Exponent®

*Electrical Engineering and Computer Science Practice*

# Magnetic Field Assessment

# Ocean City 138th Street Substation

# May, 2018

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Prepared for

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# Contents

# List of Figures

# List of Tables

# Limitations

At the request of Delmarva Power & Light (Delmarva), Exponent measured the magnetic-field levels associated with the 138th Street Substation in Ocean City, Maryland. This report summarizes work performed to date and presents the findings resulting from that work. Delmarva has confirmed to Exponent that the data contained herein are not subject to Critical Energy Infrastructure Information restrictions. Although Exponent has exercised usual and customary care in the conduct of this analysis, the responsibility for the design and operation of the project remains fully with the client.

The findings presented herein are made to a reasonable degree of engineering and scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein for other than permitting of the project are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

# Executive Summary

Delmarva Power & Light (Delmarva) has upgraded the existing 138th Street Substation in Ocean City, Maryland, by adding a Static VAR Compensator for line voltage regulation. At the request of Delmarva, and to fulfill the requirements of the Conditional Use Agreement #12-12100002, Exponent measured the levels of 60-Hertz magnetic fields at the boundary of the properties across the streets surrounding the substation, as well as along eight transects extending outward into the adjacent residential areas. Post-construction measurements taken semi-annually around January and July since June 2014 have been reported previously.

Measurements were performed between approximately 11:30 PM on May 21 and 1:00 AM on May 22, 2018. The highest measured magnetic-field level around the perimeter of the 138th Street Substation was approximately 33 milligauss (mG) and, consistent with previous measurements, was recorded south of the substation along 137th Street in front of the adjacent water treatment plant. Away from the substation perimeter, the highest recorded magnetic-field level along any of the transects extending into the residential areas was approximately 9.6 mG, more than 350 feet away from the substation. All measured magnetic-field levels were many times lower than the reference levels published by the International Commission on Non-Ionizing Radiation Protection and the International Committee on Electromagnetic Safety. The reference levels for maximum permissible exposure of the general public published by those organizations are 2,000 mG and 9,040 mG, respectively.

# Introduction

## Background

Delmarva Power & Light (Delmarva) upgraded the existing 138th Street Substation in Ocean City, Maryland, by adding a Static VAR Compensator (SVC) for line voltage regulation. At the request of Delmarva, and in accordance with Conditional Use Agreement #12-12100002, dated January 7, 2013, Exponent measured the levels of 60-Hertz (Hz) magnetic fields at the boundary of the properties across the streets surrounding the substation, as well as along eight transects extending outward into the adjacent residential areas. The measurements provided herein were recorded between approximately 11:30 PM on May 21 and 1:00 AM on May 22, 2018. Measurements have previously been taken semi-annually around January and July since June 2014.

## Technical Background

All things connected to our electrical system—power lines; wiring in our homes, businesses, and schools; and all electric appliances and machines—are sources of magnetic fields. In North America, most electricity is transmitted as alternating current (AC) at a frequency of 60 cycles per second measured in Hz (i.e., 60 Hz). The magnetic fields from these AC sources are commonly referred to as power-frequency or extremely low frequency magnetic fields.

## Magnetic Fields

As mentioned above, magnetic fields are produced by any source that generates, transmits, or uses electricity. Electricity travels as current from distant generating sources on high-voltage transmission lines to substations, then on to local distribution lines, and finally to our homes and workplaces for consumption. The strength of a magnetic field is expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G = 1,000 mG. In general, the strength of a magnetic field increases as the current increases, but the strength also depends on characteristics of the source—in the case of transmission lines, this includes the arrangement and separation of the conductors. Magnetic fields that result from the flow of electric currents through wires and electrical devices are not easily blocked by conducting objects.[1]

The intensity of magnetic fields diminishes with increasing distance from the source. Also, since the strength of magnetic fields associated with the transmission system varies depending on load conditions (i.e., the amount of current flowing in a conductor), the strength of magnetic fields from a particular source (such as transmission lines, distribution lines, and substation equipment) typically changes with time as the demand for electricity varies.

## Magnetic Field Guidance

Neither the federal government nor the state of Maryland has enacted standards for magnetic fields from transmission lines or other sources at power frequencies; however, two international scientific organizations—the International Committee on Electromagnetic Safety (ICES) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP)—have developed exposure limits to protect health and safety and are based on weight-of-evidence reviews and evaluations of relevant health research.[2] Table 1 summarizes the recommended exposure reference values put forth by these organizations. Exposure below these values comply with recommended limits on internal field levels but even higher levels also may comply following appropriate dosimetric assessments.

**Table 1. Reference values for whole body exposure to 60-Hz fields: general public**

| Organization | Magnetic field limits |
|---|---|
| ICNIRP (reference level) | 2,000 mG |
| ICES (maximum permissible exposure) | 9,040 mG |

[1] The electric field within the substation, unlike the magnetic field, is effectively blocked by the walls surrounding the substation and therefore does not significantly affect existing levels from other sources and was not measured.

[2] International Committee on Electromagnetic Safety (ICES). IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz C95.6-2002. Piscataway, NJ: IEEE, 2002, reaffirmed 2007; International Commission on Non-Ionizing Radiation Protection (ICNIRP). Limiting exposure to time-varying electric and magnetic fields. Health Phys 99:818-836, 2010.

# Measurements

Electrical elements that contribute to the magnetic fields in the vicinity of the substation include two 138-kilovolt transmission lines (13731 and 13732), four distribution circuits (429, 430, 431 and 432), as well as electrical elements within the substation itself such as transformers, buswork, and the SVC. The resulting levels of 60-Hz magnetic fields from all sources around the perimeter of the substation and along select transects perpendicular to the perimeter path were measured.

Magnetic-field measurements were conducted between approximately 11:30 PM on May 21 and 1:00 AM on May 22, 2018. The minimum, maximum, and average power loads (reported in mega-volt-amperes [MVA]) on the transmission lines, distribution lines, and substation equipment during these hours are summarized in Table 2. These loads represent snapshot measurements that reflect the current carried on the various circuit elements at the time of measurement. The loading values for each element are shown in Table 2. Average loadings for 2017 are provided for comparison.

**Table 2. Circuit loading**

| | Recorded Loading May 21 and 22, 2018 (11:30 PM to 1:00 AM) | | | |
|---|---|---|---|---|
| Element | Minimum (MVA) | Maximum (MVA) | Average (MVA) | 2017 Average (MVA) |
| 13732 | 12 | 14 | 13 | 26 |
| 13731 | 27 | 29 | 28 | 27 |
| 429 | 1.8 | 1.9 | 1.8 | 4.0 |
| 430 | 3.0 | 3.2 | 3.1 | 6.8 |
| 431 | 1.6 | 1.9 | 1.7 | 3.6 |
| 432 | 2.2 | 2.5 | 2.4 | 10.3 |
| SVC* | -45 | -41 | -44 | -43 |

*Units for SVC loading are reported in MVA, a measure of apparent power; the negative numbers indicate that the SVC is operating in an inductive mode (i.e., removing reactive power from the power system).

The strength of the magnetic field was measured in units of mG with a data-logging EMDEX II, 3-axis magnetic-field meter with survey wheel (the calibration certificate for the EMDEX II is included in Appendix A). This meter recorded the total (resultant) root-mean-square magnetic field and the magnetic field along the x, y, and z axes. This meter meets the IEEE instrumentation standard for obtaining accurate field measurements at power-line frequencies and appropriate measurement procedures were followed.[3]

Magnetic-field measurements were taken along nine paths in the vicinity of the substation. The first measurement path was along the outer perimeter of the city block containing the substation. Measurements were taken starting at the southwest corner of the intersection of 137th Street and Derrickson Avenue, and followed the sidewalk across the street from the substation in a counter-clockwise direction back to the original location (blue line in Figure 1). For reference, 31 locations are marked along the perimeter in Figure 1. These locations are detailed in Table 3.

**Table 3. Marked measurement locations along the outer perimeter measurement path presented in Figure 1**

| Measurement Marker | Measurement Location |
|---|---|
| A.0, A.1 | SW, SE corners of 137th Street & Derrickson Avenue intersection |
| A.2, A.3 | Locations opposite substation gates on S side of 137th Street |
| A.4, A.5, A.6 | SW, SE, NE corners of 137th Street and Sinepuxent Avenue intersection |
| A.7 | Parallel to the front door of Elks Lodge, along Sinepuxent Avenue |
| A.8, A.9, A.10 | SE, NE, NW corners of 138th Street and Sinepuxent Avenue intersection |
| A.11, A.12 | E, W edges of 13801A Sinepuxent Avenue* |
| A.13, A.14 | E, W edges of 204 138th Street* |
| A.15, A.16 | E, W edges of 206 138th Street* |
| A.17, A.18 | E, W edges of 208 138th Street* |
| A.19, A.20 | E, W edges of 13800 Derrickson Avenue, on 138th Street* |
| A.21, A.22 | NE, SW corners of 138th Street & Derrickson Avenue intersection |
| A.23, A.24 | N, S edges of 301 138th Street* |
| A.25, A.26 | N, S corners of S Bay Drive and Derrickson Avenue intersection |
| A.27, A.28, A.29 | N, Center, S of 13611 Derrickson Ave* |
| A.30 | SW corner of 137th Street and Derrickson Avenue intersection |

*Measurement pairs recorded at the edges of a specified address were aligned with the edges of the housing structure located at that address.

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[3] Institute of Electrical and Electronics Engineers (IEEE). IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 100 kHz (IEEE Std. C95.3.1-2010). New York: IEEE, 2010.

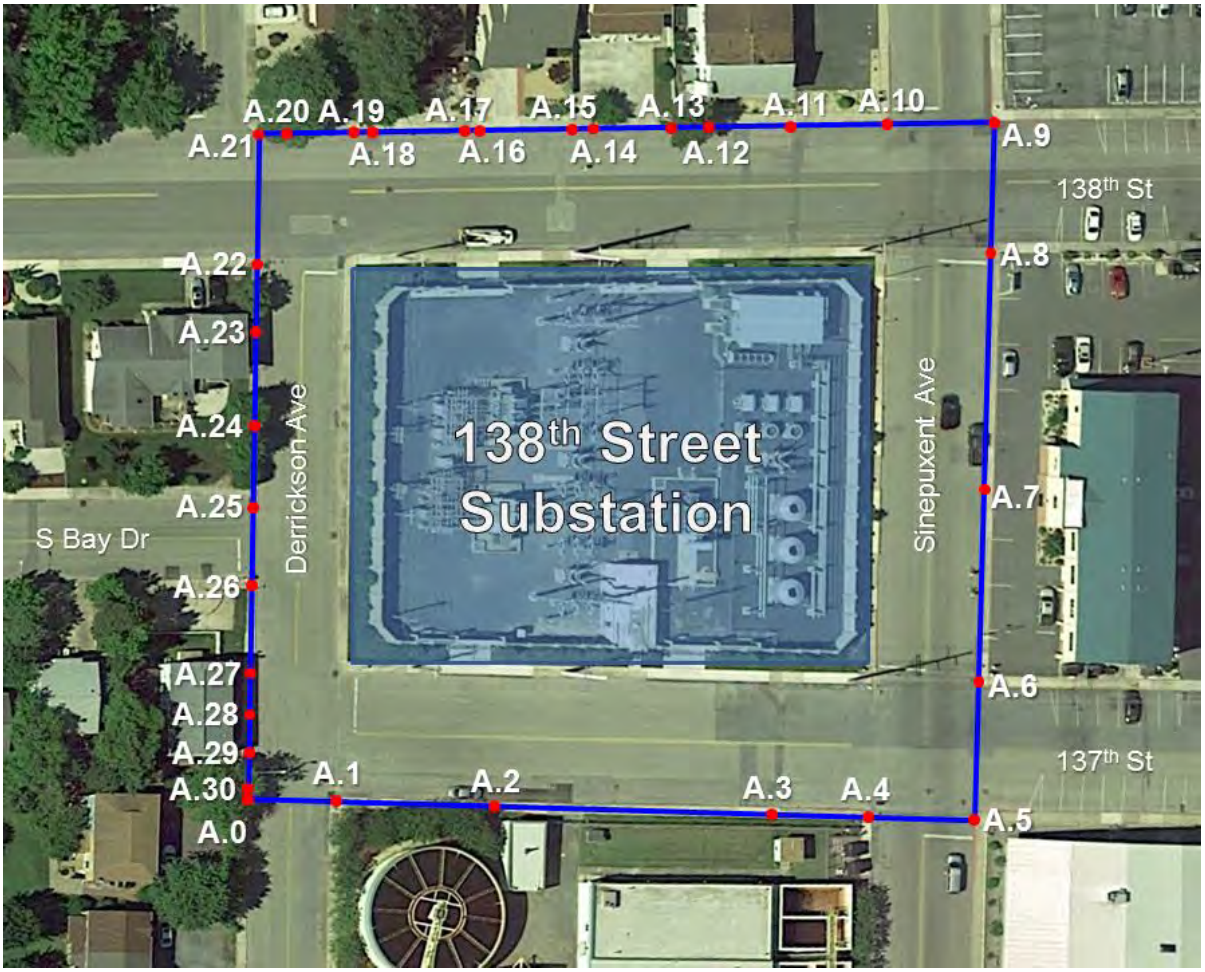


Figure 1. Aerial view of the 138th Street Substation between Derrickson Avenue and Sinepuxent Avenue showing the measurement path along the outer perimeter across the street from the substation.

The magnetic field was measured along the outer perimeter of the city block containing the substation as indicated by the blue path. Land markers A.0 – A.30 are shown for reference and are detailed in Table 3.

In addition to the perimeter measurements surrounding the substation, Exponent also measured the magnetic-field level as a function of distance along the eight separate transect locations shown in Figure 2. These transects recorded magnetic fields in front of all residences (on both sides of the street, when applicable) within at least 300 feet of the outer perimeter of the block containing the 138th Street Substation.[4]

- Transects B and C measure magnetic-field levels in front of all residences west of Derrickson Avenue and within approximately 350 feet of the substation block along the north and south sides of 138th Street, respectively.

- Transects D and E measure magnetic-field levels in front of all residences east of Derrickson Avenue and within approximately 400 feet of the substation block along the north and south sides of South Bay Drive, respectively.

- Transect F measures magnetic-field levels in front of all residences south of 137th Street and within approximately 325 feet of the substation block along the west side of Derrickson Avenue.

- Transects G and H measure magnetic-field levels in front of all residences north of 138th Street and within approximately 300 feet of the substation block along the west and east sides of Derrickson Avenue, respectively.

- Transect I measures magnetic-field levels in front of all residences north of 138th Street and within approximately 300 feet of the substation block along the west side of Sinepuxent Avenue.

[4] Magnetic-field measurements are presented in front of all residences bordering the substation block. These measurements are provided in the "perimeter measurement."


Figure 2. Aerial view of the 138th Street Substation showing transect locations.

The magnetic field was measured along each path starting at the lower index (e.g., B.0) closer to the substation and ending at the higher index (e.g., B.1) farther from the substation.

# Results and Discussion

Figure 3 shows the magnetic-field levels measured along the boundaries of the properties across the street from the substation along the measurement path. The median magnetic field measured around these properties was approximately 6.2 mG. The highest measured magnetic-field level in the vicinity of the substation was approximately 33 mG, recorded near the southwest corner of the intersection of 137th Street and Sinepuxent Avenue (between measurement locations A.3 and A.4). Away from this location, the next highest measured level of approximately 26 mG was recorded between the residences at 13801A Sinepuxent Avenue and 204 138th Street (between measurement locations A.12 and A.13 near what appears to be an underground electrical service). These locations correspond to the largest local peaks in the magnetic-field level shown in Figure 3.

Since magnetic-field levels decrease with increasing distance from the source, magnetic fields from the substation would be expected to decrease monotonically with increasing distance from the substation (e.g., as shown in Transect I, Figure 11). Measurements of the magnetic field along other transects going away from the substation in Figures 4 through 10, however, show higher (or in the case of Transect E, Figure 8, relatively flat) levels at various locations caused by the presence of local sources in the neighborhood surrounding the substation, primarily underground distribution lines and service lines to residences.[5] The maximum measurement along any of these transects was approximately 9.6 mG, observed along Transect B, at a distance of approximately 350 feet from the northwest corner of the intersection of 138th Street and Derrickson Avenue. The minimum, maximum, and median magnetic-field levels for each transect are summarized in

[5] Magnetic-field levels along Transects B and C are consistent with measurements parallel to an underground distribution line, while magnetic-field levels along Transects D, E, and F (out to a distance of approximately 200 feet) are generally flat. Magnetic-field levels on Transect G are consistent with approaching and then paralleling an underground distribution line, and magnetic-field levels on Transect H are consistent with crossing over an underground distribution line. Transect I shows a decrease in magnetic-field levels away from the overhead transmission line combined with paralleling an underground distribution line out to approximately 150 feet.

Table 4. An occasional local maximum was observed in these transect measurements that is consistent with the presence of underground cables.[6]

**Table 4. Summary of magnetic-field measurements at the outer perimeter and transects**

| | Magnetic Field (mG) | | |
|---|---|---|---|
| **Location** | **Minimum** | **Median** | **Maximum** |
| Perimeter A | 1.1 | 6.2 | 33 |
| Transect B | 3.1 | 5.7 | 9.6 |
| Transect C | 3.8 | 6.1 | 8.0 |
| Transect D | 1.7 | 2.9 | 4.2 |
| Transect E | 1.7 | 2.6 | 3.5 |
| Transect F | 1.4 | 3.0 | 3.6 |
| Transect G | 0.8 | 1.9 | 9.5 |
| Transect H | 0.3 | 0.7 | 8.6 |
| Transect I | 1.2 | 4.0 | 7.0 |

[6] Delmarva has communicated to Exponent that there are a number of underground distribution cables present in this area traveling away from the substation that provide electricity to local customers.

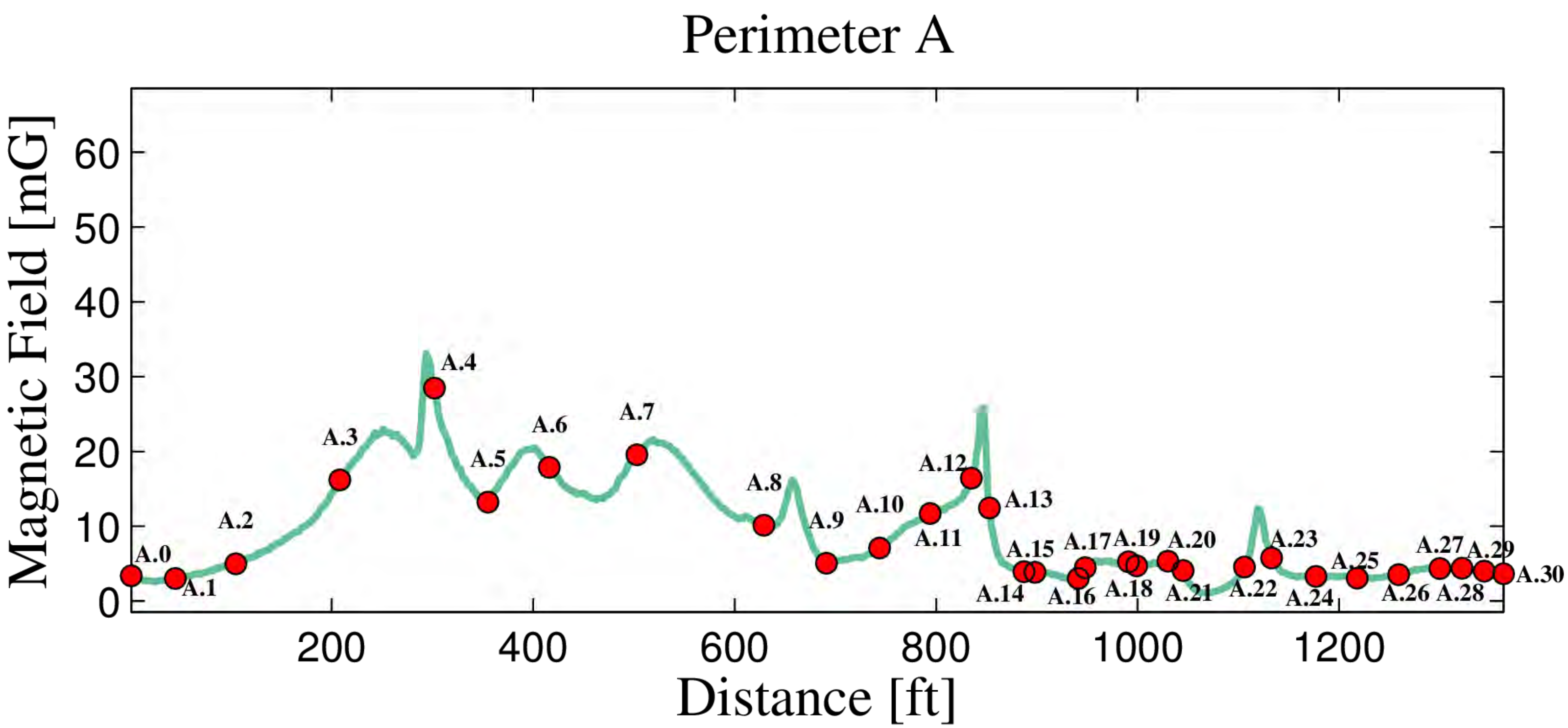


Figure 3. Resultant magnetic field measured around the perimeter of the substation as shown by the blue line in Figure 1.

Measurements started at the southwest corner of 137th Street and Derrickson Avenue and followed the sidewalk across the street from the substation in a counter-clockwise direction back to the original location.

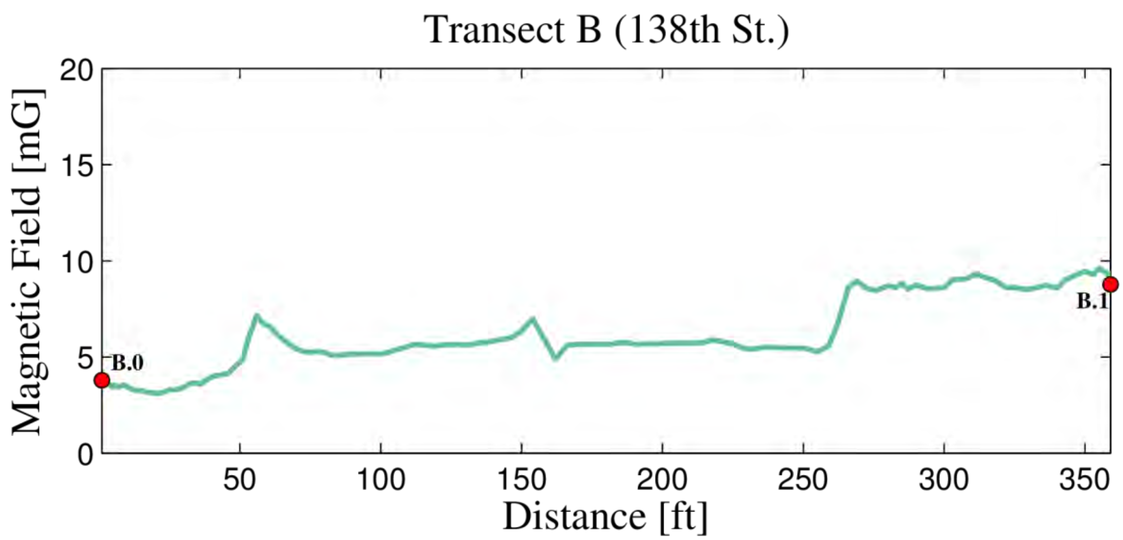


Figure 4. Resultant magnetic field measured along Transect B as shown in Figure 2.

Transect B starts at the northwest corner of the intersection of 138th Street and Derrickson Avenue and extends to the west.

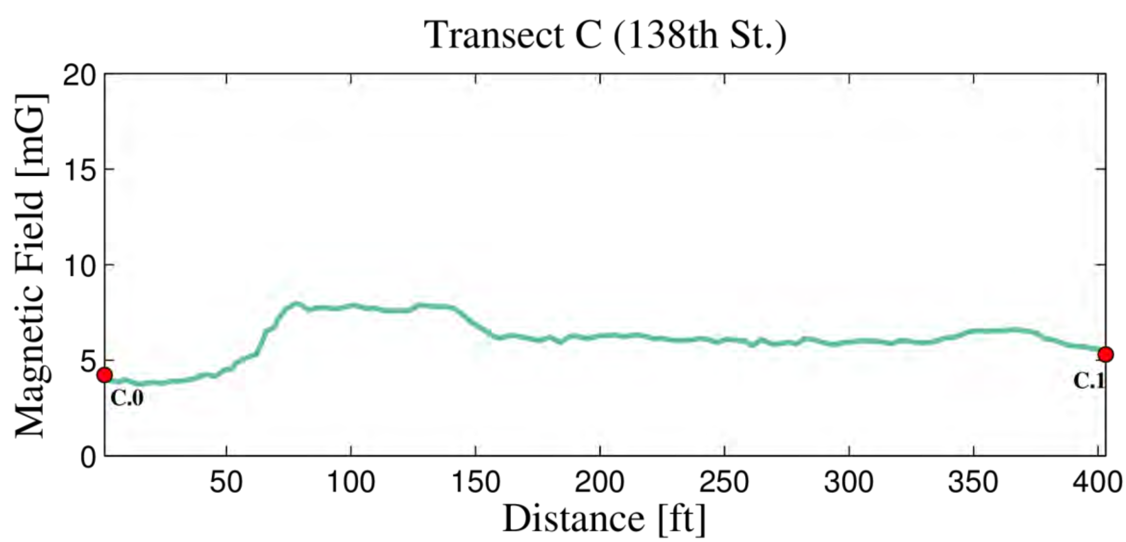


Figure 5. Resultant magnetic field measured along Transect C as shown in Figure 2.

Transect C starts at the southwest corner of the intersection of 138th Street and Derrickson Avenue and extends to the west.

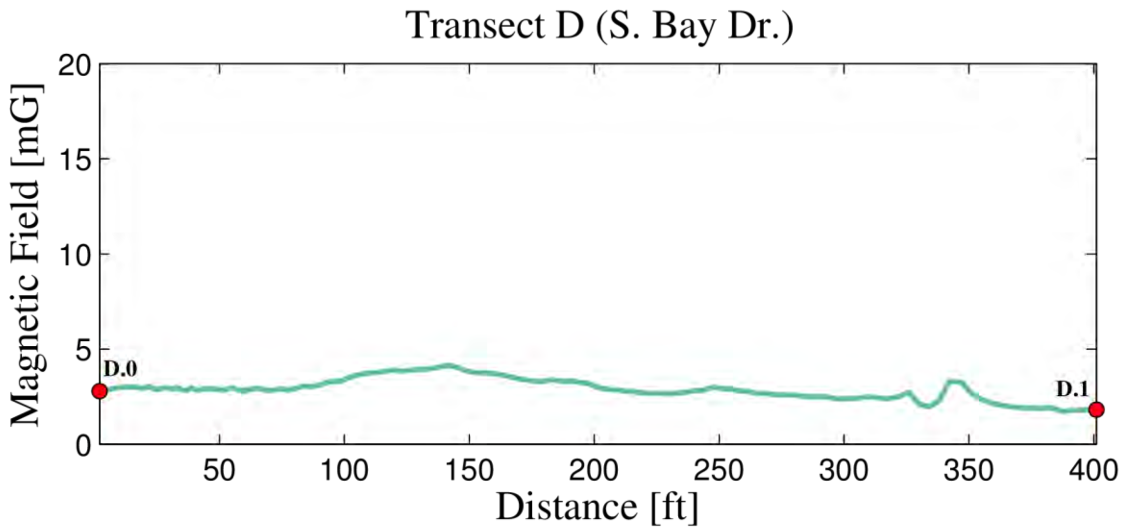


Figure 6. Resultant magnetic field measured along Transect D as shown in Figure 2.

Transect D starts at the northwest corner of the intersection of South Bay Drive and Derrickson Avenue and extends to the west.

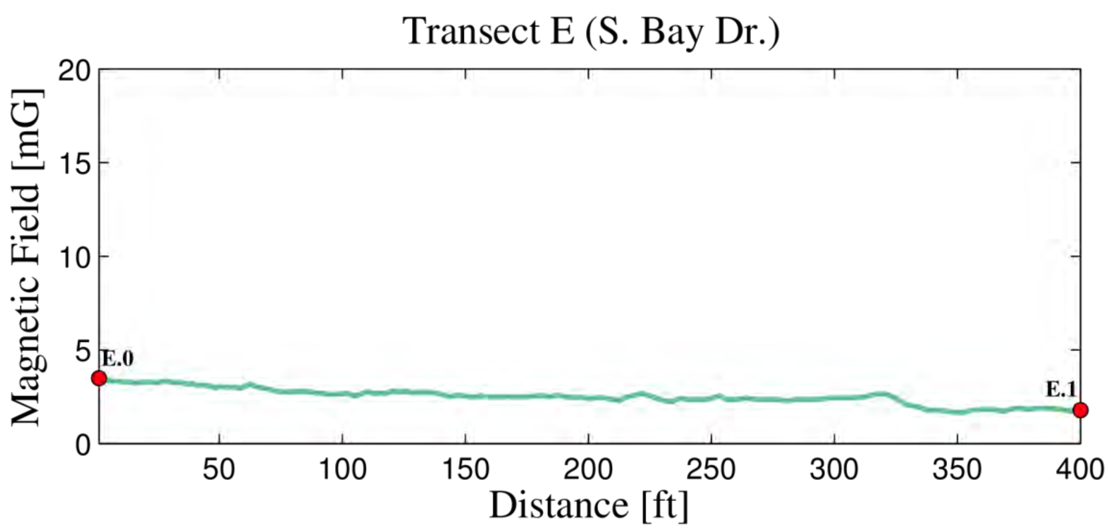


Figure 7. Resultant magnetic field measured along Transect E as shown in Figure 2.

Transect E starts at the southwest corner of the intersection of South Bay Drive and Derrickson Avenue and extends to the west.

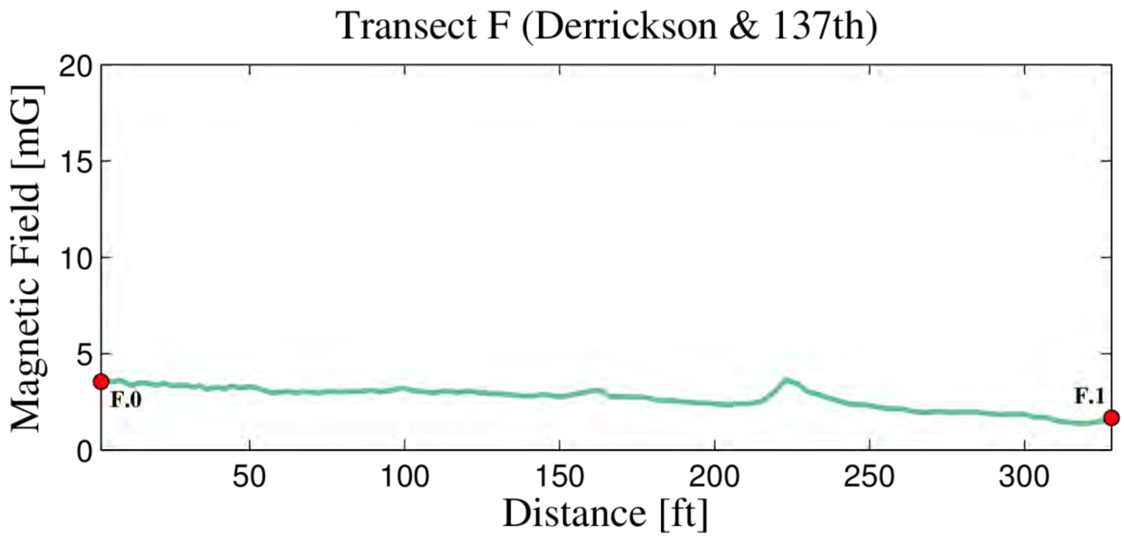


Figure 8. Resultant magnetic field measured along Transect F as shown in Figure 2.

Transect F starts at the southwest corner of the intersection of 137th Street and Derrickson Avenue and extends to the south.

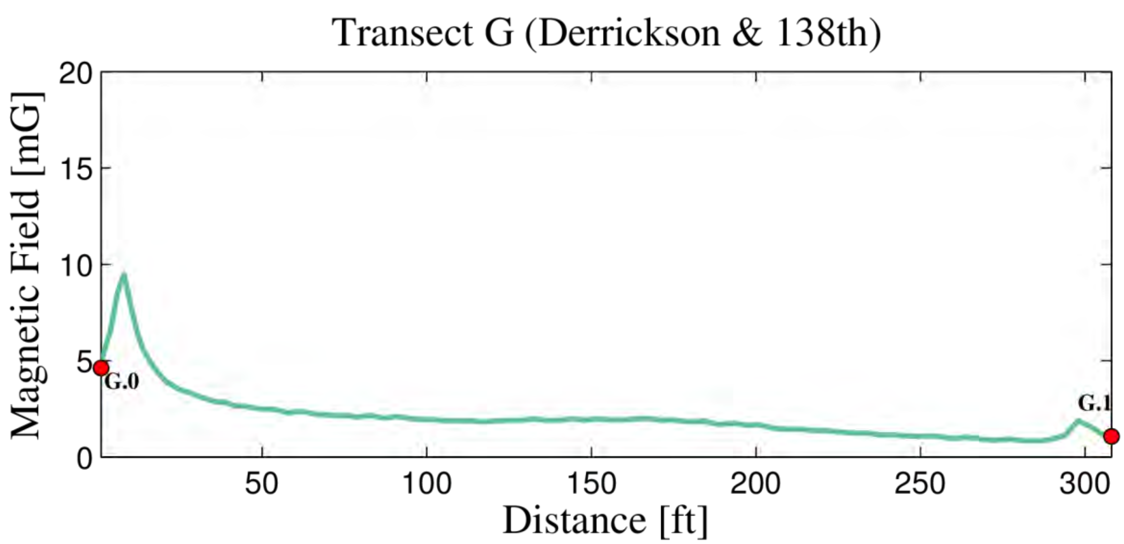


Figure 9. Resultant magnetic field measured along Transect G as shown in Figure 2.

Transect G starts at the northwest corner of the intersection of 138th Street and Derrickson Avenue and extends to the north.

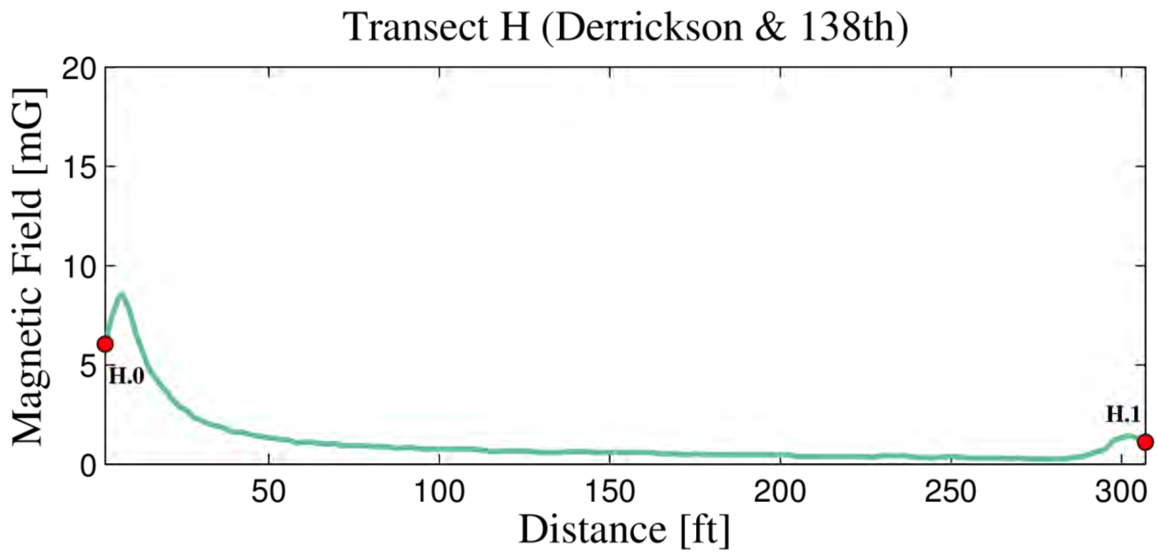


Figure 10. Resultant magnetic field measured along Transect H as shown in Figure 2.

Transect H starts at the northeast corner of the intersection of 138th Street and Derrickson Avenue and extends to the north.

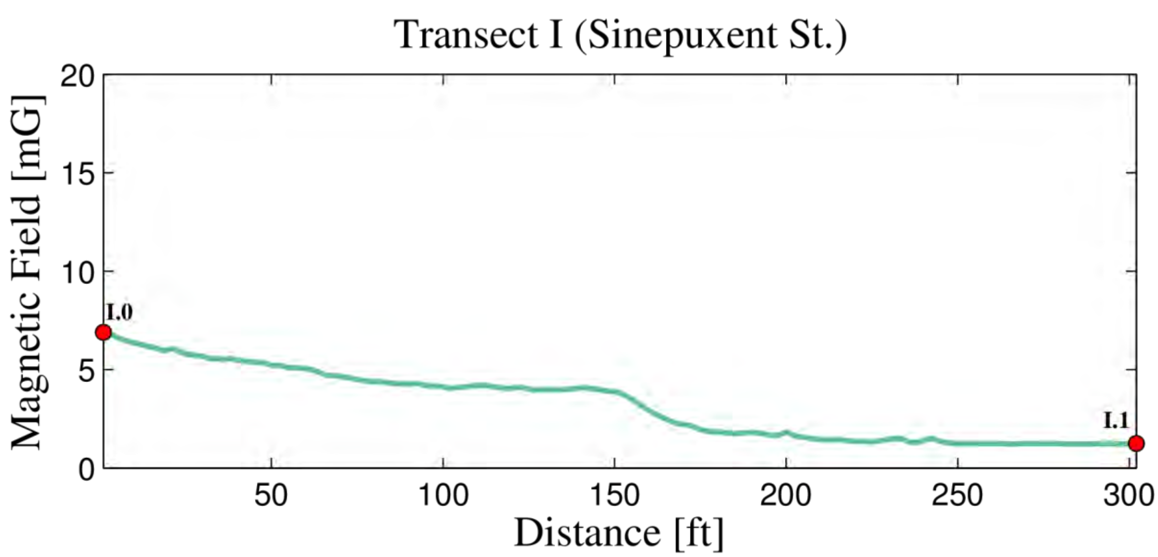


Figure 11. Resultant magnetic field measured along Transect I as shown in Figure 2.

Transect I starts at the northwest corner of the intersection of 138th Street and Sinepuxent Avenue and extends to the north.

# Conclusion

Magnetic-field measurements made on the sidewalk in front of adjacent properties around the substation are well below the ICNIRP reference level of 2,000 mG and the ICES maximum permissible exposure value of 9,040 mG. In particular, measured magnetic-field levels along this sidewalk perimeter of the substation were no greater than approximately 33 mG, which was measured near the southwest corner of the intersection of Sinepuxent Avenue and 137$^{th}$ Street. Measurements of the magnetic field along the transects moving away from the substation show that the measured magnetic-field levels are generally consistent with the presence of underground distribution or service lines, not the substation. The highest recorded magnetic-field level along any of the transects from these other sources in the residential areas was approximately 9.6 mG, measured more than 350 feet from the substation.

# Appendix A

# EMDEX II Calibration Certificate

# *Certificate of Calibration*

The calibration of this instrument was controlled by documented procedures as outlined on the attached Certificate of Testing Operations and Accuracy Report using equipment traceable to N.I.S.T., ISO 17025, and ANIZ540-1 COMPLIANT.

Instrument Model: EMDEX II

Frequency: 60 Hertz

Serial Number: 3363

Date of Calibration: 9/29/2017

Re-Calibration suggested at one year from above date.

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