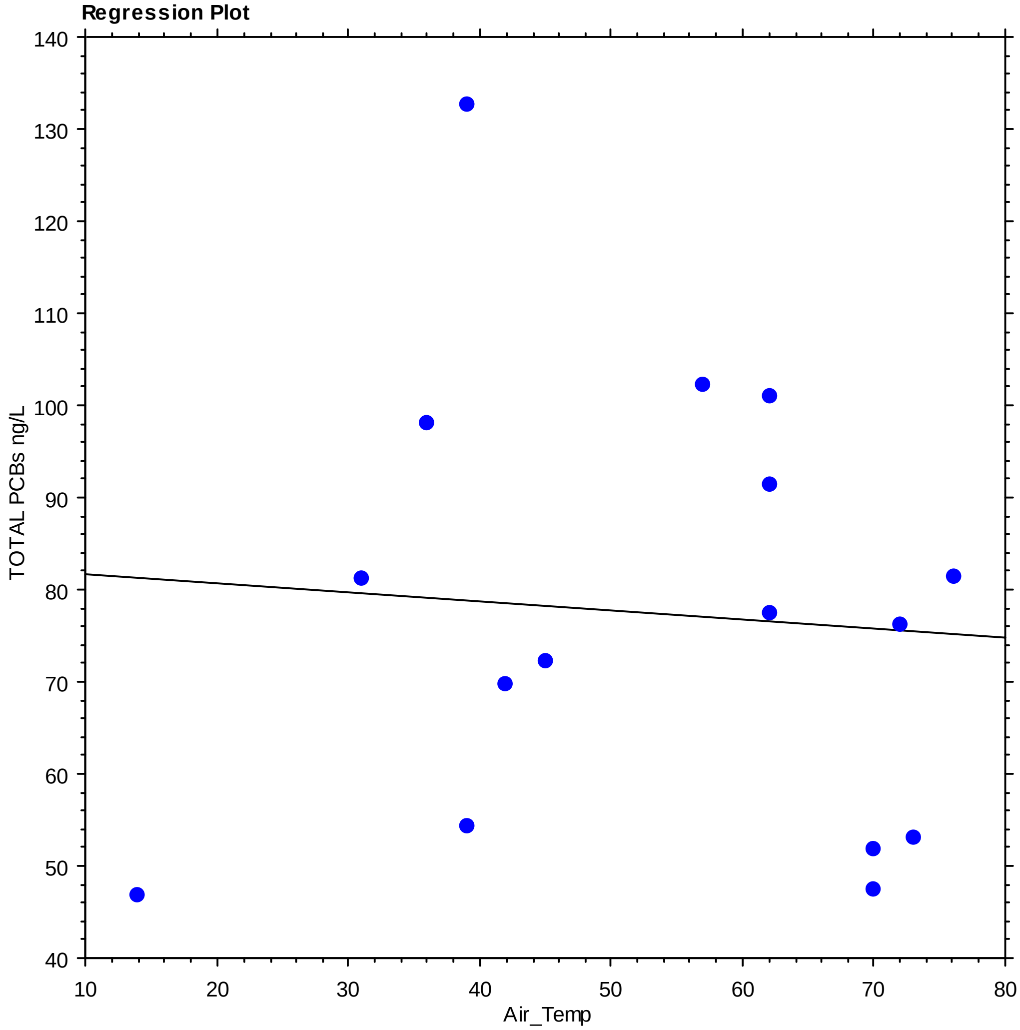
ANOVA Table
TOTAL PCBs ng/L vs. Air_Temp

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	48.803	48.803	.080	.7811
Residual	14	8513.555	608.111		
Total	15	8562.359			

Regression Coefficients
TOTAL PCBs ng/L vs. Air_Temp

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	82.637	19.530	82.637	4.231	.0008
Air_Temp	-.099	.349	-.075	-.283	.7811

Regression Plot



Y = 82.637 - .099 * X; R^2 = .006

Regression:
1994-1995 Kalamazoo River Water Column PCB ~ Discharge

Regression Summary
Total PCB (ng/L) vs. Discharge (cfs)

Count	40
Num. Missing	3
|R|	.472
R Squared	.223
Adjusted R Squared	.202
RMS Residual	8.977

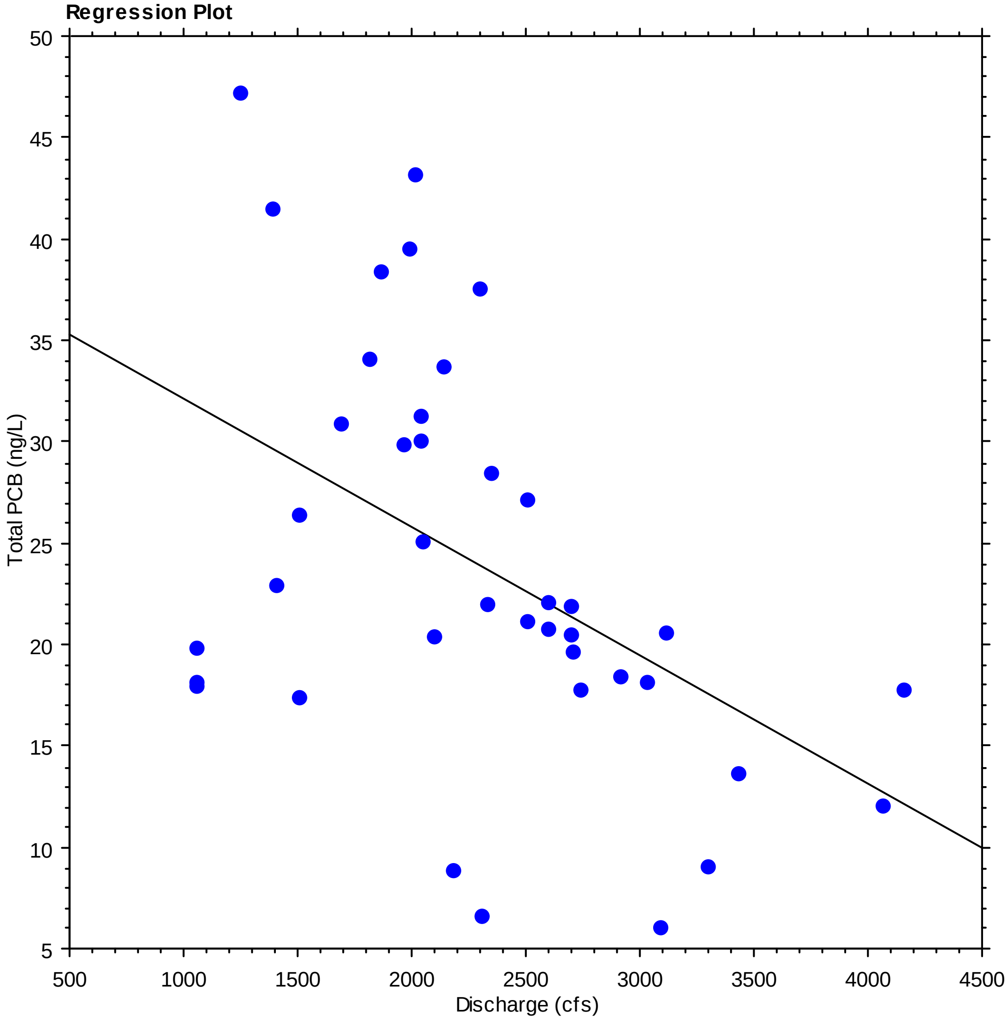
ANOVA Table
Total PCB (ng/L) vs. Discharge (cfs)

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	877.650	877.650	10.892	.0021
Residual	38	3062.000	80.579		
Total	39	3939.650			

Regression Coefficients
Total PCB (ng/L) vs. Discharge (cfs)

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	38.417	4.612	38.417	8.330	<.0001
Discharge (cfs)	-.006	.002	-.472	-3.300	.0021

Regression Plot



Y = 38.417 - .006 * X; R^2 = .223

Regression:
1994-1995 Kalamazoo River Water Column PCB ~ Air Temperature

Regression Summary
Total PCB (ng/L) vs. Air Temperature - South Bend

Count	40
Num. Missing	3
R	.593
R Squared	.352
Adjusted R Squared	.335
RMS Residual	8.197

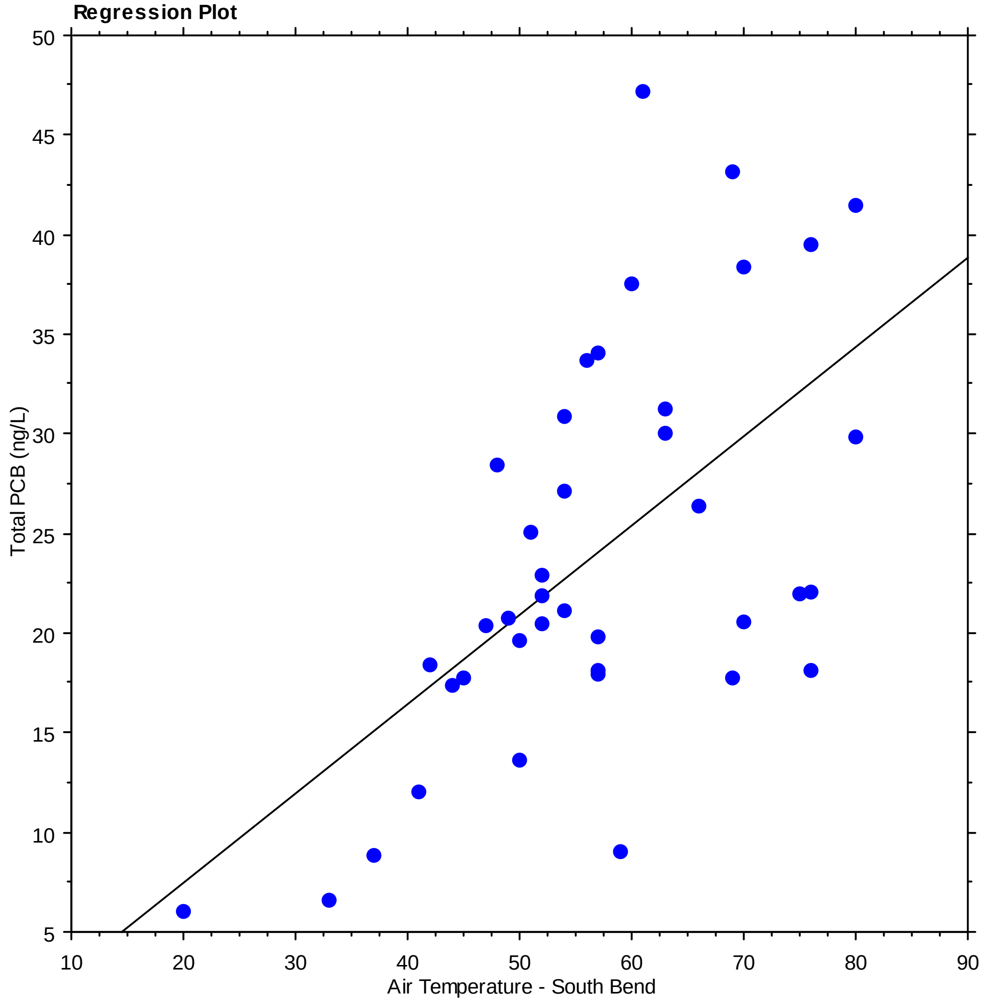
ANOVA Table
Total PCB (ng/L) vs. Air Temperature - South Bend

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	1386.133	1386.133	20.628	<.0001
Residual	38	2553.517	67.198		
Total	39	3939.650			

Regression Coefficients
Total PCB (ng/L) vs. Air Temperature - South Bend

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-1.537	5.756	-1.537	-.267	.7909
Air Temperature - South Bend	.448	.099	.593	4.542	<.0001

Regression Plot



Y = -1.537 + .448 * X; R^2 = .352

Kalamazoo River

	ALL	w/o WINTER
mean	23.51	24.80
stdev	10.29	9.54
CV	0.44	0.38

Monte-Carlo Simulation Results:
Percentage chance of correctly rejecting null hypothesis that 1994-1995 mean = 2005-2006 mean

Effect Size	Sample Size 3	6	9	12	15	18	21	24	27	30	33	36	39
0.1	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.3	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.4	93.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.5	72.8%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.6	48.4%	88.1%	97.4%	99.7%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.7	28.2%	51.3%	73.0%	83.4%	90.6%	94.5%	97.3%	97.4%	99.1%	99.3%	99.7%	99.7%	100.0%
0.8	16.9%	22.1%	29.6%	35.5%	41.7%	50.9%	53.6%	59.6%	62.7%	65.9%	67.8%	72.1%	73.3%
0.9	9.7%	7.6%	7.0%	9.9%	9.0%	7.9%	9.9%	9.8%	11.3%	11.4%	10.0%	11.8%	10.9%

effect mean	Δ/σ	n	n	n
2.35	2.06	4	5	2
4.70	1.83	5	6	3
7.05	1.60	6	8	4
9.41	1.37	9	12	5
11.76	1.14	12	17	7
14.11	0.91	19	26	11
16.46	0.69	34	46	19
18.81	0.46	77	104	43
21.16	0.23	307	415	173

Fox River

	ALL	w/o WINTER
mean	55.70	59.48
stdev	30.68	28.35
CV	0.55	0.48

Monte-Carlo Simulation Results:
Percentage chance of correctly rejecting null hypothesis that 1994-1995 mean = 2005-2006 mean

Effect Size	Sample Size 3	6	9	12	15	18	21	24	27	30	33	36	39
0.1	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.3	98.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.4	82.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.5	56.4%	92.8%	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.6	31.6%	63.2%	81.7%	93.0%	95.4%	98.6%	99.1%	99.8%	99.8%	99.8%	99.9%	99.9%	100.0%
0.7	17.4%	31.4%	44.9%	54.9%	63.9%	69.9%	77.0%	82.2%	83.0%	86.7%	89.8%	92.6%	91.7%
0.8	9.9%	13.2%	18.0%	20.4%	23.3%	26.0%	29.5%	31.1%	32.0%	31.8%	36.8%	38.1%	38.4%
0.9	7.1%	5.3%	6.9%	6.1%	6.4%	5.7%	6.5%	5.7%	5.3%	5.6%	4.7%	5.9%	4.2%

effect mean	Δ/σ	n	n	n
5.57	1.63	6	8	3
11.14	1.45	8	10	4
16.71	1.27	10	13	6
22.28	1.09	13	18	8
27.85	0.91	19	26	11
33.42	0.73	30	41	17
38.99	0.54	54	73	30
44.56	0.36	121	164	68
50.13	0.18	485	657	274

Grand Calumet River

Monte-Carlo Simulation Results:
Percentage chance of correctly rejecting null hypothesis that 1994-1995 mean = 2005-2006 mean

Effect Size	Sample Size 3	6	9	12	15	18	21	24	27	30	33	36	39
0.1	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.4	99.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.5	91.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.6	70.2%	97.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.7	39.4%	71.0%	86.8%	93.5%	96.7%	98.3%	99.6%	99.5%	99.9%	99.8%	100.0%	100.0%	100.0%
0.8	17.5%	28.0%	34.6%	40.8%	43.0%	50.6%	56.9%	58.3%	60.6%	63.8%	63.5%	69.9%	69.6%
0.9	7.9%	7.5%	6.7%	4.9%	5.3%	6.3%	5.0%	5.5%	3.8%	4.6%	3.7%	2.8%	4.2%

	ALL	w/o WINTER
mean	77.39	73.88
stdev	23.89	18.21
CV	0.31	0.25

effect mean	Δ/σ	n	n	n
7.74	2.92	2	3	1
15.48	2.59	2	3	1
23.22	2.27	3	4	2
30.95	1.94	4	6	2
38.69	1.62	6	8	3
46.43	1.30	10	13	5
54.17	0.97	17	23	10
61.91	0.65	38	52	21
69.65	0.32	153	206	86

Grand River

Monte-Carlo Simulation Results:
Percentage chance of correctly rejecting null hypothesis that 1994-1995 mean = 2005-2006 mean

Effect Size	Sample Size 3	6	9	12	15	18	21	24	27	30	33	36	39
0.1	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.4	98.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.5	87.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.6	67.4%	99.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.7	42.1%	87.7%	98.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.8	23.2%	51.5%	70.9%	83.0%	89.2%	95.3%	96.9%	98.7%	98.6%	99.4%	99.9%	100.0%	99.9%
0.9	12.2%	19.9%	24.7%	33.2%	37.5%	44.7%	47.8%	55.1%	58.0%	63.2%	66.4%	69.8%	71.5%

	ALL	w/o WINTER
mean	2.18	2.22
stdev	0.73	0.73
CV	0.33	0.33

effect mean	Δ/σ	n	n	n
0.22	2.74	2	3	1
0.44	2.44	3	4	2
0.67	2.13	4	5	2
0.89	1.83	5	6	3
1.11	1.52	7	9	4
1.33	1.22	11	15	6
1.55	0.91	19	26	11
1.78	0.61	43	58	24
2.00	0.30	172	233	97

KEY

"Rule of Thumb" sample size calculation. N=16/delta**2; alpha=0.05, beta = 0.2 (POWER=0.8)	eqn 2, http://www.epa.gov/owow/monitoring/tech/chap09.html, alpha=0.05, beta=0.05 (POWER=0.95), single-sided test	eqn 2, http://www.epa.gov/owow/monitoring/tech/chap09.html, alpha=0.1, beta=0.2 (POWER=0.8), single-sided test