Exelon Victoria County Station EPZ
Siren Acoustic Study

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1.0 Executive Summary

The overall objective for this study was to determine the acoustical coverage of Exelon Victoria County Station's (VCS) Omni directional outdoor warning sirens located in the VCS Emergency Planning Zone (EPZ). The acoustic map(s) (see Appendix A for maps) depicts the sound contours (effective coverage areas) of the sirens to be placed in the VCS EPZ at 60dBc and 70dBc, as appropriate to existing population densities (based on the 2000 U.S. Census), overlaid on a base map containing features which may include topography, local roads, bodies of water, parks, forests, municipal boundaries and boundaries of the EPZ.

This study was performed by engineering calculations incorporating site walkdown information. The site is a proposed "Greenfield" site that currently has no active power station. FEMA guidance NUREG-0654/FEMA-REP-1 and FEMA-REP-10 both define how the report should be structured when performing a siren system analysis. FEMA-REP-10 recommends the use of the FEMA CPG 1-17 10dB attenuation factor when field data is not available. NUREG-0654/FEMA-REP-1 defines the coverage requirements for the system as being:

- For areas with population densities greater than 2000 people per square mile, the system must be designed to produce a minimum of 70dBc. There are no areas with these population densities in the EPZ according to the US Census Bureau report for 2000.
- For areas with population densities less that 2000 people per square mile, the siren system must produce a minimum of 60dBc.

For this study, sirens were placed to provide complete coverage within the EPZ without reference to other warning mechanisms which may or may not be employed at the plant.

This study used the Whelen WPS2910 Siren series with a sound pressure level (SPL) of 126dBc @ 100' for determination of expected sound coverage. While the manufacturer's recent literature has upgraded the WPS2910 SPL to 129 dBc@100', previous empirical data shows that typical field measurements have been 3 dB lower than peak, on average. Furthermore, other national manufacturer's literature shows that they can achieve this level within +/- 2dB of rated output, which would provide the plant a choice of manufacturers when the system is implemented.

This report is not intended to recommend any particular siren manufacturer. Other manufacturers meeting or exceeding this sound pressure level should achieve similar results.

2.0 References

"Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," U.S. Nuclear Regulatory Commission and Federal Emergency Management Agency, NUREG-0654/FEMA-REP-1, Rev. 1, Washington D.C., November 1980.

"Guide for the Evaluation of Alert and Notification Systems for Nuclear Power Plants," FEMA-REP-10, November 1985.

"Out Door Warning Systems Guide," FEMA CPG 1-17, March 1, 1980.

3.0 Terms, Definitions, Acronyms

ANSI – American National Standards Institute.

Decibel (dB) – Unit of measurement for sound pressure level. The data collected for this study used the C-weighted scale (dBc).

Estimated Coverage – Coverage determined in this report through calculations and field data.

FEMA – Federal Emergency Management Agency.

EPZ – Emergency Planning Zone.

Predicated Coverage – Coverage used to determine test points for this study.

Sound Pressure Level (SPL) – In decibels, ten times the common logarithm of the square of the ratio of the sound pressure to the reference sound pressure of 20 micropascals.

$$dB = 10Log_{10}\left(\frac{p_x}{p_r}\right)^2$$

USGS – United States Geological Survey.

Whelen Engineering, Inc. – Siren manufacturer for the sirens studied in this report. See product literature for additional information. http://www.whelen.com.

4.0 Process

This study was performed using engineering calculations and incorporating site walkdown information without the gathering of sound data for the siren system. The field walkdown was done to ensure no large buildings or geological features would interfere with the acoustic path of the sirens. FEMA guidance FEMA-REP-10 defines the methods to be employed for studies without field data when developing a design report:

> "The sound contours may be based on Appendix 3 of NUREG-0654/ REMA-REP-1, Revision 1, including the use, in the absence of intervening topographical features, of the 10dB loss per distance doubled sound attenuation factor used in FEMA CPG 1-17. However, topographical features that act as sound barriers must be considered in such contour calculations."

FEMA-REP-1 Appendix 3 defines the sound levels the system must achieve in reference to population density. For areas with population densities greater than 2000 people per square mile, the system must be designed to produce a minimum of 70dBc. For areas with population densities less that 2000 people per square mile, the siren system must produce a minimum of 60dBc. Population density for this report was based on the U.S. 2000 Census. The smallest geographic area that the Census Bureau defines is the "Block." A map depicting these blocks is not included as there is no area, as shown by the U.S. Census of 2000, that meets these population levels.

5.0 Data Analysis/Findings

5.1 Objective/Criteria

Develop a siren sound level contour map for the Victoria County Station (VCS) Emergency Planning Zone (EPZ). The map will depict the sound contours (effective coverage areas) of the sirens to be located in the VCS EPZ at 60dBc and 70dBc, as appropriate to existing population densities (based on the 2000 U.S. Census), overlaid on a base map containing features which may include topography, local roads, bodies of water, parks, forests, municipal boundaries and boundaries of the EPZ.

5.2 Siren Specifications Utilized

The siren equipment utilized for purposes of calculations for this report was the Whelen WPS2910 Siren Series with an SPL rating of 129dBc @100'. Based upon empirical evidence obtained at other sites, this siren was de-rated to 126dBc for the initial SPL used for the calculations. In addition to the expected attenuation at the 410-650Hz frequency, SAFER included an additional 15% de-rating factor to account for the extreme effects of wind in the surrounding area. Utilizing the sound calculations herein, SAFER calculated an estimated 0.7735 mile radius of 70dB coverage for each siren and an estimated 1.547 mile radius of 60 dB coverage for each siren.

5.3 Exelon Victoria Initial Walkdown

To accurately assess the surrounding area of the Exelon Victoria County Station within the EPZ, a tour of the site was conducted on May 30th, 2008. No prominent geological features such as large hills or rivers were found that would severely obstruct the path of sound from the sirens. The San Antonio and Guadeloupe rivers that run through the site do not contain fast moving water so the SPL should not be noticeably attenuated by these features. Examples of the surrounding terrain are shown in Appendix B. Most of the area is farmland and grasslands with sparse populations throughout. The only populated area within the EPZ is a town called Bloomington west of the plant. Four (4) sirens were placed around this area to ensure the necessary coverage for the population. The ambient sound readings were well within the bounds of the calculations performed.

5.4 Engineering Analysis

5.4.1 Nature of Sound

In performing an acoustic analysis, there are several key aspects of sound that must be understood in order to interpret the collected data.

First, sound pressure levels are dynamic. These levels may change depending upon the background conditions, environmental changes, topography over which the sound wave travels and many other factors contributing to the propagation of sound waves from the emanating source to the final measuring device.

Second, sound waves are subject to the principal of superposition. They can be added together to increase the sound pressure level at a given point or they can be canceled out thereby decreasing the sound pressure level at a given point. In either case, the recorded sound pressure level at a given point may change depending upon the reflecting boundaries present in the field of study (i.e., large buildings or rock formations) or the presence of other interfering sound waves.

5.4.2 Sound Attenuation

Sound decreases in magnitude proportional to its distance from its source. This decrease is called attenuation with distance, and it is caused by a number of factors. Typically, as the distance from the source is doubled, starting from an initial reference distance, the loss in decibels is 6.0dB. FEMA, in CPG 1-17 states that a loss of 10dB per distance doubled should be used when doing acoustical propagation. This loss factors in variables such as: attenuation caused by ground effects, barriers, atmospheric refraction, and absorption by the atmosphere. The amount of sound available to warn a listener can be calculated with the following equation:

Amount of sound available to warn, in dBc	=	Sound output of audible warning device, in dBc	-	Attenuation with distance, in dBc	-	Other attenuation factors (wind, humidity, etc.)

All of these factors suggest that a warning sound must be loud enough to overcome attenuation with distance, to exceed the background noise, and to attract attention. Yet, it cannot be too loud or there is risk of injuring the hearing of the people who may be listening.

For urban (>2000ppl/mi^2) areas, an ending sound pressure level of 70dBc was used per FEMA CPG 1-17 “Guide To Outdoor Warning Systems” and NUREG-0654/FEMA-REP-1 to calculate the expected distance or radius of coverage for each siren during the testing phase. To approximate a 10dB per distance doubled model, the following formula was used:

$$ESP = BSP - \left[A_f \left(\log_{10} \left(\frac{D_2}{100} \right) \right) \right]$$ (Equation 1)

where,

ESP = Ending Sound Pressure level
BSP = Beginning Sound Pressure level
A_f = Attenuation factor (≈ 33.3 for the 10dB per distance doubled model)
D = Distance from source (or the radius of coverage of the siren)

Solving for D,

$$D = 100(10^{\frac{BSP-ESP}{A_f}})$$ (Equation 2)

5.4.3 Calculation Assumptions

While it is beyond the scope of this report to fully explain the nature of sound, the above points illustrate the caution that must be incorporated in analyzing sound data for a given system. This report, in an attempt to be conservative, uses the FEMA value of 10dB loss per distance doubled sound attenuation factor when generating this report. It should be noted that the actual attenuation factor for the area surrounding Exelon Victoria County Station may be more or less. Because no siren acoustic data for the model of siren studied was provided for this report, the 10dB loss per distance doubled sound attenuation factor was chosen as recommended by FEMA-CPG 1-17.

5.4.4 System Analysis

For the final system analysis, different factors were taken into account. Distance from source, topography, and terrain. The 10dBc per distance doubled model that was described previously is used in determining final coverage.

Topography is a factor that is easy to observe, but can be difficult to calculate. Many factors such as hills, depressions or valleys, bodies of water, trees, and grass all create different acoustical surfaces for which the sound reacts. USGS maps and information collected were used in determining what effect they would have. Geographical features were included in the analysis. Engineering experience and judgment were then used to take these factors into account when determining the sound coverage.

Each siren's estimated output was used when generating isopleths of the acoustic output. This map contains isopleths for the 70dBc and 60dBc acoustic levels determined during analysis.

6.0 Recommendations

SAFER recommends that the Victoria County Station install sixty-eight (68) sirens rated at a minimum of 126dB @100' (for field measured results) throughout the EPZ as shown on the map in Appendix A. Please note, the area excluded from the 60 dB isopleths is the plant reservoir area, which does not require coverage. All remaining areas are covered as shown.

SAFER offers no guarantee that the recommended number or placement of sirens will be adequate to achieve the required coverage. Many factors can affect the actual field placement of the sirens such as obtaining land easements. Additionally, field factors (i.e. new subdivision, commercial development, etc.) may change the overall ambient levels affecting the ultimate coverage area of the installed sirens. SAFER therefore recommends that a field acoustic study be performed after the sirens are installed to record actual field sound levels achieved and compare against the expected coverage calculations. Siren placements may need to be adjusted or added depending upon the results of this study.

7.0 Engineering Statement

The results of this study are valid for current field conditions and time period only. No warranty, either written or verbal, is implied. This report is offered for information only. All final decisions for proper siren purchase and placement are left to the customer's discretion.

8.0 Appendices

Appendix A – EPZ Sub Areas and Siren Acoustical Coverage Map
Appendix B – Pictures of the EPZ
Appendix C – Latitude and Longitude of Siren Locations

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Appendix A
EPZ Sub Areas and Siren Acoustical Coverage Map

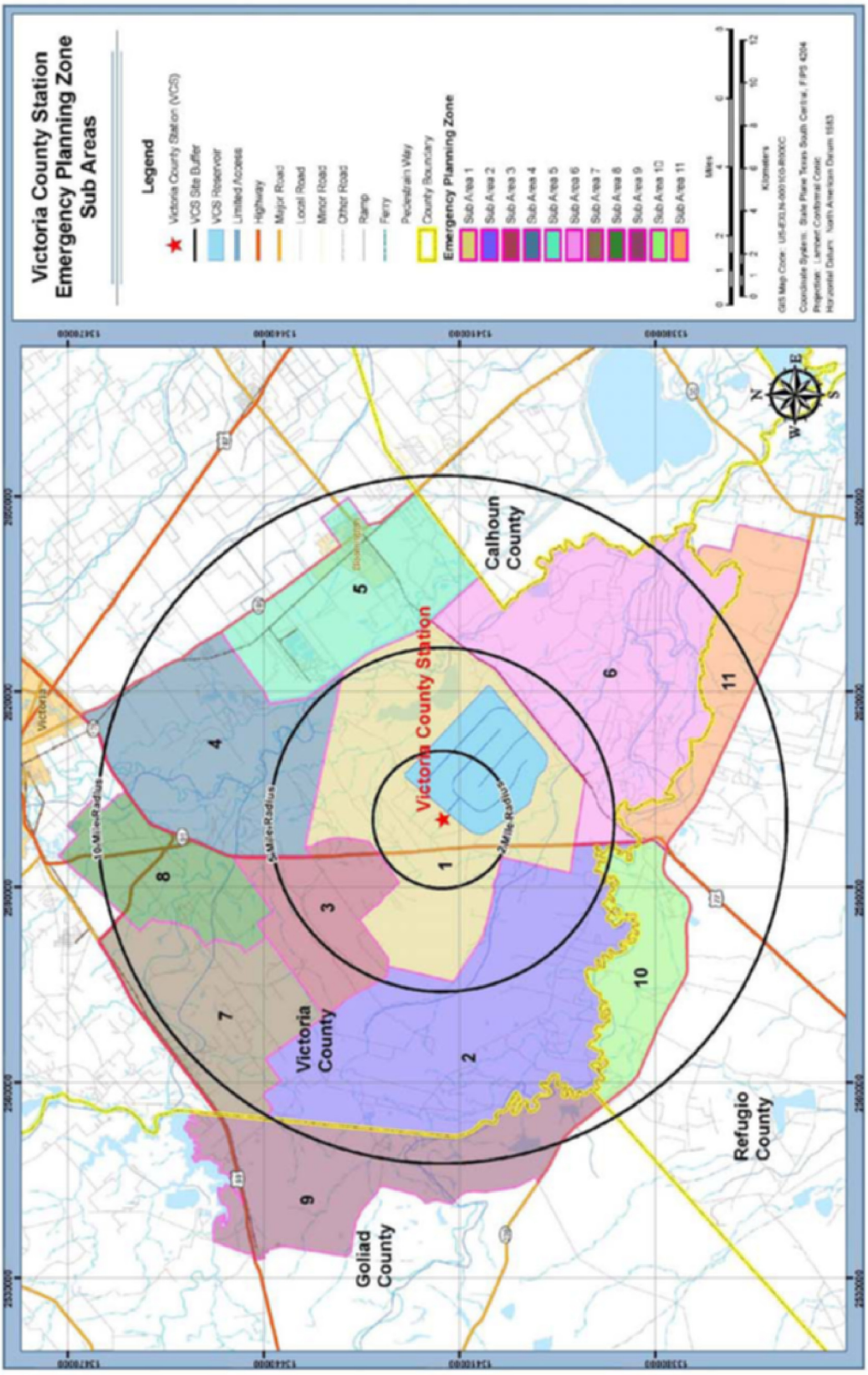

Figure A1 – Proposed VCS EPZ Sub Areas

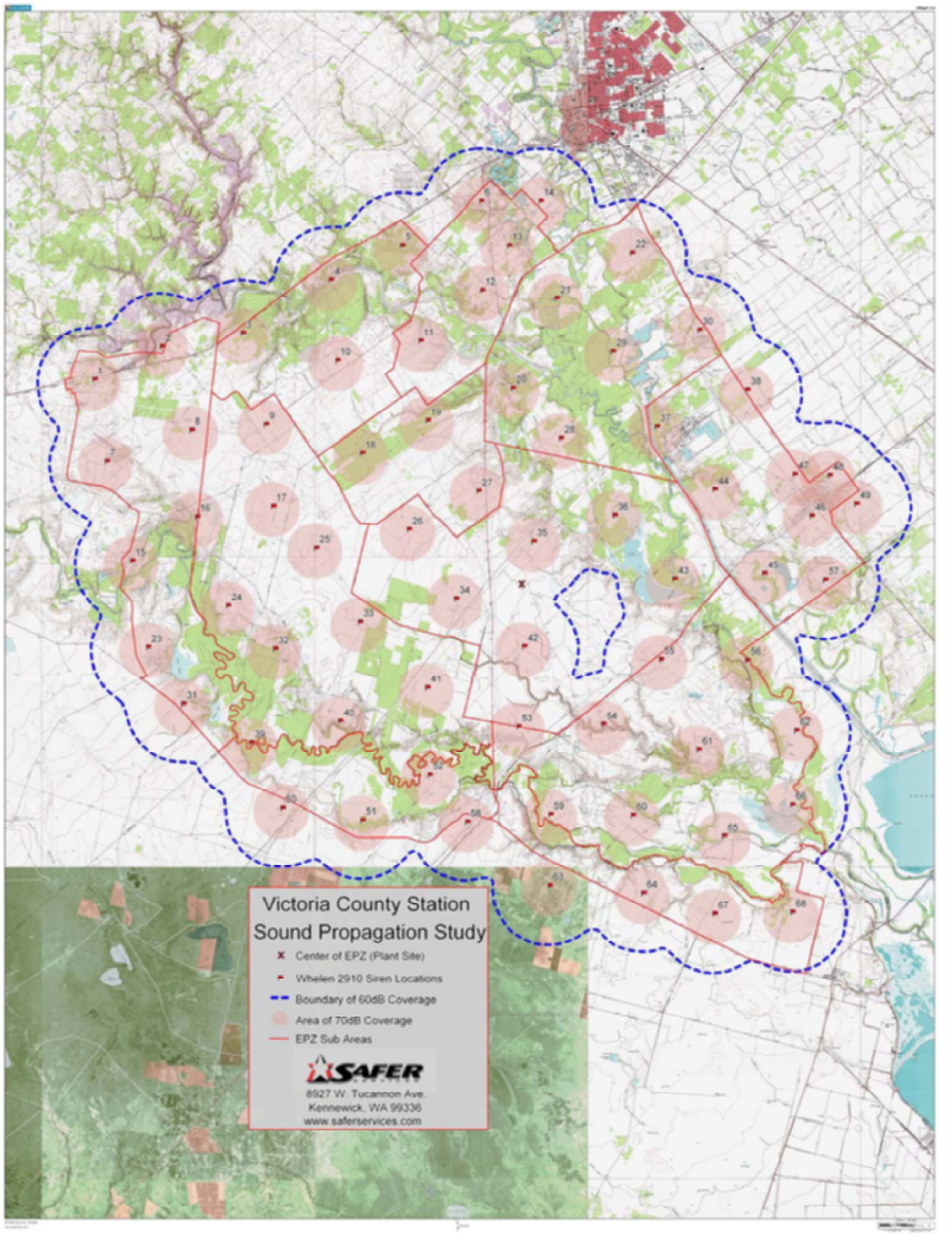

Figure A2 – Proposed VCS EPZ Siren Locations and Coverage

Appendix B
Pictures of the EPZ (Typical)






Appendix C
Latitude and Longitude of Siren Locations

Siren Number	Latitude	Longitude	Siren Number	Latitude	Longitude
1	28.694959	-97.226659	35	28.629942	-97.02552
2	28.708155	-97.195838	36	28.640563	-96.988498
3	28.713627	-97.15878	37	28.675969	-96.96907
4	28.73487	-97.11842	38	28.690774	-96.927649
5	28.74871	-97.085765	39	28.549154	-97.154915
6	28.766413	-97.049485	40	28.557844	-97.114227
7	28.662128	-97.221155	44	28.650863	-96.942679
8	28.674681	-97.182263	41	28.571362	-97.074272
9	28.676934	-97.14814	42	28.587778	-97.029919
10	28.702683	-97.115485	43	28.614814	-96.961006
11	28.710408	-97.077326	45	28.617067	-96.919952
12	28.730686	-97.049074	46	28.640327	-96.898299
13	28.748667	-97.03674	47	28.656979	-96.906023
14	28.766413	-97.022316	48	28.656549	-96.890082
15	28.622217	-97.209417	49	28.64507	-96.877798
16	28.63992	-97.179697	50	28.522761	-97.140619
17	28.644104	-97.14484	51	28.517933	-97.103963
18	28.665347	-97.104113	52	28.536279	-97.073173
19	28.678458	-97.074027	53	28.555591	-97.032485
20	28.691418	-97.035135	54	28.556557	-96.99363
21	28.727467	-97.014951	55	28.582628	-96.967238
22	28.745813	-96.980462	56	28.582306	-96.92765
23	28.587456	-97.2022	57	28.614492	-96.892094
24	28.604193	-97.165545	58	28.517289	-97.055945
30	28.714914	-96.949643	59	28.520186	-97.017823
25	28.627367	-97.125223	60	28.519864	-96.980068
26	28.63477	-97.082703	61	28.546257	-96.95001
27	28.650219	-97.050812	62	28.553982	-96.90529
28	28.671463	-97.013057	63	28.49154	-97.018189
29	28.706224	-96.98927	64	28.488643	-96.975302
31	28.564925	-97.186072	65	28.511496	-96.93828
32	28.586812	-97.143918	66	28.524048	-96.907123
33	28.597755	-97.105063	67	28.480275	-96.942656
34	28.60709	-97.061076	68	28.480918	-96.907123