Electrical Engineering and Computer Science Practice

Magnetic Field Assessment

Ocean City 138th Street Substation

July 2023

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Prepared for:

Delmarva Power & Light Company
An Exelon Company
New Castle Regional Office
Mail Stop 79NC64
PO Box 9239
Newark, DE 19714-9239

Prepared by:

Exponent
17000 Science Drive, Suite 200
Bowie, MD 20715

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Limitations

At the request of Delmarva Power & Light (Delmarva), an Exelon company, Exponent measured the magnetic-field levels associated with the 138th Street Substation in Ocean City, Maryland on July 13, 2023. 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) 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 9:00 PM and 11:00 PM on July 13, 2023. The highest measured magnetic-field level around the perimeter of the 138th Street Substation was approximately 48 milligauss (mG) and was measured north-east of the substation near the middle of 138th Street at the intersection with Sinepuxent Avenue. Away from the substation perimeter, the highest recorded magnetic-field level along any of the transects extending into the residential areas was approximately 17 mG, more than 350 feet away from the substation and in close proximity to a ground-level, pad-mounted neighborhood distribution transformer. 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 9:00 PM and 11:00 PM on July 13, 2023. 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 Std C95.1™ IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz. Piscataway, NJ: IEEE C95.1-2019, Incorporates IEEE Std C95.1-2019/Cor 1-2019/Cor 2-2020). New York: IEEE, 2019; 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 60-Hz magnetic field levels from all sources around the perimeter of the substation and along select transects perpendicular to the perimeter path were measured.

Magnetic-field measurements were taken on July 13, 2023 between approximately 9:00 PM and 11:00 PM. The minimum, maximum, and average power loads (reported in mega-volt-amperes [MVA]) on the transmission lines, distribution lines, and substation equipment during measurements 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 2022 are provided for comparison.

Table 2. Circuit loading

	Recorded Loading July 13, 2023 (During Measurements)			
Element	**Minimum (MVA)**	**Maximum (MVA)**	**Average (MVA)**	**2022 Average (MVA)**
13732	35	38	37	19
13731	17	34	29	21
429	2.7	2.7	2.7	2.8
430	4.0	4.8	4.2	4.7
431	2.6	2.6	2.6	3.0
432	3.6	4.0	3.7	3.8
SVC*	-49	-16	-39	-22

* 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 for magnetic field frequencies between 40 and 800 Hz. This meter meets the IEEE instrumentation standard for obtaining accurate field measurements at power-line frequencies and appropriate measurement procedures were followed.[3] The calibration of the meter also was checked just before and after the measurements in Exponent's calibration coil for any evidence of drift in the magnetic field meter since last calibration.

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.

[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 300 GHz (IEEE Std. C95.3-2021). New York: IEEE, 2021.

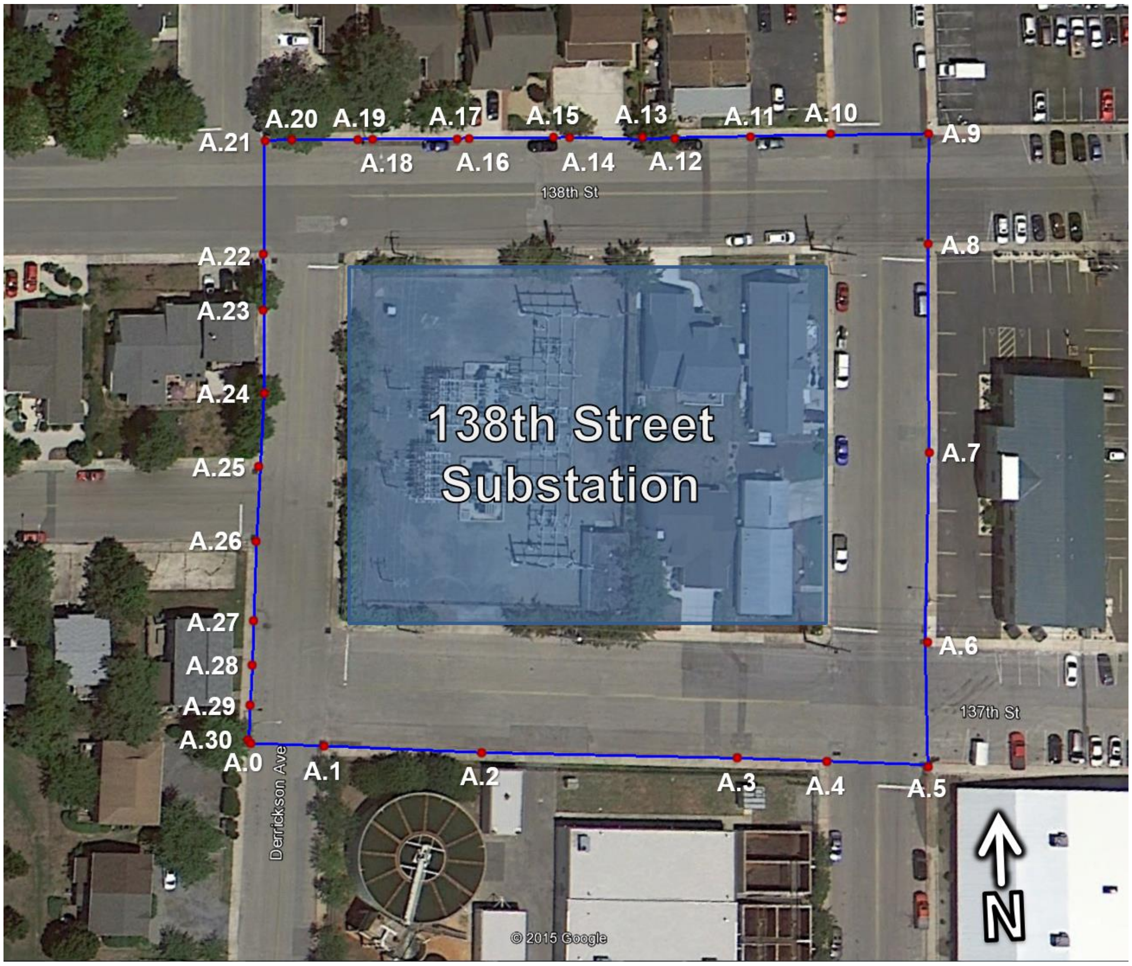

Figure 1. Aerial view of the 138th Street Substation between Derrickson Avenue and Sinepuxent Avenue showing the measurement path along the outer perimeter across the street from the substation.

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 transect paths 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 show magnetic-field levels in front of all residences west of Derrickson Avenue and within approximately 350 feet to 400 feet of the substation block along the north and south sides of 138th Street, respectively.

- Transects D and E show magnetic-field levels in front of all residences west 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 shows 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 show 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 shows 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 also are shown in front of all residences bordering the substation block. These measurements are included in the "perimeter measurement."

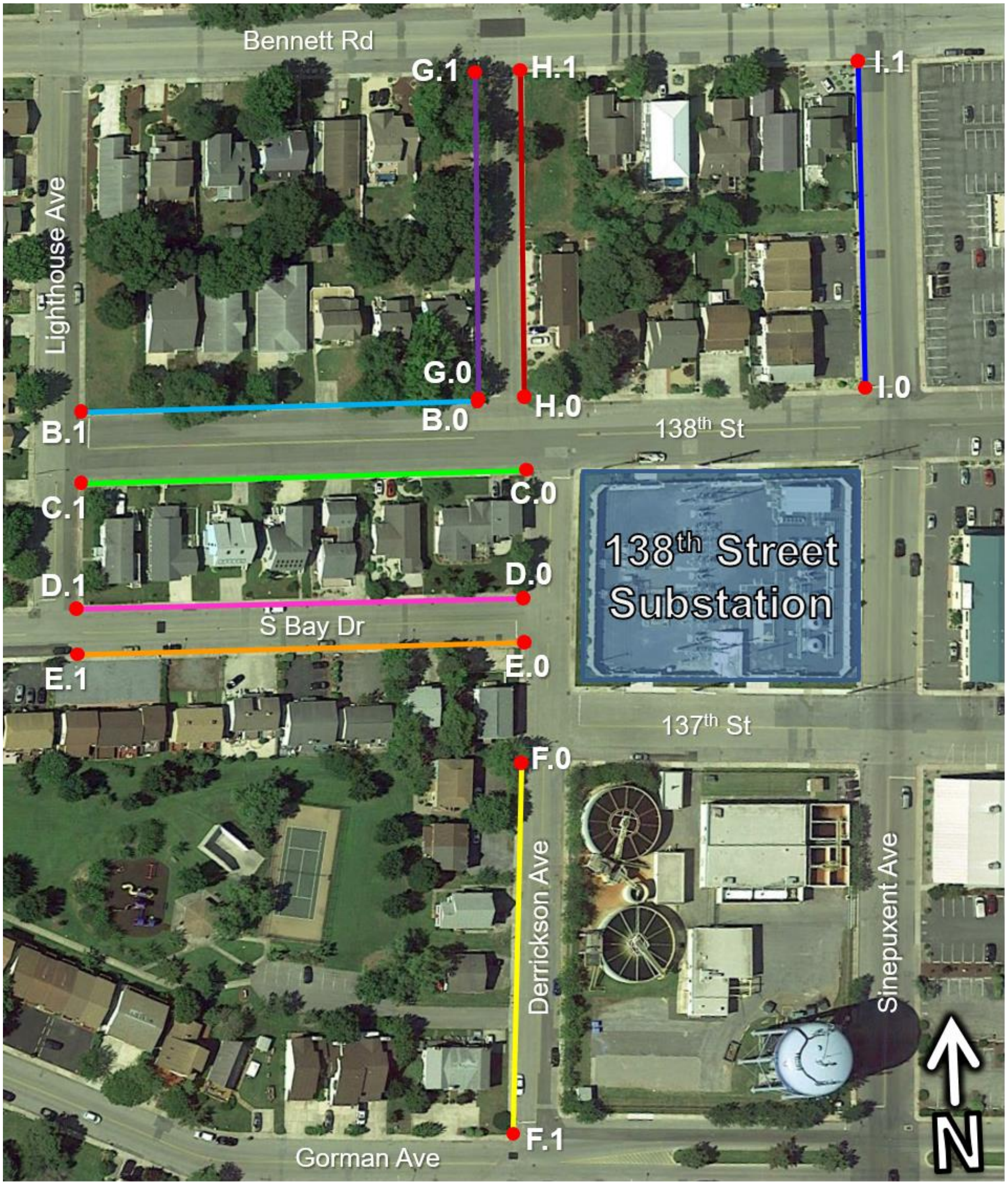

Figure 2. Aerial view of the 138th Street Substation showing transect locations.

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 Perimeter A measurement path. The median magnetic field measured around these properties in Perimeter A was 12 mG. At several points on Perimeter A, a higher magnetic field was measured. the highest measured magnetic level of approximately 48 mG was recorded between measurement locations A.8 and A.9 on Sinepuxent Avenue near the center of 138th Street above an underground electrical service. The next highest peak was measured at a point near the southwest corner of the intersection of 137th Street and Sinepuxent Avenue (in front of the water treatment plant and between measurement locations A.3 and A.4) where the magnetic field was measured to be 46 mG. A still lower level, approximately 23 mG, was recorded north of the substation (on 138th Street between measurement locations A.12 and A.13). These locations correspond to the highest local peaks in the magnetic-field level shown in Figure 3.

Since magnetic-field levels decrease with increasing distance from the source, the magnetic fields from the substation would be expected to decrease monotonically with increasing distance from the substation along the transects. However, this monotonic decrease was observed only in Transect I (Figure 11) consistent with a combination of a decline in the magnetic field with distance from the overhead power line running along 138th Street and from an underground distribution line running parallel to Sinepuxent Ave. In contrast, the measured magnetic field levels along all other transects going away from the substation (in Figures 4 through 10) show higher magnetic field levels at locations away from the substation, or relatively constant magnetic field levels both near and far from the substation. The maximum measurement along any of these transects was approximately 17 mG, observed along Transect B, more than 350 feet away from the substation and in close proximity to a ground-level, pad-mounted neighborhood distribution transformer. The minimum, maximum, and median magnetic-field levels for each transect are summarized in Table 4. The occasional local maximum value of the magnetic field observed in these transect measurements is generally consistent with the presence of underground cables or neighborhood distribution transformers.[5]

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

Location	Magnetic Field (mG)		
	Minimum	**Median**	**Maximum**
Perimeter A	2.8	12	48
Transect B	7.2	12	17
Transect C	5.4	6.6	15
Transect D	1.6	3.1	5.4
Transect E	4.7	6.2	9.7
Transect F	2.1	4.7	6.7
Transect G	2.4	9.3	12
Transect H	1.3	2.1	13
Transect I	1.4	3.6	12

5 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.

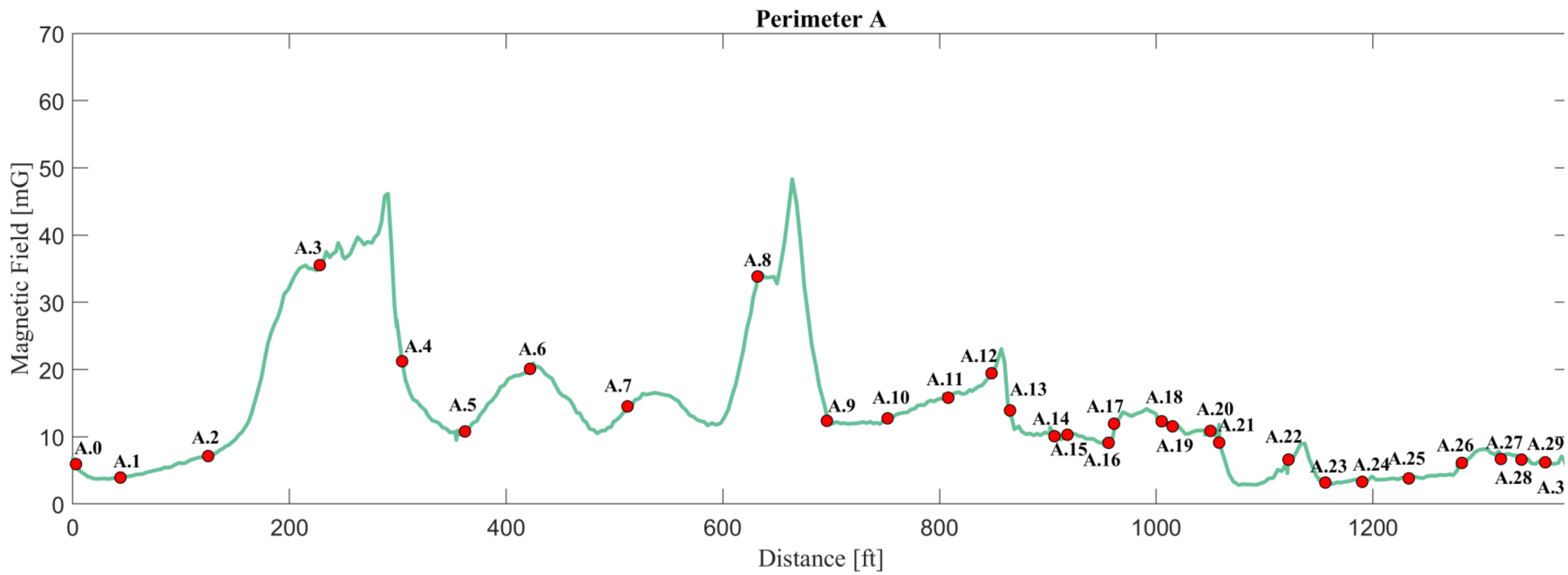

Figure 3. Resultant magnetic field measured around the perimeter of the substation as shown by the solid line in Figure 1.

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.

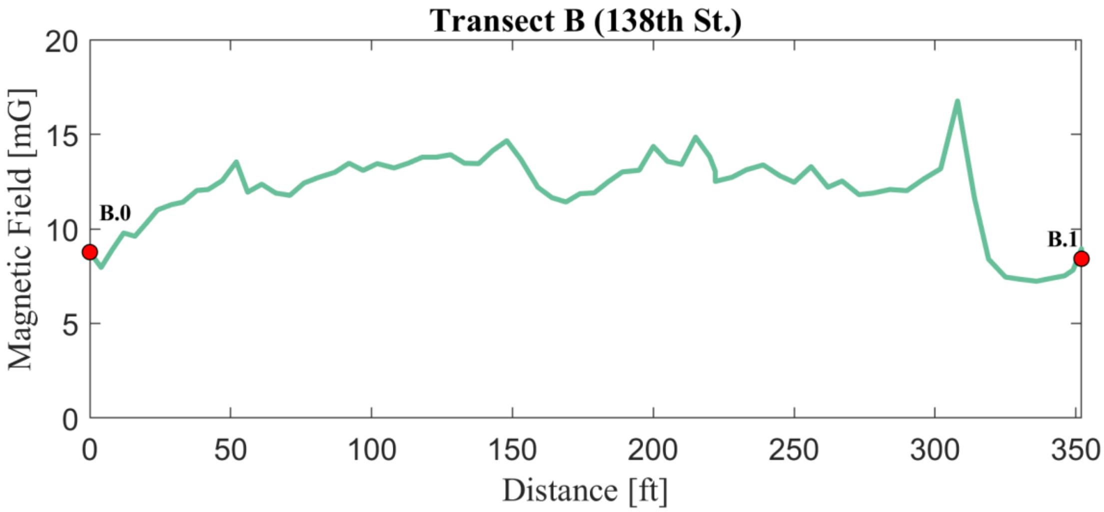

Figure 4. Resultant magnetic field measured along Transect B as shown in Figure 2.

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

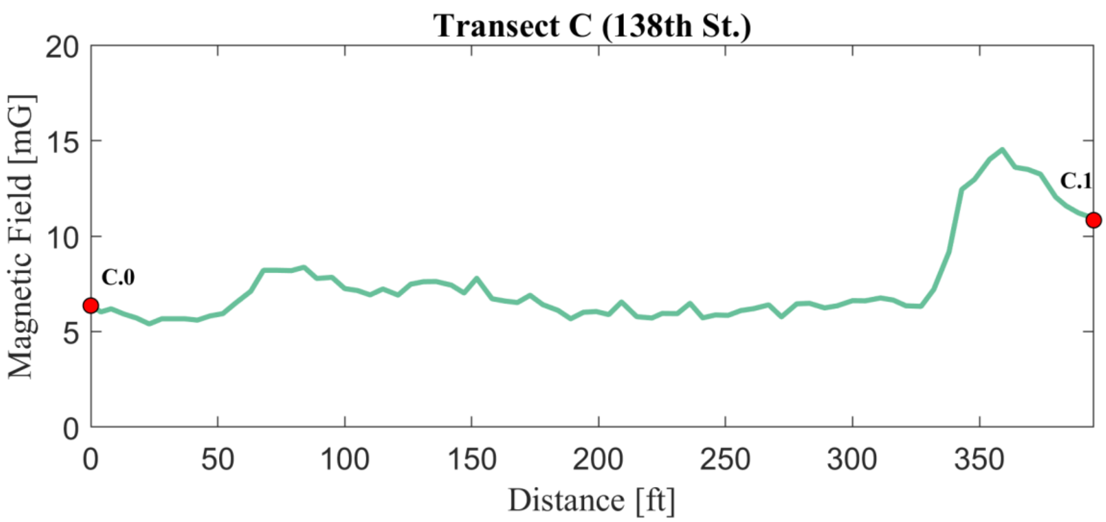

Figure 5. Resultant magnetic field measured along Transect C as shown in Figure 2.

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

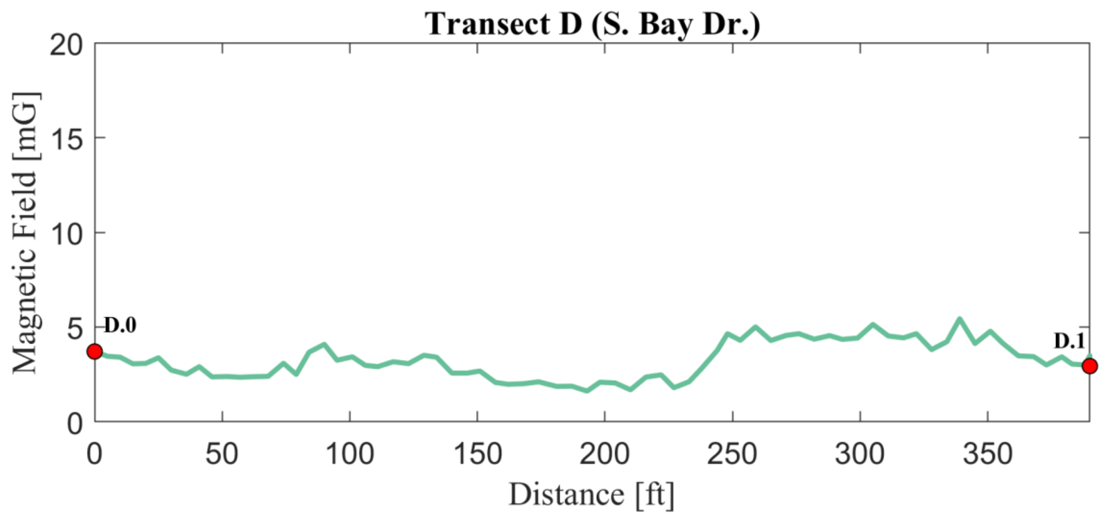

Figure 6. Resultant magnetic field measured along Transect D as shown in Figure 2.

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

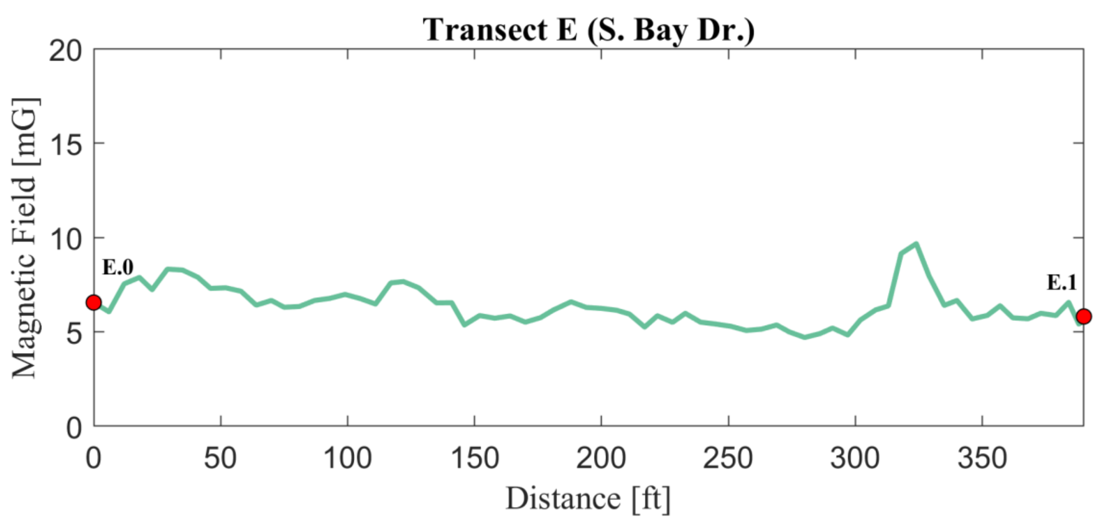

Figure 7. Resultant magnetic field measured along Transect E as shown in Figure 2.

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

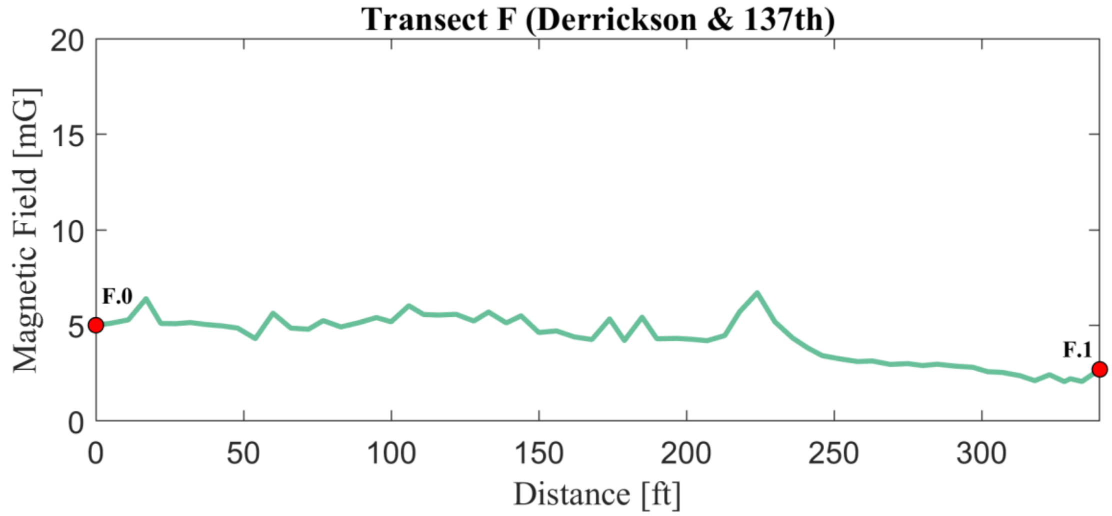

Figure 8. Resultant magnetic field measured along Transect F as shown in Figure 2.

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

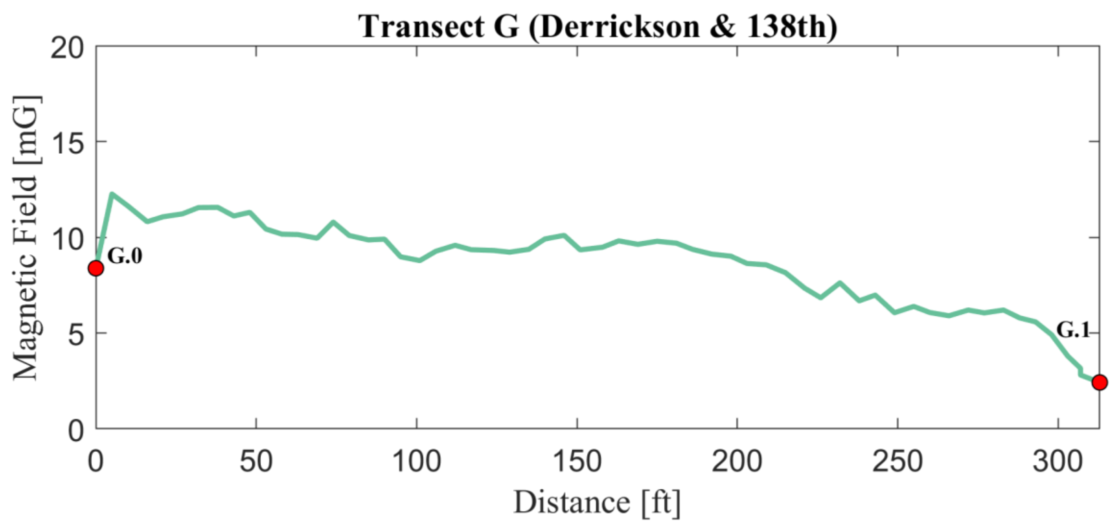

Figure 9. Resultant magnetic field measured along Transect G as shown in Figure 2.

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

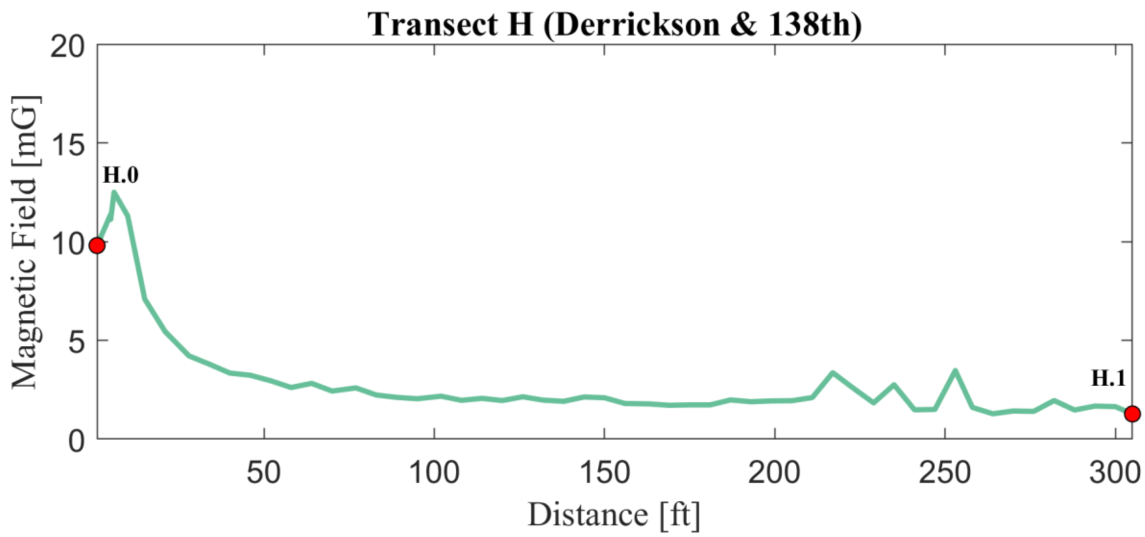

Figure 10. Resultant magnetic field measured along Transect H as shown in Figure 2.

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

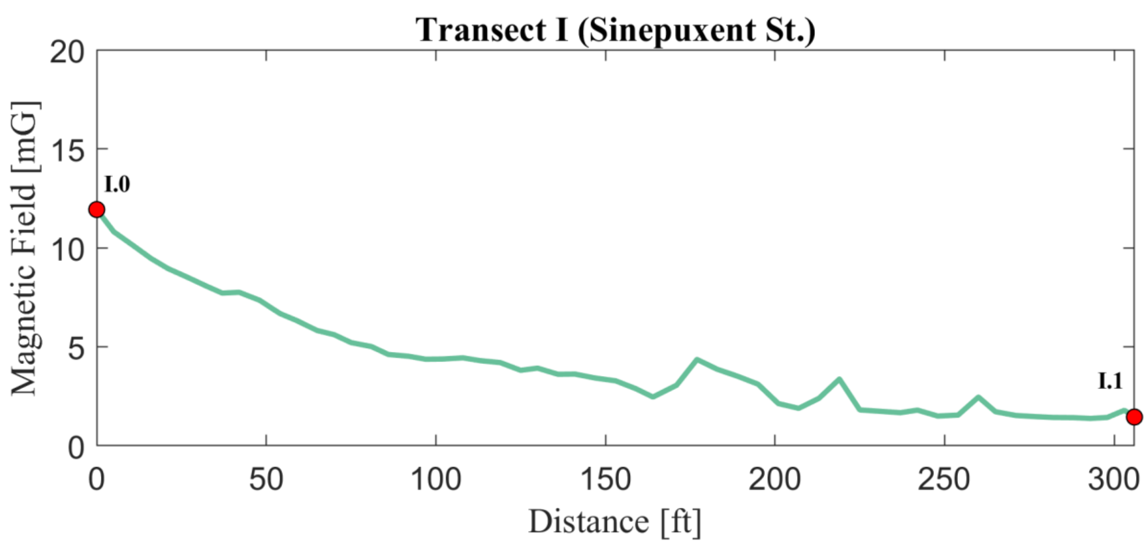

Figure 11. Resultant magnetic field measured along Transect I as shown in Figure 2.

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

Conclusion

The magnetic fields measured on the sidewalk in front of properties around the perimeter of the substation are well below the ICNIRP reference level of 2,000 mG and the ICES exposure reference level of 9,040 mG. The highest magnetic field measured along the perimeter of the substation was approximately 48 mG and was recorded on Sinepuxent Avenue near the center of 138th Street. Other measurements of the magnetic field along the transects moving away from the substation show that the measured magnetic-field levels are generally associated with the presence of an adjacent overhead line, distribution transformers and 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 17 mG, measured more than 350 feet away from the substation and in close proximity to a ground-level, pad-mounted neighborhood distribution transformer.

Appendix A

EMDEX II Calibration Certificate

Certificate of Calibration

The calibration of this instrument was controlled by documented procedures as outlined on the Certificate of Testing Operations and Accuracy Report using equipment traceable to N.I.S.T., ISO/IEC 17025:2017(E), and ANIZ540-1 COMPLIANT.

Instrument Model: EMDEX II - Standard

Frequency: 60 Hz

Serial Number: 1134

Date of Calibration: 01/25/2023

Re-calibration suggested at one year from above date.

Calibration Inspector: H. Christopher Hooper

EMDEX LLC
1356 Beaver Creek Drive
Patterson, California 95363
(408) 866-7266