Status Report on Development and Testing of the EMVAP System

EMVAP – Emissions Variability Processor

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Outline of Presentation

- EPA Modeling Guideline procedures
- Nature of variable emissions distributions
- Description of procedures for Monte Carlo analysis approach to handle variable emissions: EMVAP
- Evaluation of EMVAP with 3 AERMOD evaluation databases
- Sensitivity of results to number of simulated years
- Conclusions

EPA Appendix W Modeling Procedures

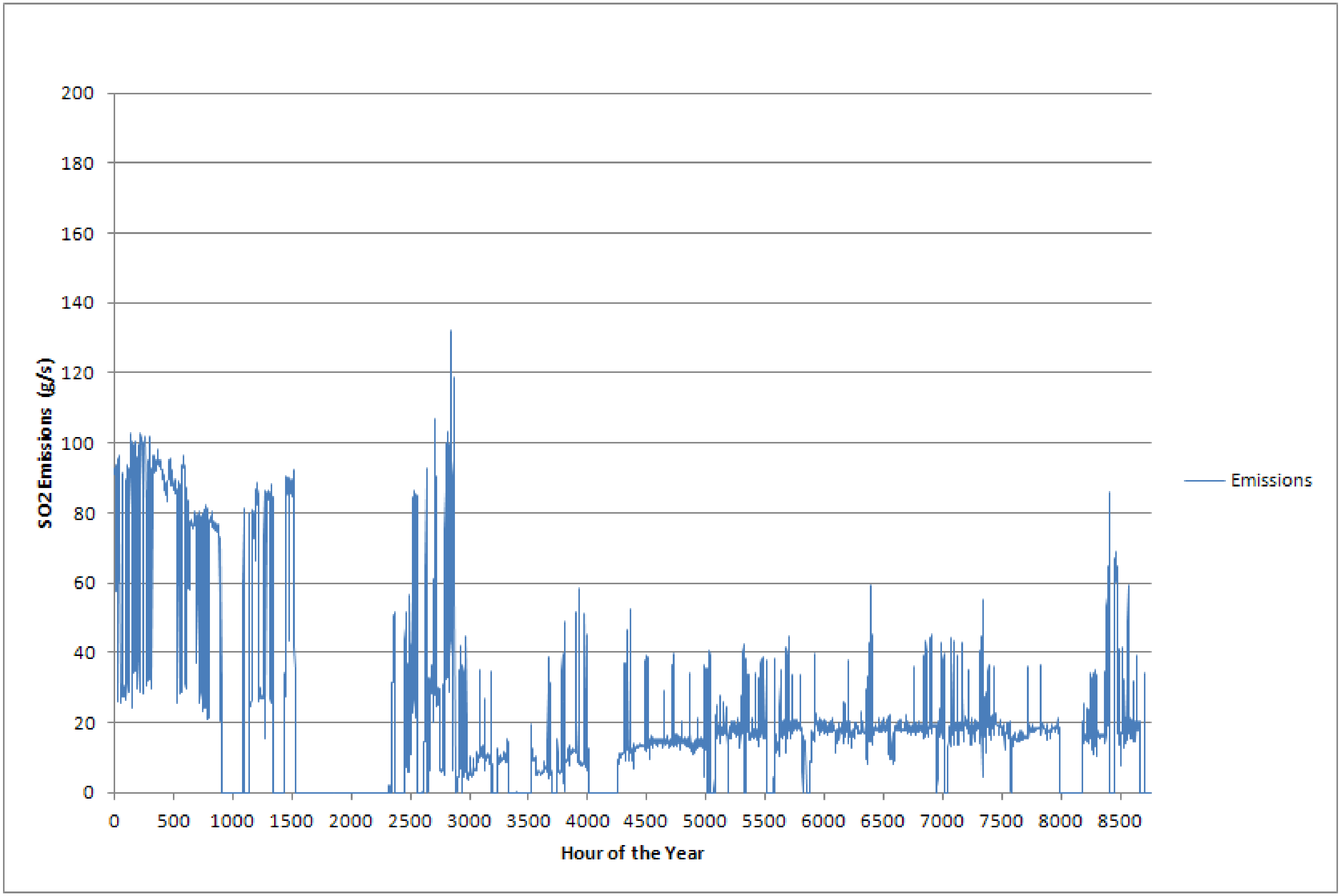
- Modeled emission rate input (for short-term averages) is:
  - Emission limit x operating level x operating factor
    (lb/MMBtu) (MMBtu/hr) (hours/year)
  - Max. emission limit x design capacity x continuous operation

- Modeling continuous operation for intermittent sources or maximum emission limits for variable emission sources is of concern, particularly for a probabilistic NAAQS

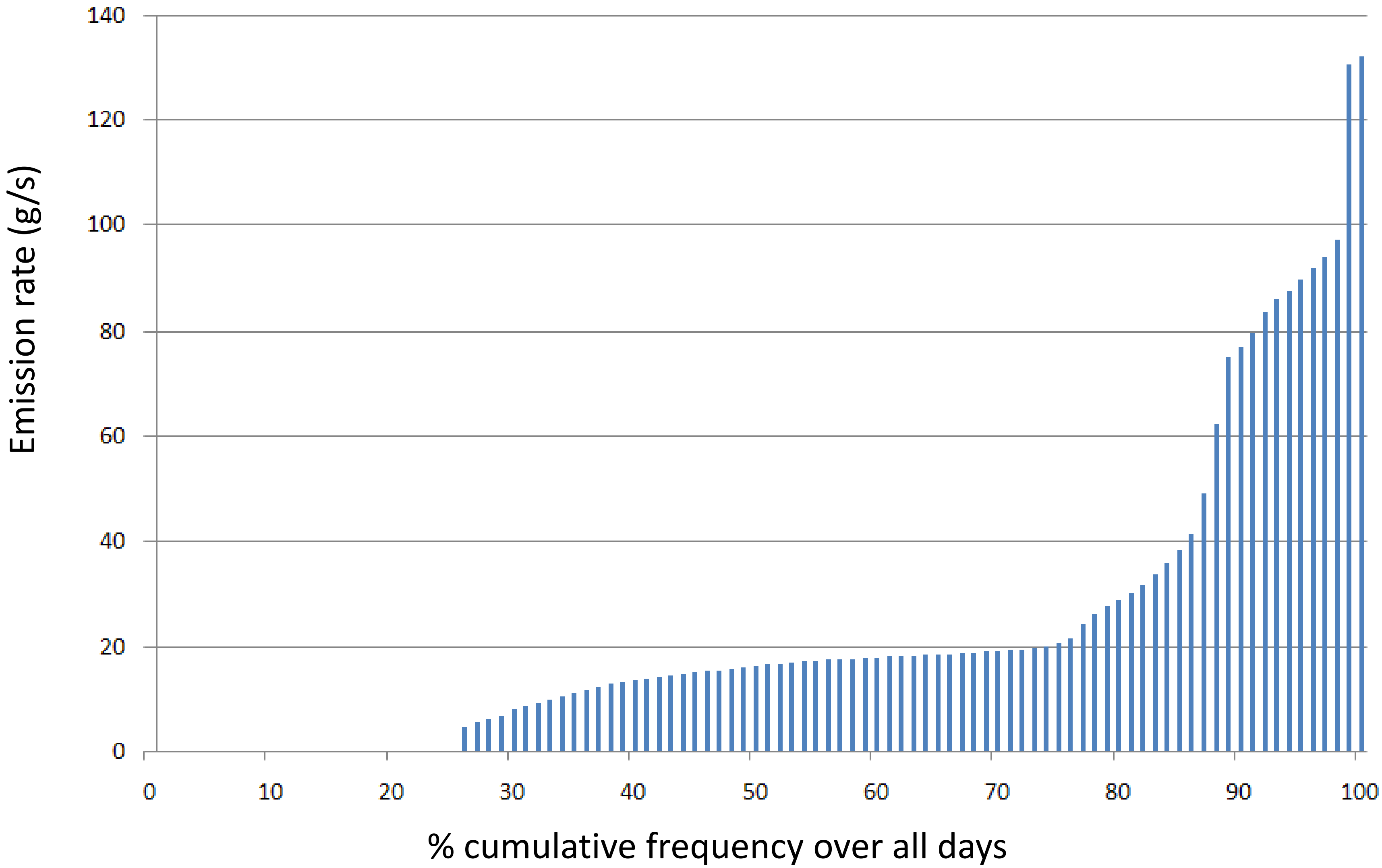
Emission Rate Variability

- Large variation possible over the course of a year
- Intermittent sources (e.g., emergency backup engines or bypass stacks) present modeling challenges
- For these sources, assuming fixed peak 1-hour emissions on a continuous basis <u>will</u> result in unrealistic modeled results
- Better approach is to assume a prescribed <u>distribution</u> of emission rates
- EMVAP (Emissions Variability Processor), described below, uses this information to develop alternative ways to indicate modeled compliance using a range of emission rates <u>instead of just one value</u>

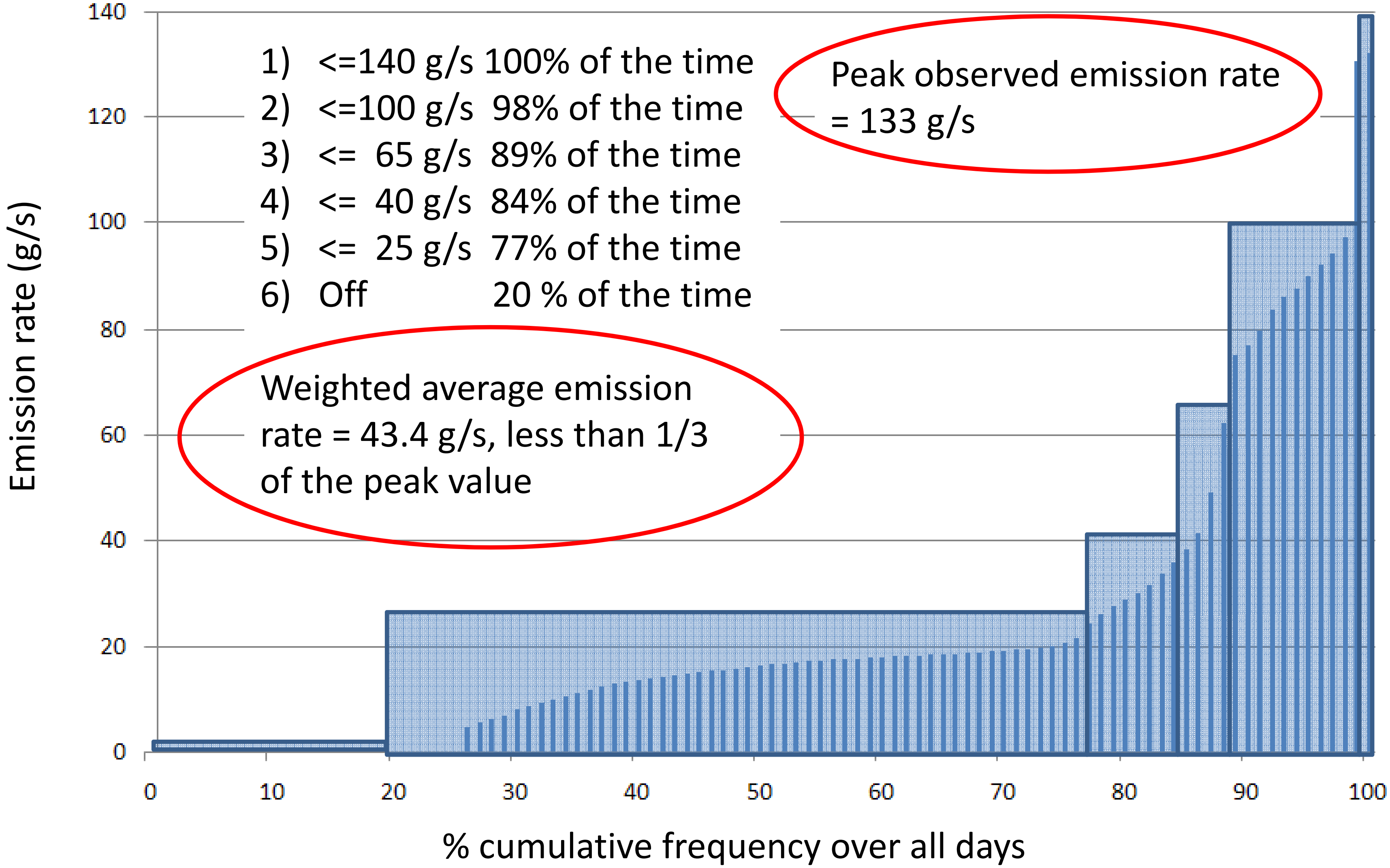
Example of Hourly Emissions Sequence



Example Emission Cumulative Frequency Distribution



Example Emission Cases for EMVAP



Approach (“EMVAP”) for Multiple Allowable Emissions Modeling

- Create an emissions frequency distribution
- <u>Model the source with unit emissions</u> (up to 5 “real” years) – different runs maybe needed over a range of exhaust parameters
- Create many (e.g. 1,000) simulated annual realizations of conc. with random number generator for emission rate
- Randomly assign an <u>emission rate multiplier</u> for each hour using the source-specific emissions distribution
- Process summary statistics over each year/receptor
- Use post-processing software to add concentrations for multiple sources plus background

Random Selection Process

- In some cases, peak emissions occur in groups of hours
- The form of the 1-hour NO_2 and SO_2 standard involves only the highest concentration hour in any given day
- Therefore, it is likely conservative to distribute peak emission rates randomly rather than in groups
- Use of a random selection process, such as a Monte Carlo procedure, is appropriate
- But, sources that operate in tandem can be treated with the same sequence of random numbers

Purpose and Definition

- The EMVAP system is a probabilistic post-processor for AERMOD designed to more realistically model emission sources against short-term NAAQS
- The EMVAP system consists of three modules + AERMOD:
  - *EMDIST* emissions analyzer : aids in determining emission inputs for AERMOD runs
  - *EMVAP* probabilistic emission simulator: used to randomly generate modeled concentrations based on source emissions frequencies
  - *EMPOST* post-processor: takes EMVAP output and performs statistical analyses, generating modeled concentrations in the form of the NAAQS

EMDIST

- Statistical Analysis to Aid in Emissions Input to EMVAP
- Required Inputs
  - Takes in up to 5 years of emissions data in either AERMOD input file format or put into EMDIST format (described in read-me file)
- Optional Inputs
  - If hourly stack exit temperature and velocity data are available, it is used in recommended emission case calculations
  - EMDIST can also import hourly ambient temperature data and report corresponding emission rates and ambient temperature data

EMVAP

- Probabilistic Emissions Simulator Post-processor for AERMOD (used after AERMOD is run for all cases)
- Required Inputs
  - Number and list of years included in the analysis
  - The NAAQS standard for which the EMVAP results are to be compared
  - The number of Monte Carlo simulations to perform
  - File containing the receptors used in the AERMOD runs
  - Random number file used in generating emissions randomly each hour – <u>sources can be linked with a common sequence of random numbers</u>
  - For each of up to 10 source data sets:
    - The load cases and names of the AERMOD result files
    - Emission cases and associated frequencies

EMPOST

- Results Determination and Reporting for EMVAP
- Required Inputs
  - Number and list of years in the analysis
  - Name of the file containing receptor coordinates.
  - The number of modeling iterations performed in EMVAP and the names of the iteration files
  - Definition of statistics to report, if desired

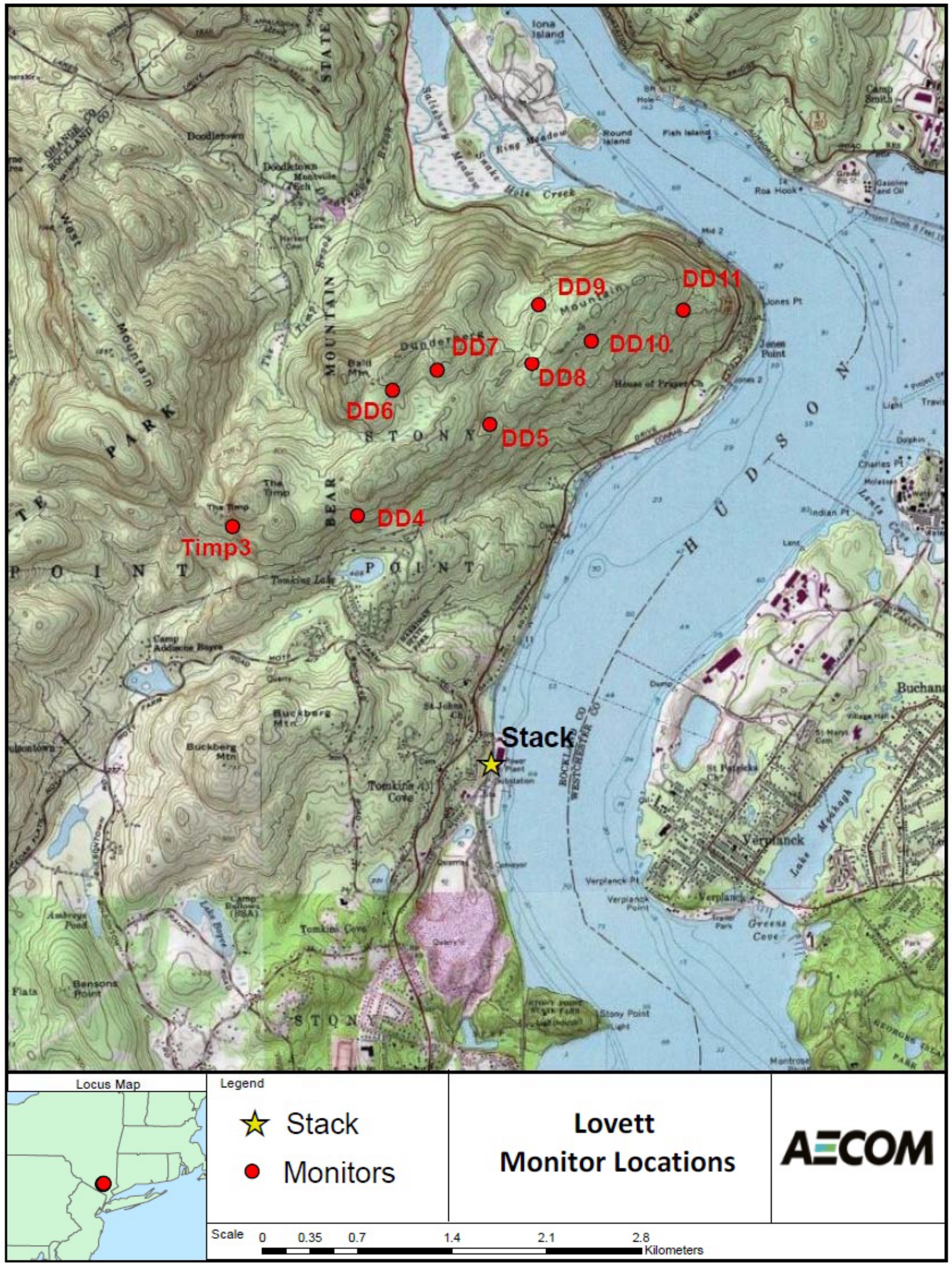
EMVAP Evaluation

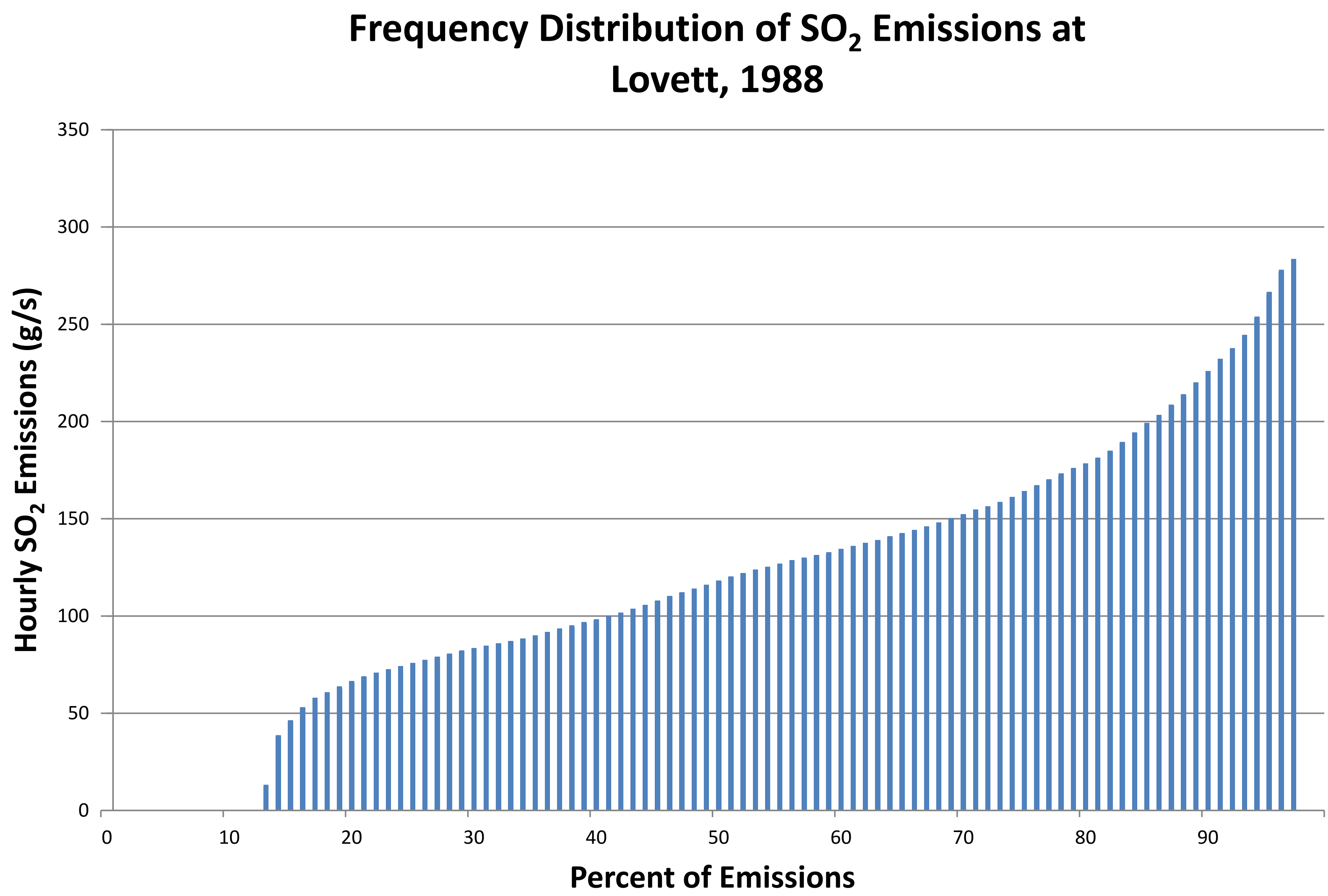
- Selected 3 AERMOD Databases with variety of terrain settings
- Ran AERMOD with both actual and constant peak (allowable) hourly emissions – got 99th percentile peak daily 1-hour max pre vs. obs
- Ran EMVAP to get the same result from median value over 1000 simulated years
- Expectation: EMVAP result would be between that of actual and allowable emissions

Evaluation Databases

- Lovett Generating Station – complex terrain (Hudson River Valley)
  - 1 full year test case, 8 monitors
- Clifty Creek Generating Station – Ohio River gorge
  - 1 full year with 3 units with differing load profiles, 6 monitors
- Kincaid Power Station – flat corn fields of Illinois
  - Partial year case, 1 stack, 28 monitors

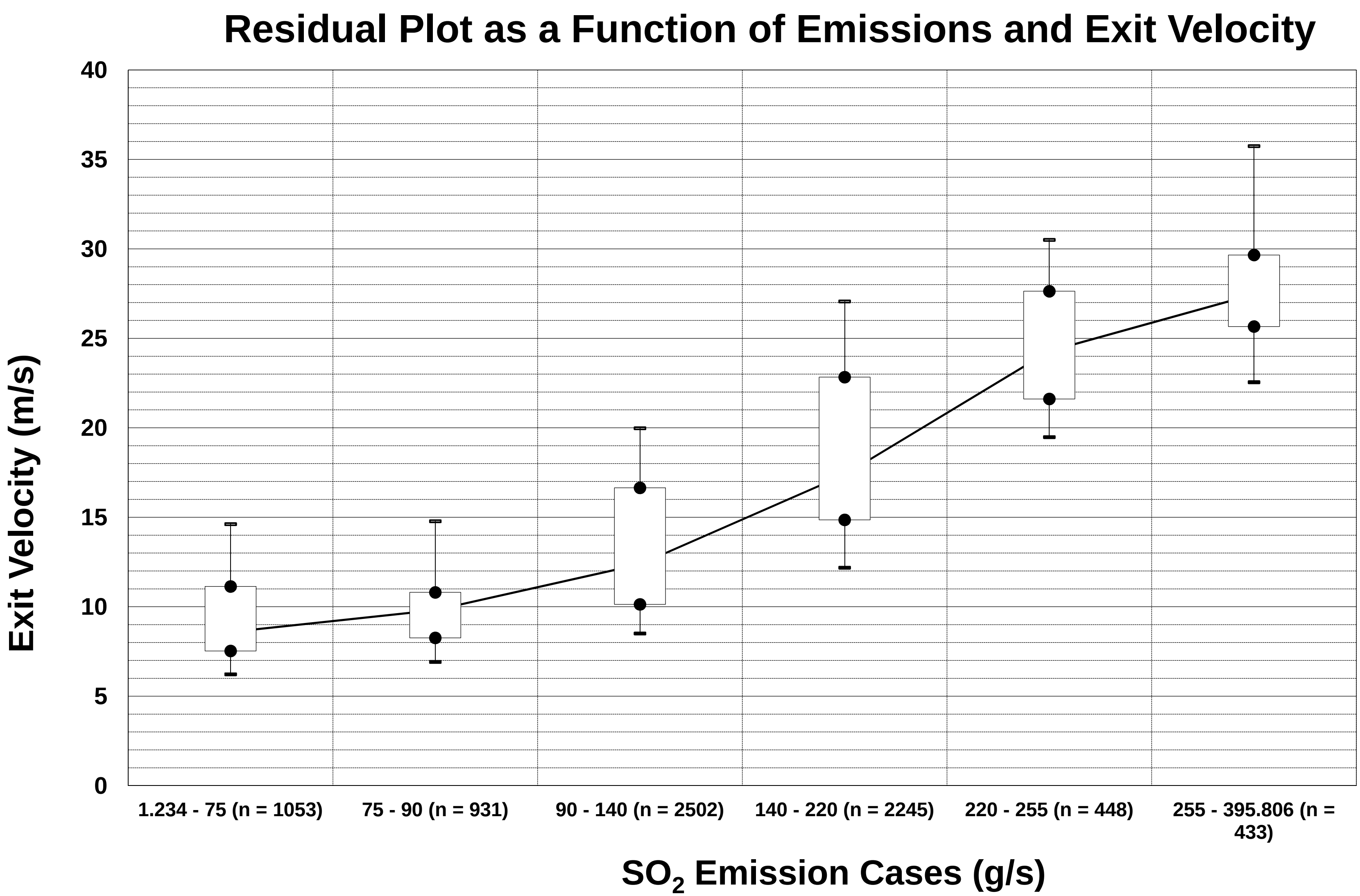
Lovett

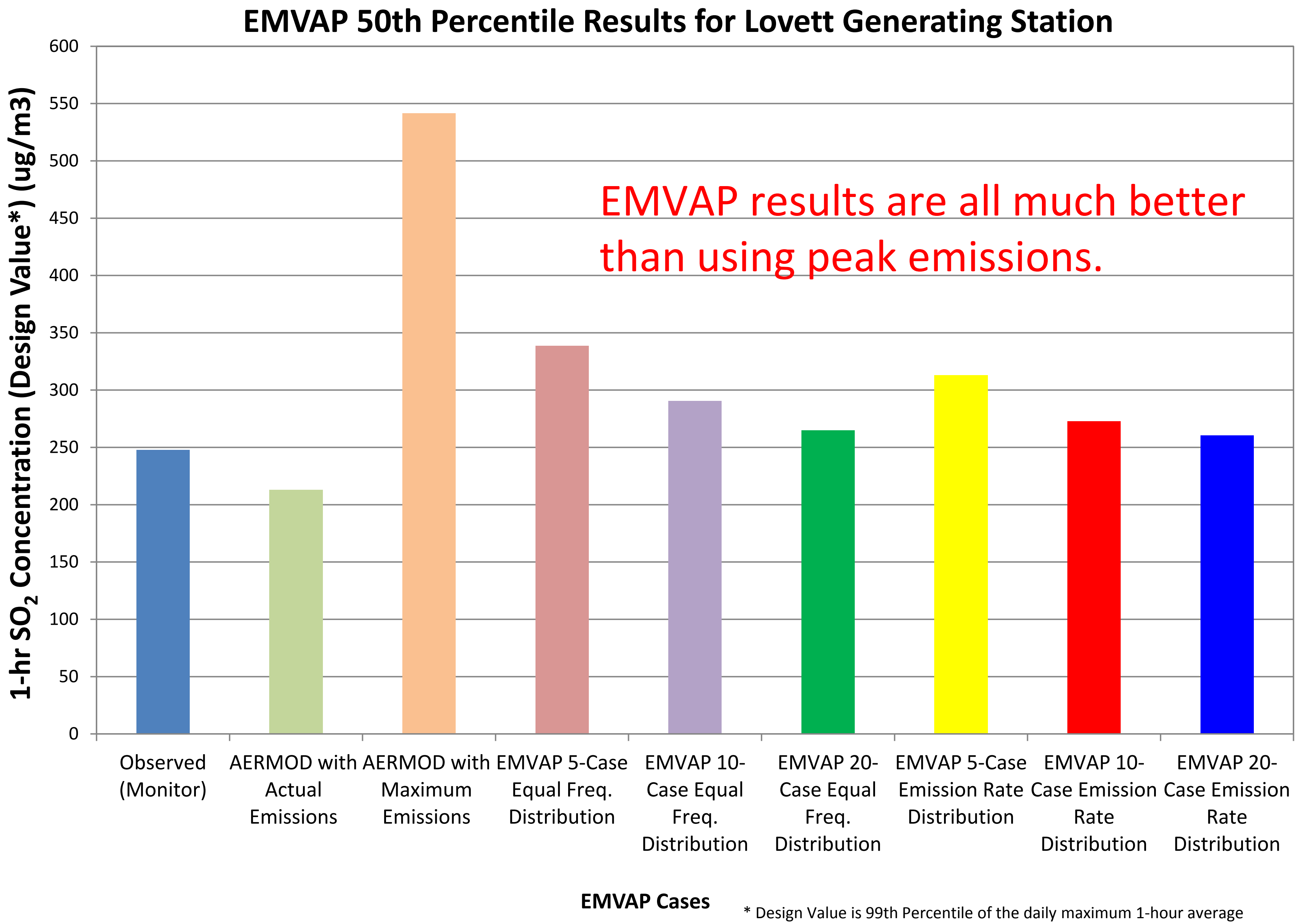

DD9
DD11
DD7
DD10
DD8
DD6
DD5
DD4
Timp3
Stack
Locus Map
Legend
Stack
Monitors
Lovett
Monitor Locations
AECOM
Scale 0 0.35 0.7 1.4 2.1 2.8
Kilometers



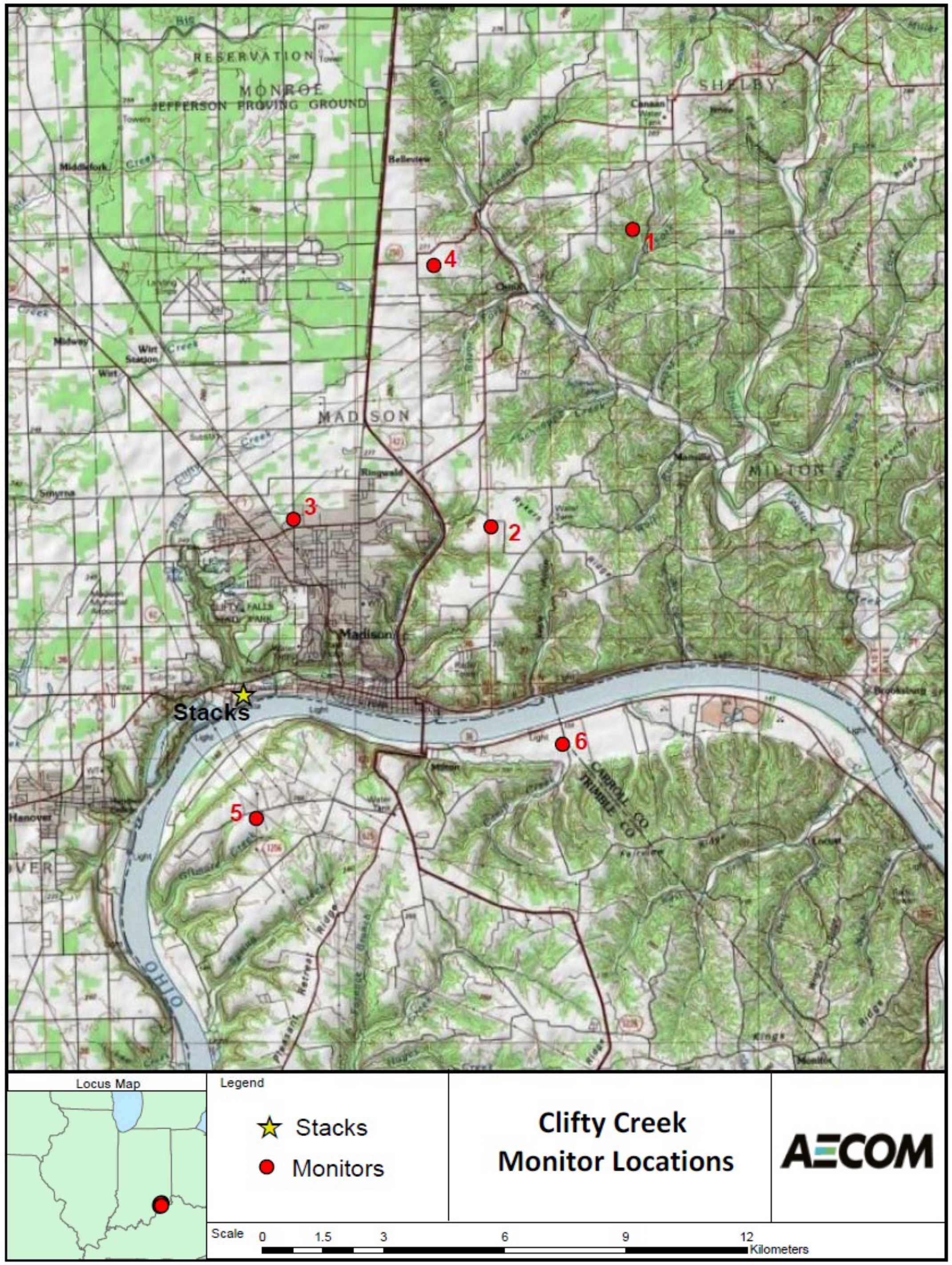
Frequency Distribution of SO_2 Emissions at Lovett, 1988
Hourly SO_2 Emissions (g/s)
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
80
90
Percent of Emissions

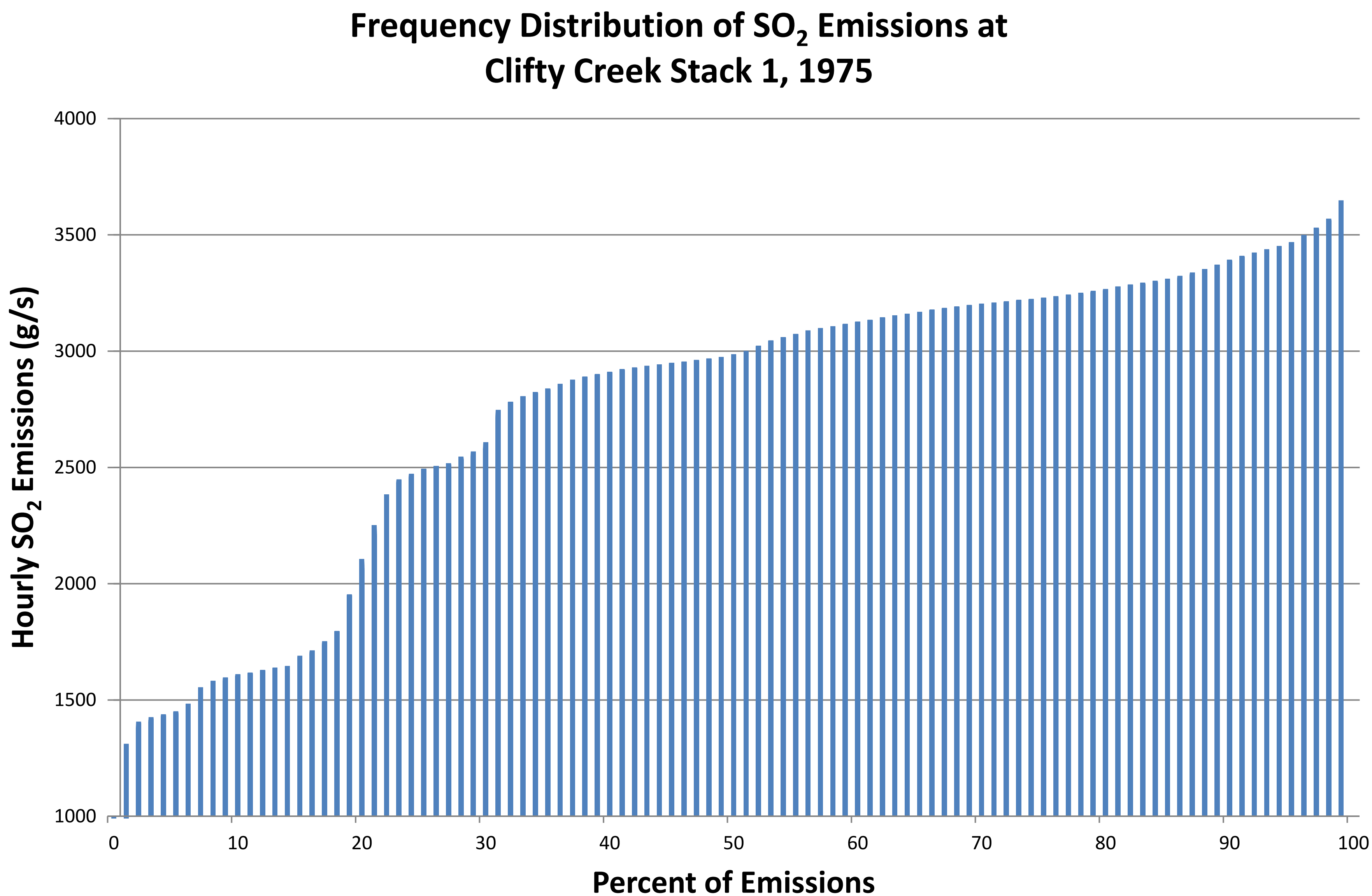
Lovett Generating Station – Exit Velocity vs. Emission Rate




EMVAP 50th Percentile Results for Lovett Generating Station
1-hr SO_2 Concentration (Design Value*) (ug/m3)
600
550
500
450
400
350
300
250
200
150
100
50
0
EMVAP results are all much better than using peak emissions.
Observed (Monitor)
AERMOD with Actual Emissions
AERMOD with Maximum Emissions
EMVAP 5-Case Equal Freq. Distribution
EMVAP 10-Case Equal Freq. Distribution
EMVAP 20-Case Equal Freq. Distribution
EMVAP 5-Case Emission Rate Distribution
EMVAP 10-Case Emission Rate Distribution
EMVAP 20-Case Emission Rate Distribution
EMVAP Cases
* Design Value is 99th Percentile of the daily maximum 1-hour average

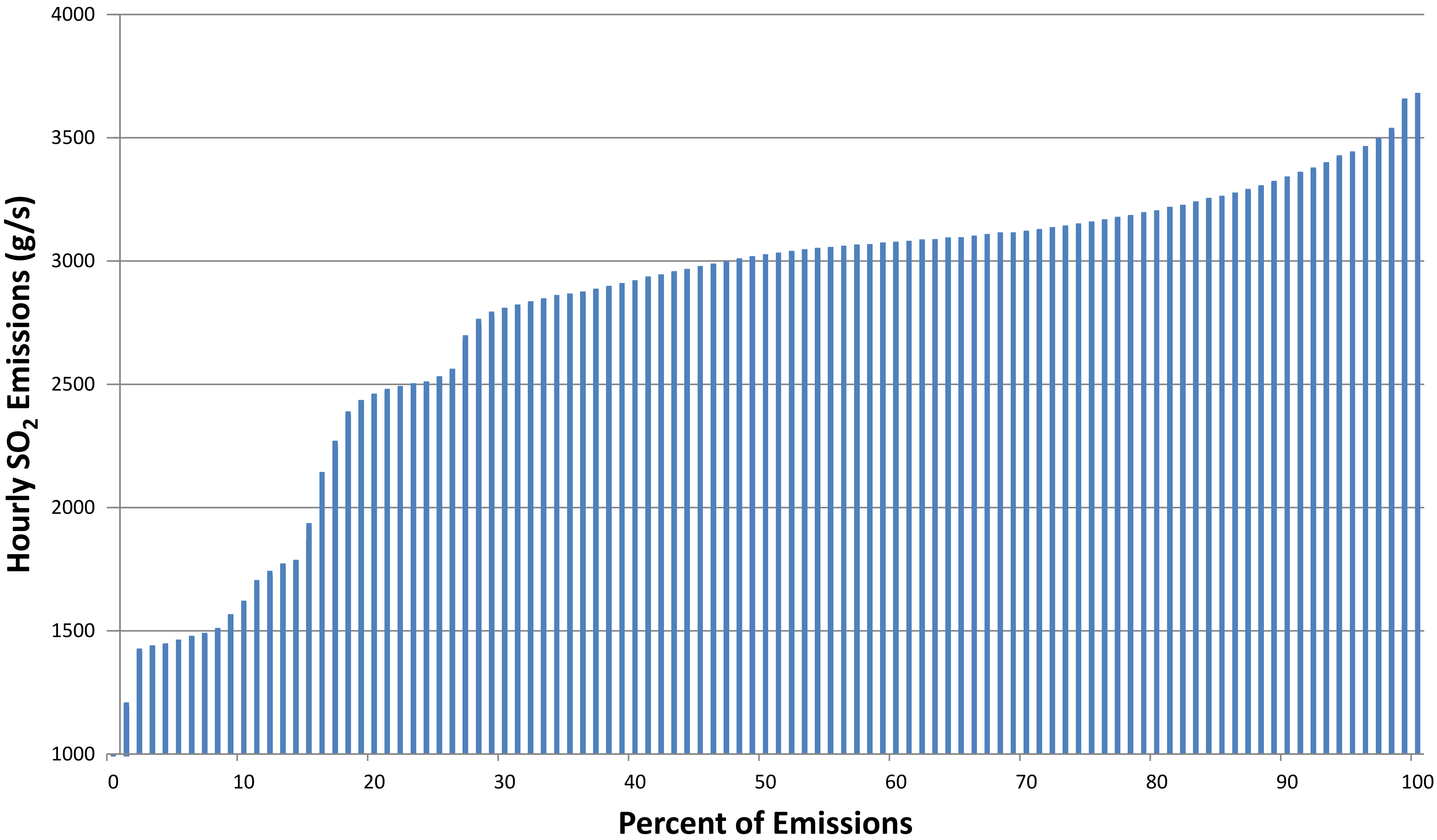
Clifty Creek



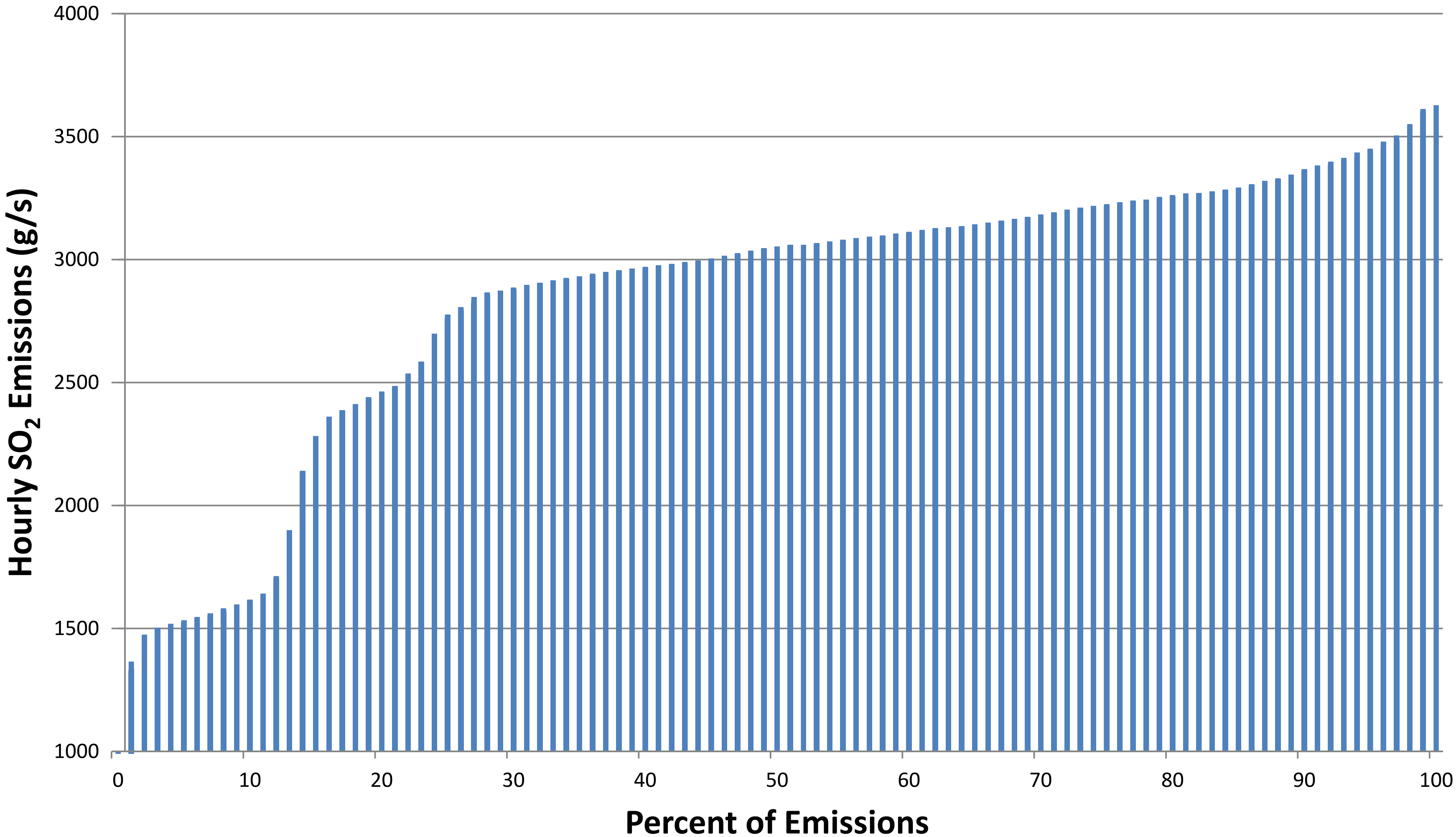


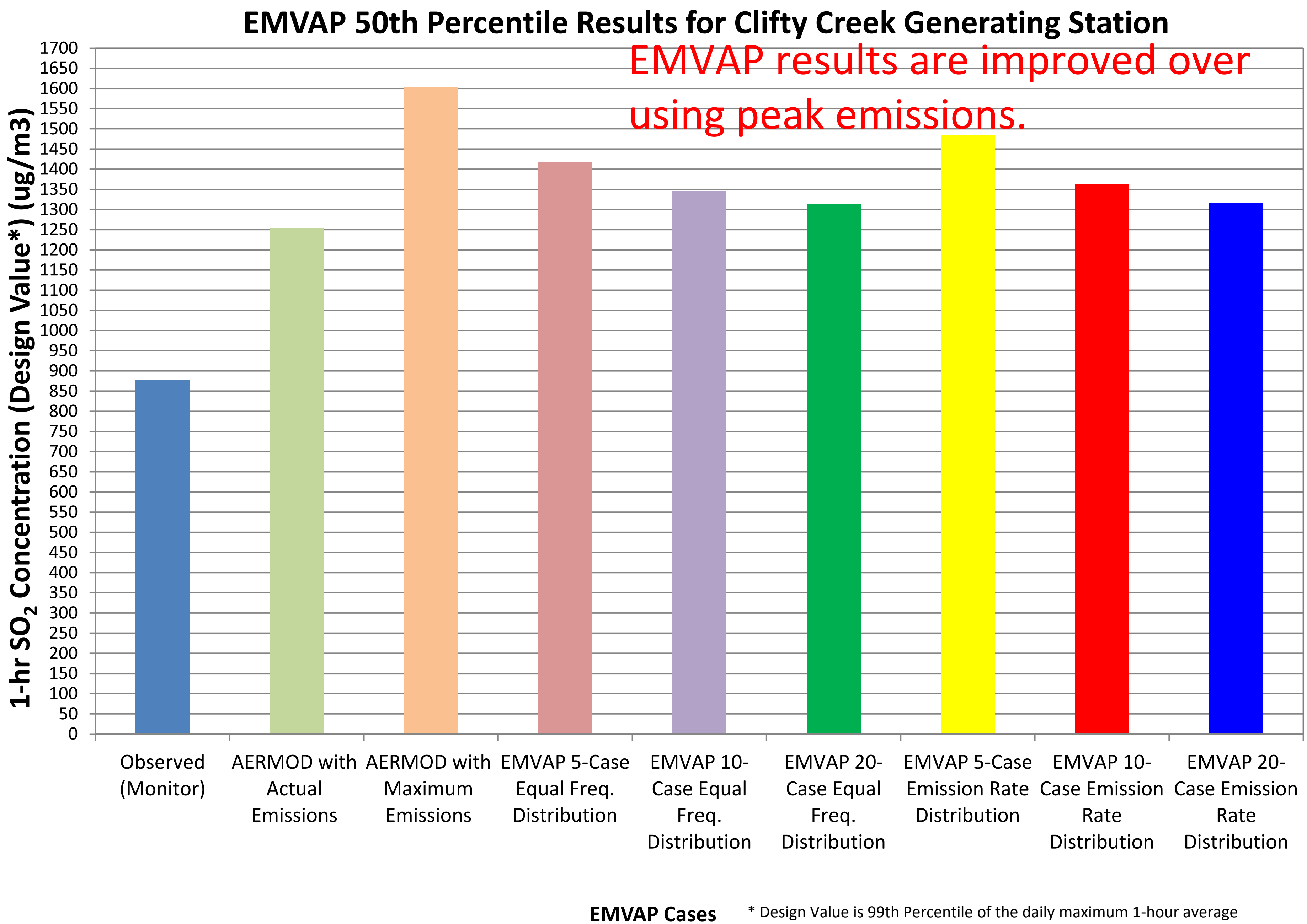
Frequency Distribution of SO2 Emissions at
Clifty Creek Stack 1, 1975
Hourly SO2 Emissions (g/s)
4000
3500
3000
2500
2000
1500
1000
0
10
20
30
40
50
60
70
80
90
100
Percent of Emissions

Frequency Distribution of SO_2 Emissions at Clifty Creek Stack 2, 1975

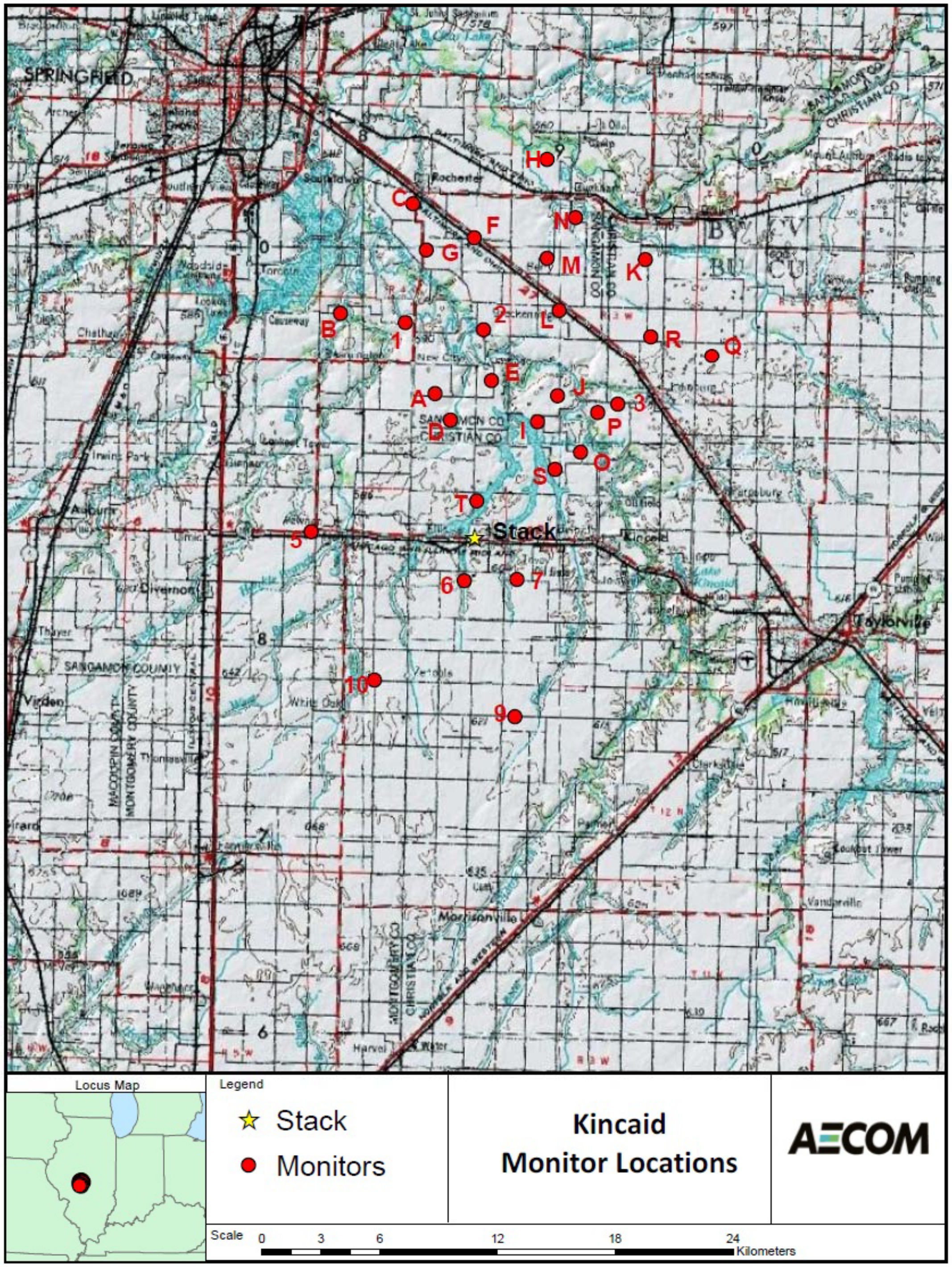


Frequency Distribution of SO_2 Emissions at Clifty Creek Stack 3, 1975

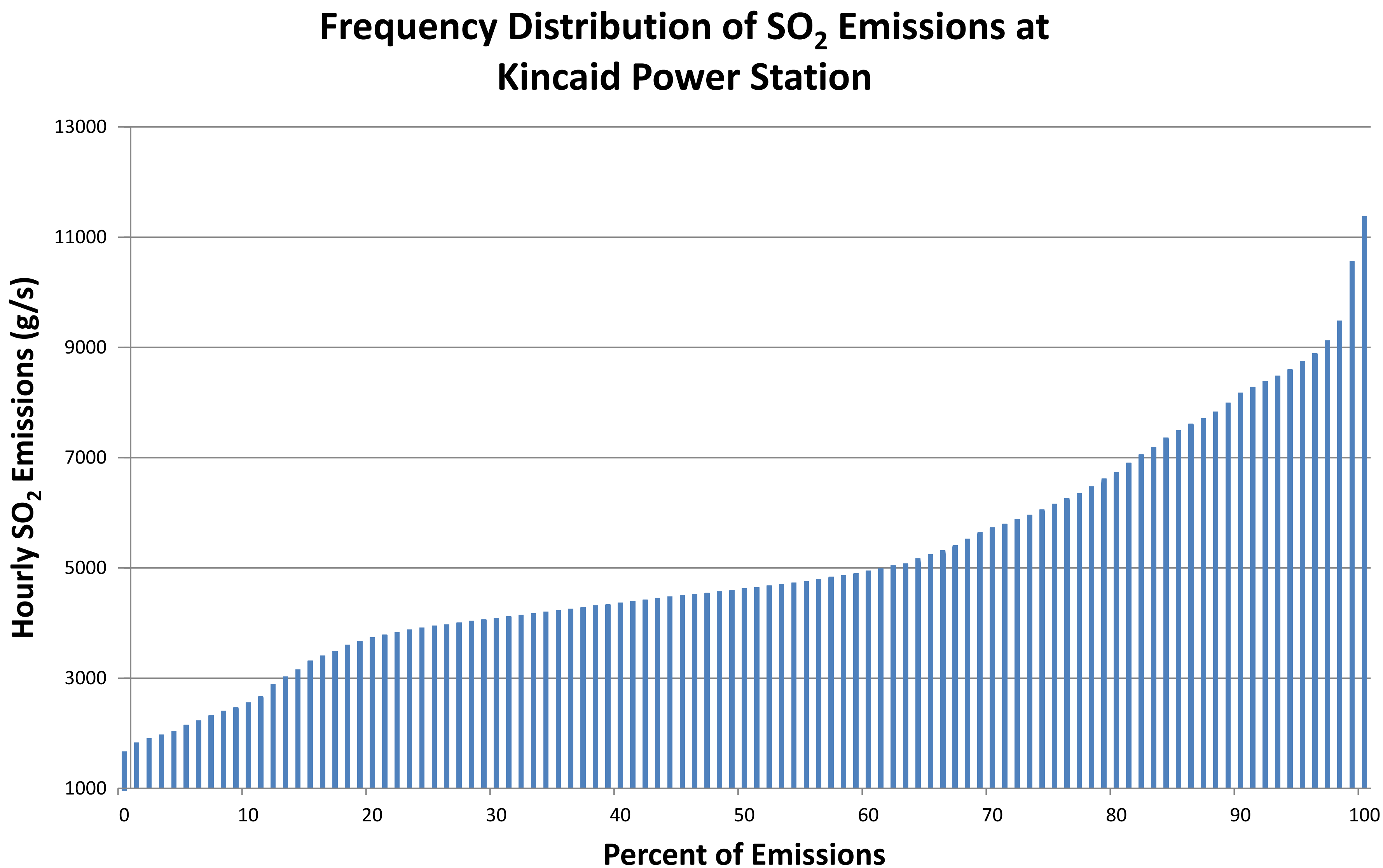



EMVAP 50th Percentile Results for Clifty Creek Generating Station
EMVAP results are improved over using peak emissions.
1-hr SO_2 Concentration (Design Value*) (ug/m3)
1700
1650
1600
1550
1500
1450
1400
1350
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Observed (Monitor)
AERMOD with Actual Emissions
AERMOD with Maximum Emissions
EMVAP 5-Case Equal Freq. Distribution
EMVAP 10-Case Equal Freq. Distribution
EMVAP 20-Case Equal Freq. Distribution
EMVAP 5-Case Emission Rate Distribution
EMVAP 10-Case Emission Rate Distribution
EMVAP 20-Case Emission Rate Distribution
EMVAP Cases
* Design Value is 99th Percentile of the daily maximum 1-hour average

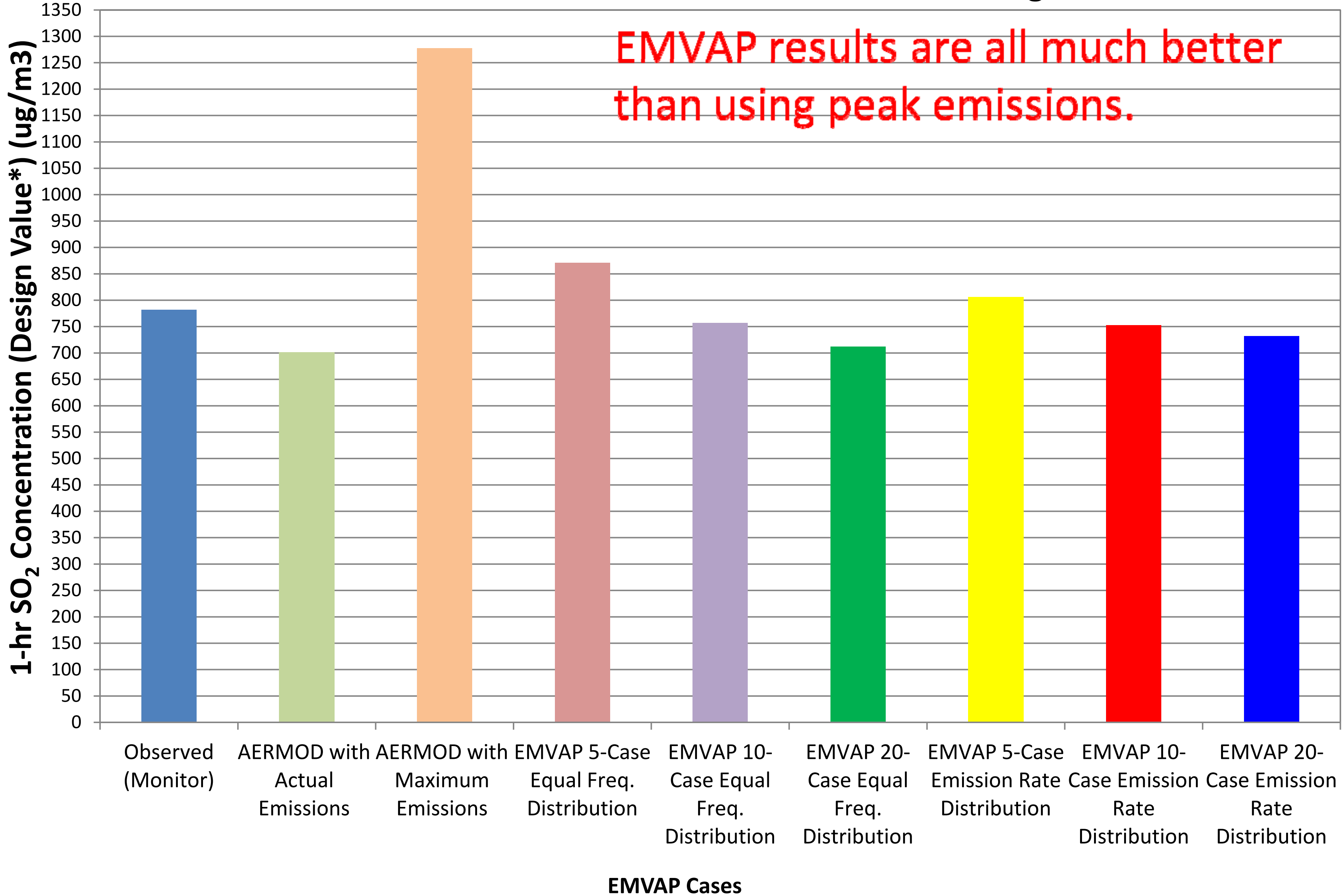
Kincaid



SPRINGFIELD
Stack
Taylorville
Locus Map
Legend
Stack
Monitors
Kincaid
Monitor Locations
AECOM
Scale
0
3
6
12
18
24
Kilometers


Frequency Distribution of SO_2 Emissions at
Kincaid Power Station
13000
11000
9000
7000
5000
3000
1000
0
10
20
30
40
50
60
70
80
90
100
Hourly SO_2 Emissions (g/s)
Percent of Emissions

EMVAP 50th Percentile Results for Kincaid Generating Station



* Design Value is 99th Percentile of the daily maximum 1-hour average

Sensitivity Analysis of Design Conc. By Number of Iterations Performed – Lovett (μg/m^3)

Iterations	50th	75th	90th	Max.
50	348.99	374.81	413.85	458.40
500	347.32	374.81	412.31	460.45
1000	347.32	374.81	412.31	534.39
2500	347.32	374.81	412.31	541.62
5000	347.32	374.81	412.31	614.78

Current Limits in EMVAP

- Receptors: no effective limit (tested so far with 10000 receptors)
- Source groups to be combined: 10 (can include groups with constant emissions, or background)
- Load cases per source group: 20
- Iterations: 5000 simulated years
- Years of modeled data per iteration: 5

Typical run time is a few minutes to an hour on a standard computing platform.

Conclusions and Status

- EMVAP is currently operational for EPRI beta testing and consideration of implementation approaches
- Evaluation against field data shows expected results: critical predictions are somewhat higher than those from actual emissions and lower than those from peak emissions
- Further development and testing is currently underway by EPRI