The Impacts of Mercury Emissions from Coal Fired Power Plants on Local Deposition and Human Health Risk

Terry Sullivan

Brookhaven National Laboratory

Presented at the Pennsylvania Mercury Rule Workgroup Meeting

October 28, 2005

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Introduction

- Brookhaven has been working on looking at the impacts of mercury emissions from coal-fired power plants for over 10 years.
- Work includes deposition modeling, soil and vegetation sampling, and risk assessment.
- Today's focus is on measured soil concentrations near coal-fired power plants and impacts of reduction in releases on risk.

Hot Spots?

- March 15, 2005, EPA issued the Clean Air Mercury Rule (CAMR) that includes a cap-and-trade program.
- March 16, 2005 “Hot spots are a concern with me.” I advise anyone who eats fish caught in a lake or stream near a power plant that they are at risk, and this rule will do nothing to protect them – and might make things worse” John A. Paul co-chairman EPA advisory committee on mercury and Ohio regulator.
- May 18, 2005 “A cap-and-trade program for mercury further dilutes an already weak rule and create the risk of perpetuating dangerous mercury hotspots that threaten the health of our communities and children” Bradley M. Campbell, Commissioner New Jersey DEP.
- Lawsuit filed by 14 states and environmental group against the CAMR. Cite hot spots as a concern.

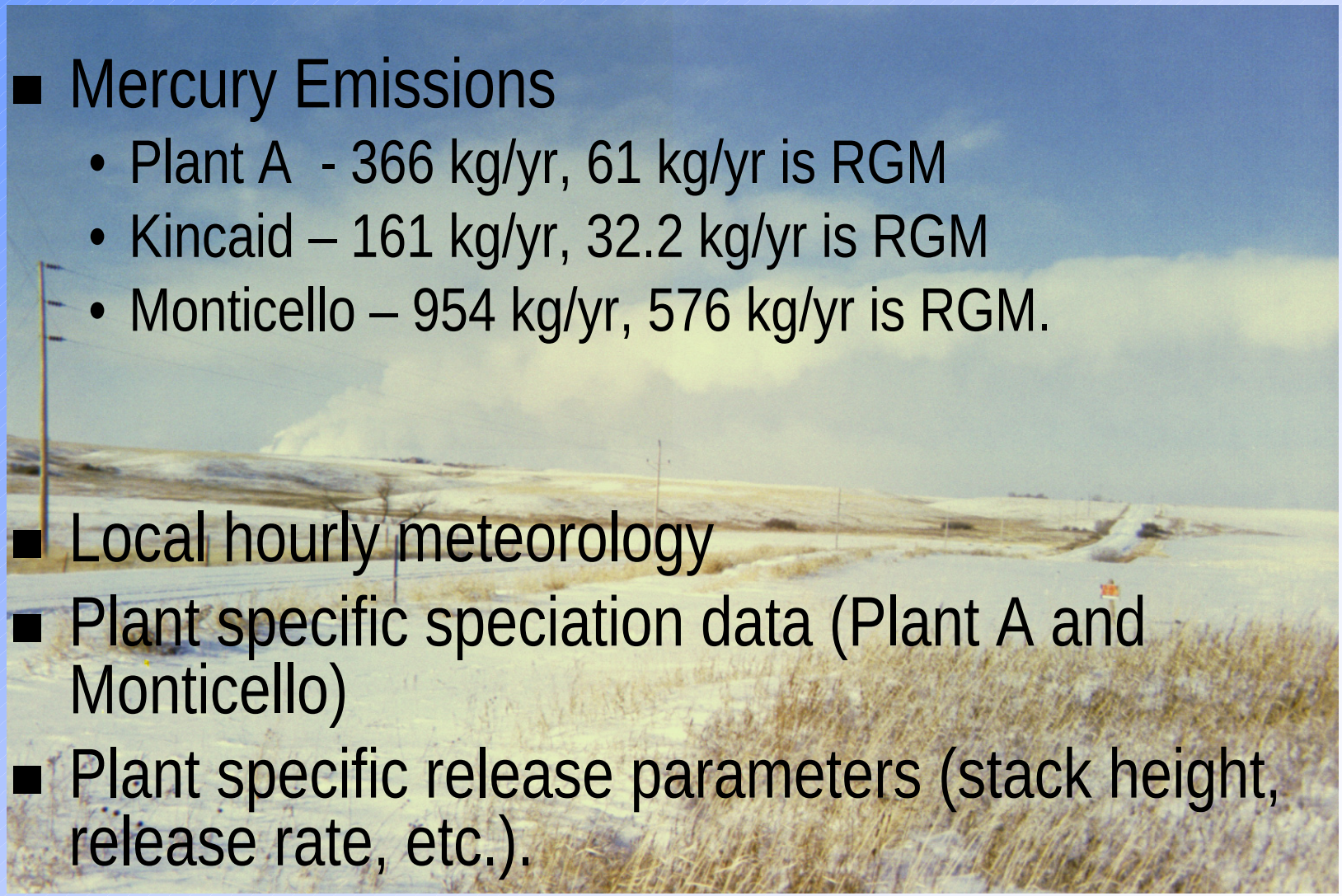
What is a hot spot?

- Spatially large region in which environmental concentrations far exceed expected values.
- Statistically, region with concentrations 2 to 3 standard deviations above the relevant mean.
- EPA – Utility hotspot is a water body with Methylmercury fish tissue concentrations greater than 0.3 mg/kg, attributable solely to the utility.

Do Coal Fired Power Plants Produce Mercury Hot Spots?

- This study examined soil and vegetation samples around 3 coal fired power plants looking for evidence of hot spots.
- Modeled mercury deposition arising from the plant and compared to measured concentrations.
- Hot spot defined as a region in excess of 5 km^2 in which concentrations are more than two standard deviations above the mean.

Deposition Modeling

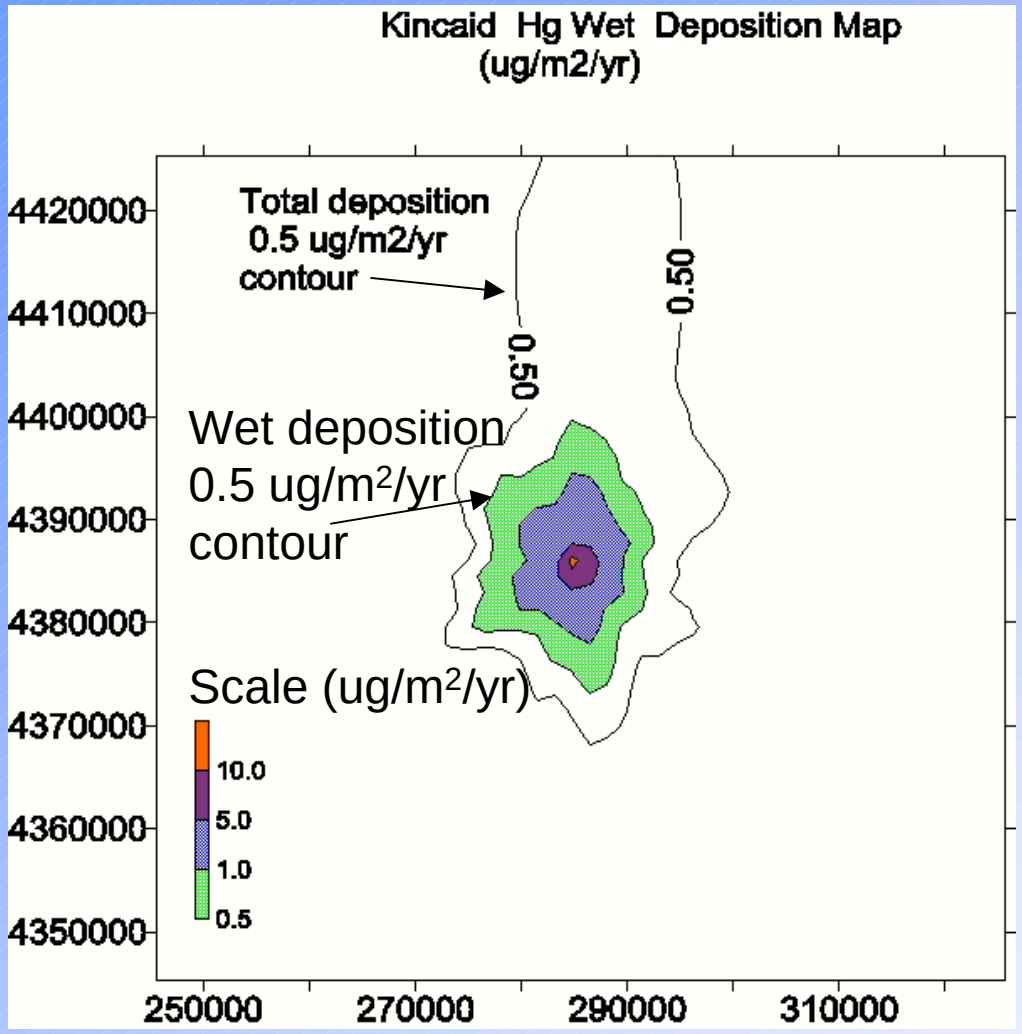


- Mercury Emissions
  - Plant A - 366 kg/yr, 61 kg/yr is RGM
  - Kincaid – 161 kg/yr, 32.2 kg/yr is RGM
  - Monticello – 954 kg/yr, 576 kg/yr is RGM.
- Local hourly meteorology
- Plant specific speciation data (Plant A and Monticello)
- Plant specific release parameters (stack height, release rate, etc.).

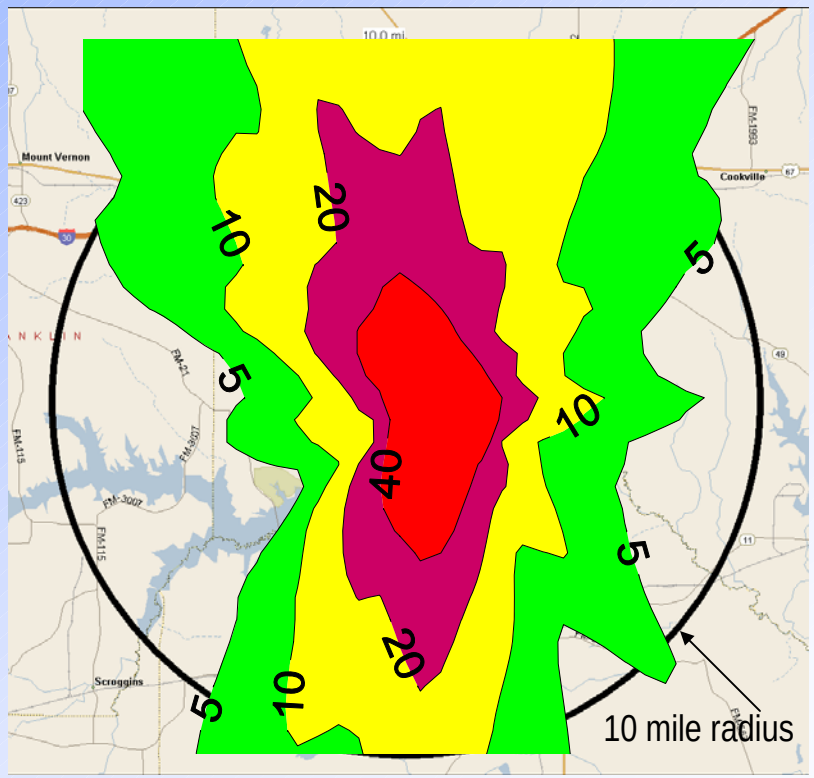
Deposition Modeling

- Wet deposition of RGM dominates.
- Predicted high deposition rates around the plant for several kilometers in the direction of wind flow during precipitation events.
- Dry deposition predicted to peak tens of kilometers from the plant but at rates much lower than wet deposition.

Modeled Excess Deposition due to coal fired power plant

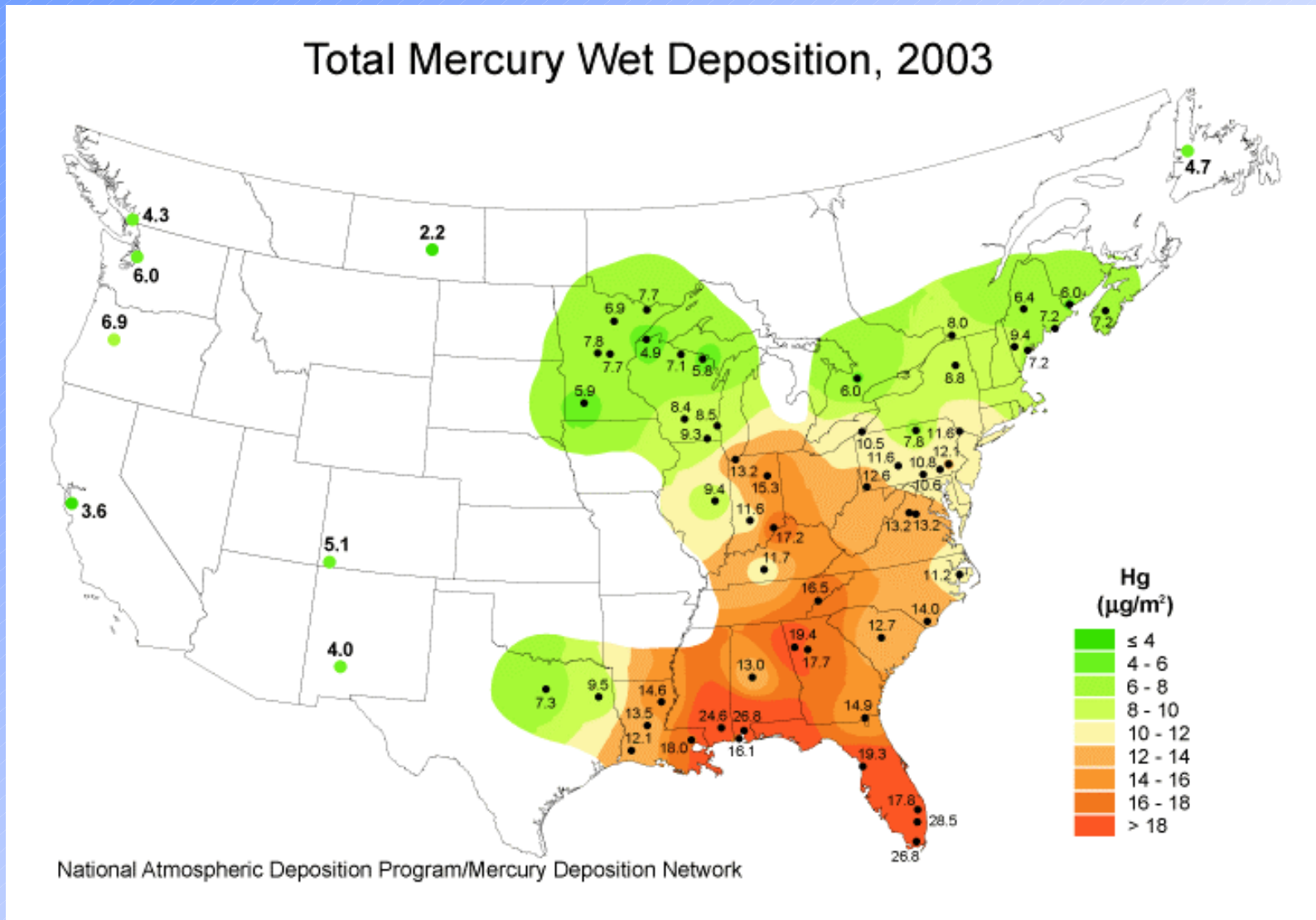


Kincaid Predicted Hg Deposition



Monticello Predicted Hg Deposition

Measured Wet Deposition of Mercury (ug/m^2/y)

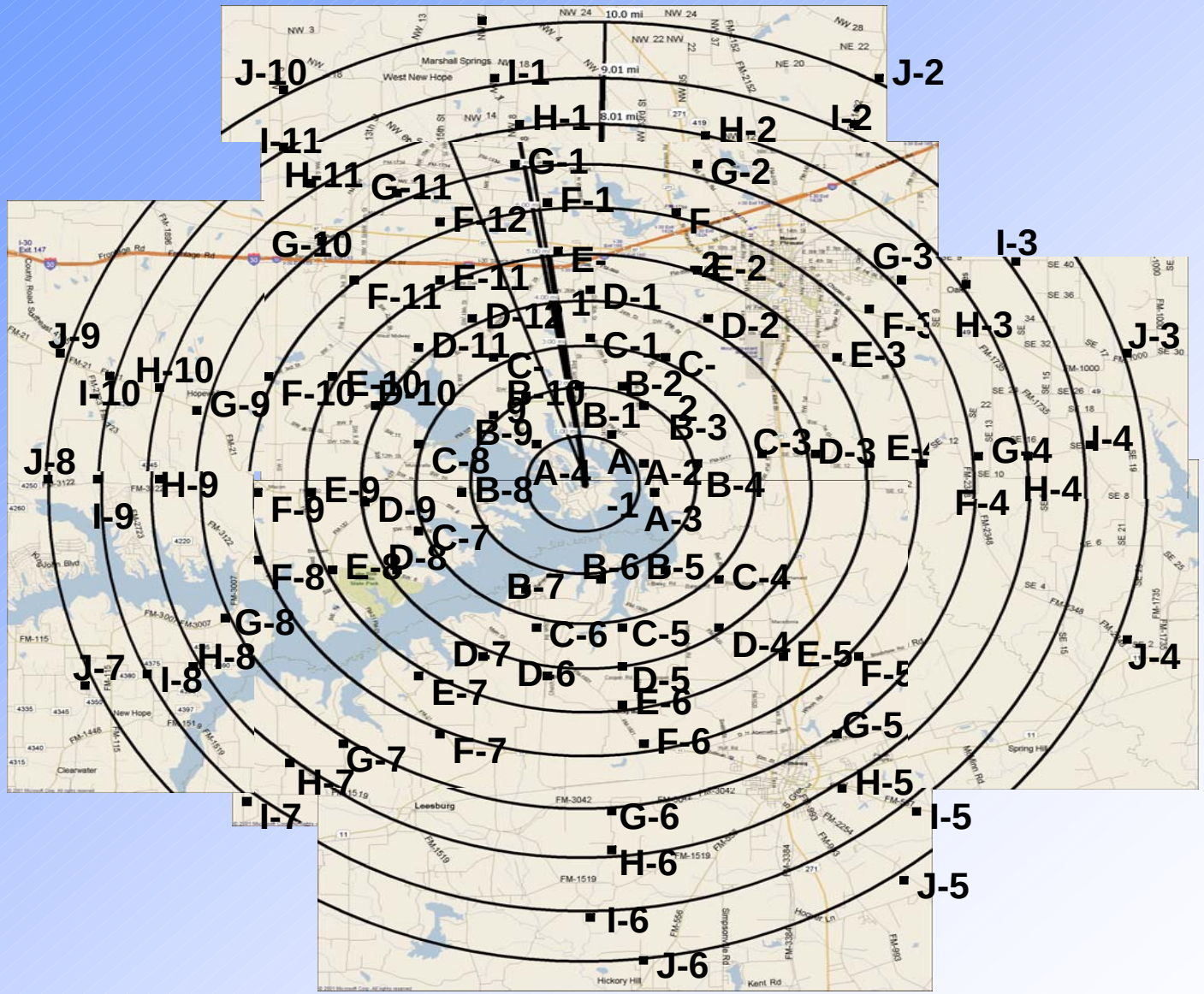


SAMPLING




- Sample area based on deposition modeling.
- 10% Blind Duplicates
- At each location
  - 3 surface samples,
  - 1 deep sample (5 – 10 cm)
  - 1 vegetation sample

Monticello Sample Design



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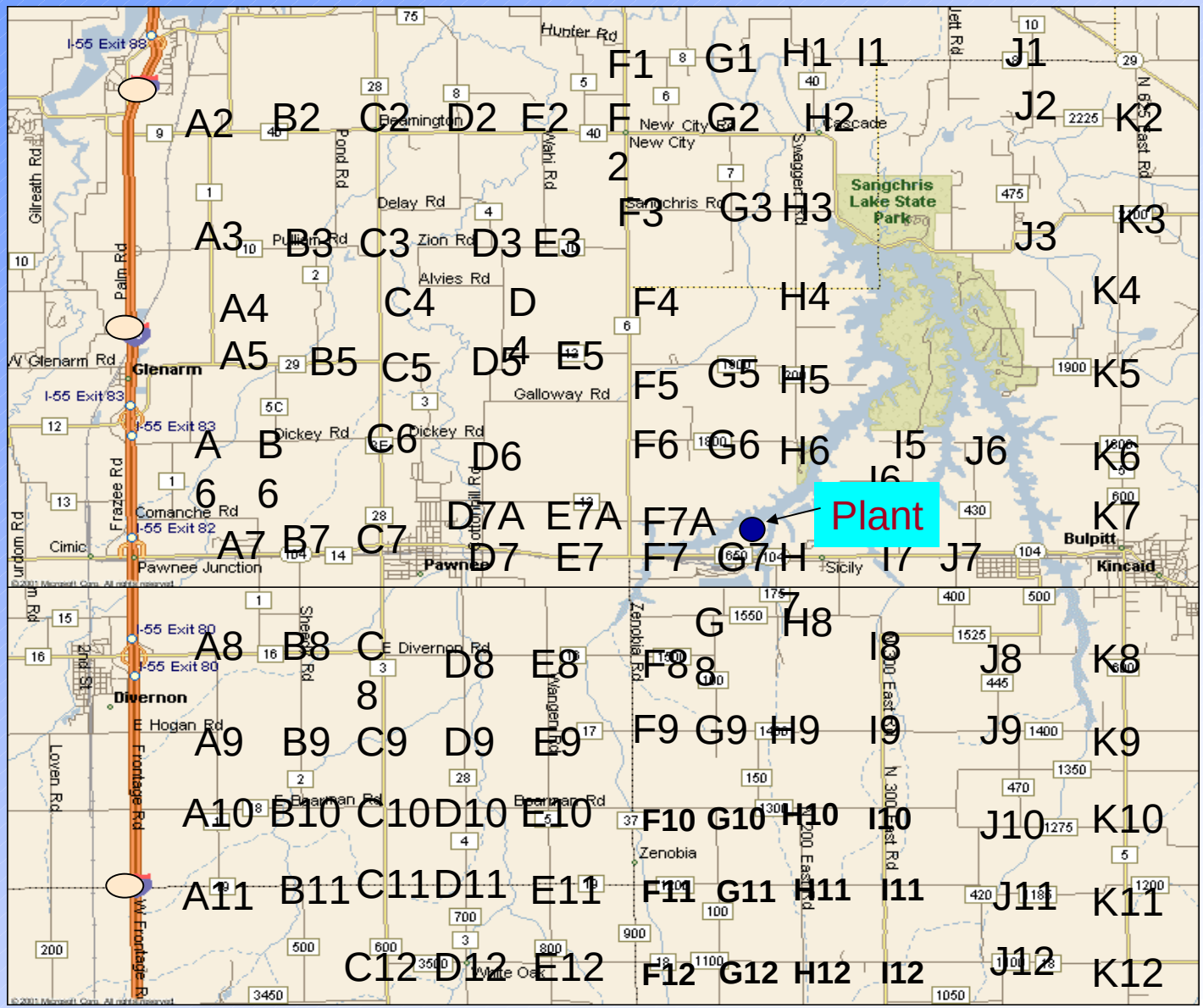
Kincaid Sampling Map



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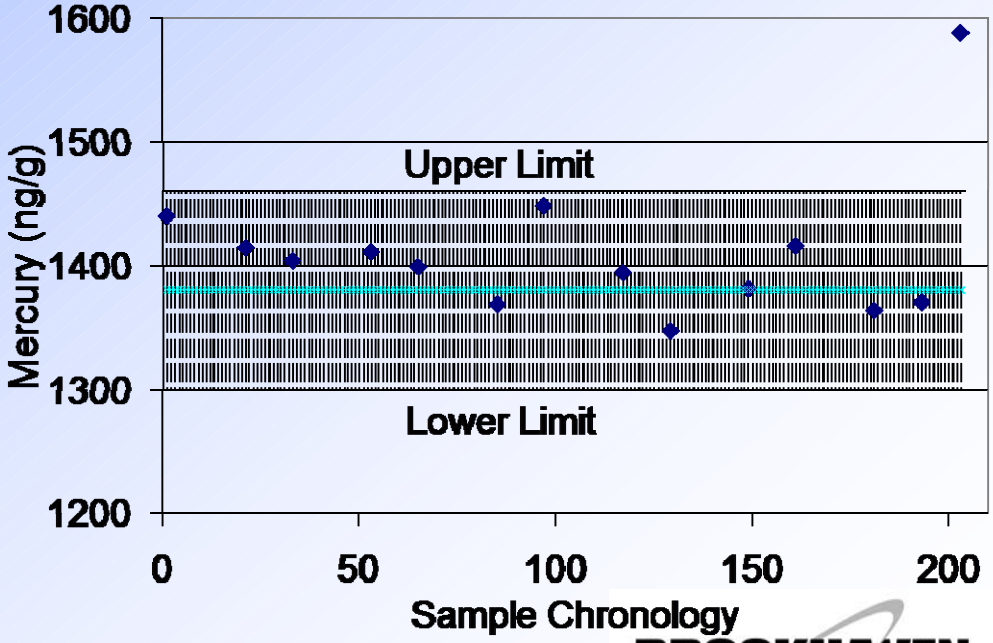
Sample Analysis and QA

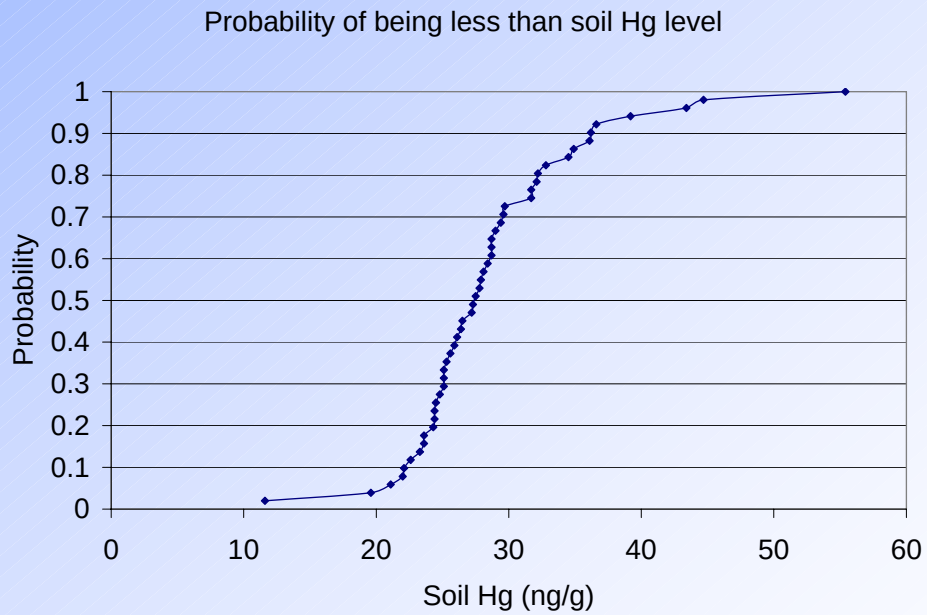
- Samples analyzed on Direct Mercury Analyzer (1 ppb MDL).
- All samples analyzed in triplicate
- 10% NIST standards
- 10% Blank
- 10% Blind dup.

San Joaquin Soil QA Tests



Data Results – Plant A

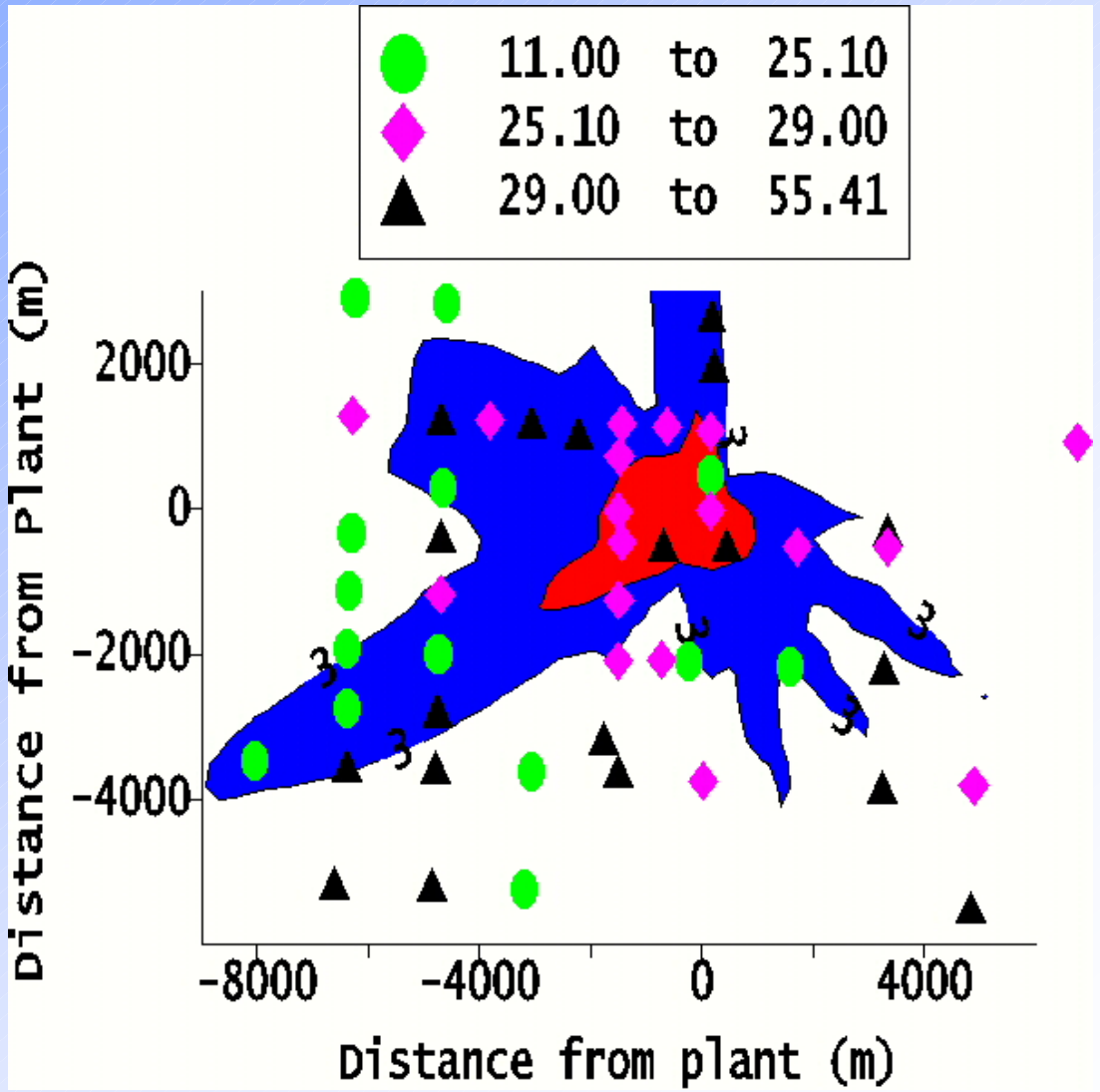
- 51 Sample Sites Average 28.7 ng/g
  - Median 27.4 ng/g
  - Standard Deviation – 7 ng/g
  - Maximum – 55 ng/g
  - Minimum – 11.6 ng/g



Data Results – Plant A

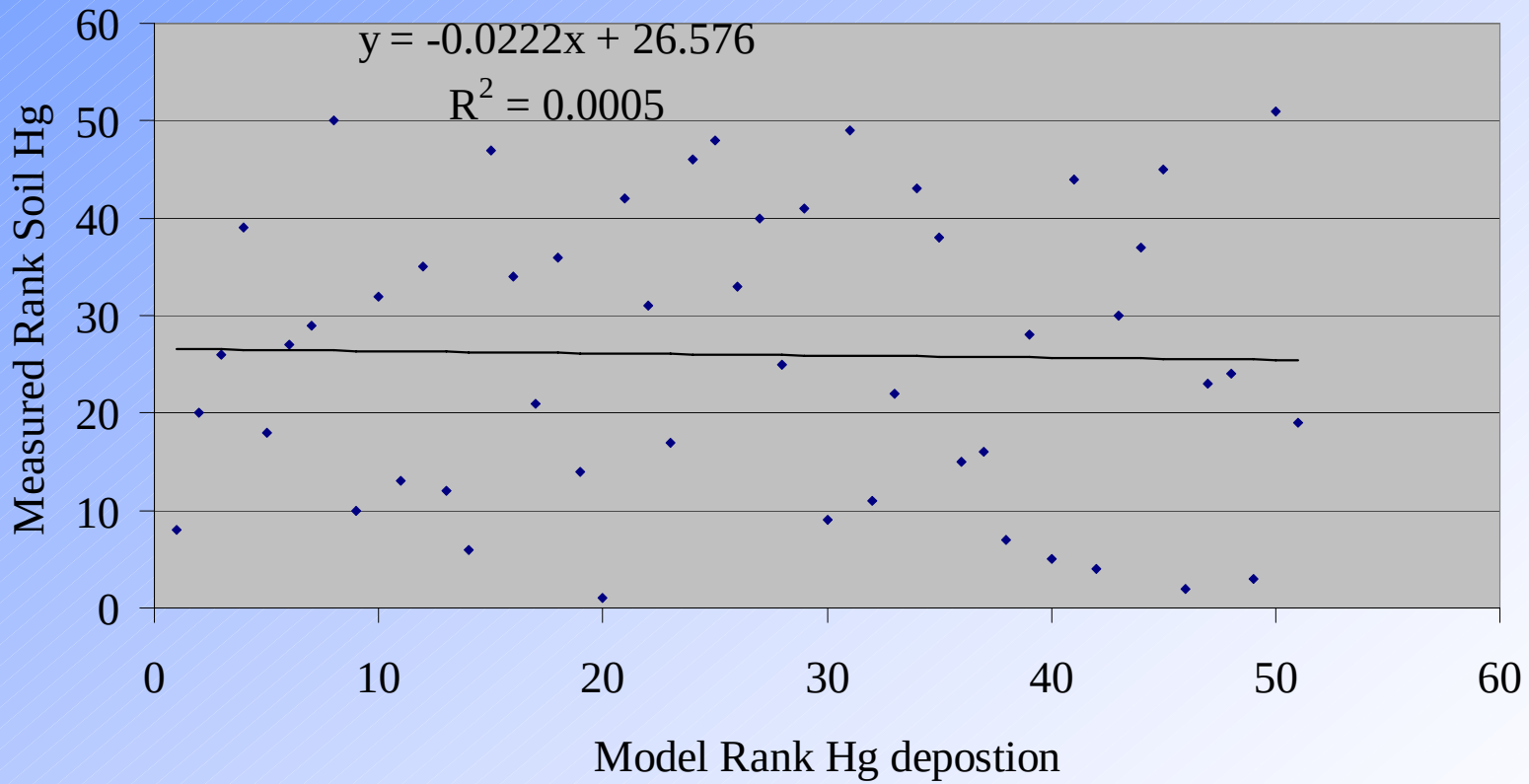
- No general agreement Between modeled deposition and soil Hg concentrations.

- Estimates of mercury deposition over this 8 km square region were less than 0.5% of total plant emissions.



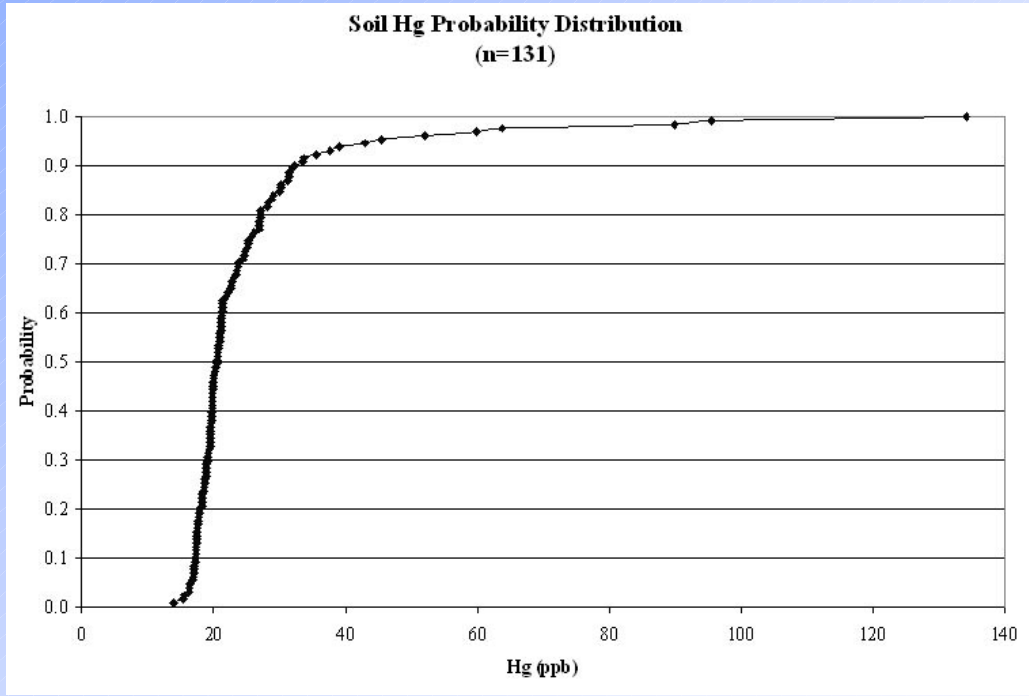
Data Results – Plant A

Rank Correlation between modeled deposition and measured soil data

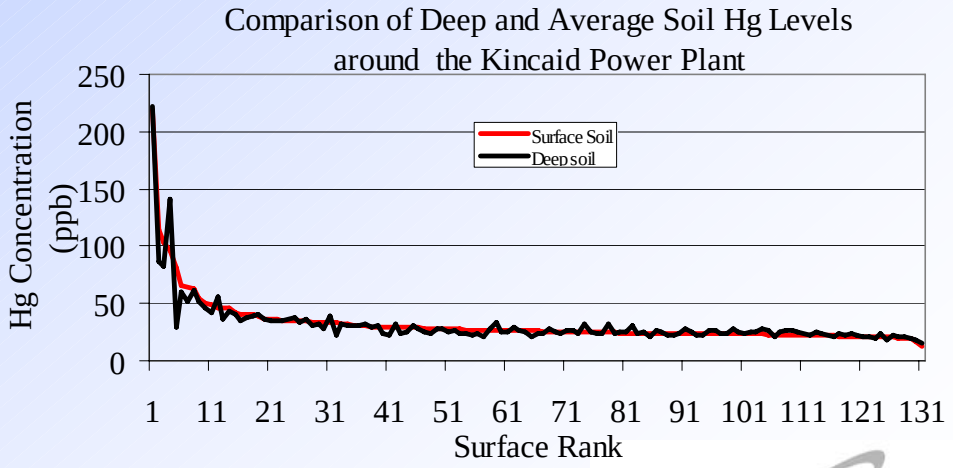


Data Results – Kincaid

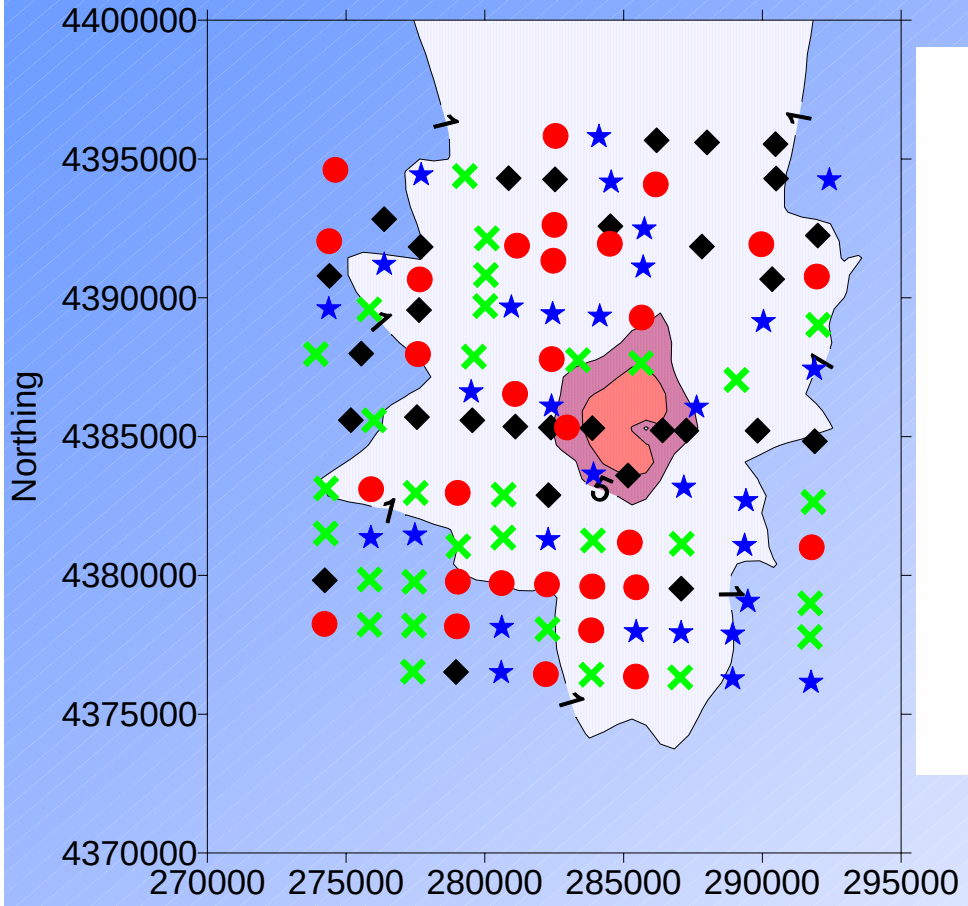
124 Sample Sites
Average 32 ng/g
Median 25.9 ng/g
Standard Deviation – 16.9 ng/g
Maximum – 155.6 ng/g
Minimum – 16.9 ng/g



Strong correlation between surface and deep samples. True at all three sites.

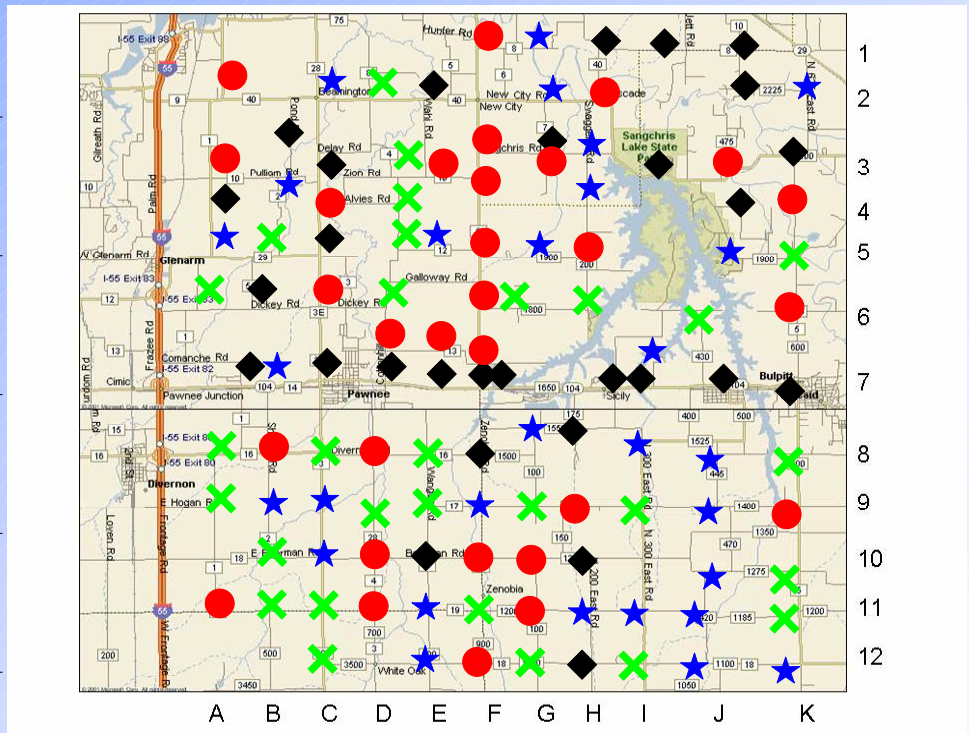


Data Results - Kincaid



Soil Hg Levels (ppb)

- 16.9 to 24.9
- 24.9 to 27.1
- 27.1 to 33.1
- 33.1 to 155.7



Soil Hg Levels (ppb)

- 16.9 to 24.6
- 24.6 to 27.0
- 27.0 to 31.3
- 31.3 to 65.2

No correlation with predicted deposition.
Correlation with busiest road.

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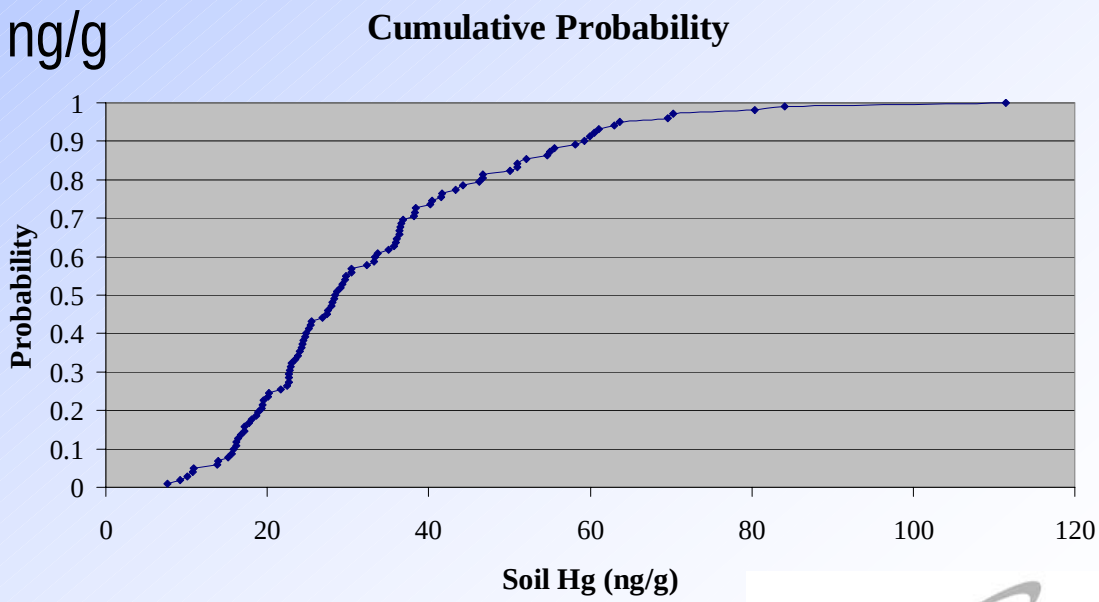
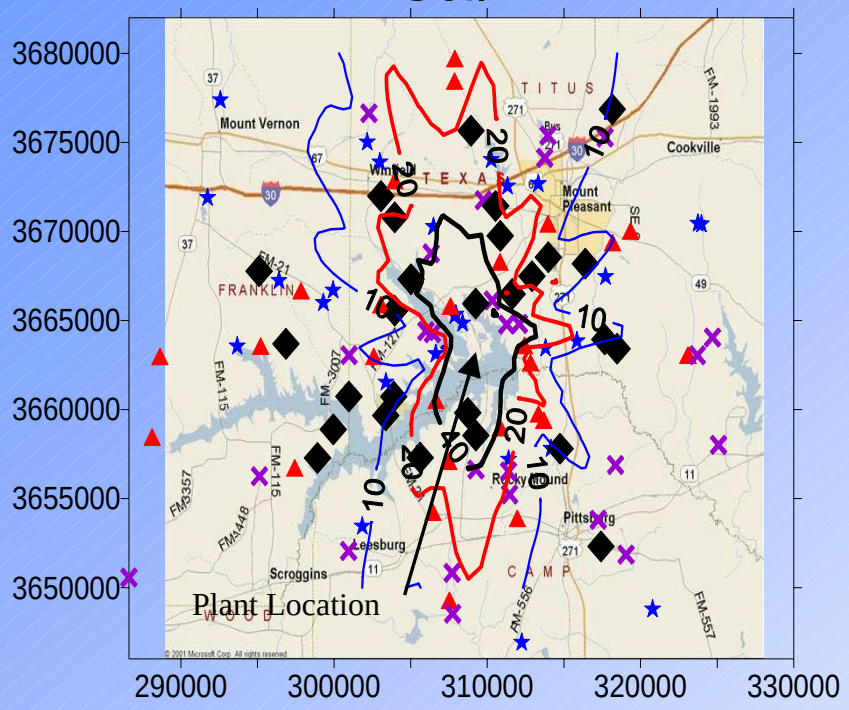
Data Results – Monticello

- 102 Sample Sites
- Average 33.5 ng/g
  - Median 28.5 ng/g
  - Standard Deviation – 18.0 ng/g
  - Maximum – 111.5 ng/g
  - Minimum – 7.6 ng/g

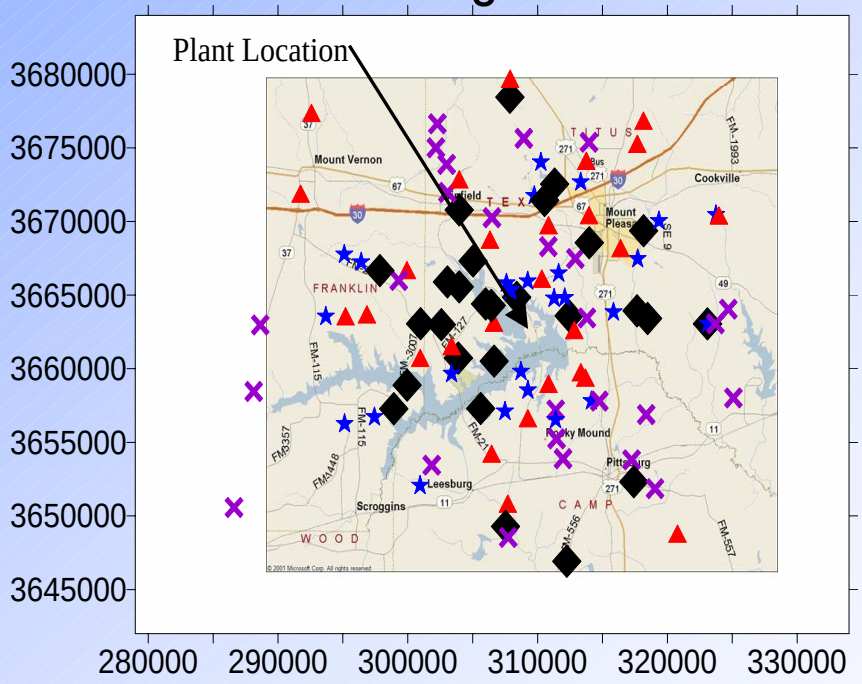


Monticello Results

Soil



Vegetation



Key to soil Hg (ng/g) data

- 7.60 to 21.70
- 21.70 to 28.40
- 28.40 to 40.40
- 40.40 to 111.50

Key: Vegetation Hg (ng/g)

- 1.76 to 10.88
- 10.88 to 19.06
- 19.06 to 27.13
- 27.13 to 184.40

Poor correlation with predicted deposition.

Correlation with soil characteristics.

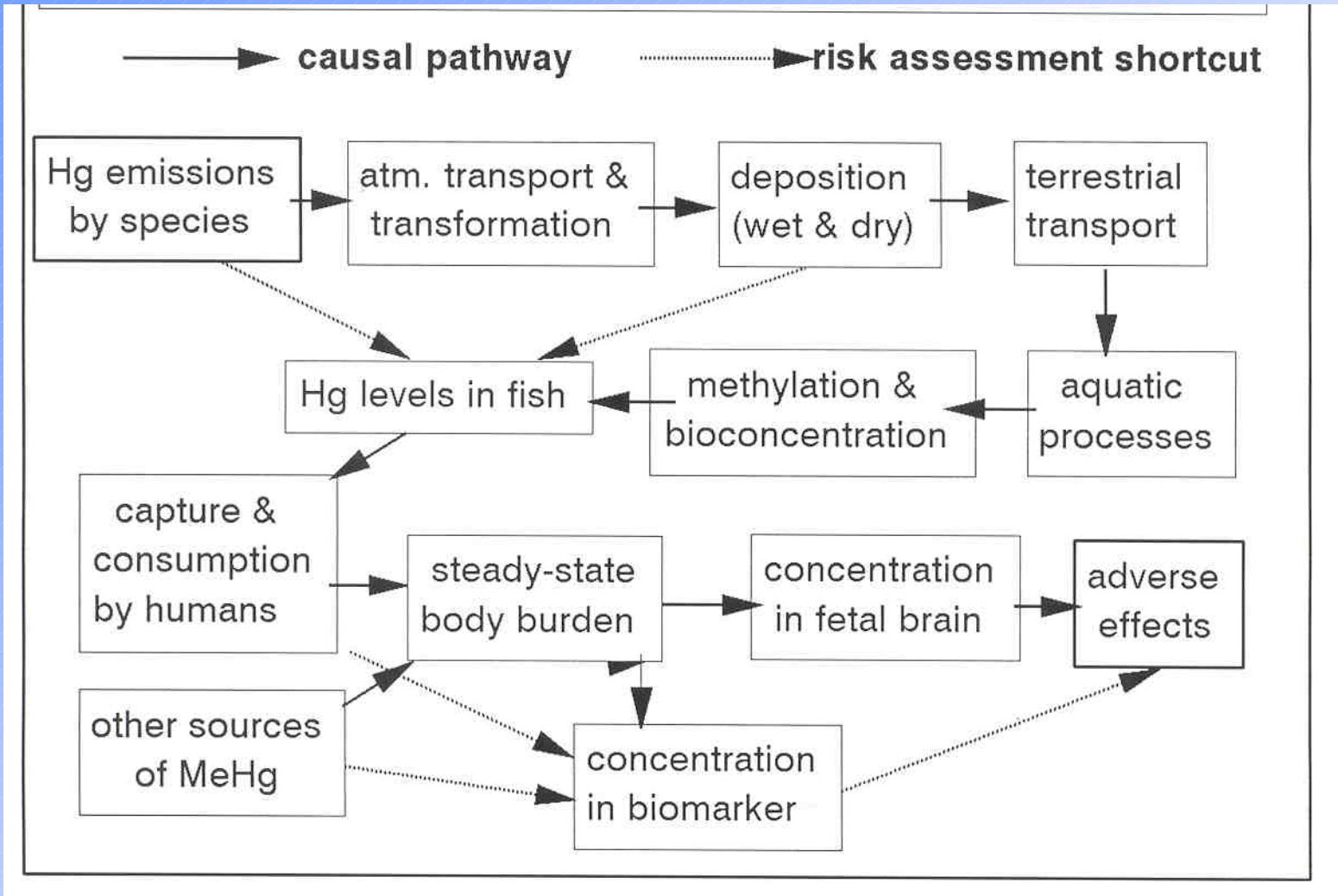
Summary

- At all 3 locations there was no correlation between predicted deposition and soil/vegetation concentrations.
- At all 3 locations there was a strong agreement between deep and surface soil samples.
- Averaging of Hg content at locations with high values (2 – 5 X average) with nearest neighbors had values within 15-20% of average.
- Estimated increases in soil concentration and modeled deposition rates suggest less than 2% depositing close to the plant.

Overview of Hg Risk Assessment

- EMISSIONS and DEPOSITION - Impacts of Coal Fired Power Plants
- EXPOSURE - Consumption of Fish, Levels of Hg in fish; Human biomarker levels.
- DOSE RESPONSE - Review epidemiological studies; Develop pooled Bench Mark Dose Limit.
- RISK ASSESSMENT – Population Risks and their detriments

Risk Assessment Flow Chart



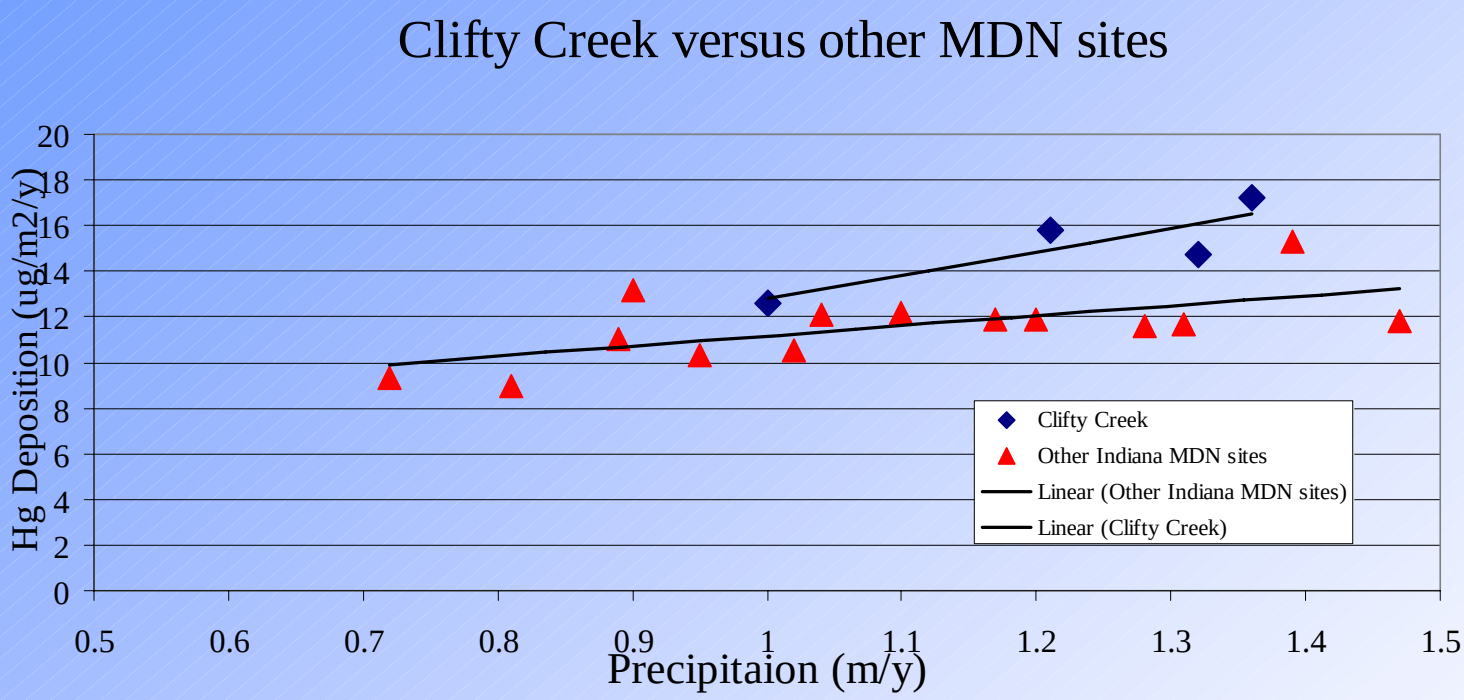
Potential Reduction in Hg Deposition from Coal Fired Power Plants

Reference	% Natural	% Global Anthropogenic	% U.S. Anthropogenic	Reduction in deposition for a 50% decrease in Hg emissions form coal	Reduction in deposition for a 90% decrease in Hg emissions form coal
EPRI	50	25	25	4.2%	7.5%
Minnesota	30	30	40	6.7%	12%
EPA	40		60	10%	18%
French, 1997 (EPA)				8.6%	15.5%

Local Effects on Hg Deposition

- EPA Report to Congress: Modeled % of deposition downwind from a large coal fired plant:
  - 52% at 2.5 Km
  - 17% at 10 Km
  - 7% at 25 Km

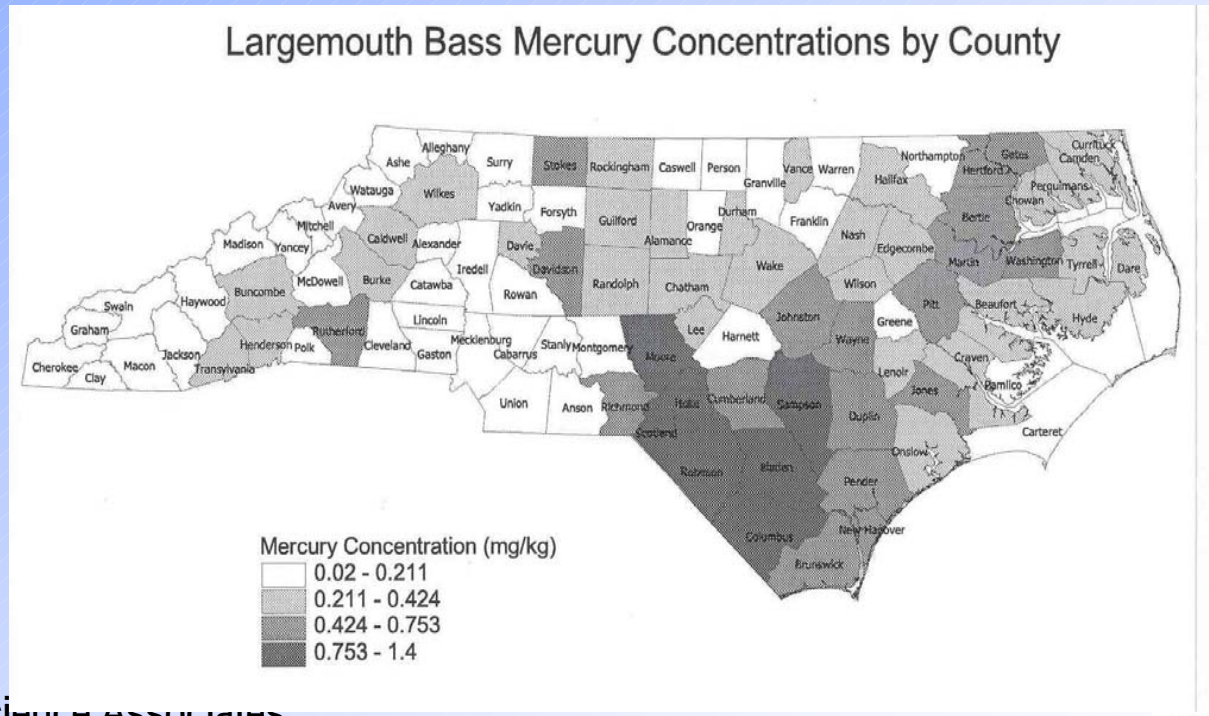
Clifty Creek MDN Station



Clifty Creek MDN station 3 km fro Clifty Creek Power Plant
4 Other Indiana stations spread throughout the state without a nearby Coal-fired power plant.

Link Between Hg Deposition and Hg in Fish

- No conclusive data at this time:
  - USGS study link to MeHg in water and fish MeHg.
  - METAALICUS (EPA, USGS, Canada) Study just started
  - Deposition Maps and Levels in Fish (North Carolina)



Hg in Fish and Consumption of Fish

- Substantial amount of data on Hg levels in fish
- Develop probability distributions for different fish in 3 target geographic regions
- Develop probability distributions for consumption of fish by different populations.
- Assume that freshwater fish mercury concentration is proportional to total mercury deposition from all sources.
- Link Hg consumption to dose response functions through Hair Hg.

Mercury Concentration in Fish by region

Region	Mean	Std Deviation
U.S. (all fish)	0.21	0.15
Great Lakes/Ohio Valley Sport fish	0.18	0.33
Northeast	0.39	0.82
Southeast	0.53	0.47

Link Between Consumption and Exposure

- Develop Distributions of Hg in sport fish
- Define exposed populations (women of child bearing age)
- Define fish consumption patterns for selected populations. Link to fish species.
- Generate probability distribution functions (PDF) for Hg exposure for each exposed population. (Current conditions, assumed conditions after reduction of coal emissions)
- Link consumption of fish containing mercury to biomarkers (Hg in hair or blood). Use dose response as a function of biomarkers to estimate risk.

Benchmark Dose (BMD) (CHILDREN)

- BMD is the estimated dose corresponding to a specified incremental risk over and above background.
- EPA specified the risk increment to be 5%.
- BMD is based on regression analysis of dose-response and takes into account the full range of data, not just the low end. This is the advantage of the BMD over the NOAEL.

Bench-Mark Dose Estimates from NAS Study (values in Hair Hg ppm)

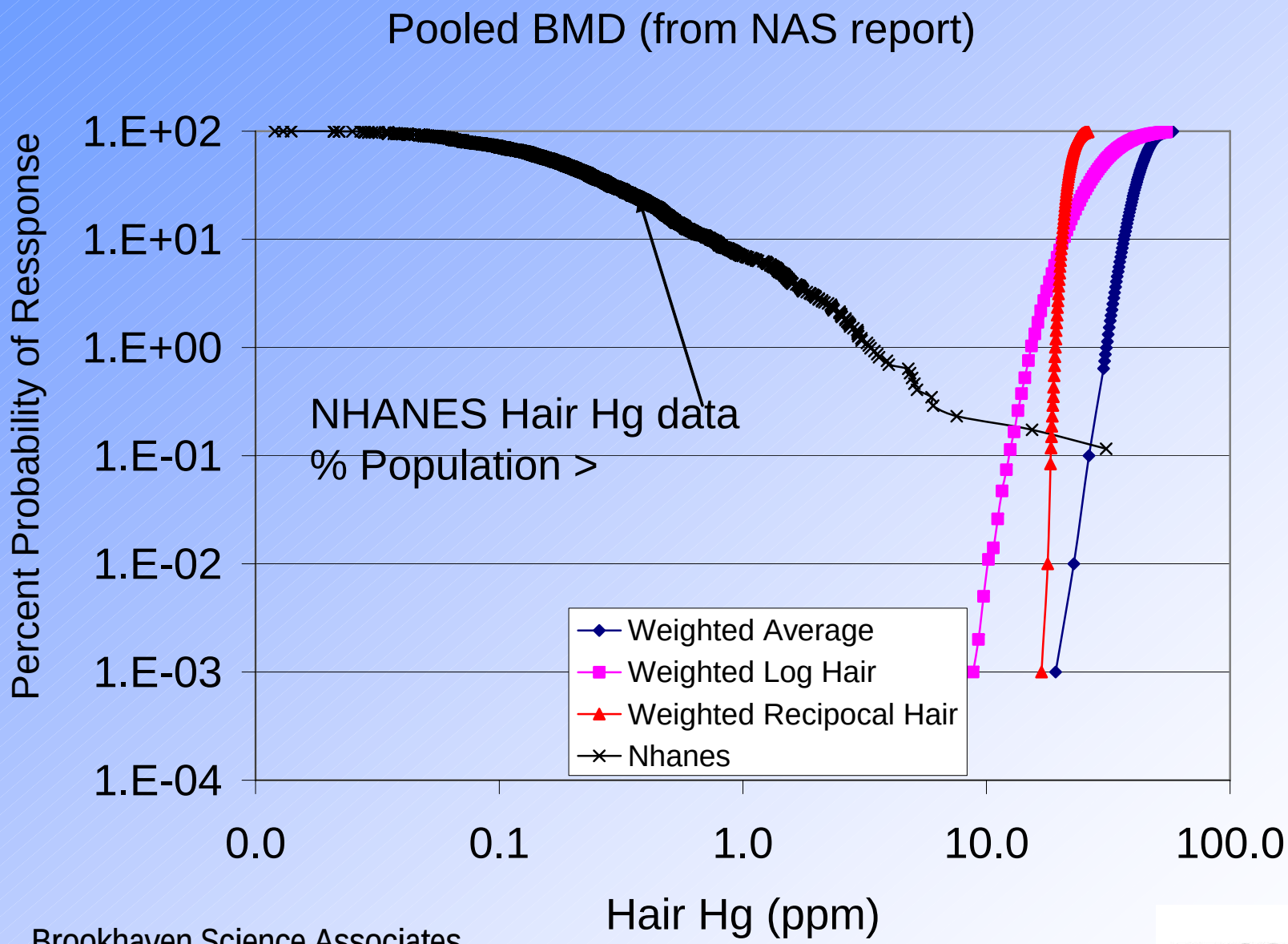
		BMD	std error
Seychelles study	(weight=1)		
Bender copying errors		100*	38.3
Child behavior checklist		21	2.0
McCarthy general cognitive		100*	39.3
Preschool language scale		100*	39.3
WJ applied problems		100*	39.8
WJ Letter/Word recognition		100*	39.8
		* values > 100	
Faroes study	(weight=1)		
Finger tapping		20	4.1
CPT reaction time		17	3.6
Bender copying errors		28	6.6
Boston naming test		15	2.6
CVLT:delayed recall		27	6.6
New Zealand study	(weight=0.6)		
TOLD language development		12	3.1
WISC-R:PIQ		12	3.1
WISC-R:FSIQ		13	3.6
McCarthy perceptual performance		8	2.0
McCarthy motor test		13	3.6

weighted mean BMDs (ppm)		
linear	44.4	5.7
log	28.8	2.4
(negatives disregarded)		
reciprocal	19.9	14.2
(includes negatives)		

Pooled Bench-Mark Dose

- Pooling BMDs across studies and endpoints may offer a more reliable metric.
- The frequency distribution obtained by pooling BMDs and their standard errors constitutes a dose response function, where the response is the probability of having a chance of experiencing any of the various endpoints that were pooled.
- Multiple approaches to pooling BMDs.

Effect of Weighting Procedure on BMD Distribution



Risk Calculation

- Population - Women 16- 49 (children of these women)
- Region -Northeast
- Dose Response Function – log, linear, reciprocal
- Reduction in Hg emissions from Coal plant (90%)
- Reduction in Hg deposition (15.5%)

Population Risk Based on log BMD

- Northeast Baseline – 0.000017 risk of a child having a any of the 16 adverse effects based on the logistic BMD.
- In the U.S., 4,000,000 births/yr. Therefore, 68 children have a chance of exhibiting effects of MeHg each year.
- 90% reduction in coal fired power plant emissions will result in 54 children that are likely to have a chance of exhibiting effects of MeHg each year; a reduction of 14 children/yr.

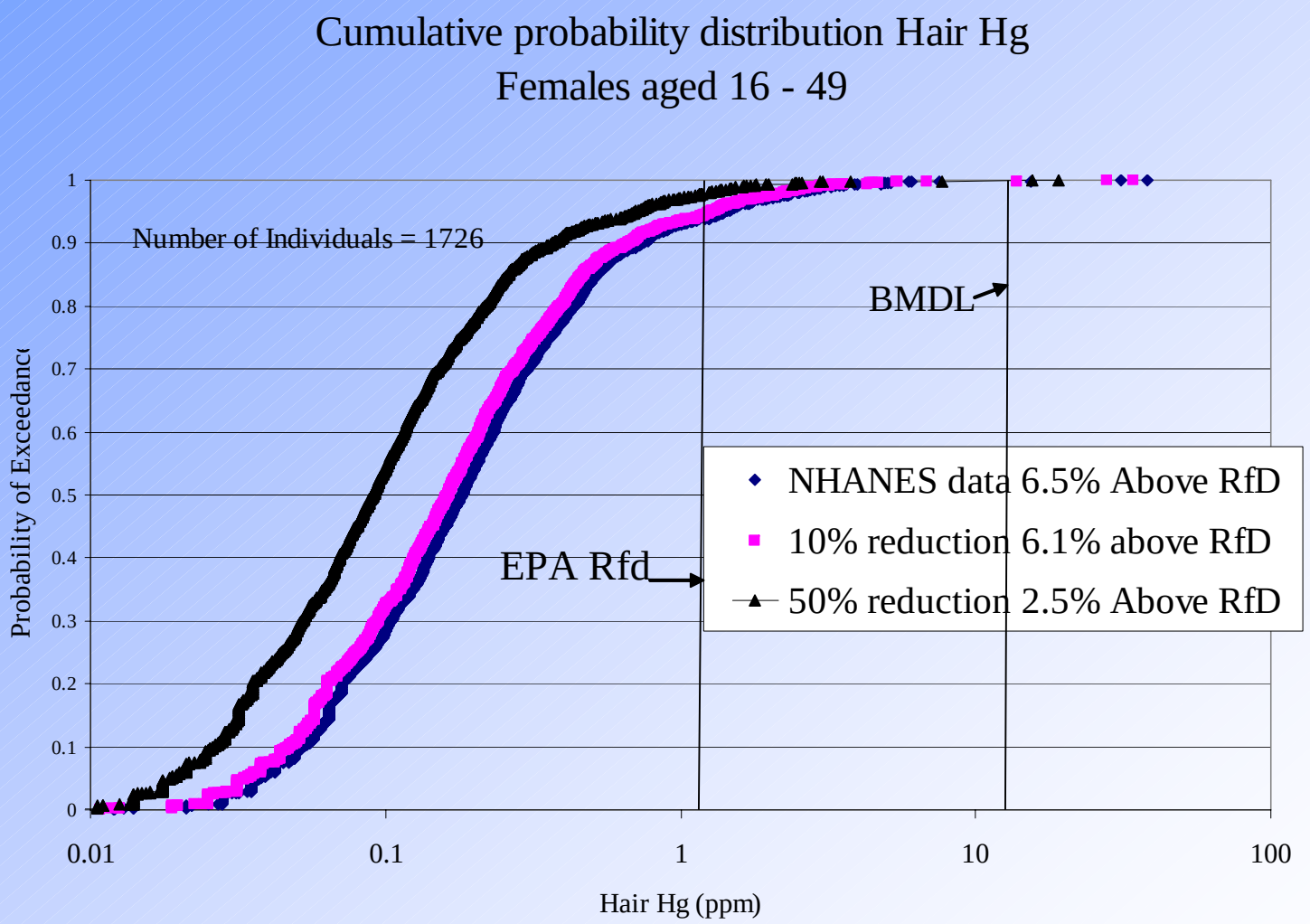
Risks to Children of SE Subsistence Fishers

- Under current conditions, for one group of subsistence fishers, about 0. 4% of the children are likely to exhibit adverse effects from MeHg.
- With 90% reduction in Hg emissions from coal fired power plants, about 0.3% of the children of subsistence fishers who live in the region will exhibit adverse effects of MeHg.

What happened to the estimate of 640,000 children at risk?

- 4 million births per year
- Approximately 8% of females of child-bearing age have mercury body burdens in excess of EPA RfD.
- 640,000 children are at risk of having their mother have a Hg body burden above the RfD.
- Risk of adverse effect is lower.

Impacts of reduction in mercury deposition on Hair Hg (risk)



Conclusions

- Is there a hot spot?

  These three field studies suggest that there is no evidence from soil or vegetation data of large regions (>10 km^2) with mercury concentrations substantially greater than the average. Thus, it appears that a utility hot spot as defined by EPA is unlikely at these sites.

  - Sediment, and deposition data suggest 20 – 30% increase in local deposition (< 5 Km). Minimal increase in deposition beyond 30 Km.

Conclusions on Risk

- Reducing Hg emissions from coal-fired power plants by 90% will lead to 5 – 15% reduction in deposition.
- With appropriate assumptions and caveats, a 10% reduction in deposition will lead to a 10% reduction in body burden
- A 10% reduction in body burden would reduce the number of women above the RfD by < 0.5%.
- Impact of a 10% reduction on human health risk is much less than 1%.

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Questions?

Terry Sullivan
Environmental Research and Technology Division
Brookhaven National Laboratory
631 344-2840
TSullivan@bnl.gov

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