DRAFT FOR REVIEW

Exponent®

E X T E R N A L   M E M O R A N D U M

TO:	Peter Johnson-Staub Julian Suso Frank Duffy
FROM:	Benjamin Cotts, Ph.D. William Bailey, Ph.D.
DATE:	January 27, 2022
PROJECT:	2101755.000
SUBJECT:	Updated Mayflower Document Review

At the request of the Town of Falmouth, Exponent has reviewed additional documents provided by Mayflower Wind and submits this memorandum, which serves to update and expand upon the review submitted on December 21, 2021. All documents were reviewed in the context of "EMF [electric and magnetic field] engineering, human health and environmental effects" related to the Mayflower Wind proposal for the export cable from the offshore wind farm to come ashore in the Town of Falmouth and to be installed in underground duct banks through the town of Falmouth to the proposed Mayflower Wind onshore substation.

Background on EMF

The proposed offshore and onshore export cables will be sources of 60 Hertz (Hz) EMF. Any source of electricity, such as transmission lines, distribution lines, household appliances and equipment in our homes and workplaces, produces both electric and magnetic fields. Most electricity in North America is transmitted as alternating current at a frequency of 60 Hz (i.e., it changes direction and magnitude in a continuous cycle that repeats 60 times per second). For the submarine and underground cables proposed for Mayflower Wind, no electric fields will be produced above ground and so electric fields are not discussed further.

Magnetic fields (MF) are created by current that flows in transmission line conductors. The strength of magnetic fields is often expressed as magnetic flux density in units of milligauss (mG), where 1 Gauss (G) = 1,000 mG. Magnetic fields are not blocked by conductive objects; however, the intensity of magnetic fields diminishes with increasing distance from the source. In the case of transmission lines, magnetic fields generally decrease with distance from the conductors in proportion to the square of that distance.

Assessment Criteria

Magnetic-field levels can be assessed in terms of standards and guidelines developed by scientific and health agencies. Several such agencies that have published limits of exposure to 60-Hz electric and magnetic fields include the International Committee on Electromagnetic Safety (ICES) and the

International Commission on Non-Ionizing Radiation Protection (ICNIRP). The assessment levels set by these organizations are 2,000 mG for ICNIRP and 9,040 mG for ICES for the exposures of the general public.

The federal government has no regulations regarding MF levels from transmission lines; however, as part of the Hydro-Québec project (Massachusetts Electric Company, 12 DOMSC 119, 228-242, 1985) the Massachusetts Energy Facilities Siting Board (EFSB) previously deemed magnetic field levels of 85 mG at the edge of transmission line rights-of-way (ROWs) to be acceptable in the licensing of 345-kV transmission line facilities. Subsequent decisions of the EFSB have assessed MF on a case-by-case basis. The MA EFSB has "*encouraged the use of practical and cost-effective design to minimize magnetic fields along transmission ROW. The EFSB requires EMF mitigation which in its judgment is consistent with minimizing cost.*" (Massachusetts Energy and Environmental Affairs Case No. EFSB 08-2/08-105/08-106:page 84). This practice is also consistent with the recommendations of the World Health Organization (WHO Extremely Low Frequency Fields. Environmental Health Criteria 238, 2007).

Other jurisdictions, such as the Connecticut Siting Council (CSC) have a similar approach. The CSC adopted "EMF Best Management Practices for the Construction of Electric Transmission Lines in Connecticut" (BMP) based upon a consensus of health and scientific agencies that the scientific evidence "*reflects the lack of credible scientific evidence for a causal relationship between MF [magnetic field] exposure and adverse health effects*" (CSC BMP, 2014, p. 3). Nevertheless, the CSC concluded that precautionary measures for the siting of new transmission lines in the state of Connecticut are appropriate and advocates for "*the use of effective no-cost and low-cost technologies and management techniques on a project-specific basis to reduce MF exposure to the public while allowing for the development of efficient and cost-effective electrical transmission projects*" (CSC BMP, 2014, p. 4).

Methods of Reducing Magnetic Field Levels

Common methods for reducing magnetic-field levels are described succinctly by the CSC BMPs as,

1.	Distance	Greater distance from the source reduces MF levels
2.	Height of Structure	Taller structures (or greater burial depth) reduces MF levels
3.	Conductor Separation	Smaller conductor-conductor separation reduces MF levels
4.	Conductor Configuration	Some designs (e.g., delta) reduce MF levels more than others
5.	Optimum Phasing	For multi-circuit installations, arrangement of phase conductors can significantly reduce MF levels
6.	Increased Voltage	For a constant power flow, higher voltage will lead to lower electric current levels and hence lower MF levels.
7.	Underground Installation	Installation underground generally results in very small conductor separations (#3) reducing MF levels

Underground transmission lines such as those proposed for the Mayflower Wind project inherently reduce MF levels due to the close spacing of phase conductors (#3) and underground installation (#7) but may provide smaller distances (#1) between the duct banks and people because they are typically not installed on dedicated rights-of-way. The remaining items of burial depth (#2), conductor configuration (#4), optimum phasing (#5), and increased voltage (#6) depend on the design of the transmission line and are addressed in greater detail below in relation to the reviewed documents.

Review of Mayflower Documents

Exponent initially received and reviewed the following documents, which were discussed in the December 21, 2021 review:

1. Mayflower_30% Central Park HDD Plan_2021-09-07.pdf
2. Mayflower_30% Worcester Avenue HDD Plan and Profile_2021-05-12.pdf
3. Mayflower_30% Central Park UG Drawing Package_2021-09-15.pdf
4. Mayflower_30% Worcester Avenue UG Drawing Package_2021-07-02.pdf
5. Mayflower_30% Worcester Avenue UG Traffic Management_2021-08-18.pdf

Exponent has now also reviewed the following additional documents, which have been added to this update:

1. Appendix P1. Electric and Magnetic Field Assessment for the Proposed Mayflower Wind Project
2. Appendix P2. High Voltage Direct Current Electric and Magnetic Field Assessment

In addition, Exponent reviewed the Mayflower EMF Fact Sheet provided by Mayflower on their project website.[1] Review of the EMF Fact Sheet indicates that magnetic field levels at the beach were calculated to be ≤ 10 mG because of a burial depth greater than 50 feet for the cables in an HDD configuration, but were calculated to be much higher over the "transition vault" (≤ 350 mG) or directly above the buried cable duct banks (≤ 500 mG) on portions of the onshore route where the cables are to be installed at shallower depths.[2] Review of Appendix P1 provided additional information regarding the results of the EMF modeling. Magnetic field levels at the two beach landfall sites [Shore St. and Worcester Avenue] were calculated to be ≤ 39 mG and ≤ 4 mG directly above the cables, assuming cable burial depths of 10 ft and ≤ 50 ft, respectively. These values decreased with increasing distance from the cables, resulting in magnetic field levels of ≤ 6.2 mG at a distance of 25 feet from the outer cables. Similarly, the magnetic-field levels calculated at the "transition joint bay" at the two sites decreased from ≤ 86 mG directly over the cables to ≤ 10.3 mG at a distance of 25 feet from the outer cables. Appendix P1 also included calculated magnetic field levels for the onshore underground route (discussed in more detail below); the magnetic-field levels decreased from ≤ 403 mG directly above the buried cables to ≤ 32.4 mG at a distance of 25 feet from the duct bank centerline. All magnetic field levels were calculated at ground surface level, using the assumption that people may lie or sit down on the ground.

As all the calculated values are well below international guidelines recommended by the World Health Organization (ICNIRP; ICES), the appropriate focus should be on calculations of magnetic fields at residences along the routes where there may be some potential for long-term exposure, which is the exposure scenario for which statistical associations between estimated magnetic field levels have been associated with childhood leukemia in the past (cf. IARC, 2002; WHO, 2007). The significance of those reported associations is now in question; however, as analyses of later studies show a weakening of an association (Swanson et al., 1999) to the point where Amoon et al (2021) report that a pooled analysis of epidemiological studies of childhood leukemia in the past 10 years indicated no statistically significant association with magnetic fields at levels above 4 mG with childhood leukemia.

[1] https://mayflowerwind.com/wp-content/uploads/2021/01/EMF-Fact-Sheet-012921.pdf

[2] https://mayflowerwind.com/wp-content/uploads/2021/01/Gradient-Technical-Memo.pdf

Exponent reviewed the Mayflower 30% Drawings and the magnetic field modeling results in Appendix P1 for two proposed landing sites for the horizontal directional drilling (HDD) [Central Park and Worcester Avenue] as well as underground (UG) drawing packages for these sites. Appendix P1 also included modeling results for a third, alternate landing site (Shore St.). Observations related to the HDD include:

- Three HDD boreholes are proposed for the Central Park HDD Plan, while four are proposed for the Worcester Avenue Plan. It is unclear from this information whether this means that only three export cables may be needed or if there is an additional potential landing site that may need to be considered in the case that Central Park is selected.
- The HDD profile drawing for the Worcester Avenue Plan indicates that the burial depth of the export cables will be greater than 50 feet for the majority of the HDD, a depth at which it is unlikely to result in levels of MF much above typical background levels.
- No profile drawing was provided for the Central Park HDD Plan. It is unclear if this is a result of preliminary design or some other aspect. Assuming that the HDD burial depth is similar to the Worcester Avenue profile, potential MF levels would be similarly low.
- Both the Worcester Avenue and Central Park terminate with splice vaults in an open green space. The Worcester Avenue option would terminate in a green space with splice vaults beneath or very near to existing park benches. The Central Park option would terminate with splice vaults beneath a soccer field near the intersection of Central Park Avenue and Crescent Avenue. Based upon the modeling levels reported by Mayflower in the EMF Fact Sheet, MF levels above the transition vaults would be up to 350 mG, which is also reported in Appendix P1. In addition, calculated magnetic field levels directly above the transition joint bays were ≤ 86 mG, which decreased to ≤ 10.3 mG at a distance of 25 feet. These levels are higher than commonly found in communities but, as noted below, at these locations exposures would be short-term, i.e., a few hours, and therefore should not be treated as if exposures at these locations contributed very much to a person’s long-term average exposure. The predominant sources of long-term magnetic field exposure occur indoors at homes, schools, and offices. Nevertheless, it is surprising that Mayflower has not considered a plan to place splice vaults away from green space areas or implement optimal phasing were possible to minimize magnetic field exposures.
- Review of the UG drawing packages indicates that for either the Worcester Avenue or Central Park landing sites a number of duct bank configurations are proposed for carrying the power from the transition vaults to the onshore substation. These are listed as “typical duct bank cross sections” Sections A through H (Central Park) or Sections A through M (Worcester Avenue).
    - We note that all the double-circuit duct bank cross-sections do not include optimal phasing. Optimal phasing is recognized by the MA EFSB, CSC, and WHO as a low-cost or no-cost measure for reducing magnetic fields.
        - For the Central Park UG Drawing Package Sections A and B do not include the optimal phasing.[3]
        - For the Worcester Ave UG Drawing Package at least Sections “A, B, C, and L do not include the optimal phasing.[3]
        - Other configurations (C, D, E, F, and G for Central Park) and (D, E, F, G, J, K, and M for Worcester Avenue) are single-circuit and so phase optimization cannot reduce field levels.
            - However, some single-circuit configurations (e.g., flat) are generally known to result in higher MF levels than others (e.g., delta).

[3] Section H would need further analysis to determine if it could be optimized to reduce magnetic field levels.

        - Additionally, single-circuit duct banks often result in higher magnetic-field levels than multiple-circuits in a single duct bank for which mutual cancellation of magnetic fields can reduce overall MF levels through phase optimization.
- Appendix P1 reported onshore calculated magnetic-field levels at maximum loading and minimum burial depth (3 ft) for six duct bank configurations.
    - This included five configurations corresponding to Worcester Avenue Sections A, B, D, E, and F, and one delta configuration:
        - Three cable circuits arranged in a 2-deep-by-5-wide (2D×5W) duct bank configuration;
        - Two cable circuits in a 3-deep-by-2-wide (3D×2W) duct bank configuration;
        - One cable circuit in a 2-deep-by-2-wide (2D×2W) duct bank configuration;
        - One cable circuit in a 1-deep-by-4-wide (1D×4W) duct bank configuration;
        - One cable circuit in a splice vault 3-deep-by-2-wide (3D×2W) duct bank configuration; and
        - Three cable circuits in a buried trefoil (delta) configuration.
    - Magnetic-field levels directly above the duct banks were calculated to be ≤ 403.3 mG. The values decreased with increasing distance from the duct banks; at distances of 10 feet and 25 feet, the calculated levels were ≤ 156.7 mG and ≤ 32.4 mG, respectively. These levels are all far below the international standards for the general public of 2,000 mG for ICNIRP and 9,040 mG for ICES.
- Appendix P2 provides a general review of exposures to DC magnetic field sources to place the exposures from buried DC cables, if chosen as alternative to AC cables, into context. While inference from the review is that the DC magnetic field exposures from HVDC underground cables will be far, far lower than any exposure standard or identified adverse effect, no calculations of the DC magnetic field expected from buried DC cables during operation at maximum loading for this project were provided to support that inference.

Summary

Although the calculated AC MF levels calculated by Mayflower Wind (≤ 500 mG) are far below international standards that have recommend limits for exposure of the general public (≥2,000 mG), the calculated AC MF levels for the Mayflower Wind project are incomplete as to the field levels that might be produced at residences. Given concerns by some members of the public about AC EMF, Mayflower Wind could have estimated the effect of the project on magnetic fields at distances where they might contribute to long-term average exposure. Also, plans to include optimal phasing of conductors in multi-circuit duct banks were incomplete. Thus, the designs for the transmission line duct banks are mostly inconsistent with the recommendations of the WHO, MA EFSB, and CSC as they do not incorporate this well-known no-cost measure for reducing magnetic-field levels. An alternative technology for bringing electricity to the grid via an HVDC cable has been considered but only to the extent of a review of health assessments, and no calculations of the static DC magnetic fields for this project were presented.

Limitations

The town of Falmouth, MA, requested that Exponent perform a high-level review of documents related to electric and magnetic fields for the Mayflower Wind Project. The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein for purposes other than intended for project permitting are at the sole risk of the user.

The role of Exponent in this project is advisory in nature, and the opinions, analyses, conclusions, results, suggestions, and the like, hereafter referred to as "work products," must be assessed by the town of Falmouth with respect to its services. Falmouth assumes full and complete responsibility for all uses and applications of work products, or failure to use work products, as well as for the application of any data captured through use of the work products. Exponent involvement is based on scientific literature, industry standards, and the training, education, and experience of the Exponent consulting staff. Work products do not represent safety certification of any sort.

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 if it becomes available.