SOUTHWEST CONNECTICUT RELIABILITY PROJECT

BY

THE CONNECTICUT LIGHT AND POWER COMPANY

DOING BUSINESS AS EVERSOURCE ENERGY

VOLUME 1: DESCRIPTION OF THE PROPOSED PROJECT AND ALTERNATIVES ANALYSIS

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VOLUME 1: DESCRIPTION OF THE PROPOSED PROJECT AND ALTERNATIVES ANALYSES

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http://www.transmission-nu.com/contractors/pdf/CT_BMP.pdf

EXECUTIVE SUMMARY

ES.1 PROPOSED PROJECT PURPOSE AND LOCATION

The Connecticut Light and Power Company doing business as Eversource Energy (Eversource) proposes to construct a new 3.4-mile 115-kilovolt (kV) overhead electric transmission line from its existing Plumtree Substation in the Town of Bethel, through the eastern portion of the City of Danbury, to Brookfield Junction[1] in the Town of Brookfield. Eversource also proposes to modify facilities and existing 115-kV line interconnections at its existing Stony Hill Substation, also located in the Town of Brookfield.

These proposed electric transmission system upgrades are required to improve the reliability of the 115-kV electric system in the Southwest Connecticut (SWCT) area generally and in the Housatonic Valley-Norwalk–Plumtree sub-area of SWCT (referred to herein as the Housatonic Valley sub-area) in particular. Figure ES-1 illustrates the existing electric transmission system in SWCT, including the Housatonic Valley sub-area.

The proposed improvements, referred to as the SWCT Reliability Project (Project), will eliminate potential thermal overloads and voltage violations, as identified in studies conducted by the Independent System Operator New England (ISO-NE), the independent transmission system planning authority for the New England states. The installation of the new 115-kV between Plumtree Substation and Brookfield Junction also would provide an additional source of electricity into a load pocket within the Housatonic Valley sub-area. In addition to eliminating reliability criteria violations, the proposed new 115-kV line would have better voltage performance, would not adversely affect existing transfer limits; and would be cost-effective compared to other system alternatives initially considered. The proposed Project facilities were identified as a result of system planning studies and alternatives analyses performed by ISO-NE.

[1] A transmission system "junction" is a location where different transmission lines intersect.

Figure ES-1: SWCT Region

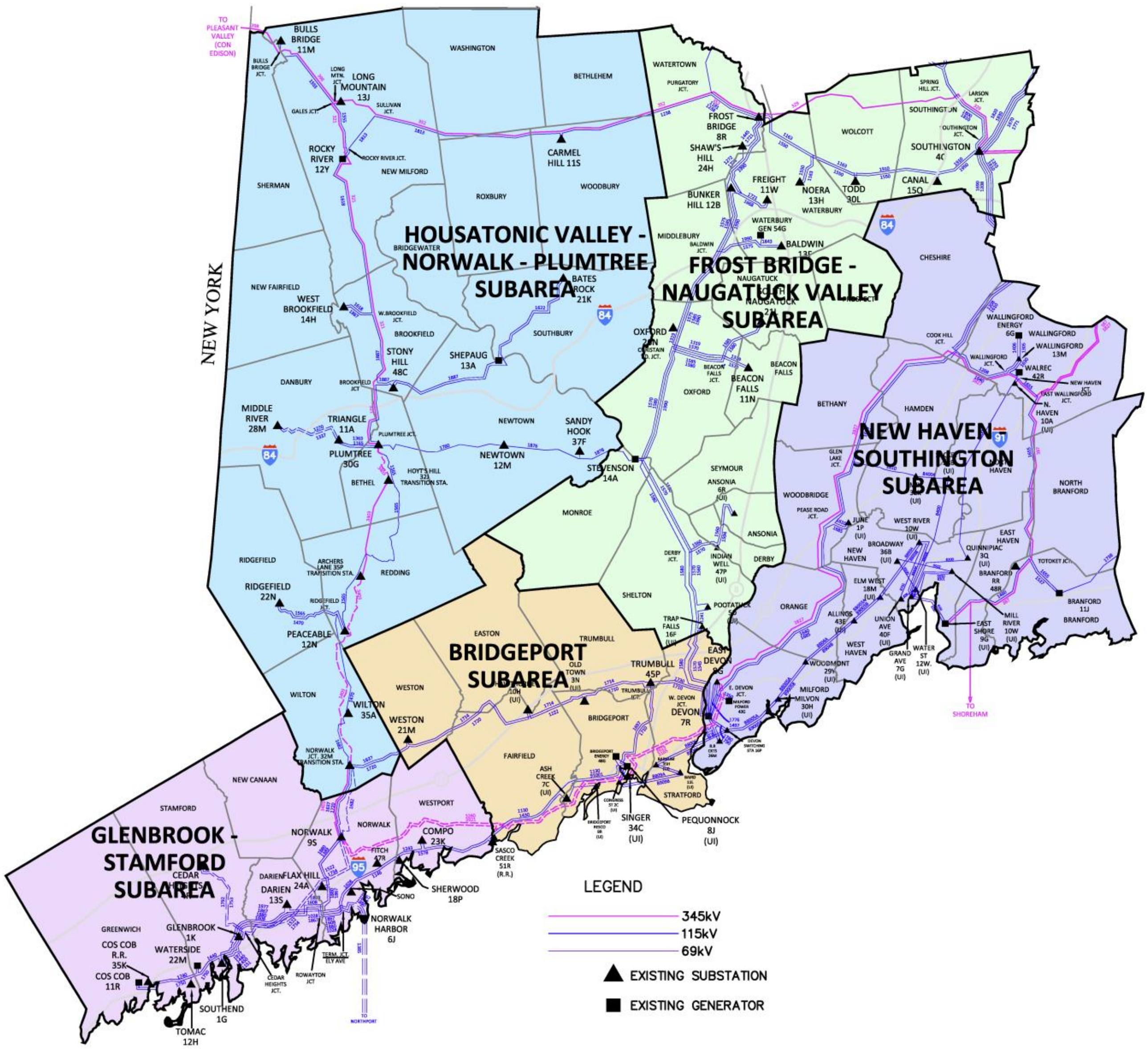
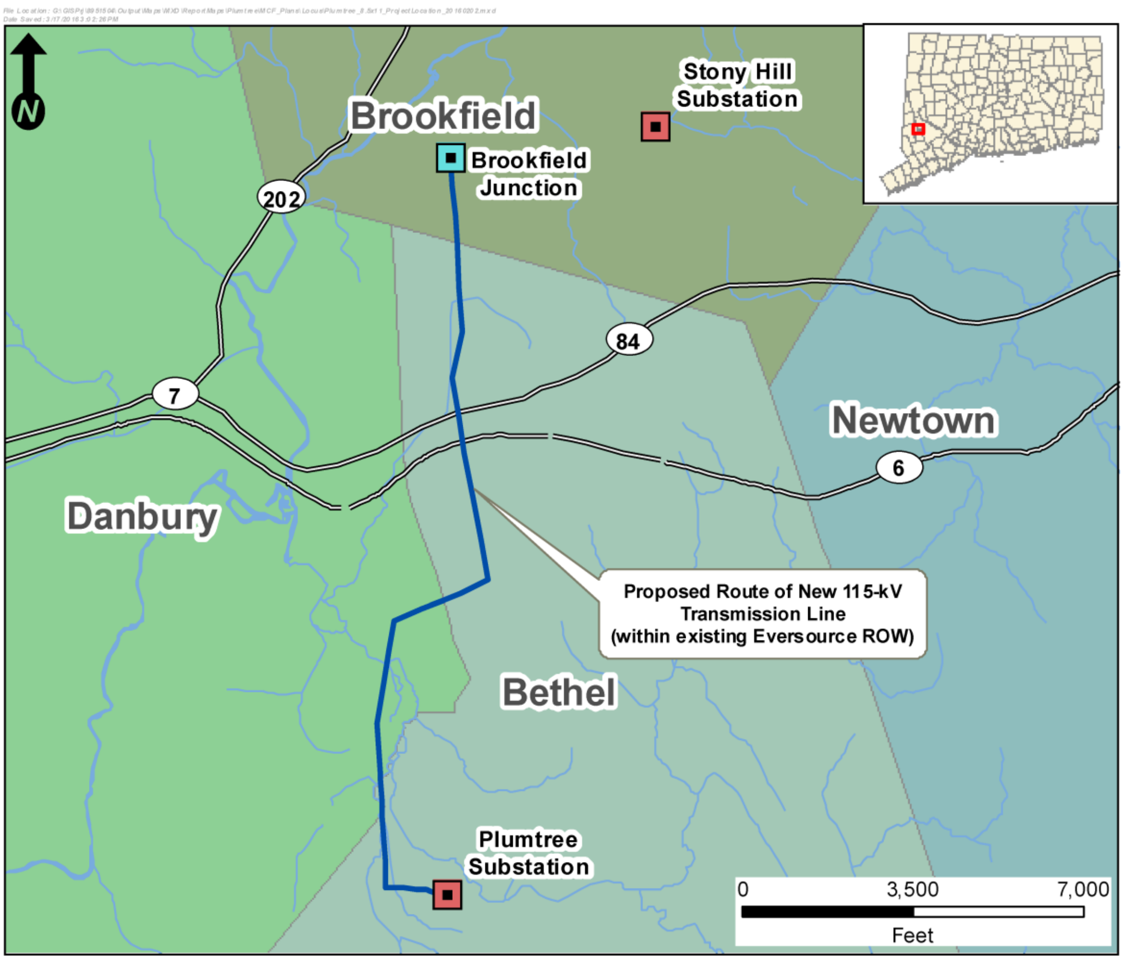


Figure ES-2 shows the general location of the proposed 115-kV modifications, all of which would be in the northwestern portion of Fairfield County.

Figure ES-2: Proposed Project Location



The proposed Project facilities, all of which would be accommodated within Eversource's existing transmission line rights-of-way (ROWs) or on Eversource-owned property, would consist of the following:

- ***New 115-kV Overhead Transmission Line***. Construct a new, approximately 3.4-mile 115-kV overhead electric transmission line (designated as the 1887 Line) connecting Plumtree Substation to Brookfield Junction. At present, the 1887 Line connects Shepaug Substation (located in the Town of Southbury), Stony Hill Substation, and West Brookfield Substation (located in the Town of Brookfield), passing through Brookfield Junction. The new 3.4-mile transmission line will extend the 1887 Line to Plumtree Substation, providing another 115-kV connection to that substation.

The new 115-kV transmission line would be aligned entirely within Eversource's existing approximately 175-foot-wide transmission line ROW, adjacent to two other overhead lines (a 115-kV line [the 1770 Line] and a 345-kV line [the 321 Line]), which are supported together on double circuit structures. The Proposed Route of the new 115-kV line would be entirely within the Eversource ROW, generally east of the existing lines. This ROW has been devoted to utility use for many years. The new 115-kV line would interconnect to Plumtree Substation within the presently developed substation.

- ***Modifications to Stony Hill Substation and to Existing Transmission Lines***. Modify the substation and reconfigure two existing 115-kV transmission lines (i.e., the 1770 Line and the 1887 Line) that presently connect to the substation. The proposed work, which will be performed on Eversource property within or adjacent to the substation, would include:
  - Connect an existing 115-kV capacitor bank to a different bus.
  - Reconfigure two existing overhead 115-kV lines, both of which presently connect to the substation, as follows:
    - ✓ Reconfigure the existing three-terminal 1770 Line that extends from Plumtree Substation to Bates Rock Substation (in the Town of Southbury) into separate two-terminal lines between Plumtree and Stony Hill substations and between Stony Hill and Bates Rock substations. After this reconfiguration, the 1770 Line will be re-numbered (although no physical changes will be made to the line other than at Stony Hill Substation). Thus, from Plumtree to Stony Hill substations, the former 1770 Line will be re-designated the 1268 Line, whereas the portion of the 1770 Line connecting Stony Hill and Bates Rock substations will become the 1485 Line.
    - ✓ Reconfigure the existing 1887 Line into a three-terminal line between Plumtree, West Brookfield, and Shepaug substations. The existing 1887 Line interconnection to Stony Hill Substation will be eliminated; thus, after the proposed reconfiguration, the 1887 Line will bypass Stony Hill Substation.

ES.2 PURPOSE OF THE MUNICIPAL CONSULTATION FILING

The proposed Project is subject to the regulations of the Connecticut Siting Council (Council or CSC) and other state regulatory agencies. In the second quarter of 2016, Eversource plans to submit an *Application for a Certificate of Environmental Compatibility and Public Need* (Application) to the Council. Prior to the submission of such an Application, the Council requires applicants to provide project information, in the form of a Municipal Consultation Filing (MCF), to the potentially affected municipalities.

The MCF is a key mechanism both for informing the public and municipal representatives about a proposed project and for soliciting comments about the project. To provide the public and municipal representatives with currently-available information concerning this Project, the format of this MCF follows the anticipated format of the Application and includes five volumes, as follows:

- **<u>Volume 1</u>** presents detailed information about the proposed Project, including the Proposed Route, transmission facilities design, construction and operation procedures, existing environmental conditions, potential environmental effects and mitigation measures, and electric and magnetic field (EMF) mitigation. In addition, Volume 1 identifies the alternatives considered to the proposed Project.
- **<u>Volume 2</u>** includes information concerning wetlands and water resources along the Proposed Route, including wetland delineation forms.
- **<u>Volume 3</u>** provides environmental reports concerning breeding birds, vernal pools, cultural resources, and visual resources.
- **<u>Volume 4</u>** consists of technical electric transmission system planning reports.
- **<u>Volume 5</u>** presents Project maps and drawings, including a U.S. Geological Survey (USGS) map of the proposed Project, aerial photography based maps at scales of 1"=400' and 1"=100', Plan and Profile maps, as well as cross-sections of the proposed transmission line, and drawings of the proposed substation modifications.

ES.3 PROPOSED PROJECT FACILITIES

New 115-kV Transmission Line. The proposed new 115-kV transmission line would be located adjacent to the existing 321/1770 overhead transmission lines that presently occupy Eversource's ROW between Plumtree Substation and Brookfield Junction. The existing transmission lines are supported on steel lattice or monopole structures that are approximately 85 feet tall near Plumtree Substation, but are typically 150 feet in height along the majority of the ROW.

The proposed overhead 115-kV line would be supported on steel monopole structures in a vertical configuration. The existing Eversource ROW is sufficiently wide to accommodate the new monopoles without affecting the existing transmission lines (i.e., without requiring the relocation or rebuilding of existing structures).

The new monopole structures would be steel, with typical structure heights 95-135 feet above ground, depending on terrain. Four three-pole horizontal structures approximately 30-40 feet in height will be installed to the west of Plumtree Substation. Thus, the new 115-kV structures would typically be shorter than the existing double-circuit 345-kV/115-kV transmission line structures.

The length that the new 115-kV line would traverse through each of the three municipalities, as well as the ROW width in each community, is summarized in Table ES-1.

Table ES-1: ROW Length and Width by Municipality

Municipality	Eversource ROW Characteristics	
	Length (Approx. Miles)	Width Range (Feet, Typical)
Bethel	2.2	175-225
Danbury	0.9	175-225
Brookfield	0.3	175
Total	**3.4**	

Stony Hill Substation Modifications. At Stony Hill Substation, all of the proposed modifications will be accomplished within the substation or on Eversource property directly adjacent to the substation. Within the substation, the existing 22K 115-kV capacitor bank connection to Bus A1 will be removed and the capacitor bank will instead be connected to existing Bus A3. This work will include the removal of existing bus-related equipment and support structures and the installation of new bus equipment and support facilities. Lightning arrestors also will be installed.

In addition to the work within the substation fence, three existing structures associated with the existing 1770/1887 line interconnections to the station will be removed. The structures to be removed are wood poles with typical heights of approximately 85 feet and are located on Eversource property north of the substation fence. Two of the structures will be replaced to re-connect Stony Hill Substation to the 1770 Line (which then will be re-designated as the 1268 and 1485 lines). One of these structures, which will support the newly-designated 1268 Line will consist of an approximately 85-foot direct embedded weathering steel structure, whereas the structure that will support the newly-designated 1485 Line will be an approximately 70-foot-tall engineered steel pole on a caisson foundation.

ES.4 CONSTRUCTION AND OPERATION / MAINTENANCE PROCEDURES

Eversource would construct, operate, and maintain the proposed transmission facilities in accordance with all regulatory approvals and its standard practices. Construction of the proposed facilities would be performed in several stages, some overlapping in time.

***Transmission Line*:** The primary activities involved in the construction of the new overhead transmission line would include the following:

- Survey to stake the vegetation clearing boundaries and proposed structure locations.
- Mark the boundaries of previously delineated wetland and watercourse areas, as well as areas to be avoided (e.g., sensitive cultural or environmental resource areas).
- Establish construction field office(s) and material staging sites (e.g., storage, staging and laydown areas) to support the construction effort. The preferred locations for such areas are typically in the vicinity of the ROW.
- Perform vegetation clearing along those portions of the ROW to be used for the construction of the transmission line.
- Install erosion and sedimentation controls in accordance with best management practices.
- Construct new access roads (and/or improve existing roads) and work pads for structure and conductor installation.
- Construct foundations and erect/assemble new structures.
- Install conductors and shield wires.
- Restore disturbed sites.

After the installation of the new 115-kV transmission line, Eversource would manage the ROW in accordance with its established vegetation management program.

Stony Hill Substation Modifications: The modifications within the Stony Hill Substation would involve standard construction procedures (e.g., site preparation, implementation of erosion and sedimentation controls, modifications to equipment and structures, and site stabilization with crushed stone or equivalent). The reconfiguration of the existing 1770 and 1887 lines would entail procedures similar to those described for the construction of the new 115-kV line, except that three existing wood pole structures, located within the Eversource ROW adjacent to the substation, would be removed and properly disposed of. Two new structures would be installed to complete the line reconfigurations. The operation and maintenance of the substation modifications would not substantially affect or alter existing practices at the station.

ES.5 ENVIRONMENTAL RESOURCES, POTENTIAL EFFECTS, AND MITIGATION MEASURES

Eversource conducted comprehensive research to compile existing baseline environmental data concerning the Project area, as well as field surveys to characterize the existing environmental resources along the existing Eversource ROW in which the new line is proposed to be located and in the vicinity of Stony Hill Substation. Environmental information for the Project was compiled, mapped, and described in accordance with the Council's A*pplication Guide for an Electric Transmission and Fuel Transmission Line Facility* (February 2016).

Along the proposed transmission line ROW and at the Stony Hill Substation, field investigations were performed to identify site-specific natural resources (e.g., soils, topography, wetlands, watercourses, vegetative communities, breeding bird habitat), cultural resources, land uses, and visual resources. In addition, data were compiled regarding Eversource's existing fee-owned properties and easements, including ROW widths, transmission line structures (locations, types, heights), and access roads. Using this baseline information, Eversource described the existing environmental conditions in the Project area. The following features (among others) along the Proposed Route, at Stony Hill Substation, and in the immediately surrounding region are also illustrated on the aerial-photography-based maps in Volume 5:

- Existing transmission line ROWs, transmission line structure locations, access roads, and substations.
- Eversource-owned properties.
- Vegetative community types.
- Areas of steep slopes.
- Land uses, including residential, commercial, and industrial areas.
- Municipal boundaries and zoning classifications.
- Federal and state jurisdictional wetlands, watercourses, and other waterbodies.
- Federal Emergency Management Agency (FEMA) floodplain and Floodway boundaries.
- Public recreational, scenic, or open space parcels areas, including the East Swamp Wildlife Management Area and Bethel's Bennett and Meckauer parks.
- Existing infrastructure, including roads, railroads, and pipelines.

Using both the baseline environmental data and the plans for the development of the proposed Project, Eversource identified and analyzed the potential short- and long-term effects that the construction and operation of the proposed facilities would have on the environment, ecology, and scenic, cultural, and recreational values. In addition, Eversource identified possible measures for avoiding, minimizing, or mitigating adverse effects. The avoidance, minimization, and mitigation of adverse effects to environmental resources, land uses, and cultural resources were key considerations in the Project planning process and will continue to be important during the finalization of Project design and the preparation of Development & Management (D&M) Plans.[2]

Based on current Project engineering plans, analyses of the existing environmental data, and the mitigation measures identified to date, the proposed Project would have localized environmental effects. Specifically, the Project would:

- Result in minimal, short-term, and localized soil disturbance as a result of on-ROW construction activities and substation modifications.
- Have no effect on vernal pools (none would be affected by the Project).
- Have comparatively minor effects on wetlands and watercourses. No wetlands or watercourses would be affected by the Stony Hill Substation modifications. Although 11 of the proposed 28 new 115-kV structures must unavoidably be located in wetlands (due to the extent of the wetland complex that extends across the southern portion of the ROW), the new structures will involve less than 0.03 acre of permanent fill in wetlands. Approximately 5 acres of wetlands will be temporarily affected during Project construction (e.g., by the construction of access roads using timber mats); this temporary fill will be removed after the installation of the new 115-kV line. Eversource will coordinate with the involved regulatory agencies to provide appropriate compensatory mitigation for this permanent fill. None of the seven watercourses along the Proposed Route will be permanently affected by the Project.
- Require the placement of 12 new transmission structures within the FEMA designated 100-year flood zone. Of these 12 structures, five would be within the FEMA-designated Floodway of Limekiln Brook / East Swamp Brook in Bethel. Alignment of the new structures within the floodplain and Floodway cannot be avoided given the alignment of the existing ROW and the locations of the floodplain and Floodway boundaries.
- Convert approximately 9.5 acres of forested habitat (6.0 acres of forested upland and 3.5 acres of forested wetland) into upland or wetland shrub communities.
- Use best management practices to avoid or minimize potential adverse effects on sensitive resource areas.
- Result in incremental and generally localized visual effects associated with the installation of the new 115-kV overhead line along the existing ROW. However, the new 115-kV structures would be similar in appearance to, but shorter than, the existing 321/1770 Line structures.

2 A D&M Plan is a pre-requisite condition of the Council's issuance of an approval to construct the Project. The Project D&M Plans would include specifications for Project construction, including environmental mitigation measures. It is anticipated that separate D&M Plans would be prepared for the substation and transmission line components of the Project.

In general, the proposed Project would minimize adverse environmental effects by co-locating the new 115-kV transmission line entirely within Eversource's existing ROW, adjacent to long-established overhead transmission lines, and by developing the proposed Stony Hill Substation modifications on property that is already designated for utility use.

ES.6 EMF ANALYSES

As required pursuant to the Council's 2014 Electric and Magnetic Fields (EMF) *Best Management Practices for the Construction of Electric Transmission Lines in Connecticut* (EMF BMP), Eversource calculated EMF along the Plumtree Substation to Brookfield Junction ROW associated with the existing transmission facilities, as well as the changes in EMF levels that can be expected once the new line is constructed and in-service. These calculations show that the addition of the new line will not substantially increase electric or magnetic fields at the edge of the ROW, and will amount to only a small fraction of the EF and MF limits set forth by international guidelines.

ES.7 ALTERNATIVES CONSIDERED

The proposed Project is the result of a comprehensive evaluation process conducted by ISO-NE, Eversource, The United Illuminating Company, and other stakeholders. This process began with a determination of the need for a solution to reliability issues in the SWCT region, then continued with the identification and analysis of alternative solutions for addressing the need, and concluded with the examination of specific alternative routes for the proposed transmission facilities. As a result of these analyses, the Proposed Route and overhead line configuration were selected for the new 115-kV line, and the proposed modifications to the Stony Hill Substation and associated transmission line interconnections were defined as part of the Project. The alternatives considered included:

- **No Action Alternative**. Under this alternative, no action would be taken and the electric transmission system in the Housatonic Valley sub-area of SWCT would not be improved. The No Action Alternative was rejected because it would not resolve the identified regional electric reliability problems. Thus, the electric supply system in the region would not comply with national and regional reliability standards and criteria.
- **System Alternatives**. Following the evaluations of the need for the Project, transmission system alternatives that would potentially meet that need were identified and evaluated. The results of these analyses led to the selection of a 115-kV transmission solution that would connect Eversource's Plumtree Substation and Brookfield Junction, thereby extending the 1887 Line to Plumtree Substation. The associated modifications to Stony Hill Substation would allow the reconfiguration of the existing 1887 Line and the 1770 Line. Although potential non-transmission system alternatives (e.g., generation, demand reduction) that could address the need

served by the transmission solution were investigated, no practical and cost effective non-transmission alternative was identified.

- **Overhead and Underground Transmission Line and Route Alternatives**. After a new 115-kV circuit between Plumtree Substation and Brookfield Junction was selected as the preferred transmission system solution, Eversource identified and evaluated potential routes and configurations for the new line. As part of this process, Eversource evaluated both overhead and underground transmission line designs, with potential alignments along or adjacent to various existing ROWs, as well as alignments along entirely new ROWs. All of the route alternatives were evaluated against standard Eversource criteria and objectives for overhead and underground transmission lines. The Proposed Route within Eversource's existing ROW, using an overhead transmission line design, was determined to be the preferred alternative. This alternative does not require the acquisition of any additional property or ROW, represents the lowest cost solution, and would avoid or minimize environmental and social impacts to the extent practical.
- **Potential Variations to the Proposed Transmission Line Route**. Because the proposed 115-kV line can be entirely accommodated within the existing ROW, no potentially viable route variations to portions of the new 115-kV route were identified.

ES.8 COST AND SCHEDULE

The estimated capital cost of the Project is approximately $24.4 million. Project construction is anticipated to commence in the first quarter of 2018, with a scheduled in-service date by the end of 2018.

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1. DESCRIPTION OF THE PROPOSED PROJECT

1.1 PROJECT OVERVIEW: OBJECTIVES AND LOCATION

The Connecticut Light and Power Company doing business as Eversource Energy (Eversource or the Company) proposes to improve the reliability of the 115-kilovolt (kV) electric system in the Southwest Connecticut (SWCT) area generally and within the Housatonic Valley-Norwalk–Plumtree sub-area of SWCT (referred to herein as the Housatonic Valley sub-area) in particular. [1] The Housatonic Valley sub-area, which encompasses multiple municipalities in Fairfield and Litchfield counties, is illustrated on Figure 1-1. The locations of the proposed 115-kV electric transmission system improvements, referred to as the SWCT Reliability Project (Project), are generally illustrated on Figure 1-2. These proposed improvements are part of a suite of projects required to bring the electric supply system in the Housatonic Valley sub-area of SWCT into compliance with applicable national and regional reliability standards and criteria.

The proposed Project is subject to the regulations of the Connecticut Siting Council (Council)[2] and other state and federal agencies. Accordingly, in the second quarter of 2016, Eversource plans to submit an *Application for a Certificate of Environmental Compatibility and Public Need* (Application) for the Project to the Council.

The proposed 115-kV modifications, all located in the northwestern portion of Fairfield County and all within Eversource's existing transmission line rights-of-way (ROWs) or on Eversource's substation properties, are as follows:

- **New 115-kV Transmission Line**. Construct a new, approximately 3.4-mile 115-kV overhead electric transmission line extending from Eversource's Plumtree Substation in the Town of Bethel, through northeastern Bethel and the eastern portion of the City of Danbury, to Brookfield Junction[3] in the Town of Brookfield. This new line, which would be located within an existing Eversource ROW occupied by a 345-kV line and a 115-kV line (the 321/1770 lines), will extend

1 For electrical system planning purposes, SWCT is a large area comprised of five sub-areas: Housatonic Valley-Norwalk-Plumtree, Frost Bridge –Naugatuck Valley, Bridgeport, New Haven – Southington, and Glenbrook-Stamford. The Housatonic Valley/Norwalk-Plumtree sub-area extends from Carmel Hill Substation in the Town of Woodbury west to Bulls Bridge Substation in New Milford and south to Plumtree Substation and south to Norwalk Substation in the City of Norwalk. Section 2 provides details regarding the electric transmission system in SWCT, including the 115-kV reliability issues in the Housatonic Valley/Norwalk – Plumtree sub-area.

2 Apart from the proposed Project, Eversource performs transmission line and substation maintenance activities to maintain the reliability of the electric system. Such activities are not subject to siting agency review.

3 A transmission system "junction" is a location where different transmission lines intersect.

Eversource's existing 115-kV 1887 Line to Plumtree Substation. At present, the 1887 Line connects Shepaug Substation (located in the Town of Southbury), Stony Hill Substation (Town of Brookfield), and West Brookfield Substation (located in the Town of Brookfield), passing through Brookfield Junction.

- **Stony Hill Substation and Related Line Modifications**. Modify the Stony Hill Substation and reconfigure two existing 115-kV transmission lines (i.e., the 1770 Line and the 1887 Line) that presently connect to the substation. The proposed work, which will be performed within or adjacent to the substation, includes:

    - Connect an existing 115-kV capacitor bank to a different bus.

    - Reconfigure two existing overhead 115-kV lines, both of which presently connect to the substation, as follows:

        ✓ Reconfigure the existing three-terminal 1770 Line that extends from Plumtree Substation to Bates Rock Substation (in the Town of Southbury) into separate two-terminal lines between Plumtree and Stony Hill substations and between Stony Hill and Bates Rock substations. After this reconfiguration, the 1770 Line will be re-numbered (although no physical changes will be made to the line other than at Stony Hill Substation). Thus, from Plumtree to Stony Hill substations, the former 1770 Line will be re-designated the 1268 Line, whereas the portion of the 1770 Line connecting Stony Hill and Bates Rock substations will be re-numbered as the 1485 Line.

        ✓ Reconfigure the existing 1887 Line into a three-terminal line between Plumtree, West Brookfield, and Shepaug substations. As part of the reconfiguration, the existing 1887 Line interconnection to Stony Hill Substation will be eliminated; thus, when reconfigured as proposed, the 1887 Line will bypass the Stony Hill Substation.

The proposed Project will enhance the reliability of the 115-kV electric system in SWCT, particularly in the Housatonic Valley sub-area, and will eliminate potential thermal overloads and voltage violations, as identified in studies conducted by Independent System Operator New England (ISO-NE)[4], the independent transmission system planning authority for the New England states. The installation of the new 115-kV 1887 Line between Plumtree Substation and Brookfield Junction also would provide an additional source of electricity into the Housatonic Valley sub-area (the 1770 Line is presently the only 115-kV line connecting to Plumtree Substation from the north).

4 In addition to eliminating reliability criteria violations, the proposed new 115-kV line would have better voltage performance, would not adversely affect existing transfer limits; and would be cost-effective compared to other system alternatives initially considered. Refer to the discussion of Project Need in Section 2, as well as to the systems alternatives analyses in Section 10.

Figure 1-1: Housatonic Valley-Sub-area

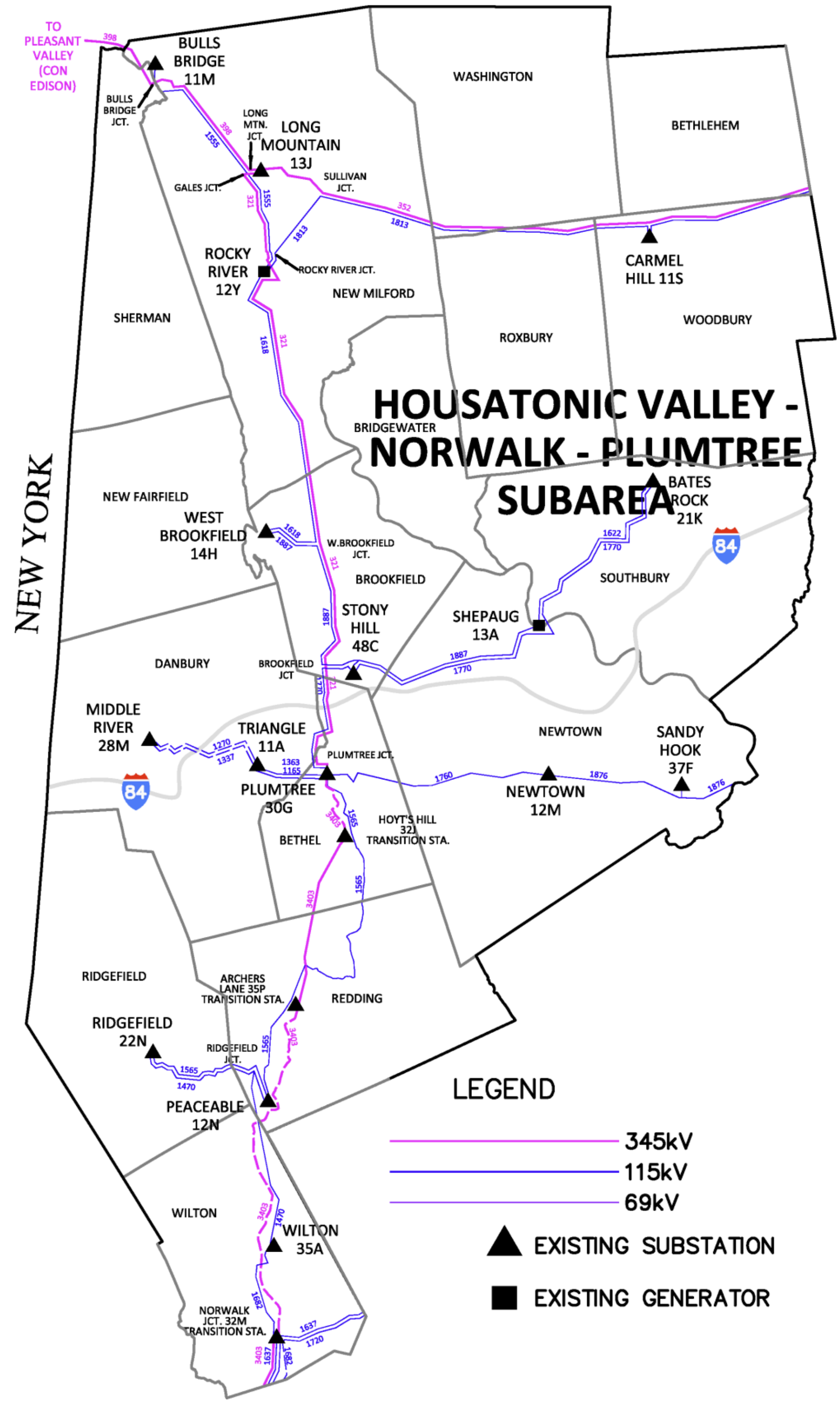
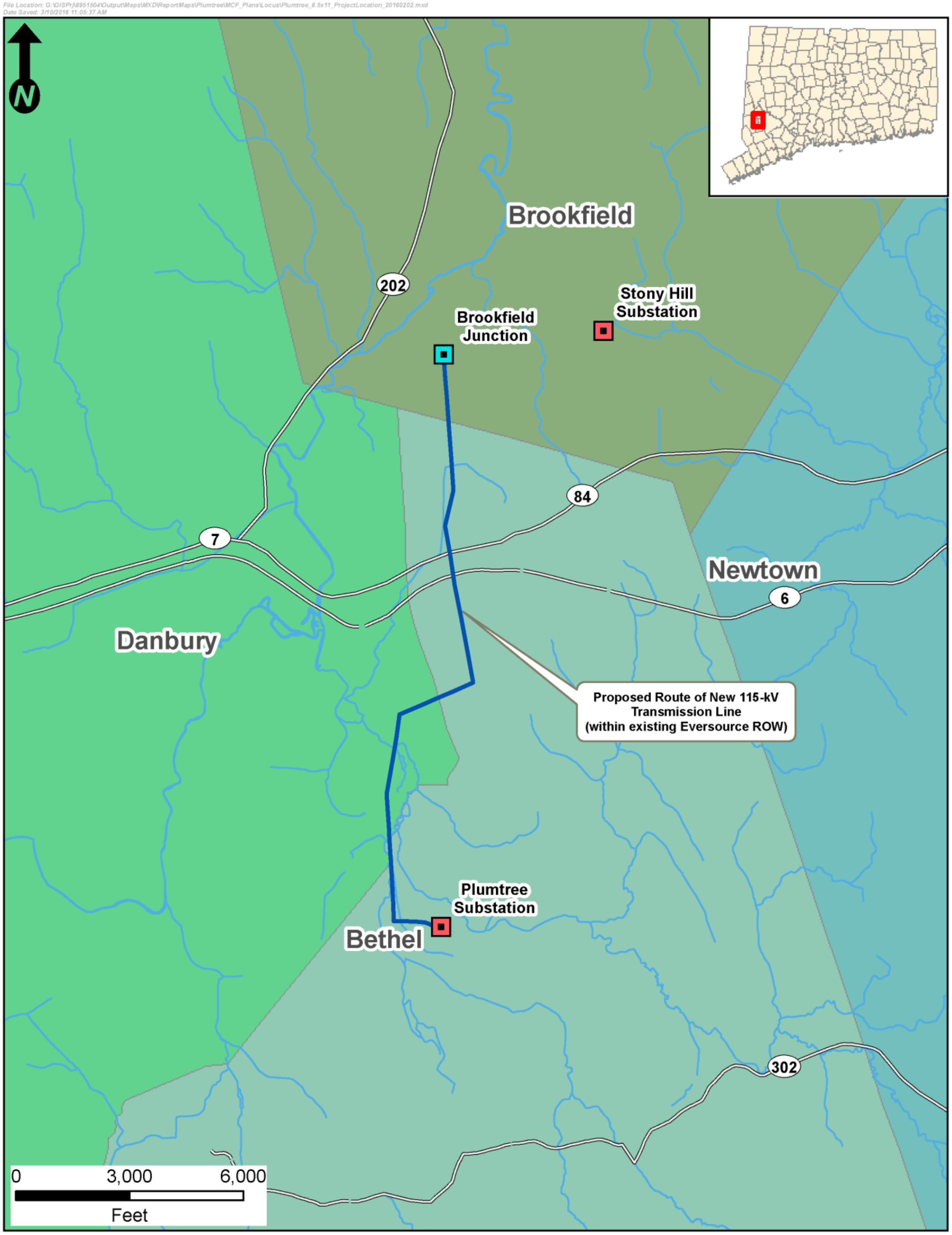


Figure 1-2: Proposed Project Location



The facilities proposed for the Project were identified as a result of system planning studies and alternatives analyses performed by ISO-NE. After these studies determined a need for a new 115-kV transmission line in the Housatonic Valley sub-area, Eversource developed and analyzed potential alternatives before identifying the Proposed Route and a proposed overhead configuration for the new transmission line, as well as the need for the proposed modifications to Stony Hill Substation.[5]

The proposed Project reflects Eversource's primary objectives for designing transmission facilities that can be constructed and operated to:

- Comply with state and federal statutory requirements, regulations, and siting policies.
- Minimize adverse effects to natural and human resources.
- Achieve a reliable, operable, and cost-effective solution.

Based on these overarching objectives, the principal factors considered in selecting the proposed Project facilities were:

- Availability of existing public, utility, or other ROWs or Eversource-owned property where the proposed facilities could be developed so as to avoid or minimize the need for additional easement acquisition.
- Avoidance or minimization of effects on environmental resources, significant cultural resources (archaeological and historical), and designated scenic resources.
- Consideration of visual effects.
- Constructability/engineering considerations.
- Minimization of conflicts with developed areas.
- Maintenance of public health and safety.
- Accessibility for construction and maintenance.
- Cost.

The proposed Project facilities best meet these objectives, while representing Eversource's preferred solution for providing reliable, cost-effective, and environmentally sound improvements to the regional 115-kV electric transmission system.

5 Analyses of alternative routes and transmission line configurations conducted for the Project are detailed in Section 11.

1.2 PROPOSED PROJECT FACILITIES

1.2.1 New 115-kV Transmission Line

The proposed 3.4-mile 115-kV transmission line would extend the existing 1887 Line in an overhead configuration, from Eversource's existing Plumtree Substation (located at 16 Walnut Hill Road in the Town of Bethel), through the eastern portion of the City of Danbury, to Brookfield Junction (located south of and adjacent to the Housatonic Railroad tracks and west of Vail Road in the Town of Brookfield). The new 115-kV line would be aligned adjacent to Eversource's existing 1770 Line (115-kV) and 321 Line (345-kV), which presently occupy Eversource's typically 175 to 225-foot-wide ROW between Plumtree Substation and Brookfield Junction. The entire route of the new line (i.e., the Proposed Route) would be located within this long-established existing Eversource ROW.

The new 1887 Line would interconnect to Plumtree Substation within the existing, developed substation fence line. No expansion of the Plumtree Substation would be required for the proposed Project.

The existing 1770 and 321 lines are supported on double-circuit monopole structures, with the exception of lattice steel structures near Plumtree Substation. These structures typically are 150 feet in height.

The new 1887 Line would be located generally on the eastern portion of the existing Eversource ROW. No additional easements would be required for the Project, with the possible exception of off-ROW access road easements to facilitate construction and/or maintenance.

Table 1-1 summarizes the length of the new 115-kV transmission line in each of the three municipalities along the Proposed Route. The table also provides a key to the location of the Proposed Route as depicted on the aerial photography-based mapsheets in Volume 5, and identifies the Cross-Section (XS) drawings in Section 3 (Appendix 3A) in this Volume and in Volume 5 that illustrate the proposed alignment and configuration of the new overhead line along each ROW segment.

Table 1-1: Proposed 115-kV Transmission Line ROW by Municipality

Municipality	ROW Characteristics		Volume 5, 400 Scale Mapsheet No.	Cross-Section (refer to Section 3, Volume 1, and Volume5)
	Length (Approx. Miles)	Width Range (Feet, Typical)*		
Bethel	2.2	175-225	1, 2, 3	XS-1, XS-2
Danbury	0.9	175-225	1, 2	XS-2
Brookfield	0.3	175	3, 4	XS-2, XS-3
Total	**3.4**			

*ROW widths vary; refer to cross-section drawings.

Along the Proposed Route, the new overhead 115-kV transmission line would be supported on steel monopole structures in a vertical configuration. With structure heights between 95 and 135 feet above ground, depending on terrain, the new 115-kV structures would typically be substantially shorter than the existing 321/1770 line structures.

1.2.2 Stony Hill Substation and Related Transmission Line Modifications

Stony Hill Substation is located at 49 Stony Hill Road in the southern portion of the Town of Brookfield. The developed (fenced) substation occupies a portion of a larger Eversource property that is otherwise characterized predominantly by forest vegetation (refer to 400-scale Mapsheet No. 4 in Volume 5). The substation property, which is accessible via an access road off Stony Hill Road, is bordered to the north by the Housatonic Railroad Company corridor and Eversource’s 1770/1887 transmission line corridor, to the west by Stony Hill Road, to the south by residences along Deer Trail Drive, and to the east by undeveloped land.

The Stony Hill Substation presently connects to both the existing 115-kV 1770 and 1887 lines, which occupy the same ROW from Shepaug Substation to Brookfield Junction, interconnecting to Stony Hill Substation between these two locations. The two 115-kV lines are supported in a double-circuit configuration on lattice steel towers, which are typically 85 feet in height. The 1770 Line occupies the south position on the towers, while the 1887 Line occupies the north. Stony Hill Substation is located south of the 1770/1887 line ROW. As part of the Project, the Stony Hill Substation and its interconnections to the 1770 and 1887 lines will be modified as summarized in the following subsections.[6]

1.2.2.1 Reconfiguration of Capacitor Bank Bus Connections

Within Stony Hill Substation, the existing 22K 115-kV capacitor bank (37.8 megavolt ampere reactive [MVAR]) connection to Bus A1 will be removed and this capacitor bank instead will be connected to Bus A3. This work will be performed within the substation's fence line[7], and will include the following activities:

- Remove rigid bus, bus support structure, and associated foundations between capacitor banks 48C-21K and 48C-22K, which will separate the 22K capacitor bank from the 115-kV Bus A1.
- Install new rigid bus, three-phase high bus support structure, 115-kV underground pothead structure and associated foundations to the south of the 22K capacitor bank.
- Install 115-kV underground duct bank, 115-kV underground pothead structure, manually-operated vertical break disconnect switch, switch structure, three-phase high and low bus support structures, as well as rigid bus and associated foundations to reconnect the capacitor bank 22K to the 115-kV Bus A3.
- Install three lightning arrestors (LAs) on each pothead structure (for a total of six LAs).

1.2.2.2 Reconfigure the Existing 1770 and 1887 Lines

As part of the Project, the existing 115-kV 1770 and 1887 line connections to Stony Hill Substation will be modified, requiring work both within the substation and on nearby Eversource property. The reconfiguration will consist of the following:

- The existing 1770 Line will be looped into the substation, thereby creating two terminal lines from the original 1770 Line: the 1268 Line extending from Stony Hill Substation to Plumtree Substation and the 1485 Line extending from Stony Hill Substation to Bates Rock Substation.
- The existing 1887 Line tap into the east side of Stony Hill Substation will be removed, eliminating the 1887 Line connection to the substation. (After this reconfiguration, the 1887 Line will bypass the substation).
- Three existing wood deadend structures (75, 80, and 55 feet in height) that presently connect the 1770 and 1887 lines to the Stony Hill Substation will be removed. Two new steel structures,

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6 In conjunction with these improvements, remote end maintenance type modifications will be performed at Bates Rock Substation in Southbury. These minor modifications, all within the substation fence, include the replacement of a wave trap and a line tuner within the substation.

7 Prior to the development of this Project, Eversource plans to expand the Stony Hill Substation. The proposed substation expansion, which will be located entirely on Eversource property, will be addressed in a separate filing to the Council.

approximately 70 and 85 feet in height, will be installed to re-connect the 1770 Line (thereafter designated the 1268 and 1485 lines) to the substation.

1.3 PURPOSE OF THE MUNICIPAL CONSULTATION FILING

The proposed Project is subject to the regulations of the Council and other state regulatory agencies. Prior to the submission of an Application to the Council (which Eversource plans to file for this Project in the second quarter of May 2016), the Council requires applicants to provide project information, in the form of a Municipal Consultation Filing (MCF), to the municipalities potentially affected by the planned project. The MCF is a key mechanism both for informing the public and municipal representatives about a potential project and for soliciting comments about the project.

To provide the public and representatives of Bethel, Danbury, and Brookfield with currently-available information concerning this Project, the format of this MCF follows the anticipated format of the Application. Accordingly, the MCF includes five volumes, consisting of the following:

- This **Volume 1**, which describes the proposed Project (including Project need, technical specifications, construction and operation procedures, existing environmental / cultural resource characteristics and potential environmental / cultural resource impacts and mitigation measures, electric and magnetic field data, and alternatives analyses);
- **Volumes 2-4**, which provide detailed information supporting the analyses in Volume 1; and
- **Volume 5**, which presents Project mapping, including aerial-based maps, plans, and drawings of the proposed new transmission line and proposed modifications to Eversource's existing substation facilities.

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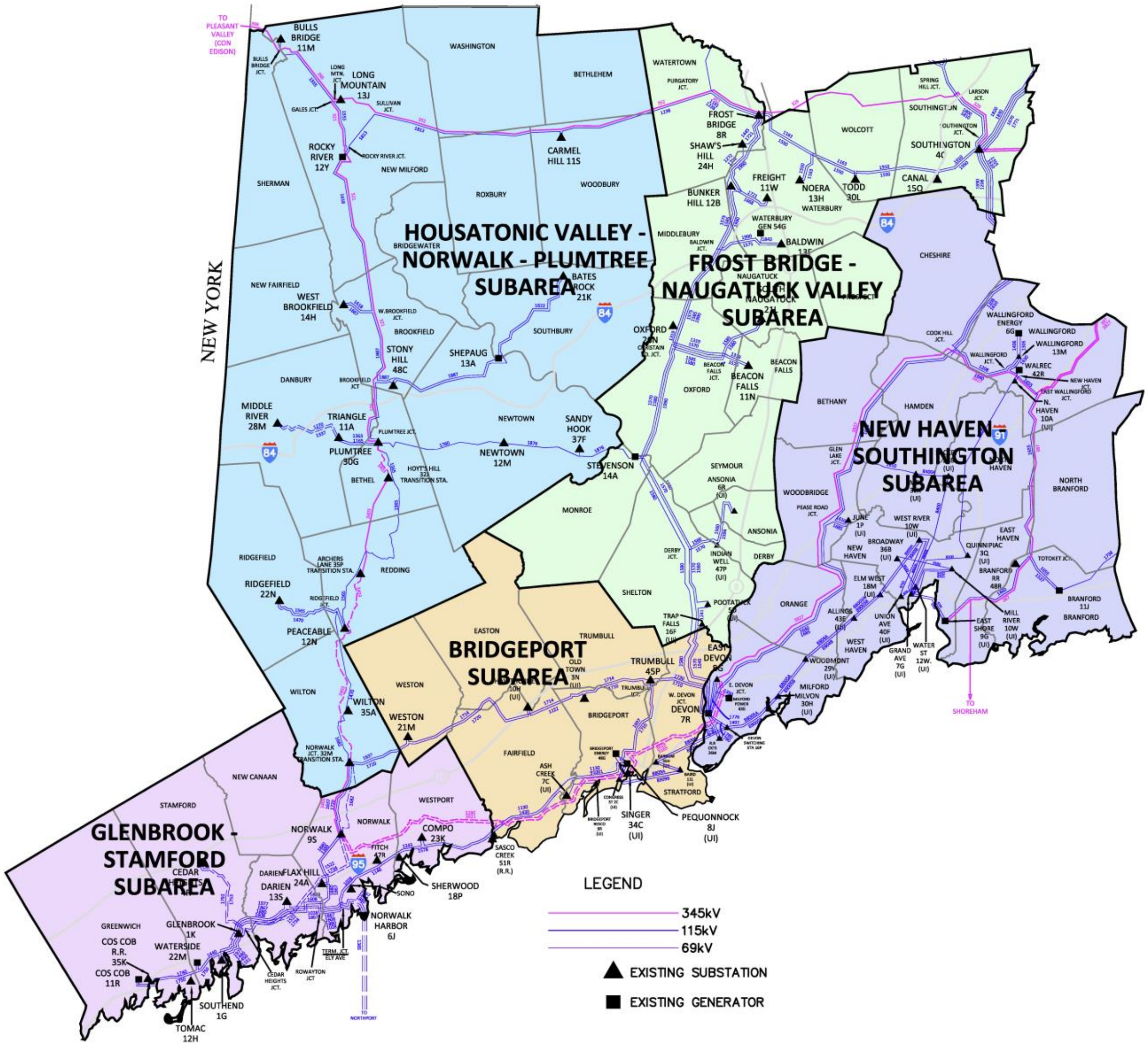
2. PROJECT BACKGROUND AND NEED

The regional electric grid administrator, ISO-NE, has completed a study of the electric transmission network that delivers power to substations serving Southwest Connecticut (SWCT) and has determined that the area transmission network faces a number of issues that, under certain conditions, could hinder its ability to adequately serve the electrical demand in the area. Although Eversource upgraded bulk power transmission service to SWCT within the last decade by creating a new 345-kV "loop" to the region, the region requires improvements to the 115-kV system to maintain the reliability of electric supplies to consumers, particularly in areas of high electric demand like the Housatonic Valley sub-area, which includes the municipalities of Bethel, Danbury, and Brookfield. Figure 2-1, illustrates the SWCT Region and Housatonic Valley sub-area.

Bethel, Danbury, and Brookfield are served by local area substations, which, in turn, are supplied power by two electric transmission lines (1238 and 1770 lines). Without the proposed Project's transmission system upgrades, the current 115-kV system in the Housatonic Valley sub-area is vulnerable to reliability problems, which could increase the risk of outages to customers or load shedding under certain conditions.

This section explains how the Project was developed to upgrade the transmission system serving the Housatonic Valley sub-area so that it would comply with applicable mandatory reliability standards. The section first identifies the applicable reliability standards and reviews how they evolved as the North American electric supply system was developed; then summarizes ISO-NE's *SWCT Connecticut Area Transmission 2022 Needs Assessment* study (SWCT Needs Report) and *SWCT Connecticut Area Transmission 2022 Solutions Study Report* (SWCT Solutions Report) that identified, respectively, the need for a group of projects to resolve reliability problems throughout SWCT and the solutions to these needs. Lastly, the section describes the set of components that are the subject of this MCF and how these components will address the reliability issues in the Housatonic Valley sub-area.

Figure 2-1: SWCT Region



2.1 THE SYSTEM PLANNING PROCESS AND RELIABILITY CRITERIA

Maintaining continuity of service to customers has been a primary objective of electric utilities in North America since their very beginning. As electric supply systems have grown and become more complex, more interconnected, and increasingly critical to human welfare and a healthy economy, standards for ensuring continuity of service have become mandatory and more stringent, requiring the use of increasingly complex analytical tools. Today, engineers using detailed, highly sophisticated and accurate computer models are able to evaluate the reliability of the existing interconnected transmission system and to plan modifications or additions needed to comply with those standards by simulating the performance of the existing system, as well as the system with potential improvements to it. The following sections review the development of reliability planning standards and their current application.

2.1.1 A Brief History of Electric Reliability Planning

During the first half of the 20th Century, individual power systems each developed and applied their own planning criteria. By mid-century, however, with the dramatic growth of synchronous interconnections and the increasing use of the electric transmission system to move power over longer distances, utilities began to coordinate their planning activities.

When the Northeast Blackout of 1965 occurred, it became obvious that a more closely coordinated strategy was necessary. Shortly after the blackout, the electric utilities involved formed the Northeast Power Coordinating Council (NPCC) to promote and improve the reliability of the interconnected bulk power system in northeastern North America, including the six New England states, New York State, and the Canadian provinces of Ontario, Québec, New Brunswick, and Nova Scotia. The U.S. systems of the NPCC also formed two new power pools: the New England Power Pool, which eventually became the ISO-NE, and the New York Power Pool, which evolved into the New York Independent System Operator (NYISO). Other utilities across North America also formed similar regional reliability councils, which together eventually encompassed most of the continent.

Each regional reliability council established its own reliability criteria. Each also developed procedures for assessing conformance. With time, individual electric utilities and power pools often developed their own more detailed and stringent planning and operating procedures to ensure the reliability of their portions of the interconnected bulk-power electric system; however, those procedures had to continue to comply with the broader regional criteria requirements.

In 1968, the U.S. regional reliability councils formed the National Electric Reliability Council (NERC) to coordinate their activities nationally and developed voluntary reliability guidelines for their collective systems. NERC has evolved over the years. In 1981, its name was changed to the North American Electric Reliability Council, to reflect the addition of Canadian members. But the most dramatic changes occurred in the wake of the August 14, 2003 Northeast Blackout. The Energy Policy Act of 2005 (EPAct) directed the Federal Energy Regulatory Commission (FERC) to establish an Electric Reliability Organization (ERO), whose major role would be to develop and enforce mandatory reliability standards for planning and operations. After a period of study, FERC designated NERC as the ERO, and its name was changed to the North American Electric Reliability Corporation, Inc.

2.1.2 Modern Reliability Standards and Criteria

The NERC standards today are subject to approval by FERC and are much more specific than they were in the past, and transmission owners' compliance is mandatory under federal law. Violations are punishable by fines as high as $1 million per day per violation. Regional reliability councils may have their own criteria,[10] but these must conform to all NERC requirements – planning, system design, and operations. Similarly, an Independent System Operator (ISO) and individual electric systems may also have their own criteria and procedures, but they all must conform to both NERC standards and the regional criteria. Thus, in conducting planning studies, all transmission owners in New England are required to comply with NERC standards, NPCC criteria, and ISO-NE planning procedures. ISO-NE has developed a *Transmission Planning Technical Guide* for the implementation of these standards and criteria, a copy of which is included in Volume 4.

2.1.3 Simulating Contingencies

A key element of the reliability standards is the consideration of "contingency" events wherein generation and/or transmission facilities are assumed to suddenly and unexpectedly trip out of service. Such contingency events could be caused by weather; by generator, transmission line, or substation equipment failures; by contingencies on other transmission systems connected to the New England transmission system; or by some combination of these factors.

[10] Although "standards" and "criteria" may be synonymous in many cases, in electric reliability planning, "standards" are correctly used to refer to the mandatory NERC standards, and "criteria" to the rules adopted by subordinate reliability organizations, which must be consistent with the NERC standards.

NERC, NPCC, and ISO-NE standards, criteria, and procedures specify the contingencies that must be considered in planning studies. The NPCC criteria and ISO-NE procedures must be consistent with all NERC standards. Thus, NPCC criteria may be more stringent than, but must at a minimum conform to, the NERC standards. Likewise, ISO-NE procedures may be even more stringent, but also must conform to the NPCC criteria and NERC standards.

When a generating unit or a transmission line suddenly and unexpectedly trips out of service, power flows increase instantaneously on the transmission lines that remain in-service. (This is in accordance with the laws of physics as applied to electric power systems). Thus, an area's transmission system must be designed not only to transmit and/or import power required to offset anticipated generation deficits with all transmission facilities in service, but also must be capable of transmitting or importing power reliably following specific contingencies as required by the mandatory national standards and regional criteria. Otherwise, post-contingency power flows could exceed emergency transmission element ratings and/or result in low voltage conditions (below prescribed minimum levels) on portions of the electric system.

Because each transmission line must be able to carry the additional current that would instantaneously flow in the event of the sudden loss of a generating unit, transmission line, or other system element, normal power flows on transmission lines will typically be well below the thermal ratings of the line.

Contingencies, as specified by NERC, NPCC, and ISO-NE standards and criteria, are usually characterized as loss of a single system element – that is, a generator, transmission line, bus section, etc. Sometimes, however, a single contingency can result in the loss of two transmission elements, such as where two electric circuits share a common set of towers, forming a "double-circuit tower" (DCT) transmission line. Both of these types of events are referred to as "N-1" contingency events. Another type of contingency involves the occurrence of two separate and unrelated outages within a short period of time (30 minutes per NPCC criteria and ISO-NE procedures). These are referred to as "N-1-1" events. When such a contingency event is simulated, reliability standards and criteria require an assumption that there will be sufficient time between contingency events for the system operator to implement specific "manual system adjustments" to the system before the second contingency event occurs.

Thus, the reliability standards and criteria applicable to the New England control area (the Applicable Reliability Standards) require that in a planning study, after performing each of the required N-1 contingency analyses with all transmission facilities assumed to be initially in service, planning engineers test the ability of the system to be operated reliably with a facility out of service. To do this, they apply a contingency; measure and document system performance prior to readjusting or reconfiguring the system (with "manual system adjustments"); then apply a second (unrelated) contingency; and subsequently study the electric system's response. The criteria governing planning studies for the New England control area provide that, to make the system ready for the next contingency, only those manual adjustments that can be implemented within 30 minutes may be considered. These include adjusting the output of generation units, changing phase angle regulator taps, and other manual adjustments meeting these criteria.

To evaluate compliance with the applicable reliability standards, the specified contingencies are simulated on computer models developed to represent the power grid with expected future modifications and additions, operating with projected future loads. If the simulations show that currents on a transmission element will exceed its thermal ratings (a thermal overload), or that system voltages cannot be maintained within acceptable limits following one or more of the contingencies (a voltage violation), appropriate solutions must be developed and implemented in order to maintain the reliability of the electric grid.

Because years are required for the design, siting, engineering, and construction of major transmission improvements once they are recognized to be needed, transmission reliability studies are conducted by modeling expected future system conditions, including expected future generation resources, other planned transmission improvements, and projected future loads. A study year in the future is selected, and conditions expected for that year are modeled. ISO-NE uses a 10-year planning horizon, so that typically expected conditions 10 years in the future from the date a study is commenced are considered.

Modelling of the specific contingencies prescribed by the NERC standards for power-flow analyses identifies improvements that will protect the transmission system against the actual occurrence of those design contingencies. That is, should one of the specified contingency events occur, the remainder of the system would survive without a transmission element overload, an unacceptably low voltage condition, instability, cascading outages, system separation, or loss of firm customer load. However, modeling of these specific contingencies does more than demonstrate how the power grid would perform should the specific events being modeled occur. These simulations also represent stresses that could result from multiple other potential events, some of which may not even be foreseeable at present. The objective of the simulations is not just to ensure that the system will withstand the specific contingencies defined by the standards, under the specific conditions modeled, but also to document that the system will be strong and robust enough to survive a wide range of potential events that could impose comparable stresses.

2.1.4 Generation Dispatches in Power-Flow Simulations

In accordance with the reliability criteria and procedures of NPCC and ISO-NE, the regional transmission power grid must be designed for reliable operation during stressed system conditions. Stressed conditions are simulated, in part, by developing generation dispatches. First, a base case that reflects the planners' expectation of likely resource availability in the study period is constructed. Resources may be assumed to be unavailable in the base case taking into consideration operating experience, announced retirement, or other reasons. Then, to simulate critical system conditions, at least the largest and most critical generating unit or station in an area is assumed to be out of service (OOS) and, in most cases, two generation resources are assumed as OOS. Assuming generators to be OOS in a base case addresses issues such as the following:

- Higher generator forced outage rates than other transmission system elements.
- Higher generator outages and limitations during stressed operating conditions such as a heat wave or a cold snap.
- Past experience with simultaneous unplanned outages of multiple generators.
- High cost of Reliability Must Run Generation.
- Generator maintenance requirements.
- Unanticipated generator retirements.
- Fuel shortages.

As with modelling contingencies, simulating existing generators as OOS in planning studies is not conducted simply to ensure that the system will be able to do without those generators in specific system conditions. This technique also tests the performance of the system under stresses that it may be required to withstand, whether from the unavailability of those specific generators or for other reasons.

Generating units assumed to be unavailable or otherwise OOS should not be confused with the loss of a generating unit as a contingency, as described earlier. The former is a base case assumption – the system as represented before any contingency is applied. The latter is one of the many contingencies specified by the NERC, NPCC, and ISO-NE standards, criteria, and procedures, which the pre-contingency system must be able to withstand without experiencing a transmission line or substation element overload, a low voltage condition, instability, cascading outages, system separation, or loss of firm customer load.

2.1.5 Coordinating Ongoing Studies

At any point in time, there are numerous studies of the New England transmission system. The New England planning process requires study teams to communicate with each other to ascertain if the different teams have identified issues that may be addressed, in whole or in part, by a common solution, or if changes to the transmission system are being proposed that might impact their study. In order to assure that needed improvements to the system will be identified and designed efficiently and cost-effectively, studies of area needs are sometimes combined and/or split apart as they proceed, as was the case during the development of this Project, as described in Section 2.2.

2.2 THE DEVELOPMENT OF THE PROJECT

2.2.1 The SWCT Planning Studies

The proposed Project is the product of more than a decade of planning studies regarding the SWCT region. Studies that were conducted over 15 years ago led to the construction of major projects approved by the Council in Docket 217 (Bethel to Norwalk 345-kV line), Docket 272 (Middletown – Norwalk 345-kV line), and Docket 292 (Glenbrook – Norwalk cables). These projects not only created a 345-kV transmission "loop" that provided 345-kV backbone service to the region (thereby increasing the import capacity of the SWCT and Norwalk-Stamford interfaces), but also addressed numerous criteria violations in SWCT as a whole and in the Norwalk-Stamford sub-area identified in the planning studies.

During the course of those studies, transmission planners noted that several 115-kV lines within SWCT were near or above their thermal loading limits, that some 115-kV substations in the SWCT area had low voltage issues, and that these issues would not be fully resolved by construction of the 345-kV loop. At that time, transmission planners determined that the region's 345-kV projects would move forward, and that follow-up studies would be performed to identify and then correct any local criteria violations in SWCT. In its 2005 *Findings of Fact* supporting the issuance of a Certificate of Environmental Compatibility and Public Need for the Middletown-Norwalk Project, the Council found that more than 20 thermal overloads identified in the planning studies would remain after completion of that 345-kV loop, and noted that "[t]hese remaining overloads would be addressed locally through substation or transmission line upgrades" to be constructed in the future. (Docket No. 272, Findings of Fact, Finding #65, pp. 7-8). In short, transmission planners determined more than a decade ago that the region should move forward with the completion of the 345-kV loop feeding SWCT, but recognized that a follow-up needs assessment and solutions study would be needed in the future to address the local criteria violations remaining in SWCT after the 345-kV loop was completed. The SWCT Reliability Project is one result of these follow-up studies.

In 2012, ISO-NE formed a Working Group consisting of transmission planners from ISO-NE, Northeast Utilities Service Company (now Eversource Energy Service Company), and The United Illuminating Company to prepare a "10-year look ahead" evaluating the reliability of the transmission system serving the SWCT study area for the projected system conditions in 2022. The Working Group divided the SWCT study area into the following sub-areas, extending from Southington, Connecticut south to Long Island Sound and west to the New York state border:

- Housatonic Valley sub-area;
- Frost Bridge-Naugatuck Valley sub-area;
- Bridgeport sub-area;
- New Haven-Southington sub-area; and
- Glenbrook-Stamford sub-area.[11]

The objective of the SWCT planning study was to assess the reliability performance of the system and to identify reliability-based transmission needs in SWCT, based upon:

- Anticipated future load growth;
- Reliability over a range of generation patterns and transfer levels;
- Assessment of system compliance with all applicable NERC, NPCC, and ISO-NE transmission planning reliability standards;
- Regional and local reliability issues;
- Existing and planned supply and demand resources; and,
- Limited short circuit margin concerns in the SWCT study area.

The SWCT planning study considered potential interdependencies in the load serving needs and potential solutions for all of the SWCT sub-areas. For purposes of its study, the SWCT Working Group combined the Housatonic Valley sub-area and the Frost Bridge-Naugatuck Valley sub-area together to evaluate possible interactions between these sub-areas, and the Working Group considered both "local" and "global"

[11] The Working Group determined that no improvements were needed in the Glenbrook-Stamford sub-area.

solutions to the reliability issues in these two areas. The two "local solutions" that were developed and evaluated were designed to solve the violation in each individual load pocket separately, while the two potential "global solutions" considered for the Housatonic Valley sub-area and the Frost Bridge-Naugatuck Valley sub-area would provide an additional link to both sub-areas that would be mutually beneficial. The Working Group ultimately determined that the optimal solutions for these two sub-areas were "local" solutions that addressed the reliability needs in each sub-area separately. After multiple presentations to ISO-NE's Planning Advisory Committee (PAC) [12], ISO-NE published a final *SWCT Connecticut Area Transmission 2022 Needs Assessment* in June, 2014 (the "*SWCT Needs Report*").[13] Because the study scope and assumptions were determined in 2012, the study considered system needs in the study year of 2022, consistent with ISO-NE's 10-year planning horizon. In early 2015, ISO-NE published a report identifying preferred solutions for the needs of the entire SWCT study area (the *SWCT Solutions Report,*[14]*)*, including for the Housatonic Valley sub-area. After further studies, and a positive recommendation by its Reliability Committee, on April 16, 2015, ISO-NE issued a technical approval of the preferred SWCT solutions for all four sub-areas.

2.2.2 The Housatonic Valley Sub-area

The Housatonic Valley sub-area extends from Carmel Hill Substation in the Town of Woodbury west to Bulls Bridge Substation in the Town of New Milford, and south to Plumtree Substation in the Town of Bethel and Norwalk Substation in the City of Norwalk.[15] Figure 2-2 is a "one-line" map of the sub-area:

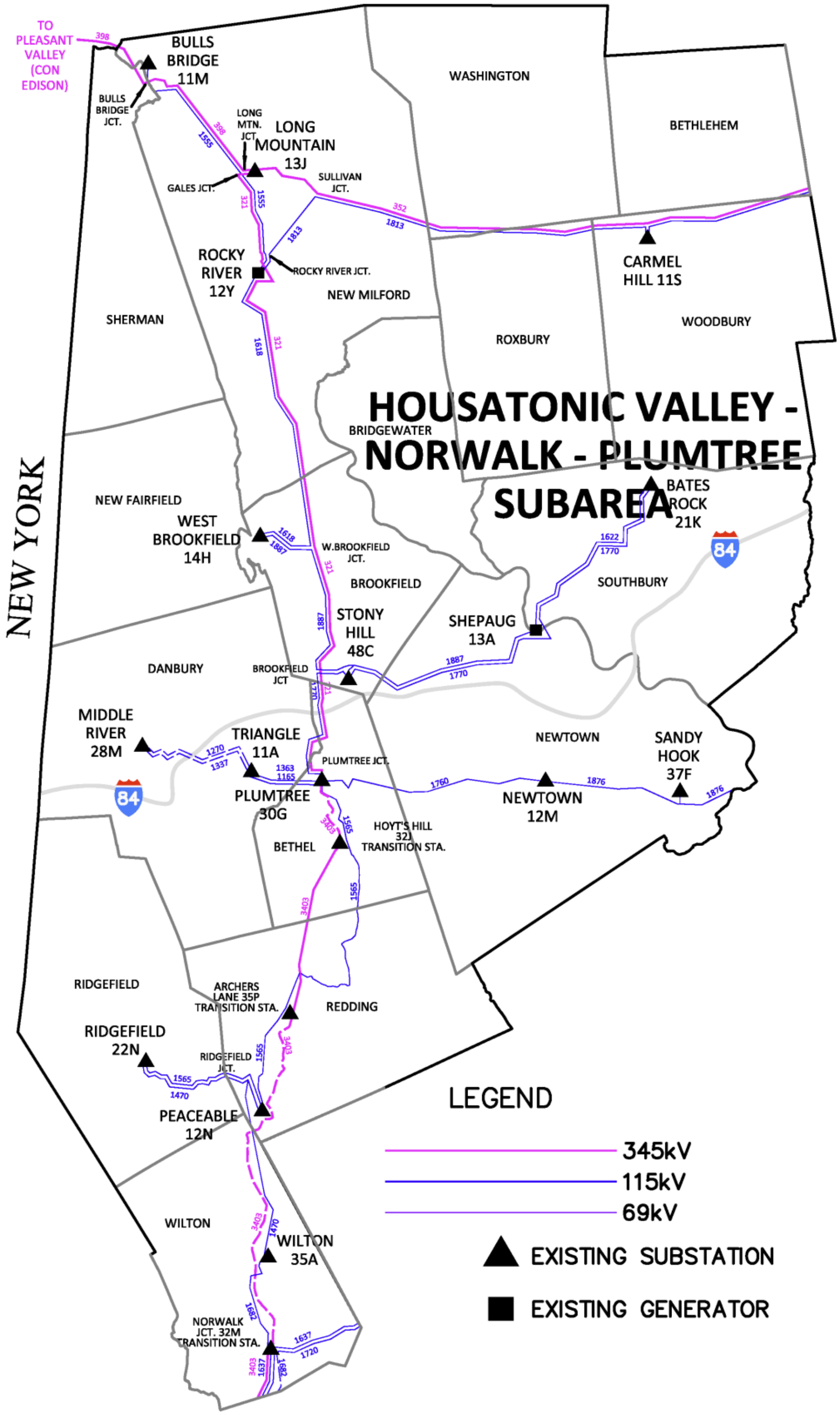
[12] The ISO-NE PAC is an advisory committee open to all parties interested in regional system planning activities in New England. ISO-NE is required by its FERC-approved tariff to conduct an open and transparent planning process. Pursuant to this requirement, ISO-NE presents to the PAC the scope of work, assumptions, and draft results for its annual Regional System Plan and for supporting studies, including Needs Assessments and Solution Studies, and considers the comments of the PAC members in developing its final plans and recommendations.

[13] A copy of this document, redacted to delete Critical Energy Infrastructure Information (CEII) that Eversource is required to keep confidential, is provided as part of Volume 4 of this MCF. A complete copy will be filed with the Council pursuant to its CEII filing procedure after Eversource files its application for the Project, and will be made available to qualified participants in the proceeding.

[14] A copy of this document, redacted to delete Critical Energy Infrastructure Information (CEII) that Eversource is required to keep confidential, is provided as part of Volume 4 of this MCF. A complete copy will be filed with the Council pursuant to its CEII filing procedure after Eversource files its application for the Project, and will be made available to qualified participants in the proceeding.

[15] The following municipalities are located in the Housatonic Valley-Norwalk-Plumtree sub-area: Bethel, Danbury, Brookfield, Wilton, Redding, Ridgefield, Newtown, Southbury, Bridgewater, New Fairfield, Sherman, New Milford, Roxbury, Woodbury, Washington, and Bethlehem.

Figure 2-2: Housatonic Valley Sub-area



The Housatonic Valley sub-area net load for 2022, after demand resources are subtracted, is about 860 MW. The Housatonic Valley sub-area has four generation facilities, consisting of three hydro-electric facilities (at Rocky River, Bull's Bridge, and Shepaug) and the Kimberly Clark facility. The available generation totals approximately 28.8 MW, with Rocky River and Shepaug modeled at OOS based on their historical performance, Bull's Bridge modeled at 0.8 MW (10% of its nameplate rating), and Kimberly Clark at 28 MW.

These generation resources are far from adequate to serve the sub-area's electric demands. Thus, the Housatonic Valley sub-area relies on net imports of energy to serve local load. The major transmission elements that presently deliver power into the sub-area are:

- Two Plumtree 345/115 kV autotransformers (Plumtree 1X and 2X);
- One 115-kV line from Norwalk to Wilton (Line 1682);
- One 115-kV line from the Stevenson generation facility to Sandy Hook to Newtown (Line 1876); and,
- One 115-kV line from Frost Bridge (Watertown) to Carmel Hill (Line 1238).

2.2.3 The Need for Transmission Improvements in the Housatonic Valley Sub-area

The SWCT planning study showed that there were criteria violations in the Housatonic Valley sub-area "load pocket". A load pocket is an area that has insufficient generation and transmission to serve its load. The electric system in the Housatonic Valley load pocket is subject to thermal overloads and voltage violations when the system attempts to serve peak load under many contingent conditions.

All of the criteria violations for the Housatonic Valley sub-area were related to serving load within the pocket, as opposed to power transferring through the sub-area to serve another part of the system. The SWCT planning study indicated that, when contingencies removed one or more transmission supplies to the load pocket, the remaining transmission connections and local generation in this sub-area were insufficient to serve the load, causing thermal overloads and severe low voltage conditions.

2.2.3.1 Power-Flow Modeling Assumptions

The assumptions built into the power-flow modeling are set forth in detail in the *SWCT Needs Report* (refer to Volume 4). In summary, the power flow study cases were derived from the ISO-NE model representing the New England electric system, with selected upgrades to reflect relevant system conditions in 2022. All transmission projects with ISO-NE's Proposed Plan Application approvals as of the October 2012 *Regional System Plan Project* listing were included in the base case. These projects included the three New England East-West Solution (NEEWS) 345-kV projects - the Greater Springfield Reliability Project (GSRP), the Rhode Island Reliability Project (RIRP) and the Interstate Reliability Project (Interstate). The Central Connecticut Reliability Project, another originally planned NEEWS project, was not included in the case, because the need for it was being reassessed.

Existing generation plants and new projects expected to be in-service during the study years (because they have accepted a Forward Capacity Market [FCM] Capacity Supply Obligation) were included in the study base case. All existing and proposed units that accepted a supply obligation in ISO-NE's Forward Capacity Auction #7 (FCA 7) were included. FCA 7 was held in February 2013, and resulted in the purchase of resources to meet forecasted demand in 2016 – 2017. Certain generation units that were expected to retire imminently were assumed to be out of service (OOS). (Units assumed out of service were Bridgeport Harbor 2, AES Thames, Norwalk 1, 2 and 10, and John Street 3, 4, and 5). The proposed Towantic Generating Station in the Town of Oxford was not included in the study because it was not entered in FCA 7. ISO-NE is currently conducting a supplemental analysis regarding the impact of the construction of Towantic Generating Station.

In accordance with ISO-NE planning procedures, the modeled load was based on the 90/10 weather forecast for 2022 in ISO's 2013 CELT load forecast.[16] The forecast 2022 summer peak 90/10 for New England was 34,105 MW. This load, adjusted to take system losses into account, was distributed across New England based on 2013 load distribution data. The forecast Connecticut load was 8,825 MW, and the net load for the Housatonic Valley sub-area, after demand resources are subtracted, was estimated at approximately 860 MW. Area loads were then adjusted downwards to reflect the effect of passive and active demand response measures committed to in FCA 7 and predicted future energy efficiency measures that were expected to be implemented by 2022, based on the 2013 CELT forecast. Transfers of power into and out New England were modeled in accordance with applicable reliability criteria and standard practice.

[16] The 90/10 forecast of peak demand is used by ISO-NE for utility infrastructure planning. "The 90/10 forecast is a plausible worst-case hot weather scenario. It means there is only a 10 percent chance that the projected peak load would be exceeded in a given year, while the odds are 90 percent that it would not be exceeded in a given year. Put another way, the forecast would be exceeded, on average, only once every ten years. While this projection is extremely conservative, it is reasonable for facility planning because of the potentially severe disruptive consequences of inadequate facilities: brownouts, blackouts, damage to equipment and other failures. State utility planners must be conservative in estimating risk because they cannot afford the alternative." Connecticut Siting Council, *Review of the Ten Year Forecast of Connecticut Electric Loads and Resources*, 2008 – 2017, at 6.

Eleven generator dispatch scenarios were identified and assessed. The dispatches were set up by taking one or two critical units OOS. ISO – NE planning practice requires an assumption that approximately 20% of fast start generation will be OOS. The Connecticut fast-start units were dispatched such that approximately 80% of the fast-start capability in Connecticut was online. At all locations in the study area where a single fast-start unit was available, that unit was assumed to be OOS. For sub-areas in which multiple fast-start units are located, one of the fast-start units was assumed to be OOS and the rest were assumed online and available.[17]

The Rocky River and Shepaug units were modeled at OOS based on their historical performance, whereas Bull's Bridge was modeled at 0.8 MW (10% of its nameplate rating) and Kimberly Clark was modeled at 28 MW. In accordance with ISO-NE Planning Procedure #3, the output of generation in the SWCT study area and its vicinity was reduced following a first contingency if the re-dispatch would position the system so that a second contingency would not result in a violation.

2.2.3.2 Power-Flow Modeling Results for the Housatonic Valley Sub-area: Thermal and Voltage Criteria Violations

The planning study showed many thermal criteria and voltage criteria violations in the Housatonic Valley sub-area for N-1 and N-1-1 contingency events. The detailed results are provided in the *SWCT Needs Report* (refer to Volume 4). In particular, as identified in the planning studies, the Housatonic Valley sub-area had three transmission elements with N-1 thermal violations and six 115-kV buses with N-1 low-voltage violations, as well as two non-Pool Transmission Facility (PTF) buses with N-1 low-voltage violations. Under N-1-1 conditions, there were eight elements with thermal violations, twelve 115-kV PTF buses with low-voltage violations, and four non-PTF buses with low-voltage violations. There were no N-0 violations. The contingencies that lead to the criteria violations are typically loss of import paths into the sub-area; the worst case violations, under various dispatches, arise after the loss of the transmission path that connects Plumtree Substation to Stony Hill Substation.

Although the study year modelled in the *SWCT Needs Report* was 2022, the study showed that the improvements required to meet the identified needs should be constructed as soon as possible. ISO-NE calculates a "year of need" for system improvements by estimating when the "critical load level" (CLL) for

[17] For the steady-state portion of Transmission Needs Assessments and Solutions Studies at peak load, the fast start units can be simulated as "on" in the base case and left on when the first contingency occurs. The effect of the second contingency will then be the same as if the fast starts had been initially modeled as "off" and were then turned on after the first contingency. This technique is used for the sake of modeling efficiency.

which improvements are needed will be reached. The CLL is the demand level at which criteria violations begin to occur. Above this load level, the system needs to be expanded to continue to reliably support the demand. The *SWCT Needs Report* found that the year of need for the Housatonic Valley improvements was 2013, because the Connecticut net load forecast for 2013 was 7,776 MW,[18] whereas thermal violations began to occur at a 4,163 MW net load and low voltage violations began to occur at a 5,218 MW net load.

2.3 THE PROPOSED SOLUTION FOR THE HOUSATONIC VALLEY SUB-AREA NEEDS

2.3.1 Introduction

The *SWCT Solutions Report* identified preferred solutions for the load serving problems documented in the *SWCT Needs Report* in each of the four load-serving sub-areas included in the study. In addition to the solutions defined for the Housatonic Valley sub-area, the *SWCT Solutions Report* recommended improvements in each of the other three SWCT sub-areas studied (specifically, the Frost Bridge-Naugatuck Valley sub-area; New Haven-Southington sub-area; and Bridgeport sub-area). However, the proposed solutions in these other SWCT sub-areas are not interdependent with those of the Housatonic Valley sub-area. The reliability issues in these other SWCT sub-areas will be addressed independently in other projects to be proposed by Eversource and The United Illuminating Company in the future.

The SWCT Working Group ultimately determined that the optimal solution for the reliability issues in the Housatonic Valley sub-area was a "local" solution – referred to as "Local 2" in the *SWCT Solutions Report*.[19] The components of the "Local 2" solution in the Housatonic Valley sub-area were designed by the Working Group to address all thermal and voltage issues in the sub-area. The key components of this solution are the new 115-kV line between Plumtree Substation and Brookfield Junction, coupled with the reconfiguration of the 1887 Line and the 1770 Line, which will provide a new 115-kV source into the Housatonic Valley sub-area.

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18 The actual 2013 peak net load for Connecticut that actually occurred was 7,128 MW. Although lower than the predicted load, it was also well in excess of the CLL.

19 The components of the "Local 2" solution described in the *SWCT Solutions Report* included solutions for the reliability issues in both the Housatonic Valley sub-area and the Frost Bridge- Naugatuck Valley sub-area. However, the solution components in each of the sub-areas are not interdependent, and were designed to be implemented independently to address all criteria violations in each particular sub-area.

Eversource is already in the process of implementing other reliability upgrades in the Housatonic Valley sub-area, as referenced in the *SWCT Solutions Report*. These upgrades address system reliability needs that are independent from those addressed by this Project, and therefore they are being implemented separately.[20] The completion of the SWCT Reliability Project in December 2018 will be the "last piece of the puzzle" that will resolve all the thermal and voltage issues in the Housatonic Valley sub-area identified in the *SWCT Needs Report*.

2.3.2 Provision of a New 115-kV Source within the Housatonic Valley Sub-area

The major element of the solution recommended for the Housatonic Valley sub-area by the SWCT Working Group is the addition of a new 3.4 mile 115-kV line from Plumtree Substation in Bethel to Brookfield Junction in Brookfield. This new 115-kV line, together with the reconfiguration of the 1887 Line and the 1770 Line, will bring a new 115-kV source into the load pocket within the Housatonic Valley sub-area, which would be available to serve customers in the load pocket, including those in municipalities of Bethel, Danbury, and Brookfield.

The new 115-kV line will represent an extension of the 1887 Line, such that when this Project is completed, the 1887 Line will be a three-terminal line connecting Plumtree Substation, West Brookfield Substation, and Shepaug Substation. The addition of this new line into the sub-area provides an additional system element to share load that is automatically redistributed upon the failure of other system elements, and provides a source to help maintain continuity of supply to the load from external sources in such an event. The "pre-Project" configuration of the 115-kV lines connecting Plumtree Substation, Stony Hill Substation, and West Brookfield Substation is illustrated in Figure 2-3. Following construction of the new 115-kV line (i.e., the extension of the 1887 Line) from Plumtree Substation to Brookfield Junction and the reconfiguration of the existing 1887 Line and 1770 Line between Plumtree Substation, Stony Hill Substation, and West Brookfield Substation, there will be a new 115-kV source within the sub-area, as shown in Figure 2-4.

[20] The system improvements for the Housatonic Valley sub-area that are being implemented independently from this SWCT Project include the following improvements identified in the *SWCT Solutions Report*: (i) installing a synchronous condenser at Stony Hill Substation; (ii) reconductoring the 1887 Line between West Brookfield Substation and West Brookfield Junction, both of which are located in Brookfield; (iii) installing two 14.4 MVAR capacitor banks at West Brookfield Substation; (iv) relocating the 22K 115-kV capacitor bank at Stony Hill Substation; (v) rebuilding a portion of the 1682 Line between Wilton Substation in Wilton and Norwalk Substation in Norwalk; (vi) reconductoring the 1470-1 Line from Wilton Substation to Ridgefield Junction in Redding; and (vii) reconductoring the 1470-3 Line from Peaceable Substation in Redding to Ridgefield Junction. These improvements are the subject of siting petitions and exempt modifications to be filed with the Council prior to the filing of the Application for the SWCT Reliability Project, and these improvements will be completed prior to the in-service date of the Project.

Figure 2-3: "Pre-Project" Configuration of the 1887 and 1770 Lines

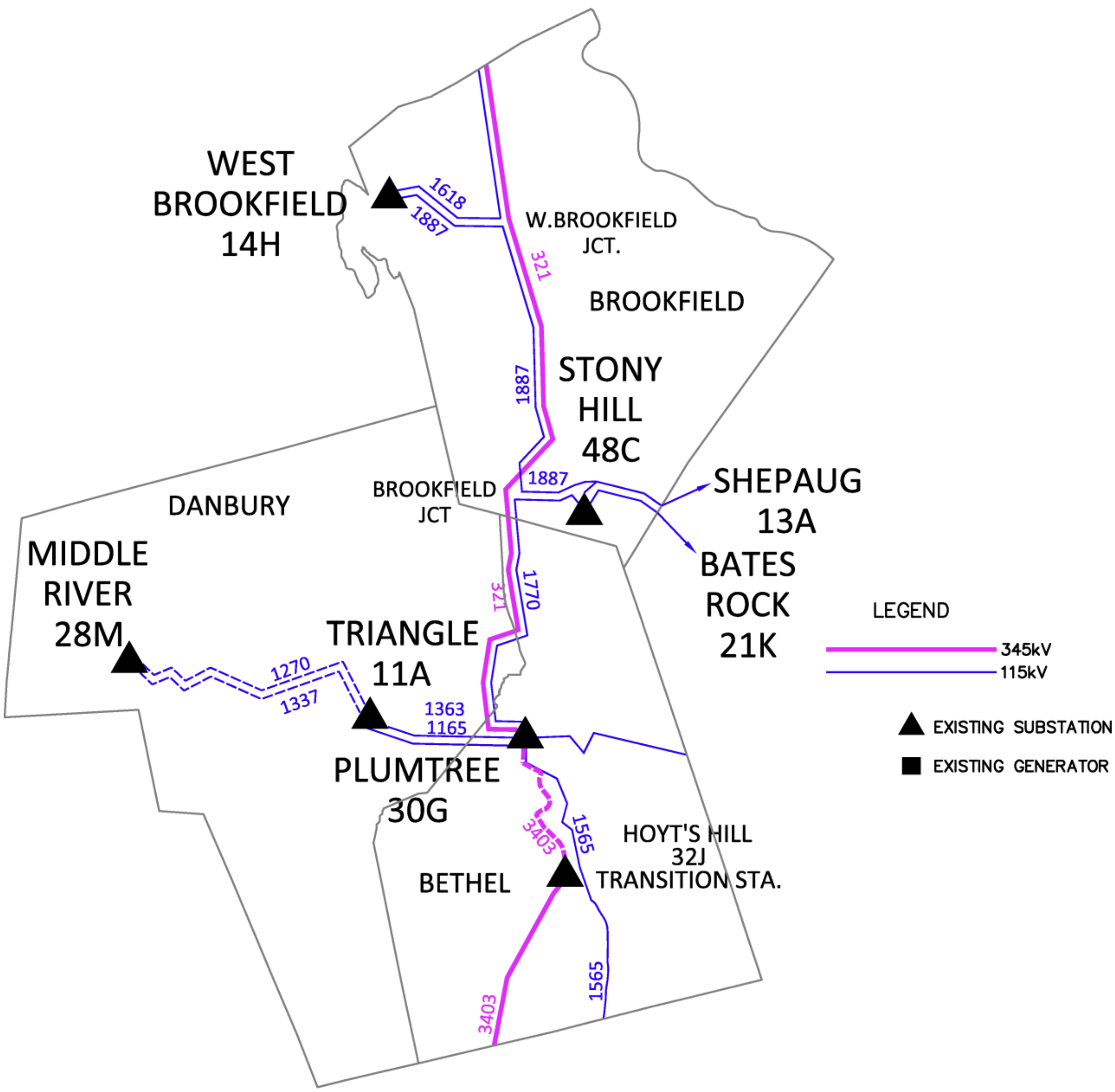
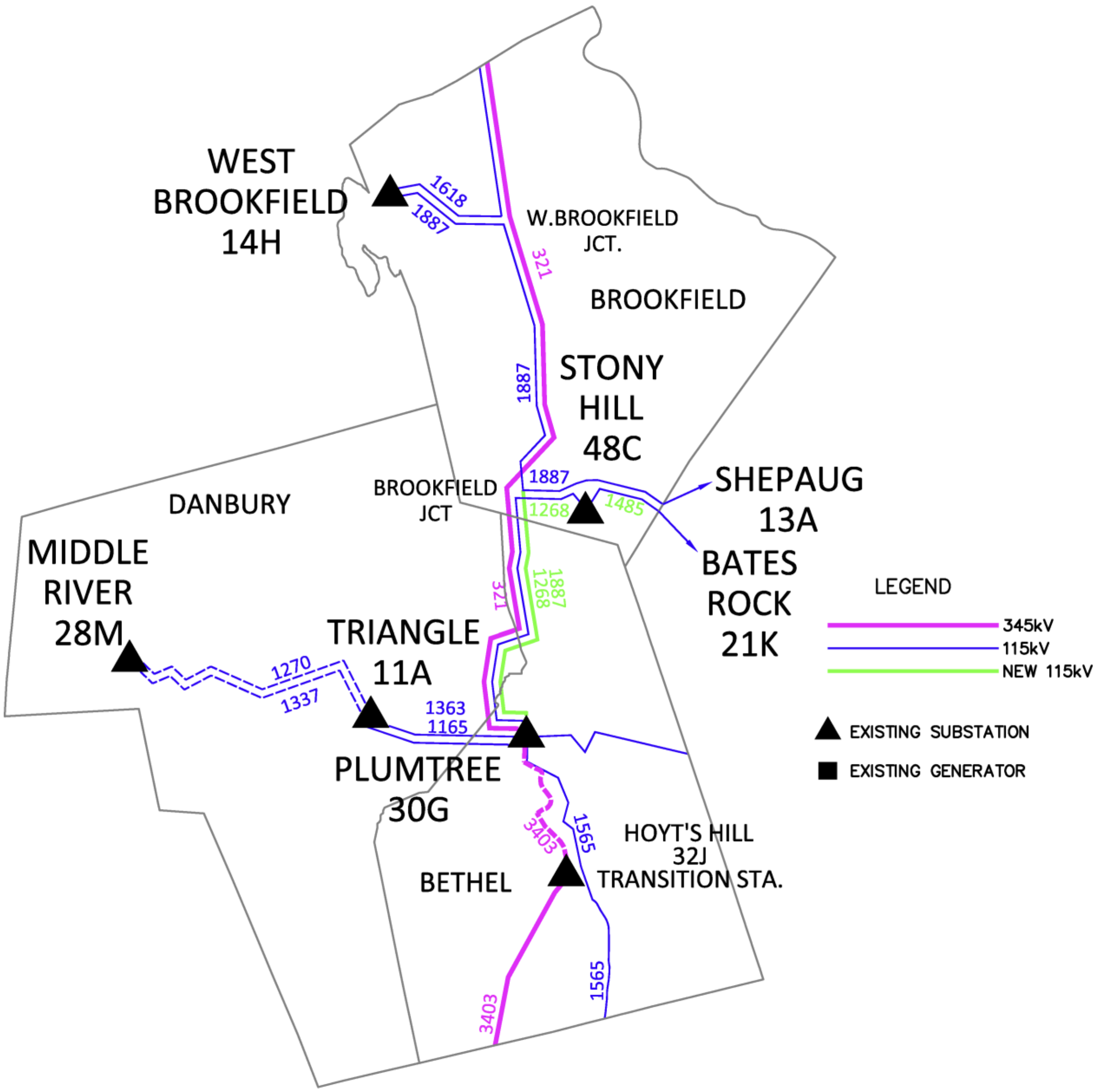


Figure 2-4: "Post-Project" Configuration of the 1887 and 1770[21] Lines



21 The 1485 and 1268 lines, shown as "new" 115-kV lines, represent the planned re-numbering of the existing 1770 Line.

2.3.3 Other Proposed Reliability Improvements: Reconfiguration of Stony Hill Capacitor Bank Bus Connections

In addition to the construction of the new 115-kV line and the reconfiguration of certain existing 115-kV lines as described above, a capacitor bank at Stony Hill Substation will be reconfigured to address the reliability needs identified by the SWCT Working Group. Capacitors are installed in substations to support voltage, among other things. Several capacitor cans are combined into a "bank," the capacity of which is measured in mega VARs (MVAR).

There are currently three capacitor banks in Stony Hill Substation, two rated at 37.8 MVAR and one rated at 25.2 MVAR. The two 37.8 MVAR capacitor banks are connected to the "A1" 115-kV bus, while the 25.2 MVAR capacitor bank is connected to the "A2" 115-kV bus. The SWCT studies showed that there are contingencies that would result in the loss of the two 37.8 MVAR capacitor banks, which would cause low voltage violations at various substations, including Carmel Hill, Bulls Bridge, Rocky River, West Brookfield, Shepaug, Bates Rock, and Stony Hill. Reconfiguring one of Stony Hill Substation's 37.8 MVAR capacitor banks to the same side as the 25.2 MVAR capacitor bank will improve the post-contingent voltage in the area.

2.3.4 Conformance to Long-Range Plan for Expansion of Electric Power Serving the State and Interconnected Utility Systems

Federal Energy Regulatory Commission (FERC) has charged ISO-NE with the responsibility for conducting long-term transmission system planning for New England. To discharge that responsibility, ISO-NE continually assesses the needs of the entire New England bulk power system, through the preparation of annual Regional System Plans and long term studies. As explained in Section 2.2.1, the proposed Project is an outgrowth of the planning studies that led to the the completion of the major projects considered by the Council in its Docket 217 (Bethel to Norwalk 345-kV line); Docket 272 (Middletown – Norwalk 345-kv line); and Docket 292 (Glenbrook – Norwalk 115-kV cables). The studies identified – and the Council – specifically noted the existence of local reliability issues that would remain even after the completion of a 345-kV loop serving SWCT.

Ultimately, the load serving needs of all the sub-areas of SWCT (Housatonic Valley; Frost Bridge-Naugatuck Valley; Bridgeport; New Haven-Southington; and Glenbrook-Stamford) were examined together in the SWCT Needs Analysis. The grouping of these needs into a single study was to assure that co-ordinated and cost efficient solutions to the identified needs in SWCT would be developed.

In parallel, ISO-NE also examined transmission needs in the Greater Hartford area remaining after the completion of the NEEWS projects considered by the Council in its Docket No. 370 (GSRP) and Docket No. 424 (Interstate Reliability Project). The SWCT and Greater Hartford studies were coordinated so as to avoid redundant solutions. Together, the SWCT and Greater Hartford Central Connecticut studies identify coordinated solutions for Connecticut's transmission system that will comply with applicable reliability requirements through 2022, and that form a part of the ISO-NE Regional System Plan for all of New England.

2.3.5 Identification of Facility in the Forecast of Loads and Resources

Pursuant to Section 16-50r(a) of the Connecticut General Statutes (CGS) concerning forecasts of electric loads and resources, Transmission Owners are required to file with the Council periodic reports that include, among other items, a list of planned transmission lines on which proposed route reviews are being undertaken or for which certificate applications have already been filed, and a decription of the steps taken to upgrade existing facilities. In its 2016 *Forecast of Loads and Resources* dated March 1, 2016, Eversource notified the Council of the completion of the *SWCT Needs Report* and the *SWCT Solution Report*, and provided information regarding the SWCT Projects to the Council, including the projects designed to address reliability issues in the Housatonic Valley sub-area.

2.4 CONCLUSION

The Project is the result of more than a decade of careful evaluation and analysis by system planners charged with the duty of addressing the reliability needs of the transmission system serving SWCT. The Project would resolve violations of thermal and voltage reliability criteria in the Housatonic Valley sub-area identified in the planning studies, and would ensure that Eversource meets its obligation to maintain the reliability of the transmission system in accordance with mandatory federal and regional standards and criteria.

3. TECHNICAL PROJECT SPECIFICATIONS

This section describes the technical specifications for the Project, including:

- The new 3.4-mile 115-kV overhead electric transmission line (i.e., the extension of the 1887 Line) along the Proposed Route between Plumtree Substation and Brookfield Junction.
- Modifications to the Stony Hill Substation and reconfiguration of the existing 1770 and 1887 lines that presently connect to the substation.

The technical information provided for the Project includes:

- Conductor size and specifications;
- Overhead structure design, appearance, and height;
- Route length, by municipality, and terminal points;
- Initial and design voltages and capacities;
- ROW and proposed on- and off-ROW access roads;
- Proposed structure location envelopes (i.e., as needed for structure installation, conductor/ Optical Ground Wire [OPGW] pulling, guard structures);
- Proposed structure locations;
- Substation connections and proposed modifications; and
- Estimated capital (construction) and life-cycle costs.

3.1 PROPOSED TRANSMISSION LINE FACILITIES

The proposed overhead 115-kV transmission line, designated as the 1887 Line, would extend for approximately 3.4 miles, and would be aligned adjacent to other existing 115-kV and/or 345-kV transmission lines, as summarized in Table 3-1. The new 115-kV line would be located such that sufficient space exists between the proposed and existing lines for safe and reliable line operations.

The 3.4-mile Proposed Route for the new transmission line would be located entirely within an existing Eversource ROW that ranges in width from approximately 175 to 225 feet.

Table 3-1: Existing Transmission Lines Sharing ROWs with the Proposed 115-kV Transmission Line

Existing Transmission Line Number	Line Location Description	Line Voltage / Structure Type
321	Long Mountain Substation to Plumtree Substation	345 kV (Lattice Tower/Steel Monopole)
1770	Plumtree Substation to Stony Hill Substation to Bates Rock Substation	115 kV (Lattice Tower/Steel Monopole)
1363*	Triangle Substation to Plumtree Substation	115 kV (Steel Monopole)
1165*	Triangle Substation to Plumtree Substation	115 kV (Steel Monopole)

* The 1363 and 1165 lines occupy the same ROW as the 321 and 1770 lines for only 0.25 mile, extending west from Plumtree Substation. The 1363 and 1165 lines continue west toward Triangle Substation (located in the City of Danbury), whereas the ROW occupied by the 321/1770 lines diverges north to Brookfield Junction.

3.1.1 115-kV Conductor Size and Specifications

The new overhead 115-kV transmission line would consist of three sets of phase conductors. Each set is comprised of one 1,590,000 circular mil (1,590-kcmil) Aluminum Conductor Steel Supported (ACSS). This selection is a standard Eversource conductor utilized for new 115-kV line construction.

The new line would be protected by one overhead lightning shield wire. The overhead shield wire would also contain optical glass fibers for communication purposes (also referred to as Optical Ground Wire or "OPGW").

3.1.2 Proposed Line Overhead Design, Appearance, and Heights

New 115-kV Transmission Line

The new 3.4-mile 115-kV transmission line would be located entirely within an existing Eversource ROW. The entire 3.4-mile ROW is occupied by an existing 115-kV transmission line (i.e., the 1770 Line) and a 345-kV transmission line (i.e., the 321 Line). In addition, for approximately 0.25 mile heading west from the Plumtree Substation exit, the ROW is occupied by two other 115-kV lines (i.e., the 1363 Line and 1165 Line; refer to Table 3-1) that extend to Triangle Substation.

The existing 115-kV 1770 Line and 345-kV 321 Line are supported primarily on double circuit steel monopole structures with a typical height of approximately 150 feet, with the exception of immediately near Plumtree Substation, where steel lattice towers are used. The 115-kV 1165 Line and 1363 Line, which occupy the ROW for the first 0.2 mile west from Plumtree Substation, are supported on single circuit steel monopole structures. These 115-kV structures have a typical height of approximately 85 feet.

As illustrated on the maps located in Volume 5, most of the new transmission line structures would generally be placed near or adjacent to existing line structures. However, in certain locations, new structure sites were shifted longitudinally to avoid sensitive environmental or cultural areas, to address constructability and design issues, or to minimize potential impacts to property owners.

Along the majority of the 3.4-mile Proposed Route, the new 115-kV transmission line would be installed on weathering steel monopoles. The proposed structure design and configuration for the new 115-kV line would be a combination of direct-buried and self-supported tubular steel monopoles in a vertical configuration, with a typical height of approximately 95-135 feet. Self-supported vertical tubular steel monopoles would be used at angle points and as deadend structures. Along the 0.1-mile segment of the Proposed Route where the new 115-kV line would connect to Plumtree Substation, the new 115-kV transmission line would be on four self-supported three-pole structures. This structure design and configuration is required to accommodate multiple angles in the Proposed Route around the outside of the substation and to better allow crossings of other transmission lines (1363, 1770, and 321 lines) that also interconnect to the substation.

Cross-sections drawings depicting the typically proposed structure types and general location in relation to the existing structures along each ROW segment are included in Appendix 3A, located at the end of this section.[22] Although the cross-sections illustrate the typical proposed structures, in certain locations along each ROW segment (such as at turns [angles] in the ROW), structures of the same type (e.g., monopole), but with slightly different appearance would be used. Appendix 3B (also found at the end of this section) provides illustrations of the family of structure types that Eversource uses in steel-pole lines with horizontal or vertical conductor configurations.

[22] These cross-sections are also included in Volume 5.

3.1.3 Design Voltage and Capacity

The single 1,590-kcmil ACSS conductors would provide approximately 401 megavolt amperes (MVA) of summer normal line capacity and a summer long-term emergency (LTE) capacity of 525 MVA at 115 kV.

3.1.4 Proposed Structure Locations

Along the overhead line route, the preliminary location for each of the proposed transmission line structures was determined using transmission line design software (Power Line System's "PLS-CADD"™). The proposed structure locations are shown on the Plan and Profile Drawings in Volume 5, as well as on the 400 scale and 100 scale maps in Volume 5.

As a starting point in the Project design process, all proposed new 115-kV line structures were initially aligned adjacent to existing structures. This design approach was based on the assumptions that alignment of the new structures adjacent to the existing structures would maximize the use of existing on-ROW access roads (which are already situated to reach most existing structures), minimize changes to the visual environment, and mimic existing span lengths to minimize potential clearance violations under certain high-wind conditions. Based on these analyses, Eversource determined that 14 of the 28 new 115-kV structure locations, as determined by the initial structure siting (i.e., placement of new structures adjacent to existing structures) would be in wetlands.

Following this preliminary structure siting, each proposed structure location was further evaluated to account for other factors, such as potential environmental effects. Based on the constructability studies that have been performed thus far, three of the 14 structures initially proposed for location in wetlands were shifted to upland locations. The remaining 11 structures must unavoidably be located in wetlands that extend for long distances along and adjacent to the ROW and thus cannot be avoided completely.

Structure locations may further change as the Project design process continues. Future changes could occur based on information obtained from more detailed field studies (e.g., subsurface investigations, final engineering and environmental surveys, constructability reviews), as well as input from municipalities, the Council, and other regulatory agencies. After this additional information has been evaluated, final detailed line engineering would be performed to determine the exact locations of the new structures. Typically, the final structure locations are expected to be within 100 feet (longitudinally along the line) of the proposed structure locations, as depicted on the Volume 5, 100 scale maps.

3.1.5 ROW and Access Road Requirements

ROW Requirements and Easement Acquisition

Eversource proposes to construct and operate the new 115-kV transmission line along its existing ROW without the need for any additional easement acquisition. The typical easement widths along different segments of the existing transmission line ROW are summarized in Table 3-2 (located at the end of Section 3.1) and shown on the cross-section drawings (refer to Appendix 3A at the end of this section and to the Volume 5 maps).

As part of the Project design process, Eversource reviewed the existing easement rights and restrictions for its existing ROW along the entire Proposed Route. Eversource has sufficient rights within existing easement agreements to construct the Project. New easements may be required for off-ROW access roads.

Access Road Requirements

Various access roads are already established along and within the Eversource ROW ("on-ROW access roads"), where existing transmission lines have been operated and maintained for almost 40 years. To construct, operate, and maintain the new overhead 115-kV transmission line along the Proposed Route, contiguous access along the ROW is not required and these existing access roads would be used to the extent practical.

However, access to each new transmission structure location, as well as to pulling pads and guard structure sites, would be required. As a result, additional temporary and permanent access roads must be established and most of the existing on-ROW access roads would require improvements to allow the safe movement of the heavy construction equipment needed to install the new 115-kV line.

In addition, other temporary access along the ROW may be required to facilitate vegetation removal during construction. Refer to Section 4.1.4.2 for further information regarding temporary access for vegetation removal.

Further, in some areas, to avoid traversing linearly along the ROW over rugged terrain or through sensitive environmental or cultural resources, access roads to the ROW would be developed or improved across private property or across land owned by Eversource ("off-ROW access roads").

The locations and type of new access roads and access road improvements would depend on the terrain, presence / absence of environmental features, and whether the access road would be temporary (used only during construction) or permanent (retained for long-term maintenance of the line). Access roads must have appropriate grades and sufficient width and capacity to support the large, heavy construction equipment (such as flat-bed tractor-trailers, drilling rigs, cranes, and concrete trucks) required to construct the new 115-kV line. The need for access by flat-bed trailers and concrete trucks (including turning radii) typically determines the scope of access road improvements.

In general, all construction access roads (on- or off-ROW) must have a stable base and grades of 10% or less. Whether restored, improved, or newly constructed for the Project, on- and off-ROW access roads would have a typical 16-to-20-foot-wide travel way and, overall, a 20-to-25-foot-wide footprint (including road shoulders). However, access road widths would vary depending on site-specific conditions (principally slope and presence of water resources) and on factors such as the amount of grading (cutting and filling) required and on whether a particular section of road must accommodate equipment turning radii and/or equipment passing/turn-out locations.

Access roads would be graveled or would consist of temporary construction (timber) mats or equivalent. In general, gravel would most commonly be used in constructing access roads in upland areas. In some locations, particularly on steep slopes and at intersections with public roads, asphalt millings could be used to improve road stability and vehicle traction.

Across wetlands where only temporary (construction) access is required, timber mats would typically be used. These mats would be removed upon the completion of construction. Where permanent access is unavoidably required across wetlands, road construction would be more extensive and would involve the use of gravel. To maintain drainage patterns across the ROW, access road construction would typically incorporate construction mat (or equivalent) bridges, flumes, or culverts as needed. Refer to Section 4.2.1 for additional information regarding water resource crossings, including permanent access roads in wetlands.

New access roads would have to be constructed to reach certain proposed structure locations where sufficient access does not currently exist. However, permanent access roads would typically not be developed through long expanses of wetlands with deep standing water or unstable soils, or in locations where consecutive line structures are separated by long distances. In such areas, off-ROW access roads that provide ingress and egress to work sites on the ROW may be required to facilitate construction or to avoid crossings of sensitive environmental resources, such as rivers or large wetland complexes.

As part of the Project planning, Eversource evaluated the existing public roads leading to or intersecting with the transmission line ROW. Based on that review, an inventory of public roads that could provide access to the ROW was prepared. Table 4-2 in Section 4 identifies the public roads, or sites, that potentially could be used for access to the transmission line ROW. The Volume 5 maps illustrate locations of these roads with respect to the Proposed Route.

Eversource would conduct a detailed evaluation of the access requirements for the Project as part of final design. Access road information would be included in the Project-specific *Development and Management (D&M) Plans*, which would be required as a condition of the Council's approval.

3.1.6 Facilities on ROW Post-Construction (Proposed Line Design)

The configurations of the proposed 115-kV line are illustrated on the typical cross-sections presented in Appendix 3A, as well as on the maps located in Volume 5. Table 3-2 (located at the end of Section 3.1) summarizes the information presented in the cross-sections, identifying both the existing and proposed transmission line configurations.

Cross-sections are provided for each of the three different segments of the ROW, beginning at Plumtree Substation and proceeding to Brookfield Junction. For each ROW segment, the cross-sections depict the configurations of both the existing transmission lines and the new 115-kV transmission line that Eversource proposes.

The following subsections summarize the typical proposed configurations for the new 115-kV line, by ROW segment. These descriptions correspond to the cross-sections included in Appendix 3A, and Volume 5.

3.1.6.1 Plumtree Substation to 0.2 miles out of Plumtree Substation – XS-1

XS-1 illustrates the typical configuration of the proposed 0.2-mile segment of the 115-kV line from Plumtree Substation toward proposed Structure 1005 in the Town of Bethel. This cross-section illustrates the typical configuration along this segment of ROW, as viewed to the west. As the cross-section shows, along this segment of ROW, the new transmission line would be installed within either Eversource fee-owned property or Eversource's existing 225-foot-wide ROW. Along this segment, the new 115-kV line would typically be installed on three-pole structures because of multiple line crossings and angles from the substation to proposed Structure 1003, then would be installed on single circuit steel monopole structures from proposed Structure 1004 to proposed Structure 1005. The cross section represents the location of the line after it has already crossed under the 1363, 1170, and 321 lines.

3.1.6.2 0.2 to 3.4 miles out of Plumtree Substation to Brookfield Junction – XS-2

XS-2 illustrates the typical proposed transmission line configuration along the 3.2-mile segment of ROW extending from proposed Structure 1005 to proposed Structure 1026 in the municipalities of Bethel, Danbury and Brookfield. The proposed steel vertical monopole 115-kV structures would be located between the 321 Line and the edge of the existing 175-foot-wide ROW. This cross-section illustrates the proposed layout of the new 115-kV line, presenting a typical view, looking north, along the ROW.

3.1.6.3 3.4 miles out of Plumtree Substation at Brookfield Junction – XS-3

XS-3 illustrates the typical proposed transmission line configuration along the 0.1-mile segment of ROW at proposed Structure 1027 in the Town of Brookfield. The proposed steel horizontal three-pole deadend tap 115-kV structures would be located between the 321 Line and the edge of the existing 175 foot-wide ROW. This structure will serve as the connection to the existing 1887 Line at Brookfield Junction. XS-3 illustrates the proposed layout of the new 115-kV line, presenting a typical view, looking north, along the ROW.

Table 3-2: Summary of Existing and Proposed Transmission Line Configurations

Transmission Line By Cross-Section (Municipality)	Approx. ROW Mileage	Existing Line Configurations and Typical ROW Width		Proposed 115-kV Transmission Line Reference Case Configurations and Typical ROW Width	
		Typical Structure Type and Approximate Height (above ground)	**ROW Width (feet)**	**Typical Structure Type and Approximate Height (above ground)**	**Typical ROW Width (feet)**
XS-1 (Bethel)	0.2	One 345-kV circuit supported on Double Circuit Steel Lattice Towers and Double Circuit Steel Monopole structures; heights vary, ranging from 110 to 120 feet. Shared structure with a 115-kV circuit. One 115-kV circuit supported on Double Circuit Steel Lattice Towers and Double Circuit Steel Monopole structures; heights vary, ranging from 110 to 120 feet. Shared structure with 345-kV circuit. One 115-kV circuit supported on Single Circuit Steel Lattice Towers and Double Circuit Steel Monopole structures; typical height of 85 feet. One 115-kV circuit supported on Single Circuit Steel Lattice Towers and Double Circuit Steel Monopole structures; typical height of 85 feet.	225	Install one 115-kV circuit supported on steel 3-Pole Horizontal structures with a typical height of 30 feet and vertical Single Circuit Steel Monopole structures with heights approximately 100 feet.	225 (No additional ROW required)
XS-2 (Bethel, Danbury, & Brookfield)	3.2	One 345-kV circuit supported on Double Circuit Steel Monopole structures; typical heights of 150 feet. Shared structure with a 115-kV circuit. One 115-kV circuit supported on Double Circuit Steel Monopole structures; typical heights of 150 feet. Shared structure with 345-kV circuit. *Note: In one location southwest of Chimney Drive in the Town of Bethel (where there is a severe angle in the ROW), the existing 345-kV- and 115-kV lines are placed on two separate monopoles that are 130 feet in height. At this location, the monopoles are located on Eversource property.*	175	Install one 115-kV circuit on Steel Vertical Monopole Structures between existing 115-kV / 345-kV Double Circuit Steel Monopole structures and the edge of the ROW; heights vary, ranging from 95 to 135 feet, with a typical height of 120 feet.	175 (No additional ROW required)
XS-3 (Brookfield)	0.1	One 345-kV circuit supported on Double Circuit Steel Monopole structures; typical heights of 150 feet. Shared structure with a 115-kV circuit. One 115-kV circuit supported on Double Circuit Steel Monopole structures; typical heights of 150 feet. Shared structure with 345-kV circuit.	175	Install one 115-kV circuit supported on steel 3-Pole Horizontal Tap structure with a typical height of 85 feet	175 (No additional ROW required)

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3.2 STONY HILL SUBSTATION AND RELATED TRANSMISSION LINE MODIFICATIONS

Stony Hill Substation is located at 49 Stony Hill Road in the southern portion of the Town of Brookfield. The developed (fenced) substation occupies approximately 1.7 acres of a 42.3-acre Eversource property that is otherwise characterized predominantly by forest vegetation. The substation property, which is accessible via an access road off Stony Hill Road, is bordered to the north by a railroad, to the west by Stony Hill Road, to the south by Deer Trail Drive, and to the east by undeveloped land.

The substation presently connects to both the existing 115-kV 1770 and 1887 lines. Both lines extend from Shepaug Substation to Brookfield Junction, interconnecting to Stony Hill Substation between these two locations. The two 115-kV lines are supported in a double-circuit configuration on lattice steel towers, which are typically 85 feet in height. The 1770 Line occupies the south position on the towers, while the 1887 Line occupies the north. Stony Hill Substation is located south of the 1770/1887 Line ROW.

As part of the SWCT reliability improvements, the Stony Hill Substation and its interconnections to the 1770 and 1887 lines will be modified as summarized in the following subsections.[23]

3.2.1 Reconfiguration of Capacitor Bank Bus Connections

Within the substation, the existing 22K 115-kV capacitor bank (37.8 mega volt ampere reactive [MVAR]) connection to Bus A1 will be removed and the capacitor bank instead will be connected to Bus A3. This work will be performed within the substation fence line[24], and will include the following:

- Remove rigid bus, bus support structure, and associated foundations between capacitor banks 48C-21K & 48C-22K, which will separate 22K from the 115-kV Bus A1.
- Install new rigid bus, three-phase high bus support structure, 115-kV underground pothead structure and associated foundations to the south of capacitor bank 22K.
- Install 115-kV underground duct bank, 115-kV underground pothead structure, manually-operated vertical break disconnect switch, switch structure, three-phase high & low bus support structures, rigid bus and associated foundations to reconnect capacitor bank 22K to 115-kV Bus A3.
- Install three lightning arrestors (LAs) on each pothead structure (for a total of six LAs).

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[23] In addition, in conjunction with these improvements, remote end modifications will be made to Bates Rock Substation in Southbury. These minor modifications, all within the substation fence, include the replacement of a wave trap and a line tuner within the substation control house.

[24] Eversource plans to expand the Stony Hill Substation prior to the development of this Project. The proposed substation expansion will be addressed in a separate filing to the Council.

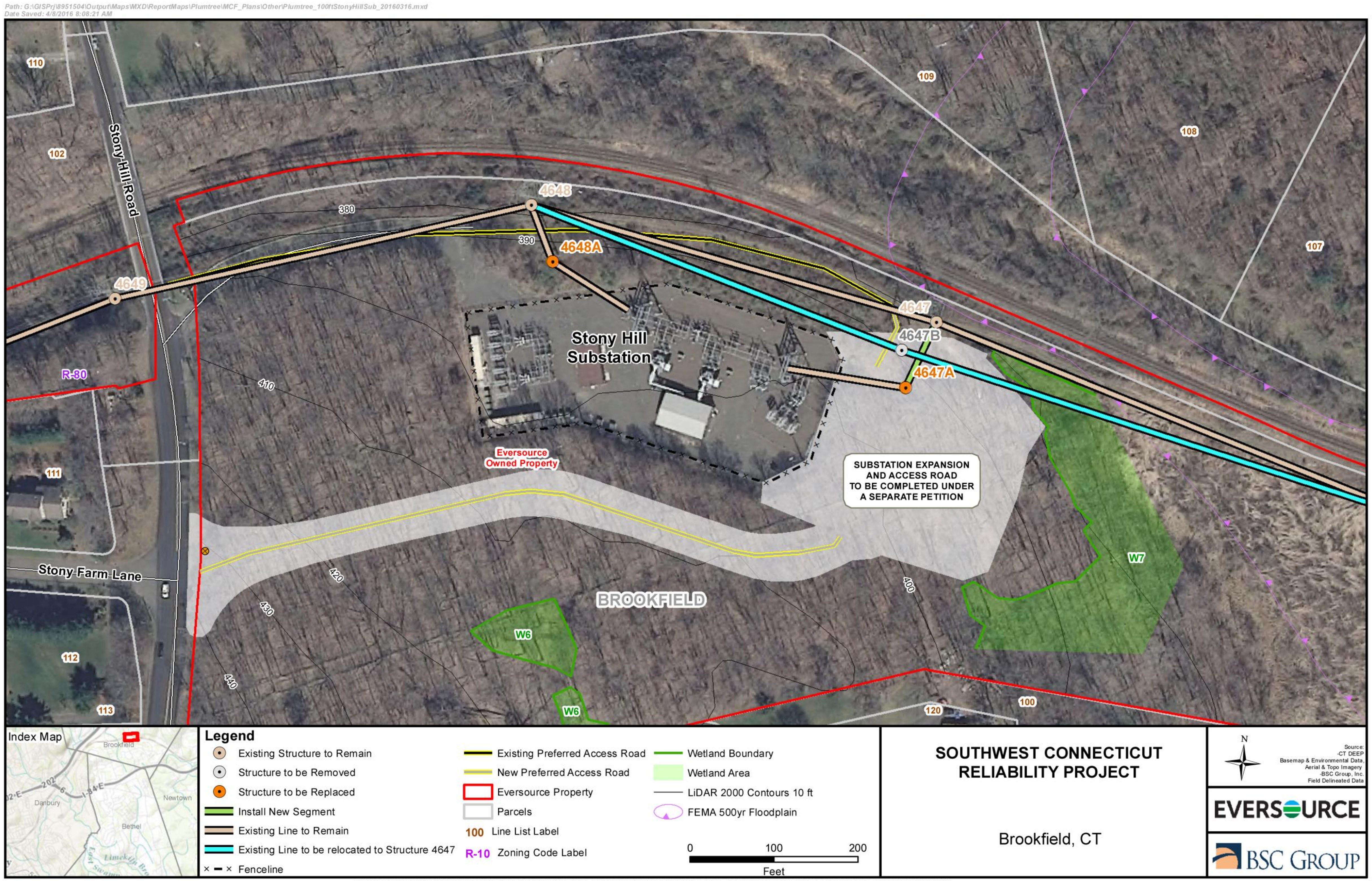
3.2.2 Reconfigure the Existing 1770 and 1887 Lines

As part of the Project, the existing 115-kV 1770 and 1887 lines will be reconfigured at and in the immediate vicinity of Stony Hill Substation. The reconfiguration will consist of the following:

- The existing 1770 Line will be looped into the substation, thereby creating two terminal lines (referred to as the 1268 and 1485 lines).
- The existing 1887 Line tap into the east side of the substation will be eliminated such that the line will no longer connect to the substation.
- Three existing transmission line structures that presently connect the 1770 and 1887 lines to the substation will be removed. Two new steel monopole structures, approximately 70 feet in height, will be installed. One structure will be a direct buried structure, while the other will be on a concrete foundation.

Figure 3-1 depicts the reconfiguration of the existing 1770 and 1887 lines outside of Stony Hill Substation. (refer also to Volume 5).

Figure 3-1: Stony Hill Substation Reconfiguration Map



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3.3 ESTIMATED PROJECT COSTS

3.3.1 Estimated Capital Cost

The estimated capital cost for the Project is approximately $24.4 million, with the transmission line construction accounting for approximately $18.9 million and substation modifications accounting for approximately $5.5 million.

3.3.2 Life-Cycle Cost

In accordance with the Council's *Life-Cycle Cost Studies for Overhead and Underground Transmission Lines* (2012), Eversource performed a present-value analysis of capital and operating costs over a 35-year economic life of the Project.

In accordance with the Council's Life-Cycle Cost Studies for Overhead and Underground Transmission Lines (November 15, 2012, "LCC Report"), Eversource performed a present-value analysis of capital and operating costs over a 40-year economic life of the transmission line portion of the project. The following items and assumptions were included in this study:

- Annual Carrying charges of the capital cost
- Annual Operation & Maintenance Costs
- Cost of energy losses
- Net Present Value Analysis
- Cost of Capacity (assumed to be zero for this project)

Applying these factors, the life cycle cost for the transmission lines is $32.3 million. The resulting life cycle cost per mile is $9.7 million. This is commensurate with the 2012 LCC Report Table ES-2 where total LCC for a 115-kV steel "delta" line are $8.6 million per mile. Differences include vertical construction as opposed to "delta" construction, and costs escalated to 2016 dollars.

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APPENDIX 3A

Cross-Sections

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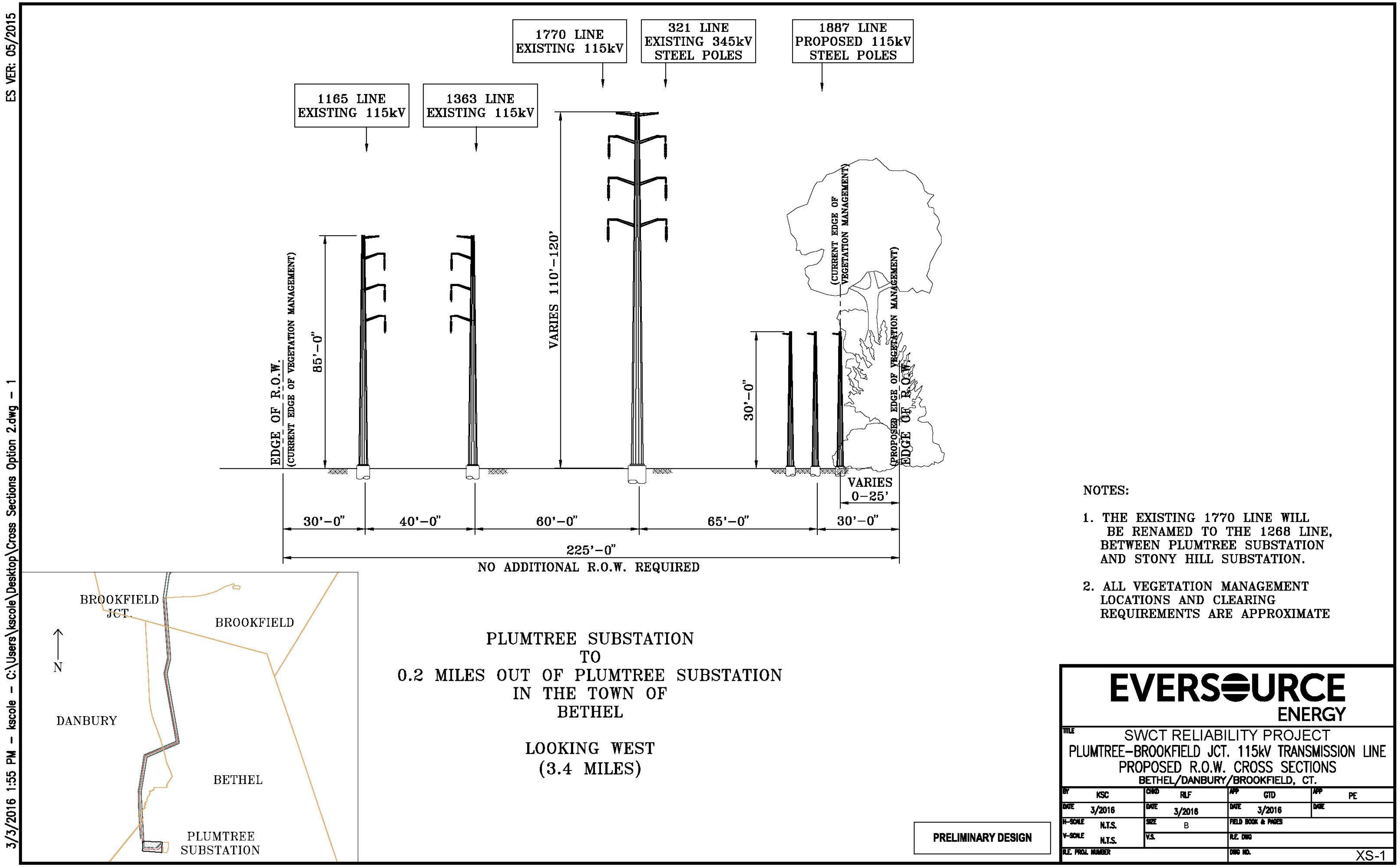
ES VER: 05/2015
1770 LINE
EXISTING 115kV
321 LINE
EXISTING 345kV
STEEL POLES
1887 LINE
PROPOSED 115kV
STEEL POLES
1165 LINE
EXISTING 115kV
1363 LINE
EXISTING 115kV
VARIES 110'-120'
85'-0"
30'-0"
EDGE OF R.O.W.
(CURRENT EDGE OF VEGETATION MANAGEMENT)
(CURRENT EDGE OF VEGETATION MANAGEMENT)
(PROPOSED EDGE OF VEGETATION MANAGEMENT)
EDGE OF R.O.W.
VARIES
0-25'
30'-0"
40'-0"
60'-0"
65'-0"
30'-0"
225'-0"
NO ADDITIONAL R.O.W. REQUIRED
NOTES:
1. THE EXISTING 1770 LINE WILL BE RENAMED TO THE 1268 LINE, BETWEEN PLUMTREE SUBSTATION AND STONY HILL SUBSTATION.
2. ALL VEGETATION MANAGEMENT LOCATIONS AND CLEARING REQUIREMENTS ARE APPROXIMATE
BROOKFIELD JCT.
BROOKFIELD
N
DANBURY
BETHEL
PLUMTREE SUBSTATION
PLUMTREE SUBSTATION
TO
0.2 MILES OUT OF PLUMTREE SUBSTATION
IN THE TOWN OF
BETHEL
LOOKING WEST
(3.4 MILES)
PRELIMINARY DESIGN
EVERSOURCE ENERGY
SWCT RELIABILITY PROJECT
PLUMTREE-BROOKFIELD JCT. 115kV TRANSMISSION LINE
PROPOSED R.O.W. CROSS SECTIONS
BETHEL/DANBURY/BROOKFIELD, CT.
KSC
RLF
GTD
PE
3/2016
3/2016
3/2016
N.T.S.
B
N.T.S.
XS-1
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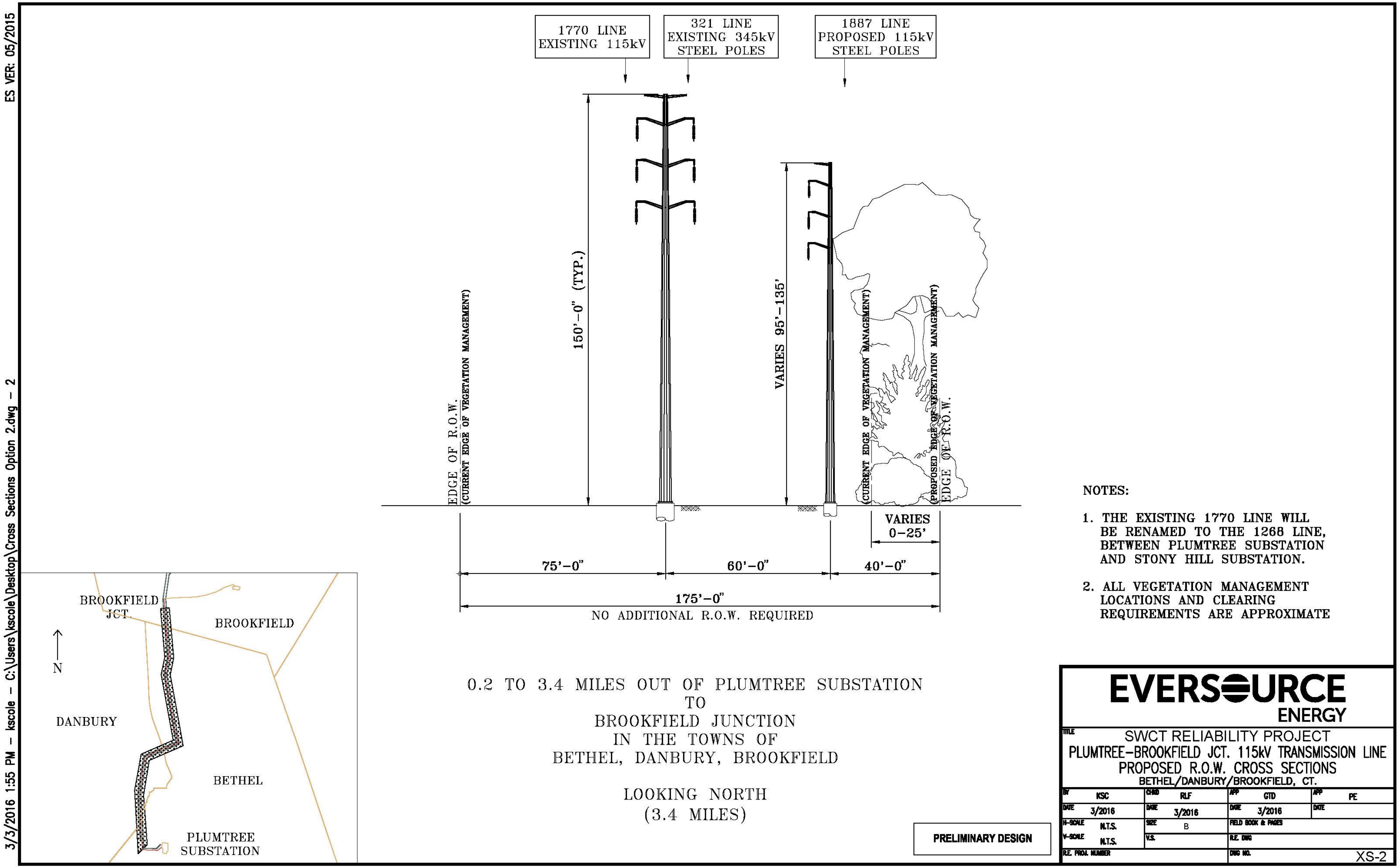
1770 LINE
EXISTING 115kV
321 LINE
EXISTING 345kV
STEEL POLES
1887 LINE
PROPOSED 115kV
STEEL POLES
150'-0" (TYP.)
VARIES 95'-135'
EDGE OF R.O.W.
(CURRENT EDGE OF VEGETATION MANAGEMENT)
(CURRENT EDGE OF VEGETATION MANAGEMENT)
(PROPOSED EDGE OF VEGETATION MANAGEMENT)
EDGE OF R.O.W.
VARIES
0-25'
75'-0"
60'-0"
40'-0"
175'-0"
NO ADDITIONAL R.O.W. REQUIRED
NOTES:
1. THE EXISTING 1770 LINE WILL BE RENAMED TO THE 1268 LINE, BETWEEN PLUMTREE SUBSTATION AND STONY HILL SUBSTATION.
2. ALL VEGETATION MANAGEMENT LOCATIONS AND CLEARING REQUIREMENTS ARE APPROXIMATE
BROOKFIELD
JCT
BROOKFIELD
N
DANBURY
BETHEL
PLUMTREE
SUBSTATION
0.2 TO 3.4 MILES OUT OF PLUMTREE SUBSTATION
TO
BROOKFIELD JUNCTION
IN THE TOWNS OF
BETHEL, DANBURY, BROOKFIELD
LOOKING NORTH
(3.4 MILES)
PRELIMINARY DESIGN
EVERSOURCE
ENERGY
SWCT RELIABILITY PROJECT
PLUMTREE-BROOKFIELD JCT. 115kV TRANSMISSION LINE
PROPOSED R.O.W. CROSS SECTIONS
BETHEL/DANBURY/BROOKFIELD, CT.
KSC
RLF
GTD
PE
3/2016
3/2016
3/2016
N.T.S.
B
N.T.S.
XS-2
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ES VER: 05/2015

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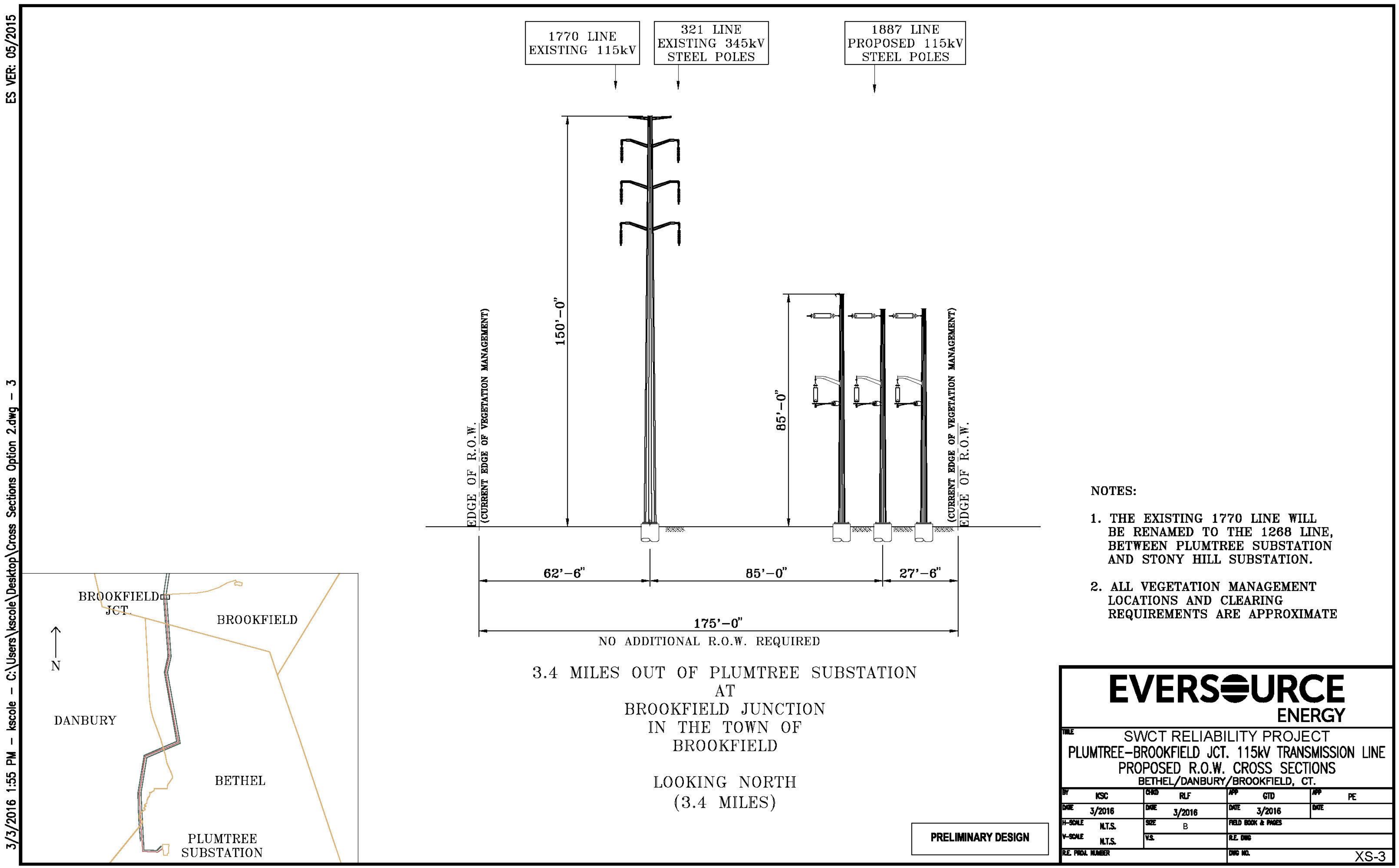
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1770 LINE
EXISTING 115kV
321 LINE
EXISTING 345kV
STEEL POLES
1887 LINE
PROPOSED 115kV
STEEL POLES
150'-0"
85'-0"
EDGE OF R.O.W.
(CURRENT EDGE OF VEGETATION MANAGEMENT)
62'-6"
85'-0"
27'-6"
175'-0"
NO ADDITIONAL R.O.W. REQUIRED
3.4 MILES OUT OF PLUMTREE SUBSTATION
AT
BROOKFIELD JUNCTION
IN THE TOWN OF
BROOKFIELD
LOOKING NORTH
(3.4 MILES)
BROOKFIELD JCT.
BROOKFIELD
N
DANBURY
BETHEL
PLUMTREE SUBSTATION
NOTES:
1. THE EXISTING 1770 LINE WILL BE RENAMED TO THE 1268 LINE, BETWEEN PLUMTREE SUBSTATION AND STONY HILL SUBSTATION.
2. ALL VEGETATION MANAGEMENT LOCATIONS AND CLEARING REQUIREMENTS ARE APPROXIMATE
EVERSOURCE ENERGY
SWCT RELIABILITY PROJECT
PLUMTREE-BROOKFIELD JCT. 115kV TRANSMISSION LINE
PROPOSED R.O.W. CROSS SECTIONS
BETHEL/DANBURY/BROOKFIELD, CT.
KSC
RLF
GTD
PE
3/2016
3/2016
3/2016
N.T.S.
B
N.T.S.
XS-3
PRELIMINARY DESIGN

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APPENDIX 3B

115-kV Transmission Line Structure Types

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115-kV TRANSMISSION LINE STRUCTURE TYPES

Transmission line structures, which are typically the element of an electric transmission system that is most apparent to the public, support the conductors (wires) that are used to transport electric power from generation sources to customer load centers.[25] Two 115-kV transmission line structure families have been identified for use on the proposed Project or as configuration options for certain segments of the proposed Project:

- Vertical Configuration - Steel Pole
- Horizontal Configuration - Steel Pole

Each of these structure families includes different functional types of structures. Where and how a particular type of structure is used along a transmission line depends on a variety of factors, such as availability of ROW, load requirements[26], and terrain (topography). In each structure family, the basic types of structures commonly used along a transmission line are:

- **Tangent structure**. Tangent structures are the type most commonly used on a transmission line and are used on relatively straight portions of the transmission line. Because the conductors are in a relatively straight line passing through them, tangent structures are designed only to handle small line angles (changes in direction) of 0 to 2 degrees. Tangent structures are usually characterized by suspension (vertical) insulators, which support and insulate the conductors and transfer wind and weight loads to the structure.
- **Angle structure**. Angle structures are used where transmission line conductors change direction. These types of structures are designed to withstand the additional forces placed on them by the change in direction. Angle structures may be: (1) similar to tangent structures, using suspension insulators to attach the conductors and transfer wind, weight, and line angle loads to the structure; or (2) similar to strain or deadend structures, using insulators in series with the conductors to bring wind, weight, and line angle loads directly to the structure.
- **Deadend structure.** A deadend structure is typically used where transmission line conductors turn at a wide angle or end. Compared to tangent structures, a deadend structure is designed to be stronger and often is a larger structure. Typically, insulators on a deadend structure are in line with the conductors (horizontal) to bring wind, weight, and line angle loads directly to the structure. A deadend structure is designed to resist the full unbalanced tension that would occur if all conductors were removed from one face of the structure.

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[25] The conductors proposed for the Project are aluminum with a steel core for strength; these conductors are connected to the transmission line structures by insulators (typically made of porcelain) that must be strong enough to support tensile forces and the weight of the conductors while preventing electrical contact between the conductors and the structure. Shield wires, which are connected directly to the structures, are installed above the conductors to protect the conductors from direct lightning strikes.

[26] Each structure must be designed for both the loads imposed on it by the weight of the conductors and dynamic loads resulting from factors such as wind and ice accumulation.

- **Strain structure**. A strain structure is similar in appearance and design strength to a tangent structure. The difference in appearance is the conductor attachment hardware. The conductor attachment hardware is the same as a deadend or large angle, where the insulator bells are in line with the conductor. Whereas a deadend structure is designed to withstand the full unbalanced tension that would occur from the loss of all conductors from one face of the structure, a strain structure is designed to withstand only unbalanced tensions associated with the loss of a single phase (bundle of two conductors) on one face of the structure.

As illustrated in this appendix, structures are self-supported and may include different insulator configurations (e.g., horizontal, vertical).

Vertical Steel Pole Family

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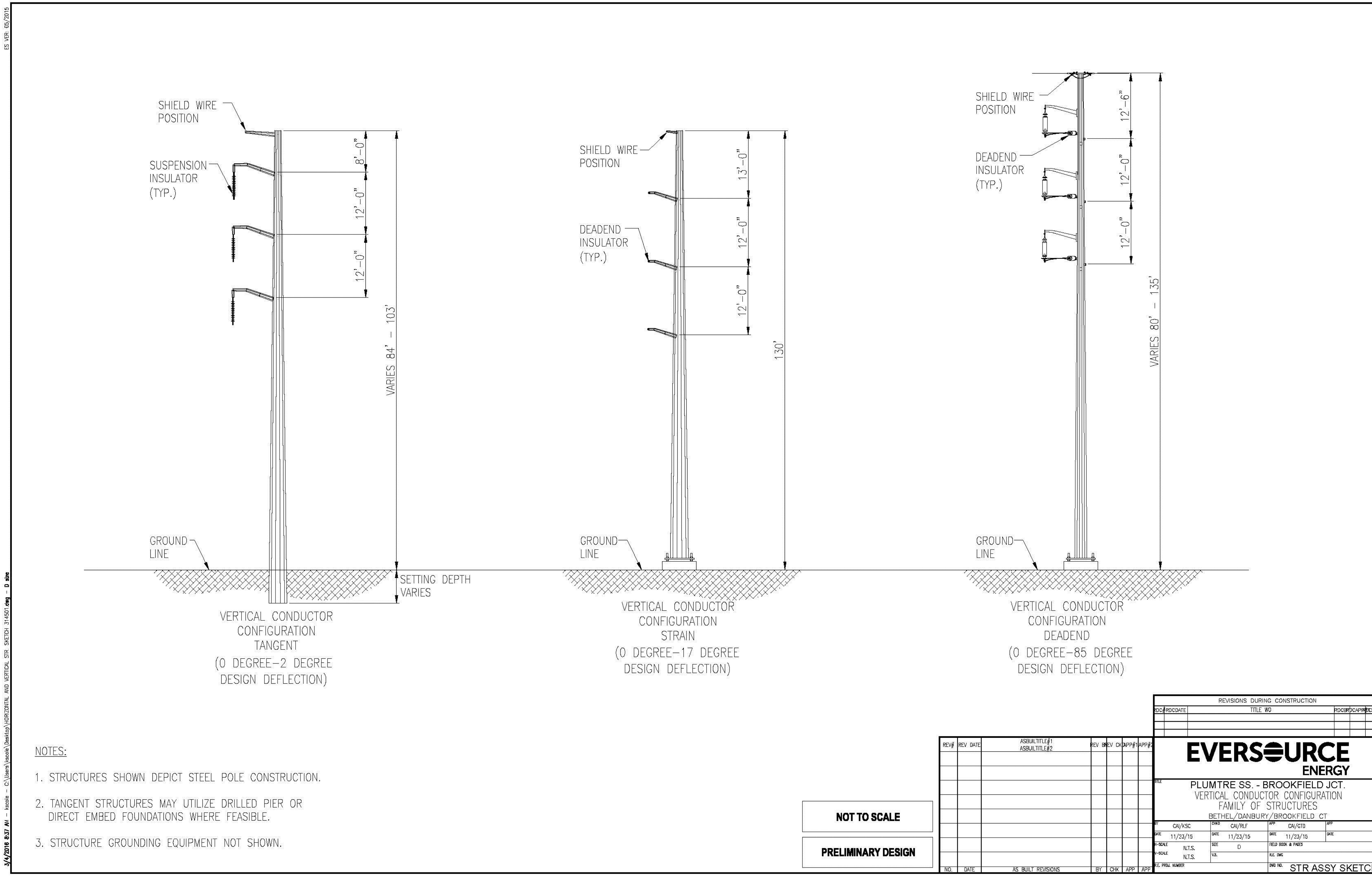
SHIELD WIRE POSITION
SUSPENSION INSULATOR (TYP.)
8'-0"
12'-0"
12'-0"
VARIES 84' - 103'
GROUND LINE
SETTING DEPTH VARIES
VERTICAL CONDUCTOR CONFIGURATION TANGENT
(0 DEGREE-2 DEGREE DESIGN DEFLECTION)
SHIELD WIRE POSITION
DEADEND INSULATOR (TYP.)
13'-0"
12'-0"
12'-0"
130'
GROUND LINE
VERTICAL CONDUCTOR CONFIGURATION STRAIN
(0 DEGREE-17 DEGREE DESIGN DEFLECTION)
SHIELD WIRE POSITION
DEADEND INSULATOR (TYP.)
12'-6"
12'-0"
12'-0"
VARIES 80' - 135'
GROUND LINE
VERTICAL CONDUCTOR CONFIGURATION DEADEND
(0 DEGREE-85 DEGREE DESIGN DEFLECTION)
NOTES:
1. STRUCTURES SHOWN DEPICT STEEL POLE CONSTRUCTION.
2. TANGENT STRUCTURES MAY UTILIZE DRILLED PIER OR DIRECT EMBED FOUNDATIONS WHERE FEASIBLE.
3. STRUCTURE GROUNDING EQUIPMENT NOT SHOWN.
NOT TO SCALE
PRELIMINARY DESIGN
REVISIONS DURING CONSTRUCTION
NO. DATE AS BUILT REVISIONS BY CHK APP APP
EVERSOURCE ENERGY
PLUMTRE SS. - BROOKFIELD JCT.
VERTICAL CONDUCTOR CONFIGURATION
FAMILY OF STRUCTURES
BETHEL/DANBURY/BROOKFIELD CT
BY CAI/KSC CHKD CAI/RLF APP CAI/GTD
DATE 11/23/15 DATE 11/23/15 DATE 11/23/15
H-SCALE N.T.S. V-SCALE N.T.S. SIZE D
DWG NO. STR ASSY SKETCH

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Horizontal 3-Pole Structure Family

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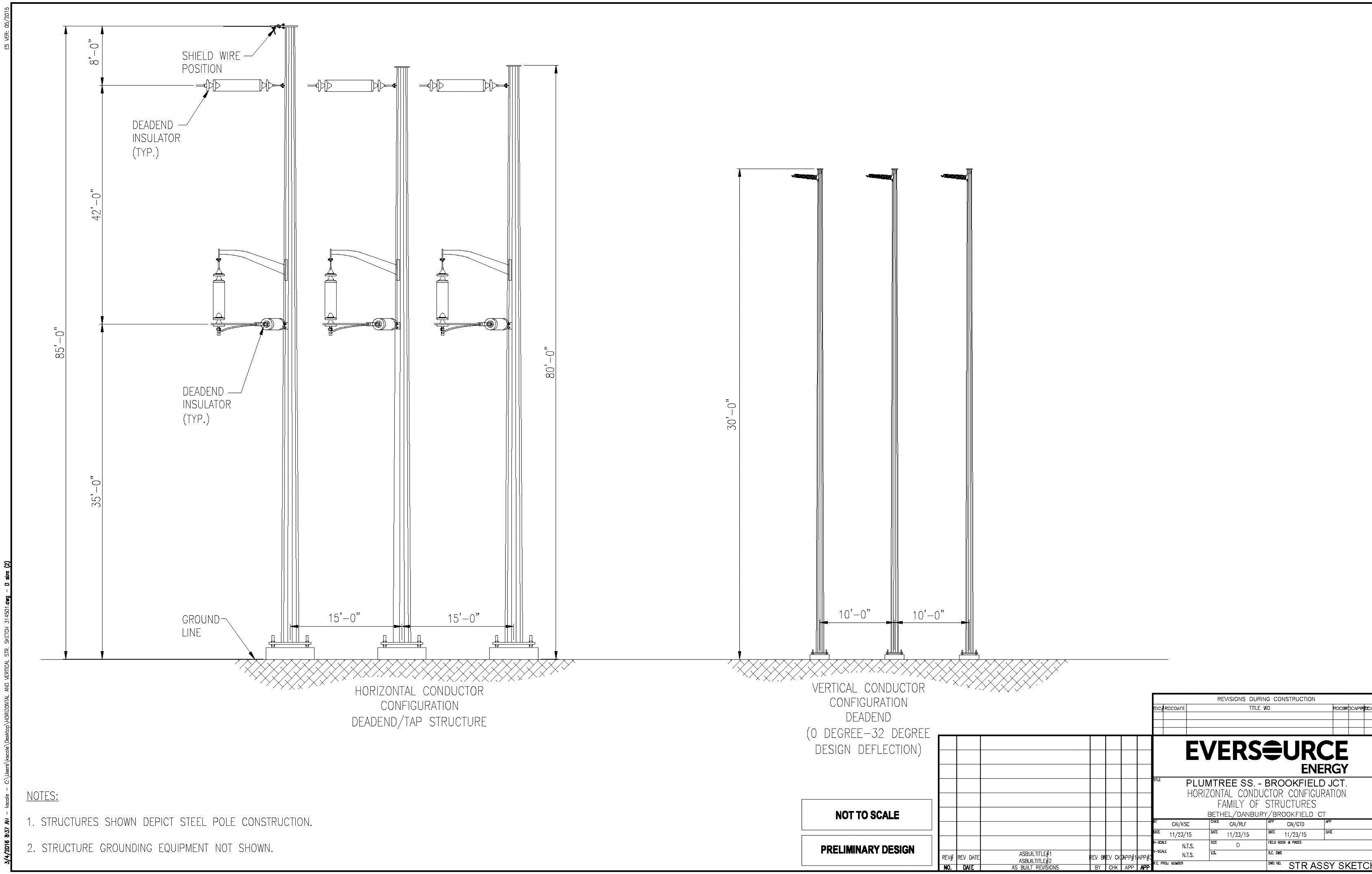
SHIELD WIRE POSITION
DEADEND INSULATOR (TYP.)
DEADEND INSULATOR (TYP.)
GROUND LINE
8'-0"
42'-0"
35'-0"
85'-0"
80'-0"
15'-0"
15'-0"
30'-0"
10'-0"
10'-0"
HORIZONTAL CONDUCTOR CONFIGURATION DEADEND/TAP STRUCTURE
VERTICAL CONDUCTOR CONFIGURATION DEADEND (0 DEGREE-32 DEGREE DESIGN DEFLECTION)
NOTES:
1. STRUCTURES SHOWN DEPICT STEEL POLE CONSTRUCTION.
2. STRUCTURE GROUNDING EQUIPMENT NOT SHOWN.
NOT TO SCALE
PRELIMINARY DESIGN
REVISIONS DURING CONSTRUCTION
TITLE WO
REV# REV DATE ASBUILTTITLE#1 ASBUILTTITLE#2
NO. DATE AS BUILT REVISIONS BY CHK APP APP
EVERSOURCE ENERGY
PLUMTREE SS. - BROOKFIELD JCT.
HORIZONTAL CONDUCTOR CONFIGURATION
FAMILY OF STRUCTURES
BETHEL/DANBURY/BROOKFIELD CT
BY CAI/KSC
CHKD CAI/RLF
APP CAI/GTD
DATE 11/23/15
DATE 11/23/15
DATE 11/23/15
H-SCALE N.T.S.
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SIZE D
FIELD BOOK & PAGES
R.E. DWG
R.E. PROJ. NUMBER
DWG NO. STR ASSY SKETCH

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4. CONSTRUCTION AND OPERATION / MAINTENANCE PROCEDURES

The proposed Project would be constructed, operated, and maintained in accordance with established industry practices, as well as pursuant to Eversource's specifications. Construction, operation, and maintenance activities also would conform to any conditions identified in the Council's Decision and Order and in federal and state permits obtained for the Project.

Section 4.1 describes the standard procedures to be used for the installation of the proposed overhead 115-kV transmission line, including construction sequencing, material staging sites, construction field offices, access roads, ROW preparation, structure installation, counterpoise installation, conductor work, ROW cleanup and restoration, and general considerations for traffic control.

Section 4.2 reviews the special procedures that would be followed when specific conditions are encountered during construction (e.g., procedures for water resource crossings, blasting, soils management, and dewatering). The proposed configurations of the 115-kV transmission line along each ROW segment are depicted on the cross-section drawings, which are included in Section 3 of this volume (refer to Appendix 3A) and in Volume 5. (The Volume 5 cross-sections are full-size, scale drawings and include detailed notes; the cross-sections in Appendix 3A and on the Volume 5, 400 scale maps are reduced-size versions).

Section 4.3 summarizes the construction methods for the proposed modifications to Stony Hill Substation. Operation and maintenance procedures applicable to the new 115-kV transmission line and Stony Hill Substation are detailed in Section 4.4.

4.1 STANDARD PROCEDURES FOR OVERHEAD TRANSMISSION LINE CONSTRUCTION

4.1.1 Introduction and Overview of Construction Sequencing

Eversource would construct the proposed Project in several stages, some overlapping in time. The following summarizes the activities, materials, and equipment generally expected to be involved in the construction of the overhead transmission line facilities:

- Survey and stake the ROW boundaries and monument line (where necessary), vegetation clearing boundaries, and proposed structure locations.
- Mark (e.g., with flagging) the boundaries of previously delineated wetland and watercourse areas, as well as other sensitive cultural or environmental resource areas (e.g., areas to be avoided or where mitigation measures are to be implemented.
- Establish construction field office area(s), typically including space for office trailer(s), equipment storage and maintenance, sanitary facilities, and parking.
- Prepare material staging sites (e.g., storage, staging and laydown areas) to support the construction effort. The preferred locations for such areas are typically in the immediate vicinity of the ROW.
- Perform vegetation clearing. Vegetation would be removed along those portions of the ROW to be used for the construction of the transmission line facility, as well as areas that contain undesirable, tall-growing, woody species that could reach heights that would interfere with the operation of the transmission line should they not be removed. For example, as part of construction, vegetation would be removed to the designated limits of clearing as required, including at work sites (work pads), as well as along existing or new access roads. Vegetation also would be removed, as necessary, along existing or new access roads that may be on the ROW (but outside the designated limits of clearing) or off the ROW (but required to reach the ROW). In addition, as authorized by its easements or permission from the landowner, hazard and danger trees outside the limits of clearing (on or off the ROW) would be removed as necessary to protect the integrity of the proposed or existing transmission lines. Vegetation removal activities typically require flatbed trucks, brush hogs or other types of mowing equipment, skidders, bucket trucks for canopy trimming, tree shears for larger trees, wood chippers, log trucks, and chip vans. Effects on wetlands, watercourses, or other environmentally sensitive areas would be minimized to the extent practicable (refer to Sections 4.2 and 6 for a discussion of potential mitigation measures). Vehicles with tracks or low-ground-pressure tires may be used to remove vegetation in wetlands. In addition, depending on soil saturation, vegetation removal activities in wetlands may include the use of temporary timber mats or timber riprap to provide a stable base for clearing equipment or hand cutting to avoid any vehicular access.
- Install erosion and sedimentation controls in accordance with best management practices (typically, controls are deployed using pickups and other small trucks, or small track vehicles). After vegetation removal, soil erosion and sedimentation controls typically are installed around work limits (e.g., access roads, work pads) in or near wetlands and streams.
- Construct new access roads or improve existing roads to provide a minimum travel-way of 16 to 20 feet in width (overall a 20-25-foot-wide footprint, including road shoulders). This typically requires bulldozers or front loaders, excavators, dump trucks for crushed stone or gravel, pickups or stake-body trucks for culverts, and/or mat installers for wetland mats. Roads may be temporary (for use during construction only) or permanent (for use during both construction and the subsequent maintenance of the lines). Temporary roads may be constructed of wood (timber) mats or gravel, whereas permanent access roads are generally constructed of gravel only. Roads must have sufficient width and capacity for heavy construction equipment for both over-the-road and off-road vehicles, including oversized tractor trailers. The need for access by flat-bed trailers and concrete trucks often determines the scope of access road improvements. Road grades must be negotiable for over-the-road trucks; acceptable grades are typically 10% maximum, less if wet weather or surface conditions result in traction problems.
- Prepare level work (crane) pads as necessary at new structure sites, conductor pulling sites, and guard structure sites. Work pad installation may involve grading and requires the installation of a

stable base (consisting of gravel, timber mats, or equivalent) for drilling and other structure installation equipment.

- Construct structure foundations and erect/assemble new structures, this requires flat-bed trucks for hauling new structure components, new hardware, and augers, other trucks for hauling reinforcing rods, drill rigs, cranes, concrete trucks for structures that require concrete for foundations, dump trucks for structures that require crushed rock backfill, and bucket trucks. Dump trucks are also needed for foundation work if excess excavated material has to be removed from the ROW. In wet conditions or if groundwater is encountered during excavation, pumping (vacuum) trucks or other suitable equipment would be used to pump water from the excavated areas. The water then would be discharged in accordance with applicable local, state, and federal requirements.
- Install counterpoise, where needed. Depending on site-specific soil conductivity, supplemental grounding will be installed. A ditch witch is typical equipment for this activity.
- Install shield wires, OPGW, and conductors. The equipment required for these activities would include conductor reels, conductor pulling and tensioner rigs, and bucket trucks. Helicopters also may be used to install the initial pulling lines for the conductors or shield wires.
- Remove temporary roads and construction debris and stabilize disturbed sites. Haul construction debris off the ROW for disposal. Vegetative materials cut along the ROW and not otherwise planned for use by the landowner (e.g., brush) may be piled, scattered, or chipped on the ROW, depending on site-specific environmental features.
- Maintain temporary erosion and sediment controls until vegetation is re-established or disturbed areas are otherwise stabilized. Steep areas may be stabilized with jute netting or pre-made erosion control fabric containing seed, mulch, and fertilizer. Culverts or crushed stone fords installed along access roads would be either left in place or removed pursuant to regulatory approvals. After site stabilization is achieved, all temporary erosion and sedimentation controls that are not biodegradable (e.g., geotextile material, twine, stakes) would be removed from the ROW and disposed of properly.

4.1.2 Material Staging Sites

To support the construction of the new 115-kV transmission line, temporary contractor yards, storage areas, staging areas, and work pads would be necessary. The preferred locations for contractor yards, as well as temporary storage and staging sites, are in the general vicinity of the ROW. Although the staging areas do not necessarily have to be adjacent to the transmission line ROW, establishing these areas in proximity to construction sites would improve construction efficiency and minimize the potential for inconvenience or nuisance effects to the public (e.g., as a result of the movement of equipment, manpower, and supplies to and from the ROW along public roads). Work pads would be located within the ROW, at individual transmission line structures, conductor pulling sites, and guard structure sites.

If practical, material storage and staging areas would be established on Eversource-owned property. Based on the general acreage requirements for each type of staging location (refer to the discussions in Sections

4.1.2.1 and 4.1.2.2), Eversource performed a preliminary review to identify its properties in the vicinity of the ROW that could potentially serve as storage and staging area locations for the Project.

However, it is likely that additional material storage and staging areas would be necessary to support Project construction. If Eversource-owned properties are not available or suitable, previously developed sites (such as parking lots, previously used commercial or industrial properties) or vacant land would be evaluated for use as contractor yards, material storage, or staging areas, taking into consideration parcel size requirements and location in relation to the Proposed Route. At any location not already developed (e.g., paved parking lots) or previously used for such construction support work would likely be required to prepare the site for use as a contractor yard, material storage, or staging area. Such site preparation work may include vegetation removal, grading, adding gravel, installing fencing, and installing crushed stone anti-tracking pads at vehicular access points from public roads.

The actual locations of the contractor yards, staging, and storage sites would be determined by, or with input from, the contractor responsible for constructing the line. The contractor would be responsible for finalizing the locations of yards, staging, and storage areas, and also for making arrangements with property owners regarding the use of the properties. Eversource would review and approve the contractor's proposed construction support sites, and would obtain approval from the Council and, if necessary, from other regulatory agencies.

The development, use, and restoration of any staging sites would conform to conditions of the Council's approval and any other applicable federal, state, and local requirements. Because the locations of the staging sites would not be finalized until after a construction contractor is selected, Eversource would either specify such sites in the D&M Plans for the Project or submit them separately to the Council for approval prior to use.

4.1.2.1 Temporary Storage Areas

Temporary storage areas typically range in size from approximately 2 to 5 acres, but may be larger. These areas would be used to temporarily store construction materials, equipment, and supplies. Storage areas also would be used for mobile construction offices, parking the personal vehicles of construction crew members, parking construction vehicles and equipment, and performing minor maintenance, if needed, on construction equipment.

In addition, storage areas may function as staging areas. For example, components for new transmission line structures may be temporarily stored at these locations prior to delivery to structure sites. Transmission line materials or structures also may be assembled at storage areas prior to delivery to the ROW.

Storage areas for the proposed Project would typically be selected based upon proximity to work locations along the ROW. As the construction of the transmission lines progresses, subsequent storage areas are typically used to keep equipment and materials close to the locations where line construction work is being performed. Once a storage area is no longer used to support construction activities, it would be restored pursuant to the use agreement with the property owner.

4.1.2.2 Staging Areas

Staging areas, which are generally less than 2 acres in size, are typically used for temporarily stockpiling materials for transmission line construction (e.g., erosion and sedimentation control materials, poles and structure components, insulators and hardware, and construction equipment). In addition, staging areas may be used to temporarily stockpile materials removed from the ROW or used during the construction process, prior to off-site disposal. The number and proposed locations of staging areas required to support the construction effort would be determined by the transmission line construction contractor.

Staging areas would be required in proximity to the transmission line route and may be located on or off the ROW. Eversource-owned property that is presently used for utility purposes would be used for staging areas to the extent practical. Locations along the ROW could also be used, provided sufficient easement rights exist.

As construction progresses, subsequent staging areas would likely be used to coincide with nearby construction work. When a particular staging area is no longer required, the site would be restored pursuant to the use agreements with the property owners.

4.1.3 Construction Field Offices

Field offices for both the contractor and Eversource provide headquarters for construction field representatives, engineers, and other Project field personnel near the areas where work is being performed. Optimally, such construction field offices are located in existing commercial or industrial facilities near the Project, including at Eversource substations. If not practical to locate in existing commercial or industrial facilities, these field office sites typically would consist of trailers, portable sanitary facilities, and associated parking areas.

The field offices also may be co-located with other construction support sites, such as staging or storage areas. At the completion of the Project, the office trailers and other construction support equipment or materials would be removed, and the area would be restored.

For construction office sites located on private property, restoration would be in accordance with landowner agreements. If field office sites are located on Eversource-owned property, restoration would be pursuant to Eversource's requirements.

4.1.4 Right-of-Way Preparation

Along with the development or improvement of access roads (refer to Section 4.1.5), ROW preparation constitutes the first step in the transmission line construction process. ROW preparation activities typically involve vegetation removal and the associated deployment of erosion and sedimentation controls (typically in conjunction with access road development or improvement). In addition, during this phase of construction, exclusion fencing or other types of boundary markings are typically installed to demarcate areas of restricted construction access or environmental sensitivity.

4.1.4.1 Temporary Erosion and Sedimentation Controls

Temporary erosion controls (e.g., silt fence, hay/straw bales, filter socks, mulch, and seeding) would be initially installed as practicable prior to and/or during vegetation clearing operations, in compliance with the 2002 *Connecticut Guidelines for Soil Erosion and Sedimentation Control* and Eversource's 2011 Best Management Practices (BMP) manual entitled, "*Best Management Practices Manual: Construction and Maintenance Environmental Requirements for Connecticut"* (BMP Manual).

Temporary controls, such as silt fence, hay/straw bales, straw waddles, and filter socks, also may be deployed during any of the transmission line construction phases involving soil disturbance. Such controls would be maintained (i.e., repaired and replaced as necessary) throughout the construction period, until disturbed areas are revegetated or otherwise stabilized. After stabilization is achieved, these materials would be removed and disposed of appropriately.

Generally, in areas where soils have been or would be disturbed near sensitive environmental resources (e.g., wetlands, vernal pools, watercourses, threatened and endangered species habitat), temporary controls would be deployed as appropriate to minimize the potential for erosion and sedimentation off ROW or into water resources (on or off the ROW).[27] In addition, temporary erosion and sedimentation controls (e.g., silt fence, straw/hay bales), orange construction fencing, or signage may be deployed after vegetation removal to demarcate the limits of work within sensitive environmental areas (i.e., limits of access roads, work pads).

The need and extent of temporary erosion and sedimentation controls would be a function of considerations such as:

- Slope (steepness, potential for erosion, and presence of environmentally sensitive resources, such as wetlands or streams, at the bottom of the slope).
- Type of vegetation removal method used and the extent of vegetative cover remaining after clearing (e.g., presence/absence of understory or herbaceous vegetation to minimize the potential for erosion and degree of soil disturbance as a result of the clearing equipment movements).
- Type of soil.
- Soil moisture regimes.
- Schedule of future construction activities.
- Proximity of cleared areas to water resources, roads, or other sensitive environmental resources.
- Time of year. The types of erosion and sedimentation control methods utilized along the ROW would depend on the time of year construction work is initiated and completed. For example, re-seeding is typically ineffective during the winter months. In winter, with frozen ground, controls other than re-seeding (such as wood chips, straw and hay, geotextile fabric, erosion control logs) typically would be deployed or maintained to control erosion and sedimentation and thus to stabilize disturbed areas until reseeding can be performed under optimal seasonal conditions.

[27] In some locations, such as areas where vegetation is cleared and water resources are situated nearby but no further earth-disturbing construction activities are required, soils may be stabilized with permanent measures (e.g., final revegetation). Refer to Section 4.1.7.1 for a discussion of final revegetation and permanent erosion control measures.

4.1.4.2 Vegetation Removal, Including Tree Clearing

Vegetation Clearing Requirements and Estimates

Along all of the 3.4-mile Proposed Route, the new 115-kV transmission line would be located adjacent to one or more existing overhead transmission lines, which are situated within Eversource's ROW that varies in width from approximately 175-225 feet. Beneath and in the vicinity of the existing transmission lines that occupy this ROW, Eversource routinely manages vegetation pursuant to requirements for the reliable operation of the overhead transmission lines.

Since April 7, 2006, Eversource's ROW vegetation management practices have been required to comply with mandatory standards adopted by NERC following the August 14, 2003 Northeast blackout.[28] These vegetation management practices are designed to allow the reliable operation of the transmission facilities by preventing the growth of trees or invasive vegetation that would otherwise interfere with the transmission facilities or hinder access along the ROWs. As a result, the vegetation within the managed portions of Eversource's ROWs typically consists of shrubs, herbaceous species, and other low-growing species.

To accommodate the construction and subsequent operation of the new 115-kV line, additional vegetation removal would be required. Vegetation along the ROW would be removed to allow for construction equipment at each structure location, to provide cleared access roads and spurs to structure sites, as needed, and to provide no imminent risk to the new line along the new or existing edge from danger trees. However, the amount and type of vegetation clearing required would vary and would depend on factors such as the existing width of the managed ROW, vegetation communities present (e.g., forested, herbaceous, scrub-shrub, open field), the type of the new 115-kV transmission structures, configuration and spacing of the transmission line conductors, transmission line span lengths, and terrain.

Along the ROW within which the new 115-kV line would be located, the width of the currently managed portions varies, depending on the number and configuration of the existing transmission lines that occupy each ROW segment. The cross-sections illustrate the location of the proposed transmission line along each ROW segment (refer to Section 3, Appendix 3A of this Volume and in Volume 5).

Predominantly, along the 3.2 miles of the 3.4 mile proposed route from the vicinity of proposed structures 1005 to 1026 (refer to XS-2), the 175-foot-wide ROW currently includes one 345-kV circuit and one 115-

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28 Transmission line outages triggered by overgrown vegetation in Ohio were substantial factors in causing the blackout.

kV circuit. The new 115-kV line is proposed for location near the east edge of the ROW, between the 345-kV circuit and the edge of existing ROW. Because Eversource already manages most of this ROW segment for low-growth vegetative communities, clearing for the construction of the new 115-kV line would predominantly involve the removal of scrub-shrub type vegetation. However, some areas of taller-growing vegetation are predominant within the limits of clearing for the new 115-kV transmission line and thus would have to be removed.

Table 4-1 summarizes the widths of the ROW segments along which the proposed 115-kV line would be located, together with the typical widths of the existing managed portions of the ROW and the anticipated additional widths of vegetation removal required along each ROW segment of the Project.

Table 4-1: Summary (by Cross-Section) of Total ROW Widths, Existing Managed ROW Widths, and Additional New Vegetation Clearing Widths Required for the Proposed 115-kV Transmission Line

Municipality	Existing Eversource ROW			
	Cross-Section Reference (refer to Vol. 1, Appendix 3A and to Vol. 5)	Total ROW Width (feet)	Width of Current Vegetation Management Area along ROW (feet, typical)	Estimated Width of New Vegetation Clearing* Required for Proposed 115-kV Transmission Line (feet)
Bethel	XS-1	225	200	225
Bethel, Danbury, & Brookfield	XS-2	175	125	175
Brookfield	XS-3	175	175	175

*Note: The estimated width of new vegetation clearing refers to the additional areas of the ROW, outside of the portions of the ROW that Eversource presently manages, where vegetation (typically forest) would have to be removed for the new 115-kV transmission line. To accommodate the construction of the new transmission line, vegetation (mostly shrub-scrub) would also have to be removed along portions of the ROW where Eversource performs vegetation management consistent with the safe and reliable operation of the existing transmission lines.

As part of the construction of the new transmission line, undesirable, tall-growing, woody species within the ROW near the new line would be removed. Desirable species would be preserved to the extent practical. In selected cases, certain desirable, low-growing trees may be kept on the ROW in specific locations and only trimmed to ensure adequate clearance from wires and structures, pursuant to Eversource's *Right-of-Way Vegetation Initial Clearance Standard for 115-kV and 345-kV Transmission Lines*. Generally, all tall-growing tree species would be removed from the managed portion of the ROW and low-growing tree species and taller shrub species would be retained (if possible) in the areas outside of the conductor zones (the area directly under the conductors extending outward a distance of 15 feet from the outermost conductors).

These activities would modify, but not eliminate, vegetation and wildlife habitats along the ROW. In general, the principal long-term effect of vegetation removal along the ROW would be to forested habitat. Specifically, within the additional areas where new vegetation clearing would be required to accommodate the proposed Project, trees would be removed and would not be allowed to regenerate. Over time, these previously forested areas would be recolonized by native shrubs, herbaceous flowering plants, and grasses, creating additional old field and scrub-shrub communities.

Landowner Outreach and Beneficial Use of Forestry Products

The timber resources along the Proposed Route belong to the landowners across whose properties the ROW is aligned, where Eversource has an easement interest in the ROW. Eversource's policy is to pro-actively coordinate with landowners regarding the disposition and use of the trees to be removed along the ROW. If requested by the landowner, the timber portions of the trees would be left on the landowner's property, in upland areas on the edge of the vegetatively managed portion of the ROW. After the limbs are removed, the wood would be piled in tree lengths for landowners to cut and remove at their convenience.

Timber removed along the ROW on Eversource-owned property or on parcels where the landowners are not interested in retaining the wood would become the property of the Project's land clearing contractor. Eversource would competitively bid the vegetation removal work for the Project and would select a contractor taking into consideration the contractor's plans for the beneficial use of the forest products.

Vegetation Clearing Methods

Vegetation would be typically removed from the proposed transmission line construction workspace (including the areas of managed vegetation in the vicinity of the new line) using mechanical methods. Where necessary, Eversource will encourage the selected vegetation clearing contractor to use low-impact tree clearing means and methods to remove forested vegetation. Low-impact tree clearing incorporates a variety of approaches, techniques, and equipment to minimize site disturbance and to protect wetlands, watercourses, soils, rare species and their habitats, and cultural resources.

During vegetation removal, timber mats or equivalent may be used to provide a stable base for clearing equipment across or within wetlands along the ROW. Such temporary support would minimize rutting in wetlands and would be removed after the clearing activities are completed. The locations where temporary support would be required would be determined in the field, based on site-specific conditions (e.g., soil saturation) present at the time of construction, and may not be the same as the permanent or temporary access roads illustrated on the Volume 5 maps.

Appropriate erosion and sedimentation controls would be deployed as necessary (refer to Section 4.1.4.1). Where removal of woody vegetation is required, vegetation would typically be cut to within 3 inches of ground surface to the extent possible. Where practical, trees would be felled parallel to and within the ROW to minimize the potential for damage to residual vegetation.

Eversource would direct the Project contractor to retain lower growing vegetation along stream banks and within wetlands, to the extent possible. In general, Eversource may alter to some degree vegetation management activities in the following areas, provided that the construction and operation of the facilities remain in accordance with national transmission line vegetation management standards and consistent with Project permits and approvals:

- Areas of visual sensitivity where vegetation removal may be limited for aesthetic purposes;
- Steep slopes and valleys spanned by transmission lines; and
- Residential areas where maintained landscapes do not interfere with the construction, maintenance, or operation of the transmission lines.

Danger and Hazard Trees

During and/or after the initial vegetation removal activities, a licensed arborist will evaluate trees beyond the proposed edge of clearing (i.e., both on and off-ROW) to identify and mark any hazard and danger trees that pose an imminent risk to the new 115-kV transmission line.[29] Individual “danger” or “hazard” trees are typically determined based on factors such as species, soil conditions (including wetland vs. upland, susceptibility to flooding, depth of rock), health of the tree, inclination of trunk and shape of crown, etc.. Hazard or danger trees located in un-managed areas outside of the limits of Project clearing would be removed after identification; prior to the removal of any such trees off-ROW, Eversource would inform the affected landowner.

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[29] A danger tree is a tree that, due to its location and height, could cause a flashover or damage to the transmission line structures or conductors, or violate conductor zones, if it were to fall toward the transmission line. A hazard tree is a tree that exhibits some type of defect or damage (e.g., weakness, broken limbs, decay, infestation) that increases the risk of it falling into the transmission line.

4.1.5 Access Roads

As discussed in Section 3.1.5, access roads are required during construction. "On-ROW access roads" would be used to move equipment and material between structure locations. "Off-ROW access roads" would be used to access structures that cannot be accessed directly from locations where the ROW traverses public roads or to avoid or reduce impacts to sensitive resource areas such as wetlands.

Depending on site-specific conditions, grading may be required to develop or to improve access roads. Some access roads would be needed only during construction and thus would be used temporarily, whereas other access roads will be required permanently for the long-term operation and maintenance of the new transmission line.

During construction, at points of intersection between access roads and public roads, Eversource would typically install temporary signs that specify the access roads are for construction purposes and are restricted from use by public vehicular traffic. In addition, where on-ROW access roads or off-ROW dirt roads intersect with public roads, construction entrance track pads (rock aprons or equivalent) would typically be installed to minimize tracking of dirt from the ROW onto the public road as a result of construction vehicle movements. Public roads in the vicinity of access roads would also be periodically swept to remove dirt that is tracked from construction activities.

4.1.5.1 On-ROW Access Roads

Contiguous access along the entire existing ROW will generally be necessary for the construction of the proposed 115-kV overhead transmission line. Access to each proposed transmission structure location is required. Along most of the Proposed Route, the ROW has been used for electric transmission purposes for approximately 40 years and, as a result of the operation and maintenance of those transmission lines, many access roads are already established. Such existing access roads would be used for the construction of the Project wherever possible. Where there is no existing access road or an identified sensitive cultural or environmental resource areas is present, a temporary access road would be installed. The on-ROW access roads expected to be used for the proposed Project are illustrated on the maps in Volume 5.

Most of the access roads would have to be improved, widened, or otherwise modified in order to be used safely and effectively during construction. For example, to safely support the heavy construction equipment (e.g., flat-bed trailers, cranes, drill rigs, and concrete trucks) required to install 115-kV transmission line structure foundations and structures, access roads must be sufficiently wide, with a stable base and grades that typically must be 10% or less.

Access road improvements typically include clearing adjacent vegetation and widening roads as needed to provide a minimal travel surface approximately 16 to 20 feet wide (additional width would be needed at turning or passing locations). Access roads will be graveled. Where access roads traverse streams or wetlands, culverts and timber mats (or equivalent) may be used. Existing culverted crossings may also be improved. Erosion and sedimentation controls would be installed as necessary before the commencement of any improvements to or development of access roads.

4.1.5.2 Off-ROW Access Roads

Along portions of the Proposed Route, terrain and environmental features (e.g., steep slopes, wetland complexes, East Swamp Brook, Limekiln Brook) make linear construction access along the ROW difficult or impractical. In such locations, to avoid or minimize adverse environmental effects while allowing safe access to the ROW, Eversource may use off-ROW access roads as necessary. Such off-ROW access roads will entail the use of public roads or access roads across private property.

Eversource performed an initial review of existing access roads leading to the transmission line ROW for the Project. Based on this initial review, an inventory of possible access roads was prepared. Table 4-2 lists the public roads that provide access to the transmission line ROW.

Table 4-2: Potential Public Road Access to ROW by Municipality

1”=400’ Aerial Mapsheet No. (Volume 5)	Existing Access to ROW via the following Town/City Streets or Sites
Bethel	
1 of 4	Shelter Rock Road
2 of 4	Payne Road
2 of 4	Hearthstone Drive
2 of 4	Chimney Drive
2 of 4	Sky Edge Lane
2 of 4	Stony Hill Road (US-6)
3 of 4	Research Drive
Danbury	
2 of 4	Payne Road
Brookfield	
3 of 4	Stony Hill Road

As planning for the Project continues and off-ROW access roads are further defined, some of the in-ROW access roads depicted on the Volume 5 maps may be modified or eliminated to minimize adverse effects on environmental resources (e.g., to avoid or minimize wetland crossings). Conversely, new access roads that optimize ingress and egress to the ROW may be identified. A detailed evaluation of the access roads required for construction would be conducted and included in the D&M Plans to be prepared for the Project.

4.1.5.3 Work Pads

Work pads would be required at each transmission line structure site, as well as at conductor and OPGW pulling sites and at locations where temporary road/rail guard structures are necessary during conductor installation.

At each transmission line structure site, a work pad is required to stage structure components for final on-site assembly and to provide a safe, level work base for the construction equipment used to install foundations and erect the structure. The size and configuration of the work pad at a particular line structure location would vary based on site-specific conditions; however, a typical pad for a tangent structure averages about 100 feet by 100 feet and for a deadend structure averages about 200 feet by 100 feet.

The preliminary location and configuration of the work pads, as determined based on the environmental field studies and constructability reviews conducted to date, are included on the Volume 5 maps. The exact locations and configurations of work pads would be determined during final Project design, based on site-specific conditions (e.g., to avoid or minimize work in wetlands or other environmentally- or culturally-sensitive areas). These final work pad locations would be illustrated in the D&M Plans.

A typical (upland) installation of a work pad at a structure location involves several steps, beginning with the removal of vegetation, if necessary. The work pad site then would be graded to create a level work area and, if necessary, the upper 3 to 6 inches of topsoil (which is typically unsuitable to support the necessary construction activities) would be removed. The topsoil would be temporarily stockpiled within the ROW, typically near the work pad. A rock base, which allows drainage, would be layered on top of filter fabric (if used). Additional layers of rock with dirt/rock fines are typically placed over this rock base. Finally, a roller typically is used to flatten and compact the pad.

Pulling work pads, which would be required in certain locations along the ROW for conductor and OPGW installation, typically will be 100 feet by 200 feet, but can be as large as 100 feet by 300 feet. Pulling work pads would be constructed using techniques similar to those for work pads at structure locations.

Guard structure work pads are typically required at road and other crossings to provide locations for guard structures or equipment used during conductor and OPGW installation. Typically, such temporary guard structure work pads are 50 feet by 80 feet, with an associated 16 to 20-foot-wide access road. In areas where work pads must unavoidably be located in wetlands, timber mats are typically used to construct the pads. After the completion of construction, all work pads or portions of work pads in wetlands (typically consisting of timber mats) would be removed and the affected wetlands would be restored, pursuant to Project permits and approvals. Guard structure pads and pulling pads also would be removed.

Upon completion of the transmission line installation, work pads at structure sites in uplands would remain in place, unless directed to be removed by the landowner. Work pads located within manicured or otherwise improved residential, commercial, or industrial areas would typically be removed unless the landowner requests that they remain in place.

Where work pads would remain in place, topsoil stripped from beneath the work pad and stockpiled nearby also typically would remain in place or be spread over nearby upland areas of the ROW and re-seeded. In locations where gravel work pads must be removed, the rock base and fabric materials would be excavated and removed for appropriate off-site disposal or re-use.

4.1.6 Structure Installation

4.1.6.1 Foundation Work (Foundation Types and Excavation)

The proposed new 115-kV transmission line structures would be either direct embedded or drilled shaft foundations. The tangent structures would typically be direct embedded. Angle and deadend structures would typically have a drilled shaft foundation. Excavations for line-structure foundations are expected to be accomplished using mechanical excavators (drill rigs) and pneumatic hammers. During non-working hours, fencing or other barricades would be placed around or over open foundation excavations for structures.

If blasting is required, a controlled drilling and blasting plan would be developed by a certified blasting contractor in compliance with state and local regulations. Residents would be contacted in advance of the blasting, and pre-blast surveys would be performed as appropriate. The specific locations where blasting would be required are determined by conducting field studies (borings) at the proposed structure locations.

4.1.6.2 Structure Placement

Structures would be delivered to installation locations in sections, then assembled and installed with a crane. Insulators and connecting hardware would be installed on most structures at this time. Supplemental grounding also would be installed on the new structures. Such grounding consists of a ground ring and sometimes counterpoise (i.e., buried conductors). The type of grounding required at each structure would depend on the electrical characteristics of the soil.

4.1.6.3 Conductor Work

The installation of overhead line conductors and shield wires requires the use of special pulling and tensioning equipment, which would be positioned at pre-determined locations at intervals of 1 to 3 miles. Helicopters also may be used to install the initial pulling lines at the commencement of the conductor / shield wire pulling process.

The wires would be pulled under tension to avoid contacting the ground and other objects. The remaining insulators and hardware would then be installed at angle and deadend structures. Finally, the conductors and shield wires would be pulled to their design tensions and attached to the hardware by linemen in bucket trucks in accordance with industry standards and design specifications.

Various pulling sites would be established along the approximately 3.4-mile transmission line route. These sites, which are typically approximately 100 feet wide and 100 to 300 feet long, are usually located within the ROW. Specific conductor pulling sites would be identified by the Project construction contractor, in consultation with Eversource.

The selection of conductor pulling sites is based upon a variety of factors including: accessibility, terrain, angles within the line sections where the conductors would be pulled, the locations of deadend structures (which keep installed conductors under high tension), the length of conductors and OPGW to be pulled, puller capacity, and snub structure[30] loads. Other considerations include the placement of pullers, tensioners, conductor anchors, and other associated pulling equipment, including the installation of a temporary grounding system. Along the Proposed Route, conductor pulling sites would be determined based on the consideration of these factors, the design load of the structures, and the avoidance or minimization of environmental effects.

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[30] A structure located at one end of a sag section and considered as a zero point for sagging and clipping offset calculations. A snub is a pole stub or log that is set or buried in the ground to serve as a temporary anchor. Snubs are often used at pull and tension sites.

Steps would be taken to minimize temporary disturbance to adjacent landowners from noise and activity associated with the pulling operation. In addition, conductor pulling sites would be located outside of wetlands, and would avoid other areas of environmental sensitivity to the extent practical.

4.1.7 Cleanup and Restoration

ROW cleanup and restoration activities would include the removal of construction debris, signs, flagging, and fencing, as well as the removal of temporary access roads and work pads. Areas affected by construction would be re-graded as practical and stabilized with vegetation or other measures before removing temporary erosion and sedimentation controls.

4.1.7.1 Final Grading, Revegetation, and Permanent Erosion and Sedimentation Controls

During final grading, areas of the ROW disturbed by construction and not otherwise occupied by permanent access roads or work pads, generally would be back-bladed to approximate preconstruction contours, where possible. Some areas (e.g., slopes, bluffs) affected by construction activities may not be fully restored to original contours. Such areas would be stabilized using methods consistent with consistent with the 2002 *Connecticut Guidelines for Soil Erosion and Sedimentation Control* guidelines and the BMP Manual and as warranted by site-specific conditions.

Temporary controls, such as water diversion bars or crushed stone, would be installed as appropriate to minimize the potential for erosion and sedimentation.

Where permanent access is not required across wetlands or streams, temporary crossings (e.g., timber mats, other temporary crossing materials such as rock) would be removed and the affected areas re-graded to match the grade of areas outside of the construction work zone, to the extent practicable.

Temporary erosion and sedimentation controls would be left in place and maintained until final stabilization is achieved. Steep areas may be stabilized with jute netting, pre-made erosion and sedimentation control fabric containing seed, mulch, and fertilizer or the equivalent.

Restoration typically is deemed successful based on the effectiveness of stabilization measures as defined in accordance with applicable permit and certificate requirements. Based on the results of inspections of ROW stabilization (refer to Section 4.1.9), Eversource would determine the appropriate time frame for removing temporary erosion controls.

Upland areas disturbed by construction activities typically would be seeded with appropriate seed mixes, as needed. Mulch or other erosion controls would be applied as necessary based on slope and land use. Wetland areas disturbed by construction would be reseeded with annual rye, or an equivalent native seed mix, which would serve to provide a temporary vegetative cover until wetland species become reestablished. No fertilizer, lime, or mulch would be applied in wetlands unless specified in regulatory approvals for the Project.

Vegetative species compatible with the use of the ROW for transmission line purposes are expected to regenerate naturally over time. Eversource would promote the re-growth of desirable species by implementing vegetation management practices to control tall-growing trees, and where practicable, undesirable woody invasive species, thereby enabling native plants to dominate the ROW. Vegetation management practices along the ROW also would conform to Project-specific conditions regarding habitat restoration and enhancement as may be included in approvals from the Council, Connecticut Department of Energy and Environmental Protection (CT DEEP), and the U.S. Army Corps of Engineers (USACE).

4.1.7.2 Permanent Access Roads and Work Pads

Access roads in uplands would be left in place to facilitate future transmission line maintenance. Structure work pads in uplands would be left in place, unless directed to be removed by the landowner. Access roads and work pads located within manicured or otherwise improved residential, commercial, or industrial areas would typically be removed unless the landowner requests that they remain in place. No new permanent access roads or work pads would be left in wetlands or streams unless approved by the involved regulatory agencies. The locations where permanent access roads and work pads will remain would be identified either in the D&M Plans or in the end-of-Project report to the Council.

4.1.7.3 Methods to Prevent or Discourage Unauthorized Use of the ROW

Eversource's existing transmission line easements restrict the types of activities that can be conducted within the ROW. Easements typically prohibit the construction of buildings, pools, and other structures within its ROWs. Additionally, Eversource has policies addressing requests from property owners and other parties external to Eversource. These policies outline an evaluation process and provide guidelines for allowing certain uses (such as driveways or parking lots), where appropriate.

In addition, Eversource routinely works with landowners to discourage unwarranted access onto and use of its ROWs, such as by third-party users of off-road vehicles such as all-terrain vehicles (ATVs) and snowmobiles. Where Eversource holds an easement rather than land ownership in fee, Eversource must receive landowner approval prior to installing barriers (such as fences, gates, and access control berms) to discourage such access onto its ROWs.

Pursuant to CGS Section 14-387, written landowner permission is required for the use of ATVs and snowmobiles on privately-owned property. Eversource does not grant permission for ATV or snowmobile use on its property or easements (other than for its own purposes), and seeks the cooperation of local police departments in discouraging these off-road vehicular uses along its ROWs. In addition, upon request, Eversource will provide landowners along the ROW with "no trespassing" signs for posting on their property and will install gates[31] or other barriers at public road crossings to deter unauthorized vehicular access along the ROW.

4.1.8 Traffic Considerations and Control

During the installation of the new transmission line, construction-related vehicular and equipment movements would occur on roads in the Project area. However, the Project-related traffic is generally expected to be temporary and highly localized in the vicinity of the ROW and staging areas. Due to phasing of construction work, these Project-related traffic movements are not expected to significantly affect transportation patterns or levels of service on public roads.

During the Project construction phase, vehicles and equipment also would enter and exit the ROW from various public roads. To safely move construction vehicles and equipment onto and off the ROW while minimizing disruptions to vehicular traffic along public roads, Eversource or its Project contractor would, as appropriate, work with representatives of the three affected municipalities and the Connecticut Department of Transportation (ConnDOT). The construction contractor is typically responsible for posting and maintaining construction warning signs along public roads near work sites and for coordinating the use of flaggers or police personnel to direct traffic, as necessary.

[31] Of the possible types of access barriers, Eversource typically prefers to install locking gates, which best allow company access to the ROW when needed. Typically, locked gates are installed along the ROW at public access points (e.g., public road crossings) to deter unauthorized off-road vehicular use.

4.1.9 Construction and Post-Construction Monitoring: D&M Plans

In accordance with the Council's requirements, after the certification of the Project, Eversource would prepare and submit for Council approval D&M Plans that would detail the procedures to be used to construct the proposed transmission facilities. The D&M Plans would incorporate the conditions of the Council's Certificate of Environmental Compatibility and Public Need (Certificate) for the Project, as well as the conditions of the permits received from other regulatory agencies, as appropriate.

Eversource would retain engineering and environmental professionals to monitor the conformance of construction activities to the D&M Plans, the Council's Certificate, other regulatory requirements, and Company standards.

After the completion of construction activities (including ROW restoration), Eversource would conduct periodic monitoring of the Project ROW pursuant to state and federal permits. The monitoring would continue until ROW revegetation or other forms of stabilization are determined to be successful, as defined by Project permits.

4.2 CONDITIONS REQUIRING SPECIAL CONSTRUCTION PROCEDURES

The Proposed Route extends across various wetlands and waterbodies. In some locations, the water table also is close to the surface, resulting in the potential for encountering groundwater in excavations for structure installations. Furthermore, the Proposed Route may traverse certain areas that may potentially contain contaminated soils or groundwater.

The following subsections describe the general construction procedures that Eversource would use for water resource crossings, blasting, soils / groundwater characterization and management, and construction site dewatering. Additional, site–specific procedures would be provided in the D&M Plans, as applicable, after the completion of a final Project design.

4.2.1 Water Resource Crossings

During the construction of the Project, Eversource proposes, to the extent practical, to avoid or limit work in watercourses (streams, rivers, ponds), and to minimize the placement of structures and permanent access roads in wetlands. In addition, Eversource would implement erosion and sedimentation controls in upland areas near water resources to limit the potential for upland erosion and sedimentation into water bodies or wetlands.

All construction activities involving water resources would be performed in accordance with the conditions of the Council's Certificate, as well as pursuant to the conditions of the Project-specific water resource permits issued by the CT DEEP and the USACE. In addition, construction activities would conform to Eversource's BMP Manual, as well as to the requirements of Project-specific plans (e.g., *Stormwater Pollution Control Plan*; *Wetland Invasive Species Control Plan*, *Spill Prevention and Response Plan*), which would be prepared prior to the commencement of construction.

The water resource permit conditions and related plans would be incorporated into the D&M Plans or similar Project documents. Eversource would require the construction contractor(s) to adhere to such conditions and plans during the construction of the Project facilities.

4.2.1.1 Wetlands

To minimize or avoid adverse effects to wetlands, Eversource has attempted to locate new transmission line structures in upland areas wherever practical. Eversource will avoid access roads across wetlands if there are practical upland alternative access routes available to reach the structure locations. Where new structures must unavoidably be located in wetlands, Eversource would limit the effects to the wetlands to the extent practical. Mitigation measures may include, for example, reducing the structure work pad size or configuring the work pad, if practical, to avoid or minimize the placement of temporary fill in wetlands.

In general, where a new structure must be located in a wetland, temporary timber mats would be used for construction support. In some wetland areas, however, field conditions (such as thickness of organics, depth of water or steep slopes) may require the use of a temporary crushed stone pad to provide a safe working surface. After the completion of structure installation, the temporary fill used for the work pads in wetlands would be removed, to the extent practicable and in accordance with the conditions of the Project-specific water resource permits issued by the CT DEEP and the USACE.

The wetland boundaries along the ROW would be clearly flagged prior to the commencement of work. When working in or traversing wetlands, Eversource would:

- Comply with the conditions of the Council's certificate and of federal and state permits related to wetlands;
- Install, inspect, and maintain erosion and sedimentation controls and other applicable construction best management practices;
- Conduct vegetation clearing in wetlands to minimize adverse effects such as by using low-impact equipment and installing temporary timber mats (or equivalent) to minimize rutting;
- Pile cut woody wetland or upland vegetation in upland areas so as not to block surface water flows within wetlands or otherwise to adversely affect the wetland integrity;
- Cut forested wetland vegetation without removing stumps unless it is determined that intact stumps pose a safety concern for the installation of structures, movement of equipment, or the safety of personnel;
- Limit grading for access roads and structure foundations in wetlands to the amount necessary to provide a safe workspace;
- Install temporary construction matting or geotextile and stone pads for access roads across wetlands or to establish safe and stable construction work pads within wetlands, where necessary. The type of stabilization measures to be used in wetlands would depend on soil saturation;
- Avoid or minimize access through wetlands to the extent practical. Where access roads must be improved or developed, the roads would be designed, where practical, so as not to interfere with surface water flow or the wetland functions;
- Install and maintain temporary erosion controls around work sites in or near wetlands to minimize the potential for erosion and sedimentation;
- Implement procedures for petroleum product management that would avoid or minimize the potential for spills into wetlands. For example, to the extent practical, store petroleum products in upland areas more than 25 feet from wetlands; refuel construction equipment, except for equipment that cannot be practically moved, in upland areas and if refueling must occur within a wetland, provide temporary containment. Similarly, except for equipment that cannot be practically moved (e.g., cranes), equipment would not typically be parked overnight on access roads or work pads in wetlands;
- Restore structure work sites in – and temporary access ways through – wetlands following the completion of line installation activities; and
- Restore wetlands, after transmission facility construction, to pre-construction configurations and contours to the extent practicable, and stabilize such areas by initial re-vegetation with annual ryegrass or native seed equivalent.

To provide new access across wetlands (where no access road currently exists), Eversource would either construct a new gravel and crushed stone access road underlain by geotextile fabric, or install a timber mat road. In wetlands where there is a deep organic layer or the wetlands are prone to extended inundation, the crushed stone access roads would remain in place permanently to provide a firm base for future access to the transmission facilities. The surficial fill materials used to construct the access roads would be removed down to the pre-construction elevation so as to not interfere with the wetland surface hydrology. The underlying material serves as either a firm base for equipment access or for the future placement of temporary timber mats to cross these larger wetland systems. Eversource anticipates this practice of establishing a permanent “access road base” may occur in some wetland systems. All other timber mat or gravel access roads would be removed in their entirety after construction.

4.2.1.2 Waterbodies

Eversource proposes to avoid direct construction work in watercourses to the extent feasible and to limit the potential for effects associated with erosion, sedimentation, or spills into streams, rivers, and ponds from construction activities. The proposed transmission line conductors would span all major watercourses, and no transmission line structures are proposed for location in waterbodies. However, temporary and possibly permanent access would be required (i.e., use of existing access roads or creation of new access roads) across some of the smaller streams along the ROW.

In contrast, temporary access across streams along the ROW would be required. However, the installation of new access roads for construction equipment crossings would be minimized to the extent practical. Whenever possible, equipment would use existing (permanent) culverted access roads to traverse watercourses. As part of pre-construction planning, Eversource would conduct integrity inspections of the existing culverted access roads.

Alternatively, temporary bridges consisting of timber mats, metal bridges, or equivalent may be used for equipment stream crossings. The temporary bridges would be installed and removed to limit or avoid direct effects to banks and stream-bottom sediments.

Where practical at stream crossings, vegetation removal will be limited to that necessary for the safe construction and operation of the transmission facilities. If possible, vegetation removal near streams would be performed selectively, preserving desirable streamside vegetation within a 25-foot-wide riparian zone adjacent to either stream bank for habitat enhancement, shading, bank stabilization, and erosion/sedimentation control.

Eversource would take the following actions for construction activities across or near watercourses:

- Where existing access roads crossing stream bottoms must be improved, clean materials would be used (e.g., clean riprap or equivalent, rock fords). To the extent possible, the improvement of existing access roads across streams supporting fishery resources would be scheduled to avoid conflicts with fish spawning/migration;
- Water flows (if water is present at the time of construction) would be unconstrained throughout construction; and
- Concrete would not be mixed, placed, or disposed of so as to create the potential to enter a watercourse.

4.2.1.3 Vernal Pools

No vernal pools are present along the ROW or in the immediate vicinity.

4.2.1.4 Floodplain and Floodway

A portion of the Project is located within the 100-year flood zone/floodway of Limekiln Brook and the East Swamp Brook. Structures 1000-1008 and 1010-1012 are proposed in the zone. Of those 12 structures within the 100-year floodplain, five are also located in the Floodway (1004, 1006-1008, and 1011). All construction activities within the floodzone or Floodway would be performed in accordance with the conditions of the Council's Certificate, as well as pursuant to the conditions of the Project-specific water resource permits issued by the CT DEEP and the USACE.

The Company would utilize the BMPs to minimize any impacts in these areas including the use of timber mats for access in floodplains/Floodway to ensure that hydrology is not affected. Prior to significant storm events, Eversource will secure the timber mats to impede lateral movement during temporary flooding. All timber mats would be removed after the Project is complete. Areas of disturbance would be promptly stabilized in order to minimize the potential for soil erosion and the flow of sediments into nearby resource areas.

4.2.2 Blasting

If blasting is necessary (e.g., for access, word pads, structure foundations), Eversource would take the following steps:

- A certified blasting specialist would develop site-specific blasting procedures, taking into account geologic conditions and nearby structures, and ensuring compliance with state regulations;
- The blasting plan would be provided to the local Fire Marshal for approval. Blasting charges would be designed to loosen only the material that must be removed to provide a stable foundation, and to avoid fracturing other rock;
- Eversource would seek to meet with each property owner in proximity to the blasting to explain where and when the blasting is expected to occur, and why blasting is necessary;
- Pre-blast surveys, to document existing conditions, would be conducted for any property within a specified distance of the area where blasting is to occur. This distance would be determined by Eversource's blasting contractor, in consultation with the Fire Marshal, and with Eversource's approval;
- The areas where blasting is to occur would be covered with heavy blanketing materials and charges would be sized appropriately;
- Seismographs would measure each blast to confirm that levels are within prescribed limits; and
- Excavated material that cannot otherwise be used at the site would be removed and properly disposed of elsewhere, pursuant to Project specifications.

4.2.3 Soils and Groundwater Testing and Management

4.2.3.1 Pre-Construction Studies and Plans

Soils and groundwater will be managed in accordance with applicable state regulations during the construction of the Project. As part of the final Project design, Eversource would implement specific plans for characterizing the soils and groundwater (i.e., presence/absence of contaminants) along the ROW, and subsequently for handling and managing such materials during construction. These plans would be developed based upon the results of a due diligence review of existing data regarding the current and historical uses of areas along the ROW, properties along the ROW, and nearby off-site sources. The scope of the due diligence work would comply with Sections 8.1 and 8.2 of the American Society for Testing and Materials (ASTM) Standard E1527-05. The objective of the work would be to identify known locations of potential past or current contamination sources, such as leaking underground storage tanks, sites designated as hazardous by federal or state government, and locations of reported spills of petroleum products or hazardous material, etc.

For soil and groundwater testing and management, Eversource would conform to the guidance issued by the CT DEEP for Utility Company Excavation. This guidance applies to cases where contaminated soils / waste are encountered during construction or maintenance activities on property not owned by the utility and the contamination was not created by the utility. The utility may reuse the contaminated soil in the same excavation, within the same area of concern, without prior approval by CT DEEP provided:

- Any condition that would be a significant environmental hazard, as defined in CGS Section 22a-6(u), is reported by the utility and that the location is identified on a map submitted to the CT DEEP Remediation Division;
- Any excess contaminated material is disposed of appropriately in accordance with solid and hazardous waste regulations; and
- The upper 1 foot of the excavation is filled with clean fill material or paved.

Construction contractors would be required to conform to CT DEEP requirements and to any Project-specific material handling plans.

4.2.3.2 Soils / Groundwater Handling and Management

The approach used to handle and manage soils disturbed by construction activities would depend on whether or not contamination is present, as determined by the due diligence work described in Section 4.2.3.1.

If the results of investigations indicate that contaminants may exceed acceptable concentrations, Eversource typically would prepare material handling guidelines, or equivalent, to assist the Contractor in properly handling and disposing potentially impacted soils or groundwater. Material handling guidelines would be implemented in areas where the excavation of potentially contaminated soils or the dewatering of potentially contaminated groundwater may be necessary during Project construction and would detail the procedures that would be followed to properly handle and manage such materials in order to minimize exposure to the general public and environmental receptors.

Excavated materials to be transported from the ROW would be loaded directly onto trucks for off-site disposal at an appropriate facility, or stockpiled temporarily on-site or at a permitted facility before being disposed at a permanent facility. Soil transported from the ROW would be transported under a Bill of Lading or a Hazardous Waste Manifest, as appropriate. These soils would be disposed of in accordance with the applicable federal, state and local regulations.

4.2.4 Groundwater and Construction Site Dewatering

Neither the construction nor the operation of the Project is expected to result in adverse effects on groundwater resources or public water supplies. During construction, care would be taken to avoid effects to municipal water lines that may be located within road ROWs or that otherwise extend across the transmission line ROW.

If groundwater is encountered during excavations for transmission line structure foundations, the water would be pumped from the excavated areas and discharged in accordance with applicable local and state requirements. Depending on regulatory authorizations, the water may be discharged on-site into an appropriate sediment control basin/filter bag or directly into municipal storm water catch basins, if available. Proper catch-basin inlet protection would be installed as needed to prevent disturbed soils excavate and construction debris from entering storm water systems.

Contaminated groundwater; if encountered, may require treatment before being discharged to either the storm water or municipal sanitary sewer system. Contaminated groundwater may also be pumped into a temporary fractionization (frac) tank and then pumped into a tanker truck for disposal at appropriate wastewater treatment facilities. Residual silt/sediment collected at the bottom of the frac tanks would be disposed off-site at an appropriately designated disposal facility.

4.3 CONSTRUCTION PROCEDURES FOR STONY HILL SUBSTATION AND RELATED TRANSMISSION LINE MODIFICATIONS

4.3.1 Overview of Proposed Construction

The proposed Project will involve modifications to Eversource's Stony Hill Substation and to the configuration of the existing 1770 and 1887 lines at the substation. This section summarizes the basic construction activities and methods of construction for these proposed modifications. More detailed construction requirements and, as appropriate, environmental mitigation measures, may be defined during the Council's Project review process.

4.3.2 Site Preparation

The site preparation work required for the Stony Hill Substation and related line modifications would involve the following typical tasks, the sequence of which may vary slightly during actual construction activities:

- Establish construction office and material staging sites (likely on the existing substation property)
- Install and maintain, as necessary, temporary soil erosion and sedimentation controls (e.g., silt fence, hay/straw bales) around areas of planned soil disturbance
- Remove minimal vegetation (if present) from work areas and equipment staging locations
- Create or improve temporary access to work sites for heavy construction equipment
- Grade (rough), if necessary, to create level work areas
- Excavate unsuitable soils
- Install protective fencing around work sites

Site preparation work typically could involve the use of construction equipment such as bulldozers, backhoes, man-lift vehicles, compressors, trucks (various sizes), a large capacity crane (e.g., 100-ton), and flat-bed trailers.

4.3.3 Foundations and Equipment Installation

The foundation installation process, for both direct bury and concrete caisson foundations, generally involve excavation, form work, use of steel reinforcement, and concrete placement. Excavated material would either be reused on-site or disposed of off-site in accordance with applicable requirements.

If groundwater is encountered in excavations, the procedures described in Section 4.2.4 would be followed. Similarly, if contaminated soils are encountered, the procedures summarized in Section 4.2.3.1 would be followed.

After the foundations are installed, construction activities would shift to the erection of structures and equipment as specified for each station modification. Such structures and equipment include steel structures, bus and insulators, circuit breakers, switches, voltage transformers, lightning masts, relay / control enclosures or expansion of existing enclosures, cable trench, ground grid, surge arresters, conduits and cables.

4.3.4 Structure Removal

After removal of the existing conductors, shield wires, and insulators, the three existing structures would be removed and would then be properly disposed of or recycled. The equipment required for these activities would be generally the same as required for installing the new structures, as described in Section 4.1.

4.3.5 Testing and Interconnections

New structures and associated conductors and wires would be installed, as necessary, to connect the new 115-kV facilities at the substation. All of the substation equipment would be tested and commissioned prior to final connection to the transmission grid.

4.3.6 Final Cleanup, Site Security, and Landscaping

After the completion of construction, any remaining construction debris would be collected and removed from the station sites. Temporary erosion controls would be maintained until the disturbed areas are satisfactorily stabilized.

Because the proposed Project modifications would be within the developed (fenced) area at Stony Hill Substation, landscaping is not expected to be warranted.

4.4 OPERATION AND MAINTENANCE PROCEDURES

4.4.1 ROW Vegetation Management

Eversource's long-term vegetation management program includes the selective removal of targeted species (e.g., tall growing trees and selected state-listed invasive woody shrubs) within the portions of its ROWs occupied by transmission lines. In addition to tree removal within the ROW, hazard trees adjacent to the managed ROW that could fall onto a conductor will be trimmed or removed. Brush control within Eversource's ROWs is performed every four years, and side trimming (i.e., removal of trees or tree limbs that encroach along the edge of the managed ROW) is performed every 10 years. All work is performed in accordance with Eversource's *Specification for Rights-of-Way Vegetation Management (2015)*.

In addition, based on recent experience in the development of other new transmission line facilities, Eversource anticipates that a *Wetland Invasive Species Control Plan*, or similar documentation of an approach for the control of invasive species in wetlands along the ROW, would be required for the Project.

If required, a *Wetland Invasive Species Control Plan* (or equivalent) would be developed after consultations with the USACE, CT DEEP, and other involved agencies regarding the types of wetland invasive species to be targeted for control along the Project ROW and the overall objectives of the control program. Typically, the *Wetland Invasive Species Control Plan* is prepared as part of Eversource's regulatory applications to the USACE and CT DEEP.

4.4.2 Substation Maintenance

The proposed Project modifications to the Stony Hill Substation and the nearby 1770 and 1887 lines would not substantially affect or alter existing maintenance practices.

4.4.3 Compliance with Applicable Codes and Standards

The proposed Project would be constructed in full compliance with the National Electrical Safety Code (NESC), standards of the Institute of Electrical and Electronic Engineers (IEEE) and the American National Standards Institute (ANSI), good utility practice, and the CT DEEP PURA regulations covering the method and manner of high voltage line construction.

4.4.3.1 Emergency Operations and Shutdown

If a transmission line experiences an insulation or conductor failure, then protective relaying would immediately remove the line from service, thereby protecting the public and the line. If equipment at the substations experiences a failure, then protective relaying would immediately remove the equipment from service, thereby protecting the public and the equipment within the substations.

Protective relaying equipment would be incorporated into the Project design to automatically detect abnormal system conditions and send a protective trip signal to the respective circuit breaker(s) at each end of a line to isolate the faulted section of the transmission system. The protective relaying schemes include fully redundant primary and backup equipment. This ensures that if a line or station equipment failure were to occur at a time when one of the protective relaying schemes fails or is removed from service for maintenance, the redundant protective relaying scheme would initiate the removal from service of the faulted transmission facility being monitored.

Fiber optic strands will be installed within the lightning shield wires above the overhead line. These strands provide a robust and reliable communications path for the protective relaying systems. Additionally, the overhead transmission line facilities may also provide for electronic communications between substations using signals impressed upon line conductors (carrier signal) for protective relaying and operations.

4.4.3.2 Fire Suppression Technology

A smoke detection system is already in place in the existing relay and control enclosure at Plumtree and at Stony Hill substations.

4.4.4 Security of Facilities

Pursuant to Section VI.N.4 of the Council's A*pplication Guide*, a description of siting security measures for the proposed Project facilities, consistent with the Council's "White Paper on the Security of Siting Energy Facilities," will be prepared. This facilities security description will be included in the Application.

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5. DESCRIPTION OF EXISTING ENVIRONMENT

This section describes the existing environment and cultural resources along, and in the vicinity of, the proposed Project. Existing environmental and cultural conditions are discussed in detail for areas in the vicinity of the proposed new 115-kV transmission line, including the terminal points at Plumtree Substation and Brookfield Junction (Section 5.1), and in the vicinity of the proposed upgrades to the existing Stony Hill Substation (Section 5.2). The information concerning these existing environmental and cultural features reflects the results of baseline desktop reviews of resource areas, as well as field investigations conducted along the Project ROW in 2015 and 2016.

Two sets of aerial photography based maps are provided in Volume 5 depicting the environmental and cultural conditions along the Proposed Route: 400-scale maps show the proposed Project facilities in relation to environmental features in the surrounding areas, whereas the 100-scale maps provide a closer view of the conditions in the intermediate vicinity of the proposed Project facilities. The principal environmental conditions, land use features, and natural resources shown on the Project maps include, but are not limited to:

- Location of the existing Plumtree Substation, Brookfield Junction, and Stony Hill Substation;
- Location of the existing and proposed features such as the transmission line ROW, transmission line structures, access roads, and work pads;
- Location of Eversource fee-owned properties;
- Vegetative cover types;
- Topography;
- Land uses including agricultural, residential, commercial, and industrial areas;
- Municipal boundaries;
- Municipal zoning classifications;
- Federal and State jurisdictional wetlands delineated within the ROW;
- Water resources, including streams, rivers, and ponds; [32]

[32] No vernal pools were identified in the vicinity of the proposed Project.

- Floodplains as designated by the Federal Emergency Management Agency ([FEMA]; Special Flood Hazard Areas[33] and the Regulatory Floodway[34]);
- Public recreational, scenic, open space, and other protected areas, including forests, parks, water supply areas, hunting/wildlife management areas, and designated recreational trails;
- Schools and community facilities; and,
- Existing infrastructure including roads, utility corridors and railroads.

5.1 PROPOSED ROUTE: PLUMTREE SUBSTATION TO BROOKFIELD JUNCTION

The Proposed Route traverses approximately 3.4 miles in a general northerly to northeasterly direction, extending between Eversource's existing Plumtree Substation and Brookfield Junction. The Proposed Route is located within an existing Eversource ROW and the new 115-kV line would be aligned adjacent to an existing 115/345-kV double circuit line, through portions of the municipalities of Bethel, Danbury, and Brookfield in Fairfield County.

5.1.1 Topography, Geology and Soils

The information presented in this section is based on analyses of existing published information and – in the case of soils – field investigations conducted as part of wetland surveys. Prior to final Project engineering design, additional investigations will be performed in some areas along the Proposed Route to further characterize the physical and structural characteristics of the subsurface geologic features. The results of such investigations would be used in the design of structure foundations.

5.1.1.1 Topography

The Proposed Route is situated mostly within the Southern Marble Valley physiographic region of Connecticut (Dowhan 1976).[35] This region is characterized by metamorphosed limestone and marble overlain by glacial drift comprised of sand, silt, and boulders left by receding glaciers. The areas on either side of the Marble Valley are comprised of the Southwest Hills physiographic region, which is characterized

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33 Special Flood Hazard Areas are defined as the area that will be inundated by the flood event having a 1% chance of being equaled or exceeded in any given year. The 1% annual chance flood is also referred to as the 100-year flood.

34 Regulatory Floodways are defined as the channel of a river or other watercourse and the adjacent land areas that muse be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height. The Floodway represents the areas with deepest and fastest discharge rates during the 100-year flood event.

35 Dowhan, J.J., and R.J. Craig. 1976. *Rare and Endangered Species of Connecticut and Their Habitats.* State Geological and Natural History Survey of Connecticut, Department of Environmental Protection. Report of Investigations No. 6. 137 p.

by Dowhan as "low, rolling to locally rugged hills of moderate elevation, broad areas of upland, and local areas of steep rugged topography." Elevations along the Proposed Route range from approximately 300 feet near Plumtree Substation to about 520 feet near the midpoint of the Proposed Route on a hill south of US Route 6 in Bethel. The lower elevations along the Proposed Route, between Plumtree Substation and existing double-circuit Structure 10260, are present within wetlands associated with East Swamp Brook and Limekiln Brook in the Town of Bethel and City of Danbury.

The Proposed Route does not traverse any traprock ridge[36] or amphibolite ridge[37] areas as specified in Connecticut General Statutes (CGS) § 8-1aa (1) and no such geologic formations are located within the Project area towns. Following Eversource's existing ROW, the Proposed Route generally does not parallel ridgelines.[38]

5.1.1.2 Geology

Connecticut's bedrock geology has a direct effect on landscape forms due to differing resistances to weathering and erosion. Bedrock geologic mapping indicates that the Proposed Route is situated within the Carbonate Shelf Terrane from Plumtree Substation to Payne Road and within the Connecticut Valley Terrane north of Payne Road to the Brookfield Junction. Both formations are divided by the Cameron's Line Fault, which crosses the Proposed Route in a southwest to northeast alignment between existing double-circuit structures 10260 and 10259 in Danbury.

The Connecticut Valley Terrane is a geologic formation, which consists of metamorphosed sedimentary and igneous rocks, particularly schist and gneiss of the Hartland and Gneiss Dome Belts.[39] The Carbonate Shelf Terrane is a geologic formation composed of marble, schist, and quartzite of a continental shelf

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36 According to definitions provided in the CGS, Chapter 124, § 8-1aa, "traprock ridge" means Beacon Hill, Saltonstall Mountain, Totoket Mountain, Pistapaug Mountain, Fowler Mountain, Beseck Mountain, Higby Mountain, Chauncey Peak, Lamentation Mountain, Cathole Mountain, South Mountain, East Peak, West Peak, Short Mountain, Ragged Mountain, Bradley Mountain, Pinnacle Rock, Rattlesnake Mountain, Talcott Mountain, Hatchett Hill, Peak Mountain, West Suffield Mountain, Cedar Mountain, East Rock, Mount Sanford, Prospect Ridge, Peck Mountain, West Rock, Sleeping Giant, Pond Ledge Hill, Onion Mountain, The Sugarloaf, The Hedgehog, West Mountains, The Knolls, Barndoor Hills, Stony Hill, Manitook Mountain, Rattlesnake Hill, Durkee Hill, East Hill, Rag Land, Bear Hill, Orenaug Hills.

37 According to definitions provided CGS § 8-1aa, "amphibolite ridge" means Huckleberry Hill, East Hill, Ratlum Hill, Mount Hoar, Sweetheart Mountain.

38 According to definitions provided in CGS § 8-1aa, "ridgeline" means the line on a traprock or amphibolite ridge created by all points at the top of a 50% slope, which is maintained for a distance of 50 horizontal feet perpendicular to the slope and which consists of surficial basalt geology, identified on the map prepared by Stone et al., United States Geological Survey, entitled "Surficial Materials Map of Connecticut".

39 Rodgers, J. 1985. Bedrock Geologic Map of Connecticut. Connecticut Geological and Natural History Survey, CT Department of Environmental Protection. Hartford CT. 1:125,000.

sequence. All of the emergent swamps associated with East Swamp Brook and Limekiln Brook (W1) are located within the Carbonate Shelf.

The predominant surficial geology in the vicinity of the southern portion of the Proposed Route is represented by natural postglacial deposits. Within the Limekiln Brook and East Swamp Brook wetland complex (which extends from Plumtree Substation to the vicinity of Shelter Rock Road), surficial geology is composed of swamp deposits that overlay sand or sand and gravel glacial outwash deposits. Farther north along the ROW (near Shelter Rock Road in Bethel), these deposits transition to swamp deposits over fine (i.e., very fine sand, silt and clay) outwash deposits. Deposits transition to sand overlying sand and gravel between existing 321/1770 Line Structure 10261 and Old Sherman Turnpike in the City of Danbury. Glacial outwash deposits, typically characterized by stratified sand and gravel, were derived from meltwater steams flowing from retreating glacial ice.

From Old Sherman Turnpike to Brookfield Junction, the ROW crosses areas where surficial deposits alternate between shallow and thick glacial ice-laid till deposits. Where these deposits are present, the slopes and outline of the landform generally reflect the form of the underlying bedrock, which is draped by a shallow mantle of till. Thin till is characterized by 10-15 feet of loose to moderately compact, generally sandy and commonly stony till over bedrock. Thick till deposits occur where glacial ice overriding the land surface pushed up rounded hills oriented along the localized travel direction of the last continental ice sheet. These rounded hills, or drumlins, generally have till depths exceeding 15 feet and depths of 100 feet are not uncommon[40] and are composed of an upper (surficial) and lower till. The lower till is typically moderately to very compact and is commonly finer grained and less stony than the surficial upper till.

Gravel and fine deposits from glacial meltwaters, composed of coarse deposits of gravel, which includes gravel to boulder-sized particles with minor amounts of sand in separate layers, are also found in isolated locations along the Proposed Route. Specifically, gravel deposits are present in the southwest of existing double-circuit Structure 10267 and along portions of the ROW between Sky Edge Lane and to Stony Hill Road (U.S. Route 6) in Bethel. Fine deposits, composed of well-sorted, thin layers of alternating silt and clay, or thicker layers of very fine sand and silt, are predominant from Berkshire Boulevard in Bethel, north to the Bethel-Brookfield border.

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[40] Melvin, R.L., Stone, B.D., Stone, J.R., and N.J. Trask. 1992. *Hydrogeology of Thick Till Deposits in Connecticut*. U.S. Geological Survey Open-File Report. p. 92-43.

5.1.1.3 Soils

Information regarding the soils along the Proposed Route was obtained from on-line soil surveys and maps published by the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS).[41] These surveys and maps provide soil classifications and characteristics, including depth to bedrock, slope, drainage, and erosion potential. Table 5-1 summarizes the principal soil associations, as identified by the NRCS along and in the general vicinity of the Proposed Route.

The table also identifies soils classified by the NRCS as "Prime Farmland" soils or "Farmlands of Statewide Importance." Soil classifications designated as Prime Farmland and Farmland of Statewide Importance are present along the Propose Route, however no lands along or adjacent to the Proposed Route are currently being used for agricultural purposes.

The baseline soils information obtained from the NRCS maps and surveys is a supplement to the field investigations that are required to identify Connecticut wetlands, which are defined based on the presence of poorly drained, very poorly drained, or floodplain soils. Wetlands along the Proposed Route were delineated by registered professional soil and wetland scientists, working along with biologists, as part of field studies conducted along the ROW in the April and May of 2015. Refer to Section 5.1.2 and Volume 2 for information regarding the wetlands along the Proposed Route.

5.1.2 Water Resources

Water resources along the existing Eversource ROW include inland wetlands, watercourses (intermittent and perennial streams and rivers), and waterbodies (ponds), as well as groundwater resources, including public water supplies. The ROW also extends across FEMA-designated 100-year floodplain and the regulatory Floodway associated with East Swamp Brook and Limekiln Brook. To identify water resources along the Proposed Route, Eversource commissioned both baseline research to identify Project area water resources, and field investigations to delineate state and federal wetlands and watercourses.

In the April and May of 2015, Eversource's consultants delineated water resource areas along the Proposed Route. Consultants delineated water resources along the entire width of the existing Eversource ROW between Plumtree Substation and Brookfield Junction. The new 115-kV transmission line would be located principally along the eastern portion of this ROW.

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[41] Web Soil Survey, accessed 2015.

Table 5-1: Soils and Soil Characteristics Along the Proposed Route[1]

Soil Map Unit		Parent Material	Hydric Soil	Depth to Restrictive Feature (inches)[3]	Depth to Water Table (inches)[3]	Hazard of – Off-Road or Off-Trail Erosion
Symbol	Name					
3	Ridgebury, Leicester, and Whitman soils, extremely stony	Coarse-loamy lodgment till derived from granite and/or schist and/or gneiss; or coarse-loamy melt-out till derived from granite and/or schist and/or gneiss.	Yes	12-30 to Dense material	0-18	Slight
12	Raypol silt loam[2]	Coarse-loamy eolian deposits over sandy and gravelly glaciofluvial deposits derived from granite and/or schist and/or gneiss.	Yes	—	0-12	Slight
17	Timakwa and Natchaug soils	Woody organic material over sandy and gravelly glaciofluvial deposits; Woody organic material over loamy alluvium and/or loamy glaciofluvial deposits and/or loamy till.	Yes	—	0-12	Very Severe
18	Catden and Freetown soils	Woody organic material; organic material.	Yes	—	0-12	Very Severe
21A	Ninigret and Tisbury soils, 0 to 5 percent slopes[1]	Coarse-loamy eolian deposits over sandy and gravelly glaciofluvial deposits derived from granite and/or schist and/or gneiss; Coarse-silty eolian deposits over sandy and gravelly glaciofluvial deposits derived from granite and/or schist and/or gneiss.	No	—	18-30	Slight
38C	Hinckley gravelly sandy loam, 3 to 15 percent slopes[2]	Sandy and gravelly glaciofluvial deposits derived from granite and/or schist and/or gneiss.	No	—	>80	Slight
62D	Canton and Charlton soils, 15 to 35 percent slopes, extremely stony	Coarse-loamy over sandy and gravelly melt-out till derived from granite and/or schist and/or gneiss; Coarse-loamy melt-out till derived from granite and/or schist and/or gneiss.	No	—	>80	Moderate
73C	Charlton-Chatfield complex, 3 to 15 percent slopes, very rocky	Coarse-loamy melt-out till derived from granite and/or schist and/or gneiss.	No	20-40 to Lithic bedrock	>80	Slight
75E	Hollis-Chatfield-Rock outcrop complex, 15 to 45 percent slopes	Loamy melt-out till derived from granite and/or schist and/or gneiss; Coarse-loamy melt-out till derived from granite and/or schist and/or gneiss.	No	0-40 to Lithic bedrock	>80	Moderate
84B	Paxton and Montauk fine sandy loams, 3 to 8 percent slopes[1]	Coarse-loamy lodgment till derived from granite and/or schist and/or gneiss; Coarse-loamy lodgment till derived from granite and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from granite.	No	20-43 to Dense material	18-37	Slight

Table 5-1: Soils and Soil Characteristics Along the Proposed Route[1]

Soil Map Unit		Parent Material	Hydric Soil	Depth to Restrictive Feature (inches)[3]	Depth to Water Table (inches)[3]	Hazard of – Off-Road or Off-Trail Erosion
Symbol	Name					
84C	Paxton and Montauk fine sandy loams, 8 to 15 percent slopes[2]	Coarse-loamy lodgment till derived from granite and/or schist and/or gneiss; Coarse-loamy lodgment till derived from granite and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from granite.	No	20-43 to Dense material	18-37	Slight
84D	Paxton and Montauk fine sandy loams, 15 to 25 percent slopes	Coarse-loamy lodgment till derived from granite and/or schist and/or gneiss; Coarse-loamy lodgment till derived from granite and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from granite.	No	20-43 to Dense material	18-37	Moderate
86D	Paxton and Montauk fine sandy loams, 15 to 35 percent slopes, extremely stony	Coarse-loamy lodgment till derived from granite and/or schist and/or gneiss; Coarse-loamy lodgment till derived from granite and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from gneiss and/or coarse-loamy lodgment till derived from granite.	No	20-43 to Dense material	18-37	Moderate
108	Saco silt loam	Coarse-silty alluvium.	Yes	—	0-6	Slight
238C	Hinckley-urban land complex, 3 to 15 percent slopes	Sandy and gravelly glaciofluvial deposits derived from granite and/ or schist and/or gneiss	No	—	>80	Slight
284B	Paxton-Urban land complex, 3 to 8 percent slopes	Coarse-loamy lodgment till derived from gneiss, granite, and/or schist	No	20-39 to Dense material	18-37	Slight
305	Udorthents-Pits complex, gravelly	Gravelly outwash.	No	—	24-54	Moderate/ Severe
306	Udorthents-Urban land complex	Drift.	No	—	54-72	Moderate
307	Urban land	Miscellaneous area.	No	—	—	Moderate
308	Udorthents, smoothed	Drift.	No	—	24-54	Moderate
W	Water	Miscellaneous area.	Yes	—	0	—

Source: USDA Natural Resources Conservation Service, Online Soil Surveys, Geographic Data and Soil Data Mart information of Fairfield, accessed December 2015.

[1] Soils classified as Prime Farmland Soils.
[2] Soils classified as Farmland Soils of Statewide Importance.
[3] '—' No Data Given. No restrictive features or water encountered to survey depth.

During the delineations, wetlands and watercourses were field-demarcated using numbered flagging. These boundary flags were subsequently surveyed using a Trimble Global Positioning System (GPS) unit. Water resource areas are depicted on the Volume 5 maps, discussed in the following subsections and described in detail in the *Wetlands and Watercourses Report* in Volume 2.

Delineated wetlands and streams along the Project Route were numbered sequentially with an alpha-numerical label (e.g. W1, W2, … and S1, S2, …) from south to north starting at Plumtree Substation and ending at Brookfield Junction. The one waterbody, an unnamed pond, is labelled as WB-1, independent from the stream and wetland series numbering convention.

5.1.2.1 Drainage Basins, Waterbodies and Water Quality

Connecticut is divided geographically into eight major drainage basins and 45 regional basins. The Proposed Route is located in portions of the Housatonic (major) drainage basin. This basin is characterized by watercourses that flow into the Housatonic River, which flows in a south to southeasterly direction from western Massachusetts, through Connecticut, and discharges into Long Island Sound at Milford Point, Connecticut. The Proposed Route is located within the Still River regional drainage basin. Originating at Sanford's Pond in Danbury, in the vicinity of the New York border, the Still River flows northeast to its confluence with the Housatonic River in New Milford.

CT DEEP maintains detailed water resources information concerning the drainage basins in Connecticut and promotes watershed management efforts to improve water quality. As a central element of the state's clean water program, CT DEEP also has established Water Quality Standards and Classifications, which identify the water quality management objectives for each waterbody.

Overall, Connecticut's water quality policies are established to protect surface and groundwater from degradation; restore degraded surface waters to conditions suitable for fishing and swimming; restore degraded surface and groundwater to protect existing and designated uses; and to provide a framework for establishing priorities for pollution abatement. The use goals that the state has established for surface waters and groundwater are summarized in Table 5-2.

Table 5-2: Summary of Connecticut Water Use Goals[1]

Water Resource	Classification Use Description
Surface Waters	
Class AA	Public water supply, fish and wildlife habitat, recreation.
Class A	Potential public water supply, fish and wildlife habitat, recreation, industrial water supply, agricultural water supply.
Class B	Fish and wildlife habitat, recreation, industrial water supply, agricultural water supply, discharge of treated wastewaters.
Class C, D	Goal is Class B. Impaired water quality affecting one or more Class B uses.
Ground Waters	
Class GAA	Public water supply.
Class GAAs	Existing or potential public supply, stream base flow industrial and miscellaneous, tributary to a public reservoir. Natural quality, or suitable for drinking
Class GA	Existing private water supply and potential public water supply suitable for drinking without treatment.
Class GB	Industrial water supply and miscellaneous non-drinking supply.
Class GC	Assimilation of wastes, such as landfill leachate.

[1]Water Quality Classifications. CT DEEP, November 2015.

The Proposed Route crosses eight watercourses (including waterbodies and a stormwater conveyance), all in Bethel or Danbury. Of these, four are perennial watercourses; one is a perennial pond; two are intermittent watercourses; and one is a riprap-lined stormwater conveyance channel. Table 5-3 summarizes the major characteristics, including surface water classifications, of the delineated watercourses and waterbodies along the Proposed Route. No vernal pools were identified along or near the Project Route.

Two of the four perennial watercourses, East Swamp Brook and Limekiln Brook, are associated with the same wetland complex (W1) located along the southern portion of the Proposed Route. The channels of these two watercourses vary in width from approximately 6 to 25 feet. East Swamp Brook meanders through the ROW from existing Structure 10268 to Structure 10264, near its confluence with Limekiln Brook. In the Project area, Limekiln Brook crosses undeveloped areas on the eastern portion of Eversource's property near Plumtree Substation and then flows northerly, generally parallel to and east of the existing Eversource ROW. Limekiln Brook crosses the ROW once, south of existing Structure 10261. The two other perennial watercourses located along the Proposed Route are un-named and are approximately 6-10 feet wide. None of these perennial watercourses meet the criteria for federal designation as navigable[42] pursuant to Section 10 of the Rivers and Harbors Act of 1899.

Table 5-3: Watercourses and Waterbodies along the Proposed Route

Volume 5 Mapsheet #		Municipality (s)	Waterbody/ Watercourse		Associated Wetland	Flow Regime	Water Quality Classification[1]	Approximate Width (feet)
100' Scale	400' Scale		ID	Name				
2-4	1	Bethel, Danbury	S1	East Swamp Brook	W1	Perennial	A	10-15
1,4-6	1-2	Bethel, Danbury	S2	Limekiln Brook	W1	Perennial	A, B	6-25
6	2	Danbury	S3	-	W1	Intermittent	A	1-2
7	2	Danbury	S4	-	W2	Intermittent	A	~1
8-9	2	Bethel	S5	-	W3	Perennial	A	6-10
10	2-3	Bethel	S6	-		Perennial	A	6-10
11	3	Bethel	S7	-	W4	Stormwater Conveyance	n/a	1
11	3	Bethel	WB-1	Unnamed Pond		Perennial	A	

The Proposed Route also encompasses one pond (designated as WB-1), which is located north of Interstate 84 in a Bethel commercial park. The banks of the pond are armored by stone rip-rap and the surrounding upland habitat consists mainly of manicured lawn. The pond primarily serves to collect stormwater from the surrounding corporate business park, as is evident by stormwater discharge pipes. The two intermittent, unnamed streams are both located along the Proposed Route in Danbury. The stormwater conveyance channel is associated with the corporate office/industrial park in Bethel.

Eversource's existing overhead transmission lines presently span all of these watercourses / water bodies. The locations of these water features were delineated during field surveys in 2015. The banks of East Swamp Brook and Limekiln Brook were located, in part, and estimated based on aerial photograph interpretation in order to supplement field locations where the bank was not readily accessible or identifiable due to water depths within the surrounding emergent marsh system (Wetland W1).

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42 The USACE's general definition of navigable waters of the United States is "those waters subject to the ebb and flow of the tide shoreward to the mean high water mark and/or presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce." Waterways considered to be navigable waters may be subject to regulatory jurisdiction under Section 10 of the Rivers and Harbors Act.

The Proposed Route does not cross any rivers designated as a National Wild and Scenic River under the National Wild and Scenic Rivers Act (16 U.S.C. §§ 1271-1287). The Connecticut Protected Rivers Act (CGS §§ 25-200 through 25-210) requires CT DEEP to adopt a list of rivers in the state considered appropriate for designation as protected river corridors. To date, the CT DEEP has not proposed any eligible rivers along the Proposed Route under the Protected Rivers Act.

5.1.2.2 Wetlands

In 2015, wetlands and watercourses were delineated within the entire approximately 175 to 225-foot width of the existing ROW[43]. Wetlands were delineated using both state and federal criteria, as summarized below.

Summary of Wetland Delineation Methods

State jurisdictional wetlands were characterized using Connecticut delineation methodology pursuant to the Connecticut Inland Wetlands and Watercourses Act, CGS §§ 22a-36 through 22a-45 (the Act). The Act defines a wetland as land, including submerged land, consisting of poorly drained, very poorly drained, alluvial, and floodplain soils as defined by the USDA Cooperative Soil Survey. Such areas may include filled, graded, or excavated sites possessing an aquic (saturated) moisture regime as defined by the USDA Cooperative Soil Survey. The Act defines watercourses as rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and also other bodies of water, natural or artificial, public or private, contained within, flow through or border upon the state, or any portion thereof.

As part of the Project field investigations, federal jurisdictional wetlands were delineated in accordance with the USACE's *Wetland Delineation Manual* (Technical Report Y-87-1, "1987 USACE Manual") and *Regional Supplement to the Corps of Engineers Delineation Manual*[44] (Regional Supplement) and *Field Indicators for Identifying Hydric Soils in New England, Version 3.*[45] According to the 1987 USACE Manual, areas must exhibit three distinct characteristics to be considered federal jurisdictional wetlands:

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43 Wetland and watercourse delineations (including surveys for vernal pools) were performed by BSC Group, Inc. (BSC). These field investigations were performed by certified soil scientists and wetland delineators, as well as personnel experienced in vernal pool /amphibian breeding evaluations.

44 Wetlands Regulatory Assistance Program. (2012). *Regional Supplement to the Corps of Engineers Wetlands Delineation Manual: Northcentral and Northeast*, U.S. Army Engineer Research and Development Center, Vicksburg, MS

45 New England Hydric Soils Technical Committee. 2004. *Field Indicators for Identifying Hydric Soils in New England, 3rd ed*.. New England Interstate Water Pollution Control Commission, Lowell, MA.

1. **Vegetation**. The prevalent vegetation must consist of plants adapted to life in hydric soil conditions. These species, due to morphological, physiological, and/or reproductive adaptations, can and do persist in anaerobic soil conditions.
2. **Hydric Soils**. Soils in wetlands must be classified as hydric or they must possess characteristics associated with reducing soil conditions (typically resulting in redoximorphic features or gleyed soils).
3. **Hydrology**. The soil must be inundated either permanently or periodically at mean water depths less than 6.6 feet (2 meters) or the soil must be saturated at the surface for some time during the growing season of the prevalent vegetation.

Wetlands meeting the above technical criteria and determined to be traditional navigable waters, tributaries to traditional navigable waters, or wetlands exhibiting significant nexus are subject to federal jurisdiction under Section 404 of the Federal Clean Water Act (33CFR 320-332).

Delineated wetlands and streams delineated for the Project that coincide with the Project Route were numbered sequentially with an alpha-numerical label (e.g. W1, W2,… and S1, S2,…) from south to north starting at the Plumtree Substation in Bethel and ending at Brookfield Junction.[46] One waterbody, an unnamed pond, is labelled as WB-1, independent from the stream and wetland series numbering convention.

Due to differences in state and federal wetland delineation criteria and methodology, the boundaries of state and federal jurisdictional wetlands may not correspond in all cases. For example, in Connecticut, areas of alluvial and floodplain soils, which are not hydric soils or exhibit evidence of wetland hydrology, are state jurisdictional wetlands, but not federal, jurisdictional wetlands. For the most part, however, the state and federal wetland boundaries along the Proposed Route are the same. Wetland W-1 is the only wetland identified with variations between the Federal and State wetland boundaries. A State-only alluvial/floodplain wetland associated with Limekiln Brook is present to the north of the existing Plumtree Substation in Bethel, roughly coinciding with the regulatory Floodway boundary for the brook (refer to the Volume 5 maps).

46 Refer to Section 5.2 for a discussion of wetlands near Stony Hill Substation.

In accordance with *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979), wetlands were classified as palustrine[47] forested (PFO), palustrine scrub-shrub (PSS), palustrine emergent (PEM), or palustrine open water (POW).

These wetland classifications are characterized as follows:

- **Palustrine Forested Wetlands (PFO):** Forested wetlands are characterized by woody vegetation that is 6 meters (approximately 20 feet) tall or taller and normally includes an overstory of trees, an understory of young trees or shrubs and an herbaceous layer. These wetland types are located predominantly in the unmanaged areas of the existing ROW or in adjacent off-ROW areas.
- **Palustrine Scrub-Shrub Wetlands (PSS):** Scrub-shrub wetlands are typically dominated by woody vegetation less than 6 meters (approximately 20 feet) tall. Scrub-shrub wetland types may represent a successional stage leading to a forested wetland and include shrubs, saplings, and trees or shrubs that are small and/or stunted due to environmental conditions or human vegetation management practices.
- **Palustrine Emergent Wetlands (PEM):** Emergent wetlands are characterized by erect, rooted, herbaceous hydrophytes not including mosses and lichens. These wetlands maintain the same appearance year after year, are typically dominated by perennial plants, and the vegetation of these wetlands is present for the majority of the growing season.
- **Palustrine Open Water (POW):** Areas of permanent open water that border on palustrine systems are referred to as POW. Area of open water may exist as man-made or natural waterbodies.

Wetlands Delineated Along the Proposed Route

As summarized in Table 5-4, six wetlands[48], one of which is and open water pond (POW), were delineated along the 3.4-mile ROW as a result of the field investigations. Specific descriptions of wetlands along the ROW are included in the *Wetlands and Watercourses Report* in Volume 2, which summarizes the characteristics of each wetland and includes representative photographs and associated wetland data forms. The maps in Volume 5 illustrate the locations of the wetlands along the Proposed Route.

Wetlands identified along the ROW were typically PEM or PSS habitats within the managed portions of the ROW and typically PFO within the unmanaged portions. An invasive species, common reed (*Phragmites australis*), was observed in all wetlands present along the Proposed Route and, in most cases,

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47 Palustrine wetlands are wetlands occurring in the Palustrine System, one of five systems in the classification of wetlands and deepwater habitats. Palustrine wetlands include all non-tidal wetlands dominated by trees, shrubs, persistent emergent plants, or emergent mosses or lichens, as well as small, shallow open water ponds or potholes. Palustrine wetlands are often referred to as swamps, marshes, potholes, bogs, or fens.

48 The Project, including the Proposed Route and substation modifications, identified a total of eight wetlands. Refer to Section 5.2.2 for a description of the two additional wetlands (W6 and W7) located in the vicinity of Stony Hill Substation.

represents the dominant cover within the ROW. Wetland W1, a large wetland complex associated with East Swamp Brook and Limekiln Brook, is principally a PEM wetland within and outside of the managed portions of the ROW; however, in certain locations, mature stands of shrubs and trees are also present. All but two of the wetlands are associated with streams, or in one case a stormwater conveyance channel (S7), along the Proposed Route (refer to Table 5-4).

Table 5-4: Delineated Wetlands along the Proposed Route

Mapsheet #		Municipality(s)	Wetland ID [1]	Dominant NWI Class[2]	Other NWI Classes Present	Water Regime	Associated Watercourses/ Waterbodies[3]
100' Scale	400' Scale						
1-6	1-2	Bethel, Danbury	W1*	PEM	PFO, PSS	Semi-permanently flooded	S1, S2, S3
6-7	2	Danbury	W2	PEM	PFO	Temporarily flooded	S4
8	2	Bethel	W3	PSS	PFO	Seasonally flooded	
11	3	Bethel	W4	PEM	PFO	Temporarily flooded	S7
11	3	Bethel	WB-1	POW	PEM	Permanently flooded	
12	3	Bethel	W5	PEM	-	Saturated	

[1] Wetland ID refers to wetlands identified in the 2015 field surveys for wetlands in and adjacent to the Project ROW. Wetland IDs are consistent with those depicted in the Volume 2 maps.
[2] Wetlands classifications and water regimes are characterized according to Cowardin et al 1979; PEM = Palustrine Emergent Wetland; PFO = Palustrine Forested Wetland; PSS = Palustrine Scrub-Shrub Wetland; POW = Palustrine Open Water.
[3] No associated vernal pools were identified within the Project ROW, refer to Vernal Pool Assessment in Volume 3.
*Wetland W1 is a large wetland complex, portions of which extend along the ROW in both Bethel and Danbury.

The pond identified along the Proposed Route (designated as WB-1) is classified as palustrine open water (POW). WB-1 is included in this section because wetland habitat, dominated by common reed (*Phragmites australis*), is present with the shallow portions (i.e., within the banks) of the pond. East of the ROW, wetlands are present outside of the banks of the pond.

The results of the wetland field surveys demonstrate that wetland types within Eversource's existing ROW vary. Near the existing 321/1770 line structures, Eversource manages vegetation to promote low-growing species consistent with the safe operation of the overhead transmission lines; thus, in these locations, the majority of the wetlands within the existing cleared portion of the ROW are dominated by PEM and PSS communities. These wetland types typically transition into PFO wetlands within the unmanaged portion of the ROW that are characterized by a mixed hardwood deciduous forest.

5.1.2.3 Groundwater Resources, Public Water Supplies, and Aquifer Protection Areas

In the vicinity of the Proposed Route, potable water is derived from groundwater wells and surface water supplies or reservoirs. For the most part, in the vicinity of the Proposed Route, the groundwater quality is classified as "GA" (i.e., existing private and potential public or private water supply suitable for drinking without treatment). One area within a portion of Wetland W1 (to the north of Shelter Rock Road) is classified as "GB" (i.e., industrial process water and cooling waters presumed to not be suitable for human consumption without treatment) due mainly to the proximity to the Danbury Landfill, a gravel pit operation, and industrial development.

In general, CT DEEP has identified the quality of most surface waters in the vicinity of the Proposed Route as Class A. Class A waters include the following designated uses: potential drinking water supplies, fish and wildlife habitat, recreational use, agricultural and industrial supply, emergency and clean water supplies. One portion of Limekiln Brook near existing Structure 10261 10261 (located east of the Danbury Landfill) in the City of Danbury is identified as a Class B. Class B waters are designated for the following uses: recreational use, fish and wildlife habitat, agricultural and industrial supply, and potential uses, such as navigation.

CT DEEP's Aquifer Protection Area Program identifies Level A and Level B Aquifer Protection Areas (APAs) by municipality. Aquifer Protection Areas are delineated for active public water supply wells in stratified drift that serve more than 1,000 people, in accordance with CGS § 22a-354c and §22a-354z. Level A mapping delineates the final APA, which becomes the regulatory boundary for land use controls designated to protect the well from contamination. Level B mapping delineates a preliminary APA, providing an estimate of the land use controls designated to protect the well from contamination.

According to the CT DEEP, the Proposed Route does not traverse any APAs (refer to the Volume 5 USGS locus map in Exhibit 1).[49] The following APAs are located in the general vicinity of, but are not traversed by, the Proposed Route:

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49 CT DEEP Aquifer Protection Area Maps: http://www.ct.gov/dep/cwp/view.asp?a=2685&q=322248&depNav_GID=1654 (Accessed December 2015)

- Maple Avenue APA (final, not adopted; Level A) is located approximately 1-mile south and upgradient of Plumtree Substation in Bethel.
- Chimney Heights APA (final, adopted; Level A) is located approximately 0.8 mile east and upgradient of existing Structure 10257 in Bethel.

No preliminary (Level B) APAs are located in the vicinity of the Proposed Route. However, the Town of Brookfield identifies an Aquifer Protection District in the vicinity of Brookfield Junction.[50]

The water quality of surface water reservoirs is also protected by the Connecticut Public Health Code (PHC). PHC Section 25-37c-1 and 2 establishes criteria for classification of water company-owned land and provides definitions for classes of land warranting different levels of protection. Section 25-37d-1 of the PHC establishes a process for permitting changes in ownership or the land use of watershed lands owned by water companies. Review standards require the Commissioner of Public Health to determine that the action would not have a significant adverse impact upon the purity and adequacy of the public drinking water supply before a permit for such an action may be issued.

The following identifies the drinking water supplies for the three municipalities traversed by the Proposed Route.[51]

- **Bethel** – Bethel is served by two public water supplies: 70% of the town's potable water supply is obtained from the Maple Avenue Wells and 30% is obtained from the Chestnut Ridge Reservoir.52 As discussed above, the boundary of the Maple Avenue APA is approximately 1 mile south and upgradient of Plumtree Substation. This aquifer is characterized as a Level A groundwater supply. The Chestnut Ridge Reservoir, which is a Class AA surface water, is located approximately three miles south and upgradient of Plumtree Substation.
- **Danbury** – Danbury is served by a combination of water sources including eight reservoirs and one groundwater well. The nearest Danbury water supply to the Proposed Route is approximately 2.6 miles southwest of Plumtree Substation (Eureka Reservoir, a Class AA water). The majority of Danbury's public water supplies are situated in the southern and westernmost areas of the city, at least 2 miles from the Proposed Route.
- **Brookfield** – Brookfield is served largely by private groundwater wells and over 150 community water systems. Many densely developed areas of town are served by private water supply companies, such as Aquarion. The Meadowbrook APA (final, adopted; Level A) is located

50 Town of Brookfield online GIS Mapping Application: http://brookfield.mapxpress.net/ags_map/ (Accessed December 2015)

51 Information on groundwater quality and municipal water supplies was obtained from CT DEEP Geographic Information System Ground Water Quality Classifications, August 12, 2010 and by personal communication with municipal officials and/or through review of municipal planning documents.

52 Town of Bethel Utility Department Website: http://www.bethel-ct.gov/content/117/385/409.aspx (Accessed December 2015)

approximately 3 miles northwest of Brookfield Junction and serves wells operated by the Aquarion Water Company.

5.1.2.4 Flood Zones

The FEMA classifies flood zones for insurance and floodplain management purposes and has prepared maps designating certain areas according to the frequency of flooding. Areas within the 100-year flood designation have a 1% chance of flooding each year or are expected to flood at least once every 100 years. FEMA Regulatory Floodway (the "Floodway") characterizes the channel of a river and the adjacent land area that discharges the base flood and experience highest velocities within the floodplain during the 100-year flood.

A review of FEMA maps indicates that the Proposed Route extends across the 100-year flood plain and Floodway associated with both East Swamp Brook and Limekiln Brook. These two watercourses, both of which are located along the southern portion of the 3.4-mile ROW, share the same floodplain and, to some extent, the same Floodway (the Volume 5 Exhibit 1C maps illustrate these floodplain and Floodway boundaries, which are also shown on the 100-scale maps in Exhibit 2).

All of Plumtree Substation and most of the existing access road to the substation from Walnut Hill Road are located within the 100-year floodplain. In addition, the northeast corner of the substation is located within the mapped floodway. All but two of the existing 321/1770 line structures located between Plumtree Substation east to existing Structure 10267 and north to Structure 10260 are located within the 100-year floodplain and two are located within the floodway (Structures 10261 and 10268). Residential areas, public roadways, public parks, the Danbury Landfill, and a gravel mine are also located within the 100-year floodplain in the vicinity of the Proposed Route.

5.1.3 Biological Resources

5.1.3.1 Vegetative Communities

Vegetation along the Proposed Route consists of a mix of associations and cover types, providing a variety of wildlife habitats. Vegetation is currently managed within the ROW to ensure consistency with existing transmission line use and to provide the required clearance from conductors.

Along the existing Plumtree Substation to Brookfield Junction ROW, vegetation management clearance widths range from approximately 100 feet to 150 feet. Eversource does not manage the remaining portions of the existing ROW, which is currently characterized by forested land, paved surfaces (e.g. roads, driveways, parking lots), and residential and commercial lawns. From Sky Edge Lane (in Bethel) north to Brookfield Junction, the ROW extends across commercial/industrial areas and is characterized by maintained lawns, some ornamental landscaping, and pavement.

Eight habitat types/land uses were documented either within the managed portions of the existing ROW or in adjacent, presently unmanaged portions of the ROW where the proposed 115-kV transmission line would be aligned. These habitat types are illustrated on the Volume 5 Exhibit 1 maps and summarized as follows:

- **Old Field/Shrub land**: This habitat type includes portions of the existing managed ROW as well as adjacent abandoned fields, natural shrub lands, and early successional forests.
- **Upland Forest**: This forest type includes mature mixed deciduous/coniferous forests adjacent to the existing ROW in upland areas. Mature mixed forests consist typically of tree species common to the Northeast such as maples, oaks, hickories, spruce, and pine. The ratio of deciduous to coniferous species and age of stands varies.
- **Forested Wetland**: Forested wetlands generally include swamps dominated by a mature canopy including deciduous and coniferous trees.
- **Scrub-Shrub Wetland**: Shrub swamp areas exist either within or adjacent to the existing ROW. These types of wetlands typically include components of emergent marsh, where shrub coverage is substantial.
- **Emergent Wetland**: Emergent marshes are dominated by herbaceous wetland plant species.
- **Open Water**: This includes areas of open water found along the existing ROW, including ponds and larger streams, with the vegetation found along the shorelines of these areas. Most open water areas would be spanned or avoided, with no clearing required.
- **Urban Areas**: Urban areas refer to suburban and urban residential developments, subdivisions, areas developed for industrial or commercial use, recreational areas such as parks, maintained lawns, and roadside vegetation.

In accordance with Eversource’s ROW vegetation management program, woody vegetation that could interfere with the operation of the overhead transmission lines is periodically removed from the managed portion of the ROW, and trees located along the edges of the managed ROW are periodically trimmed or removed. The vegetation within the ROW is managed on an approximate four-year rotating basis.

As a result of Eversource’s vegetation management program, the predominant vegetation types within the managed portions of the transmission line ROW consist of dense shrub and herbaceous species (old field/shrubland or equivalent PSS or PEM wetland types). In New England, old field/shrubland areas are often disturbance-dependent and ephemeral. Historically, the occurrence and distribution of shrublands and other early successional cover types were largely influenced by humans. The widespread abandonment of farms in the early 20th Century, along with increases in suburban development and fire suppression, has led to a consistent decline in the area of early successional cover types over the last century and the subsequent decline in several wildlife species dependent on this habitat.[53]

5.1.3.2 Wildlife and Fisheries Resources

This section describes the general wildlife resources expected to be common in the vicinity of the Proposed Route, and then presents specific location information, including data developed as a result of research and field investigations within the ROW.

5.1.3.2.1 General Wildlife Description

The following summarizes the wildlife habitats and some of the species that commonly occur in the principal vegetative communities found along and in the vicinity of the Proposed Route

- **Upland Forest**: Forests in Southern New England support a wide array of wildlife and are the dominant cover type in Connecticut. Typically, common mammalian species in forested habitats include a variety of rodents (e.g., mice, voles, moles and shrews), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), grey fox (*Urocyon cinereoargenteus*), white-tailed deer (*Odocoileus virginianus*), striped skunk (*Mephitis mephitis*), Virginia opossum (*Didelphis virginiana*), chipmunk (*Tamias striatus*) and grey squirrel (*Sciurus carolinensis*). Less common forest-dwelling species include black bear (*Ursus americanus*), fisher (*Martes pennanti*) and porcupine (*Erithizon dorsatum*). Birds typical of forested areas include raptors (owls, hawks), wild turkey, woodpeckers and migratory songbirds, including a number of species solely associated with forested habitats (i.e., habitat specialists). Reptiles and amphibians likely to occur include vernal pool specialists (e.g., mole salamanders), toads and *hylid* tree frogs.
- **Old Field/Shrublands**: Old field/shrubland habitats are some of the rarest and most critical wildlife habitats in Connecticut. Common mammalian wildlife includes small mammals such as meadow voles (*Blarina brevicauda*), shrews, various mice, woodchuck (*Marmota monax*), rabbits, and white-tailed deer. Predatory and scavenging species such as red fox, coyote, weasels, skunk, and raccoon (*Procyon lotor*) often forage or bed in fields. Various species of shrubland-dependent birds including the prairie warbler (*Setophaga discolor*) and blue-winged warbler (*Vermivora cyanoptera*) are common.
- **Wetlands/Open Water**: Freshwater wetlands and other aquatic habitat (e.g., streams, ponds) provide excellent habitat for a wide range of wetland-dependent wildlife. Many of the species using upland forest and shrubland habitats also utilize forested wetland, shrub swamp, shallow marsh, or wet meadow communities. Several common mammalian species are adapted primarily to wetlands or other aquatic habitat including beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*). Reptiles and amphibians are particularly adapted to wetlands and aquatic habitats.

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[53] Liviatis, J.A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7:4, and Liviatis J.A. 2003. Shrublands and early-successional forests: critical habitats dependent on disturbance in the northeastern United States. Forest Ecology and Management 185:1-4

Typical species include mole salamanders, *Ranid* frogs, toads (*Bufo sp.*), *Hylid* tree frogs, spotted turtle (*Clemmys guttata*) and various snakes including the eastern ribbon snake (*Thamnophis sauritus*).

- **Urban Lands**: A variety of wildlife habitats are included in this category. These include suburban and urban residential areas, commercial and industrial developments, developed recreational areas (e.g., state and federal parks, municipal parks, playgrounds), maintained lawns, and road corridors. Wildlife in these habitats can be abundant, as animals are attracted to human food sources (e.g., crop fields, orchards, bird feeders, landfills), but the species inhabiting them must be tolerant to some degree of human disturbance. Some of the most recognizable wildlife species can be found in these areas, such as white-tailed deer, raccoon, woodchuck, and birds such as Canada geese (*Branta canadensis*), robin (*Turdus migratorius*), house sparrow (*Passer domesticus*), and other numerous bird species frequenting feeders. Other common but less visible species, such as red fox, coyote and skunk are also common. Nuisance wildlife species such as crows, rats, and other small rodents are also often abundant in these habitats. Some wildlife species are even dependent on human activity to thrive, such as birds nesting almost exclusively in human structures (e.g., chimney swift, barn swallow). Reptiles and amphibians tend to be scarce in these habitats because they are typically less tolerant of human activity than birds or mammals. Common amphibian and reptile species in suburban habitats include green frog (*Rana clamitans*), bullfrog (*Rana catesbeiana*) and garter snake (*Thamnophis sirtalis*).

5.1.3.2.2 Fisheries

As summarized in Table 5-3, the Proposed Route traverses eight different freshwater watercourses or waterbodies; however, only East Swamp Brook and Limekiln Brook support fisheries.

The CT DEEP's inland fisheries management efforts for rivers and streams are directed primarily toward providing recreational fishing opportunities, particularly for trout – a species that has traditionally been an important part of Connecticut's angling activity. The implementation of CT DEEP's 1999 *Trout Management Plan*, developed based upon the compilation of fish population, physical habitat and water chemistry information for approximately 800 Connecticut streams, is designed to improve fishing quality by diversifying angler opportunities. The *Trout Management Plan* designates various special management areas for trout. These include streams where self-sustaining wild trout populations are encouraged through catch-and-release angling, trout management areas, streams where CT DEEP stocks catchable size hatchery trout, trophy trout areas (stocked with larger hatchery trout), and trout parks (offering easy access to the public and stocked more frequently to promote angler success).

Based on a review of the CT DEEP's *2015 Connecticut Angler's Guide*, which identifies actively stocked or managed fishing areas, East Swamp Brook and Limekiln Brook are the only active fisheries in the vicinity of the Proposed Route. CT DEEP stocking areas for these brooks are on Shelter Rock Road (East Swamp Brook) and in Bennett Memorial Park (Limekiln Brook). East Swamp Brook meanders within the

ROW from existing Structure 10268 north to Structure 10264 near its confluence with Limekiln Brook. Limekiln Brook is present to the north of Plumtree Substation and crosses the Proposed Route once, south of existing Structure 10261. In 2014, East Swamp Brook and Limekiln Brook were stocked with brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and Rainbow Trout (*Oncorhynchus mykiss*).[54] CT DEEP also stocks fish in the Still River (located 0.5 miles east of the Proposed Route), more than 500 feet upstream of its confluence with Limekiln Brook. CT DEEP does not identify any streams along the Project Route as Special Management Areas for Trout (Trout Management Areas, Trout Parks, Trophy Trout Streams, Wild Trout Management Areas, or Sea-Run Trout Streams) in their Trout Management Brochure.[55]

The CT DEEP also has a Bass Management Plan (1999), which recognizes the importance of warm water species like largemouth and smallmouth bass, chain pickerel, northern pike, walleye, channel fish, panfish, brown bullhead and American eel. The existing ROW is not near any of the warm-water fisheries located in towns coinciding with the Project Route such as Candlewood Lake (Danbury and Brookfield), Lake Lillinonah (Brookfield), and Lake Kenosia (Danbury).

5.1.3.2.3 Vernal Pools

During the spring of 2015, the Proposed Route and adjacent areas visible from the existing ROW (within approximately 100-200 feet of the ROW boundaries) were surveyed to identify candidate vernal pools for further evaluation based on vernal pool indicators. Additionally, aerial imagery was used to supplement the field investigations, based on methods described in Burne 2001,[56] to evaluate whether the Proposed Route may be within the migratory range of vernal pool species that might use off-ROW vernal pools.

As a result of these investigations, no candidate vernal pool habitat was identified within the Eversource ROW during the field surveys in April and May 2015. Additionally, no potential vernal pool habitat was identified within 500 feet of the Proposed Route, based on the desktop analysis. A detailed description of the field and desktop assessment and results is presented in the *Vernal Pool Assessment* in Volume 3.

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54 CT DEEP Fish Stocking Report, 2014. http://www.ct.gov/deep/lib/deep/fishing/general_information/fishdistributionreport.pdf (access December 2015)

55 CT DEEP Trout Management Program Brochure: http://www.ct.gov/deep/lib/deep/fishing/freshwater/troutbroc.pdf (accessed December 2015).

56 Burne, Matthew R. 2001. Massachusetts Aerial Photo Survey of Potential Vernal Pools. Natural Heritage & Endangered Species Program Massachusetts Division of Fisheries and Wildlife. Westborough, MA.

5.1.3.2.4 Birds

In accordance with Council guidance, Eversource commissioned an inventory of breeding birds and their habitats in the Project vicinity. The initial inventory, which is included in the *Breeding Bird Assessment* (*Assessment*, copy included in Volume 3), lists all breeding birds that are reasonably expected to occur in the Project area, as well as the habitat(s) that each species utilizes. This initial inventory was performed in 2015 and early 2016, and will be refined based on field surveys to be conducted in the spring and summer of 2016, when breeding birds are most active.

Various sources were analyzed in order to develop the inventory of all bird species known to breed in the vicinity of the Project. The primary sources used for this assessment included *The Atlas of Breeding Birds of Connecticut* (*Atlas)*[57] and the species listed as *Species of Greatest Conservation* Need (SGCN) within the Connecticut's *Wildlife Action Plan (WAP).*[58] The *Atlas* is the result of a five-year study (1982-1986) of all bird species known to breed in the state. The study is the most comprehensive review to date of Connecticut's breeding birds, involving the efforts of more than 500 individuals and covering virtually the entire 5,009-square-mile area of the state. The online *Breeding Bird Atlas* identifies bird species whose presence are *possible, probably, or confirmed*. Search queries for the *Atlas* are populated based on USGS quadrangle maps that have been divided into six smaller quadrants. Two of these quadrants (76D and 76F), which encompass the Proposed Route and surrounding areas, were reviewed to compile an initial inventory of potential breeding birds in the Project area.

This list was refined based on the presence of suitable habitat within the Project area, bio-geographical distribution, the presence or absence of critical habitat features and minimum patch size requirements. The inventory is subdivided by habitat type. A species is listed under the habitat which represents its primary breeding type. However, a species should be considered to be potentially present within ecotones associated with their primary habitat at any given time. In order to evaluate the Project area's value for species of high-conservation priority as opposed to common species and habitat generalists, the inventory of birds was prioritized based on conservation status (refer to the *Breeding Bird Assessment* in Volume 3). Species that are included either on Connecticut's List of Endangered, Threatened and Special Concern Species (2010) or classified as Species of Greatest Conservation Need (SGCN) by Connecticut's Wildlife Action Plan (WAP) were considered to be species of high conservation priority. The WAP was created to establish

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57 Bevier, L. R. (Ed.). Atlas of Breeding Birds of Connecticut. 1994. Bulletin 113. State Geological and Natural History Survey of Connecticut. 461 p.

58 Connecticut's Wildlife Action Plan, formerly known as Connecticut's Comprehensive Wildlife Conservation Strategy (2005) is currently under revision by the CTDEEP. Portions of the plan, such as the SGCN list, have been released in draft form and have been used in this report.

a framework for proactively conserving Connecticut's fish and wildlife, including their habitats. SGCN fall into three categories in descending order of significance: most important, very important, and important.

Results

As described in the *Assessment* (Volume 3), the Project area is dominated by forest fragments (patch or perforated), non-forest, and edge forest that surrounds small core (<250 acres) forest. The Proposed Route does not coincide with core forest or edge forest of medium or large core forest (250-500 acres and >500 acres, respectively). The small core edge forests and forest fragments typical of the areas near the Proposed Route may provide some breeding habitat for forest-interior species but are generally considered sub-optimal, and may serve as population sinks.[59] Significant forest patches are not present in proximity to the Project area and none of the forest blocks to be impacted by the Project constitute high-value forest.

According to the *Breeding Bird Atlas*, total of 66 breeding birds were identified as *possible, probable,* or *confirmed* breeders in areas in the vicinity of the Proposed Route. Of the 66 potential breeding birds, two state-listed species (3%) designated as Species of Special Concern and no federally listed species were considered potentially present. A total of 23 species (35% of the 66 total species) are SGCN. Of those 23 species, three are classified as most important, 11 as very important, and nine as important.

Of the 23 SGCN species identified, nine (39%) are associated with managed, early successional ROW vegetation (i.e., shrubland and PSS wetlands) and eight (35%) are associated with forested habitats (i.e., upland forest and PFO wetlands). The remaining six SGCN species (26%) are associated with edge habitats or developed lands. Out of the three SGCN species identified as most important, two are associated with managed early successional ROW vegetation as opposed to forested habitat.

Bird species likely to breed in the vicinity of the Proposed Route are those that are shown to use open brushy ground, deep emergent marsh, and mature second growth forest. Species adapted to breeding in human influenced sites, including residential areas with a mix of fragmented forest blocks and open lawn, are also likely to be present.

Due to the fragmented nature of the forest types and level of development in the Project area, the most common species are likely to be habitat generalists and those that are tolerant of a mix of developed,

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59 2006 CLEAR Forest Fragmentation Study
http://clear.uconn.edu/projects/landscape/forestfrag/forestfrag_public%20summary.pdf

forested and open habitat. The large wetland (W1) associated with Limekiln Brook and East Swamp Brook is dominated by an invasive species - common reed (*Phragmites australis*), which outcompetes other vegetation in open marsh habitat. As a result, *Phragmites* is associated with a reduction in the diversity of bird species because it reduces the variability of vegetation present, and consequently, the variability of habitat present.

The prevalence of forested and shrubland habitats in the Project area is reflected in the composition of breeding bird species expected to occur. The majority of bird species listed in the *Assessment* are forest-breeding songbirds and woodpeckers, shrubland and shrub swamp-breeding songbirds, species that utilize forest edges, and habitat generalists.

Waterbirds, including ducks, wading birds, shorebirds, gulls, and terns, make up a relatively small percentage of breeding birds in the Project area despite the abundance of wetlands. This is primarily because many species of water birds, particularly ducks, do not breed in Connecticut, but rather breed in more northerly latitudes such as northern New England and Canada. Many water birds that do breed in Connecticut tend to concentrate in coastal areas. Waterbirds included in the inventory include those species associated with freshwater wetlands (e.g., Canada goose and mallard) and rivers (e.g., waterthrush).

5.1.3.3 Federal and State Listed or Proposed Threatened, Endangered, or Special Concern Species

Eversource initiated consultation with the CT DEEP Bureau of Natural Resources – Wildlife Division, Natural Diversity Database (NDDB), and the United States Fish and Wildlife Service (USFWS) Information, Planning, and Conservation System (IPaC) to determine whether there is a potential for the Project to affect federal- or state-listed species, or designated critical habitat, associated with species that are classified as threatened, endangered, or species of concern. The following sections describe the listed species that may potentially occur in the Project vicinity based on the reviews conducted to date.

IPaC Identified Federal-listed Species

Screening using the USFWS IPaC indicated that two federally-listed species may be present in proximity to the Proposed Route: northern long-eared bat *(Myotis septentrionalis*; "NLEB"*)*, a Federally-Threatened[60] and State-Endangered[61] species; and bog turtle (*Glyptemys muhlenbergii*), a Federally-Threatened[62] and State-Endangered species. Eversource has initiated consultation with USFWS and CT DEEP to determine if there are known occurrences of either species in the vicinity of the Proposed Route.

NDDB Identified State-listed Species

To assess the potential for the Project facilities to be located in or near habitat of State-listed species, Eversource initially reviewed publically-available maps depicting large "polygon" areas within which listed-species may occur. In addition, because of its state-wide transmission facilities and projects, Eversource has a data-sharing agreement with CT DEEP whereby authorized Eversource personnel and its representatives are allowed to review more specific, confidential information about the potential location of listed species within a polygon. As a part of this data sharing agreement, the CT DEEP Bureau of Natural Resources Wildlife Division provided Eversource with species information associated with the publically-available NDDB polygons in the Project area.

Following a review of the CT DEEP provided NDDB polygon data, two state-listed species were identified in the vicinity of the Proposed Route, one plant (State-listed Special Concern) and one reptile (State-listed Special Concern). Initial investigations were conducted in November 2015 through field studies to assess the presence of suitable habitat for the two listed species identified as potentially occurring in the Project Area. Potential suitable habitat was determined to be present for both species, however, field investigations will continue in the spring and summer 2016 to verify if either species is present.

Additional Potentially Occurring State-listed Bird Species

In addition to the above-referenced species, two State-listed bird species were identified as potentially occurring in the area based on available data of known observations included in *The Atlas of Breeding Birds of Connecticut (Atlas)* [63] through the use of the online *Breeding Bird Atlas Explorer*[64] (*Atlas Explorer*). As identified in the *Assessment*, these two species are brown thrasher (*Toxostoma rufum* - State-listed Special

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60 USFWS listing as Federally Threatened became effective on May 4, 2015.
61 State listing as an Endangered species became effective in August 2015.
62 Listed as Federally-Threatened on November 4, 1997.
63 Bevier, L. R. (Ed.). *Atlas of Breeding Birds of Connecticut*. 1994. Bulletin 113. State Geological and Natural History Survey of Connecticut. 461 p.
64 North American *Breeding Bird Atlas Explorer:* http://www.pwrc.usgs.gov/bba/index.cfm?fa=explore.ProjectHome&BBA_ID=CT1982

Concern) and American kestrel (*Falco sparverius* - State-listed Threatened). Descriptions of these species and their habitat are described below. The methodology and results of this assessment are summarized in Section 5.1.3.4 and discussed in detail in the copy of the *Assessment* provided in Volume 33.

Brown Thrasher

Brown thrashers inhabit wetland or upland thickets, brushy hillsides and woodland edges in suburban and rural areas (Bevier, 1994). Maturation of forest and other factors causing loss of early successional habitat are driving the decline in this species. Shrubland dominated (managed) portions of the Project ROW represent suitable breeding habitat for the thrasher. Although more information is needed to adequately assess the population trend of this species in Connecticut, Breeding Bird Survey data shows a steady decline of 3.5% annually over the last four decades. The brown thrasher is considered a stewardship species of continental importance by Partners in Flight.[65] Shrubland dominated portions of the ROW, including areas from Old Sherman Turnpike in Danbury to areas north of Sky Edge Lane, represent potentially suitable breeding habitat for thrasher.

American Kestrel

The American kestrel can be found in a wide variety of open to semi-open habitats, including meadows, grasslands, early old field successional communities, open parkland, agricultural fields, and both urban and suburban areas. The American kestrel's breeding territories are characterized by either large or small patches covered by short ground vegetation, with taller woody vegetation either sparsely distributed or lacking altogether. Suitable nest trees and perches are required. Typical breeding habitat in the Northeast U.S. is large (>25 ha) pasture or recently fallowed field, with one or few isolated large dead trees for nesting and several potential perches.

For the most part, there is limited suitable habitat available for American kestrel within the Project area due to the narrow linear configuration of early-successional habitats available and the limited un-mowed, grass-dominated areas.

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65 Leenders, A. A. (Ed.). 2009. *Connecticut State of the Birds*. Connecticut Audubon Society. Fairfield, CT. 52 p.

5.1.3.4 Designated Wildlife Management Areas (WMAs)

The Proposed Route does not cross any national wildlife refuges, forests, or parks. One State-designated Wildlife Management Area (WMA), the East Swamp WMA, is located in Bethel, east of Plumtree Substation.

State-designated WMAs are established by use of funding related to the federal Pittman-Robertson Act of 1937, which specifies the use of taxes/fees on hunting for game management. As identified on the Volume 5 maps, the East Swamp WMA is comprised of two separate parcels that total 85 acres. Access to the WMA is from Ballfield Road in Bethel. Hunting permissible in the WMA includes waterfowl, small game, and spring and fall firearms use for turkey. This property is also a Designated Deer Bow Hunting Only Area.[66]

5.1.3.5 Designated Critical Habitat

CT DEEP identifies 25 rare and specialized wildlife habitats in the state, based on a compilation of ecological information collected by state agencies, conservation organizations, and individuals (2007-2009).[67] Critical habitats are key habitats for SGCN in the *WAP* and serve to highlight ecologically significant areas and to target areas of species diversity.

Critical Habitat designated as an alluvial swamp floodplain forest associated with the Limekiln Brook stream complex (S-2) is present along the Proposed Route. Mapped Critical Habitat is present within the ROW north of Shelter Rock Road to areas south of Old Sherman Turnpike. Although this area is mapped as floodplain forest, the portion of the Critical Habitat area located within the existing managed ROW is represented by an emergent swamp.

5.1.4 Land Uses and Scenic Resources

The Proposed Route for the new 115-kV transmission line would be aligned within Eversource's existing transmission line ROW between Plumtree Substation and Brookfield Junction. Lands in the general Project region are characterized by a variety of uses and types, and are dominated by residential, commercial, and industrial developments, as well as transportation corridors, such as Interstate 84, U.S. Route 6, and railroad (e.g., the Housatonic Railroad Company, Metro-North Railroad).

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66 CT DEEP. *Public Hunting Areas.* http://www.eregulations.com/connecticut/hunting/public-hunting-areas/ (Accessed December 2015)

67 UConn Clear. Connecticut Critical Habitats. http://cteco.uconn.edu/guides/Critical_Habitat.htm

Eversource's ROW encompasses both lands occupied by existing overhead lines and lands within the utility easement, but not presently managed for utility use. Beneath and in the vicinity of the portions of the ROW occupied by existing transmission lines, Eversource conducts vegetation management to promote shrub or similar low-growth vegetation, consistent with utility use. Lands within the unmanaged portions of the ROW are undeveloped and consist of forested, shrub, and agricultural or other open lands. Within the ROW, developed land uses (e.g., buildings) are not permitted, pursuant to Eversource's easement agreements with landowners.

To identify and assess land uses along the ROW, as well as existing and future land use plans and conditions in the Project vicinity, Eversource consulted existing published resources using a geographic information system (GIS); analyzed aerial photography and maps; examined state, local, and regional land-use plans (including data concerning federal- and state–designated recreational areas or open space); and reviewed data concerning public and private recreational resources. In addition, Eversource conducted research to identify whether any parcels preserved by land trusts (e.g., Bethel Land Trust, Brookfield Land Trust, and the Land Trust of Danbury) are located near the Proposed Route. Based on this research, Eversource determined that the Project is not located near any Connecticut Heritage Areas, national scenic trails, state- or federally-designated scenic roads, federal or state park or forest lands, or ConnDOT scenic land strips.

However, various recreational areas are traversed by or located in the vicinity of the Proposed Route. These include the following: a National Historic Trail, two municipal (Bethel) recreational areas, and numerous Protected open space parcels as designated by local land trusts, municipalities, or by the CT DEEP.

The following subsections describe existing land uses along the Proposed Route, as well as community facilities, and designated protected open space and potential scenic resources. Zoning classifications of properties along and in the vicinity of the ROW are identified on the Volume 5 maps.

5.1.4.1 Existing Land Uses

Commencing at Eversource's existing Plumtree Substation in the Town of Bethel, the Proposed Route for the new 115-kV transmission line would extend first west-northwest and then north-northeast across portions of the Town of Bethel, City of Danbury, and Town of Brookfield before terminating at Brookfield Junction. The entire route would be aligned within a long-established Eversource ROW that traverses or borders a variety of land uses. The ROW extends across properties that Eversource owns in fee and across private or public lands over which Eversource has easements for utility use.

Table 5-5 summarizes the length of the Proposed Route in each of the three municipalities, along with the Eversource-owned and the publicly-owned property (length) traversed along the ROW. Table 5-6 summarizes the land uses along the proposed 115-kV transmission line route within the existing Eversource ROW, by land use type.

Table 5-5: Approximate Distance Traversed by Proposed Route, by Municipality, and Across Eversource-Owned Property or Public Lands

Municipality	Approximate Distance Traversed (Miles)		
	Total ROW	Eversource-Owned Property	Public Property
Bethel	**2.2**	**0.76**	**Total: 0.3 miles** *East Swamp Brook WMA* *Meckauer Park (Town of Bethel)* *Unnamed open Space:* *(State of CT, Town of Bethel, Bethel Land Trust)* *I-84 and US Route 6*
Danbury	**0.9**	**0.16**	**Total: 0.5 Miles** *City of Danbury (Danbury Landfill parcel))*
Brookfield	**0.3**	**0**	**Total: 0 Miles**
TOTAL	**3.4**	**0.9**	**0.8**

Table 5-6: Approximate Area (Acres) of Each Land Use within the Project ROW and Eversource Parcels[1], by Municipality

Land Use Type[2]	(Approximate Area by Land Use , in Acres)			Total Acres
	Bethel	Danbury	Brookfield	
Upland Forest	**12.2**	**3.3**	**1.5**	**16.9**
Old Field /Shrubland	**6.5**	**3.9**	**1.1**	**11.5**
Agricultural Land	**0.0**	**0.0**	**0.0**	**0.0**
Urban Areas[3]	**22.2**	**0.8**	**5.8**	**28.9**
Wetlands	**25.1**	**11.8**	**0.0**	**36.9**
Open Water	**0.6**	**0.2**	**0.0**	**0.7**
TOTAL	**66.6**	**19.9**	**8.4**	**94.9**

[1] Eversource parcels included in this calculation includes Eversource-owned parcels along the Proposed Route from Plumtree Substation to Brookfield Junction, including Plumtree Substation.
[2] Land use types are depicted on the Volume 5, 400 scale maps. Land use type boundaries were determined using aerial mapping and field reconnaissance in some places.
[3] Includes Commercial/Industrial, House/Yard and Other as depicted on the Volume 5, 400 scale maps.

The following summarizes the primary land-use patterns, by municipality, along and in the vicinity of the Proposed Route (refer to Volume 5 maps). In general, Eversource currently manages most of the land within the ROW for utility use characterized by lower-growing vegetation consistent with required clearances from overhead transmission line conductors. As a result, although there are areas of forest and taller-growing shrub vegetation along the margins of the Project ROW, most of the land within the ROW consists of scrub-shrub land or grassland (lawn). The new 115-kV line will be generally aligned adjacent to and east of the existing 321/1770 transmission lines, within areas of the ROW that Eversource does not presently manage.

Town of Bethel

Traversing generally north from the Plumtree Substation (and crossing Shelter Rock Road, Payne Road, Stony Hill Road, and Interstate 84, to Research Drive), the Proposed Route would extend approximately 2.2 miles through western portions of the Town of Bethel. For approximately 0.8 miles in Bethel, the new 115-kV transmission line would be aligned within Eversource fee-owned parcels.

Along the southern segment of the Proposed Route, the majority of the Project ROW is characterized by PEM wetlands, with small areas of taller-growing shrubs (PSS) or forested wetlands (PFO) along the unmaintained margins of the ROW. This segment also crosses various local roads: the East Swamp WMA and unmanaged portions of the Town property associated with Meckauer Park. Two parcels protected as open space owned by the Bethel Land Trust are located southwest of Plumtree Substation, but not along the Proposed Route. Areas adjacent to the Project ROW also include residential areas, such as the Lexington Meadows Condominiums, and single-family residential areas located in the vicinity of Payne Road.

The northern segment of the ROW in Bethel is dominated by upland shrub land or grasslands (lawn) within the maintained portions of the ROW and upland forest along the unmaintained margins. A few scrub-shrub and emergent wetlands and one open water pond are also located in the segment. This ROW segment begins in a residential area (crossing Hearthstone and Chimney drives and Skye Edge Lane), continues through commercial areas, and ends in an industrial/corporate park (Berkshire Corporate Park) north of Interstate 84. Along Eversource's existing ROW, the Proposed Route crosses various local roads, US Route 6, and I-84; a small portion of open space owned by the Town of Bethel; and parking lots associated with commercial properties such as Target and the Berkshire Corporate Park

City of Danbury

The Proposed Route traverses approximately 0.9 miles from Shelter Rock Road and Payne Road through eastern portions of the City of Danbury. For approximately 0.2 miles of the Project Route located in Danbury, the new 115-kV would be aligned within Eversource fee-owned parcels.

Land uses in the vicinity of the Proposed Route consist of a mix of emergent wetland, forested wetlands, forested uplands, and industrial/commercial land. No recreational areas or open space are located within the Danbury portion of the Project area. Emergent wetlands and upland scrub lands dominate the cleared portions of the existing ROW. Industrial areas include the Danbury Landfill and a gravel pit. The Proposed Route only crosses the parcel that contains the Danbury Landfill and is located to the east of the landfill itself. According to the Danbury Public Utilities Division website, the Danbury Landfill is a Resource Conservation and Recovery Act (RCRA) land disposal site, which has been closed since 1997. The closed landfill is operated under a CT DEEP Stewardship Permit, which consolidates all landfill closure requirements under a single permit. The Public Utilities Division operates the Landfill Gas Collection and Treatment Facility at the landfill, in accordance with CT DEEP requirements

Town of Brookfield

The Proposed Route traverses approximately 0.3 miles, from Research Drive north to Brookfield Junction, through southern portions of the Town of Brookfield. No Eversource-owned parcels are located along the Proposed Route in Brookfield.

Land uses in the vicinity of the Proposed Route in Brookfield are dominated by commercial and industrial development associated with the Berkshire Corporate Park, through which the ROW extends. The Housatonic Railroad ROW is located directly north of Brookfield Junction. Land cover consists mostly of manicured lawn; isolated areas along the margins of the existing ROW are forested. No open space or recreational areas are located in the vicinity of the Proposed Route in Brookfield.

5.1.4.2 Federal, State, and Local Use Plans/Future Land-Use Development

To assess the relationship of the proposed Project with respect to established land use plans and policies, Eversource compiled and reviewed federal, state, regional, and local land use plans, including Connecticut's *Conservation and Development Policies Plan* (C&D Plan, 2013). Each municipality along the Proposed Route has established municipal land use plans, all having goals and objectives consistent with the operation of transmission lines within Eversource's existing ROW, where the new 115-kV line would be located.

5.1.4.2.1 State and Regional Plans

Eversource reviewed the 2013 C&D Plan prepared by the Connecticut Office of Policy and Management. The objective of the C&D Plan is to guide and balance response to human, environmental, and economic needs in a manner that best suits Connecticut's future. Based on the general planning information provided in the C&D Plan, the Project is consistent with the overall goals and objectives of the C&D Plan and is particularly relevant to the Plan's Growth Management Principle #1: Redevelop and Revitalize Regional Centers and Currently Planned Infrastructure. The Project would serve a public need by providing an environmentally-sound approach to the reliable transmission of electricity, which, as the C&D Plan (p. 8) notes is needed, along with other physical infrastructure, to "*…take full advantage of Connecticut's strategic location within the Northeast Megaregion, while also proactively addressing the needs and desires of a changing demographic base.*"

In addition, the Western Connecticut Council of Governments (WestCOG) is a regional planning agency that serves the three municipalities in the Project area. The regional planning agency establishes land use, conservation and development policies to assist in coordinating regional growth patterns, with the objective of maximizing efficiencies in shared environmental, economic, and infrastructure facilities. WestCOG has identified the implementation of priority infrastructure improvements, including transportation and utilities, as part of the necessary steps to support their objective to improve regional economic development infrastructure.[68]

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[68] Western Connecticut Economic Development Alliance, Housatonic Valley Council of Elected Officials, and Greater Danbury Chamber of Commerce. *Western Connecticut Comprehensive Development Strategy.* 2013. P. 164

5.1.4.2.2 Local Land-Use Plans

All three of the municipalities traversed by the Proposed Route have published plans of conservation and development:

- Bethel: Plan of Conservation and Development (2007)
- Danbury: Plan of Conservation and Development (2013)
- Brookfield: Plan of Conservation and Development (July 2015)

In general, these plans identify the areas traversed by the Proposed Route as continuing to maintain current land use patterns in the future (e.g., public recreational or protected lands, low-density residential development). None of the plans identify local land use policies that would be inconsistent with the development of the new 115-kV transmission line within Eversource's existing ROW.

5.1.4.3 Community Facilities

The Council's *Application Guide for Electric and Fuel Transmission Facilities* (February 2016; Section VI.G) specifies that the proximity of the proposed Project to certain community facilities, as listed below, must be identified. These facilities are, in particular:

- Public and private schools, licensed daycare centers, licensed youth camps, and public playgrounds;
- Hospitals;
- Group homes; and
- Recreational areas.

Recreational areas, including public playgrounds, are discussed in Section 5.1.4.4.

A review of public records indicates the Proposed Route is not located within 500 feet of any schools, licensed residential child day-care facilities, youth camps, hospitals, or group homes.[69] No public schools are located within the general vicinity of the Proposed Route. The nearest public schools include Shelter Rock Elementary School in Danbury (which is located approximately 0.6 mile to the east of the ROW), as well as various Bethel public schools (which are located together on an educational type campus approximately 0.6 to 1.1 miles south of Plumtree Substation. These Bethel schools are Anna H. Rockwell

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[69] Department of Children & Families, *DCF Lisenced Programs, Facilities and Out-of-State Approved Agencies, Child Caring Agencies and Facilities*: http://www.dir.ct.gov/dcf/Licensed_Facilities/listing_CCF.asp; The State of Connecticut eLicensing Website: https://www.elicense.ct.gov/Lookup/DownloadRoster.aspx (Accessed January 2016)

Elementary School, Frank A. Berry School, R.M.T. Johnson School, Bethel High School, and Bethel Middle School. Playgrounds are present at many of these schools and are also present at Meckauer Park and Bennett Memorial Park, both of which are located adjacent to the Proposed Route. Of these two parks, Bennett Memorial Park is located within 500 feet of Plumtree Substation.

Three group day-care facilities are located within 0.5 mile of the Proposed Route: Danbury Headstart (7 Old Sherman Turnpike in Danbury) is located approximately 0.3 miles north of the Proposed Route; the Bee U Daycare Learning Center (15 Park Lawn Drive in Bethel) is located approximately 0.3 mile to the east of the Proposed Route; and the Kids Club Daycare (94 Old State Road in Brookfield) is located approximately 0.5 miles north of the Brookfield Junction.

Although not a registered community facility, Ability Beyond, a 501(c) (3) not-for-profit organization that offers community-based support for people with disabilities, is located at 4 Berkshire Road, in an office building directly east of the Eversource ROW just north of I-84. Ability Beyond offers a variety of services, including day programs, job training, and transportation services, among others.

5.1.4.4 Public Forests, Parks, Open Space, Recreational / Public Trust Lands, and Trails

The Proposed Route traverses or is located near various parks, open space lands, and recreational areas located in the Town of Bethel, including Meckauer Park and Bennett Memorial Park. No similar areas are located near the Proposed Route in either Danbury or Brookfield. No state-designated greenways are located within or near the Project Route.

The Town of Bethel has two developed recreational areas near the Proposed Route, Meckauer Park and Bennett Memorial Park, located adjacent to the existing Eversource ROW north of the Plumtree Substation and generally east of existing Structure 10265. Bennett Memorial Park is primarily used for public functions, with a pavilion, kitchen facilities, and picnic areas available for rent. The park also has recreational areas for fishing, a small playground, and areas for outdoor games such as horseshoes. The impounded pond on the property is also used as a trout stocking location for Limekiln Brook.

Meckauer Park, which abuts Bennett Memorial Park to the north, has a small, paved walking trail loop, pavilion, playground, and fields for recreational use.

An unnamed property owned by the Town of Bethel is located on Chimney Drive and is listed as protected open space. The East Swamp WMA, owned by CT DEEP and protected for hunting is located to the west of the Plumtree Substation (refer to Section 5.1.3.4).

Four parcels owned by the Bethel Land Trust are located along or proximate to the Proposed Route. Three of these parcels, all of which are unnamed and undeveloped, are located in the wetland complex associated with East Swamp Brook and Limekiln Brook (wetland W1) near the Plumtree Substation and Shelter Rock Road in Bethel. One parcel, the Sky Edge Lane Preserve, is located directly adjacent to the Project ROW to the east of existing Structure 10255. The recreational areas crossed by or near the Proposed Route are described and are summarized in Table 5-7.

Table 5-7: Public Recreational Areas, Open Space, Land-Trust Parcels, and Trails along and in the Vicinity of the Proposed Route[2]

Proximity to Route	Recreational/Scenic/Open Space Feature (Refer to Volume 5 maps for parcel locations)
Crosses	East Swamp Wildlife Management Area (CT DEEP)
Adjacent	Land trust (Bethel Land Trust)
Adjacent	Bennett Memorial Park (Town of Bethel)
Adjacent and crosses[1]	Meckauer Park (Town of Bethel)
Crosses	Unnamed protected open space (Town of Bethel)
Adjacent	Sky Edge Preserve (Bethel Land Trust)

[1] The Project Route crosses undeveloped portions of the Meckauer Park and is adjacent to the managed park area.
2 All properties described are located within the Town of Bethel. No recreational areas, public forests, parks, open space, or land trust parcels were identified along or adjacent to the Proposed Route.

Each of these recreational areas are described below and depicted on the Volume 5 maps and depicted on the Volume 5 maps.

- **East Swamp WMA,** which is comprised of two parcels totaling 85 acres, is owned and managed by CT DEEP for hunting. The WMA is located southwest of Plumtree Substation and is designated for use for hunting turkey (spring and fall), waterfowl, and small game. This area is also a Designated Deer Bowhunting Only Area. Access to the property is located off of Ballfield Road in Bethel; in addition, a series of unmanaged paths extend northward through the property. Only the northern margins of the WMA coincide with the Proposed Route, this portion is currently maintained as a utility corridor within the Eversource ROW.
- **Bennett Memorial Park** is an 8-acre parcel owned and operated by the Town of Bethel located off of Shelter Rock Road. This park, which directly abuts Plumtree Substation to the north, includes day-use public facilities such as a pavilion, kitchen, and picnic areas that are rented out to residents.

Recreational facilities on the property include a small playground, a bocce court, horseshoes, and a pond for fishing. The pond is an impounded area of Limekiln Brook that is used as a CT DEEP stocking location for trout.

- **Meckauer Park**, which encompasses 39 acres, is located north of Bennett Memorial Park, off Shelter Rock Road. Meckauer Park includes mixed recreational use similar to Bennett Memorial Park, is also owned and operated by the Town of Bethel. The park has public facilities, such as a pavilion, picnic areas, playground, and an enclosed dog park. The playground area includes a basketball court, volleyball court, and an all-purpose field. A paved biking/walking trail loop is located on the property. The maintained recreational areas of the park are located east of the existing Eversource ROW and north of Plumtree Substation. To the west of the maintained recreational areas, the majority of the parcel is open space. The existing Eversource ROW (including the Proposed Route) crosses the portion of the parcel that is considered open space.
- **Sky Edge Preserve,** is a 3-acre parcel owned by Bethel Land Trust, donated by Target in 2004, located north of Sky Edge Lane and east of the existing ROW. This site has no developed trails or recreational features. Portions of the property appear to be mowed to maintain an old/field shrub habitat type for bird habitat and bird boxes are also installed. The existing ROW does not cross the Preserve, but directly abuts the western border of the Preserve parcel.

5.1.5.5 Designated Protected and Scenic Resources

As summarized in in this section, described in more detail in the *Visual Resources Analysis* (Volume 3), and depicted on the Volume 5, 400 scale maps, the proposed 115-kV transmission line would be located within Eversource's existing ROW across or near several areas that have scenic attributes, such as protected open space or parks. Eversource's existing overhead transmission lines presently extend near all of these areas.

The ROW also crosses a National Historic Trail, the Washington-Rochambeau Revolutionary Route (Washington-Rochambeau NHT), a 680-mile route that extends through nine eastern U.S. state and Washington, D.C.. At the ROW crossing, the trail coincides with, and is not distinguishable from, Stony Hill Road (US Route 6). Land uses near the ROW at the Washington-Rochambeau NHT crossing consist of various commercial developments, including a Target superstore and Best Western motel. Interstate 84 is visible to the north of Stony Hill Road.

The Project area does not encompass any state heritage corridors, as designated in July 2009 pursuant to Connecticut Public Act No. 09-221, codified at CGS § 23-81. As set out in CGS § 23-81, a heritage area is defined as a place within Connecticut that has historic, recreational, cultural, natural, and scenic resources that form an important part of the state's heritage. State agencies must take the resources of the heritage areas into consideration in planning and project decision-making.

On December 23, 2009, the Council issued a memorandum to routine applicants / participants concerning, among other issues, the consideration of scenic quality and the aesthetic attributes of land that might be affected by projects under the Council's jurisdiction. In the same memorandum, the Council advised applicants to use photographs of aesthetic areas, particularly for use in photo-simulations that depict "leaf off" conditions. In the absence of deciduous vegetative screening, such "leaf off" conditions would tend to represent "worst case" (or maximum) views of potential project facilities.

Pursuant to the Council's specifications for visual resource analyses, Eversource conducted research to identify designated scenic, recreational, open space, and historic properties (collectively referred to herein as the "visual sites") crossed by or in the vicinity of the Proposed Route. These sites were identified based on the review of Project mapping, data contained in land use sections of town plans, and Internet searches. In general, designated scenic, recreation, open space, and historic sites crossed by or within approximately 0.5 - 1 mile of the Proposed Route were identified for further evaluation. Field inspections were conducted of each of the identified potential visual sites. The objectives of the field inspections were to:

- Assess the relationship of each potential visual site to the existing Eversource ROW within which the Project is planned;
- Determine whether Eversource's existing overhead transmission lines are currently visible from each potential visual resource site; and
- Photo-document views, as applicable, of the existing transmission lines from the visual sites. Sites that were determined to be too geographically remote from the ROW or from which views of the overhead transmission lines were blocked by intervening topography, vegetation, or land uses, were not photographed.

Initial field reviews to document visual conditions under "leaf on" conditions were conducted during October 2015, when deciduous forest vegetation was leafed out. In general, such "leaf on" conditions are representative of the spring through fall seasons when public use of most of the designated recreational or scenic areas near the ROW can be expected to be highest. Representative photographs of "leaf off" conditions were taken in January 2016.

The *Visual Resource Analysis* included in *Volume 3* details sites from which the existing Eversource transmission lines are visible during "leaf off" and "leaf on" conditions, based on field inspections. The potential scenic sites investigated included Bennett and Meckauer parks, and the Washington-Rochambeau NHT. The existing transmission lines are visible from portions of Meckauer Park and from the NHT along U.S. Route 6.

The Visual Resource Analysis also includes representative photographs photo-simulations of other areas along the Proposed Route. Many of the areas, particularly along portions of the Proposed Route north of Interstate-84, are well developed industrial/commercial areas dominated by paved surfaces (i.e., parking lots or roads) or maintained lawns and have a clear view of the existing transmission line. Within residential areas between Payne Road in Danbury and Skye Edge Lane in Bethel, the existing transmission lines and managed portions of the ROW are visible principally from public roads. Since much of wetland W1, associated with East Swamp Brook and Limekiln Brook, is an open, emergent wetland, the existing transmission lines are visible from Shelter Rock Road and partially visible from the Lexington Meadows Condominiums in Danbury, as well as Meckauer Park.

5.1.5 Transportation Systems and Utility Crossings

As illustrated on the Volume 5 maps, the Project region is characterized by a well-developed transportation network consisting of roads, railroads, and airport facilities. Utilities are located primarily within roads or in defined ROWs, such as Eversource's transmission line corridors. Two natural gas pipeline facilities also are located in the general Project area. The Volume 5 maps also depict the major utility lines crossed by the Proposed Route.

Danbury Airport, which is located approximately 2 miles (10,560 feet) west of the Proposed Route, is the only airport in the general Project vicinity. Although there are no airports immediately along the Proposed Route, the Federal Aviation Administration (FAA) has the following notification requirements associated with the construction or alteration of an electric transmission line:

- Any construction or alteration exceeding 200 feet above ground level.
- Within 20,000 feet of a public use or military airport which exceeds a 100:1 surface from any point on the runway of each airport with its longest runway more than 3,200 feet.
- Within 10,000 feet of a public use or military airport which exceeds a 50:1 surface from any point on the runway of each airport with its longest runway no more than 3,200 feet.
- Within 5,000 feet of a public use heliport which exceeds a 25:1 surface.

Danbury Airport is a municipal airport owned and operated by the City of Danbury. The airport has two asphalt runways. Runway 8/26 runs generally east-west, is 4,422 feet long and is elevation 456.6 above mean sea level. Runway 17/35 runs generally north-south, is 3,135 feet long and is elevation 451.6 above mean sea level (AMSL).[70] Most traffic from the airport is local. The Danbury Airport operates using visual flight rules (VFR)[71] with no established instrument procedures.

Based on an analysis of the proposed transmission line structures along the Proposed Route, some structures exceed the instrument approach area by approximately 67 feet and an aeronautical study is needed to determine if it will exceed a standard of subpart C of 14 CFR Part 77 (Safe, Efficient Use, and Preservation of the Navigable Airspace) and would require notice to the FAA. However, because the proposed structures would be shorter that the adjacent double-circuit structures, an aeronautical study may not be required.

As listed in Table 5-8 and shown on the maps in Volume 5, the road transportation network in the vicinity of the Proposed Route consists of a variety of federal, state, and local roads. Principal roads crossed by the Eversource ROW are e U.S. Route 6 and I-84. U.S. Route 7 is located west and north of the Project area.

Table 5-8: Road Crossings along the Proposed Route

Road Name	Road Type
Bethel	
Shelter Rock Road	Local Road
Payne Road	Local Road
Hearthstone Drive	Local Road
Chimney Drive	Local Road
Sky Edge Lane	Local Road
Stony Hill Road (US Route 6)	State Highway
Yankee Expressway (Interstate Highway)	Major State Highway
Berkshire Boulevard	Local Road
Research Drive	Local Road
Park Lawn Drive	Local Road
Danbury	
Shelter Rock Road	Local Road
Old Sherman Turnpike	Local Road
Payne Road	Local Road
Brookfield	
Research Drive	Local Road
Park Ridge Road	Local Road

70 https://www.airnav.com/airport/KDXR (Accessed January 2016)
71 http://www.usairnet.com/weather/flightrules/connecticut/ (Accessed January 2016)

Rail services in the Project region include Metro-North (which provides passenger service to Danbury and Bethel), as well as the Housatonic Railroad, Inc. (HRRC), which operates freight service over a dedicated railroad corridor that extends generally east-to-west, directly north of Brookfield Junction. The Proposed Route does not traverse either railroad corridor.

5.1.6 Energy Facilities within a Five Mile Radius

In accordance with CGS §16-50j(59)(15), Table 5-9 lists energy facilities within a 5-mile radius of the proposed Project. These facilities include the Company's transmission facilities, including transmission substations, as well as third party-owned generators and transmission lines. These facilities are located in the Towns of Brookfield, Bethel, Newtown, New Milford, Southbury, and Redding, Weston, Wilton, and in the City of Danbury and Norwalk.

Table 5-9: Energy Facilities within a Five Mile Radius of the Proposed Project

Transmission Substations	
Eversource Middle River 115-kV (Danbury)	
Eversource Triangle 115-kV (Danbury)	
Eversource Stony Hill 115-kV (Brookfield)	
Eversource West Brookfield 115-kV (Brookfield)	
Eversource Bethel 115-kV (Bethel)	
Eversource Plumtree 115/345-kV (Bethel)	
Generators	
FirstLight Power Resources Services LLC – Shepaug Generation 41.5 MW (Southbury)	
Line Numbers	**Transmission Lines**
1270	Plumtree – Middle River 115-kV (Bethel & Danbury)
1337	Middle River - Triangle 115-kV (Danbury)
1760	Plumtree - Newtown 115-kV (Bethel & Newtown)
1770	Plumtree – Bates Rock 115-kV (Southbury, Newtown, Brookfield, & Bethel)
1887	West Brookfield – Shepaug 115-kV (Brookfield)
1565	Ridgefield - Bethel 115-kV (Ridgefield, Redding, & Bethel)
1618	Gale Junction – W. Brookfield Junction 115-kV (New Milford & Brookfield)
321	Long Mountain - Norwalk 345-kV (New Milford, Brookfield, Bethel, Redding, Weston, Wilton, & Norwalk)

5.1.7 Cultural (Archaeological and Historic) Resources

Cultural resources include buried archaeological sites, standing historic structures, or thematically-related groups of structures (i.e., related structures that share a common theme). To be considered significant and eligible for listing on the National or State Registers of Historic Places (NRHP/SRHP), a cultural resource must exhibit physical integrity and contribute to American history, architecture, archaeology, technology, or culture; and must possess at least one of the following four criteria:

- Association with important historic events;
- Association with important persons;
- Distinctive design or physical characteristics; and
- Potential to provide important new information about prehistory or history.

The State Historic Preservation Office (SHPO), which is part of the Connecticut Department of Economic and Community Development, is responsible for reviewing proposed projects to ensure that significant cultural resources will be protected or otherwise preserved.

As part of the Project planning effort, Eversource's cultural resources consultant, Heritage Consultants, LLC (*Heritage*), conducted a preliminary archaeological and historical resources assessment (Phase 1) along the Proposed Route and at the Stony Hill Substation. This preliminary review is included in *Volume 3*.

The objectives of this investigation were to:

1) Gather and present data regarding previously identified cultural resources situated in the vicinity of the Proposed Project areas;
2) Investigate the Proposed Project area's natural and historical characteristics; and,
3) Evaluate the need for completing additional cultural resources investigations.

As a result of these investigations, there are no previously identified historic structures, known archaeological sites or NRHP properties on file with the Connecticut SHPO that are situated within 152 m (500 feet) of the Proposed Project. As part of this review, Heritage also reviewed aerial photographs, historic mapping, and soils distributions throughout the area. Based on this desktop analysis, the Project area was stratified into areas designated based on the likelihood that archeological sites may be encountered. Areas were designated as either "no/low" or "moderate/high" potential areas. In general, areas with low slopes proximate to freshwater sources have were identified as "moderate/high" potential areas and approximately 20-25% of the Proposed Route retain a moderate to high potential to yield intact cultural deposits from either prehistoric or historic periods. The remaining 75-80% of the line has been disturbed, contains mucky soils, and/or is buried beneath paved surfaces, or located within urban soil, which would retain little, if any, intact archaeological deposits. At this time, no field investigations have occurred, however should construction be necessary in moderate/high areas, then a Phase I Reconnaissance Survey should be conducted.

5.1.8 Air Quality

Ambient air quality is affected by pollutants emitted from both mobile sources (e.g., automobiles, trucks) and stationary sources (e.g., manufacturing facilities, power plants, and gasoline stations). Naturally occurring pollutants, such as radon gas or emissions from forest fires, also affect air quality.

In addition to emissions from sources within the state, Connecticut's air quality is significantly affected by pollutants emitted in states located to the south and west, and then transported into Connecticut by prevailing winds. Ambient air quality in the state is monitored and evaluated by the CT DEEP. Air quality conditions are assessed in terms of compliance with the National Ambient Air Quality Standards (NAAQS) for selected "criteria" pollutants, as well as conformance with regulations governing the release of toxic or hazardous air pollutants. State-wide attainment of the NAAQS established by the Federal Clean Air Act Amendment standards for CO, NO_2, Pb, SO_2, $PM_{2.5}$, and PM_{10}[72]. Fairfield County is designated as a non-attainment county for the 8-hour ozone criterion as defined in 2014[73]. New standards were defined on October 1, 2015 and information has yet to be released on changes in attainment status.

The U.S. Environmental Protection Agency (EPA) has determined that carbon dioxide (CO_2) is a pollutant and has included CO_2 in its list of criteria pollutants. Areas of non-attainment have not yet been established for CO_2 or other greenhouse gases. In an effort to reduce particulate emissions, the CT DEEP has promulgated a regulation (RCSA § 22a-174-18), that prohibits unnecessary idling for more than 3 minutes. Exceptions are made for weather extremes, certain service vehicles, and health-related conditions.

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72 http://www3.epa.gov/region1/airquality/pm-ne-nattain.html (Accessed January 2015).
73 http://www.iso-ne.com/static-assets/documents/2015/11/envtl_update20151103.pdf (Accessed January 2015).

5.1.9 Noise

Existing noise levels in the vicinity of the Proposed Route vary as a function of land use, and can be expected to range from sound levels typical of an urban environment to those typical of suburban areas. Noise levels are also variable throughout the day, and are influenced by diverse factors such as vehicular traffic, commercial and industrial activities, and outdoor activities typical of suburban environments. Table 5-10 lists typical sound levels associated with different types of environments and activities.

The State of Connecticut has noise regulations (RCSA §§ 22a-69-1 to 22a-69-7.4) identifying the sound limits that can be emitted by certain types of land uses. The state regulations define daytime vs. nighttime noise periods; classify noise zones based on land use; and identify noise standards for each zone. Table 5-11 summarizes Connecticut's noise zone standards, by emitter (source) and receptor (receiver) noise classification. In general, the regulations specify that noise emitters must not cause the emission of excessive noise beyond the boundaries of their noise zone so as to exceed the allowable noise levels on a receptor's land.

Table 5-10: Typical Noise Levels Associated with Different Indoor and Outdoor Activities

Outdoor Noise Levels	A-Weighted Sound Level (dBA)	Indoor Noise Levels
Jet aircraft take-off at 100 feet	+120	
Riveting machine at operator's position	+110	
Cut-off saw at operator's position	+100	
Elevated subway at 50 feet		
		Newspaper press
Automobile horn at 10 feet		
	+90	Industrial boiler room
Diesel truck at 50 feet		Food blender at 3 feet
Noisy urban daytime	+80	Garbage disposal at 3 feet
Diesel bus at 50 feet		
		Shouting at 3 feet
	+70	
Gas lawn mower at 100 feet		Vacuum cleaner at 10 feet
Quiet urban daytime	+60	Normal conversation at 5 - 10 feet
		Large business office
Quiet urban nighttime	+50	Open office area background level
Substation (transformer)	+43	
Quiet suburban nighttime		
	+40	Large conference room
		Small theater (background)
Quiet rural nighttime	+30	Soft whisper at 2 feet
		Bedroom at nighttime
	+20	Concert hall

Table 5-11: State of Connecticut Noise-Control Regulations by Emitter and Receptor Land-Use Classification

Noise Emitter Class	Noise Receptor Class			
	C: Industrial	B: Generally Commercial	A: Residential Day	A: Residential Night
C: Industrial	70 dBA	66 dBA	61 dBA	51 dBA
B: Generally Commercial	62 dBA	62 dBA	55 dBA	45 dBA
A: Residential	62 dBA	55 dBA	55 dBA	45 dBA

Definitions:
Day = 7:00 AM to 9:00 PM Monday – Saturday; 9:00 AM to 9:00 PM Sunday
Night = 9:00 PM to 7:00 AM Monday – Saturday; 9:00 PM to 9:00 AM Sunday

As illustrated in Table 5-11, the allowable noise levels vary by type of noise emitter and type of noise receptor. For example, an industrial noise emitter is allowed a 70 dBA (decibel, on the A-weighted scale) level on another industrial receptor's property, but only a 61 dBA (daytime) level on a residential receptor's property. Where multiple noise emitter/noise receptor types exist on the same property, the least restrictive limits apply.

The regulation also prohibits the production of prominent, audible discrete tones. If a facility produces such sounds, the applicable limits in Table 5-11 are reduced by 5 dBA to offset the undesirable nature of tonal sound in the environment. The regulation defines prominent discrete tones on the basis of one-third octave band sound levels.

Construction noise is exempted under RCSA § 22a-69-1.8(h); therefore, the noise limits presented in Table 5-8 do not apply to construction of this Project.

In accordance with CGS § 22a-73, municipalities also may adopt noise-control ordinances. Such ordinances must be approved by the Commissioner of CT DEEP and be consistent with the state noise regulations.

Of the three municipalities in the Project area, both Danbury (Chapter 12, Section 12-14) and Brookfield (Chapter 159) have a noise ordinance in effect. Bethel has proposed noise ordinances in the recent past, but has no noise ordinance currently in effect.

Danbury's ordinance prohibits "commercial construction, demolition, excavation and building operations before 7:00 a.m. Monday through Friday, before 8:00 a.m. Saturday, before 10:00 a.m. Sunday, and after 8:00 p.m. any day." The Brookfield ordinance states that no source shall emit noise in excess of 80 dBA at any time and details further restrictions based on the zoning designation of the area and timing restrictions for areas zoned as residential. Brookfield does not reference acceptable noise levels for general construction activities; however, the ordinance provides exceptions for "utility maintenance, including but not limited to, the removal of fallen trees and the installation and repair of utility wire poles."

5.2 STONY HILL SUBSTATION

Stony Hill Substation, which is located at 49 Stony Hill Road in the southern portion of the Town of Brookfield, is situated adjacent to the existing 1770 / 1887 line ROW, approximately 0.8 miles east of Brookfield Junction. The developed (fenced) substation occupies approximately 3.2 acres of a 24.0 acre-Eversource property that is otherwise characterized as predominantly forested. The substation property is presently accessible via an access road off Stony Hill Road on the northern portion of the Eversource property[74]; on-ROW existing access roads continue eastward along the existing 1770 and 1887 lines corridor and to the south alongside the HRRC railroad. The surrounding land use is characterized by forested and residential areas.

Since Stony Hill Substation is located near the northern portion of the Proposed Route, many of the existing environmental conditions described in Section 5.1 also apply to the substation area. Consequently, this section focuses on those existing environment and cultural resource characteristics that are unique to Stony Hill Substation.

5.2.1 Geology, Topography, and Soils

Stony Hill Substation is situated within the Connecticut Valley Terrane, a geology formation that consists of metamorphosed sedimentary and igneous rocks, particularly schist and gneiss of the Hartland and Gneiss Dome Belts,[75] and is located east of Cameron's Line Fault. Specifically, the Substation is situated on Dioritic Gneiss bedrock. The area consists of a rolling topography, with the substation situated at the top

74 As part of modifications to the Stony Hill Substation that are part of a separate submission to the Council, Eversource proposes to develop a new access road to the station. This new access road is proposed to extend off Stony Hill Road on the southern portion of the Eversource property.

75 Rodgers, J. 1985. *Bedrock Geologic Map of Connecticut*. Connecticut Geological and Natural History Survey, CT Department of Environmental Protection. Hartford CT. 1:125,000.

of hill. The landscape slopes down to the access road and railroad to the north, as well as an emergent wetland to the east.

The predominant surficial geology on the Eversource parcel is represented by natural deposed of ice-dammed ponds consisting of sand and gravel in the vicinity of the substation and a swamp and post-glacial deposits composed of swamp deposits on the east side of the parcel. NRCS-mapped soils in the vicinity of the substation include very to extremely stony Woodbridge fine sandy loam and Ridgebury-Leicester-Whitman complex (0 to 8% slopes). Within the wetland to the east of the substation, soils are mapped as Catden and Freetown soils, both histosols. NRCS-designated "Prime Farmland" soils and "Farmlands of Statewide Importance" were not identified at the Stony Hill Substation property, but are present in the surrounding area.

5.2.2 Water Resources, including Floodplains

Two wetlands designated as wetlands W6 and W7 (refer to Volume 5 maps and the Table 5-12) were identified in the vicinity of the Stony Hill Substation. Wetland W6 is classified as a PFO wetland and W7 is classified as an emergent (PEM) wetland. Neither wetland is within the areas that will be affected by the proposed Project modifications to the substation.

Although W7 is associated with a perennial stream, no channel was identified in the Project area. The wetland is impounded by a utility access road and railroad and ponds to the south. The surface water quality of the unnamed stream associated with wetland W7 is Class A and groundwater at the site is rated as GA.

Table 5-12: Delineated Wetlands near Stony Hill Substation in the Town of Brookfield

Volume 5 Mapsheet #		Wetland ID [1]	Dominant NWI Class[2]	Other NWI Classes	Water Regime	Associated Watercourses/ Waterbodies[3]
100' Scale	400' Scale					
14	4	W6	PFO		Seasonally flooded	-
14	4	W7	PFO	PEM	Temporarily flooded	-

[1] Wetland ID refers to wetlands identified in the 2015 field surveys for wetlands in and adjacent to the Project ROW. Wetland IDs are consistent with those depicted in the Volume 2 maps.
[2] Wetlands classifications and water regimes are characterized according to Cowardin et al 1979; PEM = Palustrine Emergent Wetland; PFO = Palustrine Forested Wetland; PSS = Palustrine Scrub-Shrub Wetland; POW = Palustrine Open Water.
[3] No associated vernal pools were identified in the area.

A review of FEMA maps indicates that the Stony Hill Substation is not located in or near any 100-year floodplains. The 500-year floodplain associated with the perennial stream that flows through Wetland W7 is located east of the Project area (refer to Volume 5 maps).

5.2.3 Biological Resources

The developed portion of the Stony Hill Substation is bordered by railroad and Eversource ROWs, as well as forested areas and the emergent wetland system associated with an unnamed perennial stream. This wetland and the surrounding forest could provide habitat for a variety of wildlife and breeding birds. Terrestrial habitats present within the property include upland forest, upland shrubland, forested wetland, and shrub wetland. A discussion of these habitats and the associated wildlife species typically associated with each is provided in Section 5.1.3.2.

As described for the Proposed Route, two Federally listed species may be present in the general vicinity of the substation, according to the USFWS IPaC report: the northern long-eared bat *(Myotis septentrionalis*; "NLEB"*)*, a Federally-Threatened[76] and State-Endangered[77] species, and bog turtle, (*Glyptemys muhlenbergii*), a Federally-Threatened[78] and State-Endangered species. Details regarding the two federally-listed species are included in Section 5.1.3.3. Based on publicly available data from CT DEEP, to date, no other state-listed species are identified within the vicinity of Stony Hill Substation.

5.2.4 Land Uses, Open Space, Visual Resources, and Community Facilities

Eversource's Stony Hill Substation property includes forested uplands, emergent wetlands, and forested wetland. The property is surrounded by forested habitat and residential areas. The developed substation area is not generally visible from Stony Hill Road or from the residential areas due to a thick, forested buffer.

Consistent with the surrounding land use, the area is zoned as residential (R-80) by the Town of Brookfield. Unnamed protected open space is present within the surrounding area including properties maintained by the Town of Brookfield and various real estate agencies as part of subdivisions.

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76 USFWS listing as Federally Threathened became effective on May 4, 2015.
77 State listing as an Endangered species became effective in August 2015.
78 Listed as Federally-Threatened on November 4, 1997.

Community facilities near the site include: the Bee U Daycare located approximately 0.8 mile to the west; Whisconier Middle School, located approximately 0.7 mile to the south, and the Kids Club Daycare approximately 1 mile to the west.

5.2.5 Transportation and Access

Stony Hill Substation is readily accessible via Stony Hill Road. The 1770 and 1887 transmission line structures are accessible from existing utility access roads located along the ROW and near the HRRC railroad ROW (refer to the Volume 5 maps).

5.2.6 Noise

Stony Hill Substation is located within an area zoned for residential use. The ambient sound environment is predominantly influenced by vehicular traffic along Stony Hill Road and occasional train movement along the railroad tracks located to the north of the substation.

The Brookfield noise ordinance (Chapter 159) states that no source shall emit noise in excess of 80 dBA at any time and details further restrictions based on the zoning designation of the area and timing restrictions for areas zoned as residential. Brookfield does not reference acceptable noise levels for general construction activities; however, the ordinance provides exceptions for “utility maintenance, including but not limited to, the removal of fallen trees and the installation and repair of utility wire poles.”

6. POTENTIAL ENVIRONMENTAL EFFECTS AND MITIGATION MEASURES

This section identifies and analyzes the potential short and long-term effects that the construction and operation of the proposed facilities would have on the environment, ecology, scenic, cultural (historical and archaeological), and recreational values. Furthermore, this section describes the measures that Eversource proposes to implement to avoid, minimize, or mitigate adverse effects. This analysis is based on the currently available information concerning the proposed Project, as well as Eversource's past experience with the installation of overhead transmission facilities and modifications to substations throughout New England. The impact and mitigation analysis may be refined after Eversource addresses input from the municipal consultation process.

Section 6.1 discusses the potential effects and measures to mitigate effects associated with the construction and operation of the new 3.4-mile 115-kV overhead electric transmission line (i.e., the extension of the 1887 Line) between Plumtree Substation and Brookfield Junction. The new transmission line, which will interconnect to Plumtree Substation at the southerly end and to the existing 1887 Line at Brookfield Junction at the northerly end, will be aligned entirely within Eversource's existing ROW, adjacent to and generally east of the existing 345-kV 321 and 115-kV 1770 lines, through portions of Bethel, Danbury, and Brookfield. Section 6.2 discusses the potential environmental effects and mitigation measures related to the modifications to the Stony Hill Substation and the reconfiguration of the two existing transmission lines (1770 and 1887 lines) presently connected to the substation.

Overall, the proposed Project would minimize adverse environmental effects by locating the new 115-kV transmission line within an existing Eversource ROW, adjacent to existing overhead transmission lines, and by developing the proposed substation modifications within uplands on Eversource property that is already designated for utility use. Although the construction and operation of the Project would result in unavoidable short- and long-term effects on certain environmental, cultural, and recreational / scenic resources, Eversource has identified measures that can be applied to mitigate these effects to the extent practical. The identified mitigation measures are based on Eversource's historical experience in the construction, operation, and maintenance of the existing transmission lines along the Project ROW; on the results of the field investigations and agency consultations conducted for the Project; and on recent, directly relevant expertise in siting and constructing 115-kV and other transmission facilities elsewhere in Connecticut and New England.

For example, as part of the Project planning process, Eversource modified the new 115-kV transmission line design to place new structures outside of wetlands and watercourses wherever possible. Of the total 28 new structures proposed along the 3.4-mile 1887 Line extension, 11 structures, all located along the southern portion of the route, would be unavoidably located within wetlands. Because of the extent of wetland complexes that extend along, across, and adjacent to the southern portion of the ROW, the placement of these 11 new structures in uplands is not practical. None of the work at or in the vicinity of Stony Hill Substation will involve structure placement in wetlands.

Similarly, as has been the case on other recent transmission line projects, Eversource would commit to prepare Project-specific construction plans related to erosion and sediment control; spill prevention; and ROW revegetation. During construction, Eversource would also preserve low-growing riparian vegetation near watercourses to the extent practical, and would avoid or minimize stream crossings by using upland access roads where possible.

Furthermore, additional measures to avoid or minimize adverse effects to the environment may be identified during the course of the Council proceedings and during the process of acquiring Project-specific permits and approvals from state and federal agencies, including the CT DEEP and the USACE. Mitigation measures, as described herein or as included as conditions of regulatory approvals, would be reflected in the final Project design and incorporated into D&M Plans or other Project specifications, as appropriate. During construction, Eversource would regularly monitor the Project construction contractors' compliance with the D&M Plans and applicable regulatory approvals.

6.1 PROPOSED ROUTE: PLUMTREE TO BROOKFIELD JUNCTION

6.1.1 Topography, Geology, and Soils

The construction and operation of the new 115-kV transmission line (extension of the 1887 line) would have negligible effects on topography and geology, and only minor, short-term, and highly localized effects on soils. These effects would be concentrated in the vicinity of work pads and access roads along the ROW. Some earth-moving activities also may be required to improve off-ROW access roads.

6.1.1.1 Topography and Geology

Generally, the construction of the Project would result in minor, localized changes in elevation only at locations where grading and filling are required, such as at certain structure sites, pulling pads, and guard structure areas where level work pads must be established, or along access roads that must be improved or developed to safely support the ingress and egress of construction equipment. Grading would not be required in instances where the terrain along the ROW is relatively level, where little or no access road improvements or new access roads are needed, or where the conductors span the underlying terrain.

At structure locations, work pads must be established to accommodate the equipment needed to safely install the structure foundation, structure, and associated conductors / hardware. The size of the work pad needed, as well as the changes in grades (e.g., cut or fill) required, will depend on the type of structure and the terrain in the vicinity of each structure. Cut and fill activities typically are localized to the work pad[79] and the immediately adjacent areas. Grading (cut and fill) similarly would be required as necessary at conductor / OPGW pulling work pads and at guard structure work pads. In addition, grading will be required along certain on-ROW and possibly off-ROW access roads to provide safe travel ways for heavy construction equipment.

The Volume 5 400-scale maps identify the general locations of access roads along the ROW, whereas the Volume 5 100-scale maps provide more detail regarding the locations of existing and potential new access roads and work areas along the Proposed Route.

6.1.1.2 Soils

Soils would be disturbed by the same types of Project construction activities that could cause localized alterations to grades, such as the creation or expansion of on- or off-ROW access roads; the establishment of staging areas and contractor yards; leveling (cut or fill) as required to create work pads; and earth-disturbing activities required to install the transmission line structures. Soils also could be disturbed as a result of vegetation removal activities along the ROW. However, the soil disturbance would be short-term, lasting only for the duration of the construction at a particular location, until revegetation or other forms of soil stabilization are achieved.

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[79] The typical construction work area for a tangent structure is 100 feet x 100 feet and the typical construction work area for a deadend structure is 200 feet x 100 feet; however, the specific size and shape of an individual work pad can vary due to site or environmental constraints.

At locations where earth-disturbing activities are required, temporary erosion and sediment control measures (e.g., silt fence, hay/straw bales, filter socks, mulching, temporary reseeding) and / or best management practices (BMPs), as detailed in Eversource's *Best Management Practices Manual Connecticut Construction & Maintenance Environmental Requirements* (2011)[80], would be used to minimize the potential for soil erosion and sedimentation off the ROW, and particularly into watercourses or wetlands (either on or off the ROW). These temporary erosion controls would be deployed as necessary after vegetation removal or after / in conjunction with grading. Typically, the erosion and sediment control measures, which would be installed based on the judgment of Eversource's in-field representatives, would be inspected and maintained throughout the construction period, until final stabilization of disturbed areas is achieved, or until permanent controls (if required) are established.

The need for and extent of temporary and permanent erosion and sedimentation controls would be a function of site-specific field considerations such as:

- Slope (steepness, potential for erosion, and presence of environmentally sensitive resources, such as wetlands or streams at the bottom of the slope);
- Type of vegetation removal method used and the extent of vegetative cover remaining after removal (e.g., presence/absence of understory or herbaceous vegetation that would minimize the potential for erosion and degree of soil disturbance as a result of clearing equipment movements);
- Type of soil and erodibility factor (K-value);
- Soil moisture regimes;
- Schedule of pending construction activities in particular ROW areas;
- Proximity to water resources (e.g., wetlands, watercourses), public roads, or other sensitive environmental resources; and
- Time of year. The types of erosion and sedimentation control methods used along the ROW would depend on the time of year construction work is initiated and completed. For example, re-seeding is typically ineffective during the winter months. In winter, with frozen ground, controls other than re-seeding (such as wood chips, straw, hay, geotextile fabric, erosion control logs, etc.) typically would be deployed or maintained to control erosion and sedimentation and thus to stabilize disturbed areas until reseeding can be performed under optimal seasonal conditions.

The measures selected would be appropriate to minimize the potential for erosion and sedimentation in particular areas of soil disturbance. Eversource would adhere to its BMP Manual and would prepare a Project-specific *Stormwater Pollution Control Plan (*SWPCP*)*. The SWPCP would conform to the

80 Available in hard-copy upon request or at the following link: http://www.transmission-nu.com/contractors/pdf/CT_BMP.pdf

requirements of CT DEEP's *General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities* and with the 2002 *Connecticut Guidelines for Soil Erosion and Sedimentation Control*.

After the completion of earth-disturbing activities, permanent soil stabilization measures (e.g., seeding, mulching, permanent work pad / access road stabilization) would be performed. Temporary erosion controls would be maintained, as necessary, throughout the period of active construction until restoration has been deemed successful, as determined by field inspections and adherence to BMPs for storm water pollution control/prevention and erosion control. The decision to remove temporary erosion controls would be made based on the effectiveness of restoration measures, such as percent vegetative cover achieved, in accordance with applicable permit and certificate requirements.

Rock Removal and Blasting

As currently designed, the proposed new 115-kV structures are weathering steel monopoles. These monopole structures would be supported by concrete caisson foundations. The preferred technique for removing rock, when encountered, would be to use mechanical methods (e.g., mechanical excavators and pneumatic hammers). In the unlikely event that structures cannot be installed via mechanical methods alone; Eversource would use controlled blasting as a supplemental measure. Potential effects from rock removal may include dust, vibration, and noise. If blasting is required, Eversource would develop a *Blasting Control Plan* in compliance with state, industry, and Eversource standards. This plan would be provided to the state and local Fire Marshals.

Furthermore, if blasting is necessary, Eversource would require its construction contractor(s) to employ methods to minimize potential adverse effects (refer to Section 4.2.2). For example, blasting charges, if required, would be designed to loosen only the material that must be removed to provide a stable foundation, and to avoid fracturing other rock. Excavated material that cannot otherwise be used at the site would be removed and properly disposed of elsewhere, pursuant to Project specifications.

6.1.2 Water Resources

The Proposed Route follows an existing Eversource ROW within and adjacent to multiple wetlands and watercourses (collectively referred to as water resources), the majority of which are traversed by the existing overhead transmission lines that currently occupy the ROW. Through Project design and construction planning, Eversource has attempted to avoid or minimize the potential for adverse direct and indirect effects to water resources to the extent practical. For effects that are unavoidable, Eversource would implement mitigation measures, including construction BMPs, such as temporary erosion and sedimentation controls, restoration, and wetland mitigation. Specific water resource mitigation measures would be designed and implemented in accordance with the Project-specific regulatory approvals received from the USACE, CT DEEP, and the Council.

Most potential effects to water resources associated with the development of the new 115-kV transmission line would be short-term and highly localized, with the exceptions of tree removal within forested wetlands and the unavoidable placement of 11 structures within wetlands. The construction of temporary access roads and work pads across wetlands and some streams, which will be unavoidable given the need to locate 11 new structures in wetlands, would represent a short-term and highly localized impact

Tree removal within forested wetlands (as required to allow construction and thereafter to maintain safe distances between vegetation and the transmission line conductors) would not represent any loss of wetland habitat, but would constitute a long-term effect by converting wetland habitat type from forested to scrub-shrub and emergent. In contrast, the unavoidable placement of 11 new transmission line structures within wetlands would involve fill, resulting in a highly localized, but permanent effect to approximately 0.03 acre of wetlands.

The operation and maintenance of the proposed facilities would not have long-term, adverse effects on water quality, watercourses, or waterbodies. The permanent effects on wetlands would largely be the result of expanding the width of the managed ROW within Eversource's existing easement and the fill associated with the installation of 11 new structures. In total, approximately3.5 acres of forested wetlands will be permanently converted to PSS or PEM in association with the expansion of the ROW (tree clearing); although the wetland habitat type would change, the wetland functions would remain. The ROW would be managed in accordance with Eversource's established vegetation management program, the objective of which is to maintain a climax vegetative community of low scrub-shrub growth that does not interfere with the overhead transmission line facilities and allows for inspection and access along the ROW.

Potential direct short-term effects on water resources could stem from erosion and sedimentation into watercourses or wetlands as a result of soil disturbance and vegetation removal along the ROW; fill or sedimentation associated with the installation and use of temporary access roads (i.e., timber mats) across wetlands and small watercourses; temporary fill required along existing access roads near wetlands; work pads in wetlands; and disturbance to wetland plant communities located along the ROW. In addition, the movement of construction equipment and vehicles along the ROW would increase the potential for inadvertent spills of fuels, lubricants or hydraulic oil, which could potentially enter water resources.

In designing and planning the construction of the new 115-kV transmission line, Eversource has incorporated, or would implement during construction, measures to avoid or limit adverse effects to water resources to the extent practical. For example, where practical, Eversource proposes to avoid direct work in watercourses, use temporary timber mats for work pads around structure locations in wetlands, and employ BMPs to limit the potential for erosion/sedimentation or for inadvertent spills of fuels and lubricants into water resources.

Eversource would prepare, and would require its construction contractor to implement, a Project-specific SWPCP, in accordance with CT DEEP requirements as specified in the *General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities*. In addition, Eversource would prepare, and its construction contractor would be required to follow, a Project-specific spill prevention and control plan. Both plans typically would be developed in conjunction with the preparation of the D&M Plans for the Project.

Moreover, any construction work potentially affecting water resources would be performed in accordance with the conditions of Project-specific regulatory approvals required from the USACE, the CT DEEP, and the Council.

Adherence to the conditions of Project permits issued by the CT DEEP and USACE would serve to further avoid, minimize, or mitigate potential adverse effects to water resources during the construction and operation of Eversource's proposed facilities. Eversource would incorporate the conditions of the environmental regulatory approvals into Project documents, and would require the Project construction contractor(s) to adhere to such conditions.

6.1.2.1 Waterbodies

As identified in Table 5-3, eight waterbodies were delineated along the Proposed Route (including four perennial streams, two intermittent streams, one pond, and one stormwater conveyance channel). All of these waterbodies will be spanned by the new 115-kV line. However, based on current construction plans, Eversource anticipates that no temporary construction access roads will be required across six of these waterbodies (i.e., access for construction equipment will be from either side of the water crossings). Temporary access would be required across two watercourses along the ROW in Bethel: East Swamp Brook (perennial stream S1, which is located between proposed structures 1005 and 1006) and the stormwater channel (designated as S7, which is located to the south of new transmission line structure 1022; refer to Volume 5, Exhibit 2B, 100-scale mapsheets 2 and 11, respectively).

The development of the proposed transmission line would not create a new ROW across any waterbodies, but would increase the width of the managed portion of the existing ROW in some sections and would add another overhead transmission line span at each crossing. No in-stream work is proposed.

Eversource would direct its contractors to cross streams, where possible, at the narrowest location such that the crossing could span from bank-to-bank above the stream. Where possible, construction activities would be planned to avoid stream crossings. In areas where streams must be traversed to gain temporary access to work sites and where riparian vegetation (e.g., tree) removal is required, temporary and localized effects to water resources, consisting of short-term increases in turbidity, removal of stream shading vegetation at the crossing, and temporary disturbance to riparian zones, would likely occur.

Potential effects on watercourses may occur from the selective removal of vegetation within riparian zones/buffers (as necessary to allow safe construction or to maintain appropriate clearance from conductors) and from the movement of construction equipment across watercourses via temporary equipment bridges. Where alternative means of access are not available, temporary bridges (consisting of timber mats, metal bridges, or equivalent) may be used for equipment crossings; erosion and sedimentation controls also would be installed as appropriate. Use of such materials would minimize or avoid direct effects to stream banks and stream bottom sediments, and would minimize sedimentation to the extent practical.

Eversource would implement the following mitigation measures to minimize the potential effects of construction activities in or near watercourses:

- Water flows in streams (if water is present at the time of construction) would be unconfined throughout construction.
- Concrete (used for structure foundations) would be mixed, placed, and disposed of so as to avoid or minimize the risk of concrete materials entering a watercourse.
- Existing riparian vegetation within 25 feet of watercourse banks would be maintained or cut selectively, to the extent practical, and consistent with ROW vegetation management requirements.
- Temporary access roads (e.g., consisting of timber mats, metal bridges, or equivalent) across streams will be removed as part of the restoration phase of the Project.
- The D&M Plans and other construction specifications would incorporate the conditions of permits received from the USACE and the CT DEEP relating to the protection of water resources.

6.1.2.2 Wetlands

As identified in Table 5-4, five wetlands were delineated within Eversource's ROW in proximity to the proposed Project activities for the installation of the new line. The construction of the new 115-kV line will affect four of the five wetlands to some degree. However, impacts to four of these wetlands would be temporary only; permanent fill impacts would occur only in wetland W1, within which 11 of the new 115-kV structures would be located. W1 (associated with East Swamp Brook and Limekiln Brook) is the largest wetland, comprising approximately 24% (30 acres) of the total area of the Eversource ROW between Plumtree Substation and Brookfield Junction, and extending along approximately 1.3 miles of the 3.4-mile Proposed Route.

In addition to permanent fill impacts to wetland W1, temporary impacts associated with access and vegetation removal activities will affect wetlands W2, W3, and W4. No impacts are expected to occur to W5 (which is located along the ROW near Research Drive in Bethel).[81] Wetlands W3 and W4 will only require temporary access for vegetation side trimming or tree clearing. Eversource has designed, and proposes to construct, the Project to avoid or minimize adverse effects to wetlands to the extent practical.

Most of the wetlands within Eversource's ROW have historically been affected, to some degree, by the vegetation management practices or other procedures associated with Eversource's operation of the existing overhead transmission lines between Plumtree Substation and Brookfield Junction. The principal effects associated with these existing lines is the ongoing maintenance of scrub-shrub and emergent wetland cover types that presently characterize the managed portions of the ROW, as well as the establishment of certain structures and access roads in wetlands.

The construction and operation of the new 115-kV transmission line along the presently un-managed portions of the existing ROW would result in similar, but incremental, effects to wetlands. Temporary effects to wetlands would occur from the development and use of temporary construction access roads (e.g., using timber mats or gravel placed over geotextile fabric) through wetlands; the placement of temporary work pads and, if required, temporary guard structure work pads or structure support poles[82] in wetlands; the removal of scrub-shrub or emergent wetland vegetation; and incidental sedimentation due to erosion.

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81 The five wetlands are those located within the footprint of the new 115-kV line and therefore potentially affected by the proposed Project construction and maintenance activities.

82 To install the new transmission line, temporary guard structure work pads (on which a bucket-type truck is positioned) or poles may have to be installed in wetlands that are located along the ROW adjacent to public road crossings. These

Long-term effects on wetlands will result from the following activities:

- The removal of vegetation within forested wetlands along the ROW as required for the construction and operation of the new transmission line.[83] Within these areas, forested wetlands would be converted to scrub-shrub or emergent marsh wetland habitats, resulting in a long-term cover type change in wetland communities, but not in an overall net wetland loss or in adverse effects on wetland functions and values.
- The installation of 11 new 115-kV structures within wetland W1. The proposed structures would result in permanent loss of less than 0.03 acre of wetland, (refer to Volume 5, Exhibit 2, mapsheets 1-14). This minor permanent fill (which represents less than 0.1% of the total 30 acres of wetland W1 within the Eversource ROW) and resulting loss of wetland habitat would not adversely affect the principal functions and values associated with wetland W1.

As summarized in Table 6-1, as a result of the proposed Project, less than 0.03 acre of wetlands would be permanently filled in association with the installation of 11 new structures. Approximately 3.6 acres of wetlands would be temporarily affected by construction work areas, such as work pads or timber mat (or equivalent) access roads; these areas will be restored following the completion of the 115-kV transmission line installation.

As also summarized in Table 6-1, approximately 3.5 acres of forested wetland vegetation along the ROW would be removed during Project construction. These forested wetlands would be permanently converted to scrub-shrub or emergent wetlands (refer to Table 6-2), representing a long-term cover type change to wetland habitat, but not either a net loss of wetlands or an adverse impact to wetland functions and values (although the wetland cover type will change, the wetland will continue to provide wildlife habitat, flood control, etc.).

temporary facilities are used during conductor / OPGW stringing to prevent the wires from sagging onto the public road. These temporary facilities (poles and/or work pads) would be removed following the completion of the conductor / OPGW stringing operation. New steel monopole structures will also be installed within wetland W1.

83 The width of vegetation removal is a function of the type of transmission line structure and existing maintained ROW width. The width of vegetation removal may be wider on Eversource fee-owned properties, to accommodate work pads or pull pads. Refer to the cross-sections in Section 3 (Appendix 3A) and the Volume 5, 100 scale maps for details.

Table 6-1: Estimated Surface Area of Wetlands Potentially Affected by the Proposed Transmission Line (Temporary and Permanent Effects)

Project Activity	Estimated Temporary Effect (Approximate Acres)	Estimated Permanent Effect (Approximate Acres)
Access Roads[1]	1.2	N/A
Work Pads and Pull Pads	3.6	N/A
Structure Foundation	N/A	0.03
Tree Clearing	N/A	3.5
Total Primary Wetland Effects (Fill)	**4.8**	**0.03**
Total Secondary Wetland Effects (Tree Removal in Forested Wetlands)	**N/A**	**3.5**[2]

[1]The majority of temporary access road impacts are associated with temporary access for tree clearing.
[2]Area assumes tree clearing will be required over all forested areas. In some areas, tree clearing may not be required where suitable clearance between the proposed new line and tree canopy already exists.

Table 6-2: Summary of Potential Wetland Effects along Proposed 115-kV Transmission Line ROW

Wetland ID[1]	Dominant NWI Classification[2]	Type of Wetland Effect	
		Permanent[3]	Temporary
Bethel			
W1	PEM	Vegetation Removal Outside of Managed ROW, 8 Structures	Work Pad and Access Road
W3	PSS	Vegetation Removal Outside of Managed ROW	Access Road
W4	PEM	Vegetation Removal Outside of Managed ROW	Access Road
Danbury			
W1	PEM	Vegetation Removal Outside of Managed ROW, 4 Structures	Work Pad and Access Road
W2	PEM	Vegetation Removal Outside of Managed ROW	Work Pad and Access Road

[1] Wetland ID refers to wetlands identified in the 2015 field surveys for wetlands in and adjacent to the Project ROW. Wetland IDs are consistent with those depicted in the Volume 2 maps.
[2] Wetlands classifications and water regimes are characterized according to Cowardin et al 1979; PEM = Palustrine Emergent Wetland; PFO = Palustrine Forested Wetland; PSS = Palustrine Scrub-Shrub Wetland; POW = Palustrine Open Water.
[3] "Vegetation Removal Outside of Managed ROW" refers to the vegetation that would have to be cleared from wetlands located within the construction footprint of the proposed 115-kV line, along the presently un-managed portions of Eversource's ROW. In many instances, this activity will also necessitate temporary access road impacts for tree clearing.

BMPs, as detailed in Eversource's *Best Management Practices Manual Connecticut Construction & Maintenance Environmental Requirements* (2011), would be used to minimize disturbances to wetlands during Project construction, as applicable. The wetland boundaries along the ROW would be clearly demarcated (e.g., re-flagged by a registered soil or wetland scientist) prior to the commencement of work. Construction personnel would be provided mapping (e.g., D&M Plans) that depict wetland boundaries in relation to work areas. When working in or traversing such wetlands, Eversource would also employ the construction procedures detailed in Section 4.2.1 and summarized below for ease of reference:

- Comply with the conditions of federal and state permits and certificates related to wetlands;
- Install, inspect, and maintain erosion and sediment controls and other applicable construction BMPs around work sites in or near wetlands to minimize the potential for erosion and sedimentation;
- Limit grading and filling for access roads and work pads in wetlands to the amount necessary to provide a safe workspace;
- Install temporary construction matting for access roads across wetlands or to establish safe and stable construction work areas/ work pads within wetlands, where necessary. The type of stabilization measures to be used in wetlands would depend on soil saturation;
- Cut forested wetland vegetation without removing stumps unless it is determined intact stumps pose a safety concern for the installation of structures, movement of equipment, or the safety of personnel;
- Implement procedures for petroleum product management that would avoid or minimize the potential for spills into wetlands (e.g., to the extent possible, store petroleum products in upland areas more than 25 feet from wetlands; refuel construction equipment, except for equipment that cannot be practically moved, in upland areas only[84]);
- Restore structure work sites in – and temporary access ways through – wetlands following the completion of line installation activities unless permanent fill is authorized in advance by the USACE and CT DEEP; and
- Restore wetlands temporarily affected by construction activities. As the final phase of transmission line construction, restore wetlands to approximate pre-construction contours and configurations to the extent practicable; replace topsoil and/or organic soils disturbed by construction (as appropriate); stabilize with temporary seeding (if necessary); and allow native vegetation to recolonize.

To compensate for the effects to wetlands that would occur as a result of the Project, Eversource would consult with the USACE and CT DEEP to assess mitigation options. The extent of compensatory wetland mitigation required would depend on the final Project design and the amount of direct permanent and

[84] Refueling would be required within wetland W1, where 11 new structures must be installed; consequently, the additional petroleum product management measures would be implemented during such activities.

temporary impacts and secondary and cumulative wetland impacts. Compensatory wetland mitigation options for the Project, which would be specifically evaluated as part of the USACE and CT DEEP regulatory review processes, may consist of wetlands restoration and/or enhancement (on or off the ROW), including invasive species control, in-lieu fee payment, wetland preservation, and/or conservation restrictions.

6.1.2.3 Groundwater Resources and Public and Private Water Supplies

The construction and operation of the new 115-kV transmission line would not adversely affect groundwater resources, including Aquifer Protection Areas, public water supplies, or private groundwater wells. As identified in Section 5.1.2.3, no public wells would be traversed by, or are located in the vicinity of the Project. Based on the most recently available CT DEEP data layers,[85] the Proposed Route does not cross any Aquifer Protection Areas (refer to the Volume 5 USGS locus map in Exhibit 1). The closest such area is Maple Avenue APA, (final, not adopted; Level A) located approximately 1 mile south of and upgradient to the Plumtree Substation. However, the Town of Bethel identifies a Preliminary APA [86] in the vicinity of the existing Plumtree Substation (refer to Volume 5 400-scale maps) and Brookfield identifies an Aquifer Protection District in the vicinity of Brookfield Junction.[87]

During construction, Eversource would require its contractors to adhere to its BMPs and any Project-specific regulatory requirements regarding the storage and handling of any hazardous materials used during the work. Proper storage, secondary containment, and handling of potentially hazardous materials such as diesel fuel, motor oil, grease and other lubricants, would be required.

Construction staging areas and contractor yards, which would be identified during the preparation of the D&M Plans or thereafter by the Project contractor(s), would typically be located at existing developed areas (parking lots, existing storage yards, warehouses, sand/gravel mining areas, etc.). At such yards, contractors may store fuels and lubricants and conduct refueling activities.

85 CT DEEP Aquifer Protection Areas GIS data layer last updated on 12/28/2015.

86 Town of Bethel online GIS Mapping Application: http://hosting.tighebond.com/bethelct/Default.html (Accessed January 2016)

87 Town of Brookfield online GIS Mapping Application: http://brookfield.mapxpress.net/ags_map/ (Accessed December 2015)

6.1.2.4 Flood Zones

The Proposed Route extends across 100-year FEMA-designated flood zones and the regulatory Floodway associated with East Swamp Brook and Limekiln Brook. Both streams largely share the same floodplain and to some extent the same Floodway. Given the location of the existing ROW, these floodplain and Floodway areas cannot be avoided. For example, all but two of the 11 existing 321/1770 line structures between Plumtree Substation and Old Sherman Turnpike are located within the 100-year floodplain, and two are located within the Floodway (existing Structures 10261 and 10268).

Because the proposed 115-kV line must be located within the eastern portion of the ROW, compared to the existing transmission line structures, some new structures must unavoidably be located in either the 100-year floodplain or the Floodway. For example, from Plumtree Substation north to near Old Sherman Turnpike, 12 new structures (proposed Structures 1000—1008 and 1010-1012) would be within the 100-year floodplain. Of these 12 structures, five (Structures 1004, 1006-8, and 1011) would be located within the mapped Floodway. Refer to the Volume 5 Exhibit 1C maps for locations of the 100-year flood plain and Floodway boundaries in relation to the ROW and the existing and proposed transmission line structures.

As a part of the Project application to CT DEEP for a 401 Water Quality Certificate, Eversource would commission hydrologic/hydraulic modeling analyses, as required, to assess the potential effects of these proposed Project activities on floodplains and the Floodway. Based on the results of these analyses and consultations with CT DEEP, Eversource would determine appropriate measures to avoid or minimize adverse effects on flood storage capacity as a result of the 12 new structures within the floodplain, including the five structures within the Floodway.

6.1.3 Biological Resources

The construction and operation of the new 115-kV transmission line would result in generally minor effects on vegetative communities and wildlife. The potential effects will be concentrated primarily within and near the existing ROW within which the proposed new line would be aligned. With the exception of the conversion of existing forested habitat to scrub-shrub habitat, these effects would typically be short-term, lasting one to two seasons post-construction. Moreover, the conversion of some portions of the ROW from forested to low-growth habitats would benefit those species that use such habitats.

6.1.3.1 Vegetation

6.1.3.1.1 Vegetation Communities Affected, including Upland and Wetland Forest Clearing

The construction and operation of the Project facilities would affect portions of the various vegetative communities that presently characterize the Eversource ROW along which the new 115-kV transmission line would be located. In general, the construction of the new 115-kV line, adjacent to Eversource's existing transmission lines, would necessitate removal of trees and shrubs within the construction footprint.

Subsequently, the operation of the Project facilities would require the management of vegetation beneath and in the vicinity of the new transmission line to maintain low-growth communities, consistent with utility industry standards. Along the majority of the existing ROW, this would increase the width of the ROW that Eversource would manage in herbaceous, shrub-scrub, or other low-growth vegetative types. In currently forested wetlands, tree removal would result in a permanent cover type change and the conversion to scrub-shrub and/or emergent wetlands, such as are characteristic of the wetlands within the presently managed portions of the ROW.

Along the approximately 3.4 miles of ROW from Plumtree Substation to Brookfield Junction, Eversource presently manages (on average) a 95- to 140-foot-wide area beneath and adjacent to the existing lines. For the new 115-kV transmission line, an additional 40-to-70-foot-wide area, located within the ROW to the east/south side of the 321/1770 lines, would be cleared of forest and shrub-scrub vegetation for construction and subsequently managed on a long-term basis in low-growth vegetation. The cross sections illustrate the typical location of the existing and proposed transmission lines along each ROW segment and the existing and proposed managed ROW widths (refer to Section 3, Appendix 3A of this volume and to Volume 5 Exhibit 4).

The existing Eversource transmission line ROW, along which the Proposed Route would be located, encompasses approximately 95 acres. Of this, 16.90 acres (17.8%) are mixed deciduous forested upland and approximately 7.6 acres (8%) are palustrine forested wetland (consisting predominantly of deciduous forest cover).

Approximately 9.41 acres of forested habitat would be affected by the Project (5.91 acres of forested upland and 3.5 acres of forested wetland; refer to Table 6-3). These acreages assume tree clearing will be required in all forested areas along the ROW, regardless of clearance to conductors. In some areas, tree clearing may not be required where clearance between the proposed new line and the existing tree canopy is adequate. The affected forested habitat would be within Eversource's existing ROW.

Table 6-3: Approximate Acres of Forest Land[1] to be Converted[2] to Scrub-Shrub Land by Municipality

Municipality	Areas within the Vegetation Removal Limits of the Proposed Route (Estimated Acres, all within Existing Eversource ROW)
Bethel	5.08
Danbury	3.17
Brookfield	1.16
TOTAL[3]	**9.41**

[1] Forest land refers to mixed deciduous tree species in both wetlands and uplands.

[2] Many areas of forest were previously agricultural or shrubland associated with post-agricultural abandonment and succession.

[3] Totals include tree removal required along the Proposed Route pursuant to 115-kV conductor clearance specifications and represent the estimated acreage that would subsequently be managed in shrubland vegetation, consistent with the operation of the 115-kV overhead transmission lines. Additional forested vegetation removal may be required along access roads and construction work areas located outside of the identified "limits of vegetation removal" for conductor clearance purposes.

Based on the results of field investigations and analyses of aerial photography / vegetative cover types, Eversource estimates that most of the forest vegetation to be removed consists of trees with an average diameter breast height (dbh) greater than 5 to 6 inches. The predominant forested communities that would be affected by the Project are mixed deciduous upland forest; this is the dominant forest community type within the Project area. Tree species composition varies along the Proposed Route; however, consistencies were noted throughout areas of similar topographic relief, depth to bedrock (and soil morphology), and prior land use. Forested portions of the ROW are not regularly maintained, and generally occur outside of a shrubland corridor that is periodically maintained to ensure safe clearance to the overhead conductors. Tree species found within mixed forest include deciduous species such as oak (*Quercus* spp.), maple (*Acer* spp.), Birch (*Betula* spp.), Ash (*Fraxinus* spp.) and hickory (*Carya* spp.), as well as coniferous species such as eastern white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*). In the areas where tall-growing trees must be removed during construction, the ROW subsequently would be managed in shrubland or old field habitat.

Converting forest to shrubland, open field, or old field vegetation along the transmission line ROW would modify habitat, representing a long-term, but not a necessarily adverse, affect. In fact, the creation of additional shrubland and early successional habitat (and the preservation of such existing habitat) along the ROW would represent a long-term benefit for many species because shrubland habitat is otherwise declining in New England. This decline is a result of various factors (e.g., conversion of farms, suburban / urban development, ecological succession, absence of fires).

In Connecticut, transmission line ROWs are a major source of shrubland habitat. The ROWs are managed to promote early successional habitats, dominated by scrub-shrub vegetation and open areas with dense grasses and other herbaceous vegetation. Scrub-shrub communities within ROWs provide a variety of wildlife habitat functions (e.g., food, cover and nesting habitat for birds and small mammals, and cover and browse for whitetail deer; Ballard et al., 2004).[88] These plant communities also offer habitats preferred by certain rare and other invertebrate species, including moths, butterflies, and bees, for certain stages of their annual life-cycles.

Other vegetative cover types within the ROW that would be affected by the construction of the Project include existing open field / shrubland, and lawn / landscaped areas associated with developed areas (e.g., houses with yards, commercial / industrial uses, road shoulders). However, the effects on these cover types and land uses would be mostly short-term. After the completion of Project construction, these community types and land uses, which are compatible and/or coexisting with the existing transmission lines, would continue to coexist with the operation and maintenance of the proposed transmission facilities.

6.1.3.1.2 Vegetation Management and Preservation Goals and Methods

The objective of Eversource's well-established vegetation management program is to maintain safe access to its transmission facilities and promote the growth of vegetative communities along its ROWs that are compatible with transmission line operation and in accordance with federal and state standards. The vegetation along the new transmission line would be managed in accordance with these standards.

Eversource has historically conducted ROW vegetation maintenance as a matter of good utility practice. However, since April 7, 2006, all public utilities have been required to comply with mandatory reliability standards adopted by the NERC following the August 14, 2003 Northeast blackout; an event which was triggered by line outages caused by overgrown vegetation. Eversource's vegetation management practices are designed to allow for the safe operation of transmission lines by preventing the growth of trees or invasive vegetation that interfere with the transmission facilities or access along the ROW. As a result, the vegetation within the managed portions of Eversource's ROW typically consists of shrubs, herbaceous

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88 Ballard, B.D., H.L. Whittier, and C.A. Nowak. 2004. *Northeastern Shrubs and Short Tree Identification, A Guide for Right-of-Way Vegetation Management*, State University of New York-College of Environmental Science and Forestry.

species, and other low-growing species. Following construction, Eversource would restore disturbed areas with appropriate herbaceous seed mixes, and mulch with hay/straw or wood chips as appropriate. Vegetative species compatible with the use of the ROW for transmission line purposes are expected to regenerate naturally, over time. Eversource promotes the re-growth of desirable species by implementing ROW vegetation management practices to control tall-growing trees and promote native plant colonization.

When performing ROW management, Eversource would take particular care to preserve vegetation along watercourses and within wetlands to the extent possible. As a general practice, Eversource may alter, to some degree, its vegetation management activities in the following types of areas (not all of which are found along this Project ROW):

- Areas of visual sensitivity where vegetation removal may be limited for aesthetic purposes;
- Steep slopes and valleys spanned by transmission lines;
- Agricultural lands;
- Near homes where owner-maintained ornamental vegetation does not interfere with the construction or operation of the facilities;
- Within wetlands, vernal pool habitats, or along streams to preserve shrub cover;
- Within the 25-foot vegetated riparian zone adjacent to watercourses and waterbodies; and
- In areas documented to support rare animal species or host plant species that support rare invertebrates.

While undesirable tall-growing woody species within the ROW and proximate to the new line would be removed during construction, desirable species are preserved to the extent practical. In selected locations, certain desirable low-growing trees or tall growing shrubs, due to their growth characteristics and locations relative to the new lines, may be allowed to remain on the ROW. These species would be trimmed to ensure that adequate clearance from wires and structures is maintained, pursuant to Eversource's *Rights-of-Way Vegetation Initial Clearance Standard for 115-kV and 345-kV Transmission Lines*. However, any vegetation preserved during construction activities may be removed in the future in accordance with Eversource's *Specification for Rights-of-Way Vegetation Management*. Generally, all tall-growing tree species would be removed from the ROW, whereas low-growing tree species and taller shrub species would be retained in the areas outside of the wire zones. The wire zone is defined as the area directly beneath the conductors extending outward a distance of 15 feet from the outermost conductors.

6.1.3.1.3 Landowner Outreach and Beneficial Use of Forestry Products

The timber and firewood resources along the Proposed Route belong to the landowners across whose property the ROW is aligned. Eversource's policy is to proactively coordinate with landowners regarding the disposition and use of the trees to be removed along the ROW. If requested by the landowner, the firewood and timber portions of the trees would be left in an upland area of the landowner's property on the edge of the ROW. After the limbs are removed, the boles of the trees would be piled in tree-lengths for landowners to cut and remove at their convenience.

Timber and firewood removed along the ROW on Eversource fee-owned property or on parcels where the landowners are not interested in retaining the wood would become the property of the Project's land clearing contractor. Eversource would competitively bid the land clearing work for the Project and would select a contractor taking into considering the contractor's plans for the beneficial use of the forest products that are not otherwise left for landowner use.

6.1.3.2 Wildlife and Fishery Resources

6.1.3.2.1 Wildlife

The development of the new 115-kV transmission line would result in both temporary and permanent alteration of wildlife habitat along the ROW, as well as direct effects on wildlife such as disturbance, displacement, or mortality. However, these effects will be localized on and in the vicinity of the ROW, and would be generally short-term (for the duration of the construction phase of the Project) and minor due to the availability of undisturbed habitat types, similar to those found on the ROW, in adjacent areas and in the Project region as a whole. Furthermore, the Project would have a long-term beneficial effect on certain wildlife species that utilize shrubland habitats.

During construction, the removal of vegetation within the construction footprint would displace wildlife and would reduce cover, nesting, and foraging habitat for some species. Other construction activities (e.g., the development of access roads and work pads; general construction equipment movements; and construction-related noise) would similarly disturb or displace mobile wildlife species, such as large mammals and birds. These species would likely move to comparable nearby habitats. Eversource would minimize adverse effects to wildlife by adhering to mitigation measures, including Project-specific procedures expected to be developed in consultation with CT DEEP and the USACE.

Within the ROW, the removal of existing forest vegetation and the conversion to low-growing vegetative communities would have a long-term beneficial effect on early-successional wildlife by providing additional habitat for species that utilize shrubland, old field, and other non-forested habitats. The wildlife species that would benefit from the additional shrubland habitat include various bird species such as Prairie Warbler, Brown Thrasher, Field Sparrow, Eastern Towhee, and Indigo Bunting, among others, as well as other taxa and species that favor this habitat. While early-successional habitat specialists will benefit from the creation of additional habitat resulting from this project, total habitat for forest-dwelling species would be reduced as a result of the Project.

Overall, although the species of wildlife utilizing the ROW would be expected to change slightly, the ROW would continue to provide diverse wildlife habitat. The exchange of forested habitats for shrublands is often interpreted as a net gain for regional biodiversity (Confer and Pascoe, 2003[89]). A study conducted by Nickerson and Thibodeau (1984) indicated an increase in wildlife utilization, especially in avian species, following clearing of ROWs.[90] The study attributed this increase in wildlife usage to the conversion of forested areas into both wetland and upland shrub and emergent plant communities. The management of ROW vegetation provided edge-effect feeding, nesting, and cover habitat for various species. ROWs also serve as open corridors connecting non-contiguous natural areas.

6.1.3.2.2 Fisheries

The construction and operation of the Project would not have a significant effect on fishery resources. With the exception of temporary construction access across certain streams, no new facilities are proposed for installation in any waterbodies. Temporary access roads across streams would be designed to avoid or minimize direct disturbance to stream banks and substrates to the extent practical, and would conform to USACE and CT DEEP permit requirements.

East Swamp Brook and Limekiln Brook are the only active fisheries identified by *CT DEEP's 2015 Connecticut Angler's Guide*[91] in the vicinity of the Proposed Route. Both streams cross the Project ROW in multiple locations. However, the construction of the new 115-kV line will not require any temporary access roads across Limekiln Brook and only one temporary access crossing of East Swamp Brook (i.e., west of Plumtree Substation, between existing Structures 10268 and 10267). This temporary access road will be removed following the completion of line installation.

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89 United States Department of Agriculture (USDA), 2001, Trends in Connecticut's Forests: A Half-Century of Change, USDA Forest Service, Northeastern Research Station and Connecticut Department of Environmental Protection, Division of Forestry, Hartford, CT.

90 Nickerson, N.H. and F.R. Thibodeau. 1984. Wetlands and Rights-of-Way. Final Report Submitted to the new England Power Company, 25 Research Drive, Westboro, MA.

91 The CT DEEP's 2015 Connecticut Angler's Guide identifies actively stocked or managed fishing areas.

Eversource recognizes that streambank vegetation provides important cover and shading for fish. Within a 25-foot-wide area adjacent to watercourses, lower-growing riparian vegetation along the ROW would be maintained, where possible. Vegetation would be cut only if required to maintain safe clearances from conductors and access to and from the transmission facilities.

Temporary soil erosion and sedimentation controls would be installed around areas of disturbed soils at work sites up-gradient from streams. These temporary erosion controls would remain in place until the disturbed areas are revegetated or otherwise stabilized.

6.1.3.2.3 Vernal Pools

Based on the results of ROW field surveys conducted in 2015, the Proposed Route is not located near any vernal pools. Therefore, no impacts to vernal pool habitat or species is anticipated.

Although no vernal pool habitat was identified during field surveys, vernal pool habitat could be present outside of the ROW in the wetland/floodplain complex (W1) of the East Swamp Brook and Limekiln Brook. However, it is unlikely that vernal pool species exist within the main or backwater channels due to the presence of predatory fish within each of these waterways. If vernal pools are present outside of the ROW, vernal pool species that enter the ROW during construction could potentially be impacted by Project activities during species migration. To prevent this from occurring, appropriate BMPs (such as exclusion silt fence barriers) discussed in the Vernal Pool Assessment (Volume 3, Exhibit 2) could be installed along the limit of work.

6.1.3.2.4 Birds

The proposed Project would result in both long-term benefits and short-term, but minor, effects on bird species that inhabit the ROW and nearby areas. Temporary effects are associated with construction activities (due to direct disturbance and noise), and localized and short-term displacement as a result of periodic vegetation management activities during the operation of Eversource's facilities. These disturbances may drive birds from the work areas or generally disrupt nesting, feeding, or other activities. Once construction is complete, avian utilization of the Project area is anticipated to resume to pre-construction levels.

Permanent effects from the proposed Project are associated with the conversion of forested habitats to shrubland or scrub-shrub wetland. The Proposed Route is characterized in part by managed ROW and is located adjacent to developed land areas; thus, the forested areas bordering the existing managed ROW are categorized as edge forest as opposed to interior forest. Edge forest is favored by ecotone specialists or forest generalists, and is not optimal breeding habitat for forest-interior birds. As described in the *Breeding Bird Assessment* (Volume 3), the Project area is dominated by forest fragments (patch or perforated), non-forest, and edge forest that surrounds small core (<250 acres) forest. As a result, none of the forest blocks that would be impacted by the Project constitute high-value forest. The Proposed Route does coincide with small core edge forests and forest fragments that may provide some breeding habitat for forest-interior species; however, such areas are generally considered sub-optimal, and may serve as population sinks.

A total of 66 breeding birds were identified as possible, probable, or confirmed (based on a review of the *Breeding Bird Atlas*) in the vicinity of the Proposed Route. Of these 66 potential breeding birds, two are state-listed species of Special Concern. In addition, 19 species identified as potentially occurring within the Project area are designated as SGCN by *Connecticut's Wildlife Action Plan*. Of those 19 species, three are classified as *most important*, eleven as *very important* and nine as *important*. A total of nine shrubland and other early-successional bird species will benefit from the conversion of forest to shrubland. These include a number of species of high-conservation priority, including the prairie warbler, blue-winged warbler and field sparrow. Shrublands in the northeastern United States are primarily disturbance-dependent and are typically ephemeral. Left unmanaged, these areas would naturally revert to forest. Despite the transient nature of shrublands and other early successional habitats, many species of birds and other wildlife require these habitats.

The decline of shrublands and other early-successional cover types in the Northeast has had considerable impacts on the populations of associated wildlife. In particular, many bird species have experienced statistically significant population declines due to the loss of suitable breeding habitat.[92] By some estimates, at least 45% of all shrubland birds in the Northeast have experienced statistically significant population declines between 1966 and 2000.[93]

Because transmission line corridors are one of the few sources of persistent early-successional habitat in the Northeast, they play an important role in supporting a variety of bird and wildlife species. This important role in maintaining essential habitat and wildlife biodiversity has been widely acknowledged, not only for bird species but also for a number of reptile and invertebrate species.

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[92] Witham, J. W., and M. L. Hunter, Jr. 1992. *Population Trends of Neotropical Migrant Landbirds in Northern Coastal New England*. In: J. M. Hagan and D. W. Johnston (Eds.), Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, D.C.

[93] Dettmers, R. 2003. Status and Conservation of Shrubland Birds in the Northeastern U.S. Forest Ecology and Management 185:81-93.

Statewide, transmission corridors remain critical habitat for shrubland and other early-successional birds. Vegetation management of transmission line corridors is recommended as part of the regional and national conservation strategy to reverse declines of priority shrubland birds in the eastern region. Askins notes that shrubland birds today are largely dependent on clearcuts and transmission line corridors, and that the latter typically supports a rich diversity of shrubland birds.[94] In the Connecticut Audubon Society's 2009 *State of the Birds* report (p.44), it was noted that "*...shrubland birds are benefitting from maintenance of powerline corridors by utility companies which remove tall-growing trees from the vicinity of wires, creating a habitat dominated by shrubs, grass and herbs."*

6.1.3.3 Federal and State Listed or Proposed Threatened, Endangered, or Special Concern Species

Eversource is coordinating with both the USFWS and the CT DEEP to determine if federal or state-listed species are present and, if present, could be affected by the Project. Should rare species be present, approved measures to avoid or minimize adverse effects on federal and state-listed species would be implemented. Eversource anticipates that no significant adverse effects would occur to any known state- or federal-listed species.

6.1.3.3.1 IPaC Identified Federally-Listed Species

Screening using the USFWS IPaC indicated that Northern Long-eared Bat (*Myotis septentrionalis,* NLEB) and Bog Turtle (*Clemmys muhlenbergii*), both federally-threatened species, may occur or could potentially be affected by activities within the Project area. However, the IPaC database has not been updated to reflect the Final 4(d) Rule, published January 16, 2016, for NLEB.

The USFWS recommends that consultations regarding NLEB be coordinated through CT DEEP. As such, Eversource will consult with CT DEEP on known records of NLEB or hibernacula in the vicinity of the Proposed Route. If hibernacula presence is confirmed, Eversource will adopt appropriate time-of-year restrictions and/or other BMPs identified by the USFWS for tree clearing to prevent adverse impacts to NLEB.

Eversource will also consult with USFWS regarding potential impacts from the Project activities on the Bog Turtle. Bog turtles generally occur in open-canopy, herbaceous meadows and fens that border wooded

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[94] Askins, R. A. 2000. Ibid.

areas. Nesting usually occurs in elevated areas within wetlands, such as hummocks. The emergent wetlands within the ROW are dominated by common reed (*Phragmites* sp.) and thus do not provide suitable breeding habitat for the Bog Turtle. However, suitable habitat may be present adjacent to the ROW.

As such, it is anticipated that biological surveys will be conducted within the Project area in spring and summer 2016. Eversource will coordinate with USFWS on the appropriate BMPs to avoid impacts to Bog Turtles.

6.1.3.3.2 State-Listed Species

Based on initial consultations with the CT NDDB, two state-listed species have been identified as occurring in the vicinity of the Proposed Route. In addition, two state-listed bird species potentially occur in the vicinity of the Proposed Route. As the planning for the Project proceeds, Eversource will consult with the CT DEEP to define species-appropriate mitigation strategies. Such mitigation would be incorporated into the D&M Plan(s) and other Project specifications.

As described in the *Breeding Bird Assessment* (Volume 3, Exhibit 1) and in Section 5.1.3, portions of the Project ROW provide suitable habitat for two state-listed species American kestrel *(Falco sparverius*) and Brown Thrasher *(Toxostoma rufum*). Both of these species utilize shrubland habitat, thus these species may potentially be found along the ROW. However, neither species was observed during field investigations. As a result, impacts to these species during construction are not anticipated. Long-term impacts to these species associated with the Project activities are anticipated to be positive, since the conversion of forested areas will provide additional shrubland habitat that will continue to be maintained for decades to come.

6.1.4 Land Use, Recreational/Scenic Resources, and Land-Use Plans

The proposed 115-kV transmission line would be located adjacent to the existing 321/1770 lines, which are supported together on double-circuit structures, within a ROW that has been used for utility purposes for several decades. The new 115-kV line will be supported on monopole structures that will be – in most locations – between 15 and 42 feet shorter than then existing 321/1770 line structures. Consequently, the overall development of the proposed new 115-kV transmission line and the related interconnection of the new line to Plumtree Substation would be consistent with existing and future land use plans and would typically result in incremental effects on land uses, recreational resources, and scenic views.

6.1.4.1 Land Use

The Project would result in both short-term and long-term effects on land uses. Because the new 115-kV transmission line would be aligned within an existing Eversource ROW that has been dedicated to utility use for decades, the overall effects on land uses will be minor and localized. The new 115-kV transmission line would be located on property subject to existing Eversource easements or within Eversource-owned properties. Consequently, the addition of the new 115-kV line within Eversource's existing ROW would not have any direct long-term effect on land uses.

Overall, approximately 50% of the new transmission line would be aligned across Eversource-owned properties or publicly-owned properties across which Eversource has existing easements; specifically, approximately 0.9 mile (26%) of the 3.4-mile transmission line route would extend across Eversource-owned land, while an additional 0.8 miles (24%) would be across federal, state, or local properties subject to Eversource easements. The construction of the proposed transmission line would convert approximately 3.5 acres of forested wetlands and approximately 6 acres of forested uplands to scrub/shrub lands (refer to Table 6-3).

The upland forest land use type would be converted to open field – shrubland, whereas the forested wetland land-use type would be converted to emergent or scrub-shrub wetlands. The construction of the proposed 115-kV line would also remove entirely or reduce the existing vegetative screening along the southern /eastern portions of the ROW, thereby making the transmission lines potentially more visible from certain residential, commercial, and industrial properties, as well as from Meckauer Park.

The proposed 115-kV transmission line would be located on the eastern portion of Eversource's ROW and would not have any effect on the inactive Danbury Landfill, which is located west of the ROW. For the construction of the new transmission line, Eversource has identified a potential alternative access road that would extend from Plumtrees Road in Danbury, around the landfill, to the ROW. This road is being considered to avoid impacts associated with temporary access road construction along a portion of the ROW. Eversource would coordinate with the City of Danbury regarding this potential access road.

6.1.4.2 Consistency with Existing and Future Land-Use Plans

Based on a review of Connecticut's C&D Plan, municipal *Plans of Conservation and Development*, and regional planning agency land use documents, the construction and operation of the Project facilities would not conflict with local land use plans, because the proposed transmission line would be located within an existing, long-established ROW already dedicated to energy use. Moreover, within the ROW, Eversource's existing easements already specify land uses that are consistent with the safe operation of overhead transmission lines, precluding permanent non-utility structures. Further, the state C&D Plan (Growth Management Principle #1) advocates the development of utility infrastructure to continue to support the state's economic growth and revitalization of regional centers.

6.1.4.3 Public Forests, Parks, Open Space, Recreational / Public Trust Lands, and Trails

The new 115-kV transmission line would be aligned within Eversource's existing ROW across portions of designated recreational areas, including a portion of the East Swamp WMA, Meckauer Park, as well as some undeveloped open space lands (see Section 5.1.4.1). These areas offer year-round recreational opportunities, although peak uses in most areas are in the spring, summer, and fall. As noted in Section 5, Eversource determined that the Project is not located near any Connecticut Heritage Areas, national scenic trails, state- or federally-designated scenic roads, or ConnDOT scenic land strips.

The ROW traverses the northern boundary of the East Swamp WMA, the smaller of the two parcels that compose the WMA. Similarly, the ROW is located within the western portion Meckauer Park. Tree clearing is anticipated within the western portion of this parcel. However, the new line construction will not impact the primary trail system within the park, since the trail system is entirely located outside of the ROW.

Transmission line construction activities may temporarily affect recreational uses by causing traffic congestion or delays on local roads leading to recreational areas; however, there are no recreational trails located within the Project Area that will be affected by the Project activities.

The proposed transmission line would be consistent with the existing utility use of the ROW that already extends across the recreational areas and thus would not result in significant adverse effects on the public uses of such areas. In general, adverse effects on recreational uses, if any, would be short-term, lasting only for the duration of construction.

The operation and maintenance of the new transmission line would not alter the use of the recreational areas traversed by the ROW. Further, the expansion of shrubland habitat could benefit some recreational activities, such as hunting within the East Swamp WMA by providing additional habitat to small game species such as Woodcock (*Scolopax minor*).

Consistent with its typical project planning process, Eversource would coordinate with the owners or managers of the public recreational areas to develop measures to maintain public safety during construction, while also avoiding or minimizing short-term impacts to recreational users. In addition, Eversource would typically provide an anticipated construction schedule to representatives of each recreational use area. The schedule would define Eversource's proposed plans for minimizing disruptions to recreational uses during construction, such as proposed road closures, detours/re-routes, signs in public use areas identifying work zones, etc.

6.1.4.4 Designated Protected and Scenic Resources

As summarized in Section 5.1.5.5, described in more detail in the *Visual Resources Analysis* (Volume 3), and depicted on the Volume 5, 400 scale maps, the proposed 115-kV transmission line would be located within Eversource's existing ROW, adjacent to Eversource's existing 345-kV/115-kV overhead lines, across or near several areas that have scenic attributes, including Bennett and Meckauer parks, the WMA, undeveloped land trust parcels, and the Washington-Rochambeau NHT (which coincides with Stony Hill Road).[95]

Eversource carefully evaluated the proposed Project facilities in relation to these areas and has attempted to minimize incremental visual effects to the extent practical by aligning new structures generally parallel to existing structures. In addition, the proposed 115-kV transmission line structures will be shorter than the existing 345-kV / 115-kV structures and therefore potentially less predominantly visible overall.

As described in Section 5.1.4.2 and in the *Visual Resources Analysis*, designated scenic, recreation, open space, and historic sites crossed by or within approximately 0.5 - 1 mile of the Proposed Route were evaluated to identify the existing and proposed visibility of transmission line structures and ROW. The *Visual Resource Analysis* describes and photo-documents the visual sites from which the existing Eversource transmission lines are visible during "leaf off" and "leaf on" conditions, based on field inspections. To assess the incremental visual effects of the new 115-kV line on the visual environment at these sites, photo-simulations were performed depicting both the existing lines and proposed new line under both "leaf on" and "leaf off" conditions.

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95 The Project area does not encompass any state heritage corridors, as designated in July 2009 pursuant to Connecticut Public Act No. 09-221, codified at CGS § 23-81.

In most cases, the Proposed Route will result in nearly unchanged visibility of the electric transmission corridor since most areas will only require a small expansion of the existing width of the maintained ROW. In addition, the new 115-kV structures will present a smaller visual profile than the existing structures.

Many of the areas, particularly in the northern portions of the Proposed Route, are already well developed industrial/commercial areas dominated by paved surfaces (i.e., parking lots or roads) or maintained lawns and will require minimal changes to the existing cleared transmission corridor width. Long views of the ROW, in general, are limited because of intervening topography, vegetation, or land use. In the vicinity of residential areas from Payne Road in Danbury to Chimney Drive, the removal of forest vegetation along the eastern portion of the ROW for the new 115-kV line will reduce the forest buffer and thus make the transmission lines more visible from nearby residences and to people traveling along these roads.

The new 115-kV line will not affect the Washington-Rochambeau NHT, which coincides with Stony Hill Road in the Project area. The proposed transmission line will span Stony Hill Road, where this NHT is not identified by any signs or other markers and where the predominant land uses consist of commercial and industrial developments and high traffic transportation corridors (i.e., I-84 and Route 6). Thus, there is no historic context for the NHT at this location, where the existing 321/1770 lines already span the road and are prominently visible. The Proposed Route would span the NHT in a similar alignment resulting in a visible, but marginal change, to the existing viewshed.

Views from Meckauer Memorial Park and Bennett Memorial Park should be unchanged from the existing views due to the presence of a forested buffer that will not be affected by the Project activities. From most locations in either park, views of proposed structures would generally be obscured by existing trees that will not be affected by the proposed Project. Since the proposed structures are similarly aligned to the existing structures, views from Bennett Memorial Park and Meckauer Park to the new structures would result in minor and incremental changes to views from each park. However, as is the case now, the transmission lines are not expected to be significant elements of the landscape as viewed by users of these parks.

6.1.4.5 Methods to Prevent and Discourage Unauthorized Use of ROW

Eversource's existing transmission line easements restrict the types of activities that can be conducted within the ROW. Easements typically prohibit the construction of buildings, pools, and other structures within the ROW. Additionally, Eversource has policies addressing requests from property owners and other parties external to Eversource. These policies outline an evaluation process and provide guidelines for allowing certain uses (such as driveways or parking lots), where appropriate. Requests prohibited by the easement agreements, or otherwise posing safety, engineering, environmental, or other concerns are rejected.

Where Eversource holds an easement as opposed to land ownership in fee, Eversource must receive landowner approval prior to installing fences, gates, etc. Eversource seeks to work with landowners and agencies to discourage unwarranted access onto and use of its ROWs, and typically installs signs warning the general public of the overhead hazards posed by contact with the high voltage transmission lines and, with landowner approval, installs fences, gates, barricades, or berms to discourage access onto the ROWs.

In addition, Connecticut law prohibits the operation of ATVs on private land without the written permission of the landowner (CGS § 14-387). Eversource does not allow ATV use on its properties or properties subject to its easements.

6.1.5 Transportation, Access, and Utility Crossings

The construction of the new transmission line would have minor, short-term, and localized effects on transportation patterns in the immediate vicinity of the Project. These effects would stem primarily from additional traffic on local roads associated with the movement of construction vehicles and equipment to and from contractor yards, staging areas, and work sites along the ROW. The proposed 115-kV transmission line conductors would span all roads.

The proposed 115-kV transmission line would not cross any railroads and would not affect other utilities (e.g., water lines, stormwater or sanitary sewers, pipelines), all of which would be spanned by the proposed overhead line. Similarly, the operation of the Project, which would not generate traffic other than that associated with periodic ROW management, would not affect transportation systems or local traffic patterns.

During construction, the well-established public road network in the Project area would afford ready access to the ROW for vehicles and equipment. Along the ROW, construction equipment, materials, and support vehicles would use existing or improved access roads to reach work sites. In certain areas, Eversource proposes to use off-ROW access roads to reach on-ROW work sites.

During construction, personnel traveling to and from work sites, as well as the movement of construction equipment, may cause temporary localized increases in traffic. When heavy equipment and large structure components must be transported along public roads for delivery to the ROW, temporary disruptions in local traffic patterns, delays, or detours could occur. Activities involving the installation of the conductors at or near road crossings also could result in minor, short-term, and localized traffic congestion, delays, or detours. However, any such traffic volume increases would be short-term, as would any detours.

Eversource would employ personnel to direct traffic at construction work sites along public roads, as needed, and would erect appropriate traffic signs to indicate the presence of construction work zones. In addition, to minimize the potential for transportation issues, Eversource would work with representatives of the affected municipalities, as appropriate, regarding traffic control measures. Eversource's construction contractor(s) would implement traffic control measures for safe ingress and egress to the ROW for construction equipment and other vehicles.

Danbury Airport is a municipal airport owned and operated by the City of Danbury open for public use located approximately 2 miles (10,560 feet) to the west of the Proposed Route. Based on an analysis of the height and location of the proposed transmission line structures along the Proposed Route, proximity of the line to the Danbury Airport, and frequencies emitted by the structures using the on-line "Notice Criteria Tool,"[96] the Project would require filing a "Notice of Proposed Construction/Alteration" to the Federal Aviation Administration (FAA). Eversource will consult with the FAA and the Connecticut Airport Authority (CAA) regarding the proposed Project.

6.1.6 Cultural (Historic and Archaeological) Resources

As part of the Project planning effort, Eversource's cultural resources consultant (Heritage) compiled baseline information about the history and prehistory of the Project area, including any known cultural resources in the vicinity of the Proposed Route and Plumtree Substation (refer to Volume 3). This review determined that are no previously identified historic structures, archaeological sites, or NRHP properties on file with the Connecticut SHPO that are situated within 500 feet of the proposed Project ROW or in the general vicinity.

[96] Federal Aviation Administration Notice Criteria Tool: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showNoNoticeRequiredToolForm

Heritage also determined that portions of the Proposed Route have either been previously disturbed by past land use developments or extend through areas (e.g., wetlands) unsuitable for the location of intact archaeological site. In such areas, Heritage recommends that no field studies are required. For remaining portions of the ROW, Heritage recommends field studies to assess the potential sensitivity for archaeological resources.

Thus, along specified portions of the Proposed Route, Eversource expects to conduct archaeological reconnaissance field investigations to assess the potential for intact archaeological sites. If sites are found, Heritage would thereafter work with Eversource to develop appropriate intensive survey testing and other research measures needed to determine the potential NRHP / SRHP eligibility of any discovered sites. This additional work would be performed based on consultations with the Connecticut SHPO and involved Native American tribes.

Any sites determined eligible for the NRHP/SRHP would be avoided if possible, using methods such as the adjustment of construction pads or access road locations; use of low-impact forest vegetation removal with no subsurface disturbance; use of protection measures such as fill or timber mats, etc. Avoidance methods can also include placement of fill material sufficient to resist all effects of construction equipment, but marked with geotextile fabric wherever fill is removed following construction to preclude subsurface disturbance during fill removal. Eversource is sensitive to Connecticut's cultural heritage and is committed to working with the SHPO in protecting and mitigating potential effects to these resources, if applicable.

If avoidance of eligible resources is not possible, mitigation strategies would be developed for review and approval by the SHPO, in consultation with interested Native American tribes. Mitigation would include data recovery sufficient to document significant information from each site.

6.1.7 Air Quality

The construction of the proposed Project facilities would result in short-term, minor, and highly localized effects on air quality, primarily from fugitive dust (as a result of soil disturbance at work sites and from vehicular movements on access roads along the ROW) and from vehicular emissions associated with construction equipment operation. No long-term effects on air quality would result from the operation of the proposed 115-kV transmission line.

To minimize short-term adverse effects to air quality during construction, as necessary, access roads and other sites would be watered to suppress fugitive dust emissions. Additionally, crushed stone aprons would be installed at all access road entrances to public roadways, minimizing tracking of soil onto the road pavement. Vehicular emissions would be limited by requiring contractors to properly maintain construction equipment and vehicles, as well as to conform to Connecticut's vehicular anti-idling regulations (RCSA§ 22a-174-18).

Unlike other criteria pollutants, greenhouse gas (GHG) impacts are global in nature, not local or regional. Consumption of fuel from construction equipment or vehicles is only a part of the global GHG emission sources. The global consumption of fuel would remain the same whether it is combusted during this Project or elsewhere in the world. Since the construction of the proposed Project facilities will be short-term, actual emissions of GHGs would be very small when compared to the carbon footprint of vehicles or permanent emission sources such as a refinery.

6.1.8 Noise

The construction of the new 115-kV transmission line would cause localized, short-term, and generally minor increases in ambient noise levels in the immediate vicinity of work sites. The operation of the transmission line would not affect the noise environment.

Construction-related noise would generally stem from construction equipment operation, truck traffic, earth-moving vehicles and equipment, jackhammers, and structure erection equipment (cranes), etc. Overall, these sound levels would be typical of construction projects.

The temporary increase in construction-related noise could potentially raise ambient sound levels at certain receptor locations near work sites, including residences, commercial office parks and designated recreational areas. The extent of a noise effect to humans at a sensitive receptor is dependent upon a number of factors, including the change in noise level from the ambient; the duration and character of the noise; the presence of other, non-Project sources of noise; people's attitudes concerning the Project; the number of people exposed to the noise; and the type of activity affected by the noise (e.g., sleep, recreation, conversation). The effect of construction-generated noise would also depend on the noise source location relative to the receptor's location because sound attenuates with distance and with the presence of vegetative buffers or other barriers.

Noise levels diminish at a rate of approximately 6 dBA per doubling of distance from a noise source. For example, a noise level of 84 dBA measured at 50 feet from the noise source to the receptor would reduce to 78 dBA at 100 feet from the source to the receptor, and reduce to 72 dBA at 200 feet from the source to the receptor.

Table 6-5 summarizes noise level data compiled for various types of construction equipment and measured at 50 feet from the source. Such construction-generated noise would be localized to the vicinity of construction work sites along the ROW. In general, construction activities would typically occur during the daytime Monday through Saturday (between 7:00 A.M. to 7:00 P.M.), when human sensitivity to noise is lower.

In accordance with the CGS § 22a-73, the City of Danbury and the Town of Brookfield have adopted noise-control ordinances. Such ordinances must be approved by the Commissioner of CT DEEP and be consistent with the state noise regulations. The City of Danbury's Noise Ordinance (Chapter 12, Section 12-14) maintains additional time and day restrictions for construction. The Town of Brookfield's noise ordinance provides exemptions for utility maintenance and installation. Eversource anticipates that the proposed Project activities will be implemented in compliance with these local ordinances, except in special situations in which continuous construction activity may be required. Construction work hours will be defined in the Project's D&M Plans, which must be submitted to and approved by the Council.

Table 6-5: Noise Ranges of Typical Construction Equipment

Equipment	Noise Levels (Leq, dBA) at 50 feet[1]
Backhoe	73-95
Compressors	75-87
Concrete Mixers	75-88
Concrete Pumps	81-85
Cranes (moveable)	75-88
Cranes (derrick)	86-89
Front Loader	73-86
Generators	71-83
Jackhammers	81-98
Paver	85-88
Pile Driving (peaks)	95-107
Pneumatic Impact Equipment	83-88
Pumps	68-72
Saws	72-82
Scraper/Grader	80-93
Tractor	77-98
Trucks	82-95
Vibrator	68-82

[1] Modern machinery equipped with noise control devices or other noise-reducing design features do not generate the same level of noise emissions as shown in this table.
Source: USEPA Office of Noise Abatement and Control, 1971 and U.S. Department of Transportation, Federal Highway Administration (http://www.fhwa.dot.gov/environment/noise/construction_noise/special_report/

6.2 STONY HILL SUBSTATION AND RELATED TRANSMISSION LINE MODIFICATIONS

The proposed modifications at the Stony Hill Substation, specifically the reconfiguration of the capacitor bank connection from Bus A1 to Bus A3, would occur both within the substation and on nearby Eversource property. The proposed modifications to the 1770 and 1887 lines will involve changes to the interconnections of the lines to Stony Hill Substation and, as such, will involve work within the existing ROW immediately adjacent to and within the substation.

Modifications to these lines include the replacement of two structures with new steel monopole structures, the removal of a 3-pole wood structure, removal of the 1887 Line tap on the east side of the substation, removal of a portion of the existing 1770 Line, and installation of a new 1770 Line segment to the east, within the existing ROW. Since the activities are limited to the existing substation and adjacent ROW, anticipated environmental effects would be minor, localized on-site, and short-term (lasting only for the duration of construction).

The proposed modifications would result in a minor change in the appearance of the Stony Hill Substation. However, these effects would be negligible because the site is already developed for electric utility use. The proposed modifications to the existing 1770/1887 lines, would also be minor since the activities are limited to the replacement or removal of existing structures and removal/replacement of overhead conductor.

After the completion of the 115-kV line modifications, the 1887 Line would bypass Stony Hill Substation, whereas the 1770 Line would loop into the substation from both the west and the east. Subsequently, Eversource will re-name the 1770 Line such that the former 1770 Line portion between Stony Hill and Plumtree substations will become the 1268 Line and the former 1770 Line portion extending between Stony Hill and Bates Rock substations will become the 1485 Line.

The following subsections review the potential environmental effects associated with the construction and operation of the Stony Hill Substation modifications, as well as the mitigation measures that Eversource has identified to date.

6.2.1 Topography, Geology, and Soils

The modifications within and outside the substation would require site preparation work, including grading and other soil disturbance (e.g., excavations) to modify the 115-kV transmission line facilities. Mechanical methods would be used to install foundations into bedrock, if encountered. As a result, no blasting is anticipated. Grading and filling, if required, may result in minor alterations to the topography and soils within the substation and adjacent ROW.

To avoid or minimize the potential for erosion and sediment transport beyond the limits of work, construction work would be performed in accordance with an SWPCC, in conformance with the 2002 *Connecticut Guidelines for Soil Erosion and Sediment Control* and CT DEEP stormwater regulatory requirements. Typically, excess soil resulting from the construction of the substation and related line modifications would be removed, rather than stockpiled on site. In addition, construction activities typically would be sequenced to the extent possible, thereby minimizing the amount of time that soils are exposed. Further, after the completion of the substation modifications, disturbed areas would be stabilized with trap rock or another type of crushed stone.

6.2.2 Water Resources

The proposed substation modifications and transmission line relocation activities will occur in upland areas only. Therefore, no direct adverse effects on water resources are anticipated.

Two wetlands (W6 and W7) were identified on undeveloped portions of Eversource's fee-owned property. However, neither wetland will be affected by the Project modifications and only wetland W7 is located in the vicinity of Stony Hill Substation and the adjacent ROW where the 1770/1887 Line modifications are planned. Specifically, wetland W7 is located approximately 160 feet east of Structures 4647 / 4647A.

During the construction of the substation modifications and structure replacement and removal activities, appropriate temporary soil erosion and sedimentation controls would be installed and maintained, pursuant to Eversource's regulatory approvals and BMPs. These erosion and sedimentation control measures would minimize the potential for off-site sedimentation. Similarly, appropriate spill prevention and clean up procedures would be implemented during construction to minimize the potential for inadvertent spills or leaks from construction equipment and, if spills occur, to properly contain and clean them up. Such procedures would be specified in the D&M Plan governing the Stony Hill Substation modification work.

The operation of the Stony Hill Substation and related 1770/1887 lines, as modified, would not affect water resources. Eversource would apply standard operation and maintenance procedures to avoid or minimize the potential for off-site erosion and sedimentation. During facility operation, Eversource also would conform to standards for minimizing the potential for spills or leaks from electrical equipment.

6.2.2.1 Flood Zones

A review of FEMA maps indicates that the Stony Hill Substation (including the proposed fence expansion area) is located beyond the limits of both the 100-year and 500-year flood zones. Therefore, no impact to flood zones would occur

6.2.3 Biological Resources

Because the proposed Stony Hill Substation modifications and 1887/1770 Line modifications would occur within the developed substation or within the adjacent existing ROW, anticipated impacts to biological resources would be temporary, if any. This area has been subjected to historic disturbance associated with the existing substation and a ROW access road. No tree removal is anticipated in order to maintain clearances from the realigned overhead conductor. Given that the activities will be limited to the existing substation and ROW, the modifications are not anticipated to have a long-term adverse impact on wildlife resources.

Based on initial consultations with the CT NDDB, no state-listed plant species have been identified as potentially occurring near Stony Hill Substation.

Screening using the USFWS IPaC indicated that Northern Long-eared Bat (*Myotis septentrionalis,* NLEB) and Bog Turtle (*Clemmys muhlenbergii*), both federally-threatened species, may occur or could potentially be affected by activities in the vicinity of Stony Hill Substation.

As noted above, no tree clearing is proposed at Stony Hill Substation and the site is not located within a town with known NLEB maternity roosts or hibernacula. According to public information provided by the New England Regional USFWS[97], Bog Turtle is not present in the Town of Brookfield. Additionally, Bog Turtle was not identified in the vicinity of the substation by the data provided by NDDB. Finally, no work

[97] New England USFWS. "Federally Listed Endangered and Threatened Species in Connecticut," February 5, 2016.

is proposed within wetlands adjacent to the Stony Hill Substation. Therefore, no impacts to federally-listed species is anticipated.

6.2.4 Land Use, Recreational / Scenic Resources, and Land-Use Plans

The proposed modifications to the existing Stony Hill Substation and 1887/1770 lines would be located on Eversource property, which abuts the HRRC railroad corridor and is set back from Stony Hill Road such that views of the substation are limited. The proposed modifications would be consistent with the existing uses of the site for utility purposes; and would not conflict with Town of Brookfield land use plans. Although the proposed modifications would slightly alter the appearance of the substation and the nearby 115-kV structures within the ROW (i.e., removal of a 3-pole structure, reconfiguration of overhead lines and installation of new structures), the changes would be minimal and would generally be similar in appearance to the existing conditions.

6.2.5 Transportation and Access

The proposed substation modifications would not adversely affect long-term transportation or access patterns. Work on the substation and related transmission line modifications will occur on Eversource property adjacent to the HRRC railroad tracks, but will not affect rail operations.

Stony Hill Road provides primary access to the Stony Hill Substation and would be the principal public road used for ingress / egress to the site during construction. At times during construction, localized traffic congestion may occur when heavy construction equipment or electric components are transported to the substation. The movement of construction workers and equipment in general also would temporarily cause minor increased traffic on local public roads leading to the sites. However, such effects would be minor, localized, and limited to only certain periods during the construction of the substation modifications. Construction activities would be staged on Eversource property, within the fenced station and ROW or on other previously disturbed Eversource fee-owned property.

Traffic on local roads would typically occur during normal work hours. However, some work will depend on the scheduling of allowable line outages and thus may have to be performed at other times.

The operation of the modified substation would have no effect on transportation patterns or traffic.

6.2.6 Cultural (Historical and Archaeological)

Because all construction activities associated with the modifications to the Stony Hill Substation would be within the existing fenced areas or within Eversource's existing ROW, in the vicinity of existing structure foundations where soils have been disturbed by past activities, the potential for encountering intact, previously unrecorded, significant archaeological resources is negligible (refer to the Heritage report in Volume 3). As a result, as indicated in the Heritage report (refer to Volume 3) no adverse effects to cultural resources would occur from the proposed Stony Hill Substation modifications.

6.2.7 Noise and Air Quality

Potential effects to air quality and noise from the activities associated with this portion of the Project are similar to the Proposed Route (see Section 6.1.6 and 6.1.8).

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7. ELECTRIC AND MAGNETIC FIELDS

7.1 ELECTRIC AND MAGNETIC FIELDS FROM POWER LINES AND OTHER SOURCES

Electric fields (EF) and magnetic fields (MF) (EF and MF, collectively "EMF") are forms of energy that surround an electrical device.

EF are produced within the surrounding area of a conducting object (e.g., a wire) when a voltage is applied to it. EF are measured in units of kilovolts per meter (kV/m). The level of an EF near an energized power line depends on the applied voltage, the distance between the conductors, and the distance to the measurement location.

Magnetic fields (MF) are produced within the surrounding area of a conductor or device that is carrying an electric current. MF are measured in units of milliGauss (mG). The level of a MF near transmission line conductors carrying current depends on the magnitude of the current, the distance between conductors, and the distance from the conductors to the measurement location.

Both electric and magnetic fields decrease rapidly as the distance from the source increases, and even more rapidly from electric equipment in comparison to line conductors. EF levels are further weakened by obstructions, such as trees and building walls, while MF pass through most obstructions.

The highest levels of EMF around the perimeter fence of a substation occur where transmission and distribution circuits cross over or under the substation boundary. The levels of fields from substation equipment decrease rapidly with distance, reaching very low levels at relatively short distances beyond the fenced-in equipment.

Substation-caused MF off the property of a substation will commonly be in similar ranges as the background MF levels in homes, approximately from 1 to 4 mG.

7.2 EMF REGULATIONS AND GUIDELINES IN CONNECTICUT

Transmission lines are common sources of EMF, as are other components of electric power infrastructure, ranging from transformers and distribution lines, to the wiring and appliances in a home. There are no state or federal laws or regulations concerning transmission line electric and magnetic fields. However, to address concerns regarding potential health risks from exposure to EMF, the Council, after a nearly two year proceeding, undertaken with the assistance of an independent expert consultant, developed a policy document entitled, *Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut* (EMF BMP Document), a copy of which is provided is provided as *Appendix 7A.*

The EMF BMP Document summarizes the latest information regarding scientific knowledge and consensus on EMF and health concerns and recommends best practices concerning the design of new transmission lines with respect to EMF. The Council most recently revised the EMF BMP Document on February 20, 2014.

In the EMF BMP Document, the Council recognized "that a causal link between power-line MF exposure and demonstrated health effects has not been established, even after much scientific investigation in the U.S. and abroad," and "that timely additional research is unlikely to prove the safety of power-line MF to the satisfaction of all." Accordingly, the Council decided to "continue its cautious approach to transmission line siting that has guided its Best Management Practices since 1993." As the Council states in the EMF BMP Document:

> [t]*his continuing policy is based on the Council's recognition of an agreement with conclusions shared by a wide range of public health consensus groups, and also, in part, on a review which the Council commissioned as to the weight of scientific evidence regarding possible links between power-line MF and adverse health effects. Under this policy, the Council will continue to advocate 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*.

Pursuant to this policy, the Council Document requires an applicant proposing to build an overhead electric transmission line to develop and present a Field Management Design Plan (FMDP) that identifies design features to mitigate MF that would otherwise occur along an electric transmission ROW, In accordance with the BMP guidelines, the proposed new Plumtree Substation to Brookfield Junction transmission line has been designed so that it will have very little effect on magnetic field levels outside the existing Eversource ROW within which it will be constructed.

The magnitude of edge of ROW magnetic fields vary greatly according to the placement and configuration of the conductors on transmission lines, and the spatial relationship and current loading of multiple lines within a single ROW. For instance, one of the EMF BMPs recommended by the Siting Council is "optimum phasing," which refers to an engineering design technique that applies in situations where more than one circuit exists within a ROW. Electric transmission circuits utilize a three-phase system, with each phase carried by one conductor, or a bundle of conductors. Optimum phasing reduces MF through partial cancellation. For a ROW with two or more circuits, the phasing arrangement of the conductors of each circuit can be arranged optimized to reduce MF levels under typical conditions. This design is the prime example of a no-cost method of reducing MF.

Both of the situations described above will exist on the Plumtree Substation to Brookfield Junction ROW after the proposed new line is constructed. The proposed new 115-kV line will be aligned adjacent to the existing double circuit steel pole line supporting the 321 Line (345-kV circuit) and the 1770 Line (115-kV circuit). As a result, the addition of the proposed new line to the Plumtree Substation to Brookfield Junction ROW will have very little effect on the pre-existing edge of ROW magnetic fields, as described below in Section 7.3.

7.3 EMF CALCULATIONS

The EMF BMP Document requires transmission line applicants to present calculations of MF under pre-project and post-project conditions, assuming the use of different transmission line design alternatives. The purpose of this requirement is to "allow for an evaluation of how MF levels differ between alternative power line configurations," in order to "achieve reduced MF levels when possible through practical design changes." However, the reduction of MF is only one of the factors that the Council will consider in approving particular line designs. Other factors include "cost, system reliability, aesthetics, and environmental quality."

Eversource prepared initial calculations of predicted MF from the transmission lines along the Proposed Route under average annual load conditions. The results of these calculations are presented in Figure 7-1. The graph illustrates the anticipated MF, calculated assuming a projected average annual loading condition in the year 2018 for the existing transmission lines and 2023 for the proposed transmission line. The calculations are made relative to the centerline of the proposed transmission line. As provided by standard protocols, the calculations apply at 1 meter (3.28 feet) above grade. The calculations assume that the lowest conductor for proposed 115-kV circuit is 30 feet above grade and that the existing 115-kV and 345-kV circuit is 35 feet above grade. These calculations confirm that the addition of the new line will increase the magnetic fields at the edges of the ROW and the peak within the ROW.

Eversource also prepared calculations of EF from the transmission lines along the Proposed Route (refer to Figure 7-2). The calculations assume that the voltages on all transmission lines are at 1.05 per unit value (the maximum permissible voltage per ISO-NE planning criteria). The conductor heights are assumed to be the same as for the magnetic field calculations discussed above. The calculations confirm that the electric fields will decrease on the west edge of the ROW and the peak within the ROW, but will increase slightly at the East edge of the ROW. All calculations are summarized in Table 7-1:

Table 7-1 - Summary of Electric and Magnetic Field Calculations

Electric and Magnetic Field Calculation Summary (Average Annual Loads)						
Section	West Edge of ROW		Max in ROW		East Edge of ROW	
	Pre	Post	Pre	Post	Pre	Post
Electric Fields (kV/m)	0.17	0.16	4.58	4.30	0.17	0.22
Magnetic Fields (mG)	9.9	12.9	65.5	78.5	12.2	14.0

Figure 7-1 - Calculated Magnetic Fields (Average Annual Loads)

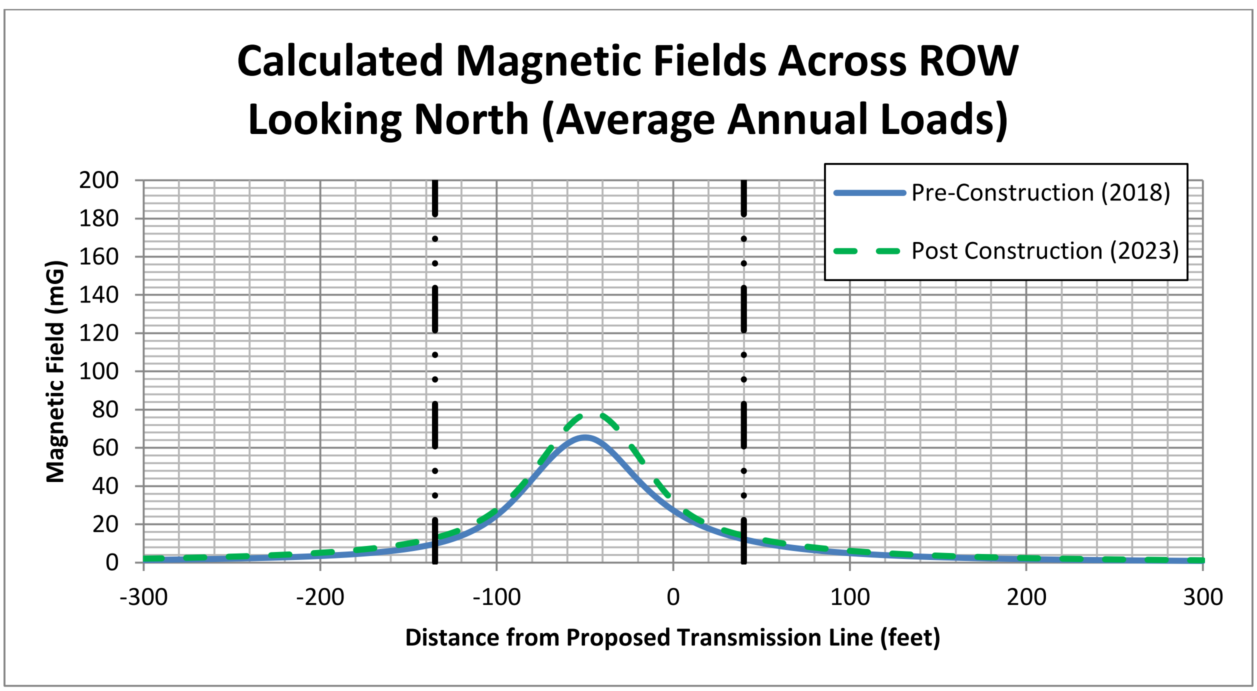
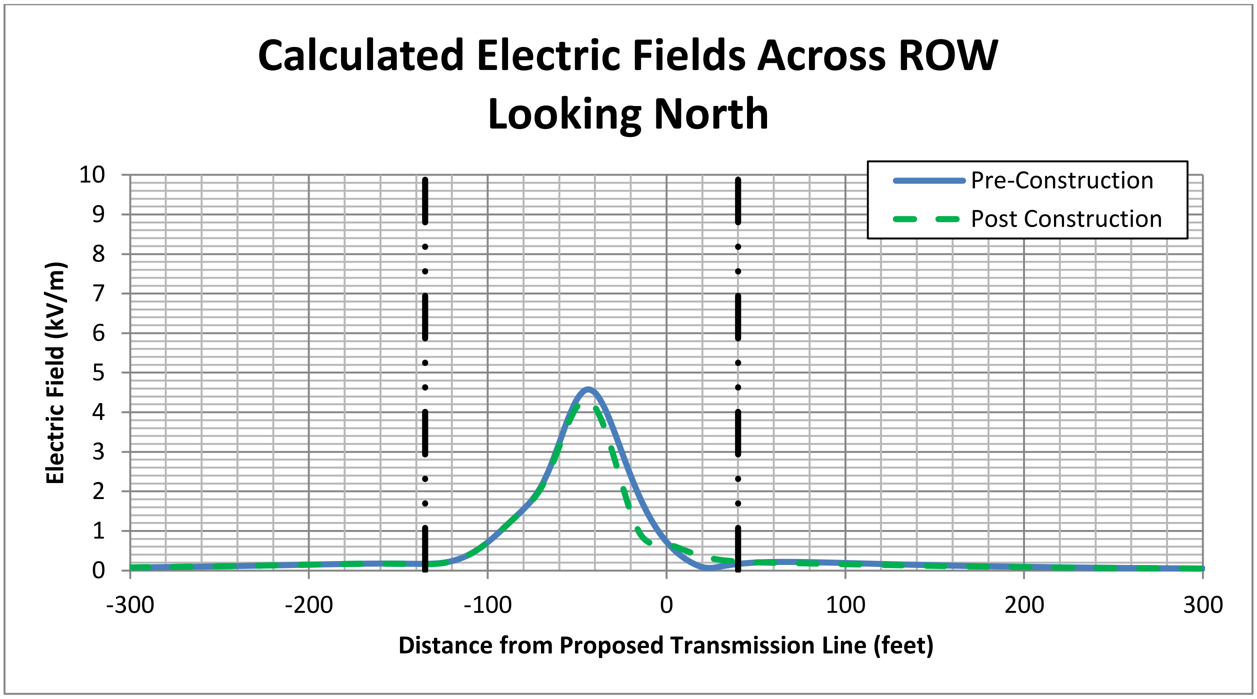


Figure 7-2 - Calculated Electric Fields



7.3.1 Comparison of Edge of ROW Magnetic Fields to International Guidelines

Although there are no binding regulations limiting EMF exposures, there are guidelines that have been developed by the international scientific community, in particular the International Committee on Electromagnetic Safety ("ICES", a committee of the Institute of Electrical and Electronics Engineers) and the International Council on Non-Ionizing Radiation Protection (ICNIRP), a specially chartered independent scientific organization. Under all projected operating conditions after the proposed line is placed in service, the calculated electric and magnetic fields will be a small fraction of the ICNIRP and ICES guidelines, which are summarized Table 7-2.

Table 7-2: International Restrictions for Electric and Magnetic Fields

	EF (kV/m)	MF (mG)
ICES	26.8	9,150
ICNIRP	36.4	12,400

The calculations presented in Section 7.3 project that after the new line is constructed, under typical (annual average) operating conditions, edge of ROW magnetic fields will range from 12.9 mG to 14.0 mG and electric fields will range from 0.16 to 0.22 kV/m.

7.4 REVIEW OF SCIENTIFIC LITERATURE ON HEALTH EFFECTS ASSOCIATED WITH EMF

In addition to the calculations required, the BMP also require that the applicant provide information documenting the changes and developments in research into the effects of EMF on human health. To address this need, Eversource retained Exponent, Inc. to prepare a report on the state of the science with regard to health effects of electric and magnetic fields. This report is included as Attachment 7A.

7.5 CONCLUSION ON HEALTH AND SAFETY OF PROPOSED TRANSMISSION FACILITY.

Based on the calculations provided, and a review of the scientific literature attached, there is no basis to include that the proposed transmission facility will have a negative impact on the health and safety of the public from electric and magnetic fields.

APPENDIX 7A

Electric and Magnetic Fields Best Management Practices For the Construction of Electric Transmission Lines in Connecticut

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February 21, 2014

TO: Parties and Intervenors

FROM: Melanie Bachman, Acting Executive Director MAB

RE: **Petition 754 - Best Management Practices for Electric and Magnetic Fields**

Please find attached the Council's "Electric and Magnetic Field Best Management Practices for the Construction of Electric Transmission Lines in Connecticut" as revised. This guidance document was approved by the Council on February 20, 2014.

Enclosure

Electric and Magnetic Fields Best Management Practices
For the Construction of Electric Transmission Lines in Connecticut

Revised on February 20, 2014

I. Introduction

To address a range of concerns regarding potential health risks from exposure to transmission line electric and magnetic fields (EMF), whether from electric transmission facilities or other sources, the Connecticut Siting Council (Council) (in accordance with Public Act 04-246) issues this policy document "*Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut.*" It references the latest information regarding scientific knowledge and consensus on EMF health concerns; it also discusses advances in transmission-facility siting and design that can affect public exposure to EMF.

Electric and magnetic fields (EMF) are two forms of energy that surround an electrical device. The strength of an electric field (EF) is proportional to the amount of electric voltage at the source, and decreases rapidly with distance from the source, diminishing even faster when interrupted by conductive materials, such as buildings and vegetation. The level of a magnetic field (MF) is proportional to the amount of electric current (not voltage) at the source, and it, too, decreases rapidly with distance from the source; but magnetic fields are not easily interrupted, as they pass through most materials. EF is often measured in units of kilovolts per meter (kV/m). MF is often measured in units of milligauss (mG).

Transmission lines are common sources of EMF, as are other substantial components of electric power infrastructure, ranging from transformers at substations to the wiring in a home. However, any piece of machinery run by electricity can be a source of EMF: household objects as familiar as electric tools, hair dryers, televisions, computers, refrigerators, and electric ovens.

In the U.S., EMF associated with electric power have a frequency of 60 cycles per second (or 60 Hz). Estimated average background levels of 60-Hz MF in most homes, away from appliances and electrical panels, range from 0.5 to 5.0 mG (NIEHS, 2002). MF near operating appliances such as an oven, fan, hair dryer, television, etc. can range from 10's to 100's of mG. Many passenger trains, trolleys, and subways run on electricity, producing MF: for instance, MF in a Metro-North Railroad car averages about 40-60 mG, increasing to 90-145 mG with acceleration (Bennett Jr., W. 1994). As a point of comparison to these common examples, the Earth itself has an MF of about 570 mG (USGS 2007). Unlike the MF associated with power lines, appliances, or computers, the Earth's MF is steady; in every other respect, however, the Earth's MF has the same characteristics as MF emanating from man-made sources.

Concerns regarding the health effects of EMF arise in the context of electric transmission lines and distribution lines, which produce time-varying EMF, sometimes called extremely-low frequency electric and magnetic fields, or ELF-EMF. As the weight of scientific evidence indicates that exposure to electric fields, beyond levels traditionally established for safety, does not cause adverse health effects, and as safety concerns for electric fields are sufficiently addressed by adherence to the National Electrical Safety Code, as amended, health concerns regarding EMF focus on MF rather than EF.

MF levels in the vicinity of transmission lines are dependent on the flow of electric current through them and fluctuate throughout the day as electrical demand increases and decreases. They can range from about 5 to 150 mG, depending on current load, height of the conductors, separation of the conductors, and distance from the lines. The level of the MF produced by a transmission line decreases with increasing distance from the conductors, becoming indistinguishable from levels found inside or outside homes (exclusive of MF emanating from sources within the home) at a distance of 100 to 300 feet, depending on the design and current loading of the line (NIEHS, 2002).

In Connecticut, existing and proposed transmission lines are designed to carry electric power at voltages of 69, 115, or 345 kilovolts (kV). Distribution lines, i.e. those lines directly servicing the consumer's building, typically operate at voltages below 69 kV and may produce levels of MF similar to those of transmission lines. The purpose of this document is to address engineering practices for proposed electric transmission lines with a design capacity of 69 kV or more and MF health concerns related to these projects, but not other sources of MF.

II. Health Concerns from Power-Line MF

While more than 40 years of scientific research has addressed many questions about EMF, the continuing question of greatest interest to public health agencies is the possibility of an association between time weighted MF exposure and demonstrated health effects. The World Health Organization (WHO) published its latest findings on this question in an Electromagnetic Fields and Public Health fact sheet, June 2007) http://www.who.int/peh-emf/publications/facts/fs322/en/index.html The fact sheet is based on a review by a WHO Task Group of scientific experts who assessed risks associated with ELF-EMF. As part of this review, the group examined studies related to MF exposure and various health effects, including childhood cancers, cancers in adults, developmental disorders, and neurobehavioral effects, among others. Particular attention was paid to leukemia in children. The Task Group concluded "that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukemia". (WHO, 2007) For childhood leukemia, WHO concluded recent studies do not alter the existing position taken by the International Agency for Research on Cancer (IARC) in 2002, that ELF-MF is "possibly carcinogenic to humans."

Some epidemiology studies have reported an association between MF and childhood leukemia, while others have not. Two broad statistical analyses of these studies reported an association with estimated average exposures greater than 3 to 4 mG, but at this level of generalization it is difficult to determine whether the association is significant. In 2005, the National Cancer Institute (NCI) stated, "Among more recent studies, findings have been mixed. Some have found an association; others have not . . . . Currently, researchers conclude that there is limited evidence that magnetic fields from power lines cause childhood leukemia, and that there is inadequate evidence that these magnetic fields cause other cancers in children." The NCI stated further: "Animal studies have not found that magnetic field exposure is associated with increased risk of cancer. The absence of animal data supporting carcinogenicity makes it biologically less likely that magnetic field exposures in humans, at home or at work, are linked to increased cancer risk."

The National Institute of Environmental Health Sciences (NIEHS) concluded in 1999 that EMF exposure could not be recognized as "*entirely safe*" due to some statistical evidence of a link with childhood leukemia. Thus, although no public health agency has found that scientific research suggests a causal relationship between EMF and cancer, the NIEHS encourages "inexpensive and safe reductions in exposure" and "suggests that the power industry continue its current practice of siting power lines to reduce exposures" rather than adopting strict regulatory guidelines (NIEHS, 1999, pp. 37-38). In 2002 NIEHS restated that while this evidence was "weak" it was "still sufficient to warrant limited concern" and recommended "continued education on ways of reducing exposures" (NIEHS, 2002, p. 14).

Reviews by other study groups, including IARC (2002), the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (2003), the British National Radiation Protection Board (NRPB) (2004a), and the Health Council of the Netherlands ELF Electromagnetic Fields Committee (2005), are similar to NIEHS and NCI in their uncertainty about reported associations of MF with childhood leukemia. In 2004, the view of the NRPB was:

> "[T]he epidemiological evidence that time-weighted average exposure to power frequency magnetic fields above 0.4 microtesla [4 mG] is associated with a small absolute raised risk of leukemia in children is, at present, an observation for which there is no sound scientific explanation. There is no clear evidence of a carcinogenic effect of ELF EMFS in adults and no plausible biological explanation of the association can be obtained from experiments with animals or from cellular and molecular studies. Alternative explanations for this epidemiological association are possible...Thus: any judgments developed on the assumption that the association is causal would be subject to a very high level of uncertainty." (NRPB, 2004a, p. 15)

Although IARC classified MF as "possibly carcinogenic to humans" based upon pooling of the results from several epidemiologic studies, IARC further stated that the evidence suggesting an association between childhood leukemia and residential MF levels is "limited," with "inadequate" support for a relation to any other cancers. The WHO Task Group concluded "the evidence related to childhood leukemia is not strong enough to be considered causal" (WHO, 2007).

The Connecticut Department of Public Health (DPH) has produced an EMF Health Concerns Fact Sheet (May 2007) that incorporates the conclusions of national and international health panels. The fact sheet states that while "the current scientific evidence provides no definitive answers as to whether EMF exposure can increase health risks, there is enough uncertainty that some people may want to reduce their exposure to EMF."
http://www.ct.gov/dph/lib/dph/environmental_health/eoha/pdf/emf_fact_sheet_-_2008.pdf

In the U.S., there are no state or federal exposure standards for 60-Hz MF based on demonstrated health effects. Nor are there any such standards world-wide. Among those international agencies that provide guidelines for acceptable MF exposure to the general public, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) established a level of 833 mG, based on an extrapolation from experiments involving transient neural stimulation by MF at much higher exposures. Using a similar approach, the International Committee on Electromagnetic Safety (ICES) calculated a guideline of 9,040 mG for exposure to workers and the general public (ICNIRP, 1998; ICES/IEEE, 2002). This situation reflects the lack of credible scientific evidence for a causal relationship between MF exposure and adverse health effects.

In November 2010, ICNIRP updated its guidelines. The new guideline establishes 2,000 mG as an acceptable exposure level for the general public replacing the previous 1998 exposure guideline of 833 mG. (See "ICNIRP Statement – Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz). Health Physics 99(6):818-836; 2010" http://www.icnirp.org/documents/LFgdl.pdf and "Fact Sheet on the Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz) Published in Health Physics 99(6):818-836;2010" http://www.icnirp.org/documents/FactSheetLF.pdf at www.icnirp.org.)

III. Policy of the Connecticut Siting Council

The Council recognizes that a causal link between power-line MF exposure and demonstrated health effects has not been established, even after much scientific investigation in the U.S. and abroad. Furthermore, the Council recognizes that timely additional research is unlikely to prove the safety of power-line MF to the satisfaction of all. Therefore, the Council will continue its cautious approach to transmission line siting that has guided its Best Management Practices since

1993. This continuing policy is based on the Council's recognition of and agreement with conclusions shared by a wide range of public health consensus groups, and also, in part, on a 2006 review which the Council commissioned as to the weight of scientific evidence regarding possible links between power-line MF and adverse health effects[1]. Under this policy, the Council will continue to advocate 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. This approach does not imply that MF exposure will be lowered to any specific threshold or exposure limit, nor does it imply MF mitigation will be achieved with no regard to cost.

The Council has developed its precautionary guidelines in conjunction with Section 16-50p(i) of the Connecticut General Statutes, enacted by the General Assembly to call special attention to their concern for children. Subject to technological feasibility, the Act restricts the siting of overhead 345-kV transmission lines in areas where children congregate. These restrictions cover transmission lines adjacent to "residential areas, public or private schools, licensed child day-care facilities, licensed youth camps, or public playgrounds."

Developing Policy Guidelines

One important way the Council seeks to update its Best Management Practices is to integrate policy with specific project development guidelines. In this effort, the Council has reviewed the actions of other states. Most states either have no specific guidelines or have established arbitrary MF levels at the edge of a right-of-way that are not based on any demonstrated health effects. California, however, established a no-cost/low-cost precautionary-based EMF policy in 1993 that was re-affirmed by the California Public Utilities Commission in 2006. California's policy aims to provide significant MF reductions at no cost or low cost, a precautionary approach consistent with the one Connecticut has itself taken since 1993, consistent with the conclusions of the major scientific reviews, and consistent with the policy recommendations of the Connecticut Department of Public Health and the WHO. Moreover, California specifies certain benchmarks integral to its policy. The benchmark for "low-cost/no-cost" is an increase in aggregate project costs of zero to four percent. The benchmark for "significant MF reduction" is an MF reduction of at least 15 percent. With a policy similar to Connecticut's, and concrete benchmarks as well, California offers the Council a useful model in developing policy guidelines.

No-Cost/Low-Cost MF Mitigation

The Council seeks to continue its precautionary policy, in place since 1993, while establishing a standard method to allocate funds for MF mitigation methods. The Council recognizes California's cost allotment strategy as an effective method to achieve MF reduction goals; thus, the Council will follow a similar strategy for no-cost/low-cost MF mitigation.

The Council directs the Applicant to initially develop a baseline Field Management Design Plan that depicts the proposed transmission line project designed according to standard good utility practice and incorporating "no-cost" MF mitigation design features. The Applicant shall then modify ~~the~~ this base design by adding low-cost MF mitigation design features specifically where portions of the project are adjacent to residential areas, public or private schools, licensed child day-care facilities, licensed youth camps, or public playgrounds. The overall cost of low-cost design features are to be calculated at four percent of the initial Field Management Design Plan, including related substations. The best estimates of total project costs that are worked out during the Council proceedings should be employed, with the amounts proposed to be incurred for MF mitigation excluded. It is important to note that the four percent guideline is not an absolute cap, because the

[1] Current Status of Scientific Research, Consensus, and Regulation Regarding Potential Health Effects of Power-Line Electric and Magnetic Fields (EMF) http://www.ct.gov/csc/lib/csc/emf_bmp/emf_report.pdf

Council does not want to eliminate prematurely a potential measure that might be available and effective but would cost more than the four percent, or exclude arbitrarily an area adjacent to the ROW that might be suitable for MF mitigation. Nor is the four percent an absolute threshold, since the Council wants to encourage the utilities to seek effective field reduction measures costing less than four percent. In general, the Council recognizes that projects can vary widely in the extent of their impacts on statutory facilities, necessitating some variance above and below the four percent figure.

The four percent guideline for low-cost mitigation should aim at a magnetic field reduction of 15 percent or more at the edge of the utility's ROW. This 15 percent reduction should relate specifically to those portions of the project where the expenditures would be made. While experience with transmission projects in Connecticut since 1993 has shown that no-cost/low-cost designs can and do achieve reductions in MF on the order of 15 percent, the 15 percent guideline is no more absolute than the four percent one, nor must the two guidelines be correlated by rote. The nature of guidelines is to be constructive, rather than absolute.

The Council will consider minor increases above the four percent guideline if justified by unique circumstances, but not as a matter of routine. Any cost increases above the four percent guideline should result in mitigation comparably above 15 percent, and the total costs should still remain relatively low.

Undergrounding transmission lines puts MF issues out of sight, but it should not necessarily put them out of mind. After all, soils and other fill materials do not shield MF; rather, MF is reduced by the underground cable design (refer to page 9 for further information). However, special circumstances may warrant some additional cost in order to achieve further MF mitigation for underground lines. The utilities are encouraged, prior to submitting their application to the Council, to determine whether a project involves such special circumstances. Note that the extra costs of undergrounding done for purposes other than MF mitigation should be counted in the base project cost and not as part of the four percent mitigation spending.

Additionally, the Council notes two general policies it follows in updating its EMF Best Management Practices and conducting other matters within its jurisdiction. One is a policy to support and monitor ongoing study. Accordingly, the Council, during the public hearing process for new transmission line projects, will consider and review evidence of any new developments in scientific research addressing MF and public health effects or changes in scientific consensus group positions regarding MF. The second Council policy is to encourage public participation and education. The Council will continue to conduct public hearings open to all, update its website to contain the latest information regarding MF health effect research, and revise these Best Management Practices to take account of new developments in MF health effect research or in methods for achieving no-cost/low-cost MF mitigation.

During its review of two recent transmission-line projects–Docket No. 424, approved December 27, 2012 and Docket No. 435, approved September 5, 2013–the Council pursued its policy of monitoring research on EMF.

In Council Docket No. 424 the document titled, "*Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Interstate Reliability Project, June 10, 2011*" was centered around the WHO 2007 report examining reports or scientific statements regarding the potential health effects of ELF-EMF over the ~~past~~ previous five years. In Council Docket No. 435 the document titled, "*Update of Research on Extremely Low Frequency Electric and Magnetic Fields and Health May 1, 2011 – July 31, 2012 Stamford Reliability Cable Project August 30, 2012*" provides a bibliography of peer-reviewed national and international research and reviews. In general, the conclusions of these two documents are consistent with the scientific consensus articulated by the WHO and other scientific organizations and have not found any *consistent* associations with regard to ELF EMF exposure and any type of cancer or disease, except childhood leukemia, nor have they concluded that there is a cause-and-effect link with any health effect, including childhood leukemia.

Applying its policy of encouraging public participation and education the Council will continue to require that notices of proposed overhead transmission lines provided in utility bill enclosures pursuant to Conn. Gen. Stats. §16-50/(b) state the proposed line will meet the Council's Electric and Magnetic Fields Best Management Practices, specifying the design elements planned to reduce magnetic fields. The bill enclosure notice will inform residents how to obtain siting and MF information specific to the proposed line at the Council's website; this information will also be available at each respective town hall. Phone numbers for follow-up information will be made available, including those of DPH and utility representatives. The project's final post-construction structure and conductor specifications, including calculated MF levels, shall also be available at the Council's website and each respective town hall.

Finally, we note that Congress has directed the Department of Energy (DOE) periodically to assess congestion along critical transmission paths or corridors and apply special designation to the most significant ones. Additionally, Congress has given the Federal Regulatory Commission supplemental siting authority in DOE-designated areas. This means the Council must complete all matters in an expeditious and timely manner. Accordingly, the cooperation of all parties will be of particular importance in fulfilling the policies set forth above.

IV. MF Best Management Practices: Further Management Considerations

The Council's EMF Best Management Practices will apply to the construction of new electric transmission lines in the State, and to modifications of existing lines that require a certificate of environmental compatibility and public need. These practices are intended for use by public service utilities and the Council when considering the installation of such new or modified electric transmission lines. The practices are based on the established Council policy of reducing MF levels at the edge of a right-of-way (ROW), and in areas of particular interest, with no-cost/low-cost designs that do not compromise system reliability or worker safety, or environmental and aesthetic project goals.

Several practical engineering approaches are currently available for reducing MF, and more may be developed as technology advances. In proposing any particular methods of MF mitigation for a given project, the Applicant shall provide a detailed rationale to the Council that supports the proposed MF mitigation measures. The Council has the option to retain a consultant to confirm that the Field Management Design Plan and the proposed MF reduction strategies are consistent with these EMF Best Management Practices.

A. MF Calculations

When preparing a transmission line project, an applicant shall provide design alternatives and calculations of MF for pre-project and post-project conditions, under 1) peak load conditions at the time of the application filing, and 2) projected seasonal maximum 24-hour average current load on the line anticipated within five years after the line is placed into operation. This will allow for an evaluation of how MF levels differ between alternative power line configurations. The intent of requiring various design options is to achieve reduced MF levels when possible through practical design changes. The selection of a specific design will also be affected by other practical factors, such as the cost, system reliability, aesthetics, and environmental quality.

MF values shall be calculated from the ROW centerline out to a distance of 300 feet on each side of the centerline, at intervals of 25 feet, including at the edge of the ROW. In accordance with industry practice, the calculation shall be done at the location of maximum line sag (typically mid-span), and shall provide MF values at 1 meter above ground level, with the assumption of flat terrain and balanced currents. The calculations shall assume "all lines in" and projected load growth five years beyond the time the lines are expected to be put into operation, and shall include changes to the electric system approved by the Council and the Independent System Operator – New England.

As part of this determination, the applicant shall provide the locations of, and anticipated MF levels encompassing, residential areas, private or public schools, licensed child day care facilities, licensed youth camps, or public playgrounds within 300 feet of the proposed transmission line. The Council, at its discretion, may order the field measurement of post-construction MF values in select areas, as appropriate, and compare and contrast projected values with actual measured values.

B. Buffer Zones and Limits on MF

As enacted by the General Assembly in Section 4 of Public Act No. 04-246, a buffer zone in the context of transmission line siting is deemed, at minimum, to be the distance between the proposed transmission line and the edge of the utility ROW. Buffer zone distances may also be guided by the standards presented in the National Electrical Safety Code (NESC), published by the Institute of Electrical and Electronic Engineers (IEEE). These standards provide for the safe installation, operation, and maintenance of electrical utility lines, including clearance requirements from vegetation, buildings, and other natural and man-made objects that may arise in the ROW. The safety of power-line workers and the general public are considered in the NESC standards. None of these standards include MF limits.

In assessing whether a right-of-way provides a sufficient "buffer zone," the Council will emphasize compliance with its own Best Management Practices, but may also take into account approaches of other states, such as those of Massachusetts, New York, and Florida.

Since 1985, the Massachusetts Energy Facilities Siting Board (EFSB) has used an edge-of-ROW level of 85 mG as a benchmark for comparing different design alternatives. This benchmark, however, has not served as a generally applicable standard or guide. Rather, in particular cases since 1985 where a proposed transmission line has caused public concern, such as in densely populated areas and near schools, 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 approach is similar to Connecticut's.

Massachusetts has not adopted any generally applicable standards or guidelines concerning transmission facility magnetic fields. However, since 1985, the EFSB has considered projected magnetic field exposures in its proceedings for approval of electric transmission lines and substations. Where a transmission line is proposed in densely populated areas and near schools, the EFSB will "require EMF mitigation which in its judgment is consistent with minimizing cost."

New York and Florida have general MF guidelines that are designed to maintain the "status quo", i.e., that fields from new transmission lines not exceed those of existing transmission lines. In 1991, the New York Public Service Commission established an interim policy based on limits to MF. It required new high-voltage transmission lines to be designed so that the maximum magnetic fields at the edge of the ROW, one meter above ground, would not exceed 200 mG if the line were to operate at its highest continuous current rating. This 200 mG level represents the maximum calculated magnetic field level for 345 kV lines that were then in operation in New York State. The Council confirms no change to the New York policy.

The Florida Environmental Regulation Commission established a maximum magnetic field limit for new transmission lines and substations in 1989. The MF limits established for the edge of 230-kV to 500-kV transmission line ROWs and the property boundaries for substations ranged from 150 mG to 250 mG, depending on the voltage of the new transmission line and whether an existing 500-kV line was already present. In 2008, the Florida policy was revised to add a provision making the 250 mG magnetic field limit at the edge of the ROW and at substation property boundaries applicable to transmission lines and substations with a nominal voltage greater than 500-kV. Florida limits apply to one meter above ground level under an assumption that the transmission line is operating at its maximum continuous current rating.

Although scientific evidence to date does not warrant the establishment of MF exposure limits at the edge of a ROW, the Council will continue to monitor the ways in which states and other jurisdictions determine MF limits on new transmission lines.

C. Engineering Controls that Modify MF Level

When considering an overhead electric transmission-line application, the Council will expect the applicant to examine the following engineering controls to limit MF in publicly accessible areas: distance, height, conductor separation, conductor configuration, optimum phasing, increased voltage, and underground installation. Any design change may also affect the line's impedance, corona discharge, mechanical behavior, system performance, cost, noise levels and visual impact. The Council will consider all of these factors in relation to the MF levels achieved by any particular engineering control. Thus, utilities are encouraged to evaluate other possible engineering controls that might be applied to the entire line, or just specific segments, depending upon land use, to best minimize MF at a low or no cost.

Consistent with these Best Management Practices and absent any line performance and visual impacts, the Council expects that applicants will propose no-cost/low-cost measures to reduce magnetic fields by one or more engineering controls, including:

Distance

MF levels from transmission lines (or any electrical source) decrease with distance; thus, increased distance results in lower MF. Horizontal distances can be increased by purchasing wider ROWs, where available. Other distances can be increased in a variety of ways, as described below.

Height of Support Structures

Increasing the vertical distance between the conductors and the edge of the ROW will decrease MF: this can be done by increasing the height of the support structures. The main drawbacks of this approach are an increase in the cost of supporting structures, possible environmental effects from larger foundations, potential detrimental visual effects, and the modest MF reductions achieved, unless the ROW width is unusually narrow.

Conductor Separation

Decreasing the distances between individual phase conductors can reduce MF. Because at any instant in time the sum of the currents in the individual phase conductors is zero, or close to zero, moving the conductors closer together improves their partial cancellation of each other's MF. In other words, the net MF produced by the closer conductors reduces the MF level associated with the line. Placing the conductors closer together has practical limits, however. The distance between the conductors must be sufficient to maintain adequate electric code clearance at all times, and to assure utility employees' safety when working on energized lines. One drawback of a close conductor installation is the need for more support structures per mile (to reduce conductor sway in the wind and sag at mid-span); in turn, costs increase, and so do visual impacts.

Conductor Configuration

The arrangement of conductors influences MF. Conductors arranged in a flat, horizontal pattern at standard clearances generally have greater MF levels than conductors arranged vertically. This is due to the wider spacing between conductors found typically on H-frame structure designs, and to the closer distance between all three conductors and the ground. For single-circuit lines, a compact triangular configuration, called a "delta configuration", generally offers the lowest MF levels. A simple vertical configuration –one conductor above another–may cost more and may have increased visual impact. Where the design goal is to minimize MF levels at a specific location within or beyond the ROW, conductor configurations other than vertical or delta may produce equivalent or lower fields.

Optimum Phasing

Optimum phasing applies in situations where more than one circuit exists in an overhead ROW or in a duct bank installed underground. Electric transmission circuits utilize a three-phase system with each phase carried by one conductor, or a bundle of conductors. Optimum phasing reduces MF through partial cancellation. For a ROW with more than two circuits, the phasing arrangement of the conductors of each circuit can generally be optimized to reduce MF levels under typical conditions. The amount of MF cancellation will also vary depending upon the relative loading of each circuit. For transmission lines on the same ROW, optimizing the phasing of the new line with respect to that of existing lines is usually a low-cost method of reducing MF.
MF levels can be reduced for a single circuit line by constructing it as a "split-phase" line with twice as many conductors, and arranging the conductors for optimum cancellation. Disadvantages of the split-phase design include higher cost and increased visual impact.

Increased Voltage

MF are proportional to current, so, for example, replacing a 69-kV line with a 138-kV line, which delivers the same power at half the current, will result in lower MF. This could be an expensive mitigation to address MF alone because it would require the replacement of transformers and substation equipment.

Underground Installation

Burying transmission lines in the earth does not, by itself, provide a shield against MF, since magnetic fields, unlike electric fields, can pass through soil. Instead, certain inherent features of an underground design can reduce MF. The closer proximity of the currents in the wires provides some cancellation of MF, but does not eliminate it entirely. Underground transmission lines are typically three to five feet below ground, a near distance to anyone passing above them, and MF can be quite high directly over the line. MF on either side of an underground line, however, decreases more rapidly with increased distance than the MF from an overhead line.

The greatest reduction in MF can be achieved by "pipe-type" cable installation. This type of cable has all of the wires installed inside a steel pipe, with a pressurized dielectric fluid inside for electrical insulation and cooling. Low MF is achieved through close proximity of the wires, as described above, and through partial shielding provided by the surrounding steel pipe. While this method to reduce MF is effective, system reliability and the environment can be put at risk if the cable is breached and fluid is released.

Lengthy high-voltage underground transmission lines can be problematic due to the operational limits posed by the inherent design. They also can have significantly greater environmental impacts, although visual impacts associated with overhead lines are eliminated. The Council recognizes the operational and reliability concerns associated with current underground technologies and further understands that engineering research regarding the efficiency of operating underground transmission lines is ongoing. Thus, in any new application, the Council may require updates on the feasibility and reliability of the latest technological developments in underground transmission line design.

V. Bibilography

Australian Radiation Protection and Nuclear Safety Agency (ARPNSA). Electricity and Health Fact Sheet web page updated April 5, 2013.
http://www.arpansa.gov.au/radiationprotection/Factsheets/is_electricity.cfm (accessed 12/19/13)

Bennett, Jr., W., Health and Low Frequency Electromagnetic Fields, Yale University Press, 1994.

British National Radiation Protection Board (NRPB) (now Health Protection Agency or HPA). 2004a. Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz). Documents of the NRPB. 15(2)
http://www.hpa.org.uk/Publications/Radiation/NPRBArchive/DocumentsOfTheNRPB/Absd1502/ (accessed 12/16/13)

British National Radiation Protection Board (NRPB) (now Health Protection Agency or HPA). 2004b. Review of the Scientific Evidence for Limiting Exposure to (0 to 300 GHz) Electromagnetic Fields. Documents of the NRPB. 15(3)
http://www.hpa.org.uk/Publications/Radiation/NPRBArchive/DocumentsOfTheNRPB/Absd1503/ (accessed 12/16/13)

California Public Utilities Commission. Order Instituting Investigation on the Commission's Own Motion to Develop Policies and Procedures for Addressing the Potential Health Effects of Electric and Magnetic Fields of Utility Facilities. Decision No. 93-11-013, Investigation No. 91-01-012 (Filed January 15, 1991). November 2, 1993. San Francisco, CA.

California Public Utilities Commission. Order Instituting Rulemaking to update the Commission's policies and procedures related to electromagnetic fields emanating from regulated utility facilities. Decision 06-01-042 (Filed August 19, 2004). January 26, 2006. San Francisco, CA.
http://www.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/53181.htm. (accessed 12/16/13)

California Public Utilities Commission. EMF Design Guidelines for Electrical Facilities. July 21, 2006.
ftp://ftp.cpuc.ca.gov/puc/energy/environment/electromagnetic+fields/california+guidelines+for+electrical+facilities+072106+published.pdf (accessed 12/16/13)

Commonwealth Associates, Inc. and IIT Research Institute, Electric and Magnetic Fields (EMF) RAPID Program Engineering Project 8: FINAL REPORT, Evaluation of Field Reduction Technologies, Volume 1 (Report) and Volume 2 (Appendices), 1997.

Connecticut Department of Public Health (DPH). 2004. EMF Health Concerns Fact Sheet.
http://www.ct.gov/dph/lib/dph/environmental_health/eoha/pdf/emf_fact_sheet_-_2008.pdf (accessed 12/16/13)

Exponent Inc. January 10, 2011. Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Interstate Reliability Project http://www.ct.gov/csc/lib/csc/pendingproceeds/docket_424/424_application/v1interstate_csc_application_v1.pdf (Appendix D EMF Health Report) (accessed 12/16/13)

Exponent Inc. August 30, 2012. Update of Research on Extremely Low Frequency Electric and Magnetic Fields and Health May 1, 2011 – July 31, 2012 Stamford Reliability Cable Project http://www.ct.gov/csc/lib/csc/pendingproceeds/docket_435/app_d_emf_supporting_documentation.pdf (accessed 12/16/13)

Institute of Electrical and Electronics Engineers (IEEE). 2002. C95.6-2002 IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 kHz, Prepared by Subcommittee 3, Safety Levels with Respect to Human Exposure ISBN 0-7381-3389-2, 2002.

Institute of Electrical and Electronics Engineers (IEEE). 2002. C2-2002 National Electric Safety Code, American National Standards Institute, 2002.

International Committee on Electromagnetic Safety (ICES) / International Agency for Research on Cancer (IARC). 2002. Static and Extremely Low-Frequency Electric and Magnetic Fields: http://monographs.iarc.fr/ENG/Monographs/vol80/mono80.pdf (accessed 12/16/13)

International Commission on Non-Ionizing Radiation Protection (ICNIRP). 1998. Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz). http://www.icnirp.org/documents/LFgdl.pdf (accessed 12/16/13)

Johnson, G.B., Power Research Engineering, Field Management Technologies, EMF Engineering Symposium, 1998.

Minnesota State Interagency Working Group on EMF Issues, A White Paper of Electric and Magnetic Field (EMF) Policy and Mitigation Options, 2002.

National Cancer Institute. Magnetic Field Exposures and Cancer: Questions and Answers. April 21, 2005. http://www.cancer.gov/cancertopics/factsheet/Risk/magnetic-fields (accessed 12/16/13)

National Institute of Environmental Health Sciences. 2002. EMF Questions and Answers. EMF RAPID Program.
http://www.niehs.nih.gov/health/materials/electric_and_magnetic_fields_associated_with_the_use_of_electric_power_questions_and_answers_english_508.pdf#search=%20emf%20rapid%20report (accessed 12/19/13)

National Institute of Environmental Health Sciences, Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields, 1999.

National Research Council. 1999. Research on Power Frequency Fields Completed Under the Energy Policy Act of 1992. http://www.nap.edu/catalog/9587.html (accessed 12/16/13)

Public Service Commission of Wisconsin. May 2013. EMF – Electric and Magnetic Fields Brochure. http://psc.wi.gov/thelibrary/publications/electric/Electric12.pdf (accessed 12/19/13)

United States Geological Survey
http://geomag.usgs.gov/learn/introtogeomag.php (accessed 12/19/13)

World Health Organization (2007) Fact Sheet N322, Electromagnetic Fields and Public Health, Exposure to extremely low frequency fields.
http://www.who.int/peh-emf/publications/facts/fs322/en/index.html (accessed 12/19/13)

APPENDIX 7B

Electric and Magnetic Fields Health Report

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Health Sciences Practice

Exponent®

Research on Extremely Low Frequency Electric and Magnetic Fields and Health

August 1, 2012 – July 31, 2015

Eversource Energy Transmission Projects Update

Research on Extremely Low Frequency Electric and Magnetic Fields and Health

August 1, 2012 – July 31, 2015

Eversource Energy Transmission Projects Update

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Acronyms and Abbreviations

AC	Alternating current
ALL	Acute lymphoblastic leukemia
ALS	Amyotrophic lateral sclerosis
AMI	Acute myocardial infarction
BMP	Best Management Practices
CI	Confidence interval
CSC	Connecticut Siting Council
CVD	Cardiovascular disease
DMBA	dimethylbenz[a]anthracene
ELF	Extremely low frequency
EMF	Electric and magnetic fields (or electromagnetic fields)
EPA	Environmental Protection Agency
F344	Fischer 344
G	Gauss
GD	Gestational day
GHz	Gigahertz
Hz	Hertz
IARC	International Agency for Research on Cancer
ICES	International Committee for Electromagnetic Safety
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kV	Kilovolt
kV/m	Kilovolts per meter
mG	Milligauss
NIEHS	National Institute for Environmental and Health Sciences
NRPB	National Radiation Protection Board of Great Britain
OR	Odds ratio
ROW	Right of way
RR	Relative risk
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
TWA	Time weighted average

V/m	Volts per meter
WHO	World Health Organization

Limitations

At the request of Eversource Energy, Exponent prepared this summary report on the status of research related to extremely low-frequency electric- and magnetic-fields and health. The findings presented herein are made to a reasonable degree of scientific certainty. Exponent reserves the right to supplement this report and to expand or modify opinions based on review of additional material as it becomes available, through any additional work, or review of additional work performed by others.

The scope of services performed during this investigation may not adequately address the needs of other users of this report for purposes other than project permitting, and any re-use of this report or its findings, conclusions, or recommendations presented herein is 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.

The following Executive Summary provides only an outline of the material discussed in this report. Exponent's technical evaluations, analyses, conclusions, and recommendations are included in the main body of this report, which at all times is the controlling document.

Executive Summary

This report was prepared to address the topic of exposure to extremely low frequency (ELF) electric and magnetic fields (EMF) and health for the Connecticut Siting Council (CSC) at the request of Eversource Energy to be filed with Applications for Certificates of Environmental Compatibility and Public Need for projects in preparation at the time of the drafting of this report.

ELF EMF are invisible fields surrounding all objects that generate, use, or transmit electricity. People living in developed countries are almost constantly exposed to ELF EMF in their environments, because electricity is an essential infrastructure of technologically-advanced societies. Sources of man-made ELF EMF include, for example, appliances, wiring in homes, and electric motors, as well as distribution and transmission lines. Section 2 of this report provides information on the nature and sources of ELF EMF, and typical exposure levels.

Research on EMF and health began with the goal of finding therapeutic applications and understanding biological electricity (i.e., the role of electrical potentials across cell membranes and current flows between cells in our bodies). Since the late 1970s, researchers have examined whether EMF from man-made sources can cause short- or long-term health effects in humans using a variety of study designs and techniques. Research on ELF EMF and long-term human health effects was prompted by an epidemiologic study conducted in 1979 of children in Denver, Colorado, which reported that children with cancer were more likely to live near distribution and transmission lines that appeared to be capable of producing higher magnetic-field levels. The results of that study prompted further research on childhood leukemia and other cancers. Childhood leukemia has remained the focus of ELF EMF and health research, although many other diseases have been studied, including other cancers in children and adults, neurodegenerative diseases, reproductive and developmental effects, cardiovascular diseases, and psychological and behavioral effects such as depression or suicide.

Guidance on the possible health risks of all types of exposures comes from health risk assessments (i.e., systematic weight-of-evidence evaluations of the cumulative literature), on a particular topic conducted by expert panels organized by national and international scientific organizations.

The World Health Organization (WHO) published one of the most comprehensive health risk assessments of EMF in the ELF range in 2007 that critically reviewed the cumulative epidemiologic and laboratory research through 2005, taking into account the strength and quality of individual research studies. The public and policy makers should look to the conclusions of reviews such as this, because they are conducted by scientists representing the various disciplines required to understand the topic at hand using validated scientific standards and systematic methods. This WHO report was one of the most recent health agency reviews that informed the CSC when it updated its EMF Best Management Practices (BMP) in 2007. In its revised BMP, issued on February 20, 2014, the CSC further considered the scientific literature up to 2012 based on systematic reviews provided by two documents submitted with previous applications to the CSC.[1]

In a health risk assessment of any exposure, it is essential to consider the type and strength of research studies available for evaluation. Human health studies vary in methodological rigor and, therefore, in their capacity to extrapolate findings to the population at large. Furthermore, all studies in three areas of research—epidemiologic, *in vivo* (experimental whole animal), and *in vitro* (experimental in cells and tissues)—must be evaluated to understand possible health risks. Epidemiologic and *in vivo* studies provide the primary basis for a human health risk assessment, with *in vitro* studies contributing supplementary, secondary information on potential biological mechanisms.

Section 3 of this report provides a summary of the methods used to conduct a health risk assessment. Section 4 provides a summary of the WHO's conclusions with regard to various health outcomes (childhood leukemia and brain cancer, adult breast cancer, brain cancer, leukemia/lymphoma; reproductive and developmental effects; neurodegenerative disease; and cardiovascular disease). Finally, this report contains a systematic literature review and a critical evaluation of all relevant epidemiologic studies in these areas of research and *in vivo* animal studies of cancer published between August 1, 2012 and July 31, 2015 (Section 5).

[1] Docket No. 424, "Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Interstate Reliability Project, June 10, 2011"; Docket No. 435, "Update of Research on Extremely Low Frequency Electric and Magnetic Fields and Health May 1, 2011 – July 31, 2012, Stamford Reliability Cable Project, August 30, 2012."

1 Introduction

In response to public concern regarding extremely low frequency (ELF) electric and magnetic fields (EMF) and health, the Connecticut Siting Council (CSC) adopted "EMF Best Management Practices for the Construction of Electric Transmission Lines in Connecticut" (BMP) on December 14, 2007. This BMP was updated on February 20, 2014. The BMP policy is founded on the recognition of consistent conclusions by "a wide range of public health consensus groups," as well as their own commissioned weight-of-evidence review (CSC BMP, 2014, p. 4). The CSC summarized the current scientific consensus by noting the conclusions of these public health consensus groups, including the most comprehensive review by the World Health Organization (WHO) in 2007, and earlier reviews published by the National Institute for Environmental and Health Sciences (NIEHS) in 1999, the International Agency for Research on Cancer (IARC) in 2002, the Australian Radiation Protection and Nuclear Safety Agency in 2003, the National Radiological Protection Board of Great Britain (NRPB) in 2004, and the Health Council of the Netherlands in 2005.

The WHO report provided the following overall conclusions:

> New human, animal, and in vitro studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF as a possible human carcinogen (WHO, 2007, p. 347).
>
> Acute biological effects [i.e., short-term, transient health effects such as a small shock] 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 (WHO, 2007, p. 355).

The CSC summarized the current scientific consensus as expressed in the above-mentioned reviews as follows: there is limited evidence from epidemiologic studies of a statistical association between estimated, average exposures greater than 3-4 milligauss (mG) and childhood leukemia; the cumulative research, however, does not indicate that magnetic fields are a cause of childhood leukemia, since animal and other experimental studies do not suggest that magnetic fields are carcinogenic and the epidemiologic studies are of limited quality. The CSC also noted the WHO's recent conclusion with respect to other diseases: "the scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukemia" (CSC BMP, 2014, p. 2).

Based on this scientific consensus, the CSC concluded that proportional precautionary measures for the siting of new transmission lines in the state of Connecticut should include "the use of effective no-cost and low-cost technologies and management techniques on a project-specific basis to reduce MF [magnetic field] exposure to the public while allowing for the development of efficient and cost-effective electrical transmission projects" (CSC BMP, 2014, p. 4).

The BMP also stated that the CSC will "consider and review evidence of any new developments in scientific research addressing MF [magnetic fields] and public health effects or changes in scientific consensus group positions regarding MF" (CSC BMP, 2014, p. 5).

While the initial CSC BMP policies were based largely on the conclusions of the WHO report from 2007, the current BMP, revised in 2014, considers the scientific literature up to 2012 based on systematic reviews provided by two reports submitted as part of previous applications to the CSC.[2]

This Exponent report contains a systematic review and a critical evaluation of the literature, including all relevant epidemiologic studies for various outcomes and *in vivo* studies of carcinogenicity published between August 1, 2012 and July 31, 2015, which were identified in our literature searches. This new report, along with the two previous summaries, provides an analysis of the status of research on ELF EMF inclusive of 2006 through mid-2015.

The studies evaluated in the current and the previous two reports do not provide sufficient evidence to alter the basic conclusion of the WHO: the research does not support the conclusion that ELF EMF at the levels we encounter in our everyday environment are a cause of cancer or any other disease.

There are no national guidelines or standards in the United States to regulate ELF EMF. The WHO recommends adherence to the International Commission on Non-Ionizing Radiation Protection's (ICNIRP) standards or those developed by the IEEE's International Committee for Electromagnetic Safety (ICES) for the prevention of acute, short-term health effects at high exposure levels (ICES, 2002; ICNIRP, 2010). In light of the epidemiologic data on childhood leukemia, these scientific organizations are still in agreement that only no-cost or low-cost interventions to reduce ELF EMF exposure are appropriate.

This policy approach is consistent with the recommendation of the CSC for the use of effective no-cost and low-cost technologies to reduce the public's magnetic-field exposure. While the large body of existing research does not indicate any harm associated with ELF EMF exposure, research on this topic will continue to reduce remaining scientific uncertainty.

[2] Docket No. 424. "Current Status of Research on Extremely Low Frequency Electric and Magnetic Fields and Health: Interstate Reliability Project, June 10, 2011"; Docket No. 435. "Update of Research on Extremely Low Frequency Electric and Magnetic Fields and Health May 1, 2011 – July 31, 2012 Stamford Reliability Cable Project, August 30, 2012."

2 Extremely Low Frequency Electric and Magnetic Fields: Nature, Sources, Exposure, and Known Effects

Nature of ELF EMF

Electricity is transmitted as current from generating sources to high-voltage transmission lines, substations, distribution lines, and then finally to our homes and workplaces for consumption. The vast majority of electricity is transmitted as alternating current (AC), completing full cycles of direction changes 60 times per second (i.e., a frequency of 60 Hertz [Hz]) in North America. ELF EMF from these AC sources is often referred to as power-frequency EMF.

Everything that is connected to our electrical system (i.e., power lines, appliances, and wiring) produces ELF EMF (Figure 1). Electric fields and magnetic fields are both properties of the space near these electrical sources. Forces are experienced by objects capable of interacting with these fields; electric charges are subject to a force in an electric field, and moving charges experience a force in a magnetic field.

- **Electric fields** are the result of voltages applied to electrical conductors and equipment. The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m), where 1 kV/m = 1,000 V/m. Conducting objects including fences, buildings, and our own skin and muscle easily block electric fields. Therefore, certain appliances within homes and workplaces are the major source of electric fields indoors, while power lines are the major source of electric fields outdoors.

- **Magnetic fields** are produced by the flow of electric currents. Unlike electric fields, however, most materials (including the earth) do not readily block magnetic fields. The strength of a magnetic field is expressed as magnetic flux density in units of gauss (G) or mG, where 1 G = 1,000 mG.[3] The strength of the magnetic field at any point depends on characteristics of the source, including (in the case of power lines) the arrangement of conductors, the amount of current flow, and distance from the conductors.

Sources and exposure

The intensity of both electric fields and magnetic fields diminishes with increasing distance from the source. For example, higher EMF levels are measured close to the conductors of distribution and transmission lines and decrease rapidly with increasing distance from the conductors. Transmission line EMF generally decreases with distance from the conductors in proportion to the square of the distance, creating a bell-shaped curve of field strength to either side of the line.

Since electricity is such an integral part of our infrastructure (e.g., transportation systems) and our homes and businesses, people living in modern communities are surrounded by these fields (Figure 1). While EMF levels decrease with distance from the source, any home, school, or

[3] Scientists also refer to magnetic flux density at these levels in units of microtesla. Magnetic flux density in mG units can be converted to microtesla by dividing by 10 (i.e., 1 mG = 0.1 microtesla).

office tends to have a background EMF level as a result of the combined effect of the numerous EMF sources present in these locations.

Figure 1. Common sources of ELF EMF in the home (appliances, wiring, currents running on water pipes, and nearby distribution and transmission lines).

Figure 2 outlines typical EMF levels measured in residential settings and occupational environments (all of which contribute to a person's background EMF level) compared to typical EMF levels measured at a typical transmission line's right-of-way (ROW).[4] In general, the background magnetic-field level as estimated from the average of measurements throughout a house away from appliances may range up to approximately 5 mG, while levels can be hundreds of mG in close proximity to appliances. Background levels of electric fields range from 10-20 V/m, while appliances produce levels up to several tens of V/m (WHO, 1984).

Experiments have yet to show which aspect of ELF EMF exposure, if any, may be relevant to biological systems. The most commonly used metric of EMF exposure for health research is long-term, average personal exposure, which is the average of all exposures to the varied electrical sources encountered in the many places we spend our days and nights. As expected, this exposure is different for every person and is difficult to approximate. Exposure assessment is a source of uncertainty in epidemiologic studies of ELF EMF and health (WHO, 2007). Some basic conclusions drawn from surveys of the general public's exposure to magnetic fields are:

[4] The fields from underground transmission lines are not included in this figure because they are a rare source of EMF exposure. The magnetic field over buried conductors can be as high, or even higher, than an overhead line, but the magnetic field will diminish more quickly with distance. No electric field will be produced above ground by underground cables.

- *Residential sources of magnetic-field exposure:*
    - Residential magnetic-field levels are caused by currents carried by nearby transmission and distribution systems, pipes or other conductive paths, and electrical appliances (Zaffanella, 1993).
    - The highest magnetic-field levels are typically found directly next to appliances (Zaffanella, 1993). NIEHS (2002) identified field levels at various distances from a number of common appliances in the home—the highest reported measured values at 6-inches from selected appliances were as follow: can opener, 1,500 mG; dishwasher; 200 mG; electric range, 200 mG; and washing machine, 100 mG; to name a few.
    - Several parameters affect personal magnetic-field exposures at home: residence type, residence size, type of water line, and proximity to overhead power lines. Persons living in small homes, apartments, homes with metallic piping, and homes close to three-phase electric power distribution and transmission lines tended to have higher at-home magnetic-field levels (Zaffanella and Kalton, 1998).
- *Personal magnetic-field exposure:*
    - A survey of approximately 1,000 randomly selected persons in the United States who wore a magnetic field meter that recorded the magnetic field twice each second reports that the average of all measurements taken over 24-hours, i.e., their time-weighted average (TWA) exposure, is less than 2 mG for the vast majority of persons (Zaffanella and Kalton, 1998).[5]
    - In general, personal magnetic-field exposure is greatest at work and when traveling (Zaffanella and Kalton, 1998).
- *Workplace magnetic-field exposure*
    - Some occupations (e.g., electric utility workers, sewing machine operators, telecommunication workers, industrial welders) have higher exposures due to work near equipment with high ELF EMF levels (NIEHS, 2002).
- *Power-line magnetic-field exposure*
    - The EMF levels associated with power lines vary substantially depending on their configuration and current load, among other factors. At a distance of 300 feet and during average electricity demand, however, the magnetic-field levels from many transmission lines are often similar to the background levels found in most homes (Figure 2).

[5] TWA exposure 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 a chemical or physical agent. The average is determined by sampling the exposure of interest throughout the time period.

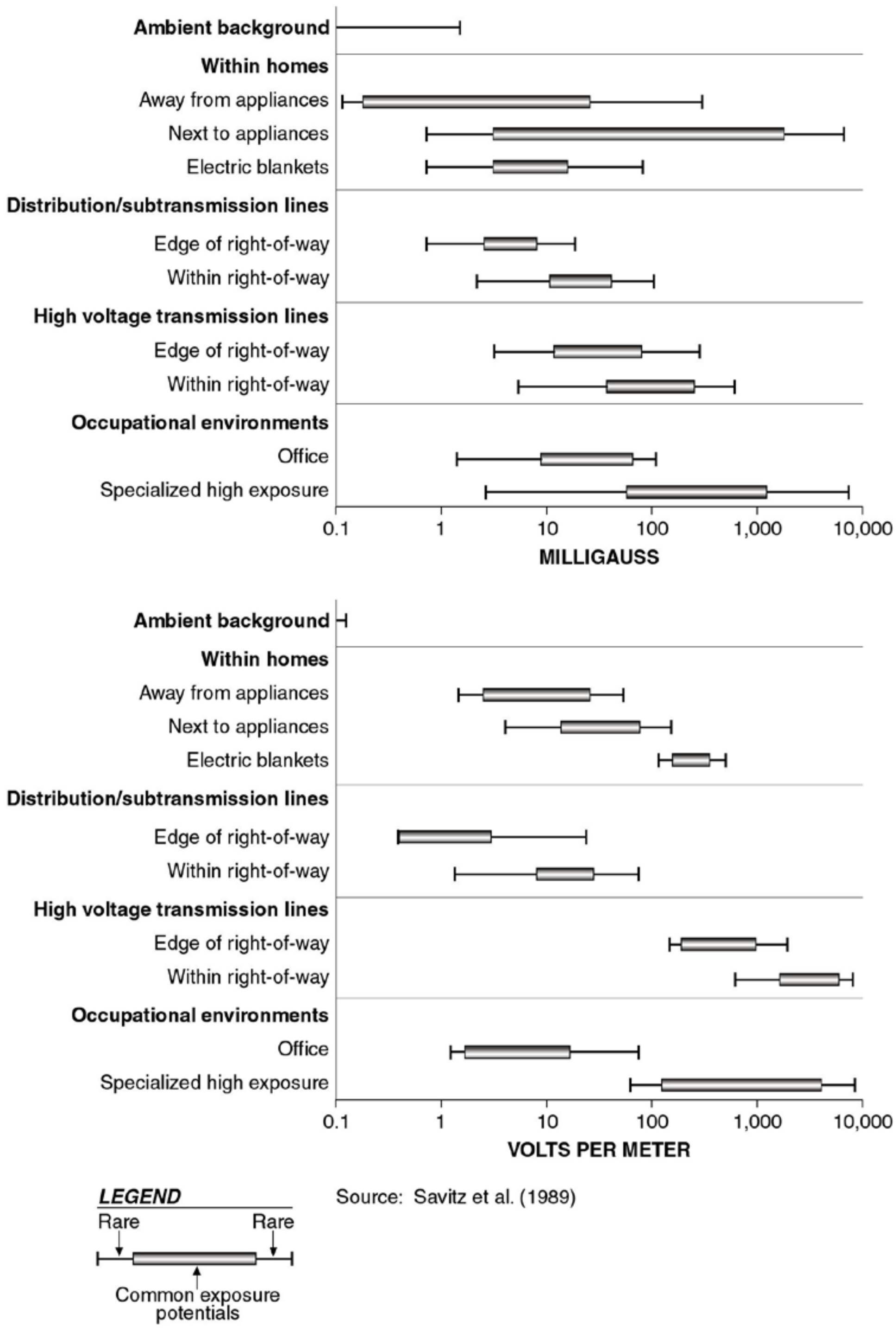

Figure 2. ELF magnetic field (upper panel) and electric field (lower panel) levels in various environments.

Known effects

There is a greater opportunity for long-term exposure to magnetic fields since electric fields are effectively blocked by common conductive objects. For this reason, among others, research on long-term health effects has focused on magnetic fields rather than electric fields.

Like virtually any exposure, adverse effects can be expected from exposure to very high levels of ELF EMF. If the current density or electric field induced by an extremely strong magnetic field exceeds a certain threshold, excitation of muscles and nerves is possible. Also, strong electric fields can induce charges on the surface of the body or ungrounded objects that can lead to small shocks (i.e., micro shocks) when discharged. These effects have no long-term damage or health consequences. Limits for the general public and workplace have been set to prevent these effects, but there are no real-life situations where these levels are exceeded on a regular basis.

Two international scientific organizations, ICNIRP and ICES, have published guidelines for limiting public exposure to ELF EMF to protect against these acute effects (ICES, 2002; ICNIRP, 1998, 2010). These guidelines were developed following weight-of-evidence reviews of the literature, including epidemiologic and experimental evidence related to both short-term and long-term exposure. Both reviews concluded that the stimulation of nerves and the central nervous system could occur at very high exposure levels immediately upon exposure, but that the research did not suggest any long-term health effects.

The ICNIRP guideline states that exposure to magnetic fields should be below 2,000 mG for the general public and 10,000 mG for workers "[to] provide protection against all established adverse health effects" (ICNIRP, 2010). The ICES recommends a maximum permissible magnetic-field exposure of 9,040 mG for the general public (ICES, 2002). For reference, in a survey by Zaffanella and Kalton (1998), only about 1.6% of the general public experienced exposure to magnetic fields of at least 1,000 mG during a 24-hour period.

The ICNIRP's screening value for exposure to 60-Hz electric fields for the general public is 4.2 kV/m and the ICES screening value is 5 kV/m. Both organizations allow higher exposures if it can be demonstrated that exposures do not produce electric fields within tissues that exceed basic restrictions on internal electric fields.

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

Organization recommending limit	Magnetic fields	Electric fields
ICNIRP restriction level	2,000 mG	4.2 kV/m
ICES maximum permissible exposure	9,040 mG	5 kV/m 10 kV/m[a]

[a] This is an exception within transmission line ROWs because people do not spend a substantial amount of time at these locations and very specific conditions are needed before a response is likely to occur (i.e., a person must be well insulated from ground and must contact a grounded conductor) (ICES, 2002, p. 27).

The literature over the past few years includes a number of studies of workers with the potential for high field exposures that characterize occupational exposure and evaluate compliance with standards. They include a study of spot measurements of EMF during work tasks at 110-kV switching and transforming stations in Finland to evaluate compliance with ICNIRP reference levels (Korpinen et al., 2011a) and a study of occupational electric field exposure at the same 110-kV switching station that evaluated compliance with the European Union's Directive 2004/40/EC (Korpinen et al., 2012); 3-hour TWA magnetic-field measurements of dentists and spot measurements near dental equipment in Taiwan (Huang et al., 2011); spot measurements and personal monitoring of magnetic fields in hospital personnel in Spain (Ubeda et al., 2011); spot measurements and personal monitoring of magnetic fields in railway workers in Italy (Contessa et al., 2010); and a study of electric fields, current densities, and contact currents at a 400-kV substation in Finland (Korpinen et al., 2011b). More recent publications reported measured magnetic-field values inside 110-kV substations in Finland and the Ukraine (Korpinen and Pääkkönen, 2015; Okun et al., 2014). The highest measured field levels were 2,500 and 4,200 mG in the two papers, respectively, in the immediate vicinity of busbars and cables. In general, the measured magnetic fields in these studies were below the occupational reference values of ICNIRP. At some locations within substations, worker exposure to electric fields could exceed the reference level (Korpinen et al., 2011b, 2012), but the induced current density in the central nervous system did not exceed the ICNIRP basic restriction value.

3 Methods for Evaluating Scientific Research

Science is more than a collection of facts. It is a method of obtaining information and of reasoning to ensure that the information and conclusions are accurate and correctly describe physical and biological phenomena. Many misconceptions in human reasoning occur when people casually interpret their observations and experience. Therefore, scientists use systematic methods to conduct and evaluate scientific research and assess the potential impact of a specific agent on human health. This process is designed to ensure that more weight is given to those studies of better quality and studies with a given result are not selected out from all of the studies available to advocate or suppress a preconceived idea of an adverse effect. Scientists and scientific agencies and organizations use these standard methods to draw conclusions about the many exposures in our environment.

Weight-of-evidence reviews

The scientific process entails looking at *all* the evidence on a particular issue in a systematic and thorough manner to evaluate if the overall data present a logically coherent and consistent picture. This is often referred to as a weight-of-evidence review, in which all relevant studies are considered together, giving more weight to studies of higher quality and using an established analytic framework to arrive at a conclusion about a possible causal relationship. Weight-of-evidence reviews are typically conducted within the larger framework of health risk assessments or evaluations of particular exposures or exposure circumstances that qualitatively and quantitatively define health risks. Weight-of-evidence and health risk assessment methods have been described by several agencies, including the IARC, which routinely evaluates substances such as drugs, chemicals, and physical agents for their ability to cause cancer; the WHO International Programme for Chemical Safety; and the US Environmental Protection Agency (EPA), which set guidance for public exposures (USEPA, 1993; WHO, 1994; USEPA, 1996; Rooney et al., 2014; OHAT, 2015). Two steps precede a weight-of-evidence evaluation: a systematic review to identify the relevant literature and an evaluation of each study to determine its strengths and weaknesses.

The following sections discuss important considerations in the evaluation of human health studies of ELF EMF in a weight-of-evidence review, including exposure considerations, study design, methods for estimating risk, bias, and the process of causal inference. The purpose of discussing these considerations here is to provide context for the later weight-of-evidence evaluations.

EMF exposure considerations

Exposure assessment methods range widely in studies of EMF. These methods include the classification of residences based on the relative capacity of nearby power lines to produce magnetic fields (i.e., wire code categories); occupational titles; calculated magnetic-field levels based on job histories (e.g., a job-exposure matrix); residential distance from nearby power lines; spot measurements of magnetic-field levels inside or outside residences; 24-hour and 48-hour measurements of magnetic fields in a particular location in the house (e.g., a child's bedroom);

calculated magnetic-field levels based on the characteristics of nearby power installations; and, finally, personal 24-hour and 48-hour magnetic-field measurements.

Each of these methods has strengths and limitations (Kheifets and Oksuzyan, 2008). Since magnetic-field exposures are ubiquitous and vary over a lifetime as the places we frequent and the sources of EMF in those places change, determining valid estimates of personal magnetic-field exposure is challenging. Furthermore, without a biological basis to define a relevant exposure metric (e.g., average or peak exposure) and a defined critical period for exposure (e.g., *in utero* or shortly before diagnosis), relevant and valid assessments of exposure are problematic. Exposure misclassification is one of the most significant concerns in epidemiologic studies of ELF EMF.

In general, long-term personal exposure measurements are the metric recommended by most epidemiologists to estimate exposure in their studies. Changes in the study subjects' behavior or environment that may be related to the disease under investigation, however, could potentially result in misclassification of the exposure when personal measurements are conducted following disease development. Other methods are also subject to exposure misclassification because they may not be strong predictors of long-term exposure and do not take into account all magnetic-field sources.

EMF can be estimated indirectly by assigning an estimated amount of EMF exposure to an individual based on calculations considering nearby power installations or a person's job title. For example, a relative estimate of exposure could be assigned to all machine operators based on historical information on the magnitude of the magnetic field produced by the machine. Indirect measurements are not as accurate as direct measurements because they do not contain information specific to that person or the exposure situation. In the example of machine operators, the indirect measurement may not account for how much time any one individual spends working at that machine or any potential variability in magnetic fields produced by the machines over time, and occupational measurements do not take into account the worker's residential magnetic-field exposures.

While an advance over earlier methods, job-exposure matrices still have some important limitations, as highlighted in a review by Kheifets et al. (2009) summarizing an expert panel's findings.[6] A person's occupation provides some relative indication of the overall magnitude of his or her occupational magnetic-field exposure, but it does not take into account the possible variation in exposure due to different job tasks within occupational titles, the frequency and intensity of contact to relevant exposure sources, or variation by calendar time. This was highlighted in a study of 48-hour magnetic-field measurements of 543 workers in Italy in a variety of occupational settings, including: ceramics, mechanical engineering, textiles, graphics, retail, food, wood, and biomedical industries (Gobba et al., 2011). There was significant variation in this study among the measured TWA magnetic-field levels for workers in many of the International Standard Classification of Occupations' job categories, which the authors attributed to variation in industry within the task-defined categories.

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[6] Kheifets et al. (2009) reports on the conclusions of an independent panel organized by the Energy Networks Association in the United Kingdom in 2006 to review the current status of the science on occupational EMF exposure and identify the highest priority research needs.

Types of health research studies

Research studies can be broadly classified into two groups: 1) epidemiologic observations of people and 2) experimental studies conducted on humans, animals (*in vivo*), and cells and tissues (*in vitro*) in laboratory settings.

Epidemiologic studies investigate how disease is distributed in populations and what factors influence or determine this disease distribution (Gordis, 2000). Epidemiologic studies attempt to establish causes for human disease while observing people as they go about their normal, daily lives. Such studies are designed to quantify and evaluate the associations between disease and reported exposures to environmental factors.

The most common types of epidemiologic studies in the EMF literature are case-control and cohort studies. In case-control studies, the exposures of people with and without the disease of interest are compared. Often, people are interviewed or their personal records (e.g., medical records or employment records) are reviewed in order to establish the exposure history for each individual. The exposure histories of the diseased (case) and non-diseased (control) populations are compared to determine whether any statistically significant differences in exposure histories exist. A difference in the exposure of the case and control populations may suggest an association between the exposure and the disease. In cohort studies, on the other hand, individuals within a defined cohort of people (e.g., all persons working at a utility company) are classified as exposed or non-exposed and followed over time for the incidence of disease. Researchers then compare disease incidence in the exposed and non-exposed groups and so can directly estimate exposure related risks.

Experimental studies are designed to test specific hypotheses under controlled conditions and are vital to assessing cause-and-effect relationships. An example of a human experimental study relevant to this area of research would be a study that measures the impact of magnetic-field exposure on acute biological responses in humans, such as hormone levels. These studies are conducted in laboratories under controlled conditions.

In vivo and *in vitro* experimental studies are also conducted under controlled conditions in laboratories. *In vivo* studies expose laboratory animals to very high levels of a chemical or physical agent to determine whether exposed animals develop cancer or other diseases at higher rates than unexposed animals, while attempting to control other factors that could possibly affect disease rates (e.g., diet and genetics). *In vitro* studies of isolated cells and tissues are also important because they can help scientists understand biological mechanisms as they relate to the same exposure in intact humans and animals.

The results of experimental studies of animals, and particularly those of isolated tissues or cells, however, may not always be directly extrapolated to human populations. In the case of *in vitro* studies, the responses of cells and tissues outside the body may not reflect the response of those same cells if maintained in a living system, so their relevance cannot be assumed. Therefore, it is both necessary and desirable to explore agents that could present a potential health threat in epidemiologic studies as well.

Both of these approaches—epidemiologic and experimental laboratory studies—have been used to evaluate whether exposure to EMF has any adverse effects on human health. Epidemiologic studies are valuable because they are conducted in human populations, but they are limited by their non-experimental design and typical retrospective nature. In epidemiologic studies of EMF, for example, researchers cannot control the amount of individual exposure to EMF, the contribution from different field sources, how exposure occurs over time, or individual behaviors that could affect disease risk, such as diet or smoking. In valid risk assessments of EMF, epidemiologic studies are considered alongside experimental studies of laboratory animals, while studies of isolated cells and tissues are generally acknowledged as being supplementary.

Estimating risk

Epidemiologists measure the statistical association between exposures and disease in order to estimate risk. In this context, risk simply refers to an exposure that is associated with a health event and does not imply that a causal relationship has been established.[7] This brief summary of risk is included to provide a foundation for understanding and interpreting statistical associations in epidemiologic studies as risk estimates.

Two common types of risk estimates are absolute risk and relative risk (RR). Absolute risk, also known as incidence, is the amount of new disease that occurs in a given period of time. For example, the absolute risk of invasive childhood cancer in children ages 0-19 years for 2004 was 14.8 per 100,000 children (Ries et al., 2007). RR estimates are calculated to evaluate whether a particular exposure or inherent quality (e.g., EMF, diet, genetics, race) is associated with a disease outcome. This is calculated by looking at the absolute risk in one group relative to that in a comparison group. For example, white children in the 0-19 year age range had an estimated absolute risk of childhood cancer of 15.4 per 100,000 in 2004, and African American children had an estimated absolute risk of 13.3 per 100,000 in the same year. By dividing the absolute risk of white children by the absolute risk of African American children, we obtain a RR estimate of 1.16. This RR estimate can be interpreted to mean that white children have a risk of childhood cancer that is 16% greater than the risk of African American children. Additional statistical analysis is needed to evaluate whether this association is statistically significant, as defined in the following sub-section.

It is important to understand that risk is estimated differently in cohort and case-control studies because of the way the studies are designed. Traditional cohort studies can provide a direct estimate of RR, while case-control studies can only provide indirect estimates of RR, called odds ratios (OR). For this reason, among others, cohort studies usually provide more reliable estimates of the risk associated with particular exposures. Case-control studies are more common than cohort studies, however, because of they are less costly and more time efficient.

[7] The following definition is provided of a risk factor in a dictionary of epidemiology terms: "…an aspect of personal behavior or lifestyle, an environmental exposure, or an inborn or inherited characteristic, that, on the basis of epidemiological evidence, is known to be associated with health-related condition(s) considered important to prevent" (Last, 2001, p. 160).

Thus, the association between a particular disease and exposure is measured quantitatively in an epidemiologic study as either the RR estimate (cohort studies) or OR (case-control studies). The general interpretation of a RR estimate equal to 1.0 is that the exposure is not associated with the occurrence of the disease. If the RR estimate is greater than 1.0, the inference is that the exposure is associated with an increased incidence of the disease. On the other hand, if the RR estimate is less than 1.0, the inference is that the exposure is associated with a reduced incidence of the disease. The magnitude of the RR estimate is often referred to as its strength (i.e., strong vs. weak). Stronger associations are given more weight because they are less susceptible to the effects of bias.

Statistical significance

Statistical significance testing provides an idea of whether or not a statistical association is caused by chance alone, i.e., whether the association is likely to be observed upon repeated testing or whether it is simply a chance occurrence. The terms “statistically significant” or “statistically significant association” are used in epidemiologic studies to describe the tendency of the level of exposure and the occurrence of disease to be linked, with chance alone as an unlikely explanation. Statistically significant associations, however, are not automatically an indication of cause-and-effect, because the interpretation of statistically significant associations depends on many other factors associated with the design and conduct of the study, including, how the data were collected and the size of the study. Statistical significance testing in itself does not provide any information on potential sources of systematic error or bias in the study.

Confidence intervals (CI) are typically reported along with RR and OR values. A CI is a range of values for an estimate of effect that has a specified probability (e.g., 95%) of including the true estimate of effect; CIs evaluate statistical significance, but do not address the role of bias, as described further below. A 95% CI indicates that, if the study were conducted a very large number of times, 95% of the measured estimates would be within the upper and lower confidence limits.

The range of the CI is also important for interpreting estimated associations, including the precision and statistical significance of the association. A very wide CI indicates great uncertainty in the value of the true risk estimate. This is usually due to a small number of observations. A narrow CI provides more certainty about where the true RR estimate lies (assuming no bias in the study). Another way of interpreting the CI is if the 95% CI does not include 1.0, the probability of an association being due to chance alone is 5% or lower and the result is considered statistically significant, as discussed above. Statistical variation, however, while easily estimated, is just one of the sources of uncertainty in the characterization of epidemiological associations. Additional uncertainties may result from bias (e.g., participation, selection, or recall biases) and confounding by alternative exposures. These additional uncertainties are not quantified by statistical testing and the assessment of their influence on the overall interpretation requires expert evaluation of information from outside the studies themselves.

Meta-analysis and pooled analysis

In epidemiologic research, the results of studies with a smaller number of participants may be difficult to distinguish from normal, random variation. This is also the case for sub-group analyses where few cases are estimated to have high exposure levels (e.g., in case-control studies of childhood leukemia and TWA magnetic-field exposure greater than 3-4 mG). Meta-analysis is an analytic technique that combines the published results from a group of studies into one summary result. A pooled analysis, on the other hand, combines the raw, individual-level data from the original studies and analyzes all of the data from the studies together. These methods are valuable because they increase the number of individuals in the analysis, which allows for a more robust and stable estimate of association. Meta- and pooled analyses also are an important tool for quantitatively synthesizing the results of a large group of studies.

The disadvantage of meta- and pooled analyses is that they can convey a false sense of consistency across studies if *only* the combined estimate of effect is considered (Rothman and Greenland, 1998). These analyses typically combine data from studies with different study populations, methods for measuring and defining exposure, and disease definitions. This is particularly true for analyses that combine data from case-control studies, which often use very different methods for the selection of cases and controls and exposure assessment. Therefore, in addition to the synthesis or combining of data, meta- and pooled analyses should be used to understand what factors cause the results of the studies to vary (e.g., publication date, study design, possibility of selection bias), and how these factors affect the associations calculated from the data of all the studies combined (Rothman and Greenland, 1998).

Meta- and pooled analyses are a valuable technique in epidemiology; however, in addition to calculating a summary RR, they should follow standard techniques (Stroup et al., 2001) and analyze the factors that contribute to any heterogeneity between the studies. It is also important to note that potential biases present in the original individual studies will also impact the results of the meta- and pooled analyses.

Bias in epidemiologic studies

One key reason that results of non-experimental epidemiologic studies cannot directly provide evidence for cause-and-effect is the potential presence of bias. Bias is defined as “any systematic error in the design, conduct or analysis of a study that results in a mistaken estimate of an exposure’s effect on the risk of disease” (Gordis, 2000, p. 204). In other words, sources of bias are factors or research situations that can mask a true association or cause an apparent association in the study that does not truly exist. As a result, the extent of bias, as well as its types and sources, is one of the most important considerations in the interpretation of epidemiologic studies. Since it is not possible to fully control human populations, perfectly measure their exposures, or control for the effects of all other risk factors, bias will exist in some form in all epidemiologic studies of human health. Experimental studies, on the other hand, more effectively manage bias because of the tight control the researchers have over most study variables.

One important source of bias occurs when a third variable confuses the relationship between the exposure and disease of interest because of its relationship to both. Consider an example of a researcher whose study finds that people who exercise have a lower risk of diabetes compared to people who do not exercise. It is known that people who exercise more also tend to consume healthier diets and healthier diets may lower the risk of diabetes. If the researcher does not control for the impact of diet, it is not possible to say with certainty that the lower risk of diabetes is due to exercise and not to a healthier diet. In this example, diet is the confounding variable.

Cause vs. association and evaluating evidence regarding causal associations

Epidemiologic studies can help suggest factors that may contribute to the risk of disease, but they are not used as the sole basis for drawing inferences about cause-and-effect relationships. Since epidemiologists do not have control over the many other factors to which people are exposed in their studies (e.g., chemicals, pollution, infections) and diseases can be caused by a complex interaction of many factors, the results of epidemiologic studies must be interpreted with caution. A single epidemiologic study is rarely unequivocally supportive or non-supportive of causation; rather, a weight is assigned to the study based on the validity of its methods and all studies (epidemiologic, *in vivo*, and *in vitro*) must be considered together in a weight-of-evidence review to arrive at a conclusion about possible causality between an exposure and disease.

Scientific guidance for assessing the overall epidemiologic evidence for causality was formally proposed by Sir Austin Bradford Hill (Hill, 1965). Hill put forth nine criteria for use in an evaluation of causality for associations observed in epidemiologic studies. These criteria included strength of association, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy. Hill cautioned that, while none of these criteria are *sine qua non* of causality, the more the epidemiologic evidence meets these guidelines, the more convincing the evidence is for a potential causal interpretation. The use of these guidelines is recommended after chance is ruled out with reasonable certainty as a potential explanation for the observed epidemiologic association.

In 1964, the Surgeon General of the United States published a landmark report on smoking-related diseases (HEW, 1964). As part of this report, nine criteria, similar to those proposed by Hill for evaluating epidemiologic studies (along with experimental data) for causality, were outlined. In a more recent version of this report, these criteria have been reorganized into seven criteria. In the earlier version, coherence, plausibility, and analogy were considered as distinct items, but are now summarized together because they have been treated in practice as essentially reflecting one concept (HHS, 2004). Table 2 provides a listing of the criteria and a brief description of each.

Table 2. Criteria for evaluating whether an association is causal

Criteria	Description
Consistency	Repeated observation of an association between exposure and disease in multiple studies of adequate statistical power, in different populations, and at different times.
Strength of the association	The larger (stronger) the magnitude and statistical strength of an association is between exposure and disease, the less likely such an effect is the result of chance or unmeasured confounding.
Specificity	The exposure is the single (or one of a few) cause of disease.
Temporality	The exposure occurs prior to the onset of disease.
Coherence, plausibility, and analogy	The association cannot violate known scientific principles and the association must be consistent with experimentally demonstrated biologic mechanisms.
Biologic gradient	This is also known as a dose-response relationship, i.e., the observation that the stronger or greater the exposure is, the stronger or greater the effect.
Experiment	Observations that result from situations in which natural conditions imitate experimental conditions. Also stated as a change in disease outcome in response to a non-experimental change in exposure patterns in population.

Source: Department of Health and Human Services, 2004

The criteria were meant to be applied to statistically significant associations that have been observed in the cumulative epidemiologic literature, i.e., if no statistically significant association has been observed for an exposure then the criteria are not relevant. It is important to note that these criteria were not intended to serve as a checklist; rather, they were intended to serve as a guide in evaluating associations for causal inference. Theoretically, it is possible for an exposure to meet all seven criteria, but still not be deemed a causal factor. Also, no one criterion can provide indisputable evidence for causation, nor can any single criterion, aside from temporality, rule out causation.

In summary, the judicious consideration of these criteria is useful in evaluating epidemiologic studies, but they cannot be used as the sole basis for drawing inferences about cause-and-effect relationships. In line with the criteria of "coherence, plausibility, and analogy," epidemiologic studies are considered along with *in vivo* and *in vitro* studies in a comprehensive weight-of-evidence review. Epidemiologic support for causality is usually based on high-quality studies reporting consistent results across many different populations and study designs that are supported by the experimental data collected from *in vivo* and *in vitro* studies.

Biological response vs. disease in human health

When interpreting research studies, it is important to distinguish between a reported biological response and an indicator of disease. This is relevant because exposure to EMF may elicit a biological response that is simply a normal response to environmental conditions. This response, however, might not be a disease, cause a disease, or be otherwise harmful. There are many exposures or factors encountered in day-to-day life that elicit a biological response, but the response is neither harmful nor does it cause disease. For example, when an individual walks from a dark room indoors to a sunny day outdoors, the pupils of the eye naturally constrict to limit the amount of light passing into the eye. This constriction of the pupil is a biological response to the change in light conditions. Pupil constriction, however, is neither a disease itself, nor is it known to cause disease.

4 The WHO 2007 Report: Methods and Conclusions

The WHO is a scientific organization within the United Nations system whose mandate includes providing leadership on global health matters, shaping health research agendas, and setting norms and standards. The WHO established the International EMF Project in 1996, in response to public concerns about exposure to EMF and possible adverse health outcomes. 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 health and environmental effects of exposure to static and time-varying fields in the frequency range 0-300 Gigahertz (GHz). A key objective of the EMF Project was to evaluate the scientific literature and make a status report on health effects to be used as the basis for a coherent international response, including the identification of important research gaps and the development of internationally acceptable standards for EMF exposure.

Methods

As part of their Environmental Health Criteria Programme, the WHO published a Monograph in June 2007 summarizing health research on EMF exposure in the ELF range. The Monograph used standard scientific procedures, as outlined in its Preamble and described above in Section 3, to conduct the review. The Task Group responsible for the report's overall conclusions consisted of 21 scientists from around the world with expertise in a wide range of disciplines. The Task Group relied on the conclusions of previous weight-of-evidence reviews,[8] where possible, and mainly focused on evaluating studies published after an IARC review of ELF EMF (with regard to cancer) in 2002 .

The WHO Task Group and IARC use specific terms to describe the strength of the evidence in support of causality between specific agents and cancer. These categories are described here because, while they are meaningful to scientists who are familiar with the IARC process, they can be confusing and can create an undue level of concern with the general public.

Sufficient evidence of carcinogenicity is assigned to a body of epidemiologic research if a positive association has been observed in studies in which chance, bias, and confounding can be ruled out with reasonable confidence. *Limited evidence of carcinogenicity* describes a body of epidemiologic research where the findings are inconsistent or there are outstanding questions about study design or other methodological issues that preclude making a conclusion. *Inadequate evidence of carcinogenicity* describes a body of epidemiologic research where it is unclear whether the data are supportive or unsupportive of causation because there is a lack of data or there are major quantitative or qualitative issues. A similar classification system is used for evaluating *in vivo* studies and mechanistic data for carcinogenicity.

8 The term weight-of-evidence review is used in this report to denote a systematic review process by a multidisciplinary, scientific panel involving experimental and epidemiologic research to arrive at conclusions about possible health risks. The WHO Monograph on EMF does not specifically describe their report as a weight-of-evidence review. Rather, they describe conducting a health risk assessment. A health risk assessment differs from a weight-of-evidence review in that it also incorporates an exposure and exposure-response assessment.

Summary categories are assigned by considering the conclusions of epidemiologic and *in vivo* evidence together (Figure 3).[9] Categories include (from highest to lowest risk): known carcinogen; probable carcinogen; possible carcinogen; not classifiable; and probably not a carcinogen. These categories are intentionally meant to err on the side of caution, giving more weight to the possibility that the exposure is truly carcinogenic and less weight to the possibility that the exposure is not carcinogenic. In the IARC classification system, possible carcinogen denotes exposures for which there is limited evidence of carcinogenicity in epidemiologic studies and less than sufficient evidence of carcinogenicity in studies of experimental animals.

	Epidemiology Studies				Animal Studies			
	Sufficient evidence	Limited evidence	Inadequate evidence	Evidence suggesting lack of carcinogenicity	Sufficient evidence	Limited evidence	Inadequate evidence	Evidence suggesting lack of carcinogenicity
Known Carcinogen	✓							
Probable Carcinogen		✓			✓			
Possible Carcinogen		✓				✓	✓	
Not Classifiable			✓			✓	✓	
Probably not a Carcinogen				✓				✓

Sufficient evidence in epidemiology studies—A positive association is observed between the exposure and cancer in studies, in which chance, bias and confounding were ruled out with "reasonable confidence."

Limited evidence in epidemiology studies—A positive association has been observed between the exposure and cancer for which a causal interpretation is considered to be credible, but chance, bias or confounding could not be ruled out with "reasonable confidence."

Inadequate evidence in epidemiology studies—The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available.

Evidence suggesting a lack of carcinogenicity in epidemiology studies—There are several adequate studies covering the full range of levels of exposure that humans are known to encounter, which are mutually consistent in not showing a positive association between exposure to the agent and any studied cancer at any observed level of exposure. The results from these studies alone or combined should have narrow confidence intervals with an upper limit close to the null value (e.g. a relative risk of 1.0). Bias and confounding should be ruled out with reasonable confidence, and the studies should have an adequate length of follow-up.

Sufficient evidence in animal studies—An increased incidence of malignant neoplasms is observed in (a) two or more species of animals or (b) two or more independent studies in one species carried out at different times or indifferent laboratories or under different protocols. An increased incidence of tumors in both sexes of a single species in a well-conducted study, ideally conducted under Good Laboratory Practices, can also provide sufficient evidence.

Limited evidence in animal studies—The data suggest a carcinogenic effect but are limited for making a definitive evaluation, e.g. (a) the evidence of carcinogenicity is restricted to a single experiment; (b) there are unresolved questions regarding the adequacy of the design, conduct or interpretation of the studies; etc.

Inadequate evidence in animal studies—The studies cannot be interpreted as showing either the presence or absence of a carcinogenic effect because of major qualitative or quantitative limitations, or no data on cancer in experimental animals are available

Evidence suggesting a lack of carcinogenicity in animal studies—Adequate studies involving at least two species are available which show that, within the limits of the tests used, the agent is not carcinogenic.

Figure 3. Basic IARC method for classifying exposures based on potential carcinogenicity.

9 *In vitro* research is not described in Figure 3 because it provides ancillary information and, therefore, is used to a lesser degree in evaluating carcinogenicity. *In vitro* studies are classified simply as strong, moderate, or weak.

As of September 2015, the IARC has reviewed close to 1,000 substances and exposure circumstances to evaluate their potential carcinogenicity. About 80% of exposures fall in the categories possible carcinogen (29%) or not classifiable (51%). This occurs because it is nearly impossible to prove that something is completely safe and few exposures show a clear-cut or probable risk, so most agents will end up in either of these two categories. Throughout the history of the IARC, only one agent has been classified as probably not a carcinogen, which illustrates the conservatism of the evaluations and the difficulty in proving the absence of an effect beyond all doubt.

Conclusions

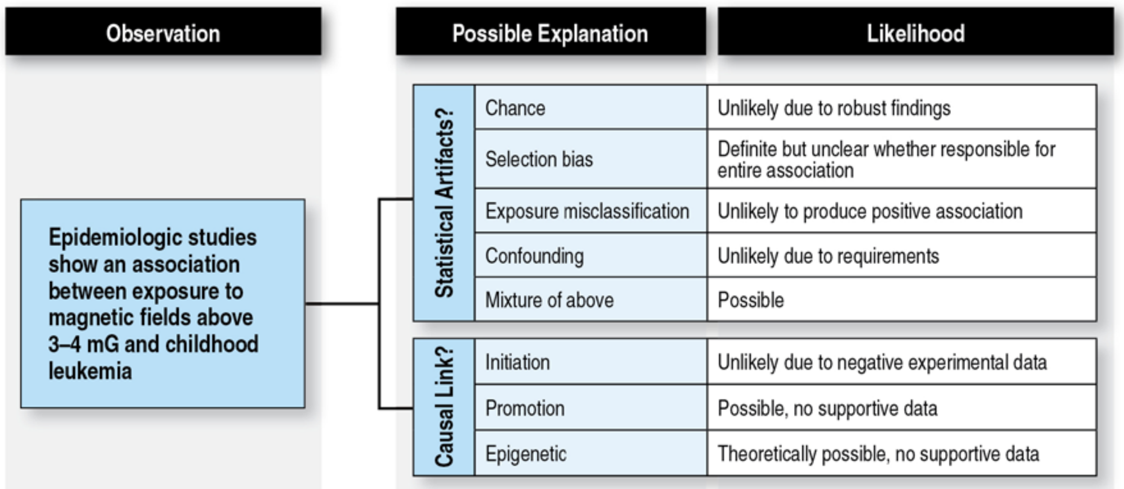
The WHO report provided the following overall conclusions with regard to ELF EMF:

> New human, animal, and *in vitro* studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF as a possible human carcinogen (WHO, 2007, p. 347).
>
> Acute biological effects [i.e., short-term, transient health effects such as a small shock] have been established for exposure to ELF electric and magnetic fields in the frequency range up to 100 kHz [kilohertz] 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 (WHO, 2007, p. 355).

With regard to specific diseases, the WHO concluded the following:

Childhood cancers. The WHO report paid particular attention to childhood leukemia because the most consistent epidemiologic association in the area of ELF EMF and health research has been reported between this disease and TWA exposure to high, magnetic-field levels. Two pooled analyses reported an association between childhood leukemia and TWA magnetic-field exposure greater than 3-4 mG (Ahlbom et al., 2000; Greenland et al., 2000); these data, categorized as limited epidemiologic evidence, resulted in the classification of ELF magnetic fields as a possible carcinogen by the IARC in 2002.

The WHO report systematically evaluated several factors that might be partially, or fully, responsible for the consistent association, including: chance; misclassification of magnetic-field exposure; confounding from hypothesized or unknown risk factors; and selection bias (Figure 4). The authors concluded that chance is an unlikely explanation since the pooled analyses had a large sample size and decreased variability. Control selection bias probably occurs to some extent in these studies and would result in an overestimate of the true association, but would likely not entirely explain the observed association. It is less likely that confounding occurs, although the possibility that some yet-to-be identified confounder is responsible for the association cannot be fully excluded. Finally, exposure misclassification would likely result in an underestimate of the true association, although that may not always be the case. The WHO concluded that reconciling the epidemiologic data on childhood leukemia and the negative experimental findings (i.e., no hazard or risk observed) through innovative research is currently the highest priority in the field of ELF EMF research. Given that few children are expected to have average magnetic-field exposures greater than 3-4 mG, however, the WHO stated that the public health impact of magnetic fields on childhood leukemia would likely be minimal, if the association was determined to be causal.



Source: Adapted from Schüz and Ahlbom (2008)

Figure 4. Possible explanations for the observed association between magnetic fields and childhood leukemia.

Fewer studies have been published on magnetic fields and childhood brain cancer compared to studies of childhood leukemia. The WHO Task Group described the results of these studies as inconsistent and limited by small sample sizes. They recommended a meta-analysis to clarify the research findings.

Breast cancer. The WHO concluded that the more recent published studies on breast cancer and ELF EMF exposure were higher in quality compared with earlier studies, and for that reason, they provided strong support to previous consensus statements that magnetic-field exposure does not influence the risk of breast cancer. In summary, the WHO stated "[w]ith these [recent] studies, the evidence for an association between ELF magnetic-field exposure and the risk of female breast cancer is weakened considerably and does not support an association of this kind" (WHO, 2007, p. 9). The WHO recommended no further research with respect to breast cancer and magnetic-field exposure.

Adult leukemia and brain cancer. The WHO concluded, "In the case of adult brain cancer and leukaemia [*sic*], the new studies published after the IARC monograph do not change the conclusion that the overall evidence for an association between ELF [EMF] and the risk of these diseases remains inadequate" (WHO, 2007, p. 307). The WHO panel recommended updating the existing European cohorts of occupationally-exposed individuals and pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association.

In vivo research on carcinogenesis. The WHO concluded the following with respect to *in vivo* research, "[t]here is no evidence that ELF exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour [*sic*] development in combination with carcinogens is inadequate" (WHO, 2007, p. 10). Recommendations for future research included the development of a rodent model for childhood acute lymphoblastic leukemia (ALL) and the continued investigation of whether magnetic fields can act as a co-carcinogen.

In vitro research on carcinogenesis. The WHO concluded that magnetic-field exposure below 50,000 mG was not associated with genotoxicity *in vitro*. There was some evidence, however, to suggest that magnetic fields above these levels might interact with other genotoxic agents to induce damage. Evidence for an association between magnetic fields and altered apoptosis or expression of genes controlling cell cycle progression was considered inadequate.

Reproductive and developmental effects. The WHO concluded that, overall, the body of research does not suggest that maternal or paternal exposures to ELF EMF cause adverse reproductive or developmental outcomes. The evidence from epidemiologic studies on miscarriage was described as inadequate and further research on this possible association was recommended, although it was designated as low priority.

In vivo research on reproductive and developmental effects. The WHO Task Group concluded that the available *in vivo* studies were inadequate for drawing conclusions regarding the potential effects of magnetic fields on the reproductive system. Furthermore, the Task Group concluded that studies conducted in mammalian models showed no adverse developmental effects associated with magnetic-field exposure.

Neurodegenerative disease. The WHO reported that the majority of epidemiologic studies have reported associations between occupational magnetic-field exposure and mortality from Alzheimer's disease and amyotrophic lateral sclerosis (ALS), although the design and methods of these studies were relatively weak (e.g., disease status was based on death certificate data; exposure was based on incomplete occupational information from census data; and there was no control for confounding factors). The WHO concluded that there is inadequate data in support of an association between magnetic fields and Alzheimer's disease or ALS. The panel highly recommended that further studies be conducted in this area, particularly studies where the association between magnetic fields and ALS is estimated while controlling for the possible confounding effect of electric shocks.

In vivo research on neurological effects. The WHO stated that various animal models were used to investigate possible field-induced effects on brain function and behavior. Few brief, transient responses had been identified.

Cardiovascular disease. It has been hypothesized that magnetic-field exposure reduces heart rate variability, which in turn increases the risk for acute myocardial infarction (AMI). With one exception (Savitz et al., 1999), however, none of the studies of cardiovascular disease morbidity and mortality has shown an association with exposure. Whether a specific association exists between exposure and altered autonomic control of the heart remains speculative and the overall evidence does not support an association. Experimental studies of both short- and long-term exposure indicate that, while electric shock is an obvious health hazard, other hazardous cardiovascular effects associated with ELF EMF are unlikely to occur at exposure levels commonly encountered environmentally or occupationally.

5 Current Scientific Consensus

The following sections identify and describe epidemiologic and *in vivo* studies related to ELF EMF and health published from August 1, 2012 through July 31, 2015. The purpose of this section is to evaluate whether the findings of these recent studies alter the conclusions published by the WHO in their 2007 report, as described in Section 4.

A structured literature search was conducted using PubMed, a search engine provided by the National Library of Medicine and the National Institutes of Health that includes over 15 million up-to-date citations from MEDLINE and other life science journals for biomedical articles (http://www.pubmed.gov). A well-defined search strategy was used to identify literature indexed August 1, 2012 through July 31, 2015.[10] While PubMed contains an extensive database of publications, some studies are indexed well after their publication date. For that reason, there may be studies included in this report that were actually published prior to August 1, 2012, but indexed after that date.

All fields (title, abstract, keywords, among others) were searched with various search strings that referenced the exposure[11] and diseases of interest.[12] A scientist with experience in this area reviewed the titles and abstracts of these publications for inclusion in this evaluation. Only peer-reviewed, epidemiologic studies and pooled- or meta-analyses of 50-Hz or 60-Hz AC ELF EMF and recognized disease entities are included. *In vivo* animal and human studies of 50-Hz or 60-Hz AC ELF EMF are also included, but only on the topic of cancer.

In addition to PubMed, EMF-Portal was also searched for relevant articles published during the same timeframe.[13] EMF-Portal is an extensive online database dedicated to scientific research related to potential effects of EMF. EMF-Portal currently includes over 21,000 publications and over 5,000 research summaries in a searchable format. EMF-Portal is maintained by Aachen University in Germany.

Methodological research is now being pursued in many areas of ELF EMF research to identify the possible impact of certain aspects of study design or biases on the studies' results. Therefore, articles evaluating the impact of methodological aspects of epidemiologic studies in this field are discussed, where appropriate. Systematic review articles of relevant topics are also noted, where appropriate. Studies published prior to the scope of this update are noted in certain circumstances to provide context.

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[10] While extensive efforts were made to identify relevant studies, it is possible that some studies reporting on the association between a disease and some measure of EMF exposure were missed. Many occupational and environmental case-control studies of cancer are published, some of which examine a large number of possible exposures; if no reference to EMF is made in the abstract, title, or keywords, for example, these studies may not have been identified using our search strategy. The most informative studies in this field, however, will be identified by our search strategy.

[11] EMF, magnetic fields, electric fields, or electromagnetic.

[12] Cancer (cancer, leukemia, lymphoma, carcinogenesis), neurodegenerative disease (neurodegenerative disease, Alzheimer's disease, amyotrophic lateral sclerosis, or Lou Gehrig's disease), cardiovascular effects (cardiovascular or heart rate), or reproductive outcomes (miscarriage, reproduction, or development).

[13] http://www.emf-portal.de

Epidemiologic studies are evaluated below by outcome (childhood cancer; adult cancer; reproductive or developmental effects; neurodegenerative diseases; and cardiovascular effects), followed by an evaluation of *in vivo* research in the field of cancer. Tables 3-11 list the relevant studies in these areas, including the study's first author and the title of the article.

Childhood leukemia

In 2002, the IARC assembled and reviewed research related to ELF EMF to evaluate the strength of the evidence in support of carcinogenicity. The IARC expert panel noted that, when studies with the relevant information were combined in a pooled analysis, a statistically significant two-fold association was observed between childhood leukemia and estimated exposure to high, average levels of magnetic fields (i.e., greater than 3-4 mG of average 24- and 48-hour exposure). This evidence was classified as limited evidence in support of carcinogenicity, falling short of sufficient evidence because chance, bias, and confounding could not be ruled out with reasonable confidence. Largely as a result of the findings related to childhood leukemia, the IARC classified magnetic fields as a possible carcinogen, a category that describes exposures with limited epidemiologic evidence and inadequate evidence from *in vivo* studies (see Figure 3). The classification of possible carcinogen was confirmed by the WHO in their June 2007 review.

Recent studies (2012 – 2015)

Childhood leukemia continues to be the main focus of ELF EMF epidemiologic research. In recent years, several large case-control studies from France, Denmark, and the United Kingdom have assessed the risk of childhood leukemia in relation to residential proximity to high-voltage power lines (Sermage-Faure et al., 2013; Bunch et al., 2014; Bunch et al., 2015; Pedersen et al., 2014a). The French study used geocoded information on residential addresses and power line locations to examine the risk of childhood leukemia in association with distance to power lines between 2002 and 2007. Overall, the study included 2,779 cases of childhood leukemia and 30,000 control children (Sermage-Faure et al., 2013) and reported no statistically significant increase in leukemia risk with distance to power lines. The authors, however, noted a statistically non-significant risk increase in a sub-analysis within 50 meters of 225-kV – 400-kV lines, but this was based on a small number of cases (n=9). A similar study from Denmark included 1,698 cases of childhood leukemia and 3,396 healthy control children (Pedersen et al., 2014a). The authors reported no risk increases for childhood leukemia with residential distance to power lines. The same authors also evaluated whether consideration of other potential risk factors for childhood leukemia may influence the results for distance to power lines (Pedersen et al., 2014b). No influence of adjustment for socioeconomic status, mother's age, birth order, domestic radon exposure, or traffic-related air pollution was observed in the power-line specific results. While the authors reported a statistical interaction between distance to power lines and radon exposure, they attributed these findings to chance, as these results were based on a small number of cases.

Bunch et al. (2014) reported on a study that updated and extended the 2005 study conducted by Draper et al. in the United Kingdom. The update extended the study period by 13 years, included Scotland in addition to England and Wales, and included 132-kV lines in addition to 275-kV and 400-kV transmission lines. Bunch et al. is the largest case-control study to date—it included over 53,000 childhood cancer cases, diagnosed between 1962 and 2008, and over

66,000 healthy children as controls. Overall, the authors reported no association with residential proximity to power lines with any of the voltage categories. In the overall analysis of the updated data, the statistical association that was reported in the earlier study (Draper et al., 2005) was no longer apparent. An analysis by calendar time indicated that the association was evident only in the earlier decades (1960s and 1970s) but not present in the later decades starting from the 1980s (Bunch et al., 2014). This weakens the argument that the associations observed earlier are due to magnetic-field effects. Population mixing (with potential infectious etiology) has been proposed to explain the associations observed in the earlier years but no empirical data are available in support of this hypothesis (Jeffers, 2014). In a follow up analysis of the same study population, the investigators also examined residential distance to high-voltage underground cables (mostly AC 275 kV and 400 kV) to case and control residences (Bunch et al., 2015). Over 52,000 cases of childhood cancer occurring between 1962 and 2008 in England and Wales, along with their matched controls, were included in these analyses. The authors reported no statistically significant associations or exposure-response trends between childhood leukemia and distance to power lines or calculated magnetic-field levels from the underground cables. The authors concluded that their results further detract from the hypothesis that exposure to magnetic fields explains the associations observed in earlier studies.

The strengths of these studies include their large size and their population-based design that minimized the potential for selection bias. These studies, however, primarily relied on distance to power lines as their main exposure metric, which is known to be a poor predictor of actual residential magnetic-field exposure. The limitations of distance as an exposure proxy also have been discussed by several observers in the scientific literature in the context of the French study (Bonnet-Belfais et al., 2013; Clavel et al., 2013). In addition, Chang et al. (2014) recently provided a detailed discussion of the limitations of exposure assessment methods based on geographical information systems. Swanson et al. (2014a) also concluded, based on their analysis of data from the British study (Bunch et al., 2014), that geocoding information that is not based on exact address but only on post code information is “probably not acceptable for assessing magnetic-field effects” (Swanson et al., 2014a, p. N81).

Epidemiologists from Italy have published two papers that describe the methods and results of a childhood leukemia case-control study and residential exposure to 50-Hz magnetic fields (Magnani et al., 2014; Salvan et al., 2015). In total, 412 leukemia cases under the age of 10 years diagnosed between 1998 and 2001 and 587 controls were included in the study. Exposure to residential ELF magnetic fields was assessed by extended (24 – 48-hr) measurements in the children’s bedroom. Conditional logistic regression was used to calculate RR and adjust for potentially confounding variables. In their analyses, the researchers evaluated a number of exposure metrics (measures of central tendency or peak-exposure measures; continuous or categorical exposures based on measurements during nighttime, weekend, or entire measurement periods). The potential role of residential mobility of the subjects in the observed associations was also assessed. No consistent exposure-response patterns were observed in any of the analyses. The main limitations of the study include the potential for differential participation of controls and cases and differences in participation rates of the study subjects based on their socioeconomic status, which in combination may result in a reference group that is not fully representative of the underlying population at risk. This, in turn, may bias the calculated effect estimates. The low prevalence of highly-exposed subjects (particularly exposure above 3 mG) results in a limitation of the statistical power of the study.

A hospital-based case-control study of EMF and childhood leukemia included 79 cases and 79 matched controls in the Czech Republic (Jirik et al., 2012). Exposure was measured in the participants' homes, in the "vicinity" of the residences, and the participants' schools. No association was reported between the measured magnetic field and leukemia risk. The study was small and provided insufficient information on the methods of case ascertainment, control selection, subject recruitment, and exposure assessment to fully assess its quality.

An even smaller cross-sectional study of 22 cases of childhood ALL and 100 controls from Iran reported a statistically significant association with "prenatal and postnatal childhood exposure to high voltage power lines" (Tabrizi and Bigdoli, 2015, p. 2347). The study, however, would carry very little, if any, weight in an overall evaluation, because of its cross-sectional study design and very small sample size, and due to the complete lack of information on exposure assessment in the study.

A recent pooled analysis (Schüz et al., 2012) aimed to follow up on two earlier studies that, based on small numbers of cases, reported poorer survival among cases of childhood leukemia with increased average exposure to magnetic fields, suggesting the magnetic fields may play a role in the progression in the disease following diagnosis (Foliart et al., 2006; Svendsen et al., 2007). The pooled analysis included exposure and clinical data on more than 3,000 cases of childhood leukemia from Canada, Denmark, Germany, Japan, the United Kingdom, and the United States. The authors reported no association between magnetic-field exposure and overall survival or relapse of disease in children with leukemia after diagnosis.

Researchers also examined the association between occupational exposures of fathers and the risk of childhood leukemia in their children in the United Kingdom (Keegan et al., 2012). The study included a total of 15,785 cases of childhood leukemia diagnosed between 1962 and 2006 and a similar number of matched controls in the analyses. EMF exposure was among the 33 investigated occupational exposures. Occupational EMF exposure of the fathers did not show a statistically significant relationship to leukemia in their children when all types of leukemia, lymphoid leukemia (the most common type), or myeloid leukemia were considered. The authors reported a statistically significant increase for leukemia classified as "other types," which included but 7% of the leukemia cases.

Zhao et al. (2014a) conducted a meta-analysis of nine case-control studies of EMF exposure and childhood leukemia published between 1997 and 2013. The authors reported a statistically significant association between average exposure above 4 mG and all types of childhood leukemia (OR 1.57; 95% CI 1.03–2.4). The meta-analysis relied on published results from some of the same studies included in previous pooled analyses, thus provided little new insight.

Swanson et al. (2014b) investigated the potential role of corona ions from AC power lines in childhood cancer development in a large British epidemiologic study of childhood cancer (Bunch et al., 2014). This work is a follow up on a hypothesis suggesting that charged aerosol particles generated by corona activity might increase exposure to ambient airborne substances leading to increased risk of certain cancers, including childhood cancers. The authors used an improved model to predict exposure to corona ions using meteorological data on wind conditions, power line characteristics, and proximity to residential address. The authors concluded that their results provided no empirical support for the corona ion hypothesis.

Several methodological studies have also examined the potential role of causal and alternative, non-causal explanations for the reported epidemiologic associations. Swanson and Kheifets (2012) proposed that if the biological mechanism explaining the epidemiologic association involves free radicals then, due to the small timescale of the reactions, the effects of ELF EMF and the earth's geomagnetic fields would be similar. Thus, to test this hypothesis the authors evaluated whether the magnitude of the earth's geomagnetic field modifies the effects reported by ELF EMF childhood leukemia studies from various parts of the world. The results were not in full support of the hypothesis. Swanson (2013) examined differences in residential mobility among residents who lived at varying distances from power lines in order to assess if these differences in mobility may explain the statistical association of leukemia with residential proximity to power lines. The study reported some variations in residential mobility, "but only small ones, and not such as to support the hypothesis" (Swanson, 2013, p. N9). A third study evaluated whether selection bias may play a role in the association between childhood leukemia and residential magnetic-field exposure (Slusky et al., 2014). The authors used wire code categories to assess exposure among participant and nonparticipant subjects in the Northern California Childhood Leukemia Study. While the authors reported systematic differences between participant and nonparticipant subjects in both wire code categories and socioeconomic status, these differences did not appear to influence the association between childhood leukemia and exposure estimates. The limitations of the study include the use of wire code categories to assess exposure, which is known to be a poor predictor for actual magnetic-field exposure, and that the study showed no association between magnetic fields and childhood leukemia among the participant subjects.

Recent reviews continue to highlight that the observed epidemiologic association between EMF and childhood leukemia remains unexplained and there are no supportive data from laboratory animal studies or known biophysical mechanisms that could explain a carcinogenic effect (Ziegelberger et al., 2011; Teepen and van Dijck, 2012; Grellier et al., 2014). In contrast, Leitgeb (2014) concluded, based on his combined analysis of 36 childhood leukemia epidemiologic studies, that overall, childhood leukemia is not linked to ELF magnetic field exposure when results from all epidemiologic studies are considered together. He reached his conclusions after plotting ORs as a function of the number of exposed cases and the publication year of the studies. As the analysis is not a conventional meta- or pooled analysis and it does not consider any of the design features and characteristics of the individual studies (e.g., exposure assessment methods, potential sources of bias), no firm conclusion could be drawn based on these results.

Grellier et al. (2014) estimated that, if the association was causal, ~1.5% to 2% of childhood leukemia cases in Europe might be attributable to ELF EMF. They conclude that "this contribution is relatively small and is characterised [*sic*] by considerable uncertainty" (Grellier et al., 2014, p. 61). Authors continue to emphasize that further understanding may be gained by studies of improved methodology and reduced potential for bias and by international and interdisciplinary collaborations (Ziegelberger et al., 2011; Teepen and van Dijck, 2012; Mezei et al., 2014).

Assessment

In summary, while some of the recently published large and methodologically advanced studies showed no association (e.g., Bunch et al., 2014, Pedersen et al., 2014a, 2014b), the association between childhood leukemia and magnetic fields observed in some studies remains unexplained. Thus, the results of recent studies do not change the classification of the epidemiologic data as limited, which is also the assessment of the most recent weight-of-evidence review released in 2015 by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR).[14]

It should be noted that magnetic fields are just one small area in the large body of research on the possible causes of childhood leukemia. There are many other hypotheses under investigation that point to possible genetic, environmental, and infectious explanations for childhood leukemia, which have similar or stronger support in epidemiologic studies (Ries et al., 1999; McNally and Parker, 2006; Belson et al., 2007; Rossig and Juergens, 2008; Eden, 2010).

Table 3. Relevant studies of childhood leukemia

Author	Year	Study Title
Bunch et al.	2014	Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008.
Bunch et al.	2015	Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables
Chang et al.	2014	Validity of geographically modeled environmental exposure estimates
Grellier et al.	2014	Potential health impacts of residential exposures to extremely low frequency magnetic fields in Europe
Jirik et al.	2012	Association between childhood leukaemia and exposure to power-frequency magnetic fields in middle Europe
Keegan et al.	2012	Case–control study of paternal occupation and childhood leukaemia in Great Britain, 1962–2006
Leitgeb	2014	Childhood leukemia not linked with ELF magnetic fields
Magnani et al	2014	SETIL: Italian multicentric epidemiological case-control study on risk factors for childhood leukaemia, non hodgkin lymphoma and neuroblastoma: study population and prevalence of risk factors in Italy
Pedersen et al.	2014a	Distance from residence to power line and risk of childhood leukemia: a population-based case-control study in Denmark
Pedersen et al.	2014b	Distance to high-voltage power lines and risk of childhood leukemia - an analysis of confounding by and interaction with other potential risk factors
Salvan et al.	2015	Childhood leukemia and 50 Hz magnetic fields: findings from the Italian SETIL case-control study
Schüz et al.	2012	Extremely low-frequency magnetic fields and survival from childhood acute lymphoblastic leukemia: an international follow-up study
Sermage-Faure et al.*	2013	Childhood leukaemia close to high-voltage power lines – the Geocap study, 2002–2007
Slusky et al.	2014	Potential role of selection bias in the association between childhood leukemia and residential magnetic fields exposure: a population-based assessment
Swanson	2013	Residential mobility of populations near UK power lines and implications for childhood leukaemia
Swanson and Kheifets	2012	Could the geomagnetic field be an effect modifier for studies of power-frequency magnetic fields and childhood leukaemia?
Swanson et al.	2014a	Relative accuracy of grid references derived from postcode and address in UK epidemiological studies of overhead power lines.

[14] On July 8, 2015, SCENIHR was renamed the Scientific Committee on Health, Environment, and Emerging Risks (SCHEER). Since any publications by this body referenced in this report were published before the name was changed, all citations to their publications will note SCENIHR rather than SCHEER.

Author	Year	Study Title
Swanson et al.	2014b	Childhood cancer and exposure to corona ions from power lines: an epidemiological test.
Tabrizi and Bidgoli	2015	Increased risk of childhood acute lymphoblastic leukemia (ALL) by prenatal and postnatal exposure to high voltage power lines: a case control study in Isfahan, Iran
Teepen and van Dijck	2012	Impact of high electromagnetic field levels on childhood leukemia incidence
Zhao et al.	2014a	Magnetic fields exposure and childhood leukemia risk: a meta-analysis based on 11,699 cases and 13,194 controls
Ziegelberger et al.	2011	Review. Childhood leukemia: Risk factors and the need for an interdisciplinary research agenda
*Comments and Replies on Sermage-Faure et al.:		
Bonnet-Belfais et al.	2013	Comment: childhood leukaemia and power lines--the Geocap study: is proximity an appropriate MF exposure surrogate?
Clavel et al.	2013	Reply: comment on 'Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007'--is proximity an appropriate MF exposure surrogate?

Childhood brain cancer

Compared to the research on magnetic fields and childhood leukemia, there have been fewer studies of childhood brain cancer. The data are less consistent and limited by smaller numbers of exposed cases than studies of childhood leukemia. The WHO review recommended the following:

> As with childhood leukaemia, a pooled analysis of childhood brain cancer studies should be very informative and is therefore recommended. A pooled analysis of this kind can inexpensively provide a greater and improved insight into the existing data, including the possibility of selection bias and, if the studies are sufficiently homogeneous, can offer the best estimate of risk (WHO, 2007, p. 18).

Recent studies (2012 – 2015)

There have been two new publications that examined the potential relationship between residential proximity to overhead and underground transmission lines and childhood brain cancer (Bunch et al., 2014; Bunch et al., 2015). The previously described case-control epidemiologic study by Bunch et al. (2014) also included cases of brain cancer (n=11,968) and other solid tumors (n=21,985) among children in the United Kingdom between 1962 and 2008 in the analysis of overhead power lines. No statistical association was reported in any of the analyses for childhood brain cancer and proximity to overhead lines. In the analyses of residential proximity to high-voltage underground cables (Bunch et al., 2015) in the same study population, the authors report a statistical association for childhood brain cancer with distance, but only in an intermediate category (20 – 49.9 meters), without clear support for an exposure-response pattern. No statistically significant associations were reported with calculated magnetic fields from underground cables.

Assessment

The recent publications by Bunch et al. (2014, 2015) did not report any consistent association between estimated magnetic-field exposure and brain tumors among children. This is in line with the previous assessment that the weight of the recent data does not support an association between magnetic-field exposures and the development of childhood brain cancer (Kheifets et al., 2010; SCENIHR, 2015). The recent data do not alter the classification of the epidemiologic data in this field as inadequate.

Table 4. Relevant studies of childhood brain cancer

Authors	Year	Study Title
Bunch et al.	2014	Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008.
Bunch et al.	2015	Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables

Breast cancer

The WHO reviewed studies of breast cancer and residential magnetic-field exposure, electric blanket usage, and occupational magnetic-field exposure. These studies did not report consistent associations between magnetic-field exposure and breast cancer. The WHO concluded that the more recent body of research they reviewed on this topic was less susceptible to bias compared with previous studies, and, as a result, it provided strong support to previous consensus statements that magnetic-field exposure does not influence the risk of breast cancer. Specifically, the WHO stated:

> Subsequent to the IARC monograph [2002] a number of reports have been published concerning the risk of female breast cancer in adults associated with ELF magnetic field exposure. These studies are larger than the previous ones and less susceptible to bias, and overall are negative. With these studies, the evidence for an association between ELF exposure and the risk of breast cancer is weakened considerably and does not support an association of this kind (WHO, 2007, p. 307).

The WHO did not recommend any specific research with respect to breast cancer and magnetic-field exposure.

Recent studies (2012 – 2015)

Researchers in the United Kingdom published a large case-control study that investigated risk of adult breast cancer, leukemia, brain tumors, and malignant melanoma, in relation to magnetic-field exposure and residential distance to high voltage power lines (Elliott et al., 2013). The study included incident cancer cases, including 29,202 female breast cancer cases, from England and Wales diagnosed between 1974 and 2008, and a total of over 79,000 controls between the age of 15 and 74 years. Location of power lines and residential addresses were identified based on data from geographical information systems. Magnetic-field exposure was calculated for each control address and for each case address for the year of and 5 years prior to diagnosis. Risk of female breast cancer showed no association with distance to power lines or with estimated magnetic fields. Following publication, the study received criticism regarding its exposure assessment, exposure categorization, and the potential for confounding (de Vocht, 2013; Philips et al., 2013; Schüz, 2013).

Sorahan (2012) studied cancer incidence among more than 80,000 electricity generation and transmission workers in the United Kingdom between 1973 and 2008. Standardized registration rates were calculated among the workers compared to rates observed in the general population. No statistically significant increases were reported for breast cancer among either men or women. There was no trend for breast cancer incidence with year of hire, years of being employed, or years since leaving employment. The strengths of the study include its prospective nature and its large size. It is, however, limited in exposure assessment because risk was not calculated by magnetic-field exposure levels, and incidence rates were compared to an external reference group.

Koeman et al. (2014) investigated occupational exposure to ELF magnetic fields and cancer incidence in a cohort of about 120,000 men and women in the Netherlands Cohort study. The researchers used a case-cohort approach to analyze their data and identified 2,077 breast cancer cases among women and no breast cancer among men in the cohort. Exposure to ELF magnetic fields was assigned based on job title using a job-exposure matrix. Breast cancer showed no association with the level of estimated ELF magnetic-field exposure, or the length of employment, or cumulative exposure in the exposed jobs.

Li et al. (2013) conducted a nested case-cohort analysis of breast cancer incidence among more than 267,000 female textile workers in Shanghai. The researchers identified 1,687 incidence breast cancer cases in the cohort between 1989 and 2000 and compared their estimated exposure to 4,702 non-cases. Exposure was assessed based on complete work history and a job-exposure matrix specifically developed for the cohort. No association was observed between cumulative exposure and risk of breast cancer regardless of age, histological type, and whether a lag period was used or not. An accompanying editorial opined that this well-designed study further adds to the already large pool of data not supporting an association between ELF EMF and breast cancer (Feychting, 2013). The editorial suggests that further studies on breast cancer “have little new knowledge to add,” following the considerable improvement in study quality over time in breast cancer epidemiologic studies, and with the evidence being “consistently negative” (Feychting, 2013, pp. 1046).

Meta-analyses for breast cancer were conducted by Chinese investigators for both female (Chen et al., 2013; Zhao et al., 2014b) and male breast cancers (Sun et al., 2013). The meta-analysis for female breast cancer included 23 case-control studies published between 1991 and 2007. Based on all 23 studies, the authors estimated a slight, but statistically significant association between breast cancer and ELF magnetic-field exposure (OR 1.07; 95% CI 1.02-1.13), which was slightly higher for estrogen receptor positive and premenopausal cancer (OR 1.11) (Chen et al., 2013). The conclusion of the authors that ELF magnetic fields might be related to breast cancer is contrary to the conclusion of the WHO and other risk assessment panels, which may be due to their reliance on earlier and methodologically less advanced studies in the meta-analysis. Zhao et al. (2014b) reported the results of their meta-analysis of 16 case-control epidemiologic studies of ELF EMF and breast cancer published between 2000 and 2007. They reported a weak but statistically significant association, which appeared to be stronger among non-menopausal women. The conclusion of the authors that ELF magnetic fields might be related to breast cancer is contrary to the conclusion of the WHO and other risk assessment panels. Similar to the previous meta-analysis, this may be due to the inclusion of earlier and methodologically less advanced studies in the meta-analysis. Sun et al (2013) conducted a meta-analysis of male breast cancer including 7 case-control and 11 cohort studies. The studies, with one exception that estimated residential exposure, estimated occupational exposure to ELF magnetic fields. The combined analysis showed a statistically significant association between male breast cancer and exposure to ELF EMF (OR 1.32; 95% CI 1.14-1.52). Methodological limitations, the small number of cases in the individual studies, and the potential for publication bias may contribute to the findings.

Assessment

The recent large case-control and cohort studies, which report no association with female breast cancer, add to growing support against a causal role for magnetic-field exposure, both in residential and occupational settings, in breast cancer development. A recent review by SCENIHR (2015) concluded that, overall, studies on “adult cancers show no consistent associations” (p. 158).

Table 5. Relevant studies of breast cancer

Authors	Year	Study
Chen et al.	2013	A meta-analysis on the relationship between exposure to ELF-EMFs and the risk of female breast cancer.
*Elliott et al.	2013	Adult cancers near high-voltage overhead power lines
Feytching	2013	Invited commentary: extremely low-frequency magnetic fields and breast cancer--now it is enough!
Koeman et al.	2014	Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort
Li et al	2013	Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China
Sorahan et al.	2012	Cancer incidence in UK electricity generation and transmission workers, 1973–2008
Sun et al.	2013	Electromagnetic field exposure and male breast cancer risk: a meta-analysis of 18 studies
Zhao et al.	2014b	Relationship between exposure to extremely low-frequency electromagnetic fields and breast cancer risk: a meta-analysis
*Comment and Replies on Elliot et al.		
De Vocht	2013	Letter to the Editor: Adult cancers near high-voltage power lines
Philips et al.	2013	Letter to the Editor: Adult cancers near high-voltage power lines
Schüz	2013	Commentary: power lines and cancer in adults: settling a long-standing debate?

Adult brain cancer

Brain cancer was studied along with leukemia in many of the occupational studies of EMF. The findings were inconsistent, and there was no pattern of stronger findings in studies with more advanced methods, although a small association could not be ruled out. The WHO classified the epidemiologic data on adult brain cancer as inadequate and recommended (1) updating the existing European cohorts of occupationally-exposed individuals and (2) pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association.

The WHO stated the following:

> In the case of adult brain cancer and leukaemia, the new studies published after the IARC monograph do not change the conclusion that the overall evidence for an association between ELF [EMF] and the risk of these disease remains inadequate (WHO, 2007, p. 307).

Recent studies (2012 – 2015)

The Elliot et al. (2013) study of residential proximity and magnetic-field exposure from power lines, described above, also included 6,781 brain cancer cases. The risk of brain cancer showed no statistically significant increase with either distance or estimated magnetic-field levels in the study.

Sorahan (2012, 2014a) also examined the incidence of brain cancer in his analyses in the cohort of electricity generation and transmission workers in the United Kingdom. He made both internal comparisons (within the cohort of workers) and external comparisons (to the general population of the United Kingdom) and considered cumulative, recent, and distant occupational exposures to occupational ELF EMF. He reported no increased risk for brain cancer among either men or women. No trend was reported for brain cancer with year of hire, years of employment, years since employment in the study, or with estimates of cumulative, recent, or distant exposure to occupational ELF magnetic fields.

Koeman (2014) identified 160 male and 73 female cases of brain cancer in the Netherlands Cohort Study, described above. No statistically significant risk increase or trend was observed for cumulative ELF magnetic-field exposure among either men or women.

Turner et al. (2014) reported results from the INTEROCC study, which is an international case-control study of brain cancer and occupational exposure to ELF EMF. A total of 3,761 cases of brain cancer and 5,404 controls were included from Australia, Canada, France, Germany, Israel, New Zealand, and the United Kingdom between 2000 and 2004. Exposure was assessed based on individual job history and a job-exposure matrix. There was no association with lifetime cumulative exposure, average exposure, or maximum exposure for either glioma or meningioma. The authors, however, reported an association for both brain cancer types with exposure in the 1 to 4 year time-window prior to diagnosis. A statistical decrease in risk for glioma was also reported in the highest maximum exposure category.

Assessment

Recent studies did not report a consistent overall increase of brain cancer risk with either occupational or residential exposure to ELF EMF. While an association still cannot be ruled out *entirely* because of remaining deficiencies in exposure assessment methods, there is no strong evidence in support of a relationship between magnetic fields and brain cancer. The data remain inadequate as reported earlier (EFHRAN, 2012). As mentioned above, the most recent SCENIHR report (2015) states that, overall, studies on “adult cancers show no consistent associations” (p. 158).

Table 6. Relevant studies of adult brain cancer

Authors	Year	Study
Elliott et al.	2013	Adult cancers near high-voltage overhead power lines
Koeman et al.	2014	Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort
Sorahan	2012	Cancer incidence in UK electricity generation and transmission workers, 1973–2008
Sorahan	2014a	Magnetic fields and brain tumour risks in UK electricity supply workers
Turner et al	2014	Occupational exposure to extremely low frequency magnetic fields and brain tumour risks in the INTEROCC study

Adult leukemia and lymphoma

There is a vast amount of literature on adult leukemia and EMF, most of which is related to occupational exposures. Overall, the findings of these studies are inconsistent—with some studies reporting a positive association between measures of EMF and leukemia and other studies showing no association. No pattern has been identified whereby studies of higher quality or design are more likely to produce positive or negative associations. The WHO subsequently classified the epidemiologic evidence for adult leukemia as "inadequate." They recommended updating the existing occupationally-exposed cohorts in Europe and updating a meta-analysis on occupational magnetic-field exposure.

Recent studies (2012 – 2015)

Elliott et al (2013) included 7,823 cases of adult leukemia and reported no elevated risk or trend in association with distance or estimated magnetic-field exposure from high-voltage power lines in the United Kingdom. In the cohort of electricity power plant and transmission workers in the United Kingdom, Sorahan (2012) reported no increase in risk for leukemia, when compared to the general population of the United Kingdom, either among men or women, and no increasing trend was observed with length of employment. Sorahan also analyzed leukemia risk in relation to estimated occupational exposure to ELF magnetic fields within the cohort of employees; he reported that RR estimates were "unexceptional," and were close to unity for all exposure categories based on cumulative, recent, and distant exposures (Sorahan, 2014b). Sorahan (2014b) reported a statistical association for ALL in a sub-analysis, but attributed this, in the main, to unusually low risk in the reference category.

Koeman et al. (2014) identified 761 and 467 hematopoietic malignancies among men and women, respectively, in the Netherlands Cohort Study. No increases in risk or trend were observed in association with cumulative exposure to ELF magnetic fields among either men or women.

Rodriguez-Garcia and Ramos (2012) reported inverse correlations between acute myeloid leukemia, ALL, and the distance to thermoelectric power plants and high-density power line networks in their study of hematologic cancers in a region of Spain from 2000 to 2005. This study, however, has severe limitations due to the use of aggregated data, rudimentary methods of exposure assessment, and the lack of an adequate comparison group.

Talibov et al. (2015) reported on a large case-control study of acute myeloid leukemia and occupational exposure to ELF EMF and electric shocks. The study included 5,409 cases diagnosed between 1961 and 2005 in Finland, Iceland, Norway, and Sweden and 27,045 controls matched on age, sex, and country. Lifetime occupational exposure to ELF EMF and shocks were assessed with job-exposure matrices based on jobs reported on the censuses. Potential confounding variables, such as work-related exposure to benzene and ionizing radiation, were adjusted for in the analyses. No associations between leukemia and exposure to ELF EMF or electric shocks were reported among either men or women.

Assessment

Recent studies did not provide substantial new evidence in support of an association between EMF and leukemia and lymphoma in adults. While some scientific uncertainty remains on a potential relationship between adult lymphohematopoietic malignancies and magnetic-field exposure because of the remaining deficiencies in study methods, the current database of studies provides inadequate evidence for an association (EFHRAN, 2012; SCENIHR, 2015).

Table 7. Relevant studies of adult leukemia/lymphoma

Authors	Year	Study
Elliott et al.	2013	Adult cancers near high-voltage overhead power lines
Koeman et al.	2014	Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort
Rodriguez-Garcia and Ramos	2012	High incidence of acute leukemia in the proximity of some industrial facilities in El Bierzo, northwestern Spain
Sorahan	2012	Cancer incidence in UK electricity generation and transmission workers, 1973–2008
Sorahan	2014b	Magnetic fields and leukaemia risks in UK electricity supply workers
Talibov et al.	2015	Occupational exposure to extremely low-frequency magnetic fields and electrical shocks and acute myeloid leukemia in four Nordic countries

In vivo studies of carcinogenesis

In the field of ELF EMF research, a number of research laboratories have exposed rodents, including those with a particular genetic susceptibility to cancer, to high levels of magnetic fields over the lifetime of the animals and performed tissue evaluations to assess the incidence of cancer in many organs. In these studies, magnetic-field exposure has been administered alone (to test for the ability of magnetic fields to act as a complete carcinogen), in combination with a known carcinogen (to test for a promotional or co-carcinogenetic effect), or in combination with a known carcinogen and a known promoter (to test for a co-promotional effect).

The WHO review described four large-scale, long-term studies of rodents exposed to magnetic fields over the course of their lifetime that did not report increases in any type of cancer related to the intensity of exposure (Mandeville et al., 1997; Yasui et al., 1997; McCormick et al., 1999; Boorman et al., 1999a, 1999b). The highest intensity studied was 50,000 mG (Yasui et al., 1997). At the time of the WHO report, no directly relevant animal model for childhood ALL had been developed. Some animals, however, develop a type of lymphoma similar to childhood ALL and studies exposing predisposed transgenic mice to ELF magnetic fields did not report an increased incidence of this lymphoma type (Harris et al., 1998; McCormick et al., 1999; Sommer and Lerchl, 2004).

Studies investigating whether exposure to magnetic fields can promote cancer or act as a co-carcinogen used known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. No effects were observed for studies on chemically-induced preneoplastic liver lesions, leukemia or lymphoma, skin tumors, or brain tumors; however, the incidence of 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors was increased with magnetic-field exposure in a series of experiments in Germany (Löscher et al., 1993, 1994, 1997; Mevissen et al., 1993a, 1993b, 1996a, 1996b, 1998; Baum et al., 1995; Löscher and Mevissen, 1995; Mandeville et al., 1997), suggesting that magnetic-field exposure increased the proliferation of mammary tumor cells. These results were not replicated in a subsequent series of experiments in a laboratory in the United States (Anderson et al., 1999; Boorman et al., 1999a, 1999b), possibly due to differences in experimental protocol and the species strain. In Fedrowitz et al. (2004), exposure enhanced mammary tumor development in one sub-strain (Fischer 344 [F344] rats), but not in another sub-strain of rats that was obtained from the same breeder, which argues against a promotional effect of magnetic fields.[15]

Two laboratories have reported an increase in genotoxic effects among exposed animals (e.g., DNA strand breaks in the brains of mice at field levels between 100 and 5,000 mG [e.g., Lai and Singh, 2004]). Other investigators have reported no effect of magnetic field exposure and thus did not replicate these results.

In summary, the WHO concluded the following with respect to *in vivo* research on carcinogenesis: "There is no evidence that ELF [EMF] exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate" (WHO, 2007, p. 322). Recommendations for future research included the development of a rodent model for childhood ALL and the continued investigation of whether magnetic fields can act as a promoter or co-carcinogen.

Recent studies (2012 – 2015)

Studies published since Exponent's 2012 update that investigated the potential carcinogenic effects of electric- and magnetic-field exposure in animals are listed in Table 8. As noted above, none of the past large-scale, long-term bioassays of magnetic-field exposures have reported that lifetime exposure to magnetic fields initiate or promote tumor development in rodents. In some other studies, increases of DMBA-initiated mammary tumors in a particular strain of rats exposed to magnetic fields were reported in a single laboratory. To further investigate this phenomenon, Fedrowitz and Löscher (2012) evaluated gene expression in pooled samples of mammary tissue from both F344 rats (magnetic-field susceptible)[16] and Lewis rats (magnetic-field insensitive) following 2 weeks of continuous exposure to 1,000 mG, 50-Hz magnetic fields. Control rats of both strains were sham exposed and analyses were conducted in a blinded manner. Based on a 2.5-fold change in gene expression as the cut-off for establishing an

[15] The WHO concluded with respect to the German studies of mammary carcinogenesis, "Inconsistent results were obtained that may be due in whole or in part to differences in experimental protocols, such as the use of specific substrains" (WHO, 2007, p. 321).

exposure-related response, only 22 of 31,100 gene transcripts were found to be altered with magnetic-field exposure in the two rat strains combined. Genes showing the greatest change in expression in response to magnetic-field exposure in F344 rats (with no change in gene expression observed in Lewis rats) were α-amylase (a 832-fold decrease), parotid secretory protein (a 662-fold decrease), and carbonic anhydrase 6 (a 39-fold decrease).

To follow-up on these findings, Fedrowitz et al. (2012) examined α-amylase activity in mammary tissues collected from the two rat strains in previous experiments. In initial experiments using tissues collected in 2005 through 2006, magnetic-field exposure was associated with increased α-amylase activity in cranial mammary tissues, but not caudal mammary tissues, from both F344 and Lewis rats. Thus, the response did not appear to correlate with the observed rat strain susceptibility to magnetic-field exposure. In later experiments using tissues collected in 2007 through 2008, α-amylase activity in the cranial tissues was unaffected by magnetic-field exposure, but increased in the caudal tissues of F344 rats (and not the tissues of Lewis rats) in response to magnetic-field treatment. Additional experiments looked at α-amylase protein expression and its correlation with tissue differentiation following treatment with diethylstilbestrol. Overall, the findings of this study are contradictory, making interpretation difficult regarding the potential role of α-amylase expression in the observed sensitivity of F344 rats to magnetic-field exposure.

Another recent study (Qi et al., 2015) examined the effects of exposure to 500 mG, 50-Hz magnetic fields on tumor development in mice. The exposures were begun during *in utero* development with 1 week (12 hours per day) exposure of pregnant females and continued for 15.5 months after birth. Controls were not sham-exposed (i.e., in the same exposure apparatus, but with the system turned off) and analyses were not reported to have been conducted in a blinded manner. Further, the exposure apparatus and conditions (including the number of animals per cage and control for potential confounding variables including light, vibration, and noise) were not described. Both male and female offspring were reported to exhibit significantly reduced body weights compared to controls. Tumors were not increased in exposed male mice. The incidence of chronic myeloid leukemia was reported to be significantly higher, however, in exposed females compared to controls. Interpretation of these data is difficult because of the limited experimental detail reported and because overall survival data and the expected background incidence for tumors in these mice were not reported. Further, these data are contradictory to the largely negative large-scale rodent carcinogenesis studies, as reviewed by the WHO (2007).

Other studies investigated the therapeutic potential of high magnetic-field exposures in the treatment of tumors. El-Bialy and Rageh (2013) injected female mice with Ehrlich ascites carcinoma cells, then treated them with 3 mg/kg cisplatin on days 1, 4, and 7, or exposed them to 100,000 mG, 50-Hz magnetic fields for 14 days (1 hour per day), or both. A control group was saline-treated, but not sham exposed to magnetic fields, and analyses were not reported to have been conducted in a blinded manner. Both magnetic-field exposure and cisplatin treatment, alone or in combination, were associated with reduced tumor volume; the strongest response was observed with the combination treatment. This response appeared to be associated with reduced cell proliferation, but also increased DNA damage (as assessed using the Comet and micronucleus assays). In another study (Mahna et al., 2014), female Balb/c mice were injected with spontaneous mouse mammary tumor cells, followed by exposure to 150,000 mG, 50-Hz magnetic fields for 10 minutes per day for 12 days. Other groups of animals were exposed to the magnetic field and also to electrochemotherapy, which is a combination of chemotherapy with pulsed electric current applied to the skin in an attempt to increase permeability of cancers cells to drugs, thus to increase the drugs' efficiency. A sham-exposed control group was included, but analyses were not reported to have been conducted in a blinded manner. Magnetic-field exposure alone or in combination with the other treatments was reported to reduce tumor volume. Although these studies suffer from various limitations, the results suggest that magnetic-field exposure may have therapeutic applications in the treatment of tumors. Field strengths, however, were relatively high in the studies, and it is possible that the observed response was due to an induced electric field.

Several recent studies examined the genotoxic potential of magnetic-field exposure. Miyakoshi et al. (2012) continuously exposed 3-day old rats to 100,000 mG, 50-Hz magnetic fields for 72 hours, treated them with 5 or 10 mg/kg bleomycin, or both; control animals were sham exposed (with the exposure system turned off). Brain astrocytes were then examined in culture for the presence of micronuclei. In other experiments, the animals were treated as just described, but also administered tempol, an antioxidant. Magnetic-field exposure alone or in combination with 5 mg/kg bleomycin appeared to have no effect on micronuclei formation, but was reported to increase the frequency of micronuclei resulting from co-treatment with 10 mg/kg bleomycin. Tempol co-exposure was reported to reduce micronuclei formation, suggesting a role for activated oxygen species in their formation. In a study by Villarini et al. (2013), male mice were exposed to 1,000 to 20,000 mG, 50-Hz magnetic fields for 7 days (15 hours per day), then sacrificed immediately after exposure or 24 hours later. The striatum, hippocampus, and cerebellum were evaluated for DNA damage using the Comet assay. Control mice were sham-exposed (with the exposure system turned off); mice exposed to whole-body X-irradiation served as DNA-damage positive controls. Further, the Comet assay data were evaluated in a blinded manner. Mice exposed to 10,000 or 20,000 mG, but not lower strength magnetic fields, showed evidence of DNA fragmentation in the brain tissues when sacrificed immediately following exposure. By 24 hours post-exposure, however, the levels of DNA fragmentation were back to baseline, indicating either that any associated DNA damage was reversible or that the fragmentation was an indicator of apoptosis, which disappeared as the apoptotic cells were removed during the 24-hour recovery period. Male mice were exposed to 2,000 mG, 50-Hz magnetic fields for 7, 14, 21, or 28 days in a study by Alcaraz et al. (2014). No sham-exposed controls were included. Mice exposed to 50 centi-Gray of X-rays were included as positive controls and analyses were conducted in a blinded manner. The authors reported an increase in micronuclei (i.e., small nucleus-like structures containing DNA indicative of a chromosomal break) in bone marrow erythrocytes 24 hours after magnetic-field exposure. The increase was not duration-dependent, however, and was substantially lower than that induced by X-irradiation.

Wilson et al. (2015) examined the effect of exposure to 100 mG, 1,000 mG, or 3,000 mG, 50-Hz magnetic fields for 2 or 15 hours on the gene mutation frequency in sperm and blood cells in mice. Sham-exposed mice were included as negative controls, while mice exposed to 1 Gray of X-irradiation were included as positive controls. Mutation frequencies in blood cells among magnetic-field exposed mice were similar to those of the negative controls at 12 weeks after exposure. Mutation frequencies in sperm cells were slightly, but significantly, increased among magnetic-field exposed mice, although not in a dose- response-related pattern. In contrast, X-irradiation significantly increased the mutation frequency in both cell types.

Saha et al. (2014) studied DNA double-strand breaks in the embryonic neuronal stem cell compartment of mouse embryos following exposure to 1,000 mG, 50-Hz magnetic fields for 2 hours on gestational day (GD) 13.5 or with continuous or intermittent exposure (5 minutes on, 10 minutes off) to a 3,000 mG magnetic field for 15 hours starting on GD 12.5. The study included sham-exposed controls as well as multiple positive control groups exposed to 10-200 milli-Gray of X-irradiation on GD 13.5. Using appropriate statistical methods to account for litter effects, Saha et al. (2014) reported no increase in double-strand breaks in DNA in the groups exposed to magnetic fields. In a follow-on study (Woodbine et al., 2015), the same group of researchers using the same experimental system then assessed whether concomitant exposure to magnetic fields and X-rays, which are known to alter the rate of repair of DNA double-strand breaks, would have an effect. The mouse embryos were exposed on GD 13.5 to 3,000 mG, 50-Hz for 3 hours before and up to 9 hours after exposure to 100 milli-Gray of X-rays. Controls were exposed to X-rays, but sham-exposed to magnetic fields. Additional controls included unexposed mice; X-ray-only exposed mice; magnetic-field-only, sham-exposed mice; and X-ray-only sham-exposed mice. Sham treatments had no effect on the number of DNA double-strand breaks observed. X-irradiation significantly increased the number of DNA double-strand breaks at 1 hour post-exposure; these decreased to control levels by 6 to 11 hours post-exposure as the DNA double-strand breaks were repaired. Magnetic-field exposure had no effect on the response observed following X-irradiation, indicating that magnetic fields did not affect the DNA repair process under the conditions of the study. The data from this study were assessed in a blinded manner and using the litter as the statistical unit of analysis; however, the number of maternal animals per group was relatively small (n=1-4/group).

Korr et al. (2014) continuously exposed mice for 8 weeks to 1,000 mG or 10,000 mG, 50-Hz magnetic fields. Controls were not sham-exposed, but maintained in the same room as the magnetic-field-exposed animals. At the end of the exposure period, the animals were injected with radiolabeled thymidine to look for DNA single-strand breaks and unscheduled DNA synthesis in the liver, kidneys, and brain using an autoradiographic method. A slight reduction in mitochondrial DNA synthesis was observed in the epithelial cells of the kidney collecting ducts at 1,000 mG, but no increase in DNA single-strand breaks was observed. At 10,000 mG, a slight reduction in unscheduled DNA synthesis (likely related to reduced mitochondrial DNA synthesis) was observed in the epithelial cells of the choroid plexus of the brain's fourth ventricle and the kidney collecting duct, but again, there was no difference in the degree of DNA single-strand breaks observed between treated and control animals. These investigations were conducted in a blinded manner.

Two recent studies examined DNA damage in human subjects exposed to EMF. Tiwari et al. (2015) investigated the level of DNA damage in the peripheral blood lymphocytes of 142 workers exposed to EMF; these subjects were employed for at least 2 years (and for a mean of 9 years) at a 132-kV high-voltage electrical substation in India. The exposed subjects were matched with a non-exposed group of 151 individuals of similar socioeconomic status. However, the authors did not report how the control subjects were identified. The analyses did not consider or control for the potential confounding effect of other occupational exposures that may be encountered in the workplace. DNA damage was assessed in both sample populations using the alkaline Comet assay and coded examination of slides; other parameters related to plasma epinephrine concentrations, lipid peroxidation, and nitric oxide expression levels were also assessed. Although the Comet tail length exhibited a slightly larger range in the exposed group than in the non-exposed group, there was no significant difference between the two groups in the degree of DNA damage observed.

In another study of human subjects (Villarini et al., 2015), DNA damage was again assessed using the alkaline Comet assay, but the evaluation extended to three different parameters related to DNA damage. The exposed group included 21 electric arc welders exposed to EMF as well as various metal fumes as a result of their occupation. The control group included 21 non-exposed individuals of similar age, residence, and smoking status. Magnetic-field exposure was measured in the exposed individuals using personal dosimeters that were worn for a single work shift and found to average 78 mG; magnetic-field exposure was not assessed in the non-exposed controls. Comet tail length was similar in both the welders and controls; however, the welders exhibited significantly lower tail intensity and tail moment values than did controls, suggesting that they had a lower degree of DNA damage than the controls. The authors suggested that this unexpected finding may be related to the type of DNA damage that might occur. Welders are exposed to various metal fumes, including chromium and nickel, both of which are able to induce DNA-protein cross-links. The DNA-protein cross-links might reduce the amount of DNA available to migrate as the tail in a Comet assay, thereby resulting in reduced Comet tail parameters.

A well-designed double-blind study (Kirschenlohr et al., 2012) examined gene expression in the white blood cells of 17 pairs of human subjects following exposure to a 620 mG, 50-Hz magnetic field on four different days (2 hours per day) over 2 weeks. On each exposure day, one member of each pair was exposed to the magnetic field and the other either exposed to sham conditions (with the current passing through the two coils of the exposure apparatus in opposing directions so that the magnetic field was cancelled, but the total current remained the same) or not exposed. On the next day, the exposures were reversed (the previously exposed subject was sham exposed or not exposed, and vice-versa). Blood samples were collected just prior to and following exposures, as well as at multiple times throughout the exposure period. Gene expression in one set of the collected blood samples (collected in week 1) was determined via microarray analysis with an emphasis on genes previously reported to respond to EMF exposure (i.e., immediate early genes involved in stress, inflammatory, and proliferative and apoptotic responses). The samples collected just prior to exposure were used as reference samples. Any indications of a possible positive finding were verified using the second set of collected blood samples. Based on their analyses, the study investigators reported that no genes showed a consistent response to magnetic-field exposure.

In a similarly well-conducted study, Kabacik et al. (2013) looked for changes in the expression of genes in the bone marrow of juvenile mice exposed to a 1,000 mG, 50-Hz magnetic field for 2 hours. The premise for conducting this research was that many types of leukemia are derived from cells in the bone marrow; thus, changes in gene expression in the bone marrow may relate to the development of these cancers. Control mice were sham-exposed and the experiment repeated in multiple groups of exposed and unexposed mice. In order to confirm consistent changes with exposure, gene expression in these replicate samples was analyzed in a blinded manner using multiple methods and in different laboratories. Again, no consistent changes in gene expression in response to magnetic-field exposure were found.

Assessment

A single new animal bioassay of long-term magnetic-field exposure as a possible carcinogen has been conducted since the last update. This study reported increased chronic myeloid leukemia in female, but not male mice, exposed to magnetic fields from prior to birth through 15.5 months of age—a finding that conflicts with those of the other large-scale rodent bioassays reviewed by the WHO in 2007. Further, the new bioassay suffers from substantial methodological and reporting flaws which affect its weight in the overall assessment.

In addition to this study, various shorter-term studies have been conducted to investigate the potential genotoxicity of magnetic-field exposure and its possible effects on gene expression in cells associated with cancer in humans. Many of these studies suffer from various methodological deficiencies, including small samples sizes, the absence of sham-exposure treatment groups, and analyses that were not conducted in a blinded manner. Further, consistency across the body of studies is commonly lacking in terms of the exposures applied, the cell types assessed, and the specific parameters evaluated. These studies do not change the WHO's conclusion that the overall evidence from *in vivo* studies does not support a role of EMF exposures in direct genotoxic effects.

Two particularly well-conducted studies evaluated potential differences in gene expression resulting from magnetic-field exposure. These studies employed sham exposures, replicate samples, and blinded analyses using multiple experimental methods of measuring gene expression in multiple laboratories; they also took into consideration the potential statistical power of the studies. Neither of these studies reported consistent changes in gene expression due to magnetic-field exposure.

Two studies looked at the possible anti-carcinogenic therapeutic potential associated with high magnetic-field strengths, an area for which more research is still warranted to address the influence of potential confounding variables on observed outcomes. Overall, the *in vivo* studies published since the last update do not alter the previous conclusion that there is inadequate evidence of carcinogenicity due to ELF EMF exposure.

Table 8. Relevant *in vivo* studies related to carcinogenesis

Authors	Year	Study
Alcaraz et al.	2014	Effect of long-term 50 Hz magnetic field exposure on the micronucleated polychromatic erythrocytes of mice.
El-Bialy and Rageh	2013	Extremely low-frequency magnetic field enhances the therapeutic efficacy of low-dose cisplatin in the treatment of Ehrlich carcinoma
Fedrowitz and Löscher	2012	Gene expression in the mammary gland tissue of female Fischer 344 and Lewis rats after magnetic field exposure (50 Hz, 100 µT) for 2 weeks
Fedrowitz et al.	2012	Effects of 50 Hz magnetic field exposure on the stress marker α-amylase in the rat mammary gland
Kabacik et al.	2013	Investigation of transcriptional responses of juvenile mouse bone marrow to power frequency magnetic fields
Korr et al.	2014	No evidence of persisting unrepaired nuclear DNA single strand breaks in distinct types of cells in the brain, kidney, and liver of adult mice after continuous eight-week 50 Hz magnetic field exposure with flux density of 0.1 mT or 1.0 mT
Mahna et al.	2014	The effect of ELF magnetic field on tumor growth after electrochemotherapy.
Miyakoshi et al.	2012	Tempol suppresses micronuclei formation in astrocytes of newborn rats exposed to 50-Hz, 10-mT electromagnetic fields under bleomycin administration
Qi et al.	2015	Effects of extremely low-frequency electromagnetic fields (ELF-EMF) exposure on B6C3F1 mice
Saha et al.	2014	Increased apoptosis and DNA double-strand breaks in the embryonic mouse brain in response to very low-dose X-rays but not 50 Hz magnetic fields.
Tiwari et al.	2015	Epinephrine, DNA integrity and oxidative stress in workers exposed to extremely low-frequency electromagnetic fields (ELF-EMFs) at 132 kV substations
Villarini et al.	2013	Brain hsp70 expression and DNA damage in mice exposed to extremely low frequency magnetic fields: Adose-response study
Wilson et al.	2015	The effects of extremely low frequency magnetic fields on mutation induction in mice.
Woodbine et al.	2015	The rate of X-ray-induced DNA double-strand break repair in the embryonic mouse brain is unaffected by exposure to 50 Hz magnetic fields

Reproductive/developmental effects

Over a decade ago, two studies received considerable attention because of a reported association between peak magnetic-field exposure greater than approximately 16 mG and miscarriage: a prospective cohort study of women in early pregnancy (Li et al., 2002) and a nested case-control study of women who miscarried compared to their late-pregnancy counterparts (Lee et al., 2002).

These two studies improved on the existing body of literature because average exposure was assessed using 24-hour personal magnetic-field measurements (earlier studies on miscarriage were limited because they used surrogate measures of exposure, including visual display terminal use, electric blanket use, or wire code data). The Li et al. study was criticized by the NRPB *inter alia* because of the potential for selection bias, a low compliance rate, measurement of exposure after miscarriages, and the selection of exposure categories after inspection of the data (NRPB, 2002).

Following the publication of these two studies, however, a hypothesis was put forth that the observed association may be the result of behavioral differences between women with healthy pregnancies that went to term (i.e., less physically active) and women who miscarried (i.e., more physically active) (Savitz, 2002). It was proposed that physical activity is associated with an increased opportunity for peak magnetic-field exposure, and the nausea experienced in early, healthy pregnancies and the cumbersomeness of late, healthy pregnancies would reduce physical activity levels, thereby decreasing the opportunity for exposure to peak magnetic fields. This hypothesis received empirical support from studies that reported consistent associations between activity (mobility during the day) and various metrics of measures of peak magnetic-field exposure (Mezei et al., 2006; Savitz et al., 2006; Lewis et al., 2015). These findings suggest that the association between maximum magnetic-field exposure and miscarriage is due to differing activity patterns of the cases and controls, not to an effect of the magnetic field on embryonic development and viability. Furthermore, nearly half of women who had miscarriages reported in the cohort by Li et al. (2002) had magnetic-field measurements taken after miscarriage occurred, when changes in physical activity may have already occurred, and all measurements in Lee et al. (2002) occurred post-miscarriage.

The scientific panels that have considered these two studies concluded that the possibility of this bias precludes making any conclusions about the effect of magnetic fields on miscarriage (NRPB, 2004; FPTRPC, 2005; WHO, 2007). The WHO concluded, “There is some evidence for increased risk of miscarriage associated with measured maternal magnetic-field exposure, but this evidence is inadequate” (WHO, 2007, p. 254) and recommended further epidemiologic research.

Recent studies (2012-2015)

Three epidemiologic studies investigated the relationship between ELF magnetic-field exposure and miscarriage or stillbirth. A study in China (Wang et al., 2013), identified 413 pregnant women at 8 weeks of gestation between 2010 and 2012. The researchers measured magnetic-field levels at the front door and the alley in front of the participants’ homes. No statistically significant association was seen with average exposure at the front door, but the authors reported an association with maximum magnetic-field values measured in the alleys in front of the homes. Magnetic-field levels measured at the front door are very poor predictors of home and personal exposure, thus the study provides only a limited contribution to current knowledge.

A study from Iran (Shamsi Mahmoudabadi et al., 2013) reported results of a hospital-based case-control study that included 58 women with spontaneous abortion and 58 pregnant women. The measured magnetic-field levels reported a statistically significant increase among the cases compared to controls. The study provides little weight to an overall assessment, however, due to limited information provided on subject recruitment, exposure assessment, type of metric used and potential confounders, and the small number of subjects.

A Canadian study (Auger et al., 2012) investigated the association between stillbirth and residential proximity to power lines. The authors identified over 500,000 births and 2,033 stillbirths in Québec and determined distance between postal code at birth address and the closest power line. No consistent association or trend was reported between stillbirth and residential distance. Reliance on distance to power lines and using the postal code for address information is a major limitation of the study’s exposure assessment.

Two studies examined various birth outcomes in relation to ELF EMF exposure. A study from the United Kingdom investigated birth outcomes in relation to residential proximity to power lines during pregnancy between 2004 and 2008 in Northwest England (de Vocht et al., 2014). The researchers examined hospital records of over 140,000 births and distance to the nearest power lines were determined using geographical information systems. The authors reported moderately lower birth weight within 50 meters of power lines, but observed no statistically significant increase in risk of any adverse clinical birth outcomes (such as preterm birth, small for gestational age, or low birth weight). The limitations of the study include its reliance on distance for exposure assessment and the potential for confounding by socioeconomic status as also discussed by the authors. A follow-up analysis of the same data suggested that the observed association in the de Vocht et al. (2014) study, at least partially, could be due to confounding and missing data (de Vocht and Lee, 2014).

A study from Iran reported no association between ELF EMF and pregnancy and developmental outcomes, such as duration of pregnancy, birth weight and length, head circumference, and congenital malformations (Mahram and Ghazavi, 2013). The study, however, provided little information on subject selection and recruitment, thus it is difficult to assess its quality.

An Italian study reported that blood melatonin levels showed a statistically significant increase among 28 newborns 48 hours after being taken from incubators with assumed elevated ELF EMF exposure, but not among 28 control newborns who were not in incubators (Bellieni et al., 2012). Neither the before nor the after values were statistically different from each other in the two groups (incubator vs. control), however, thus the clinical significance of the findings, if any, is unclear.

A cross-sectional study conducted in China examined correlations between magnetic-field exposure and embryonic development (Su et al., 2014). The study population was comprised of 149 pregnant women who were seeking induced termination of pregnancy during the first trimester. Exposure to EMF was assessed using personal 24-hour measurements within four weeks of the termination. Embryonic bud and sac lengths were determined by ultrasound prior to the termination. Since exposure to magnetic fields was measured following the termination of the pregnancy, the examiner completing the ultrasound examination could not be aware of the measured field levels. An association between maternal daily magnetic-field exposure and embryonic bud length was reported. The study provides little, if any weight in a weight-of-evidence assessment due to its severe limitations, the most important of which are the cross-sectional design of the study and the lack of consideration of gestational age, which is a major determinant of embryonic bud length.

Assessment

The recent epidemiologic studies on pregnancy and reproductive outcomes provided little new insight in this research area and do not change the classification of the data from earlier assessments as inadequate. The recent review by (SCENIHR, 2015) concluded that "recent results do not show an effect of ELF MF [magnetic field] exposure on reproductive function in humans."

Table 9. Relevant studies of reproductive and developmental effects

Authors	Year	Study
Auger et al.	2012	Stillbirth and residential proximity to extremely low frequency power transmission lines: a retrospective cohort study
Bellieni et al.	2012	Is newborn melatonin production influenced by magnetic fields produced by incubators?
de Vocht and Lee	2014	Residential proximity to electromagnetic field sources and birth weight: Minimizing residual confounding using multiple imputation and propensity score matching
de Vocht et al.	2014	Maternal residential proximity to sources of extremely low frequency electromagnetic fields and adverse birth outcomes in a UK cohort
Mahram and Ghazavi	2013	The effect of extremely low frequency electromagnetic fields on pregnancy and fetal growth, and development
Shamsi Mahmoudabadi et al.	2013	Exposure to Extremely Low Frequency Electromagnetic Fields during Pregnancy and the Risk of Spontaneous Abortion: A Case-Control Study
Su et al.	2014	Correlation between exposure to magnetic fields and embryonic development in the first trimester
Wang et al.	2013	Residential exposure to 50 Hz magnetic fields and the association with miscarriage risk: a 2-year prospective cohort study

Neurodegenerative diseases

The WHO panel concluded that there is inadequate data in support of an association between magnetic fields and Alzheimer's disease or ALS. The panel recommended more research in this area using better methods; in particular, studies that enrolled incident Alzheimer's disease cases (rather than ascertaining cases from death certificates) and studies that estimated electrical shock history in ALS cases were recommended. Specifically, the WHO concluded, "When evaluated across all the studies, there is only very limited evidence of an association between estimated ELF exposure and [Alzheimer's] disease risk" (WHO, 2007, p. 194) and "overall, the evidence for an association between ELF exposure and ALS is considered inadequate" (WHO, 2007, p. 206).

Recent studies (2012 – 2015)

A population-based case-control study (Frei et al., 2013) examined the relationship between residential distance to power lines and neurodegenerative diseases covering the entire population of Denmark between 1994 and 2010. Distance from the nearest power line to the residential address for all newly-reported cases and matched controls were determined using geographical information systems. Overall, none of the investigated diseases, including Alzheimer disease and other types of dementia, ALS, Parkinson's disease, or multiple sclerosis was related to residential proximity to power lines. The inclusion of newly-diagnosed cases from hospital discharge records represents a significant methodological improvement over mortality studies. The study, however, was limited by the methods used for the exposure assessment.

Seelen et al. (2014) conducted a population-based case-control study including 1,139 ALS cases diagnosed in the Netherlands between 2006 and 2013 and 2,864 frequency-matched controls. Case and control addresses were geocoded and the shortest distance to the nearest high-voltage power line (50 – 380 kV) was determined. No statistically significant associations were reported for ALS with residential proximity to power lines with any of the included voltages. A combined analysis of the current results with two previously published studies (Marcilio et al., 2011; Frei et al., 2013) resulted in an overall OR of 0.9 (95% CI 0.7-1.1) for living within 200 meters of a high-voltage power line. Reconstruction of lifetime residential history represents a methodological improvement of the current study. The main limitation, similarly to previous power-line studies, is the use of distance to power lines as a surrogate for magnetic-field exposure.

Data from the Swiss National Cohort study was used to examine the relationship between occupational exposure to EMF and electric shocks and ALS mortality from 2000 to 2008 (Huss et al., 2014). Occupations reported at the 1990 and 2000 censuses along with job-exposure matrices were used to estimate exposure. A total of 2.2 million subjects were included in the analyses with available data from both censuses. Among these, 278 cases of ALS were identified. The authors reported an association with medium and high estimates of ELF EMF exposure, but not with estimates of exposure to electric shocks. Yu et al. (2014) reported results of a small case-control study of ALS, including 66 cases and 66 controls, examining various lifestyle, environmental, and work-related variables as potential risk factors. Their results on occupational exposure to EMF, however, cannot be interpreted because of a severe error of combining estimates of ionizing and non-ionizing radiation exposures in their analysis.

In a study of 3,050 Mexican Americans, aged 65+, enrolled in Phase I of the Hispanic Established Population for the Epidemiologic Study of the Elderly study, the association between severe cognitive dysfunction and occupational ELF magnetic-field exposure was examined (Davanipour et al., 2014). Information on occupational history, and socio-demographic variables were obtained by in-person interviews. Occupational exposure to magnetic fields was classified as low, medium, and high. The mini-mental state exam was used to evaluate cognitive function. Cognitive dysfunction was defined as an exam score below 10. The study is a cross-sectional survey, even though the authors describe it as a population-based case-control study. The authors report a statistically significant association between estimated occupational magnetic-field exposure and severe cognitive dysfunction. The reported association is, however, difficult to interpret due to the number of severe limitations of the study; including the cross-sectional design, the lack of clear clinical diagnosis for case-definition, and the rudimentary assessment of exposure to occupational EMF.

Koeman et al. (2015) analyzed data from the Netherlands Cohort Study, a longitudinal follow-up study of approximately 120,000 men and women enrolled in 1986, to study the relationship between various occupational exposures and non-vascular dementia. Between 1986 and 2003, 798 male and 1,171 female cases were identified. Lifetime occupational history was obtained by questionnaire. Based on occupational titles and with the use of various job-exposure matrices, occupational exposures to solvents, pesticides, metals, ELF magnetic fields, electric shocks, and diesel exhaust were assessed. No association was reported for exposure to electric shocks. The authors reported moderate, but statistically non-significant, associations for the highest estimates of exposures to metals, chlorinated solvents, and ELF magnetic fields. The association for ELF fields, however, showed no exposure-response relationship based on cumulative exposure and the authors concluded that the association observed for ELF magnetic fields and solvents might be attributable to confounding by exposure to metals.

Brouwer et al. (2015) identified cases of Parkinson's disease between 1986 and 2003 in a cohort of approximately 120,000 adults (i.e., the Netherlands Cohort Study, noted above). They assessed occupational exposure to EMF and electric shocks among the study subjects using job-exposure matrices. Based on a total of 609 cases of Parkinson's disease, the authors concluded that their results generally do not provide strong support for an association with EMF or electric shocks. A hospital-based case-control study in the Netherlands included 444 cases of Parkinson's disease and 876 matched controls (van der Mark et al., 2014). Occupational exposure to EMF and electric shocks was assessed using work history and a job-exposure matrix. No associations were reported between any of the exposure metrics and Parkinson's disease.

Weak to no evidence of an association was presented in recent meta-analyses of occupational exposure to ELF magnetic fields and neurodegenerative disease (Zhou et al., 2012; Vergara et al., 2013; Capozzella et al., 2014; Huss et al., 2015); hence, the authors concluded that potential within-study biases, evidence of publication bias, and uncertainties in the various exposure assessments greatly limit the ability to infer an association, if any, between occupational exposure to magnetic fields and neurodegenerative disease. In sum, these recent meta-analyses provide no convincing evidence of a relationship between ELF magnetic fields and neurodegenerative disease.

It has been previously suggested that the weak and inconsistent association between ELF EMF and ALS might be explained by electric shocks in occupational environments. Several recent studies, however, addressed the issue of the potential role of electric shocks in the development of neurodegenerative and neurological diseases, but none of them presented convincing evidence for an association (Das et al., 2012; Grell et al., 2012; Vergara et al., 2015; van der Mark et al., 2014).

Assessment

The recent studies continue to be limited by uncertainties about the estimates of magnetic-field exposure. Further research in this area will be needed to address the limitations of research to date on neurodegenerative disease. The most recent SCENIHR report (2015) concluded that newly published studies "do not provide convincing evidence of an increased risk of neurodegenerative diseases, including dementia, related to ELF MF [magnetic field] exposure" (SCENIHR, 2015, p. 186).

Table 10. Relevant studies of neurodegenerative disease

Authors	Year	Study
Brouwer et al	2015	Occupational exposures and Parkinson's disease mortality in a prospective Dutch cohort
Capozella et al.	2014	Work related etiology of amyotrophic lateral sclerosis (ALS): a meta-analysis
Das et al.	2012	Familial, environmental, and occupational risk factors in development of amyotrophic lateral sclerosis
Davanipour	2014	Severe cognitive dysfunction and occupational extremely low frequency magnetic field exposure among elderly Mexican Americans
Frei et al.	2013	Residential distance to high-voltage power lines and risk of neurodegenerative diseases: a Danish population-based case-control study
Huss et al.	2014	Occupational exposure to magnetic fields and electric shocks and risk of ALS: The Swiss National Cohort
Huss et al.	2015	Extremely Low Frequency Magnetic Field Exposure and Parkinson's Disease--A Systematic Review and Meta-Analysis of the Data
Grell et al.	2012	Risk of neurological diseases among survivors of electric shocks: a nationwide cohort study, Denmark, 1968-2008
Koeman et al.	2015	Occupational exposures and risk of dementia-related mortality in the prospective Netherlands Cohort Study
Seelen et al.	2014	Residential exposure to extremely low frequency electromagnetic fields and the risk of ALS
Van der Mark et al.	2014	Extremely low-frequency magnetic field exposure, electrical shocks and risk of Parkinson's disease
Vergara et al.	2013	Occupational exposure to extremely low-frequency magnetic fields and neurodegenerative disease: A meta-analysis
Yu et al.	2014	Environmental risk factors and amyotrophic lateral sclerosis (ALS): a case-control study of ALS in Michigan
Zhou et al.	2012	Association between extremely low-frequency electromagnetic fields occupations and amyotrophic lateral sclerosis: A meta-analysis

Cardiovascular disease

It has been hypothesized that magnetic-field exposure reduces heart rate variability, which in turn is a marker of increased susceptibility for AMI. In a large cohort of utility workers, Savitz et al. (1999) reported an increased risk of arrhythmia-related deaths and deaths due to AMI. Previous and subsequent studies did not report a statistically significant increase in cardiovascular disease mortality or incidence related to occupational magnetic-field exposure (WHO, 2007). The WHO concluded, “Overall, the evidence does not support an association between ELF exposure and cardiovascular disease” (WHO, 2007, p. 220).

Recent studies (2012 – 2015)

One study from the Netherlands evaluated the relationship between occupational exposure to ELF EMF and cardiovascular disease mortality (Koeman et al., 2013). The study identified more than 8,000 cardiovascular deaths among the more than 120,000 men and women in the Netherlands Cohort Study during a 10-year period. Occupational exposure was determined by linking occupational histories to an ELF-magnetic-field job-exposure matrix. The authors reported no association between cumulative occupational ELF-magnetic-field exposure and cardiovascular mortality or death due to any of the subtypes of cardiovascular disease. The authors concluded that their results add “to the combined evidence that exposure to ELF-MF [magnetic fields] does not increase the risk of death from CVD [cardiovascular disease]” (Koeman et al., 2013, p. 402).

Assessment

The recent study reported no association between ELF magnetic fields and cardiovascular disease, thus confirming earlier conclusions about the lack of an association between magnetic fields and cardiovascular disease.

Table 11. Relevant studies of cardiovascular disease

Authors	Year	Study Title
Koeman et al.	2013	Occupational exposure to extremely low-frequency magnetic fields and cardiovascular disease mortality in a prospective cohort study

6 Reviews by Scientific Organizations

Several reports with regard to the possible health effects of ELF EMF have been published by national and international scientific organizations since 2012 (NZMH, 2015; SCENIHR, 2015; SSM, 2013, 2014, 2015). Although none of these documents represents a cumulative weight-of-evidence review of the depth of the WHO review published in June 2007, their conclusions are of relevance. In general, the conclusions of these reviews are consistent with the scientific consensus articulated in Sections 4 and 5. The most comprehensive recent scientific review was published by SCENIHR in 2015, which updated the previous report on potential health effects of EMF issued by the same committee in 2009 (SCENIHR, 2009). The conclusions of the 2015 SCENIHR review are consistent with earlier comprehensive reviews, most notably the WHO review discussed in detail above. SCENIHR (2015) did not conclude that the available scientific evidence confirms a causal link between any adverse health effects (including both cancer and non-cancer health outcomes) and EMF exposure. With respect to epidemiologic results of childhood leukemia, the review concludes that: "… no mechanisms have been identified and no support is existing [*sic*] from experimental studies that could explain these findings, which, together with shortcomings of the epidemiological studies prevent a causal interpretation" (SCENIHR, 2015, p. 7).

The WHO and other scientific organizations have not found any *consistent* associations with regard to ELF EMF exposure and any type of cancer or disease, except childhood leukemia, nor have they concluded that there is a cause-and-effect link with any health effect, including childhood leukemia (WHO, 2007; SCENIHR, 2009, 2015; EFHRAN, 2010, 2012; ICNIRP, 2010; SSM, 2010; NZMH, 2015).

In summary, over the past decades, reviews published by scientific organizations using weight-of-evidence methods have concluded that the cumulative body of research to date does not support the hypothesis that ELF EMF causes any long-term adverse health effects at the levels we encounter in our everyday environments. An evaluation of current research does not point to better quality or stronger evidence that is sufficient to change the conclusions of these assessments.

7 Summary

A number of epidemiologic and *in vivo* studies have been published on EMF and health since Exponent's 2012 update to the WHO report. The weak statistical association between high, average magnetic fields and childhood leukemia remains largely unexplained and unsupported by the experimental studies. The recent *in vivo* studies confirm the lack of experimental data supporting a leukemogenic risk associated with magnetic-field exposure or other effects on health.

Overall, the current body of research supports the conclusion that there is no association between magnetic fields and adult cancer or cardiovascular disease, although future research is needed to improve methods to estimate exposure. Recent literature does not confirm an earlier suggestion that there is an association between magnetic fields and Alzheimer's disease.

In conclusion, no recent studies provide evidence to alter the conclusion that the scientific evidence does not confirm that ELF EMF exposure is the cause of cancer or any other disease process at the levels we encounter in our everyday environment.

8 References

Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M, McBride M, Michaelis J, Olsen JH, Tynes T, Verkasalo PK. A pooled analysis of magnetic fields and childhood leukaemia. Br J Cancer 83: 692-698, 2000.

Alcaraz M, Olmos E, Alcaraz-Saura M, Achel DG, Castillo J. Effect of long-term 50 Hz magnetic field exposure on the micronucleated polychromatic erythrocytes of mice. Electromagn Biol Med 33: 51-57, 2014.

Anderson LE, Boorman GA, Morris JE, Sasser LB, Mann PC, Grumbein SL, Hailey JR, McNally A, Sills RC, Haseman JK. Effect of 13 week magnetic field exposures on DMBA-initiated mammary gland carcinomas in female Sprague-Dawley rats. Carcinogenesis 20: 1615-1620, 1999.

Auger N, Park AL, Yacouba S, Goneau M, Zayed J. Stillbirth and residential proximity to extremely low frequency power transmission lines: a retrospective cohort study. Occup Environ Med 69: 147-149, 2012.

Baum A, Mevissen M, Kamino K, Mohr U, Löscher W. A histopathological study on alterations in DMBA-induced mammary carcinogenesis in rats with 50 Hz, 100 muT magnetic field exposure. Carcinogenesis 16: 119-125, 1995.

Bellieni CV, Tei M, Iacoponi F, Tataranno ML, Negro S, Proietti F, Longini M, Perrone S, Buonocore G. Is newborn melatonin production influenced by magnetic fields produced by incubators? Early Hum Dev 88: 707-710, 2012.

Belson M, Kingsley B, Holmes A. Risk factors for acute leukemia in children: a review. Environ Health Perspect 115: 138-145, 2007.

Bonnet-Belfais M, Lambrozo J, Aurengo A. Comment: childhood leukaemia and power lines--the Geocap study: is proximity an appropriate MF exposure surrogate? Br J Cancer 109: 1382-1383, 2013.

Boorman GA, Anderson LE, Morris JE, Sasser LB, Mann PC, Grumbein SL, Hailey JR, McNally A, Sills RC, Haseman JK. Effect of 26 week magnetic field exposures in a DMBA initiation-promotion mammary gland model in Sprague-Dawley rats. Carcinogenesis 20: 899-904, 1999a.

Boorman GA, McCormick DL, Findlay JC, Hailey JR, Gauger JR, Johnson TR, Kovatch RM, Sills RC, Haseman JK. Chronic toxicity/oncogenicity evaluation of 60 Hz (power frequency) magnetic fields in F344/N rats. Toxicol Pathol 27: 267-278, 1999b.

Brouwer M, Koeman T, van den Brandt PA, Kromhout H, Schouten LJ, Peters S, Huss A, Vermeulen R. Occupational exposures and Parkinson's disease mortality in a prospective Dutch cohort. Occup Environ Med 72: 448-455, 2015.

Bunch KJ, Keegan TJ, Swanson J, Vincent TJ, Murphy MF. Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008. Br J Cancer 110: 1402-1408, 2014.

Bunch KJ, Swanson J, Vincent TJ, Murphy MF. Magnetic fields and childhood cancer: an epidemiological investigation of the effects of high-voltage underground cables. J Radiol Prot 35: 695-705, 2015.

Capozzella A, Sacco C, Chighine A, Loreti B, Scala B, Casale T, Sinibaldi F, Tomei G, Giubilati R, Tomei F, Rosati MV. Work related etiology of amyotrophic lateral sclerosis (ALS): a meta-analysis. Ann Ig 26: 456-472, 2014.

Chang ET, Adami HO, Bailey WH, Boffetta P, Krieger RI, Moolgavkar SH, Mandel JS. Validity of geographically modeled environmental exposure estimates. Crit Rev Toxicol 44: 450-466, 2014.

Chen Q, Lang L, Wu W, Xu G, Zhang X, Li T, Huang H. A meta-analysis on the relationship between exposure to ELF-EMFs and the risk of female breast cancer. PLoS One 8: e69272, 2013.

Clavel J, Sermage-Faure C, Demoury C, Rudant J, Goujon-Bellec S, Guyot-Goubin A, Deschamps F, Hemon D. Reply: comment on 'Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007'--is proximity an appropriate MF exposure surrogate? Br J Cancer 109: 1383-1384, 2013.

Connecticut Siting Council (CSC). Electric and Magnetic Fields Best Mangement Practices for the Construction of Transmission Lines in Connecticut. New Britain, CT: Connecticut Siting Council, December 14, 2007.

Connecticut Siting Council (CSC). Electric and Magnetic Fields Best Mangement Practices for the Construction of Transmission Lines in Connecticut (Revised February 20, 2014). New Britain, CT: Connecticut Siting Council, 2014.

Contessa GM, Falsaperla R, Brugaletta V, Rossi P. Exposure to magnetic fields of railway engine drivers: a case study in Italy. Radiat Prot Dosimetry 142: 160-167, 2010.

Das K, Nag C, Ghosh M. Familial, environmental, and occupational risk factors in development of amyotrophic lateral sclerosis. N Am J Med Sci 4: 350-355, 2012.

Davanipour Z, Tseng CC, Lee PJ, Markides KS, Sobel E. Severe cognitive dysfunction and occupational extremely low frequency magnetic field exposure among elderly Mexican Americans. Br J Med Med Res 4: 1641-1662, 2014.

de Vocht F. Adult cancers near high-voltage power lines. Epidemiology 24: 782, 2013.

de Vocht F, Hannam K, Baker P, Agius R. Maternal residential proximity to sources of extremely low frequency electromagnetic fields and adverse birth outcomes in a UK cohort. Bioelectromagnetics 35: 201-209, 2014.

de Vocht F and Lee B. Residential proximity to electromagnetic field sources and birth weight: Minimizing residual confounding using multiple imputation and propensity score matching. Environ Int 69: 51-57, 2014.

Draper G, Vincent T, Kroll ME, Swanson J. Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study. BMJ 330: 1290, 2005.

Eden T. Aetiology of childhood leukaemia. Cancer Treat Rev 36: 286-297, 2010.

El-Bialy NS and Rageh MM. Extremely low-frequency magnetic field enhances the therapeutic efficacy of low-dose cisplatin in the treatment of Ehrlich carcinoma. Biomed Res Int 2013: 189352, 2013.

Elliott P, Shaddick G, Douglass M, de Hoogh K, Briggs DJ, Toledano MB. Adult cancers near high-voltage overhead power lines. Epidemiology 24: 184-190, 2013.

European Health Risk Assessment Network on Electromagnetic Fields Exposure (EFHRAN). Report on the Analysis of Risks Associated to Exposure to EMF: *In Vitro* and *In Vivo* (Animals) Studies. Milan, Italy: European Health Risk Assessment Network on Electromagnetic Fields Exposure, 2010.

European Health Risk Assessment Network on Electromagnetic Fields Exposure (EFHRAN). Risk Analysis of Human Exposure to Electromagnetic Fields (Revised). Report D2 of the EFHRAN Project. Milan, Italy: European Health Risk Assessment Network on Electromagnetic Fields Exposure, 2012.

Federal-Provincial-Territorial Radiation Protection Committee (FPTRPC). Health Effects and Exposure Guidelines Related to Extremely Low Frequency Electric and Magnetic Fields - An Overview. Ottawa: Health Canada, 2005.

Fedrowitz M, Kamino K, Löscher W. Significant differences in the effects of magnetic field exposure on 7,12-dimethylbenz(a)anthracene-induced mammary carcinogenesis in two substrains of Sprague-Dawley rats. Cancer Res 64: 243-251, 2004.

Fedrowitz M and Löscher W. Gene expression in the mammary gland tissue of female Fischer 344 and Lewis rats after magnetic field exposure (50 Hz, 100 muT) for 2 weeks. Int J Radiat Biol 88: 425-429, 2012.

Fedrowitz M, Hass R, Löscher W. Effects of 50 Hz magnetic field exposure on the stress marker alpha-amylase in the rat mammary gland. Int J Radiat Biol 88: 556-564, 2012.

Feychting M. Invited commentary: extremely low-frequency magnetic fields and breast cancer--now it is enough! Am J Epidemiol 178: 1046-1050, 2013.

Foliart DE, Pollock BH, Mezei G, Iriye R, Silva JM, Ebi KL, Kheifets L, Link MP, Kavet R. Magnetic field exposure and long-term survival among children with leukaemia. Br J Cancer 94: 161-164, 2006.

Frei P, Poulsen AH, Mezei G, Pedersen C, Cronberg Salem L, Johansen C, Röösli M, Schüz J. Residential distance to high-voltage power lines and risk of neurodegenerative diseases: a Danish population-based case-control study. Am J Epidemiol 177: 970-978, 2013.

Gobba F, Bravo G, Rossi P, Contessa GM, Scaringi M. Occupational and environmental exposure to extremely low frequency-magnetic fields: a personal monitoring study in a large group of workers in Italy. J Expo Sci Environ Epidemiol 21: 634-645, 2011

Gordis L. Epidemiology. Philadelphia: WB Saunders Company, 2000.

Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Childhood Leukemia-EMF Study Group. Epidemiology 11: 624-634, 2000.

Grell K, Meersohn A, Schüz J, Johansen C. Risk of neurological diseases among survivors of electric shocks: a nationwide cohort study, Denmark, 1968-2008. Bioelectromagnetics 33: 459-465, 2012.

Grellier J, Ravazzani P, Cardis E. Potential health impacts of residential exposures to extremely low frequency magnetic fields in Europe. Environ Int 62: 55-63, 2014.

Harris AW, Basten A, Gebski V, Noonan D, Finnie J, Bath ML, Bangay MJ, Repacholi MH. A test of lymphoma induction by long-term exposure of E mu-Pim1 trangenic mice to 50 Hz magnetic fields. Radiat Res 149: 300-307, 1998.

Health Council of the Netherlands (HCN). Electromagnetic Fields: Annual Update 2005. Publication No. 2005/14. The Hague: Health Council of the Netherlands, 2005.

Hill AB. The Environment and Disease: Association or Causation? Proc R Soc Med 58: 295-300, 1965.

Huang SM, Lin YW, Sung FC, Li CY, Chang MF, Chen PC. Occupational exposure of dentists to extremely-low-frequency magnetic field. J Occup Health 53: 130-136, 2011.

Huss A, Spoerri A, Egger M, Kromhout H, Vermeulen R, for The Swiss National Cohort. Occupational exposure to magnetic fields and electric shocks and risk of ALS: The Swiss National Cohort. Amyotroph Lateral Scler Frontotemporal Degener1-6, 2014.

Huss A, Koeman T, Kromhout H, Vermeulen R. Extremely Low Frequency Magnetic Field Exposure and Parkinson's Disease--A Systematic Review and Meta-Analysis of the Data. Int J Environ Res Public Health 12: 7348-7356, 2015.

International Agency for Research on Cancer (IARC). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 80: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. Lyon, France: IARC Press, 2002.

International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz).

Health Phys 74: 494-522, 1998.

International Commission on Non-ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys 99: 818-836, 2010.

International Committee on Electromagnetic Safety (ICES). IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz. Piscataway, NJ: IEEE, 2002.

Jeffers D. Comment on 'Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008'. Br J Cancer 111: 2199-2200, 2014.

Jirik V, Pekarek L, Janout V, Tomaskova H. Association between childhood leukaemia and exposure to power-frequency magnetic fields in Middle Europe. Biomed Environ Sci 25: 597-601, 2012.

Kabacik S, Kirschenlohr H, Raffy C, Whitehill K, Coster M, Abe M, Brindle K, Badie C, Sienkiewicz Z, Bouffler S. Investigation of transcriptional responses of juvenile mouse bone marrow to power frequency magnetic fields. Mutat Res 745-746: 40-45, 2013.

Keegan TJ, Bunch KJ, Vincent TJ, King JC, O'Neill KA, Kendall GM, MacCarthy A, Fear NT, Murphy MF. Case-control study of paternal occupation and childhood leukaemia in Great Britain, 1962-2006. Br J Cancer 107: 1652-1659, 2012.

Kheifets L and Oksuzyan S. Exposure assessment and other challenges in non-ionizing radiation studies of childhood leukaemia. Radiat Prot Dosimetry 132: 139-147, 2008.

Kheifets L, Bowman JD, Checkoway H, Feychting M, Harrington JM, Kavet R, Marsh G, Mezei G, Renew DC, van Wijngaarden E. Future needs of occupational epidemiology of extremely low frequency electric and magnetic fields: review and recommendations. Occup Environ Med 66: 72-80, 2009.

Kheifets L, Ahlbom A, Crespi CM, Feychting M, Johansen C, Monroe J, Murphy MF, Oksuzyan S, Preston-Martin S, Roman E, Saito T, Savitz D, Schüz J, Simpson J, Swanson J, Tynes T, Verkasalo P, Mezei G. A pooled analysis of extremely low-frequency magnetic fields and childhood brain tumors. Am J Epidemiol 172: 752-761, 2010.

Kirschenlohr H, Ellis P, Hesketh R, Metcalfe J. Gene expression profiles in white blood cells of volunteers exposed to a 50 Hz electromagnetic field. Radiat Res 178: 138-149, 2012.

Koeman T, Slottje P, Kromhout H, Schouten LJ, Goldbohm RA, van den Brandt PA, Vermeulen R. Occupational exposure to extremely low-frequency magnetic fields and cardiovascular disease mortality in a prospective cohort study. Occup Environ Med 70: 402-407, 2013.

Koeman T, van den Brandt PA, Slottje P, Schouten LJ, Goldbohm RA, Kromhout H, Vermeulen R. Occupational extremely low-frequency magnetic field exposure and selected cancer outcomes in a prospective Dutch cohort. Cancer Causes Control 25: 203-214, 2014.

Koeman T, Schouten LJ, van den Brandt PA, Slottje P, Huss A, Peters S, Kromhout H, Vermeulen R. Occupational exposures and risk of dementia-related mortality in the prospective Netherlands Cohort Study. Am J Ind Med 58: 625-635, 2015.

Korpinen LH, Kuisti HA, Paakkonen R, Vanhala P, Elovaara JA. Occupational exposure to electric and magnetic fields while working at switching and transforming stations of 110 kV. Ann Occup Hyg 55: 526-536, 2011a.

Korpinen LH, Elovaara JA, Kuisti HA. Occupational exposure to electric fields and induced currents associated with 400 kV substation tasks from different service platforms. Bioelectromagnetics 32: 79-83, 2011b.

Korpinen LH, Kuisti HA, Tarao H, Elovaara JA. Occupational exposure to electric fields and currents associated with 110 kV substation tasks. Bioelectromagnetics 33: 438-442, 2012.

Korpinen L and Paakkonen R. Examples of occupational exposure to electric and magnetic fields at 110-kV gas-insulated substations (GISS). Radiat Prot Dosimetry, 2014.

Korr H, Angstman NB, Born TB, Bosse K, Brauns B, Demmler M, Fueller K, Kantor O, Kever BM, Rahimyar N, Salimi S, Silny J, Schmitz C. No evidence of persisting unrepaired nuclear DNA single strand breaks in distinct types of cells in the brain, kidney, and liver of adult mice after continuous eight-week 50 Hz magnetic field exposure with flux density of 0.1 mT or 1.0 mT. PLoS One 9: e109774, 2014.

Lai H and Singh NP. Magnetic-field induced DNA strand breaks in brain cells of the rat. Environ Health Perspect 113: 687-694, 2004.

Lee GM, Neutra RR, Hristova L, Yost M, Hiatt RA. A nested case-control study of residential and personal magnetic field measures and miscarriages. Epidemiology 13: 21-31, 2002.

Leitgeb N. Childhood leukemia not linked with EMF magnetic fields. J Electromagn Anal 6: 174-183, 2014.

Lewis RC, Evenson KR, Savitz DA, Meeker JD. Temporal variability of daily personal magnetic field exposure metrics in pregnant women. J Expo Sci Environ Epidemiol 25: 58-64, 2015.

Li DK, Odouli R, Wi S, Janevic T, Golditch I, Bracken TD, Senior R, Rankin R, Iriye R. A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage. Epidemiology 13: 9-20, 2002.

Li W, Ray RM, Thomas DB, Yost M, Davis S, Breslow N, Gao DL, Fitzgibbons ED, Camp JE, Wong E, Wernli KJ, Checkoway H. Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China. Am J Epidemiol 178: 1038-1045, 2013.

Löscher W, Mevissen M, Lehmacher W, Stamm A. Tumor promotion in a breast cancer model by exposure to a weak alternating magnetic field. Cancer Lett 71: 75-81, 1993.

Löscher W, Wahnschaffe U, Mevissen M, Lerchl A, Stamm A. Effects of weak alternating magnetic fields on nocturnal melatonin production and mammary carcinogenesis in rats. Oncology 51: 288-295, 1994.

Löscher W and Mevissen M. Linear relationship between flux density and tumor co-promoting effect of prolonged magnetic field exposure in a breast cancer model. Cancer Lett 96: 175-180, 1995.

Löscher W, Mevissen M, Haussler B. Seasonal influence on 7,12-dimethylbenz[a]anthracene-induced mammary carcinogenesis in Spague-Dawley rats under controlled laboratory conditions. Pharmacol Toxicol 81: 265-270, 1997.

Magnani C, Mattioli S, Miligi L, Ranucci A, Rondelli R, Salvan A, Bisanti L, Masera G, Rizzari C, Zambon P, Cannizzaro S, Gafa L, Luzzatto LL, Benvenuti A, Michelozzi P, Kirchmayer U, Cocco P, Biddau P, Galassi C, Celentano E, Guarino E, Assennato G, de Nichilo G, Merlo DF, Bocchini V, Pannelli F, Mosciatti P, Minelli L, Chiavarini M, Cuttini M, Casotto V, Torregrossa MV, Valenti RM, Forastiere F, Haupt R, Lagorio S, Risica S, Polichetti A. SETIL: Italian multicentric epidemiological case-control study on risk factors for childhood leukaemia, non hodgkin lymphoma and neuroblastoma: study population and prevalence of risk factors in Italy. Ital J Pediatr 40: 103, 2014.

Mahna A, Firoozabadi SM, Shankayi Z. The effect of ELF magnetic field on tumor growth after electrochemotherapy. J Membr Biol 247: 9-15, 2014.

Mahram M and Ghazavi M. The effect of extremely low frequency electromagnetic fields on pregnancy and fetal growth, and development. Arch Iran Med 16: 221-224, 2013.

Mandeville R, Franco E, Sidrac-Ghall S, Paris-Nadon L, Rocheleau N, Mercier G, Desy M, Gaboury L. Evaluation of the potential carcinogenicity of 60 Hz linear sinusoidal continuous-wave magnetic fields in Fisher F344 rats. FAESB Journal 11: 1127-1136, 1997.

Marcilio I, Gouveia N, Pereira Filho ML, Kheifets L. Adult mortality from leukemia, brain cancer, amyotrophic lateral sclerosis and magnetic fields from power lines: a case-control study in Brazil. Rev Bras Epidemiol 14: 580-588, 2011.

McCormick DL, Boorman GA, Findlay JC, Hailey JR, Johnson TR, Gauger JR, Pletcher JM, Sills RC, Haseman JK. Chronic toxicity/oncogenicity evaluation of 60 Hz (power frequency) magnetic fields in B6C3F1 mice. Toxicol Pathol 27: 279-285, 1999.

McNally RJ and Parker L. Environmental factors and childhood acute leukemias and lymphomas. Leuk Lymphoma 47: 583-598, 2006.

Mevissen M, Stamm A, Buntenkotter S, Zwingleberg R, Wahnschaffe U, Löscher W. Effects of magnetic fields on mmmary tumor development induced by 7,12-dimethylbenz(a)anthracene in rats. Bioelectromagnetics 14: 131-143, 1993a.

Mevissen M, Stamm A, Buntenkotter S, Zwingleberg R, Wahnschaffe U, Löscher W. Effects of AC Magnetic Field on DMBA-induced Mammary Carcinogenesis in Sprague-Dawley Rats. In Electricity and Magnetism in Biology and Medicine, edited by Blank M. San Francisco, CA: San

Francisco Press, 1993b.

Mevissen M, Lerchl A, Löscher W. Study on pineal function and DMBA-induced breast cancer formation in rats during exposure to a 100-mg, 50-Hz magnetic field. J Toxicol Environ Health 48: 169-185, 1996a.

Mevissen M, Lerchl A, Szamel M, Löscher W. Exposure of DMBA-treated female rats in a 50-Hz, 50 microTesla magnetic field: effects on mammary tumor growth, melatonin levels, and T lymphocyte activation. Carcinogenesis 17: 903-910, 1996b.

Mevissen M, Haussler M, Lerchl A, Löscher W. Acceleration of mammary tumorigenesis by exposure of 7,12-dimethylbenz[a]anthracene-treated female rats in a 50-Hz, 100-microT magnetic field: replication study. J Toxicol Environ Health 53: 401-418, 1998.

Mezei G, Bracken TD, Senior R, Kavet R. Analyses of magnetic-field peak-exposure summary measures. J Expo Sci Environ Epidemiol 16: 477-485, 2006.

Mezei G, Sudan M, Izraeli S, Kheifets L. Epidemiology of childhood leukemia in the presence and absence of Down syndrome. Cancer Epidemiol 38: 479-489, 2014.

Miyakoshi Y, Kajihara C, Shimizu H, Yanagisawa H. Tempol suppresses micronuclei formation in astrocytes of newborn rats exposed to 50-Hz, 10-mT electromagnetic fields under bleomycin administration. Mutat Res 747: 138-141, 2012.

National Institute of Environmental Health Sciences (NIEHS). Health Effects from Exposure to Power Line Frequency Electric and Magnetic Fields. NIH Publication No. 99-4493. Research Triangle Park, NC: NIEHS, 1999.

National Institute of Environmental Health Sciences (NIEHS). EMF Questions & Answers (NIH Publication 02-4493). Research Triangle Park, NC: NIEHS, 2002.

National Radiological Protection Board (NRPB). Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300 GHz), Volume 15, No. 3. Didcot, Oxfordshire: National Radiological Protection Board, 2004.

National Radiological Protection Board (NRPB). Magnetic fields and miscarriage. Radiol Prot Bull No 1 (The eBulliten), June 2002.

New Zealand Ministry of Health (NZMH). Interagency Committee on the Health Effects of Non-Ionising Fields: Report to the Ministers 2015. Wellington, New Zealand: Ministry of Health, 2015.

Office of Health Assessment and Translation (OHAT). Handbook for Conducting a Literature-Based Health Assessment Using OHAT Approach for Systematic Review and Evidence Integration. Research Triangle Park, NC: National Toxicology Program, U.S. Department of Health and Human Services, 2015.

Okun O, Shevchenko S, Korpinen L. A comparison of magnetic fields inside and outside high-voltage urban 110-kV power substations with the exposure recommendations of the Ukrainian regulatory authorities. Radiat Prot Dosimetry 154: 417-429, 2013.

Pedersen C, Raaschou-Nielsen O, Rod NH, Frei P, Poulsen AH, Johansen C, Schüz J. Distance from residence to power line and risk of childhood leukemia: a population-based case-control study in Denmark. Cancer Causes Control 25: 171-177, 2014a.

Pedersen C, Brauner EV, Rod NH, Albieri V, Andersen CE, Ulbak K, Hertel O, Johansen C, Schüz J, Raaschou-Nielsen O. Distance to high-voltage power lines and risk of childhood leukemia - an analysis of confounding by and interaction with other potential risk factors. PLoS One 9: e107096, 2014b.

Philips A, O'Carroll M, Henshaw D, Lamburn G. Adult cancers near high-voltage power lines. Epidemiology 24: 782-783, 2013.

Qi G, Zuo X, Zhou L, Aoki E, Okamula A, Watanebe M, Wang H, Wu Q, Lu H, Tuncel H, Watanabe H, Zeng S, Shimamoto F. Effects of extremely low-frequency electromagnetic fields (ELF-EMF) exposure on B6C3F1 mice. Environ Health Prev Med 20: 287-293, 2015.

Ries L, Smith MA, Gurney JG, Linet M, Tamra T, Young JL, Bunin GR, eds. Cancer Incidence and Survival among Children and Adolescents: United States SEER Program 1975-1995 (NIH Publication No. 99-4649). Bethesda, MD: National Cancer Institute, 1999.

Ries L, Melbert D, Krapcho M, Mariotto A, Miller BA, Feuer EJ, Clegg L, Horner MJ, Howlander N, Eisner MP, Reichman M, Edwards BK, eds. SEER Cancer Statistics Review. Bethesda, MD: National Cancer Institute, 2007.

Rodriguez-Garcia JA and Ramos F. High incidence of acute leukemia in the proximity of some industrial facilities in El Bierzo, northwestern Spain. Int J Occup Med Environ Health 25: 22-30, 2012.

Rooney AA, Boyles AL, Wolfe MS, Bucher JR, Thayer KA. Systematic review and evidence integration for literature-based environmental health science assessments. Environ Health Perspect 122: 711-718, 2014.

Rossig C and Juergens H. Aetiology of childhood acuted leukaemias: current statis of knowledge. Radiat Prot Dosimetry 132: 114-118, 2008.

Rothman KJ and Greenland S. Modern Epidemiology. Philadelphia: Lippencott-Raven Publishers, 1998.

Saha S, Woodbine L, Haines J, Coster M, Ricket N, Barazzuol L, Ainsbury E, Sienkiewicz Z, Jeggo P. Increased apoptosis and DNA double-strand breaks in the embryonic mouse brain in response to very low-dose X-rays but not 50 Hz magnetic fields. JR Soc Interface 11: 20140783, 2014.

Salvan A, Ranucci A, Lagorio S, Magnani C. Childhood leukemia and 50 Hz magnetic fields: findings from the Italian SETIL case-control study. Int J Environ Res Pub Health 12: 2184-2204, 2015.

Savitz D, Pearce N, Poole C. Methodological issues in the epidemiology of electromagnetic fields and cancer. Epidemiol Rev 11: 59-78, 1989.

Savitz DA, Liao D, Sastre A, Kleckner RC, Kavet R. Magnetic field exposure and cardiovascular disease mortality among electric utility workers. Am J Epidemiol 149: 135-142, 1999.

Savitz DA. Magnetic fields and miscarriage. Epidemiology 13: 1-4, 2002.

Savitz DA, Herring AH, Mezei G, Evenson KR, Terry JW, Jr., Kavet R. Physical activity and magnetic field exposure in pregnancy. Epidemiology 17: 222-225, 2006.

Schüz J, Grell K, Kinsey S, Linet MS, Link MP, Mezei G, Pollock BH, Roman E, Zhang Y, McBride ML, Johansen C, Spix C, Hagihara J, Saito AM, Simpson J, Robison LL, Dockerty JD, Feychting M, Kheifets L, Frederiksen K. Extremely low-frequency magnetic fields and survival from childhood acute lymphoblastic leukemia: an international follow-up study. Blood Cancer J 2: e98, 2012.

Schüz J. Commentary: power lines and cancer in adults: settling a long-standing debate? Epidemiology 24: 191-192, 2013.

Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Health Effects of Exposure to EMF. Brussels, Belgium: European Commission, 2009.

Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Opinion on Potential Health Effects of Exposure to Electromagnetic Fields (EMF). Brussels, Belgium: European Commission, 2015.

Seelen M, Vermeulen RC, van Dillen LS, van der Kooi AJ, Huss A, de Visser M, van den Berg LH, Veldink JH. Residential exposure to extremely low frequency electromagnetic fields and the risk of ALS. Neurology 83: 1767-1769, 2014.

Sermage-Faure C, Demoury C, Rudant J, Goujon-Bellec S, Guyot-Goubin A, Deschamps F, Hemon D, Clavel J. Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007. Br J Cancer 108: 1899-1906, 2013.

Shamsi Mahmoudabadi F, Ziaei S, Firoozabadi M, Kazemnejad A. Exposure to Extremely Low Frequency Electromagnetic Fields during Pregnancy and the Risk of Spontaneous Abortion: A Case-Control Study. J Res Health Sci 13: 131-134, 2013.

Slusky DA, Does M, Metayer C, Mezei G, Selvin S, Buffler PA. Potential role of selection bias in the association between childhood leukemia and residential magnetic fields exposure: a population-based assessment. Cancer Epidemiol 38: 307-313, 2014.

Sommer AM and Lerchl A. The risk of lymphoma in AKR/J mice does not rise with chronic exposure to 50 Hz magnetic fields (1 microT and 100 microT). Radiat Res 162: 194-200, 2004.

Sorahan T. Cancer incidence in UK electricity generation and transmission workers, 1973-2008. Occup Med (Lond) 62: 496-505, 2012.

Sorahan T. Magnetic fields and brain tumour risks in UK electricity supply workers. Occup Med (Lond) 64: 157-165, 2014a.

Sorahan T. Magnetic fields and leukaemia risks in UK electricity supply workers. Occup Med (Lond) 64: 150-156, 2014b.

Stroup DF, Thacker SB, Olson CM, Glass RM, Hutwagner L. Characteristics of meta-analyses related to acceptance for publication in a medical journal. J Clinical Epidemiol 54: 655-660, 2001.

Su XJ, Yuan W, Tan H, Liu XY, Li D, Li DK, Huang GY, Zhang LW, Miao MH. Correlation between exposure to magnetic fields and embryonic development in the first trimester. PLoS One 9: e101050, 2014.

Sun JW, Li XR, Gao HY, Yin JY, Qin Q, Nie SF, Wei S. Electromagnetic field exposure and male breast cancer risk: a meta-analysis of 18 studies. Asian Pac J Cancer Prev 14: 523-528, 2013.

Svendsen AL, Weihkopf T, Kaatsch P, Schüz J. Exposure to magnetic fields and survival after diagnosis of childhood leukemia: a German cohort study. Cancer Epidemiol Biomarkers Prev 16: 1167-1171, 2007.

Swanson J and Kheifets L. Could the geomagnetic field be an effect modifier for studies of power-frequency magnetic fields and childhood leukaemia? J Radiol Prot 32: 413-418, 2012.

Swanson J. Residential mobility of populations near UK power lines and implications for childhood leukaemia. J Radiol Prot 33: N9-N14, 2013.

Swanson J, Vincent TJ, Bunch KJ. Relative accuracy of grid references derived from postcode and address in UK epidemiological studies of overhead power lines. J Radiol Prot 34: N81-86, 2014a.

Swanson J, Bunch KJ, Vincent TJ, Murphy MF. Childhood cancer and exposure to corona ions from power lines: an epidemiological test. J Radiol Prot 34: 873-889, 2014b.

Swedish Radiation Safety Authority (SSM). Recent Research on EMF and Health Risks: Seventh annual report from SSMs independent Expert Group on Electromagnetic Fields 2010. Report Number: 2010:44. Stockholm, Sweden: Swedish Radiation Safety Authority, 2010.

Swedish Radiation Safety Authority (SSM). Research 2013:19. Eighth Report from SSM:s Scientific Council on Electromagnetic Fields. Stockholm, Sweden: Swedish Radiation Safety Authority, 2013.

Swedish Radiation Safety Authority (SSM). Research 2014:16. Recent Research on EMF and Health Risk. Ninth report from SSM's Scientific Council on Electromagnetic Fields. Stockholm, Sweden: Swedish Radiation Safety Authority 2014.

Swedish Radiation Safety Authority (SSM). Research 2015:19. Recent Research on EMF and Health Risk - Tenth report from SSM's Scientific Council on Electromagnetic Fields. Stockholm, Sweden: Swedish Radiation Safety Authority 2015.

Tabrizi MM and Bidgoli SA. Increased risk of childhood acute lymphoblastic leukemia (ALL) by prenatal and postnatal exposure to high voltage power lines: a case control study in Isfahan, Iran. Asian Pac J Cancer Prev 16: 2347-2350, 2015.

Talibov M, Guxens M, Pukkala E, Huss A, Kromhout H, Slottje P, Martinsen JI, Kjaerheim K, Sparen P, Weiderpass E, Tryggvadottir L, Uuksulainen S, Vermeulen R. Occupational exposure to extremely low-frequency magnetic fields and electrical shocks and acute myeloid leukemia in four Nordic countries. Cancer Causes Control 26: 1079-1085, 2015.

Teepen JC and van Dijck JA. Impact of high electromagnetic field levels on childhood leukemia incidence. Int J Cancer 131: 769-778, 2012.

Tiwari R, Lakshmi NK, Bhargava SC, Ahuja YR. Epinephrine, DNA integrity and oxidative stress in workers exposed to extremely low-frequency electromagnetic fields (ELF-EMFs) at 132 kV substations. Electromagn Biol Med 34: 56-62, 2015.

Turner MC, Benke G, Bowman JD, Figuerola J, Fleming S, Hours M, Kincl L, Krewski D, McLean D, Parent ME, Richardson L, Sadetzki S, Schlaefer K, Schlehofer B, Schüz J, Siemiatycki J, Van Tongeren M, Cardis E. Occupational exposure to extremely low frequency magnetic fields and brain tumour risks in the INTEROCC study. Cancer Epidemiol Biomarkers Prev 23: 1863-1872, 2014.

Ubeda A, Martinez MA, Cid MA, Chacon L, Trillo MA, Leal J. Assessment of occupational exposure to extremely low frequency magnetic fields in hospital personnel. Bioelectromagnetics 32: 378-387, 2011.

US Department of Health and Human Services (HHS). Health Consequences of Smoking: A Report to the Surgeon General. Washington, DC: HHS, 2004.

US Department of Health Education and Welfare (HEW). Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service. PHS Publication No. 1103. Washington, DC: HEW, Public Health Service, Center for Disease Control, 1964.

US Environmental Protection Agency (USEPA). Reference Dose (RfD): Description and Use in Health Risk Assessments. Washington, DC: USEPA1993.

US Environmental Protection Agency (USEPA). Proposed Guidelines for Carcinogen Risk Assessments. EPA/600/P-92/003C. Washington, DC: USEPA1996.

van der Mark M, Vermeulen R, Nijssen PC, Mulleners WM, Sas AM, van Laar T, Kromhout H, Huss A. Extremely low-frequency magnetic field exposure, electrical shocks and risk of Parkinson's disease. Int Arch Occup Environ Health 88: 227-234, 2014.

Vergara X, Kheifets L, Greenland S, Oksuzyan S, Cho YS, Mezei G. Occupational exposure to extremely low-frequency magnetic fields and neurodegenerative disease: a meta-analysis. J Occup Environ Med 55: 135-146, 2013.

Villarini M, Ambrosini MV, Moretti M, Dominici L, Taha E, Piobbico D, Gambelunghe C, Mariucci G. Brain hsp70 expression and DNA damage in mice exposed to extremely low frequency magnetic fields: a dose-response study. Int J Radiat Biol 89: 562-570, 2013.

Villarini M, Dominici L, Fatigoni C, Levorato S, Vannini S, Monarca S, Moretti M. Primary DNA damage in welders occupationally exposed to extremely-low-frequency magnetic fields (ELF-MF). Ann Ig 27: 511-519, 2015.

Wang Q, Cao Z, Qu Y, Peng X, Guo S, Chen L. Residential exposure to 50 Hz magnetic fields and the association with miscarriage risk: a 2-year prospective cohort study. PLoS One 8: e82113, 2013.

Wilson JW, Haines J, Sienkiewicz Z, Dubrova YE. The effects of extremely low frequency magnetic fields on mutation induction in mice. Mutat Res 773: 22-26, 2015.

Woodbine L, Haines J, Coster M, Barazzuol L, Ainsbury E, Sienkiewicz Z, Jeggo P. The rate of X-ray-induced DNA double-strand break repair in the embryonic mouse brain is unaffected by exposure to 50 Hz magnetic fields. Int J Radiat Biol 91: 495-499, 2015.

World Health Organization (WHO). Environmental Health Criteria 35: Extremely Low Frequency (ELF) Fields. Geneva, Switzerland: WHO, 1984.

World Health Organization (WHO). International Programme on Chemical Safety (IPCS). Environnemental Health Criteria 170 Assessing Human Health Risks of Chemicals: Derivation of Guidance Values for Health-based Exposure Limits. Geneva, Switzerland: WHO, 1994.

World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. Geneva, Switzerland: WHO, 2007.

Yasui M, Kikuchi T, Ogawa M, Otaka Y, Tsuchitani M, Iwata H. Carcinogenicity test of 50 H sinusoidal magnetic fields in rats. Leuk Lymphoma 49: 531-540, 1997.

Yu Y, Su FC, Callaghan BC, Goutman SA, Batterman SA, Feldman EL. Environmental risk factors and amyotrophic lateral sclerosis (ALS): a case-control study of ALS in Michigan. PLoS One 9: e101186, 2014.

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

Zaffanella LE and Kalton GW. Survey of Personal Magnetic Field Exposure Phase II: 1,000 Person Survey. EMF Rapid Program, Engineering Project #6. Lee, Massachusetts: Enertech Consultants, 1998.

Zhao L, Liu X, Wang C, Yan K, Lin X, Li S, Bao H, Liu X. Magnetic fields exposure and childhood leukemia risk: a meta-analysis based on 11,699 cases and 13,194 controls. Leuk Res 38: 269-274, 2014a.

Zhao G, Lin X, Zhou M, Zhao J. Relationship between exposure to extremely low-frequency electromagnetic fields and breast cancer risk: a meta-analysis. Eur J Gynaecol Oncol 35: 264-269, 2014b.

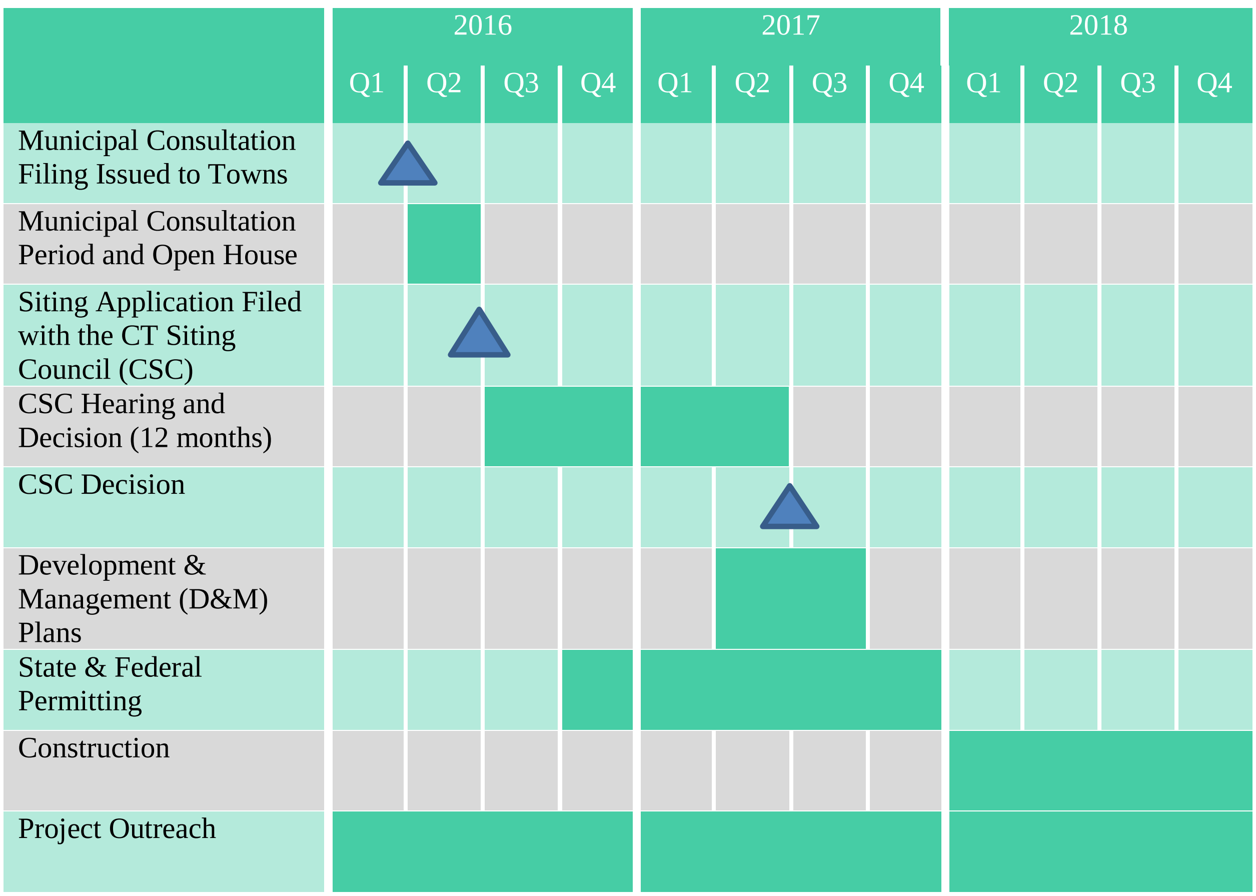
Zhou H, Chen G, Chen C, Yu Y, Xu Z. Association between extremely low-frequency electromagnetic fields occupations and amyotrophic lateral sclerosis: A meta-analysis. PLoS One 7: e48354 doi: 10.1371/journal.pone.0048354, 2012.

Ziegelberger G, Dehos A, Grosche B, Hornhardt S, Jung T, Weiss W. Childhood leukemia--risk factors and the need for an interdisciplinary research agenda. Prog Biophys Mol Biol 107: 312-314, 2011.

8. PROPOSED PROJECT SCHEDULE

Figure 8-1 lists the key activities in Eversource's proposed schedule for developing the SWCT Reliability Project. As indicated on the schedule, Eversource expects to submit its application to the CSC toward the end of the second quarter of 2016 after completing the MCF process. The schedule in Figure 8-1 does not list the planning activities that Eversource performed on the Project prior to the submittal of the MCF, but rather focuses on the future Project timeline.

Figure 8-1: SWCT Reliability Project – Estimated Timeline



*Note that the construction timeline refers to the installation of the new 115-kV transmission lines and substation modifications, and does not necessarily include the completion of all ROW restoration and post-installation monitoring activities.

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9. PERMITS, APPROVALS, AND CONSULTATIONS

As part of the Project planning process, Eversource initiated consultations with representatives of the three municipalities that would be traversed by the proposed new 115-kV transmission line along the Proposed Route, as well as with representatives of the federal and state regulatory agencies from which approvals for the Project would be required. Eversource will continue such proactive consultations as the planning for and review of the Project proceeds. This section identifies the permits and approvals that would be required for the construction and operation of the Project, and summarizes the federal and state agency and municipal consultations that Eversource has conducted to date concerning it.

9.1 AGENCY PERMITS AND APPROVALS REQUIRED FOR THE PROJECT

In addition to a Certificate of Environmental Compatibility and Public Need from the Council, the Project will require permits and approvals from other Connecticut and federal agencies. At the federal level, the Project must comply with the Clean Water Act (CWA), the Endangered Species Act, the National Historic Preservation Act and the Federal Avian Act. At the state level, along with compliance with the Council's requirements, Eversource will have to obtain Project-specific permits or approvals pertaining to water quality (pursuant to Section 401 of the CWA), stormwater management, flood management, threatened and endangered species, and cultural resources. Approval of the Method and Manner of construction also will be required from PURA. Additional state approvals may be required, depending on the final design of the Project.

Table 9-1 summarizes the federal and state permits and approvals expected to be required for the proposed Project. This summary is based on currently available data concerning the Project, and may be modified as the Project planning, design, and review process moves forward.

Table 9-1: Potential Permits, Reviews, and Approvals Required for the Project

Agency	Certificate, Permit, Review, Approval or Confirmation	Activity Regulated
FEDERAL		
U.S. Army Corps of Engineers (USACE), New England District	Section 404 CWA	Discharge of dredge or fill material into waters of the U.S. (wetlands or watercourses)
U.S. Fish and Wildlife Service (USFWS)	Coordinates with USACE regarding endangered or threatened species (non-marine); provides input to USACE permit application review	Construction or operation activities that may affect federally-listed endangered or threatened species
U.S. Environmental Protection Agency (USEPA)	Provides input to USACE permit application review	Construction or operation activities that may affect water, air, or other resources
Advisory Council on Historic Preservation (ACHP)	Involved if significant cultural resource sites would be potentially affected by the Project	Section 106 National Historic Preservation Act compliance; input to USACE permit review, if applicable
Federal Aviation Administration (FAA)	Notice of Proposed Construction or Alteration	All obstructions, whether permanent or temporary, are subject to the notice requirement outlined in 14 CFR Part 77
CONNECTICUT		
Connecticut Siting Council (CSC, Council)	Certificate of Environmental Compatibility and Public Need Development & Management Plan approval prior to construction	General transmission line need, siting, construction, environmental compatibility, safety, maintenance, and ROW management procedures
Department of Energy and Environmental Protection (CT DEEP)	401 Water Quality Certification	Conformance to Section 401 of the CWA; Section 401 approval from CTDEEP is required prior to USACE permit issuance
	Water Discharge General Permit	Stormwater management during construction
	Threatened, Endangered, and Special Concern Species (NDDB)	Approval of species-specific mitigation plans as part of Council's process, 401 Water Quality Certification approval
	Flood Management Certification	Work in floodplain and/or Floodway
CT DEEP Public Utilities Regulatory Authority	Approval pursuant to CGS Section 16-243	Method & Manner of Construction Approval to Energize Lines
State Historic Preservation Office (SHPO)[98]	Approval of proposed Project consistency with the National Historic Preservation Act; comments during Council and USACE processes	Construction and operation activities that may affect archaeological or historic resources.
Connecticut Department of Transportation (ConnDOT)	Encroachment permit	Transmission line crossing of state highways (i.e., Interstate 84, U.S. Route 6)

9.2 FEDERAL AND STATE AGENCY CONSULTATIONS

In conjunction with the overall Project planning, Eversource initiated consultations with the federal and state agencies likely to be involved in the review or approval of the new 115-kV transmission line and related Stony Hill Substation modifications. The purpose of these initial consultations was to provide the agencies with preliminary information regarding the proposed Project, and to solicit baseline information concerning the Project area or input concerning potential Project-related issues. Table 9-2 summarizes the federal and state agency consultations conducted to date. Section 9 includes copies of correspondence to and from agencies (conducted to date) regarding the Project.

Table 9-2: List of Federal and State Agency Consultations to Date or Expected to be Consulted

AGENCY	DATE	AGENCY CONTACT
FEDERAL		
USACE, New England District	First Quarter 2016	Susan Lee
U.S. Environmental Protection Agency	First Quarter 2016	Jackie LeClair
U.S. Department of Interior - Fish & Wildlife Service	First Quarter 2016	Susan von Ottingen (USFWS)
CONNECTICUT		
CT DEEP – Natural Diversity Database	First Quarter 2016	Dawn M. McKay Jenny Dickson Laura Saucier
Tribal Historic Preservation Office (THPO)	First Quarter 2016	Mohegans, Mashantucket, Pequots
State Historic Preservation Office (SHPO)	First Quarter 2016	Todd Levine

9.3 MUNICIPAL, PUBLIC, AND OTHER CONSULTATIONS

In February of 2016, Eversource initiated consultations with municipal officials in Bethel, Brookfield, and Danbury. The purpose of the consultations was to inform the municipal officials of the proposed Project and solicit their input. In addition, key state and federal elected officials, and other stakeholders were or will be offered briefings on the proposed Project.

Shortly after the submittal of the MCF, property owners and abutters to the proposed new transmission line will be notified of the proposed Project and offered briefings. This part of the public outreach process

[98] The SHPO is part of the Connecticut Department of Economic and Community Development.

conforms to the Council's MCF requirements. In addition, in May, Eversource will host a regional open house to provide interested members of the public with information about the project. Eversource will continue to proactively communicate with affected property owners and other stakeholders as the Project moves forward.

The overall objective of the municipal consultation process is to solicit input regarding the proposed Project from representatives of each of the municipalities potentially affected by the proposed transmission facilities, as well as from other interested public. In accordance with the Council's requirements, within 15 days of filing the Application for the Project, Eversource will provide to the Council a summary of the consultations that were conducted with the towns, including any comments or recommendations made by the municipalities, as well as copies of comments received from the public.

Table 9-3 summarizes the primary meetings that Eversource has held to date with municipal officials and state and federal officials.

Table 9-3: Meetings Held To-Date with Municipal Officials, State and Federal Officials, and Other Key Stakeholder Groups

Stakeholder Group	Date of Meeting	Purpose of Meeting
Municipal Officials		
Town of Bethel First Selectman Matt Knickerbocker	March 2, 2016	Project Introduction MCF Briefing
Town of Danbury Mayor Mark D. Boughton	March 8, 2016	Project Introduction MCF Briefing
Town of Brookfield First Selectman Stephen Dunn	March 8, 2016	Project Introduction MCF Briefing
State and Federal Officials		
Congresswoman Elizabeth Esty 5th District	April 2016	Project Introduction
Senator Chris Murphy	April 2016	Project Introduction
Senator Richard Blumenthal	April 2016	Project Introduction
State Senator Clark Chapin 30th District (Brookfield)	April 2016	Project Introduction
State Representative Steve Harding 107th District (Brookfield and Bethel)	April 2016	Project Introduction
Senator Toni Boucher 26th District (Bethel)	April 2016	Project Introduction
Senator Michael McLachlan 24th District (Bethel and Danbury)	April 2016	Project Introduction
State Representative Dan Carter 2nd District (Bethel and Danbury)	April 2016	Project Introduction
State Representative Bob Godfrey 110th District (Danbury)	April 2016	Project Introduction
State Representative David Arconti 109 (Danbury)	April 2016	Project Introduction
State Representative Jan Giegler 138th District (Danbury)	April 2016	Project Introduction
State Representative Richard Smith 108th District (Danbury)	April 2016	Project Introduction

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10. SYSTEM ALTERNATIVES

This section complies with the provision in the Council's *Application Guide* (February 2016) that requires an applicant to identify "system alternatives and the advantages and disadvantages of each." First, in Section 10.1, a "No Action" alternative is briefly discussed. Next, in Section 10.2, transmission system alternatives are discussed. This section describes the process by which a preferred transmission solution for SWCT was developed as part of the SWCT planning study. Finally, in Section 10.3, the evaluation of potential non-transmission system alternatives (NTAs) is discussed. NTAs include the addition of generation resources, often referred to as "supply-side" measures, and strategies to reduce load, often referred to as demand-side management or "DSM" measures.

10.1 NO ACTION ALTERNATIVE

The existing conditions in the Housatonic Valley sub-area are such that, in the event of a loss of power to one of the two transmission lines into this area, severe thermal and voltage violations may occur that could result in load shedding. Under the no-action alternative, no new transmission facilities would be developed and no improvements would be made to the existing electrical transmission system or to supply or demand resources in the Housatonic Valley sub-area. This alternative was rejected because it would do nothing to correct violations of national and regional reliability standards and criteria. Thus, under the no-action alternative, the Housatonic Valley sub-area would continue to be at risk for electric outages and Eversource would be subject to fines by FERC for its failure to take action to resolve identified criteria violations. Failure to take action to bring the Housatonic Valley electric supply into conformity with applicable reliability standards and criteria would also undermine the long-range plan of ISO-NE and Eversource for providing reliable transmission service throughout Connecticut and neighboring states.

10.2 TRANSMISSION ALTERNATIVES

Transmission alternatives are improvements to the transmission system that would resolve reliability problems with different electrical configurations or technologies than those of the preferred solution. The SWCT Working Group, comprised of transmission planners from ISO-NE, Eversource Utilities Service Company, and The United Illuminating Company, evaluated reliability needs and transmission solutions in the five SWCT sub-areas studied, including the Housatonic Valley sub-area. (No need was identified for the Glenbrook-Stamford sub-area). For the Housatonic Valley sub-area, the Working Group evaluated four transmission alternatives.

10.2.1 Process for Developing the Housatonic Valley Transmission Alternatives

The *SWCT Needs Report* identified numerous reliability issues on the existing 115-kV network in SWCT. Most of these weaknesses were defined in areas where large pockets of load are being served from a few weak 115-kV connections to the high voltage 345-kV network. N-1-1 modeling analyses demonstrated that if a combination of these connections were removed (out-of-service), the remaining lines in-service were unable to handle the increased loading. This would cause thermal overloads and low voltage, resulting in potential voltage collapse in the load pocket (i.e., weak or no customer service).

To strengthen the 115-kV connections to the load pockets, the SWCT Working Group investigated transmission solutions that would add new electrical sources into the pockets, thereby improving the remaining elements after N-1-1 contingency events. Section 10.2.2 describes each of these alternative solutions.

All of the transmission alternatives were first evaluated to ensure that the solution components would resolve all of the identified criteria violations detailed in the *Needs Assessment*. Then, the alternative solution components were compared based on estimated cost and other key factors, such as ease of permitting, constructability, and expandability.

Early on in its analyses of transmission alternatives, the SWCT Working Group found that possible interactions between certain of the sub-areas could potentially affect the solutions study. Possible interactions were specifically identified between the Housatonic Valley sub-area and the Frost Bridge – Naugatuck Valley sub-area[99].

To effectively capture these interactions in the analyses, these two sub-areas were grouped together and a complete set of transmission solution alternatives was tested with the objective of resolving all violations in the two combined sub-areas. After a preferred alternative was identified for the grouped sub-areas, an overall preferred transmission solution was then tested for the two combined sub-areas to ensure all violations were resolved and the combined solution did not have any adverse interactions.

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[99] There were also interactions found between the Bridgeport sub-area and the Southington–New Haven sub-area.

After combining the Housatonic Valley sub-area and the Frost Bridge-Naugatuck Valley sub-area to evaluate possible interactions, the Working Group then considered both "local" and "global" solutions to the reliability issues in these two sub-areas. The two "local solutions" that were developed and evaluated by the Working Group (referred to in the *SWCT Solutions Report* as "Local 1" and "Local 2") were designed to solve the violations in each sub-area separately, while the two potential "global solutions" considered for the Housatonic Valley sub-area and the Frost Bridge-Naugatuck Valley sub-area (referred to as "Global 1" and "Global 2") would provide an additional link to both sub-areas that would be mutually beneficial in addressing the reliability issues in both sub-areas. This "link" would be provided by the construction of a new 10.7-mile 115-kV line from Eversource's existing Bunker Hill Substation in Waterbury to Bates Rock Substation in Southbury.

As described in further detail in Section 10.2.2 the Working Group ultimately determined that the optimal solution for the Housatonic Valley sub-area was "Local 2", a solution that addressed the reliability needs in this sub-area separately from the solution" for the Frost Bridge-Naugatuck Valley sub-area. The potential transmission solutions were tested by simulations using assumptions and procedures consistent with those that had been applied to identify the reliability needs in the entire SWCT study area.

The *SWCT Solutions Report,* a copy of which is provided in Volume 4, explains and justifies the selection of Local 2 as the transmission solution for Housatonic Valley sub-area over the other three transmission alternatives. A summary of the SWCT Working Group's analysis leading to the selection of Local 2 as the preferred alternative is outlined in Section 10.2.2.[100]

10.2.2 Transmission Alternatives Considered

The majority of the criteria violations in the Housatonic Valley and Frost Bridge-Naugatuck Valley sub-areas were related to serving load within each pocket, as opposed to violations related to the transfer of power through the sub-area to serve another part of the electrical system. Specifically, contingency pairs removed one or more transmission supplies to the load pocket, and the remaining transmission connections

[100] The Housatonic Valley sub-area has demonstrated significant voltage issues up to a possible voltage collapse following certain contingency events. In addition to addressing the thermal violations in the sub-area, the SWCT Working Group conducted an analysis to determine the most cost-effective reactive power solution for the region. A step-by-step process was done to mitigate the violations in the area using the existing devices in the area to the best extent possible and adding new devices at strategic locations. As part of its evaluation of the performance of the transmission alternatives, each of the four solution alternatives was tested from the current configuration to a final reactive solution to address each violation. This evaluation is discussed in detail in the *SWCT Solutions Report.*

and local generation were insufficient to serve the load. This would cause severe low voltage violations and thermal overloads.

Initially, two local solution alternatives were developed in both sub-areas to solve all the violations in the individual load pockets. During that analysis, another alternative was proposed to build a new 115-kV line between the Bates Rock and Bunker Hill substations. This new line would provide an additional link between the two sub-areas that would be mutually beneficial. This alternative became the "global" solution and two alternatives were created using this new line as the basis. These four solution alternatives - two local (Local 1 and Local 2) and two global (Global 1 and Global 2) – were then studied for the combined sub-areas. Table 10-1 summarizes the components that comprise the four transmission alternatives:

Table 10-1: Summary of Solution Components: Global 1 and 2; Local 1 and 2

Solution Component	Sub-area	Global 1	Global 2	Local 1	Local 2
Install a 115 kV capacitor bank (25.2 MVAR) at Oxford substation on 1319 line terminal	Frost Bridge	X	X	X	X
Close the normally open 115 kV 2T circuit breaker at Baldwin substation	Frost Bridge	X	X	X	X
Reconductor the 1887 line between West Brookfield substation and West Brookfield Junction (~1.4 miles); expected summer ratings:201/260/277 MVAR	Housatonic Valley	X	X	X	X
Install a 115 kV circuit breaker (63 kA interrupting capability) in series with the existing 29T breaker at Plumtree substation	Housatonic Valley	X	X	X	X
Install two capacitor banks (14.4 MVAR each) at West Brookfield substation on the 1618 line terminal	Housatonic Valley	X	X	X	X
Install a new 115 kV line (~3.4 miles) from Plumtree to Brookfield Junction; expected summer ratings: 401/525/626 MVA	Housatonic Valley	X	X	X	X
Relocate the existing 37.8 MVAR capacitor bank at Plumtree substation from 115 kV B bus to 115 kV A bus	Housatonic Valley	X	X	X	X
Upgrade the 115 kV 1876 line terminal equipment at Newtown substation expected new line ratings after upgrade: 293/378/432 MVA	Housatonic Valley	X	X	X	X
Reduce the 12Y-10K (25.2 MVAR) capacitor cans at Rocky River substation to 14.4 MVAR	Housatonic Valley	X	X	X	X
Loop the 115 kV 1570 line in and out of Pootatuck substation (formerly known as Shelton)	Frost Bridge	X	X	X	X
Install two 115 kV capacitor banks (25 MVAR each) at Ansonia substation, one on the 1560 line terminal and one on the 1594 line terminal	Frost Bridge	X	X	X	X
Expand Pootatuck substation (formerly Shelton) to 4-breaker 115 kV ring bus and install a 115 kV Capacitor bank (30 MVAR) on 1570 line terminal	Frost Bridge	X	X	X	X
Loop the 115 kV 1990 line in and out of Bunker Hill substation	Frost Bridge	X	X	X	X
Replace two Freight 115 kV 25 kA breakers with 63 kA interrupting capability	Frost Bridge	X	X	X	X
Rebuild Bunker Hill substation into a 115 kV breaker-and-a-half configuration with 11 circuit breakers	Frost Bridge	X	X		
Install a new 115 kV line (~10.7 miles) from Bunker Hill to Bates Rock substations; expected new line ratings: 401/524/626 MVA	Both Sub-areas	X	X		
Expand Bates Rock substation 7-breaker 115-kV ring bus configuration	Housatonic Valley	X	X		
Rebuild a portion of the 115 kV 1682 line from Wilton to Norwalk substations (~1.5 miles); expected new line ratings after upgrade: 309/435/435 MVA	Housatonic Valley	X	X		

Table 10-1: Summary of Solution Components: Global 1 and 2; Local 1 and 2

Solution Component	Sub-area	Global 1	Global 2	Local 1	Local 2
Rebuild Bunker Hill substation into a 115 kV breaker-and-a-half configuration with 9 circuit breakers	Frost Bridge			X	X
Rebuild a portion of the 115 kV 1682 line from Wilton to Norwalk substations (~1.5 miles) and upgrade Wilton substation terminal equipment; expected new line ratings after upgrade: 285/378/432 MVA	Housatonic Valley			X	X
Reconductor the 115 kV 1470-1 line from Wilton substation to Ridgefield Junction (~5.1 miles) expected new line ratings after upgrade: 255/331/364 MVA	Housatonic Valley			X	X
Reconductor the 115 kV 1470-3 line from Peaceable to Ridgefield Junction (~0.04 miles); expected new line ratings after upgrade: 255/331/364 MVA	Housatonic Valley			X	X
Reconductor the 115 kV 1575 line from Bunker Hill to Baldwin Junction (~3.0 miles); expected new 556 ACSS line ratings after upgrade: 201/260/277 MVA	Frost Bridge			X	X
Rebuild the 115 kV 1887-2 line from Shepaug to Brookfield Junction (~7.4 miles)	Housatonic Valley		X		
Reduce the 21K (37.8 MVAR) capacitor cans at Stony Hill S/S to 25.2 MVAR	Housatonic Valley	X		X	
Reconfigure the 115 kV 1887 line into 2 lines segments, one from Plumtree to West Brookfield to Stony Hill substations and one from Stony Hill to Shepaug substations. Reconfigure the 115 kV 1770 line into a 2 terminal line from Plumtree to Bates Rock substations.	Housatonic Valley	X		X	
Relocate the 22K (37.8 MVAR) capacitor bank to the same side as the 10K (25.2 MVAR) capacitor bank at Stony Hill substation	Housatonic Valley		X		X
Reconfigure the 115 kV 1887 line into a 3-terminal line from Plumtree to West Brookfield to Shepaug substations. Reconfigure the 115 kV 1770 line into 2 two terminal lines from Plumtree to Stony Hill and Stony Hill to Bates Rock substations	Housatonic Valley		X		X
Rebuild the 115 kV 1887-2 line from Shepaug to Brookfield Junction (~0.9 miles)	Housatonic Valley			X	
Install 2 synchronous condensers (+25/-12.5 MVAR) at Stony Hill substation	Housatonic Valley			X	
Install 1 synchronous condenser (+25/-12.5 MVAR) at Stony Hill substation	Housatonic Valley				X

10.2.3 Comparison of the Transmission Alternatives

The transmission alternatives were compared based on system performance, estimated cost, and other key factors such as ease of permitting, constructability, and expandability. Local 2 is the preferred solution because it:

(1) Resolves all thermal and voltage criteria violations in the 10-year planning horizon;

(2) Provides the least-cost alternative to resolve the criteria violations in the sub-area; and

(3) Minimizes environmental and social impacts by focusing the 115-kV transmission upgrades within existing ROWs and on or in the vicinity of existing substations.

10.2.3.1 Comparative Performance

All four transmission alternatives – the two global and two local solutions - would solve the thermal and voltage criteria violations in the Housatonic Valley sub-area, and their operational performance were all comparable. Therefore, this factor did not provide a basis for selecting the preferred option. The study results for each of the transmission alternatives are discussed in detail in the *SWCT Solutions Report.*

10.2.3.2 Comparative Cost

As shown in the Table10-2, a comparison of the costs of the solution alternatives for the Housatonic Valley sub-area demonstrates that the global solution alternatives are far more expensive. The substantially greater cost of the global solutions arises from the fact that both Global 1 and Global 2 include the cost of constructing a new 115-kV line between Bunker Hill and Bates Rock substations on a new, “greenfield” ROW because there are no existing ROWs connecting these substations.

Table 10-2: Cost Comparison of Transmission Alternatives[1]

SOLUTION ALTERNATIVE	COST ESTIMATE
Global 1	$261.0 million
Global 2	$331.2 million
Local 1	$187.4 million
Local 2	$165.7 million

[1] Note that some of the projects included in these cost estimates would be built by Eversource, while others would be built by The United Illuminating Company.

Further, the SWCT Working Group determined that the cost of Local 1 would be materially higher than that of Local 2. The “unique elements” of Local 1 (i.e., those components not included in Local 2) were estimated to cost $47.8 million, while the cost of the unique elements of Local 2 were estimated to cost $26.1 million. The primary reason for this cost differential is that Local 1 would require the installation of two synchronous condensers at Stony Hill Substation, while Local 2 only requires one. Both alternatives also required common elements with an estimated cost of $139.6 million, thus making the overall cost comparison, $187.4 million for Local 1 and $165.7 million for Local 2.

10.2.3.3 Comparison of Environmental Impacts, Permitting, Constructability, and Other Factors

The Global 1 and Global 2 solutions were eliminated from further consideration based on their substantially higher costs (compared to Local 1 and Local 2), as well as the environmental impacts, permitting risks, and constructability issues associated with the construction of a new 10-mile transmission line on a "greenfield" ROW between Bunker Hill Substation in Waterbury and Bates Rock Substation in Southbury. In light of all these factors, the SWCT Working Group determined that neither of the global alternatives would be a practical solution to the reliability issues in these combined sub-areas.

The SWCT Working Group also compared the environmental and constructability issues associated with Local 1 and Local 2, which contain several common components (refer to Table 10-1 for a complete list of the Local 1 and Local 2 components). To differentiate between these two local solution options, the Working Group evaluated and compared only the project components that are not common to each alternative. Based on the Working Group's analyses, both Local 1 and Local 2 are expected to have minimal permitting risks and environmental impacts because the components of both could be developed within existing ROWs and would involve modifications to existing substations, rather than the development of new substations. Similarly, both alternatives were determined to be constructible and are not expected to require complex or lengthy outages during construction. Finally, both alternatives were expected to be in-service by 2017. In sum, none of these "non-cost" factors provided a basis for selecting between the two local alternatives.

10.2.4 Conclusion

Compared to the other transmission alternatives for the Housatonic Valley sub-area, the "Local 2" alternative would be less costly than all of the other alternatives (i.e., approximately $21.6 million less than Local 1 and substantially less expensive than either of the global alternatives), would achieve comparable system performance (by addressing all the thermal and voltage criteria violations at issue), and would result in potentially fewer environmental and social impacts than the two global solutions given its use of existing transmission ROWs. Accordingly, the Working Group selected Local 2 as preferred solution. In this MCF, Eversource proposes to construct specific elements of Local 2 (i.e., the new 115-kV line between Plumtree Substation and Brookfield Junction, reconfiguration of the existing 1887 and 1170 lines, and modifications to Stony Hill Substation). Other components of Local 2 are the subject of other petitions and exempt modification filings before the Council.[101]

10.3 NON-TRANSMISSION ALTERNATIVES (NTA)

Eversource engaged an expert consultant, London Economics International, LLC (LEI), to study non-transmission alternatives to the preferred transmission solution for the Housatonic Valley sub-area identified in the *SWCT Solutions Report*, which includes the proposed transmission improvements that are the subject of this document. LEI is a consulting firm with expertise in analyses of the New England power markets, including economic evaluations, simulation modeling, asset valuation, price forecasting, and market design. LEI has prepared studies of non-transmission alternatives for other transmission solutions that have been the subject of prior Siting Council proceedings, most recently for the Frost Bridge to Campville 115-kV Project (Docket No. 466).

As the starting point for LEI's analysis, Eversource system planners identified quantities of injections of power into the electrical system or load reductions that would be required at particular electrical locations in the Housatonic Valley sub-area in order to obviate the need for regulated transmission improvements. However, Eversource did not determine the types of resources and technology that could, in reality, provide such injections or reductions of demand at each location. Such a determination requires consideration of the suitability of the available technologies for the particular application, including performance characteristics, cost, land requirements, and access to cooling water (if necessary), availability of fuel supplies, and other factors for developing and bringing to commercial operations a new demand reduction program or supply-side resource. Eversource planners also did not undertake to estimate the cost of the NTA solutions to be compared to the cost of the transmission solution. LEI performed all analyses regarding the suitability of available technologies and the cost of such technologies.

[101] The components of the "Local 2" solution described in the *SWCT Solutions Report* included solutions for the reliability issues in both the Housatonic Valley sub-area and the Frost Bridge- Naugatuck Valley sub-area. However, the solution components in each of the sub-areas are not interdependent, and were designed to be implemented independently to address all criteria violations in each particular sub-area.

Eversource planners also determined that demand-side resources alone could not properly address thermal overloads and voltage violations observed in the sub-area and, as such, could not be a technically viable alternative to the proposed transmission solution. Supply-side resources, however, could potentially qualify as technically feasible alternatives to the proposed solution. Eversource identified the quantity and locations of NTAs that would alleviate both thermal system overloads and voltage violations in the sub-area.

Eversource planners determined that a total injection of 247 MW of power over four locations (50 MW at Stony Hill Substation; 47 MW at West Brookfield Substation in Brookfield; 50 MW at Triangle Substation in Danbury; and 100 MW at Peaceable Substation in Redding) would be required to alleviate reliability needs in the sub-area in lieu of transmission upgrades. In addition to the active power requirements (MW), Eversource planners determined that these locations also require reactive power regulation of up to 16 MVAR (Stony Hill and Triangle substations), 15 MVAR (West Brookfield substation), and 33 MVAR (Peaceable substation). Using these assumptions, LEI examined what actual supply-side resources – whether alone or in combination with demand-side resources - could fulfill these energy injection amounts, and selected hypothetical technically feasible NTA technologies for cost analysis, based on the location, costs and other practical factors of consideration. "Technically feasible technologies" are those technologies that could hypothetically be implemented based on planning criteria and technology- specific operating profiles. A technically feasible NTA technology therefore meets the reliability issues being addressed by the proposed transmission components. The results of LEI's studies, as well as a detailed description of their analyses, are contained in a report (LEI Report), a copy of which is included in Volume 4.

As explained in detail in its report, LEI considered two cases in its analysis: (i) an NTA solution solely based on supply-side resources (Supply Case) and (ii) an NTA solution combining both demand and supply-side resources (Combination Case). In light of the determination by Eversource planners that demand-side resources alone would not be sufficient to address reliability concerns, LEI decided to include a Combination Case as an alternative analysis to determine whether combining both demand and supply-side resources would lower the costs associated with an NTA solution.

In both the Supply Case and the Combination Case, LEI identified supply-side resources including slow discharge batteries, peaker aeroderivative and fuel cells as technically feasible NTA technologies at all four substations serving as the injection points. The assessment of technical feasibility included the ability to provide reactive power instantaneously. In the Combination Case, energy efficiency resources (limited to load availability and load reduction capability) were assumed by default to be part of the NTA solution, and as such would cover a portion of the megawatt requirement, while a supply-side resource would address the remainder of the energy requirement, as well as provide reactive power. Some technologies such as gas-fired aeroderivative peakers feature this capability by design; however, providing reactive power instantaneously would require the plant to be constantly running. LEI assumed that all the considered technologies (including engine-based technologies such as gas-fired generation) would need to be accompanied by a synchronous condenser to address the instantaneous nature of the voltage requirement. Although LEI explored the technical feasibility of solar photovoltaic (PV) as NTA at the considered locations, such technology was excluded from the analysis due to cost, the volume of nameplate capacity needed, and the associated land requirements.

LEI then assessed whether the technically feasible NTAs could be cost-effective or practical. LEI employed industry-standard levelized costing principles to select the least cost NTA for each location from the group of technically feasible NTA technologies. Since no merchant sponsor has proposed to build the NTAs, and the NTAs would not generate a return that would attract private investors, LEI assumed that they would be built only if their net costs were imposed on electric ratepayers. LEI estimated the net direct cost to Connecticut ratepayers of the NTAs by deducting expected average annual market-related revenues from levelized annual gross costs.

Tables 10-3 and 10-4 summarize the total requirements and technically feasible NTA technologies, by substation:

Table 10-3: Supply Case - List of Qualified Technologies and Requirements for Each Substation

Substations	Stony Hill	West Brookfield	Triangle	Peaceable
Requirements at substation (MW)	50	47	50	100
Requirements at substation (MVAR)	16	15	16	33
NTA Technologies:				
Aeroderivative Peaker (MW)	59	55	59	118
Synchronous Condenser (MVAR)	25	25	25	50

Table 10-4: Combination Case - List of Qualified Technologies and Requirements for Each Substation

Substations	Stony Hill	West Brookfield	Triangle	Peaceable
Requirements at substation (MW)	50	47	50	100
Requirements at substation (MVAR)	16	15	16	33
NTA Technologies:				
Energy Efficiency (MW)	8	7	10	5
Aeroderivative Peaker (MW)	49	47	48	111
Synchronous Condenser (MVAR)	25	25	25	50

In this case, LEI determined that the least cost NTA solution was the Supply Case; it entails the development of 291 MW of gas-fired peakers (using aeroderivative technology) across four locations (and each of the peaking facilities would include a synchronous condenser for voltage regulation) at a direct cost to customers totaling $53 million per year. By comparison, the direct cost to customers for the Combination Case (combining 31 MW of incremental Energy Efficiency resources and 255 MW of supply-side NTA technologies) was $82 million per year. The direct cost to customers under both the Supply Case and the Combination Case was significantly more than the $2.1 million per year estimated by Eversource as the Connecticut taxpayer's allocated share of the annual revenue requirement associated with the transmission solution for the Housatonic Valley identified in the *SWCT Solutions Report*. This enormous cost differential compelled the conclusion that an NTA would not provide a practical alternative to the transmission solution.

Although Stony Hill Substation is located comparatively near a gas pipeline (less than 0.1 miles), the West Brookfield Substation is about 1.3 miles away from the nearest gas pipeline, while Triangle Substation and Peaceable Substation are located 1.5 miles and 8.2 miles, respectively, from the nearest gas pipelines. For any new NTA involving a gas-fired generator, new gas pipeline laterals would have to be constructed between the existing gas pipelines and these substations. The development of such pipelines would require the potential acquisition of new ROW from private landowners (if road ROWs could not be used) and would result in additional environmental and social impacts associated with construction. This would further increase the cost for Connecticut end-users. Similarly, the NTA estimates above do not include the cost of any transmission system upgrades that may be required to interconnect the NTA technologies. Furthermore, the NTA costs projected by LEI are not inclusive of any locational premiums associated with developing and building in Fairfield County, Connecticut as opposed to more generally in New England.

If the Supply Case and Combination Case NTAs identified by LEI were to be considered further, each would have to be tested in the same manner as the transmission solution was tested in the ISO-NE solution study. In such a study, a generation dispatch would be constructed that would assume one or two of the most critical units in the Housatonic Valley sub-area to be out of service and that approximately 80% of the fast start units in the sub-area (which would include the peaking units) would come on when requested. The results of this study could have indicated that additional capacity beyond that included in the LEI NTA would be necessary to provide, with the required degree of reliability, the injection quantities assumed by LEI.

Such further studies would also have to evaluate a full range of the non-economic costs and benefits of the NTAs, compared to those of the transmission solution. For instance, the environmental effects of the NTAs (e.g., noise impacts and air emissions from the aeroderivative and combined cycle gas turbine (CCGT) plants) would have to be specifically determined and subsequently compared to those of the transmission alternative, which are extensively described in this document (see Section 6). In addition, forward-looking simulation modeling would have to be performed to assess the relative longevity of both the transmission solution and the potential NTA technologies, and to compare the various services and other benefits that each could provide.

However, the cost difference between the NTAs (both the Supply Case and the Combination Case) and transmission solutions in this case is decisive, illustrating that an NTA solution to resolve the reliability issues in the Housatonic Valley sub-area would be economically impractical. Indeed, the economic impracticality of the NTA solution is suggested by the fact that no one has proposed to implement such an NTA for the Housatonic Valley sub-area. Pursuant to the ISO-NE Open Access Transmission Tariff, since no market solution for a reliability need has been implemented, Eversource is required to proceed with a "backstop" regulated transmission solution, as proposed in this MCF.

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11. TRANSMISSION LINE ROUTE / CONFIGURATION ALTERNATIVES

11.1 ROUTING OBJECTIVES AND ALTERNATIVE ROUTE ANALYSIS PROCESS

After a new 115-kV transmission line to connect Plumtree Substation and Brookfield Junction was selected as the preferred transmission system solution to resolve SWCT / Housatonic Valley sub-area reliability issues, Eversource identified and evaluated alternative routes and configurations for the new line. All of the potential alternative routes for the new line would have to interconnect Plumtree Substation and Brookfield Junction to achieve the Project's technical objectives. This section describes the approach that Eversource used to identify and evaluate route alternatives for the proposed line and, from among these alternatives, select the preferred route (i.e., Proposed Route) and overhead line design for the Project.

As described in Section 1[102], the Proposed Route would be located entirely within Eversource's existing approximately 175 to 225-foot-wide transmission line ROW, primarily adjacent to the existing 1770 and 321 lines. Within the Eversource ROW, the new 115-kV line would be aligned adjacent to Eversource's existing 321/1770 lines. This ROW has been devoted to utility use for many years.

11.1.1 Routing Objectives

For the alternatives analysis, Eversource applied an established set of route selection objectives to identify and compare potential routes for the new 115-kV transmission line between Plumtree Substation and Brookfield Junction. These defined line routing objectives, which are listed in Table 11-1, include the following overarching goals:

- The selection of a cost-effective and technically feasible solution to achieve the required transmission system reliability improvements and to interconnect the specified substations; and
- The avoidance, minimization, or mitigation of adverse environmental and cultural effects and minimizing impacts to the community to the extent possible.

102 The modifications to Stony Hill Substation, including the changes to the interconnecting 1887 and 1770 lines, were not included in this alternatives routing study because there are no geographically distinct options for modifying the existing substation and line interconnections.

Table 11-1: Eversource Transmission Line Route Selection Objectives

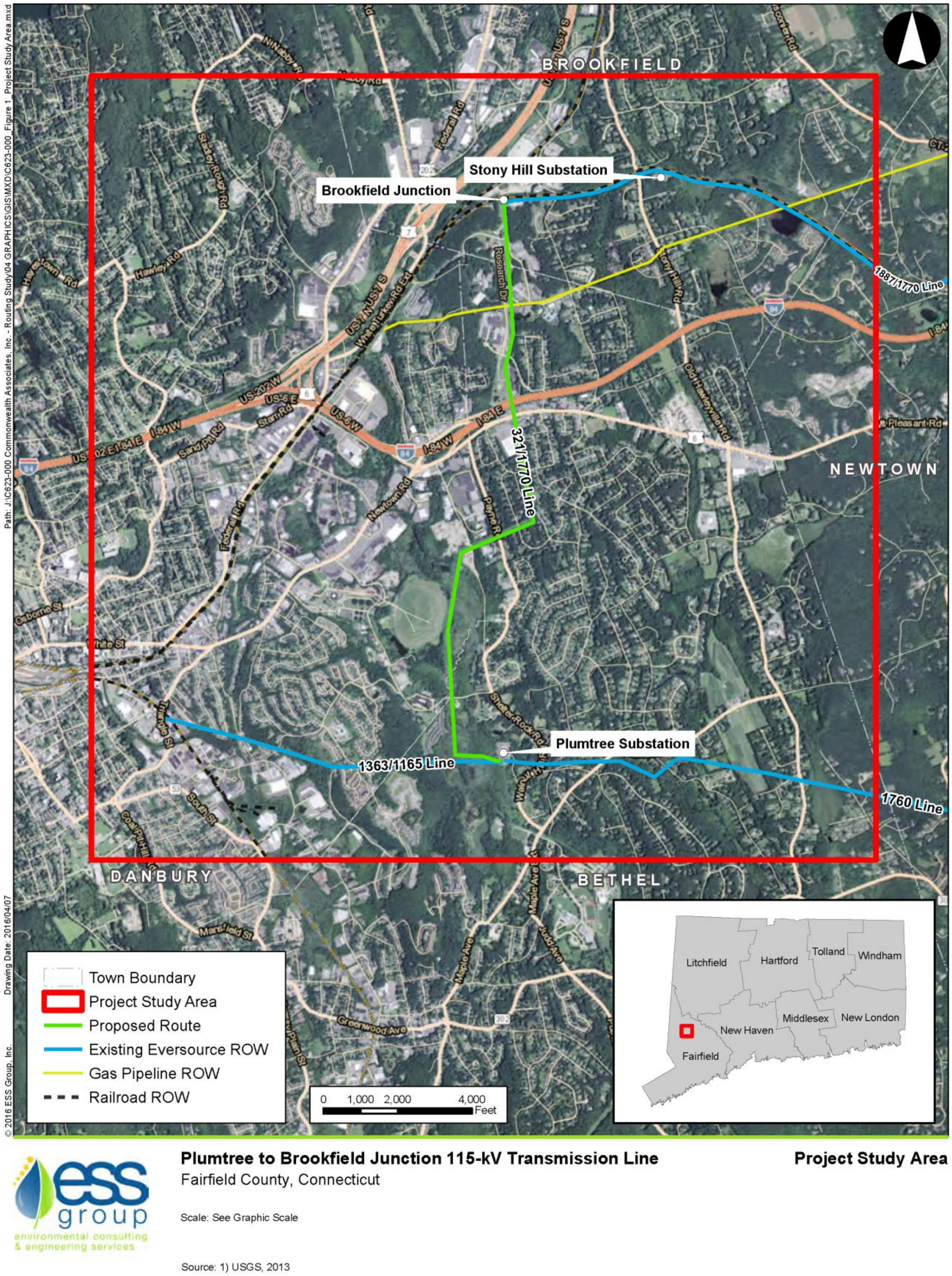
- Comply with all statutory requirements, regulations, and state and federal siting agency policies
- Maximize the reasonable, practical, and feasible use of existing linear corridors (e.g., transmission line, highway, railroad, pipeline rights-of-way)
- Minimize adverse effects to sensitive environmental resources
- Minimize adverse effects to significant cultural resources (archaeological and historical)
- Minimize adverse effects on designated scenic resources
- Minimize conflicts with local, state and federal land use plans and resource policies
- Minimize the need to acquire property by eminent domain
- Maintain public health and safety
- Achieve a reliable, operable and cost-effective solution

11.1.2 Overview of the Alternative Route Identification and Analysis Process

Eversource applied the transmission line route selection objectives listed in Table 11-1 to identify potential 115-kV transmission line route alternatives involving both overhead and underground configurations. These potential route alternatives were then examined, using Eversource's route evaluation criteria for overhead transmission lines (as discussed in Section 11.2) and underground transmission cables (as discussed in Section 11.3), to assess the viability of each option based on operability and reliability, technical feasibility, potential effects on property, potential effects on environmental and cultural resources, and cost. Because overhead and underground transmission line construction and operation are inherently different, the emphasis placed on some of the route evaluation criteria in the analysis of potential route options varied for these two line designs.

As the first step in the alternative route analyses, a Project Study Area was defined taking into general consideration land use and physical constraints, as well as the distance from the two points that the new line must interconnect (i.e., Plumtree Substation and Brookfield Junction). The Project Study Area, which is shown in Figure 11-1, extends approximately 2 miles west and 2 miles east of Eversource's existing ROW that presently extends generally south-north, connecting the substation and Brookfield Junction.

Figure 11-1: Project Study Area



As the next step in the alternative route analysis, Eversource[103] reviewed the Study Area to identify major, geographically distinct, existing linear corridors (e.g., railroad, road, pipeline, transmission line ROWs). In accordance with its routing objective for co-locating new transmission facilities along existing linear corridors where practical, the purpose of this review was to assess whether or not there was available space either within or adjacent to these corridors to accommodate the new 115-kV line. Figure 11-1 identifies the major existing linear corridors in the Study Area, including Eversource's existing ROW between Plumtree Substation and Brookfield Junction. The Study Area was also reviewed to determine the potential viability of new greenfield ROW routes (i.e., not within or adjacent to any existing corridors) for the new transmission line.

This initial investigation involved the review of aerial photography of the Study Area and available geographic information system (GIS) data, including general land uses and environmental features (e.g., vegetative communities, water resources, major designated recreational areas, and developed residential, commercial, and industrial areas). Using this baseline information, Eversource assessed various existing linear corridors to determine if the new 115-kV line could be co-located within or adjacent to such ROWs. Existing corridors reviewed in the Study Area included, among others:

- Highways and major roads (i.e., I-84 and U.S. Route 6 [Stony Hill Road]);
- Local roads (such as Payne Road, Research Drive, and Taunton Lake Road in the Town of Bethel; Vail Road in the towns of Bethel and Brookfield);
- Existing Eversource transmission line ROWs (i.e., the ROW between Plumtree Substation and Brookfield Junction currently occupied by the 321/1770 line, the 1363/1165 Line ROW that extends west from Plumtree Substation, and the 1760 Line ROW that extends east from Plumtree Substation into the Town of Newtown);
- A natural gas pipeline ROW that traverses west-to-east through the northern portion of the Project area; and
- Railroads (i.e., the Housatonic Railroad Company's Berkshire Line [Beacon, New York to Pittsfield, Massachusetts and Maybrook Line).

In addition, Eversource assessed regional topographic and land use conditions to determine whether any opportunities existed to site the new 115-kV transmission line in an entirely new greenfield ROW.

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103 The alternative routes were identified and evaluated by a team consisting of Eversource staff, as well as specialized engineering and environmental consultants. This team conducted field reconnaissance, performed baseline data collection and reviewed aerial photography to determine the characteristics of each route alternative and to assess each in terms of the Project objectives and Eversource's route evaluation criteria.

As a result of this initial review, 10 potential routes were identified. These included the alignment ultimately selected as the Proposed Route (along Eversource's existing ROW between Plumtree Substation and Brookfield Junction), as well as nine other alternatives. Along these alternative routes, Eversource evaluated the alignment of the new 115-kV line in either overhead or underground configurations, or combinations thereof. In total, the analysis resulted in the identification and evaluation of the Proposed Route, in addition to five all overhead route alternatives, one all-underground route alternative, and three combination overhead/underground route alternatives.

Five of the nine alternative routes identified also included segments of greenfield ROW. However, given the comparatively dense urban / suburban development in the Study Area (as illustrated in Figure 11-1), Eversource's analyses determined that there are no feasible locations[104] where an entirely new utility corridor could be established to connect Plumtree Substation and Brookfield Junction.

Figures 11-2 and 11-3 illustrate the general locations of the Proposed Route and the route alternatives, which are identified as follows:

- Proposed Route – Along Eversource's existing ROW
- Alternative 1 – Old Sherman Turnpike to Greenfield to Railroad Route
- Alternative 2 – West on Greenfield to Railroad Route
- Alternative 3 – Utility ROW West to Railroad Route
- Alternative 4– Utility ROW West to Greenfield to Railroad Route
- Alternative 5 – U.S. Route 6/I-84 West to Railroad Route
- Alternative 6 – Utility ROW East to Old Hawleyville Road to Railroad Route
- Alternative 7 – East on U.S. Route 6 and Roads to Greenfield Route
- Alternative 8 – U.S. Route 6 East to Greenfield to Railroad Route
- Alternative 9 – All Underground Route

Using its established route evaluation criteria for overhead and underground transmission line siting, Eversource conducted more detailed analyses of each of these alternatives, comparing them to the Proposed

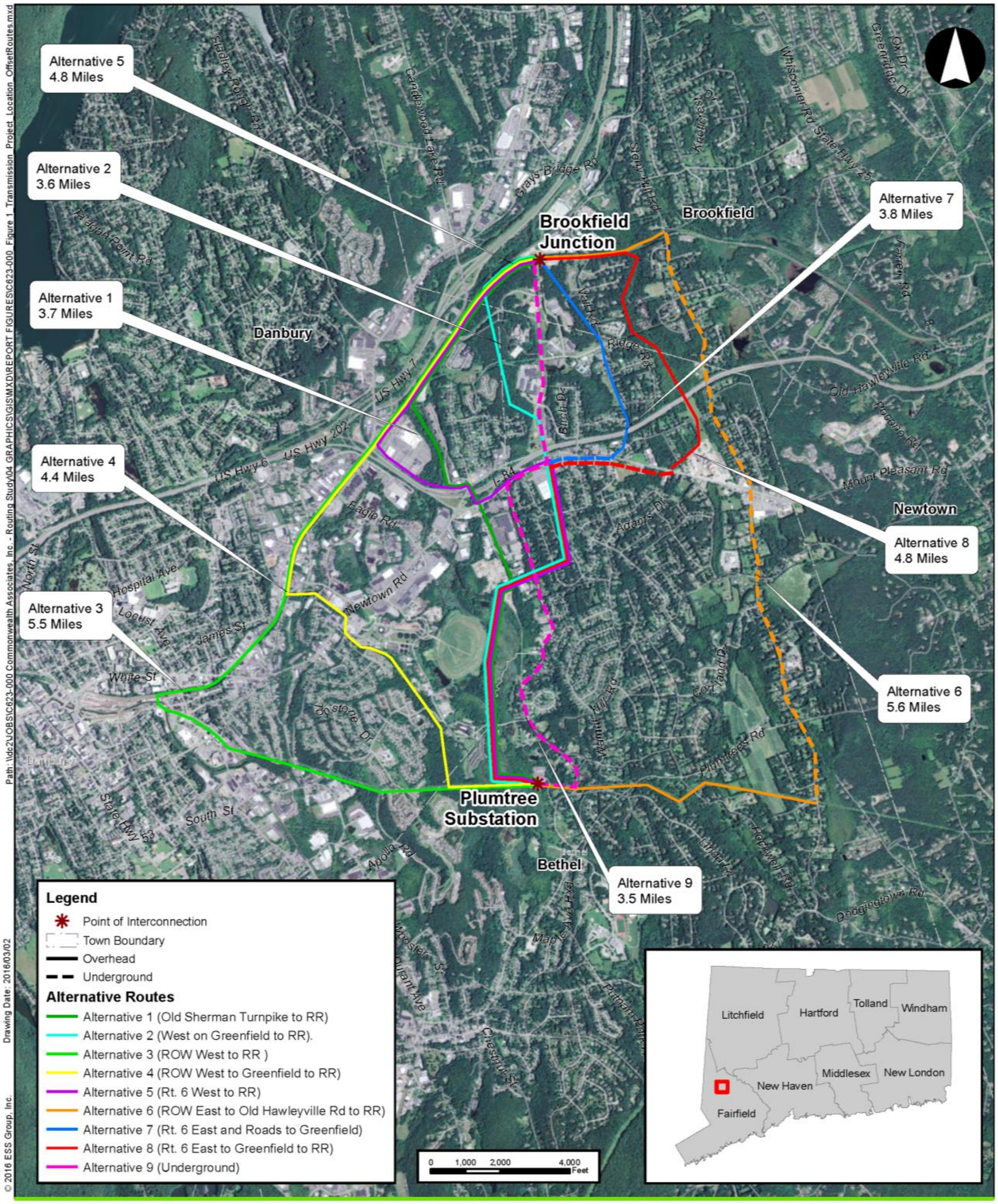
[104] Creation of an entirely new ROW for the proposed 115-kV line would require the acquisition of private property and removal of existing structures (e.g., homes, commercial buildings), which would not be consistent with Eversource's routing objectives.

Route and taking into consideration environmental and social impacts, constructability, and cost, among other factors.

The routing criteria and the results of the alternative route evaluations are discussed in Sections 11.2 (for the all overhead route alternatives) and 11.3 (for the all underground line design route alternatives or a combination of overhead / underground line design route alternatives).

Section 11.4 summarizes Eversource's rationale for preferring to locate the new 115-kV transmission line along the Proposed Route, in an overhead configuration, rather than along any of the route alternatives. Figure 11-3 shows a closer view of the Proposed Route.

Figure 11-2 Alternative Route Map



Plumtree to Brookfield Junction 115-kV Transmission Line
Fairfield County, Connecticut

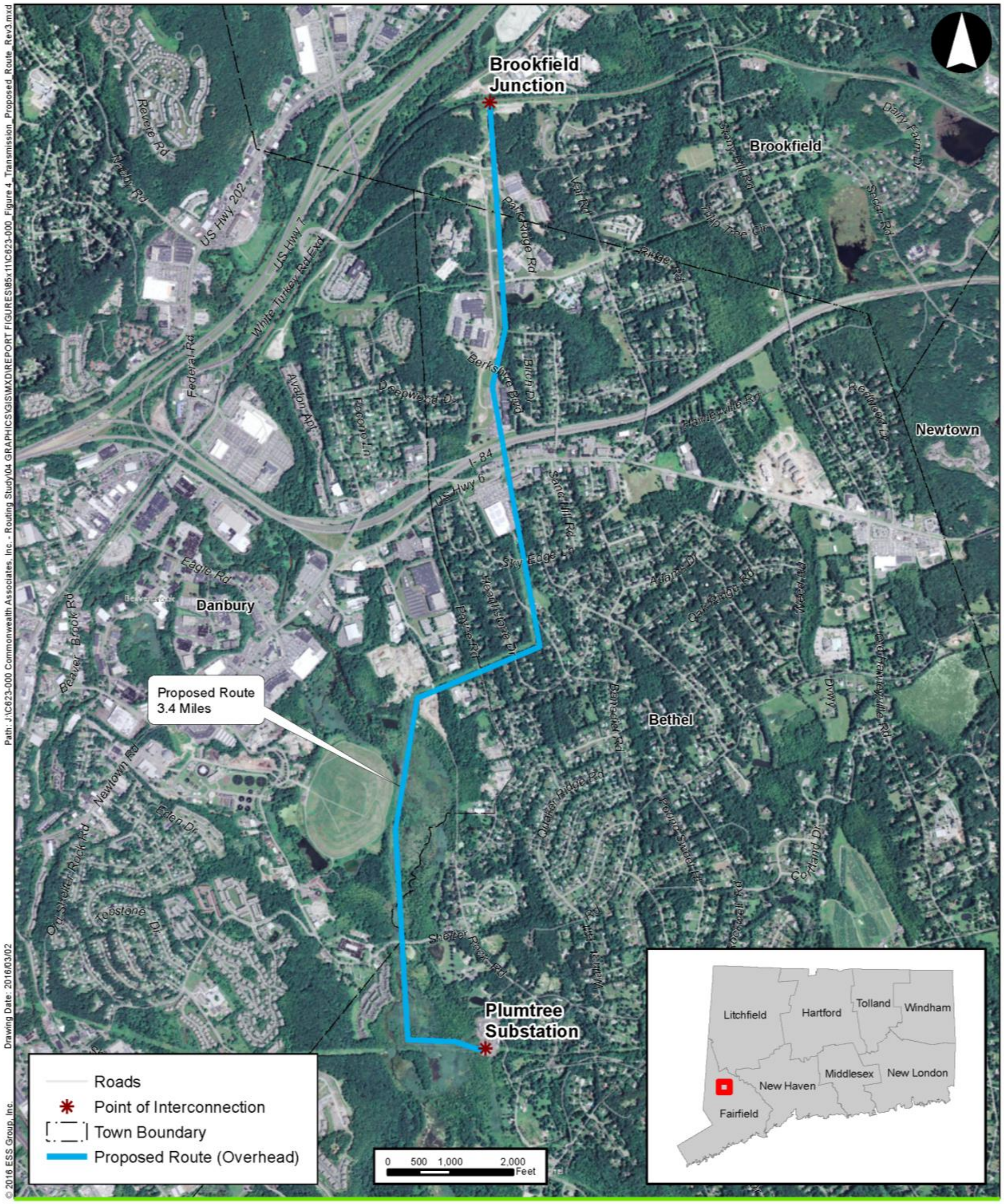
Alternative Routes

ess group environmental consulting & engineering services

Scale: See Graphic Scale

Source: 1) USGS, 2013

Figure 11-3: Proposed Route Map



Plumtree to Brookfield Junction 115-kV Transmission Line
Fairfield County, Connecticut

Proposed Route

Scale: See Graphic Scale

Source: 1) World Orthoimagery, 2015

11.2 OVERHEAD TRANSMISSION LINE ROUTES: ALTERNATIVES ANALYSIS

11.2.1 Route Evaluation Criteria

Along with the route selection objectives listed in Table 11-1, Eversource applied an established set of route evaluation criteria to identify, evaluate and compare potential overhead transmission line routes for the proposed Plumtree Substation to Brookfield Junction line.

Overhead transmission lines allow some design flexibility, provided that a continuous ROW of adequate width is available. Individual transmission line structures often can be located to avoid, or to allow the conductors to span over, sensitive environmental areas (e.g., wetlands, watercourses and lakes, steep slopes, important wildlife habitat).

Overhead lines require ROWs within which certain land uses (such as building a new permanent structure) are precluded and along which vegetation must be managed to prevent tall-growing trees within conductor zones. (Refer to Section 4 for information regarding overhead transmission line construction and ROW vegetation management procedures).

Taking these factors into account, Eversource gave primary consideration to the criteria listed in Table 11-2 when evaluating potential routes for a new overhead 115-kV transmission line. Potential route alternatives for the new 115-kV line, aligned in an overhead configuration, were considered along (within or adjacent to) existing utility ROWs, interstate highways, local roads, and railroad corridors, as well as through greenfield areas where a new ROW for the line would have to be developed.

Section 11.2.2 describes the primary factors considered in evaluating potential overhead alternatives for the new 115-kV line. Section 11.2.3 discusses and compares to the Proposed Route the specific characteristics of the five overhead line route alternatives identified and ultimately eliminated from consideration for the Project.

Table 11-2: Route Evaluation Criteria for 115-kV Overhead Transmission Line Siting

ROUTING CRITERIA	DESCRIPTION
Availability of Existing ROWs for the New Line to Follow	The potential co-location of the 115-kV transmission facilities along existing ROWs where linear uses are already established (e.g., transmission lines, highways, railroads, pipelines) is a primary routing consideration. The co-location of linear utilities within existing utility corridors is strongly favored by the Federal Energy Regulatory Commission's *Guidelines for the Protection of Natural, Historic, Scenic, and Recreational Values in the Design and Location of Rights-of-Way and Transmission Facilities*, with which any electric transmission line approved by the Council must be consistent.[105] **New ROW**. The ROW width required for an entirely new 115-kV overhead line route would vary depending on the type of transmission line structure, which affects the conductor clearance required from vegetation. Typically, a line with a delta configuration would require a minimum 90-foot-wide ROW, a line with a horizontal (H-frame) configuration would require a, 100-foot-wide ROW, and a line with a vertical configuration would require a 70-foot-wide ROW. **Existing ROW.** The placement of a new 115-kV transmission line within an existing corridor (parallel to existing transmission lines) may require a lesser expansion of an existing ROW or may not require any additional ROW at all, providing that the existing ROW is wide enough and has sufficient un-used space for the new 115-kV transmission line. Typically, to accommodate a new 115-kV delta transmission line adjacent to an existing H-frame or delta 115-kV transmission line, approximately 50 feet of additional ROW would be required. Aligning a new 115-kV H-frame adjacent to an H-frame or delta 115-kV transmission line would require approximately additional 60 feet. A new vertically-configured 115-kV line, located adjacent to an existing 115-kV line, supported on H-frame or delta structures, would require only an additional 30 feet of ROW.
Engineering Considerations	Whether on existing or new ROWs, the terrain and location of the transmission line route and constructability issues must be considered since both may have a significant bearing on cost and effects on environmental resources. Among the constructability factors considered is the ability to avoid or minimize the location of structures along steep slopes or embankments, in areas of rock outcroppings, or within environmentally sensitive areas, such as wetlands. Engineering requirements for the transmission line and access roads (as necessary) to cross streams, railroads, and other facilities are also assessed. Terrain and access constraints (e.g., side slopes, rugged topography) due to extreme side slopes are assessed.
Avoidance or Minimization of Conflicts with Developed Areas	Where possible, it is preferable to avoid or minimize conflicts with residential, commercial, and industrial land uses such as homes, businesses, and airport approach zones. One of Eversource's primary routing objectives for any proposed transmission line is to minimize the need to acquire (by condemnation or voluntary sale) homes or commercial buildings to accommodate the new transmission facilities.
Consideration of Visual Effects	Because 115-kV transmission line structures typically range from 70 to 105 feet tall (depending on structure configuration), structure visibility is a design consideration. In recognition of public opinion regarding structure visibility, it is desirable to avoid placing structures in areas of visual or historic sensitivity; to consider designs for minimizing structure height; and to assess the potential visual effects of removing mature trees along ROWs, as required to conform to electrical clearance requirements (i.e., the potential implications of removing trees that provide vegetative screening). Vertical structures typically have the greatest visibility effects. However, structure visibility effects are incremental if new overhead lines are placed within existing ROWs along which overhead transmission lines are already part of the visual landscape.
Avoidance or Minimization of Environmental Resource Effects	In accordance with federal, state, and municipal environmental protection policies, the avoidance or minimization of new or expanded corridors through sensitive environmental resource or recreation areas such as parks, wildlife management areas, and wetlands is desired.
Accessibility	An overhead line must be accessible to both construction and maintenance equipment. Although access along the entire overhead line route is typically not needed, vehicular access to each structure location from some access point is required.

105 CGS Section 16-50p(a)(3)(D)

11.2.2 Summary of Alternative Overhead Line Routing Considerations in the Study Area

The following section identifies and summarizes the principal factors associated with the various types of routing options considered for siting the new 115-kV line in an overhead configuration. Figure 11-1 illustrates the principal existing ROWs (highways, transmission line, pipeline, and railroad) that traverse the Study Area and that are discussed as potential routes for the new 115-kV line in the following subsections.

The five alternatives, which along with the Proposed Route, that are illustrated on Figures 11-2 and 11-3, are:

- Proposed Route – Along Eversource's existing ROW
- Alternative 1 – Old Sherman Turnpike to Greenfield to Railroad Route
- Alternative 2 – West on Greenfield to Railroad Route
- Alternative 3 – Utility ROW West to Railroad Route
- Alternative 4– Utility ROW West to Greenfield to Railroad Route
- Alternative 5 – U.S. Route 6/I-84 West to Railroad Route

11.2.2.1 Alternative Routes in New Rights-of-Way

As Figure 11-1 illustrates, the Project Study Area encompasses densely-developed portions of Bethel, Danbury, and Brookfield. As a result of these extensive suburban and urban land uses, Eversource's evaluations quickly found that the development of the proposed 115-kV line on an entirely new greenfield ROW between Plumtree Substation and Brookfield Junction would be infeasible.

In particular, given the density of development in the Study Area, it would be impossible to create a new transmission line ROW between Plumtree Substation and Brookfield Junction without significant direct impacts to existing residential, commercial, and industrial land uses (i.e., as a result of acquisition of easements over private property), as well as adverse impacts to environmental resources. Assuming the use of a delta structure configuration for the new line (refer to Table 11-2), a minimum 90-foot-wide ROW easement would need to be acquired.

The requisite transmission line easements to create a new greenfield ROW would restrict property owners' land uses within the ROW to those that are compatible with the operation of the transmission facilities. Removal or relocation of existing buildings might be required and specific types of land uses would be precluded. The ROW would have to be managed in low-growing vegetation, and access to the transmission line structures would typically be required.

In addition to these easement acquisition issues, the majority of the vegetation along any greenfield ROW would have to be removed and access roads would have to be created within the new ROW to construct the proposed 115-kV transmission line. The creation and maintenance of such a greenfield ROW can cause greater environmental impacts (e.g., permanent fill in wetlands due to new access roads and structures, development of a new linear corridor through undisturbed forested communities, crossings of water resources, and preclusion of certain other land uses within the corridor). Moreover, because of the dense urban / suburban character of the Study Area, the remaining undeveloped lands typically consist of areas with environmental constraints (e.g., extensive wetland complexes, watercourses such as the Still River, steep topography, Danbury Landfill) or protected open space (land trust properties, public parks).

In addition, the creation of a new transmission line corridor, when existing ROWs are available and practical to use, does not conform to federal and state policies regarding the co-location of linear facilities and requirements to find the least environmentally damaging practical alternative to avoid or minimize adverse effects to water resources and other environmental and cultural resource features. In general, the installation of new transmission line facilities along existing ROWs (e.g., transmission line ROWs, pipeline corridors, highways, railroads) is environmentally preferable to creating entirely new corridors through properties previously unaffected by linear developments.

Given the overall density of urban and suburban development in the Study Area, any alternatives involving an entirely new greenfield ROW between Plumtree Substation and Brookfield Junction were determined to be impractical based on significant impacts to existing property owners and land uses, the cost and time for acquiring the new easements from property owners, environmental considerations, and the potential availability of various existing linear corridors within the Study Area (e.g., Eversource's existing ROWs, roads, and railroads).

11.2.2.2 Alternative Routes along Highway Rights-of-Way

Within the Study Area, Eversource investigated the collocation of the new 115-kV line within or along various road ROWs, including I-84, U.S. Route 6, and local roads. Key considerations in the review of these alternative routes were the locations of roads in relation to the substation and junction that must be interconnected, as well as construction feasibility and potential environmental resource and social effects. The following road networks were evaluated:

- **<u>I-84 and U.S. Route 6 (Stony Hill Road</u>)**. I-84, a controlled access highway within the Study Area, and U.S. Route 6 were both reviewed to assess potential route opportunities for the new 115-kV line. Although both highways extend generally east-west and would not directly connect Plumtree Substation and Brookfield Junction, portions of each were considered because, compared to most local roads, these highways have wider ROWs, including undeveloped areas outside of paved travel lanes, where land may be available to accommodate an overhead transmission line. This situation is particularly true of limited-access highways such as I-84.

  Generally, in order to construct a new overhead, delta-configured, 115-kV transmission line, a 90-foot-wide ROW would be required; however, if an agreement could be reached with ConnDOT to share the outer portion of the highway corridor with an overhead transmission line easement, then the required new ROW width could be possibly be reduced.

  Conversely, longitudinal co-location of transmission lines in ConnDOT limited access highway corridors is not permitted except in special circumstances under the Utility Accommodation Policy as provided in ConnDOT's Utility Accommodation Manual (2009). As determined during the review of previous Eversource transmission line projects, ConnDOT opposes the co-location of transmission lines in state road ROWs, particularly if other routing alternatives, such as the use of existing utility ROWs, are available.

  In addition, these corridors would pose particular challenges for the development of a new transmission line because of physical, land use, or environmental constraints. Most portions of the highways within the Study Area extend through areas constrained by residential or commercial land uses. Wherever the transmission line ROW could not be located within the highway easement, new ROW would have to be acquired from private landowners.

- **<u>Local Road ROWs</u>**. The alignment of the new 115-kV transmission line within or adjacent to local road ROWs or other two-lane highways pose similar constraints. For example, the primary determinant of construction feasibility is a lack of adequate space for a new overhead 115-kV transmission line ROW. That could require displacement of homes or businesses located adjacent to the road.

  The development and operation of a new overhead transmission line adjacent to either two-lane state highways or local road ROWs also would affect the aesthetic environment because the new transmission line would be visible both to travelers on the highways and to local residents and business patrons. Additionally, while overhead electric distribution lines and telephone lines can be configured to follow winding roads, high voltage transmission lines are designed for mostly straight-line, longer-span construction.

  As a result, the design and construction of a new 115-kV transmission line adjacent to these roads would be both technically difficult and costly, and would result in potentially significant land use and environmental impacts (e.g., as a result of the removal of vegetation adjacent to road ROWs to achieve mandated conductor clearances, possible need to acquire new utility easements from private landowners, depending on the width of the road ROWs). Further, compared to structure heights along a typical transmission line ROW, the transmission line structures along a local road ROW would likely have to be taller to maintain conductor clearances over the distribution and telephone lines that are presently aligned along the roads.

11.2.2.3 Alternative Routes along Railroad Rights-of-Way

Within the Study Area, there are two railroad corridors owned by the Housatonic Railroad Company:

- The Berkshire Line, which extends between Beacon, New York and Pittsfield, Massachusetts, traversing generally southwest – northeast through the western portion of the Study Area; and
- The Maybrook Line, which extends west – southeast between the Town of Brookfield to the Town of Derby/City of Shelton, generally bordering the northern portion of the Study Area.

Neither of these railroad corridors would offer a direct interconnection between Plumtree Substation to Brookfield Junction; however, portions of the rail corridors were considered for segments of the overhead route alternatives (refer to Section 11.2.3).

Generally, in order to construct a new overhead, delta-configured, 115-kV transmission line, a 90-foot-wide ROW would be required. The railroad ROWs are often narrow, and may not have sufficient available space for that design. While the required width may be reduced somewhat, discussions would be required with the railroad to determine the required specification for the transmission line, which would include offsets and clearances over the railroad. Rights would be required in the form of a license or easement for the installation. Due to the traffic on the railroad, construction and future maintenance of the line would need to consider possible work windows or other scheduling constraints.

The use of railroad ROWs as potential overhead transmission line routes for the Project are typically found to be impractical due to construction difficulties and constraints; and the social effects associated with impacted commercial or residential property, as discussed further in the Section 11.3.2. Also, the need to follow railroad ROWs that do not provide direct routes between the substations that must be interconnected, and the number and extent of acquisitions of property rights would result in comparatively higher costs than would the development of an overhead line within the existing transmission line ROW that already extends directly between Plumtree Substation and Brookfield Junction.

11.2.2.4 Alternative Routes along Transmission Line and Pipeline Rights-of-Way

Existing transmission line and pipeline ROWs in the Study Area were reviewed to assess whether the new 115-kV line could practically be constructed within all or portions of these corridors. In addition to Eversource's existing 321/1770 Line ROW between Plumtree Substation and Brookfield Junction, four other utility corridors were examined within the Study Area (refer to Figures 11-1 and 11-2):

- Three existing Eversource corridors (all occupied by 115-kV overhead lines):
  - ✓ The 1363/1165 Line ROW, which traverses west from Plumtree Substation to the existing Triangle Substation in the City of Danbury;
  - ✓ The 1760 Line ROW, which extends east from Plumtree Substation toward Newtown Substation (in the Town of Newtown); and
  - ✓ The 1887/1770 Line ROW, which extends east from Brookfield Junction along and adjacent to the railroad, to Stony Hill Substation.
- An interstate natural gas pipeline ROW that extends west-to-east across the northern part of the Study Area, north of I-84.

Except for the Proposed Route along the existing 321/1770 Line ROW, none of these existing corridors would provide a direct connection to both Plumtree Substation and Brookfield Junction (refer to Figure 11-1). The natural gas pipeline corridor was eliminated from consideration because it is aligned west-to-east and offers no potential connection to either Project end point; however, alternative routes using portions of the existing Eversource ROWs, combined with segments of other existing corridors in the Study Area (e.g., road, railroad), were found to merit further consideration as alternatives to the Proposed Route.

11.2.3 Overhead Route Alternatives Considered but Eliminated

Five all-overhead route alternatives were identified and evaluated for the new 115-kV line. To the extent practical, these alternatives were routed to optimize the use of linear corridors. Given the extent of land use development in the Study Area, all of the route alternatives involved the use of existing utility ROWs, combined with railroad or highway corridors and, in two cases, new greenfield ROW segments.

Table 11-3 summarizes the principal characteristics of the all-overhead route alternatives, compared to the Proposed Route, while Figure 11-2 illustrates the locations of these five overhead route alternatives. Compared to the development of the new 115-kV line along the Proposed Route, Eversource's analyses determined that each of these routes would be longer, more costly, and would be less suitable for the development of a new transmission line due to factors such as engineering constraints, geologic conditions, need for new utility easements, and/or the potential for significant environmental, social, or economic effects.

The following subsections provide additional information concerning each route alternative, including the primary factors that led Eversource to eliminate each from consideration.

Table 11-3: Summary and Comparison of All-Overhead Route Alternatives Considered and Eliminated

Route Alternative Characteristic	Route Alternative (Number)					Proposed Route
	1	2	3	4	5	
LENGTH*						
Total Length (Miles)	3.66	3.63	5.50	4.36	4.79	3.34
Length, by Municipality (Miles):						
• Bethel	0.63	2.12	0.51	0.51	1.63	2.16
• Danbury	2.59	1.07	4.55	3.41	2.72	0.85
• Brookfield	0.44	0.44	0.44	0.44	0.44	0.34
ROW CHARACTERISTICS						
Length within Transmission Line ROWs (miles)	1.33	2.47	1.70	0.46	2.23	3.34
Length along Local/State Road ROWs (miles)	0.59	0	0	0	0.59	0
Length along RR Corridors (miles)	1.11	0.34	3.72	2.36	1.40	0
Length of Greenfield ROW (miles)	0.51	0.82	0	1.53	0	0
Need to Acquire New ROW	Yes	Yes	Yes	Yes	Yes	No

*Length totals may not be exact due to rounding of segment lengths

11.2.3.1 Alternative 1 – Old Sherman Turnpike to Greenfield to Railroad Route

Alternative 1, which would be approximately 3.7 miles long, would be located along a combination of Eversource transmission line ROW, road ROWs, a greenfield ROW segment, and a railroad ROW.

Specifically, this alternative would extend north from Plumtree Substation following the same Eversource ROW as the Proposed Route, before diverging due north adjacent to Old Sherman Road and then crossing both U.S. Route 6 (Stony Hill Road) and I-84. In the vicinity of the densely developed area near Old Sherman Turnpike, U.S. Route 6, and I-84, the location of the new 115-kV line would likely affect abutting commercial and industrial properties. Further, an overhead crossing of I-84 could pose constructability issues due to the density of land use development on either side of the crossing.

North of I-84, Alternative Route 1 would be aligned along a greenfield ROW segment for approximately 1.3 miles. Within this segment, the alternative route would extend along the wooded riparian corridor of the Still River, traversing between the Avalon Danbury condominium development along East Ridge Drive and a commercial area (containing a Lowes Home Improvement, Best Buy, and AME Loews movie theater complex). In this area, new ROW would have to be acquired from private property owners, and forest and other vegetation clearing would be required. A majority of this alternative route segment would be within the Still River floodplain and wetlands.

The greenfield ROW segment of Alternative 1 would connect to the railroad corridor south of White Turkey Road Extension, and would extend northeast parallel to this corridor to Brookfield Junction. Portions of this railroad corridor include two rail lines; the corridor is bordered by wooded vegetation.

Route Alternative 1 would be longer than the Proposed Route, would be challenging to site across I-84 and would involve impacts to private property owners and environmental resources. Because this route does not offer any significant advantage over the Proposed Route, it was eliminated from further consideration.

11.2.3.2 Alternative 2 – West on Greenfield to Railroad Route

Alternative 2 would extend north from Plumtree Substation following Eversource's existing 321/1770 Line ROW (i.e., the Proposed Route). The alternative would be aligned along the Eversource ROW for 2.47 miles, crossing U.S. Route 6 and I-84, before deviating west from existing ROW onto a greenfield ROW just south of Research Drive in Bethel. The greenfield ROW segment would traverse undeveloped forest land west of Duracell's corporate headquarters and east of residential areas along Craigmoor Terrace/Deepwood Drive and White Oak Drive. However, this alternative would avoid the alignment of a new overhead transmission line within most of the Berkshire Corporate Park. The total length of this alternative would be approximately 3.6 miles.

For the first 2.47 miles, this alternative would affect the same environmental and cultural resources as the Proposed Route; however, along the greenfield ROW portion of this route, Eversource would have to acquire utility easements for the new 115-kV line across private properties. In addition, to construct and operate the new line along the greenfield ROW portion of the route, approximately 9 acres of forested vegetation would have to be removed and access roads would have to be created within the new ROW. Because of the additional impacts associated acquiring utility easements and the tree removal with the creation of greenfield ROW, this alternative was eliminated from further consideration.

11.2.3.3 Alternative 3 - Utility ROW West to Railroad Route

This overhead alternative route would involve the alignment of the new 115-kV line along a combination of existing Eversource ROWs and railroad corridors. The alternative route would extend west from Plumtree Substation, following Eversource's existing 1363/1165 transmission line ROW through developed portions of the City of Danbury to an intersection with the railroad line near Chestnut Street Extension. The alternative route would be aligned adjacent to the railroad corridor to Brookfield Junction.

At 5.5 miles in length, Alternative 3 is the longest of the route alternatives. This alternative route would extend through densely developed residential, commercial, and industrial areas, as well as some areas of steep slopes. Because of the density of development (primarily commercial and industrial uses) adjacent to the railroad corridor, space to install a new overhead transmission line would be constrained. As a result, Alternative 3 would provide no advantages over the Proposed Route and was eliminated from further consideration.

11.2.3.4 Alternative 4 – Utility ROW West to Greenfield to Railroad Route

Alternative 4 is similar to, but (at 4.36 miles) is shorter than, Alternative 3. Like Alternative 3, Alternative 4 would extend west from Plumtree Substation following Eversource's existing 1363/1165 transmission line ROW; however, after approximately 0.5 mile, this alternative route would deviate from the existing transmission line ROW, turning north to traverse a wooded undeveloped parcel between Concord and Woodcrest lanes (along which a large condominium / townhouse development is located). Alternative 4 would continue northwest along a greenfield ROW for approximately 1.5 miles, traversing woodlands behind residential areas, as well as near industrial developments (such as the Danbury sewage treatment plant) and extensive commercial areas along and north of Newtown Road. The route also would cross the Still River before intersecting the railroad corridor and turning northeast to parallel the rail line to Brookfield Junction (as described for Alternative 3).

Alignment of this route along the greenfield ROW corridor would require the acquisition of new ROW easements from private landowners, as well as an estimated 18 acres of forested vegetation clearing. Additional easements and removal of forested vegetation also would likely be required along the railroad. Given the congested industrial and residential areas on both sides of the Alternative 4 ROW, space constraints are prevalent along the route.

Due to these space constraints and environmental factors, and the fact that this option would be 1 mile longer than the Proposed Route and therefore more costly, Alternative 4 does not offer any overall advantage over the Proposed Route. Thus, Alternative 4 was eliminated from consideration.

11.2.3.5 Alternative 5 – Route 6/I-84 West to Railroad Route

The approximately 4.8-mile Alternative 5 would be aligned along Eversource's existing 321/1770 Line ROW, as well as road and railroad corridors. In particular, this alternative route would follow Eversource's existing ROW (i.e., the Proposed Route) for approximately 2.2 miles to the intersection with U.S. Route 6 near Target, where the alternative route would diverge to the west, following U.S. Route 6 (eastbound lanes) to the vicinity of the Old Sherman Turnpike. At Old Sherman Turnpike, Alternative 5 would cross I-84 and then would be aligned west along the I-84 corridor, crossing the Still River and passing adjacent to Loews Cinemas and Best Buy, before intersecting with the railroad corridor near Eagle Road.

After review, Alternative 5 was eliminated from consideration as a viable route for the new 115-kV line. At 4.8 miles, the route would be 41% longer than the Proposed Route and would result in comparatively greater environmental and social impacts. Further, collocation within the I-84 corridor would conflict with ConnDOT policies and the crossing of I-84 in the constrained area near the Still River and residential / commercial developments would pose constructability issues. Thus, apart from avoiding alignment through the Brookfield Corporate Park, Alternative 5 offers no advantages over the Proposed Route. Accordingly, this alternative was eliminated from consideration.

11.3 UNDERGROUND TRANSMISSION LINE ROUTE ALTERNATIVES

The vast majority of transmission lines in Connecticut as well as throughout the United States are overhead transmission lines. Underground transmission cable systems, consisting of both buried electric cables and splice chambers[106] (or "splice vaults", which are required at specified intervals along a cable route), may warrant consideration when overhead lines are impractical due to site-specific environmental, social, construction, or regulatory factors, or in the rare case where there is not a large cost difference between overhead and underground alternatives. The typical costs for constructing an underground 115-kV transmission cable system are five to 10 times greater than those for installing and equivalent length of overhead 115-kV transmission line within an existing ROW (refer to Section 11.3.1.4 for a discussion of cost considerations regarding underground cable systems).

[106] Appendix 11A describes the components of a 115-kV cable system, as well as cable system construction procedures.

Compared to overhead transmission lines, an underground cable system can fit within a narrower ROW. However, an underground cable system entails a continuous trench and the installation of underground splice vaults, both of which must remain completely accessible by large vehicles for utility maintenance purposes. Environmentally sensitive areas, such as wetlands and streams, cannot be spanned by an underground cable as they can with overhead lines. Careful siting is required to avoid or minimize significant effects to environmental resources and other utilities as a result of trenching activities, as well as to provide accessibility to the cable system if maintenance or repair is required during the operation of the facility.

Within the past twelve years, the Company has sited and installed underground transmission cable systems in Connecticut as part of the Bethel-Norwalk Project (345-kV and 115-kV transmission cables), Middletown-Norwalk Project (345-kV and 115-kV transmission cables), the Glenbrook Cables Project (115-kV transmission cables), and the Stamford Reliability Cable Project (115-kV transmission cable). As a result, the Company has extensive, recent experience in underground transmission cable routing, construction, and cost analysis.

Eversource applied this extensive experience to the consideration of underground alternatives for the new Plumtree Substation to Brookfield Junction 115-kV line. This section first reviews overall considerations with respect to underground cable system routing and construction (Sections 11.3.1 and 11.3.2) and then describes the all-underground and combination overhead/underground route alternatives considered for the Project's new 115-kV line (Section 11.3.3). However, as described in the following sections, because of environmental, social, constructability, and cost considerations (including the availability of an existing transmission line ROW within which a new overhead line could be entirely accommodated), all of the underground route alternatives for the new 115-kV line were determined to be less preferable than the Proposed Route and overhead line design.

11.3.1 Cable Technology Considerations and Route Evaluation Criteria

Underground cable systems and overhead transmission lines represent different technologies for transporting power. In an individual system application, one of these line types may not be practical to use, given specific project considerations, such as the length of the transmission line to be installed, terrain, availability of ROWs, urbanization, etc. Further, for this Project, considering the electrical system capacity requirements at Plumtree Substation, any underground transmission line would need to be in a double circuit configuration.

In addition, there are technical issues with respect to the installation of underground cable systems, such that extensive technical studies by power system engineers may be required to determine the feasibility of a particular underground installation. In this case, power system studies that would be required to analyze the performance and possible technical limitations of an underground system were not performed. Rather, the feasibility of the identified all-underground or combination underground/overhead alternatives discussed in Section 11.3.3 were assumed for the purpose of this routing analysis, the objective of which was to determine if any underground routes were practical, compared to overhead line routes, based on cost, constructability, and environmental / social factors.

11.3.1.1 Selection of Underground Transmission Cable Technology

There are two distinct types of 115-kV underground cables that are in common use in the Eversource transmission system: High Pressure Fluid Filled (HPFF) and Cross-linked Polyethylene (XLPE). The principal characteristics of each of these technologies are:

- **HPFF.** Three individual cables, called cores, are used to form a circuit. The cores are encased in a steel pipe that is filled with insulating fluid and then pressurized to a nominal 200 pounds per square inch (psi), which requires pressurization plants and reservoirs. These reservoirs hold thousands of gallons of insulating fluid. HPFF cable was traditionally the primary technology used for 115-kV underground transmission lines in the United States.
- **XLPE**. XLPE cables are a newer technology. Here again, three single cores are necessary to form a circuit. However, they are installed separately, often within individual ducts, usually made from a plastic material. Each XLPE core is surrounded with a solid insulating material rather than fluid, and the insulating material is protected by a water-impervious sheath. No insulating fluid is involved.

HPFF and XLPE cables are both reliable at 115-kV, but each has different features and requirements that are considered in choosing between them when either is suitable for a given application.

For example, HPFF cables can be provided in longer lengths, such that fewer splice vaults and cable splices are necessary, resulting in lower construction costs compared to XLPE cables. HPFF cable systems also have the ability to circulate the dielectric fluid to smooth out (mitigate) hot spots along the cable route, effectively increasing the circuit capacity. This provides an advantage over XLPE cable systems when the cable system is aligned parallel to existing heat sources (e.g., existing distribution circuits near substations, which might otherwise require de-rating of the cable circuit). In addition, for many applications, the cost of HPFF cables will be lower.

The fluid system within HPFF cable systems requires more maintenance and planned outages than XLPE cable systems. In addition, HPFF cables have higher electrical losses, lower capacity for equivalent size conductors, and much higher capacitive charging requirements. Further, over rugged terrain with variable topography, such as characterizes the Project area, the ability to maintain the required pressure in the HPFF cable system would be difficult.

Based on the capacity required for the Plumtree Substation to Brookfield Junction solution and Eversource's experience on recent underground cable projects, XLPE cable would be the preferred cable technology for the new 115-kV line.

11.3.1.2 Route Evaluation Criteria

When performing analyses of potential underground cable-system routes, Eversource typically applies a set of standard routing criteria, reflecting the consideration of environmental, social, construction, engineering, and economic factors. Given typical cable-system design, installation, and maintenance considerations, the criteria summarized in Table 11-4 are factored into the identification and evaluation of potential underground cable-system route alternatives. Cost, as described separately in Section 11.3.1.4, also is a critical factor in the consideration of underground cable systems.

Table 11-4: Route Evaluation Criteria for Underground Transmission Cable-System Siting

ROUTING CRITERIA	DESCRIPTION
Environmental Considerations	Underground cables are preferably sited away from, rather than through, significant environmental resources. Whereas an overhead transmission line can span wetlands, watercourses, vegetation, rock outcroppings and, steep slopes, the installation of an underground cable system requires the excavation of a continuous trench. The operation of the cable system requires continuous permanent access along the entire route so that any splice vault or portion of the cable duct bank can be reached by heavy equipment as necessary for maintenance and repairs. Therefore, any sensitive environmental resources (such as watercourses, wetlands, or endangered species habitat) located along an underground cable route may be directly affected by the excavations required for the cable system. To mitigate such impacts, the cables can be installed, for relatively short distances, beneath these resources using subsurface construction technology, such as jack and bore or horizontal directional drilling, but at great expense. Existing public road corridors are usually considered for the installation of underground cables in preference to overland electric transmission line ROWs. Road corridors typically provide continuous permanent access along the underground cable route and often are characterized by gradual slopes. However, when sited in or adjacent to roadways, underground cables must avoid conflicts with existing underground utilities. Furthermore, alignment of underground cables along road ROWs may pose other potential environmental issues, such as excavation through areas of contaminated groundwater or soils; traffic congestion; difficult crossings of watercourses and wetlands that the roads traverse or bridge; and disturbance to vegetation and land uses adjacent to the roads (due to construction staging, heavy equipment operation, etc.).
Engineering Considerations	Steep terrain poses serious problems for underground cable construction and may cause down-hill migration and overstressing of the cable and cable splices (the point where two cables are physically connected together). Accordingly, one of the primary engineering objectives for an underground cable system is to identify routes that are relatively straight, direct, and have gradual slopes and inclines to minimize construction and maintenance costs, and to avoid downhill cable migration.
Availability of Useable ROW	A new 115-kV underground XLPE cable system typically requires a minimum 30-to-40-foot-wide work area for construction. Additionally, land must be available for burying splice vaults, each of which is approximately 8 feet wide by 8 feet deep and up to 24 feet in length. The installation of each vault would typically require an excavation of 12 feet wide, 12 feet deep, and 28 feet in length. Such vaults, which must be placed at approximately 1,600-to-2000 foot intervals along a 115-kV cable route, are required to allow the individual cable lengths to be spliced together and also must be accessible, via manholes, for cable-system maintenance and repair. Due to constraints posed by buried utilities within road travel lanes or conflicts with public highway use policies, vaults must sometimes be located beneath road shoulders or on private lands adjacent to public road corridors.
Social Considerations	Cable construction requires considerable time and results in noise, disruptions to traffic and impediments to access to adjacent land uses, and potential conflicts with existing in-ground utilities. Consequently, where possible, a routing consideration is to limit the length of cable installation through densely developed residential areas and central business districts. These social effects must be carefully considered and balanced against the potential lesser effects of constructing and operating overhead line segments in comparable areas.

11.3.1.3 Routing Considerations for Cable Installation along Road ROWs

Because the Study Area is characterized by extensive suburban / urban development with an expansive road network, Eversource devoted particular attention to the identification and evaluation of potential routes for the new 115-kV line, in an underground configuration, along local, state, or federal road corridors. In-road alignments for underground cable systems usually offer environmental advantages, particularly if the underground cable construction can be confined principally to paved or previously disturbed portions of the road ROWs. As a result, in-road cable-system construction would typically be expected to affect fewer environmental resources (e.g., forested areas, wetlands) than underground routes along greenfield ROW or existing utility ROWs.[107]

To install the underground cable system within road ROWs, an approximately 30-to-40-foot-wide working area would be required adjacent to or within the existing highway travel lanes. The exact location of the cable system would require discussions with ConnDOT (for state and federal highways) or municipal highway authorities. To the extent that the cable system could be located within public road ROWs, Eversource would not have to acquire easements.

If the underground transmission line could not be installed within the road ROWs (due to conflicts with ConnDOT policy, presence of existing underground utilities), a primary consideration is the availability of land adjacent to the road ROWs for the installation and operation of the cable system, without having to displace adjacent homes or businesses. In such situations, Eversource would have to acquire easements from private property owners. This easement acquisition process would affect both a project's costs and schedule. Other considerations for installations in public road ROWs included:

- Presence of road embankments and elevated portions of road ROWs, which would make cable-system excavations difficult.
- Presence of areas of rock, where excavation would potentially require highway closures for blasting.
- Location of wetlands and waterways adjacent to or crossed by the road ROWs, beneath which the underground cable system would have to be buried.
- Construction and future maintenance activities causing traffic delays and congestion.
- ConnDOT policy of not allowing co-location of transmission lines within and parallel to the ROWs of limited access highways.

[107] Railroad corridors, which also traverse the Study Area, offer some of the advantages of road ROWs for underground construction. However, railroad corridors are less readily accessible and are often bordered directly by areas that are either densely developed or are characterized by environmental resources (e.g., wetlands, watercourses, forested areas).

11.3.1.4 Cost

Cost is a key consideration in the evaluation of underground cable technology versus overhead technology. As noted previously, the typical costs for constructing an underground 115-kV transmission cable system are five to ten times greater than those for installing an equivalent length of overhead 115-kV transmission line on an existing ROW.

In addition, except where underground cable routes can be aligned entirely within highway ROWs and/or within existing Eversource ROWs where Eversource's easements include underground cable rights, Eversource would have to acquire new easement rights from private landowners for the installation and operation of the cable system. Along state highway ROWs, ConnDOT policy requires the locations of splice vaults outside of the highway ROW; as a result, for any cable systems aligned along state roads, easements from private landowners would be required to accommodate the splice vaults and the interconnecting portions of the duct bank that are outside the highway ROWs.

As a result, where existing ROWs have sufficient space to accommodate a new overhead transmission line or can be expanded for comparatively low cost, the capital costs of building the overhead transmission line are significantly less than the costs of building a comparable underground 115-kV cable system.

The difference in the cost to Connecticut consumers for a 115-kV underground cable system, compared to an overhead line, is even greater because of federal tariff provisions. Because this Project is expected to qualify for inclusion in New England regional transmission rates, the Project costs would be shared by consumers throughout New England, based on each electric transmission company's share of the regional electric load. Connecticut accounts for approximately 25% of the New England load; therefore, Connecticut consumers would bear approximately 25% of the Project cost included in regional rates.

Recovery of Project costs through regional rates, however, is not automatic. Only costs determined by ISO-NE to be eligible for regionalization according to specific tariff provisions would be included in regional rates. Experience has shown that where a transmission line or line segment that in conformity with good utility practice could be constructed overhead, is instead constructed underground, ISO-NE would not allow the extra costs of underground line construction to be included in regional rates. Instead, such extra costs are "localized" and must be recovered solely from consumers in the area in which the underground system is situated.

In Connecticut, the effect of localizing excess underground cable costs is that in-state consumers would bear approximately 25% of the cost of an overhead line (or segment), plus 100% of the difference between that cost and the cost of an underground cable system. For example, if Eversource were to build an all-underground line that cost 10 times more than a comparable overhead line (constructed in accordance with standard good utility practice), the cost to Connecticut consumers for the underground cable system could be 37 times more than that of the overhead line [(1 x 25%) + (9 x 100%)] = (9.25 ÷ 0.25) = 37.0].

11.3.2 Construction Considerations and Procedures

Underground cable-system construction requires vastly different procedures and considerations than overhead transmission line construction. Such systems are most often located within or adjacent to public roads, which provide both a linear corridor for the cable route and roadway access along the entire cable system for construction and maintenance. Appendix 11A describes the construction procedures that would typically be used to install an underground XLPE 115-kV transmission cable system. The appendix includes the following information:

- The typical construction activities and sequence for underground cable-system installation within or adjacent to road ROWs;
- The different construction procedures that would be required to develop a cable system outside of road ROWs (e.g., along a transmission line ROW or a greenfield utility corridor);
- The typical requirements for equipment staging areas, as well as the dimensions for cable trenches and splice vaults; and
- Data regarding specific underground cable construction considerations (e.g., splice vault locations, erosion controls, traffic management).

11.3.3 Underground Alternative Routes Considered but Eliminated

To identify potential underground route alternatives for the new 115-kV line, Eversource applied the underground routing criteria identified in Table 11-4 and took into consideration the underground cable factors described above. As illustrated in Figure 11-2, four alternative routes were thus identified: one an all underground option and the other three a combination of overhead and underground configurations.

Those routes are as follows:

- Alternative 6 – Utility ROW East to Old Hawleyville Road to Railroad Route
- Alternative 7 – East on U.S. Route 6 and Roads to Greenfield Route
- Alternative 8 – U.S. Route 6 East to Greenfield to Railroad Route
- Alternative 9 – All Underground Route

An all-underground route located within the existing Eversource ROW between Plumtree Substation and Brookfield Junction was not considered because installing a cable trench across the extensive wetlands that characterize the southern portion of the route would result in significant water resource impacts.

Table 11-5 identifies the primary characteristics of the all-underground route alternative and the overhead/underground route alternatives that were considered compared to the Proposed Route; the following subsections describe each of these alternatives, and explain why each was eliminated from consideration as a feasible option for the proposed 115-kV line between Plumtree Substation and Brookfield Junction.

Table 11-5: Summary and Comparison of Underground Route Alternatives and Combination Underground /Overhead Route Alternatives Considered and Eliminated

Route Alternative Characteristic	Route Alternative				Proposed Route
	6	7	8	9	
LENGTH*					
Total Length (Miles)	5.60	3.82	4.82	3.46	3.34
• Miles Above Ground	2.30	3.32	3.92	0	3.34
• Miles Underground	3.30	0.50	0.90	3.46	0
Length, by Municipality:					
• Bethel	4.11	2.46	2.80	2.30	2.16
• Danbury	0	0.85	0.85	0.81	0.85
• Brookfield	1.46	0.51	1.16	0.34	0.34
ROW CHARACTERISTICS					
Length within Transmission Line ROWs (miles)	1.54	2.23	2.23	1.34	3.34
Length along Local/State Road ROWs (miles)	3.28	1.04	0.61	2.11	0
Length along RR Corridors (miles)	0.70	0	0.47	0	0
Length of Greenfield ROW (miles)	0	0.55	1.51	0	0
Need to Acquire New ROW	Yes	Yes	Yes	Yes	No

*Length totals may not be exact due to rounding of segment lengths

11.3.3.1 Alternative 6 – Overhead / Underground Combination: Transmission Line ROW East to Old Hawleyville Road / Railroad Route

At approximately 5.6 miles, Alternative 6 is the longest of all of the route alternatives evaluated. This alternative is comprised of a combination of overhead and underground line configurations.

Under Alternative 6, the new 115-kV line would extend east from Plumtree Substation in an overhead configuration, following Eversource's existing 1760 Line ROW toward Newtown Substation for approximately 1.5 miles. Along this segment, Eversource's ROW is bordered by single-family residences, as well as Blue Jay Orchards and Limekiln Brook. At the intersection of the transmission line ROW with Old Hawleyville Road, the new 115-kV line would transition to an underground configuration and would extend along the road for approximately 3.3 miles. Old Hawleyville Road is bordered predominantly by single-family residences, except in the vicinity of U.S. Route 6, which is characterized by a local park (Mitchell Park) and retail uses (e.g., Big Y shopping center). The route would follow Old Hawleyville Road across I-84 to the HRRC railroad corridor, and then would traverse east adjacent to and south of the rail lines (following Eversource's existing 1770/1887 Line ROW) to Brookfield Junction.

Alternative 6 was eliminated from consideration because it would be the longest of the routes, would be the most costly, and would provide no advantages to the Proposed Route in terms of cost, constructability, or social / environmental impacts.

11.3.3.2 Alternative 7 – East on Route 6 and Roads to Greenfield Route

Alternative 7, which would extend for approximately 3.8 miles, would involve a combination of overhead and underground line designs, as well as the use of transmission line, road, and greenfield ROWs. For approximately 2.2 miles, the alternative route would be aligned overhead, following Eversource's existing 321/1770 Line ROW north from Plumtree Substation to U.S. Route 6. At the intersection with U.S. Route 6, the alternative would transition to an underground configuration, diverging from the Eversource ROW to extend along U.S. Route 6 for approximately 0.5 mile before turning north on Vail Road. The alternative would continue in an underground configuration along Vail Road, crossing I-84. After crossing I-84 and continuing along Vail Road for a short distance, the line would transition back to an overhead configuration and would traverse along a greenfield ROW through a large wooded area (east of Brookfield Corporate Park) to Brookfield Junction.

Compared to the Proposed Route and overhead line design, Alternative 7 would offer no environmental, social, or cost advantages. The alignment of the route, in an underground configuration linearly along U.S. Route 6 would be inconsistent with ConnDOT policies and would pose constructability challenges given the high-use commercial areas nearby and general traffic volumes. Further, the alignment of the new line across Vail Road, in an underground configuration, could require a horizontal directional drill (HDD), which would be costly and would require relatively large staging areas on either side of the highway. The creation of a greenfield ROW segment would require forested clearing and the long-term maintenance of a new transmission line ROW.

11.3.3.3 Alternative 8 – Route 6 East to Greenfield to Railroad Route

Like Alternative 7, this 4.8-mile alternative would involve the new 115-kV line to utilize both overhead and underground configurations, along a combination of existing transmission line ROW, road ROW, and greenfield ROW. Further, like Alternative 7, this alternative also would follow the existing 321/1770 Line ROW to U.S. Route 6. However, Alternative 8 would extend farther east along U.S. Route 6 to a point near McNeil Road, where the new 115-kV line would switch to an overhead configuration and diverge to follow a greenfield ROW though fields and forested areas. The alternative route would traverse along this greenfield ROW for 1.5 miles north to the railroad ROW and then would turn west to following the rail line to Brookfield Junction.

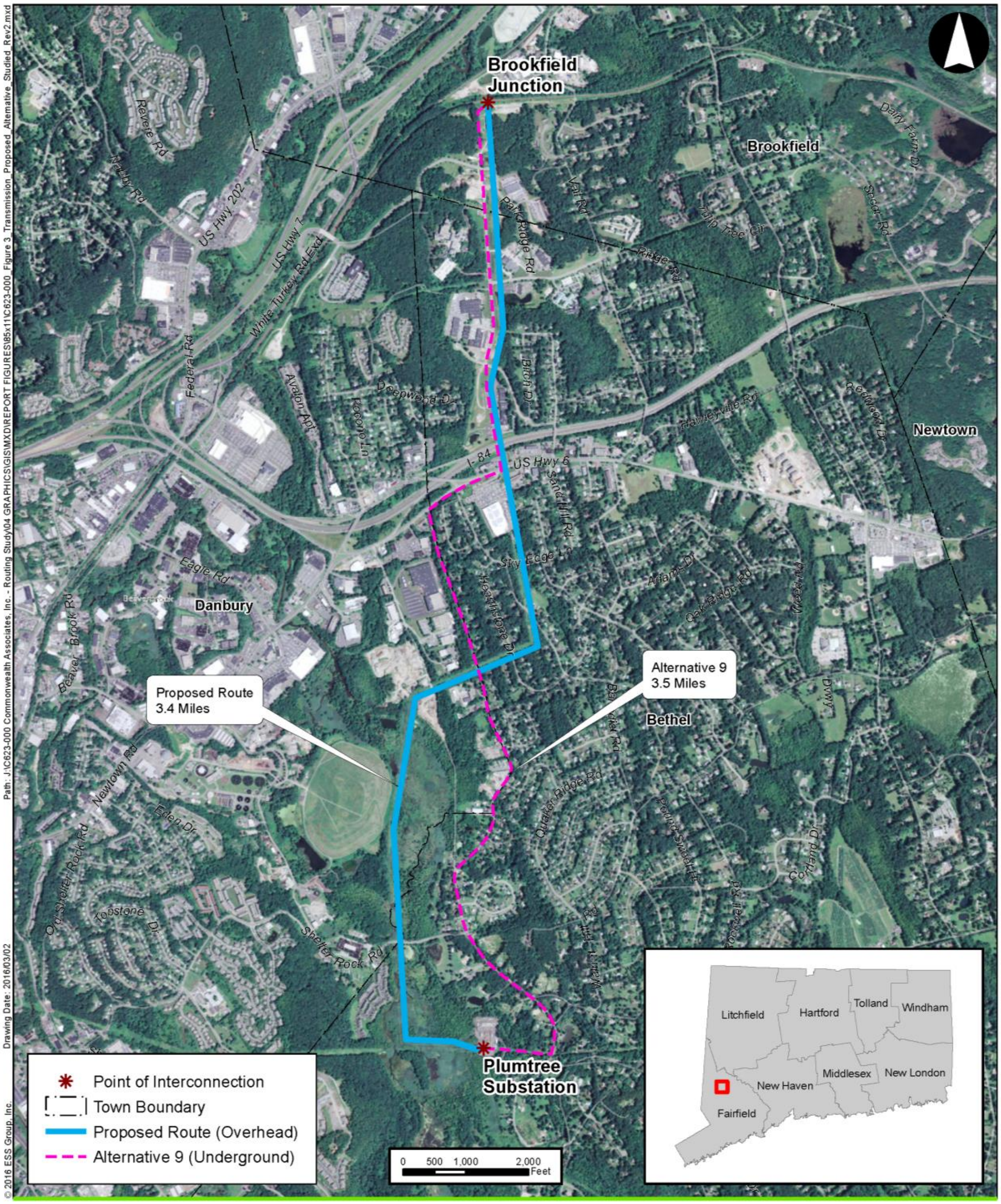
Compared to the Proposed Route and overhead line design, Alternative 8, like Alternative 7, would offer no environmental, social, or cost advantages. The alignment of the route, in an underground configuration linearly along U.S. Route 6 would be inconsistent with ConnDOT policies and would pose constructability challenges given the high-use commercial areas nearby and general traffic volumes. The creation of a greenfield ROW segment would require forested clearing and the long-term maintenance of a new transmission line ROW.

11.3.3.4 Alternative 9 – All Underground Route

Alternative 9 is an all-underground alternative (refer to Figures 11-2 and 11-4). This alternative is approximately 3.5 miles in length and would involve the alignment of the underground cable predominately along road ROWs.

Extending east from Plumtree Substation along Eversource's substation access road, this alternative route then would be aligned north along Shelter Rock and Payne roads before diverging east to follow U.S. Route 6. At the existing 321/1770 line ROW crossing of I-84, Alternative 9 would turn north from U.S. Route 6, crossing beneath I-84 and then extending north along Research Drive and a gravel pit area to Brookfield Junction.

Figure 11-4: All-Underground Alternative 9 and the Proposed Route



Plumtree to Brookfield Junction 115-kV Transmission Line
Fairfield County, Connecticut

Proposed Route and Underground Alternative

Scale: See Graphic Scale

Source: 1) USGS, 2013

Alternative 9 would avoid the extensive wetland complex, as well as Limekiln and East Swamp brooks (and their associated floodways and floodplains), located along the Proposed Route north of Plumtree Substation. Consequently, this option would minimize potential water resource impacts.

However, this all-underground alternative would pose significant challenges, not only with respect to constructability issues and consistency with ConnDOT policy regarding collocation within U.S. Route 6, but also because both Shelter Rock Road and Payne Road are narrow, winding, two-lane local roads bordered principally by residential or commercial / industrial developments. Lane or full road closures and detours would be required to install the cable within these roads. Trees overhanging these local roads also would have to be trimmed or removed to provide access for the equipment needed to install the underground cable system. Further, the cable would have to be installed beneath I-84 using an HDD, which would be costly and would require staging areas of several acres on either side of the crossing.

Compared to the Proposed Route and overhead line design, Alternative 9 would avoid or minimize impacts to water resources (wetlands, floodplains, floodways) and cultural resources (since the underground cable system would be located predominantly in previously-disturbed road ROWs). This alternative also would avoid the installation of a second 115-kV overhead line along Eversource's ROW near residences near Hearthstone, Chimney, and Sky Edge drives (i.e., the residential area south of Target store).

With Alternative 9, the underground cable system would result in social and businesses impacts along Shelter Rock and Payne roads, particularly in terms of traffic disruption / detours, noise, fugitive dust, and vegetation removal if the cable must be located adjacent to and not within the paved road ROWs. Further, because ConnDOT policy is to require longitudinal utility occupancy outside of paved road areas, along U.S. Route 6, the underground cable system would have to be aligned in the adjacent road shoulder, including potentially within a wooded area between Payne Road and Sky Edge Lane and in front of Target that would need to be cleared, causing additional visual impacts.

Locating the underground cable system within Shelter Rock Road, Payne Road, and U.S. Route 6 also could pose constructability issues that would need to be further evaluated with a study of the location of existing subsurface utilities and conditions. In addition, as noted previously, an underground cable system is typically five to 10 times more expensive than a similarly sited overhead line. Thus, Alternative 9 would be substantially more costly even though only slightly longer than the Proposed Route (3.5 vs. 3.4 miles).

Finally, apart from the avoidance of water resource impacts (which would be mitigated for the installation of the new overhead line along the Proposed Route), Alternative 9 offers no attributes that would warrant the significant additional cost. Consequently, this alternative was eliminated as a viable option.

11.4 JUSTIFICATION FOR THE SELECTION OF THE PROPOSED TRANSMISSION LINE ROUTE AND CONFIGURATION

After considering various alternative technologies and routes for the new 115-kV line, Eversource identified an overhead line as the preferred configuration and the use of the existing transmission line ROW as the preferred alignment for the new 115-kV line between Plumtree Substation and Brookfield Junction. The Proposed Route and configuration meets all Project objectives and represents the most cost-effective, least amount of environmental impact, and is the most practical alternative.

The proposed route and overhead line design represent the optimal Project configuration for the following reasons:

- **Maximizes the Use of Existing ROW and Avoids the Need to Acquire Additional Property for Utility Use**. The new overhead 115-kV line would be located entirely within Eversource's existing ROW, which is already devoted to utility use and has sufficient unutilized space to accommodate the new line without requiring relocation of the existing lines or the acquisition of additional easements. The co-location of the new line within this existing ROW also would be consistent with federal policies regarding linear energy facility siting, as well as with Eversource objectives.
- **Minimizes Environmental and Land Use Effects.** Although unavoidable temporary effects and minor long-term impacts to site-specific environmental resources would occur as a result of the construction and operation of the proposed 115-kV transmission line within Eversource's existing ROW, the development of the Project along this existing utility corridor would be consistent with state and local land use policies and would minimize long-term adverse environmental impacts to the maximum extent practical.
- **Achieves a Reliable, Operable, and Cost-Effective Solution.** The Proposed Route and overhead line design represent the most cost-effective alternative to Connecticut consumers and offer the optimal solution to the defined 115-kV reliability issues in the Housatonic Valley sub-area.

APPENDIX 11A

Underground Cable Construction

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INTRODUCTION

This appendix provides general information regarding the construction procedures that would be used to install an underground XLPE 115-kV transmission cable system. The appendix includes the following information:

- The typical construction activities and sequence for underground cable-system installation within or adjacent to road ROWs;
- The different construction procedures that would be required in the development of a cable system outside of road ROWs (e.g., along transmission line ROWs or along a greenfield utility corridor);
- Data regarding specific underground cable construction considerations (e.g., splice vault locations, erosion controls, traffic management).

11.A.1 General Construction Sequence: Cable Systems in or Adjacent to Road ROWs

Underground transmission cable systems are most often situated within or adjacent to public roads. Public roads provide both linear corridors for the cable route and roadway access along the entire cable system for construction and maintenance. This section summarizes the typical construction activities involved in underground cable installation within or adjacent to roads.

The sequence in which some of these activities are performed depends on site-specific factors and construction scheduling. The types of activities generally included in a 115-kV cable system installation along or adjacent to a road ROW are illustrated on Figure 11A-1 and summarized below.

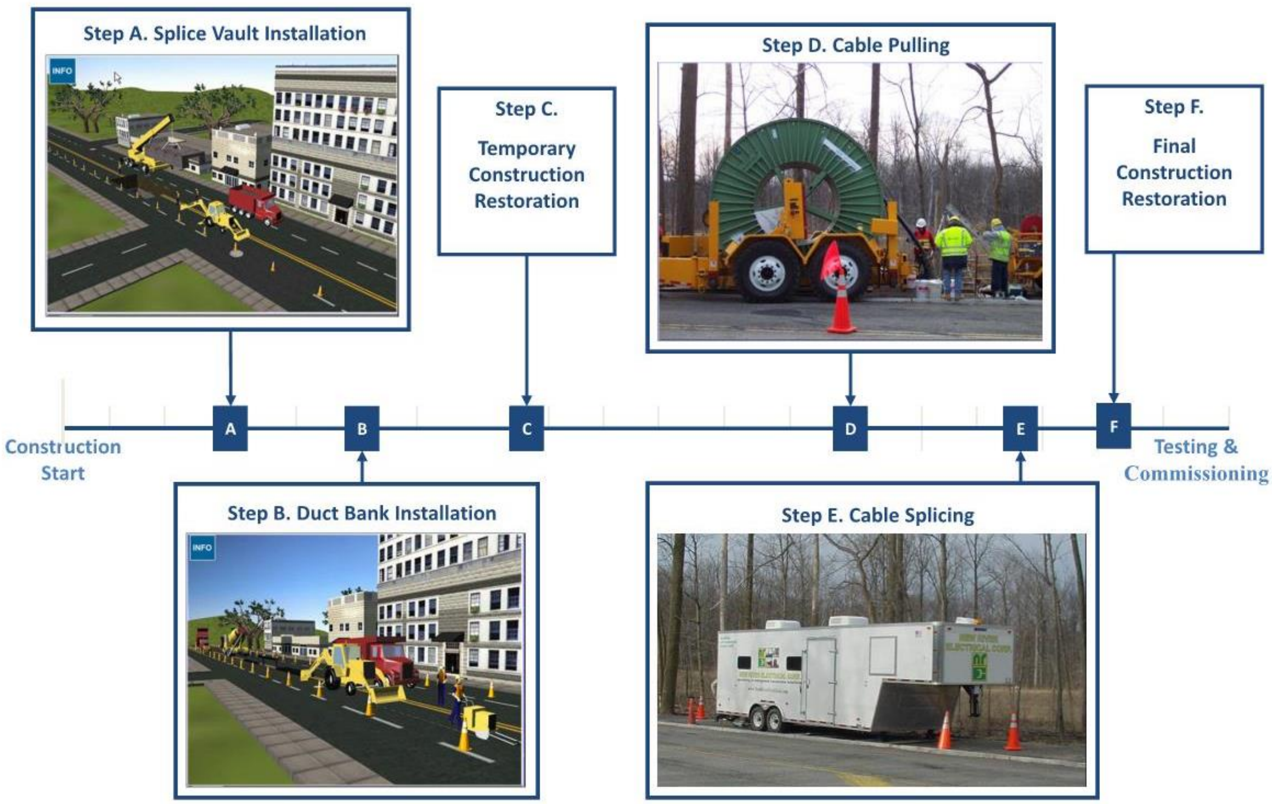
Most of the following activities also apply to underground cable construction outside of road ROWs. (Refer to Section 11A.2 for additional information regarding the differences in cable-system installation and operation in non-road areas).

Cable-System Land Requirements and General Sequence

- **Construction Staging, Storage, and Laydown Areas**. Cable-system construction requires construction contractor yard(s), as well as a combination of other staging, storage, and laydown support areas. These areas, which typically would range in size from 2 to 5 acres, would optimally be located on previously disturbed sites and would be selected based on availability and proximity to work locations. Construction support sites near the cable-system route are preferred to facilitate the construction work and to minimize adverse effects on traffic resulting from the movement of equipment and materials to work sites.

  Generally, these support sites would be used for construction offices, parking for workers' personal vehicles, equipment staging, the storage of cable-system construction materials (e.g., conduit, trench boxes, backfill), and the temporary storage of excavated materials (e.g., rock, soil, dewatering wastewater).

Figure 11A-1: Typical Underground Cable-System Construction within Road ROW



- **<u>Install Erosion Controls and Pavement Cutting / Removal</u>**. The first step in the construction process would be to deploy appropriate erosion and sedimentation controls (e.g., catch basin protection, silt fence, or straw bales) at locations where pavement or soils would be disturbed. Within roads and other paved areas, the pavement over the cable route and splice vault locations would then be saw-cut and removed.

- **<u>Excavate and Install Splice Vaults.</u>** At approximately 1,800-to-2,000-foot intervals along the cable route, pre-cast concrete splice vaults would be installed below ground. The length of an underground cable section between splice vaults (and therefore the location of the splice vaults) is determined based upon engineering requirements (such as maximum allowable pulling tensions, the cable weight/length that can fit on a reel and be safely shipped, and cross-bonding requirements) and land constraints. The specific locations of splice vaults would be determined during final engineering design, and in some areas, distances between vaults could be significantly less than the typical 1,800-to-2000-foot interval stated above.

  The outside dimensions of splice vaults for 115-kV XLPE cables are approximately 8 feet wide by 8 feet high and up to 24 feet long. The installation of each splice vault therefore typically requires an excavation area approximately 12 feet wide, 12 feet deep, and 28 feet long. The actual burial depth of each vault would vary, based on site-specific topographic conditions and on the depth of the adjacent cable sections that must interconnect within the vault (the depth of the cables at any location would be based on factors such as the avoidance of other buried utilities).

  For safety purposes, the splice vault excavations would be shored and fenced. Vault sites may also be isolated by concrete (Jersey) barriers or the equivalent. Vault installation within roadways may require the closure of two travel lanes in the immediate vicinity of the vault construction. Each vault would have two entry points to the surface. The splice vaults would be installed at a minimum depth of cover (depth from existing ground surface to top-of-vault) of approximately 2.5 feet. Backfill would be placed on top of each vault to bring the ground surface back to the pre-construction elevation. After backfilling, these entry points are identifiable as manhole covers, which are set flush with the ground or road surface.

- **<u>Trench and Install Duct Bank</u>**. To install the duct bank for the XLPE-insulated cables, a trench typically 7 to 10 feet deep and approximately 5 feet wide would be excavated within a minimum linear 30-foot-wide construction area. This trench would typically be stabilized using trench boxes or another type of shoring.

  Excavated material (e.g., pavement, subsoil) would be placed directly into dump trucks and hauled away to a suitable disposal site, or hauled to a temporary storage site for screening/testing prior to final disposal or re-use in the excavations for backfill. If groundwater is encountered, dewatering would be performed in accordance with authorizations from applicable regulatory agencies and may involve discharge to catch basins, temporary settling basins, frac tanks, surface waters, or vacuum trucks.

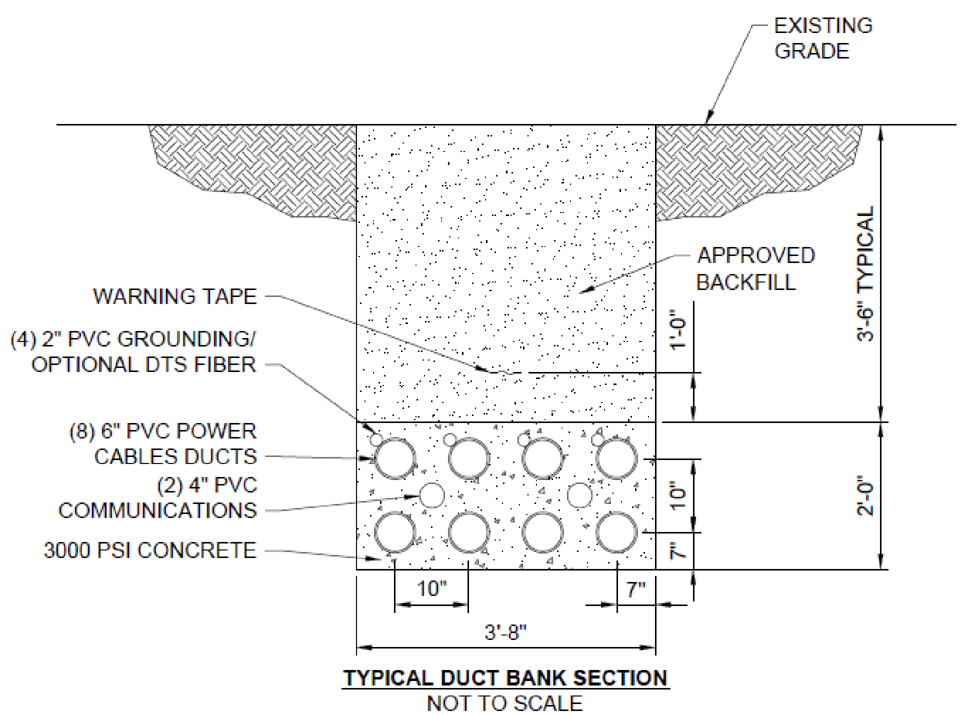
  Because underground cable installation would involve both the excavation of a continuous trench and areas for splice vaults, it is very probable that rock would be encountered. Such rock would have to be removed using mechanical methods, or possibly mechanical methods supplemented by drilling and controlled blasting. Should drilling and controlled blasting be necessary for the underground cable, it would be performed only pursuant to a plan incorporating multiple safeguards that would be subject to specific approval by the Council, and in consultation with local authorities.

The duct bank system that would be required for this Project, which is a function of both the system voltage and the required loading, would consist of six 6-inch polyvinyl chloride (PVC) conduits for the XLPE-insulated cables, two 6-inch PVC conduits as power cable maintenance conduits, two 2-inch PVC conduits for the ground-continuity conductors, two 4-inch PVC conduits for the fiber optic relaying cables, and two 2-inch conduits for the temperature-sensing fiber optic cables. Figure 11A-2 illustrates this 115-kV duct bank cross-section.

The conduit would be installed in sections, each about 10 to 20 feet long, and would have a bell and spigot connection. Conduit sections would be joined by swabbing the bell and spigot with glue and then pushing the sections together. After installation in the trench, the conduits would be encased in concrete. The duct bank would then be backfilled with approved backfill with sufficient thermal characteristics to dissipate the heat generated by the cable system.

Trenching, conduit installation, and backfilling would proceed progressively along the route such that relatively short sections of trench (under favorable conditions, typically 200 feet per crew) would be open at any given time and location. During non-work hours, temporary cover (steel plates) would be installed over the open trench within paved roads to maintain traffic flow over the work area. After backfilling, the trench area would be repaved using a temporary asphalt patch or equivalent. Disturbed areas would be permanently repaved as part of final restoration.

Figure 11A-2: Typical Duct-Bank Cross Section for 115-kV XLPE Cables System and Project Loading



- **<u>Trenchless Duct Installation.</u>** The installation of an underground cable system beneath certain obstacles (such as waterways, railroads, and limited-access highways) where excavating an open trench may present constructability or regulatory issues, may require the use of trenchless construction methods. Trenchless installation involves subsurface excavation to align the cable duct beneath the obstacle in question.

  Two trenchless installation methods are typically used in underground cable construction – horizontal directional drilling (HDD) and horizontal boring. HDD involves the excavation of a bore along a curved path starting and ending near the ground surface on either side of the obstacle. As necessary, the bore path is enlarged from its initial size with successive passes with larger drill heads. Once the final bore path diameter is reached, the pre-assembled conduit package is pulled through. Alternatively, a horizontal bore involves the excavation of a vertical shaft on each side of the obstacle, and then the excavation of a straight, horizontal bore between the two shafts. Various methods exist to accomplish this, including pipe jacking, auger boring, and microtunneling; with the choice of method a function of bore length, size, soil conditions, and presence of ground water.

  Any trenchless installation technique involves staging areas on either side of the subsurface crossing. These staging areas, which typically must be at least 0.3 acre on the launching side and 0.1 acre on the receiving side, are required to accommodate the specialized HDD and boring equipment, as well as the materials needed for the subsurface crossing.

- **<u>Duct Swabbing and Testing.</u>** After the vaults and duct bank are in place, the ducts would be swabbed and tested (proofed), using an internal inspection device (mandrel) to check for defects. Mandrelling is a testing procedure in which a ‘pig’ (a painted aluminum or wood cylindrical object slightly smaller in diameter than the conduit) is pulled through the conduit. This is done to ensure the ‘pig’ can pass easily, verifying the conduit has not been crushed, damaged, or installed improperly. After successful proofing, the transmission cables and ground-continuity conductors would be installed and spliced. Cable reels would be delivered by special tractor trailers to the vaults, where the cable would be pulled into the conduit using a truck-mounted winch and cable handling equipment.

- **<u>Cable Installation</u>**. To install each transmission cable and ground-continuity conductor within the conduits, a large cable reel would be set up over a splice vault, and a winch would be set up at one of the adjacent splice-vault locations. The cables and ground-continuity conductors (during separate mobilizations) would then be pulled into their conduits by winching a pull rope attached to the ends of each cable. In a separate pulling operation, the splice vaults would also be used as pull points for installing the temperature-sensing fiber optic cables. Additionally, pull boxes would be installed near the splice vaults for the pulling and splicing operations required for the remaining fiber optic cables.

- **<u>Cable Splicing</u>**. After the transmission cables and ground-continuity conductors are pulled into their respective conduits, the ends would be spliced together in the vaults. Because of the time-consuming and precise nature of splicing high-voltage transmission cables, the sensitivity of the cables to moisture (moisture is detrimental to the life of the cable), and the need to maintain a clean working environment, splicing XLPE-insulated cables involves a complex procedure and requires a controlled atmosphere. The ‘clean room’ atmosphere would be provided by an enclosure or vehicle that must be located over the manhole access points during the splicing process.

  It typically takes 7 to 10 days to complete the splices in each vault (three XLPE 115-kV cable splices in each splice vault). Each cable and associated splice would then be stacked vertically and supported on the wall of the splice vault.

- **Cable Termination**. At each end of a 115-kV cable system, termination equipment is required. This would consist of steel structures on which the cable terminations would be mounted. The duct bank itself would be routed to the termination structure, and the ducts turned to vertical to allow the cables to be pulled up and out of the duct bank and attached to the terminations assemblies. The terminations are typically located with substations on each end of the underground cable system; however, terminations could also be located where an overhead line segment transitions to underground or vice versa.
- **Restoration.** After the installation of the duct banks and splice vaults, disturbed road ROWs or other paved areas (e.g., parking lots) would be restored to appropriate grade levels and re-paved. Sidewalks, curbs, and road shoulder or median areas affected by construction also would be restored. Non-paved areas affected by construction (e.g., vegetated road shoulders, lawns, or other previously vegetated areas disturbed by cable-system construction) would be seeded, mulched, and allowed to revegetate.

11.A.2 Additional Requirements for Cable-System Construction Outside of Road ROWs

To install and operate a transmission cable system within or adjacent to non-road ROWs (such as Eversource's existing overhead transmission line ROW) or along an entirely new cross-country, or greenfield ROW, the ROW requirements and typical construction procedures described in Section 11A.1 would be used, with the following exceptions:

- **Construction Workspace**. Because the cable system would not be aligned along existing roads, the workspace required to construct the system could be wider than 30 feet to accommodate construction equipment, trench excavation, splice vaults, and access roads along the entire cable route. Additional ROW width and temporary construction work spaces also could be needed in certain areas to account for topography and subsurface conditions, which may affect the width of the excavations that would be required to achieve the specified cable and splice vault depths. The required width of the construction workspace would depend on site-specific conditions.
- **Easement Requirements**. Eversource might need to purchase easements from private landowners for an underground cable system installed outside of road ROWs, even for transmission cables aligned along its own overhead transmission line ROWs (where the existing easements do not encompass sufficient rights for underground transmission systems). Permanent underground easements would have to be acquired.
- **Vegetation Clearing and Grading**. For any cable system located outside of paved corridors, all vegetation would have to be cleared and removed along the entire width of the construction ROW, which would then have to be graded both to create an access road along the length of the cable route and to achieve appropriate elevations for the installation of the duct banks and splice vaults. Additional construction work spaces, such as in areas of side slopes, wetlands, and adjacent to stream crossings, and temporary construction support areas (e.g., crane pads adjacent to splice vaults, temporary material staging sites) also would have to be cleared and graded as appropriate to site-specific conditions. Because the Project region is characterized by rugged, forested, terrain, shallow depth to bedrock, and multiple water resources (wetlands and streams), the vegetation clearing and grading that would be required to create an acceptable ROW for an underground cable system would involve significant environmental impacts. Extensive hammering and/or blasting

would be required to create level grades for work pads and for the cable system ROW, permanently altering topography along the cable route.

- **Access Roads.** Because permanent access would be required along the entire route for cable-system maintenance purposes (i.e., for immediate access to the duct banks and splice vaults), gravel-type roads, with a typical 20-foot-wide travel area, would likely be developed during the construction phase. The roads would have to be constructed to handle all anticipated construction equipment and material deliveries, including trench boxes, concrete trucks, splice vaults, cranes, and cable reel trucks. Access road construction would involve cutting and filling activities (including permanent fill in wetlands along the cable route), as well as the installation of permanent watercourse crossings (e.g., culverts, bridges) as needed.
- **Erosion and Sedimentation Controls.** Because of the soil disturbance along the length of the cable-system route, erosion and sedimentation controls would have to be deployed and maintained both along and across the ROW as necessary to minimize the potential for impacts to adjacent properties and to environmental resources. Soil erosion and sedimentation controls would consist of the measures as summarized in Section 11A.1. Where the ROW intersects public roads, crushed stone anti-tracking pads would have to be installed along the ROW to minimize the amount of soil tracked onto the pavement from construction-related activities.
- **Restoration**. Restoration activities would consist of reseeding and mulching disturbed soil areas. With the exception of the permanent access road, disturbed areas would be allowed to revegetate, but would be managed in low-growth vegetation, consistent with the operation of the underground cable system.

Underground cable-system construction outside of roadway ROWs also typically must address site-specific environmental conditions. For example, wetlands are typically characterized by soils that are relatively poor in terms of thermal characteristics for heat dissipation, compared to granular soils typically found beneath roadways. Organic soils require over-excavation, or the use of different phase spacing within the duct bank. In addition, wetlands and watercourses could pose significant obstacles to underground construction, requiring either direct trenching or costly and time-consuming trenchless duct-bank installation methods (such as jack and bore or horizontal directional drill [HDD], both of which would require potentially extensive staging areas on either side of the water crossing).

11.A.3 Splice-Vault Requirements

Due to current-carrying limitations and the assumed underground duct-bank configuration requiring two cables per phase, two separate splice vaults would be required at each cable-splice interval along the length of an underground line. The outside dimensions of a splice vault for 115-kV XLPE cables are approximately 8 feet wide by 8 feet deep and up to 24 feet in length (one vault per three XLPE cables).

The installation of each splice vault therefore requires an excavation area approximately 12 feet wide, 12 feet deep, and 28 feet long. At each splice-vault location, pre-cast splice vaults would be installed below ground. Splice vaults located along, but outside of public road ROWs, require a minimum of 12,000 square feet of permanent easement for future access to perform maintenance and repairs. An additional minimum 4,300 square feet of temporary easement would be required for cable-system construction. Therefore, the construction of each vault would require approximately 0.4 acre (exclusive of access).

Along a cable route, the actual burial depth of each vault would vary, depending on site-specific topographic conditions and the depth of the interconnecting duct bank. For cable systems aligned along roads, the below-grade elevation of the duct banks (and therefore the depth at which vaults must be placed) often depends on the depth required to avoid conflicts with other buried utilities.

Vaults may be installed beneath public road travel lanes or, in order to avoid conflicts with other utilities buried beneath the roads, may be installed in other suitable locations adjacent to roads (e.g., beneath parking lots, sidewalks, road shoulders, road medians). However, in locations where the duct bank extends beneath a road but vaults must be installed off-road, the duct bank may need to cross other parallel buried utilities twice to interconnect each vault, greatly complicating the cable-system design and construction process.

For cable-systems aligned along linear corridors other than road ROWs (e.g., Eversource’s overhead transmission line ROW, railroad ROW), vaults would be installed within or adjacent to these ROWs so as to avoid conflicts with the existing facilities. However, along such ROWs, vault installation may be more difficult due to factors such as unfavorable topographic conditions (e.g., need for grading or filling, presence of rock that must be excavated and removed, dewatering needs, and needs for developing and maintaining suitable access for the heavy construction equipment such as cranes). Extra work areas adjacent to the vaults also would be required for crane pads, which would be needed to place each vault. The crane-pad area required at each splice vault would be approximately 80 feet wide by 130 feet long.

11.A.4 Temporary Erosion and Sedimentation Controls

Temporary erosion and sedimentation controls (e.g., silt fence, hay/straw bales, filter socks, inlet and catch basin protection) would be installed as needed prior to or in conjunction with the commencement of cable-system construction activities that would involve soil disturbance. The controls would be installed in compliance with the 2002 Connecticut *Guidelines for Soil Erosion and Sedimentation Control*. The need for, type, and extent of erosion and sedimentation controls would be a function of considerations such as:

- Whether the underground cable route is within or adjacent to road ROWs or along Eversource transmission line or other utility ROWs (for example, catch basin protection would be required for cable-system construction within roads)
- Slope (steepness, potential for erosion) and presence of resources, such as wetlands or streams, at the bottom of the slope
- Type of soil disturbed
- Soil moisture regimes
- Schedule of future construction activities
- Proximity of cleared areas to water resources, roads, or other sensitive environmental resources
- Time of year, as this dictates the types of erosion and sedimentation control methods for a particular area. For example, re-seeding is not typically effective during the winter months. In winter, with frozen ground, controls other than re-seeding (such as wood chips, straw and hay, geotextile fabric, waterbars, or crushed stone) would be used to stabilize disturbed areas until seeding can be performed.
- Extreme weather conditions during or immediately following soil disturbance.

11.A.5 Vegetation Clearing (Within / Adjacent to Roads vs. Other Sites)

Compared to an above ground transmission line, minimal vegetation clearing is typically required for underground cable-system construction within or adjacent to road ROWs. Some landscaping or other vegetation bordering the cable route within roads may need to be removed or trimmed to allow the safe operation of construction equipment, and vegetation also would have to be removed at off-road splice vault locations (unless the vaults are located in paved areas). Similarly, vegetation may be affected by temporary staging or material storage sites.

In contrast, underground cable-system construction within Eversource's transmission line ROWs or other non-roadway corridors would involve the removal of all vegetation within a typical minimum 40-foot-wide construction work area. Additional vegetation clearing would also be needed at the locations of line transition stations, splice vaults, splice vault work (crane) pads, and staging areas.

11.A.6 Special Procedures: Rock Removal (Drilling/Blasting), Dewatering, Material Handling

Based on a review of field conditions, it is likely that the excavations for any cable system would encounter rock and groundwater in many locations. Compared to the installation of overhead transmission line structures at defined locations, underground cable construction, which involves both the excavation of a continuous trench and areas for splice vaults, would require substantially more rock digging and removal and would require the management of significantly greater quantities of both dewatering wastewater and excavated soils. All of these excavated materials must be properly disposed.

Generally, rock encountered during underground cable-system construction would be removed using mechanical methods, or mechanical methods supplemented by controlled drilling and blasting. If drilling and blasting are necessary, Eversource would adhere to the same standard procedures as described for the overhead transmission line construction in Volume 1, Section 4. Similarly, dewatering wastewaters and excess excavated soils would be managed as described for overhead transmission line construction in Section 4; however, substantially greater quantities of excess soil and dewatering wastewater would be involved in the underground cable-system installation. Further, dewatering could result in discharges to catch basins, sanitary sewers, temporary settling basins, tanker trucks (for eventual off-site transport), or watercourses.

11.A.7 Traffic Management

Traffic issues are often of primary concern with respect to the construction of underground cable systems within or adjacent to public road ROWs. The installation of the duct banks and splice vaults typically requires temporary travel lane closures, which would potentially cause traffic disruption, delays, detours, or congestion.

To minimize traffic-related impacts, Eversource would typically coordinate with municipal and state highway authorities regarding peak and non-peak travel times in order to identify construction schedules that would limit potential interference with traffic flow along public roads. Eversource also would employ personnel to direct traffic at construction sites, and would erect appropriate traffic signs and install work area protection measures and signs to clearly denote the presence of construction work zones.

11.A.8 Construction Scheduling and Work Hours

Cable-system construction is time-consuming and highly dependent on subsurface conditions. Duct-bank construction could proceed at a rate of only 50 feet / day and the excavation and installation of a splice vault could require a week to complete.

In addition, cable-system construction schedules would depend on the location of the underground route (e.g., within public road travel lanes, near developed land uses, timing for crossing of sensitive environmental resources, such as streams that support fisheries). Where underground cables are routed within public road ROWs, construction work must be coordinated with state or local highway authorities to avoid peak travel times and thus may occur at night. In contrast, in areas where the underground cable system traverses adjacent to residential areas, work would be scheduled during daylight hours, to minimize nighttime noise disturbance to residents.

Cable-system installation beneath watercourses that support fishery resources or that are classified as high quality waters would be performed and scheduled in accordance with CT DEEP and USACE requirements. Often, cables must be installed beneath larger watercourses using trenchless technologies such as horizontal directional drilling or jack and bore. Using either of these techniques, the installation of the duct bank beneath a watercourse typically requires several weeks or months to complete.

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12. PROPOSED SUBSTATION MODIFICATIONS: ALTERNATIVES REVIEW

To meet the Project objectives, the new 115-kV transmission line must extend between and connect to the existing Plumtree Substation to Brookfield Junction. As a result, there are no alternative, geographically distinct substation sites that could be developed or modified to achieve the Project objectives. Similarly, for the reasons summarized below, the minor modifications to the Plumtree and Stony Hill substations, as proposed, would avoid or minimize environmental impacts and represent the most cost-effective and efficient approach for interconnecting the new 115-kV line and capacitor banks to the power grid.

Plumtree Substation and Stony Hill Substation were developed approximately 44 and 27 years ago, respectively, and each is situated within a larger parcel of Eversource-owned property. Specifically, the 4.6-acre Plumtree Substation is situated on a 13.8-acre Eversource property, whereas the existing 1.7-acre Stony Hill Substation is located within an 18.8-acre Eversource parcel.

12.1 PLUMTREE SUBSTATION

The proposed new 115-kV transmission line will extend from Plumtree Substation to Brookfield Junction and will tie into the existing 1887 Line. This will require terminal upgrades at Plumtree Substation, as well as the installation of new protection, control, and indication equipment. The Project modifications would be located within the presently operated, fenced portion of the substation.

As proposed, the new line would connect to a spare position at Plumtree Substation. This spare position already has major equipment and structures in place to accept the new line. The new line would be terminated on the existing steel A-frame structure and tie into the substation between two existing 115-kV circuit breakers. Terminal equipment, which includes the line disconnect switch and wave trap, require upgrading to meet line capacity requirements.

After a review of possible alternatives, Eversource concluded that connecting the new line into the spare position is the most cost-effective, environmentally-acceptable, and efficient approach. All other existing 115-kV bay positions at the substation are already connected to transmission lines. Connecting the new transmission line in another location would require a re-build of the 115-kV yard by expanding the 115-kV A and B busses and installation of a new bay position, which would include installation of all associated steel structures, towers, and foundations. This would also require expansion of the substation fence line, which would result in increased environmental impacts because much of the surrounding area is wetlands and/or within floodplains or the floodway.

12.2 STONY HILL SUBSTATION

The existing 22K 115-kV capacitor bank (37.8 MVAR) at the Stony Hill Substation will be electrically relocated by the use of underground cable within the substation along the south perimeter, from the A1 Bus to the A3 Bus position. The A3 Bus position is located on the east side of the substation. The existing 22K capacitor bank is located on the west side of the substation.

The selected design consists of an extension of the A3 Bus on the east side of the substation to accommodate connection of the underground cable from the existing 22K capacitor bank. This bus extension is designed such that it extends to the east before turning 90 degrees and traversing to the south. This bus extension will be located within a developed portion of the substation. This configuration and substation expansion would also provide future connection of equipment to the A3 Bus position. A synchronous condenser will be part of a separate petition and is presently planned to be located in the expanded substation area.

One alternative considered was the physical relocation of the existing 22K capacitor bank to the east side of the substation for connection to the A3 Bus position. This alternative would involve new foundations and structures for the 22K capacitor bank and an associated disconnect switch on the east side of the substation. This equipment would occupy space in the eastern expansion of the substation and limit future options for substation modifications. As this equipment is presently installed on the west side of the substation, Eversource determined that it would be most efficient to electrically relocate the capacitor bank to the A3 Bus position on the east side of the substation by use of underground cable. This minimizes equipment that will be located in the eastern portion of the substation and subsequently reduces the required size of the substation expansion.

Another alternative that was considered also involved the electrical relocation of the 22K capacitor bank to the A3 Bus position with a different route for the underground cabling. This alternative, which would involve routing the underground cabling along the north side of the substation, was not selected because the space between existing structures within the substation and the northern station fence was not sufficient to perform the underground installation without expanding the substation fence farther to the north. Routing the underground cable from the 22K capacitor bank on the west side of the substation to the A3 Bus position on the east side of the substation along the south side, within the substation fence, was determined to have the least impact on the required substation expansion.

In summary, after review of alternatives, the upgrades to the existing Stony Hill Substation by electrically relocating an existing 115-kV capacitor bank within the substation fence line avoid or minimize environmental impacts and represent the most cost-effective and efficient approach to adding the capacitors to the transmission system.

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13. GLOSSARY AND TERMS

115-kV: 115 kilovolts or 115,000 volts
345-kV: 345 kilovolts or 345,000 volts
AAL: Annual average loads
AC (alternating current): An electric current that reverses its direction of flow periodically. (In the United States this occurs 60 times a second-60 cycles or 60 Hertz). This is the type of current supplied to homes and businesses.
ACSR: Aluminum Conductor, Steel Reinforced, a common type of overhead conductor.
ACSS: Aluminum Conductor with Steel Support, a common type of overhead conductor.
Ampere: (Amp): A unit measure for the flow (current) of electricity. A typical home service capability (i.e., size) is 100 amps; 200 amps is required for homes with electric heat.
AMSL: Above mean sea level
ANSI: American National Standards Institute
APL: Annual peak load
Arrester: Equipment that protects lines, transformers and equipment from lightning and other voltage surges by carrying the charge to ground. Arresters serve the same purpose as a safety valve on a steam boiler.
ASTM: American Society for Testing and Materials
BMP: Best Management Practice
BMP Manual: Eversource's Best Management Practices Manual: Connecticut Construction & Maintenance Environmental Requirements (2011). Available via: http://www.transmission-nu.com/contractors/pdf/CT_BMP.pdf
C&D: Conservation and Development (plan)
C&LM: Conservation and Load Management.
Cable: A fully insulated conductor usually installed underground but in some circumstances can be installed overhead.
CCGT: Combined Cycle Gas Turbines
CCRP: Central Connecticut Reliability Project
CCVT: Capacitor coupling voltage transformers
CEII: Confidential Energy Infrastructure Information
CELT: ISO-NE, Forecast Report of Capacity, Energy, Loads and Transmission
Certificate: Certificate of Environmental Compatibility and Public Need (from the Connecticut Siting Council)
CFPA: Connecticut Forest and Park Association
CGS: Connecticut General Statutes
Circuit: A system of conductors (three conductors or three bundles of conductors) through which an electrical current is intended to flow and which may be supported above ground by transmission structures or placed underground.
Circuit Breaker: A switch that automatically disconnects power to the circuit in the event of a fault condition. Located in substations. Performs the same function as a circuit breaker in a home.
CLL: Critical Load Level
ConnDOT: Connecticut Department of Transportation
Conductor: A metallic wire, busbar, rod, tube or cable that serves as a path for electric current flow.
Conduit: Pipes, usually PVC plastic, typically encased in concrete, for housing underground power cables.

Contingency: The unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch or other electrical element

CONVEX: Connecticut Valley Electric Exchange.

Council or CSC: Connecticut Siting Council

CT DEEP: Connecticut Department of Energy and Environmental Protection

CWA: Clean Water Act (federal)

D&M Plan: Development and Management Plan (required by the Connecticut Siting Council)

dBA: Decibel, on the A-weighted scale.

DBH: Diameter breast height

DC: (direct current): Electricity that flows continuously in one direction. A battery produces DC power.

DCT: Double-circuit transmission line

Deadend Structure: A line structure that is designed to have the capacity to hold the lateral strain of the conductor in one direction

Demand: The total amount of electricity required at any given time by an electric supplier's customers.

DESPP: Department of Emergency Services and Public Protection (Connecticut)

DG: Distributed Generation. Refers to modular electric generation or storage, located near the point of electric use, and generally involves the use of small generators located close to electric demand sources, to decrease end-users' electric purchases and to reduce the need for electricity generated by large, centrally-located power plants and power transport to load centers on transmission lines.

Distribution: Line, system. The facilities that transport electrical energy from the transmission system to the customer.

Disconnect Switch: Equipment installed to isolate circuit breakers, transmission lines or other equipment for maintenance or sectionalizing purposes.

DR: Demand response

DRP: Demand-response program.

DSM: Demand side management

Duct: Pipe or tubular runway for underground power cables (see also Conduit).

Duct Bank: A group of ducts or conduit usually encased in concrete in a trench.

Electric Field: Produced by voltage applied to conductors and equipment. The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m); 1 kV/m is equal to 1,000 V/m.

Electric Transmission: The facilities (69 kV+) that transport electrical energy from generating plants to distribution substations.

EMF: Electric and magnetic fields.

EMF BMP Document: Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut.

EPA: United States Environmental Protection Agency

EPAct: Energy Policy Act of 2005

ERO: Electric Reliability Organization

ESRI: Environmental Systems Research Institute, Inc. (database of environmental information)

Eversource: also referred to as "the **Company**": The Connecticut Light and Power Company doing business as Eversource Energy, a legal entity authorized to provide electric transmission and distribution services in Connecticut.

Eversource Service: Eversource Energy Service Company (formerly, Northeast Utilities Service Company); a company within the Eversource Energy organization that provides services to the public utility subsidiaries, such as Eversource and to the other subsidiaries of Eversource Energy.

FAA: Federal Aviation Administration

Fault: A failure (short circuit) or interruption in an electrical circuit.

FCM: Forward Capacity Market

FEMA: Federal Emergency Management Agency

FERC: Federal Energy Regulatory Commission

FTB: Fluidized thermal backfill
G: Gauss; 1G = 1,000 mG (milligauss); the unit of measure for magnetic fields.
GHCC: Greater Hartford Central Connecticut
GIS: Geographic Information System
GPS: Global Positioning System
Ground Wire: Cable/wire used to connect wires and metallic structure parts to the earth. Sometimes used to describe the lightning shield wire.
HAER: Historic American Engineering Record
HDD: Horizontal directional drill
H-frame Structure: A wood or steel structure constructed of two upright poles with a horizontal cross-arm and bracings.
HPFF: High-pressure fluid-filled; a type of underground transmission line.
IEC: International Electro-technical Commission
IEEE: Institute of Electrical and Electronics Engineers
Impedance: The combined resistance and reactance of the line or piece of electrical equipment which determines the current flow when an alternating voltage is applied
IPac: Information, Planning, and Conservation System (USFWS)
ISO: Independent System Operator
ISO-NE: Independent System Operator New England, Inc. New England's independent system operator.
kcmil: 1,000 circular mils, approximately 0.0008 sq. in.
kV: kilovolt, equals 1,000 volts
kV/m: Electric field unit of measurement (kilovolts/meter)
Lattice-type Structure: Transmission or substation structure constructed of lightweight steel members.
LEI: London Economics International, LLC
Lightning Shield Wire: Electric cable located to prevent lightning from striking transmission circuit conductors.
Line: A series of overhead transmission structures that support one or more circuits; or in the case of underground construction, a duct bank housing one or more cable circuits.
Load: Amount of power delivered as required at any point or points in the system. Load is created by the power demands of customers' equipment (residential, commercial, industrial).
Load Pocket: A load area that has insufficient transmission import capacity and must rely on out-of-merit order local generation.
MF, Magnetic Field: Produced by the flow of electric currents; however, unlike electric fields, most materials do not readily block magnetic fields. The level of a magnetic field is commonly expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G = 1,000 mG.
Manhole: See Splice Vault
MCF: Municipal Consultation Filing (required by Connecticut Siting Council)
mG: milligauss (see Magnetic Field)
MRA: Market Resource Alternatives
MVA: (Megavolt Ampere) Measure of electrical capacity equal to the product of the voltage times the current times the square root of 3. Electrical equipment capacities are sometimes stated in MVA.
MVAR: (Megavolt Ampere Reactive) Measure of reactive power.
MW(s): (Megawatt(s)) One megawatt equals 1 million watts, measure of the work electricity can do.
MWh: Megawatt hour
NAAQS: National Ambient Air Quality Standards
NDDB: Connecticut Natural Diversity Data Base (CT DEEP)
NEEWS: New England East – West Solution
NEPOOL: New England Power Pool

NERC: North American Electric Reliability Council, Inc. (initially, the National Electric Reliability Council)
NESC: National Electrical Safety Code
NGVD: National Geodetic Survey Datum
NHPA: National Historic Preservation Act
NHT: National Historic Trail
NPCC: Northeast Power Coordinating Council
NPH: Notice of Presumed Hazard (FAA)
NRCS: Natural Resources Conservation Service (United States Department of Agriculture)
NRHP: National Register of Historic Places
NTAs: Non-transmission alternatives
NWI: National Wetlands Inventory
NY-ISO: New York Independent System Operator
OH (Overhead): Electrical facilities installed above the surface of the earth.
OOS: Out-of-service (as in a generating unit or station)
OPGW: Optical groundwire (a shield wire containing optical glass fibers for communication purposes)
PAC: Planning Advisory Committee (ISO-NE)
PDAL: Peak average daily loads
PEM: Palustrine emergent (wetlands)
PFO: Palustrine forested (wetlands)
Phases: Transmission (and some distribution) AC circuits are comprised of three phases that have a voltage differential between them.
POW: Palustrine open water (wetlands)
Protection/Control Equipment: Devices used to detect faults, transients and other disturbances in the electrical system in the shortest possible time. They are customized or controlled per an entity's operational requirements.
PSI: Pounds per square inch
PSS: Palustrine scrub-shrub (wetlands)
PT: Potential transformer
PTF: Pool Transmission Facilities
PUB: Palustrine unconsolidated bottom (wetlands)
PUESA: Public Utilities Environmental Standards Act
PURA: Public Utilities Regulatory Authority (part of CT DEEP)
PVC: Polyvinyl chloride (conduits for XLPE-insulated cable)
Rebuild: Replacement of an existing overhead transmission line with new structures and conductors generally along the same route as the replaced line.
ROW: Right-of-Way; as used in this document, a defined strip of land over which Eversource has rights to construct, operate, and maintain electric transmission lines, together with various ancillary rights. Typically, these rights have been conveyed to Eversource by the owner of the underlying land. In some cases, Eversource may own the land itself in fee.
RPS: Renewable Portfolio Standards
RSP: Regional System Plan prepared annually by ISO-NE.
SCADA: Supervisory Control and Data Acquisition
SGCN: Species of Greatest Conservation Need (as classified by Connecticut's Wildlife Action Plan [WPA])
Shield Wire: See Lightning Shield Wire
SHPO: State Historic Preservation Office
Splice: A device to connect together the ends of bare conductor or insulated cable.
Splice Vault: A buried concrete enclosure where underground cable ends are spliced and cable-sheath bonding and grounding is installed.
SRHP: State Register of Historic Places

S/S (Substation): A fenced-in yard containing switches, transformers, line-terminal structures, and other equipment enclosures and structures. Adjustments of voltage, monitoring of circuits and other service functions take place in this installation.
Steel Lattice Tower: See Lattice-Type Structure
Steel Monopole Structure: Transmission structure consisting of a single tubular steel column with horizontal arms to support insulators and conductors.
Stormwater Pollution Control Plan, SWPC Plan: Is a sediment and erosion control plan that also describes all the construction site operator's activities to prevent stormwater contamination, control sedimentation and erosion, and comply with the requirements of the Clean Water Act
SWCT: Southwest quadrant of the State of Connecticut
Terminal Point: The substation or switching station at which a transmission line terminates.
Terminal Structure: Structure typically within a substation that ends a section of transmission line.
T&E: Threatened and endangered species
TOs: Transmission owners
Transformer: A device used to transform voltage levels to facilitate the efficient transfer of power from the generating plant to the customer. A step-up transformer increases the voltage while a step-down transformer decreases it.
Transmission Line: Any line operating at 69,000 or more volts.
USACE: United States Army Corps of Engineers (New England District has jurisdiction in Connecticut)
USDA: Unites States Department of Agriculture
USFWS: United States Fish and Wildlife Service
USGS: United States Geological Survey (U.S. Department of the Interior).
VAR: Volt-ampere reactive power. The unit of measure for reactive power.
Vault: See Splice Vault.
Voltage: A measure of the push or force that transmits energy
Watercourse: Rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private.
Wetland: An area of land consisting of soil that is saturated with moisture, such as a swamp, marsh, or bog.
WMA: Wildlife Management Area (CT DEEP)
XS: Cross section (drawing)
XLPE: Cross-linked polyethylene (solid dielectric) insulation for transmission