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THE IMPACT OF NEARBY STRUCTURES AND TREES ON SIGMA THETA MEASUREMENTS

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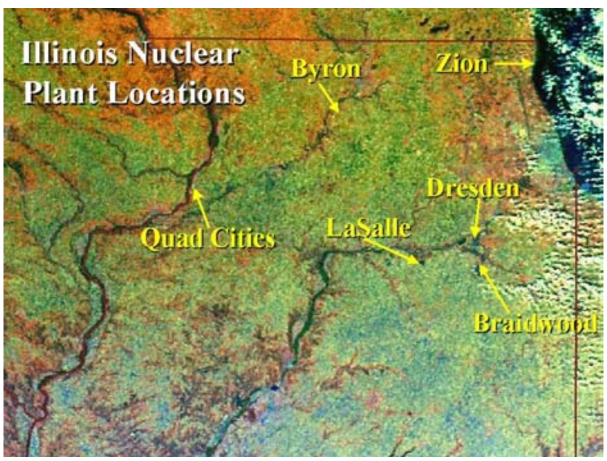
1. INTRODUCTION

The impetus for this study was the encroachment of trees upon the Zion Nuclear Power plant meteorological tower. This study was conducted to determine if the nearby trees were impacting the sigma theta (standard deviation of wind direction) measurements on the tower. The impact of nearby buildings was an outgrowth of this study. The study spread to include the Braidwood, Byron, Dresden, LaSalle, and, Quad Cities nuclear plant sites when the results for Zion showed unexpected impacts from the plant buildings. Here is where the Illinois nuclear plants used in this study are located:



2. BACKGROUND

The most important meteorological parameter for emergency response is the wind (Crawford, 1990). The wind provides the basis for answering where accidental releases will travel and when they will arrive. To obtain the best possible wind measurements for emergency response, it is important that the meteorological tower be located in an area that avoids wind modifications by obstructions such as large structures, large trees, or nearby terrain. Regulatory guidance such as ANSI/ANS-3.11-2000 states that the separation between a wind between a wind sensor and a nearby obstruction should be ten times the obstruction height. If nearby obstructions are impacting a wind direction sensor, these impacts can be easily seen in sigma theta measurements. Noting where impacts occur from nearby structures will ultimately assist emergency response efforts and clarify uncertainty.

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3. SIGMA THETA AVERAGING

For each nuclear plant site, 15-minute average sigma thetas were averaged by wind direction. Sigma thetas for each tower level were averaged for every 10 degrees of wind direction (0º-10º, 10º-20º, etc.). Thus, 36 averages covering 0-360º for each level at each site were derived. Sigma theta values with wind speeds less than 2.2 m/s (5 mph) were not used to remove natural meandering with little potential to cause wind direction distortion. The time period of the data used for each site is as follows:

Braidwood	Dec 1998 ------- Dec 2001
Byron	Jan 2002 -------- Apr 2002
Dresden	Dec 1998 ------- Dec 2001
LaSalle	Dec 1998 ------- Dec 2001
Quad Cities	Jan 2002 -------- Apr 2002
Zion	Jul 1990 --------- Dec 2001

4. RESULTS AND DISCUSSION

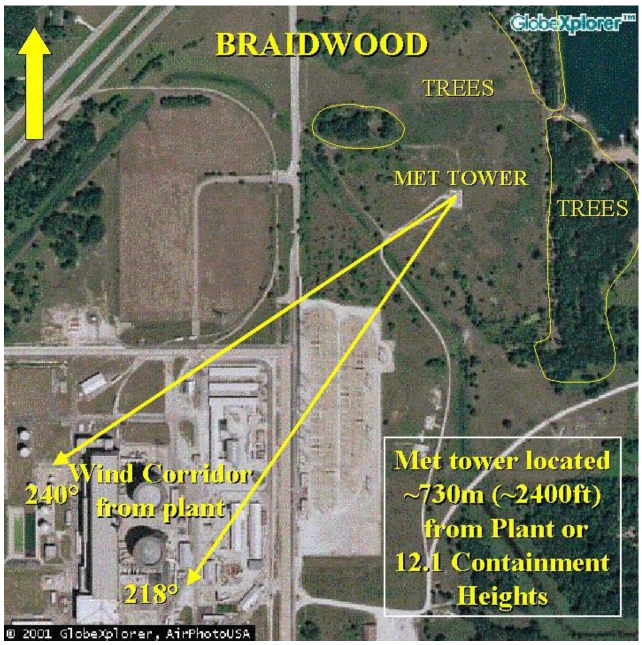
Average sigma thetas for each tower level for the Braidwood, Byron, Dresden, LaSalle, Quad Cities, and Zion sites are presented below. Aerial photographs of each site show the location of the plant buildings, meteorological tower, nearby trees, nearby industrial areas, the distance to the plant buildings/containment, and the wind corridor from the plant that can impact the sigma theta measurements. As expected, all sites show that sigma theta averages decrease with increasing height.

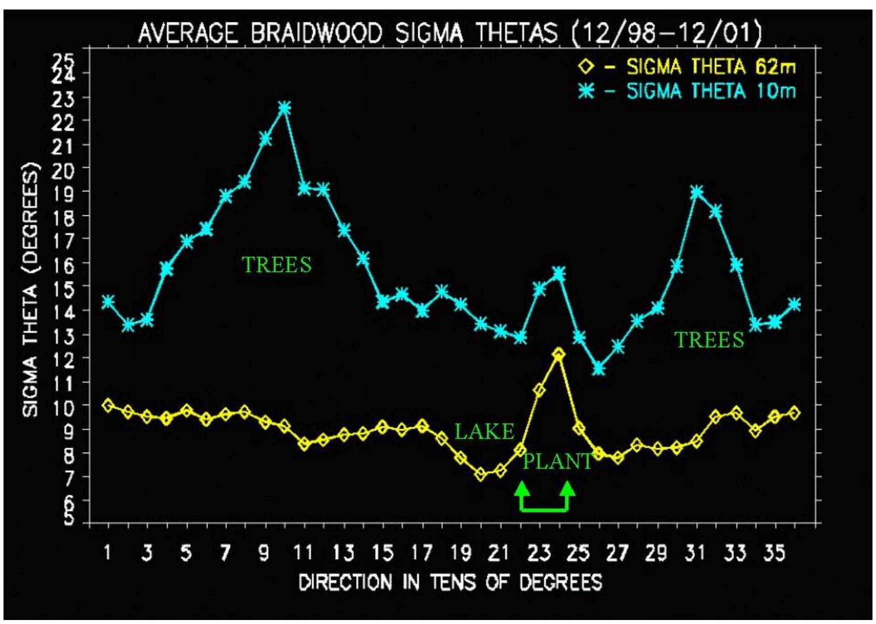
a) Braidwood site:

Shown below are an aerial photograph of the Braidwood site and a graph of the average Braidwood sigma thetas. A yellow line shows the 62-meter average sigma thetas and a cyan line shows the 10-meter average sigma thetas. The locations of the plant and nearby trees are also shown on this graph.

This site has two areas of trees that impact the 10-meter level sigma thetas. One area is located about 140 meters to the east (90º) of the tower and runs north and south for about 275 meters. This explains the peak from the east (90º) and the resulting decrease to the northeast (45º) and southeast (135º) as the trees become farther away from the tower. The other area is a small grove of trees located about 150 meters roughly northwest (315º) of the tower. A peak in sigma thetas is seen from this grove from 300º-320º.

The plant buildings and containment impact the 10-meter and 62-meter sigma thetas. The impact from the plant is slightly greater for the 62-meter level than the 10-meter level. The 62-meter level sigma thetas also show a minimum from 190º-210º that is explained by a long, friction-free fetch over the plant cooling lake (not seen in the aerial photograph).

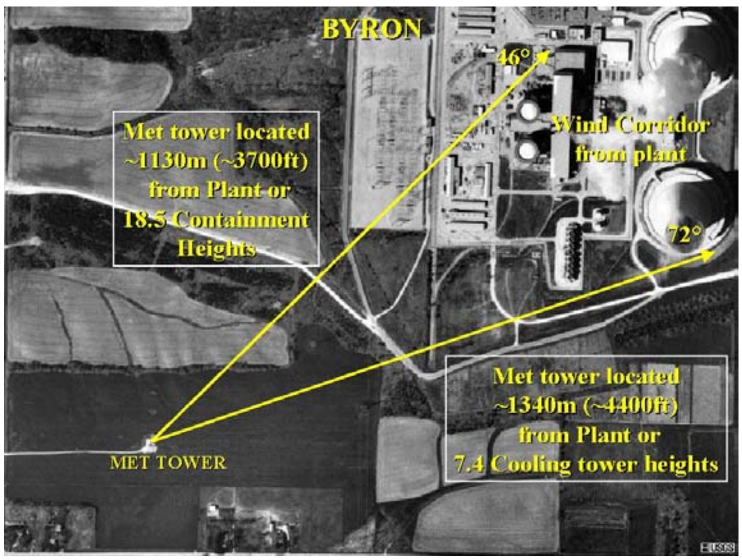


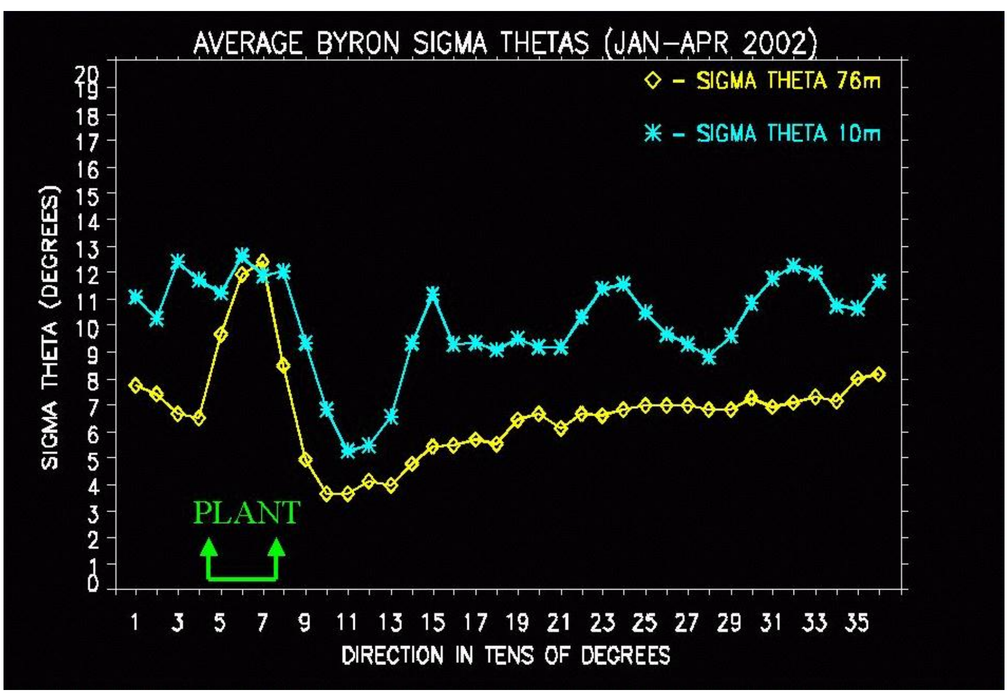


b) Byron site

Shown below are an aerial photograph of the Byron site and a graph of the average Byron sigma thetas. A yellow line shows the 76-meter average sigma thetas and a cyan line shows the 10-meter average sigma thetas. The location of the plant is shown on this graph. This site has three small groves of trees that impact the 10-meter level sigma thetas (not shown) on the aerial photograph). They are each located about 250-275 meters southeast, southwest, and northwest of the tower. Small peaks in sigma theta are seen from these trees. The impact of the plant buildings, containment, and cooling towers is very evident in both the 76-meter and 10-meter level sigma thetas. In one instance for winds from 60º-70º, the 76-meter level sigma thetas are higher than the 10-meter level sigma thetas due largely to the turbulence caused by the cooling towers. When considering the cooling towers, the Byron site is the only site in this study that does not comply with the regulatory guidance of 10 times the obstruction height away from the meteorological tower

Both the 76-meter and 10-meter level sigma thetas show a minimum for winds from 100º-120º. This could be due the lack of trees for quite some distance from the tower, minor terrain features, and/or the small number of observations collected in this wind corridor.





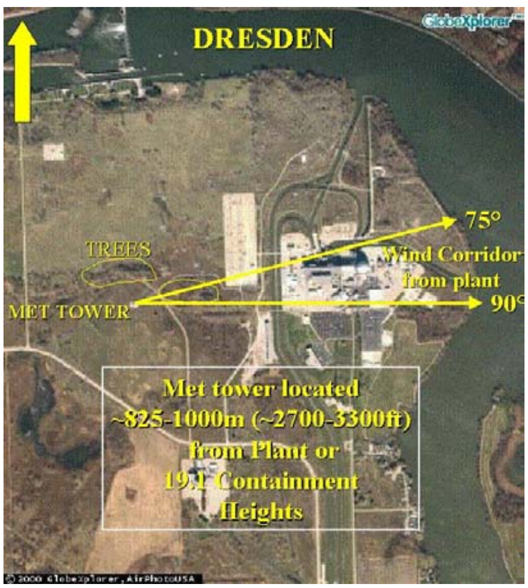
c) Dresden site:

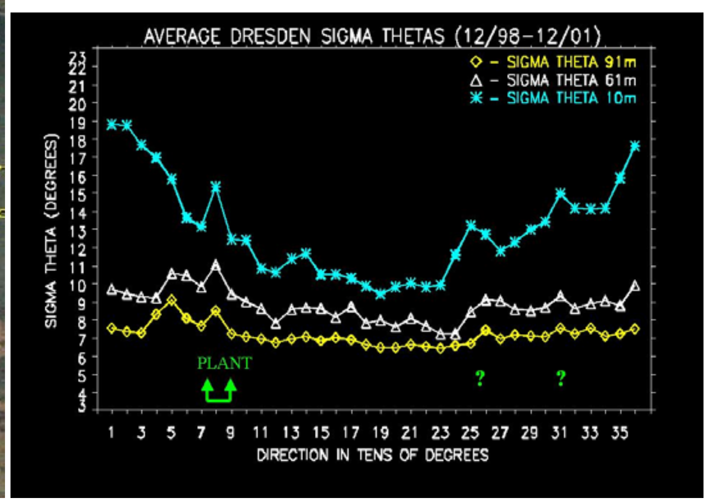
Shown below are an aerial photograph of the Dresden site and a graph of the average Dresden sigma thetas. A yellow line shows the 91-meter average sigma thetas, a white line shows the 61-meter average sigma thetas, and a cyan line shows the 10-meter average sigma thetas. The locations of the plant and nearby industrial areas (denoted with a ?) are also shown on this graph.

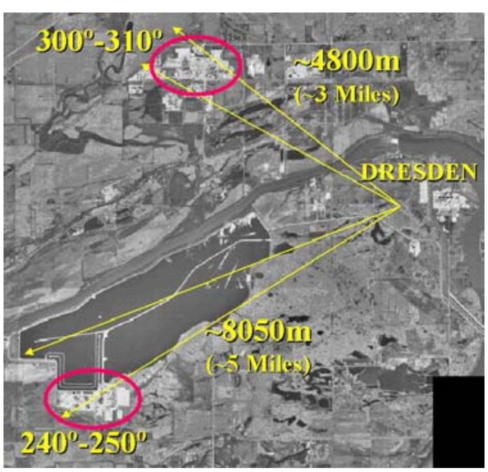
This site shows no noticeable impact from any nearby trees since the trees are not as tall and as densely packed as other sites. Due to the distance and orientation of plant buildings, only a small peak in sigma thetas is seen at about 80º at all levels. Small peaks at the 91-meter and 61-meter level from 37º-62º may be caused by turbulence from a 37-meter (100 foot) drop over a cliff located about 1900 meters (1.2 miles) upstream from the tower.

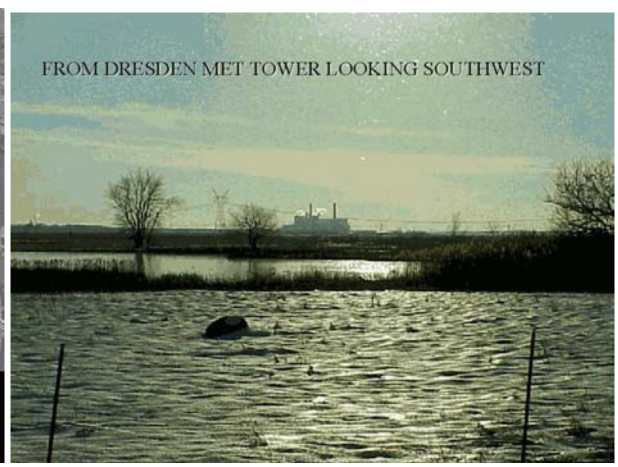
Two other small peaks, seen primarily in the 10-meter sigma thetas, occur for winds from 240º-250º and 300º-310º. Turbulence from a large power plant located about 8 kilometers (5 miles) to the southwest (~250º) and from a large refinery located about 4.8 kilometers (3 miles) to the northwest (300º-310º) may be responsible for these small peaks (both seen in the other two photographs below). This is plausible, particularly for the large power plant, since there are no trees and very little change in terrain between the tower and the large power plant.

The bowl shape of the 10-meter sigma thetas, lower from the south and higher from the north, may be the result of turbulence created as wind flows across the Illinois River valley. Since Dresden is located in the Illinois River valley, the 61-meter and 91-meter level sigma thetas may be above the turbulence created by the valley.







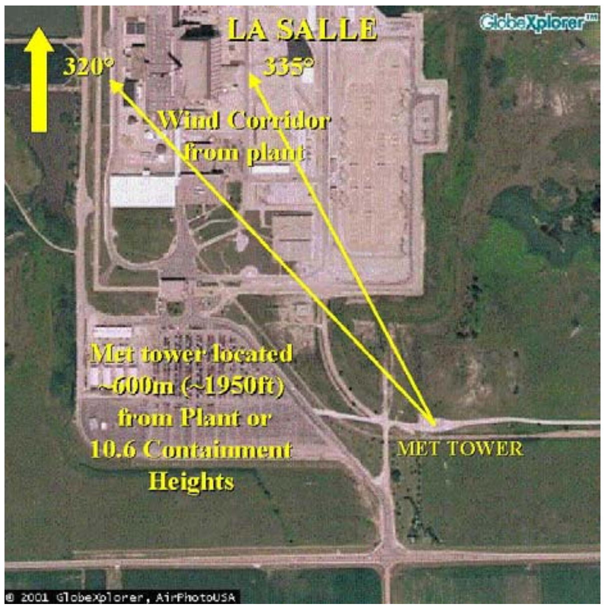


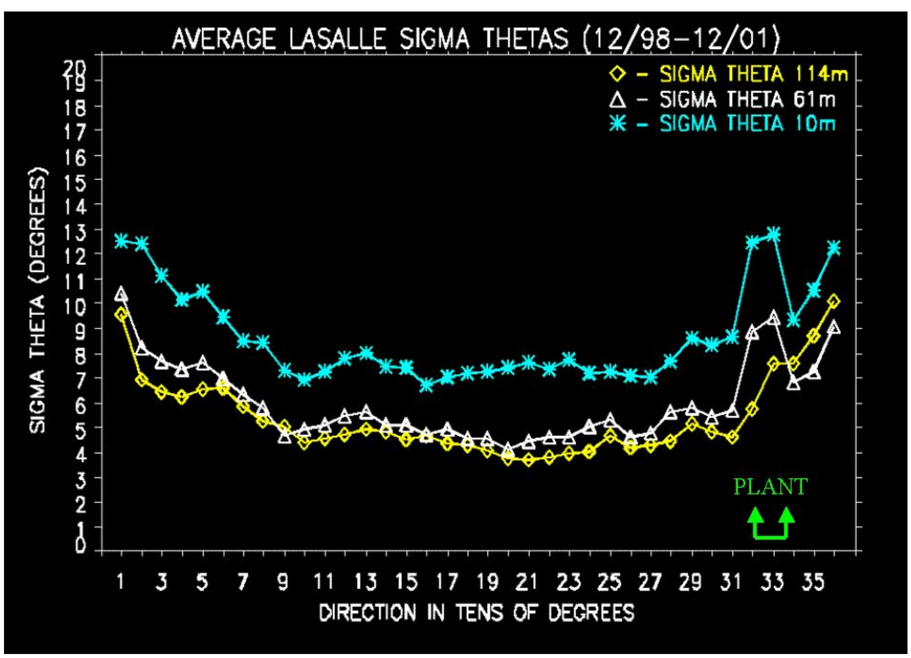
d) LaSalle site:

Shown below are an aerial photograph of the LaSalle site and a graph of the average Lasalle sigma thetas. A yellow line shows the 114-meter average sigma thetas, a white line shows the 61-meter average sigma thetas, and a cyan line shows the 10-meter average sigma thetas. The location of the plant is also shown on this graph.

This site is almost completely devoid of trees. The only peaks in any sigma thetas are for winds from 310º-330º and are directly downwind of the turbulence created by the plant. The impact of the plant decreases with height and almost none existent at the 114-meter level.

Sigma thetas at all levels exhibit a bowl shape, lower from the south and higher from the north, and may be the result of turbulence created as wind flows across and out of the Illinois River valley. Given that this site is located about 8 kilometers (5 miles) south of the Illinois River valley, this explanation seems plausible.

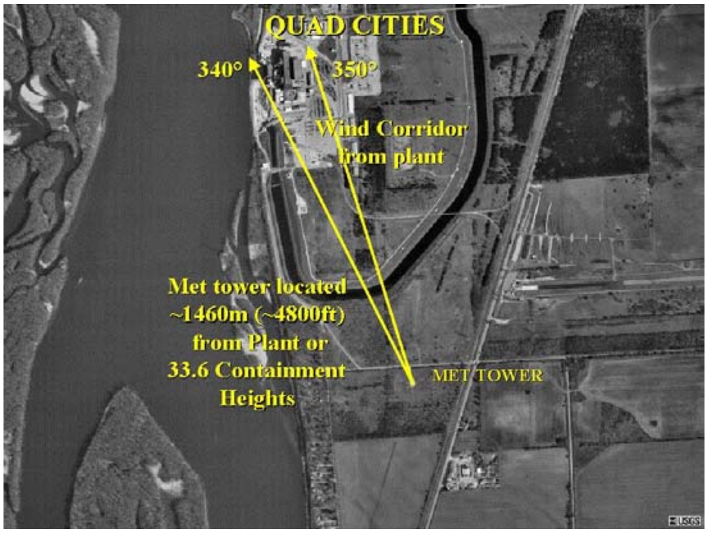


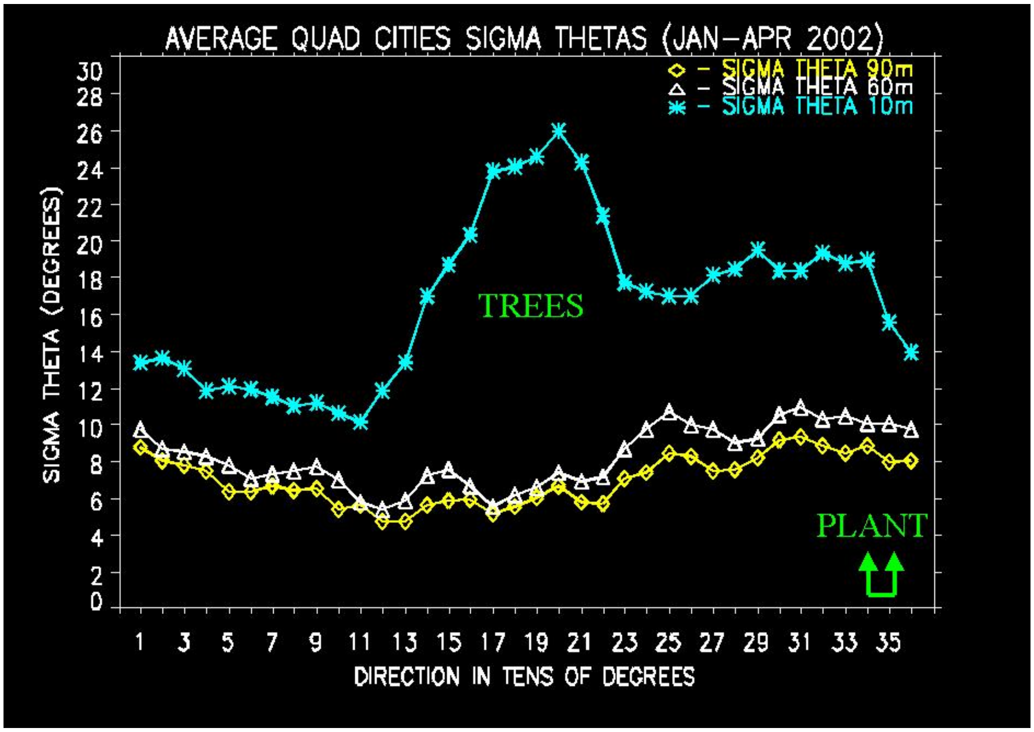


e) Quad Cities Site:

Shown below are an aerial photograph of the Quad Cities site and a graph of the average Quad Cities sigma thetas. A yellow line shows the 90-meter average sigma thetas, a white line shows the 60-meter average sigma thetas, and a cyan line shows the 10-meter average sigma thetas. The locations of the plant and nearby trees are also shown on this graph.

This site has an extensive, continuous stand of trees encircling the tower from 120º-330º about 100 meters from the tower. The trees are very dense within the 120º-220º corridor. The trees impact the 10-meter sigma thetas and the peaks are most pronounced where the densest trees occur. As a result, sigma thetas from this corridor are almost always classified improperly as unstable (Class A). Not depicted in the data, the impact on the 10-meter sigma thetas is greatly enhanced as the nearby trees develop leaves. No impact from the plant is seen due to the distance of the plant from the tower and the orientation of the plant buildings.

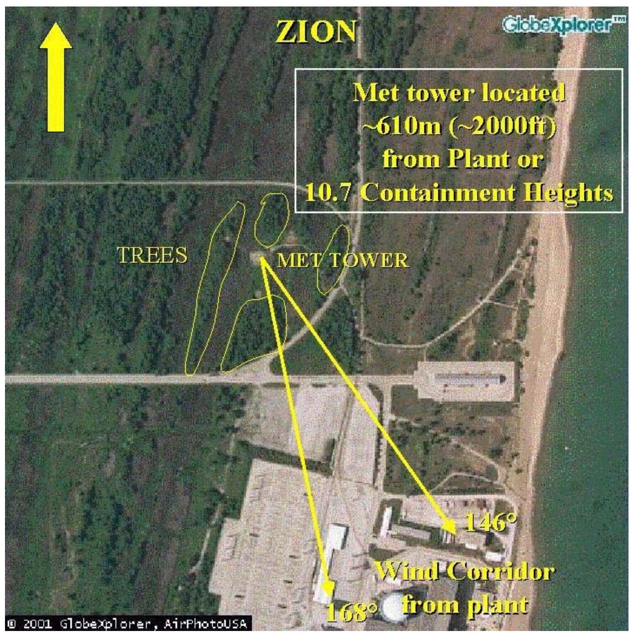


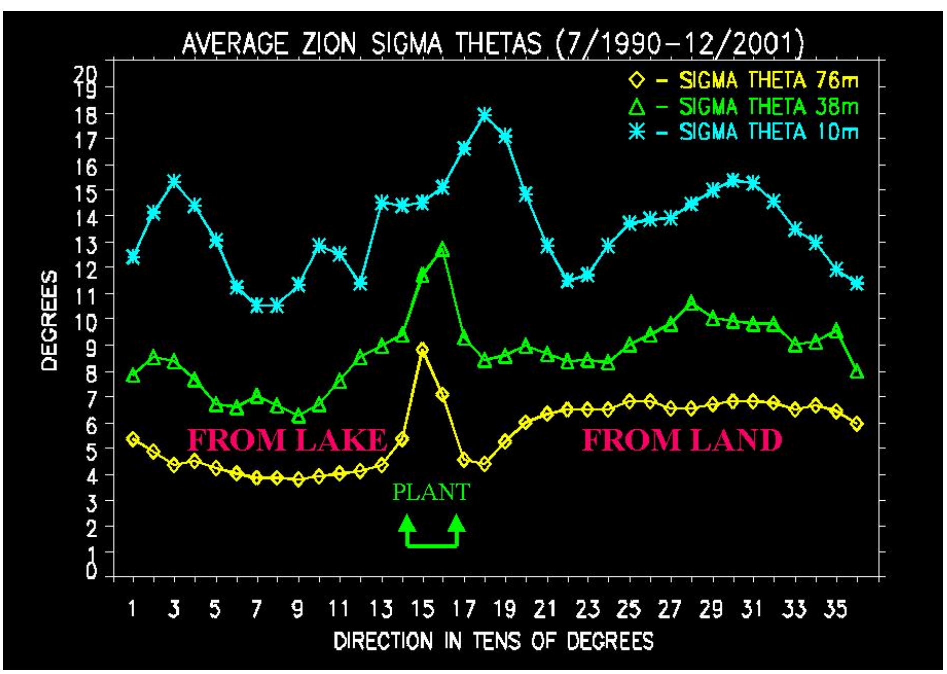


f) Zion site:

Shown below are an aerial photograph of the Zion site and a graph of the average Zion sigma thetas. A yellow line shows the 76-meter average sigma thetas, a green line shows the 38-meter average sigma thetas, and a cyan line shows the 10-meter average sigma thetas. The location of the plant is shown on this graph.

Since this site is located within the Illinois Beach State Park, numerous trees located about 60 meters from tower generally surround the site. The trees are the densest in the corridors from 0º-45º, 155º-200º, and 245º-325º. Higher peaks caused by trees in the 10-meter sigma thetas are found in these corridors. Turbulence caused by plant buildings and containment are seen as sharp peaks in sigma thetas at the 38-meter and 76-meter levels. The effect of Lake Michigan is also seen in the 76-meter and 38-meter level sigma thetas. Sigma thetas for wind flow with long, friction-free fetches from Lake Michigan are a few degrees less than those coming over land.





5. SUMMARY

This study provides the following useful information to those obtaining and using wind measurements from the northern Illinois nuclear power plants:

a) It identifies the wind corridors where wind measurements may be impacted by nearby structures and trees.
b) It stresses the importance of initially selecting a good site for the meteorological tower and conducting proper maintenance of the area around the tower.
c) It depicts the strength of building wake effects downwind from nuclear power plants and stresses the importance of using a building wake algorithm in any atmospheric modeling and dose assessment.
d) It underscores the need to use sigma thetas for stability classification with great care.
e) It shows that any topographic features, including small and large lakes, can affect atmospheric transport and dispersion.
f) It should caution modelers in using the meteorological data from one tower site and applying it to broad areas without accounting for various local features.

6. REFERENCES

Crawford, T.V., Meteorological Measurements for Emergency Response, Meteorological Aspects of Emergency Response, American Meteorological Society, 1990, 15-36.

Determining Meteorological Information at Nuclear Facilities, ANSI/ANS-3.11-2000.