Electric and Magnetic Field Assessment: The Kings Highway Substation

Electric and Magnetic Field Assessment: The Kings Highway Substation

Prepared for

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April 14, 2017

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Notice

At the request of Public Service Enterprise Group – Long Island (PSEG-LI), Exponent modeled the magnetic-field levels associated with the proposed Kings Highway Substation in the Hamlet of Hauppauge, Town of Islip, Suffolk County, New York. This report summarizes work performed to date and presents the findings resulting from that work. In the analysis, we have relied on geometry, material data, usage conditions, specifications, and various other types of information provided by PSEG-LI. We cannot verify the correctness of this input data, and rely on the client for the data's accuracy. 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. PSEG LI has confirmed to Exponent that the summary of data provided to Exponent contained herein is not subject to Critical Energy Infrastructure Information (CEII) restrictions.

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 readers of this report outside of the regulatory proceedings relating to this Project, and any re-use of this report or its findings, conclusions, or recommendations presented herein 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

Public Service Enterprise Group of Long Island (PSEG-LI) has proposed the construction of the Kings Highway Substation (The Project) fronting Rabro Drive, adjoining the existing Pilgrim-West transmission line right-of-way (ROW) in the Hamlet of Hauppauge, NY. At the request of PSEG-LI, Exponent modeled the magnetic fields associated with the proposed substation equipment and adjacent overhead transmission lines. In the proposed configuration, the southernmost of the two existing transmission lines will be divided into two new transmission lines terminating at the proposed substation.

The effect of the substation on existing magnetic-field levels was evaluated by modeling magnetic fields for pre- and post-Project conditions. For the pre-Project conditions, the loading on the existing overhead circuits was calculated without any of the proposed equipment in service. Exponent also measured background magnetic-field levels at the proposed substation site on March 24, 2017.

The post-Project condition includes magnetic-field contributions from the proposed substation equipment and a new 138-kilovolt (kV) loop in and out of the new substation yard. In the post-Project condition, two load cases were studied, corresponding to average load and peak load for the proposed equipment and overhead 138-kV transmission lines. Electric fields from the substation were not modeled because they are effectively blocked by the metal fence and landscaping around the substation yard.

The modeling shows that the substation equipment and proposed 138-kV interconnection have little effect on the calculated magnetic field levels at workplaces and residences in the neighborhood. The overhead interconnection would be located on the north edge of the substation parcel, set back from Rabro Drive and Wheeler Road by approximately 250 feet. At workplaces along Wheeler Road, for instance, the calculated magnetic field would increase on average by less than 2.6 mG with operation of the Project. These changes can be attributed to an increase in loading on the 138 kV transmission line on the existing ROW west of the Kings Highway Substation, and an increase in distribution loads along Wheeler Road.

The greatest Project-related increase in calculated magnetic-field level would occur near the western edge of the proposed site, where proposed underground feeders pass below the substation fence. Directly over the proposed feeders, the calculated magnetic-field level would be approximately 40 mG for average-load conditions and 100 milligauss (mG) for peak-load conditions. The region where the calculated magnetic fields would be elevated above background levels extends for approximately 50 feet on either side of the proposed underground feeders.

Overall, the calculated and measured magnetic field levels associated with the Project fall within the range of typical levels encountered within homes and businesses. The Project-related increases in the calculated magnetic field are small, and are on average below 2.6 mG at workplaces and dwellings in the vicinity of the proposed substation.

Proposed Configuration

The proposed location for the Kings Highway Substation is located on a 3.6-acre property at 225 East Rabro Drive, on the east side of Wheeler Road and south of the existing Pilgrim-West 138 kV ROW. *See* Figure 1.

The proposed substation equipment includes a new 138-kV ring bus having two circuit positions, six gas circuit breakers, three 138/13.8-kV transformers, and three power centers with metal-clad switchgear. In the proposed configuration, the 13.8-kV feeders exit west from the substation, and continue north along Wheeler Road in underground duct banks.

In addition to the new equipment inside the substation fence, the Project includes two overhead interconnections to the existing 138-kV transmission line adjoining the proposed site to the north. In the proposed configuration, the existing 138-kV Transmission Line "B" will be segmented into two transmission lines, Transmission Line "B" West and "B" East, terminating at the substation.

Figure 2 shows the existing and proposed structures located on the existing ROW. Presently, Transmission Lines "A" and "B" are supported on double-circuit steel monopoles in the center of the existing 80-foot ROW. Figure 2a shows the existing double-circuit structure design at locations where the transmission centerline changes direction. Figure 2b shows the existing double-circuit structures at tangent locations where the transmission-line alignment is straight. Transmission Lines "A" and "B" are operated at 138 kV and built with 345 kV clearances. The existing lines having a vertical conductor spacing of 20-21 feet and a conductor height of 36 feet above ground at midspan (the point of greatest conductor sag between structures). Figure 2c shows the dimensions of two proposed dead-end monopoles located to the north of the proposed King Highway Substation. These single-circuit structures support the conductors of Transmission Line "B" West and "B" East where they turn south to terminate within the substation yard.

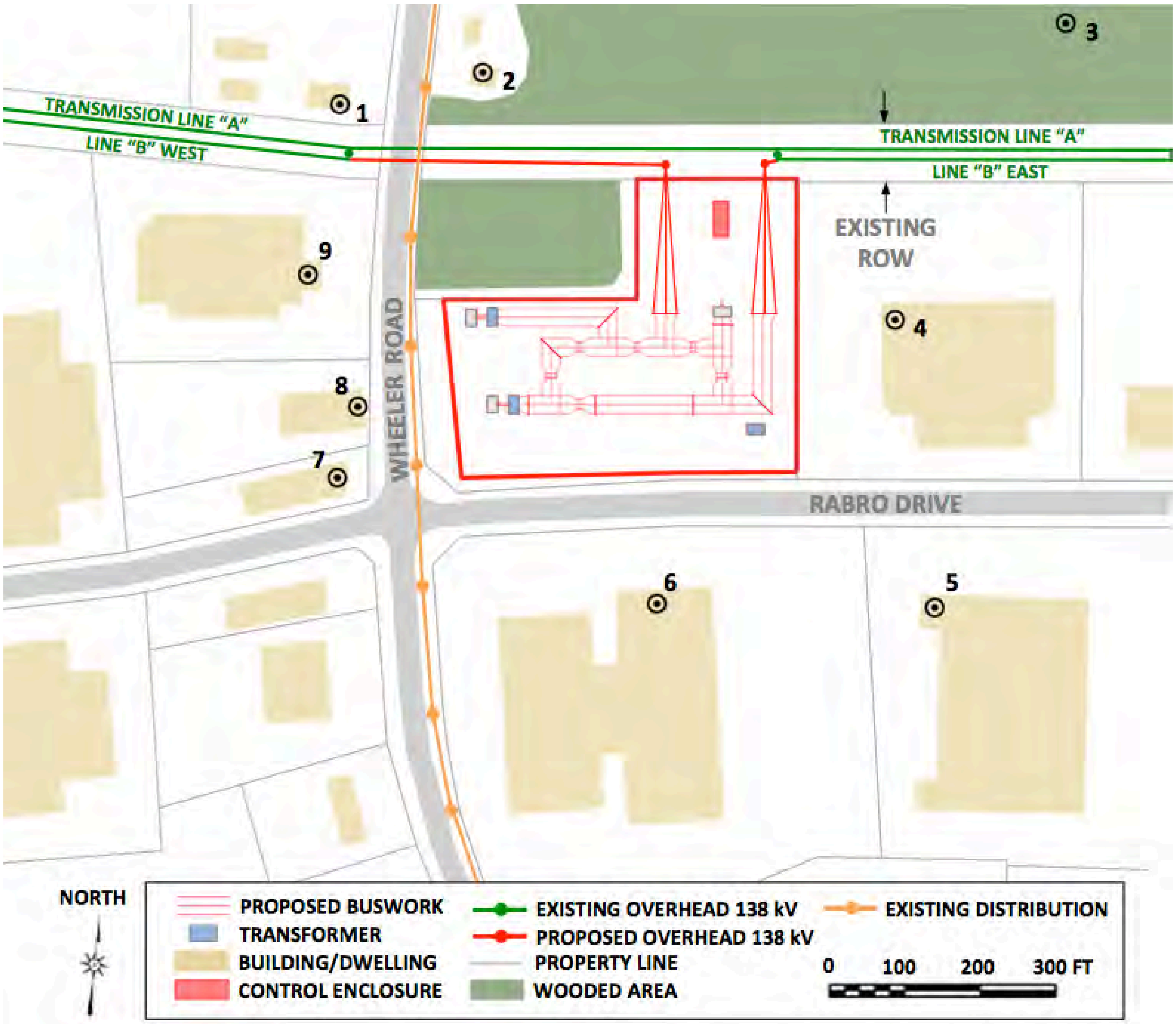

Figure 1. Proposed layout of the Kings Highway Substation and existing overhead circuits in relation to the existing ROW.

The numbered labels designate reporting locations for Project-related magnetic fields, which are summarized in Table 5.

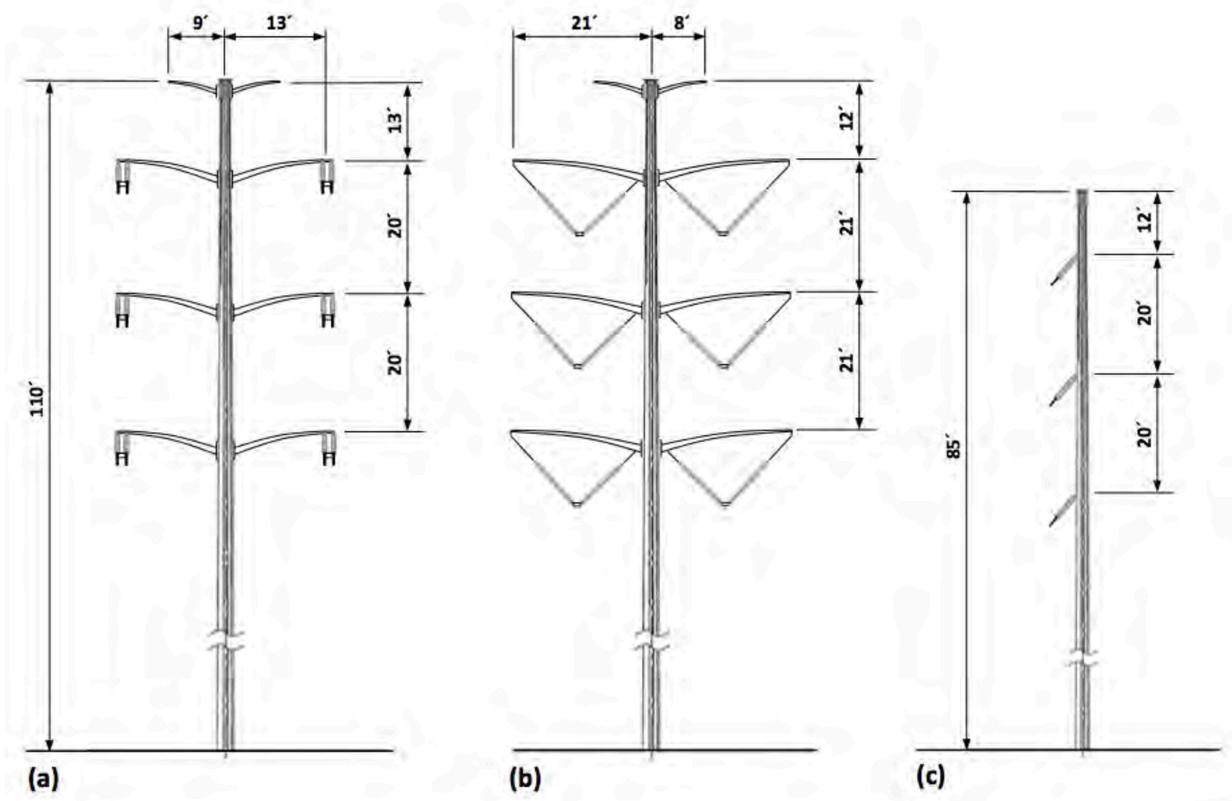

Figure 2. Structure dimensions used in SUBCALC model: (a) existing double-circuit structure at angle locations; (b) existing double-circuit monopole at tangent locations; and (c) proposed dead-end structures where Transmission Lines "B" West and East turn south to terminate within the proposed Kings Highway Substation.

Methods

Magnetic Field Modeling

The magnetic field around the perimeter of the proposed Kings Highway Substation and surrounding neighborhood was calculated using SUBCALC, which is part of the Enertech EMF Workbench Suite. SUBCALC models the magnetic fields in and around substations, accounting for the transformers and the three-dimensional arrangement of buswork and transmission-line interconnections (Figure 4). The SUBCALC model was built using the substation plan and profile data provide by PSEG-LI. The inputs to the program include data on the voltage, current flow, circuit phasing, and conductor configurations, which were also provided by PSEG-LI.[1] In particular, the SUBCALC model incorporates sag elevation data for each transmission line span and the elevation of conductor attachments.

Exponent calculated the magnetic field along four profiles perpendicular to the substation fence, directed outward towards adjoining properties as shown in Figure 3:

Profile 1 is aligned with the southwest transformer bank in the substation yard, and proceeds west across Wheeler Road.

Profile 2 starts at the middle of the south substation fence, and crosses Rabro Drive.

Profile 3 begins near the overhead interconnection to Transmission Line “B” East, and proceeds east onto adjoining property.

Profile 4 models the magnetic field starting at the north edge of the substation yard between Transmission Line “B” West and “B” East, and proceeds north across the existing ROW

Additional Profiles 5 and 6, shown in Figure 3, characterize the magnetic field along transects perpendicular to the overhead route of the existing overhead 138 kV transmission lines. As described in greater detail below, measurements of background magnetic field levels were recorded along Profiles 1 – 4 on March 24, 2017. All magnetic fields were calculated at heights referenced to the elevation of the substation yard.

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1 The sources of the electric field within the substation are set back by 25 feet or more within the property line and their intensity diminishes quickly with distance. In addition, many objects are conductive—including fences, shrubbery, and buildings—and thus shield electric fields. Thus, the electric field from the Kings Highway Substation was not calculated since it will be effectively shielded by the substation fence and landscaping.

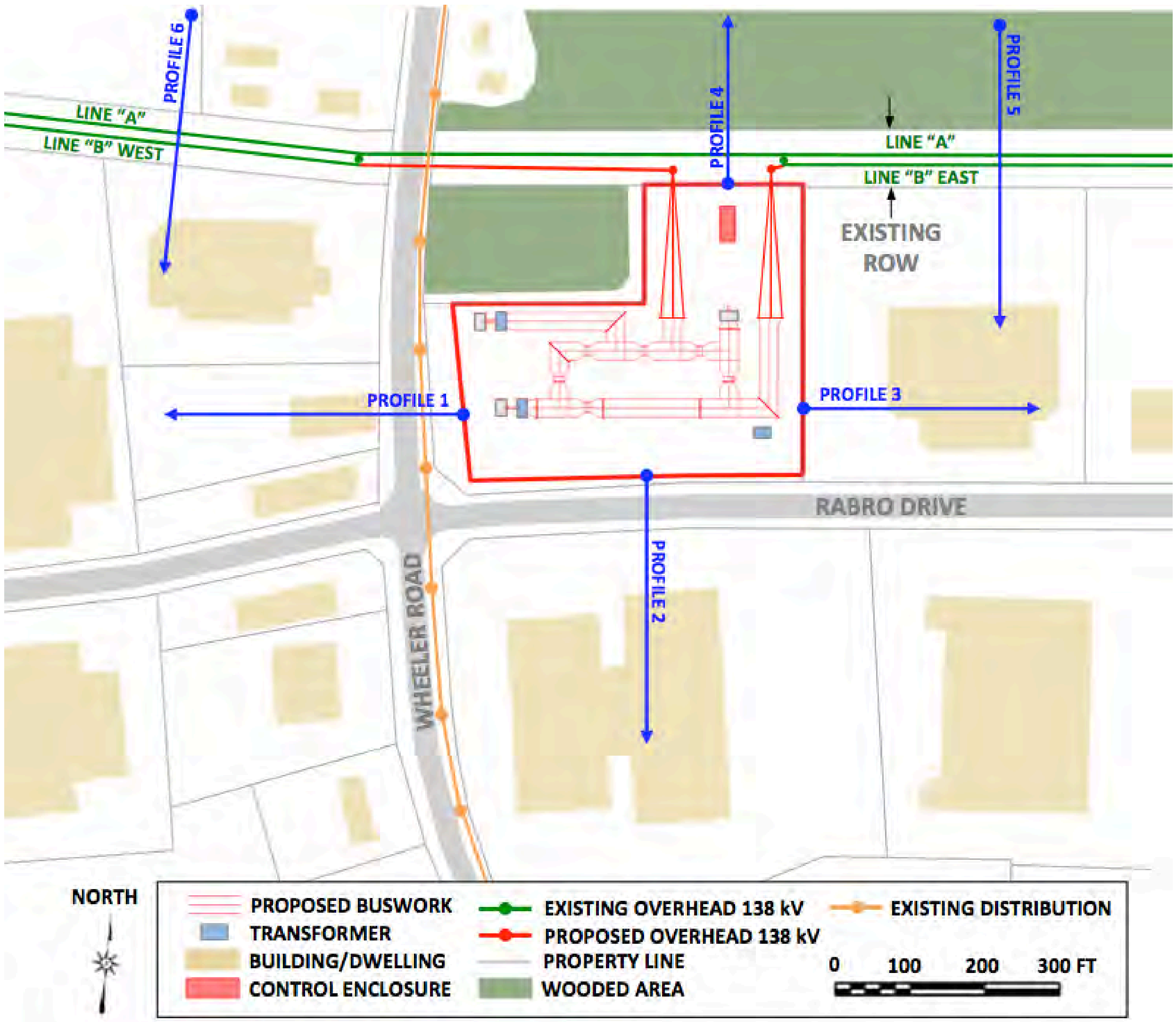

Figure 3. Plan view of the proposed Kings Highway Substation, showing the location of magnetic-field profiles and the overhead route of 138 kV transmission lines.

Along the perimeter of the substation property and Profiles 1-6, the magnetic field was calculated at 1 meter (3.28 feet) above ground, in accordance with IEEE Std. C95.3.1-2010.[2] Calculated magnetic fields are reported as the resultant of x, y and z magnetic field vectors in units of milligauss (mG).[3]

Magnetic fields surrounding conductors depend on current, which increases with increasing load. The current flows (loadings) for the transmission lines and transformers used in the model

2 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. New York: IEEE. IEEE Std. C95.3.1™-2010.

3 The resultant magnetic field is the Euclidian norm (square root of the sum of the squares) of the component magnetic-field vectors calculated along vertical, transverse, and longitudinal axes.

are summarized in Appendix A. Appendix A provides average loads for the in-service year of 2017, as well as a peak loads, corresponding to the highest load anticipated during the summer months in the year 2017.

Figure 4. Overview of the three-dimensional SUBCALC model used to calculate magnetic-field profiles in the vicinity of the proposed Kings Highway Substation for the average and peak loading cases.

Orange lines represent overhead transmission-line conductors, including the proposed 138 kV loop in and out of the Kings Highway Substation. Not shown in the perspective view are underground distribution feeders, which proceed north along Wheeler Road and are proposed as part of the reinforcement project in the surrounding community.

Measurements

In order to characterize background EMF levels at the proposed site of the Kings Highway Substation, magnetic fields were measured outside the proposed substation fence on March 24, 2017. The measurements were taken at a height of 1 meter (3.28 feet) above ground in accordance with the standard methods for measuring near power lines (IEEE Std. 644-1994a). Measured magnetic fields are expressed as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[4] The magnetic field was measured in units of mG by orthogonally-mounted sensing coils whose output was logged by a digital recording meter (EMDEX II) manufactured by Enertech Consultants. This instrument meets the Institute of Electrical and Electronics Engineers **(**IEEE) instrumentation standard for obtaining accurate field measurements at power line frequencies (IEEE Std.1308-1994b). The meter was calibrated by the manufacturer by methods like those described in IEEE Std. 644-1994a.

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4 The resultant magnetic field is the Euclidian norm (square root of the sum of the squares) of the component magnetic-field vectors calculated along vertical, transverse, and longitudinal axes. Root mean square refers to the common mathematical method of defining the effective voltage, current, or field of an AC system.

Results and Discussion

The measured and calculated magnetic fields around the fence line of the proposed Kings Highway Substation are depicted in Figure 5. To characterize the background sources along the perimeter of the proposed site, the pre-Project profile in Figure 5 shows the magnetic-field levels measured on March 24, 2017. The measured profile reflects pre-Project conditions, in which no proposed facilities are constructed or in service.[5] The measured magnetic-field levels are highest at the north side of the property (approximately 10 mG), closest to the existing 138-kV transmission lines on the existing ROW. Along the east, west, and south sides of the substation property, the measured magnetic fields were on average below 2 mG, with a maximum of 5 mG in the vicinity of existing distribution sources along Wheeler Road.

The "post-Project" profile in in Figure 5 shows the magnetic field calculated using SUBCALC along the property line of the proposed Kings Highway Substation for average-load conditions. The calculated field reflects the contribution of proposed substation equipment within the yard and the proposed overhead interconnections to Transmission Line "B" West and "B" East. The SUBCALC model also includes proposed underground distribution feeders exiting the substation to the west, and proceeding north on Wheeler Road in underground duct banks. Both the measured and calculated profiles in Figure 5 begin at the southeast corner of the substation property, and continue counter-clockwise along the fence to the southwest, northwest, and northeast corners of the property.

The highest calculated magnetic field at the substation property line (42 mG) occurs beneath the conductors of Transmission Line "B" West where they pass above the north fence. On the east side of the substation property, adjacent to the terminal structures of Transmission Line "B" East, the calculated magnetic field is less (below 20 mG at average load). Fronting Rabro Drive to the south, the calculated magnetic field is 6 mG or less at average load. Along the west side of the substation property, the highest calculated magnetic field is approximately 41 mG directly over the proposed underground feeders exiting the substation onto Wheeler Road. The calculated magnetic field from the underground feeders falls off rapidly with distance, and is equal to background levels at distances of approximately 50 feet from the underground cables.

Figure 6 shows the calculated magnetic-field profile along the same path as in Figure 5 modeled using peak loading rather than average loading. The highest calculated magnetic field at the substation property line (230 mG) is again set back more that 300 feet from Wheeler Road and Rabro Drive, beneath the conductors of Transmission Line "B" West where they pass above the north fence. Fronting Wheeler Road, the highest calculated magnetic field is approximately 100 mG directly over the proposed underground feeders.

Figures 7 – 12 depict the calculated magnetic field levels along Profiles 1 – 6 for average-load conditions in 2017. Figures 7 – 9 include background magnetic-field measurements recorded on

[5] The measured profile in Figure 5 provides a "snapshot" of background magnetic-field levels. On a given day, throughout a week, or over the course of months and years, the measured magnetic field can change depending upon the patterns of power demand within the surrounding community. In general, the measured magnetic will increase during summer months when power demand on Long Island is higher.

March 24, 2017. Table 1 summarizes calculated magnetic-field levels at various distances from the substation fence in Profiles 1 – 4, for average load conditions. Table 2 likewise summarizes calculated magnetic fields for Profiles 5 – 6, at various distances from the centerline of the overhead circuits, for average-load conditions. Tables 3 and 4 include the calculated magnetic fields at the same locations as Tables 1 and 2, but for peak-load rather than average-load conditions.

Referring to the calculated profiles in Figures 7 – 9, operation of the Project elevates calculated magnetic field levels above existing background levels within about 100 feet of the substation fence. These results are consistent with IEEE Standard 1127-2013 that states "[i]n a substation, the strongest fields near the perimeter fence come from the transmission and distribution lines entering and leaving the substation. The strength of fields from equipment inside the fence decreases rapidly with distance, reaching very low levels at relatively short distances beyond substation fences." (IEEE Std. 1127-2013). The greatest Project-related increase in calculated magnetic-field levels is encountered in Profile 1 (Figure 7), proceeding west from the proposed substation yard. These changes can be attributed to an increase in loading on the Transmission Line "B" West compared the existing Transmission Line "B," and an increase in distribution loads along Wheeler Road. As presented in Appendix A, the loading of proposed Transmission Line "B" East is less that the loading of the existing Transmission Line "B." As a result, calculated magnetic fields 100 feet or more to the east of the substation property tend to decrease compared to the existing conditions. In Profile 3 for instance (Figure 9), the calculated magnetic field decreases slightly (1.6 mG) compared to existing conditions (1.8 mG) at 150 feet from the substation fence. *See* Table 1 and Table 3.

Referring to Profiles 5 and 6 (Figure 11 and Figure 12), the results show that operation of the Project slightly decreases calculated magnetic fields across the ROW to the east of the Kings Highway Substation (Figure 11), and slightly increases calculated magnetic fields across the ROW west of the substation (Figure 12). This effect is due to the decreased loading of Transmission Line "B" East and increased loading of Transmission Line "B" West, compared to the loading of existing Transmission Line "B." *See* Table 2 and Table 4. .

Table 1. Summary of calculated magnetic fields (mG) for Profiles 1-4, average-load case

Profile	Condition	Distance from Substation Fence (ft)			
		0	50	100	150
1	Pre-Project	0.7	0.7	0.7	0.7
	Post-Project	16.9	*14.5	5.1	2.1
2	Pre-Project	0.5	0.4	0.3	0.2
	Post-Project	9.3	2.0	0.9	0.6
3	Pre-Project	1.8	1.8	1.8	1.8
	Post-Project	14.1	3.5	2.0	1.6
4	Pre-Project	21.2	26.5	13.1	5.9
	Post-Project	2.0	15.5	10.3	5.2

* Underground distribution circuits are present at this location.

Table 2. Summary of calculated magnetic fields (mG) for Profiles 5-6, average-load case

Profile	Load case	Offset from existing ROW				
		100 ft north of ROW edge	ROW edge north	Max on ROW	ROW edge south	100 ft south of ROW edge
5	Pre-Project	4.0	21.5	34.0	24.6	4.3
	Post-Project	3.5	19.2	28.5	19.5	3.5
6	Pre-Project	4.1	22.8	34.0	23.2	4.1
	Post-Project	4.5	26.0	41.6	29.1	5.4

Table 3. Summary of calculated magnetic fields (mG) for Profiles 1-4, peak-load case

Profile	Condition	Distance from Substation Fence (ft)			
		0	50	100	150
1	Pre-Project	3.6	3.6	3.5	3.4
	Post-Project	43.2	*37.9	14.2	7.1
2	Pre-Project	2.4	1.8	1.5	1.2
	Post-Project	24.4	5.9	3.0	1.9
3	Pre-Project	9.2	9.2	9.1	9.0
	Post-Project	56.8	15.1	9.4	8.0
4	Pre-Project	109	136	67.0	30.2
	Post-Project	9.9	77.9	51.3	25.1

* Underground distribution circuits are present at this location.

Table 4. Summary of calculated magnetic fields (mG) for Profiles 5-6, peak-load case

Profile	Load case	Offset from existing ROW				
		100 ft north of ROW edge	ROW edge north	Max on ROW	ROW edge south	100 ft south of ROW edge
5	Pre-Project	20.3	110	175	127	22.2
	Post-Project	17.8	97.5	146	100	18.0
6	Pre-Project	21.1	117	175	120	21.3
	Post-Project	24.0	134	215	150	27.1

Structures and Buildings

Table 5 shows the magnetic field calculated at reporting locations 1 – 9 (see Figure 1), which are workplaces and dwellings around the proposed site of the Kings Highway Substation. Table 5 provides the calculated magnetic field levels at both average and peak loading, before and after operation of the Project. The "average" column was calculated using the average loads provided in Appendix A. The "peak" column reflects the peak loads provided in Appendix A, and is anticipated to occur for a few days and hours during the year when power demand is highest in the surrounding community. Closest to the existing ROW east of the proposed substation (locations 8 and 9), the increase in calculated magnetic field is approximately 2.6 mG for average-load conditions and 6-8 mG for peak-load conditions. This change reflects an increase in loading of Transmission Line "B" West compared to the existing Transmission Line "B," as well as increased loading on distribution circuits along Wheeler Road.

At other reporting locations, operation of the Project has a small effect on calculated magnetic fields. To the east of the proposed substation, for instance, post-Project magnetic fields at structures 3 and 4 decrease slightly compared to existing conditions (pre-Project). This change reflects the decrease loading of Transmission Line "B" East compared to the existing Transmission Line "B."

Table 5. Summary of calculated magnetic fields (mG) at designated structures

	Average Load		Peak Load	
Building designator*	**pre-Project**	**post-Project**	**pre-Project**	**post-Project**
1	10.1	9.4	51.5	54.2
2	9.7	12.1	49.2	53.0
3	2.0	1.8	10.1	8.9
4	2.1	2.1	10.6	10.0
5	0.2	0.2	0.9	0.8
6	0.2	0.6	1.2	2.0
7	0.4	1.2	2.2	4.1
8	0.8	3.3	4.1	10.2
9	3.2	5.8	16.6	24.6

* The location of each building is shown in Figure 1.

Comparison with Background Levels

Since electricity is such an integral part of our infrastructure (e.g., transportation systems, homes, and businesses), people living in modern communities are surrounded by sources of electric and magnetic fields. Figure 13 describes typical EMF levels measured in residential and occupational environments, compared to levels measured on or at the edge of transmission-line rights-of-way. While EMF levels decrease with distance from the source, any home, school, or office tends to have a "background" EMF level as a result of the combined effect of the numerous EMF sources. In general, the background magnetic-field level in a house away from appliances is typically less than 20 mG, while levels can be hundreds of mG in close proximity to appliances.

Little research has been done to characterize the general public's exposure to magnetic fields, although some basic conclusions are available from the literature. The vast majority of people in the United States have a *time-weighted average* (TWA) exposure to magnetic fields less than 2 mG.[6] The highest magnetic-field levels are typically found directly next to appliances.[7] For example, Gauger (1985) reported the maximum AC magnetic field at 3 centimeters from a sampling of appliances as 3,000 mG (can opener), 2,000 mG (hair dryer), 5 mG (oven), and 0.7 mG (refrigerator).[8]

Overall, the calculated and measured magnetic field levels associated with the Project fall within the range of typical levels encountered within homes and businesses. The Project-related increases in the calculated magnetic field are small, and are on average less than 2.6 mG at workplaces in the vicinity of the proposed Kings Highway Substation.

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[6] TWA is the average exposure over a given specified time period (i.e., an 8-hour workday or a 24-hour day) of a person's exposure to magnetic fields. The average is determined by sampling the exposure of interest throughout the time period. *See* Zaffanella LE and Kalton GW. Survey of Personal Magnetic Field Exposure Phase II: 1,000 Person Survey. EMF Rapid Program, Engineering Project #6. Lee, MA: Entertech Consultants, 1998.

[7] *See* Zaffanella LE. Survey of Residential Magnetic Field Sources. Volume 2: Protocol, Data Analysis, and Management. EPRI TR-102759-V2. Palo Alto, CA: EPRI, 1993.

[8] *See* Gauger JR. Household appliance magnetic field survey. IEEE Trans Power App Syst 104: 2436-2444, 1985.

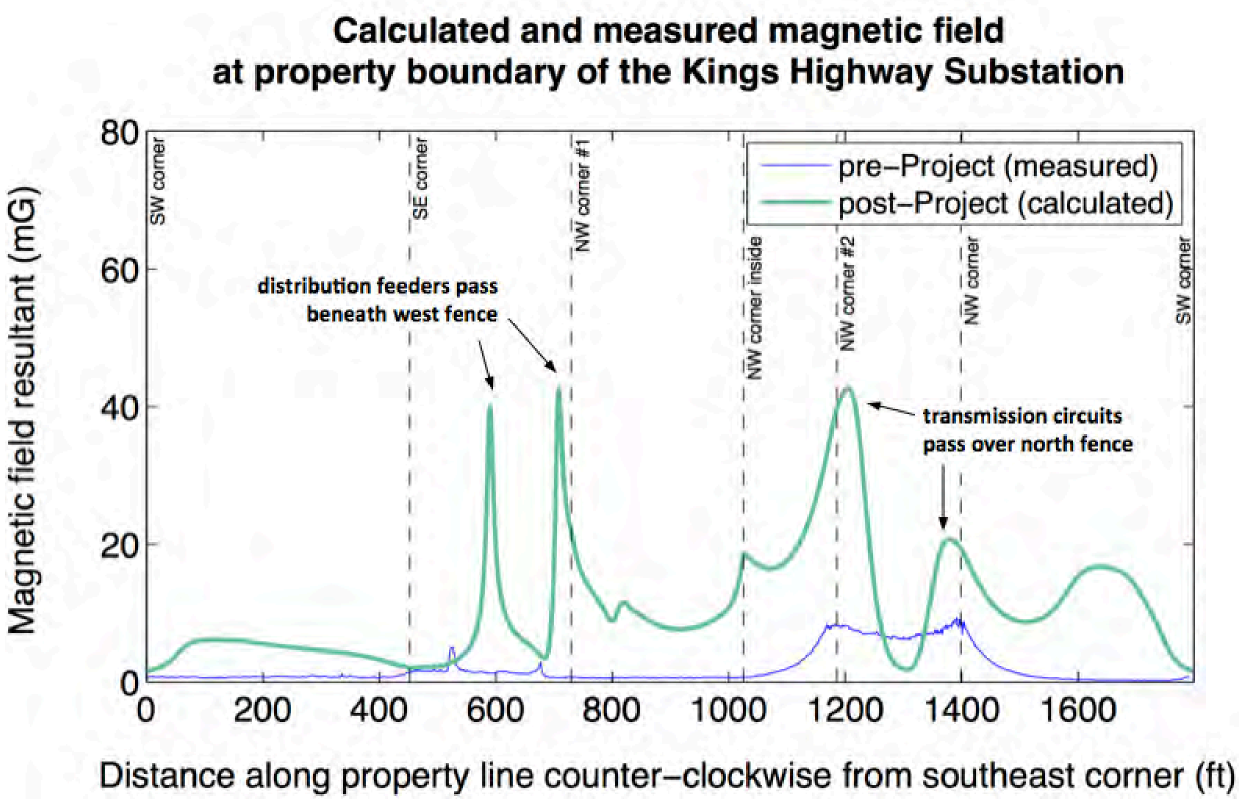
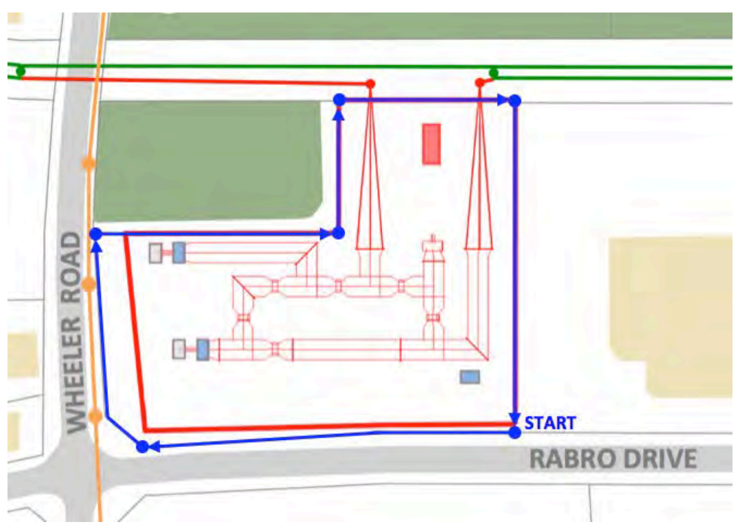


Figure 5. Calculated and measured magnetic-field levels around the property line of the proposed Kings Highway Substation for average-load conditions in 2017.



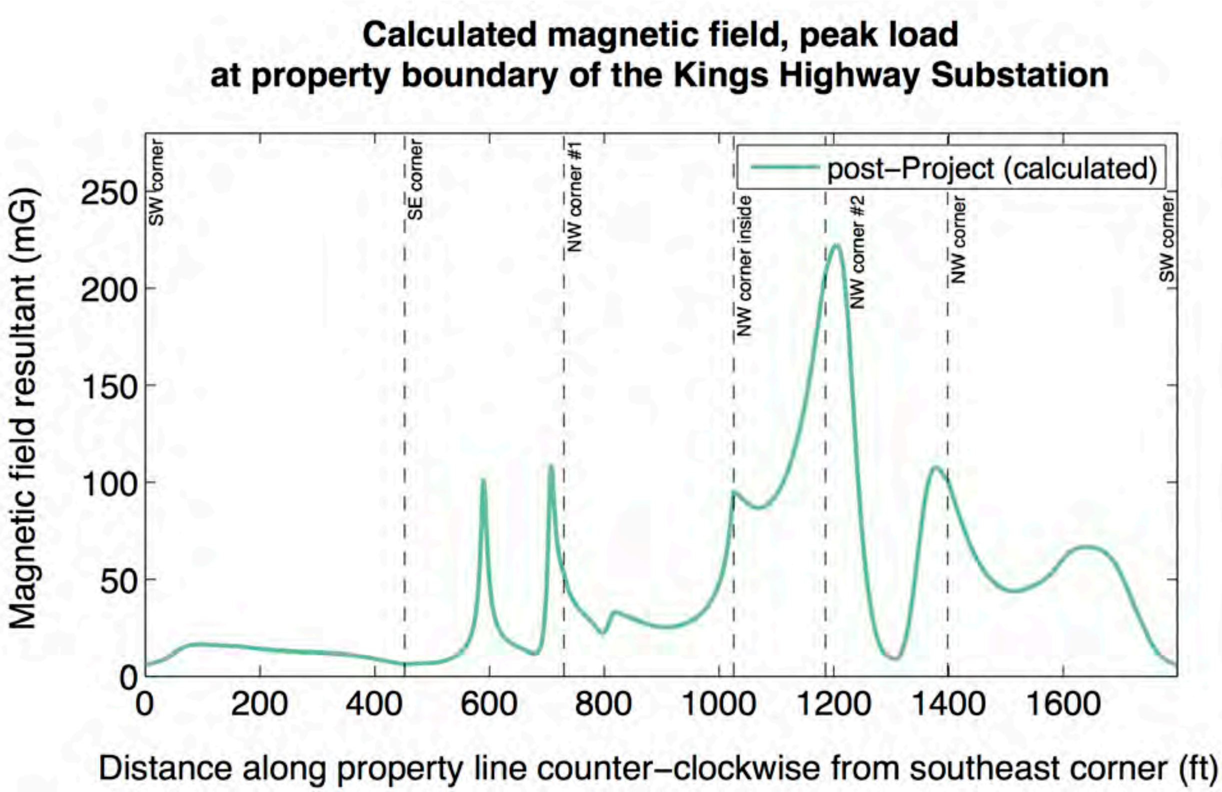


Figure 6. Calculated magnetic-field levels around the property line of the proposed Kings Highway Substation for peak-load conditions in 2017.

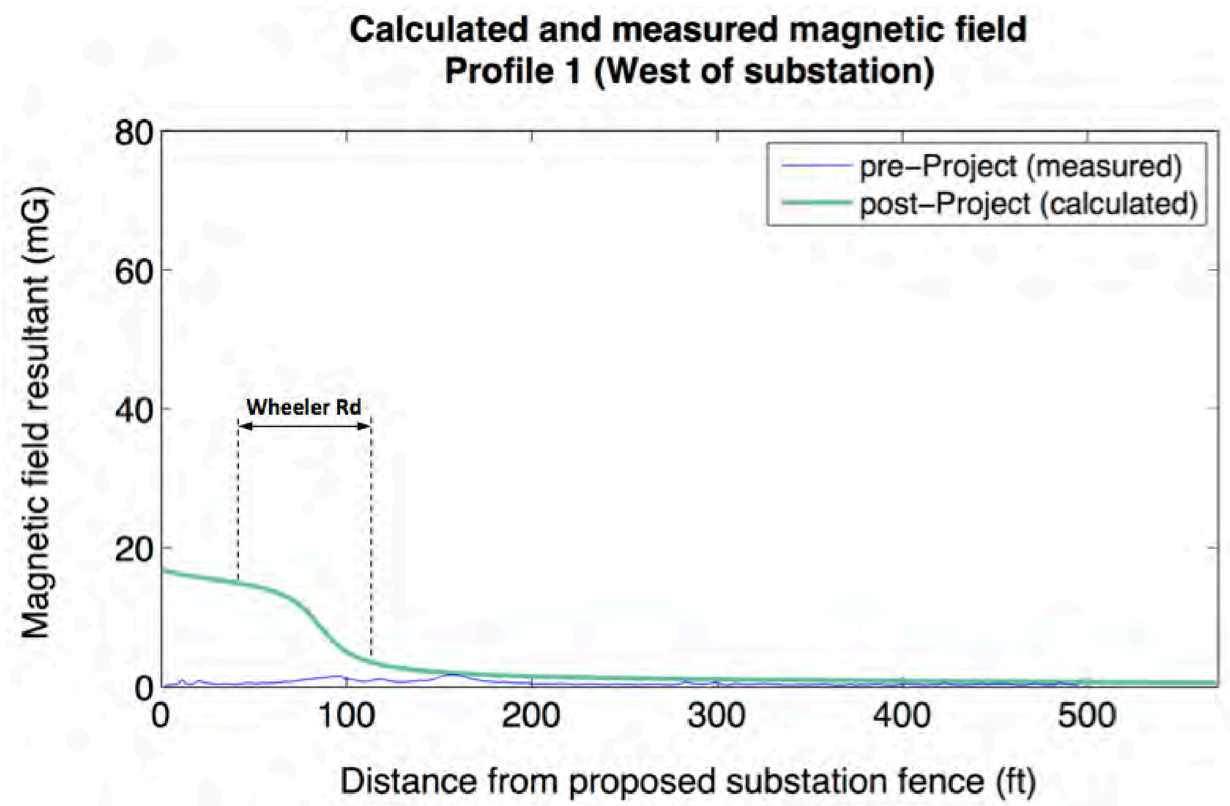


Figure 7. Calculated and measured magnetic-field levels along Profile 1 going to the west across Wheelrer Road for average-load conditions in 2017.

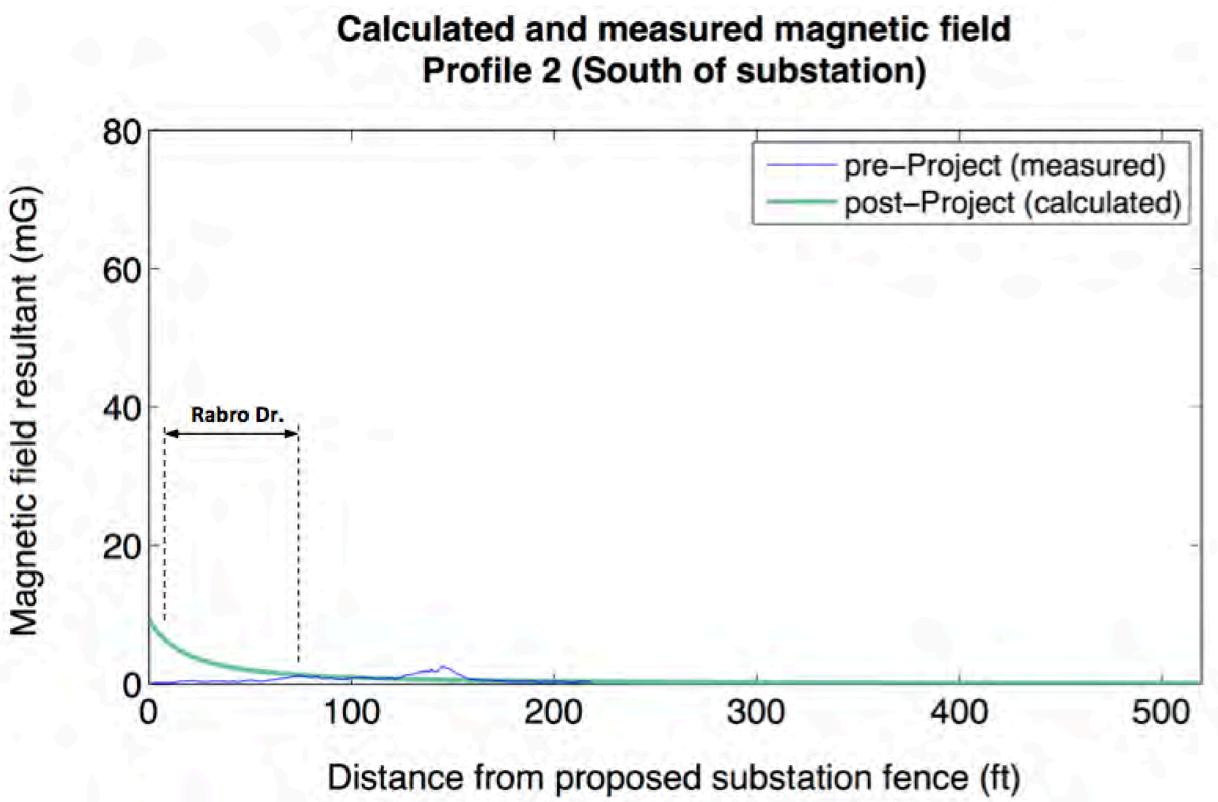


Figure 8. Calculated and measured magnetic-field levels along Profile 2 going to the south across Rabro Drive for average-load conditions in 2017.

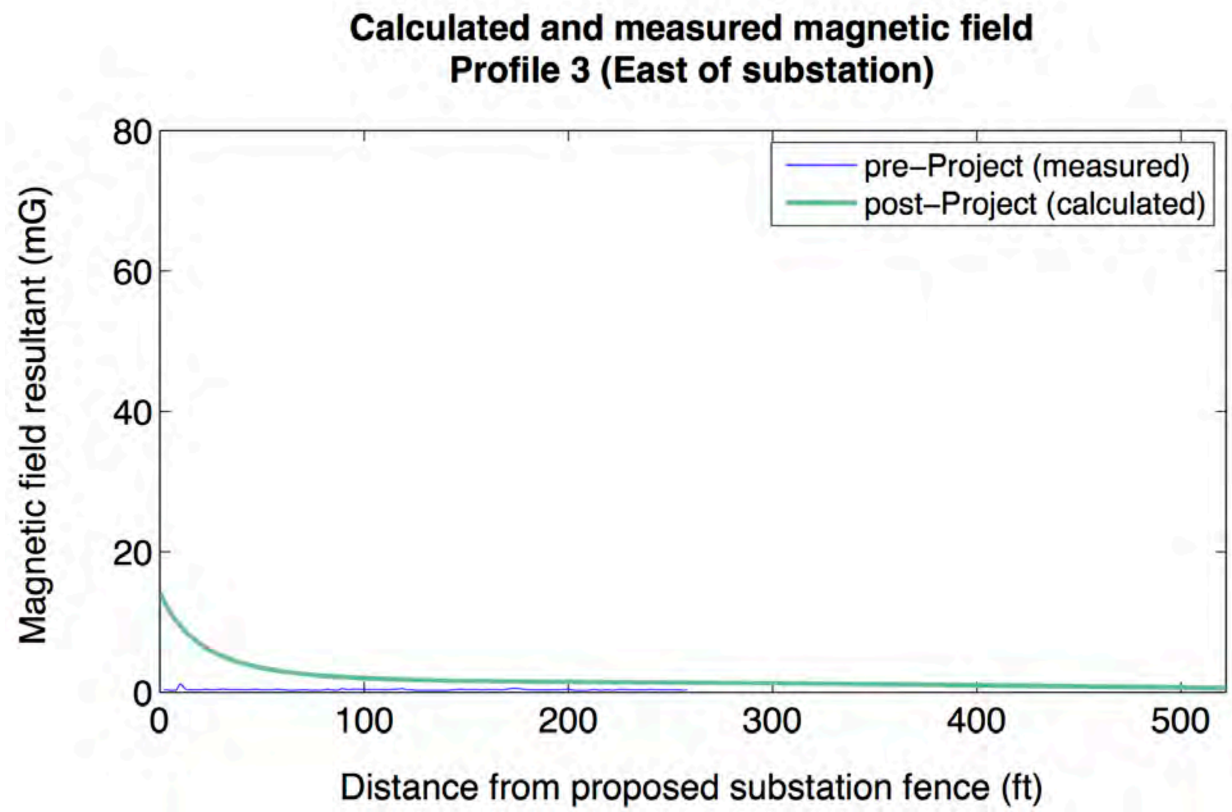


Figure 9. Calculated and measured magnetic-field levels along Profile 3 going to the east for average-load conditions in 2017.

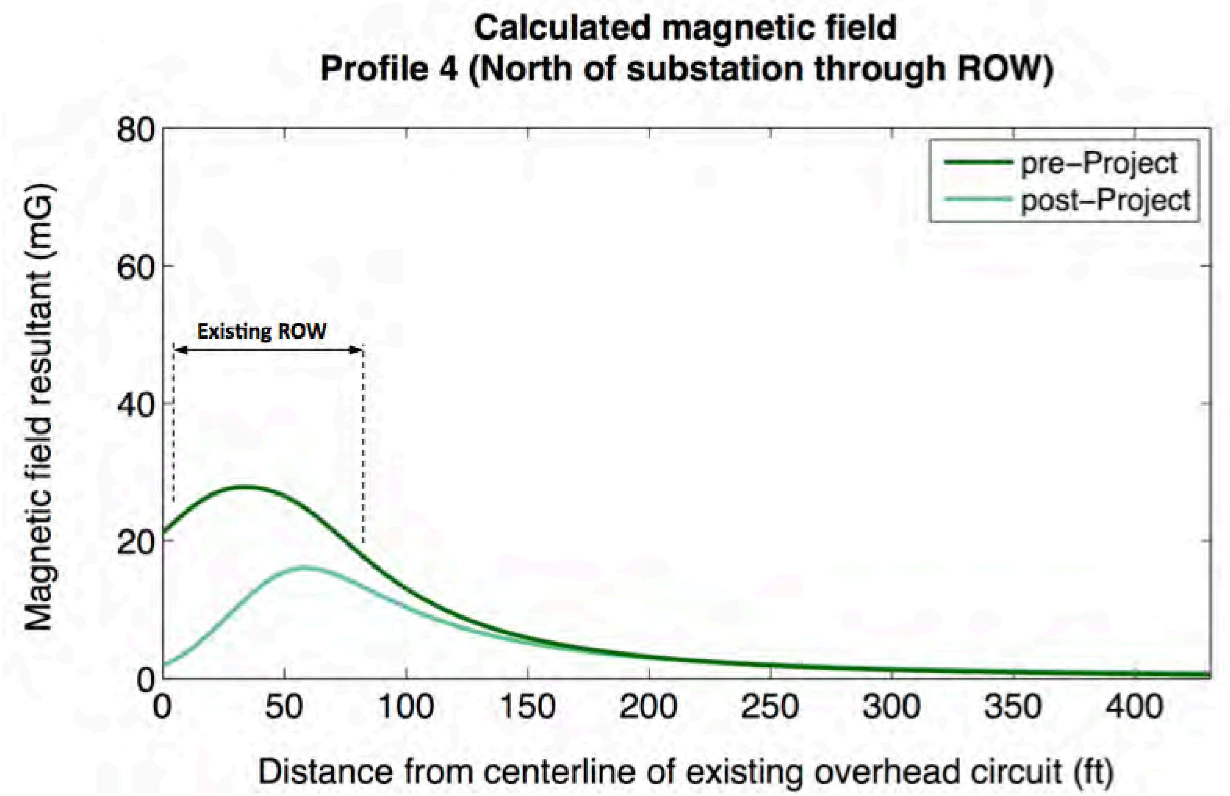


Figure 10. Calculated magnetic-field levels along Profile 4 going to the north across the existing ROW for average-load conditions in 2017.

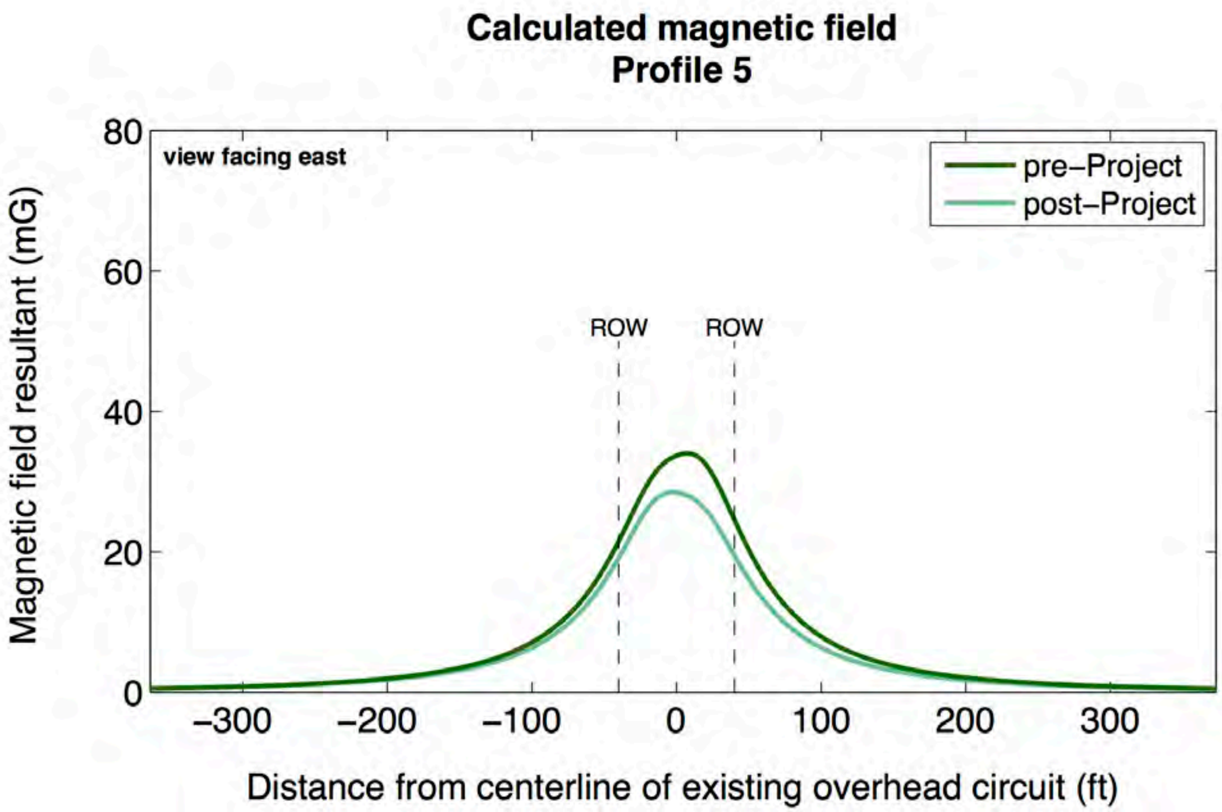


Figure 11. Calculated magnetic-field levels along Profile 5 (east of substation along the ROW) for average-load conditions in 2017.

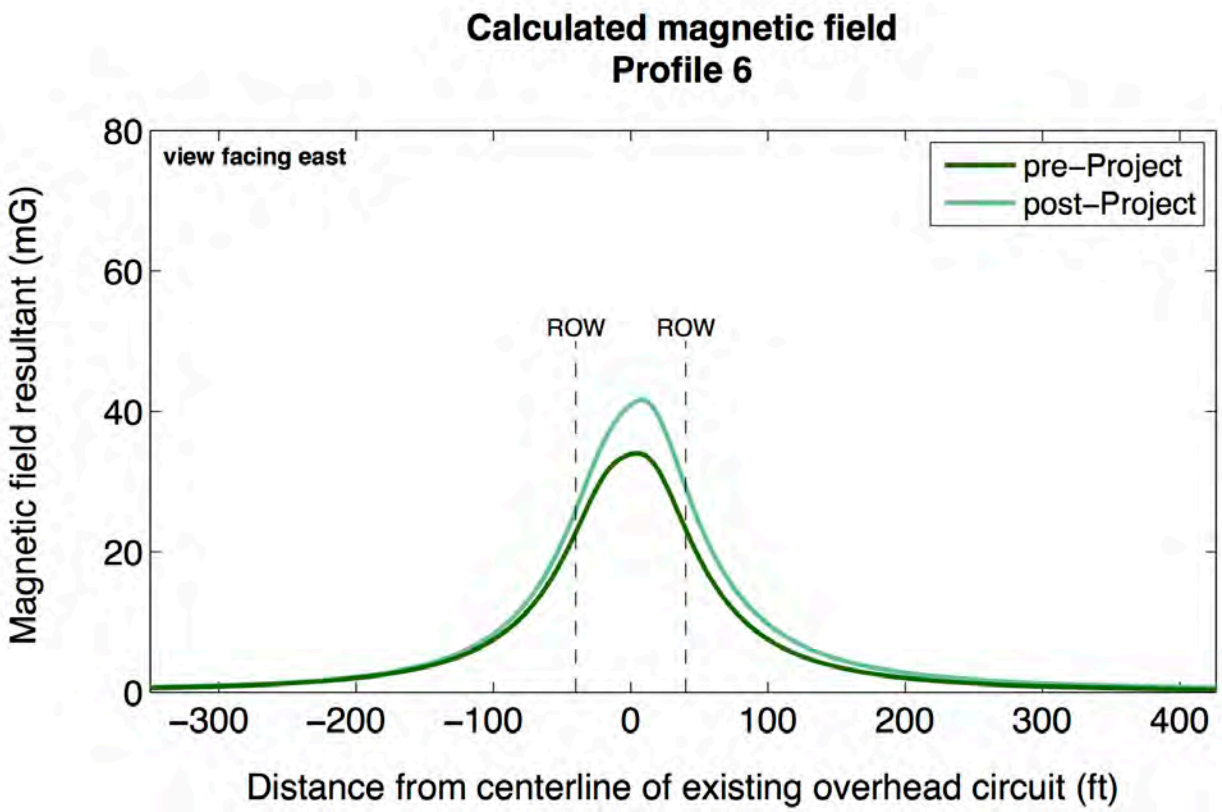


Figure 12. Calculated magnetic-field levels along Profile 6 (west of substation along the ROW) for average-load conditions in 2017.

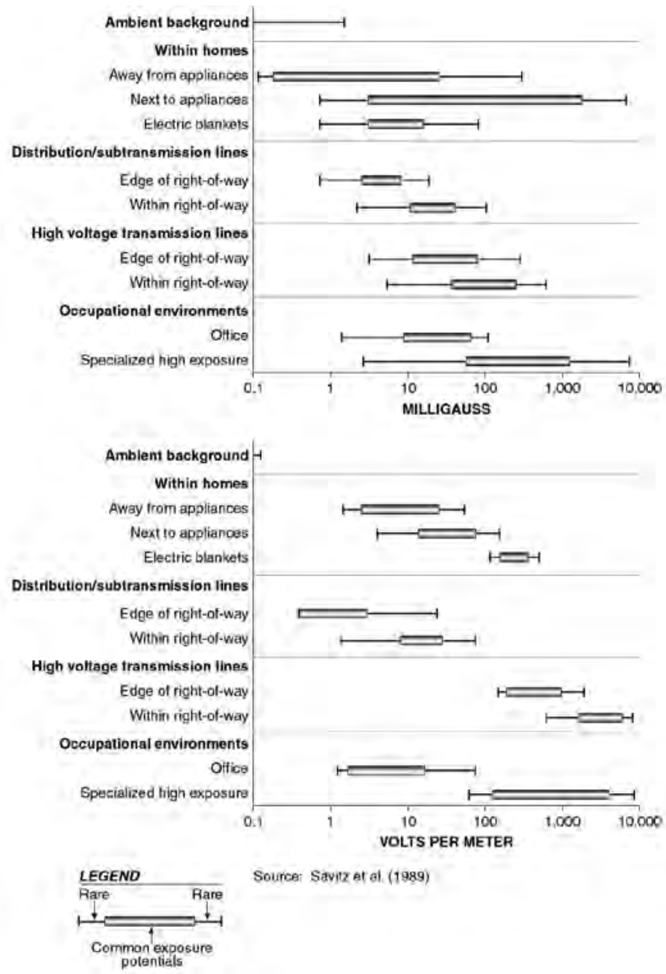


Figure 13. Electric- and magnetic-field strengths in the environment.

Appendix A

Magnetic fields surrounding conductors depend on current, which increases with increasing load. The current flows (loadings) for transmission lines and transformers used in the model are summarized in Table A1. Table A1 provides the average and peak loadings in amperes under existing conditions over the past five years (without Kings Highway), as well as the estimated average and peak loadings in amps under proposed conditions (with Kings Highway). For the existing conditions, loadings are provided for circuit 138-881 (the existing circuit on the south side of the ROW that will be segmented into circuits 13-880 and 13-881) and circuit 138-882 (located on the north side of the ROW). For the existing conditions, loadings are provided for circuits 138-880, 138-881, and 138-882.

Table A1. Circuit and equipment loading (amperes) used in the SUBCALC model

Circuit or Equipment	Voltage (kV)	Existing (Without Kings Highway)		Proposed (Estimates With Kings Highway)	
		Average	Peak	Average	Peak
138-881*	138	241	1256	166	867
138-882†	138	190	962	196	991
138-880	138	—	—	321	1671
Transformer 1	138/13.8	—	—	308	749
Transformer 2	138/13.8	—	—	308	749
Transformer 3	138/13.8	—	—	308	749

*Existing circuit will be tapped creating circuits 138-880 (Transmission Line "B" West) and 138-881 (Transmission Line "B" East).
†Transmission Line "A"

Exponent®

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June 20, 2016

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Notice

At the request of Public Service Enterprise Group – Long Island (PSEG-LI) and GEI Consultants, Inc. P.C., Exponent modeled the magnetic-field levels associated with the proposed West Bartlett Substation in the Town of Brookhaven, New York. This report summarizes work performed to date and presents the findings resulting from that work. In the analysis, we have relied on geometry, material data, usage conditions, specifications, and various other types of information provided by PSEG-LI. We cannot verify the correctness of this input data, and rely on the client for the data's accuracy. 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. PSEG LI has confirmed to Exponent that the summary of data provided to Exponent contained herein is not subject to Critical Energy Infrastructure Information (CEII) restrictions.

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 readers of this report outside of the regulatory proceedings relating to this Project, and any re-use of this report or its findings, conclusions, or recommendations presented herein 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

Public Service Enterprise Group of Long Island (PSEG-LI) has proposed the construction of the West Bartlett Substation (The Project) fronting West Bartlett Road, 500 feet south of the existing Coram-Ridge transmission line right-of-way (ROW) in the Town of Brookhaven, NY. At the request of PSEG-LI, Exponent modeled the magnetic fields associated with the proposed substation equipment, existing overhead transmission line, and the proposed overhead interconnection to the existing transmission line.

The effect of the substation on existing magnetic-field levels was evaluated by modeling magnetic fields for pre- and post-Project conditions. For the pre-Project conditions, the loading on the existing overhead circuits was calculated without any of the proposed equipment in service. Exponent also measured background magnetic-field levels at the proposed substation site on March 30, 2016.

The post-Project condition includes magnetic-field contributions from the proposed substation equipment and a new 69-kilovolt (kV) loop in and out of the new substation yard. In the post-Project condition, two load cases were studied, corresponding to average load and peak load for the proposed equipment and overhead 69-kV transmission lines. Electric fields from the substation were not modeled because they are effectively blocked by the metal fence and landscaping around the substation yard.

The modeling shows that the substation equipment and proposed 69-kV interconnection have little effect on the calculated magnetic field levels at residences in the neighborhood. The overhead interconnection would be located on the eastern edge of the substation parcel, set back from existing residences by more than 300 feet. At dwellings on the east side of West Bartlett Road, for instance, the calculated magnetic field would increase on average by less than 0.3 mG with operation of the Project. These changes can be attributed to an increase in loading on the 69 kV transmission line on the existing ROW north of the West Bartlett Substation, and an increase in distribution loads along West Bartlett Road.

The greatest Project-related increase in calculated magnetic-field level would occur near the southwest corner of the proposed site, where proposed underground feeders pass below the substation fence. Directly over the proposed feeders, the calculated magnetic-field level would be 10 mG for average-load conditions and 21 milligauss (mG) for peak-load conditions. The region where the calculated magnetic fields would be elevated above background levels extends for approximately 50 feet on either side of the proposed underground feeders.

Overall, the calculated and measured magnetic field levels associated with the Project fall within the range of typical levels encountered within homes and businesses. The Project-related increases in the calculated magnetic field are small, and are on average within 0.3 mG at dwellings adjacent to the proposed substation.

Proposed Configuration

The proposed location for the West Bartlett Substation is located on a 3.9-acre property on the east side of West Bartlett Road between Park Lane and Rose Lane in the Town of Brookhaven, south of the existing Coram-Ridge 69 kV ROW. See Figure 1.

The proposed substation equipment includes positions for two 69-kV transmission circuits to terminate, three gas circuit breakers, two 69/13.8-kV transformers, and two metal-clad switchgear power centers with terminations for 13.8-kV feeders. In the proposed configuration, the 13.8-kV feeders exit the substation underground onto West Bartlett Road, and interconnect to the existing overhead distribution circuits in the surrounding community.

In addition to the new equipment inside the substation fence, the Project includes two overhead interconnections to the existing 69-kV transmission line located approximately 0.12 miles (600 feet) north of the proposed site. In the proposed configuration, the existing 69-kV transmission line between the Coram and Ridge Substations will be looped into and out of at the new West Bartlett Substation as follows:

1) The proposed western segment of the interconnection loop would extend the existing 69-kV Line "A" from Coram to a new dead-end structure on the existing ROW. The circuit would proceed overhead in the center of a new 50-foot wide, maintained ROW located along the eastern edge of the substation parcel. The conductors of Line "A" would be supported on the west side of a double-circuit structure. See Figure 2(c). The Line "A" overhead interconnection would turn west at the southeast corner of the parcel, and terminate within the substation fence at the eastern side of the yard.

2) The proposed eastern segment of the interconnection loop (Line "B") would begin at a terminal structure within the substation fence, near the southeast corner of the yard. Line "B" would proceed overhead as a three-phase circuit, having the same configuration as Line "A." The conductors of the Line "B" interconnection would be installed on the same double-circuit structures as Line "A" on the opposite set of insulators. The conductors of the Line "B" interconnection would proceed north to a new dead-end structure on the existing ROW, and turn east toward Ridge.

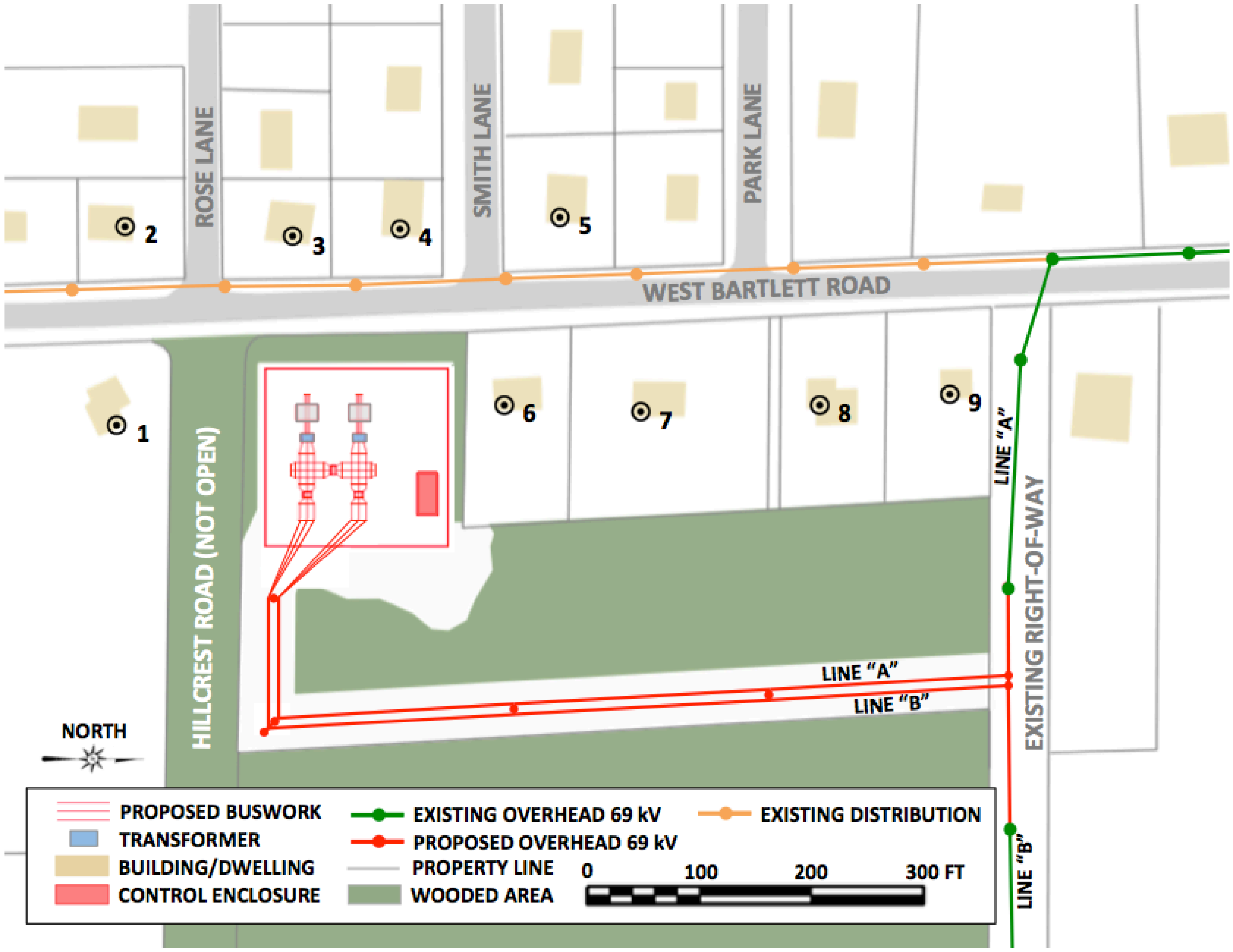

Figure 1. Proposed layout of the West Bartlett Substation and proposed overhead circuits in relation to the existing ROW and buildings in the vicinity of the Project

The numbered labels designate reporting locations for Project-related magnetic fields, which are summarized in Table 5.

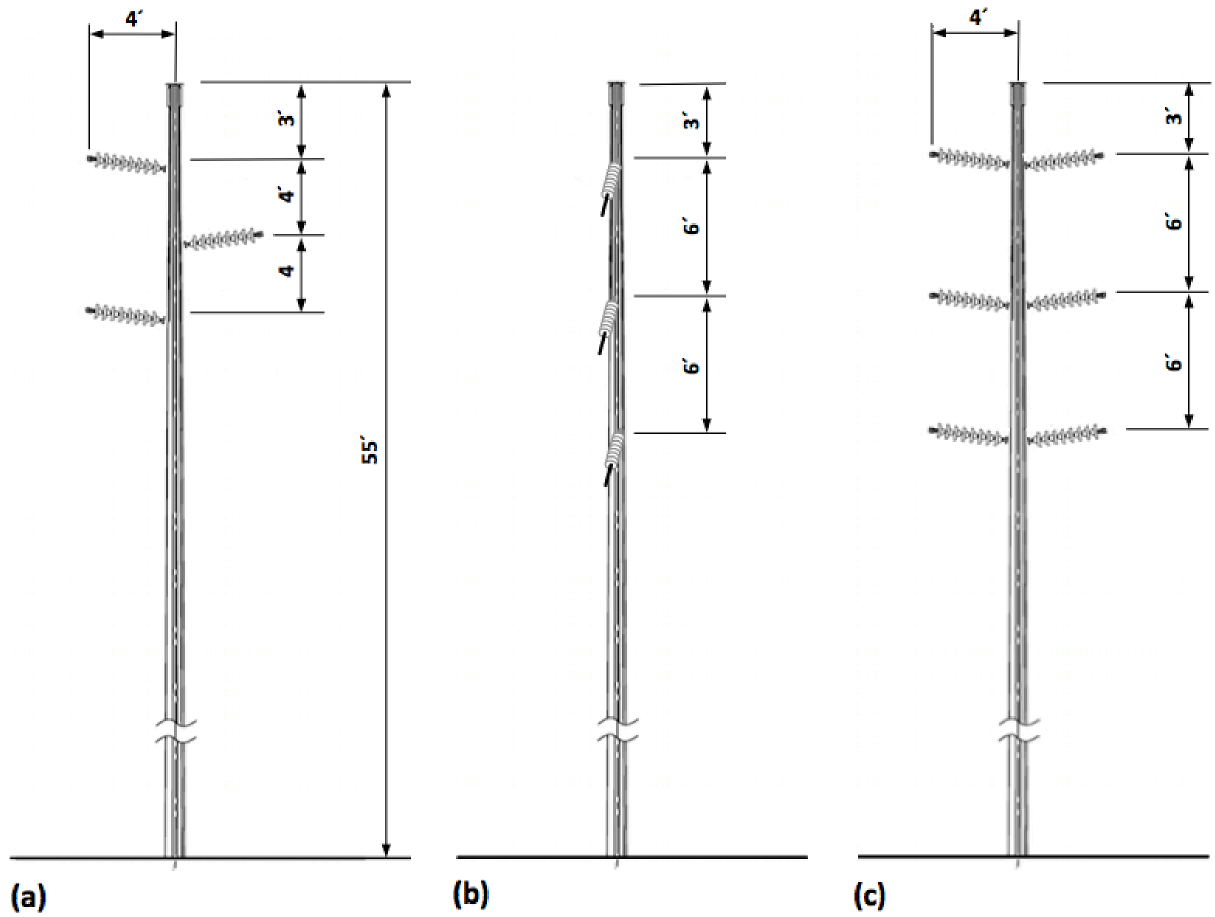

Figure 2. Structure dimensions used in SUBCALC model: (a) existing delta structure at tangent locations; (b) existing vertical single-circuit monopole at dead-end locations; and (c) double-circuit monopole for 69-kV interconnection.

Methods

Magnetic Field Modeling

The magnetic field around the perimeter of the proposed West Bartlett Substation and surrounding neighborhood was calculated using SUBCALC, which is part of the Enertech EMF Workbench Suite. SUBCALC models the magnetic fields in and around substations, accounting for the transformers and the three-dimensional arrangement of buswork and transmission-line interconnections (Figure 4). The SUBCALC model was built using the substation plan and profile data provide by PSEG-LI. The inputs to the program include data on the voltage, current flow, circuit phasing, and conductor configurations, which were also provided by PSEG-LI. [1]In particular, the SUBCALC model incorporates sag elevation data for each transmission line span and the elevation of conductor attachments. The short low-voltage underground connections from existing distribution lines into the substation were not included in the model.

Exponent calculated the anticipated magnetic field along four profiles perpendicular to the expanded substation perimeter, directed outward towards adjoining properties as shown in Figure 3:

Profile 1 is aligned with the transformer of Bank 1 in the substation yard, and proceeds west across West Bartlett Road.

Profile 2 starts 40 feet south of the northwest corner of the substation yard, and crosses West Bartlett Road.

Profile 3 begins near the control building on the north side of the substation yard, and proceeds north onto the adjoining property.

Profile 4 models the magnetic-field starting at the southern edge of the substation yard and proceeds south across Hillcrest Road (unopened) and onto the adjoining property.

Additional Profiles 5 – 7, shown in Figure 3, characterize the magnetic field along a transect perpendicular to the overhead route of the existing overhead 69 kV transmission line and proposed 69 kV interconnection. As described in greater detail below, measurements of background magnetic field levels were recorded along Profiles 1 – 2 and 4 – 7 on March 30, 2016. All magnetic fields were calculated at heights referenced to the elevation of the substation yard.

[1] The sources of the electric field within the substation are set back by 25 feet or more within the property line and their intensity diminishes quickly with distance. In addition, many objects are conductive—including fences, shrubbery, and buildings—and thus shield electric fields. Thus, the electric field from the West Bartlett Substation was not calculated since it will be effectively shielded by the substation fence and landscaping.

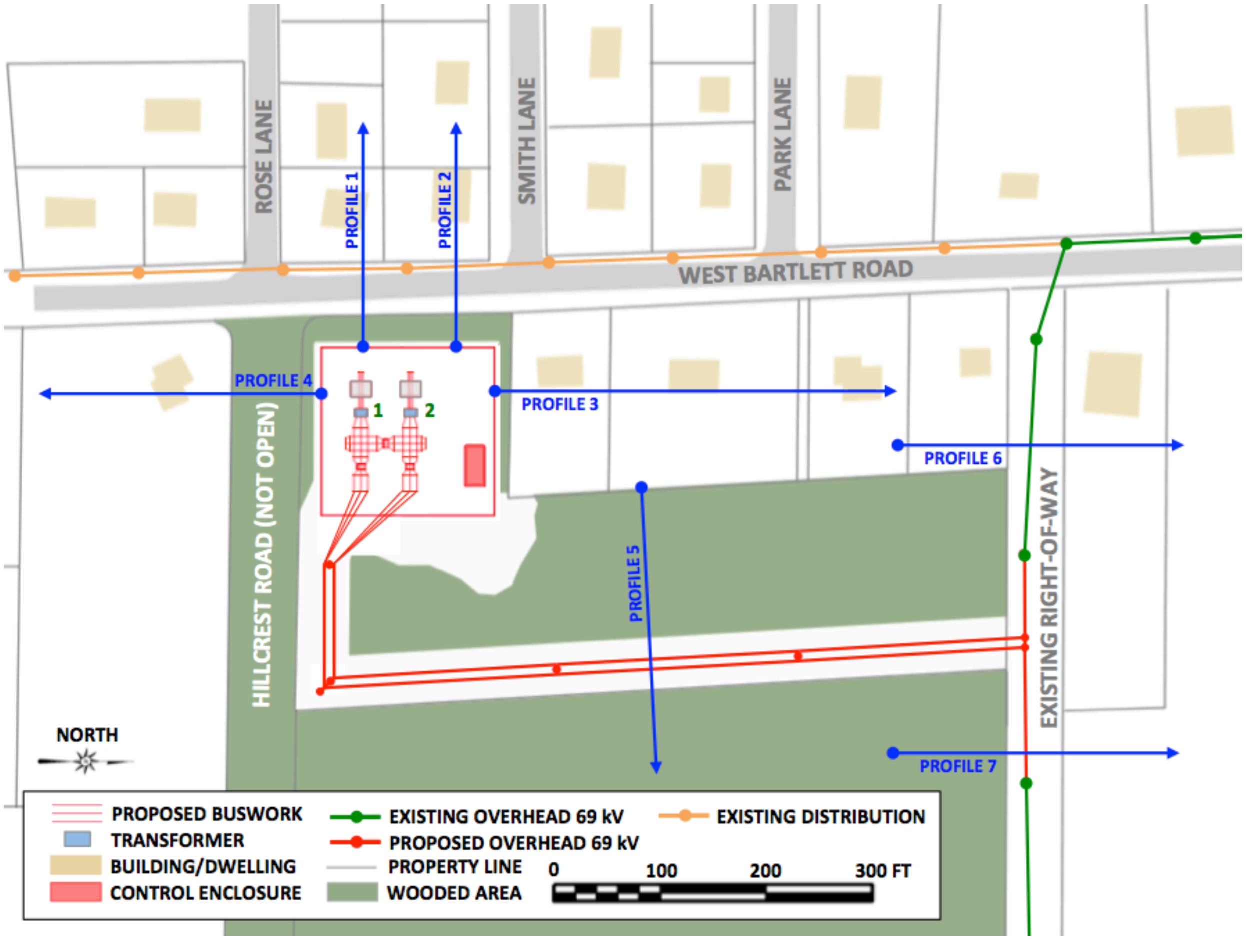

Figure 3. Plan view of the proposed West Bartlett Substation, showing the location of magnetic-field profiles and the proposed overhead route of Circuit A and Circuit B.

Along the fence line, perimeter of the property, and Profiles 1-7, the magnetic field was calculated at 1 meter (3.28 feet) above ground, in accordance with IEEE Std. C95.3.1-2010.[2] Calculated magnetic fields are reported as the resultant of x, y and z magnetic field vectors in units of milligauss (mG).[3]

Magnetic fields surrounding conductors depend on current, which increases with increasing load. The current flows (loadings) for the transmission lines, tie breaker, and transformers used in the model are summarized in Appendix A. Appendix A provides average loads for the in-service year of 2017, as well as a peak loads, corresponding to the highest load anticipated during the summer months in the year 2017.

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2 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. New York: IEEE. IEEE Std. C95.3.1™-2010.

3 The resultant magnetic field is the Euclidian norm (square root of the sum of the squares) of the component magnetic-field vectors calculated along vertical, transverse, and longitudinal axes.

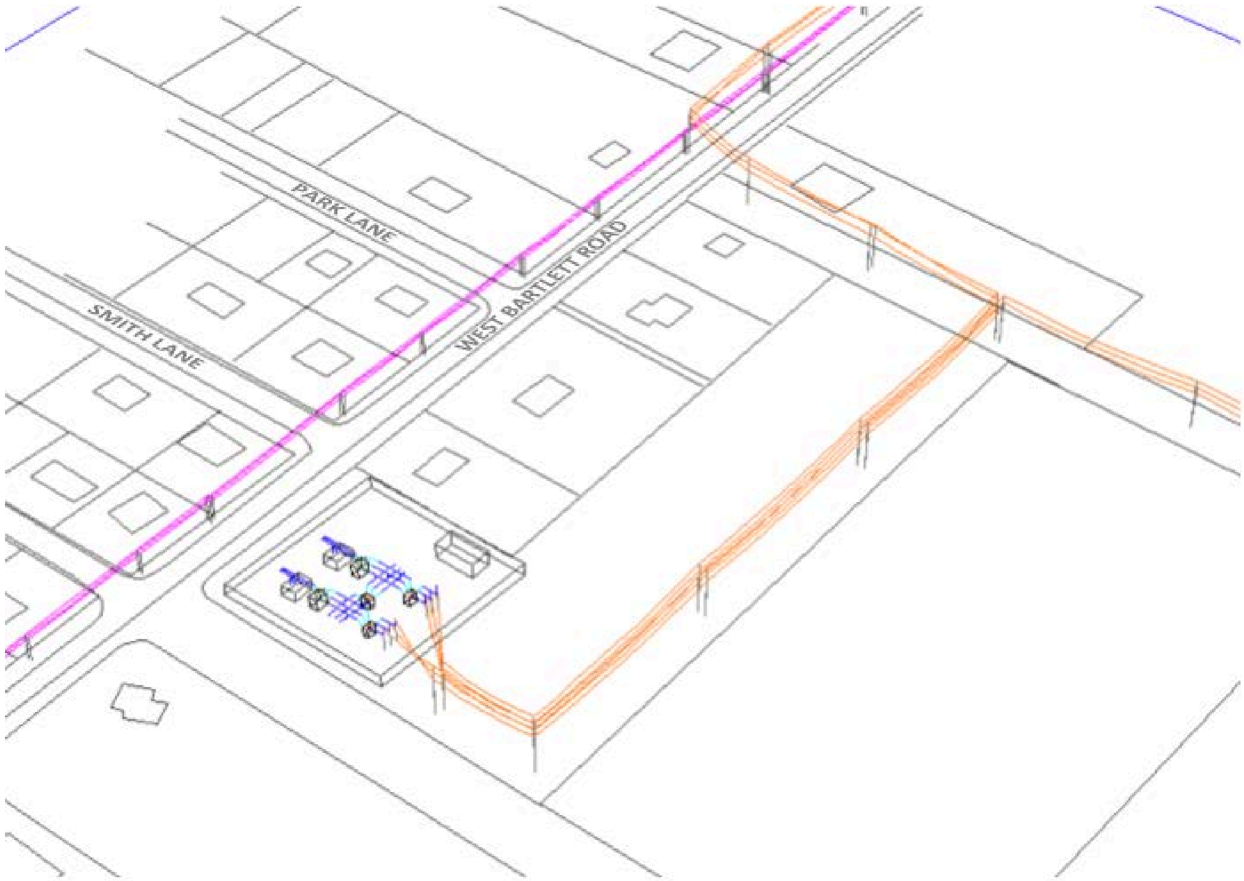

Figure 4. Overview of the three-dimensional SUBCALC model used to calculate magnetic-field profiles in the vicinity of the proposed West Bartlett Substation for the average and peak loading cases in 2017.

Orange lines represent overhead transmission-line conductors, including the proposed 69 kV loop in and out of the West Bartlett Substation. The purple line along West Bartlett road represents overhead distribution conductors, which are proposed to be rebuilt as part of the reinforcement project in the surrounding community.

Measurements

In order to characterize background EMF levels at the proposed site of the West Bartlett Substation, magnetic fields were measured outside the proposed substation fence on March 30, 2016. The measurements were taken at a height of 1 meter (3.28 feet) above ground in accordance with the standard methods for measuring near power lines (IEEE Std. 644-1994a). Measured magnetic fields are expressed as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[4] The magnetic field was measured in units of mG by orthogonally-mounted sensing coils whose output was logged by a digital recording meter (EMDEX II) manufactured by Enertech Consultants. This instrument meets the Institute of Electrical and Electronics Engineers **(**IEEE) instrumentation standard for obtaining accurate field measurements at power line frequencies (IEEE Std.1308-1994b). The meter was calibrated by the manufacturer by methods like those described in IEEE Std. 644-1994a.

4 The resultant magnetic field is the Euclidian norm (square root of the sum of the squares) of the component magnetic-field vectors calculated along vertical, transverse, and longitudinal axes. Root mean square refers to the common mathematical method of defining the effective voltage, current, or field of an AC system.

Results and Discussion

The measured and calculated magnetic fields around the fence line of the proposed West Bartlett Substation are depicted in Figure 5. To characterize the existing sources around the proposed site, the "measured" profile in Figure 5 shows the magnetic-field levels recorded on March 30, 2016. The measured profile reflects pre-Project conditions at the site, in which no proposed facilities are constructed or in service.[5] The measured magnetic-field levels can be accurately modeled by two existing magnetic-field sources: (1) the overhead distribution circuit on the west side of West Bartlett Road, and (2) the overhead 69-kV transmission line on the existing ROW between Coram and Ridge. These sources were included in the calculated "pre-Project" profile in Figure 5, and in other calculated profiles in Figures 6 – 14. The measured magnetic fields from these sources were below 1 mG along the north, west, and south sides of the substation fence. At all locations on the east side of the proposed substation fence and in the adjacent wooded area, the measured magnetic field levels were below 0.2 mG.

The "post-Project" profile in in Figure 5 shows the magnetic field calculated by SUBCALC along the fence line of the proposed West Bartlett Substation for average-load conditions. The calculated field reflects the contribution of proposed substation equipment within the yard and the proposed overhead interconnection to the existing 69 kV transmission line to the north. The SUBCALC model also includes proposed underground distribution feeders exiting the substation onto West Bartlett Road, and interconnecting to overhead distribution lines in the surrounding community. Both the measured and calculated profiles in Figure 5 begin at the southwest corner of the substation yard, and continue counter clockwise along the fence to the southeast, northeast, and northwest corners of the yard.

Figure 6 shows the measured and calculated magnetic-field levels along the property line of the proposed West Bartlett Substation. The profile in Figure 6 begins at the southwest corner of the parcel, and continue counter clockwise along the fence to the southeast, northeast, and northwest corners of the L-shaped property. Figure 7 shows the calculated magnetic-field profile along the same path as in Figure 6, modeled using peak loading rather than average loading.

Figures 8 – 17 depict the calculated magnetic field levels along Profiles 1 – 7 for average-load conditions in 2017. All of these figures except Figure 10 include background magnetic-field measurements recorded in March 30, 2016. Table 1 summarizes calculated magnetic-field levels at various distances from the substation fence in Profiles 1 – 4, for average load conditions. Table 2 likewise summarizes calculated magnetic fields for Profiles 5 – 7, at various distances from the centerline of the overhead circuits, for average-load conditions. Tables 3 and 4 include the calculated magnetic fields at the same locations as Tables 1 and 2, but for peak-load rather than average-load conditions.

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[5] The measured profile in Figure 5 provides a "snapshot" of background magnetic-field levels. On a given day, throughout a week, or over the course of months and years, the measured magnetic field can change depending upon the patterns of power demand within the surrounding community. In general, the measured magnetic will increase during summer months when power demand on Long Island is higher.

Referring to the calculated profiles in Figure 5 and Figure 6, operation of the Project elevates calculated magnetic field levels above existing background levels. The greatest Project-related increase in calculated magnetic-field levels would be on the eastern edge of the proposed substation yard (away from residences and West Bartlett Road), where the proposed overhead circuits pass above the substation fence. The calculated magnetic-field level on the eastern edge is 16 mG for average-load conditions and 33 mG for peak-load conditions. On West Bartlett Road, where the proposed underground feeders pass below the substation fence, the calculated magnetic-field level is 10 mG for average-load conditions and 21 mG for peak-load conditions. These results are consistent with IEEE Standard 1127-2013 that states “[i]n a substation, the strongest fields near the perimeter fence come from the transmission and distribution lines entering and leaving the substation. The strength of fields from equipment inside the fence decreases rapidly with distance, reaching very low levels at relatively short distances beyond substation fences.” (IEEE Std. 1127-2013).

Referring to the southwest corner of the substation property in Figure 6 and Figure 7, the region where the calculated magnetic fields are elevated above the background level extends for approximately 50 feet on either side of the proposed underground feeders. As shown in Figure 8 (Profile 1), the calculated magnetic field is between 5-10 mG across West Bartlett Road, parallel to the path of the underground feeders exiting the substation. In Figure 9 (Profile 2), which is located 100 feet north of Profile 1, the calculated magnetic field reflects the loading of distribution lines on the west side of West Bartlett Road. These distribution loads are anticipated to increase with operation of the Project, since a greater proportion of load to the surrounding community will be served from the proposed West Bartlett Substation.

Extending north (Profile 3, Figure 10) and south (Profile 4, Figure 11) from the substation yard, the calculated magnetic field for average-load conditions remains nearly unchanged with operation of the Project. For peak-load conditions, the calculated increase is greater (0.5-1.0 mG, comparing pre-Project and post-Project cases). *See* Table 1 and

Table 3. This small increase reflects the fact that the substation equipment will be set back 25 to 90 feet from the substation fence.

The proposed 69-kV interconnection also has little effect on the calculated magnetic field levels at residences in the neighborhood. The overhead interconnection will be located on the eastern edge of the substation parcel, and set back from existing residences by more than 300 feet. Referring to Profile 5 (Figure 12), the calculated magnetic field 100 feet west of the 69 kV interconnection is 0.5 mG under average-load conditions and 0.9 mG under peak-load conditions. These magnetic-field levels represent an increase of 0.2-0.7 mG increase over the existing levels. *See* Table 2 and Table 4.

Across the existing ROW, the calculated magnetic field increases with operation of the Project, reflecting an increase in loading on the existing overhead transmission line. Referring to Profile 6 (Figure 13), the calculated magnetic field increases from 0.6 mG to 1.5 mG at locations 100 feet south of the existing centerline of the 69 kV circuit. The calculated increase is greater (2.4 mG pre-Project, versus 4.2 mG post-Project), for peak-load conditions. *See* Table 2 and Table 4.

Table 1. Summary of calculated magnetic fields (mG) for Profiles 1-4, average-load case

		Distance from Substation Fence (ft)			
Profile	**Condition**	**0**	**50**	**100**	**150**
1	Pre-Project	0.9	2.2	1.9	0.8
	Post-Project	9.0	5.7	2.8	0.8
2	Pre-Project	0.8	2.0	2.1	0.9
	Post-Project	0.8	3.1	3.3	0.9
3	Pre-Project	0.5	0.5	0.5	0.5
	Post-Project	0.5	0.5	0.5	0.5
4	Pre-Project	0.5	0.5	0.5	0.5
	Post-Project	0.8	0.5	0.5	0.5

* Underground distribution circuits are present at this location.

Table 2. Summary of calculated magnetic fields (mG) for Profiles 5-7, average-load case

		Offset from centerline of proposed circuits				
Profile	**Load case**	**100 ft west/south**	**50 ft west/south**	**0 ft**	**50 ft east/north**	**100 ft east/north**
5	Pre-Project	0.2	0.1	0.1	0.1	0.1
	Post-Project	0.5	1.2	4.0	0.7	0.1

6	Pre-Project	0.6	1.9	4.2	1.8	0.6
	Post-Project	1.4	2.8	7.1	2.8	1.0
7	Pre-Project	0.7	1.8	4.8	2.0	0.7
	Post-Project	1.0	2.9	8.0	3.5	1.2

Table 3. Summary of calculated magnetic fields (mG) for Profiles 1-4, peak-load case

Profile	Condition	Distance from Substation Fence (ft) 0	50	100	150
1	Pre-Project	0.9	2.2	1.9	0.8
	Post-Project	26.1*	16.1*	6.9	1.2
2	Pre-Project	0.8	2.0	2.1	0.9
	Post-Project	1.6	7.4	7.9	1.6
3	Pre-Project	0.5	0.5	0.5	0.5
	Post-Project	1.0	0.9	0.8	0.8
4	Pre-Project	0.5	0.5	0.5	0.5
	Post-Project	1.5	0.5	0.5	0.5

* Underground distribution circuits are present at this location.

Table 4. Summary of calculated magnetic fields (mG) for Profiles 5-7, peak-load case

		Offset from centerline of proposed circuits				
Profile	Load case	100 ft west/south	50 ft west/south	0 ft	50 ft east/north	100 ft east/north
5	Pre-Project	0.2	0.2	0.2	0.2	0.2
	Post-Project	0.9	2.7	10.0	1.9	0.3
6	Pre-Project	2.4	6.5	14.4	6.4	2.4
	Post-Project	4.2	8.5	19.7	7.7	2.8
7	Pre-Project	2.2	6.5	16.6	7.0	2.6
	Post-Project	2.7	7.4	20.5	9.0	3.1

Structures and Buildings

Table 5 shows the magnetic field calculated at reporting locations 1 – 9 (see Figure 1), which are dwellings around the proposed site of the West Bartlett Substation. Table 5 provides the calculated magnetic field levels at both average and peak loading, before and after operation of the Project. The "average" column was calculated using the annual average loads provided in Appendix A. The "peak" column reflects the peak loads provided in Appendix A, and is anticipated to occur for a few days and hours during the year when power demand is highest in the surrounding community. Closest to the existing ROW (location 9), the average increase in calculated magnetic field is 0.2 mG for average-load conditions and 0.5 mG for peak-load conditions. This change reflects an increase in loading on the existing overhead transmission line with operation of the Project.

At other dwellings along the west side of West Bartlett Road, the Project-related increase in calculated magnetic fields is 0.2 mG or lower for average-load conditions and 1.4 mG or lower for peak-load conditions. This change reflects the increased peak loading of overhead distribution circuits along West Bartlett Road, as part of the overall reinforcement project in the surrounding community.

Table 5. Summary of calculated magnetic fields (mG) at designated structures

	2017 Average Load		2017 Peak Load	
Building designator*	**pre-Project**	**post-Project**	**pre-Project**	**post-Project**
1	0.3	0.3	0.3	0.3
2	0.5	0.6	0.5	0.7
3	1.0	1.1	1.0	2.1
4	1.2	1.2	1.2	2.6
5	1.1	1.2	1.1	2.4
6	1.1	1.3	1.1	2.4
7	0.6	0.7	0.6	1.0
8	0.5	0.5	0.5	0.8
9	0.5	0.7	0.8	1.3

* The location of each building is shown in Figure 1.

Comparison with Background Levels

Since electricity is such an integral part of our infrastructure (e.g., transportation systems, homes, and businesses), people living in modern communities are surrounded by sources of electric and magnetic fields. Figure 15 describes typical EMF levels measured in residential and occupational environments, compared to levels measured on or at the edge of transmission-line rights-of-way. While EMF levels decrease with distance from the source, any home, school, or office tends to have a “background” EMF level as a result of the combined effect of the numerous EMF sources. In general, the background magnetic-field level in a house away from appliances is typically less than 20 mG, while levels can be hundreds of mG in close proximity to appliances.

Little research has been done to characterize the general public’s exposure to magnetic fields, although some basic conclusions are available from the literature. The vast majority of people in the United States have a *time-weighted average* (TWA) exposure to magnetic fields less than 2 mG.[6] The highest magnetic-field levels are typically found directly next to appliances.[7] For

[6] TWA is the average exposure over a given specified time period (i.e., an 8-hour workday or a 24-hour day) of a person’s exposure to magnetic fields. The average is determined by sampling the exposure of interest throughout the time period. *See* Zaffanella LE and Kalton GW. Survey of Personal Magnetic Field Exposure Phase II: 1,000 Person Survey. EMF Rapid Program, Engineering Project #6. Lee, MA: Entertech Consultants, 1998.

example, Gauger (1985) reported the maximum AC magnetic field at 3 centimeters from a sampling of appliances as 3,000 mG (can opener), 2,000 mG (hair dryer), 5 mG (oven), and 0.7 mG (refrigerator).[8]

Overall, the calculated and measured magnetic field levels associated with the Project fall within the range of typical levels encountered within homes and businesses. The Project-related increases in the calculated magnetic field are small, and are on average within 0.3 mG at dwellings adjacent to the proposed West Bartlett Substation.

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[7] *See* Zaffanella LE. Survey of Residential Magnetic Field Sources. Volume 2: Protocol, Data Analysis, and Management. EPRI TR-102759-V2. Palo Alto, CA: EPRI, 1993.

[8] *See* Gauger JR. Household appliance magnetic field survey. IEEE Trans Power App Syst 104: 2436-2444, 1985.

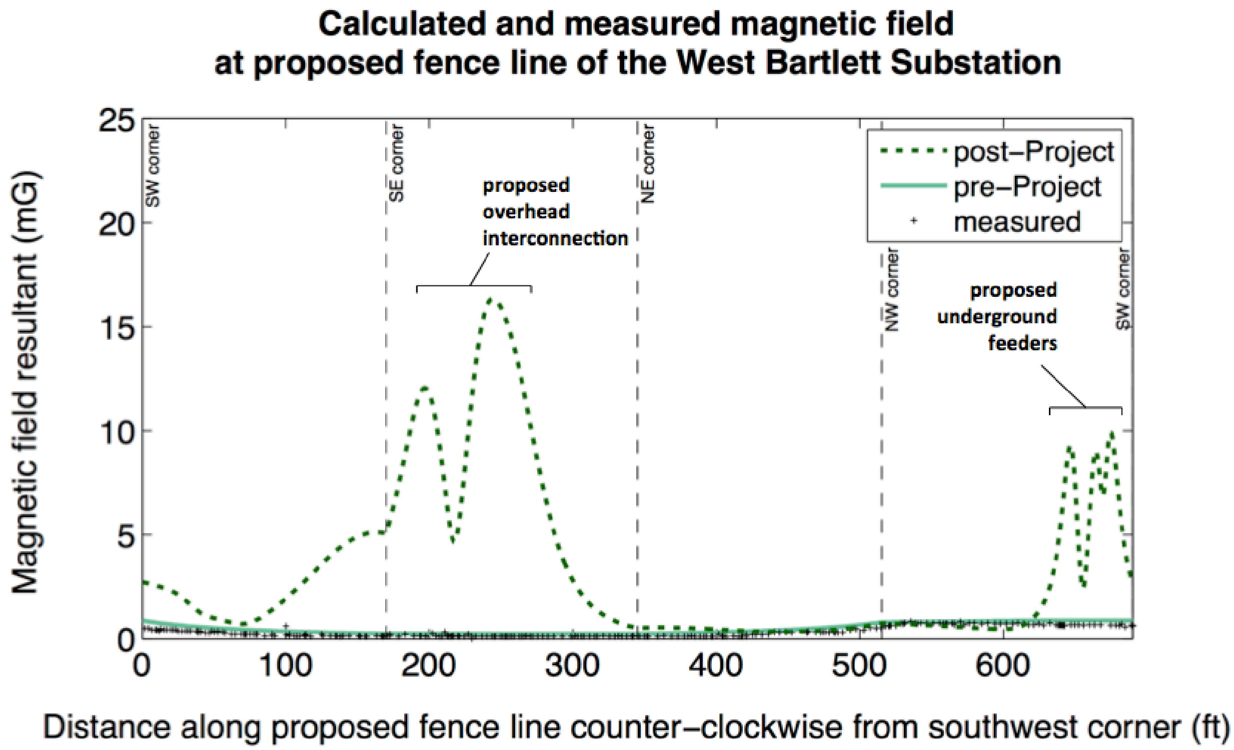
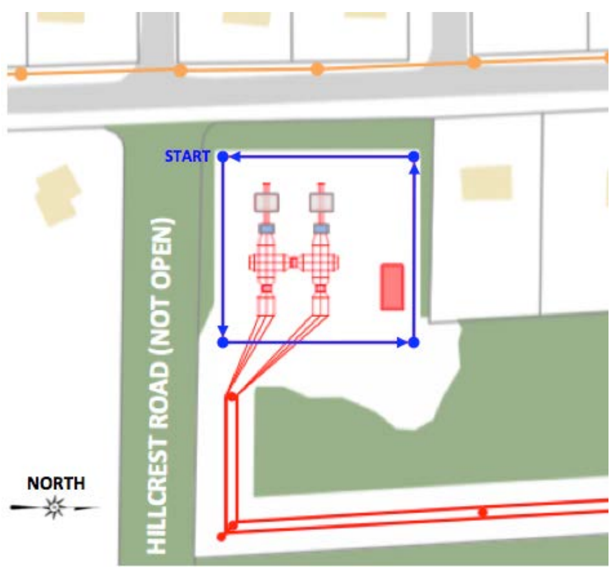


Figure 5. Calculated and measured magnetic-field profiles around the fence line of the proposed West Bartlett Substation for average-load conditions in 2017.

The measured profile shows the magnetic fields measured on March 30, 2016.



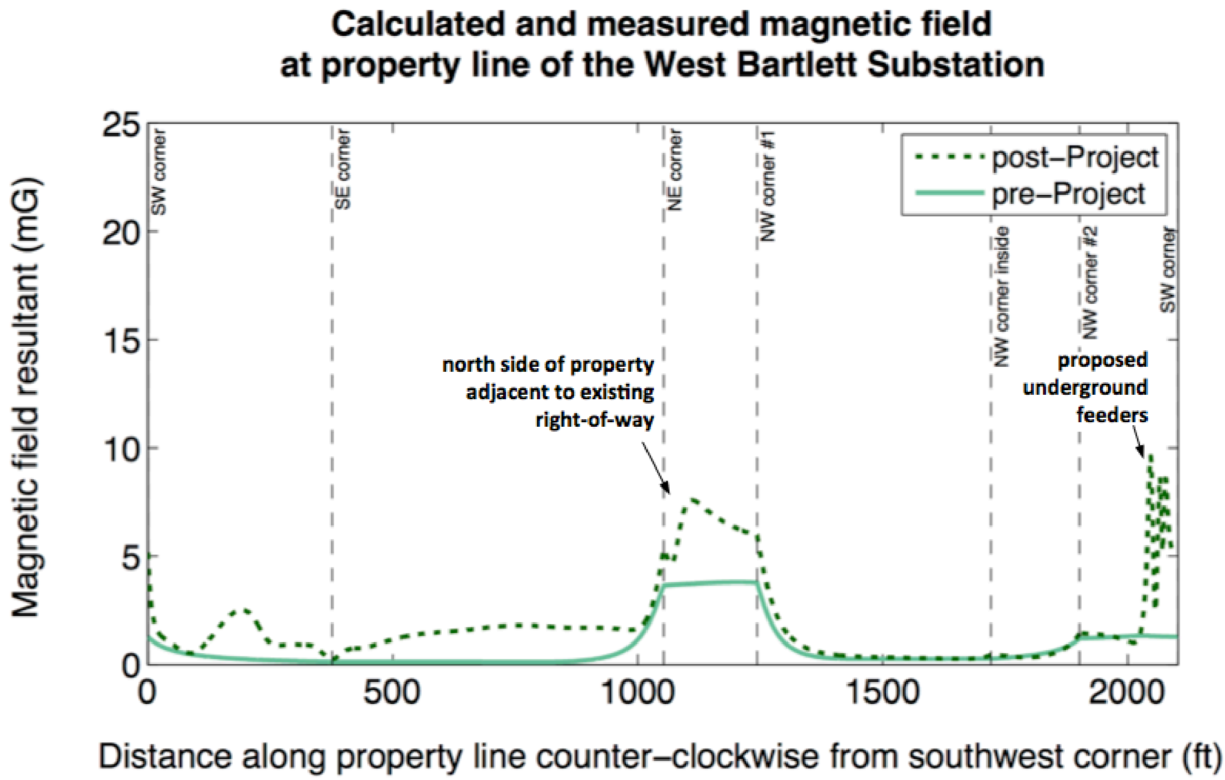
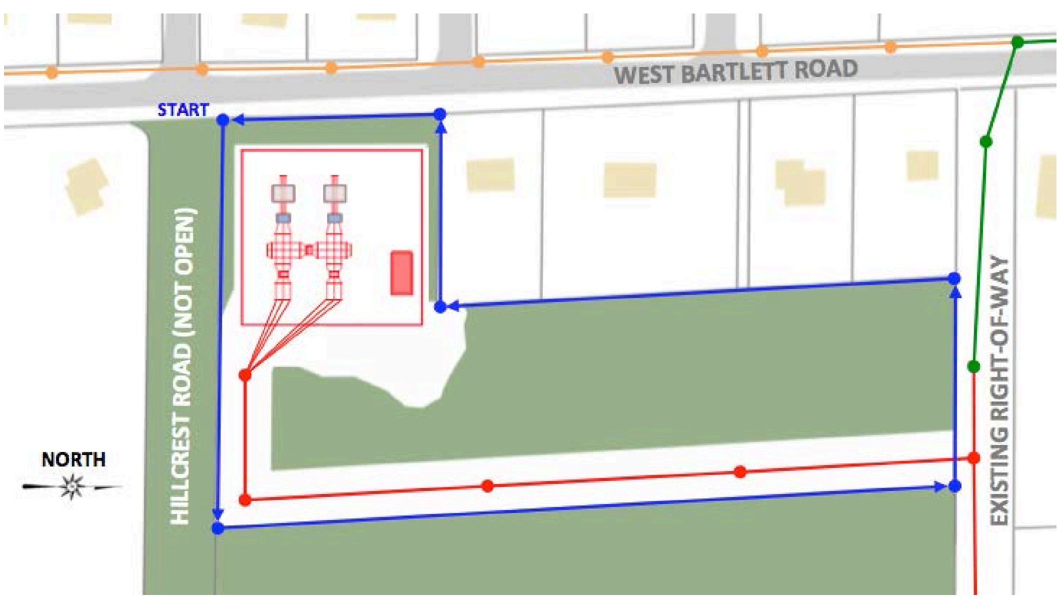


Figure 6. Calculated magnetic-field profile around the property line of the proposed West Bartlett Substation for average-load conditions in 2017.



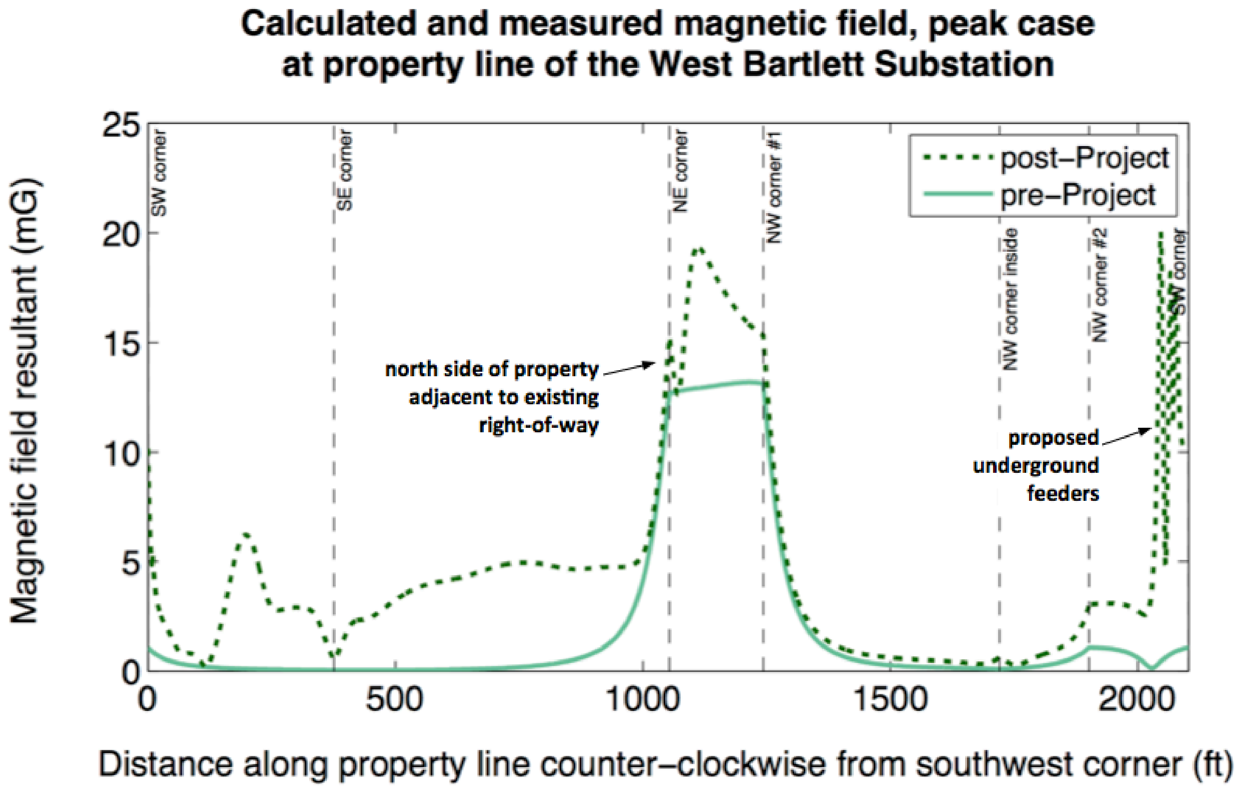


Figure 7. Calculated magnetic-field profile around the property line of the proposed West Bartlett Substation for peak-load conditions in 2017.

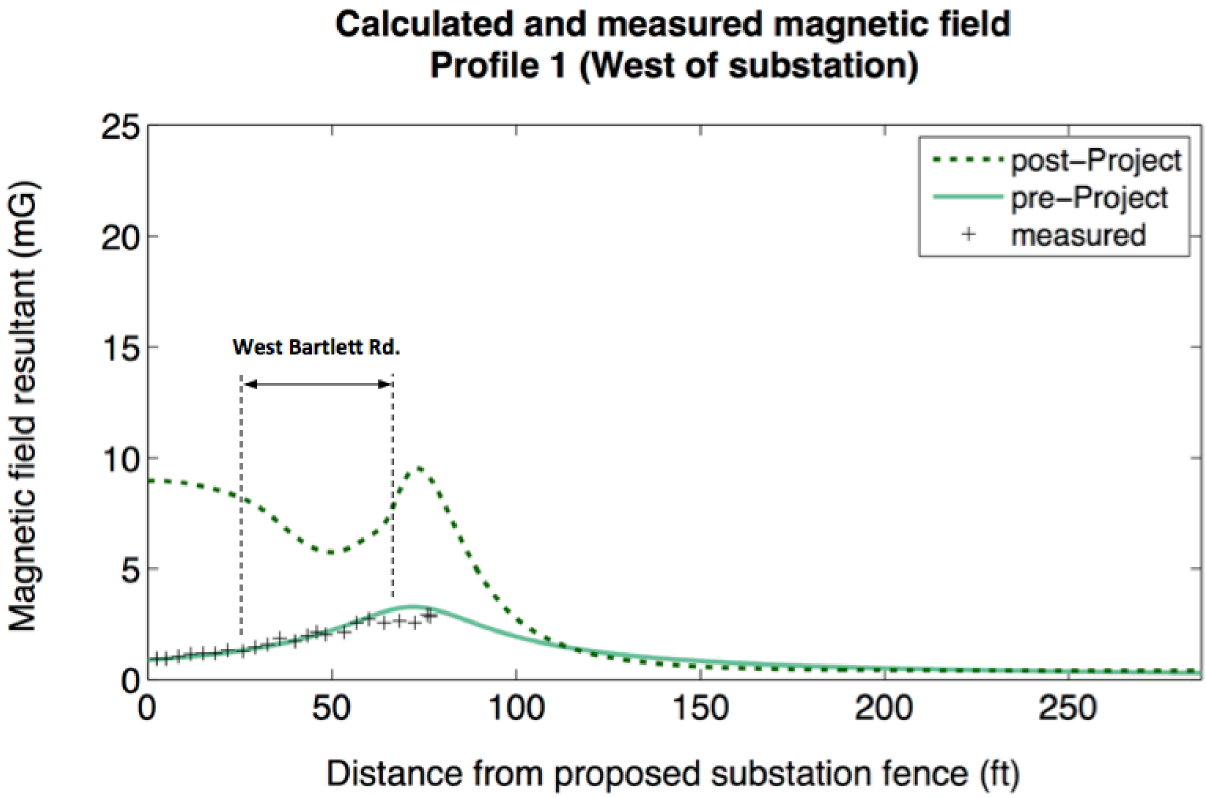


Figure 8. Measured and calculated magnetic-field levels along Profile 1 going to the west for average-load conditions in 2017.

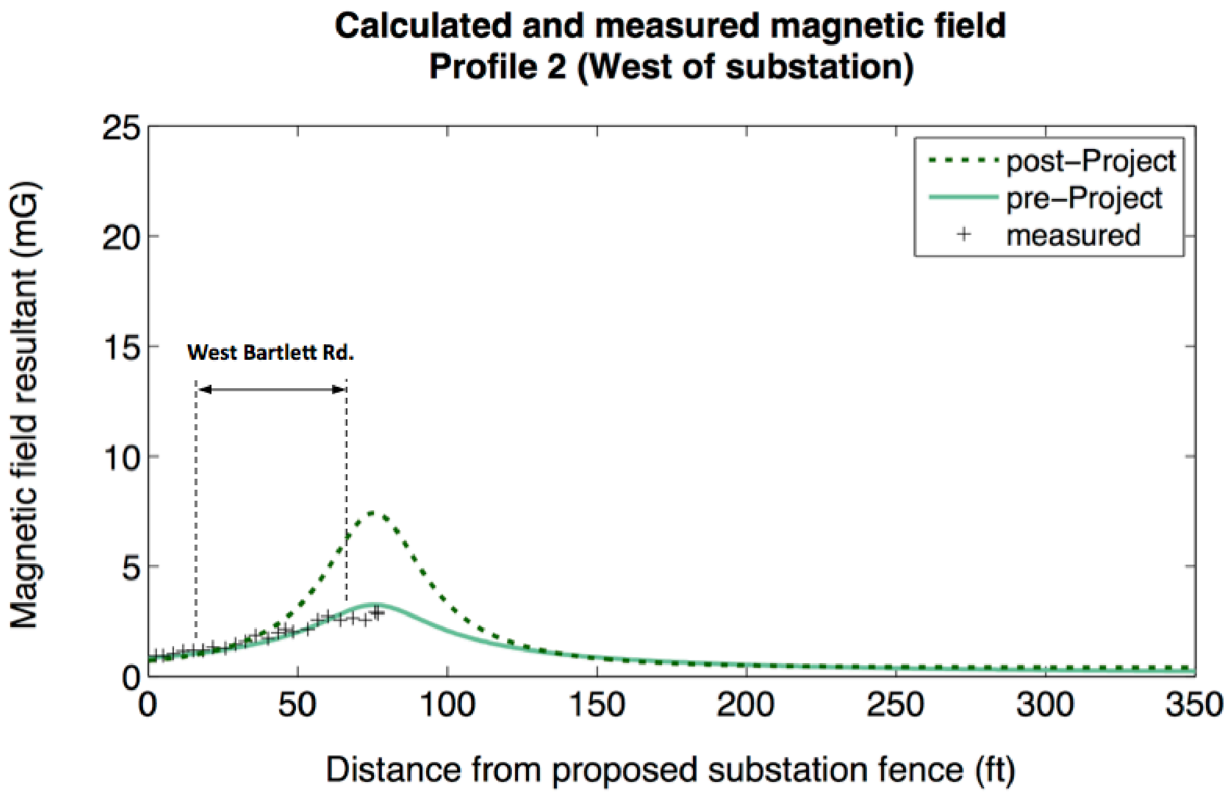


Figure 9. Measured and calculated magnetic-field levels along Profile 2 going to the west for average-load conditions in 2017.

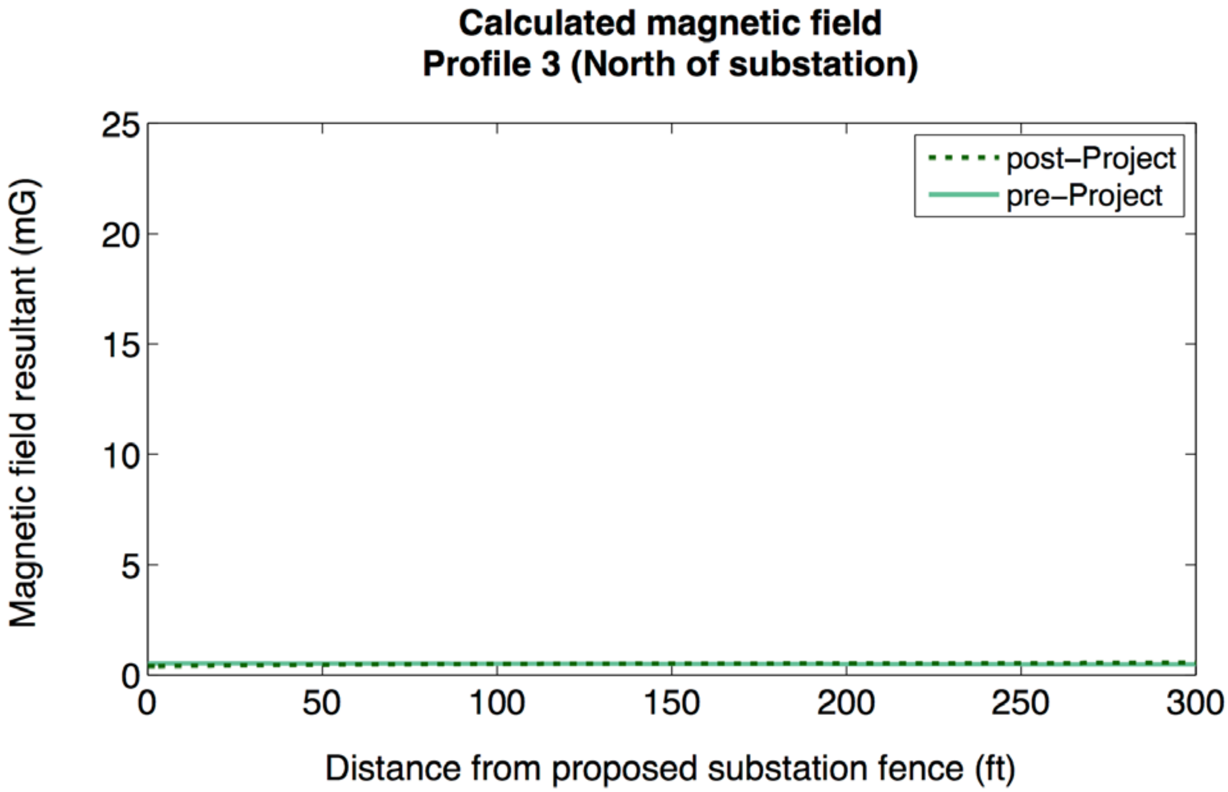


Figure 10. Calculated magnetic-field levels along Profile 3 going to the north for average-load conditions in 2017.

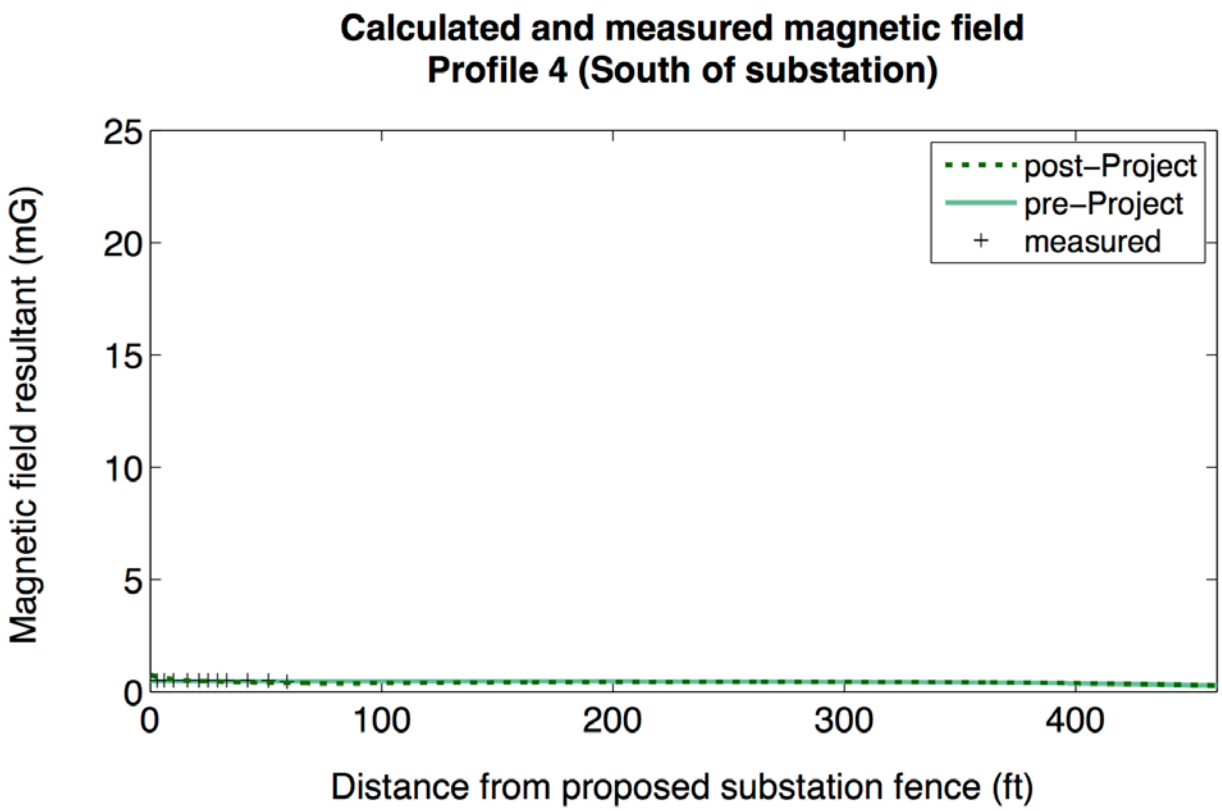


Figure 11. Measured and calculated magnetic-field levels along Profile 4 going to the south for average-load conditions in 2017.

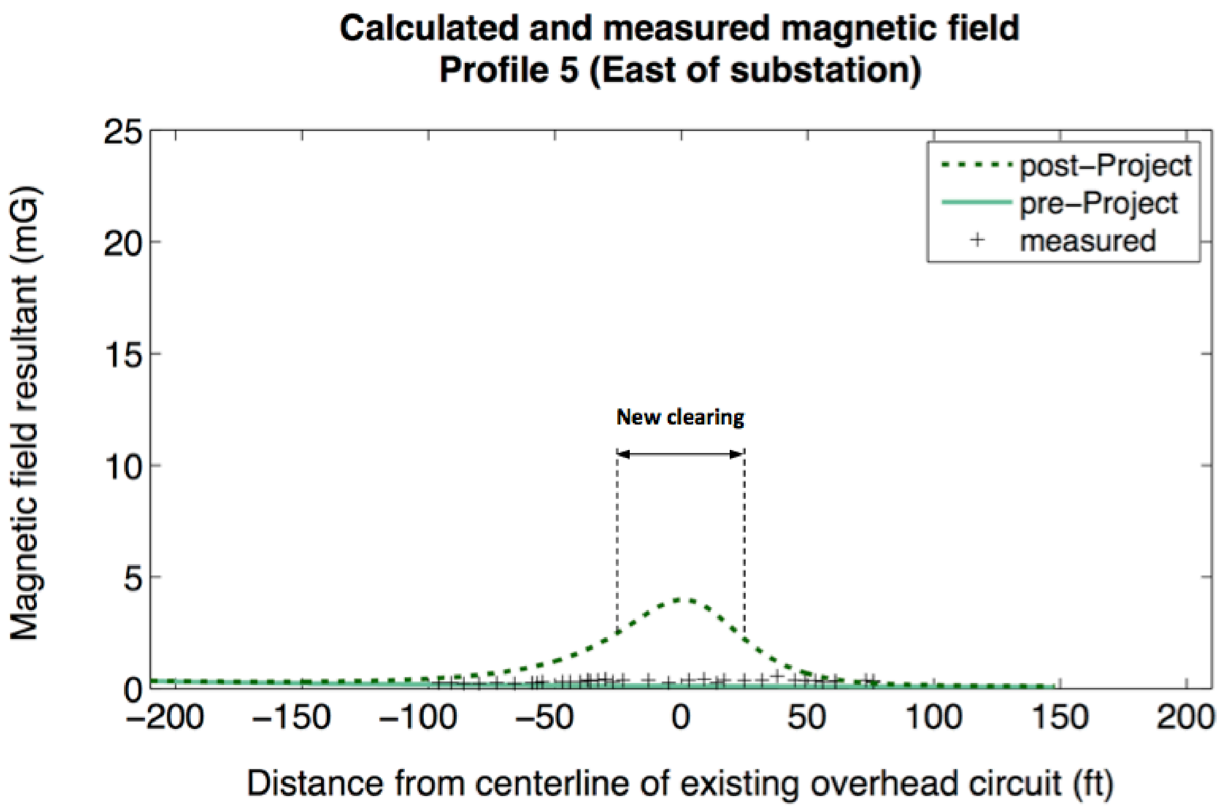


Figure 12. Measured and calculated magnetic-field levels along Profile 5 for average-load conditions in 2017. View looking north.

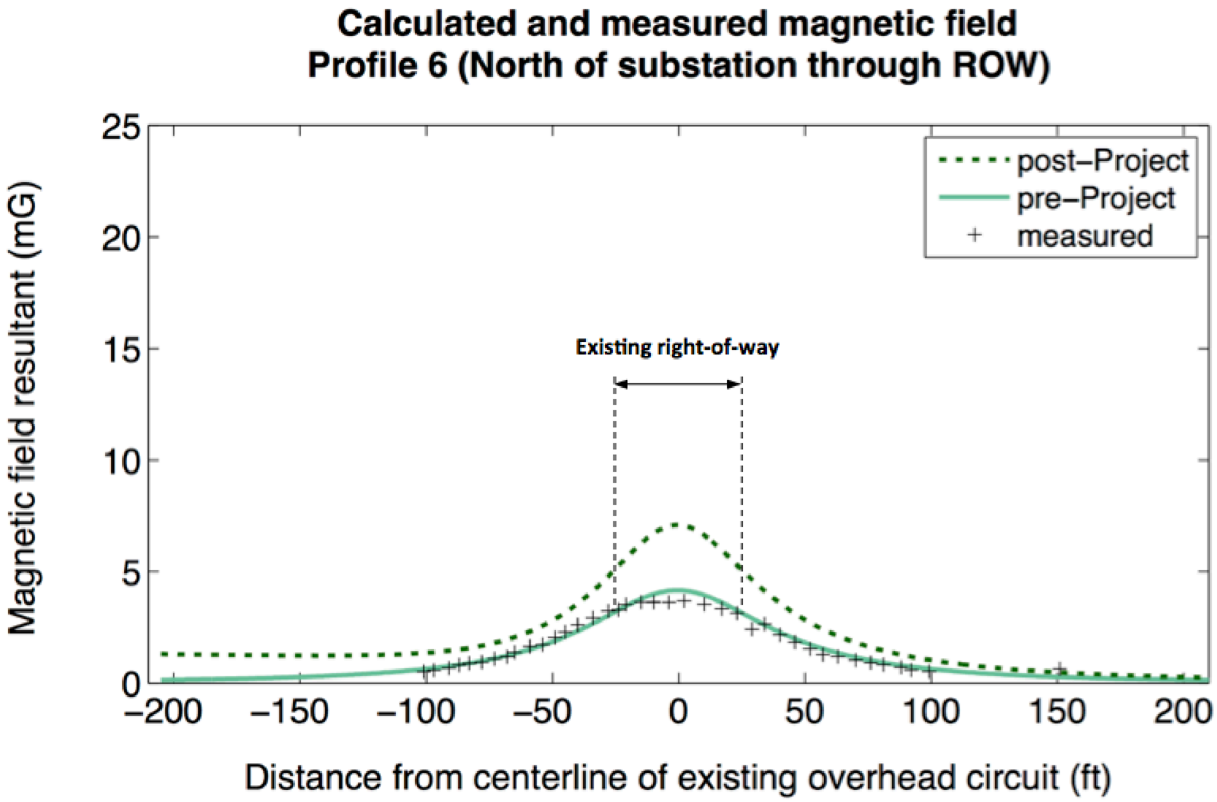


Figure 13. Measured magnetic-field levels along Profile 6 going to the north

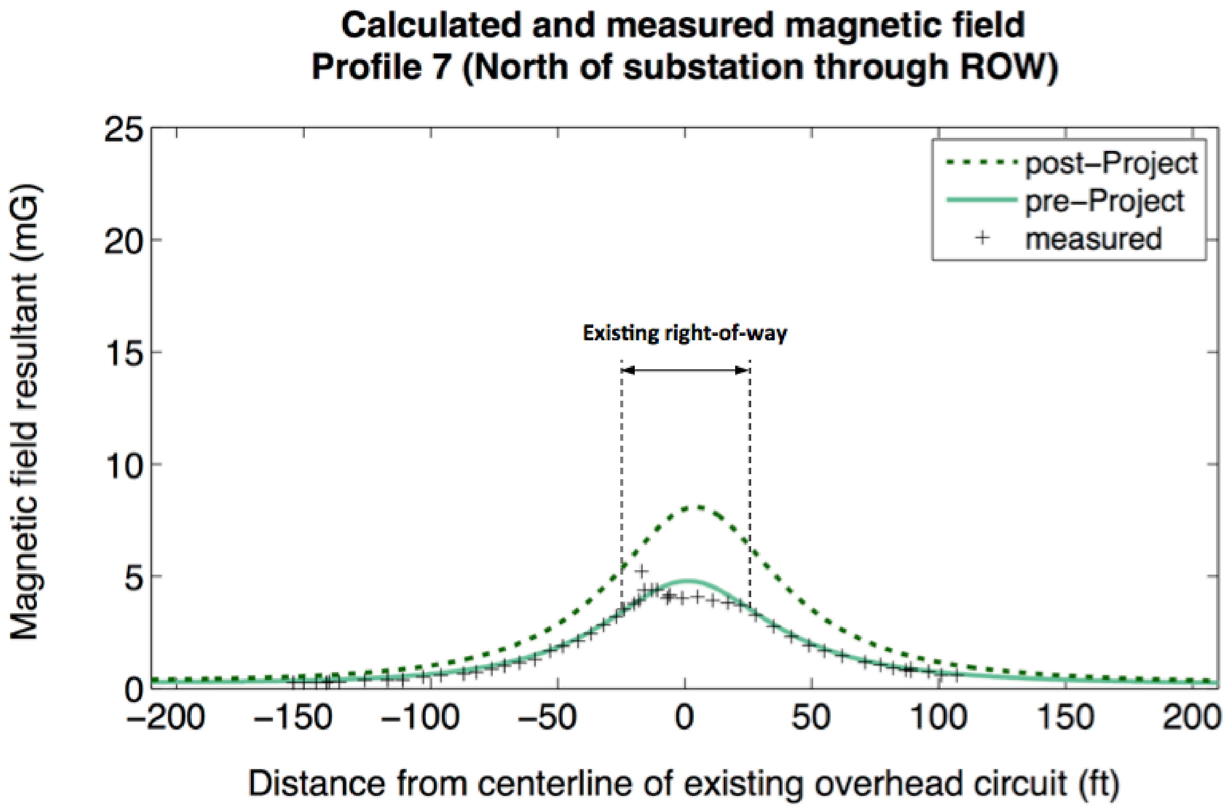


Figure 14. Measured magnetic-field levels along Profile 7 going to the north

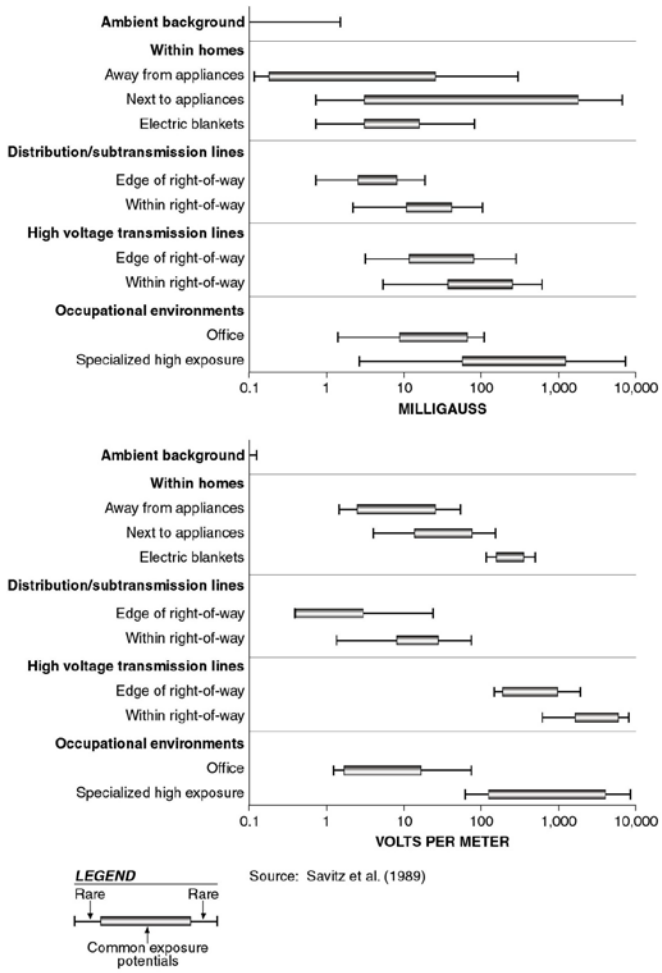


Figure 15. Electric- and magnetic-field strengths in the environment.

Appendix A

Magnetic fields surrounding conductors depend on current, which increases with increasing load. The current flows (loadings) for transmission lines, tie breaker, and transformers used in the model are summarized in Table A1 and Table A2. The loadings in Table A1 correspond to the average load for the in-service year of 2017. Loadings for modeled transmission lines for a peak loading case are provided in Table A2, and correspond to the annual peak load anticipated during the summer months in the year 2017.

Table A1. Circuit loading for average-load case in 2017

Circuit or Equipment	Voltage (kV)	Condition	MW	MVAR	MVA	Current Magnitude (A)	Current Angle (degrees)
Circuit A	69	Pre-Project	13.0	1.1	13.1	109	5.0
		Post-Project	22.0	1.9	22.1	184	5.0
Circuit B	69	Pre-Project	13.0	1.1	13.1	109	5.0
		Post-Project	18.0	1.6	18.1	151	5.0
Transformer Bank 1	69/13.8	Pre-Project	—	—	—	—	—
		Post-Project	4.0	0.3	4.0	165	5.0
Tie breaker	69	Pre-Project	—	—	—	—	—
		Post-Project	22.0	1.9	22.1	184	5.0

Table A2. Circuit loading for peak-load case in 2017

Circuit or Equipment	Voltage (kV)	Condition	MW	MVAR	MVA	Current Magnitude (A)	Current Angle (degrees)
Circuit A	69	Pre-Project	46.0	4.0	46.2	384	5.0
		Post-Project	57.0	5.0	57.2	477	5.0
Circuit B	69	Pre-Project	46.0	4.0	46.2	384	5.0
		Post-Project	50.0	4.4	50.2	418	5.0
Transformer Bank 1	69/13.8	Pre-Project	—	—	—	—	—
		Post-Project	7.0	0.6	7.0	295	5.0
Tie breaker	69	Pre-Project	—	—	—	—	—
		Post-Project	57.0	5.0	57.2	477	5.0

Electric and Magnetic Field Assessment: The Berry Street Substation

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The Berry Street Substation

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August 28, 2016

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Notice

At the request of Public Service Enterprise Group – Long Island (PSEG-LI) and GEI Consultants, Inc. P.C., Exponent modeled the magnetic-field levels associated with the proposed Berry Street Substation in North Lindenhurst, New York. This report summarizes work performed to date and presents the findings resulting from that work. In the analysis, we have relied on geometry, material data, usage conditions, specifications, and various other types of information provided by PSEG-LI. We cannot verify the correctness of this input data, and rely on the client for the data's accuracy. 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. PSEG LI has confirmed to Exponent that the summary of data provided to Exponent contained herein is not subject to Critical Energy Infrastructure Information (CEII) restrictions.

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 readers of this report outside of the regulatory proceedings relating to this Project, and any re-use of this report or its findings, conclusions, or recommendations presented herein 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

PSEG-LI has proposed the construction of the Berry Street Substation (The Project) on a property 300 feet south of an existing Long Island Railroad (LIRR) and PSEG LI transmission line right-of-way (ROW) in Lindenhurst, NY. At the request of PSEG-LI, Exponent modeled the magnetic fields associated with the proposed substation equipment, nearby existing overhead transmission lines, proposed underground distribution feeders, and the proposed underground interconnections to the existing transmission lines.

The effect of the substation on existing magnetic-field levels was evaluated by modeling magnetic fields for pre- and post-Project conditions. For the pre-Project conditions, the loading on the existing overhead circuits was calculated without any of the proposed equipment in service. Exponent also measured background magnetic-field levels at the proposed substation site on March 25, 2016.

The post-Project condition includes magnetic-field contributions from the proposed substation equipment and new 69-killivolt (kV) loop in and out of the new substation yard. In the post-Project condition, two load cases were studied, corresponding to average load and peak load for the proposed equipment and 69-kV interconnection. Electric fields from the substation were not modeled because they are effectively blocked by the metal fence and landscaping around the substation yard

The modeling shows that the calculated magnetic fields increase on all sides of the proposed site, but fall off rapidly with distance. At the middle of the western edge of the substation property, for instance, the calculated magnetic field is 5 mG for average-load conditions and 10 mG for peak-load conditions. At distances of 100 feet or more west of the substation fence, the calculated magnetic field is lower, and is below 3.7 mG for average-load conditions and 7.9 mG for peak-load conditions. For comparison, measured magnetic fields from existing distribution sources along residential streets in the vicinity of the Project range between 3.5 and 7.5 mG.

A Project-related increase in calculated magnetic-field levels occurs near the northeast corner of the proposed site, where the proposed underground circuits pass beneath the substation fence. Here, the calculated magnetic-field level is 27 mG for average-load conditions and 56 mG for peak-load conditions. This area is furthest from dwellings to the south and east of the proposed site.

In summary, models of operation of the proposed Berry Street Substation show that it will not materially add to existing levels of magnetic fields at residences in the neighborhood.

Proposed Configuration

The proposed location for the Berry Street Substation is located on an undeveloped property on the west side of Wellwood Avenue between New Horizons Boulevard and Berry Street, as shown in Figure 1.

The proposed substation equipment includes positions for two 69-kV transmission circuit to connect, three gas circuit breakers, two 69/13.8-kV transformers, and two metal-clad switchgear power centers with a capacity to connect a total of ten 13.8-kV feeders. In the proposed configuration, the 13.8-kV feeders exit the substation in underground duct banks, and continue along Wellwood Avenue, Berry Street, and New Horizons Blvd.

In addition to the new equipment inside the substation fence, the Project includes two underground interconnections to the existing 69-kV transmission line located on the railroad ROW 300 feet north of the proposed site. In the proposed configuration, the existing 69-kV transmission line between the South Farmingdale and West Babylon Substation will be looped into and out of at the new Berry Street Substation. Existing poles at tangent locations west of the Wellwood Avenue will be removed, and new 69-kV loop components will be constructed as follows:

1) The proposed western segment of the interconnection loop extends the existing 69-kV Circuit A from South Farmingdale to a new dead-end structure #42 north of the railroad tracks. Conductors of Circuit A pass above the railroad tracks to steel riser pole 42A. The circuit proceeds underground as three 2500 kcmil solid-dielectric cables, each installed in separate 6″ ducts and buried in a trench to a depth of 42 inches. *See* Figure 2. The underground portion of Circuit A proceeds east along the railroad ROW, turning south onto the west side of Wellwood Avenue. The underground conductors pass beneath the fence of the proposed Berry Street Substation near the northeast corner of the property, and terminate above ground at the north end of the proposed buswork within the substation fence.

2) The proposed eastern segment of the interconnection loop (Circuit B) begins above ground at the south end of the proposed buswork within the substation fence. Circuit B proceeds underground as three cables in ducts, having the same configuration as the underground portion of Circuit A. The conductors of Circuit B are installed in a separate trench, parallel to the Circuit A trench at a separation of 10 feet or more. The underground cables terminate on new riser pole #43A on the south side of the railroad tracks, and connect to conductors of the existing overhead portion of Circuit B. The overhead conductors cross above the railroad tracks to new dead-end structure #43, and turn east toward West Babylon.

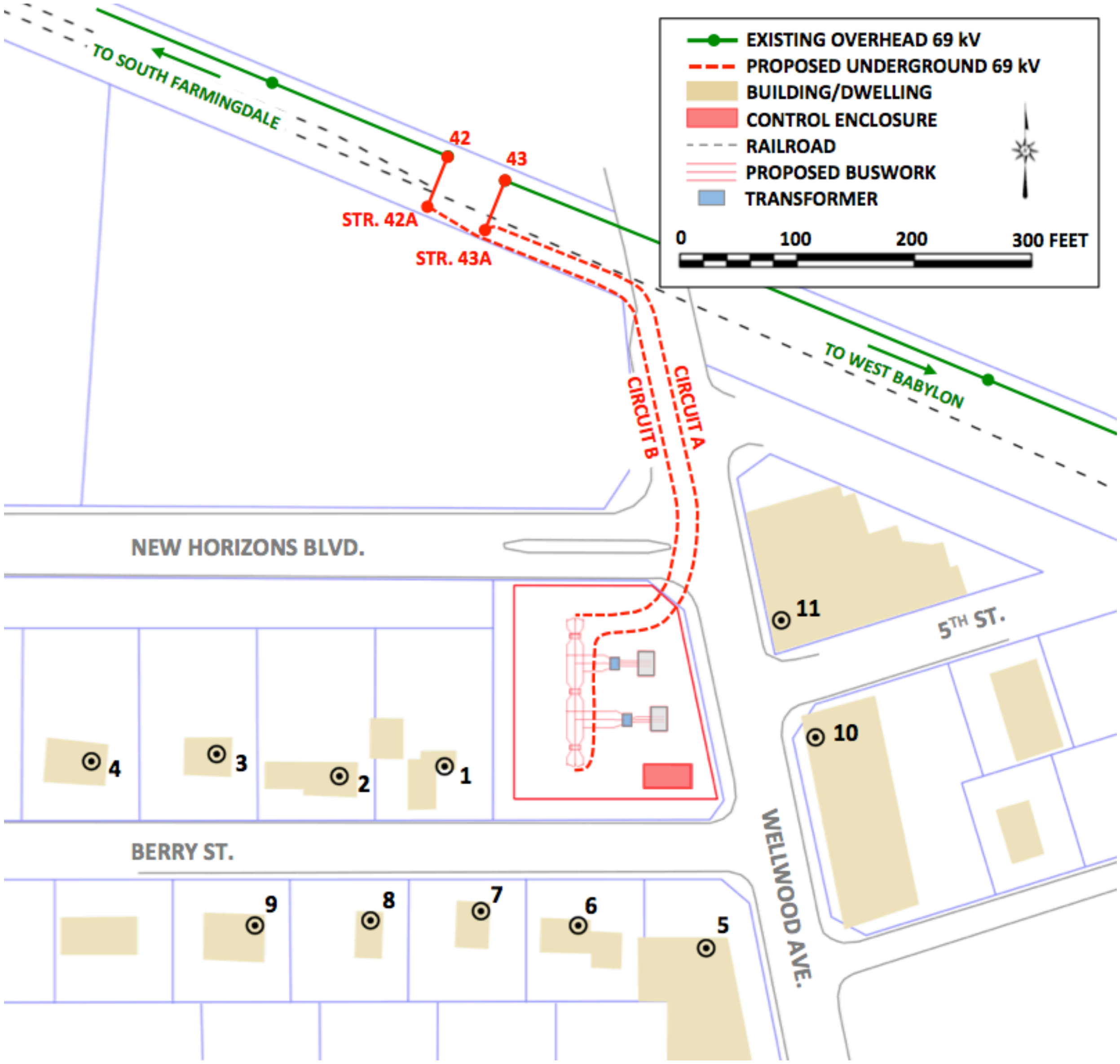

Figure 1. Proposed layout of the Berry Street Substation and proposed underground circuits in relation to the existing ROW and buildings in the vicinity of the Project

The numbered labels designate reporting locations for Project-related magnetic fields, which are summarized in Table 5.

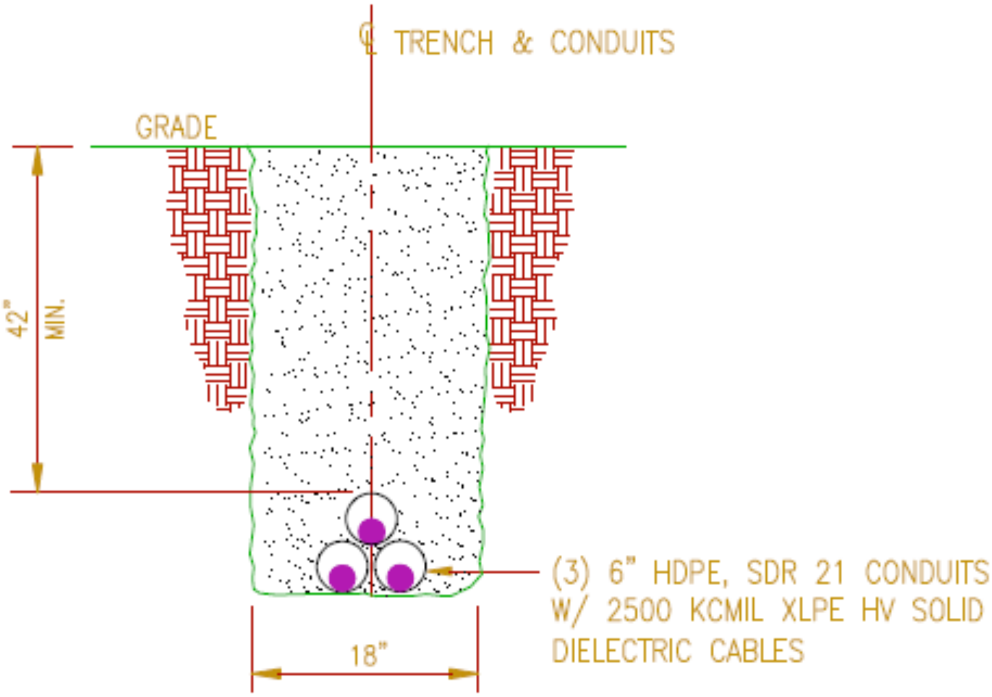

Figure 2. Trench cross-section depicting a schematic view of the underground portion of Circuits A and B.

Methods

Magnetic Field Modeling

The magnetic field around the perimeter of the proposed Berry Street Substation and surround neighborhood was calculated using SUBCALC, which is part of the Enertech EMF Workbench Suite. SUBCALC models the magnetic fields in and around substations, accounting for the transformers and the three-dimensional arrangement of buswork and transmission-line interconnections (Figure 4). The SUBCALC model was built using the substation plan and profile data provide by PSEG-LI. The inputs to the program include data on the voltage, current flow, circuit phasing, and conductor configurations, which were also provided by PSEG-LI.[1] In particular, the SUBCALC model incorporates sag elevation data for each transmission line span and the elevation of conductor attachments. The short low-voltage underground connections from existing distribution lines into the substation were not included in the model.

Exponent calculated the magnetic field along four profiles perpendicular to the expanded substation perimeter, directed outward towards adjoining property as shown in Figure 3:

Profile 1 models the magnetic-field starting at the western substation perimeter and proceeding westward onto adjoining property.

Profile 2 is aligned with proposed bus work in the substation yard, and proceeds north across New Horizons Blvd.

Profile 3 begins near the transformers on the east side of the substation yard, and proceeds east-north-east across Wellwood Avenue and along 5th Street.

Profile 4 runs south from the substation perimeter nearest to the proposed bus work, and crosses Berry Street to the south.

An additional Profile 5, shown in Figure 3, characterizes the magnetic field along a transect perpendicular to the proposed underground route of the South Farmingdale to Berry Street transmission line and the Berry Street to West Babylon Transmission Line. As described in greater detail below, measurements of background magnetic field levels were recorded along Profiles 2-5 on March 25, 2016. Profile 6 shows the location of additional measurements collected along the north side of Berry Street, since Profile 1 was inaccessible on March 25th. There is no appreciable change in elevation in and around the site, and all magnetic fields were calculated at heights referenced to the elevation of the substation yard.

[1] The sources of the electric field within the substation are set back by 20 feet or more within the property line and their intensity diminishes quickly with distance. In addition, many objects are conductive—including fences, shrubbery, and buildings—and thus shield electric fields. Thus, the electric field from the Berry Street Substation was not calculated since it will be effectively shielded by the substation fence and landscaping.

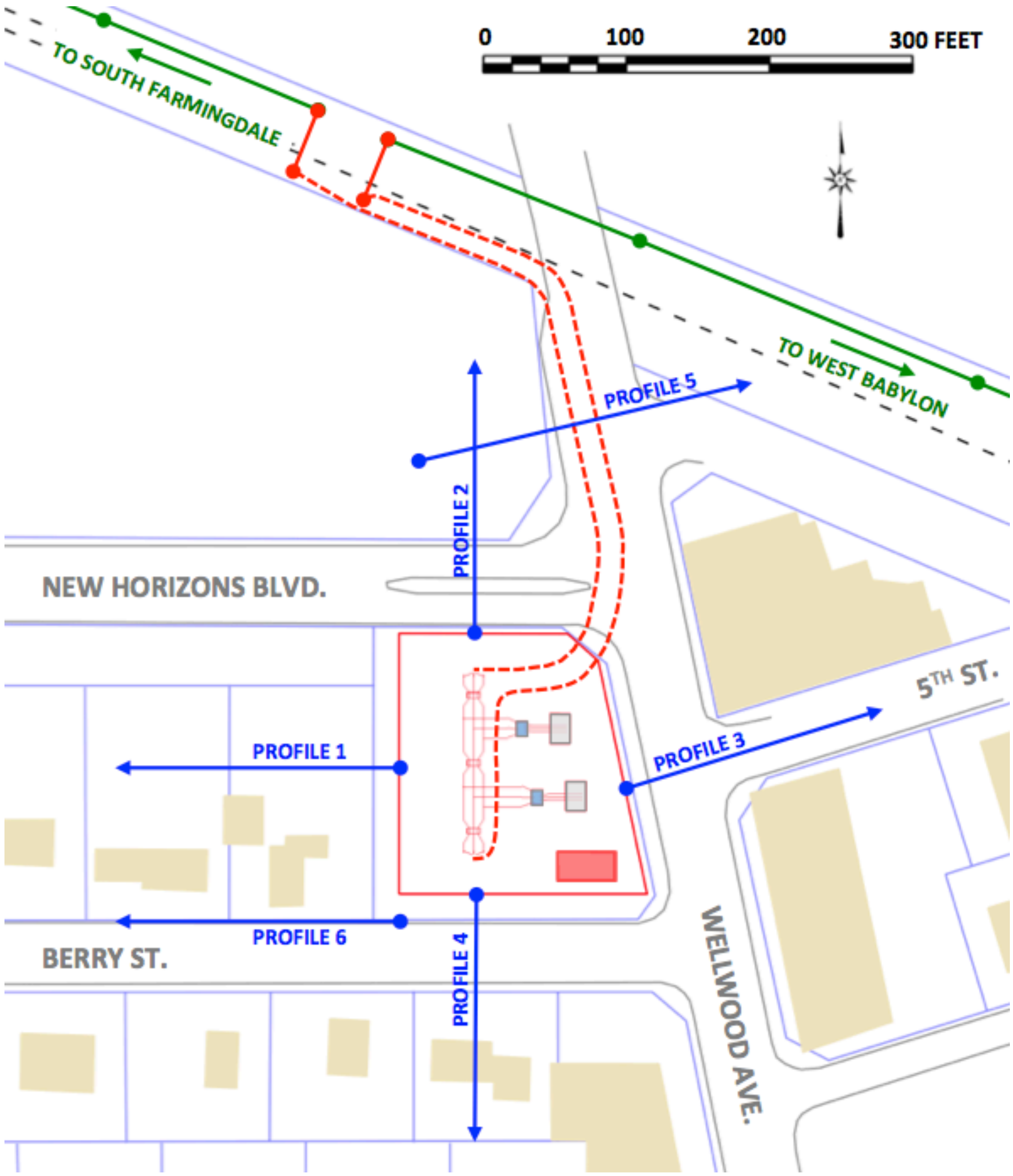

Figure 3. Plan view of the proposed Berry Street Substation, showing the location of magnetic-field profiles and the proposed underground route of the Circuit A and Circuit B.

Along the fence line, perimeter of the property, and Profiles 1-5, the magnetic field was calculated at 1 meter (3.28 feet) above ground, in accordance with IEEE Std. C95.3.1-2010.[2]

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2 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. New York: IEEE. IEEE Std. C95.3.1™-2010.

Calculated magnetic-fields are reported as the resultant of x, y and z magnetic field vectors in units of milligauss (mG).[3]

Magnetic fields surrounding conductors depend on current, which increases with increasing load. The current flows (loadings) for transmission lines, tie breaker, and transformers used in the model are summarized in Appendix A. Appendix A provides average loads for the in-service year of 2017, as well as a peak loads, corresponding to the highest load anticipated during the summer months in the year 2017.

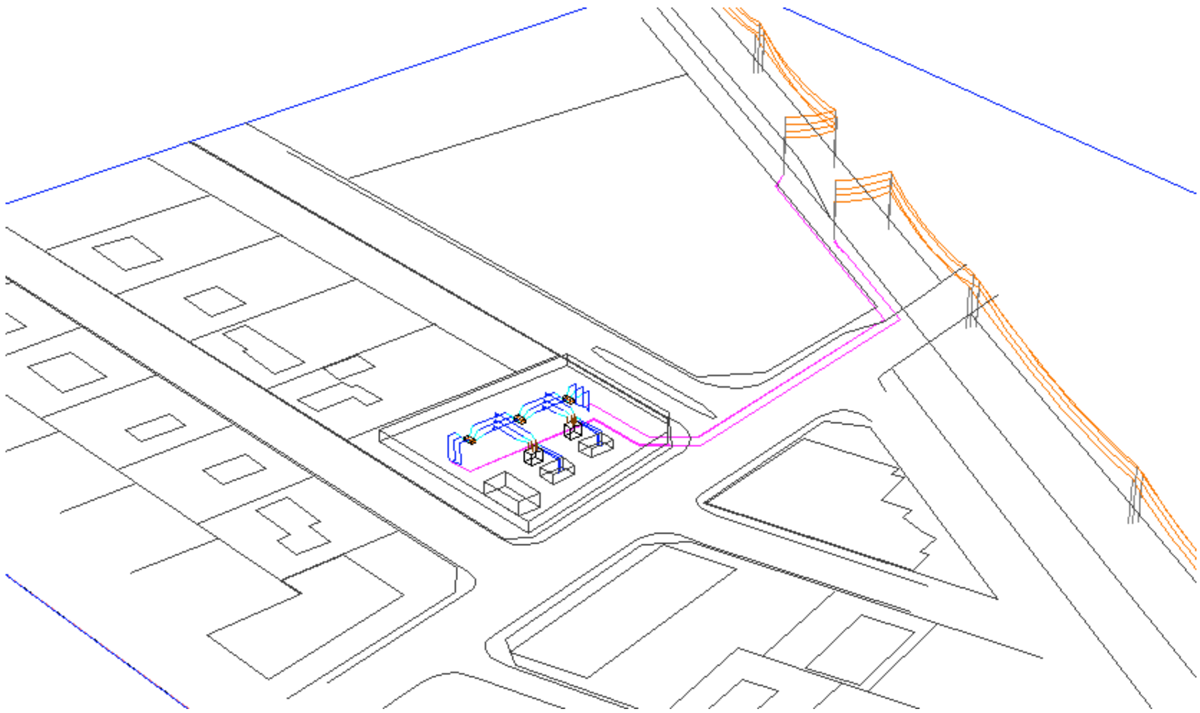

Figure 4. Overview of the three-dimensional SUBCALC model used to calculate magnetic-field profiles in the vicinity of the proposed Berry Street Substation for the average and peak loading cases in 2017.

Orange lines represent overhead transmission-line conductors and the proposed underground portion of the transmission lines that loop in and out of the Berry Street Substation are represented by purple lines.

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[3] The resultant magnetic field is the Euclidian norm (square root of the sum of the squares) of the component magnetic-field vectors calculated along vertical, transverse, and longitudinal axes.

Measurements

In order to characterize background EMF levels at the proposed site of the Berry Street Substation, magnetic fields were measured outside the proposed substation fence on March 25, 2016. The measurements were taken at a height of 1 meter (3.28 feet) above ground in accordance with the standard methods for measuring near power lines (IEEE Std. 644-1994a). Measured magnetic fields are expressed as the total field computed as the resultant of field vectors measured along vertical, transverse, and longitudinal axes.[4] The magnetic field was measured in units of milligauss (mG) by orthogonally-mounted sensing coils whose output was logged by a digital recording meter (EMDEX II) manufactured by Enertech Consultants. This instrument meets the Institute of Electrical and Electronics Engineers **(**IEEE) instrumentation standard for obtaining accurate field measurements at power line frequencies (IEEE Std.1308-1994b). The meter were calibrated by the manufacturer by methods like those described in IEEE Std. 644-1994a.

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4 The resultant magnetic field is the Euclidian norm (square root of the sum of the squares) of the component magnetic-field vectors calculated along vertical, transverse, and longitudinal axes. Root mean square refers to the common mathematical method of defining the effective voltage, current, or field of an AC system.

EMF Guidance

After more than 30 years of research that includes hundreds of studies, none of the scientific organizations conducting reviews of scientific and medical research has concluded that exposure to ELF EMF is a demonstrated cause of any long-term adverse health effect.

The evidence in support of a causal relationship is weak because it is founded largely, if not entirely, on some epidemiology studies that reported statistical associations between magnetic field exposure (or some proxy of exposure) and a disease. Scientists have placed less weight on these associations because they are weak, often inconsistent between studies, and possibly due to errors in the way the study was designed or conducted. Overall, animal studies have not reported an increase in cancer among animals exposed to high levels of electric or magnetic fields, and no mechanism has been discovered in laboratory studies that would explain how electric or magnetic fields could initiate disease. Most notably, a weak association has been reported between childhood leukemia and estimates of long-term exposure to high, average magnetic field levels (IARC, 2002). Combined with the limitations of epidemiology and the lack of consistent findings from animal and laboratory studies, however, the overall body of research does not indicate that this association, or any other, is causal in nature.

More relevant EMF assessment criteria are the exposure limits recommended by scientific organizations. These exposure limits were developed to protect health and safety and are based on reviews and evaluations of relevant health research. These guidelines include exposure limits for the general public recommended by the International Committee on Electromagnetic Safety (ICES) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to address health and safety issues (ICES 2002; ICNIRP 2010).

The only confirmed relationship between electric fields or magnetic fields and an adverse biological or health effect is when electric currents, at very high levels of exposure, are experienced in the body as a shock-like effect. The levels at which these short-term effects occur are typically much higher than levels found under transmission lines, and higher than levels found in most homes or commercial establishments. As mentioned, ICES and ICNIRP have recommended exposure limits to protect against the occurrence of these acute adverse effects from short-term exposures. Table 1 summarizes the recommended exposure limits.

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

Organization	Magnetic fields	Electric fields[5]
ICNIRP, reference level	2,000 mG	4.2 kV/m
ICES, maximum permissible exposure (MPE)	9,040 mG	5 kV/m 10 kV/m[6]

[5] Both organizations judged that evidence for effects from long-term exposure was insufficient for setting exposure standards.

[6] Exception within a transmission line ROW.

The World Health Organization (WHO) established the International EMF Project in 1996, in response to public concerns about exposures to EMF and possible adverse health effects. The Project's membership includes 8 international organizations, 8 collaborating institutions and over 54 national authorities. The overall purpose of the Project is to assess any possible health and environmental effects of exposure to static and time-varying EMF. A key objective is to evaluate the scientific literature and make a status report on health effects, to be used as the basis for a coherent international response. The review was prepared by 21 scientists from around the world with expertise in a wide range of disciplines and published in June 2007 as part of WHO's Environmental Health Criteria (EHC) Programme.

The WHO concluded the following:

> Acute biological effects have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz that may have adverse consequences on health. Therefore, exposure limits are needed. International guidelines exist that have addressed this issue. Compliance with these guidelines provides adequate protection. Consistent epidemiological evidence suggests that chronic low-intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted. (p. 355)

The absence of clear evidence for adverse effects after continued research and testing increases the certainty that there is not an adverse effect, or that any risk associated with the exposure is small. Because of the inherent limitations of scientific investigation, no review panel can ever completely rule out the possibility that EMF in our communities and workplaces might have some adverse effect. However, given the amount and quality of research that has been conducted thus far, the opinion is strong that there is not a cause-and-effect relationship between ELF EMF and long-term, adverse health effects.

Results and Discussion

The calculated and measured magnetic fields around the property line of the proposed Berry Street Substation are depicted in Figure 5. To characterize the existing sources around the proposed site, the "measured" profile in Figure 5 shows the magnetic-field levels recorded on March 25, 2016. The measured profile reflects pre-Project conditions at the site, in which no proposed facilities are constructed or in service. The measured profile in Figure 5 therefore provides a "snapshot" of background magnetic-field levels.[7] Existing magnetic-field sources include overhead distribution circuits on the east site of Wellwood Avenue, underground and overhead distribution circuits along Berry Street, and underground illumination circuits on the south side of New Horizons Boulevard. The measured magnetic fields from these sources were below 3 mG along the north, east, and south sides of the substation property line. The measured magnetic fields on the west side of the property line were slightly lower, below 0.2 mG at distances of 10 feet or more from Berry Street and New Horizons Boulevard.

The "calculated" profile in in Figure 5 shows the magnetic field calculated by SUBCALC along the property line of the proposed Berry Street Substation for average-load conditions. The calculated field reflects the contribution of proposed substation equipment within the yard and the proposed underground interconnection to the existing 69 kV transmission line to the north. No existing distribution sources were included in the SUBCALC model.[8] Both the measured and calculated profiles in Figure 5 begin at the southwest corner of the property, and continue clockwise along the property line to the northwest, northeast, and southeast corners of the parcel.

Figure 6 shows the calculated magnetic-field profile along the same path as in Figure 5, modeled using peak-load conditions rather than average-load conditions. Figure 7 shows the measured and calculated magnetic-field levels along the proposed substation fence. At fence locations, the contribution of the modeled sources is greater than the existing sources, since the substation fence is set back 10-20 feet from the property line.

Figures 8-12 depict the calculated magnetic field levels along Profiles 1-5 for average-load conditions in 2017. All of these figures except Figure 8 include background magnetic-field measurements recorded in March 25, 2016. Since Profile 1 was inaccessible for measurements on March 25, Profile 6 includes measurements recorded along a path parallel to Profile 1. These measurements are provided in Figure 13. Table 2 summarizes calculated magnetic-field levels at various distances from the substation fence in Profiles 1-4. Table 3 likewise summarizes calculated magnetic fields for Profile 5, at various distances east and west of the centerline between the Circuits A and B.

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7 On a given day, throughout a week, or over the course of months and years, the measured magnetic field can change depending upon the patterns of power demand within the surrounding community. In general, the measured magnetic will increase during summer months when power demand on Long Island is higher.

8 The only modeled magnetic-field source in the Pre-Project condition is the existing 69-kV transmission line along the LIRR corridor. This source is located more than 300 feet to the north of the property line of the Berry Street Substation. The calculated magnetic-field levels from this existing source were less than 0.1 mG along the property line.

Referring to the calculated profiles in in Figure 5 and Figure 6, the additions to the existing substation will increase the magnetic fields on all sides of the substation property. The greatest Project-related increase in calculated magnetic-field levels is on the southwest side, where the proposed underground feeders pass beneath the substation fence. Here, the calculated magnetic-field level is 33 mG for average-load conditions and 68 mG for peak-load conditions. This is consistent with IEEE Standard 1127-2013 that states "[i]n a substation, the strongest fields near the perimeter fence come from the transmission and distribution lines entering and leaving the substation. The strength of fields from equipment inside the fence decreases rapidly with distance, reaching very low levels at relatively short distances beyond substation fences." (IEEE Std 1127-1990IEEE Std 1127™-2013). Calculated magnetic field levels at the northeast corner of the property match the calculated levels in Profile 5, which transects the underground route of circuits A and B. *See* Figure 12 and Table 3.

Along New Horizons Boulevard, the highest calculated magnetic field is 5.8 mG (average-load) and 11 mG (peak load) nearest to the risers and termination of circuit A. Calculated magnetic fields fall off rapidly with distance from the substation fence. As shown for Profile 2 in Figure 9 and Table 2, calculated magnetic fields fall below 3 mG on the north side of New Horizons Boulevard. At greater distances to the north, the calculated magnetic field increases as Profile 2 approaches the existing 69-kV overhead transmission line on the railroad ROW.

On the western edge of the substation fence, the calculated magnetic field is highest west of the proposed tie breaker, and is 4.8 mG for average-load conditions and 10 mG for peak load conditions. *See* Profile 1 in Figure 8 and Table 2. Calculated magnetic fields fall off somewhat with distance from the substation fence, but remain above 3.5 mG (average lod) since Profile 1 runs parallel to the path of proposed feeders on Berry Street. Compared with the existing distribution sources measured in Profile 6 (Figure 13), the calculated magnetic field levels are comparable in magnitude to the existing distribution sources encountered on Berry Street west of the substation property.

On the east side of the substation fence, the calculated magnetic field levels from transmission sources falls below measured background levels. *See* Profile 3 in Figure 10 and Table 2.

On the southern edge of the substation fence, the calculated magnetic field is highest south of the circuit B riser, and is 32 mG for average-load conditions and 67 mG for peak load conditions. *See* Profile 4 in Figure 12 and Table 2. Calculated magnetic fields fall off rapidly with distance from the substation fence. Along Profile 4 at distances of 100 feet or more from the substation fence, the calculated magnetic has decreased further, and is below 3.5 mG for all load conditions.

Structures and Buildings

Table 4 shows the magnetic field calculated at reporting locations 1 – 11 (see Figure 1), which are dwellings and commercial buildings around the proposed site of the Berry Street Substation. Table 4 provides the Project-related increase in calculated magnetic field levels at both average and peak loading. The "average" column represents the annual average change in calculated magnetic field levels for the loads provided in Appendix A. The "peak" column represents the highest change in calculated magnetic fields for the loads provided in Appendix A, and is anticipated to occur for a few days and hours during the year when power demand is highest in the surrounding community. At the closest dwelling, the average increase in calculated magnetic field is 6.1 mG for average-load conditions and 12.7 mG for peak-load conditions. At other dwellings along Berry Street, the Project-related increase in calculated magnetic fields is less, 2-5 mG on average.

Table 2. Summary of calculated magnetic fields (mG) for Perpendicular Profiles 1-4

		Distance from Substation Fence (ft)			
Profile	**Load case**	**0**	**50**	**100**	**150**
1	average	4.8	4.1	3.7	3.5
	peak	10.1	8.7	7.9	7.4
2	average	6.9	2.4	2.6	3.0
	peak	14.6	5.1	5.4	6.3
3	average	34.3	6.3	1.9†	1.0
	peak	72.2	13.2	1.9†	2.1
4	average	31.6	3.8*	1.5	0.9
	peak	66.6	8.0*	3.2	1.9

* Underground distribution circuits are present at this location.
† Overhead distribution circuits are present at this location.

Table 3. Summary of calculated magnetic fields (mG) for Profile 5

		Offset from centerline of proposed circuits				
Profile	**Load case**	**100 ft west**	**50 ft west**	**0 ft**	**50 ft east**	**100 ft east**
5	average	1.0	1.6	13.6	1.1*	0.5
	peak	2.1	3.4	28.6	2.3*	1.1

* Underground distribution circuits are present at this location.

Table 4. Summary of calculated magnetic fields (mG) at designated structures

Building designator*		Load case	
		average	peak
1	dwelling	6.1	12.7
2	dwelling	5.8	12.2
3	dwelling	4.8	10.0
4	dwelling	4.3	9.1
5	commercial	0.7	1.6
6	dwelling	1.4	3.0
7	dwelling	2.1	4.5
8	dwelling	2.6	5.4
9	dwelling	2.6	5.4
10	commercial	1.7	3.5
11	commercial	2.3	4.9

* The location of each building is shown in Figure 1.

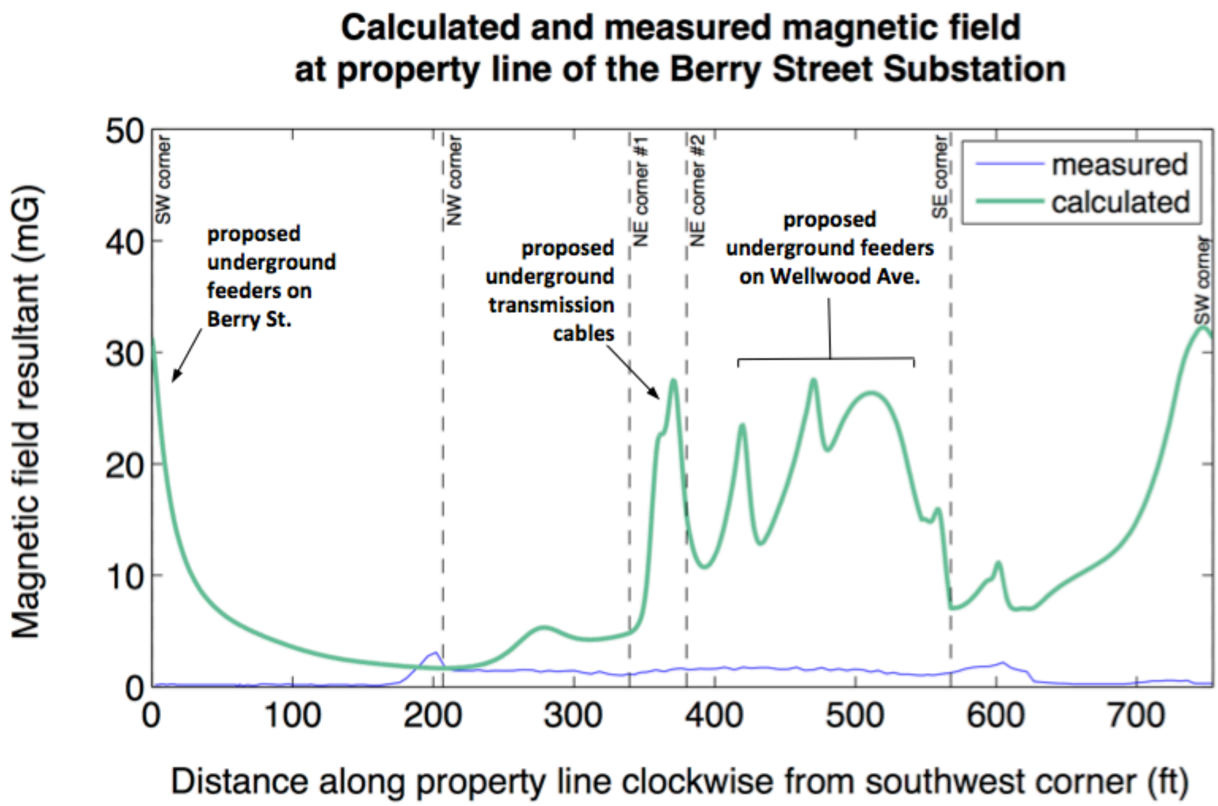


Figure 5. Calculated magnetic-field profile around the property line of the proposed Berry Street Substation for average-load conditions in 2017.

The measured profile shows the magnetic fields from unmodeled distribution sources measured on March 25, 2016.

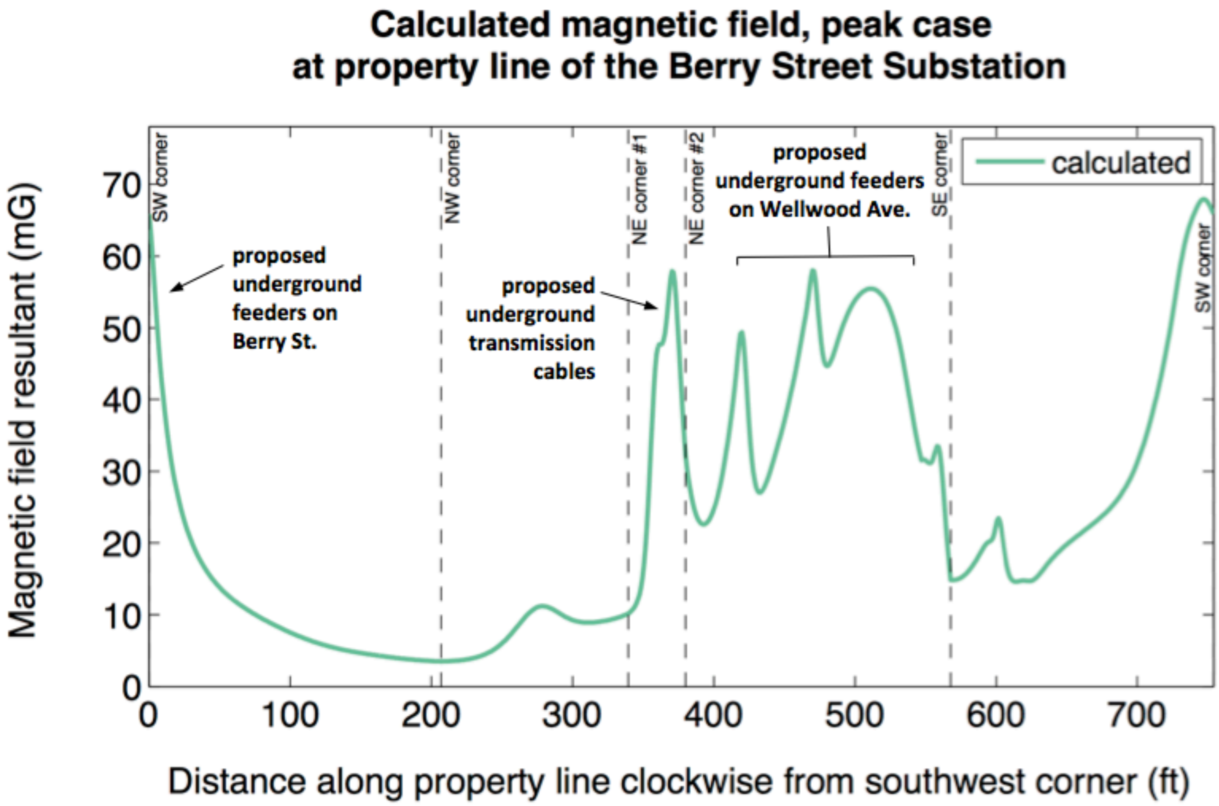


Figure 6. Calculated magnetic-field profile around the property line of the proposed Berry Street Substation for peak-load conditions in 2017.

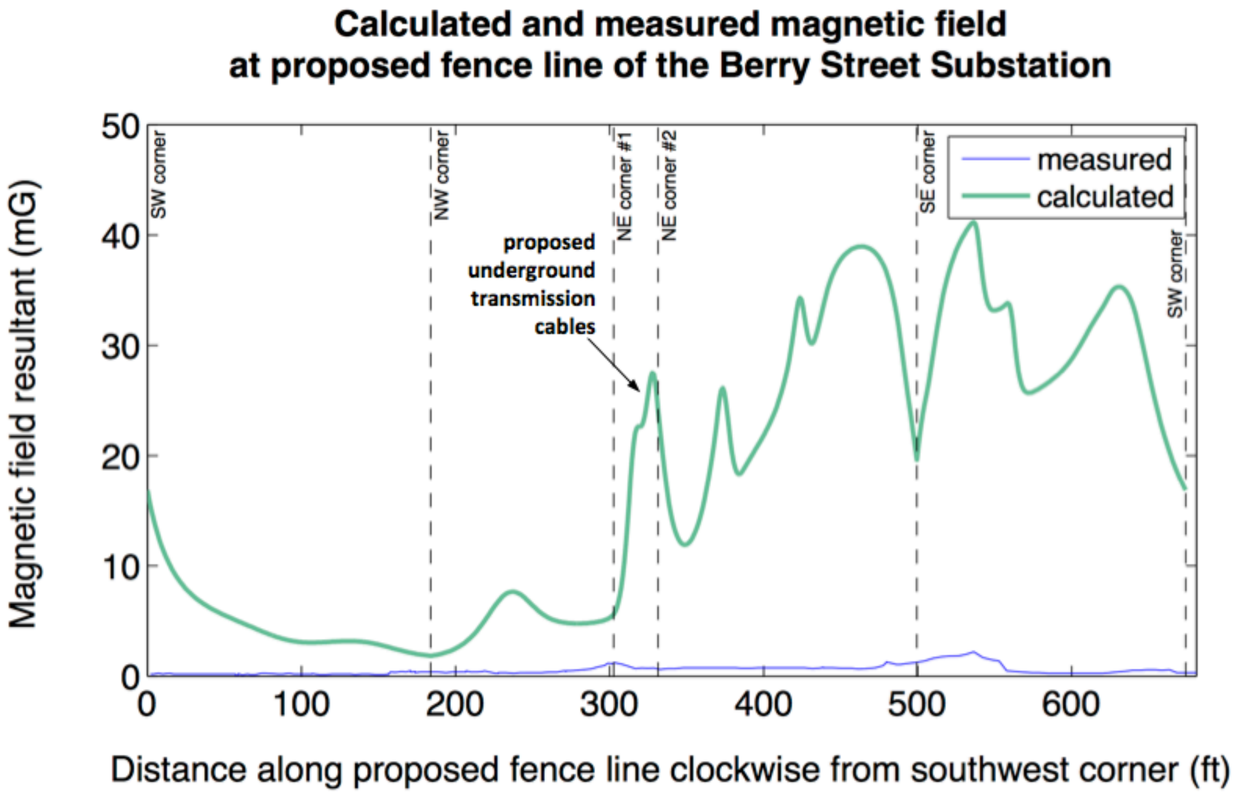
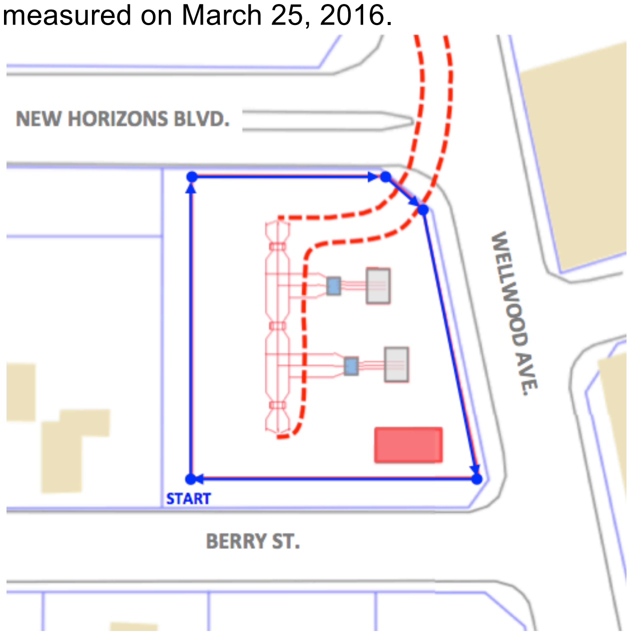


Figure 7. Calculated magnetic-field profiles around the fence line of the proposed Berry Street Substation for average-load conditions in 2017.

The measured profile shows the magnetic fields from unmodeled distribution sourced measured on March 25, 2016.



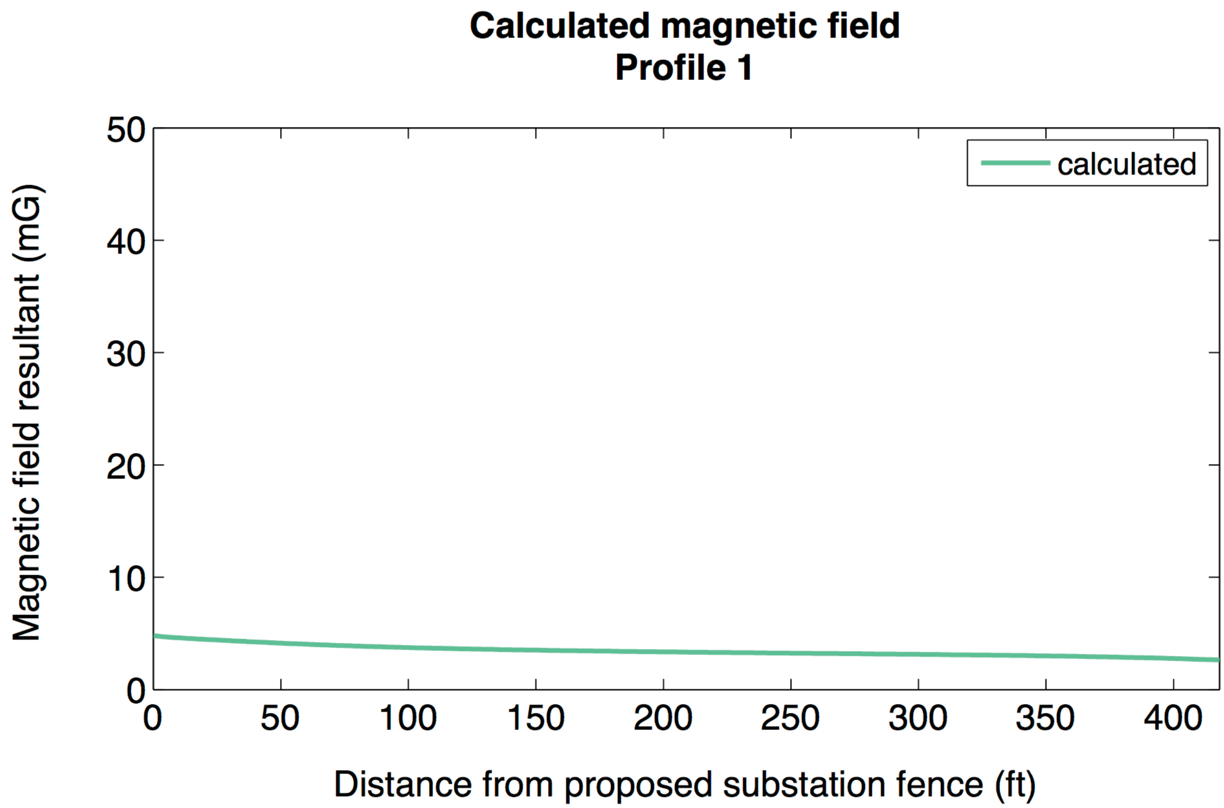


Figure 8. Calculated magnetic-field levels along Profile 1 going to the west for average-load conditions in 2017.

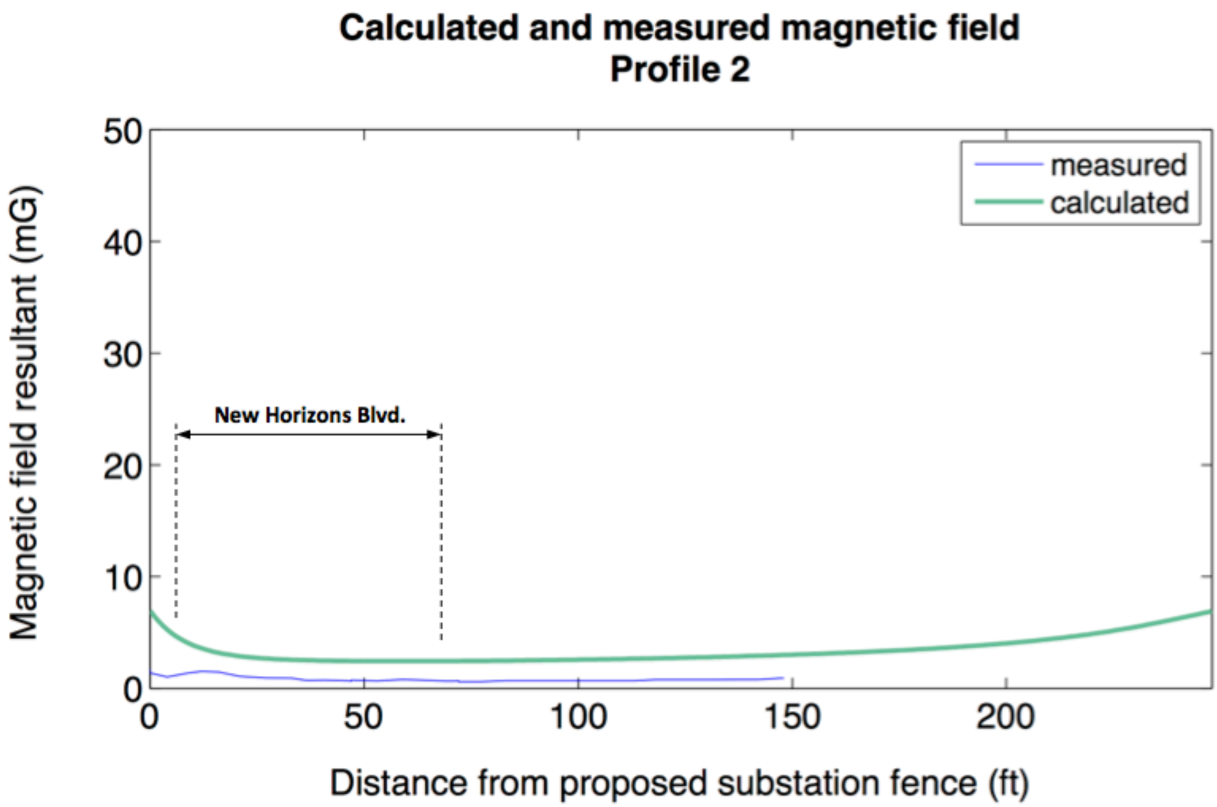


Figure 9. Measured and calculated magnetic-field levels along Profile 2 going to the north for average-load conditions in 2017.

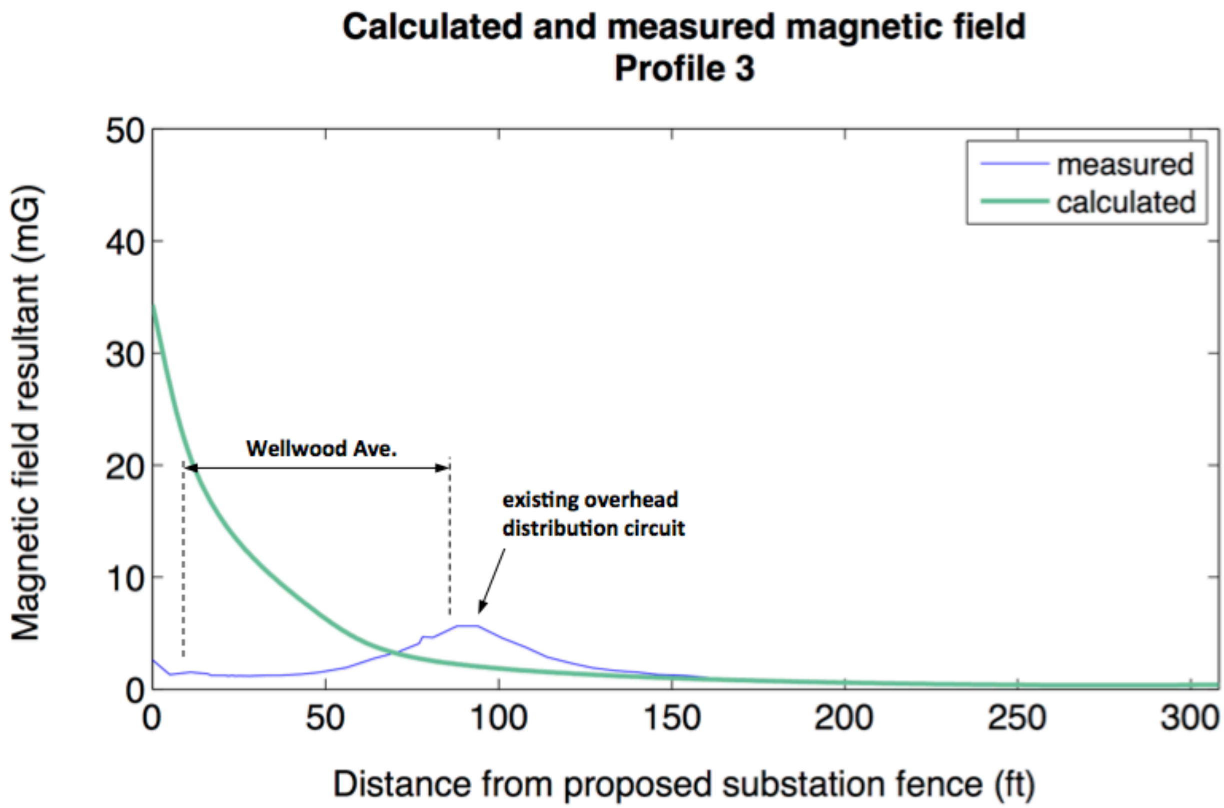


Figure 10. Measured and calculated magnetic-field levels along Profile 3 going to the east for average-load conditions in 2017.

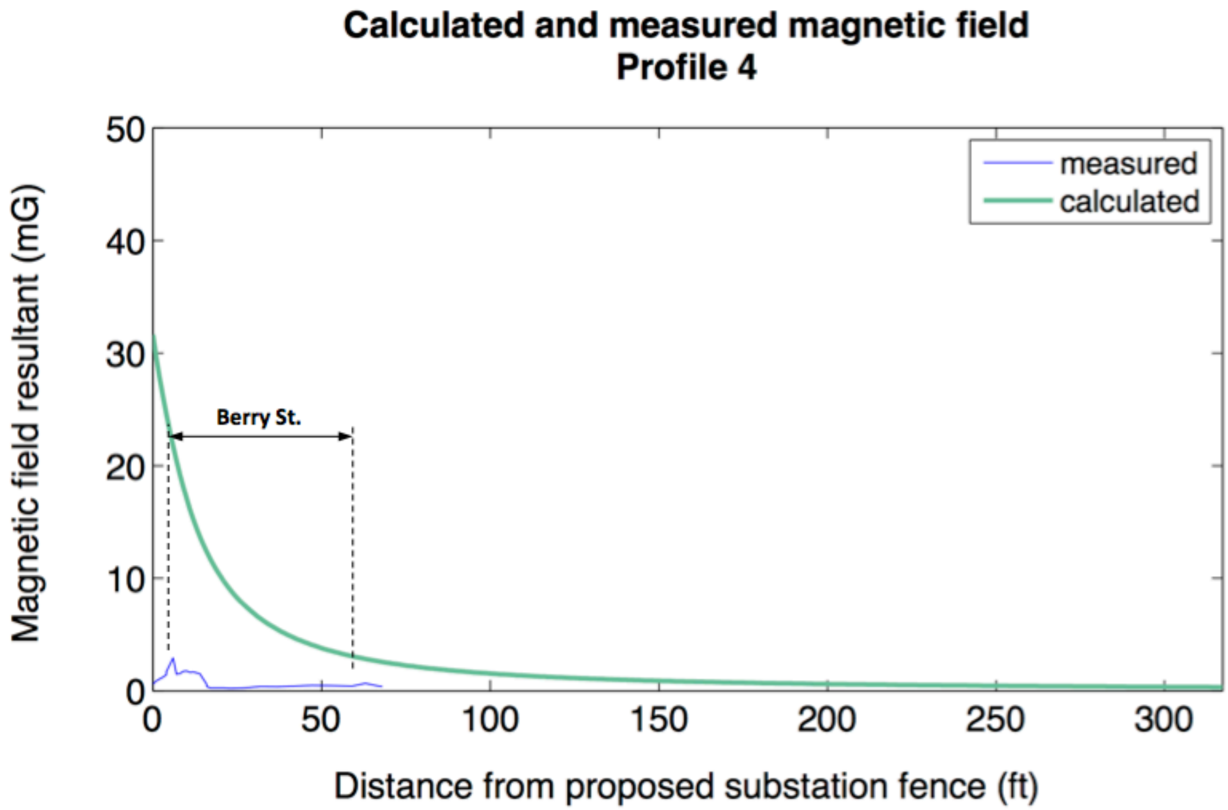


Figure 11. Measured and calculated magnetic-field levels along Profile 4 going to the south for average-load conditions in 2017.

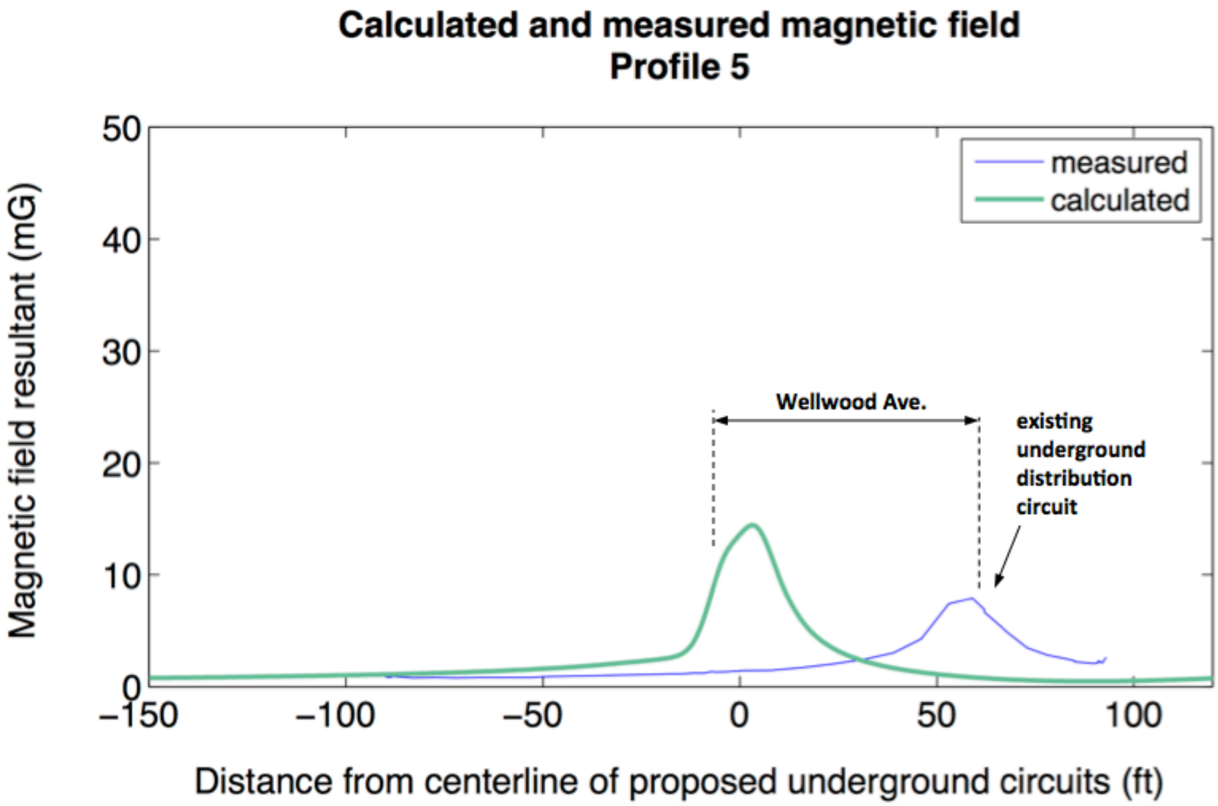


Figure 12. Measured and calculated magnetic-field levels along Profile 5 for average-load conditions in 2017. View looking north.

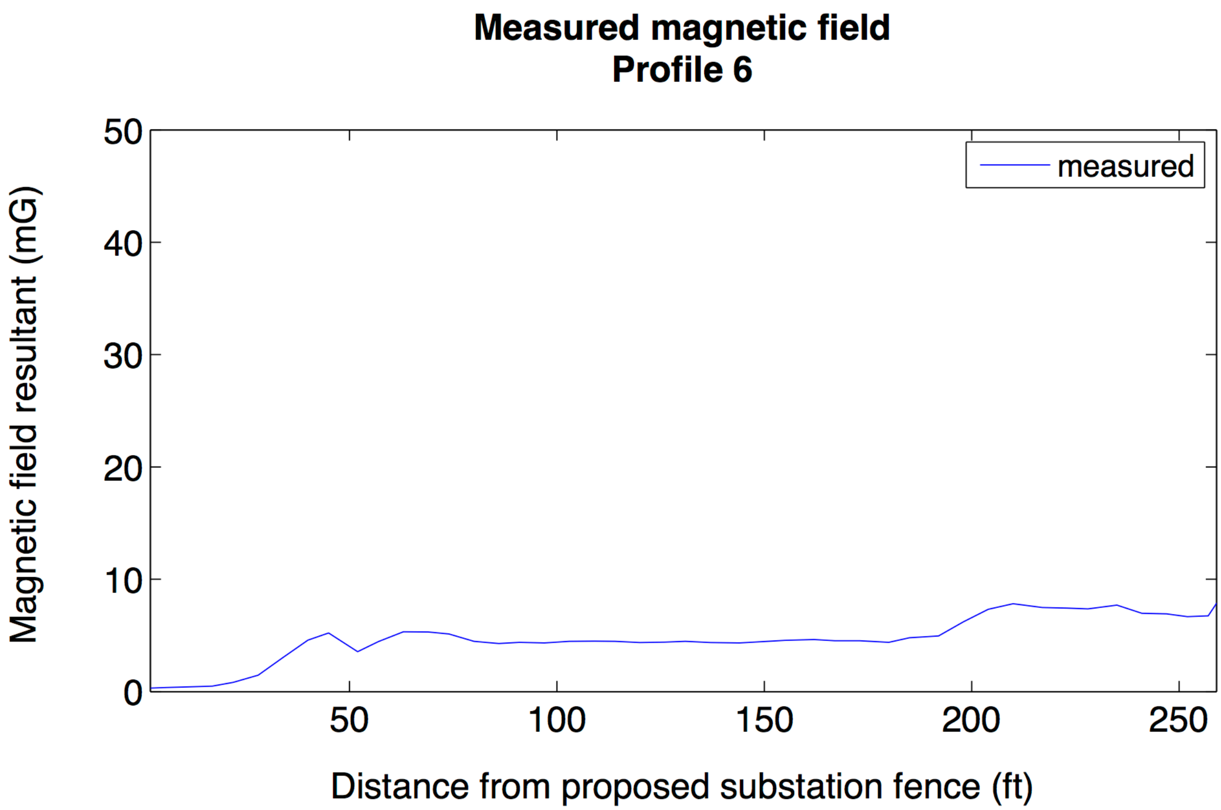


Figure 13. Measured magnetic-field levels along Profile 6 going to the west

Appendix A

Magnetic fields surrounding conductors depend on current, which increases with increasing load. The current flows (loadings) for transmission lines, tie breaker, and transformers used in the model are summarized in Table A1 and Table A2. The loadings in Table A1 correspond to the average load for the in-service year of 2017. Loadings for modeled transmission lines for a peak loading case are provided in Table A2, and correspond to the annual peak load anticipated during the summer months in the year 2017.

Table A1. Circuit loading for average-load case in 2017

Circuit or Equipment	Voltage (kV)	Condition	MW	MVAR	MVA	Current Magnitude (A)	Current Angle (degrees)
Circuit A	69	Pre-Project	15.4	3.9	15.9	133	14.2
		Post-Project	27.8	2.3	27.9	233	4.7
Circuit B	69	Pre-Project	15.4	3.9	15.9	133	14.2
		Post-Project	15.4	3.9	15.9	133	14.2
Transformer Bank 1	69/13.8	Pre-Project	—	—	—	—	—
		Post-Project	6.7	-0.9	6.8	57	-7.4
Transformer Bank 2	69/13.8	Pre-Project	—	—	—	—	—
		Post-Project	5.7	-0.7	5.7	48	-7.4
Tie breaker	69	Pre-Project	—	—	—	—	—
		Post-Project	22.1	3.0	22.3	187	7.8

Table A2. Circuit loading for peak-load case in 2017

Circuit or Equipment	Voltage (kV)	Condition	MW	MVAR	MVA	Current Magnitude (A)	Current Angle (degrees)
Circuit A	69	Pre-Project	34.7	5.2	35.1	294	8.5
		Post-Project	58.5	8.3	59.1	494	8.1
Circuit B	69	Pre-Project	34.7	5.2	35.1	294	8.5
		Post-Project	34.7	5.2	35.1	294	8.5
Transformer Bank 1	69/13.8	Pre-Project	—	—	—	—	—
		Post-Project	12.9	1.7	13.0	109	7.4
Transformer Bank 2	69/13.8	Pre-Project	—	—	—	—	—
		Post-Project	10.9	1.4	11.0	92	7.4
Tie breaker	69	Pre-Project	—	—	—	—	—
		Post-Project	47.6	6.9	48.1	402	8.2